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INFILTRATION TESTING RESULTS FOR AKAROA TREATED WASTEWATER DISPOSAL VIA IRRIGATION – ROBINSONS BAY AND POMPEYS PILLAR

1.0 Introduction

This is the second round of on-site investigations as part of the ongoing Christchurch City Council (Council) investigation into a land disposal system for treated wastewater from the proposed new Akaroa Wastewater Treatment Plant (WWTP). Pattle Delamore Partners Limited (PDP) carried out an initial desktop analysis in May 2016 to identify suitable land for disposal of wastewater to land. This analysis was discussed in the Council consultation report 'Akaroa Treated Wastewater Disposal Options (May 2016)'. Infiltration tests were undertaken on land on the Takamatua Peninsula and within the Takamatua Valley. The results were reported to Council in the report 'Infiltration Testing Results for Akaroa Wastewater Disposal Via Irrigation' (PDP, June 2016).

At the same time Beca undertook geotechnical investigations. The results were that the land on Takamatua Peninsula was geotechnically unstable where slopes downhill of the irrigation area are steeper than 15 degrees (Akaroa Wastewater Upgrade Irrigation - Preliminary Geotechnical Assessment (CH2M Beca, June 2016)). Following this, another desktop assessment was carried out to identify alternative land options that were further from the proposed treatment plant and could be suitable for the disposal of treated wastewater. The criteria used for the desktop assessment and the land identified for further investigation is reported in 'Akaroa Wastewater Disposal Alternative Sites Stage 2 - Geotechnical Report' (Beca, November 2016). On the basis of this report, PDP has been engaged by Beca to carry out site investigations at eight locations within Robinsons Bay and Pompeys Pillar to assess their suitability for discharge of treated wastewater to land.

The land that was investigated (as a part of this investigation) is shown in Figure 1, Appendix A. Each of the sites was selected to provide an indication of the different soil types and other geological and hydrogeological conditions of the different areas. Landowners were approached by Council regarding the potential use of this land for investigation.

The purpose of this report is to present the latest findings of the site investigations of the alternative land disposal options, discuss the suitability and constraints of each site, and provide recommendations to Council about the suitability of the land for the irrigation of treated wastewater. The results of the field work indicated that the field parameters of the soils differ from the previous results and initial estimates. As a result PDP were requested to provide revised details of the storage pond, and irrigated land area requirements previously reported to Council in March 2016. Additionally, the annual drainage volume to ground has also been assessed.

2.0 Method

Site investigations were carried out from 26 - 29 September 2016. These were carried out in conjunction with the installation of six environmental monitoring bores BH1 - BH6. The PDP investigations involved:

- assessing the soil type at each selected location (including the depth of the topsoil, presence and depth of any low permeability layer);
- measuring the depth of root penetration to assist in estimating the Profile Available Water (PAW); and
- measuring the infiltration rate at the ground surface and any deeper low permeability layers.

Infiltration tests were carried out at the locations shown in Figure 2A and 2C, Appendix A. The monitoring bore locations are also shown in Figure 2A and 2B, Appendix A. The installation of these bores can be seen in Photographs 15 – 19 (Appendix B). Sixteen infiltration tests were carried out using a double ring infiltrometer for a target minimum period of 90 minutes. Two infiltration tests, one in the surface soils and one in the lower permeable sub-surface soils, Photographs 1 – 15 (Appendix B), were carried out at eight locations (IT1 – 5 and IT8 - 10) to determine a representative infiltration rate for Robinsons Bay and Pompeys Pillar areas, respectively.

2.1 Double Ring Infiltrometer Test Methodology

A double ring infiltration test involves a small ring positioned inside a larger outer ring. Each ring is sunk into the ground to provide a preferential flow path for water. When both rings are filled, water infiltrates both laterally and vertically from the outer ring leaving infiltration in the vertical direction as the prominent flow path for water in the inner ring. Measurements of the water level in the inner ring are taken periodically and the drop in water level against time is plotted. If necessary, water may need to be added to the rings until a stable infiltration rate is measured. The double ring infiltrometers were covered during periods of rainfall to avoid any inaccuracy of the measurements. Note the rainfall would not affect the results of infiltration as the stabilised rate is meant to be at saturation. The measured infiltration rate for design purposes is the stabilised rate measured over a minimum duration of 30 minutes. The photographs of the tests are shown in Photographs 1 -14, Appendix B.

The double ring infiltrometer was deemed to be the most suitable method of testing the infiltration rate because of the relatively low permeability materials. The infiltration test results are sufficiently accurate to indicate the permeability of the soil and whether it is suitable for irrigation. The double ring infiltration test can be carried out using a falling head procedure or a static head. The former allows the water level to fall over time and is replenished with new water if the water level has dropped too far. Generally the depth of water is maintained between 100 mm and 200 mm deep. Alternatively, the latter maintains the water level at a constant depth by continually replacing the lost water from a reservoir. This method eliminates the potential for the head of water impacting the infiltration rate. This test requires additional equipment and setup compared with the falling head test and is particularly useful where infiltration rates are high.

For this investigation the falling head procedure was used as it was simpler to set up on site and is considered to give representative results of the soil permeability sufficient to assess its suitability for irrigation. Stabilised infiltration rates were obtained indicating that the head of water had little impact on the measured infiltration rates.

3.0 Soil Description

A description of soil type during the investigation works indicated that the soils in the investigation area comprised Barry Soils, Pawson Hills Soils and Takahe Soils. Pawson Hills Soils and Takahe Soils are the same soils that were found during the first round of infiltration testing in Takamatua Valley. Table 1 provides a detailed description of the Barry Soils, Pawson Hills Soils and Takahe Soils. These descriptions are from "General Survey of the Soils of South Island, New Zealand" (DSIR, 1968). All soils are derived from the parent material of greywacke loess and basalt. Barry Soils are granular, and the main difference in the profile of Pawson Hills Soils and Takahe Soils is the pale olive grey layer directly beneath the topsoil. Barry Soils are vulnerable to some stream bank erosion. Pawson Hills Soils and Takahe Soils are vulnerable to sheet erosion, slumps on hills or slips on steeper slopes.

Movement of groundwater through the loess can cause tunnel gullies to form and also contribute to land instability. This is consistent with the description of liability of soil erosion of Pawson Hills Soils and Takahe Soils (DSIR, 1968).

Table 1: Soil Description

Soil Name	Parent Material	Topography	Representative Profile(s)	Liability to Soil Erosion
Barry Soils (mostly silt loams)	Alluvium from reworked greywacke loess and basic igneous rocks	Flat to gently sloping Up to 153 m	150 mm dark brown nutty/granular silt loam; firm, On olive mottled dark brown silt loam – clay loam; firm. **Also** from more basaltic alluvium: 200 mm dark brown granular/crumb heavy silt loam; friable, on brown-red brown blocky/granular clay loam; firm.	Some stream bank
Pawson Hill Soils (mostly silt loams)	Greywacke loess (with minor basalt)	Moderately steep with rolling ridges; few short steep slopes with rock outcrops Up to 370 m	150 mm dark grey brown crumb/nutty silt loam; friable, 75 mm pale olive grey lightly mottled orange crumb/nutty silt loam; friable, 200 mm pale yellow brown lightly mottled orange nutty/blocky silt loam; firm, on pale yellow brown (grey veins) prismatic silt loam; very firm.	Sheet if cultivated; slumps on hills; trees survive in gullies and provide protection
Takahe Soils (silt loams, fine sandy loams)	Greywacke loess of varying thickness overlying basalt	Rolling to easy rolling broad spurs with narrow strips of moderately steep sides Up to 305 m	(150 mm dark grey brown crumb silt loam; friable 250 mm yellow mottled orange blocky silt loam; friable 300 mm olive grey lightly mottled orange crumb/nutty silt loam; friable on pale yellow brown (grey veins) prismatic silt loam; very firm.	Sheet and tunnel gully; slips on steeper slopes

4.0 Infiltration and Test Pit Results

Table 2 summarises the data of the surface and sub-surface infiltration tests including location, depth and soil type. Figure 2A and 2C, Appendix A shows the locations of the infiltration tests carried out. Photographs of the infiltration tests (IT) and test pit (TP) materials are included in Photographs, Appendix B.

Table 2: Infiltration Tests

Test ID	Locations	Depth of Infiltration Test (mm)	Depth of Topsoil (m)	Soil Type[1]	Elevation[2] (m above sea level)
IT1	Robinsons Bay	420	0.13	Barry	1.3
IT2	Robinsons Bay	550	0.09	Barry	12.5
IT3	Robinsons Bay	520	0.12	Barry	30.7
IT4	Robinsons Bay	350	0.12	Takahe	60
IT5 & TP5	Robinsons Bay	480	0.12	Pawson Hills	145.6
IT8	Pompeys Pillar	400	0.17	Takahe	240
IT9	Pompeys Pillar	440	0.19	Takahe	165
IT10	Pompeys Pillar	460	0.13	Takahe	140

Note:

1. *Soil types from Sheet 9 of "General Survey of Soils of the South Island" DSIR (1968).*
2. *Elevations were taken from ECan LiDAR Collection Contour Map.*

4.1 Robinsons Bay

IT1 was carried out within a flat section and close to the coast. The soils encountered during the IT1 sub-surface infiltration test were consistent with the Barry Soil description. The topsoil at this site was dispersed with the subsurface layer, and there was root penetration throughout the topsoil layer with continuation into the yellow brown friable subsoil.

IT2 was also carried out within a flat section, further up Robinsons Bay Valley, approximately 30 m from the stream. The soils encountered in IT2 sub-surface infiltration test were consistent with the Barry Soil description. It is evident in the Photograph 2 (Appendix B) that there was a pale olive grey layer beneath the topsoil, and underlying this was yellow brown lightly mottled orange friable materials. Despite the shallow depth of topsoil, there was good root penetration in this excavation. It was observed in the bore hole installation that gravels were encountered at 1.5 m below ground level (bgl).

IT3 was within flat land, with a good depth of topsoil and root penetration continuing through the subsoil. The materials encountered in the sub-surface infiltration test were consistent with the Barry Soil description. This site was approximately 40 m from the stream, and again gravels were encountered at 1.5 m bgl.

IT4 was situated on a gentle slope. It appeared that the materials in the excavation for the sub-surface infiltration test more closely matched Takahe Soils, rather than Barry Soil. There was no pale olive grey beneath the topsoil, underlying the topsoil was yellow brown nutty friable material. There was root penetration throughout the topsoil layer with some continuation into the yellow brown friable subsoil.

IT5 were carried out upon a reasonably steep slope, and further up the hill were scattered rocky outcrops. The infiltration testing was carried out in a gently sloping section of this relatively steep land parcel. The soils encountered during the excavation for the sub-surface infiltration test were consistent with the Takahe Soil description.

In lieu of an environmental monitoring bore at the furthest site up the valley, a test pit (TP5) was excavated to a depth of 3.5 m bgl to identify the sub-surface materials. The strata were consistent with the Takahe Soil description. At approximately 1.5 and 2.3 m bgl a layer of slightly stiff silty layer, trace clays and light grey veins mottled orange were encountered.

4.2 Pompeys Pillar

IT8 was carried out on a relatively steep section of Pompeys Pillar. There was a very good depth of topsoil with root penetration continuing through the underlying soil. The materials encountered in the sub-surface infiltration test were consistent with Takahe Soils description.

IT9 was situated on a very gently sloping section, further up the hill were scattered rocky outcrops. It appeared that the materials in the sub-surface infiltration test more closely matched Takahe Soils. Similarly to observations in IT8, there was a good depth of topsoil, and underlying this was yellow brown mottled orange silty sand. There was some good root penetration throughout the topsoil layer with some continuation into this yellow brown mottled orange friable subsoil.

IT10 was carried out within a flat area close to the shearing sheds. The soils encountered in the sub-surface infiltration test were consistent with the Takahe Soil description. There was less topsoil than IT8 and IT9, however there was good root penetration throughout the topsoil layer with some continuation into the subsoil.

4.3 Summary

Consistently between all the sub-surface infiltration tests the topsoil was dark or very dark brown friable material with good root penetration. Topsoil at test locations IT1 – IT3 were underlain by a thin layer of pale olive grey silt, which is indicative of Barry Soils. This pale olive grey was not observed at areas with a higher elevation (IT4 and IT5, and IT8 – IT10). Topsoil at test locations IT4 and IT5, and IT8 – IT10 were underlain by a yellow brown mottled orange nutty friable silt material which is indicative of Takahe Soils.

