OPUS

Comox Valley Regional District

Sanitary Pumping and Alignment Review

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Contents

List of Figures

List of Tables

Project Background

1 Introduction

1.1 Background

The Comox Valley Regional District (CVRD) operates the sanitary conveyance system for the City of Courtenay and the Town of Comox. The system consists of two pump stations and one common forcemain which together pump sewage to the Comox Valley Water Pollution Control Centre (CVWPCC), located in the eastern area of Comox near the Willemar Bluffs.

The system has been operating for over 30 years; however, it has been identified that the forcemain along the Willemar Bluffs section is at increased risk of failure due to slope instability. This risk is related to exposure of the forcemain due to scouring and erosion by wave action. This was identified by Northwest Hydraulic Consultants Ltd. (NHC) in 2003 and in 2016 (*Risk Analysis of CVRD Forcemain on Balmoral Beach*, NHC, 2016).

This erosion was found in 2002 with portions of the forcemain along the foreshore exposed. A forcemain re-alignment study was performed in 2005 to assess various options for re-routing the forcemain away from Willemar Bluffs such that that section could be decommissioned. The recommended re-alignment involved tying into the existing forcemain near Goose Spit and routing the forcemain overland to the CVWPCC. This new route resulted in a higher elevation forcemain which required a new pumping facility to increase the downstream hydraulics.

Further work was undertaken to advance the location and size of this facility, referred to as Comox No. 2 Pump Station. The preferred site was selected on Beech St. at an elevation of approximately 16 meters.

Opus International Consultants Ltd. (Opus) was retained by the CVRD to prepare an updated evaluation of forcemain and pump station options as it has been over 12 years since the original study was completed, and factors such as development, population, capital costs for Comox No. 2 pump station and forcemain conditions have changed over time. The intent of this report is to evaluate the future potential forcemain alignments and pump station configurations to evaluate the long-term options for the Comox Valley sanitary collection system.

1.2 Information Sources

The following references were used in the preparation of this report:

- Forcemain Re-alignment Study, CH2MHILL, December 2005
- Comox Valley Regional District Sanitary Sewerage Master Plan, McElhanney Consulting Services Ltd., May 2011
- Courtenay Pump Station Upgrade Sewerage Systems Upgrading and Staging Plan, AECOM, February 2013

- Risk Analysis of CVRD Forcemain on Balmoral Beach, Northwest Hydraulic Consultants, September 2016
- Spill Response Plan, Associated Engineering, January 2017

1.3 Report Preparation

This report was prepared by Walt Bayless, P.Eng., Opus International Consultants with input from Mr. Roger Warren, P.Eng.; Mr. Al Gibb, P.Eng; Doug Grimes, PGeo, McMillen Jacobs Associates; and Mr. Garr Jones, PE (retired).

2 Projected Future Population and Flows

2.1 Population

The design population and flows were adopted from McElhanney growth rate structure and flow projections. This structure, applied over a 50-year timeline, yields an annual growth of 1.72%. Table 2-1 and Table 2-2 summarize the historic and projected growth rates and populations.

Table 2-1: Projected Population Growth Rates

Year	Courtenay	Comox
2008-2018	4.0%	4.0%
2019-2028	3.0%	3.0%
2029-2038	2.0%	2.0%
2039-2058	1.0%	1.0%

Table 2-2: Historic Population and 50-year Population Projections

Year	Courtenay	Comox	Total
2006	22,021	12,385	34,406
2011	24,099	13,627	37,726
2016	25,599	14,028	39,627
2018	27,688	15,173	42,861
2028	37,210	20,391	57,601
2038	45,359	24,856	70,215
2048	50,105	27,457	77,561
2058	55,347	30,329	85,676
2068	61,137	33,503	94,640

2.2 Sanitary Flow Rate

Previous reports have reviewed the system design flows which are discussed below.

2.2.1 CH2M Report

The CH2M report is based on a design flow of 355 L/capita/day. This was determined by reviewing average dry weather flow (ADWF) and correlating it to the 2005 population. Inflow and infiltration (I&I) were determined by evaluating observed flows during wet weather and correlating them to the

ADWF. Empirical I&I values for Courtenay and Comox were 9,300 m^3/day and 7,600 m^3/day, respectively. The peaking factor was based on the Harmon equation. Table 5 shows the CH2M flow projections.

Table 2-3: CH2M flow projections

Flow [L/d/c]	355	355
I/I [m3/d]	9,300	7,600

Year	Peak Sewage and I/I Flow [L/s] (b)		
	Courtenay	Comox	Total [(a)]
2005	343	237	**580**
2015	425	275	**700**
2025	529	327	**856**
2035	666	393	**1,059**
2045	848	478	**1,326**
2055	1,090	585	**1,675**
(a) incorrect report values adjusted			
(b) peaking factor - Harmon			

2.2.2 McElhanney Report

The McElhanney report evaluated flows entering both the Courtenay and Jane pump stations. Through assessment of the populations and observed flows between dry and wet weather they provided recommended design flows. For both Courtenay and Comox per capita sewerage flows of 240 L/capita/day were developed and I&I rates of 0.17 L/s/hectare were recommended, for the majority of the area. The peaking factor was recommended to be based on MMCD sanitary design standards. Flows calculated based on the projected population and recommendations are shown in Table 6.

Table 2-4: McElhanney projected flows

Flow [L/d/c]	240	240
I/I [L/s/ha]	0.17	0.17
Area [Ha]	1950	650

Year	Courtenay (L/s)	Comox (L/s)	Total (L/s)
2008	477.1	191.2	**668**
2018	538.0	225.0	**763**
2028	600.1	259.4	**860**
2038	651.9	288.1	**940**
2048	681.5	304.6	**986**
2058	713.9	322.5	**1,036**

2.2.3 ISL Report

The ISL report looked at historical flows from 2011 to 2015 and correlated these values with the population. An average per capita flow rate of 350 L/capita/day was calculated, and a peaking factor of 2.3 was observed during peak flows. I&I was not broken out of this Figure. Based on ISL population values and calculated flow rates and peaking factors are shown in Table 7.

Table 2-5: Flows based on ISL data

Flow [L/d/c]	350
Year	**Total (L/s)**
2011	351
2021	431
2031	495
2041	568
2051	661
2061	747
2066	800

2.2.4 Greenwood Trunk Sewer

The CVRD, with support from Courtenay and Comox, has undertaken the construction of the Greenwood Trunk Sewer. This new collection system will collect significant portions of the future sewage generated in the two communities. As a result, not all future growth will result in new flows being received at the Courtenay Pump Station and Jane Street Pump Station.

The current scope does not involve a detailed assessment of the proposed growth programs within each community. Therefore, a sensitivity approach has been adopted to evaluate the impact on the proposed long-term development plans. It is proposed to adopt two additional development scenarios:

- 50% of all new growth is directed to the Greenwood Trunk Sewer;
- 75% of all new growth is directed to the Greenwood Truck Sewer.

Design volumes for the system are provided in the next section.

2.2.5 Design Flow Rates

Pump station flow data was provided by the CVRD for both pump stations. The data consisted of daily totalized flow for the 2016 year and totalized flow per minute for the December 2016. Flow data was evaluated and compared to the population to determine a per capita daily flow. Average per capita daily flow for Courtenay and Comox were found to be 390 L/capita/day and 315 L/capita/day, respectively. This value is inclusive of I&I.

Based on comparison to the McElhanney and ISL data, these calculated values are deemed to corroborate values reported previously.

Due to the fact that McElhanny provides the most relevant design value recommendations and the design population is based on McElhanny annual growth rates, the design flow is based on the McElhanny design recommendations. Table 8 provides the design flows.

Table 2-3 provides the resulting system demand over the next 50 years, which is used as the design flow for the regional colllection system. These projections are based on the 2011 estimated flow by McElhanney and 2016 census. A peaking factor based on the MMCD design guidelines has been is used to forecast the sewage flows per Equation 1 below, where P is population.

$$\text{Peaking Factor} = 6.75 \times P^{-0.11} \qquad \text{(Equation 1)}$$

Table 2-6: Projected Future Flows for the Regional Collection System

Year	Total Population	Courtenay PS		Jane PS		Total
		PF	Flow [L/s]	PF	Flow [L/s]	Flow [L/s]
2016	39,627	2.2	489	2.4	203	691
2028	57,601	2.1	551	2.3	239	790
2038	70,215	2.1	593	2.2	264	857
2048	77,561	2.1	617	2.2	278	895
2058	85,676	2.0	644	2.2	293	937
2068	94,640	2.0	673	2.1	310	983

Growth estimates incorporating the Greenwood Truck Sewer are provided in Table 2-7 below. These are based on 50% and 75% of all new sewage flows being directed to the Greenwood system.

Table 2-7: Flow Projection for the Courtenay and Jane PS using 50% Flow Direction to the Greenwood Truck Sewer (L/s)

Year	Courtenay			Jane			CMX No. 2		
	0%	50%	75%	0%	50%	75%	0%	50%	75%
2016	489	489	489	203	203	203	691	691	691
2028	551	520	505	239	221	212	790	741	717
2038	593	541	515	264	234	218	857	775	733
2048	617	553	521	278	241	222	895	794	743
2058	644	566	528	293	248	226	937	814	754
2068	673	581	535	310	257	230	983	838	765

3 Existing System

3.1 Existing Pump Stations and Forcemain

The CVRD operates and maintains the Courtenay-Comox trunk sewer system that discharges into the Comox Valley Water Pollution Control Centre (CVWPCC). The Courtenay pump station (Courtenay PS) located on Comox Road, near the Highway 19A bridge that crosses the Puntledge River, and the Jane Place pump station (Jane PS) located at Jane Place near the Comox Valley Marina, are the two main pump stations along this trunk sewer.

Currently, sewage is conveyed from Courtney in a ø860 mm reinforced concrete pipe (Hyprescon) eastward along Comox Road and Bayside Road before routing into the foreshore. Sewage from Jane PS is directly tied into the forcemain in the intertidal zone. The forcemain crosses Goose Spit and continues in the foreshore along Willemar Bluffs to CVWPCC. Figures 3-1 and 3-2 presents the existing forcemain alignment.

In 2002, the Regional District discovered that a significant section of the forcemain along the Willemar Bluffs in the foreshore were being exposed leaving the forcemain without the protective cover material. This was assumed to have been caused by changes in soil deposition patterns and erosion. This was identified by NHC in 2003, which was again reaffirmed in the 2016 *Risk Analysis of CVRD Forcemain on Balmoral Beach* report by NHC.

In 2003/2004 gabion basket were installed along sections of the pipe as a temporary emergency protection until plans to relocate forcemain away from the foreshore where implemented

A risk analysis of the forcemain along the Willemar Bluffs was prepared by NHC in 2016. It was concluded that the forcemain is at risk of failure along the beach section and that it would take up to 24-hours to fix any major failures to the forcemain. The study recommended that the affected portion of the forcemain to be relocated off-the-beach.

