Preliminary Stormwater Soakage Testing

Ladies Mile Masterplan Area,

Queenstown

Report prepared for:

Queenstown Lakes District Council

Report prepared by:

GeoSolve Limited

Distribution:

Queenstown Lakes District Council

Candor3

GeoSolve Limited (File)

May 2021

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1	10/05/2021	Issue to QLDC and Candor3	MBS	MDP/FAW

GEOTECHNICAL WATER RESOURCES PAVEMENTS

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1 Introduction

1.1 General

This report summarises the results of preliminary stormwater soakage testing carried out by GeoSolve Ltd for the Ladies Mile masterplan area. Investigations were undertaken within each of the proposed stormwater management areas to assess the potential for below ground stormwater disposal and to aid preliminary soakage design.

Photograph 1a – Site photo taken on the hills east of the site, looking south across the masterplan area.

The investigation was carried out for Queenstown Lakes District Council in accordance with GeoSolve Ltd.'s proposal dated 24 March 2021, which outlines the scope of work and conditions of engagement.

1.2 Proposed Development

We understand five stormwater management areas are proposed within the Ladies Mile masterplan area. A location plan has been provided by Candor3.

2 Site Description

2.1 General

The Ladies Mile masterplan area is approximately 160 Ha in size, and is located between Shotover River and Lake Hayes, as shown in Figure 1 below. State Highway 6 (Frankton-Ladies Mile Highway) runs in an east-west direction through the site.

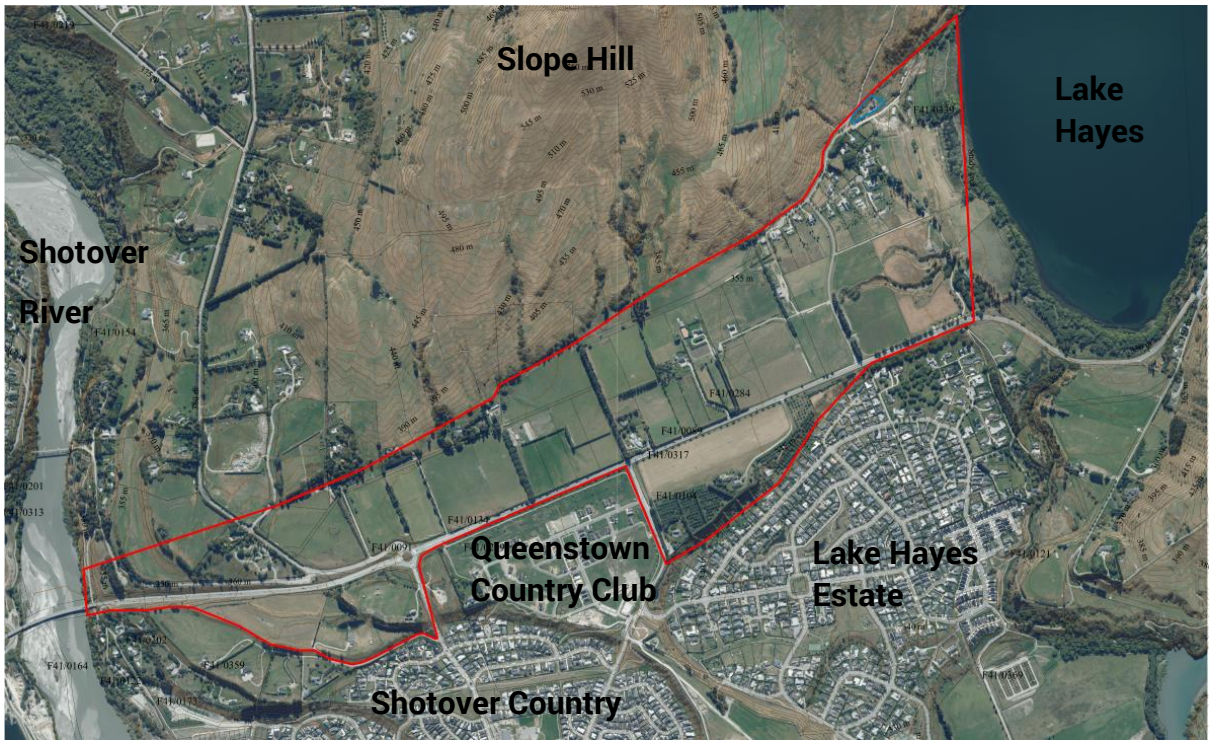


Figure 1 – Site location plan. The Ladies Mile Masterplan Area of Focus is marked in red ***(map sourced from maps.qldc.govt.nz/qldcviewer).***

The site area is largely undeveloped and comprises farmland, associated farming infrastructure, council infrastructure, roading networks, scattered residential dwellings and associated outbuildings. There is sporadic vegetation across the area.

