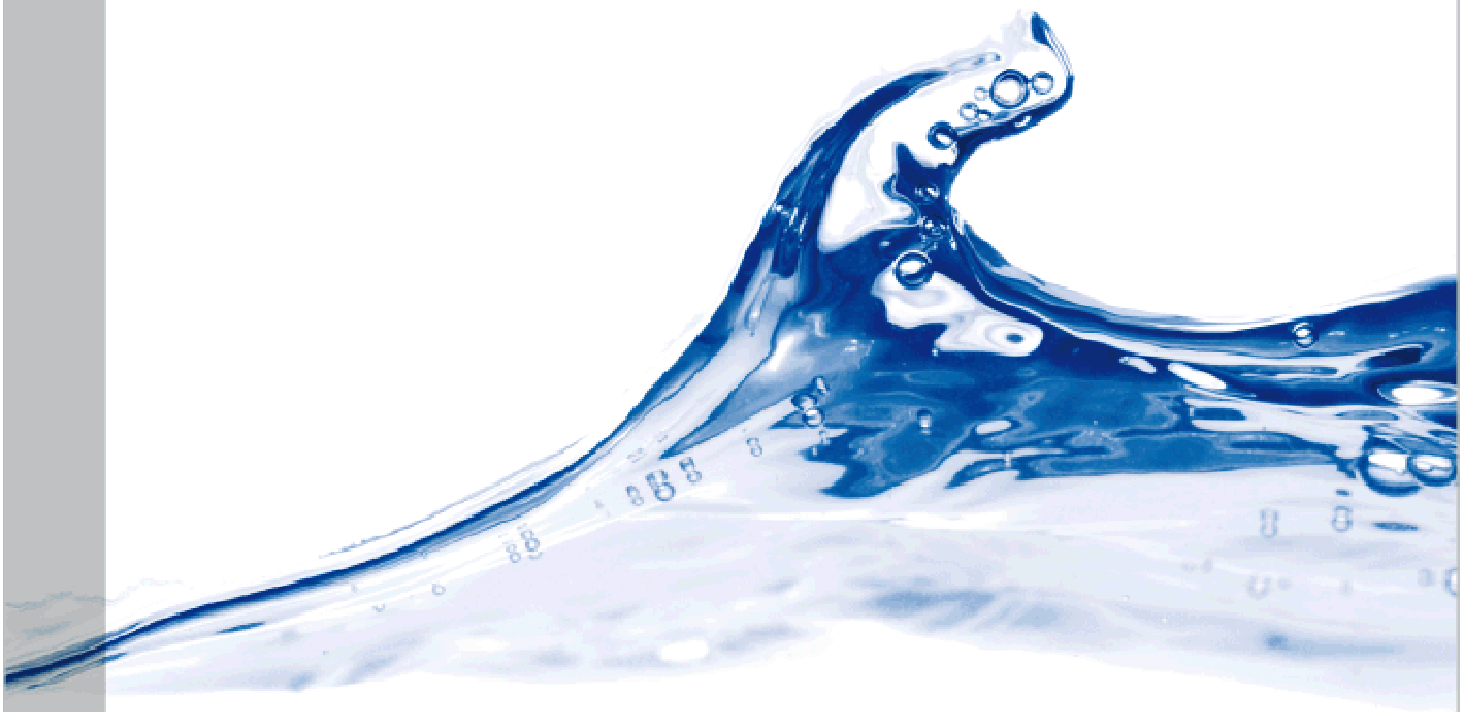
Featherston Groundwater Infiltration Investigation

South Wairarapa District Council

December 2013 – Final



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Action	Name	Title, Company	Signed	Date
Originated by	Chris Park	Engineer, AWT Water Ltd		19 December 2013
Approved by	Peter Stephens	General Manager, AWT Water Ltd		19/12/2013

REVISION HISTORY

Version	Prepared by	Description	Date
Working Draft	Chris Park	Results of Night Flow Isolation Investigations for Featherston	13 November 2013
Draft	Chris Park	Night flow results and rehabilitation costing	15 November 2013
Final	Chris Park	Final recommendations	19 December 2013

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1 BACKGROUND

South Wairarapa District Council (SWDC) are currently investigating options for the treatment and disposal of wastewater from Martinborough, Featherston and Greytown. A review of historical influent data to the existing pond system at Featherston showed that dry weather flow is 2-5 times what is expected for the population (depending on season). Various indicators strongly suggested that the majority of additional flow was groundwater infiltration (GWI) that appeared to be entering year round and increasing significantly in winter. A high level concept analysis of costs for potential treatment and disposal options at Featherston concluded that, reducing flows through network improvements could significantly reduce capital as well as ongoing operational costs. As the overall cost benefit of flow reduction will largely depend on how much of the network needs to be remediated and the effectiveness of the works, SWDC engaged AWT Water (AWT) to investigate and quantify the sources of GWI. To do this, the entire Featherston network was broken into specific pipe lengths and mini-catchments so that GWI sources could be isolated at a detailed level.

A review by AWT in September 2013[1], of historical infiltration and inflow (I/I) data from 2004, highlighted direct stormwater inflow issues in some catchments. In the case of Featherston direct inflow is seen as secondary to GWI due to the comparatively small volume it will contribute to any proposed treatment scheme. There are however specific issues with direct inflows that are relevant to this project. The key problem being that the rapid nature of flow input can cause overflows, surcharging and WWTP bypasses. To address this component of I/I a catchment wide flow monitoring study will be required to capture data from wet weather events. This GWI study and the future wet weather monitoring will provide the basis for a targeted I/I source detection and remediation strategy.

2 METHODOLOGY

2.1 Defining GWI

For the purposes of this study GWI is defined as the component of dry weather flow that enters a wastewater network from saturated surrounding soils (including trenching and backfill) through defects in infrastructure. GWI is best observed during winter (when network submerge is greatest) in dry weather and manifests as elevated base flow for a long period of time (usually months). It differs from rain depended infiltration (RDI) which causes elevated flows following wet weather when surrounding soils become saturated and eventually recede or “dry out” (usually in days or weeks). A pipe with GWI issues will usually have RDI issues however, a pipe with RDI may not have GWI. Both are indicative of the same type of defects in network infrastructure.

During dry weather it is difficult to separate the portion of flow that is GWI from the wastewater portion (without monitoring and subtracting inputs from individual households). It is also difficult (if not impossible) to define when direct stormwater inflow stops and GWI begins following rainfall. For simplicity the severity of GWI is assumed to be directly linked to the dry weather night flow which can be easily measured. Night flow includes a constant wastewater component from normal residential water use as well as GWI which can fluctuate depending on defects, GW levels, rainfall and geology. It is generally defined as the minimum hourly flow rate recorded between 01:00am and 05:00am during dry weather. As the wastewater component is assumed to be constant and limited based on population, any additional dry weather flow measured at night is deemed to be the result of GWI. The residential nature and stable population in Featherston reduces the effect of industrial and commercial inputs that can influence night flow, reinforcing the viability of using night flow measurements as a GWI indicator.

2.2 Night Flow Isolation

Night flow isolation was the method used for estimating the volume of GWI entering the network and isolating sources at a detailed level. The general concept is to measure flows within small sections of pipe or mini-catchments in winter (while the network is

[1] AWT Water (2013), Featherston Wastewater Flow Monitoring Review, Draft report.

most susceptible to being submerged by groundwater) to determine the rate of infiltration. The resulting flow rate will depend on the severity of defects, the magnitude of groundwater submergence and the groundwater flow rate through the surrounding materials (soils etc). The results can then be used to determine a priority for remedial work.

For the Featherston investigations the network was divided into 17 study areas (see figure 2 on the following page). The night flow from each study area was measured using a portable flow measurement weir which is installed in the inlet or inlets to a manhole (see figure 1 below). Instantaneous measurements are taken between 01:00-05:00 (night flow) to reduce the influence of domestic and commercial flows thereby isolating GWI. Dry weather is required during and prior to the study to ensure the flow is not affected by stormwater inflows. It is important to note that the measured flow is sourced from all network infrastructure upstream of the monitoring point including public mains, manholes and private laterals.

The study in Featherston was carried out on 7-8th October 2013 when flow to the WWTP was 2363m^3/day, which is near to the average annual daily flow rate of approx. 2600 m^3/day. This flow rate is consistent with previous recorded winters, although flows have reached up to 3000-3500 m^3/day. There was also an extended period of dry weather prior to the study eliminating interference from any stormwater inflows. The results are therefore deemed to be representative of the typical dry weather, winter, night flow contributions from the pipes measured in the study. The sections of pipe identified as having GWI issues should therefore represent the most critical for remediation.

Traditional flow monitoring for I/I analysis uses similar basic methodology and equipment, the key difference being, that flow monitoring is continuous and on a much larger scale of pipe length (approx. 3km minimum). Portable weirs provide greater accuracy than traditional flow meters especially in low flow conditions typical of night flows. Rather than continuous measurement, discrete measurements are made by the field crew over a short period. The results represent a snapshot of night flow conditions hence the need for optimal timing.

For condition assessment and planning of renewals, using this technique has advantages over other methods such as CCTV as it quantifies the actual flow contribution as opposed to a perceived level of infiltration based on visible condition.

Figure 1 Portable Weir Installed in Featherston Sewer

A map of the 17 study areas is provided in figure 2 below.

