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Abbreviations

AEP	Alberta Environment and Parks
CCE	calcium carbonate equivalent
C&R Plan	conservation and reclamation plan
CEA Agency	Canadian Environmental Assessment Agency
CEAA	*Canadian Environmental Assessment Act*
EIA	*environmental impact assessment*
EPEA	*Alberta Environmental Protection and Enhancement Act*
LAA	local assessment area
LCC	agricultural land capability
LiDAR	light detection and ranging
LSRS	land suitability rating system
m asl	metres above sea level
NRCB	Natural Resources Conservation Board
PDA	project development area
RAA	regional assessment area
TOR	terms of reference
TLRU	Traditional Land and Resource Use
TUS	Traditional Use Studies
VC	valued component

9.0 ASSESSMENT OF POTENTIAL EFFECTS ON TERRAIN AND SOILS

9.1 SCOPE OF THE ASSESSMENT

Terrain and soils define the landscape of the Project area and form the basis for vegetation development and the creation of wildlife habitat. Agricultural land use is dependent on soil quality and quantity.

9.1.1 Regulatory and Policy Setting

The scope of the terrain and soils assessment is directed by the terms of reference (TOR) set out for the project by Alberta Environment and Parks (AEP) (Alberta Environment and Sustainable Resource Development 2015) and the guidelines from the Canadian Environmental Assessment Agency (CEA Agency) (2016). Stakeholder and Aboriginal group meetings also informed the process of identifying environmental issues and evaluating potential project effects on terrain and soils. Other policy frameworks included the South Saskatchewan Regional Plan (Alberta Government 2013). Specific regulations pertaining to soils include:

- *Alberta Environmental Protection and Enhancement* Act (EPEA 2016)
- *Conservation and Reclamation Regulation (115/1993) under the EPEA*

9.1.2 Engagement and Key Concerns

Alberta Transportation carried out an engagement and consultation program for the Project with both the public and Aboriginal communities. This program and the results are discussed in Volume 1, Section 6 and Section 7.

Issues and key concerns identified by the public include the loss of high quality agricultural land, effects of added sediment after a flood (changes to soil quality), post-flood odours from the soil, concerns with wind-blown dust from both construction and flood deposition, and changes to the water table (i.e., saturated soils). Flood issues are addressed in Volume 3B.

Alberta Transportation's engagement with Indigenous groups began in 2014 with five Indigenous communities. In June 2016, an additional eight Indigenous communities were engaged as outlined in the CEA Agency Guidelines. Indigenous engagement has been ongoing prior to and through the environmental impact assessment (EIA) process and will continue until a decision is made by Natural Resources Conservation Board (NRCB). Detailed information regarding the Indigenous engagement program is presented in Volume 1, Section 7 and Volume 4, Appendix B.

Traditional Land and Resource Use (TLRU) information was gathered through Project-specific Traditional Use Studies (TUS) conducted by potentially affected Indigenous groups and through the results of Alberta Transportation's Indigenous engagement program. In addition to project-specific sources, publicly-available literature was reviewed for TLRU information relevant to the Project.

TLRU information was considered during the preparation of all aspects of the EIA, including both methodology and analysis, as stipulated by the CEA Agency project guidelines. TLRU information contributed to the understanding of existing conditions and informed the assessment of potential project effects. While this information did not directly affect the significance definition it has been incorporated into the analysis of effects on which the significance determination was based. Generally, issues and concerns related to effects of industrial development on terrain and soils, as reported by Indigenous groups through the review of Project-specific and publicly-available TLRU information, include:

Piikani Nation (PN n.d.) observed two things about siltation related to dams and flooding in the Oldman river. First, silt has been found to settle at the bottom of the dam's collecting basin, covering the soils and rocks every spring. Second, winds were blowing that sediment into their community.

As of January 1, 2018, no project-specific intangible concerns were identified with respect to terrain and soils.

9.1.3 Potential Effects, Pathways and Measurable Parameters

Table 9-1 lists the potential effects, pathways and measurable parameters for terrain and soils.

Table 9-1 Potential Effects, Effects Pathways and Measurable Parameters for Terrain and Soils – Construction and Dry Operations Phases

Potential Environmental Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in terrain stability	• Construction can affect terrain stability by changing slope morphology and drainage paths. This could occur in areas prone to landslides, or made prone to landslides by changes in slope conditions or drainage pathways.	• terrain stability class ratings

Table 9-1 Potential Effects, Effects Pathways and Measurable Parameters for Terrain and Soils – Construction and Dry Operations Phases

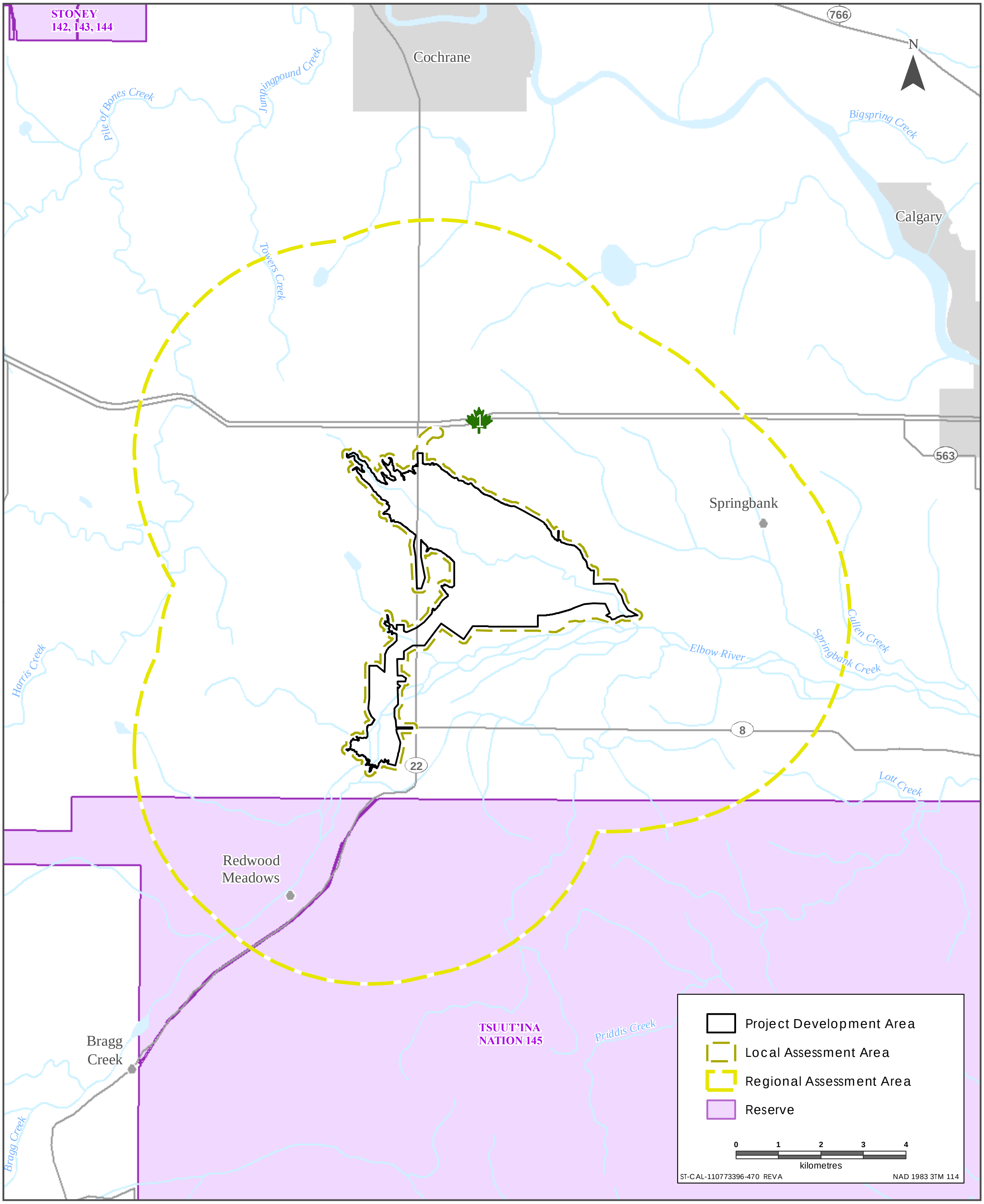
Potential Environmental Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in soil quality and quantity	• Construction and reclamation activities that alter the landscape can change agricultural land capability and reclamation suitability because of admixing, compaction and rutting, and wind and water erosion. These activities could also result in a change in soil thickness or loss of soil volume. Dust mobilization and deposition could affect the agricultural land capability of receiving soils.	• agricultural land capability (LCC) using the Land Suitability Ratings System for Agricultural Crops (Agronomic Interpretations Working Group, 1995) • reclamation suitability classes (AAFRD 1987) • stripping volume and replacement depth effects on agricultural land capability ratings • risk of wind or water erosion assessed using standard rating equations (Wall et al. 2002; Coote and Pettapiece 1989)

9.1.4 Boundaries

9.1.4.1 Spatial Boundaries

Figure 9-1 shows the spatial boundaries for the terrain and soils assessment which consist of the following:

- The project development area (PDA) is the immediate area of project activities and is approximately 1,440 ha.
- The local assessment area (LAA) for terrain and soils is approximately 1,887 ha and encompasses the PDA and areas that may be directly or indirectly affected by project activities.
- The regional assessment area (RAA) for terrain and soils is 22,540 ha and is the area where the Project's environmental effects may interact cumulatively with the environmental effects from other projects or activities that have been, or will be, carried out.



Sources: Base Data - ESRI, Natural Earth, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Spatial Boundaries - Terrain and Soils

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 9-1

9.1.4.2 Temporal Boundaries

Project construction would take place over a 36-month period. Assuming regulatory approval by Q4 2018, construction would commence in Q1 2019. By Q4 2020, the Project would be able to accommodate a 1:100 year flood. Construction would be complete by Q1 2022 at which time the Project would be able to accommodate water volumes equal to the 2013 flood. Dry operations of the Project will occur indefinitely (i.e., permanent installation) after construction, with periods of dry operations alternating with flood and post-flood phases.

9.1.5 Residual Effects Characterization

Table 9-2 presents definitions for residual environmental effects on terrain and soils.

Table 9-2 Characterization of Residual Effects on Terrain and Soils

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive** – a residual effect that moves measurable parameters in a direction beneficial to terrain and soil relative to existing conditions. **Adverse** – a residual effect that moves measurable parameters in a direction detrimental to terrain and soil relative to existing conditions. **Neutral** – no net change in measurable parameters for the terrain and soil relative to existing conditions.

Table 9-2 Characterization of Residual Effects on Terrain and Soils

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible** – Terrain[1]: no change to overall terrain stability within LAA following construction and dry operations compared to existing conditions). Soils: no change in mode[2] of agricultural land capability (LCC) in the LAA and no more than 1% decline in area of LCC mode compared to existing conditions **Low** – Terrain[1]: less than 5% change to overall terrain stability within LAA; however, minor slumping is expected following construction and dry operations compared to existing conditions. Soils: no change in mode of LCC in the LAA and no more than 5% decline in area of LCC mode compared to existing conditions **Moderate** – Terrain[1]: 5 - 10% change to overall terrain stability within LAA; however, expected to contain areas with slight increase in landslide initiation following construction and dry operation compared to existing conditions. Soils: no change in the mode of LCC in the LAA and no more than 10% decline in area of LCC mode compared to existing conditions **High** – Terrain[1]: more than 10% change overall terrain stability within LAA and expected to contain areas with appreciable increase in landslide initiation following construction and dry operation compared to existing conditions. Soils: a change in the mode of LCC in the LAA or a decline of more than 10% in area of LCC compared to existing conditions
Geographic Extent	The geographic area in which a residual effect occurs	PDA – residual effects are restricted to the PDA LAA – residual effects extend into the LAA RAA – residual effects interact with those of other projects in the RAA

Table 9-2 Characterization of Residual Effects on Terrain and Soils

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	Single event Multiple irregular event – occurs at no set schedule Multiple regular event – occurs at regular intervals Continuous – occurs continuously
Duration	The period of time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured or otherwise perceived	Short-term Terrain: residual effect restricted to 2 years after construction or dry operations. Soils: residual effect restricted to one growing season after the completion of construction or less Medium-term Terrain: residual effect extends through 2 to 25 years. Soils: residual effect extends through 5 years, the time estimated for soils to recover after reclamation Long-term Terrain: residual effect is greater than 25 years after construction or dry operations. Soils: residual effect is greater than 25 years
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	Reversible – the residual effect is likely to be reversed after activity completion and reclamation Irreversible – the residual effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	Undisturbed – area is relatively undisturbed or not adversely affected by human activity Disturbed – area has been substantially previously disturbed by human development or human development is still present

Table 9-2 Characterization of Residual Effects on Terrain and Soils

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Timing	Periods of time where residual effects from Project activities could affect the VC	Seasonality – residual effect is greater in one season than another (e.g., spring/summer vs. fall/winter) Time of day – residual effect is greater during daytime or nighttime Regulatory – provincial or federal restricted activity periods or timing windows (e.g., migration, breeding, spawning) related to the VC Not applicable - the residual effect of Project activities will have the same effect on the VC, regardless of timing
NOTES: [1] Adapted from Mapping and Assessing Terrain Stability Guidebook 1999. [2] The class of greatest extent is the mode of the distribution. In the LAA, class 3 is the mode of land capability because class 3 land makes up the greatest extent of the different classes.		

