APPENDIX H

STORM WATER

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THE SHUSWAP TRAIL ALLIANCE

SHUSWAP NORTH OKANAGAN RAIL TRAIL STORMWATER MANAGEMENT REPORT

PREPARED BY

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1.0 INTRODUCTION

1.1 Background

TRUE Consulting was retained by the Shuswap Trail Alliance to prepare a Stormwater Management Report to support detailed design and secure funding for the Shuswap North Okanagan (Sicamous to Armstrong) Rail Trail.

The Sicamous to Armstrong rail corridor has been owned by the Canadian Pacific Railway (CP) since 1891, and most recently has been operated by OmniTRAX Inc. from November 1998 until August 2009. Control of the rail line returned to CP in August 2009 and CP began the formal process of discontinuing the rail line. The northern segment of the rail corridor (Mile: 0.3 to 16.4) was formally discontinued by CP in November 2012, and the southern segment (Mile: 16.4 to 31.63) was formally discontinued in April 2014. [1]

On January 9, 2018, the Regional District of North Okanagan (RDNO) and the Columbia Shuswap Regional District (CSRD) announced that they have successfully concluded the purchase of 43 km of the rail corridor from Sicamous to Armstrong [2]. The Splatsin First Nation had acquired the remaining 7 km of the 50 km rail corridor prior [1]. The three (3) owner jurisdictions (RDNO, CSRD, Splatsin FN) intend to develop the rail corridor into a continuous non-motorized recreational greenway for pedestrians and cyclist, and link to the Okanagan (Vernon to Kelowna) Rail Trail and 200 km south to Osoyoos.

The Shuswap North Okanagan (Sicamous to Armstrong) Rail Trail vision is to protect agricultural, environmental and Secwepemc cultural values as well as provide transportation and tourism benefits to the region.

1.2 Location

The Shuswap North Okanagan (Sicamous to Armstrong) Rail Trail begins in the District of Sicamous on the west side of Sicamous Narrows (channel connecting Shuswap Lake and Mara Lake) at Congreve Road and extends to Lansdowne Road just north of Highway 97A on the outskirts of the City of Armstrong, see **Figure 1.1**. The rail trail is planned to link the following communities and areas: District of Sicamous, Mara, Grindrod, City of Enderby, Splatsin First Nation, City of Armstrong, CSRD Area E, RDNO Area F and the Township of Spallumcheen.

The roughly 50 km rail trail is mostly flat and traverses lakefront shoreline at Mara Lake and Rosemond Lake, river and creek shoreline at the Shuswap River, Fortune Creek and other streams, forested hillsides and cliffs, farmland and rural towns.

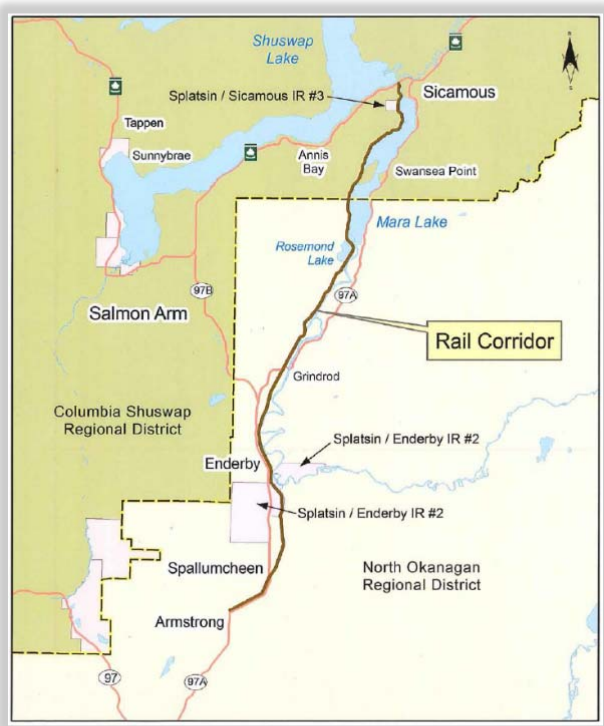

Figure 1.1 – Shuswap North Okanagan (Sicamous to Armstrong) Rail Trail

1.3 Scope of Work

The rail trail spans across numerous drainage courses and stormwater infrastructure including culverts and bridges. Condition assessment of stormwater infrastructure within the project area is required via field inspection to identify critical infrastructure, and identify potential required upgrades, maintenance and mitigation measures.

TRUE Consulting's scope of work includes the following key tasks:

- Data Collection and Review
- Field Inspection of Culverts and Bridges
- Stormwater Management Report and Figures
  - Identify Major Drainage Courses
  - Identify / Inventory Stormwater Infrastructure
  - Provision of Recommended Culvert and Bridge Hydraulic Maintenance, Upgrades and /or Mitigation Measures

2.0 DATA COLLECTION AND REVIEW

2.1 Data Collection

Western Water Associates Ltd. (WWAL) provided TRUE with a map set indicating locations of stormwater infrastructure consisting of 13 culverts and four (4) bridges throughout the project area. Additional culverts locations were indicated on the map set by markers, but were not numbered.

Urban Systems Ltd. (USL), the lead engineer on this project provided TRUE with two (2) kmz files. The kmz files indicated stormwater infrastructure consisting of 25 culverts, five (5) potential culverts and four (4) bridges throughout the project area, as well as other drainage and non-drainage issues.

2.2 Review

Based on the data received from WWAL and USL, a total of 27 culverts, five (5) potential culverts and four (4) bridges have been identified as stormwater infrastructure. To note, some storm infrastructure has been identified by both WWAL and USL on their respective maps and were therefore counted once. A drainage pipe draining towards the rail corridor and a City of Enderby storm outfall crossing the rail corridor have also been identified. Some other drainage and non-drainage issues identified include removed culverts, wet areas, falling rocks, erosion and active landslides.

The following table lists all storm infrastructure, drainage and non-drainage issues identified to be assessed and further investigated in the field. Approximate stations (km) were obtained from the maps. Storm infrastructure is highlighted green; potential culverts, outfalls and removed culverts are highlighted purple; other drainage issues are highlighted blue; and non-drainage issues are highlighted red, see **Table 2.1**.

TABLE 2.1 - STORM INFRASTRUCTURE AND ISSUES

Station (km)	Infrastructure Type or Problem Area	Map Source
1.70	Wet Area	USL
1.85	Drainage Pipe	USL
1.90	Culvert	WWAL/USL
3.25	Flood damaged section - water and mud along ditch	USL
4.50	Culvert	WWAL/USL
4.60	Culvert & drainage draw in cliff	WWAL/ USL
4.95	Falling Gabions - Caution	Subconsultant Letter
7.70	Culvert	WWAL/ USL
11.25	Wetland Section	USL
11.30	Culvert	WWAL/ USL
11.40	Culvert	WWAL
11.60	Culvert	WWAL/ USL
12.05	Wet Section	USL
12.10	Culvert	WWAL/ USL
12.15	Culvert	WWAL/ USL
12.16	Wet Section	USL

12.25	Wet Section	USL
12.30	Culvert	WWAL/ USL
12.40	Wet Section	USL
12.45	Culvert	WWAL/ USL
13.50	Wet Section	USL
14.80	Bridge #1	WWAL/ USL
15.50	Flood Debris	USL
17.70	Discarded Culvert	USL
18.00	Culvert Collapse - potential flooding	USL
18.30	Culvert	WWAL/ USL
18.35	Uneven Surface & Wet Area	USL
21.05	Small Culvert Pipes	USL
21.10	Culvert Request	USL
21.20	Gravel Piles	USL
21.25	Culvert	USL
21.70	Culvert	USL
21.90-22.60	Falling Rocks - Caution	USL
24.00	Culvert - with slight rise	USL
25.00	Culvert - potentially plugged causing flooding	USL
27.60	Check for Culverts	USL
28.05	Culvert - blocked, flooding in spring	WWAL/ USL
30.45	Culvert - old culverts seem discarded	WWAL/ USL
32.00-32.60	Barbed Wire Fence - Caution - reclose due to Cattle	Subconsultant Letter
32.55	Culvert & Wet Area	USL
32.75	Severe Riverbank Erosion - Caution	Subconsultant Letter
32.75	Check for Culvert & Drainage - behind Enderby Timber Mill	USL
34.60	Check for Culvert	USL
37.00	Dugout Channel - seems like a STM Outfall (Enderby)	USL
37.15	Culvert	USL
37.35	Culvert	USL
37.50	Active Landslip - Caution	Subconsultant Letter
40.60	Bridge #2	WWAL/ USL
42.50	Bridge #3	WWAL/ USL
43.20	Culvert removed - flood mitigation	USL
44.40	Culvert	WWAL/ USL
46.30	Culvert	USL
46.50	Culvert removed	Phil/ USL
47.60	Check for Culvert	USL
48.25	Culvert	WWAL
48.60	Culvert	WWAL
48.90	Bridge #4	WWAL/ USL
49.50-50.00	Owned by CP	Subconsultant Letter

3.0 FIELD INVESTIGATION

3.1 Introduction

The field investigation of the storm infrastructure along the rail trail corridor was conducted between June 08 – 10, 2020 by two (2) TRUE staff members. The field investigation started at km 0 in the District of Sicamous on the west side of the Sicamous Narrows and ended at km 50 in the City of Armstrong. Trail conditions were mostly dry, with the exception of km 15.20 – 15.80 where lake water was spilling over the rail bed. Some areas of the rail trail are very overgrown with branches overhanging the trail and, in some areas, trees have fallen onto the trail.

3.2 Methodology

3.2.1 Culvert Inspection and Assessment

For culvert inspection and assessment, the MoTI Culvert Inspection Form was used in the field. The culverts were assessed according to the following criteria:

- **General Information**
  - Diameter
  - Material
  - Length
  - Culvert Type
- **Rail Trail Surface**
- **General Culvert**
  - Alignment
  - Baffles
  - Bolted Connections
  - Coupled Connections
  - Coating
  - Embedment Materials
  - Culvert Cover
  - Roof
  - Sidewalls
  - Floor
  - Headwalls
  - Wingwalls
  - Inlet
  - Outlet
  - Projection
  - Overall
  - Rip Rap
  - Trash Rack
  - Weir/Backwater Structures
  - Footing
- **Stream Channel**
  - Estimated Present Water Level Depth
  - Estimated Present Water Level Width
  - Estimated High Water Clearance (Freeboard)
- **Stream Hazards**
  - High Water
  - Scour
  - Debris
  - Aggradation
- **Repairs**
  - Priority
  - Repair Description

GPS survey equipment was used to collect the location and elevation of the upstream and downstream inverts, top of rail trail at centreline, present water level and any other important information to UTM coordinates. Located culverts are identified by stationing (km) based on actual locations shot with the GPS and may not fully match preliminary stationing in Section 2.0. Inventory photos of culverts were taken as well.

3.2.2 Bridge Inspection and Assessment

Bridges were assessed according to hydrological factors such as stream cross section, depth of flow, debris, location of piers and bridge freeboard. GPS survey equipment was used to collect the location and elevation of bridge elements such as bridge decking and pier locations, as well as present water level and stream cross sections to UTM coordinates. Located bridges are identified by stationing (km) based on actual locations shot with the GPS and may not fully match preliminary stationing in Section 2.0. Inventory photos of bridges were taken as well.

Some streams had deep and/or fast flowing water making it unsafe to enter the watercourse to obtain stream cross sections and depth of flow. Therefore, at those streams only bridge elements (decking and pier location) and water level could be surveyed. An overall representation of the bridge structures can be obtained from the inventory photos.

A condition assessment of the bridges was not conducted as this is within the scope of structural work.

3.3 Culverts

3.3.1 Located Culverts

A total of 29 culverts were located and inspected. The culvert sizes ranged from 300 – 2000mm in diameter and mostly consisted of Corrugated Steel Pipes (CSP). The culvert cluster at km 21.05 consisted of 2 – 150mm Cast Iron (CI) and 2 – 75mm PVC pipes. The CP owned section from km 49.50 – 50.00 was also inspected, however no culverts were located along this section.

A culvert summary is appended in **Appendix A,** and individual culvert inventory sheets are appended in **Appendix B**.

3.3.2 Culverts Not Located and Removed Culverts

A total of eight (8) culverts identified as culverts or potential culvert locations could not be located and are listed below:

- Km 11.40 – Identified as Culvert #4 on WWAL map set, but not shown on USL kmz map.
- Km 12.15 – Identified as culvert on USL kmz map.
- Km 18.00 – Identified as a partially collapsed culvert on USL kmz map.

Figure 3.1 – Km 25.00 – Standing water

- Km 25.00 – Culvert possibly submerged and not visible due to high standing water, see **Figure 3.1**.
- Km 27.60 – Identified as potential culvert location. Two (2) 100mm PVC drainage pipes from Sure Crop Feeds found draining into the ditch at back of property. No culvert located.
- Km 32.75 – Identified as potential culvert location. Catch basin located behind North Enderby Timber Mill. Catch basin outfall not located, could be draining into rock pit. No culvert located.
- Km 34.60 – Identified as potential culvert location.
- Km 48.60 – Identified as Culvert #13 on WWAL map set, but not shown on USL kmz map.

Two (2) culverts have been removed and are listed below:

- Km 43.14 – Culvert has been removed at Hussard Creek and a channel has been provided. At time of inspection, water was standing in channel. Upstream from the removed culvert, a 1500mm CSP culvert crosses Stepney Road. See **Figure 3.3.**
- Km 46.45 – Culvert removed, but no channel provided. Water being dammed in the ditch between Highway 97A and the rail trail. At time of inspection, standing water on both sides of rail trail. See **Figure 3.2**.

Figure 3.2 – Km 46.45 – Culvert removed

Figure 3.3 – Km 43.14 – Hussard Creek
Left: Culvert removed and channel provided Right: 1500mm CSP Culvert at Stepney Road

3.4 Bridges

Four (4) bridges along the rail trail were inspected and surveyed. The bridges are short span timber rail bridges. One bridge crosses Larch Hills Creek which connects Mara Lake and Rosemond Lake, two bridges cross Fortune Creek, and one bridge crosses Harland Creek which is a tributary stream of Fortune Creek. [3]

3.4.1 Bridge #1 – km 14.81 – Larch Hills Creek

Bridge #1 crosses Larch Hills Creek at km 14.81. Larch Hills Creek is the connecting stream between Mara Lake and Rosemond Lake. The bridge spans approximately 12.5 metres, is about 3.6 metres wide and has two bridge piers. The elevation of the bridge deck is 349.66, which is below the 200 year flood level of 350.70 and below the 20 year flood level of 350.30. The flood levels were obtained from the British Columbia government floodplain maps and include 0.6m freeboard. [4]

Typically, Larch Hills Creek is a small stream channel connecting the two lakes as seen in **Figure 3.4,** obtained from USL kmz map. However, at the time of inspection on June 08, 2020, lake levels were high due to spring freshet, and channel cross sections and water depth could not be obtained as water depth at the bridge was over 3 metres. The water level elevation was 348.91, which corresponds to a freeboard of 0.75 metres to the top of decking and is 1.39 metres below the 20 year flood level indicated above.

