Associated Engineering | 75 YEARS

REPORT

Saskatchewan Heavy Construction Association

Impacts of Drainage on Rural Municipality Infrastructure

JULY 2022

TABLE OF CONTENTS

SECTION			PAGE NO.
Table of Contents			i
List of Tables			ii
List of Figures			iii
1	Introduction		1
	1.1	Glossary of Terms	1
	1.2	Demonstration Project Locations	2
	1.3	Existing Infrastructure	3
2	Infrastructure assessment		1
	2.1	Site Inspection	1
	2.2	Design Criteria	2
	2.3	Hydrologic Assessment	3
	2.4	Infrastructure Adequacy and Performance	3
3	Conclusions and Recommendations		1
	3.1	Proposed Culvert Upgrades	1
	3.2	Conclusions	2
	3.3	Recommendations	2
Closure			
Appendix A – Terms of Reference			
Appendix B – Inspection Reports			
Appendix C – PMEL Letter			

LIST OF TABLES

PAGE NO.

Table 2-1 Mitigated Scenario 4
Table 2-2 Fully Drained Scenario 5
Table 3-1 Culvert Upgrade Recommendations 1
Table 3-2 Probable Cost of Crossing Upgrades 2

LIST OF FIGURES

PAGE NO.

Figure 1-1 Demonstration Project Locations 3

1 INTRODUCTION

In July 2020, Water Security Agency (WSA) announced $1 million in funding to partner with ten stakeholder organizations in support of finding new and effective ways to manage water through 11 agricultural water management demonstration projects. Saskatchewan Heavy Construction Association (SHCA) is one of the aforementioned stakeholder organizations and has retained Associated Engineering (AE) to assess the drainage impact on RM infrastructure at three demonstration project locations. The assessment was completed in collaboration with SHCA, WSA, Rural Municipalities (RM), and the Saskatchewan Association of Rural Municipalities (SARM). The assessment at each demonstration site location included background data collection, survey and inspection, and hydraulic analysis using contributing flows provided by Saskatchewan Research Council (SRC). Ultimately, these assessments will be used to inform the development of technical tools and reference materials to install and manage RM infrastructure.

The Terms of Reference for the project are included in Appendix A.

1.1 Glossary of Terms

Throughout this report, several terms are used that are commonly used by engineers and technical staff that may not be commonly understood. The following glossary defines these terms.

Bedding: The earth of other material on which a pipe, conduit, or culvert is supported.

Compaction: The process of soil densification, at a specified moisture content, by the application of pressure through rolling, kneading, tamping, rodding, or vibratory actions of mechanical or manual equipment.

Contributing Area: Region or area contributing to the supply of a stream or lake.

Corrugated Steel Pipe (CSP): Pipe with a series of ridges and grooves running parallel to each other on its surface, typically following a pattern perpendicular or angled to the direction of flow. A typical culvert is constructed of CSP.

Dewatering: The process of draining rainwater or groundwater from an excavated area before construction can begin, usually done by dewatering pumps.

Embankment (or fill): A bank of earth, rock or other material constructed above the natural ground surface.

Erosion: Wear or scouring caused by hydraulic traffic or by the wind.

Geosynthetic stabilization: Synthetic products used to stabilize terrain including products such as geotextiles, geogrids, geomembranes and geocomposites.

Granular: Technical term generally describing the uniformity of grain size of gravel, sand or crushed stone.

Headwater: The water level upstream of a structure, measured from the invert at the first full cross-section of the culvert.

Invert: The lowest point on the inner diameter of a pipe, and is located at the pipe end.

Piping: Subsurface erosion caused by the movement or percolation of water through fill material or natural ground. This is typically seen along the edges of culverts and is a common failure mode.

Plastic soils: Soil with the ability to expand without cracking, fracturing or rupturing when liquid is added.

Preferential Flowpath/weakness planes: A physical process in soils in which the fast transport of water and other compounds takes place only in a small portion of the pore system which can cause weakness in the surrounding material.

Proof rolls: A practice to examine the mass response of subgrade to vehicle-type loads before road driving surface is placed.

Return period: The average period in years between occurrences of a storm event discharge equalling or exceeding a given value. For example, a 1 in 25-year return period indicates a storm intensity that you expect to see once every 25 years.

Sediment: Soils or other materials transported by wind or water as a result of erosion.

Settlement: Soil movement in the vertical direction induced by an applied load or natural reduction of voids due to gravity.

Subgrade: The surface of a portion of the roadbed on which paving, railroad track ballast, or other structure is placed.

Tailwater: The water just downstream from a culvert as measured from the invert of the culvert invert.

1.2 Demonstration Project Locations

SHCA provided three demonstration project locations for assessment with various hydrologic characteristics. The project locations are shown in Figure 1-1 (on the following page) and are briefly described herein.

- Arm River Farms near Bethune (RM of Dufferin and RM of Lumsden) - Drainage network upstream of an RM road;
- Gust Project near Davidson (RM of Willner and RM of Arm River) – Drainage network adjacent to Highway 11; and
- Forte à la Corne Project near Melfort (RM of Willow Creek and RM of Kinistino) – Drainage network upstream of Highway 6.

