NORTH CENTRAL REGION GRMP
EDSON / STONY PLAIN
Call Out Inspection

SITE NUMBER AND NAME: BF75014 Pembina River Bridge	**LOCATION:** About 0.5 km west of Entwistle, AB	**HIGHWAY:** 16:10	**KM:** 28.703
LEGAL DESCRIPTION: SW-20-53-7-W5	**NAD83 COORDINATES:** UTM11U 5939985 N, 632165 E		
AVERAGE ANNUAL DAILY TRAFFIC (AADT): 8040		**CONTRACTOR MAINTENANCE AREA (CMA):** 508 / 509	

	DATE	**PF**	**CF**	**TOTAL**
PREVIOUS INSPECTION:	N/A	-	-	-
CURRENT INSPECTION:	November 23, 2023	13	8	104
INSPECTED BY:	Stantec: Gustavo Padros and Sam Toms. Transportation and Economic Corridors (TAC): Rishi Adhikari, Brent Herrick, Lucas Martinez and Todd Warshawski.			
REPORT ATTACHMENTS:	Figure 1 – Site Plan Figure 2 – BF75014 Bridge General Layout Site Photographs			

PRIMARY SITE ISSUE:

Erosion and gullying adjacent to and on the west and east bridge abutments.

APPROXIMATE DIMENSIONS:

On the west abutment, the maximum gulley size was estimated to be about 4 m deep by 8 m wide.

On the east abutment, the maximum gulley size was estimated to be about 2 m deep by 4 m wide.

SITE HISTORY:

The bridge was built in 1962. A site plan and the bridge general layout are shown in Figures 1 and 2, respectively.

Based on the bridge layout shown in Figure 2, the elevation of the valley top and the edge of the Pembina River were estimated at about 780 m and 724 m respectively, corresponding to a vertical drop of about 56 m. The inclination of the west abutment was about 21 degrees (2.6H:1V). The inclination of the east abutment was steeper, at about 29 degrees (1.8H:1V).

The design of the highway ditch drainage at each side of the Pembina River valley (east and west) appears to have consisted of joining the combined surface water discharge from the north and south sides of the highway and channeling them together into a single stormwater pipe. This approach was applied to the highway on both sides of the river (east and west). As a result, a single stormwater pipe was installed on each side of the river (east and west riverbanks), extending from the valley top to the river.

On the west riverbank, a 610 mm diameter CSP stormwater pipe was used to conduct the combined flow from the north and south ditches. The location selected for the installation of the stormwater was adjacent to the abutment, about 15 m north of the bridge face.

On the east riverbank, a 762 mm diameter CSP stormwater pipe was used to conduct the flow from the north and south ditches. The stormwater pipeline was located on the ROW of the CN bridge (designated as “Entwistle CN Train Bridge” in Figure 1), about 60 m north of the BF75014 Pembina Bridge.

The subsurface conditions on the west abutment comprised clay till over bedrock, consisting of sandstone, siltstone, and clay shale strata. The subsurface conditions on the east abutment comprised clay till over layers of silt and clay, over bedrock, consisting of sandstone, siltstone, and clay shale strata.

A review of TEC’s archived documents pertaining to the BF75014 Pembina River Bridge was conducted. The following observations and history of repairs of the surface water drainage measures on the abutments is summarized in the following:

- 1992: Horizontal and vertical tie backs (rock anchors) were installed on the east riverbank, at Pier 1.

- 2003: A new stormwater pipeline was installed on the west abutment, replacing the original stormwater system that consisted of two pipelines with parallel alignment, located adjacent to the NW and SW corners of Pier 5. These pipelines conducted the surface water from the ditches downwards to the river, and presumably had their inlets west of the bridge. The original stormwater pipe had been destroyed due to erosion gulleys starting just below the headscarp of the west valley slope, extending downwards to the river. Based on available photos, the bigger gulley was on the NW of the bridge, and had a depth of about 1 m.
- 2003: An attempt to backfill the gulley resulting from the failure of the original stormwater pipeline located adjacent to the NW corner of Pier 5 was undertaken, using a gabion mattress over geotextile.
- 2005: Erosion gullies were observed on the east abutment.
- 2008: Erosion and damage of the gabion mattress adjacent to the NW corner of Pier 5 was observed.
- 2010: Damage of the stormwater pipeline installed in 2003 was observed. CSP segments were observed to be separated due to the presence of erosion gullies.
- 2012: The stormwater pipeline installed on the west abutment in 2003 had lost its initial alignment and was broken into pieces. Severe erosion of the gabion mattress was observed, which had their wire baskets broken and their gravel migrated.