Debris consisting of mostly logs has built up southwest of the bridge at Rosemond Lake and may pose a safety hazard to the bridge.

Figure 3.4 – Km 14.81 – Bridge #1 – Left: Fall 2017 (USL kmz map) Right: Spring – June 08, 2020

3.4.2 Bridge #2 – km 40.60 – Fortune Creek

Figure 3.5 – Km 40.60 – Bridge #2

Bridge #2 crosses Fortune Creek at km 40.60, see **Figure 3.5**. The bridge spans approximately 13.35 metres, is about 3.05 metres wide and has two bridge piers. The elevation of the bridge deck is 353.70. At approximately km 36.80 (±3.8 km downstream), Fortune Creek confluences with the Shuswap River at the City of Enderby. At the confluence location, the 200 year flood level is 353.40 and the 20 year flood level is 352.80. As the bridge is located upstreams from the confluence, it is assumed that the flood levels at the bridge are at a slightly higher elevation. Therefore, it is assumed that Bridge #2 is at or near the 200 year flood level. The flood levels were obtained from the British Columbia government floodplain maps and include 0.6m freeboard. [4]

At the time of inspection on June 10, 2020, Fortune Creek at Bridge #2 had high stream levels and fast flowing water due to spring freshet, and channel cross sections and water depth could not be obtained. The water level elevation was 351.43, which corresponds to a freeboard of 2.27 metres to the top of decking.

3.4.3 Bridge #3 – km 42.53 – Harland Creek

Bridge #3 crosses Harland Creek at km 42.53, see **Figure 3.6**. Harland Creek is a tributary stream of Fortune Creek. The bridge spans approximately 4.60 metres and is about 2.95 metres wide. The elevation of the bridge deck is 353.73.

At the time of inspection on June 10, 2020, Harland Creek at Bridge #3 consisted of fast flowing water with a flow depth of about 0.12 metres. Channel cross sections downstream from the bridge were obtained. However, upstream channel cross sections could not be obtained, due to trees and brush inhibiting the GPS signal. The water level elevation was about 352.54, which corresponds to a freeboard of 1.19 metres to the top of decking.

About 19 metres upstream, a 2000mm CSP culvert crosses Stepney Road, see **Figure 3.7**. The water level in the culvert was 352.76. However, sediments were present on the culvert floor.

Figure 3.6 – Km 42.53 – Bridge #3

Figure 3.7 – Km 42.53 – Culvert at Stepney Road upstream of Bridge #3

3.4.4 Bridge #4 – km 48.86 – Fortune Creek

Figure 3.8 – Km 48.86 – Bridge #4

Bridge #4 crosses Fortune Creek at km 48.86, see **Figure 3.8**. The bridge spans approximately 13.60 metres, is about 2.95 metres wide and has two bridge piers. The elevation of the bridge deck is 362.84.

At the time of inspection on June 10, 2020, Fortune Creek at Bridge #4 consisted of fast flowing water, making it unsafe to enter the water. Approximate channel cross section and water depth were obtained from shore. The water level elevation on June 10, 2020 was 360.91, which corresponds to a freeboard of 1.93 metres to the top of decking. Water flow depth was about 0.43 metres.

3.5 Outfalls

Five (5) storm outfalls within the City of Enderby were located along the rail corridor and are assumed to be the property of the City of Enderby. Four (4) outfalls drain into the west ditch of the rail trail. However, one (1) outfall crosses the rail trail at km 37.02 and drains into a channel on the east side of the rail trail. This channel drains east towards Fortune Creek/Shuswap River.

The outfall at km 37.02 was inspected as it crosses the rail trail. The outfall is included in the culvert summary in **Appendix A** and in the individual culvert inventory sheets in **Appendix B**.

The remaining four (4) outfalls were not inspected as they do not cross the rail trail and only drain into the rail trail ditch, and the condition of these outfalls does not affect the rail trail. These four (4) outfalls are summarized below:

- Km 37.10 – One (1) 200mm CSP and one (1) 300mm CSP outfall were located within a few metres of each other. These outfalls drain into the west ditch of the rail corridor and at the time of inspection were dry. See **Figure 3.9**.

Figure 3.9 – Km 37.10 – 200mm and 300mm CSP Outfalls

- Km 37.25 – An outfall pipe was not located. However, rip rap and reeds were observed indicating presence of water. A manhole cover was observed on the other side of fence. Therefore, it was assumed that an outfall is located at that location. See **Figure 3.10**.

Figure 3.10 – Km 37.25 – Assumed Outfall

- Km 37.40 – An outfall pipe was not located. However, rip rap and flowing water was observed. Therefore, it was assumed that an outfall is located at that location. See **Figure 3.11**. The water from the outfall is draining towards the 600mm culvert at km 37.36.

Figure 3.11 – Km 37.40 – Assumed Outfall

Maintenance and any upgrades to the outfalls is assumed to be the responsibility of the City of Enderby.

3.6 Stormwater Issues

During the field investigation, the following stormwater issues were observed along the rail corridor:

- Km 0.00 – 14.80 – Standing water was observed within ditches in low lying areas along the west side of the rail trail. Based on our observations, this water is associated to groundwater/lake water backing up from Mara Lake due to the rail corridor's close proximity to Mara Lake and the ditch bottom elevations being below current lake levels. See **Figure 3.12**.

- Km 1.70 – Standing water in west ditch.

- Km 3.30 – Significant sediments and water in ditch. Possibly previous flooding. See **Figure 3.13**.

- Km 15.20 – 15.80 – Lake water spilling over the rail bed at an approximate depth of 0.15m. See **Figure 3.14**.

- Km 20.50 – Standing water in west ditch.

- Km 21.10 – Identified as a culvert request on USL's kmz map. This location is mostly dry with some standing water in the west ditch. Km 21.04 is a more optimal culvert location to drain standing water from the ditch.

- Km 24.30 – Standing water in west ditch. Corresponds with the location of Violet Creek, a major drainage course.

Figure 3.12 – Km 0.00 – 14.80 – Standing water

- Km 25.00 – High standing water on both sides of the rail corridor, see **Figure 3.1**.

- Km 35.00 – Standing water in ditch between Hwy 97 and the rail corridor.

- Km 38.00 – 40.10 – Standing water in ditch.

- Km 42.70 – 43.00 – Standing water in ditch.

- Km 49.00 – 50.00 – CP owned section of the rail corridor was also inspected. No drainage issues were observed along this section.

Figure 3.13 – Km 3.30 – Sediments in ditch

Figure 3.14 – Km 15.20 – 15.80 – Lake water spilling onto rail bed

4.0 MAJOR DRAINAGE COURSES AND FISH BEARING STORM INFRASTRUCTURE

The field investigation findings of storm infrastructure assessed within the project area were shared and discussed with WWAL to identify, review and document major drainage courses. The coordination with WWAL also determined which storm infrastructure is considered fish bearing or non-fish bearing.

4.1 Major Drainage Courses

The BC Water Resources Atlas [3] was used to identify major and minor drainage courses within the project area, see **Table 4.1**. The major drainage courses were identified during the discussion and review with WWAL and are highlighted green in **Table 4.1**.

TABLE 4.1 - DRAINAGE COURSES				
Stream ID	**Stream Name**	**Station (km)**	**Stream Order**	**Major Drainage Course**
1	Unnamed	2.26	1st	No
2	Unnamed	7.30	1st	No
3	Unnamed	7.70	1st	No
4	Unnamed	10.88	1st	No
5	Larch Hills Creek	14.81	1st	Yes
6	Unnamed	17.71	1st	No
7	Unnamed	19.98	1st	No
8	Unnamed	23.11	1st	No
9	Violet Creek	24.28	6th	Yes
10	Unnamed	24.79	4th	Yes
11	Gardom Creek	28.04	6th	Yes (Figure 4.1)
12	Unnamed	30.43	1st	No
13	Unnamed	31.65	1st	No
14	Unnamed	33.50	1st	Yes
15	Leduc Creek	37.93	1st	Yes
16	Unnamed	40.00	1st	No
17	Fortune Creek	40.60	-	Yes
18	Harland Creek	42.53	5th	Yes
19	Hussard Creek	43.14	3rd	Yes
20	Sneesby Creek	44.42	2nd	Yes (Figure 4.2)
21	Unnamed	44.75	1st	No
22	Lindsay Creek	45.24	3rd	Yes
23	Glanzier Creek	46.37	5th	Yes
24	Kendry Creek	47.13	4th	Yes
25	Alderson Creek	47.59	4th	Yes
26	Unnamed	47.77	1st	No
27	Fortune Creek	48.86	-	Yes

Most of the major drainage courses are named, however some are unnamed or the stream name could not be determined. The major drainage courses vary in stream order; from first order up to sixth order. The minor drainage courses are all unnamed and are all first order streams, which may only flow seasonally and/or during flood events.

Figure 4.1 – Km 28.04 – Gardom Creek

The majority of major drainage courses are located between the City of Enderby and the City of Armstrong (km 37.50 to km 50.00), an area known to be swampy. At the time of inspection on June 10, 2020 numerous streams were observed in this area with significant standing water in ditches along the rail corridor.

Figure 4.2 – Km 44.42– Sneesby Creek

The field investigation identified ten (10) culverts as transmitting stream flow, in addition to the four (4) bridges. However, some of these streams are minor drainage courses and only flow seasonally. Storm infrastructure was located at several major drainage courses, but not all, as summarized below in **Table 4.2**:

TABLE 4.2 – MAJOR DRAINAGE COURSES				
Stream ID	**Stream Name**	**Station (km)**	**Storm Infrastructure**	**Size (mm)**
5	Larch Hills Creek	14.81	Bridge #1	-
9	Violet Creek	24.28	-	-
10	Unnamed	24.79	-	-
11	Gardom Creek	28.04	Culvert #16	1000
14	Unnamed	33.50	-	-
15	Leduc Creek	37.93	-	-
17	Fortune Creek	40.60	Bridge #2	-
18	Harland Creek	42.53	Bridge #3	-
19	Hussard Creek	43.14	*	1500*
20	Sneesby Creek	44.42	Culvert #24	2 - 600
22	Lindsay Creek	45.24	-	-
23	Glanzier Creek	46.37	Culvert #26	2 - 1200
24	Kendry Creek	47.13	Culvert #27	600
25	Alderson Creek	47.59	Culvert #28	800
27	Fortune Creek	48.86	Bridge #4	-

* Culvert removed, 1500mm culvert upstream

Figure 4.3 – Km 7.70 – Unnamed Stream diverted through ditch to Culvert #4

The field investigation findings indicate that the majority of storm infrastructure assessed provide drainage of ditches along the rail corridor. However, some of these ditches intercept streams and divert stream flows to culverts in the vicinity. This has been observed at km 7.70 (Culvert #4), see **Figure 4.3**, and km 40.00 (Culvert #23). Both streams are minor drainage courses.

A summary of the minor and major drainage courses is appended in **Appendix C,** and are further summarized in relation to storm infrastructure in the culvert summary appended in **Appendix A**.

4.2 Fish Bearing Storm Infrastructure

All culverts located during the field investigation were discussed and reviewed with WWAL to determine if they are fish bearing or non-fish bearing. Culverts were considered fish bearing based on the following criteria:

- Their drainage paths are connected to other bodies of water (Mara Lake, Shuswap River, Fortune Creek, etc.) allowing fish to travel upstream from these bodies of water and through the culverts,
- have a gradient of less than 20%, and
- water drops of less than 0.3 metres into scour pools.

27 out of 29 (93%) culverts were determined to be fish-bearing. Two (2) culverts were determined to be non-fish bearing and are located at km 12.44 (Culvert #9) and km 37.17 (Culvert #21), see **Figure 4.4**. Culvert #9 has a downstream water drop of about 1 metre onto rocks below making fish access impossible. Culvert #21 was dry at the time of inspection on June 10, 2020 and drops over 2.15 metres in elevation over its length. This means that fish can only access Culvert #21 during high flow events on Fortune Creek, but cannot pass through due to the elevation difference between the upstream and downstream culvert ends. Fish would only be able to access the upstream end of the culvert at or exceeding a 200 year flood event.

Figure 4.4 – Km 37.17 – Culvert #21

The City of Enderby's storm outfall at km 37.02 was also considered fish bearing, as fish would be able to access the storm sewer during high flow events on Fortune Creek.

Fish bearing storm infrastructure is further summarized in the culvert summary appended in **Appendix A**.

5.0 MAINTENANCE, UPGRADES AND MITIGATION MEASURES

All storm infrastructure and stormwater issues were assessed and rated based on their repair priority. The repair priority rating is summarized as follows:

- High 0 – 5 years
- Medium 5 – 10 years
- Low 10 – 25 years

Repair action items were recommended in regard to maintenance, upgrade and mitigation measures for all storm infrastructure and stormwater issues. These recommended repair action items and their repair priority rating are summarized in a spreadsheet appended in **Appendix D,** and are further detailed in this section.

5.1 Culvert Rehabilitation and Replacement

As discussed in section 3.2, culverts were assessed to a wide ranging criteria during the field investigation and subsequent review and creation of the culvert sheets. This criterion incorporated various factors that covered general culvert information, culvert condition, culvert cover/surface condition, culvert embedment material condition, stream channel condition and stream hazards. These factors were used to rate each culvert and determine the required repair action item regarding culvert rehabilitation or replacement.

5.1.1 Culvert Repair Priority and Repair Action Item

The number of culverts in each repair priority rating category for the 29 culverts and one (1) outfall found during the field investigation are as follows:

- High 12 culverts
- Medium 7 culverts
- Low 9 culverts, 1 outfall
- Unrated 1 culvert

Culvert #10 at km 18.27 is unrated, as it was submerged at the time of inspection on June 08, 2020 and visual access of the culvert's interior could not be achieved. Therefore, the culvert's interior condition could not be assessed.

The recommended culvert repair action items are summarized as follows:

- Clean out rocks, sediments and/or debris from culvert,
- Clean out rocks, sediments, debris and/or vegetation/trees from ditch,
- Clean out rocks, sediments, debris and/or vegetation/trees from culvert inlet/outlet,
- Replace culvert due to corrosion,
- Replace culvert due to damaged culvert ends,
- Replace culvert due to collapse or detached segment(s), and

- Replace culvert due to low capacity.

Some culverts require more than one of the above repair action items to be rehabilitated. The recommended repair action items for each culvert are indicated in the culvert inventory sheets appended in **Appendix B**, and are summarized in the culvert summary appended in **Appendix A.**

Recommended culvert repair action items summarized in the culvert summary are based on the culvert's worst condition and a repair priority rating is assigned based on when that repair action item is believed to be required. However, some culverts require a replacement repair action item, but are rated at a lower repair priority, indicating that the culvert condition is still acceptable in the short term (e.g. Medium rating – Replace due to corrosion). However, other issues may be present in the short term, most notably rock, sediment and/or debris accumulation within the culverts. Therefore, it is recommended that these culverts be cleaned from rocks, sediments and/or debris in the near term regardless of rating, to restore the hydraulic capacity and maintain the service life of the culvert.

