8. SOILS, LANDFORMS AND PERMAFROST

Introduction

The findings of the environmental impact assessment for soils, landforms and permafrost for the Mackenzie Gas Project (see EIS Volume 5, Section 8) were based on the following components (see Section 1, Introduction, of this document):

- anchor fields
- gathering pipelines and associated facilities
- NGL and gas pipeline corridor
- infrastructure
- NGTL NWML Dickins Lake Section

The two NGTL pipeline sections, Dickins Lake Section and Vardie River Section, are located in northwestern Alberta. The Dickins Lake assessment was included in the EIS. This EIS supplemental information includes:

- updated information for the Dickins Lake Section
- new information for the Vardie River Section
- an impact assessment for northwestern Alberta based on the updated and new information
- a combined project effects assessment that includes the Mackenzie Gas Project and NGTL's Dickins Lake and Vardie River sections

See under EIS Summary for a summary of the EIS findings for soils, landforms and permafrost.

EIS Summary

Potential effects from the Mackenzie Gas Project on soils, landforms and permafrost were related primarily to surface disturbance during construction and a changed subsurface thermal regime (see EIS Volume 5, Section 8). Effects on soils, landforms and permafrost were limited to the local study area.

Mackenzie Gas Project effects were assessed on the following VCs:

- ground stability
- uncommon landforms
- soil quality

Some moderate-magnitude effects were predicted in the EIS for ground stability, particularly with respect to settlement along the pipeline right-of-way, and erosion and frost heave in sensitive aeolian deposits along the pipeline right-of-way. Moderate-magnitude, long-term effects related to patterned ground were predicted for glaciofluvial and aeolian deposits. Low-magnitude, far-future effects were predicted for patterned ground, and moderate-magnitude, long-term effects were predicted for soil quality. No significant effects on soil quality were predicted. Patterned ground and aeolian deposits do not occur in northwestern Alberta.

Study Areas

Two study areas were defined to assess the geographic extent of the effect of adding the Vardie River Section:

- local study area (LSA)
- regional study area (RSA)

The LSA is a 1-km band centred on the Dickins Lake and Vardie River sections and a 500-m buffer around the site footprint at the NGTL Thunder Creek compressor station.

The RSA is a 60-km-wide corridor, centred on the Dickins Lake and Vardie River sections. It was used to evaluate potential changes in soils, landforms and permafrost in a larger regional context.

For a full description of these study areas, see EIS Volume 5, Section 8.

Baseline

Methods

A combination of historical references, published traditional knowledge studies, field studies and air photograph interpretation was used to determine baseline conditions for the proposed Dickins Lake and Vardie River sections and associated facilities. For detailed descriptions of the methods used to determine baseline conditions, see EIS Volume 3, Section 8.

Moraine Deposits

Moraine and organic deposits are the two most common landform units in the LSA and RSA.

A unit of moraine characterized by crevasse fillings is found in the central part of the Dickins Lake Section. Crevasse fillings form short, linear ridges with gentle to moderate slopes. The crevasse fillings lie within an extensive, flat-lying bog plain. The area is locally crossed by ancient glacial meltwater channels and a glaciofluvial ridge is found near the northern extent of the moraine unit with crevasse fillings.

Streamlined moraine with drumlins is found at the northern end of the Dickins Lake Section. The pipeline route crosses several small drumlins with gentle slopes. The area between drumlins is commonly composed of organic veneers over moraine.

In the Vardie River Section, moraine commonly forms flat to gently undulating plains with low rolling hills. Locally, moraine was deposited as distinct ridges with gentle to moderate slopes. In undulating terrain, lowland depressions in moraine contain organic veneers and thicker units of organic bog or fen. Permafrost is uncommon in moraine but might exist locally as patches in bogs.

Moraine landforms account for about 19% of the LSA (see Table 8-1). Permafrost is uncommon in these deposits but might be encountered in low-lying depressions with organic soil cover. Brunisolic and Luvisolic soils are common.

