



Ōroua River

Gravel Resource and Sediment Study

June 2026

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Front Cover Photo

Ōroua River near Taonui Road/XS 61010m
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Executive Summary

This study examines changes in sedimentation along the Ōroua River using cross-section survey data from 2022 to 2024, assessed through both gravel and silt volumetric changes and corresponding changes in mean bed levels. The findings are intended to inform river management decision making, particularly with respect to the sustainable allocation and extraction of sediment resources.

The study area for this report is broken into three reaches:

1. Silt phase: 0.0 km – 24.3 km from the Manawatū River confluence
2. Lower gravel phase: 24.3 km – 43.5 km from the Manawatū River confluence
3. Upper gravel phase: 43.5 km – 115.725 km from the Manawatū River confluence

The reaches above follow the 2023 Gravel Resource and Sediment Study (King, 2023). The methodology of this study also aligns with the 2023 study, to allow direct comparison between the previous results. The current study additionally analysed the upper gravel phase, which the 2023 study was unable to assess due to insufficient data. Cross-section-based volumetric change analyses have a considerable margin of uncertainty that is difficult to quantify – these uncertainties have been minimised where possible and are discussed within this report. For gravel volume calculations, only the cross-sections between 43.5 km and 69.06 km were analysed, as the large (> 4 km) distances between cross-sections beyond this point would produce unreliable results. However, the mean bed level analysis covers the full reach to 115.725 km.

Overall, the lower Ōroua River (silt and lower gravel phases) generally exhibits a pattern of aggradation whereas the upper Ōroua shows an overall trend of degradation over the 2022–2024 period. This study has found that in the silt phase, net average annual sediment accumulation for 2022–2024 was approximately 227,000 m³ per year, representing a 360% increase compared with 2016–2022. In the lower gravel phase, net average annual sediment accumulation is approximately 81,000 m³ per year – this is an increase of > 450% relative to the previous study period. In contrast, the upper gravel phase shows net average annual sediment loss of approximately 111,000 m³ per year. These results likely reflect the impact of Cyclone Gabrielle on sediment transport, and it is likely that the river will require some time to absorb this change.

Under the One Plan, the Ōroua River has a long-term average annual allocable gravel volume of 10,000 m³ per year upstream of Menzies Ford and 55,000 m³ per year downstream of Menzies Ford. For the period from January 2022 to December 2024, 15,495 m³ was extracted from the reach downstream of Menzies Ford under ATH-2006011146.02, and 35,993 m³ was extracted from the reach upstream of Menzies Ford under ATH-2004010097.01. Both consents are held by Horizons Regional Council.

Previous gravel studies have looked at the changes in sediment volume for the lower Ōroua River using surveys conducted in 1998, 2012, 2016, and 2022. Combining the findings of these previous studies with the findings of this study has shown that the long-term average annual rate of sediment flux for the lower gravel phase (i.e., gravel volume change downstream of Menzies Ford) is less than the One Plan average allocable volume. Between 1998 and 2012, the lower gravel phase was degrading at a rate of approximately 20,000 m³/year; between 2012 and 2024, it has aggraded at a rate of approximately 30,000 m³/year, with a net average annual sediment flux of approximately 45,000 m³/year when factoring in gravel extraction.

Given the potential net degradation in the upper gravel phase and localised areas of degradation in the lower gravel phase between 2022 and 2024, and the low annual average rate of net sediment flux in the lower gravel phase between 1998 and 2024, it is recommended to reduce the One Plan limit to 30,000 m³/year for the reach downstream of Menzies Ford. This is the same recommendation provided in the 2023 gravel study. There is currently not enough available cross-section data to estimate long-term change for the upper gravel phase/upstream of Menzies Ford.

When comparing sediment volume in 2024 to 1998, the silt phase has aggraded by approximately 2,198,000 m³. Silt extraction may therefore be undertaken with guidance from River Management to ensure that potential effects on local channel behaviour and stability are appropriately considered. It is recommended to undertake an analysis of the impact of sediment aggradation on flood carrying capacity, particularly in the lower Ōroua.

A full river survey is recommended for 2029–2030, including all 2024 cross-sections to maintain data comparability. In the Upper Ōroua, cross-section spacing should be standardised at approximately 400 m for more reliable results. Before the next gravel study, obtaining an updated LiDAR survey is recommended to supplement cross-section data and support a trial Geomorphic Change Detection analysis.

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Introduction

Catchment Setting

The Ōroua River is situated in the southwest of the North Island and is a tributary of the Manawatū River. The river has a length of approximately 141 kilometres, and a catchment area of an estimated 910 square kilometres (Figure 1). The headwaters of the river are located in the western Ruahine Ranges, with the mainstem flowing southwest through Feilding and joining the Manawatū River at Rangiotū between Palmerston North and Shannon.

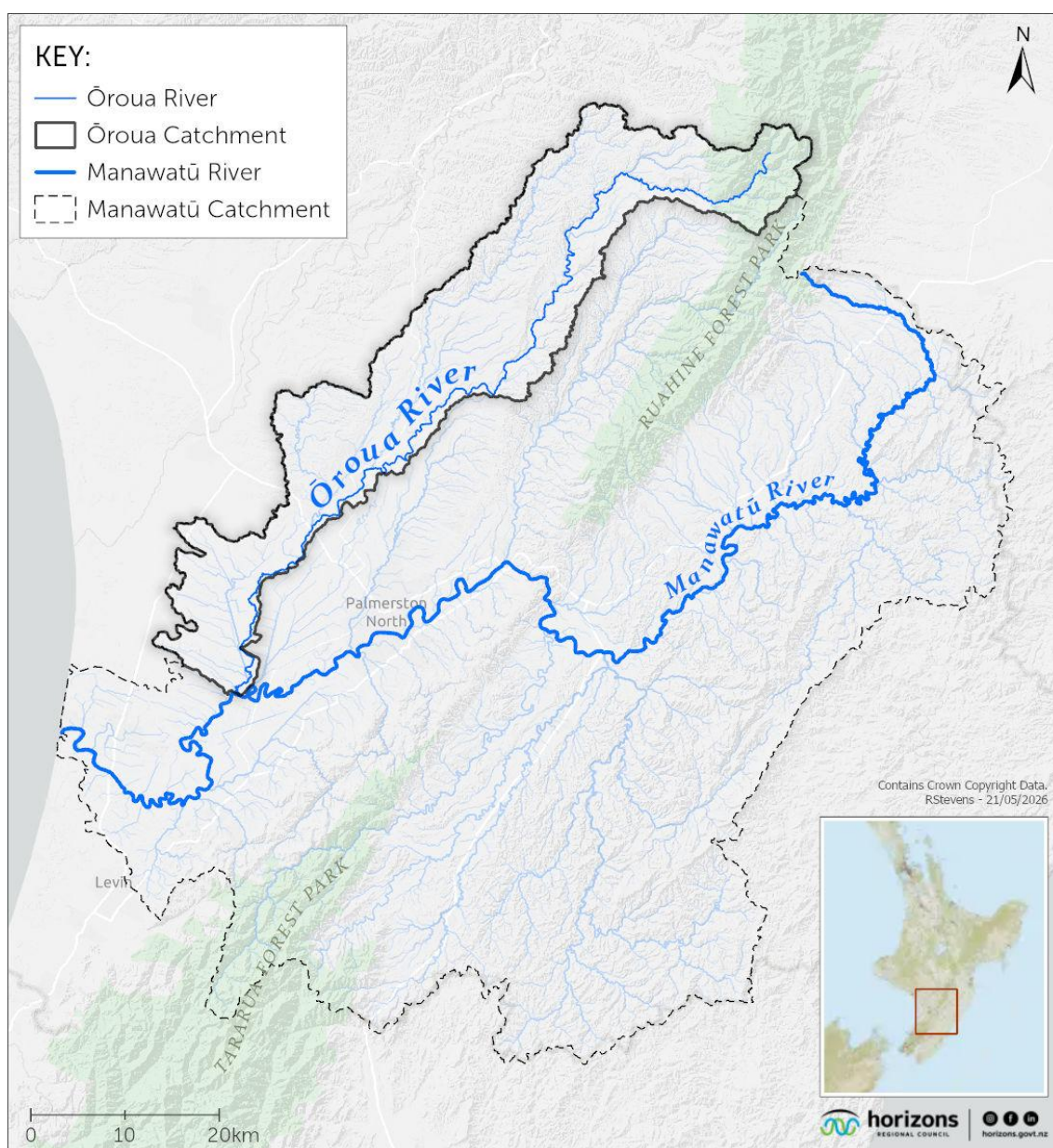


Figure 1

Map of the Ōroua River catchment, which is within the Manawatū River catchment in the lower North Island, New Zealand.

The Ōroua River from Apiti Road to the confluence with the Manawātū River is serviced by two River Schemes administered by Horizons Regional Council. From Apiti Road to Mahua Road is serviced by the Pohangina-Ōroua River scheme which provides for erosion protection. This reach of the Ōroua is a gravel bed, single thread meandering river, largely confined by dramatic alluvial terraces until Taonui Road.

From Mahua Road to the confluence with the Manawātū River, the Ōroua is serviced by the Lower Manawātū River Scheme for River maintenance, which includes erosion protection and stop banking for flood protection. Mahua road to Kopane road is a single thread meandering gravel bed river. At Kopane Road the channel changes to a silt bed, with confined, relatively low sinuosity channel form. Stop banks on both sides of the channel are continuous from State Highway 3 to the confluence with the Manawātū River and are considered to provide 1% AEP protection to the communities of the adjacent floodplain (Blackwood, 2012).

The study area is split into three phases, each with distinct geomorphic character based on the dominant grain size of the active channel and the valley confinement (Figure 2). For consistency, the present study will adopt the same study areas and cross-section distances as outlined in the 2023 study. Please note that cross-section distances refer to the distance (in metres) of the cross-section site from the confluence with the Manawātū River as measured along the centreline of the floodplain, and benchmark refers to the cross-section distance in kilometres.

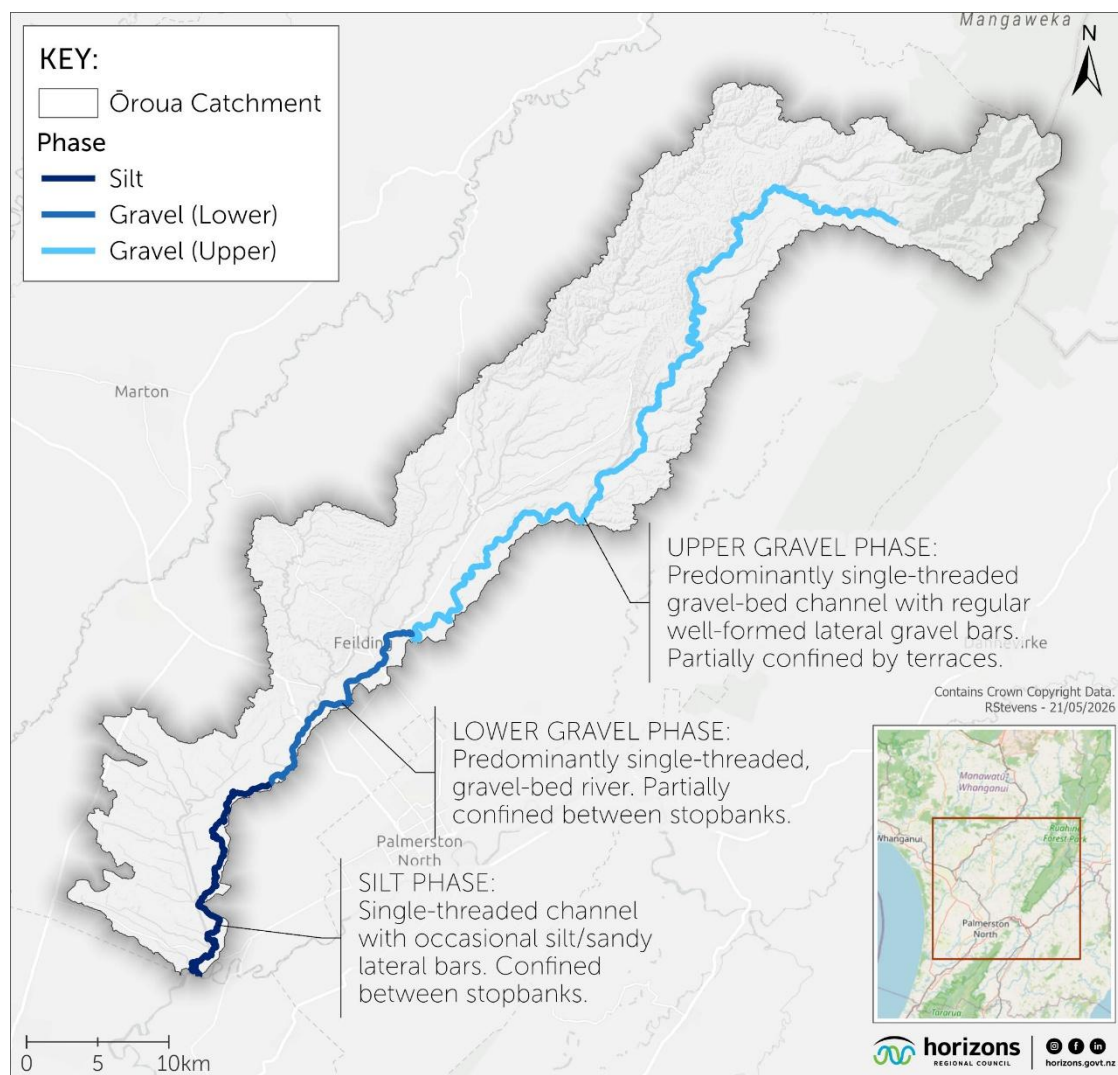


Figure 2
Phases of the Ōroua River within the study area.

Table 1

Photos of the Ōroua River phases (captured by Horizons Catchment Operations and Science Teams).

Silt Phase



Near XS 7025m (taken 21/02/2019)



Near XS 22500m (taken 21/02/2019)

Lower Gravel Phase



Near XS 29125m (taken 12/05/2026)



Near XS 43500 (taken 14/01/2026)

Upper Gravel Phase



Near XS 81740m (taken 5/12/2023)



Near XS 78600m (taken 21/01/2025)

Study Area

Silt Phase

XS 0000m – XS 24325m

The silt phase of the Lower Ōroua extends from its confluence with the Manawatū River at benchmark 0.0 km to Kopane bridge at benchmark 24.8 km (Figure 3), including cross-section sites 0000m to 24325m.

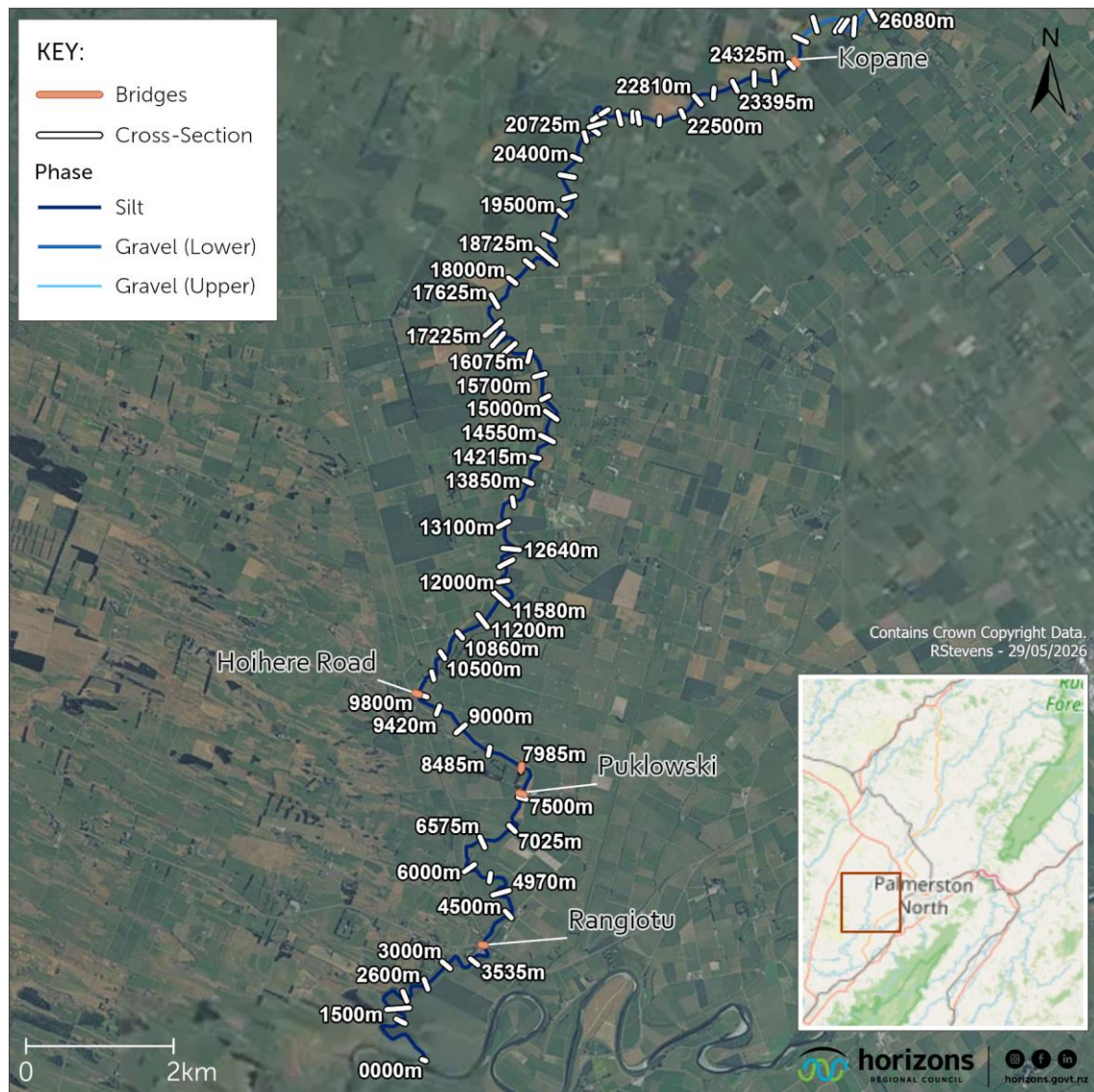


Figure 3
Map showing the extent of the silt phase of the study area, located in the lower Ōroua River.

The Ōroua through the silt phase is a confined single-threaded channel with occasional silt/sandy lateral bars. This reach occurs through the Taonui basin (Blackwood, 2012), which has been subject to significant drainage infrastructure to enable agricultural land use. One of the largest drains ('Main Drain') discharges into the Ōroua above Rangiotū Road bridge at approximately 4 km above the confluence. The channel is confined between stop banks. On average, stop banks are 50 m set back from the channel, but this is highly variable in relation to the meander pattern of the river.

Lower Gravel Phase

XS 24765m – XS 43500m

The gravel phase of the Ōroua is split into two reaches. The lower gravel phase (also known as Gravel Phase 2) starts from Kopane bridge at benchmark 24.8 km and extends to just below Mahua Road bridge at benchmark 45.4 km (Figure 4), including cross-section sites 24765m to 43500m.

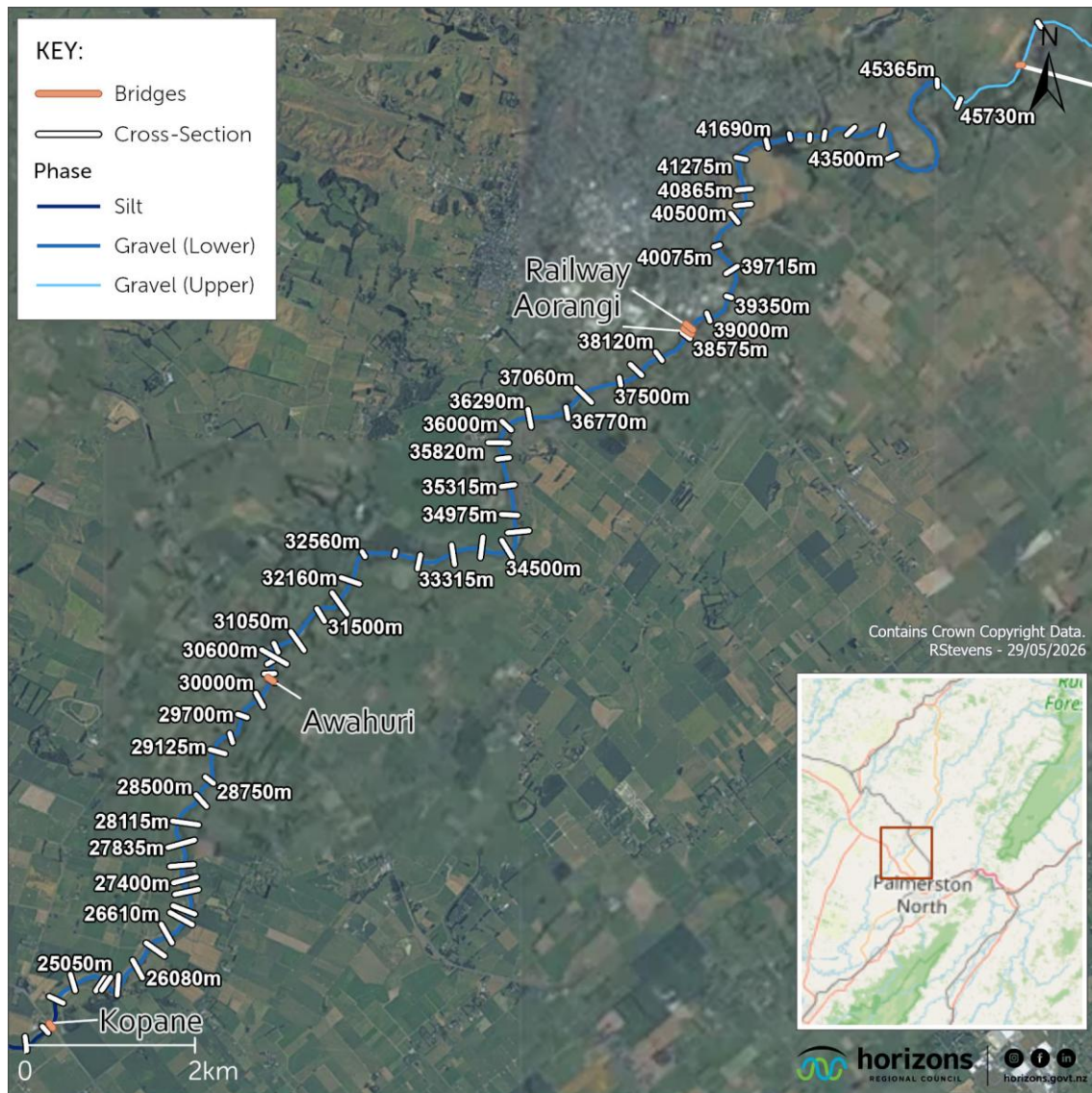


Figure 4

Map showing the extent of the lower gravel phase of the study area, in the lower Ōroua River.

The Ōroua through the lower gravel phase is predominantly a single-threaded, gravel bed river. At 42.2 km, the Kiwitea Stream tributary joins the Ōroua River. Immediately downstream of the confluence, channel widening is observed as well as increased lateral bars with some sections developing multi-threaded channels until 2-3 km downstream.

At the top end of this reach, the Ōroua runs on the southwest edge of the settlement of Feilding. From 38.57 km, land use is predominantly agricultural. There are some sections of stop banking which become continuous at 30.0 km.

Upper Gravel Phase

XS 45365m – XS 115725m

The upper gravel phase (also known as Gravel Phase 1) of the Ōroua River extends from above Mahua Road at 43.5 km to 115.7 km (Figure 5), including cross-section sites 45365m to 115725m.

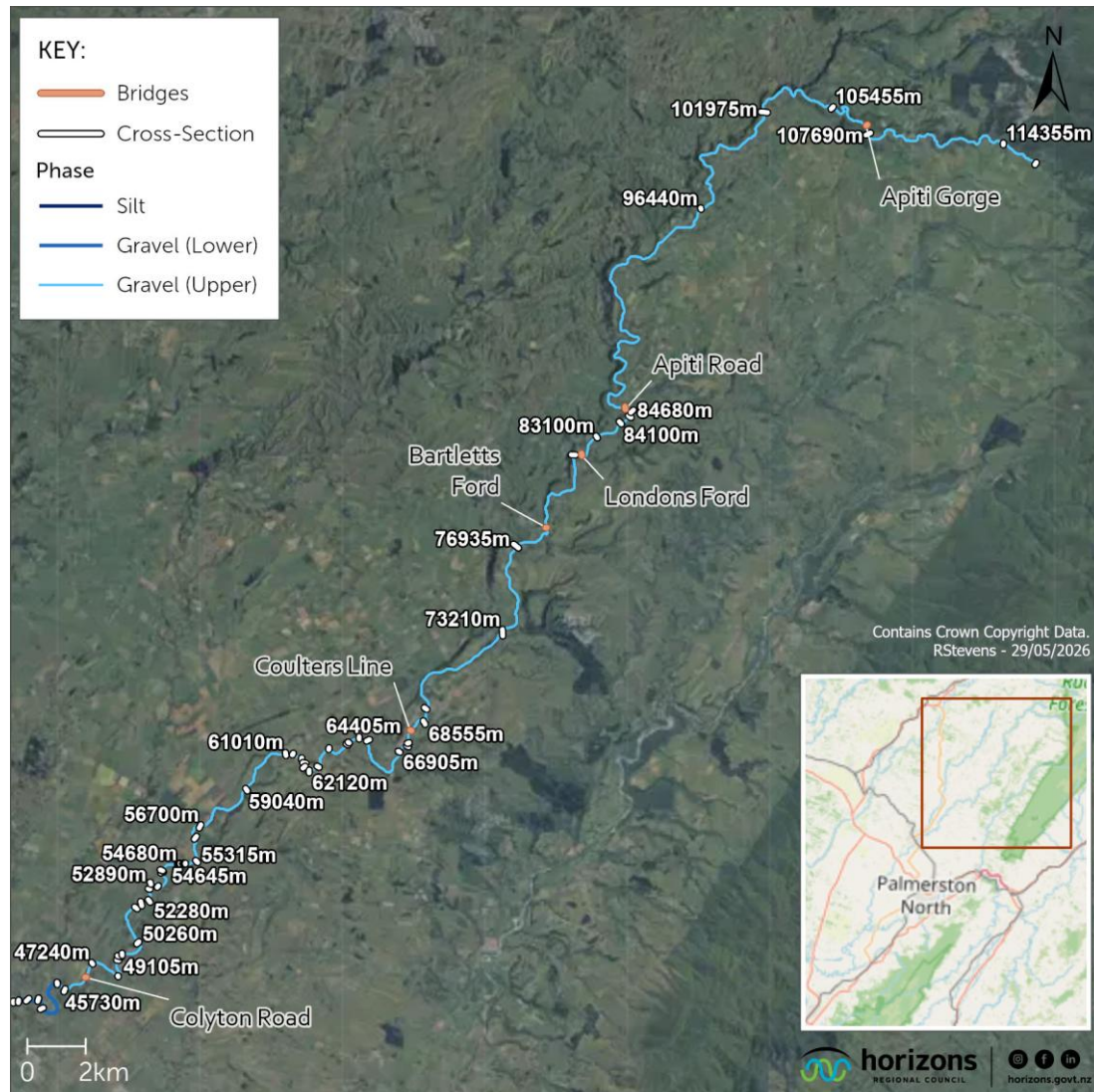


Figure 5

Map showing the extent of the upper gravel phase of the study area, in the upper Ōroua River.

The Ōroua through the upper gravel phase is a predominantly single-threaded gravel bed channel with regular well-formed lateral gravel bars. Between 86.5 km to approximately 55.5 km, the channel is confined in the north/northeast by alluvial terraces. The surrounding land use is primarily agricultural.

There has been no gravel analysis done in this reach of the Ōroua in the past because of unavailable cross section data. This report will be the first to undertake gravel analysis because of the recent 2022-2024 comparable dataset. Note that for gravel volume calculations, this study analysed only the 2022 and 2024 cross-section surveys between 43.5 km and 84.68 km. Extending the analysis beyond this point would require interpolating across very large distances between cross-sections, which would produce unrealistic and unreliable volume estimates. In contrast, the mean bed level analysis covers the full reach from 43.5 km to 115.725 km upstream of the Manawātū River confluence.

Previous Gravel Resource Studies

2012 Gravel Resource Study

The 2012 study, which assessed changes between 1998 and 2012, concluded the following:

- Between 1998 and 2012, there appears to be a general trend of degradation in the reach from Kaimatarau Road to just upstream of the confluence with the Kiwitea Stream, and an aggradation trend downstream to the Manawatū confluence.
- There is approximately 900,000 m³ more material beneath the active channel in 2012 than there was in 1998, a large proportion of which is likely to be silt.
- It is particularly important to monitor the levels of aggradation in the lower half of the reach, below Kaimatarau Road, as a continuation in this trend could lead to a loss of flood carrying capacity in the river channel.

2019 Gravel Resource Study

The 2019 study, which assessed changes between 2012 and 2016, concluded the following:

- Consistent with the findings of the 2012 study, there was a trend of aggradation in the silt phase (188,600 m³ or 47,150 m³/year on average), with siltation on the berm and a narrowing channel.
- Rates of aggradation in the silt phase imply the need for management activities to address sedimentation in order to maintain flood protection levels.
- Overall aggradation was indicated in the lower gravel phase (Reach 2). The upper gravel phase (Reach 1) was unable to be analysed due to lack of data. Total gravel volume is estimated to have aggraded by 94,100 m³ across the gravel reach, or an average 23,525 m³/year.
- Aggradation volumes are positively correlated with Mean Bed Level, which increased on average between 0 m to 0.2 m.
- Net gravel volumes are calculated to be 10,000 m³/year less than anticipated One Plan volumes, therefore extraction volumes for the lower gravel phase (Reach 2) should be reduced to 45,000 m³/year for sustainable gravel management.

2023 Gravel Resource Study

The 2023 study, which assessed changes between 2016 and 2022, concluded the following:

- Overall, the silt phase net average annual sediment deposition is approximately 55,000 m³. This is a 16% increase in average annual sediment volume accumulation compared to 2011-2016.
- In the study area of the lower gravel phase (Reach 2) the study calculates a net average annual aggradation of approximately 27,000 m³. This is approximately 40% reduction in net average annual aggradation compared to 46,000 m³/yr 2011-16.
- The report recommends including the upper gravel phase (Reach 1) for the next study as the 2023 one only reports changes for the lower gravel phase (Reach 2).
- The report suggests the maximum allocable volumes be reduced to 30,000 m³/yr with the caveat that greater volumes may be appropriate after significant weather events if sediment stores (vegetated bars) are mobilised in the upper sections of the reach.

Methodology

This study utilises river cross-section surveys, which use repeated GPS measurements to model the elevation change across the profile of a riverbed. Cross-section surveys have historically been the primary tool used by regional councils to monitor changes in riverbed levels and gravel transport rates; however, it is widely acknowledged that the sparse spatial and temporal distribution of cross-sections, combined with the fluctuating way in which riverbed material moves, sets limitations on gravel volume changes calculated between cross-sections (Basher, 2006). Figure 6 shows the high variability of Ōroua River cross-section surveys, colour-coded to show data that was included in this study. The long-term analysis compares data from 1998/1999, 2011/2012, 2016, 2022, and 2024 at cross-sections where survey data was available for all years. The short-term analysis compares only the 2022 survey data with the 2024 survey data.

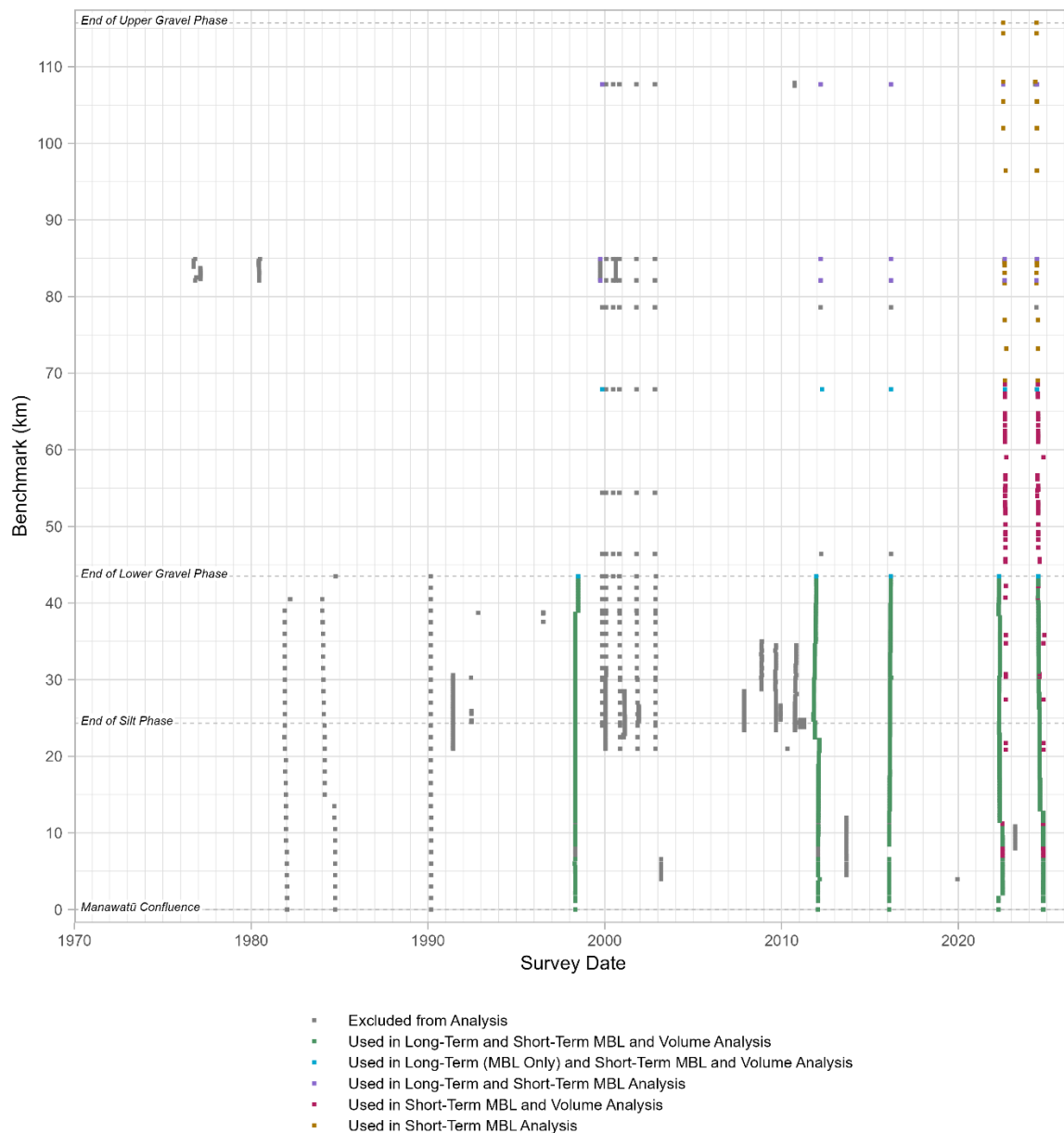


Figure 6

Plot of the spatial and temporal distribution of cross-section surveys for the Ōroua River. Each point represents a survey at that cross-section site.

Area Under the Section

Following the 2023 study, the Ōroua River was next resurveyed in 2024. The present analysis utilises the 2022 and 2024 cross-section datasets, referenced to the NZVD2016 vertical datum. Cross section offsets from the previous study were adopted where available. Hilltop Hydro - REACH was used to obtain the area under the section (to a datum of 0). The defined offsets can be found in Appendix B.

Offsets

Silt Phase

This study defines the extents of the active channel for the silt phase as the change in sediment volume across the channel and river berms between the toes of the stop banks (Figure 7).

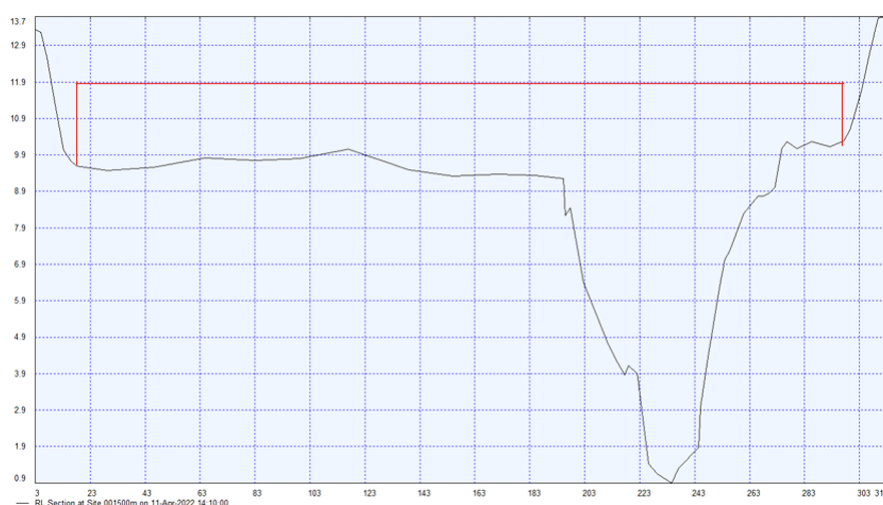


Figure 7
Typical silt phase cross section. Area under bed for volume change measured between toes of stop banks (King, 2023).

Gravel Phase

This study defines the extents of the active channel for the gravel phases as the change in sediment volume across the channel between the top of the active channel banks (Figure 8).

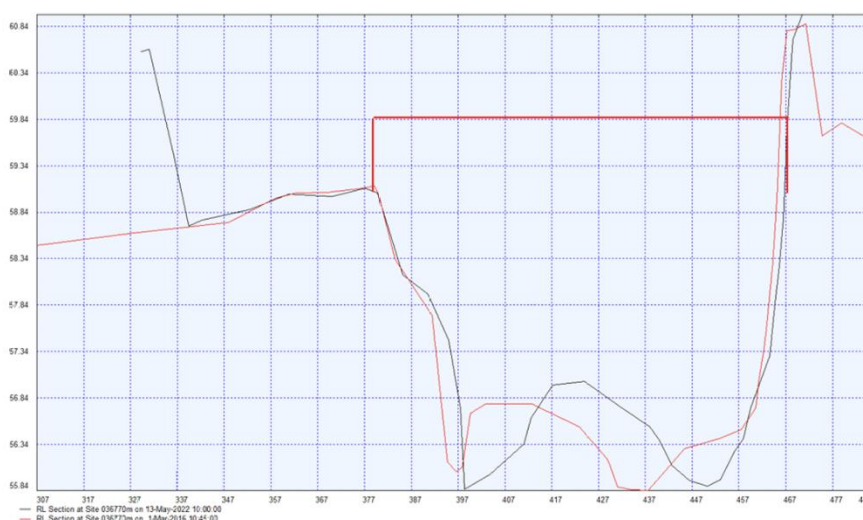


Figure 8
Example Section with active channel indicated for volume calculations (King, 2023).

Interpolated Volume

The mean average area under the bed for consecutive cross-sections is taken and multiplied by the distance between the two sections to derive a volumetric change for the length.

$$\text{Change in volume} = V_{new} - V_{old}$$

$$V_x = (S_2 - S_1) \times ((A_2 + A_1) \div 2)$$

Where:

- V_{new} is the calculated volume at a cross-section site using the more recent survey data
- V_{old} is the calculated volume at a cross-section site using the older survey data
- S_1 is the downstream section distance from the confluence with the Manawatū River
- S_2 is the upstream section distance from the confluence with the Manawatū River
- A_1 is the area under the bed at the downstream section
- A_2 is the area under the bed at the upstream section

For the maps showing change in normalised volume, the normalised volume is the change in volume (as calculated above) at that cross-section in m^3 , divided by the distance to the next cross-section in m. This value is reported in m^3/m change, as it is different from the raw area under the section results because the change in area at the upstream cross-section influences the normalised change in volume.

Mean Bed Level (MBL)

Hilltop was used to analyse each survey of the individual cross-sections. The extent of the offsets for the mean bed level are set at the base of the banks (Clement & Fuller, 2020) or the high point of a lateral bar for single-thread sections (King, 2023) and covers the wetted channel and any mid-channel bars (Figure 9). Inputting the left and right offsets found in Appendix C, the mean bed levels of each year were obtained using the "Section over Time" feature found under the Reach tab of Hilltop Hydro. The minimum bed level is the lowest point along the cross-section within the bed.

The change in mean bed level is calculated by differentiating the MBL between survey years:

$$\text{Change in MBL} = \text{MBL}_{new} - \text{MBL}_{old}$$

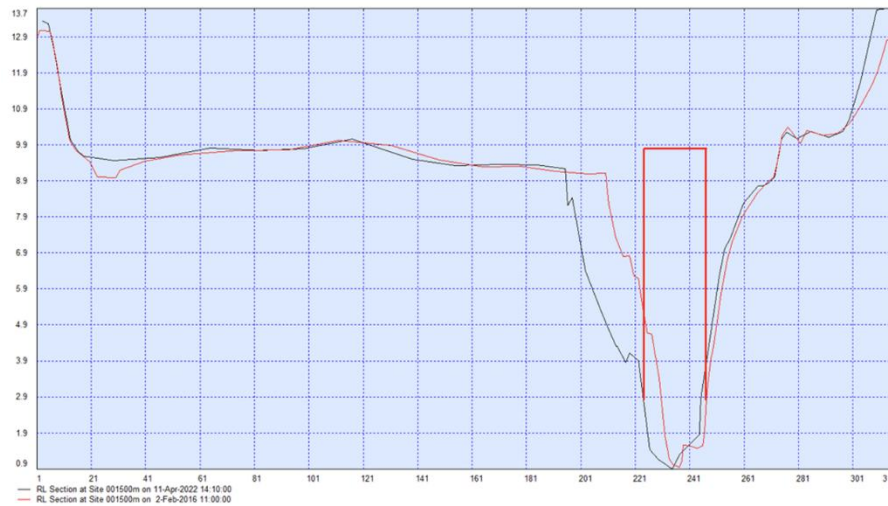


Figure 9
Example typical cross section silt phase. Wetted channel section for MBL following measures from 2019 report (King, 2023).



Figure 10
Example Section from the gravel phase with active channel indicated for Men Bed Level calculations. Multiple thread channel sections include both invert. Single thread sections are taken bank to bank or bank to highpoint of lateral bar (King, 2023).

Uncertainties and Limitations

This assessment is subject to several uncertainties and limitations that influence the interpretation of results. These arise from data availability, field conditions, and natural variability within the river system. Understanding these limitations is essential for placing the findings in context and for guiding future monitoring and analysis.

The data collected by GPS-based cross-section surveys is highly accurate for the time and space it was captured; a relatively small uncertainty arises from the nominal accuracy of the survey equipment and the variation in topology across the uneven grain assemblages of a river bed (i.e., sampling on top of versus next to a piece of gravel on the river bed). The median grain size should be considered when assessing the vertical accuracy of the elevation points, which (as per the 2026

Natural Character Index Assessment) varies along the river but is approximately a maximum of 45 mm.

The greatest limitation for this kind of sediment study arises from the spatial and temporal sparsity of the cross-sections. To estimate the volumetric change in sediment in the river, the change in area under the section between survey years is calculated and multiplied by the distance to the next upstream cross-section to get change in volume. This method assumes that the change seen at the cross-section site is representative of that section of river. Particularly in a dynamic, gravel-bed river such as the Ōroua River, this is often not the case.

The further the cross-sections are from each other, the greater the uncertainty when interpolating between cross-sections. A study by Vale & Fuller (2009) of the Motueka River found that the accuracy of sediment budgets is maximised at a critical cross section spacing not exceeding 90 m, which is not practicable for regular surveying in a river as long as the Ōroua River. Vale & Fuller (2009) also found that cross-section-based sediment analysis underestimated sediment transfer by c. 30% when compared to a digital elevation model (DEM) analysis.

A DEM-based analysis can capture more information about changes between cross-sections, but topographic LiDAR does not capture elevation data in the wetted part of the channel and can be heavily influenced by the groundcover and steepness of the terrain. However, it is possible to minimise these uncertainties through combining bathymetric data where available and calculating an error margin. Uncertainty analysis is not usually carried out for cross-section-based analysis, as it is difficult to quantify. Regardless of this, a DEM-based analysis requires two comparable DEMs, and at the time of this study, the Ōroua River only has one DEM (surveyed in 2025) that captures the whole river, meaning a cross-section-based analysis is the most practicable method for estimating sediment change.

To minimise uncertainties arising from the large distances between cross-sections, the volume analysis for the 2022-2024 comparison has an upper limit of cross-section 69060m. Above this point, the distance between cross-sections can be in excess of 4 km, meaning any misrepresentative cross-sections will have a disproportionately large impact on the overall sediment budget. Figure 11 shows the distribution of distances between cross-sections for each of the river phases and highlights the reduction in maximum cross-section distance when limiting the study to 69060m. The area under the section and MBL results for all cross-sections has still been included in the results for reference.

The length of time between surveys varies both between and within the survey years; for example, surveys were undertaken in 2016, then 2022, and then 2024, showing an irregular number of years between survey years. Because the Ōroua River is so long, several months are required to undertake a full survey of the river; for example, the 2024 surveys were captured during the period from May 2024 to November 2024. To account for this variation in survey dates, the exact difference in survey dates between survey years at each cross-section (as a fractional year) has been used to calculate the rate of change. The variability of the timing between surveys and the range of survey dates within each survey year means sediment may have been transported between sections during this time, which could lead to sediment being measured twice or not captured at all, depending on the timing of cross-section surveys.

Given that the transition from gravel to silt bed substrate is gradual, it is likely that the sediment volume change estimated for the silt phase will contain a small proportion of gravel flux. Further analysis comparing the volumetric change in the berm versus between the top of the banks could be undertaken to compare the amount of aggradation in the berm to the aggradation within the active channel, as well as further grain size analysis to better understand the silt-gravel transition.

Mean bed level analysis and volume analysis rely on the cross-section survey capturing the deepest parts of the wetted channel, which is not always feasible depending on river conditions. If the wetted channel is not fully captured, this can cause an overestimation of the mean bed level or area under the section. Both analyses are also heavily influenced by the position of the offsets chosen during the calculations, which is highly subjective.

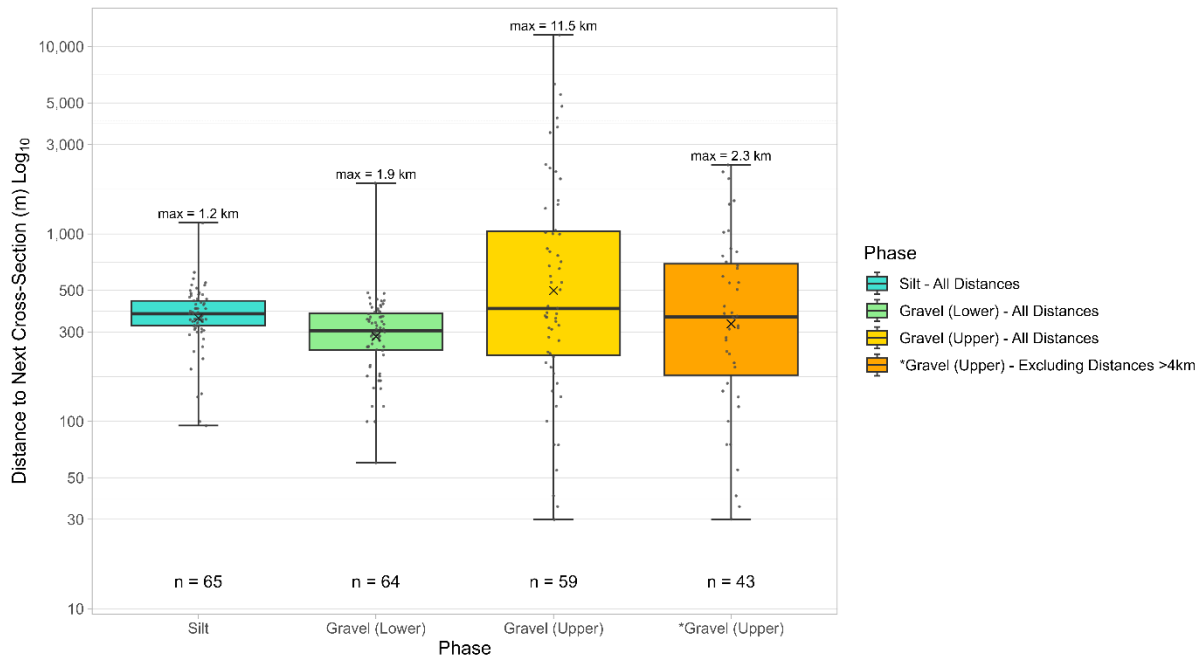


Figure 11
Box and whisker plot showing the distribution of distances between cross-sections surveyed in 2022 and 2024. The orange box on the far right shows the improvements to the cross-section distances from limiting the upper gravel phase volume analysis to the cross-section at 69060m, which is the first site to have a distance greater than 4 km to the next upstream cross-section.

Since the most recent river survey was carried out in 2024, a significant flood event occurred in February 2026 which is not captured in this analysis. While this event had a lesser impact than Cyclone Gabrielle in February 2023, the flood event did mobilise sediment and cause changes to the channel in some places. The short time span between these flood events highlights the usefulness of frequent surveys of the full length of the river, particularly following large flood events.