Test locations IT1 – IT3 were located close to the stream that runs through Robinsons Bay Valley. The observed soils are consistent with the geological information in the Beca report and are indicative of alluvial materials. Materials encountered for the sub-surface infiltration test at IT1 – IT3 consisted of a more granular sandy silt material than at IT4 and IT5 and IT8 – IT10. It is presumed, due to the similar proximity to the coast, that the windswept loess material encountered at Pompeys Pillar was similar to those encountered within Takamatua Valley.

Overall, the geology that was observed during the site investigations were in line with the expectations of material recorded in the General Survey of Soils of the South Island (1968) and the PDP report ‘Hydrogeological Review for Proposed Akaroa Wastewater Treatment and Disposal (May 2016)’.

5.0 Infiltration Test Results

Sixteen infiltration tests were carried out at the locations shown in Figure 2A and 2C, Appendix A. To enable a comparative analysis of the land, the tests were carried out within low (alluvial) (IT1 – IT3), intermediate (loess colluvium) (IT 4 and IT5), and high (loess) (IT8 – IT10) areas. Over the week that infiltration testing was carried out, 37 mm of rain was recorded at the Akaroa electronic weather station (EWS) (36593) (Cliflo, 2016). This is not expected to have influenced the stabilised infiltration testing results.

The double ring infiltrometer was sunk in 100 mm at ground level or at the base of excavation. The depths of the excavations are recorded in Table 3. The excavations at the infiltration test locations indicated the presence of a lower permeability layer directly below the topsoil. The sub-surface infiltration testing was carried out within this lower permeability layer. The topsoil depth varied from location to location.

The surface infiltration rate measured in IT3 (Robinsons Bay) was much less than anticipated for the hill soils, and the subsoil infiltration rate measured was much faster than anticipated. It is possible that the infiltrometer for each test may not have been inserted far enough into the soils, and/or the proximity of the testing to the drill rig may have had some effect on the infiltration rates. For this reason, the infiltration results from IT3-surface and sub-surface are not thought to be representative of the land, and have been excluded from our analysis but have been included for completeness.

The results of the infiltration tests are shown in Table 3 below. The USEPA (1981) report that the double ring infiltration test can over-estimate the true infiltration rate by as much as 40%. Therefore, the likely saturated rates are in the order of 0 to 129 mm/hr.

Table 3: Infiltration Test Results

Infiltration Test ID	Location	Depth Below Ground Level (m bgl)	Test Duration (minutes)	Infiltration Rate (mm/hr)
IT1 - surface	Robinsons Bay	0	115	87
IT1 – sub-surface		0.42	92	11
IT2 - surface	Robinsons Bay	0	100	180
IT2 - sub-surface		0.55	90	33
IT3 - surface	Robinsons Bay	0	136	2
IT3 - sub-surface		0.52	122	229
IT4 - surface	Robinsons Bay	0	132	15
IT4 - sub-surface		0.35	108	4
IT5 - surface	Robinsons Bay	0	134	44
IT5 - sub-surface		0.48	110	11
IT8 - surface	Pompeys Pillar	0	115	16
IT8 - sub-surface		0.40	90	1
IT9 - surface	Pompeys Pillar	0	130	14
IT9 - sub-surface		0.44	90	1
IT10 - surface	Pompeys Pillar	0	100	11
IT10 - sub-surface		0.46	90	3

5.1 Summary

The observations indicate that all the land investigated is suitable for irrigation, although the areas with the poorly drained sub-soil may need to be limited to irrigation in summer, spring and autumn only. Measurements at IT4 and IT5 indicate areas with poorly drained sub-soils.

As discussed in Section 4, tests IT1 – IT3 were located close to the stream that runs through Robinsons Bay Valley and sub-surface soils were indicative of alluvial materials (these was seen in the cores recovered during bore installation). The stabilised infiltration rates at test locations IT1 – IT3 were faster than those measured at IT4 and IT5 and IT8 – IT10. The stabilised infiltration rates were slower through the less permeable surface and sub-surface loess material encountered at test locations IT4 and IT5 and IT8 – IT10.

The impacts of the measured infiltration rates for the potential irrigation options, in conjunction with the other factors, are discussed in Section 8.

6.0 Environmental Monitoring Bores

As discussed in the PDP report 'Hydrogeological Review for Proposed Akaroa Wastewater Treatment and Disposal (May 2016)', there is a large amount of uncertainty with regard to groundwater levels in the vicinity of the proposed WWTP. The depth to groundwater has been identified as being a potential limitation to the suitability of land for the disposal of treated wastewater. To address the uncertainty with respect to groundwater levels and confirm the viability of the various disposal options four environmental monitoring bores (BH1 – BH4) were installed in close proximity to infiltration test locations IT1 – IT3 (Robinsons Bay). Two bores (BH3 and BH4) were installed in the vicinity of test location IT3 as a result of the observed strata where a shallower gravel layer was observed between 1.5 m and 3.2 m bgl. BH3 was installed and screened within the underlying gravel layer, whilst BH4 was installed and screened within the near surface gravel lens. The purpose of the two wells was to determine which strata the groundwater table is present or whether the surface gravel layer may be a conduit and act as a perched groundwater table. In addition, two environmental monitoring bores (BH5 and BH6) were installed in Takamatua Valley to monitor the groundwater level at Takamatua, to supplement the investigations carried out by PDP in June 2016.

Photographs of these installed bores can be seen in Photograph 15 – 19, Appendix B. Table 4 summarises the installation information and the static water level (pre-development). Beca installed transducers within the bores to monitor the groundwater level for approximately one month (October 2016), except for BH4 which was dry.

Bores were not installed at Pompeys Pillar as it was assessed that groundwater would likely be located several metres down, either at the base of the loess material or in the underlying volcanic rocks. At this depth there would be no impact on the suitability of the site for irrigation. Figures 19 and 20 show the depth to groundwater for the bores in Robinsons Bay and Takamatua, respectively. This data was recorded and analysed by Beca.

Table 4: Environmental Monitoring Bores

Bore ID	Locations	Depth of Bore (m)	Elevation[1] (m above sea level)	Static Water Level[2] (m bgl)
BH1	Robinsons Bay	6.00	1.3	0.55
BH2	Robinsons Bay	4.40	12.5	2.34
BH3	Robinsons Bay	6.08	30.7	2.46
BH4	Robinsons Bay	3.04	30.7	Dry
BH5	Takamatua	4.56	9	0.47
BH6	Takamatua	3.00	34.4	1.30

Note:

1. *Elevations were taken from ECan LiDAR Collection Contour Map.*
2. *This level was recorded prior to development.*

The results show that for BH1 the depth to groundwater varied from about 0.3 m bgl to approximately 0.6 m bgl. The groundwater level appeared to respond to the rainfall between 26 to 29 September but did not respond to other rainfall events. It should be noted that the rainfall data is from the Akaroa EWS (36593) and it is possible that the daily rainfall at the locations of the boreholes differed from that at the weather station.

The data at BH1 shows that it is influenced to a small extent by the tide. Groundwater levels at BH2 have steadily declined despite a number of rainfall events, including 20 mm on 15 October 2016. Groundwater levels at BH3 have remained constant with no notable change over this period.

The depth to groundwater measured at BH1 may restrict the irrigation of the land adjacent to this bore as it could induce ponding. The depth to groundwater further up the valley (BH2 and BH3, and absence of groundwater at TP5 to 3.5 m bgl) appears to be sufficiently deep to not impact on the irrigation of treated effluent on that land. Shallow well BH4 was dry, however, the water level in BH3 was at the interface with the upper gravel lens. Further monitoring would be needed to determine if the upper gravel layer may act as a conduit or perched water table at times.

With regard to the bores installed in the Takamatua Valley, the bore closest to the coast (BH5) is located in close proximity to a roadside drain. The depth to groundwater is quite shallow and responds rapidly during rainfall events. This could potentially limit when land in this area could be irrigated. Further up the valley (BH6) the depth to groundwater increases to a depth that would not impact on the potential of this land to be irrigated.

7.0 Assessment of Land for Irrigation Purposes

The profile available water (PAW) is a measure of the amount of water potentially available for plant growth that can be stored within the rooting zone of the soil. This is generally reported for a depth of 600 mm for pasture and 1,000 mm for crops. However if there is a soil layer which limits root penetration (e.g. a pan) at a shallower depth then the PAW is modified to account for the restriction.

The PAW is derived from research, the interim assessment of soils for these locations was based on the information in the interim Canterbury soils maps in conjunction with the New Zealand Fundamental Soils (NZFS) layer of the ECan database.

The NZFS layer indicates the average PAW for Barry Soils is given as 200 mm with a range from 150 to 249 mm, and for Pawson Silt Loam and Takahe Soils the average PAW is given as 75 mm with a range from 60 to 89 mm.

7.1 Robinsons Bay

The infiltration testing carried out as discussed in Section 5.0 indicates that the surface and sub-surface soils at IT1 - IT3 are moderately draining. The surface soils at IT4 and IT5 are also moderately draining but the presence of the low permeability sub-surface soils observed in the excavations suggest that the sites may be susceptible to field saturation during the winter months which would limit the application rates. The high groundwater observed at BH1 could also limit the irrigation during the winter months, or at times of high rainfall.

The S-maps map identifies the soils in Robinsons Bay area as Mayfield*f* and Claremont*f* soil, which are described as deep and moderately deep silty loam (Mayfield*f* and Claremont*f* soils are also loess derived soils similar in nature to the Takahe and Pawson soils). The soil reports, attached in Appendix B, indicate that the potential soil rooting depth and depth to the slower permeability horizon is between 500 – 1000 mm and 500 - 900 mm respectively. According to the S - maps soil reports for the Mayfield*f* and Claremont*f* soil the PAW is 49 mm and 48 mm, respectively, within 0 – 300 mm of the surface or until a root barrier.

From the sub-surface infiltration tests that were carried out, the depth to the slow permeability horizon was measured between 90 – 120 mm bgl. At test locations IT1 - IT3 the potential soil rooting depth was more than the depth of topsoil, however the rooting depth at test locations IT4 and IT5 was approximately equal to the depth of soil. At test location IT5 the soils underlying the topsoil were somewhat friable and there was some root penetration into this material, but it did not seem that there was significant growth past this interface.

The PAW assumed and used in the preliminary assessment of the irrigation requirements (PDP May 2016) was 72 mm. After preliminary observations in Takamatua Valley (PDP June 2016), the rooting depth for the pasture appeared to be limited to the topsoil layer (150 to 270 mm bgl) and the PAW was reduced to 48 mm to allow a reassessment of the likely size of the irrigation system, storage ponds and drainage. The observations in Robinsons Bay Valley indicate that the rooting depth for the pasture at land adjacent to IT1 – IT3 is not as limited to the topsoil layer as those within close proximity to IT4 and IT5.

7.2 Pompeys Pillar

The infiltration testing, as discussed in Section 5.0, indicates that the surface soils are moderately draining. However, the presence of low permeability sub-surface soils may limit the application rate of treated wastewater. The S-maps map identifies the soils in Pompeys Pillar area as Claremont*f* soil, as detailed above.

From the excavations that were made to carry out sub-surface infiltration testing the depth to the slow permeability horizon was measured between 130 – 190 mm bgl. Some root penetration was observed into the underlying loess materials, but it did not seem that there was significant growth past the topsoil.

The PAW was reduced to 48 mm for Takamatua Valley after it was estimated from observations that the rooting depth for the pasture appeared to be limited to the topsoil layer. The soil observations in Pompeys Pillar resemble those made in Takamatua. The land where tests IT8 – IT10 were carried out had a good depth of topsoil but the rooting depth for the pasture seemed to be limited to the topsoil layer.

8.0 Impact of Investigations on Potential Irrigation

8.1 Robinsons Bay

The results indicate that there will be low permeability sub-soil layers present within the land identified near to test locations IT4 and IT5 which may be restrictive on the potential rooting depth and irrigation of the land. Based on the soil assessment, the S-maps data and the NZFS data, PDP recommends that a PAW value of 150 mm be used for land identified within the proximity to test locations IT1 - IT3 (Barry Soils) for further assessments of the irrigation area and storage requirements. For the land identified near to test locations IT4 and IT5, a PAW value of 48 mm should be used (Pawson Hills Soils). Due to the lower rooting depth, these PAW values are consistent with the lower end of the PAW range supplied in the NZFS layer. These different irrigable areas are shown in Figure 21 and 22, Appendix A.

