

South Eastern Ruahine Scheme Gravel Resource Study

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REGIONAL COUNCIL

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EXECUTIVE SUMMARY

This study examines the gravel resource in eight streams and one river that form part of the South Eastern Ruahine Scheme. It is based on an analysis of cross-sectional surveys that have been conducted in 2013 and the most recent one in 2019/2020. The purpose of this analysis is to identify any trends of aggradation or degradation occurring in the gravel resources of the streams and river.

This study examines each stream and river individually and looks at how the mean bed levels and gravel resource have changed through time, and reported gravel volumes extracted to assess sustainability of extraction volumes.

Gravel reserves were established in the upper reaches of the streams and river in the South East Ruahine Scheme. This served as a gravel storage in case it needed to be released. For instance, when the downstream reach has a dearth of gravels, the gravel reserve upstream could be opened to release the gravels downstream. Weirs were also installed throughout the scheme which functions to control the flow of water and stabilise the river reach.

This report excludes the effects of Cyclone Gabrielle February 2023, following the completed survey period.

The overall trend of the streams and river analysed reported a degrading trend in gravel resources over the study period of 2013 –2019/2020. In some cases survey information was too sparse to consider all cross sections for the length of the river and analysis was focused specific reaches.

The Rokaiwhana stream had a clear trend of degradation with a significant drop in gravel volume of 138,782.75 m^3. The Tamaki River had seen a degrading trend in the lower reaches but was generally stable trend in the middle to the upper reaches of the river. A total net loss of 64,481 m^3 was found to have occurred at Tamaki Stream, which is about 9,200 m^3 per annum of gravel degradation. The Raparapawai Stream overall net loss of 1,470m^3 of gravel volume change. The Oruakeretaki stream recorded a degrading trend with a net gravel loss of 15,220 m^3. The Otamarahu stream had a net deficit in gravel volume of 653.5 m^3. The Kumeti Stream showed there is a degrading trend with a net loss of gravel volume of 27,654.50 m^3 and the Otamaraho Stream saw an overall degradation with a net loss of gravel volume of 18,116 m^3.

The overall trend of the cross sections in the Mangapukakakahu recorded aggradation with the total aggradation of 4,205 m^3 for the period. An aggrading trend was also recorded on the Manga-atua Steam with a net gain of 2840.30 m^3 from the period.

A resurvey in 2025 – 2026 is recommended to be conducted for the South East Ruahine Scheme streams and rivers including all the cross sections surveyed in 2019/2020. Additionally, it is recommended that a more recent LiDAR (Light Detection and Ranging) be flown to enable DoD (Difference of DEMs [Digital Elevation Model]) analysis. The DoD would enable a spatial representation (morphology) of the gravel volume and change of gravel volume along the river based on two DEMs (Digital Elevation Model) of different years.

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South Eastern Ruahine Scheme Gravel Study

1.0 Introduction

The South Eastern Ruahine Scheme covers an area of approximately 630 km^2. The Scheme includes that part of the Manawatu River catchment draining eastwards from the Ruahine Ranges from the headwaters of the Manawatu River to the upstream end of the Manawatu Gorge. The Manawatu River itself is excluded from the Scheme except for the portion above Kopua. The eastern extent of the Scheme is defined by the boundaries of the Upper Manawatu and Lower Mangahao Scheme. The western edge is largely the eastern boundary of the Ruahine Forest Park.

The Scheme provides landowners, within the Scheme area, a degree of protection against channel erosion, from gravel inundation of productive farmland, improvements to drainage and to some areas a degree of protection against flooding (see below for location map).

1.1 Pre-scheme History

Prior to European settlement of the area, the eastern side of the Ruahine Ranges was covered in dense and extensive forest. Pioneer settlement of the area bought extensive bush burning. Later a large sawmilling industry developed following the arrival of the railway from Napier in the late 1870s. By the early 1900s the burning and milling had cleared extensive areas of land and largely formed the present farming pattern that exists today (South East Ruahine Scheme Review, 2003).

The area between the Ruahine Ranges and the Upper Manawatu River is an alluvial plain. Over an extended period of time sediment has been transported out of mountains to form the plain.

Before the area was developed for farming the forest vegetation provided substantial strength to the stream banks and impeded the movement of alluvial material. The forest- covered alluvial fans regulated the outflow of the stream bed load on to the plain.

Being composed of unconsolidated alluvium, the fans tended to cause the water to seep underground and remerge at the base of the fans as springs. To better meet the needs of agricultural farming drainage schemes were constructed. The construction of these schemes upset the natural equilibrium maintaining channel gradients which led to the streams aggrading with material being carried onto the alluvial plains, which had been developed into farmland.

The removal of the original forest and its replacement with pasture led to a significant reduction in the stability of the stream banks and also to channel widening. To combat this willows were planted to reintroduce channel stability, however, the willows have created channel congestion issues.

In summary, previously forested catchments which by the early 1920s most of the lowland forest had been removed and it is thought that during the 1930, gravel debris movement, initiated by mountain land erosion, began. This erosion is attributed to the combined effect of deforestation, introduced animals and climatic extremes.

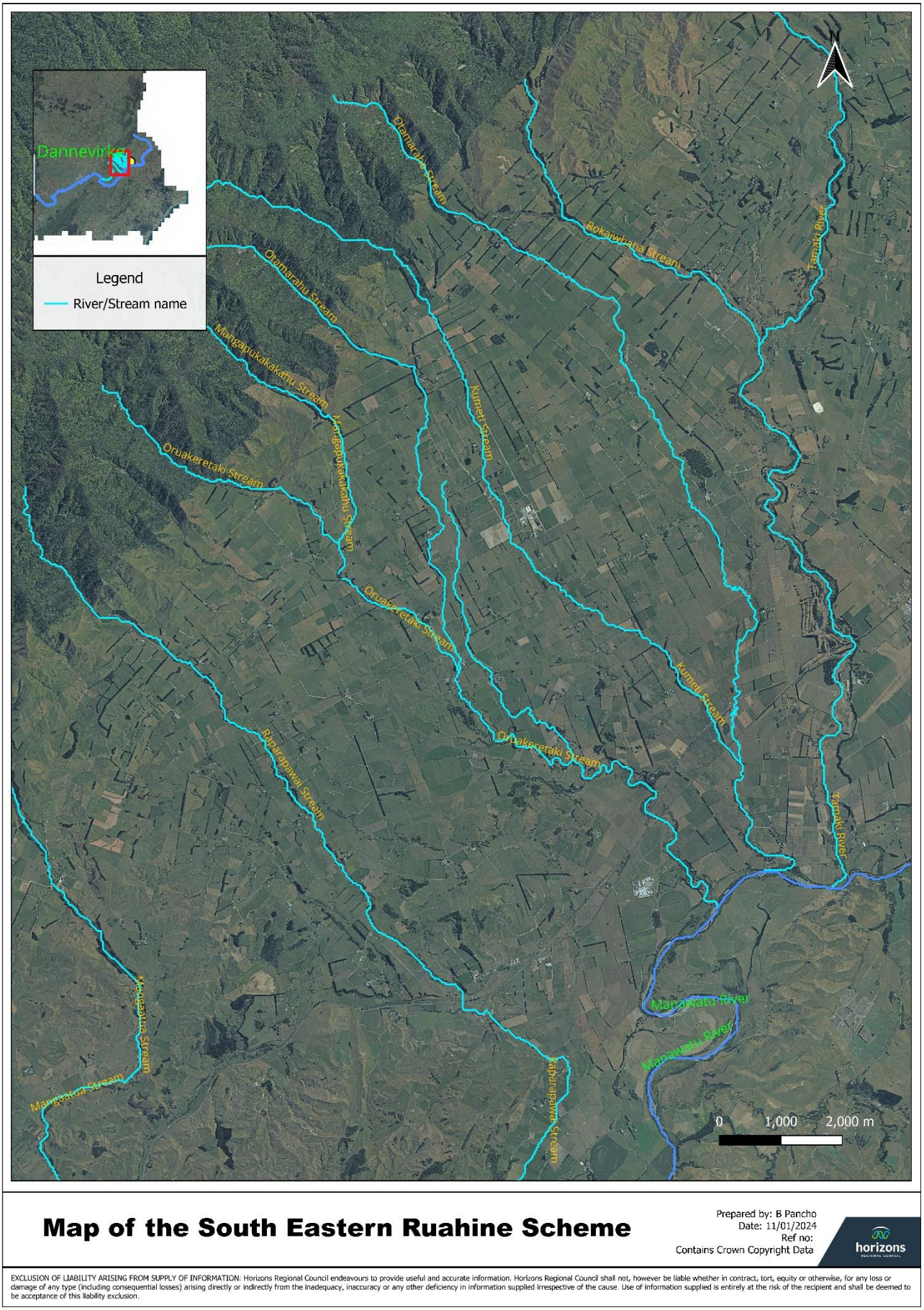


Figure 1: Map of South Eastern Ruahine Scheme Rivers and Streams

1.2 History of the Scheme

During the early 1970s, detailed studies and specialist reports were prepared on the modes of sediment transport, hydrology and gravel control (South East Ruahine Scheme, 2003). In 1974, investigation began into the work necessary to establish a Scheme. Following the investigation works, the South-Eastern Ruahine Management Scheme 1980-2000 was submitted in 1978 containing long term works requirements and a five-year plan of works for the period 1980 to 1985.

The investigations established that, in transporting sediment, the rivers in the Scheme play an important role in the continuing process of landscape evolution. From time to time, catastrophic events dump large amounts of detritus into the stream channels and thus give rise to most of the problems associated with the management of the streams within the Scheme.

As part of the Scheme, three principles were established for the management of these extraordinary sediment loads. These principles were:

- That river training works are designed to allow a majority of stream sediment to pass through the river system. Stream works are to be designed to retain, retard or remove only the overload of sediment;
- That the streams are systems that extend throughout the whole length of the catchment and are an integral part of that catchment; and
- That for the period of 1980-1985, greater priority be given to stabilising channel and riparian land than to the stabilising of upper catchment lands.

The findings of the Catchment Board showed that sediment was derived from two main sources. These sources being:

1st Erosion of the upper catchment lands – the Ruahine Ranges; and

2nd The erosion of stored sediments in channel deposits, gravel fans and the flood plain generally.

It was identified that the benefits of stabilising the upper catchment are longer term, while the benefits of stabilising channel sources are more immediate. It is for this reason that the Scheme gave higher priority to stabilising sediments stored in the channels, valley throats and fans via weir construction and management of gravel reserves.

The 2003 Scheme

A Scheme Review prepared by John Philpott (Horizons RC, 2003, as cited in Bell, 2016) found that the programme proposed for the original Scheme had "to a large extent been implemented" and that "continuing with its implementation will ensure that the overall objectives are achieved."

It was also noted that "it is likely that over time changes may be required to meet the changing needs of landowners and in response to changes in weather patterns and large flood events."

The 2003 Scheme Review found that "the future direction of the Scheme will not vary greatly from that envisaged when the Scheme was established in 1981." It was stated that the overall purpose of the Scheme is "to minimise the loss in farm production caused by erosion, floods, gravel overflows and poor drainage whilst maintaining and enhancing wherever practicable the natural state of the stream channels and surrounding environment.

1.3 2016 Gravel Study

The 2016 South Eastern Ruahine gravel study was broken down into 9 streams or rivers. It has set out the following points:

1. Manga-atua Stream
   - There has generally been a degradation of gravel since the 1994 surveys, but no meaningful conclusion has been reached since there is a lack of directly comparable surveys.
2. Raparapawai Stream
   - No significant conclusion was made because of the irregularity of surveys particularly in the lower reaches of the stream.
3. Oruakeretaki Stream
   - Gravel resource above Top Grass Road has been relatively stable over the study period. Significant degradation of the gravel resource immediately downstream of Top Grass Road and the gravel traps have been seen.
4. Mangapukakakahu Stream
   - The period between 1997 and 2001 saw an aggradation that has been approximately balanced by the degradation that occurred between 2001 and 2013.
5. Otamarahu Stream
   - From the surveys that have been conducted in the gravel trap reach of the Otamarahu Stream, it appears that generally speaking, the gravel traps are working well and there is a gradual aggradation of the gravel resource in this reach. However, there has been a significant degradation of the bed, and hence the gravel resource over a short reach at the downstream end of the study area.
6. Kumeti Stream
   - Both the mean bed level comparison and the analysis of the changes in gravel volume can be seen that the shingle traps above Thorburns Road have been successful in stabilising the gravel resource in the upper reaches of the stream.
7. Otamaraho Stream
   - The long-term trend appears to be an aggradation of the gravel resource. This is likely to be due to the gravel traps that have been installed in this reach of the river. The surveys' focus was only on a 3.2 km reach of the stream immediately below the bush line. As such it is not possible to comment on how the gravel resource in the lower reaches of the stream has changed over time.
8. Rokaiwhana Stream
   - Overall, between 2002 and 2013, the surveyed reach of the Rokaiwhana Stream has seen a degradation of gravel volume. However, this degradation is confined to the lower reaches of the stream. The top 1 km of the surveyed reach (below the bush line) has seen a build-up of gravel over this period.
9. Tamaki River
   - Between 1989 and 2013, overall the 3km reach of the river has lost approximately 100,000 m^3 of gravel. However, due to the lack of survey information it was not possible to say if this reduction in gravel quantity was due to excessive movement of sediments downstream or a starvation of the supply of gravel moving out of the Ruahine Ranges.

The 2016 gravel study did not specify what datum it was using, but it is assumed that when the study was conducted, the Napier datum was used. The present study uses the updated datum of NZVD2016. Furthermore, the 2016 study used different sets of offsets, therefore it is worth mentioning that the values will yield different results with the present 2023 study.

2.0 Methodology

To determine the change in the gravel resource of the South East Ruahine Scheme, the mean bed level and gravel volume under the active channel was calculated using Hilltop Manager and Microsoft Excel. This study analyses the 9 streams/river individually which can be grouped into 5 catchments as below:

Catchment 1: Manga-atua Stream
Catchment 2: Raparapawai Stream
Catchment 3: Oruakeretaki Stream, Mangapukakakahu Stream, Otamarahu Stream
Catchment 4: Kumeti Stream, Otamaraho Stream
Catchment 5: Rokaiwhana Stream, Tamaki Stream

The catchment groupings are used to aid the conclusions.

Detailed discussions can be found in the subsequent sections.

2.1 Analysis of Cross-section survey data for all streams

The active channel is defined in this study as the area that includes the wetted channel and the gravel beaches located above normal water levels. The mean bed level was assessed in this study which considers the boundaries of the wetted channel. The One Plan (2014) defines active bed as the bed of a river that is intermittently flowing and where the bed is predominantly unvegetated and comprises sand, gravel, boulders, or similar material. Figure 2 below illustrates the channel cross-section areas of analysis for a gravel cross-section.

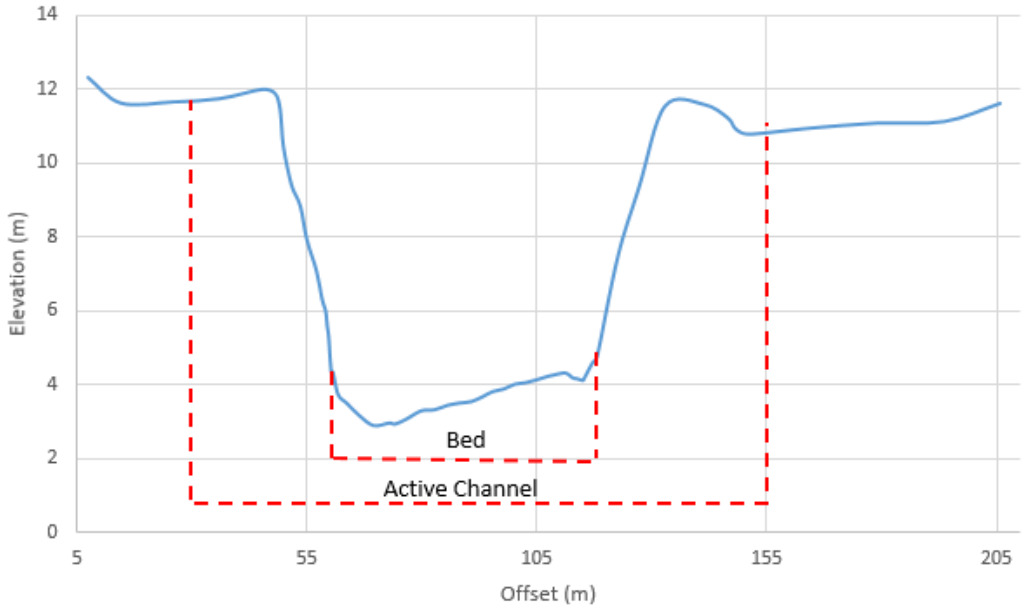


Figure 2: Conceptual channel cross-section for a gravel reach

Cross-sections were over-plotted and analysed in Hilltop Manager (see Appendices A to I) to determine the extents of the active channel at each cross-section location. In cases where visual inspection was not feasible, historical aerial images using ArcMap were examined to determine cross-section extents. Hilltop Hydro was used to calculate gravel volume and the mean bed level. The cross sectional fluvial surveys, defined offsets, and datum used can be found in the Appendices (A to I of this report).

2.2 Analysis of Gravel Resources under the Active Channel

Each period of the individual cross sections was analysed using Hilltop whereby the study period of 2013 and 2019/2020 was plotted using the over plot function on Hilltop Manager. A new set of offsets were established due to the dynamics of the river, the recent fluvial surveys, and recent aerial images. Bearing in mind the aforementioned definitions of the active channel and the active bed, the offsets were determined using visual inspection of the overplotted cross sections. The extents for the mean bed level offsets only cover the wetted portion of the channel, or the active bed. The offset extents for the area calculation should cover the active channel or the wetted channel plus the gravel beaches located above normal water levels. In cases where visual inspection is unclear, aerial images were used for confirmation. The left and right offsets can be found in Appendix A to I. The datum for the purposes of this analysis was set as 0. The area under the section of each year was obtained using the "Section over Time" feature of Reach function in Hilltop Hydro - REACH.

The volume was then calculated using the following formula:

Change in volume = (A2–A1) [½ (X3–X2) + ½ (X2–X1)]

Where:

- X1 is the downstream section distance from the confluence with the Manawatu River
- X2 is the distance of the cross-section of interest
- X3 is the upstream section distance from the confluence with the Manawatu River
- A1 is the area under the section in 2013
- A2 is the area under the section in 2019/2020

This formula was the same formula used in the previous gravel study to maintain comparability of analysis results. The mean average area under the bed for consecutive cross sections is taken, measured and multiplied by the distance between the two sections to derive a volumetric change for the length of the river.

2.3 Analysis of the Mean Bed Level

Each period of the individual cross sections was analysed using Hilltop whereby the years of interest were over plotted. Inputting the left and right offsets found in Appendix A to I, the mean bed level of each year was obtained using the "Section over Time" feature found under the Reach tab of Hilltop Hydro.

3.0 Manga-atua Stream

The Manga-atua stream has a catchment area of approximately 89km^2 above the Woodville-Pahiatua SH2 bridge. Philpott (Horizons RC, 2003) found that "the upper reaches of the stream drain a very unstable catchment, which contributes large volumes of fine to medium sized gravel to the stream system."

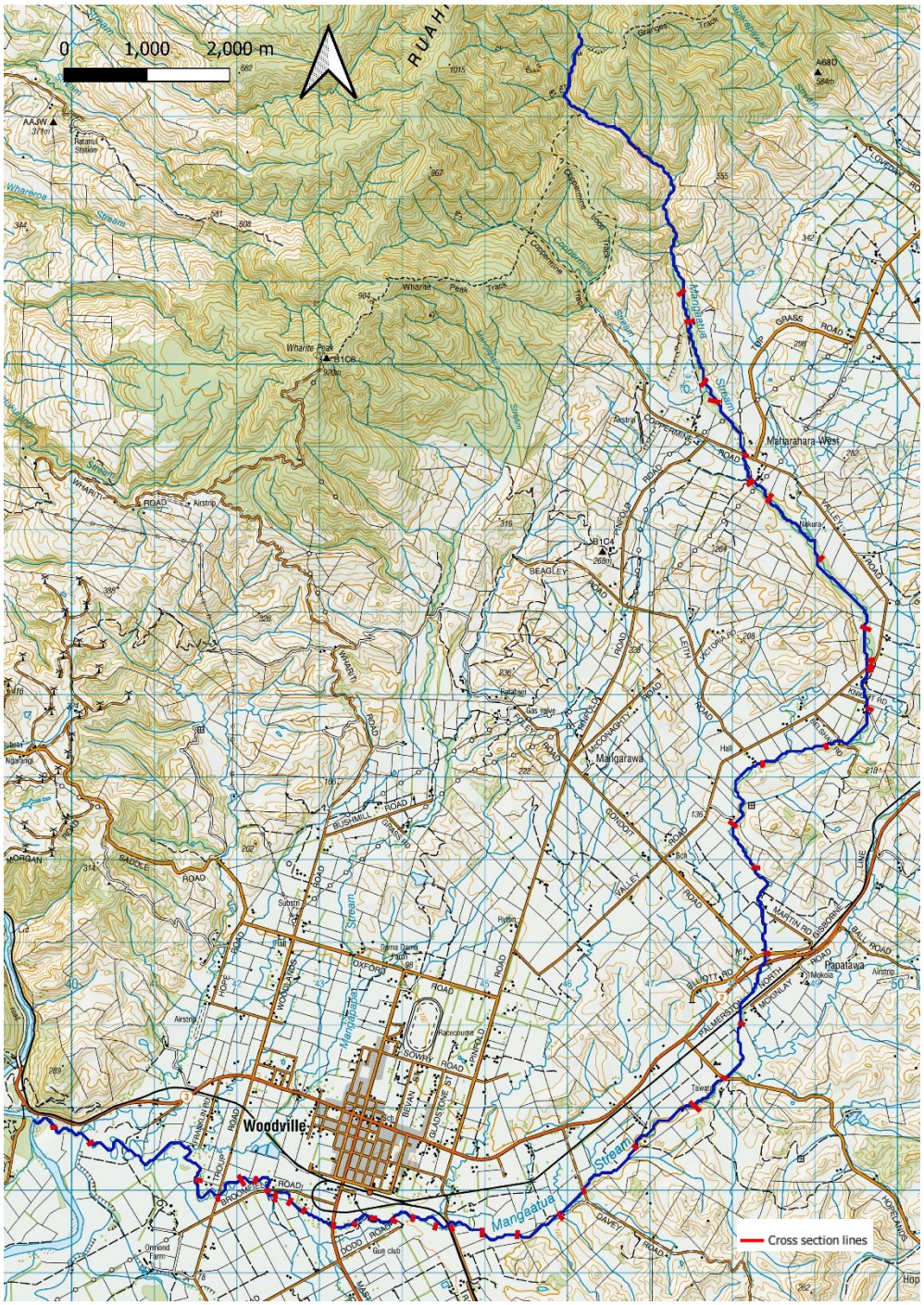


Figure 3.1: Manga-atua Stream with cross section locations

3.1 Cross-Section Survey Data

Over the period 1971-2020 a total of 64 cross-sections (see Appendix A1 for locations) have been surveyed at various times. Table 2.1 summarizes the survey history of each cross section.

Table 3.1 - Summary of Manga-atua Cross Section Surveys 1971-2019/2020

Cross Section (Chainage (m))	Additional Info	Survey Date											
		Aug-71	Feb-72	Aug-72	Jul-73	Oct-74	Aug-76	Feb-83	May-91	Mar-94	Jul-97	2013	2020/2019
0													
800													
1610													
2410													
3220													
3520													
4220	Troup Bridge												
5030													
5100													
5310	Broomfield Bridge												
5480													
5710													
5980													
6240													
6380	Highway Bridge												
6492													
6604													
6680													
6716													
6828													
6880													
6940													
7052													
7164													
7250													
7276													
7440													
7550													
7850													
8050	Range Bridge												
8750													
9190													
9660													
9960	Davey Bridge												
10760													
11570													
12370	Hopelands Bridge												
13180													
14180	Highway Bridge												
14990													
15790													
16600													
17400													
18210													
19010													
19600	Lower Valley Bridge												
20060													
20520													
20620													
20980													
21420													
21450													
21900													
22230													
22370													
22810	Upper Valley Bridge												
23640													
23647													
24440													
24452													
24782													
25152													
25250													
25650													

As Table 3.1 shows, not all cross sections were surveyed in each year. The surveys conducted in the early 1970s were mainly focused on the 6 km reach between Troup Bridge and Davey Bridge. The 1974 survey then focused on the upper 12.5 km of the study reach.

This data was supplemented by the 1976 survey which looked at the full 25.7 km reach down to the Manga-atua's confluence with the Manawatu River.

A survey in 1991 focused on the reach between the Lower Valley Bridge and the Upper Valley Bridge. This reach was re-surveyed in 1994 as well as the lower reach between Troup Bridge and the Highway Bridge. This lower reach was surveyed again in 1997 as well as a couple of additional sections to cover the reach to Range Bridge.

In 2013, a full survey on the Manga-atua was undertaken, covering sections through the whole 25 km study reach. Survey sections were chosen wherever possible to be at the same geographic location as those surveyed in 1997 to provide a clear indication of changes in the river over time.

In 2019/2020, a full survey was conducted that focused mainly on the cross sections surveyed in 1976 and all of 2013. This allowed for a better comparison of the changes and provided a baseline for future studies of the stream.

3.2 Analysis of Cross-Section Data

3.2.1 Mean Bed Levels

Figure 3.2 below shows the change in mean bed level below State Highway for the year 2013 to 2019/2020. The figure shows an aggrading trend for all the cross-sections of interest but it is to be noted that the maximum mean bed level change did not exceed one metre. A fluctuation of ± 300 mm is considered to be within the range of natural variability that one would expect to see in a gravel bed river.

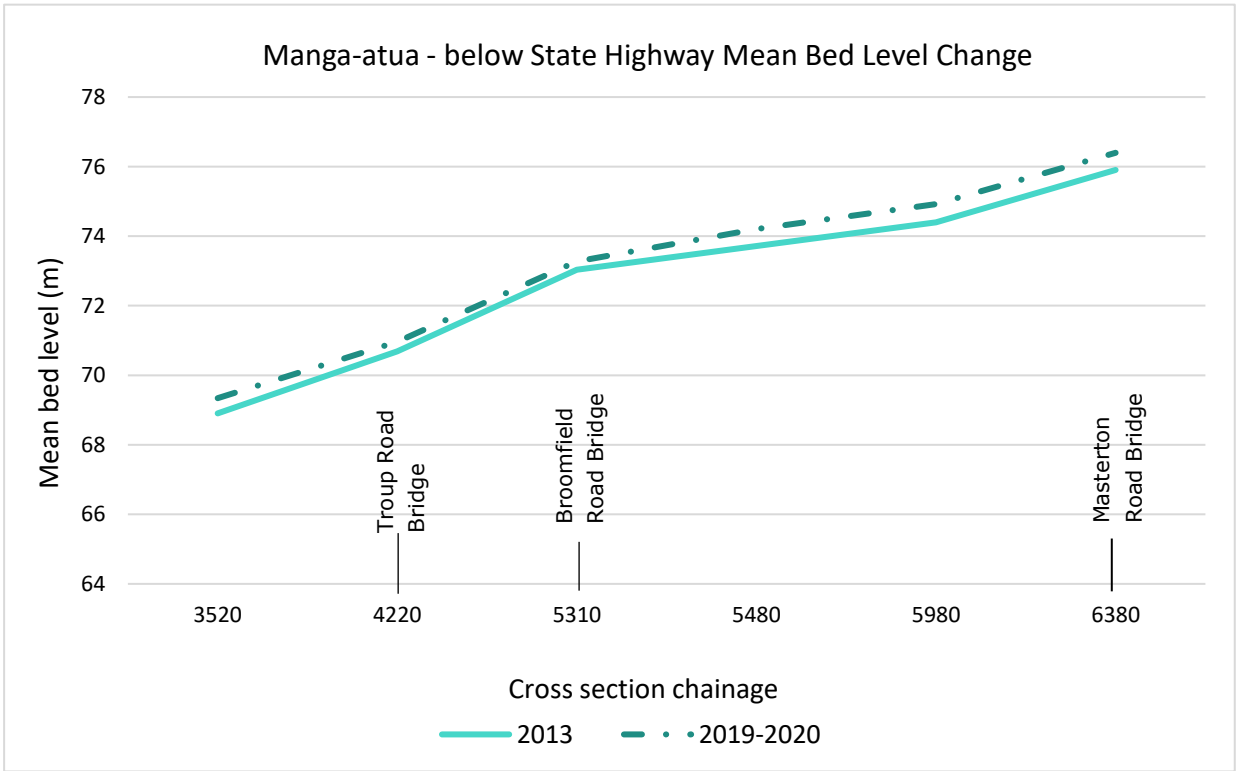


Figure 3.2 Mean bed level change at Manga-atua Stream- below State Highway

Figure 3.3 shows general stability in the middle reach of Manga-atua Stream except for the negative spike at the last cross section 8050 which resulted in a bed degradation of 0.436m.

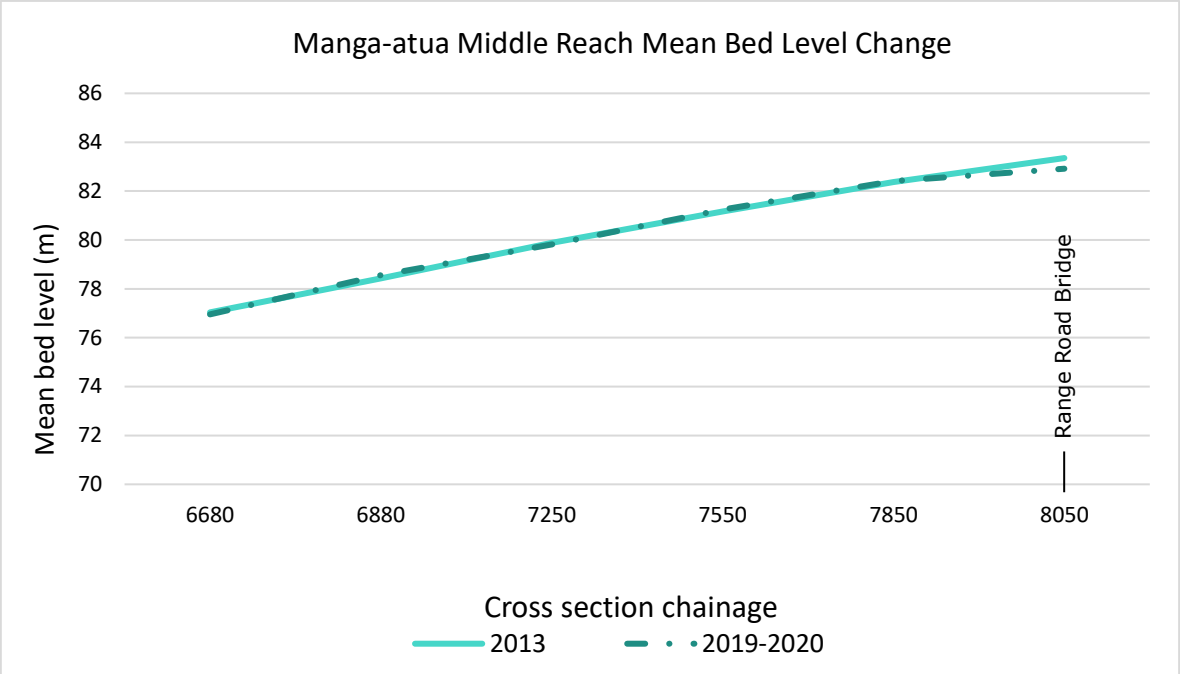


Figure 3.3 Mean bed level change at Manga-atua Stream- Middle Reach

Figure 3.4 shows a fluctuating trend of decrease and increase in the mean bed level change for the Manga-atua Stream above Range Bridge and a bed degradation of 0.614 m at cross section 19600. There was no appreciable (i.e. greater than one metre change) bed degradation or aggradation for this reach of the stream.

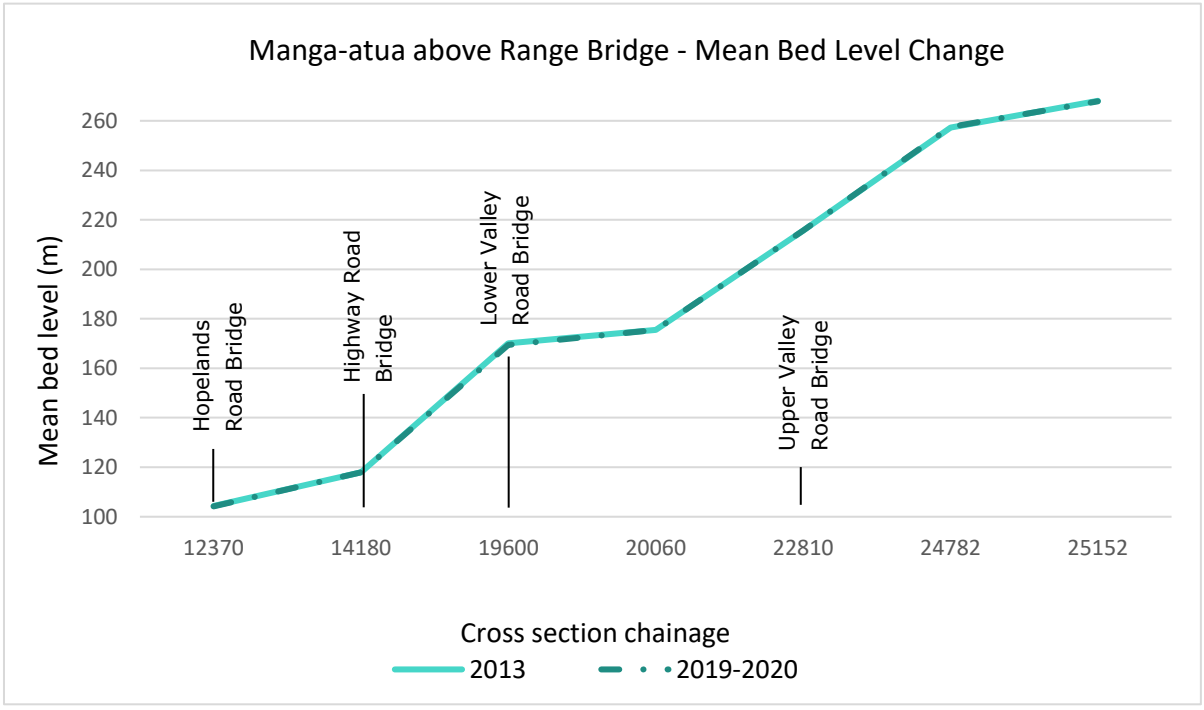


Figure 3.4 Mean bed level change at Manga-atua Stream- above Range Bridge

3.2.2 Gravel Volume

The change in gravel volume at Manga-atua Stream below the State Highway (see Figure 3.5) showed an aggrading trend throughout the cross-sections for the year 2013 to 2019/2020. The total aggrading net change in gravel volume for this reach is 11,322.90 m^3 which corresponds to 1,600 m^3 per annum of aggradation.

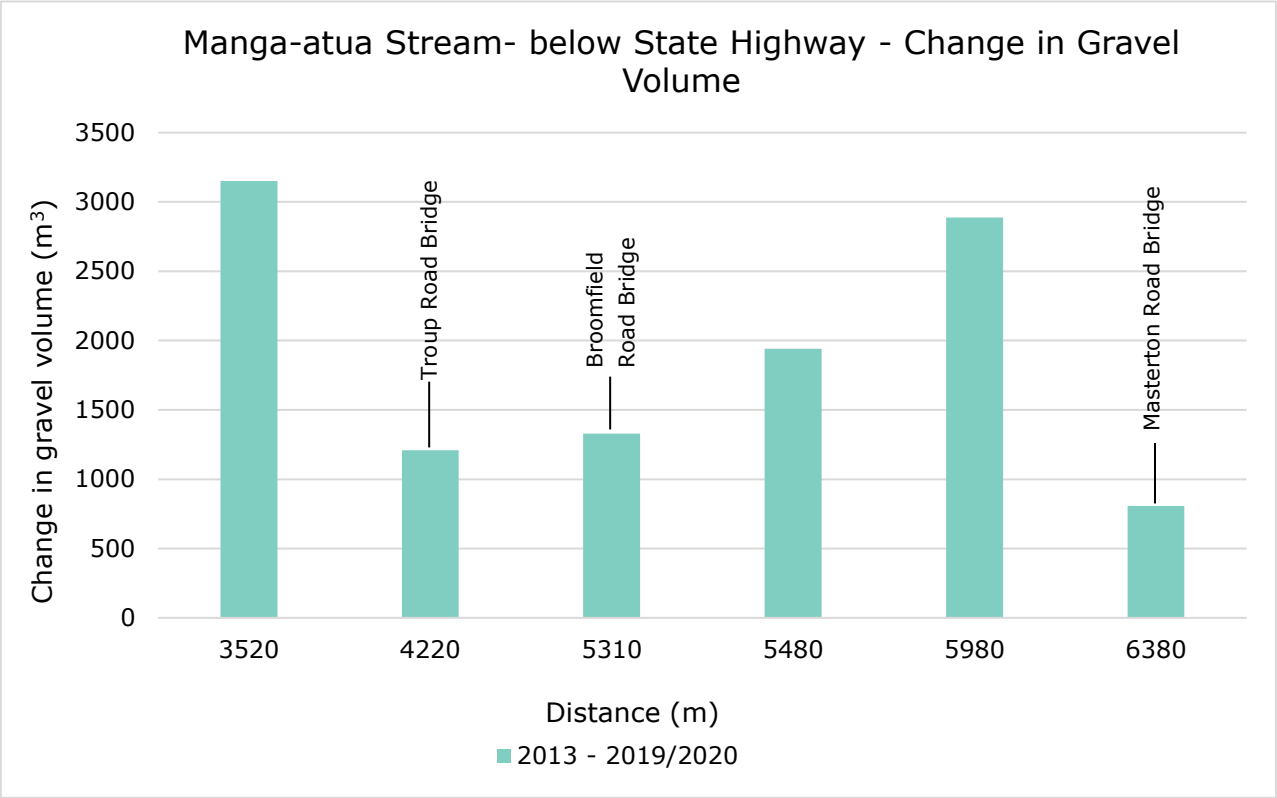


Figure 3.5 Change in Gravel Volume at Manga-atua Stream- below State Highway

The middle reach of Manga-atua stream shows a stable trend in volume from cross-section 6680 until 7850, however there is a significant drop at cross-section 8050 with a degradation of 4,095 m^3. An overall degrading net change of gravel volume of 3,226.20 m^3 has been calculated for the period 2013 to 2019/2020, which is about 450 m^3 per annum of gravel degradation.

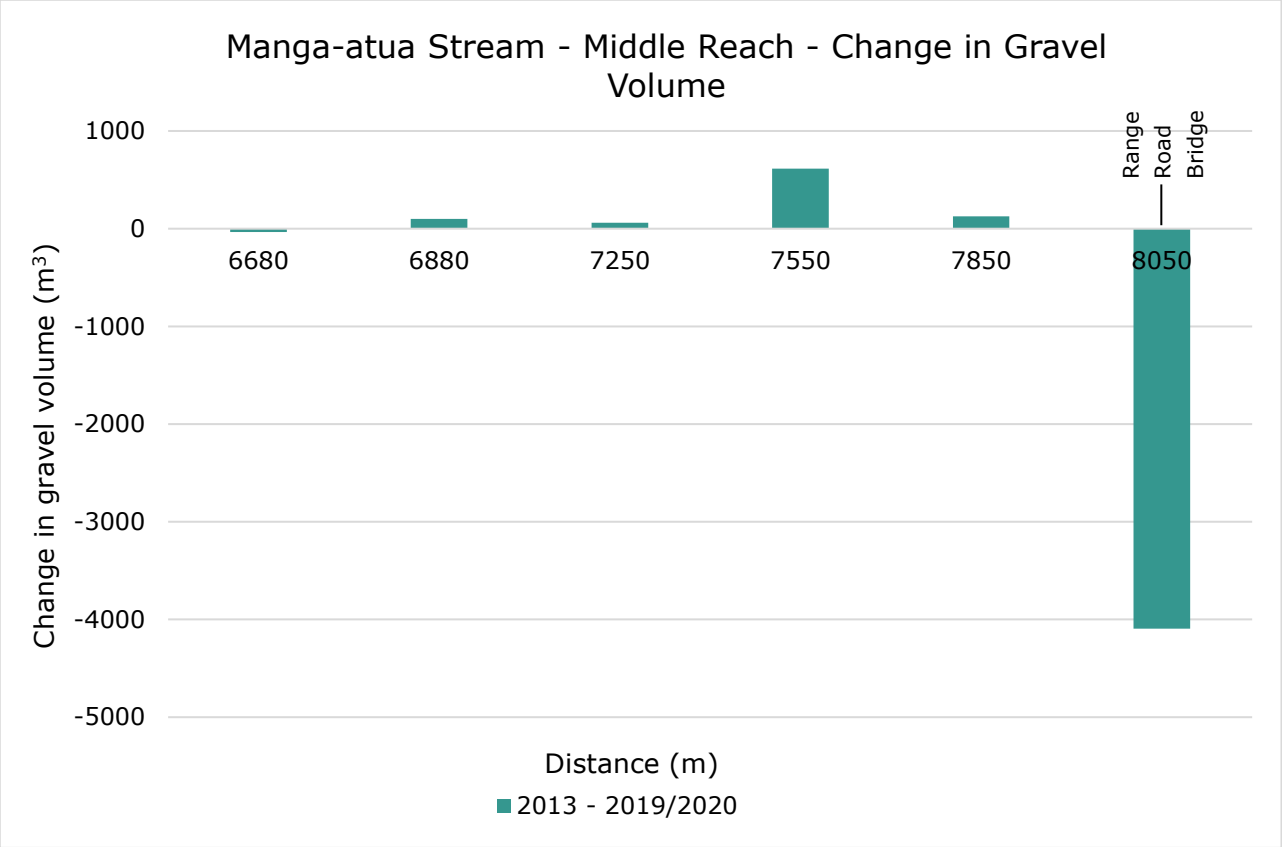


Figure 3.6 Change in Gravel Volume at Manga-atua Stream – Middle Reach

The trend above Range Bridge at Manga-atua Stream (see Figure 3.7) shows an alternate degrading and aggrading trend. The gravel volume change can be seen as fairly constant, except at the 19600 cross section which saw an abrupt drop of over 8,000 m^3. A total net loss of 5,256.4 m^3 has occurred for this reach of the Manga-atua Stream. This corresponds to 750m^3 of gravel degradation per annum.

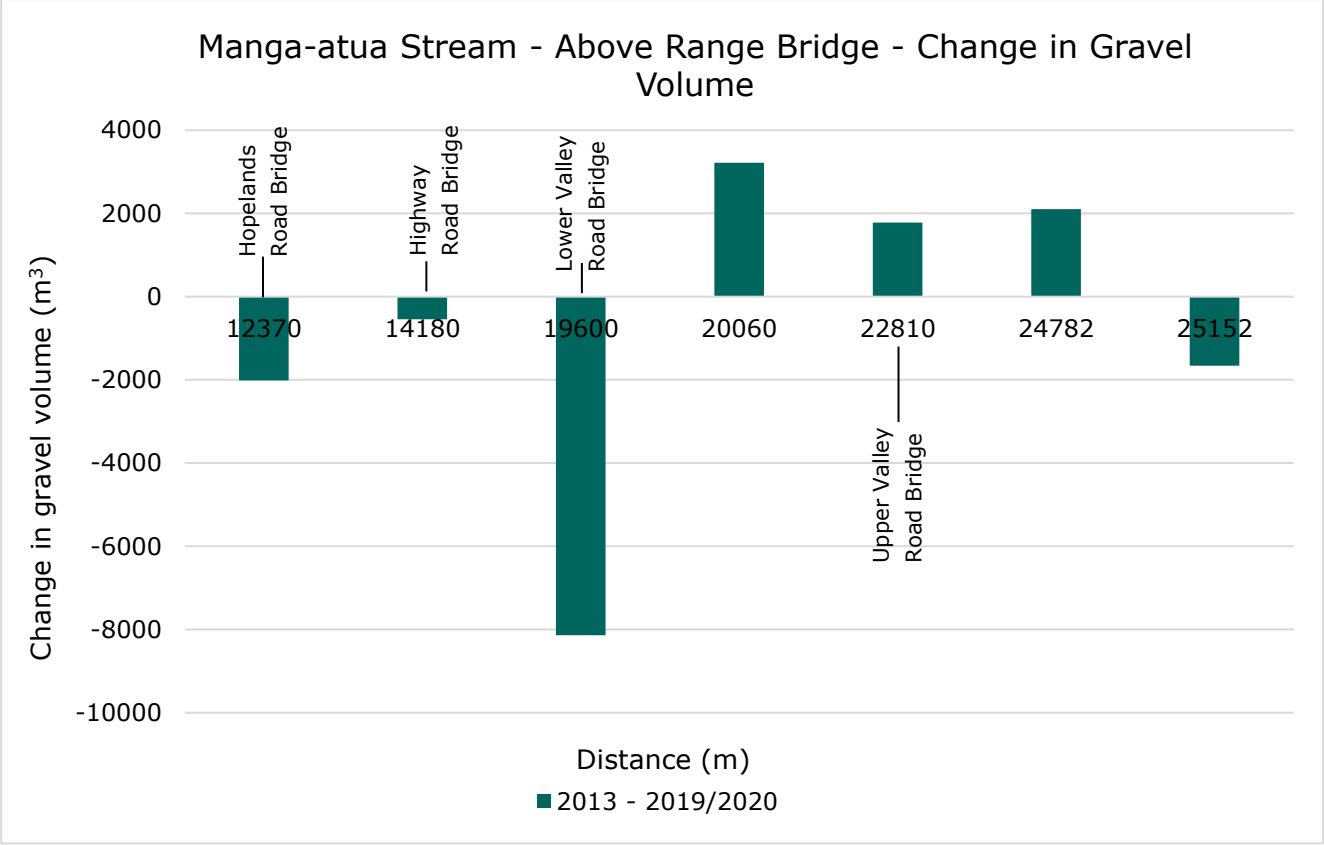


Figure 3.7 Change in Gravel Volume at Manga-atua Stream – Above Range Bridge

4.0 Raparapawai Stream

The Raparapawai Stream has a catchment area of approximately 16 km^2 at Top Grass Road which is around the vicinity of the gravel reserves. As part of the Scheme works a gravel reserve has been established from the bush line to Top Grass Road.

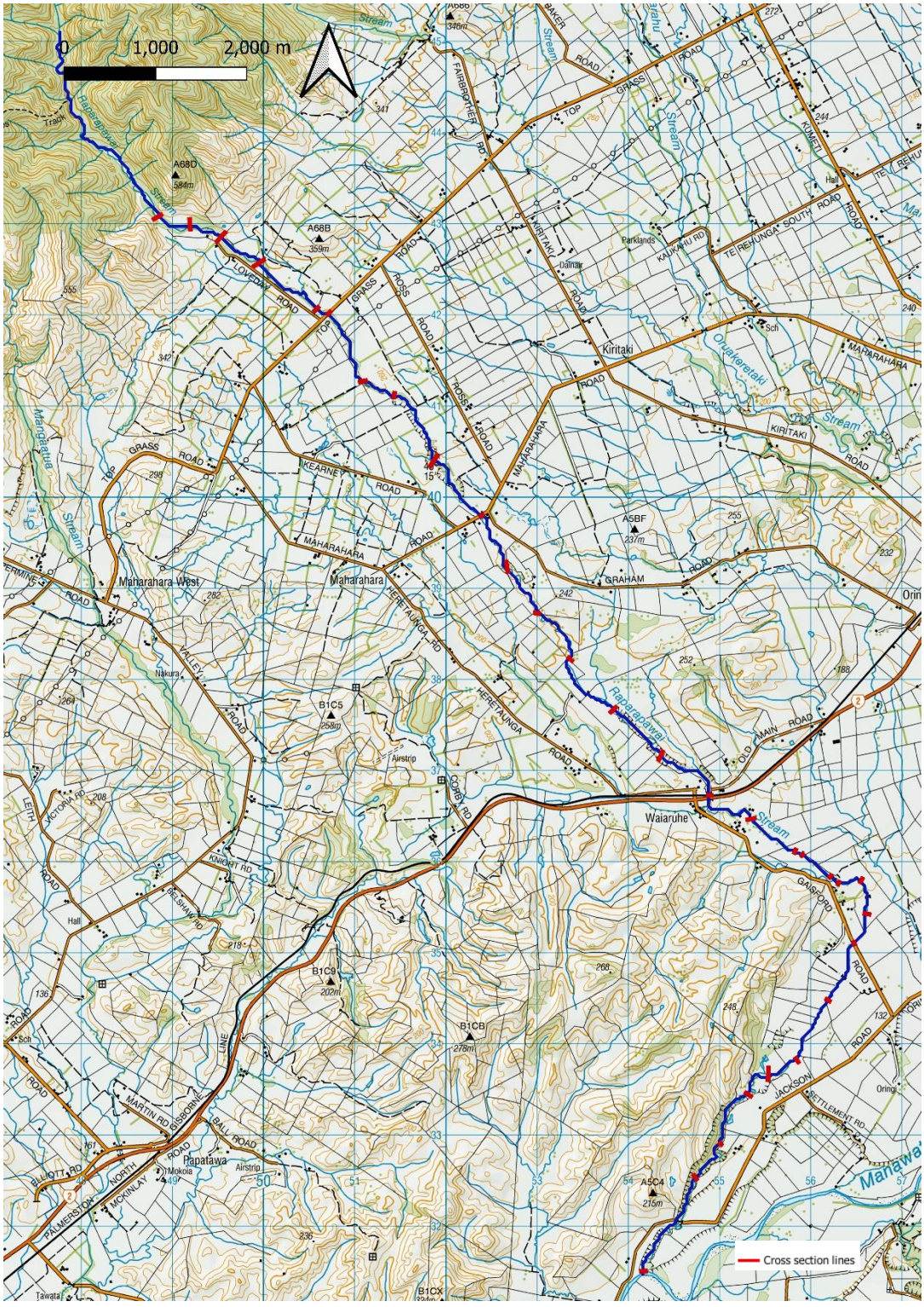


Figure 4.1: Raparapawai Stream with Cross section locations

4.1 Cross-Section Survey Data

Over the period 1976-2020 a total of 33 cross sections (the locations of which can be seen in Appendix B1) have been surveyed at various times. The survey history of these cross sections is summarised in Table 4.1.

Table 4.1 - Summary of Raparapawai Stream Cross Section Surveys 1976-2020

Cross-Section	Chainage (m)	Survey Date						
		1976	1982	1994	1997	2002	2013	2019/2020
5710000	0							
5710160	1600							
5710240	2400							
5710320	3200							
5710400	4000							
5710480	4800							
5710560	5600							
5710565	5650							
5710575	5750							
5710580	5800							
5710590	5900							
5710600	6000							
5710650	6500							
5710720	7200							
5710800	8000							
5710880	8800							
5710960	9600							
5711040	10400							
5711120	11200							
5711210	12100							
5711280	12800							
5711350	13500							
5711360	13600							
5711440	14400							
5711520	15200							
5711600	16000							
5711670	16700							
5711680	16800							
5711760	17600							
5711820	18200							
5711840	18400							
5711860	18600							
5711900	19000							

An extensive survey, covering 18.4 km of the Raparapawai Stream, was carried out in 1976. In 1994, 1997 & 2002 surveys were conducted that focused mainly on the upper 5.5 km of the study reach and gravel reserves.

In 2013 a survey was conducted that focused mainly on the cross sections surveyed in the 1990s and 2002 as well as a number of other cross sections in the lower part of the study reach.

In 2020, a fluvial survey was conducted that covered almost all of the cross-sections in the entire reach of the stream. These sections were chosen to see how the stream has evolved over recent years and to provide a baseline for future studies of the stream.

4.2 Analysis of Cross-Section Data

4.2.1 Mean Bed Levels

Raparapawai Stream mean bed level change illustrated in Figure 4.2 shows a fluctuating trend but not a significant one. The maximum change in mean bed level in this stream did not exceed 0.3m which falls well within the range of natural variability that one would expect to see in a gravel bed river.

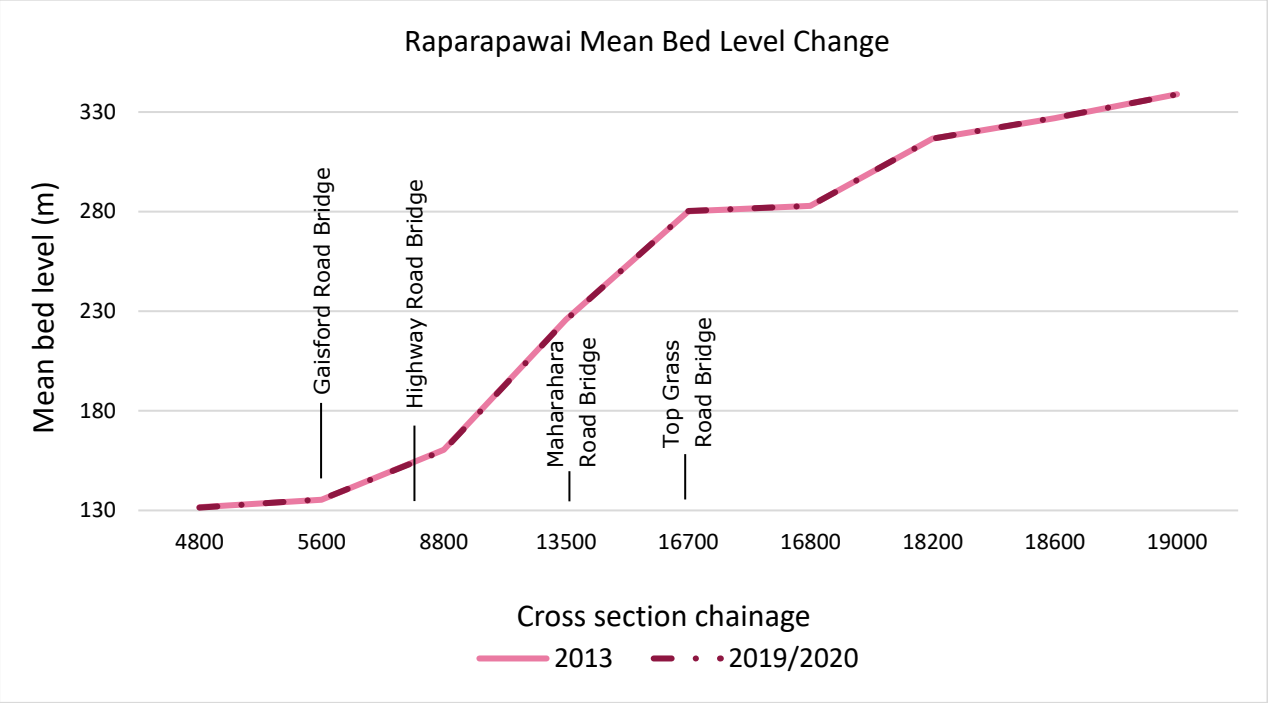


Figure 4.2: Mean Bed Level Change at Raparapawai Stream

4.2.2 Gravel volume

Figure 4.3 below shows the change in gravel volume of Raparapawai Stream for the period 2013 to 2019/2020. The cross sections 8800 and 13500 exhibit a degrading and then aggrading movement that balances out the generally stable catchment length trend. There was an overall net loss of 1,470 m^3 amounting to 210 m^3 of degradation per year.

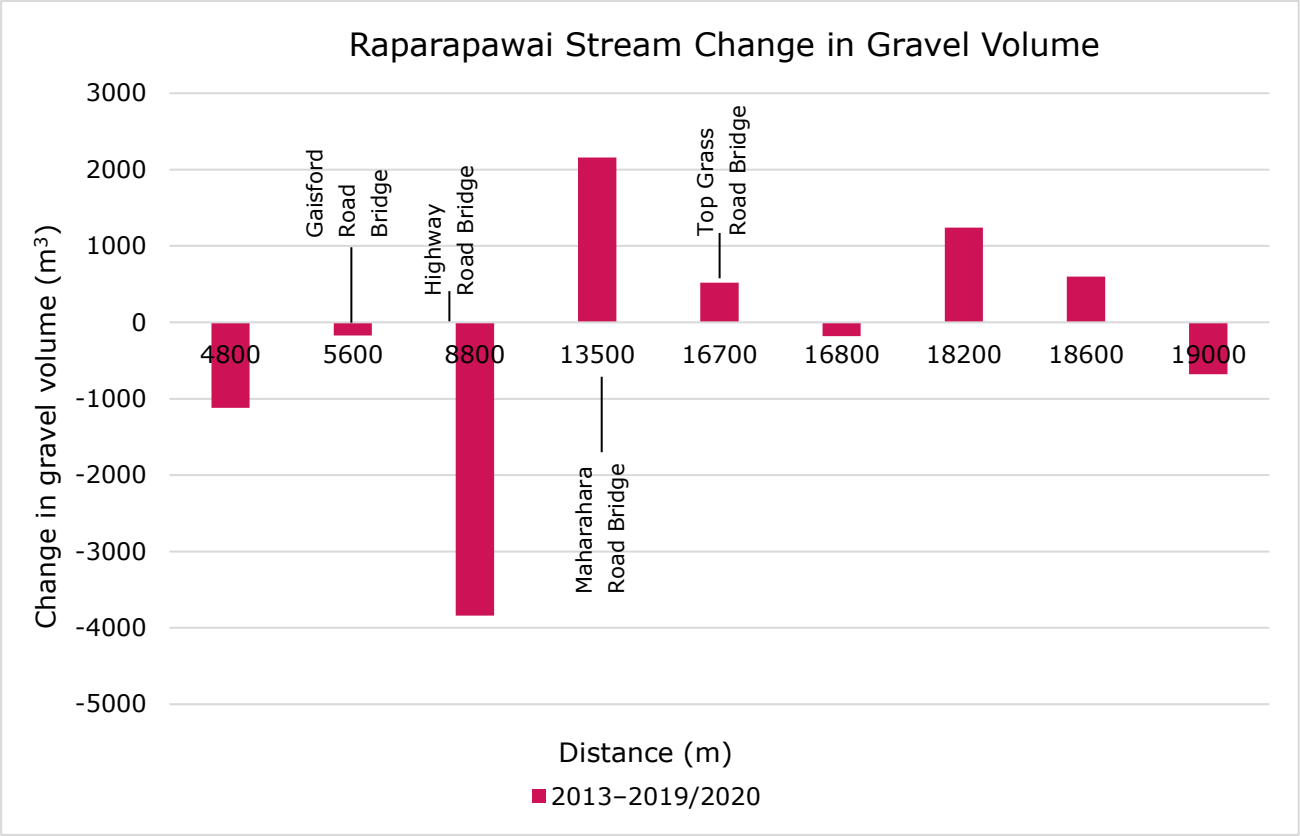


Figure 4.3: Change in Gravel Volume at Raparapawai Stream

5.0 Oruakeretaki Stream

The Oruakeretaki Stream has a catchment area of approximately 10 km^2 at the Mangapukakakahu Stream confluence and 16 km^2 at Top Grass Road around the vicinity of the gravel reserves.

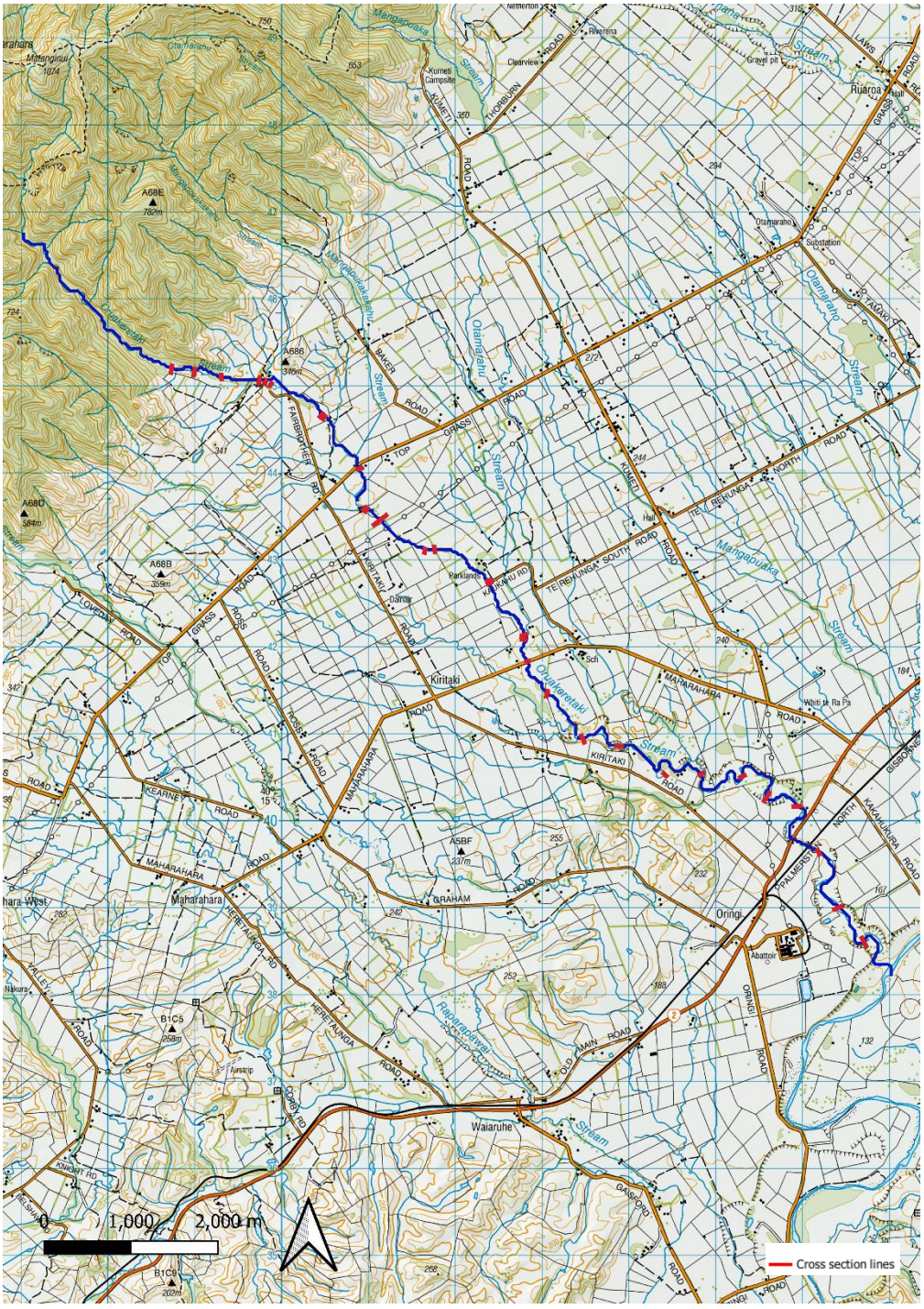


Figure 5.1: Oruakeretaki Stream with cross section locations

5.1 Cross-Section Survey Data

Over the period 1976-2020 a total of 21 cross sections (the locations of which can be seen in Appendix C1) have been surveyed at various times.

Table 5.1 summarises the survey history of each cross section.

Cross-Section	Chainage (m)	Survey Date					
		1976	1994	1997	2001	2013	2020
4910080	800						
4910160	1600						
4910240	2400						
4910320	3200						
4910400	4000						
4910480	4800						
4910560	5600						
4910640	6400						
4910720	7200						
4910800	8000						
4910880	8800						
4910960	9600						
4911040	10400						
4911120	11200						
4911200	12000						
4911280	12800						
4911360	13600						
4911440	14400						
4911490	14900						
4911520	15200						
4911550	15500						

Table 5.1 - Summary of Oruakeretaki Stream Cross Section Surveys 1976-2020

An extensive survey covering approximately 14.4 km of the Oruakeretaki Stream was carried out in 1976. The years 1994, 1997 and 2001 saw surveys which focused on cross sections in the upper 3 km of the study reach. This upper reach covers the gravel reserve area between Top Grass Road and the bush line. To enable a useful analysis of change in the stream over time, the 1994 cross sections and a number of 1976 surveyed cross sections were re-surveyed in 2013.

In 2020, the cross sections originally surveyed in 2013 as well as a few cross sections surveyed in 1976 were resurveyed in 2020 to provide a baseline for future studies of the stream.

5.2 Analysis of Cross-Section Data

5.2.1 Mean Bed Levels

The Oruakeretaki stream has seen a fluctuating trend in the change of mean bed level throughout the period of 2013 to 2020. However, no appreciable mean bed level change was observed in that it did not exceed one metre change. The maximum mean bed level change occurred in cross section 12800 where 0.576m of degradation was seen.

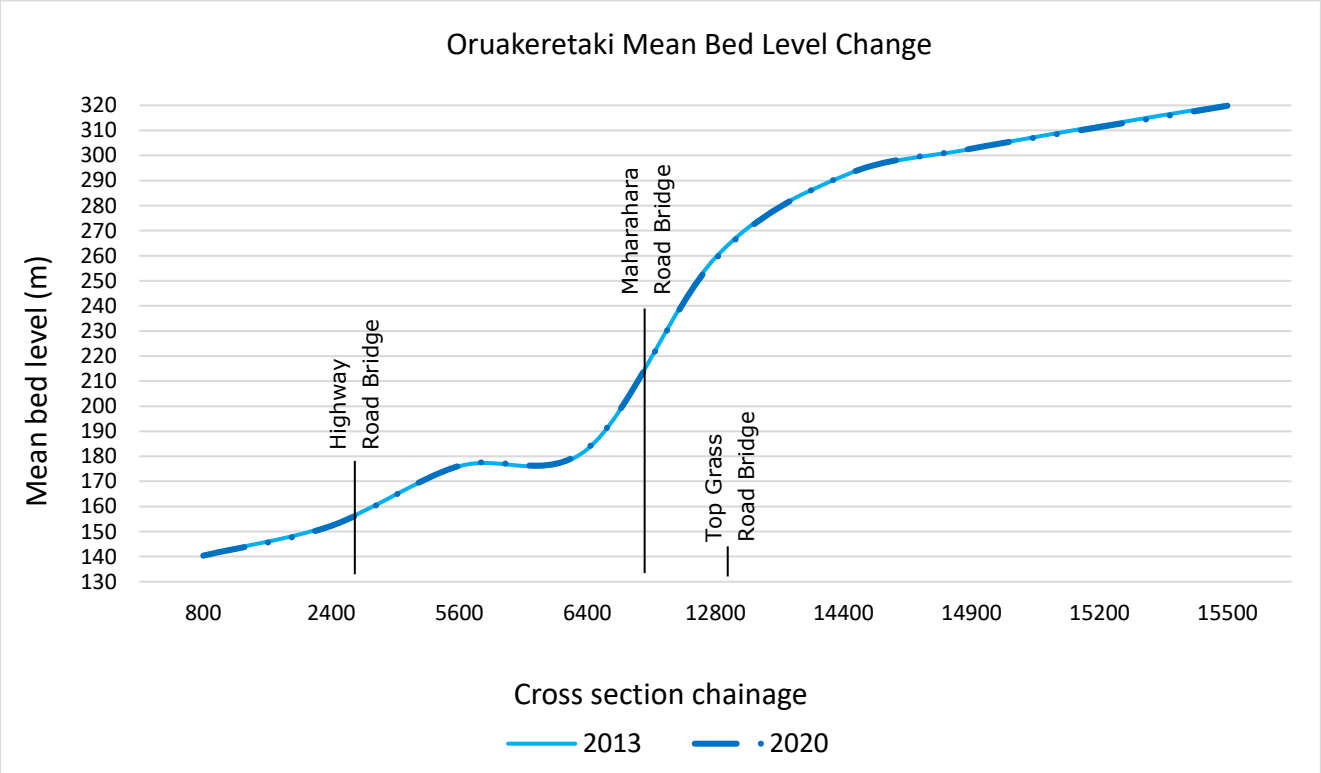


Figure 5.2: Mean Bed Level Change at Oruakeretaki Stream

5.2.2 Gravel volume

The gravel volume change in Oruakeretaki stream has recorded the same trend as the mean bed level change. The maximum change in gravel volume is at cross section 12800 with a net gravel volume loss of negative 6,560 m^3. There was an overall degrading net gravel volume change of 15,220 m^3 which is approximately 2,100 m^3 per annum of gravel degradation for the stream.

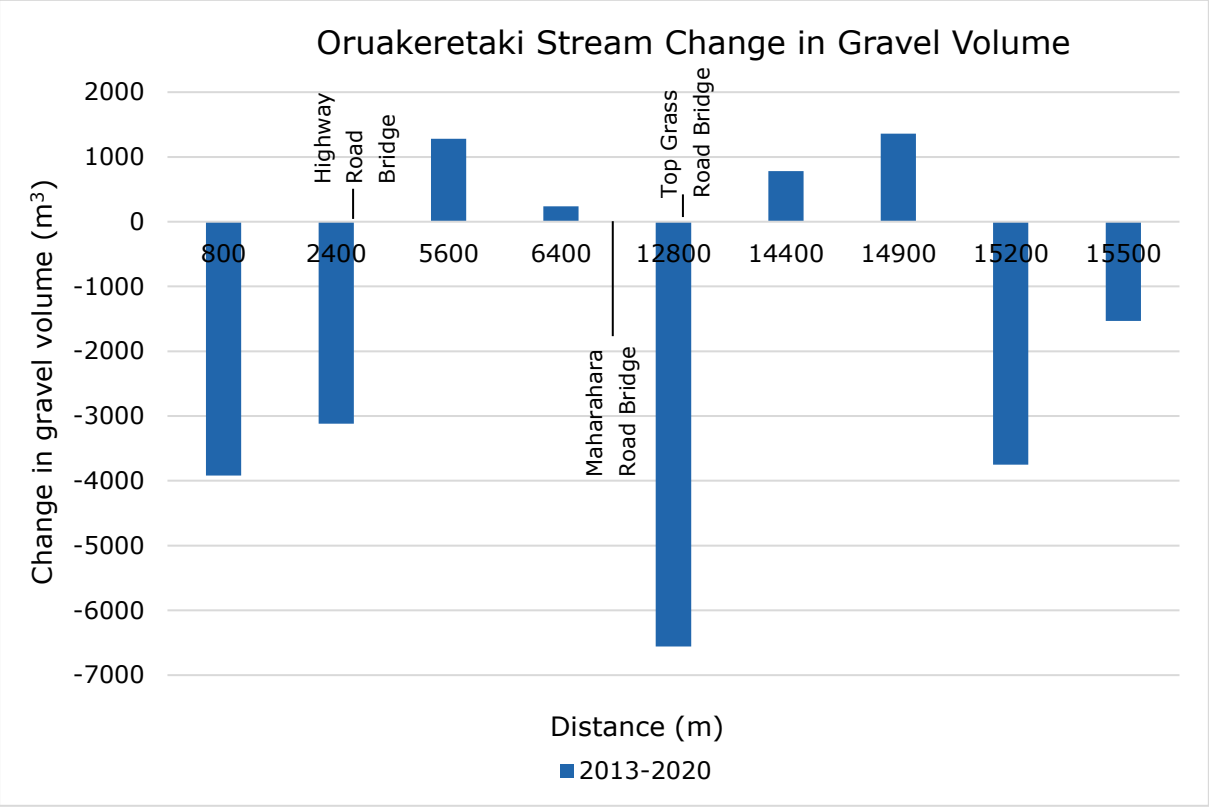


Figure 5.3: Change in Gravel Volume at Oruakeretaki Stream

6.0 Mangapukakakahu Stream

The Mangapukakakahu Stream has a small catchment of approximately 6 km^2 above its confluence with the Oruakeretaki Stream.