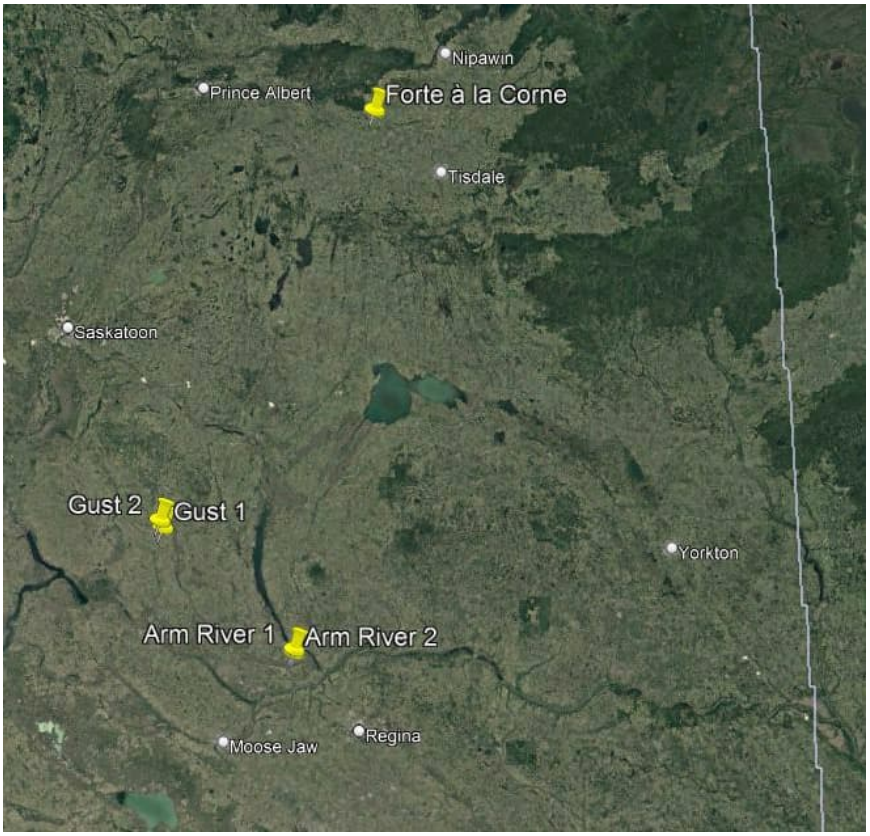

Figure 1-1
Demonstration Project Locations

1.3 Existing Infrastructure

The following sections summarize the existing infrastructure at each demonstration project location.

1.3.1 Arm River Farms Location

Culvert 1 at the Arm River location is a 600 mm corrugated steel pipe culvert (CSP) through the gravel grid, Arm River Road. The culvert conveys water from the east to the west ditch into a roughly 24-hectare wetland. Upstream of the culvert inlet is a small marsh area which collects runoff from surrounding cultivated land. The road centerline is several meters above the culvert invert due to the low-lying area.

Culvert 2 is also a 600 mm CSP through Arm River Road 1.3 km south of Culvert 1. The gravel grid road over Culvert 2 is low profile with the surrounding cultivated land generally flat with some rolling hills. The culvert conveys water from the east to the west along a defined drainage path.

1.3.2 Gust Project Location

Culvert 1 at the Gust project is an arched CSP with a width of 3050 mm and a height of 2000 mm with 0.5 m cover. The culvert conveys water through a gravel super grid road directly east of Highway 11. The culvert conveys water from the north to the south before eventually crossing Highway 11 on a well-defined drainage path. The area surrounding the culvert is marshy with standing water and cattails.

Culvert 2 in the Gust project is upstream of Culvert 1 under Highway 747, a minor paved highway. The arch CSP has a width of 1750 mm and a height of 1150 mm with 1.4 m of cover. The culvert conveys water in a drainage ditch from the north to the south along the east side of Highway 11.

1.3.3 Forte à la Corne Project Location

The culvert at Forte à la Corne is a 1,700 mm round CSP and skewed 25^{o} from perpendicular to the gravel RM road. The culvert conveys water in a well-defined drainage ditch from north to south. The road centerline of the gravel road is several metres higher than the culvert invert due to the depth of the drainage ditch.

2 INFRASTRUCTURE ASSESSMENT

Three demonstration project locations were assessed for their flow capacity and existing culvert condition.

2.1 Site Inspection

Culvert Assessment Forms for each location can be found in Appendix B. The forms include culvert images, measurements, and inspection notes for all three locations.

2.1.1 Arm River Farms Location

AE completed a site inspection of both Arm River culverts on December 17, 2021, which included a culvert assessment and survey of both crossings. The survey included road cross-sections on either side of the culvert and present culvert details. There were no marked utilities near either culvert.

The outlet of Culvert 1 appears crushed and rusted with several inches of sediment transfer buildup. The culvert inlet is in decent shape with minimal sediment build-up. It appears that the culvert experiences relatively small flows regularly although the RM foreman said that this location “flooded to 14 feet above the road centerline in 2014”. Judging from the faint rust lines marking the culvert walls, the typical flow depth is approximately 200 mm. There appears to be no runoff ponding on the inlet side of the road which indicates that the culvert generally functions well.

Both inlet and outlet of Culvert 2 appear to be in good condition, though the pipe appears to sag under the road. There is 150 mm of sediment buildup at the pipe outlet, though no standing water around the crossing indicates that it still functions relatively well. The pipe inlet was blocked by loose barbed wire and fence posts, as well as long grass. This made access difficult but doesn’t seem to be blocking the flow. At the time of inspection, the culvert was dry but faint markings on the culvert walls indicate a typical high water level of 200 mm.

2.1.2 Gust Project Location

AE completed a site inspection of both Gust project area culverts on December 17, 2021, which included culvert assessment and survey of both crossings. The survey included cross-sections on either side of the culverts, marked utilities and drainage channels in the immediate vicinity.

The top of Culvert 1 has been crushed on the inlet side and appears to be bowed under the road, likely due to a lack of proper cover. The area surrounding the inlet is marshy and covered in cattails with a defined drainage path at the outlet. The bottom half of the culvert pipe appears rusted on the inside. Though the culvert was dry at the time of inspection, rust lines on the culvert walls indicate that the typical high water flow depth is 400-500 mm. A marked underground Sasktel line was surveyed 45 m north of the pipe inlet.