As reported in ‘Infiltration Testing Results for Akaroa Wastewater Disposal Via Irrigation (June 2016)’ the initial proposed irrigation rates were based on irrigation rates used for Wainui. Most of the sites investigated for this report are located on moderately steep lower slopes of Banks Peninsula volcanics with a thick loess cover and were expected to have similar ground conditions to the chosen Wainui irrigation sites, which were confirmed during the assessment of soils. The land area around test locations IT1 - IT3 are on flatter land which is more alluvial in nature with potentially higher infiltration rates. Test locations IT4 and IT5 were located on steeper slopes.

For Wainui, where a pine plantation is irrigated, PDP assessed that the weekly application depths should not exceed 37.5 mm/week in summer and 17.5 mm/week in winter. The measured infiltration rates during the assessment of Wainui ranged between 20 mm/hr to 49 mm/hr (surface soils) and 3 mm/hr to

30 mm/hr (sub-surface soils). Discounting the unusual infiltration results IT3 (surface and sub-surface), these are similar to the measured infiltration rates for the hill soils at Robinsons Bay and Pompeys Pillar. The testing at Robinsons Bay (IT1 – IT5) indicated topsoil infiltration rates of between 14 - 185 mm/hr, whereas the infiltration rates of the sub-surface soil ranged from 4 - 33 mm/hr. The bulk hydraulic conductivity of the loess in the area is of a similar magnitude to Wainui. As a precautionary approach PDP recommends that similar values should be used for the continued assessment of the potential for irrigation until sufficient land has been secured for irrigation. If this land includes land around test locations IT1 - IT3, then higher weekly application depths may be considered during detailed design.

As suggested in 'Infiltration Testing Results for Akaroa Wastewater Disposal Via Irrigation (June 2016)' the irrigation of the hilly land around where tests IT4 and IT5 were carried out may be suited to more frequent applications and lower application depths to minimise the potential for ponding to occur on the low permeability layer. If ponding were to occur the soils may become saturated, which can impact the soil structure and risk of runoff from the land. As the poorly drained layers are relatively close to the soil surface it may be possible to deep rip these soils to help improve the sub-soil drainage allowing higher application rates and the potential to irrigate all year if required.

The greater PAW of Barry Soils as observed at test locations IT1 - IT3 could impact on the management of irrigation (area irrigated and storage required) compared with previous estimates. The preliminary groundwater level data in BH1 indicates that groundwater can be relatively close to the surface. Shallow groundwater could limit the irrigation depth at this site. Based on the recorded data to date the groundwater level appears to be influenced by the rainfall and water level in the nearby stream but does seem to be generally declining. Comparatively, at BH2 and BH3 the depth to groundwater is greater than 1.9 m bgl. Traditionally in Canterbury the highest groundwater levels are associated with winter recharge and occur in late the September to October period. Therefore, the groundwater data suggests that the water level is on the decline and that the peak water levels for this year have already occurred. Note this is based on one month's data and some weather extremes may result in changes to this. It is unlikely that shallow groundwater will restrict irrigation on land adjacent to test locations IT2, IT3, IT4 and IT5 but may restrict irrigation on the low lying land near test location IT1, particularly after heavy rainfall or in late winter, early spring. The groundwater level in these wells will continue to be monitored and this will provide greater certainty of any limitations the depth to groundwater may impose on the irrigation of this area. For those areas with high groundwater, it may be necessary to determine what the acceptable depth to groundwater is before irrigation ceases. For example, the discharge of treated effluent at the Blenheim sewage treatment plant irrigation site ceases irrigation when groundwater is within 300 mm of the ground surface.

The irrigation of pasture would normally be carried out on an irrigation rotation where part of the area is irrigated each day. The PAW of the Barry Soils at land adjacent to IT1 - IT3 is estimated at 150 mm, and land adjacent to IT4 and IT5 is estimated at 48 mm for the Pawson Hills Soils. It is not normally acceptable to apply more than half the PAW in a single application (i.e. 75 mm and 24 mm respectively). Therefore, as an initial design estimate it is likely that the irrigation area would be split into a minimum of five zones with a maximum application depth of 75 mm and 24 mm respectively.

8.2 Pompeys Pillar

The results indicate that there will be low permeability sub-soil layers present within the Pompey Pillar land, as observed in IT8 – IT10, which limits the potential rooting depth. Based on the soil assessment, the S-maps data and the NZFS data PDP recommend a PAW of 48 mm should be used for this land, if chosen for detailed design. This is a conservative estimate as this PAW value is consistent with the lower end of the PAW range in the NZFS layer on the ECan database.

The testing at Pompeys Pillar (IT8 – IT10) indicated topsoil infiltration rates of between 9 - 16 mm/hr and sub-soil infiltration rates of 1 - 3 mm/hr.

8.3 Hydrophobicity of Soils

As reported in 'Infiltration Testing Results for Akaroa Wastewater Disposal Via Irrigation (June 2016)' the surface infiltration rates (mm/hr) are sufficiently high that spray irrigation can be used with minimal chance of instantaneous runoff when the soils are moist. However, if the soils are allowed to dry out then most New Zealand soils can be described as repellent to moisture. The initial application of irrigation (or rainfall) does not penetrate but sits on the surface and could result in some runoff. This can be accounted for by testing the how strongly the soil repels the soil (hydrophobicity) prior to detailed design.

Further testing to determine the hydrophobicity of the soils and a water balance assessment are suggested before a recommendation could be made as to whether a higher application depth could be considered acceptable.

9.0 Soil Moisture Modelling

9.1 Estimation of Land Area and Storage Requirements at Robinsons Bay

An initial soil moisture balance was performed to determine the effectiveness of the land that had been chosen for the potential irrigation of treated wastewater to pasture. Based on the S-maps GIS information that was entered into the soil moisture balance model, the depth to the impeded drainage layer and the maximum rooting depth was 710 mm. From these inputs the profile available water (PAW) was calculated to be 72 mm. After observations in the field, it has been increased to 150 mm for Barry Soils, and as per observations in Takamatua the PAW is 48 mm for Pawson Hills Soils. The NZLRI soil polygons were used to differentiate between the areas with different PAW values. The total irrigable area for drip irrigation is approximately 55.61 ha and for K-line irrigation is approximately 42.56 ha. The irrigation to trees option, as previously discussed, is not limited by the PAW. Previously it has been estimated that a minimum of 27 ha is required for pasture irrigation. It is considered that within the land identified at Robinsons Bay there is at least 27 ha of land that can be used for year round irrigation.

PDP has re-run the soil moisture balance modelling on that basis with the new soil types and found that a maximum storage volume of 35,000 m^3 is required. This has not changed from the previous estimated volume as a result of very wet periods not allowing irrigation regardless of the soil type and PAW. As discussed in the 'Infiltration Testing Results for Akaroa Wastewater Disposal via Irrigation' (PDP, June 2016), year round irrigation could be achieved either by obtaining sufficient irrigable land or modifying the permeability of identified land. It is recommended that the low lying area (i.e. IT1/BH1) be excluded from year round irrigation due to the potentially high groundwater, but the potential to modify the permeability (e.g. by ripping) of Pawson Hill Soils (i.e. IT4 and IT5) could enable year round irrigation to the remaining land within Robinsons Bay.

9.2 Estimation of Soil Drainage at Robinsons Bay

When water (rainwater or irrigation) occurs when the soil water holding capacity is full then water either ponds and runs off or drains through the soil to the underlying groundwater. This impacts on the risk to the land stability and also results in the leaching of nutrients (particularly nitrogen in the form of nitrates) to the groundwater. Irrigation increases the drainage from the topsoil compared with when there is no irrigation. From the soil moisture balance for the current un-irrigated situation the annual drainage is estimated to average 216 mm. Table 5 shows the average annual drainage for the irrigable area of 27 ha.

Table 5: Drainage for Pasture Irrigation	
Irrigation	**Average Annual Drainage (mm/year)**
	27 ha
No irrigation	216
Drip	448
K-line	401

For the drip irrigation options the drainage increases by 232 mm for 27 ha and for the spray irrigated options the drainage increases by 185 mm.

The soil moisture balance was carried out using the combined rainfall and evapotranspiration data measured from 2008 to 2015 at the Akaroa EWS) and forecasted data from NIWA's virtual climate station network (Stn 20249, NIWA VCNS) from 1972 to 2016. The Ministry for the Environment's (MfE) Climate Change Projections for New Zealand (2016) reports that the annual precipitation changes for the Canterbury region for four different representative concentration pathways ranges (RCP) between 0 – 1 % change between 1986–2005 and 2031–50. Annual precipitation for the Canterbury region may not vary significantly, but it is expected that the rainfall intensity of extreme events could increase. It is difficult to determine how detrimental the change in magnitude of extreme rainfall events will affect the Banks Peninsula region in 2040 (design horizon), but it appears that the change in magnitude will not materially impact the estimated storage requirements and annual drainage.

9.3 Estimation of Land Area and Storage Requirements at Pompeys Pillar

The soils observed at Pompeys Pillar are similar to those at Takamatua Peninsula, except that the sub-surface infiltration rates are consistently low. However, there is much more land available (93 ha) than the minimum 27 hectares required for pasture irrigation. With a combination of deep ripping of the soils and an increased irrigation area, all year round irrigation could occur at this location. On this basis an estimated 35,000 m^3 of storage would be required.

10.0 Recommendations

The results indicate that irrigation of the sites investigated will be possible. The depth to groundwater may limit irrigation in the low lying area (i.e. IT1/BH1) in Robinsons Bay and the permeability of the Pawson Hills sub-soil may be modified by deep ripping to allow for year round irrigation Pompeys Pillar. Overall the depth to groundwater and soil types at Robinsons Bay indicates that this land would be preferred for irrigation compared with the land at Pompeys Pillar.

To further estimate the area required for irrigation (and subject to a preferred irrigation method) the following parameters are recommended:

- For Barry Soils the PAW = 150 mm;
- For Pawson Hills Soils the PAW = 48 mm;
- Application Rates for irrigation to trees should not exceed 37.5 mm/week in summer, and 17.5 mm/week in winter;
- Application Rates for irrigation to pasture should not exceed 7 mm/day in summer;

- Irrigation to pasture to the low lying area (represented by IT1), should be limited to periods when the depth to groundwater will not result in ponding of treated effluent; and

More detailed investigations of the soils and groundwater conditions will be required prior to detailed design (subject to a preferred irrigation method and the selected site) to confirm:

- Application Rates (mm/hr) by measuring the hydrophobicity of the soil;
- Application depths (mm) and return periods; and
- Extent of low permeability layers over selected irrigation areas and potential to modify the permeability (e.g. by ripping).
- The depth to groundwater which will not result in ponding of treated effluent. The depth can be determined by further testing of the permeability of the soil and gravel layer in which the groundwater can be found along with continued monitoring of the depth to groundwater.

These tests are in addition to general agricultural soil tests to determine the current nutrient state of the soils and appropriate measures to maximise growth of trees or pasture to maximise nutrient and water uptake from the applied treated wastewater.

