GROUNDWATER TECHNICAL REPORT FOR THE TRANS MOUNTAIN PIPELINE ULC TRANS MOUNTAIN EXPANSION PROJECT

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Prepared for:

TRANSMOUNTAIN

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EXECUTIVE SUMMARY

This report provides information and discussion on the existing groundwater-related conditions, potential effects and recommended mitigation requirements along the proposed pipeline corridor of the Trans Mountain Expansion Project (the Project). The objectives of this report were to:

- describe the setting as it relates to groundwater indicators along the proposed pipeline corridor;
- identify groundwater quality and quantity potential effects as they relate to the proposed pipeline corridor and construction of the pipeline; and
- recommend mitigation requirements.

The assessment was based on the selected indicators of groundwater quality and quantity. The mitigation endpoints for groundwater quality included:

- shallow groundwater with potential existing contamination;
- areas susceptible to drilling mud release during trenchless crossing construction;
- areas in the aquifer susceptible to sedimentation;
- areas of shallow groundwater susceptible to blasting effects;
- areas with potential artesian conditions; and
- aquifers or wells vulnerable to possible future contamination from an accident or malfunction.

The mitigation endpoints for groundwater quantity included:

- areas susceptible to changes in groundwater flow patterns;
- areas where dewatering may be required during pipeline construction activities;
- areas with potential artesian conditions; and
- areas of shallow groundwater susceptible to blasting effects.

The summary of the results identified the following:

- in Alberta, the proposed pipeline corridor crosses 34 potential aquifers, including 21 undifferentiated Quaternary aquifers (unconsolidated materials), 3 buried valley aquifers (unconsolidated materials), and 9 bedrock aquifers.
- in BC, the proposed pipeline corridor crosses 35 mapped aquifers, including:
  - 8 Quaternary aquifers (unconsolidated material) and 1 bedrock aquifer (Hargreaves to Darfield Segment);
  - 7 Quaternary aquifers (unconsolidated material) and 3 bedrock aquifers (Black Pines to Hope Segment);
  - 15 Quaternary aquifers (unconsolidated material) (Hope to Burnaby Segment); and
  - 1 Quaternary aquifer (unconsolidated material) (Burnaby to Westridge Segment).

The following facilities overlie mapped aquifers:

- the Darfield Pump Station;

- the Black Pines Pump Station;
- the Sumas Pump Station; and
- the Burnaby Terminal.

Proposed horizontal directional drilled (HDD) trenchless crossings with potential artesian conditions, include:

- 6 proposed HDD in the Edmonton to Hinton Segment, of these 4 potentially have artesian conditions;
- 8 proposed HDD in the Hargreaves to Darfield Segment;
- 7 proposed HDD in the Black Pines and Hope Segment;
- 5 proposed HDD in the Hope to Burnaby Segment; and
- no proposed HDD in the Burnaby to Westridge segment.

Pipeline corridor segments where potential groundwater quantity effects were identified, include:

- the Edmonton to Hinton Segment (26), Hargreaves to Darfield Segment (14), Black Pines to Hope Segment (6), Hope to Burnaby Segment (2) and Burnaby to Westridge Segment (1) were identified as areas susceptible to changes in groundwater flow pattern;
- the Edmonton to Hinton Segment (21), Hargreaves to Darfield Segment (10), Black Pines to Hope Segment (7), Hope to Burnaby Segment (3) and possibly along the Burnaby to Westridge Segment were identified as areas where dewatering may be required; and
- sections along the Edmonton to Hinton Segment, Hargreaves to Darfield Segment (1), Black Pines to Hope Segment (3) were identified as areas where blasting may be required.

Facilities where potential groundwater quantity effects were identified, include:

- the Westridge Marine Terminal was identified as a facility susceptible to changes in groundwater flow pattern;
- the Wolf Pump Station, Black Pool Pump Station, Black Pines Pump Station, Kingsvale Pump Station, Sumas Pump Station and Westridge Marine Terminal were identified as facilities that may require dewatering; and
- no facilities were identified where blasting may be required.

Facilities where potential groundwater quality effects were indentifies, include:

- the Edmonton Terminal, Jasper Pump Station, Blackpool Pump Station, Kamloops Pump Station, Sumas Terminal were identified as facilities where potential contamination was noted.

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DEFINITIONS AND ACRONYM LIST

Definition/Acronym	Full Name
BC	British Columbia
CEA	Canadian Environmental Assessment
Element	a technical discipline or discrete component of the biophysical or human environment identified in the NEB *Filing Manual*
EPP	Environmental Protection Plan
ESA	Environmental and Socio-economic Assessment
groundwater quality	Groundwater quality depends on the source of the water and the material through which it flows (*e.g.,* sulphate containing clay till, clean sand and gravel), as well as whether the groundwater encounters contamination. Both natural and human influences can affect groundwater quality. Surface water that recharges into the ground can affect groundwater quality; as conversely, groundwater may affect surface water quality.
groundwater quantity	The flow of groundwater is controlled by gravity and the physical characteristics of the materials through which it flows. Groundwater flow patterns can be affected as a result of natural (*e.g.,* surface water flooding) or human influences (*e.g.,* dewatering, construction of reservoirs).
Indicator	a biophysical, social, or economic property or variable that society considers to be important and is assessed to predict Project-related changes and focus the effects assessment on key issues. One or more indicators are selected to describe the present and predicted future condition of an element. Societal views are understood by the assessment team through published information such as management plans and engagement with regulators, public, Aboriginal, and other interested groups.
Local Study Area	the zone of influence or area where the element and associated indicators are most likely to be affected by Project construction and operation. This generally represents a buffer from the centre of the proposed pipeline corridor.
LSA	local study area
m bgl	metres below ground level
mitigation measures	mean measures for the elimination, reduction or control of a project’s adverse environmental effects, including restitution for any damage to the environment caused by such effects through replacement, restoration, compensation or any other means.
NEB	National Energy Board
OD	outside diameter
Post-construction monitoring	A type of monitoring program that may be used to verify that mitigation measures effectively mitigated the predicted adverse environmental effects.
proposed pipeline corridor	generally a 150 m wide corridor encompassing the pipeline construction right-of-way, temporary workspace
Regional Study Area	the area extending beyond the Local Study Area boundary where the direct and indirect influence of other activities could overlap with Project-specific effects and cause cumulative effects on the environmental or socio-economic indicator
RSA	regional study area
supplemental studies	• studies to be conducted post submission of the application to confirm the effects assessment conclusions and gather site-specific information for the implementation of mitigation from the Project-specific environmental protection plans
the Project	Trans Mountain Expansion Project
vulnerability	Vulnerability of an aquifer as the potential for an aquifer to be degraded (Berardinucci and Ronneseth [2002]). The vulnerability was determined based on: • depth to the water table – the shallower the water table the greater the vulnerability; • permeability of materials above the aquifer – the more permeable the sediments the higher the vulnerability; and • thickness and extent of confining sediments – the less areally extensive and the thinner the confining sediments, the greater the vulnerability.

1.0 INTRODUCTION

This report provides information and discussion on the existing groundwater-related conditions, potential effects and recommended mitigation measures along the proposed pipeline corridor of the Trans Mountain Expansion Project (the Project) based on selected indicators. The selected indicators include groundwater quality and quantity.

1.1 Project Overview

Trans Mountain Pipeline ULC (Trans Mountain) is a Canadian corporation with its head office located in Calgary, Alberta. Trans Mountain is a general partner of Trans Mountain Pipeline L.P., which is operated by Kinder Morgan Canada Inc. (KMC), and is fully owned by Kinder Morgan Energy Partners, L.P. Trans Mountain is the holder of the National Energy Board (NEB) certificates for the Trans Mountain pipeline system (TMPL system).

The TMPL system commenced operations 60 years ago and now transports a range of crude oil and petroleum products from Western Canada to locations in central and southwestern British Columbia (BC), Washington State and offshore. The TMPL system currently supplies much of the crude oil and refined products used in BC. The TMPL system is operated and maintained by staff located at Trans Mountain's regional and local offices in Alberta (Edmonton, Edson, and Jasper) and BC (Clearwater, Kamloops, Hope, Abbotsford, and Burnaby).

The TMPL system has an operating capacity of approximately 47,690 m^3/d (300,000 bbl/d) using 23 active pump stations and 40 petroleum storage tanks. The expansion will increase the capacity to 141,500 m^3/d (890,000 bbl/d).

The proposed expansion will comprise the following:

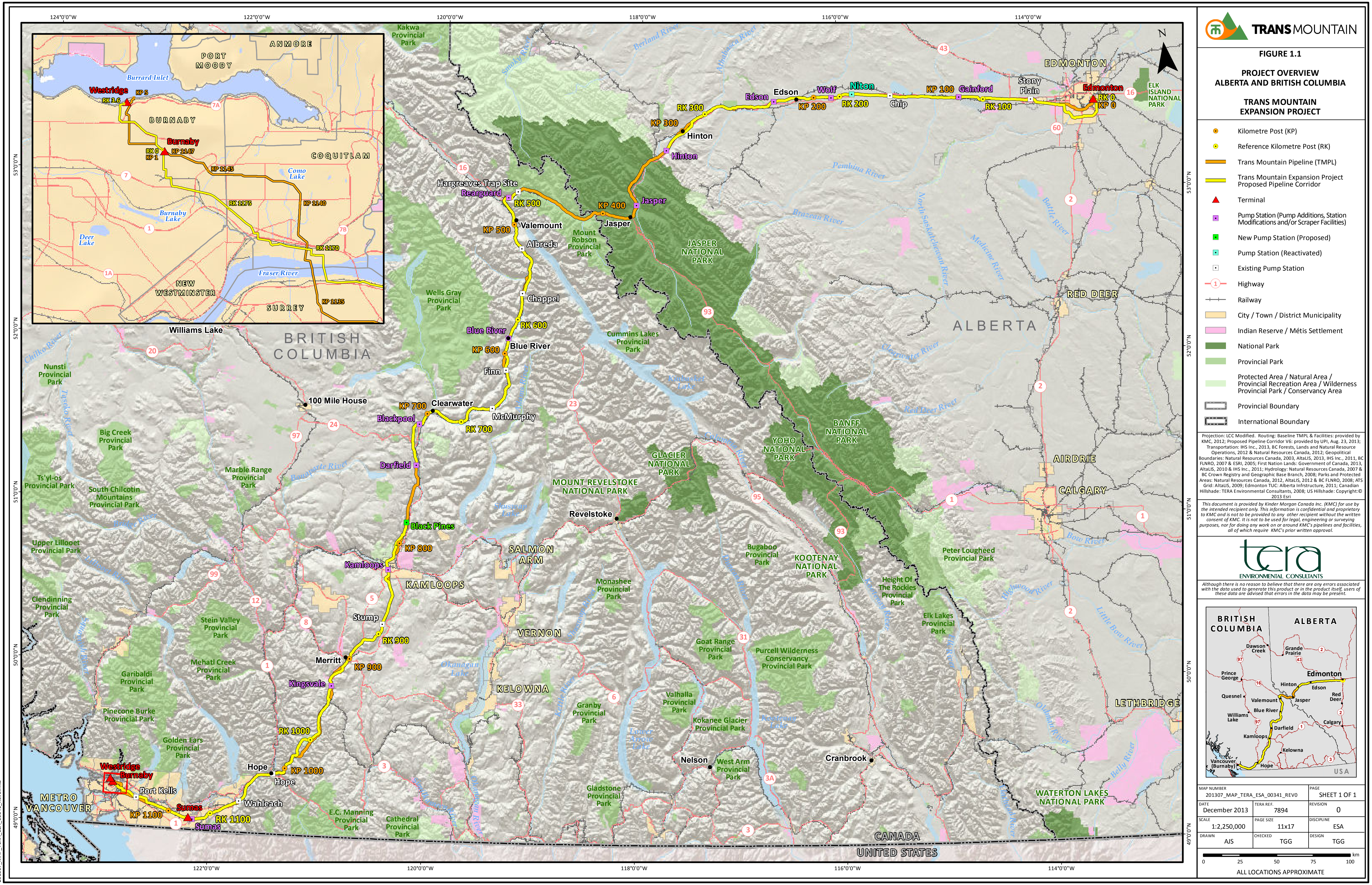
- pipeline segments that complete a twinning (or "looping") of the pipeline in Alberta and BC with about 987 km of new buried pipeline.
- new and modified facilities, including pump stations and tanks.
- three new berths at the Westridge Marine Terminal in Burnaby, BC, each capable of handling Aframax class vessels.

The expansion has been developed in response to requests for service from Western Canadian oil producers and West Coast refiners for increased pipeline capacity in support of growing oil production and access to growing West Coast and offshore markets. NEB decision RH-001-2012 reinforces market support for the expansion and provides Trans Mountain the necessary economic conditions to proceed with design, consultation, and regulatory applications.

Application is being made pursuant to Section 52 of the *National Energy Board Act* (*NEB Act*) for the proposed Trans Mountain Expansion Project (referred to as "TMEP" or "the Project"). The NEB will undertake a detailed review and hold a Public Hearing to determine if it is in the public interest to recommend a Certificate of Public Convenience and Necessity (CPCN) for construction and operation of the Project. Subject to the outcome of the NEB Hearing process, Trans Mountain plans to begin construction in 2016 and go into service in 2017.

Trans Mountain has embarked on an extensive program to engage Aboriginal communities and to consult with landowners, regulatory authorities (*e.g.*, regulators and municipalities), stakeholders, and the general public. Information on the Project is also available at www.transmountain.com.

Figure 1.1 provides the location of the proposed Project.



TRANS MOUNTAIN
FIGURE 1.1
PROJECT OVERVIEW
ALBERTA AND BRITISH COLUMBIA
TRANS MOUNTAIN
EXPANSION PROJECT
Kilometre Post (KP)
Reference Kilometre Post (RK)
Trans Mountain Pipeline (TMPL)
Trans Mountain Expansion Project Proposed Pipeline Corridor
Terminal
Pump Station (Pump Additions, Station Modifications and/or Scraper Facilities)
New Pump Station (Proposed)
Pump Station (Reactivated)
Existing Pump Station
Highway
Railway
City / Town / District Municipality
Indian Reserve / Métis Settlement
National Park
Provincial Park
Protected Area / Natural Area / Provincial Recreation Area / Wilderness Provincial Park / Conservancy Area
Provincial Boundary
International Boundary
Projection: LCC Modified. Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V6: provided by UPI, Aug. 23, 2013; Transportation: IHS Inc., 2013, BC Forests, Lands and Natural Resource Operations, 2012 & Natural Resources Canada, 2012; Geopolitical Boundaries: Natural Resources Canada, 2003, AltaLIS, 2013, IHS Inc., 2011, BC FLNRO, 2007 & ESRI, 2005; First Nation Lands: Government of Canada, 2013, AltaLIS, 2010 & IHS Inc., 2011; Hydrology: Natural Resources Canada, 2007 & BC Crown Registry and Geographic Base Branch, 2008; Parks and Protected Areas: Natural Resources Canada, 2012, AltaLIS, 2012 & BC FLNRO, 2008; ATS Grid: AltaLIS, 2009; Edmonton TUC: Alberta Infrstructure, 2011; Canadian Hillshade: TERA Environmental Consultants, 2008; US Hillshade: Copyright:© 2013 Esri
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KOOTENAY NATIONAL PARK
GLACIER NATIONAL PARK
MOUNT REVELSTOKE NATIONAL PARK
WATERTON LAKES NATIONAL PARK
ELK ISLAND NATIONAL PARK
Edmonton
Stony Plain
Gainford
Chip
Niton
Wolf
Edson
Hinton
Jasper
Hargreaves Trap Site
Rearguard
Valemount
Albreda
Chappel
Blue River
Finn
Clearwater
McMurphy
Blackpool
Darfield
Black Pines
Kamloops
Stump
Merritt
Kingsvale
Hope
Wahleach
Sumas
Port Kells
Westridge
Burnaby
Williams Lake
100 Mile House
Revelstoke
Nelson
Cranbrook
KP 0
RK 0
KP 100
RK 100
KP 200
RK 200
KP 300
RK 300
KP 400
KP 500
RK 500
KP 600
RK 600
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ANMORE
PORT MOODY
BURNABY
COQUITLAM
NEW WESTMINSTER
SURREY
Burrard Inlet
Fraser River
Burnaby Lake
Deer Lake
Como Lake
RK 3.6
KP 5
KP 1147
KP 1145
KP 1140
KP 1135
RK 1175
RK 1170

1.2 Objectives

The objectives of the groundwater quality and quantity technical report were to:

- understand groundwater use requirements for the Project;
- identify potential interactions between the Project and local groundwater resources within the groundwater local study area (LSA);
- describe contaminants (spills, etc.) potentially associated with the project and their potential effects on groundwater quality; and
- assess mitigation for any adverse potential groundwater quantity or quality effects.

This report describes the desktop review/literature review and groundwater field survey methods, the approach for, and results of field work, as well as provides general groundwater mitigation recommendations for the construction and reclamation phases of the Project. The results of this groundwater assessment report provides the results of desktop/literature review and field results as well as the recommended mitigation measures to protect groundwater resources during pipeline construction and operation. Volume 5A ESA – Biophysical provides the potential residual and cumulative effects of the Project on groundwater quantity and quality, including an evaluation of significance.

1.3 Regulatory Standards

Design, construction and operation of the Project will be in compliance with all applicable codes, standards and regulations.

1.3.1 Federal Standards

The National Energy Board (NEB) *Filing Manual* (2013) provides guidance with respect to groundwater quantity and quality assessment to determine the anticipated effects from the Project. The NEB *Filing Manual* requirements include:

- project-specific water use assessment that identifies and describes the water resources and quality of those resources potentially affected by the Project to meet withdrawal or discharge needs for the Project;
- descriptions of interactions between the Project and groundwater that may impose a potential change in groundwater flows and any subsequent effects, and any wells that may be located nearby for which the quantity or quality of groundwater extracted from these wells may be affected;
- contaminant descriptions that may be potentially associated with the Project and that may affect water quality;
- mitigation measures for any potential effects on groundwater or well water quantity or quality, including pre- and post- construction monitoring; and
- groundwater management plans that may be appropriate.

The Project is also a designated project under the *Canadian Environmental Assessment Act, 2012*.

1.3.2 Provincial Standards in Alberta

Provincial standards, guidelines and best management practices related to groundwater in Alberta include:

- *Water Act* and *Water (Ministerial) Regulation*;
- Guide to Groundwater Authorization (2011);
- *Code of Practice for Pipelines and Telecommunication Lines Crossing a Water Body* (2013);

- *Code of Practice for Watercourse Crossings* (2013);
- *Code of Practice for the Temporary Diversion of Water for Hydrostatic Testing of Pipelines* (No. 205, 1999);
- *Water (Ministerial) Regulation* for dewatering, diversion for dust control and facility/staff needs;
- *Environmental Protection and Enhancement Act*:
  - Interim Guide to Content for Industrial Approvals (2013);
  - Alberta Tier 1 *Soil and Groundwater Remediation Guidelines* (2010);
  - Alberta Tier 21 *Soil and Groundwater Remediation Guidelines* (2010);
  - *Code of Practice for Compressor and Pumping Stations and Sweet Gas Processing Plants* (1996);
  - *Activities Designation Regulation* (No. 276, 2003); and
  - Interim Guide to Content for Industrial Approvals (2013);
- Energy Resources Conservation Board (ERCB):
  - Directive 055 - Storage Requirements for the Upstream Petroleum Industry.

1.3.3 Provincial Standards in British Columbia

BC provincial standards, guidelines and best management practices related to groundwater include:

- *Oil and Gas Activities Act* ([SBC 2008] CHAPTER 36 – *Environmental Protection and Management Regulation* B.C. Reg. 200/2010 - includes amendments up to B.C. Reg. 148/2012, June 25, 2012; and
- the *BC Environmental Assessment Act (BC EAA)* [SBC 2002] also covers many of the similar groundwater requirements as the NEB *Filing Manual*.

1.3.4 Land Use and Management Plans in Alberta

Municipalities and counties within Alberta within which the Project is located have created land use and management plans some of which discuss groundwater within the context of water use as well as source water protection. Those that included mention of groundwater are summarized in Table 1.3-1.

TABLE 1.3-1

LAND USE AND MANAGEMENT PLANS IN ALBERTA WITH MENTION OF GROUNDWATER

Management Plan	Summary of Key Water Quality and Quantity Goals and Objectives
Water for Life – Alberta's Strategy for Sustainability (AENV 2003); Water for Life – A Renewal (Alberta Environment 2008); and Water For Life – Action Plan (Alberta Environment 2009)	Safe, secure drinking water supply. Healthy aquatic ecosystems. Reliable, quality water supplies for a sustainable economy.
Municipal Development Plan: Bylaw 15100	Protect, maintain and continually enhance the water quality of the North Saskatchewan Watershed. Ensure water resources are conserved and used efficiently by the public, industry and the City of Edmonton. Contaminated Sites: The presence, in association with soil, water, groundwater, air, ground surface or structures, of a substance or substances that may present a risk to human health or the environment.
Capital Region Growth Plan	Minimize the impact of development on regional watersheds.

TABLE 1.3-1 Cont'd

Management Plan	Summary of Key Water Quality and Quantity Goals and Objectives
Strathcona County Municipal Development Plan Bylaw 1-2007	Section 8.26: Work with the appropriate jurisdictions to establish an ongoing groundwater monitoring and comprehensive water testing program to protect and maintain groundwater quality and quantity. Section 8.27: Protect lands where sensitive groundwater resources have been identified, through environmental protection instruments and policies.
Parkland County – Integrated Community Sustainability Plan	Mentions requiring a groundwater supply study for potable water.
Parkland County Municipal Development Plan, Bylaw No. 37-2007	However, traditional subdivisions with larger lots and private on-site services are becoming increasingly unsustainable, particularly in regard to water supply, groundwater contamination from private sewage systems, and long term road maintenance.
City of Spruce Grove Municipal Development Plan 2010-2020	Develop an integrated watershed management approach that will sustainably manage the impact of development on the watershed, conserve water use and improve water quality. Prohibit the discharge of hazardous wastes or contaminants into surface water or groundwater. Work with developers, landowners and Alberta Environment to protect surface water and groundwater flow which supports environmentally significant areas affected by development within the City of Spruce Grove boundaries.
City of Spruce Grove Environmental Sustainability Action Plan (City of Spruce Grove 2011)	Maintain quality of local watersheds. Reduce water consumption
Stoney Plain - Municipal Development Plan 2005-2020	The MDP conceptually identifies natural areas as well as lands subject to natural hazards such as flooding, high water tables, and steep slopes.
Town of Wabamun – Municipal Development Plan - Bylaw 06-2010	Prior to the Canadian National (CN) train derailment in 2005 that caused 1.3 million litres of oil to spill into Lake Wabamun, water for the Village was taken from Lake Wabamun via the TransAlta cooling channel. However, since the oil spill occurred the Village has been relying upon groundwater as its water source, and currently has a capacity of serving approximately 1,000 residents. Based upon the evaluation of the assessment (audit), the Village may prohibit developments which may result in contamination of local groundwater supplies, watercourses, adjacent lands, or any other feature which is determined to be environmentally significant by the Village of Wabamun. In Wabamun such design might also be useful in dealing with the high water table experienced in some areas.
Yellowhead County Municipal Development Plan, Bylaw No. 1.06	Peers - high water table Consider the results of the Edson Aquifer Study when evaluating applications in the Edson Urban Fringe area. Section 5.2.1 e: Niton Junction does not have an Area Structure Plan. The previous MDP indicates that there is some capacity to accommodate development in the northeast and northwest corners of the hamlet. A high water table is a development constraint and must be addressed with respect to any future development. A hydrological study must be undertaken if any water systems are to be installed in Niton Junction.
Yellowhead County Municipal Development Plan, Bylaw No. 1.06	Section 7.3 b vi: measures that will be taken to address natural and man-made hazards that may impact the development. Hazards may include soils, landfill sites, sewage lagoons, flood plains, high water tables, watercourses susceptible to flooding, sour gas sites, high pressure pipelines, rail rights-of-way, steep slopes (*e.g.* over 20%), unstable slopes and others. Section 10.2 g: Continue to support the protection of aquifers in the region. Section 12.2 e: Maintain and enhance surface and groundwater quality in area water systems with a focus on the "Water for Life" strategy as developed by the Province. Section 12.4 b: Work with the province to support a safe, secure drinking water supply for residents through ongoing record-keeping of water supply and quality from surface and groundwater sources throughout the County.
Yellowhead County land use bylaw	Mentions groundwater in terms of subdivision development.