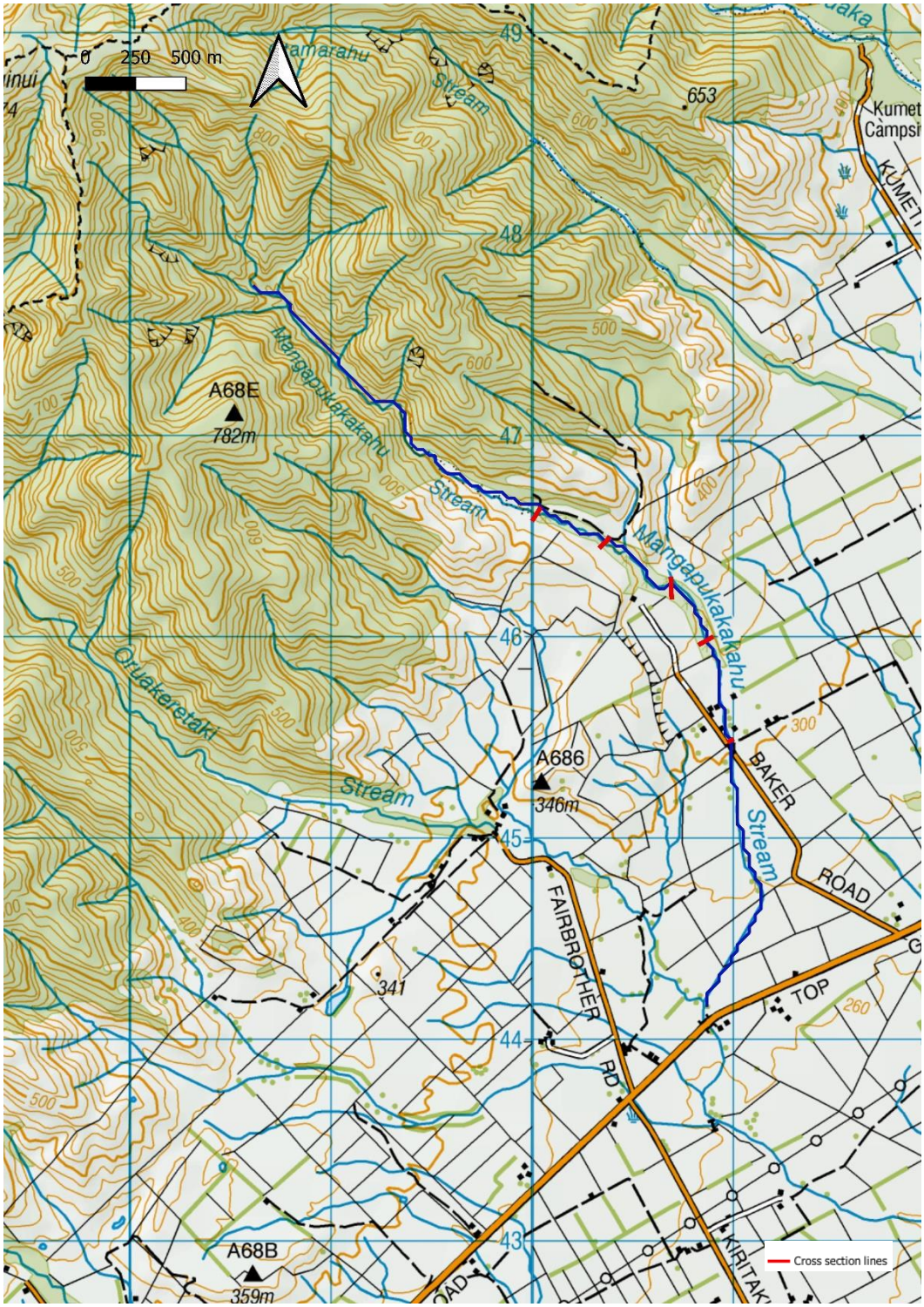


Figure 6.1: Mangapukakakahu Stream with cross section locations

6.1 Cross-Section Survey Data

Between 1994 and 2020, five cross sections covering a 1.5 km reach of the Mangapukakakahu Stream have been surveyed on four occasions. The cross sections are located through the gravel trap area of the stream between Baker Road and the bush line. The history of these surveys is summarised in Table 6.1, and the locations of the cross sections can be seen in Appendix D1.

Table 6.1 Summary of Mangapukakakahu Stream Cross-section surveys 1994-2020

Cross Section	Chainage (m)	Survey Date				
		Mar-94	Dec-97	Aug-01	Apr-13	2020
3881440	14400					
3881500	15000					
3881520	15200					
3881550	15500					
3881590	15900					

6.2 Analysis of Cross-Section Data

6.2.1 Mean Bed Levels

No appreciable (i.e. greater than one metre change) change was seen throughout the reach of Mangapukakakahu Stream. An overall positive change can be observed from this reach where the maximum value is at cross section 15900 having a mean bed level change of positive 0.422m for the period of 2013 to 2020.

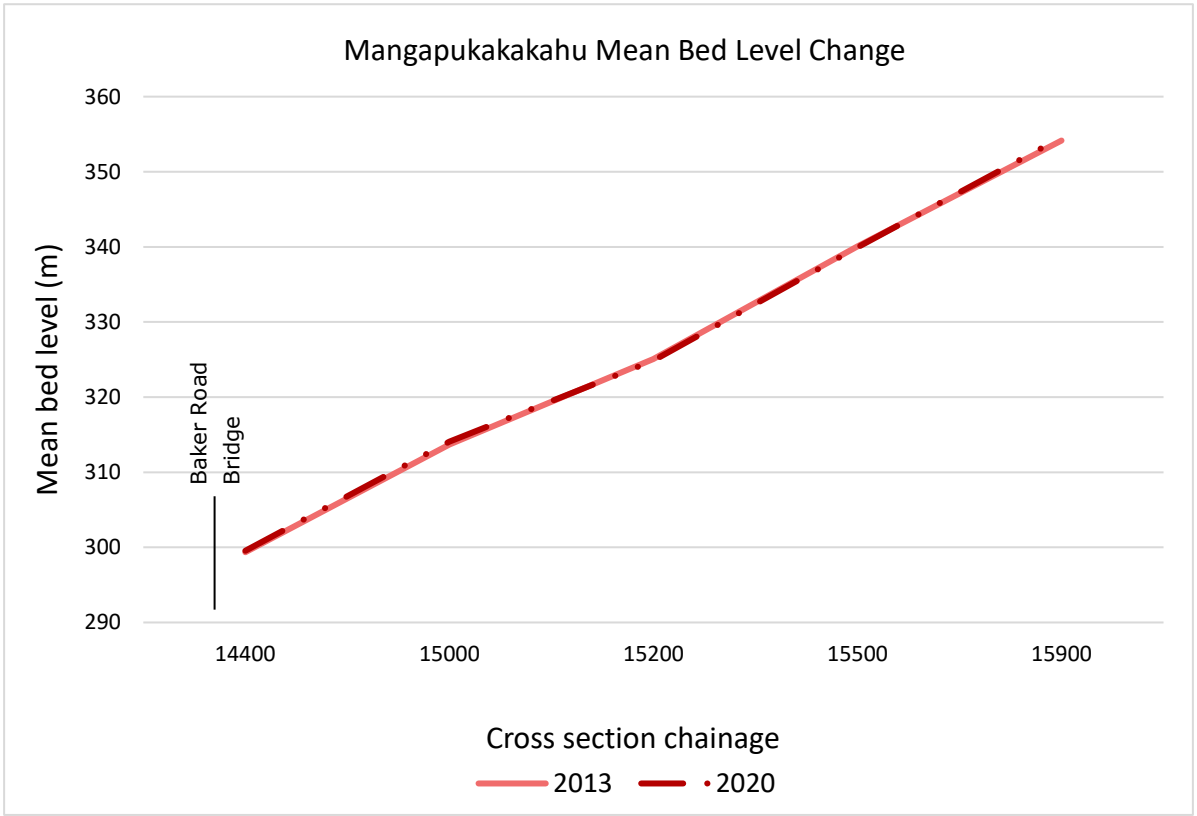


Figure 6.2: Mean Bed Level Change at Mangapukakakahu Stream

6.2.2 Gravel volume

It was observed that as Mangapukakakahu's mean bed level change increases or decreases, the gravel volume change also increases or decreases. The gravel volume change for Mangapukakakahu resulted in an overall net aggrading volume of 4,205 m^3 which amounts to approximately 600 m^3 per annum of aggradation.

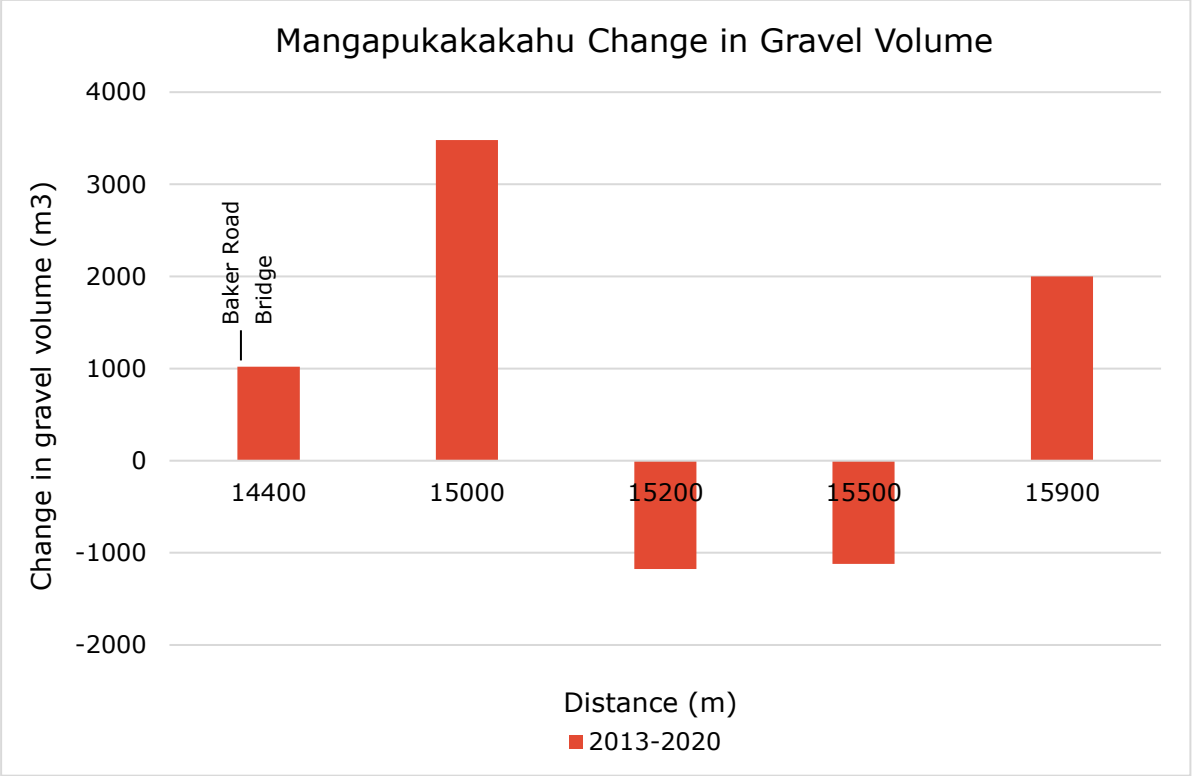


Figure 6.3: Change in Gravel Volume at Mangapukakakahu Stream

7.0 Otamarahu Stream

The Otamarahu Stream has the smallest of all the catchments in the South Eastern Ruahine Scheme at only 3 km^2 above Kumeti Road.

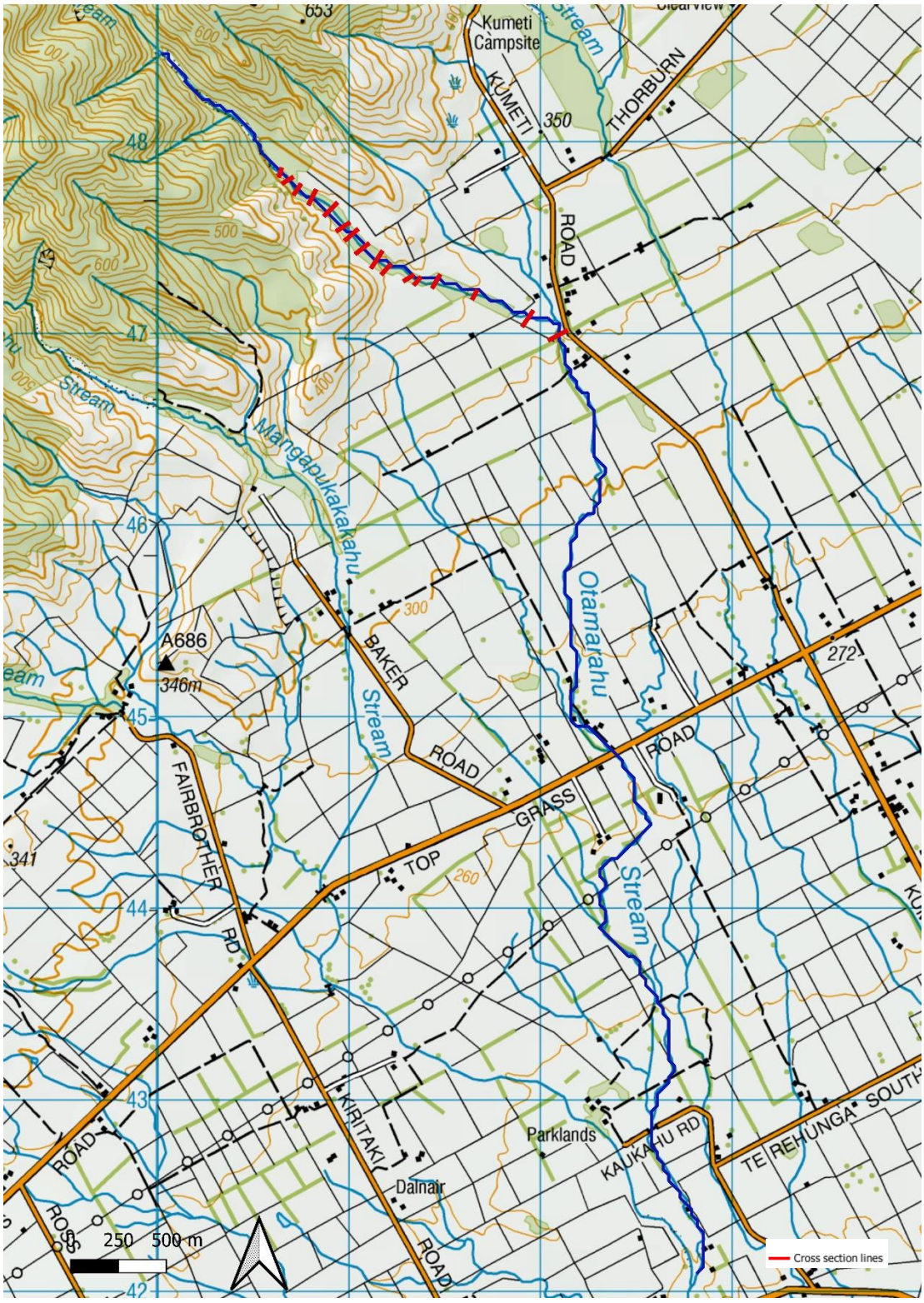


Figure 7.1: Otamarahu Stream with cross section locations

7.1 Cross-Section Survey Data

Between 1978 and 2019 a total of 16 cross sections, covering 20 km of the Otamarahu Stream, have been surveyed at various times. The locations of these cross sections can be seen in Appendix E1 and the history of these surveys is summarised Table 7.1.

Table 7.1 Summary of Otamarahu Stream Cross-section Surveys 1978-2019

Cross Section (Chainag	Chainage (m)	Survey Date																		
		1978	1983	1984	1985	1987	May-88	Nov-88	Feb-89	Feb-90	Mar-90	Apr-91	Jun-92	Feb-94	Jul-95	Dec-97	May-00	Jan-02	Feb-13	2019
5041779	17790																			
5041805	18050																			
5041835	18350																			
5041857	18570																			
5041869	18690																			
5041873	18730																			
5041892	18920																			
5041899	18990																			
5041910	19100																			
5041919	19190																			
5041926	19260																			
5041937	19370																			
5041950	19500																			
5041960	19600																			
5041968	19680																			
5041975	19750																			

As Table 7.1 shows, an extensive survey record of a 2 km reach of the Otamarahu Stream exists. The reach, which covers the gravel traps below the bush line, was regularly surveyed between 1984 and 2013. All of the previously surveyed cross sections were resurveyed in 2019.

7.2 Analysis of Cross-Section Data

7.2.1 Mean Bed Levels

A fluctuating trend was observed for the Otamarahu Stream. The maximum mean bed level change was observed to be 0.893 m aggradation and 0.811 m degradation.

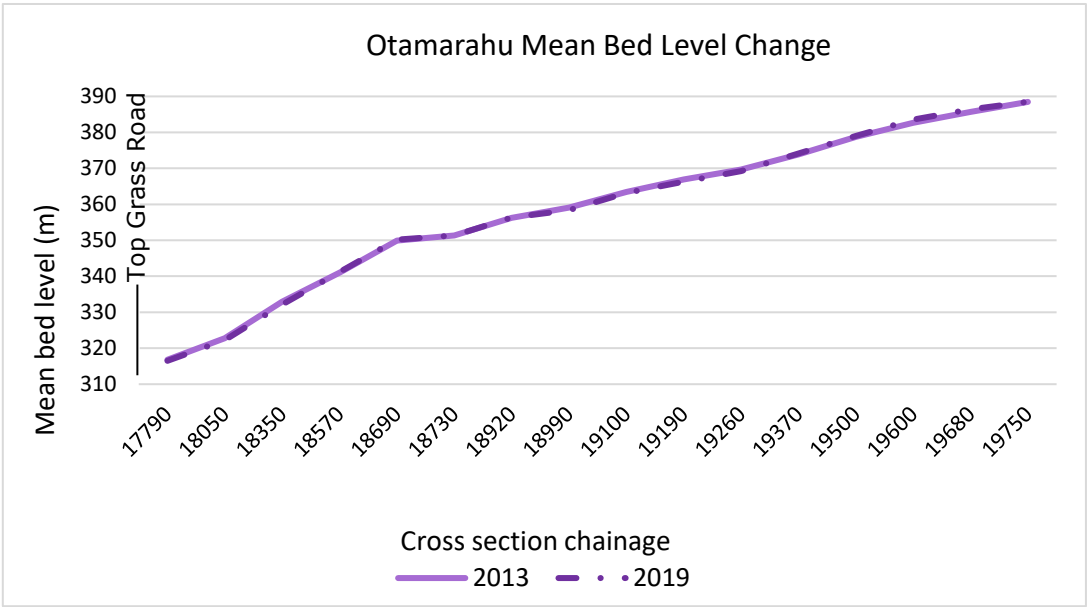


Figure 7.2: Mean Bed Level Change at Otamarahu Stream

7.2.2 Gravel volume

Figure 7.3 shows a degrading trend in the lower reaches, aggradation in the upper reaches, and fluctuating in the middle reaches. The overall net change in gravel volume is 653.5 m^3 degradation which is approximately 100 m^3 per year.

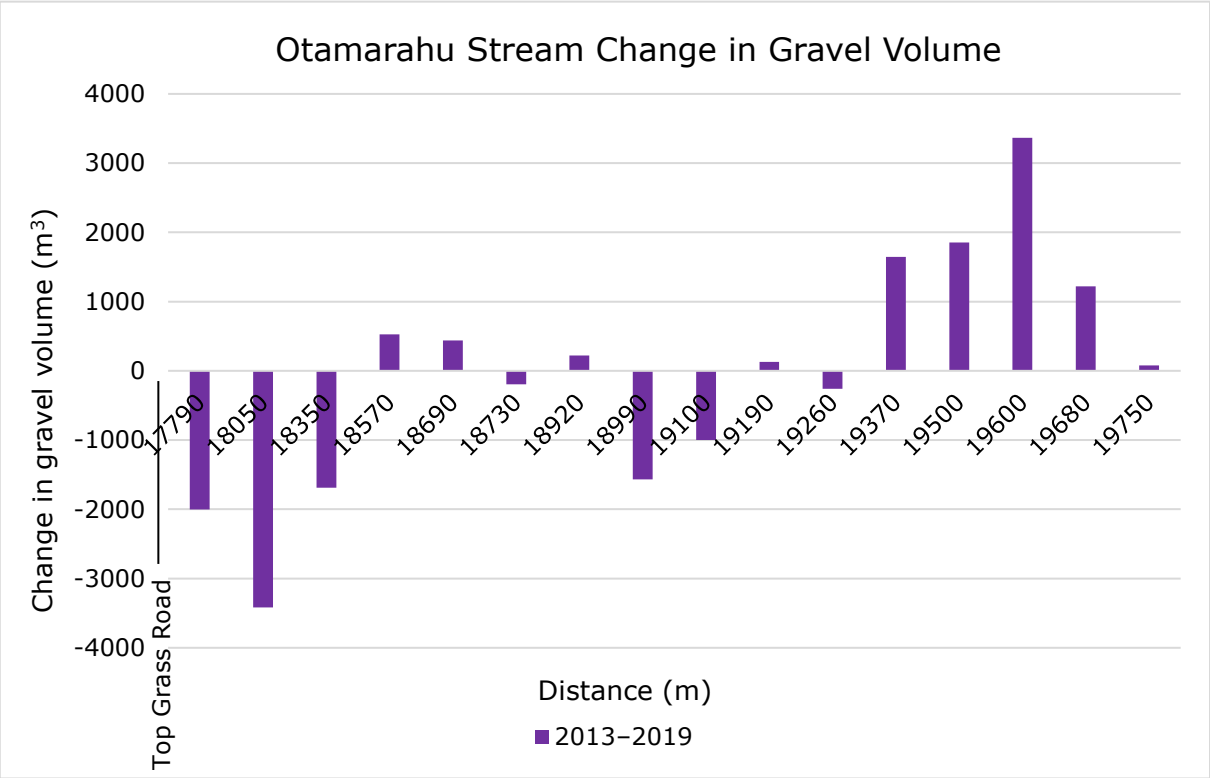


Figure 7.3: Change in Gravel Volume at Otamarahu Stream

8.0 Kumeti Stream

The Kumeti Stream has a catchment area of approximately 9 km^2 at Thorburns Road. Starting off as a drain constructed by the Public Works Department in 1918, erosion of the stream channel quickly became a problem as it scoured a deep channel through the underlying gravel deposits. From 1947 to 1960 both the Ministry of Works and the Manawatu Catchment Board carried out works in an attempt to control this erosion. In 1952 the Ministry of Works acquired some 58 acres above Thorburns Road to establish shingle traps and constructed a series of concrete weirs. These were installed in the channel downstream of Thorburns Road to raise the bed level (Bell, 2016).

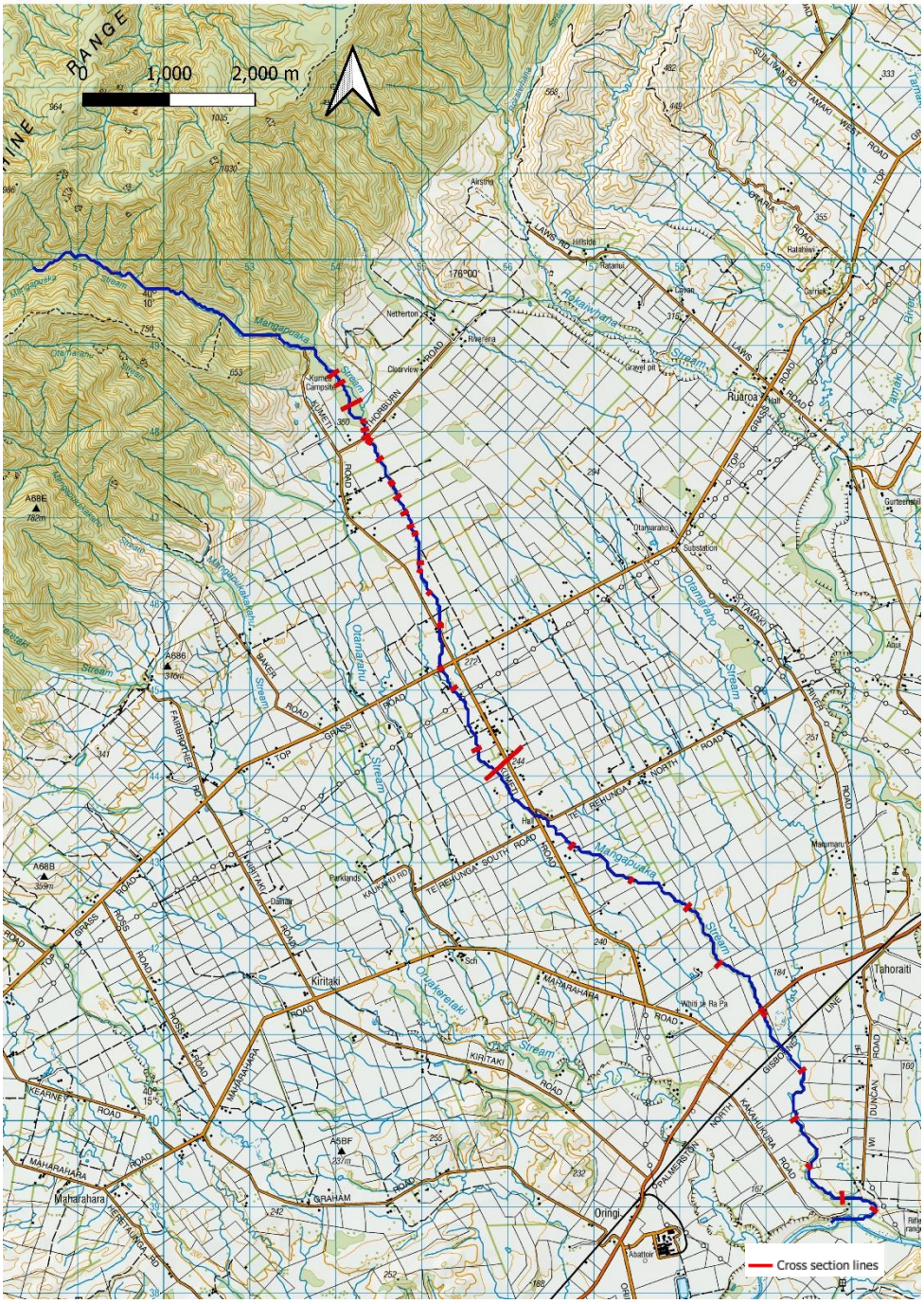


Figure 8.1: Kumeti Stream with cross section locations

8.1 Cross-Section Survey Data

The Kumeti Stream has been surveyed a number of times between 1975 and 2013. During this period a total of 26 cross sections have been surveyed at various times. The locations of these cross sections can be seen in Appendix F1. Table 8.1 summarises the survey history of each cross section. The 1975 survey covered 13.5 km of the stream. Throughout the 1980s, 1990s and early 2000s the upper 3 km of the study reach was regularly surveyed. In 2013, the survey covered those sections last surveyed in 2002 as well as five sections in the lower reach, last surveyed in 1975. The 2019-2020 survey covers as much as that of 2013 and four more sections in the lower reach last surveyed in 1975.

Table 8.1 Summary of Kumeti Stream Cross-section Surveys 1975-2019/2020

Cross-Section (Chainage (m))	Chainage (m)	Survey Date																		
		1975	1977	1980/81	1982	1983	1985	1987	Jun-88	Nov-88	1990	1991	1993	1994	1995	1997	2000	2002	2013	2019/2020
2720020	200																			
2720100	1000																			
2720180	1800																			
2720263	2630																			
2720340	3400																			
2720420	4200																			
2720500	5000																			
2720580	5800																			
2720655	6550																			
2720740	7400																			
2720908	9080																			
2720981	9810																			
2721058	10580																			
2721060	10600																			
2721098	10980																			
2721140	11400																			
2721180	11800																			
2721220	12200																			
2721270	12700																			
2721285	12850																			
2721295	12950																			
2721300	13000																			
2721310	13100																			
2721335	13350																			
2721360	13600																			
2721380	13800																			

8.2 Analysis of Cross-Section Data

8.2.1 Mean Bed Levels

Figure 8.2 below shows the change in mean bed level at each cross section location for the period of 2013 to 2019/2020. Cross section 12850 has had appreciable (i.e. greater than one metre change) degradation of 1.045 m while cross section 10580 shows a positive 0.997 m change in mean bed level. The ±1.0 m fluctuation is not considered to be a significant variation over such a long period of time (Bell, 2016).

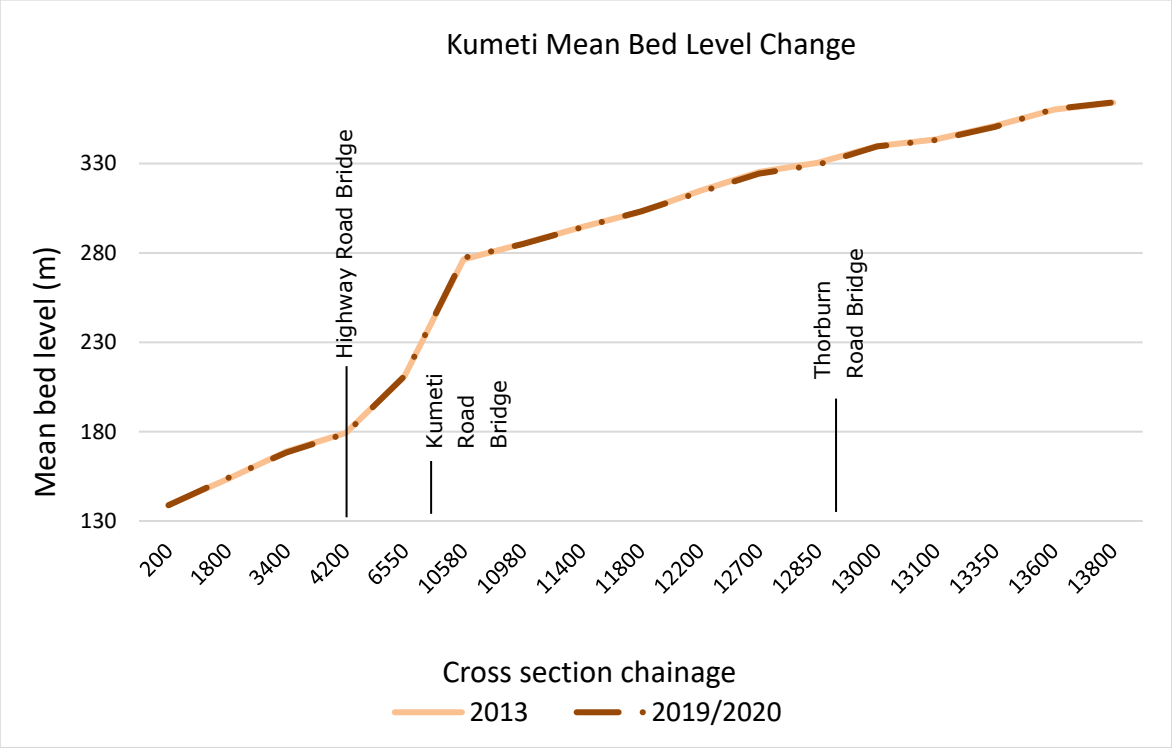


Figure 8.2: Mean Bed Level Change at Kumeti Stream

8.2.2 Gravel volume

The overall trend in the Kumeti Stream is that of degradation. A total net loss of 27,654.50m^3 has occurred which amounts to about 3,900 m^3 per annum of degradation.

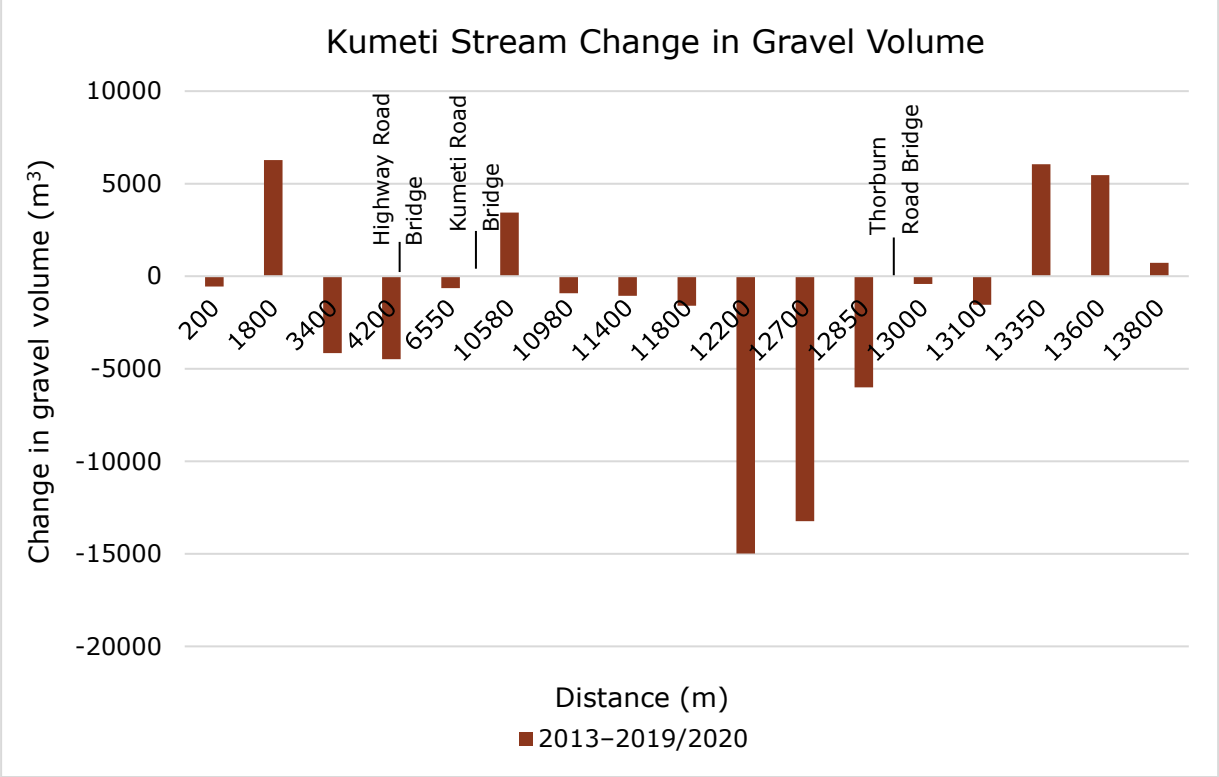


Figure 8.3: Change in Gravel Volume at Kumeti Stream

9.0 Otamaraho Stream

The Otamaraho Stream has a catchment area of approximately 4.5 km^2 at Thorburns Road.

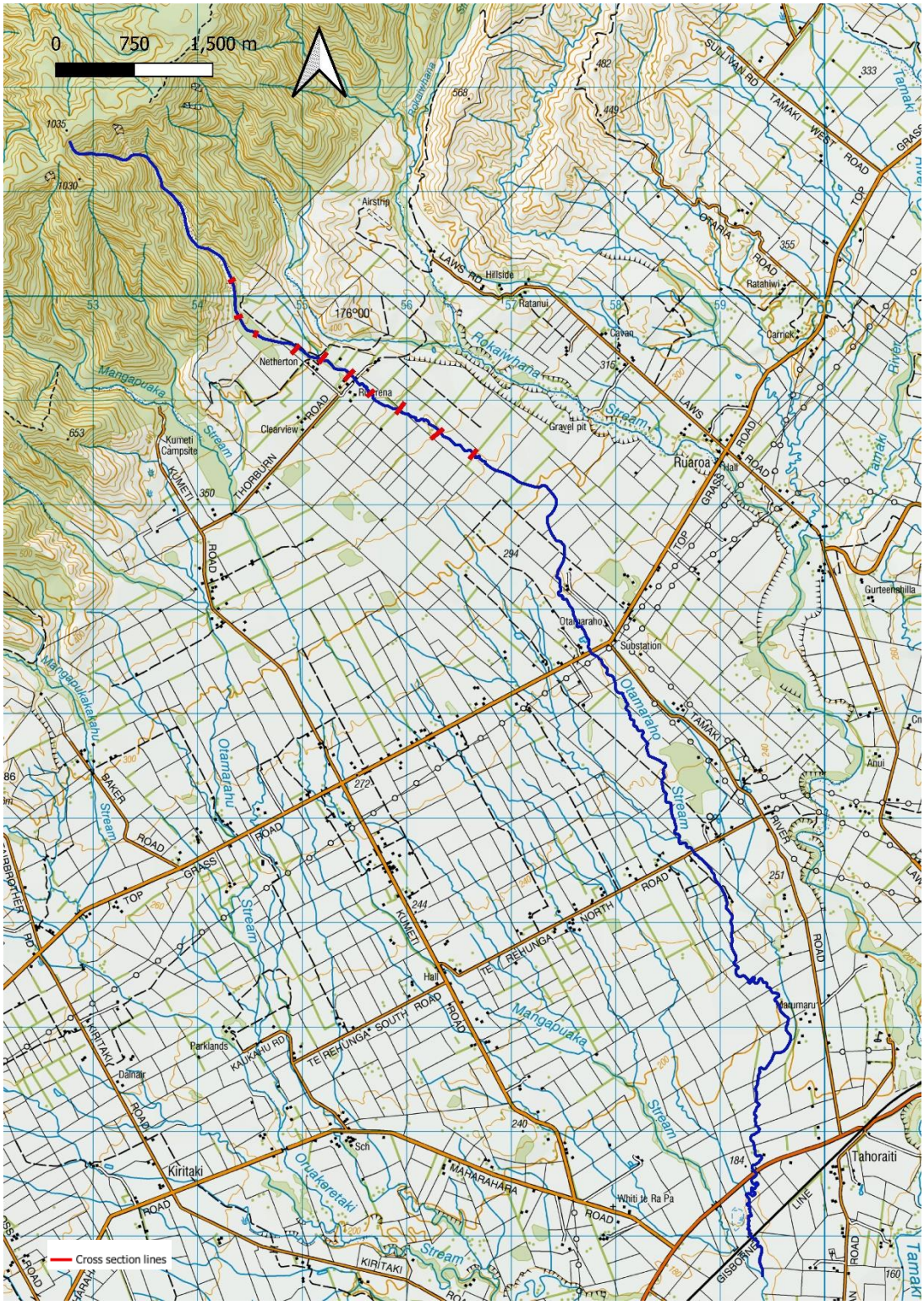


Figure 9.1: Otamaraho Stream with cross section locations

9.1 Cross-Section Survey Data

A total of 10 cross sections have been surveyed at various times, between 1981 and 2020, through a 3 km reach of the Otamaraho Stream. The locations of these cross sections can be seen in Appendix G1. The history of surveys of the various cross sections in summarised in Table 9.1.

Table 9.1 Summary of Otamaraho Stream Cross-section Surveys 1981-2020

Cross Section (Chainag	Chainage (m)	Survey Date														
		1981/82	1983	1984	1985	1987	May-88	Dec-88	1990	1991	1994	1995	2000	2002	2013	2020
5031747	17470															
5031789	17890															
5031836	18360															
5031870	18700															
5031899	18990															
5031930	19300															
5031959	19590															
5032005	20050															
5032031	20310															
5032068	20680															

9.2 Analysis of Cross-Section Data

9.2.1 Mean Bed Levels

Figure 9.2 shows an overall degrading trend for the mean bed level change for the period of 2013 to 2020 at Otamaraho Stream. No appreciable change in mean bed level was seen. The maximum value can be seen at cross section 19590 having a negative 0.579 m change of mean bed level.

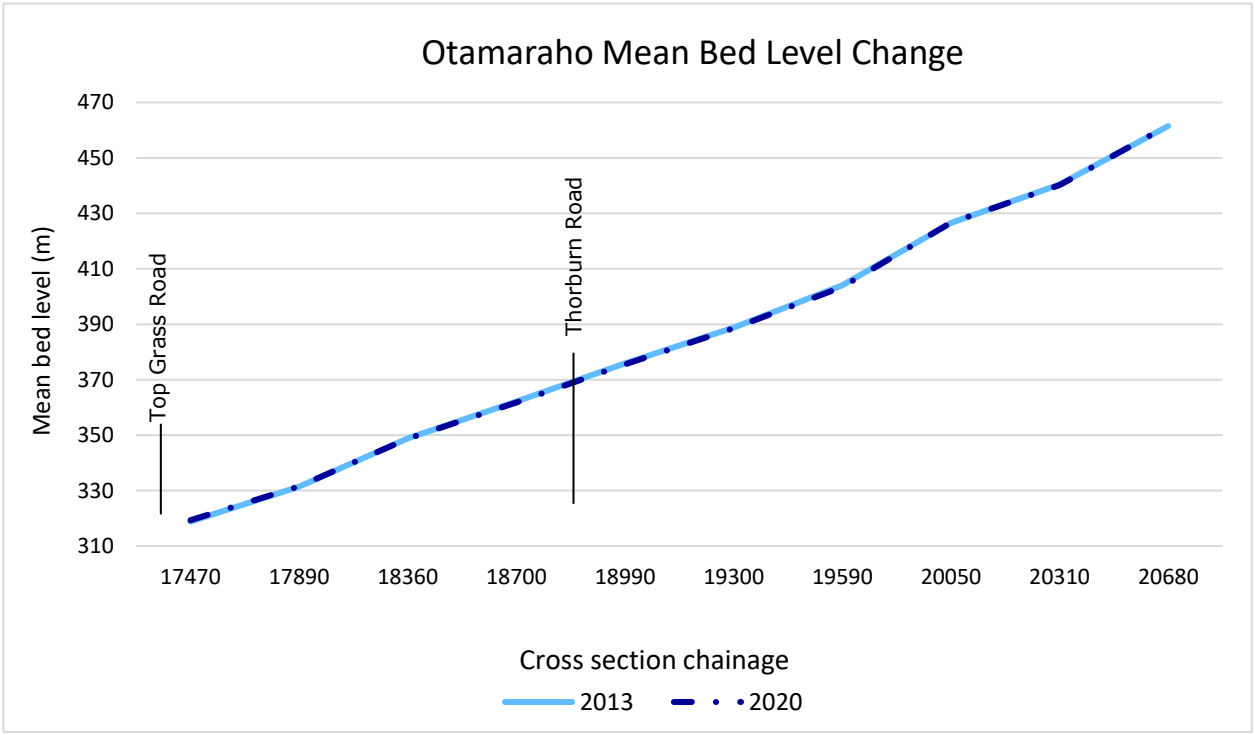


Figure 9.2: Mean Bed Level Change at Otamaraho Stream

9.2.2 Gravel volume

The change in gravel volume for the period of 2013 to 2020 at Otamaraho stream saw an overall degrading trend. Figure 9.3 below shows that there was an overall degrading net gravel volume change of 18,116 m^3, which is 2,588 m^3 per annum.

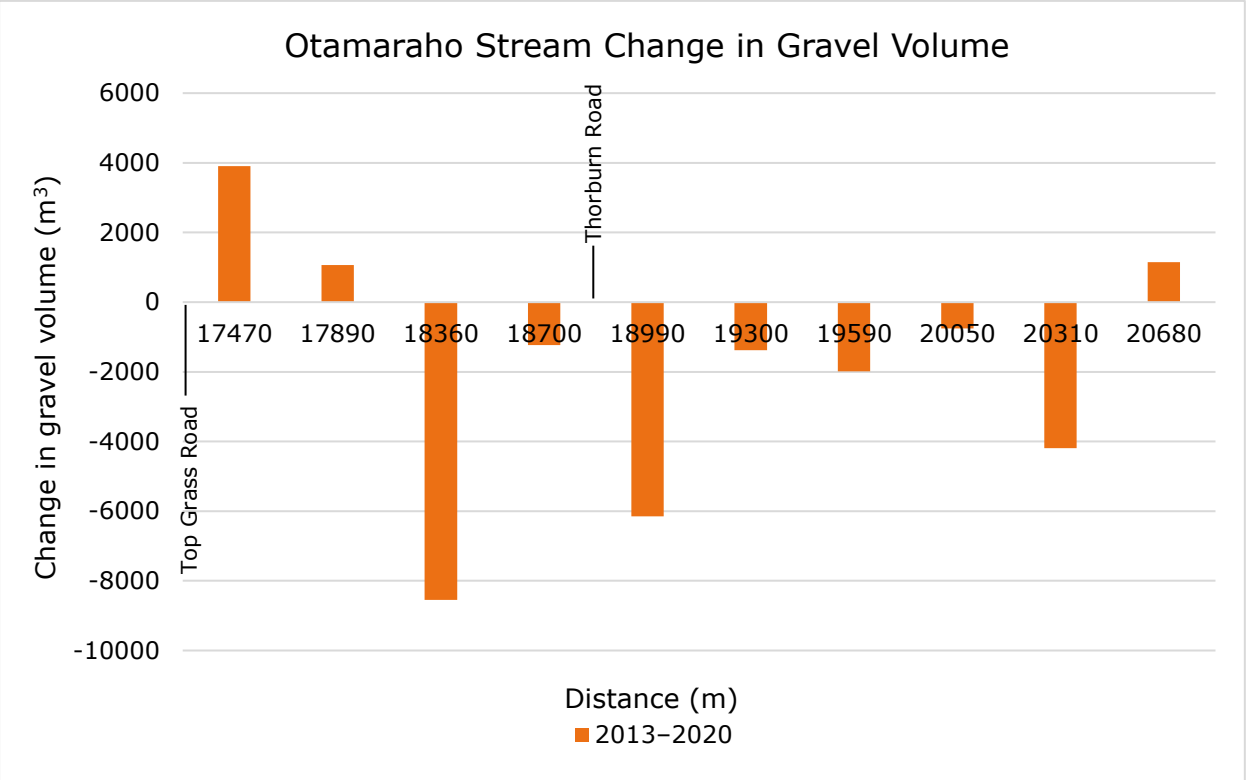


Figure 9.3: Change in Gravel Volume at Otamaraho Stream

10.0 Rokaiwhana Stream

The Rokaiwhana Stream has a catchment area of approximately 12 km^2 above Top Grass Road around the vicinity of the gravel reserves.

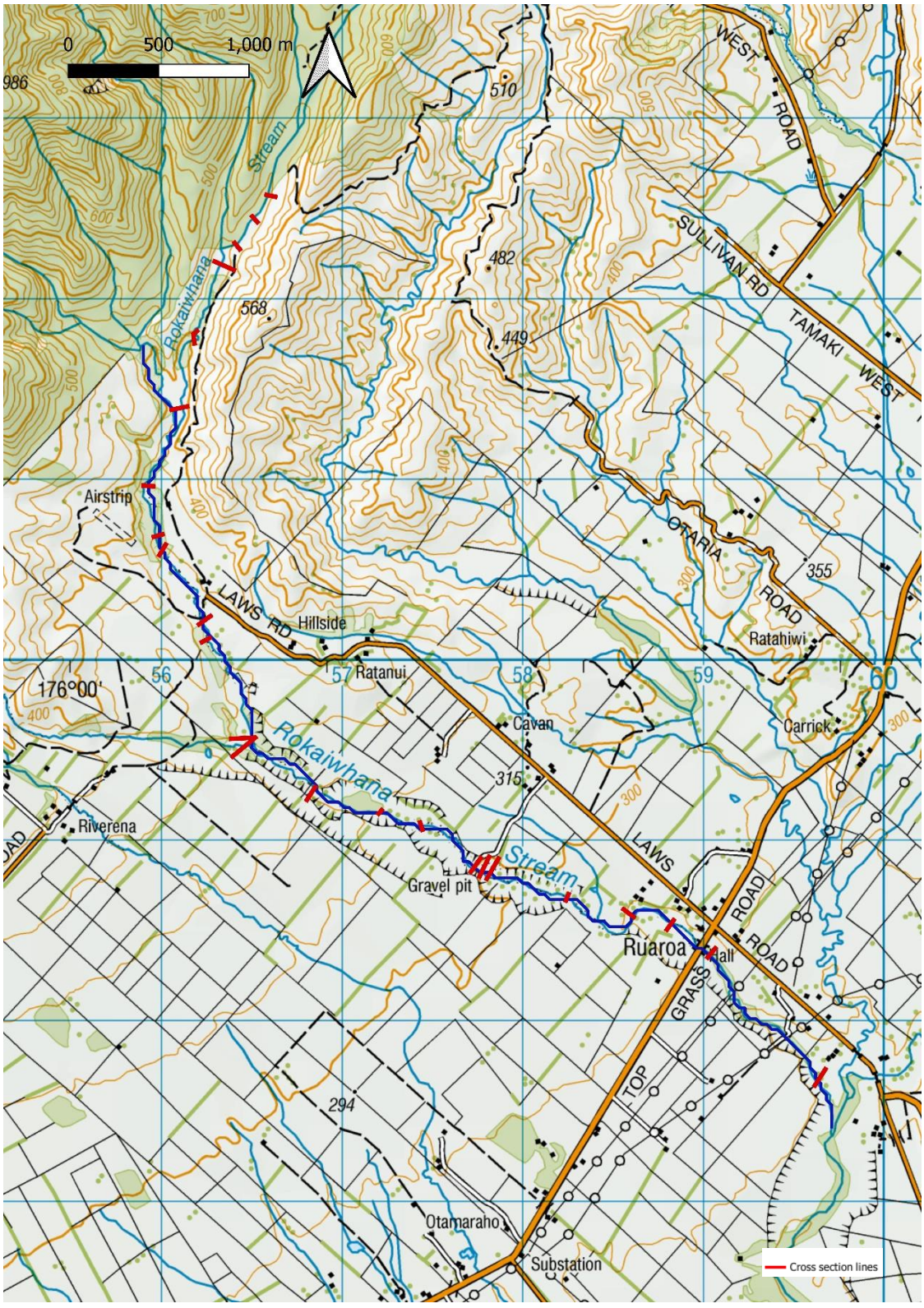


Figure 10.1: Rokaiwhana Stream with cross section locations

10.1 Cross-Section Survey Data

Between 1994 and 2019, some 23 cross sections have been surveyed at various times along the Rokaiwhana Stream. The locations of these cross sections can be seen in Appendix H1 and the history of their survey is summarised in Table 10.1. These cross-sections cover the 8 km reach of the stream from the bush line to its confluence with the Tamaki River.

Table 10.1 Summary of Rokaiwhana Stream Cross-Section Surveys 1994-2019

Cross-Section	Chainage (m)	Survey Date				
		1994	1995	2002	2013	2019
1	310					
2	1300					
3	1570					
4	1835					
5	2900					
6	3300					
7	3960					
8	4410					
9	4460					
11	5085					
12	5200					
13	5425					
14	5650					
15	5800					
16	6115					
17	6550					
18	7065					
19	7140					
20	7500					
21	7700					
22	7850					
23	8030					

10.2 Analysis of Cross-Section Data

10.2.1 Mean Bed Levels

The change in mean bed level for Rokaiwhana Stream in Figure 10.2 shows a degrading trend for the whole reach. Additionally, no appreciable mean bed level change was observed in that it did not exceed one metre change. The maximum mean bed level change of negative 0.984 m was observed at cross section 7065.

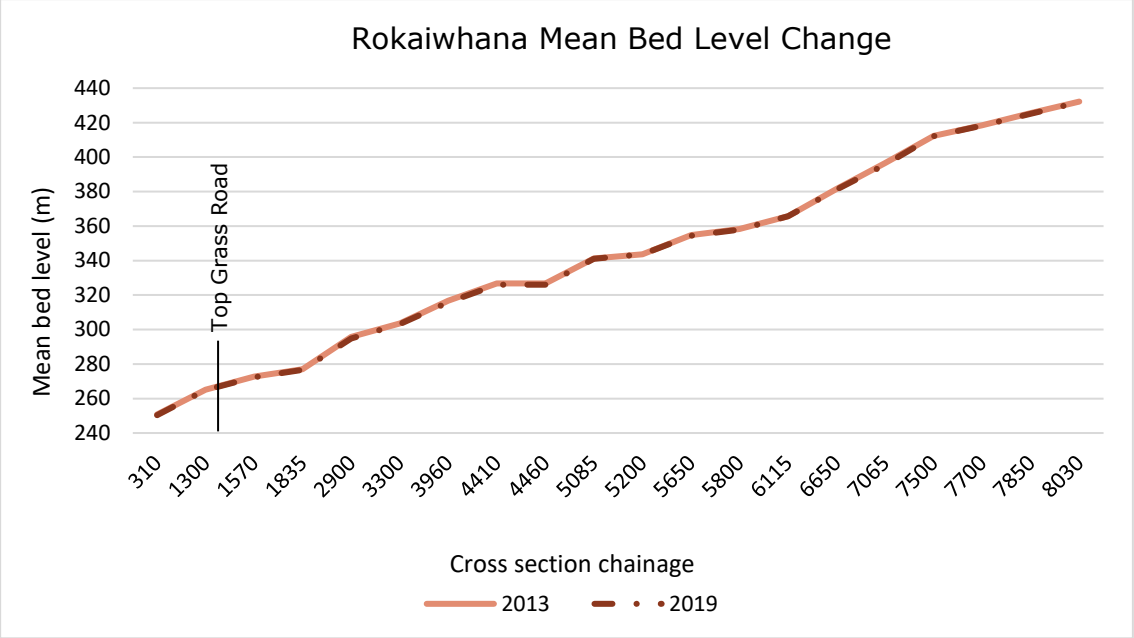


Figure 10.2: Mean Bed Level Change at Rokaiwhana Stream

10.2.2 Gravel volume

Figure 10.3 shows that a gravel volume degradation pattern is dominant across the entire reach of the Rokaiwhana Stream for the period 2013 to 2019. A total net loss of 138,782.75 m^3 has occurred amounting to approximately 23,130.46 m^3 of gravel degradation per annum.

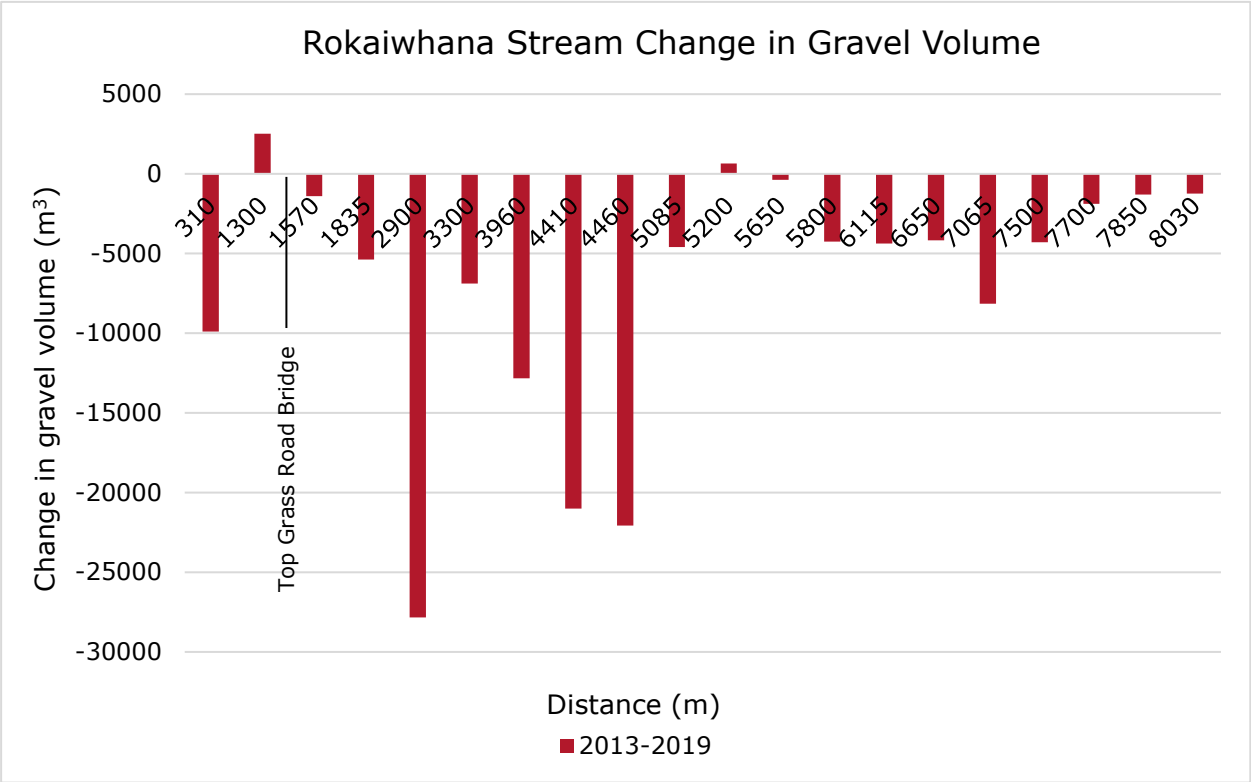


Figure 10.3: Change in gravel volume at Rokaiwhana Stream

11.0 Tamaki River

One of the largest river systems draining from the South Eastern Ruahine Range the Tamaki River has a catchment area of approximately 11 km^2 at the bush line and 25 km^2 at Top Grass Road.

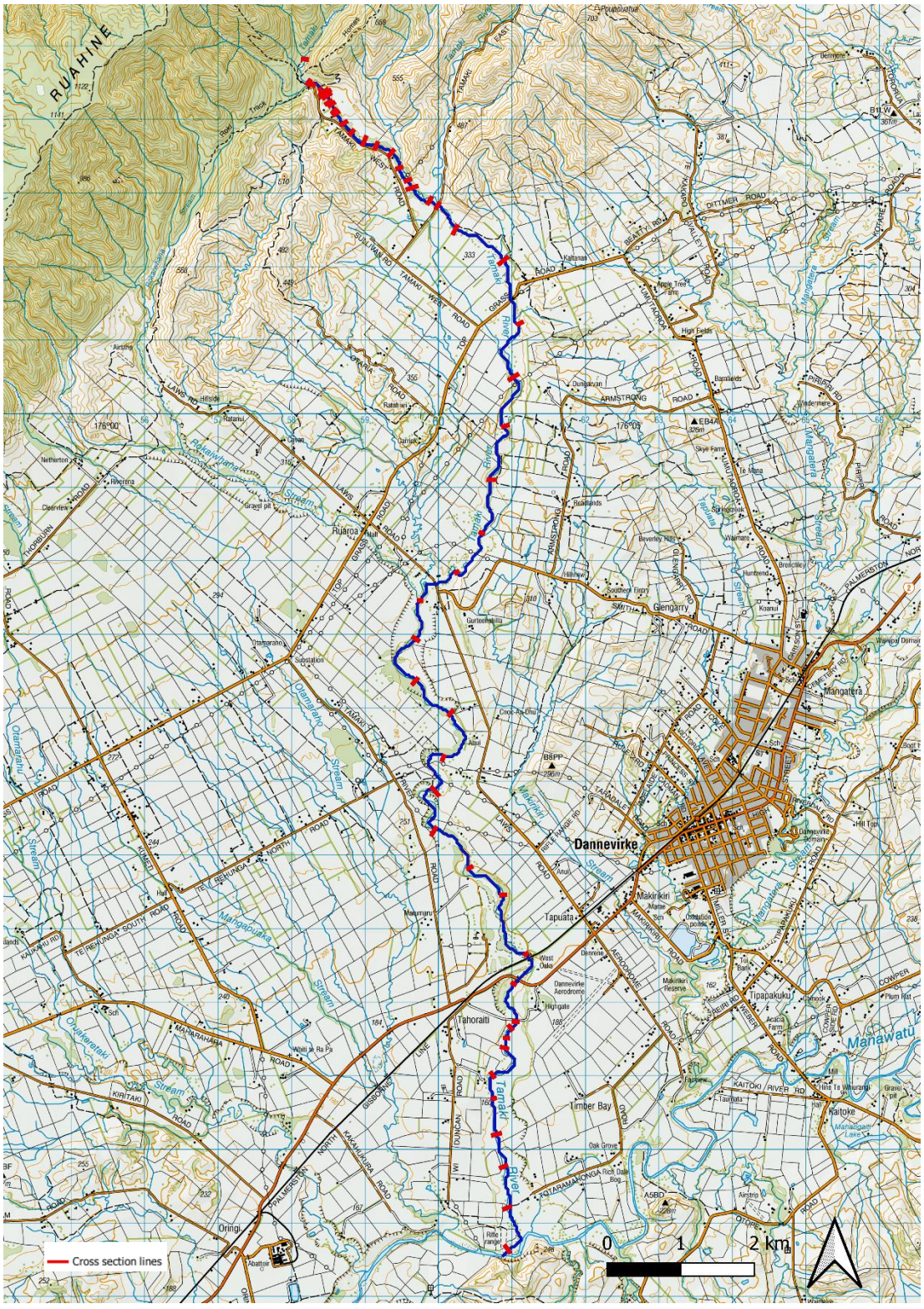


Figure 11.1: Tamaki River with cross section locations

11.1 Cross-Section Survey Data

The survey history of the Tamaki River is summarised in Table 11.1. As the table clearly shows, the upper 2.5 km of the study reach has been regularly surveyed in some detail since the early 1980s. The 2013 and 2019/2020 survey also picked up six cross sections, in the lower part of the study reach, that were originally surveyed in 1974.

Table 11.1 Summary of Tamaki River Cross-section Surveys 1974-2019/2020

Cross Section (Chainag	Chainage (m)	Survey Date																		
		1974	1978	1983	1984	1985	1987	May-88	Dec-88	1989	1990	1991	1992	1994	1995	1997	2000	2002	2013	2019/ 2020
6250080	800																			
6250160	1600																			
6250240	2400																			
6250320	3200																			
6250400	4000																			
6250970	9700																			
6251200	12000																			
6251280	12800																			
6251360	13600																			
6251440	14400																			
6251680	16800																			
6251760	17600																			
6252061	20610																			
6252073	20730																			
6252103	21030																			
6252116	21160																			
6252139	21390																			
6252162	21620																			
6252186	21860																			
6252204	22040																			
6252227	22270																			
6252244	22440																			
6252261	22610																			
6252265	22650																			
6252275	22750																			
6252280	22800																			
6252289	22890																			
6252293	22930																			
6252296	22960																			
6252302	23020																			

11.2 Analysis of Cross-Section Data

11.2.1 Mean Bed Levels

The Tamaki River mean bed level change saw a degrading trend in the lower reaches and overall aggradation in the upper reaches of the river. The maximum mean bed level change is -0.741 m at cross section 22270.

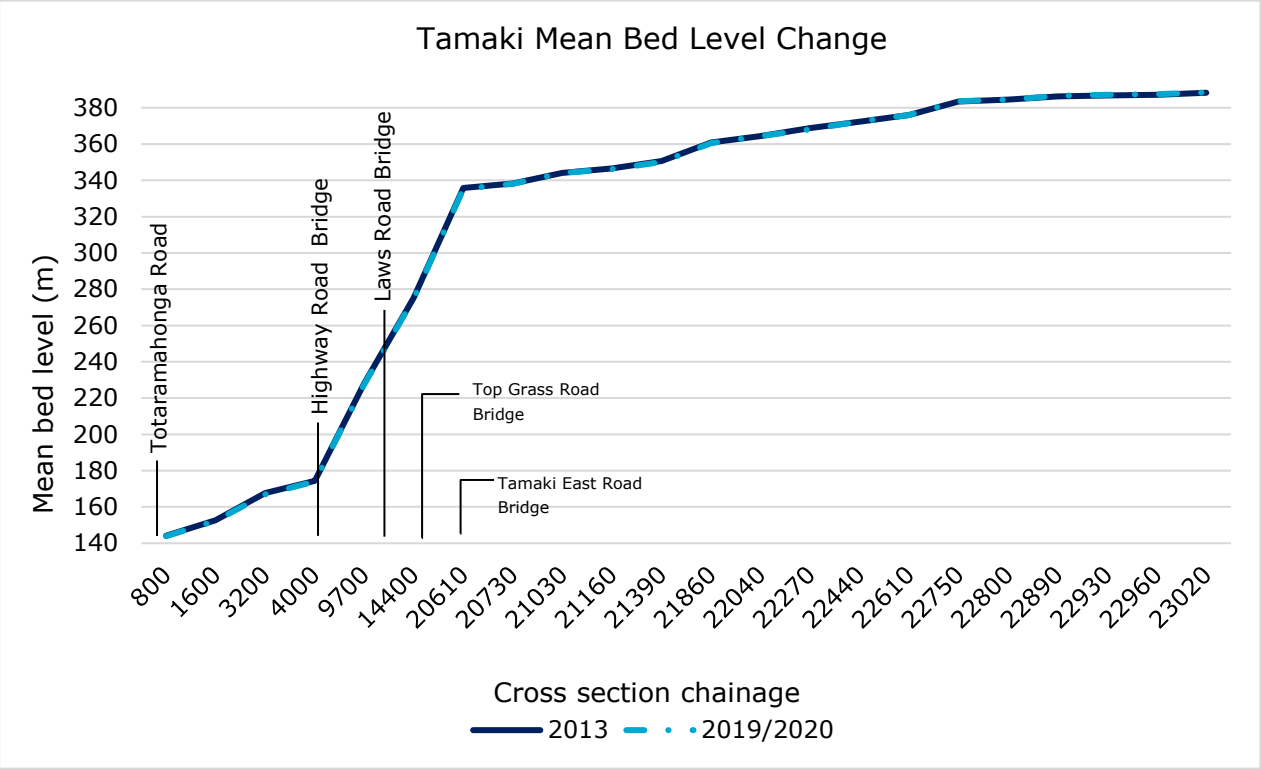


Figure 11.2: Mean Bed Level Change at Tamaki River

11.2.2 Gravel volume

Little to no change in gravel volume was observed in the middle to upper reaches while degradation was seen in the lower reaches of the Tamaki River. A total net loss of 64,481 m^3 was found to have occurred for the years 2013 to 2019/2020, which is about 9,200 m^3 per annum of gravel degradation (see Figure 11.3).

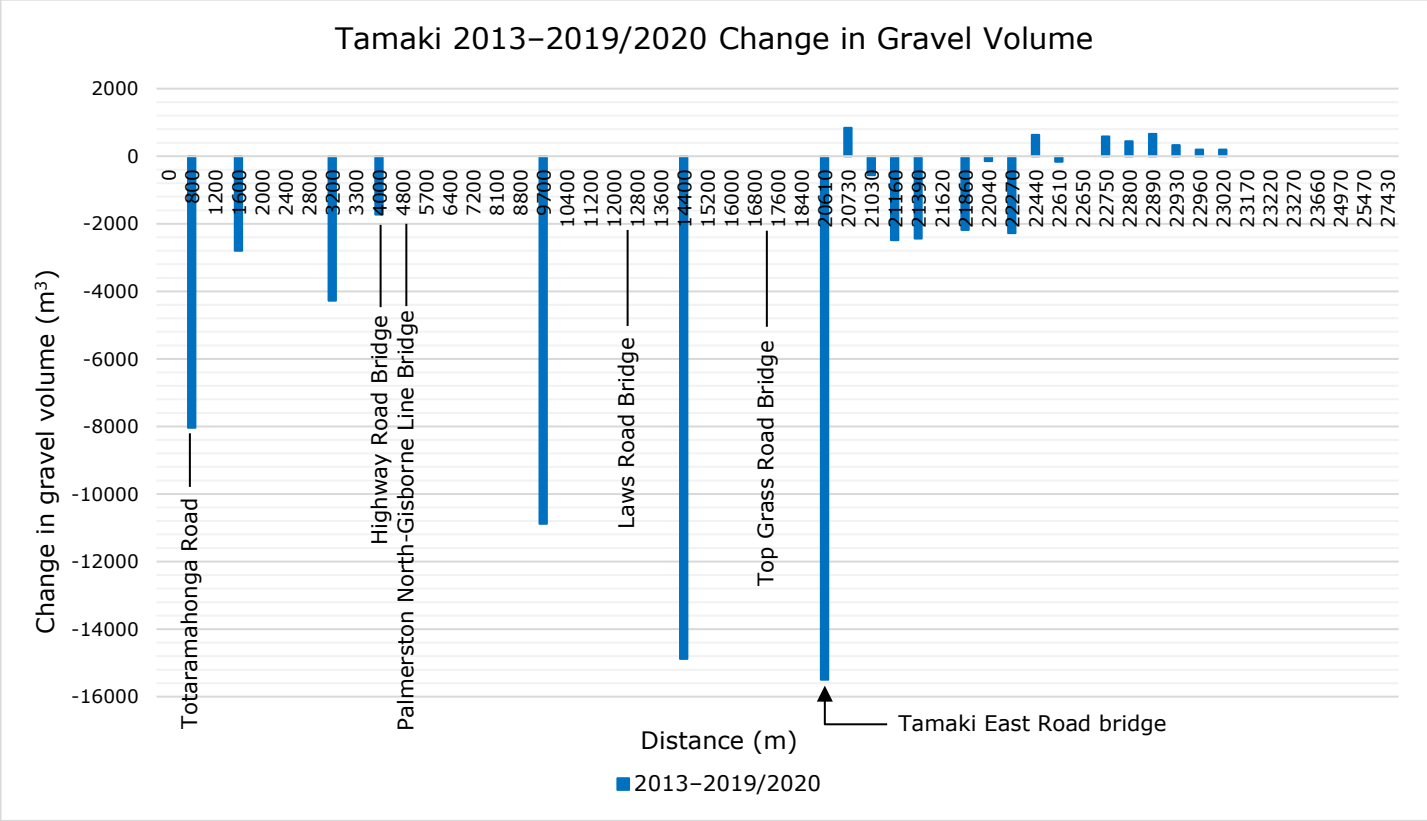


Figure 11.3: Change in gravel volume at Tamaki River

12.0 Map of the change of gravel volume across the streams/river

The map in Figure 12.1 shows the spatial change in gravel volume for each stream or river, concentrated around gravel reserves in the scheme. Cross sections are highlighted, where data is available, to denote whether the cross section of the river is aggrading or degrading. Red and orange zones denote degradation, while the shades of green denote aggradation zone. White areas indicate minor changes in the gravel volume. Based on the available data, the Rokaiwhana stream has mostly experienced degradation from 2013 to 2020.

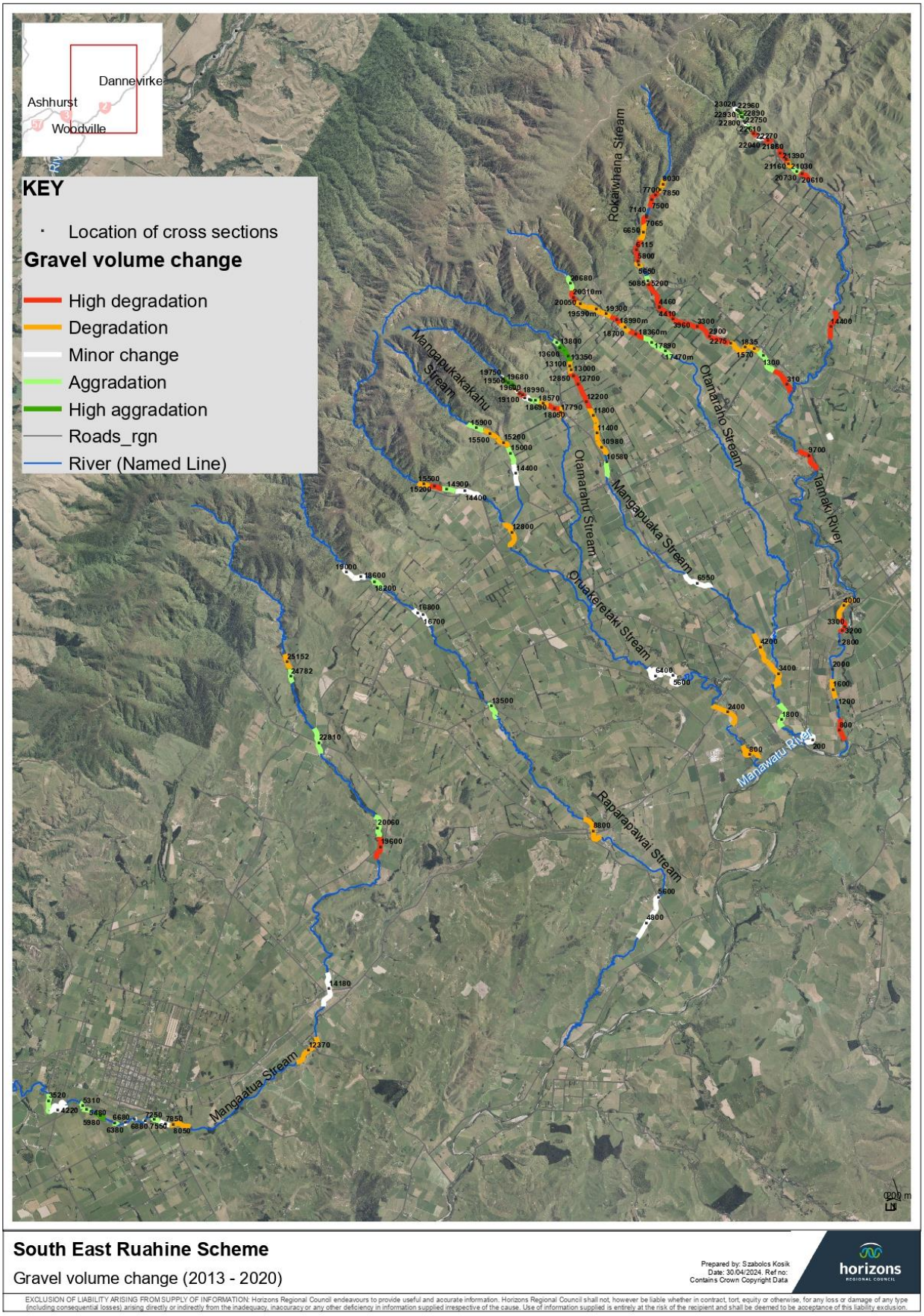


Figure 12.1 Gravel Volume Change of South East Ruahine Scheme from 2013-2020

13.0 Gravel Extraction Allowance and One Plan

Table 13.1 shows the summary of the One Plan long term annual average volume of gravel available for extraction for each of the streams or river in the South East Ruahine Scheme.

Stream or river name	Volume (m^3)
Manga-atua	5,000
Raparapawai	3,000
Oruakeretaki	5,000
Mangapukakakahu	-
Otamarahu	1,000
Kumeti	3,000
Otamaraho	2,000
Rokaiwhana	10,000
Tamaki	20,000

Table 13.1: One Plan long term average annual allocable volumes of gravel

Horizons Regional Council holds current ATH-2005010750.01, which authorises the extraction of 73,500 m^3 of gravels per year along the rivers, streams and tributaries within the South East Ruahine Scheme for channel maintenance and flood protection purposes.