Organic Deposits

The two main categories of organic terrain in northwestern Alberta are bogs and fens. Bogs are raised above the level of the surrounding wetland and can locally contain patches of permafrost. Fens can occupy shallow depressions in moraine plains, are commonly unfrozen and form layers more than 3 m thick. Organic deposits are composed of poorly to moderately well decomposed sedges, sphagnum peat and ericaceous shrubs.

The most abundant landforms are organic deposits that cover about 78% of the LSA (see Table 8-2). Permafrost could be encountered in up to 10 to 30% of these areas. Fibrisols are the most common soil type with lesser amounts of Gleysols and Cryosols.

Other Landforms

Other landforms in northwestern Alberta include glaciofluvial and colluvial landforms. These deposits are less common and cover 1.8% (192 ha) of the LSA. The remaining portion of the LSA, 1.2% (192 ha), consists of water. Permafrost is not expected in these deposits. The remaining portion of the LSA, 1.2% (126 ha), is composed of water.

For common soil types in these deposits, see Table 8-3.

Table 8-1: Morainal Landforms

Landforms	Topography	Drainage Description	Composition	Dominant Soil Subgroups	Associated Processes	Permafrost Conditions				LSA Areal Extent (ha)	LSA Areal Extent (% total)
						Temp. (°C)	Active Layer Depth (Estimated) (m)	Estimated Frozen Moisture Content[1] (%)	Comments		
Low-relief moraine	Level to moderate slopes	Well to imperfectly drained	Silt and clay, some sand and trace gravel	• Orthic Gray Luvisol • Gleyed Gray Luvisol • Orthic Eutric Brunisol • Gleyed Eluviated Eutric Brunisol	N/A	N/A	N/A	N/A	No permafrost	1,072	10.3
		Imperfectly to poorly drained	Silt and clay, some sand and trace gravel	• Gleyed Gray Luvisol • Orthic Gleysol • Orthic Luvic Gleysol • Terric Fibric Mesisol	N/A	N/A	N/A	N/A	No permafrost	119	1.1
Streamlined moraine	Gentle to moderate slopes	Crest well drained, depressions poorly to very poorly drained	Silt and clay, some sand and trace gravel	• Orthic Gray Luvisol • Eluviated Eutric Brunisol • Gleyed Gray Luvisol • Orthic Luvic Gleysol	N/A	N/A	N/A	N/A	No permafrost	89	0.9

Table 8-1: Morainal Landforms (cont'd)

Landforms	Topography	Drainage Description	Composition	Dominant Soil Subgroups	Associated Processes	Permafrost Conditions				LSA Areal Extent (ha)	LSA Areal Extent (% total)
						Temp. (°C)	Active Layer Depth (Estimated) (m)	Estimated Frozen Moisture Content[1] (%)	Comments		
Moraine with crevasse fillings	Very gentle to moderate	Crest rapidly drained, depressions poorly to very poorly drained	• Gravelly to sandy • Pockets of unsorted silt, sand and gravel common	• Orthic Gray Luvisol • Eluviated Eutric Brunisol • Gleyed Gray Luvisol • Orthic Luvic Gleysol	N/A	N/A	N/A	N/A	No permafrost	627	6.0
Ridged moraine	Gentle to strong slopes	Rapidly to imperfectly drained	Silt and clay, some sand and trace gravel	• Orthic Eutric Brunisol • Eluviated Eutric Brunisol • Orthic Gray Luvisol • Gleyed Gray Luvisol	N/A	N/A	N/A	N/A	No permafrost	70	0.7
Total morainal landforms										1,977	19.0

NOTES:
N/A = not applicable
1 Moisture content = weight of water, ice or both divided by weight of dry soil. Large amounts of ice in the soil can result in moisture contents exceeding 100%. Typical ranges of moisture content are provided for specific soil types.