ITEM	**CONDITIONS EXIST**		**DESCRIPTION AND LOCATION**	**NOTICEABLE CHANGE FROM LAST INSPECTION (1)**	
	YES	**NO**		**YES**	**NO**
Pavement Distress		X		N/A	N/A
Slope Movement		X		N/A	N/A
Erosion/Gullying	X		Erosion gulleys up to 4 m deep were estimated on the west abutment, NW side of the bridge (Photos 10 to 12). Erosion gulleys up to 2 m deep were estimated on the east abutment, NE side of the bridge (Photos 1, 3, and 4 to 7). Shallow gullies were observed on the east and west abutments below the sandstone outcrops (Photos 3 to 6 and 15 to 17).	N/A	N/A
Seepage		X		N/A	N/A
Bridge/Culvert Distress	X		Erosion and rockfall at Piers 1 and 5, which are supported on footings (Photos 14 to 18) (Pier 1 was reinforced with tie-backs in 1992). The north face of Pier 3 (located near the toe of the west abutment headslope) has been encroached by an erosion gulley approximately 1 m deep (Photos 12 and 13).	N/A	N/A
Rockfall	X		The near vertical exposed rock mass below the east abutment generally contains horizontal bedding with near vertical joints/fractures creating blocks/wedges that detach from the rock face falling below and are undermining the abutment (Photos 3 to 5) The exposed rock mass below the west abutment is sloped at approximately 70 degrees and does not have a strong visible bedding/joint pattern as the	N/A	N/A

			east rock face. However, displaced blocks are visible on the slope surface (Photos 10, 13 and 18).		
Note: 1. This is Stantec's first inspection of the site.					

ASSESSMENT

OVERVIEW:

- The east and west stormwater pipelines that discharge surface water from Highway 16 into the Pembina River have malfunctioned. The surface water collected from the ditches is not properly contained in functioning pipelines towards the river, having separated resulting in channeling and erosion of deep gullies on both riverbanks, extending nearly from the valley top to the river. The gullies have produced total separation of the stormwater pipes due to lack of support on both riverbanks. The gulley on the west abutment encroached to Pier 3. At that location, the gulley has a depth of about 1 m and exposes the north side of the pier, previously embedded.
- The Pembina River bridge is supported on footings. The sandstone outcrops supporting Pier 1 and 5 show rock fall and erosion including the presence of erosion gullies caused by uncontrolled surface water flow. The performance of the footings supporting the above-mentioned piers require adequate resistance of the sandstone strata. Further rock fall and erosion of the sandstone located on the east and west bridge headslopes should be reduced and managed.

WEST ABUTMENT:

