14 ENVIRONMENTAL EFFECTS ON THE PROJECT

This section addresses the environmental effects on the project and mitigation measures that might be used to reduce any potential adverse effects.

Key elements associated with the effects are discussed under the following topics:

- terrain stability
- hydrologic processes
- weather
- forest fires
- ecologically or culturally important flora and fauna
- human use and values

The effect pathways of environmental effects on the project are in many cases interrelated. Changes in weather could affect fire, which could affect terrain stability and hydrologic processes. This section focuses on processes that could have direct effects and not those that could have indirect effects. For example, fire could directly affect the project by damaging facilities. Fire could also cause loss of vegetation, which in turn could lead to increased thaw settlement that could then affect the project. Fire as a direct effect is discussed. However, fire as an indirect cause of effects is not addressed, although thaw settlement as a process with direct effects is considered.

Effects of climate change on the environment are discussed in Section 11, Climate Change.

14.1 Terrain Stability

Terrain stability will have an effect on project design and operations and is considered one of the major project issues. Of primary concern is the potential risk of physical or thermal mechanisms causing terrain instability, which could threaten the integrity of the project components. In particular, the following processes are of concern:

- slope failure
- thaw settlement
- erosion
- channel migration
- karst settlement
- seismicity

Many of the protection measures addressing terrain stability are described in detail in Volume 7, Environmental Management, and their site-specific applications are identified in Volume 8, Environmental Alignment Sheets.

14.1.1 Slope Failure

Slope failure is a result of a combination of several processes that could adversely affect the project. The effects of the project on slope stability are discussed in Volume 5, Section 8, Soils, Landforms and Permafrost.

14.1.1.1 Potential Changes

Types of slope failure that could affect the project include:

- shallow-seated slumps, debris flows or slides that could result in the movement of soils and surface materials on the right-of-way

- deeper-seated mass movements that could threaten the integrity of the pipeline and facilities

Large-scale, deep-seated landslides and rockslides are unlikely in the areas through which the project has been routed, and are not considered here.

14.1.1.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for slope failure were considered:

- controlling drainage on slopes to reduce the saturation of surface materials. Where applicable, this might be achieved by (see Volume 7, Section 4, Environmental Protection Plan):
  - installing cross ditches and berms
  - providing gaps in the trench crown on sidehills
  - installing trench breakers and, potentially, subdrains
- restoring slopes leading to watercourses with bank protection
- using bioengineering restoration techniques, e.g., brush layering
- restoring vegetation on slopes as soon as practical after construction
- implementing site-specific slope-stability monitoring programs where required (see Section 8, Soils, Landforms and Permafrost)
- monitoring right-of-way integrity during operations through periodic surveillance flights and inline surveys with inspection tools (see Volume 7, Section 3, Environmental Management Plans, and Volume 2, Section 4, Pipelines)

14.1.2 Thaw Settlement

Thaw settlement is a natural process in which permanently frozen, high-ice-content soils melt, leading to a collapse in soil structure. See Section 8, Soils, Landforms and Permafrost, for a discussion of thaw settlement caused by the project.

Concerns regarding frost heave are primarily caused by the project (see Section 5, Hydrology, and Section 8, Soils, Landforms and Permafrost).

14.1.2.1 Potential Changes

Thaw settlement could affect the project through:

- ground settlement
- pond formation
- disrupted drainage
- erosion
- slope instability

Each of these concerns could threaten the integrity of the right-of-way, the pipeline and facilities.