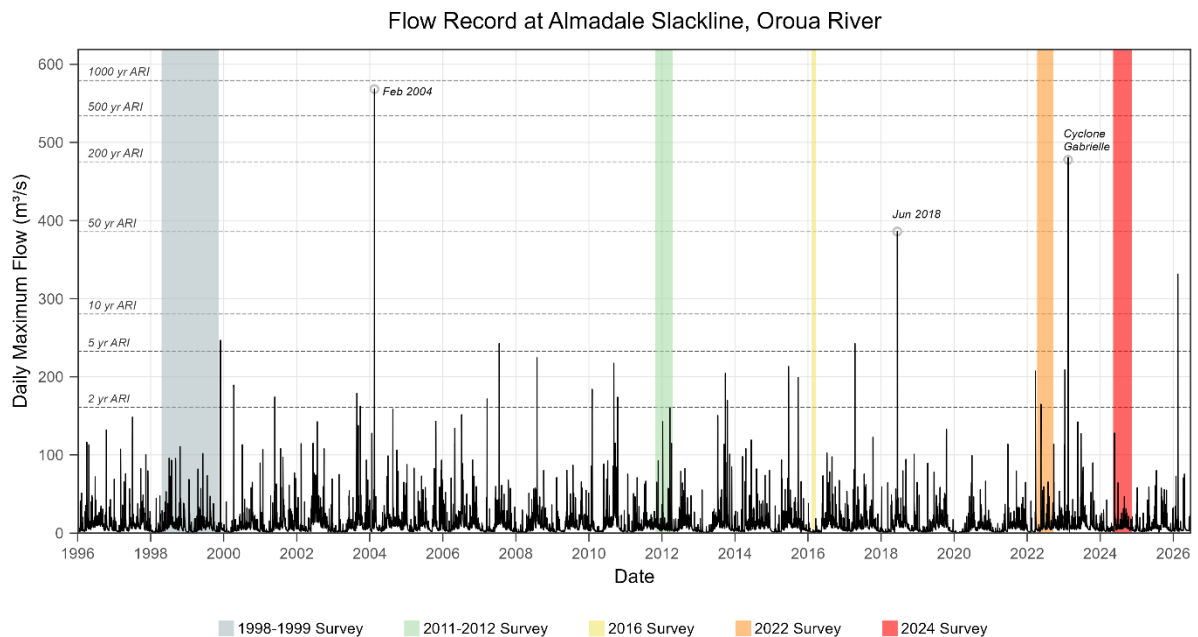


Figure 12
Flow record at Almadale Slackline, Ōroua River, from January 1996 to June 2026, showing the flood peaks of the February 2004 flood, Cyclone Gabrielle in February 2023, and the smaller flood peak in February 2026 which occurred after the most recent survey data was captured. Average recurrence interval (ARI) is the estimated return period of a given flood peak (ARI data from Horizons (2026)).

Silt Phase to Upper Gravel Phase

A few of the cross sections in the Ōroua River were not surveyed completely due to unsafe conditions. The following cross sections were completed on 21 May 2025 following the 2024 partial survey: XS 2600m, XS 3000m, XS 3535m, and XS 39715m.

Cross-sections XS 73210m and XS 84500m have incomplete surveys due to unsafe field conditions, and no follow-up surveys were undertaken to finish them. As a result, the true left final surveyed point for each of these sections lies partway through the wetted channel (**Figure 13**). Both of these sites are situated beyond the extent of the volume analysis for this study.

In several locations along the Ōroua River, the cross sections have not been surveyed completely to the top of the banks. To complete these profiles, the cross-section lines were extended using the 2025 Horizons DEM (**Figure 14**), or, where only a small extension was required, projected horizontally along the existing alignment. The extended cross-sections are listed below:

XS 02125	XS 42755	XS 54850	XS 64405
XS 07985	XS 48285	XS 55315	XS 67230
XS 09800	XS 51970	XS 59040	XS 81740
XS 30720	XS 52890	XS 61755	XS 84680
XS 40700	XS 54710	XS 62120	

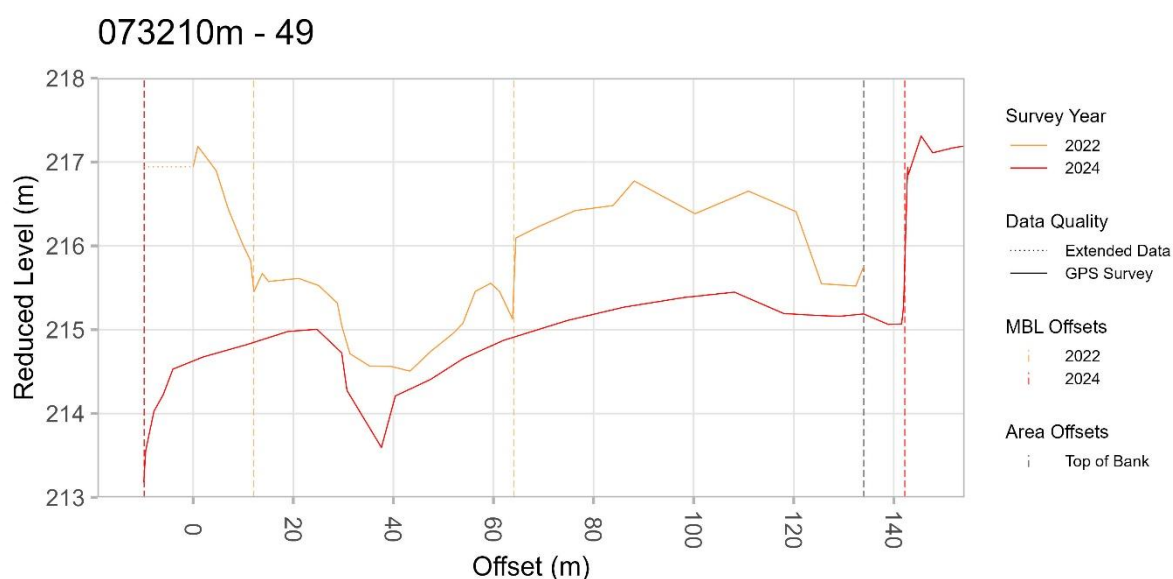


Figure 13

Example of a cross-section that has been extended in Hilltop in a straight horizontal line to maximise comparable data between survey years.

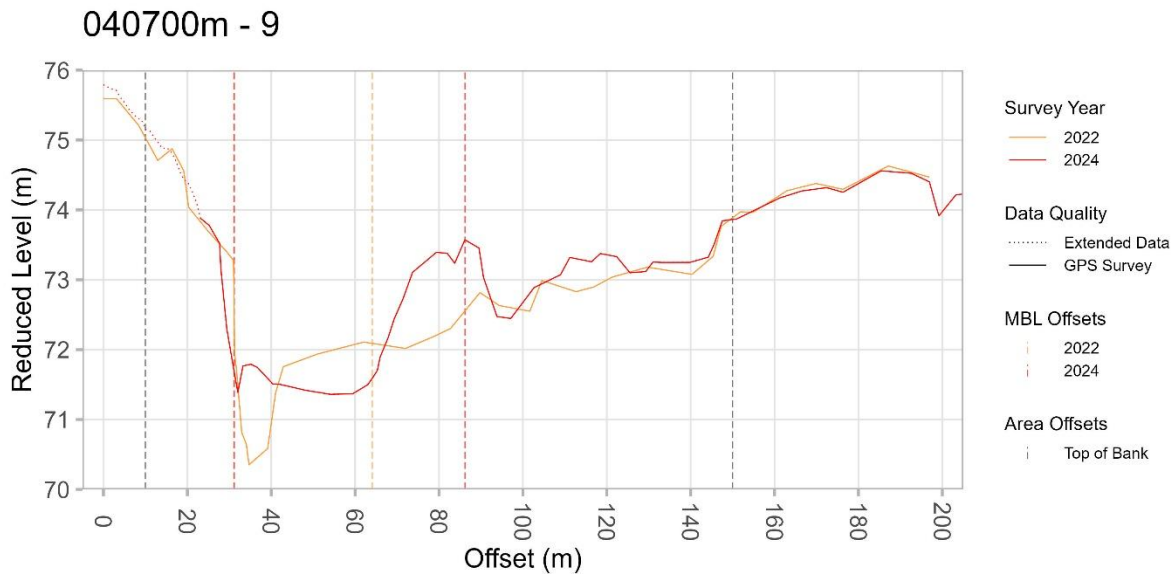


Figure 14
Example of cross-section 40700m showing the cross-section survey lines before and after extension of the 2024 left offset using the 2025 DEM.

Results and Discussion

Short-Term Analysis – All Phases

As shown in Figure 15, change in mean bed level varies along the river, with the greatest variation seen in the silt phase (approx. -0.5 m to 1 m of MBL change). The area under the section and volume analysis (Figure 16 and Figure 17 respectively) found that both the silt phase and the lower gravel phase show a clear trend of sediment aggradation, with the upper gravel phase showing no clear trend. In the upper gravel phase, two cross-section sites (XS 59040m and XS 73210m) show a large decrease in area under the section of $>-100 \text{ m}^2$ and after analysis of the aerial imagery and cross-section data, are potential outliers. XS 73210m is outside of the limits of the volume analysis, but XS 59040m has a significant influence on the volume analysis results due to large distances between neighbouring cross-sections.

The left bank cliff of both XS 73210m and XS 84500m had eroded after the cyclone, and it was not safe to cross the river at either of these sections due to the depth and speed of the flow. Even if these cross-sections were revisited now, the surveyor still would not be able to safely cross the river. As a result, both cross-sections have incomplete surveys, with the true left survey points terminating partway into the wetted channel. The apparent degradation at these locations may be a result of the substantial erosion that occurred following the cyclone, the wide spacing between cross-sections, or a combination of both factors.

Change in MBL Between 2022 and 2024

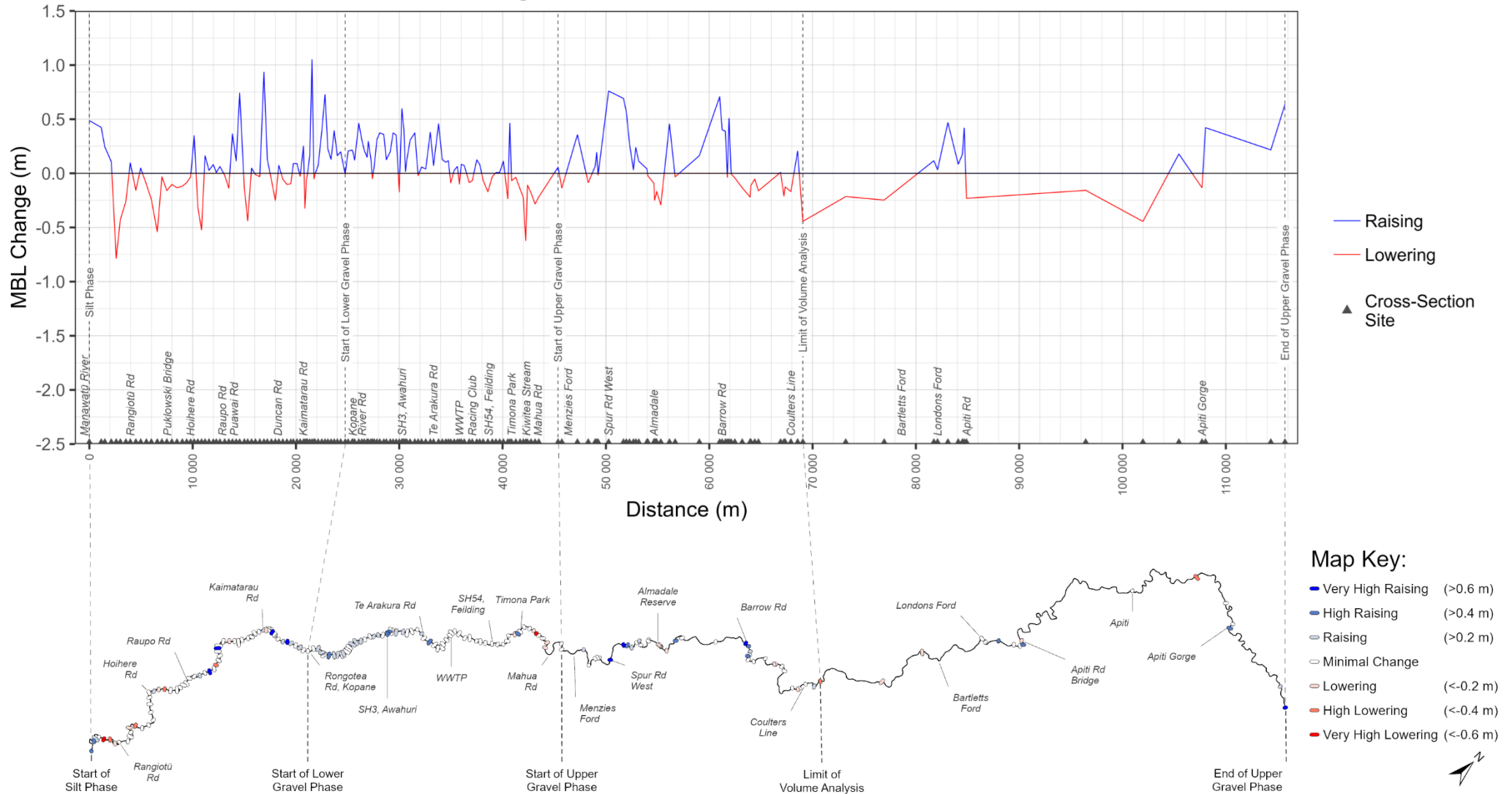


Figure 15

Change in mean bed level (MBL) between 2022 and 2024, for all cross-section sites surveyed in both 2022 and 2024. The map beneath the plot shows the plan view of the river.

Change in Area Under the Section Between 2022 and 2024

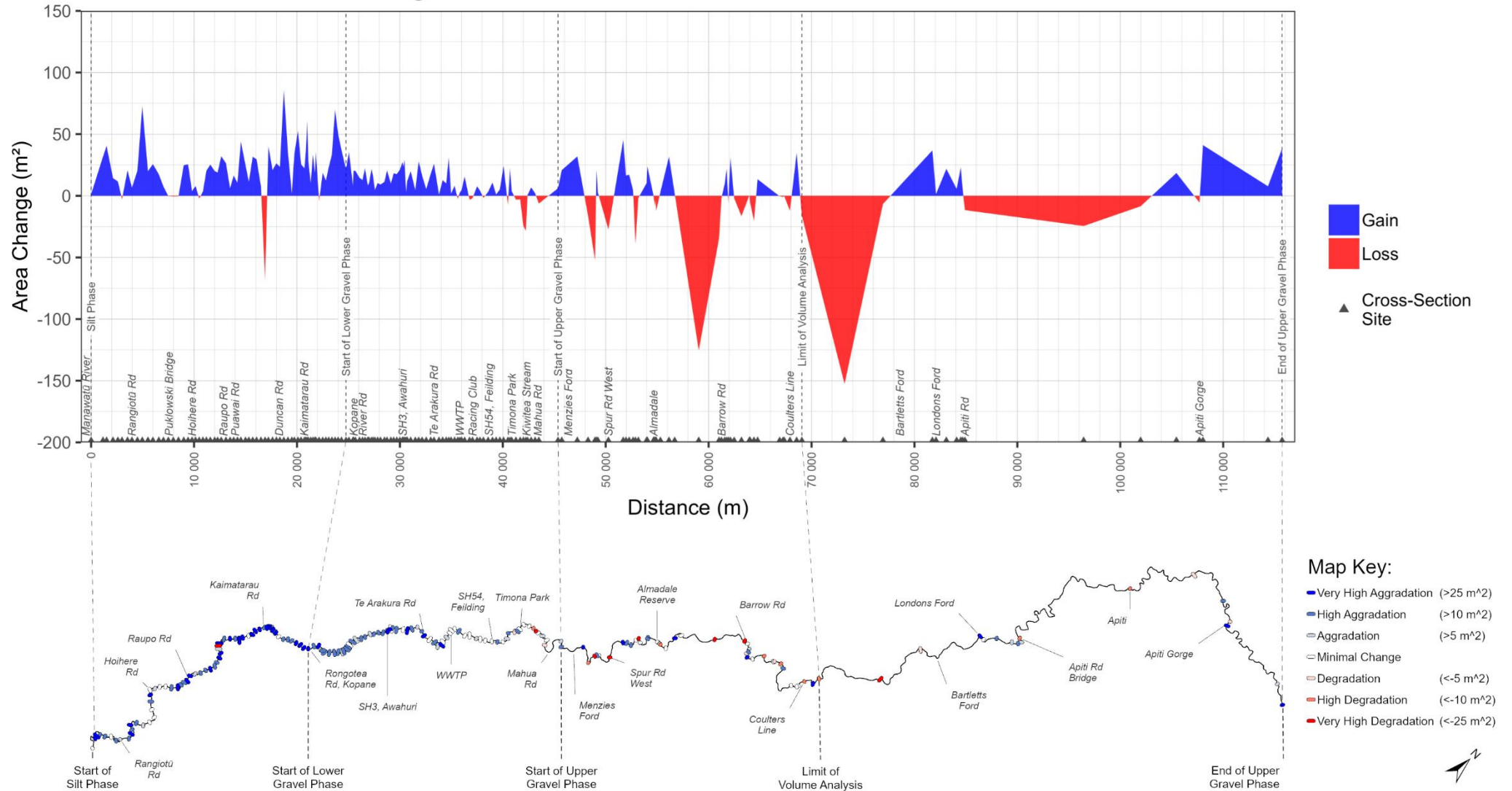


Figure 16

Change in area under the section between 2022 and 2024, for all cross-section sites surveyed in both 2022 and 2024. The map beneath the plot shows the plan view of the river.

Change in Volume Between 2022 and 2024

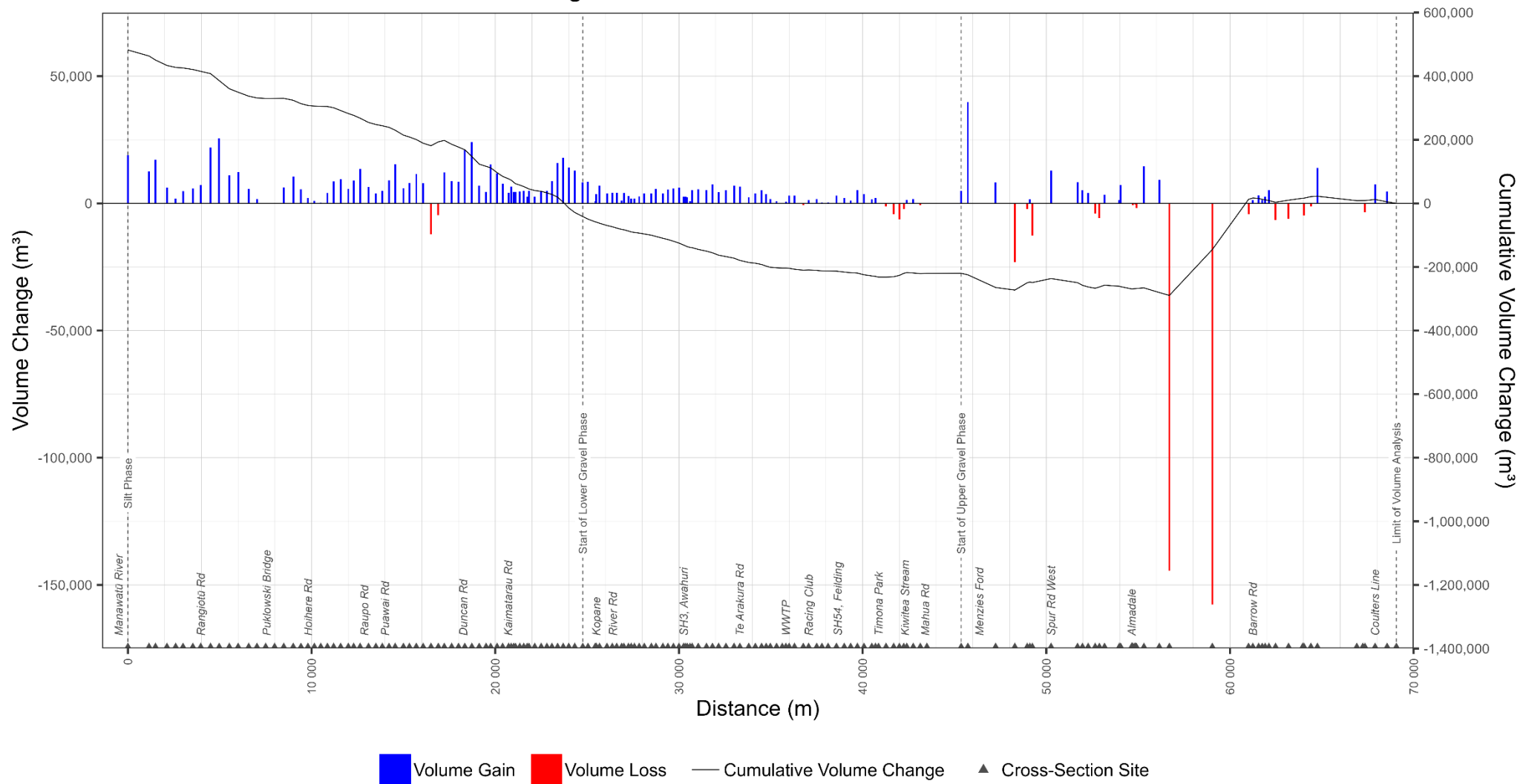


Figure 17

Change in volume between 2022 and 2024 for all cross-section sites surveyed in both 2022 and 2024 up to 69060m, where the cross-section distance becomes >4km. The map beneath the plot shows the plan view of the river.

At XS 73210m, the river has shifted its position within the active channel after Cyclone Gabrielle, meaning the survey path is at a different bearing to the wetted channel. As shown in Figure 18, the survey in 2022 is near perpendicular to the wetted channel, whereas the survey in 2024 is almost parallel to the flow for a large portion of the cross-section. This highlights the limitations of cross-section surveys in river reaches that have the capacity to be highly dynamic. As this cross-section is upstream of the limits of the volume analysis, it does not impact the sediment budget.



Figure 18

Aerial imagery showing changes in channel position at XS 73210m between 2022 and 2024, leading to the cross-section survey no longer being near-perpendicular to the river channel. The river is flowing from east to west (right to left of image).

At XS 59040m, gravel has been extracted from the cross-section site in between the 2022 and 2024 surveys. While the change in area under the section between surveys accurately reflects the changes in the channel at that location, it is not representative of the entire reach between adjacent cross-sections, which extends 2.34 km downstream and 1.97 km upstream of XS 59040m. As shown in Figure 19, the sediment removal seen at XS 59040m is not continuous throughout this reach, meaning the change in area under the section at this cross-section is likely to cause an overestimation of the amount of sediment lost from this reach when it is used as part of the volume analysis.



Figure 19

Aerial imagery showing changes to the channel at XS 59040m between 2022 and 2024. The river is flowing from north to south (top to bottom of image)

By removing XS 59040m from the dataset and recalculating the volume changes, the net change in volume for the upper gravel phase increases from -220,000 m³ to 12,000 m³, with a rate of net change in volume of 5,000 m³/year, bringing the cumulative sediment change for the river to 714,000 m³ (for the period 2022 to 2024). However, in doing this, the distance from the preceding cross-section (XS 056700m) to the next upstream cross-section increases from 2.34 km to 4.31 km. By instead limiting the volumetric analysis of the upper gravel phase to XS 056700m, the net change in volume for the upper gravel phase becomes 70,000 m³, with a rate of net change in volume of 37,000 m³/year, bringing the cumulative sediment change for the river to 772,000 m³ (for the period 2022 to 2024).

Following the methodology of previous gravel studies, gravel extraction should be considered when estimating sediment flux. Gravel that has been extracted from the river would otherwise have been captured in the area under the section analysis, so as such it is added on to the calculated net sediment change when estimating overall sediment flux. There are a number of active consents on the Ōroua River that allow for gravel extraction, for which gravel extraction volumes are required to be recorded and submitted to Horizons. As shown in Figure 20, gravel extraction records are often provided as a monthly total for the entire consented reach, meaning it can be difficult to tell exactly where and when gravel was extracted in relation to the specific cross-section location and survey date. This introduces another source of error when estimating total sediment flux, due to instances of ambiguity around whether a cross-section survey was carried out prior to, during, or after extraction.

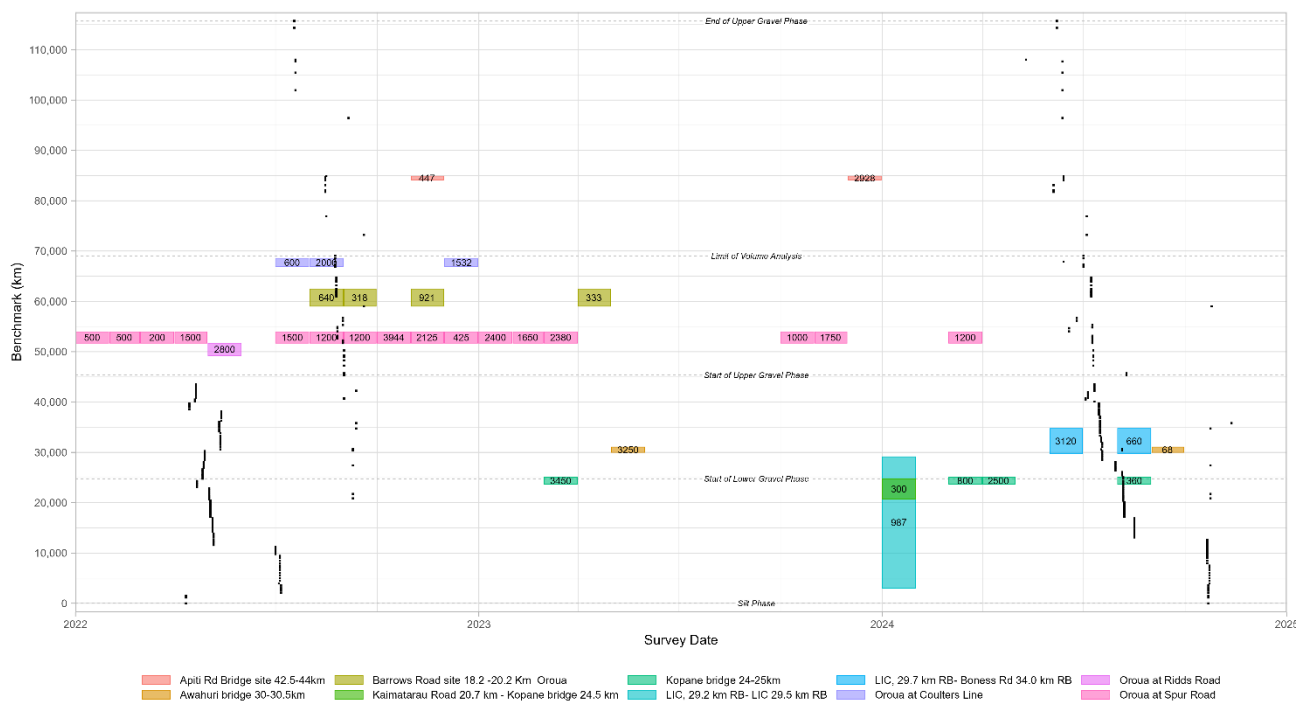


Figure 20

Plot showing the timings of each cross-section survey for the 2022 and 2024 Ōroua River surveys, overlaid on the recorded gravel extraction volumes (reported as monthly totals). Each black point indicates a survey.

Gravel extraction records are summarised in Table 2. Extractions that definitively occurred prior to a cross-section survey in 2022 or after survey in 2024 have been removed, as well as extractions above XS 69060m (the limit of the volume analysis). Where gravel extraction was reported to have occurred in the same month as a cross-section was surveyed, this is indicated as a ± error value, because it is uncertain whether gravel has been removed prior to survey.

Table 2

Gravel extraction from the 2019 and 2023 gravel studies, as well as extraction during the period between the 2022 and 2024 cross-section surveys. The 2012 study did not discuss gravel extraction quantities. Extractions above the limit of the volume analysis (XS 69060m) have been removed. Uncertainties ($\pm$) indicate extraction records that were reported in the same month that a cross-section was surveyed, where it is unclear whether extraction has or has not occurred prior to the survey.

Phase	Gravel Extracted (m ³)								
	2012 -2016		2016-2022		2022-2024				
	Total	Annual Average	Total	Annual Average	2022	2023	2024	Total	Annual Average
Silt						3,450	3,600 $\pm$ 360	7,050 $\pm$ 360	3,530 $\pm$ 180
Gravel (Lower)	90,100	22,530	76,620	12,770		3,250	4,110 $\pm$ 660	7,360 $\pm$ 660	3,680 $\pm$ 330
Gravel (Upper)	91,520	22,880	101,900	16,980	8,950 $\pm$ 5,360	9,510	1,200	19,660 $\pm$ 5,360	9,830 $\pm$ 2,680
Total	181,620	45,510	178,520	29,750	8,950 $\pm$ 5,360	16,2130	8,910 $\pm$ 1,020	34,070 $\pm$ 6,380	17,030 $\pm$ 3,190

The estimated net sediment flux for 2022 to 2024 is approximately 520,000 m³ of aggradation, with 530,000 m³ of aggradation in the silt phase, 190,000 m³ of aggradation in the lower gravel phase, and 200,000 m³ of degradation in the upper gravel phase. However, due to the potential outlier in the upper gravel phase skewing the results and disproportionately increasing degradation, this value for the upper gravel phase should be treated with caution. Table 3 shows the results of both the MBL and volume short-term analyses, including significant change in volume budget for the upper gravel phase when limiting the study to exclude the outlier in the upper gravel phase (XS 59040m).

Table 3

Results of the short-term (2022 to 2024) mean bed level (MBL) and volume study. Cross-sections where surveys were not undertaken at either year are excluded, and the volume analysis excludes cross-sections above XS 69060m, where the distance between cross-sections is >4 km. MBL values rounded to one decimal place, volume values rounded to the nearest 10m³.

Phase	No. of XS	Mean Bed Level					
		Net Δ MBL (m)	Average Δ MBL per XS (m)		Rate of Net Δ MBL (m/yr)		
Silt	65	2.6	0.0		0.0		
Gravel (Lower)	64	6.2	0.1		0.0		
Gravel (Upper)	60	4.2	0.1		0.0		
Total	189	13.0	0.1		0.0		

Phase	No. of XS	Volume					
		Net Δ Volume (m ³)	Average Δ Volume per XS (m ³)	Rate of Net Δ Volume (m ³ /yr)	Total Sediment Excavation (m ³)	Net Sediment Flux (m ³)	Average Annual Sediment Flux (m ³ /yr)
Silt	65	523,790	8,060	226,640	7,050 $\pm$ 360	530,840 $\pm$ 360	265,420 $\pm$ 180
Gravel (Lower)	64	178,420	2,790	81,100	7,360 $\pm$ 660	185,780 $\pm$ 660	92,890 $\pm$ 330
Gravel (Upper)	43	-219,920	-5,110	-110,890	19,660 $\pm$ 5,360	-200,260 $\pm$ 5,360	-100,130 $\pm$ 2,680
Total	172	482,290	2,800	196,860	34,070 $\pm$ 6,380	516,360 $\pm$ 6,380	258,180 $\pm$ 3,190
Gravel (Upper)*	24	69,770	2,910	36,790	16,870 $\pm$ 2,400	86,640 $\pm$ 2,400	43,320 $\pm$ 1,200
Total*	153	771,980	5,050	344,530	31,280 $\pm$ 3,420	803,260 $\pm$ 3,420	401,630 $\pm$ 1,710

*Analysis limited to below XS 56700m

Silt Phase

Volume Change

The silt phase shows an overall trend of aggradation (Figure 21), with degradation only shown at 4 out of the 65 cross-section sites. Between 2022 and 2024, the reach experienced a net gain of approximately 524,000 m³ of silt, equivalent to an aggradation rate of approximately 227,000 m³ per year. This is a substantial 360% increase compared with the previous study's 2016–2022 estimate of 49,000 m³ per year.

XS 4970m experienced a significant increase in volume between 2022 and 2024, with a net gain of approximately 25,500 m³. In contrast, XS 16500m and XS 16900m showed significant degradation. This result may be attributed to the three sizeable weather events that occurred in 2023, the largest being Cyclone Gabrielle.

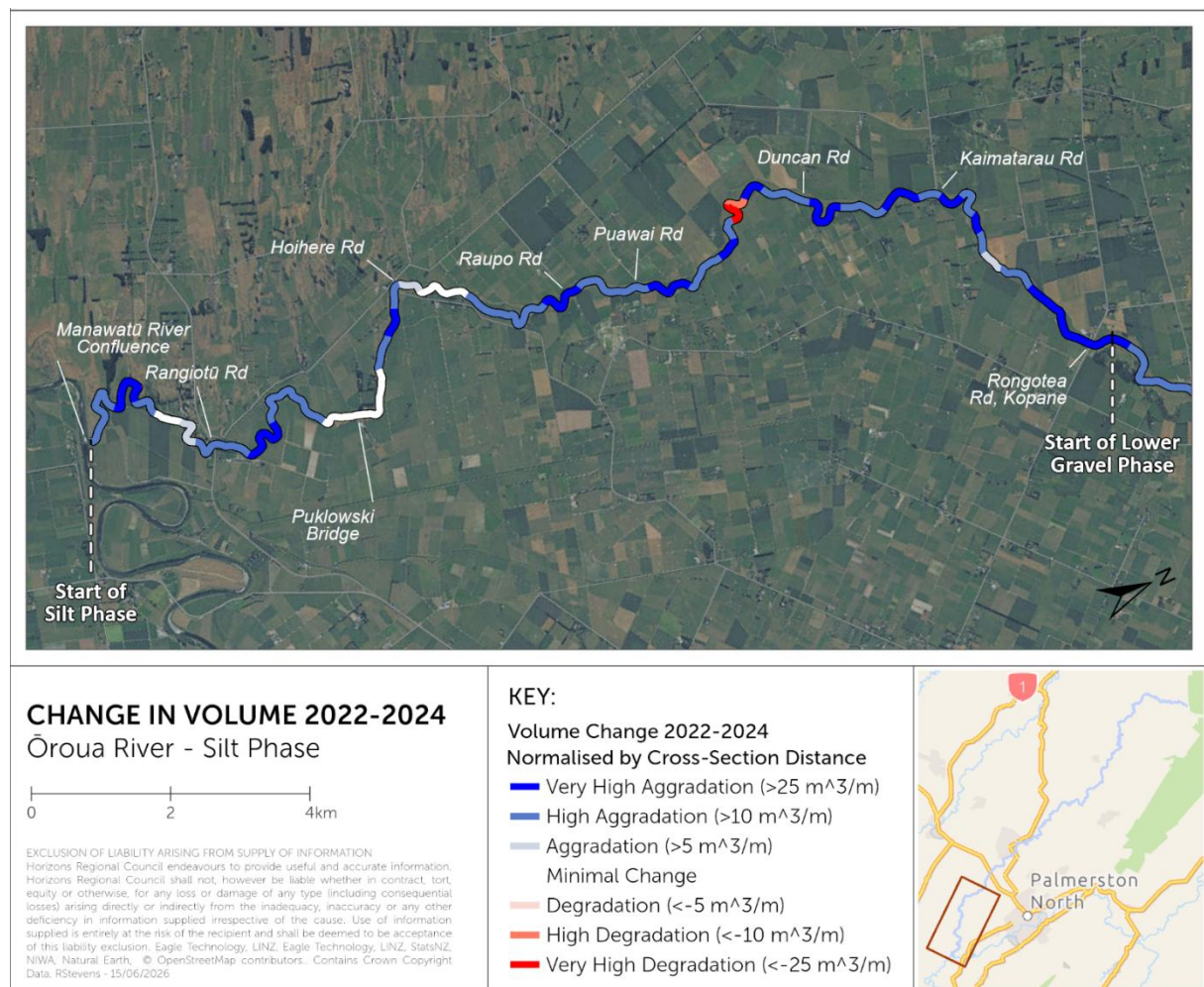


Figure 21

Map showing the normalised volume change (volume change/distance). Volume changes are reported at each cross-section but represent change from one cross-section to the next upstream cross-section.

As shown in Figure 22, flooding during Cyclone Gabrielle resulted in the draping of silt in the berm area between stopbanks.

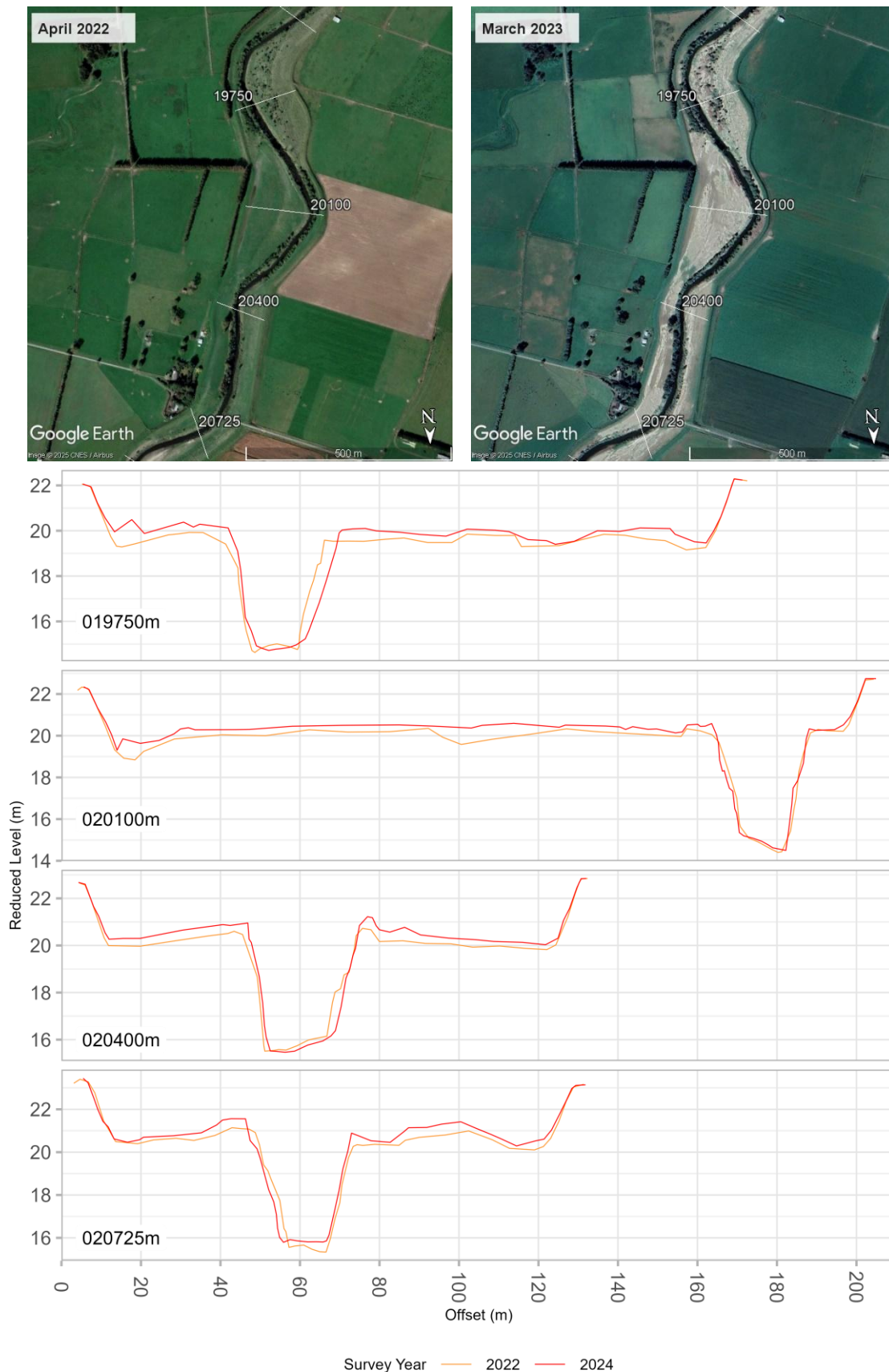


Figure 22

Aerial imagery and cross-section graphs showing deposition of silt on the berm area between stopbanks in the lower Ōroua River, just downstream of Kaimatarau Road, caused by Cyclone Gabrielle in February 2023. White lines indicate cross-section locations. The river is flowing from the bottom of the map to the top, with the true left on the left (East) and the true right on the right (West). NB: the map has been rotated 180 degrees.

Alongside the deposition of silt in the berm area, Cyclone Gabrielle also resulted in changes within the active channel. Figure 23 shows that from 2022 to 2024, at XS 16900m, substantial changes have taken place. Aerial imagery from 2021 (Figure 24) shows a large peninsula extending across the channel at XS 16900m, which is consistent with the 2022 cross-section. The 2024 cross section (Figure 23) shows that the peninsula had retreated by more than 30 m, the riverbed had risen 1–2.5 m in places, and the true right bank had shifted about 5 m into the channel. Furthermore, the berm portion of the peninsula had built up by roughly 0.2 m, which is quite common in this area after flood events (C. Reid, personal communication, 17 June 2025). It was also determined that at the beginning of 2019, approximately 9,000 m³ of silt was removed from the beaches at XS 16500m, XS 16900m, and XS 17200m (A. Williams, personal communication, 19 June 2025).

The previous gravel study identified degradation in this section, and the current analysis confirms that this trend has continued. Where overlapping DEMs are available for this section, a DEM of difference analysis may be useful for estimating siltation in the berm area between cross-sections.

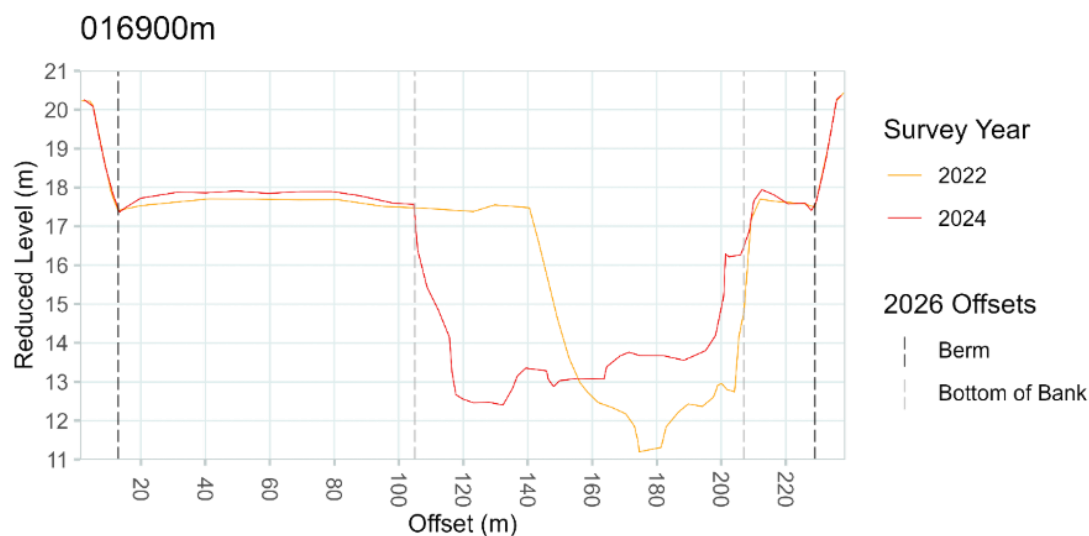


Figure 23
Cross-sectional changes at 16900m from 2022 to 2024.



Figure 24
Aerial imagery from 2021 (left) and 2024 (right) at cross-section 16900m.

Mean Bed Level Change

The silt phase results show considerable variability, with mean bed levels alternating between increases and decreases across the reach (Figure 25). Interestingly, these mean bed level changes do not consistently align with the gravel volume results. In several locations, an increase in gravel volume does not correspond to a rise in mean bed level; in fact, some cross sections have decreasing mean bed levels. This suggests that sediment behaviour in the silt phase may be influenced by factors beyond simple volumetric change—such as local channel geometry, fine sediment redistribution, or survey uncertainty as outlined in the previous section.

The 2023 study found a generally balanced average bed level across the entire reach, but larger bed change levels at specific sections. This is seen again for the 2022-2024 period, with approximately 65% of the section's points falling within 0.2 m of change (negative or positive) which is within natural variation (Whale, 2019).

Of the seven cross-sections showing MBL change $> \pm 0.5\text{m}$, three of these (XS 2600m, XS 6575m, and XS 14550m) appear to be outliers caused by missing GPS survey points within the wetted channel. XS 10860m shows a MBL lowering of 0.5 m, with the minimum bed level also lowering by 1.1 m; XS 22810m and XS 21550m both show an increase in MBL $> 0.5\text{m}$, with the minimum bed level rising by 0.6 m and 0.7 m respectively - however, there again appears to be limited GPS survey points within the wetted channel at these three sites. As discussed above, XS 16900m has undergone significant channel change as a result of Cyclone Gabrielle, leading to an increase in MBL of 0.9m, and an increase in minimum bed level of 1.2 m.

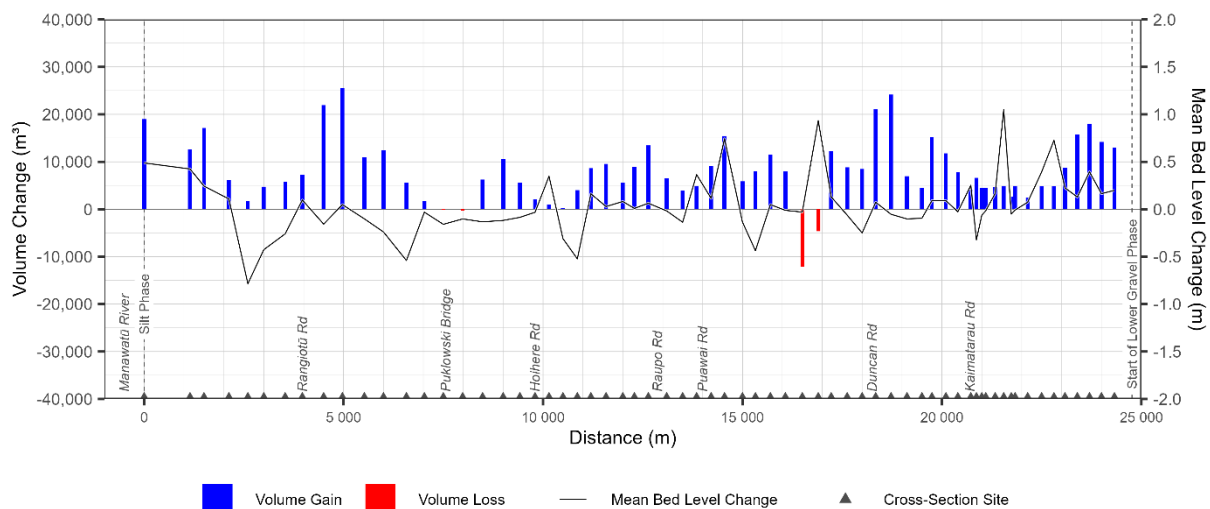


Figure 25

Plot showing change in sediment volume and mean bed level (MBL) from 2022-2024 for the lower gravel phase (Lower Ōroua). Volume changes are reported at each cross-section but represent change from one cross-section to the next upstream cross-section.

Lower Gravel Phase

Volume Change

The lower gravel phase of the Lower Ōroua has seen an overall aggradation of $178,400 \text{ m}^3$ of gravel which is approximately $81,100 \text{ m}^3/\text{yr}$ from 2022 to 2024. This trend is consistent with the 2023 study and reflects an approximate $> 450\%$ increase in the net average annual gravel volume, rising from $14,500 \text{ m}^3/\text{yr}$. All previously degrading cross-sections, except for XS 43140, have shifted to

aggradation in the current study, while several cross-sections that were aggrading in the previous assessment—such as 35625, 36770, 41275, 41690, and 42000—now show a reversal to degradation.

This increase in the gravel volume is higher than the One Plan allocable extraction volume for downstream of Menzies Ford which is 55,000 m³/yr.



Figure 26

Map showing the normalised volume change (volume change/distance) between 2022 and 2024 for the silt phase of the lower Ōroua River. Volume changes are reported at each cross-section but represent change from one cross-section to the next upstream cross-section.

Mean Bed Level Change

A general increase in mean bed level is evident across the downstream portion of the lower gravel phase, particularly between XS 24765m and XS 33315m. Upstream of this reach, the cross-sections show alternating patterns of bed level raising and lowering, indicating a more variable gravel transport environment. From XS 41275m to XS 43500m, the trend shifts to a consistent decrease in mean bed level, suggesting degradation near the Kiwitea Stream Confluence.

The largest negative mean bed level change occurs at XS 42240m, where the MBL has lowered by approximately 0.6 m, with the minimum bed level also lowering by 0.6 m. MBL raising of 0.6 m is seen at XS 30250m, with the minimum bed level raising by 0.8 m. At XS 40500m and XS 43500m, MBL change is relatively small (approx. -0.2m), however both sites show a decrease in minimum bed level of over 0.8 m, indicating incision of the wetted channel. Similarly, XS 34750m and XS

377850m show MBL raising of approx. 0.1 m, but minimum bed level raising of approx. 0.6 m. At XS 40700m, MBL has risen by 0.5 m, with the minimum bed level increasing by 1 m.

The mean bed level results generally align with the gravel volume changes. Where gravel volume increased, the mean bed level also tended to rise; conversely, decreases in gravel volume were accompanied by corresponding reductions in mean bed level. This consistency between the two metrics reinforces the reliability of the observed trends.