Table 8-2: Organic Landforms

Landforms	Topography	Drainage Description	Composition	Dominant Soil Subgroups	Associated Processes	Permafrost Conditions				LSA Areal Extent (ha)	LSA Areal Extent (% total)
						Temp. (°C)	Active Layer Depth (Estimated) (m)	Estimated Frozen Moisture Content[1] (%)	Comments		
Bogs	Level to very gentle slopes	• Drainage is poor to very poor • Drainage type controlled by permafrost and topography	Organic	• Typic Fibrisol • Mesic Fibrisol • Fibric Organic Cryosol • Mesic Organic Cryosol	Permafrost	-0.0 to -0.5	0.5–0.7	1,000–2,000 (organic)	• Possibility of encountering permafrost is 10–30% • No permafrost in wet bogs	4,503	43.2
Shallow bogs over moraine	Level to very gentle slopes	• Drainage is poor to very poor • Closed basin drainage type is common in depressions	• Organic, up to 2 m, with silt and clay • Some sand and trace gravel below	• Terric Fibrisol • Terric Mesic Fibrisol • Fibric Organic Cryosol • Orthic Gleysol	Permafrost – palsas, peat plateaus	-0.0 to -0.5	0.5–0.7	1,000–2,000 (organic) 80–100 (moraine)	• Possibility of encountering permafrost is 10-30% • No permafrost in wet bogs	582	5.6
Fens	Level to very gentle slopes	• Water table is near or at the surface in most cases • Drainage is poor to very poor	Organic	• Mesic Fibrisol • Typic Fibrisol • Terric Fibrisol • Terric Mesic Fibrisol	N/A	N/A	N/A	N/A	No permafrost	672	6.5

Table 8-2: Organic Landforms (cont'd)

Landforms	Topography	Drainage Description	Composition	Dominant Soil Subgroups	Associated Processes	Permafrost Conditions				LSA Areal Extent (ha)	LSA Areal Extent (% total)
						Temp. (°C)	Active Layer Depth (Estimated) (m)	Estimated Frozen Moisture Content[1] (%)	Comments		
Shallow fens over fluvial	Level to very gentle slopes	• Water table is near or at the surface in most cases • Drainage is poor to very poor	• Organic, up to 2 m, with silt and clay • Some sand and trace gravel below	• Terric Mesic Fibrisol • Typic Fibrisol • Typic Mesisol • Orthic Gleysol	N/A	N/A	N/A	N/A	No permafrost	133	1.3
Undifferentiated organic deposits	Level to very gentle slopes	• Drainage is imperfect to poor	Organic	• Typic Fibrisol • Mesic Fibrisol • Mesic Organic Cryosol • Fibric Organic Cryosol	Permafrost – palsas, peat plateaus	-0.0 to -0.5	0.5–0.7	1,000–2,000 (organic)	• Possibility of encountering permafrost is 10–30% • No permafrost in wet area	1,611	15.5

Table 8-2: Organic Landforms (cont'd)

Landforms	Topography	Drainage Description	Composition	Dominant Soil Subgroups	Associated Processes	Permafrost Conditions				LSA Areal Extent (ha)	LSA Areal Extent (% total)
						Temp. (°C)	Active Layer Depth (Estimated) (m)	Estimated Frozen Moisture Content[1] (%)	Comments		
Shallow undifferentiated organic deposits over moraine, lacustrine, colluvial, or fluvial deposit	Variable, mostly level to very gentle slopes	Variable, mostly imperfectly to very poorly drained	• Organic, up to 2 m, with silt and clay • Some sand and trace gravel below	• Orthic Gleysol • Typic Fibrisol • Terric Mesic Fibrisol • Terric Fibric Mesisol	Meandering	N/A	N/A	N/A	No permafrost	440	4.2
	Level to gentle slopes	• Water table is near or at the surface in most cases • Drainage is poor to very poor • Blanket slope drainage type is common on very gentle slopes	• Organic, up to 2 m, with silt and clay • Some sand and trace gravel below	• Terric Mesic Fibrisol • Orthic Gleysol • Typic Fibrisol • Terric Fibric Organic Cryosol	• Deflation (potential) • Meandering – annual frequency, bank erosion • Permafrost	-0.0 to -0.5	0.5–0.8	1,000–2,000 (organic) 30–50 (moraine)	Possibility of encountering permafrost is less than 10–30% within raised organic plateaus over moraine	173	1.7
Total organic landforms										8,114	77.9

NOTES:
1 Moisture content = weight of water, ice or both divided by weight of dry soil. Large amounts of ice in the soil can result in moisture contents exceeding 100%. Typical ranges of moisture content are provided for specific soil types.