Table 13.2 summarises the volume extracted in the South East Ruahine Scheme for each year starting in the year 2013 to 2019/2020. The total volume of gravel extracted for the entire South East Ruahine scheme for the period of 2013 to 2020 amounted to 128,983 m^3 which equates to an average extraction rate of 18,400 m^3 per annum. The effects of the gravel extraction from 2021 and 2022 are not considered in this study.

YEAR	Manga-atua	Raparapawai	Oruakeretaki	Mangapukakakahu	Otamarahu	Kumeti	Otamaraho	Rokaiwhana	Tamaki
1993			-					152.00	1,382.00
1994			-			32.00		516.00	1,404.00
1995			4,200.00		700.00	40.00		1,020.00	2,044.00
1996			-		704.00	1,714.00		8,675.00	-
1997			8,050.00			2,463.00		8,926.00	-
1998			-		137.00	-		396.00	16,750.00
1999			2,300.00		30.00	96.00		9,424.00	3,200.00
2000			6,000.00			520.00		5,292.00	8,700.00
2001			5,100.00					498.00	12,400.00
2002								1,019.00	7,100.00
2003								891.00	14,500.00
2004								387.00	19,750.00
2005								772.00	7,700.00
2006								418.00	11,300.00
2007								380.00	7,000.00
2008								425.00	4,350.00
2009									-
2010									-
2011									2,700.00
2012									2,500.00
2013									7,550.00
2014		1,300.00				200.00		400.00	10,850.00
2015	700.00					200.00		2,300.00	15,935.00
2016								2,000.00	17,900.00
2017		700.00	3,600.00			750.00		1,700.00	5,200.00
2018	200.00	2,000.00	4,000.00					2,050.00	7,000.00
2019		4,560.00					220.00	5,600.00	15,724.00
2020		600.00							15,744.00
2021						4,004.00			5,812.00
2022	360.00					2,573.00			3,871.00

Table 13.2: Summary of reported gravel volumes extracted (m^3) in the South East Ruahine Scheme from 2013 to 2022

14.0 Streams and river site visits

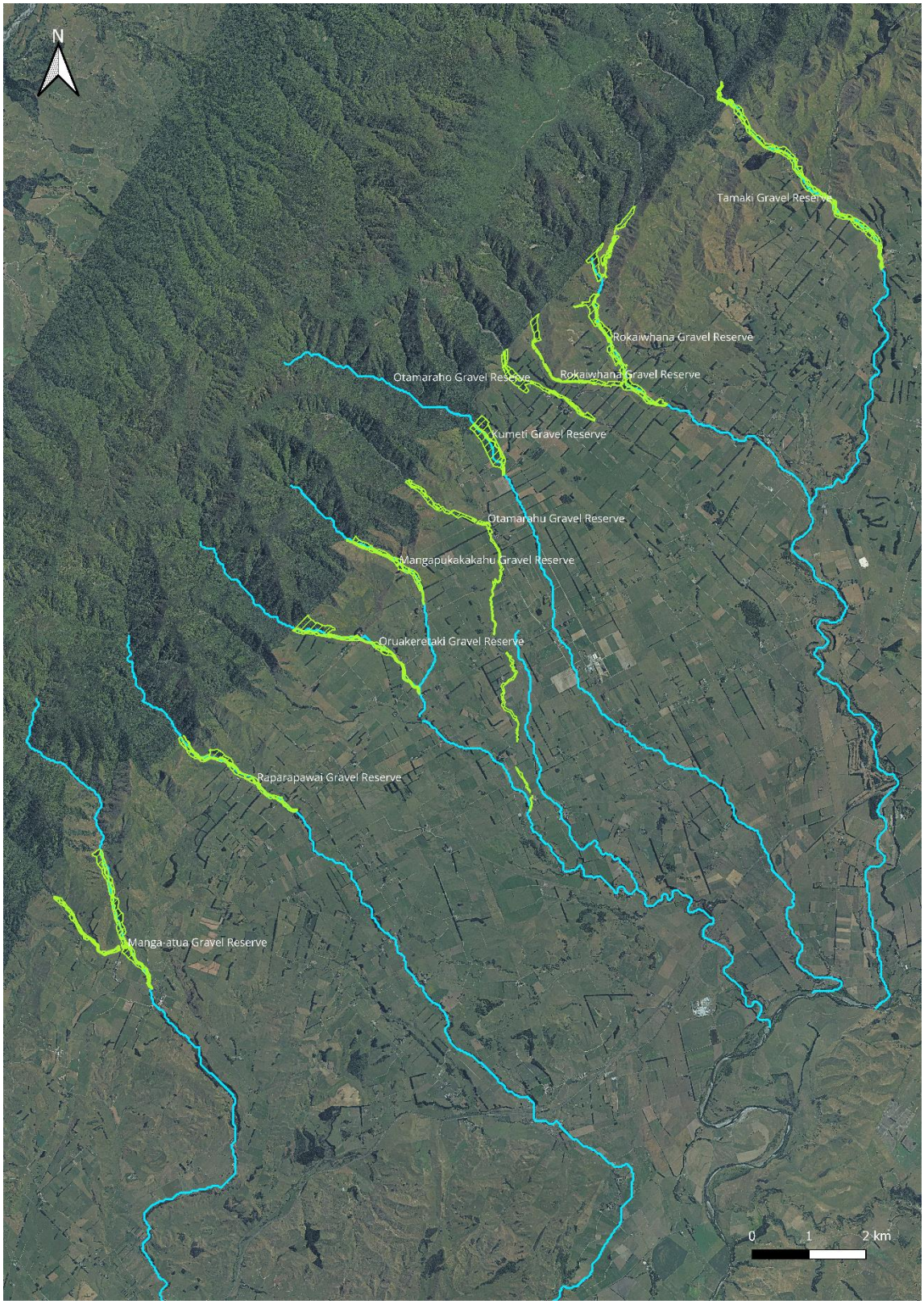


Figure 14.1 Map of South East Ruahine gravel reserves

On 6 December 2023, site visits were conducted to determine the actual status of the various streams and river under the South East Ruahine scheme, particularly on the gravel situation following Cyclone Gabrielle (February 2023). Gravel reserves and weirs were also visited as they were present in most of the scheme's streams. See Appendix J for the actual site photos. The overall finding of the areas visited is both fairly stable and degrading.

Gravel reserves were found to be in every stream and river as can be seen in the map of Figure 14.1 but only a few of them were visited: Manga-atua stream, Raprapawai stream, Kumeti Stream, and Otamaraho stream.

The Manga-atua Stream has a gravel reserve between XS 20060 and 19600 where a lot of gravel was seen with vegetation growing throughout (see Appendix J1 and J2). The cross sectional analysis showed that between the aforementioned cross sections, 19600 was found to be degrading while 20060 was aggrading.

The Raparapawai Stream has a gravel extraction site near XS 8800 (see Figure J4) and had natural gravel piles creating a "gravel wall". Additionally, a farmer created a gravel diversion for irrigation purposes, which changed the stream flow. The stream was thought to be fairly stable. Further upstream, a gravel reserve is situated between XS 16800 and XS 16700.

No gravel beach was visible in the Mangapukakakahu stream by the bridge near XS 14400. Kumeti stream had a gravel reserve along XS 13800, 13600, 13350, 13100, 13000, and 12850 (see Figure J6). A weir was also installed in the stream (see Figure J7).

The Otamaraho Stream had a gravel reserve and multiple weirs at XS 19300 (see Figure J9 and J10). Additionally, the Otamaraho stream also had a gravel extraction site and wooden weir near XS 18700 (see Figure J11).

The Tamaki River downstream of XS 9700 had a gravel extraction site (see Figure J13 and J14). Evidence of huge gravel beaches have formed in the Rokaiwhana Stream (see Figure J16) and a weir was also installed in the stream (see Figure J17). This stream was noted to have lost heaps of gravel as an observation of the effects of the cyclone.

15.0 Summary and recommendations

This study examined eight streams and one river that form part of the South East Ruahine Scheme. This report excludes the effects of Cyclone Gabrielle which occurred in February 2023.

The conclusions for each catchment are summarised below:

1. Catchment 1: Manga-atua Stream
   - ❖ Considering all the available cross sections, there is generally an aggrading trend of gravel volume change in the Manga-atua stream from the period of 2013 to 2019/2020. A total net gain of 2840.30 m^3 has occurred throughout the reach of the stream.

2. Catchment 2: Raparapawai Stream
   - ❖ Due to the lack of surveys from 2013, significant conclusions about the trends in the gravel resource of the Raparapawai Stream could not be effectively drawn. Using comparable survey data, the results show there was an overall net loss of 1,470m^3 of gravel volume change in the stream from 2013 to 2020.

3. Catchment 3: Oruakeretaki Stream, Mangapukakakahu Stream, Otamarahu Stream
   - ❖ No substantial conclusion can be drawn for the whole catchment because of the sparsity of the surveys done in the past. However, analysing the surveys with comparable data, the Oruakeretaki stream shows a generally degrading trend with a total degrading net gravel volume change of 15,220 m^3 for the period of 2013 to 2020. The overall trend of the cross sections in the Mangapukakakahu show aggradation. The total change in gravel volume amounted to 4,205 m^3 for the period of 2013 to 2020. The Otamarahu stream had a net change in gravel volume of 653.5 m^3 degradation for the period of 2013 to 2019.

4. Catchment 4: Kumeti Stream, Otamaraho Stream
   - ❖ The Kumeti Stream did not have complete surveys in the year 2013, but those that can be compared with the 2019/2020 survey showed there is generally a degrading trend with a net loss of gravel volume of 27,654.50 m^3.
   - ❖ The Otamaraho Stream only covered 3.2 km of surveys immediately below the bush line which does not include how the gravel resource in the lower reaches of the stream has changed over time. This saw an overall degradation with a net loss of gravel volume of 18,116 m^3.

5. Catchment 5: Rokaiwhana Stream, Tamaki Stream
   - ❖ The surveyed reach of Rokaiwhana Stream has seen an overall degradation of gravel volume. A total net loss of 138,782.75 m^3 has occurred for the period of 2013 to 2019 for the entire stream.
   - ❖ Little to no change in gravel volume was observed in the middle to upper reaches while degradation was seen in the lower reaches of the Tamaki River. A total net loss of 64,481 m^3 was found to have occurred for the years 2013 to 2019/2020 at Tamaki Stream, which is about 9,200 m^3 per annum of gravel degradation.

It is recommended that a resurvey will be conducted in 2025-2026 for the eight streams and one river that form the South East Ruahine Scheme, and that as a minimum, should cover all the cross sections surveyed in 2019/2020. Additionally, surveys should be increased for those streams that ddidn't cover the whole stream in order to capture a more comprehensive change over time.

It is further recommended that the use of a most up-to-date LiDAR (Light Detection and Ranging) and Difference of Digital elevation models (DoD) analysis be incorporated in addition to the cross sectional analysis. The DoD analysis provides a spatial assessment of the morphological bedform (shape) response of the channel, if and where the channel is aggrading or degrading. Two digital elevation models (DEMs) will be compared and provide a spatial variability in elevation and a volume of gravel change. This will provide a greater context and measurement of spatial morphologic response and volume change of gravel in the catchment.

16.0 References

Bell, J. (2016). South Eastern Ruahine Scheme Gravel Resource Study.

Horizons Regional Council (2014). One Plan.

Horizons Regional Council (2003). South East Ruahine Scheme Review, prepared by John Philpott.

17.0 Appendices

Appendix A1: Manga-atua cross section locations




Martin Rd
14180
SH 2
Condoit Rd
McKinlay Rd
Elliott Rd
SH 2
Hopelands Rd
Wellington Rd
Woodville St
Church St
17370
0 100 200 m


25152
24782
23810
20060
19600
Top Grass Rd
Kearney Rd
Maharahara Rd
Coppermine Rd
Heretaunga Rd
Pinfold Rd
Valley Rd
Beagley Rd
Corby Rd
Victoria Rd
Leith Rd
McConaghty Rd
0
500
1,000 m

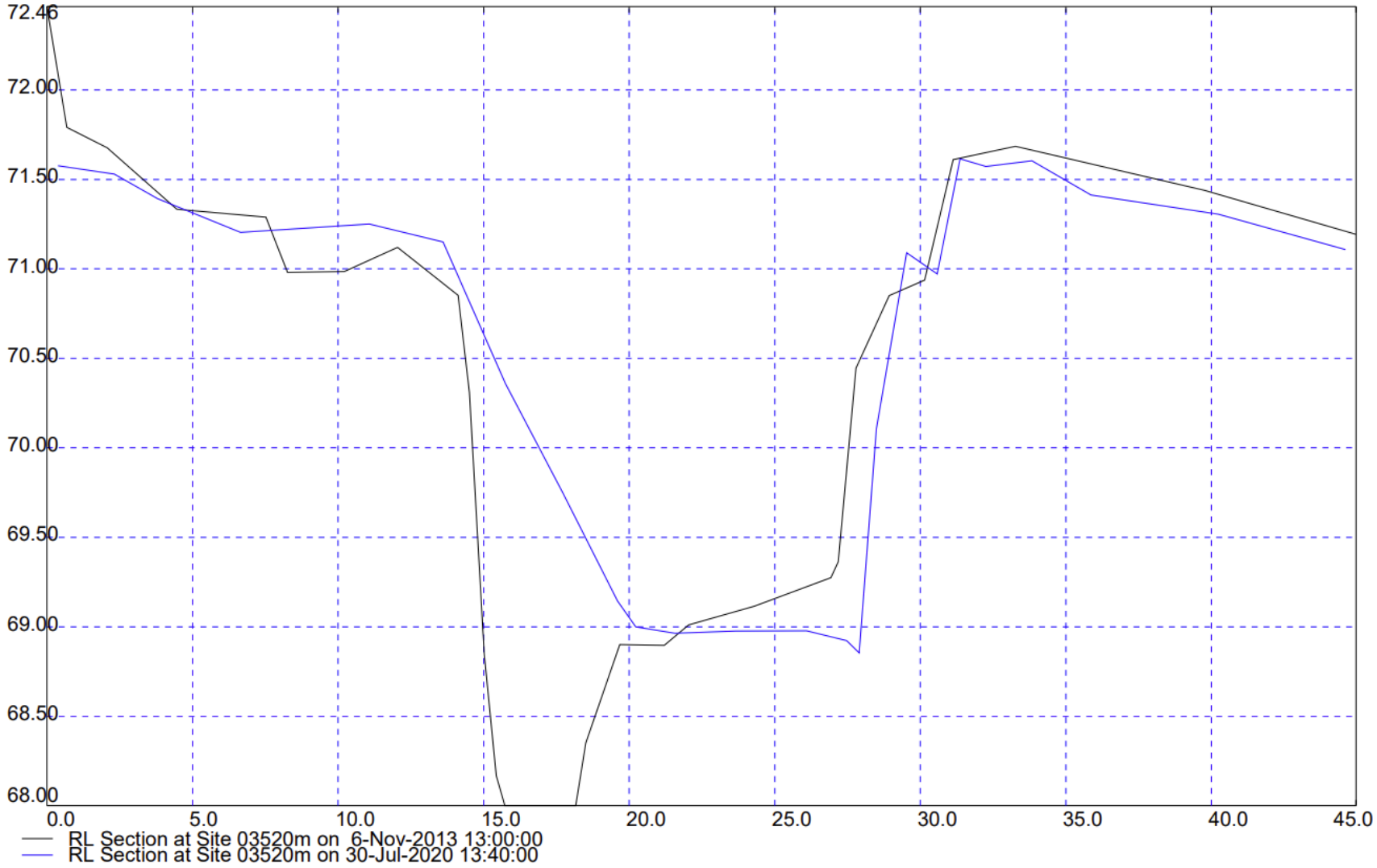
Appendix A2: Manga-atua Mean Bed Level Data (2013 – 2020)

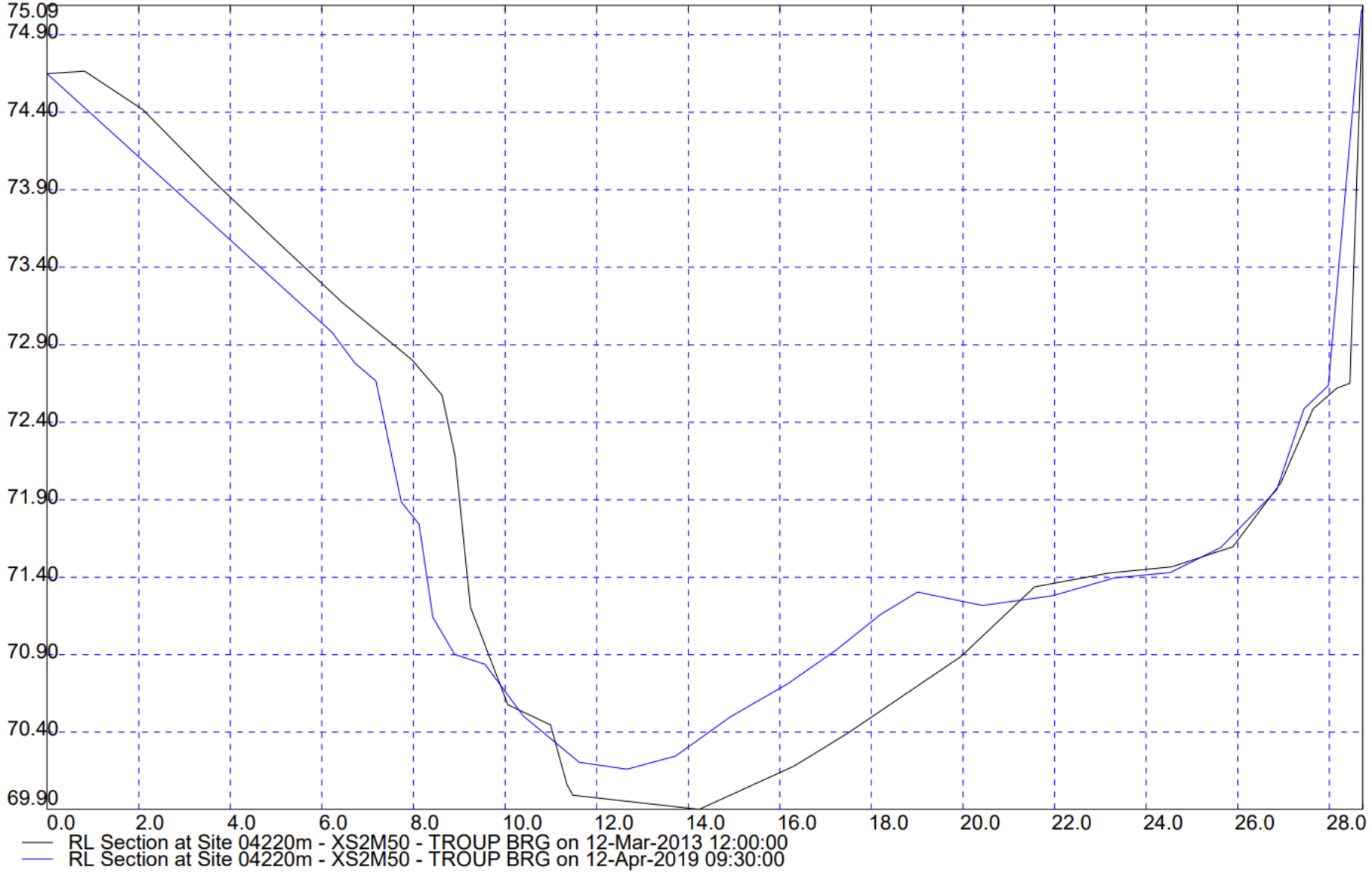
Manga-atua Mean Bed Level Change					
Cross Section	Left Extent	Right Extent	MBL 2013	MBL 2019/ 2020	MBL change (2019/2020 - 2013)
3520	14.6	28.45	68.903	69.34	0.437
4220	11.5	26	70.691	70.962	0.271
5310	3.35	18.5	73.036	73.275	0.239
5480	6	19.7	73.72	74.202	0.482
5980	11.6	21.6	74.393	74.922	0.529
6380	8.6	24.6	75.904	76.397	0.493
6680	4.5	14.05	77.037	76.955	-0.082
6880	2.6	13.5	78.425	78.559	0.134
7250	13.5	22.8	79.882	79.819	-0.063
7550	16.4	26	81.166	81.249	0.083
7850	14.46	25.9	82.367	82.408	0.041
8050	9.9	27	83.352	82.916	-0.436
12370	6.7	23.2	104.344	104.175	-0.169
14180	4	16	117.899	117.944	0.045
19600	6.61	27.9	170.081	169.467	-0.614
20060	48	54.8	175.454	175.503	0.049
22810	4.2	13.5	215.658	215.558	-0.1
24782	21.7	40.4	257.316	257.584	0.268
25152	22.8	39.33	268.072	267.873	-0.199

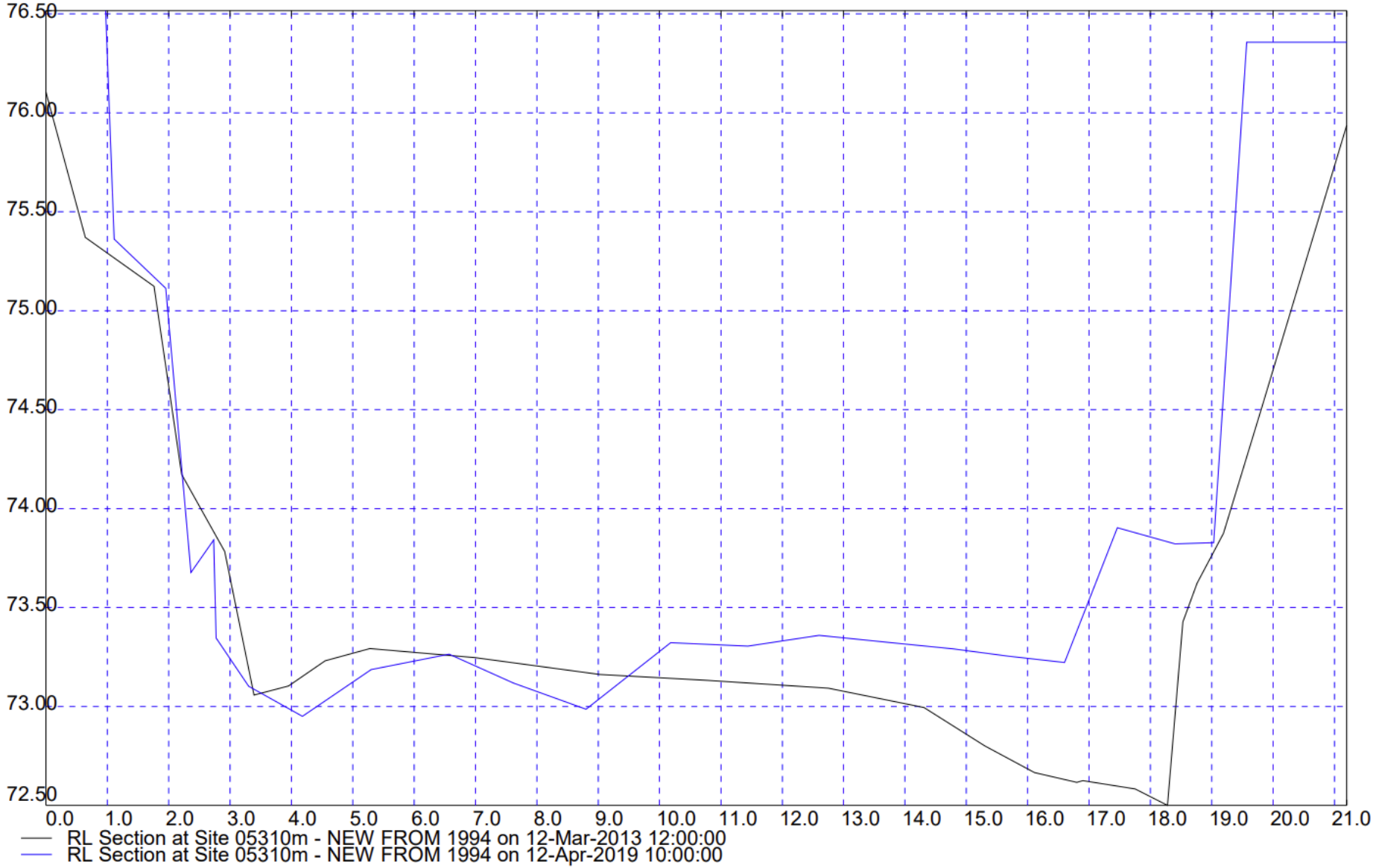
Appendix A3: Manga-atua Change in Gravel Volume (2013 – 2020)

Manga-atua Stream Change in Gravel Volume						
Running distance	Left Extent	Right Extent	Datum=0	Area under section 2013	Area under section 2019/2020 (m^2)	Change in volume 2013-2019/2020 (m^3)
3520	10	35	0	1748.3	1754.6	3150
4220	4	28.7	0	1762.7	1764.3	1208
5310	0.22	21	0	1526.4	1533.4	1330
5480	-5.3	29.7	0	2608.9	2618.6	1940
5980	3.6	27.6	0	1809.9	1820.8	2888.5
6380	4.6	26.6	0	1679.6	1686	806.4
6680	0.7	18.7	0	1402.2	1401.6	-33.6
6880	-2.4	22.6	0	1988	1989.8	100.8
7250	7.8	25.5	0	1429.9	1431	61.6
7550	12	30	0	1474.8	1477.8	615
7850	8	30	0	1830.3	1830.8	125
8050	7.9	28	0	1678.7	1669.6	-4095
12370	3	27	0	2516.4	2513.9	-2012.5
14180	1	22	0	2493.3	2492.7	-543
19600	1.9	27.9	0	4432.4	4416.9	-8137.5
20060	34.8	69.8	0	6168.4	6175.4	3220
22810	3.2	20.2	0	3676.3	3679.1	1778
24782	0.4	49.9	0	12777	12783	2100
25152	15	50	0	9402.2	9395.1	-1661.4

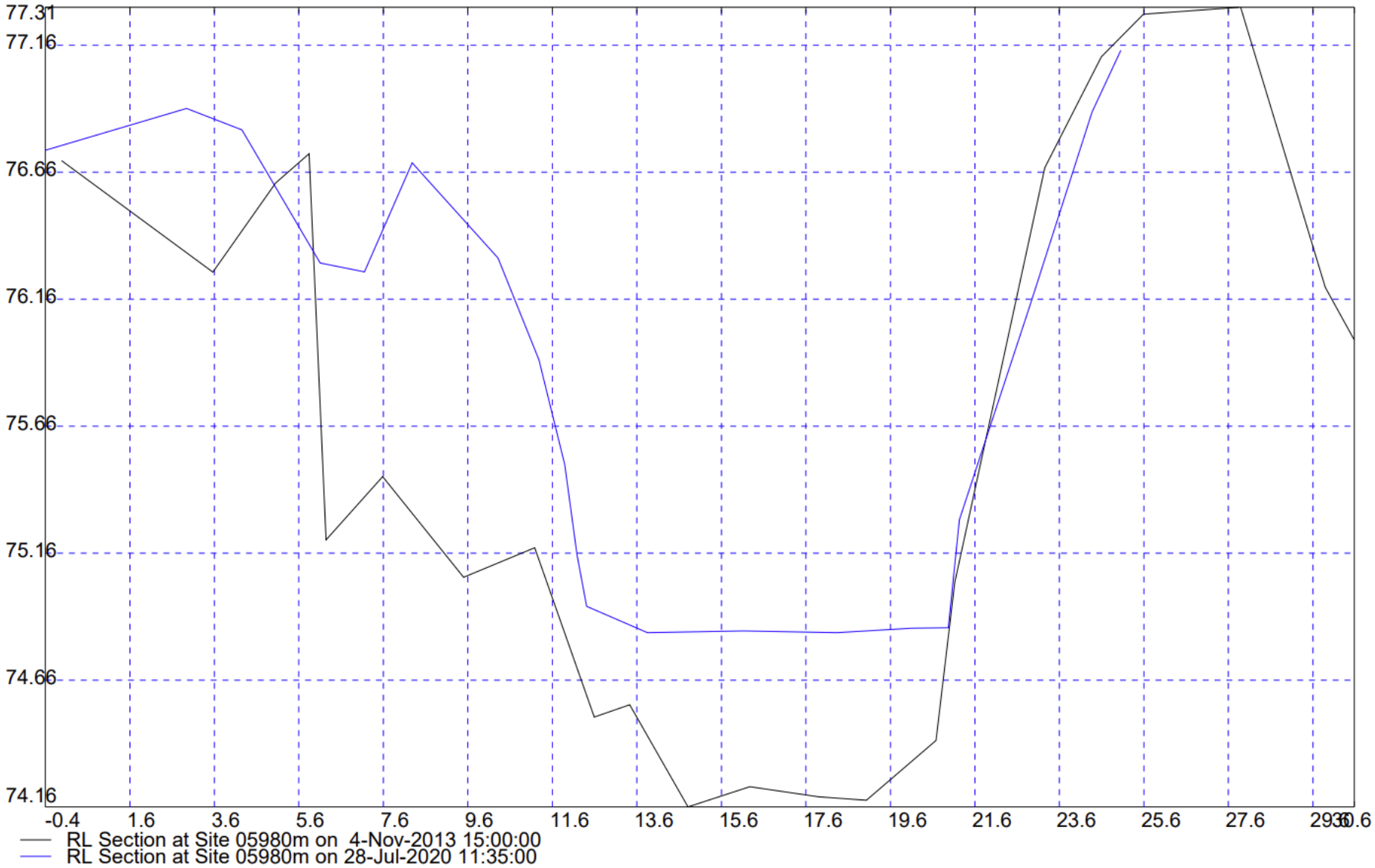
Appendix A4: Cross-sections at Manga-atua Stream

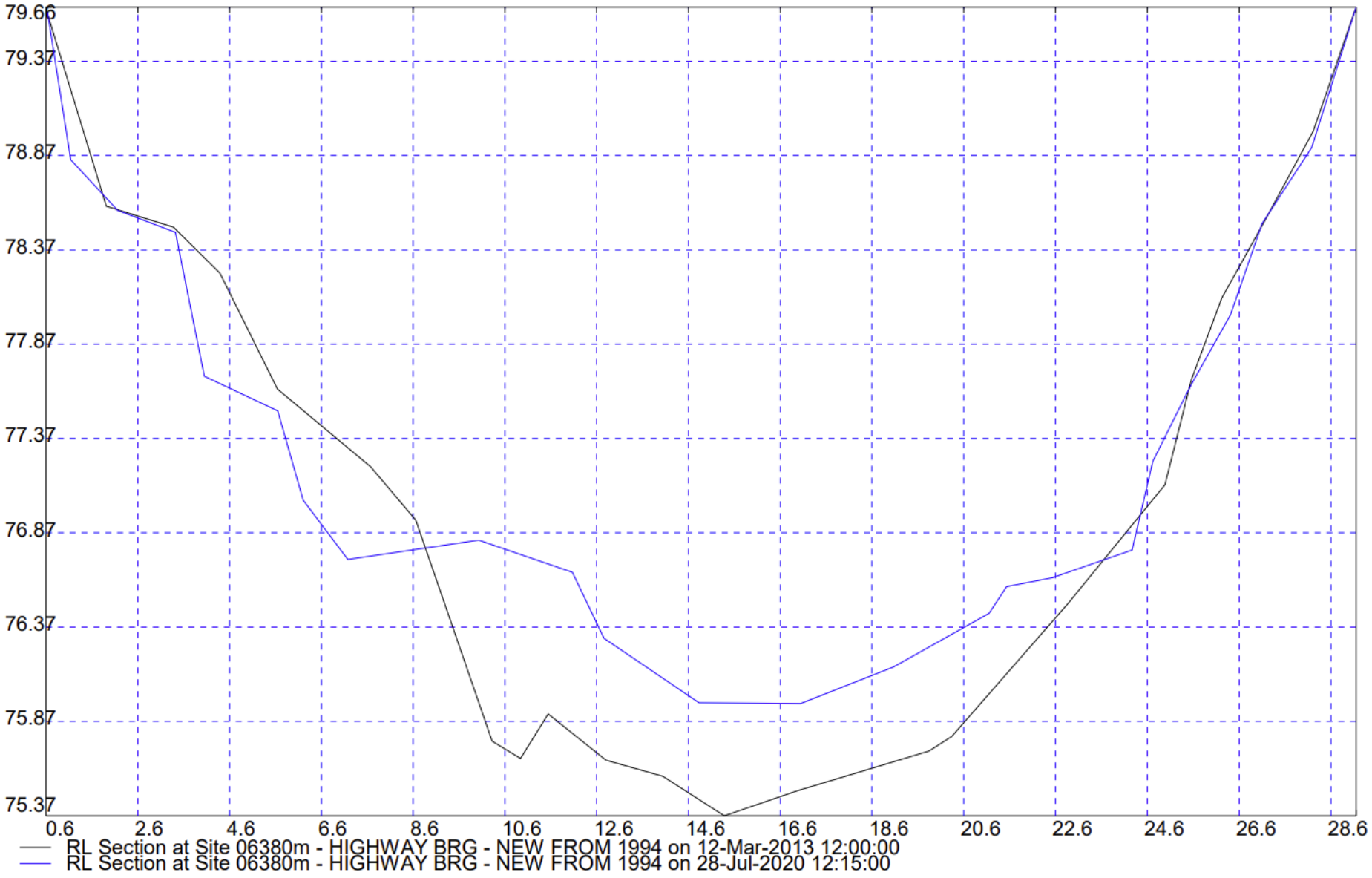


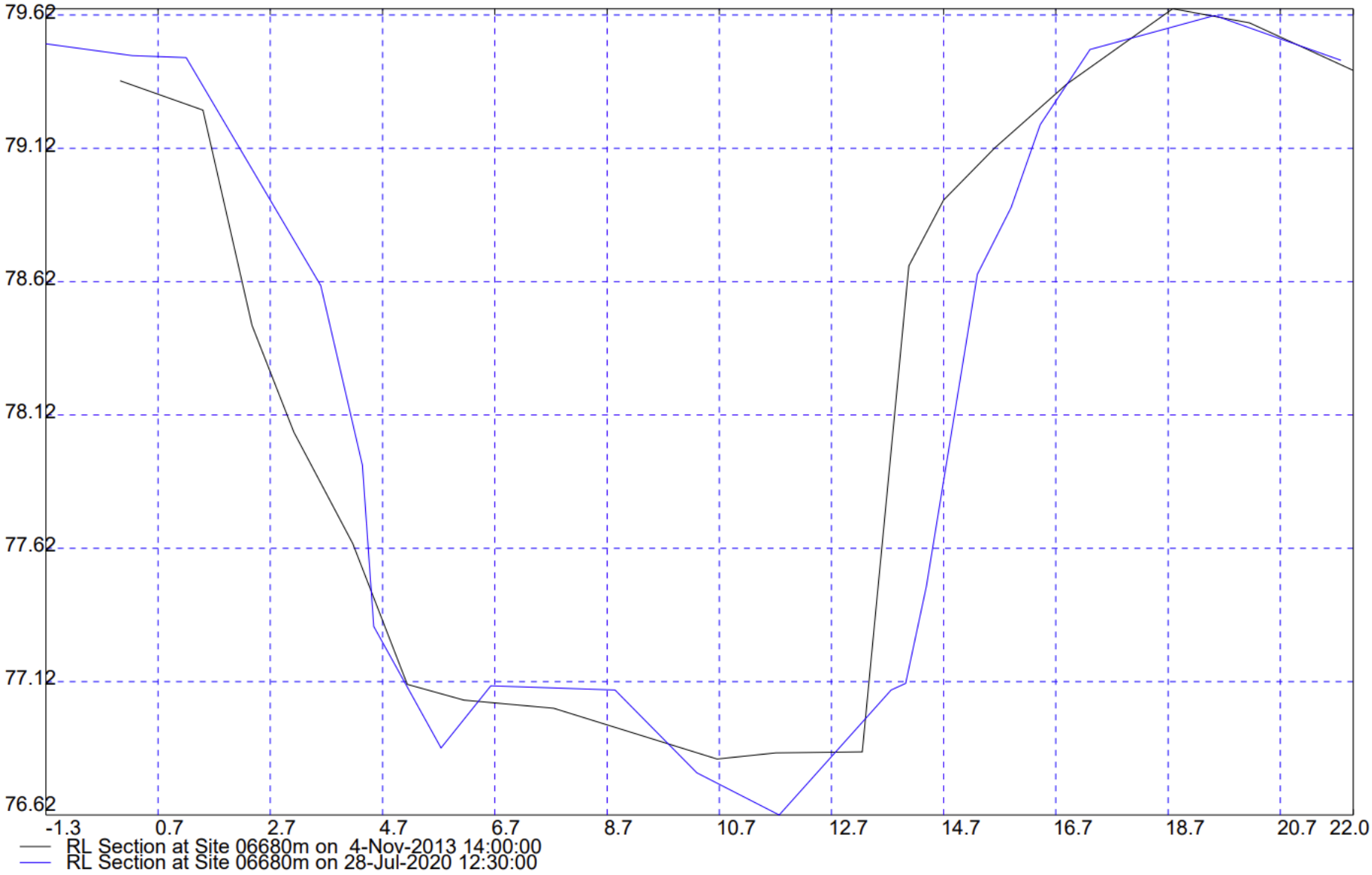

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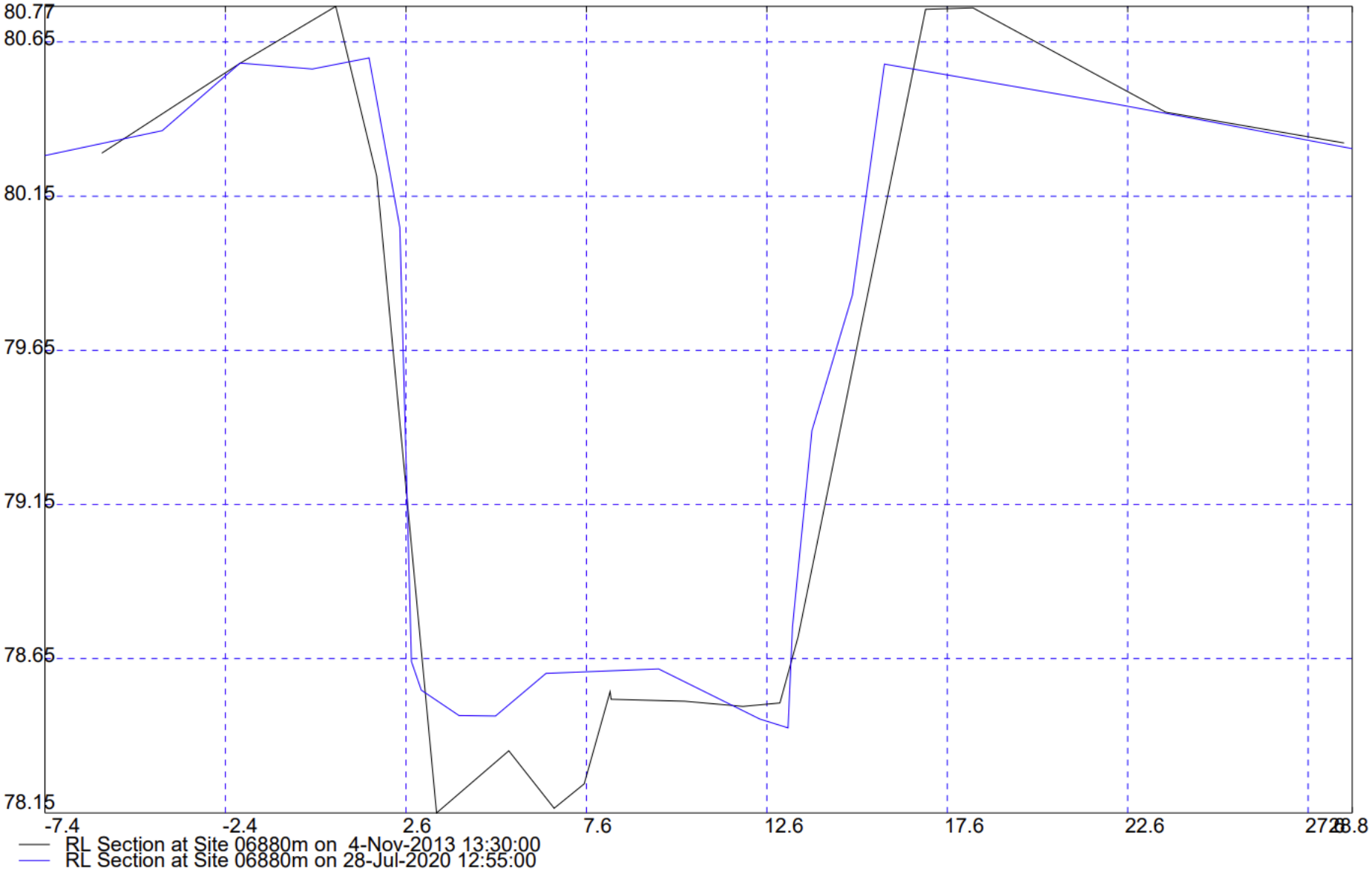

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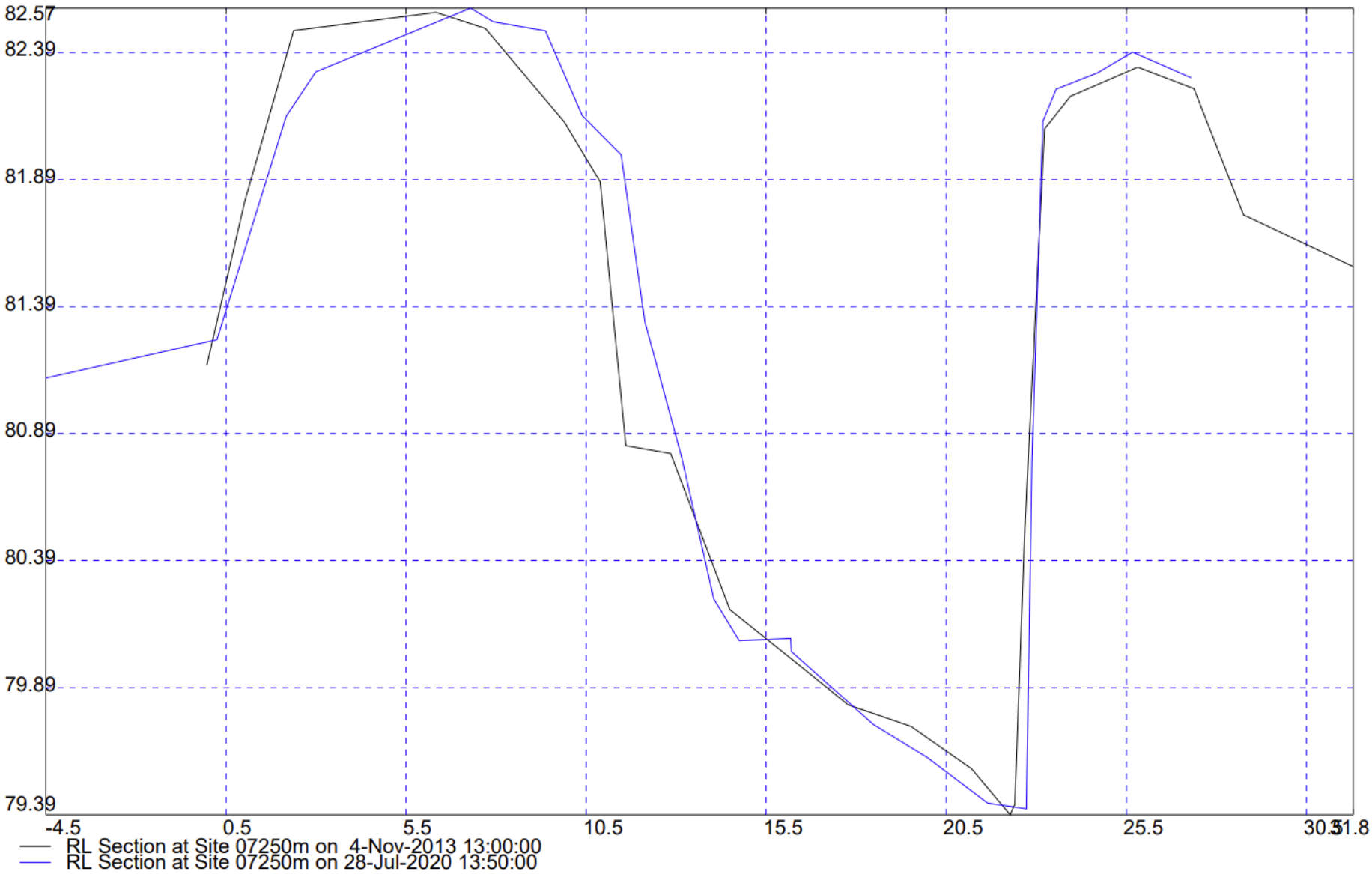

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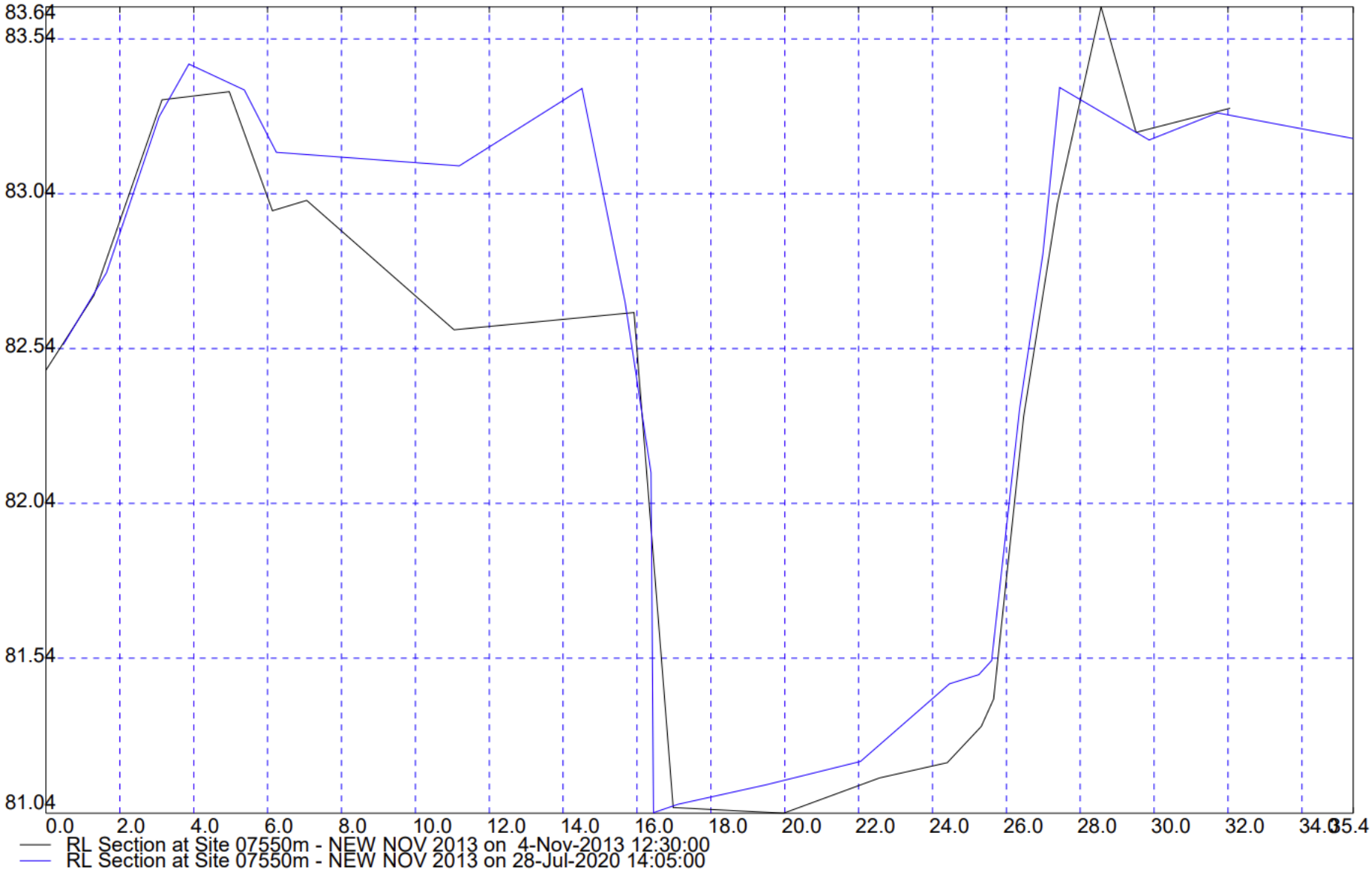

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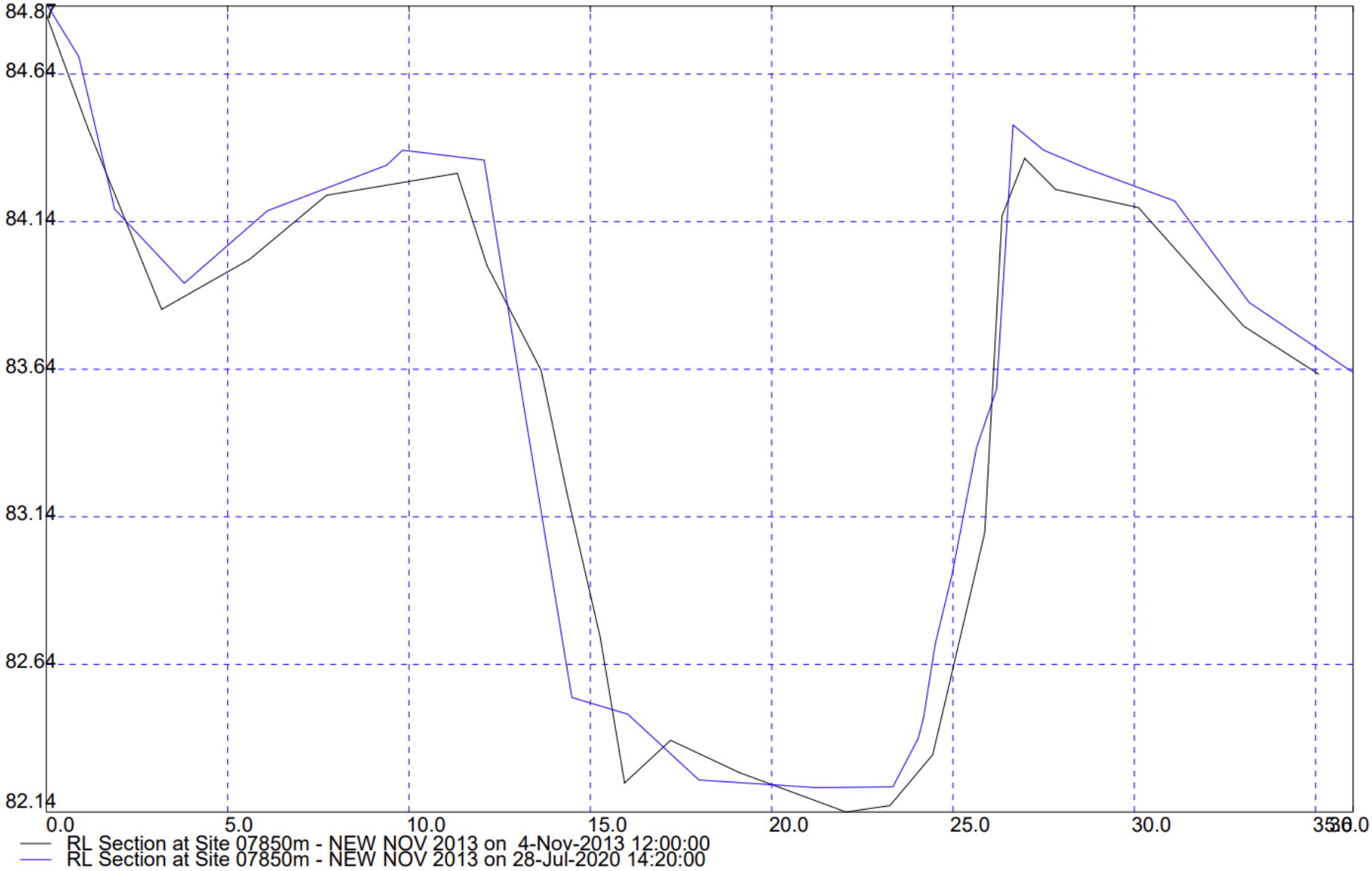

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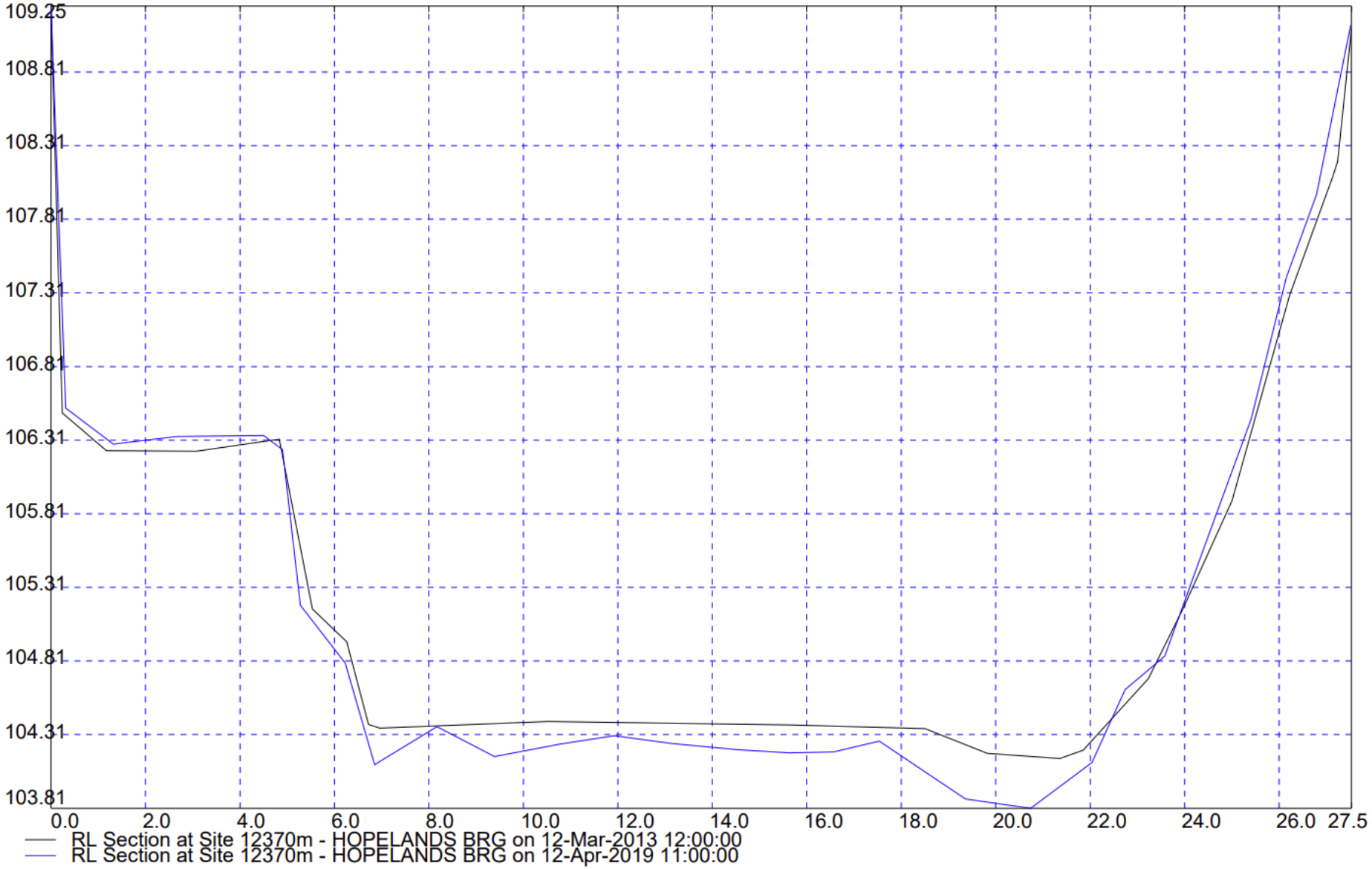

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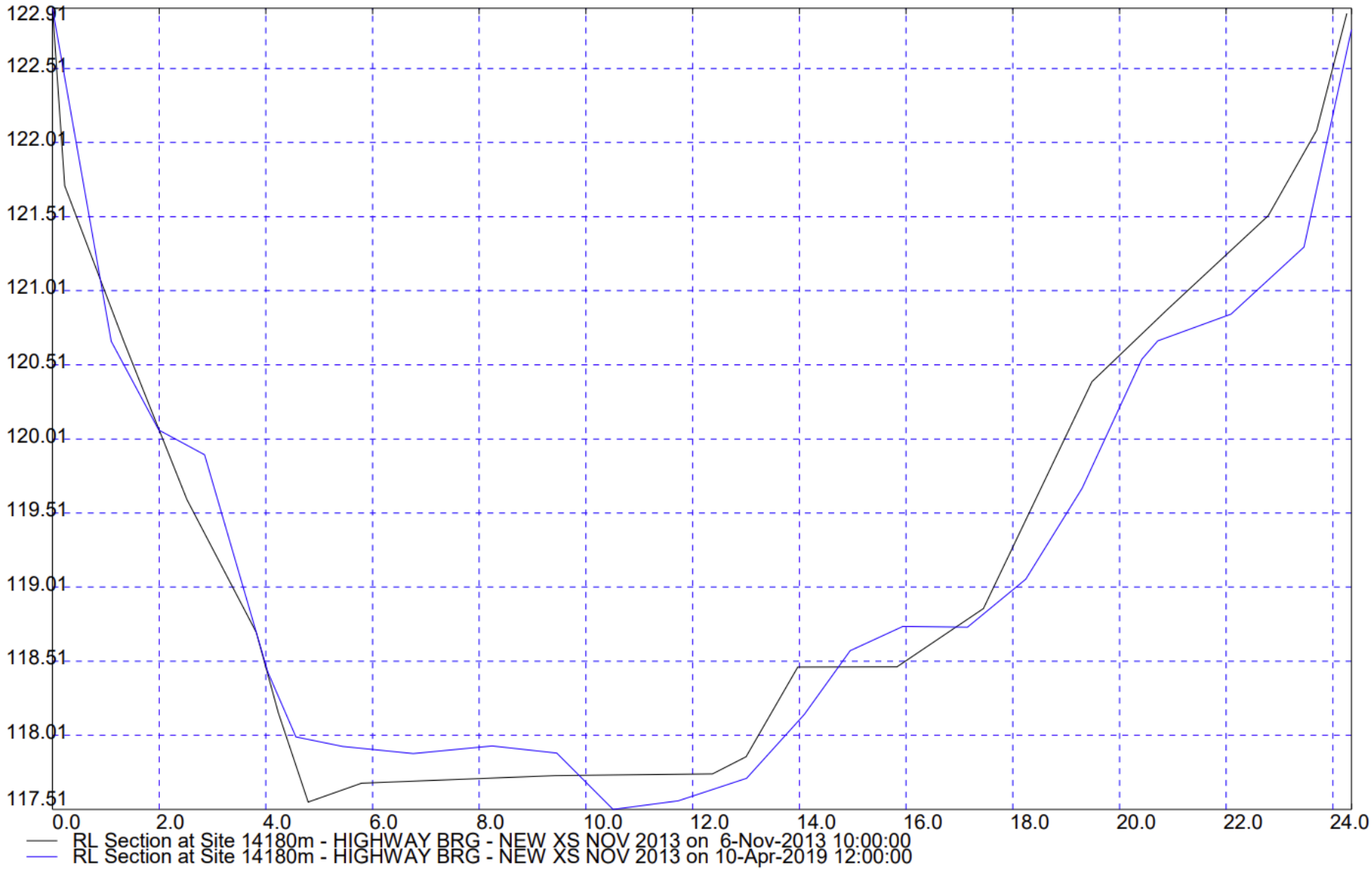

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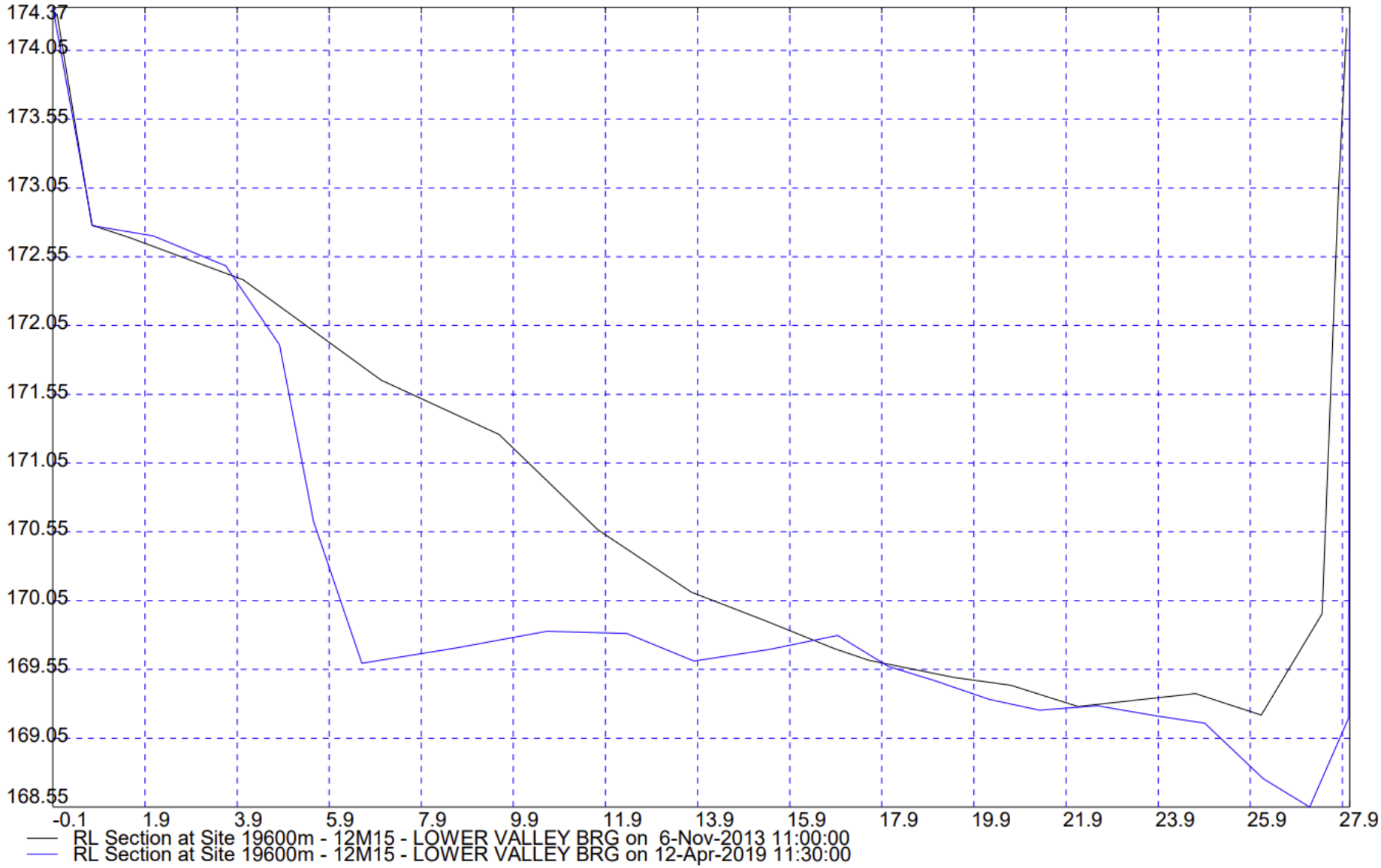

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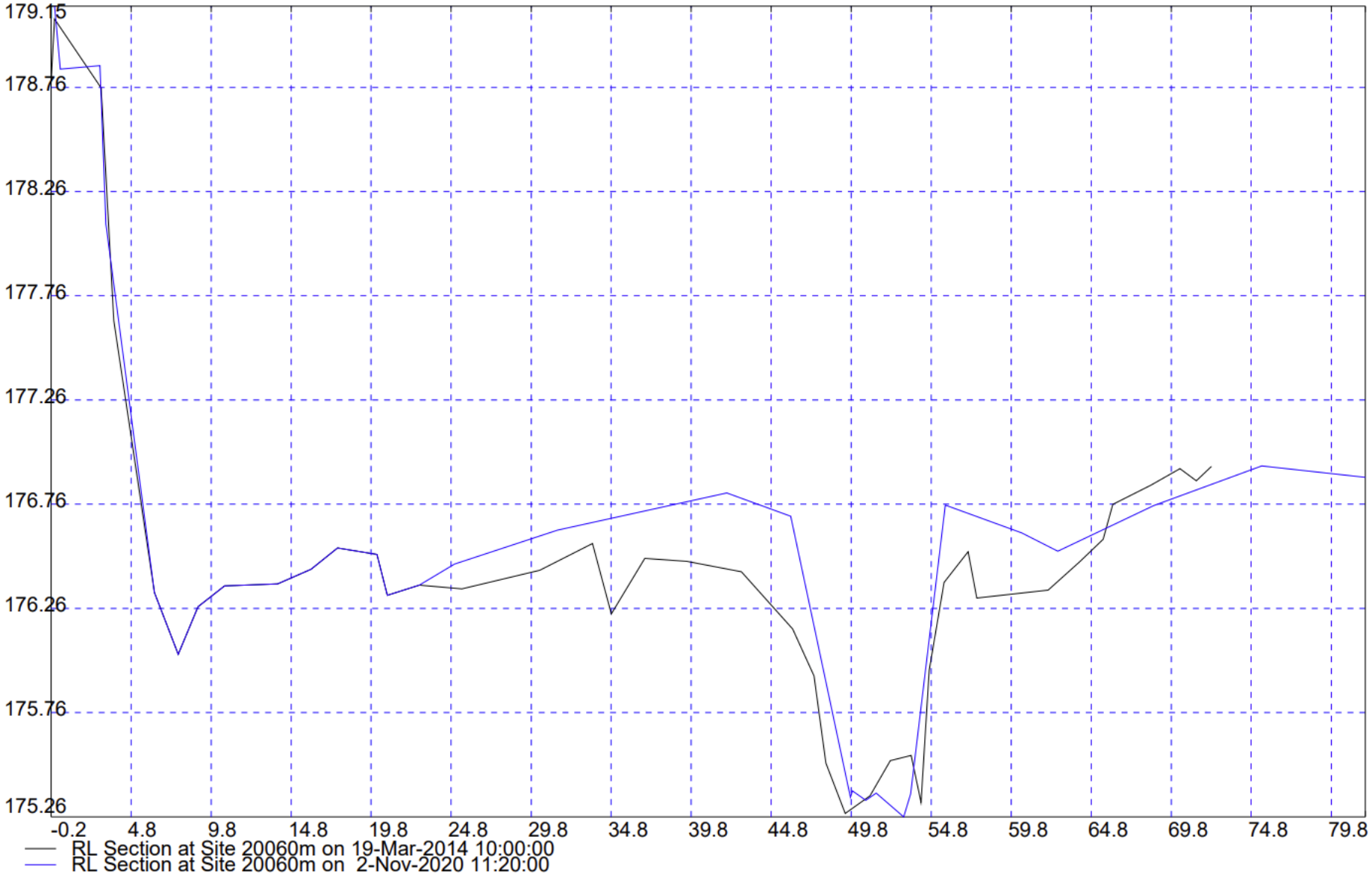

84.87
84.64
84.14
83.64
83.14
82.64
82.14
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
RL Section at Site 07850m - NEW NOV 2013 on 4-Nov-2013 12:00:00
RL Section at Site 07850m - NEW NOV 2013 on 28-Jul-2020 14:20:00

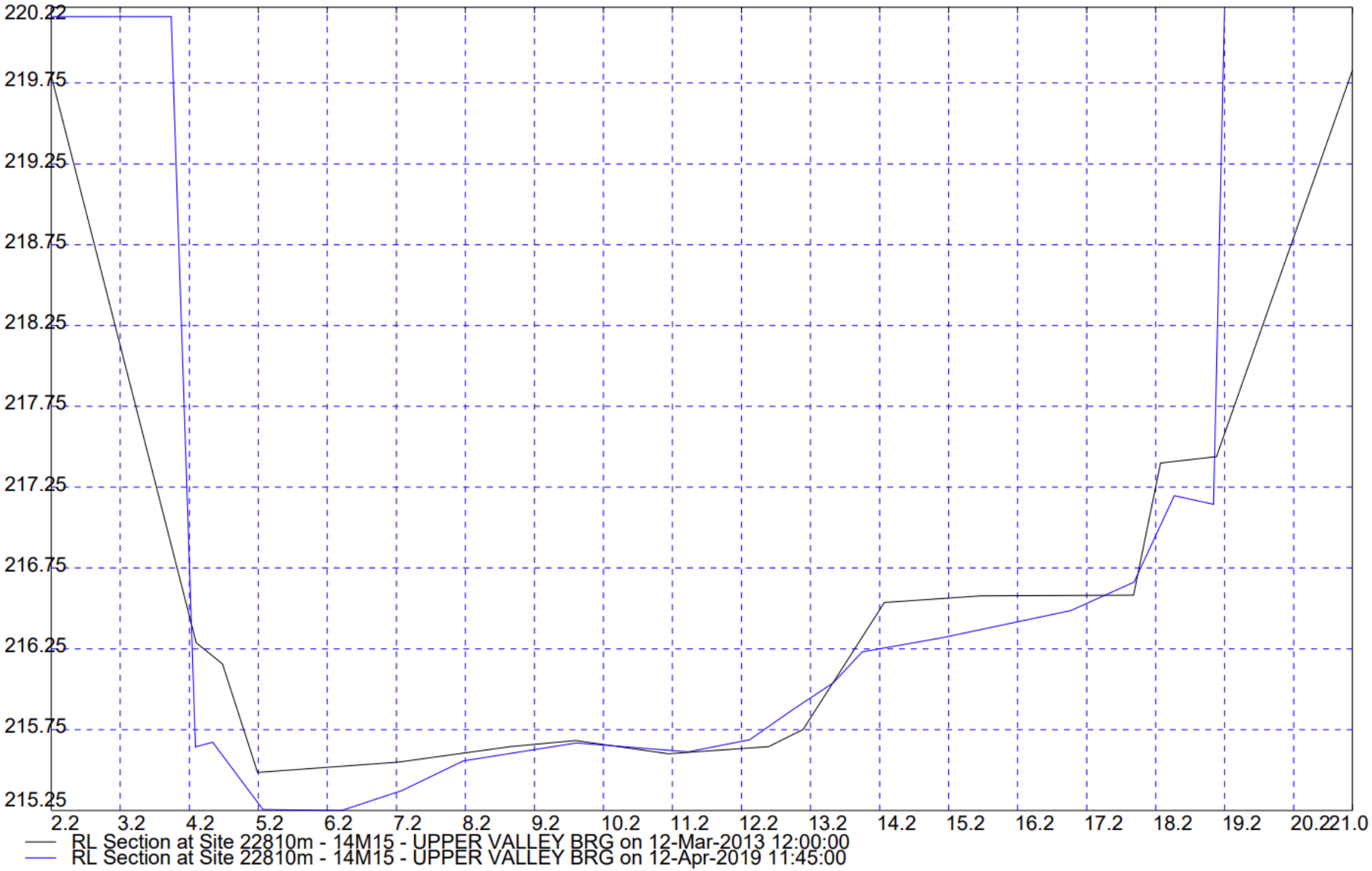

86.04
85.66
85.16
84.66
84.16
83.66
83.16
82.66
82.16
-0.1
1.9
3.9
5.9
7.9
9.9
11.9
13.9
15.9
17.9
19.9
21.9
23.9
25.9
27.9
RL Section at Site 08050m - XS5M00 - RANGE BRG on 12-Mar-2013 12:00:00
RL Section at Site 08050m - XS5M00 - RANGE BRG on 12-Apr-2019 10:30:00


109.25
108.81
108.31
107.81
107.31
106.81
106.31
105.81
105.31
104.81
104.31
103.81
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
27.5
RL Section at Site 12370m - HOPELANDS BRG on 12-Mar-2013 12:00:00
RL Section at Site 12370m - HOPELANDS BRG on 12-Apr-2019 11:00:00