14.1.2.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for thaw settlement were considered (see Volume 2, Project Description, and Volume 7, Environmental Management):

- operating the pipeline system north of Inuvik at -1°C or colder, to ensure that the pipeline operating temperatures do not lead to thaw settlement along the pipeline
- operating the pipeline system south of Inuvik with seasonal temperature cycling to limit the effects of pipeline temperature on the discontinuous permafrost zone
- ensuring building temperatures do not melt the permafrost by constructing facilities on:
  - piles
  - insulated pads
- constructing the right-of-way using techniques that limit disruption of surface vegetation. This will reduce exposure of soils to the sun, which will reduce potential thaw settlement.
- monitoring right-of-way integrity during operations through periodic surveillance flights and inline surveys with inspection tools

14.1.3 Erosion

Erosion along the right-of-way or in the vicinity of facilities is a concern as it could lead to:

- damage to facilities
- damage to public and private property
- interruption in service

14.1.3.1 Potential Changes

Types of erosion that could affect the project include:

- development of rills and gullies on gently to steeply sloping disturbed land
- loss of wind-erodible soils
- washout along sunken trenches
- washout of backfill on slopes
- channel migration and loss of shoreline
- ice and water scour on buried pipelines and instream facilities

14.1.3.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for erosion were considered (see Volume 7, Environmental Management):

- implementing erosion-control measures on all project-disturbed land susceptible to wind and water erosion, including:
  - revegetating exposed soils
  - spreading slash and installing specialized erosion-control products
  - bioengineering, e.g., brush layering
- diverting surface water off the right-of-way with cross ditches and berms
- preventing water from coursing down the trench by using subdrains and trench plugs accompanied by cross ditches and berms
- placing pipe over-bends and sag-bends at river crossings sufficiently far back from the bank to reduce the risk of exposure
- burying pipelines 1.2 m or deeper to prevent water or ice scour at crossing locations
- monitoring right-of-way integrity during operations through periodic surveillance flights and inline surveys with inspection tools (see also Volume 2, Project Description)

14.1.4 Channel Migration

Channel migration poses a concern to the project because of the dynamic nature of the Mackenzie Delta (see Section 5, Hydrology).

14.1.4.1 Potential Changes

Erosion of the bank or avulsion of a stream on the right-of-way could expose the pipeline, or damage facilities and infrastructure.

14.1.4.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for channel migration were considered:

- designing watercourse crossings according to (see Volume 2, Section 4, Pipelines):
  - stream type
  - scour potential
  - streambed soil conditions
  - bank stability
- designing pipe over-bends and sag-bends at river crossings sufficiently far back from the bank to ensure sufficient depth of cover is maintained
- installing suitable bank-protection measures along unstable banks on the right-of-way (see Volume 7, Section 4, Environmental Protection Plan)
- monitoring right-of-way integrity during operations through periodic surveillance flights (see Volume 7, Section 3, Environmental Management Plans)

14.1.5 Karst Settlement

The project covers areas that exhibit karst features and are prone to karst settlement. Karst terrain comprises sinkholes and underground caverns that form with the dissolution of carbonate-rich rock. Information on the locations of karst-susceptible deposits in the region is provided in Volume 3, Section 8, Soils, Landforms and Permafrost.

14.1.5.1 Potential Changes

Karst settlement poses a particular concern because of the potential for settlement or caving of existing karst features, although these processes are relatively slow in their development. Settlement or collapse of karst features might lead to structural damage, pipeline exposure and operational interruptions.

14.1.5.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for karst settlement were considered:

- selecting an appropriate pipeline route (see Volume 2, Section 2, Route and Site Selection)

- monitoring right-of-way integrity during operations through periodic surveillance flights and inline surveys with inspection tools (see Volume 7, Section 3, Environmental Management Plans, and Volume 2, Section 4, Pipelines)

14.1.6 Seismicity

The project traverses areas that could be affected by naturally occurring seismic activity.

Seismic hazard ratings across Canada are divided into seven seismic zones (0 to 6), with higher zoning, i.e., a larger number, representing increased seismic risk. The production area is rated Zone 1 and the pipeline corridor, Zone 0.

14.1.6.1 Potential Changes

Seismic mechanisms, such as ground vibration or earthquakes, could lead to:

- displacement of the ground surface
- changes to soil strength such as liquefaction
- changes to surface and subsurface drainage

The effects to the project could include:

- structural damage
- pipeline exposure
- changes in buoyancy
- interruption of operations

Land subsidence or uplift from a large-scale catastrophic seismic event is not known in the study area. Slope failures from seismic activity associated with hilly or mountainous terrain and high-magnitude seismic events are not applicable to the project.