TABLE 1.3-1 Cont'd

Management Plan	Summary of Key Water Quality and Quantity Goals and Objectives
Entwhistle Area Structure Plan By-law 23-2012	The Hamlet primarily utilizes the sandstone aquifer of the Paskapoo Formation for its water needs. Water levels in the aquifer, monitored by Alberta Environment over a 40 year period, show no indication that water levels have declined as a result of supplying the Hamlet. However, the groundwater availability in the area is sensitive due to the nature of the system, so drawdown is limited. As a result of the Pembina River Valley walls being very steep and incised into bedrock, the river valley functions as a drain on the shallow sandstone aquifer. Conversely, the aquifer is recharged by sand and gravel deposits which contain water that overlie the bedrock (Omni-McCann Consultants Ltd. 2005). Entwhistle has been authorized by Alberta Environment to divert 327 m^3/day from the sandstone aquifer and presently three wells supply the Hamlet with water on a rotation basis (Omni-McCann Consultants Ltd. 2005). Wells appear to lie 400 m north of the pipeline centre line. Section 9.3.9 iii: Environmentally significant features such as the Pembina River Valley, adjacent riparian areas, groundwater recharge areas, and wetlands shall be protected from adverse impacts due to development of the industrial business park.
Sustainable Resource and Environmental Management Strategy, 2003	Principal issues: There are concerns about the supply of freshwater and the potential for aquifer depletion in certain areas. There are concerns about the sustainability of the groundwater supply and aquifer depletion in certain areas. Groundwater contamination due to industrial effluent discharges and agricultural practices is a potential concern. Section 4.1.2: Ensure that regional air quality, surface and groundwater quality meets or exceeds existing standards. Section 4.2.5: Ensure use of regional surface and groundwater resources remains at sustainable levels and that water supply and quality is adequate for downstream use.
Area structure plan	Town receives water supply from 3 wells located 4 km south of the water treatment plant S1/2-13-053-08W5. Max rate is 230 m^3/day from 2 wells; the other is held in reserve. Has four day storage capacity. Wells are 2.6 km south of pipeline right-of-way.
Wildwood Area Structure Plan - April 2005	Lands lying below the 794 m contour interval may exhibit near surface groundwater conditions that restrict some forms of development. That portion of the Plan Area that is located along the Lobstick River and Chip Lake below the Low Lands Boundary contour interval may be suitable for country residential subdivision, but is more likely to exhibit near surface groundwater conditions that preclude development than the higher land. Continued agricultural and natural area use, therefore, provides the best future land use option.
Edson Urban Fringe Intermunicipal Development Plan	The Town of Edson is supplied with water from nine groundwater wells. Page 13: An Aquifer Management Planning Study prepared by Komex International Ltd. in 2001 concludes that there are sufficient groundwater resources to supply Edson through year 2010. Two aquifers presently serve Edson: Paskapoo Formation (90% of total supply) and the Edson Channel Aquifer (10% of supply) - south of the town. The main areas of concern in using the aquifers as water supplies are the quantity and quality of water. Muskeg areas reflect a high water table that, in turn, affects developability, particularly when combined with soils conditions. In the northwest potion of the Plan Area, the depth of material overlying the aquifer is quite thin (< 5 m) so land use could have significant negative impacts on this protective layer. Projections of available groundwater quantities in the Komex report indicate that only the short to medium term demand can be met. The results of the Komex Study suggest that development in the northwest portion of the Plan may negatively influence the aquifer. Cooperate in the protection of the McLeod River, Bench Creek, aquifer recharge areas and drainage channels that are important to the integrity of the local water supply and environment. However, because the present water diversion may be approaching the capacity limits of the groundwater aquifers although ongoing aquifer management may extend the groundwater supply to 2011, the consortium should start investigating long term water supply options in advance of 2011.

TABLE 1.3-1 Cont'd

Management Plan	Summary of Key Water Quality and Quantity Goals and Objectives
Edson Urban Fringe Intermunicipal Development Plan (cont'd)	*Infrastructure Policy 7.1.3*: As an interim measure, the Town of Edson shall implement the Aquifer Management Plan as developed and recommended by the Komex International Ltd. Aquifer Management Planning Study.
Jasper National Park of Canada Management Plan (Parks Canada 2010)	Maintain aquatic ecosystems within their range of natural variability for factors such as water quality, water levels and flow regimes. Ensure that instream flow needs for aquatic and riparian areas take precedence over withdrawals or diversions of surface and ground water.

1.3.5 Land Use and Management Plans in British Columbia

Municipalities and counties along the proposed pipeline corridor have established land use and management plans of which select plans discuss groundwater within the context of water use as well as source water protection. Those that included mention of groundwater are summarized in Table 1.3-2.

TABLE 1.3-2

LAND USE AND MANAGEMENT PLANS IN BRITISH COLUMBIA WITH MENTION OF GROUNDWATER

Management Plan	Summary of Key Water Quality and Quantity Goals and Objectives
Mount Robson Park Management Plan (2011)	Protect and maintain water quality and quantity resources within the provincial park.
Robson Valley Land and Resource Management Plan-Summary (BC MFLNRO 1999)	Protect or restore water quantity and natural hydrologic regime of each watershed.
Land and Resource Management Plan	Where necessary, limit further development according to a rate of cut for each watershed to prevent further changes to natural rates of direct runoff, groundwater runoff, evapo-transpiration and stream flow.
Village of Valemount Official Community Plan (Bylaw 595, 2006)	Maintain the integrity of the Swift Creek Watershed so that the supply of drinking water is not adversely affected.
Regional Growth Strategy (Bylaw 1767, 2000)	Protect and enhance the quality and quantity of the water of the region's lakes, rivers, streams and groundwater sources.
Bylaw No. 2409, 2013. A Bylaw to Amend Regional Growth Strategy Bylaw No. 1767, 1999, of the Thompson-Nicola Regional District. Schedule "A"	Section 1.13: Ensure that the increased consumption of groundwater in proposed rural residential development does not deplete surface or groundwater supplies. Consider groundwater management plans in areas of water depletion.
Official Community Plan, 2011	Ensure the protection of creeks, rivers, lakes, riparian areas and groundwater supplies within the plan area. Due to the value of lakes, watercourses, wildlife habitat and groundwater resources, it is the objective of the board of directors to recognize and provide special protection for creeks, rivers, lakes, riparian areas, groundwater supplies, and habitat areas within the plan area. There shall be no development in the Wellhead Protection Area that would have a negative impact on the Blue River community water system groundwater supply.
District of Clearwater Official Community Plan (District of Clearwater 2012)	To protect and enhance the quality of Clearwater area lakes, rivers, streams and groundwater sources thereby supporting the Clearwater River and North Thompson River watershed ecosystem and the Russell, Hascheak, and McDougall Creek watersheds.
Airport Land Use Plan	Two known or suspected contaminated sites on airport lands - has both soil and groundwater contamination. Is currently being monitored. Plume of hydrocarbons at the groundwater table.
Kamloops Land Resource Management Plan (1995)	Section 2.1 Recognize interaction of groundwater and surface water sources; establish groundwater aquifer management plan; implement groundwater monitoring sites.
Kamloops North Official Community Plan (2011)	Because most surface water sources within the Plan Area have been essentially committed to existing water licensing, it is a policy of the Board of Directors to promote groundwater as the prime source of water supply for all new parcels created for residential purposes. Surface water for new developments can only be used when derived from the North Thompson River or from sources which can be backed up by storage.
Official Community Plan Bylaw No. 2116, 2011	Aggressively pursue water conservation measures and efforts aimed at managing demand for water, including the summer water conservation program, thereby optimizing the use of this important resource, maximizing the useful life of the City's pumping and distribution systems, and minimizing impact on the City's aquifer.

TABLE 1.3-2 Cont'd

Management Plan	Summary of Key Water Quality and Quantity Goals and Objectives
Official Community Plan Bylaw No. 2116, 2011 (cont'd)	Implementing and aquifer protection plan.
Nicola Valley Official Community Plan Bylaw 1450 (2011)	Recognize all Improvement District groundwater wells and surface water intake locations and provide necessary protection of these public utilities/facilities from development and potential sources of contamination. Intergovernmental Policies: 9.6 Recognize all Improvement District groundwater well, surface water intake locations, easement and rights-of-way and provide for the necessary protection of these public utilities/facilities from subdivision, development and potential sources of contamination. Intergovernmental Policies: 10.6 In cooperation with the appropriate Provincial authorities having authority, the Regional District will encourage the preparation of a groundwater inventory to more accurately determine development potential within the Plan Area and, specifically, those areas which have experienced groundwater problems.
Regional Growth Strategy 2004	Groundwater sources in B.C. have limited and sometimes conflicting protection in terms of Provincial and Federal legislation. It is, therefore, essential that the RGS support ongoing monitoring and management of the region's groundwater supply through water conservation measures, nutrient management initiatives, Best Management Practices in commerce and industry, environmental farm plans, and groundwater protection legislation. Although most of the groundwater resources in the FVRD are currently in good health, several of the aquifers, such as the Abbotsford-Sumas, Vedder, and Chilliwack-Rosedale aquifers, are considered vulnerable to contamination. B.C. is the only province in Canada that has no legislation to protect groundwater resources. Action: Protect the region's potable surface and groundwater resources by supporting water conservation and stormwater management measures and by supporting the development of needed water protection legislation.
Fraser Valley Regional District Official Community Plan for Electoral Area "E" Bylaw No. 1115, 2011. (FVRD 2011)	Activities or developments that may result in potential inputs to groundwater or substantial groundwater withdraws, or which could otherwise negatively affect the groundwater system, will require hydrological assessment to identify and mitigate impacts.
Hope Official Community Plan 2011	Bylaw 1192 Jul06: A major water bottling plant approximately 1 km east of Kawkawa Lake. This major employer is dependent on a continuous supply of high quality water from an on-site well. This aquifer is also a major domestic water source to meet the future needs of the District of Hope. Both well locations are dependent on groundwater from the Coquihalla River and, to a lesser extent, the steep surrounding mountain slopes in the area. Protect the high water quality of the aquifer required by the District of Hope and the water bottling plant. Ref: Piteau Associates Engineering Ltd. (January 1999). Hydrogeologic Assessment of Proposed Source for Bottled Water, Hope, B.C. The Hope Environmental Protection Development Permit Area #7 consists of …. Coquihalla River Aquifer Protection area (east of Kawkawa Lake).
Agricultural Area Plan	BC Living Smart Plan: A priority in the Plan is securing a water supply for Agricultural Land Reserve lands, possibly introducing water reserves, increasing water licensing (including groundwater), and adoption of improved water use efficiency measures. The high quality water used in Chilliwack is presently accessed from the Sardis-Vedder aquifer. Although there may be additional sources of quality water, possibly in the Unsworth Road/Lickman Road area, the capacity of the aquifer is finite and must be used efficiently to service existing and increasing demands over the longer term. In 1997, a groundwater protection plan was developed for the City of Chilliwack. Risk of contamination to the groundwater was identified as an important concern.
Chilliwack Official Community Plan, 1998	Chilliwack is dependent upon its large aquifer for high quality water supply. As the valley is developed, the aquifer is increasingly exposed to surface contamination. Future development will need to address the risks of surficial and groundwater contamination. The uplands contribute to several aquifers, which supply domestic water to a large part of the region. Chilliwack is dependent upon its large aquifer for high quality water supply. As the valley is developed, the aquifer is increasingly exposed to surface contamination. Future development will need to address the risks of surficial and groundwater contamination.

TABLE 1.3-2 Cont'd

Management Plan	Summary of Key Water Quality and Quantity Goals and Objectives
Chilliwack Official Community Plan, 1998 (cont'd)	Aquifers need to be protected from surficial and groundwater pollution. The City has become a leader in municipal groundwater protection by establishing an *Aquifer Management Policy*. Policy: Request assistance from MELP in protecting aquifers and groundwater. 4.3.14 Aquifer Protection Policies Chilliwack's aquifers provide high quality drinking water. Our water has been rated the best quality drinking water in Canada and is achieved with limited treatment requirements. Aquifers need to be protected from surficial and groundwater pollution. The City has become a leader in municipal groundwater protection by establishing an aquifer management policy. Objective .1 To ensure the long-term protection of the City's primary source of potable drinking water. Protect the aquifers from surface and groundwater pollution. Policies .1 Protect the capture zone of the Vedder Aquifer through available municipal legislative tools. .2 Require professional certification for all new commercial and industrial development to provide evidence of no contamination risk. .3 Harmonize underground parking facilities with the aquifer protection policy. .4 Request assistance from MELP in protecting aquifers and groundwater. Chilliwack owns and operates a system of 3 wells located on the Sardis aquifer.
City of Abbotsford Agriculture Strategy	Concerns about the sustainability of the agricultural system have emerged with respect to: …surface and groundwater contamination.
City in the Country Plan 2004	City residents receive water from several sources, including: private wells, Clearbrook Water Utility (groundwater); and the municipal water system sourced at Norrish Creek north of the Fraser River. Abbotsford-Sumas Aquifer Stakeholder Group - a committee of Council that addresses issues relating to this important aquifer. Examples of high sensitivity include: ravines, flood plain, the Abbotsford-Sumas Aquifer, etc. (Airport reserve land). Mount Lehman predominant soils are Whatcom - silty surfaces, clay subsoils and sometimes perched water tables and seepage (Appendix I 1). Airport Reserve water table below 2 m (Appendix I 2).
Strategic Directions With Key 2012 Initiatives	Much of Abbotsford overlays the Abbotsford-Sumas Aquifer, which serves as a source of drinking water for many rural residents in the southwest part of Abbotsford.
Metro Vancouver 2040 - Shaping Our Future. Regional Growth Strategy (Bylaw 1136, 2011)	In collaboration with the province and the Agricultural Land Commission, identify and pursue strategies and actions to increase actively farmed agricultural land, emphasize food production, reduce barriers to the economic viability of agricultural activities, ensure the management of farmlands is in concert with groundwater resources, and minimize conflicts among agricultural, recreation and conservation, and urban activities.
Draft Agricultural Viability Strategy	In the Township of Langley, groundwater is the primary source of water for residential, agricultural, industrial, and commercial purposes with approximately 80% of the Township water supply provided from municipal and private wells. Local well drillers have reported groundwater table drops in the Hopington area with residents drilling deeper wells as older ones dried up. Township communities of Aldergrove and Gloucester are currently supplied with potable water that comes from seven groundwater wells treated through sand filtration.
Water Management Plan	Reduce groundwater use (reduce demand, optimize supply) and enhance recharge areas. Maintain suitable baseflows and water levels in riparian and wetland areas and minimize contamination risks. Another concern is the increasing threat of contamination of the groundwater. Three out of the nine most vulnerable aquifers in the Fraser Valley are located in Langley – Brookswood, Hopington and Abbotsford-Sumas. Water quality studies have consistently shown elevated nitrate levels in groundwater for the past 10 years.

TABLE 1.3-2 Cont'd

Management Plan	Summary of Key Water Quality and Quantity Goals and Objectives
Water Management Plan (cont'd)	Two of the core recommendations were related to the phasing in of water meters on private wells and establishing a fee system to charge penalties for groundwater overuse and waste. Water meters and an overuse penalty were considered the most cost effective way to (1) ensure that there would be a sustainable supply of groundwater, (2) protect well owners' security of access to groundwater, and (3) inform responsible water resources management in the future. The overarching goal for the WMP is to "ensure safe and sustainable groundwater for the community for generations to come." The WMP targets a 30% reduction in groundwater use by 2020. Sidebar: Sustainable: human impacts on groundwater cannot exceed nature's ability to restore it.
Official Community Plan (1979)	Policy - Implement the Water Management Plan to ensure safe and sustainable groundwater for the community for generations to come.
Official Community Plan Bylaw 12900 (1996)	Protect and enhance the aquatic environment of the Fraser, Nicomekl, Serpentine, and Campbell Rivers, as well as creeks and aquifers throughout the City and along the City's ocean shoreline. Address environmental issues, such as water quality of the Serpentine River and aquifers for ground water in consultation with the Environmental Advisory Committee.
Official Community Plan Bylaw 3479 2001	Coquitlam residents receive a dependable, clean supply of drinking water from the Coquitlam and Seymour Reservoirs. These reservoirs are managed by the Greater Vancouver Regional District (GVRD). Many residents in less developed parts of the City draw their drinking water from underground wells. **OBJECTIVE** To explore the feasibility of developing measures to protect groundwater. **POLICIES** a) Refine existing efforts toward groundwater protection. Partner with regulatory authorities in data gathering on local groundwater resources. b) Encourage the provincial government to prepare groundwater protection legislation.

2.0 CONSULTATION AND ENGAGEMENT

Trans Mountain and its consultants have conducted a number of consultative activities to inform Aboriginal communities, stakeholders, the public and regulatory authorities about the approach to assessing potential environmental and socio-economic effects of the Project, and to seek input throughout the Project planning process.

2.1 Public Consultation, Aboriginal Engagement and Landowner Relations

Trans Mountain has implemented and continues to conduct open, extensive and thorough public consultation, Aboriginal engagement and landowner relations programs. These programs were designed to reflect the unique nature of the Project as well as the diverse and varied communities along the proposed pipeline and marine corridors. These programs were based on Aboriginal communities, landowner and stakeholder groups' interests and inputs, knowledge levels, time and preferred methods of engagement. In order to build relationships for the long-term, these programs were based on the principles of accountability, communication, local focus, mutual benefit, relationship building, respect, responsiveness, shared process, sustainability, timeliness, and transparency.

Feedback related to groundwater that was raised through various Aboriginal engagement and public consultation activities including public open houses, ESA Workshops, Community Workshops and one-on-one meetings, is summarized below and was considered in the development of this technical report, and the assessment of groundwater in Volume 5A:

- limited land area of Indian Reserves for water wells;
- potential effects on groundwater quality and quantity;
- alteration of water patterns as a result of pipeline installation;
- artesian flow near the Fraser River;
- potential effects on private wells and aquifers; and
- specific concerns for the Fraser Valley Aquifer and personal wells near Mount Lehman, Sumas Prairie, and Bradner, BC.

In addition, concerns related to the potential effects of spills on freshwater environments were also raised and detailed information on pipeline spills is provided in Volume 7.

The full description of the public consultation, Aboriginal engagement and landowner relations programs are located in Volumes 3A, 3B and 3C, respectively. Section 3.0 of Volume 5A summarizes the consultation and engagement activities that have focused on identifying and assessing potential issues and concerns related to groundwater which may be affected by the construction and operation of the Project. Information collected through the public consultation, Aboriginal engagement and landowner relations programs for the Project was considered in the development of this technical report, and the assessment of groundwater in Volume 5A.

2.2 Regulatory Consultation

In addition to the public consultation and Aboriginal engagement, Waterline Resources consulted with various provincial regulatory authorities and municipalities regarding groundwater interactions with the Project. Alberta Environment and Sustainable Resources Development were in attendance at the ESA Edmonton Workshop where the groundwater approach was discussed. Table 2.2-1 provides a summary of the regulatory consultation.

TABLE 2.2-1

SUMMARY OF CONSULTATION ACTIVITIES RELATED TO GROUNDWATER QUANTITY AND QUALITY

Stakeholder Group/Agency Name	Name and Title of Contact	Method of Contact	Date of Consultation Activity	Reason For Engagement	Issues/Concerns	Commitments/ Follow-up Actions/Comments
PROVINCIAL CONSULTATION – BRITISH COLUMBIA						
BC Ministry of Forest, Lands and Natural Resource Operations (BC MFLRNO)	Michele Lepitre, Regional Hydrogeologist, South Coast Region, BC MFLRNO	Email	November 11, 2012	Project Introduction Discuss review of Vedder River Fan Aquifer in Chilliwack concerns, Sumas Mountain spill in 2012.	Vedder River Fan Aquifer identified as highly vulnerable, MFLRNO aware of public concerns related to the aquifer. Sumas Mountain spill was of public concern, however, MFLRNO was not contacted in relation to any related groundwater issues.	None
BC Ministry of Environment (BC MOE)	Vicki Carmichael, Senior Hydrogeologist, Water Protection & Sustainability Branch Environmental Sustainability Division	Telephone	February 20, 2013	Project Introduction Request a teleconference/webex to allow the TMEP team to discuss the project and obtain information for the groundwater review process	MOE is unable to comment on the process until the regulatory review process is initiated.	The TMEP is under the jurisdiction of the NEB.
STAKEHOLDER CONSULTATION – BRITISH COLUMBIA						
City of Chilliwack	David Blain	Meeting	November 9, 2012	To introduce project and to identify water sources among other subjects.	Raised concerns about groundwater and the Vedder River Fan Aquifer, potential effects of an accident or malfunction on groundwater	None
Community of Blue River	Hughes, P. Director of Environmental Services. Thompson-Nicola Regional District	Meeting	May 29, 2013	To introduce project and to identify water sources.	Two community drinking water system wells.	Confirm location of wells relative to proposed pipeline corridor.
Community of Vavenby	Hughes, P. Director of Environmental Services. Thompson-Nicola Regional District	Meeting (Clearwater)	June 5, 2013	To introduce project and to identify water sources.	North Thompson River – no wells.	None
District of Clearwater	Madden, S. Services Coordinator. Thompson-Nicola Regional District	Meeting	June 5, 2013	To introduce project and to identify water sources.	Deep well that serves the fire department near proposed pipeline corridor.	Confirm location of well relative to proposed pipeline corridor.
City of Kamloops	Fretz, J. Sustainability and environmental Services Manager	Meeting	June 6, 2013	To introduce project and to identify water sources.	Campbell Creek community system and the Heffley private water utility which are both sourced from wells.	Confirm location of wells relative to proposed pipeline corridor.

3.0 METHODS

3.1 Project Interactions and Identification of Potential Effects

Pipeline, pump stations, tanks, temporary facilities, Westridge Marine Terminal, power line construction and operation and pipeline reactivation activities have the potential to directly and indirectly affect groundwater quantity and quality resources. These key issues are summarized below and discussed in further detail in Volume 5A, Section 7.0).

Potential issues or concerns associated with groundwater along the proposed pipeline corridor are primarily limited to shallow groundwater within a few metres below the ground surface. Near surface groundwater along the proposed pipeline corridor usually exist as water table aquifers in the flat, poorly drained areas, or in topographically low-lying areas including gentle slopes, where shallow groundwater flow follows the terrain topography. Shallow groundwater in topographically low areas has the potential to discharge in the form of springs and/or seeps; or, if confined, to be under pressure and create flowing artesian conditions. Construction of the pipeline may disturb the natural groundwater flow system and create undesirable effects such as permanent wet areas or seepage zones. Pipeline construction may also be affected by shallow groundwater which can destabilize trench walls requiring dewatering activities to control inflow.

Groundwater may be used as a water supply source during construction for drinking and household use water for temporary camps and during operational phases to support new or expanded facilities. The use and/or discharge requirements can affect the local groundwater resource quantity and quality.

Blasting activities can disturb water quality and quantity in nearby wells completed in both unconsolidated deposits and bedrock. Typically, the water quality issues involve a short-term increase in turbidity. Depending on the specific geological conditions and proximity of wells to the blasting sites, the potential exists, particularly for bedrock wells, for fractures to shift and either open or close, thereby changing the local well capacity.

Deeper groundwater zones may be of primary concern at river crossings, as the erosionally-incised river valleys usually form local or regional groundwater discharge zones. Where these crossings require intrusive drilling, a potential exists for the release of drilling mud to the surface environment, surface water, or aquifers, and the release of artesian groundwater flows that can potentially affect water quality in shallower aquifers or surface water bodies, cause flooding near the drill site and potentially inhibit successful horizontal directional drill (HDD) activities. Under such circumstances, either open cut, or HDD may require special measures to mitigate or prevent affects caused by groundwater inflows. Within sedimentary basin deposits, deeper aquifers may contain methane gas. The occurrence of methane gas is enhanced in the presence of coal or carbonaceous shale deposits. In such cases, aquifer drilling should include mitigation strategies to safely handle and vent this flammable gas.