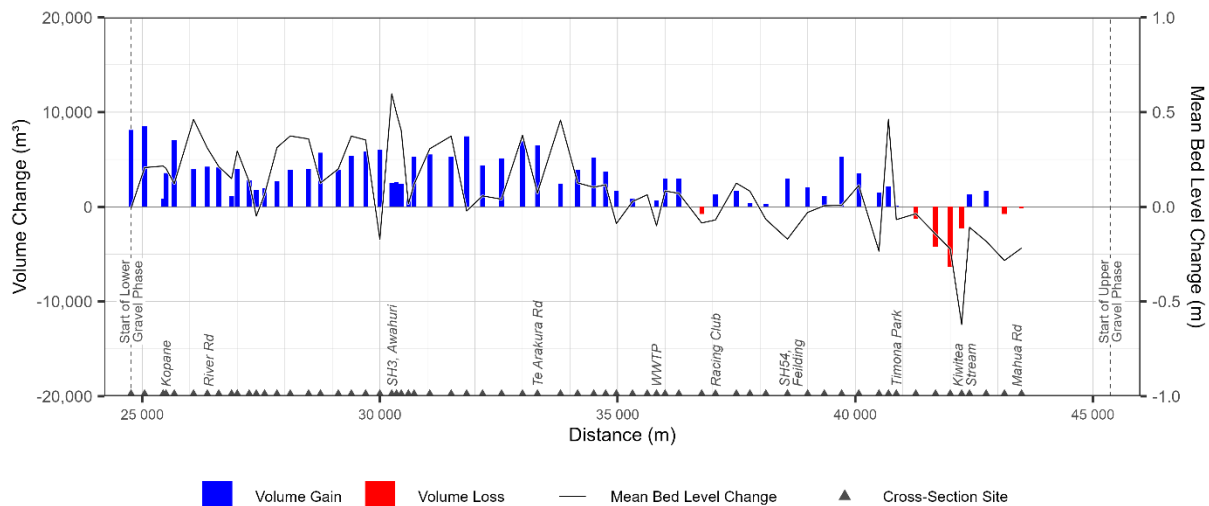


Figure 27

Plot showing change in sediment volume and mean bed level (MBL) from 2022-2024 for the lower gravel phase (Lower Ōroua). Volume changes are reported at each cross-section but represent change from one cross-section to the next upstream cross-section.

Upper Gravel Phase

Volume Change

The upper gravel phase exhibits an overall trend of degradation, with a net loss of approximately 220,000 m³ of gravel, equivalent to about -111,000 m³ per year. Note that these results should be interpreted with caution due to the wide spacing between cross-sections in this reach. Potential outliers in Figure 28 — specifically XS 56700m and XS 59040m — are influenced by the large distances to their upstream cross-sections. XS 56700m and XS 59040m each have gaps of approximately 2 km to the next upstream survey line, which contributes to the larger calculated changes, resulting in amplified gravel volume changes that may not fully represent local channel behaviour. The wide spacing between cross-sections relative to the highly variable and dynamic nature of the upper Ōroua increases interpolation uncertainty and can exaggerate the magnitude of calculated gravel volume change.

Mean Bed Level Change

The mean bed level results generally align with the gravel volume changes. Where gravel volume increased, the mean bed level also tended to rise; conversely, decreases in gravel volume were accompanied by corresponding reductions in mean bed level. This consistency between the two metrics reinforces the reliability of the observed trends. Notably, at XS 84900m (Āpiti Rd Bridge), mean bed level has only decreased by 0.2 m, but the minimum bed level has decreased by 1 m. At XS 59040m, XS 81740m and XS 101975m, MBL has risen by approx. 0.2 m, 0.1 m and 0.1 m respectively, with minimum bed level actually decreasing by 0.9 m, 0.7 m, and 0.8 m respectively. Minimum bed level has risen over 1.2 m at XS 50260m and XS 115725m, with coincident MBL increases of 0.8 m and 0.6 m respectively.

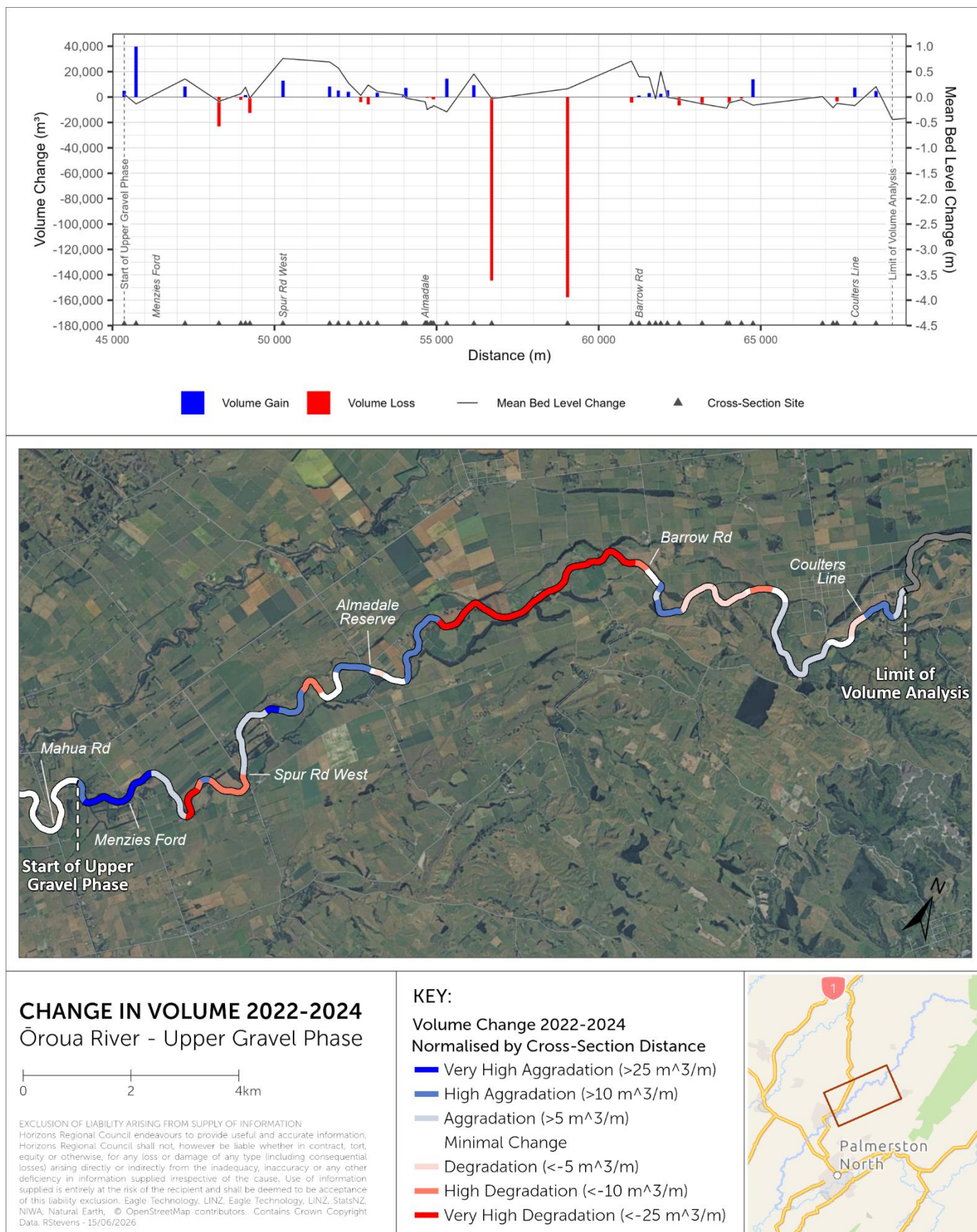


Figure 28

Plot showing change in sediment volume and mean bed level (MBL) from 2022-2024 for the upper gravel phase (Upper Ōroua) and map showing the normalised volume change (volume change/distance). Volume changes are reported at each cross-section but represent change from one cross-section to the next upstream cross-section.

Gravel Extraction and the One Plan

The One Plan (Horizons Regional Council, 2024) sets out long term average annual allocable volumes of gravel for specific rivers or reaches under Table 14 in the Regional Plan – Land and Freshwater. For the Ōroua River upstream of Menzies Ford, the annual allocable limit is 10,000 m³, and for the Ōroua River downstream of Menzies Ford, the annual allocable limit is 55,000m³. Menzies Ford is located at approximately 46.3 km upstream from the Manawatū River confluence, just downstream of XS 046400m (Colyton Rd bridge upstream). Table 4 presents the extraction records from 2022 to 2024, based on data available as of June 2026.

Table 4

Gravel extraction records for the Ōroua River, from January 2022 to December 2024.

One Plan Reach	Phase	Recorded Gravel Extraction Volume (m ³)			Total (m ³)	Average Annual Volume Extracted (m ³ /year)	One Plan long term average annual allocable volume (m ³)
		2022	2023	2024			
Downstream of Menzies Ford	Silt		3,450	3,960	7,410	2,470	
	Gravel (Lower)		3,250	4,835	8,085	2,695	
	<i>Subtotal</i>		<i>6,700</i>	<i>8,795</i>	<i>15,495</i>	<i>5,165</i>	55,000
Upstream of Menzies Ford	Gravel (Upper)	22,352	12,441	1,200	35,993	11,998	
	<i>Subtotal</i>	<i>22,352</i>	<i>12,441</i>	<i>1,200</i>	<i>35,993</i>	<i>11,998</i>	10,000
Grand Total		22,352	19,141	9,995	51,488	17,163	65,000

Based on gravel extraction levy data, the 2019 gravel study found that for 2012 to 2016, 182,000 m³ of gravel had been extracted from the Ōroua River, at a rate of 18,000 m³/year downstream of Menzies Ford, and 18,000 m³/year upstream of Menzies Ford. The 2023 study found that for 2016 to 2022, 179,000 m³ had been extracted, at a rate of 15,000 m³/year downstream of Menzies Ford, and 20,000 m³/year upstream of Menzies Ford. This indicates that the rate of gravel extraction has significantly decreased for the 2022-2024 period.

Table 5 shows the consents which allow/allowed for gravel extraction from the Ōroua River for the period of this study. Under ATH-2001009070.00, gravel extraction is allowed between State Highway 3 at Awahuri to Kaimatarau Road. This means that approximately 4 km of the consented gravel extraction reach is technically within the silt phase of the lower Ōroua River. For the purposes of this report, changes in sediment volume for the upper gravel phase of the Ōroua River will be considered to be changes in gravel volume above Menzies Ford, and changes in sediment volume for the lower gravel phase will be considered as changes in gravel volume downstream of Menzies Ford, as per the previous gravel studies.

A resource consent to extract gravel in the area approximately between Mahua Road and Ridds Road was granted in June 2026, authorising 7,500 m³/year of gravel to be extracted. This consent (ATH-2002009663.01) expires on 5 June 2031. Given that the authorised extraction locations of this consent span both upstream and downstream of Menzies Ford, and there is no specified volume limit under ATH-2000008816.0, it is difficult to confirm the current allocated extraction limits for the One Plan reaches.

There is also no cross-section survey data available in Hilltop Manager for XS 046400m for 2022 and 2024, making it difficult to align the sediment phase transitions used during the volume analysis with the One Plan reaches. In future, it is recommended to survey XS 046400m as part of the regular fluvial survey and align the phases of the volume analysis with the One Plan reaches as best as possible. It is also recommended to collate and maintain a record of silt extraction and incorporate this into future gravel studies.

Table 5

Consents active during the 2022-2024 period on the Ōroua River. The annual limit is applicable for the 2022-2024 period, and not specifically for the whole duration of the consent. MDC is Manawātū District Council, and HRC is Horizons Regional Council.

ATH	Number	Holder	Name	Locations on the Ōroua River	River Section	Annual Limit (2022-2024)	Consent Limit	Status	Commence-ment Date	Expiry Date	Note	Volume Extracted 2022-2024
ATH-2000008816.00	101369	HRC	Pohangina & Ōroua River Stability & Flood Protection Gravel Extraction	26.5-27.6km (near XS 69060m, upstream Coulters Line) (Site 6), and 37.4 - 38.3km (near XS 78600m, Bartletts Ford) (Site 7)	Upper Ōroua		0.5m below water level	Current	16/10/2000	25/09/2035	No specified volume limit	No extraction records
ATH-2001009070.00	101424 (see 101598)	HRC	Gravel Extraction (SH3 to Kaimatarau Rd)	Between State Highway 3 at Awahuri (XS 30250m) and Kaimatarau Rd (XS 20725m)	Lower Ōroua	6,000m ³ /yr	192,000m ³	Current	14/02/2001	31/12/2027 (previously 23/01/2026)	Limit to total 60,000m ³ between 23/01/2001 and 23/01/2004, then 6,000m ³ annually	No extraction records
ATH-2004010097.01	102541	HRC	Gravel Extraction (Both Reaches)	45.7 km reach between Kiwitea Stream confluence (XS 42240m) and 500 m upstream of the Apiti Bridge (500m upstream of XS 84900m)	Lower and Upper Ōroua	30,000 m ³ /yr	850,000 m ³	Expired	20/09/2007	15/12/2023	01/09/2007 to 01/09/2012 - maximum annual amount shall not exceed 80,000 m ³ , then 30,000m ³ after	2022: 22352m ³ , 2023: 12441m ³ , 2024: 1200m ³ , Total: 35993m ³ (all from Upper Ōroua)
ATH-20060111146.02	103496	HRC	Ōroua River & Lower Kiwitea Stream Channel Maintenance Gravel Extraction (Downstream of Menzies Ford)	Manawātū River confluence (XS 00000m) to Mahua Rd/Reids Line East (XS 45365m)	Lower Ōroua	15,000 m ³ /yr	650,000 m ³	Current	13/08/2008	31/12/2027 (previously 18/04/2026)	Annual limit 50,000 m ³ for years 1-10, then 15,000 m ³	2023: 6700m ³ , 2024: 8795m ³ , Total: 15495m ³
ATH-2016200840.00	N/A (Previously 105495)	MDC	Roading Aggregate River Gravel Extraction (Ōroua River, upstream of Menzies Ford)	Near Main South Rd Bridge (Apiti Gorge Bridge, near XS 107695m)	Upper Ōroua	10,000 m ³ /yr	40,000 m ³	Current	29/07/2016	31/12/2027 (previously 01/07/2021)	Replaces ATH-2011013544.00 (105495)	No extraction records

On 17 December 2025, the Resource Management (Duration of Consents) Amendment Act 2025 came into force, which automatically extended or reinstated the expiry dates for some resource consents, including ATH-2001009070.00, ATH-2006011146.02, and ATH-2016200840. This means that, at the time of this study, the One Plan reach upstream of Menzies Ford is allocated above the One Plan Table 14 limit (10,000 m³/year under ATH-2016200840.00, plus any extractions under ATH-2000008816.0 and ATH-2002009663.01), and the One Plan reach downstream of Menzies Ford is partially allocated (6,000 m³/year under ATH-2001009070.00, plus 15,000 m³/year under ATH-2006011146.02, plus any extractions done under ATH-2002009663.01).

Long-Term Analysis

Trends from 1998 to 2024, based on previous gravel study findings

The long-term analysis uses survey data spanning from 1998/1999 (combining data from survey years to form a complete set of river surveys where necessary) to 2024. This gives a better picture of the long-term trends of mean bed level and sediment volume change, outside of the dominant influence of Cyclone Gabrielle. The analysis uses the 1998 data as a baseline or reference point, which assumes that the river was in a stable sediment transfer state at that point in time, which is not necessarily the case. However, the long-term trends are useful for showing the general direction and magnitude of change over the last c. 25 years.

Sediment volume change at each cross-section (from the raw data analysis) is shown below in Figure 29. This uses estimates of change in volume from previous gravel studies, with additional estimates from this study. Note that for the 2022-2024 analysis, cross-sections where survey data was unavailable for any of the previous years were excluded (to enable cumulative change estimates), and the volumes were recalculated based on the resulting adjusted distances. There are slight variations in methodologies between gravel studies, namely the offsets used during area under the section calculations and cross-sections used, as well as previous studies being limited to the lower Ōroua River.

It should be noted that while the 2022 to 2024 period shows accelerated rates of sediment volume change in some places, this is likely due to the impacts of Cyclone Gabrielle as well as the relatively short timespan between survey years. A significant flood event occurred in February 2004, and another large flood event occurred in June 2018, however both of these events occurred during longer periods between surveys of 13 years and 6 years respectively, compared to the two-year period for Cyclone Gabrielle. Until a new set of survey data is available, it is difficult to tell how long the impacts of Cyclone Gabrielle will persist for in the active channel, and whether any accelerated rates of change could be expected to continue into future years or be absorbed as the river returns itself to a stable state.

Figure 30 shows the net sediment volume change, using the estimated cumulative change from previous studies. This provides an overview of the long-term net change in sediment for the silt phase, lower gravel phase, and total lower Ōroua (silt phase and lower gravel phase combined). Since 1998, there has been an increase in sediment volume of 2,268,000 m³ in the lower Ōroua River; 97% of this aggradation is in the silt phase (2,198,000 m³), and only 3% is in the lower gravel phase (70,000 m³). From 1998 to 2022, the lower gravel phase was showing net degradation of sediment, and after Cyclone Gabrielle, sediment volume in the lower gravel phase is slightly above the 1998 baseline.

Gravel extraction was not taken into account during the 2012 study calculations, but when considered as part of the net sediment flux (net volume change plus gravel extracted) in the 2019, 2023, and 2026 studies, does indicate an increase in gravel supply to the river. While this provides a high-level indication of the sediment flux within these reaches, there are still areas of net degradation (as shown in Figure 29) that will need to be carefully monitored, and sediment extraction therefore needs to be carefully managed. In future, both silt extraction and gravel extraction records should be collated and maintained to improve sediment flux calculations.

Volume Change - Long-Term Analysis Using Previous Gravel Study Estimates

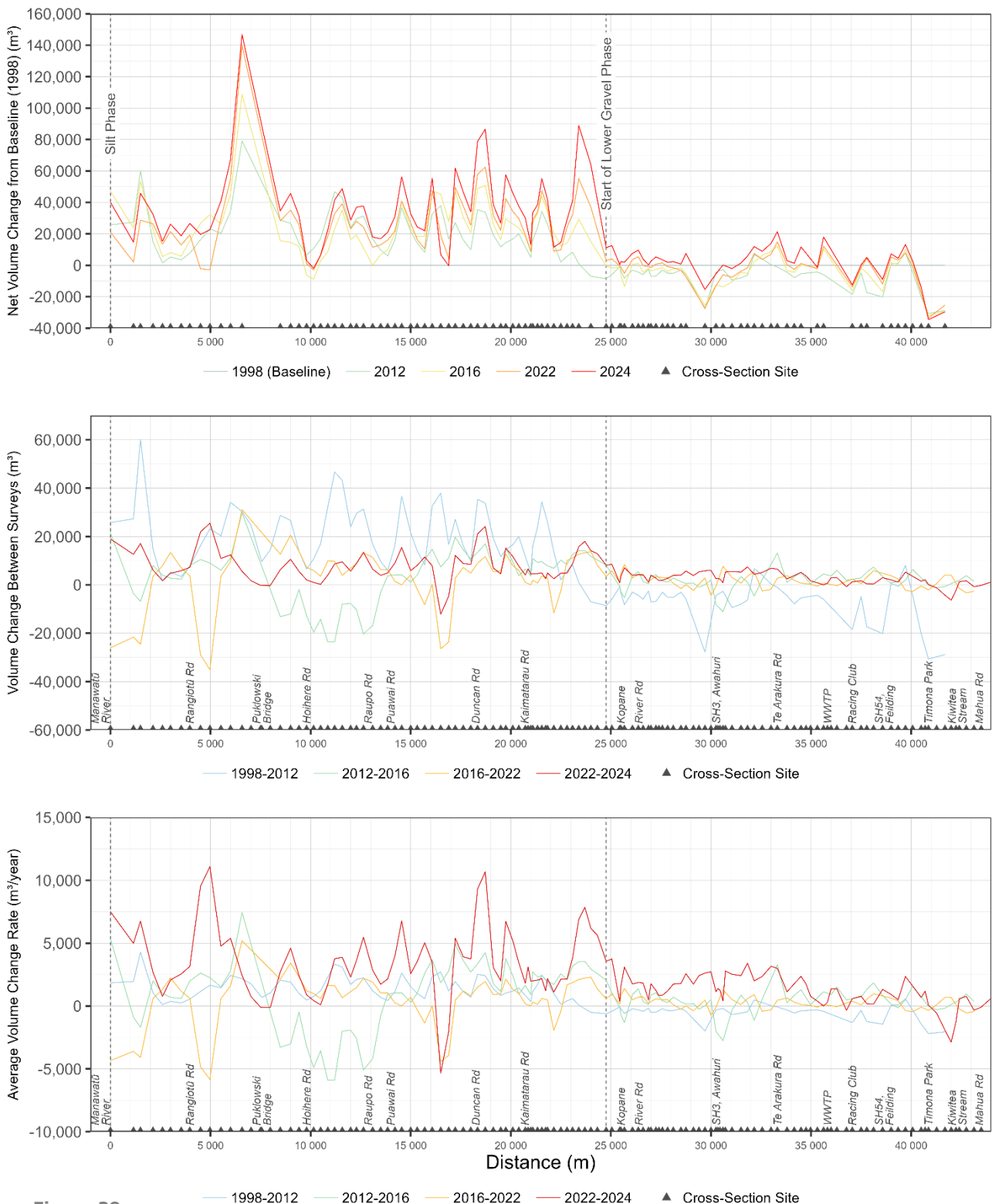


Figure 29

Sediment volume change analysis for the silt and lower gravel phases of the Ōroua River, using the raw volume changes calculated as part of previous gravel studies and this gravel study, for survey years 1998, 2012, 2016, 2022, and 2024.

The silt phase appears to consistently show aggradation, whereas there appears to be degradation in the lower gravel phase above XS 35625m. Similar to the findings of the short-term study, volume change is highly variable along the river. Further analysis could be done to incorporate the width of the active channel and the rate of volume change to help further normalise the volume change results.

As shown in Figure 30, the overall pattern of this long-term study shows that from 1998 to 2012, the silt phase of the Ōroua River shows aggradation, while the lower gravel phase showed degradation. Between 2012 and 2022, both the silt phase and the lower gravel phase show aggradation, with a significant increase in the rate of aggradation after 2022 as a result of Cyclone Gabrielle in 2023.

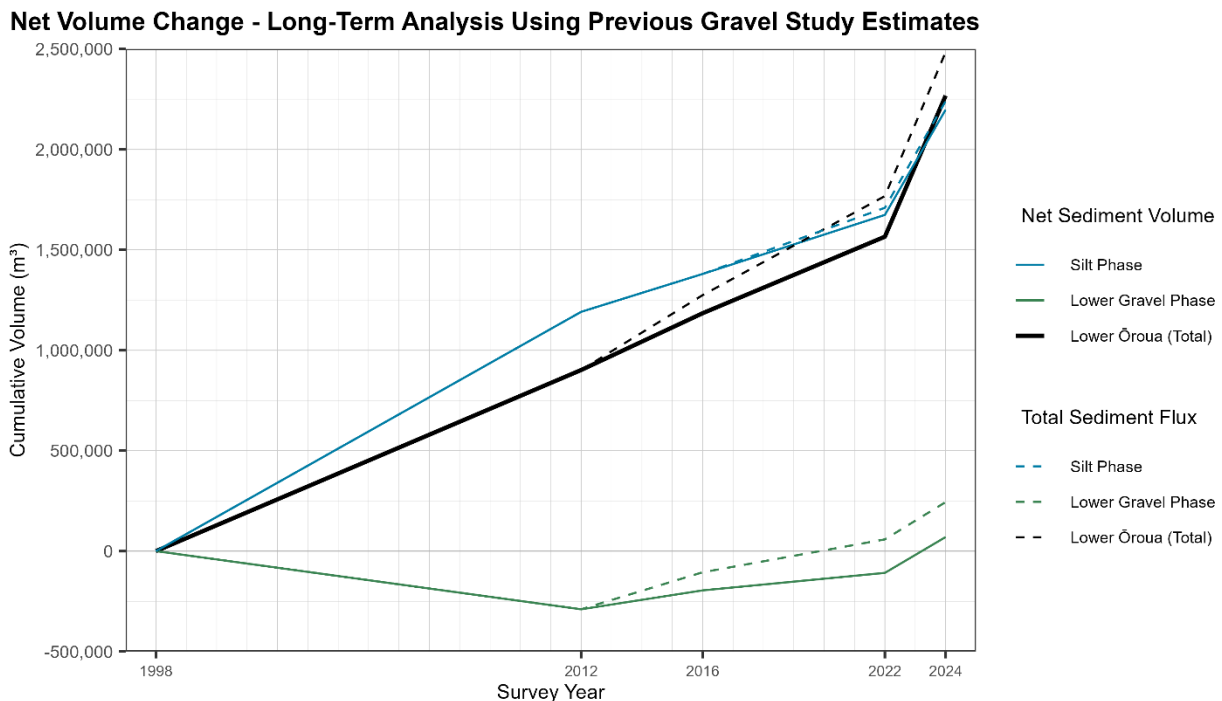


Figure 30
Net sediment volume change in the lower Ōroua River, based on cumulative net sediment volume change and total sediment flux (sediment volume change plus sediment extracted) estimated in previous gravel studies and this study. Extraction records were not included in the 2012 gravel study.

The rate of sediment flux (net volume change plus gravel extracted) is highly variable between study periods (Table 6); for the lower gravel phase, average annual sediment flux decreased from 46,000 m³/year for the 2012-2016 period to 27,300 m³/year for the 2016-2022 period and has then more than tripled for the 2022-2024 period to 92,900 m³/year. This is likely a product of the influx of gravels mobilised by Cyclone Gabrielle and should not be considered as the expected annual sediment flux going forward; rather, this reflects a sediment pulse caused by an extreme flood event.

From 1998 to 2024, the net sediment flux for the lower gravel phase is 9,400 m³/year, and net average annual volume change is only 2,700 m³/year. However, gravel extraction was not factored into the 1998-2012 study, so this may be an underestimation of net sediment flux. For the periods 2012-2024 and 2016-2024, net average annual volume change for the lower gravel phase is approximately 30,000 m³/year, and the average annual sediment flux is closer to 45,000 m³/year. This concurs with the findings of the 2019 and 2023 gravel studies that the annual gravel extraction limit of 55,000 m³ for the One Plan reach downstream of Menzies Ford is greater than the observed long-term sediment flux.

Based on the 2012 to 2024 long-term average annual sediment flux, 45,000 m³/year may be the most reasonable estimation of annual net sediment flux for the lower gravel phase. This aligns with the findings of the 2019 gravel study (Whale, 2019). However, given the potential degradation shown by this study in the upper gravel phase and the low frequency of events such as Cyclone Gabrielle that can introduce such large quantities of gravel, 30,000 m³/year as per the recommendations of the 2023 gravel study may be the most appropriate annual gravel extraction limit for the One Plan reach downstream of Menzies Ford. This is still considerably more than has been extracted in any one year since 2012.

Long-term analysis using 2022/2024 active channel offsets

Because the earliest two gravel studies (2012 and 2019) were carried out using survey data in Wellington 1953 Local Vertical Datum as opposed to the New Zealand Vertical Datum 2016 (used in 2022 onwards), the MBL results of the previous studies were not directly comparable. To make the long-term MBL analysis as consistent as possible, MBL offsets have been re-chosen for the bottom of the banks, and the Hilltop calculations rerun. The results shown in Figure 31 use these new offsets to compare survey data from 1998/1999, 2011/2012 (combining data from survey years to form a complete set of river surveys where necessary), 2016, 2022 and 2024.

The long-term change in sediment volume estimates shown at the bottom of Table 6 and in Figure 32 are based on the same left and right offsets used for the short-term study, i.e., they reflect the change in sediment volume for the position of the active channel as of 2022/2024. These offsets may be different to offsets used in previous studies, resulting in different results. The findings of the previous studies (carried out in 2012, 2019, and 2023) are likely to be more accurate for their respective epochs (1998-2012, 2012-2016, and 2016-2022), as the offsets used reflect the active channel position for each epoch, but previous studies have not followed an exact standard methodology – for example, the 2012 study does not include the berm area between stopbanks in the silt phase, and calculates volume using the change in area under the section from one cross-section to the next downstream cross-section.

Using a single set of offsets across all years increases the efficiency of the volume calculations but is more likely to incorporate changes under the section that are outside of the river's processes and/or exclude areas of change where the river has significantly migrated laterally. In future, it is recommended to recalculate the change in area under the section at each cross-section using the same methodology and vertical datum for all epochs, which will enable a more accurate comparison between survey years over the long-term than has been carried out within this study.

The raw results of the long-term analysis are shown in Table 6. The net change in sediment volume between 1998 and 2024 (using 2022/2024 offsets) for the silt phase is approximately 2,180,000 m³ and -344,000 m³ for the lower gravel phase, or 1,673,000 m³ and -505,000 m³ respectively when factoring in gravel extraction volumes to get cumulative total sediment flux. The annual rate of net change in sediment volume between 1998 and 2024 for the silt phase is approximately 83,000 m³/year and -13,000 m³/year for the lower gravel phase. Notably, the lower gravel phase shows a net degradation of sediment, which contrasts with the net aggradation seen in the 2022-2024 analysis and the cumulative results from previous gravel studies.

The 2012 gravel study found a net total gain in sediment of 900,000 m³ beneath the active channel of the lower Ōroua (1,180,000 m³ in the silt phase, and -280,000 m³ in the lower gravel phase) between 1998 and 2012. The findings of the 2026 study estimate 10% more aggradation in the silt phase and more than twice as much degradation in the lower gravel phase, with 30% more degradation overall. This is likely due to significant variation between the offsets used in the 2012 study versus this study. However, both studies have shown that there is a general trend of aggradation in the silt phase, and degradation in the lower gravel phase between 1998 and 2012.

The 2019 gravel study found that sedimentation was highly variable within the silt phase for the period between 2012 and 2016, with an overall net increase of 190,000 m³; however, degradation was observed between XS 8485m and XS 13500m due to removal of sediment from the berm for stopbank construction. The lower gravel phase was estimated to have aggraded by 94,000 m³, with a net increase in sediment volume of 280,000 m³ for the lower Ōroua. This is similar to the 2026 study estimate of a net increase in sediment of 270,000 m³, however this study estimated approximately 30% less accumulation of gravel in the lower gravel phase.

The findings of the 2023 gravel study (analysing the period 2016 to 2022) were 87,000 m³ of aggradation in the lower gravel phase and 290,000 m³ of aggradation in the silt phase. While the 2026 study shows the same volume change for the lower gravel phase, the estimated aggradation in the silt phase is half of the previous study's estimate. This is likely due to a number of cross-sections where silt had been removed from the berm area for river management purposes being excluded from the 2023 study analysis.

Table 6

Results of the long-term mean bed level and sediment volume change analysis for the silt and lower gravel phases of the lower Ōroua River. Sediment flux is the sum of net volume change and gravel extracted, however, extraction records were not included in the 2012 gravel study so are not able to be factored in to sediment flux. MBL values rounded to one decimal place, volume values rounded to the nearest 10 m³.

Phase	Mean Bed Level Change - Using 2026 Study Offsets											
	1998 - 2012			2012 - 2016			2016 - 2022			2022 - 2024		
	Net Δ MBL (m)	Average Δ MBL per XS (m)	Rate of Net Δ MBL (m/yr)	Net Δ MBL (m)	Average Δ MBL per XS (m)	Rate of Net Δ MBL (m/yr)	Net Δ MBL (m)	Average Δ MBL per XS (m)	Rate of Net Δ MBL (m/yr)	Net Δ MBL (m)	Average Δ MBL per XS (m)	Rate of Net Δ MBL (m/yr)
Silt	7.2	0.1	0.5	3.5	0.1	0.8	3.3	0.1	0.5	3.3	0.1	1.1
Gravel (Lower)	-10.5	-0.2	-0.8	0.4	0.0	0.1	0.2	0.0	0.0	5.4	0.1	2.4

Volume - Using Previous Gravel Studies' Estimates and 2026 Study Findings																
	1998 - 2012			2012	2012 - 2016			2016	2016 - 2022			2022	2022 - 2024			2024
	Net Δ Volume (m³)	Net Sediment Flux (m³)	Annual Sediment Flux (m³/yr)	Cumulative Total Sediment Flux (m³)	Net Δ Volume (m³)	Net Sediment Flux (m³)	Annual Sediment Flux (m³/yr)	Cumulative Total Sediment Flux (m³)	Net Δ Volume (m³)	Net Sediment Flux (m³)	Annual Sediment Flux (m³/yr)	Cumulative Total Sediment Flux (m³)	Net Δ Volume (m³)	Net Sediment Flux (m³)	Annual Sediment Flux (m³/yr)	Cumulative Total Sediment Flux (m³)
Silt	1,191,310	1,191,310	85,090	1,191,310	188,600	188,600	47,150	1,379,910	293,970	329,470	54,910	1,709,380	523,790	530,840	265,420	2,240,220
Gravel (Lower)	-289,660	-289,660	-20,690	-289,660	94,130	184,230	46,060	-105,430	87,090	163,710	27,290	58,290	178,420	185,780	92,890	244,060
Total	901,650	901,650	64,400	901,650	282,730	372,830	93,210	1,274,480	381,060	493,180	82,200	1,767,660	702,210	716,620	358,310	2,484,280

Volume - Using 2022/2024 Active Channel Offsets and Adjusted Cross-Section Distances																
	1998 - 2012			2012	2012 - 2016			2016	2016 - 2022			2022	2022 - 2024			2024
	Net Δ Volume (m³)	Net Sediment Flux (m³)	Annual Sediment Flux (m³/yr)	Cumulative Total Sediment Flux (m³)	Net Δ Volume (m³)	Net Sediment Flux (m³)	Annual Sediment Flux (m³/yr)	Cumulative Total Sediment Flux (m³)	Net Δ Volume (m³)	Net Sediment Flux (m³)	Annual Sediment Flux (m³/yr)	Cumulative Total Sediment Flux (m³)	Net Δ Volume (m³)	Net Sediment Flux (m³)	Annual Sediment Flux (m³/yr)	Cumulative Total Sediment Flux (m³)
Silt	1,291,130	1,291,130	92,220	1,291,130	202,140	292,240	73,060	1,364,190	154,100	230,720	38,450	1,402,640	533,820	540,870	270,440	1,673,080
Gravel (Lower)	-664,590	-664,590	-47,470	-664,590	65,910	157,430	39,360	-625,230	86,510	188,410	31,400	-593,830	168,180	175,680	87,840	-505,990
Total	626,540	626,540	44,750	626,540	268,050	449,670	112,420	738,960	240,610	419,130	69,850	808,820	702,000	716,550	358,280	1,167,090

Mean Bed Level - Long-Term Analysis

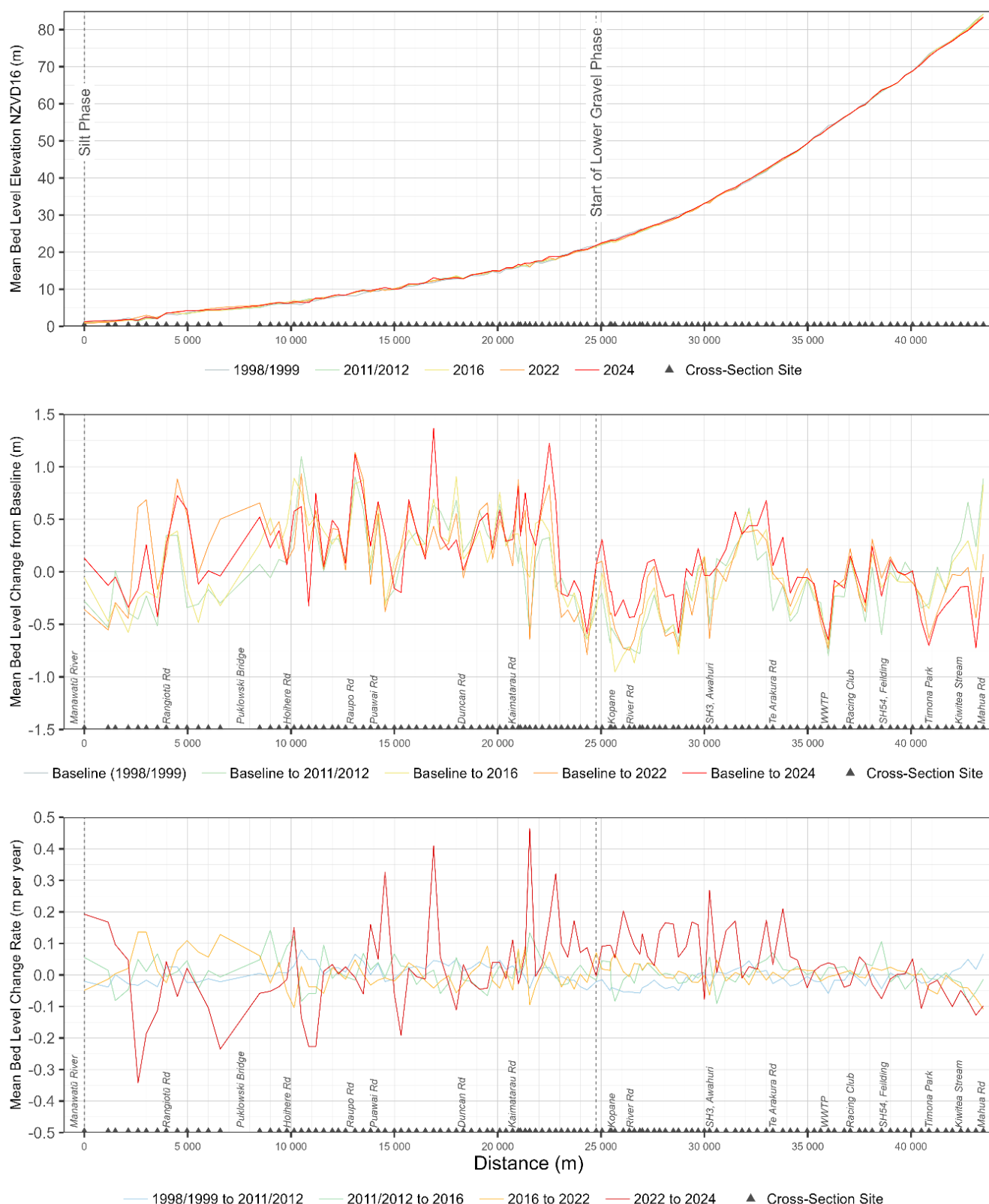


Figure 31

Mean bed level change analysis for the silt and lower gravel phases of the Ōroua River, for survey years 1998/1999, 2011/2012, 2016, 2022, and 2024, using the MBL offsets chosen as part of this study (2026) for all years.

Volume Change - Long-Term Analysis using 2022-2024 Active Channel Offsets

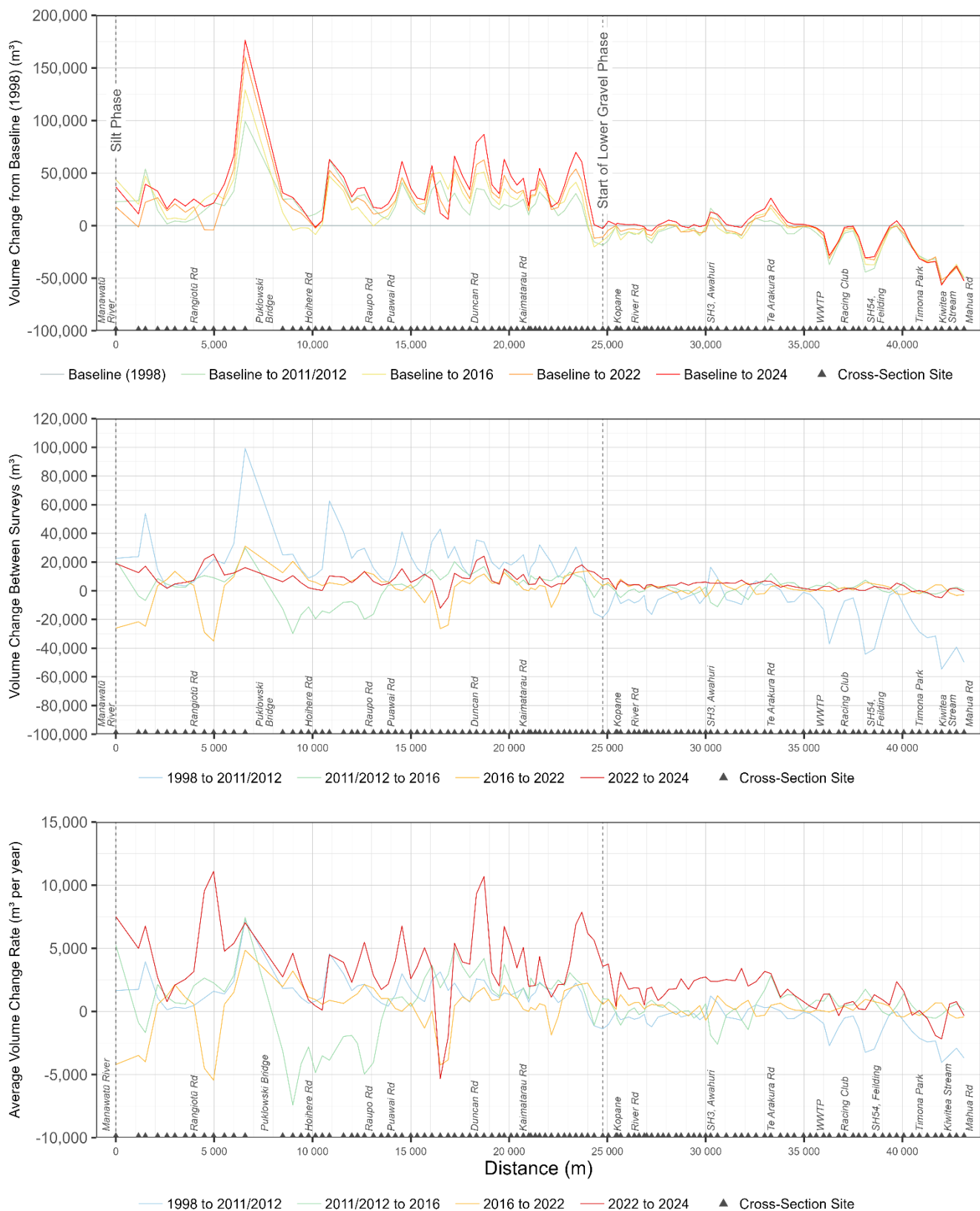


Figure 32

Sediment volume change analysis for the silt and lower gravel phases of the Ōroua River, using the 2022/2024 area under the section offsets, for survey years 1998/1999, 2011/2012, 2016, 2022, and 2024.



Figure 33
Sediment volume change between 1998 and 2024 compared to 2022 to 2024 for the silt phase of the Ōroua River (using 2022/2024 active channel offsets).

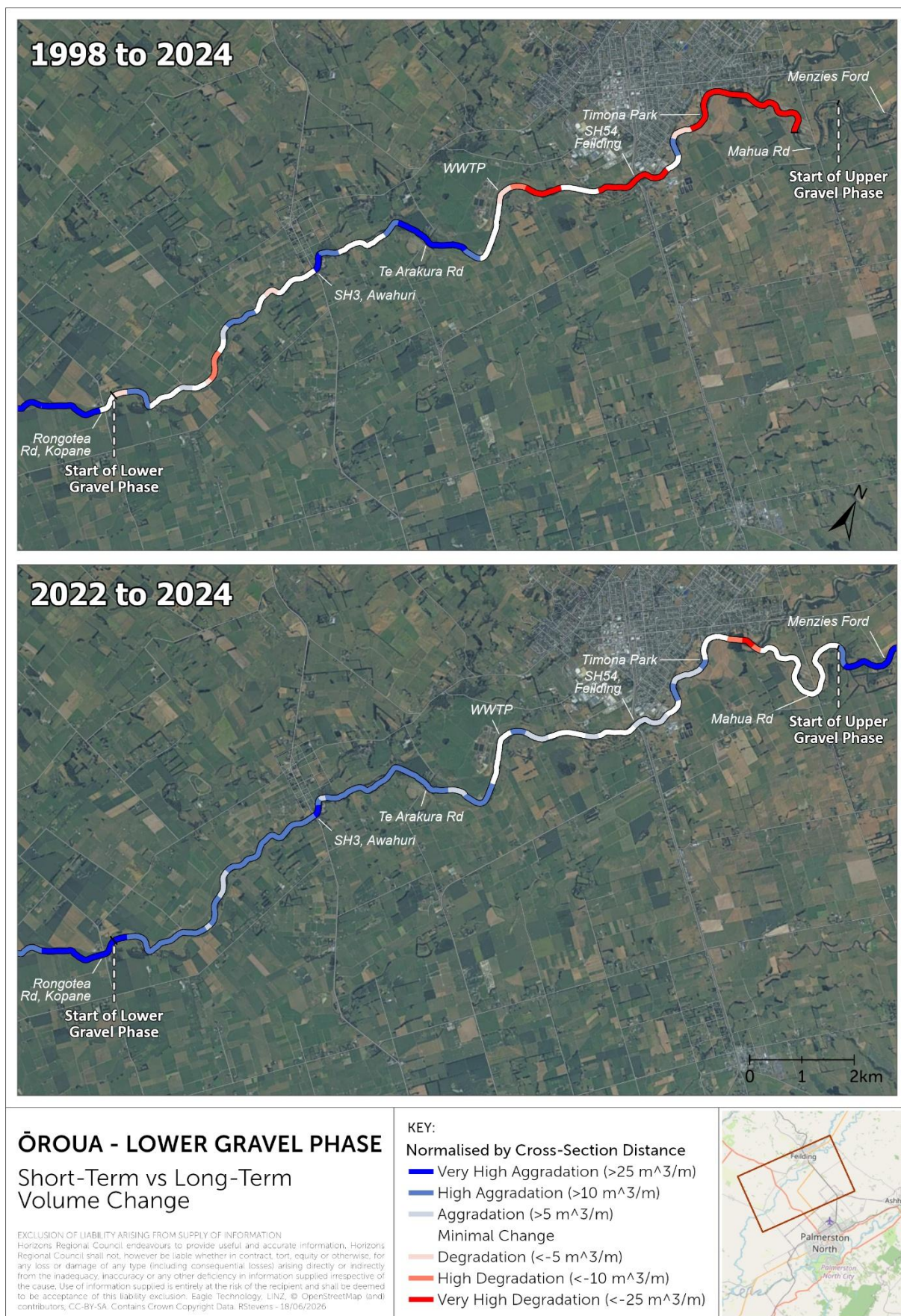


Figure 34
Sediment volume change between 1998 and 2024 compared to 2022 to 2024 for the lower gravel phase of the Ōroua River (using 2022/2024 active channel offsets).

Conclusion and Recommendations

Overall, the lower Ōroua River (silt and lower gravel phases) generally exhibits a pattern of aggradation whereas the upper Ōroua shows an overall trend of degradation over the 2022–2024 period.

The silt phase shows an overall aggradation rate of approximately 227,000 m³ of silt per year, with mean bed level changes displaying considerable variability across the reach. These fluctuations, characterised by alternating increases and decreases in mean bed levels, indicate a dynamic sediment environment. Given this variability, silt extraction may be undertaken, but only with guidance from River Management to ensure that potential effects on local channel behaviour and stability are appropriately considered. When considering the findings of the previous studies (2012, 2019, and 2023), there is approximately 2,198,000 m³ of sediment accumulation when compared to 1998 levels. It is recommended that an analysis is undertaken to assess the impact of this aggradation on flood carrying capacity.

In the lower gravel phase, the river exhibits net aggradation of approximately 178,000 m³ of gravel between 2022 and 2024, equivalent to 81,000 m³ per year. This exceeds the One Plan allocation of 55,000 m³ per year for the reach downstream of Menzies Ford – however, the long-term analysis suggests that gravel is not aggrading at this rate over the long-term. The long-term average annual sediment flux (net sediment change plus gravel extraction) between 2012 and 2024 for the lower gravel phase is approximately 45,000 m³/year.

The 2023 study recommended to reduce maximum extraction allocation downstream of Menzies Ford to 30,000 m³/yr, except where an extreme weather event mobilises significant volumes of gravel from the upper reaches. The findings of this study indicate that Cyclone Gabrielle did mobilise a large amount of sediment, as shown in the overall aggradation between 2022 and 2024 within the lower gravel phase. However, this does not mean sediment supply will remain at this elevated rate, and the current study also shows that there are localised areas of potential degradation e.g., near the confluence with the Kiwitea Stream, which should be carefully managed to prevent undermining of infrastructure.

The upper gravel phase shows a pattern of degradation, with a net loss of approximately 220,000 m³ of gravel, or approximately 111,000 m³ per year. This result is likely influenced by a potential outlier with a large distance to adjacent cross-sections, which appears to not be representative of its reach and may be causing an overestimation of degradation. However, there are points of notable degradation that should be closely managed e.g., near Spur Rd West. The mean bed level changes correspond generally with the gravel volume results.

Given this potential overall degradation in the upper gravel phase between 2022 and 2024, and the low rate of net sediment flux in the lower gravel phase between 1998 and 2024, gravel extraction should be approached with caution. The findings of this study concur with the recommendation of the 2023 gravel study that the long-term average annual allocable volume set out in Table 14 of the One Plan should be reduced to 30,00 m³/year for the reach downstream of Menzies Ford. This is a conservative limit, and potentially 45,000 m³/year based on the average annual sediment flux for 2012 to 2024 period would also be reasonable, if further analysis determines that there is not net degradation occurring in the upper gravel phase.

There is currently not enough information available to confirm the long-term trend of net sediment flux in the upper gravel phase, and as such there is no evidence requiring an adjustment to the current One Plan allocation of 10,000 m³ per year upstream of Menzies Ford unless a specific River Management need arises. Extraction may be considered on aggrading beaches where it does not exacerbate channel lowering or downstream degradation or compromise river stability.