- Almost the total length of the stormwater pipeline was malfunctioning due to full separation at multiple locations, from a few meters past the inlet all the way down to the river (Photos 11, 12 and 18).
- Two large erosion gullies were present on the west riverbank, NW side of the bridge. One erosion gully was located along the stormwater pipeline alignment. This gully started a few meters past the inlet of the stormwater pipeline and extended from the valley top all the way down to the river. This gulley had a variable size along its trajectory, achieving its maximum size near the headslope mid-height and mid-height of the valley, where it reached about 4 m depth by 8 m wide (Photo 18). The second erosion gulley was roughly parallel to the first, extending from the NW corner of Pier 5 to the river. The maximum size of the second gulley on the west abutment was about 2.5 m depth by 6 m wide (Photos 13 and 17). The 2003 repair attempt (currently destroyed) appeared to have been carried out at the second erosion gulley location, where remains of geotextile fabric and gabion mattresses were observed.
- Based on the progression shown in historical photographs, the gulleys have achieved a high rate of erosion.
- The subsurface profile exposed by the gullies generally comprised clay till over sandstone.
- The failure of the stormwater pipeline on the west abutment may have occurred due to uncontrolled surface water flow (due to potential leaks along the pipeline or runoff water from the ditch not properly captured at the inlet, flowing below or adjacent to the stormwater pipeline). The uncontrolled surface water flow extended downwards to the river, eroding the riverbank, and creating the gully.
- A very steep sandstone outcrop was present below Pier 5 and extended to Pier 4 (Photo 10 and 13). The sandstone located directly below the bridge centerline showed erosion including the presence of an erosion gulley, potentially due to the discharge of a bridge rainwater outlet. Observations of rock fall were present. The vertical drop from the outlet was estimated at about 25 m.
- Sandstone erosion including the presence of an erosion gulley were also observed on the SW corner of Pier 5. At this location, buried utilities comprising a steel pipeline and flexible cable were exposed.
- Additional erosion gullies were noted on the sandstone, extending from Pier 5 to Pier 4.
- The soil material on the surface of the headslope, particularly between Pier 3 and 4, consists of fine silty sand, potentially resulting from the erosion of the sandstone. This material is highly erodible, given that it is very loose and exposed at the surface, where scarce vegetation cover present.
- Sandstone rock blocks fallen from the outcrop were observed between Pier 5 and 4.

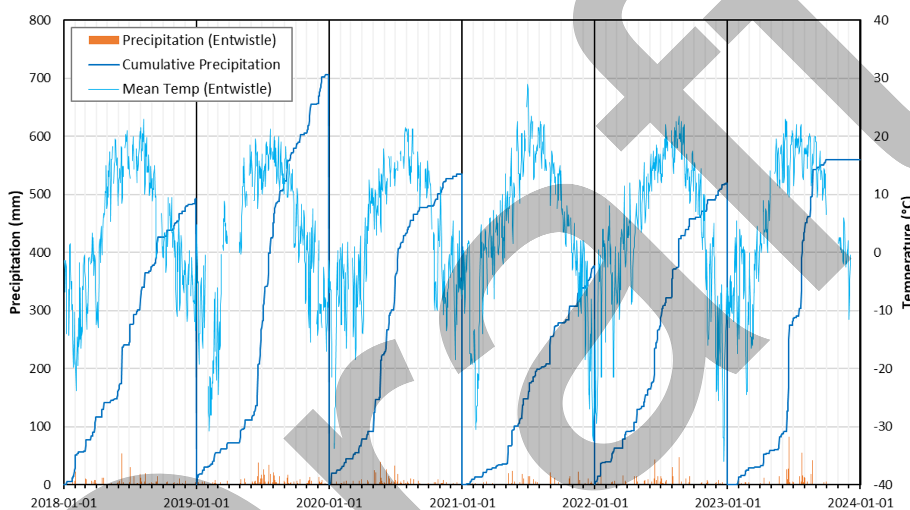
EAST ABUTMENT:

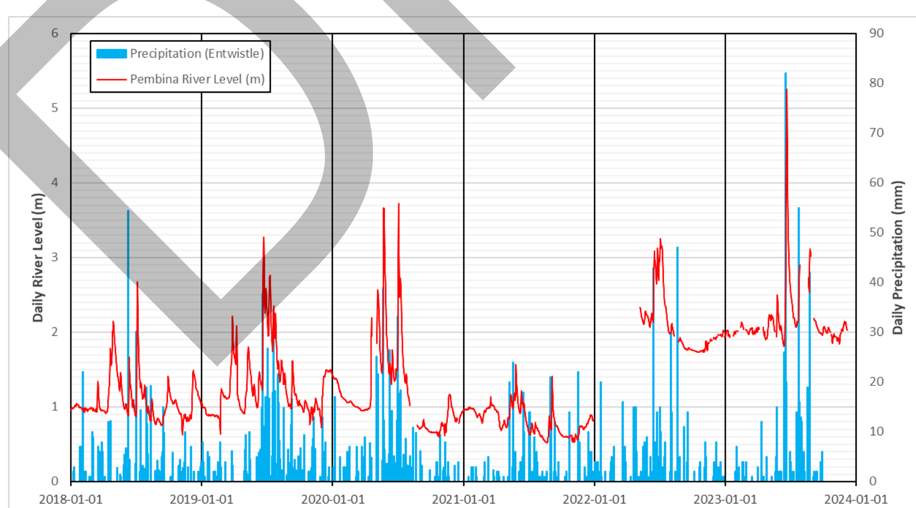
- The stormwater pipeline was observed to be sheared off at the valley crest, at the top of the sandstone outcrop. At this location, the stormwater pipeline had a near vertical drop estimated at about 20 m (Photo 8). The pipeline may have sheared off due to the suspended weight of the pipeline and runoff. The remainder of the stormwater pipeline was destroyed due to the development of a large erosion gulley resulting from uncontrolled discharge from the pipeline. The size of the gully was not directly measured, but based on photographs the maximum size appeared to be about 2 m deep by 4 m wide and extended downslope to the river (Photo 9).

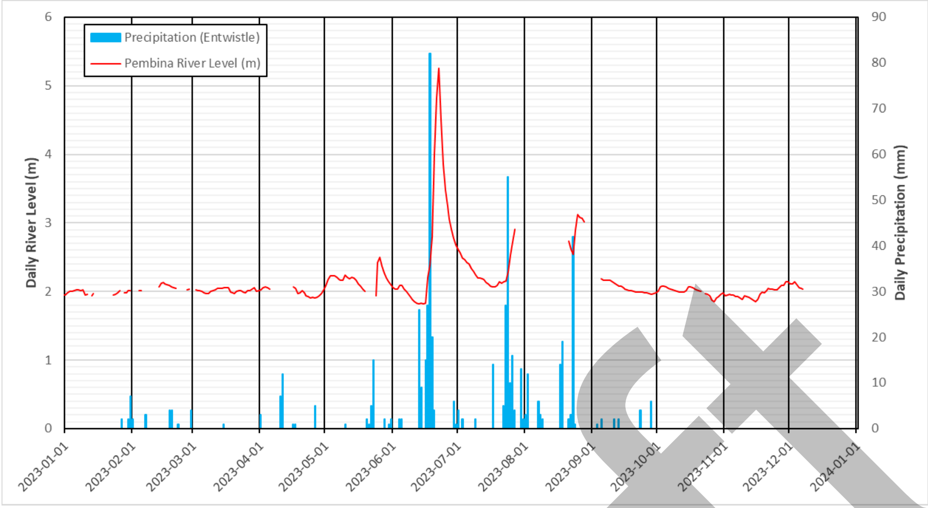
- Several smaller erosion gullies were observed below the sandstone outcrop on Pier 1. The gullies extended downslope, finishing at the riprap beside Pier No. 2 (Photo 3).
- The sandstone outcrop was observed to be horizontally bedded and had near vertical joints closely parallel to the valley sides, which result in rock fall and further loosened slabs of rock potentially in unstable conditions below the abutment and potentially undermining the abutment (Photos 4, 5 and 16).
- Sandstone blocks fallen from the outcrop were observed between Pier 1 and 2 (Photos 5 and 6).

