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Inflow and Infiltration Masterplan

Final Report
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KWL Project No. 0601.010

Prepared for:
Township of Esquimalt

Township of ESQUIMALT

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Executive Summary

The Township of Esquimalt (the Township) retained Kerr Wood Leidal Associates Ltd. (KWL) to develop an Inflow and Infiltration (I&I) Masterplan. The masterplan includes recommendations to address I&I in the Township with the objective of reducing peak wet weather flow (PWWF) to 4 X average dry weather flow (ADWF) for a five-year storm by 2030. Reducing I&I to 4 X ADWF by 2030 is a requirement of the Capital Regional District's (CRD) Core Area Liquid Waste Management Plan (CALWMP), of which Township is a member.

PWWF for all the sewer catchments within the Township were evaluated as part of the CRD's Core Area Inflow & Infiltration Management Plan 2017 Update. The Townships' sewer catchments range from about 5 X ADWF to 9 X ADWF, with an average of 5.7 X ADWF.

I&I is the driving factor for 3,760m of pipe upgrades recommended in the Townships 2019 Sanitary Sewer Collection System Modelling and Capacity Analysis. Reducing I&I would allow the Township to avoid many costly upgrades. The 2019 capacity analysis included a sensitivity analysis which determined that a 25% reduction in I&I levels would eliminate 38% of the required pipe upgrade (1,418 m less upgrades) and a 50% reduction in I&I would eliminate 90% of the required pipe upgrades (3,388 m less upgrades) as well as avoid an upgrade to the Townships Kinver sewer pump station.

The Township has completed a number of initiatives to reduce I&I over the past 12 years. This includes renewal of 25% of the system by CIPP pipe lining, removal of 126 combined manholes (82%), completed smoke testing of the entire system, redirection of 20 catchbasins that were found to be cross-connected, and completion of CCTV inspections on 34% of the sanitary system. Some reductions in I&I have been achieved through this work but I&I rates remain high.

A large percentage of the Townships sewer system is between 50 and 70 years old (57.8%). The system also has a large percentage of vitrified clay pipe (43.2%). There are however no strong correlations between mainline pipe age, material, and the rates of I&I within catchments. I&I rates are high in all catchments, regardless of mainline pipe age and material type and this would suggest that a significant portion of I&I is related more closely to service laterals.

Review and GIS mapping of CCTV condition data was completed and priority replacements, mostly of the oldest vitrified clay pipes, were identified. The review also corroborated the assumption that the majority of I&I is occurring within laterals as witnessed by reviewing CCTV conducted during rain events.

CCTV of lined pipes was reviewed and recommendations on how to address the interface between the lined pipe and laterals are made. Recommendations included cutting in tee connections prior to lining, installing top-hat liners to achieve a sealed and structural connection after lining, and avoiding cutting in new wyes for services for previously lined pipes. An alternative approach for lateral connection to lined pipes through open cut replacement of the lateral is to install an exterior sewer saddle and concrete surround at the location of the existing connection.

A number of the remaining combined manholes were inspected and recommendations are made for the removal of some direct sources of I&I.

Ultrasonic Level Loggers were installed in manholes in the Devonshire, Uganda, and Forshaw catchments throughout the winter of 2020/2021 to narrow in on areas with the greatest amount of I&I and to assess whether I&I is likely attributed to direct connections or influenced by increased groundwater levels after rainfall. At least one noted rainfall event, a few day period after a rainfall event, and a few days of dry weather data was collected before moving the loggers to different manhole locations.

The level logging work identified a number of sub-catchments with high peak wet weather flows with notably high peak I&I rates occurring in the Colville Road sub-catchment of Devonshire, near the Lampson pump station, in the upper Forshaw catchment, and in Uganda catchment near the Gorge Point Condos and Pub.

Additional CCTV inspections and smoke testing is recommended in key areas of the Devonshire, Forshaw, and Uganda catchments to attempt to locate direct connections and provide condition data to inform targeted replacement work. We recommend completing engineering analysis of the condition data and GIS mapping of priority replacements and service lateral locations. Mapping of service connection locations will assist in locating cross connections.

The I&I strategy presented in this plan seeks to achieve 4 X ADWF by 2030 by reducing I&I in the Devonshire, Forshaw, Uganda, and Kinver catchments through targeted rehabilitation programs that seek to renew both public and private laterals and line sewers mains in poor condition.

The plan requires the Township to first put in place a bylaw addressing maintenance and repair of private sewer laterals. A model bylaw was developed by the CRD, and the Township modified this bylaw and is currently in draft form for discussion with Council. Some of the key elements of this modified bylaw include:

1. Maintenance standard.
2. Definition of unauthorized discharges and connections.
3. Provides a mechanism and authority allowing the Township to enter the private lateral and conduct testing to identify defects and noncompliance with the bylaw.
4. Authority to require repair of the defects.
5. Requirements for plumbing permits.
6. Description of financial assistance for repair/renewal of for private sewer laterals.

Financial assistance and monetary incentives are needed to achieve enough participation by homeowners for targeted rehabilitation projects and to gain broader community support for the bylaw.

Targeted rehabilitation of 40% of the Colville sub-catchment in Devonshire, and 40% of the Uganda and Forshaw catchments is recommended in the first three years of the program starting in 2023. Targeting 40% rehabilitation in an area is anticipated to results in at least a 25% reduction in I&I flows for the catchment. The actual reductions will vary based on various factors and the existing monitoring program should be used to track improvements associated with rehabilitation works. In the five years spanning 2026 to 2030 additional targeted rehabilitation programs are anticipated to bring I&I rates down below 50% of existing levels in the Devonshire, Uganda, Forshaw, and Kinver Catchments.

The recommend works are estimated to resolve 90% of the capacity issues within the network as well as avoid the need to upgrade the Kinver Pump station. Eight targeted rehabilitation programs are estimated to reduce current I&I rates from 5.7 X ADWF to 4.2 X ADWF. It is expected that financial incentives offered over the course of 8 years will bring I&I rates below 4.0 X ADWF.

Table E-1 provides a summary of the recommended works, costs, and timing:

Table E-1: Program Costs and Timing

Program Item	Total Cost	Year
CCTV Condition Assessment	$163,000	2022 / 2023
Additional Smoke Testing and Level Monitoring	$25,500	2022
Combined Manhole and Sewer Abandonments	$25,000	2022 / 2023
Colville Catchment – Targeted Replacement Program	$945,000 City $210,000 Private	2023
Uganda Catchment – Targeted Replacement Program	$1,150,000 City $150,000 Private	2024
Forshaw Catchment – Targeted Replacement Program	$1,375,000 City $225,000 Private	2025
Kinver Catchment – Targeted Replacement Program	$1,150,000 City $150,000 Private	2026
Devonshire Catchment – Targeted Replacement Program (Phase 2)	$1,150,000 City $150,000 Private	2027
Forshaw Catchment – Targeted Replacement Program (Phase 2)	$1,150,000 City $150,000 Private	2028
Uganda Catchment – Targeted Replacement Program (Phase 2)	$1,150,000 City $150,000 Private	2029
Kinver Catchment – Targeted Replacement Program (Phase 2)	$1,150,000 City $150,000 Private	2030
Total Cost All Programs	**$9,433,500 City $1,335,000 Private**	

Some recommended upgrades in the Devonshire catchment, notably within the ball field near the Lampson Pump station can likely not be avoided and are a current public health risk given ongoing sewer overflows to ground that were witnessed in December 2020 following a 5-year return storm.

1. Introduction

1.1 Background

The Township of Esquimalt (the Township) retained Kerr Wood Leidal Associates Ltd. (KWL) to develop an Inflow and Infiltration (I&I) Masterplan for the Township. The masterplan will include recommendations to address I&I in the Township with the objective of reducing peak wet weather flow (PWWF) to 4 X average dry weather flow (ADWF) for a five-year storm by 2030. Reducing I&I to 4 X ADWF by 2030 is a requirement of the Capital Regional District's (CRD) Core Area Liquid Waste Management Plan (CALWMP), of which Township is a member.

Higher priority is placed on reductions in I&I within the Devonshire, Forshaw, and Uganda catchment for the purpose of avoiding costly upgrade projects that are driven by high I&I rates in these catchments.

1.2 Scope

The scope of work includes:

1. Review of existing catchment I&I flow profiles.
2. Creation of a single CCTV condition assessment database (29.7 km of inspections).
3. Review of existing smoke testing data completed in 2009 and CCTV condition data collected in 2017 through 2019.
4. Review and investigation into rehabilitation works completed to date including a large volume of CIPP lining completed in 2009
5. GIS-based mapping of pipe condition from CCTV data, smoke testing data, combined manhole locations, pipe age and materials, I&I related codes from the CCTV data, catchments and PWWF/ADWF ratios to assist in linking correlations between asset condition and I&I rates.
6. QA/QC review of the CCTV database, focussed on videos inspected during rain events.
7. GIS-based mapping of service lateral locations with suspected I&I as viewed through the QA/QC process done on sewer pipes inspected during rain events.
8. Manhole level monitoring using 7 ultrasonic level sensors moved throughout the Devonshire, Forshaw and Uganda catchments to assess I&I rates throughout these catchments.
9. Assessment of whether planned capacity upgrades can be avoided through I&I reductions.
10. Review of the Townships initiatives / draft bylaws to address private side I&I issues and make recommendations.
11. Prepare a list of recommended actions and replacements.
12. Prepare Class D cost estimate for recommended works.
13. Develop a system wide plan for I&I reduction efforts over the long-term.

1.3 Project Justification

A driver for reducing I&I for the Township is the CRD's recently constructed McLoughlin Point Wastewater Treatment Plant and implementation of the CALWMP, which requires that municipalities

reduce peak wet weather flow (PWWF) to 4 X average dry weather flow (ADWF) for a five-year storm by 2030.

PWWF for all the sewer catchments within the Township were evaluated as part of the CRD's Core Area Inflow & Infiltration Management Plan 2017 Update. The Townships' sewer catchments range from about 5 x ADWF to 9 X ADWF, with an average of 5.7 X ADWF.

I&I is the driving factor for 3,760 m of pipe upgrades recommended in the Township's Sanitary Sewer Collection System Modelling and Capacity Analysis (Modelling Report)[1]. Reducing I&I would allow the Township to avoid many costly upgrades. The 2019 capacity analysis included a sensitivity analysis which determined that a 25% reduction in I&I levels would eliminate 38% of the required pipe upgrade (1,418 m less upgrades) and a 50% reduction in I&I would eliminate 90% of the required pipe upgrades (3,388 m less upgrades) as well as avoid an upgrade to the Townships Kinver sewer pump station.

1.4 Historic Township Actions to Address I&I

As a participating member of the CALWMP, the Township has completed a number of actions to address I&I. These include the following:

1. Combined manhole separation program that separated 126 of the Townships 153 combined manholes (2005-2015).
2. Sewer main relining program that rehabilitated 25% of the Townships mainline sewers (2009).
3. A comprehensive smoke testing program that identified and removed 20 cross connected catch basins and identified possible cross connections on 63 private properties (2010).
4. Ongoing real-time sewer flow data collection.
5. Ongoing CCTV sewer inspection (2017-present).
6. Replacement of failed sewer mains (ongoing).
7. Installation of inspection chambers (IC's) at property line when work is completed on a lateral (ongoing).

The Township has reported some overall reductions in I&I through works completed to date. The current focus of the Township's Engineering department is a targeted approach to reduce I&I in the worst catchments and where those reductions can improve hydraulic performance and avoid upgrade projects.

1.5 Glossary

I&I is surface runoff and groundwater that has entered the sanitary sewer system. Many pathways exist for water to enter the sewer system, and each pathway has particular characteristics best described with a hydrograph of the I&I component of sewer flow.

The first step in reducing I&I is understanding where it comes from. The following table describes the various components that comprise sanitary, and I&I flows.

[1] GeoAdvice Engineering Inc. "Township of Esquimalt Sanitary Sewer Collection System Modelling and Capacity Analysis" 2019.

Table 1-1: Sanitary Flow Components

Component	Acronym	Calculated As	Definition/Explanation
Sanitary Flow			
Average Dry Weather Flow	ADWF		Average daily flow measured during periods of dry weather (i.e., June to September). This includes both BSF and summer GWI.
Peak Wet Weather Flow	PWWF		Peak flow recorded during storm event, or modelled as peak sanitary flow on peak I&I.
Base Sanitary Flow or Average Domestic Flow	BSF or ADF		Average daily sanitary flows originating from domestic and industrial sources.
Peak Sanitary Flow or Peak Domestic Flow	PSF or PDF	BSF x peaking factor	Peak hourly sanitary flow originating from domestic and industrial sources.
Inflow and Infiltration			
Groundwater Infiltration	GWI	85% of min. DWF	Extraneous flow from the ambient long-term water table, not influenced by individual rainfall events.
Rainfall-Induced Infiltration	RII_{RP}		Rainfall that follows a path to the sewer through the soil and/or from short-term, rainfall-based increases in water table elevation. Identifiable in two components, slow and fast.
Stormwater Inflow	SWI_{RP}		Rainwater that enters the sewer through direct (non-soil) connections to the runoff surface.
Rainfall-Dependant Inflow & Infiltration	$RDII_{RP}$	SWI_{RP} + RII_{RP}	Total peak rainfall-sourced extraneous flow, averaged over short-terms ranging from 5 minutes to 24 hours depending on catchment characteristics.
Total I&I	$I\&I_{RP}$	$RDII_{RP}$ + GWI	Total peak rainfall-sourced plus ambient extraneous flow, averaged over short terms.

RP=Return Period.
All of the rainfall-related parameters must be expressed with a return period if they have been derived from flow data or have been estimated with a hydrologic model. It may be appropriate to express the return period as 'major event' in some cases.

Typical GWI rates in the Pacific Northwest occur in the 3,000 – 5,000 L/ha/d range. High GWI can be found in catchments with poorly draining soils, deep sewers, structural decay or ungasketed joints. Achieving complete I&I reduction in such catchments will likely require an intense focus on rehabilitation of the lower portions of the system.

SWI (inflow) commonly results from directly connected roof leaders, foundation drains, sump pumps and catch basins. Defective sewer access points such as manhole frames and covers, cleanouts and inspection chambers are other potential direct connections. SWI is indicated in flow monitoring records as sharp responses to rainfall events during summer months but is nearly impossible to separate from RII during winter months. This can be quantified at a return period using the I&I Envelope Method.

RII (infiltration) enters the sewer system through leaking joints and structural defects in pipes and manholes. Service connections are typically buried at shallow depths, and can be easily damaged, and

brick risers as well as other component interfaces in manholes are not typically sealed. This allows for rapid infiltration of groundwater to occur. Infiltration in pipes and lower portions of manholes occurs more slowly but can be significant during longer wet weather events. RII is not often detected visually as CCTV inspections are usually conducted during dry weather to prevent submergence of the camera. RII becomes fully developed when soils surrounding the sanitary sewer become saturated. This is determined using the I&I Envelope Method, showing as flow events with the highest ratio of RDII to rainfall.

The following common terms and acronyms are also used in this study:

Table 1-2: Terms and Acronyms

Term	Definition
CCTV	Closed-Circuit Television
GIS	Geographic Information Systems
O&M	Operations and Maintenance
PACP	Pipeline Assessment Certification Program

2. System Information

2.1 Description of Existing System

The Township operates the sewerage system for the community, collecting sewage from property line and discharging to the CRD. The system consists of the following:

- 58.4 km of gravity mains;
- 11 pump stations; and
- 4.2 km of forcemains.

2.2 Inflow and Infiltration Estimates

The sewerage system is comprised of ten major catchments. These major catchments are monitored at the downstream end via sewer meter or mathematically derived from nearby catchments where required. Since this data has been analyzed and published by the CRD in their Core Area I&I Management Plan (update in April 2017), KWL will not be completing additional review of the catchment level data.

The following table summarizing I&I by catchment within Esquimalt has been extracted from the CRD report.

Table 2-1: Summary of I&I by Catchment

Catchment	Area (ha)	Peak 1-hr I&I Rate (L/ha/day)	5-yr, 24hr Flow X ADWF	5-yr, 24hr I&I Rate (L/ha/day)			
				2010	2012	2014	2016
Devonshire[1]	90	111,744	5.1 X ADWF	68,000	79,466	66,328	61,889
Esquimalt Panhandle	17	35,932	3.9 X ADWF	23,461	23,461	22,146	21,765
Forshaw	34	93,515	8.6 X ADWF	68,000	50,027	48,937	59,794
Grafton	34	105,865	9 X ADWF	39,017	39,282	52,358	60,118
Head	124	87,794	5.2 X ADWF	45,283	45,246	45,305	47,565
Kinver	39	84,185	5.5 X ADWF	47,118	44,105	45,225	48,205
Lang Cove Esquimalt	56	44,743	6.6 X ADWF	26,662	27,372	25,881	31,375
Uganda	18	115,200	6.1 X ADWF	68,000	57,986	57,011	59,444
Unmetered Esquimalt[1]	8	85,000	5.5 X ADWF	47,118	47,118	47,118	~48,000
Wilson	19	127,326	6.3 X ADWF	99,227	94,662	51,440	62,000

1. This catchment does not have its own sewer meter. Its data is mathematically derived using nearby catchments.

As shown in Table 2-1 above, 9 of the 10 catchments have greater than the target 4 X ADWF limit from the Liquid Waste Management Plan. There are several possible reasons for the observed high I&I rates.

1. **Cross Connections** – connections between the sanitary and storm sewer systems result in a significant source of I&I. A smoke testing program was completed in 2010 to locate cross connections, see Section 4 for further details.
2. **Pipe Age and Material** – pipes older than 50 years and/or made from certain materials (i.e., vitrified clay, concrete, etc.) are potential indicators for increased I&I rates. Esquimalt's sewer system is aging and has a significant portion of leaky pipe materials, see Section 3 for further discussion.

3. Pipe Characteristics Analysis

3.1 Data Collection

The pipe characteristics were obtained from the Township's sewer main GIS database. This database includes the following information:

1. Pipe ID.
2. Upstream & Downstream Manhole ID.
3. Upstream & Downstream Elevation.
4. Pipe diameter, material, length, and slope.
5. Street Location.
6. Install and Upgrade Dates (The age of pipe was assumed to be the difference between the upgrade date (or install date for pipes without upgrades) and 2021).

Added to this data was the sewer catchment areas used in the CRD Core Area Management Plan (discussed in Section 2) and CCTV inspection results provided by the Township.

3.2 Review of Pipe Characteristics

The total length of gravity main included in the GIS is 58.4 km across the entire Township. The breakdown of pipes by total length in each sewerage catchment in Figure 3-1 below.

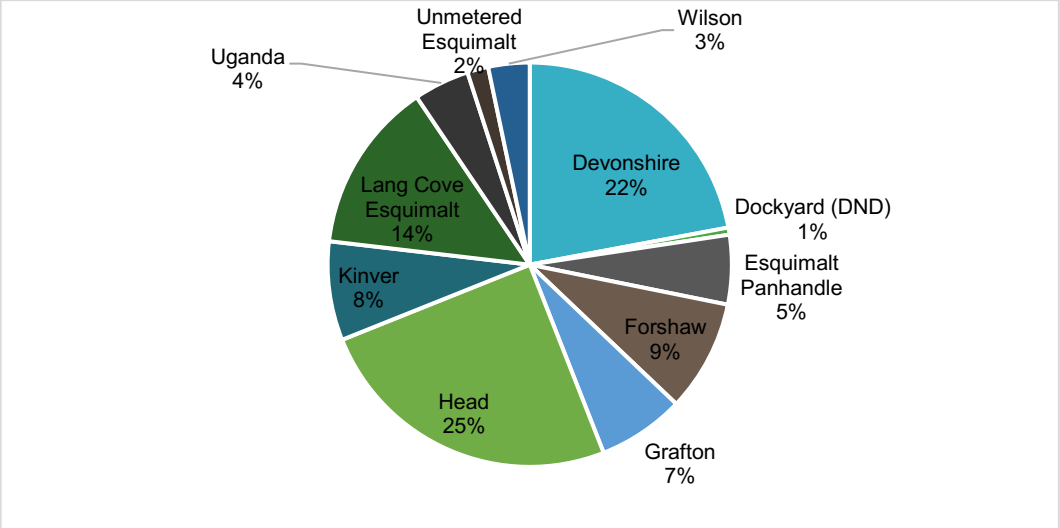

Figure 3-1: Breakdown of Length of Pipe by Catchment

The average age of pipe in the Township is 44.9 years old. Pipes older than 50 years have been found to have higher than average I&I rates and 58% of the Townships sewers are older than 50 years old. 66% of sewers are older than 40 years old. Therefore, the majority of the Township's sewers are

expected to have higher than typical I&I based on age alone. Figure 3-2 below shows the breakdown of pipe age across the Township.

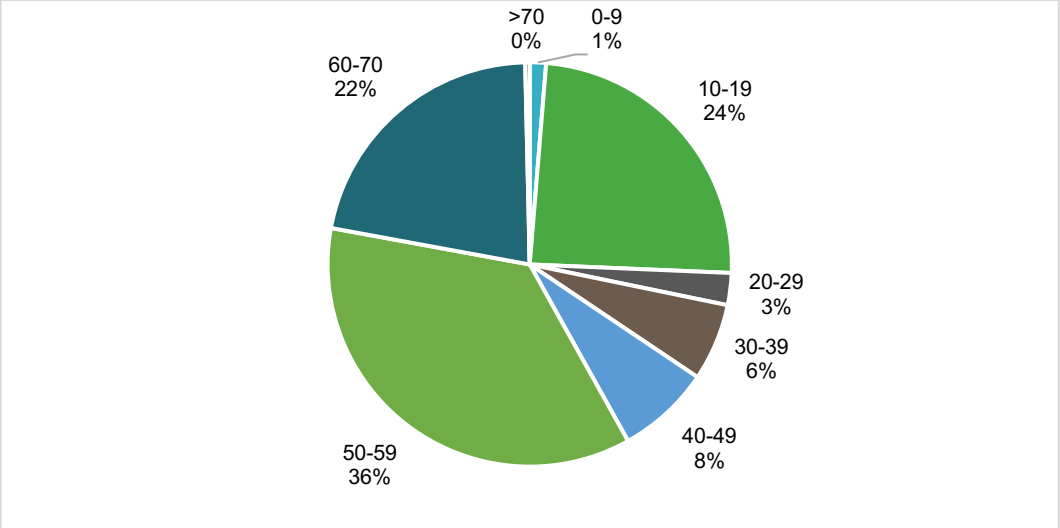

Figure 3-2: Breakdown of Length of Pipe by Age

A further breakdown of pipe age by sewer catchment can be found in Table 3-1 below. This table shows that 9 of the 10 catchments are approaching the age where significant I&I can be expected.

Table 3-1: Pipe Age by Catchment

Catchment	Average Pipe Age (Years)	Pipe Age							
		< 10 years	10 - 19 years	20 - 29 years	30 - 39 years	40 - 49 years	50 - 59 years	60 - 69 years	> 70 years
Devonshire	48.0	0.9%	21.4%	1.6%	4.5%	1.4%	52.4%	17.7%	0.1%
Esquimalt Panhandle	45.6	0%	1.7%	0%	8.4%	39.8%	50.1%	0%	0%
Forshaw	45.7	0%	21.9%	0%	14.1%	0%	46.7%	17.3%	0%
Grafton	50.8	0%	20.5%	0%	7.8%	4.7%	48.4%	16.8%	1.8%
Head	42.5	0%	36.6%	2.1%	3.4%	4.8%	22.1%	30.6%	0.3%
Kinver	43.7	0%	32.2%	6.6%	1.4%	1.4%	46.3%	12.2%	0%
Lang Cove Esquimalt	40.7	7.6%	15.4%	5.3%	13.9%	20.1%	15.7%	22.0%	0%
Uganda	50.5	1.6%	9.7%	1.6%	1.7%	2.9%	57.1%	25.4%	0%
Unmetered Esquimalt	37.6	0%	31.6%	21.7%	0%	20.1%	5.2%	21.5%	0%
Wilson	43.9	0%	46.8%	0%	0%	5.0%	0%	43.7%	4.5%
Total	**44.9**	**1.3%**	**24.6%**	**2.6%**	**6.2%**	**7.6%**	**36.0%**	**21.3%**	**0.4%**

Figure 3-3 below shows the breakdown of pipe material across the Township. Vitrified clay pipes make up 43% of the total pipes within Esquimalt. Note that in 2009 the Township completed a significant lining project, lining 24% of the system.