The site is bounded by Shotover River to the west, Slope Hill to the north, Lake Hayes to the east and the existing Lake Hayes Estate, Queenstown County Club and Shotover Country residential areas to the south.

2.2 Topography and Surface Drainage

The five proposed stormwater management areas are situated on a sub-horizontal terrace.

Surface drainage is expected to drain to more permeable layers beneath the site. It is expected that groundwater flows track towards Lake Hayes and the Kawarau River at the eastern end of the site and the Shotover River at the western end of the site.

Local culverts and drainage ditches/paths are present around the property boundaries in association with the adjacent road network.

3 Site Investigations

An engineering geological site assessment has been undertaken with confirmatory subsurface investigations. The following site investigations were carried out between the 12th and 15th of April 2021:

- 14 test pits (TP1-14) which were advanced to a maximum depth of 4 m below ground level (bgl) to produce geological logs of the subsoils, and;
- 5 soakage tests completed within test pit excavations to assess the relative permeability and soakage potential of the subsoils. The permeability tests were undertaken between 1.2 and 2.0 m depth, where safely practical.

Test pit and soakage pit locations were positioned to obtain a representative spread across the proposed stormwater management areas.

TP 13 and 14 was excavated approximately 50 m to the east compared to the location originally provided to GeoSolve as the original location was fenced off with horses grazing, and the landowner did not allow access to this area.

Test pit and soakage pit locations and logs are presented in Appendix A and B. Results from the soakage testing are presented in Appendix C.

4 Subsurface Conditions

4.1 Geological Setting

The site is located in the Wakatipu basin, a feature formed largely by glacial advances. The last advance occurred about 15,000 years ago, scouring the schist bedrock in the Lake Hayes area and depositing glacial till. On ice retreat, Lake Wakatipu initially formed at a high level (Frankton Flats - Queenstown Airport level). In the site area, sediments from the Shotover River built a large delta into the lake and silty sediments accumulated in the lakebed.

Headward erosion by the Kawarau River eventually intersected the lake and gradually lowered it to the current level. Lake Hayes, behind the delta barrier, was lowered by Hayes Creek, which cut a deep gully through the deltaic sediments in the site area. Downcutting slowed when the creek intersected a buried schist ridge, now evident in the Hayes Creek bed.

Active fault traces were not observed at the site or in the immediate vicinity, and the closest major active fault is the Nevis-Cardrona Fault system. However, significant seismic risk exists in this region from potentially strong ground shaking, associated with the rupture of the Alpine Fault, located 80 km northwest of Queenstown along the west coast of the South Island. There is a high probability that an earthquake with an expected magnitude of over M8 will occur along the Alpine Fault in the next 50 years.

4.2 Stratigraphy

The subsurface stratigraphy observed during test pitting (TPs 1-14) around the proposed stormwater management areas comprises:

- 0.1-0.25 m of **topsoil**, overlying;
- 0.3-1.5 m of **loess**, overlying;
- 3.4 m+ of interbedded **deltaic sand and gravel.**

Topsoil was observed at the surface of all test pits to a maximum depth of 0.25 m bgl and comprises dark brown, organic SILT with a trace rootlets and light brown SILT with some organics.

Loess was observed to underlie the topsoil in all test pits and extends to depths of between 0.5 and 1.7 m. Loess comprises stiff to very stiff, SILT and loose to medium dense, silty SAND.