Construction activities (*i.e.,* excavation several metres below ground) may result in short-term increases in turbidity or potential siltation in shallow water wells completed in highly vulnerable aquifers in the immediate proximity to the construction right-of-way. Environmental releases may also occur along the proposed pipeline right-of-way as a result of the handling and storage of environmentally sensitive materials during construction. Open pipe trenches during the construction phase have the potential to act as preferential pathways for shallow groundwater flow creating local flooding or the mobilization of existing subsurface soil contamination. Long-term operational activities also present the potential for an accident or malfunction that could result in an environmental release of product from the pipeline. Highly vulnerable aquifers and shallow wells are the most likely receptors to be affected by such a release.

3.2 Assessment Indicators and Measurement Endpoints

The desktop review and field survey assessment findings for potential environmental and socio-economic effects focussed on the areas of particular value or interest to regulatory authorities, Aboriginal communities and other interested groups and individuals. The degree of change in these measurable parameters is used to characterize Project-related and cumulative effects, and evaluate the significance of the potential environmental and socio-economic effects.

The selection of indicators for groundwater quantity and quality were based on the NEB *Filing Manual* requirements, experience gained during previous projects with similar conditions/potential issues, feedback from stakeholders, available research literature and the professional judgement of the assessment team. The proposed groundwater quantity and quality indicators were discussed during the ESA Workshops held in March 2013. The workshop participants generally agreed that the proposed groundwater indicators were appropriate for evaluating the effects of the Project on groundwater quantity and quality. Upon consideration of the assessment team, contaminated groundwater migration was considered to be already covered through added as indicators. Input was also sought from BC MOE and BC MFLRNO and these agencies were in agreement that the proposed groundwater indicators were appropriate and suggested no additional indicators for consideration.

The following table 4.2-1 shows the endpoints used to assess indicators of groundwater quality and quantity to fulfill filing requirements in the NEB *Filing Manual*:

TABLE 3.2-1

ASSESSMENT INDICATORS AND MEASUREMENT ENDPOINTS FOR GROUNDWATER QUALITY AND QUANTITY

Groundwater Indicator	Measurement Endpoint	Rationale for Indicator Selection
Groundwater Quality	Shallow groundwater with potential existing contamination. Areas susceptible to drilling mud release during HDD construction. Areas in the aquifer susceptible to sedimentation. Areas of shallow groundwater susceptible to blasting effects. Areas with potential artesian conditions. Aquifers or wells vulnerable to possible future contamination from an accident or malfunction.	The selection of indicators and measurement endpoints considered the NEB *Filing Manual* requirements, addressed concerns raised by participants of the ESA Workshops and was informed by regulatory authorities (*i.e.,* BC MOE and BC MFLRNO). Groundwater will not be used for hydrostatic testing, therefore, groundwater withdrawal or discharge for this purpose has not been considered. Groundwater use requirements at Trans Mountain facilities will not increase with the proposed expansion activities.
Groundwater Quantity	Areas susceptible to changes in groundwater flow patterns. Areas where dewatering may be required during pipeline construction activities. Areas with potential artesian conditions. Areas of shallow groundwater susceptible to blasting effects.	

The endpoints have been selected to allow for the identification of potentially more sensitive or vulnerable wells and aquifers located in the vicinity of the Project. The intent is that either groundwater monitoring information may be collected to better evaluate existing conditions in these areas, or mitigation measures or water management plans may be developed to reduce or prevent adverse effects to environmental or socio-economic indicators to support a successful project.

3.3 Study Area Boundaries

The groundwater quantity and quality assessment discusses water quality and quantity within the Water Quality and Quantity LSA and the Aquatics RSA. The Water Quality and Quantity LSA is the area generally extending 100 m up-gradient of the centre of the proposed pipeline corridor to a minimum of 300 m down-gradient of the centre of the proposed pipeline corridor, as well as within 300 m of the proposed pipeline corridor, facility or HDD entrance in potentially vulnerable aquifer areas in hydraulic connection with the Footprint and in consideration of surface water drainage patterns along the pipeline corridor.

The Footprint of the Project assumes certain quantitative values for the area that will be directly disturbed by Project facilities and construction activities within the proposed pipeline corridor, including a 45 m pipeline construction right-of-way.

The Aquatics RSA includes all watersheds directly affected by the Project and applies to surface water. No groundwater Regional Study Area (RSA) was established because potential effects on groundwater quantity and quality are not anticipated beyond the Water Quality and Quantity LSA.

3.4 Existing Conditions

To establish existing conditions, a comprehensive literature review of the Project has been completed to gather readily available information and to screen how Project construction and operation activities are likely to affect apparent groundwater conditions along the Footprint and Water Quality and Quantity LSA. The desk-based overview involved the review of geological, hydrogeological and topographic mapping, air photos and available federal and provincial databases. Mapped water wells and aquifers were assessed in relation to the Footprint and Water Quality and Quantity LSA. Potential HDD or open cut river crossing locations considered for the Project were examined. Areas of potential existing groundwater contamination have also been reviewed.

Areas deemed to be potentially vulnerable with respect to the selected endpoints have been flagged. The field work visited a number of these areas to confirm conditions. Groundwater specialists visited the sites to review local hydrogeological conditions and/or locate groundwater resources (*e.g.*, shallow aquifers, springs, water supply wells). Hydrogeological information will also be collected and reviewed at the HDD crossings. Other site-specific hydrogeological investigation activities may be developed to assess key issues, if required.

3.5 Literature/Desktop Review

As part of the comprehensive literature review completed prior to field work, the following sources were used to understand existing conditions:

- Alberta Water Well Database (data current to January 2013);
- EUB/AGS hydrogeology reports, Alberta;
- relevant surficial and bedrock geology maps;
- existing hydrogeological reports by various consultants;
- relevant ground surface topography maps;
- BC Water Resources Atlas (data current to March 2013);
- BC Wells database (data current to August 2013);
- BC Aquifer database (data current to March 2013);
- BC Aquifer classification system;
- digital elevation mapping;
- terrain, soils and detailed topographic mapping from BGC Engineering (October 2013);
- consultation with regulatory authorities including BC MFLRNO; and
- consultation with local municipalities.

3.6 Field Data Collection

The purpose of the field work was to provide confirmation of site characteristics and potential issues identified by the desktop study for a better understanding of existing groundwater conditions. Field survey data were collected from July 16 to August 2, 2013 through specifically selected Project features (*e.g.,* proposed pipeline corridor segments, facilities, etc.) as documented in the table below.

During the field visits, project hydrogeologists documented site-specific observations about the geological and hydrogeological conditions. Where possible, springs, water wells and particularly drinking water systems located within the proposed pipeline corridor, or on facility properties were identified. Information was collected in the field for the following:

- general location observations;
- Terrain – aids in assessment of groundwater flow direction and potential groundwater flow issues;
- Surficial geology – type of materials through which shallow groundwater may flow;
- Bedrock geology – type of material through which deeper groundwater may flow;
- Vegetation – aids in identification of potential shallow groundwater;
- Surface water – interaction with groundwater and surface water parameters such as pH, temperature and electrical conductivity;
- Groundwater – identification of seeps and spring, groundwater parameters such as pH, temperature and electrical conductivity; and
- Wells – identified wells at the location.

Identified features were located by latitude/longitude (NAD83) coordinates. Detailed notes and photographs were recorded to document any observations. The data were collected in the field using a tablet computer (Apple iPad Mini) with installed GIS software (GIS by Garafa LLC version 2.3, 2013) to allow the collection of geo-referenced data in an ESRI shapefile format. This electronic information was then uploaded into a GIS database. Table 3.6-1 summarizes the data collected from the field studies.

TABLE 3.6-1

COLLECTED FIELD DATA

RK	Date Visited	Concern Identified (Y/N)	Summary of Issue	Summary Field Data
RK 0	2013-07-22	no	--	--
RK 33.6	2013-07-30	no	--	--
RK 101.5	2013-07-30	no	--	--
RK 108.6	2013-07-30	no	--	--
RK 133	2013-07-30	no	--	--
RK 135	2013-07-29	yes	Colluvium in stream	Steep banks; shallow groundwater likely; 5-10 m overburden over sandstone bedrock.
RK 137.2	2013-07-29	no	--	--
RK 171.1	2013-07-29	no	--	--
RK 180.8	2013-07-29	no	--	--
RK 187.1	2013-07-29	no	--	--
RK 201.9	2013-07-29	no	--	--
RK 220.7	2013-07-29	yes	Colluvium in stream	Poorly drained; glaciolacustrine silty clayey till.
RK 223.6	2013-07-29	yes	Colluvium in stream	Shallow groundwater; glaciolacustrine silty clayey till; bedded sandstone.
RK 232.3	2013-07-29	no	--	--
RK 292.2	2013-07-28	no	--	--
RK 294.3	2013-07-28	no	--	--
RK 309.4	2013-07-31	yes	Colluvium in stream	Shallow groundwater; seepage from glaciofluvial sand and gravel on top of siltstone in river bank exposure.
RK 313.9	2013-07-28	no	--	--
RK 333.5	2013-07-28	no	--	--
RK 522.6	2013-07-27	yes	Shallow groundwater	Well-drained glacio-fluvial sand and gravel.
RK 525.7	2013-07-27	no	--	--
RK 531.2	2013-07-27	yes	Shallow groundwater	Well-drained; sandstone bedrock.
RK 545.7	2013-07-27	no	--	--
RK 552.1	2013-07-27	no	--	--
RK 582	2013-07-27	yes	Deeply incised creek	Shallow groundwater; well-drained; groundwater seep from bedrock.

TABLE 3.6-1 Cont'd

RK	Date Visited	Concern Identified (Y/N)	Summary of Issue	Summary Field Data
RK 609.4	2013-07-27	no	--	--
RK 611.7	2013-07-27	no	--	--
RK 613.8	2013-07-27	yes	Shallow groundwater	Shallow groundwater; well-drained; fluvial sand and gravel.
RK 616.9	2013-07-26	no	--	--
RK 642.9	2013-07-26	yes	Colluvium in stream	Poorly drained; wetland.
RK 651.6	2013-07-26	yes	Colluvium in stream	Shallow groundwater; poorly drained; fractured metamorphic bedrock.
RK 664	2013-07-26	yes	Creek Crossing	Stagnant pond/wetland but in general lowland and may have groundwater.
RK 704.3	2013-07-26	yes	Shallow well	Glaciofluvial cobbles.
RK 717.7	2013-07-25	yes	Shallow well	Shallow groundwater seepage; glaciofluvial materials to 10 m thick.
RK 725.6	2013-07-25	yes	Shallow well	Water well at higher elevation has groundwater depth of approximately 40 m bgl (well is likely 40 m above river); well-drained; likely glaciofluvial; shallow groundwater a possibility.
RK 845.3	2013-07-25	yes	Contaminations - shallow aquifer	Likely fluvial compact fine clay gravel cobbles; monitoring wells near Kamloops Pump Station.
RK 928.4	2013-07-25	yes	Colluvium in stream	Shallow groundwater; poorly drained; wet.
RK 953.8	2013-07-24	yes	Shallow well	Shallow groundwater; well-drained.
RK 970.7	2013-07-24	yes	Colluvium in stream	High electrical conductivity suggests shallow groundwater; well-drained steep till slope failing; 5 m hard till sand and gravel; volcanic bedrock.
RK 981.1	2013-07-24	yes	River	Shallow groundwater; possible spring in riprap; fluvial to glaciofluvial.
RK 1022.2	2013-07-23	yes	Shallow groundwater, Colluvium in stream	Shallow groundwater; well-drained sand and gravel high permeability (glacio-fluvial - gravel pit).
RK 1043.8	2013-07-23	yes	Unconfined aquifer	Shallow groundwater; well-drained sand and gravel; high permeability.
RK 1062	2013-07-23	yes	Unconfined aquifer	Well-drained; mod-high permeability; shallow groundwater, surface seepage; coarse sand and silt; domestic well noted.
RK 1097.2	2013-07-23	yes	Unconfined aquifer	Poorly drained; wet in winter.
RK 1102.2	2013-07-22	no	--	--
RK 1145.1	2013-07-22	no	--	--
RK 1176.9	2013-07-22	no	--	--

4.0 RESULTS OF LITERATURE/DESKTOP REVIEW AND FIELD DATA COLLECTION

This section summarizes existing information and findings related to groundwater quantity and quality,

Groundwater Quality

Groundwater quality depends on the source of the water and the material through which it flows (*e.g.,* sulphate containing clay till, clean sand and gravel), as well as whether the groundwater encounters contamination. Both natural and human influences can affect groundwater quality. Surface water that recharges into the ground can affect groundwater quality; as conversely, groundwater may affect surface water quality.

Groundwater Quantity

The flow of groundwater is controlled by gravity and the physical characteristics of the materials through which it flows. Groundwater flow patterns can be affected as a result of natural (*e.g.,* surface water flooding) or human influences (*e.g.,* dewatering, construction of reservoirs).

Vulnerability

In the following subsections describing the BC pipeline segments, the term *vulnerability* in describing aquifers is based on the definition provided by Berardinucci and Ronneseth (2002). They defined the vulnerability of an aquifer as the potential for an aquifer to be degraded. The vulnerability was determined based on:

- depth to the water table – the shallower the water table the greater the vulnerability;
- permeability of materials above the aquifer – the more permeable the sediments the higher the vulnerability; and
- thickness and extent of confining sediments – the less areally extensive and the thinner the confining sediments, the greater the vulnerability.

Note that a similar classification scheme is not available in Alberta; aquifer identification and classification not having been done to date.

The following subsections describe the general and indicator-specific environmental settings for the Project components. The information presented herein forms the basis for the field studies and several aspects of the groundwater effects assessment.

4.1 General Information

Tables describing the potential groundwater issues noted for each of the pipeline segments are included at the end of each of the segments: Edmonton to Hinton; Hargreaves to Darfield; Black Pines to Hope; Hope to Burnaby; and Burnaby to Westridge. For the potential mitigation the reader is referred to the Environmental Protection Plans (EPP) for the pipeline (Volume 6B) and the facilities (Volume 6C) as well as in Table 6.1-1. The last column of these tables assigns a possible mitigation by number to the identified potential groundwater related issues. These mitigations are summarized in Table 4.1-1 below.

TABLE 4.1-1

POTENTIAL MITIGATION OF GROUNDWATER-RELATED ISSUES

Number	Potential Type of Groundwater Concern	Description	Potential Mitigation
1	Creek crossings\deeply incised creek crossings	Related to the increased potential for a trenchless crossing or open cut to compromise the integrity of a confining unit that isolates an underlying productive aquifer (especially in valley bottom). A breach of the confining unit during pipeline construction activities may result in uncontrollable artesian flow at the entry or exit point of the trenchless crossing, or along the alignment in the open cut. This condition may lead to the development of saturated surface conditions and permanent wet conditions in the discharge areas. In addition, loss of circulation that could occur during trenchless crossing may result in drilling fluids entering the creek bed or discharging to surface along the valley slope.	• Depressurize the construction area or subsurface crossing area prior to excavation/directional drilling through, for example, drilling wells and then extracting water in order to reduce locally, the pressure in the aquifer. • Re-create the confining layers if disturbed during construction (*e.g.*, place seal/cement in annular space around pipeline). • Understand hydrogeological and geotechnical conditions, and assess the risks before commencing a trenchless crossing. Complete a trenchless crossing alignment site reconnaissance, supported, where warranted, by a drilling and testing program designed to confirm hydrogeological and geotechnical conditions. Design the trenchless crossing and pipeline installation to prevent damage caused by artesian flow.
2	River proximity or crossing/fluvial materials/colluvium in stream	The proposed pipeline corridor lies within alluvial deposits located in proximity to a surface water body. Possible direct hydraulic connection to the surface water body through saturated, coarse grained alluvial deposits. The saturated alluvial deposits become a direct pathway for pipeline releases to enter the surface water body.	• Dewater the trench, if warranted, when laying pipe in areas with high water tables. Place pumps on a tray or within an excavated sump lined with polyethylene sheeting above the ordinary high water level of the watercourse/wetland/lake. Pump water onto stable and well vegetated areas, tarpaulins or sheeting at least 50 m from the nearest waterbody in a manner that does not cause erosion or any unfiltered or silted water to re enter a watercourse [Section 8.3]. See additional dewatering measures in Section 8.3 of the Pipeline EPP. • Use floating suction hose and elevated intake, or other measures approved by Trans Mountain's Environmental Inspector(s), to prevent sediment from being sucked from the bottom of the trench. Secure the pump intake a minimum of 30 cm above the bottom of the trench [Section 8.3].
3	Shallow groundwater	Related to the increased potential to experience groundwater discharge in the open excavations by intersecting the water table or comprising the integrity of a shallow confining unit. Groundwater discharging to the pipeline ditch may then be redirected through the higher permeability backfill material, discharging as a new spring at lower elevations.	• Monitor water encountered in the trench during trenching to determine if groundwater flow is being intercepted. If spring flow has been disrupted, seek and follow the advice of the Hydrogeological or Geotechnical Resource Specialist to maintain cross drainage within the trench (*e.g.*, installation of subdrains, trench breakers, etc.) [Section 8.3]. • Assess the need for well points or other dewatering methods, prior to commencing trenching, to intercept groundwater at site-specific locations before it enters the trench [Section 8.3]. • Prevent the pipeline trench and bedding from becoming a conduit for increased groundwater flow. • Install trench breakers to force groundwater seepage along the pipeline trench to the surface, if springs are encountered along the route. Install subdrains, if warranted, to divert shallow groundwater flow from the right-of-way [Section 8.4]. • Install trench breakers, where warranted, at the edge of perched wetlands to prevent the pipeline trench from acting as a drain (see Trench Breaker – Watercourse/Wetland Drawing in Appendix R) [Section 8.4]. • Install subdrains in association with trench breakers as directed by Trans Mountain's Engineer where there is evidence of seepage or a flowing spring on a slope once the trench is excavated (see Subdrains Drawing in Appendix R) [Section 8.4]. • Backfill clay/mineral soil first, if salvaged separately from organic material in shallow peatland areas, to ensure that cross drainage is maintained [Section 8.4]. • Ensure that the lower lift of subsoil is backfilled before the upper lift of subsoil where three lift soils handling has been conducted [Section 8.4]. • Also see mitigation measures under potential effects 2 above of this table.

TABLE 4.1-1 Cont'd

Number	Potential Type of Groundwater Concern	Description	Potential Mitigation
4	Shallow well	Related to the increased potential to alter groundwater flow by open excavations, trenchless crossings that intersect the water table or comprising the integrity of a shallow confining unit. Shallow wells completed in this environment may be compromised by the change in the flow system caused by the pipeline construction activity. Shallow wells may be more vulnerable to groundwater impacts caused by pipeline spills.	• Initiate pre construction monitoring, where warranted, prior to the commencement of a specific activity during construction (*e.g.*, blasting). Monitoring may be necessary prior to, during and following construction or a specific construction activity in the vicinity of water wells or springs [Section 6.0]. • During Project field studies, the Hydrogeological Engineer in consultation with landowners and the appropriate regulatory authorities will determine if springs and wells used for domestic purposes located within the immediate vicinity of the construction right-of-way will be sampled for water quality and flow rate prior to the start of construction. Locate and flag or fence registered or known water wells in the immediate vicinity of the construction right-of-way [Section 6.0]. • During construction, avoid blasting in proximity to wells. • Monitor all registered or known potable water wells located within 200 m of any blasting prior to and following blasting. Monitoring will include measurement of well yields, static and pumping water levels as well as water sampling in accordance with *Canadian Guidelines for Drinking Water Quality* (Health Canada 2012) [Section 8.3]. • Re-establish or replace a potable water supply as required should a registered or known water well located within 30 m of the construction right-of-way be damaged (*i.e.*, diminishment in quantity and/or quality) during pipeline installation [Section 7.0].
5	Spring	Flowing (artesian) conditions indicate increased potential to experience groundwater discharge in the open excavations by intersecting the water table or comprising the integrity of a shallow confining unit. A change in the natural flow system caused by pipeline construction activities may affect natural spring flow.	• Monitor water encountered in the trench during trenching to determine if groundwater flow is being intercepted. If spring flow has been disrupted, seek and follow the advice of the Hydrogeological or Geotechnical Resource Specialist to maintain cross drainage within the trench (*e.g.*, installation of subdrains, trench breakers, etc.) [Section 8.3]. • Assess the need for well points or other dewatering methods, prior to commencing trenching, to intercept groundwater at site-specific locations before it enters the trench [Section 8.3]. • Install trench breakers to force groundwater seepage along the pipeline trench to the surface, if springs are encountered along the route. Install subdrains if warranted, to divert shallow groundwater flow from the right-of-way [Section 8.4].
6	Unconfined aquifer (Quality)	Related to the increased potential to alter groundwater flow by open excavations below the water table. A change in the natural flow system caused by pipeline construction activities may affect natural spring flow and shallow wells completed in this environment.	• Utilize acceptable Management Practices for spill prevention outlined in the Pipeline EPP including in areas where higher vulnerability wells and aquifers are identified. • Ensure that during construction no fuel, lubricating fluids, hydraulic fluids, methanol, antifreeze, herbicides, biocides, or other chemicals are dumped on the ground or into waterbodies. In the event of a spill, implement the Spill Contingency Plan (see Appendix B) [Section 7.0]. • Re-establish or replace a potable water supply as required should a registered or known water well located within 30 m of the construction right-of-way be damaged (*i.e.*, diminishment in quantity and/or quality) during pipeline installation [Section 7.0].

TABLE 4.1-1 Cont'd

Number	Potential Type of Groundwater Concern	Description	Potential Mitigation
7	Contaminated shallow aquifer (Quality)	Existing contamination of unknown extent. Increased potential to alter groundwater flow by open excavations below the water table, leading to redistribution of existing subsurface contamination.	• Ensure an environmental monitor with experience in contaminated sites is present to check for indications of potential groundwater contamination (*i.e.*, sheen, odour, adjacent soil staining) during pipeline trench excavation in urban areas and other areas where the contaminated sites review identified potential sources of contamination. Where groundwater contamination is suspected the groundwater should be sampled and analyzed by an accredited laboratory [Section 8.3]. • Ensure contaminated soil and water are not transported off-site or disposed until analytical results have been received as per federal and provincial legislation. The Construction Manager and Environmental Inspector will provide notification as to when excavations can be backfilled [Section 8.3]. • Notify and adhere to the advice of the Trans Mountain Environment, Health and Safety Department or Trans Mountain's Lead Environmental Inspector and Environmental Inspector(s) at locations where water potentially contaminated with hydrocarbons or other materials is to be discharged from the trench. Measures may include the use of tank trucks to haul discharged water to an appropriate disposal facility/site, ensuring the intake is submerged below the surface sheen, lab testing and use of sorbent booms to hold the sheen away from the pump intake [Section 8.3].

It is noted that all references to distances along the proposed pipeline corridor start at the Edmonton Terminal and continue to Burnaby Terminal. These values are prefixed by 'RK' (Reference Kilometre).

4.1.1 Edmonton to Hinton Segment

The proposed pipeline corridor originates at Trans Mountain's Edmonton Terminal in Strathcona County near Edmonton in Central Alberta. The proposed pipeline corridor passes through the southern portion of Edmonton, an urban, highly populated city setting and then parallels the existing Trans Mountain pipeline corridor westward through the predominantly rural Parkland County. Ground elevations ascend from approximately 700 m above sea level (m asl) near Edmonton to around 900 m asl along the western edge of Parkland County. From Parkland County, the proposed pipeline corridor passes into Yellowhead County in west-central Alberta and ground elevations increase to about 1,400 m asl at Hinton. Trans Mountain operates the Edmonton Terminal, which will be expanded to include additional tanks and associated infrastructure, as well as pump stations, at Gainford, Wolf, Edson, Hinton and Jasper. New power lines may be required at the Edmonton Terminal and the Edson Pump Station (to be determined by provincial regulatory authority).

Approximately 202 surface water crossings were identified along the proposed pipeline corridor in this segment. Of these, six are being investigated as potential horizontal directional drill (HDD) crossings.

Deeply incised, major watercourse crossings occur at:

- North Saskatchewan River at RK 33.5;
- Pembina River at RK 135.0;
- Wolf Creek at RK 220.6; and
- McLeod River at RK 223.9.