5.1.2 Trenchless Culvert Rehabilitation

Undamaged culverts whose structural integrity has not been compromised could be rehabilitated using trenchless culvert rehabilitation methods. However, trenchless culvert rehabilitation methods may not be as cost-effective compared to full culvert replacement as it seems due to the following reasons:

- No active traffic is currently using the rail trail. Therefore, maintaining traffic is not necessary, which eliminates one of the benefits of trenchless methods. The immediate recreation and economic impacts from full culvert replacement are therefore insignificant.
- No deep excavations for full culvert replacement are required as most culverts have less than 1.5 metres of cover.
- Most of the culverts are small in diameter (less than 600mm) and the largest cost savings are achieved with large diameter culverts when trenchless culvert rehabilitation methods are used.
- Access to culverts and requirements for a larger working area for large specialized trenchless equipment may be difficult due to the narrow rail corridor, and the site topography and vegetation adjacent to the rail corridor along some sections of the rail corridor.

Therefore, it is recommended that each culvert that could potentially make use of trenchless rehabilitation methods be analyzed further during detailed design, to determine the feasibility and cost-effectiveness of using trenchless culvert rehabilitation methods over a full culvert replacement. Trenchless culvert rehabilitation methods may therefore only be cost effective for larger diameter culverts.

Figure 5.1 – Slip lined culvert (grout tubes still in place) [6]

Culverts that potentially could make use of trenchless rehabilitation methods are indicated in the culvert summary appended in **Appendix A**.

Some common trenchless culvert rehabilitation methods that would be suitable for this project are as follows [5]:

- Slip lining, see **Figure 5.1**
- Spiral wound lining
- Fold-and-form lining, see **Figure 5.2**
- Deformed-reformed HDPE lining

Figure 5.2 – Fold-and-form lined culvert [5]

Cured-in-place pipe (CIPP) lining is not a suitable rehabilitation method for this project due to environmental concerns with the capture and disposal of styrene contaminated process water. Styrene monomer-based resins used in curing the pipe liner are toxic to fish when discharged. As most of the storm infrastructure along the rail corridor is fish-bearing and drains to fish-bearing bodies of water; CIPP liner is not suitable unless all residual water is captured for proper disposal. [5]

A trenchless culvert rehabilitation report is appended in **Appendix E**. This report was written by the Utah State University and the Utah Department of Transportation and provides a brief description about the various culvert trenchless rehabilitation methods, its installation procedure, and highlights the advantages and disadvantages of each method. This report is only intended to be informational and does not replace current jurisdictions' bylaws and regulations.

5.2 Bridge Rehabilitation and Replacement

Figure 5.3 – Debris at Bridge #1

As mentioned in section 3.2.2, a condition assessment of the bridges was not completed as this is within the scope of structural work. Therefore, no recommendations regarding the bridge structures are given.

However, debris consisting of mostly logs has built up southwest of Bridge #1 at Rosemond Lake and may pose a safety hazard to the bridge, see **Figure 5.3**. Therefore, we recommend removing the debris or relocating the debris to higher ground to prevent potential damage to the bridge.

5.3 Removed Culvert Replacement

As identified in Section 3.3.2, two (2) culverts have been removed along the rail trail at km 43.14 and km 46.45. These culverts will need to be replaced to facilitate cyclist and pedestrian movement along the rail trail.

At km 43.14, the removed culvert was located at Hussard Creek. A short distance upstream from the rail trail a 1500mm CSP culvert crosses Stepney Road. Therefore, the replacement culvert at km 43.14 should be of similar size/capacity.

At km 46.45, the removed culvert seems to be located at a tributary of Glanzier Creek or provided drainage of the Hwy 97A ditch towards Glanzier Creek through the rail corridor. Hydraulic modeling of the stormwater catchment may be required to determine the required replacement culvert size/capacity.

5.4 Stormwater Issues Mitigation Measures

As identified in Section 3.6, several stormwater issues were observed along the rail corridor during the field investigation. Some of these issues require no action and some require mitigation measures.

At Km 0.00 to 14.80, standing water was observed within ditches in low lying areas along the west side of the rail trail. Based on our observations, this water is associated to groundwater/lake water backing up from Mara Lake due to the rail corridor's close proximity to the lake and the ditch bottom elevations being below current lake levels. Therefore, no action is required.

At km 1.70, 20.50, and 35.00, standing water was observed in the ditch. Consider installing a culvert to drain towards the nearest stream or water body. Hydraulic modeling of stormwater catchments may be required to determine the required culvert size/capacity.

At km 3.30, significant sediments and water was observed in the ditch. This is possibly due to previous flooding. Therefore, clean out sediments from the ditch and consider installing a culvert to drain towards Mara Lake. Hydraulic modeling of the stormwater catchment may be required to determine the required culvert size/capacity.

At km 15.20 to 15.80, lake water was spilling over the rail bed at an approximate depth of 0.15m. This may require raising the rail trail or implementing seasonal closures of the rail trail. The rail trail should be assessed after overtopping events to confirm the structural integrity of the rail embankment.

A culvert request has been identified at km 21.10 according to USL's kmz map. This location was mostly dry at the time of inspection on June 09, 2020 with some standing water. Consider placing the culvert at a more optimal drainage location at km 21.04 to drain standing water from the ditch to the Shuswap River. Currently at km 21.04, culvert #11 is located and is rated as a high repair priority with "Replace with higher capacity culvert" repair action item. Hydraulic modeling of the stormwater catchment may be required to determine the required culvert size/capacity.

At km 24.30, standing water was observed in the west ditch, see **Figure 5.4**. This location corresponds with the location of Violet Creek, a major drainage course. The location of Violet Creek is to be determined in the field and a culvert placed at this location to direct the stream flow towards

Mara Lake. Hydraulic modeling of the stormwater catchment may be required to determine the required culvert size/capacity.

At km 25.00, high standing water was observed on both sides of the rail corridor. This location was also identified as potential existing culvert location. However, a culvert was not found at this location during the field investigation. This may be due to the culvert possibly being submerged in high standing water and not being visible. Culvert location to be determined during low water levels. If no culvert found, consider placing culvert at this location to allow the west ditch to drain towards the east ditch once the river levels subside in summer, if no other drainage paths for the west ditch are available.

Figure 5.4 – Km 24.30 – Standing water (proximity to Violet Creek)

At km 38.00 to 40.10 and km 42.70 to 43.00, standing water was observed in the ditches. Based on our field observation this water is considered seasonal flooding from Fortune Creek. No action is required as water backing up into the ditches from Fortune Creek is a normal seasonal cycle during spring freshet. As water recedes in the summer months, water levels in ditches should drop as well. However, this should be confirmed during the summer months to identify any areas that have not receded, and considerer installing a culvert at those locations to drain towards the nearest stream or water body.

5.5 Maintenance

Maintenance of storm infrastructure along the rail corridor should be upkept on a regular basis. The most common issue observed during the field investigation was rocks and sediments within culverts. Culverts shall be maintained free of rock, sediments and debris on regular basis to prevent deterioration of culvert hydraulic capacity. This is especially important during spring freshet and high flood events.

6.0 CLOSURE

The stormwater management report presented herein summarizes our field investigation findings, storm infrastructure condition assessment and review of the project site. It also provides maintenance, upgrade and mitigation measures, and has been prepared to support detailed design and secure funding for the Shuswap North Okanagan (Sicamous to Armstrong) Rail Trail project.

The stormwater management report has been prepared for the exclusive use of the Shuswap Trail Alliance and its lead consultant (Urban Systems) and is based upon the best information available at the time. Use by third parties, or purposes other than that stated herein, or for other sites or site conditions, is not permitted without the express written permission of TRUE Consulting.

7.0 REFERENCES

[1] Columbia-Shuswap Regional District, "FREQUENTLY ASKED QUESTIONS THE RAIL CORRIDOR INITIATIVE," May 2017. [Online]. Available: http://www.salmonarm.ca/DocumentCenter/View/1906/Rail-Corridor-FAQs_V3#:~:text=in%20August%202009%2C%20and%20CP,different%20transfer%20and%20discontinuance%20process.. [Accessed 24 June 2020].

[2] Columbia-Shuswap Regional District, "Media Release - Purchase of CP Rail Corridor between Armstrong and Sicamous finalized," 9 January 2018. [Online]. Available: https://www.csrd.bc.ca/sites/default/files/180109_PRSRLS_CPRaiPurchased.pdf. [Accessed 24 June 2020].

[3] DataBC, Province of British Columbia, "BC Water Resources Atlas," [Online]. Available: https://maps.gov.bc.ca/ess/hm/wrbc/. [Accessed 20 August 2020].

[4] Province of British Columbia Ministry of the Environment, "Floodplains by Region - Floodplain Mapping Shuswap River Mara Lake to Mabel Lake," June 1980. [Online]. Available: http://www.env.gov.bc.ca/wsd/data_searches/fpm/reports/keyplans-html/shuswap-r-mara-to-mabel-lakes1-10.html. [Accessed 09 July 2020].

[5] U. S. U. &. U. D. o. T. Ellen Norris, "Culvert Rehabilitation Practices," 26 February 2016. [Online]. Available: https://silo.tips/download/culvert-rehabilitation-practices. [Accessed 25 August 2020].

[6] Utah Water Research Labaratory, "IN-SITU CULVERT REHABILITATION: SYNTHESIS STUDY AND FIELD EVALUATION," [Online]. Available: https://www.google.com/url?sa=i&url=http%3A%2F%2Frosap.ntl.bts.gov%2Fview%2Fdot%2F18536%2Fdot_18536_DS1.pdf%3F&psig=AOvVaw3HBMYCuVr5UuWRUvv7ianL&ust=1598473933953000&source=images&cd=vfe&ved=0CAkQjhxqFwoTCLDMqs2Zt-sCFQAAAAAdAAAAABBL. [Accessed 25 August 2020].

APPENDIX A

Culvert Summary

CULVERT SUMMARY

SICAMOUS TO ARMSTRONG RAIL TRAIL

STORMWATER MANAGEMENT - Inspected: June 8 - 10, 2020

Project No. 1928-011

Culvert No.	Km (0 = Sicamous)	Diameter (mm)	Material	Length (m)	Upstream Invert Elev (m)	Downstream Invert Elev (m)	Rail Bed CL Elev (m)	Cover (m)	Overall Pipe Conditon	Stream							Repair Priority	Action Item	Potential for Trenchless Rehabilitation
										Flow Type	Stream Name	Major Drainage Course	Draining to	Water Depth (m)	Freeboard (m)	Fish Bearing			
1	1.92	400	CSP	6	349.16	no shot	350.17	0.61	Fair	Ditch	-	-	Mara Lake	0.10	0.71	Yes	Medium	Remove rocks from culvert	n/a
2	4.49	300	CSP	7	no shot	348.53	349.79	0.56	Poor	Ditch	-	-	Mara Lake	Lake	0.80	Yes	High	Replace - culvert corroded and damaged, clean out ditch	No
3	4.57	600	CSP	8	no shot	348.56	349.64	0.49	Excellent	Ditch	-	-	Mara Lake	Lake	0.68	Yes	Low	Clean out ditch and culvert inlet	n/a
4	7.70	600	Concrete	10	350.37	348.67	351.12	1.00	Good	Ditch	Unnamed	No	Mara Lake	0.08	0.67	Yes	Low	None	n/a
5	11.26	400	CSP	6	351.08	no shot	352.23	0.75	Poor	Ditch	-	-	Mara Lake	0.05	0.90	Yes	High	Replace - end deformed and filled with rocks, clean out ditch and culvert inlet	No
6	11.59	600	Concrete	10	351.61	349.69	352.32	1.07	Poor	Ditch	-	-	Mara Lake	0.10	0.61	Yes	High	Replace - detached segment, possible culvert undermining	No
7	12.12	300	CSP	6	351.66	351.24	352.33	0.59	Fair	Ditch	-	-	Mara Lake	0.05	0.40	Yes, seasonally	High	Clean out culvert and ditch	n/a
8	12.32	400	CSP	5.5	351.53	351.22	352.54	0.77	Good	Ditch	-	-	Mara Lake	0.09	0.92	Yes	Low	None	n/a
9	12.44	300	CSP	9	351.44	350.73	352.06	0.68	Fair	Ditch	-	-	Mara Lake	0.12	0.50	No	Medium	Replace - corrosion	Yes
10	18.27	Not Determined	Not Determined	8	Obv = 348.62	Obv = 348.52	349.78	1.21	Not Determined	Stream	-	-	Rosemond Lake	1.08	0.81	Yes	Not Determined	Could not be determined	n/a
11	21.04	2-150 & 2-75	CI & PVC	6	349.38	349.26	350.58	1.11	Poor	Ditch	-	-	Shuswap River	0.07	1.13	Yes	High	Replace with higher capacity culvert	No
12	21.25	450	CSP	8	349.35	349.02	350.92	1.29	Good	Ditch	-	-	Shuswap River	0.45	1.46	Yes	Medium	Replace - corrosion	Yes
13	21.66	450	CSP	6	350.05	350.07	351.58	1.07	Fair	Ditch	-	-	Shuswap River	0.00	1.51	Yes, high events	Medium	Replace - some corrosion	Yes
14	23.25	1400	CSP	11	351.21	350.92	353.87	1.41	Good	Stream	-	-	Shuswap River	0.05	2.61	Yes	Low	Good condition, clean out sediments	n/a
15	23.94	600	CSP	23	352.24	352.34	353.64	0.75	Good	Ditch	-	-	Shuswap River	0.8 & 0.03	0.98	Yes	Low	Pipe in good condition, may need to investigate and/or correct negative slope of culvert and lower culvert to drain pool	n/a
16	28.04	1000	CSP	20	351.70	351.24	354.86	2.39	Fair	Stream	Gardon Creek	Yes	Shuswap River	0.50	2.56	Yes	Medium	Clean out debris and sediments	n/a
17	30.43	1500	CSP	12	349.71	349.68	352.19	1.00	Excellent	Stream	Unnamed	No	Shuswap River	1.04	1.92	Yes	Low	Looks brand new, clean out some sediments	n/a
18	32.55	600	CSP	11	350.54	350.50	353.10	1.98	Poor	Stream	-	-	Shuswap River	0.50	2.06	Yes	High	Replace - corroded and damaged	No
19	31.65	2000	CSP	9	no shot	349.34	352.37	1.03	Good	Stream	Unnamed	No	Shuswap River	1.35	1.68	Yes	Low	Some cleaning, may consider removing pipes within the culvert	n/a
20	20.24	600	CSP	9	349.61	349.27	351.33	1.29	Good	Ditch	-	-	Shuswap River	0.13	1.68	Yes	Low	Clean out culvert	n/a
21	37.17	300	CSP	27	353.31	351.61	355.43	2.22	Poor	Ditch	-	-	Fortune Creek	0.00	2.12	No	High	Replace - corroded, damaged and collapsed	No
22	37.36	600	CSP	12	356.17	355.12	357.53	1.29	Good	Ditch	-	-	Fortune Creek	0.03	1.33	Yes	Low	Clean out inlet end and prevent ballast from entering culvert	n/a
23	40.00	600	CSP	8	351.95	no shot	354.56	2.01	Good	Ditch	Unnamed	No	Fortune Creek	0.03	2.41	Yes	Medium	Clean out rocks from culvert and remove tree/vegetation at outlet	n/a
24	44.42	2-600	CSP	6	351.89	351.74	353.27	0.86	Poor	Stream	Sneesby Creek	Yes	Fortune Creek	0.10	1.04	Yes	High	Clean out channel, replace culvert and headwall	Yes
25	44.61	400	CSP	6	352.03	352.10	352.94	0.48	Poor	Ditch	-	-	Fortune Creek	0.00	0.70	Yes	High	Replace - corroded	Yes
26	46.37	2-1200	CSP	10	353.94	353.76	355.95	0.90	Poor	Stream	Glanzier Creek	Yes	Fortune Creek	US: 0.4 & 1.4 DS: 0.2 & 0.5	1.02	Yes	High	Clean out and further assess culvert - internal corossion most likely, as exterior corrosion has been observed	Yes
27	47.13	600	CSP	12	356.75	356.67	357.45	0.14	Poor	Stream	Kendry Creek	Yes	Fortune Creek	US: 0.20 DS: 0.70	1.01	Yes	High	Assess culvert further during low flows regarding possible plugging or collapse, if no plugging or collapse is observed, repair priority is medium - replace - culvert corroded	Yes
28	47.59	800	CSP	8	355.59	355.24	356.78	0.57	Fair	Stream	Alderson Creek	Yes	Fortune Creek	0.22	1.06	Yes	Medium	Replace - corrosion	Yes
29	48.20	600	CSP	10	355.99	no shot	358.48	1.89	Poor	Ditch	-	-	Fortune Creek	0.00	2.49	Yes, high water	High	Replace - damaged culvert	No
STM Enderby	37.02	300	PVC Ribbed	Unknown	n/a	352.57	354.72	1.85	Good	Storm Sewer	-	-	Fortune Creek	0.30	2.34	Yes, high water	Low	none - City of Enderby's infrastructure	n/a