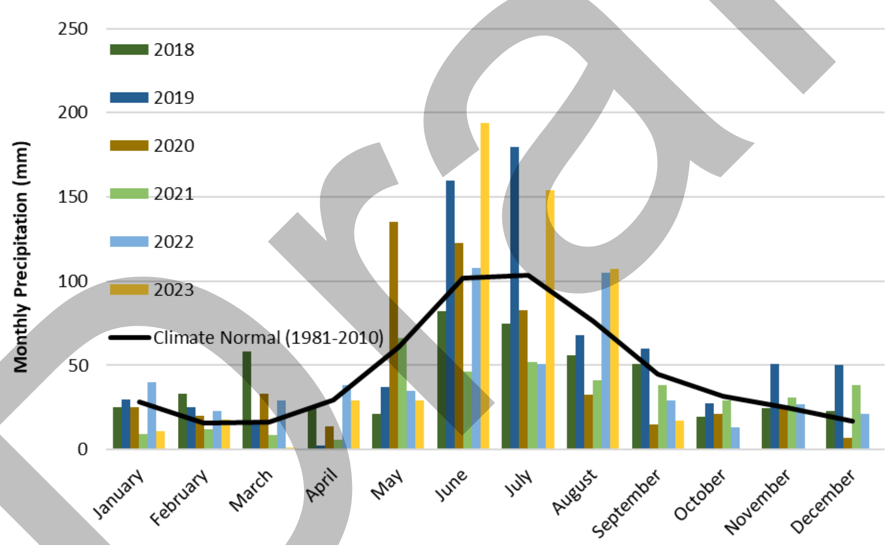
HISTORICAL CLIMATE DATA:

- Historical climate data of the region and historical Pembina River levels are presented below (source:weather.gc.ca), including the large 82 mm precipitation event of June 18 2023. The climate data illustrates that June, July and August of 2023 show greater monthly precipitation values than the climate normal. Large precipitation events and rapid snow melt will continue to exacerbate the erosion of the abutments.









PROBABILITY FACTOR AND CONSEQUENCE FACTOR:

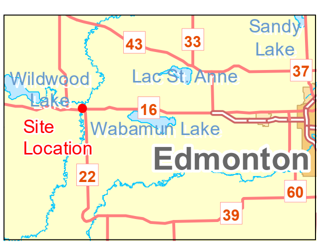
- A Probability Factor of 13 was assigned since the hazard is active with a high rate of erosion considering the progression based on historical photographs. A Consequence Factor of 8 was assigned since the erosion could trigger foundation instability, leading to a temporary closure of the highway and the need to re-route traffic.

RECOMMENDATIONS

- In the short term, it is recommended that a topographic and LiDAR survey of both abutments is performed, including at least 200 m past both sides of the river along the highway to establish catchment areas. With this information, a surface water drainage study should be done to appropriately redesign the highway stormwater discharge on both riverbanks.
- Erosion and rock fall of the sandstone located on the east and west bridge headslopes should be mitigated. For this purpose, the entire extent of the erosion gullies should be repaired, comprising undertaking an excavation to remove lose material and debris, followed by backfilling with compacted engineered fill. Given the inclination of the abutments, steep slope safety measures are required, such as benching the excavation.

- A new stormwater discharge system to collect, contain and direct the surface water runoff from the valley crest to the Pembina River should be installed on both abutments. Alternatives may comprise an above-ground CSP or HDPE stormwater pipeline supported on a steel truss resting on footings, or reinforced concrete outfalls, or a system of long reinforced concrete drainage ditches descending the riverbank in a zig-zag arrangement.
- Should the selected option for the stormwater discharge system be an above-ground CSP stormwater pipeline, the alignment selected could be similar to the inoperable pipeline, such that the footing locations could be selected with bearing on the exposed sandstone, and foundation construction could be simultaneous with the repair of the erosion gully.
- Should the selected option for the stormwater discharge system be a reinforced concrete outfall, the outfall alignment could also be selected to match the alignment of the inoperable pipeline, such that savings on excavation and gully repair costs could be optimized.
- The Pembina River bridge is supported on footings. The performance of the footings require adequate resistance of the sandstone strata. A geotechnical / geological investigation will be required, comprising drilling to characterize the compressive strength of the sandstone and including LiDAR change detection and rock discontinuity modelling using ShapeMetrix software to represent the rock joint patterns and identify wedges susceptible to undermining the abutment. Consideration to survey markers or tiltmeters to be installed on the pier footings may also be considered to allow for displacement monitoring due to undermining. Furthermore, a bridge structural analysis should be carried out to determine the loads transferred to the footing foundations.
- Monitoring through visual inspection, LiDAR change detection and deformation monitoring on both abutments is recommended.
- The high-level cost for topographic and LiDAR surveying and surface water drainage study comprising both abutments is $100,000 to $150,000. The high-level cost for a geotechnical investigation and monitoring comprising both abutments is $75,000 to $100,000. The high-level cost for the construction repairs of the gullies and a new surface water drainage system on both abutments is $900,000 to $1,500,000 including contract administration.