Culvert 2 has defined channels at both inlet and outlet. The pavement over the culvert appears newer than the rest of the highway which could indicate a recent washout, replacement, or an asphalt shim to fill potential settlement. The pipe itself appears in good condition from the outside but has extensive rust on the inner bottom half. The culvert was dry when inspected; however, rust markings on the culvert walls indicate a flow depth of more than half the culvert height. Marked utilities in the vicinity of the culvert include underground gas and telephone lines, and an overhead power line.

2.1.3 Forte à la Corne Project Location

AE completed a site inspection at the Fort à la Corne on December 20, 2021, which included a culvert assessment and survey of the culvert crossing. The survey included road cross-sections, marked utilities and the drainage channel at the inlet and outlet of the culvert.

The culvert condition and shape were in fair condition with some bowing under the road. The gravel road is in good condition with the road centreline several metres higher than the culvert invert due to the depth of the drainage ditch. There is a beaver dam at the culvert invert and a small pile of rocks 5 m from the culvert outlet. Judging by rust markings on the culvert walls, the typical high water elevation is 300-400 mm above the culvert invert, though the culvert was dry at the time of inspection. There is also an overhead power line on the upstream property line.

2.2 Design Criteria

2.2.1 Return Period for Design

According to the Ministry of Highway and Infrastructure's (MHI) Hydraulic Manual, Section 502 (HM 502-00), a design frequency of 1:25 years is to be used for Highway 747 in the Gust project area as it is a provincial highway that is not part of the National Highway System. HM 502 indicates that the design frequency for the remaining gravel grid roads should be between a 1:5 and 1:10 year event. As well, HM 502 recommends that the design flow be based on the instantaneous peak flow rather than the peak mean daily (PMD) flow. However, for the purposes of this assignment, the PMD flows were used.

2.2.2 Allowable Headwater

With reference to HM 605, the allowable headwater (AHW) elevation for the design flow should be 0.3 m below the subgrade shoulder elevation. Using Technical Bulletin No. 200-3, the calculated AHW for each crossing location is shown further down in the summary tables. These elevations were based on the surveyed cross-section at the low point in the grade minus 100 mm m of surfacing for gravel surfaces and 200 mm for paved surfaces at 1.8 m from the road centreline, minus 0.3 m of freeboard and assuming a subgrade cross slope of 3%.

2.2.3 Geotechnical Considerations

At the request of AE, P. Machibroda Engineering Ltd. (PMEL) provided an outline of general geotechnical considerations concerning RM gravel roads and culverts, particularly within wetland areas. PMEL noted that while there is no 'one size fits all' approach to the construction of RM roads and culverts and each project should be assessed on an individual basis, there are some general recommendations that should be considered for all locations. Some of these recommendations are summarized below.

- Site visit or visual review of each project location to understand site conditions
- Preferential flow paths/weakness planes caused by inadequate removal of organics should be avoided
- Maintain proper drainage routing and adequate freeboard
- Good quality, uniform fill should be used during construction. Should weak or soft subgrade soil be encountered, PMEL recommends over excavating the poor material and replacing it with good quality fill and/or geosynthetics to ensure long-term road strength
- Avoid construction during wet or frozen conditions
- Embankment settlement should be minimized with thin fill lifts and a high degree of compaction
- Erosion protection is very important to extend the life cycle of culverts

- A clay plug at culvert inlets covered with rip rap and/or a geotextile typically used to prevent preferential flow paths through culvert bedding material
- Ensure positive surface drainage on the road surface with periodic grading

There are several things that RMs can do in good practice; though if there is any doubt, PMEL strongly suggests having a site visit by a geotechnical consultant. The full letter and recommendations can be found in Appendix C.

2.3 Hydrologic Assessment

Flow estimates were provided by SRC through WSA for each of the project locations to evaluate crossing capacity. The hydrologic assessment for each demonstration project area was done based on Pre-Augmentation, Current Drainage and Fully Drained Scenarios. The drainage basin areas were identified using imagery, LiDAR data, and site visits by SRCs consultants, WSA staff and Qualified Professionals (QPs). The pre-augmentation flow refers to runoff from a contributing area without any man-made drainage channels to lower storage capacity, while the fully drained scenario refers to a landscape that has no standing water or natural storage due to extensive ditching. WSA also requested that flow estimates with flow control structures were used but did not detail what the controls specifically are. It is assumed that the flows provided do not consider the potential effects of climate change.

2.4 Infrastructure Adequacy and Performance

The adequacy and performance of each crossing were evaluated using the information gathered from site surveys and the use of CulvertMaster. Each crossing location was input into the software using best practices outlined in the Best Management Practices (BMP) memo developed by AE. The BMP memo covers recommended variables for setting up a culvert evaluation including inlet coefficients, roughness, and road overtopping settings. The existing capacities were then compared against the flows for all return periods provided by WSA for each location and minimum required upgrades were determined to support cost comparisons.