APPENDIX B

Culvert Inventory Sheets

CULVERT #1 - KM 1.92

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 8, 2020		
WWAL ID:	Culvert #1		
CULVERT:			
Diameter (mm):	400		
Material:	CSP		
Length (m):	6.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	349.16	**DS:**	no shot
Top of Rail Bed (m):	350.17		
Cover (m):	0.61		
Rail Bed Condition:	Good		

Pipe Condition:		Fair Some visible corrosion on sidewalls, filled 50% with rocks		
Inlet:		Filled 50% with rocks		
Outlet:		Filled 50% with rocks, tree growing on top of culvert		
Headwall:	**US:**	Rocks utilized as headwall		
	DS:	Rocks utilized as headwall		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Ditch flow - draining towards Mara Lake					
Water Depth (m):		0.10	**Water Level Width (m):**		0.60	**Freeboard (m):**	0.71
High Water:		No	**Scour:**	No	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

Discolouration/possible high water mark about 0.05m above current water level in culvert

REPAIR:

Repair Priority:	Medium
Repair/Action Item:	Remove rocks from culvert

CULVERT #2 - KM 4.49

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 8, 2020		
WWAL ID:	Culvert #2		
CULVERT:			
Diameter (mm):	300		
Material:	CSP		
Length (m):	7.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	2.5
Invert (m):			
US:	no shot	**DS:**	348.53
Top of Rail Bed (m):	349.79		
Cover (m):	0.56		
Rail Bed Condition:	Fair - Erosion		

Pipe Condition:		Poor Significant exterior corrosion - some spots corroded through	
Inlet:		Submerged under mud, not found	
Outlet:		Submerged under water (Mara Lake), end is deformed (smashed by lake debris)	
Headwall:	**US:**	n/a	
	DS:	n/a	
Rip Rap:	**US:**	n/a	**DS:** n/a
Trash Rack:		n/a	

STREAM:

Flow Type/Source:		Ditch flow - draining towards Mara Lake						
Water Depth (m):		Lake	**Water Level Width (m):**		Lake	**Freeboard (m):**		0.80
High Water:		Yes	**Scour:**	Yes	**Debris:**	Yes	**Aggradation:**	Yes

COMMENTS:

Erosion of rail bed on lake side (see photo above) - part of rail bed has disappeared and downstream end of culvert is exposed, high water at lake, no water at upstream end

REPAIR:

Repair Priority:	High
Repair/Action Item:	Replace - culvert corroded and damaged, clean out ditch

CULVERT #3 - KM 4.57

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 8, 2020
WWAL ID:	n/a

CULVERT:

Diameter (mm):	600		
Material:	CSP		
Length (m):	8.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	1.0
Invert (m):			
US:	no shot	**DS:**	348.56
Top of Rail Bed (m):	349.64		
Cover (m):	0.49		
Rail Bed Condition:	Fair - Erosion		

Pipe Condition:		Excellent Based on culvert exterior observations, unable to observe interior of culvert	
Inlet:		Plugged with mud, not found	
Outlet:		Submerged 75% under lake water (Mara Lake)	
Headwall:	**US:**	n/a	
	DS:	n/a	
Rip Rap:	**US:**	n/a	**DS:** n/a
Trash Rack:		n/a	

STREAM:

Flow Type/Source:		Ditch flow - draining towards Mara Lake					
Water Depth (m):		Lake	**Water Level Width (m):**		Lake	**Freeboard (m):**	0.68
High Water:		Yes	**Scour:**	Yes	**Debris:**	Yes	**Aggradation:** Yes

COMMENTS:

Some erosion/scour around culvert on lake side (Mara Lake), high water at lake, no water at upstream end, debris upstreams

REPAIR:

Repair Priority:	Low
Repair/Action Item:	Clean out ditch and culvert inlet

CULVERT #4 - KM 7.70

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 8, 2020
WWAL ID:	n/a

CULVERT:

Diameter (mm):	600		
Material:	Concrete		
Length (m):	10.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	350.37	**DS:**	348.67
Top of Rail Bed (m):	351.12		
Cover (m):	1.00		
Rail Bed Condition:	Good		

Pipe Condition:		Good		
Inlet:		Good condition - No rocks and debris		
Outlet:		Submerged 30% under lake water (Mara Lake)		
Headwall:	**US:**	Concrete headwall - some concrete has chipped off (minor)		
	DS:	Concrete headwall - at lake		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Ditch flow - draining towards Mara Lake						
Water Depth (m):		0.08	**Water Level Width (m):**		0.70	**Freeboard (m):**		0.67
High Water:		Yes	**Scour:**	No	**Debris:**	No	**Aggradation:**	No

COMMENTS:

Discolouration/possible high water mark about halfway up in culvert, high water at lake, some floating debris on lake at outlet

REPAIR:

Repair Priority:	Low
Repair/Action Item:	None

CULVERT #5 - KM 11.26

SICAMOUS TO ARMSTRONG RAIL TRAIL

STORMWATER MANAGEMENT

Project No. 1928-011

Date Inspected:	June 8, 2020		
WWAL ID:	Culvert #3		

CULVERT:

Diameter (mm):	400		
Material:	CSP		
Length (m):	6.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	351.08	**DS:**	no shot
Top of Rail Bed (m):	352.23		
Cover (m):	0.75		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Deformed, filled 50% with rocks	
Inlet:		Deformed 20%, filled 50% with rocks	
Outlet:		Not observed, unsafe slope	
Headwall:	**US:**	Rocks utilized as headwall	
	DS:	Not observed, unsafe slope	
Rip Rap:	**US:**	n/a	**DS:** n/a
Trash Rack:		n/a	

STREAM:

Flow Type/Source:	Ditch flow - draining towards Mara Lake						
Water Depth (m):	0.05	**Water Level Width (m):**		0.50	**Freeboard (m):**	0.90	
High Water:	No	**Scour:**	No	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

REPAIR:

Repair Priority:	High
Repair/Action Item:	Replace - end deformed and filled with rocks, clean out ditch and culvert inlet

CULVERT #6 - KM 11.59

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 8, 2020
WWAL ID:	Culvert #5

CULVERT:

Diameter (mm):	600		
Material:	Concrete		
Length (m):	10.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	351.61	**DS:**	349.69
Top of Rail Bed (m):	352.32		
Cover (m):	1.07		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Concrete segment has detached, cave-in at detached segment		
Inlet:		Pipe recessed from headwall, some rocks		
Outlet:		Water dropping into scour pool		
Headwall:	**US:**	Concrete headwall - some rocks, headwall seems to be toppling		
	DS:	Concrete headwall		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:	Ditch flow - draining towards Mara Lake						
Water Depth (m):	0.10	**Water Level Width (m):**		0.60	**Freeboard (m):**		0.61
High Water:	No	**Scour:**	Yes	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

Due to the detached segment, the embedment material around the culvert may be eroded away and the culvert is possibly undermined, some minor aggradation in inlet

REPAIR:

Repair Priority:	High
Repair/Action Item:	Replace - detached segment, possible culvert undermining

CULVERT #7 - KM 12.12

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 8, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	300		
Material:	CSP		
Length (m):	6.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	351.66	**DS:**	351.24
Top of Rail Bed (m):	352.33		
Cover (m):	0.59		
Rail Bed Condition:	Good		

Pipe Condition:		Fair Filled 50% with sediments, visible interior of culvert is in good condition		
Inlet:		Filled 75% with sediments, rocks and debris		
Outlet:		Filled 50% with sediments, rocks and debris		
Headwall:	**US:**	n/a		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Ditch flow - draining towards Mara Lake						
Water Depth (m):		0.05	**Water Level Width (m):**		0.40	**Freeboard (m):**		0.40
High Water:		No	**Scour:**	No	**Debris:**	Yes	**Aggradation:**	Yes

COMMENTS:

Upstreams of inlet sediments and debris have built up causing a waterfall effect into culvert

REPAIR:

Repair Priority:	High
Repair/Action Item:	Clean out culvert and ditch

CULVERT #8 - KM 12.32

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 8, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	400		
Material:	CSP		
Length (m):	5.5		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	351.53	**DS:**	351.22
Top of Rail Bed (m):	352.54		
Cover (m):	0.77		
Rail Bed Condition:	Good		

Pipe Condition:		Good Some visible corrosion on culvert floor					
Inlet:		Overgrown with vegetation					
Outlet:		Some overgrown vegetation					
Headwall:	**US:**	n/a					
	DS:	n/a					
Rip Rap:	**US:**	n/a		**DS:**	n/a		
Trash Rack:		n/a					

STREAM:

Flow Type/Source:		Ditch flow - draining towards Mara Lake					
Water Depth (m):		0.09	**Water Level Width (m):**		0.50	**Freeboard (m):**	0.92
High Water:		No	**Scour:**	No	**Debris:**	No	**Aggradation:** Yes

COMMENTS:

Discolouration/possible high water mark about halfway up in culvert, some sediments in ditch at inlet

REPAIR:

Repair Priority:	Low
Repair/Action Item:	None

CULVERT #9 - KM 12.44

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 8, 2020
WWAL ID:	Culvert #7

CULVERT:

Diameter (mm):	300		
Material:	CSP		
Length (m):	9.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	2.0
Invert (m):			
US:	351.44	**DS:**	350.73
Top of Rail Bed (m):	352.06		
Cover (m):	0.68		
Rail Bed Condition:	Good		

Pipe Condition:		Fair Visible corrosion on culvert floor and sidewalls	
Inlet:		Some debris at inlet	
Outlet:		Situated above ground, water is dropping onto rocks below - about 1 metre drop	
Headwall:	**US:**	n/a	
	DS:	n/a	
Rip Rap:	**US:**	n/a	**DS:** n/a
Trash Rack:		n/a	

STREAM:

Flow Type/Source:		Ditch flow - draining towards Mara Lake					
Water Depth (m):		0.12	**Water Level Width (m):**		0.70	**Freeboard (m):**	0.50
High Water:		No	**Scour:**	Yes	**Debris:**	Yes	**Aggradation:** No

COMMENTS:

Some scouring downstream of culvert due to water dropping from culvert

REPAIR:

Repair Priority:	Medium
Repair/Action Item:	Replace - corrosion

CULVERT #10 - KM 18.27

SICAMOUS TO ARMSTRONG RAIL TRAIL

STORMWATER MANAGEMENT

Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 8, 2020		
WWAL ID:	Culvert #8		
CULVERT:			
Diameter (mm):	Not determined		
Material:	Not determined		
Length (m):	8.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Obvert (m):			
US:	348.62	**DS:**	348.52
Top of Rail Bed (m):	349.78		
Cover (m):	1.21		
Rail Bed Condition:	Good		

Pipe Condition:		Not determined Fully submerged pipe. Water level = 348.97 (±0.4m above obvert).					
Inlet:		Not determined, submerged.					
Outlet:		Not determined, submerged					
Headwall:	**US:**	Concrete headwall - fair condition, 1913 concrete imprint.					
	DS:	Concrete headwall - fair condition, 1913 concrete imprint.					
Rip Rap:	**US:**	n/a		**DS:**	n/a		
Trash Rack:		n/a					

STREAM:

Flow Type/Source:	Stream cutting through pastures - draining towards Rosemond Lake						
Water Depth (m):	1.08	**Water Level Width (m):**		2.00	**Freeboard (m):**		0.81
High Water:	Yes	**Scour:**	No	**Debris:**	No	**Aggradation:**	No

COMMENTS:

Pipe is submerged, condition could not be assessed.

REPAIR:

Repair Priority:	Could not be determined
Repair/Action Item:	Could not be determined

CULVERT #11 - KM 21.04

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 9, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	2-150 & 2-75		
Material:	CI & PVC		
Length (m):	6.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	349.38	**DS:**	349.26
Top of Rail Bed (m):	350.58		
Cover (m):	1.11		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Not a proper culvert. Filled with rocks and sediments. Undersized.	
Inlet:		Poor condition	
Outlet:		50% filled with rocks and sediments	
Headwall:	**US:**	n/a	
	DS:	n/a	
Rip Rap:	**US:**	n/a	**DS:** n/a
Trash Rack:		n/a	

STREAM:

Flow Type/Source:	Ditch flow - draining towards the Shuswap River						
Water Depth (m):	0.07	**Water Level Width (m):**		River	**Freeboard (m):**		1.13
High Water:	Yes	**Scour:**	No	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

Flooded Shuswap RIver backing into culverts. Outlet filled with rocks, rocks removed to inspect culvert.

REPAIR:

Repair Priority:	High
Repair/Action Item:	Remove and replace with higher capacity culvert.

CULVERT #12 - KM 21.25

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 9, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	450		
Material:	CSP		
Length (m):	8.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	349.35	**DS:**	349.02
Top of Rail Bed (m):	350.92		
Cover (m):	1.29		
Rail Bed Condition:	Good		

Pipe Condition:		Good Corrossion visible on floor.	
Inlet:		Some rocks and sediments.	
Outlet:		Submerged, some rocks and sediment.	
Headwall:	**US:**	Concrete headwall	
	DS:	Concrete headwall	
Rip Rap:	**US:**	n/a	**DS:** n/a
Trash Rack:		n/a	

STREAM:

Flow Type/Source:	Ditch flow - draining towards the Shuswap River (standing water June 09)						
Water Depth (m):	0.45	**Water Level Width (m):**		1.40	**Freeboard (m):**	1.46	
High Water:	No	**Scour:**	No	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

Farmer excavated deep pools at upstream and downtream ends.

