

**Table of Contents**

<b>8</b>	<b>Soils, Landforms and Permafrost .....</b>	<b>8-1</b>
8.1	Introduction.....	8-1
8.1.1	Scope.....	8-1
8.1.2	Summary of Findings.....	8-1
8.1.3	Traditional Knowledge .....	8-3
8.2	Assessment Approach.....	8-5
8.2.1	Key Issues .....	8-5
8.2.2	Valued Components and Key Indicators .....	8-6
8.2.3	Key Questions and Effect Pathway Diagrams .....	8-9
8.2.4	Effect Descriptions.....	8-9
8.2.5	Study Areas and Boundaries.....	8-11
8.2.6	Analytical Approach .....	8-16
8.3	Effects on Landforms.....	8-21
8.3.1	Effect Pathways .....	8-21
8.3.2	Overview of Project Design and Mitigation .....	8-31
8.3.3	Niglintgak .....	8-32
8.3.4	Taglu .....	8-36
8.3.5	Parsons Lake .....	8-40
8.3.6	Gathering Pipelines and Associated Facilities .....	8-44
8.3.7	Pipeline Corridor.....	8-47
8.3.8	Northwestern Alberta.....	8-65
8.3.9	Infrastructure.....	8-65
8.3.10	Significance of Effects.....	8-72
8.4	Effects on Soil Quality.....	8-79
8.4.1	Effect Pathways .....	8-79
8.4.2	Overview of Project Design and Mitigation .....	8-90
8.4.3	Niglintgak .....	8-91
8.4.4	Taglu .....	8-96
8.4.5	Parsons Lake .....	8-101

8.4.6	Gathering Pipelines and Associated Facilities .....	8-105
8.4.7	Pipeline Corridor.....	8-112
8.4.8	Northwestern Alberta.....	8-133
8.4.9	Infrastructure.....	8-134
8.4.10	Significance of Effects.....	8-141
8.5	Monitoring .....	8-147
8.5.1	Compliance Monitoring.....	8-147
8.5.2	Effects Monitoring.....	8-148

**References**

<b>9</b>	<b>Vegetation.....</b>	<b>9-1</b>
9.1	Introduction.....	9-1
9.1.1	Focus.....	9-1
9.1.2	Summary of Findings.....	9-1
9.1.3	Traditional Knowledge .....	9-4
9.2	Assessment Approach.....	9-7
9.2.1	Key Issues .....	9-7
9.2.2	Valued Components.....	9-9
9.2.3	Key Questions and Effect Pathway Diagrams .....	9-36
9.2.4	Effect Descriptions.....	9-36
9.2.5	Study Areas and Boundaries.....	9-41
9.2.6	Analytical Approach.....	9-43
9.3	Effects on Vegetation Abundance and Distribution .....	9-45
9.3.1	Effect Pathways .....	9-45
9.3.2	Overview of Project Design and Mitigation.....	9-57
9.3.3	Niglintgak .....	9-65
9.3.4	Taglu .....	9-73
9.3.5	Parsons Lake .....	9-79
9.3.6	Gathering Pipelines and Associated Facilities.....	9-84
9.3.7	Pipeline Corridor.....	9-90

9.3.8	Northwestern Alberta.....	9-105
9.3.9	Infrastructure.....	9-106
9.3.10	Significance of Effects.....	9-113
9.4	Effects on Vegetation Health.....	9-121
9.4.1	Effect Pathways.....	9-121
9.4.2	Overview of Project Design and Mitigation.....	9-133
9.4.3	Niglintgak.....	9-137
9.4.4	Taglu.....	9-141
9.4.5	Parsons Lake.....	9-143
9.4.6	Gathering Pipelines and Associated Facilities.....	9-146
9.4.7	Pipeline Corridor.....	9-148
9.4.8	Northwestern Alberta.....	9-161
9.4.9	Infrastructure.....	9-161
9.4.10	Significance of Effects.....	9-168
9.5	Monitoring.....	9-175
9.5.1	Compliance Monitoring.....	9-175
9.5.2	Effects Monitoring.....	9-175