COMOX VALLEY REGINOAL DISTRICT

FORCEMAIN RE-ALIGNMENT EVALUATION

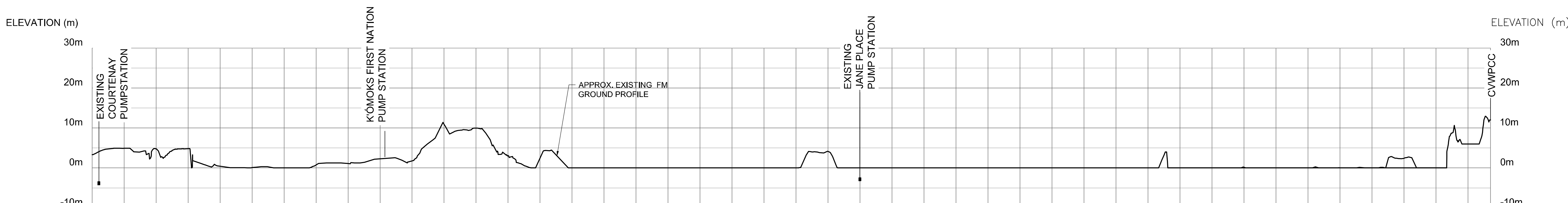
EXISTING FORCEMAIN PLAN VIEW

SCALE 1:10000

1:10000 @ ANSI D 0 100 200 300 400 500 600 700 800 900 1000 m

FIGURE 3-1

Original Sheet Size ANSI D [22"x34"] Plot Date 2017-06-27 at 3:31:58 PM Path M:\COMOX VALLEY REGIONAL DISTRICT\D-13125,00\(C) Civil\+AutoCAD\D-13125,00_FIGURE 3_EX.dwg FIGURE 3-1 DRAWN BY:CHONG WANG



STATION	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000
ELEVATION	4.93	4.77	4.81	0.43	0.08	0.03	0.73	1.10	2.27	1.76	10.88	9.98	3.02	2.45	0.00

STATION	3200	3400	3600	3800	4000	4200	4400	4600	4800	5000	5200	5400	5600	5800
ELEVATION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.13	0.00	0.00	0.00	0.00	0.00	0.00

STATION	6000	6200	6400	6600	6800	7000	7200	7400	7600	7800	8000	8200	8400	8600
ELEVATION	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.01	0.00	2.41	0.00	5.98

COMOX VALLY REGINOAL DISTRICT

FORCEMAIN RE-ALIGNMENT EVALUATION
EXISTING FORCEMAIN PROFILE

HORIZ 1:10000 VERT 1:400

1:12500 @ ANSI D 0 200 400 600 800 1000 1200 m

1:500 @ ANSI D 0 5 10 15 20 25 30 35 40 45 50 m

FIGURE 3-2

Original Sheet Size ANSI D [22"x34"] Plot Date 2017-06-27 at 3:32:13 PM Path M:\COMOX VALLEY REGIONAL DISTRICT\D-13125,00\(C) Civil\+AutoCAD\D-13125,00_FIGURE 3_EX.dwg FIGURE 3-2 DRAWN BY: CHONG WANG

3.2 Existing Hydraulics and Capacities

Courtenay PS has a wet well and dry well configuration with 3 service and 1 standby 170 HP pumps. The lead-lag-pumps-off elevation in the wet well is -4.25 m. Jane PS has a wet well configuration with 2 service and 1 standby 70 and 77 HP pumps, respectively. The lead-lag-pumps-off elevation in the wet well is -3.25 m. Both pump stations are currently pumping sewage to the CVWPCC with a high water elevation of 12 m. Currently, sewage is conveyed at 0 m elevation as the forcemain travels along the intertidal foreshore. The hydraulics of the existing systems are presented in Table 3-1.

Table 3-1: Hydraulics of Existing System

Parameter	Courtenay PS	Jane PS
Static Head to CVWPCC (m)	17	16
Line Losses (m)	12	7
Total Dynamic Head (m)	29	22

The latest assessment on the system capacity was conducted by AECOM in 2013 and it was reported that both stations can meet the peak wet weather flow (PWWF) when operating individually but not simultaneously due to the back pressure caused by the other pump stations.

Table 3-2 summarizes the existing system parameters used to calculate the PWWF at each pump station based on the 2011 McElhanney *Master Plan*. The estimated 2017 PWWF rates at Courtenay and Jane PS are 490 and 203 L/s (pop. 39,627).

Table 3-2: Existing System Demand - 2017

Parameter	Courtenay PS	Jane PS
Sewage Flow (L/capita/day)	240	
Inflow and Infiltration Rate (L/s/Ha)	0.17	
Area (Ha)	1,950	650
Estimated PWWF (L/s)	489	203

The achievable pumping capacities at either of the pump stations declines as flowrate of the other pump station increases. As such, Courtenay PS is only able to achieve 360 L/s when Jane PS is operating at PWWF, and Jane PS is only able to achieve 150 L/s when Courtenay PS is operating at PWWF. Figure 3-2 was derived from the 2013 AECOM report, demonstrating the operating rate range between the two pump stations.

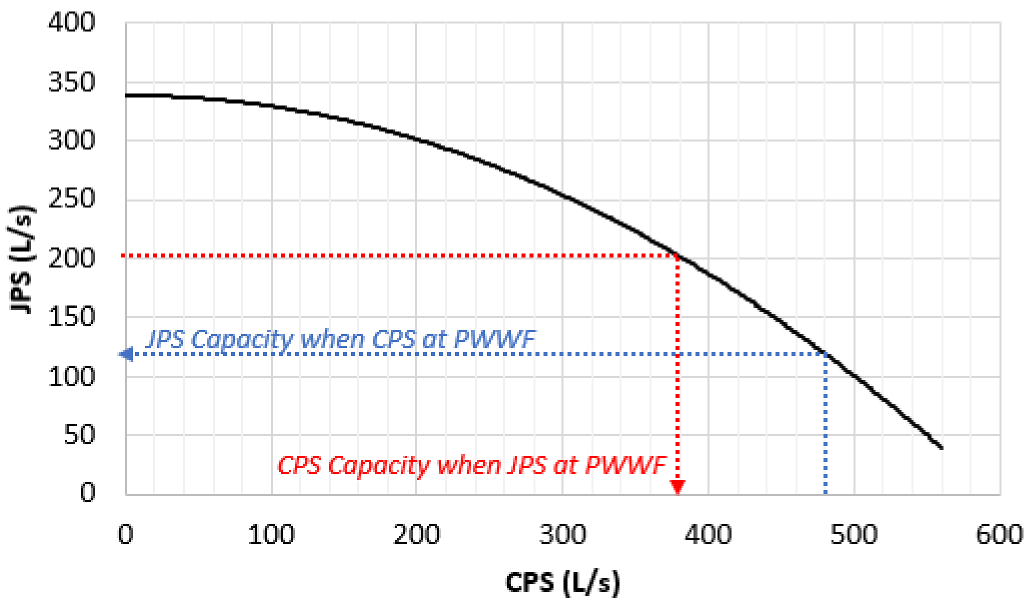


Figure 3-3: Existing System Performance

4 Considerations for Alignment and System Upgrades

A host of issues must be considered when planning a wastewater collection and pumping system. The following is pertinent only to the current planning effort and therefore must not be considered an all-inclusive discussion of the subject. The number of pumping options narrow considerably as operating head increases above 30 m and pump flow gets smaller (<60 L/s per pump). It must be understood with the higher operating speeds and lower operating flows (i.e. a high head-low flow), speeds are not the only considerations for wastewater pumping stations. As the pump discharge head increases, the number of impeller vanes increase, the size of waterway openings decrease, and the capability of individual pump selections to pass solids from unscreened wastewater sources is diminished significantly. This is especially true for the >30 m and <60 L/s/pump bench marks. Nonetheless, these factors also apply to a lesser degree with equipment intended for greater flows at heads above the 30-m benchmark. Thus, a good deal of care must be exercised during pump selection to be satisfied that proposed equipment will perform for a given higher head application.

Additionally, operating modes will often dictate pump selection. If constant speed pumps are to be applied for a given installation, then the pumps will more likely operate within a comfortable region on the pumps' head capacity curves and avoid damaging operating characteristics. However, if variable speed operation is needed to accommodate the range of operating conditions or flow control at the wastewater treatment plant, then the pumps will be likely to operate outside the stable region at high operating heads and low pumping rates, which will expose them to internal mechanical damage from cavitation erosion, vibration, and high radial thrust forces to bearings, shafts and shaft seals. Furthermore, plugging caused by suction recirculation will also be a potential hazard that needs to be considered.

Historically, operational risks associated with arrangements where two pumping stations, located and separated by a forcemain with no intermediate gravity flow section that are planned to operate in series, have rendered such arrangements as prone to operational and control failures. Past cases have shown that system dynamics are such that control of pump start-up/ shutdown and changes in rate of flow occur too rapidly for system controls to react properly thus rendering the prospect for system shutdown/overflow and damage highly likely. One large system owner in the Western US had to replace 3 such systems (interlinked variable speed pumping stations with no real time inlet condition control) with single 2-stage pumping stations in order to finally get control of system malfunctions such as damage to equipment and overflows to the environment. With technological advances in instrumentation and system controls, these risks can be largely mitigated, but at significantly elevated capital costs. Nonetheless, if an in-series system is to be implemented, an arrangement that allows for more flexibility by providing intermediate gravity flow sections or sufficient storage will minimize the associated operational risks.

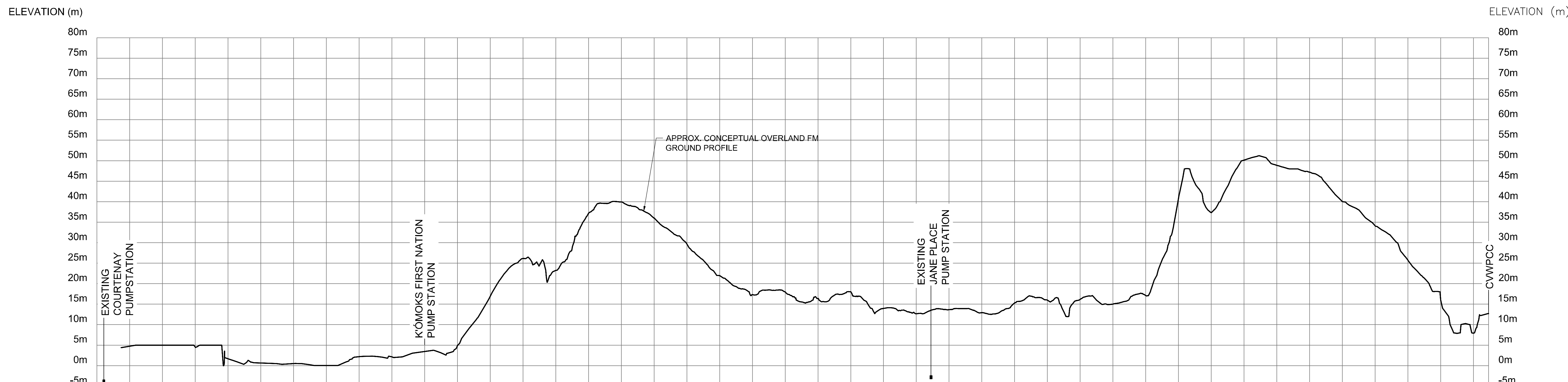
Regardless, all stations should be provided with on-site electrical generation systems and redundant controls and off-site supervisory control alarm systems are needed as well as machine health monitors (vibration, temperature, speed) and control system factors such as wet well level trending, flow trending and response time to support a comprehensive preventive maintenance program. Four options are proposed for upgrades to the existing sanitary system and discussed in detail in the following sections.

5 Forcemain Alignment Assessment

An assessment was conducted on the forcemain alignment to determine alternative conveyance routes to the existing alignment. Two conceptual alignments were assessed, an overland route and a partial marine route (marine route). The overland route would not encroach on the foreshore or any marine environment. The marine route would contain some portion of forcemain within the foreshore environment.