11.0 Limitations

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of site investigations at discrete locations, and mapped ground slope information provided by Beca. The results from the site investigations, observations and deductions may not truly represent the entire area identified as being suitable for irrigation of treated wastewater to land. PDP has not independently verified the provided information from Beca and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Beca for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

12.0 References

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Yours faithfully

PATTLE DELAMORE PARTNERS LIMITED

Prepared by

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Environmental Engineer

Reviewed by

Andrew Brough
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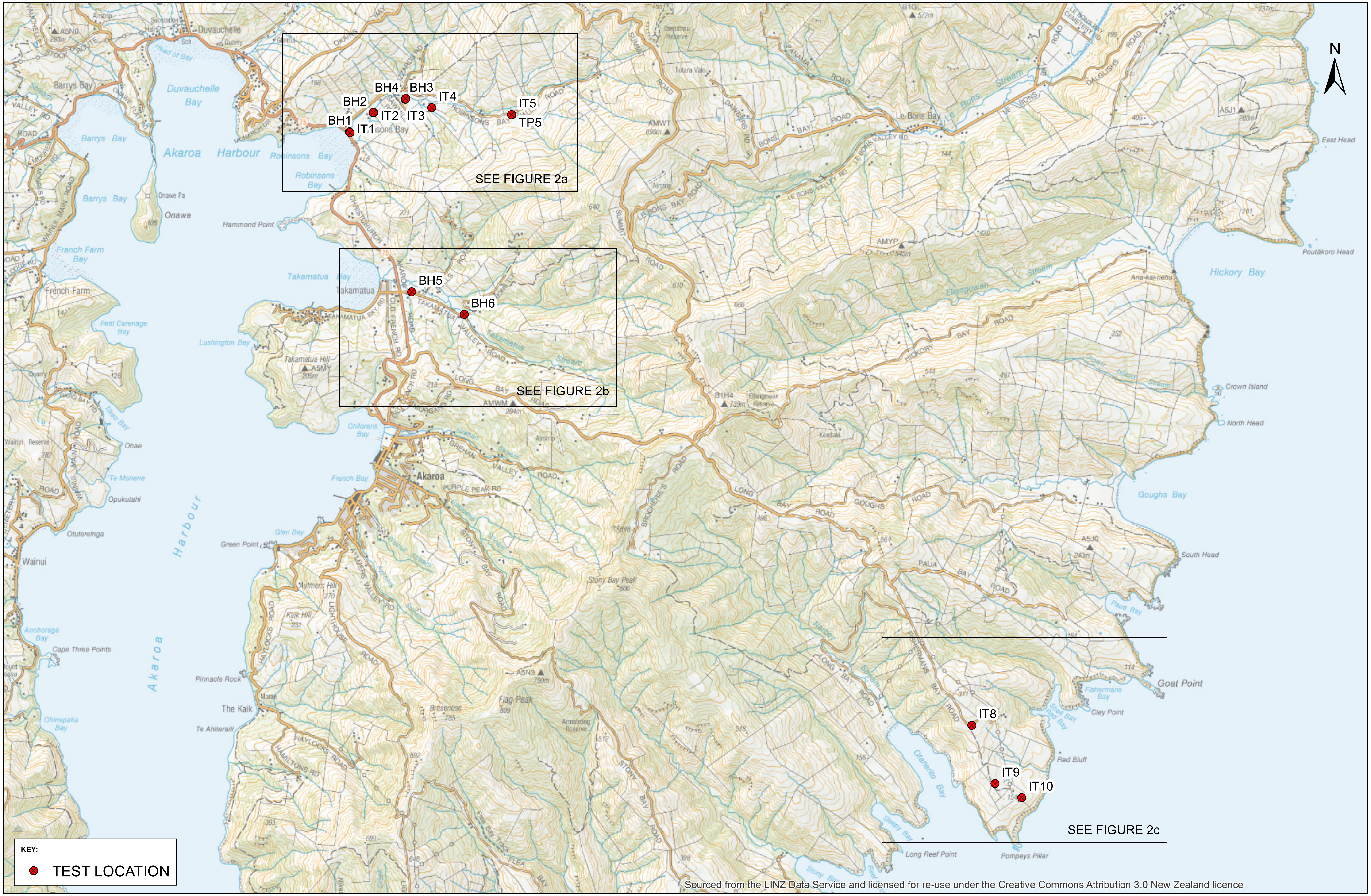
Approved by

Scott Wilson
Technical Director – Contaminated Land

Appendix A: Figures



SOURCE:
1. AERIAL IMAGEYRY SOURCED FROM CANTERBURY MAP PARTNER (ADMINISTERED BY ECAN). MAY NOT BE SPATIALLY ACCURATE

FIGURE 1: TEST LOCATIONS

SCALE: 1:50,000 (A3)

0 1 2 3 4
Kilometers

SOURCE:
1. AERIAL IMAGEYRY SOURCED FROM CANTERBURY MAP PARTNER (ADMINISTERED BY ECAN). MAY NOT BE SPATIALLY ACCURATE

FIGURE 2A: ROBINSONS BAY INFILTRATION TEST AND BORE LOCATIONS

SCALE: 1:7,500 (A3)

0 100 200 300 400
METRES

SOURCE:
1. AERIAL IMAGEYRY SOURCED FROM CANTERBURY MAP PARTNER (ADMINISTERED BY ECAN). MAY NOT BE SPATIALLY ACCURATE

FIGURE 2B: TAKAMATUA VALLEY BORE LOCATIONS

SCALE: 1:2,500 (A3)

0 50 100 150 200
METRES

SOURCE:
1. AERIAL IMAGEYRY SOURCED FROM CANTERBURY MAP PARTNER (ADMINISTERED BY ECAN). MAY NOT BE SPATIALLY ACCURATE

FIGURE 2C: POMPEYS PILLAR INFILTRATION TEST LOCATIONS

SCALE: 1:6,000 (A3)

0 100 200 300 400
METRES

Infiltration Test Plots

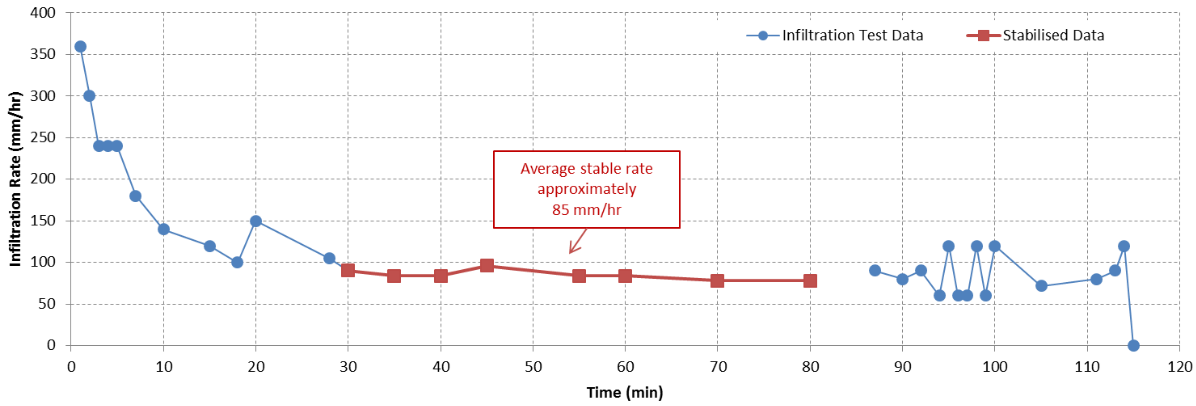


Figure 3: Infiltration Rate during Test IT1:surface.

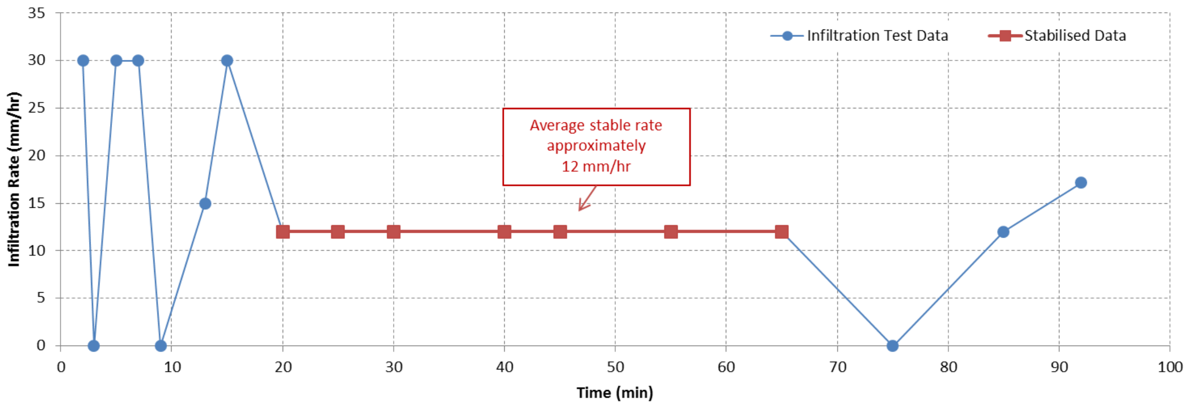


Figure 4: Infiltration Rate during Test IT1:sub-surface.

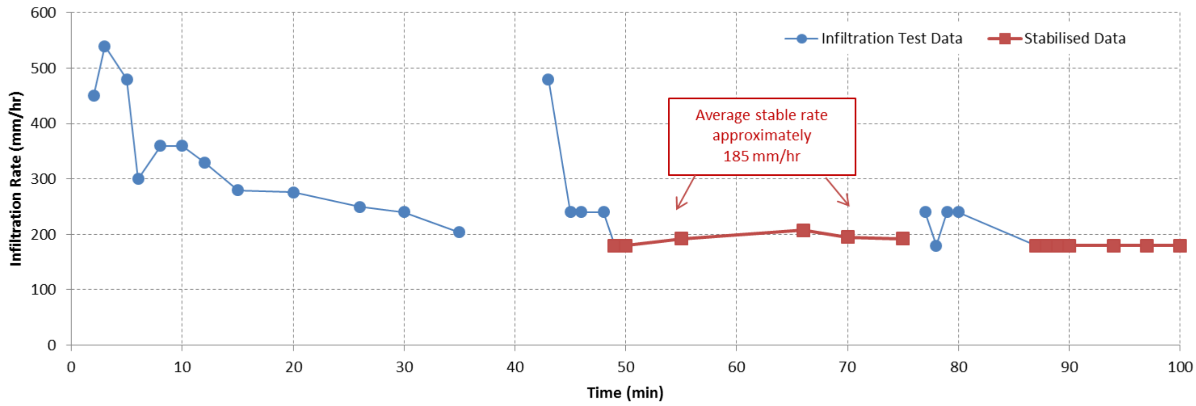


Figure 5: Infiltration Rate during Test IT2:surface.

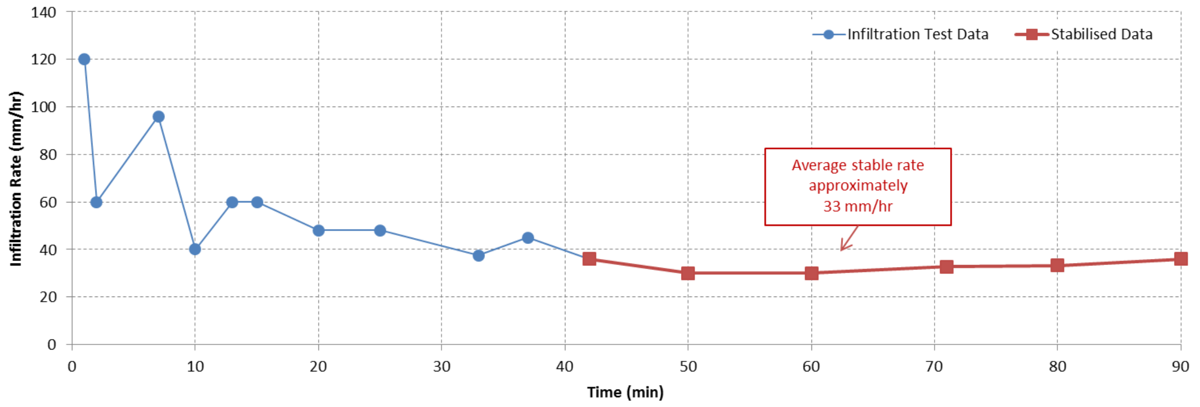


Figure 6: Infiltration Rate during Test IT2:sub-surface.

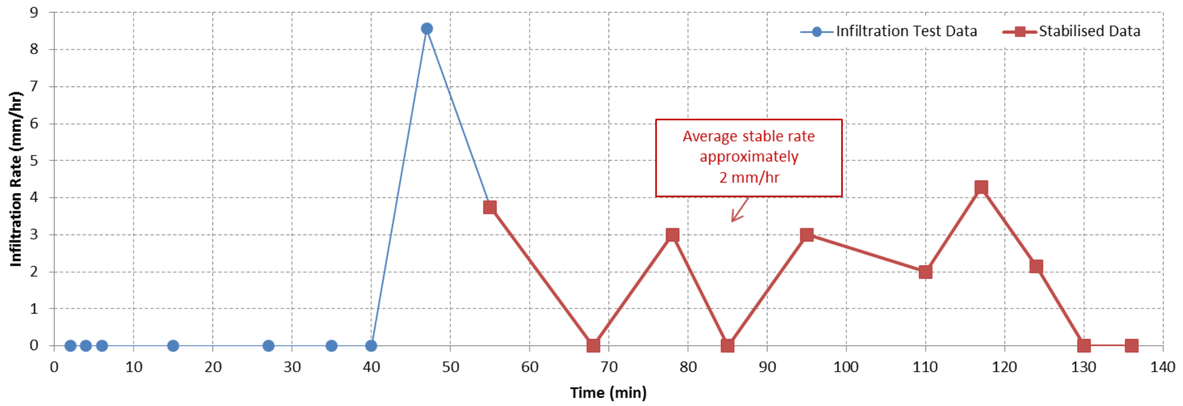


Figure 7: Infiltration Rate during Test IT3:surface.