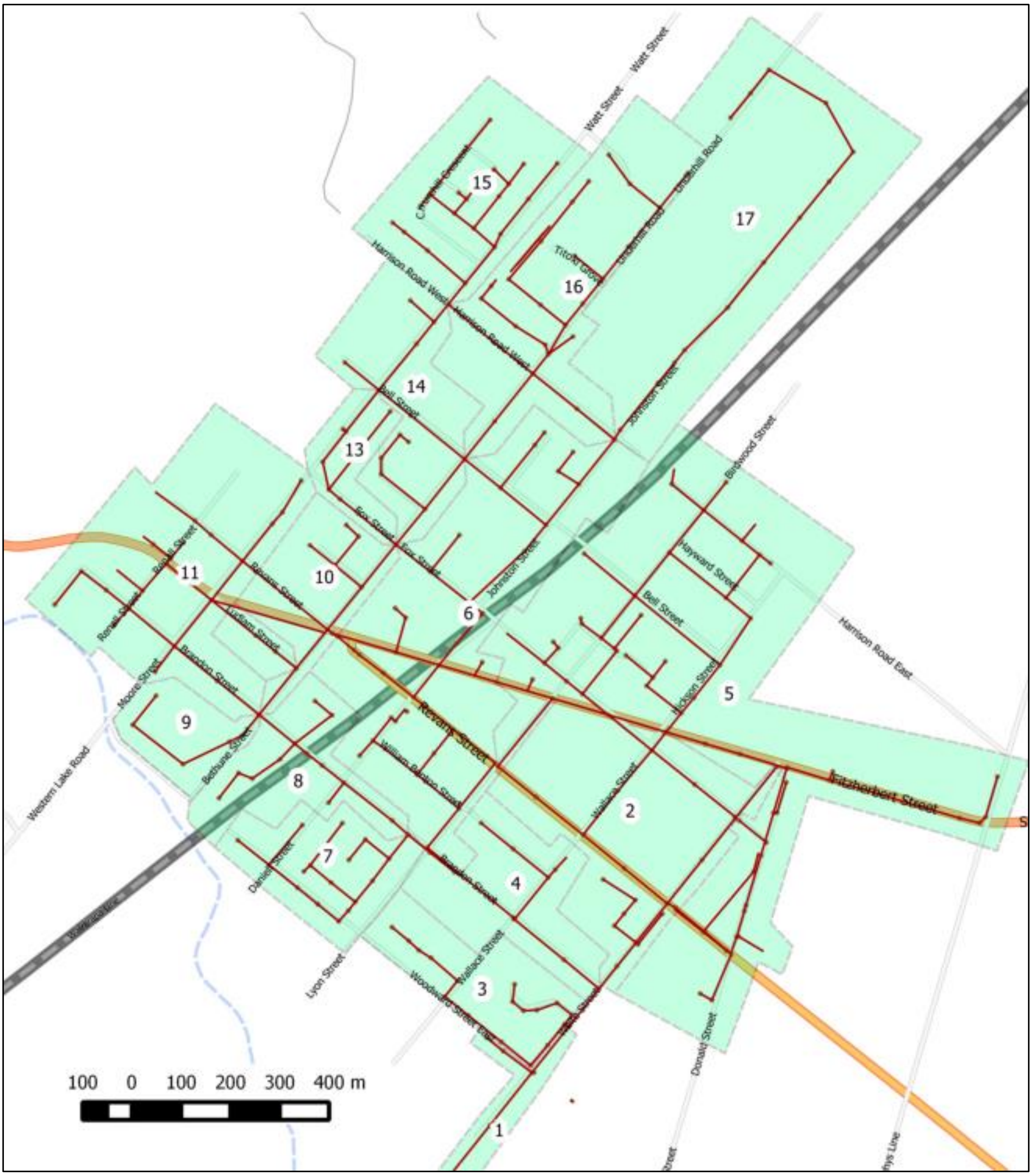


Figure 2 Featherston Groundwater Infiltration Study Catchments

3 RESULTS

Night flow isolation results deal with flows that are often small and originate from varying pipe lengths making comparison difficult. Normalising the measured night flow rate by dividing by pipe length assists with the comparison of results by giving an equivalent volume of flow per km of pipe per day (m^3/km/day). This method was used to rank each area and the results are presented in table 1 below.

Table 1. Night Flow Isolation Results

Rank	Study Area	Night Flow rate (m^3/km/day)	Net flow (L/s)	Pipe length (m)	Cumulative flow (L/s)	Cumulative Length (m)	Cumulative % flow	Cumulative % length
1	1	477	9.29	1682	9.29	1682	45%	7%
2	3	346	3.01	752	12.30	2434	60%	10%
3	2	144	3.18	1905	15.48	4339	75%	18%
4	4	144	1.39	837	16.87	5176	82%	21%
5	9	54	0.24	386	17.11	5562	83%	23%
6	5*	37	1.92	4501	19.03	10063	93%	42%
7	10	26	0.35	1149	19.38	11212	94%	46%
8	13	15	0.11	628	19.49	11840	95%	49%
9	6	14	0.51	3037	20.00	14877	97%	62%
10	8	14	0.12	786	20.12	15663	98%	65%
11	14	12	0.15	1052	20.27	16715	99%	69%
12	7	12	0.13	953	20.40	17668	99%	73%
13	11	3	0.06	1770	20.46	19438	100%	80%
14	17	1.6	0.02	1130	20.48	20568	100%	85%
15	16	1.2	0.03	2291	20.52	22859	100%	95%
16	15	0.8	0.01	1296	20.53	24155	100%	100%

**Due to catchment configuration and state highway access issues, study area 5 was larger than desired. It is possible that the 2543m of catchment north of Fitzherbert and Hickson St can be separated from study area 5 and given a lower priority due to showing very low I/I indicators (wet weather and GWI) in the 2004 study. This area can be assessed further if an accurate contribution is to be determined. For reporting purposes and calculations study area 5 includes this lower priority area. It is worth noting the high night flow rate regardless.*

Study area 1 stands out above other catchments, contributing 9.29L/s out of the total 18.75L/s of night flow measured during investigations. This catchment comprises only 7% of the total network and mainly comprises of a 375mm diameter concrete pipe with minimal private connections. It is the trunk main taking flow from the town to the WWTP over farmland.

The top 5 ranked catchments contribute 85% of the flow yet comprise only 23% of the total pipe length, implying that remedial works would be most effectively targeted in these catchments. Beyond the top 5 ranked catchments, night flow contributions become more wide spread with the remaining 17% of night flow coming from 77% of the total pipe length. Figures 3 and 4 further demonstrate the diminishing isolation beyond 23% of the total pipe length.

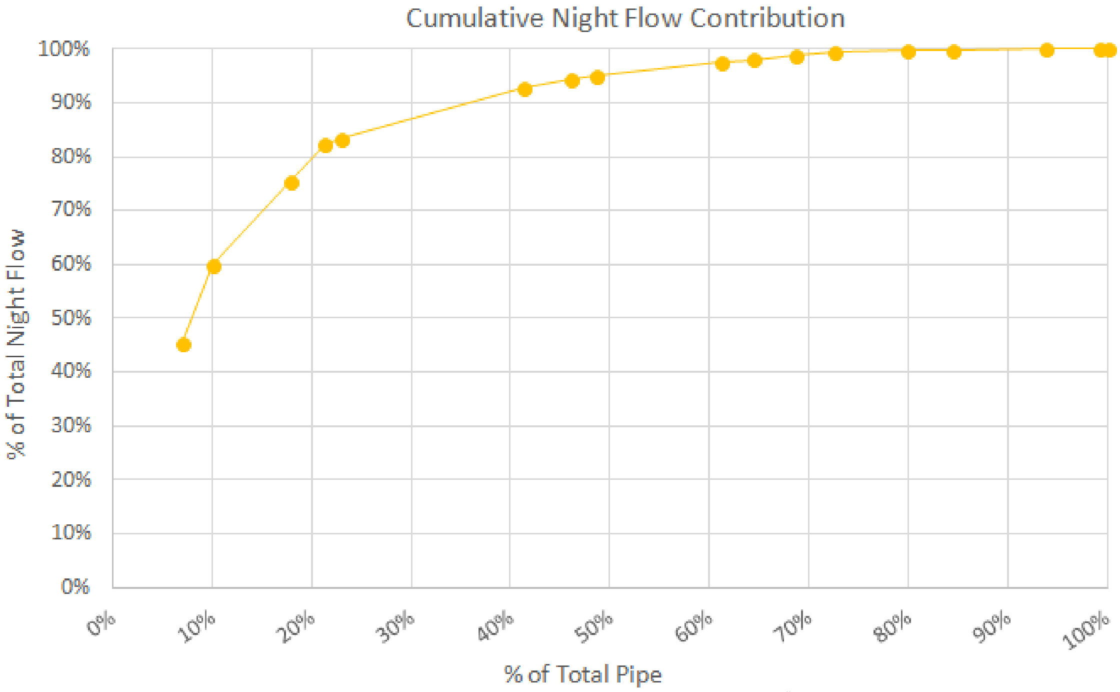


Figure 3 Cumulative Night Flow Contributions (Percentage)

Figure 3 above shows the distribution of night flow within the night flow study areas. Results are displayed by accumulating pipe length and night flow starting from the highest ranked study areas i.e. the first point is study area 1 which contains 7% of the total pipe length and 45% of the night flow. The second ranked study area (study area 3) adds a further 3% of pipe length and takes the total located night flow to 60% and so on. The key conclusion is the diminishing isolation of sources beyond the top 5 areas. Figure 4 below presents the same information using actual pipe length and night flow rate.

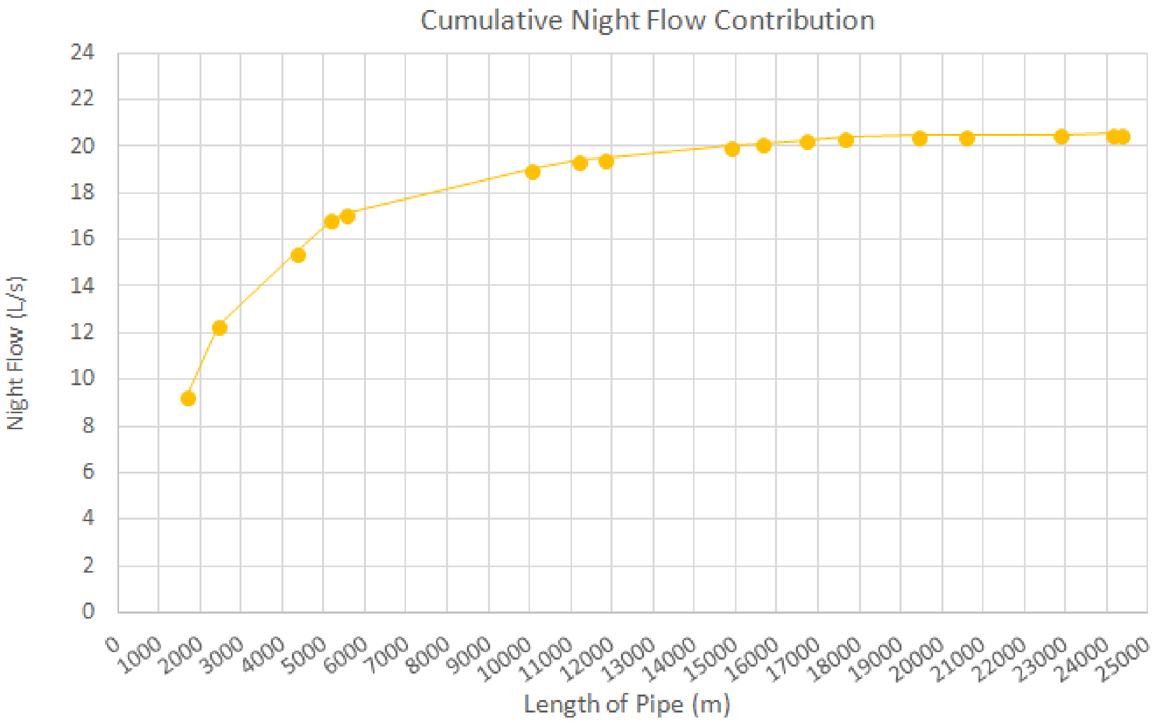


Figure 4 Cumulative Night Flow Contributions (Pipe Length and Flow Rate)

To bring meaning to the often very small night flow measurements, additional calculations were carried out to determine what an acceptable night flow rate was for Featherston. The calculations used a total daily flow volume which comprised a fixed wastewater volume based on population and a variable night flow volume based on the measured night flow rate applied to all pipes in the network. The resulting daily volume was divided by the current population of 2340 to give a wastewater production rate (WWP) that would occur if all the pipes within the network were flowing at the measured night flow rate. It was shown that if on average the night flow in Featherston was 7m^3/km/day the WWP would be. Accepted literature and standards specify that in a residential catchment anything above 250L/p/day is generally classified as higher than normal and indicates a GWI issue. Further categories were added to classify and compare catchments based on the WWP resulting from various measured night flow rates. The following map shows the classification of each study area.