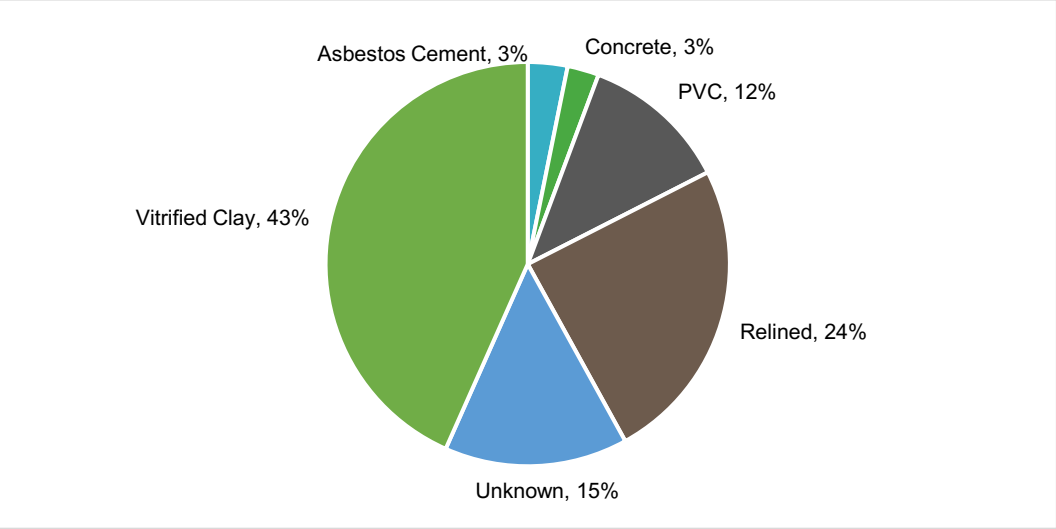

Figure 3-3: Breakdown of Pipe Length by Material

A further breakdown of pipe material by sewer catchment can be found in Table 3-2 below.

Table 3-2: Pipe Material by Catchment

Catchment	Pipe Material					
	Asbestos Cement	Concrete	PVC	Relined	Unknown	Vitrified Clay
Devonshire	6.2%	6.6%	3.3%	21.6%	15.6%	46.6%
Esquimalt Panhandle	23.1%	0%	9.7%	1.7%	36.3%	29.3%
Forshaw	0%	12.0%	10.5%	21.9%	16.0%	39.6%
Grafton	0%	0%	26.7%	20.5%	8.4%	42.6%
Head	0.3%	0%	7.6%	36.6%	16.1%	39.4%
Kinver	1.0%	0%	1.2%	32.2%	8.5%	57.0%
Lang Cove Esquimalt	2.1%	0%	35.6%	15.4%	10.3%	36.6%
Uganda	2.0%	0%	9.2%	9.7%	7.6%	71.5%
Unmetered Esquimalt	0%	0%	15.5%	31.6%	8.8%	44.1%
Wilson	0%	0%	6.1%	46.8%	4.8%	37.8%
Total	**3.2%**	**3.2%**	**11.9%**	**24.7%**	**14.3%**	**43.2%**

The pipe age and pipe material are evaluated together in Table 3-3 below.

Table 3-3: Pipe Age by Pipe Material

Pipe Material	Average Pipe Age (Years)	Pipe Age							
		< 10 years	10 - 19 years	20 - 29 years	30 - 39 years	40 - 49 years	50 - 59 years	60 - 69 years	> 70 years
Asbestos Cement	49.1	0%	0%	4.5%	2.6%	33.5%	59.4%	0%	0%
Concrete	56.3	0%	0%	0%	0.2%	0%	87.1%	12.7%	0%
PVC	40.8	9.4%	1.3%	9.9%	29.4%	9.0%	19.5%	21.5%	0%
Relined	11.9	0.8%	99.2%	0%	0%	0%	0%	0%	0%
Unknown	52.9	0%	0%	3.3%	6.6%	8.7%	50.3%	31.1%	0%
Vitrified Clay	55.5	0%	0%	1.8%	3.9%	9.5%	51.5%	33.2%	0.2%
Total	**44.8**	**1.3%**	**24.4%**	**2.6%**	**6.2%**	**7.5%**	**36.0%**	**21.8%**	**0.4%**

Based on the breakdown of the pipe age within the “Unknown” category it is expected that the majority of these pipes are Vitrified Clay or Concrete.

3.3 Assessment/Discussion

A large percentage of the Townships sewer system is between 50 and 70 years old (57.8%). The system also has a large percentage of vitrified clay pipe (43.2%). Given that there are very few sewers older than 70 years old, it would appear that the Townships lining project targeted the oldest pipes in the system that were also in the poorest condition.

The Townships 2009 CIPP lining project renewed a quarter of the system which has likely reduced the number of system backups and emergency call out work. The lining appears to have had some impact on 24 hour I&I rates, however I&I rates remains quite high in catchments such as Wilson where nearly 47% of pipes were relined.

There are no strong correlations between mainline pipe age, material, and the rates of I&I within catchments. This would suggest that a significant portion of I&I is related more closely to service laterals.

4. Mapping of 2010 Smoke Testing Results

The Township completed a smoke testing program in 2010 which identified the following:

- 71 properties with likely cross connections (additional follow-up work required to confirm direct cross connection), see Table 4-1.
- 20 direct connected catchbasins.

Based on conversations with Esquimalt staff the following work was completed based on the findings of the smoke testing program:

- On the private side letters were sent out to the 71 addresses but only eight property owners responded in 2 years and no cross connections were confirmed.
- All 20 catchbasins that were connected to sanitary sewer have been redirected to storm sewers.

Table 4-1: Properties with Positive Smoke Test Results

Address	Catchment	Address	Catchment
804 Craigflower Road	Devonshire	544 Joffree Street	Head
863 Craigflower Road	Devonshire	971 Wollaston Street	Head
881 Craigflower Road	Devonshire	950 Wollaston Street	Head
884 Lampson Street	Devonshire	946 Wollaston Street	Head
860 Lampson Street	Devonshire	537 Head Street	Head
849 Fleming Street	Devonshire	502 Paradise Street	Head
885 Pheonix Street	Devonshire	409 Fraser Street	Kinver
812 Colville Road	Devonshire	417 Fraser Street	Kinver
1243 Colville Road	Devonshire	1174 Greenwood Avenue	Kinver
1207 Colville Road	Devonshire	1142 Bewdley Avenue	Kinver
1073/1075 Colville Road	Devonshire	1172 Bewdley Avenue	Kinver
1043 Colville Road	Devonshire	1182 Bewdley Avenue	Kinver
774 Hutchinson Place	Devonshire	1116 Hadfield Avenue	Kinver
815 Anderson Avenue	Devonshire	1104 Hadfield Avenue	Kinver
932 Rankin Road	Esquimalt Panhandle	1137 Heald Avenue	Kinver
922 Forshaw Road	Forshaw	481 South Joffre Street	Kinver
1156 Craigflower Road	Forshaw	471 Kinver Street	Kinver
23-915 Glen Vale Road	Forshaw	1187 Wychbury Avenue	Kinver
490 Sturdee Street	Grafton	1175 Wychbury Avenue	Kinver
466 Sturdee Street	Grafton	1167 Wychbury Avenue	Kinver
464 Sturdee Street	Grafton	1140 Wychbury Avenue	Kinver

Address	Catchment	Address	Catchment
464 Nelson Street	Grafton	910 Alexander Road	Lang Cove Esquimalt
476/478 Nelson Street	Grafton	618 Nelson Street	Lang Cove Esquimalt
1245 Lyall Street	Grafton	1246 Rock Crest Avenue	Lang Cove Esquimalt
1168 Old Esquimalt Road	Head	305 Uganda Avenue	Uganda
625 Bryden Court	Head	307 Uganda Avenue	Uganda
654 Head Street	Head	309 Uganda Avenue	Uganda
1044 Wollaston Street	Head	319 Uganda Avenue	Uganda
1019 Wollaston Street	Head	321 Uganda Avenue	Uganda
530 Lampson Street	Head	915 Selkirk Avenue	Uganda
538 Lampson Street	Head	864 Old Esquimalt Road	Wilson
482 Lampson Street	Head	702 Aldebury Street	Wilson
496 Lampson Street	Head	837 Old Esquimalt Road	Wilson
1041 Lyall Street	Head	847 Viewfield Road	Wilson
960 Lyall Street	Head	845 Viewfield Road	Wilson
489 Swinford Street	Head		

The results of the smoke testing indicate that there are a number of private cross-connections within the system. The location at which smoke was seen was not recorded in the field notes, roof leader, missing cleanout cap, smoke coming from ground, from private lawn basin etc., was not recorded. We also do not know the level of detail to which private properties were investigated and whether smoke was only noted and reported when coming from roofs. It appears that the smoke testing program was equally focussed on located potential cross connected sanitary sewers to storm drainage as the majority of recorded incidents, not provided in the above table, were no-smoke events indicating a potential sanitary to storm drain cross connection, a failed or submerged sanitary lateral, or a lack of venting.

The results of the program also indicate that without additional authority the Township has little influence over removing direct connections on private property.

We recommend the following:

1. Additional smoke testing be completed as described in Section 10 to target areas where high I&I is causing capacity issues.
2. Complete the work of installing inspection chambers at the properties listed above in Table 4-1.
3. CCTV assess the condition of the complete lateral (public and private) once bylaws are in place to give the Township authority to complete inspections and look for wye connections in laterals. Produce inspection reports and provide copies to homeowners along with educational materials.
4. Enact a bylaw to gain the authority to address private side I&I.

5. Combined Manholes Analysis

Visual inspection of the combined storm and sewer manholes were conducted on September 30, 2020, by KWL inspection staff and Esquimalt Public works department staff.

Visual inspection steps included the following:

1. Mapping remaining combined storm/sewer manholes based on Esquimalt GIS data.
2. Estimating number of properties upstream of manhole that could be contributing into a combined storm and sewer system.
3. Visual field inspection of combined manholes, noting potential for cross connection, identification of surrounding infrastructure, and documentation of findings.
4. Estimation potential I&I contribution at combined manhole.

The combined manholes remaining are typically those that are most difficult to separate or are located at the top end of the system leaving very little I&I potential. The locations and findings of the combined manhole inspection are included in Figure 5-1 below.

Township of Esquimalt
I&I Master Plan

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Project No.	601-010
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Combined Manhole Investigation

Figure 5-1

5.1 SMH0405 @ 1151 Esquimalt Road (Archie Browning Sport Centre)

A direct storm to sewer connection was located in combined manhole SMH0686 at the Archie Browning Sport Centre outside the east entrance. The service appears to have previously been piped across the sewer main and into the storm main but appears to have been cut off inside the manhole, no flow was noted during the inspection however KWL returned to the site during a light rainfall event and noted that the pipe was flowing. The origin of the service connection is unknown but could represent a significant source of I&I if connected directly to roof or parking lot drains.

Figure 5-2: Combined Manhole at Archie Browning Sport Centre

The connection would represent a 0.6 – 0.8 L/s flow during 5-year 24-hour rainfall event assuming between 0.5 – 0.7 ha of roof or parking lot area is connected.

5.2 SMH0320 @ 861 Kindersley Road

Manhole SMH0320 located in the backyard of residence at 861 Kindersley Road includes several inlet pipes (cannot determine which is sewer and which is storm) into the manhole with a single outlet into the sewer system.

Figure 5-3: Combined Manhole at 861 Kindersley Road

The cross connection would represent up to 0.1 – 0.3 L/s during 5-year 24-hour rainfall event assuming between 0.1 – 0.4 ha area connected.

5.3 SMH0443 & SMH0444 @ 1269 Rockcrest Avenue

Two combined manholes SMH0443 and SMH0444 at 1269 Rockcrest Avenue are located on a sewer main passing between houses which is installed very deep. The storm and sewer systems are separated by a wall between the benching in the manhole. Significant surcharging in the manhole would be required for a cross-connection to occur. Due to proximity to existing houses and the depth of the system separating would be very difficult.

Potential connection only during surcharging periods.

5.4 SMH0305 @ 1176 Highrock Place

SMH0305 is a combined manhole at end of system with a wall separating storm and sewer benching. Significant surcharging in system would be required to cause a cross-connections.

Potential connection only during surcharging periods.

5.5 SMH0174 @ 847 Dunsmuir Road

Manhole SMH0174 is a combined manhole that appears to be at the top end of an abandoned sewer main. The main passes through the adjacent property, 531 West Bay Terrace. SMH0174 has a grated lid and picks up a small, grassed drainage area.

We recommend that the Township determine where the active services are located for 847 Dunsmuir Road and 531 West Bay Terrace and disconnect, cap, and abandon all non-active sewers as they are a likely source of I&I.

Figure 5-4: Area Draining to Combined Manhole at 847 Dunsmuir Road

5.6 Summary of Combined Manhole Assessment

Esquimalt has removed most combined manholes with the system over the past ten years and although we have not analyzed historical peak I&I rates, this work has likely reduced peak I&I rates. The remainder of combined manholes are largely at the top end of systems, and within easements, and likely not all significant contributors to inflow. These manholes should however be separated when ever possible through renewals work on the adjacent storm or sanitary system.

The direct connection noted above and found through our field investigation should be redirected where possible and the sewers at 847 Dunsmuir Road should be investigated to determine if they can be abandoned.

6. CCTV Inspection Analysis

Esquimalt has collected several years (2017-2019) worth of CCTV inspections of the sewerage system. KWL combined these collected CCTV inspections into a single database, completed QAQC on the inspections, and removed duplicate inspections from the database.

Inspections were completed in Pipeline Assessment Certification Program (PACP) format and cataloged in an Access database format. The inspection dataset is available for review in Granite XP and Microsoft Access format and videos are viewable with any video player. The database created by KWL is in excel format.

The PACP standard uses a standard format and methodology for collecting CCTV data, coding observations, and data storage. Observations are referenced to the distance travelled along the pipe and its 'clock' position relative to the cross-sectional view of the pipe. PACP codes are organized into four groups:

1. **Structural Defects:** defects affecting the pipe structure, visible from the inside.
2. **O&M or Service Defects:** defects affecting the hydraulic capacity of the pipe.
3. **Construction Features:** manholes, vents, connections, junctions, fittings, pipe material, pipe diameter.
4. **Miscellaneous Observations:** pipe water level, survey features, vermin, etc.

The PACP system uses a five-point grading system to rate the internal structural and operational condition of pipes based on video inspection data. The grading system is briefly described in Table 6-1.

Table 6-1: PACP Scoring System

Structural Defects Grade	Description	Deterioration Rate
5	Defects requiring immediate attention	Pipe has failed or will likely fail within the next 5 years
4	Severe defects that will become Grade 5 in the near future	Pipe will probably fail in 5 to 10 years
3	Moderate defects that will continue to deteriorate	Pipe may fail in 10 to 20 years
2	Defects that have not begun to deteriorate	Pipe unlikely to fail for at least 20 years
1	Minor defects	Failure unlikely in the foreseeable future
0	No defects	Failure unlikely in the foreseeable future

The PACP structural and O&M scoring systems can be interpreted in a couple of ways:

1. **Peak Score:** the highest graded defect observed on a manhole-to-manhole segment.
2. **Overall Score:** the sum of all defect grades for a manhole-to-manhole segment.

6.1 CCTV QAQC Results

For quality assurance, 37 videos were inspected to ensure data collected conforms to standard. The reviewed videos included sanitary sewers to be included in database only. Coding accuracy was found to be acceptable, with an average accuracy of 93%.

6.2 'Wet' Inspection Video Review Results

The videos that were reviewed for QAQC were chosen based on how they correlated with rainfall. This was done to assess I&I, specifically if laterals had continuous weeping flow. None of the storms that occurred during the inspections were significant and the criteria we used to choose inspections included very light "rain". The criteria used for choosing inspections was as follows:

1. Rainfall greater than 2 mm with Infiltration codes within the inspection.
2. Rainfall greater than 5 mm.

The intent of the review was to quantify I&I from laterals, as lateral are assumed to be the primary source of I&I, whether through cross connection or leaky joints.

Figure 6-1 displays the areas where videos were reviewed (yellow highlight) as well as the laterals that were seen to have potential I&I flows. Somewhere between 25%-75% of laterals on a given line were seen to have some amount of background flow which corroborates the assumption that the majority of I&I is from service laterals.

Path: Z:\0000-0999\0600-0699\601-010\430-GIS\MXD-Rp\FigureX_CCTV_VideosReviewed.mxd Date Saved: 6/18/2021 2:55:57 PM | Author: Bjohnson

Township of Esquimalt

I&I Masterplan

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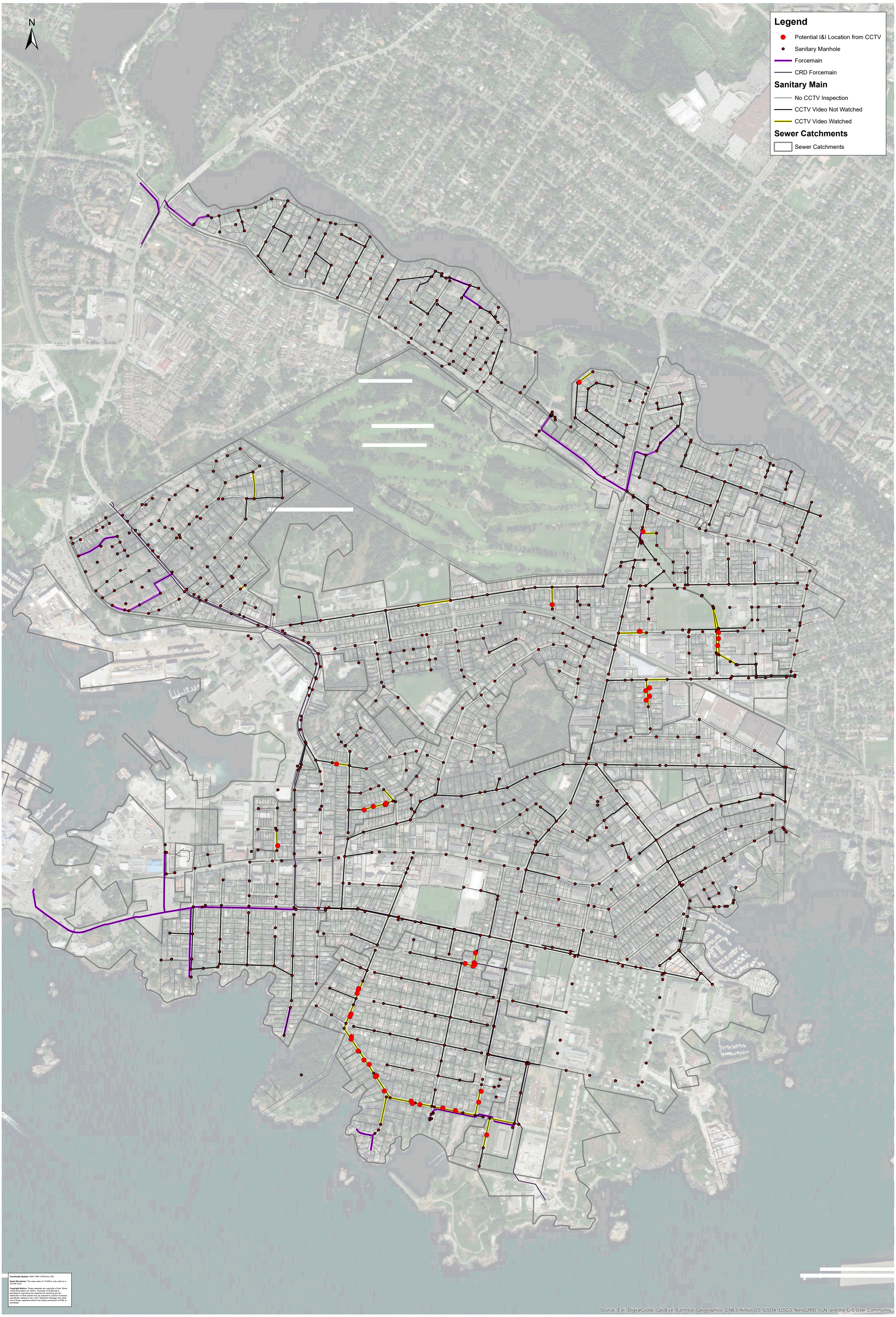

Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:6,000 is only valid on a 22"x34" print.

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Scale	1:6,000

'Wet' CCTV Inspection Video Review

Figure 6-1

6.3 Pipe Inspection Results

The 20 km of CCTV provided was broken up into several databases, KWL combined the data into a single database and removed duplicate or updated inspection data. The most recent complete pipe inspection was used. Any pipes with greater than 80% of the length inspected was assumed to be a completed inspection. The following figure shows the breakdown of inspection results of videoed pipes based on the peak structural defect score.

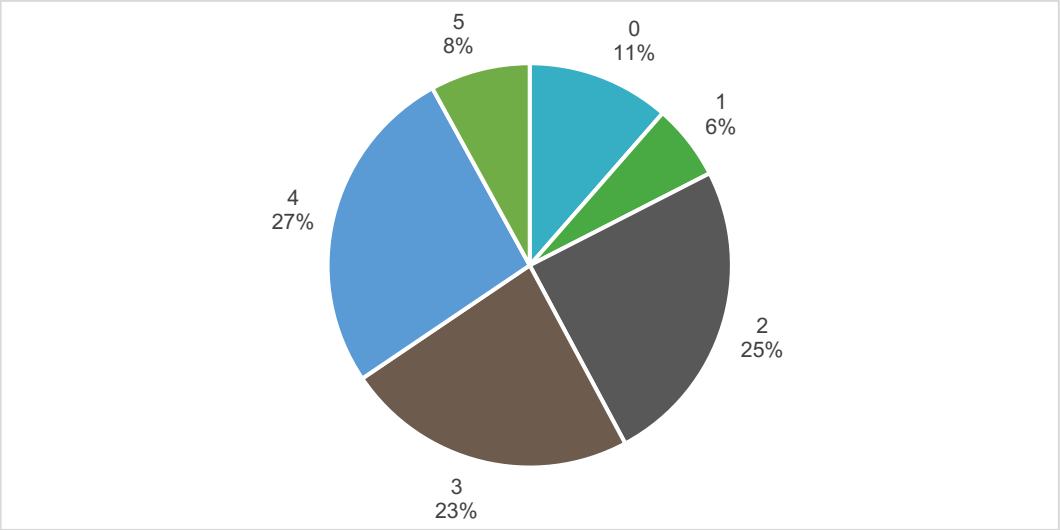

Figure 6-2: Breakdown of Inspected Pipe Length by CCTV Peak Score

The following tables show the various pipe inspection results based by catchment, pipe material, pipe age, and pipe diameter.

Table 6-2: Pipe Inspection Score by Catchment

Catchment	Average Structure Peak Score	Max Total Structural Peak Score	Average Total Structure Score	Total Length Inspected (m)
Devonshire	2.2	42	16	4,635
Esquimalt Panhandle	2.8	39	18	1,092
Forshaw	3.3	212	41	1,097
Grafton	2.0	56	20	1,167
Head	1.8	71	11	4,603
Kinver	2.4	87	19	3,048
Lang Cove Esquimalt	2.9	103	21	1,275
Uganda	2.8	111	22	1,649
Unmetered Esquimalt	1.7	26	10	660
Wilson	2.2	47	18	871

Based on the pipe inspections, the average peak score in the Forshaw and Uganda catchments is over 3; indicating that the majority of the pipes in these catchments have moderate defects that will continue to deteriorate and are expected to fail with the next 10-20 years. These catchments have many pipes that have already failed and should be targeted for replacement.

Table 6-3: Pipe Inspection Score by Pipe Material

Material Type	Average Structure Peak Score	Max Total Structural Peak Score	Average Total Structure Score	Total Length Inspected (m)
Asbestos Cement	2.0	36	21	602
Concrete	3.0	76	29	554
PVC	2.4	44	12	1,396
Relined	1.2	71	8	6,105
Unknown	2.4	38	15	305
Vitrified Clay	2.8	212	23	11,213

Based on the pipe inspections, the average peak score in concrete and vitrified clay pipes are nearing 3; indicating that the majority of the pipes of these materials have moderate defects that will continue to deteriorate and are expected to fail with the next 10-20 years. Several concrete and vitrified clay pipes were found that have already failed and should be targeted for replacement.

Table 6-4: Pipe Inspection Score by Pipe Age

Pipe Age	Average Structure Peak Score	Max Total Structural Peak Score	Average Total Structure Score	Total Length Inspected (m)
<10 years	2.7	21	9	158
10-20 years	1.1	71	8	5,989
20-30 years	2.8	43	18	575
30-40 years	2.1	35	13	842
40-50 years	2.5	60	17	1,299
50-60 years	3.1	111	28	6,493
60-70 years	2.6	212	19	4,819

Based on the pipe inspections, the pipes installed between 20-30 years ago appear to have a higher-than-expected average peak score; however, this comes from a fairly small sample size and may not be representative of all pipes of this age.