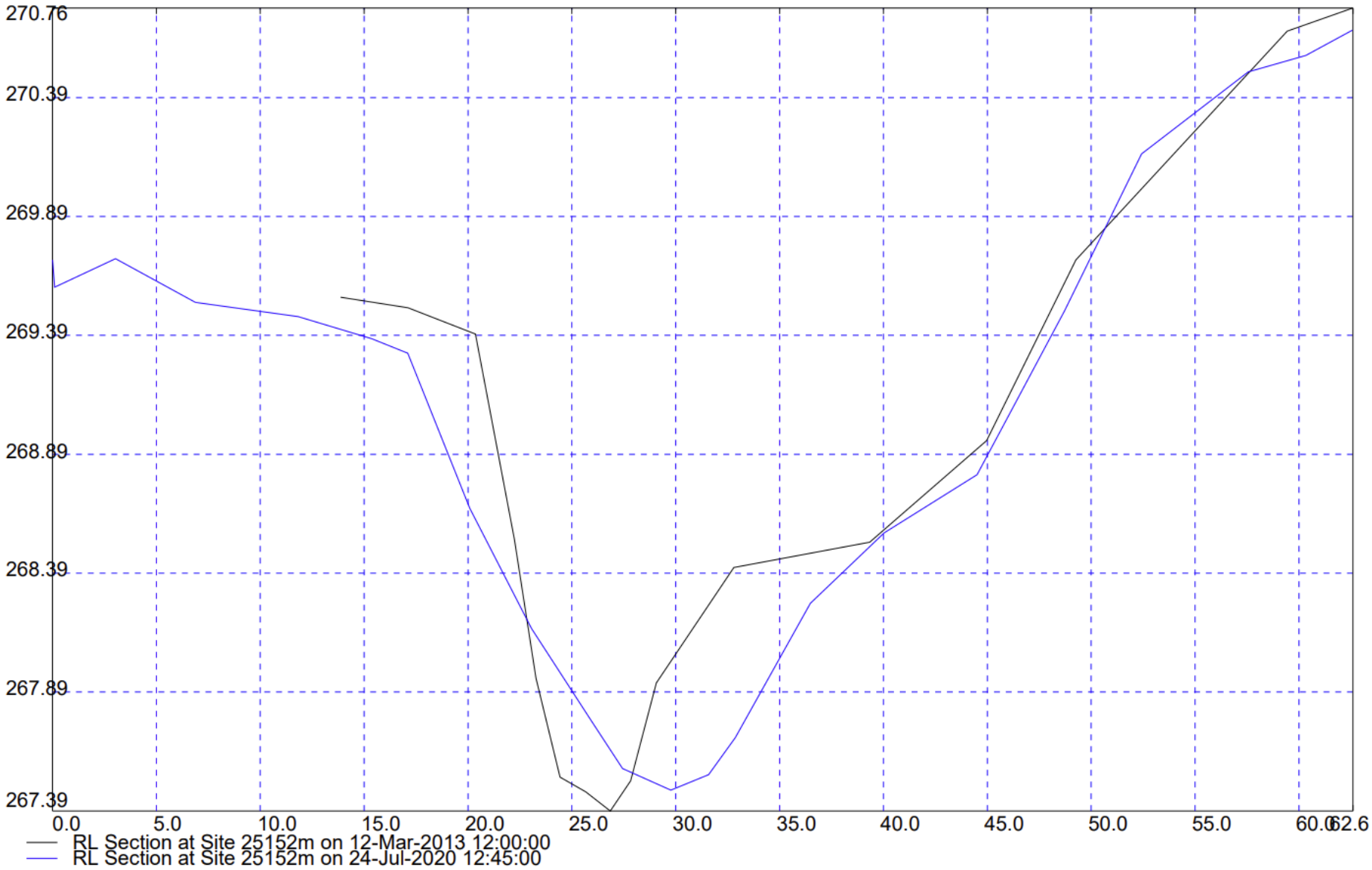

122.91
122.51
122.01
121.51
121.01
120.51
120.01
119.51
119.01
118.51
118.01
117.51
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
RL Section at Site 14180m - HIGHWAY BRG - NEW XS NOV 2013 on 6-Nov-2013 10:00:00
RL Section at Site 14180m - HIGHWAY BRG - NEW XS NOV 2013 on 10-Apr-2019 12:00:00


174.37
174.05
173.55
173.05
172.55
172.05
171.55
171.05
170.55
170.05
169.55
169.05
168.55
-0.1
1.9
3.9
5.9
7.9
9.9
11.9
13.9
15.9
17.9
19.9
21.9
23.9
25.9
27.9
RL Section at Site 19600m - 12M15 - LOWER VALLEY BRG on 6-Nov-2013 11:00:00
RL Section at Site 19600m - 12M15 - LOWER VALLEY BRG on 12-Apr-2019 11:30:00

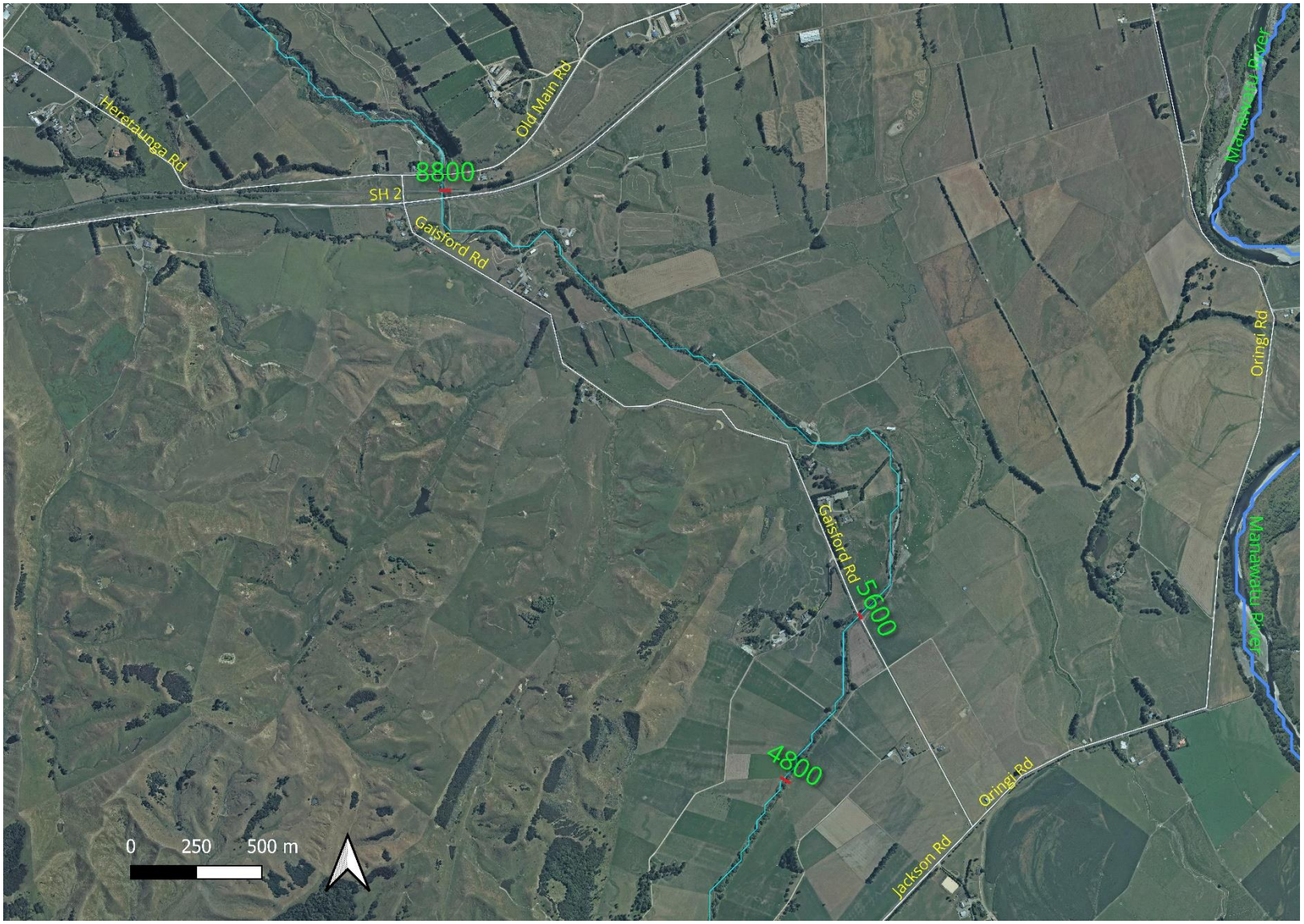

179.15
178.76
178.26
177.76
177.26
176.76
176.26
175.76
175.26
-0.2
4.8
9.8
14.8
19.8
24.8
29.8
34.8
39.8
44.8
49.8
54.8
59.8
64.8
69.8
74.8
79.8
RL Section at Site 20060m on 19-Mar-2014 10:00:00
RL Section at Site 20060m on 2-Nov-2020 11:20:00


220.22
219.75
219.25
218.75
218.25
217.75
217.25
216.75
216.25
215.75
215.25
2.2
3.2
4.2
5.2
6.2
7.2
8.2
9.2
10.2
11.2
12.2
13.2
14.2
15.2
16.2
17.2
18.2
19.2
20.2
21.0
RL Section at Site 22810m - 14M15 - UPPER VALLEY BRG on 12-Mar-2013 12:00:00
RL Section at Site 22810m - 14M15 - UPPER VALLEY BRG on 12-Apr-2019 11:45:00


261.49
260.99
260.49
259.99
259.49
258.99
258.49
257.99
257.49
256.99
-19.6
-14.6
-9.6
-4.6
0.4
5.4
10.4
15.4
20.4
25.4
30.4
35.4
40.4
45.4
50.2
RL Section at Site 24782m on 12-Mar-2013 12:00:00
RL Section at Site 24782m on 24-Jul-2020 12:55:00


270.76
270.39
269.89
269.39
268.89
268.39
267.89
267.39
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
62.6
RL Section at Site 25152m on 12-Mar-2013 12:00:00
RL Section at Site 25152m on 24-Jul-2020 12:45:00

Appendix B1: Raparapawai cross section locations




19000
18500
18200
Loveday Rd
16800
16700
Top Grass Rd
Kiritaki Rd
Ross Rd
Maharahara Rd
Top Grass Rd
Kearney Rd
13500
Graham Rd
0
250
500 m

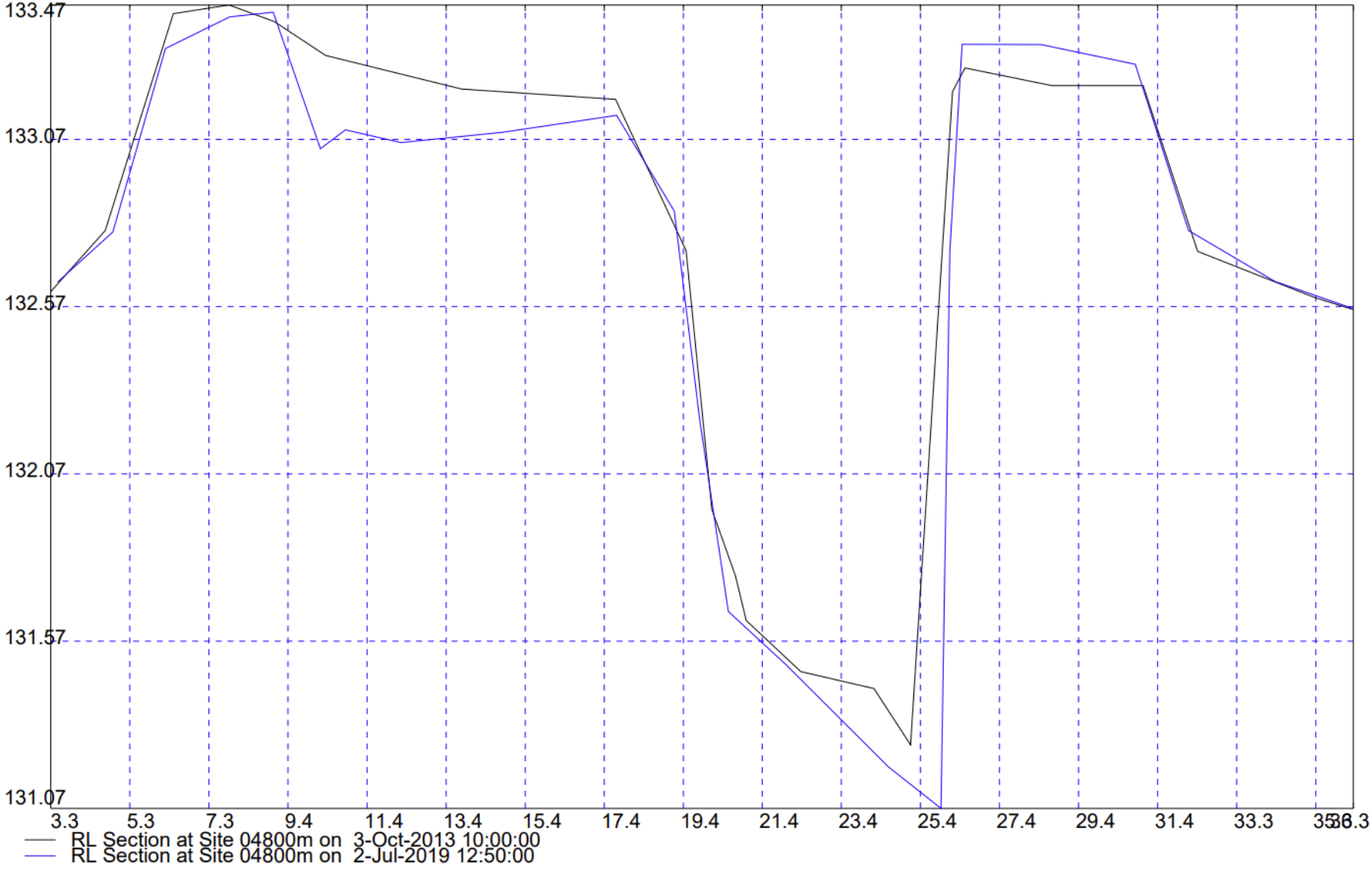
Appendix B2: Raparapawai Mean Bed Level Data (2013 – 2020)

Raparapawai Mean Bed Level Change					
Cross Section	Left Extent	Right Extent	MBL 2013	MBL 2019/2020	MBL change (2020-2013)
4800	20	26	131.61	131.397	-0.213
5600	9.2	14.9	135.427	135.537	0.11
8800	17.4	29	160.392	160.177	-0.215
13500	9	20.206	225.778	225.716	-0.062
16700	0.607	16.65	280.242	280.266	0.024
16800	1.25	10	282.917	282.908	-0.009
18200	48	93.5	316.627	316.701	0.074
18600	44.1	59.1	326.885	327.043	0.158
19000	21.5	38	338.934	338.833	-0.101

Appendix B3: Raparapawai Change in Gravel Volume (2013 – 2020)

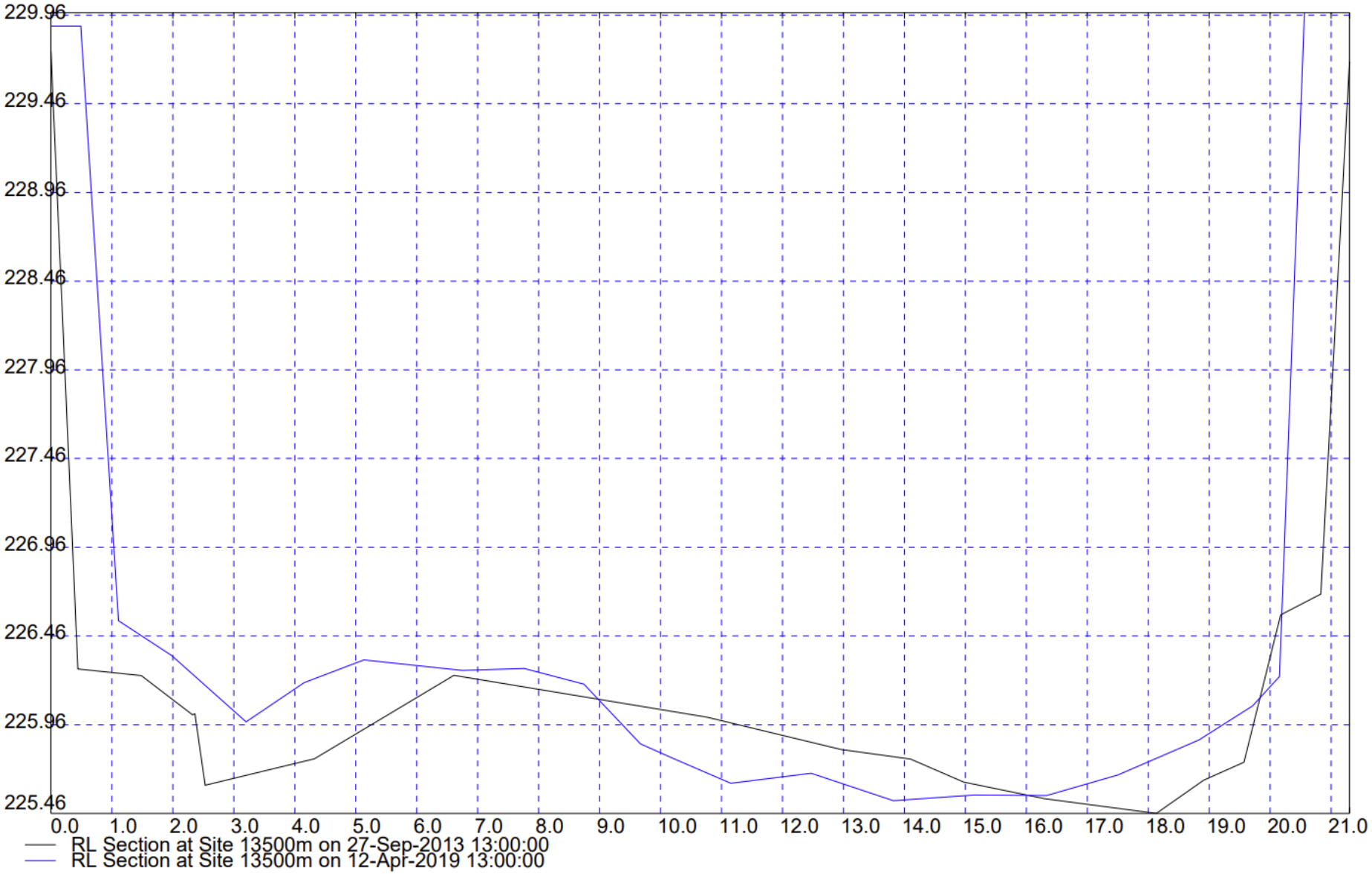
Raparapawai Stream Change in Gravel Volume						
Cross section	Left Extent	Right Extent	Datum=0	Area under the section 2013	Area under the section 2019/2020	Change in volume 2020/2019 - 2013 (m^3)
4800	15.4	29.4	0	1854.5	1853.1	-1120
5600	5.7	15.5	0	1331.5	1331.1	-170
8800	13.9	31.9	0	2896.1	2891.3	-3840
13500	0	21	0	4745.2	4750.6	2160
16700	0	18	0	5045.6	5046.9	520
16800	0	20	0	5670.1	5669.7	-180
18200	38	108	0	22184.1	22187.2	1240
18600	38	74	0	11780.5	11782.5	600
19000	9.3	49.3	0	13577.5	13575.8	-680

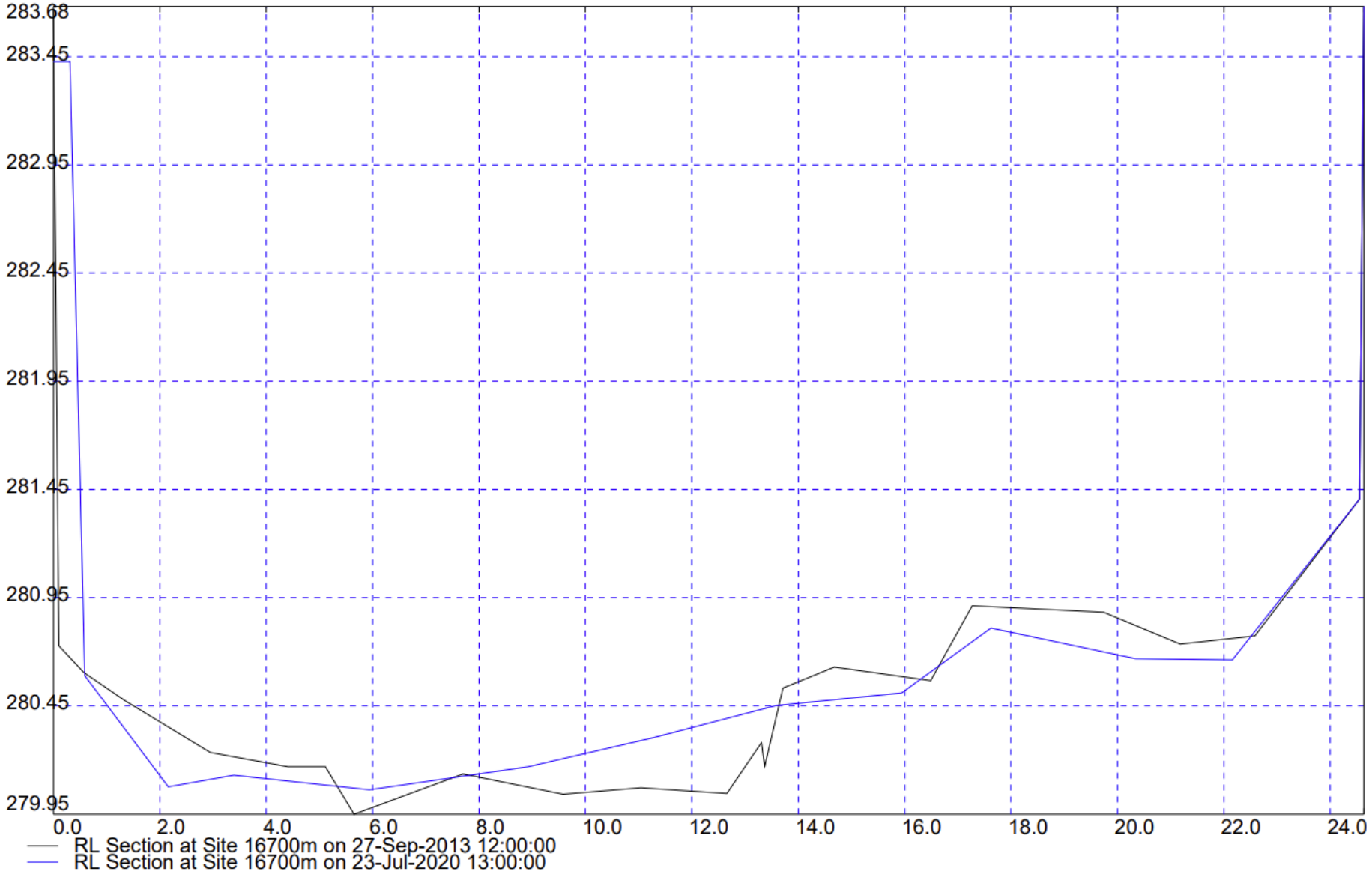
Appendix B4: Cross-sections at Raparapawai Stream




139.09
138.83
138.33
137.83
137.33
136.83
136.33
135.83
135.33
-0.3
0.7
1.7
2.7
3.7
4.7
5.7
6.7
7.7
8.7
9.7
10.7
11.7
12.7
13.7
14.7
15.5
RL Section at Site 05600m on 27-Sep-2013 14:00:00
RL Section at Site 05600m on 2-Jul-2019 11:55:00


164.70
164.30
163.80
163.30
162.80
162.30
161.80
161.30
160.80
160.30
159.80
-0.1
1.9
3.9
5.9
7.9
9.9
11.9
13.9
15.9
17.9
19.9
21.9
23.9
25.9
27.9
29.9
31.9
33.2
RL Section at Site 08800m - NEW OCT 2013 on 3-Oct-2013 12:00:00
RL Section at Site 08800m - NEW OCT 2013 on 2-Jul-2019 00:00:00

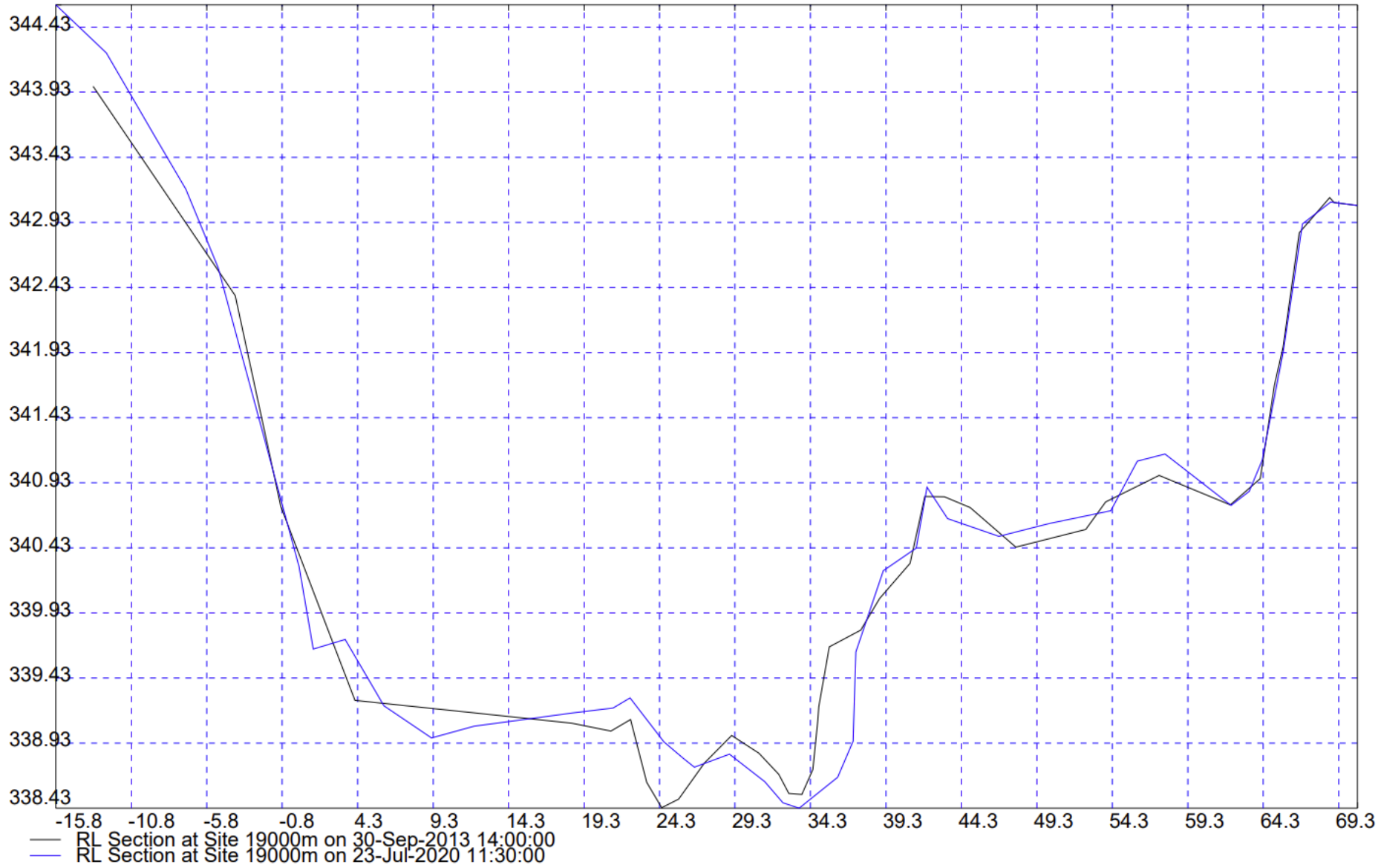

229.96
229.46
228.96
228.46
227.96
227.46
226.96
226.46
225.96
225.46
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
RL Section at Site 13500m on 27-Sep-2013 13:00:00
RL Section at Site 13500m on 12-Apr-2019 13:00:00


283.68
283.45
282.95
282.45
281.95
281.45
280.95
280.45
279.95
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
RL Section at Site 16700m on 27-Sep-2013 12:00:00
RL Section at Site 16700m on 23-Jul-2020 13:00:00

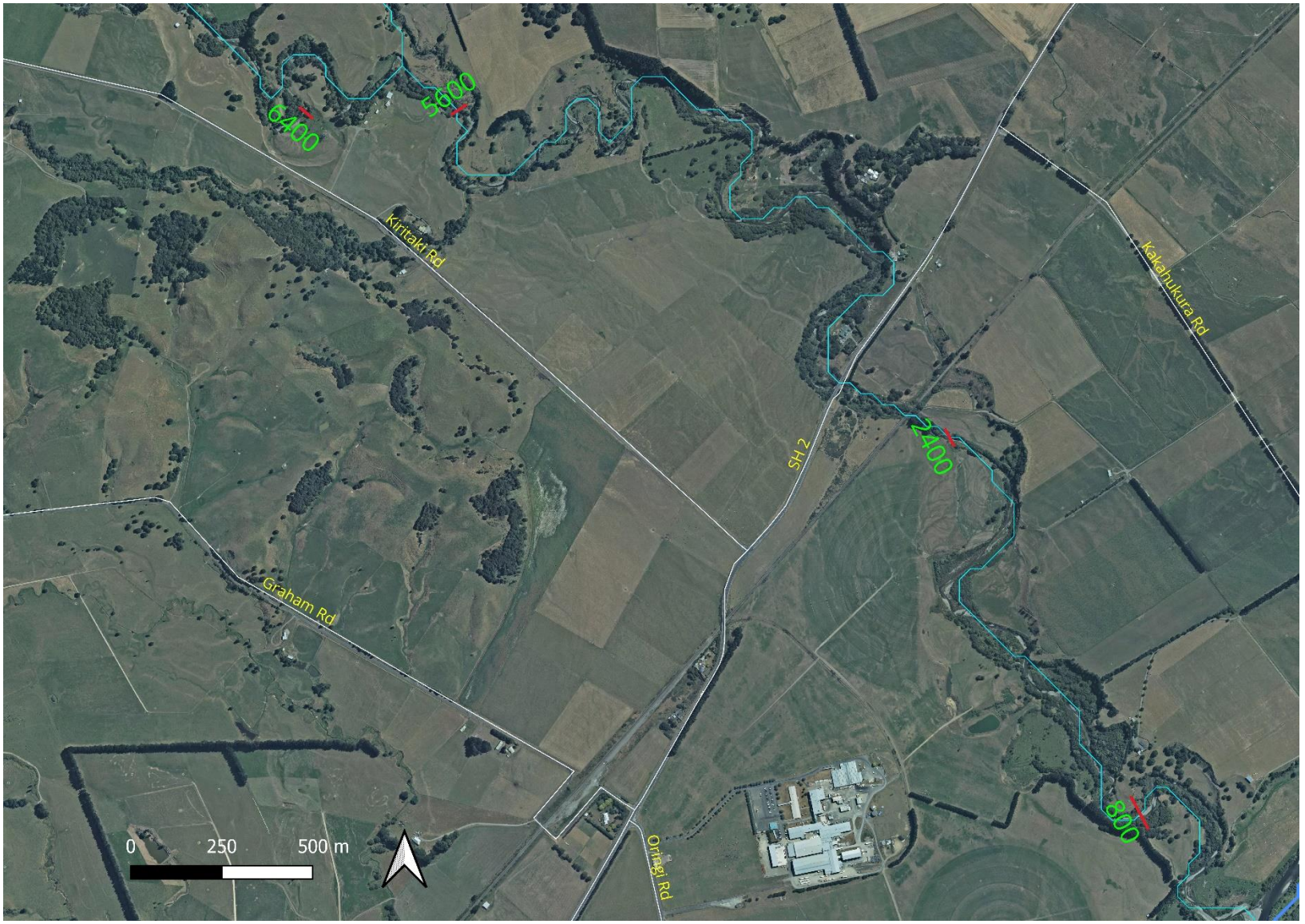

285.59
285.43
284.93
284.43
283.93
283.43
282.93
282.43
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
48.1
RL Section at Site 16800m on 27-Sep-2013 10:30:00
RL Section at Site 16800m on 23-Jul-2020 12:45:00

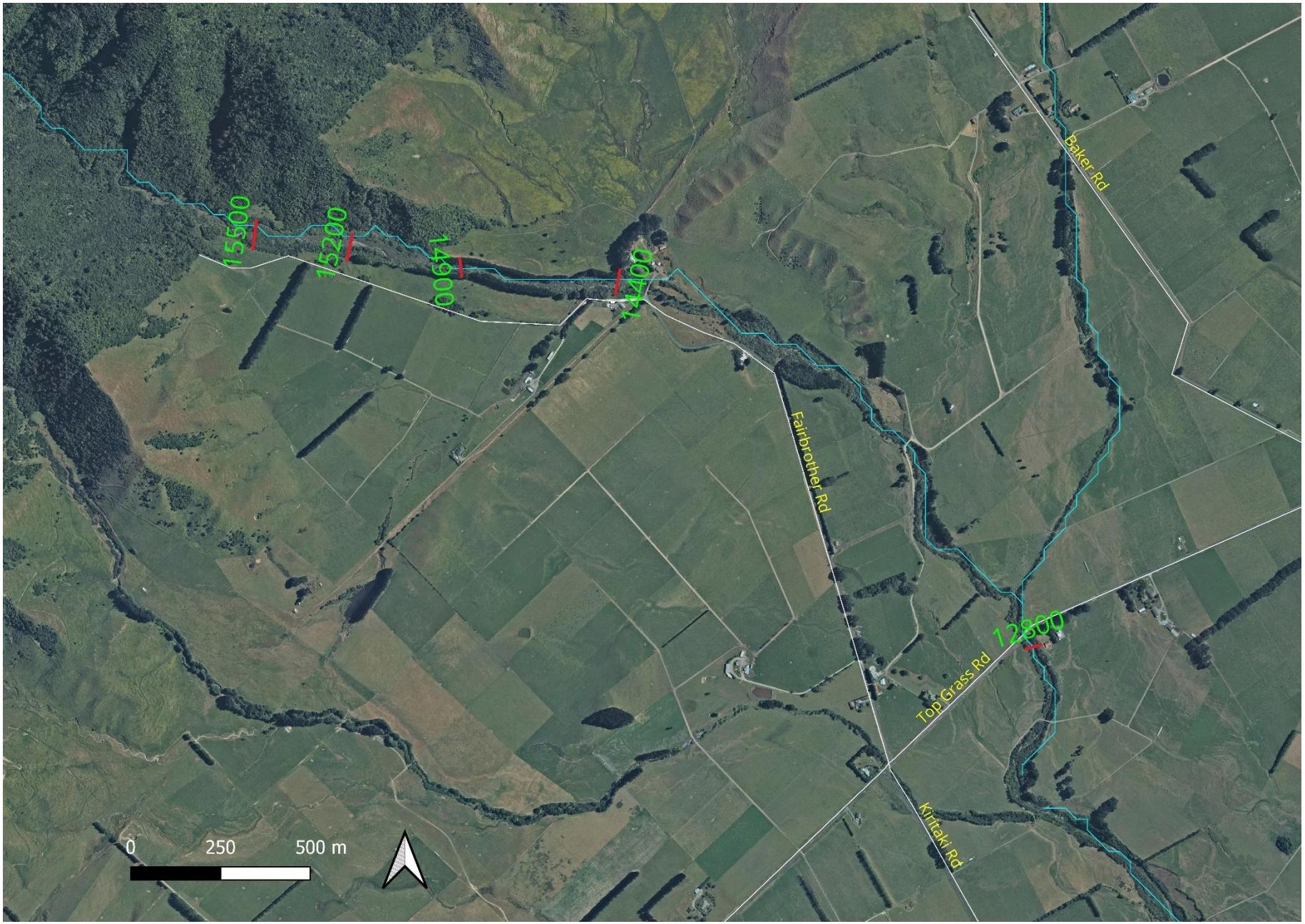

321.34
321.08
320.58
320.08
319.58
319.08
318.58
318.08
317.58
317.08
316.58
316.08
-2
8
18
28
38
48
58
68
78
88
98
108
118
124
RL Section at Site 18200m on 30-Sep-2013 13:00:00
RL Section at Site 18200m on 23-Jul-2020 12:05:00


330.58
330.46
329.96
329.46
328.96
328.46
327.96
327.46
326.96
326.46
-30.9 -25.9 -20.9 -15.9 -10.9 -5.9 -0.9 4.1 9.1 14.1 19.1 24.1 29.1 34.1 39.1 44.1 49.1 54.1 59.1 64.1 69.1 74.1
RL Section at Site 18600m on 30-Sep-2013 13:30:00
RL Section at Site 18600m on 23-Jul-2020 11:45:00


344.43
343.93
343.43
342.93
342.43
341.93
341.43
340.93
340.43
339.93
339.43
338.93
338.43
-15.8
-10.8
-5.8
-0.8
4.3
9.3
14.3
19.3
24.3
29.3
34.3
39.3
44.3
49.3
54.3
59.3
64.3
69.3
RL Section at Site 19000m on 30-Sep-2013 14:00:00
RL Section at Site 19000m on 23-Jul-2020 11:30:00

Appendix C1: Oruakeretaki cross section locations




15500
15200
14900
14400
12800
Baker Rd
Fairbrother Rd
Top Grass Rd
Kiritaki Rd
0
250
500 m

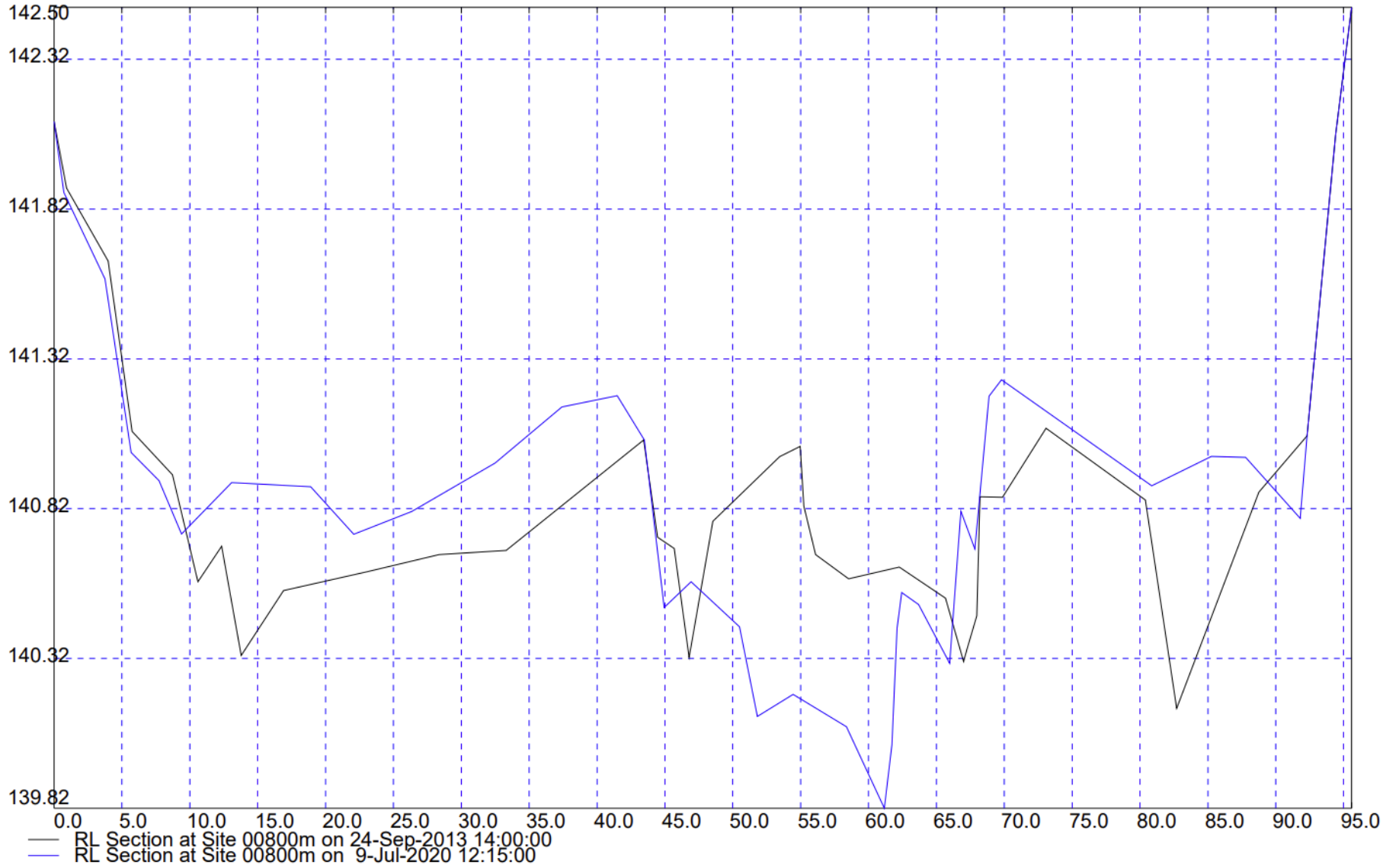
Appendix C2: Oruakeretaki Mean Bed Level Data (2013 – 2020)

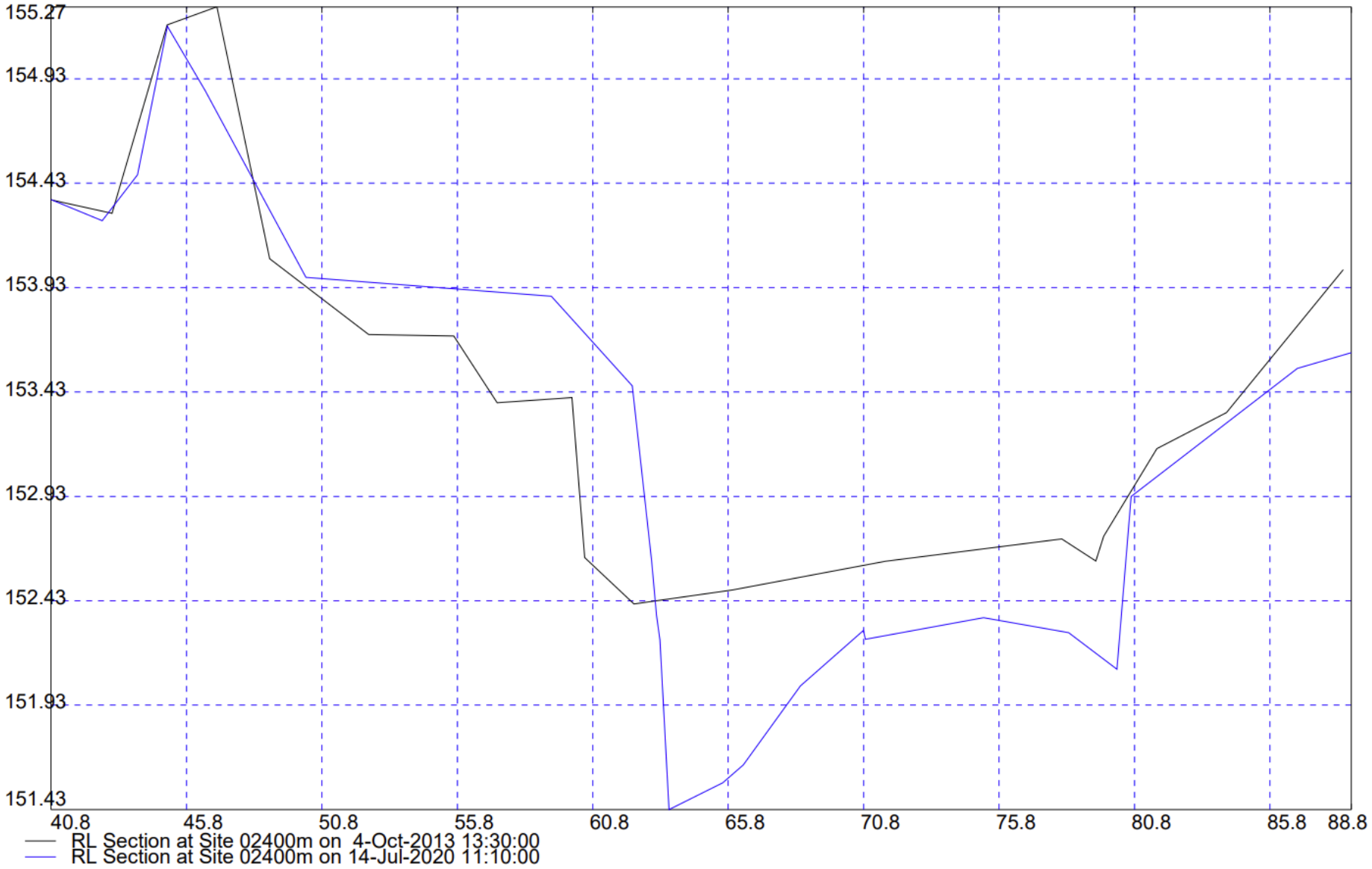
Oruakeretaki Mean Bed Level Change					
Cross Section	Left Extent	Right Extent	MBL 2013	MBL 2020	MBL change (2020-2013)
800	45	70	140.688	140.38	-0.308
2400	60.8	81.6	152.612	152.268	-0.344
5600	6.7	19.4	176.041	176.227	0.186
6400	6.9	17.9	182.853	183.162	0.309
12800	14	26	259.236	258.66	-0.576
14400	21.45	49.608	291.832	291.944	0.112
14900	20	31.6	302.658	302.728	0.07
15200	31.5	53.1	311.831	311.293	-0.538
15500	1	12.7	320.266	319.813	-0.453

Appendix C3: Oruakeretaki Change in Gravel Volume (2013 – 2020)

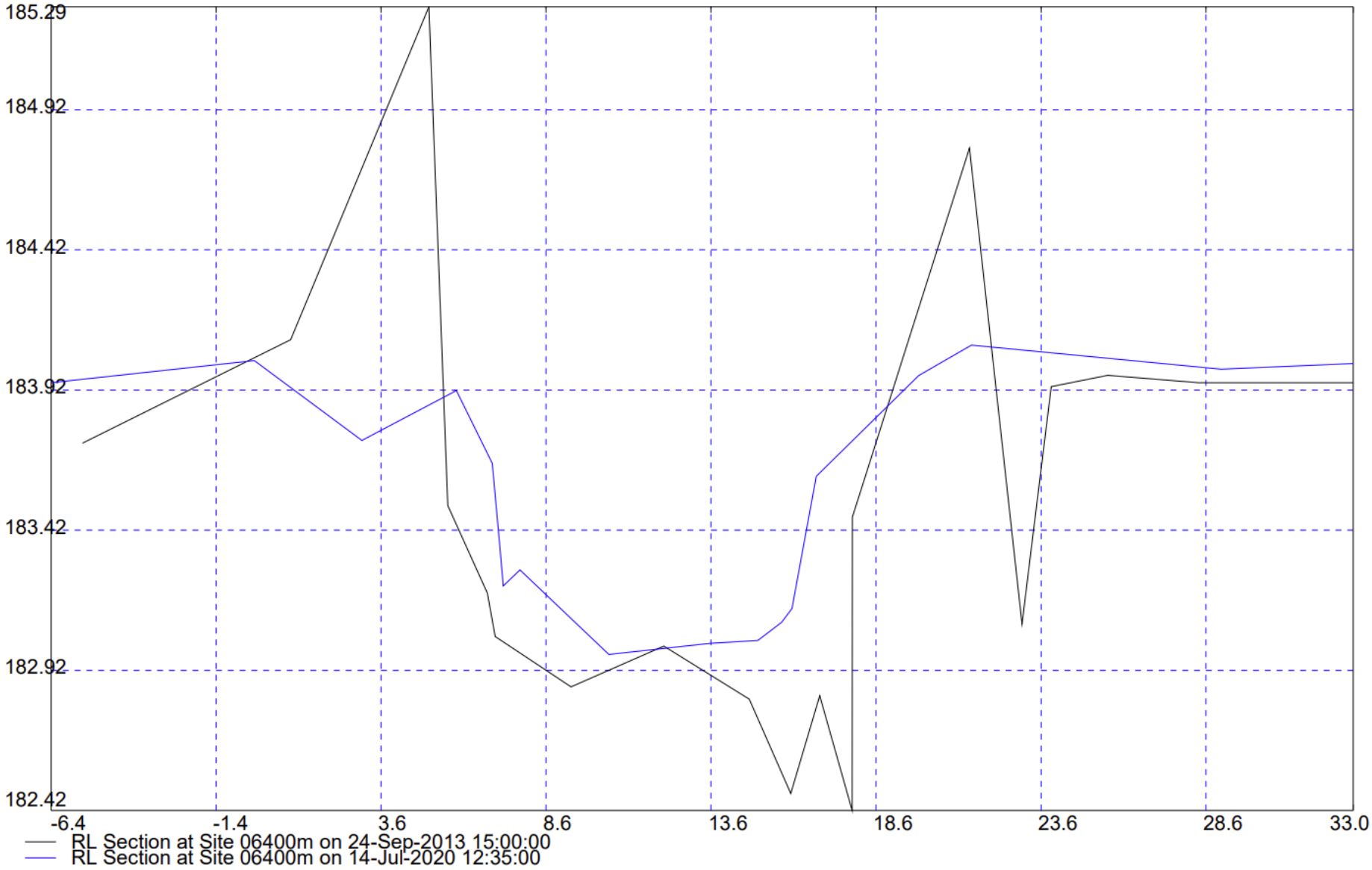
Oruakeretaki Stream Change in Gravel Volume						
Cross Section	Left Extent	Right Extent	Datum=0	Area under section 2013	Area under section 2020	Change in volume 2013 - 2020
800	35	75	0	5631.1	5626.2	-3920
2400	50.8	85.8	0	5353.7	5349.8	-3120
5600	1.3	22.9	0	3811.7	3813.3	1280
6400	-1.4	28.6	0	5509.4	5509.7	240
12800	0.9	39	0	9952.6	9944.4	-6560
14400	12.6	62.6	0	14616.7	14617.9	780
14900	10	40	0	9087.1	9090.5	1360
15200	23.1	63.1	0	12482.6	12470.1	-3750
15500	1	21	0	6411.9	6406.8	-1530

Appendix C4: Cross-sections at Oruakeretaki Stream



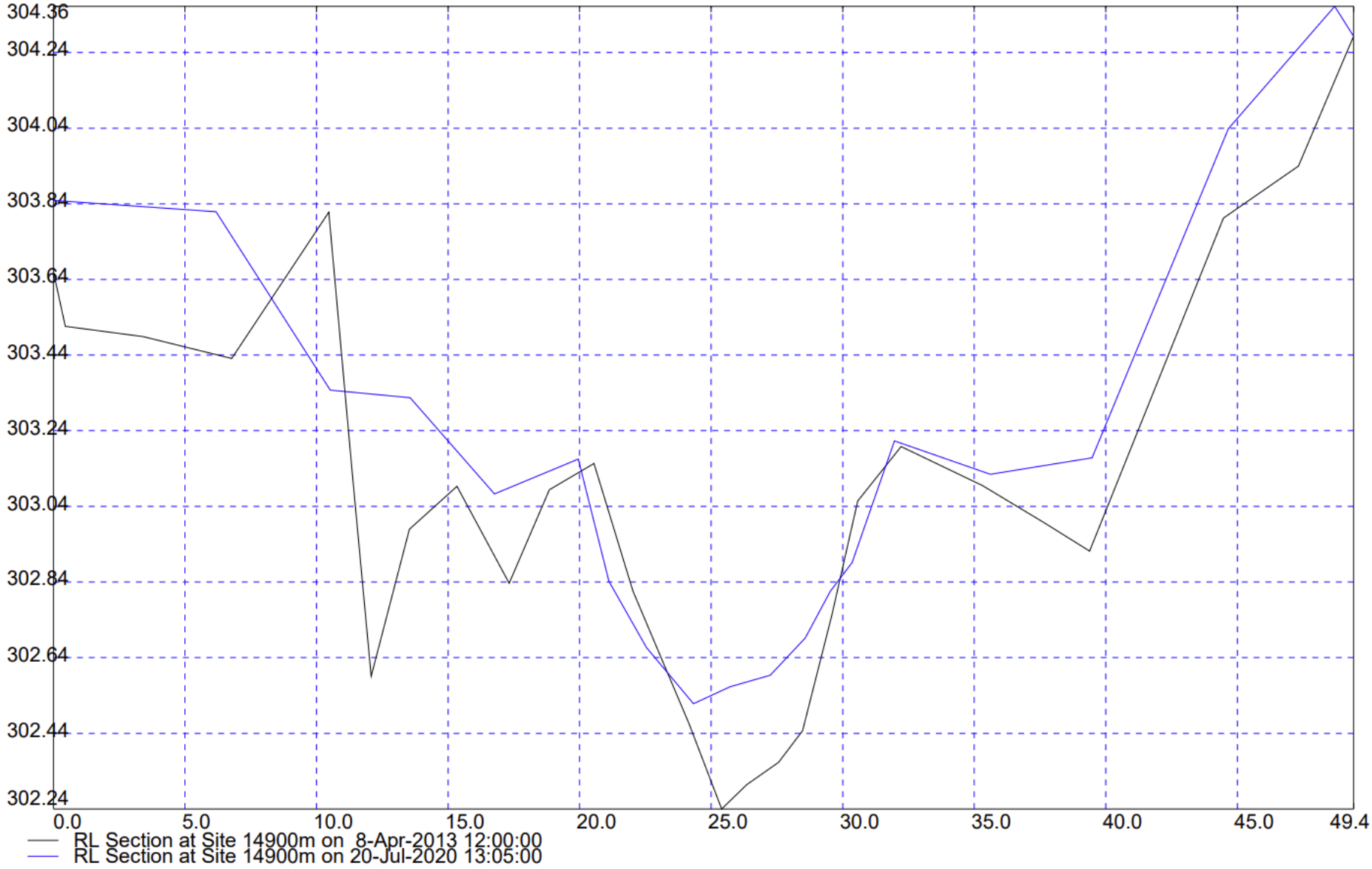

155.27
154.93
154.43
153.93
153.43
152.93
152.43
151.93
151.43
40.8
45.8
50.8
55.8
60.8
65.8
70.8
75.8
80.8
85.8
88.8
RL Section at Site 02400m on 4-Oct-2013 13:30:00
RL Section at Site 02400m on 14-Jul-2020 11:10:00


179.21
178.79
178.29
177.79
177.29
176.79
176.29
175.79
-17.1
-12.1
-7.1
-2.1
2.9
7.9
12.9
17.9
22.9
26.2
RL Section at Site 05600m on 24-Sep-2013 14:30:00
RL Section at Site 05600m on 14-Jul-2020 12:05:00

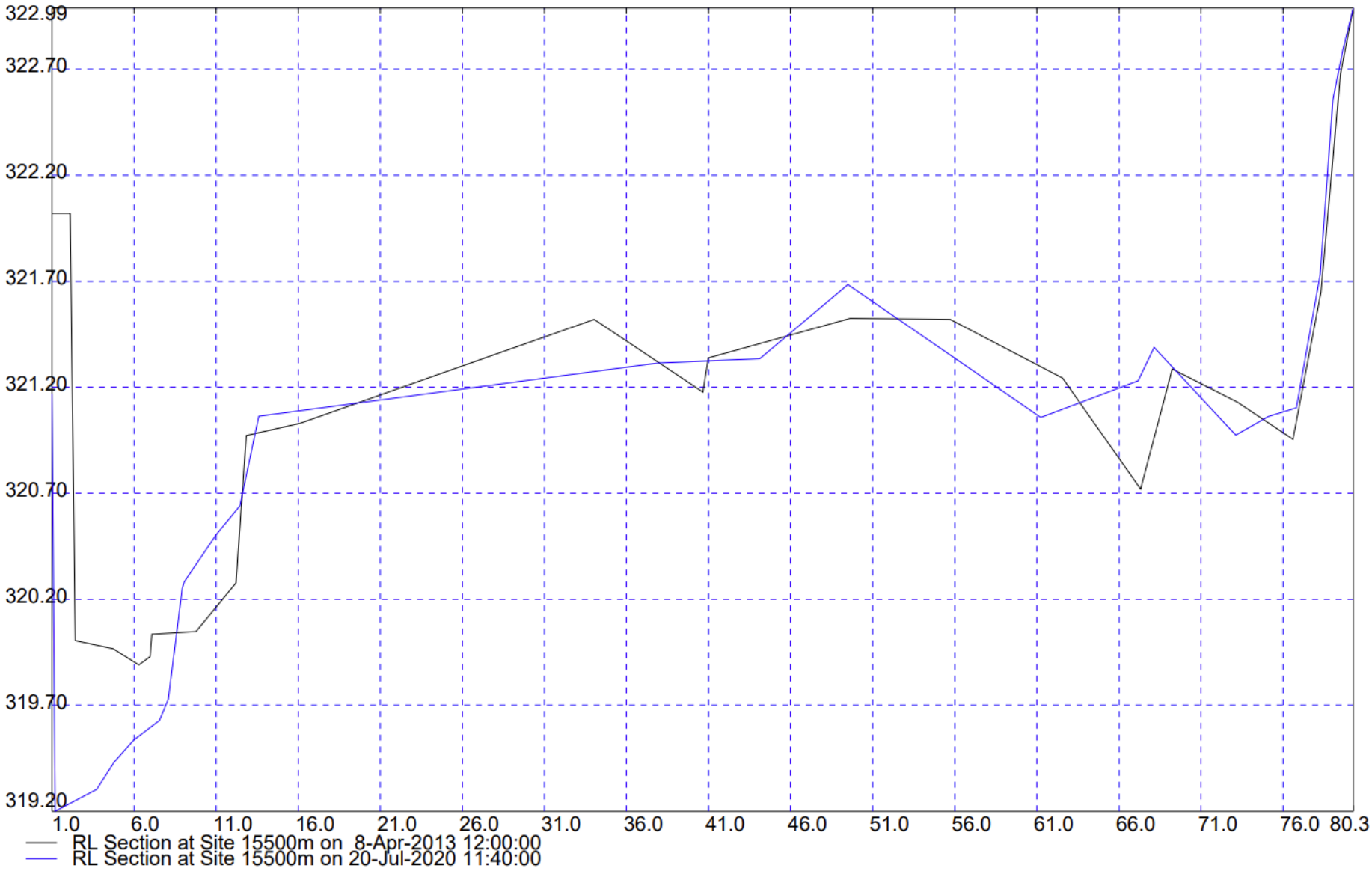

185.29
184.92
184.42
183.92
183.42
182.92
182.42
-6.4
-1.4
3.6
8.6
13.6
18.6
23.6
28.6
33.0
RL Section at Site 06400m on 24-Sep-2013 15:00:00
RL Section at Site 06400m on 14-Jul-2020 12:35:00


263.19
262.78
262.28
261.78
261.28
260.78
260.28
259.78
259.28
258.78
258.28
257.78
-14.1
-9.1
-4.1
0.9
5.9
10.9
15.9
20.9
25.9
30.9
35.9
39.2
RL Section at Site 12800m on 8-Apr-2013 12:00:00
RL Section at Site 12800m on 20-Jul-2020 13:50:00

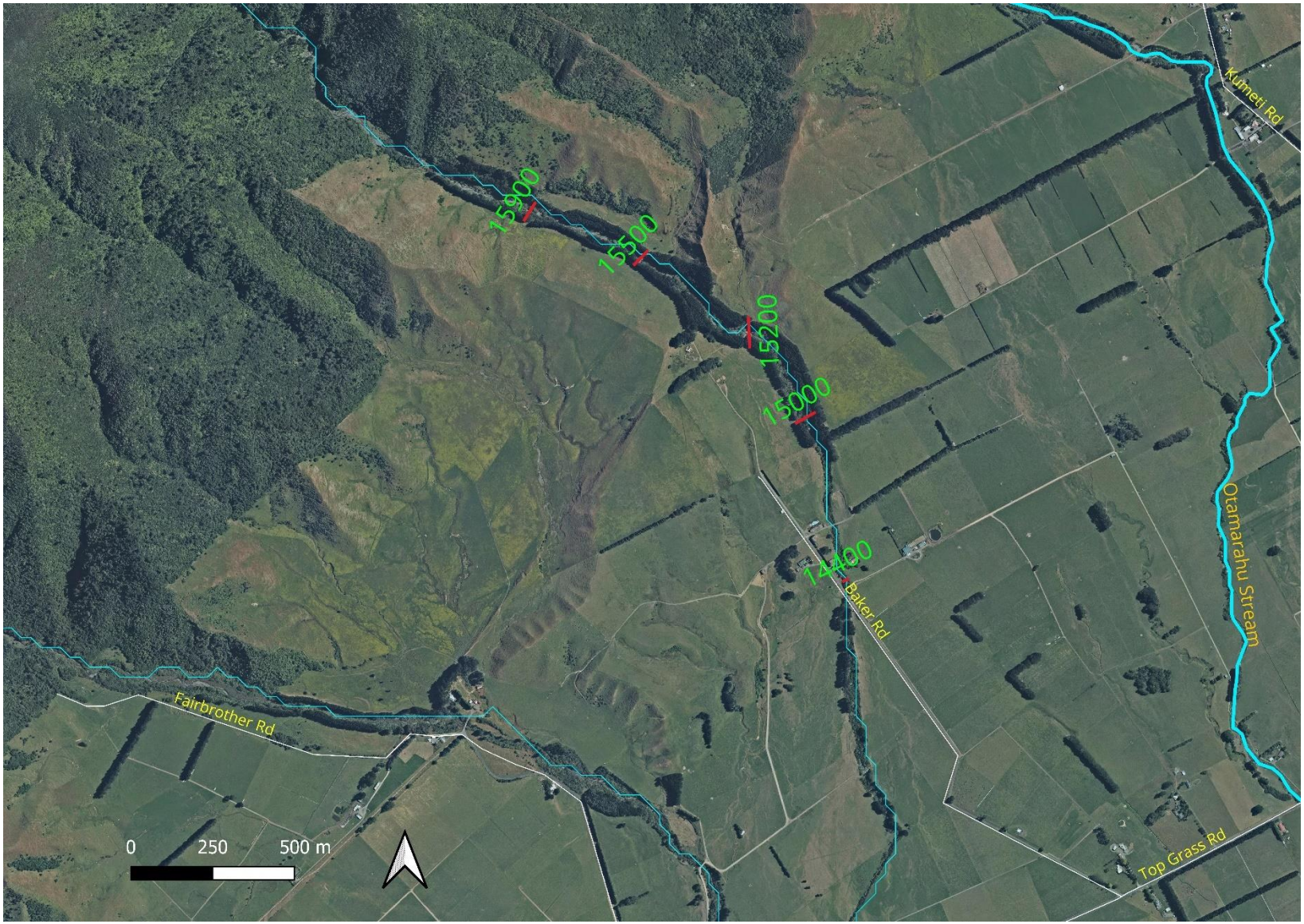

295.04
294.80
294.30
293.80
293.30
292.80
292.30
291.80
291.30
-2.4
2.6
7.6
12.6
17.6
22.6
27.6
32.6
37.6
42.6
47.6
52.6
57.6
62.6
RL Section at Site 14400m on 8-Apr-2013 12:00:00
RL Section at Site 14400m on 20-Jul-2020 14:30:00


304.36
304.24
304.04
303.84
303.64
303.44
303.24
303.04
302.84
302.64
302.44
302.24
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
49.4
RL Section at Site 14900m on 8-Apr-2013 12:00:00
RL Section at Site 14900m on 20-Jul-2020 13:05:00


316.15
315.65
315.15
314.65
314.15
313.65
313.15
312.65
312.15
311.65
311.15
310.65
18.1
23.1
28.1
33.1
38.1
43.1
48.1
53.1
58.1
63.1
68.1
73.1
78.1
83.1
88.1
RL Section at Site 15200m on 8-Apr-2013 12:00:00
RL Section at Site 15200m on 20-Jul-2020 12:05:00


322.99
322.70
322.20
321.70
321.20
320.70
320.20
319.70
319.20
1.0
6.0
11.0
16.0
21.0
26.0
31.0
36.0
41.0
46.0
51.0
56.0
61.0
66.0
71.0
76.0
80.3
RL Section at Site 15500m on 8-Apr-2013 12:00:00
RL Section at Site 15500m on 20-Jul-2020 11:40:00

Appendix D1: Mangapukakakahu cross section locations



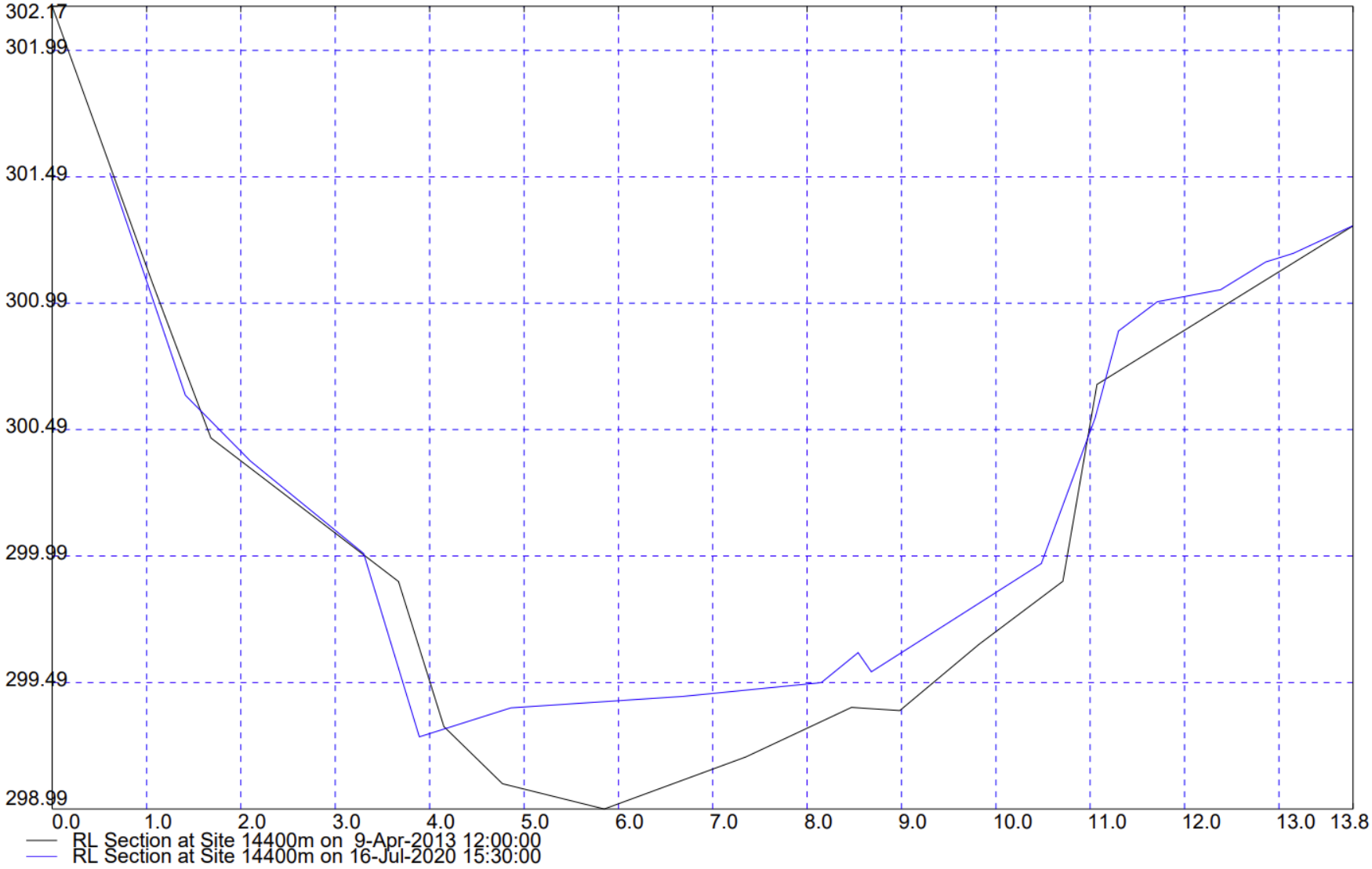
Appendix D2: Mangapukakakahu Mean Bed Level Data (2013 – 2020)

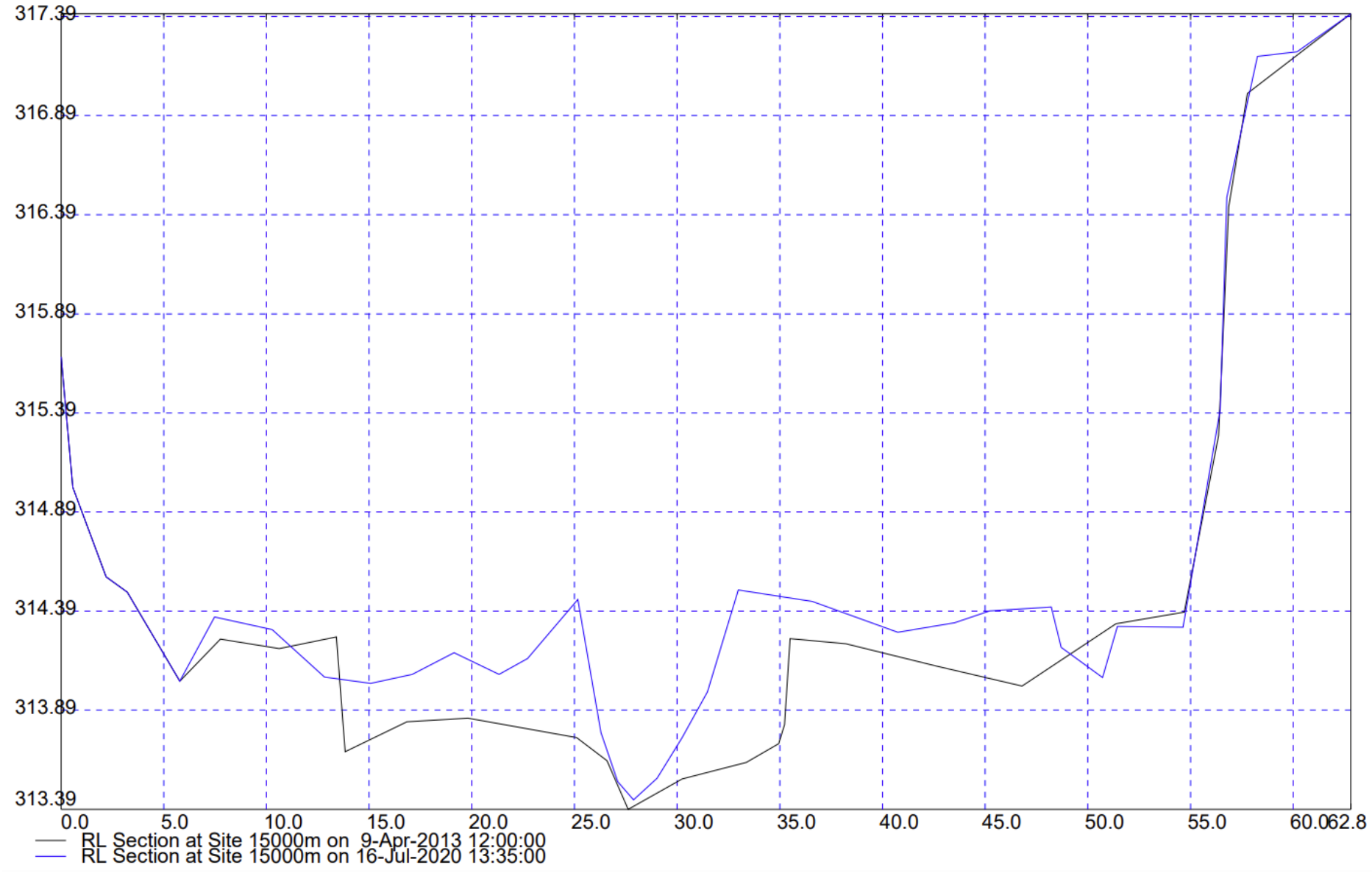
Mangapukakakahu Mean Bed Level Change					
Cross Section	Left Extent	Right Extent	MBL 2013	MBL 2020	MBL change (2020-2013)
14400	3.3	10.7	299.351	299.544	0.193
15000	15	35	313.694	314.056	0.362
15200	36	61.4	325.086	324.875	-0.211
15500	13.5	32.812	340.077	339.946	-0.131
15900	36.3	48.5	354.155	354.577	0.422

Appendix D3: Mangapukakakahu Change in Gravel Volume (2013 – 2020)

Mangapukakakahu Stream Change in Gravel Volume						
Cross Section	Left Extent	Right Extent	Datum = 0	Area under section 2013	Area under section 2020	Change in volume 2020-2013 (m^3)
14400	1	13	0	3597.9	3599.6	1020
15000	7.7	40	0	10138	10146.7	3480
15200	25	70	0	14650.2	14645.5	-1175
15500	5	45	0	13632.6	13629.4	-1120
15900	26.3	56.3	0	10649.3	10654.3	2000

Appendix D4: Cross-sections at Mangapukakakahu Stream




317.39
316.89
316.39
315.89
315.39
314.89
314.39
313.89
313.39
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
62.8
RL Section at Site 15000m on 9-Apr-2013 12:00:00
RL Section at Site 15000m on 16-Jul-2020 13:35:00