On the basis of available information, it is concluded that the potential for earthquakes and related impacts on the project is a minor consideration.

14.1.6.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for seismicity were considered:

- adhering to Canadian Standards Association Code Z662 (CSA 2003) and National Building Code requirements (National Building Code 1995)
- monitoring right-of-way integrity during operations through periodic surveillance flights and inline surveys with inspection tools (see Volume 7, Section 3, Environmental Management Plans, and Volume 2, Section 4, Pipelines)

14.2 Hydrologic Processes

Hydrologic processes that will have an effect on project design, construction and operations include:

- flooding
- spring breakup and ice movement
- extreme runoff

14.2.1 Flooding

Flooding of the Mackenzie River and its tributaries is a common event in the project area. A considerable number of both large and small rivers and lakes along the Mackenzie River flood in spring (see Volume 3, Section 5, Hydrology). Flooding in the Mackenzie Delta is a result of the following processes:

- spring breakup and ice blockage at the coast (see Section 14.2.2, Spring Breakup and Ice Movement)
- extreme runoff (see Section 14.2.3, Extreme Runoff)
- storm surges
- natural geological subsidence

Subsidence, resulting from hydrocarbon extraction, is an effect of the project on the environment and is addressed in Volume 5, Biophysical Impact Assessment.

14.2.1.1 Potential Changes

Flooding could adversely affect the project through:

- inundating and damaging the anchor field areas and facilities
- inundating select infrastructure sites and damaging stored equipment and pipe
- inundating and eroding portions of the gathering pipeline rights-of-way
- increasing bank erosion and channel migration on the right-of-way
- disrupting barging activities and the barge-based gas conditioning facility

14.2.1.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for flooding were considered:

- constructing production facilities 2 to 3.5 m above ground on pads or elevated platforms (see Volume 2, Section 3, Anchor Fields)

- storing fuel, hazardous material and other sensitive material appropriately to control leaks and spills (see Volume 7, Section 4, Environmental Protection Plan)

- designing watercourse crossings according to (see Volume 2, Section 4, Pipelines):

  - stream type
  - scour potential
  - streambed soil conditions
  - water flow during construction
  - bank stability

- placing pipe over-bends and sag-bends at river crossings sufficiently back from the bank to ensure a sufficient depth of cover is maintained

- designing the barge-based gas conditioning facility to accommodate a 5- to 6-m rise in water level (see Volume 2, Section 3, Anchor Fields)

14.2.2 Spring Breakup and Ice Movement

Spring breakup on the Mackenzie River and its tributaries and in the Beaufort Sea is a dynamic process. Channels in the outer delta are greatly influenced by spring breakup and ice movement (see Volume 3, Section 5, Hydrology)

14.2.2.1 Potential Changes

It is expected that breakup and ice movement could have an adverse effect on the project by causing:

- flooding (see Section 14.2.1, Flooding)

- damage to facilities, delays in construction and interruption of operations from ice floes, ice rafting and large-scale ice movements

- an increase in bank erosion and channel migration on the right-of-way

- damage to barge landing areas and docking facilities

- disruption of barging activities and damage to the barge-based gas conditioning facility

- restricted shipping in the Beaufort Sea

14.2.2.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for spring breakup and ice movement were considered:

- constructing production facilities 2 to 3.5 m above ground on pads or elevated platforms (see Volume 2, Section 3, Anchor Fields)
- storing fuels, hazardous material and other sensitive materials appropriately to control leaks and spills (see Volume 7, Section 4, Environmental Protection Plan)
- designing the Niglintgak barge option to account for breakup and ice movement (see Volume 2, Section 3, Anchor Fields)
- installing and removing spud barges at barge landings annually (see Volume 2, Section 6, Infrastructure)
- developing contingency plans for access during breakup
- scheduling shipping and barging in the Beaufort Sea for ice-free periods (see Volume 7, Section 4, Environmental Protection Plan)

14.2.3 Extreme Runoff

Extreme runoff is a common occurrence in sparsely vegetated and permafrost areas where heavy precipitation or meltwater is not absorbed into the frozen ground.