The surficial geology along the proposed pipeline corridor through Parkland and Yellowhead counties is variable, but typically comprises glacial to lacustrine clay deposits that overlie bedrock. Occasional alluvial and fluvial deposits are mapped along the proposed pipeline corridor (Shetsen 2002, Roed 1970). Unconsolidated deposits are generally reported to be greater than 20 m thick up to approximately

RK 128, less than 20 m thick up to RK 226.3, greater than 20-30 m thick from RK 226 to RK 238 and then shallower (less than approximately 10 m thick) to RK 247.

Sand and gravel deposits typically have the highest permeability. These overburden materials accumulate in fluvial and glaciofluvial depositional environments, following the existing stream and river valleys. Some buried channels have been identified along the proposed pipeline corridor; however, the aquifers are generally confined by low permeability overburden materials that are unlikely to be compromised by shallow pipeline construction (1.8-3 m).

Lacustrine clay and glacial till deposits typically represent low permeability materials that confine the deeper-seated aquifers. Glaciofluvial and alluvial deposits characterized by a clayey matrix can also provide effective barriers to vertical and horizontal groundwater flow. Most water wells extend to bedrock and are completed in regional fractured sandstone units defined as domestic use aquifers. These aquifers are generally confined by low permeability overburden materials and low permeability bedrock shale units. Water wells completed in unconsolidated over burden deposits are usually exploiting local aquifers.

Regional groundwater contamination risk mapping has been interpreted from surficial geology descriptions along the Edmonton to Hinton Segment (Hydrogeological Consultants Ltd. [HCL] 1998, 2004). The risk is high when the near-surface materials are permeable; the risk is low when the near-surface materials are less permeable.

Edmonton obtains its water supply from the North Saskatchewan River. The City of Spruce Grove (approximately RK 58) and the Town of Stony Plain (approximately RK 65) are serviced via a water main from Edmonton. The groundwater contamination risk mapping shows that conditions are generally moderate to high risk of contamination immediately west of Edmonton through to approximately RK 119. The risk of potential contamination becomes generally lower risk with patches of higher risk though to the western border of Parkland County. Of note, Wabumun Lake area is mapped as being at a higher risk of groundwater contamination (HCL 1998). The Village of Wabamun (approximately RK 97) has switched to using groundwater from Wabamun Lake Provincial Park. A pipeline to supply water to the Village of Wabamun from the Town of Stoney Plain is currently under construction (During pers. comm.).

In addition, the hamlets of Entwistle (approximately RK 134), Evansburg (approximately RK 136) and Wildwood (approximately RK 150) depend on groundwater.

Aquifers located in Alberta have not been defined in a systematic fashion. The Alberta Geological Survey has identified the Haynes and Sunchild members of the bedrock Paskapoo Formation as aquifers. Possible aquifers in unconsolidated materials along the proposed pipeline corridor in the Edmonton to Hinton Segment were identified as part of this Project. This identification was based on HCL's assessment of areas at risk to groundwater contamination (HCL 1998, 2004), the presence of sand and gravel aggregate, near surface sand and gravel, and the utilization of groundwater through the presence water wells. The Table 4.1-2 below lists possible aquifers crossed by the Edmonton to Hinton Segment. The aquifers are presented on the maps for each segment in Appendix A.

TABLE 4.1-2

POSSIBLE AQUIFERS IN THE EDMONTON TO HINTON SEGMENT

RK	Possible Aquifer Type	Name or Material
RK 33.8 to RK 33.9	Buried valley aquifer (Thalweg)	(none)
RK 36.4 to RK 57.6	Unconsolidated	sand and gravel
RK 62.1 to RK 65.8	Unconsolidated	sand and gravel
RK 67.6 to RK 67.7	Buried valley aquifer (Thalweg)	Drayton
RK 69.2 to RK 79.3	Unconsolidated	sand and gravel
RK 83.2 to RK 85	Unconsolidated	sand and gravel
RK 86.5 to RK 89.8	Unconsolidated	sand and gravel
RK 91.4 to RK 92.8	Unconsolidated	sand and gravel
RK 94.7 to RK 96	Unconsolidated	sand and gravel
RK 97.7 to RK 100.2	Unconsolidated	sand and gravel

TABLE 4.1-2 Cont'd

RK	Possible Aquifer Type	Name or Material
RK 103.3 to RK 111.6	Unconsolidated	sand and gravel
RK 112.9 to RK 117.6	Unconsolidated	sand and gravel
RK 121.5 to RK 123.5	Unconsolidated	sand and gravel
RK 121.6 to RK 121.7	Buried valley aquifer (Thalweg)	Onoway
RK 125 to RK 125.4	Unconsolidated	sand and gravel
RK 129.5 to RK 133.9	Unconsolidated	sand and gravel
RK 162.9 to RK 165.3	Unconsolidated	sand and gravel
RK 170.3 to RK 174.1	Unconsolidated	sand and gravel
RK 176.5 to RK 189.4	Bedrock	Sunchild member
RK 184.8 to RK 199.3	Bedrock	Haynes member
RK 185 to RK 186.3	Unconsolidated	sand and gravel
RK 195.3 to RK 198.8	Bedrock	Sunchild member
RK 198.3 to RK 200.2	Unconsolidated	sand and gravel
RK 205 to RK 218.8	Bedrock	Haynes member
RK 211.8 to RK 216.8	Unconsolidated	sand and gravel
RK 217.7 to RK 222.3	Unconsolidated	sand and gravel
RK 221.9 to RK 224.4	Bedrock	Sunchild member
RK 227.3 to RK 230.1	Unconsolidated (plus Thalweg)	sand and gravel and Edson
RK 231.5 to RK 339.44	Unconsolidated	sand and gravel
RK 256.5 to RK 261.5	Bedrock	Sunchild member
RK 259.9 to RK 283.4	Bedrock	Haynes member
RK 270.9 to RK 280.1	Bedrock	Sunchild member
RK 285 to RK 299.4	Bedrock	Sunchild member

The eastern half of Yellowhead County has a predominantly low risk of groundwater contamination, grading to moderate or higher risk near the Town of Edson. Between Edson and Hinton, the regional mapping shows that the risk of groundwater contamination is generally high (HCL 2004). Surficial geology mapping through sections of Yellowhead County have identified the presence of organic deposits (muskeg), which may indicate shallow perched groundwater conditions.

The Town of Edson (RK 230) is supplied by groundwater from 10 municipal supply water wells, 2 of which are located approximately 80 m (ID# 481637; currently not in use) and 300 m (ID# 483171; in use) south of the proposed pipeline corridor, while the Town of Hinton relies on the Athabasca River as its water supply source. The rural areas between Edson and Hinton predominantly use groundwater for drinking water and other water use purposes. The well density is considered moderate along the proposed pipeline corridor in the Edmonton to Hinton Segment. Typically, there are very few wells in close proximity of the proposed pipeline corridor.

Potential groundwater-related issues raised as part of the desktop study and subsequent field work for the Edmonton to Hinton Segment are summarized in the Table 4.1-3 below.

TABLE 4.1-3

POTENTIAL GROUNDWATER-RELATED ISSUES IN THE EDMONTON TO HINTON SEGMENT

Location	Potential Groundwater Related Issue	Summary of Issue	Possible Mitigation*
RK 17.9	Well 85713 - Could have potential groundwater issue, bored stock well, total depth (TD) = 14.3 m and water level (WL) = 3.15 m bgl. Regional geology indicates ice-contacted fluvial deposits.	Shallow well; colluvium.	4
RK 24.1 to RK 24.4	Deep Blackmud Creek crossing - colluvial deposits.	Colluvium in stream.	2
RK 28 to RK 28.2	Deep Whitemud Creek crossing - colluvial deposits.	Colluvium in stream.	2
RK 34.4 to RK 34.6	North Saskatchewan River Crossing - colluvial and fluvial deposits.	Colluvium in stream.	2
RK 36.8 to RK 37.1	Deep unnamed creek crossing - colluvial deposits.	Colluvium in stream.	2

TABLE 4.1-3 Cont'd

Location	Potential Groundwater Related Issue	Summary of Issue	Possible Mitigation*
RK 39.6	Well 2093324 - Could have potential groundwater issue, stock well, well depth = 14.3 m and Water level = 3.1 m bgl. Regional geology indicates lacustrine deposits.	Shallow well.	4
RK 41.6	Well 75019 – well depth = 9.1 m for domestic use, Well #75018 – well depth 14.0 m for domestic/stock. Potential groundwater because of depth and possible WL.	Shallow well.	4
RK 50.9	12 well records related to water table test site near here. Other wells do not indicate groundwater issue, however, the reason for water table test site may cause concern.	Shallow well.	4
RK 56.9	Well #81074 - potential groundwater issue. Hand dug domestic/stock use with well depth = 11.6 m and water level = 6.1 m. Just outside 150 m radius so need to verify location. Lacustrine deposits may eliminate concern.	Shallow well.	4
RK 89.2	Well 459883 - could have potential groundwater issue, bored stock well depth = 10.4 m and water level = 0.3 m bgl. Shallow Ephemeral unknown creek no groundwater concern.	Shallow well.	4
RK 90.2	Well 459880 - could have potential groundwater issue, bored stock well depth = 8.53 m and water level = 1.21 m bgl. Shallow ephemeral unknown creek no groundwater concern.	Shallow well.	4
RK 134.9 to RK 135.6	Pembina River Crossing - fluvial deposits. Field visit = Steep banks, shallow groundwater likely; 5-10 m overburden over sandstone bedrock.	Colluvium in stream.	2
RK 171.4 to RK 171.5	Lake Crossing - glacial sediments but top of bedrock at 7.1 m - potential groundwater concerns.	Shallow well.	4
RK 185.3	Shallow Lobstick River crossing - fluvial deposits may cause potential groundwater issue.	Colluvium in stream.	2
RK 220.6	Wolf Creek crossing in fluvial deposits - potential groundwater concern. Field visit = Poorly drained; glaciolacustrine silty clayey till.	Colluvium in stream.	2
RK 223.7 to RK 224.1	McLeod River crossing in fluvial deposits - potential groundwater concern. Field visit = Shallow groundwater; glaciolacustrine silty clayey till; bedded sandstone.	Colluvium in stream.	2
RK 224.7 to RK 225	Fluvial deposits near the McLeod River.	Colluvium in stream.	2
RK 309.1 to RK 311.1	Trail Creek and unknown ephemeral creek crossing in fluvial/alluvium deposits. Full section passes near Athabasca River. Field visit = Shallow groundwater: seepage from glaciofluvial sand and gravel on top of siltstone in river bank exposure.	Colluvium in stream.	2
RK 319.8 to RK 320.1	Hardisty Creek crossing in Till near fluvial deposits - potential groundwater concern (approximately 20 m elevation change).	Colluvium in stream.	2
RK 327.5 to RK 327.7	Shallow Maskuta Creek crossing in fluvial sediments - most wells deep, but there is spring in area - potential concern.	Colluvium in stream; spring.	2,5
RK 329.5	Shallow wells in glaciofluvial sediments with no confining layers - potential groundwater concern, would have to confirm locations.	Shallow well.	4
RK 337.2 to RK 337.5	Two shallow unknown creek crossings in fluvial sediments. Well 485176 in fluvial sediments with no confining layers - potential groundwater concern.	Colluvium in stream.	2

Note: - More detailed information is provided in Appendix B.

4.1.2 Hargreaves to Darfield Segment

The Hargreaves to Darfield Segment originates within the upper Fraser River Watershed, east of Rearguard Falls within the Fraser Fort George Regional District of BC. The proposed pipeline corridor follows the existing Trans Mountain pipeline corridor and Highway 5 for most of its length. Trans Mountain operates the Rearguard, Blue River, Blackpool and Darfield pump stations along this portion of the proposed pipeline corridor.

The area through which the proposed pipeline corridor passes is predominantly rural with several small villages scattered along the route. Rearguard Falls, Jackman Flats, Blue River Black Spruce, Finn Creek and the North Thompson River Provincial Parks are located either within or close to the proposed pipeline corridor.

Ground elevations descend from over 900 m asl near RK 490.0 to approximately 450 m asl at RK 769.0. Groundwater flows generally follow local topography with recharge occurring either directly over the aquifers or from the valley walls (mountain sides), and discharge feeding the local river systems or flowing within fluvial sediments down the valley base.

Approximately 350 surface water crossings were identified along the proposed pipeline corridor in this segment. Of these, eight are being investigated as potential HDD crossings.

Watercourses recommended as potential HDD crossings are summarized below:

- North Thompson River at RK 581.2;
- Blue River at RK 613.8;
- Unnamed channel at RK 619.8;
- Multiple North Thompson River crossings at RK 619.9 and RK 651.6;
- Raft River at RK 717.7;
- Clearwater River at RK 725.5; and
- Mann Creek at RK 735.0.

Maps showing surficial geology from RK 489.7 to RK 636 were considered to be poor quality due to the small scale. From RK 636.0; however, regional mapping appears underlain by colluvium up to RK 639.0, which transitions to glacial till bordering fluvial deposits along major drainages. The proposed pipeline corridor passes over predominantly fluvial and glaciofluvial deposits from RK 648.0 to RK 769.0 (Fulton 1986, Tipper 1971, Gough 1987). The proposed pipeline corridor intersects short sections of mapped glacial till, colluviums and bedrock through this area, however, most of the well logs reviewed indicated the presence of sand and gravel overlying or bedrock mapped as surface outcrop (BC Ministry of Environment [MOE] 2013).

Additional description of surficial geology for this segment is described in Section 5.1.1.2.

No aquifers have been mapped from RK 490 to RK 524 (from Hargreaves to Valemont). The locations of aquifers are shown on maps in Appendix A. In general, groundwater level depths from RK 490 to RK 524, where reported, are considered moderate (>6 m below ground level [bgl]), to deep (>30 m bgl). Few wells are located in the Water Quantity and Quality LSA of the proposed pipeline corridor in this segment. The Valemount Aquifer (#799) is mapped as a glaciofluvial sand and gravel deposit between approximately RK 516 and RK 524.1. This aquifer has been classified in the BC provincial aquifer classification system as having relatively low demand, low vulnerability and a moderate productivity. The average well depth through the area is greater than 28 m bgl. A second glaciofluvial sand and gravel deposit is mapped within the Valemount area, the South Valemount Aquifer (#800) from RK 526 to RK 530. This aquifer is classified as having low demand, low productivity and a moderate vulnerability. The average well depth through this aquifer is greater than approximately 50 m bgl (BC MOE 2013).

Potentially shallow groundwater areas are noted at a few locations between the Village of Valemount and Community of Blue River (particularly around Blue River), although information on groundwater depths is limited because of the lack of wells in the area (BC MOE 2013). Aquifer #825 is described as a glaciofluvial sand and gravel deposit mapped near the Community of Blue River. It intersects the proposed pipeline corridor from RK 611.8 to RK 617.5. It is classified as a low demand, moderate productivity and highly vulnerable aquifer (BC MOE 2013). No aquifers have been mapped between the communities of Blue River and Vavenby, though available information suggests there may be shallow groundwater present along the proposed pipeline corridor. Aquifer #807 is a glaciofluvial sand and gravel deposit extending from the Community of Vavenby to the District of Clearwater. The proposed pipeline corridor intersects Aquifer #807 from RK 698 to RK 717.6. The aquifer is classified as having moderate demand, productivity and vulnerability. Reported well depths are generally deep (>30 m bgl) and water depths vary from shallow to deep (BC MOE 2013).

Aquifer #773 is encountered from RK 717.6 to RK 719.4. This aquifer is defined as a glaciofluvial sand and gravel deposit with high demand, moderate productivity and low vulnerability (BC MOE 2013). The water well density increases substantially around the District of Clearwater. Within the District of Clearwater, the south side of the proposed pipeline corridor encounters Aquifer #772 (a bedrock aquifer with moderate productivity, moderate vulnerability and low demand) and Aquifer #770, described as a sand and gravel deposit with high productivity, demand and vulnerability at RK 723.1. Aquifer #770 transitions to Aquifer #769, described as a sand and gravel deposit with moderate productivity, moderate demand and high vulnerability for a short section of the proposed pipeline corridor. No aquifers are mapped along the proposed pipeline corridor from RK 729.5 to RK 769.0. Reported water levels near the District of Clearwater range from shallow (<5 m bgl) to moderate (5-30 m bgl) (BC MOE 2013).

Aquifer #296 has been mapped as an alluvium and alluvial fan sand and gravel deposit between RK 748.5 and RK 756.8. The aquifer has low demand and moderate productivity and vulnerability. Aquifer #293 is a second alluvium and alluvial fan sand and gravel deposit mapped south of Clearwater (RK 756.8 to approximately RK 769) (BC MOE 2013).

There are no community-owned drinking water supply wells in the Village of Valemount, communities of Albreda (RK 545.3), Avola (RK 652.7), Vavenby (RK 695.7), the District of Clearwater (RK 714.7), Blackpool (RK 726.5) or the Community of Darfield (RK 765). A portion of the Community of Blue River (approximately RK 614) is supplied by groundwater (Hughes, pers. comm. and Madden pers. comm.); however, the source wells are mapped over 1 km from the proposed pipeline corridor. North Thompson River Provincial Park is supplied by two water wells that are located in proximity to the proposed pipeline corridor. The rural areas between Clearwater and North Thompson River Provincial Park are predominantly supplied by groundwater for drinking water and other water use purposes (BC MOE 2013).

Potential groundwater-related issues identified as part of the desktop study and subsequent field work for the Hargreaves to Darfield Segment are summarized in the Table 4.1-4 below.

TABLE 4.1-4

POTENTIAL GROUNDWATER-RELATED ISSUES IN THE HARGREAVES TO DARFIELD SEGMENT

Location	Potential Groundwater Related Issue	Summary of Issue	Possible Mitigation*
RK 514.3	Creek crossing.	Creek crossing.	1
RK 515.5	Creek crossing.	Creek crossing.	1
RK 517.8	Creek crossing.	Creek crossing.	1
RK 522.5	Creek crossing; potential shallow groundwater in terrace; unconfined. Field visit = Well-drained glacio-fluvial sand and gravel.	groundwater shallow.	3
RK 523.7	Creek and marsh crossing.	Creek crossing.	1
RK 531.3	Canoe River crossing; groundwater at or above river level. Field visit: Well-drained; sandstone bedrock.	groundwater shallow.	3
RK 533	Generally swampy area, shallow groundwater.	groundwater shallow.	3
RK 534.5	Creek crossing.	Creek crossing.	1
RK 545.8 to RK 545.9	Shallow groundwater.	groundwater shallow.	3
RK 559	Stream crossing, groundwater in alluvium.	Colluvium in stream.	2
RK 559	groundwater in alluvium.	Colluvium in stream.	2
RK 561.2	Deep creek crossing.	Deeply incised creek.	1
RK 563.4 to RK 563.5	Deep creek crossing.	Deeply incised creek.	1
RK 565.9	Deep creek crossing.	Deeply incised creek.	1
RK 567.6	Deep creek crossing.	Deeply incised creek.	1
RK 571.9	Deep creek crossing.	Deeply incised creek.	1
RK 573.5	Creek crossing.	Creek crossing.	1
RK 576.3	Creek crossing.	Creek crossing.	1
RK 580.4	Deep creek crossing. Field visit = Shallow groundwater, well-drained; groundwater seep from bedrock.	Deeply incised creek.	1
RK 581.2	North Thompson River crossing.	River.	2
RK 590.3	Creek crossing.	Creek crossing.	1
RK 592.9 to RK 593	Creek crossing, alluvial fan.	Colluvium in stream.	2
RK 600.2 to RK 600.3	Thunder River crossing.	River	2
RK 611.7 to RK 611.8	Creek crossing; very close to North Thompson River.	Creek crossing.	1

TABLE 4.1-4 Cont'd

Location	Potential Groundwater Related Issue	Summary of Issue	Possible Mitigation*
RK 613.7	Sand deposits hosting water table aquifer may be used locally - potentially sensitive to contamination. Field visit: Shallow groundwater, well-drained, fluvial sand and gravel.	Groundwater shallow.	3
RK 613.8	Blue River crossing.	River.	2
RK 619.9	North Thompson River crossing; alluvial terrace high groundwater.	Colluvium in stream.	2
RK 621 to RK 622.9	Pipeline corridor close to river in alluvial terrace.	Colluvium in stream.	2
RK 622.9 to RK 625.4	Pipeline corridor close to North Thompson River in alluvial terrace. Highly sensitive area.	Colluvium in stream.	2
RK 625.4 to RK 626.9	Pipeline corridor close to North Thompson River in alluvial terrace. Sensitive area.	Colluvium in stream.	2
RK 626.6	Froth Creek crossing; potentially seasonal high flow.	Creek crossing.	1
RK 634		Deeply incised creek.	1
RK 638.8	Finn Creek crossing; sand and boulders aquifer, high groundwater level.	groundwater shallow.	3
RK 642 to RK 643.5	Close to braided North Thompson River crossing.	Colluvium in stream.	2
RK 645.3 to RK 645.8	Close to North Thompson River crossing. Field visit = Poorly drained, metamorphic bedrock.	Colluvium in stream.	2
RK 646.8 to RK 648.2	Cose to North Thompson River crossing.	Colluvium in stream.	2
RK 648.9	Tumtum Creek crossing; alluvial fan.	Colluvium in stream.	2
RK 651.3 to RK 651.8	North Thompson River crossing; alluvial terraces. Field visit = Shallow groundwater; poorly drained; fractured metamorphic bedrock.	Colluvium in stream.	2
RK 659.8 to RK 660.7	Very close to North Thompson River in alluvial deposits.	Colluvium in stream.	2
RK 663.2 to RK 663.5	Creek bed.	Creek Crossing.	1
RK 668.4 to RK 668.9	Very close to North Thompson River.	Colluvium in stream.	2
RK 669 to RK 671.2	Very close to North Thompson River.	Colluvium in stream.	2
RK 682.8 to RK 684.2	Close to North Thompson River.	Colluvium in stream.	2
RK 706	Wells in proposed pipeline corridor; depth from 20-60 m; aquifer somewhat protected by fine material; low rates. Field visit = Glacio-fluvial cobbles.	Shallow well.	4
RK 709.6	Close to river; alluvial material (?).	Colluvium in stream.	2
RK 711.5	Well in proposed pipeline corridor; close to 50 m dry gravel(?), then water-bearing gravel.	Shallow well.	4
RK 713.4	Wells in proposed pipeline corridor; appear as low sensitivity.	Shallow well.	4
RK 715.6	River deposits.	Colluvium in stream.	2
RK 717.5	Wells in proposed pipeline corridor, low rate to dry(?) somewhat protected by clay and till layers. Field visit = Shallow groundwater seepage; glaciofluvial materials to 10 m thick.	Shallow well.	4
RK 725.6 to RK 725.7	Clearwater River crossing; wells in proposed pipeline corridor 30-40 m deep; poorly protected by dirty sand/gravel. Field visit = Water well at higher elevation has groundwater depth of approximately 40 m bgl (well is likely 40 m above river); well-drained, likely glacio-fluvial; shallow groundwater a possibility.	Shallow well.	4
RK 728.8 to RK 729.5	Blackpool community ; shallow wells 6- 12 m, water table unprotected aquifer.	Shallow well.	4
RK 731 to RK 731.6	Shallow wells 12 m deep; unprotected water table aquifer.	Shallow well.	4
RK 734.9 to RK 735.1	Mann Creek crossing; apparently alluvial terrace shallow, water table aquifer.	Colluvium in stream.	2
RK 740.7 to RK 740.8	Very close to Lake Lemieux; check geology for material permeability.	Colluvium in stream.	2

Note: - More detailed information is provided in Appendix B.

4.1.3 Black Pines to Hope Segment

The Black Pines to Hope Segment begins approximately 50 km north of Kamloops within the North Thompson River valley. The proposed pipeline corridor continues south along the Westside Barrier Road through the City of Kamloops where it crosses the Thompson River upstream from Kamloops Lake. South of Kamloops, the proposed pipeline corridor passes between Highways 5 and 5A until it intersects Highway 5 north of Nicola Lake and follows closely with this highway through to Merrit. South of Merrit, the pipeline continues to follow the existing TMPL right-of-way through high elevation areas near the Coquihalla Summit, along Coldwater Road, Brookmere Road and Highway 5. South of the Summit, the proposed pipeline corridor follows the Coquihalla River and Old Coquihalla highway for 26 km to the junction of Highway 5 and Shylock Road near Hope. Trans Mountain operates the Kamloops and Kingsvale pump stations along the Black Pines to Hope Segment. A new pump station and power line will be constructed at a site in Black Pines. A new power line will also be required at Kingsvale Pump Station.