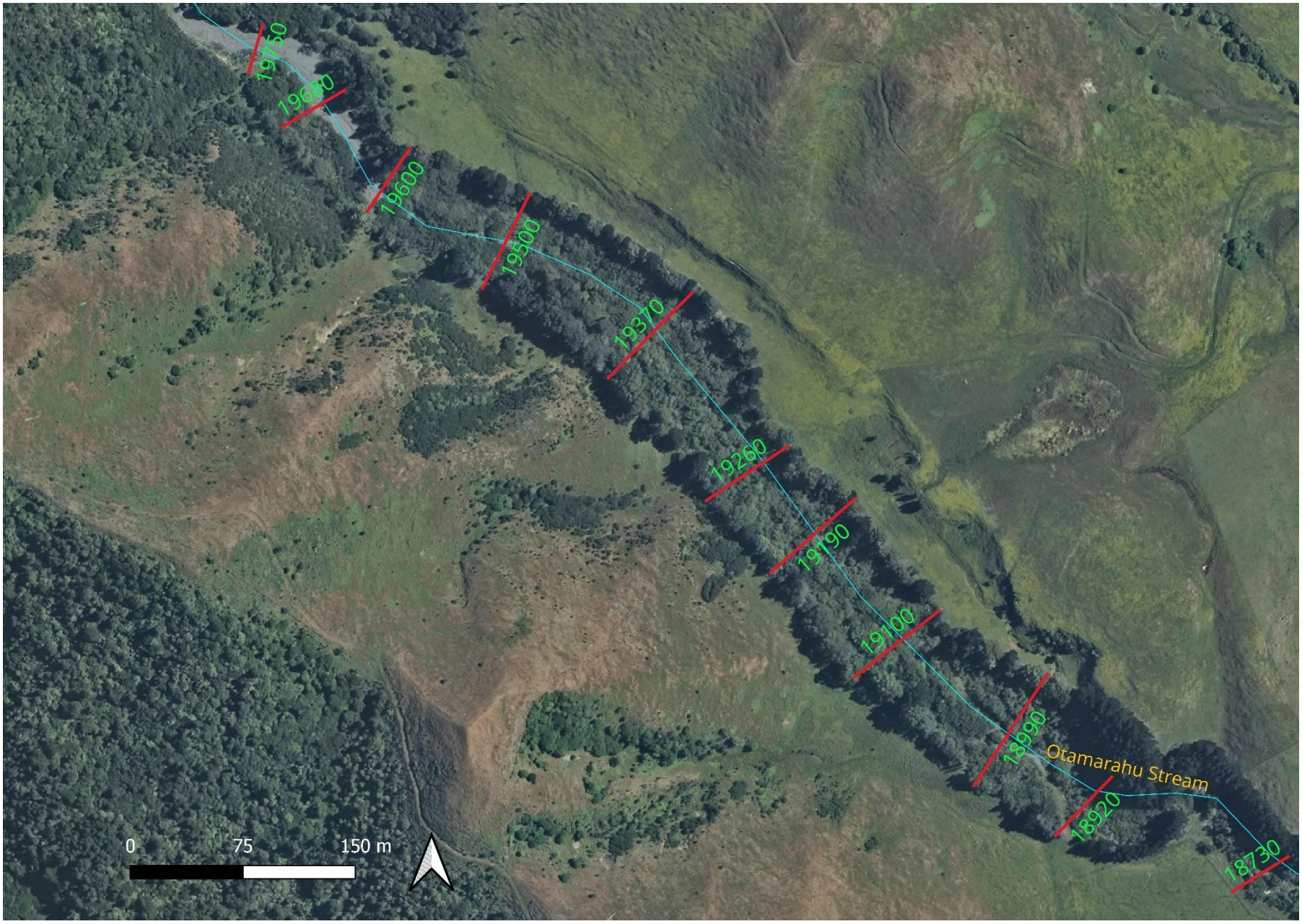

329.72
329.22
328.72
328.22
327.72
327.22
326.72
326.22
325.72
325.22
324.72
324.22
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
89.5
RL Section at Site 15200m on 9-Apr-2013 12:00:00
RL Section at Site 15200m on 16-Jul-2020 14:10:00


343.50
343.00
342.50
342.00
341.50
341.00
340.50
340.00
339.50
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
RL Section at Site 15500m on 9-Apr-2013 12:00:00
RL Section at Site 15500m on 17-Jun-2020 12:50:00


362.7
361.7
360.7
359.7
358.7
357.7
356.7
355.7
354.7
353.7
11.3
16.3
21.3
26.3
31.3
36.3
41.3
46.3
51.3
56.3
61.3
66.3
71.3
RL Section at Site 15900m on 9-Apr-2013 12:00:00
RL Section at Site 15900m on 16-Jul-2020 11:40:00

Appendix E1: Otamarahu cross section locations




19750
19650
19600
19500
19370
19260
19190
19100
18990
18920
18730
Otamarahu Stream
0
75
150 m

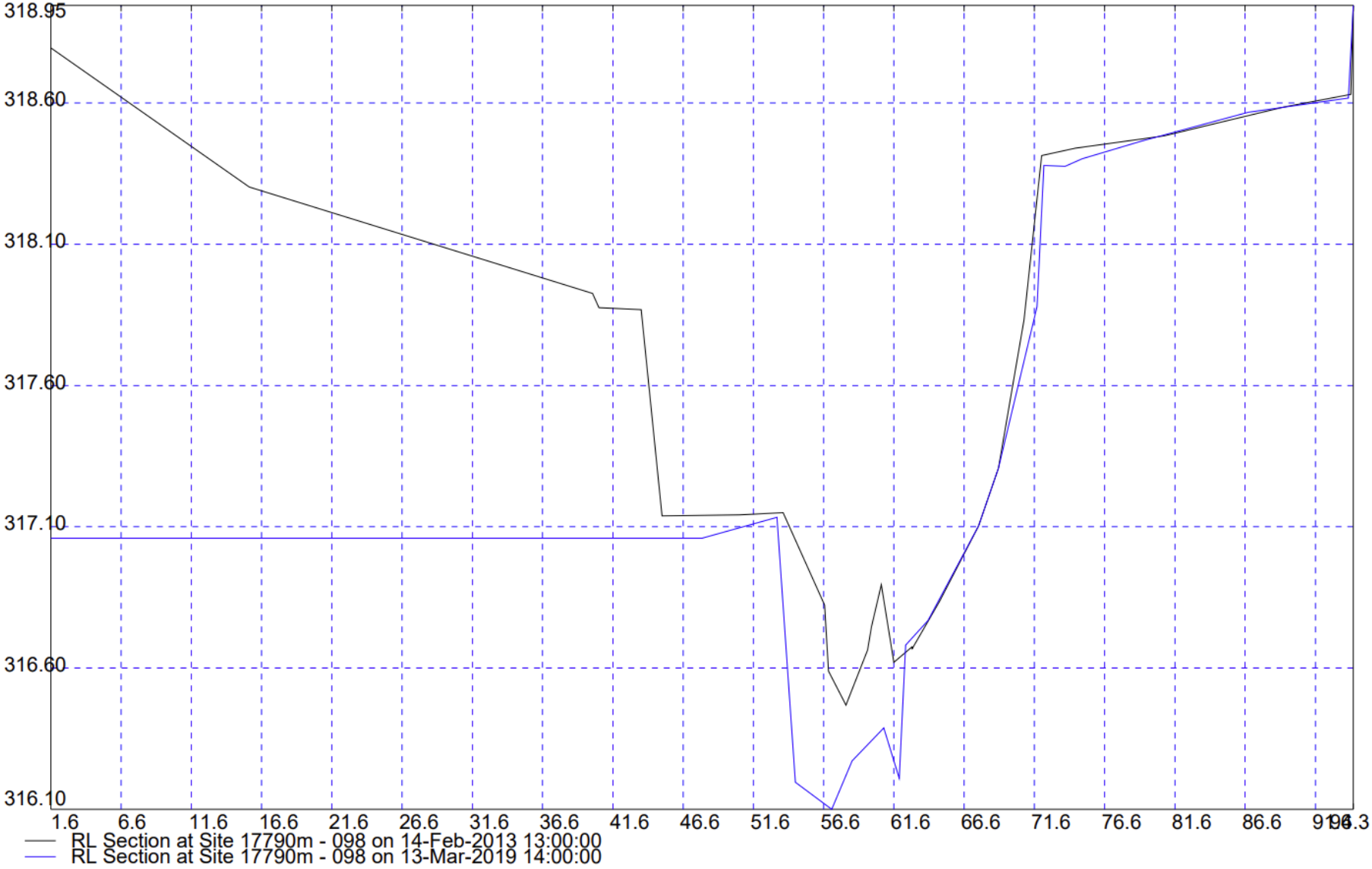
Appendix E2: Otamarahu Mean Bed Level Data (2013 – 2019)

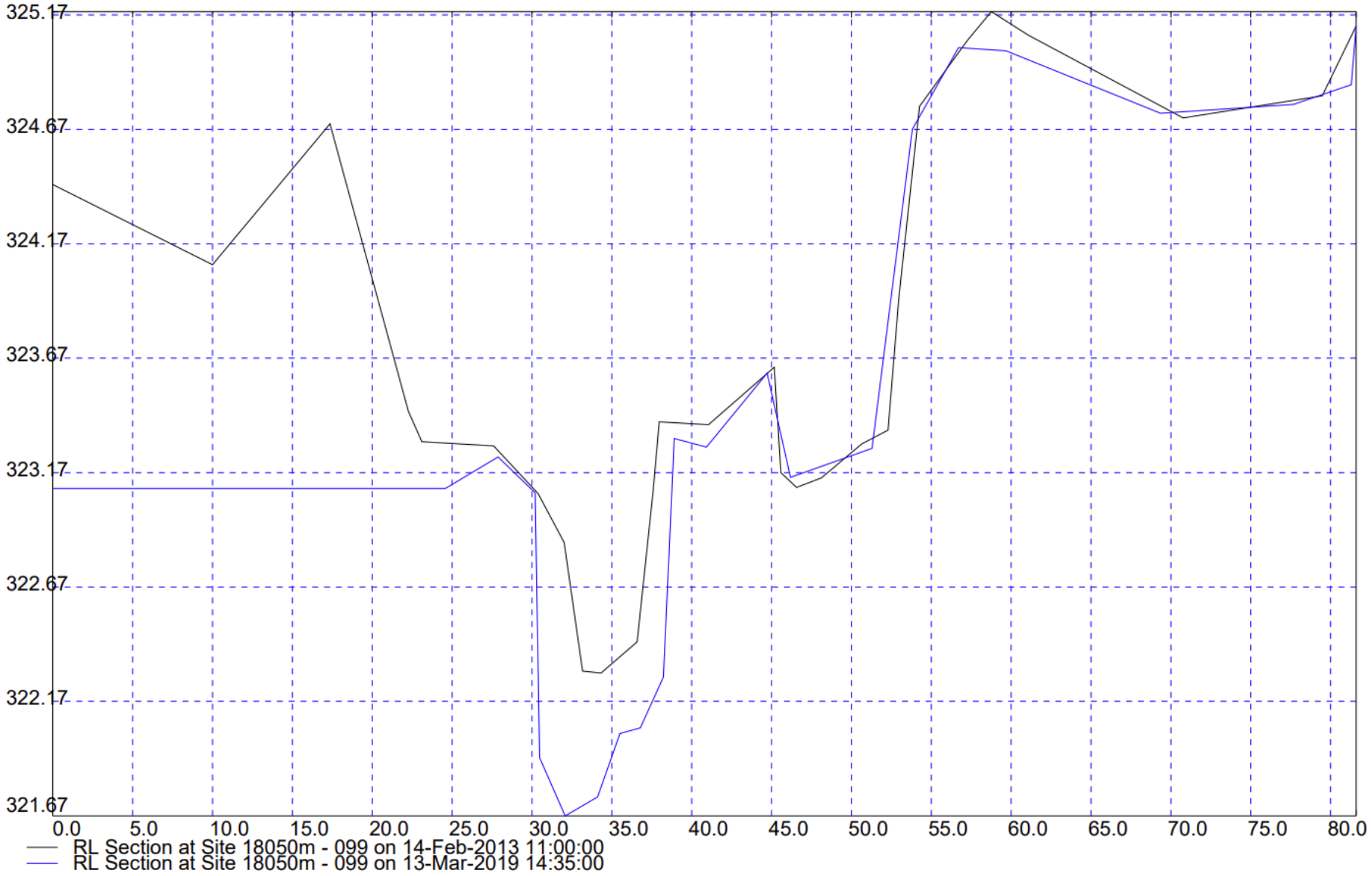
Otamarahu Mean Bed Level Change					
Cross Section	Left Extent	Right Extent	MBL 2013	MBL 2019	MBL change (2019-2013)
17790	53.2	67.2	316.802	316.496	-0.306
18050	27.61	38.9	322.815	322.258	-0.557
18350	26.8	37.5	332.911	332.1	-0.811
18570	17.3	31.1	341.054	341.22	0.166
18690	13.8	33.2	349.901	350.158	0.257
18730	7.9	36.5	351.327	351.307	-0.02
18920	17.7	23.12	356.242	356.345	0.103
18990	51.5	70	359.063	358.373	-0.69
19100	3.1	66	363.424	363.173	-0.251
19190	37.4	64.5	366.881	366.296	-0.585
19260	21.3	29	369.709	369.187	-0.522
19370	7	71.2	373.88	374.082	0.202
19500	9.2	63	378.738	379.029	0.291
19600	9.1	50.6	382.646	383.539	0.893
19680	27.7	52.7	385.733	386.442	0.709
19750	7.3	30.1	388.477	388.496	0.019

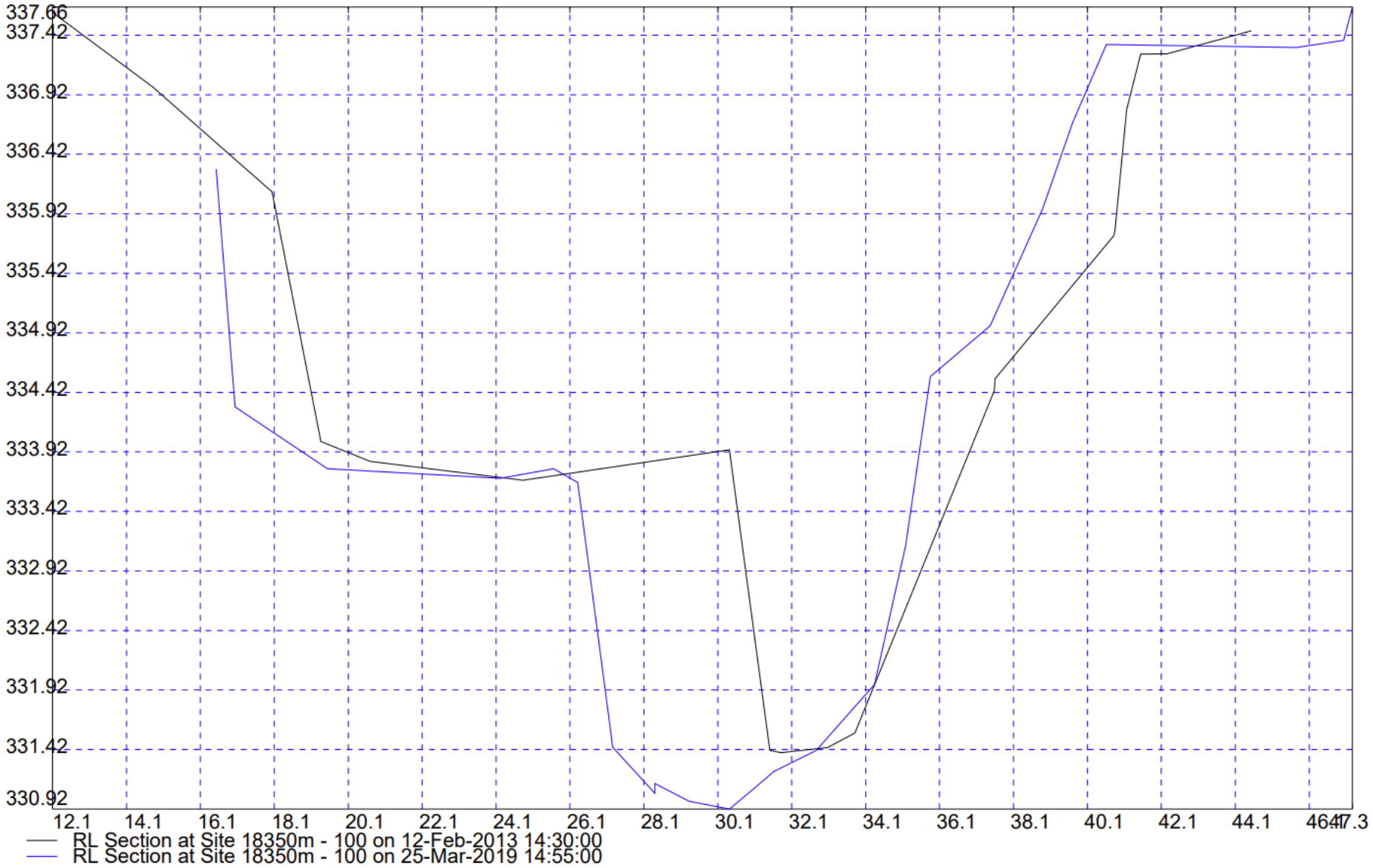
Appendix E3: Otamarahu Change in Gravel Volume (2013 – 2019)

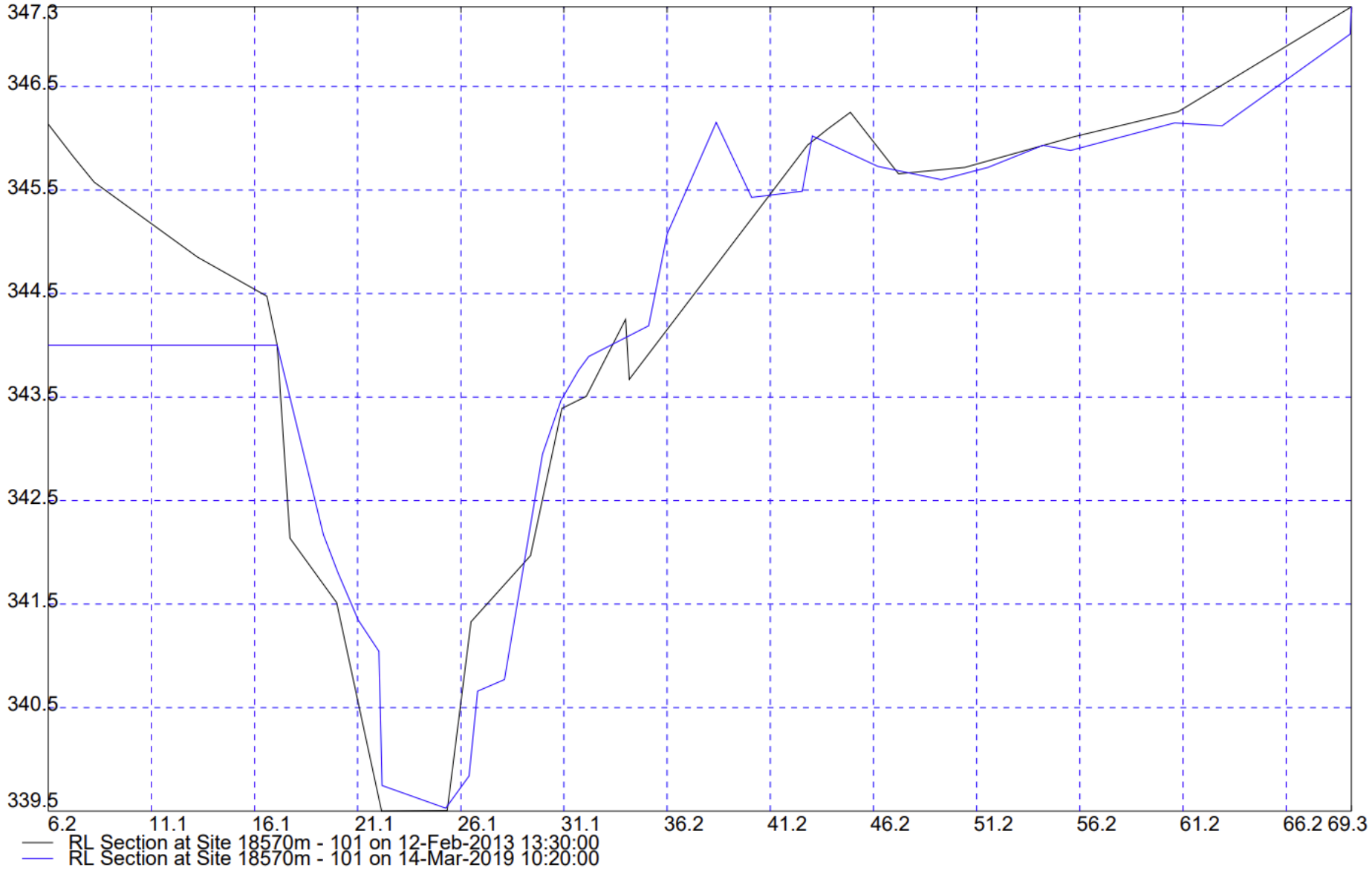
Otamarahu Stream Change in Gravel Volume						
Cross Section	Left Extent	Right Extent	Datum=0	Area under section 2013	Area under section 2019	Change in volume 2013 - 2019 (m^3)
17790	41.6	76.6	0	11105.1	11097.4	-2002
18050	17.3	50	0	10570.7	10558.5	-3416
18350	20.1	40.2	0	6702.9	6696.4	-1690
18570	11.1	41.2	0	10321.2	10324.3	527
18690	12.5	38.5	0	9105.2	9110.7	440
18730	3	42.9	0	14028.5	14026.8	-195.5
18920	12	39.5	0	9816.1	9817.8	221
18990	45	75	0	10779.5	10762.1	-1566
19100	0	70	0	25444.9	25434.9	-1000
19190	7.1	70	0	23085.8	23087.4	128
19260	10	35	0	9244.8	9241.9	-261
19370	9.1	74.1	0	24303.4	24317.1	1644
19500	5	65	0	22725.4	22741.5	1851.5
19600	5	54.6	0	18989.9	19027.3	3366
19680	20	62.7	0	16483.2	16499.5	1222.5
19750	5.3	31.3	0	10102.2	10103.3	77

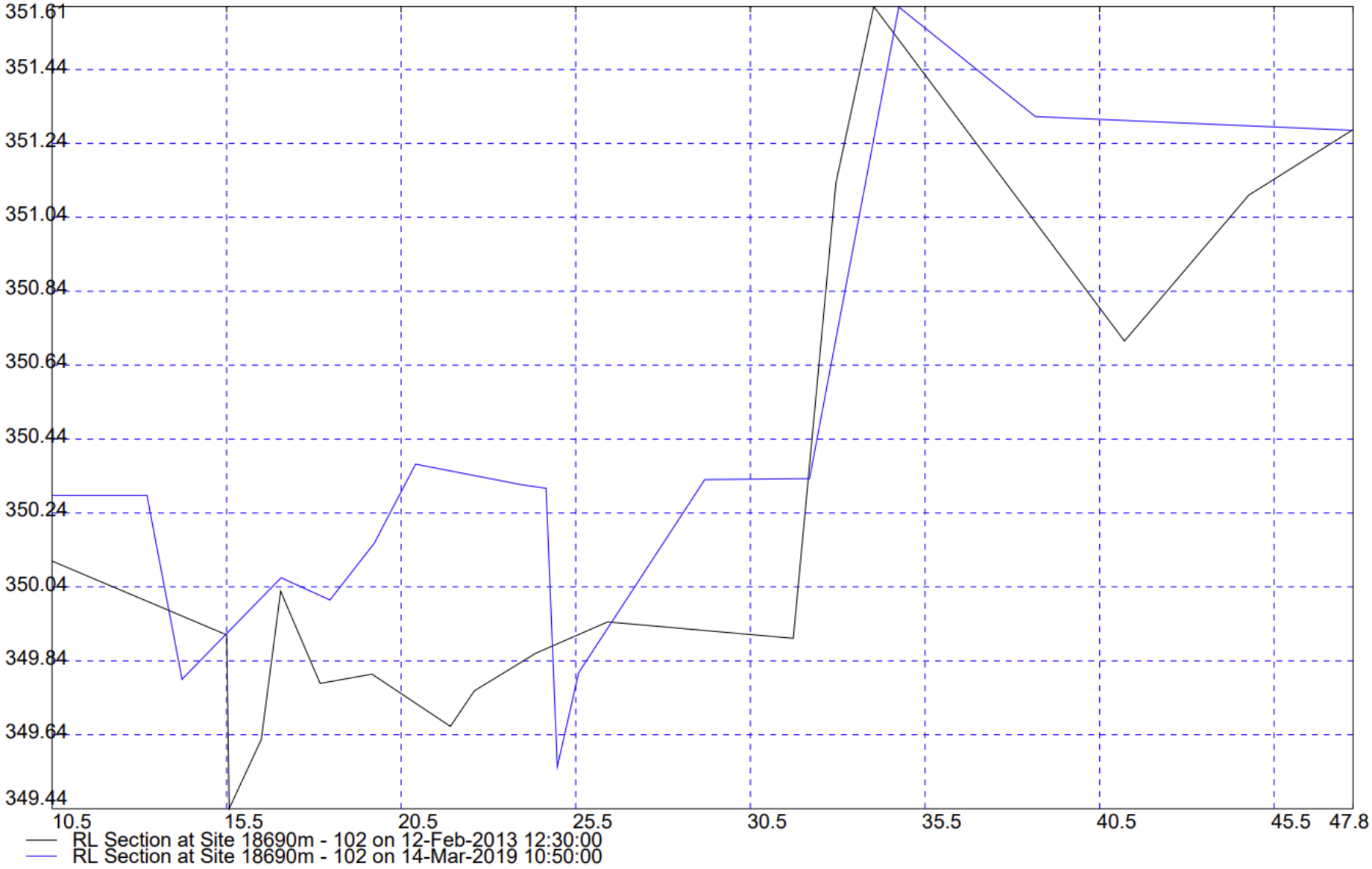
Appendix E4: Cross-sections at Otamarahu Stream

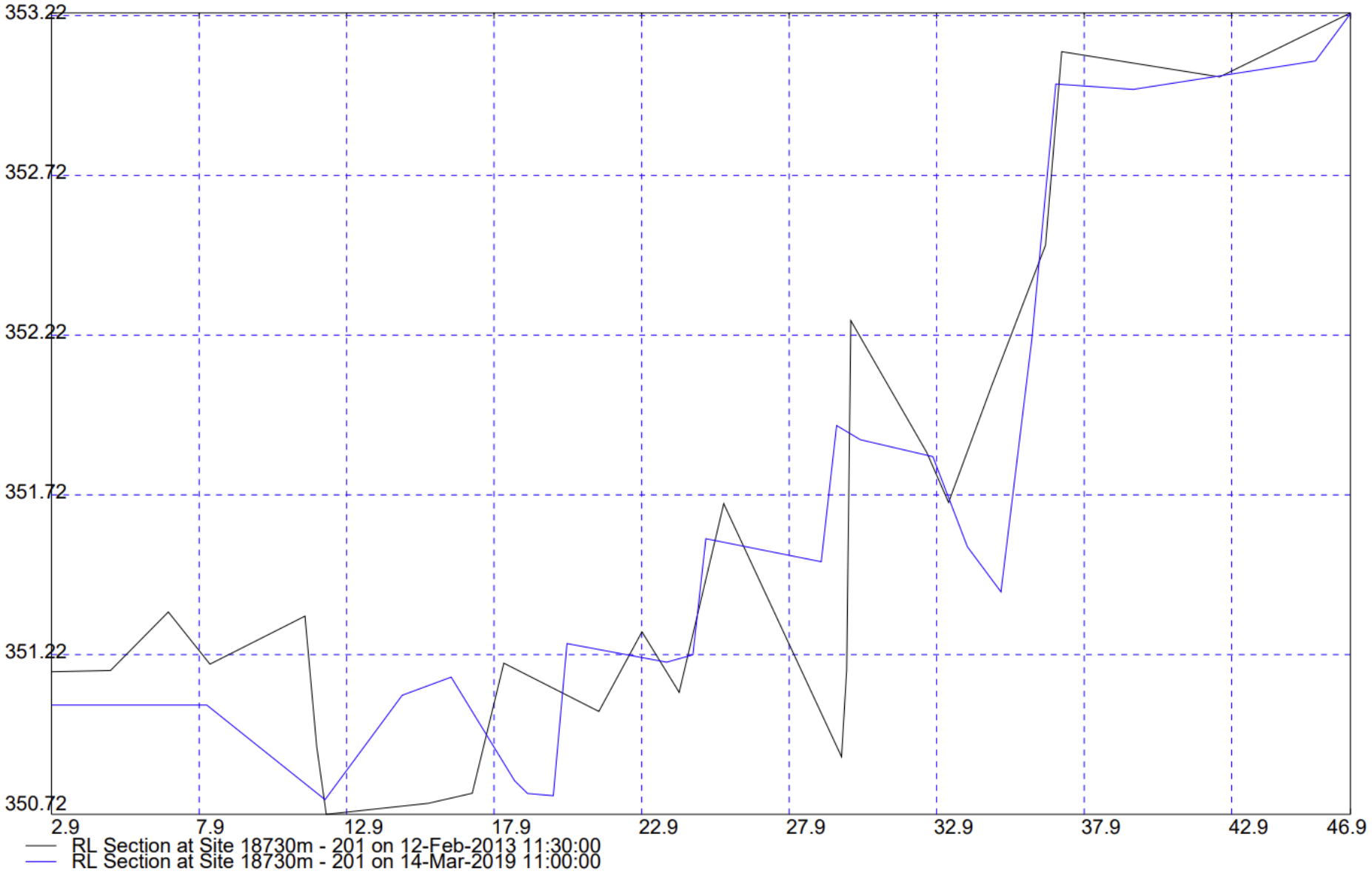


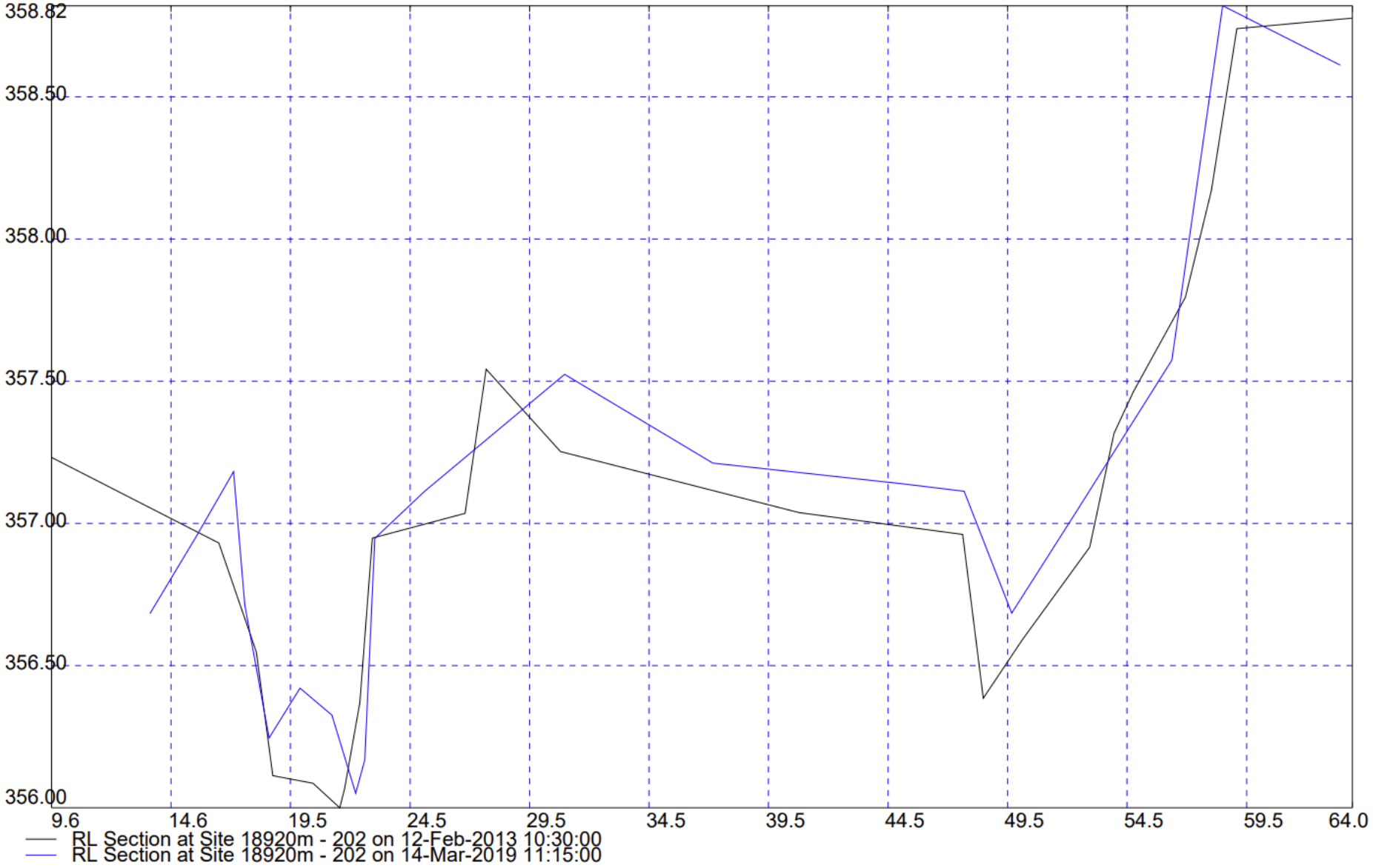

325.17
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324.17
323.67
323.17
322.67
322.17
321.67
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5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
RL Section at Site 18050m - 099 on 14-Feb-2013 11:00:00
RL Section at Site 18050m - 099 on 13-Mar-2019 14:35:00


337.66
337.42
336.92
336.42
335.92
335.42
334.92
334.42
333.92
333.42
332.92
332.42
331.92
331.42
330.92
12.1
14.1
16.1
18.1
20.1
22.1
24.1
26.1
28.1
30.1
32.1
34.1
36.1
38.1
40.1
42.1
44.1
46.1
47.3
RL Section at Site 18350m - 100 on 12-Feb-2013 14:30:00
RL Section at Site 18350m - 100 on 25-Mar-2019 14:55:00

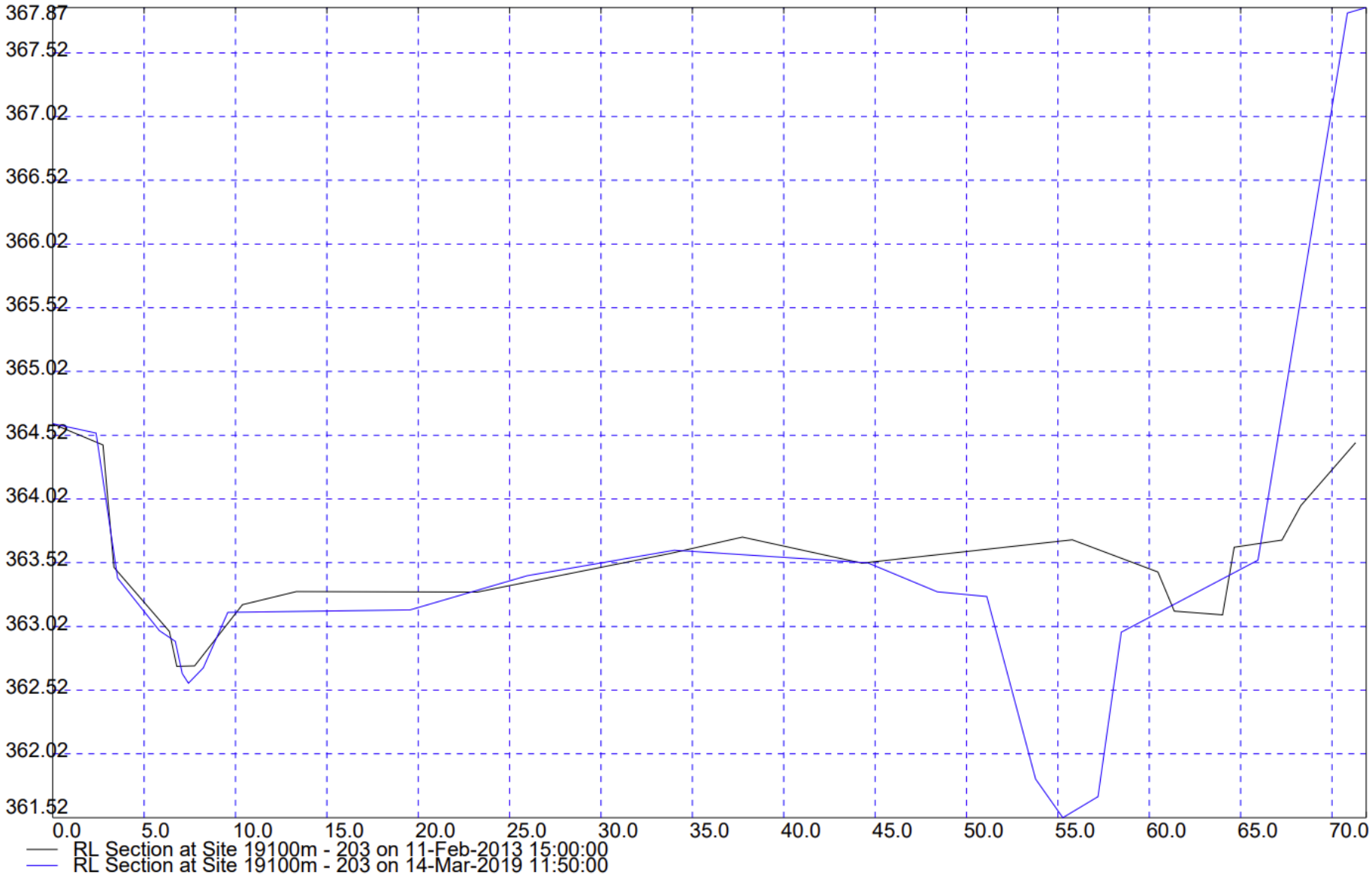

347.3
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345.5
344.5
343.5
342.5
341.5
340.5
339.5
6.2
11.1
16.1
21.1
26.1
31.1
36.2
41.2
46.2
51.2
56.2
61.2
66.2 69.3
RL Section at Site 18570m - 101 on 12-Feb-2013 13:30:00
RL Section at Site 18570m - 101 on 14-Mar-2019 10:20:00


351.61
351.44
351.24
351.04
350.84
350.64
350.44
350.24
350.04
349.84
349.64
349.44
10.5
15.5
20.5
25.5
30.5
35.5
40.5
45.5
47.8
RL Section at Site 18690m - 102 on 12-Feb-2013 12:30:00
RL Section at Site 18690m - 102 on 14-Mar-2019 10:50:00


353.22
352.72
352.22
351.72
351.22
350.72
2.9
7.9
12.9
17.9
22.9
27.9
32.9
37.9
42.9
46.9
RL Section at Site 18730m - 201 on 12-Feb-2013 11:30:00
RL Section at Site 18730m - 201 on 14-Mar-2019 11:00:00

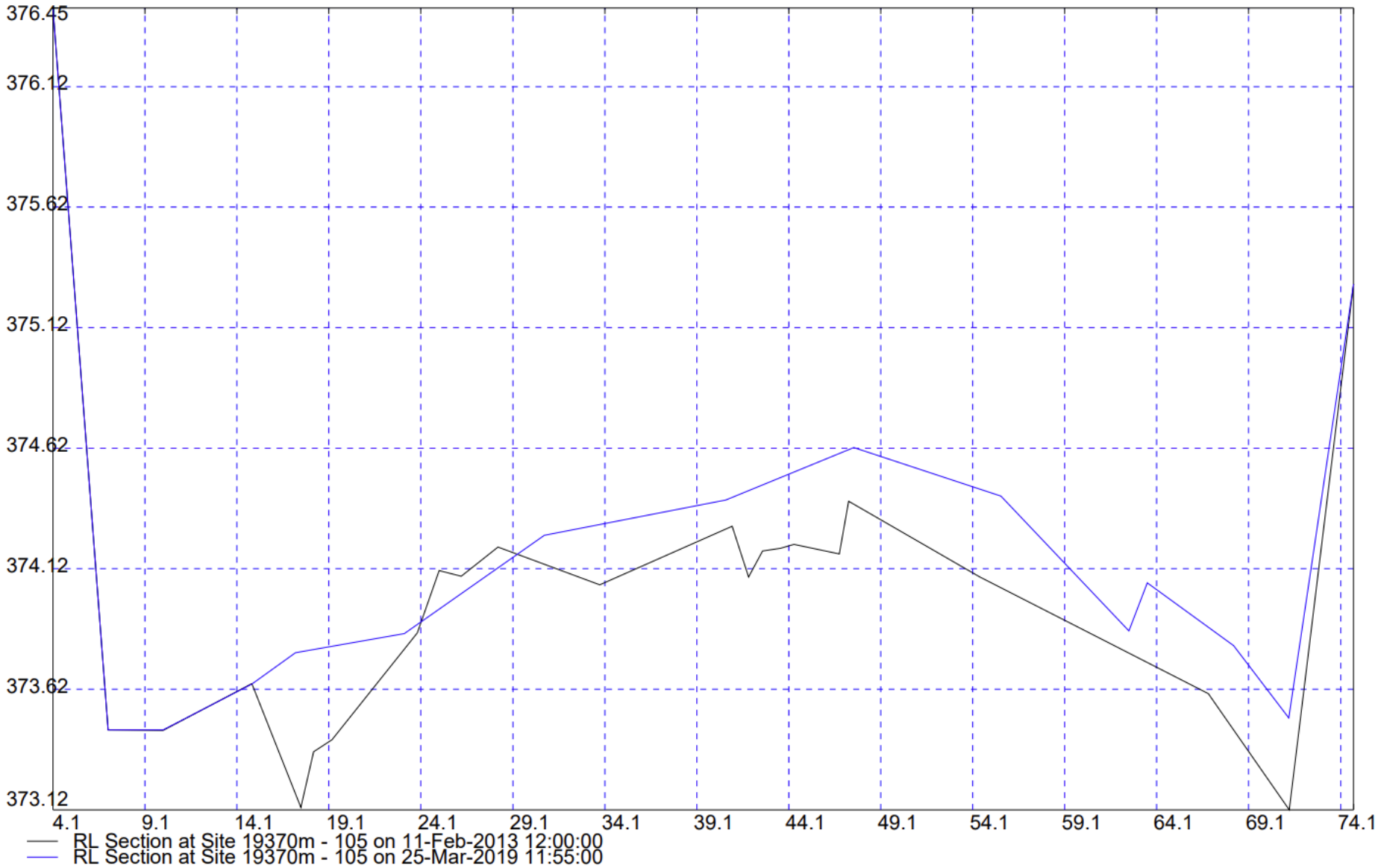

358.82
358.50
358.00
357.50
357.00
356.50
356.00
9.6
14.6
19.5
24.5
29.5
34.5
39.5
44.5
49.5
54.5
59.5
64.0
RL Section at Site 18920m - 202 on 12-Feb-2013 10:30:00
RL Section at Site 18920m - 202 on 14-Mar-2019 11:15:00

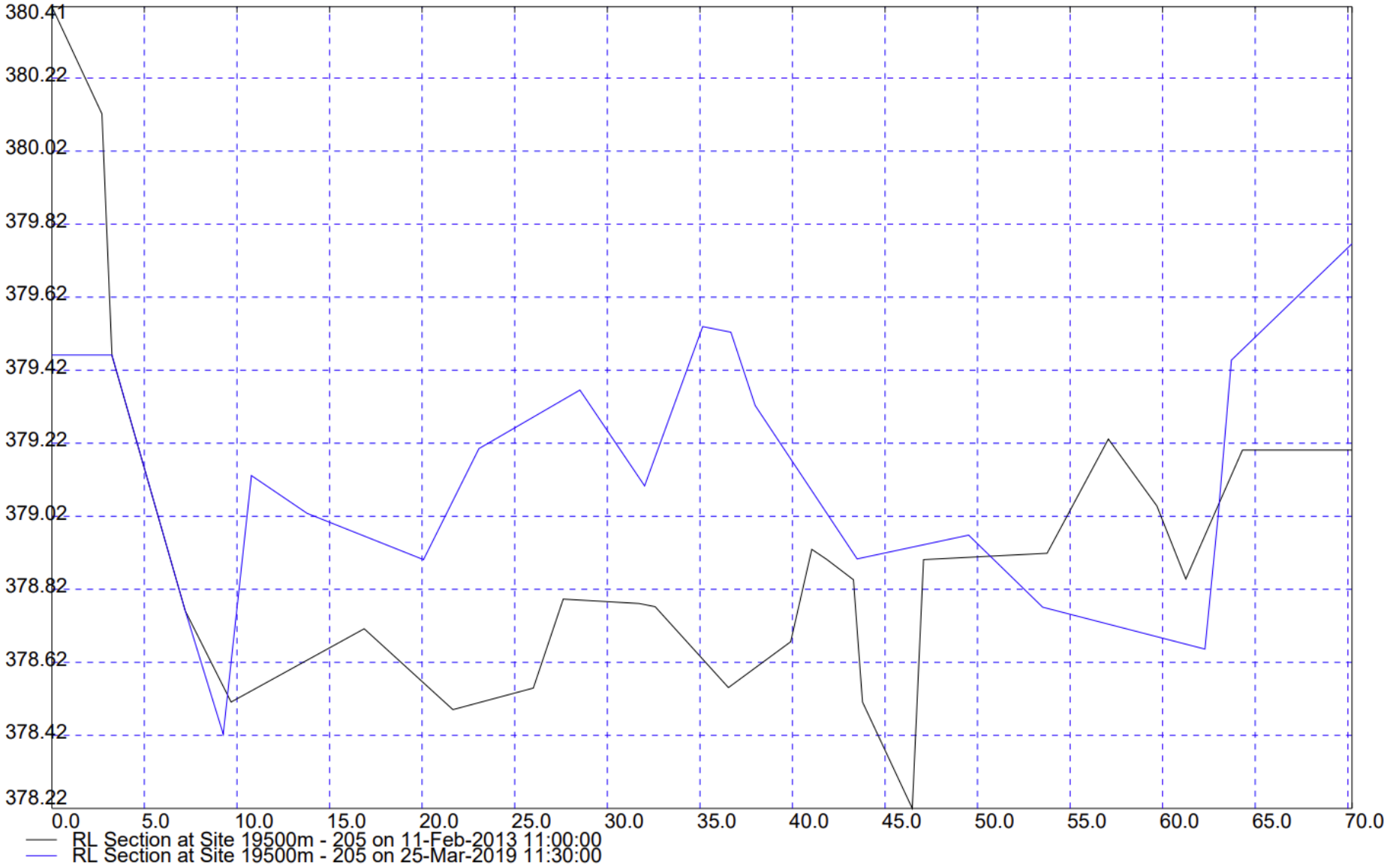

362.79
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362.00
361.50
361.00
360.50
360.00
359.50
359.00
358.50
358.00
357.50
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
89.0
RL Section at Site 18990m - 103 on 12-Feb-2013 09:30:00
RL Section at Site 18990m - 103 on 14-Mar-2019 11:30:00


367.87
367.52
367.02
366.52
366.02
365.52
365.02
364.52
364.02
363.52
363.02
362.52
362.02
361.52
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
RL Section at Site 19100m - 203 on 11-Feb-2013 15:00:00
RL Section at Site 19100m - 203 on 14-Mar-2019 11:50:00

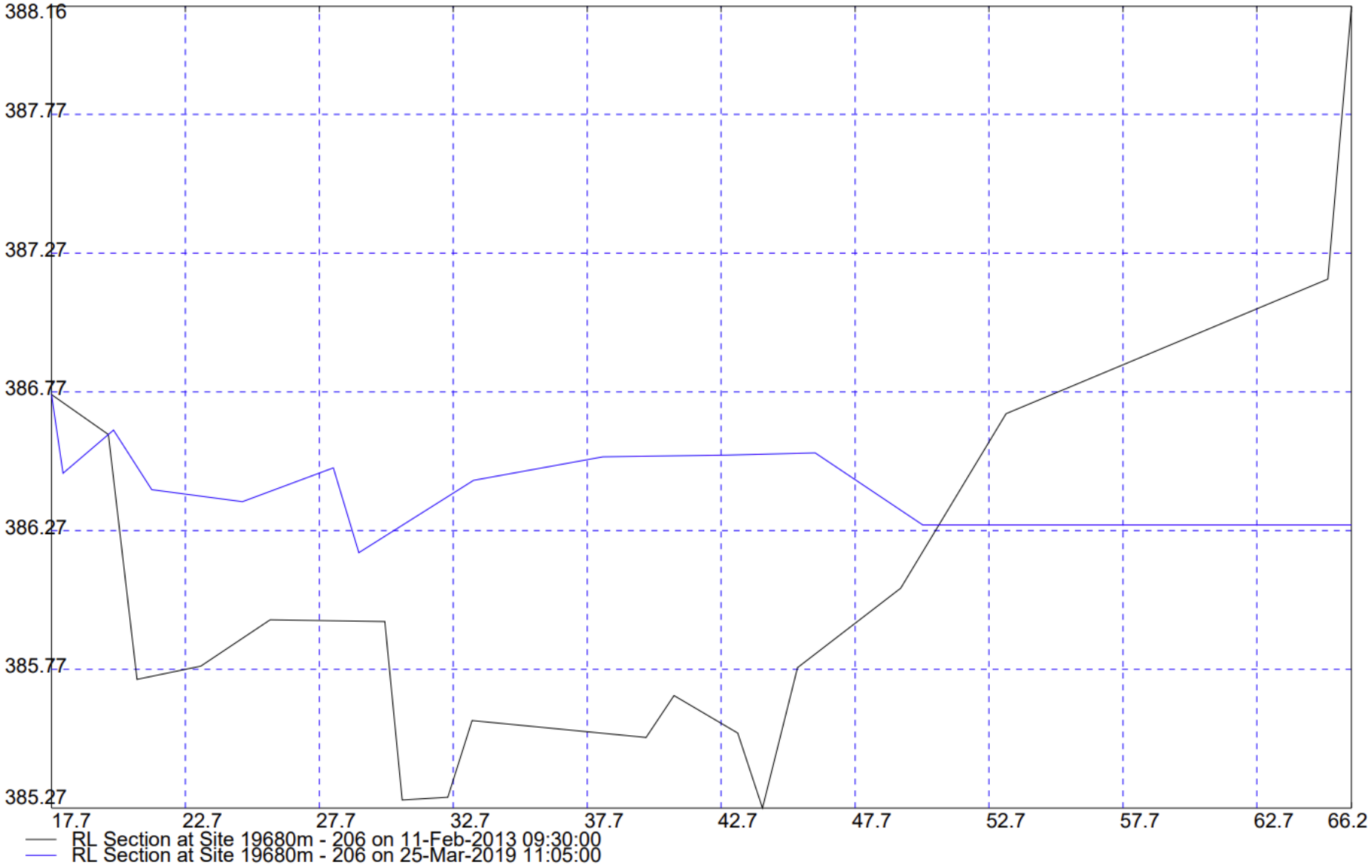

368.50
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367.82
367.32
366.82
366.32
365.82
365.32
-2.9
2.1
7.1
12.1
17.1
22.1
27.1
32.1
37.1
42.1
47.1
52.1
57.1
62.1
67.1
71.2
RL Section at Site 19190m - 104 on 11-Feb-2013 14:00:00
RL Section at Site 19190m - 104 on 25-Mar-2019 13:30:00

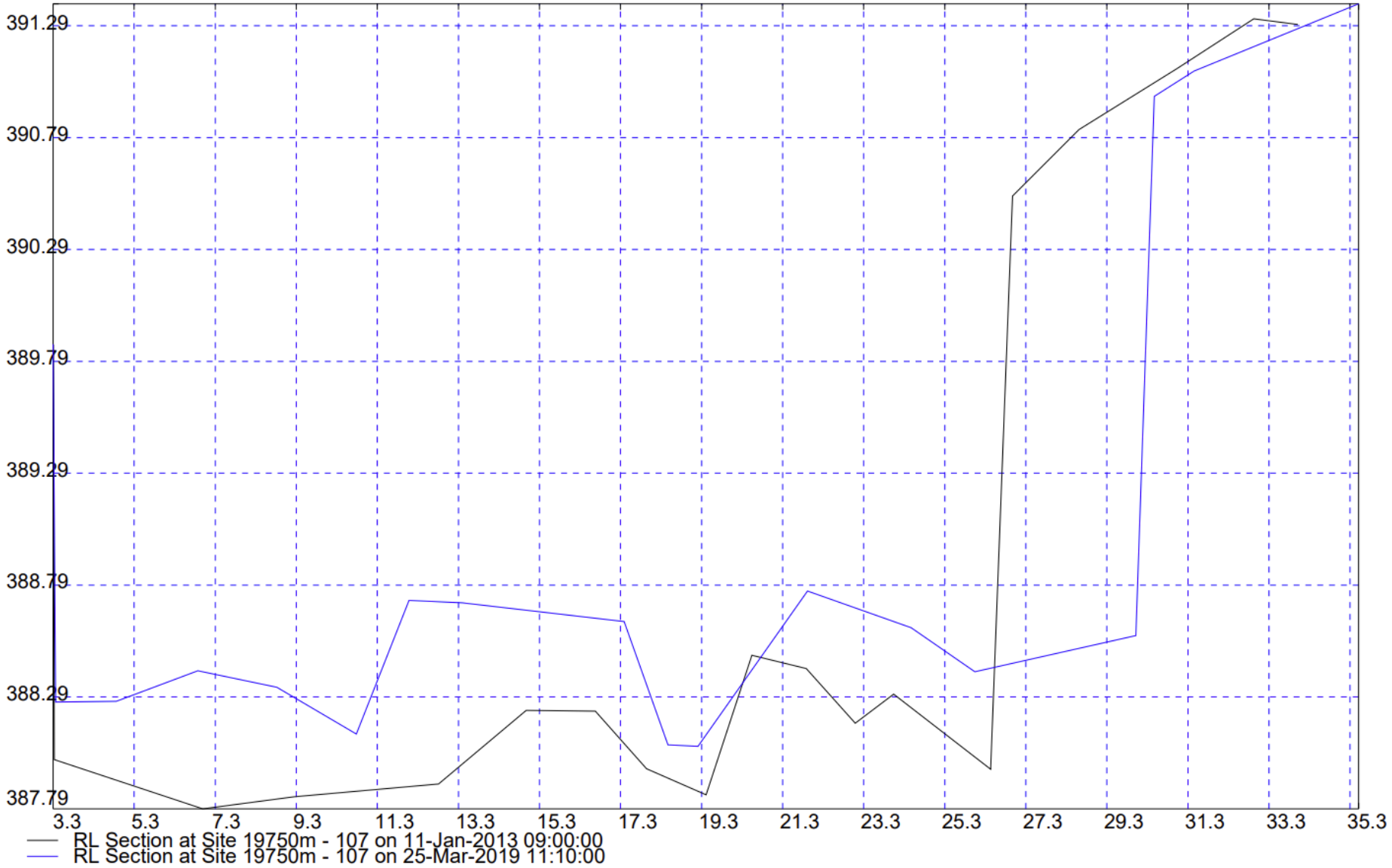

370.31
370.22
370.02
369.82
369.62
369.42
369.22
369.02
368.82
368.62
368.42
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
64.7
RL Section at Site 19260m - 204 on 11-Feb-2013 13:00:00
RL Section at Site 19260m - 204 on 25-Mar-2019 12:50:00


376.45
376.12
375.62
375.12
374.62
374.12
373.62
373.12
4.1
9.1
14.1
19.1
24.1
29.1
34.1
39.1
44.1
49.1
54.1
59.1
64.1
69.1
74.1
RL Section at Site 19370m - 105 on 11-Feb-2013 12:00:00
RL Section at Site 19370m - 105 on 25-Mar-2019 11:55:00

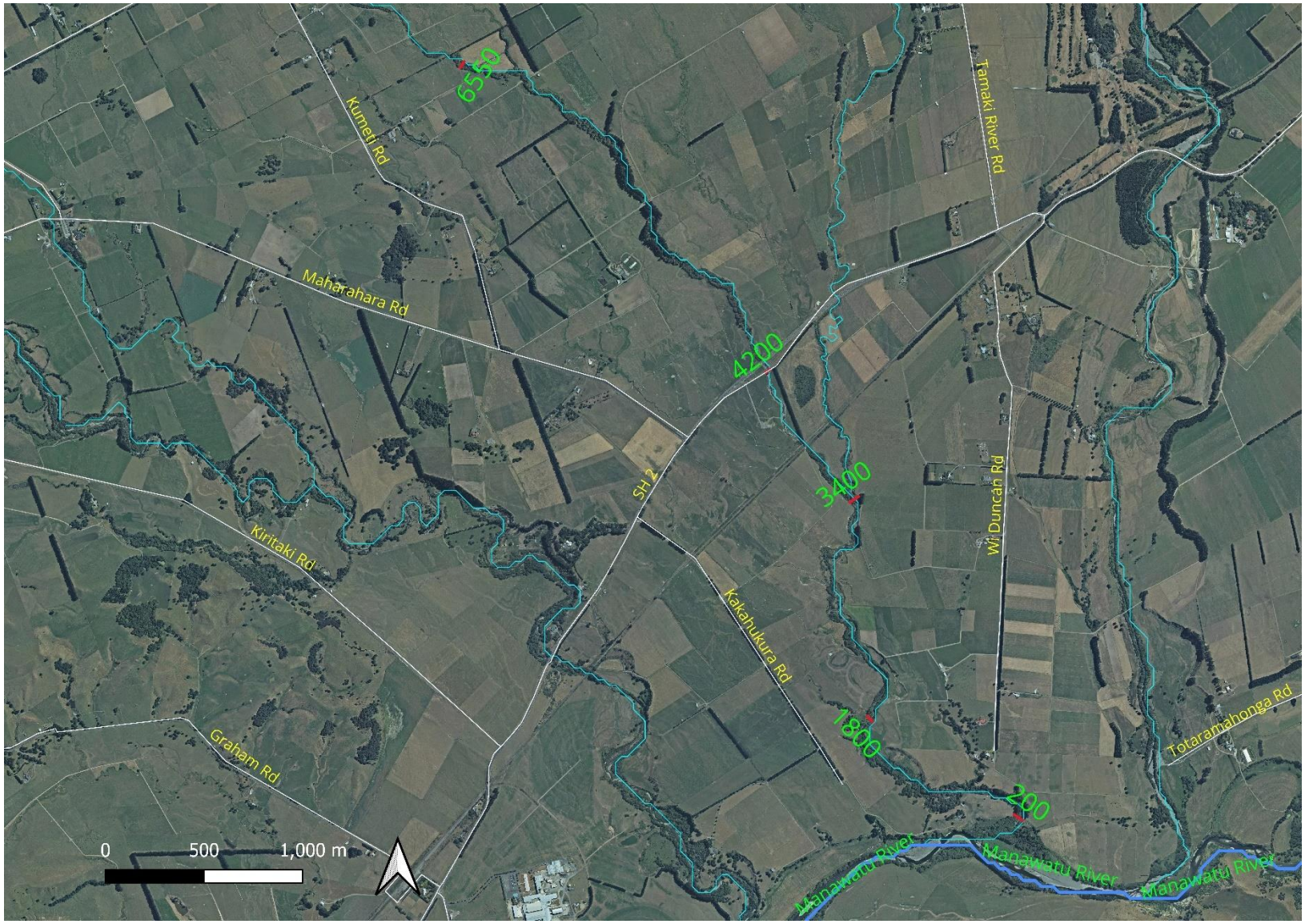

380.41
380.22
380.02
379.82
379.62
379.42
379.22
379.02
378.82
378.62
378.42
378.22
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
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RL Section at Site 19500m - 205 on 11-Feb-2013 11:00:00
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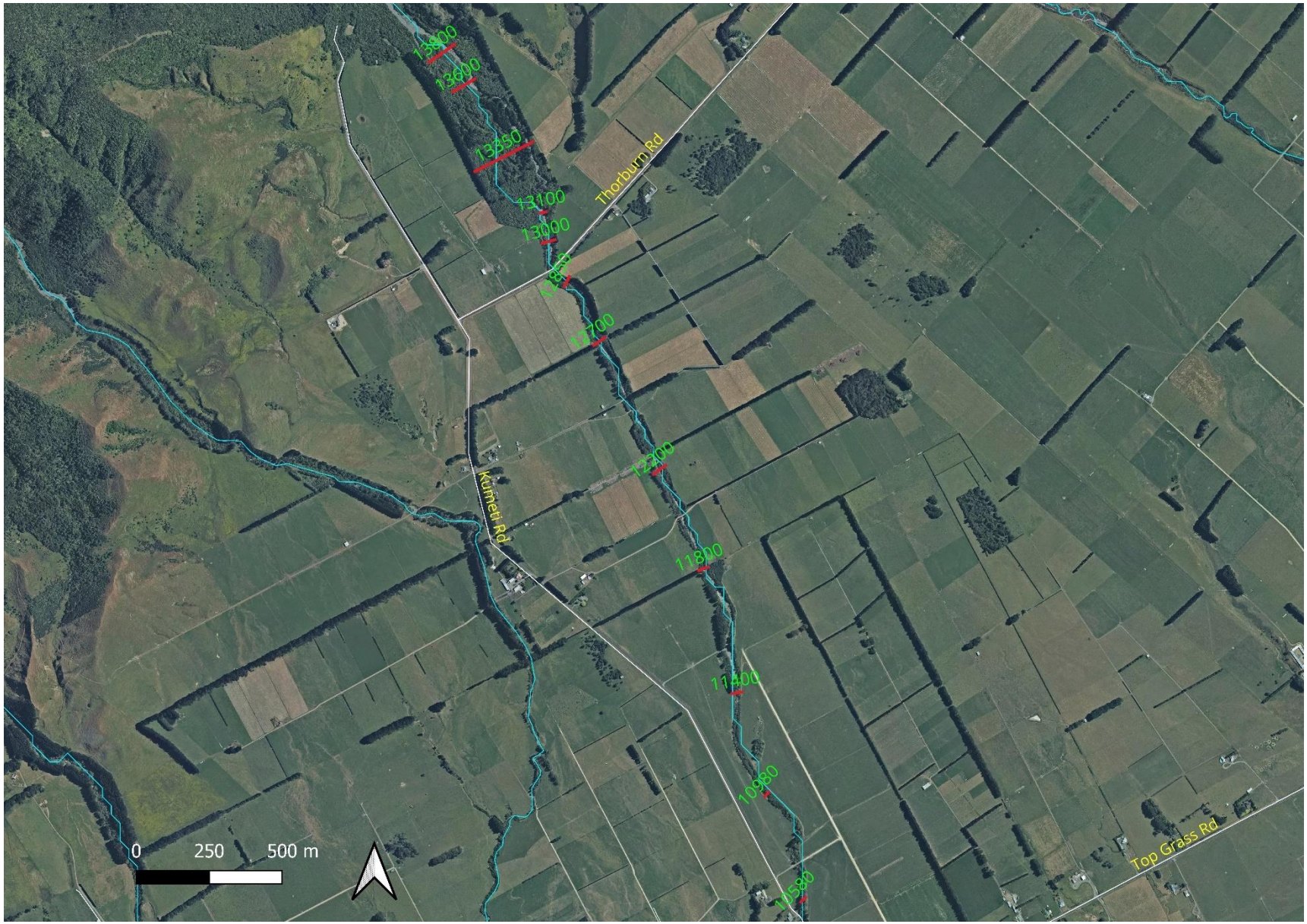

384.19
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382.28
381.78
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5.0
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15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
54.6
RL Section at Site 19600m - 106 on 11-Feb-2013 10:00:00
RL Section at Site 19600m - 106 on 25-Mar-2019 10:55:00


388.16
387.77
387.27
386.77
386.27
385.77
385.27
17.7
22.7
27.7
32.7
37.7
42.7
47.7
52.7
57.7
62.7
66.2
RL Section at Site 19680m - 206 on 11-Feb-2013 09:30:00
RL Section at Site 19680m - 206 on 25-Mar-2019 11:05:00


391.29
390.79
390.29
389.79
389.29
388.79
388.29
387.79
3.3
5.3
7.3
9.3
11.3
13.3
15.3
17.3
19.3
21.3
23.3
25.3
27.3
29.3
31.3
33.3
35.3
RL Section at Site 19750m - 107 on 11-Jan-2013 09:00:00
RL Section at Site 19750m - 107 on 25-Mar-2019 11:10:00

Appendix F1: Kumeti cross section locations




13800
13600
13350
13100
13000
12850
12700
12300
11800
11400
10980
10580
Thorburn Rd
Kumeti Rd
Top Grass Rd
0
250
500 m

Appendix F2: Kumeti Mean Bed Level Data (2013 – 2019/2020)

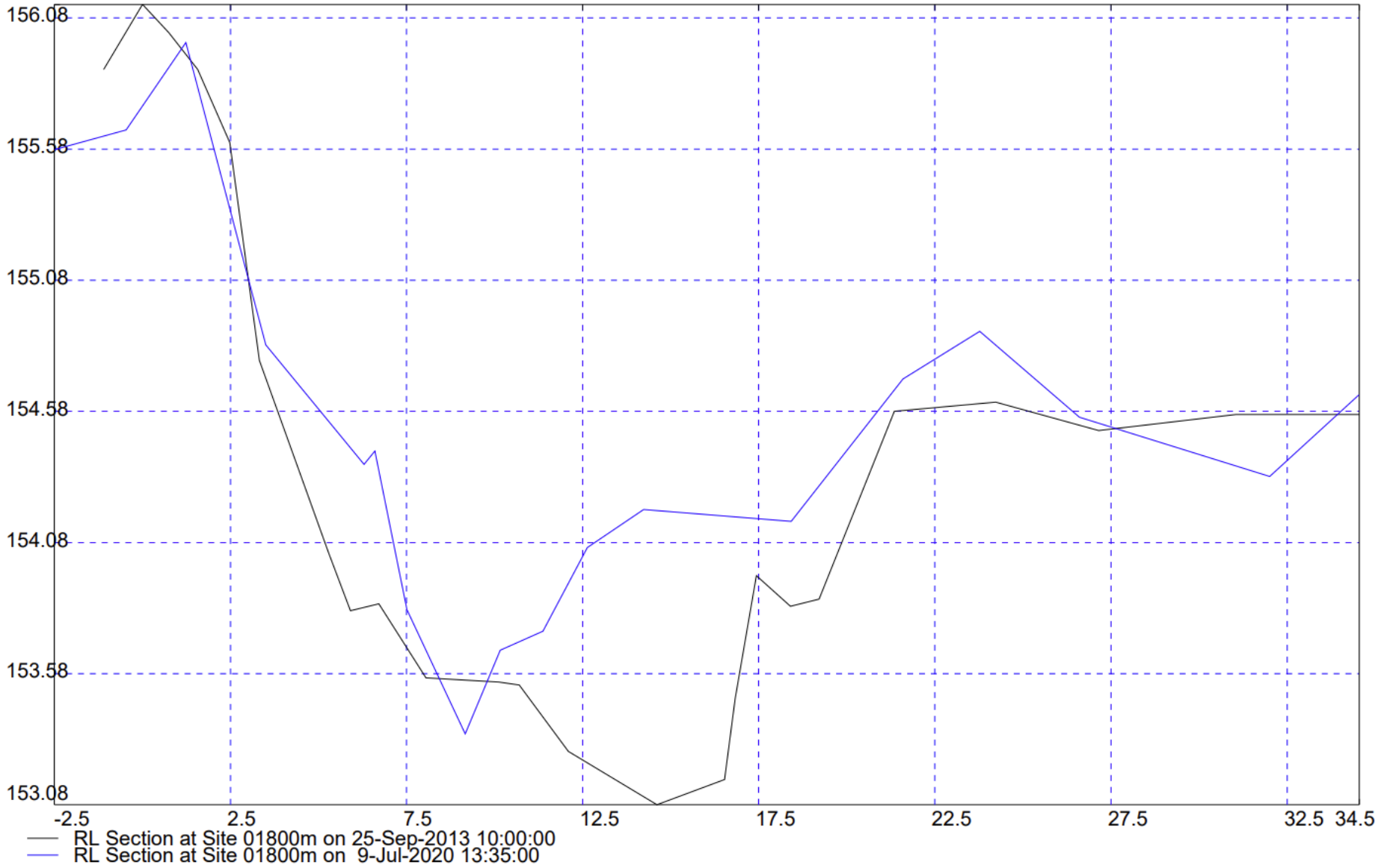
Kumeti Mean Bed Level Change					
Cross section	Left Extent	Right Extent	MBL 2013	MBL 2019/2020	MBL change (2019/2020 - 2013)
200	7	23.1	138.959	138.822	-0.137
1800	6.67	18.4	153.435	153.949	0.514
3400	31.72	44.6	168.865	168.419	-0.446
4200	4	18	179.221	178.85	-0.371
6550	21	29	211.077	211.208	0.131
10580	0.6	8.6	276.27	277.267	0.997
10980	7	16	285.111	284.98	-0.131
11400	9.24	21.21	294.394	294.237	-0.157
11800	11	26	303.111	303.309	0.198
12200	10.7	37.9	314.676	314.053	-0.623
12700	8.5	33	325.201	324.271	-0.93
12850	10.1	27.6	330.394	329.349	-1.045
13000	6.5	23.2	339.842	339.634	-0.208
13100	4	19	343.553	343.19	-0.363
13350	16.2	32	351.098	350.543	-0.555
13600	61.7	131.7	360.13	360.505	0.375
13800	67.4	87.4	364.082	364.212	0.13

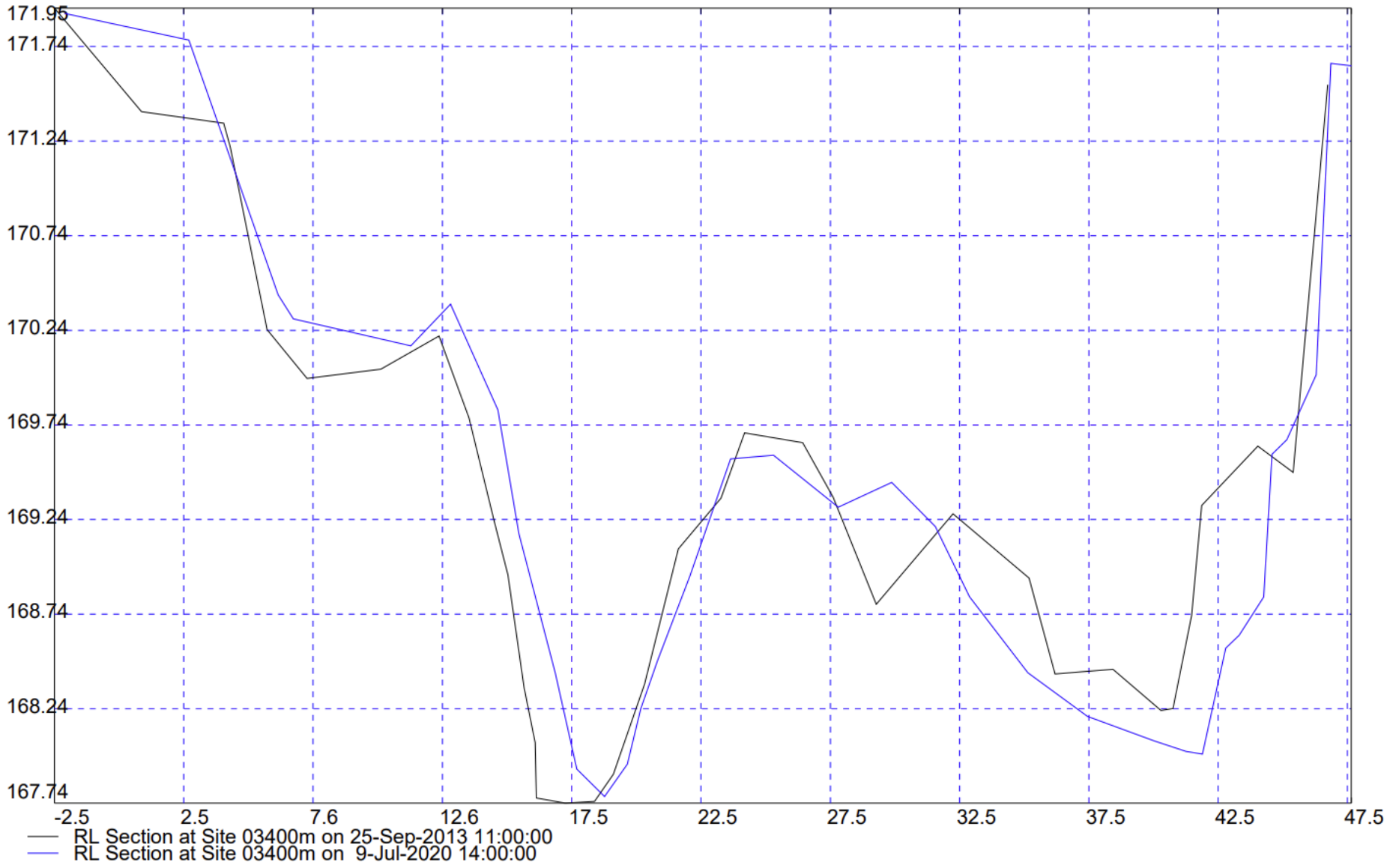
Appendix F3: Kumeti Change in Gravel Volume (2013 – 2019/2020)