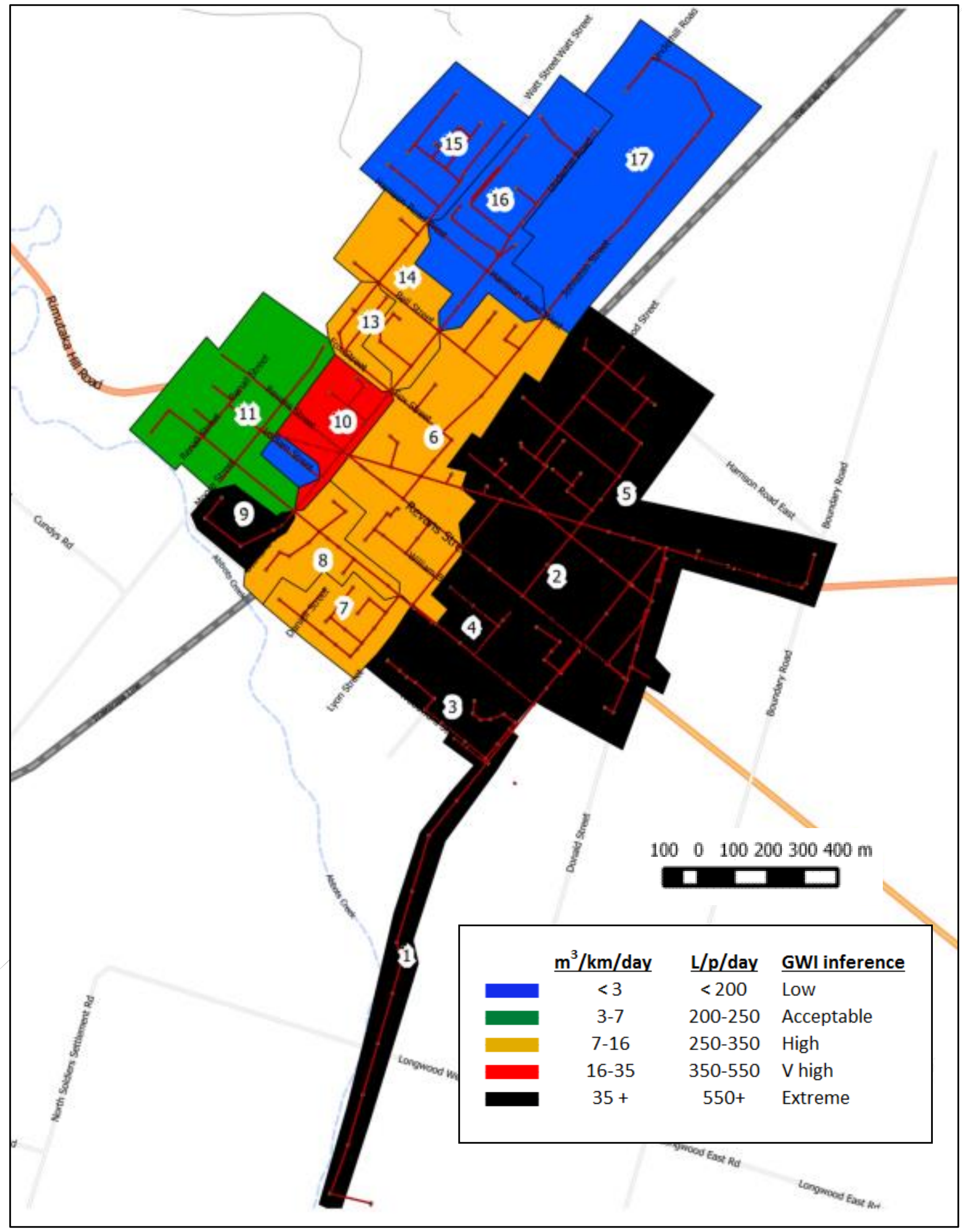


Figure 5: Classification of Study Areas Based on Night Flow Rate

4 REHABILITATION COST ESTIMATES

This section presents cost estimates for rehabilitating network infrastructure in each of the study areas based on current industry rates. For this study two rehabilitation scenarios have been assessed:

1) Reline all public mains and seal all manholes within the identified catchment

2) Reline public mains, seal manholes and reline all private laterals. The actual cost may vary depending on the final technique chosen for rehabilitation which can only be determined after a CCTV inspection and detailed assessment have been carried out.

Flow reductions are also estimated for the different rehabilitation scenarios. They are based on the effectiveness of previous work carried out in New Zealand and Actual reductions are difficult to anticipate due to the relative contribution of public mains and laterals being unknown. Additionally the effectiveness of any work will depend on the quality control. The table below shows the costs and reductions that have been assumed for this analysis.

4.1 Rehabilitation costs

Table 2. Rehabilitation costs and flow reductions

	Rehabilitation Costs			Night flow reductions	
Level of rehabilitation	Pipe relining ($/m)	Manhole sealing ($/MH)	Lateral relining ($/m)	Minimum	Maximum
Scenario 1	$200-$350	$1500	na	50%	60%
Scenario 2	$200-$350	$1500	$350	65%	75%

The table below gives the details of network infrastructure and the cost for rehabilitation based on these rates. Lateral length has been estimated at 15m per property in the catchment.

Table 3. Rehabilitation costs

		Network information				Catchment Rehabilitation Costs			
Study Area	Rank	Pipe length (m)	Manholes	Properties	Lateral length (@ 15m per property)	MH remediation	Public main relining	Lateral relining	Total Rehabilitation
1	1	1682	14	34	510	$ 21,000	$ 555,550	$ 178,500	$ 755,050.00
2	3	1905	21	168	2520	$ 31,500	$ 467,250	$ 882,000	$ 1,380,750.00
3	2	752	17	80	1200	$ 25,500	$ 150,400	$ 420,000	$ 595,900.00
4	4	837	13	79	1185	$ 19,500	$ 201,225	$ 414,750	$ 635,475.00
5	6	4501	65	330	4950	$ 97,500	$ 900,200	$ 1,732,500	$ 2,730,200.00
6	9	3037	37	173	2595	$ 55,500	$ 647,650	$ 908,250	$ 1,611,400.00
7	12	953	16	95	1425	$ 24,000	$ 190,600	$ 498,750	$ 713,350.00
8	10	786	12	65	975	$ 18,000	$ 157,200	$ 341,250	$ 516,450.00
9	5	386	5	33	495	$ 7,500	$ 77,200	$ 173,250	$ 257,950.00
10	7	1149	10	56	840	$ 15,000	$ 229,800	$ 294,000	$ 538,800.00
11	13	1770	22	160	2400	$ 33,000	$ 354,000	$ 840,000	$ 1,227,000.00
12	17	220	2	5	75	$ 3,000	$ 44,000	$ 26,250	$ 73,250.00
13	8	628	8	51	765	$ 12,000	$ 125,600	$ 267,750	$ 405,350.00
14	11	1052	12	86	1290	$ 18,000	$ 214,500	$ 451,500	$ 684,000.00
15	16	1296	21	93	1395	$ 31,500	$ 259,200	$ 488,250	$ 778,950.00
16	15	2291	26	103	1545	$ 39,000	$ 458,200	$ 540,750	$ 1,037,950.00
17	14	1130	13	21	315	$ 19,500	$ 226,000	$ 110,250	$ 355,750.00

4.2 Post rehabilitation flow reductions

The tables below shows the estimated minimum and maximum flow reductions achieved by rehabilitation in each study area.

Table 4. Flow reduction from relining all public mains and sealing manholes

Flow reduction estimation -Relining public mains and sealing manholes						
Study Area	Rank	Rehabilitation cost	Minimum night flow reduction (50%)		Maximum night flow reduction (60%)	
			Net night flow reduction (m3/day)	Total Featherston night flow reduction (%)	Net night flow reduction (m3/day)	Total Featherston night flow reduction (%)
1	1	$ 576,550.00	401	25%	482	30%
2	3	$ 498,750.00	137	8.5%	165	10%
3	2	$ 175,900.00	130	8.0%	156	10%
4	4	$ 220,725.00	60	3.7%	72	4.4%
5	6	$ 997,700.00	83	5.1%	100	6.1%
6	9	$ 703,150.00	22	1.3%	26	1.6%
7	12	$ 214,600.00	5.7	0.4%	6.9	0.4%
8	10	$ 175,200.00	5.2	0.3%	6.2	0.4%
9	5	$ 84,700.00	10	0.6%	13	0.8%
10	7	$ 244,800.00	15	0.9%	18	1.1%
11	13	$ 387,000.00	2.8	0.2%	3.3	0.2%
12	17	$ 47,000.00	0.0	0.0%	0.0	0.0%
13	8	$ 137,600.00	4.6	0.3%	5.5	0.3%
14	11	$ 232,500.00	6.5	0.4%	7.8	0.5%
15	16	$ 290,700.00	0.5	0.0%	0.6	0.0%
16	15	$ 497,200.00	1.4	0.1%	1.7	0.1%
17	14	$ 245,500.00	0.9	0.1%	1.0	0.1%

Table 5. Flow reduction from relining all public mains, sealing manholes and relining all laterals

Flow reduction estimation -Relining public mains, sealing manholes and relining all laterals						
Study Area	Rank	Rehabilitation cost	Minimum night flow reduction (65%)		Maximum night flow reduction (75%)	
			Net night flow reduction (m3/day)	Total Featherston night flow reduction (%)	Net night flow reduction (m3/day)	Total Featherston night flow reduction (%)
1	1	$ 755,050.00	522	32%	602	37%
2	3	$ 1,380,750.00	179	11.0%	206	13%
3	2	$ 595,900.00	169	10.4%	195	12%
4	4	$ 635,475.00	78	4.8%	90	5.6%
5	6	$ 2,730,200.00	108	6.7%	124	7.7%
6	9	$ 1,611,400.00	28	1.8%	33	2.0%
7	12	$ 713,350.00	7.5	0.5%	8.6	0.5%
8	10	$ 516,450.00	6.7	0.4%	7.8	0.5%
9	5	$ 257,950.00	14	0.8%	16	1.0%
10	7	$ 538,800.00	19.7	1.2%	22.7	1.4%
11	13	$ 1,227,000.00	3.6	0.2%	4.1	0.3%
12	17	$ 73,250.00	0.0	0.0%	0.0	0.0%
13	8	$ 405,350.00	6.0	0.4%	6.9	0.4%
14	11	$ 684,000.00	8.4	0.5%	9.7	0.6%
15	16	$ 778,950.00	0.6	0.0%	0.7	0.0%
16	15	$ 1,037,950.00	1.8	0.1%	2.1	0.1%
17	14	$ 355,750.00	1.1	0.1%	1.3	0.1%

4.3 Costs and flow reductions

The following tables and graphs show the cumulative cost of remediating each of the study areas in order of priority and the resulting total dry weather flow reductions. The two levels of rehabilitation are detailed with maximum and minimum flow reduction scenarios.