PREPARED BY: Sam Toms, E.I.T.	**PREPARED BY:** Gustavo Padros, M.Sc., P.Eng.
REVIEWED BY: Carrie Murray, M.Eng., P.Eng.	**PERMIT TO PRACTICE**



- Site Location
- Ground Elevation Contours (m AMSL)
- Direction of Waterflow

m AMSL - metres above mean sea level

0 20 40 metres

(At original document size of 8.5x11)
1:1,650

Stantec

Project Location
SW-20-053-07W5,
Entwistle, Alberta

Prepared by MK on 2023-12-06
QR by GP on 2023-12-06
IR by CM on 2023-12-06

Client/Project
123315222
Transportation and Economic Corridors
Geohazard Monitoring Program
Hwy 16 Bridge over Pembina River, Entwistle

Figure No.
1
DRAFT

Title
Site Plan

Notes
1. Coordinate System: NAD 1983 UTM Zone 11N
2. Data Sources: Geogratis, ©Department of Natural Resources Canada, All rights reserved.
3. Background: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
4. Ground Contours: AltaLIS, Parkland County GIS Services (accessed from AGO in December 2023).

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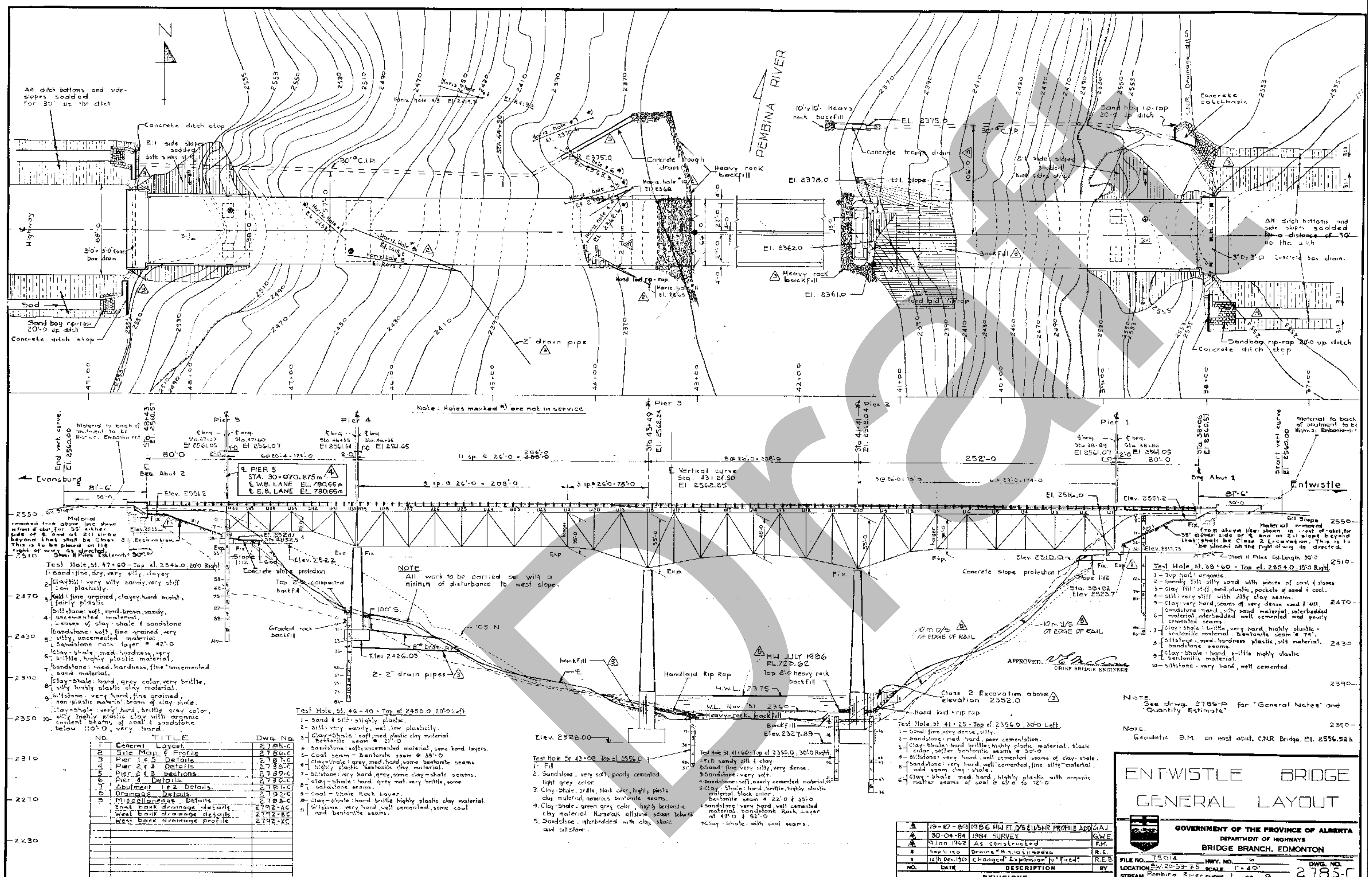
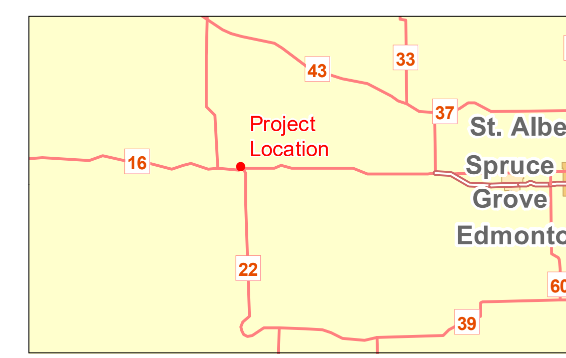