Interbedded **deltaic sand and gravel** was observed beneath the loess from depths of between 0.5 and 1.7 m to the full depth of the test pits (maximum depth 4.0 m bgl). The deltaic sand comprises loose to medium dense, silty SAND to gravelly SAND. The deltaic gravel comprises loose to medium dense, sandy GRAVEL with occasional silt to sandy GRAVEL and GRAVEL with some to minor sand and cobbles. ORC well data (F41/0134 and F41/0239) indicate the sands and gravels are present to at least 67 m depth beneath the site.

Full details of the observed subsurface stratigraphy can be found within the test pit logs contained in Appendix B.

4.3 Groundwater

The regional groundwater level is expected to lie at depth beneath the site. Otago Regional Council (ORC) well data indicates the regional groundwater table is at depths of approximately 39-51 m below the site.

5 Stormwater Disposal

5.1 Suitability of Soil Types

From discussions with QLDC and Candor3 it is understood that below ground soakage is proposed for the five stormwater management areas within the Ladies Mile Masterplan area. Sub-surface investigations have identified the area below the site is predominantly underlain by moderate permeability deltaic sand and gravel, which is expected to extend at least 50 m depth beneath the site.

5.2 Field Soakage Testing

Soakage testing was undertaken within loess, deltaic sand and gravel at five locations (refer to Appendix A, B and C for test locations, logs and results respectively).

Prior to undertaking soakage testing, deep test pits were excavated within each of the five stormwater management areas to log the subsoil conditions and determine a suitable layer for soakage testing. A smaller test pit/soak pit was then excavated within each stormwater management area. The dimensions of the soakage pits were recorded to calculate volumes and areas of soakage during testing.

Before soakage testing was undertaken, all soakage pits were pre-soaked for between 2 and 24 hours depending on the observed soil type at the infiltration depth. This was undertaken by introducing water from a 10,000 L water cart. The deltaic sand and gravel soils were subject to a 2-4 hour pre-soak (TPs 3, 6, 9 and 12). The loess was subject to a 24 hour pre-soak (TP14).

Soakage testing was undertaken at depths of between 1.2 and 2.0 m depth.

Soakage testing was performed by introducing water from the 10,000 L watercart until the water level of the pit reached the designated testing level. The inflow was then ceased and the time it took for the water level to drop was recorded. Tests were completed within each soakage pit until a representative amount of testing had been achieved for each test location.

The regional groundwater table was not encountered during test pit investigations and is expected to lie approximately 39-51 m beneath the site. Therefore, the regional groundwater table is not expected to influence soakage rates on this site.

Results from the field soakage testing have been analysed to determine indicative infiltration rates which are provided below in Table 1.

5.3 Permeability Analysis

The results from field soakage testing are presented below in Table 1 and Appendix C.

Table 1 - Calculated Infiltration Rates.

Location	Test Depth (m bgl)	Soil Description at Base of Soak Test	Infiltration Rate (m/s)*
TP 3	1.4	SAND, underlain by sandy GRAVEL at 1.5 m bgl	$2.3x10^{-5}$
TP 6	1.2	Sandy GRAVEL, underlain by SAND with some silt at 1.6 m bgl	$3.4x10^{-5}$
TP 9	2.0	Sandy GRAVEL with a trace of silt, underlain by silty SAND at 2.5 m bgl	$3.6x10^{-5}$
TP 12	1.5	Sandy GRAVEL with a trace of silt, underlain by SAND with some silt at 2.6 m bgl	$2.7x10^{-4}$
TP 14	1.5	Silty SAND underlain by SAND with some silt at 1.7 m bgl	$5.5x10^{-7}$
* Values presented above do not include any reduction factor to account for loss of soakage performance overtime. It is recommended that a 0.5 reduction factor is adopted for design.			

The loess silty SAND observed a significantly lower soakage rate compared to the underlying deltaic sand and gravel. It is recommended the deltaic sand and gravel is targeted for stormwater disposal across the site.