2.4.1 CulvertMaster Setup

Following the hydraulic assessment, AE proceeded with assessing the existing culvert hydraulics using the CulvertMaster software. CulvertMaster is commercially available software that is capable of analyzing culvert hydraulic systems with multiple barrels, different shapes and sizes, special tailwater considerations and road overtopping. The software input parameters include:

- Culvert characteristics (inverts, length, slope, size, condition, roughness)
- Inlet condition treatments
- Tailwater conditions
- Road crest information which allows overtopping via weir flow
- Flow rates

2.4.2 Culvert Capacity Assessment

The following tables provide a summary of the culverts analyzed, culvert capacity and, mitigated (Table 2-1) and fully drained (Table 2-2) flow conditions. To remain conservative in the capacity estimates, it was assumed that all culverts had tailwater conditions equal to two-thirds the height of the culvert. A Manning's number of 0.027 was used for all culverts. Return period flows were provided by the WSA and compared against the estimated capacity at each crossing. The culvert capacity assessment highlights the current and future deficiencies in both the mitigated flow and

fully drained scenarios for five different event return periods. Green text indicates the flow is equal to or less than the current capacity of the crossing while red text indicates expected flows are greater than the current capacity. Included with the red text are the minimum upgrades (additions or replacements) required to meet the flow requirements of that return period in mm.

Table 2-1
Mitigated Scenario

Culvert Location	Existing Size (mm)	Allowable Headwater Elevation (m)	Estimated Capacity (cms)	Event Return Period (cms)				
				1:2	1:5	1:10	1:25	1:50
Arm River 1	600	529.25	0.635	0.123	0.152	0.585	1.13 *(replace 825)*	1.50 *(replace 900)*
Arm River 2	600	540.84	0.537	0.123	0.152	0.585 *(replace 675)*	1.13 *(replace 900)*	1.50 *(replace 2x 750)*
Gust 1	3050 x 2000	602.80	8.95	0	1.06	2.20	3.56	4.85
Gust 2	1750 x 1150	610.34	3.97	0.413	1.27	2.09	3.38	4.67 *(add 675)*
Forte à la Corne	1700	422.47	9.49	2.42	4.09	6.37	9.41	12.31 *(replace 2x 1350)*

Table 2-2
Fully Drained Scenario

Culvert Location	Existing Size (mm)	Allowable Headwater Elevation (m)	Estimated Capacity (cms)	Event Return Period (cms)				
				1:2	1:5	1:10	1:25	1:50
Arm River 1	600	529.25	0.635	0.366	0.607	1.61 *(replace 900)*	2.89 *(replace 1200)*	3.80 *(replace 2x 1050)*
Arm River 2	600	540.84	0.537	0.366	0.607 *(replace 675)*	1.61 *(replace 2x 750)*	2.89 *(replace 2x 1200)*	3.80 *(replace 3x 1050)*
Gust 1	3050 x 2000	602.80	8.95	0.700	2.54	4.44	7.09	9.67 *(add 750)*
Gust 2	1750 x 1150	610.34	3.97	0.962	2.66	4.29 *(add 450)*	6.85 *(add 1200)*	9.39 *(replace 2x 1850 x 1400)*
Forte à la Corne	1700 *	422.47	9.49	3.80	6.73	10.26 *(replace 2x 1350)*	14.89 *(replace 2x 1500)*	19.14 *(replace 2x 1800)*

* As the existing culvert is located along a defined ditch through a deep embankment, adding additional culverts was deemed hydraulicly inefficient. Therefore, the culverts are proposed to be replaced to align them along the ditch and install them at the appropriate elevations.

3 CONCLUSIONS AND RECOMMENDATIONS

The work outlined in this report summarizes our assessment of the existing RM infrastructure and notes upgrades required to meet various event return periods for the current drainage and fully drained scenarios. The following sections outline the proposed culvert upgrades, opinions of probable cost, conclusions and recommendations.

3.1 Proposed Culvert Upgrades

As detailed in Section 2, the following table summarizes the culvert upgrade recommendations along with the resulting capacities.

Table 3-1
Culvert Upgrade Recommendations

Culvert Location	Existing Size (mm)	Proposed Size (mm)	Proposed Capacity (cms)	Design Return Period	Current Drainage Scenario Flow (cms)	Fully Drained Scenario Flow (cms)
Arm River 1	600	900	1.67	1:10	0.585	1.61
Arm River 2	600	2x 750	1.67	1:10	0.858	1.61
Gust 1	3050 x 2000	3050 x 2000	8.95	1:10	2.20	4.44
Gust 2	1750 x 1150	1750 x1150 and 1200	6.93	1:25	3.38	6.85
Forte à la Corne	1700	2x 1350	12.50	1:10	6.37	10.26

Based on Table 3-1, Table 3-2 summarizes the probable cost of the crossing upgrades along with the incremental cost to accommodate the fully drained scenario. Please note that the costs presented were derived from contractor pricing that is based on the current market price for materials and recent tender trends.

Table 3-2
Probable Cost of Crossing Upgrades

Culvert Location	Existing Size (mm)	Proposed Size (mm)	Proposed Cost to Replace Existing	Proposed Cost to Construct Fully Drained Scenario	Incremental Cost of Drainage
Arm River 1	600	900	$6,000	$9,000	50%
Arm River 2	600	2x 750	$5,000 (shorter)	$12,000	140%
Gust 1	3050 x 2000	3050 x 2000	$80,000	$80,000	n/a
Gust 2	1750 x 1150	1750 x1150 and 1200	$70,000	$90,000	29%
Forte à la Corne	1700	2x 1350	$45,000	$70,000	56%

3.2 Conclusions

In most cases, the existing culverts were not sized to accommodate the fully drained scenario flows. In one instance, the existing culvert was not even sized to accommodate the mitigated scenario flows. Based on our assessment we can conclude the following:

- RMs do not have an adequate direction for the installation, maintenance, or replacement of culvert infrastructure.
- In the absence of expertise, RMs should engage with technical experts and regulators for guidance.
- There is an incremental cost to RMs in the maintenance and upgrade of their infrastructure as a result of drainage.

3.3 Recommendations

In completing the assessments summarized herein, several best practices and standards were referenced. Although most technical experts are aware of these practices and standards, most RM staff are not. Further, there is no consistent approach among technical experts on how to design culvert installations. To provide RM staff and technical experts with the necessary resources to install and maintain culverts, technical tools and reference materials should be developed and made readily available to practitioners.