**References**

**Glossary**



**List of Figures**

Figure 8-1:	Ecological Zones – North Regional Overview Map.....	8-13
Figure 8-2:	Ecological Zones – Central Regional Overview Map .....	8-14
Figure 8-3:	Ecological Zones – South Regional Overview Map.....	8-15
Figure 8-4:	Effect Pathways – Landforms.....	8-22
Figure 8-5:	Potential Pond Formation After Disturbance of Insulating Layers.....	8-25
Figure 8-6:	Potential Altered Drainage Patterns Caused by Frost Bulb or Frost Heave.....	8-26
Figure 8-7:	Slope Instability Mechanisms Caused by Permafrost Thawing .....	8-28
Figure 8-8:	Erosion Processes.....	8-30
Figure 8-9:	Effect Pathways – Soil Quality .....	8-80
Figure 9-1:	Ecological Zones.....	9-2
Figure 9-2:	Regional Study Area.....	9-42
Figure 9-3:	Effect Pathways – Abundance and Distribution of Vegetation Species and Associations.....	9-46
Figure 9-4:	Terrain and Vegetation Structures Sensitive to Damage from Winter Vehicle Traffic .....	9-50
Figure 9-5:	Rare Plant Locations – Tundra Ecological Zone .....	9-74
Figure 9-6:	Rare Plant Locations – Transition Forest Ecological Zone .....	9-92
Figure 9-7:	Rare Plant Locations – North Taiga Plains Ecological Zone .....	9-95
Figure 9-8:	Rare Plant Locations – South Taiga Plains Ecological Zone .....	9-96
Figure 9-9:	Effect Pathways – Health of Vegetation Species and Associations .....	9-122
Figure 9-10:	Nitrogen Deposition at Little Chicago Compressor Station .....	9-152
Figure 9-11:	Nitrogen Deposition at Norman Wells Compressor Station .....	9-153
Figure 9-12:	Nitrogen Deposition at Blackwater River Compressor Station .....	9-155
Figure 9-13:	Nitrogen Deposition at Trail River Compressor Station.....	9-156



**List of Tables**

Table 8-1:	Selection Criteria for Valued Components.....	8-6
Table 8-2:	Valued Components and Key Indicators .....	8-7
Table 8-3:	Key Questions, Related Key Issues and Valued Components .....	8-9
Table 8-4:	Definition of Direction.....	8-10
Table 8-5:	Definition of Magnitude .....	8-11
Table 8-6:	Definition of Geographic Extent.....	8-11
Table 8-7:	Definition of Duration.....	8-11
Table 8-8:	Applicable Pathways for Project Effects on Landforms.....	8-21
Table 8-9:	Mitigation Strategies for Ground Stability and Uncommon Landforms .....	8-31
Table 8-10:	Summary of Landforms in the Niglintgak LSA .....	8-32
Table 8-11:	Effects on Landforms – Niglintgak: Barge-Based or Land-Based Gas Conditioning Facility.....	8-33
Table 8-12:	Areas of Potential Ground Stability Effects – Niglintgak .....	8-34
Table 8-13:	Areas of Potential Uncommon Landforms Effects – Niglintgak .....	8-35
Table 8-14:	Summary of Landforms in the Taglu LSA .....	8-37
Table 8-15:	Effects on Landforms – Taglu .....	8-38
Table 8-16:	Areas of Potential Ground Stability Effects – Taglu .....	8-38
Table 8-17:	Areas of Potential Uncommon Landforms Effects – Taglu.....	8-39
Table 8-18:	Summary of Landforms in the Parsons Lake LSA .....	8-41
Table 8-19:	Effects on Landforms – Parsons Lake .....	8-42
Table 8-20:	Areas of Potential Ground Stability Effects – Parsons Lake.....	8-42
Table 8-21:	Areas of Potential Uncommon Landforms Effects – Parsons Lake .....	8-43
Table 8-22:	Summary of Landforms in the Gathering Pipelines and Associated Facilities LSA.....	8-44
Table 8-23:	Effects on Landforms – Gathering Pipelines and Associated Facilities .....	8-45
Table 8-24:	Areas of Potential Ground Stability Effects – Gathering Pipelines and Associated Facilities.....	8-46
Table 8-25:	Areas of Potential Uncommon Landforms Effects – Gathering Pipelines and Associated Facilities.....	8-47
Table 8-26:	Summary of Landforms in the Transition Forest Ecological Zone LSA.....	8-48
Table 8-27:	Summary of Landforms in the North Taiga Plains A Ecological Zone LSA.....	8-49
Table 8-28:	Summary of Landforms in the North Taiga Plains B Ecological Zone LSA.....	8-50
Table 8-29:	Summary of Landforms in the South Taiga Plains A Ecological Zone .....	8-51