5.4 Preliminary Soakage Design Recommendations and Considerations

- Stormwater soakage to ground within topsoil and loess overlying deltaic sand and gravel is not recommended. It is recommended that stormwater is discharged directly to the deltaic sand and gravel in all cases. Lower permeability layers within the deltaic sand and gravel (silty SAND) as observed in the test pits limit the soakage/infiltration rates in these soil types;
- Infiltration rates are provided above in Table 1. Test results within TP 3, 6 and 9 were observed to be relatively consistent. A greater infiltration rate was observed within TP 12, likely due to the 1.1 m thickness of sandy GRAVEL present beneath the base of the soakage pit. A lower infiltration rate was observed in TP 14, which was undertaken within silty SAND (loess);
- To allow for any loss of soakage performance over time we recommend a reduction factor of at least 0.5 be applied to any adopted value for detailed design purposes;
- A geotechnical practitioner who is familiar with the findings of this report should inspect the base of any soakage area during earthworks construction;
- Provision should be included for long-term inspection and routine maintenance of any soakage system;
- An emergency overflow/overland flowpath should be identified for extreme storm events where surcharging is possible.

6 Conclusions and Recommendations

- The site is underlain by topsoil and loess overlying interbedded deltaic sand and gravel. The deltaic sand and gravel were observed to the base of all deep test pits however nearby ORC wells indicate sand and gravel is present to at least 67 m depth;
- The regional groundwater table was not encountered in any of the test pit excavations and based on borehole data is expected to lie at depths of 39-51 m below the site.
- 14 test pits including five soakage tests were undertaken within the proposed stormwater management areas to assess the suitability of stormwater soakage to ground for the proposed development. Infiltration rates have been provided within Table 1;
- To allow for any loss of soakage performance over time we recommend a reduction factor of at least 0.5 be applied to any adopted value for design purposes;
- It is recommended that a geotechnical practitioner should inspect the base of any soakage pit constructed within the subdivision to confirm conditions are in accordance with the findings of this report and there are no issues which may limit future stormwater soakage.

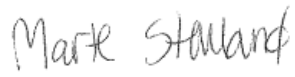
7 Applicability

This report has been prepared for the benefit of Queenstown Lakes District Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

This testing and report is intended for preliminary purposes only and should be followed up with further testing and analysis during detailed design.

It is important that we be contacted if there is any variation in subsoil conditions from those described in this report.

Report prepared by:



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Appendix A: Site Investigation Plan

Key

TP1 = Test Pit

TP3 = Test Pit / Soak Pit

= Approximate Location for Soakage Test Pits (provided by Candor3)

Scale 1:4000

0 40 80 120 160 200 (m)

CADFILE:	Sketch 1.xar	DRAWN	MBS	04/2021
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	MBS	04/2021
PROJECT No:	200353.01	APPROVED	FAW	04/2021

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Queenstown Lakes District Ciuncil
Soakage Testing
Ladies Mile, Queenstown
Site Investigation Plan

FIG No: FIGURE 1

REV. 1

Appendix B: Test Pit and Soakage Pit Logs

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TEST PIT LOG

EXCAVATION NUMBER: **TP 1**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Depth (m)
TOPSOIL	SILT with some organics; light brown, sub-horizontal. Firm; dry to moist; uniform; top 50mm rootlets.	0m
LOESS	SILT; tan brown, sub-horizontal. Stiff to very stiff; dry; uniform.	0.1m
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL; grey, sub-horizontal. Loose; dry; poorly graded; sand, medium to coarse; gravel, subangular to angular.	0.5m
DELTAIC SAND	Fine SAND with minor silt; grey, sub-horizontal. Loose; dry; uniform.	0.75m
DELTAIC GRAVEL	Fine to coarse GRAVEL with some to minor sand and cobbles; grey, mottled orange, sub-horizontal. Loose; dry; sand, medium to coarse; gravel, subrounded to subangular; cobbles, subrounded to subangular, up to 150 mm diameter.	1.2m
DELTAIC SAND	Fine to medium SAND; grey, sub-horizontal. Loose; dry.	2m
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL; grey, sub-horizontal. Loose; dry; sand, fine to coarse.	2.1m
DELTAIC SAND	Fine to medium SAND; grey, sub-horizontal. Loose; dry.	2.7m
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL; grey, sub-horizontal. Loose; dry; sand, fine to coarse.	3m
DELTAIC SAND	SAND; grey, sub-horizontal. Loose; dry.	3.4m
		3.8m