5.1 Overland Route Option

There are several routes through the Town of Comox. Specific development of an alignment is beyond the scope of this study; however, every route follows a similar topology and would require similar pumping systems. The proposed overland route would follow the existing forcemain from the Courtenay PS for the initial 3 km before re-routing through the Town of Comox to the CVWPCC. An approximate profile is shown in Figure 5-1. An approximate conveyance distance of an overland route would be approximately 8,000 - 9,000 m. Overland alignment options would consider following contours to minimize low points in the system and following public right-of-ways.



ELEVATION	4.75	5.00	4.55	1.68	0.64	0.51	0.03	2.18	2.15	3.46	4.86	16.92	26.14	23.24	37.13	39.93	36.01	29.67	21.97	17.33	17.99
STATION	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200

ELEVATION	16.37	18.00	13.98	12.66	13.67	12.91	15.33	15.99	16.18	15.03	17.10	40.82	37.33	50.15	48.87	47.19	40.03	34.10	25.74	15.91	7.93
STATION	4400	4600	4800	5000	5200	5400	5600	5800	6000	6200	6400	6600	6800	7000	7200	7400	7600	7800	8000	8200	8400

COMOX VALLY REGINOAL DISTRICT

FORCEMAIN RE-ALIGNMENT EVALUATION

CONCEPTUAL OVERLAND FORCEMAIN ALIGNMENT PROFILE

HORIZ 1:10000 VERT 1:400

1:12500 @ ANSI D 0 200 400 600 800 1000 1200 m

1:500 @ ANSI D 0 5 10 15 20 25 30 35 40 45 50 m

FIGURE 5-1

Original Sheet Size ANSI D [22"x34"] Plot Date 2017-06-27 at 3:33:19 PM Path M:\COMOX VALLEY REGIONAL DISTRICT\D-13125.00\(C) Civil\+AutoCAD\D-13125.00_FIGURE 1_LAND.dwg FIGURE 5-2 DRAWN BY: CHONG WANG

In general, any overland alignment will need to overcome hills at Glacier View Drive and Lazo Road, as shown in the elevation profile. The latter governs the static head requirement of the system at 51 m of elevation.

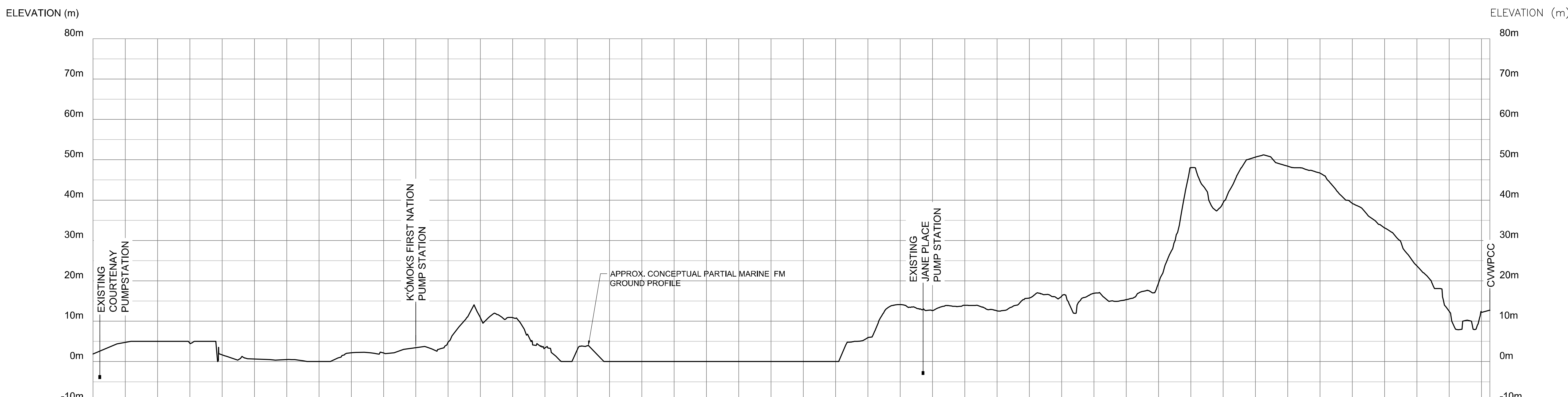
5.2 Marine Route Option

The proposed marine alignment option is a combination of an overland and marine forcemain as shown on Figure 5-2. This approach was selected to reduce the risks of having a lengthy marine pipeline, while reducing the construction impacts of building the forcemain inland. The proposed alignment would parallel the existing forcemain to the Comox Marina before routing inland and continuing along an overland alignment. This could remove up to 2.5 km of construction through the Town of Comox and would avoid routing over the Glacier View Drive hill.

The marine route presents various environmental concerns not only during the construction but also throughout the life cycle of the forcemain. In evaluating these concerns, the water body around the cove is divided into three major areas, namely estuary, marina, and foreshore & Willemar Bluffs.

The estuary area is a significant wildlife sanctuary and any work within this area would be subject to permitting and environmental impact reviews by DFO, MOE and K'ómoks First Nations. To a lesser degree this would apply to all maintenance and emergency repair work conducted through the life-span of the pipe.

Any pipe routed through the estuary and marina would need to be buried sufficiently to avoid any incidental contact with boats or anchors. The Willemar Bluffs area has been documented to be unsuitable for any pipeline installation.



ELEVATION	4.75	5.00	4.55	1.68	0.64	0.51	0.03	2.18	2.15	3.46	4.81	10.81	10.88	3.38
STATION	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800

ELEVATION	2.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.95	14.11	12.67	13.94	12.58
STATION	3000	3200	3400	3600	3800	4000	4200	4400	4600	4800	5000	5200	5400	5600

ELEVATION	15.76	16.17	16.93	15.33	19.49	48.03	39.34	50.67	48.40	46.69	39.20	33.13	23.73	12.46	12.26
STATION	5800	6000	6200	6400	6600	6800	7000	7200	7400	7600	7800	8000	8200	8400	8600

COMOX VALLY REGINOAL DISTRICT

FORCEMAIN RE-ALIGNMENT EVALUATION

CONCEPTUAL PARTIAL-MARINE FORCEMAIN ALIGNMENT PROFILE

HORIZ 1:10000 VERT 1:400

1:12500 @ ANSI D 0 200 400 600 800 1000 1200 m

1:500 @ ANSI D 0 5 10 15 20 25 30 35 40 45 50 m

FIGURE 5- 2

Original Sheet Size ANSI D [22"x34"] Plot Date 2017-06-27 at 3:34:18 PM Path M:\COMOX VALLEY REGIONAL DISTRICT\D-13125.00\(C) Civil\+AutoCAD\D-13125.00_FIGURE 2_MARINE.dwg FIGURE 5-4 DRAWN BY: CHONG WANG

5.3 Considerations

Each of the options presented above provide certain advantages and disadvantages that must be considered thoroughly. The main considerations can be categorized as follows

Topography

Most variations of the overland route will require the forcemain to cross two high elevation ridges, resulting high head requirements at the upstream pump stations and leading to higher energy costs than a marine alignment. Although the marine route will bypass the high ground at Glacier View Drive, it will be subject to the high elevation on Lazo Road as it will be routed inland at some location to the west of this area. As the Lazo Road hill is the larger of the two, the pumping stations will still be required to be of relatively high head, therefore negating the lower elevation alignment provided by the marine environment.

Construction

The overland option will cause significant interruption as it passes through heavily populated areas for its entire length. The marine route will only pass through such areas for approximately half of its length. Although, construction of a large diameter pipeline in the intertidal zone will carry significant constructability challenges both in terms of ground conditions and tidal working restrictions.

Emergency Repair and Maintenance

The majority of the length of the overland route will be constructed in populated areas where any breaks or leaks would be immediately identified. Located mostly along roads through the Town, the forcemain will be easily accessible and crew and equipment mobilization will not be significantly burdensome. However, as discussed by the 2016 NHC risk analysis of the forcemain, breaks or leaks along the foreshore will take a significant amount of time to be identified after which mobilization and repair will be a time-consuming and costly exercise. Furthermore, repair work conducted in the marine environment would be completed when required, rather than during regulated fisheries windows. As such, discussions with DFO would be necessary.

Environment

Numerous environmental factors must be considered in the work area for both routes as populations of at risk species have been identified in this region. However, the overland route will carry no unique environmental risks or regulatory burdens as compared to the marine route. As outlined by the 2017 Associate Engineering *Spill Response Plan*, various regulatory bodies and stakeholders must be engaged and informed in case of any spills in the marine environment including but not limited to BC Ministry of Environment, Canadian Coast Guard, Environment and Climate Change Canada, Fisheries and Oceans Canada, K'ómoks First Nations, BC Shellfish Growers Association, and the First Nation Fisheries Council. The significant regulatory and engagement burden of the marine route will significantly hinder any work that is to be completed in the foreshore area.

Social

The foreshore in the region is a highly-valued asset to the community. From both an industrial and recreational use standpoint, this area plays a large role in the lives of the citizens in the area.

Therefore, any interruption or risk to the foreshore must be considered. The overland route diverts in land from the start of the alignment whereas the marine route will remain in the foreshore for a significant portion of its length.

5.4 Route Selection

Upon comparing the overland and marine routes, the significant risks associated with constructability, emergency repair and maintenance, the environment, and social issues render the marine route as less favourable. Furthermore, as the marine route must transition to a terrestrial alignment and pass over the Lazo Hill high point, the hydraulic benefits are largely negated. Variations of the overland route can largely mitigate topographical burdens and diligent scheduling and phasing of the construction will minimize interruption to residents. For this reason, the overland option is the preferred option.

6 Overland Option Variations

Variations of the overland route in the previous section are discussed below.

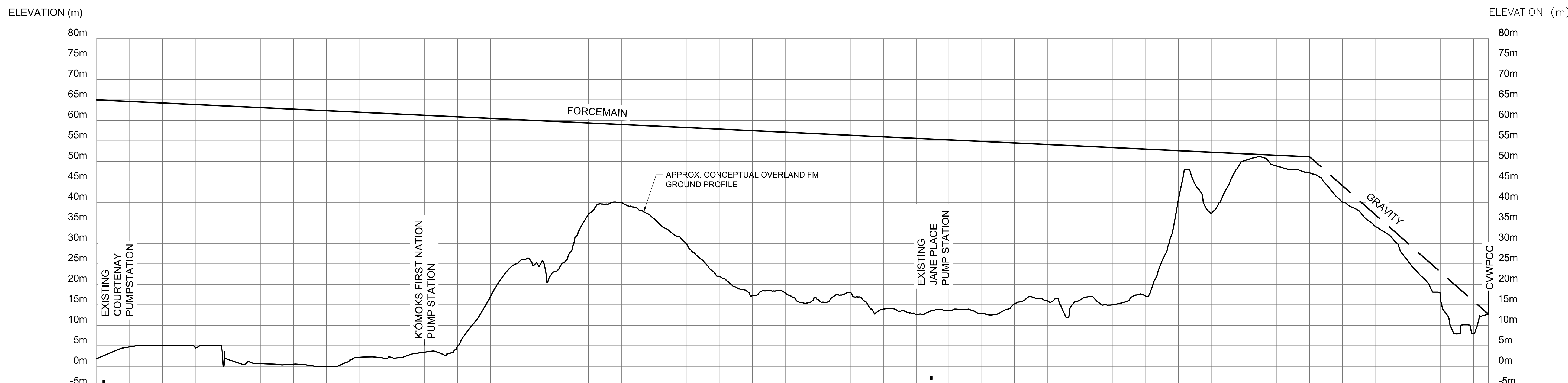
6.1 Option 1 – High Head Overland Pumping Facility

This option would continue to use two pump stations to service the Courtenay and Comox sanitary flows. Higher head pumps would pump the sewage over the Glacier View Hill and the Lazo Road hill. From the peak of the Lazo Road hill, the sewage will then continue to flow by gravity to the CVWPCC. The total conveyance distances via forcemain and gravity are approximately 7300 and 1400 m, respectively.