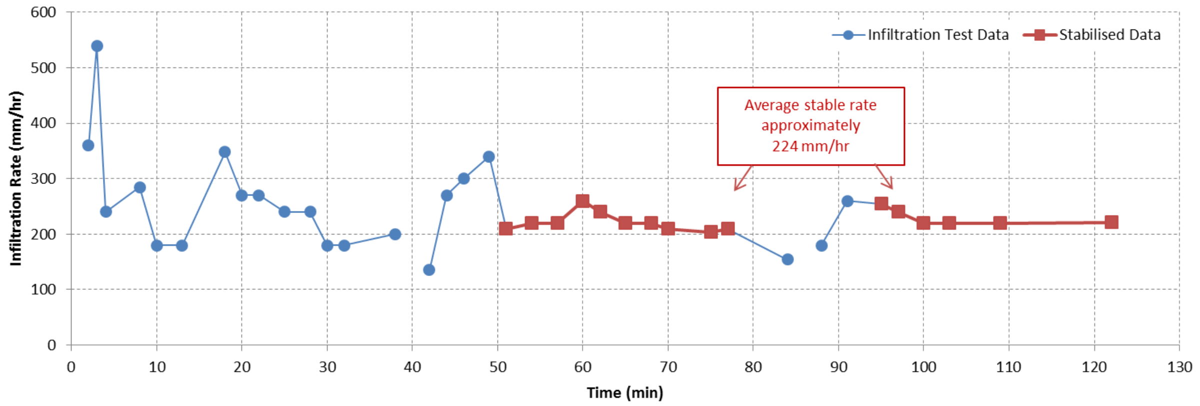


Figure 8: Infiltration Rate during Test IT3:sub-surface.

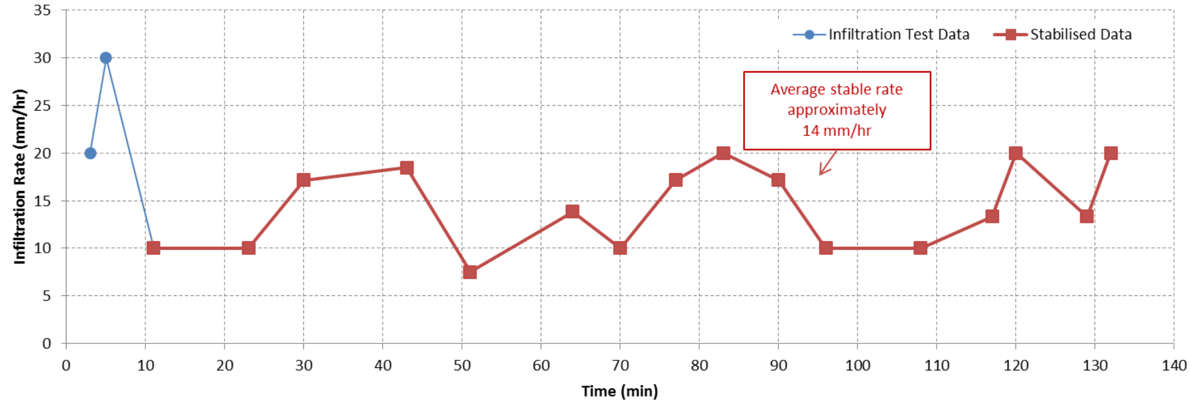


Figure 9: Infiltration Rate during Test IT4:surface.

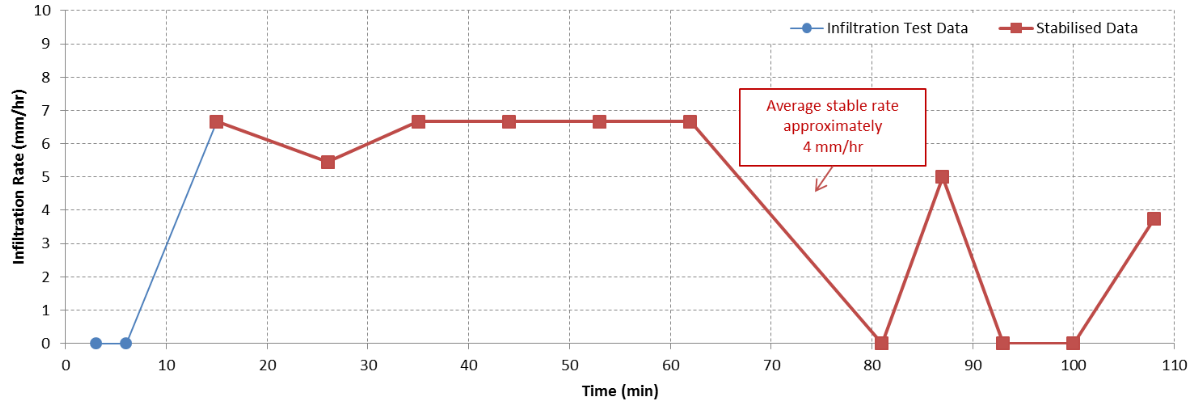


Figure 10: Infiltration Rate during Test IT4:sub-surface.

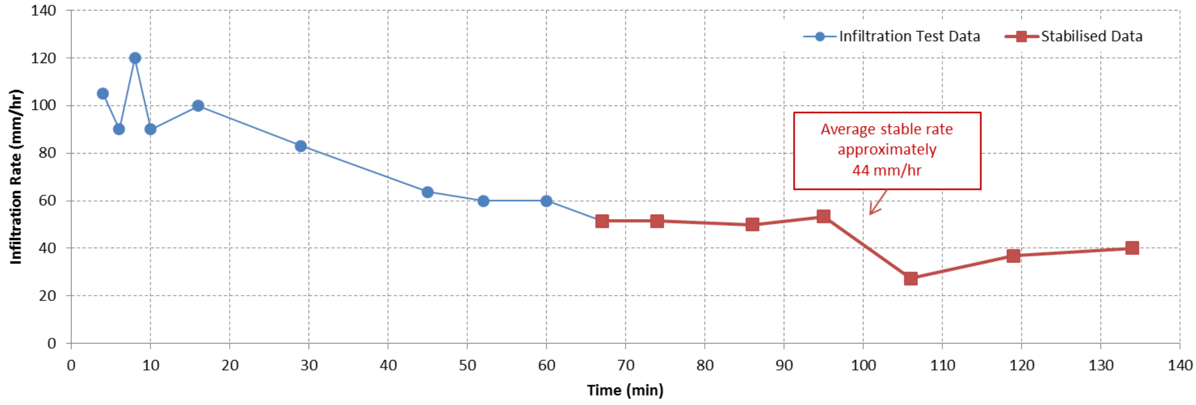


Figure 11: Infiltration Rate during Test IT5:surface.

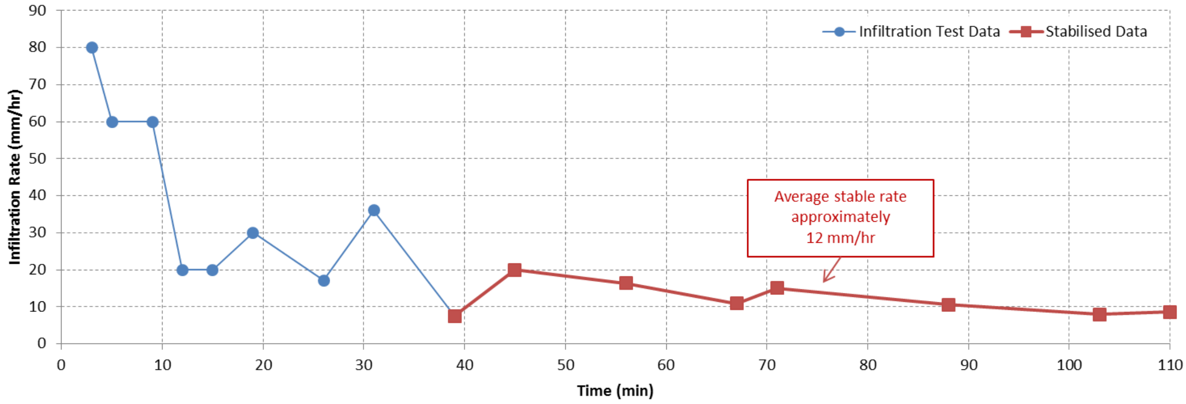


Figure 12: Infiltration Rate during Test IT5:sub-surface.

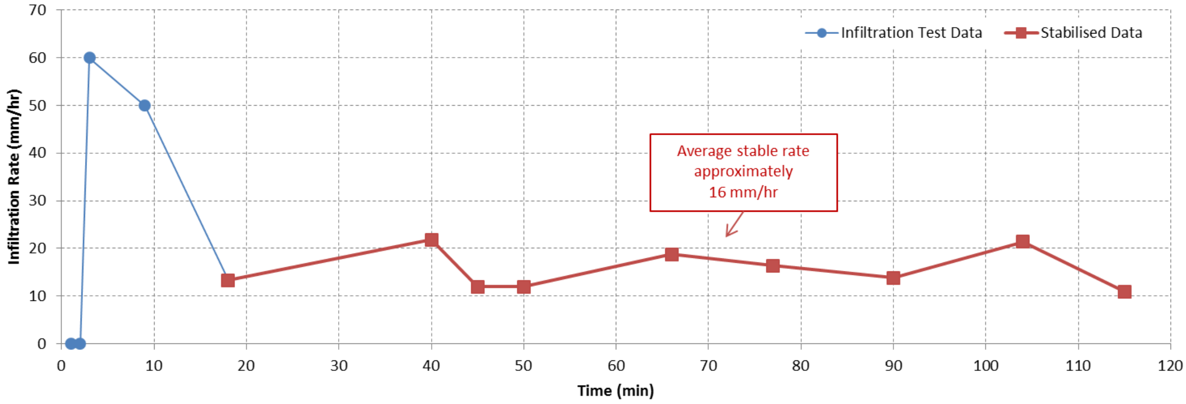


Figure 13: Infiltration Rate during Test IT8:surface.

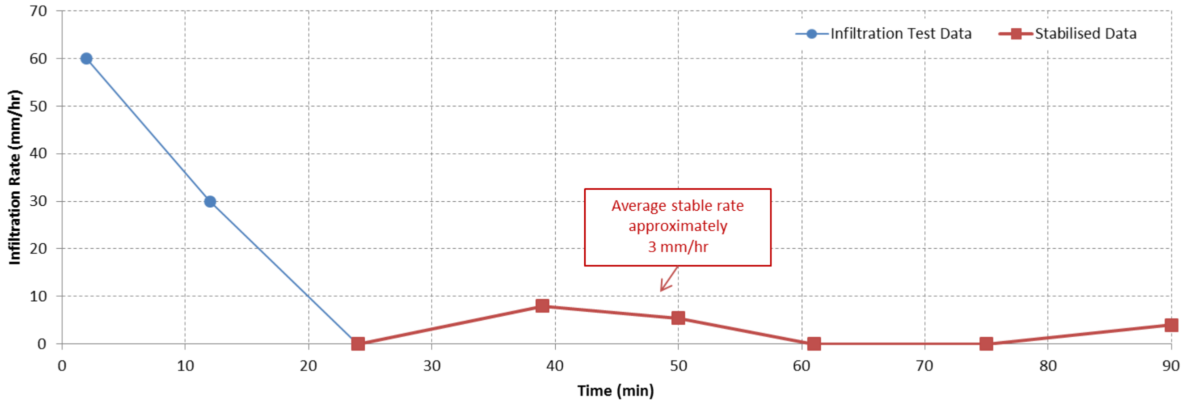


Figure 14: Infiltration Rate during Test IT8:sub-surface.