9.1.6 Significance Definition

A significant adverse environmental effect on terrain and soils is one that results in:

- A change in terrain stability resulting in an increase in areas with a moderate to high likelihood of landslide initiation as compared to existing conditions, which cannot be offset through mitigation or
- A change in soil quality or quantity resulting in a reduction in agricultural land capability which cannot be offset through mitigation or compensation measures.

9.2 EXISTING CONDITIONS FOR TERRAIN AND SOILS

9.2.1 Terrain Methods

The terrain data was obtained through a combination of desktop terrain and terrain stability mapping and collection of new terrain data through a field program. Existing data for the LAA was obtained from published sources including surficial geology of the Calgary Urban Area (Moran 1986). The methods used to obtain new terrain data for the LAA are presented in Volume 4, Appendix G (Terrain and Soils Technical Data Report). Terrain data—include surficial material type, surface expression, depth-to-bedrock, slope steepness, soil drainage and geomorphological processes, for example—were collected at 66 sites in the LAA during 2016. Approximately 41% of the mapped polygons were field checked. Terrain field data was used to verify the desktop terrain mapping and used as input into the terrain stability class ratings for the LAA.

9.2.2 Terrain Overview

9.2.2.1 Physiography

The Project is in western Alberta, approximately 15 km west of Calgary, entirely within the Okotoks Uplands District of the Western Benchlands Section of the Southern Alberta Uplands Physiographic Region. The region is characterized by low relief, undulating and hummocky terrain, with some rolling areas controlled by underlying bedrock (Pettapiece 1986). The PDA extends onto the floodplain of the Elbow River and the adjacent escarpment dissected by the Elbow River. Evidence of landslides, such as slumps and debris avalanches, were observed in the field and during the preliminary terrain mapping along the escarpment adjacent to the Elbow River and tributary streams.

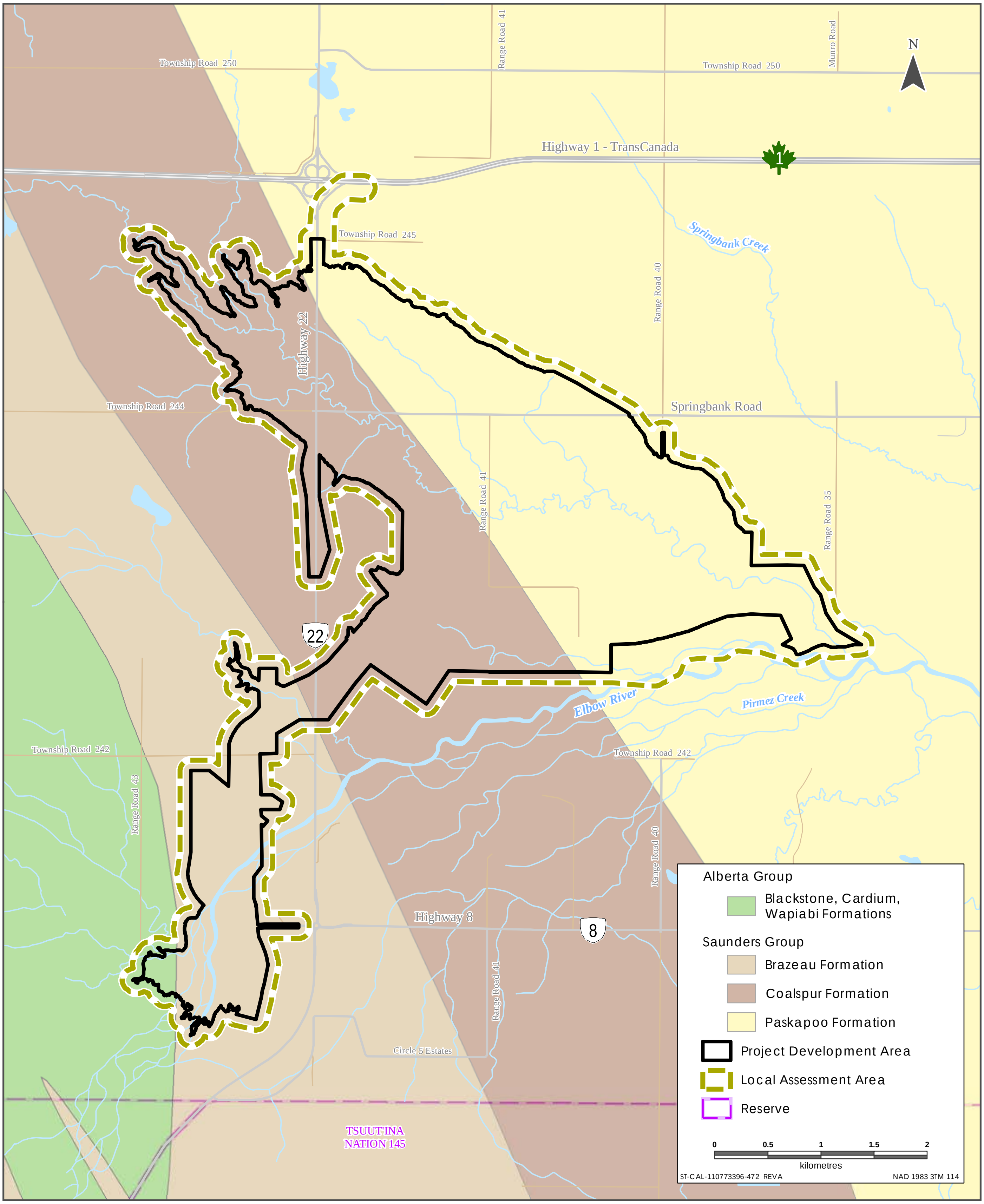
The PDA is drained by the Elbow River and its tributary streams between Range Road 35 and Range Road 43. The proposed reservoir area lies in the watershed of an unnamed tributary to the Elbow River (referred to hereon as the tributary stream). The tributary stream watershed is broad and flat to gently sloped. The elevations in the LAA range from approximately 1,165 m asl at the confluence of the Elbow River and the tributary stream to approximately 1,263 m asl, west of the diversion structure.

9.2.2.2 Bedrock Geology

The LAA is underlain by Upper Cretaceous to Paleogene-aged (Alberta Group and Saunders Group) sedimentary rocks with the strata becoming younger towards the northeast (Prior et al. 2013; Figure 9-2).

The Alberta Group is a largely clastic marine sequence made up of mudstone and shale with occasional sandstone beds. It extends through the southern and central foothills, east into the plains and north to the Athabasca River area (Glass 1997). In ascending order, the Alberta Group is made up of the Blackstone, Cardium and Wapiabi Formations. The Blackstone Formation is a dark grey marine shale. Concretionary mudstone units towards the top grade into the sandstone of the overlying Cardium Formation. The Cardium Formation is a mixed marine and nonmarine unit dominated by prominent sandstone beds separated by shale. The Wapiabi Formation is a dark marine shale with a sandstone unit near the top (Stott 1963).

The Saunders Group is a largely clastic continental sequence made up of sandstone, siltstone, mudstone and coal with minor amounts of conglomerate. In ascending order, the Saunders Group is made up of the Brazeau Formation, Coalspur Formation and Paskapoo Formation. The Brazeau Formation is a succession of interbedded sandstone, siltstone and mudstone with minor beds of coal and bentonite, deposited in an anastomosing river system (Putnam 1993). Chert-pebble conglomerate occurs in the lower part of the formation. In southwestern Alberta, the Brazeau Formation is conformably underlain by the Wapiabi Formation (Alberta Group) and conformably overlain by the Coalspur Formation. The Coalspur Formation comprises (thin bedded to massive) sandstone, siltstone, mudstone and coal with minor amounts of conglomerate, bentonite and tuff (Glass 1997). The Coalspur Formation is a fluvial unit with locally thick lake and swamp (coal) deposits. The Paskapoo Formation is a Paleogene unit deposited in southwestern Alberta during final uplift of the Rocky Mountains. The formation consists of recessive shale and mudstone interbedded with resistant sandstone and calcareous siltstone. Massive channel sandstone sequences are abundant. Depositional environments are interpreted to be fluvial and include channel and overbank deposits. The upper part of the sequence has been removed by erosion and is overlain by glacial drift (Glass 1997).



Sources: Base Data - Government of Alberta, Government of Canada. Thematic Data - Stantec Ltd.
Bedrock Geology: Prior, G.J., Hathaway, B., Glombick, P.M., Pana, D.I., Banks, C.J., Hay, D.C., Schneider, C.L., Grobe, M., Elgr, R., and Weiss, J.A. 2013. Bedrock Geology of Alberta; Alberta Energy Regulator, AER/AGS Map 600, scale 1:1,000,000.
http://ags.aer.ca/publications/DIG_2013_0019.html