REPAIR:

Repair Priority:	Medium
Repair/Action Item:	Replace - corrosion

CULVERT #13 - KM 21.66

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 9, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	450		
Material:	CSP		
Length (m):	6.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	350.05	**DS:**	350.07
Top of Rail Bed (m):	351.58		
Cover (m):	1.07		
Rail Bed Condition:	Good		

Pipe Condition:		Fair Scattered visibile corrossion with varying severity. Sediments and rocks in culvert. Culvert is flat.						
Inlet:		Some sediments and significant corrosion.						
Outlet:		Some sediments and significant corrosion.						
Headwall:	**US:**	Concrete headwall - overgrown.						
	DS:	Concrete headwall - overgrown.						
Rip Rap:	**US:**	n/a		**DS:**	n/a			
Trash Rack:		n/a						

STREAM:

Flow Type/Source:		Ditch flow - draining towards the Shuswap River (dry on June 09)					
Water Depth (m):		0.00	**Water Level Width (m):**		0.50	**Freeboard (m):**	1.51
High Water:		No	**Scour:**	No	**Debris:** No	**Aggradation:**	Yes

COMMENTS:

REPAIR:

Repair Priority:	Medium
Repair/Action Item:	Replace, some corrosion.

CULVERT #14 - KM 23.25

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 9, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	1400		
Material:	CSP		
Length (m):	11.0		
Mitered:	n/a		
Projection Length (m):			
US:	0.9	**DS:**	2.0
Invert (m):			
US:	351.21	**DS:**	350.92
Top of Rail Bed (m):	353.87		
Cover (m):	1.41		
Rail Bed Condition:	Good		

Pipe Condition:		Good Some sediments					
Inlet:		Significant sediments (±0.3m)					
Outlet:		Some sediment					
Headwall:	**US:**	n/a					
	DS:	n/a					
Rip Rap:	**US:**	n/a		**DS:**	n/a		
Trash Rack:		n/a					

STREAM:

Flow Type/Source:		Stream flow - draining towards the Shuswap River					
Water Depth (m):		0.05	**Water Level Width (m):**		1.5 & 2.5	**Freeboard (m):**	2.61
High Water:		No	**Scour:**	No	**Debris:**	Some	**Aggradation:**	Some

COMMENTS:

Water Level Width US = 1.5m DS = 2.5m

REPAIR:

Repair Priority:	Low
Repair/Action Item:	Good condition, clean out sediments.

CULVERT #15 - KM 23.94

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 9, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	600		
Material:	CSP		
Length (m):	23.0		
Mitered:	n/a		
Projection Length (m):			
US:	0.6	**DS:**	0.5
Invert (m):			
US:	352.24	**DS:**	352.34
Top of Rail Bed (m):	353.64		
Cover (m):	0.75		
Rail Bed Condition:	Good		

Pipe Condition:		Good Slight rise - negative slope, some very minor corrossion has started						
Inlet:		75% submerged, culvert invert above channel invert (±0.39m)						
Outlet:		Invert higher than US Invert - reduced capacity						
Headwall:	**US:**	n/a						
	DS:	n/a						
Rip Rap:	**US:**	n/a			**DS:**	n/a		
Trash Rack:		n/a						
STREAM:								
Flow Type/Source:		Ditch flow - draining towards the Shuswap River						
Water Depth (m):		0.8 & 0.03	**Water Level Width (m):**			3.0 & 1.0	**Freeboard (m):**	0.98
High Water:		Yes	**Scour:**	No	**Debris:**	No	**Aggradation:**	No

COMMENTS:

Water depth: US 0.8m standing water, DS 0.03m
Water Level Width: 3.0 US, 1.0 DS
Culvert installed higher than the pool and at a negative slope - standing water with limited drainage

REPAIR:

Repair Priority:	Low
Repair/Action Item:	Pipe in good condition, may need to investigate and/or correct negative slope of culvert and lower culvert to drain pool

CULVERT #16 - KM 28.04

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 9, 2020
WWAL ID:	Culvert #9

CULVERT:

Diameter (mm):	1000		
Material:	CSP		
Length (m):	20.0		
Mitered:	n/a		
Projection Length (m):			
US:	0.2	**DS:**	0.5
Invert (m):			
US:	351.70	**DS:**	351.24
Top of Rail Bed (m):	354.86		
Cover (m):	2.39		
Rail Bed Condition:	Good		

Pipe Condition:		Fair Partly submerged, debris buildup and blockage		
Inlet:		60% submerged, 75% debris buildup and blockage, small pool		
Outlet:		95% submerged, large deep pool		
Headwall:	**US:**	Rocks utilized as headwall		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Stream flow - draining towards the Shuswap River					
Water Depth (m):		0.50	**Water Level Width (m):**		2.00	**Freeboard (m):**	2.56
High Water:		Yes	**Scour:**	No	**Debris:**	Yes	**Aggradation:**	Yes

COMMENTS:

Downstream pool very deep, unsafe to enter.

REPAIR:

Repair Priority:	Medium
Repair/Action Item:	Clean out debris and sediment.

CULVERT #17 - KM 30.43

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 9, 2020		
WWAL ID:	Culvert #10		

CULVERT:

Diameter (mm):	1500		
Material:	CSP		
Length (m):	12.0		
Mitered:	n/a		
Projection Length (m):			
US:	1.5	**DS:**	2.0
Invert (m):			
US:	349.71	**DS:**	349.68
Top of Rail Bed (m):	352.19		
Cover (m):	1.00		
Rail Bed Condition:	Good		

Pipe Condition:		Excellent 40% submerged, some sediments		
Inlet:		Excellent condition		
Outlet:		Scour pool (±0.45m)		
Headwall:	**US:**	n/a		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Stream flow - draining towards the Shuswap River						
Water Depth (m):		1.04	**Water Level Width (m):**		2.50	**Freeboard (m):**		1.92
High Water:		No	**Scour:**	Some	**Debris:**	No	**Aggradation:**	Some

COMMENTS:

REPAIR:

Repair Priority:	Low
Repair/Action Item:	Looks brand new, clean out some sediments.

CULVERT #18 - KM 32.55

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 9, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	600		
Material:	CSP		
Length (m):	11.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	350.54	**DS:**	350.50
Top of Rail Bed (m):	353.10		
Cover (m):	1.98		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Severe corrosion, damaged - reduced capacity, 80% submerged		
Inlet:		Severe corrosion, 80% submerged		
Outlet:		Culvert end squished - only 50% capacity, severe corrosion , 75% submerged		
Headwall:	**US:**	n/a		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Steam flow or ditch drainage from timber mill - draining towards the Shuswap River					
Water Depth (m):		0.50	**Water Level Width (m):**		2.00	**Freeboard (m):**	2.06
High Water:		Yes	**Scour:**	No	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

Oil and sediments coming from upstream timber mill - channel is sediment laden.

REPAIR:

Repair Priority:	High
Repair/Action Item:	Corroded and damaged - replace.

CULVERT #19 - KM 31.65

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 9, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	2000		
Material:	CSP		
Length (m):	9.0		
Mitered:	Yes		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	no shot	**DS:**	349.34
Top of Rail Bed (m):	352.37		
Cover (m):	1.03		
Rail Bed Condition:	Good		

Pipe Condition:		Good 68% submerged in standing water, pipes within the culvert reduce capacity		
Inlet:		68% submerged, mitered end		
Outlet:		68% submerged, not able to access fully due to brush		
Headwall:	**US:**	n/a		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:	Stream flow - draining towards the Shuswap River						
Water Depth (m):	1.35	**Water Level Width (m):**		Pool	**Freeboard (m):**	1.68	
High Water:	Yes	**Scour:**	No	**Debris:**	Yes	**Aggradation:**	Yes

COMMENTS:

A 300mm CSP and a 100mm zinc coated pipe are mounted within the culvert - seems to be intended for agricultural irrigation and was most likely illegially installed by a farmer. The pipes and hangars within the culvert can also catch debris during flowing water and plug the culvert. Some log and branches at culvert.

REPAIR:

Repair Priority:	Low
Repair/Action Item:	Some cleaning, may consider removing pipes within the culvert

CULVERT #20 - KM 20.24

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 9, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	600		
Material:	CSP		
Length (m):	9.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	349.61	**DS:**	349.27
Top of Rail Bed (m):	351.33		
Cover (m):	1.29		
Rail Bed Condition:	Good		

Pipe Condition:		Good Some mild corrosion starting on culvert floor, internal culvert coating is flaky, some sediments			
Inlet:		Good condition			
Outlet:		Good condition, some sediments and overgrown vegetation			
Headwall:	**US:**	n/a			
	DS:	na/			
Rip Rap:	**US:**	n/a		**DS:**	n/a
Trash Rack:		n/a			

STREAM:

Flow Type/Source:		Ditch flow - draining towards the Shuswap River					
Water Depth (m):		0.13	**Water Level Width (m):**		0.80	**Freeboard (m):**	1.68
High Water:		No	**Scour:**	No	**Debris:** No	**Aggradation:**	Some

COMMENTS:

REPAIR:

Repair Priority:	Low
Repair/Action Item:	Clean out culvert

CULVERT #21 - KM 37.17

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 10, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	300		
Material:	CSP		
Length (m):	27.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	1.9
Invert (m):			
US:	353.31	**DS:**	351.61
Top of Rail Bed (m):	355.43		
Cover (m):	2.22		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Very minor corrosion, ends damaged - reducing capacity					
Inlet:		Culvert end is corroded, cracked and collapsed					
Outlet:		Culvert end is squished - 50% capacity.					
Headwall:	**US:**	n/a					
	DS:	n/a					
Rip Rap:	**US:**	n/a		**DS:**	n/a		
Trash Rack:		n/a					

STREAM:

Flow Type/Source:	Ditch flow - draining towards Fortune Creek						
Water Depth (m):	0.00	**Water Level Width (m):**		Creek DS	**Freeboard (m):**		2.12
High Water:	Yes	**Scour:**	No	**Debris:**	No	**Aggradation:**	No

COMMENTS:

Downstream culvert end located close to Fortune Creek - about 2m from creek (high water level at time of inspection). Currently no flow through culvert, upstream ditch is dry.

REPAIR:

Repair Priority:	High
Repair/Action Item:	Corroded, damaged and collapsed - replace

CULVERT #22- KM 37.36

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 10, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	600		
Material:	CSP		
Length (m):	12.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	0.6
Invert (m):			
US:	356.17	**DS:**	355.12
Top of Rail Bed (m):	357.53		
Cover (m):	1.29		
Rail Bed Condition:	Good		

Pipe Condition:		Good Some corrosion on culvert floor, coating gone on floor, remaining coating is flaky	
Inlet:		Some ballast rock at inlet	
Outlet:		Good condition	
Headwall:	**US:**	n/a	
	DS:	n/a	
Rip Rap:	**US:**	n/a	**DS:** n/a
Trash Rack:		n/a	

STREAM:

Flow Type/Source:		Ditch flow - draining towards Fortune Creek					
Water Depth (m):		0.03	**Water Level Width (m):**	0.40		**Freeboard (m):**	1.33
High Water:		No	**Scour:**	No	**Debris:**	No	**Aggradation:** Some

COMMENTS:

REPAIR:

Repair Priority:	Low
Repair/Action Item:	Clean out inlet end and prevent ballast from entering culvert

CULVERT #23 - KM 40.0

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 10, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	600		
Material:	CSP		
Length (m):	8.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	351.95	**DS:**	no shot
Top of Rail Bed (m):	354.56		
Cover (m):	2.01		
Rail Bed Condition:	Good		

Pipe Condition:		Good 30% filled with rocks		
Inlet:		Rocks sliding into inlet, top of culvert end deflected		
Outlet:		Not able to access due to unsafe slope & toppling headwall rocks		
Headwall:	**US:**	Rocks utilized as headwall		
	DS:	Rocks utilized as headwall		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Ditch/stream flow - draining towards Fortune Creek					
Water Depth (m):		0.03	**Water Level Width (m):**		0.70	**Freeboard (m):**	2.41
High Water:		No	**Scour:**	No	**Debris:**	No	**Aggradation:** Yes

COMMENTS:

Tree blocking outlet - reducing capacity to 50%

REPAIR:

Repair Priority:	Medium
Repair/Action Item:	Clean out rocks from culvert and remove tree/vegetation at outlet

CULVERT #24 - KM 44.42

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 10, 2020		
WWAL ID:	Culvert #11		
CULVERT:			
Diameter (mm):	2 - 600		
Material:	CSP		
Length (m):	6.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	351.89	**DS:**	351.74
Top of Rail Bed (m):	353.27		
Cover (m):	0.86		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Some corrosion, filled 35% with sediments, 60% submerged, coating is flaking off. Both culverts are in similar condition.	
Inlet:		35% filled with sediment	
Outlet:		50% filled with sediment	
Headwall:	**US:**	Concrete sandbag headwall - erosion headwall and wing wall being undermined	
	DS:	n/a	
Rip Rap:	**US:**	n/a	**DS:** n/a
Trash Rack:		n/a	

STREAM:

Flow Type/Source:	Stream flow - draining towards Fortune Creek						
Water Depth (m):	0.10	**Water Level Width (m):**		2.30	**Freeboard (m):**	1.04	
High Water:	No	**Scour:**	No	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

Significant sediments within culvert, channel is sediment laden

REPAIR:

Repair Priority:	High
Repair/Action Item:	Clean out channel, replace culvert and headwall

CULVERT #25 - KM 44.61

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 10, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	400		
Material:	CSP		
Length (m):	6.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	352.03	**DS:**	352.10
Top of Rail Bed (m):	352.94		
Cover (m):	0.48		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Severely corroded floor and sidewalls, filled 35-50% with rocks, negative slope (downstream is at a higher elevation than upstreams)					
Inlet:		Filled 35% with rocks, submerged 50% under standing water					
Outlet:		Filled 50% with rocks					
Headwall:	**US:**	n/a					
	DS:	n/a					
Rip Rap:	**US:**	n/a		**DS:**	n/a		
Trash Rack:		n/a					
STREAM:							
Flow Type/Source:		Ditch flow - draining towards Fortune Creek					
Water Depth (m):		0.00	**Water Level Width (m):**		2.00	**Freeboard (m):**	0.70
High Water:		No	**Scour:**	No	**Debris:**	Some	**Aggradation:** Yes

COMMENTS:

Standing water upstreams, no water downstream

REPAIR:

Repair Priority:	High
Repair/Action Item:	Corroded - replace

CULVERT #26 - KM 46.37

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 10, 2020
WWAL ID:	n/a

CULVERT:

Diameter (mm):	2-1200		
Material:	CSP		
Length (m):	10.0		
Mitered:	n/a		
Projection Length (m):			
US:	0.5	**DS:**	n/a
Invert (m):			
US:	353.94	**DS:**	353.76
Top of Rail Bed (m):	355.95		
Cover (m):	0.90		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Significant sediments within culvert, over 90% submerged, visible exterior corrosion, internal assessment of culvert could not be completed due to the culvert being submerged		
Inlet:		65% filled with sediments, 95% submerged		
Outlet:		65-75% filled with sediments, 100% submerged		
Headwall:	**US:**	Erosion undermining headwall		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Stream flow - draining towards Fortune Creek						
Water Depth (m):		see blw.	**Water Level Width (m):**		2.50		**Freeboard (m):**	1.02
High Water:		Yes	**Scour:**	Yes	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