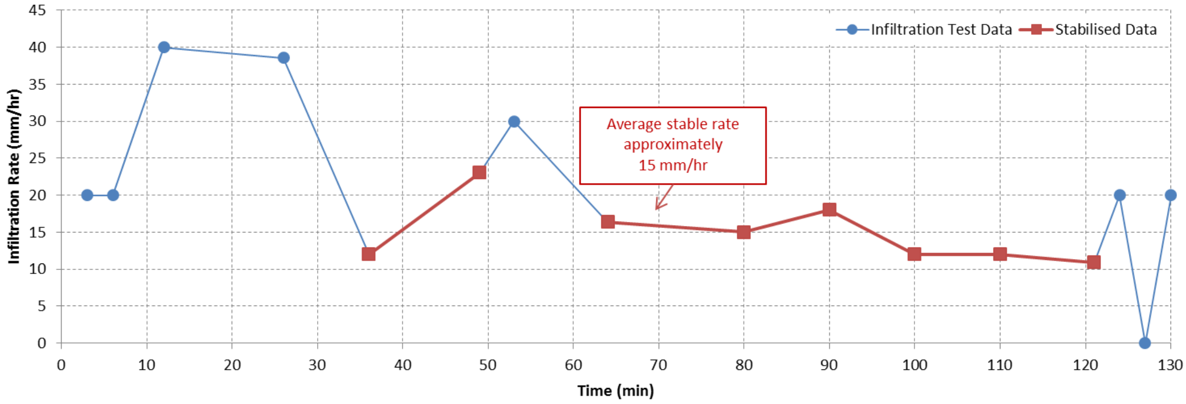


Figure 15: Infiltration Rate during Test IT9:surface.

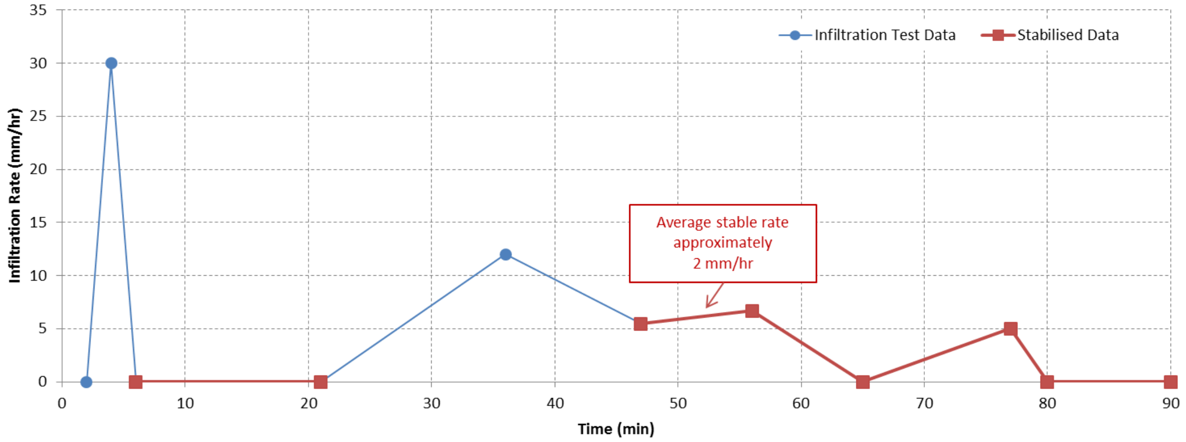


Figure 16: Infiltration Rate during Test IT9:sub-surface.

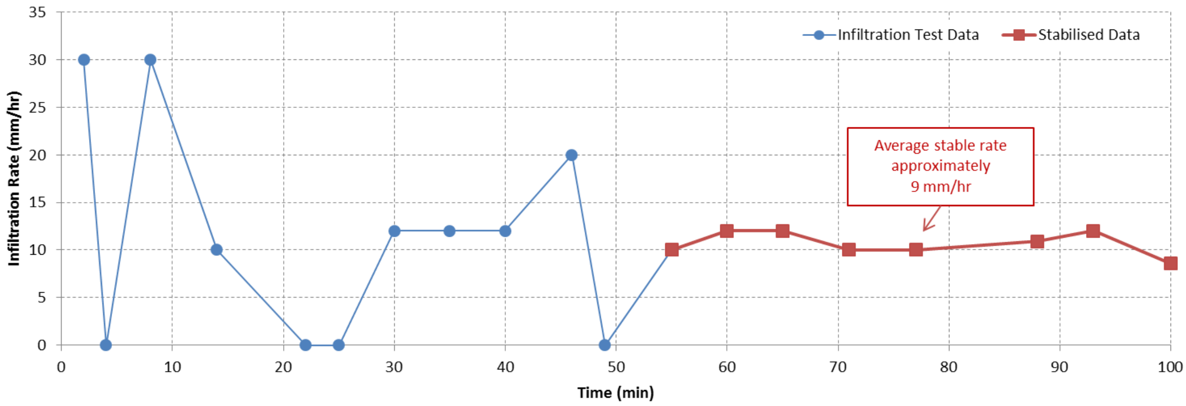


Figure 17: Infiltration Rate during Test IT10:surface.

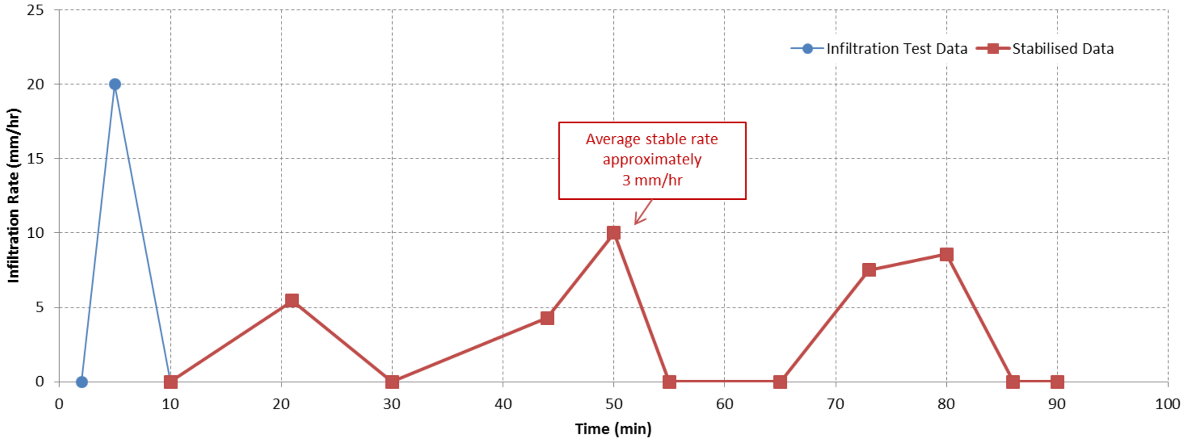


Figure 18: Infiltration Rate during Test IT10:sub-surface.

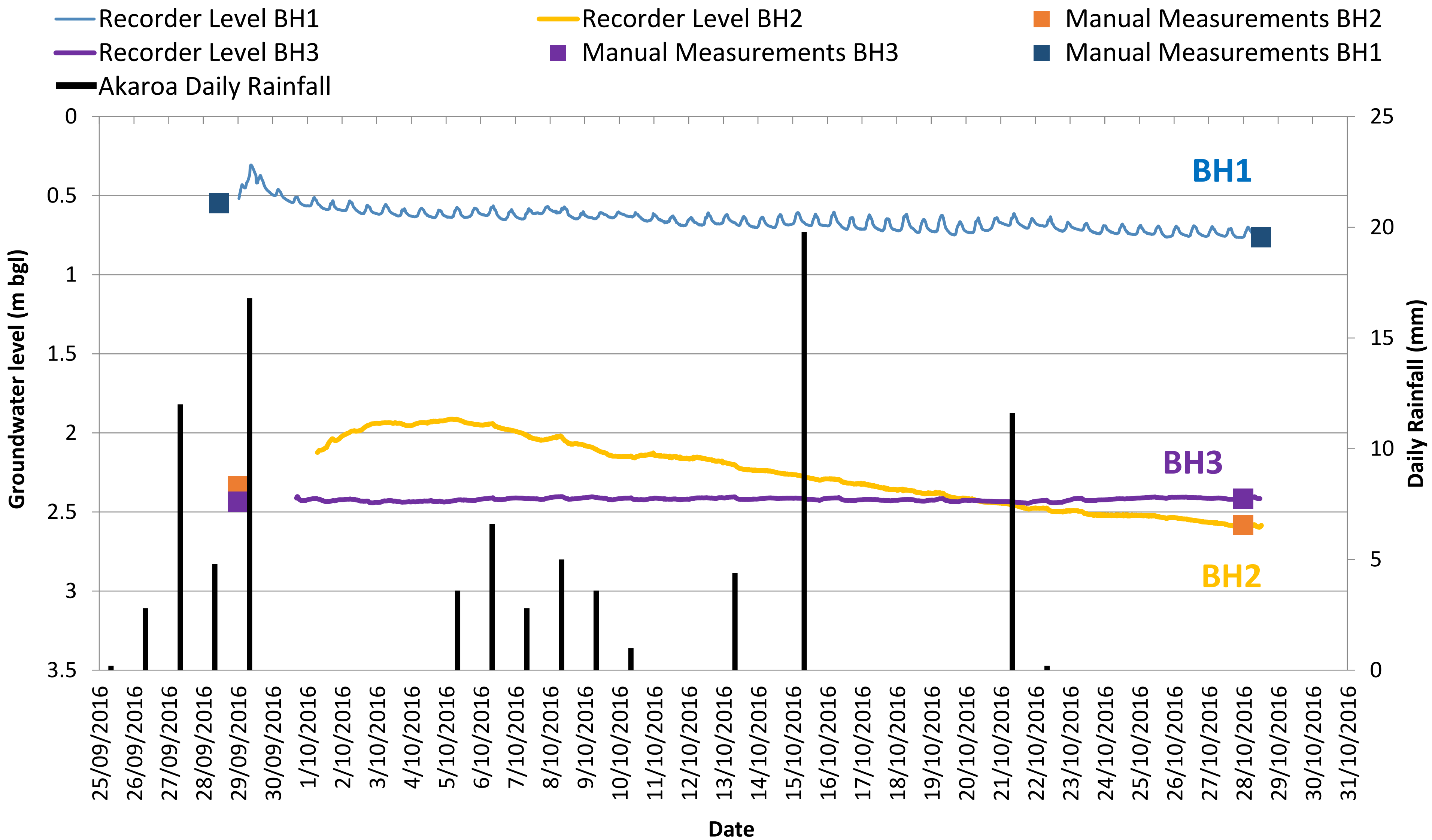


Figure 19 : Groundwater levels Robinsons Bay (Bore 1 – 3)