The estimated head to overcome from the pump-off elevations at Courtenay and Jane PS's are 65 and 56 m, respectively. This is an increase of 36 and 34 m from the existing discharge pressure at the Courtenay and Jane PS (Table 3-1), respectively. The proposed pipe size of ø1200 mm is sufficient for gravity sewer application from the peak of the Lazo Road hill to the existing CVWPCC. Table 6-1 summarizes the hydraulic parameters and Figure 6-1 illustrates the proposed hydraulic gradient line (HGL) for the high head configuration option at the 2068 projected flow.

Table 6-1: Proposed Hydraulics for Option 1

Parameters	Courtenay PS	Jane PS
Wet Well Elevation (m)	-4.25	-3.25
Static Head to Overcome (m)	56	55
Line Losses (m)	9	1
TDH (m)	65	56



ELEVATION	4.75	5.00	4.55	1.68	0.64	0.51	0.03	2.18	2.15	3.46	4.86	16.92	26.14	23.24	37.13	39.93	36.01	29.67	21.97	17.33	17.99
STATION	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200

ELEVATION	16.37	18.00	13.98	12.66	13.67	12.91	15.33	15.99	16.18	15.03	17.10	40.82	37.33	50.15	48.87	47.19	40.03	34.10	25.74	15.91	7.93
STATION	4400	4600	4800	5000	5200	5400	5600	5800	6000	6200	6400	6600	6800	7000	7200	7400	7600	7800	8000	8200	8400

5100 m | 2300 m | 1100 m

COMOX VALLY REGINOAL DISTRICT

FORCEMAIN RE-ALIGNMENT EVALUATION

CONCEPTUAL OVERLAND FORCEMAIN ALIGNMENT PROFILE

OPTION 1 - HIGH HEAD OVERLAND PUMPING FACILITY

HORIZ 1:10000 VERT 1:400

1:12500 @ ANSI D 0 200 400 600 800 1000 1200 m

1:500 @ ANSI D 0 5 10 15 20 25 30 35 40 45 50 m

Original Sheet Size ANSI D [22"x34"] Plot Date 2017-06-27 at 3:34:59 PM Path M:\COMOX VALLEY REGIONAL DISTRICT\D-13125,00\(C) Civil\+AutoCAD\D-13125,00_FIGURE 1_LAND.dwg FIGURE 6-1 DRAWN BY: CHONG WANG

FIGURE 6-1

This option minimizes the loss of energy resulting in breaking head at the intermediate pumping facility between the Courtenay PS and the CVWPCC. However, the system has a number of additional technical issues as noted below.

As discussed in Section 4.0 the proposed discharge pressures for the Courtenay PS and Jane PS are considered high for sanitary systems and result in additional complications when selecting the pumps and higher maintenance challenges due to plugged pumps. This is most pronounced with the Jane PS as the flows are relatively small (200 to 300 L/s total station) which limit options for large pumps. Furthermore, it is unlikely that the existing Jane PS could be reliably upgraded to function as a low flow-high head facility. The major technical challenges are summarized in Table 6-2 below.

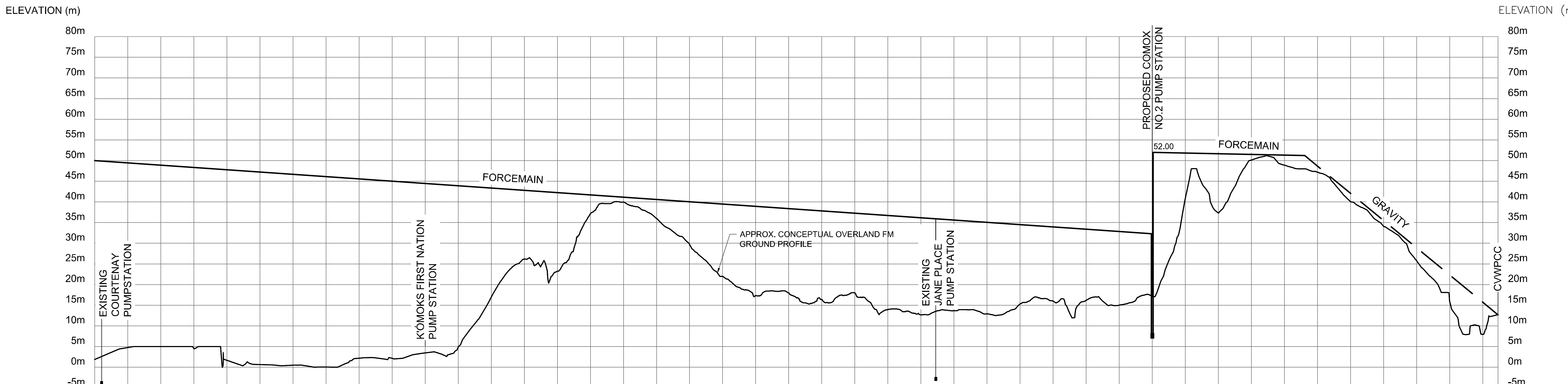
Table 6-2: Option 1 Advantages and Disadvantages

Advantage	Disadvantage
Maximizes pumping efficiencies	Both Courtenay and Jane pump stations are very high head
No single point of failure	Increased plugging issues at the Jane PS
Maximize use of existing pumping facilities	Likely unable to modify the Jane PS to a high head system. Would require a new station which would be problematic at the site.
No new pumping facilities	Reduced pump operating life due to low-flow high-head application

6.2 Option 2 – New Comox No. 2 Pump Station at Beech Street

The low head scenario assumes that a new Pump Station (No. 2 PS) would be built as per the 2011 master plan by McElhanney. The proposed location for No. 2 PS is along Beech Street, which aligns with CH2MHill 2005 recommendation that is to build the pump station below the elevation of Lazo Road. The proposed No.2 PS would collect sewage from both Courtenay and Jane PS and pump over Lazo Road hill to the CVWPCC.

At No. 2 PS, sewage would be collected in the wet well and pumped to a 52m discharge pressure to pass over the Lazo Road hill before it gravity flows into CVWPCC. Figure 6-2 illustrates the proposed HGL for the low head scenario and Table 6-3 summarizes the hydraulic parameters of the proposed system at the 2068 projected flow.



ELEVATION	4.75	5.00	4.55	1.68	0.64	0.51	0.03	2.18	2.15	3.46	4.86	16.92	26.14	23.24
STATION	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800

ELEVATION	37.13	39.93	36.01	29.67	21.97	17.33	17.99	16.37	18.00	13.98	12.66	13.67	12.91	15.33
STATION	3000	3200	3400	3600	3800	4000	4200	4400	4600	4800	5000	5200	5400	5600

ELEVATION	15.99	16.18	15.03	17.10	40.82	37.33	50.15	48.87	47.19	40.03	34.10	25.74	15.91	7.93
STATION	5800	6000	6200	6400	6600	6800	7000	7200	7400	7600	7800	8000	8200	8400

5100 m | 1300 m | 900 m | 1150 m

COMOX VALLY REGINOAL DISTRICT

FORCEMAIN RE-ALIGNMENT EVALUATION

CONCEPTUAL OVERLAND FORCEMAIN ALIGNMENT PROFILE

OPTION 2 - NEW COMOX NO.2 PUMP STATION AT BEECH STREET

HORIZ 1:10000 VERT 1:400

1:12500 @ ANSI D 0 200 400 600 800 1000 1200 m

1:500 @ ANSI D 0 5 10 15 20 25 30 35 40 45 50 m

Original Sheet Size ANSI D [22"x34"] Plot Date 2017-06-27 at 3:35:14 PM Path M:\COMOX VALLEY REGIONAL DISTRICT\D-13125.00\(C) Civil\+AutoCAD\D-13125.00_FIGURE 1_LAND.dwg FIGURE 6-2 DRAWN BY: CHONG WANG

FIGURE 6-2

Table 6-3: Proposed Hydraulics for Option 2

Parameters	Courtenay PS	Jane PS	No.2 PS
Wet Well Elevation (m)	-4.25	-3.25	7
Static Head to Overcome (m)	43	35[a]	44
Line Losses (m)	7	2	1
TDH (m)	50	37	45

Notes:

a) Discharge head required to meet hydraulic grade line

Utilizing the proposed pump station at Beech street would off-set the need to operate Jane PS as a high head facility. Once the flows from Courtenay pass the Glacier View Dr. Hill they would be routed down either a gravity main – which would have to follow the contours – to the No. 2 PS. Alternatively, the forcemain would continue from the top of Glacial View Drive Hill into Comox and back up to the Beech Street property. This introduces an inverted siphon to the system further complicating the arrangement.

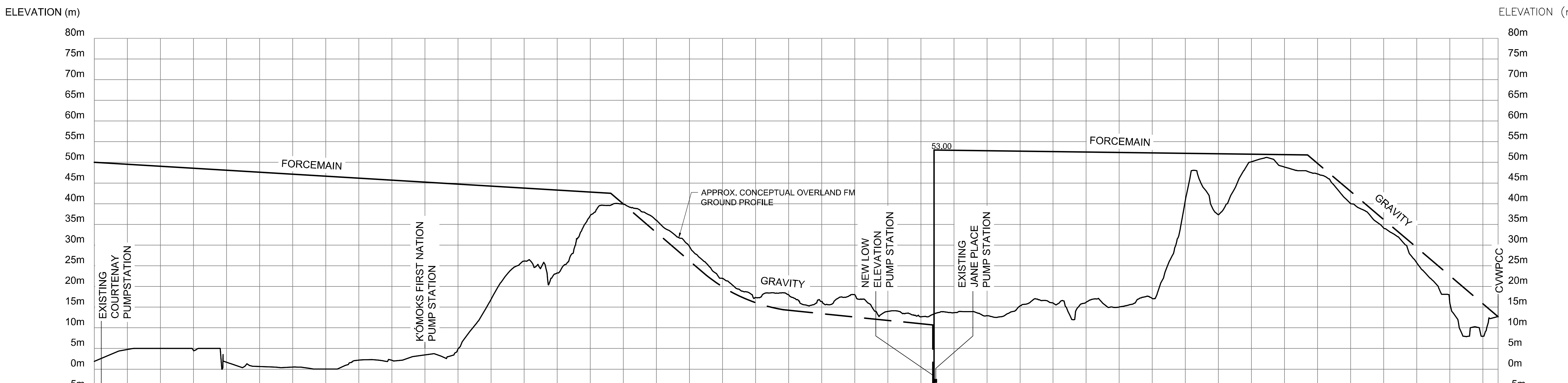
This arrangement also requires the No. 2 PS to operate in series with the Courtenay and Jane Street pump stations without any attenuating flow management provided by a gravity collection system. As a result, overall system risk is higher with pump stations operating in series and therefore, pump controls, operational and redundancy requirements increase significantly to avoid problematic operation.