Table 8-3: Soil Types in Associated Landforms

Landform	Common Soil Types
Glaciofluvial	Orthic and Eluviated subgroups of Eutric and Dystric Brunisols, and Orthic Gray Luvisols
Colluvial	Orthic Regosols and Orthic Eutric Brunisols

Effects on Uncommon Landforms and Ground Stability

Effect Pathways

The pathway diagram for northwestern Alberta (see Figure 8-1) is the same as that in EIS Volume 5, Section 8. It shows key and intermediate pathways, indicating how the Dickins Lake and Vardie River sections could affect uncommon landforms and ground stability. Effects on landforms were determined by examining potential effects on ground stability and uncommon landforms.

All pathways were considered applicable in northwestern Alberta, except for the effects of:

- barge traffic on erosion
- gas extraction on subsidence
- gas extraction on thermal regime
- construction of pads and all-weather roads

Effect Attributes

Definitions of Effect Attributes

The attributes of the effects on uncommon landforms and ground stability were rated for direction, magnitude, geographic extent and duration (see Table 8-4). These attributes are the same as those used in EIS Volume 5, Section 8.

Analysis and Significance

For results of the assessment of effects on uncommon landforms and ground stability in the LSA by project phase, see Table 8-5.

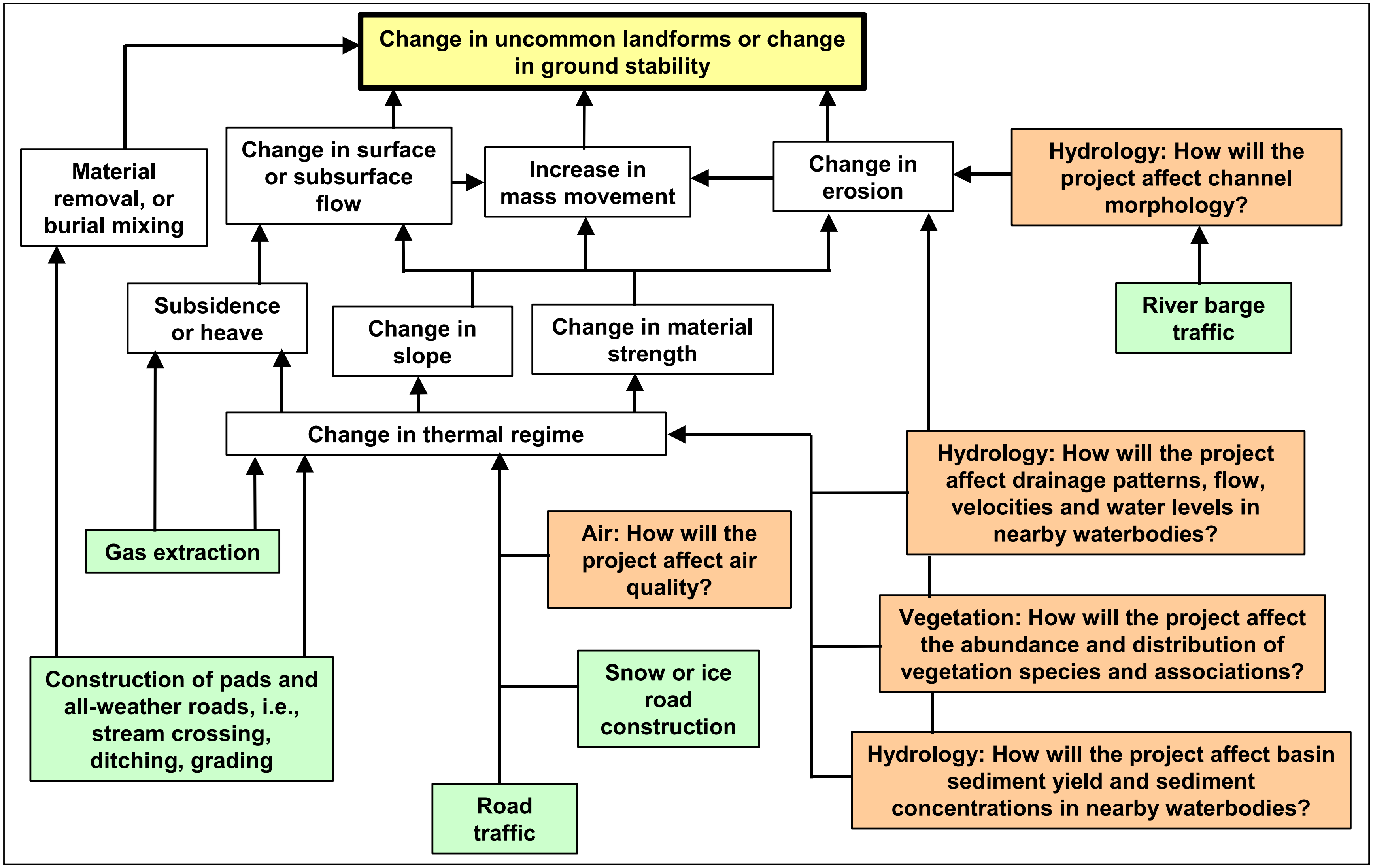

Figure 8-1: Effect Pathways – Uncommon Landforms and Ground Stability

Table 8-4: Definitions of Effect Attributes for Uncommon Landforms, Ground Stability and Soil Quality

Rank	General Definition
Direction	
Adverse	Effect on VC or KI is worsening: • ground is less stable • uncommon landforms are lost • soil quality is reduced
Neutral	Effect on VC or KI is not changing: • ground stability is unchanged • uncommon landforms are unchanged • soil quality is unchanged
Positive	Effect on VC or KI is improving: • ground is more stable • uncommon landforms are more abundant • soil quality is increased
Magnitude	
No effect	Stability factors or stability of ground are not affected Amount or volume of uncommon landforms are not affected Soil quality is not affected
Low effect	Project predicted to cause a <5% change in ground stability in LSA Project predicted to cause a <5% change in uncommon landforms in LSA Project predicted to cause a <5% change in a soil quality key indicator in LSA, or a change in soil quality might or might not be detectable and is unlikely to affect plant growth