Bedrock Geology

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Figure 9-2

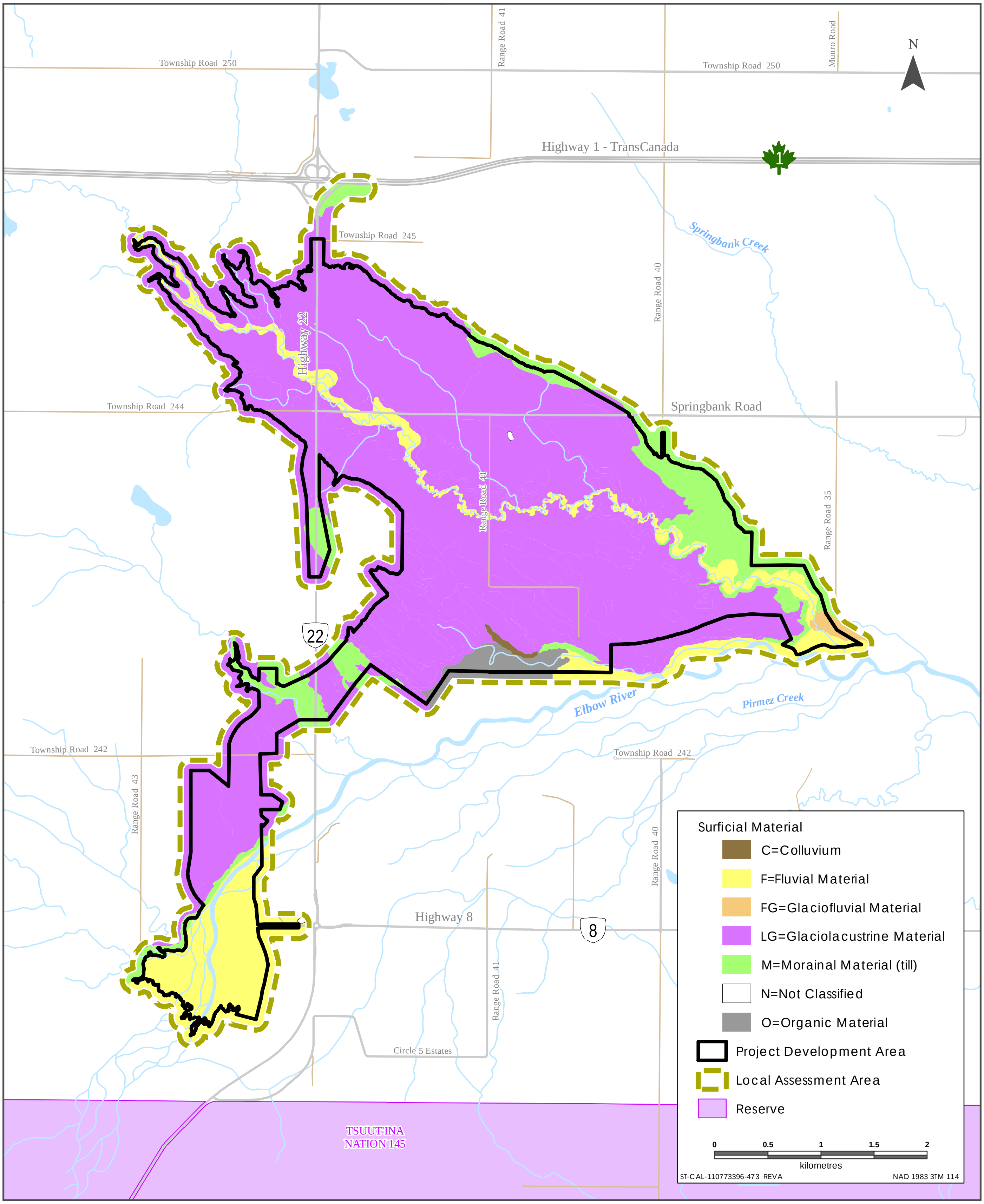
9.2.2.3 Late Glacial History

During the latest Late Wisconsinan Glaciation (approximately 30,000 to 27,000 years ago), the Project area was overridden by ice from both the Cordilleran Ice Sheet, advancing from the mountains in the northwest, and the Laurentide Ice Sheet, advancing from the east. The earliest advance of ice into the Project area in the Late Wisconsinan, was from a valley glacier advancing eastwards from the foothills down the Bow River valley (Moran 1986). As it advanced, this glacier encountered the Laurentide Ice Sheet, and was diverted southward along the mountain front (Jackson 1980). As the climate warmed, the Laurentide Ice Sheet dammed meltwater from the retreating mountain glaciers and runoff from streams in the Rocky Mountains, resulting in the formation of a series of glacially-dammed lakes during its retreat (Moran 1986).

The distribution of surficial materials mapped in the LAA (Figure 9-3) are summarized in Table 9-3. The most widespread surficial material is glaciolacustrine materials. In general, glaciolacustrine materials consist of silt and clay with no coarse fragments occurring as deep deposits along the lowlands and draped over till along topographic highs. Fluvial sediments (silt, sand, and gravel) are the second most widespread surficial material and mapped along the floodplains of the Elbow River and the tributary stream. Till directly deposited by glacier ice is the third most widespread. The local till has a clayey silt texture with low (< 20%) coarse fragment content. Lesser extents of organic material, glaciofluvial silt, sand and gravels, colluvium, and bedrock make up the remainder of the LAA. For additional information on surficial materials characteristics at and their distribution, see Volume 4, Appendix G.

Table 9-3 Surficial Materials in the LAA

Surface Material	Area (ha)	Percentage of Total Area (%)
Glaciolacustrine	1,311.8	69.5
Fluvial	271.3	14.4
Till	254.2	13.5
Organic	35.4	1.9
Glaciofluvial	8.1	0.4
Colluvium	4.0	0.2
Open water	1.0	0.1
Bedrock	0.6	0.0
Total	**1,886.4**	**100.0**



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Surficial Materials

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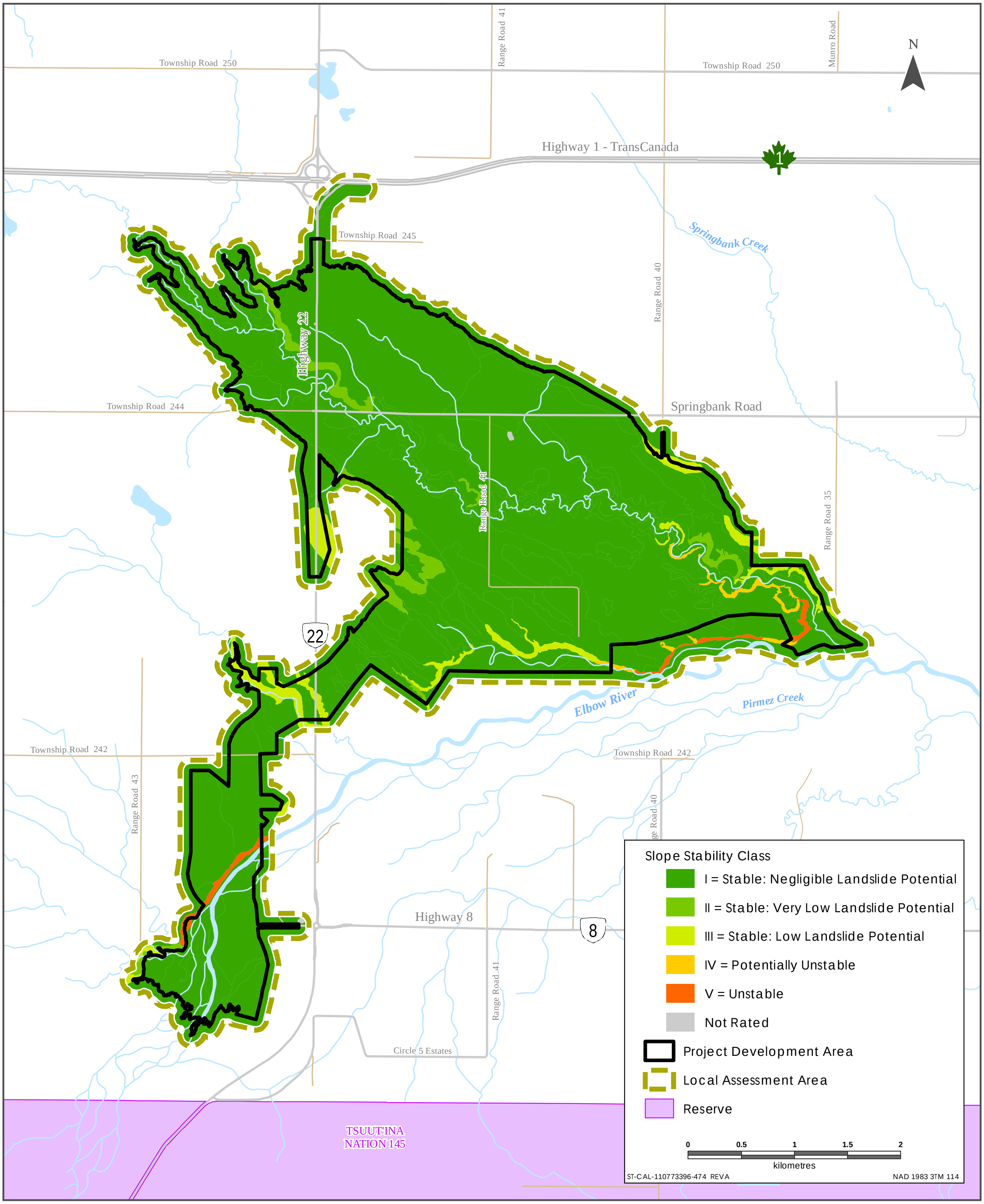
Figure 9-3

The qualitative terrain stability mapping within the LAA (Figure 9-4) is summarized in Table 9-4.

Table 9-4 Terrain Stability in the LAA

Terrain Stability Class	Terrain Stability Class Definition	Area (ha)	Percentage of Total Area (%)
I	Stable: Expected to have a negligible likelihood of landslide initiation.	1,743.5	92.4
II	Stable: Expected to have a low likelihood of landslide initiation on slopes ranging from 10-20% steepness.	55.5	2.9
III	Stable: Expected to have a low likelihood of landslide initiation on slopes steeper than 20%.	64.3	3.4
IV	Potentially unstable: Expected to contain areas with a moderate likelihood of landside initiation.	9.6	0.5
V	Unstable: Expected to contain areas with a high likelihood of landslide initiation.	12.6	0.7
Total		**1,886.5**	**100.0**

The terrain in the PDA is generally subdued with landslide-prone terrain (terrain stability class IV and V) restricted to the Elbow River escarpment and streambanks.



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Terrain Stability Map

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Figure 9-4

9.2.3 Soils Methods

Soil and landscape data for the LAA and the RAA were obtained through a combination of desktop review and of the collection of new data through a field program, as described in Volume 4, Appendix G. Existing data for both the LAA and RAA were obtained from published sources including AGRASID (Alberta Soil Information Centre 2003) and from the soil survey for the Calgary Urban perimeter (MacMillan 1987). The methods used to obtain new soil data for the LAA are presented in Appendix G and are based on the Canadian System of Soil Classification (Expert Committee on Soil Survey 1998). Soil profile data were collected at 360 sites in the LAA during 2016. In addition, 49 samples from 18 profiles were collected and submitted for laboratory analysis of select parameters such as organic carbon, pH, salinity and particle size distribution. Terrain and soil data were used to map the soil in the LAA. Both field and existing data were integrated to map the soils in the LAA to the standards of the Mapping Systems Working Group (1981). Soil resources were evaluated for risk of degradation due to wind and water erosion, compaction and rutting. Soil quality was evaluated against such standards as the Land Suitability Rating System (Agronomic Interpretations Working Group 1995), and the soil quality criteria for reclamation (AAFRD 1987). Detailed soil mapping is presented in Volume 4, Appendix G, Soils and Terrain Technical Data Report.

9.2.4 Soil Overview

Figure 9-5 shows the soil distribution in the LAA. Characteristics of soil units are presented in Table 9-5. Soil units include series or phases from the Chernozemic, Regosolic, and Gleysolic, soil orders. Slopes range from class 1 (level) to class 8 (extreme). Ranked in order of extent, fine to very fine textured units dominated by Chernozems and Gleysols occupy approximately 76.8% of the LAA. Moderately to very coarse textured units (Regosolic soils are next most abundant, especially in the Elbow River floodplain occupying approximately 9.1%. Lesser extents of medium textured units (Chernozems) make up approximately 2.0% of the LAA. Complex soil units with a range of materials, taxonomy or textures occupy approximately 6.9% of the LAA. Reclaimed and disturbed land makes up approximately 5.2% of the LAA.

Agricultural land capability in the LAA is presented in Table 9-6 and Figure 9-6. Reclamation suitability of topsoil and subsoil in the LAA is presented in Table 9-7, Table 9-8, Figure 9-7 and Figure 9-8. Topsoil water erosion risk is presented in Table 9-9 and Figure 9-9. Topsoil wind erosion risk is presented in Table 9-10 and Figure 9-10. The ratings assume bare, dry conditions to be conservative (that is, effects are overestimated).

For additional information on soil properties and soil distribution, see Volume 4, Appendix G.