Graphic Log

Depth (m): 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8

Groundwater / Seepage: NO SEEPAGE

Scala Penetrometer

Total Excavation Depth = 3.8 m

COMMENT:	Test pit dry. Test pit terminated - side wall collapse.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 2**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT; light brown, sub-horizontal. Firm; moist; uniform; top 50mm rootlets. (0m – 0.1m)	0.0 – 0.1		
LOESS	SILT; tan brown, sub-horizontal. Stiff to very stiff; dry; uniform. (0.1m – 0.75m)	0.1 – 0.7		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL; grey, sub-horizontal. Loose; dry; poorly graded; sand, medium to coarse; gravel, subangular to angular. (0.75m – 1.15m)	0.7 – 1.1		
DELTAIC SAND	Fine to medium SAND; grey, sub-horizontal. Loose; dry; uniform. (1.15m – 1.6m)	1.1 – 1.6		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL; grey, sub-horizontal. Loose; dry; poorly graded; sand, medium to coarse; gravel, subangular to angular. (1.6m – 2m)	1.6 – 2.0		
DELTAIC SAND	Fine SAND with minor silt; grey, sub-horizontal. Loose; dry; uniform. (2m – 2.9m)	2.0 – 2.9		
DELTAIC SILT/SAND	Sandy SILT to silty fine SAND; grey, sub-horizontal. Loose/stiff; dry. (2.9m – 3.5m)	2.9 – 3.5		
DELTAIC SAND	Fine SAND with minor to some silt to silty SAND; grey, sub-horizontal. Loose; dry; uniform. (3.5m – 4m)	3.5 – 4.0	NO SEEPAGE	

Total Excavation Depth = 4.0 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 3**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	SILT with some organics; light brown, sub-horizontal. Firm; dry to moist; uniform; top 50mm rootlets. (0m)		0.0		
LOESS	SILT; tan brown, sub-horizontal. Stiff to very stiff; dry; uniform. (0.1m)		0.1 – 0.6		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL; grey. Loose; sand, medium to coarse; gravel, subangular to angular. (0.9m)		0.6 – 0.9		
DELTAIC SAND	Fine to medium SAND; grey. Loose. (1.5m)		0.9 – 1.5		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL; grey. Loose; sand, medium to coarse; gravel, subangular to angular. (2m)		1.5 – 2.0	NO SEEPAGE	

Total Excavation Depth = 2.0 m

COMMENT:	Soakage test @ 1.4 m depth.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 4**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Firm. 0m – 0.25m		0.0 – 0.2		
LOESS	Silty fine SAND; light brown, massive. Loose to medium dense; moist. 0.25m – 0.7m		0.2 – 0.7		
DELTAIC SAND	Fine SAND with some silt; grey, massive. Loose to medium dense; dry. 0.7m – 1m		0.7 – 1.0		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; sand, fine to coarse. 1m – 1.4m		1.0 – 1.4		
DELTAIC SAND	Fine SAND with some silt; light grey, massive. Loose to medium dense; dry. 1.4m – 2.7m		1.4 – 2.7		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; brown grey, bedded. Loose to medium dense; dry; sand, fine to coarse. 2.7m – 3.2m		2.7 – 3.2		
DELTAIC SAND	Silty fine SAND; light grey, massive. Loose to medium dense; dry. 3.2m – 4m		3.2 – 4.0	NO SEEPAGE	

Total Excavation Depth = 4.0 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 5**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Depth	Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Firm.	0m 0.2m		0.0 0.1 0.2		
LOESS	Silty fine SAND; light brown, massive. Loose to medium dense; moist.	0.6m		0.3 0.4 0.5 0.6		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; light brown, bedded. Loose; dry.	0.85m		0.7 0.8		
DELTAIC SAND	Silty fine SAND; light grey, massive. Loose; dry.	1m		0.9 1.0		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse.	1.6m		1.1 1.2 1.3 1.4 1.5		
DELTAIC SAND	Fine SAND with some silt; grey, massive. Loose to medium dense; dry.	1.8m		1.6 1.7 1.8		
DELTAIC SAND	Fine to coarse SAND with some gravel and minor silt; grey, bedded. Loose to medium dense; dry; gravel, fine to coarse.	2.8m		1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse.	3.6m		2.9 3.0 3.1 3.2 3.3 3.4 3.5		
DELTAIC SAND	Silty fine SAND; grey, massive. Loose to medium dense; dry.	3.8m		3.6	NO SEEPAGE	
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse.	4m		3.7 3.8 3.9 4.0		