Moderate effect	Project predicted to cause a change in soil stability of between 5–10% in LSA Project predicted to cause a change in uncommon landforms of between 5–10% in LSA Project predicted to cause a change in a soil quality key indicator of between 5–10% in LSA, or a change in soil quality will occur, but is unlikely to seriously restrict plant growth
High effect	Project predicted to cause a >10% change in soil stability in LSA Project predicted to cause a >10% change in uncommon landforms in LSA Project predicted to cause a >10% change in a soil quality key indicator in LSA, or a change in soil quality is likely to seriously restrict plant growth
Geographic Extent	
Local	Effect on VCs or KIs within LSA
Regional	Effect on VCs or KIs within RSA
Beyond regional	Effect on VCs or KIs extends beyond RSA
Duration	
Short term	Effect is limited to less than three years
Medium term	Effect occurs from three to nine years
Long term	Effect lasts longer than nine years, but does not extend more than 30 years after decommissioning and abandonment
Far future	Effect extends more than 30 years after decommissioning and abandonment

Table 8-5: Effects on Uncommon Landforms and Ground Stability

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Ground stability	Construction	Adverse	Low	Local	Long term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Long term	No
Uncommon landforms[1]	Construction	Adverse	Low	Local	Long term to far future	No
	Operations	Adverse	Low	Local	Long term to far future	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No

NOTES:
N/A = not applicable
1 Ratings were based on low magnitude combined with long-term or far-future duration, and on moderate magnitude combined with long-term duration

Predicted effects on landforms will not be significant. Most predicted effects on uncommon landforms are of low to moderate magnitude and long term. Predicted effects on ground stability are of low or moderate magnitude and have a duration that will not exceed long term.

Uncommon Landforms

For a summary of assessed effects on uncommon landforms in northwestern Alberta, see Table 8-6. Parts of the Dickins Lake and Vardie River sections are located in areas of glaciofluvial deposits. About 5 ha of the right-of-way extends over glaciofluvial deposits.