The 2023 study recommended undertaking a gravel assessment for the upper gravel phase of the Ōroua River. This study has now formally addressed and fulfilled that recommendation, providing an updated understanding of sediment transport across a much larger reach of the river. In addition, a

Natural Character Index (NCI) analysis was carried out for the full Ōroua River reach (0.0–115.7 km), as recommended in the 2023 study. This analysis was completed by Tonkin & Taylor Ltd in 2025.

It is recommended that a full survey of the Ōroua River be undertaken in or prior to 2029–2030, including all cross-sections surveyed in 2016, 2022, or 2024 to ensure continuity and comparability of data. For the Upper Ōroua, the cross-section spacing should be consistent, ideally with an average interval of 400 m, consistent with the average spacing used in the Lower Ōroua. Prior to the next gravel study, it would be beneficial to acquire updated LiDAR (Light Detection and Ranging) data to supplement cross-section information and enable a trial of geomorphic change detection using digital elevation model differencing.

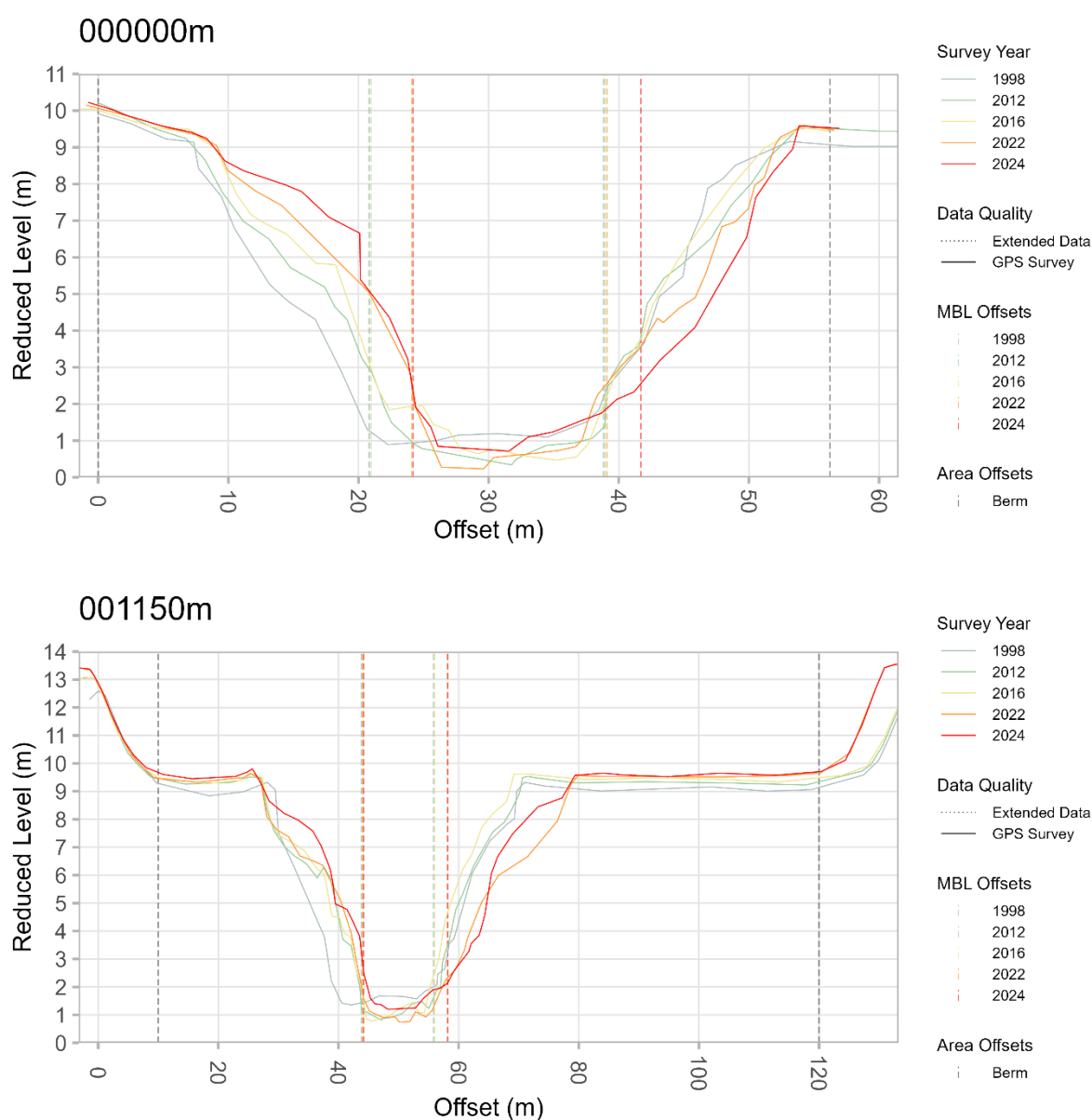
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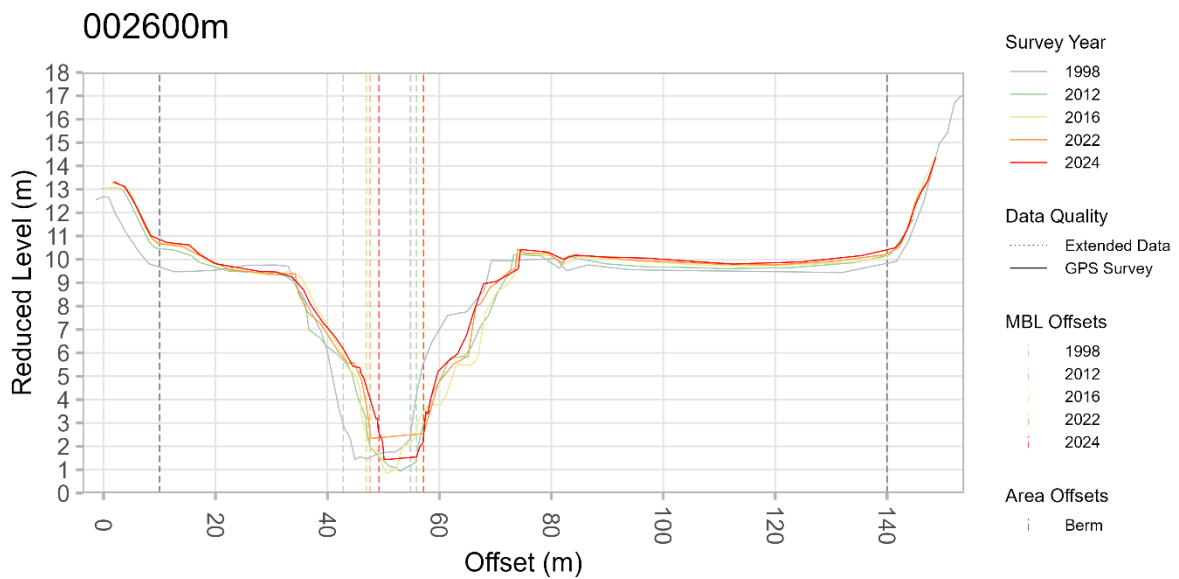
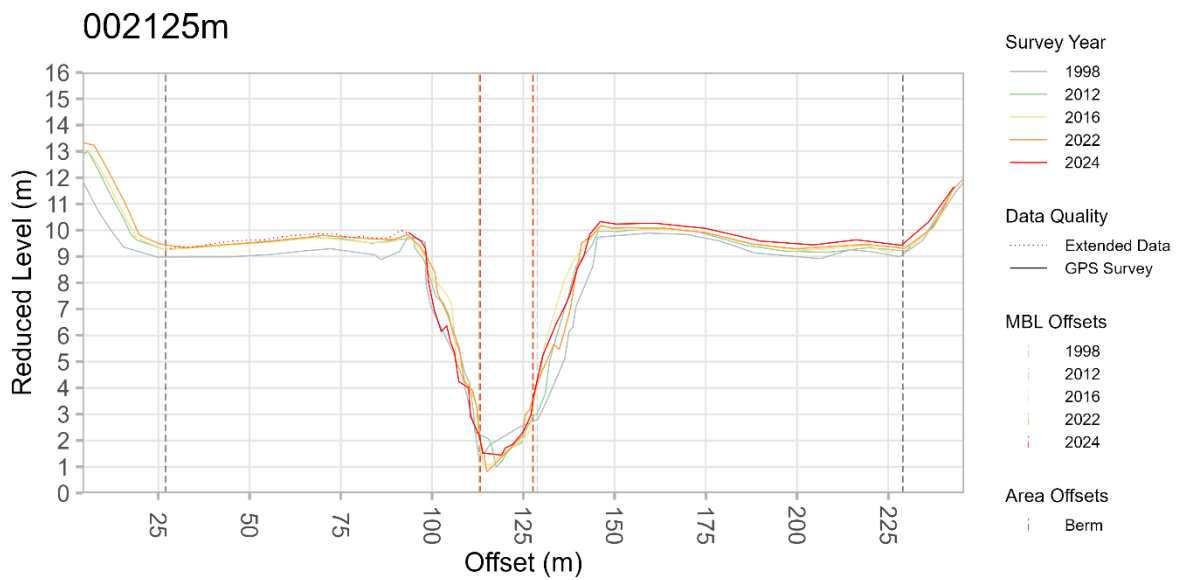
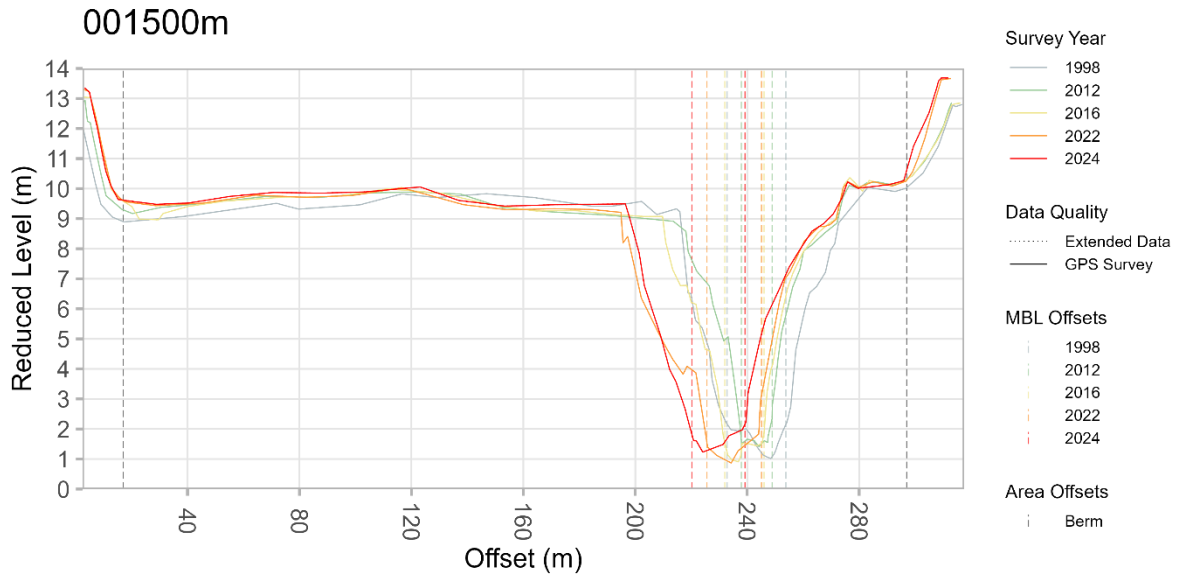
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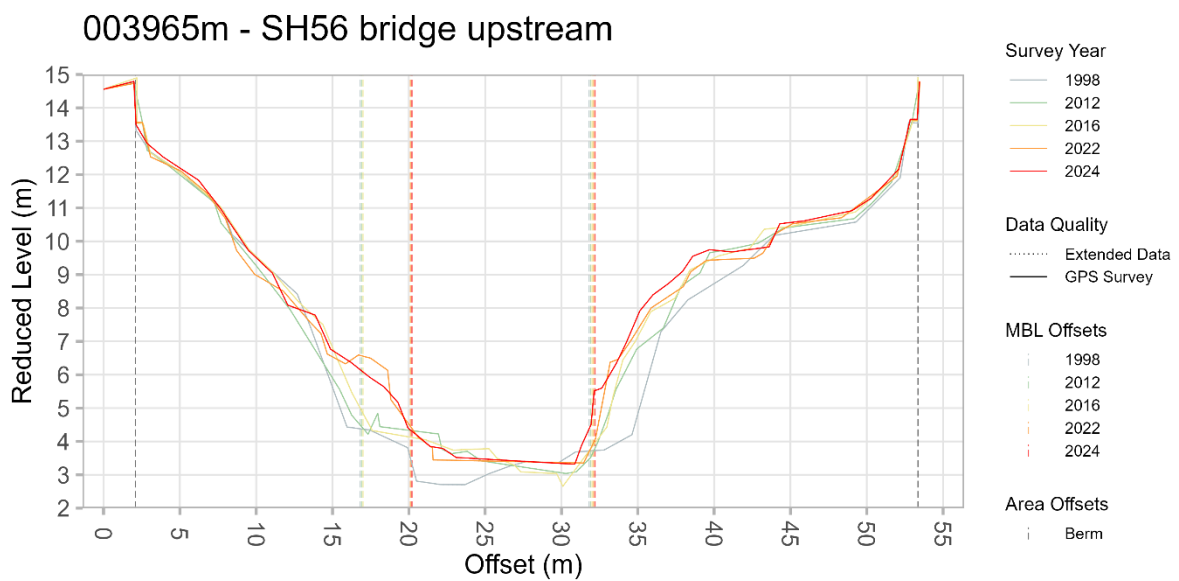
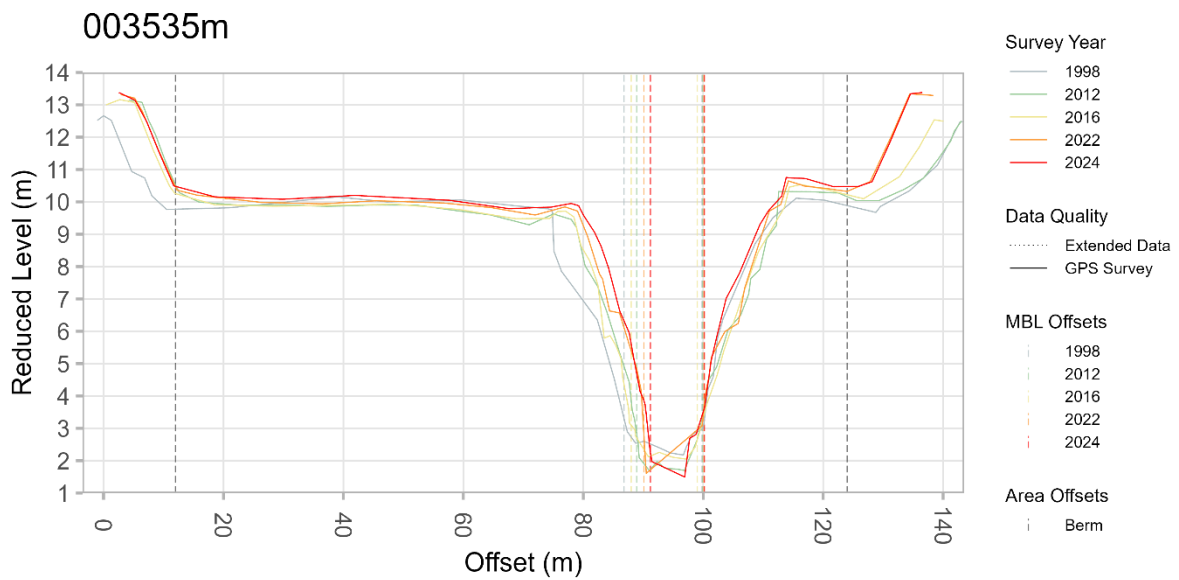
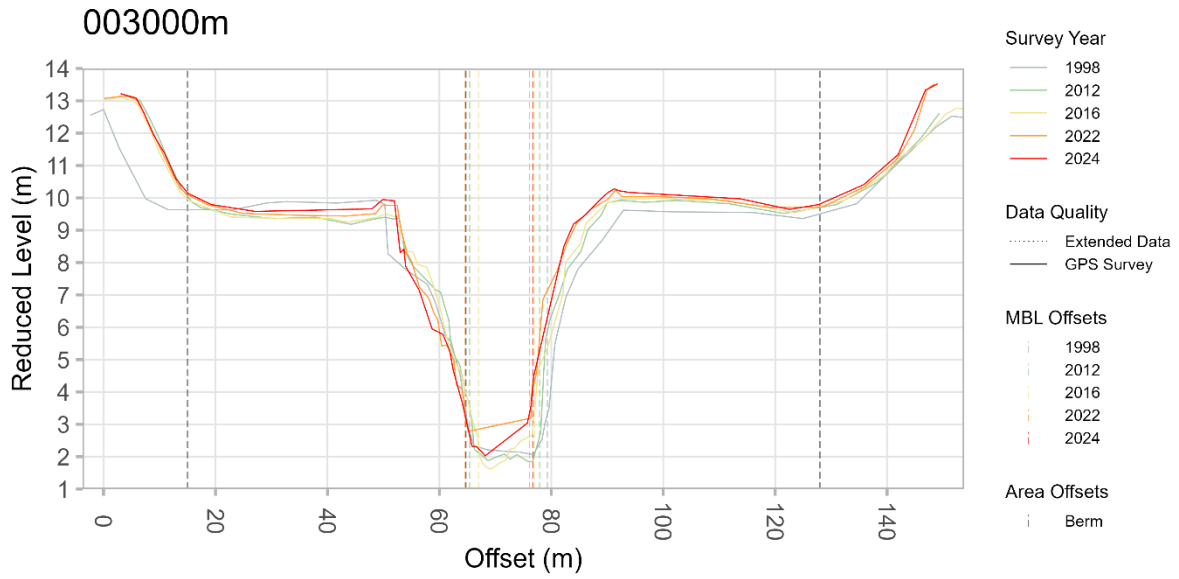
Appendices

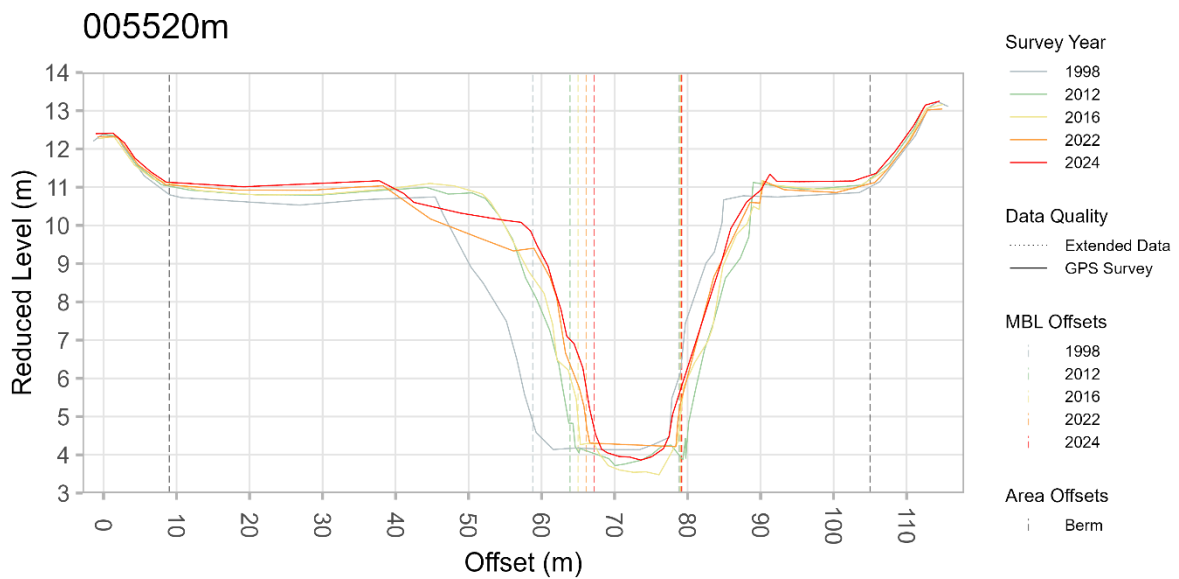
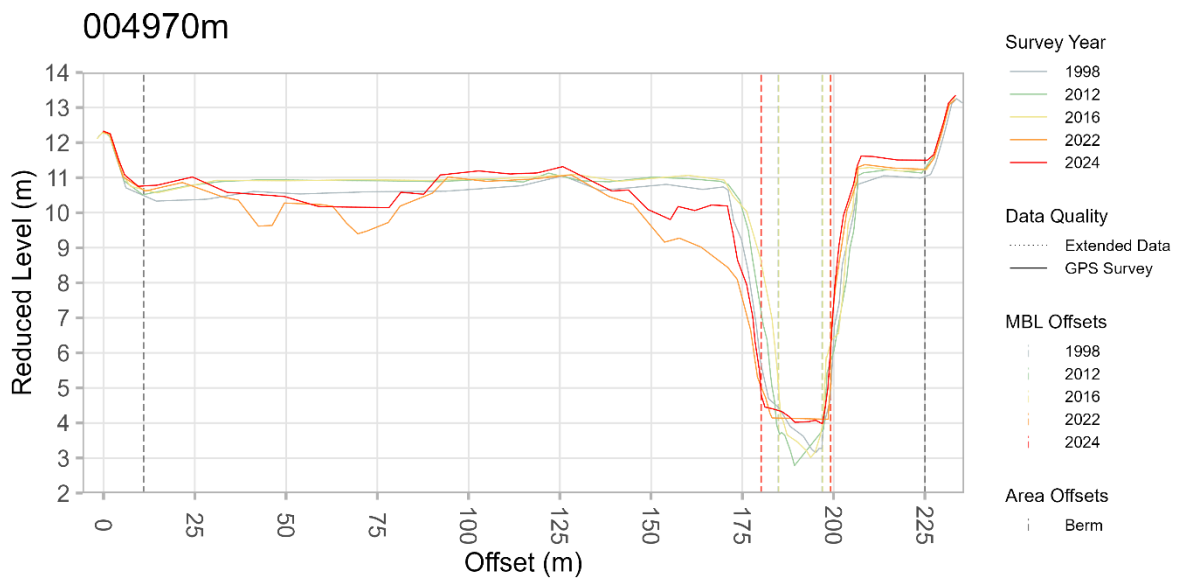
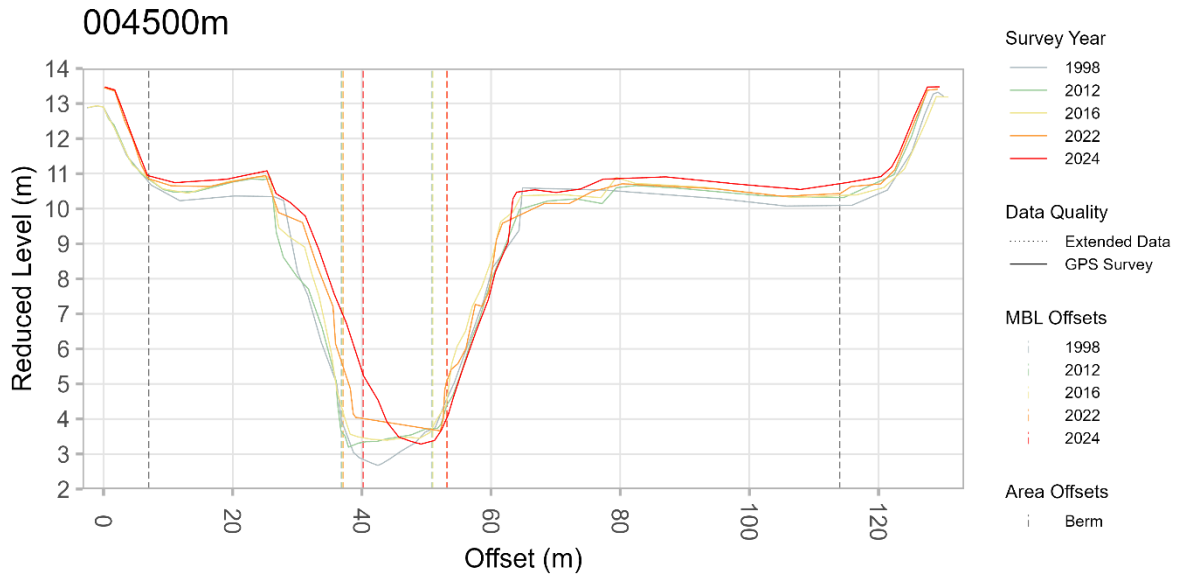
Appendix A

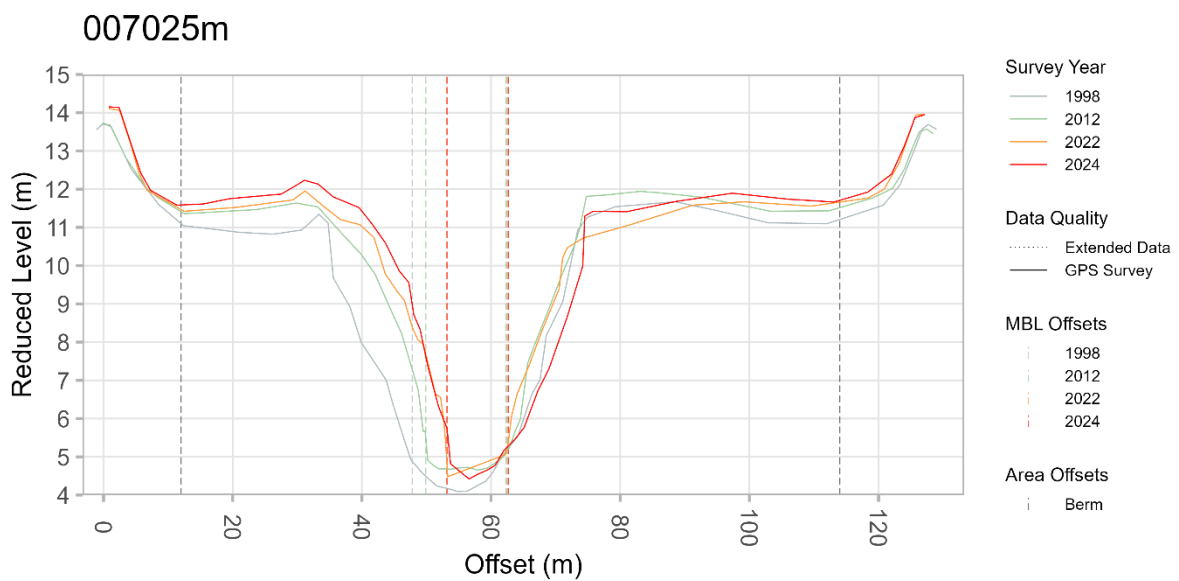
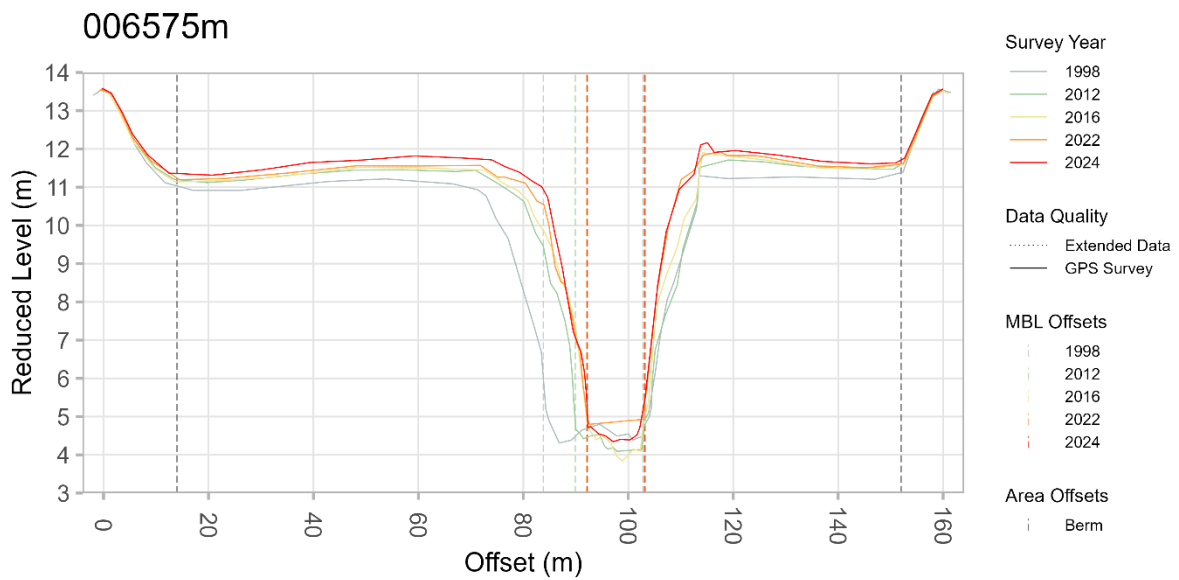
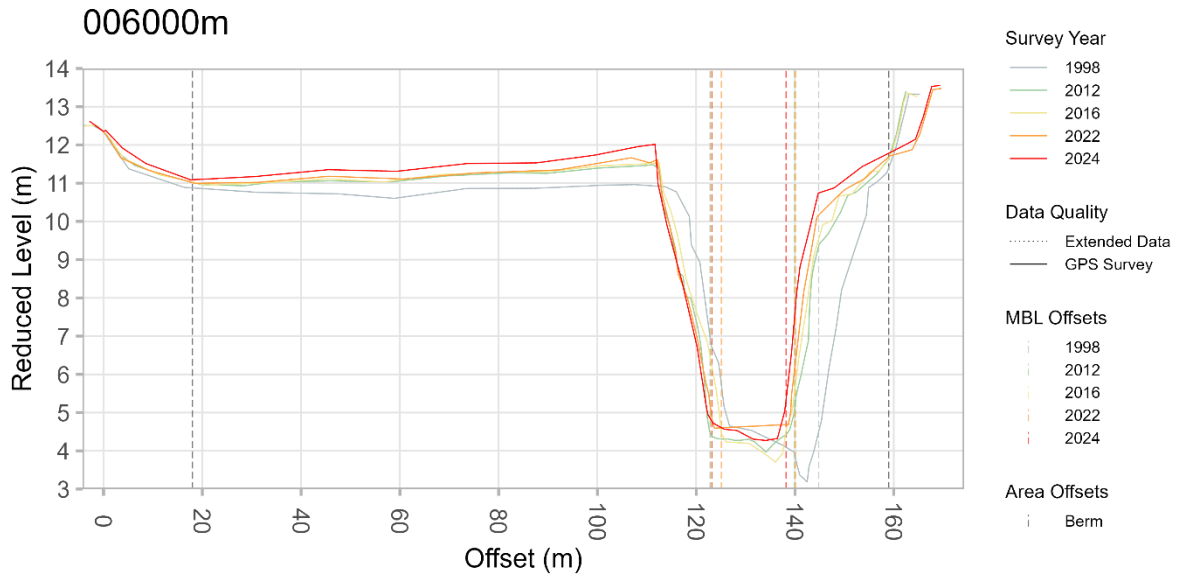
Cross-section surveys of the Ōroua River, carried out in 1998/1999, 2011/2012, 206, 2022, and 2024. Graphs show the reduced levels for each survey, i.e., the change in elevation (NZVD16) across the river channel from true left to true right, as well as the left and right offsets used during the Mean Bed Level (MBL) and Area Under the Section calculations. Each plot title indicates the distance of the cross-section site upstream from the Manawatū River confluence. Extended data includes sections of the survey which have been extended using additional data post-ground survey (either using 2025 LiDAR where available for the 2024 surveys or using a straight horizontal line).

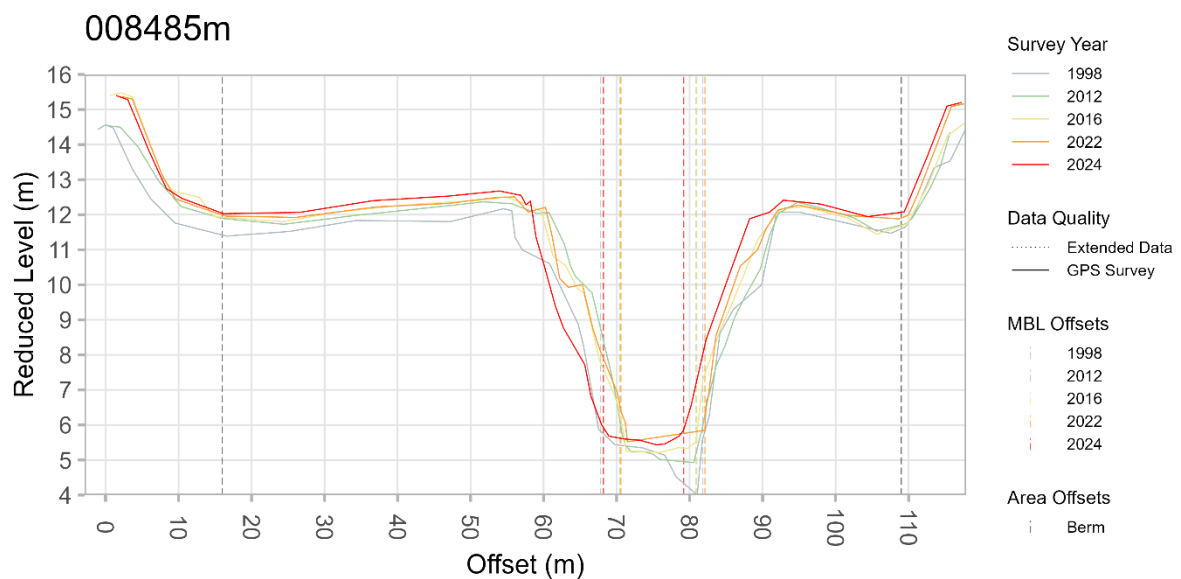
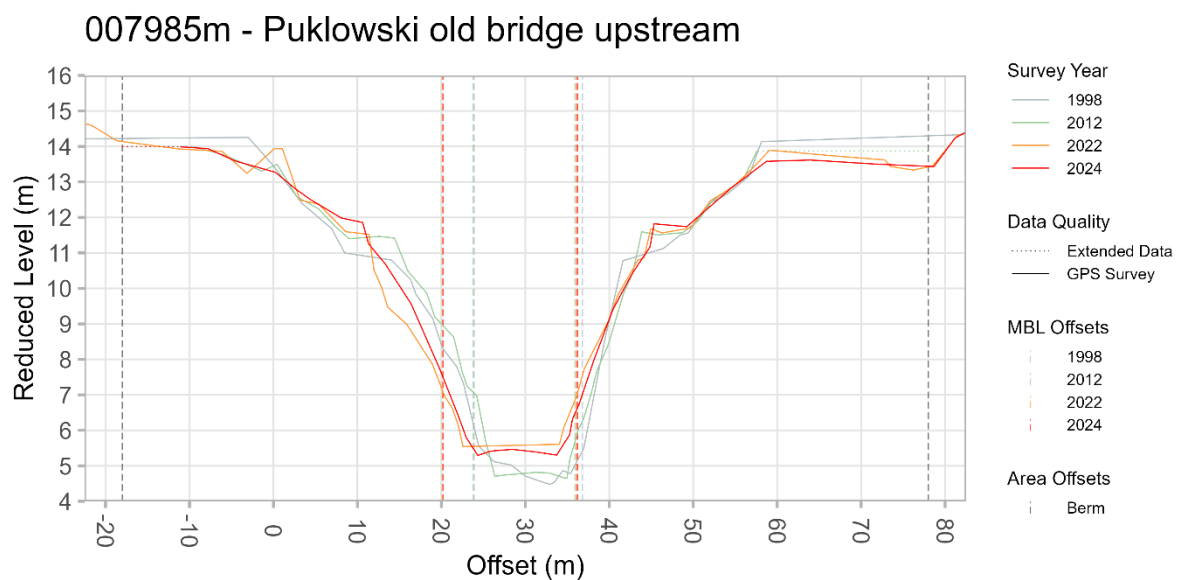
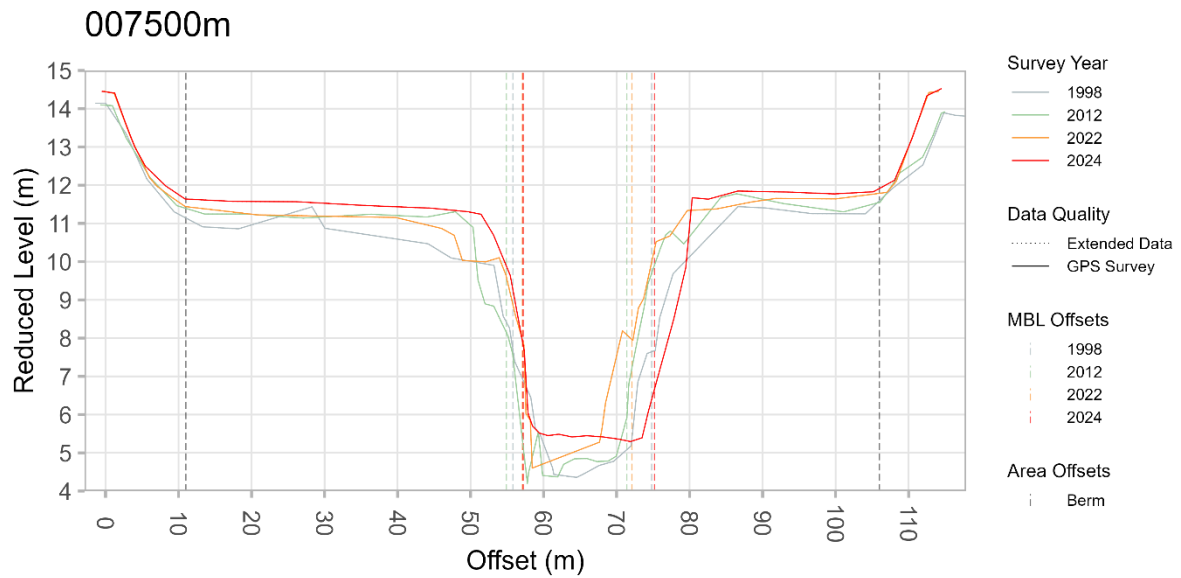


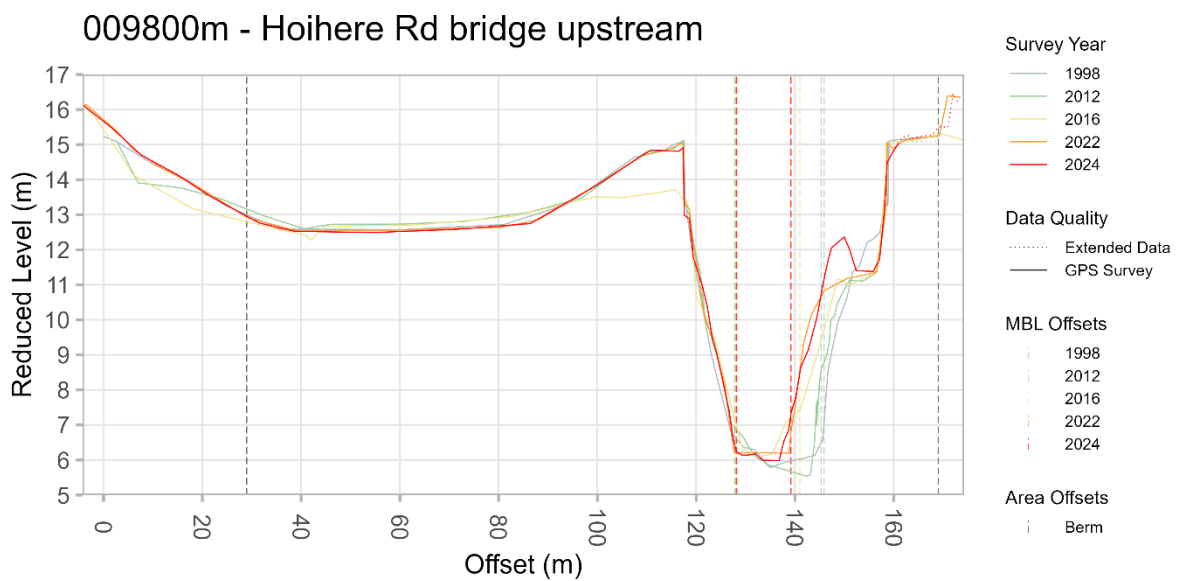
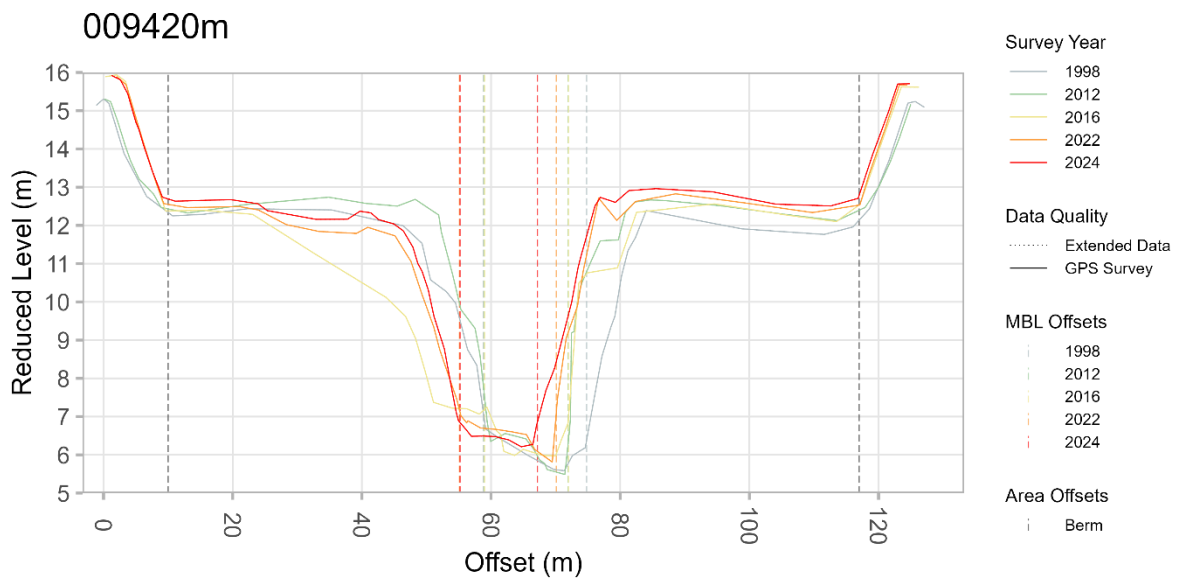
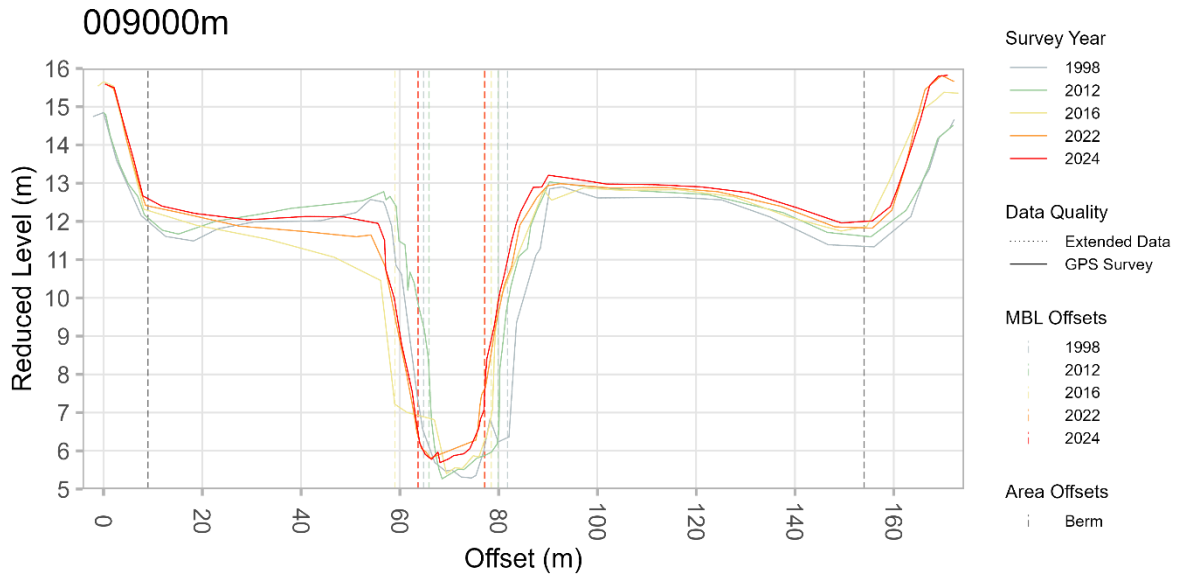


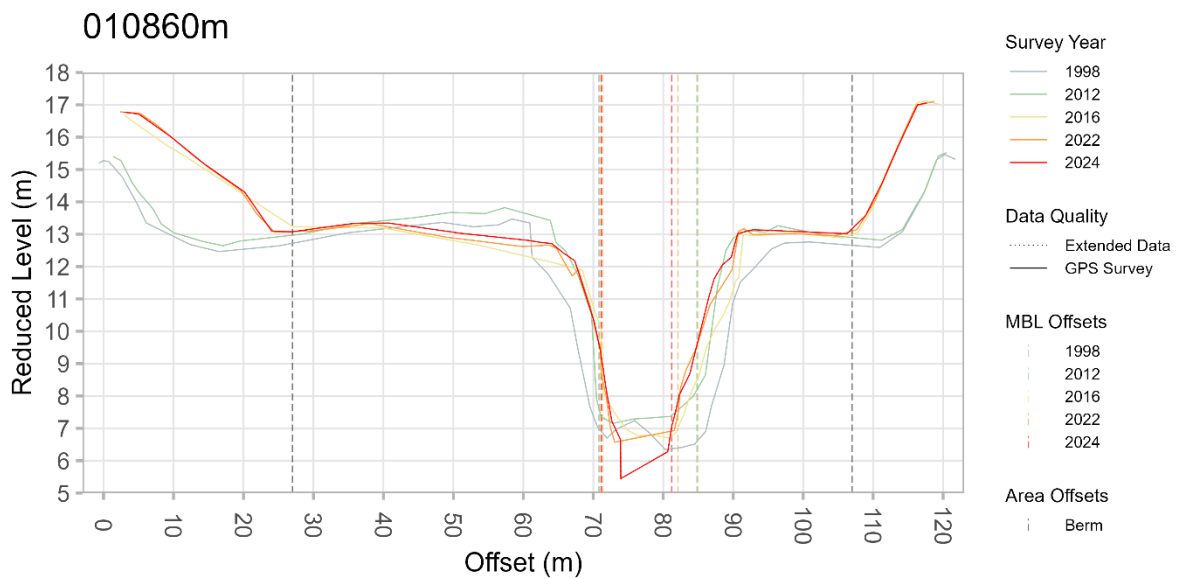
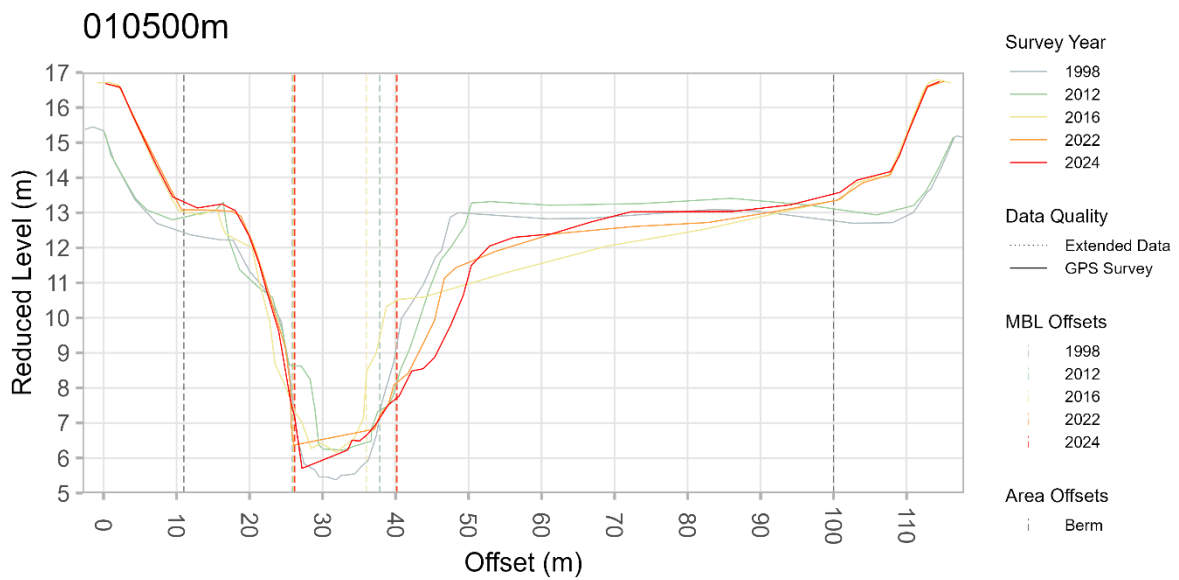
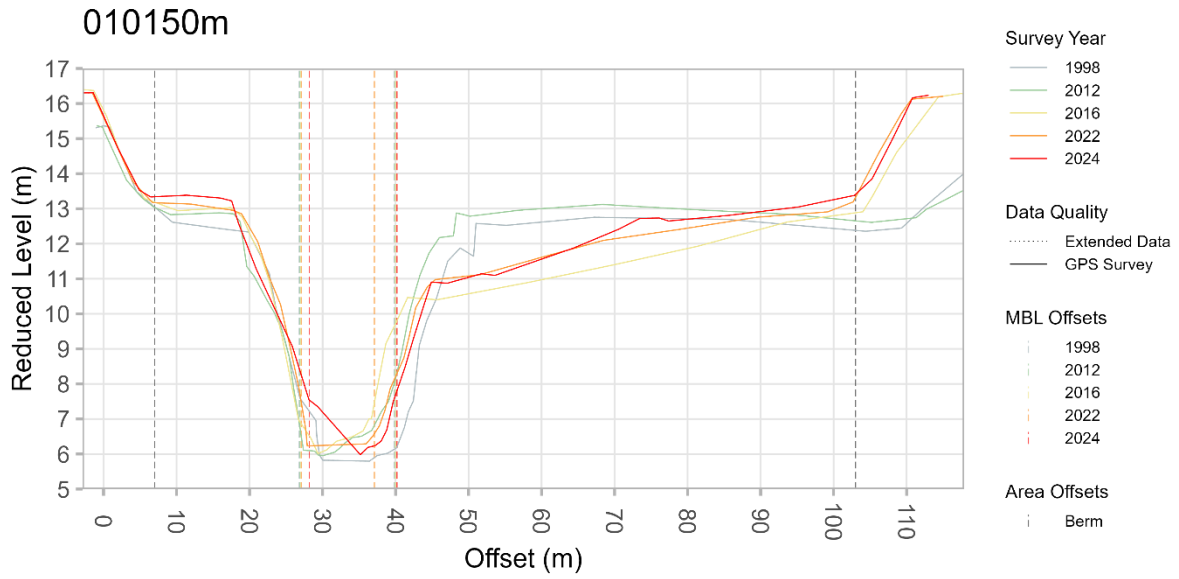