Table 6.Cumulative costs and flow reduction from relining all public mains and sealing manholes

Cumulative rehabilitation costs and resulting flow reductions - Manhole sealing and reling public mains							
Rank	Study Area	Cumulative cost		Minimum night flow reduction (50%)		Maximum night flow reduction (60%)	
				Post rehab total dry weather flow	Total dry weather flow reduction	Post rehab total dry weather flow	Total dry weather flow reduction
1	1	$	576,550.00	1962	17%	1881	20%
2	3	$	752,450.00	1832	22%	1725	27%
3	2	$	1,251,200.00	1694	28%	1561	34%
4	4	$	1,471,925.00	1634	31%	1488	37%
5	9	$	1,556,625.00	1624	31%	1476	38%
6	5	$	2,554,325.00	1541	35%	1376	42%
7	10	$	2,799,125.00	1526	35%	1358	43%
8	13	$	2,936,725.00	1521	36%	1353	43%
9	6	$	3,639,875.00	1499	37%	1326	44%
10	8	$	3,815,075.00	1494	37%	1320	44%
11	14	$	4,047,575.00	1488	37%	1312	44%
12	7	$	4,262,175.00	1482	37%	1306	45%
13	11	$	4,649,175.00	1479	37%	1302	45%
14	17	$	4,894,675.00	1478	37%	1301	45%
15	16	$	5,391,875.00	1477	38%	1300	45%
16	15	$	5,682,575.00	1476	38%	1299	45%
17	12	$	5,729,575.00	1476	38%	1299	45%

Table 7. Cumulative cost and flow reduction from relining all public mains, sealing manholes and relining all laterals

Cumulative rehabilitation costs and resulting flow reductions - Manhole sealing, reling public mains and relining laterals							
Rank	Study Area	Cumulative cost		Minimum night flow reduction (65%)		Maximum night flow reduction (75%)	
				Post rehab total dry weather flow	Total dry weather flow reduction	Post rehab total dry weather flow	Total dry weather flow reduction
1	1	$	755,050.00	1841	22%	1761	25%
2	3	$	1,350,950.00	1672	29%	1566	34%
3	2	$	2,731,700.00	1494	37%	1360	42%
4	4	$	3,367,175.00	1416	40%	1270	46%
5	9	$	3,625,125.00	1402	41%	1254	47%
6	5	$	6,355,325.00	1294	45%	1130	52%
7	10	$	6,894,125.00	1274	46%	1107	53%
8	13	$	7,299,475.00	1268	46%	1100	53%
9	6	$	8,910,875.00	1240	48%	1067	55%
10	8	$	9,427,325.00	1233	48%	1059	55%
11	14	$	10,111,325.00	1225	48%	1050	56%
12	7	$	10,824,675.00	1217	48%	1041	56%
13	11	$	12,051,675.00	1214	49%	1037	56%
14	17	$	12,407,425.00	1213	49%	1036	56%
15	16	$	13,445,375.00	1211	49%	1034	56%
16	15	$	14,224,325.00	1210	49%	1033	56%
17	12	$	14,297,575.00	1210	49%	1033	56%

The following graphs display the cumulative rehabilitation costs and flow reductions as per tables 6 and 7.

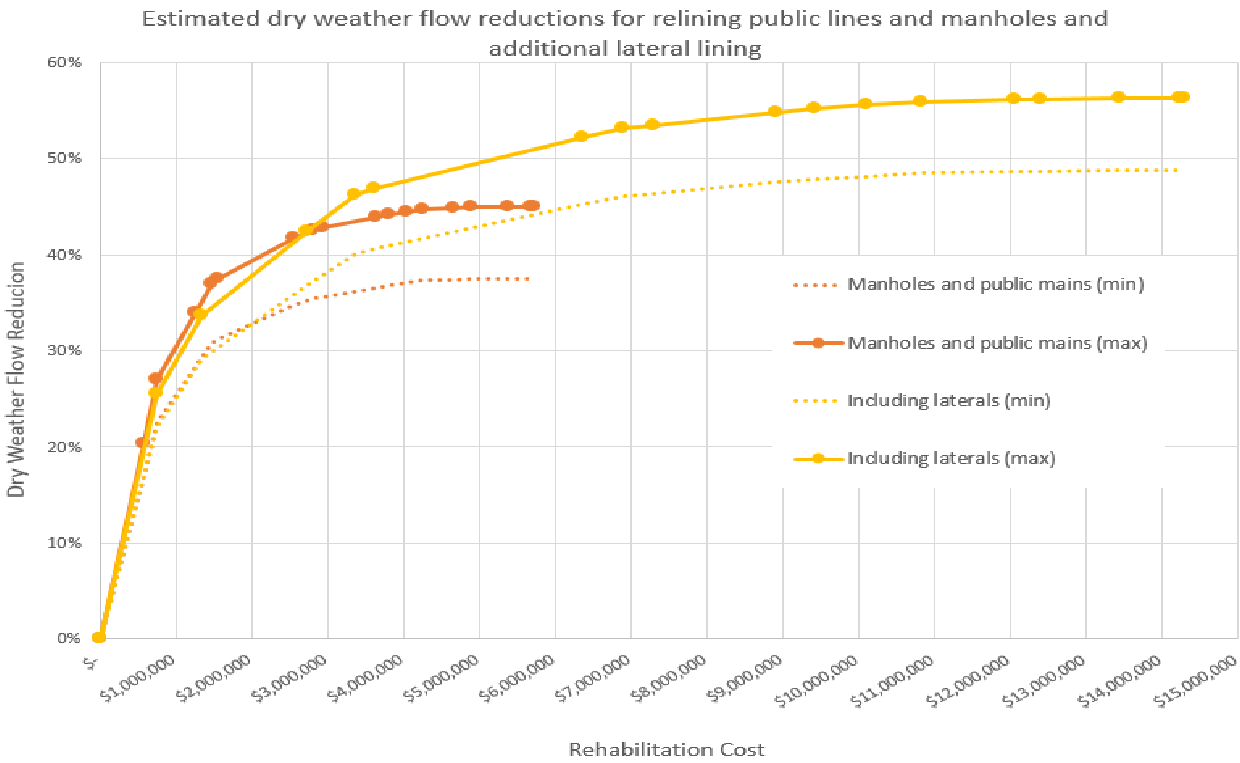


Figure 6: Cumulative costs and % flow reductions

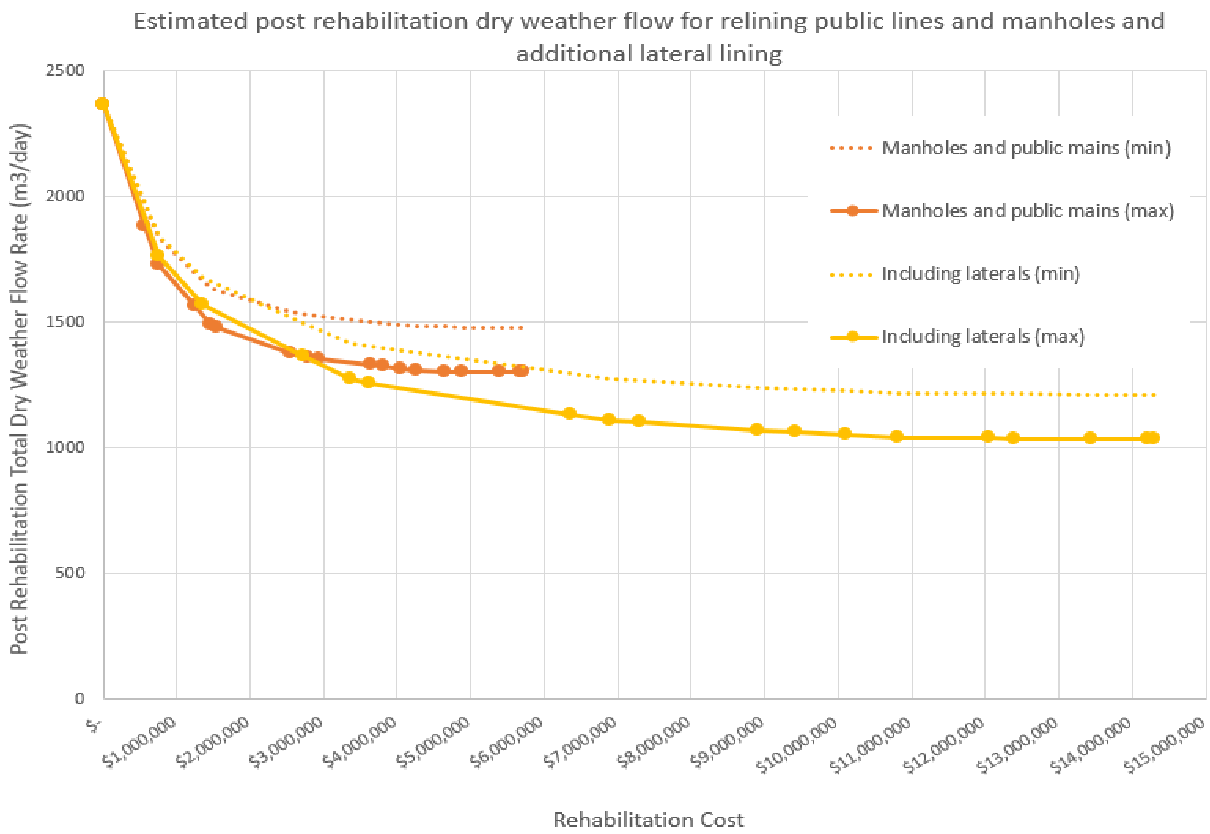


Figure 7: Cumulative costs and post rehabilitation dry weather flow

5 CONCLUSIONS AND RECOMMENDATIONS

The night flow investigations divided the Featherston network into 17 study areas and ranked them by the volume of night flow contribution (which is directly related to GWI). It is important to note that the flow measured from each study area is sourced from all network infrastructure upstream of the monitoring point including public mains, manholes and private laterals.

According to SWDC's WWTP influent flow monitor, the daily flow rate at the time of the study was 2363 m^3/day which is approximately the average annual daily dry weather flow volume of 2600 m^3/day. Historical influent data shows seasonal fluctuations in GW and flows exceeding 3000m^3/day during winter dry weather. While the timing of this study did not allow the higher flow conditions to be captured, the project was carried out during average conditions (which still indicate significant GWI issues) and therefore highlights the parts of the network requiring more urgent remediation as they are contributing excessive GWI consistently. Additionally these areas are likely to contribute more GWI under higher GW conditions.

The extent to which SWDC wishes to reduce the identified flow will depend on budget and the cost benefit of the remedial works (and subsequent flow reductions) on the future treatment and disposal schemes. One of the key applications of the results was the refinement of the original I/I remediation and treatment cost sensitivity analysis which showed that effective I/I rehabilitation could significantly reduce the cost of the chosen treatment scheme. To enable such refinement, estimates of remediation costs for each study area were calculated as well as expected average dry weather flow reduction ranges post-rehabilitation. Upon completion of the sensitivity analysis (as presented to SWDC in November 2013) it was shown that for high rate treatment the optimal level of average dry weather flow reduction was 31% which could be achieved by spending $1.26M on relining public mains and manholes the in top 3 ranked study areas. Only the top 2 ranked study areas would require remediation if laterals are also addressed. This work would reduce the cost of treatment by $3.89M ($2.63M net saving). For land disposal the optimal level of average dry weather flow reduction was 35% which could be achieved by spending $1.9M on relining public mains and manholes the in top 6 ranked study areas. Only the top 3 ranked study areas would require remediation if laterals are also addressed. This work would reduce the cost of treatment by $6.86M ($4.96M net saving). Beyond the stated extents of remediation addressing I/I is not cost effective for the Featherston wastewater scheme as the achieved flow reductions would come at a greater cost than the benefit to the treatment scheme (I/I sources become too widespread). It is important to note however, that I/I remediation needs to be carried out as a part of ongoing asset renewal and maintenance which should continue as a separate works program beyond the immediate works associated with the treatment scheme.

The decision on the inclusion of laterals will be critical. Addressing a greater length of public mains and manholes only may be seen as a better option with less disruption to residents. Alternatively, if laterals are addressed, there may be opportunity for residents to contribute to the cost.