Table 9-5 Soil Units in the LAA

Unit[1]	Slope Classes[2]	Genetic Materials	Drainage Regimes	Soil Classes	Extent (ha)	Extent (%)
Units with fine to very fine-textured till and glaciolacustrine parent materials					1448.4	76.8
DVFS1	3, 4, 5, 5-6, 6	till and glaciolacustrine	Moderately well to well	Orthic Black Chernozem, Calcareous Black Chernozem	55.2	3.0
DVFS2	2, 3, 4	till and glaciolacustrine	Imperfect to well	Orthic Black Chernozem, Calcareous Black Chernozem, Gleyed Black Chernozem	304.3	16.2
DVG1	1-3, 2, 3, 4, 5, 6, 6-7, 6-8, 7, 7-8, 8	developed on moderately to strongly calcareous, mixed continental and Cordilleran Till	Moderately well to well	Orthic Black Chernozem, Calcareous Black Chernozem	281.5	14.8
FSH1	3, 4, 5,	developed on non-saline, moderately calcareous glaciolacustrine	Moderately well	Orthic Black Chernozem, Calcareous Black Chernozem	276.7	14.7
FSH2	1, 2, 3, 4	glaciolacustrine	Imperfect to moderately well	Orthic Black Chernozem, Calcareous Black Chernozem, Gleyed Black Chernozem	437.2	23.1
POT1	1,2,3	till and glaciolacustrine	Poor	Orthic Humic Gleysol	30.0	1.7
POT2	1, 2	till and glaciolacustrine	Poor to imperfect	Orthic Humic Gleysol, Gleyed Black Chernozem	20.5	1.0
POT6	2, 3, 6	till and glaciolacustrine	Poor to moderately well	Orthic Humic Gleysol, Gleyed Black Chernozem, Orthic Black Chernozem	43.1	2.3

Table 9-5 Soil Units in the LAA

Unit[1]	Slope Classes[2]	Genetic Materials	Drainage Regimes	Soil Classes	Extent (ha)	Extent (%)
Units with medium-textured fluvial parent materials, sometimes gravelly					38.1	2.0
SRC1	1, 2	fluvial	Well	Calcareous Black Chernozem	35.8	1.9
SRC4	1	fluvial	Well to rapid	Calcareous Black Chernozem, Gravelly Calcareous Black	2.3	0.1
Units with moderately coarse to very coarse-textured fluvial and glaciofluvial parent materials					172.1	9.1
TBR1	1-6, 3	fluvial and glaciofluvial	Rapid	Orthic Regosol	6.4	0.3
TBR2	1-5, 1-6, 3	fluvial and glaciofluvial	Imperfect to rapid	Orthic Regosol, Gleyed Regosol	50.7	2.8
TBR4	1-6, 3	fluvial and glaciofluvial	Rapid	Orthic Regosol, Gravelly Regosol	11.4	0.6
TBRgr1	2	fluvial, active channel deposits	Rapid	Gravelly Regosol	61.9	3.3
TBRgr2	1-6	fluvial, active channel deposits	Poor to rapid	Gravelly Gleyed Regosol, Humic Gleysol	6.8	0.4
ZGC1	2	fluvial	Poor	Humic Gleysols	35.0	1.9
Undifferentiated, transitional areas, variable texture					129.7	6.9
POT7	1-6, 2	till and glaciolacustrine with variably textured fluvial parent materials	Poor to imperfect	Orthic Humic Gleysol, Gleyed Regosol	81.7	4.4
TBR6	1-6	fluvial, with inclusions of till and glaciolacustrine erosional remnants	Well to rapid	Orthic Regosol, Black Chernozem	15.1	0.8
TBSR1	1-6, 2	fluvial	Well to rapid	Orthic Regosol, Calcareous Black Chernozem	30.0	1.6

Table 9-5 Soil Units in the LAA

Unit[1]	Slope Classes[2]	Genetic Materials	Drainage Regimes	Soil Classes	Extent (ha)	Extent (%)
MSTB1	7	colluvium overlying residuum (sandstone and shale)	Well to rapid	Rego Black Chernozem, Orthic Regosol	2.8	0.2
Other					98.2	5.2
ZDL	N/A	N/A	N/A	N/A	97.1	5.1
ZREC	3	anthropogenically disturbed soils over till or glaciolacustrine	Moderately well	N/A	1.1	0.1
Total					1886.5	100.0

Table 9-5 Soil Units in the LAA

NOTES:
Areas and proportions will not sum exactly to totals because of rounding.

[1]

Unit Abbreviations	Soils
DVFS1	Dunvargan and Fish Creek
DVFS2	Dunvargan, Fish Creek and other Fish Creek phases
DVG1	Dunvargan
FSH1	Fish Creek
FSH2	Fish Creek and other Fish Creek phases
POT1	Pothole Creek
POT2	Pothole Creek and other phases of Fish Creek
POT6	Pothole Creek and other phases of Fish Creek
SRC1	Sarcee
SRC4	Sarcee and other phases of Sarcee
TBR1	Twin Bridges
TBR2	Twin Bridges and other phases of Twin Bridges
TBR4	Twin Bridges and other phases of Twin Bridges
TBRgr1	Twin Bridges gravelly
TBRgr2	Twin Bridges gravelly and other phases of gravelly Twin Bridges
ZGC1	Miscellaneous coarse textured Gleysolic
POT7	Pothole Creek, Regosols and Gleysols
TBR6	Twin Bridges and Dunvargan
TBSR1	Twin Bridges and Sarcee
MSTB1	Mesa Butte and Twin Bridges
ZDL	Miscellaneous disturbed land
ZREC	Miscellaneous reclaimed land

Table 9-5 Soil Units in the LAA

[2] Slope Classes	Associated Range of Slope Gradients
1	0-0.5%
1-3	0 to 5%
1-5	0 to 15%
1-6	0 to 30%
2	0.5 to 2%
3	2 to 5%
4	6 to 9%
5	10 to 15%
5-6	10 to 30%
6	15 to 30%
6-7	15 to 45%
6-8	15 to 70%
7	30 to 45%
7-8	30 to 70%
8	45 to 70%

Table 9-6 Agricultural Land Capability in the LAA

Agricultural Land Capability Class	Area of LAA (ha)	% of LAA
1	0.0	0.0
2	0.0	0.0
3	1426.3	75.6
4	133.5	7.1
5	85.9	4.6
6	142.2	7.5
7	1.4	0.1
Not Applicable	97.1	5.1
Total	**1,886.5**	**100.0**
NOTE: Areas and proportions will not sum exactly to totals because of rounding		

Table 9-7 Reclamation Suitability Topsoil in the LAA

Reclamation Suitability Rating	Areal Extent in LAA (ha)	% of LAA
Good	84.6	4.5
Fair	1412.9	74.9
Poor	222.3	11.8
Unsuitable	-	-
Not Applicable	97.1	5.1
Not Rated	69.5	3.7
Total	**1886.5**	**100.0**
NOTE: Areas and proportions might not add up to totals because of rounding		

Table 9-8 Reclamation Suitability Subsoil in the LAA

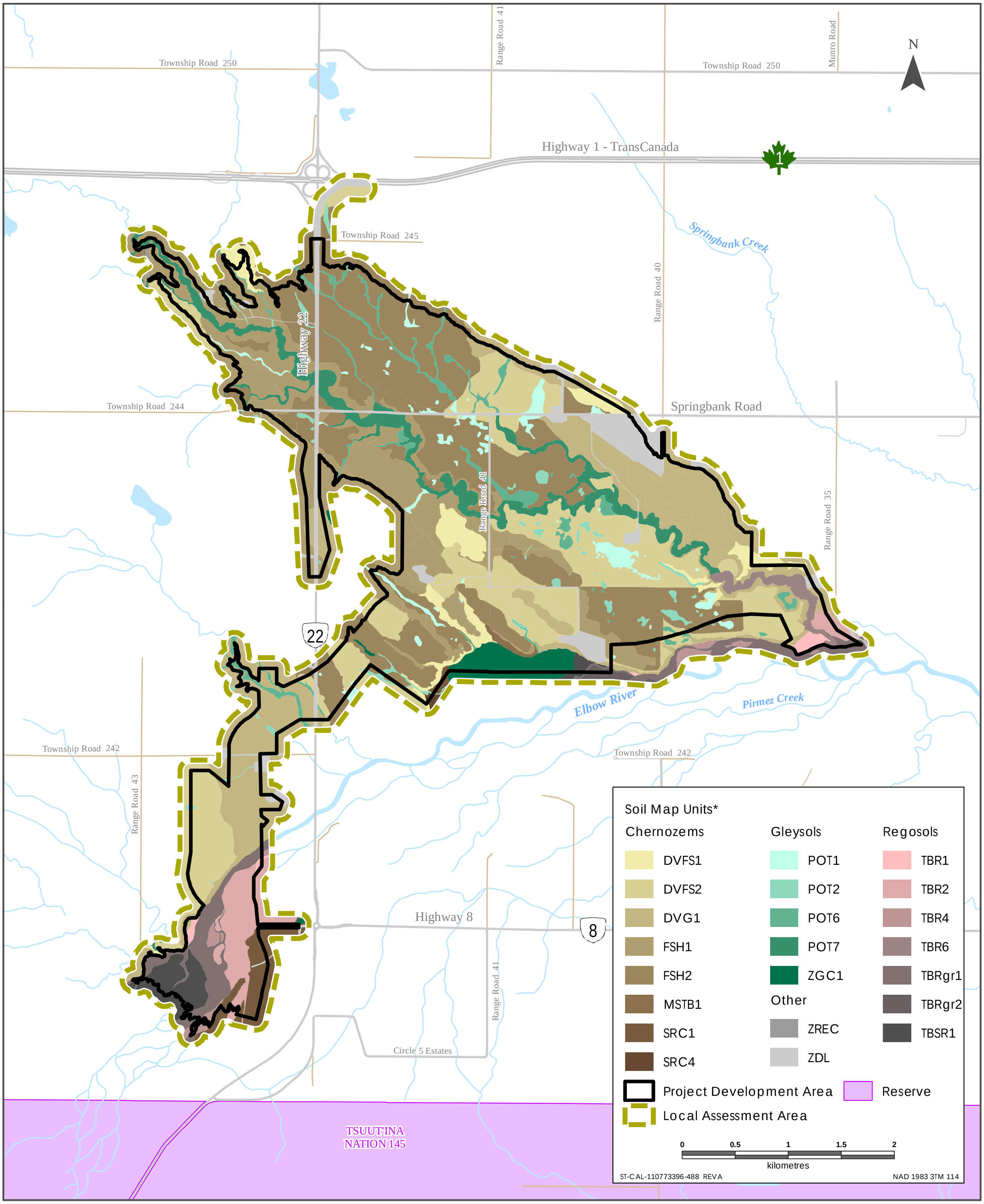
Reclamation Suitability Rating	Areal Extent in LAA (ha)	% of LAA
Good	84.6	4.5
Fair	105.4	5.6
Poor	1528.5	81.0
Unsuitable	71.0	3.8
Not Applicable	97.1	5.1
Not Rated	-	-
Total	**1886.5**	**100.0**
NOTE: Areas and proportions might not add up to totals because of rounding		

Table 9-9 Topsoil Water Erosion Ratings for the LAA

Wind Erosion Rating	Areal Extent of Topsoil in LAA (ha)	% of Topsoil in LAA
Severe	14.0	0.7
High	0.0	0.0
Moderate	5.1	0.3
Low	11.1	0.6
Very Low	1759.1	93.2
Not Applicable	97.1	5.1
Total	**1886.5**	**100.0**
NOTE: Areas and proportions will not sum exactly to totals because of rounding		

Table 9-10 Topsoil Wind Erosion Ratings for the LAA

Wind Erosion Rating	Areal Extent in LAA (ha)	% of LAA
Severe	0.0	0.0
High	234.8	12.4
Moderate	0.0	0.0
Low	1554.6	82.4
Negligible	0.0	0.0
Not Applicable	97.1	5.1
Total	**1886.5**	**100.0**
NOTE: Areas and proportions might not add up to totals because of rounding		



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.
* Refer to Table 9-5 for Soil Map Unit descriptions.