14.2.3.1 Potential Changes

Extreme runoff events could result in high stream velocities and water levels, adversely affecting the project by causing:

- bridge and culvert failures that could result in restricted access to sites
- increased bed, bank and slope erosion that could increase the potential for pipeline exposure

14.2.3.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for extreme runoff were considered:

- installing permanent and temporary bridges to withstand spring flood and ice jams (see Volume 7, Section 4, Environmental Protection Plan)

- installing culverts to withstand 150% of maximum expected flow or five-year flood level (see Volume 7, Section 4, Environmental Protection Plan)

- designing watercourse crossings according to (see Volume 2, Section 4, Pipelines):

  - stream type
  - scour potential
  - streambed soil conditions
  - water flow during construction
  - bank stability

- placing pipe over-bends and sag-bends at river crossings sufficiently back from the bank to ensure a sufficient depth of cover is maintained

- implementing suitable bank-protection measures along unstable banks on the right-of-way (see Volume 7, Section 4, Environmental Protection Plan)

- monitoring right-of-way integrity during operations through periodic surveillance flights (see Volume 7, Section 3, Environmental Management Plans)

14.3 Weather

Weather conditions could have an effect on project design and operations and have been considered by the project engineering team. The harsh climate of the Mackenzie Valley could also affect project logistics, requiring measures to ensure that uncertainty in meteorological conditions is accounted for in the scheduling. The factors likely to affect the project include:

- temperature
- precipitation
- wind
- fog
- lightning

See Section 11, Climate Change, for a discussion on climate change.

14.3.1 Temperature

The project area is subject to extreme fluctuations in temperature (see Volume 3, Section 2, Air Quality). Meteorological data indicate that temperature extremes can be 20°C greater than summer normals and 20°C less than winter normals.

14.3.1.1 Potential Changes

Extreme temperatures could affect the project in the following ways:

- large variations in temperature could have an adverse effect on the performance of materials, equipment and personnel
- extreme temperatures could adversely affect construction activities and in some cases might result in worker safety issues
- unseasonable temperatures could affect timing of ice roads, ice bridges and winter roads opening and closing, resulting in construction delays

14.3.1.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for temperature were considered:

- designing facilities and planning construction and logistics to address the extremes of the northern climate (see Volume 2, Project Description)
- preparing contingency plans to address thawing conditions on the right-of-way, if unseasonably warm temperatures affect construction activities (see Volume 7, Section 5, Contingency Plans)

- considering the opening and closing of ice roads, ice bridges and winter roads (see Volume 7, Section 4, Environmental Protection Plan)

- reducing travel of personnel and equipment by keeping the pipeline spread length short (see Volume 2, Section 4, Pipelines)

14.3.2 Precipitation

The total annual precipitation in the Mackenzie Basin is generally low (see Volume 3, Section 2, Air Quality, and Volume 3, Section 5, Hydrology). Precipitation increases from north to south along the Mackenzie Valley, and rainfall is minimal in the north Mackenzie Valley near the Arctic coast. The wettest months in the production area and along the pipeline corridor are July and August. The driest months are March and April. Snowfall accounts for about half the total annual precipitation.

14.3.2.1 Potential Changes

Extreme precipitation could affect the project in the following ways:

- minor delays or shutdowns in construction could be expected because of heavy rain or snowfall

- heavy precipitation might adversely affect aerial patrols or other transportation needs

- heavy rainfall could lead to increased erosion of the right-of-way (see 14.1.3, Erosion and Section 14.2.3, Extreme Runoff)

- precipitation at facilities sites could result in substances being washed onto the pad or into the environment

- drought could limit the amount of snow that could be used for construction

14.3.2.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for precipitation were considered:

- preparing contingency plans to address wet conditions on the right-of-way (see Volume 7, Section 5, Contingency Plans)

- installing surface and subsurface erosion control devices along the right-of-way to control precipitation runoff (see Section 14.1.1, Slope Failure, Section 14.1.3, Erosion, and Volume 7, Section 4, Environmental Protection Plan)

- containing precipitation at facility sites where required (see Volume 2, Section 5, Pipeline Facilities)

- adding water to winter roads in the absence of sufficient snow (see Volume 2, Section 6, Infrastructure)

14.3.3 Wind

Average and extreme winds are important factors to consider in project design. Coastal areas of the Beaufort Sea, including Niglintgak, Taglu and Tuktoyaktuk, are most affected by extreme wind conditions and are particularly susceptible to storm surges (see Volume 3, Section 2, Air Quality, and Volume 3, Section 5, Hydrology).