Total Excavation Depth = 4.0 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 6**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description		Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Firm.	0m 0.2m		0.0 0.1	NO SEEPAGE	
LOESS	Silty fine SAND; light brown, massive. Loose to medium dense; moist.	0.5m		0.2 0.3 0.4 0.5		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; light brown, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse.			0.6 0.7		
DELTAIC SAND	Silty fine SAND; light grey. Loose; dry.	0.7m 0.9m		0.8 0.9		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse.	1.2m		1.0 1.1 1.2		

Total Excavation Depth = 1.2 m

COMMENT:	Soakage testing @ 1.2 m depth.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 7**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Soft; moist. 0m – 0.2m	0.0 – 0.2		
LOESS	Silty fine SAND; yellow brown, massive. Loose to medium dense; dry. 0.2m – 0.7m	0.2 – 0.7		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; light brown, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse. 0.7m – 1.25m	0.7 – 1.2		
DELTAIC SAND	Silty fine SAND; light grey, massive. Loose; dry. 1.25m – 1.4m	1.2 – 1.4		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse. 1.4m – 2.5m	1.4 – 2.5		
DELTAIC SAND	Silty fine SAND; grey, massive. Loose; dry. 2.5m – 2.7m	2.5 – 2.7		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse. 2.7m – 3m	2.7 – 3.0		
DELTAIC SAND	Silty fine SAND; grey, massive. Loose; dry. 3m – 3.3m	3.0 – 3.3		
DELTAIC GRAVEL	Sandy GRAVEL; grey, bedded. Medium dense; dry. 3.3m – 3.9m	3.3 – 3.9	NO SEEPAGE	

Total Excavation Depth = 3.9 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

GEOSOLVE
ENGINEERING CONSULTANTS

TEST PIT LOG

EXCAVATION NUMBER: **TP 8**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Soft; moist. 0m – 0.2m		0.0 – 0.2		
LOESS	Silty fine SAND; yellow brown, massive. Loose to medium dense; dry. 0.2m – 0.95m		0.2 – 0.9		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; light brown, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse. 0.95m – 1.3m		0.9 – 1.3		
DELTAIC SAND	Silty fine SAND; light grey, massive. Loose; dry. 1.3m – 1.6m		1.3 – 1.6		
DELTAIC SAND	Gravelly fine to coarse SAND; grey, bedded. Loose to meidum dense; dry; gravel, fine to coarse, subrounded to subangular. 1.6m – 1.8m		1.6 – 1.8		
DELTAIC SAND	Silty fine SAND; grey, massive. Loose; dry. 1.8m – 2m		1.8 – 2.0		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse. 2m – 3.1m		2.0 – 3.1		
DELTAIC SAND	Fine to medium SAND with some silt and a trace of gravel; grey, massive. Loose to medium dense; dry; gravel, fine to medium. 3.1m – 3.8m		3.1 – 3.8	NO SEEPAGE	

Total Excavation Depth = 3.8 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 9**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description		Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Soft; moist.	0m 0.2m		0.0 0.1 0.2		
LOESS	Silty fine SAND; yellow brown, massive. Loose to medium dense; dry.	0.7m		0.3 0.4 0.5 0.6 0.7		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; light brown, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse.	1.3m		0.8 0.9 1.0		
DELTAIC SAND	Silty fine SAND; light grey, massive. Loose; dry.	1.5m		1.1 1.2		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; light brown, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse.	1.7m		1.3 1.4 1.5		
DELTAIC SAND	Silty fine SAND; light grey, massive. Loose; dry.	1.8m		1.6 1.7		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; light brown, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; sand, fine to coarse.	2m		1.8 1.9 2.0	NO SEEPAGE	

Total Excavation Depth = 2.0 m

COMMENT:	Soakage testing @ 2.0 m depth.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 10**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Soft; moist. 0m – 0.2m		0.0 – 0.2		
LOESS	Silty fine SAND; yellow brown, massive. Loose to medium dense; dry. 0.2m – 1.1m		0.2 – 1.1		
DELTAIC SAND	Fine SAND with some silt; grey, massive. Loose to medium dense; dry. 1.1m – 2.2m		1.1 – 2.2		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; sand, fine to coarse. 2.2m – 2.5m		2.2 – 2.5		
DELTAIC SAND	Fine SAND with some silt; grey, massive. Loose to medium dense; dry. 2.5m – 3.3m		2.5 – 3.3		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Medium dense; dry; sand, fine to coarse. 3.3m – 3.9m		3.3 – 3.9	NO SEEPAGE	