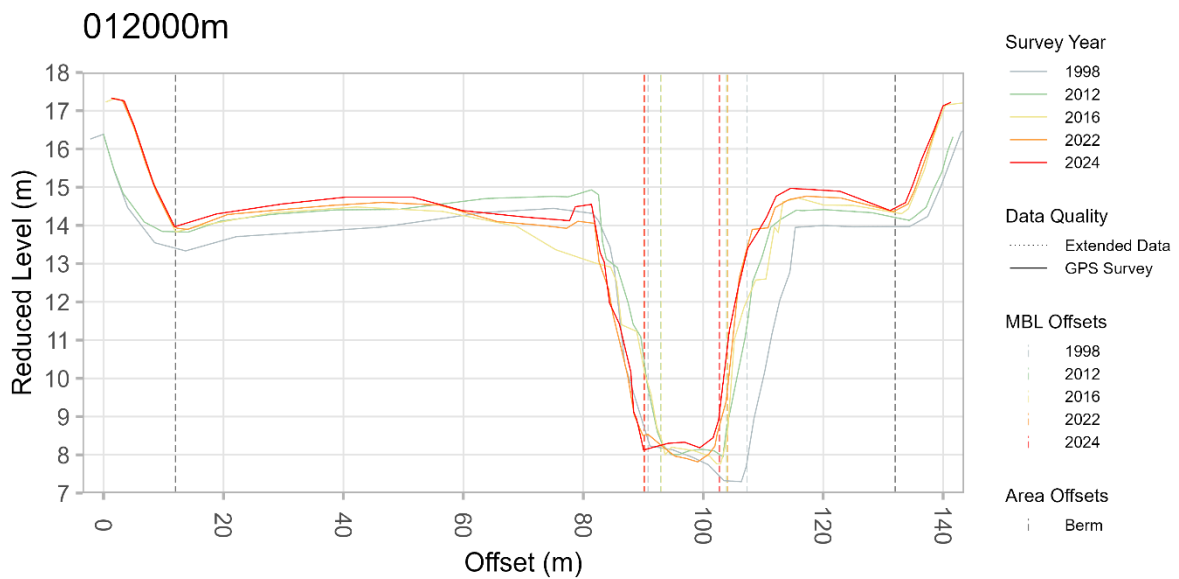
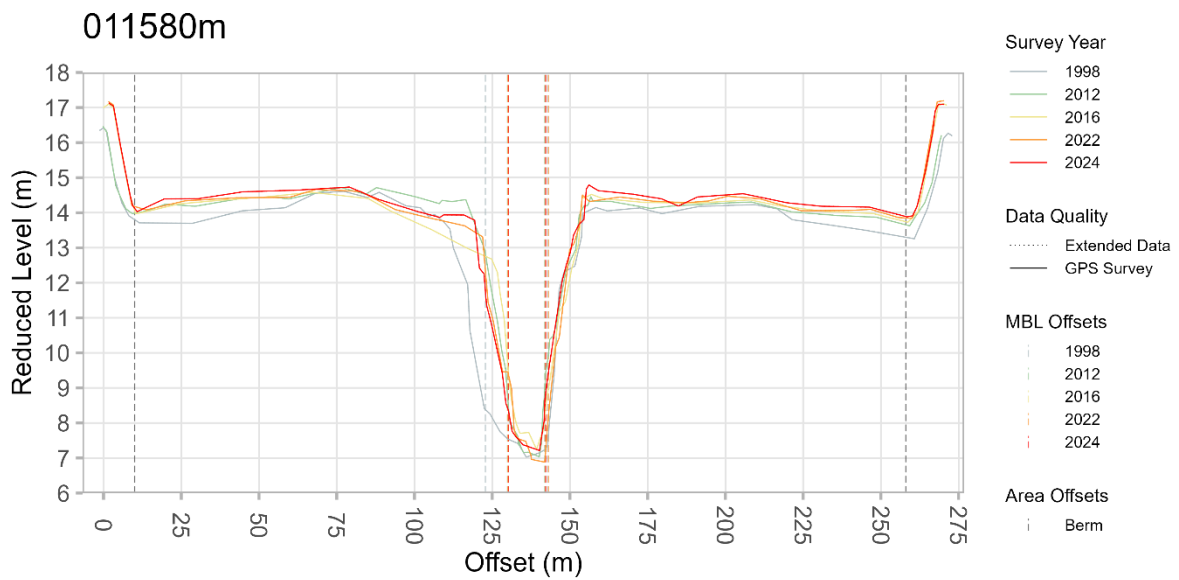
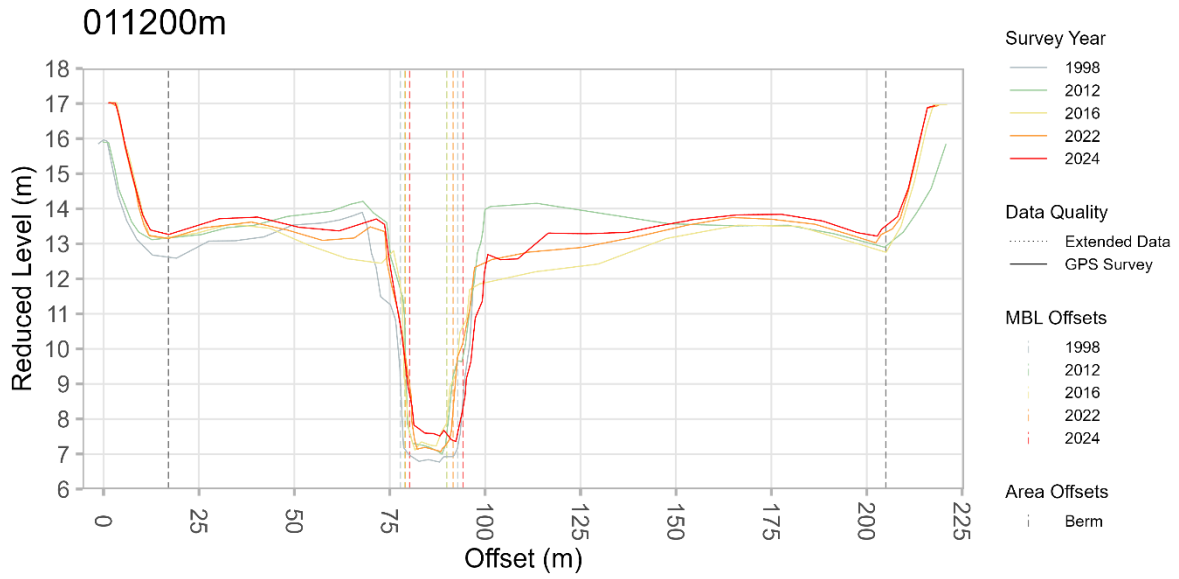


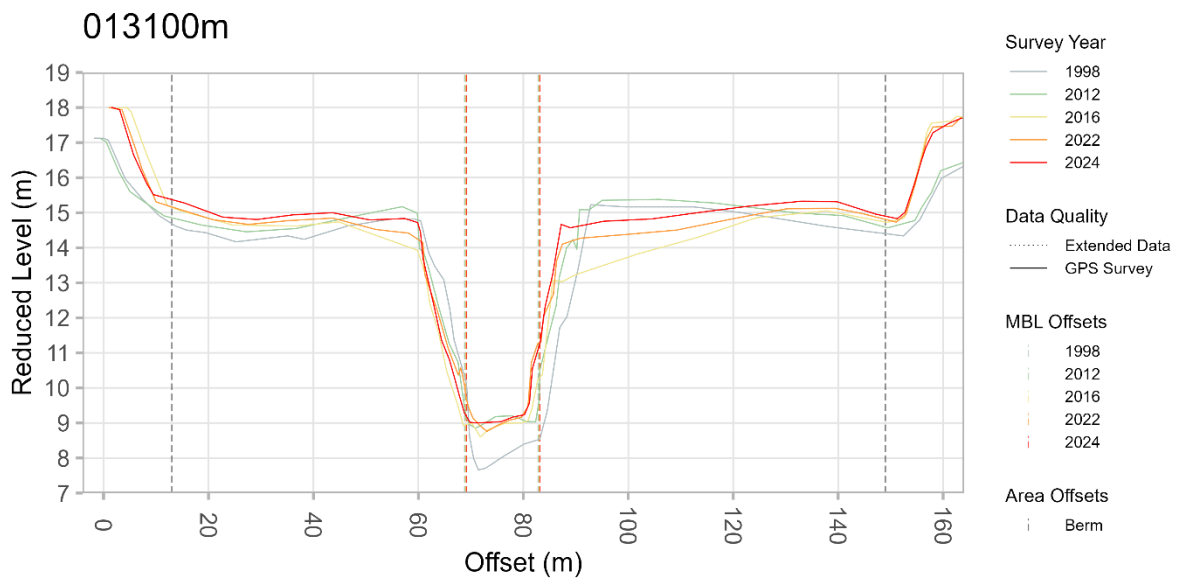
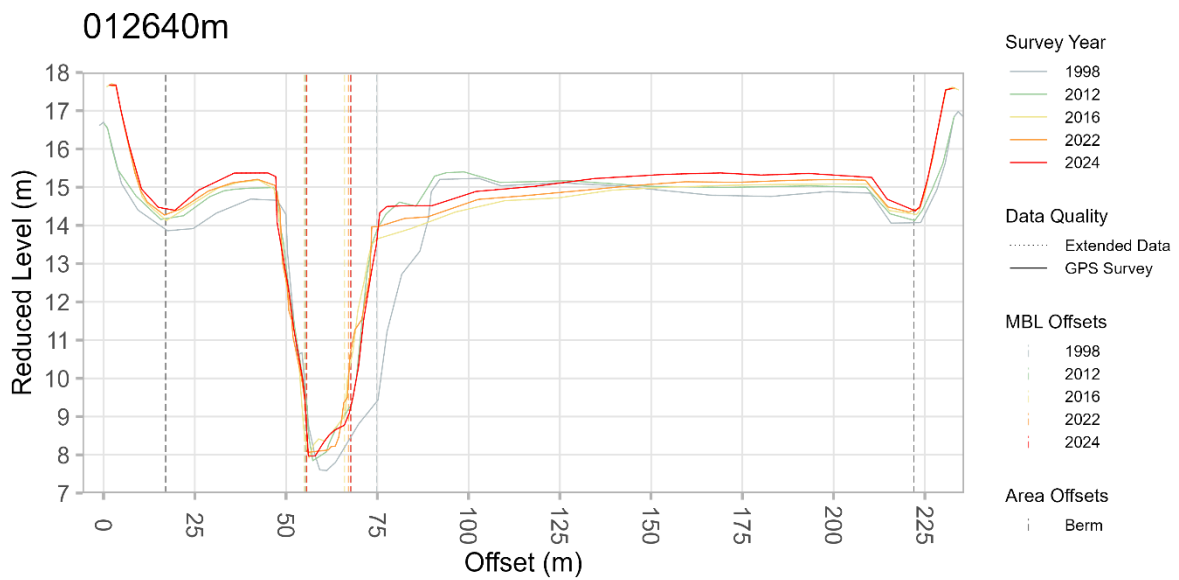
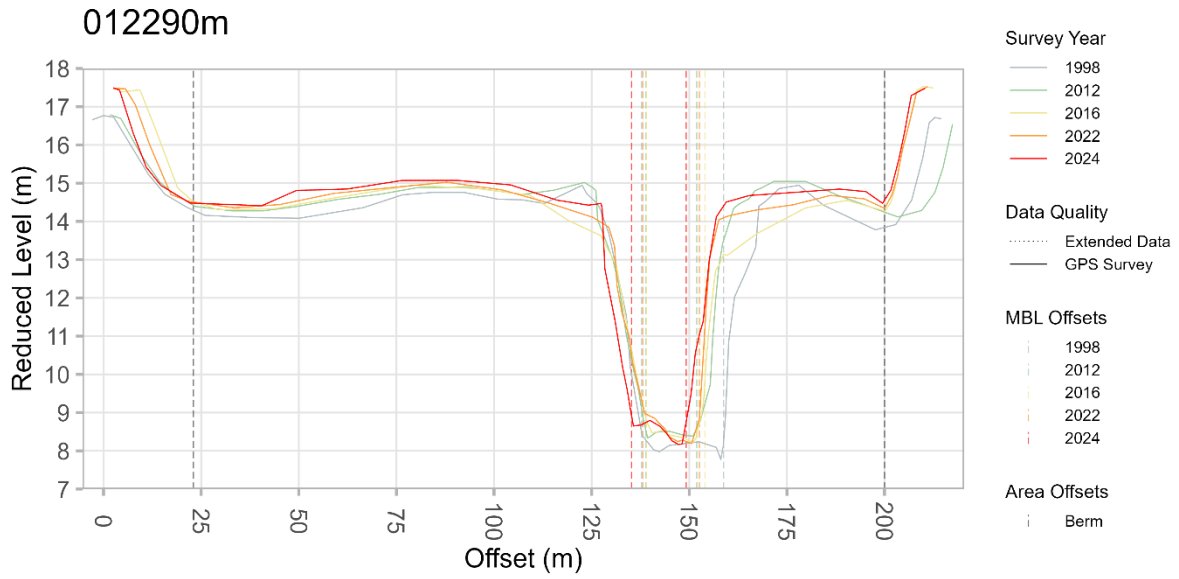


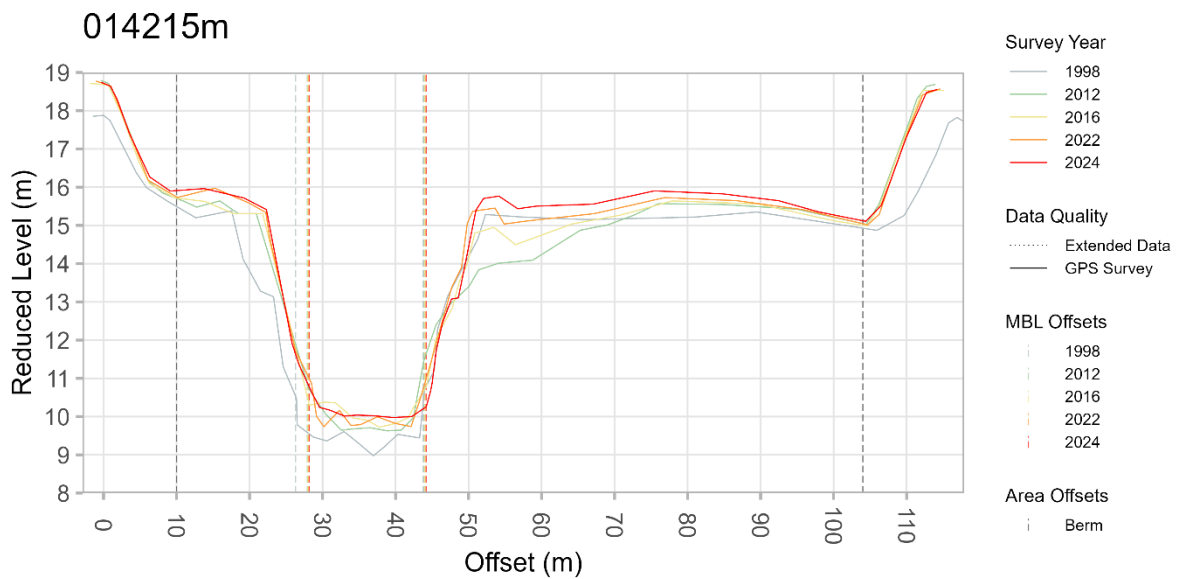
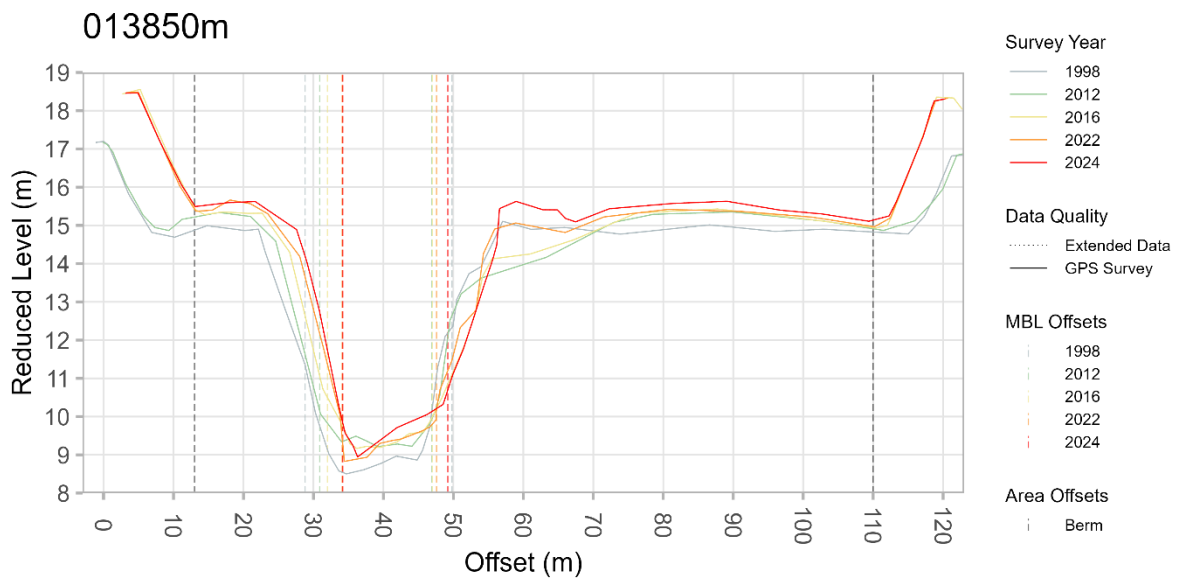
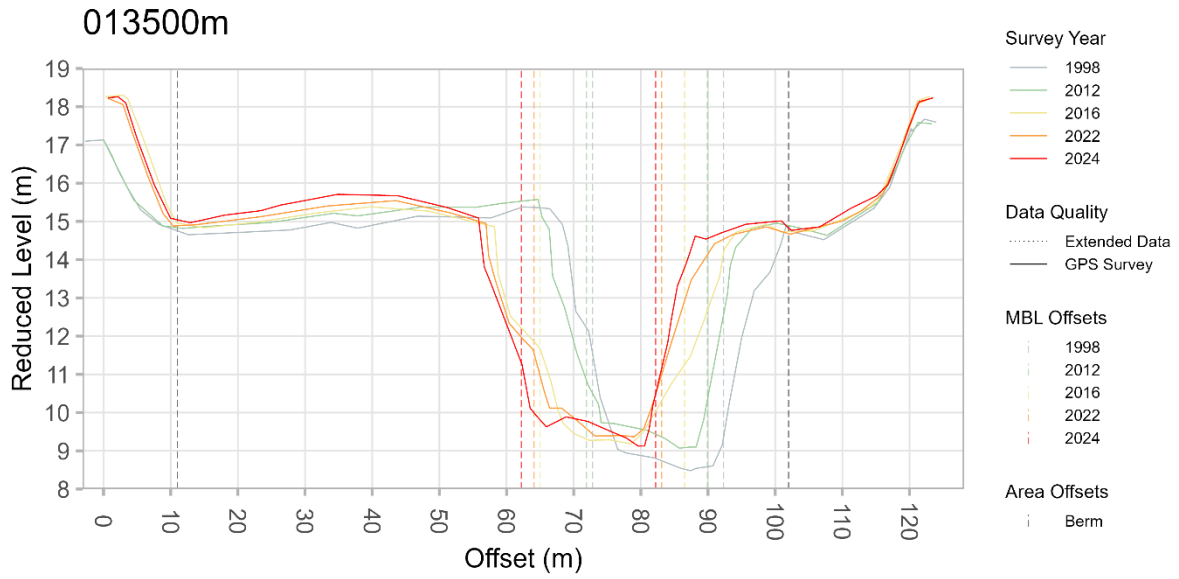


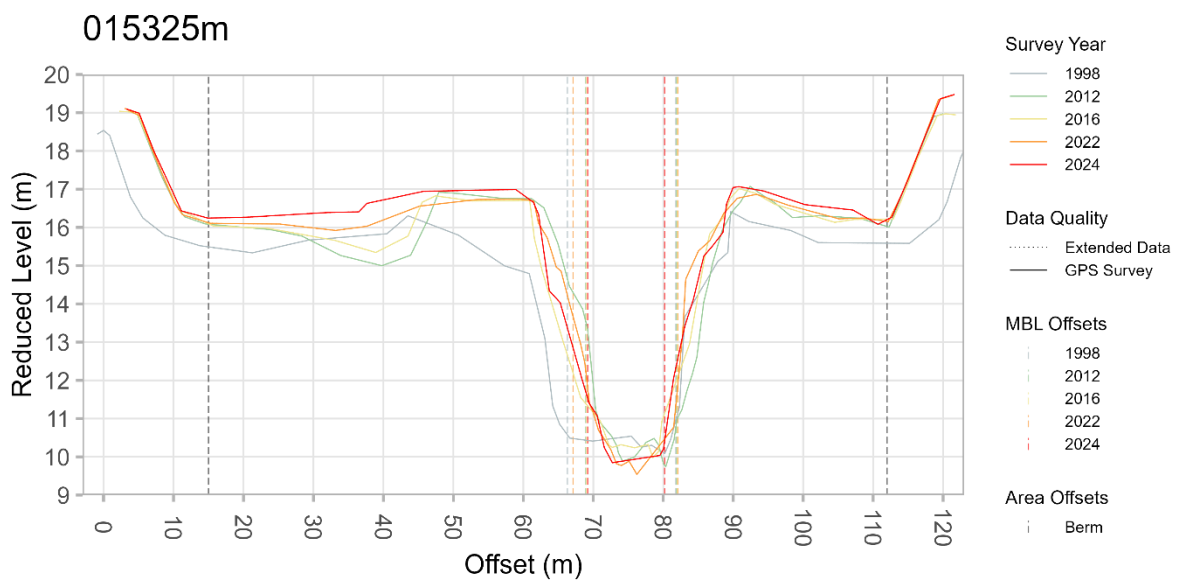
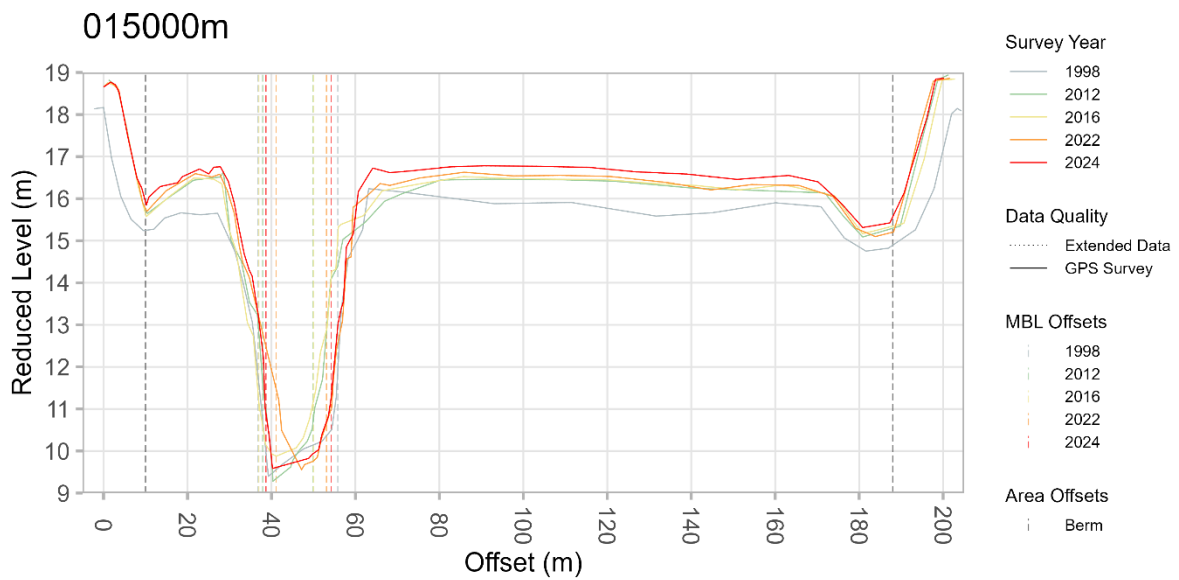
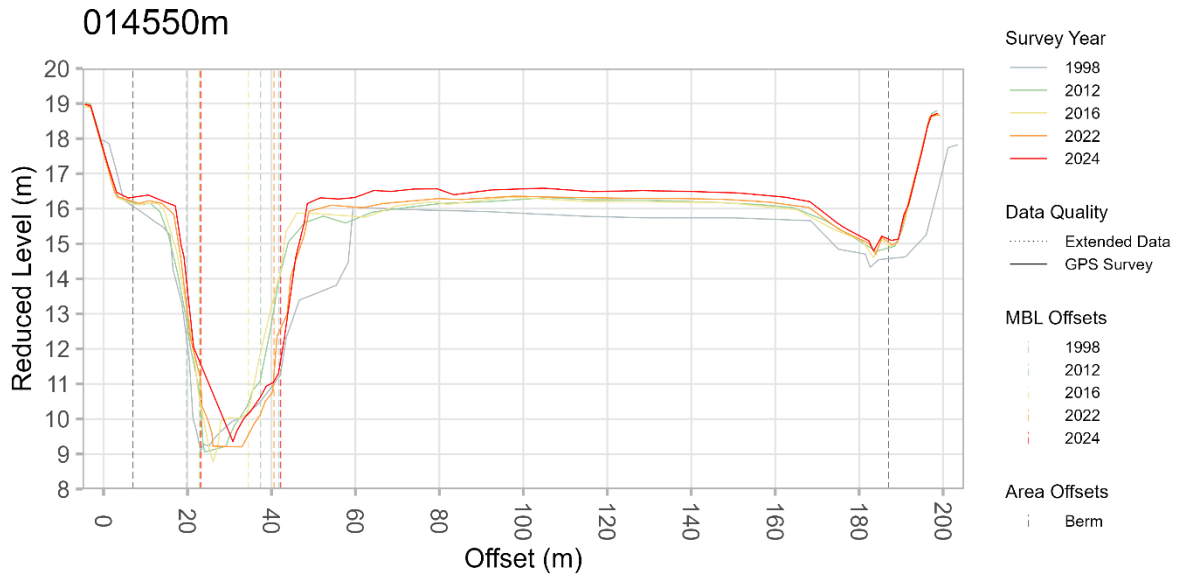


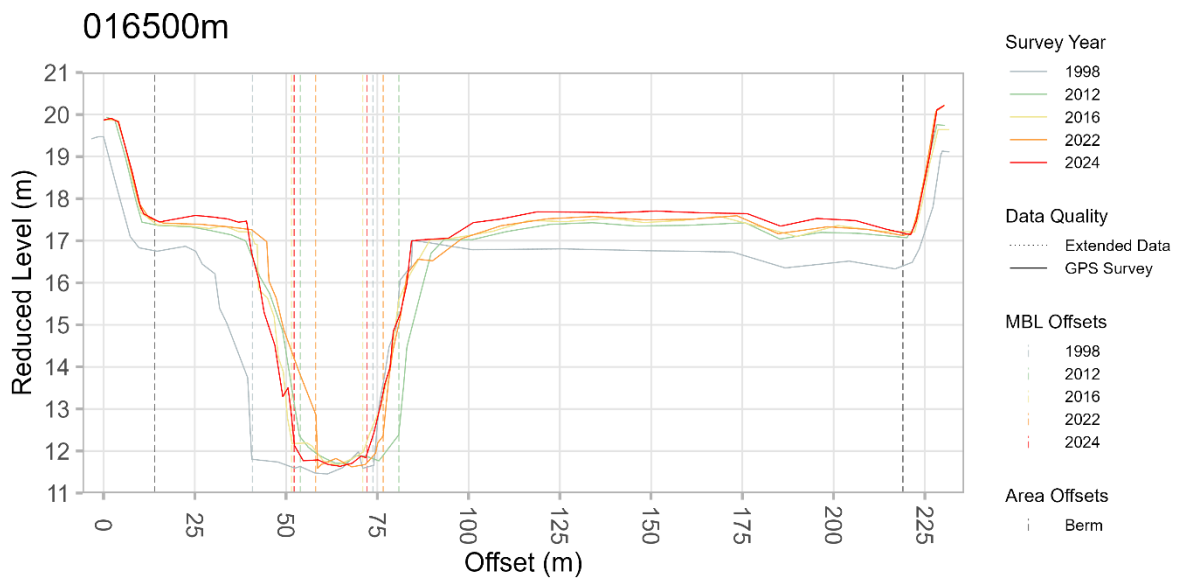
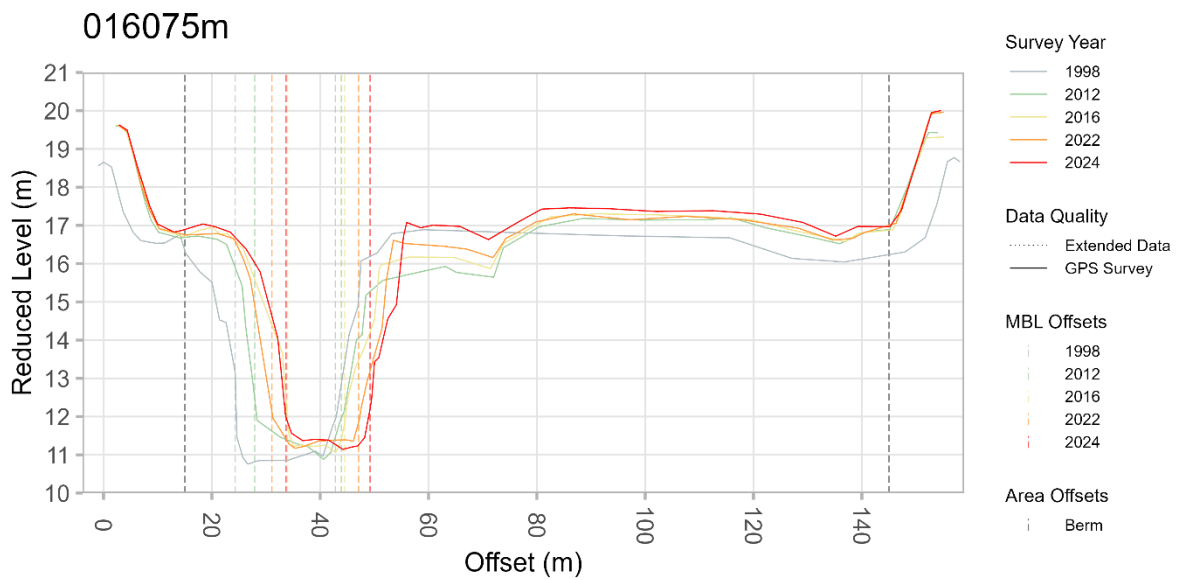
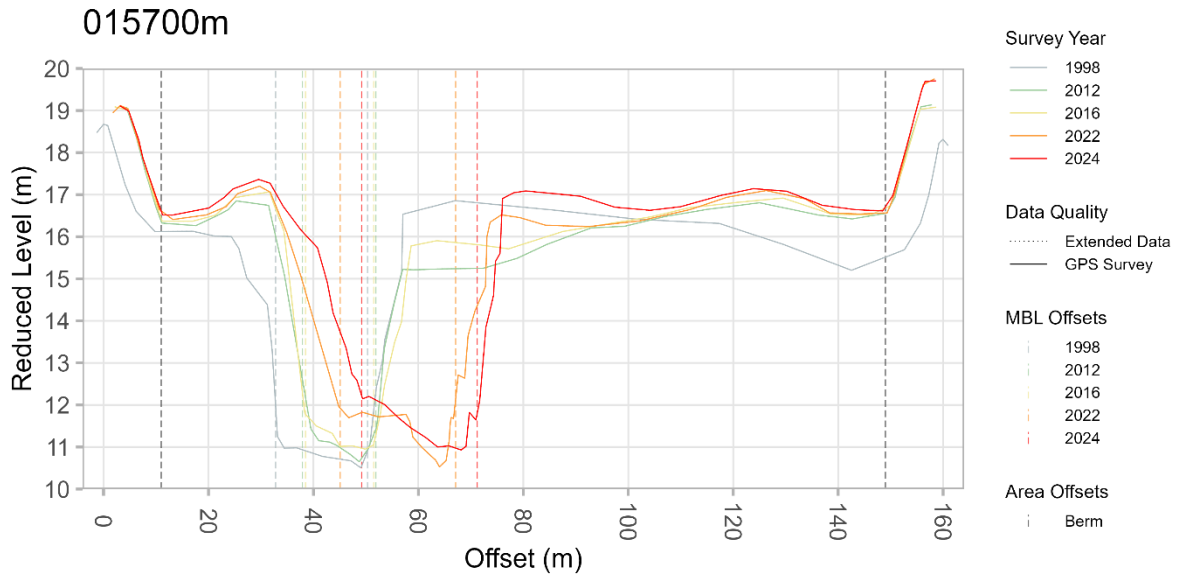


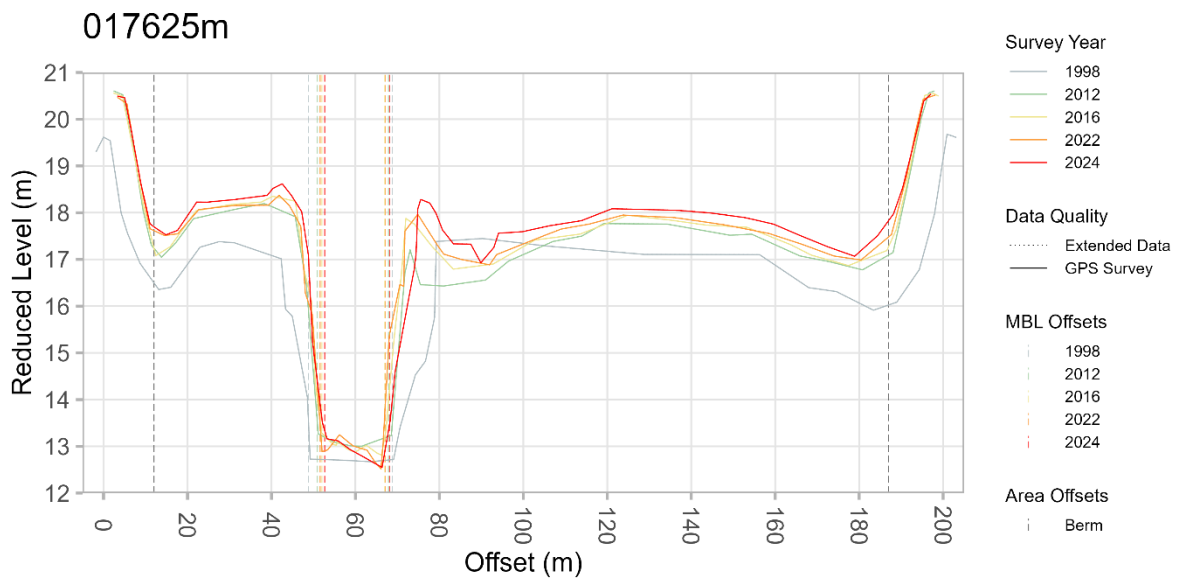
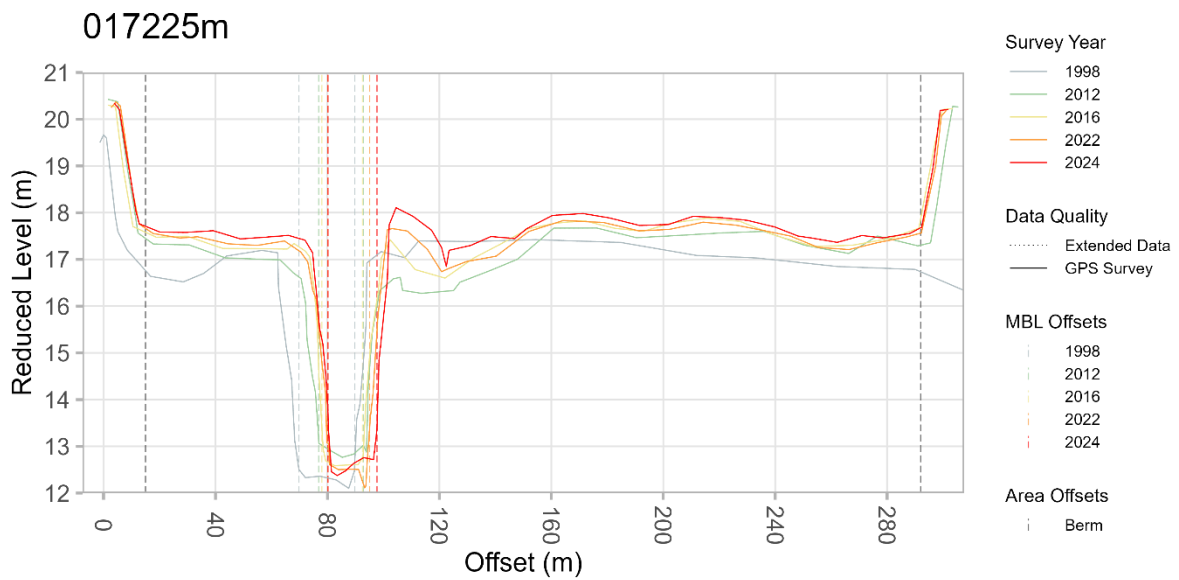
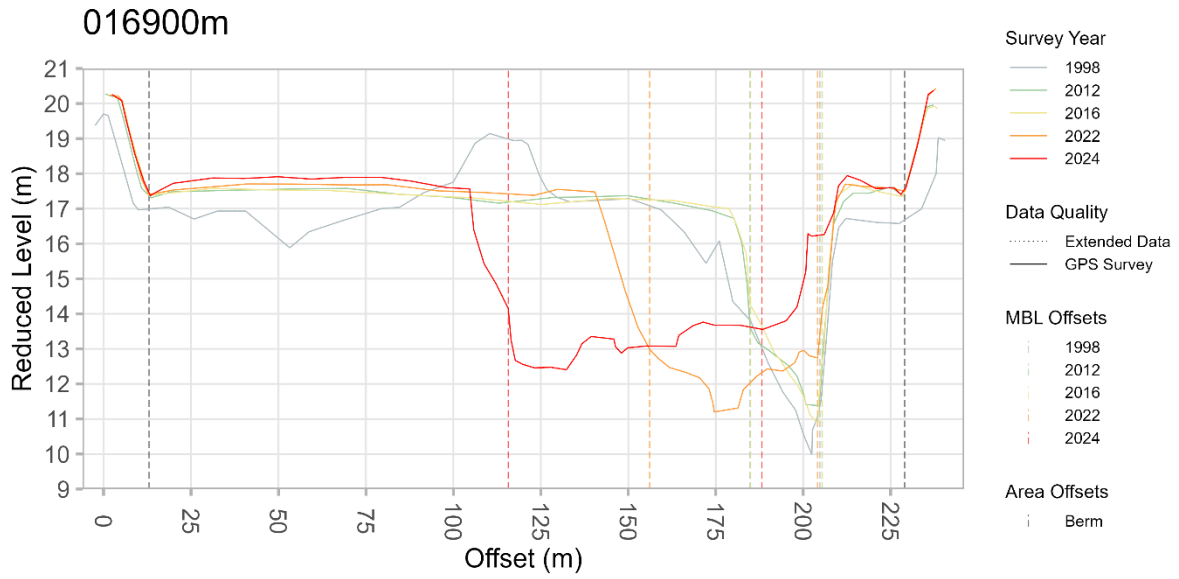


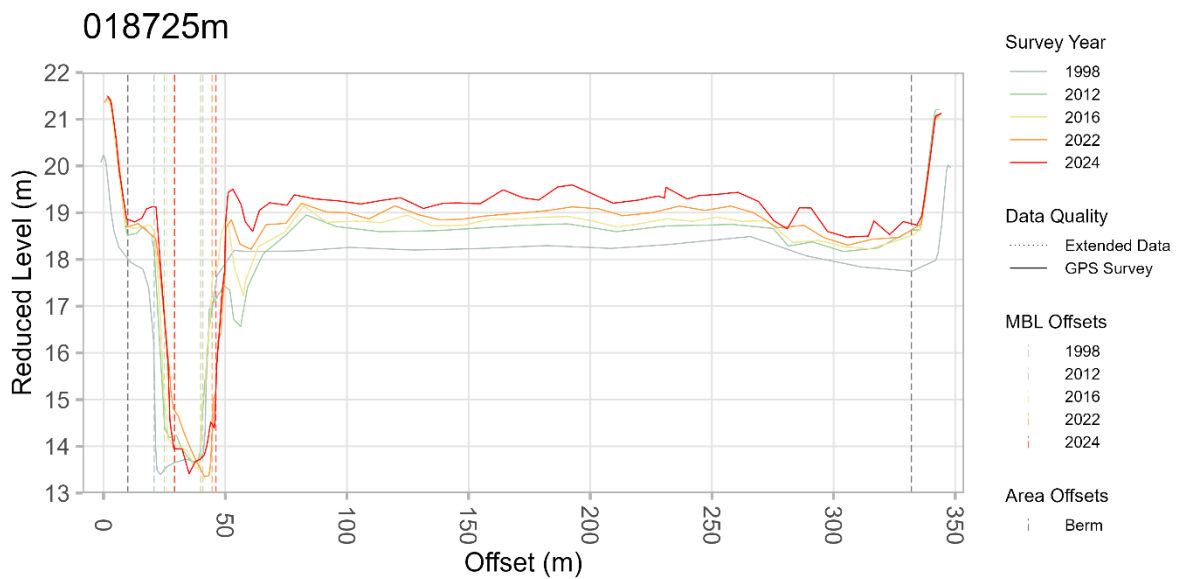
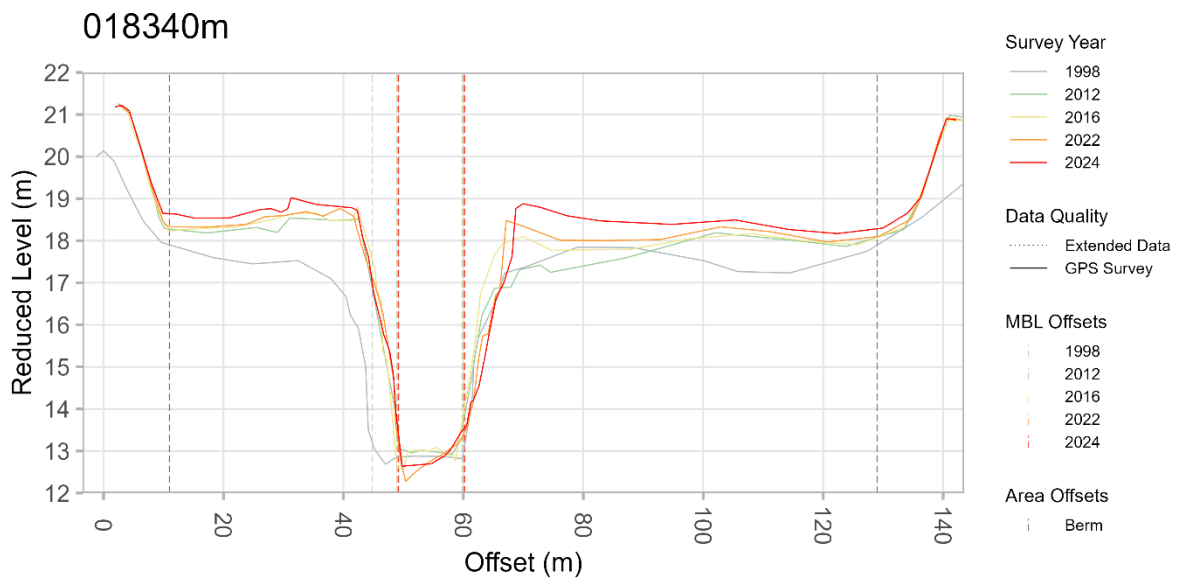
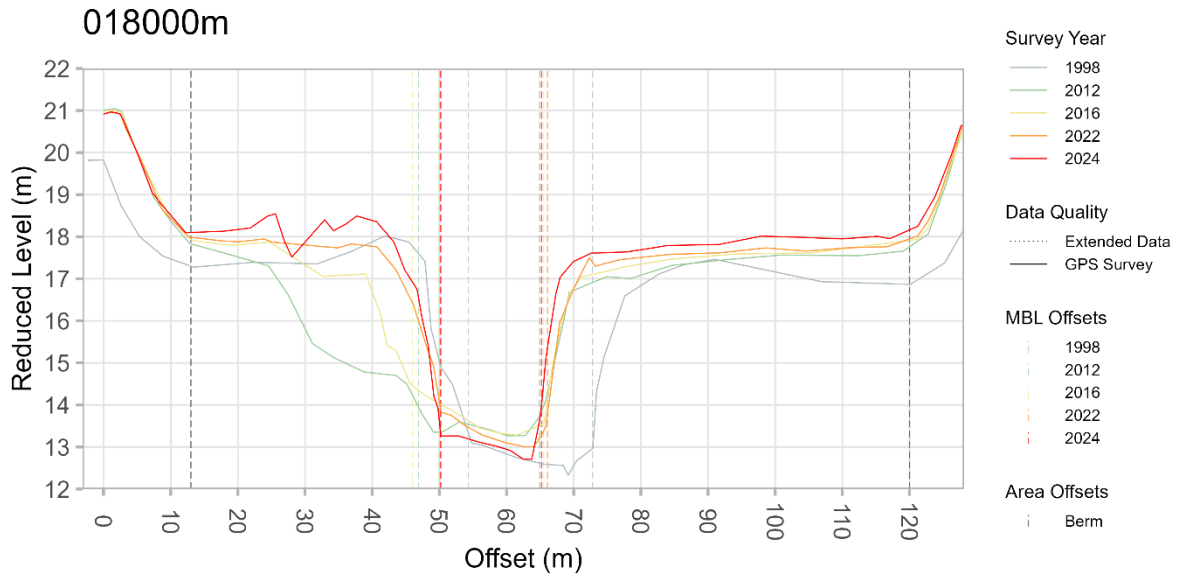