Table 6-5: Pipe Inspection Score by Pipe Diameter

Pipe Diameter	Average Structure Peak Score	Max Total Structural Peak Score	Average Total Structure Score	Total Length Inspected (m)
150 mm	2.8	103	22	2,114
200 mm	2.4	212	18	14,730
250 mm	1.8	40	13	1,459
300 mm	1.8	21	10	702
375 mm	1.7	46	22	938
400 mm	2.0	26	26	91
450 mm	2.0	36	36	140

There does not appear to be a significant pattern linking pipe diameter and condition based on the CCTV inspections completed.

6.4 Structural Condition Prioritization

To prioritize upgrades based on the structural inspection results a prioritization rating is used. For this assessment, the following order of descending importance was used for prioritization:

1. Structural Peak Score.
2. Structural Overall Score.

A higher priority is assigned to peak score than overall score as the most severe structural defect present is the best indication of structural pipe integrity. Even if only a small section of a pipe collapses, the entire manhole-to-manhole pipe run may become blocked, leading to backups or overflows. Table 6-6 below shows the scoring matrix used to create the replacement priority list.

Table 6-6: Prioritization Scoring Matrix

Prioritization Rating	Structural Peak Score	Total Structural Score
1	5	Any
2	4	Any
3	3	> 50
4	3	> 15 & < 50
5	3	< 15

Prior to replacement of a pipe the CCTV video should be reviewed to determine if the coded structural score is misleading, examples of misleading coded results are included in Section 6.5 below. Relined pipes that were coded with a “Lining Failure” structural defect were removed from the prioritized replacement list as it was found that minor wrinkles have been coded as lining failures.

We do not generally recommend CIPP lining of mainline sewers that are 150mm given maintenance concerns following the diameter reduction, however some circumstances such as difficult easement work may make lining these mains the favorable option.

A list of priority replacements in the Devonshire, Forshaw, and Uganda catchments are included in Table 6-7 below. Results for prioritized replacements for all Esquimalt catchments is included in Appendix A.

Table 6-7: Priority Replacement List for Devonshire, Forshaw, and Uganda Catchments

Pipe ID	Sewer Catchment	Pipe Material	Length (m)	Pipe Diameter (mm)	Pipe Age (years)	Prioritization Rating
SGM0021	Devonshire	Vitrified Clay	76	200	56	1
SGM0030	Devonshire	Vitrified Clay	101	200	64	1
SGM0144	Uganda	Vitrified Clay	88	200	56	1
SGM0336	Devonshire	Vitrified Clay	77	200	56	1
SGM0561	Forshaw	Relined	78	150	12	1
SGM0790	Forshaw	Vitrified Clay	126	200	64	1
SGM0862	Uganda	Vitrified Clay	84	150	56	1
SGM1053	Forshaw	Concrete	46	200	56	1
SGM0009	Devonshire	Vitrified Clay	84	200	58	2
SGM0010	Devonshire	Vitrified Clay	89	200	58	2
SGM0037	Devonshire	Concrete	49	300	60	2
SGM0040	Devonshire	Vitrified Clay	51	200	68	2
SGM0053	Devonshire	Relined	55	200	4	2
SGM0127	Devonshire	Vitrified Clay	43	150	60	2
SGM0143	Uganda	Vitrified Clay	32	150	56	2
SGM0150	Uganda	Vitrified Clay	51	200	56	2
SGM0172	Uganda	Vitrified Clay	79	200	65	2
SGM0181	Forshaw	Concrete	40	200	56	2
SGM0237	Devonshire	Vitrified Clay	119	250	59	2
SGM0241	Devonshire	Relined	76	200	12	2
SGM0274	Uganda	Vitrified Clay	86	200	56	2
SGM0307	Forshaw	Vitrified Clay	68	150	64	2
SGM0342	Forshaw	Vitrified Clay	58	150	56	2
SGM0377	Uganda	Vitrified Clay	43	150	58	2
SGM0473	Forshaw	PVC	37	150	63	2
SGM0507	Uganda	Vitrified Clay	61	200	64	2
SGM0518	Devonshire	Relined	73	200	12	2
SGM0543	Uganda	Vitrified Clay	61	200	68	2
SGM0628	Forshaw	Relined	94	200	12	2
SGM0648	Uganda	PVC	22	150	56	2
SGM0772	Devonshire	Vitrified Clay	28	200	64	2
SGM0832	Uganda	Relined	61	200	12	2
SGM0871	Forshaw	Vitrified Clay	79	150	56	2
SGM0903	Uganda	Vitrified Clay	49	200	68	2
SGM0929	Forshaw	Vitrified Clay	73	150	56	2
SGM0943	Uganda	Relined	46	200	12	2
SGM1029	Uganda	Vitrified Clay	76	200	56	2
SGM1120	Uganda	Vitrified Clay	89	150	56	2
SGM0001	Devonshire	Vitrified Clay	68	200	56	4
SGM0011	Devonshire	Concrete	54	375	58	4
SGM0034	Devonshire	Vitrified Clay	40	200	26	4
SGM0038	Devonshire	Vitrified Clay	33	300	60	4
SGM0052	Devonshire	Relined	61	200	4	4
SGM0170	Devonshire	Vitrified Clay	108	250	56	4
SGM0455	Devonshire	Vitrified Clay	41	250	60	4
SGM1021	Devonshire	Vitrified Clay	106	250	35	4
SGM0022	Devonshire	Vitrified Clay	52	200	56	5
SGM0039	Devonshire	Concrete	31	200	68	5
SGM0500	Devonshire	Vitrified Clay	61	250	60	5
SGM0870	Uganda	PVC	91	200	56	5
SGM0891	Forshaw	Concrete	122	200	56	5
SGM1014	Uganda	Vitrified Clay	91	200	68	5

6.5 Notes on CIPP Lining Issues

CIPP lining creates a new pipe containing no joints within an existing pipe often containing many leaky joints. A primary challenge for CIPP lined pipes is at the service interface. Issues include:

- Cut-outs can be non-circular and too much material is sometimes removed. This sometimes includes damage, holes cut into newly installed PVC wyes, installed just prior to lining. The skill of the operator and the equipment and sharpness of tools used play a large roll.
- Service cut-outs can be a source of I&I. I&I can come from either the existing lateral interface or from the void space between the host pipe and liner – the host pipe continues to be leaky and water is funnelled towards the service cut-out locations.
- There is no structural connection to the host pipe if the service is only cut-out.
- Where a tee is cut into a lined sewer for a new services or replacement, joints are added and sagging of the cut-in wye is common. This creates hydraulic and maintenance issues as well as new sources of I&I.

Below are examples of the above noted issues:

Figure 6-3: A New Wye Cut-in to a CIPP Lined Sewer that has Sagged (Picture 1)

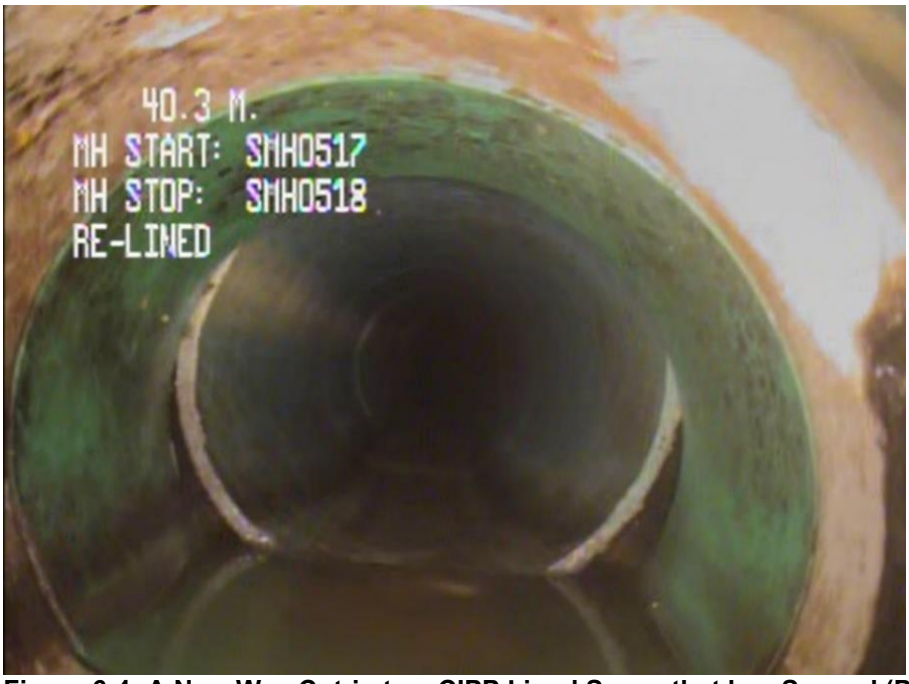

Figure 6-4: A New Wye Cut-in to a CIPP Lined Sewer that has Sagged (Picture 2)

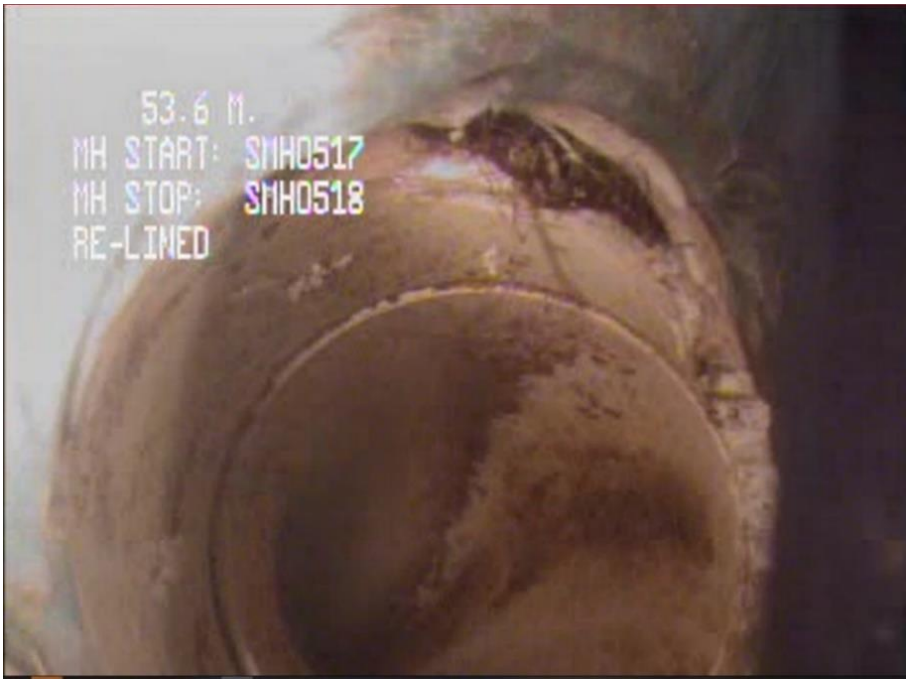

Figure 6-5: Overcut Lateral Connection with Damage to the Lateral and Root Intrusion

Figure 6-6: I&I at a Lateral Cutout (Picture 1)

Figure 6-7: I&I at a Lateral Cutout (Picture 2)

Figure 6-8: Root Intrusion at a Lateral Interface – No Structural Connection of Lateral and Main

Figure 6-9: Soil Visible at a Lateral Interface – No Structural Connection of Lateral and Main

It is also noted that the PACP system includes codes for liner wrinkles, that in our opinion do not affect the structural integrity of the line if they passed original inspection during construction. The PACP

scoring index assigns a Class 4 structural defect to these codes. We reviewed a few lined pipes with high defect scores and found the wrinkles to be insignificant. Example images are provided below:

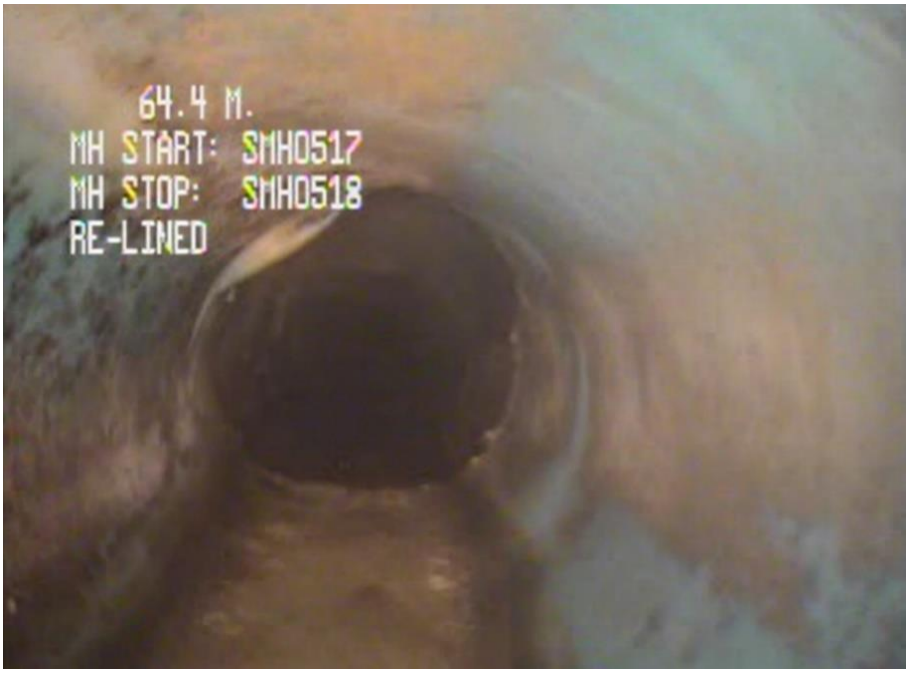

Figure 6-10: Liner Wrinkle at Manhole Interface – Not Affecting Structural Integrity or Hydraulics

Figure 6-11: Liner Wrinkle – Not Affecting Structural Integrity or Hydraulics

We recommend the following for future lining projects and renewal of laterals on CIPP lined pipes:

- Install tee connections and renewal of the lateral sweep close to the main (within the excavation) prior to CIPP lining. Tee connections are recommended over wye as wyes are easily damaged through the CIPP cutout process.
- Do not cut in wyes for connections of new laterals to previously lined pipes. Connect to the existing hole and utilize a banded service saddle or concrete incase the service connection. Care must be taken to draw witness lines and ensure laterals do not intrude too far into the connection.
- A structural connection can also be achieved by installing CIPP top-hat liners and this can be done instead of the first bullet point or to strengthen connections to existing CIPP lined pipes after the fact. In this case, the Township would keep a list of lateral connections where top-hats should be installed such that they can be added to a larger CIPP lining contract.

7. Flow Level Analysis

7.1 Data Collection

7.1.1 Weather Data

KWL operates a weather station at Langford City Hall collecting and monitoring rainfall data from the rainfall bucket system installed on the roof of the office, collecting data at a 5-min interval. This weather data is used to evaluate the rainfall characteristics of the storm to determine if noted level response in the sewer system is associated with I&I. Note that rainfall may not align perfectly between Langford monitoring station and Esquimalt since there is a 7 km distance between the two communities.

7.1.2 Ultrasonic Level Loggers

Ultrasonic Level Loggers were installed in three locations on December 21, 2020, in order to start collection of data during rainy season due to shipping delays with the Echo Level Loggers. The locations of the Ultrasonic Level Loggers were chosen to view the majority of the inflow to the trunk mains between Lampson Road and Hereward Road (Dominion Road).

The Ultrasonic Level Loggers work by bouncing an ultrasonic beam off the surface below and measure the distance to the surface based on the return time. The ultrasonic sensors are mounted in the manhole by rock hammering to the wall of the manhole and installing anchor screws for the mounting bracket. The battery and storage unit is separate to the sensor and must also be hung within the manhole. The antenna used for automatic calling is installed outside of the manhole, typically on the manhole lid, recessed when possible to minimize damage from traffic passing over the manhole.

Figure 7-1 below shows the typical setup of the Ultrasonic Level Logger.

Figure 7-1: Ultrasonic Level Logger Setup

7.1.3 Echo Level Loggers

The Echo Level Loggers were received in January after shipping delays. These loggers were better suited for quick setups and moving around the chosen catchment since installation typically takes a couple of hours without any specialize equipment. The loggers were setup in three rounds around the Devonshire, Forshaw, and Uganda Catchments that all report to the trunk main between Lampson Road and Hereward Road (Dominion Road).

The Echo Level Loggers use the same technology as the Ultrasonic level loggers to measure the depth from the sensor to the sewer level. The unit is self-contained and is hung from an expandable screw post friction fit below the manhole lid. The antenna used for automatic calling is installed outside of the manhole, typically on the manhole lid, recessed when possible, to minimize damage from traffic passing over the manhole.

Figure 7-2 below shows the typical setup of the Echo Level Logger.

Figure 7-2: Echo Level Logger Setup

7.2 Assessment Methodology

The aim of the flow level sensors program was to evaluate at least one noted rainfall event, a few day period after a rainfall event, and a few days of dry weather. This allowed for the ability to identify the following:

1. Typical nighttime dry weather flow level.
2. Typical nighttime wet weather flow level response.
3. Peak dry weather flow level.
4. Peak wet weather flow level.

These four sewer levels were then used to identify long term (multi-day) increases to base flow level after a rainfall event (GWI) and peak weather inflows (direct I&I contributions). These changes in levels were converted to an order of magnitude estimate of flow using the Hazen-Williams equation for gravity flow through the surrounding pipe.

GWI contributions were converted to a per area daily inflow value and graded according to Table 7-1 below.

Table 7-1: GWI Leakage Score Matrix

GWI Leakage Score	Calculated GWI Range (L/ha/day)
Low	< 2,000
Medium	2,000 – 10,000
High	10,000 – 20,000
Very High	> 20,000

Direct I&I contributions inflows were calculated, and the order of magnitude estimate was provided where applicable. It should be noted that the stated direct I&I contributions are not associated with a specific return event storm (majority are on annual storms) and provide a qualitative look at if direct connections exist upstream of the monitoring location only.

7.3 Devonshire Catchment Assessment

The Devonshire Catchment was selected for the flow level monitoring program due to planned upgrades of the twinned gravity trunk mains from Lampson Road to Hereward Road (Dominion Road). A reduction of I&I in this catchment could provide an opportunity to delay construction on the planned upgrades.

Figure 7-3 shows the locations monitored with the Devonshire Catchment.

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I & I Masterplan

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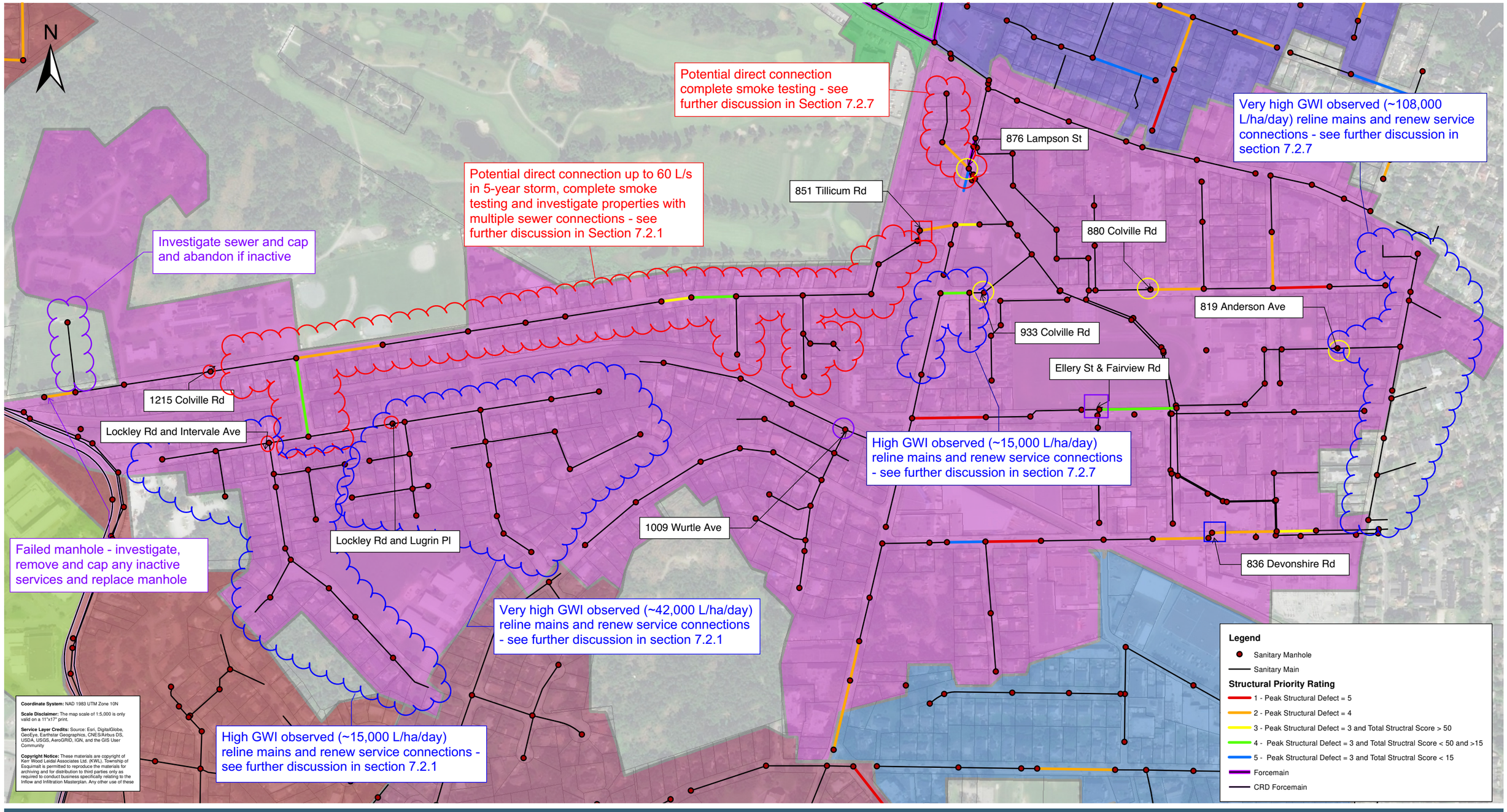

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Manhole Level Sensor Program Map for Devonshire Catchment

Figure 7-3

7.3.1 Colville Area

The monitoring locations within the Colville Area are shown in red on Figure 7-3 above. This area encompasses the area west of Transfer Street and was monitored at the downstream end at 851 Tillicum Road and further broken down at 1215 Colvillle, Lockley Road and Intervale Avenue, and Lockley Road and Lugrin Place. This area encompasses primarily residential land use with some ICI land use at the upstream end of the catchment.

851 Tillicum Road (Transfer Street)

An Ultra Sonic Level Sensor was installed at 851 Tillicum Road (Transfer Street) on December 15, 2020 and monitored continuously until January 5, 2021. Findings of the monitoring are included in Table 7-2 below and graphs including monitored results can be found in Appendix B.

Table 7-2: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	17 mm	December 19 to 25, 2020	Medium GWI
Direct Connections	135 mm 103 mm	December 21, 2020 January 2, 2021	~ 60 L/s Direct Connection ~ 45 L/s Direct Connection

The level monitoring at 851 Tillicum indicated medium GWI and a significant source of direct infiltration in the catchment upstream of the monitoring manhole. Additional monitoring was completed in the upper reaches of the catchment to try and narrow down the search area (see discussion on Lockley Area to follow).

Additionally, a review of service locations was completed using available CCTV along Colville Road to determine the number of services fronting each lot. Duplex and triplex lots were assumed to have two legitimate sanitary services as this was seen in the number of services to these lots. Figure 7-4 shows the 1100 block of Colville Road where there are suspected abandoned services that are contributing to I&I as well as possible direct connections.

Figure 7-4: Mapped Sewer Services along 1100 Block of Colville Road

Lockley Area (Lockley Road and Intervale Avenue, Lockley Road and Lugrin Place, and 1215 Colville Road)

Echo Level Sensors were installed at 1215 Colville Road, Lockley Road and Intervale Avenue, and Lockley Road and Lugrin Place on January 19, 2021 and monitored continuously until February 11, 2021. Findings of the monitoring are included in Table 7-3 below and graphs including monitored results can be found in Appendix B.

Table 7-3: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI (1215 Colville Road)	8 mm	February 1 to 7, 2021	Medium GWI
GWI (Lockley Rd & Intervale Ave))	8 mm	February 1 to 7, 2021	High GWI
GWI (Lockley Rd & Lugrin Pl)	15 mm	February 1 to 7, 2021	Very High GWI
Direct Connections	No observed direct connections		

The level monitoring in the Lockley Area did not indicate the direct connection observed downstream at 851 Tillicum occurred at any of the monitored manholes; therefore, the direct connection is expected to occur between Transfer Street and Lockley Drive along Colville Road.

The monitoring indicated GWI ranging from medium to very high upstream of the monitoring manhole.