Table 8-6: Effects on Areas of Potential Uncommon Landforms

Uncommon Landform	Area in LSA	Pipeline Right-of-Way	
	(ha)	(ha)	(%)
Glaciofluvial	157	5	3.3

Construction

A low magnitude effect is assigned to uncommon landforms during construction in this region because less than 5% of the glaciofluvial landforms in the LSA are affected by the pipeline right-of-way. The remaining effect attributes of construction are similar to those in the other ecological zones in the Northwest Territories.

Operations

Effects of pipeline operations on uncommon landforms will be low magnitude because only small amounts of these landforms will be affected.

Decommissioning and Abandonment

Decommissioning and abandonment activities are not expected to affect uncommon landforms.

Ground Stability

The KIs used to assess potential effects are:

- potential for erosion
- drainage disruption from frost bulb formation

For a summary of assessed effects on ground stability in northwestern Alberta, see Table 8-7.

Table 8-7: Effects on Areas of Potential Ground Stability

Parent Material	Area in LSA	Area with Potential for Water Erosion		Area with Potential for Frost Heave and Drainage Disruption	
	(ha)	(ha)	(%)	(ha)	(%)
Moraine	1,977	10	0.5	27	1.4
Organic	8,114	0	0	0	0
Other	322	4	1.2	4	1.2
Total	10,413	14	0.1	31	0.3

Construction

The sparse amount of permafrost in the study area results in generally stable ground conditions. However, areas are still prone to water erosion and frost heave. Areas prone to effects on ground stability comprise less than 5% of the landform area in the northwestern Alberta LSA. Therefore, the magnitude of effects is assessed as low.

Operations

Pipeline and compressor station operations activities and effects in northwestern Alberta are expected to be low. If settlement occurs, the situation can be controlled by adding fill to reduce pond expansion. Frost effects are possible during operations, but the areas for any given landform are less than 5% of the total amount of the LSA.

Decommissioning and Abandonment

Thaw of frost bulbs might result in small adverse effects on drainage or erosion during decommissioning. The effects are expected to stabilize within 30 years following decommissioning and abandonment. Based on areas with identified frost effects potential, the low-magnitude effect is expected to stabilize over the long term.

Prediction Confidence

Because of the precautionary approach used to predict effects on uncommon landforms and ground stability of adding the Vardie River Section, there is a high degree of confidence in the assessment of significance of effects. The level of confidence is consistent with that in EIS Volume 5, Section 8.

Effects on Soil Quality

Effect Pathways

For the pathways through which the Dickins Lake and Vardie River sections might have effects on soil quality, see Figure 8-2. These pathways are the same as those used in the EIS.

Effects on soil quality were determined by examining potential effects on:

- soil drainage
- soil loss
- soil and physical characteristics

All pathways were considered applicable in northwestern Alberta except for effects of:

- air emissions and deposition on soil chemical properties
- construction of granular pads and all-weather roads