Soil Map Units in the Project Development Area and Local Assessment Area

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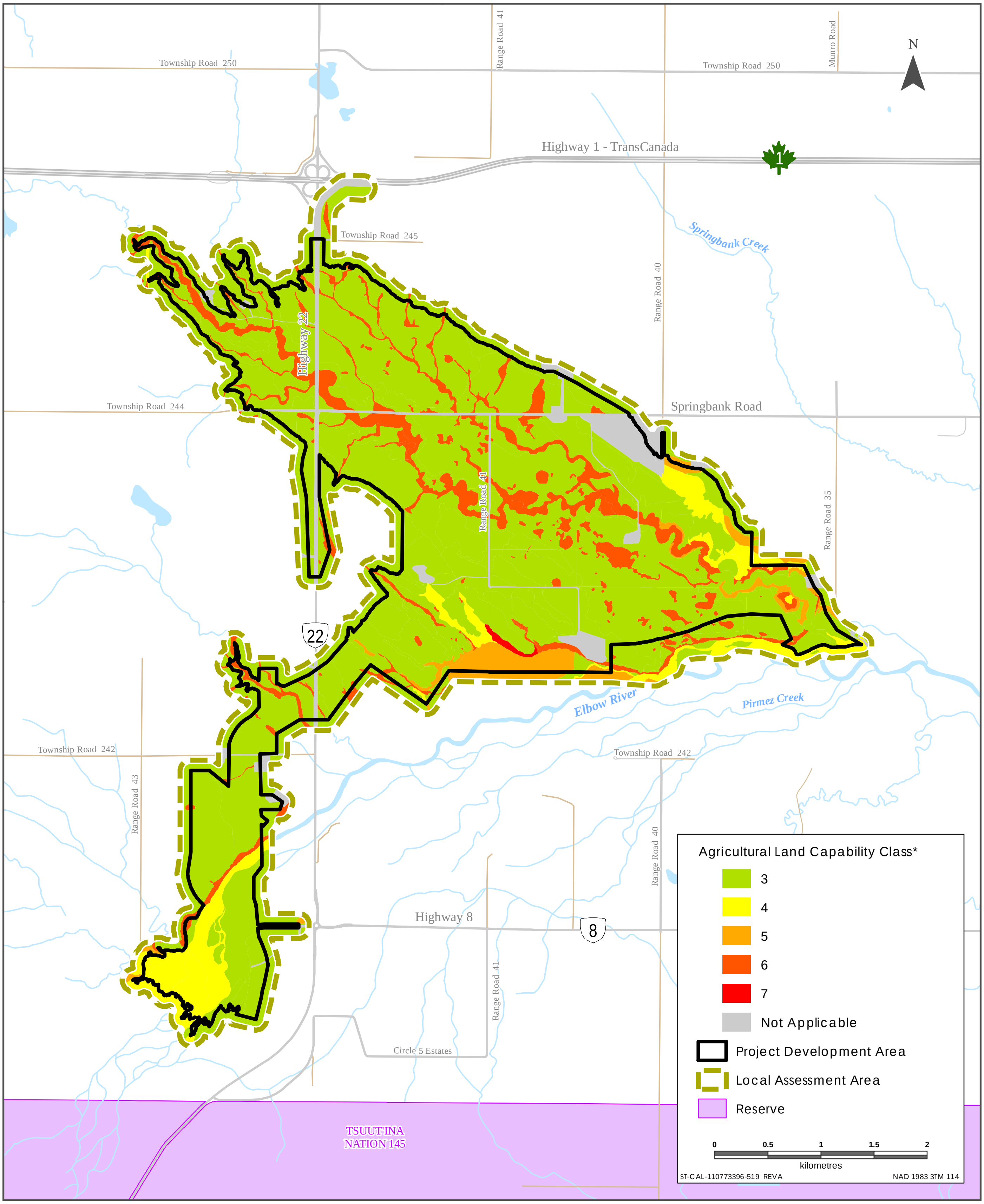
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 9-5



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.
**Refer to Tables D7-15 and D7-16 for Agricultural Land Capability Class descriptions.*

Agricultural Land Capability Classes for the
Project Development Area and Local Assessment Area

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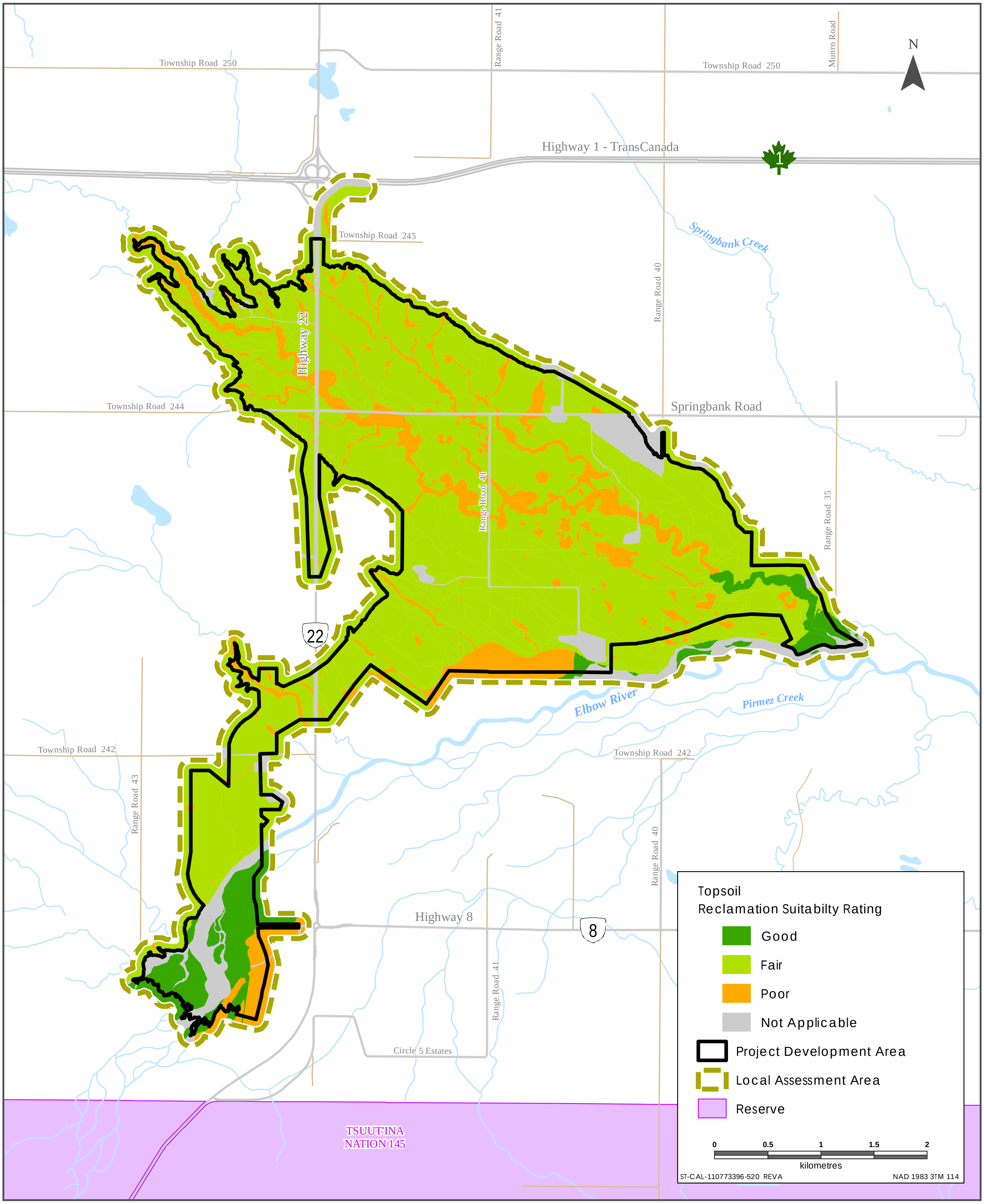

Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Topsoil Reclamation Suitability for the Project Development Area and Local Assessment Area

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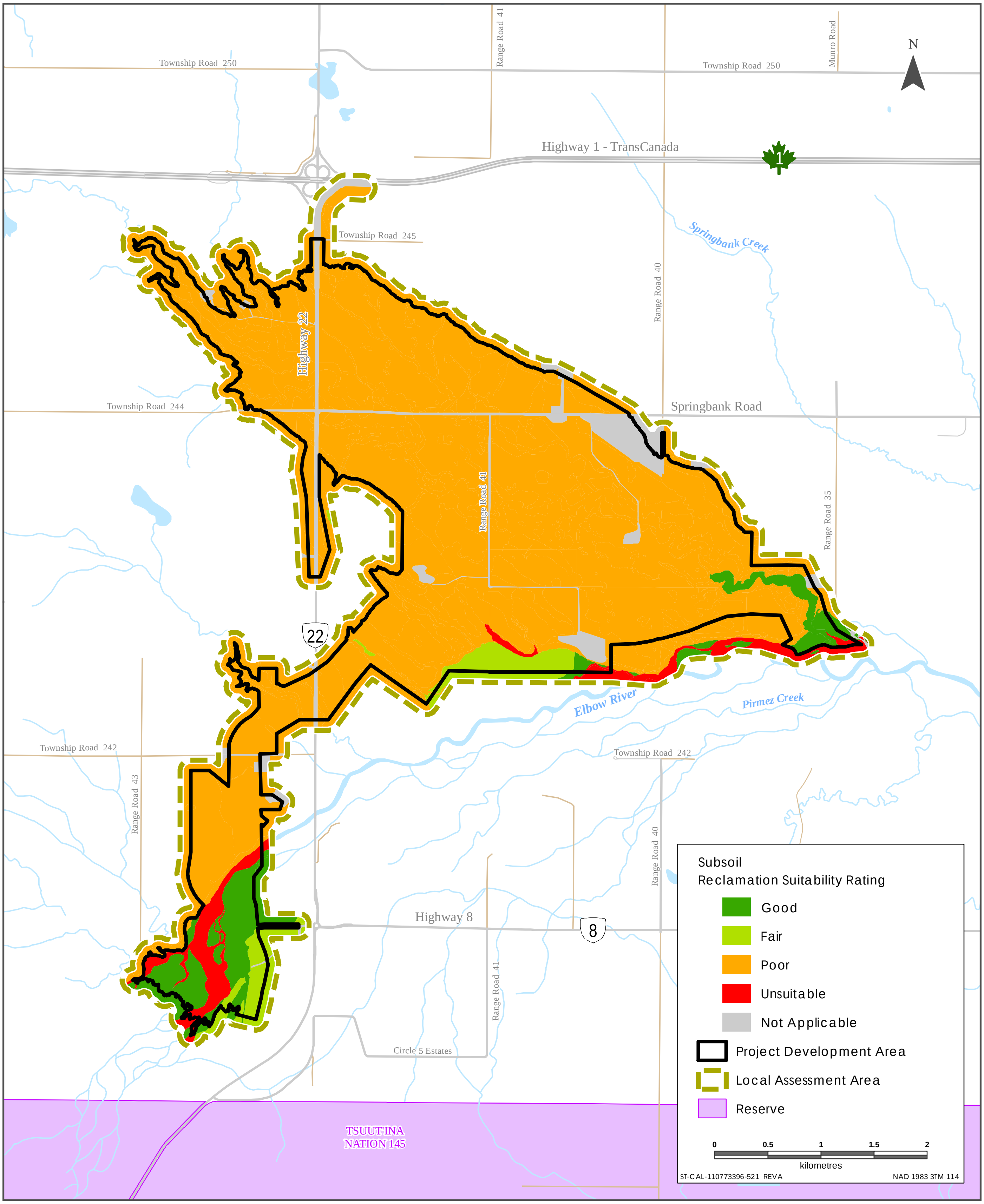
Figure 9-7



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Subsoil Reclamation Suitability for the Project Development Area and Local Assessment Area