Total Excavation Depth = 3.9 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 11**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Depth	Graphic Log
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Soft; moist.	0m – 0.2m	
LOESS	Silty fine SAND; yellow brown, massive. Loose to medium dense; dry.	0.2m – 1m	
DELTAIC SAND	Fine SAND with some silt; grey, massive. Loose to medium dense; dry.	1m – 1.2m	
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; gravel, fine to coarse.	1.2m – 2.6m	
DELTAIC SAND	Fine SAND with some silt; grey, massive. Medium dense; dry.	2.6m – 3m	
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Medium dense; dry; gravel, subrounded to subangular; gravel, fine to coarse.	3m – 3.8m	

Depth (m): 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8

Groundwater / Seepage: NO SEEPAGE

Scala Penetrometer

Total Excavation Depth = 3.8 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER:
TP 12

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT with a trace of rootlets; dark brown. Soft; moist. 0m – 0.2m		0.0 – 0.1 – 0.2	NO SEEPAGE	
LOESS	Silty fine SAND; yellow brown, massive. Loose to medium dense; dry. 0.8m		0.3 – 0.4 – 0.5 – 0.6 – 0.7 – 0.8		
DELTAIC SAND	Fine SAND with some silt; grey, massive. Loose to medium dense; dry. 1.1m		0.9 – 1.0 – 1.1		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; gravel, fine to coarse. 1.5m		1.2 – 1.3 – 1.4 – 1.5		

Total Excavation Depth = 1.5 m

COMMENT:	Soakage testing @ 1.5 m depth. .	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 13**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT; dark brown. Soft; moist. 0m – 0.2m		0.0 – 0.2		
LOESS	Silty fine SAND; yellow brown, massive. Loose to medium dense; dry. 0.2m – 1.7m		0.2 – 1.7		
DELTAIC SAND	Fine SAND with some silt; grey, massive. Loose to medium dense; dry. 1.7m – 2.5m		1.7 – 2.5		
DELTAIC GRAVEL	Sandy fine to coarse GRAVEL with a trace of silt; grey, bedded. Loose to medium dense; dry; gravel, subrounded to subangular; gravel, fine to coarse. 2.5m – 4m		2.5 – 4.0	NO SEEPAGE	

Total Excavation Depth = 4.0 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

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TEST PIT LOG

EXCAVATION NUMBER: **TP 14**

PROJECT:	Ladies Mile Soakage			JOB NUMBER:	200353.01
LOCATION:	See Site Plan	INCLINATION:	Vertical		