We note that the end of line manhole, pictured in Figure 7-5 below, appears to be failed and is full of dirt and there does not appear to be a purpose for the sewer from SMH0493 to SMH0105 that crosses the soccer field. These are potential sources of some of the GWI upstream of 1215 Colville Road manhole.

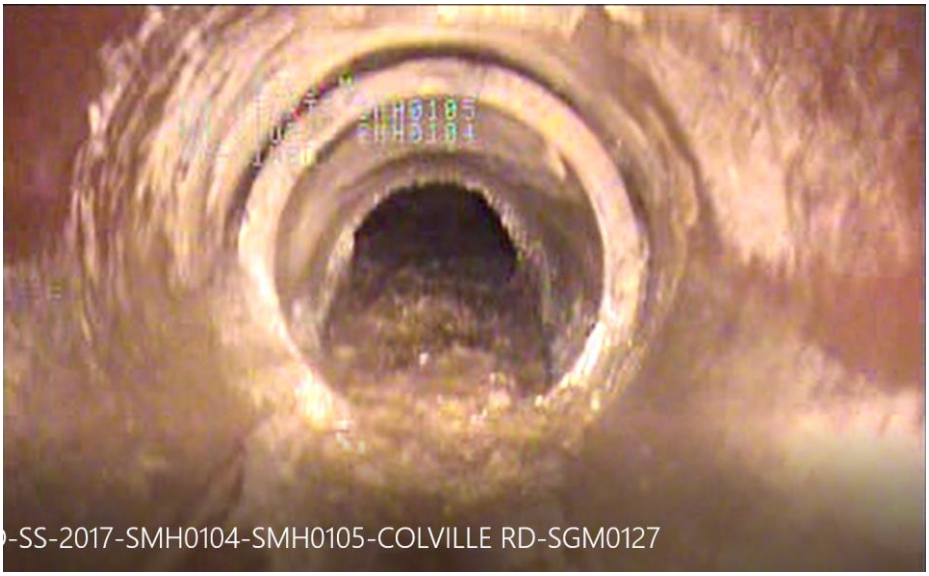

Figure 7-5: End of Line Colville Manhole SMH0104 – Full of Dirt

7.3.2 Recommended Actions in Colville Area

- Complete additional smoke testing and dye testing work to locate the direct connection upstream of 851 Tillicum Road. Finding and addressing the direct connection at this location directly affects the flow at upgrade projects 2, 3, 6, and 7 identified in the Modelling Report.
- Renew mains and/or service connections in the area upstream of Lockley Road & Lugrin Place and Lockley Road & Intervale Avenue. Reducing the overall I&I contribution at this location directly affects the flow at upgrade projects 2, 3, 6, 7, and 8 identified in the Modelling Report.
- Investigate sewer line (between SMH0493 to SMH0105) and manhole at end of Colville Road (near Colville Field) and cap and abandoned the main if inactive and replace failed manhole.

7.3.3 Ellery Street Area

The monitoring locations within the Ellery Street Area are shown in purple on Figure 7-5 above. This area encompasses the northern end of Rockheights and Ellery Street up to Fairview Road. This area encompasses residential land use and commercial land use.

Ellery Street and Fairview Road

A level logger was installed at Ellery Street and Fairview Road on December 15, 2020. The sensor was replaced on January 5, 2021, with the sensor previously installed at 851 Tillicum Road. The sensor was replaced due to poor data signal; however, this did not resolve the issue.

Data signal at the Ellery Street and Fairview Road site was poor throughout the duration of the monitoring period and cannot be used to estimate any I&I contribution upstream of this location. Graphs including monitored results can be found in Appendix B

1009 Wurtle Avenue

An Echo Level Sensor was installed at 1009 Wurtle Avenue on March 3, 2021 and monitored continuously until June 9, 2021. Findings of the monitoring are included in Table 7-4 below and graphs including monitored results can be found in Appendix B.

Table 7-4: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	No GWI observed		
Direct Connections	No observed direct connections		

The level monitoring at 1009 Wurtle Avenue did not yield evidence of significant I&I in the upstream area.

7.3.4 Recommended Actions in Ellery Street Area

No specific issues were noted in the Ellery Street area. Continue with regular maintenance and upkeep in the area. Cap and abandon inactive sewers.

7.3.5 Devonshire Industrial Area

The monitoring locations within the Devonshire Industrial Area are shown in blue on Figure 7-3 above. This area encompasses Devonshire Road between Lampson Street and Cave Street. This area encompasses primarily industrial and commercial land use with some residential infill at the upstream end.

836 Devonshire Road (Lighthouse Brewery)

An Ultrasonic style logger was installed at 836 Devonshire Road on December 15, 2021. The manhole was too deep to register the level in the manhole due to the angle of the beam used in measurement. An extension was added to the setup on January 12, 2021, which improved the data quality and allowed for analysis. The site was monitored continuously until February 12, 2021. Findings of the monitoring are included in Table 7-5 below and graphs including monitored results can be found in Appendix B.

Table 7-5: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	9 mm	February 1 to 7, 2021	Medium GWI
Direct Connections	No direct connection observed		

The level monitoring at 836 Devonshire Road (Lighthouse Brewing) did not show evidence of a direct connection upstream of the monitoring manhole but did indicate medium GWI upstream of the monitoring manhole.

There were some flow spikes in the data set; however, they do not appear to align with rainfall events. The monitoring location is located in an industrial area and this flow is expected to be legitimate ICI usage.

7.3.6 Recommended Actions in Devonshire Industrial Area

No major issues were noted in the Devonshire Industrial Area. Continue with regular maintenance and upkeep in the area. Cap and abandon inactive sewers.

7.3.7 Esquimalt High School Area

The monitoring locations within the Esquimalt High School Area are shown in yellow on Figure 7-3 above. This area encompasses Colville Road and Anderson Avenue between Lampson Street and Dominion Road. This area encompasses primarily residential land use with some commercial infill.

880 and 933 Colville Road

Echo Level Sensors was installed at 880 and 933 Colville Road on January 19, 2021 and monitored continuously until February 10, 2021. Findings of the monitoring are included in Table 7-6 below and graphs including monitored results can be found in Appendix B.

Table 7-6: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI (880 Colville Road)	10 mm	February 1 to 7, 2021	Medium GWI
GWI (933 Colville Road)	10 mm	February 1 to 7, 2021	High GWI
Direct Connections	No observed direct connections		

The level monitoring at 880 and 933 Colville Road did not show evidence of a direct connection upstream of the monitoring manhole but did indicate medium to high GWI upstream of the monitoring manholes.

819 Anderson Avenue

An Echo Level Sensor was installed at 819 Anderson Avenue on January 19, 2021 and monitored continuously until February 10, 2021. Findings of the monitoring are included in Table 7-7 below and graphs including monitored results can be found in Appendix B.

Table 7-7: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	14 mm	February 1 to 7, 2021	Very High GWI
Direct Connections	No direct connection observed		

The level monitoring at 819 Anderson Avenue did not show evidence of a direct connection upstream of the monitoring manhole but did indicate a very high GWI upstream of the monitoring manhole.

876 Lampson Street

An Echo Level Sensor was installed at 876 Lampson Street on January 29, 2021 and monitored continuously until February 10, 2021. Findings of the monitoring are included in Table 7-8 below and graphs including monitored results can be found in Appendix B.

Table 7-8: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	No GWI observed		
Direct Connections	12 mm	February 1, 2021	~ 2 L/s Direct Connection

The level monitoring at 876 Lampson Street shows evidence of a direct connection upstream of the monitoring manhole during the storm but little indication of elevated GWI.

7.3.8 Recommended Actions in Esquimalt High School Area

The following list of action items in the Esquimalt High School Area are recommended based on the results of the level monitoring analysis. Locations can also be found on Figure 7-3 above.

- Complete additional smoke and dye testing work to locate the direct connection upstream of 876 Lampson Street. Finding and addressing the direct connection at this location directly affects the flow at upgrade projects 2, 3, and 6 identified in the Modelling Report.
- Renew mains and/or service connections in area upstream of 819 Anderson Avenue and 933 Colville Road. Reducing the overall I&I contribution at this location directly affects the flow at upgrade project 6 identified in the Modelling Report.

7.4 Forshaw and Uganda Catchment Assessments

The Forshaw and Uganda Catchments was added to the flow level monitoring program because the pump stations from these catchments discharge to the planned upgrades of the twinned gravity trunk mains from Lampson Road to Hereward Road (Dominion Road). A reduction of I&I in this catchment could provide an opportunity to delay construction on the planned upgrades.

Figure 7-6 shows the locations monitored with the Forshaw and Uganda Catchments.

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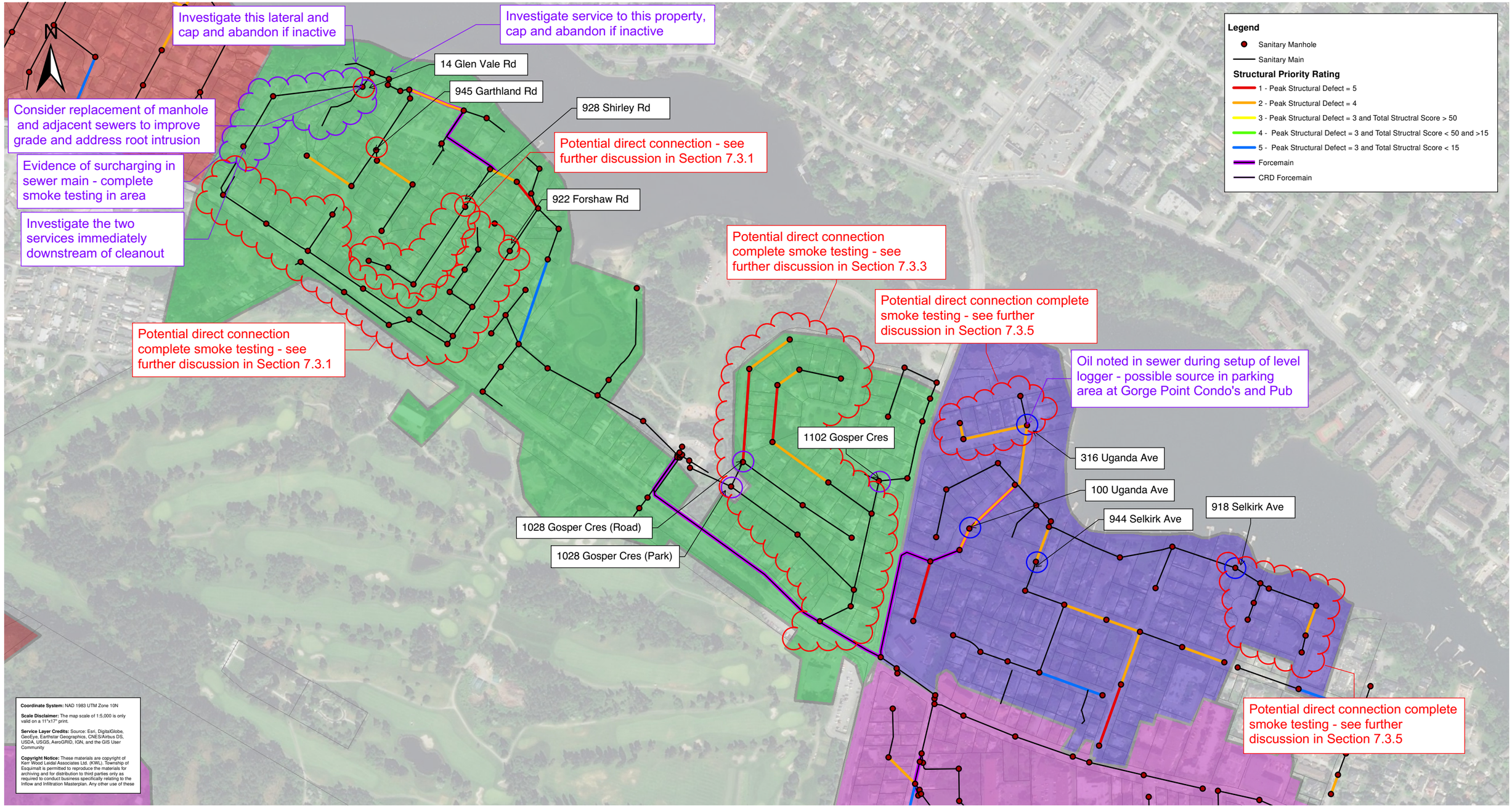
Township of Esquimalt
I & I Masterplan

KERR WOOD LEIDAL
consulting engineers



Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:5,000 is only valid on a 11"x17" print.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Project No. 601-010
Date August 2021
Scale 1:5,000

Manhole Level Sensor Program Map for Forshaw and Uganda Catchments

Figure 7-6

7.4.1 Upper Forshaw Area

The monitoring locations within the Upper Forshaw Area are shown in red on Figure 7-6 above. This area encompasses the streets feeding into the Glen Vale Pump Station and the trunk main at Sioux Place. This area encompasses primarily residential land use with adjacent park land.

14 Glen Vale Road

An Echo Level Sensor was installed at 14 Glen Vale Road on February 11, 2021 and monitored continuously until March 3, 2021. The storm event on February 15, 2021, was snowfall and which may not result in a direct I&I response but can result in significant long-term I&I with snowmelt. The data from this site appears to show evidence of surcharging in the surrounding 150 mm sewers and cannot be used to identify I&I. A significant amount of standing sewage was noted in the manhole when installing and removing the level sensor. Appendix B includes a graph of the results of the monitoring along with local rainfall data. Note that depths of approximately 100-110 mm on the figure indicate a surcharged outlet.

A review of available CCTV data was completed on Glen Vale Road. At the top end of the sewer there are two services, one being 150 mm diameter and the other 100 mm diameter, that appear to be duplicate. Directly downstream of these services the sewer is clean up until the point where the downstream property services tie-in. At this location there is tide line evidence that the sewer surcharges, indicating that the two upstream services may be a significantly sized direct connection. It is noted that smoke testing in 2010 also identified a possible cross connection at this location.

The sewer entering manhole SMH0843, where flow monitoring was conducted, is at a flat grade as it enters the manhole. Significant signs of surcharging are seen at this location and there is standing water due to poor grade and poor benching in SMH0843. SMH0843 is also adjacent a cedar hedge and root intrusion into the manhole is significant.

Downstream of SMH0843, between SMH0092 and SMH0093 there is a lateral main on the ocean side of units 13-915 and 14-915 that does not appear to have a purpose as these properties are serviced upstream. There is also a service mid way between these manholes that is to a grassed area adjacent the ocean. This service lateral also contains a wye. These are suspected sources of I&I.

945 Garthland Road

An Echo Level Sensor was installed at 945 Garthland Road on February 11, 2021 and monitored continuously until March 3, 2021. The level sensor data was intermittent and could not be used to identify I&I response. A graph of the results is included in Appendix B showing the results of the monitoring along with local rainfall data.

928 Shirley Road

An Echo Level Sensor was installed at 928 Shirley Road on February 11, 2021 and monitored continuously until March 3, 2021. Findings of the monitoring are included in Table 7-9 below and graphs including monitored results can be found in Appendix B.

Table 7-9: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	10 mm 16 mm	February 14 to 21, 2021 February 21 to 24, 2021	High GWI Very High GWI
Direct Connections	31 mm 48 mm	February 14, 2021 (snowfall) February 21, 2021	~ 1 L/s Direct Connection ~ 3 L/s Direct Connection

The level monitoring at 928 Shirley Road shows evidence of a direct connection upstream of the monitoring manhole and high to very high GWI.

922 Forshaw Road

An Echo Level Sensor was installed at 922 Forshaw Road on February 11, 2021 and monitored continuously until March 3, 2021. Findings of the monitoring are included in Table 7-10 below and graphs including monitored results can be found in Appendix B.

Table 7-10: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	10 mm	February 14 to March 3, 2021	High GWI
Direct Connections	17 mm	February 21, 2021	~ 7 L/s Direct Connection

The level monitoring at 922 Forshaw Road show evidence of a direct connection upstream of the monitoring manhole and high GWI. Note the storm event on February 15, 2021, was snowfall and which may not result in a direct I&I response but can result in significant long-term I&I with snowmelt.

7.4.2 Recommended Actions in Upper Forshaw Area

The following list of action items in the Upper Forshaw Area are recommended based on the results of the level monitoring analysis. Locations can also be found on Figure 7-6 above.

- Complete additional smoke and dye testing work to locate the direct connection upstream of 928 Shirley Road and 922 Forshaw Road. Finding and addressing the direct connection at this location directly affects the flow at the Forshaw Pump Station.
- Complete smoke testing on the Glen Valve Road sewers. Investigate the two services at the very top end of the system near SMH0841 (which is a cleanout). Investigate the lateral main fronting 13-915 and 14-915 (tied in between SMH0092 and SMH0093), investigate the service at 940 Garthland that is tied into the sewer between SMH0092 and SMH0093.
- Consider replacement of manhole SMH0843 and adjacent sewers in order to improve grade through the manhole and remove the significant root intrusion issue.

7.4.3 Gosper Crescent Area

The monitoring locations within the Gosper Crescent Area are shown in purple on Figure 7-6 above. This area encompasses the Gosper Crescent neighbourhood area west of Tillicum Road up to the pump station at 1100 Craigflower Road. This area encompasses primarily residential land use with adjacent park land.

1028 Gosper Crescent (Park Location)

An Echo Level Sensor was installed at 1028 Gosper Crescent in the roadway on March 3, 2021 and monitored continuously until June 10, 2021. Findings of the monitoring are included in Table 7-11 below and graphs including monitored results can be found in Appendix B.

Table 7-11: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	8 mm	February 14 to March 3, 2021	Medium GWI
Direct Connections	24 mm	February 21, 2021	~ 6 L/s Direct Connection

The level monitoring within the park at 1028 Gosper Crescent indicates a potential direct connection and a medium GWI upstream of the monitoring manhole. The storm event on February 15, 2021, was snowfall and which may not result in a direct I&I response but can result in significant long-term I&I with snowmelt.

1028 Gosper Crescent (Road Location) and 1102 Gosper Crescent

Echo Level Sensors were installed at 1028 Gosper Crescent in the roadway and at 1102 Gosper Crescent on March 3, 2021 and monitored continuously until June 10, 2021. Findings of the monitoring are included in Table 7-12 below and graphs including monitored results can be found in Appendix B.

Table 7-12: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	No GWI observed		
Direct Connections (1028 Gosper Cres (Roadway))	13 mm	March 24, 2021	~ 2 L/s Direct Connection
Direct Connections (1102 Gosper Cres)	No direct connection observed		

The level monitoring within the roadway at 1028 Gosper Crescent indicates a potential direct connection but little indication of GWI. The level monitoring at 1102 Gosper Crescent did not indicate any evidence of substantial I&I.

7.4.4 Recommended Actions in Gosper Crescent Area

The following list of action items in the Gosper Crescent Area are recommended based on the results of the level monitoring analysis. Locations can also be found on Figure 7-6 above.

- Complete additional work to locate the direct connection upstream of 1028 Gosper Crescent. A potential direct connection was noted in both the roadway and park manholes, this indicates there is likely a connection on the loop upstream of the roadway but does not eliminate multiple direct connections in the area. The level monitoring at 1102 Gosper Crescent did not indicate any potential direct connection upstream. Finding and addressing the direct connection at this location directly affects the flow at the Forshaw Pump Station.

7.4.5 Uganda Catchments

The monitoring locations within the Uganda Catchment are shown in blue on Figure 7-6 above. This area encompasses the area border to the east by Tillicum Road, the Gorge to the north, Craigflower Road to the south, and Dingley Dell to the west. The catchment drains to the Uganda pump station which discharge upstream of the gravity trunk through the Devonshire Catchment. This area encompasses primarily residential land use with adjacent park land.

100 and 316 Uganda Ave

Echo Level Sensors were installed at 100 and 316 Uganda Avenue on March 3, 2021 and monitored continuously until June 10, 2021. Findings of the monitoring are included in Table 7-13 below and graphs including monitored results can be found in Appendix B.

Table 7-13: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI	No GWI observed		
Direct Connections (316 Uganda Ave)	15 mm	March 24, 2021	~ 2 L/s Direct Connection
Direct Connections (100 Uganda Ave)	No direct connection observed		

The level monitoring at 316 Uganda Avenue indicates a potential direct connection but no sign of excessive GWI. The monitoring at 100 Uganda Avenue did not show any evidence of excessive I&I.

Additionally, oil was noted in the manhole during installation of the level monitor. The service appears to be coming from the Gorge Point Condo and Pub property and could potentially include drainage from parking lot areas.

918 and 944 Selkirk Avenue

Echo Level Sensors were installed at 918 and 944 Uganda Avenu8e on February 11, 2021 and monitored continuously until March 4, 2021. Findings of the monitoring are included in Table 7-14 below and graphs including monitored results can be found in Appendix B.

Table 7-14: GWI and RDII Found During Level Monitoring

I&I Type	Change in Level (mm)	Dates Observed	Findings
GWI (918 Selkirk Ave)	5 mm	February 14 to March 3, 2021	Low GWI
GWI (944 Selkirk Ave)	4 mm	February 14 to March 3, 2021	Medium GWI
Direct Connections (918 Selkirk Ave)	5 mm	February 21, 2021	~ 1 L/s Direct Connection
Direct Connections (944 Selkirk Ave)	No direct connection observed		

The level monitoring at 918 Selkirk Avenue indicates a potential direct connection and low GWI upstream of the monitoring manhole. At 944 Selkirk Avenue medium GWI was observed upstream of the manhole. The storm event on February 15, 2021, was snowfall and which may not result in a direct I&I response but can result in significant long-term I&I with snowmelt.

7.4.6 Recommended Actions in Uganda Catchment

The following list of action items in the Uganda Catchment are recommended based on the results of the level monitoring analysis. Locations can also be found on Figure 7-6 above.

- Complete additional smoke and dye testing work to locate the direct connection upstream of 316 Uganda Ave and 918 Selkirk Avenue. Finding and addressing the direct connections at these locations directly affects the flow at the Uganda pump station.
- Identify the source of oil found in the manhole at 316 Uganda Avenue, could include parking lot drainage from Gorge Point Condos and Pub. Smoke testing in this area could be affected by the nearby Uganda Pump Station and isolation from any overflows and combined manholes in the area would be required.

8. Private Side Sewer I&I Assessment and Policy

Private side laterals represent approximately 40% of the total sewer system and studies done on other systems show that approximately half of all I&I originates on private property. High private side I&I is suspected in Esquimalt based on the work done to date and it is quite likely that the private side contribution exceeds 50% of the total.

High I&I rates on private property in Esquimalt are due to:

- roof and perimeter drainage cross connections that appear to be a significant issue in a number of catchments given the results of smoke testing and speed at which I&I enters the system after a rain event; and
- a lack of assessment, maintenance, and renewal by homeowners. Private side maintenance and renewal is assumed to be almost exclusively driven by sewage backups. It is assumed that when maintenance does occur the primary goal is to get the sewer flowing; homeowners will often choose a least cost solution such as root cutting or point repair over full asset renewal. There are currently no other drivers or incentives in Esquimalt to motivate homeowners to complete lateral renewals and reduce their I&I contribution.

Esquimalt's ability to reduce I&I to less than 4 X ADWF or low enough to remove sewer capacity issues caused by high I&I rates is linked to the Townships ability/authority and willingness to facilitate work on private property and homeowners' willingness to participate. Educational material will be part of the solution but when used alone, public outreach will not create notable reductions. With regards to creating public education materials for specific projects, we recommend that the Township utilize the assistance of the CRD who have offered their assistance as part of the Core Area I&I Management Plan.

8.1 Bylaw for Maintenance and Repair of Private Sewer Laterals

The Township does not have any existing bylaws with adequate mechanisms that allow the Township to inspect private sewer laterals. It also does not have the ability to coordinate the repair or renewal of these laterals. The repair or renewal of these laterals will assist in the control and elimination on inflow and infiltration on the private portion of the sewer collection system. Esquimalt must put in place a bylaw to begin the work of reducing private side I&I.

Through the CRD Core Area Inflow and Infiltration working group, a model bylaw was produced to address the issue of inflow and infiltration. The Township has modified this bylaw and is currently in draft form for discussion with Council. Some of the key elements of this modified bylaw include:

1. Maintenance standard.
2. Definition of unauthorized discharges and connections.
3. Provides a mechanism and authority allowing the Township to enter the private lateral and conduct testing to identify defects and noncompliance with the bylaw.
4. Authority to require repair of the defects.
5. Requirements for plumbing permits.
6. Description of financial assistance for repair/renewal of for private sewer laterals.

The Township must put in place a bylaw to begin the work of reducing private side I&I. We recommend finalizing the draft form of the bylaw currently in discussion with Council.