The area through which the proposed pipeline corridor passes is predominantly rural, but the proposed pipeline corridor route passing the communities of Kamloops, Merritt and Hope is more urban and populated. The Lac Du Bois Grasslands Protected Area, the Coquihalla Summit Recreation Area and the Coquihalla River Provincial Park are located either within or close to the proposed pipeline corridor.

Ground elevations increase from approximately 350 m asl at RK 813 to approximately 1,240 m asl at the Coquihalla Summit at RK 1001.4, then decrease to approximately 60 m asl in Hope at RK 1045.4. Groundwater flows generally follow local topography with recharge occurring either directly over the aquifers or from the valley walls (mountain sides) and discharge feeding the local river systems or flowing within fluvial sediments down the valley base. Sections of the proposed pipeline corridor along the Coquihalla Highway are heavily confined by steep mountain approaches on both sides of the pass.

Approximately 315 surface water crossings were identified along the proposed pipeline corridor in this segment. Of these, 7 are being investigated as potential HDD crossings.

Major watercourse crossings are summarized below:

- Thompson River at RK 846.8;
- Nicola River at RK 928.0;
- multiple Coldwater River crossings at RK 957.9, RK 970.3, RK 980.0 and RK 990.0; and
- Coquihalla River at RK 1043.2.

Regional surficial geology mapping by Young (1983) between RK 813 and RK 847.5 is mostly fluvial or glaciofluvial with occasional areas described as colluvium. South of Kamloops (RK 848), the proposed pipeline corridor enters into an area dominated by glacial till and where fluvial or glaciofluvial deposits are only occasionally encountered at stream crossings. Between RK 892.6 and RK 934.2, the proposed pipeline corridor crosses glacial till, colluvium, glaciofluvial, fluvial and lacustrine deposits intermittently. Glacial till is the dominant surficial deposit between RK 934.6 and RK 958.8 (Fulton 1986), after which no surficial geology information is available through to the end of this segment.

Additional description of surficial geology for this segment is described in Section 5.1.1.3.

Aquifer #283 is mapped in the proposed pipeline corridor from RK 812 to RK 821. The locations of aquifers are shown on maps in Appendix A. This aquifer is described as a modern alluvial fan sand and gravel deposit. It reportedly has low demand, and moderate productivity and vulnerability. Water wells reported in the area are generally deep (>60 m bgl) and water depths are considered to be moderate until RK 820 where shallow water depths are reported. Aquifer #282, an alluvial sand and gravel deposit with moderate demand, moderate productivity and high vulnerability is encountered by the proposed pipeline corridor north of the Thompson River in the Kamloops area from RK 844.7 to RK 846.6. South of the Thompson River, the proposed pipeline corridor crosses a short section of Aquifer #284, an alluvial sand and gravel deposit with similar characteristics as Aquifer #282 (BC MOE 2013).

Bedrock Aquifer #276 is crossed by the proposed pipeline corridor from RK 851.8 to RK 857.3; this aquifer is classified as having low demand, low productivity and moderate vulnerability. Perched shallow groundwater may be encountered near local surficial water bodies. No aquifers have been mapped between RK 857.3 and RK 865.6. A second bedrock aquifer, Aquifer #274, is encountered at RK 865.6. Aquifer #274 has similar characteristics as Aquifer #276. No aquifers have been mapped from RK 871.8 to RK 931.1 and little hydrogeological information is available due to the scarcity of water wells. Near Merritt, the proposed pipeline corridor crosses Aquifer #75, described as a sand and gravel deposit with moderate demand, moderate productivity and low vulnerability from RK 931.1 to RK 932.7. Well depths in this area are deep and the groundwater levels are generally variable. No aquifers have been mapped from RK 932.7 to RK 1042.2 (Merritt to Hope). The proposed pipeline corridor crosses Aquifer #1005 from RK 1041.9 to RK 1043.1 as it enters Hope. This aquifer is described as a sand and gravel deposit with moderate demand, moderate productivity and moderate vulnerability. It is underlain by Aquifer #1009, a bedrock aquifer with moderate demand, moderate productivity, but reportedly high vulnerability. Water levels range from shallow to deep in this area. West of RK 1042.9, Aquifer #1007, a sand and gravel deposit with low demand, high productivity and high vulnerability, is mapped within the Water Quantity and Quality LSA.

Well densities are considered high in proximity to the proposed pipeline corridor in the Kamloops, Merritt and Hope areas (BC MOE 2013). The Kamloops Airport and School District 24 operate drinking water systems in proximity (approximately 400 m and 100 m respectively) to the proposed pipeline corridor. A District of Hope community well and two drinking water system wells are identified in Aquifer #1005 potentially within the proposed pipeline corridor. Spectra Energy Corporation operates a water supply system well near RK 952.8 that is within 200 m of the proposed pipeline corridor. The Coldwater First Nation's water supply wells also are identified in proximity to the existing pipeline corridor and are approximately 1,220 m from RK 642.5 the proposed pipeline corridor.

Potential groundwater-related issues raised as part of the desktop study and subsequent field work for the Black Pines to Hope segment are summarized in the Table 4.1-5 below.

TABLE 4.1-5

POTENTIAL GROUNDWATER-RELATED ISSUES IN THE BLACK PINES TO HOPE SEGMENT

Location	Potential Groundwater Related Issue	Summary of Issue	Possible Mitigation*
RK 844.8 to RK 845.8	North Thompson River terraces; potential for shallow aquifer contamination from both off-site and on-site land uses. Field visit = Likely fluvial compact fine clay gravel cobbles; monitoring wells near Kamloops Station.	Contaminations - shallow aquifer.	7
RK 846.5 to RK 847.5	North Thompson River crossing; including river terrace with shallow groundwater.	Groundwater shallow.	3
RK 858.3 to RK 858.5	Ravine crossing; shallow groundwater.	Groundwater shallow.	3
RK 869.7 to RK 870.1	Proposed pipeline corridor encroaching Menanteau Lake; wetland; shallow groundwater.	Groundwater shallow.	3
RK 881.7	Very close to Anderson Lake; high groundwater table and connection to lake.	Groundwater shallow.	3
RK 910.1	Encroaching wetland.	Creek crossing.	1
RK 927.8 to RK 928	Nicola River crossing and alluvial terraces; groundwater shallow and connected to river. Field visit = Shallow groundwater; poorly drained; wet.	Colluvium in stream.	2
RK 956.2	Shallow well; aquifer confined but not deep. Field visit= Shallow groundwater; well-drained.	Shallow well.	4
RK 957.8 to RK 957.9	Coldwater River crossing; possible terraces with shallow groundwater.	Groundwater shallow.	3
RK 963.1 to RK 963.6	Very close to Fig Lake; possible shallow groundwater.	Groundwater shallow.	3
RK 970.2 to RK 970.3	Coldwater River crossing and in close proximity to the river. Field visit = High electrical conductivity suggests shallow groundwater; well-drained steep till slope failing; 5 m hard till sand and gravel; volcanic bedrock.	Colluvium in stream.	2
RK 980 to RK 980.1	Coldwater River crossing; Field visit = Shallow groundwater - possible spring in riprap; fluvial to glaciofluvial.	River.	2
RK 1021.8	Coquihalla River crossing; shallow groundwater in alluvial terraces. Field visit = Shallow groundwater; well-drained glacio-fluvial (gravel pit).	Groundwater shallow; colluvium in stream.	2,3
RK 1022.9	Dewdney Creek crossing; shallow water in alluvial deposits.	Groundwater shallow.	3
RK 1026.5	Coquihalla River crossing.	River.	2
RK 1028.6 to RK 1028.7	Coquihalla River crossing; shallow groundwater in alluvium.	Groundwater shallow.	3
RK 1032.6	Coquihalla River crossing; shallow groundwater in alluvium.	Groundwater shallow.	3
RK 1040.1	Well in the proposed pipeline corridor; shallow and unconfined (unnamed) aquifer.	Shallow well.	4

TABLE 4.1-5 Cont'd

Location	Potential Groundwater Related Issue	Summary of Issue	Possible Mitigation*
RK 1040.6	Well in the proposed pipeline corridor; shallow (unnamed) aquifers poorly confined and/or not confined.	Shallow well.	4
RK 1042.2 to RK 1043.3	Shallow (within 20 m) unconfined (unnamed) aquifer and at end point Coquihalla River crossing. Field visit = Shallow groundwater; well-drained glacio-fluvial (gravel pit).	Unconfined aquifer.	6

Note: - More detailed information is provided in Appendix B.

4.1.4 Hope to Burnaby Segment

The Hope to Burnaby Segment extends from Hope along Highway 1 through predominantly agricultural lands in the Fraser Valley and the rural communities of Chilliwack, Abbotsford and Langley before entering into the more urban communities of Surrey, Coquitlam and Burnaby. The F.H. Barber and the Bridal Veil Falls Provincial Parks are located either within or close to the proposed pipeline corridor. Trans Mountain operates the Sumas Pump Station, the Sumas Terminal and the Burnaby Terminal within the Hope to Burnaby Segment and Project activities are proposed at each facility.

Ground elevations transition from approximately 60 m asl near Hope to approximately 175 m asl near Burnaby. Groundwater flows will generally follow local topography with recharge occurring directly over the aquifers and discharge feeding the local river systems.

Approximately 131 surface water crossings were identified along the proposed pipeline corridor in this segment. Of these, five have been proposed as potential HDD crossings.

Major watercourse crossings are summarized below:

- Chilliwack/Vedder River at RK 1102.1; 1102.3 and 1102.4;
- Sumas River at RK 1114.6; and
- Fraser River at RK 1168.9.

No surficial geology mapping is available between Hope and Bridal Falls. Regional surficial geology mapping by Armstrong (1980) extends west of Bridal Falls. Armstrong describes the surficial geology west of Bridal Falls (RK 1079.4 to RK 1085.9) as complex, consisting of Salish bog, swamp and shallow lake deposits consisting of either lowland peat, organic silt loam and silty clay loam (0.3 to 10 m thick) overlying Fraser River overbank and channel deposits, sandy loam, loamy silt or Salish slope deposits consisting of fan and landslide sand and gravel up to 10 m thick. The surficial geology from RK 1079.4 to RK 1085.9 is summarized in Table 4.1-6. Additional description of surficial geology for this segment is described in Section 6.1.1.4.

TABLE 4.1-6

SURFICIAL GEOLOGY RK 1079.4 TO RK 1085.9

RK	Surficial Sediment Description
RK 1079.4 to RK 1080.7	Bog swamp deposits – 0.4 - 10 m thick.
RK 1080.7 to RK 1081.5	Slope deposits (sand and gravel) – to 10 m thick.
RK 1081.5 to RK 1082.2	Channel and overbank deposits (sand and gravel).
RK 1082.2 to RK 1083.3	Slope deposits (sand and gravel) – to 10 m thick.
RK 1083.3 to RK 1083.9	Bog swamp deposits – 0.4 to 10 m thick.
RK 1083.9 to RK 1084.6	Slope deposits (sand and gravel) – to 10 m thick.
RK 1084.6 to RK 1084.8	Bog swamp deposits – 0.4 - 10 m thick.
RK 1084.8 to RK 1085.9	Slope deposits (sand and gravel) – to 10 m thick.

Source: Armstrong 1980

From RK 1085.9 to RK 1093.0, the material encountered consists of either channel and overbank sediments consisting of silty clay loam or Salish bog, swamp or shallow lake deposits of lowland peat and organic silt loam (Armstrong 1980). From RK 1093.9 to RK 1100.4, the material encountered consists of mountain stream channel and floodplain sediments composed of sand and gravel deposited by the Chilliwack River in Sumas Valley up to 15 m thick (Armstrong 1980). From RK 1100.4 to RK 1108.4, the surficial material consists of stream deposits of sand and gravel up to 15 m thick (Armstrong 1961). From RK 1108.4 to RK 1114.4 (western edge of Sumas Mountain), the proposed pipeline corridor encounters lacustrine deposits consisting of sand up to 4.5 m overlying silt, clayey silt and silty clay (Armstrong 1961). From RK 1114.4 to RK 1121.2, the near surface materials consist of the bedrock exposed at Sumas Mountain.

The surficial sediments encountered from RK 1121.2 to RK 1138.2 are variable as shown in Table 4.1-7.

TABLE 4.1-7

SURFICIAL GEOLOGY FROM RK 1121.1 TO RK 1138.2

RK	Surficial Sediment Description
RK 1121.1 to RK 1121.7	Slopewash sand to 3 m thick resting on silty clay and clayey silt
RK 1121.7 to RK 1123.3	Fraser River floodplain silty clay and clayey silt up to 9 m thick and overlying sand.
RK 1123.3 to RK 1124.1	Salish swamp deposits (lowland peat) up to 10.6 m thick in most places resting on silty clay and in some places overlying sand and sandy silt.
RK 1124.1 to RK 1128.2	Fraser River floodplain silty clay and clayey silt up to 9 m thick and overlying sand.
RK 1128.2 to RK 1129.2	Salish swamp deposits (lowland peat) up to 10.6 m thick in most places resting on silty clay and in some places overlying sand and sandy silt.
RK 1129.2 to RK 1130.1	Glaciolacustrine deposits of silt, clayey silt, silty clay, fine sand and minor coarse sand and gravel.
RK 1130.1 to RK 1130.9	Abbotsford outwash, ice contact, gravel, sand and lenses of till.
RK 1130.9 to RK 1133.4	Glacial Sumas sandy till from less than 1.5 m to 10.6 m thick.
RK 1133.4 to RK 1137.9	Fort Langley Formation (Whatcom) glaciomarine deposits of stony clayey silt and silty clay, clay, silt and sand from 7.6 m to 91.4 m thick.
RK 1137.9 to RK 1138.2	Huntingdon Gravel consisting of gravel and sand up to 30.5 m thick underlying either Sumas Till or Whatcom glaciomarine deposits.

Source: Armstrong 1961

West of RK 1140.4, the surficial geology mapping was completed by Armstrong and Hicock (1980). Here the glaciomarine sediments are referred to as the Fort Langley Formation which on the older maps was called the Whatcom glaciomarine deposits (Armstrong 1961). The surficial geology for the Project from RK 1140.8 to RK 1168.6 (Fraser River crossing) is described in Table 4.1-8 based on mapping by Armstrong and Hicock (1980).

TABLE 4.1-8

SURFICIAL GEOLOGY FROM RK 1138.2 TO RK 1168.6

RK	Surficial Sediment Description
RK 1138.2 to RK 1144.8	Fort Langley Formation (Whatcom) glaciomarine deposits of stony clayey silt and silty clay, clay, silt and sand from 7.6 m to 91.4 m thick.
RK 1144.8 to RK 1146.3	Salish swamp deposits (lowland peat) up to 10.6 m thick in most places resting on silty clay and in some places overlying sand and sandy silt.
RK 1146.3 to RK 1148.4	Capilano sediments – marine silt loam to clay loam with minor sand and silt and stones to 18.3 m thick.
RK 1148.4 to RK 1150.4	Fraser River deposits – overbank sandy to silt loam to 2 m thick overlying 15 m or more of deltaic channel till (sandy to silt loam.
RK 1150.4 to RK 1151.4; RK 1152.4 to RK 1154.4	Fort Langley Formation - marine silty clay to fine sand. From RK 1151.4 to RK 1152.4 and from RK 1153.4 to RK 1154.4 consists of lowland peat up to 14 m thick overlying Fraser River sediment sandy to silt loam.
RK 1154.4 to RK 1157.6	Sumas drift – proglacial deltaic gravel and sand up to 40 m thick.
RK 1157.6 to RK 1160.1	Capilano sediments mainly marine silt loam to clay loam up to 60 m thick.
RK 1160.1 to RK 1163.6	Salish sediments - lowland peat up to 14 m thick overlying Fraser River sediment sandy to silt loam.
RK 1163.6 to RK 1168.4	Pre-Vashon Quadra fluvial channel fill and marine interbedded fine sand to clayey silt. From RK 1166.4 to RK 1167.1 consists of lowland peat up to 14 m thick overlying Fraser River sediment sandy to silt loam.
RK 1168.4 to RK 1168.6	Lowland peat up to 14 m thick overlying Fraser River sediment sandy to silt loam.

Source: Armstrong and Hicock 1980

North of the Fraser River crossing at RK 1169.2, the surficial geology consists of Tertiary bedrock overlain by Vashon Till (Armstrong and Hicock 1980). However, where the proposed pipeline corridor follows valley bottoms, the surficial geology shows much variation as outlined in Table 4.1-9.

TABLE 4.1-9

SURFICIAL GEOLOGY FROM RK 1169.2 TO RK 1179.77

RK	Surficial Sediment Description
RK 1169.2 to RK 1172.3	Fraser River overbank deposits of sandy to silt clay loam up to 2 m thick overlying 15 m or more deltaic and channel till sandy to silt loam. Manmade fill exists from RK 1171.7 to RK 1172.1.
RK 1172.4 to RK 1173.1	Lowland peat up to 14 m thick overlying Fraser River sediment sandy to silt loam (small amount of Pre-Vashon Quadra fine sand to clayey silt at RK 1173.4).
RK 1173.9 to RK 1176.5	Marine shore and fluvial sand up to 8 m thick.
RK 1176.5 to RK 1177.0	Vashon Drift and Capilano sediments generally <8 m thick consists of marine shore and fluvial sand).
RK 1177.0 to RK 1177.2	Marine shore and fluvial sand up to 8 m thick.
RK 1177.2 to RK 1179.0	Vashon Drift and Capilano sediments generally <8 m thick consists of marine shore and fluvial sand).
RK 1179.0 to RK 1179.8 (Burnaby Terminal)	Capilano Sediments – raised beach deposits consisting of poorly sorted sand to gravel 1-8 m thick.

Source: Armstrong and Hicock 1980

Aquifer #1 is mapped in the Hope area from approximately RK 1045.4 to RK 1051.5. The locations of aquifers are shown on maps in Appendix A. This aquifer is described as a Fraser River Sediments sand and gravel deposit. It reportedly has moderate demand, high productivity and high vulnerability. Water levels reported on records completed for local water wells appear to be shallow to moderate in depth, averaging around 8 m bgl. Aquifer #3 is located immediately south of Hope from approximately RK 1054.6 to RK 1065.1. This aquifer is also a Fraser River sand and gravel deposit with similar characteristics as Aquifer #1 (BC MOE 2013).

Aquifer #6 extends from RK 1077.2 to RK 1094. This sand and gravel deposit is identified as the 'Chilliwack-Rosedale Aquifer' and is classified as having a low demand, high productivity and high vulnerability. The proposed pipeline corridor is in proximity to several probable drinking water systems with wells in this aquifer including the Tzeachten Indian Reserve (BC MOE 2013).

Aquifer #8, the 'Vedder River Fan Aquifer', is located at approximately RK 1094 and is also known locally as the Sardis Aquifer. The Vedder River Fan Aquifer is described as a sand and gravel deposit with high demand, productivity and vulnerability. The City of Chilliwack community wells are located within this aquifer and the mapped well capture zones cross the proposed pipeline corridor. The proposed pipeline corridor crosses the Chilliwack/Vedder River at RK 1102.2 and continues west through Aquifer #8. The Yarrow Waterworks District wells are located within Aquifer #8 on the south side of the Chilliwack/Vedder River, more than 800 m from the proposed pipeline corridor. The proposed pipeline corridor continues to overlie Aquifer #8 through to Aquifer #21, the 'Sumas Prairie' aquifer in Abbotsford. Aquifer #21 is described as a sand and gravel deposit with moderate demand, productivity and vulnerability. No aquifers are mapped from RK 1114.6 to RK 1121.2 (BC MOE 2013).

The proposed pipeline corridor passes briefly across a series of saturated sand and gravel deposits defined as aquifers between Abbotsford and Surrey (BC MOE 2013) (Table 4.1-10).

TABLE 4.1-10

AQUIFERS IDENTIFIED BETWEEN ABBOTSFORD AND SURREY, BC

RK	Aquifer #	Type	Demand	Productivity	Vulnerability	Comment
RK 1121.1 to RK 1129.9	22	regionally extensive; sand and gravel deposit.	Low	Low	Low	Water levels in this aquifer range from shallow to moderate depth. The Sto: Lo First Nation and another potential drinking water system are located near RK 1121.2.
RK 1129.9 to RK 1130.9	16	Sumas Drift sand and gravel deposit.	Low	Low	High	Water levels in this aquifer range from shallow to moderate depth. There is a high density of wells in proximity to the proposed pipeline corridor in this area.

TABLE 4.1-10 Cont'd

RK	Aquifer #	Type	Demand	Productivity	Vulnerability	Comment
RK 1130.6 to RK 1132.4 and RK 1135.7	27	Fort Langley Formation sand and gravel deposit.	High	High	Low	Water levels in this aquifer range from moderate to deep. There is a high density of wells in proximity to the proposed pipeline corridor in this area.
Does not cross the proposed pipeline corridor, but is located within the Water Quantity and Quality LSA.	29	Fort Langley Formation sand and gravel deposit.	Low	Moderate	Low	Water levels in this aquifer range from moderate to deep. There is a high density of wells in proximity to the proposed pipeline corridor in this area.
RK 1132.9 to RK 1133.9	30	Fort Langley Formation sand and gravel deposit.	Low	Moderate	High	Water levels in this aquifer range from moderate to deep. There is a high density of wells in proximity to the proposed pipeline corridor in this area.
RK 1138 to RK 1138.9	32	Sand and gravel deposit.	Moderate	Moderate	Low	Water levels in this aquifer range from moderate to deep. There is a high density of wells in proximity to the proposed pipeline corridor in this area.
Do not cross the proposed pipeline corridor, but are located within the Water Quantity and Quality LSA.	35 (Hopington) and 36	Both are sand and gravel deposit.	High (35) High (36)	High (35) Moderate (36)	High (35) High (36)	The Hopington Aquifer has been identified as in intensive use for water supply with declining water levels and increasing nitrate concentrations.
RK 1145.4 to RK 1159.7	58 (Nicomeki-Serpentine)	Sand and gravel deposit.	moderate	moderate	low	Several potential drinking water systems owned by the Township of Langley and a Langley school, among others, were identified. Water levels in this aquifer range from shallow to moderate depths. There is a high density of wells in proximity to the proposed pipeline corridor in this area.
Do not cross the proposed pipeline corridor, but are located within the Water Quantity and Quality LSA.	59 and 60	Sand and gravel.	Moderate	Moderate	Low	
RK 1163.4 to RK 1165.4 and from RK 1167.8 to RK 1168.	61	Quadra Sand aquifer.	Low	High	Low	Water levels in this aquifer range from shallow to moderate depths. There is a high density of wells in proximity to the proposed pipeline corridor in this area including potential drinking water system wells owned by Mountford, Corporation of Surrey, the Greater Vancouver Regional District (GVRD) and numerous commercial/industrial names.
RK 1165.4 to RK 1167.8 and from RK 1167.2 to the Fraser River at RK 1168.6	48	Sand and gravel deposit.	Low	Moderate	Moderate	Few water wells are located in this area.
RK 1169.1 close to the Fraser River to RK 1173.2	46	Sand and gravel deposit.	Low	Moderate	High	Few water wells are located in this area.
RK 1173.2 to RK 1179.4 at the southern edge of the Burnaby Terminal	49	Sand and gravel deposit	Low	Moderate	Moderate	Burnaby is supplied by GVRD water from a remote surface water source and few wells are identified in the area.

Potential groundwater-related issues identified as part of the desktop study and subsequent field work for the Hope to Burnaby segment are summarized in Table 4.1-11 below.