Table 6-4: Option 2 Advantages and Disadvantages

Advantage	Disadvantage
Jane PS discharge head minimized	New pump station has no attenuating gravity supply
Comox No. 2 pump station sufficiently high flow to select high-head pumps for the application.	Direct forcemain discharge and significant increase in operational challenges.
Allows staging of the sewer system upgrades	Potentially requires an additional siphon in Comox or routing of the forcemain around Comox to retain grades.
	Single point of failure at the Comox No. 2 Pump station site which would render the entire system offline, resulting in an overall increase in the risk of catastrophic system failure.
	Higher annual operating costs due to power and asset management

6.3 Option 3 – New Comox No. 2 Pump Station in Comox

This option would require relocating the new PS to a lower elevation as a collection point for Courtenay and Comox's sewage. As such, Courtenay PS will need to be upgraded to overcome the Glacier View Drive hill in a forcemain, which can then flow by gravity to the new low-elevation PS. Sewage from Comox will be rerouted to the new low-elevation PS and pumped directly to the CVWPCC over the Lazo Road hill. For areas in Comox that are located at lower in elevation than the new PS, sewage collection will be maintained at the Jane PS and pumped to the new PS. Figure 6-3 illustrates the proposed HGL for this configuration and Table 6-5 summarizes the hydraulic parameters of the proposed system at the 2068 projected flow.



ELEVATION	4.75	5.00	4.55	1.68	0.64	0.51	0.03	2.18	2.15	3.46	4.86	16.92	26.14	23.24	37.13	39.93	36.01	29.67	21.97	17.33	17.99
STATION	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200

ELEVATION	16.37	18.00	13.98	12.66	13.67	12.91	15.33	15.99	16.18	15.03	17.10	40.82	37.33	50.15	48.87	47.19	40.03	34.10	25.74	15.91	7.93
STATION	4400	4600	4800	5000	5200	5400	5600	5800	6000	6200	6400	6600	6800	7000	7200	7400	7600	7800	8000	8200	8400

3100 m | 1950 m | 2250 m | 1150 m

COMOX VALLY REGINOAL DISTRICT
FORCEMAIN RE-ALIGNMENT EVALUATION
CONCEPTUAL OVERLAND FORCEMAIN ALIGNMENT PROFILE
OPTION 3 - NEW COMOX NO.2 PUMP STATION IN COMOX
HORIZ 1:10000 VERT 1:400

1:12500 @ ANSI D 0 200 400 600 800 1000 1200 m
1:500 @ ANSI D 0 5 10 15 20 25 30 35 40 45 50 m

Original Sheet Size ANSI D [22"x34"] Plot Date 2017-06-27 at 3:35:29 PM Path M:\COMOX VALLEY REGIONAL DISTRICT\D-13125.00\(C) Civil\+AutoCAD\D-13125.00_FIGURE 1_LAND.dwg FIGURE 6-3 DRAWN BY: CHONG WANG

FIGURE 6-3

Table 6-5: Proposed Hydraulics for Option 3

Parameters	Courtenay PS	Jane PS	Low-El PS
Wet Well Elevation (m)	-4.25	Facility Flow Negligible	-5
Static Head to Overcome (m)	43		56
Line Losses (m)	7		2
TDH (m)	50		58

The location of a new sanitary facility at the lowest elevation in Comox would alleviate the challenges of operating multiple pump stations in series without the benefit of an attenuating intermediate gravity system. Furthermore, this would concentrate the sanitary flows to a large facility which affords a greater selection of pumps and operating conditions to avoid the low-flow high-head problems. The size is also sufficient that 2-stage sanitary pumping conditions could be considered.

An intercepting sewer main would be required to direct flows from the current Jane PS to a new high capacity system. Jane PS would be retained but only service areas which fall below the elevation of the intercepting sewer.

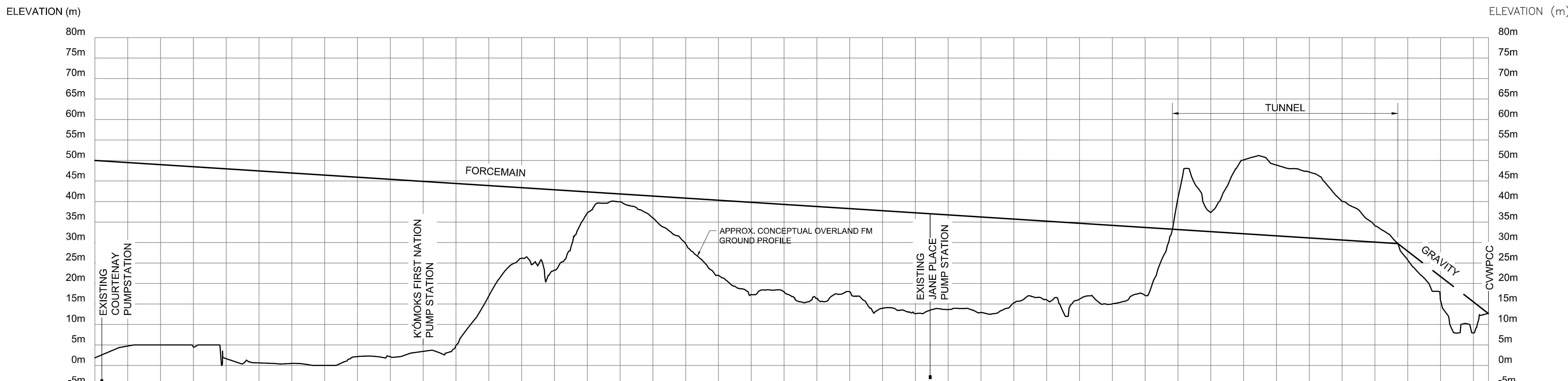
This arrangement results in the concentration of all the sanitary flows to one-central facility which increases the overall system operational risks. However, it is supplied from a gravity network which aids to attenuate the balancing flow requirements, and it can be selected in an area with adequate land to accommodate the station.

Table 6-6: Option 3 Advantages and Disadvantages

Advantage	Disadvantage
Jane PS capacity reduced, limited changes required at the facility.	Single point of failure
Comox No. 2 pump station sufficiently high flow to select high head pumps for the application.	Likely requires a 2-stage pump station to meet the head requirements, relatively unique system design.
Gravity system used to attenuate flows to the new high-flow high-head pump station.	Requires an interception sewer to redirect sanitary flows
New station located at the lowest point in the system to collect all flows by gravity.	

6.4 Option 4 – Tunnelling through Lazo Hill

This configuration would involve a tunnel through the Lazo Road hill at an acceptable TDH for both Courtenay and Jane PS. This option would however still require Courtenay PS to overcome the Glacier View Drive hill and Jane PS to be upgraded to meet the HGL prior to the tunnel. Figure 6-4 illustrates the proposed HGL for the tunnel configuration and Table 6-7 summarizes the hydraulic parameters of the proposed system at the 2068 projected flow.



STATION	ELEVATION
200	4.75
400	5.00
600	4.55
800	1.68
1000	0.64
1200	0.51
1400	0.03
1600	2.18
1800	2.15
2000	3.46
2200	4.86
2400	16.92
2600	26.14
2800	23.24
3000	37.13
3200	39.93
3400	36.01
3600	29.67
3800	21.97
4000	17.33
4200	17.99
4400	16.37
4600	18.00
4800	13.98
5000	12.66
5200	13.67
5400	12.91
5600	15.33
5800	15.99
6000	16.18
6200	15.03
6400	17.10
6600	40.82
6800	37.33
7000	50.15
7200	48.87
7400	47.19
7600	40.03
7800	34.10
8000	25.74
8200	15.91
8400	7.93

5100 m | 1500 m | 1350 m | 500 m

COMOX VALLY REGINOAL DISTRICT

FORCEMAIN RE-ALIGNMENT EVALUATION

CONCEPTUAL OVERLAND FORCEMAIN ALIGNMENT PROFILE

OPTION 4 - TUNNELLING THROUGH LAZO HILL

HORIZ 1:10000 VERT 1:400

1:12500 @ ANSI D 0 200 400 600 800 1000 1200 m

1:500 @ ANSI D 0 5 10 15 20 25 30 35 40 45 50 m

FIGURE 6-4

Original Sheet Size ANSI D [22"x34"] Plot Date 2017-06-27 at 3:35:44 PM Path M:\COMOX VALLEY REGIONAL DISTRICT\D-13125.00\(C) Civil\+AutoCAD\D-13125.00_FIGURE 1_LAND.dwg FIGURE 6-4 DRAWN BY: CHONG WANG

Table 6-7: Proposed Hydraulics for Option 4

Parameters	Courtenay PS	Jane PS
Wet Well Elevation (m)	-4.25	-3.25
Static Head to Overcome (m)	43	35[a]
Line Losses (m)	7	2
TDH (m)	50	37

Notes:
a) Discharge head required to meet hydraulic grade line

The use of a microtunnel through the Lazo Road Hill would alleviate the head challenges associate with the previously discussed options. Courtenay PS would operate at relatively high head, but reasonable high flow, and generated sufficient pressure to discharge on the eastern end of the Lazo Hill. The Jane PS would connect to the forcemain around a 37 m TDH. Detailed reviews could look at an additional tunnel through the Glacial View Drive hill to reduce the TDH at the Courtenay and Jane PSs.

This system would allow both the Courtenay and Jane pump stations to operate within normal conditions for a sanitary facility of their respective sizes. This would increase the ability to select suitable pumps for long term operation. However, a tunnel length of about 1,500 m would be required.

Table 6-8: Option 4 Advantages and Disadvantages

Advantage	Disadvantage
Reduced head and pumping requirements	Requires a minimum of one 1.5 km microtunnel
Lower head operation for Courtenay and Jane pump stations	
Operates using only 2 pump stations	
Mitigates the steep grades between the top of Glacial View Dr. into Comox and Lazo Hill to the WWTP.	
Lowest operational costs and carbon footprint	

7 Cost Estimates

In order to evaluate the four options discussed in the previous section a life-cycle financial model has been developed. As the infrastructure being constructed would be in use for a period of time in excess of 50 years two analysis periods have been assed, namely 50 years and 100 years. The basis of the costing and results are discussed in this section.

7.1 Basis of Costing

Capital cost estimates used for the financial model are based on Class D estimates and are considered reasonable for options comparison. The following costs have been used for developing the comparative options. Cost estimates are all based on a common 2017 dollar value.

7.1.1 Capital Costs

Each potential project has been provided a Project ID used in the financial analysis as several options have been assumed to have similar capital costs but varying operating costs. The assumed costs are noted in Table 1.

Table 7-1: Project Capital Cost Estimates and Peak Power Requirements

Project ID	Description	Capital Cost Estimate Class 'D' 2017$	Peak Power (kW)	Labour (Hrs/d)
1A	Courtenay PS Option 1	$4,174,000	570	2.5
1B	Jane PS Option 1	$4,100,000	250	3.0
1C	Courtenay PS Option 2	$4,174,000	460	2.5
1D	Jane PS Option 2	$1,392,000	130	2.3
1E	CMX No. 2 - Option 2 - Beech St.	$10,500,000	670	3.0
1F	Courtenay Option 3	$4,174,000	450	2.5
1G	Jane PS Option 3	Pump Station Decommissioned		
1H	CMX No. 2 - Option 3	$11,500,000	710	3.0
1I	Courtenay Option 4	$4,174,000	470	2.5
1J	Jane PS Option 4	$1,392,000	140	2.3
2A	Courtenay to Beech St. Forcemain	$13,210,000	Not Applicable	
2B	Beech St. to CVWWTP Forcemain	$6,285,000		
2C	Jane St. PS Forcemain	$397,000		
2D	Comox to WWTP	$11,400,000		
2E	Courtenay to Comox	$10,770,000		
2F	Tunnel	$9,000,000		

Notes on Table 7-1:

- Courtenay Pump Station (Project ID: 1A, 1C, 1F) – Refurbishment of the existing facility, including replacement of the pumps and major electrical equipment. Costs are based on the 2013 costs prepared by AECOM in the Sewerage and Staging plan.
- Jane St. Pump Station (Project ID: 1B) – Replacement of the existing facility with a high head facility for only the Comox flows.
- Jane St. Pump Station (Project ID: 1D, 1G)– Refurbishment of the existing facility, including replacement of the pumps and major electrical equipment. Costs are based on the 2013 costs prepared by AECOM in the Sewerage and Staging plan.
- Comox No. 2 Pump Station at Beech Street (Project ID: 1E) – Construction of a new facility on Beech Street to pump the combined Courtenay and Jane St. Pump Stations to the CVWWTP. Costs based on the Opus 2017 Draft Indicative Design Memo.
- Comox No. 2 Pump Station at Comox (Project ID: 1H) – Construction of a new facility Comox to collect and pump both Courtenay and Comox sewer to the CVWWTP. Costs based on the Opus 2017 Draft Indicative Design plus a $1,000,000 allowance for two stage pumping.
- Transmission Mains are based on pipe diameter, length and unit rates for excavation, pipe supply, fusing and road restoration. Pipe and fusing costs have been provided by Corix Waterworks.