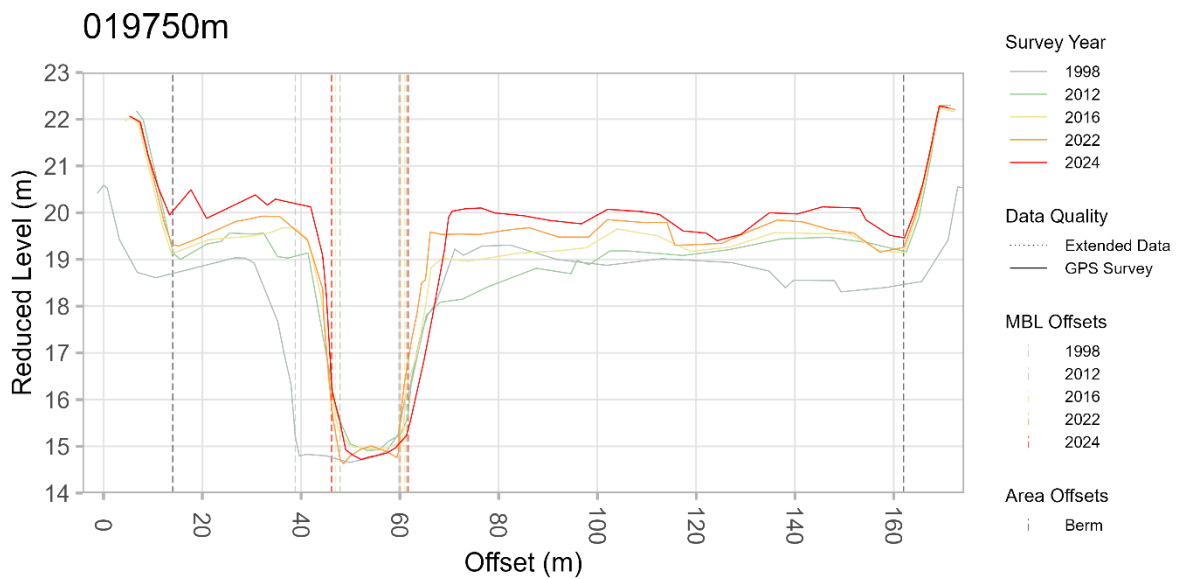
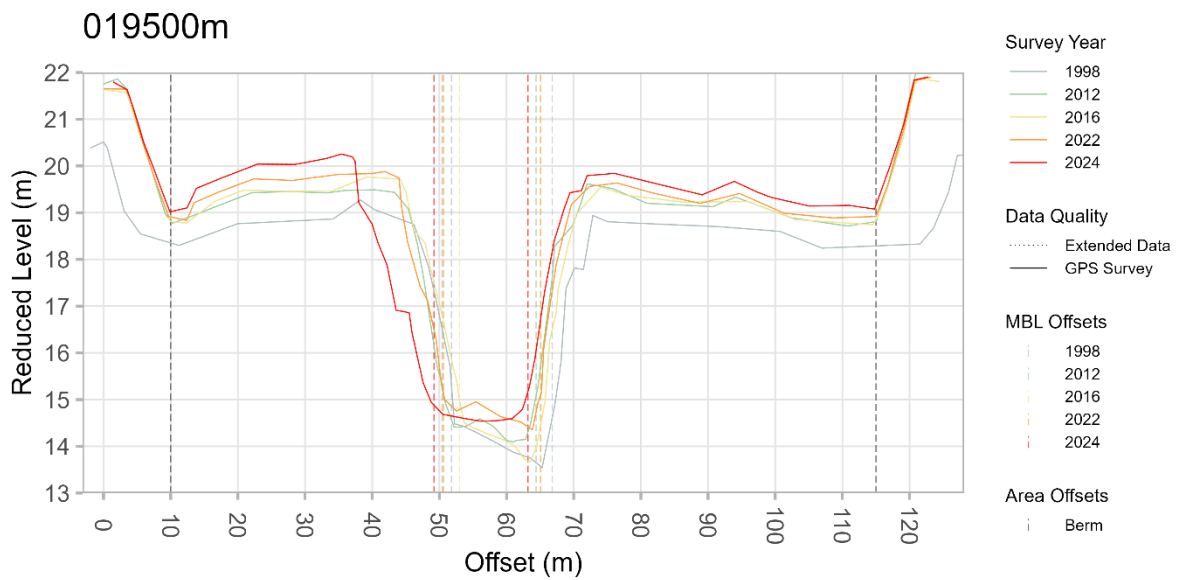
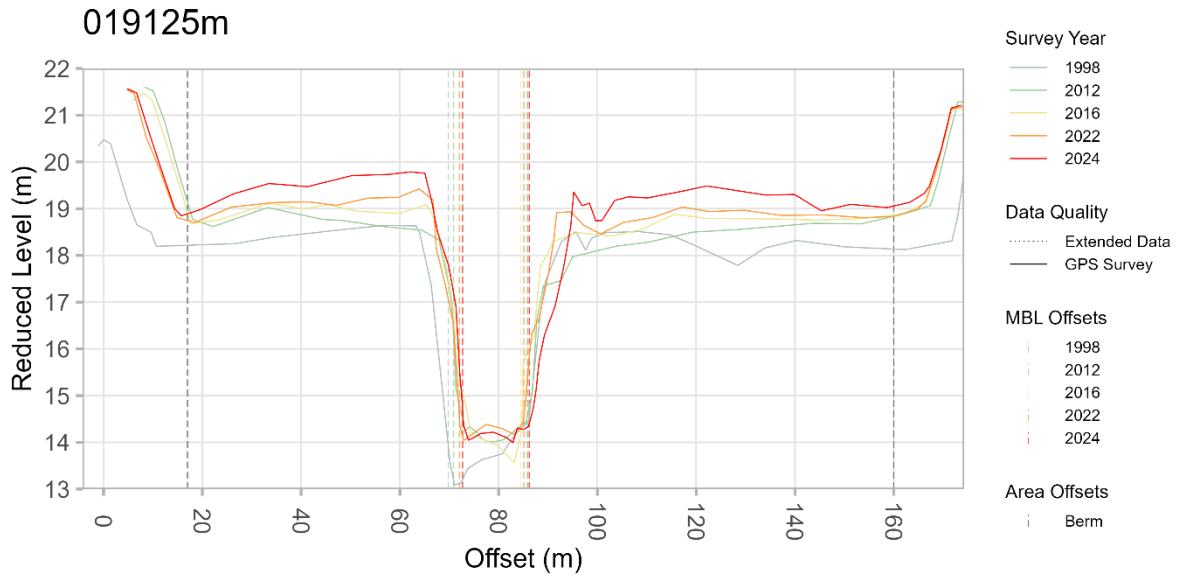


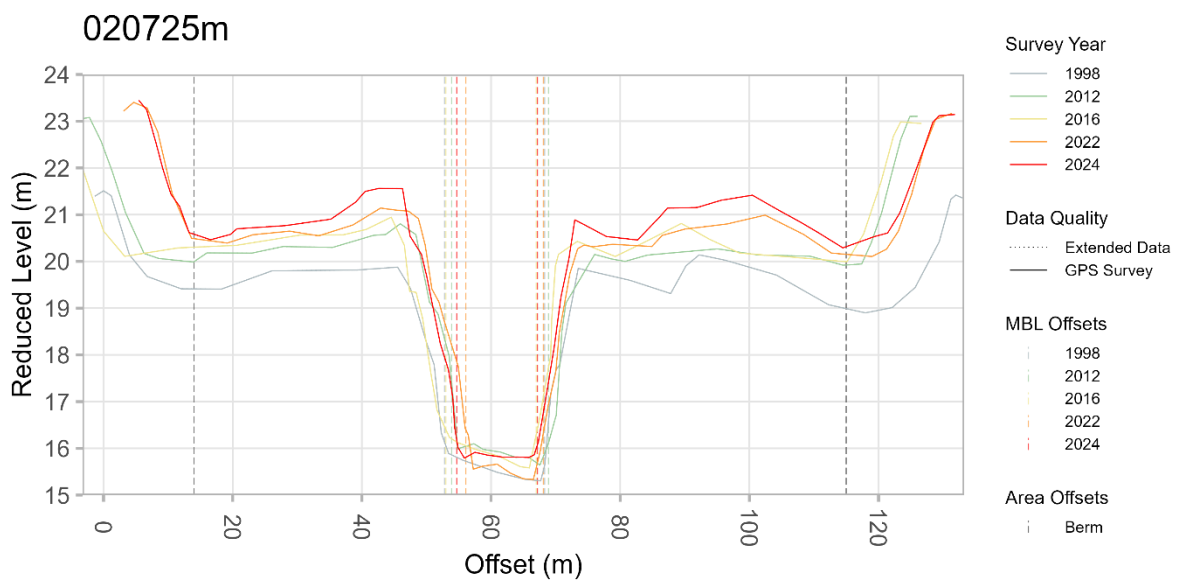
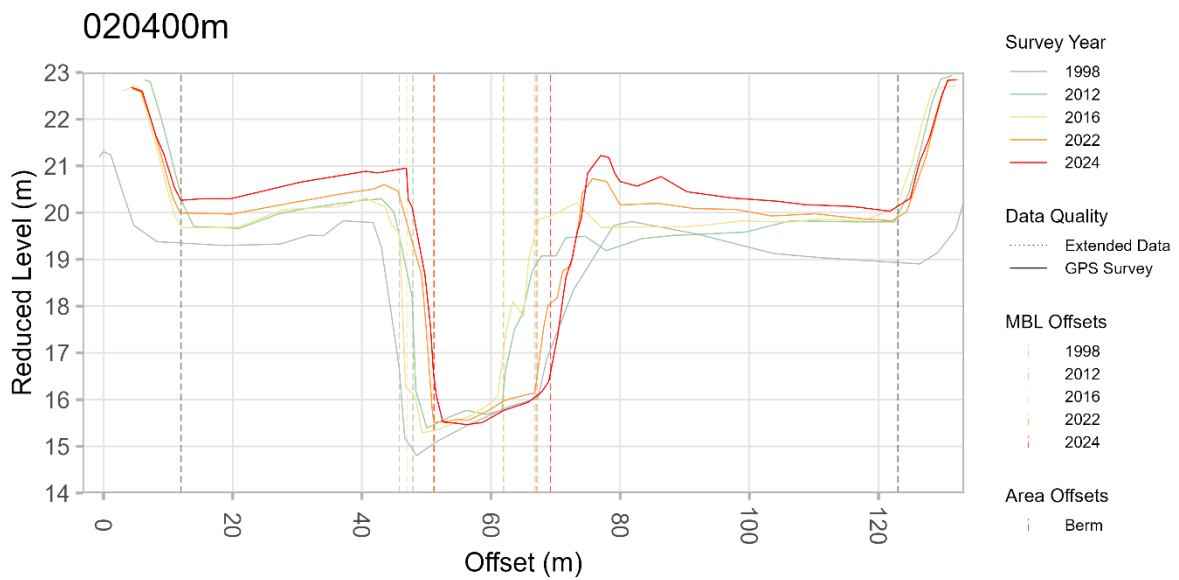
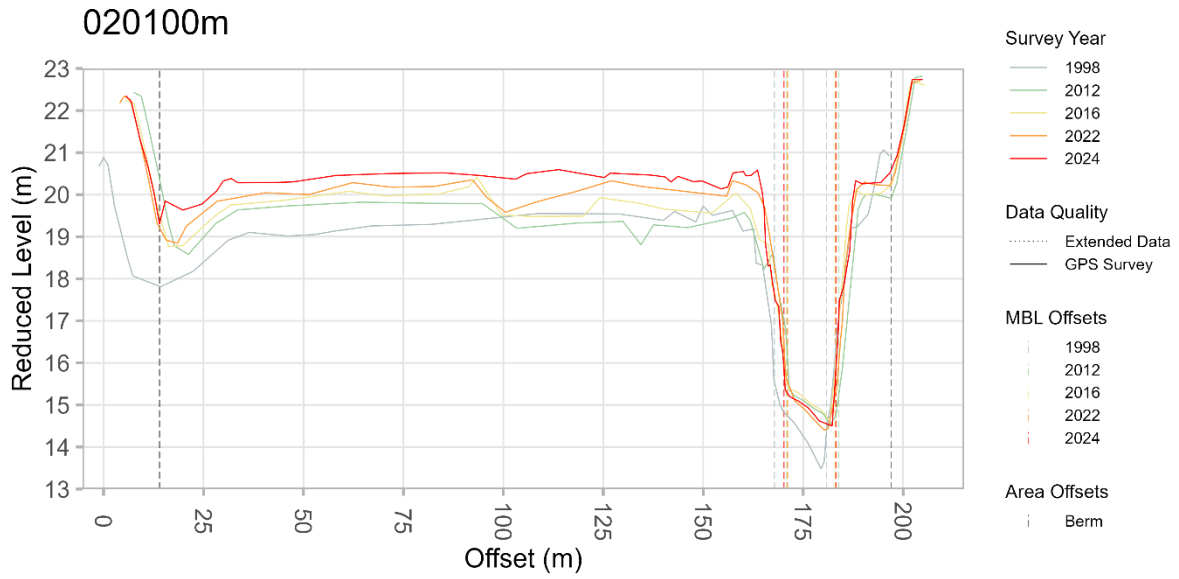




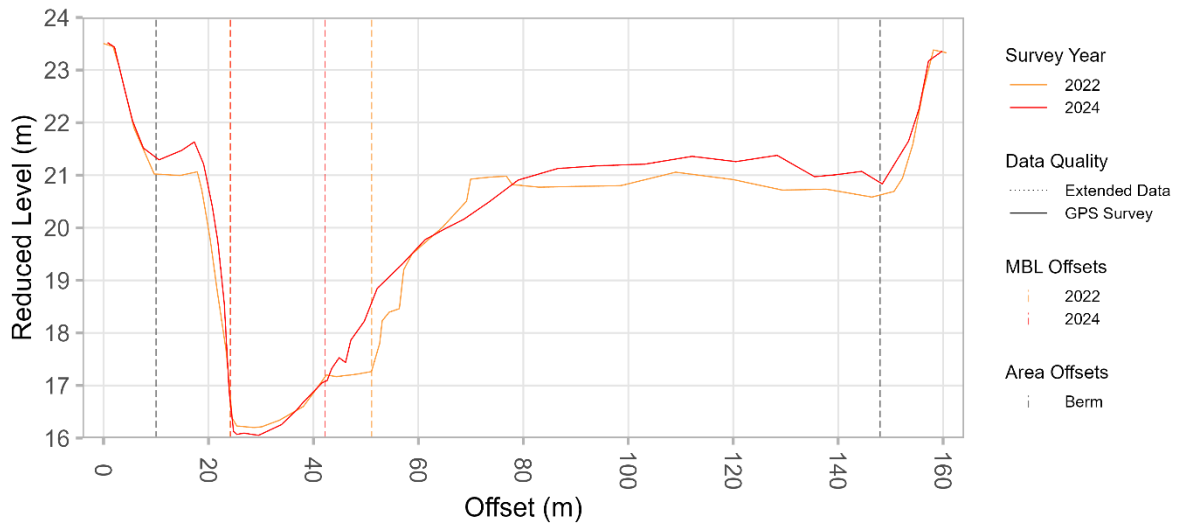




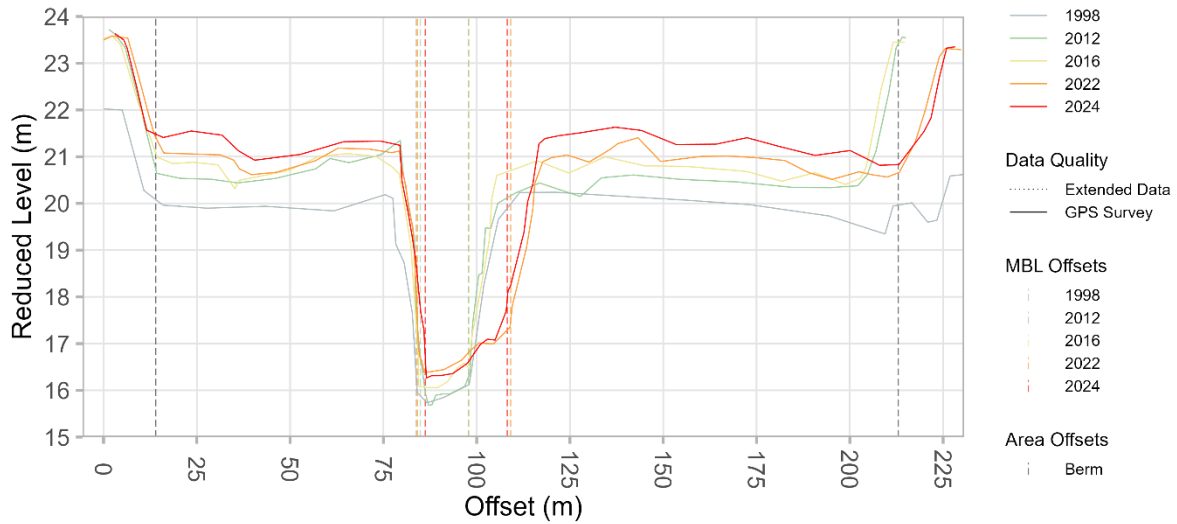




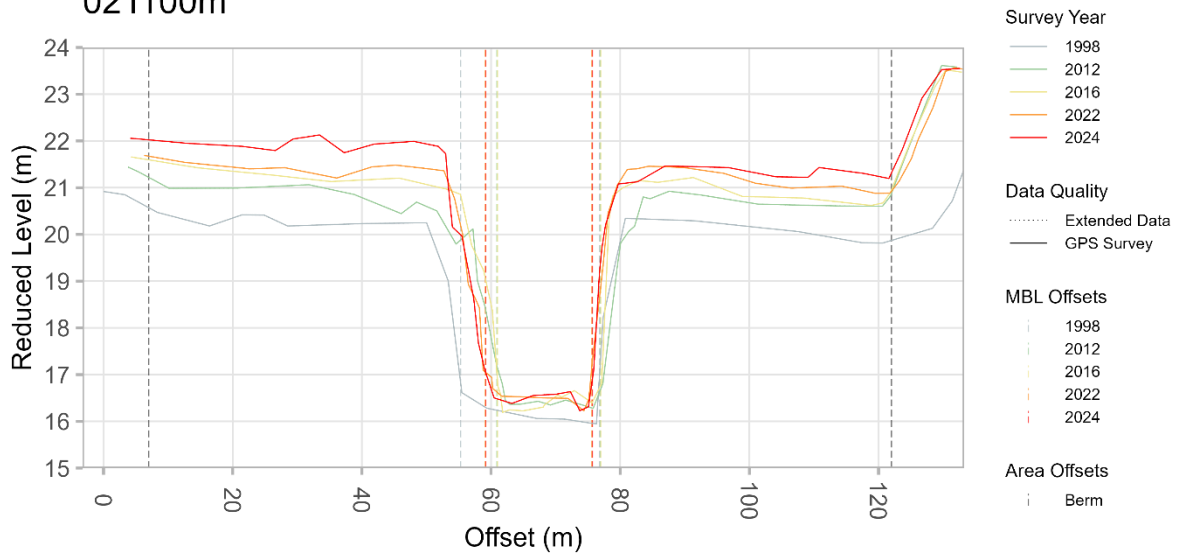
020865m - 1

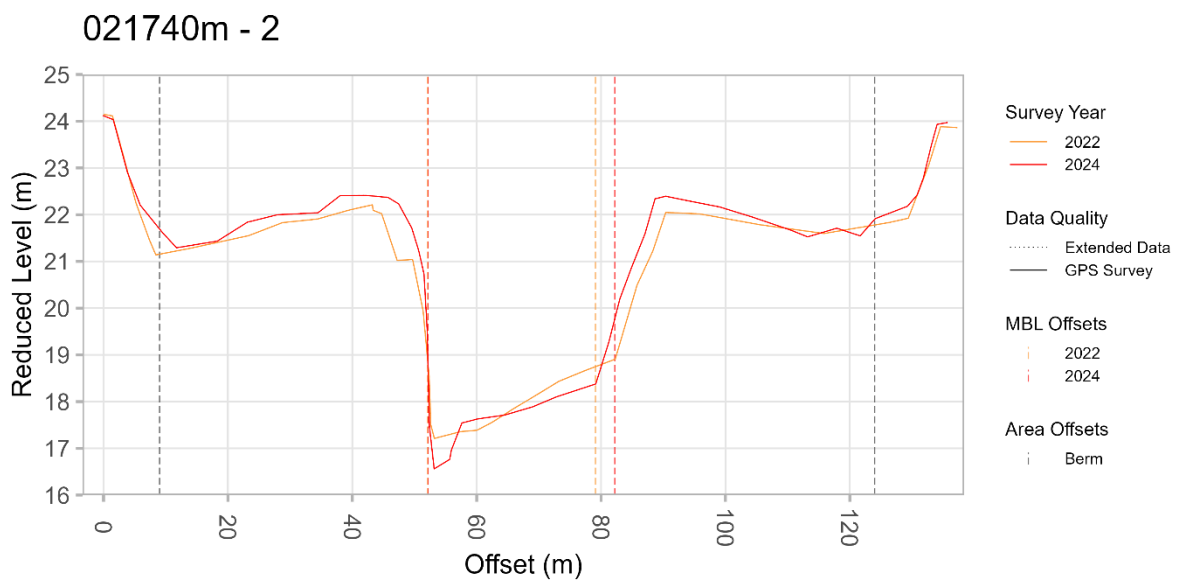
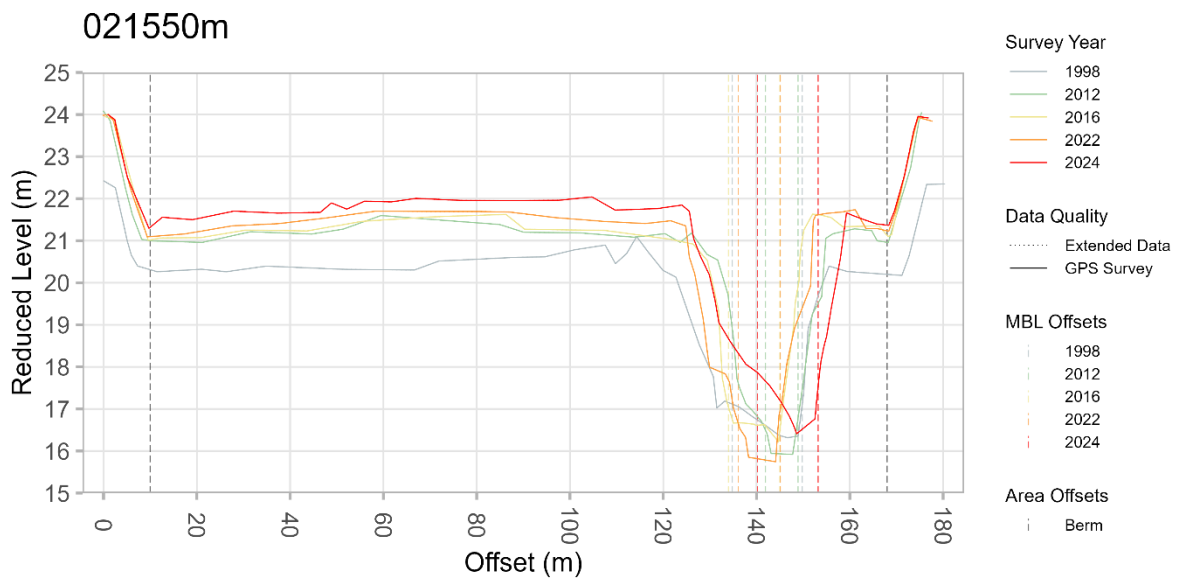
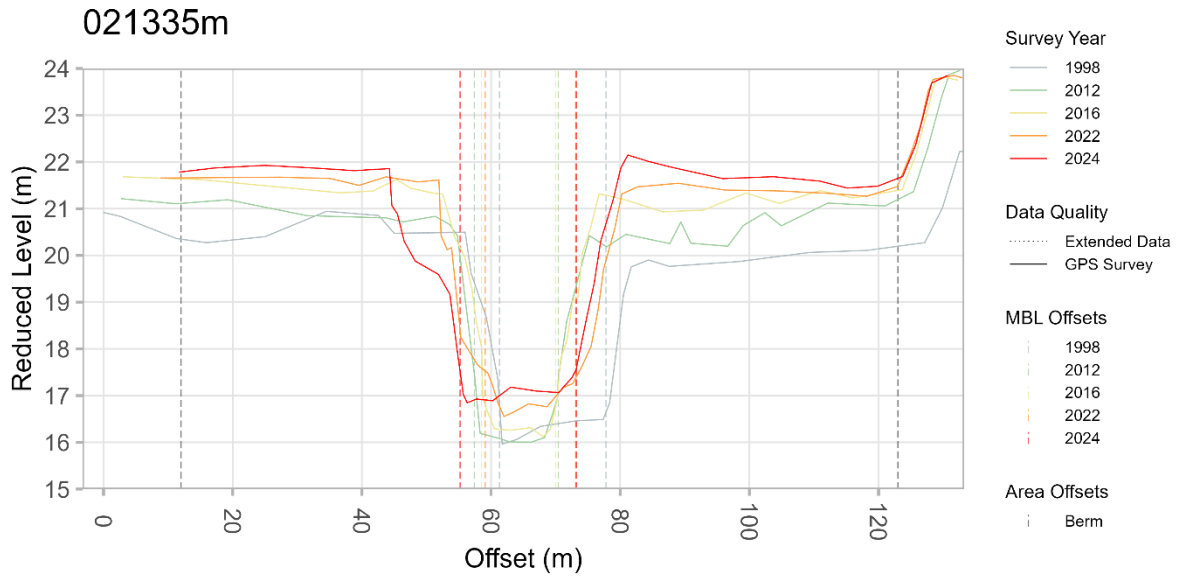


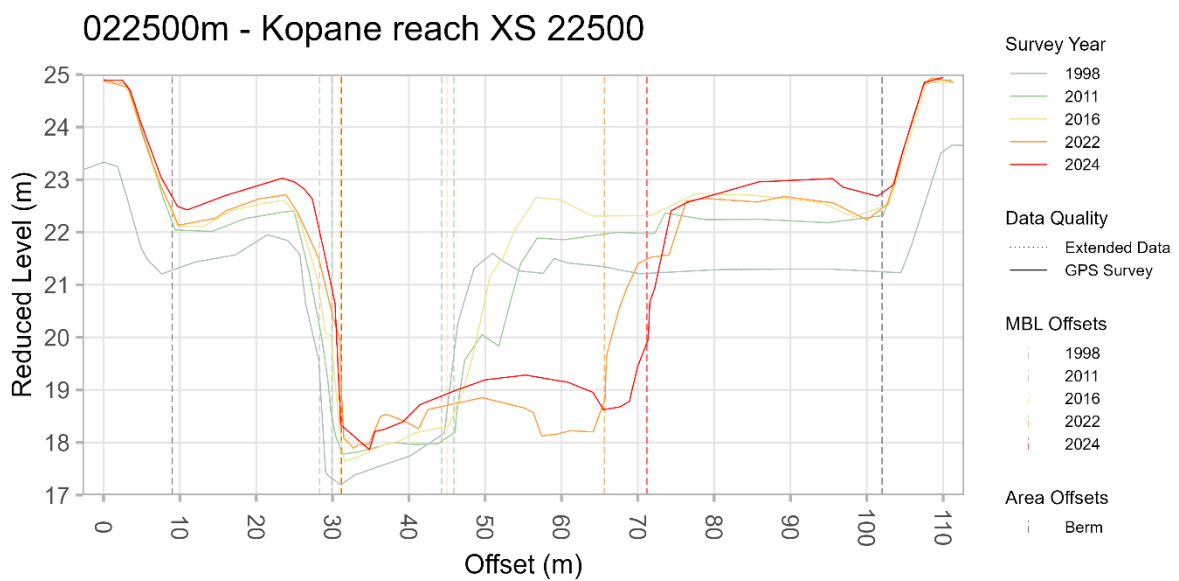
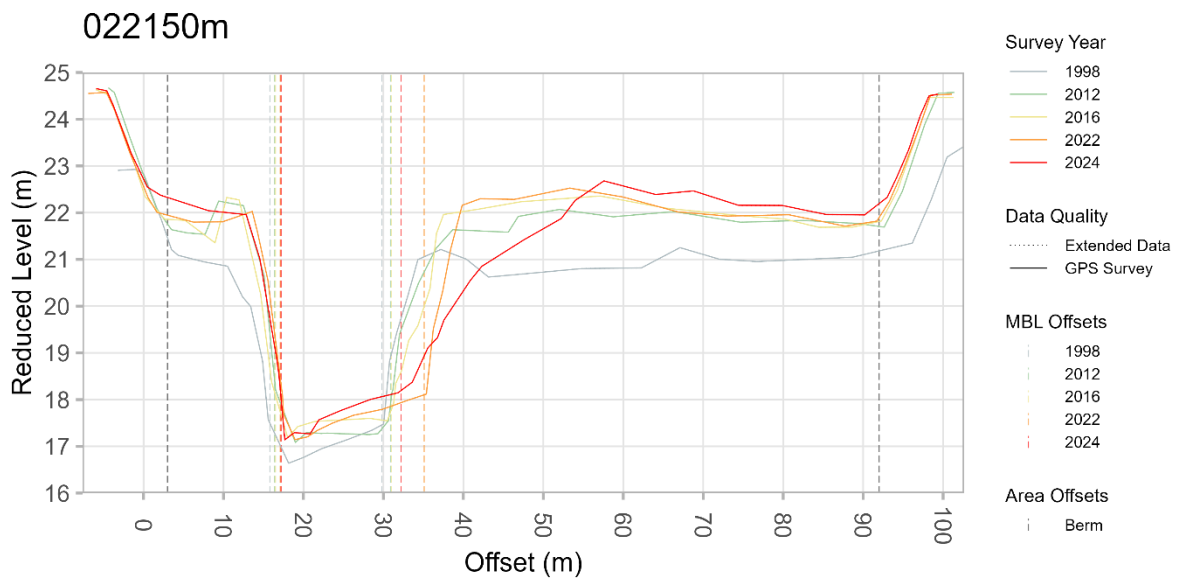
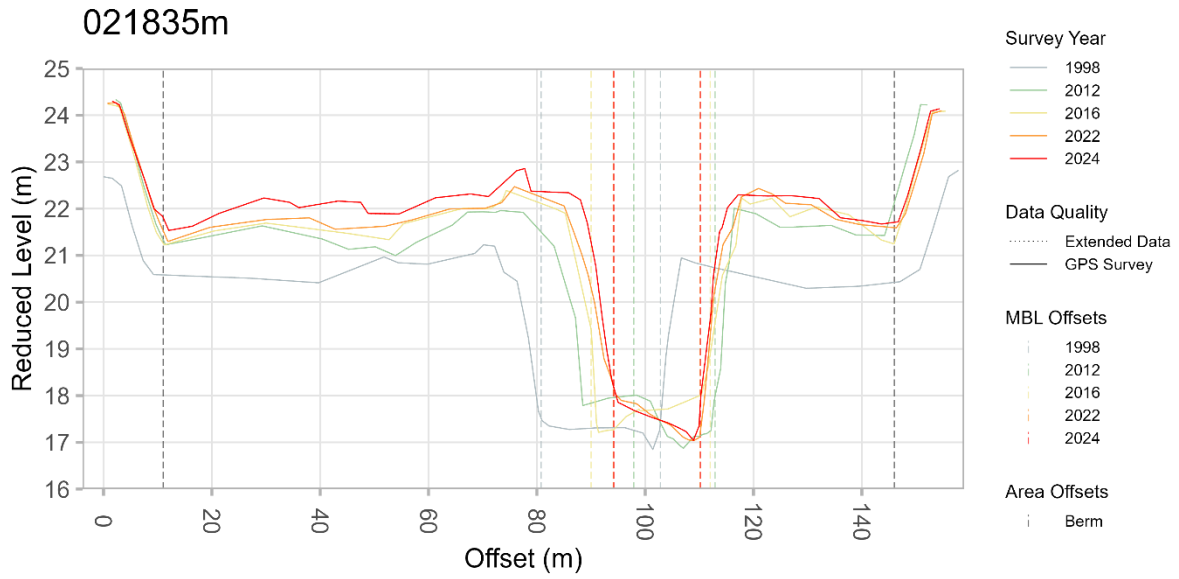
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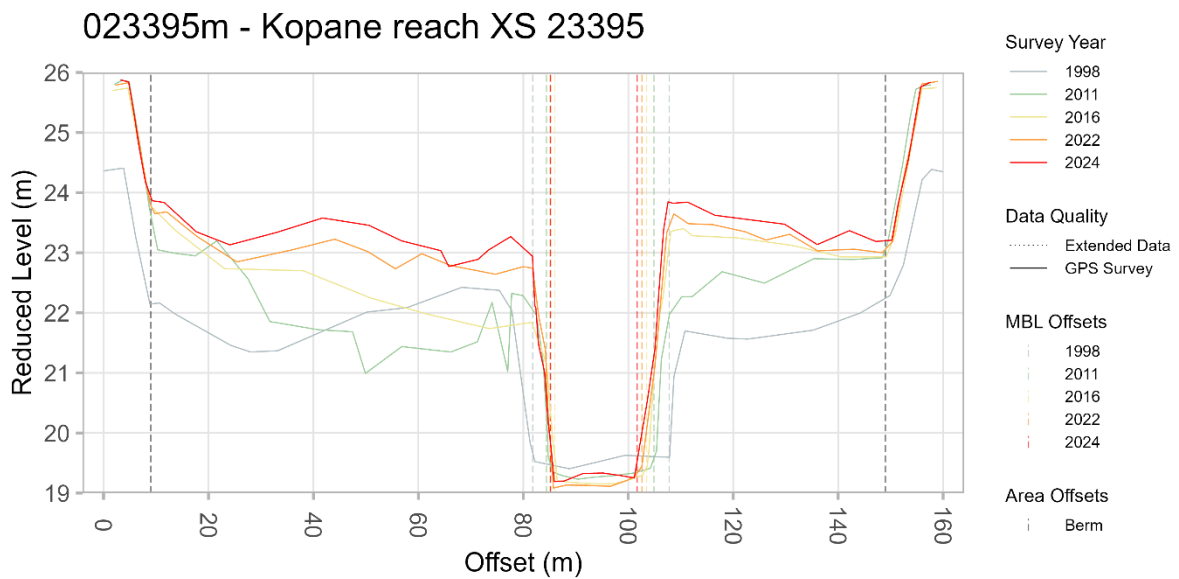
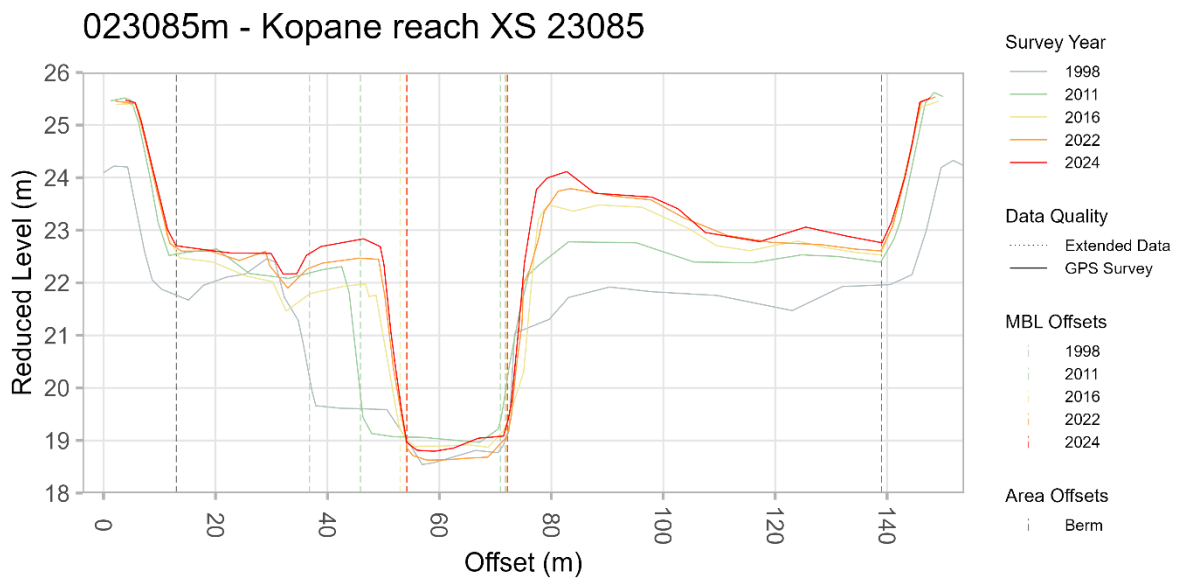
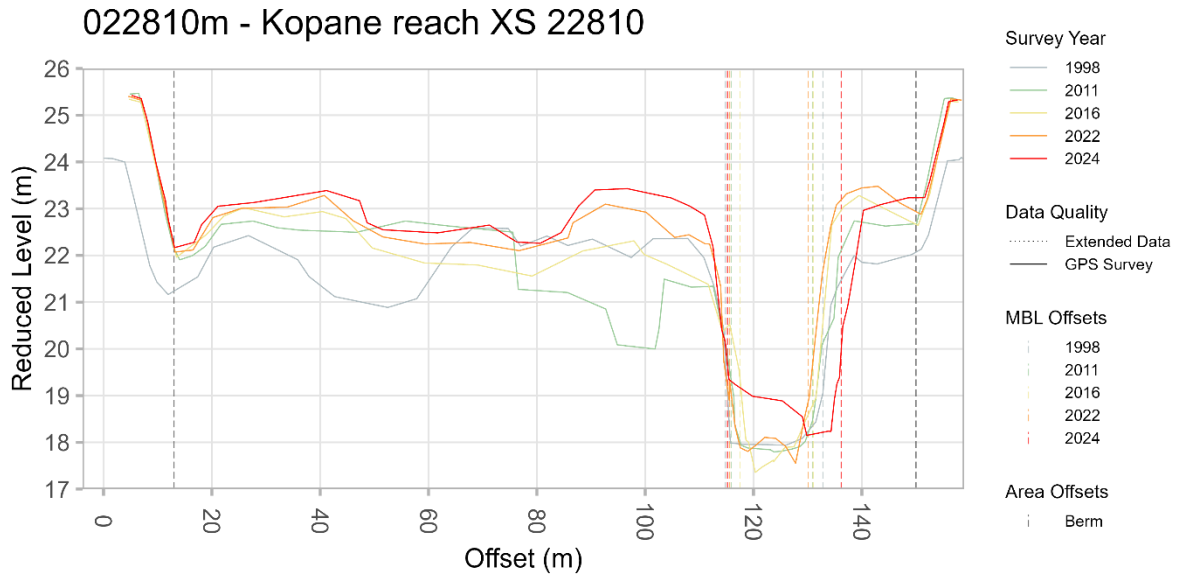


021100m

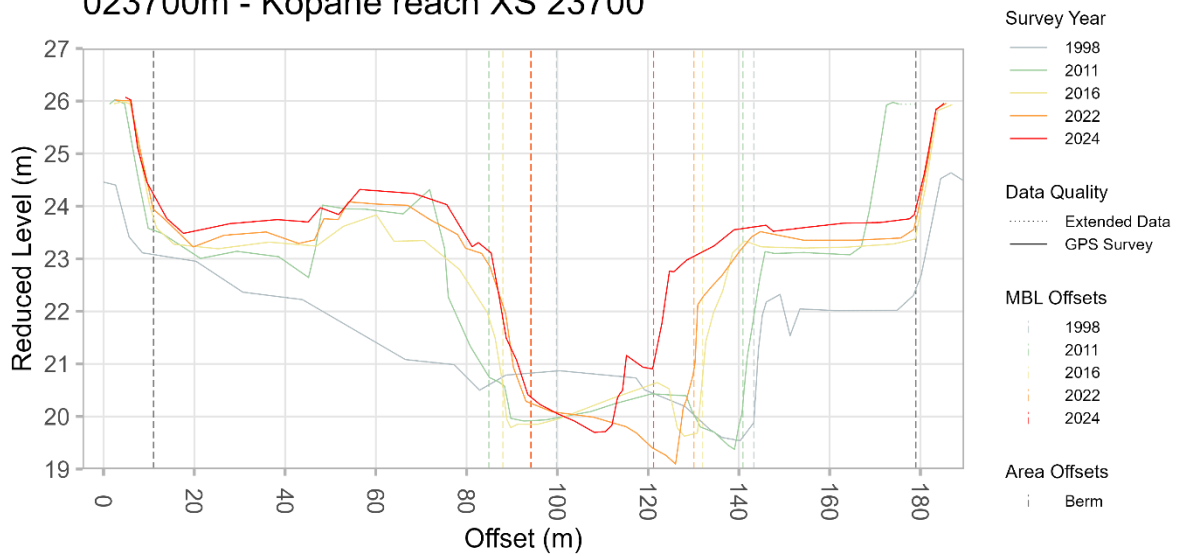




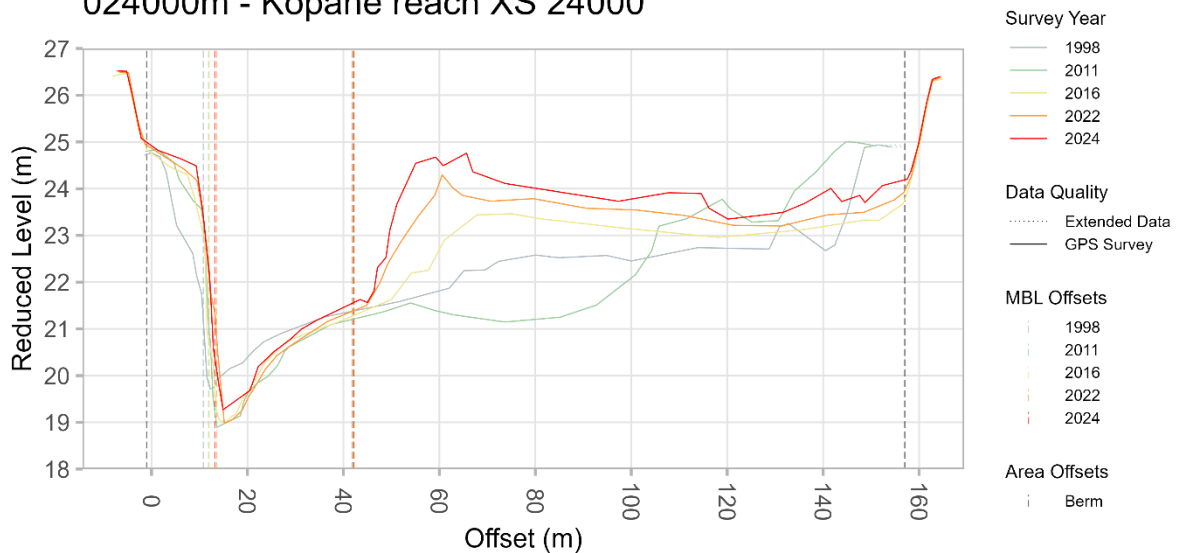




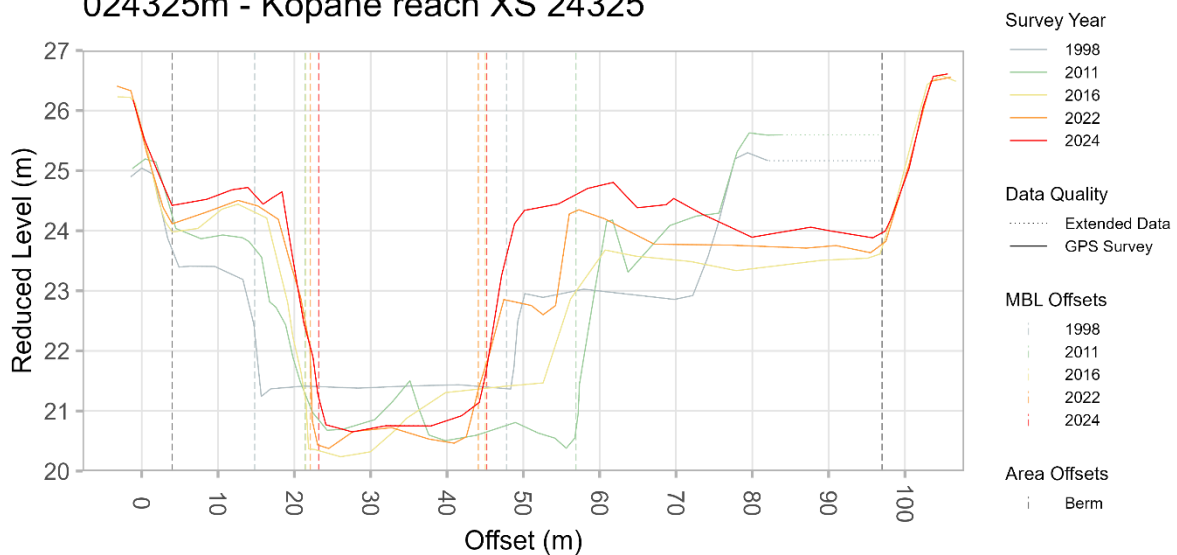
023700m - Kopane reach XS 23700



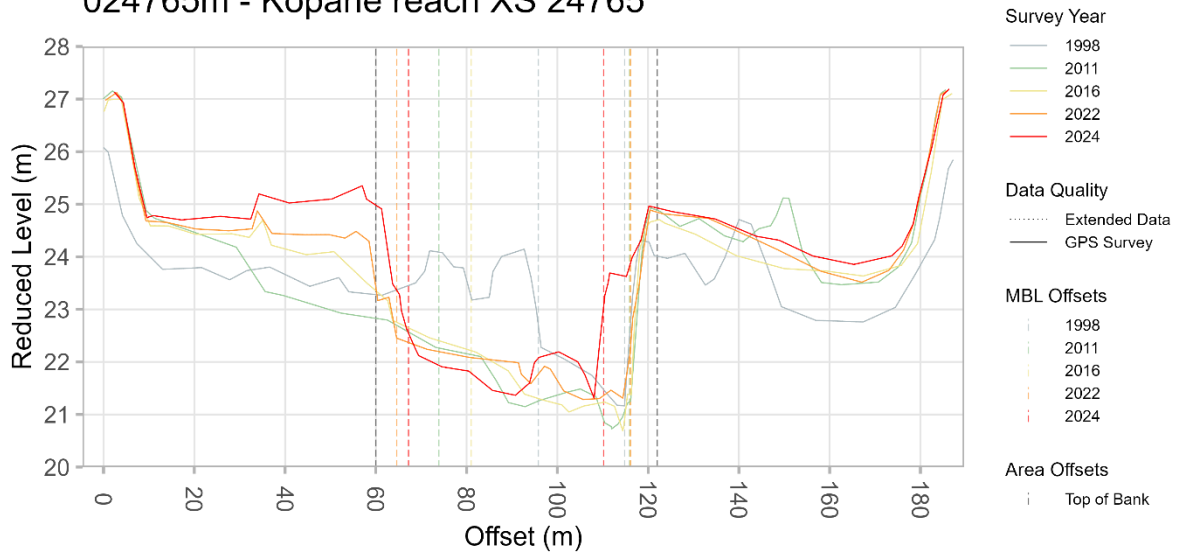
024000m - Kopane reach XS 24000



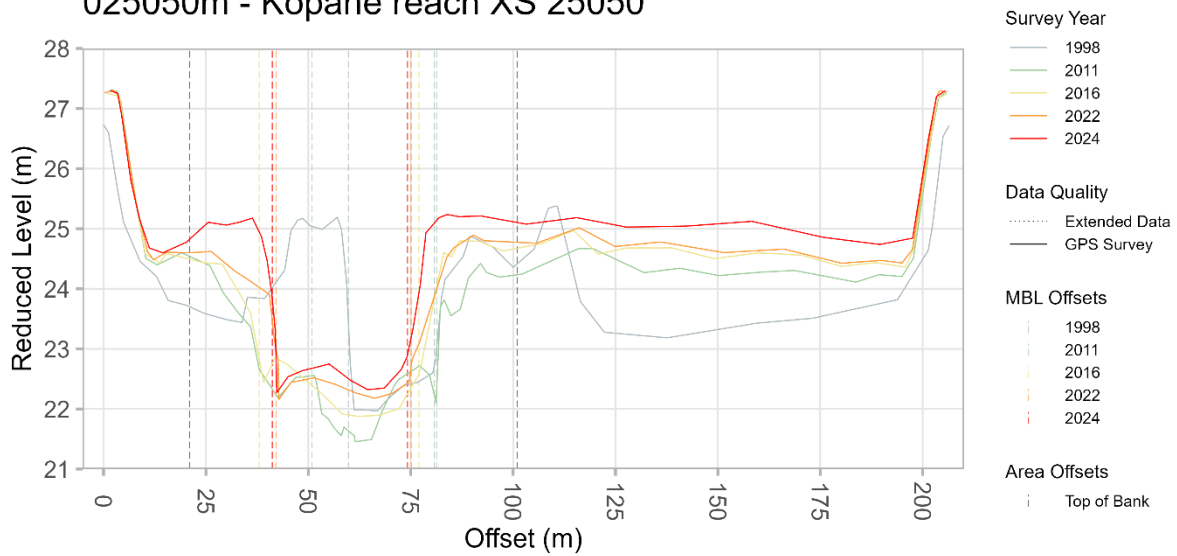
024325m - Kopane reach XS 24325



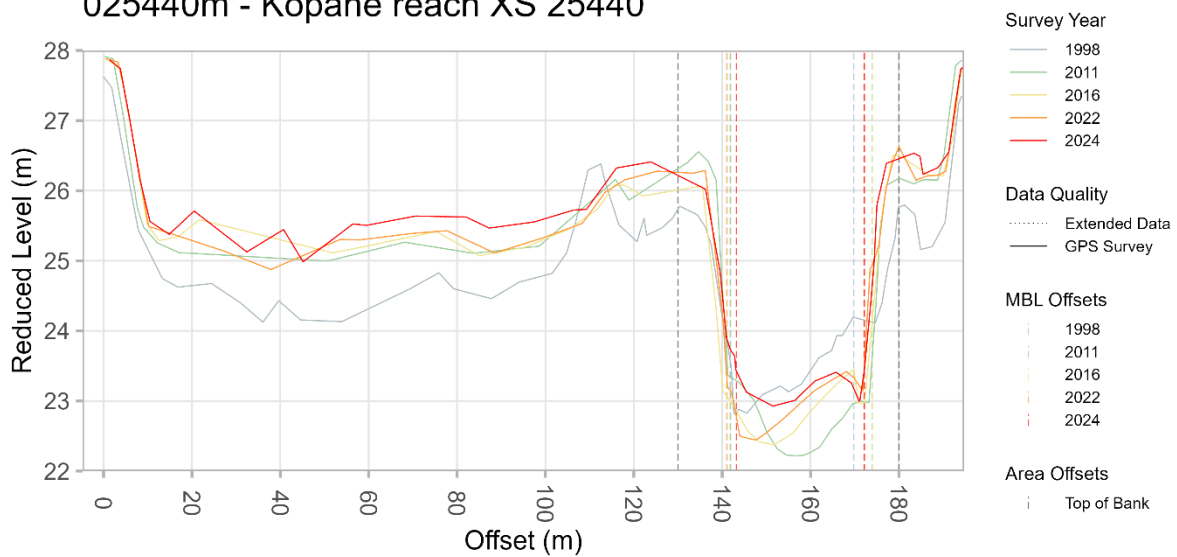
024765m - Kopane reach XS 24765

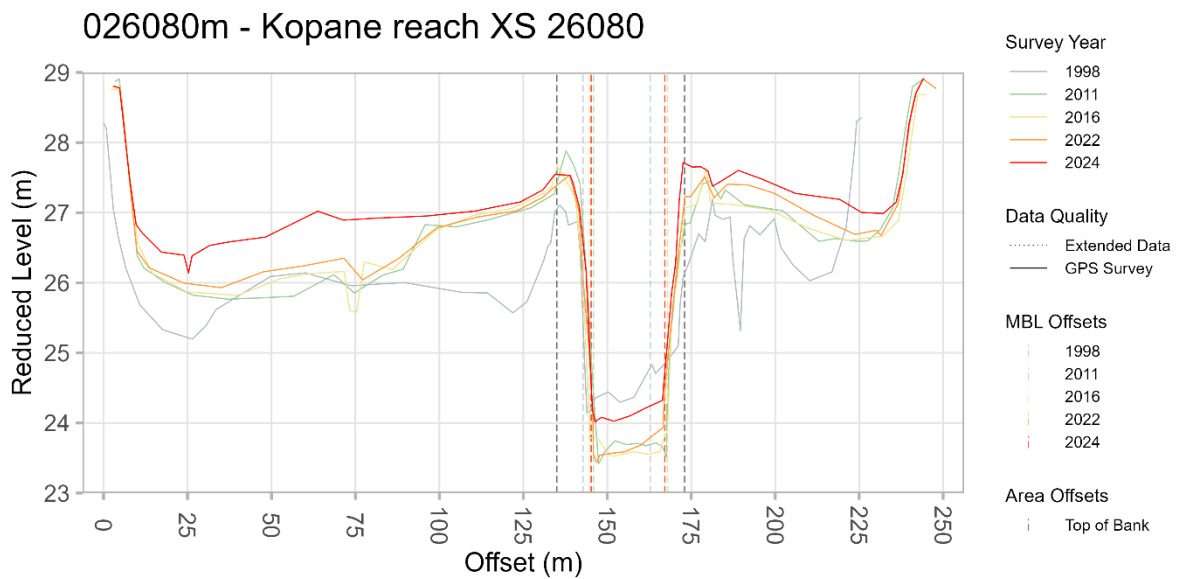
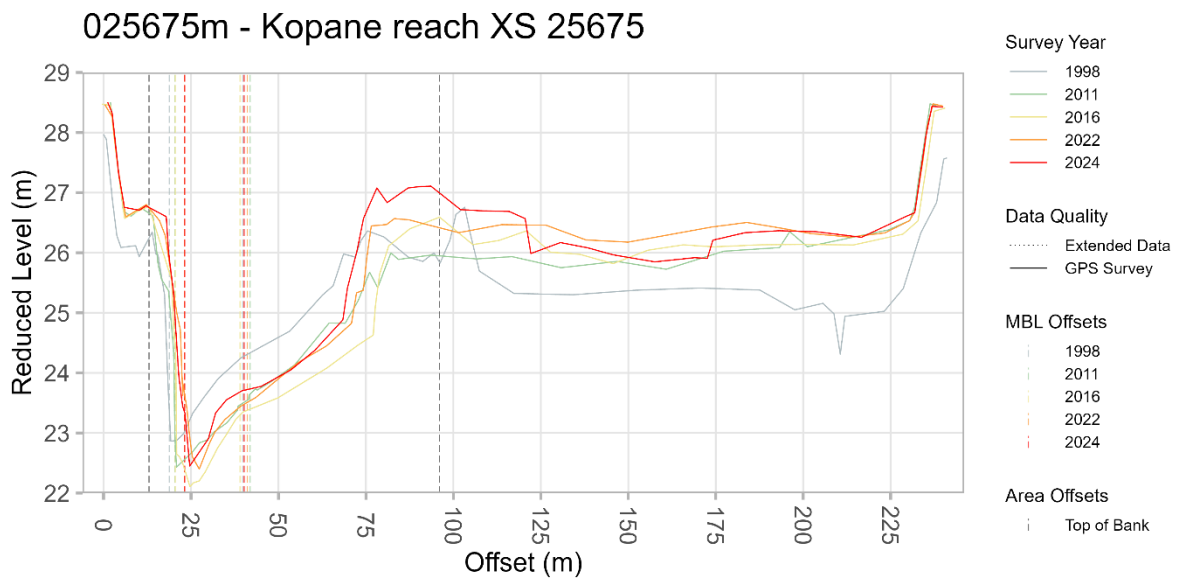
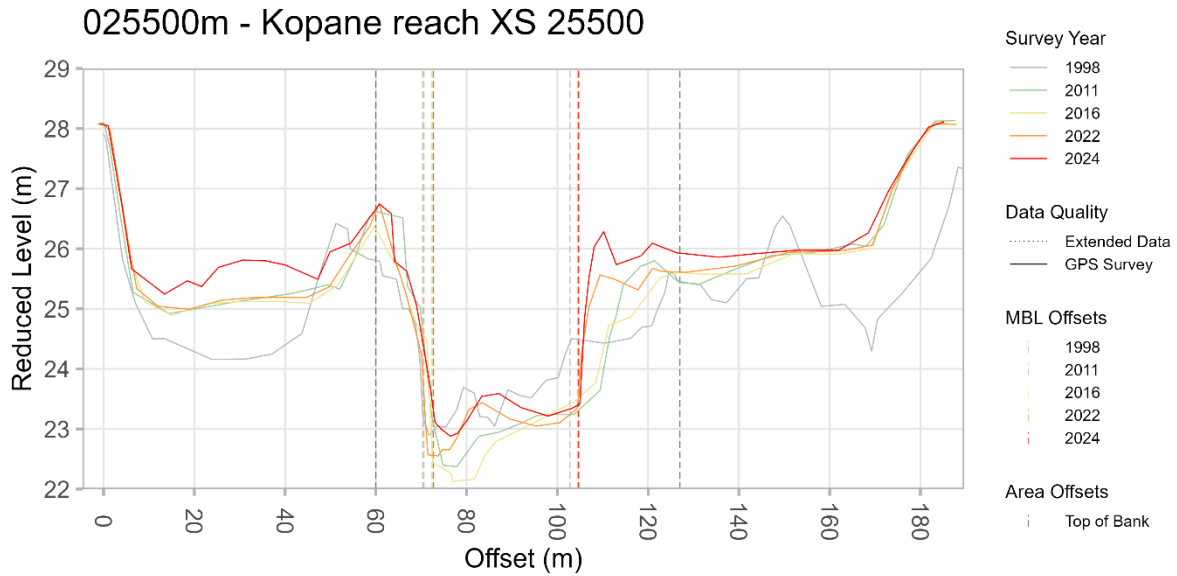