TABLE 4.1-11

POTENTIAL GROUNDWATER-RELATED ISSUES IN THE HOPE TO BURNABY SEGMENT

Location	Potential Groundwater Related Issue	Summary of Issue	Possible Mitigation*
RK 1047.6	Shallow unconfined aquifer; RK in the mid-point of wellfield.	Unconfined aquifer.	6
RK 1049.3 to RK 1051.6	Shallow unconfined aquifer; wells in the proposed pipeline corridor.	Unconfined aquifer.	6
RK 1054.6 to RK 1062.8	Poorly confined to unconfined, shallow (within 10 m) aquifer along the corridor; high production rates up to 800 gpm; 2 creek crossings. Field visit = Well-drained; mod-high permeability; Shallow groundwater; surface seepage; coarse sand and silt; domestic well noted.	Unconfined aquifer.	6
RK 1057.6	Two wells within the proposed pipeline corridor; somewhat confined; no identified concerns.	Shallow well.	4
RK 1062.8 to RK 1065.1	Poorly confined to unconfined aquifer within 20 m; high production rates likely.	Unconfined aquifer.	6
RK 1077.3 to RK 1089.9	Potentially confined aquifer; 20 to 30 m thick; a few wells identified; low to medium concerns.	Unconfined aquifer.	6
RK 1080.1 to RK 1083.1	Entire length of corridor over an unconfined; prolific aquifer; 20-30 m thick; numerous wells identified.	Unconfined aquifer.	6
RK 1089.9 to RK 1094.2	Shallow sandy aquifer, top at 8-10 m; mostly unconfined; high rates; entire area should be classified sensitive.	Unconfined aquifer.	6
RK 1094.2 to RK 1094.9	Chilliwack/Vedder Aquifer; sensitive zone. Field visit = New subdivision - could have wells; coarse sandy till; cobbles.	Unconfined aquifer.	6
RK 1094.9 to RK 1097.9	Shallow sandy aquifer; top at 810 m; mostly unconfined; expected high production rates; entire area should be classified sensitive; no wells marked in corridor.	Unconfined aquifer.	6
RK 1097.9 to RK 1101.1	Chilliwack/Vedder Aquifer; sensitive zone	Unconfined aquifer.	6
RK 1101.2 to RK 1104.7	Chilliwack/Vedder Aquifer; sensitive zone; no confining layers; shallow; Chilliwack/Vedder River crossing at RK 1102.6.	Unconfined aquifer.	6
RK 1104.7 to RK 1107.5	Chilliwack/Vedder Aquifer; sensitive zone; no confining layers; shallow.	Unconfined aquifer.	6
RK 1114.6 to RK 1114.7	Sumas River crossing.	River.	2
RK 1147.4	Wells in the proposed pipeline corridor; confined aquifer at 60 + m bgl; Salmon River crossing at RK 1147.8.	Shallow well.	4
RK 1159	Numerous wells in the corridor; some dry; some 120 m deep; some very shallow (< 20 m); high to medium sensitivity.	Shallow well.	4
RK 1168.6 to RK 1169.3	Fraser River crossing.	River.	2

Note: - More detailed information is provided in Appendix B.

4.1.5 Burnaby to Westridge Segment

The Burnaby to Westridge Segment extends approximately 5 km from the Burnaby Terminal to the Westridge Marine Terminal along the Burrard Inlet. Please note, the RK designations restart at the Burnaby Terminal. The Westridge Marine Terminal will be expanded under the Project.

No surface water crossings have been identified along the proposed pipeline corridor and no HDD crossings are proposed through this segment.

Ground elevations decrease from approximately 175 m asl at Burnaby to 0 m asl at the Westridge Marine Terminal. Groundwater flows generally follow local topography with recharge occurring directly over the aquifers and discharge feeding the local river systems and Burrard Inlet.

Regional surficial geology for the Burnaby to Westridge Segment is summarized in Table 4.1-12.

TABLE 4.1-12

SURFICIAL GEOLOGY FROM RK 0 TO RK 3.6

RK	Surficial Sediment Description
RK 0 to RK 1	Capilano Sediments – raised beach deposits consisting of poorly sorted sand to gravel 1-8 m thick.
RK 1 to RK 2.8	Vashon Drift and Capilano sediments generally <8 m thick but up to 25 m thick of till and interbeds of glaciofluvial sand to gravel.
RK 2.8 to RK 3.6 (Westridge Marine Terminal)	Undivided pre-Vashon till, glacio-fluvial and marine sediments.

Source: Armstrong and Hicock 1980

Additional description of surficial geology for this segment is described in Section 5.1.1.5.

Aquifer #49 is mapped in the Burnaby area from RK 1.7 to RK 3.5. This aquifer is described as a Quadra Sands deposit with low demand, moderate productivity and vulnerability. The locations of aquifers are shown on maps in Appendix A. Burnaby is supplied by GVRD water from a remote surface water source and few wells are identified in the area.

No additional aquifers are identified between RK 3.5 and the Westridge Marine Terminal at RK 3.6.

More detailed information is provided in Appendix B.

4.1.6 Edmonton Terminal

The Edmonton Terminal is located at RK 0. Land use in the area is noted as disturbed industrial. The terrain is reported to be generally level and groundwater flow likely follows topography towards the North Saskatchewan River which lies 1,100 m to the northwest of the site. At the site, groundwater flow direction was noted by EBA Engineering Consultants Ltd. (2012) to the northwest with local southwest directed groundwater flow in the southwest corner of the site. The surficial geology beneath the site is mapped lacustrine fine sediment silt and clay in the northwest half; the southwest half is underlain by a stagnation moraine glacial till of uneven thickness (Shetsen 1990). One water well record indicated as a spring is located in or near the site at SW-05-053-23 W4M (ESRD 2013). No water supply wells are mapped within the site boundary and no wells are located within the surrounding Water Quality and Quantity LSA (ESRD 2013).

The Edmonton Terminal does not overlie any mapped aquifers.

Historical known spills at the Edmonton Terminal will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Facilities EPP of Volume 6C) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

4.1.7 Gainford Pump Station

The Gainford Pump Station is located at RK 117.5. Land use in the area is noted as industrial and forested. The terrain is reported to be generally level and groundwater flow likely follows topography towards Wabamun Lake which lies 1,800 m to the southeast of the site. The surficial geology beneath the site is mapped stagnation moraine glacial till of uneven thickness (Shetsen 1990). No water supply wells are mapped within the site boundary (ESRD 2013). Four water well records are indicated within NE 13-053-06 W5M designated as domestic use (ESRD 2013). Additional water well records are noted to the east in 13-18-053-05 W5M with depths of 36 m and water levels ranging from 7.9 to 18.2 m bgl. These wells are all deeper than 30 m with water levels in the range of 0.9 to 23 m bgl (ESRD, 2013).

The Gainford Pump Station does not overlie any mapped aquifers.

4.1.8 Wolf Pump Station

The Wolf Pump Station is located at RK 206.2. Land use in the area is noted as Industrial and forested. The terrain is reported as sloping slightly from south to north and groundwater flow likely follows topography towards January Creek located 160 m to the northwest. The surficial geology beneath the site is mapped as Edson Till consisting of moraine deposits stones in a silty clay matrix (Roed 1970). Water well records indicate 3 flowing shot-holes within the Water Quality and Quantity LSA; two nearby water wells have water levels of approximately 4 to 6 m bgl. No water supply wells are mapped within the site boundary (ESRD 2013).

The Wolf Pump Station does not overlie any mapped aquifers.

4.1.9 Edson Pump Station

The Edson Pump Station is located at RK 247.1. Land use in the area is noted as Industrial. The terrain is reported generally level with a gentle slope from north to south. Groundwater flow likely follows topography towards Sundance Creek approximately 150 m to the south. The surficial geology beneath the site is mapped as Marlboro Till consisting of moraine deposits stones in a silty clay matrix and the underlying materials in the southwest half of the site consist of glaciolacustrine lake sediments (Roed 1970). Water wells, for which information is available, are completed in bedrock. No water supply wells are mapped within the site boundary (ESRD 2013).

The Edson Pump Station does not overlie any mapped aquifers.

4.1.10 Hinton Pump Station

The Edson Pump Station is located at RK 339.4. Land use in the area is noted as Industrial and forested. The terrain is reported sloping from west to east and groundwater flow likely follows topography towards Maskuta Creek located approximately 280 m to the east-southeast. The surficial geology beneath the site is mapped as moraine silty sand till (unsorted clay to bolder size material) (Roed 1970). No water well records are noted at the facility site or within the Water Quality and Quantity LSA. No water supply wells are mapped within the site boundary (ESRD 2013).

The Edson Pump Station does not overlie any mapped aquifers.

4.1.11 Jasper Pump Station

The Jasper Pump Station is located at NW 2-46-1 W6M. Land use in the area is noted as industrial. The terrain is reported sloping slightly from west to east and groundwater flow likely follows topography towards the Athabasca River located approximately 500 m to the east. The surficial geology beneath the site is mapped as glaciofluvial deposits (Holland and Coen 1983). Four water well records occur near the site and within the Water Quantity and Quality LSA; these indicate groundwater depths of 5 to 28 m bgl. One water supply well (possibly ID #442074) owned by ATCO Electric Ltd. is located within the Water Quality and Quantity (ESRD 2013) withdrawing water from 37 m bgl.

Historical known spills at the Jasper Pump Station will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Facilities EPP of Volume 6C) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

The Jasper Pump Station does not overlie any mapped aquifers.

4.1.12 Rearguard Pump Station

The Rearguard Pump Station, located at approximately RK 498.3. Land use in the area is noted as industrial and disturbed forested lands.

The terrain is reported to be generally level and groundwater flow likely follows topography towards southwest towards the Fraser River. The surficial geology beneath the site is mapped as predominantly Glaciofluvial and lacustrine sediments (Archand 1973, BGC Engineering 2013). No water supply wells are mapped within the site boundary nor within the surrounding Water Quality and Quantity LSA (BC MOE 2013). Groundwater levels in the area are expected to be moderately deep based on water well records identified east and west of the station.

The Rearguard Pump Station does not overlie any mapped aquifers (BC MOE 2013).

4.1.13 Blue River Pump Station

The existing Blue River Pump Station is located at approximately RK 614.7. Land use in the area is noted as industrial.

The terrain is generally level. Groundwater flow direction is likely toward Eleanor Lake approximately 150 m to the east-northeast; there may also be a component of groundwater flow to the southwest toward the North Thompson River. The surficial geology beneath the site is mapped as predominantly fluvial (Tipper 1971). No water supply wells are mapped within the site boundary; however, one well is located within the surrounding Water Quality and Quantity LSA (BC MOE 2013). Groundwater levels in the area are expected to be moderately deep based on water well records identified southwest of the station.

The Blue River Pump Station does not overlie any mapped aquifers (BC MOE 2013).

4.1.14 Blackpool Pump Station

The existing Blackpool Pump Station is located at approximately RK 736.8. Land use in the area is noted as industrial. The terrain generally level and groundwater flow likely follows topography south and southwest towards the North Thompson River. The surficial geology beneath the site is mapped as predominantly fluvial (Tipper 1971). Seacor Environmental Inc (2005) mapped the materials beneath the site as consisting of gravel and sand fill to 1.5 m bgl then sand to 2.4 m bgl; gravel was encountered to a depth of 10.7 m bgl (depth of investigation). No water supply wells are mapped within the site boundary and one well is located within the surrounding Water Quality and Quantity LSA (BC MOE 2013). Monitoring wells at the site indicate groundwater levels ranged from 2.7 m bgl to 3.5 m bgl.

The Blackpool Pump Station does not overlie any mapped aquifers (BC MOE 2013).

Historical known spills at the Blackpool Pump Station will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Facilities EPP of Volume 6C) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

4.1.15 Darfield Pump Station

The existing Darfield Pump Station is located at approximately RK 769. Land use in the area is noted as industrial and agricultural. The terrain is generally level with groundwater flow likely following topography east and southeast towards the North Thompson River. The surficial geology beneath the site is mapped as predominantly fluvial (Tipper 1971). No water supply wells are mapped within the site boundary or surrounding Water Quality and Quantity LSA (BC MOE 2013). Groundwater levels in the area are expected to be moderately deep based on water well records identified south of the station.

The Darfield Pump Station overlies Aquifer #293, a moderately vulnerable, sand and gravel deposit (BC MOE 2013).

4.1.16 Black Pines Pump Station

The Black Pines Pump Station will be located at approximately RK 811.9. Land use in the area is noted as forested.

The terrain is generally level with groundwater flow likely following topography towards east/southeast towards the North Thompson River. The surficial geology beneath the site is mapped as predominantly fluvial (Young 1983). No water supply wells are mapped within the site boundary or surrounding Water Quality and Quantity LSA (BC MOE 2013). Groundwater levels in the area are expected to be deep based on water well records identified south of the station.

The proposed Black Pines Pump Station overlies #283, defined as a moderately vulnerable, sand and gravel deposit (BC MOE 2013).

4.1.17 Kamloops Pump Station

The existing Kamloops Pump Station is located at RK 850.8. Land use in the area is noted as industrial.

The terrain is generally level with a gentle slope to the northeast. Groundwater flow direction is likely toward the east and then northeast to the Thompson River. The surficial geology beneath the site is mapped as ablation till (Young 1983). Two water supply wells are defined within the site boundary (ID #18637 and #14817). Well #14817 is owned and operated by Trans Mountain. One other well is located within the surrounding Water Quality and Quantity LSA (BC MOE 2013). Groundwater levels in the area are not reported, but are expected to be moderate to deep.

The Kamloops Pump Station does not overlie any mapped aquifers (BC MOE 2013).

Historical known spills at the Kamloops Pump Station will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Facilities EPP of Volume 6C) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

4.1.18 Kingsvale Pump Station

The existing Kingsvale Pump Station is located at RK 955.6. Land use in the area is noted as industrial.

The terrain slopes down to the west across the site and site drainage and groundwater flow is expected to be towards the Coldwater River located approximately 500 m west of the site. The surficial geology beneath the site is mapped as glacial till (BGC Engineering Inc. 2013). No water supply wells are located on the site and approximately 10 water wells are located within the Water Quality and Quantity LSA. Groundwater levels in the area appear variable with reported water levels from driller's records ranging from 4 to 60 m bgl.

The Kingsvale Pump Station does not overlie any mapped aquifers (BC MOE 2013).

4.1.19 Sumas Pump Station

The existing Sumas Pump Station is located at RK 1113.8. Land use in the area is noted as industrial. The terrain is level and considered relatively stable though a high water table is noted in the area. The surficial geology beneath the site is mapped as lacustrine deposits consisting of silt, clayey silt and silty clay up to 15 m thick but normally less than 3 m thick overlying sand (Armstrong 1961). One water supply well is located on the site (ID # 15012), but its current use is unknown. One other well is located within the Water Quality and Quantity LSA.

The Sumas Pump Station overlies the Sumas Prairie Aquifer, Aquifer #21, a moderately vulnerable aquifer (BC MOE 2013).

4.1.20 Sumas Terminal

The existing Sumas Tank Farm is located at RK 1117. Land use in the area is noted as industrial and undisturbed forested lands. The terrain is sloped. Groundwater flow direction inferred to be to southeast (SNC Lavalin Inc. 2013). The surficial geology beneath the site is mapped as bedrock within 7.6 m of surface covered by drift likely Sumas till (Armstrong 1961). The site is located over a topographic divide with drainage flowing to the south-southwest on the southern half of the site and to the northeast on the northern half of the site. Three water supply wells are located within the site boundaries (ID #6686, #67529 and #75552) though their uses have not been confirmed. Nine wells are located within the Water Quality and Quantity LSA. Groundwater levels are expected to be approximately 8-15 m bgl based on local monitoring wells. Depth to groundwater ranged from 1.6 m bgl to 4.2 m bgl.

The Sumas Terminal does not overlie any mapped aquifers (BC MOE 2013).

Historical known spills at the Sumas Terminal will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Facilities EPP of Volume 6C) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

4.1.21 Burnaby Terminal

The existing Burnaby Terminal is located at RK 1179.8. Land use in the area is industrial. The terrain is sloped and will require additional grading. Groundwater flow direction is inferred to be to the southwest. The surficial geology beneath the site is mapped as Capilano sediments consisting of beach deposits of poorly sorted sand to gravel normally less than 1 m thick, may be up to 8 m thick. The extreme northeast corner of the facility is underlain by Tertiary bedrock (Armstrong and Hicock 1980). The ground slopes down to the northeast across the site. No water supply wells are mapped on the site or within the Water

Quality and Quantity LSA. Stantec (2011) noted groundwater levels ranging from artesian (0.79 m above ground level) to 9.57 m bgl in on-site monitoring wells.

The southwestern corner of the Burnaby Terminal appears to overlie Aquifer #49, a moderately vulnerable aquifer, based on regional mapping (BC MOE 2013).

4.1.22 Westridge Marine Terminal

The Westridge Terminal is located at RK 3.6 on the proposed Burnaby to Westridge Segment. Land use in the area is reclaimed foreshore. The terrain is moderately sloping toward the north to Burrard Inlet. The surficial geology beneath the site consists of Vashon drift and Capilano sediments consisting of glacial drift including till, glaciofluvial sand to gravel and glaciolacustrine stony silt up to 25 m thick but in most places less than 8 m thick (Armstrong and Hicock 1980). No water supply wells are mapped on the site or within the Water Quality and Quantity LSA. The nearest water well records lie approximately 450 m to the west but no water level data were available for these wells.

The Westridge Marine Terminal does not overlie any mapped aquifers (BC MOE 2013).

4.2 Groundwater Quantity

The groundwater quantity indicator and the related measurement endpoints are summarized below in tables for each loop and facility. More detailed information is provided in Appendix B.

4.2.1 Edmonton to Hinton Segment

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) based on BGC Engineering Inc. (2013) terrain stability data:

- RK 12;
- RK 24 to RK 24.5;
- RK 27.7 to RK 28.3;
- RK 33 to RK 34;
- RK 36.8;
- RK 100 to RK 102;
- RK 107.5 to RK 109;
- RK 113.5;
- RK 135;
- RK 135.5;
- RK 220 to RK 221;
- RK 223.7;
- RK 242;
- RK 252 to RK 253;
- RK 259;
- RK 288.5 to RK 290.5;
- RK 295.5;

- RK 298.5;
- RK 302.5 to RK 303.5;
- RK 306.8;
- RK 308.7 to RK 310;
- RK 319.8 to RK 320;
- RK 323;
- RK 327.3;
- RK 330 to RK 332.3; and
- RK 333.5 to RK 335.3.

Areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater) based on occurrence of flowing (artesian) seismic shotholes, springs and wetlands:

- RK 64.5 to RK 65;
- RK 88.5 to RK 89;
- RK 89.5 to RK 93;
- RK 97.3 to RK 98;
- RK 108;
- RK 120 to RK 121;
- RK 130.5;
- RK 145.4;
- RK 153 to RK 158.5;
- RK 162 to RK 163;
- RK 176 to RK 181;
- RK 185.5;
- RK 189 to RK 190;
- RK 192;
- RK 199 to RK 214;
- RK 218 to RK 221;
- RK 229.5;
- RK 235 to RK 236;
- RK 239 to RK 240;
- RK 266;

- RK 272.5 to RK 275.5;
- RK 291.5; and
- RK 315 to RK 319.

Areas with potential artesian conditions (*i.e.,* areas where HDD are planned and potential artesian conditions are expected relative to local wells/geology) include the following:

- North Saskatchewan River at RK 33.5 – no wells within LSA;
- Pembina River at RK 135.0 – no wells within the Water Quality and Quantity LSA;
- Wolf Creek at RK 220.6 – three water well within the Water Quality and Quantity LSA; and
- McLeod River at RK 223.9 – no wells within Water Quality and Quantity LSA;

No blasting is anticipated in this segment, although at RK 108, there is a shallow well with bedrock at 3 m bgl.

4.2.2 Hargreaves to Darfield Segment

Areas susceptible to changes in groundwater flow patterns include:

- RK 489.6 to RK 496.6;
- RK 497 to RK 499.6;
- RK 500.5 to RK 506.5;
- RK 552.5 to RK 555.2;
- RK 572 to RK 576.3;
- RK 578.9 to RK 580.4;
- RK 582.8 to RK 591.3;
- RK 593.4 to RK 596.3;
- RK 597.8 to RK 600;
- RK 601.5 to RK 604.9;
- RK 605.6 to RK 607.3;
- RK 627.6 to RK 628.9;
- RK 633 to RK 635; and
- RK 746 to RK 747.9.

Areas where dewatering may be required during pipeline construction activities (*i.e.,* shallow groundwater areas):

- RK 529.1 to RK 530.1 in Aquifer #800;
- RK 545.2 to RK 551.2 near Albreda station;
- RK 560.1 to RK 567;

- RK 607.8 to RK 613.3;
- RK 615.7 to RK 617.7;
- RK 637.6 to RK 667.7;
- RK 705.7 to RK 720.4;
- RK 729.9 to RK 732.9;
- RK 739.8 to RK 740.9; and
- RK 749.9.

Areas with potential artesian conditions (HDD crossings where Project could interact with potential artesian conditions if present:

- North Thompson River at RK 581.2 – no mapped aquifer, possible artesian conditions, no wells noted;
- Blue River at RK 613.8 – Aquifer #825 – highly vulnerable with wells within corridor and Water Quality and Quantity LSA;
- unnamed channel at RK 619.8 – no mapped aquifer, possible artesian conditions, no wells noted;
- North Thompson River at RK 619.9 and RK 651.6– no mapped aquifer, possible artesian conditions, no wells noted;
- Raft River at RK 717.7 – Aquifer #807 – moderate vulnerability and Aquifer #773, low vulnerability, with multiple wells within corridor and within the Water Quality and Quantity LSA;
- Clearwater River at RK 725.5 – highly vulnerable Aquifer #770 and high density of wells within the Water Quality and Quantity LSA including community system wells for the North Thompson River Provincial Park, as well as highly vulnerable Aquifer #769; and
- Mann Creek at RK 735.0 – no mapped aquifer, but multiple wells within the Water Quality and Quantity LSA.

Areas susceptible to blasting effects (areas with shallow bedrock wells) include within Clearwater, the south side of the proposed pipeline corridor is bounded by Aquifer #772 (RK 722.5), a bedrock aquifer with moderate productivity and multiple wells within the corridor and Water Quality and Quantity LSA.

4.2.3 Black Pines to Hope Segment

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope):

- RK 821 to RK 845;
- RK 850 to RK 854;
- RK 893 to RK 905.5;
- RK 912 to RK 926.5;
- RK 932 to RK 937; and
- RK 938.5 to RK 1039.

Areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater):

- RK 844 to RK 848;
- RK 857;
- RK 867 to RK 870;
- RK 908.5 to RK 911;
- RK 950.6 to RK 959;
- RK 1033.3 to RK 1035.2; and
- RK 1036.1 to RK 1039.4.

Areas with potential artesian conditions (*i.e.,* areas where HDD are planned and potential artesian conditions are expected relative to local wells/geology):

- Thompson River at RK 846.8 – Aquifer #284 highly vulnerable, water wells within Water Quality and Quantity LSA;
- Nicola River at RK 928.0 – no mapped aquifer, water wells within Water Quality and Quantity LSA;
- Coldwater River at RK 957.9 – no mapped aquifer, water wells within Water Quality and Quantity LSA north and south of crossing;
- Coldwater River at RK 970.3 – no mapped aquifer, no wells within Water Quality and Quantity LSA;
- Coldwater River at RK 980.0 – no mapped aquifer, no wells within Water Quality and Quantity LSA;
- Coldwater River at RK 990.0; and
- Coquihalla River at RK 1043.2.

Areas susceptible to blasting effects (*i.e.,* areas with shallow wells in shallow bedrock aquifers):

- Aquifer #1009 – highly vulnerable bedrock aquifer with high density of wells in area. 2 potential drinking water system wells within the Water Quality and Quantity Water Quality and Quantity LSA; and
- Aquifers #276 and #274 - are moderately vulnerable bedrock aquifers near RK 855 and RK 865, respectively; however, no drinking water wells are mapped in the area.

4.2.4 Hope to Burnaby Segment

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope):

- RK 1051 to RK 1057; and
- RK 1060 to RK 1063.

Areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater):

- RK 1045 to RK 1065.1;
- RK 1116.6 to RK 1117; and
- RK 1154 to RK 1168.6.