Water Depth (m): US - Right Culvert = 0.4, Left Culvert = 1.4 > DS - Right Culvert = 0.2, Left Culvert = 0.5
Upstream Left Culvert has deep pool

REPAIR:

Repair Priority:	High
Repair/Action Item:	Clean out and further assess culvert - internal corossion most likely, as exterior corrosion has been observed

CULVERT #27 - KM 47.13

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 10, 2020
WWAL ID:	n/a

CULVERT:

Diameter (mm):	600		
Material:	CSP		
Length (m):	12.0		
Mitered:	Yes		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	356.75	**DS:**	356.67
Top of Rail Bed (m):	357.45		
Cover (m):	0.14		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Corrosion, sediments, partly submerged		
Inlet:		Some sediments, scouring, 40% submerged		
Outlet:		Sediments, 100% submerged		
Headwall:	**US:**	n/a		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Stream flow - draining towards Fortune Creek						
Water Depth (m):		see blw.	**Water Level Width (m):**		1.00	**Freeboard (m):**	1.01	
High Water:		Yes	**Scour:**	Yes	**Debris:**	No	**Aggradation:**	Yes

COMMENTS:

Water Depth (m): US = 0.2 DS = 0.7
Culvert partially plugged or collapsed

REPAIR:

Repair Priority:	High
Repair/Action Item:	Assess culvert further during low flows regarding possible plugging or collapse, if no plugging or collapse is observed, repair priority is medium - culvert corroded - replace

CULVERT #28 - KM 47.59

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Date Inspected:	June 10, 2020		
WWAL ID:	n/a		
CULVERT:			
Diameter (mm):	800		
Material:	CSP		
Length (m):	8.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	355.59	**DS:**	355.24
Top of Rail Bed (m):	356.78		
Cover (m):	0.57		
Rail Bed Condition:	Good		

Pipe Condition:		Fair Visible corrosion on culvert floor		
Inlet:		Some erosion and scouring		
Outlet:		Scour pool, some erosion		
Headwall:	**US:**	n/a		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:		Stream flow - draining towards Fortune Creek						
Water Depth (m):		0.22	**Water Level Width (m):**		1.00		**Freeboard (m):**	1.06
High Water:		No	**Scour:**	Yes	**Debris:**	No	**Aggradation:**	No

COMMENTS:

REPAIR:

Repair Priority:	Medium
Repair/Action Item:	Corrosion - replace

CULVERT #29 - KM 48.20

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 10, 2020		
WWAL ID:	Culvert #12		
CULVERT:			
Diameter (mm):	600		
Material:	CSP		
Length (m):	10.0		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	n/a
Invert (m):			
US:	355.99	**DS:**	no shot
Top of Rail Bed (m):	358.48		
Cover (m):	1.89		
Rail Bed Condition:	Good		

Pipe Condition:		Poor Culvert caved in or downstream culvert end squished - culvert damaged					
Inlet:		25% filled with sediments					
Outlet:		High headwall, overgrown, unsafe to access					
Headwall:	**US:**	Rocks utilized as headwall					
	DS:	Rocks utilized as headwall					
Rip Rap:	**US:**	n/a		**DS:**	n/a		
Trash Rack:		n/a					

STREAM:

Flow Type/Source:		Ditch flow - draining towards Fortune Creek					
Water Depth (m):		None	**Water Level Width (m):**		None	**Freeboard (m):**	2.49
High Water:		No	**Scour:**	No	**Debris:** No	**Aggradation:**	Yes

COMMENTS:

Cave-in or downstream culvert end squished observed at the upstream end by looking through the culvert - downstream end could not be accessed safely

REPAIR:

Repair Priority:	High
Repair/Action Item:	Replace - damaged culvert

STORM OUTFALL ENDERBY - KM 37.02

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

Date Inspected:	June 10, 2020		
WWAL ID:	n/a		

CULVERT:

Diameter (mm):	300		
Material:	Ribbed PVC		
Length (m):	Unknown		
Mitered:	n/a		
Projection Length (m):			
US:	n/a	**DS:**	0.5
Invert (m):			
US:	n/a	**DS:**	352.57
Top of Rail Bed (m):	354.72		
Cover (m):	1.85		
Rail Bed Condition:	Good		

Pipe Condition:		Good		
Inlet:		Unrated, storm sewer		
Outlet:		City of Enderby storm outfall, scour pool with channel		
Headwall:	**US:**	n/a		
	DS:	n/a		
Rip Rap:	**US:**	n/a	**DS:**	n/a
Trash Rack:		n/a		

STREAM:

Flow Type/Source:	City of Enderby storm system - draining towards Fortune Creek							
Water Depth (m):		0.30	**Water Level Width (m):**		1.30	**Freeboard (m):**	2.34	
High Water:		No	**Scour:**	Yes	**Debris:**	No	**Aggradation:**	No

COMMENTS:

Storm sewer appears to be coming from park adjacent to the rail trail

REPAIR:

Repair Priority:	Low
Repair/Action Item:	none - City of Enderby's infrastructure

APPENDIX C

Minor and Major Drainage Courses

MINOR AND MAJOR DRAINAGE COURSES

SICAMOUS TO ARMSTRONG RAIL TRAIL
STORMWATER MANAGEMENT
Project No. 1928-011

TRUE CONSULTING

Stream ID	Stream Name	Station (km)	Stream Order	Major Drainage Course	Culvert Found Nearby	Culvert Size (mm)	Comments
1	Unnamed	2.26	1st	No	No	-	Nearest culvert at km 1.92 (400mm)
2	Unnamed	7.30	1st	No	No	-	
3	Unnamed	7.70	1st	No	Yes	600	
4	Unnamed	10.88	1st	No	No	-	
5	Larch Hills Creek	14.81	1st	Yes	-	-	Bridge #1 - connects Mara Lake and Rosemond Lake
6	Unnamed	17.71	1st	No	No	-	
7	Unnamed	19.98	1st	No	No	-	
8	Unnamed	23.11	1st	No	No	-	Nearest culvert at km 23.25 (1400mm)
9	Violet Creek	24.28	6th	Yes	No	-	Metcalfee Creek flows into Violet Creek upstreams
10	Unnamed	24.79	4th	Yes	No	-	
11	Gardom Creek	28.04	6th	Yes	Yes	1000	
12	Unnamed	30.43	1st	No	Yes	1500	
13	Unnamed	31.65	1st	No	Yes	2000	
14	Unnamed	33.50	1st	Yes	No	-	
15	Leduc Creek	37.93	1st	Yes	No	-	
16	Unnamed	40.00	1st	No	Yes	600	
17	Fortune Creek	40.60	-	Yes	-	-	Bridge #2
18	Harland Creek	42.53	5th	Yes	-	-	Bridge #3
19	Hussard Creek	43.14	3rd	Yes	Yes	-	Culvert removed, 1500mm culvert upstream
20	Sneesby Creek	44.42	2nd	Yes	Yes	2 - 600	
21	Unnamed	44.75	1st	No	No	-	Nearest culvert at km 44.61 (400mm)
22	Lindsay Creek	45.24	3rd	Yes	No	-	
23	Glanzier Creek	46.37	5th	Yes	Yes	2 - 1200	
24	Kendry Creek	47.13	4th	Yes	Yes	600	
25	Alderson Creek	47.59	4th	Yes	Yes	800	Joyce Creek flows into Alderson Creek upstreams
26	Unnamed	47.77	1st	No	No	0	Tributary of Alderson Creek
27	Fortune Creek	48.86	-	Yes	-		Bridge #4

APPENDIX D

Maintenance, Upgrades and Mitigation Summary

MAINTENANCE, UPGRADES AND MITIGATION SUMMARY

SICAMOUS TO ARMSTRONG RAIL TRAIL

STORMWATER MANAGEMENT - Inspected: June 8 - 10, 2020

Project No. 1928-011

TRUE CONSULTING

CULVERTS

ID	Km (0 = Sicamous)	Diameter (mm)	Material	Length (m)	Cover (m)	Overall Pipe Conditon	Repair Priority	Action Item	Potential for Trenchless Rehabilition
1	1.92	400	CSP	6	0.61	Fair	Medium	Remove rocks from culvert	n/a
2	4.49	300	CSP	7	0.56	Poor	High	Replace - culvert corroded and damaged, clean out ditch	No
3	4.57	600	CSP	8	0.49	Excellent	Low	Clean out ditch and culvert inlet	n/a
4	7.70	600	Concrete	10	1.00	Good	Low	None	n/a
5	11.26	400	CSP	6	0.75	Poor	High	Replace - end deformed and filled with rocks, clean out ditch and culvert inlet	No
6	11.59	600	Concrete	10	1.07	Poor	High	Replace - detached segment, possible culvert undermining	No
7	12.12	300	CSP	6	0.59	Fair	High	Clean out culvert and ditch	n/a
8	12.32	400	CSP	5.5	0.77	Good	Low	None	n/a
9	12.44	300	CSP	9	0.68	Fair	Medium	Replace - corrosion	Yes
10	18.27	Not Determined	Not Determined	8	1.21	Not Determined	Not Determined	Could not be determined	n/a
11	21.04	2-150 & 2-75	CI & PVC	6	1.11	Poor	High	Replace with higher capacity culvert	No
12	21.25	450	CSP	8	1.29	Good	Medium	Replace - corrosion	Yes
13	21.66	450	CSP	6	1.07	Fair	Medium	Replace - some corrosion	Yes
14	23.25	1400	CSP	11	1.41	Good	Low	Good condition, clean out sediments	n/a
15	23.94	600	CSP	23	0.75	Good	Low	Pipe in good condition, may need to investigate and/or correct negative slope of culvert and lower culvert to drain pool	n/a
16	28.04	1000	CSP	20	2.39	Fair	Medium	Clean out debris and sediments	n/a
17	30.43	1500	CSP	12	1.00	Excellent	Low	Looks brand new, clean out some sediments	n/a
18	32.55	600	CSP	11	1.98	Poor	High	Replace - corroded and damaged	No
19	31.65	2000	CSP	9	1.03	Good	Low	Some cleaning, may consider removing pipes within the culvert	n/a
20	20.24	600	CSP	9	1.29	Good	Low	Clean out culvert	n/a
21	37.17	300	CSP	27	2.22	Poor	High	Replace - corroded, damaged and collapsed	No
22	37.36	600	CSP	12	1.29	Good	Low	Clean out inlet end and prevent ballast from entering culvert	n/a
23	40.00	600	CSP	8	2.01	Good	Medium	Clean out rocks from culvert and remove tree/vegetation at outlet	n/a
24	44.42	2-600	CSP	6	0.86	Poor	High	Clean out channel, replace culvert and headwall	Yes
25	44.61	400	CSP	6	0.48	Poor	High	Replace - corroded	Yes
26	46.37	2-1200	CSP	10	0.90	Poor	High	Clean out and further assess culvert - internal corossion most likely, as exterior corrosion has been observed	Yes
27	47.13	600	CSP	12	0.14	Poor	High	Assess culvert further during low flows regarding possible plugging or collapse, if no plugging or collapse is observed, repair priority is medium - replace - culvert corroded	Yes
28	47.59	800	CSP	8	0.57	Fair	Medium	Replace - corrosion	Yes
29	48.20	600	CSP	10	1.89	Poor	High	Replace - damaged culvert	No
STM Enderby	37.02	300	PVC Ribbed	Unknown	1.85	Good	Low	none - City of Enderby's infrastructure	n/a

CULVERTS REMOVED

ID	Km (0 = Sicamous)	Diameter (mm)	Material	Length (m)	Cover (m)	Overall Pipe Conditon	Repair Priority	Action Item	Potential for Trenchless Rehabilition
1	43.14	TBD	TBD	TBD	TBD	n/a	High	Replace culvert	n/a
2	46.45	TBD	TBD	TBD	TBD	n/a	High	Replace culvert	n/a

BRIDGES

ID	Km (0 = Sicamous)	Material	Number of Bridge Piers	Span (m)	Width (m)	Freeboard (June 8-10) (m)	Repair Priority	Action Item
1	14.81	Timber	2	12.50	3.60	0.75	High	Remove built up debris at bridge
2	40.60	Timber	2	13.35	3.05	2.27	Low	None
3	42.30	Timber	0	4.60	2.95	1.19	Low	None
4	48.86	Timber	2	13.60	2.95	1.93	Low	None

STORMWATER ISSUES

ID	Km (0 = Sicamous)	Description of Issue	Repair Priority	Action Item
1	0.00 - 14.80	Standing water within ditches in low lying areas	Low	None - groundwater/lake water backing up due to proximity to Mara Lake
2	1.70	Standing water in ditch	Low	Install culvert
3	3.30	Sediments and water in ditch	High	Clean out sediments and install culvert
4	15.20 - 15.80	Lake water spilling over rail bed	Low	Raise rail trail or seasonal closures of rail trail
5	20.50	Standing water in ditch	Low	Install culvert
6	21.10	Culvert request - some standing water	High	Install culvert at km 21.04 - corresponds to Culvert #11 location
7	24.30	Standing water in ditch - proximity to Violet Creek	High	Locate stream and install culvert at Violet Creek
8	25.00	High standing water in both ditches of the rail corridor	High	Locate culvert once water levels recede - if no culvert and drainage paths in west ditch found, install culvert
9	35.00	Standing water in ditch	Low	Install culvert
10	38.00 - 40.10	Standing water in ditch	Low	None - Fortune Creek backing up, confirm water levels have receded in summer
11	42.70 - 43.00	Standing water in ditch	Low	None - Fortune Creek backing up, confirm water levels have receded in summer

APPENDIX E

Trenchless Culvert Rehabilitation Report

Culvert Rehabilitation Practices

TABLE OF CONTENTS

REHABILITATION METHODS

Report Objective

The purpose of this report is to provide pertinent information regarding culvert rehabilitation (repair) methods that may be applicable in Utah. This manual is not meant to replace the installation manual provided by the manufacturer, but rather to provide a brief description of each method and its installation procedure and highlight the advantages and disadvantages of each method. This manual was developed based on the *General Culvert Barrel Rehabilitation Techniques* (Caltrans, 2003), *Culvert pipe liner guide and specification* (Central Federal Lands Highway Division, 2005), a literature review and interaction with the Utah Department of Transportation.

INTRODUCTION

Many aging culverts in the State of Utah have deteriorated to the point where replacement or repair is warranted. When deciding whether to replace or repair, it is typically more cost effective, as a rule-of-thumb, to repair when the Average Daily Traffic exceeds 1000 vehicles, the maximum cover over a culvert is more than 4 feet, and the detour route for the work area is greater than 20 minutes.

Prior to deciding whether to replace or rehabilitate the culvert, a determination of the structural integrity of the host pipe must be made. If the existing pipe is incapable of sustaining design loads, it should be replaced rather repaired (see *Figure 1*).