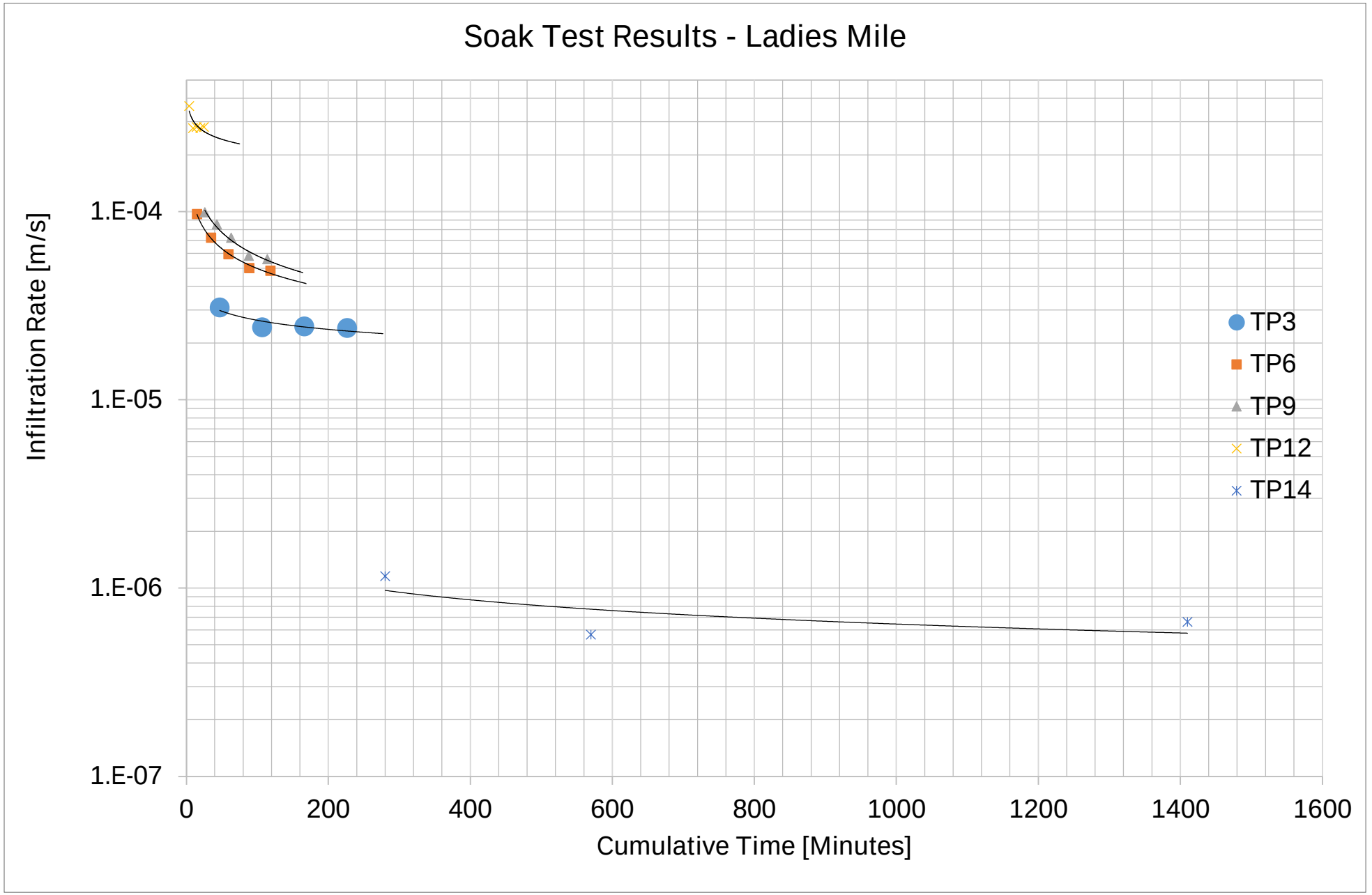
EASTING:		EQUIPMENT:	14 T wheel digger	OPERATOR:	Johnny
NORTHING:		COORD. SYSTEM:		COMPANY:	Parcell Contracting
ELEVATION:		EXCAV. DATUM:	Ground Level	HOLE STARTED:	12/04/2021
METHOD:	Aerial Photography	ACCURACY:		HOLE FINISHED:	12/04/2021

Soil / Rock Type	Description	Graphic Log	Depth (m)	Groundwater / Seepage	Scala Penetrometer
TOPSOIL	Organic SILT; dark brown. Soft; moist. 0m – 0.2m		0.0 – 0.2		
LOESS	Silty fine SAND; yellow brown, massive. Loose to medium dense; dry. 0.2m – 1.5m		0.2 – 1.5	NO SEEPAGE	

Total Excavation Depth = 1.5 m

COMMENT:	Test pit dry. Walls remained stable during excavation.	LOGGED BY:	MBS
		CHECKED DATE:	03/05/2021
		SHEET:	1 of 1

Appendix C: Soakage Test Results


Soak Test Results - Ladies Mile
Infiltration Rate [m/s]
1.E-04
1.E-05
1.E-06
1.E-07
0
200
400
600
800
1000
1200
1400
1600
Cumulative Time [Minutes]
TP3
TP6
TP9
TP12
TP14


Soak Test Results - Ladies Mile excl. TP14
Infiltration Rate [m/s]
1.E-04
1.E-05
0
50
100
150
200
250
300
350
Cumulative Time [Minutes]
TP3
TP6
TP9
TP12