- Tunnelling costs based on $1.6M for 1 launching and 1 receiving tunnel pits plus $7,500/m for micro-tunnelling costs for a total of $13,000,000 over the 1.5 km length. The cost has been discounted by $3,000,000 to off-set the cost of the overland forcemain carried in the Comox to WWTP line item (Project ID: 2D).
- Peak power is based on the maximum flow and the highest total dynamic head. A factor of 2:1 has been used to convert from maximum day flow to annual average flows.

7.1.2 Capital Cost Adjustments for Flow Reduction

The future flows at the Courtenay and Janes Pump Stations will be reduced as the Greenwood Truck main will collect a significant portion of future growth in sewage. The impact on the project capital costs will be nominal as the existing load will not be reduced, nor will the Greenwood Main negate the need to undertake capital improvements at the Courtenay Pump Station, Marine Forcemain and, to a lesser degree, the Jane Pump Station.

The Courtenay Pump Station will require a new pump system and electrical upgrade to increase the system head to accommodate a future overload forcemain route. The impact of flow results in a change in flow from 535 L/s to 674 L/s. Given the discharge head is governed by static elevation change, not dynamic losses, the individual pump power requirements is only nominally reduced (an increase of approximately 10% power). To accommodate the reduction in costs for mechanical and electrical equipment a 5% and 10% reduction in capital costs has been assumed. It must be recognized that no equipment is eliminated, only the size of pumps, motors and drives are reduced by approximately one size.

The forcemain is largely unchanged as the marine forcemain will still require an overload route per the Sewage Master Plan. A minor savings might be recognized as the diameter could be reduced by one size (i.e. 48” to 42”). Costs related to excavation, conflicts and surface restoration are unchanged. A 5% and 10% reduction in cost is provided for this condition.

The Jane Pump Station upgrade would be required under Option 1, upgrades required for Option 2 and 4 might be limited to the routine asset replacement, that is no overall increased in discharge pressure. Option 3 is unchanged. It must also be recognized that under Options 2 and 4, the upgrade capital cost for Jane Pump Station is $1,392,000 which is less than 1% of the life cycle costs. As a result, changes in the upgrades at Jane Pump Station will not impact the final conditions. However, for analysis a similar 5% and 10% reduction costs for lower upgrade equipment costs had been allowed.

7.1.3 Operating Costs

Operating costs include a labour allowance, power costs and asset renew costs. A summary of operating costs is provided in Table 7-2 below.

Table 7-2: Operating Costs use for Financial Analysis

Cost	Rate	Unit
BCH Fixed Rate	11.21	$/kW
BCH Variable Rate	0.055	$/kW-hr
BCH Annual Rate Increase	5%	Per year

Cost	Rate	Unit
Average Pump Station Operating hrs/day	12	Hr
Labour Rate	$100,000	Per year
Labour Inflation	3.00%	Per year

Each option contains an allowance for 2-hrs of operational time per day. Additional labour has been added to address cleaning and de-ragging of higher head facilities due to smaller water ways in the pump impellors. This is reflected in the analysis of each option discussed below.

7.1.4 Asset Management Costs

Assets refurbishment is assumed as follows:

- 20 years between pump and electrical refurbishment for stations where the pumps operate around 1800 RPM.
- 35 years between pump and electrical refurbishment for stations were the pumps operation around or below 1200 RPM.
- Pipelines are assumed to have an asset life of 70 years. Tunnels are assumed at 100 years.
- Facilities which are new have an assumed 40% cost associated with refurbishment. Where capital costs are carried initially as a refurbishment expenditure then the future refurbishment cost is assumed to be 100% of the current refurbishment cost.

7.1.5 Life Cycle Cost Analysis

Future capital cost has been inflated equal to the past 10 year ENR Construction Price Index which is taken as **3.02% per year**.

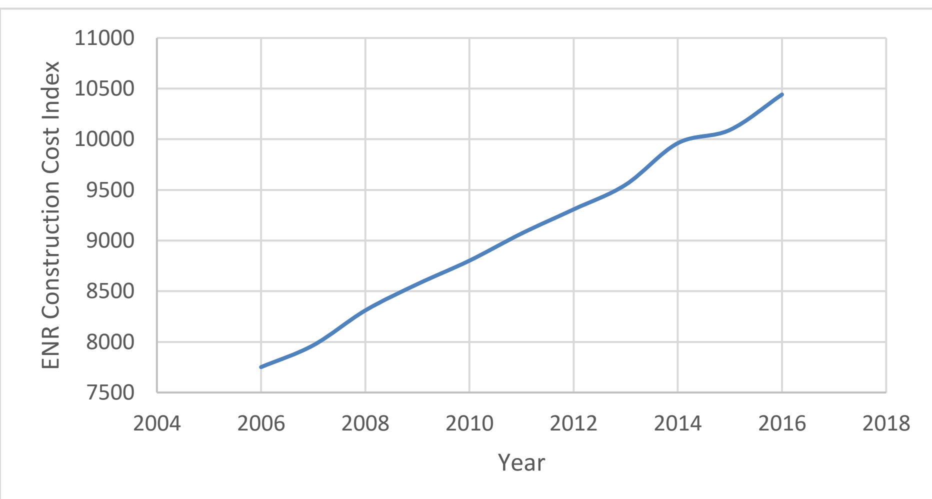


Figure 7-1: 10-year ENR Construction Cost Index Trend (3.02% per year)

Interest rates use to convert future costs to present worth costs have been deflated at the BC MFA Interest rates value of **2.80%** based on a 10-year rate.

7.2 Cost Comparisons

Option 1 – High Head Overland Pumping Facility

This option includes the refurbishment of the Courtenay Pump Station and the replacement of the Jane Street Pump Station with a high head facility. A new forcemain from the Courtenay pump station to the WWTP would be required. In addition, a new forcemain from the Jane St. Pump Station to the overland forcemain is necessary. Total costs and investment year are summarized in Table 7-3.

Table 7-3: Capital Investment Program for Option 1 High Head Overland Option

Project ID	Description	Capital Cost % Flow Diversion			Inv. Year
		0	50	75	
1A	Courtenay PS Option 1	$4,174,000	$3,965,000	$3,756,000	2018
1B	Jane PS Option 1	$4,100,000	$3,895,000	$3,690,000	2018
2D	Comox to WWTP	$11,400,000	$10,830,000	$10,260,000	2018
2E	Courtenay to Comox	$10,770,000	$10,231,500	$9,700,000	2018
2C	Jane St. PS Forcemain	$397,000	$377,150	$360,000	2018

Asset and operating costs for this option are summarized in Table 7-4 below. Labour has been increased for the Courtenay Pump Station to allow 1 day/month for a two person crew to clean the pump impellors. The Jane St. PS has been provided with a maintenance period of 1 day/2 week cycle to clean the pump impellors.

Table 7-4: Option 1 Operating Cost Assumptions

Project ID	Description	Renewal Frequency (yrs)	Renewal %	Total Power	Labour
1A	Courtenay PS Option 1	25	100%	570	2.5
1B	Jane PS Option 1	25	40%	250	3
2D	Comox to WWTP	60	100%	0	0
2E	Courtenay to Comox	60	100%	0	0
2C	Jane St. PS Forcemain	60	100%	0	0

Option 2 – New Comox No.2 Pump Station at Beech Street

This option includes the construction of a new pump station on Beech Street which collects sewage from both Courtenay and Jane St. pump stations. The total capital expenditures for this option are summarized in Table 7-5.

Table 7-5: Option 2 Low Head System with Comox No. 2 at Beech Street

Project ID	Description	Capital Cost % Flow Diversion			Inv. Year
		0	50	75	
1C	Courtenay PS Option 2	$4,174,000	$3,965,000	$3,756,000	2020
1D	Jane PS Option 2	$1,392,000	$1,322,000	$1,252,000	2020
1E	CMX No. 2 - Option 2 - Beech St.	$10,500,000	$9,975,000	$9,450,000	2018
2A	Courtenay to Beech St. Forcemain	$13,210,000	$12,549,000	$11,900,000	2033
2B	Beech St. to CVWWTP Forcemain	$6,285,000	$5,971,000	$5,600,000	2018
2C	Jane St. PS Forcemain	$397,000	$377,000	$357,000	2033

Asset and operating costs for this option are summarized in Table 7-6 below. Labour has been increased for the Courtenay Pump Station to allow 1 day/month for a two person crew to clean the pump impellors. The Jane St. PS has been provided with a maintenance period of 1 day/2 month cycle to clean the pump impellors.

The Beech Street facility has been provided with an additional maintenance period of 1 day/2 week cycle for pump overhaul due to the critical nature of this facility as an in-series booster station.

Table 7-6: Option 2 Operating Cost Assumptions

Project ID	Description	Renewal Frequency (yrs)	Renewal %	Total Power	Labour
1C	Courtenay PS Option 2	35	100%	460	2.5
1D	Jane PS Option 2	35	25%	130	2.25
1E	CMX No. 2 - Option 2 - Beech St.	25	25%	670	3
2A	Courtenay to Beech St. Forcemain	70	100%		
2B	Beech St. to CVWWTP Forcemain	70	100%		
2C	Jane St. PS Forcemain	70	100%		

Option 3 – New Comox No.2 Pump Station in Comox

This option includes the refurbishment of the Courtenay Pump Station and the near decommissioning of the Jane facility by replacing it with a large 2-stage pumping facility in Comox. A new forcemain from the Courtenay pump station to the WWTP would be required. In addition a new forcemain from the Jane St. Pump Station to the overland forcemain is necessary. Total costs and investment year are summarized in Table 7-7.

Table 7-7: Option 3 New High-Head Flow Pump Station

Project ID	Description	Capital Cost % Flow Diversion			Inv. Year
		0%	50%	75%	
1F	Courtenay Option 3	$4,174,000	$3,965,000	$3,756,000	2018
1H	CMX No. 2 - Option 3	$1,322,000	$10,925,000	$10,350,000	2018
2D	Comox to WWTP	$9,975,000	$10,830,000	$10,260,000	2018
2E	Courtenay to Comox	$12,549,000	$10,231,000	$9,700,000	2018
2C	Jane St. PS Forcemain	$397,000	$377,000	$357,000	2018

Asset and operating costs for this option are summarized in Table 7-8 below. Labour has been increased for the Courtenay Pump Station to allow 1 day/month for a two person crew to clean the pump impellors. The Comox facility has been provided with an additional maintenance period of 1 day/2 week cycle for pump overhaul due to the critical nature of this facility as an in-series booster station.