8.2 Financial Assistance and Monetary Incentives

Over the past several years, the Township has been exploring financial implications for control of inflow and infiltration. Attention has been paid to how the inspection, repair, renewal of private side laterals would be carried out and the financial implication to the Township and the homeowner. The current direction this discussion has taken is that inspection/repair/renewal of both the public and private portions of the sanitary collection system for inflow and infiltration control will be financed through a Parcel Tax.

This tax will by utilized to fund inspection/repair/renewal for the pubic portion of the sanitary collection system and the public portions of the sewer laterals. Inspection/repair/renewal for the private portion of the sewer laterals will be funded on a 50/50 split of the cost for the work between the Township and the homeowner. The homeowner portion a mechanism would be developed to allow for either direct payment at the time of work or repayment for the costs over time through taxation.

We recommend the Township utilize the Parcel Tax system to finance work on the private side of the sewer laterals. This program will allow the municipality to complete targeted rehabilitation work that includes private side renewals and will also provide a positive financial benefit within the new bylaw, to gain broader community support for what would otherwise be strictly an enforcement-based approach.

9. Targeted Sewer Rehabilitation Strategy

Targeted rehabilitation programs seek to renew sewers in areas of high I&I. Programs including renewal of private and public laterals and have been found to be very successful in reducing I&I. The City of Victoria's James Bay I&I program is an example of such a program.

Examples and results of these programs, including a program in Westlake Ohio, are provided in Appendix A of the CRD's Core Area I&I Management Plan. The Westlake Ohio project targeted private side sewer renewals in 8 catchments and resulted in 80 - 95% reduction in I&I.

A targeted approach to sewer rehabilitation for the purpose of I&I reduction is recommended as follows:

1. Target efforts that will reduce I&I in sewers where upgrades are recommended based on the current rates of I&I. This includes targeting sewers:
    a. connected to the Colville Street sewer in the Devonshire catchment;
    b. within the Forshaw catchment;
    c. within the Uganda catchment;
    d. within the greater Devonshire catchment; and
    e. within the Kinver catchment.
2. Complete remaining CCTV inspections in the Forshaw, Uganda, and Devonshire catchments.
3. Map structural condition and determine priority of replacement in these catchments.
4. Map sewer lateral locations in GIS from CCTV data, approximating lateral locations as perpendicular to property line from sewer. Ensure not to map laterals that are noted as capped at main.
5. Adopt a complete sewer rehabilitation approach; replace/rehabilitate public side laterals, install IC's at PL, incentivize homeowners to rehabilitate private laterals at the same time as part of the public construction contract. Below is a suggested list of actions to initiate and complete these projects:
    a. Target areas as mentioned above and with sewers that are priority 1 and 2 for structural repair.
    b. Round out program to an amount that includes approximately 40% of sewer laterals within each catchment which is estimated to achieve a targeted 25% reduction in I&I for the catchment (See discussion at the end of this section). Target areas where potential cross-connections were noted by 2010 smoke testing program or future smoke testing efforts.
    c. Determine rehabilitation method for mainline: CIPP, CIPP after point repairs, or open cut replacement.
    d. Create a larger work program for CIPP lining within budget constraints. Ensure a large enough CIPP program to see good value on a cost per meter basis given the high costs of mobilization for this work.
    e. Inform homeowners of the sewer renewals on their street, provide educational information informing of the need to renew laterals to protect against root intrusion, failure and sewer backups causing basement flooding, and describing trenchless renewal techniques that may be offered. Inform that an inspection chamber will be installed at property line and that the private lateral will be inspected as per the bylaw (once adopted). Inform that the homeowners will be offered the ability to renew their lateral as part of the project with financial assistance and incentives as provided in the Townships bylaw (once adopted).

f. Install IC's on all sewer laterals. If multiple laterals exist to a property, determine the source through dye testing and cap/abandon at PL, redirect to public storm main or leave connected as determined through the inspection.

g. Inspect both public and private side of lateral. Inspect for the presence of wyes before or near the edge of dwellings where lateral will likely change material to cast iron. Create a report for each lateral that includes assessment of whether CIPP lining can be used for public and private renewal, if replacement is required, and 1-2 representative photos of structural and I&I issues and any existing wyes on the private side lateral.

h. Inform homeowners of the work program timing and provide them with the lateral report, renewal recommendation and details on costs and how to opt into the program (mail-out). If wyes exist, inform homeowner of municipal bylaws and program cost for removal of cross connections.

i. Following the mail-out and a period for homeowners to have opted in by contacting the Township, complete door to door canvassing to inform on the program and gain signups to the program.

j. If CIPP can be used for mainline, install tee connections for any public laterals requiring open cut replacement and replace lateral prior to CIPP mainline lining.

k. Design/Tender and complete rehabilitation of the mainline sewer. CIPP lining to include grouting of annular space between host pipe and liner.

l. Design/Tender and complete lateral renewal and cross connection removal program: all public side laterals and signed up private side laterals.

6. Review the program results. Assess the following:

   a. level of success in private side participation and adjust strategy to include more in person door to door activity as necessary to increase participation rates.

   b. program costs and the pricing structure offered to homeowners.

   c. pump station flow data in the winter following the program and determine the results and percentage reduction in I&I.

7. Continue program based on results of program review.

9.1 Discussion on Expected Reduction from Targeted Rehabilitation Program

Rehabilitating 40% of a catchments sewer mains and laterals will bring the expected unit I&I rate for the rehabilitated section of the catchment down to a new build rate (< 20,000 L/ha/day), this assumption allows for calculation of an anticipated new I&I rate for the catchment. A 40% rehabilitation results in an approximate 25% reduction in I&I flows for the catchment using this methodology. The actual reductions will vary based on various factors and the existing monitoring program along with portable level loggers (i.e., Echo Level Sensor or Smart Manhole Cover) should be used to track improvements associated with rehabilitation works.

Potential factors affecting the I&I reductions associated with rehabilitation work includes:

- buy-in with the private side lateral rebate program (assumed to be around 50%);
- areas selected for rehabilitation should be focused in areas with worst conditioned sewers and may have I&I rates higher than the catchment-wide averages; and

- I&I rate for rehabilitated sewers may vary (for example catchments in Saanich and Langford have been found to be less than 10,000 L/ha/day in rehabilitation or newly constructed areas in the CRD I&I Management Plan).

9.2 Discussion on Requirements to Achieve CRD's CALWMP Project Targets

Each of the proposed target replacement programs discussed replace 40% of the catchment or sub-catchment and is expected to address approximately 25% in I&I in the catchment. We estimate that the first three yeas of the target rehabilitation projects will bring the Township's overall I&I rate down from 5.7 X ADWF to 5.0 X ADWF.

To achieve the CRD's CALWMP Project Targets of 4 X ADWF, an additional five targeted replacement programs would be required as well as supporting a financial incentive program to renew approximately 50 private side laterals per year. It is estimated that the additional five targeted replacement programs will achieve a 4.2 X ADWF and additional private side renewals completed through the incentive program will bring I&I rates to below 4.0 X ADWF.

After each completed targeted replacement program, the actual I&I reduction should be evaluated via the existing monitoring program and with additional monitoring via in manhole level monitoring sensors (i.e., Echo Level Sensors or Smart Manhole Covers).

The remaining 5 targeted replacement programs are recommended to be located in the Forshaw, Uganda, Devonshire and Kinver catchments with a target of achieving a 50% reduction in I&I within the catchment from existing rates (i.e., 80% rehabilitation in each catchment).

10. Recommended Actions

The recommended actions based on the findings of the completed work are broken up into the following categories:

1. Completion of CCTV Condition Assessment program.
2. Additional follow up Smoke Testing program.
3. Combined Manholes and Sewer Abandonments program.
4. Target Sewer Rehabilitation program.

10.1 CCTV Condition Assessment

Prioritize CCTV inspections as follows:

1. Complete CCTV inspections in Forshaw catchment – 4.1 km of inspections remaining.
2. Complete CCTV inspections in Uganda catchment – 951 m of inspections remaining.
3. Complete CCTV inspections in Devonshire Catchment connected to the Colville sub-catchment – 2.4 km of inspections remaining.
4. Complete remainder of CCTV inspections in Devonshire Catchment – 8.2 km of inspections remaining.
5. Complete CCTV inspections in the Kinver catchment – 1.6 km of inspections remaining.

10.2 Smoke Testing

Prioritize follow up smoke testing as follows:

1. Colville Street: Ensure that inspectors look for smoke at the base hospital, at properties noted on Figure 7-4, and golf course lands as well as all other areas serviced by the sewer.
2. Uganda areas (as identified on Figure 7-6): Ensure inspectors investigate at the Gorge Point Condos and Gorge Point Pub as there are suspected cross connected CB's at this location. Ensure inspectors investigate the frontages of the waterfront properties. Smoke testing in this area could be affected by the nearby Uganda Pump Station and isolation from any overflows and combined manholes in the area would be required.
3. Forshaw areas (as identified on Figure 7-6): Ensure to investigate locations noted on Glen Vale Road. Investigate the service at 940 Garthland that is tied into the sewer between SMH0092 and SMH0093.

10.3 Combined Manholes and Sewer Abandonments

Prioritize separation of combined manholes as follows:

1. Determine source of direct storm to sewer connection in combined manhole SMH0686 at the Archie Browning Sport Centre outside the east entrance. Redirect to storm system, if possible.
2. Separate manhole SMH0320 located in the backyard of residence at 861 Kindersley Road. Manhole includes several inlet pipes of unknown origin with a single outlet into the sewer system.

3. Determine where the active services are located for 847 Dunsmuir Road and 531 West Bay Terrace and disconnect, cap and abandon all non-active sewers as they are a likely source of I&I.
4. Investigate if active services exist on the following mains and abandon mains., if possible:
   a. SMH0493 to SMH0105 at soccer pitch on base property (end of Colville Road).
   b. Sewer fronting 13-915 and 14-915 Glen Vale Road.

10.4 Targeted Sewer Rehabilitation

Following the sewer rehabilitation strategy discussed in section 9, complete the following:

Colville Catchment

- 43 m of mainline renewals at the end of Colville Street and replacement of manhole SMH0104.
- Complete lateral renewals, as described in section 9, for all properties along Colville Road from Lampson to Admirals Road, on Tillicum Road from Colville to Transfer Street, Condor Avenue, and Macleod Avenue. Estimated at approximately 100 laterals. All laterals found to be abandoned to be capped at main.
- Based on additional CCTV condition assessment (see section 10.1) completed approximately 300 to 400 m of sewer renewals (assumed to be priority 1 or 2 pipes as described in this report) in the upper Colville catchment.
- Renew all laterals connected to the 300 to 400 m of renewals in the upper Colville catchment. Assumed to be approximately 30-40 laterals.
- Monitor effects of sewer rehabilitation works via existing monitoring program and portable level sensors.

Uganda Catchment

- Complete 900 to 1,000 m of sewer renewals based on CCTV Condition assessment (Priority 1 & 2 pipes).
- Renew all laterals connected to the 900 to 1,000 m of renewals. Assumed to be approximately 90-100 laterals.
- Monitor effects of sewer rehabilitation works via existing monitoring program and portable level sensors.

Forshaw Catchment

- Complete approximately 1,000 m of sewer renewals based on CCTV Condition Assessment (Priority 1 & 2 pipes).
- Renew all laterals connected to the 1,000 m of renewals. Assumed to be approximately 100 laterals.
- Complete 50 additional lateral renewals in areas with older laterals and where sewer flow monitoring indicates high levels of direction connections and background I&I.
- Monitor effects of sewer rehabilitation works via existing monitoring program and portable level sensors.

Future Work (Devonshire/Uganda/Forshaw/Kinver Catchments)

- Develop detailed targeted rehabilitation programs based on CCTV Condition assessment of approximately 1,000 m of main line sewer renewals and 90 - 100 service laterals.
- Monitor effects of sewer rehabilitation works via existing monitoring program and portable level sensors.

11. Program Costs

The first 3 years of the target rehabilitation program have been estimated in detail and the remaining 5 years of the program have been assumed to be similar to the detailed program years at an average cost of $1.3 M per year. Program costs assume 50% participation for private side renewals.

A Class D cost estimate for the proposed I&I reduction program is included in Table 11-1 below.

Table 11-1: Class D Cost Estimate for Recommended Program

Year	Program Item	Units	Unit Cost	Total Cost
CCTV Condition Assessment				
2022	CCTV Inspections Forshaw	4,100 m	$ 8 / m	$32,800
2022	CCTV Inspections Uganda	950 m	$ 8 / m	$7,600
2022	CCTV Inspections Devonshire (Coville Sub-catchment)	2,400 m	$ 8 / m	$19,200
2022	CCTV Inspections Kinver	1,600 m	$ 8 / m	$12,800
2023	CCTV Inspections Devonshire	8,200 m	$ 8 / m	$65,600
2023	Engineering and Condition Analysis	L.S.	$25,000	$25,000
			Total Cost	**$163,000**
Smoke Testing and Flow Monitoring				
2022	Colville Street Area	1 day	$5,000	$5,000
2022	Uganda Areas	1 day	$5,000	$5,000
2022	Forshaw Areas	1 day	$5,000	$5,000
2022	Flow Monitoring Equipment	3	$3,500	$10,500
			Total Cost	**$25,500**
Combined Manhole and Sewer Abandonments				
2022	Investigate and redirect (if possible) cross connection at the Archie Browning Sport Centre outside the east entrance	L.S.	$5,000	$5,000
2022	Investigate and redirect (if possible) cross connection at the 861 Kindersley Road	L.S.	$5,000	$5,000
2022	Investigate and disconnect, cap, and abandon non-active sewer at 847 Dunsmuir Road and 531 West Bay Terrace	L.S.	$5,000	$5,000
2022	Investigate sewer main and disconnect, cap, and abandon non-active sewer at SMH0493 to SMH0105 at soccer pitch on base property (end of Colville Road)	L.S	$5,000	$5,000
2022	Investigate sewer main and disconnect, cap, and abandon non-active sewer fronting 915 Glen Vale Road	L.S	$5,000	$5,000
			Total Cost	**$25,000**

Year	Program Item	Units	Unit Cost	Total Cost
Colville Catchment – Targeted Replacement Program				
2023	Mainline Renewals (end of Colville Road)	50 m	$700 / m	$35,000
2023	Public Side Lateral Renewals (1100 Block Colville Road)	100	$4,000	$400,000
2023	Private Side Lateral Renewals (1100 Block Colville Road)	50	$4,000	$200,000
2023	Mainline Renewals (Priority replacement from CCTV Condition Assessment)	400 m	$700 / m	$280,000
2023	Public Side Lateral Renewals (Upper Area)	40	$4,000	$160,000
2023	Private Side Lateral Renewals (Upper Area)	20	$4,000	$80,000
			Total Cost	**$1,155,000**
Uganda Catchment – Targeted Replacement Program				
2024	Mainline Renewals (Priority replacement from CCTV Condition Assessment)	1,000 m	$700 / m	$700,000
2024	Public Side Lateral Renewals	100	$4,000	$400,000
2024	Private Side Lateral Renewals	50	$4,000	$200,000
			Total Cost	**$1,300,000**
Forshaw Catchment – Targeted Replacement Program				
2025	Mainline Renewals	1,000 m	$700 / m	$700,000
2025	Public Side Lateral Renewals	150	$4,000	$600,000
2025	Private Side Lateral Renewals	75	$4,000	$300,000
			Total Cost	**$1,600,000**
Future Works (Devonshire/Uganda/Forshaw/Kinver Catchments) – Target Replacement Program				
2026	Annual Targeted Replacement Program	L.S.	$1,300,000	$1,300,000
2027	Annual Targeted Replacement Program	L.S.	$1,300,000	$1,300,000
2028	Annual Targeted Replacement Program	L.S.	$1,300,000	$1,300,000
2029	Annual Targeted Replacement Program	L.S.	$1,300,000	$1,300,000
2030	Annual Targeted Replacement Program	L.S.	$1,300,000	$1,300,000
			Total Cost	**$6,500,000**
			Total Cost All Programs	**$10,768,500**
			Township Contribution	**$9,183,500**
			Private (Homeowner) Contribution	**$1,585,000**

Costs for the rehabilitation of the Township owned infrastructure is expected to be **$9,183,500** over the 9-year data collection and rehabilitation program or an average cost of **$1,020,389** per year.

Costs for all private side laterals is expected to be split between the Township and homeowners via a rebate program incentivising lateral replacements. The rebate program is assumed to offer an average of $1,000 per private lateral with the homeowner covering the remaining cost with the Township offering financing options. The portion of the project financed by private homeowners for private lateral renewals is **$1,585,000** over the 8-year rehabilitation project or an average of **$198,125** per year.

11.1 Discussion on Targeted Rehabilitation Program Effects on Capacity Upgrade Projects

As part of the Modelling Report, a sensitivity analysis was completed to evaluate the capacity of the system with 25% and 50% reductions to I&I and found that up to 90% of the recommended pipe upgrades and upgrade to the Kinver Pump station, could be avoided.

As part of the targeted rehabilitation program the I&I reduction is expected to be in the order of a 50% reduction in the targeted catchments. The following Table 11-2 shows the requirement of capacity upgrade projects with the I&I reductions expected with the targeted sewer rehabilitation program.

Table 11-2: Capacity Upgrade Projects with I&I Reductions

Project No.	Project Description	Existing Diameter (mm)	Upgrade Diameter (mm)	Upgrade Length (m)	Still Required with I&I Rehab Program
1	Grafton Pump Station upgrade	N/A	N/A	251 m of forcemain	Yes
2	Pipe upgrade along Cave and Devonshire	375	750	455	No
3	Pipe upgrade under Esquimalt High School field	375	675	286	No
4	Pipe upgrade under Esquimalt Baseball fields	375	675	163	No
5	Pipe upgrade along Lampson Street and under Baseball fields	200 & 300	300 & 450	353	Yes
6	Pipe upgrade along Ellery Street between Lampson Street and Cave Street	200 & 250	300	203	No
7	Pipe upgrade along Colville Road, Tillicum Road, and Transfer Street	300	375	441	No
8	Pipe upgrade along Colville Road between Intervale Avenue to MacLoed Avenue	250	300	607	No
9	Pipe upgrades along Kinver Street between Hadfield Avenue and pump station	200	250 & 300	118	No
10	Kinver Pump Station upgrade	N/A	N/A	N/A	No
11	Pipe upgrades from Forshaw Road to pump station	200	300	474	No
12	Pipe upgrades along Head Street between Paradise Street and Lyall Street	250, 300 & 375	375 & 450	271	Yes
13	Pipe upgrades along Wilson Street to CRD outfall	200	300	36	Yes
14	Pipe upgrades along Lyall Street between Joffre Street and Lampson Street	250	300	80	Yes
15	Pipe upgrades along Munro Street to CRD outfall	200	300	19	Yes
16	Pipe upgrades along Comerford Street between Park Terrace and Lyall Street	200	250	254	Yes

12. Report Submission

Prepared by:

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31 August 2021

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Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
0	August 24, 2021	Final		BLJ/RYL

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Appendix A

Priority Pipe Replacements

Pipe ID	Sewer Catchment	Pipe Material	Length (m)	Pipe Diameter (mm)	Pipe Age (years)	Structural Peak Score	Structural Total Score	Prioritization Rating
SGM0790	Forshaw	Vitrified Clay	126	200	64	5	212	1
SGM0861	Kinver	Vitrified Clay	53	200	56	5	87	1
SGM1053	Forshaw	Concrete	46	200	56	5	76	1
SGM0561	Forshaw	Relined	78	150	12	5	71	1
SGM0144	Uganda	Vitrified Clay	88	200	56	5	54	1
SGM0030	Devonshire	Vitrified Clay	101	200	64	5	42	1
SGM0021	Devonshire	Vitrified Clay	76	200	56	5	38	1
SGM0336	Devonshire	Vitrified Clay	77	200	56	5	36	1
SGM0728	Kinver	Vitrified Clay	71	200	64	5	33	1
SGM0905	Kinver	Vitrified Clay	103	200	27	5	29	1
SGM0685	Head	Vitrified Clay	115	200	51	5	28	1
SGM0725	Lang Cove Esquimalt	Vitrified Clay	42	200	61	5	15	1
SGM0789	Head	Vitrified Clay	119	200	63	5	15	1
SGM0066	Head	Relined	122	200	12	5	14	1
SGM0993	Lang Cove Esquimalt	Relined	64	200	12	5	13	1
SGM0094	Head	Vitrified Clay	4	200	56	5	8	1
SGM0095	Head	Vitrified Clay	92	200	56	5	7	1
SGM0317	Grafton	PVC	150	200	56	5	5	1
SGM0862	Uganda	Vitrified Clay	84	150	56	5	5	1
SGM0274	Uganda	Vitrified Clay	86	200	56	4	111	2
SGM1026	Lang Cove Esquimalt	Vitrified Clay	96	150	59	4	103	2
SGM1096	Lang Cove Esquimalt	Vitrified Clay	74	200	56	4	69	2

Pipe ID	Sewer Catchment	Pipe Material	Length (m)	Pipe Diameter (mm)	Pipe Age (years)	Structural Peak Score	Structural Total Score	Prioritization Rating
SGM0386	Kinver	Vitrified Clay	79	200	56	4	60	2
SGM0871	Forshaw	Vitrified Clay	79	150	56	4	57	2
SGM0493	Grafton	Vitrified Clay	91	200	56	4	56	2
SGM0757	Head	Vitrified Clay	101	200	63	4	48	2
SGM0181	Forshaw	Concrete	40	200	56	4	47	2
SGM0384	Head	Vitrified Clay	66	200	45	4	45	2
SGM0473	Forshaw	PVC	37	150	63	4	44	2
SGM0307	Forshaw	Vitrified Clay	68	150	64	4	42	2
SGM0912	Lang Cove Esquimalt	Vitrified Clay	89	200	56	4	42	2
SGM0237	Devonshire	Vitrified Clay	119	250	59	4	40	2
SGM0985	Esquimalt Panhandle	Vitrified Clay	84	200	50	4	39	2
SGM0507	Uganda	Vitrified Clay	61	200	64	4	37	2
SGM0172	Uganda	Vitrified Clay	79	200	65	4	36	2
SGM0438	Kinver	Vitrified Clay	76	200	56	4	35	2
SGM0903	Uganda	Vitrified Clay	49	200	68	4	34	2
SGM0929	Forshaw	Vitrified Clay	73	150	56	4	34	2
SGM1029	Uganda	Vitrified Clay	76	200	56	4	34	2
SGM0691	Kinver	Vitrified Clay	107	200	56	4	33	2
SGM0574	Grafton	Vitrified Clay	98	200	60	4	32	2
SGM0009	Devonshire	Vitrified Clay	84	200	58	4	31	2
SGM0054	Wilson	Vitrified Clay	97	200	44	4	31	2
SGM0342	Forshaw	Vitrified Clay	58	150	56	4	31	2

Pipe ID	Sewer Catchment	Pipe Material	Length (m)	Pipe Diameter (mm)	Pipe Age (years)	Structural Peak Score	Structural Total Score	Prioritization Rating
SGM0945	Head	Vitrified Clay	96	200	55	4	30	2
SGM0364	Esquimalt Panhandle	Vitrified Clay	60	150	41	4	29	2
SGM0516	Esquimalt Panhandle	Vitrified Clay	72	200	48	4	29	2
SGM0545	Grafton	Vitrified Clay	73	250	64	4	29	2
SGM0948	Lang Cove Esquimalt	PVC	97	200	35	4	29	2
SGM0162	Head	PVC	79	200	55	4	28	2
SGM0495	Esquimalt Panhandle	Vitrified Clay	66	200	50	4	28	2
SGM0943	Uganda	Relined	46	200	12	4	28	2
SGM0126	Esquimalt Panhandle	Vitrified Clay	59	200	50	4	27	2
SGM0150	Uganda	Vitrified Clay	51	200	56	4	27	2
SGM0199	Kinver	Vitrified Clay	76	200	56	4	27	2
SGM0377	Uganda	Vitrified Clay	43	150	58	4	27	2
SGM0518	Devonshire	Relined	73	200	12	4	27	2
SGM0543	Uganda	Vitrified Clay	61	200	68	4	26	2
SGM0406	Esquimalt Panhandle	Vitrified Clay	60	200	50	4	25	2
SGM0538	Wilson	Vitrified Clay	51	200	64	4	25	2
SGM0897	Kinver	Vitrified Clay	58	200	56	4	25	2
SGM0127	Devonshire	Vitrified Clay	43	150	60	4	24	2
SGM0143	Uganda	Vitrified Clay	32	150	56	4	24	2
SGM0976	Esquimalt Panhandle	Vitrified Clay	40	200	50	4	24	2
SGM0986	Lang Cove Esquimalt	Vitrified Clay	55	200	59	4	24	2
SGM0591	Unmetered Esquimalt	Vitrified Clay	44	200	56	4	23	2