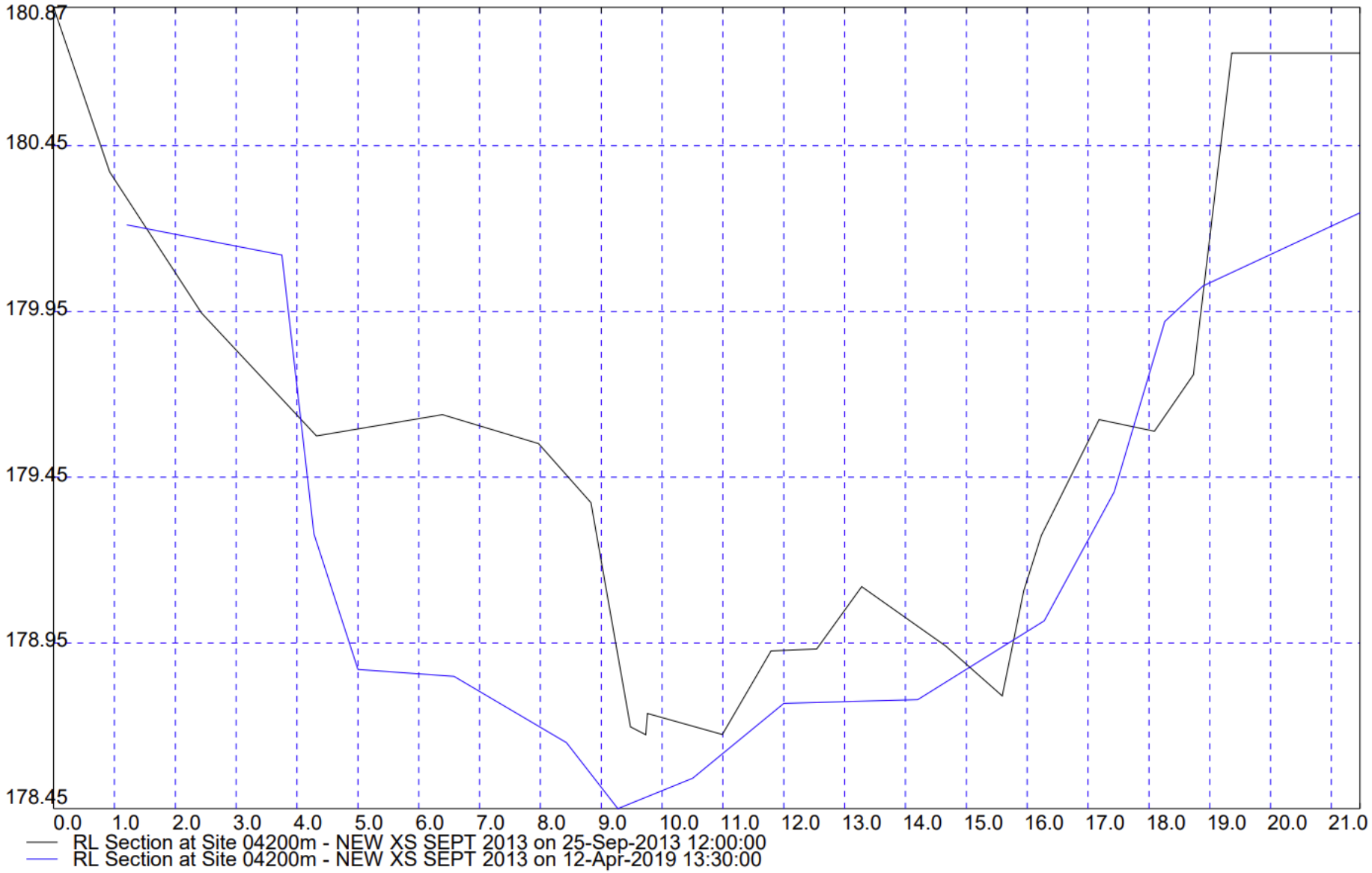
Kumeti Stream Change in Gravel Volume						
Cross Section	Left Extent	Right Extent	Datum=0	Area under section 2013	Area under section 2019/2020	Change in volume (2019/2020-2013)
200	0	40	0	5617.5	5616.8	-560
1800	-0.9	22.5	0	3606.2	3613.9	6275.5
3400	22.5	46.7	0	4093.3	4088	-4160.5
4200	2	21	0	3409.9	3404.3	-4480
6550	11	33	0	4658.5	4657.7	-640
10580	-3.4	13.6	0	4712.4	4721.1	3436.5
10980	2	19	0	4862.5	4860.2	-920
11400	2	28	0	7667.4	7664.8	-1066
11800	8.4	32.4	0	7295.9	7291.9	-1600
12200	0.7	44	0	13643	13609.7	-14985
12700	-1.5	38.1	0	12913.5	12872.8	-13227.5
12850	0.1	34	0	11253.7	11205.6	-6012.5
13000	-1.8	28.2	0	10216.3	10210.8	-412.5
13100	0	24	0	8249.4	8240.6	-1540
13350	8.6	168	0	56042.8	56067	6050
13600	57.6	141.7	0	30296.8	30321.1	5467.5
13800	53	107.4	0	19837.7	19841.3	720

Appendix F4: Cross-sections at Kumeti Stream



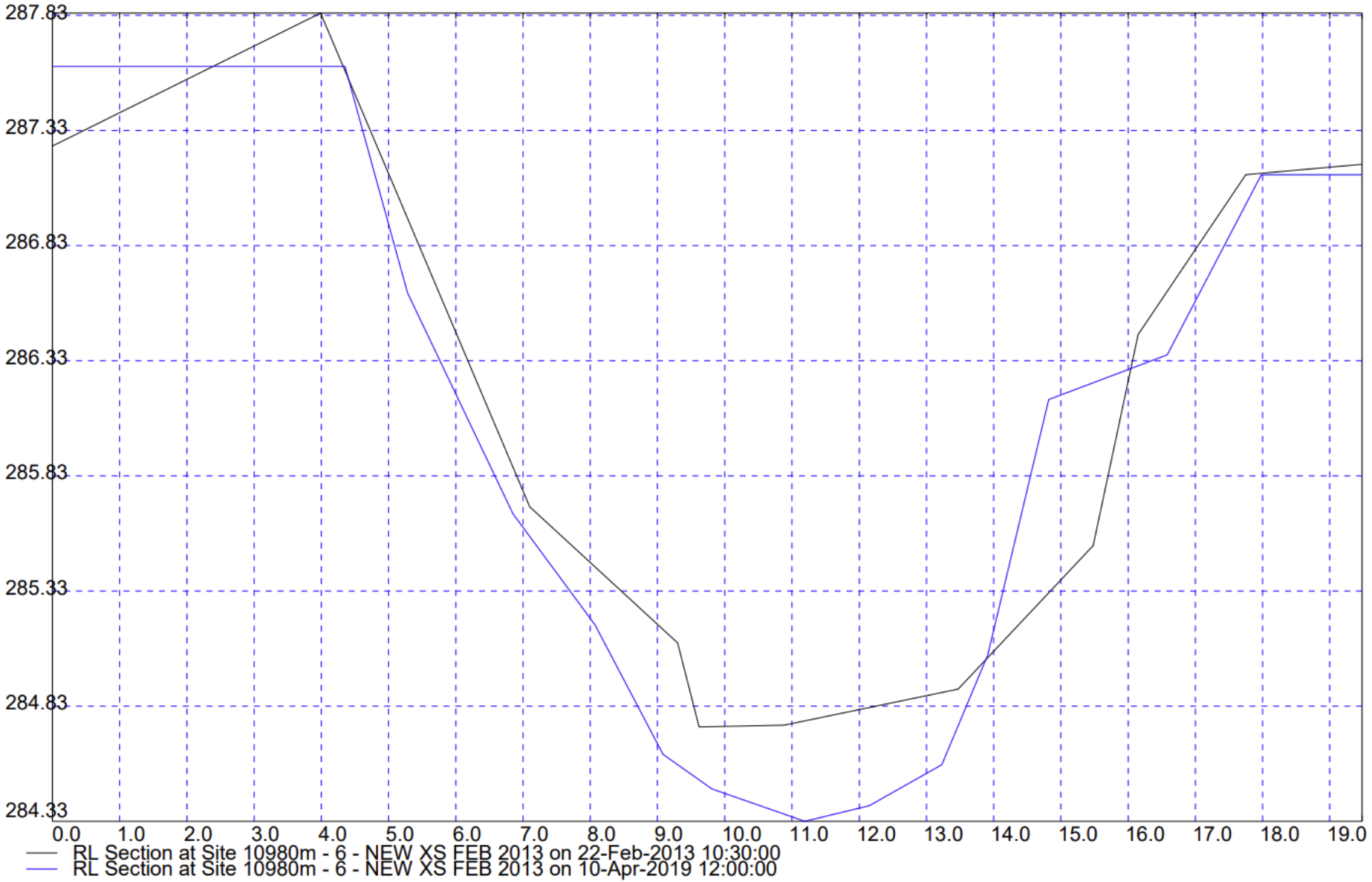

156.08
155.58
155.08
154.58
154.08
153.58
153.08
-2.5
2.5
7.5
12.5
17.5
22.5
27.5
32.5
34.5
RL Section at Site 01800m on 25-Sep-2013 10:00:00
RL Section at Site 01800m on 9-Jul-2020 13:35:00


171.95
171.74
171.24
170.74
170.24
169.74
169.24
168.74
168.24
167.74
-2.5
2.5
7.6
12.6
17.5
22.5
27.5
32.5
37.5
42.5
47.5
RL Section at Site 03400m on 25-Sep-2013 11:00:00
RL Section at Site 03400m on 9-Jul-2020 14:00:00


180.87
180.45
179.95
179.45
178.95
178.45
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0
RL Section at Site 04200m - NEW XS SEPT 2013 on 25-Sep-2013 12:00:00
RL Section at Site 04200m - NEW XS SEPT 2013 on 12-Apr-2019 13:30:00


213.59
213.14
212.64
212.14
211.64
211.14
210.64
1.0
3.0
5.0
7.0
9.0
11.0
13.0
15.0
17.0
19.0
21.0
23.0
25.0
27.0
29.0
31.0
33.0
34.7
RL Section at Site 06550m on 25-Sep-2013 12:30:00
RL Section at Site 06550m on 14-Jul-2020 13:10:00

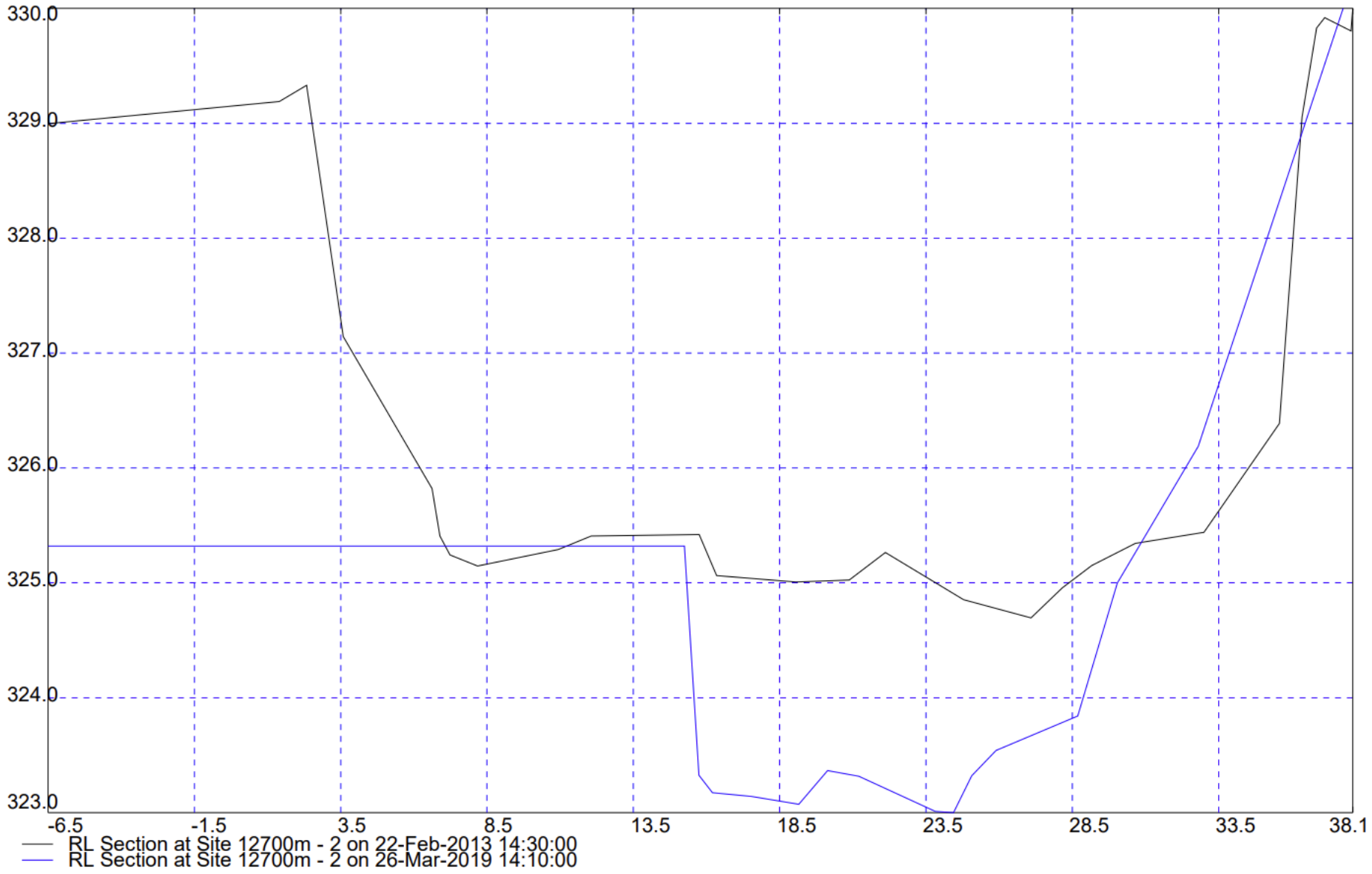

278.66
278.37
277.87
277.37
276.87
276.37
275.87
-5.4 -4.4 -3.4 -2.4 -1.4 -0.4 0.6 1.6 2.6 3.6 4.6 5.6 6.6 7.6 8.6 9.6 10.6 11.6 12.6 13.6 14.6 15.6 16.6
RL Section at Site 10580m - 7 on 27-Feb-2013 11:00:00
RL Section at Site 10580m - 7 on 26-Mar-2019 14:50:00


287.83
287.33
286.83
286.33
285.83
285.33
284.83
284.33
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
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RL Section at Site 10980m - 6 - NEW XS FEB 2013 on 10-Apr-2019 12:00:00

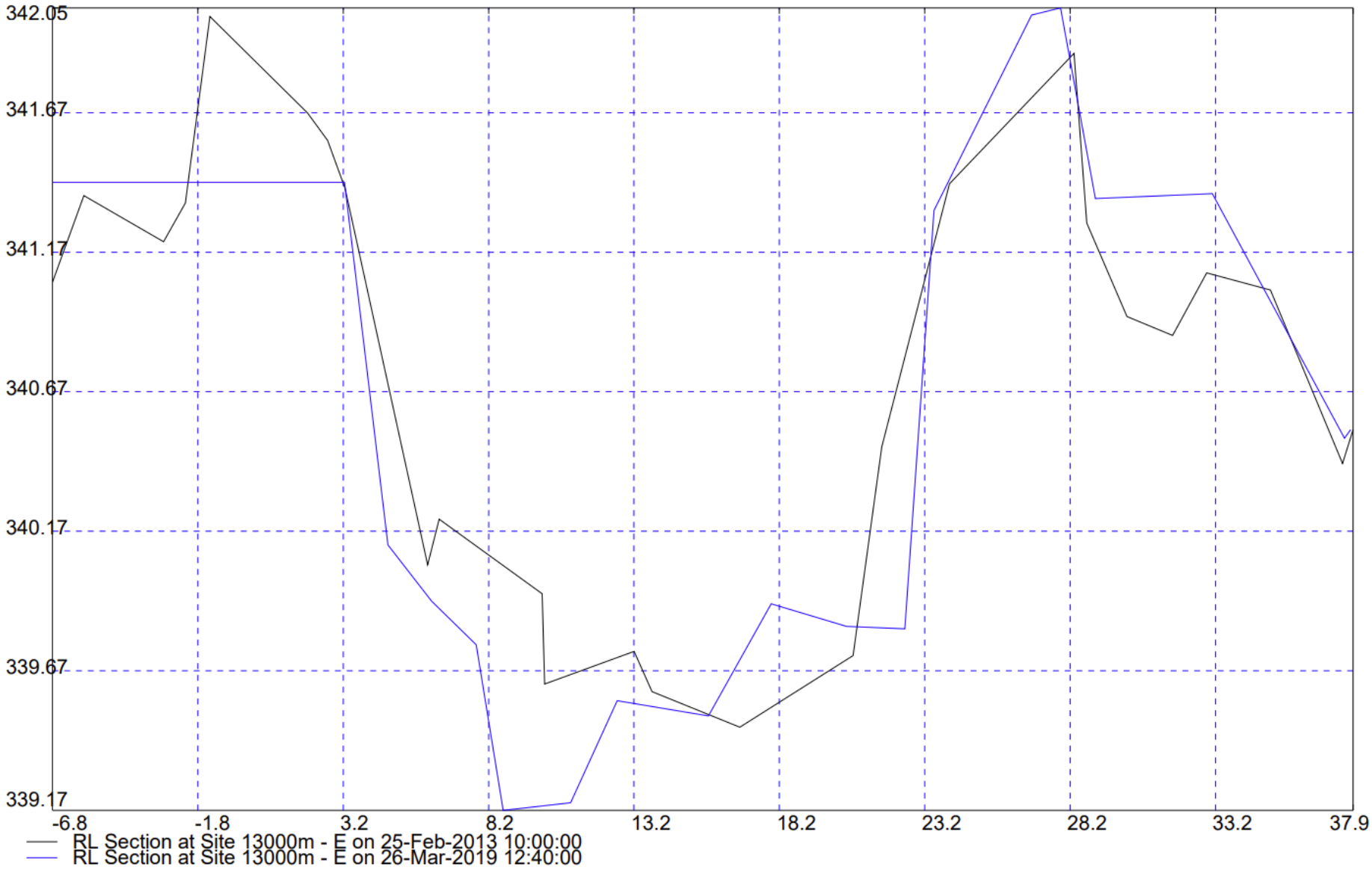

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295.38
295.18
294.98
294.78
294.58
294.38
294.18
293.98
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
32.033.6
RL Section at Site 11400m - 5 - NEW XS FEB 2013 on 22-Feb-2013 11:30:00
RL Section at Site 11400m - 5 - NEW XS FEB 2013 on 11-Apr-2019 12:00:00


307.79
307.49
306.99
306.49
305.99
305.49
304.99
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303.99
303.49
302.99
302.49
8.4
10.4
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20.4
22.4
24.4
26.4
28.4
30.4
32.4
34.4
36.4
38.4
40.4
42.1
RL Section at Site 11800m - 4 on 22-Feb-2013 12:30:00
RL Section at Site 11800m - 4 on 26-Mar-2019 13:40:00


317.10
316.77
316.27
315.77
315.27
314.77
314.27
313.77
313.27
-4.3
0.7
5.7
10.7
15.7
20.7
25.7
30.7
35.7
40.7
45.7
RL Section at Site 12200m - 3 on 22-Feb-2013 13:30:00
RL Section at Site 12200m - 3 on 26-Mar-2019 14:00:00


330.0
329.0
328.0
327.0
326.0
325.0
324.0
323.0
-6.5
-1.5
3.5
8.5
13.5
18.5
23.5
28.5
33.5
38.1
RL Section at Site 12700m - 2 on 22-Feb-2013 14:30:00
RL Section at Site 12700m - 2 on 26-Mar-2019 14:10:00

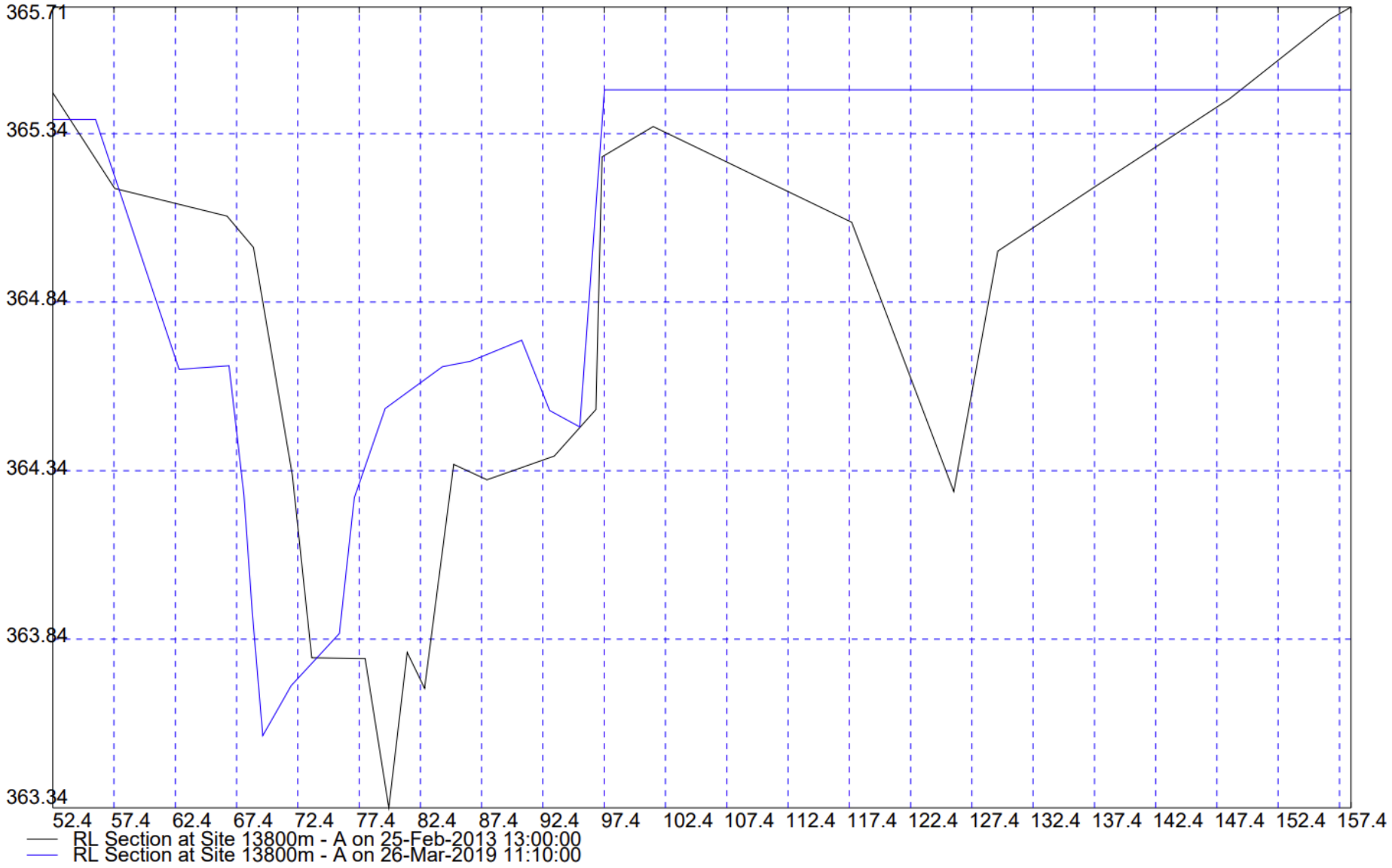

336.3
335.5
334.5
333.5
332.5
331.5
330.5
329.5
328.5
-4.9
0.1
5.1
10.1
15.1
20.1
25.1
30.1
34.1
RL Section at Site 12850m - 1 on 22-Feb-2013 15:30:00
RL Section at Site 12850m - 1 on 26-Mar-2019 14:30:00


342.05
341.67
341.17
340.67
340.17
339.67
339.17
-6.8
-1.8
3.2
8.2
13.2
18.2
23.2
28.2
33.2
37.9
RL Section at Site 13000m - E on 25-Feb-2013 10:00:00
RL Section at Site 13000m - E on 26-Mar-2019 12:40:00

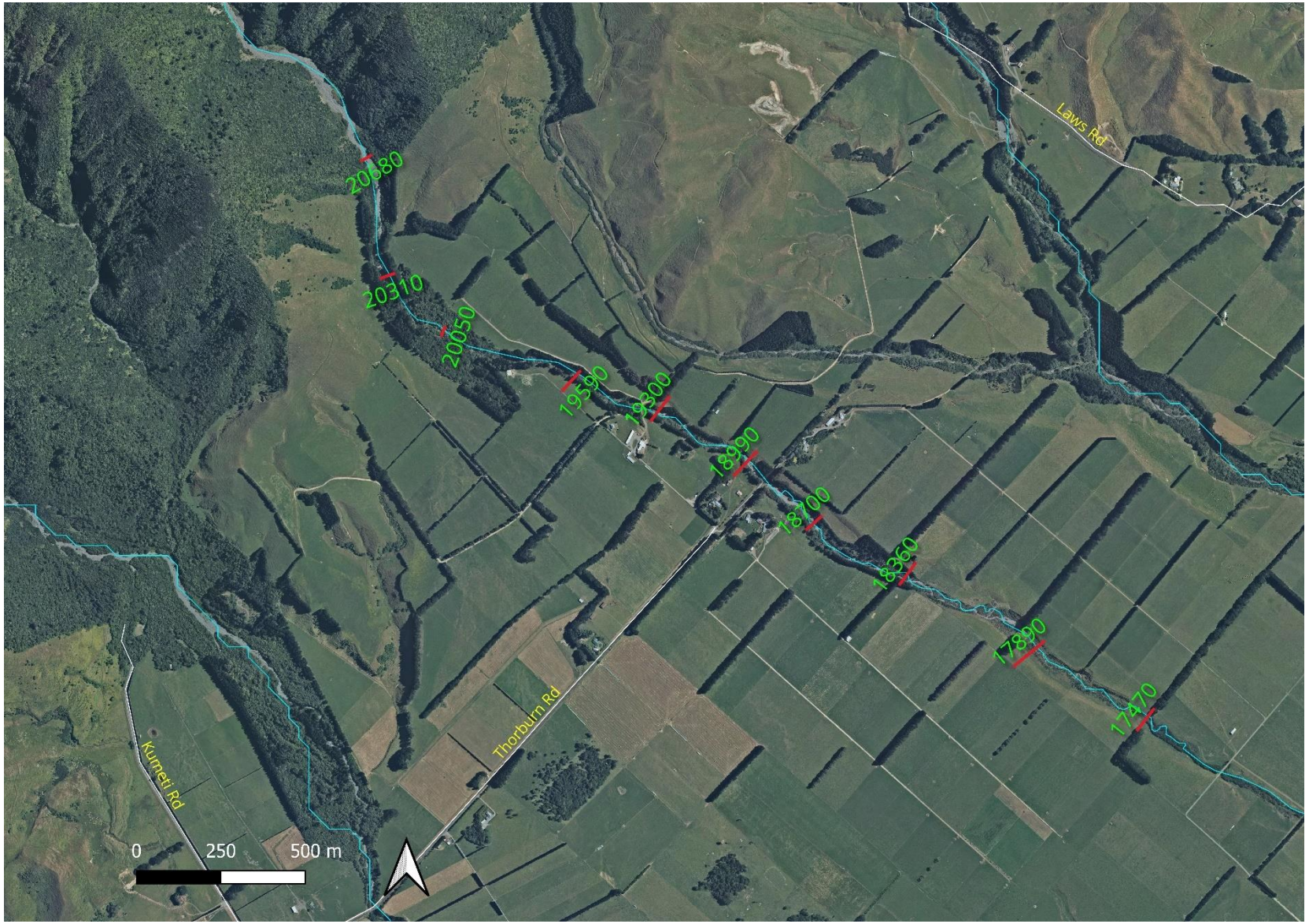

344.57
344.41
344.21
344.01
343.81
343.61
343.41
343.21
343.01
342.81
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
RL Section at Site 13100m - D - NEW XS FEB 2013 on 27-Feb-2013 11:00:00
RL Section at Site 13100m - D - NEW XS FEB 2013 on 26-Mar-2019 12:10:00


352.60
352.10
351.60
351.10
350.60
350.10
349.60
349.10
8
18
28
38
48
58
68
78
88
98
108
118
128
138
148
158
168
178
188
198
208
218
228
RL Section at Site 13350m - C on 25-Feb-2013 11:00:00
RL Section at Site 13350m - C on 26-Mar-2019 12:25:00


361.55
361.05
360.55
360.05
359.55
359.05
358.55
358.05
56.7
61.7
66.7
71.7
76.7
81.7
86.7
91.7
96.7
101.7
106.7
111.7
116.7
121.7
126.7
131.7
136.7
141.7
RL Section at Site 13600m - B on 27-Feb-2013 10:00:00
RL Section at Site 13600m - B on 26-Mar-2019 11:40:00


365.71
365.34
364.84
364.34
363.84
363.34
52.4 57.4 62.4 67.4 72.4 77.4 82.4 87.4 92.4 97.4 102.4 107.4 112.4 117.4 122.4 127.4 132.4 137.4 142.4 147.4 152.4 157.4
RL Section at Site 13800m - A on 25-Feb-2013 13:00:00
RL Section at Site 13800m - A on 26-Mar-2019 11:10:00

Appendix G1: Otamaraho cross section locations



Appendix G2: Otamaraho Mean Bed Level Data (2013 – 2019/2020)

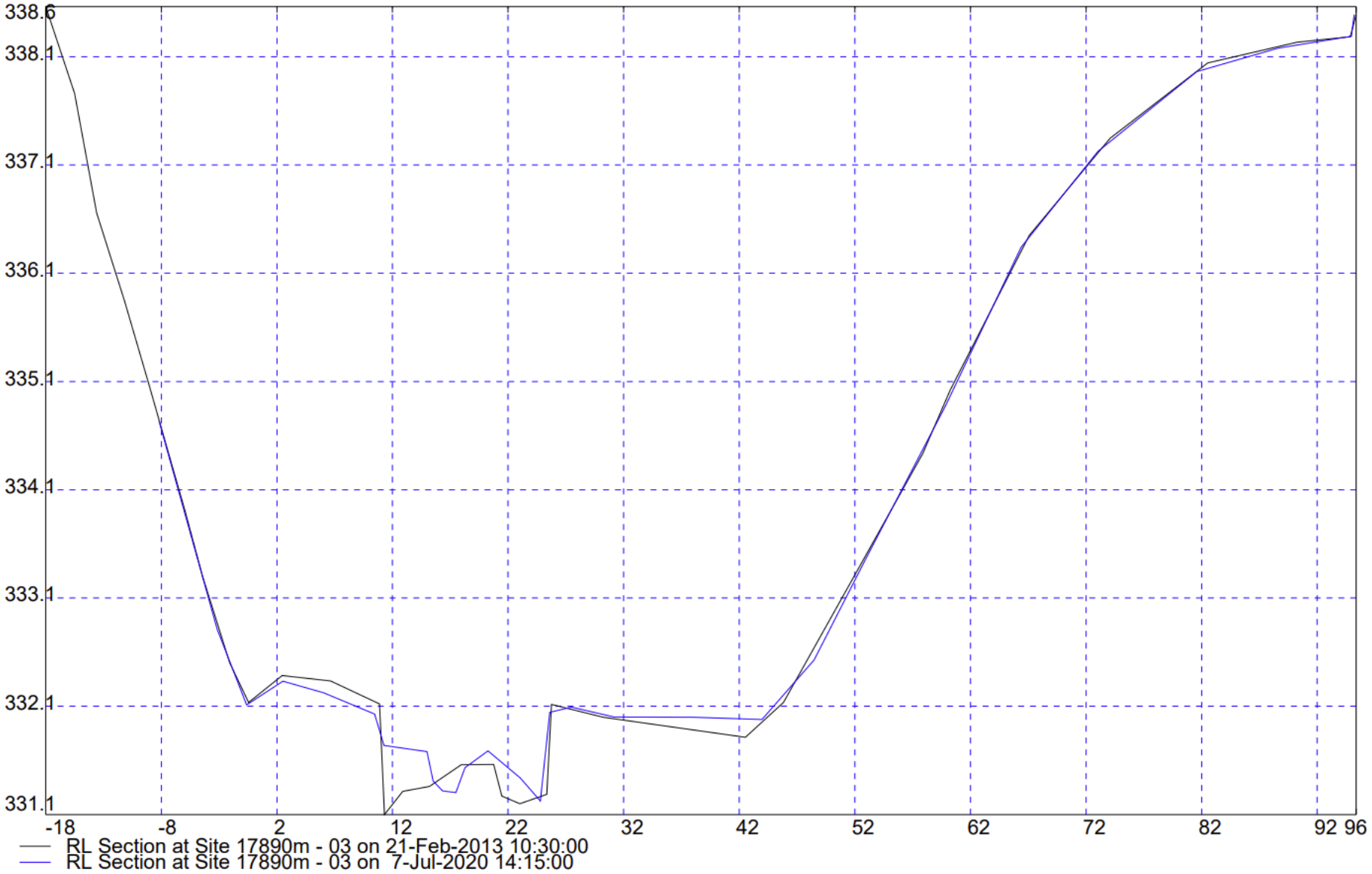
Otamaraho Mean Bed Level Change					
Cross Section	Left Extent	Right Extent	MBL 2013	MBL 2020	MBL change (2020-2013)
17470	13.8	28	318.833	319.315	0.482
17890	11.3	26.1	331.386	331.559	0.173
18360	-24.5	31.75	348.876	348.68	-0.196
18700	16.5	29.2	362.069	361.726	-0.343
18990	19.9	59.9	375.818	375.57	-0.248
19300	43.7	66.25	388.822	388.591	-0.231
19590	14.1	29.9	404.022	403.443	-0.579
20050	6.2	19	426.607	426.668	0.061
20310	1.44	37.5	440.425	440.181	-0.244
20680	11.4	23.78	461.517	461.665	0.148

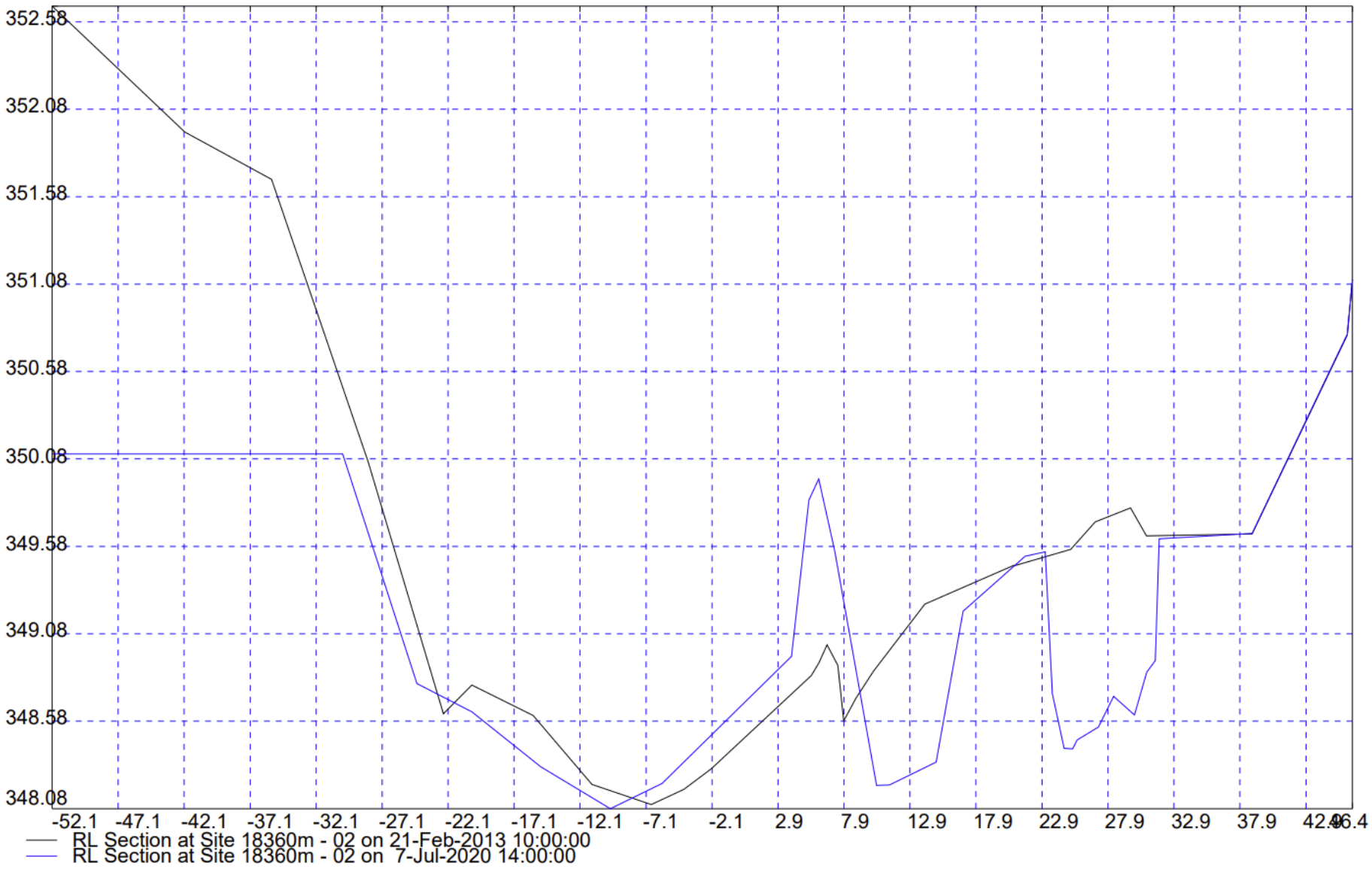
Appendix G3: Otamaraho Change in Gravel Volume (2013 – 2019/2020)

Otamaraho Change in Gravel Volume						
Cross Section	Left Extent	Right Extent	Datum=0	Area under section 2013	Area under section 2020	Change in volume 2020-2013 (m^3)
17470	1.3	41.3	0	12777.4	12786.7	3906
17890	-7.4	52	0	19727.4	19729.8	1068
18360	-37.1	37.9	0	26192.2	26171.1	-8545.5
18700	9.2	39.2	0	10866.2	10862.3	-1228.5
18990	9.9	79.9	0	26328.7	26308.2	-6150
19300	29.9	74.9	0	17519.4	17514.8	-1380
19590	4.9	49.9	0	18213.5	18208.2	-1987.5
20050	3	27	0	10254.9	10252.8	-756
20310	0	39.9	0	17580	17566.7	-4189.5
20680	-9.5	28.8	0	17694.2	17697.3	1147

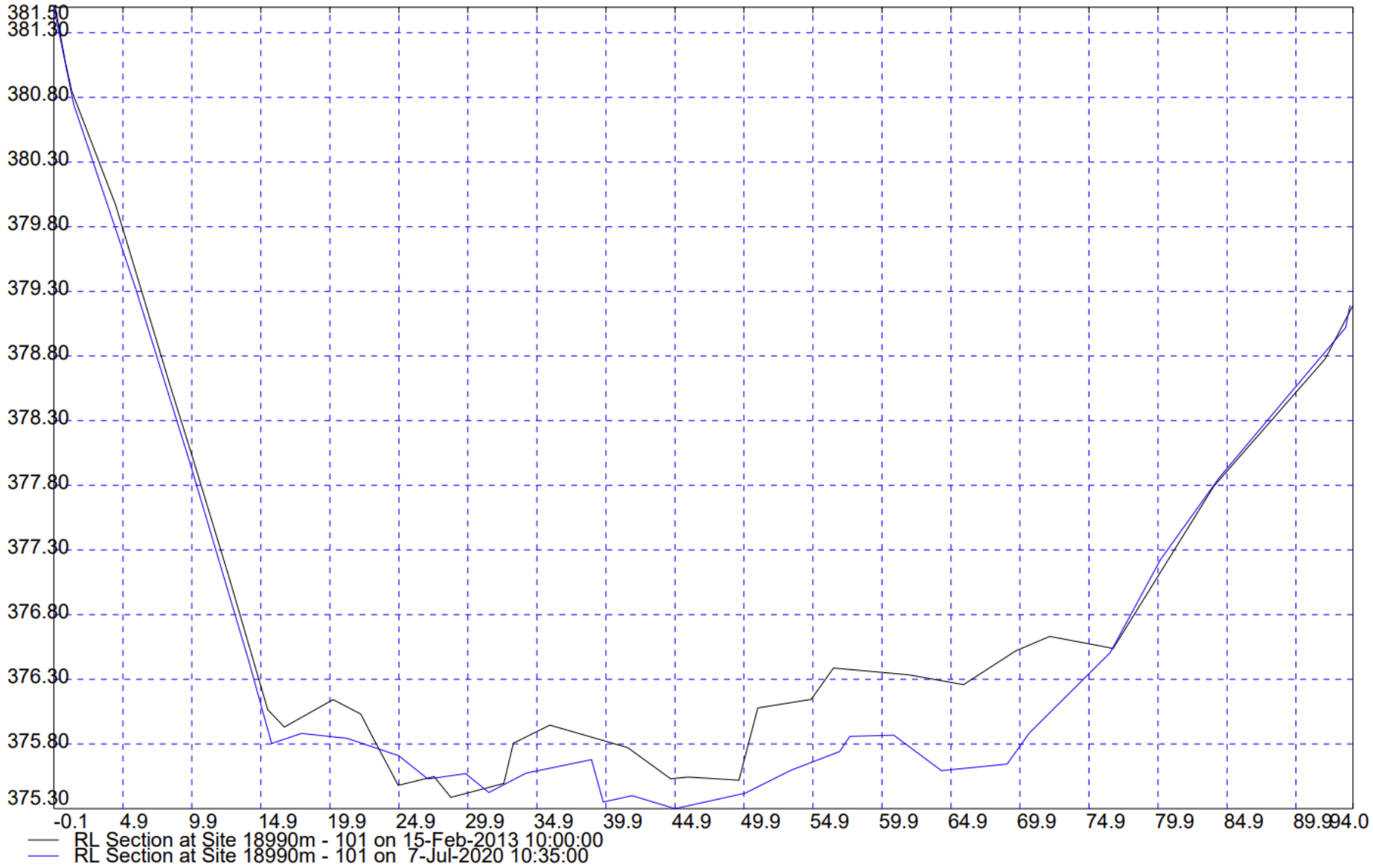
Appendix G4: Cross-sections at Otamaraho Stream

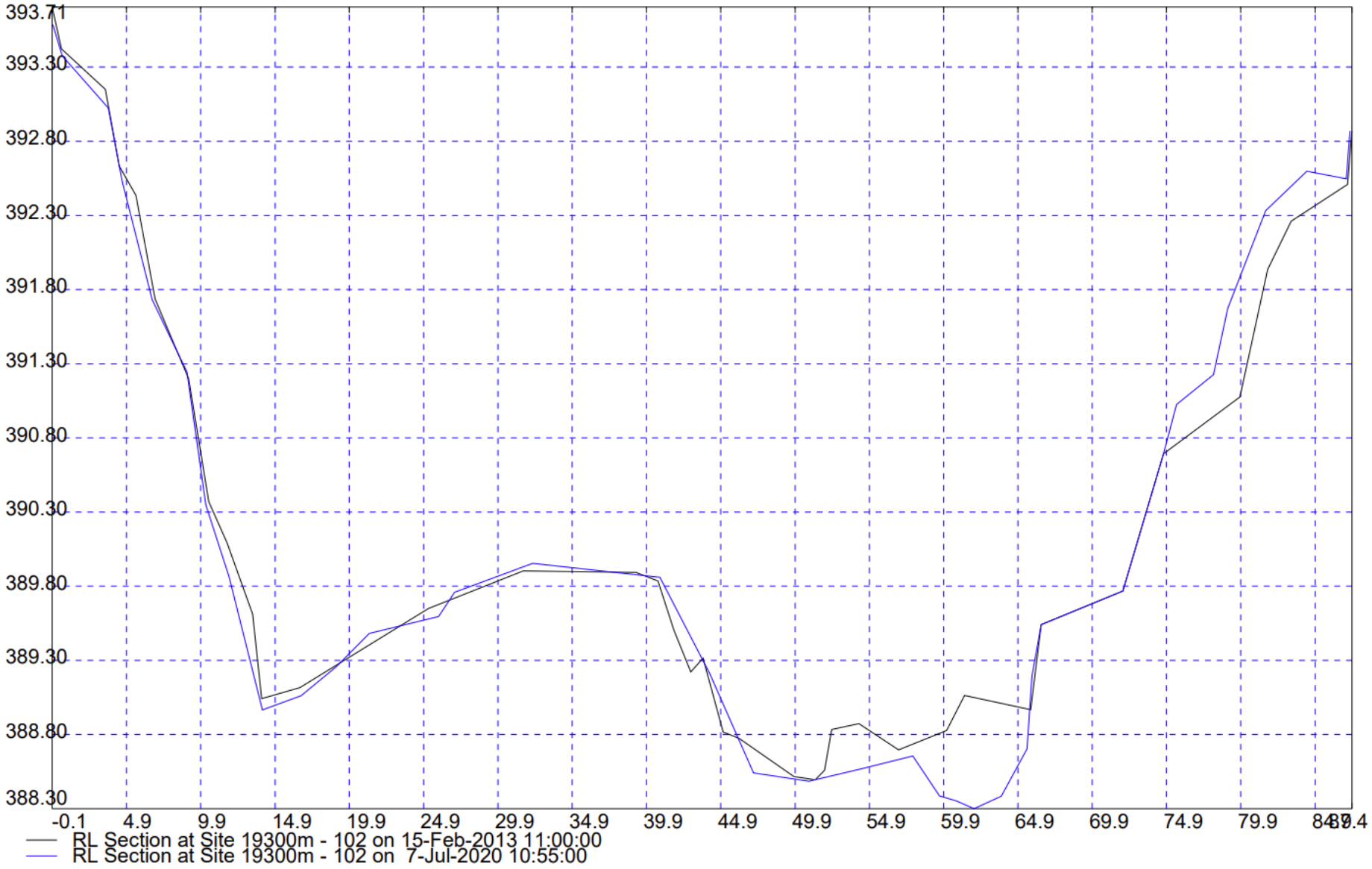


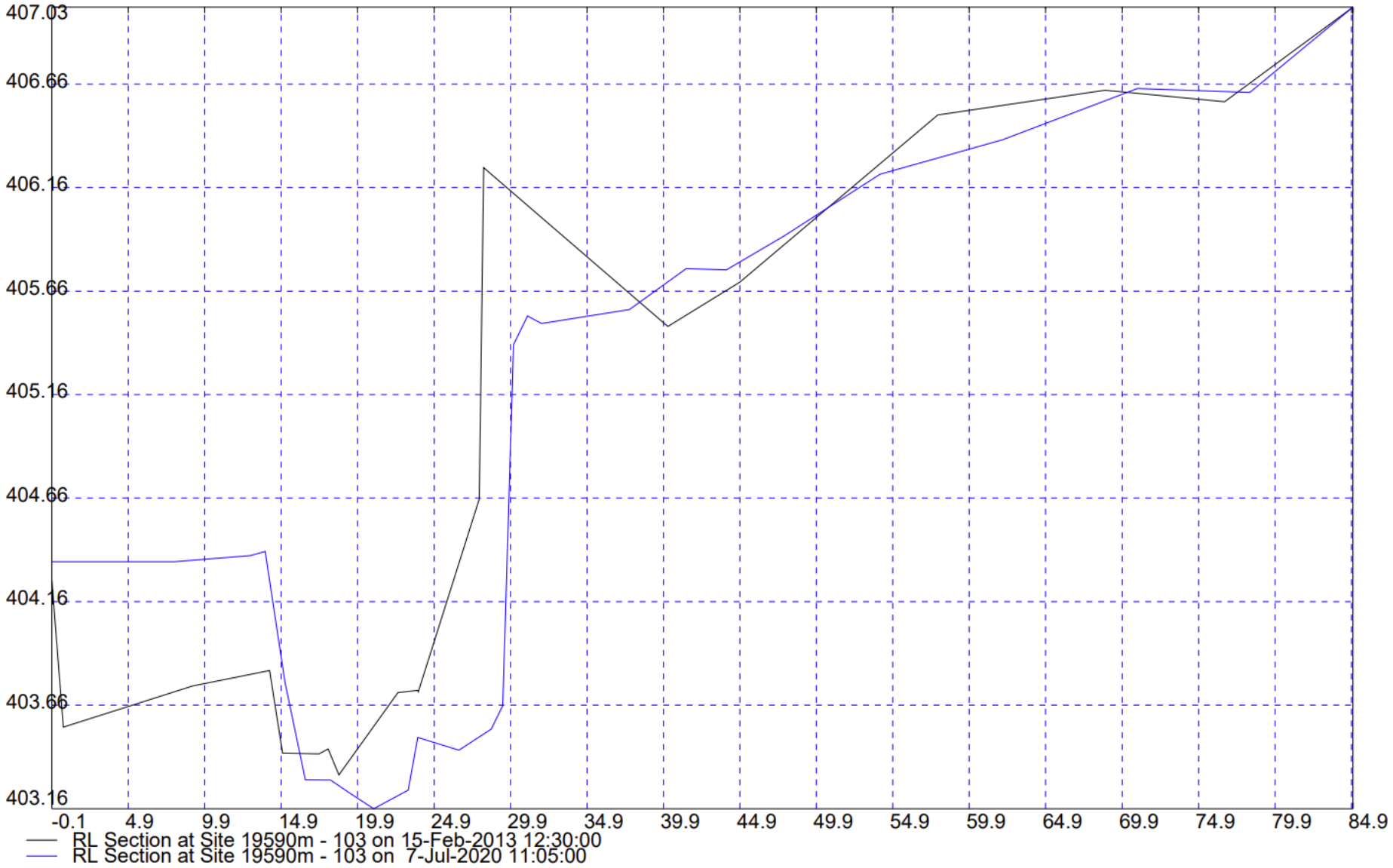

338.6
338.1
337.1
336.1
335.1
334.1
333.1
332.1
331.1
-18
-8
2
12
22
32
42
52
62
72
82
92 96
RL Section at Site 17890m - 03 on 21-Feb-2013 10:30:00
RL Section at Site 17890m - 03 on 7-Jul-2020 14:15:00

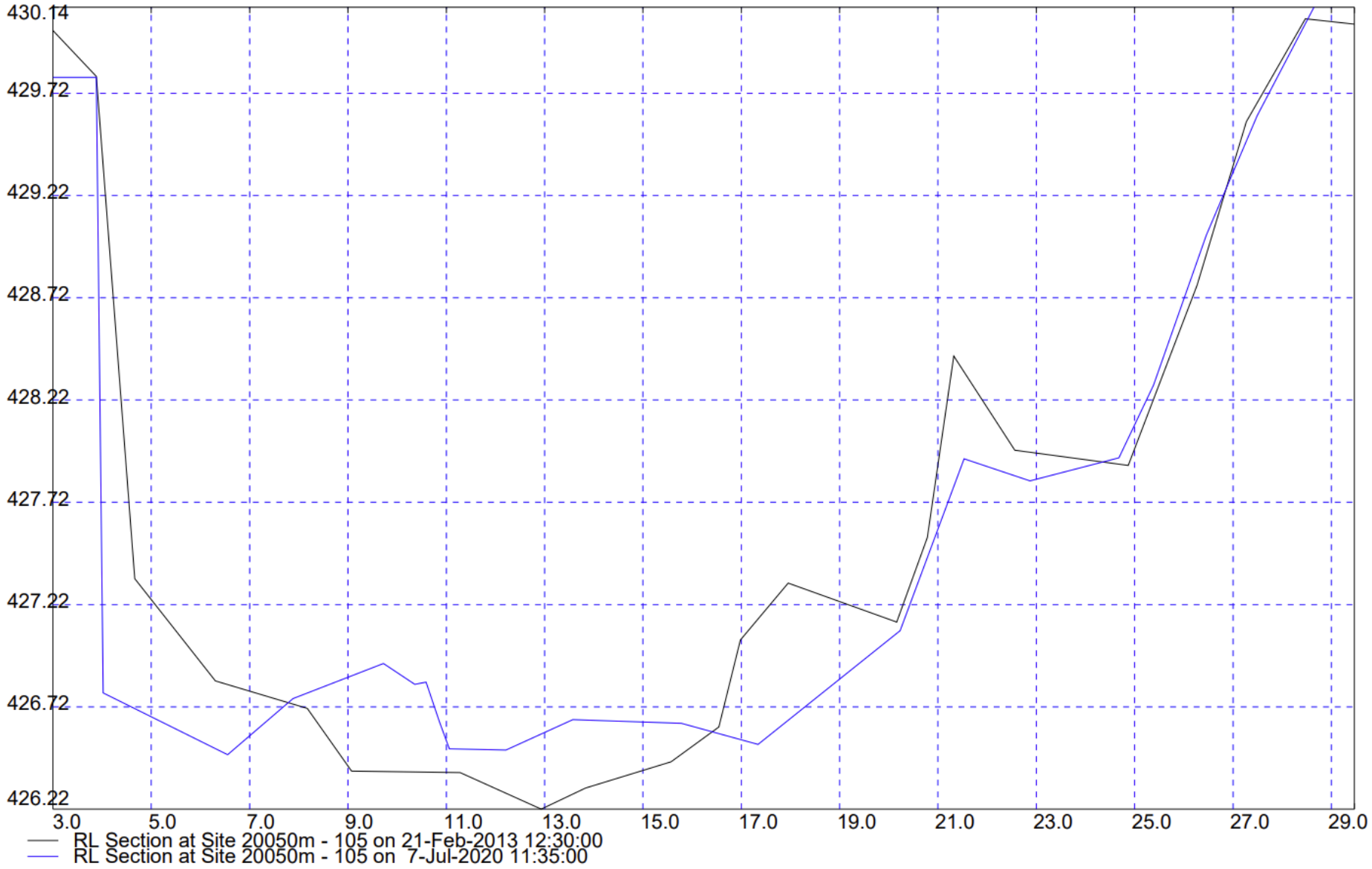

352.58
352.08
351.58
351.08
350.58
350.08
349.58
349.08
348.58
348.08
-52.1 -47.1 -42.1 -37.1 -32.1 -27.1 -22.1 -17.1 -12.1 -7.1 -2.1 2.9 7.9 12.9 17.9 22.9 27.9 32.9 37.9 42.9 46.4
RL Section at Site 18360m - 02 on 21-Feb-2013 10:00:00
RL Section at Site 18360m - 02 on 7-Jul-2020 14:00:00


362.78
362.72
362.62
362.52
362.42
362.32
362.22
362.12
362.02
361.92
361.82
361.72
361.62
361.52
361.42
-0.8
4.2
9.2
14.2
19.2
24.2
29.2
34.2
39.2
44.2
49.2
RL Section at Site 18700m - 01 on 15-Feb-2013 14:30:00
RL Section at Site 18700m - 01 on 7-Jul-2020 13:50:00

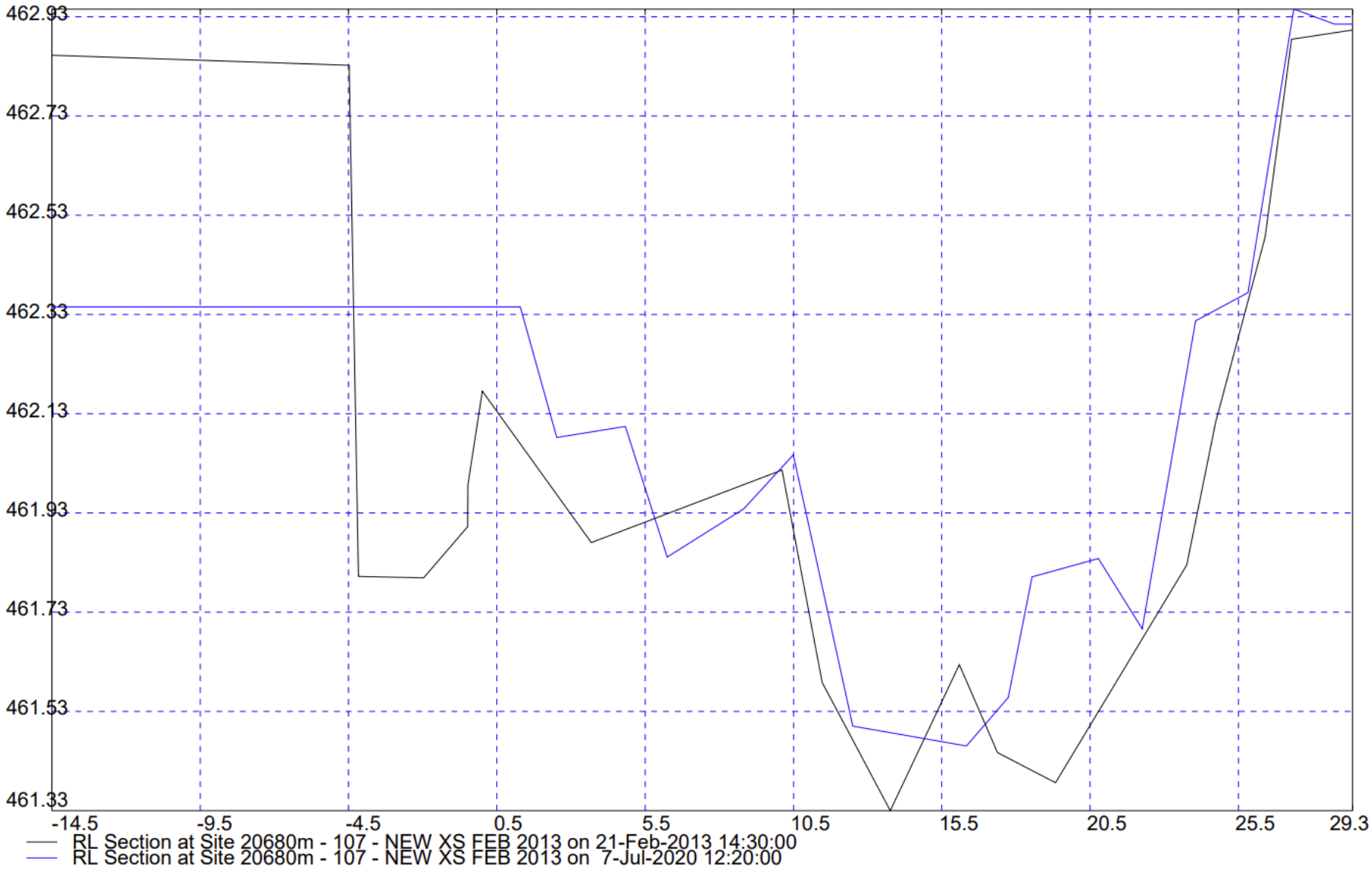

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380.30
379.80
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378.30
377.80
377.30
376.80
376.30
375.80
375.30
-0.1
4.9
9.9
14.9
19.9
24.9
29.9
34.9
39.9
44.9
49.9
54.9
59.9
64.9
69.9
74.9
79.9
84.9
89.9
94.0
RL Section at Site 18990m - 101 on 15-Feb-2013 10:00:00
RL Section at Site 18990m - 101 on 7-Jul-2020 10:35:00


393.71
393.30
392.80
392.30
391.80
391.30
390.80
390.30
389.80
389.30
388.80
388.30
-0.1
4.9
9.9
14.9
19.9
24.9
29.9
34.9
39.9
44.9
49.9
54.9
59.9
64.9
69.9
74.9
79.9
84.9
89.4
RL Section at Site 19300m - 102 on 15-Feb-2013 11:00:00
RL Section at Site 19300m - 102 on 7-Jul-2020 10:55:00

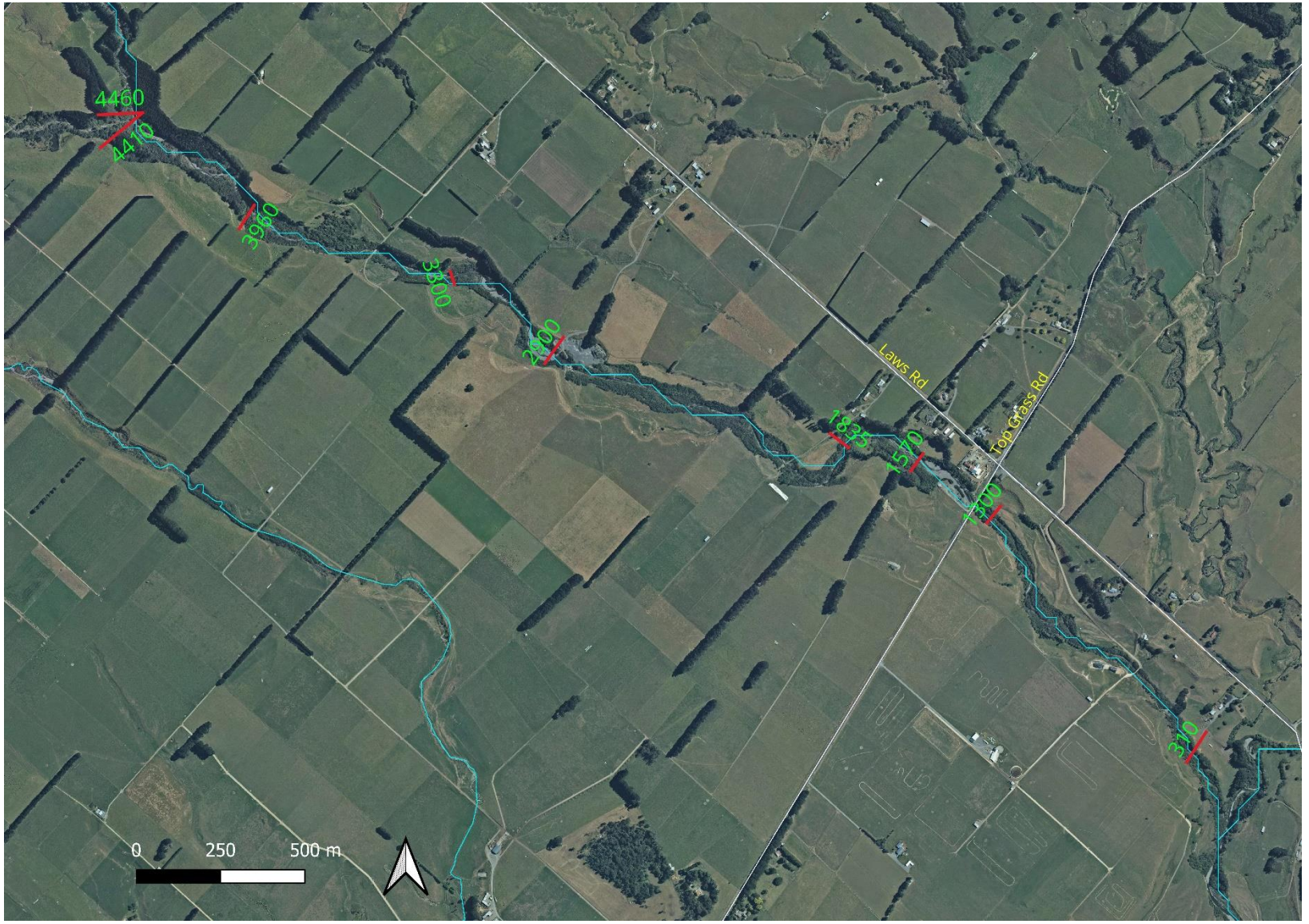

407.03
406.66
406.16
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404.66
404.16
403.66
403.16
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4.9
9.9
14.9
19.9
24.9
29.9
34.9
39.9
44.9
49.9
54.9
59.9
64.9
69.9
74.9
79.9
84.9
RL Section at Site 19590m - 103 on 15-Feb-2013 12:30:00
RL Section at Site 19590m - 103 on 7-Jul-2020 11:05:00

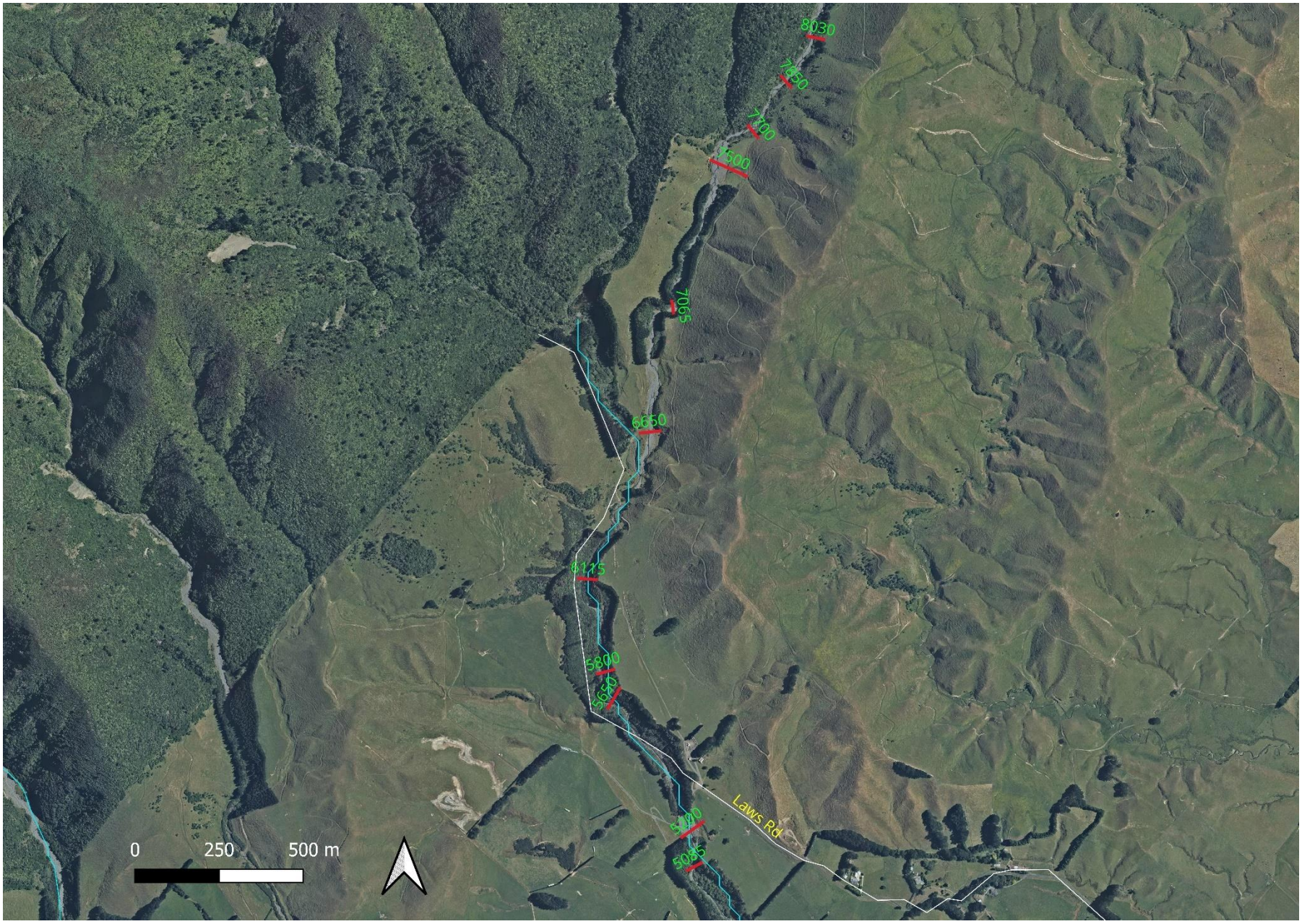

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429.72
429.22
428.72
428.22
427.72
427.22
426.72
426.22
3.0
5.0
7.0
9.0
11.0
13.0
15.0
17.0
19.0
21.0
23.0
25.0
27.0
29.0
RL Section at Site 20050m - 105 on 21-Feb-2013 12:30:00
RL Section at Site 20050m - 105 on 7-Jul-2020 11:35:00


443.05
442.56
442.06
441.56
441.06
440.56
440.06
439.56
439.06
-0.2
4.8
9.9
14.9
19.9
24.9
29.9
34.8
39.8
RL Section at Site 20310m - 106 on 21-Feb-2013 13:30:00
RL Section at Site 20310m - 106 on 7-Jul-2020 11:55:00


462.93
462.73
462.53
462.33
462.13
461.93
461.73
461.53
461.33
-14.5
-9.5
-4.5
0.5
5.5
10.5
15.5
20.5
25.5
29.3
RL Section at Site 20680m - 107 - NEW XS FEB 2013 on 21-Feb-2013 14:30:00
RL Section at Site 20680m - 107 - NEW XS FEB 2013 on 7-Jul-2020 12:20:00

Appendix H1: Rokaiwhana cross section locations




8030
7650
7300
7500
7065
6650
6175
5800
5650
5180
5085
Laws Rd
0
250
500 m

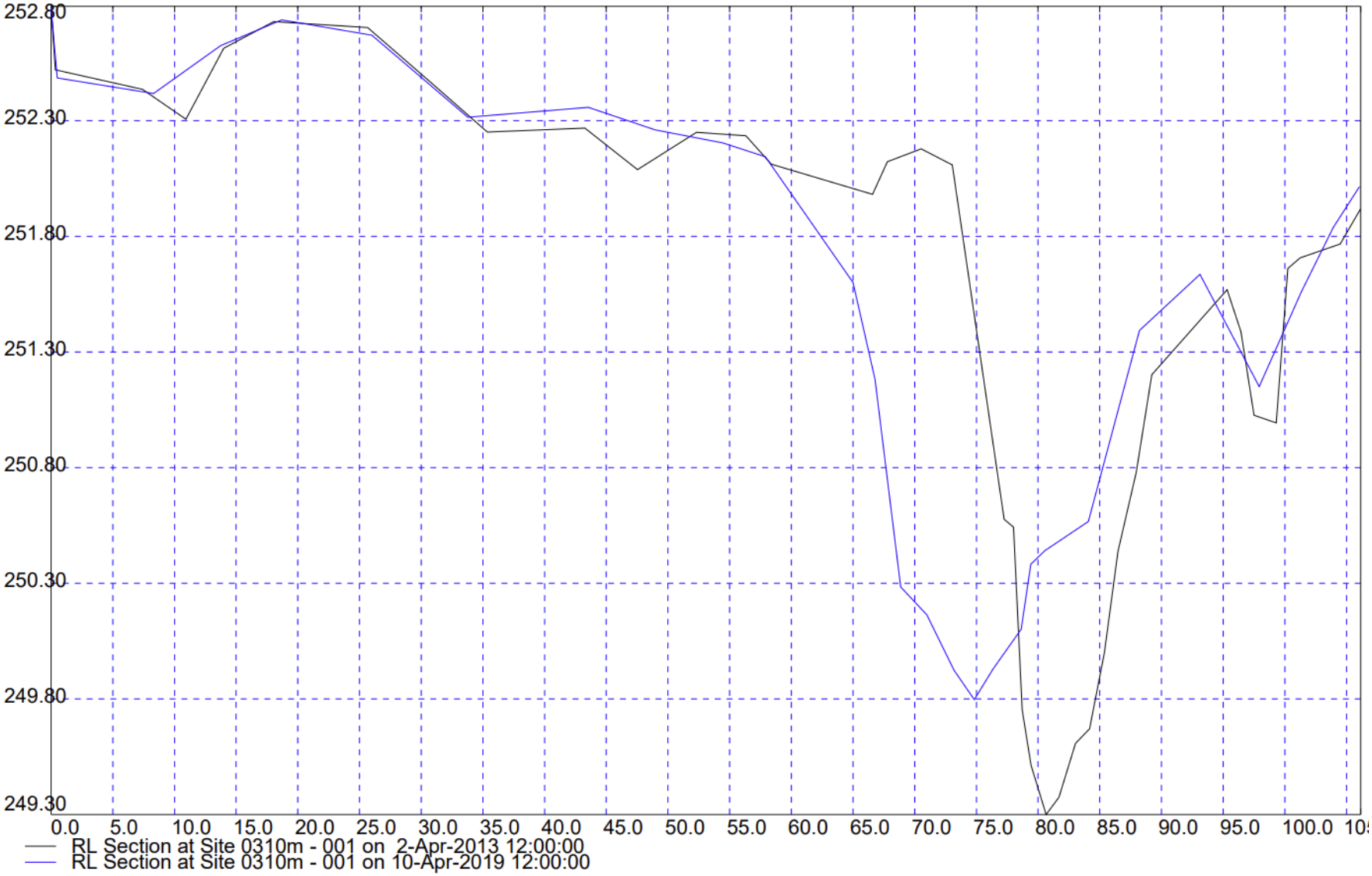
Appendix H2: Rokaiwhana Mean Bed Level Data (2013 – 2019)

Rokaiwhana Mean Bed Level Change					
Cross Section	Left Extent	Right Extent	MBL 2013	MBL 2019	MBL change (2019-2013)
310	68.3	88	250.742	250.338	-0.404
1300	34	45	265.065	264.842	-0.223
1570	7.7	39.4	272.667	272.413	-0.254
1835	50	65	277.035	276.719	-0.316
2900	50.7	96.5	295.786	294.879	-0.907
3300	46.1	65.3	303.529	303.206	-0.323
3960	19.45	41.5	316.777	315.865	-0.912
4410	10	70	326.672	326.042	-0.63
4460	17.5	40	326.746	326.002	-0.744
5085	11	40	341.277	341.124	-0.153
5200	35	66.7	343.592	343.694	0.102
5650	43.6	63.5	354.725	354.405	-0.32
5800	25	46	358.279	357.901	-0.378
6115	17.1	45	365.665	365.714	0.049
6650	11.3	41.3	381.473	381.165	-0.308
7065	-2.1	30.6	396.573	395.589	-0.984
7500	3.5	60.5	412.338	412.066	-0.272
7700	10	40.75	418.552	418.366	-0.186
7850	12.2	27.7	425.536	425.104	-0.432
8030	25	46.1	432.209	431.894	-0.315