Table 7-8: Option 3 Operating Cost Assumptions

Project ID	Description	Renewal Frequency (yrs)	Renewal %	Total Power	Labour
1F	Courtenay Option 3	25	100%	450	2.5
1H	CMX No. 2 - Option 3	25	25%	710	3
2D	Comox to WWTP	70	100%		
2E	Courtenay to Comox	70	100%		
2C	Jane St. PS Forcemain	70	100%		

Option 4 – Tunnelling through Lazo Hill

This option includes the refurbishment of the Courtenay Pump Station and the refurbishment of the Jane St. Pump Station. A new forcemain from the Courtenay pump station to the WWTP would be required. In addition, a new forcemain from the Jane St. Pump Station to the overland forcemain is necessary. Total costs and investment year are summarized in Table 7-9.

Table 7-9: Capital Investment Program for Option 4 Tunnelling

Project ID	Description	Capital Cost % Flow Diversion			Inv. Year
		0%	50%	75%	
1I	Courtenay Option 4	$4,154,000	$3,965,000	$3,756,000	2018
1J	Jane PS Option 4	$1,385,000	$1,322,400	$1,252,000	2018
2C	Jane St. PS Forcemain	$397,000	$377,000	$357,000	2018
2D	Comox to WWTP	$11,400,000	$10,830,000	$10,260,000	2018
2E	Courtenay to Comox	$10,770,000	$10,231,000	$9,700,000	2018
2F	Tunnel	$9,000,000	$8,550,000	$8,100,000	2018

Asset and operating costs for this option are summarized in Table 7-10 below. Labour has been increased for the Courtenay Pump Station to allow 1 day/month for a two person crew to clean the pump impellors. The Jane St. PS has been provided with a maintenance period of 1 day/2 month cycle to clean the pump impellors.

Table 7-10: Option 4 Operating Cost Assumptions

Project ID	Description	Renewal Frequency (yrs)	Renewal %	Total Power	Labour
1I	Courtenay Option 4	25	100%	470	2.5
1J	Jane PS Option 4	35	100%	140	2.25
2C	Jane St. PS Forcemain	70	100%		
2D	Comox to WWTP	70	100%		
2E	Courtenay to Comox	70	100%		
2F	Tunnel	100	100%		

7.3 Net Present Value

Net Present Value has been used to compare the options while considering the remaining life in assets, replacement frequency and annual power costs. In addition to capture the replacement of the forcemain a life-cycle period of 50 and 100 years has been used.

Table 7-11 and 7-12 below provide the present worth capital, operating and total costs for each of the 4 option previously discussed.

Table 7-11: 50 Year Life Cycle Cost Estimate

Option	Description	PW Capital	PW Operating	PW Total
No Flow Diversion				
1	High Head Overland Pumping Facility	$43,100,000	$31,000,000	$74,400,000
2	CMX No. 2 @ Beech St.	$46,600,000	$47,100,000	$93,700,000
3	CMX No. 2 @ Comox	$53,100,000	$42,300,000	$96,400,000
4	Tunnel	$47,400,000	$23,500,000	$70,900,000
50% Flow Diversion				
1	High Head Overland Pumping Facility	$41,000,000	$29,000,000	$70,000,000
2	CMX No. 2 @ Beech St.	$44,300,000	$42,800,000	$87,100,000
3	CMX No. 2 @ Comox	$50,500,000	$39,700,000	$90,200,000
4	Tunnel	$45,100,000	$21,500,000	$66,600,000
75% Flow Diversion				
1	High Head Overland Pumping Facility	$38,800,000	$27,300,000	$66,100,000
2	CMX No. 2 @ Beech St.	$41,900,000	$40,800,000	$82,700,000
3	CMX No. 2 @ Comox	$47,800,000	$38,000,000	$85,800,000
4	Tunnel	$42,700,000	$20,500,000	$63,200,000

Table 7-12: 100-Year Life Cycle Cost Estimate

Option	Description	PW Capital	PW Operating	PW Total
No Flow Diversion				
1	High Head Overland Pumping Facility	$74,100,000	$110,900,000	$185,000,000
2	CMX No. 2 @ Beech St.	$76,700,000	$167,600,000	$244,300,000
3	CMX No. 2 @ Comox	$85,800,000	$155,900,000	$241,700,000
4	Tunnel	$78,400,000	$82,500,000	$160,900,000
50% Flow Diversion				
1	High Head Overland Pumping Facility	$70,400,000	$102,200,000	$172,600,000
2	CMX No. 2 @ Beech St.	$72,800,000	$151,400,000	$224,200,000
3	CMX No. 2 @ Comox	$81,500,000	$142,100,000	$223,600,000
4	Tunnel	$74,500,000	$75,000,000	$149,500,000
75% Flow Diversion				
1	High Head Overland Pumping Facility	$66,700,000	$96,000,000	$162,700,000
2	CMX No. 2 @ Beech St.	$69,000,000	$143,900,000	$212,900,000
3	CMX No. 2 @ Comox	$77,200,000	$135,900,000	$213,100,000
4	Tunnel	$70,600,000	$71,300,000	$141,900,000

In both the 50-year and 100-year assessment period Option 4 using a tunnel has the lowest life-cycle costs. This is the direct result of this option having the lowest annual costs. Figure 7-2 through 7-4 provides a graphical depiction of the present dollar cash flow for each option. Option 1, the High-Head Overland configuration has the 2nd lowest initial costs while Option 4, the tunnel option is the lowest overall option and falls below all other scenarios at about the 44th year of operation.

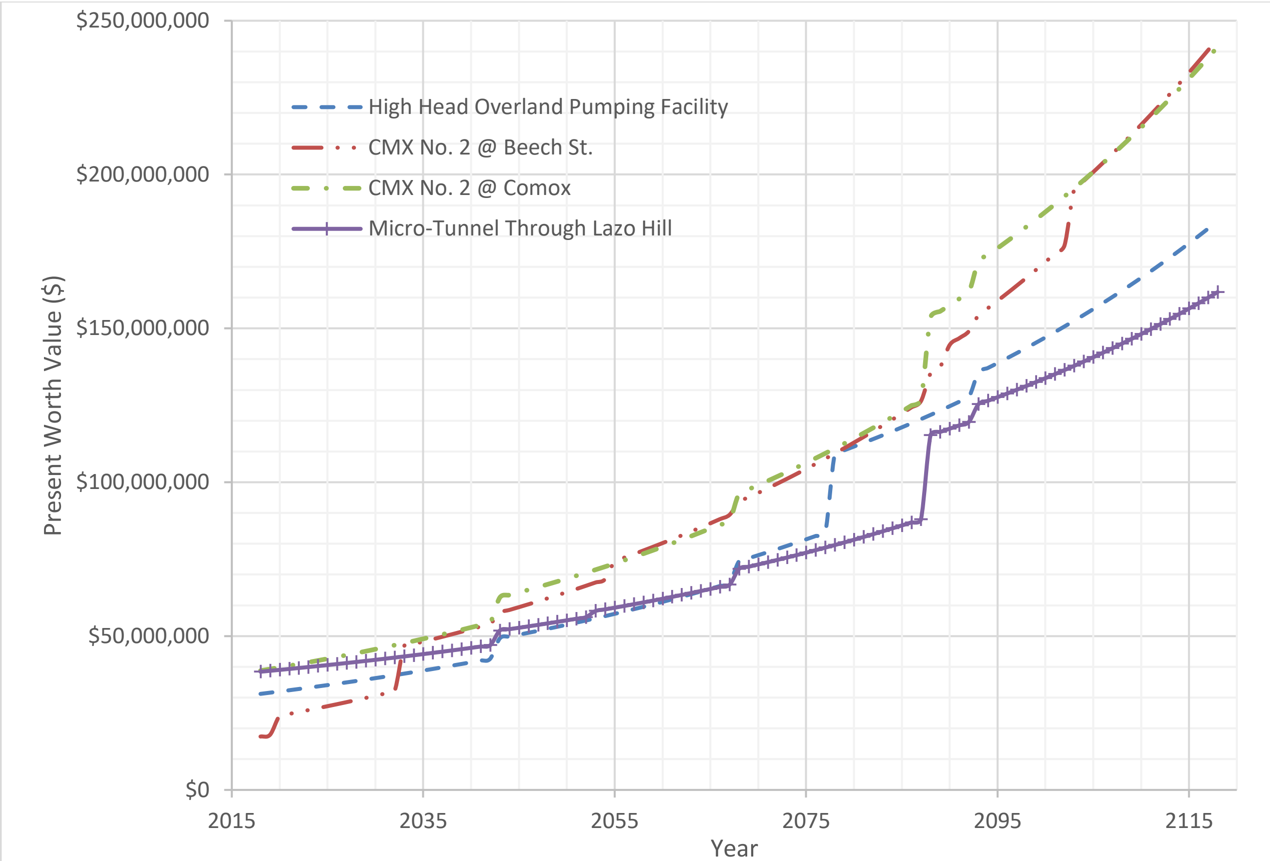


Figure 7-2: Total Projected Cash Flow in Present Dollars (at no Flow Diversion)

Figure 7-3: Total Projected Cash Flow in Present Dollars (at 50% Flow Diversion)

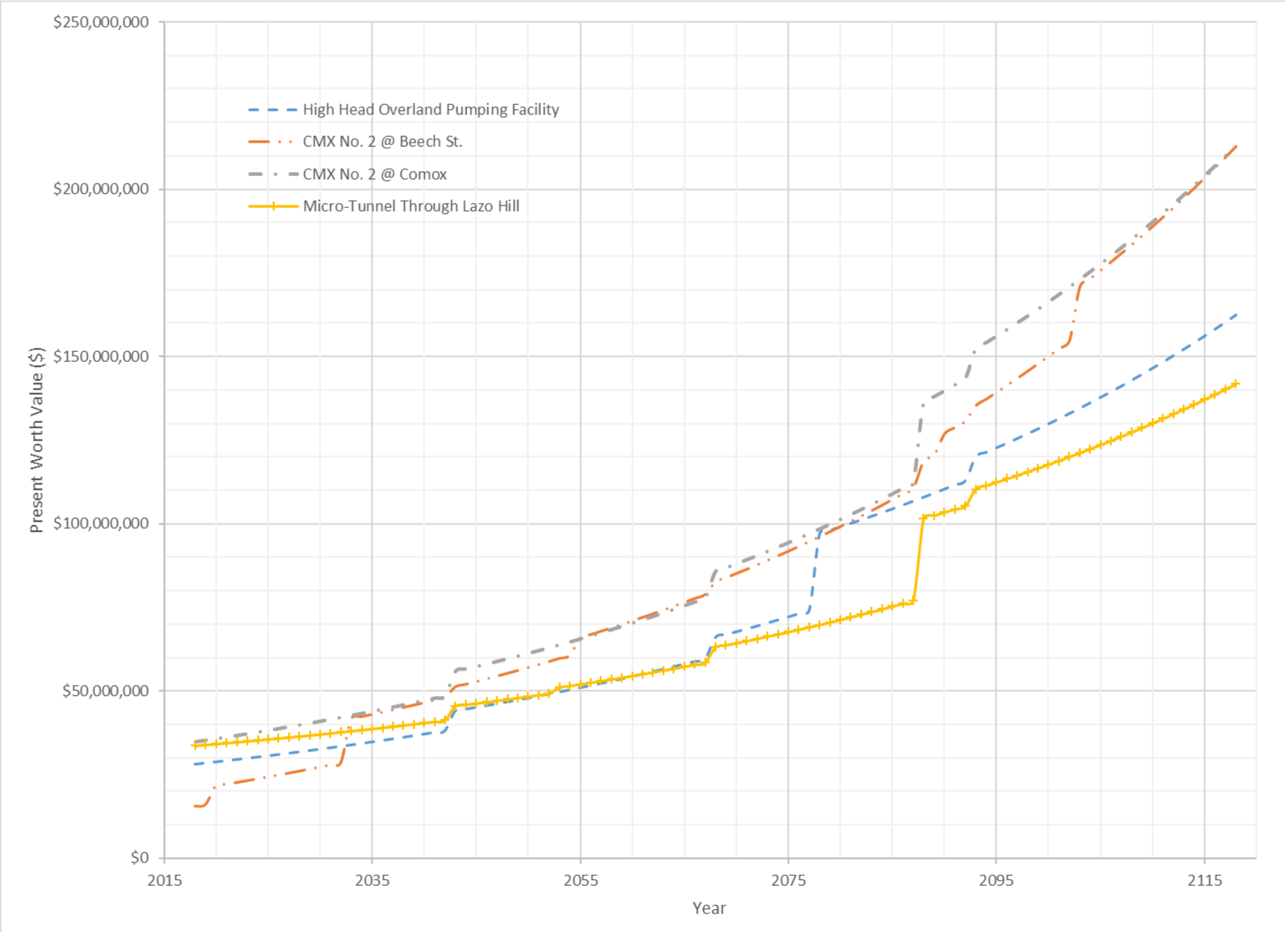


Figure 7-4: Total Projected Cash Flow in Present Dollars (at 75% Flow Diversion)