Pipe ID	Sewer Catchment	Pipe Material	Length (m)	Pipe Diameter (mm)	Pipe Age (years)	Structural Peak Score	Structural Total Score	Prioritization Rating
SGM0037	Devonshire	Concrete	49	300	60	4	21	2
SGM0772	Devonshire	Vitrified Clay	28	200	64	4	21	2
SGM0648	Uganda	PVC	22	150	56	4	20	2
SGM0208	Wilson	Vitrified Clay	106	200	63	4	19	2
SGM0477	Kinver	Vitrified Clay	104	200	68	4	19	2
SGM1120	Uganda	Vitrified Clay	89	150	56	4	18	2
SGM0196	Wilson	Vitrified Clay	13	200	64	4	16	2
SGM0941	Kinver	Vitrified Clay	24	200	56	4	16	2
SGM0467	Esquimalt Panhandle	Unknown	18	200	48	4	15	2
SGM0071	Head	Vitrified Clay	80	250	62	4	14	2
SGM0241	Devonshire	Relined	76	200	12	4	14	2
SGM0643	Lang Cove Esquimalt	Relined	102	150	12	4	12	2
SGM0831	Kinver	Relined	61	200	12	4	12	2
SGM0463	Lang Cove Esquimalt	Vitrified Clay	22	200	44	4	10	2
SGM0465	Kinver	Relined	67	200	12	4	8	2
SGM0832	Uganda	Relined	61	200	12	4	8	2
SGM0852	Head	Relined	77	200	12	4	8	2
SGM0654	Unmetered Esquimalt	PVC	145	200	26	4	6	2
SGM0846	Head	Relined	106	200	12	4	6	2
SGM0010	Devonshire	Vitrified Clay	89	200	58	4	5	2
SGM0040	Devonshire	Vitrified Clay	51	200	68	4	4	2
SGM0084	Head	Vitrified Clay	65	375	45	4	4	2

Pipe ID	Sewer Catchment	Pipe Material	Length (m)	Pipe Diameter (mm)	Pipe Age (years)	Structural Peak Score	Structural Total Score	Prioritization Rating
SGM0053	Devonshire	Relined	55	200	4	4	4	2
SGM0177	Head	Relined	104	200	12	4	4	2
SGM0268	Kinver	Relined	102	150	12	4	4	2
SGM0375	Head	Relined	133	200	12	4	4	2
SGM0485	Kinver	Relined	91	200	12	4	4	2
SGM0628	Forshaw	Relined	94	200	12	4	4	2
SGM1063	Head	Vitrified Clay	137	200	45	3	60	3
SGM0355	Kinver	Vitrified Clay	96	200	56	3	54	3
SGM0011	Devonshire	Concrete	54	375	58	3	41	4
SGM1021	Devonshire	Vitrified Clay	106	250	35	3	35	4
SGM0932	Kinver	Vitrified Clay	101	200	56	3	32	4
SGM1059	Head	Vitrified Clay	54	150	61	3	31	4
SGM0170	Devonshire	Vitrified Clay	108	250	56	2	31	4
SGM0249	Kinver	Vitrified Clay	76	200	57	3	29	4
SGM0768	Head	Vitrified Clay	95	200	55	3	25	4
SGM0225	Kinver	Vitrified Clay	61	200	56	3	23	4
SGM0112	Head	Vitrified Clay	52	200	51	3	22	4
SGM0440	Esquimalt Panhandle	PVC	71	200	31	3	22	4
SGM0575	Lang Cove Esquimalt	Vitrified Clay	69	200	61	3	22	4
SGM0455	Devonshire	Vitrified Clay	41	250	60	3	21	4
SGM0052	Devonshire	Relined	61	200	4	3	21	4
SGM0001	Devonshire	Vitrified Clay	68	200	56	3	20	4

Pipe ID	Sewer Catchment	Pipe Material	Length (m)	Pipe Diameter (mm)	Pipe Age (years)	Structural Peak Score	Structural Total Score	Prioritization Rating
SGM0244	Head	Vitrified Clay	40	200	55	3	19	4
SGM0034	Devonshire	Vitrified Clay	40	200	26	3	18	4
SGM0219	Wilson	Unknown	28	200	64	3	18	4
SGM0038	Devonshire	Vitrified Clay	33	300	60	3	17	4
SGM1125	Head	Vitrified Clay	17	200	51	3	17	5
SGM0500	Devonshire	Vitrified Clay	61	250	60	3	10	5
SGM0891	Forshaw	Concrete	122	200	56	3	7	5
SGM0022	Devonshire	Vitrified Clay	52	200	56	3	6	5
SGM1025	Grafton	PVC	104	150	56	2	6	5
SGM0582	Lang Cove (DND)	Vitrified Clay	78	300	61	3	5	5
SGM1007	Wilson	Vitrified Clay	122	200	65	3	5	5
SGM0039	Devonshire	Concrete	31	200	68	3	3	5
SGM1070	Esquimalt Panhandle	Unknown	70	200	40	3	3	5

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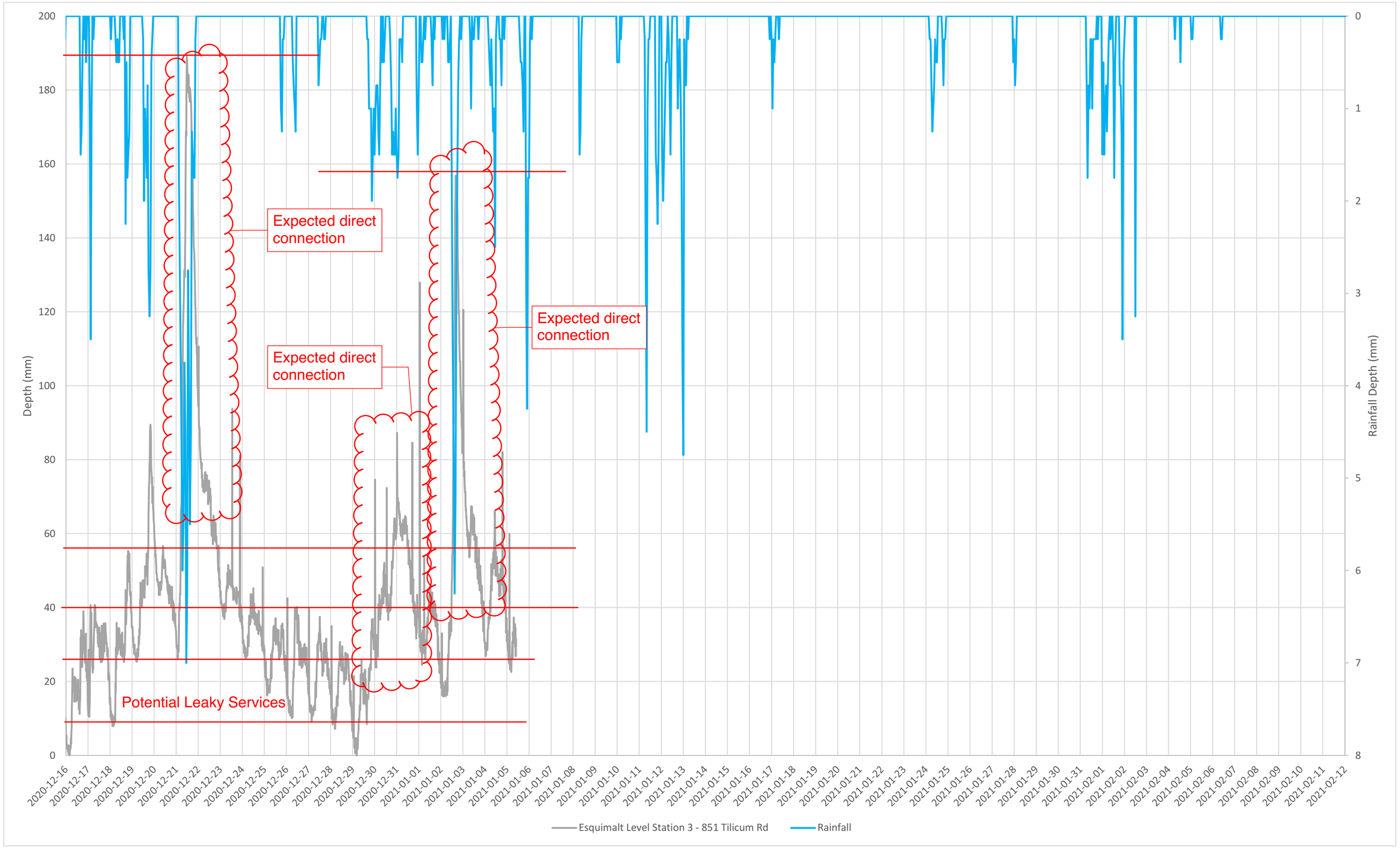
Appendix B

Level Logging Results


Depth (mm)
Rainfall Depth (mm)
200
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
Expected direct connection
Expected direct connection
Expected direct connection
Potential Leaky Services
2020-12-16
2020-12-17
2020-12-18
2020-12-19
2020-12-20
2020-12-21
2020-12-22
2020-12-23
2020-12-24
2020-12-25
2020-12-26
2020-12-27
2020-12-28
2020-12-29
2020-12-30
2020-12-31
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2021-01-30
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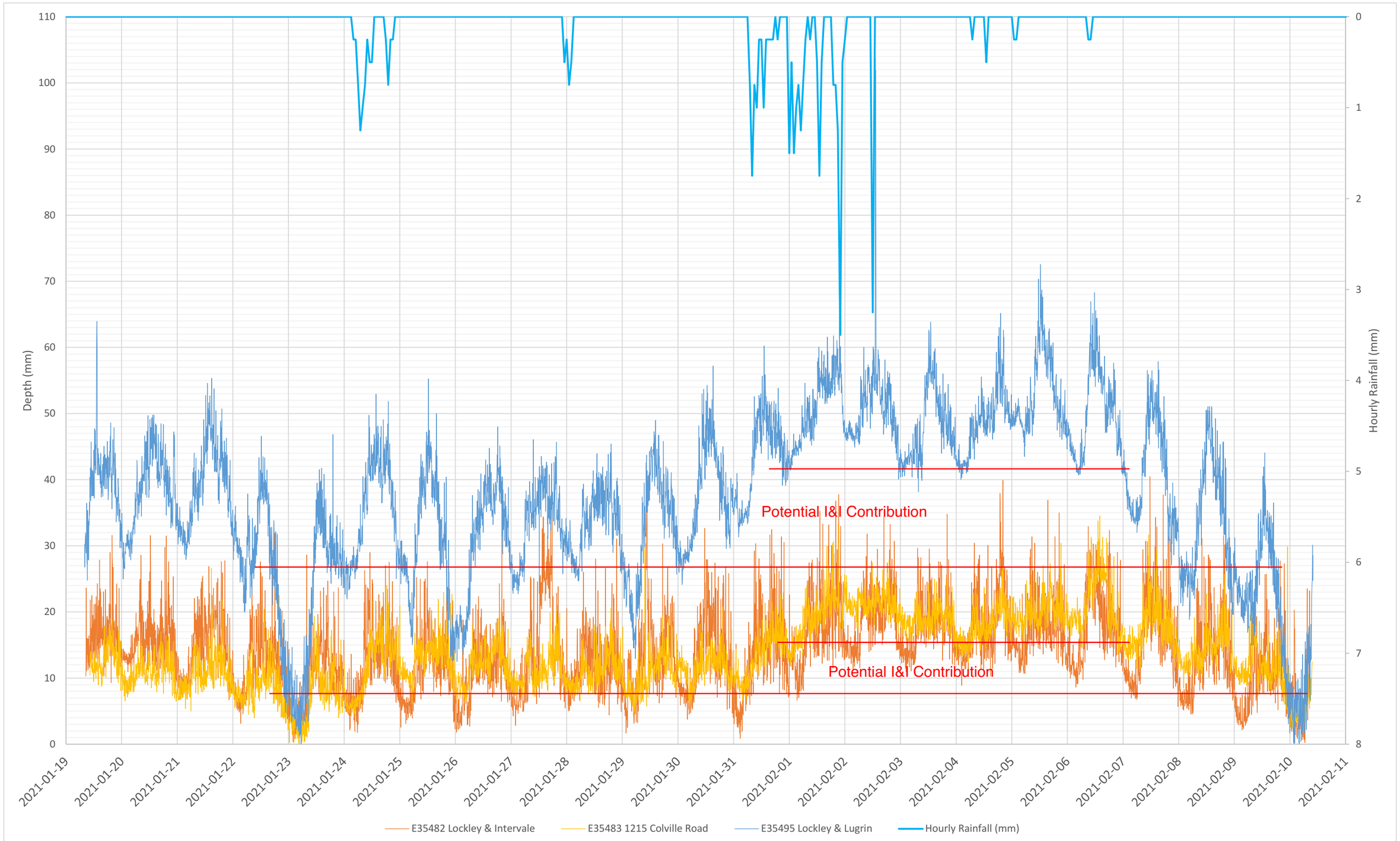
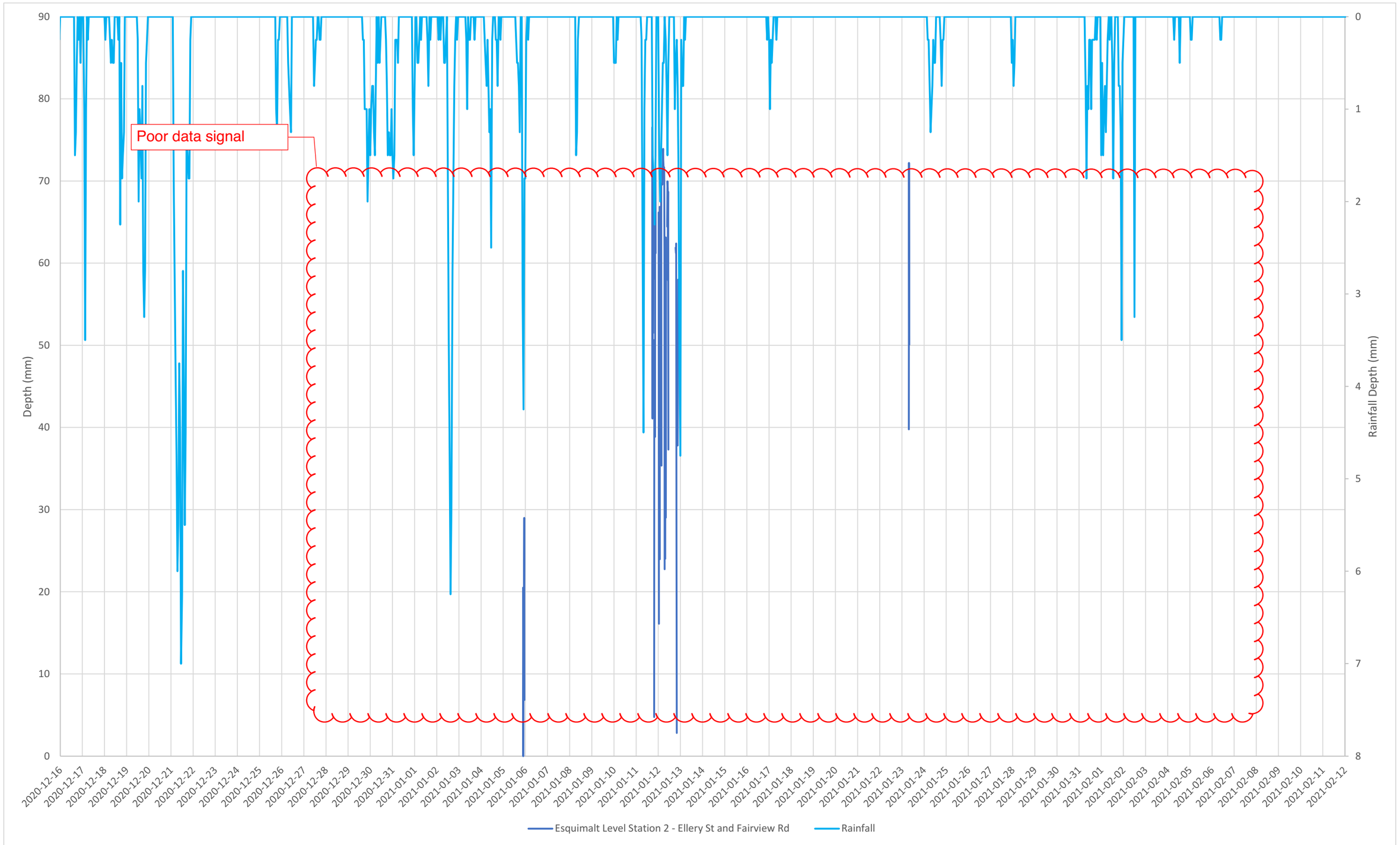
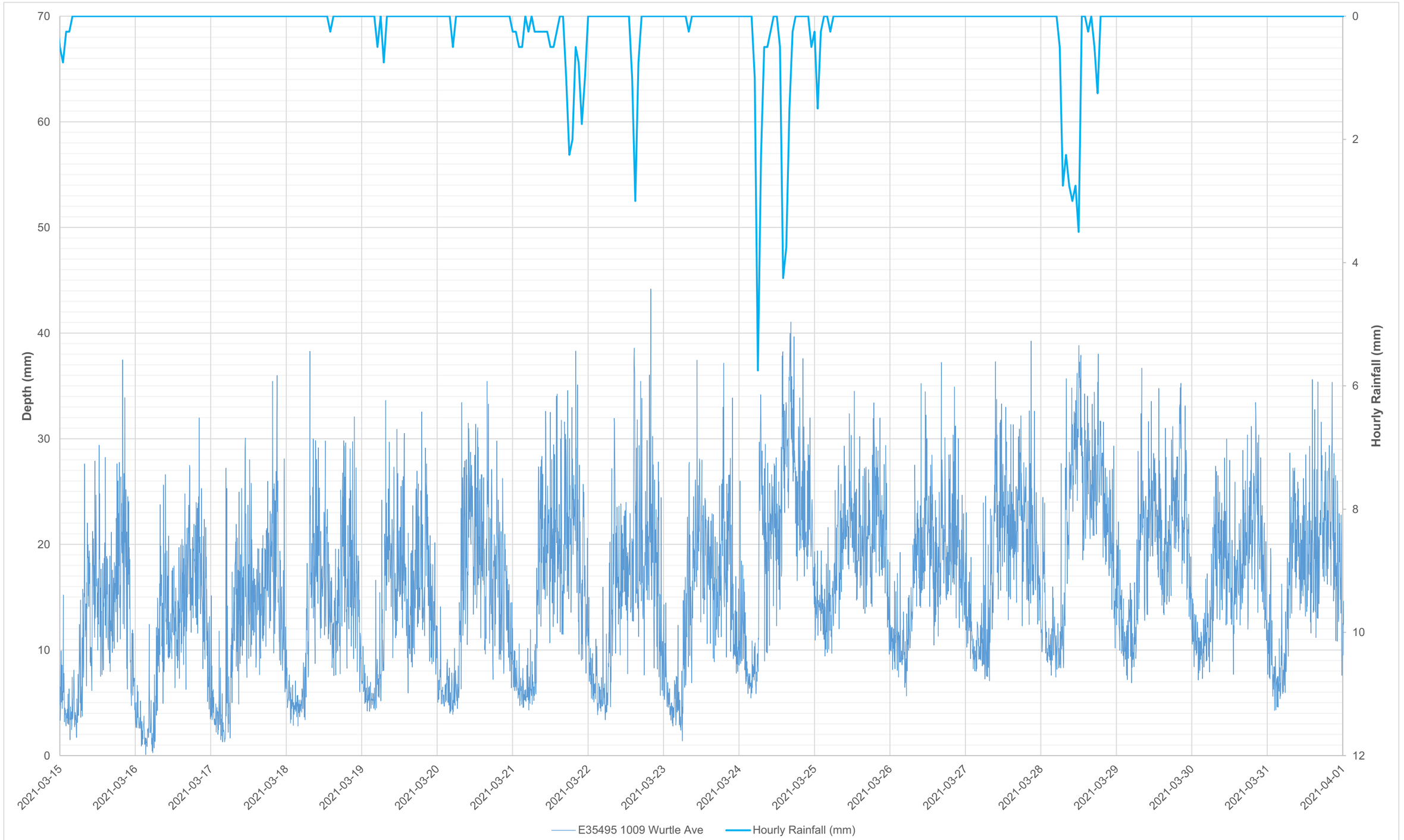
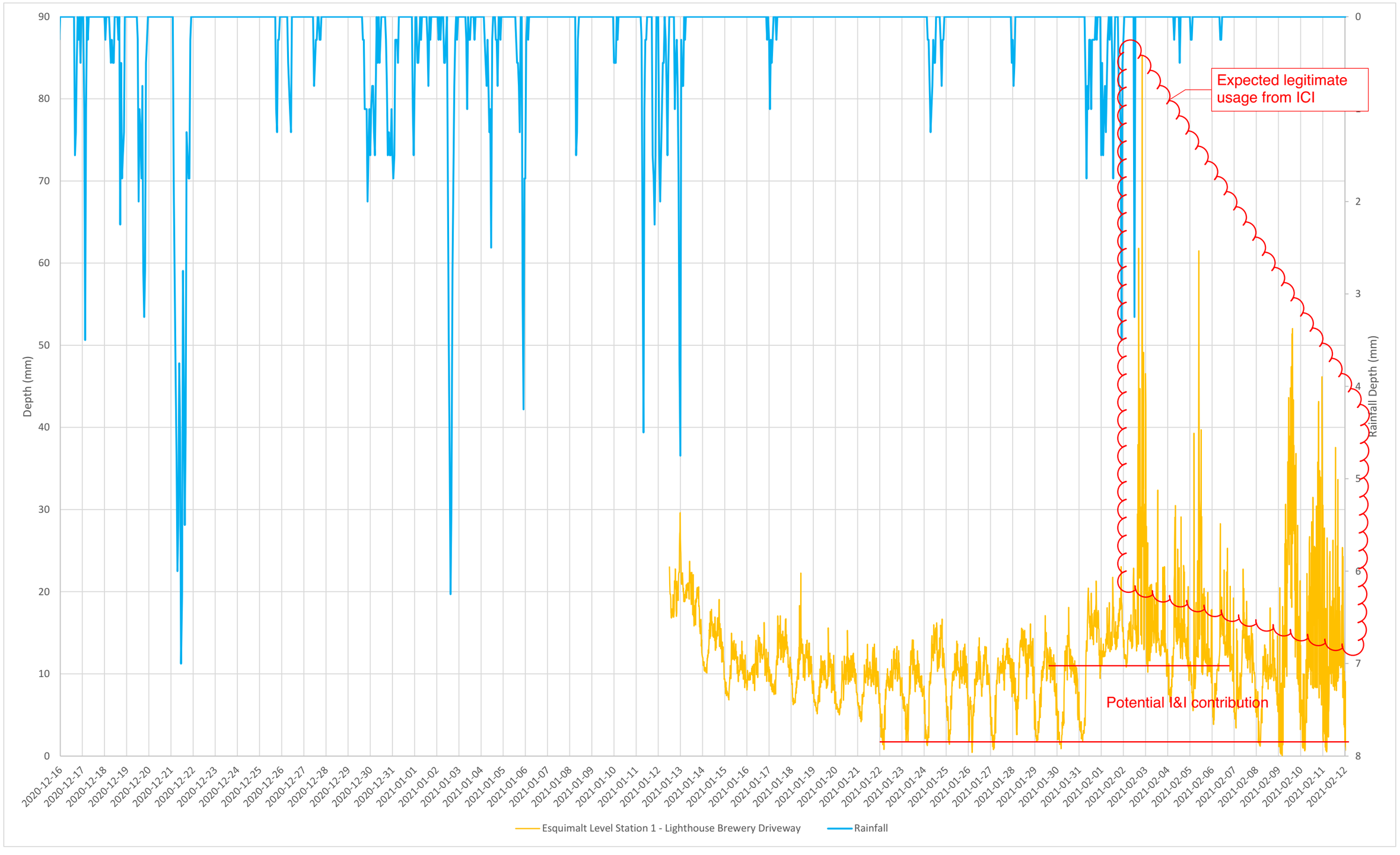
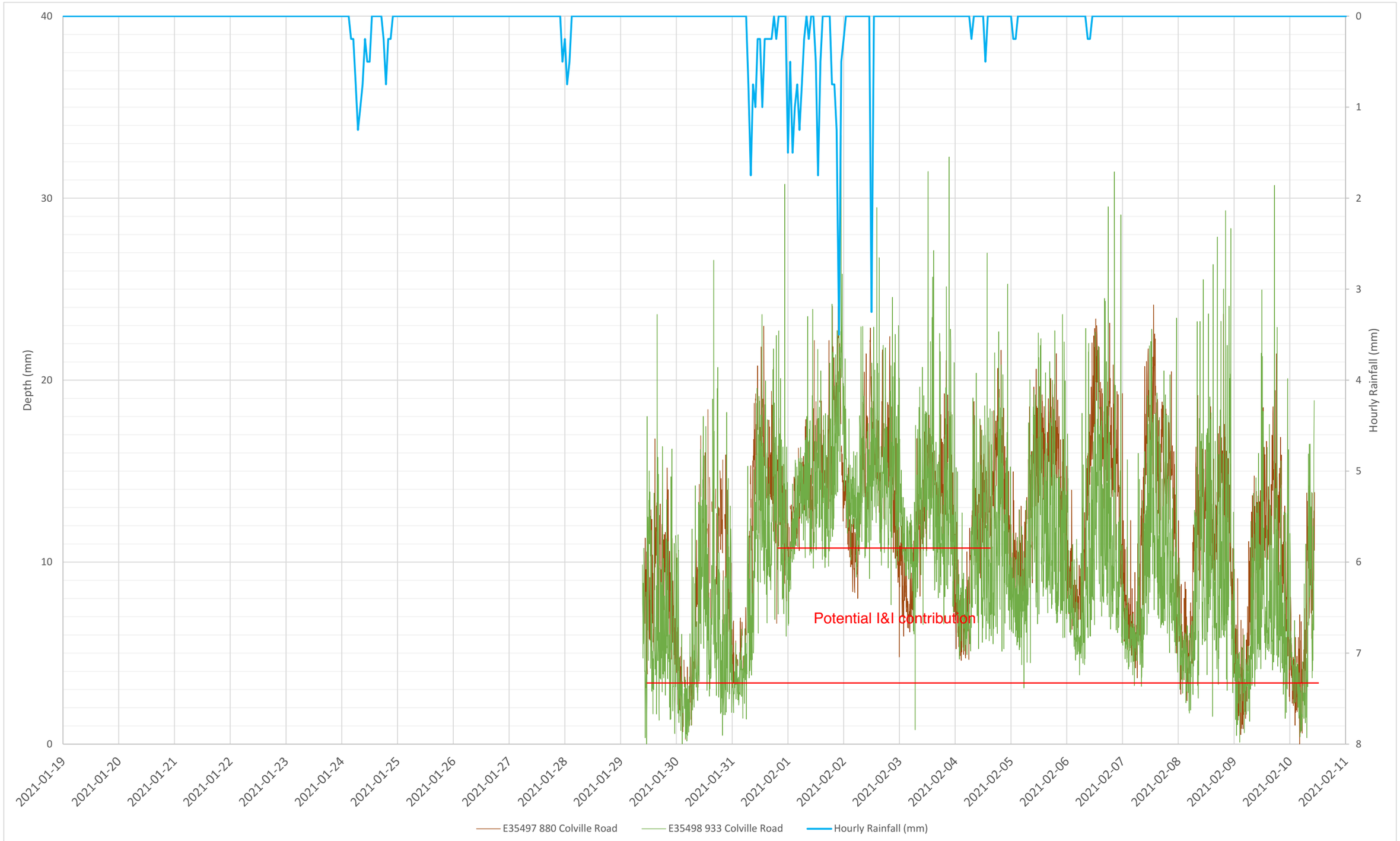
2021-02-01
2021-02-02
2021-02-03
2021-02-04
2021-02-05
2021-02-06
2021-02-07
2021-02-08
2021-02-09
2021-02-10
2021-02-11
2021-02-12
Esquimalt Level Station 3 - 851 Tilicum Rd
Rainfall