When developing technical tools and reference materials, the following considerations should be addressed:

- The audience varies greatly and therefore the documents need to be easy to read and follow.
- Where practicable, standard terminology should be defined.
- A consistent design approach needs to be outlined including a recommended design event.
- Clear guidance on replacements that are large in scope and require regulatory input and approval.
- Standard installation details should be provided.

CLOSURE

This report was prepared for the Saskatchewan Heavy Construction Association to assess the impacts of drainage at three demonstration project locations and ultimately inform the development of technical tools and reference materials to install and manage RM infrastructure.

The services provided by Associated Engineering (Sask.) Ltd. in the preparation of this report was conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (Sask.) Ltd.

Prepared By:

Karisa Purvis, P.Eng.
Project Engineer

Reviewed By:

Ryan Karsgaard, P.Eng.
Project Manager

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Civil	09141	

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Signature: _____

Date: July 8, 2022

APPENDIX A – TERMS OF REFERENCE

SHCA Consultant Terms of Reference

Background

The Saskatchewan Heavy Construction Association (SHCA) received funding from the Water Security Agency (WSA) to provide engineering and consulting services to look at the impacts of drainage on Rural Municipality (RM) infrastructure in demonstration project areas. SHCA will hire the consultant and manage the contract with the consultant. Further to this, the consultant will work with Rural Municipalities (RM's), Saskatchewan Association of Rural Municipalities and WSA to develop technical tools and reference materials to install and help manage RM infrastructure. Engineering services can include conceptual, preliminary and detailed evaluations, designs and costs for the RM infrastructure maintenance and replacement. It will also include preparation of manuals or technical tools.

SHCA, Saskatchewan Research Council (SRC) and WSA will determine the demonstration projects for investigation *(likely 2 or 3 projects)*. The investigation will look at the impacts of drainage from a mitigation scenario and a continued wetland loss scenario. SRC will be responsible for providing the hydrologic information (peak flow and where available hydrographs) for the two scenarios to the consultant.

Tasks:

- The consultant will meet with WSA and SHCA in a kickoff meeting where the project information will be supplied and where goals and objectives are discussed.
- The consultant will review the demonstration project information including mapping, drainage area and hydrologic assessments, supplied at the start of the project from WSA and SRC.
- The consultant will work with the appropriate RM's to gather information on the current RM infrastructure in place in the demonstration project area.
- The consultant will gather detailed site-specific infrastructure information to allow for detailed hydraulic assessments at each RM crossing in the project drainage basin.
- The consultant will assess the current condition of the infrastructure.
- Using the peak flows provided by SRC for the mitigation scenario and the fully drained scenario, the consultant will evaluate the adequacy and performance of the existing infrastructure, and if necessary, recommend new infrastructure.
- The consultant will estimate costs for replacement of current and recommended infrastructure, using unit costs of the infrastructure and estimated construction costs.
- The consultant will:
    - Complete a needs assessment with a number of RM's (TBD) and SARM to determine the types of technical tools or reference materials required by RM's for drainage or water management.
    - Using the needs assessment and consultation with SARM and WSA, the consultant will develop tools and/or reference materials for use by RM's. This

may include tools for culvert sizing, standard designs for road crossings or standard designs for using roads and road crossings for flow controls.

- The consultant will provide monthly updates to SHCA
- On a quarterly basis, throughout the project the consultant will meet with SHCA, SARM and WSA to review progress, raise any questions or concerns and obtain feedback for the project.
- The consultant will provide completed reports on the impacts of the drainage scenarios on RM infrastructure and final versions of the tools and or reference materials.

Schedule (to be determined through conversations with WSA and potentially SARM)

APPENDIX B – INSPECTION REPORTS

Saskatchewan Heavy Construction Association
Drainage Impacts on Rural Municipality Infrastructure

Associated Engineering

Culvert #		Arm River 1
Location	N	5619168.977
	E	496135.146

Inspector:	K. Purvis/R. Karsgaard
Inspection Date:	Dec 17/21

Culvert Data

Culvert Type	CSP
Culvert Shape	Round
Culvert Height (mm)	600
Culvert Width (mm)	600
Culvert Length Inlet to Outlet (m)	17.96
Culvert Thickness (mm)	2.1
Skew Angle	80°
End Section	Projecting
Embankment Height (Invert to Road CL) (m)	2.31

Culvert Condition

Corrosion Rust:	[X] Good	[ ] Fair	[ ] Poor	
Shape:	[ ] Good	[ ] Fair	[X] Poor	
Seam/Erosion Failure:	[X] Good	[ ] Fair	[ ] Poor	
Crimping:	[X] Good	[ ] Fair	[ ] Poor	
Spalling:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Cracking:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Separation Failure:	[X] Good	[ ] Fair	[ ] Poor	
Scouring/Washout:	[X] Good	[ ] Fair	[ ] Poor	
Piping:	[ ] Good	[X] Fair	[ ] Poor	

Blockage:

Type:	Sediment transfer buildup
Distance from Inlet:	At inlet
Distance from Outlet:	At outlet

Water Elevation:	None
Notes:	Water elevation in 2014 was 14 ft above road top

Background Info

Road condition:	Arm River Road is a gravel road in good condition
Culvert performance:	Culvert is deformed and dirt has built up along bottom. Performance is not great
Utilities:	None
Natural obstructions	N/A

Pictures

Description: Culvert Inlet

Description: Upstream View

Description: Culvert Outlet

Description: Downstream View

Description: Road

Description: Inside Culvert

Saskatchewan Heavy Construction Association
Drainage Impacts on Rural Municipality Infrastructure