Areas with potential artesian conditions (*i.e.,* areas where HDD are planned and potential artesian conditions are expected relative to local wells/geology):

- Chilliwack/Vedder River at RK 1102.1; 1102.3 and 1102.4 – potential – artesian wells reported nearby;
- Sumas River at RK 1114.6 – potential – insufficient data to confirm; and
- Fraser River at RK 1168.9 – potential – other wells along Fraser River have been reported to be artesian – insufficient data to confirm.

No blasting anticipated through this proposed pipeline corridor or within the Water Quality and Quantity Water Quality and Quantity LSA through this segment.

4.2.5 Burnaby to Westridge Segment

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope):

- possibly from RK 1180.7 to RK 1182.

Areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater):

- insufficient information to assess – no groundwater level data available.

Construction activities not expected to be deep enough to encounter artesian conditions through this segment. No blasting anticipated through this proposed pipeline corridor or within the Water Quality and Quantity Water Quality and Quantity LSA through this segment.

4.2.6 Facilities and Terminals

The facilities and terminals considered in this section for groundwater quantity include:

- Edmonton Terminal;
- Gainford Pump Station;
- Wolf Pump Station;
- Edson Pump Station;
- Hinton Pump Station;
- Jasper Pump Station;
- Rearguard Pump Station;
- Blue River Pump Station;
- Blackpool Pump Station;
- Darfield Pump Station;
- Black Pines Pump Station;
- Kamloops Pump Station;
- Kingsvale Pump Station;
- Sumas Pump Station;

- Sumas Terminal;
- Burnaby Terminal; and
- Westridge Marine Terminal.

4.2.6.1 Edmonton Terminal

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There is insufficient information available in the provincial water well database to assess whether there are areas where dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater).

Construction activities not expected to be deep enough to encounter artesian conditions through this section. No blasting anticipated at this facility or within the Water Quality and Quantity LSA through this section.

4.2.6.2 Gainford Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There is insufficient information available in the provincial water well database to assess whether there are areas where dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater). One water well record (ID# 471241) indicates a depth to water of 0.91 m whereas other wells in the vicinity of the pump station (*e.g.,* ID# 471242) indicates a depth to groundwater of 18.3 m.

No blasting is anticipated at the pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.3 Wolf Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

Water well records in the provincial database indicate there are flowing seismic shotholes in the vicinity of the site suggesting shallow groundwater and possible artesian conditions. This suggests there are areas where dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.4 Edson Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There is insufficient information available in the provincial water well database to assess whether there are areas where dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater). Depths to groundwater vary from 4.3 to 23.3 m bgl.

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.5 Hinton Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There is insufficient information available in the provincial water well database to assess whether there are areas where dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.6 Jasper Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

Monitoring wells at the site indicate that the depth to groundwater is in excess of 20 m bgl indicating that dewatering is unlikely to be required during construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.7 Rearguard Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There is insufficient information available in the provincial water well database to assess whether there are areas where dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.8 Blue River Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There is insufficient information available in the provincial water well database to assess whether there are areas where dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater). Depth to ground water in wells is generally greater than 6 m.

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.9 Blackpool Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There is potential for shallow groundwater based on observed ponded water on-site, thus dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.10 Darfield Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There is insufficient information available in the provincial water well database to assess whether there are areas where dewatering may be required during construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.11 Black Pines Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

There may be areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater) because the site is located adjacent to the North Thompson River.

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.12 Kamloops Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

Insufficient information to assess whether there are areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.13 Kingsvale Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

Based on information from local wells, areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater) are not expected.

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.14 Sumas Pump Station

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are dependent on the degree of dewatering required.

A shallow water table is anticipated suggesting that dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this pump station or within the Water Quality and Quantity LSA through this section.

4.2.6.15 Sumas Terminal

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

Areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater) are not anticipated.

No blasting anticipated at this terminal or within the Water Quality and Quantity LSA through this section.

4.2.6.16 Burnaby Terminal

Areas susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope) are not anticipated.

Areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater) are not anticipated.

No blasting anticipated at this terminal or within the Water Quality and Quantity LSA through this section.

4.2.6.17 Westridge Marine Terminal

The pipeline cuts perpendicular to slope along northern edge of the Westridge Marine Terminal. The slope areas are susceptible to changes in groundwater flow patterns (*i.e.,* areas where the pipeline cuts across a slope).

Potential shallow groundwater conditions expected adjacent to Burrard Inlet. These are areas where dewatering may be required during pipeline construction activities (*i.e.,* areas of shallow groundwater).

No blasting anticipated at this terminal or within the Water Quality and Quantity LSA through this section.

4.3 Groundwater Quality

The groundwater quality indicator and the related measurement endpoints are summarized below in tables for each segment and facility. The information is grouped by groundwater quality endpoint.

4.3.1 Edmonton to Hinton Segment

Shallow groundwater with potential existing contamination:

- RK 272.2 - Historical known spills on the pipeline will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Pipeline EPP of Volume 6B) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

Areas susceptible to drilling mud release during HDD construction and areas with potential artesian conditions:

- North Saskatchewan River at RK 33.5 – no wells within the Water Quality and Quantity LSA;
- Pembina River at RK 135.0 – one water well within the Water Quality and Quantity Water Quality and Quantity LSA;
- Wolf Creek at RK 220.6 – one water well within the Water Quality and Quantity Water Quality and Quantity LSA; and
- McLeod River at RK 223.9 – no wells within the Water Quality and Quantity LSA.

Areas susceptible to siltation in the aquifer and vulnerable areas or wells to possible contamination from accident or malfunction:

- conditions are generally moderate to high risk immediately west of Edmonton through to Township 053, Range 02 W5M;
- Wabumun Lake area is mapped as higher risk of groundwater contamination and community concerns exist in this area due to a petroleum hydrocarbon spill that occurred a few years ago and affected the aquifer and lake. The Wabumun Lake Provincial Park is also located within this area;
- the eastern half of Yellowhead County is more predominantly low risk grading to moderate or higher risk near the Town of Edson; and
- between Edson and Hinton, the regional mapping shows that the risk of groundwater contamination is generally high.

No blasting anticipated through this proposed pipeline corridor or within the Water Quality and Quantity Water Quality and Quantity LSA through this section.

No areas or wells appear to be vulnerable to possible contamination from an accident or malfunction:

4.3.2 Hargreaves to Darfield Segment

Shallow groundwater with potential existing contamination:

- RK 491.5 and RK 493.6 - Historical known spills on the pipeline will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Pipeline EPP of Volume 6B) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

Areas susceptible to drilling mud release during HDD construction and areas with potential artesian conditions:

- Blue River at RK 613.8 – Aquifer #825 – highly vulnerable with wells within corridor and Water Quality and Quantity LSA;
- Raft River at RK 717.7 – Aquifer 807 – moderate vulnerability and Aquifer #773, low vulnerability, with multiple wells within corridor and within the Water Quality and Quantity Water Quality and Quantity LSA;
- Clearwater River at RK 725.5 – highly vulnerable Aquifer #770 and high density of wells within the Water Quality and Quantity LSA including community system wells for the North Thompson River Provincial Park; and
- Mann Creek at RK 735.0 – no mapped aquifer, but multiple wells within the Water Quality and Quantity LSA.

Areas susceptible to siltation in the aquifer (vulnerable aquifers only):

- Aquifer #825 - highly vulnerable aquifer near the Village of Blue River (RK 613.7);
- Aquifer #770, a highly vulnerable aquifer at RK 723 in Clearwater;
- Aquifer #769, a highly vulnerable aquifer to RK 728.9; and
- The North Thompson River Provincial Park, near Clearwater, is supplied by two water wells that are located in proximity to the proposed pipeline corridor.

Areas susceptible to blasting effects:

- within Clearwater, the south side of the proposed pipeline corridor is bounded by Aquifer #772 (RK 722.4), a bedrock aquifer with moderate productivity and multiple wells within the corridor and Water Quality and Quantity LSA.

Areas or wells vulnerable to possible contamination from an accident or malfunction (highly to moderately vulnerable aquifers have been included where potential drinking water systems have been identified):

- a moderately vulnerable glaciofluvial sand and gravel aquifer (#800) is mapped within the Valemont area;
- within Clearwater, the south side of the proposed pipeline corridor is bounded by Aquifer #772, a bedrock aquifer with moderate vulnerability, but relatively high density for the area;
- Aquifer #770, a high vulnerability aquifer located at RK 723.1 also in Clearwater;

- Aquifer #769, a highly vulnerable aquifer located near RK 728; and
- the North Thompson River Provincial Park is supplied by two water wells that are located in proximity to the proposed pipeline corridor.

4.3.3 Black Pines to Hope Segment

Shallow groundwater with potential existing contamination:

- RK 866.7 and RK 968.1 - Historical known spills on the pipeline will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Pipeline EPP of Volume 6B) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

Areas susceptible to drilling mud release during HDD construction:

- Thompson River at RK 846.8 – Aquifers #282 and #284 – both highly vulnerable – School District #68 well on north side of Thompson River, Trans Mountain well on south side;
- Nicola River at RK 928.0 – insufficient information about aquifer or nearby well ID #98214 (within the Water Quality and Quantity LSA);
- multiple Coldwater River crossings at RK 957.9, RK 970.3, RK 980.0, and RK 990.0 - insufficient information about aquifer, however, no water wells within the Water Quality and Quantity LSA; and
- Coquihalla River at RK 1043.2 – potential highly vulnerable bedrock aquifer #1009, high density of wells in area, 2 potential drinking water system wells within the Water Quality and Quantity LSA.

Areas susceptible to siltation in the aquifer (vulnerable aquifers only):

- Aquifers #282 and 284 – both highly vulnerable – School District #68 well on north side of Thompson River, Trans Mountain well on south side;
- Aquifer #1009 – highly vulnerable aquifer near RK 1041.8;
- Aquifer #1007 – highly vulnerable aquifer near RK 1043.3; and
- Aquifer #1 – highly vulnerable aquifer in the Hope area.

Areas susceptible to blasting effects:

- Aquifer #1009 – highly vulnerable bedrock aquifer with high density of wells in area. 2 potential drinking water system wells within the Water Quality and Quantity LSA; and
- Aquifers #276 and #274 - are moderately vulnerable bedrock aquifers near RK 854.9 and RK 865.8, respectively; however, no drinking water wells are mapped in the area.

Areas or wells vulnerable to possible contamination from an accident or malfunction (highly to moderately vulnerable aquifers have been included where potential drinking water systems have been identified)

- Thompson River at RK 846.8 – Aquifers #282 and #284 – both highly vulnerable – School District #68 well on north side of Thompson River, Trans Mountain well on south side;
- Aquifer #1005 – moderate vulnerability aquifer near RK 1042.2 – District of Hope drinking water supply wells are noted in this aquifer;
- Aquifer #1009 – highly vulnerable aquifer near RK 1041.9;
- Aquifer #1007 – highly vulnerable aquifer near RK 1043.3;

- Aquifer #1 – highly vulnerable aquifer in the Hope area; and
- well densities in the Kamloops, Merritt and Hope areas are considered high in proximity to the proposed pipeline corridor in these areas. A District of Hope community well and two drinking water system wells are identified in Aquifer #1005 potentially within the corridor (RK 1040.1). Spectra Energy Corporation operates a water supply system well near RK 952.8 that is within 200 m of the corridor. The Coldwater First Nation's water supply wells are identified in proximity to the existing pipeline corridor and are approximately 1,220 m from RK 642.5 of the proposed pipeline corridor.

4.3.4 Hope to Burnaby Segment

Shallow groundwater with potential existing contamination was not noted in this segment.

Areas susceptible to drilling mud release during HDD construction:

- Chilliwack/Vedder River at RK 1102.1, RK 1102.3 and RK 1102.4 – Aquifer #8 - highly vulnerable aquifer;
- Sumas River at RK 1114.6 – potential although insufficient data to confirm; and
- Fraser River at RK 1168.9 – highly vulnerable aquifer, but no water wells within proposed pipeline corridor or Water Quality and Quantity LSA.

Areas susceptible to siltation in the aquifer (vulnerable aquifers only):

- Aquifer #1 – highly vulnerable aquifer in the Hope area between approximately RK 1045.2 to RK 1051.5;
- Aquifer #3 - highly vulnerable aquifer south from Hope to approximately RK 1065.1;
- Aquifer #6 – 'Chilliwack-Rosedale' - highly vulnerable aquifer from RK 1077.1 to RK 1094. The proposed pipeline corridor crosses in proximity to several probable drinking water systems with wells in this aquifer including the Tzeachten Indian Reserve;
- Aquifer #8 – 'Vedder River Fan Aquifer' - highly vulnerable aquifer in the Chilliwack area from RK 1094. The City of Chilliwack community wells are located within this aquifer and the mapped well capture zones cross the proposed pipeline corridor;
- Aquifer #16 – highly vulnerable aquifer located between RK 1129.9 and RK 1130.7. A high density of wells exist in proximity to the corridor in this area;
- Aquifer #30 – highly vulnerable aquifer located between RK 1133 to RK 1133.9. A high density of wells exist in proximity to the corridor in this area; and
- Aquifers #35 (Hopington) and #36 are not located directly beneath the corridor, but are located within the Water Quality and Quantity LSA. Both aquifers are described as having high vulnerability.

Areas with potential artesian conditions:

- Chilliwack/Vedder River at RK 1102.1, RK 1102.3 and RK 1102.4 – potential – artesian wells reported nearby;
- Sumas River at RK 1114.6 – potential – insufficient data to confirm; and
- Fraser River at RK 1168.9 – potential – other wells along Fraser River have been reported to be artesian – insufficient data to confirm.

No blasting anticipated through this proposed pipeline corridor or within the Water Quality and Quantity LSA through this section.

Areas or wells vulnerable to possible contamination from an accident or malfunction (highly to moderately vulnerable aquifers have been included where potential drinking water systems have been identified):

- Aquifer #1 – highly vulnerable aquifer in the Hope area between approximately RK 1045.2 to RK 1052.1;
- Aquifer #3 - highly vulnerable aquifer south from Hope to approximately RK 1065.1;
- Aquifer #6 – 'Chilliwack-Rosedale' - highly vulnerable aquifer from RK 1077.1 to RK 1094. The proposed pipeline corridor crosses in proximity to several probable drinking water systems with wells in this aquifer including the Tzeachten Indian Reserve;
- Aquifer #8 – 'Vedder River Fan Aquifer' - highly vulnerable aquifer in the Chilliwack area from RK 1094. The City of Chilliwack community wells are located within this aquifer and the mapped well capture zones cross the proposed pipeline corridor;
- Aquifer #16 - located between RK 1129.9 and RK 1130.7, is a Sumas Drift sand and gravel aquifer with low demand, moderate productivity and high vulnerability. A high density of wells exist in proximity to the corridor in this area;
- Aquifer #30 – highly vulnerable aquifer located between RK 1133 to RK 1133.9. A high density of wells exist in proximity to the corridor in this area;
- Aquifers #35 (Hopington) and #36 are not located directly beneath the corridor, but are located within the Water Quality and Quantity LSA. Both aquifers are described as sand and gravel aquifers with high vulnerability;
- Aquifer #58 (Nicomeki-Serpentine), located between RK 1145.5 and RK 1158.8, is a sand and gravel aquifer with low vulnerability according to provincial mapping; however, several potential drinking water systems owned by the Township of Langley and a Langley School, among others, were identified. Water levels in this aquifer range from shallow to moderate depths. A high density of wells exist in proximity to the corridor in this area; and
- Aquifer #61, located between RK 1163.4 and RK 1168.4, is described as a Quadra Sand aquifer with low vulnerability; a high density of wells exist south of the corridor from RK 1164.5 to RK 1165.5.

4.3.5 Burnaby to Westridge Segment

Shallow groundwater with potential existing contamination was not noted in this segment.

No HDDs planned within proposed pipeline corridor or within the Water Quality and Quantity LSA through this section.

No vulnerable aquifers mapped beneath proposed pipeline corridor or within the Water Quality and Quantity LSA through this section.

Construction activities not expected to be deep enough to encounter artesian conditions through this section.

No blasting anticipated through this proposed pipeline corridor or within the Water Quality and Quantity LSA through this section.

No vulnerable aquifers or water wells identified beneath proposed pipeline corridor or within the Water Quality and Quantity LSA through this section.

4.3.6 Facilities and Terminals

The facilities and terminals considered in the groundwater quality indicator section include:

- Edmonton Terminal;
- Gainford Pump Station;
- Wolf Pump Station;
- Edson Pump Station;
- Hinton Pump Station;
- Jasper Pump Station;
- Rearguard Pump Station;
- Blue River Pump Station;
- Blackpool Pump Station;
- Darfield Pump Station;
- Black Pines Pump Station;
- Kamloops Pump Station;
- Kingsvale Pump Station;
- Sumas Pump Station;
- Sumas Terminal;
- Burnaby Terminal; and
- Westridge Marine Terminal.

The discussions below are grouped by measurement endpoint for the groundwater quality indicator.

4.3.6.1 Shallow Groundwater With Potential Existing Contamination

Edmonton Terminal

For details refer to Section 5.1.6.

Jasper Pump Station

For details refer to Section 5.1.11.

Blackpool Pump Station

Historical known spills at the Blackpool Pump Station will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Facilities EPP of Volume 6C) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

Kamloops Pump Station

Historical known spills at the Kamloops Pump Station will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Facilities EPP of Volume 6C) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

Sumas Terminal

For details refer to Section 5.1.20.

Burnaby Terminal

Historical known spills at the Burnaby Terminal will be monitored during construction. If contamination is found or anticipated, the Contamination Discovery Contingency Plan (Appendix B of the Facilities EPP of Volume 6C) will be implemented. Following construction and if groundwater contamination is anticipated to be affected, groundwater sampling and remediation would be completed.

4.3.6.2 Areas Susceptible to Drilling Mud Release During HDD Construction

No planned trenchless crossing or horizontal directional drilling activities are planned at any of the terminals or facilities.

4.3.6.3 Areas Susceptible to Siltation in the Aquifer

The following facilities or terminals do not have vulnerable aquifers mapped beneath the facility or within the Water Quality and Quantity LSA:

- Edmonton Terminal;
- Wolf Pump Station;
- Jasper Pump Station;
- Rearguard Pump Station;
- Blackpool Pump Station;
- Kingsvale Pump Station; and
- Westridge Marine Terminal.

The following facilities or terminals have possible or vulnerable aquifers mapped beneath the facility or within the Water Quality and Quantity LSA:

- Gainford Pump Station - lies just north of a possible aquifer;
- Edson Pump Station - overlies a possible aquifer;
- Hinton Pump Station - overlies a possible aquifer
- Blue River Pump Station overlies Aquifer #825,a sand and gravel deposit of high vulnerability;
- Darfield Pump Station - overlies Aquifer #293 a sand and gravel deposit of moderate vulnerability;
- Black Pines Pump Station - overlies Aquifer #283 a sand and gravel deposit of moderate vulnerability;
- Kamloops Pump Station - lies just north of bedrock aquifer #276 within the Water Quality and Quantity LSA;
- Sumas Pump Station - overlies Aquifer #21 a sand and gravel deposit of moderate vulnerability;

- Sumas Terminal - at its northern edge overlies Aquifer #987 a bedrock aquifer of low vulnerability; and
- Burnaby Terminal - at its south western edge overlies Aquifer #49 a sand and gravel deposit of moderate vulnerability.

4.3.6.4 Areas With Potential Artesian Conditions

Construction activities are not anticipated to be deep enough to encounter artesian conditions at any of the above facilities and terminals.

4.3.6.5 Areas Susceptible to Blasting Effects

Blasting is not an anticipated activity at any of the terminals or pump stations.

4.3.6.6 Areas or Wells Vulnerable to Possible Contamination From an Accident or Malfunction

The following facilities or terminals do not have vulnerable water wells or aquifers mapped beneath the facility or within the Water Quality and Quantity LSA:

- Rearguard Pump Station;
- Blackpool Pump Station; and
- Westridge Marine Terminal.

The following facilities or terminals have water wells or possible or vulnerable aquifers mapped beneath the facility or within the Water Quality and Quantity LSA:

- Edmonton Terminal - a water well is indicated within the site ;
- Gainford Pump Station - water well records and possible aquifer located within Water Quality and Quantity LSA;
- Wolf Pump Station - a water well is located within the Water Quality and Quantity LSA;
- Edson Pump Station - water well records and possible aquifer located within the Water Quality and Quantity LSA;
- Hinton Pump Station - overlies a possible aquifer; no water well records within Water Quality and Quantity LSA;
- Jasper Pump Station - water well records within the site and the Water Quality and Quantity LSA;
- Blue River Pump Station - water well records within Water Quality and Quantity LSA and overlies Aquifer #825,a sand and gravel deposit of high vulnerability;
- Darfield Pump Station - overlies Aquifer #293 a sand and gravel deposit of moderate vulnerability;
- Black Pines Pump Station - overlies Aquifer #283 a sand and gravel deposit of moderate vulnerability;
- Kamloops Pump Station – water well records within the site and within the Water Quality and Quantity LSA; it also lies just north of bedrock aquifer #276 within the Water Quality and Quantity LSA;
- Kingsvale Pump Station – water well records within the Water Quality and Quantity LSA;
- Sumas Pump Station – water well record within the site and it overlies Aquifer #21 a sand and gravel deposit of moderate vulnerability;

- Sumas Terminal – water well records within the site and within the Water Quality and Quantity LSA; also at its northern edge overlies Aquifer #987 a bedrock aquifer of low vulnerability; and
- Burnaby Terminal at its south western edge overlies Aquifer #49 a sand and gravel deposit of moderate vulnerability.

5.0 DISCUSSION AND MITIGATION RECOMMENDATIONS

The selection of indicators for groundwater quality and quantity were based on the NEB *Filing Manual* requirements, experience gained during previous projects with similar conditions/potential issues, feedback from stakeholders, relevant scientific studies including various maps, drilling records, water wells, groundwater information, field inspection and professional judgement of the assessment team. The following section identifies the potential effects of the Project on groundwater indicators and provides recommended mitigation measures.

5.1 Pipeline

5.1.1 Potential Effects

Potential effects of pipeline construction and operation on water quality and quantity indicators are listed in Table 5.1-1. These interactions are based on: results of the literature review; desktop analysis; field work; interviews; consultation with landowners, regulatory authorities, stakeholders and the general public as well as the professional experience of the assessment team.

Standard pipeline construction activities are designed to avoid diversion and/or unnatural retention of water along the construction right-of-way by following recommendations from various industry and provincial guidelines (AENV 1988, 1994a; BC OGC 2013; CAPP 1999; CAPP *et al*. 2005). In addition, applicable measures from several industry and provincial and federal regulatory guidelines have been incorporated into Table 4.1-1 to reduce the severity of the potential effects of pipeline construction and operation on groundwater indicators including groundwater regulations under the BC *Oil and Gas Activities Act* (*Environmental Protection and Management Regulation*) and the BC *Environmental Assessment Act*.

The potential direct and indirect effects of an operational pipeline are evaluated in Volume 7, including the risk of a spill, spill response plans, and the potential effects of hypothetical spill scenarios.

TABLE 5.1-1

POTENTIAL EFFECTS AND MITIGATION MEASURES OF PIPELINE CONSTRUCTION AND OPERATION ON GROUNDWATER INDICATORS

	Potential Effect	Pipeline Segment(s)	Spatial Boundary[1]	Key Recommendations/Mitigation Measures [EPP Reference][2]
1.	**Water Quality and Quantity Indicator – Groundwater Quality**			
1.1	Shallow groundwater with existing contamination encountered during trenching.	All, but predominantly urban areas <u>Black Pines to Hope</u> RK 844.8 to RK 845.8	LSA	• Ensure an environmental monitor with experience in contaminated sites is present to check for indications of potential groundwater contamination (*i.e.*, sheen, odour, adjacent soil staining) during pipeline trench excavation in areas where there is higher potential for encountering contamination (e.g., urban areas). Where groundwater contamination is suspected the groundwater should be sampled and analyzed by an accredited laboratory [Section 8.3]. • Ensure contaminated soil and water are not transported off-site or disposed until analytical results have been received as per federal and provincial regulations. The Construction Manager and Environmental Inspector will provide notification as to when excavations can be backfilled [Section 8.3]. • Notify and adhere to the advice of the Trans Mountain Environment, Health and Safety Department or Trans Mountain's Lead Environmental Inspector and Environmental Inspector(s) at locations where water potentially contaminated with hydrocarbons or other materials is to be discharged from the trench. Measures may include the use of tank trucks to haul discharged water to an appropriate disposal facility/site, ensuring the intake is submerged below the surface sheen, lab testing and use of sorbent booms to hold the sheen away from the pump intake [Section 8.3].