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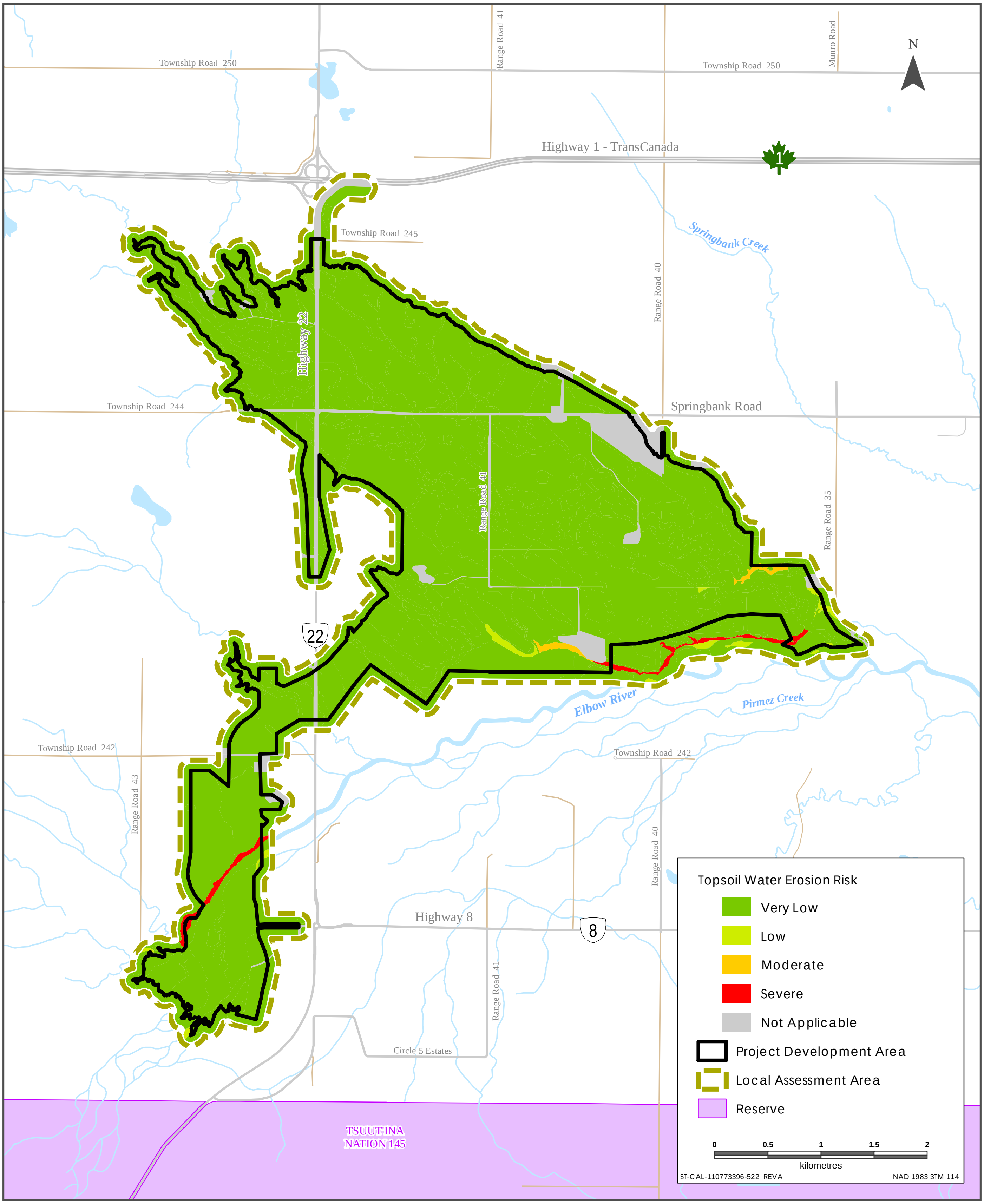
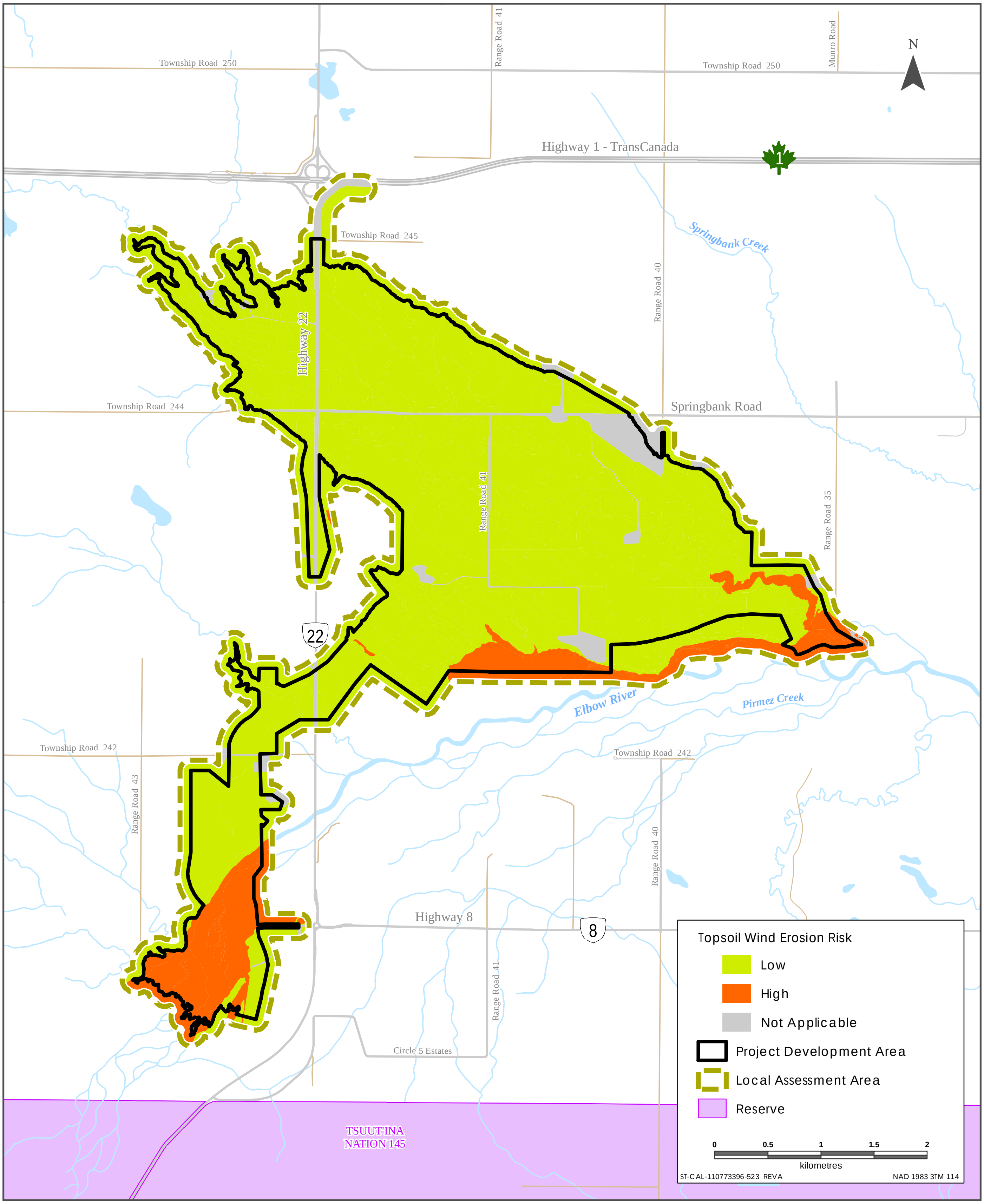
Figure 9-8



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Topsoil Water Erosion Risk Ratings for the Project Development Area and Local Assessment Area



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Topsoil Wind Erosion Risk Ratings for the Project Development Area and Local Assessment Area

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 9-10

9.3 PROJECT INTERACTIONS WITH TERRAIN AND SOILS

Table 9-11 identifies interactions of the Project with terrain and soils. Section 9.4 discusses the interactions in the context of effects pathways, standard and project-specific mitigation and residual effects. A justification for no interaction is provided following the table.

Table 9-11 Project-Environment Interactions with Terrain and Soils during Construction and Dry Operations

Project Components and Physical Activities	Environmental Effects	
	Change to Soil Quality and Quantity	Change to Terrain Stability
Construction		
Clearing	✓	-
Channel excavation	✓	✓
Water diversion construction	✓	✓
Dam and berm construction	✓	✓
Low-level outlet works construction	✓	✓
Road construction	✓	✓
Bridge construction	✓	–
Lay down areas	✓	–
Borrow extraction	✓	✓
Reclamation	✓	✓
Dry Operations		
Maintenance	–	–
NOTES: ✓ = Potential interaction – = No interaction		

No interaction with terrain stability is expected during clearing, bridge construction, utility realignment, and at lay down areas because the terrain is flat and stable at these areas.

Maintenance activities during dry operations are not expected to interact with terrain stability, soil quality or soil quantity because these activities would not change the erosion risk or land capability of soils in the LAA nor would they affect soil quality.

9.4 ASSESSMENT OF RESIDUAL ENVIRONMENTAL EFFECTS ON TERRAIN AND SOILS

9.4.1 Analytical Assessment Techniques

Project effects on terrain stability during construction in the LAA is assessed by means of terrain stability class ratings (BC Ministry of Forests and BC Ministry of Environment 1999). The qualitative terrain stability class rating is based on field data and professional judgement. The class rating considers the surficial material physical properties, slope steepness, soil drainage and existing geomorphological processes.

Project effects on soil quality and quantity during construction in the LAA is assessed by means of changes to agricultural land capability (LCC), reclamation suitability, and wind and water erosion risk. LCC represents project effects on soil quality and quantity. When calculated by means of the Land Suitability Rating System (LSRS) (Agronomic Interpretations Working Group 1995), LCC is a metric that can account for project-related effects on soils, quantitatively.

Reclamation suitability (AAFRD 1987) characterizes soil quality based on attributes of soil including pH, salinity, sodicity, texture, consistence, coarse fragment content and calcium carbonate equivalent (CCE). Comparisons of areal extent by class quantifies residual effects on this parameter. Wind (Coote and Pettapiece 1989) and water erosion risk (Wall et al. 2002) metrics are also calculated.

9.4.2 Change in Terrain Stability

9.4.2.1 Project Pathway

Channel excavation, diversion construction, dam construction, low-level outlet works construction, road construction and borrow extraction may affect terrain stability in areas prone to landslides by changing slope morphology (e.g., steepening of slopes) and changing natural drainage paths. Landslide-prone areas include the Elbow River escarpment at or near the diversion structure and the channel banks along the tributary stream intersecting the low-level outlet works area and dam site. The diversion channel, borrow source areas, waste storage sites and high road cuts may contain steepened slopes that have potential for minor sliding/sloughing. There is a potential for locally exposing acid generating bedrock (i.e., coal strata) but can be managed through site-specific acid rock drainage/metal leaching assessments where coal is encountered.