Associated Engineering

Culvert #		Arm River 2
Location	N	5617849.315
	E	496106.452

Inspector:	K. Purvis/R. Karsgaard
Inspection Date:	Dec 17/21

Culvert Data

Culvert Type	CSP
Culvert Shape	Round
Culvert Height (mm)	600
Culvert Width (mm)	600
Culvert Length Inlet to Outlet (m)	13.29
Culvert Thickness (mm)	2.8
Skew Angle	90^{o}
End Section	Projecting
Embankment Height (Invert to Road CL) (m)	1.69

Culvert Condition

Corrosion Rust:	[X] Good	[ ] Fair	[ ] Poor	
Shape:	[X] Good	[ ] Fair	[ ] Poor	
Seam/Erosion Failure:	[X] Good	[ ] Fair	[ ] Poor	
Crimping:	[X] Good	[ ] Fair	[ ] Poor	
Spalling:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Cracking:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Separation Failure:	[X] Good	[ ] Fair	[ ] Poor	
Scouring/Washout:	[X] Good	[ ] Fair	[ ] Poor	
Piping:	[X] Good	[ ] Fair	[ ] Poor	

Blockage:

Type:	Sediment Transport Buildup
Distance from Inlet:	At inlet
Distance from Outlet:	At outlet

Water Elevation:	None
Notes:	Bottom quarter of pipe packed with sediment. Barbed wire fencing around the pipe inlet made access difficult

Background Info

Road condition:	Arm River Road is a gravel road in good condition
Culvert performance:	Culvert performance is good
Utilities:	None
Natural obstructions	N/A

Pictures

Description: Culvert Inlet

Description: Upstream View

Description: Culvert Outlet

Description: Downstream View

Description: Road

Description: Inside Culvert

Saskatchewan Heavy Construction Association
Drainage Impacts on Rural Municipality Infrastructure

Culvert # Gust 1
Location N 5677124.954
E 432772.007

Inspector: K. Purvis/R. Karsgaard
Inspection Date: Dec 17/21

Culvert Data

Culvert Type	CSP
Culvert Shape	Arch
Culvert Height (mm)	2,000
Culvert Width (mm)	3,050
Culvert Length Inlet to Outlet (m)	18.3
Culvert Thickness (mm)	2.9
Skew Angle	90°
End Section	Projecting
Embankment Height (Invert to Road CL) (m)	2.657

Culvert Condition

Corrosion Rust:	[ ] Good	[X] Fair	[ ] Poor	
Shape:	[ ] Good	[ ] Fair	[X] Poor	
Seam/Erosion Failure:	[X] Good	[ ] Fair	[ ] Poor	
Crimping:	[X] Good	[ ] Fair	[ ] Poor	
Spalling:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Cracking:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Separation Failure:	[X] Good	[ ] Fair	[ ] Poor	
Scouring/Washout:	[X] Good	[ ] Fair	[ ] Poor	
Piping:	[X] Good	[ ] Fair	[ ] Poor	

Blockage:

Type: N/A
Distance from Inlet:
Distance from Outlet:

Water Elevation:	N/A
Notes:	No blockages noted

Background Info

Road condition:	Gravel super grid in good condition
Culvert performance:	Culvert seems to perform well, though bowed due to inadequate cove
Utilities:	Sasktel underground line 45 m from N invert
Natural obstructions	N/A

Pictures

Description: Culvert Inlet

Description: Upstream View

Description: Culvert Outlet

Description: Downstream View

Description: Road

Description: Inside Culvert

Saskatchewan Heavy Construction Association
Drainage Impacts on Rural Municipality Infrastructure

Culvert # Gust 2
Location N 5680397.552
E 431333.117

Inspector: K. Purvis/R. Karsgaard
Inspection Date: Dec 17/21

Culvert Data

Culvert Type	CSP
Culvert Shape	Arch
Culvert Height (mm)	1,150
Culvert Width (mm)	1,750
Culvert Length Inlet to Outlet (m)	21.92
Culvert Thickness (mm)	4
Skew Angle	90°
End Section	Projecting
Embankment Height (Invert to Road CL) (m)	2.56

Culvert Condition

Corrosion Rust:	[ ] Good	[X] Fair	[ ] Poor	
Shape:	[ ] Good	[ ] Fair	[X] Poor	
Seam/Erosion Failure:	[X] Good	[ ] Fair	[ ] Poor	
Crimping:	[X] Good	[ ] Fair	[ ] Poor	
Spalling:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Cracking:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Separation Failure:	[X] Good	[ ] Fair	[ ] Poor	
Scouring/Washout:	[X] Good	[ ] Fair	[ ] Poor	
Piping:	[X] Good	[ ] Fair	[ ] Poor	

Blockage:

Type: N/A
Distance from Inlet:
Distance from Outlet:

Water Elevation:	N/A
Notes:	No blockages noted

Background Info

Road condition:	Paved Highway 747 in good condition
Culvert performance:	Culvert seems to perform well
Utilities:	Nearby overhead power and, underground telephone and gas
Natural obstructions	N/A

Pictures

Description: Culvert Inlet

Description: Upstream View

Description: Culvert Outlet

Description: Downstream View

Description: Road

Description: Inside Culvert

Saskatchewan Heavy Construction Association
Drainage Impacts on Rural Municipality Infrastructure

Associated Engineering

Culvert #		Forte à la Corne
Location	N	5877432.115
	E	532364.332

Inspector:	K. Purvis/R. Karsgaard
Inspection Date:	Dec 20/21

Culvert Data

Culvert Type	CSP
Culvert Shape	Round
Culvert Height (mm)	1,700
Culvert Width (mm)	1,700
Culvert Length Inlet to Outlet (m)	28.19
Culvert Thickness (mm)	2.1
Skew Angle	25°
End Section	Projecting
Embankment Height (Invert to Road CL) (m)	5.18