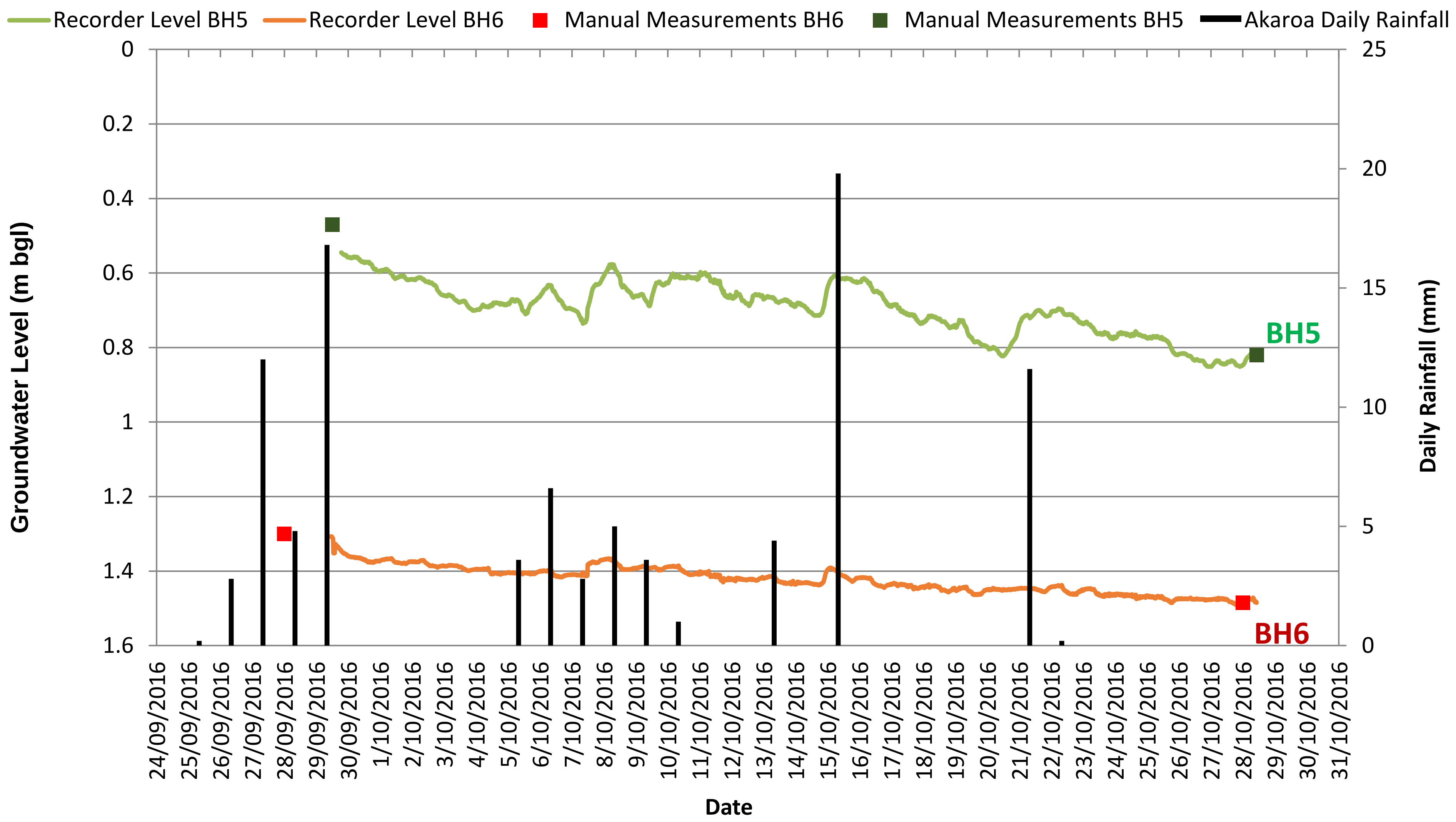
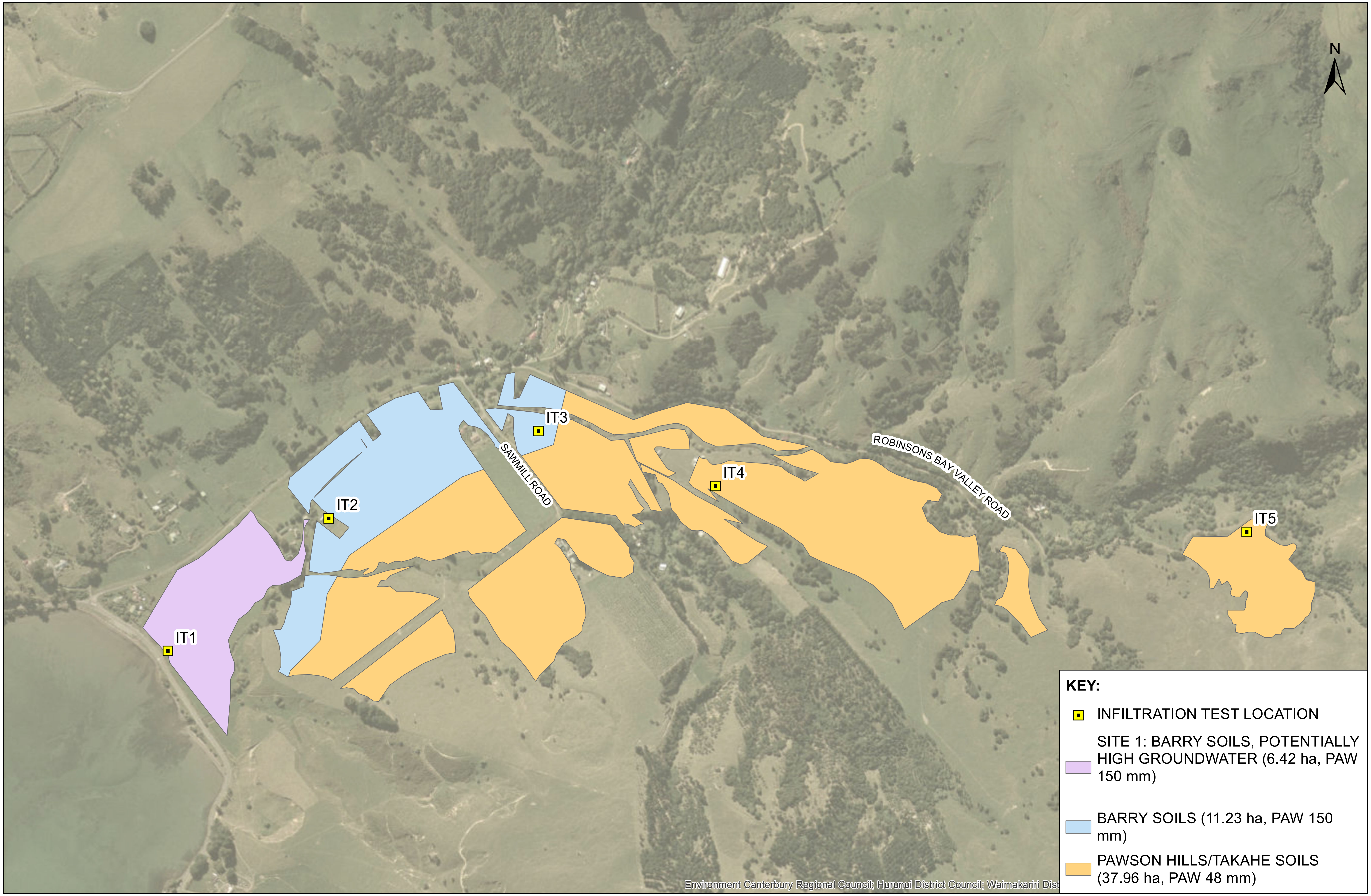
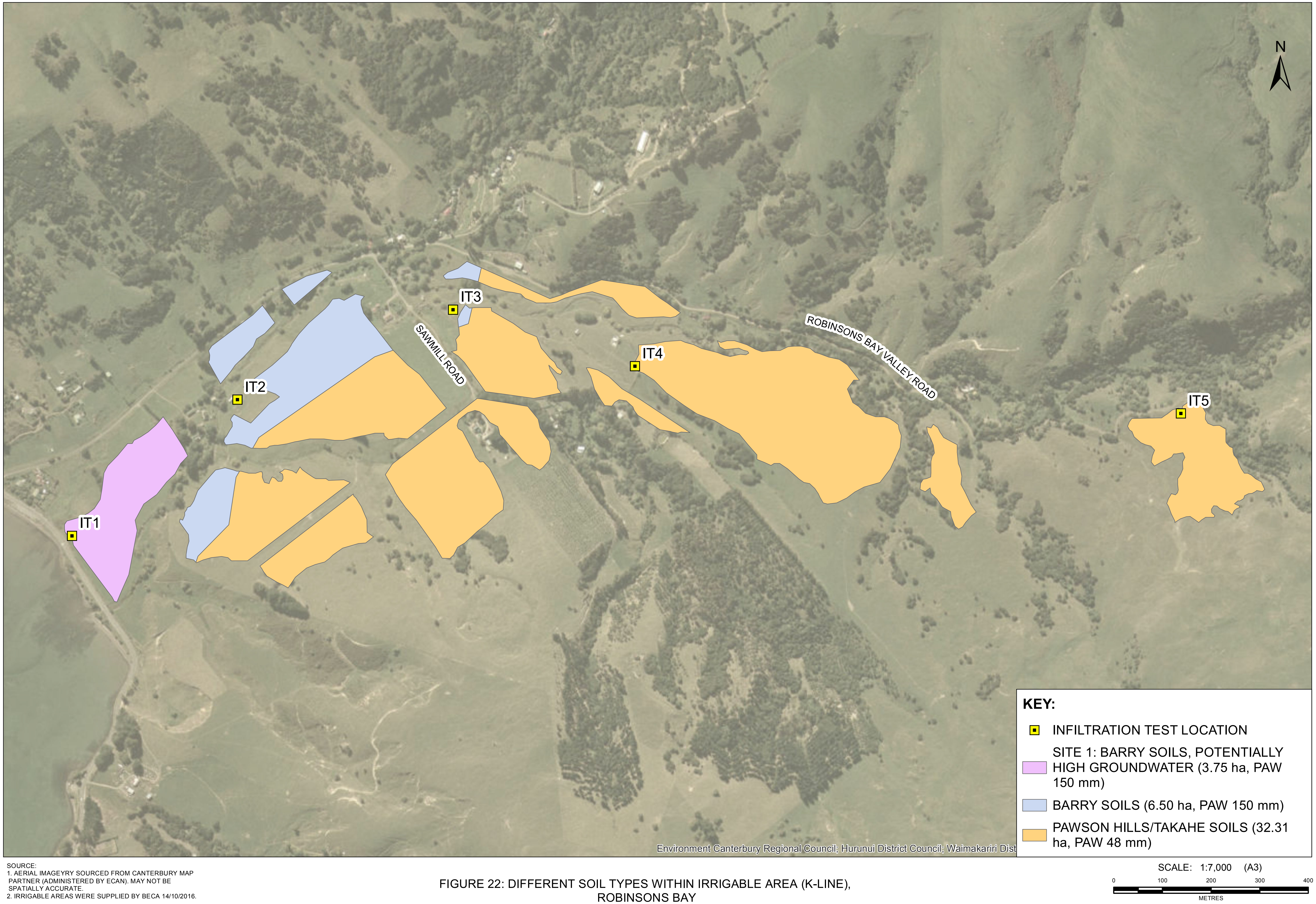


Figure 20 : Groundwater levels Robinsons Bay (Bore 5 – 6)



SOURCE:
1. AERIAL IMAGEYRY SOURCED FROM CANTERBURY MAP PARTNER (ADMINISTERED BY ECAN). MAY NOT BE SPATIALLY ACCURATE.
2. IRRIGABLE AREAS WERE SUPPLIED BY BECA 14/10/2016.

FIGURE 21: DIFFERENT SOIL TYPES WITHIN IRRIGABLE AREA (DRIP), ROBINSONS BAY



SOURCE:
1. AERIAL IMAGEYRY SOURCED FROM CANTERBURY MAP PARTNER (ADMINISTERED BY ECAN). MAY NOT BE SPATIALLY ACCURATE.
2. IRRIGABLE AREAS WERE SUPPLIED BY BECA 14/10/2016.

FIGURE 22: DIFFERENT SOIL TYPES WITHIN IRRIGABLE AREA (K-LINE), ROBINSONS BAY

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Appendix B: Photographs

Photograph 1: Infiltration Test IT1 surface infiltration test within Robinsons Bay (Site 1).

Photograph 2: Infiltration Test IT1 sub-surface infiltration test within Robinsons Bay (Site 1).

Photograph 3: Infiltration Test IT2 sub-surface infiltration test within Robinsons Bay (Site 2), surface test IT2 not shown..

Photograph 4: IT3 sub-surface pit within Robinsons Bay (Site 3), surface test IT3 not shown.

Photograph 5: Infiltration Test IT4 surface and subsurface within Robinsons Bay (Site 4).

Photograph 6: Site 4 surrounding land.

Photograph 7: Infiltration Test IT5 surface within Robinsons Bay (Site 5).

Photograph 8: Infiltration Test IT5 sub-surface pit within Robinsons Bay (Site 5).

Photograph 9: Infiltration Test IT8 surface test within Pompeys Pillar (Site 8).

Photograph 10: Infiltration Test IT8 sub-surface test within Pompeys Pillar (Site 8).

Photograph 11: Infiltration Test IT9 surface and sub-surface test within Pompeys Pillar (Site 9).

Photograph 12: Infiltration Test IT9 sub-surface test pit within Pompeys Pillar (Site 9).

Photograph 13: Infiltration Test IT10 surface and sub-surface tests within Pompeys Pillar (Site 10).

Photograph 14: IT10 sub-surface pit within Pompeys Pillar (Site 10).

Photograph 15: BH1, Robinsons Bay (Site 1).

Photograph 16: BH2, Robinsons Bay (Site 2).

Photograph 17: BH3 (right) and BH4 (left), Robinsons Bay (Site 3).

Photograph 18: BH5, Takamatua Valley Road (revised Site 6).