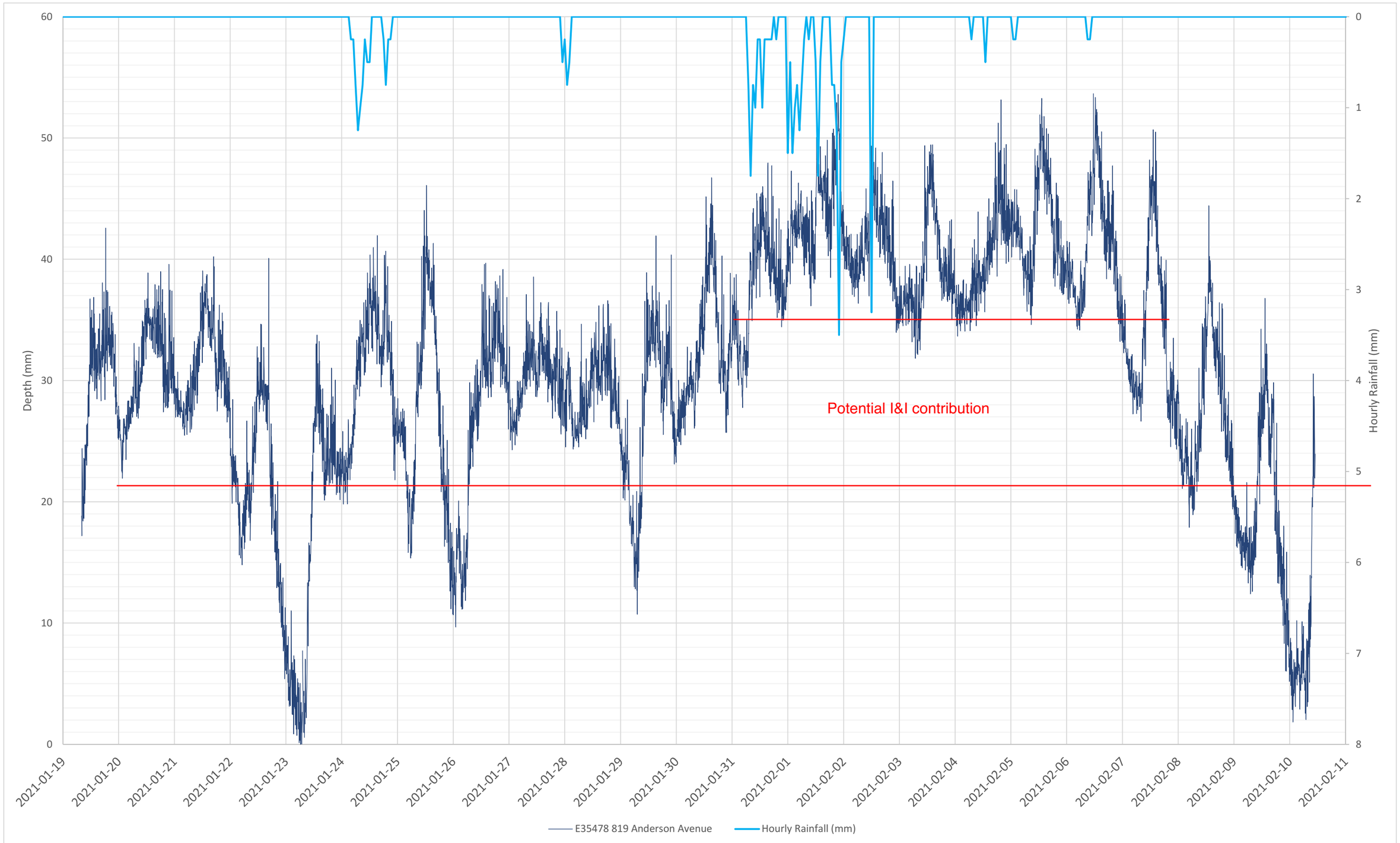

Depth (mm)
Hourly Rainfall (mm)
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
Potential I&I Contribution
Potential I&I Contribution
2021-01-19
2021-01-20
2021-01-21
2021-01-22
2021-01-23
2021-01-24
2021-01-25
2021-01-26
2021-01-27
2021-01-28
2021-01-29
2021-01-30
2021-01-31
2021-02-01
2021-02-02
2021-02-03
2021-02-04
2021-02-05
2021-02-06
2021-02-07
2021-02-08
2021-02-09
2021-02-10
2021-02-11
E35482 Lockley & Intervale
E35483 1215 Colville Road
E35495 Lockley & Lugrin
Hourly Rainfall (mm)

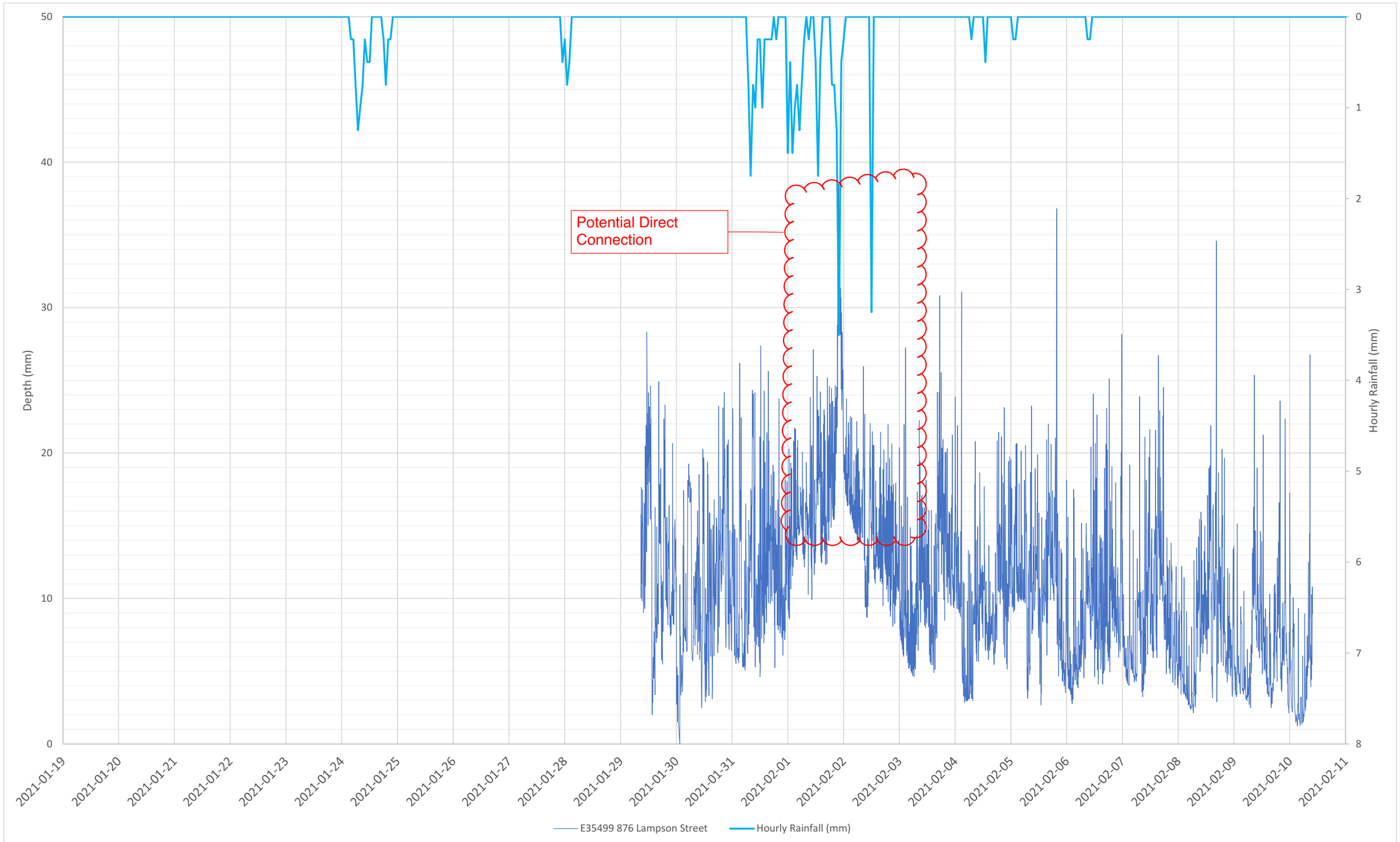

Poor data signal
Depth (mm)
Rainfall Depth (mm)
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
2020-12-16
2020-12-17
2020-12-18
2020-12-19
2020-12-20
2020-12-21
2020-12-22
2020-12-23
2020-12-24
2020-12-25
2020-12-26
2020-12-27
2020-12-28
2020-12-29
2020-12-30
2020-12-31
2021-01-01
2021-01-02
2021-01-03
2021-01-04
2021-01-05
2021-01-06
2021-01-07
2021-01-08
2021-01-09
2021-01-10
2021-01-11
2021-01-12
2021-01-13
2021-01-14
2021-01-15
2021-01-16
2021-01-17
2021-01-18
2021-01-19
2021-01-20
2021-01-21
2021-01-22
2021-01-23
2021-01-24
2021-01-25
2021-01-26
2021-01-27
2021-01-28
2021-01-29
2021-01-30
2021-01-31
2021-02-01
2021-02-02
2021-02-03
2021-02-04
2021-02-05
2021-02-06
2021-02-07
2021-02-08
2021-02-09
2021-02-10
2021-02-11
2021-02-12
Esquimalt Level Station 2 - Ellery St and Fairview Rd
Rainfall

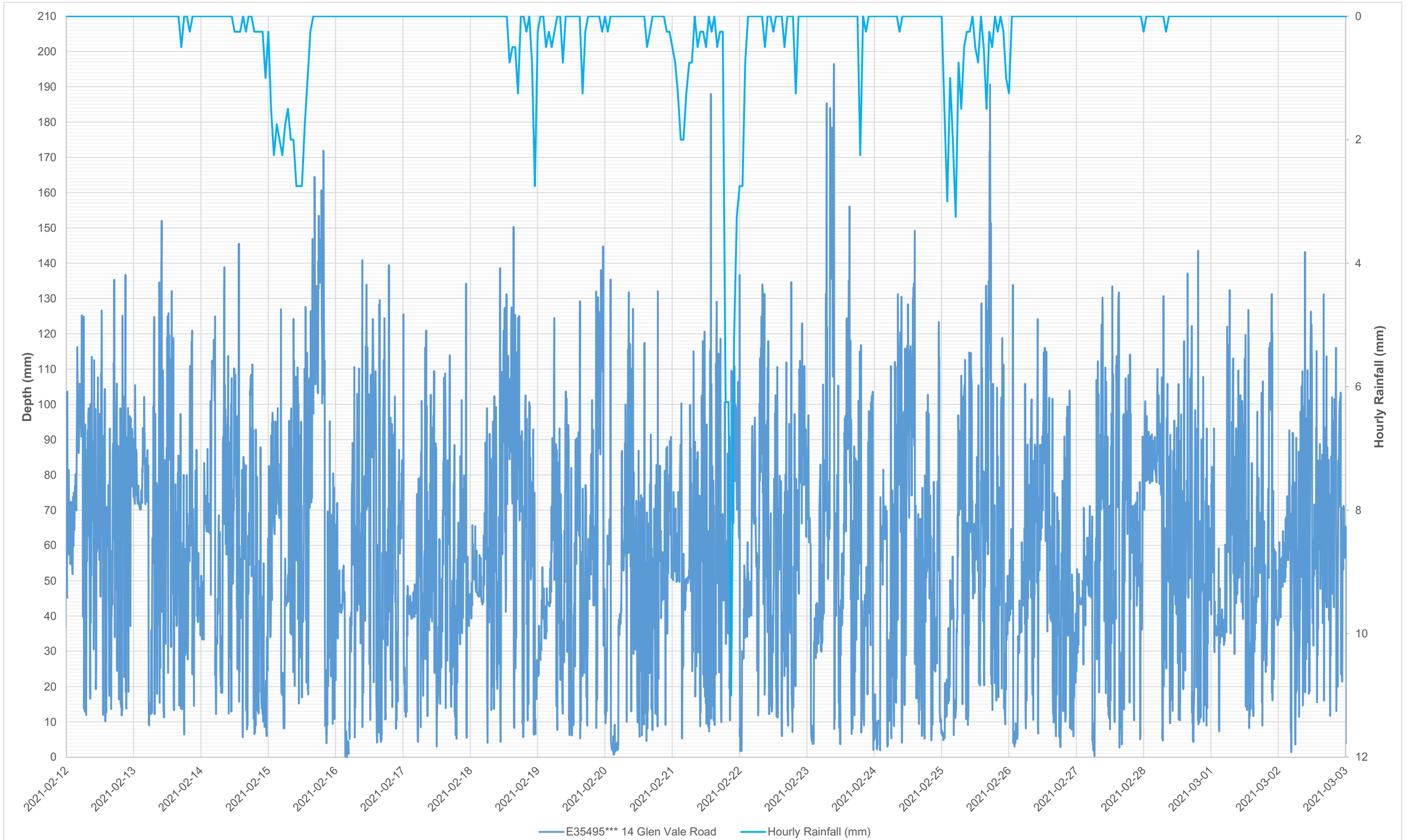

Depth (mm)
Hourly Rainfall (mm)
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
2021-03-15
2021-03-16
2021-03-17
2021-03-18
2021-03-19
2021-03-20
2021-03-21
2021-03-22
2021-03-23
2021-03-24
2021-03-25
2021-03-26
2021-03-27
2021-03-28
2021-03-29
2021-03-30
2021-03-31
2021-04-01
E35495 1009 Wurtle Ave
Hourly Rainfall (mm)

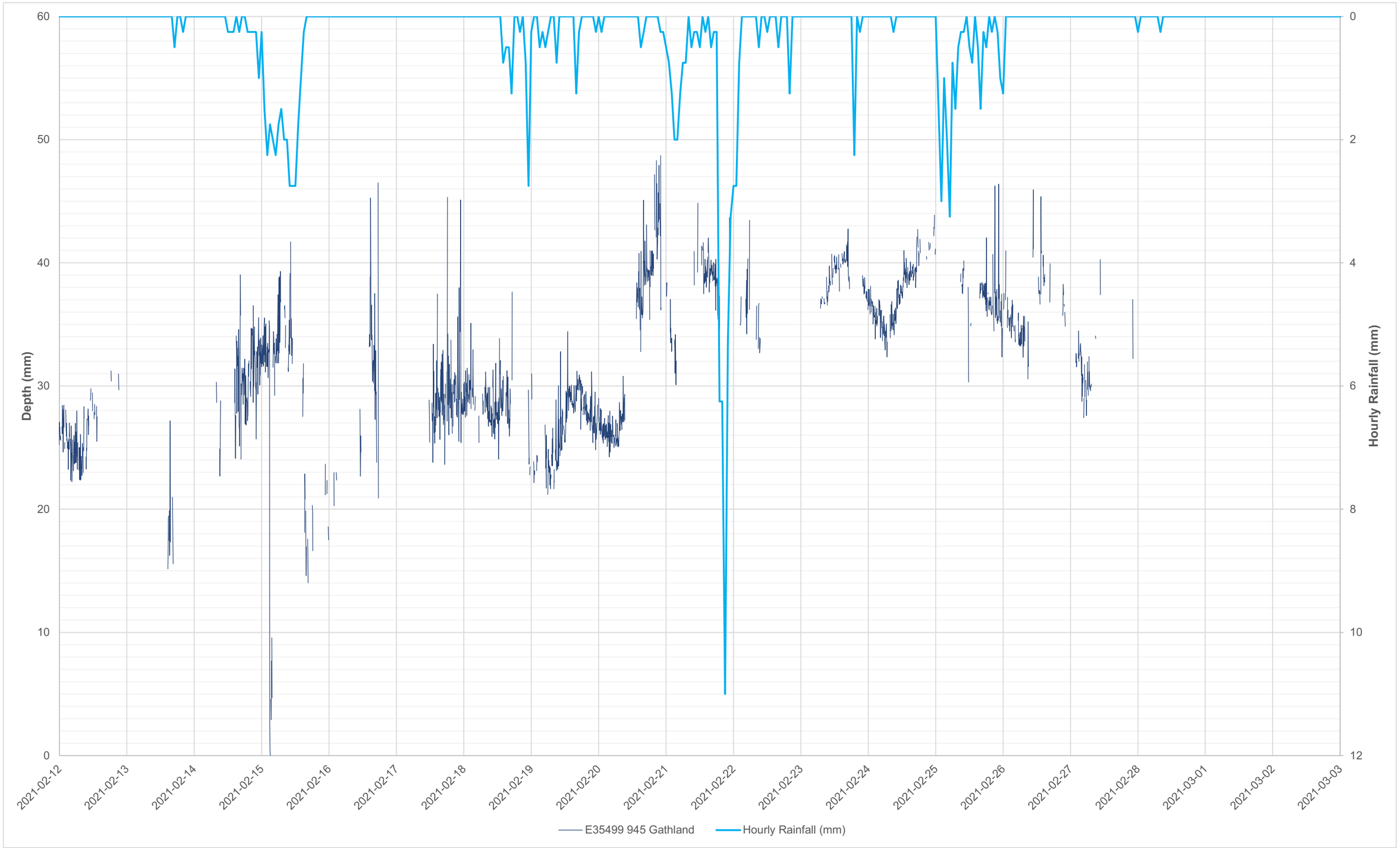

Depth (mm)
Rainfall Depth (mm)
Expected legitimate usage from ICI
Potential I&I contribution
Esquimalt Level Station 1 - Lighthouse Brewery Driveway
Rainfall

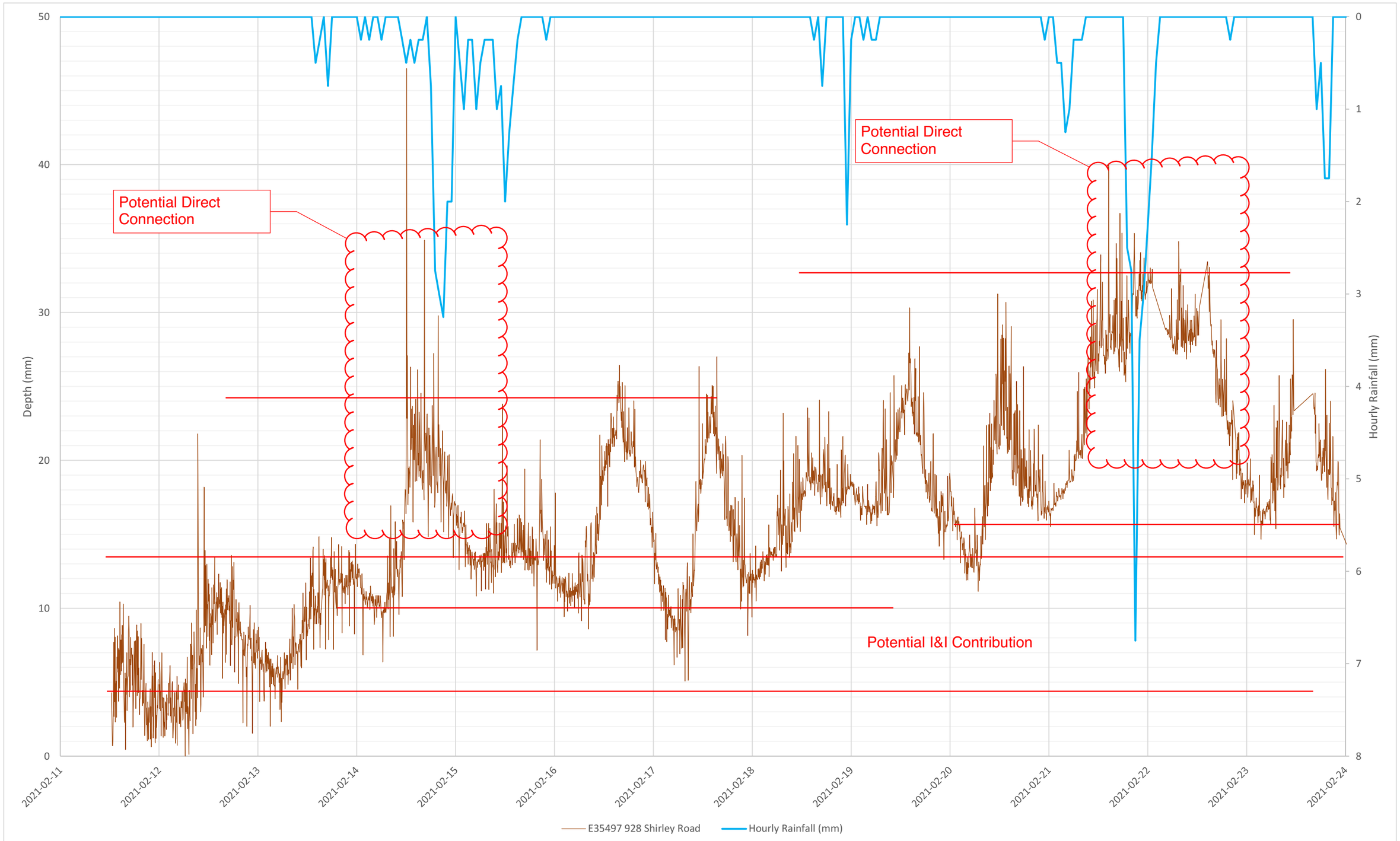

Depth (mm)
Hourly Rainfall (mm)
40
30
20
10
0
0
1
2
3
4
5
6
7
8
2021-01-19
2021-01-20
2021-01-21
2021-01-22
2021-01-23
2021-01-24
2021-01-25
2021-01-26
2021-01-27
2021-01-28
2021-01-29
2021-01-30
2021-01-31
2021-02-01
2021-02-02
2021-02-03
2021-02-04
2021-02-05
2021-02-06
2021-02-07
2021-02-08
2021-02-09
2021-02-10
2021-02-11
Potential I&I contribution
E35497 880 Colville Road
E35498 933 Colville Road
Hourly Rainfall (mm)