14.3.3.1 Potential Changes

Wind could affect the project by:

- suspending construction activities
- eroding soils
- compromising structural integrity of buildings and flare stacks
- delaying and impeding fixed-wing and helicopter flights
- delaying and impeding barge traffic
- impeding vehicle traffic, e.g., with blowing snow or dust
- causing storm surges and flooding (see Section 14.2.1, Flooding)

14.3.3.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for wind were considered:

- implementing protection measures, where required, to address wind erosion along the right-of-way (see Volume 7, Section 4, Environmental Protection Plan)

- designing flare stacks and buildings in accordance with the National Building Code (1995) to accommodate wind loading

14.3.4 Fog

Fog and ice fog are more common in coastal areas than inland regions. Fog occurs throughout the year in settlement areas. However, fog reduces visibility to less than 1 km for only about two to three weeks a year, with visibility poorest during September, October and November.

14.3.4.1 Potential Changes

Fog and ice fog could affect the project by:

- restricting air and ground access to project facilities
- stranding crews in the field or at facility sites

14.3.4.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures for fog were considered (see Volume 2, Project Description:

- designing an emergency shelter at Niglintgak to accommodate evacuees from the barge-based gas conditioning facility in case of evacuation delays caused by weather

- designing permanent facilities to include accommodation quarters and food supplies

14.3.5 Lightning

The project area is subject to lightning, although this is less common farther north.

14.3.5.1 Potential Changes

Lightning could adversely affect the project by:

- interrupting power supply
- damaging buildings and facilities
- delaying pipeline construction
- posing a safety hazard for personnel

14.3.5.2 Design Considerations and Mitigation

All buildings and facilities will be constructed according to the National Building Code (National Building Code 1995) and CSA Code Z662, to reduce the adverse effects of a lightning strike.

14.4 Forest Fires

Forest fires are a common occurrence along the pipeline corridor.

14.4.1 Potential Changes

Forest fires could affect the project by:

- damaging or destroying construction equipment
- damaging above-ground facilities
- interrupting operations
- restricting access to some sites
- delaying construction
- conscripting project workers for firefighting

14.4.2 Design Considerations and Mitigation

In project design and construction, environmental protection and operations planning, the following mitigation measures were considered for forest fires:

- implementing the wildfire contingency plan (see Volume 7, Section 5, Contingency Plans)

- clearing fire breaks around above-ground facilities (see Volume 2, Section 5, Pipeline Facilities)

- equipping major facilities, e.g., compressor stations and the heater station, with fire-suppression systems (see Volume 2, Section 5, Pipeline Facilities)

14.5 Important Flora and Fauna

Ecologically or culturally important flora and fauna are found throughout the project area. These species are discussed in Volume 3, Section 9, Vegetation, and Section 10, Wildlife. For the special mitigation measures proposed to manage adverse effects on ecologically or culturally important flora and fauna, see:

- Section 9, Vegetation, and Section 10, Wildlife
- Volume 7, Environmental Management
- Volume 8, Environmental Alignment Sheets

14.6 Human Use and Values

The project area is subject to a variety of traditional and nontraditional uses, and therefore, values have been attached to various areas that could affect the project. Issues and mitigation measures are discussed in Volume 6, Socio-Economic Impact Assessment.

References

Canadian Standards Association (CSA). 2003. *Z662-03 and Z662.1: Oil and Gas Pipeline Systems.* Etobicoke, Ontario.

National Building Code. 1995. Published by National Research Council Canada's Institute for Research in Construction. NRCC 38726.