Photograph 19: BH6, Old Le Bons Track (Site 7).

Appendix C: S-maps Soil Report

S O I L   R E P O R T

Report generated: 4-Oct-2016 from http://smap.landcareresearch.co.nz

Family: Mayfield*f*

Mayfield*f* deep silty loam over clay

***** Important *****
Please read the limitations section on page 1.

Smap ref: Mayf_22a.1

Key physical properties

Depth class (diggability)		Deep (> 1 m)
Texture profile		Silty loam over clay
Potential rooting depth		Unlimited
Rooting barrier		No significant barrier within 1 m
Topsoil stoniness		Stoneless
Topsoil clay range		18 - 25 %
Drainage class		Moderately well drained
Aeration in root zone		Slightly limited
Permeability profile		Moderate over slow
Depth to slowly permeable horizon		50 - 100 (cm)
Permeability of slowest horizon		Slow (< 4 mm/h)
Profile available water	(0 - 100cm or root barrier)	Moderate to high (128 mm)
	(0 - 60cm or root barrier)	Moderate (84 mm)
	(0 - 30cm or root barrier)	Moderate (49 mm)
Depth to hard rock		No hard rock within 1 m
Depth to soft rock		No soft rock within 1 m
Depth to stony layer class		No significant stony layer within 1 m

Key chemical properties

Topsoil P retention	Low (19%)

Limitations

This S-map factsheet has been associated with a polygon from the interim soil layer which is of lower accuracy than S-map. The NZLRI polygon linework has a nominal scale 1:63,360 but for inland Canterbury, NZLRI soils are based on the General Soil Survey of the South Island 1:253,440 scale ("4 inch to mile") that mapped soil sets rather than soil types. Thus the soil information contained in this factsheet may not accurately represent the actual soil at this location.

About this publication

- This information sheet describes the *typical average properties* of the specified soil.
- For further information on individual soils, contact Landcare Research New Zealand Ltd: www.landcareresearch.co.nz
- Advice should be sought from soil and land use experts before making decisions on individual farms and paddocks.
- The information has been derived from numerous sources. It may not be complete, correct or up to date.
- This information sheet is licensed by Landcare Research on an "as is" and "as available" basis and without any warranty of any kind, either express or implied.
- Landcare Research shall not be liable on any legal basis (including without limitation negligence) and expressly excludes all liability for loss or damage howsoever and whenever caused to a user of this factsheet.

Family:Mayfield *f*

Mayfield*f* deep silty loam over clay

*** Important ***
Please read the limitations section on page 1.

Smap ref: Mayf_22a.1

Additional factors to consider in choice of management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

Contaminant management

MGM N Loss Category	Medium (on the plains and downs)
MGM P Loss Category	No significant pathways
N leaching vulnerability	Medium
P leaching vulnerability	Medium
Relative Runoff Potential	Very low
Bypass flow	Medium
Dairy effluent (FDE) risk category	D
Septic tank installation category	B3

Additional information

Soil classification	Typic Argillic Pallic Soils (PJT)
Family	Mayfield*f*
Sibling number	22
Profile texture group	Silty
Soil profile material	Stoneless soil
Rock class of stones/rocks	Not applicable
Rock origin of fine earth	From hard sandstone rock
Parent material origin	Alluvium

Characteristics of functional horizons in order from top to base of profile:

Functional Horizon	Thickness	Stones	Clay*	Sand*
Loamy Fine Slightly Firm	15 - 28 cm	0 %	18 - 25 %	0 - 15 %
Loamy Fine Slightly Firm	15 - 35 cm	0 %	20 - 35 %	0 - 15 %
Clayey Fine Firm	25 - 45 cm	0 %	30 - 45 %	0 - 15 %
Clayey Coarse	0 - 40 cm	0 %	35 - 45 %	0 - 15 %

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

Soil information for OVERSEER

The following information can be entered in the OVERSEER® Nutrient Budget model. This information is derived from the S-map soil properties which are matched to the most appropriate OVERSEER categories. Please read the notes below for further information.

Soil description page

1. Select **Link to S-map**
2. Under S-map sibling data enter the S-map name/ref: **Mayf_22a.1**

***** Important *****
Please read the limitations section on page 1.

Considerations when using Smap soil properties in OVERSEER

- The soil water values are estimated using a regression model based on soil order, parent rock, soil functional horizon information (stone content, soil density class), as well as texture (field estimates of sand, silt and clay percentages). The model is based on laboratory - measured water content data held in the National Soils Database and other Landcare Research datasets. Most of this data comes from soils under long-term pasture and may vary from land under arable use, irrigation, etc.

- Each value is an estimate of the water content of the whole soil within the target depth range or to the depth of the root barrier (if this occurs above the base of the target depth). Where soil layers contain stones, the soil water content has been decreased according to the stone content.

- S-map only contains information on soils to a depth of 100 cm. The soil water estimates in the > 60 cm depth category assume that the bottom functional horizon that extends to 100 cm, continues down to a depth of 150cm. Where it is known by the user that there is an impermeable layer or non-fractured bedrock between 100 and 150 cm, this depth should be entered into OVERSEER. Where there is a change in the soil profile characteristics below 100 cm, the user should be aware that the values provided on this factsheet for the > 60 cm depth category will not reflect this change. For example, the presence of gravels at 120 cm would usually result in lower soil water estimates in the > 60 cm depth category. Note though that this assumption only impacts on a cropping block, as OVERSEER uses soil data from just the top 60 cm in pastoral blocks.

- OVERSEER requires the soil water values to be non-zero integers (even though zero is a valid value below a root barrier), and the wilting point value must be less than the field capacity value which must be less than the saturation value. The S-map water content estimates supplied by the web service have been rounded to integers and may be assigned minimal values to meet these OVERSEER requirements. These modifications will result in a slightly less accurate estimate of Available Water to 60 cm (labelled PAW in OVERSEER) than that provided on the first page of this factsheet, but this is not expected to lead to any significant difference in outputs from OVERSEER .

S O I L R E P O R T

Report generated: 9-Jun-2016 from http://smap.landcareresearch.co.nz

Family: Claremont*f*

Claremont*f* moderately deep silty loam over clay

*** Important ***
Please read the limitations section on page 1.

Smap ref: Clar_2a.1

Key physical properties

Depth class (diggability)		Moderately deep (50 - 85 cm)
Texture profile		Silty loam over clay
Potential rooting depth		50 - 90 (cm)
Rooting barrier		Pan
Topsoil stoniness		Stoneless
Topsoil clay range		18 - 25 %
Drainage class		Poorly drained
Aeration in root zone		Limited
Permeability profile		Moderate over slow
Depth to slowly permeable horizon		50 - 90 (cm)
Permeability of slowest horizon		Slow (< 4 mm/h)
Profile available water	(0 - 100cm or root barrier)	Moderate (95 mm)
	(0 - 60cm or root barrier)	Moderate (85 mm)
	(0 - 30cm or root barrier)	Moderate (48 mm)
Depth to hard rock		No hard rock within 1 m
Depth to soft rock		No soft rock within 1 m
Depth to stony layer class		No significant stony layer within 1 m

Key chemical properties

Topsoil P retention	Low (22%)

Limitations

This S-map factsheet has been associated with a polygon from the interim soil layer which is of lower accuracy than S-map. The NZLRI polygon linework has a nominal scale 1:63,360 but for inland Canterbury, NZLRI soils are based on the General Soil Survey of the South Island 1:253,440 scale ("4 inch to mile") that mapped soil sets rather than soil types. Thus the soil information contained in this factsheet may not accurately represent the actual soil at this location.

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- Advice should be sought from soil and land use experts before making decisions on individual farms and paddocks.
- The information has been derived from numerous sources. It may not be complete, correct or up to date.
- This information sheet is licensed by Landcare Research on an "as is" and "as available" basis and without any warranty of any kind, either express or implied.
- Landcare Research shall not be liable on any legal basis (including without limitation negligence) and expressly excludes all liability for loss or damage howsoever and whenever caused to a user of this factsheet.

Family:Claremont *f*

Claremont*f* moderately deep silty loam over clay

***** Important *****
Please read the limitations section on page 1.

Smap ref: Clar_2a.1

Additional factors to consider in choice of management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

Contaminant management

MGM N Loss Category	Fragipan soil on hilly slopes
MGM P Loss Category	High risk of Runoff to surface water
N leaching vulnerability	Medium
P leaching vulnerability	Medium
Relative Runoff Potential	Very high
Bypass flow	Medium
Dairy effluent (FDE) risk category	C
Septic tank installation category	A1

Additional information

Soil classification	Fragic Perch-gley Pallic Soils (PPX)
Family	Claremont*f*
Sibling number	2
Profile texture group	Silty
Soil profile material	Stoneless soil
Rock class of stones/rocks	Not applicable
Rock origin of fine earth	From hard sandstone rock
Parent material origin	Loess

Characteristics of functional horizons in order from top to base of profile:

Functional Horizon	Thickness	Stones	Clay*	Sand*
Loamy Fine Slightly Firm	18 - 35 cm	0 %	18 - 25 %	5 - 10 %
Loamy Fine Slightly Firm	10 - 35 cm	0 %	18 - 28 %	5 - 10 %
Clayey Fine Firm	10 - 35 cm	0 %	35 - 45 %	5 - 10 %
Loamy Coarse Firm	10 - 50 cm	0 %	18 - 28 %	5 - 10 %

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

Family: Claremontf

Claremontf moderately deep silty loam over clay

***** Important *****
Please read the limitations section on page 1.

Smap ref: Clar_2a.1

Soil information for OVERSEER

The following information can be entered in the OVERSEER® Nutrient Budget model. This information is derived from the S-map soil properties which are matched to the most appropriate OVERSEER categories. Please read the notes below for further information.

Soil description page

Click the 'Soil moisture values' option. Enter the 'Sibling name': Clar_2a.1

From the 'Soil order' dropdown box select: Pallic

Soil water properties	0-30 cm	30-60 cm	> 60 cm	
Wilting point (15 bar)	19	23	28	mm per 10 cm
Field capacity	35	35	38	mm per 10 cm
Saturation	47	43	44	mm per 10 cm

From the 'Natural drainage class' dropdown box select: Poorly drained

Depth to impeded drainage layer: 71 cm (to an impermeable layer)

Maximum rooting depth: 71 cm (to a physical root barrier)

Top soil horizon chemical and physical parameters

Anion storage capacity (ASC) or phospate retention (PR): 22 %

Bulk density: 1220 kg/m³

Clay: 21 %

Sand: 7 %

Sub soil [average from 10 to 30 cm]

Subsoil clay: 21 %

Is compacted
(this depends on management so cannot be obtained from S-map)

Considerations when using Smap soil properties in OVERSEER

- The soil water values are estimated using a regression model based on soil order, parent rock, soil functional horizon information (stone content, soil density class), as well as texture (field estimates of sand, silt and clay percentages). The model is based on laboratory - measured water content data held in the National Soils Database and other Landcare Research datasets. Most of this data comes from soils under long-term pasture and may vary from land under arable use, irrigation, etc.

- Each value is an estimate of the water content of the whole soil within the target depth range or to the depth of the root barrier (if this occurs above the base of the target depth). Where soil layers contain stones, the soil water content has been decreased according to the stone content.

- S-map only contains information on soils to a depth of 100 cm. The soil water estimates in the > 60 cm depth category assume that the bottom functional horizon that extends to 100 cm, continues down to a depth of 150cm. Where it is known by the user that there is an impermeable layer or non-fractured bedrock between 100 and 150 cm, this depth should be entered into OVERSEER. Where there is a change in the soil profile characteristics below 100 cm, the user should be aware that the values provided on this factsheet for the > 60 cm depth category will not reflect this change. For example, the presence of gravels at 120 cm would usually result in lower soil water estimates in the > 60 cm depth category. Note though that this assumption only impacts on a cropping block, as OVERSEER uses soil data from just the top 60 cm in pastoral blocks.

- OVERSEER requires the soil water values to be non-zero integers (even though zero is a valid value below a root barrier), and the wilting point value must be less than the field capacity value which must be less than the saturation value. The S-map water content estimates provided on this page have been rounded to integers and may be assigned minimal values to meet these OVERSEER requirements. These modifications will result in a slightly less accurate estimate of Available Water to 60 cm (labelled PAW in OVERSEER) than that provided on the first page of this factsheet, but this is not expected to lead to any significant difference in outputs from OVERSEER.