After consideration of the above factors it is recommended that:

1) A pilot rehabilitation program is undertaken in study area 3 in the vicinity of Hardy Grove and Woodward St (Detailed catchment plan provided in appendix 1). The purpose of this work is to assess the actual effectiveness and cost of different levels of rehabilitation. The results can then be used to refine the overall I/I strategy for Featherston. The following phases are recommended:

    a) Engage a suitable contractor to CCTV all public lines and inspect all manholes. The extents of CCTV may be reduced by reviewing recent CCTV of the area. The inspections must focus on defects that are likely to be causing the GWI issue i.e. leaking pipe joints, major damage, leaking laterals (estimate flow), offset manhole risers etc. The results will allow more accurate planning and costing of the remedial works.

    b) Undertake remediation of all public mains and manholes using the most appropriate method (extending relining 10-15m up private laterals should be considered as it is often possible to do this while mains are being relined).

    c) Assess the effectiveness of rehabilitation of public mains and manholes using night flow isolation in specific pipe lengths and total flow reductions using data from an established flow monitor at the inlet to the WWTP.

Following works on the public assets private laterals should be addressed in the following phases:

d) Assess the condition of private laterals within the study area.

e) Rehabilitate private laterals using the most appropriate method.

f) Assess the effectiveness of lateral rehabilitation as described in 1c.

The total cost for the remediation component of this work has been estimated at $595,900.00. See table 3 for further details.

2) Following the pilot program, the investigation and rehabilitation work should be expanded to include other priority study areas as set out in this report. Areas should be addressed in order of priority up to the extent and budget determined by the I/I remediation and treatment cost sensitivity analysis. As previously mentioned, subsequent works should be carried out as a part of ongoing asset maintenance and renewals program. Works in should be undertaken in the order of priority set out below:

Priority (Rank)	Study Area
1	1
2	3 (pilot)
3	2
4	4
5	9
6	5
7	10
8	13
9	6
10	8
11	14
12	7
13	11
14	17
15	16
16	15

a) Engage a suitable contractor or consultant to CCTV all public lines and inspect all manholes. Historical CCTV may be used if it is less than 5 years old. The inspections must focus on defects that are likely to be causing the GWI issue i.e. leaking pipe joints, major damage, leaking laterals, offset manhole risers etc. The results will allow more accurate planning and costing of the remedial works.

b) Engage a suitable contractor or consultant to design, manage and undertake remedial works which may include work on private laterals.

c) Assess the effectiveness of rehabilitation using night flow isolation in specific pipe lengths and total flow reductions using data from an established flow monitor at the inlet to the WWTP.

3) Establish an accurate long term gauge at the WWTP inlet to monitor the effectiveness of remedial works.
   a) The gauge must measure at 5-15min intervals to ensure the data has sufficient resolution for I/I analysis.
   b) The gauge must be maintained and cleaned regularly including battery swaps and sensor cleaning to ensure maximum performance and data uptime.
   c) The gauge must be calibrated to ensure the data is accurate and will provide meaningful data for determining rehabilitation effectiveness.
4) Direct stormwater inflows and rainfall dependant infiltration must also be addressed alongside GWI as they present other issues for the Featherston scheme. It is therefore recommended to:
   a) Undertake a catchment wide flow monitoring study. This study will supplement the night flow isolation results to complete the I/I analysis. Flow monitoring allows the assessment of wet weather I/I parameters such as peaking factors, maximum flow rates and % ingress. Dry weather characteristics of the network will also be determined. Night flow isolation is very specific to GWI and does not give an overall picture of the system response to rainfall or the dry weather characteristics like a continuous flow monitoring study. It is important to understand these factors for planning of property inspections (for illegal connections of SW) and for the design of the future treatment and disposal scheme.
   b) The location of flow monitors should be as close to the 2004 locations as possible so that a comparison can be drawn between the results. As the flow study is seen as secondary to night flow isolation the number of monitors and duration of study may be reduced to a minimum that will allow the necessary DWF and WWF data to be captured, 2-3 rain events, and a week of dry weather should be sufficient.
   c) The equipment used in v-notch weir sites (less than 225mm) as well as HVQ sites (greater than 225mm) should be ADS FlowShark Tritons or ADS FlowSharks as they are the latest, most reliable and most accurate technology that is suitable of for this type of monitoring. Other ultrasonic level monitors are also acceptable in appropriate v-notch weir sites. Pump Station monitoring should be avoided as it limits the assessment of I/I.
5) Develop an optimised remediation plan by combining the results of the night flow isolation and flow monitoring study. The results of the studies will determine the extent and type of network remediation required to achieve the desired dry weather flow reduction and reduction in wet weather peak flows. This should not only be for immediate flow reductions for the WWTP scheme, but be used to guide the ongoing maintenance and renewals programme in Featherston.

APPENDIX 1

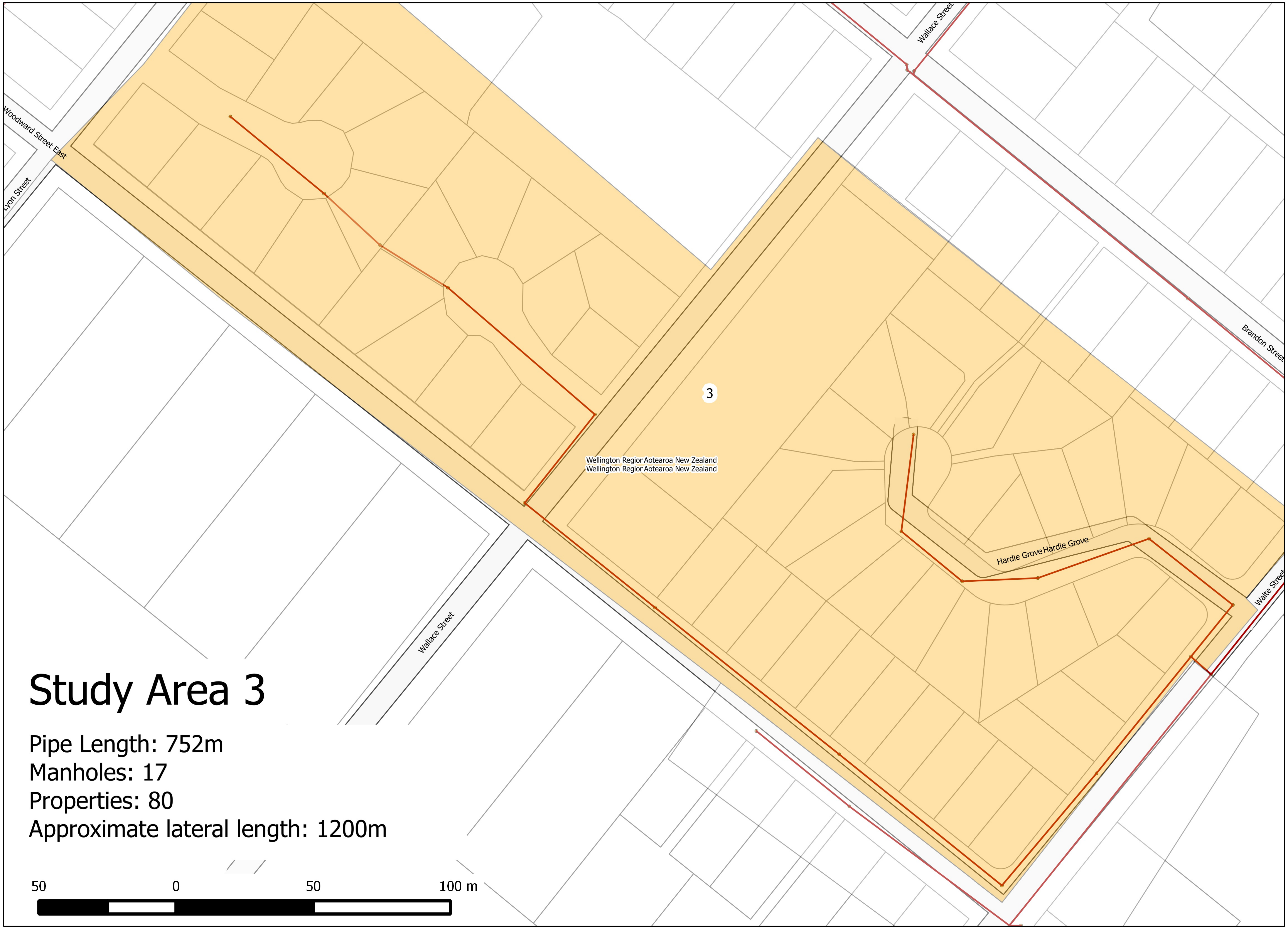
STUDY AREA MAPS

Study Area 1

Pipe Length: 1682m
Manholes: 14
Properties: 34
Approximate lateral length: 510m

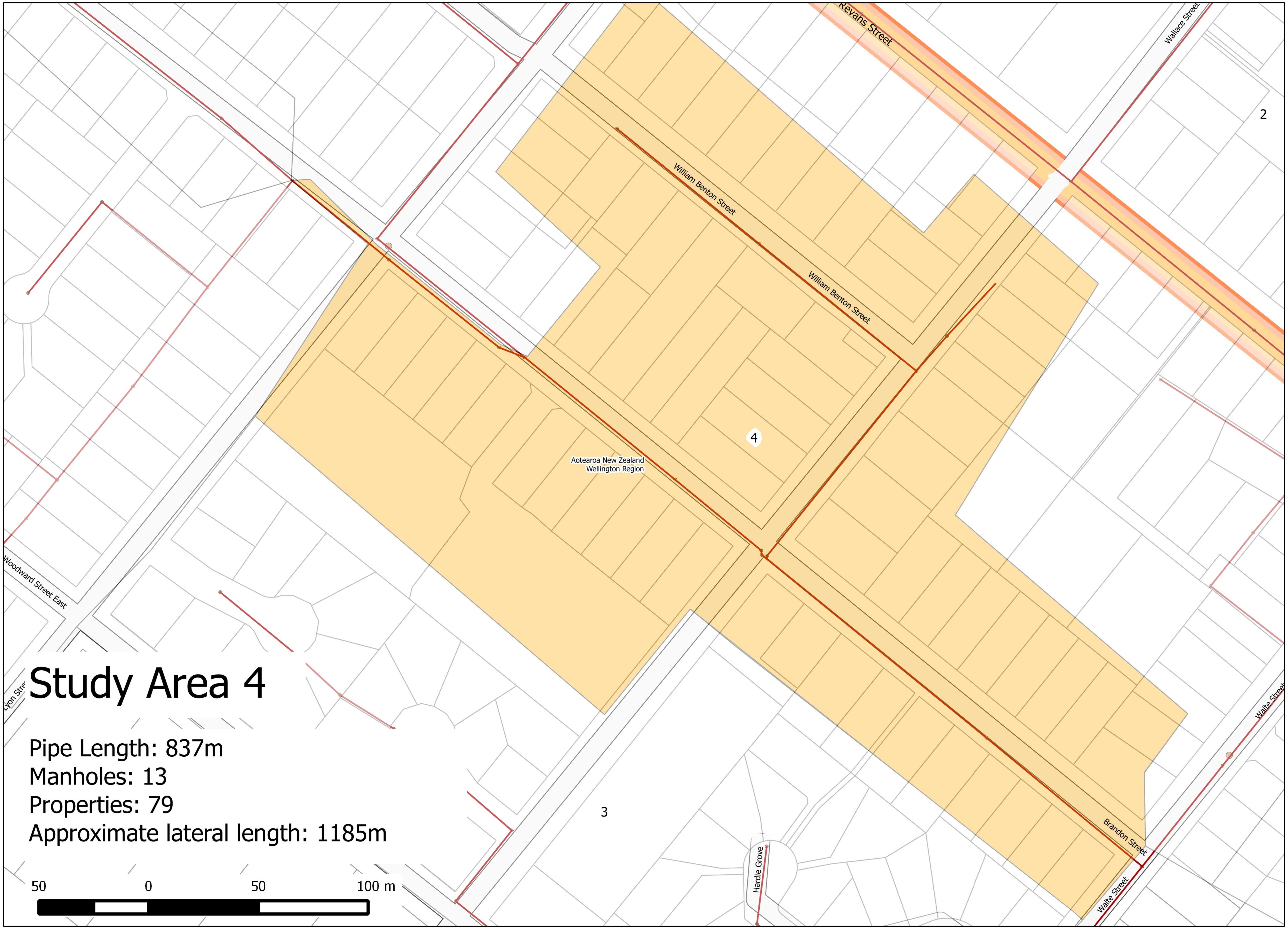
Study Area 2

Pipe Length: 1905m
Manholes: 21
Properties: 168
Approximate lateral length: 2520m