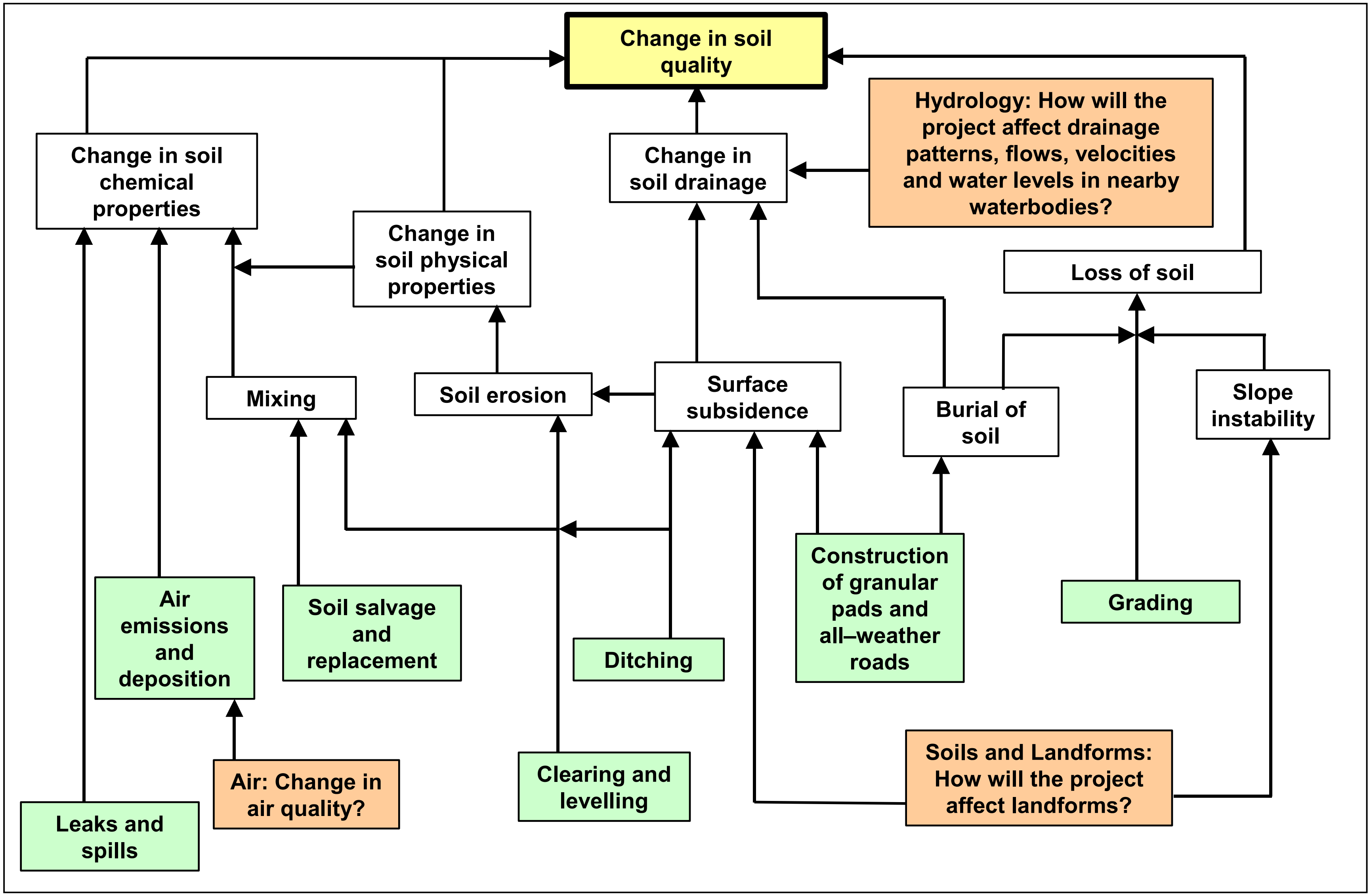

Figure 8-2: Effect Pathways – Soil Quality

Effect Attributes

For definitions of the effect attributes used to describe soil quality, see Table 8-4, shown previously.

Analysis and Significance

Construction effects on soil quality are likely to be adverse, low to moderate magnitude, local in extent and long term to far future (see Table 8-8). These effects are not significant. For causes of these effects, see EIS Volume 5, Section 8.

Operations effects on soil quality are predicted to be adverse, low magnitude, local and short term.

Effects on soil quality during decommissioning are minor and are related to surface disturbance required for decommissioning. Effects are predicted to be adverse, low magnitude, local and short term. These effects are not significant.

Table 8-8: Effects on Soil Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Soil quality[1]	Construction	Adverse	Low	Local	Long term to far future	No
	Operations	Adverse	Low	Local	Short to long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Short term	No

NOTE:
1 Ratings were based on low magnitude combined with far-future duration, and on low to moderate magnitude combined with long-term duration

Soil quality effects are determined by analyzing the effects on:

- soil drainage
- soil loss
- physical and chemical characteristics

Soil Drainage

Construction

Diversion or damming of surface drainage could cause changes in soil drainage along the pipeline right-of-way and adjacent to facility sites. If pads are used, they could change soil drainage through diversion or damming of surface water flow, although the small area of these sites reduces the potential impact on soil drainage. Changes in soil drainage that are initiated by construction activities will likely be present throughout the life of the project and beyond. Effects are considered to be adverse, low magnitude, local in extent and long term.