7.4 Discussion

There is nominal change in the capital and asset management cost based on a diversion of the future loads as existing flows must still be pumped. There is a reduction in the total life cycle costs as power is reduced for future flows.

In order to construct the tunnel a high initial capital cost is incurred; however, the annual operation costs are the lowest for all option, including:

- Asset management as pumps are running at lower RPM,
- Labour as pumps are operating against lower head and lowest clogging issues
- Power is lower as the pump run at a lower total dynamic head

The reduction in these costs reduces the dependence of the CVRD on third party rate changes, such as BC Hydro and staff labour rates. This can be observed through a sensitivity assessment of the options. The impact of BC Hydro rates on the breakpoint for Option 1 and Option 4 is in the Tables below. Further sensitivity analysis was completed to compare the change in labour costs, interest rates and ENR construction inflation. In all situations, the tunnel option provides a positive payback around a 40 to 50 year timeframe.

Table 7-13: Sensitivity of BC Hydro Inflation Rates on the Break-Even Point for Options 1 and 4

BC Hydro Rate Change	Break-even Point
3% (-2% below baseline)	58 years
5% (baseline)	49 years
7% (2% above baseline)	33 years

Table 7-14: Sensitivity of Labour Inflation Rates on the Break-Even Point for Options 1 and 4

Labour Rate Change	Break-even Point
1% (-2% below baseline)	49 years
3% (baseline)	49 years
5% (2% above baseline)	47 years

Table 7-15: Sensitivity of MFA Interest Rates on the Break-Even Point for Options 1 and 4

Interest Rate (%)	Break-even Point
2% (-0.8% below baseline)	43 years
2.8% (baseline)	49 years
4% (2% above baseline)	54 years

Table 7-16: Sensitivity of ENR Construction Rates on the Break-Even Point for Options 1 and 4

ENR Index (%)	Break-even Point
2% (-1% below baseline)	48 years
3% (baseline)	49 years
4% (1.1% above baseline)	50 years

8 Summary and Recommendations

The existing Comox Valley Regional District sanitary collection system is based on a low-head pumping system predicated on the forcemain installed along the intertidal foreshore area. In recent years the long term viability of this system has been undermined, namely due to erosion along the portion of the forcemain between Goosespit and the CVWWTP and operational emergency response challenges related to repairs of the forcemain in the marine environment. The foreshore alignment is further complicated by social and regulatory risks related to replacement of the marine sections of the forcemain.

As a result of these issues a review of alternative alignments has been completed. The focus was on terrestrial routes utilizing traditional open trench installation methods or small diameter micro-tunnels. In order to operate using a terrestrial forcemain the two primary pump stations – Courtenay and Jane St – require modifications to function under the new hydraulic conditions. Two of the options also considered a new pump station in order to mitigate risks associated with high head sanitary pumping stations. The four options considered are:

a. High-Head Pumping. This option would involve increasing the pump discharge head for both Courtenay and Jane St. Pump Stations to a sufficient pressure to overcome both the Glacial View Dr. Hill and the Lazo Hill. The forcemain would be routed overland through Comox and along Lazo Road to the CVWWTP.

b. Comox No. 2 Pump Station on Beech St. This option includes a new pump station at approximately 16 m elevation to collect all sewage from Courtenay and Comox where it would be boosted up over Lazo Hill. The existing forcemain from Courtenay to Beech St. would be retained for 15 years, at which time it would be routed through Comox to the Beech St. site.
c. Comox No. 2 Pump Station in Comox. This option includes a new pump station at the lowest elevation of the gravity collection system in Comox. This facility would collect all Courtenay and Jane St. sewage and pump it over the Lazo Hill to the CVWWTP. The Jane St. pump station would be largely decommissioned under this option.
d. Tunnel through Lazo Hill. This option would involve a micro-tunnel through the Lazo Road hill to reduce the pumping head required at the Courtenay and Jane St. pump stations. This option would still require improvements at both pumping stations to increase the operating head, albeit to a lower discharge pressure as compared to Option 1.

Several operational considerations have been reviewed as part of the system option assessment. Firstly, as the discharge pressure at a sanitary pump station increases the pump impellor waterways tend to get smaller, which increases the risk of ragging of the pumps. Furthermore, the higher the head the higher the operating RPM of the pumps. This directly impacts the operating period of the pumps and increases the risk of reduced pump suction hydraulics potential for ragging. These issues become more pronounced at lower operating flow rates, such as the Jane St. pump station.

A second operational consideration is the balancing opportunities within the pumping system. Gravity collection systems provide a level of attenuation between the peak flow events and the pump station operation, and to a lesser degree some system storage. This is further mitigated by operating larger wetwells at the pump station. Where this balancing and attenuation storage opportunity is not available, increased system redundancy and controls are required. The most difficult application is direct in-series pumping where one or more pump stations directs flow through a forcemain directly to another pump station.

Finally, the operating costs for the facility have been considered. This includes direct electricity consumption, asset management and replacement and a labour allowance for routine inspection and servicing.

The options analysis was completed using a 50 and 100-year net present worth assessment. The financial review included Class D estimates for initial capital costs, routine asset replacement, power and labour allowanced. Inflation was carried at the 10-yr ENR construction cost index and interest rates at the BC MFA 10-year borrow rates. For both the 50-year and 100-year assessment Option 4, micro-tunnelling, has the lowest overall costs. Table 8-1 provides a summary of the present worth values based on the zero flow diversion assumption. Table 8-2 provides a summary of the present worth flows assuming 75% flow diversion.

Table 8-1: 50-year and 100-year Present Worth Values

Option	Description	PW Capital	PW Operating	PW Total
50-Year Present Worth				
1	High Head Overland Pumping Facility	$43,100,000	$31,000,000	$74,400,000
2	CMX No. 2 @ Beech St.	$46,600,000	$47,100,000	$93,700,000
3	CMX No. 2 @ Comox	$53,100,000	$42,300,000	$96,400,000
4	Tunnel	$47,400,000	$23,500,000	$70,900,000
100-Year Present Worth				
1	High Head Overland Pumping Facility	$74,100,000	$110,900,000	$185,000,000
2	CMX No. 2 @ Beech St.	$76,700,000	$167,600,000	$244,300,000
3	CMX No. 2 @ Comox	$85,800,000	$155,900,000	$241,700,000
4	Tunnel	$78,400,000	$82,500,000	$160,900,000

Table 8-2: 50-year and 100-year Present Worth Based on 75% Diversion

Option	Description	PW Capital	PW Operating	PW Total
50-Year Present Worth				
1	High Head Overland Pumping Facility	$38,800,000	$27,300,000	$66,100,000
2	CMX No. 2 @ Beech St.	$41,900,000	$40,800,000	$82,700,000
3	CMX No. 2 @ Comox	$47,800,000	$38,000,000	$85,800,000
4	Tunnel	$42,700,000	$20,500,000	$63,200,000
100-Year Present Worth				
1	High Head Overland Pumping Facility	$66,700,000	$96,000,000	$162,700,000
2	CMX No. 2 @ Beech St.	$69,000,000	$143,900,000	$212,900,000
3	CMX No. 2 @ Comox	$77,200,000	$135,900,000	$213,100,000
4	Tunnel	$70,600,000	$71,300,000	$141,900,000

The tunnel option has the lowest annual operating costs, which results in a lowest long term present worth relative to all other options. In addition, the tunnel option address the operational risks, specifically:

- Lower head operation. The tunnel reduces the system operating head by approximately 20 meters (30 psi) which provides a significant benefit for the smaller Jane St. facility which has limited space for modification and due to the smaller pumps less options for high discharge heads
- System attenuation. The re-configurated system would operate with the current attenuation provided by the gravity collection system. This avoids the need for in-series booster stations and would also avoid “slug” flows at the WWTP.
- The power requirements are the lowest of all the overland routes. This reduces the impact of future BC Hydro rate changes on the CVRD operating costs.
- Lower operational and maintenance costs as no new pump station is required.
- Lower environmental risks, specifically:

  » Reduction in the response time related to a forcemain failure as the entire marine portion of the forcemain is relocated to a terrestrial alignment. Response times for the marine section could range up to days due to tidal windows and restricted access. Terrestrial sections would be accessible within hours.

   - Increased capacity to clean up sanitary contaminated soils following a forcemain failure. Portions of terrestrial soils can be excavated and washed to remove sanitary contamination. This is more difficult in the marine environment both due to tidal changes (limited time) and damage to ecosystem habitat.
   - A break on a terrestrial forcemain will be limited to causing contamination to existing drainage routes such as ditches and other storm water systems. This can be controlled and response measures implemented by operations staff – such as containment and public access restriction to reduce the risks to public health. Due to the tidal action in the marine environment it is significantly more complex to contain any sanitary discharged in the harbour.

- Increase in social benefits, specifically:

   - Reduction in the overall carbon footprint as energy requirements are reduced.
   - Reduced land use impacts as no new pumping facility is required.
   - Improved access to the system infrastructure.
   - Removal of the sanitary system from the intertidal zones.

As a result of the new overland operation the pump station improvements and forcemain construction will have to be completed as a single project. This requires a significant initial capital investment, rather than Options 2 or 3 which provide opportunities for staged expenditures. However, over the duration of the project life the initial capital costs are recovered in lower asset management and power costs. This is in addition to the implementation of a sewage conveyance system that is more reliable while using the existing Courtenay and Jane St. pump stations.

This option provides the Regional District with a sewage conveyance system with improved reliability, lower catastrophic risk failure as the system relies on fewer pump stations which operate in parallel rather than in series, lower environmental risks, lower overall life-cycle costs, removal of the sanitary system from the foreshore and in a significant increase in the access to the infrastructure by the operations staff.

In addition, this arrangement provides opportunities to review other system improvements, such as implementation of an I&I equalization storage facility to reduce overflow risks and provide improved flow balancing to the Comox Valley wastewater treatment plant.

Should the CVRD proceed with a terrestrial route a preliminary design review should be completed which would review the forcemain alignment, utility conflicts, land ownership, geotechnical and the required pump station modifications.

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