Culvert Condition

Corrosion Rust:	[ ] Good	[X] Fair	[ ] Poor	
Shape:	[ ] Good	[X] Fair	[ ] Poor	
Seam/Erosion Failure:	[ ] Good	[X] Fair	[ ] Poor	
Crimping:	[ ] Good	[X] Fair	[ ] Poor	
Spalling:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Cracking:	[ ] Good	[ ] Fair	[ ] Poor	N/A
Separation Failure:	[X] Good	[ ] Fair	[ ] Poor	
Scouring/Washout:	[X] Good	[ ] Fair	[ ] Poor	
Piping:	[X] Good	[ ] Fair	[ ] Poor	

Blockage:

Type:	Rocks and Beaver Dam
Distance from Inlet:	Beaver dam at inlet
Distance from Outlet:	Rocks 5m from outle

Water Elevation:	None
Notes:	Beaver dam is impeding flow at inlet. Rip rap at outlet is higher than invert

Background Info

Road condition:	Gravel road is in good condition
Culvert performance:	Performance is impeded by beaver dam
Utilities:	Overhead powerline at upstream property line
Natural obstructions	Beaver dam at inlet

Pictures

Description: Culvert Inlet

Description: Upstream View

Description: Culvert Outlet

Description: Downstream View

Description: Road

Description: Inside Culvert

APPENDIX C – PMEL LETTER

P.MACHIBRODA
ENGINEERING LTD.

CONSULTING GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERS AND GEOSCIENTISTS

806-48th STREET EAST
SASKATOON, SK
S7K 3Y4
P: 306.665.8444
F: 306.652.2092
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- Site Decommissioning and Clean-up
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- Piezocone (CPTu) Testing
- Soils Testing
- Concrete Testing
- Asphalt Testing
- Pile Driver Analyzer (PDA Testing)

January 24, 2022

Associated Engineering (Sask.) Ltd.
1 - 2225 Northridge Drive
Saskatoon, SK S7L 6X6

ATTENTION: Mr. Ryan Karsgaard, P. Eng., Project Manager

RE: GEOTECHNICAL CONSIDERATIONS
SASKATCHEWAN RM GRAVEL ROADS AND CULVERTS
PMEL FILE NO. 18891

1 INTRODUCTION

As per your request, P. Machibroda Engineering Ltd. (PMEL) has been asked to prepare general geotechnical considerations with respect to Saskatchewan Rural Municipality (RM) gravel roads and culverts, particularly within wetland/slough areas. This letter is intended to provide general commentary only and does not consider all situations that may exist within the province. The content should be considered as a 'first step' when assessing the construction of RM gravel roads and culverts and does not eliminate the need for location-specific geotechnical assessment/recommendations where conditions warrant.

2 GEOTECHNICAL CONSIDERATIONS

- There is no 'one size fits all' approach to the construction of RM gravel roads and culverts. Some sites are relatively 'straight forward' while others will certainly require site-specific geotechnical assessment/investigation (e.g., large diameter/critical culvert locations, high embankments, significant wetland crossings, etc.). As a minimum, there should be some sort of a review completed to understand site conditions as they pertain to the construction of roads/culvert (e.g., aerial imagery review, review of site photos, anecdotal information, review of Google Street View [if available], site visit etc.).
- Preferential flowpaths/weakness planes must be minimized, particularly through wetlands and/or where unbalanced hydraulic forces exist (i.e., water on one side of the road only). Inadequate stripping of organics and 'rolling-in' organics with the bulk fill/ditch excavation (which is/was common during construction of RM gravel roads) are construction practices which can create preferential flowpaths/weakness planes and thus should be avoided.

- Drainage is critical to the satisfactory long-term performance of roadways. Poor drainage is a leading cause of roadway issues and must be considered prior to, during and after construction. Proper location/routing of roadways and culverts is important, and maintaining adequate freeboard (i.e., 'high and dry' embankments) is desirable wherever possible.
- Good quality, uniform fill is important to ensure high quality construction and suitable long-term performance. Local soils may not always be suitable so it may be necessary to import higher quality fill (though this may not always be a feasible option and will depend on the importance of the road/culvert and the cost/practicality of importing fill material). In general, granular materials and uniform cohesive soils (preferably low to medium plastic) are considered to be 'good quality' fill materials, whereas uniform silt soils, highly plastic clay soils and soils containing appreciable organics are considered to be 'poor quality' fill materials. The environmental conditions at the time of fill placement may dictate appropriate fill types. Geotechnical laboratory analysis can provide guidance as to what constitutes 'good quality' fill.
- Stabilization of soft/weak subgrade soils is an important consideration. Rather than leaving soft/weak soils in place, over-excavation/replacement of the soft/weak soils with stable fill (preferably clean granular material) and/or geosynthetic stabilization is recommended where soft/weak subgrades exist. Leaving soft/weak subgrades in place/untreated generally leads to ongoing performance issues and increased maintenance efforts (e.g., patchwork/'bandaid' repairs, frequent placement of additional fill due to material loss/punching into the weak subgrade soils, etc.). Geosynthetics are typically utilized to provide material separation and enhance subgrade strength to allow for subsequent embankment construction. Many types of geosynthetics exist, and the most appropriate option will depend on local conditions/desired purpose and/or whether a site visit is conducted. Geotechnical consultants can provide recommendations for stabilization of soft/weak subgrade soils (i.e., general recommendations for 'typical' soft subgrade conditions or optimized/location-specific recommendations if a site visit is conducted).
- A quality assurance/control plan should be considered and implemented early in the project. This should be incorporated in the selection of fill materials to use (as noted above) and during construction (e.g., proof rolls, density testing with nuclear gauge, etc.). Completing compaction testing early in projects provides invaluable information to contractors for the required compaction effort and moisture conditioning of fill material to ensure good quality placement of fill. Geotechnical consultants can provide the necessary recommendations for a quality assurance/control plan.