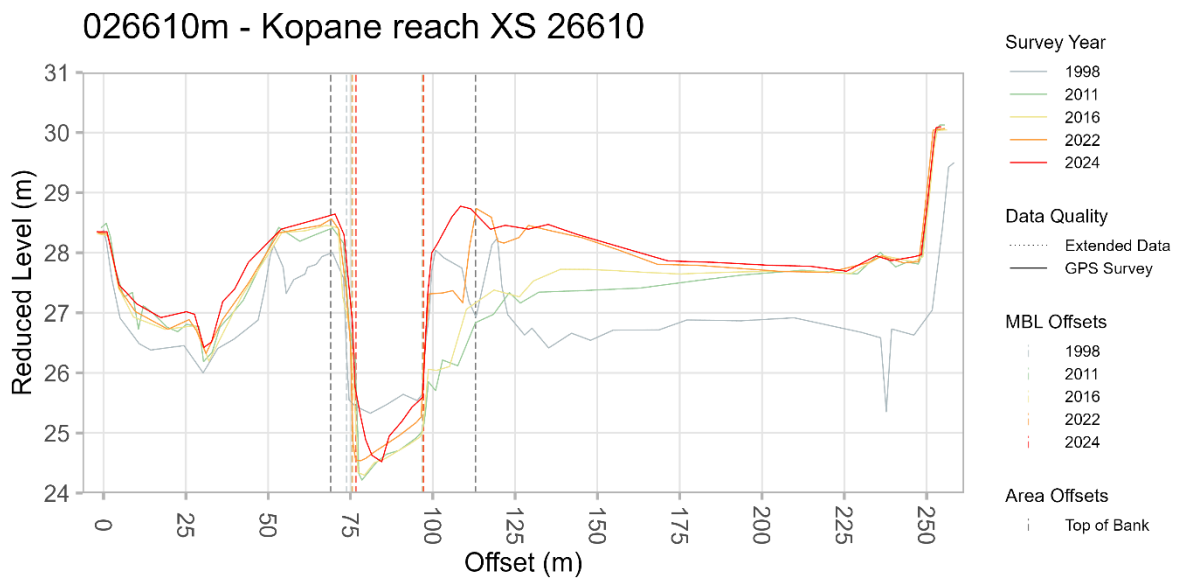
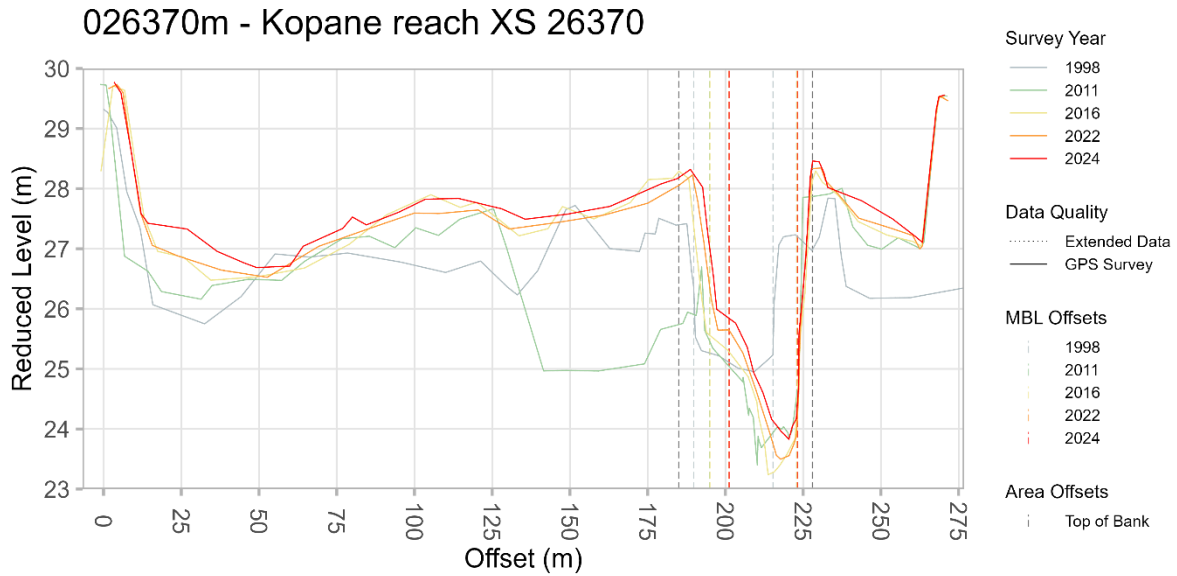
025050m - Kopane reach XS 25050

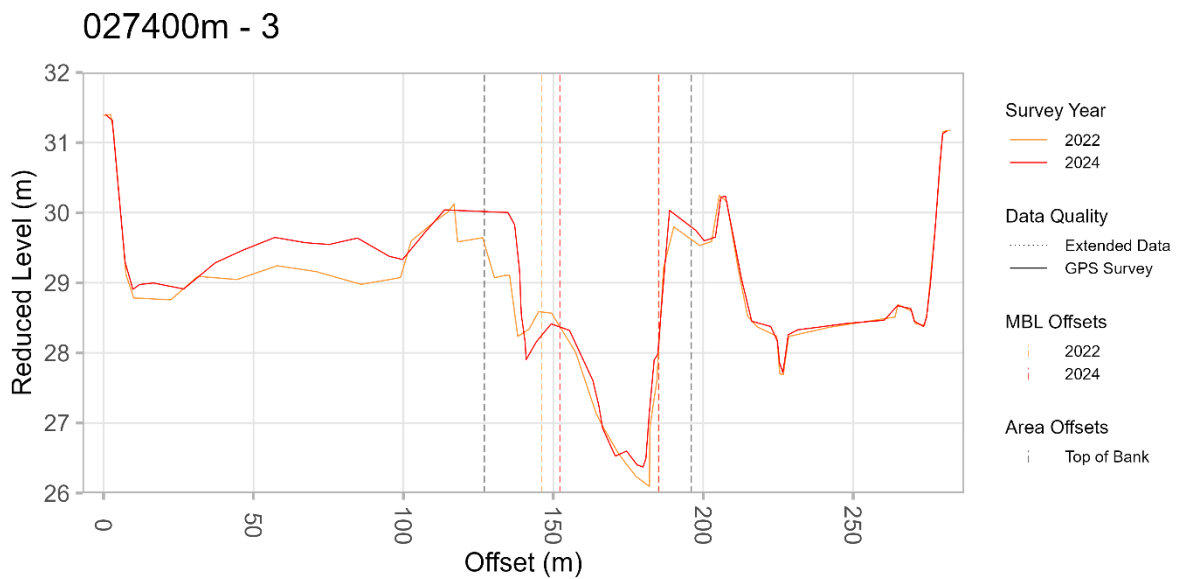
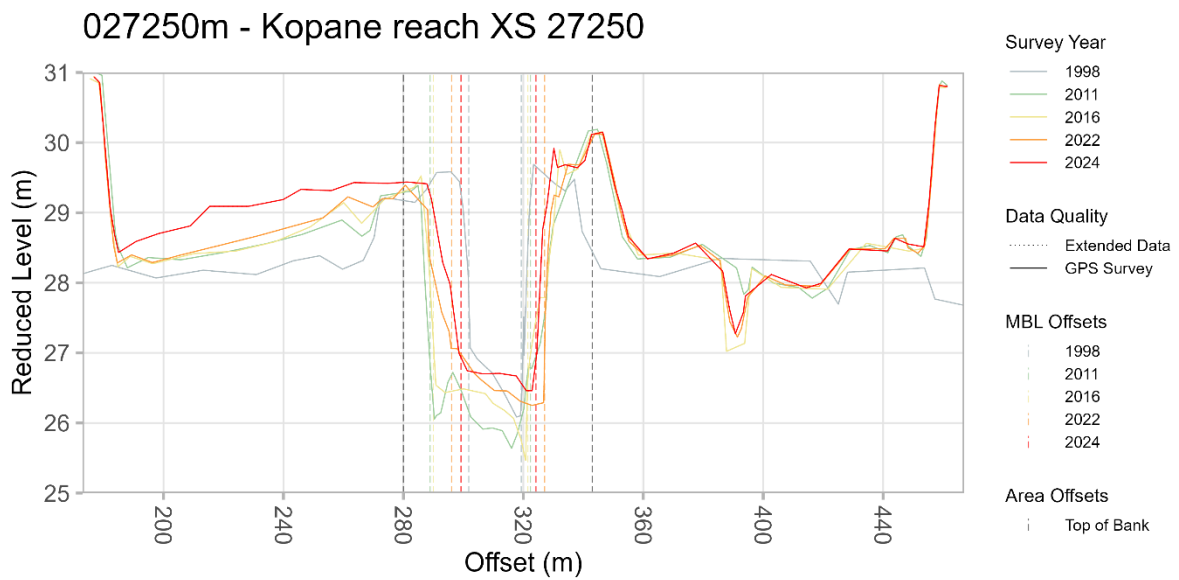
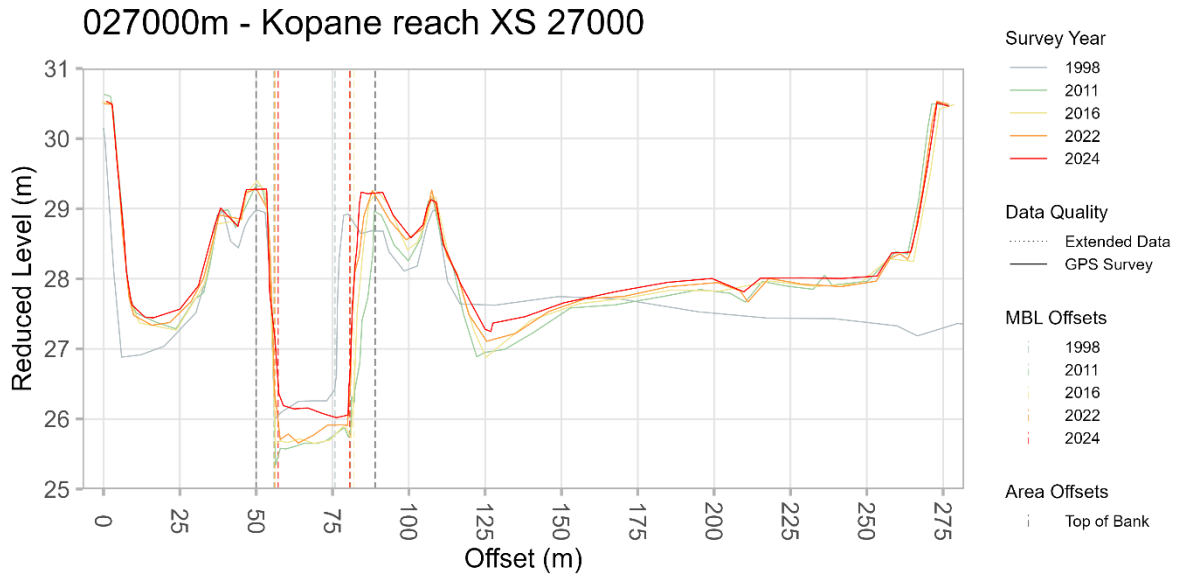


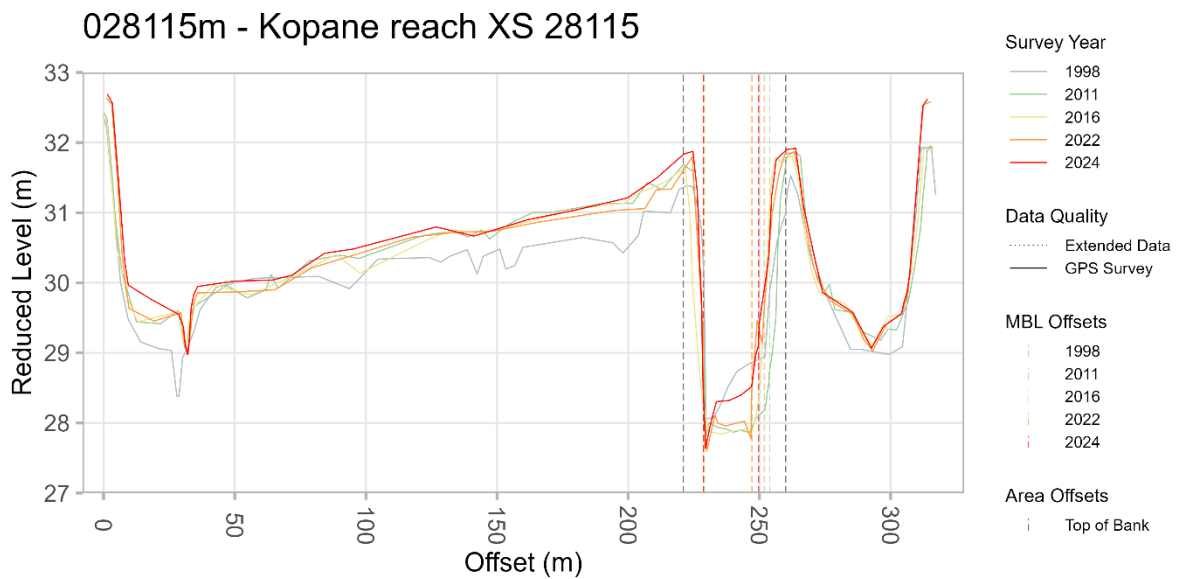
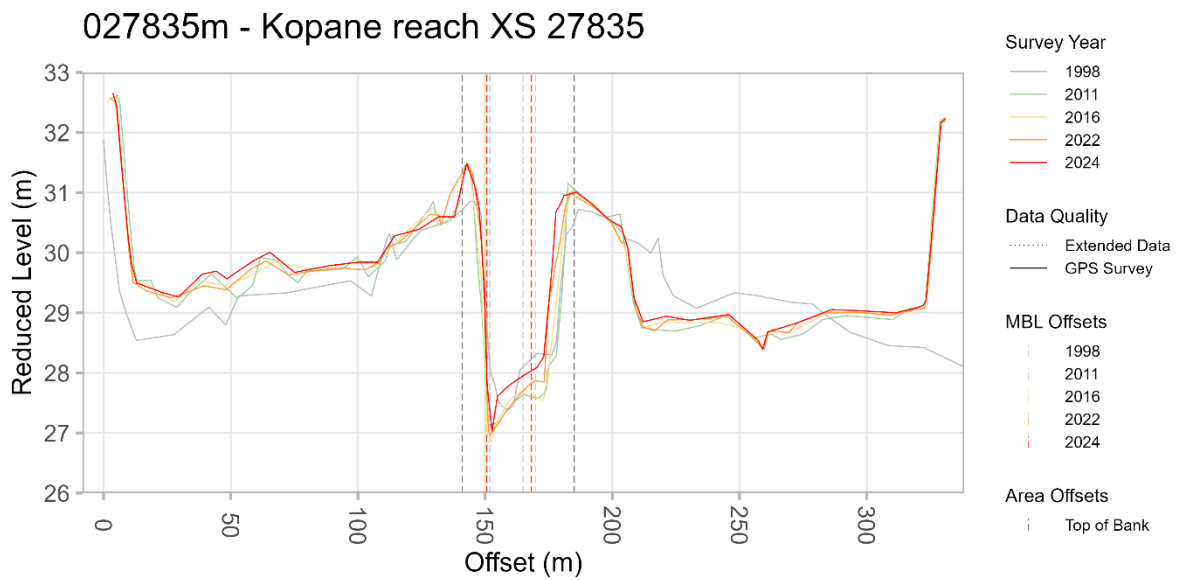
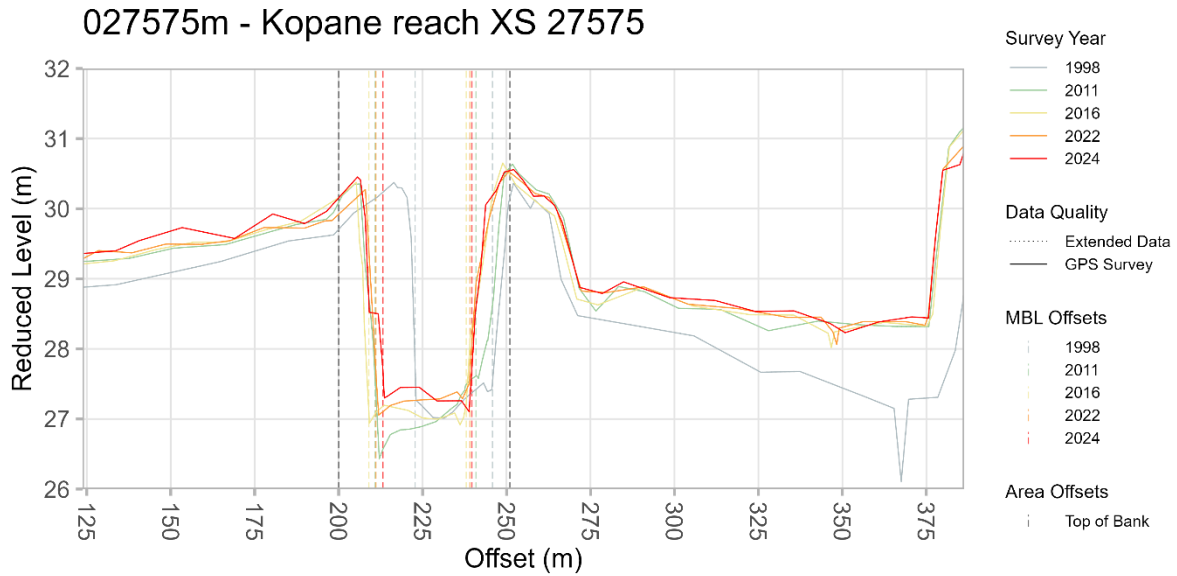
025440m - Kopane reach XS 25440

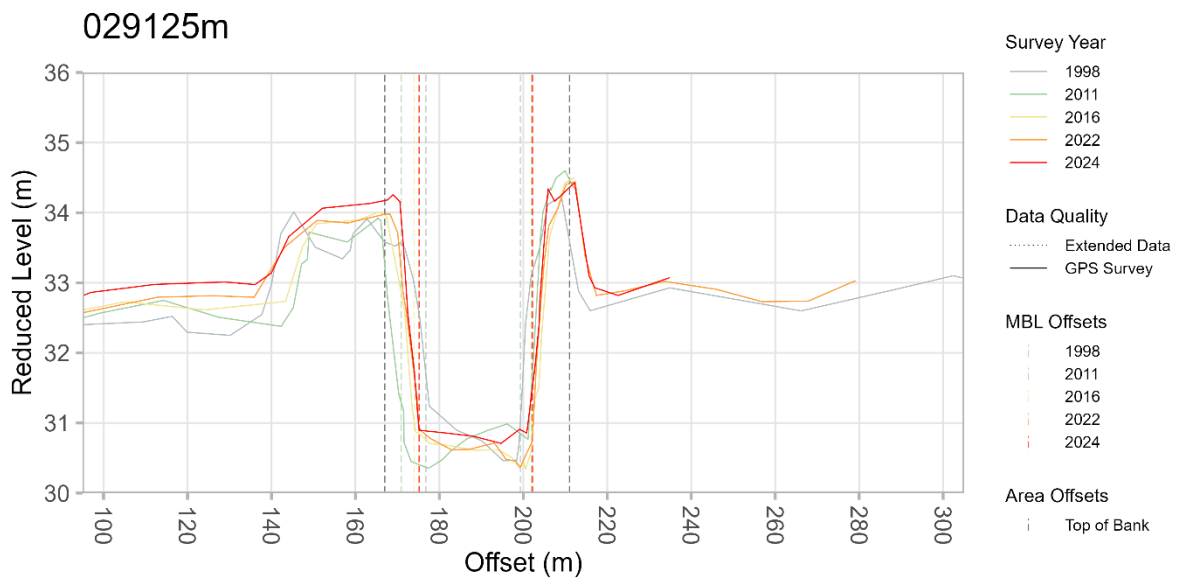
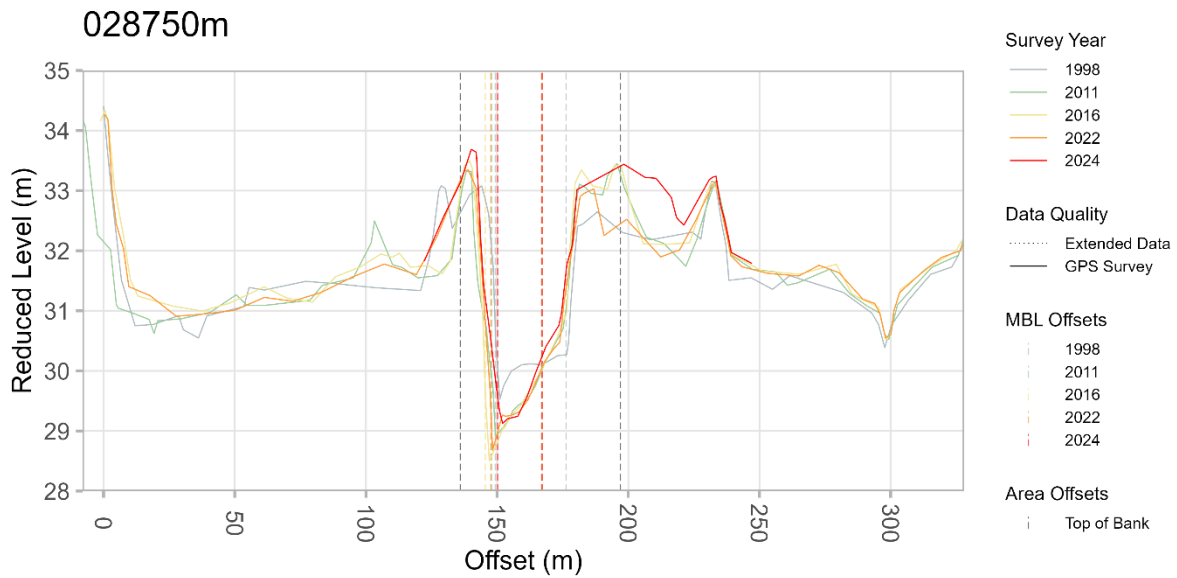
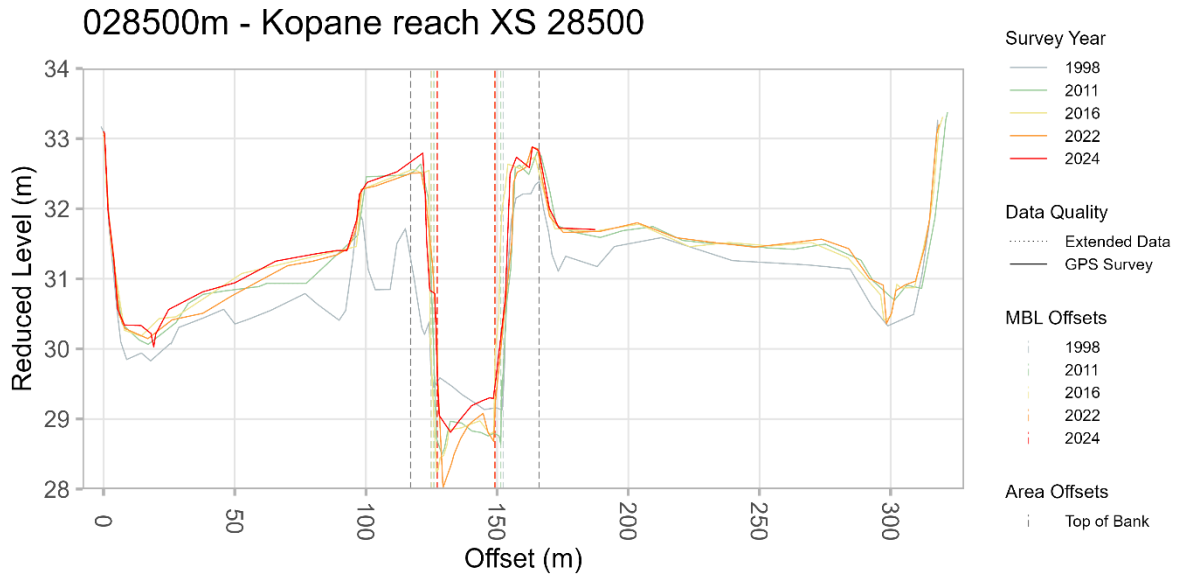


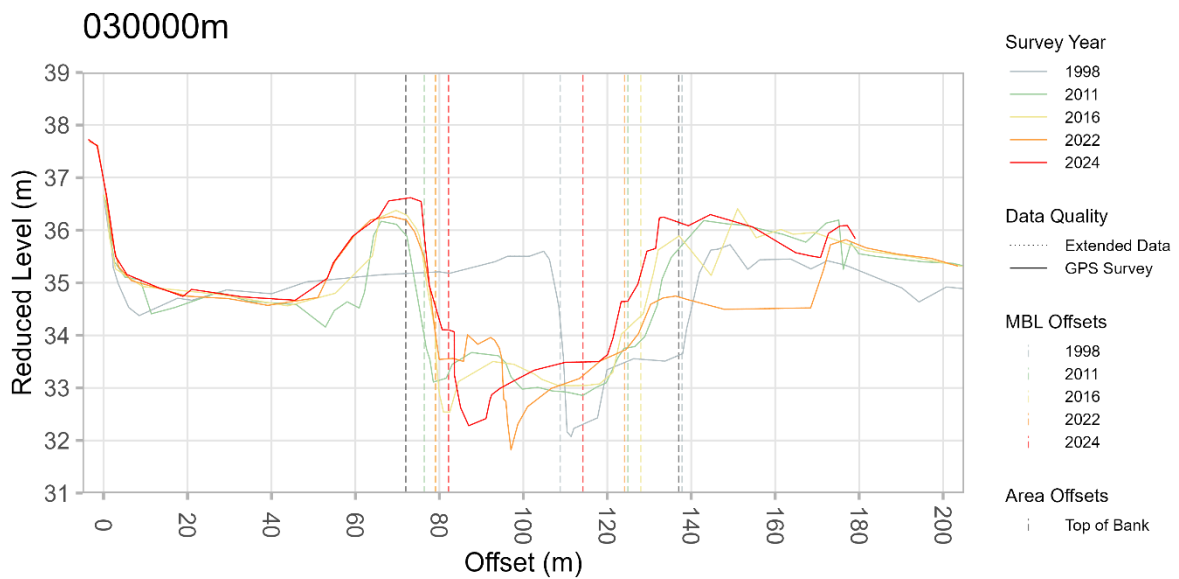
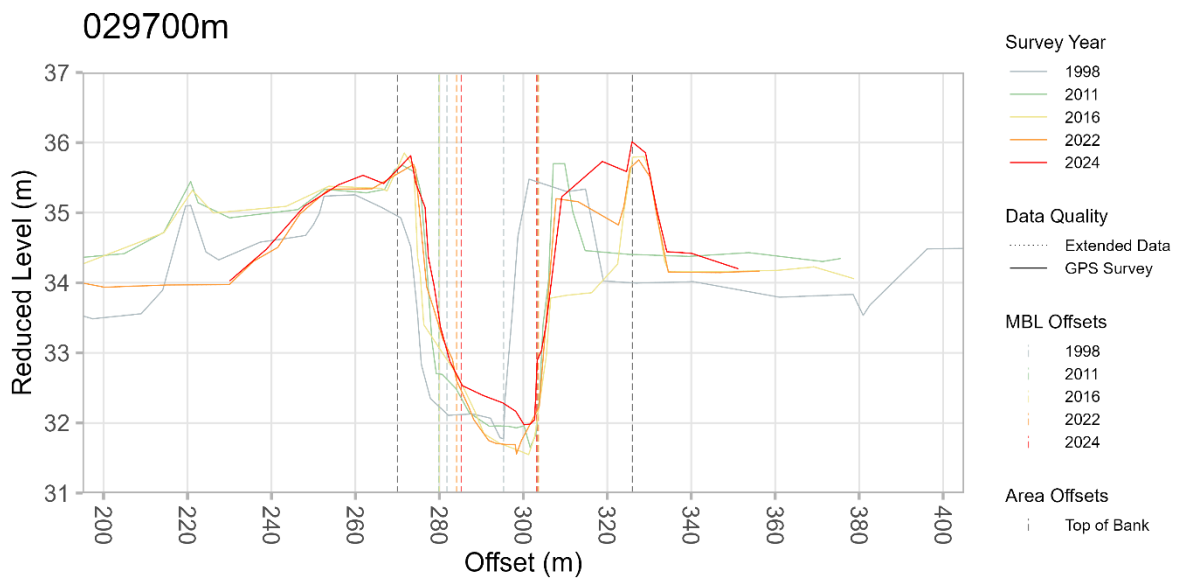
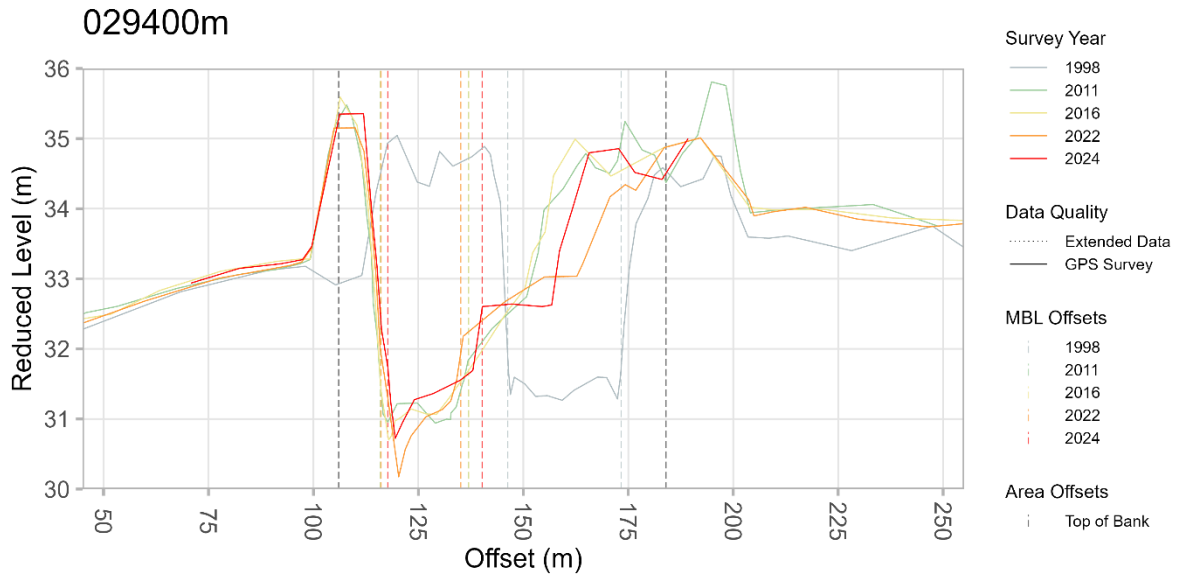




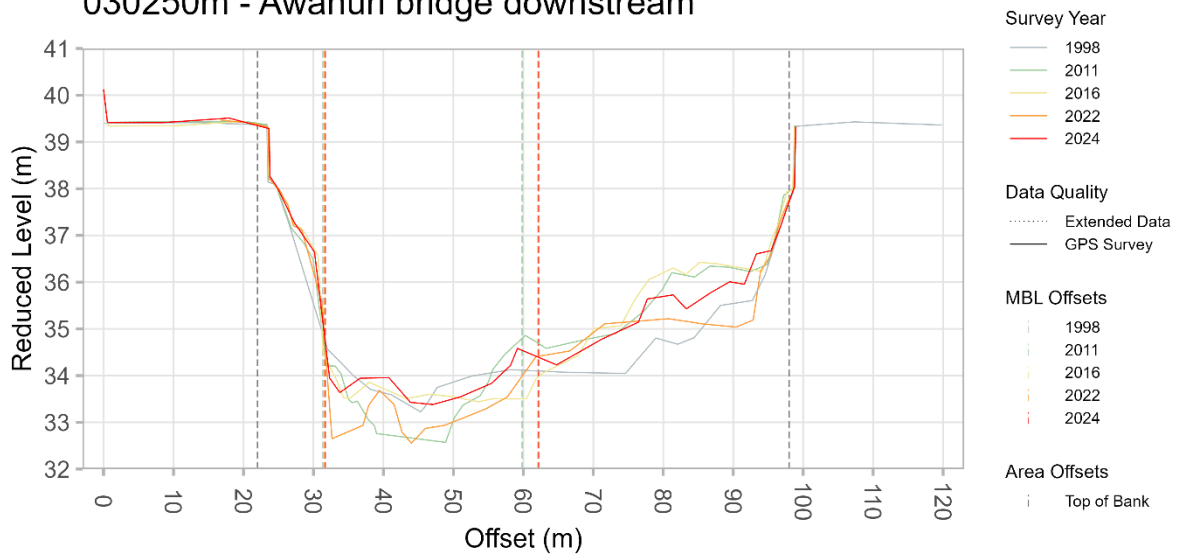




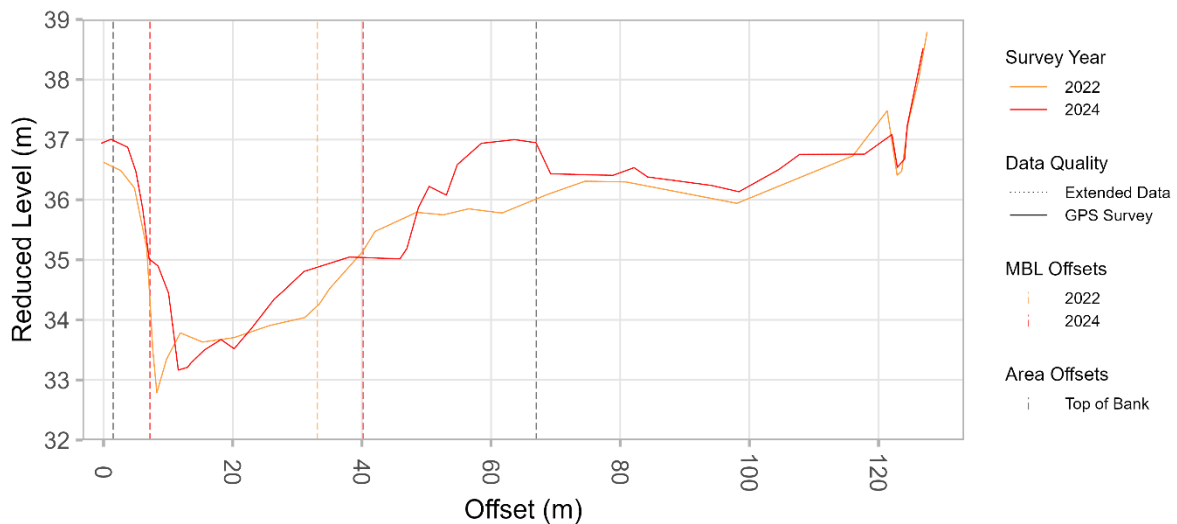




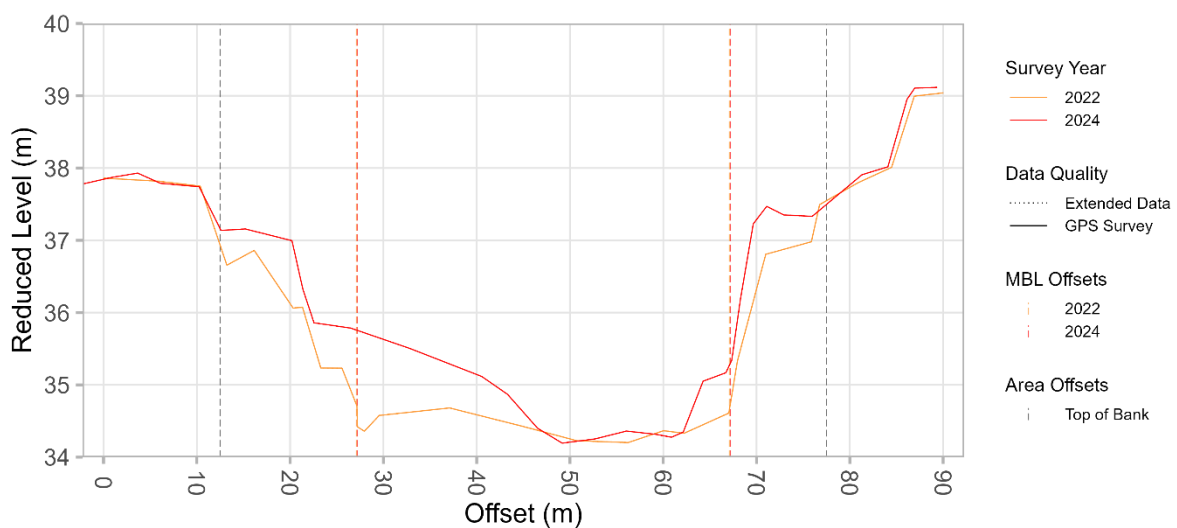
030250m - Awahuri bridge downstream

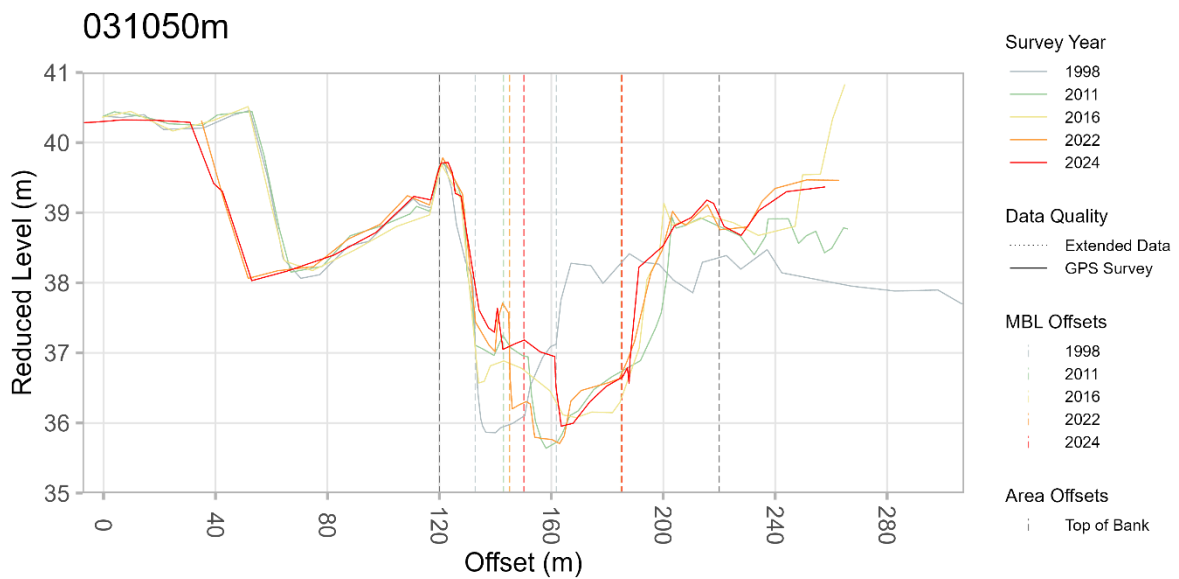
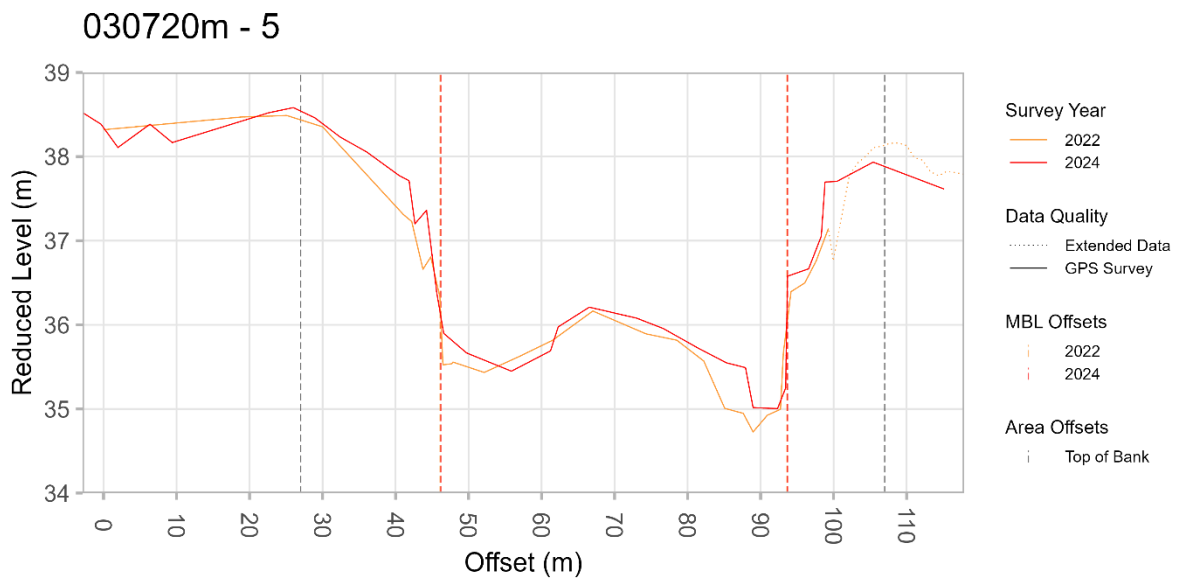
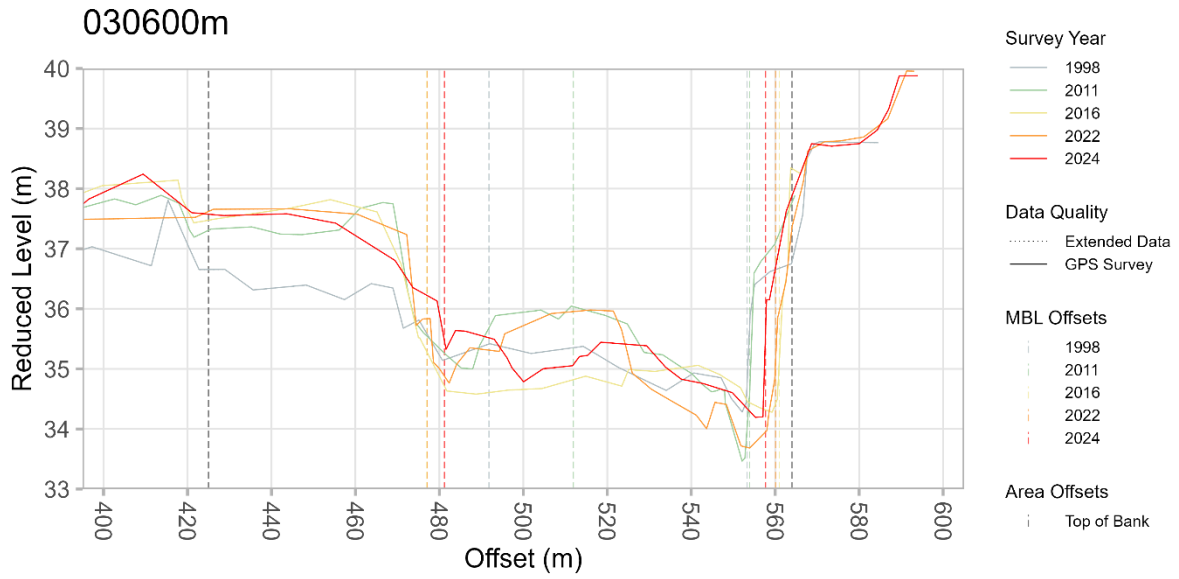