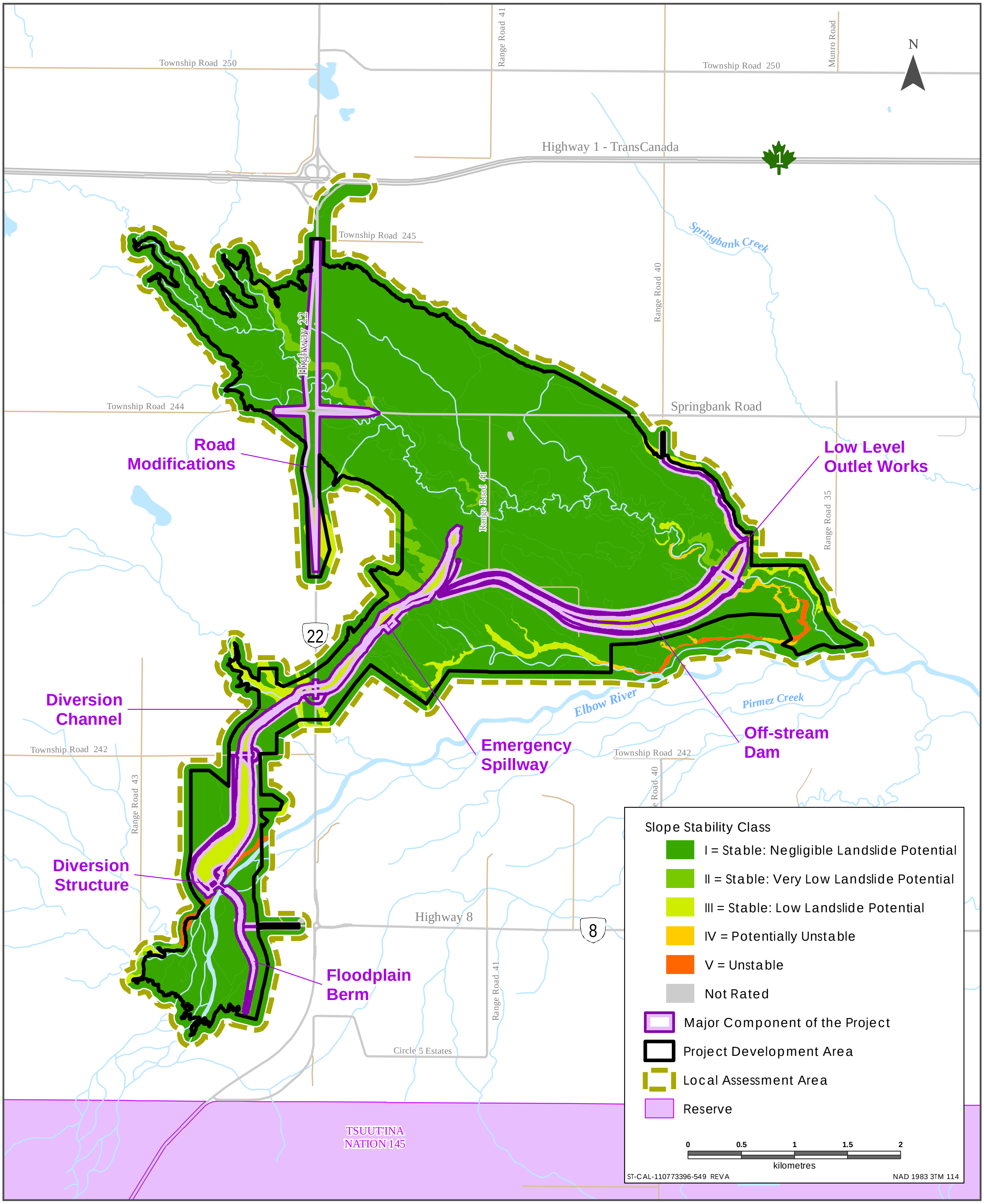
9.4.2.2 Mitigation

Standard construction mitigation that lessen residual effects on terrain stability would be:

- Slope stability visually monitored on infrastructure features such as berms, dam, and diversion channel.
- Concrete retaining wall will be designed and constructed as part of the diversion structure to stabilize the Elbow River escarpment.
- Do not stockpile materials at slopes steeper than 3H:1V. Grade slopes smooth upon completion to reduce sliding and sloughing.
- Cut side slopes in stockpile materials to reduce sliding/sloughing.
- Channel banks will be seeded and revegetated with native seed or erosion control mix to improve channel bank stability.
- Surface drainage patterns will be re-established where possible.
- Drainage and erosion control measures (e.g. silt fences) around stockpiles to prevent erosion.

9.4.2.3 Project Residual Effects

After standard construction mitigation, there would be a change in terrain stability along the excavated diversion channel banks, off-stream dam and at the diversion structure (Figure 9-11 and Table 9-12). The diversion channel would be excavated into primarily flat to gentle terrain, which would result in relatively steeper slopes along channel banks compared to existing conditions. The off-stream dam would be constructed on primarily flat to gentle terrain, which would result in relatively steeper slopes compared to existing conditions. The diversion structure would be constructed through the Elbow River escarpment which would result in stabilization of the slope compared to existing conditions. The predicted change in topography results in a low to moderate decrease in terrain stability classes I, II, IV, and V areas and a high increase in terrain stability class III area. Overall, the magnitude of the adverse residual effect following construction and dry operations is moderate**.** Timing is not applicable because effects from Project activities would be similar regardless of season or other timing characteristics**.**



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Post-construction Terrain Stability

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Figure 9-11

Table 9-12 Changes in Extent of Terrain Stability in the LAA

Terrain Stability Class	Existing Conditions (ha)	After Construction and Reclamation (ha)	Change (ha) from existing conditions	Change in % of LAA
I (stable)	1,743.5	1,643.6	-99.9	-5.3
II (stable)	55.5	52.2	-3.3	-0.2
III (stable)	64.3	168.6	+104.3	+5.5
IV (potentially unstable)	9.6	9.5	-0.8	0
V (unstable)	12.6	11.6	-1.0	-0.1

9.4.3 Change in Soil Quality and Quantity

Because LCC depends on both soil quality and quantity, it is the principal parameter used to assess project effects on soils. Changes to reclamation suitability are also used to quantify effects on soil quality. Conversion of agricultural land to industrial land is an expected outcome of constructing the components of the dry reservoir dam and associated infrastructure.

9.4.3.1 Project Pathway

Project infrastructure planned for the LAA would affect soils and the LCC of these soils. Construction and reclamation activities for infrastructure components may affect the agricultural land capability through changes to such parameters as topsoil thickness and replacement depths. Activities may affect wind erosion risk through changes to topsoil properties such as texture, organic matter content or structure. Similarly, water erosion risk may be affected by changes to topsoil texture, organic matter content, slope, and related infiltration characteristics. In some cases, areas that could support agriculture would be converted to industrial features that would not support agriculture. Changes to roads, and existing surface drainage may result in changes to soil that in turn affect distribution of LCC.

Some construction effects may also accrue in the off-stream reservoir, such as the development of erosion control mechanisms (e.g., rip-rap). These features are intended to reduce flow velocity and reduce soil erosion during a flood. For purposes of assessing project effects on LCC, these infrastructure components are generally considered to be non-soil and are not rated for LCC. Their development, however, is accounted for in changes to LCC extents. Other components of project infrastructure such as lay down areas, borrow pits and soil storage areas are to be reclaimed.

9.4.3.2 Mitigation

Mitigation measures for Project effects on soil would include:

- Strip and stockpile topsoil for future use in the reclamation of disturbed areas.
- Topsoil horizons (O, LFH, A) would be salvaged separately and stockpiled for later use from areas intended for disturbance, to prevent admixing of soils.
- A topsoil replacement plan will be developed for the reclamation of the various disturbed areas. These areas will be revegetated.
- Disturbed areas associated with project components such as the water intake, water retention, water outflow and roads will use previously salvaged topsoil material to promote vegetation re-establishment.

More detail on the planned mitigation for Project effects on soil are provided in the Conservation and Reclamation Plan (C&R Plan) in Volume 4, Appendix D.

9.4.3.3 Project Residual Effects

The distribution of soil units including areas of disturbed and reclaimed lands at post-construction is presented in Figure 9-12. A comparison of areas of soil units between existing conditions and post-construction is shown in Table 9-13.

Table 9-13 Soil Units in the LAA at Post-Construction

Soil Unit	Area at Existing Conditions (ha)	Area at Post-Construction (ha)	Change (ha)	% Change of LAA
Units with fine to very fine-textured till and glaciolacustrine parent materials				
DVFS1	55.2	48.4	-6.8	-0.4
DVFS2	304.3	251.6	-52.7	-2.8
DVG1	281.5	190.3	-91.2	-4.8
FSH1	276.6	255.1	-21.5	-1.1
FSH2	437.2	382.6	-54.6	-2.9
POT1	30.0	23.9	-6.1	-0.3
POT2	20.5	16.5	-4.0	-0.2
POT6	43.1	43.2	0.1	0.0

Table 9-13 Soil Units in the LAA at Post-Construction

Soil Unit	Area at Existing Conditions (ha)	Area at Post-Construction (ha)	Change (ha)	% Change of LAA
Units with medium-textured fluvial parent materials				
SRC1	35.8	32.0	-3.8	-0.2
SRC4	2.3	2.3	0.0	0.0
Units with moderately coarse to very coarse-textured fluvial and glaciofluvial parent materials				
TBR1	6.4	6.4	0.0	0.0
TBR2	50.7	44.8	-5.9	-0.3
TBR4	11.4	11.4	0.0	0.0
TBRgr1	61.9	61.6	-0.3	0.0
TBRgr2	6.8	6.8	0.0	0.0
ZGC1	35.0	34.6	-0.4	0.0
Undifferentiated, transitional areas				
POT7	81.7	78.0	-3.7	-0.2
TBR6	15.1	12.1	-3.0	-0.2
TBSR1	30.0	30.0	0.0	0.0
MSTB1	2.8	2.8	0.0	0.0
Disturbed Land and Reclaimed Units				
ZDL	97.1	242.9	145.8	7.7
ZREC	1.1	1.1	0.0	0.0
ZREC2A	0.0	99.0	99.0	5.2
ZREC2B	0.0	5.6	5.6	0.3
ZREC2C	0.0	2.4	2.4	0.1
ZREC3A	0.0	1.0	1.0	0.1
ZREC3B	0.0	0.2	0.2	0.0
Total	1886.5	1886.5		
NOTE: Areas and proportions will not sum exactly to totals because of rounding				

Agricultural land capability at post-construction is presented in Figure 9-13. The change in LCC distribution between existing conditions and project changes is evaluated at the post-construction point in time (Table 9-14). There is a decline in the extent of the modal LCC, class 3, of 6.9% of the area of the LAA. This decline is due to the increase of land classed as 'not applicable' as this is the land covered by project components.

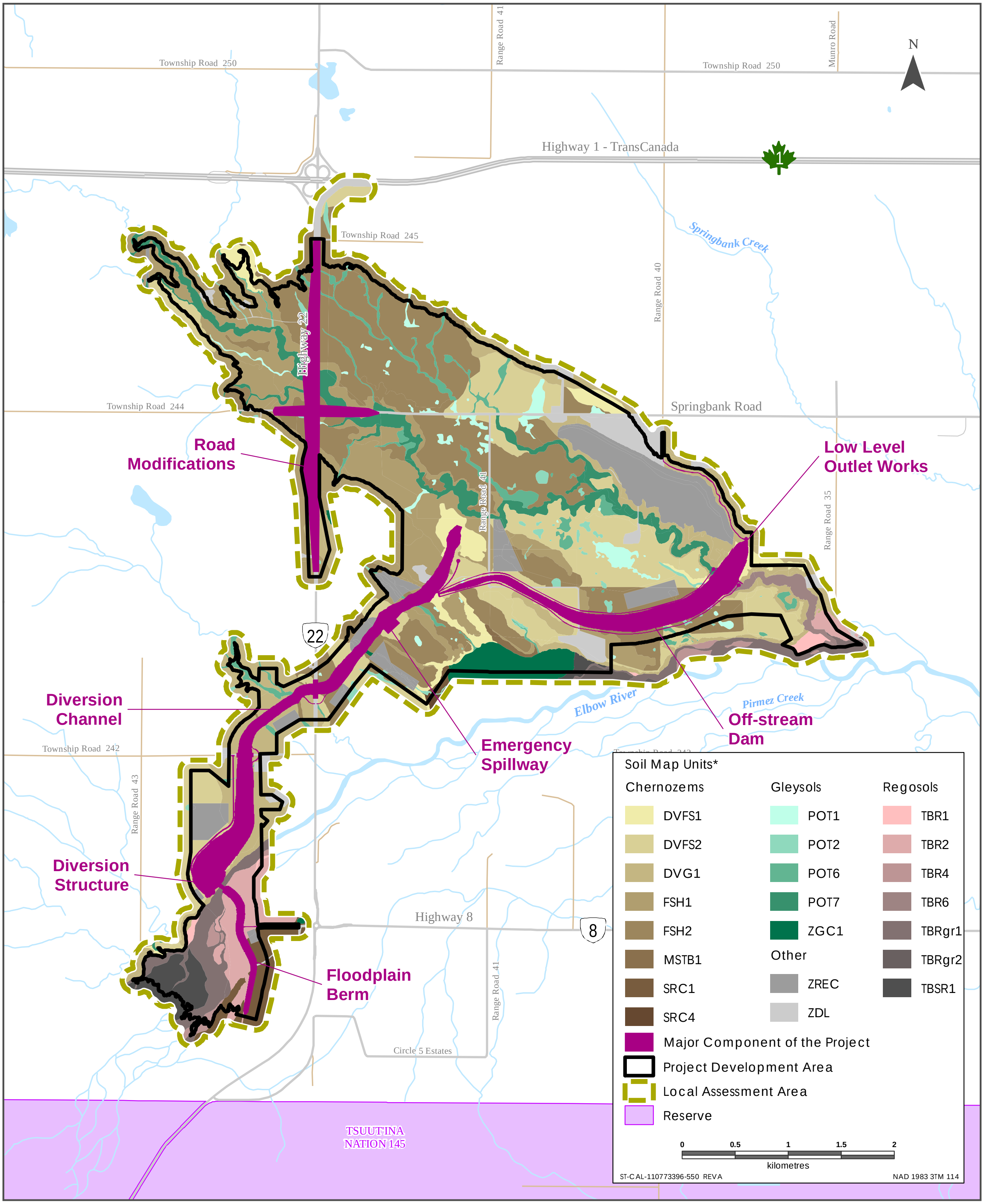
There are no anticipated effects on soil quality during dry operations. Water and wind erosion risk classes at post-construction would have no appreciable change to the proportion or rank of individual risk classes other than an increase in area not rated for water or erosion risk. These changes pertain to areas used for Project infrastructure. Timing is not applicable because effects from Project activities would be similar regardless of season or other timing characteristics.