Study Area 3

Pipe Length: 752m
Manholes: 17
Properties: 80
Approximate lateral length: 1200m



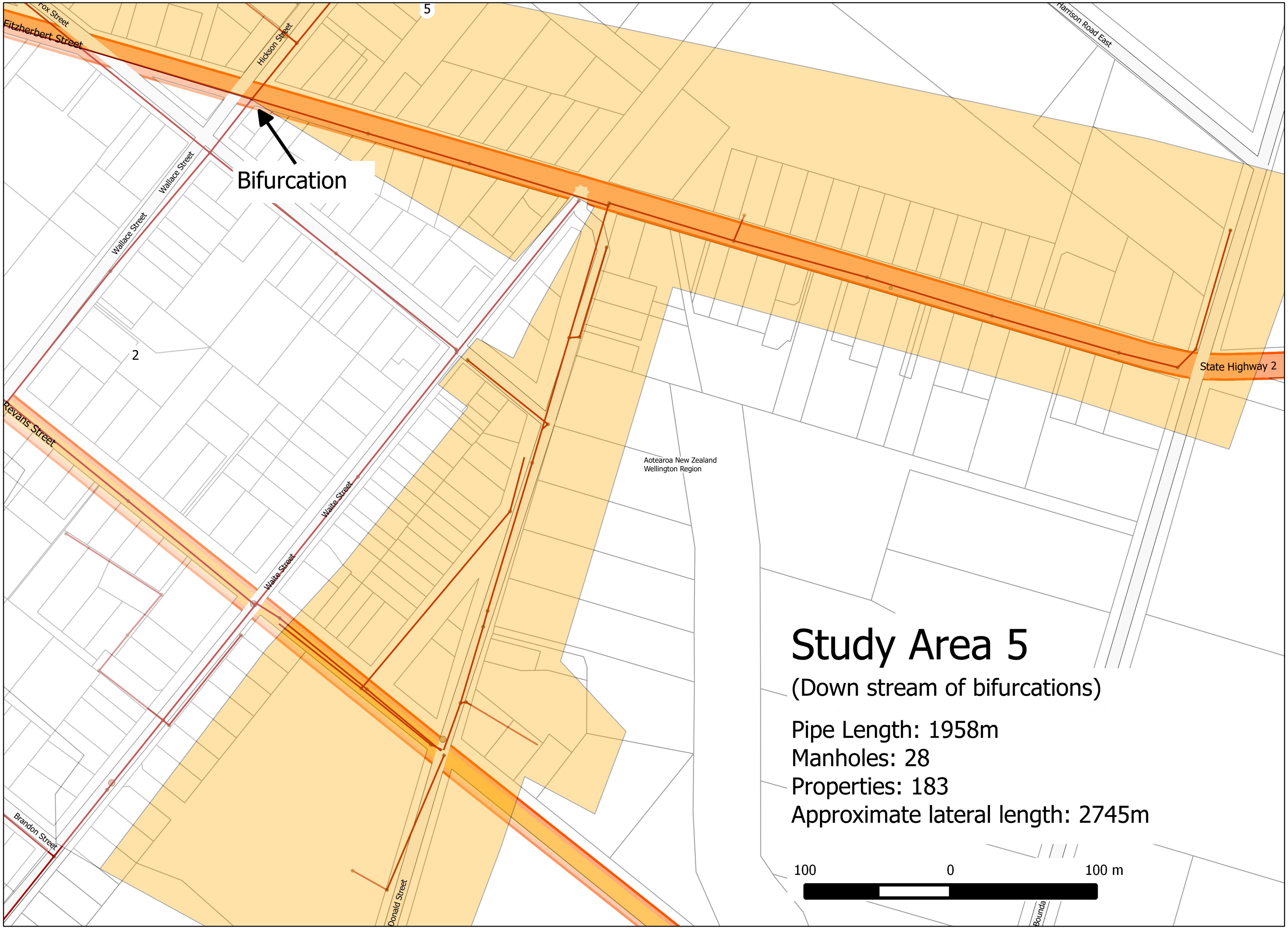
Study Area 4

Pipe Length: 837m
Manholes: 13
Properties: 79
Approximate lateral length: 1185m

Study Area 5

(Upstream of bifurcations)

Pipe Length: 2543m
Manholes: 37
Properties: 147
Approximate lateral length: 2205m



Study Area 5

(Down stream of bifurcations)

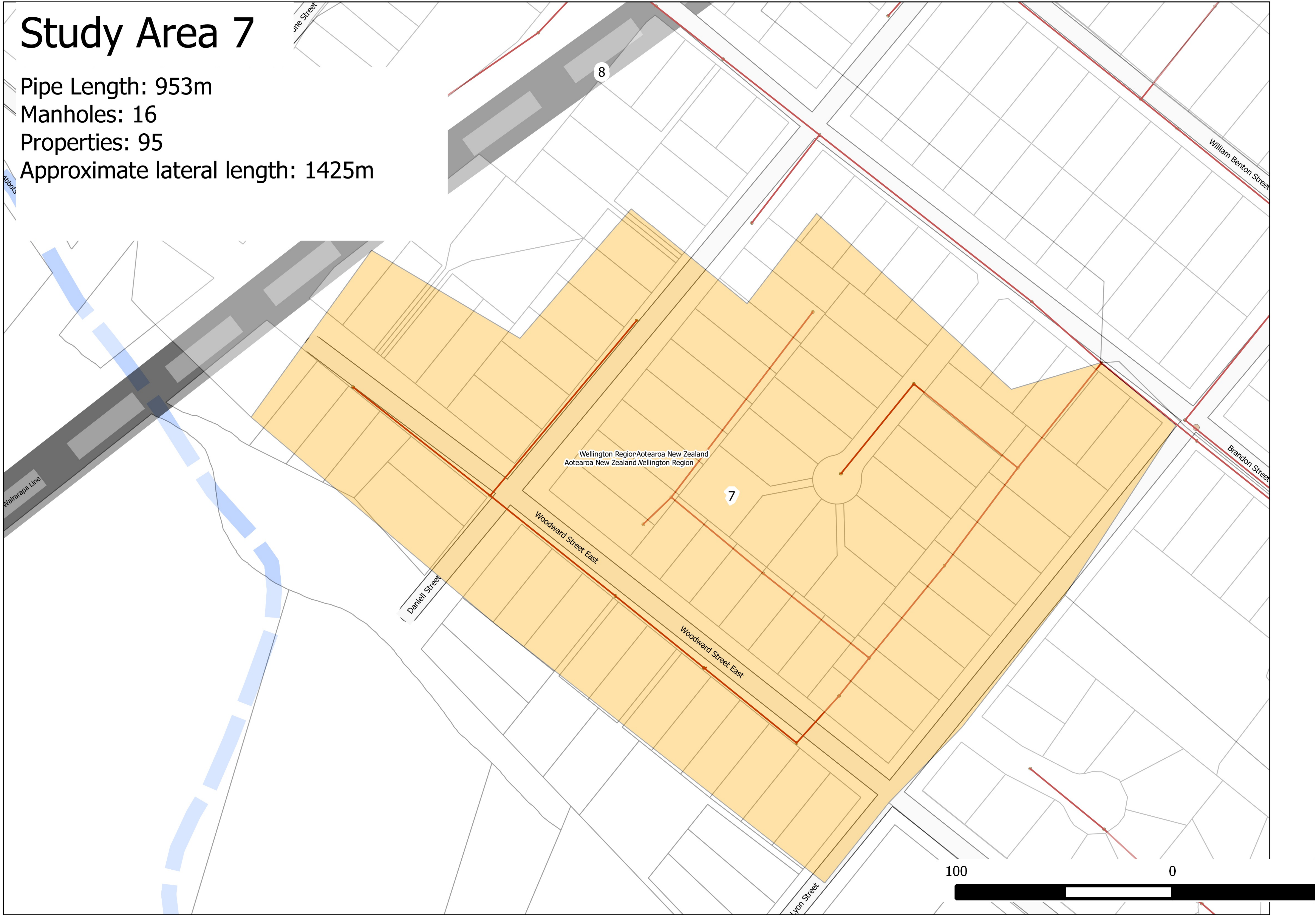
Pipe Length: 1958m
Manholes: 28
Properties: 183
Approximate lateral length: 2745m