Table 8-30:	Summary of Landforms in the South Taiga Plains B Ecological Zone .....	8-52
Table 8-31:	Effects on Landforms – Transition Forest Ecological Zone .....	8-52
Table 8-32:	Potential Ground Stability Effects – Transition Forest Ecological Zone .....	8-53
Table 8-33:	Areas of Potential Uncommon Landforms Effects – Transition Forest Ecological Zone.....	8-54
Table 8-34:	Effects on Landforms – North Taiga Plains A Ecological Zone .....	8-55
Table 8-35:	Areas of Potential Ground Stability Effects – North Taiga Plains A Ecological Zone.....	8-56
Table 8-36:	Areas of Uncommon Landforms Effects – North Taiga Plains A Ecological Zone.....	8-57
Table 8-37:	Effects on Landforms – North Taiga Plains B Ecological Zone .....	8-58
Table 8-38:	Areas of Potential Ground Stability Effects – North Taiga Plains B Ecological Zone.....	8-59
Table 8-39:	Areas of Potential Uncommon Landforms Effects – North Taiga Plains B Ecological Zone.....	8-60
Table 8-40:	Effect on Landforms – South Taiga Plains A Ecological Zone .....	8-61
Table 8-41:	Areas of Potential Ground Stability Effects – South Taiga Plains A Ecological Zone.....	8-61
Table 8-42:	Areas of Potential Uncommon Landforms Effects – South Taiga Plains A Ecological Zone .....	8-62
Table 8-43:	Effects on Landforms – South Taiga Plains B Ecological Zone .....	8-63
Table 8-44:	Areas of Potential Ground Stability Effects – South Taiga Plains B Ecological Zone.....	8-64
Table 8-45:	Areas of Potential Uncommon Landforms Effects – South Taiga Plains B Ecological Zone.....	8-65
Table 8-46:	Effects on Landforms – Production Area Infrastructure.....	8-68
Table 8-47:	Predicted Effects – Pipeline Corridor Infrastructure .....	8-70
Table 8-48:	Significance of Effects of Niglintgak on Landforms.....	8-73
Table 8-49:	Significance of Effect of Taglu on Landforms .....	8-73
Table 8-50:	Significance of Effects of Parsons Lake on Landforms.....	8-74
Table 8-51:	Significance of Effects of the Gathering Pipelines and Associated Facilities on Landforms.....	8-74
Table 8-52:	Significance of Effects of the Pipeline Corridor on Landforms .....	8-75
Table 8-53:	Significance of Effects of Infrastructure on Landforms .....	8-75
Table 8-54:	Summary of Combined Affected Areas for Ground Stability .....	8-76



Table 8-55:	Summary of Combined Affected Areas for Uncommon Landforms – Local Study Areas .....	8-77
Table 8-56:	Summary of Combined Affected Areas for Uncommon Landforms – Regional Study Area .....	8-77
Table 8-57:	Applicable Pathways for Project Effects on Soil Quality .....	8-79
Table 8-58:	Mitigation Strategies for Soil Quality During Construction .....	8-91
Table 8-59:	Effects on Soil Quality – Niglintgak .....	8-92
Table 8-60:	Extent of Potential Changes in Soil Drainage caused by Thaw Settlement at Niglintgak .....	8-94
Table 8-61:	Characteristics of Soil Loss at Niglintgak .....	8-95
Table 8-62:	Effects on Soil Quality – Taglu .....	8-98
Table 8-63:	Extent of Potential Changes in Soil Drainage caused by Thaw Settlement at Taglu .....	8-99
Table 8-64:	Characteristics of Soil Loss at Taglu .....	8-100
Table 8-65:	Effects on Soil Quality – Parsons Lake .....	8-102
Table 8-66:	Extent of Potential Changes in Soil Drainage Caused by Thaw Settlement at Parsons Lake .....	8-103
Table 8-67:	Characteristics of Soil Loss at Parsons Lake .....	8-104
Table 8-68:	Effects on Soil Quality – Gathering Pipelines and Associated Facilities .....	8-106
Table 8-69:	Extent of Potential Changes in Soil Drainage caused by Thaw Settlement along the Gathering Pipelines and Associated Facilities .....	8-108
Table 8-70:	Characteristics of Soil Loss Along the Gathering Pipelines and Associated Facilities .....	8-111
Table 8-71:	Effects on Soil Quality – Transition Forest Ecological Zone .....	8-116
Table 8-72:	Extent of Potential Changes in Soil Drainage from Thaw Settlement in the Transition Forest Ecological Zone .....	8-118
Table 8-73:	Characteristics of Soil Loss at the Intermediate Block Valve Site – Transition Forest Ecological Zone .....	8-119
Table 8-74:	Effects on Soil Quality – North Taiga Plains Ecological Zone .....	8-121
Table 8-75:	Extent of Potential Changes in Soil Drainage caused by Thaw Settlement in the North Taiga Plains Ecological Zone .....	8-123
Table 8-76:	Characteristics of Soil Loss – North Taiga Plains Ecological Zone .....	8-126
Table 8-77:	Effects on Soil Quality – South Taiga Plains Ecological Zone .....	8-128
Table 8-78:	Extent of Potential Changes in Soil Drainage from Thaw Settlement – South Taiga Plains Ecological Zone .....	8-129
Table 8-79:	Characteristics of Soil Loss – South Taiga Plains Ecological Zone .....	8-131