- Construction during wet periods and freezing conditions should be avoided when possible. Construction equipment should avoid traveling on wet/soft subgrade soils to minimize the potential for disturbance/subgrade failure. Geotechnical consultant can provide appropriate recommendations if construction during wet periods and freezing conditions cannot avoided. For wet periods, this could consist of adding drainage and surface stabilization. For freezing conditions this could consist of using non-frost susceptible materials, ensuring fill is frost free immediately prior to placement, allowing for settlement and future maintenance as ground thaws and/or delaying opening of road in spring to allow for settlement.
- Settlement must be considered (embankment itself and underlying soils), particularly where embankments are high/wide. Compaction of 'bulk' embankment fill as well as material placed below/around culverts (typically imported granular fill) is critical to limit self-settlement of embankments. Thin fill lifts, appropriate compaction equipment that can induce a high degree of compaction (typically 96 to 100 percent of standard Proctor density), moisture conditioning, uniform compaction of all fill materials and the use of uniform fill materials (un-frozen fill, preferable 'good quality' material as discussed above) are all important. Geotechnical laboratory and field material testing services are recommended to ensure uniform compaction is achieved. If 'good' construction practices are followed, it is possible to limit the self-settlement of embankment fill materials to about 1% of the fill thickness. However, if 'poor' construction practices are followed, self-settlements of 5% of the fill thickness (or more) may occur, which could lead to serviceability issues and increased maintenance requirements. Settlement of the supporting subgrade soils is more difficult to control/predict, particularly where thick deposits of weak soils exist below the embankment. If weak supporting soils are known to exist or are suspected, geotechnical support is recommended to estimate settlements and provide appropriate recommendations (this may involve field investigation and engineering analysis).
- Slope stability must be considered for high embankments and/or embankments on weak supporting soils. If weak supporting soils are known to exist or are suspected, geotechnical support is recommended to assess slope stability and provide appropriate recommendations (this will require field investigation and engineering analysis).
- Uniform support below culverts is critical to achieving good performance. The supporting soils may not be 'strong' (particularly in wetlands), but must be uniform. Settlement and slope stability must be considered for high/wide embankments and/or critical embankment/culvert locations where weak soils are known/suspected to exist (as discussed above).

- The height, width and sideslopes of the embankments are all important. Higher/wider embankments will settle more than similarly constructed lower/narrower embankments. However, properly sloped embankments are critical to long-term stability and are dependant on material type (embankment material and underlying subgrade soils). Relatively flat sideslopes may be required in some areas whereas steeper sideslopes may suffice in others. In general, sideslopes of 3H : 1V to 4H : 1V are typically constructed.
- Erosion control is important for satisfactory long-term performance of embankments (there are many types).
- Controlling material loss (piping) is critical as it can cause embankment failure. Maintaining water passage (avoid unbalanced hydraulic forces/plugged culverts) and preventing preferential flow paths is critical to long-term performance.
- Frost action/frost heaving is an important consideration as culverts are typically placed in low spots (i.e., likely high groundwater table), very often within frost-prone soils. Maintaining embankment freeboard above water as high as possible and using clean/stable granular fills can help to alleviate frost action. Uniform backfill material (composition and thickness) will help minimize differential movements related to frost heave. Construction of local drainage systems to lower the groundwater table could also be considered but this may not be feasible in all areas.
- A clay plug on culvert inverts/along slope faces (protected with rip-rap) is typically constructed to prevent preferential flow paths developing through culvert bedding material (this is less important if fill consists of uniform cohesive soils/no granular backfills). Alternately, a filter (i.e., geotextile and/or gravel/sand filter) to prevent migration of fines could be used if good quality cohesive soils not available.
- Trenchless construction (e.g., directional drilling, pipe jacking, jack and bore method, micro-tunneling etc.) may be required in some areas where conventional open-cut excavations/backfilling are not practical.
- Temporary shoring may be required during culvert installation where there is insufficient room or unstable excavation backslopes for construction using sloped excavation. Dewatering of the excavations may also be required. This may require field investigation and engineering analysis to determine feasibility of different trenchless methods.
- In order to provide positive surface drainage on the roadway surface, roads should be crowned with a minimum cross slope of 3 to 4 percent to allow surface water to freely discharge into ditches. Periodic grading will be required to maintain the positive cross slope.

- The level of initial construction effort should coincide with the importance/quality of the structure and the desired maintenance frequency of the roadways/culverts. Higher quality construction methods/materials will yield higher performing, longer lasting structures. Asphalt surfaced roadways are less 'forgiving' than gravel-surfaced roadways and thus require a higher quality of initial construction to minimize maintenance efforts.
- If in doubt, ask. A site visit by a geotechnical consultant or sound geotechnical advice can be invaluable to a project.

3 CLOSURE

We trust that this report fulfills your requirements for this project. Should you require additional information, please contact us.

P. MACHIBRODA ENGINEERING LTD.

PROFESSIONAL ENGINEER
C.C. ZUBROWSKI
MEMBER 12138
2022-01-24
SASKATCHEWAN

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
P. MACHIBRODA ENGINEERING LTD.
Number 172
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	12138	

2022-01-24

Cory Zubrowski, P.Eng.

Kelly Pardoski, P.Eng.

CZ/KP