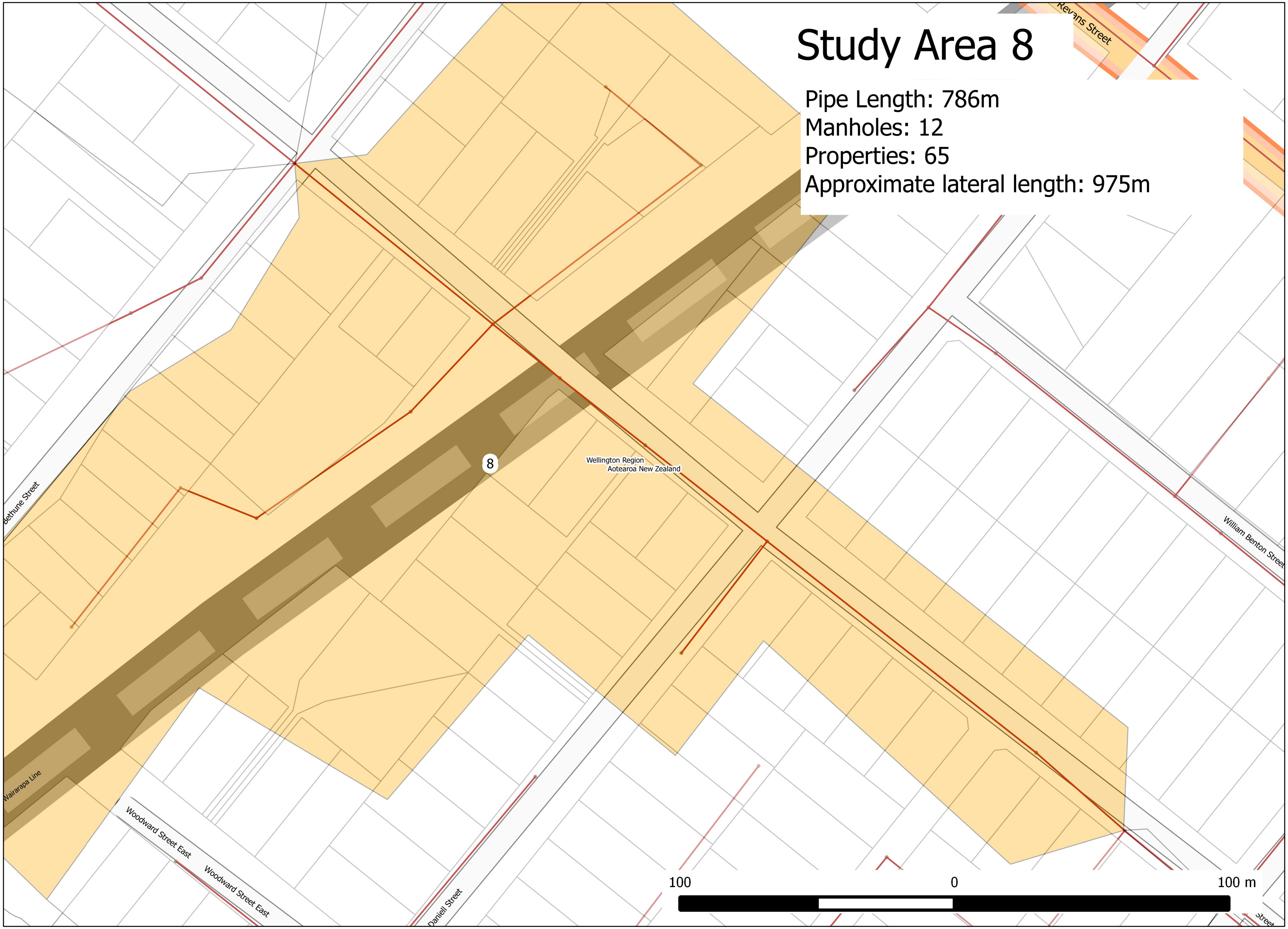
Study Area 6

Pipe Length: 3037m
Manholes: 37
Properties: 173
Approximate lateral length: 2595m

Study Area 7

Pipe Length: 953m
Manholes: 16
Properties: 95
Approximate lateral length: 1425m



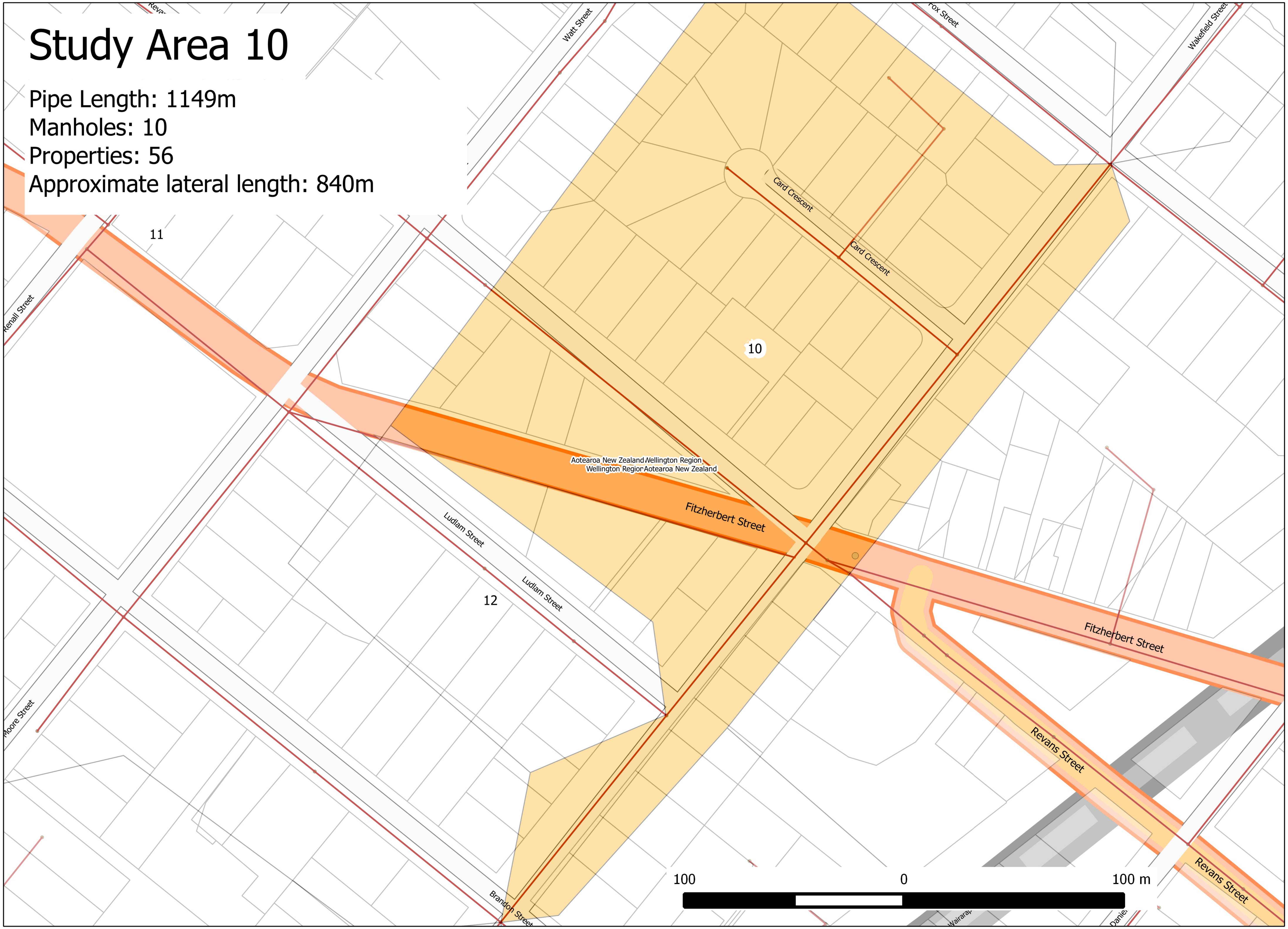

Study Area 8
Pipe Length: 786m
Manholes: 12
Properties: 65
Approximate lateral length: 975m
Revans Street
Bethune Street
William Benton Street
Wairarapa Line
Woodward Street East
Woodward Street East
Daniell Street
Wellington Region
Aotearoa New Zealand
8
100
0
100 m

Study Area 9

Pipe Length: 386m
Manholes: 5
Properties: 33
Approximate lateral length: 495m

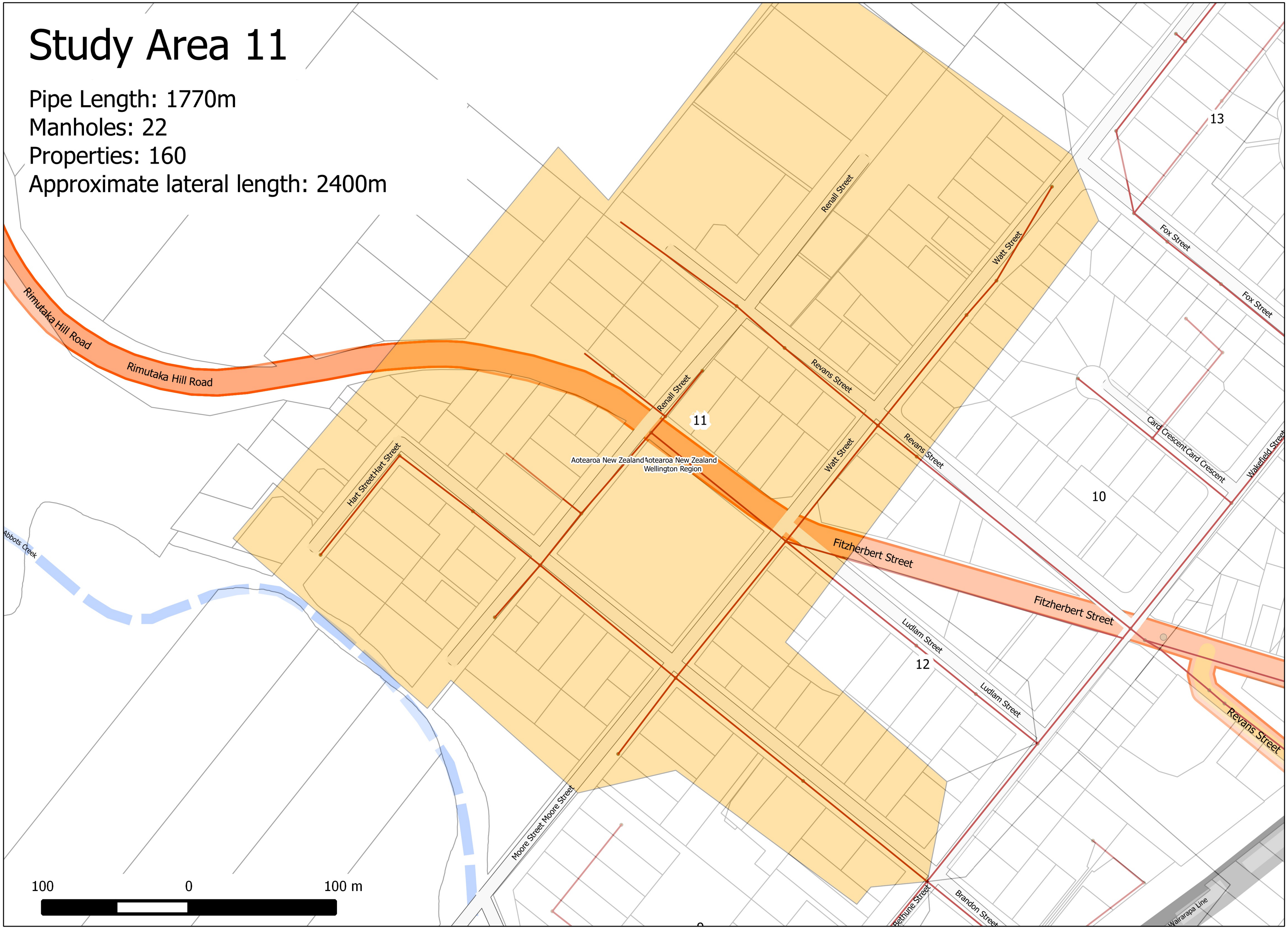
Study Area 10

Pipe Length: 1149m
Manholes: 10
Properties: 56
Approximate lateral length: 840m



Study Area 11

Pipe Length: 1770m
Manholes: 22
Properties: 160
Approximate lateral length: 2400m