Figure 1. Example of collapsed culvert
(www.mnr.gov.on.ca/images)

In other cases the existing culvert may be deformed as shown in *Figure 2A*. It is still possible to repair this culvert with a drawback that the diameter of the new "**liner**" pipe will have to be smaller (assuming a rigid-wall liner were used), relative to a non-deformed pipe (see *Figure 2B*).

Figure 2A: Deformed culvert

Figure 2B: Round culvert with rusted invert

Like traditional culverts, rehabilitated culverts can operate under inlet or outlet control depending on the culvert slope, end treatments and flow conditions. When a culvert is rehabilitated, the cross-sectional area decreases because a smaller diameter liner pipe is inserted into the old pipe. If the slip-lined culvert is hydraulically smoother than the old pipe and operates under outlet control, the decreased flow area will likely be offset by the reduction in flow resistance, resulting in a similar discharge capacity. If the slip-lined culvert operates under inlet control, then an improved end treatment may be required to minimize the amount of culvert capacity flow reduction associated with the smaller diameter inlet. Currently, most slip-lined culverts have projecting end treatments with squared off ends. Little information is currently available regarding the hydraulic characteristics of end treatments specific to slip-lined culverts, however, in many cases, they may not be considerably different from traditional projecting inlets (see *figure 3*).

Figure 3. Inlet of slip-lined culvert

General Culvert Rehabilitation

Culvert rehabilitation is typically much faster and easier than removing and replacing the old culvert, particularly where there are deep fills or where trenching would cause extensive traffic disruptions. Generally, deteriorated culverts are rehabilitated by inserting a rigid-wall or flexible liner pipe that is held in place by either grout (rigid-wall liner) or a pressure and heat based curing process (flexible liner). The following six (6) methods are current rehabilitation techniques used for deteriorated culverts.

1. Slip lining
2. Spiral wound lining
3. Cured-in-place lining
4. Fold-and-form PVC lining
5. Deformed-reformed HDPE lining
6. Cement-mortar spray-on lining

A generic summary of each method will be provided in this manual and a quick reference for the specifications, materials, advantages, and disadvantages of each technique are discussed in Table 1.

Cleaning the culvert

Before installing a new liner pipe, the existing culvert must be cleaned of all debris. Where available, a vacuum truck is used for most culvert cleaning operations, otherwise a small section of pipe attached at three points and plugged is assembled and pulled through the old culvert to remove debris (see *Figure 4*). If man entry is possible a visual inspection is recommended to check for any metal pieces the new liner may get caught on. A hammer can be used to bend these pieces back. Cleaning of the existing culvert should take place a few days prior to installation of new liner to prevent further debris from entering the existing culvert.

Figure 4. Optional cleaning device for culverts
(www.culvert-rehab.com)

Grouting

Grouting of the **annular space** between the old culvert and rigid-walled liner pipe is recommended to reduce seepage, deterioration, and soil migration. Grouting also establishes a structural connection between the liner, the host pipe, and the soil. Prior to grouting, the annular space must be sealed at both ends by **bulkheads** in order to contain the grout and keep the water out if present (see *Figure 6*). Cement bulkheads are the most common. It is best to let the cement set up for a day or two before grouting. When water is present (i.e., live stream or wetlands) within the culvert, fabricating the bulkheads of Oakum soaked in water-activated urethane sealant represents a good alternative (see *Figures 5A and 5B*). When the **Oakum** is in place it sets up within minutes.

Figures 5A: Oakum being soaked in urethane sealant

Figure 5B: Inlet sealed with Oakum

Grout may be either gravity fed or pumped through a hose or small diameter pipe (1-1/2 inch to 2 inch PVC) laid in the annular space. The grout should be a low-density foam concrete consisting of portland cement and **fly ash**. This mix allows the grout to flow easily and should fill the entire annular space (see *Figure 6)*. A high-density grout maybe required to displace the water and fill the annular space if standing water is present. Grouting in lifts is recommended when using high-density grout or when grouting a culvert with a significant change in elevation between inlet and outlet. Grouting in lifts will prevent the liner from collapsing. If voids exist in the surrounding soil of the existing culvert, grout should fill the voids to provide a uniform support and prevent sinkhole from forming.

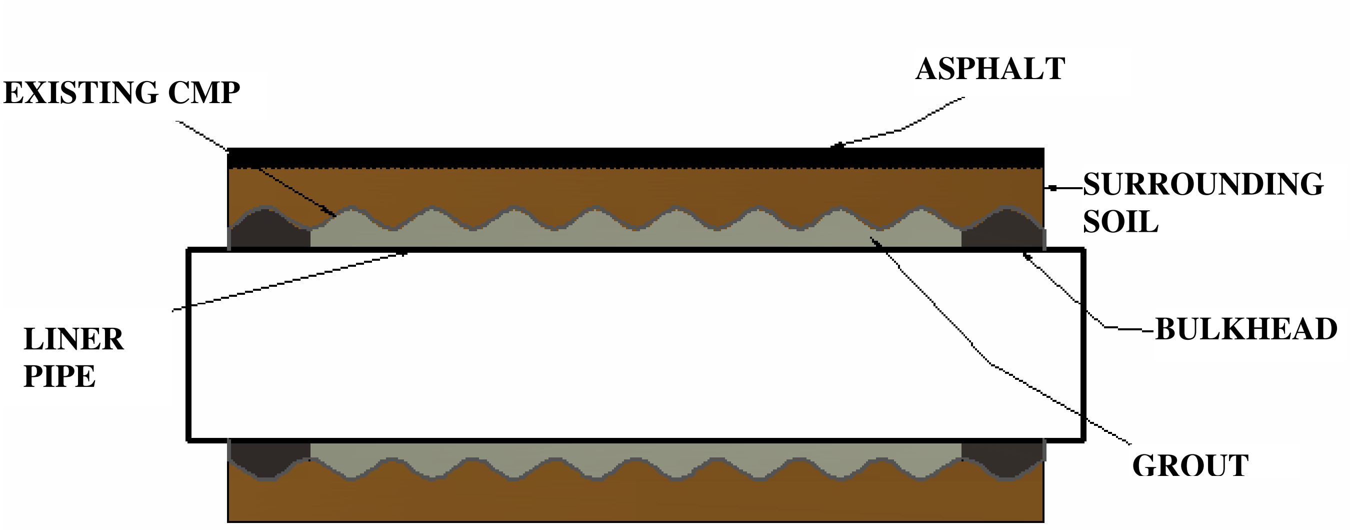

Figure 6: Model of CMP lined with HDPE liner

When preparing to pump grout, these steps are recommended: The 3 grout feed tubes running 75%, 50%, and 25% of the total length of the liner are installed. Strap the grout feed tubes to the liner every 20 feet using metal banding. 2x4 blocks are placed adjacent to the tubes to minimize direct pressure from the banding. Air tubes are placed at three, nine and twelve o'clock in each bulkhead. The air and grout feed tubes are capped when the grout begins to ooze out (see *Figure 3*). For all steps listed above refer to *Figure 7*. (This is <u>only</u> an example, designs may vary.)

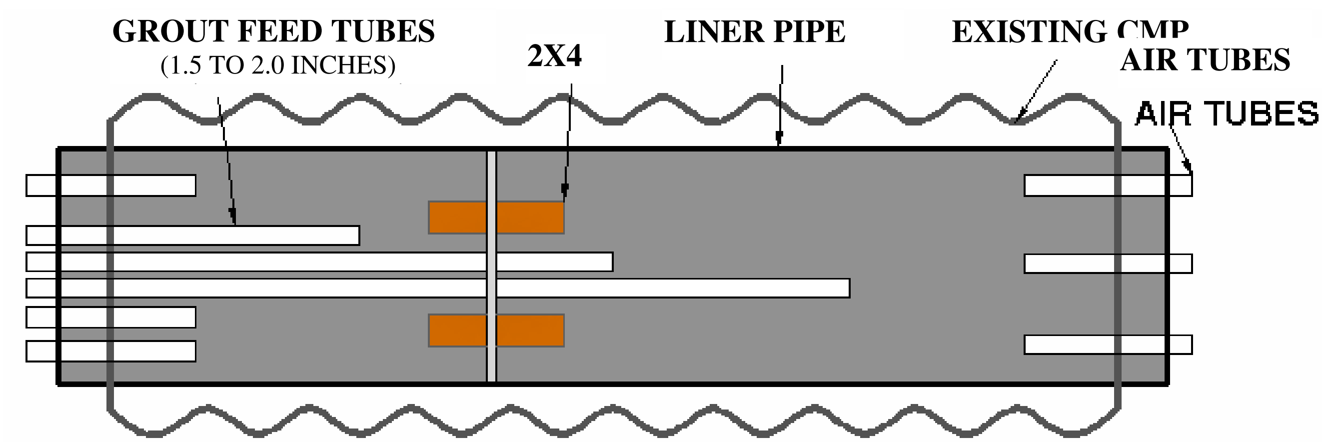

Figure 7. Plan view of model setup for grouting process.

REHABILITATION METHODS

Sliplining

Rigid-walled liner pipes are inserted into host pipe for the sliplining method. The liner pipe is moved into the culvert either one section at a time or as an entire unit after being butt-fused. The liner is pushed or pulled with jacks or construction machinery. Rigid-walled liner pipes with smooth exteriors usually will allow for easier insertion, particularly if the host pipe has a corrugated wall profile. If there are alignment changes in the old host pipe it can reduce the slip liner diameter significantly. Also, any deflections in the culvert walls will become control or pinch points. In this case a "pulling head" or "nose cone" is recommended (see *Figure 8A and 8B*). When the liner is in place, the space between the new and old culvert (annular space) and any voids that exist within the old culvert are grouted. Bulkheads must be installed before grouting to seal the ends of the pipe. Almost any type of culvert can be slip lined with an appropriately sized liner pipe. The specifications, materials, advantages, and disadvantages of slip lining are summarized in Table 1.

Figure 8A: Cutting out nose cone

Figure 8B: Nose cone

(www.cuvlert-rehab.com)

Spiral Wound Method

To line a culvert with the spiral wound method, interlocking profile strips are coiled through a winding machine that mechanically forces the strips to interlock and form a smooth, continuous, spirally wound liner (see *Figure 9*). During the interlocking process, a sealant is applied to each joint to form a watertight seam. As the material is wound and snapped together, it is forced into the existing culvert.

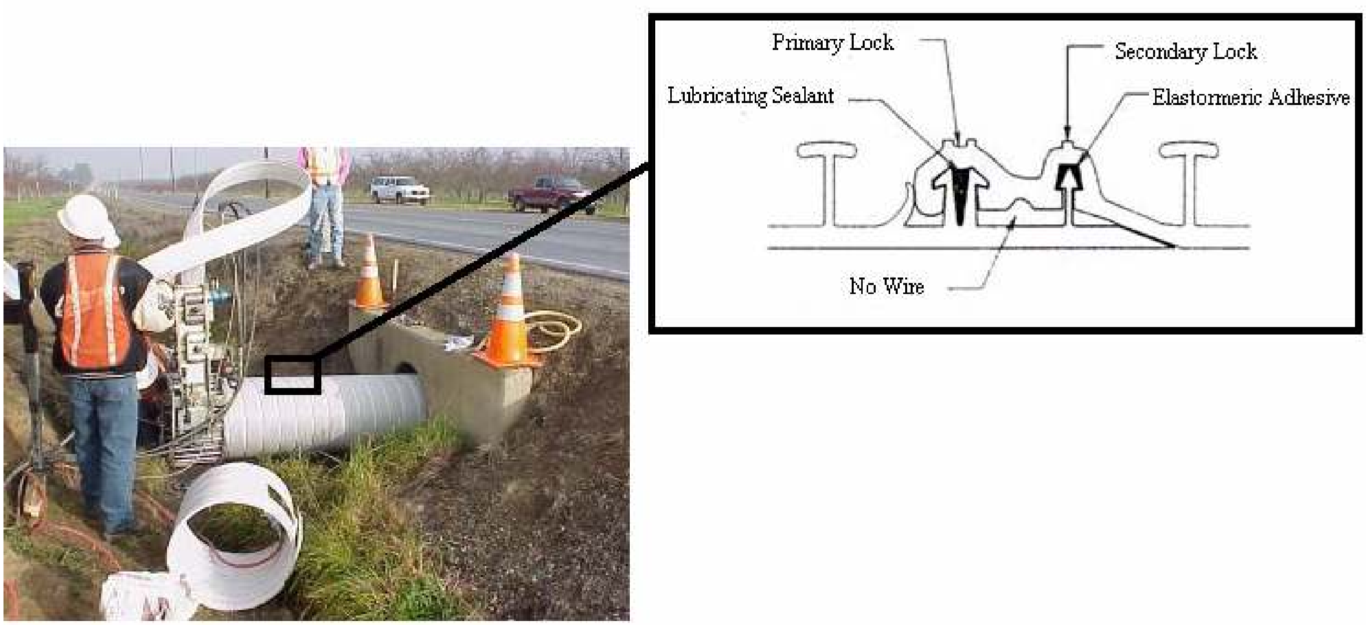

Figure 9: Rib Loc lining system
Left: (www.dot.ca.gov), Right: (www.cflhd.gov)

During installation, the spiral wound PVC liner pipe is either:

A) Inserted at a fixed diameter and then expanded until it presses against the interior surface of the existing pipe; or,
B) Inserted at a fixed diameter into the existing pipe and then grouted; or,
C) Wound against the host pipe walls by a machine that travels down the pipe.

A. Expanding liner

The expanding liner system calls for a continuous plastic strip that is spiral wound into the existing deteriorated host pipe. The male and female edges of the strip are securely locked together by the winding machine. Once a section is installed, it is expanded against the wall of the host pipe (see *Figure 10*). Both flexible and rigid pipes can be rehabilitated with this system. This lining system is similar to the fixed diameter process except that the continuous spiral joint utilizes a water activated polyurethane adhesive for sealing and no annular space grouting is required (but the pipe ends are usually grouted).

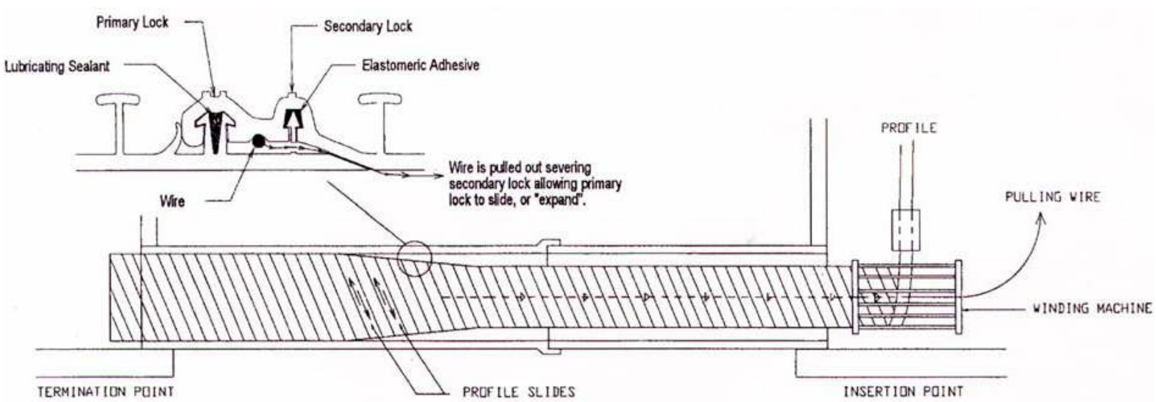

Figure 10. Spiral wound expanding system
(www.cflhd.gov)

B. Fixed-Diameter Liner (PVC or Steel Reinforced)

The fixed-diameter liner system creates a ribbed profile of PVC, requiring the annular space to be grouted. This produces an integrated structure with the PVC liner "tied" to the original pipe through the grout similar to a slip liner.