The change in reclamation suitability for both topsoil and subsoil at post-construction in the LAA is presented in Table 9-15. The changes are a result of the construction of Project infrastructure.

Table 9-14 Changes in Extent of Agricultural Land Capability

Agricultural Capability Class	Existing Conditions (ha)	After Construction and Reclamation (ha)	Change (ha) from existing conditions	Change % of LAA
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	1425.2	1295.6	-129.6	-6.9
4	134.6	123.1	-11.5	-0.6
5	85.9	91.9	6.0	0.3
6	142.2	131.5	-10.7	-0.6
7	1.4	1.4	0.0	0.0
Not Applicable	97.1	242.9	145.8	7.7
Total	1886.5	1886.5		

NOTE:
Areas and proportions will not sum exactly to totals because of rounding



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.
** Refer to Table 9-5 for Soil Map Unit descriptions.*

Soil Map Units in the Project Development Area and Local Assessment Area at Post-construction

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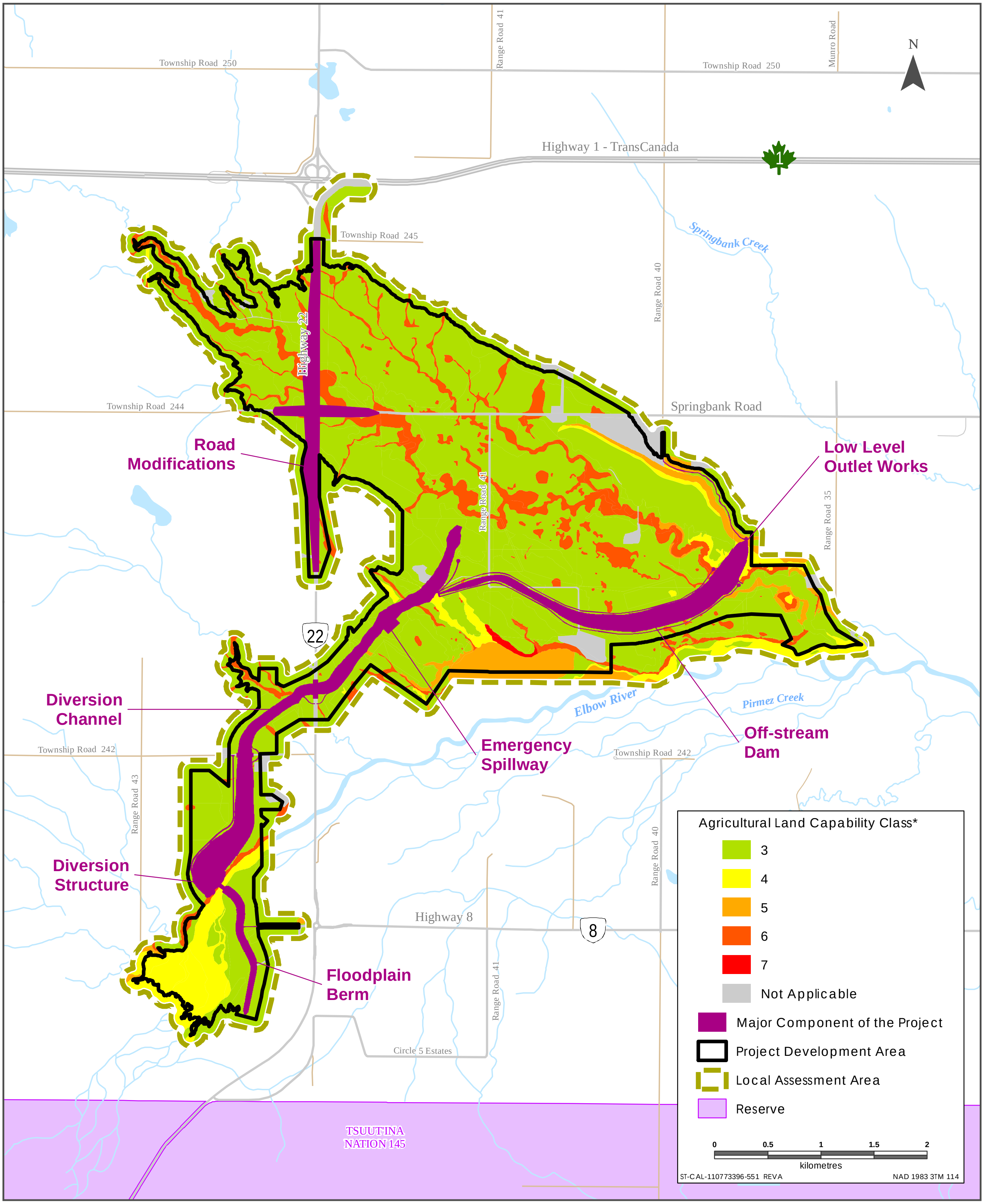
Figure 9-12



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.
*Refer to Tables D7-15 and D7-16 for Agricultural Land Capability Class descriptions.

Agricultural Land Capability Classes for the Project Development Area and Local Assessment Area at Post-construction

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Table 9-15 Changes in Extent of Reclamation Suitability Class

Reclamation Suitability Class	Existing Conditions (ha)	After Construction and Reclamation (ha)	Change (ha) from Existing Conditions	Change % of LAA
Topsoil				
Good	84.6	77.4	-7.2	-0.4
Fair	1411.8	1291.0	-120.8	-6.4
Poor	222.3	205.8	-16.5	-0.9
Unsuitable	0.0	0.0	0	0.0
Not rated	69.5	69.4	-0.1	0.0
Not Applicable[1]	97.1	242.9	145.8	7.7
Total	1886.5	1886.5	-	-
Subsoil				
Good	84.6	77.4	-7.2	-0.4
Fair	105.4	100.4	-5.0	-0.3
Poor	1528.5	1395.0	-133.5	-7.1
Unsuitable	71.0	70.8	-0.2	0.0
Not Applicable	97.1	242.9	145.8	7.7
Total	1886.5	1886.5		

NOTES:

[1] not applicable includes areas of disturbed land and areas where topsoil consists of organic horizons only. Reclamation suitability ratings do not apply to organic horizons

Areas and proportions will not sum exactly to totals because of rounding

9.4.4 Summary of Project Residual Effects

Table 9-16 summarizes the residual environmental effects on terrain and soils during construction and dry operations.

Table 9-16 Project Residual Effects on Terrain and Soils during Construction and Dry Operations

	Residual Effects Characterization								
Residual Effect	**Project Phase**	**Timing**	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological and Socio-economic Context**
Terrain Stability	C, O	N/A	Adverse	M	PDA	LT	IR	R	U
Soil Quality and Quantity	C	N/A	Adverse	M	PDA	LT	S	I	U

KEY

See Table 9-2 for detailed definitions

Project Phase
C: Construction
O: Operation (Dry)

Timing Consideration
S: Seasonality
T: Time of dayR: regulatory

Direction:
P: Positive
A: Adverse
N: Neutral

Magnitude:
N: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Duration:
ST: Short-term;
MT: Medium-term
LT: Long-term

N/A: Not applicable

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Ecological Context:
D: Disturbed
U: Undisturbed

9.5 DETERMINATION OF SIGNIFICANCE

During construction and dry operations, the residual effects on terrain stability are anticipated to be both positive and adverse dependent on the project structure (Table 9-12). For example, the concrete diversion structure would be excavated through the Elbow River escarpment, which is mapped as terrain stability class V (having a high likelihood of landslide initiation). The diversion structure would stabilize the escarpment behind a concrete wall. In contrast, the diversion channel would be excavated through flat to rolling terrain generally mapped as terrain stability classes I and II (having a negligible to very low likelihood of landslide initiation). The diversion channel side slopes will be graded to a 4H:1V ratio, effectively increasing banks to terrain stability class III (having a low likelihood of landslide initiation). Overall, the result is of moderate magnitude of change with an area increase of 5.5% of terrain having a low likelihood of landslide initiation within the total LAA. The off-stream dam will be located across the tributary stream, which in part would remove 0.8 ha of area mapped as terrain stability class IV (moderate likelihood of landslide initiation following construction compared to existing conditions). The effect of the Project on terrain during construction and dry operations in assessed as not significant.

There is a reduction in the areal extent of land rated as agricultural capability class 3 (mode) by 7% of the LAA during construction and dry operations (Table 9-13). This reduction is the result of the construction of the Project components. Because post-construction, the dam and reservoir will not be under agricultural land use, the effect of the changes on soil quality and soil quantity are assessed as not significant.

9.6 PREDICTION CONFIDENCE

Terrain instability is controlled by many factors: slope steepness, surficial material thickness, structural rock properties, water content, soil pore water pressure, and engineering properties of surficial material and weathered rock, such as cohesion and coefficient of friction (Chatwin et al. 1994). These factors are interactive and vary spatially and temporally. Thus, prediction of terrain instability should be considered best approximations. However, there is a moderate to high degree of confidence for estimation of Project residual effects on terrain stability. Guidelines of terrain survey intensity level were followed to identify terrain attributes in the LAA (BC Ministry of Forests and BC Ministry of Environment 1999). Terrain data are detailed and based on 66 inspection sites and are integrated with previous surficial materials mapping by Moran (1986) and soils mapping by MacMillan (1987). In addition, soils information from 360 inspection points and borehole data from more than 100 geotechnical investigations were also cross-referenced. Light detection and ranging (LIDAR) data with one-metre accuracy provides detailed measurements for slope steepness and characterization of topography.

There is a high degree of confidence for estimation of project residual effects on soil quality and quantity. Guidelines of survey intensity level were followed to identify soil properties in the LAA (Mapping Systems Working Group 1981). Soil data are detailed and based on 360 inspection points and are integrated with previous mapping by MacMillan (1987). In addition, mapping was supported by LIDAR imagery to allow the role of topography to be better integrated into soil mapping. Properties of individual soil series are based on laboratory results from site-specific samples. Ratings are nationally or regional accepted protocols. If borrow pit development becomes more certain, additional standards of Alberta Transportation (2013) could be applied to better characterize topsoil and subsoil properties in the specific borrow sites. Estimates of agricultural land capability follow nationally-accepted standards and are based on site-specific data.

9.7 CONCLUSIONS

9.7.1 Change in Terrain Stability

Overall, the change in terrain stability following construction and dry operations is an adverse change of moderate magnitude, with an extent that is confined to the PDA, and long term. Terrain classified as moderate to high likelihood of landslide initiation would decrease by 1.8% compared to the existing conditions. The effect of the Project on terrain stability following construction and dry operation is assessed as not significant.

9.7.2 Change in Soil Quality and Quantity

The change in soil quality and quantity following construction and dry operations is also an adverse change of moderate magnitude, confined to the PDA and long term. Area of modal LCC was class 3 and decreased by 7.0% relative to base case, and therefore the effect of this stage of the project on soil quality is assessed as not significant.

9.8 REFERENCES

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