Operations

If settlement occurs, the situation can be controlled by adding fill to reduce pond expansion. The flow of gas during pipeline operations might cause changes in soil drainage where a frost bulb forms around the pipe. Drainage restoration is expected within 30 years following decommissioning and abandonment. The effects of changes in soil drainage on soil quality are considered to be adverse, low magnitude, local and long term.

Decommissioning and Abandonment

Disturbed areas will be recontoured and drainage patterns will be re-established as required. No additional changes in soil drainage are expected during decommissioning and abandonment.

Soil Loss

Construction

Soil cover will potentially be lost over about 10 ha because of site development at existing and new facilities (see Table 8-9).

Table 8-9: Characteristics of Soil Loss

Facility	**Area of Loss** (ha)	**Landform Type**	**Terrain Texture**	**Drainage Class**	**Soil Type**	**Area of Landform in LSA** (ha)	**Loss of Landform Type in LSA** (%)
Heater at NGTL Thunder Creek compressor station	0.4	Moraine	Till	Well drained	Orthic Gray Luvisol	1,977	<0.1
Wildboy Trail Camp	9.6	Shallow bogs over moraine and undifferentiated organic material over moraine, glaciolacustrine, glaciofluvial, aeolian and fluvial deposits or bedrock	Organic	Variable, mostly imperfectly to poorly drained	Terric Mesic Fibrisol, Terric Mesisol, Orthic Gleysol and Gleyed Regosol	1,021	0.1
Total soil loss	10.0						0.1

The effects of this soil loss will extend beyond decommissioning but soils will eventually begin to develop on the facility sites. Where soil is removed and replaced, soil quality might return to predisturbance levels. Effects of soil loss are predicted to occur over 0.1% of the affected landforms and will be adverse, low magnitude, local and far future.

There will be no further soil loss during operations and decommissioning.

Decommissioning and Abandonment

The material used to construct pads might be coarser than the material being covered, so the quality of the soil that will develop might be lower. Therefore, the plant community supported would be more characteristic of drier conditions than the conditions of the soil that is covered.

Physical and Chemical Characteristics

Construction

The length of right-of-way that could be affected by water erosion is estimated to be about 4.5 km, or about 7% of the total length of the corridor in the LSA. In terms of areal extent, about 14 ha or 0.1% of the pipeline corridor LSA could be affected by water erosion, and up to 1.2% of any individual landform and soil type in the LSA could be affected.

Mixed soil will be put back in the pipeline trench after excavation and pipe placement along the entire right-of-way. The area of mixed soil, based on a 2-m-wide disturbance along the trench line, will be about 13 ha, or about 0.1% of the LSA.

Water erosion and mixing will potentially affect less than 1% of the LSA. The effects are considered to be adverse, low magnitude, local and long term.

Operations

Measurable changes in soil chemistry are not expected because of low levels of emissions from facilities. If small-scale leaks and spills occurred, they would be the main source potentially leading to an effect on soil chemistry. The combined effects are predicted to be adverse, low magnitude, local and short term.

Decommissioning and Abandonment

Potential effects on soil physical and chemical characteristics during decommissioning and abandonment will be limited to minor disturbance of soil surfaces by machinery used to remove above-ground structures. Combined effects on soil physical and chemical properties are predicted to be none to low magnitude. Effects are considered adverse, low magnitude, local and short term.

Prediction Confidence

Because of the precautionary approach used to predict effects on soil quality of adding the Vardie River Section, there is a high degree of confidence in the assessment of significance of effects. The level of confidence is consistent with that in EIS Volume 5, Section 8.

Combined Project Effects

The EIS concluded that the Mackenzie Gas Project in combination with NGTL's Dickins Lake Section would produce no significant effects on:

- uncommon landforms or ground stability
- soil quality

This assessment for northwestern Alberta concludes that the Mackenzie Gas Project combined with NGTL's Dickins Lake and Vardie River sections will also produce no significant effects.