Table 8-80:	Effects on Soil Quality – Production Area Infrastructure.....	8-135
Table 8-81:	Effects on Soil Quality – Pipeline Corridor Infrastructure .....	8-139
Table 8-82:	Significance of Effects of Niglintgak on Soil Quality .....	8-142
Table 8-83:	Significance of Effects of Taglu on Soil Quality .....	8-142
Table 8-84:	Significance of Effects of Parsons Lake on Soil Quality.....	8-143
Table 8-85:	Significance of Effects of the Gathering Pipelines and Associated Facilities on Soil Quality .....	8-143
Table 8-86:	Significance of Effects of the Pipeline Corridor on Soil Quality .....	8-144
Table 8-87:	Significance of Effects of Infrastructure on Soil Quality .....	8-145
Table 8-88:	Monitoring of Effects on Landforms and Soils .....	8-148
Table 9-1:	Selection Criteria for Valued Components .....	9-9
Table 9-2:	Species Diversity of Tundra Vegetation Types .....	9-16
Table 9-3:	Selection Criteria for Vegetation Types and Communities of Concern – Tundra Ecological Zone.....	9-17
Table 9-4:	Species Diversity of Transition Forest Ecological Zone Vegetation Types .....	9-19
Table 9-5:	Selection Criteria for Vegetation Types and Communities of Concern – Transition Forest Ecological Zone.....	9-20
Table 9-6:	Species Diversity of North Taiga Plains Ecological Zone Vegetation Types .....	9-22
Table 9-7:	Selection Criteria for Vegetation Types and Communities of Concern – North Taiga Plains Ecological Zone.....	9-23
Table 9-8:	Species Diversity of South Taiga Plains Vegetation Types.....	9-26
Table 9-9:	Selection Criteria for Vegetation Types and Communities of Concern – South Taiga Plains Ecological Zone.....	9-27
Table 9-10:	Plant Community Tracking List for the Boreal Forest Natural Region in Alberta.....	9-31
Table 9-11:	Alberta Rare Plant Community Ranking Guidelines.....	9-32
Table 9-12:	Key Questions, Related Issues and Valued Components .....	9-37
Table 9-13:	Definitions of Effect Attributes .....	9-38
Table 9-14:	Magnitude of Effects for Rare Plants of High Conservation Concern.....	9-39
Table 9-15:	Mitigation Strategies for Vegetation Abundance and Distribution .....	9-58
Table 9-16:	Area of Vegetation Types Affected – Niglintgak.....	9-66
Table 9-17:	Effects on Vegetation Abundance and Distribution – Niglintgak .....	9-67
Table 9-18:	Area of Vegetation Types Affected – Taglu.....	9-75
Table 9-19:	Effects on Vegetation Abundance and Distribution – Taglu .....	9-76
Table 9-20:	Area of Vegetation Types Affected – Parsons Lake.....	9-80
Table 9-21:	Effects on Vegetation Abundance and Distribution – Parsons Lake .....	9-81
Table 9-22:	Area of Vegetation Types Affected – Gathering Pipelines .....	9-85