TABLE 5.1-1 Cont'd

Potential Effect	Pipeline Segment(s)	Spatial Boundary[1]	Key Recommendations/Mitigation Measures [EPP Reference][2]
1.2 Areas susceptible to drilling mud release during trenchless crossing construction.	All	LSA	• Conduct investigations prior to the commencement of drilling activities to assess groundwater conditions and risks (water supply wells within LSA) in highly vulnerable aquifers. Modify the drill path of the horizontal directional drill, if feasible, to reduce the potential effects on groundwater quality and, if warranted, monitor water supply wells in the immediate area before, during and after the horizontal directional drill. Have plans in place for the supply of alternate water in the event that water quality in the wells is affected. [Section 8.7] • Plan for and use the procedures for a HDD or other trenchless crossing in accordance with those provided in the Horizontal Directional Drilling/Trenchless Planning and Procedures Management Plan (see Appendix C) [Section 8.7]. • Ensure that drilling mud composition is limited to bentonite mud drilling systems, fresh water and, if warranted, other inert additives [Appendix B]. • Cease trenchless crossing work immediately and refer to the Drilling Mud Release Contingency Plan (see Appendix B) in the event that an inadvertent release of drilling mud has occurred and the material is entering or may enter the watercourse or affect other sensitive environmental or land use features [Section 8.7]. • Follow the drilling mud frac-out monitoring and other measures outlined in the Drilling Mud Release Contingency Plan (see Appendix B) during horizontal directional drilling [Section 8.7].
1.3 Areas susceptible to sedimentation in the aquifer.	All	LSA	• Assess permeability of aquifer materials to determine the potential for sediment migration during trenching over highly vulnerable aquifers. Where poorly graded and coarse material is observed, filter fabric will be installed at the base of the trench to prevent migration of fine sediment into the aquifer, where feasible [Section 8.3].
1.4 Areas susceptible to blasting effects	All	LSA	• Notify landowners with water supply wells within the Water Quality and Quantity LSA before blasting is carried out and conduct investigations, where warranted, to assess groundwater conditions and risks [Section 6.0]. • Initiate pre-construction monitoring, where warranted, prior to the commencement of a specific activity during construction (*e.g.*, blasting). Monitoring may be necessary prior to, during and following construction or a specific construction activity in the vicinity of water wells or springs [Section 6.0]. • During Project field studies, the hydrogeological engineer in consultation with landowners and the appropriate regulatory authorities will determine if springs and wells used for domestic purposes located in the immediate vicinity of the construction right-of-way will be sampled for water quality and flow rate prior to the start of construction. Locate and flag or fence registered or known water wells in the immediate vicinity of the construction right-of-way [Section 6.0]. • Monitor all registered or known potable water wells located within 200 m of any blasting prior to and following blasting. Monitoring will include measurement of well yields, static and pumping water levels as well as water sampling in accordance with *Canadian Guidelines for Drinking Water Quality* (Health Canada 2012) [Section 8.3]. • Re-establish or replace a potable water supply as required should a registered or known water well located within 30 m of the construction right-of-way be damaged (*i.e.*, diminishment in quantity and/or quality) during pipeline installation [Section 7.0].
1.5 Areas with potential artesian conditions.	All	LSA	• Ensure that surficial materials are hydraulically isolated before drilling to deeper depths. • Use current drilling technology to ensure mud or casing seal is effective[Section 8.3]. • Depressurize the aquifer in the vicinity of the HDD area during the subsurface crossing and casing installation operations. • Seal/cement annular space around pipeline [Section 8.3]. Abandon boreholes upon completion of the HDD.

TABLE 5.1-1 Cont'd

Potential Effect	Pipeline Segment(s)	Spatial Boundary[1]	Key Recommendations/Mitigation Measures [EPP Reference][2]
1.6 Aquifers (including unconfined aquifers) or wells vulnerable to possible future contamination from a spill during construction.	All segments for wells Unconfined aquifers: Hope to Burnaby RK 1042.2 to RK 1043.3 RK 1047.6 RK 1049.3 to RK 1051.6 RK 1054.6 to RK 1062.8 RK 1062.8 to RK 1065.1 RK 1077.3 to RK 1089.9 RK 1080.1 to RK 1083.1 RK 1089.9 to RK 1094.2 RK 1094.2 to RK 1094.9 RK 1094.9 to RK 1097.9 RK 1097.9 to RK 1101.1 RK 1101.2 to RK 1104.7 RK 1104.7 to RK 1107.5	LSA	• Utilize acceptable Management Practices for spill prevention outlined in the Pipeline EPP including in areas where higher vulnerability wells and aquifers are identified. • Ensure that during construction no fuel, lubricating fluids, hydraulic fluids, methanol, antifreeze, herbicides, biocides, or other chemicals are dumped on the ground or into waterbodies. In the event of a spill, implement the Spill Contingency Plan (see Appendix B) [Section 7.0]. • Re-establish or replace a potable water supply as required should a registered or known water well located within 30 m of the construction right-of-way be damaged (*i.e.*, diminishment in quantity and/or quality) during pipeline installation [Section 7.0].
2. Water Quality and Quantity Indicator – Groundwater Quantity			
2.1 Areas susceptible to changes in groundwater flow patterns.	All	LSA	• Monitor water encountered in the trench during trenching to determine if groundwater flow is being intercepted. If spring flow has been disrupted, seek and follow the advice of the hydrogeologist or geotechnical resource specialist to maintain cross drainage within the trench (*e.g.*, installation of subdrains, trench breakers, etc.) [Section 8.3]. • Assess the need for well points or other dewatering methods, prior to commencing trenching, to intercept groundwater at site-specific locations before it enters the trench [Section 8.3]. • Prevent the pipeline trench and bedding from becoming a conduit for increased groundwater flow. • Install trench breakers to force groundwater seepage along the pipeline trench to the surface, if springs are encountered along the route. Install subdrains, if warranted, to divert shallow groundwater flow from the right-of-way [Section 8.4]. • Install trench breakers, where warranted, at the edge of perched wetlands to prevent the pipeline trench from acting as a drain (see Trench Breaker – Watercourse/Wetland Drawing in Appendix R) [Section 8.4]. • Install subdrains in association with trench breakers as directed by Trans Mountain's engineer where there is evidence of seepage or a flowing spring on a slope once the trench is excavated (see Subdrains Drawing in Appendix R) [Section 8.4]. • Backfill clay/mineral soil first, if salvaged separately from organic material in shallow peatland areas, to ensure that cross drainage is maintained [Section 8.4]. • Ensure that the lower lift of subsoil is backfilled before the upper lift of subsoil where three lift soils handling has been conducted [Section 8.4].

TABLE 5.1-1 Cont'd

Potential Effect	Pipeline Segment(s)	Spatial Boundary[1]	Key Recommendations/Mitigation Measures [EPP Reference][2]
2.2 Disruption of shallow groundwater in high permeable materials in proximity to rivers or watercourse crossings with fluviual materials or colluvium in the substrate.	Edmonton to Hinton RK 24.1 to RK 24.4 RK 28 to RK 28.2 RK 34.4 to RK 34.6 RK 36.8 to RK 37.1 RK 134.9 to RK 135.6 RK 185.3 RK 220.6 RK 223.7 to RK 224.1 RK 224.7 to RK 225 RK 309.1 to RK 311.1 RK 319.8 to RK 320.1 RK 327.5 to RK 327.7 RK 337.2 to RK 337.5 Hargreaves to Darfield RK 559 RK 559 RK 592.9 to RK 593 RK 619.9 RK 621 to RK 622.9 RK 622.9 to RK 625.4 RK 625.4 to RK 626.9 RK 642 to RK 643.5 RK 645.3 to RK 645.8 RK 646.8 to RK 648.2 RK 649 RK 651.3 to RK 651.8 RK 659.8 to RK 660.7 RK 668.4 to RK 668.9 RK 669 to RK 671.2 RK 682.8 to RK 684.2 RK 515.9 RK 715.6 RK 734.9 to RK 735.1 RK 740.7 to RK 740.8 RK 581.1 RK 600.2 to RK 600.3 RK 613.8 Black Pines to Hope RK 927.8 to RK 928 RK 970.2 to RK 970.3 RK 980 to RK 980.1 RK 1021.8 RK 1026.5	LSA	• See mitigation measures in potential effect 2.1 of this table.
2.3 Disruption of groundwater flow where springs are encountered.	Edmonton to Hinton RK 327.5 to RK 327.7	LSA	• Monitor water encountered in the trench during trenching to determine if groundwater flow is being intercepted. If spring flow has been disrupted, seek and follow the advice of the hydrogeologist or geotechnical resource specialist to maintain cross drainage within the trench (*e.g.*, installation of subdrains, trench breakers, etc.) [Section 8.3]. • Assess the need for well points or other dewatering methods, prior to commencing trenching, to intercept groundwater at site-specific locations before it enters the trench [Section 8.3]. • Install trench breakers to force groundwater seepage along the pipeline trench to the surface, if springs are encountered along the route. Install subdrains if warranted, to divert shallow groundwater flow from the right-of-way [Section 8.4].

TABLE 5.1-1 Cont'd

Potential Effect	Pipeline Segment(s)	Spatial Boundary[1]	Key Recommendations/Mitigation Measures [EPP Reference][2]
2.4 Areas where dewatering may be necessary during pipeline construction activities.	All	LSA	• Dewater the trench, if warranted, when laying pipe in areas with high water tables. Place pumps on a tray or within an excavated sump lined with polyethylene sheeting above the ordinary high water level of the watercourse/wetland/lake. Pump water onto stable and well vegetated areas, tarpaulins or sheeting at least 50 m from the nearest waterbody in a manner that does not cause erosion or any unfiltered or silted water to re-enter a watercourse [Section 8.3]. See additional dewatering measures in Section 8.3 of the Pipeline EPP. • Use floating suction hose and elevated intake, or other measures approved by Trans Mountain's environmental inspector(s), to prevent sediment from being sucked from the bottom of the trench. Secure the pump intake a minimum of 30 cm above the bottom of the trench [Section 8.3].
2.5 Disruption of groundwater flow where shallow groundwater is encountered	<u>Hargreaves to Darfield</u> RK 522.6 RK 531.2 RK 533 RK 545.8 to RK 545.9 RK 613.7 RK 638.7 <u>Black Pines to Hope</u> RK 846.5 to RK 847.5 RK 858.3 to RK 858.5 RK 869.7 to RK 870.1 RK 881.7 RK 957.8 to RK 957.9 RK 963.1 to RK 963.6 RK 1021.8 RK 1022.9 RK 1028.6 to RK 1028.7 RK 1032.6	LSA	• See mitigation measures under potential effects 2.1 and 2.4 of this table.
2.6 Areas with potential artesian conditions, including deeply incised creek crossings.	All	LSA	• Depressurize the construction area or subsurface crossing area prior to excavation/directional drilling through, for example, drilling wells and then extracting water in order to reduce locally, the pressure in the aquifer. • Re-create the confining layers if disturbed during construction (*e.g.*, place seal/cement in annular space around pipeline).
	Deeply incised creek crossings include: <u>Hargreaves to Darfield</u> RK 514.4 RK 515.9 RK 517.8 RK 523.6 RK 534.4 RK 573.5 RK 576.3 RK 590.3 RK 611.7 to RK 611.8 RK 626.6 RK 663.2 to RK 663.5 RK 910.1 RK 561.2 RK 563.4 to RK 563.5 RK 565.9 RK 567.6 RK 571.9 RK 580.3 RK 634	LSA	• Understand hydrogeological and geotechnical conditions, and assess the risks before commencing a trenchless crossing. Complete a trenchless crossing alignment site reconnaissance, supported, where warranted, by a drilling and testing program designed to confirm hydrogeological and geotechnical conditions. Design the trenchless crossing and pipeline installation to prevent damage caused by artesian flow.

TABLE 5.1-1 Cont'd

Potential Effect	Pipeline Segment(s)	Spatial Boundary[1]	Key Recommendations/Mitigation Measures [EPP Reference][2]
2.7 Areas of shallow groundwater susceptible to blasting effects.	All	LSA	• See mitigation measures for blasting under potential effect 3.4 of this table.
2.8 Impacts to shallow wells.	Edmonton to Hinton RK 39.6 RK 41.6 RK 50.9 RK 56.9 RK 89.2 RK 90.2 RK 171.4 to RK 171.5 RK 329.5 RK 17.9 Hargreaves to Darfield RK 706 RK 711.5 RK 713.4 RK 717.5 RK 725.6 to RK 725.7 RK 728.8 to RK 729.5 RK 731 to RK 731.6 Black Pines to Hope RK 956.2 RK 1040.1 RK 1040.6 Hope to Burnaby RK 1057.6 RK 1147.4 RK 1159	LSA	• Initiate pre construction monitoring, where warranted, prior to the commencement of a specific activity during construction (*e.g.*, blasting). Monitoring may be necessary prior to, during and following construction or a specific construction activity in the vicinity of water wells or springs [Section 6.0]. • During Project field studies, the hydrogeologist in consultation with landowners and the appropriate regulatory authorities will determine if springs and wells used for domestic purposes located within the immediate vicinity of the construction right-of-way will be sampled for water quality and flow rate prior to the start of construction. Locate and flag or fence registered or known water wells in the immediate vicinity of the construction right-of-way [Section 6.0]. • During construction, avoid blasting in proximity to wells. • Monitor all registered or known potable water wells located within 200 m of any blasting prior to and following blasting. Monitoring will include measurement of well yields, static and pumping water levels as well as water sampling in accordance with *Canadian Guidelines for Drinking Water Quality* (Health Canada 2012) [Section 8.3]. • Re-establish or replace a potable water supply as required should a registered or known water well located within 30 m of the construction right-of-way be damaged (*i.e.*, diminishment in quantity and/or quality) during pipeline installation [Section 7.0].

Notes: 1 LSA = Water Quality and Quantity LSA.
2 Detailed mitigation measures are outlined in the Pipeline EPP (Volume 6B).

5.1.2 Supplemental Studies

Supplemental studies are not warranted for the groundwater component.

5.1.3 General Recommendations

The potential effects on groundwater indicators associated with the construction and operation of the pipeline listed in Table 5.1-1 were identified based on the results of the literature review, desktop analysis, field surveys and engagement with regulatory authorities, stakeholders and potentially affected Aboriginal communities.

A summary of recommended mitigation measures provided in Table 5.1-1 was principally developed in accordance with industry and provincial regulatory guidelines, as well as in accordance with Trans Mountain standards.

5.1.4 Pre-Construction and Post-Construction Monitoring

Field verification and select testing of water wells located within the Water Quality and Quantity LSA either side of the proposed construction right-of-way may be needed higher risk areas where shallow, unconfined aquifers have been identified prior to the commencement of construction. Although post-construction well testing may be warranted, select baseline testing would be limited to the pre-construction phase.

Water well locations and details will need to be verified and permission will need to be obtained from the well owners prior to conducting any well tests. As indicated, post-construction testing would only be considered where concerns have been raised and pre-construction testing was conducted.

To meet the proposed objectives, the well testing scope of work will include the following tasks.

5.1.4.1 Water Well Confirmation

The hydrogeology consultant will work with Trans Mountain to confirm the number of active wells located within 150 m of the construction right-of-way. Landowners will be contacted in advance to obtain permission for land access and field testing. Inquiries will be made with regards to number, location and current state (active or inactive) of wells. Information on the well head completion and pumping system will also be requested. This information will be used to design the well test and finalize the health and safety requirements for well access (*i.e.,* well pits, pump houses, confined space entry, pitless adapter bypasses, pumping systems, pressure control system bypass, cisterns, etc.).

5.1.4.2 Field Verified Survey

A final list of the water well owners names and contact information will be developed as part of the field verified survey (FVS). The FVS procedure is summarized as follows:

- meet with the well owner and review an introductory letter. The letter is intended to summarize the pipeline well testing program, and the standard testing procedures;
- water wells will be surveyed using a handheld GPS unit in order to estimate the offset distance of the well from the pipeline construction right-of-way; and
- each well will be assigned a unique well ID number matched to the provincial well tag or ID, if available.

5.1.4.3 Water Well Testing

Baseline testing will be completed prior to construction activities to establish pre-pipeline construction conditions. Post-construction testing would only be completed in the event of a concern raised by the well owner to assess if a measurable adverse effect has occurred which can be attributed to pipeline construction activities. The well testing will include:

- the selection of an appropriate flow rate;
- monitoring water levels during 2 hour pumping and 2 hour recovery tests to determine well performance; and
- the collection of a water sample for analysis of routine water quality, total and dissolved metals, iron-related bacteria, sulphur-related bacteria, heterotrophic plate count, total coliforms and E. Coli which data will be compared to applicable criteria.

5.1.4.4 Data Analysis and Reporting

Following each well test, a brief factual report will be submitted, along with the water sample analytical results to Trans Mountain. A final report will also be issued to the well owner.

5.2 Pump Stations and Terminals

5.2.1 Potential Effects

Potential effects of Project activities at pump stations and storage tanks on groundwater quality indicator are listed in Table 5.2-1. These interactions are based on: results of the literature review, desktop analysis; consultation with regulatory authorities and stakeholders as well as the professional experience of the assessment team.

A summary of recommended mitigation measures provided in Table 5.2-1 was principally developed in accordance with industry and provincial regulatory guidelines, as well as in accordance with Trans Mountain standards.

TABLE 5.2-1

POTENTIAL EFFECTS AND MITIGATION MEASURES OF PROJECT ACTIVITIES AT PUMP STATION AND TANK FACILITIES ON WATER QUALITY AND QUANTITY

Potential Effect	Facility	Spatial Boundary[1]	Key Recommendations/Mitigation Measures [EPP Reference][2]
1. Water Quality and Quantity Indicator – Groundwater Quality			
1.1 Reduction of groundwater quality as a result of a small spill during construction.	Edmonton Terminal Black Pines Power line Kingsvale Power line Sumas Terminal Burnaby Terminal	LSA	Utilize appropriate construction standards to reduce the risk possibility of a spill.

Notes: 1 LSA = Water Quality and Quantity LSA.

2 Detailed mitigation measures are outlined in the Facilities EPP (Volume 6C).

5.2.2 Supplemental Studies

Supplemental studies are not warranted for the groundwater component.

5.2.3 Pre-Construction and Post-Construction Monitoring

Refer to Section 5.1.3 for the pre-construction and post-construction monitoring plan.

5.3 Westridge Marine Terminal

5.3.1 Potential Effects

There are no water supply wells, nor mapped aquifers within the Footprint of the Westridge Terminal, although it is expected, with the proximity to the waters of Burrard Inlet that the groundwater is shallow. No water level data are available. It is likely that groundwater flow is directed to the north toward the inlet.

A summary of recommended mitigation measures provided in Table 5.3-1 was principally developed in accordance with industry and provincial regulatory guidelines, as well as in accordance with Trans Mountain standards.

TABLE 5.3-1

POTENTIAL EFFECTS AND MITIGATION MEASURES OF CONSTRUCTION AND OPERATION AT THE WESTRIDGE MARINE TERMINAL ON WATER QUALITY AND QUANTITY

Potential Effect	Spatial Boundary[1]	Key Recommendations/Mitigation Measures [EPP Reference][2]
1. Water Quality and Quantity Indicator – Groundwater Quantity		
1.1 Localized change in the location of the groundwater/seawater interface	LSA	Ensure that measures are taken to reduce the amount of water discharged to the subsurface [Section 8.1]. Ensure that amount of pumping of groundwater is kept to a minimum to avoid ingress of seawater into water supply wells [Section 8.1]

Notes: 1 Water Quality and Quantity LSA.

2 Detailed mitigation measures are outlined in the Westridge Marine Terminal EPP (Volume 6D).

5.3.2 Supplemental Studies

Supplemental studies are not warranted for the groundwater component.

5.3.3 Pre-Construction and Post-Construction Monitoring

Refer to Section 5.1.3 for the pre-construction and post-construction monitoring plan.

6.0 SUMMARY

This report provides information and discussion on the existing groundwater-related conditions, potential effects and recommended mitigation requirements along the proposed pipeline corridor of the Trans Mountain Expansion Project (the Project). The objectives of this report were to:

- describe the setting as it relates to groundwater indicators along the proposed pipeline corridor;
- identify groundwater quality and quantity potential effects as they relate to the proposed pipeline corridor and construction of the pipeline; and
- recommend mitigation requirements.

The assessment was based on the selected indicators of groundwater quality and quantity. The mitigation endpoints for groundwater quality included:

- shallow groundwater with potential existing contamination;
- areas susceptible to drilling mud release during trenchless crossing construction;
- areas in the aquifer susceptible to sedimentation;
- areas of shallow groundwater susceptible to blasting effects;
- areas with potential artesian conditions; and
- aquifers or wells vulnerable to possible future contamination from an accident or malfunction.

The mitigation endpoints for groundwater quantity included:

- areas susceptible to changes in groundwater flow patterns;
- areas where dewatering may be required during pipeline construction activities;
- areas with potential artesian conditions; and
- areas of shallow groundwater susceptible to blasting effects.

The summary of the results identified the following:

- in Alberta, the proposed pipeline corridor crosses 34 potential aquifers, including 21 undifferentiated Quaternary aquifers (unconsolidated materials), 3 buried valley aquifers (unconsolidated materials), and 9 bedrock aquifers:
- in BC, the proposed pipeline corridor crosses 35 mapped aquifers, including:
  - 8 Quaternary aquifers (unconsolidated material) and 1 bedrock aquifer (Hargreaves to Darfield Segment);
  - 7 Quaternary aquifers (unconsolidated material) and 3 bedrock aquifers (Black Pines to Hope Segment);
  - 15 Quaternary aquifers (unconsolidated material) (Hope to Burnaby Segment); and
  - 1 Quaternary aquifer (unconsolidated material) (Burnaby to Westridge Segment).

The following facilities overlie mapped aquifers:

- the Darfield Pump Station;

- the Black Pines Pump Station;
- the Sumas Pump Station; and
- the Burnaby Terminal.

Proposed horizontal directional drilled (HDD) trenchless crossings with potential artesian conditions, include:

- 6 proposed HDD in the Edmonton to Hinton Segment, of these 4 potentially have artesian conditions;
- 8 proposed HDD in the Hargreaves to Darfield Segment;
- 7 proposed HDD in the Black Pines and Hope Segment;
- 5 proposed HDD in the Hope to Burnaby Segment; and
- no proposed HDD in the Burnaby to Westridge Segment.

Pipeline corridor segments where potential groundwater quantity effects were identified, include:

- the Edmonton to Hinton Segment (26), Hargreaves to Darfield Segment (14), Black Pines to Hope Segment (6), Hope to Burnaby Segment (2) and Burnaby to Westridge Segment (1) were identified as areas susceptible to changes in groundwater flow pattern;
- the Edmonton to Hinton Segment (21), Hargreaves to Darfield Segment (10), Black Pines to Hope Segment (7), Hope to Burnaby Segment (3) and possibly along the Burnaby to Westridge Segment were identified as areas where dewatering may be required; and
- sections along the Edmonton to Hinton Segment, Hargreaves to Darfield Segment (1), Black Pines to Hope Segment (3) were identified as areas where blasting may be required.

Facilities where potential groundwater quantity effects were identified include:

- the Westridge Marine Terminal was identified as a facility susceptible to changes in groundwater flow pattern;
- the Wolf Pump Station, Black Pool Pump Station, Black Pines Pump Station, Kingsvale Pump Station, Sumas Pump Station and Westridge Marine Terminal were identified as facilities that may require dewatering;
- no facilities were identified where blasting may be required.

Facilities where potential groundwater quality effects were indentifies, include:

- the Edmonton Terminal, Jasper Pump Station, Blackpool Pump Station, Kamloops Pump Station, Sumas Terminal were identified as facilities where potential contamination was noted.

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Waterline wishes to acknowledge those people identified in the Personal Communications for their assistance in supplying information and comments incorporated into this report.

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