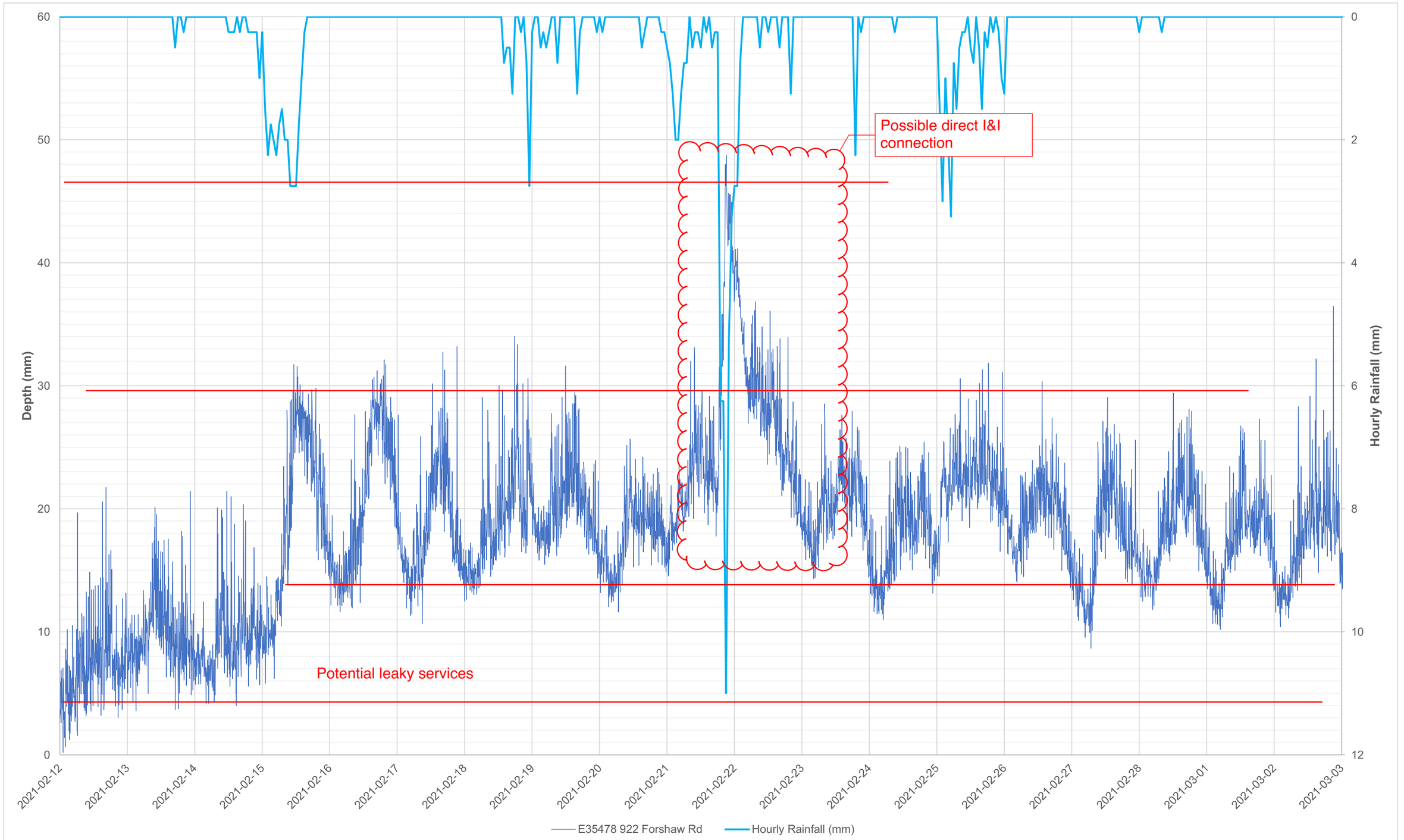

Depth (mm)
Hourly Rainfall (mm)
Potential I&I contribution
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
2021-01-19
2021-01-20
2021-01-21
2021-01-22
2021-01-23
2021-01-24
2021-01-25
2021-01-26
2021-01-27
2021-01-28
2021-01-29
2021-01-30
2021-01-31
2021-02-01
2021-02-02
2021-02-03
2021-02-04
2021-02-05
2021-02-06
2021-02-07
2021-02-08
2021-02-09
2021-02-10
2021-02-11
E35478 819 Anderson Avenue
Hourly Rainfall (mm)

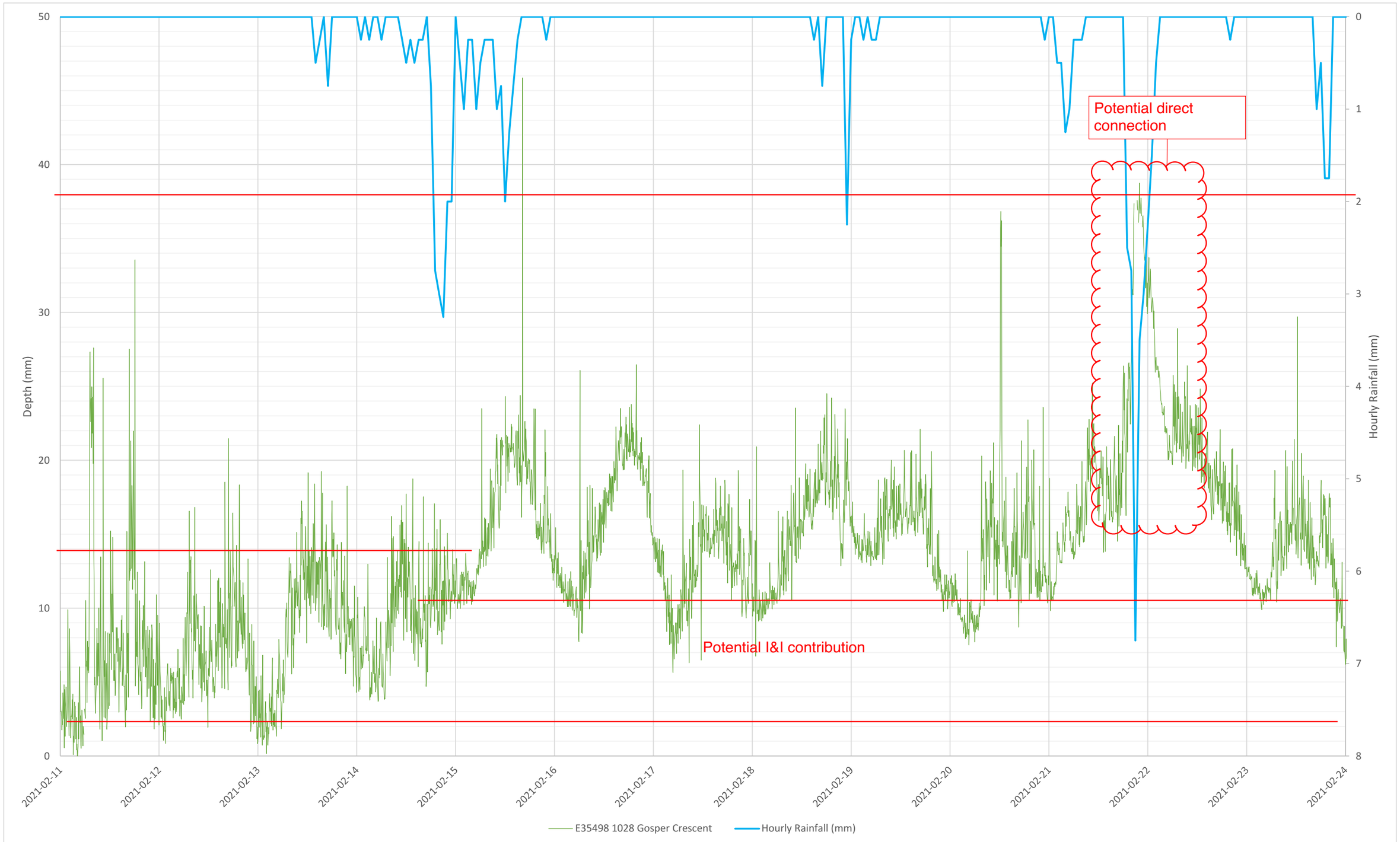

Potential Direct Connection
Depth (mm)
Hourly Rainfall (mm)
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
2021-01-19
2021-01-20
2021-01-21
2021-01-22
2021-01-23
2021-01-24
2021-01-25
2021-01-26
2021-01-27
2021-01-28
2021-01-29
2021-01-30
2021-01-31
2021-02-01
2021-02-02
2021-02-03
2021-02-04
2021-02-05
2021-02-06
2021-02-07
2021-02-08
2021-02-09
2021-02-10
2021-02-11
E35499 876 Lampson Street
Hourly Rainfall (mm)

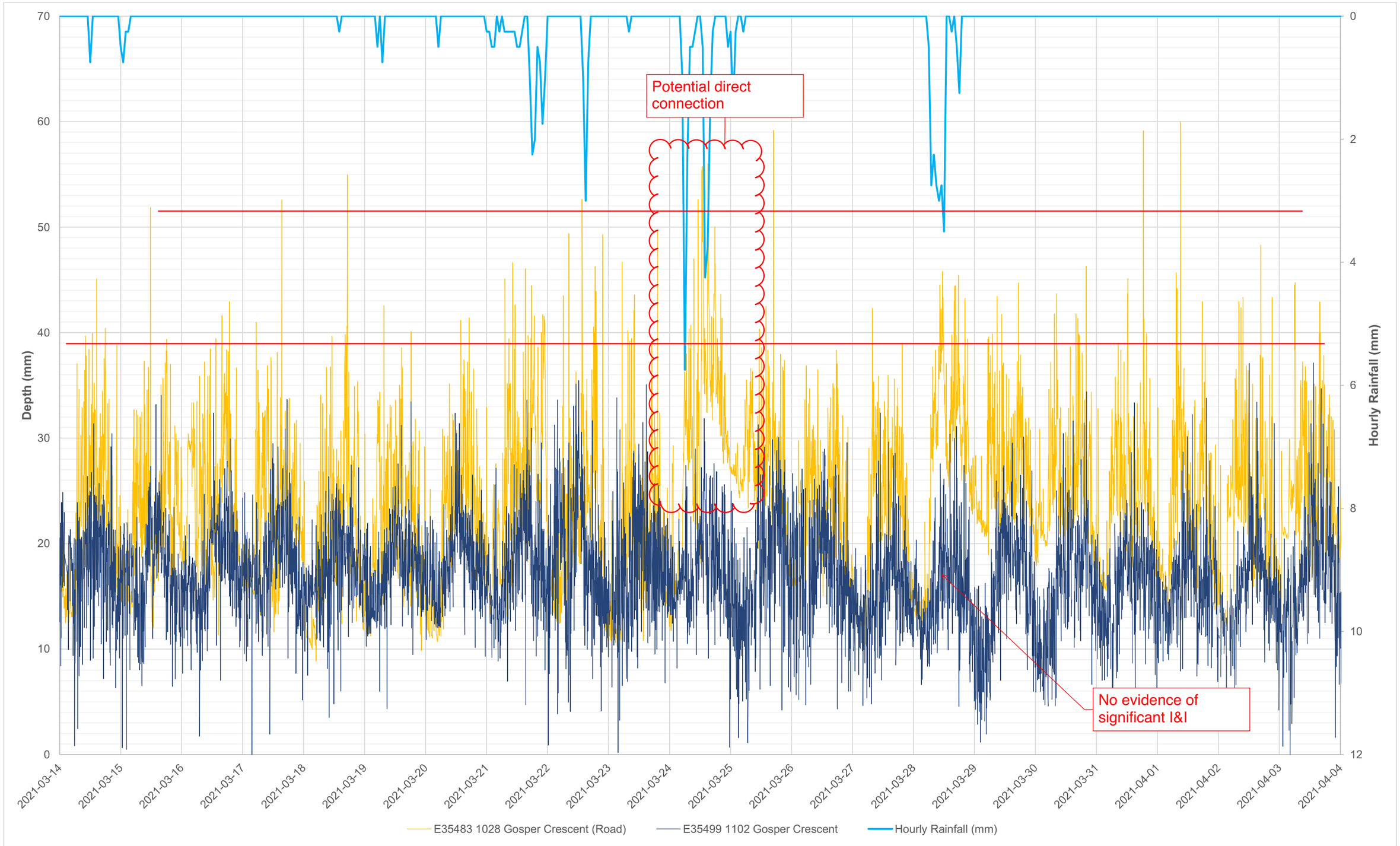

Depth (mm)
Hourly Rainfall (mm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
2021-02-12
2021-02-13
2021-02-14
2021-02-15
2021-02-16
2021-02-17
2021-02-18
2021-02-19
2021-02-20
2021-02-21
2021-02-22
2021-02-23
2021-02-24
2021-02-25
2021-02-26
2021-02-27
2021-02-28
2021-03-01
2021-03-02
2021-03-03
E35495*** 14 Glen Vale Road
Hourly Rainfall (mm)

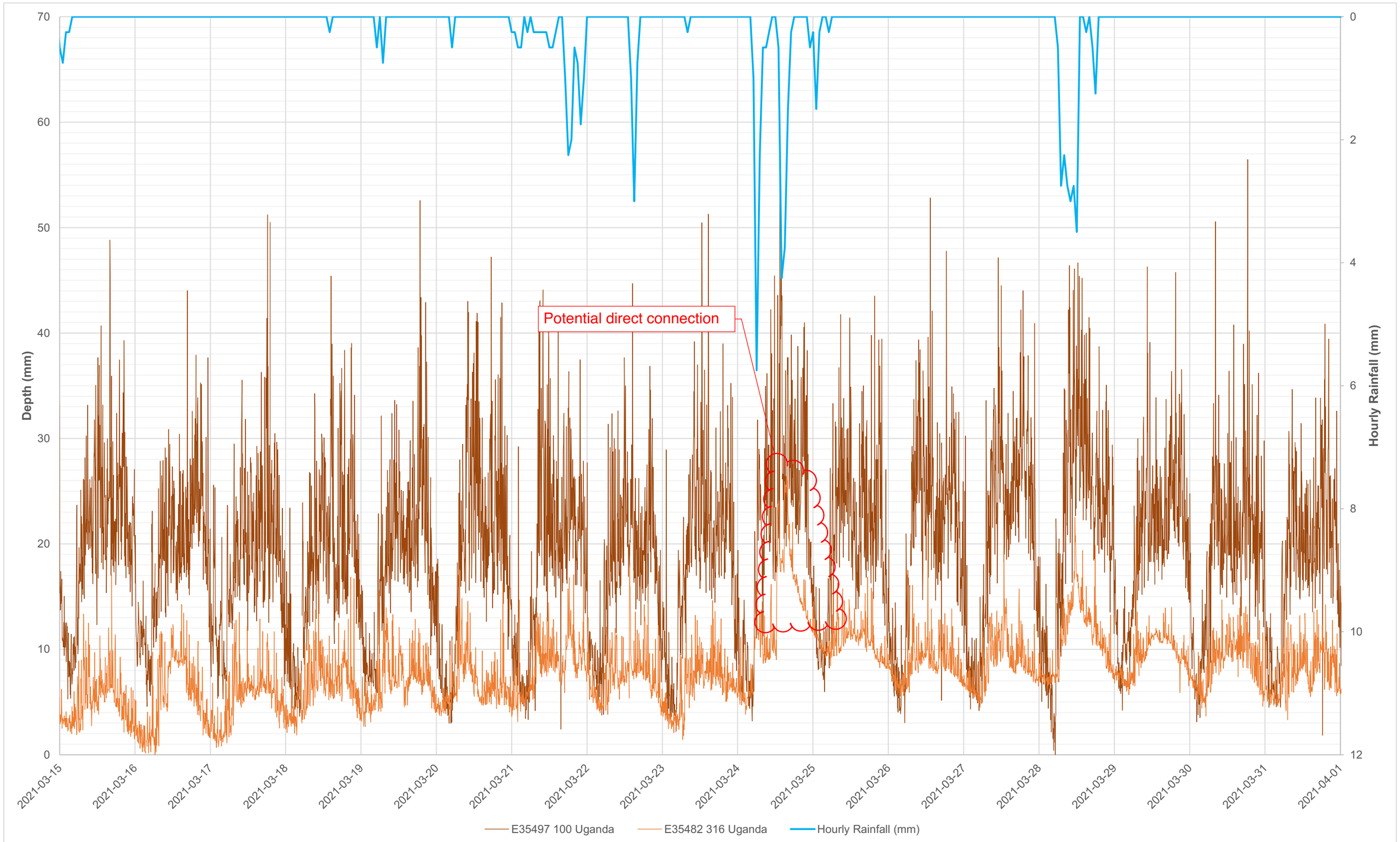

Depth (mm)
Hourly Rainfall (mm)
60
50
40
30
20
10
0
0
2
4
6
8
10
12
2021-02-12
2021-02-13
2021-02-14
2021-02-15
2021-02-16
2021-02-17
2021-02-18
2021-02-19
2021-02-20
2021-02-21
2021-02-22
2021-02-23
2021-02-24
2021-02-25
2021-02-26
2021-02-27
2021-02-28
2021-03-01
2021-03-02
2021-03-03
E35499 945 Gathland
Hourly Rainfall (mm)

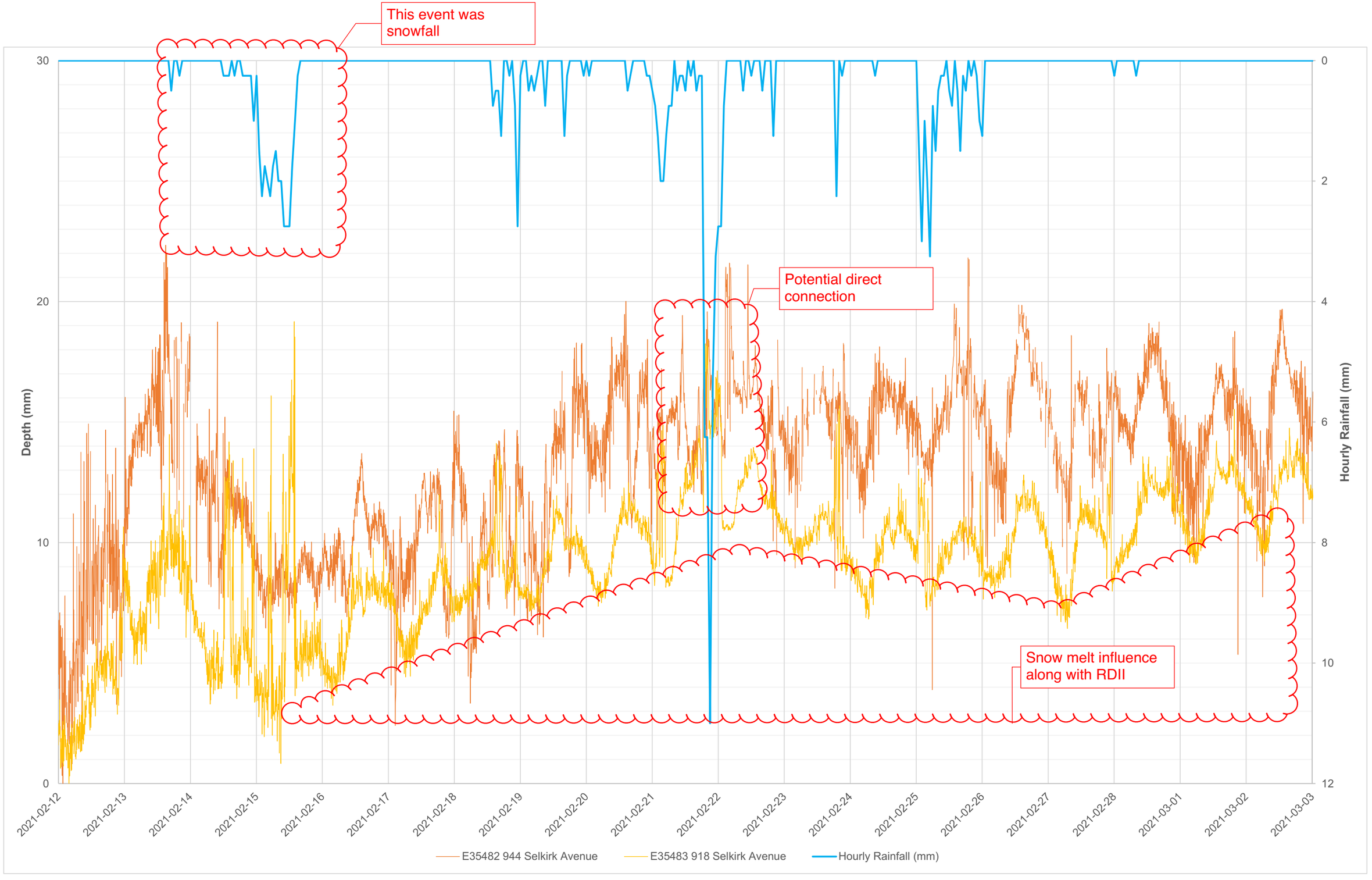

Potential Direct Connection
Potential Direct Connection
Potential I&I Contribution
Depth (mm)
Hourly Rainfall (mm)
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
2021-02-11
2021-02-12
2021-02-13
2021-02-14
2021-02-15
2021-02-16
2021-02-17
2021-02-18
2021-02-19
2021-02-20
2021-02-21
2021-02-22
2021-02-23
2021-02-24
E35497 928 Shirley Road
Hourly Rainfall (mm)


Possible direct I&I connection
Potential leaky services
Depth (mm)
Hourly Rainfall (mm)
60
50
40
30
20
10
0
0
2
4
6
8
10
12
2021-02-12
2021-02-13
2021-02-14
2021-02-15
2021-02-16
2021-02-17
2021-02-18
2021-02-19
2021-02-20
2021-02-21
2021-02-22
2021-02-23
2021-02-24
2021-02-25
2021-02-26
2021-02-27
2021-02-28
2021-03-01
2021-03-02
2021-03-03
E35478 922 Forshaw Rd
Hourly Rainfall (mm)


Potential direct connection
Potential I&I contribution
Depth (mm)
Hourly Rainfall (mm)
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
2021-02-11
2021-02-12
2021-02-13
2021-02-14
2021-02-15
2021-02-16
2021-02-17
2021-02-18
2021-02-19
2021-02-20
2021-02-21
2021-02-22
2021-02-23
2021-02-24
E35498 1028 Gosper Crescent
Hourly Rainfall (mm)


Potential direct connection
No evidence of significant I&I
Depth (mm)
Hourly Rainfall (mm)
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
2021-03-14
2021-03-15
2021-03-16
2021-03-17
2021-03-18
2021-03-19
2021-03-20
2021-03-21
2021-03-22
2021-03-23
2021-03-24
2021-03-25
2021-03-26
2021-03-27
2021-03-28
2021-03-29
2021-03-30
2021-03-31
2021-04-01
2021-04-02
2021-04-03
2021-04-04
E35483 1028 Gosper Crescent (Road)
E35499 1102 Gosper Crescent
Hourly Rainfall (mm)


Potential direct connection
Depth (mm)
Hourly Rainfall (mm)
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
2021-03-15
2021-03-16
2021-03-17
2021-03-18
2021-03-19
2021-03-20
2021-03-21
2021-03-22
2021-03-23
2021-03-24
2021-03-25
2021-03-26
2021-03-27
2021-03-28
2021-03-29
2021-03-30
2021-03-31
2021-04-01
E35497 100 Uganda
E35482 316 Uganda
Hourly Rainfall (mm)


This event was snowfall
Potential direct connection
Snow melt influence along with RDII
Depth (mm)
Hourly Rainfall (mm)
30
20
10
0
0
2
4
6
8
10
12
2021-02-12
2021-02-13
2021-02-14
2021-02-15
2021-02-16
2021-02-17
2021-02-18
2021-02-19
2021-02-20
2021-02-21
2021-02-22
2021-02-23
2021-02-24
2021-02-25
2021-02-26
2021-02-27
2021-02-28
2021-03-01
2021-03-02
2021-03-03
E35482 944 Selkirk Avenue
E35483 918 Selkirk Avenue
Hourly Rainfall (mm)