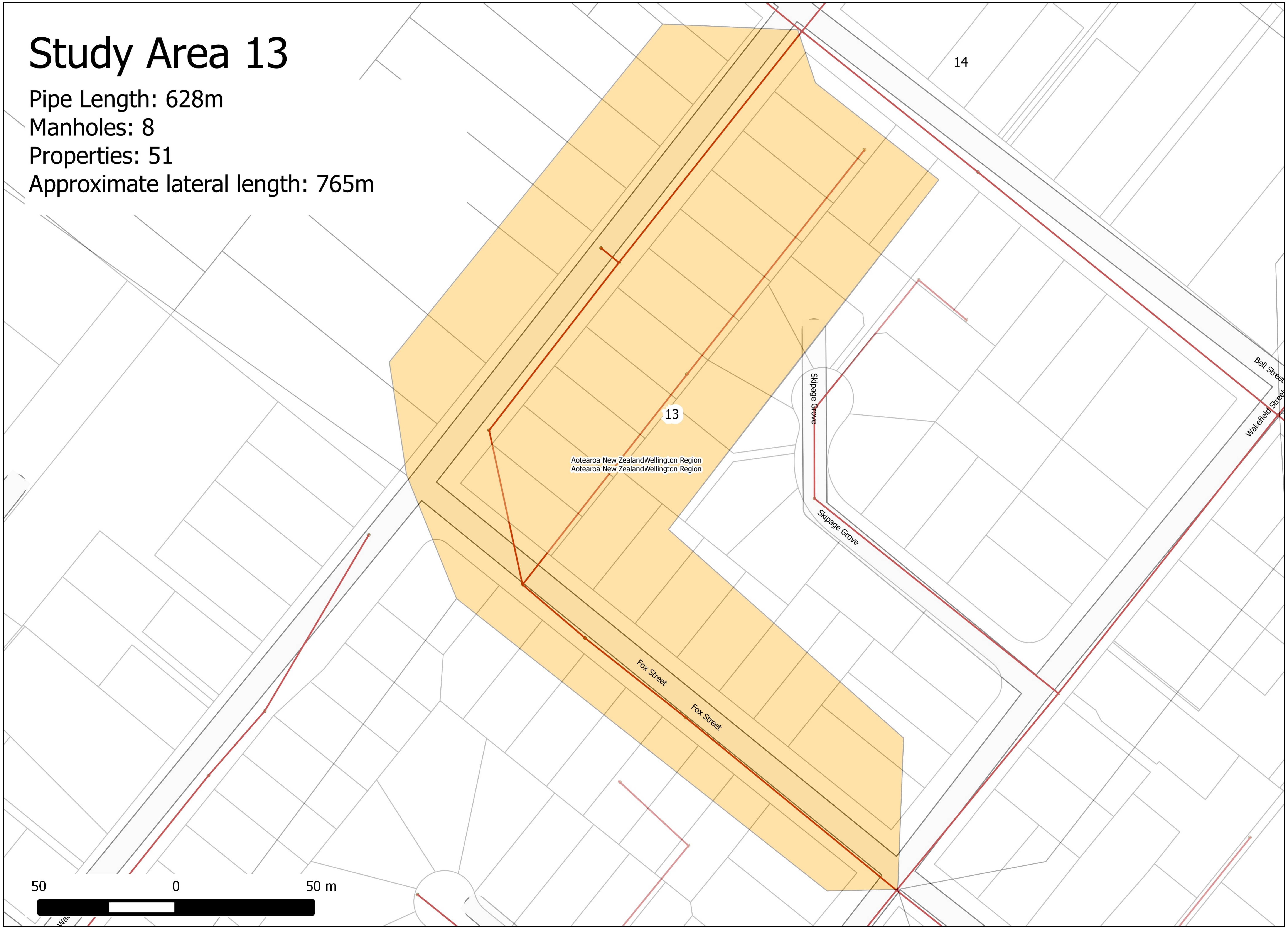


Study Area 12

Pipe Length: 220m
Manholes: 2
Properties: 5
Approximate lateral length: 75m

Study Area 13

Pipe Length: 628m
Manholes: 8
Properties: 51
Approximate lateral length: 765m

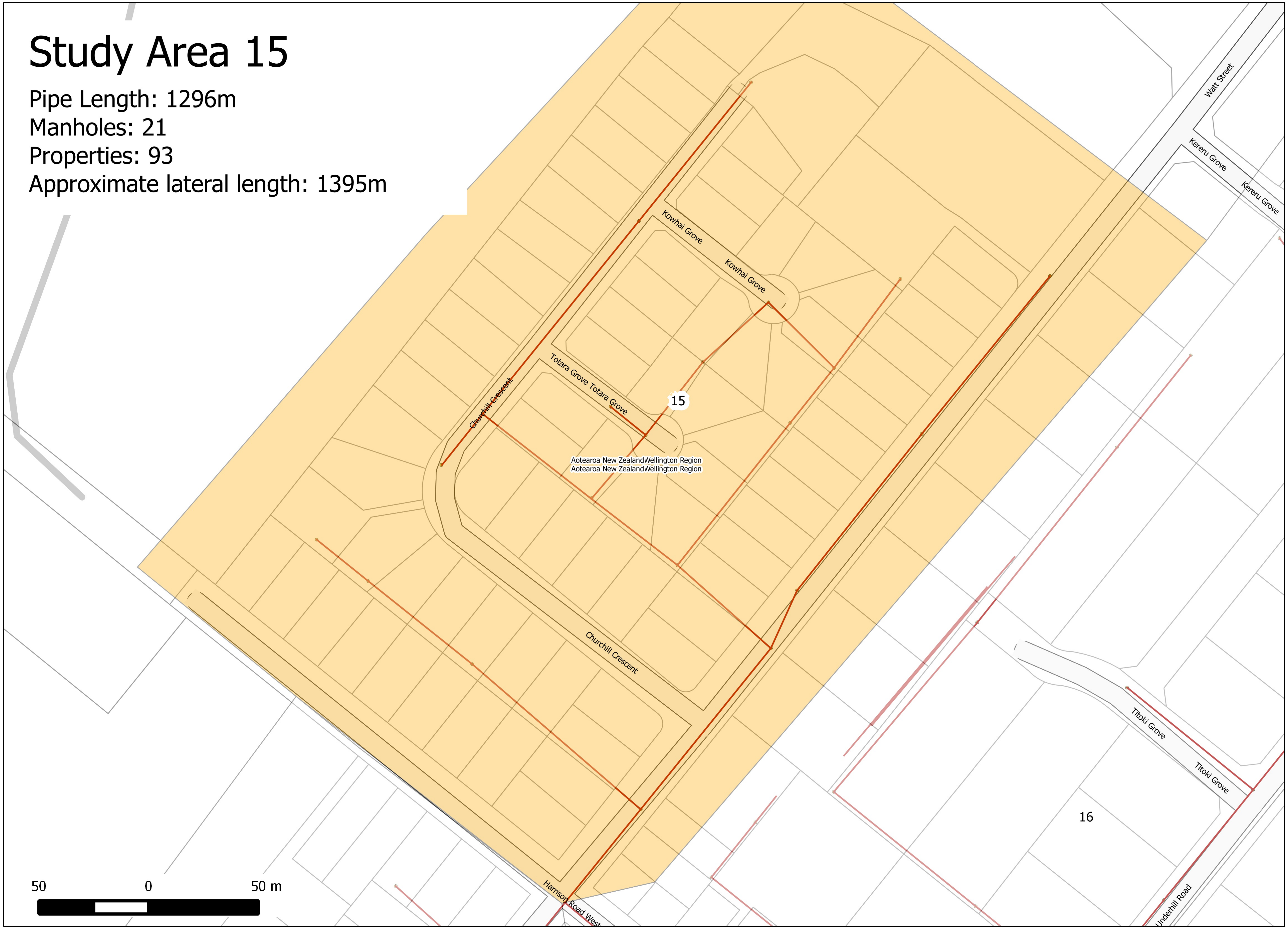


Study Area 14

Pipe Length: 1052m
Manholes: 12
Properties: 86
Approximate lateral length: 1290m

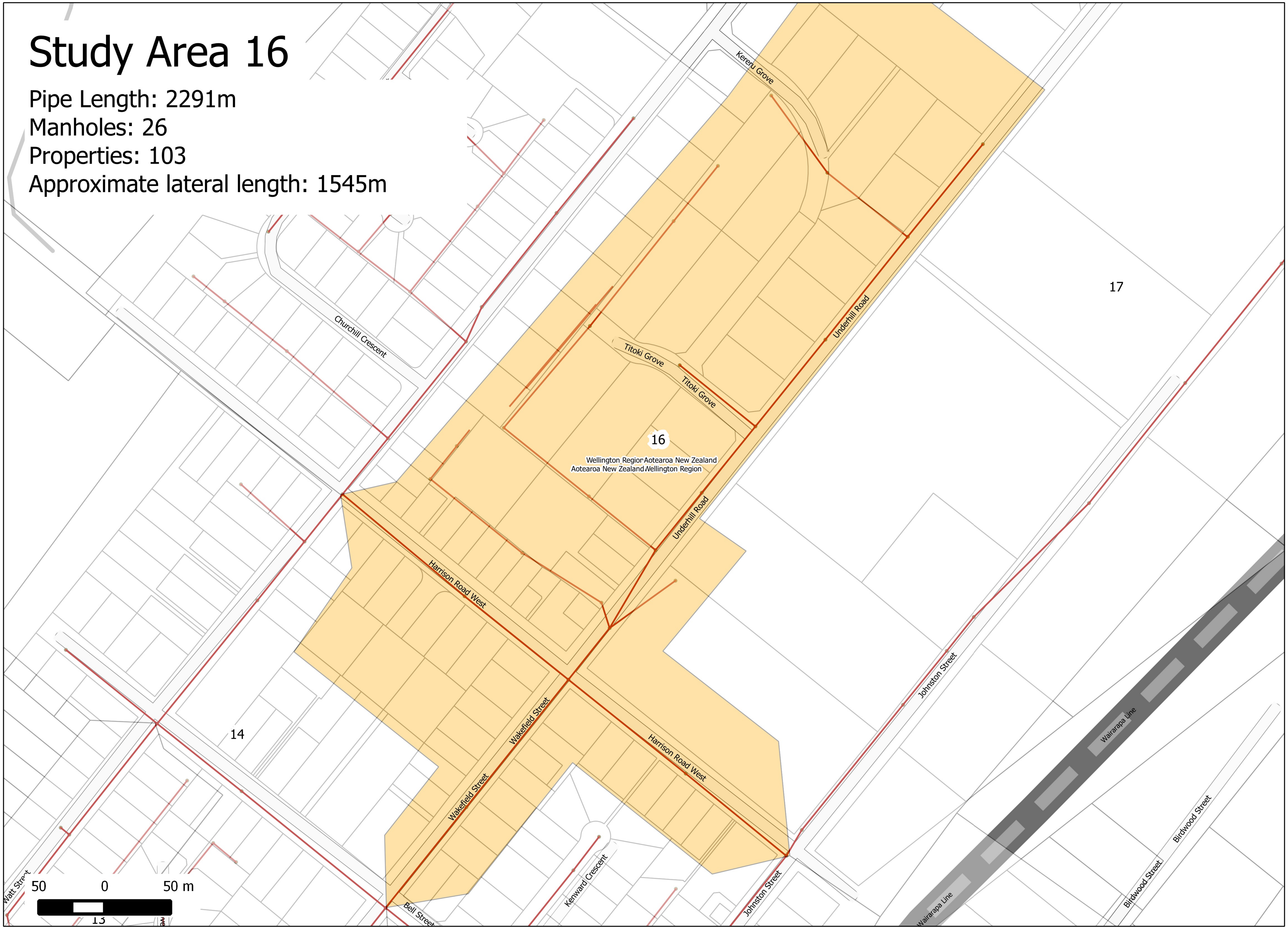
Study Area 15

Pipe Length: 1296m
Manholes: 21
Properties: 93
Approximate lateral length: 1395m



Study Area 16

Pipe Length: 2291m
Manholes: 26
Properties: 103
Approximate lateral length: 1545m



Study Area 17

Pipe Length: 1130m
Manholes: 13
Properties: 21
Approximate lateral length: 315