Notes
1. Coordinate System: NAD 1983 UTM Zone 11N
2. Inset Data Sources: Geogratis, ©Department of Natural Resources Canada, All rights reserved.



Project Location
Entwistle, Alberta

Prepared by MK on 2023-12-06
QR by ST on 2023-12-06
IR by CM on 2023-12-06

Client/Project
123315222
Transportation and Economic Corridors
Geohazard Monitoring Program
Hwy 16 Bridge over Pembina River, Entwistle

Figure No.
2

Title
BF75014 Pembina River Bridge General Layout

Photo 1: Overview of northeast slope, facing east

Photo 2: Overview of southeast slope, facing east

Photo 3: Gullies downslope of east abutment, facing northeast

Photo 4: Slope face next to east abutment, facing northeast

Photo 5: Slope face next to east abutment, facing east

Photo 6: Gullies downslope of east abutment, facing southeast

Photo 7: Slope north of east abutment, showing displaced broken culvert sections

Photo 8: Culvert north of east abutment, showing broken sections and evidence of scour

Photo 9: Erosion gully south of east abutment

Photo 10: Overview of northwest slope, facing northwest

Photo 11: Overview of northwest slope, facing west

Photo 12: Erosion gullies next to west pier at river level, facing southeast

Photo 13: Erosion gullies next to west pier at river level, facing west

Photo 14: Erosion gullies and broken culvert on north side of west abutment

Photo 15: Erosion at west abutment slope, showing abutment undermining and exposed utility cables, facing northwest

Photo 16: Erosion at west abutment slope, showing abutment undermining

Photo 17: Erosion at west abutment slope, facing west, showing broken sections of culvert and erosion gullies

Photo 18: West abutment slope, facing west, showing broken culvers and fallen trees

Photo 19: Entrance to culvert north of west abutment, facing east