For the steel reinforced PVC lining system, a continuous strip of profiled reinforcing steel is added to the outside of the plastic pipe when specified (see *Figure 11B*). The resulting liner has a smooth plastic internal surface with increased stiffness from the steel reinforcing profile. The liner's annular space is grouted. Both flexible and rigid pipes can be rehabilitated with this system.

C. Full Bore Expanding Liner Machine

The full bore, traveling machine system creates a continuous plastic strip that is spiral wound into the existing deteriorated host pipe by a machine that rotates and lays the profile against the host pipe walls as it travels through the host pipe (see *Figure 11A*). This system has the option of a steel reinforcing section for increased load carrying capacity. The specifications, materials, advantages, and disadvantages of spiral wound lining are discussed in *Table 1*.

Figure 11A: Full Bore travel expanding machine
(www.dot.ca.gov)

Figure 11B: Steel Reinforce Lining
(www.prsrohrsanierung.de)

Cured-In-Place Lining

Cured-in-place lining installations involve the insertion of a flexible fiber tube coated with a thermosetting resin into an existing culvert. The tube is inserted either by inverting it into place using water or compressed air or by pulling it in place with a winch.

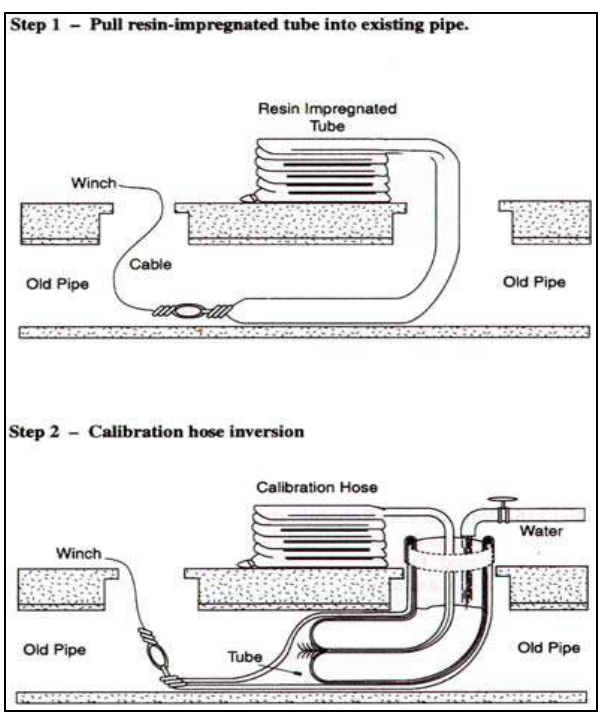

Figure 12A. Pulled in place method

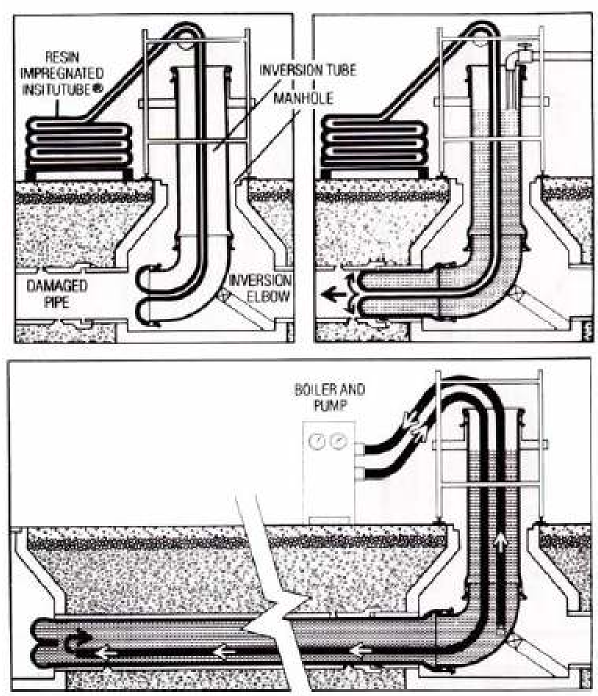

Figure 12B: Inverted method

(www.cflhd.gov)

For the pulled-in-place installation method, a winched cable is placed inside the existing pipe. The resin-impregnated liner is connected to the free end of the cable and then pulled into place between drainage structures or culvert ends. The cable is disconnected, the ends are plugged, and the liner is inflated and cured with hot water or steam (see *Figure 12A*).

For the inverted installation method, the tube is inserted inside out (inverted) and filled with water or compressed air as shown in *Figure 12B*. Generally, a polyester felt tube saturated with a liquid thermosetting resin material is used. During the process, the lining tube inverts as it travels down the pipeline. This results in the plastic outer sleeve surface becoming the inner surface of the repaired pipe and puts the resin system in contact with the existing culvert wall. Pressure inside the inverted tube, due to the water or compressed air, presses the tube against the carrier pipe wall (see *Figure 13*). Once the tube has reached the far end of the pipe section under repair, either heated water or steam is fed into the inverted tube to cure the thermosetting resin.

Figure 13. Outlet end of inverted liner

Once installed, the resin is cured under ambient conditions or through applied heat (circulating stream or hot water) throughout the tube. Unlike other lining methods, the flexible fiber lining tube is manufactured to suit specific existing culvert dimensions.

Resins, when heated, become the primary structural component of the cured-in-place system and are categorized as unsaturated polyester, vinyl ester or epoxy. Unsaturated polyester resins are the most widely used resins in cured-in-place lining systems.

Cured-in-place linings are available in felt-based, woven hose, and membrane type tubes. Felt-based lining tubes are produced from nonwoven polyester felt and coated on one face with a layer of elastomer. Felt-based tubes offer solutions to a wide range of design requirements since they can be manufactured in varying thicknesses to match individual pipe diameters. Woven hose systems, manufactured out of a circular woven, seamless, polyester fiber hose and coated on one face with a layer of elastomer, are primarily designed to rehabilitate pressure pipelines suffering from corrosion and leakage. Membrane linings are composed of very thin elastomers designed for the rehabilitation of leaking, low pressure gas mains and offer internal corrosion protection.

If water is used for curing the liner, the water must be heated continually and circulated during the curing process. Additionally, the water source to fill the tube must be accessible to the site. The application of heat hardens the resin after a few hours, forming a jointless pipe-within-a-pipe. Once set, remote controlled cutters are used to reinstate junctions and laterals.

Due to potential environmental concerns including the capture and disposal of styrene-contaminated process water, using cured-in-place lining method should generally be limited to urban drainage systems that discharge to treatment plants, otherwise all residual water will need to be captured for proper disposal. Styrene-contaminated water is fatal to fish. The specifications, materials, advantages, and disadvantages of cured-in-place lining are discussed in *Table 1*.

Fold-and-Form Lining

The fold-and-formed lining method uses a PVC pipeliner coiled on reels, which is supplied at project-specific lengths. 4- to 12-inch diameter liners are coiled in a *flat shape* as shown in *Figure 14A*. 15- to 30-inch diameter liners are coiled in an *"H" shape* as shown in *Figure 14B*.

Figure 14A. *Flat shape* liner (4- to 12-inch) (www.ultraliner.com)

Figure 14B. *"H" shape* liner (15- to 30-inch)

The liner is inserted as follows: A winch cable is fed through the host pipe and attached to the end of the pipeliner. The coiled liner is covered with a tarp and pre-heated with steam until malleable. The tarp is then removed and the liner is pulled through the host pipe. The liner is pulled through at a rate of 40 to 50 feet per minute depending on field conditions. After the liner is pulled through it is cut and sealed on both ends with pneumatic plugs (see *Figure15A* and *15B*).

Figure 15A. Cutting liner

Figure 15B. Pneumatic plug with steam and air supply line

With both ends of the liner plugged, the liner is re-heated (over several hours) and pressured using steam and air until the liner expands tightly against inside of the host pipe. The steam is replaced by compressed air to cool the liner while maintaining its shape. Once cooled, the ends of the liner are trimmed to the desired length (typically projecting some distance beyond the end of the host pipe) (see *Figure 16*). This overall process typically requires just less than a full work day per installation. The time required to heat the liner (twice) will vary with ambient temperature conditions.

Figure 16. Inlet of fold-and-form rehabilitated culvert

Deformed-Reformed HDPE Lining

During deformed-reformed lining, a HDPE solid wall pipe is deformed by mechanical force. If the nominal diameter of the HDPE liner is 18 inches or smaller, it is delivered to the job site folded on a spool (see *Figure 17A*). Larger diameters are brought to the job site in individual sections and then butt-fused and deformed on site by means of thermo-mechanical deforming equipment into a “U” shape (see *Figure 17B*).

Figure 17A: Liner installed through a drainage inlet

Figure 17B: On-site deforming equipment

(www.htliners.com)

After the liner is pulled or pushed through the existing culvert, heat is introduced into the folded liner using pressurized steam to conform the new liner to the existing culvert wall (see *Figure 18*). A remote controlled cutter reconnects laterals without excavation. The specifications, materials, advantages, and disadvantages of deformed-reformed lining are discussed in *Table 1*.

Figure 18. Steam being introduced into a 30 inch HDPE liner
(www.htliners.com)

Cement-Mortar Spray-On Lining Method

Cement-mortar spray-on liners are usually applied to existing steel and iron culverts to provide protection against corrosion. Lining is applied by the rotating head of an electric or air-powered machine (see *Figure 19A*). Mortar is supplied to the machine through a system of high-pressure hoses. A uniform thickness liner is applied as the machine moves through the existing culvert at a constant speed. The thickness of the liner applied is directly related to the speed at which the machine moves. After the liner has been applied, rotating or conical drag trowels provided a smooth troweled finish. Unless reinforced, cement-mortar spray-on lining adds little or no structural integrity to the existing culvert.

Figure 19A: Lining machine for non-man entry culverts
(www.dot.ca)

Figure 19B: Large diameter cement-mortar lining
(www.cflhd.gov)

Reinforced cement-mortar spray-on lining is limited to large diameter culverts (see *Figure 19B*). Installations are limited by pipe diameter, valve locations, bends, and length of supply hose. The specifications, materials, advantages, and disadvantages of cement-mortar lining are discussed in *Table 1*.

Conclusion

Rehabilitating rather than replacing culverts, will become more common in Utah because of the existing aging culverts are failing and population growths makes traffic control more difficult. A survey of existing culverts and site conditions and cost considerations will help determine which rehabilitation method is most appropriate.

TABLE 1. SUMMARY OF TRENCHLESS REHABILITATION METHODS.[α]

Method	Diameter (inches)	Length (feet)	Material	Advantages*	Disadvantages**
Slip lining	4 to 158	Up to 5248	HDPE, PE, PP, PVC, GRP	-Capable of large radius bends -Flow diversion not necessary during installation -Simplistic method -Low cost/less training -Applicable to all types of existing culvert materials	- Excavation required for access pits -Grouting necessary for annular space -Existing culvert must be longitudinally uniform
Cured-in-place pipe	4 to 108	Up to 3000	Thermoset Resin/ Fabric Composite	-Access pits not required -Capable of bends and varying diameters within the pipe -Grouting not required -Minimal or no reduction in flow capacity -Non-circular shapes possible -No joints	-Flow bypass is required -High material and training cost -Tubing must be specifically constructed for each project -Styrene monomer-based resins used in curing the liner are toxic to fish when discharged
Fold-and-Form	4 to 18 spool 19 to 60 onsite	300 to 400	HDPE	-Little excavation -Minimal or no reduction in flow capacity -Few or no joints -Fast installation -No grouting required -Capable of large bends	-Flow bypass is required -High material and training cost -Pipe must be specifically constructed for each project
Cement-mortar spray-on lining	3 to 276	Up to 1476	Cement, Mortar	-Does not block lateral and service connections -Protects against corrosion -Low cost	-Flow bypass is required -Existing culvert must be completely dry prior to applying the cement -Long curing time (up to seven days) -Generally fails to enhance the structural integrity of the existing pipe -Application of cement-mortar may be inconsistent
Spiral-Wound Liner	4 to 120	Up to 1000	PE, PVC, PP PVDF	-Liner formed on site -No or little excavation -Flow bypass may not be necessary -Accommodates diameter changes -Grouting not required if expandable liner is used	-Trained personnel required -Grouting may be required if fixed diameter is used -High material and training cost -Continuous fusion or sealant for joints required

α Based on sources: -Diane Purdy, Penn State. *Trenchless Technology Alternatives for Pipe Rehabilitation.* LTAP Technical Information Sheet #116, Spring 2005.
-Central Federal Lands Highway Division, *CULVERT PIPE LINER GUIDE AND SPECIFICATIONS.* July 2005
-Caltrans

* All methods restore structural integrity.

** All methods increase flow velocity which may cause scouring at outlets.

Abbreviations:

CIP:	Cast Iron Pipe	PE:	Polyethylene	PVDF:	Poly-Vinylidene Chloride
GRP:	Glass-Fiber-Reinforced Polyester	PP:	Polypropylene	RCP:	Reinforced Concrete Pipe
HDPE:	High-Density Polyethylene	PVC:	Poly-Vinyl Chloride	VCP:	Vitrified Clay Pipe

Note: Given continually changing techniques, materials and equipment, the information provided here is at best a snapshot of industry practice.

References

Caltrans. (2003). "General Culvert Barrel Rehabilitation Techniques." DIB 83-01 – 6.1-6.1.3.8 <www.dot.ca.gov/hq/oppd/dib/dib83-01-6.htm>

Central Federal Lands Highway Division. (2005). "Culvert Pipe Liner Guide and Specifications." <www.cflhd.gov/techDevelopment/completed_projects/hydraulics/culvert-pipe-liner/>

Hydro Tech Inc. <www.htliners.com>

Isco Industries Inc. Snap-Tite. <www.culvert-rehab.com>

Ultraliner Inc. <www.ultraliner.com>

Glossary

Annular space – Space between two nested pipes.

Bulkhead – Walls that are placed at the end(s) of a culvert to seal the annular space.

Cured-in-place-pipe – A resin-impregnated flexible tube cured with heat.

Deformed-reformed – A HPDE pipe folded that is reformed by heat.

Fly ash – The powdery residue of matter that remains after burning coal in a power plant. It is a fine residue that, when dry, literally flies in air.

Laterals – Small pipes that flow into larger pipes.

Liner – A material that serves as a lining inside of an existing pipe.

Oakum - Loosely twisted hemp or jute fiber for caulking seams.