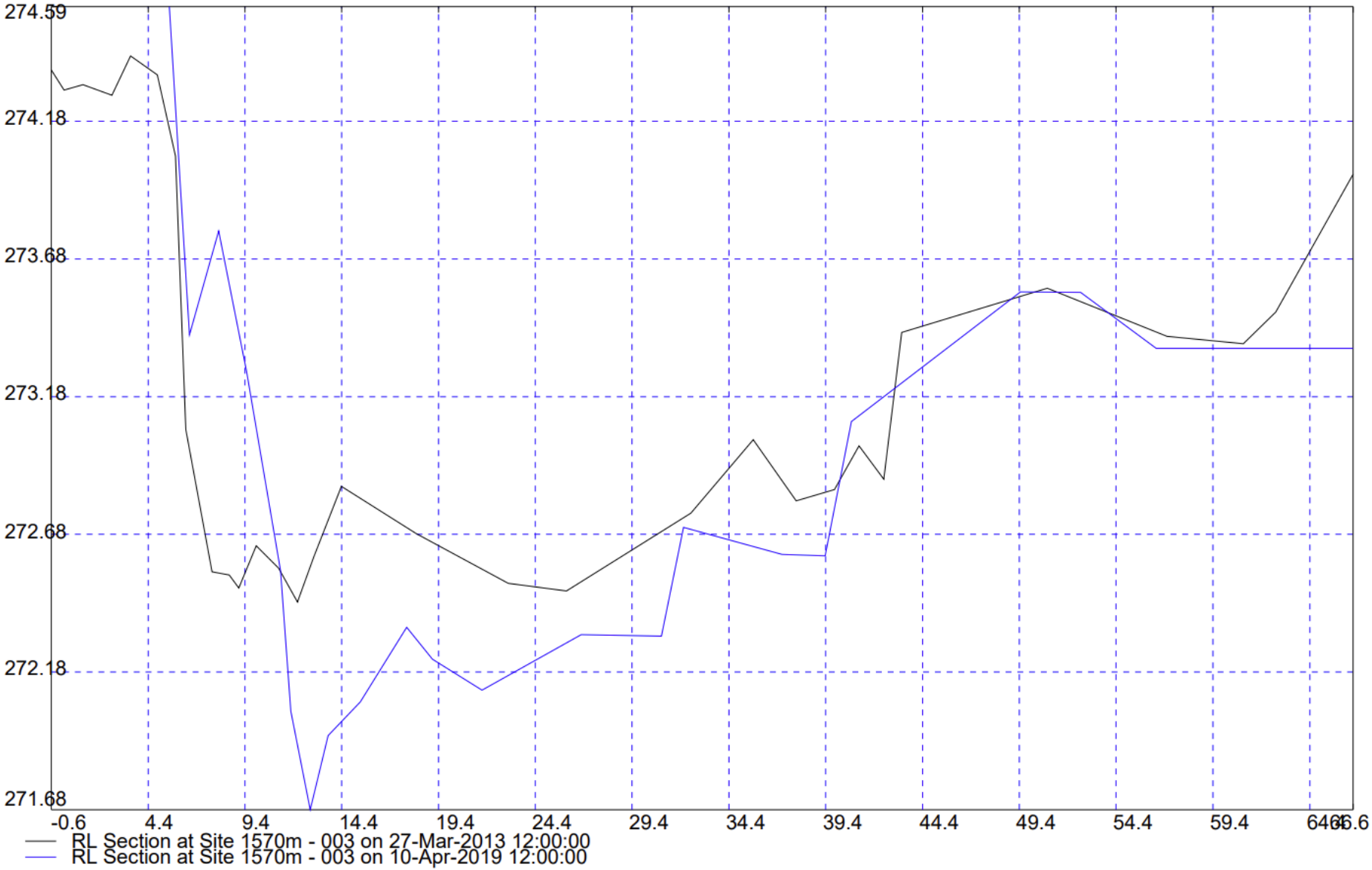
Appendix H3: Rokaiwhana Change in Gravel Volume (2013 – 2019)

Rokaiwhana Change in Gravel Volume						
Cross Section	Left Extent	Right Extent	Datum=0	Area under section 2013	Area under section 2019	Change in volume 2013-2019 (m^3)
310	45	106	0	15340.1	15330.1	-9900
1300	20	60	0	10669.3	10673.3	2520
1570	-0.6	49.4	0	13650.5	13645.3	-1391
1835	35	69.1	0	9465.7	9457.6	-5386.5
2900	35	98.9	0	18928.8	18890.8	-27835
3300	41.63	73	0	9533.4	9520.4	-6890
3960	8.1	48.1	0	12683.9	12660.8	-12820.5
4410	0	80	0	26187.7	26103.7	-21000
4460	0	60	0	19656.5	19591.1	-22072.5
5085	5	50	0	15382	15369.6	-4588
5200	11.5	72	0	20836.8	20840.6	646
5650	30	65	0	12441.6	12439.6	-375
5800	20	49.5	0	10583.9	10565.6	-4254.75
6115	10	54.8	0	16416	16405.7	-4377.5
6650	4	51.3	0	18062	18053.2	-4180
7065	-2.7	34.9	0	14912.5	14879.2	-8158.5
7500	-13	61.1	0	30586.1	30570.8	-4284
7700	0	44.2	0	18503.5	18492.7	-1890
7850	0	35	0	14902.7	14894.8	-1303.5
8030	5	48.65	0	18893.4	18886.5	-1242

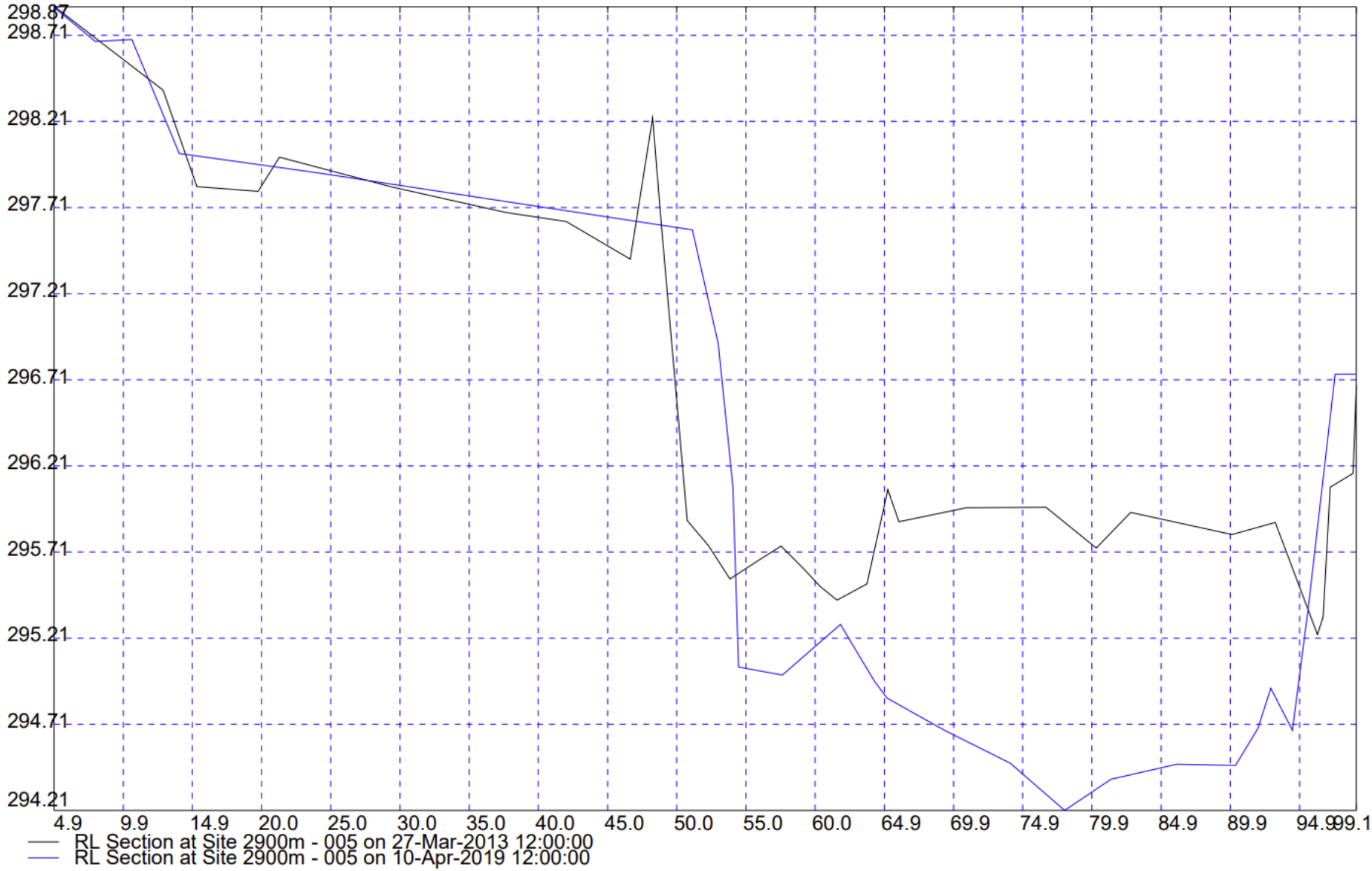
Appendix H4: Cross-sections at Rokaiwhana Stream

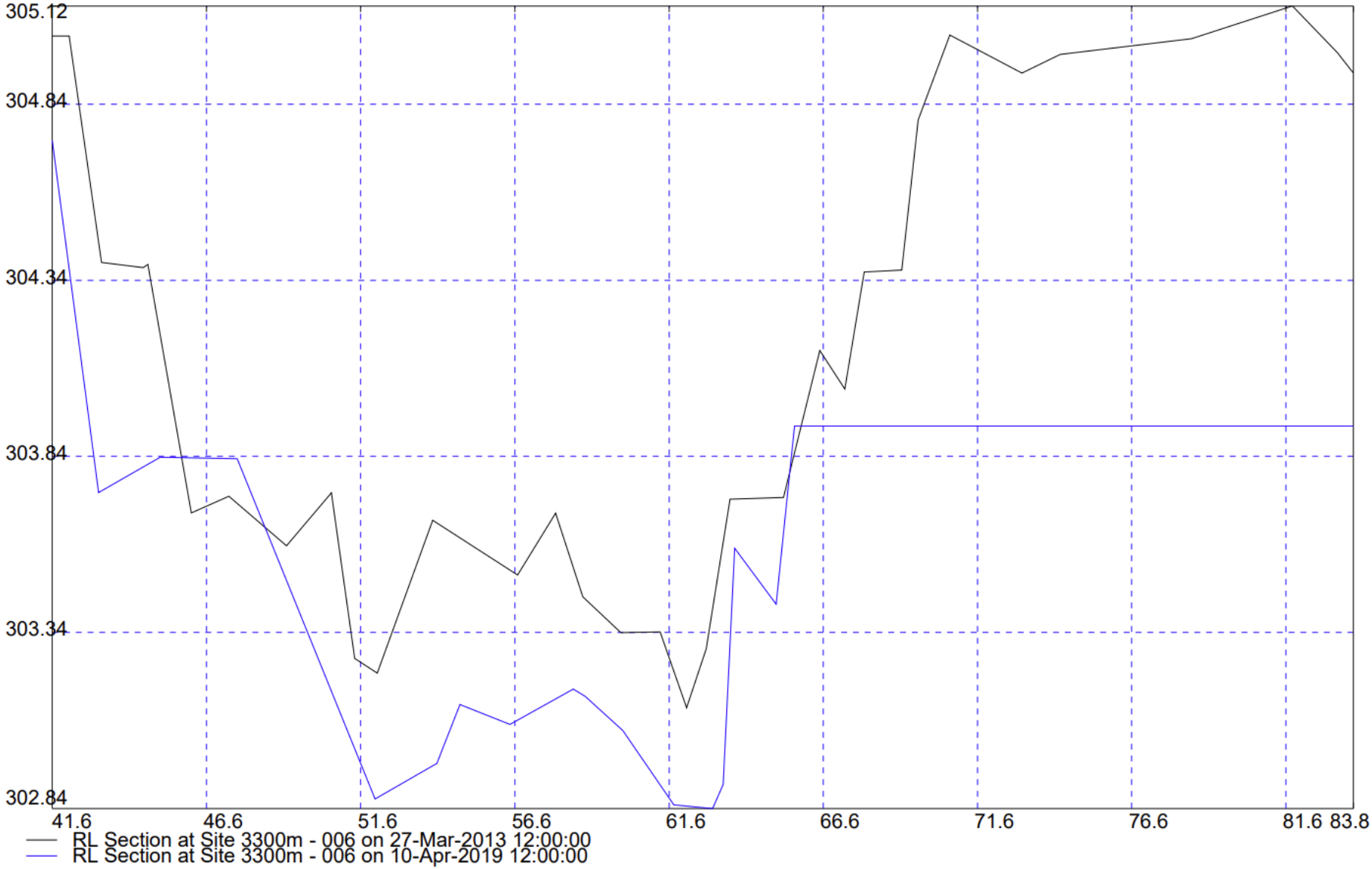


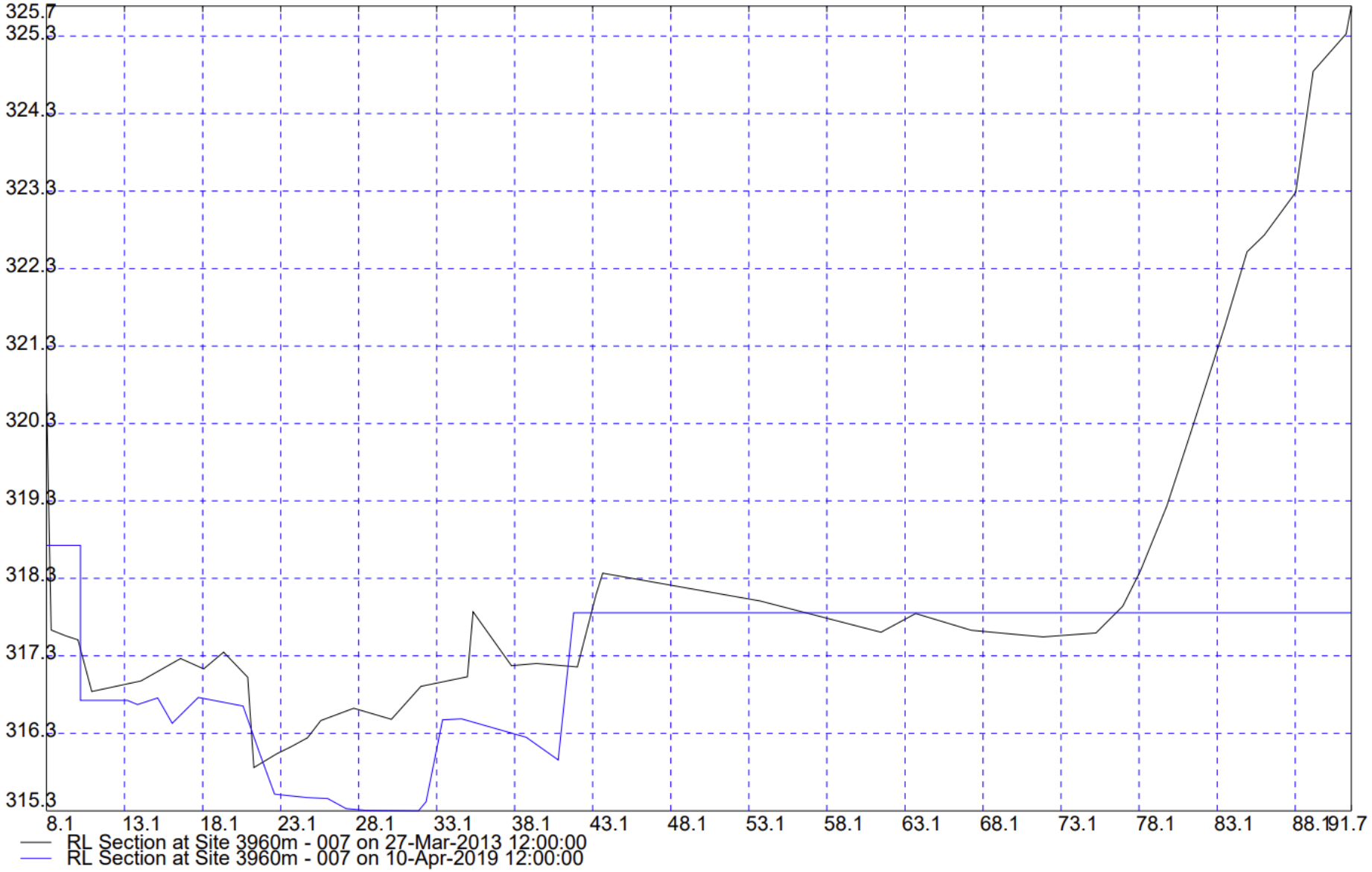

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269.32
268.82
268.32
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267.32
266.82
266.32
265.82
265.32
264.82
264.32
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RL Section at Site 1300m - 002 on 27-Mar-2013 12:00:00
RL Section at Site 1300m - 002 on 10-Apr-2019 12:00:00

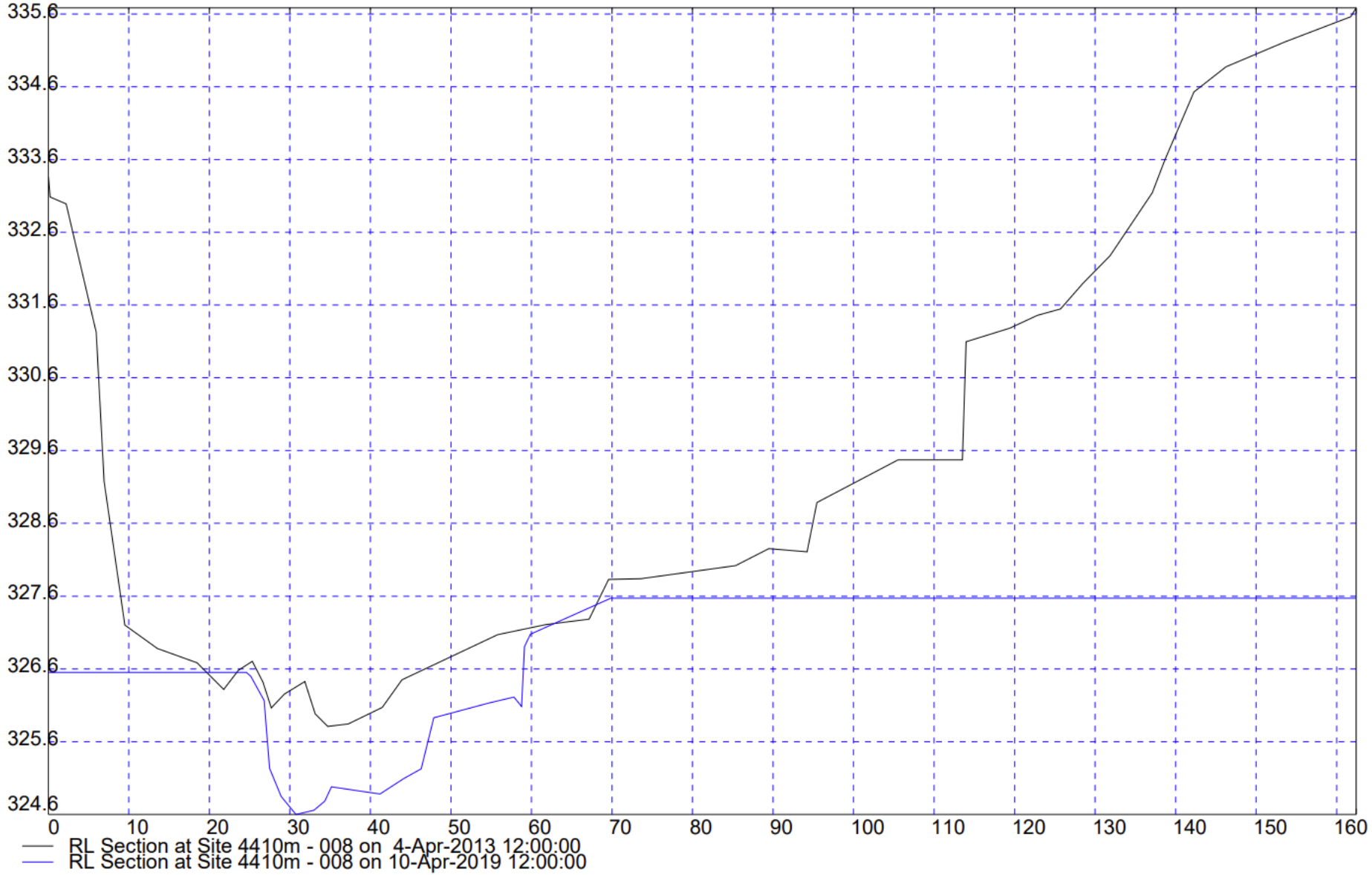

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29.4
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49.4
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64.6
RL Section at Site 1570m - 003 on 27-Mar-2013 12:00:00
RL Section at Site 1570m - 003 on 10-Apr-2019 12:00:00


281.42
281.08
280.58
280.08
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RL Section at Site 1835m - 004 on 27-Mar-2013 12:00:00
RL Section at Site 1835m - 004 on 10-Apr-2019 12:00:00

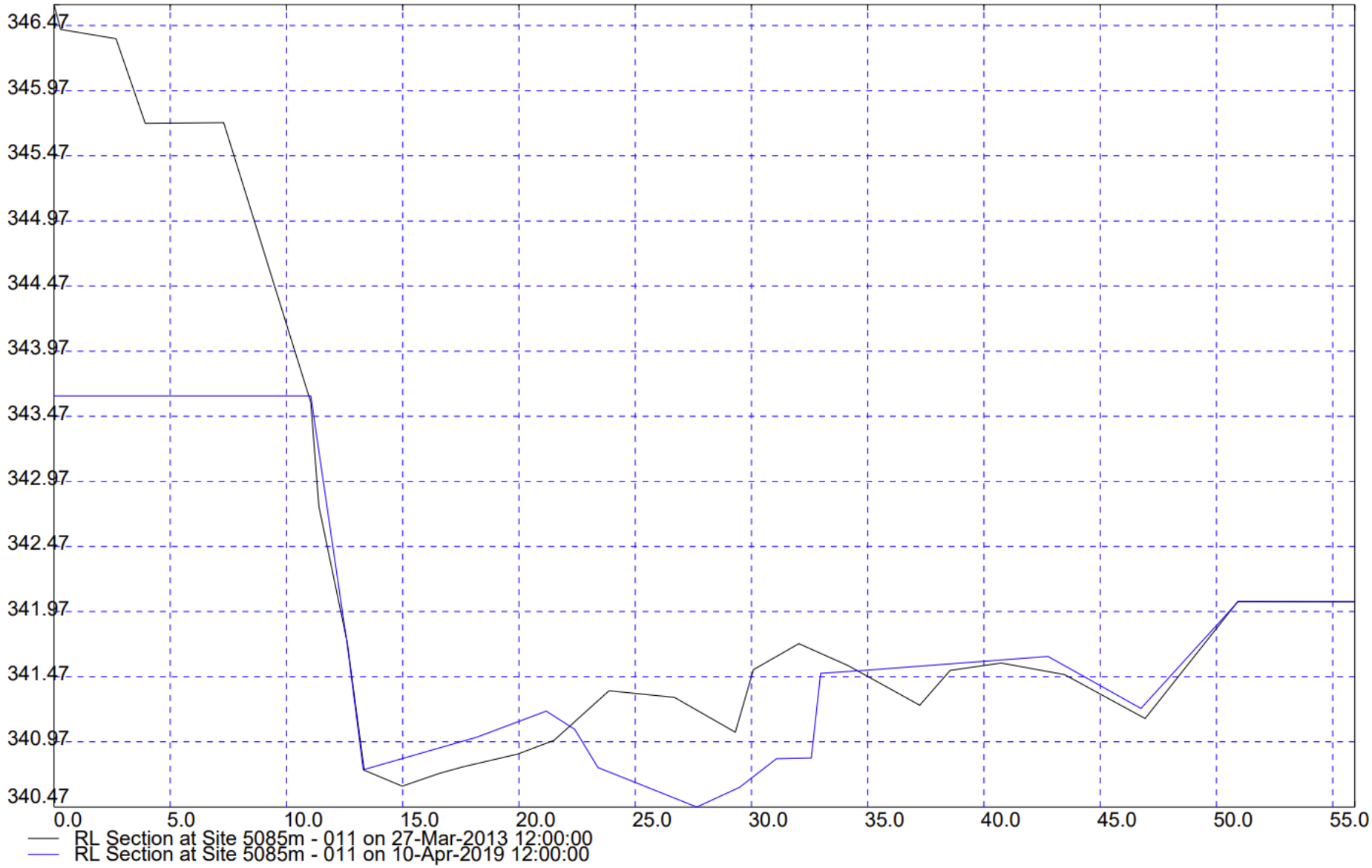

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84.9
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RL Section at Site 2900m - 005 on 10-Apr-2019 12:00:00

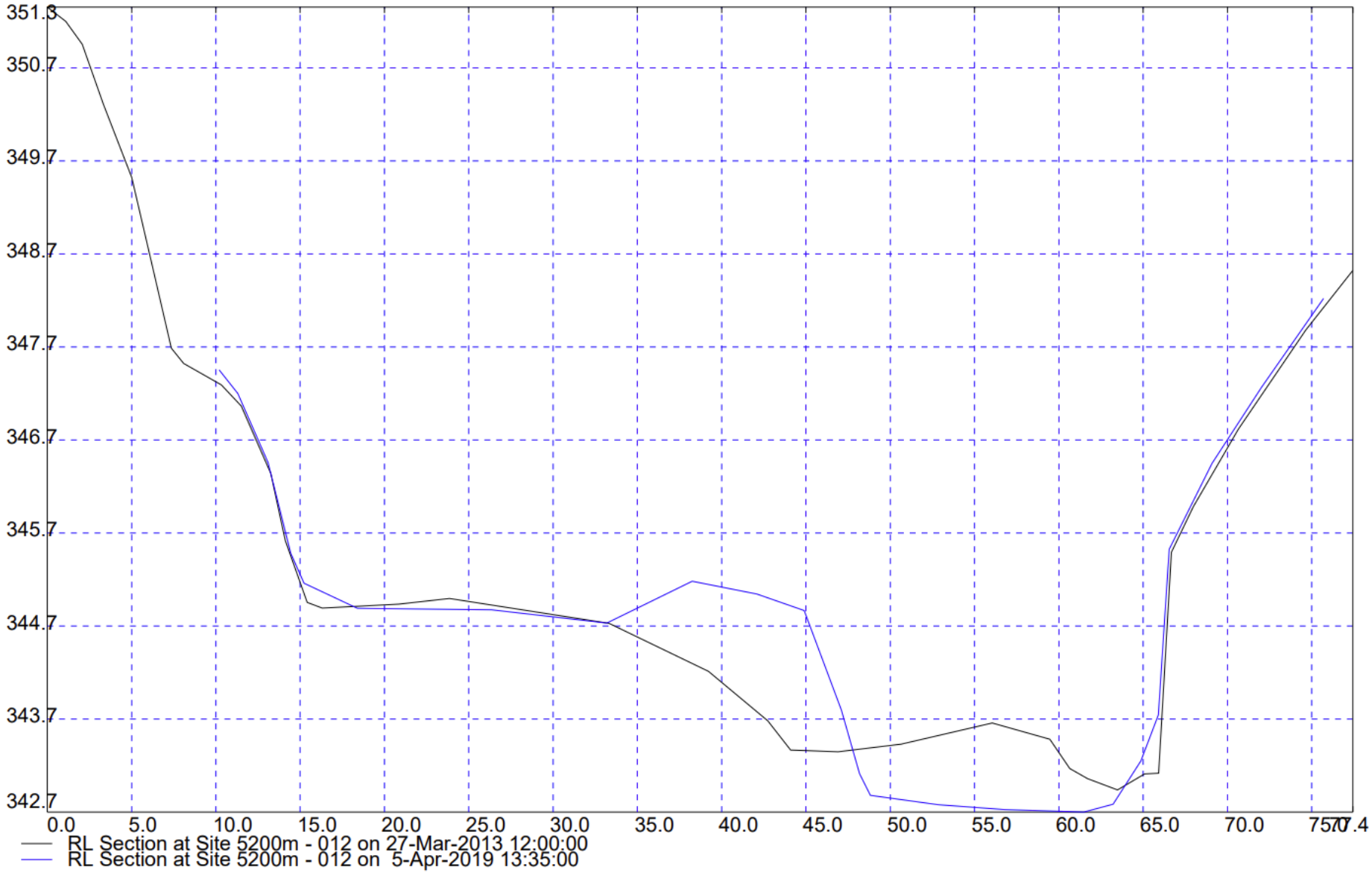

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56.6
61.6
66.6
71.6
76.6
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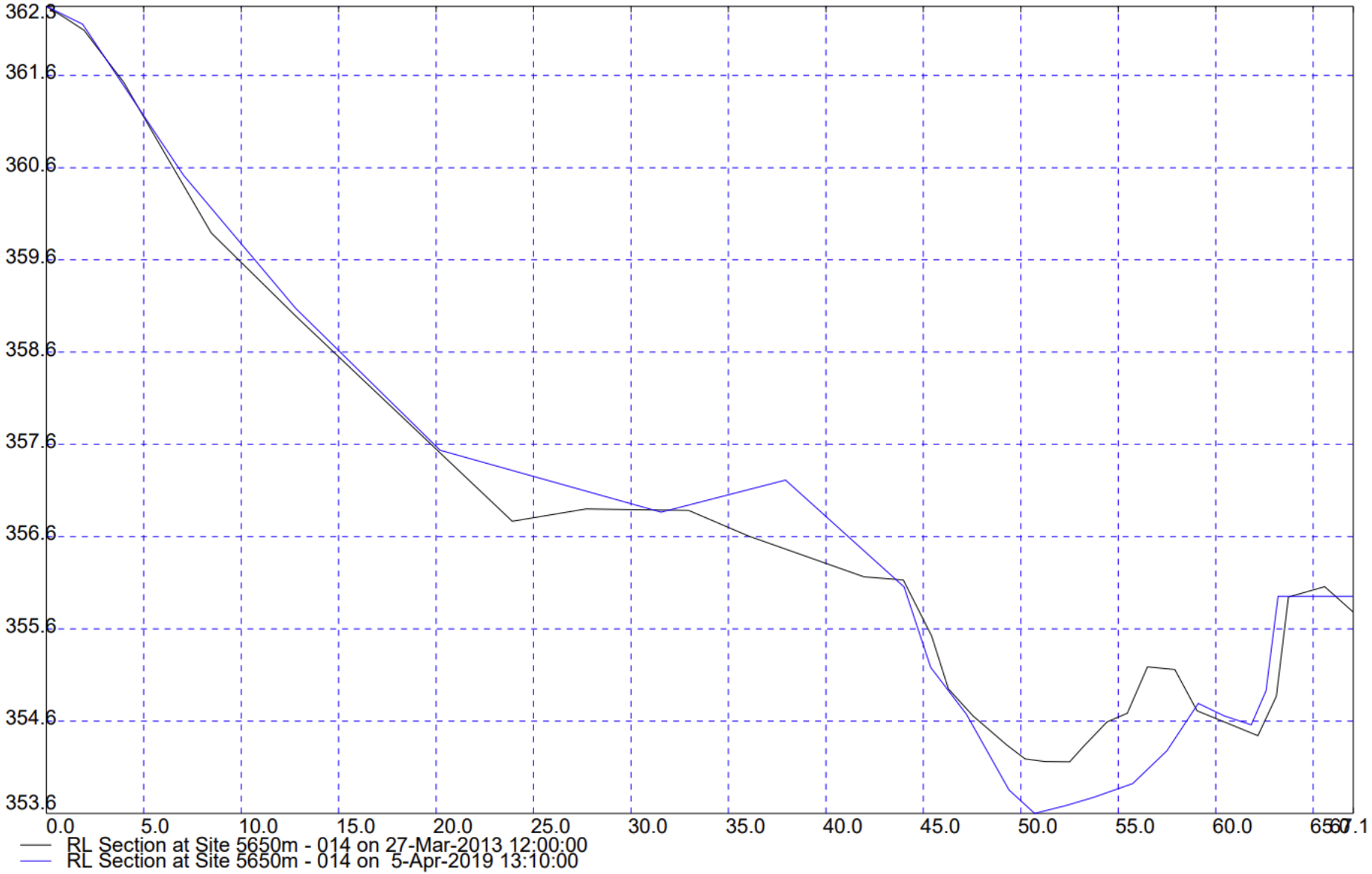

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58.1
63.1
68.1
73.1
78.1
83.1
88.1
91.7
RL Section at Site 3960m - 007 on 27-Mar-2013 12:00:00
RL Section at Site 3960m - 007 on 10-Apr-2019 12:00:00


335.6
334.6
333.6
332.6
331.6
330.6
329.6
328.6
327.6
326.6
325.6
324.6
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
RL Section at Site 4410m - 008 on 4-Apr-2013 12:00:00
RL Section at Site 4410m - 008 on 10-Apr-2019 12:00:00


343.6
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341.0
339.0
337.0
335.0
333.0
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329.0
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0
10
20
30
40
50
60
70
80
90
100
110
120
130
RL Section at Site 4460m - 009 on 4-Apr-2013 12:00:00
RL Section at Site 4460m - 009 on 10-Apr-2019 12:00:00


346.47
345.97
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340.47
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10.0
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35.0
40.0
45.0
50.0
55.0
RL Section at Site 5085m - 011 on 27-Mar-2013 12:00:00
RL Section at Site 5085m - 011 on 10-Apr-2019 12:00:00


351.8
350.7
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348.7
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346.7
345.7
344.7
343.7
342.7
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55.0
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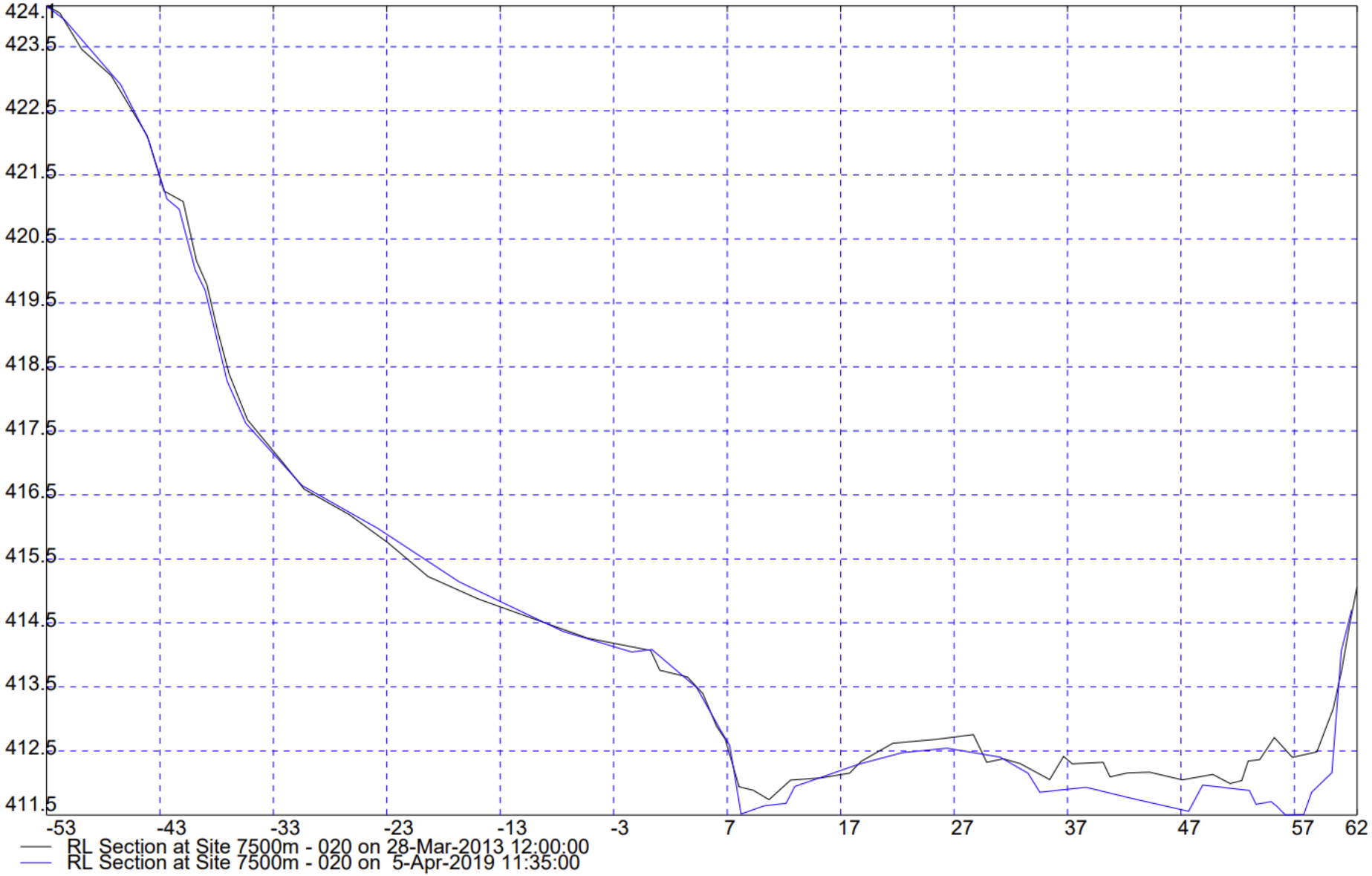

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RL Section at Site 5650m - 014 on 27-Mar-2013 12:00:00
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360.2
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358.2
357.2
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49.5
RL Section at Site 5800m - 015 on 27-Mar-2013 12:00:00
RL Section at Site 5800m - 015 on 5-Apr-2019 13:00:00


371.65
371.15
370.65
370.15
369.65
369.15
368.65
368.15
367.65
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366.65
366.15
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25.0
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RL Section at Site 6115m - 016 on 4-Apr-2019 13:25:00

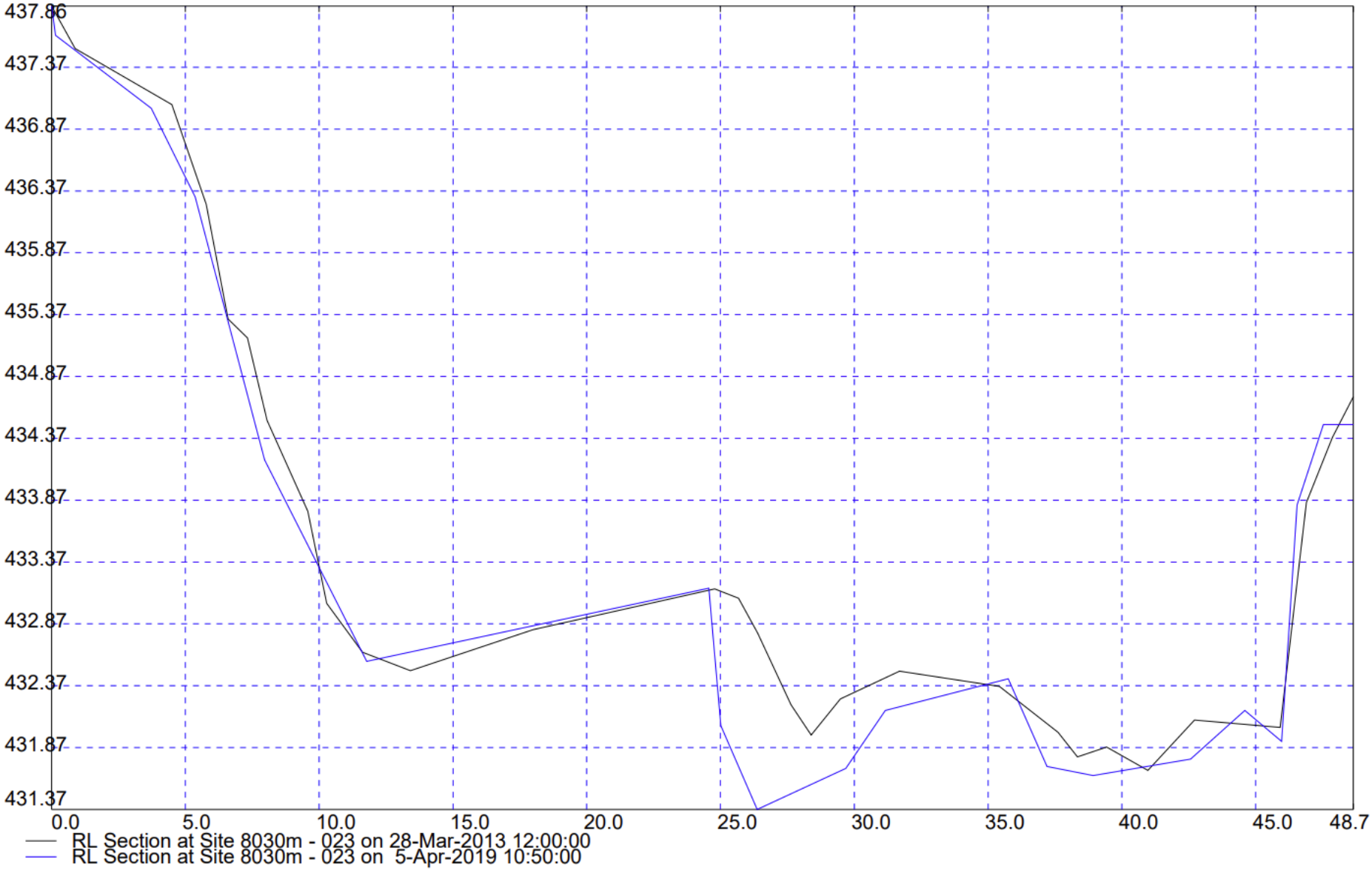

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RL Section at Site 6650m - 017 on 27-Mar-2013 12:00:00
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399.33
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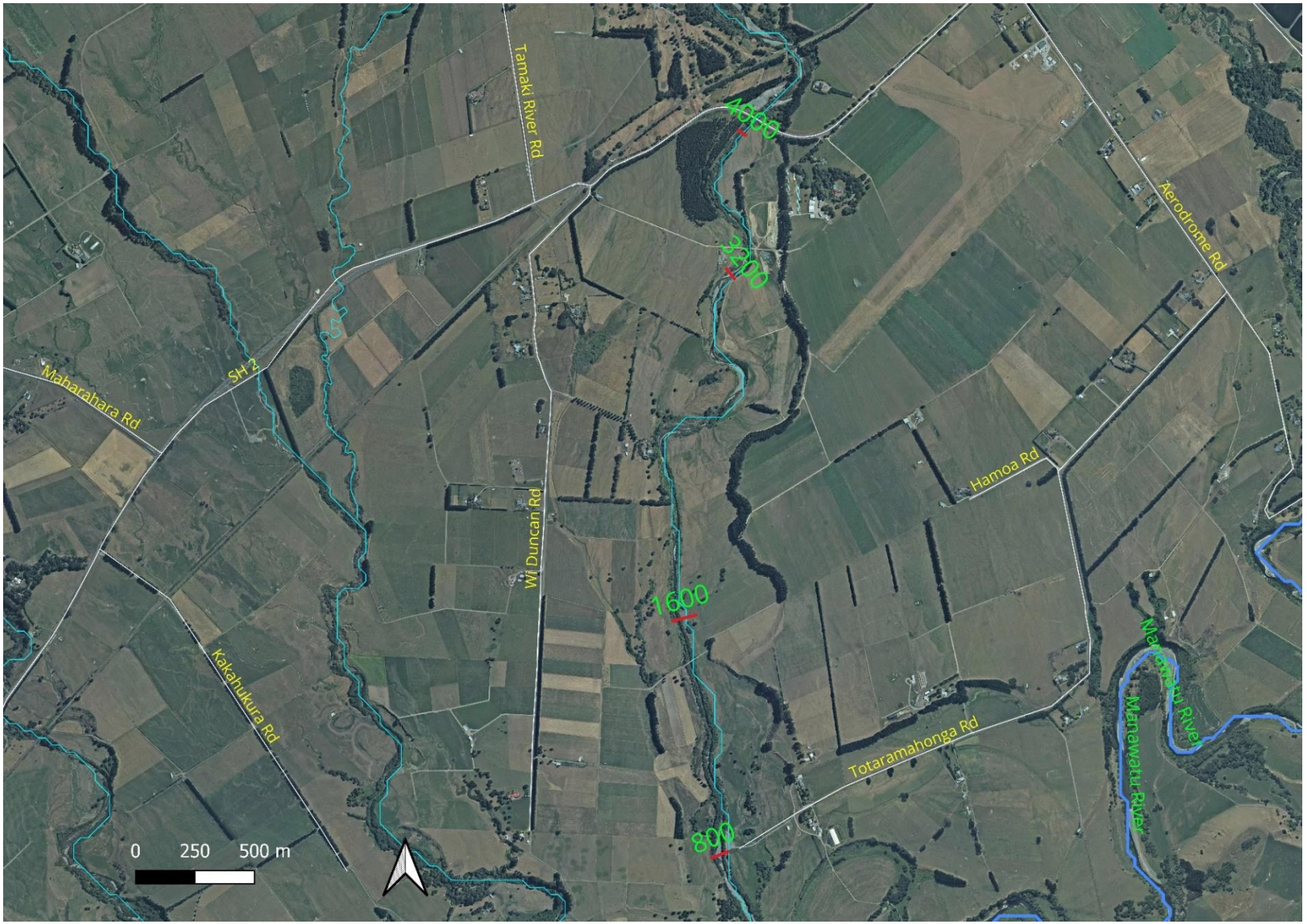

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413.5
412.5
411.5
-53
-43
-33
-23
-13
-3
7
17
27
37
47
57
62
RL Section at Site 7500m - 020 on 28-Mar-2013 12:00:00
RL Section at Site 7500m - 020 on 5-Apr-2019 11:35:00

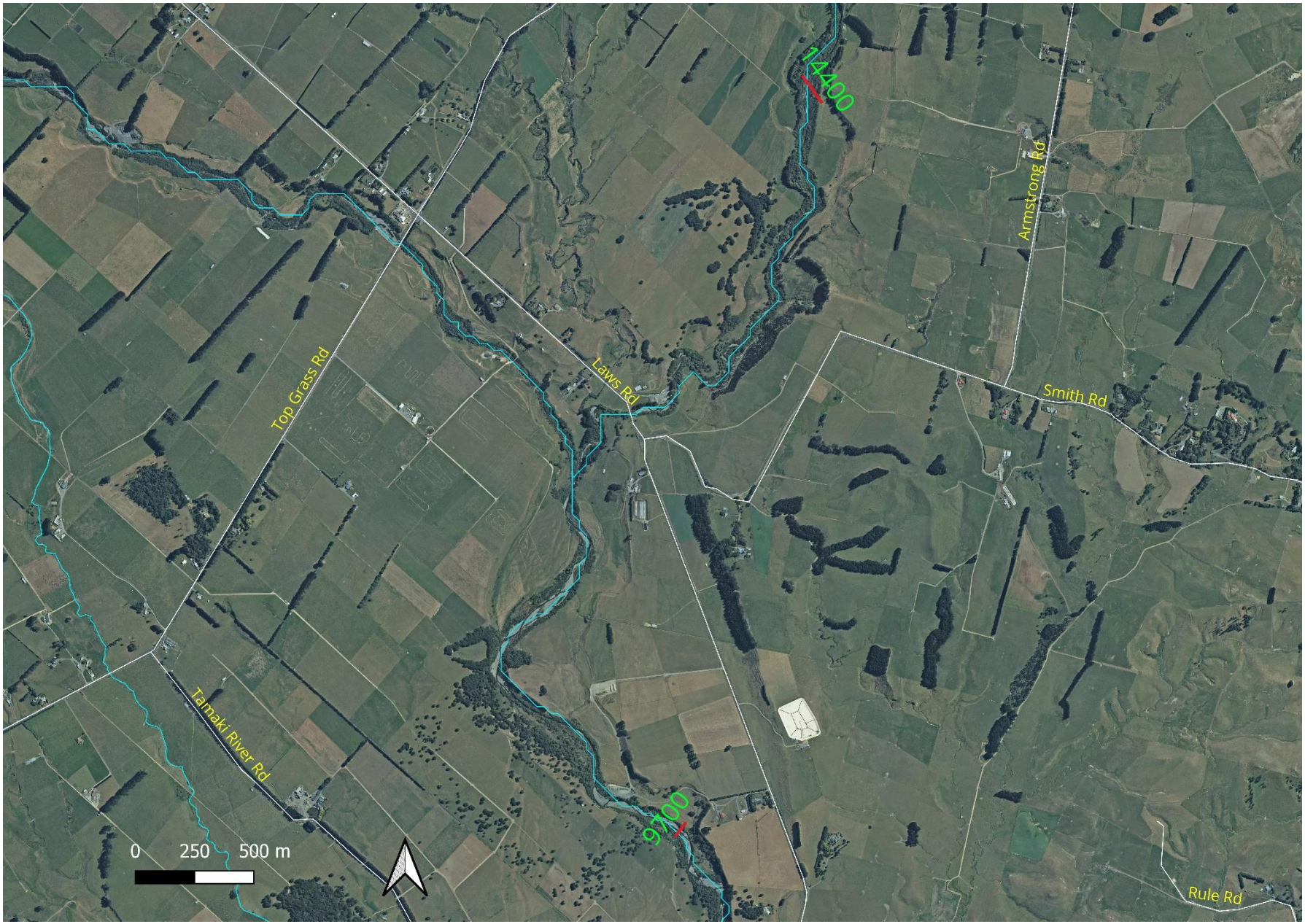

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RL Section at Site 7700m - 021 on 28-Mar-2013 12:00:00
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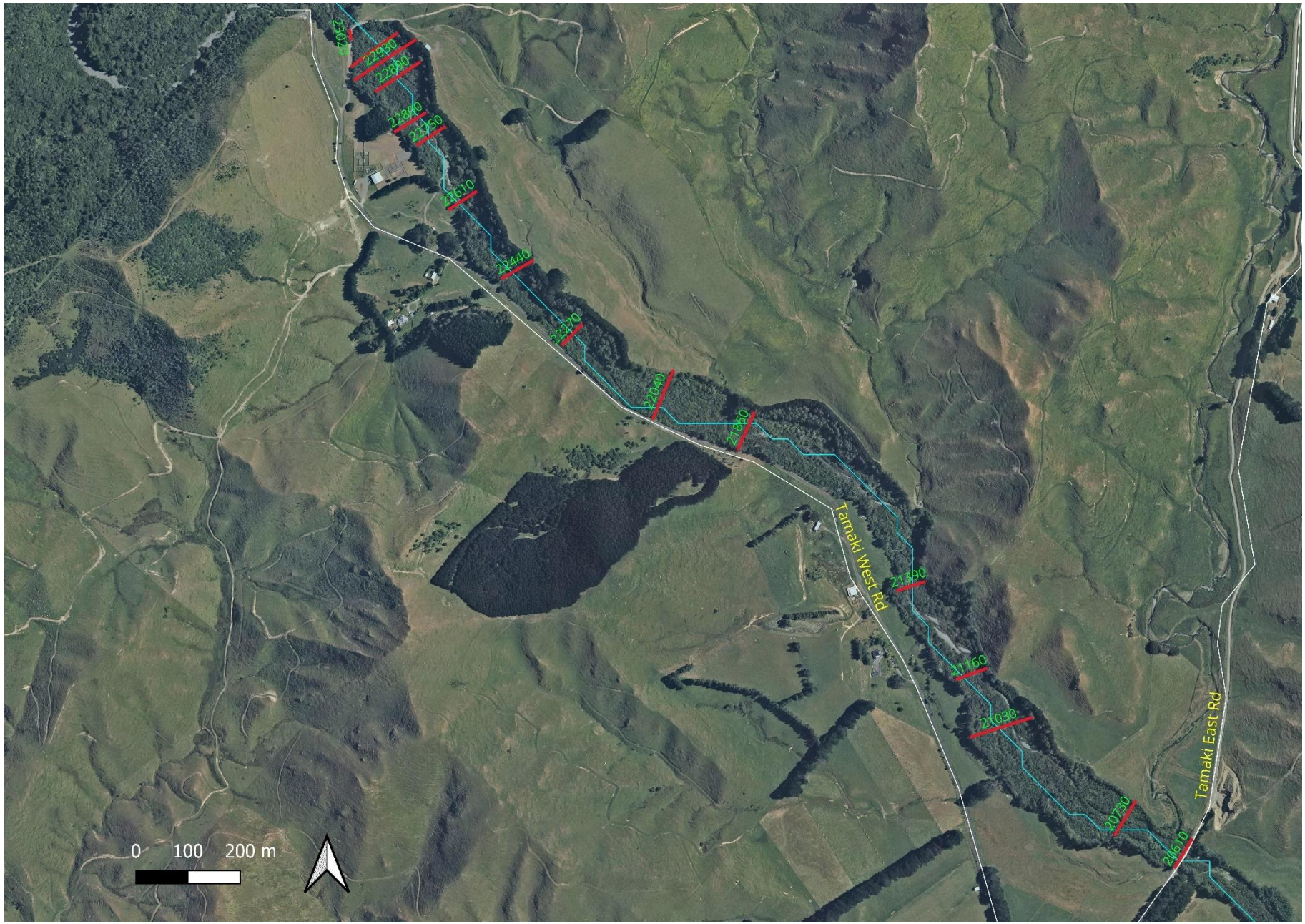

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35.0
40.0
43.9
RL Section at Site 7850m - 022 on 28-Mar-2013 12:00:00
RL Section at Site 7850m - 022 on 5-Apr-2019 11:00:00


437.86
437.37
436.87
436.37
435.87
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434.87
434.37
433.87
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432.37
431.87
431.37
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30.0
35.0
40.0
45.0
48.7
RL Section at Site 8030m - 023 on 28-Mar-2013 12:00:00
RL Section at Site 8030m - 023 on 5-Apr-2019 10:50:00

Appendix I1: Tamaki cross section locations




14400
9700
Armstrong Rd
Smith Rd
Laws Rd
Top Grass Rd
Tamaki River Rd
Rule Rd
0 250 500 m


22350
22890
22890
22750
22610
22440
22170
22040
21860
Tamaki West Rd
21390
21160
21030
20730
20610
Tamaki East Rd
0 100 200 m

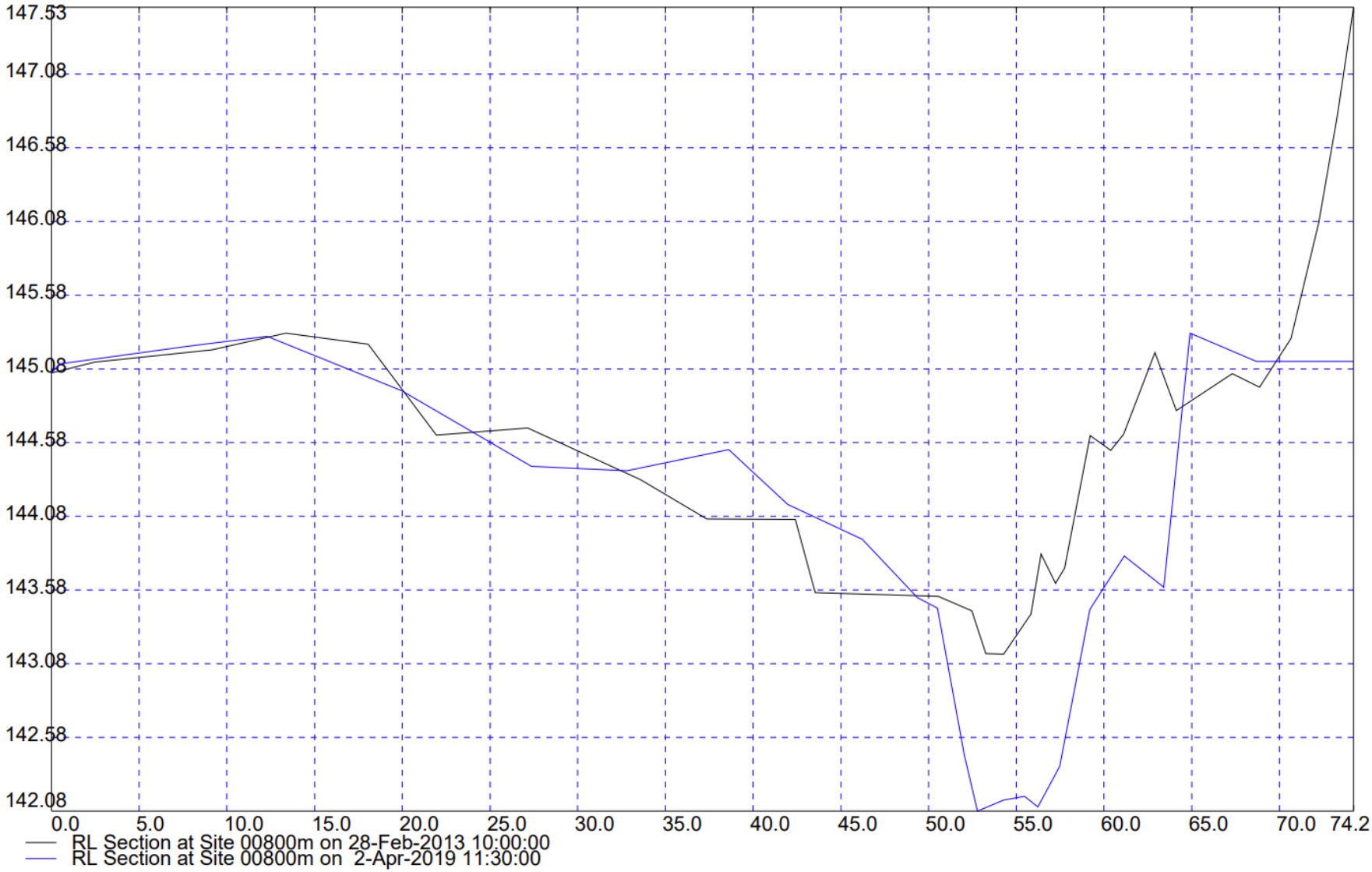
Appendix I2: Tamaki Mean Bed Level Data (2013 – 2019)

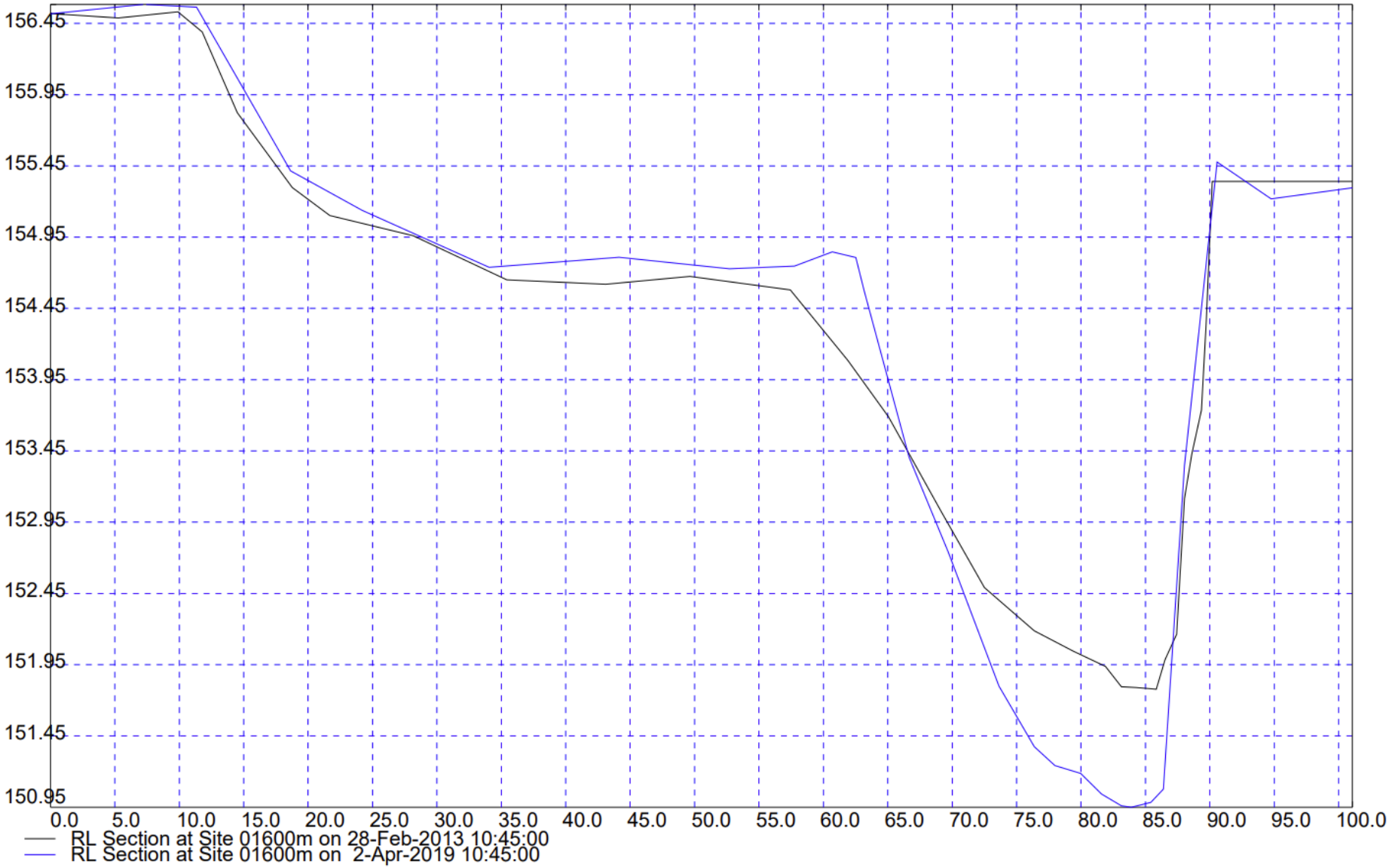
Tamaki Mean Bed Level Change					
Cross Section	Left Extent	Right Extent	MBL 2013	MBL 2019/2020	MBL change (2019/2020 - 2013)
800	20	65	144.143	143.903	-0.24
1600	62.5	90	152.641	152.278	-0.363
3200	11.9	41.1	167.585	167.042	-0.543
4000	11	26.5	174.287	174.093	-0.194
9700	10.5	38.3	228.016	227.502	-0.514
14400	50	80	275.199	274.83	-0.369
20610	11.9	35	335.741	335.206	-0.535
20730	42.5	53	338.179	338.159	-0.02
21030	28	46.6	344.165	344.041	-0.124
21160	8	30.2	346.587	346.289	-0.298
21390	23	38	350.525	350.08	-0.445
21860	40	58.4	360.792	360.446	-0.346
22040	56.4	66.1	364.427	364.386	-0.041
22270	68.6	77.75	368.782	368.041	-0.741
22440	46.2	59.2	372.251	372.5	0.249
22610	43.5	55.2	376.088	376.015	-0.073
22750	32.1	64.95	383.484	383.677	0.193
22800	44	60.64	384.442	384.514	0.072
22890	55.8	72	386.228	386.652	0.424
22930	70.4	81	386.862	387.051	0.189
22960	67.1	78.15	387.21	387.532	0.322
23020	7	13	388.266	388.433	0.167

Appendix I3: Tamaki Change in Gravel Volume (2013 – 2019)

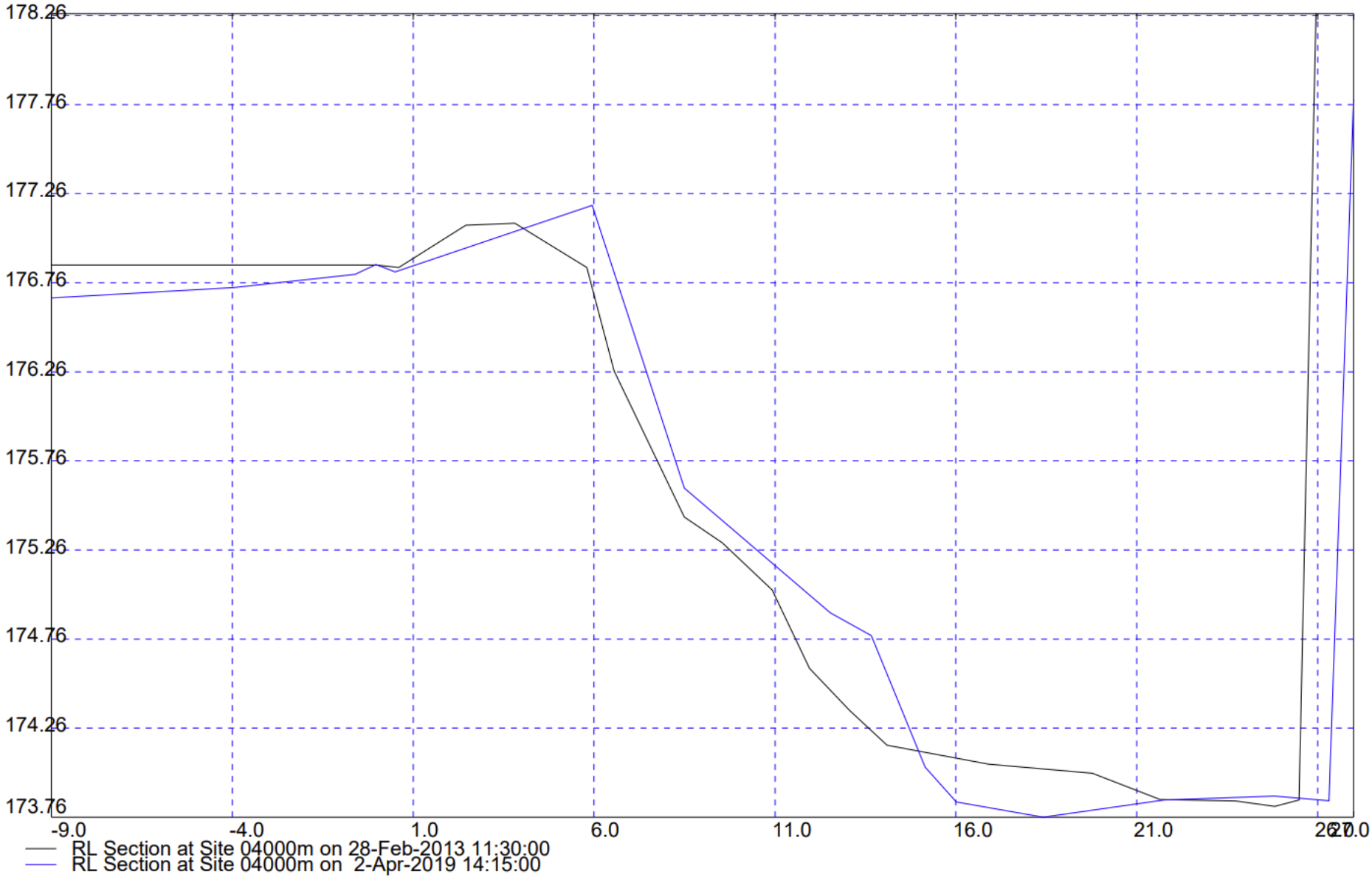
Tamaki Change in Gravel Volume						
Cross Section	Left Extent	Right Extent	Datum=0	Area under section 2013	Area under section 2019/2020	Change in volume 2013 - 2019 / 2020
800	35	74.2	0	5656.5	5643.1	-10720
1600	50	100	0	7682.2	7675.2	-5600
3200	4.8	49.8	0	7594.7	7577.6	-13680
4000	5	26.9	0	3827.8	3825.5	-7475
9700	2.9	42.9	0	9136.7	9123.1	-54400
14400	40	85	0	12390.5	12371.9	-29760
20610	5	45	0	13445.2	13431.9	-20814.5
20730	15	74.5	0	20146.6	20150.6	840
21030	10	63	0	18261.9	18259.3	-559
21160	5.2	40.2	0	12145.4	12131.6	-2484
21390	6.5	51.5	0	15789.2	15778.6	-2438
21860	25	63	0	13718	13707.6	-2184
22040	45	75	0	10960.4	10959.7	-143.5
22270	60	79	0	7023.9	7012.5	-2280
22440	38	63	0	9334.5	9338.2	629
22610	30.2	70.2	0	15116.2	15114.6	-168
22750	27.1	67.1	0	15341.8	15349.6	585
22800	35	67.2	0	12380.7	12387	441
22890	40.8	85.8	0	17399.6	17409.7	656.5
22930	51	101	0	19391.8	19401.1	325.5
22960	55.8	90.8	0	13593.8	13598.1	193.5
23020	1	15.3	0	5572.8	5574.7	114

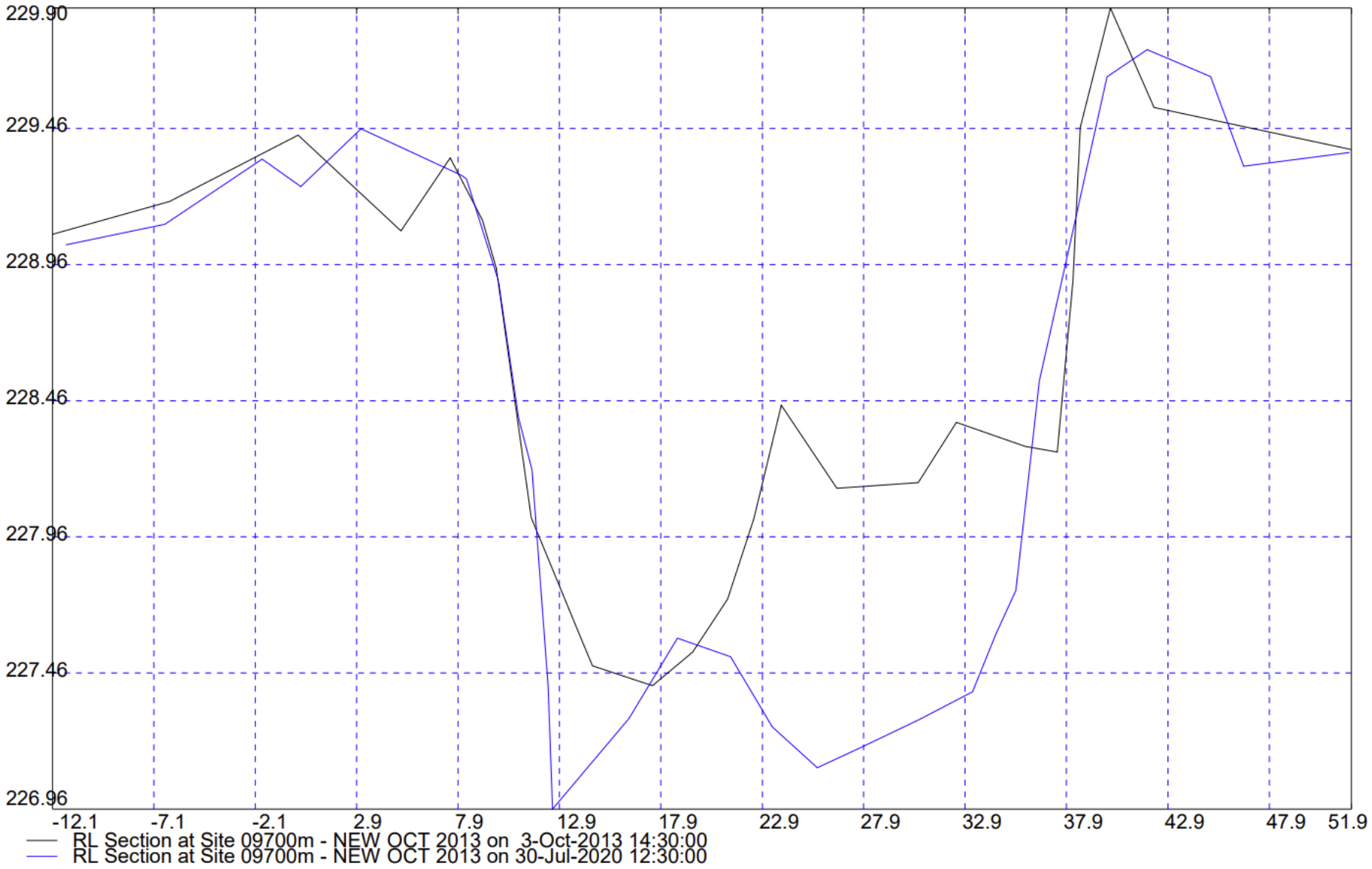
Appendix I4: Cross-sections at Tamaki River