Table 9-23:	Effects on Vegetation Abundance and Distribution – Gathering Pipelines and Associated Facilities .....	9-86
Table 9-24:	Effects on Vegetation Abundance and Distribution – Pipeline Corridor .....	9-97
Table 9-25:	Area of Vegetation Types Affected – Pipeline Corridor Transition Forest Ecological Zone .....	9-98
Table 9-26:	Area of Vegetation Types Affected – Pipeline Corridor North Taiga Plains Ecological Zone .....	9-99
Table 9-27:	Area of Vegetation Types Affected – Pipeline Corridor South Taiga Plains Ecological Zone .....	9-100
Table 9-28:	Area of Tall Forest Affected – North Taiga Plains Ecological Zone .....	9-102
Table 9-29:	Area of Tall Forest Affected – South Taiga Plains Ecological Zone .....	9-102
Table 9-30:	Rare Populations Affected by Pipeline Construction .....	9-104
Table 9-31:	Significance of Effects of Niglintgak on Vegetation Abundance and Distribution .....	9-114
Table 9-32:	Significance of Effects of Taglu on Vegetation Abundance and Distribution .....	9-115
Table 9-33:	Significance of Effects of Parsons Lake on Vegetation Abundance and Distribution .....	9-116
Table 9-34:	Significance of Effects of the Gathering Pipelines and Associated Facilities on Vegetation Abundance and Distribution .....	9-117
Table 9-35:	Significance of Effects of the Pipeline Corridor on Vegetation Abundance and Distribution .....	9-117
Table 9-36:	Significance of Effects of the Combined Project on Vegetation Abundance and Distribution .....	9-119
Table 9-37:	Effects of Road Dust on Growth of Alaskan Plant Species .....	9-124
Table 9-38:	Sensitivity of Vegetation Types to Dust Deposition .....	9-125
Table 9-39:	Sensitivity of Vegetation Types to Nitrogen Deposition .....	9-129
Table 9-40:	Nitrogen Dioxide and Nitrogen Deposition – Critical Levels and Loads for Vegetation .....	9-131
Table 9-41:	Mitigation Strategies for Vegetation Health .....	9-133
Table 9-42:	Summary of Maximum Levels of Air Quality Parameters .....	9-135
Table 9-43:	Effects on Vegetation Health – Niglintgak .....	9-138
Table 9-44:	Rare Plant Species – Niglintgak .....	9-140
Table 9-45:	Effects on Vegetation Health – Taglu .....	9-142
Table 9-46:	Effects on Vegetation Health – Parsons Lake .....	9-145
Table 9-47:	Effects on Vegetation Health – Gathering Pipelines and Associated Facilities .....	9-147
Table 9-48:	Vegetation Types of Concern – Pipeline Corridor .....	9-149
Table 9-49:	Effects on Vegetation Health – Pipeline Corridor .....	9-150
Table 9-50:	Vegetation Communities of Concern Within 100 m of Pipeline .....	9-157

Table 9-51:	Rare Plant Species Within 100 m of Pipeline – North Taiga Plains Ecological Zone .....	9-159
Table 9-52:	Rare Plant Species Within 100 m of Pipeline – South Taiga Plains Ecological Zone .....	9-160
Table 9-53:	Effects on Vegetation Health – Production Area Infrastructure.....	9-162
Table 9-54:	Rare Plant Species Located During Project Surveys – Production Area Infrastructure .....	9-163
Table 9-55:	Effects on Vegetation Health – Pipeline Corridor Infrastructure.....	9-166
Table 9-56:	Rare Plant Species Within 100 m of Pipeline Corridor Infrastructure.....	9-167
Table 9-57:	Significance of Effects of Niglintgak on Vegetation Health.....	9-169
Table 9-58:	Significance of Effects of Taglu on Vegetation Health .....	9-169
Table 9-59:	Significance of Effects of Parsons Lake on Vegetation Health.....	9-170
Table 9-60:	Significance of Effects of the Gathering Pipelines and Associated Facilities on Vegetation Health .....	9-171
Table 9-61:	Significance of Effects of the Pipeline Corridor on Vegetation Health .....	9-171
Table 9-62:	Significance of Effects of Infrastructure on Vegetation Health.....	9-172
Table 9-63:	Significance of Effects of Combined Project Components on Vegetation Health .....	9-173
Table 9-64:	Monitoring of Effects on Vegetation .....	9-175