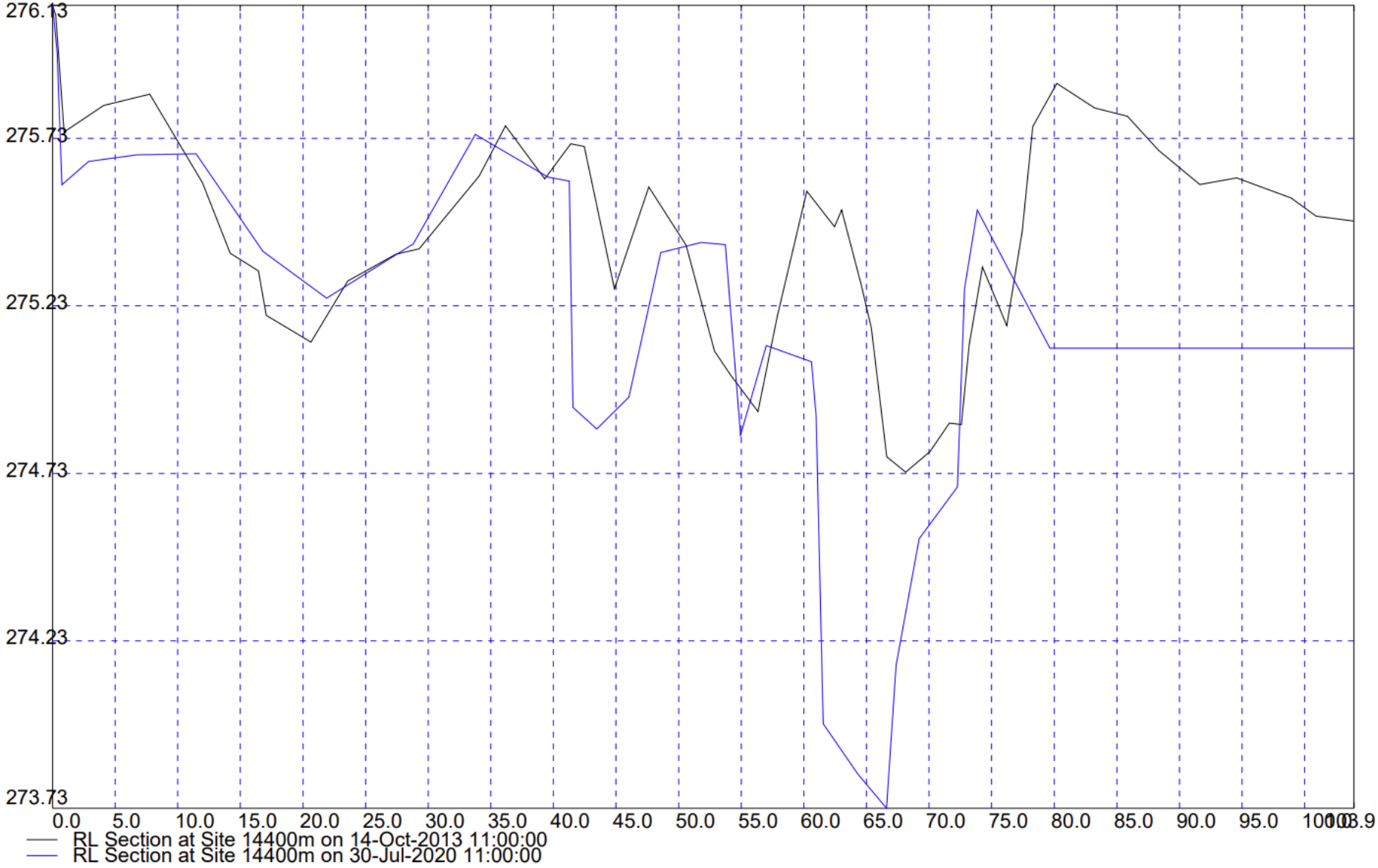


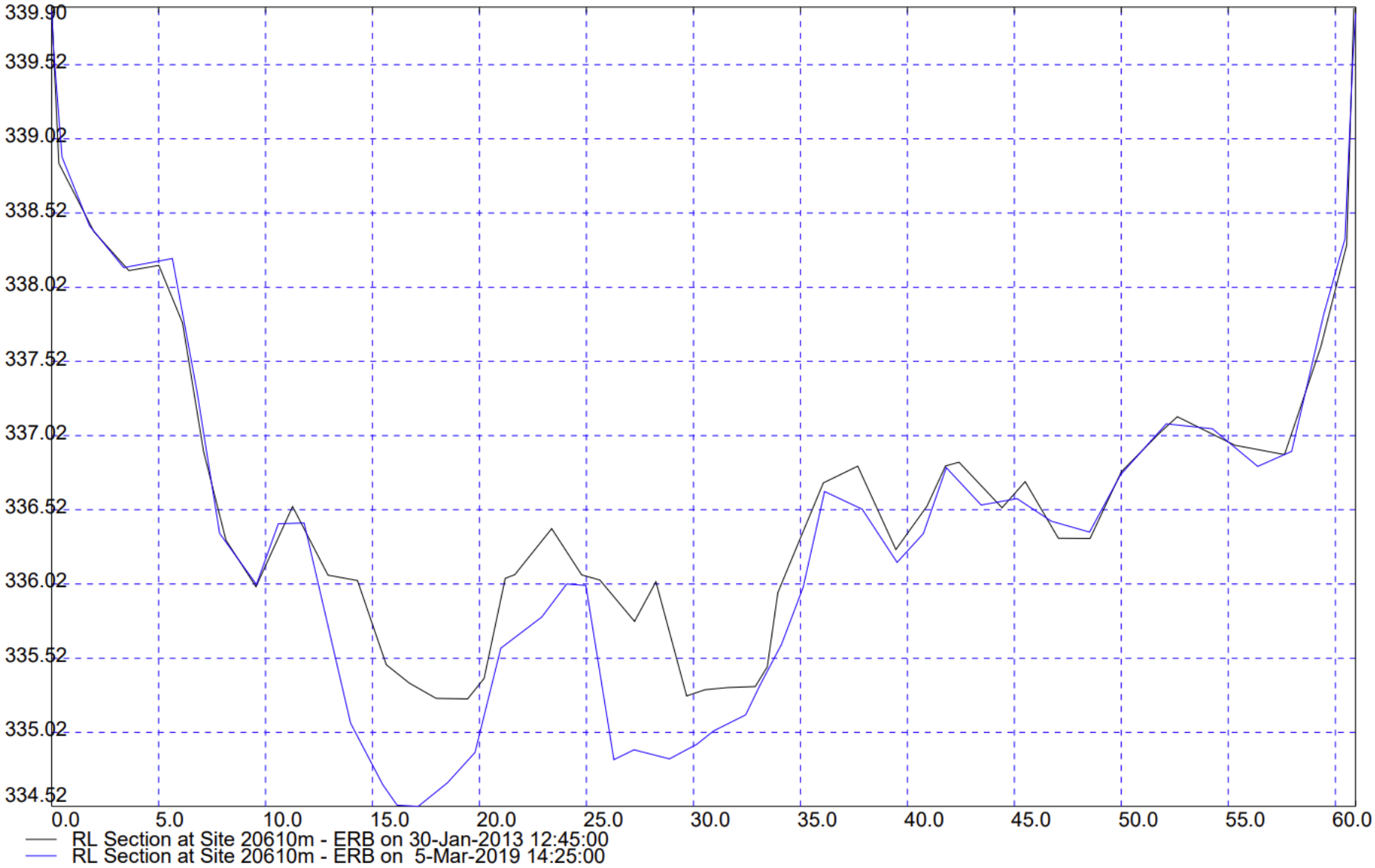

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60.0
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RL Section at Site 01600m on 28-Feb-2013 10:45:00
RL Section at Site 01600m on 2-Apr-2019 10:45:00

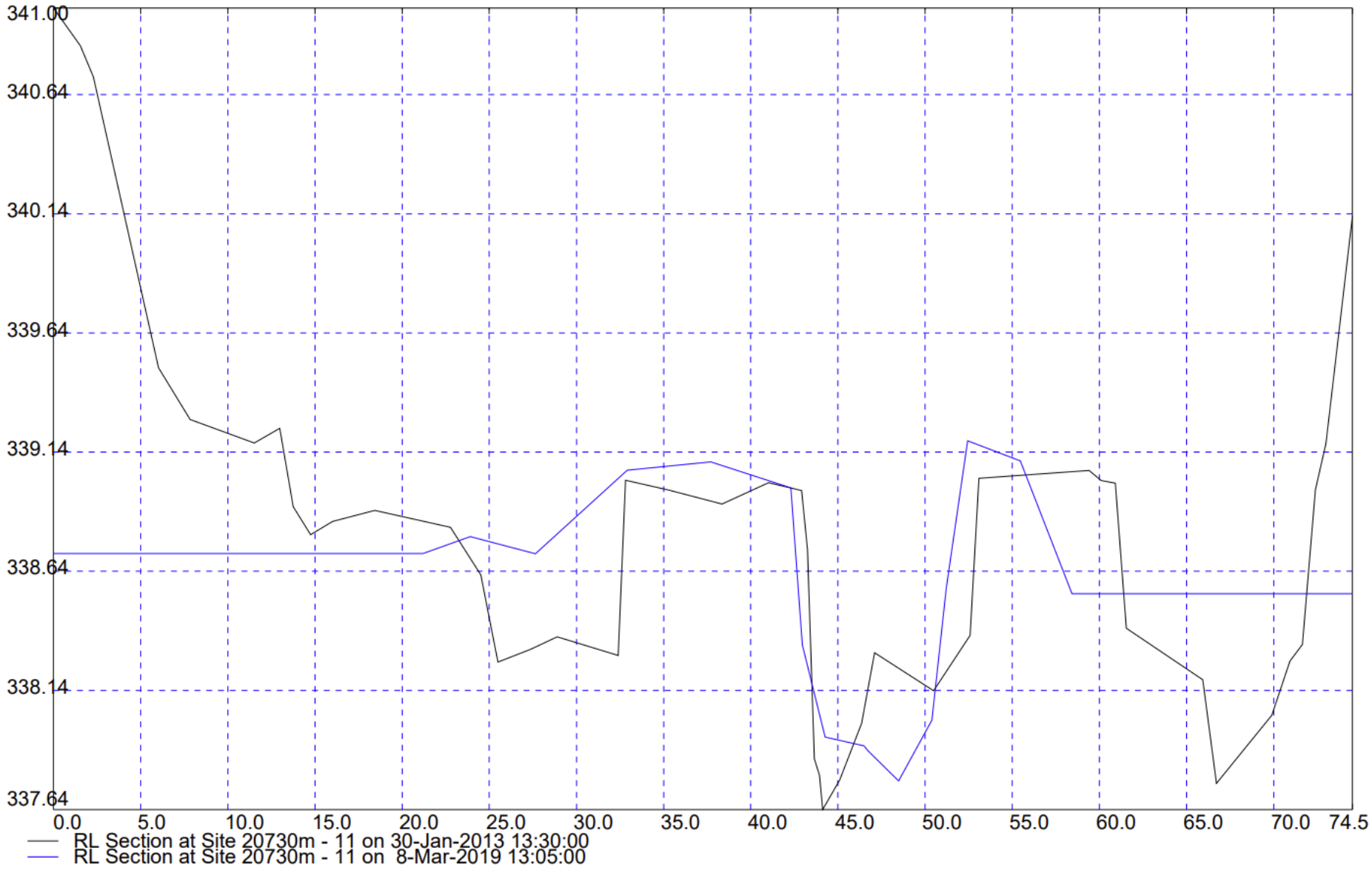

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167.01
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-0.2
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9.8
14.8
19.8
24.8
29.8
34.8
39.8
44.8
49.8 52.4
RL Section at Site 03200m - NEW OCT 2013 on 1-Oct-2013 11:00:00
RL Section at Site 03200m - NEW OCT 2013 on 2-Apr-2019 12:55:00

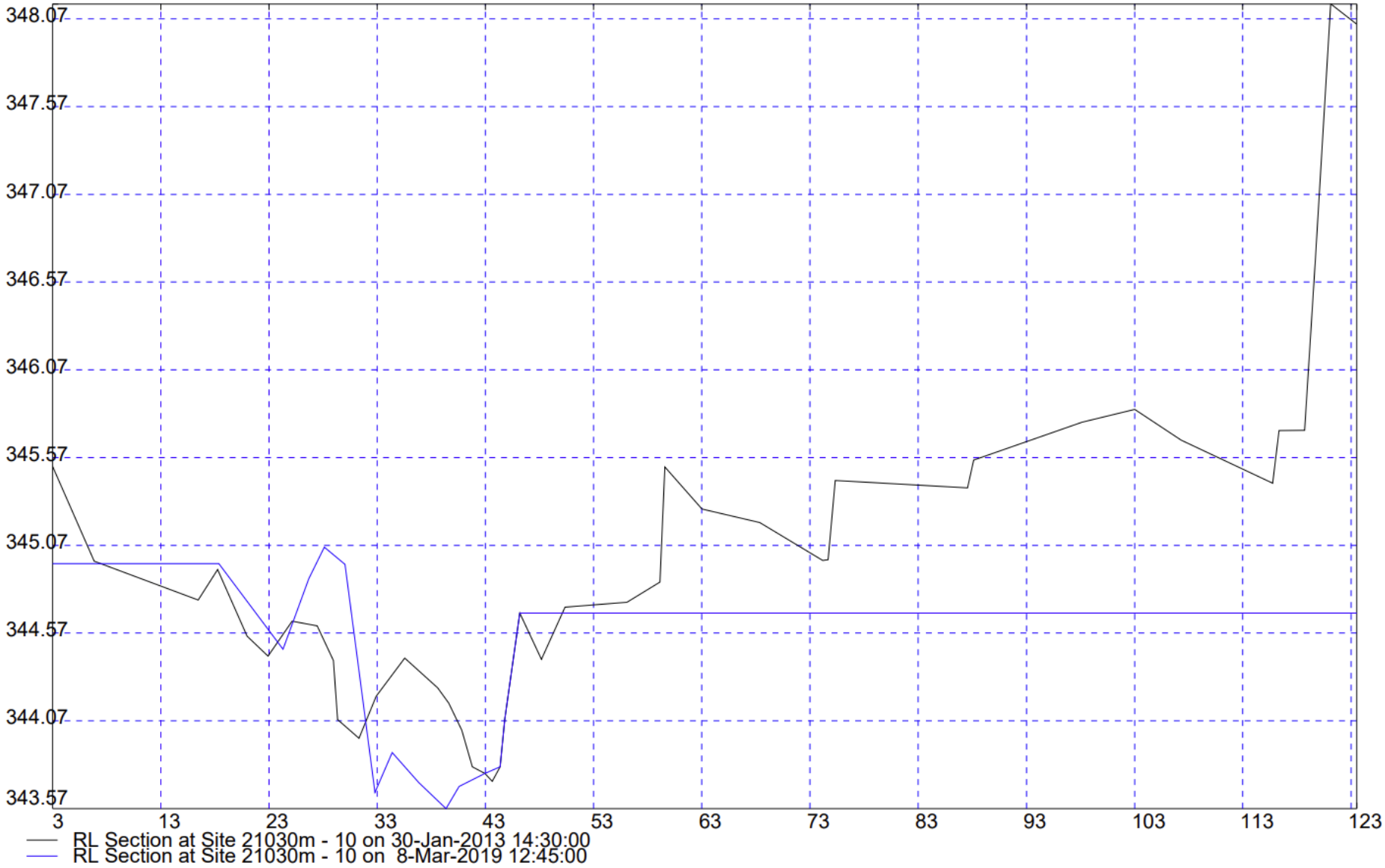

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-4.0
1.0
6.0
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RL Section at Site 04000m on 2-Apr-2019 14:15:00

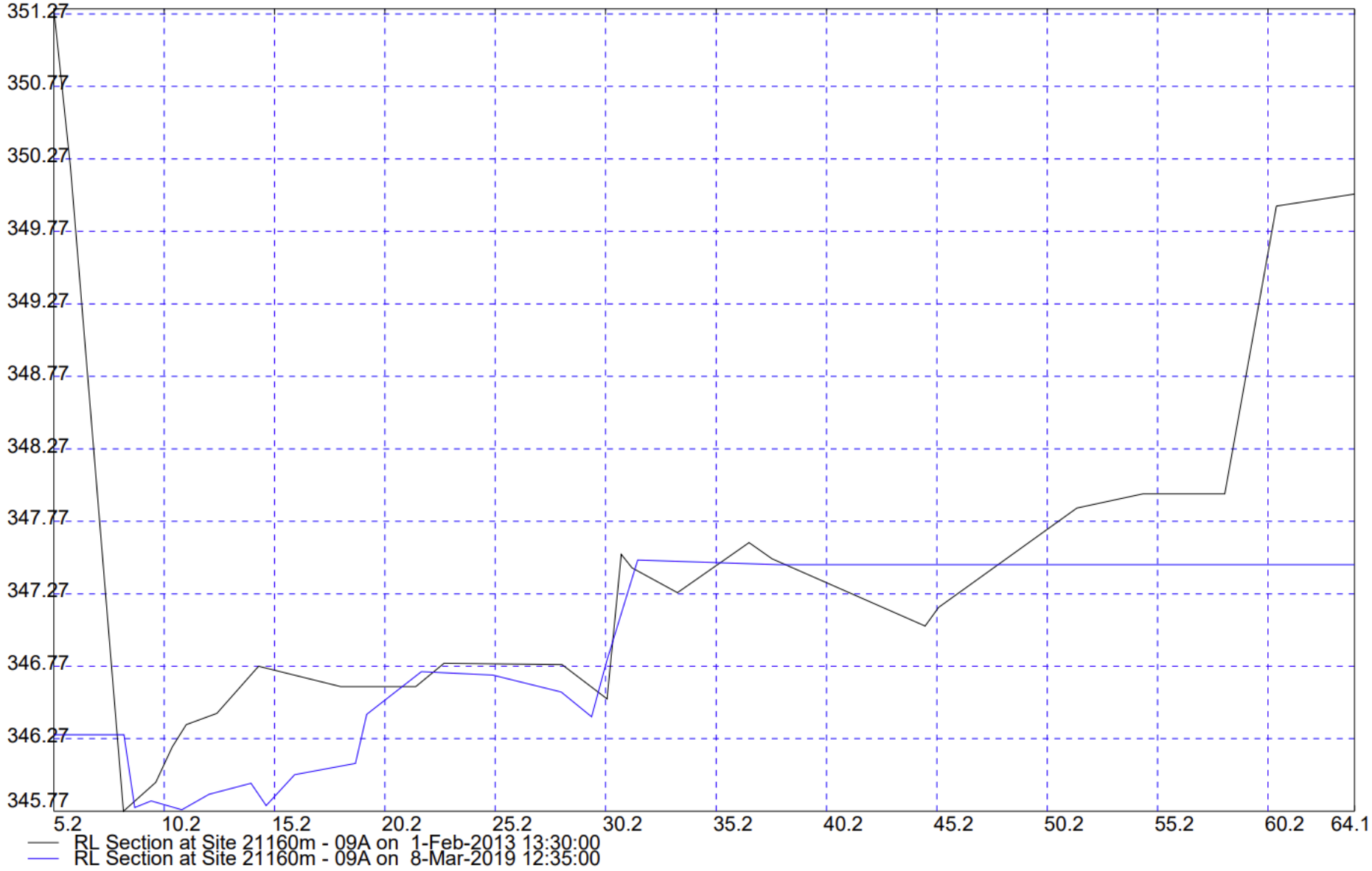

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7.9
12.9
17.9
22.9
27.9
32.9
37.9
42.9
47.9
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RL Section at Site 09700m - NEW OCT 2013 on 3-Oct-2013 14:30:00
RL Section at Site 09700m - NEW OCT 2013 on 30-Jul-2020 12:30:00

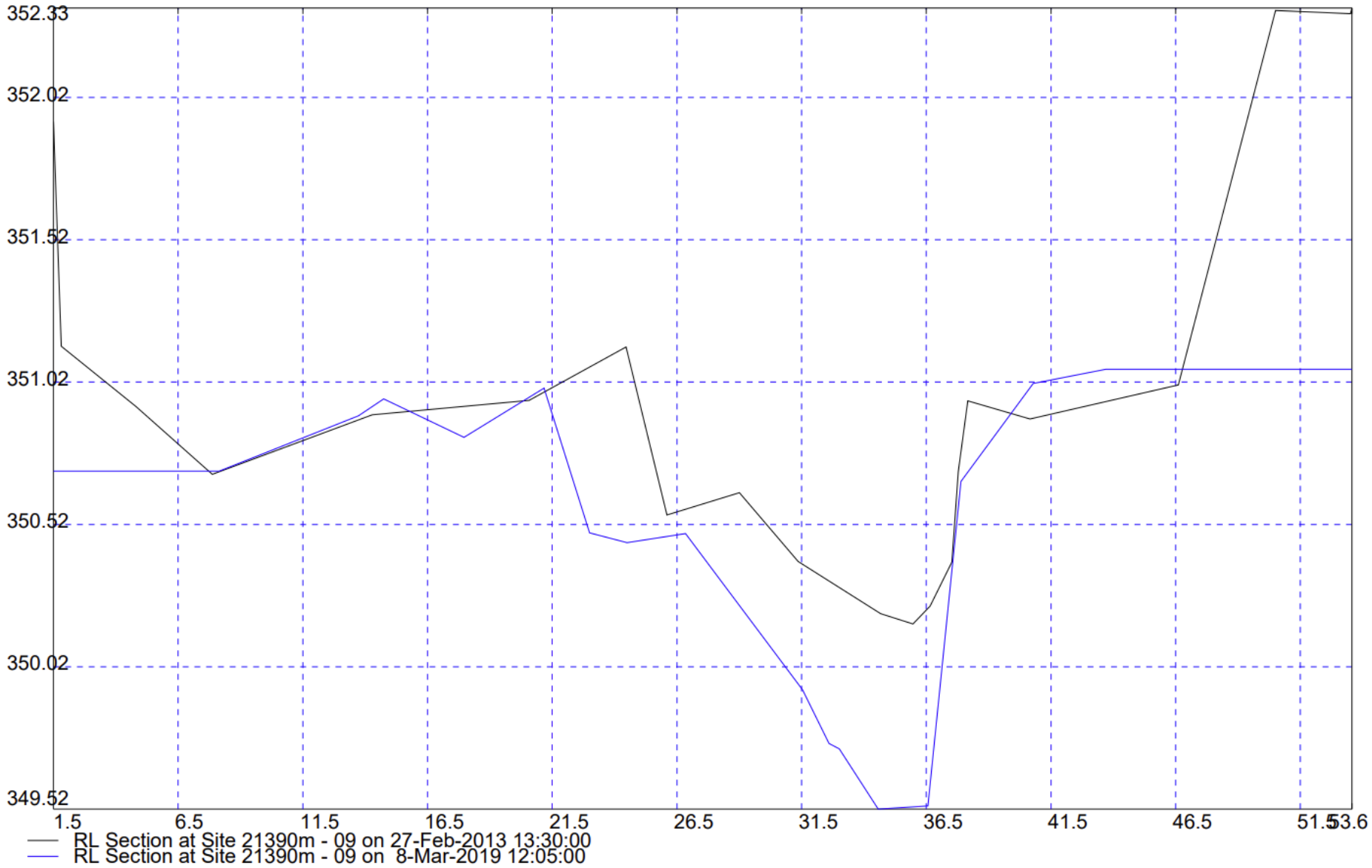

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RL Section at Site 14400m on 14-Oct-2013 11:00:00
RL Section at Site 14400m on 30-Jul-2020 11:00:00


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RL Section at Site 20610m - ERB on 5-Mar-2019 14:25:00

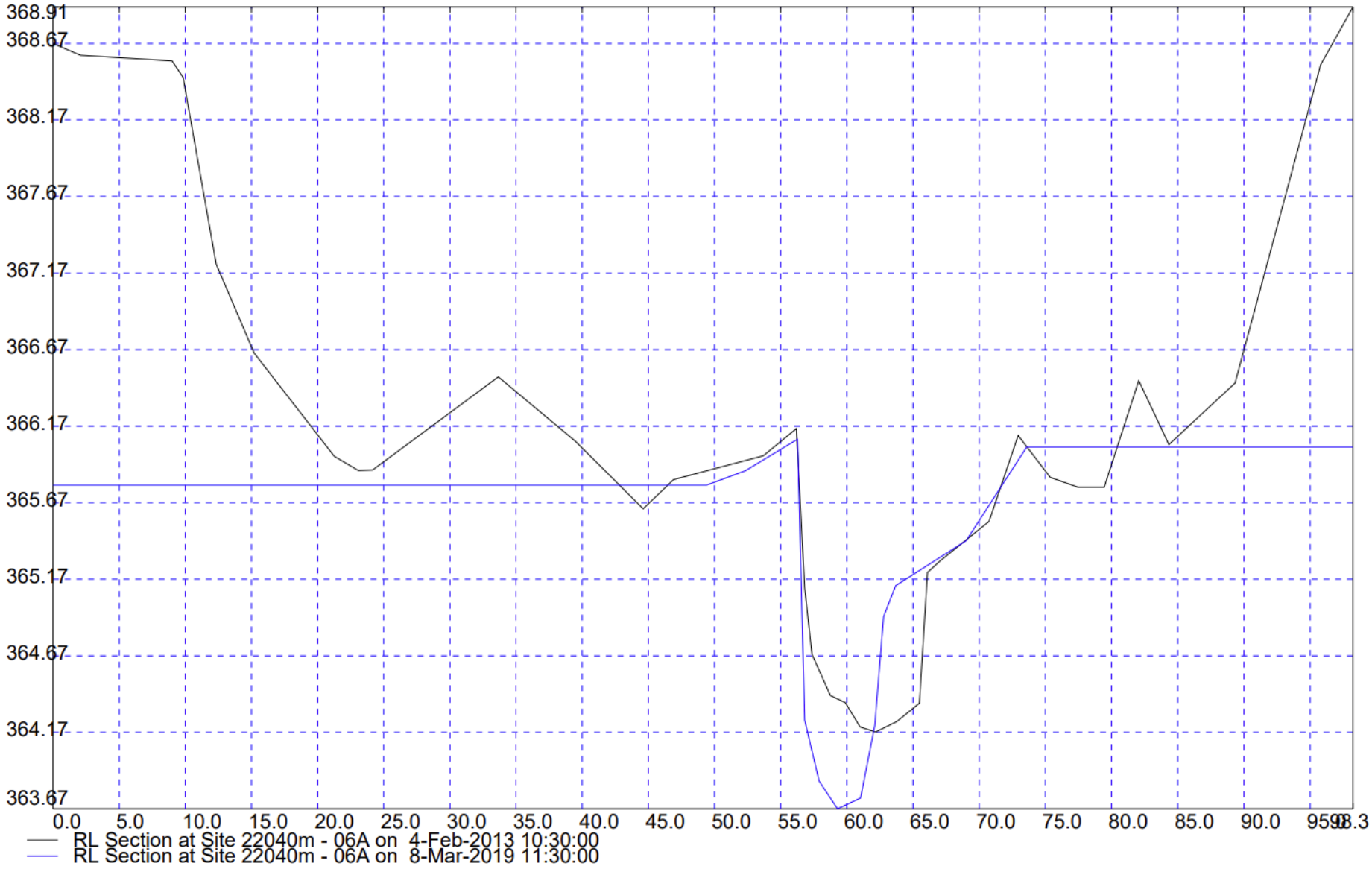

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25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
74.5
RL Section at Site 20730m - 11 on 30-Jan-2013 13:30:00
RL Section at Site 20730m - 11 on 8-Mar-2019 13:05:00


348.07
347.57
347.07
346.57
346.07
345.57
345.07
344.57
344.07
343.57
3
13
23
33
43
53
63
73
83
93
103
113
123
RL Section at Site 21030m - 10 on 30-Jan-2013 14:30:00
RL Section at Site 21030m - 10 on 8-Mar-2019 12:45:00


351.27
350.77
350.27
349.77
349.27
348.77
348.27
347.77
347.27
346.77
346.27
345.77
5.2
10.2
15.2
20.2
25.2
30.2
35.2
40.2
45.2
50.2
55.2
60.2
64.1
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RL Section at Site 21160m - 09A on 8-Mar-2019 12:35:00

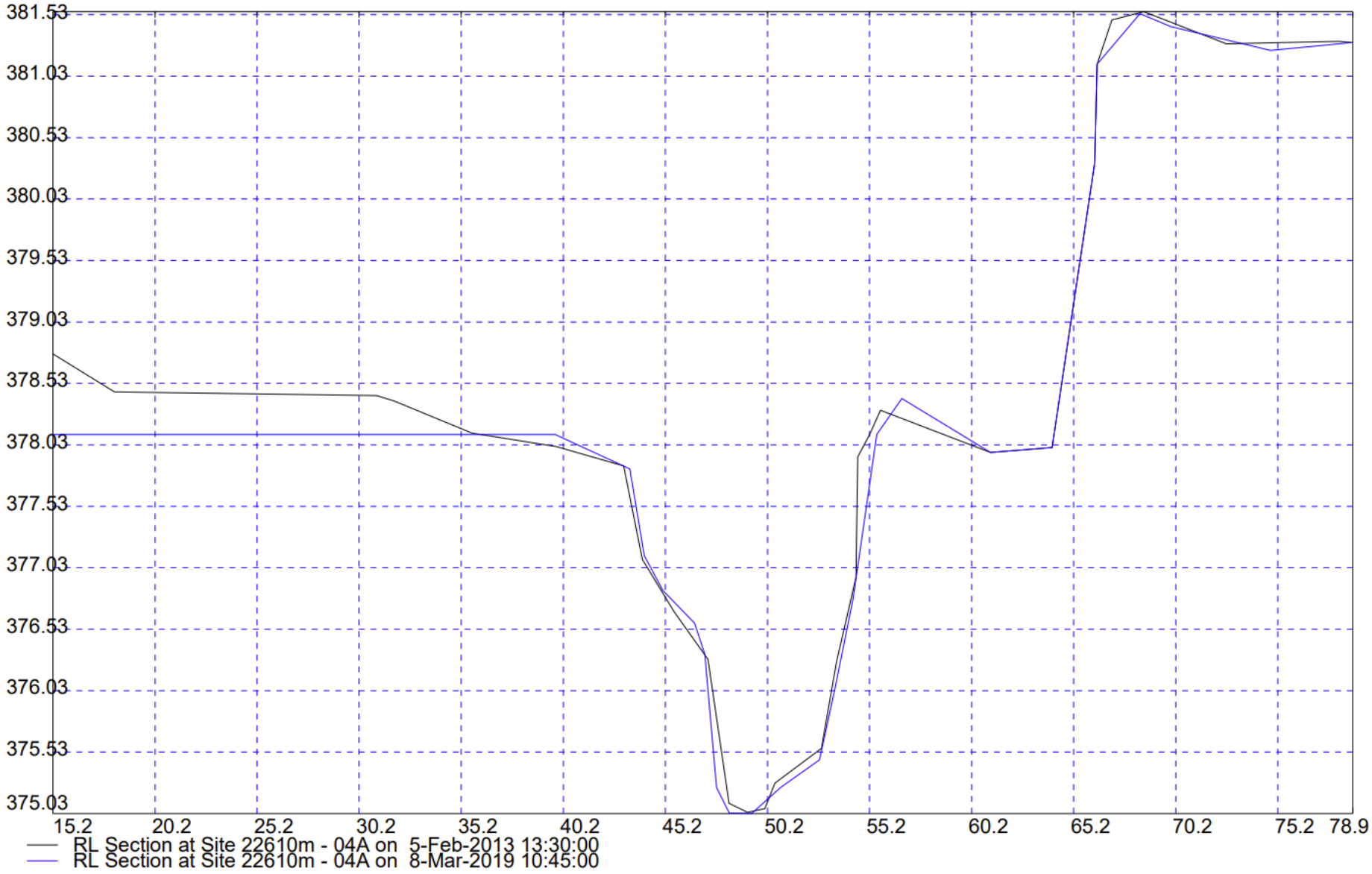

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351.52
351.02
350.52
350.02
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1.5
6.5
11.5
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21.5
26.5
31.5
36.5
41.5
46.5
51.5
53.6
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RL Section at Site 21390m - 09 on 8-Mar-2019 12:05:00

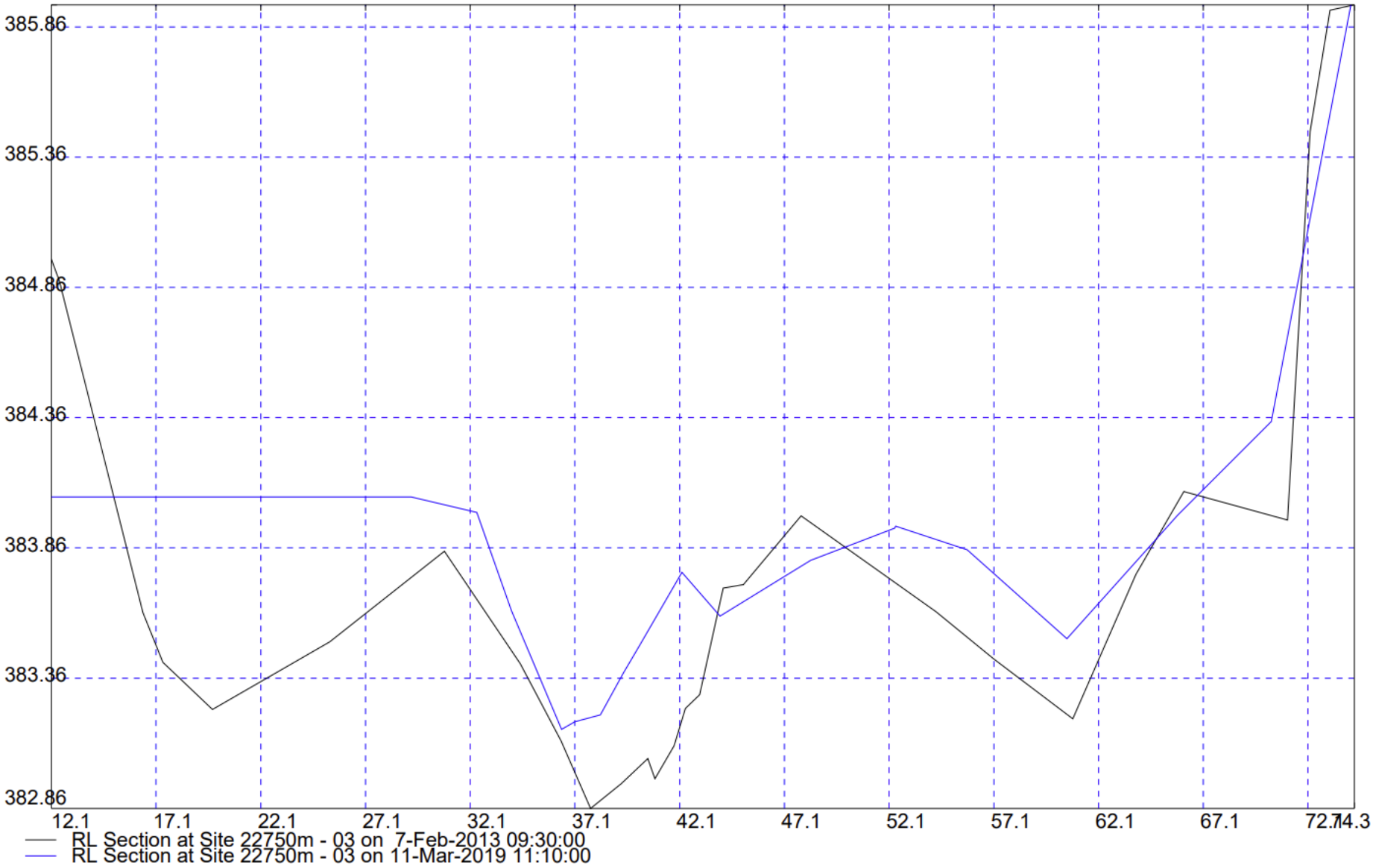

366.8
365.8
364.8
363.8
362.8
361.8
360.8
359.8
-7.3
-2.3
2.7
7.7
12.7
17.7
22.7
27.7
32.7
37.7
42.7
47.7
52.7
57.7
62.7
67.7
RL Section at Site 21860m - 07 on 4-Feb-2013 10:00:00
RL Section at Site 21860m - 07 on 8-Mar-2019 11:40:00

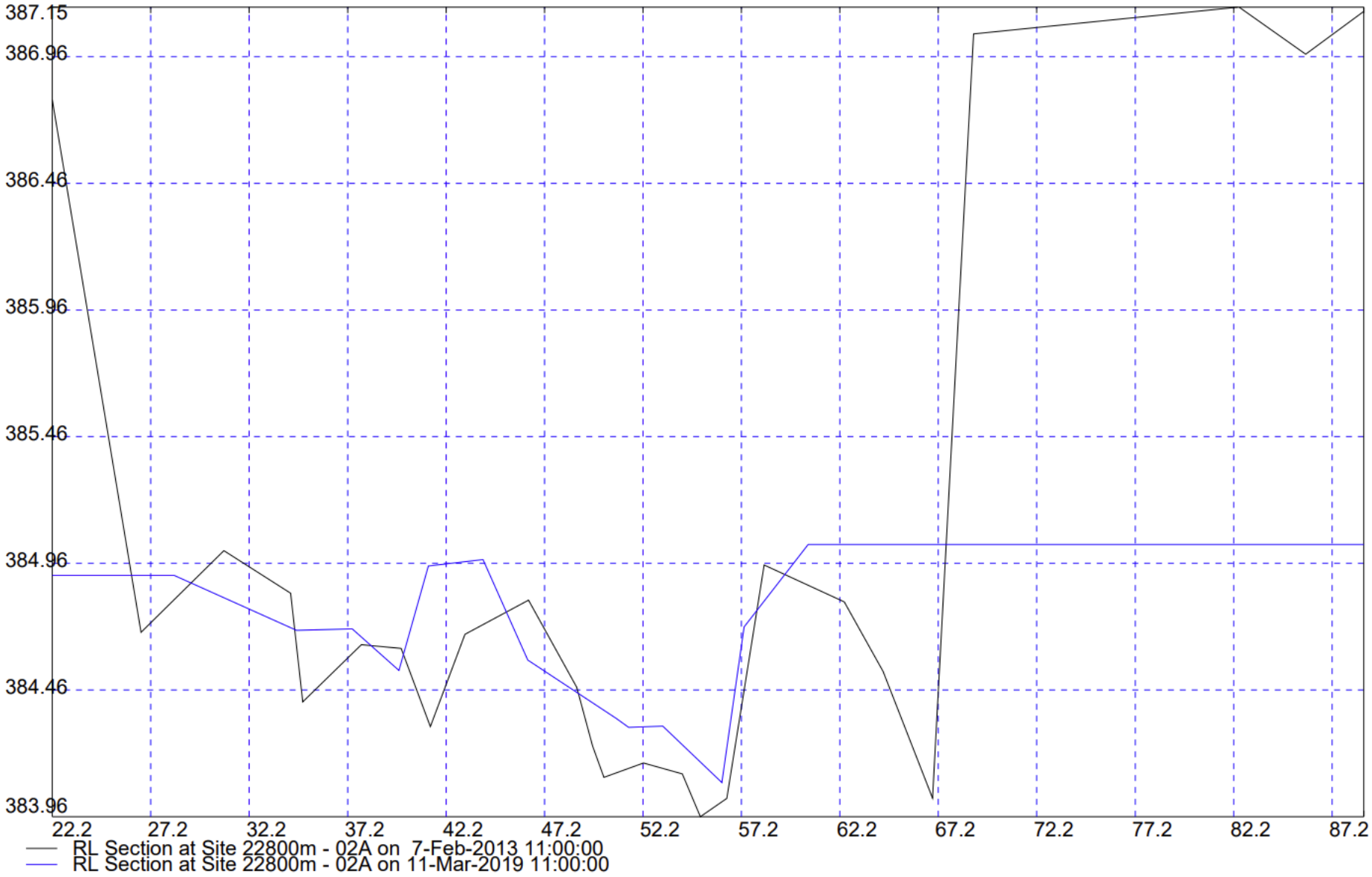

368.91
368.67
368.17
367.67
367.17
366.67
366.17
365.67
365.17
364.67
364.17
363.67
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
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55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
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RL Section at Site 22040m - 06A on 4-Feb-2013 10:30:00
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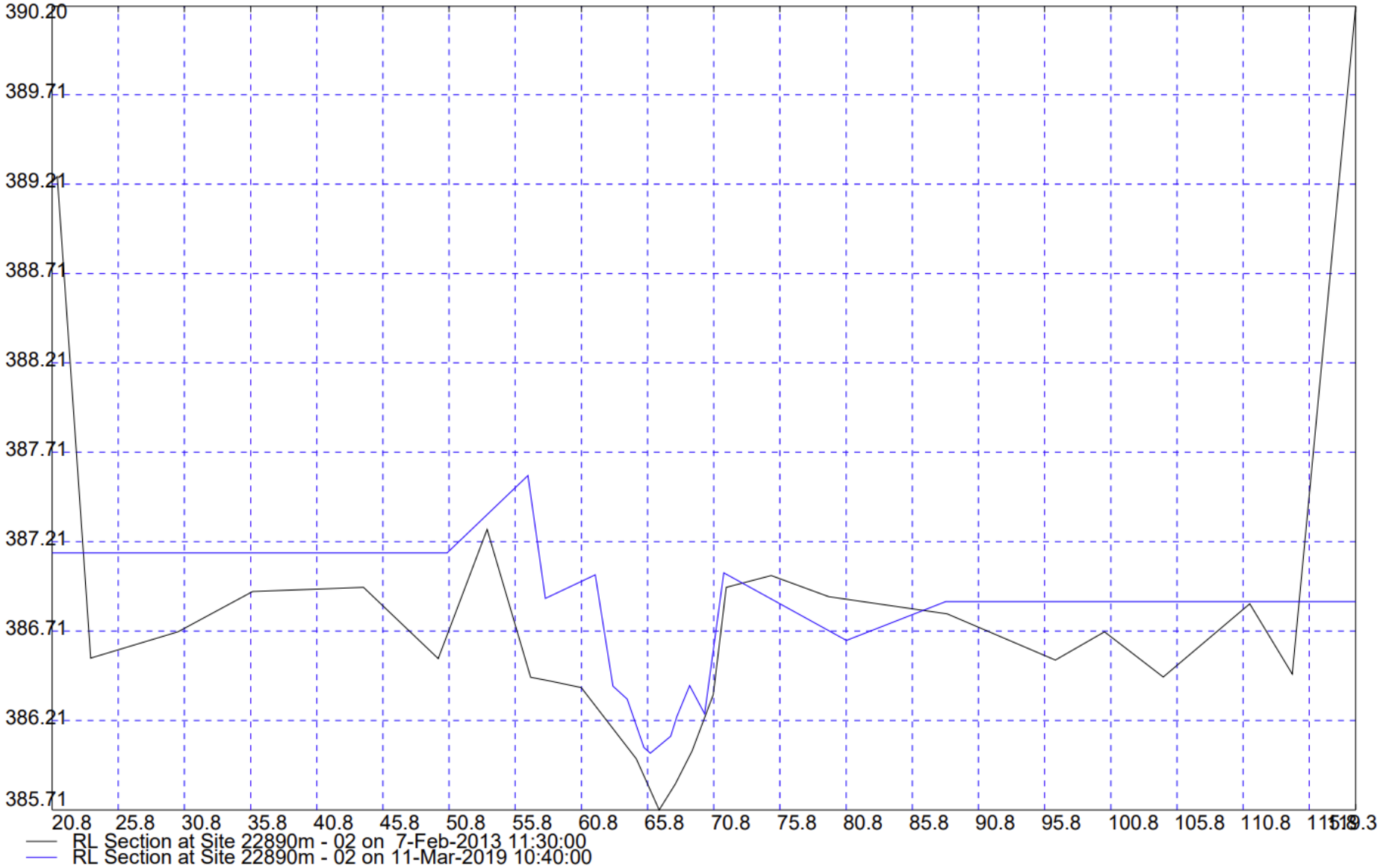

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33.3
38.3
43.3
48.3
53.3
58.3
63.3
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RL Section at Site 22270m - 06 on 4-Feb-2013 11:30:00
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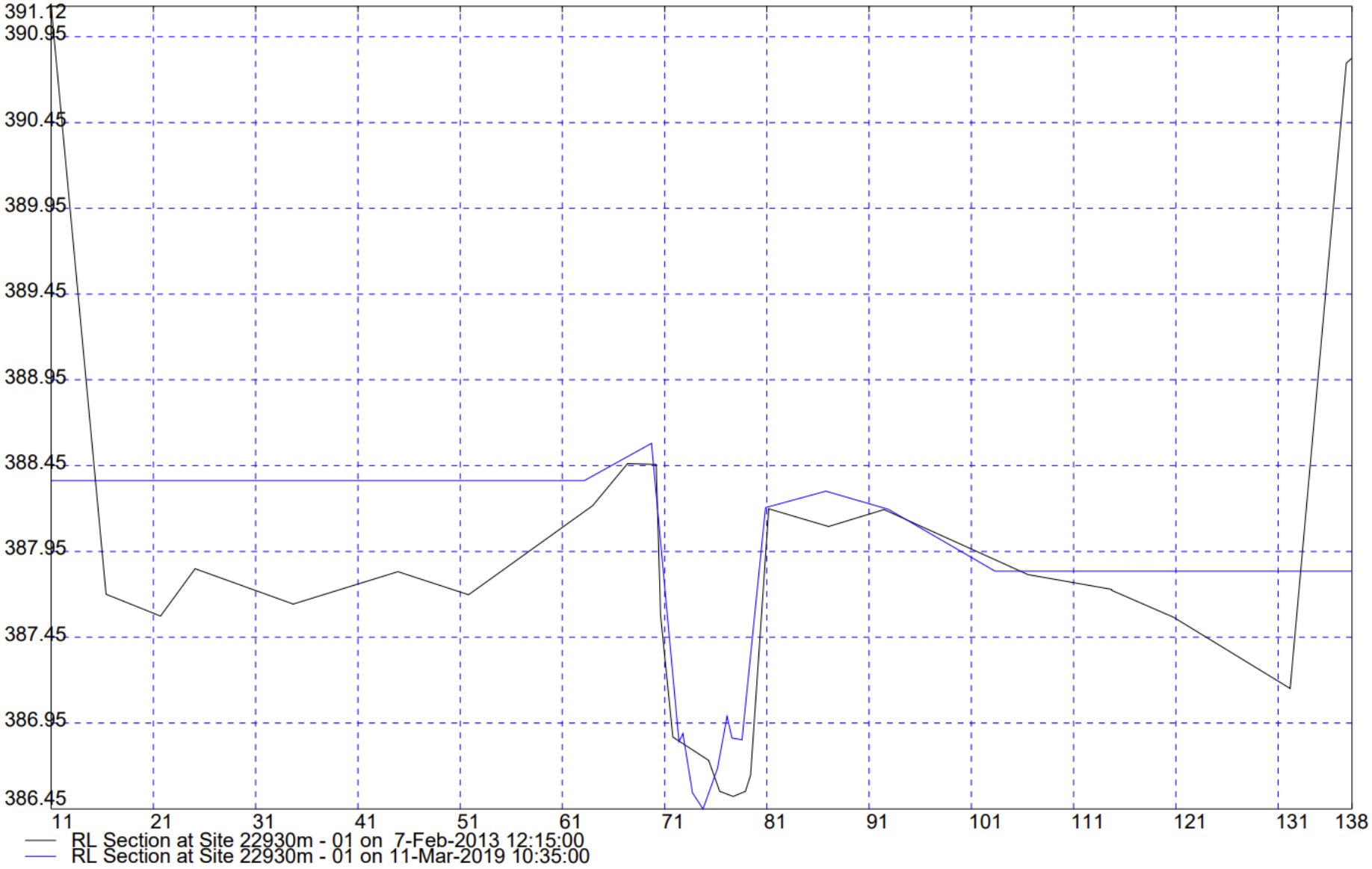

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376.09
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375.09
374.59
374.09
373.59
373.09
372.59
372.09
371.59
371.09
18.0
23.0
28.0
33.0
38.0
43.0
48.0
53.0
58.0
63.0
66.5
RL Section at Site 22440m - 05 on 4-Feb-2013 12:15:00
RL Section at Site 22440m - 05 on 8-Mar-2019 11:05:00

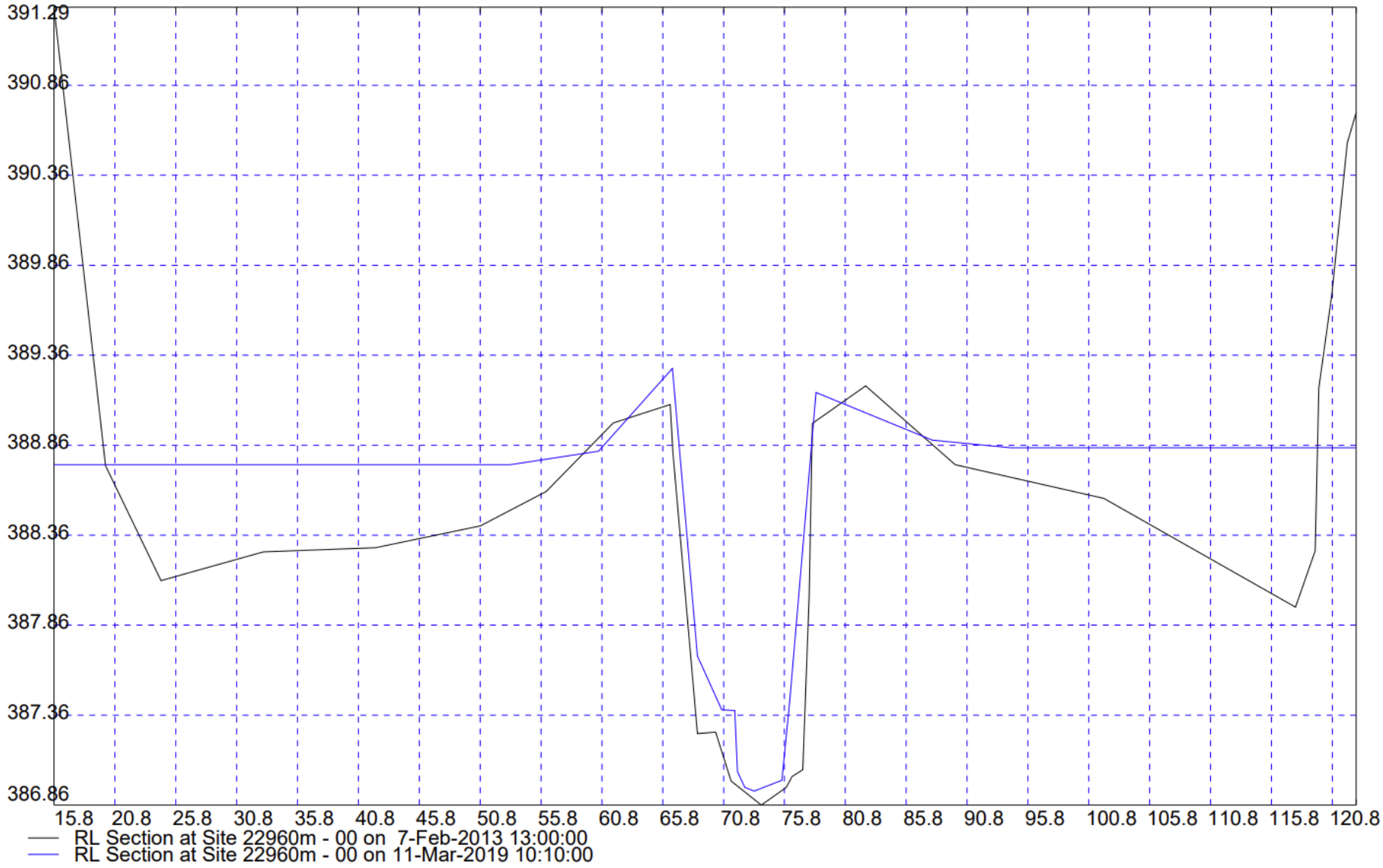

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376.53
376.03
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375.03
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45.2
50.2
55.2
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65.2
70.2
75.2
78.9
RL Section at Site 22610m - 04A on 5-Feb-2013 13:30:00
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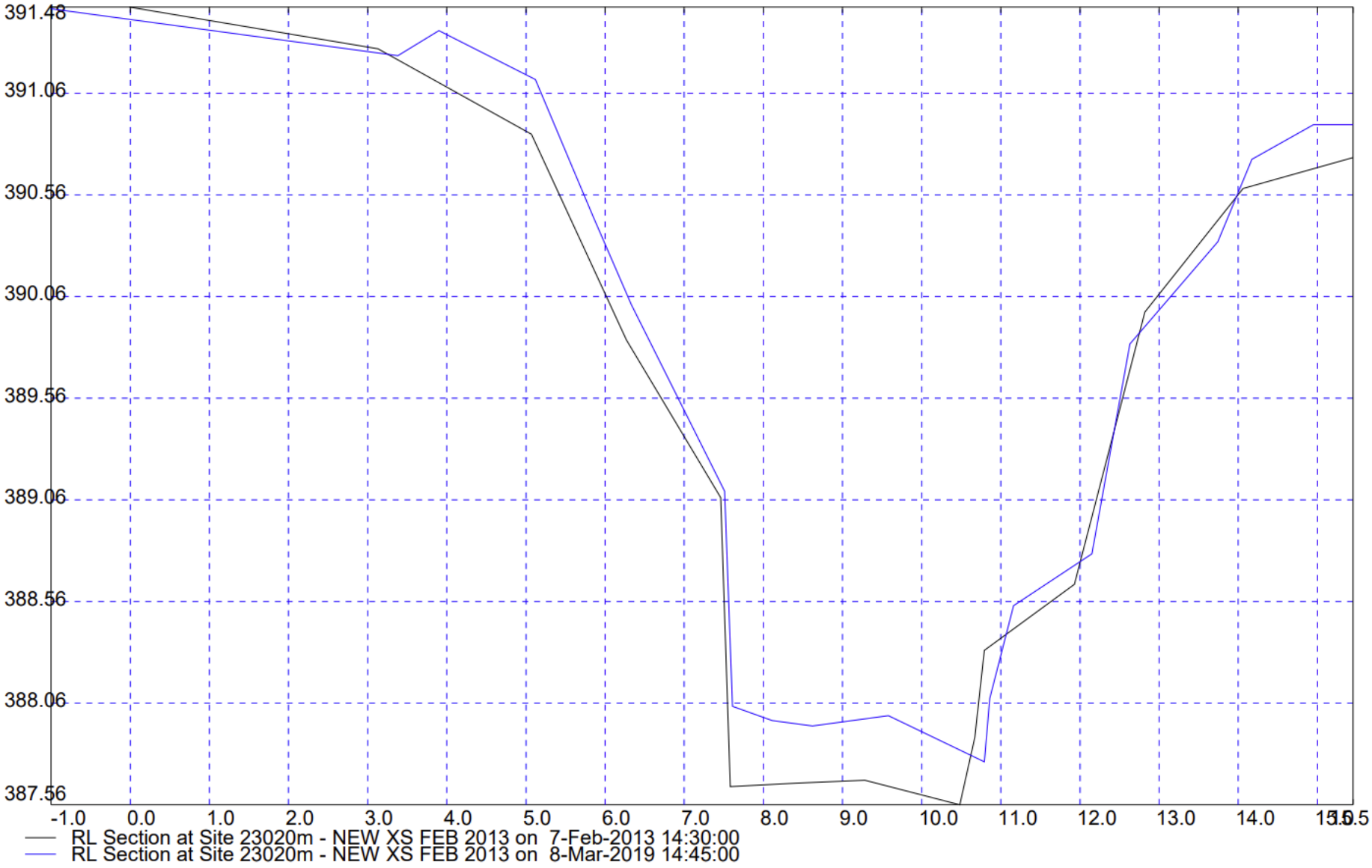

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383.36
382.86
12.1
17.1
22.1
27.1
32.1
37.1
42.1
47.1
52.1
57.1
62.1
67.1
72.1
74.3
RL Section at Site 22750m - 03 on 7-Feb-2013 09:30:00
RL Section at Site 22750m - 03 on 11-Mar-2019 11:10:00


387.15
386.96
386.46
385.96
385.46
384.96
384.46
383.96
22.2
27.2
32.2
37.2
42.2
47.2
52.2
57.2
62.2
67.2
72.2
77.2
82.2
87.2
RL Section at Site 22800m - 02A on 7-Feb-2013 11:00:00
RL Section at Site 22800m - 02A on 11-Mar-2019 11:00:00


390.20
389.71
389.21
388.71
388.21
387.71
387.21
386.71
386.21
385.71
20.8
25.8
30.8
35.8
40.8
45.8
50.8
55.8
60.8
65.8
70.8
75.8
80.8
85.8
90.8
95.8
100.8
105.8
110.8
RL Section at Site 22890m - 02 on 7-Feb-2013 11:30:00
RL Section at Site 22890m - 02 on 11-Mar-2019 10:40:00


391.12
390.95
390.45
389.95
389.45
388.95
388.45
387.95
387.45
386.95
386.45
11
21
31
41
51
61
71
81
91
101
111
121
131
138
RL Section at Site 22930m - 01 on 7-Feb-2013 12:15:00
RL Section at Site 22930m - 01 on 11-Mar-2019 10:35:00


391.29
390.86
390.36
389.86
389.36
388.86
388.36
387.86
387.36
386.86
15.8 20.8 25.8 30.8 35.8 40.8 45.8 50.8 55.8 60.8 65.8 70.8 75.8 80.8 85.8 90.8 95.8 100.8 105.8 110.8 115.8 120.8
RL Section at Site 22960m - 00 on 7-Feb-2013 13:00:00
RL Section at Site 22960m - 00 on 11-Mar-2019 10:10:00


391.48
391.06
390.56
390.06
389.56
389.06
388.56
388.06
387.56
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
15.5
RL Section at Site 23020m - NEW XS FEB 2013 on 7-Feb-2013 14:30:00
RL Section at Site 23020m - NEW XS FEB 2013 on 8-Mar-2019 14:45:00

Appendix J: South East Ruahine streams and river site photos (6 December 2023)



Figure J1: Manga-atua Stream between XS 20060 to 19600



Figure J2: Manga-atua Stream between XS 20060 to 19600

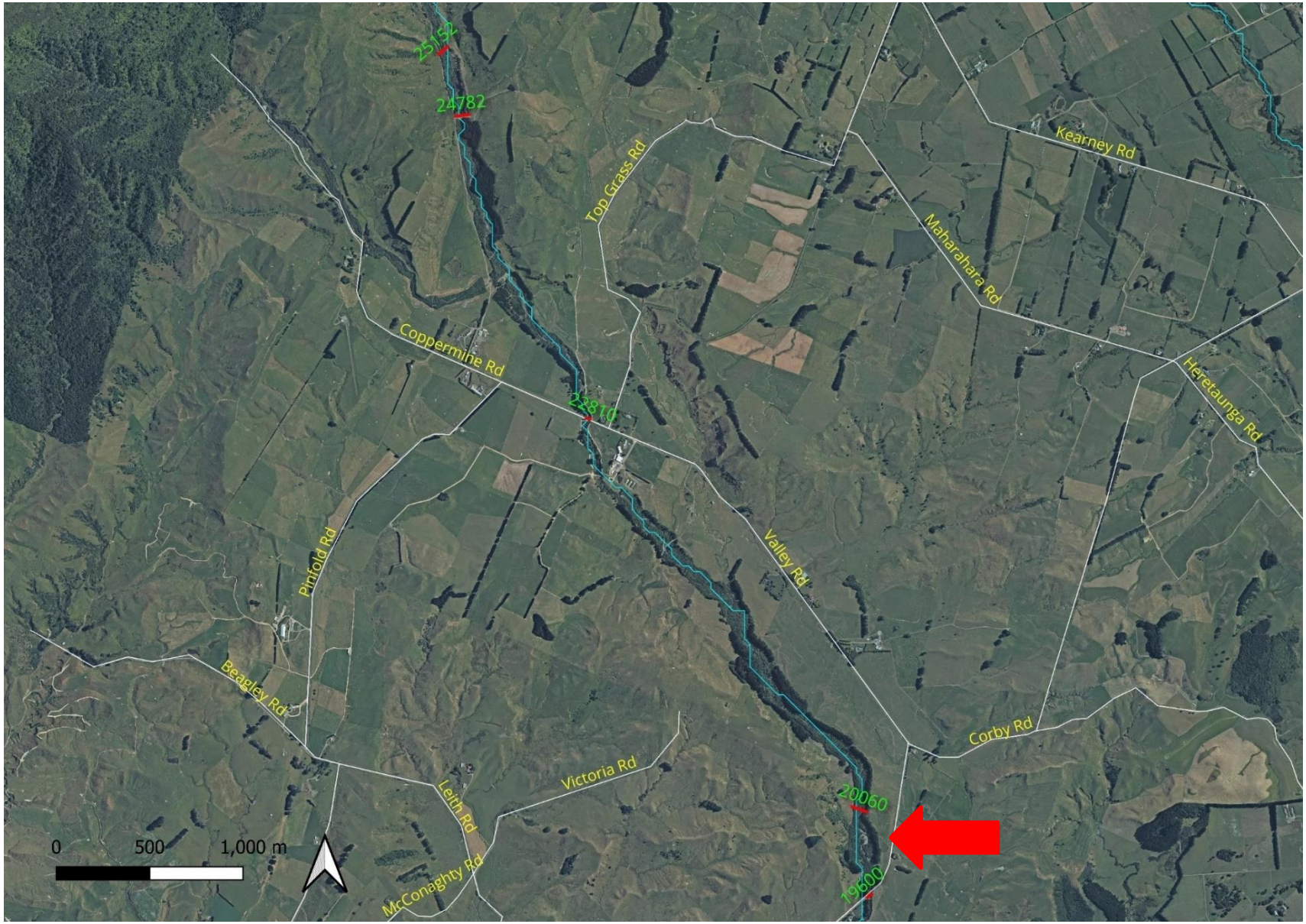


Figure J3: Manga-atua Stream between XS 20060 to 19600



Figure J4: Raparapawai Stream near XS 8800

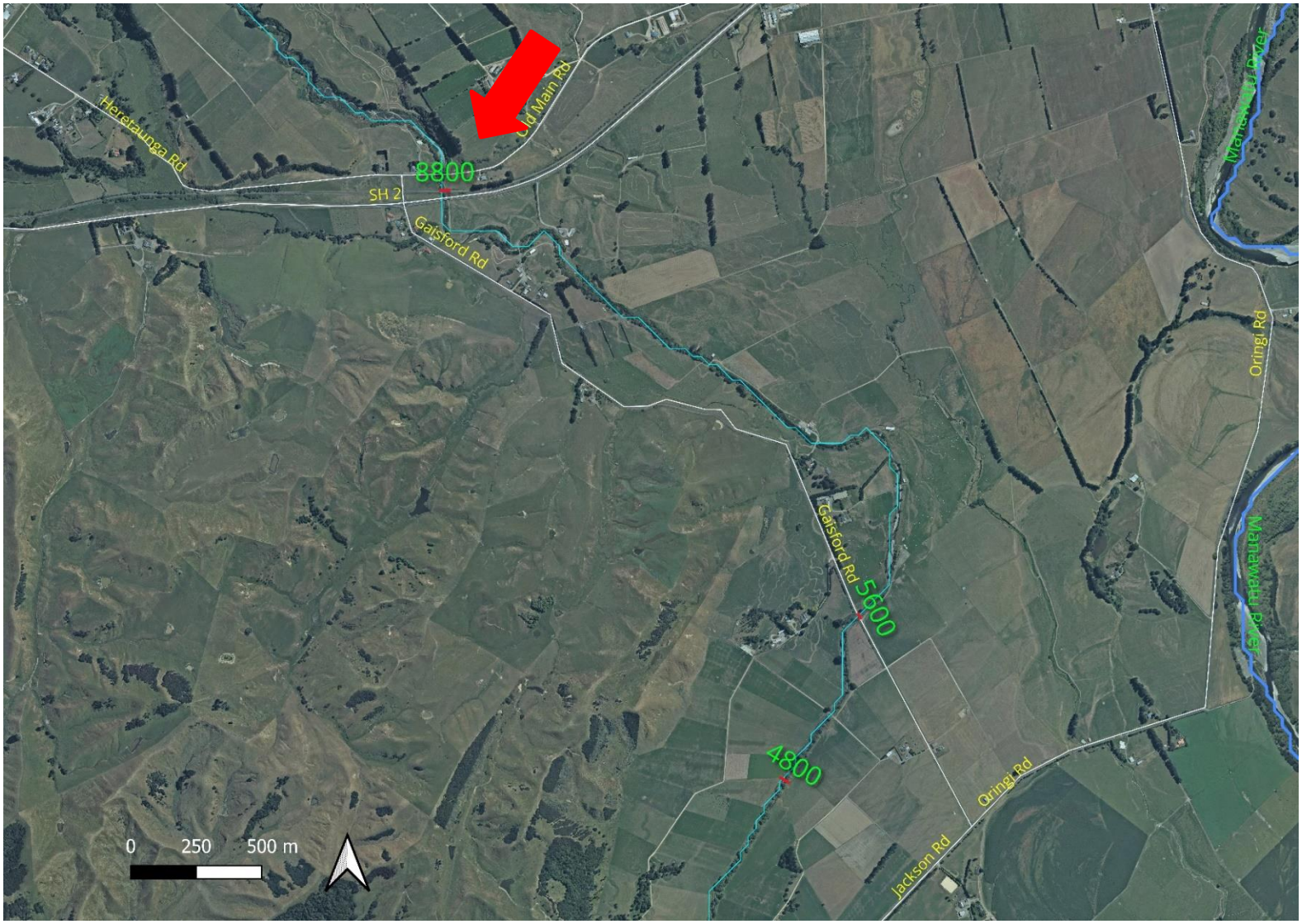


Figure J5: Raparapawai Stream near XS 8800



Figure J6: Kumeti Stream gravel reserve from XS 12850 to XS 13800



Figure J7: Weir at Kumeti Stream near XS 13000

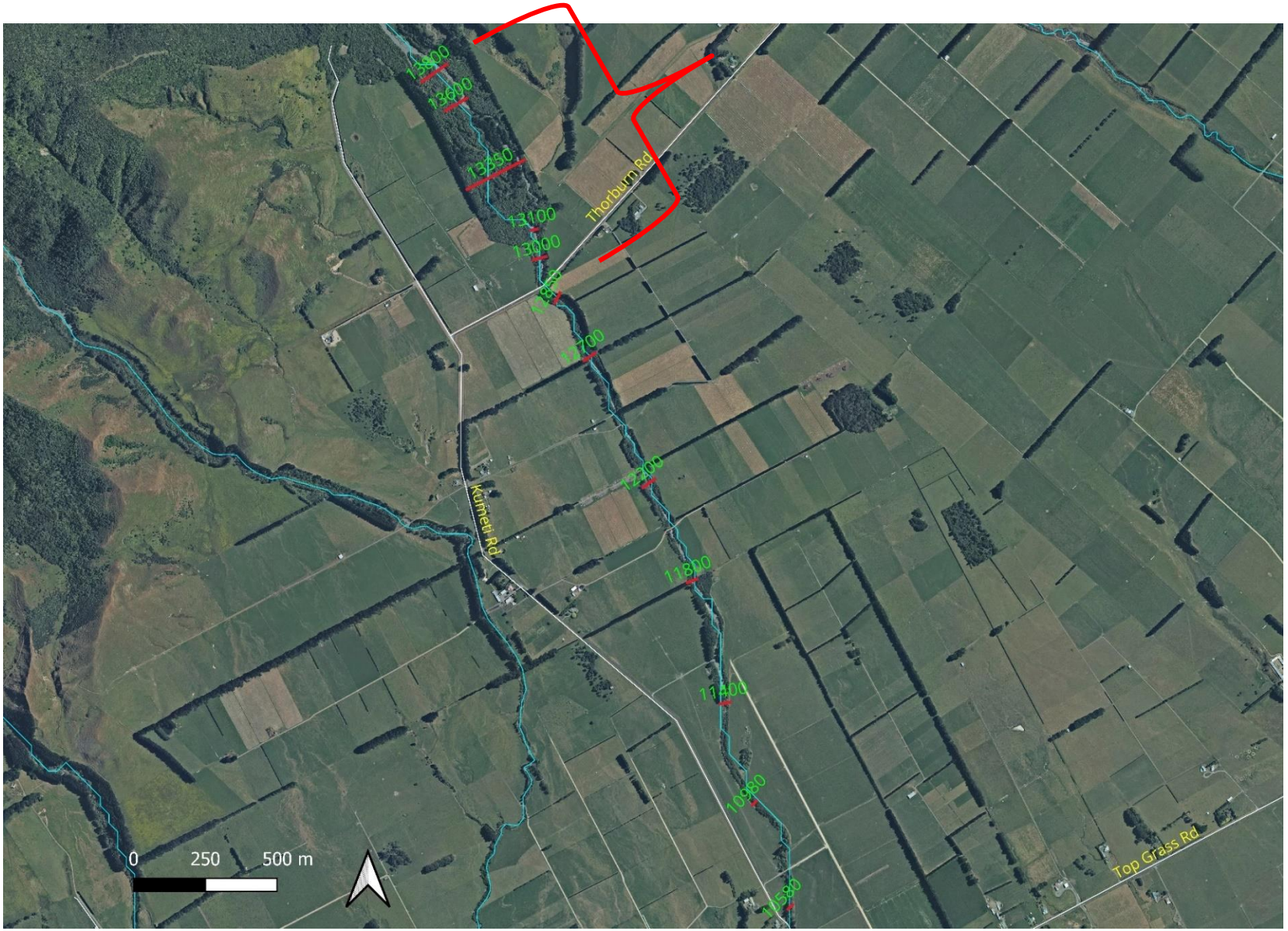


Figure J8: Kumeti Stream from XS 12850 to XS 13800



Figure J9: Gravel reserve at Otamaraho Stream near XS 19300



Figure J10: Multiple weirs at Otamaraho near XS 19300



Figure J11: Wooden weir at Otamaraho Stream gravel extraction site near XS 18700

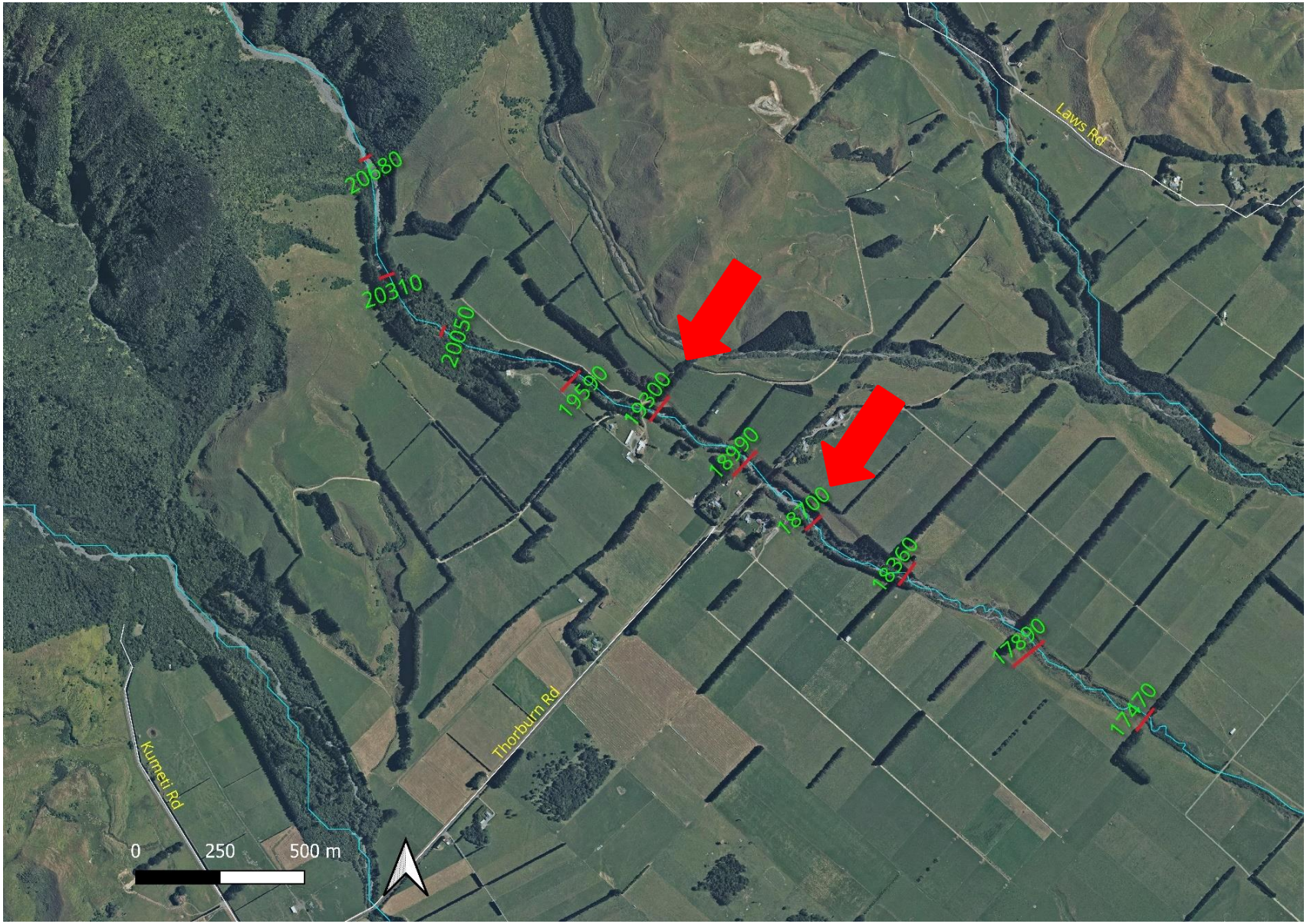


Figure J12: Multiple weirs at Otamaraho near XS 19300



Figure J13: Tamaki River gravel extraction site downstream of XS 9700



Figure J14: Tamaki River gravel extraction site downstream of XS 9700



Figure J15: Tamaki River gravel extraction site downstream of XS 9700



Figure J16: Rokaiwhana Stream gravel beach



Figure J17: Rokaiwhana Stream weir





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