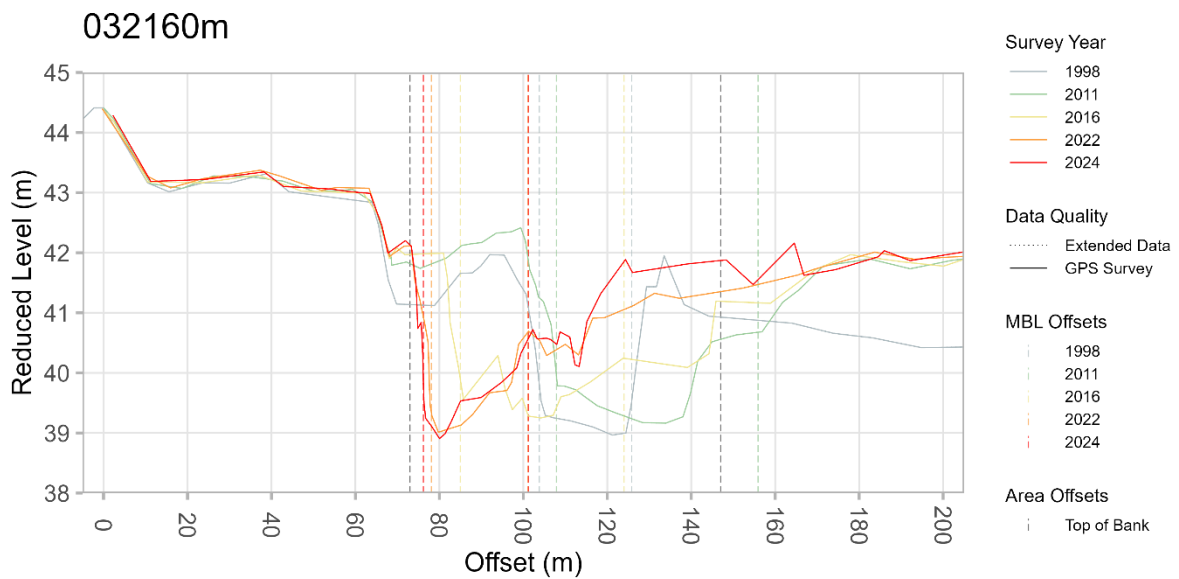
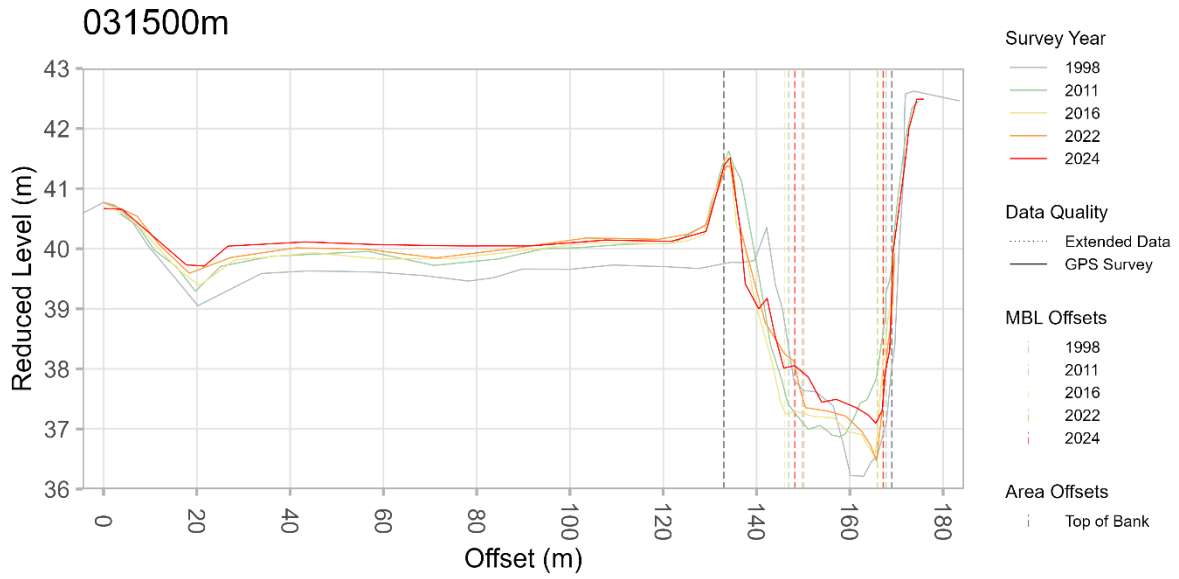
030350m - 6

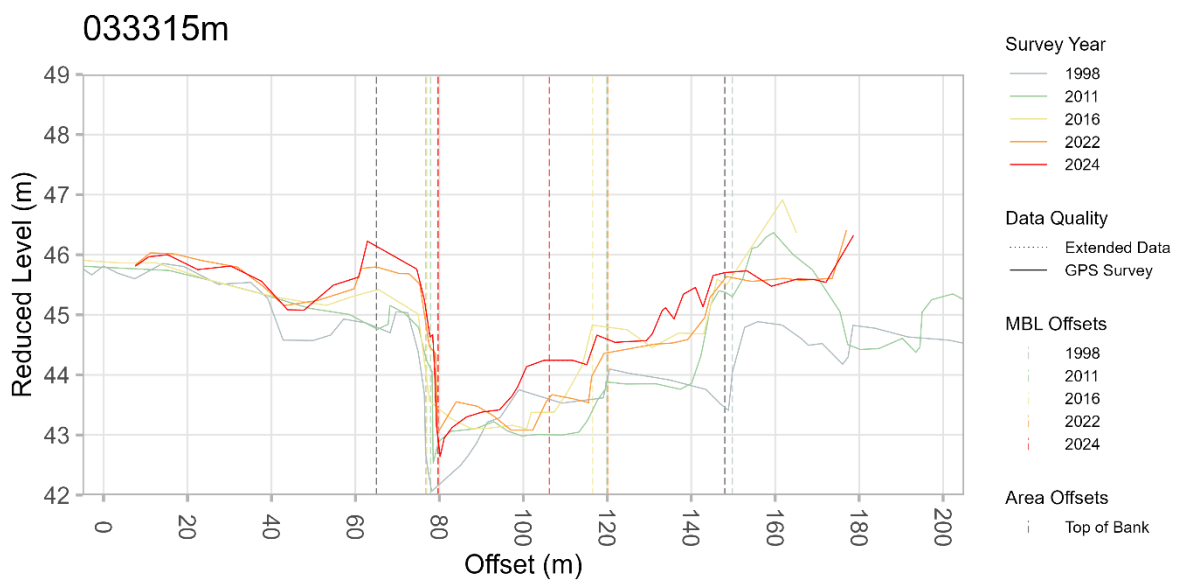
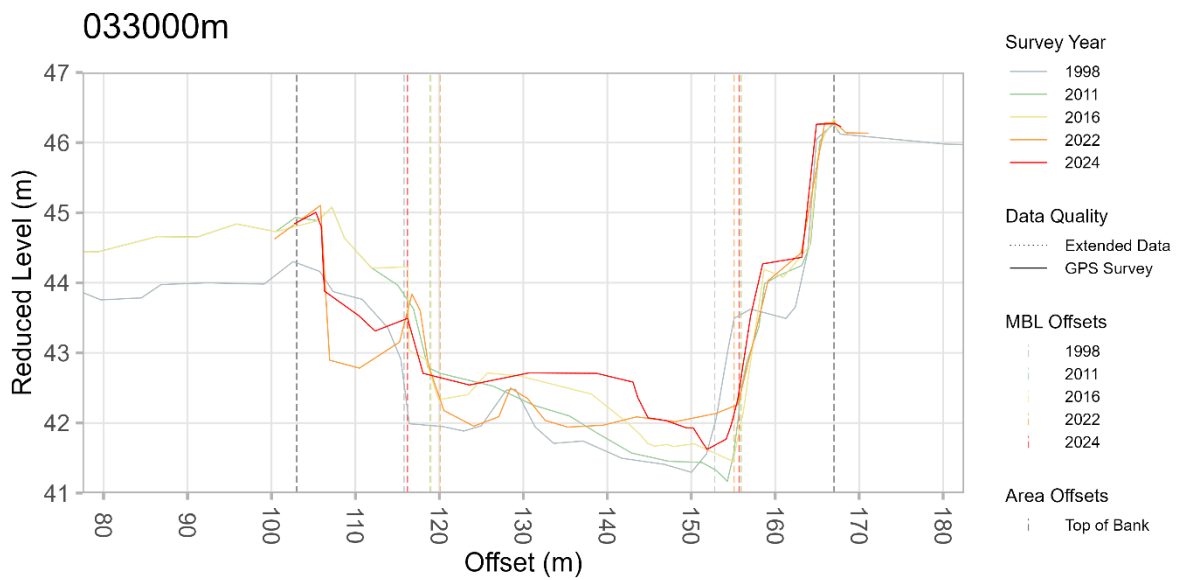
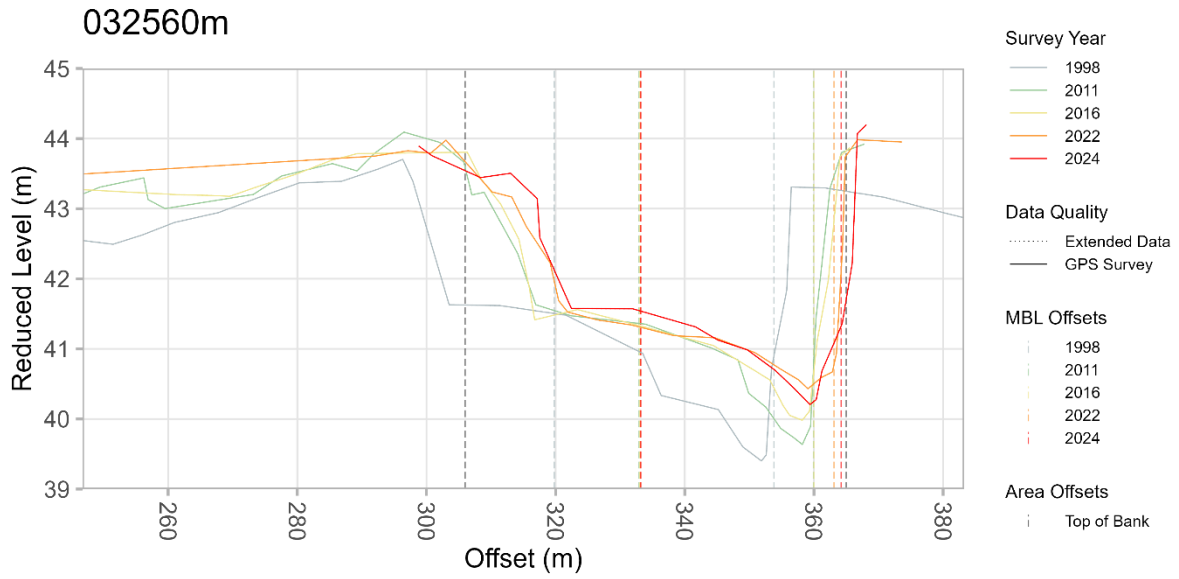


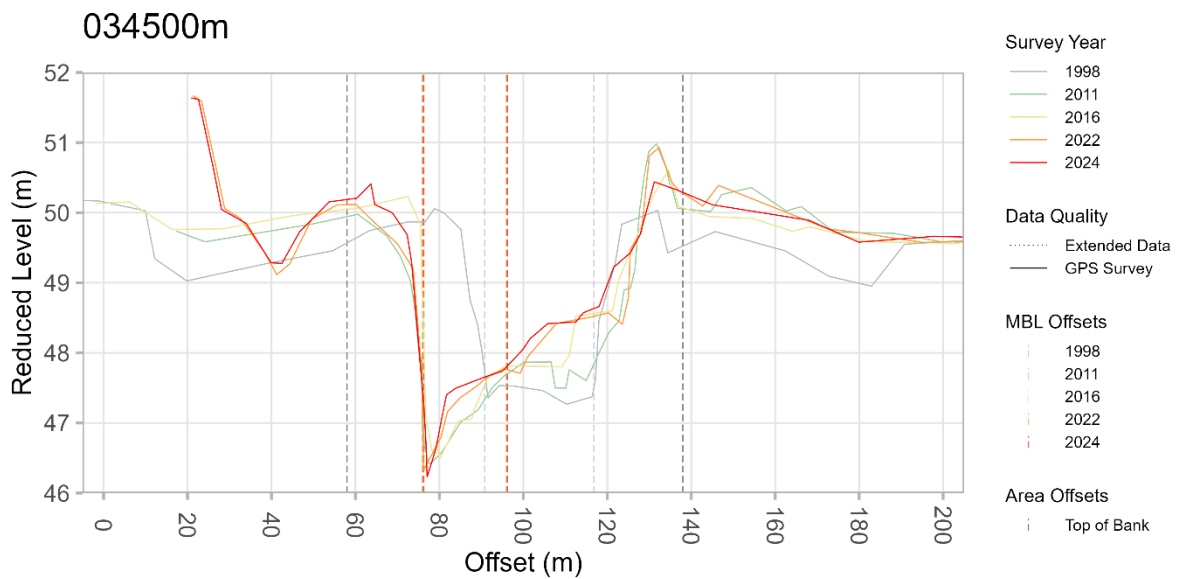
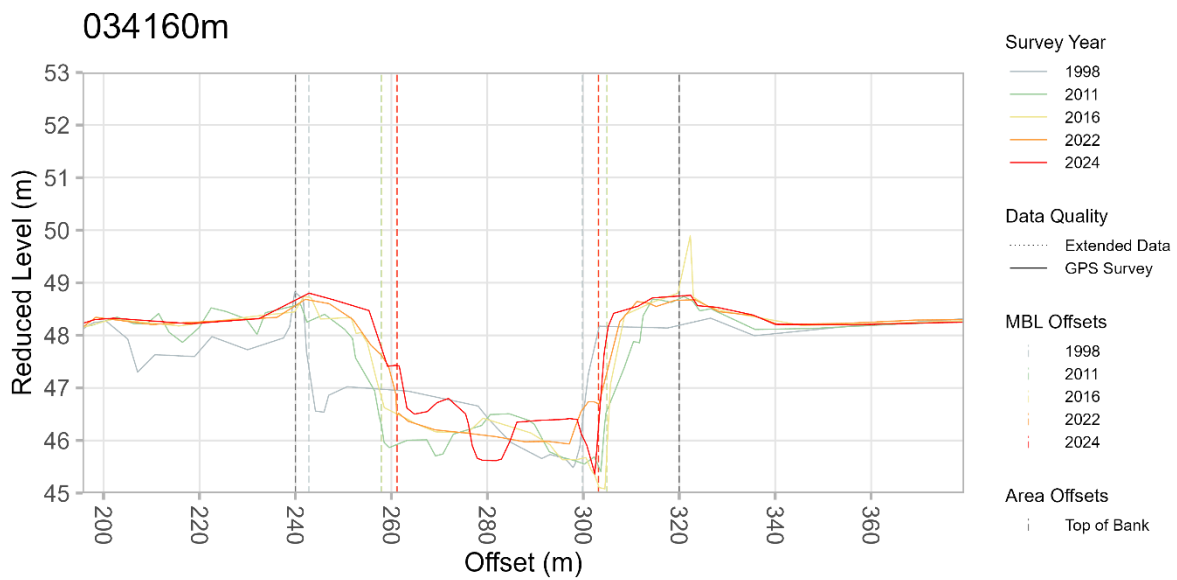
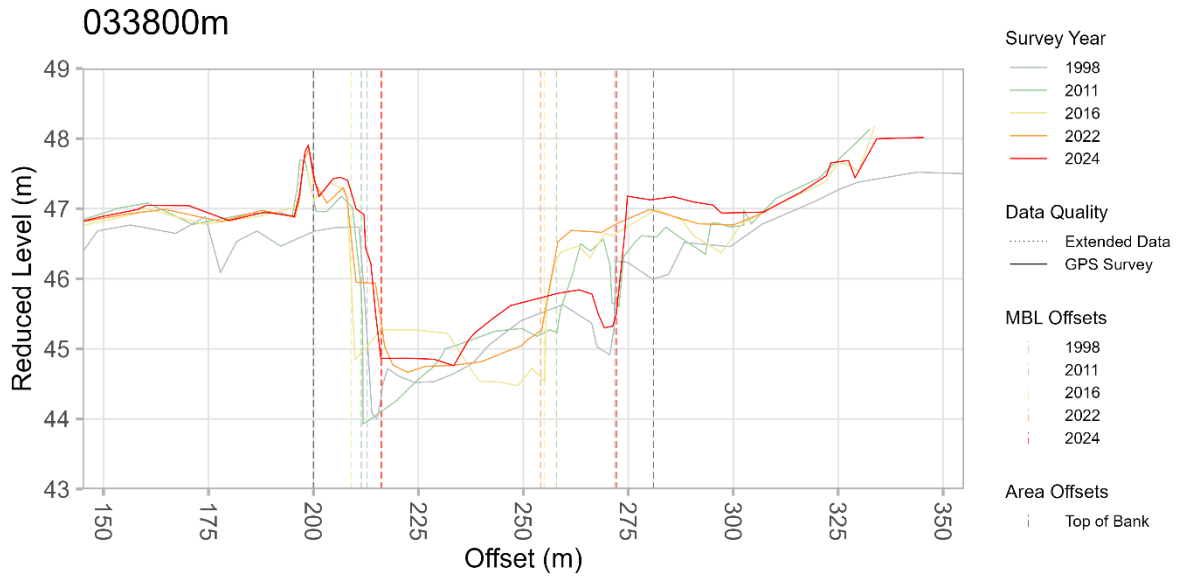
030450m - 4



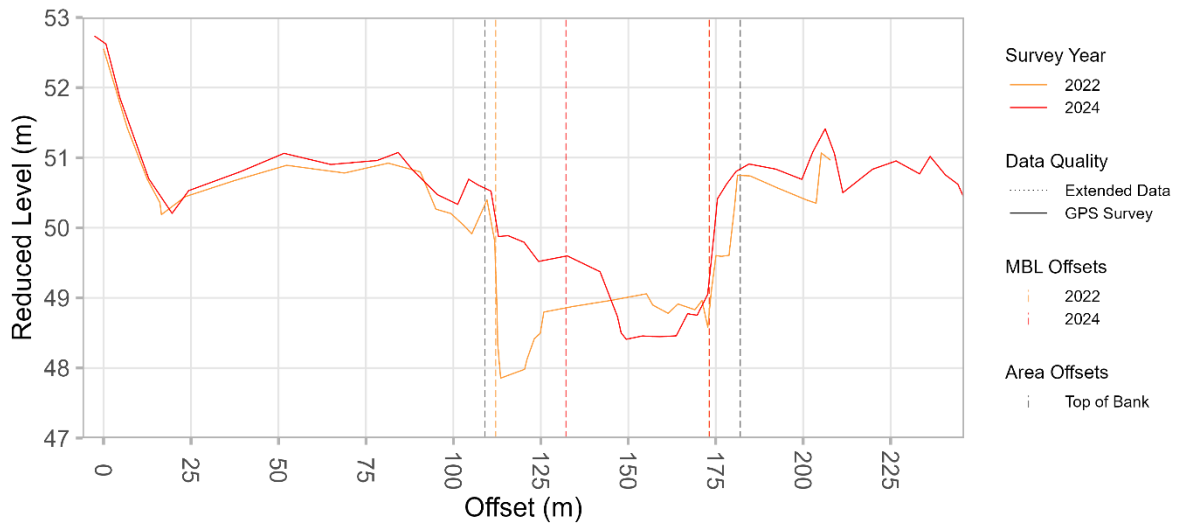




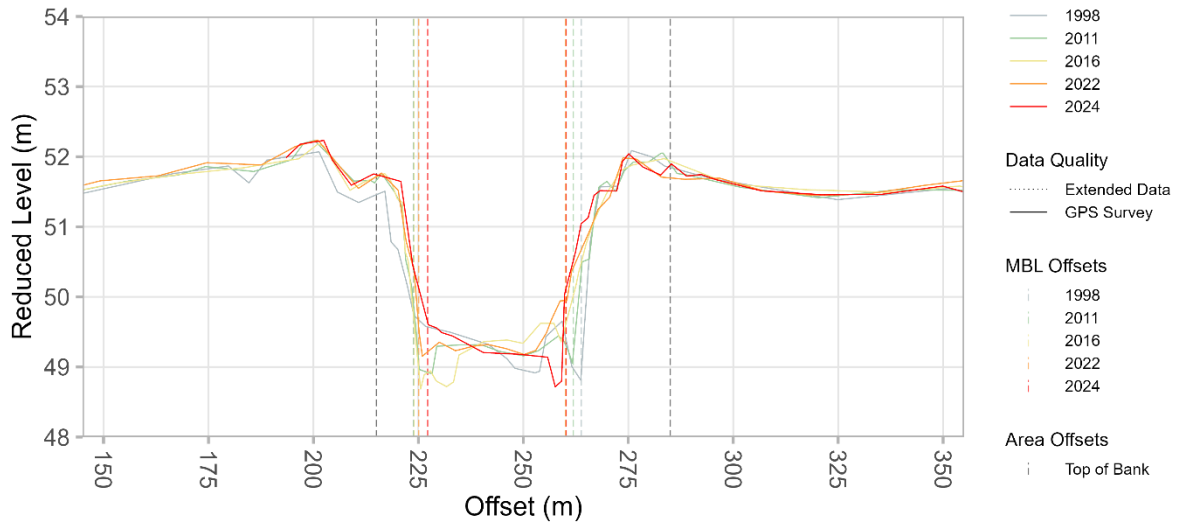




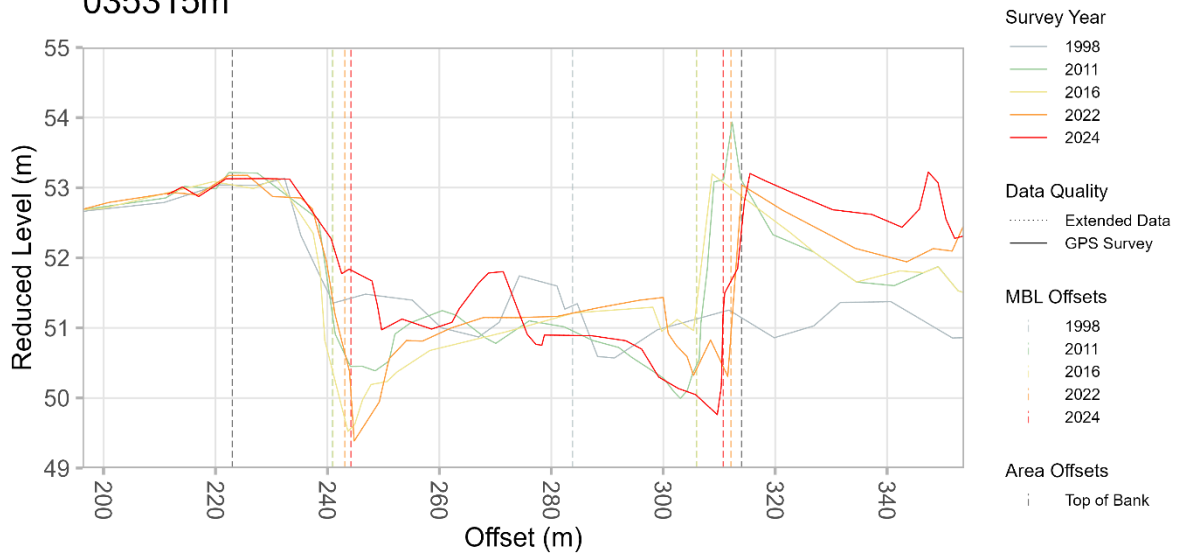
034750m - 7

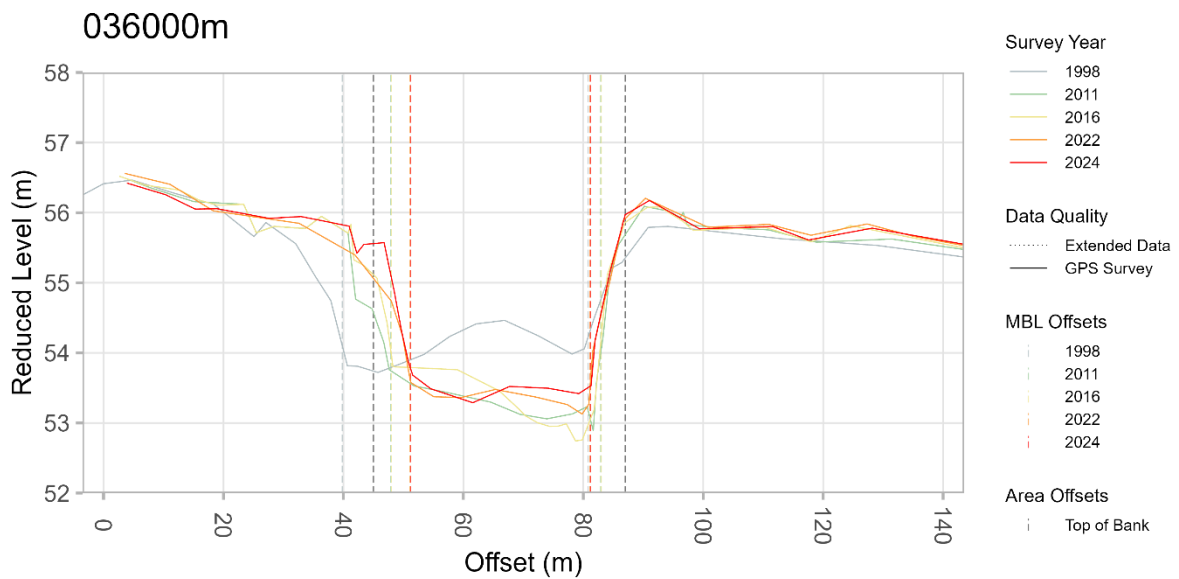
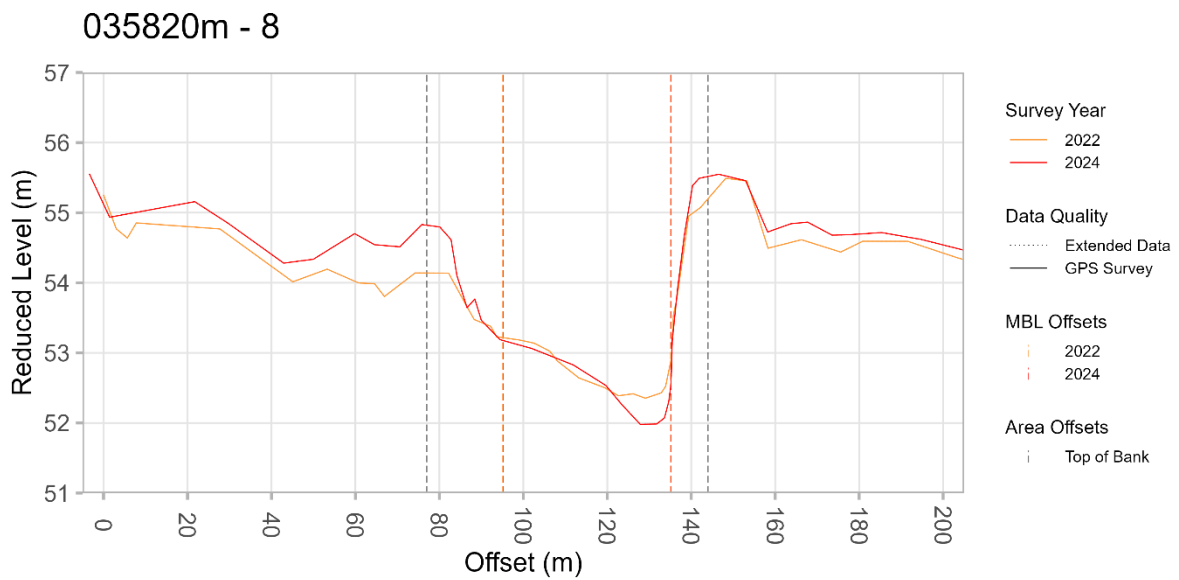
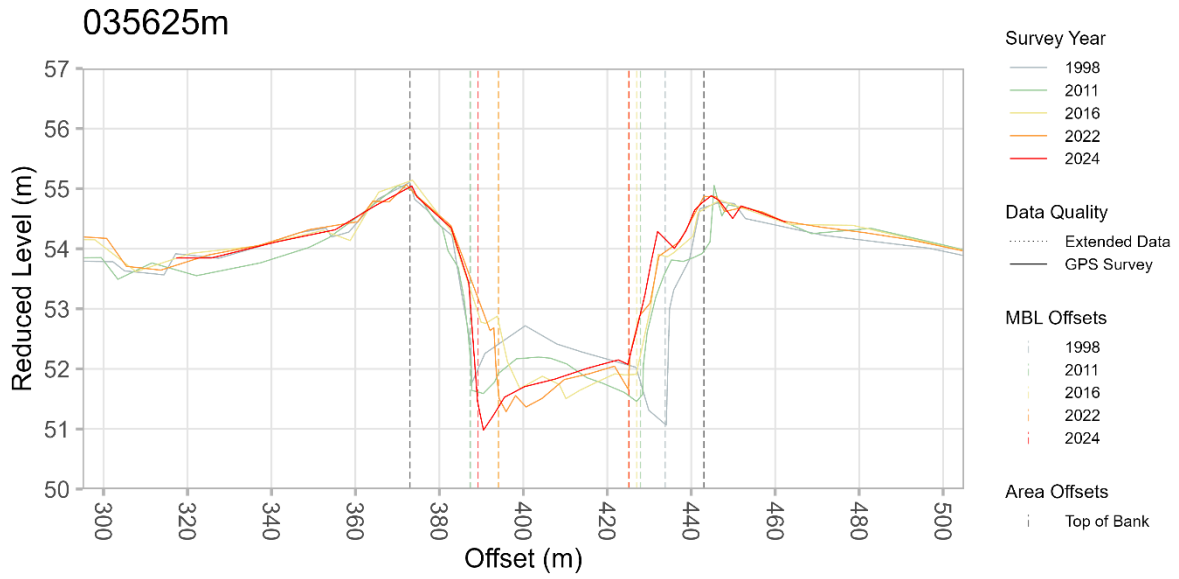


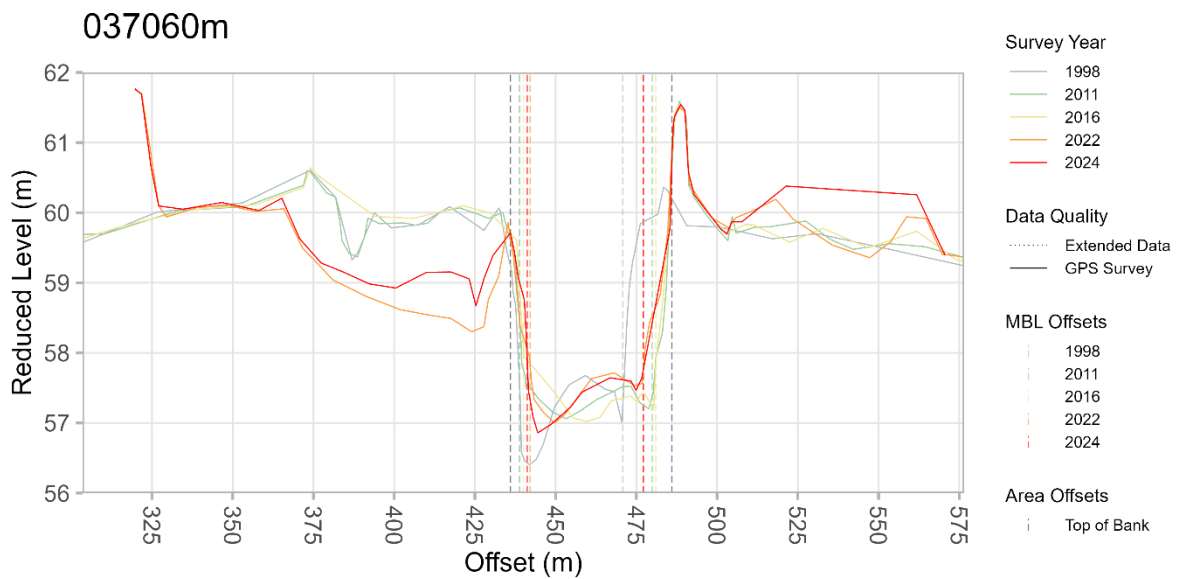
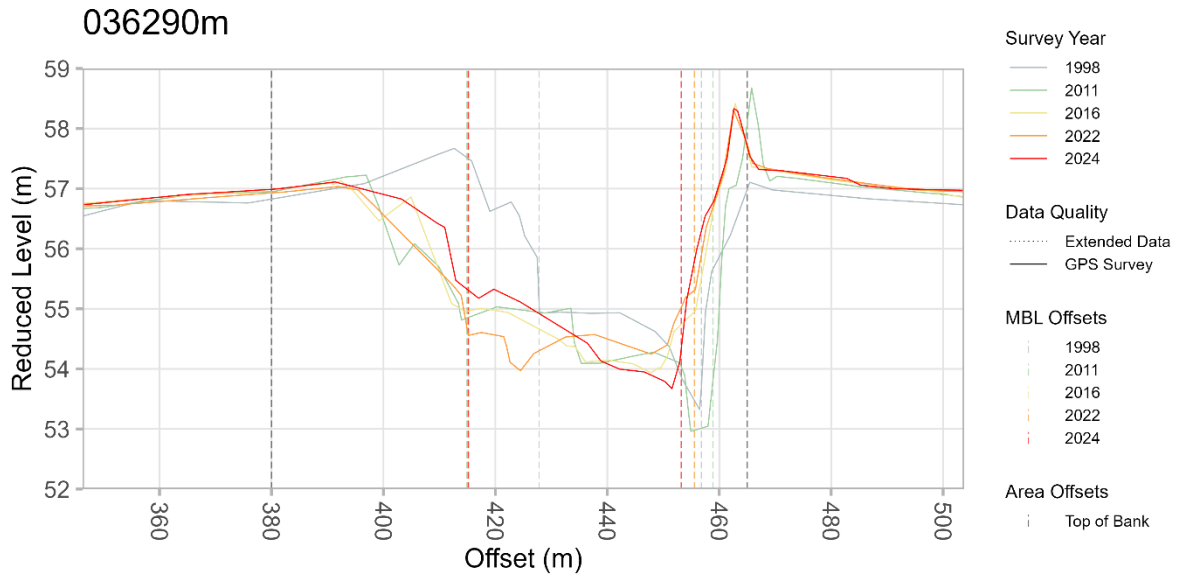
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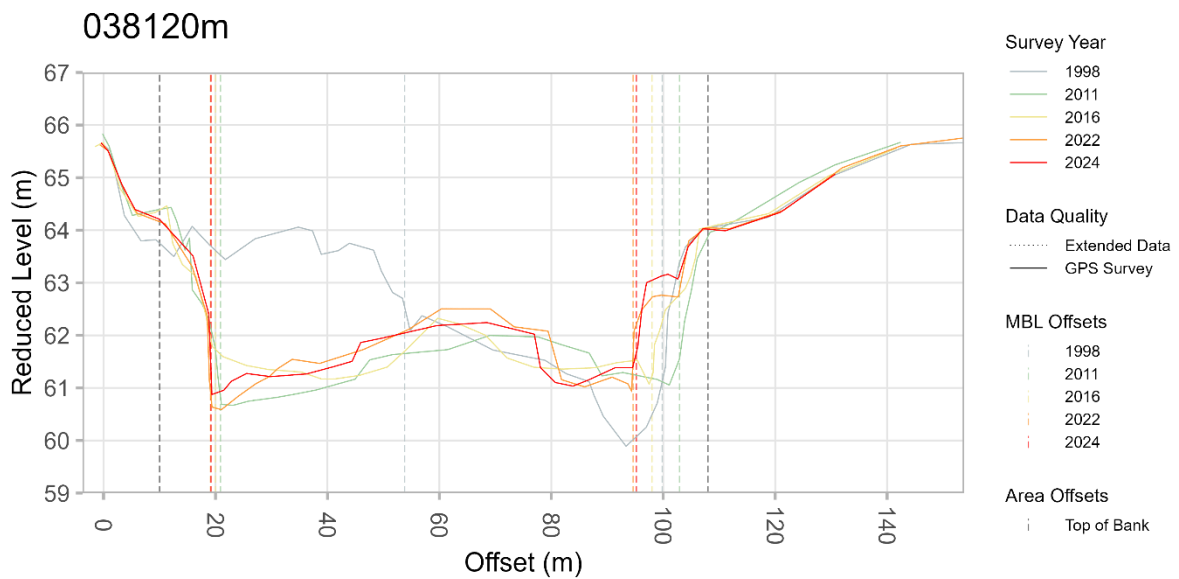
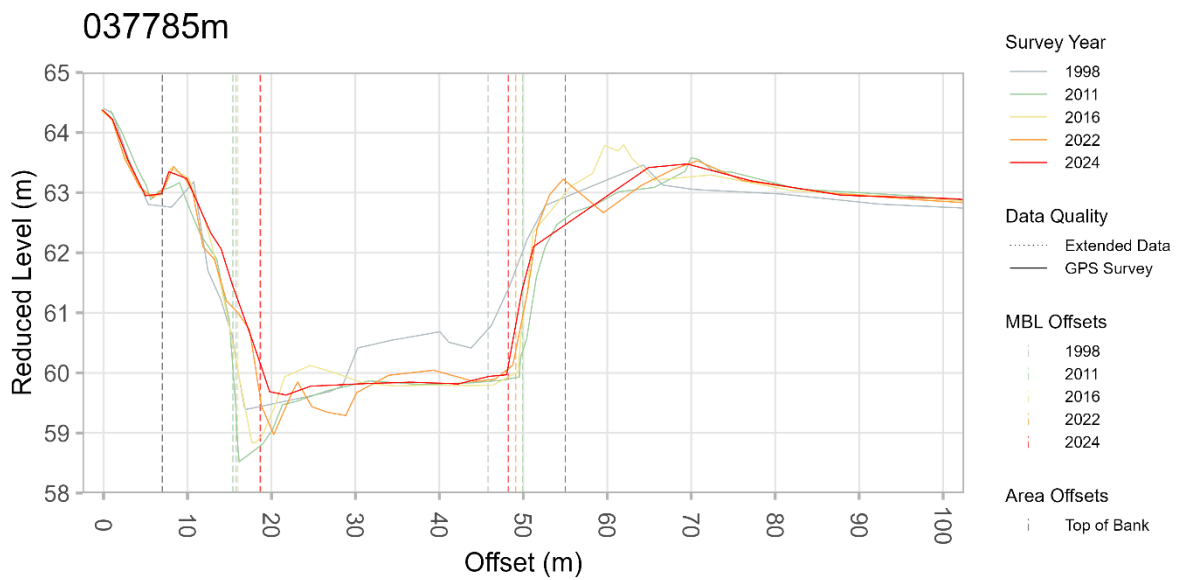
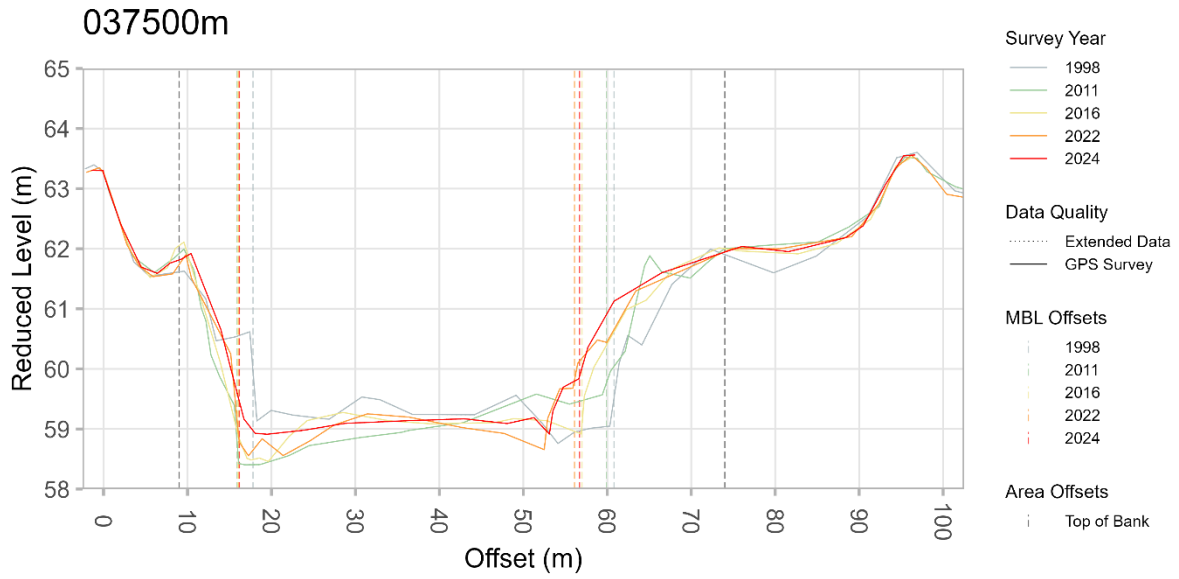


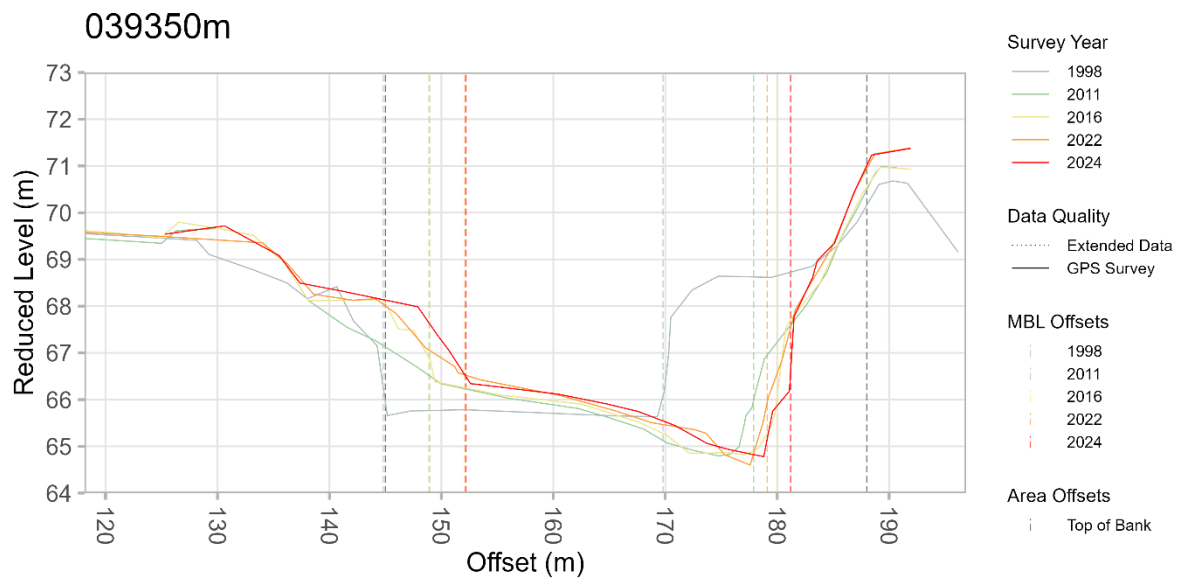
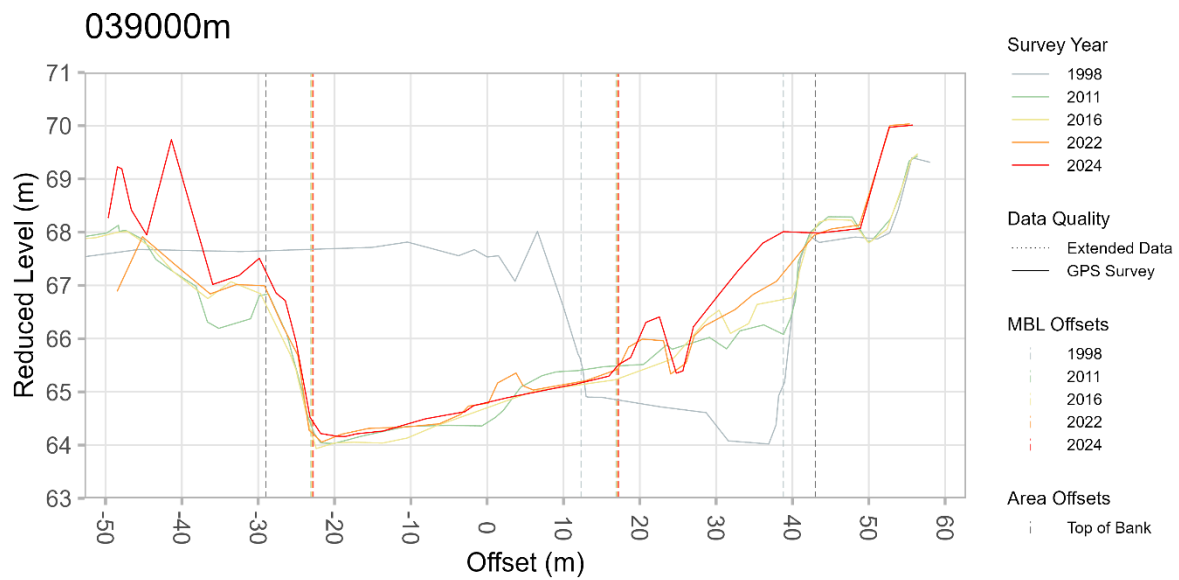
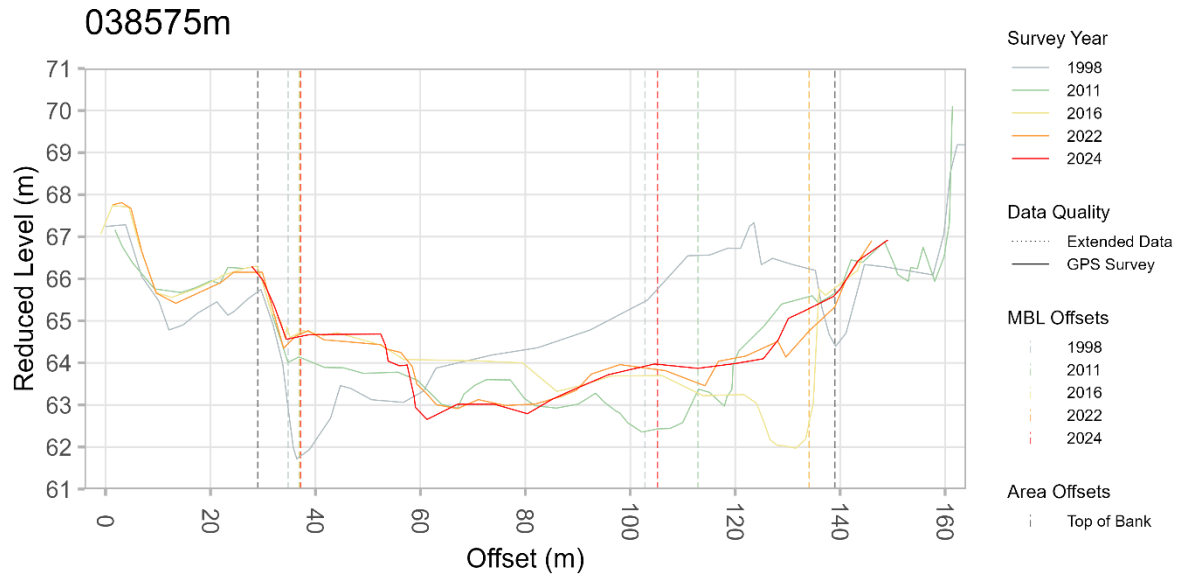
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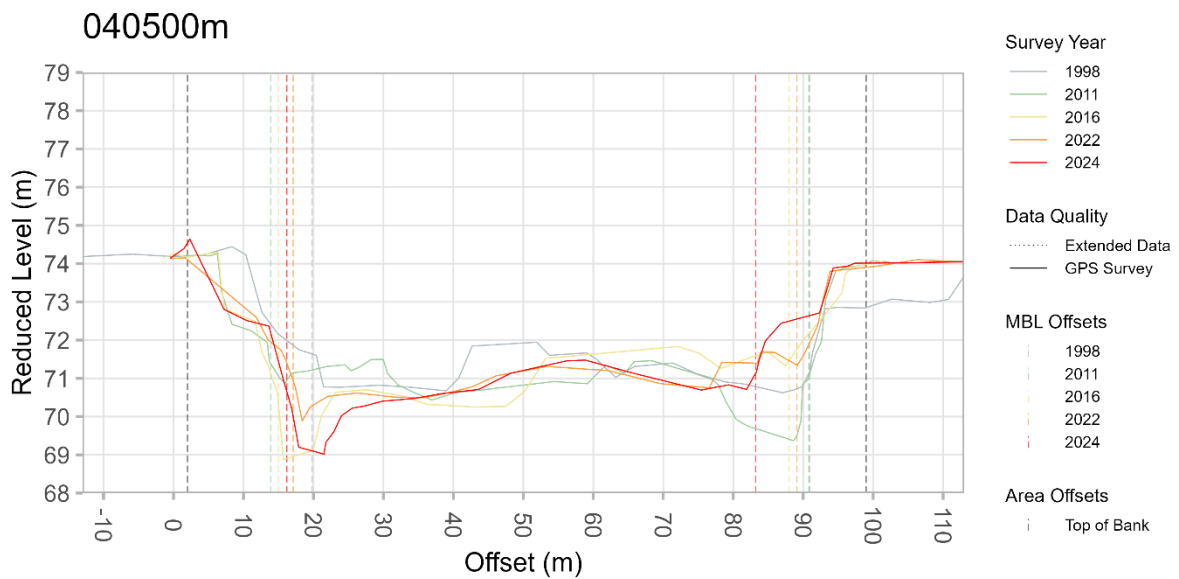
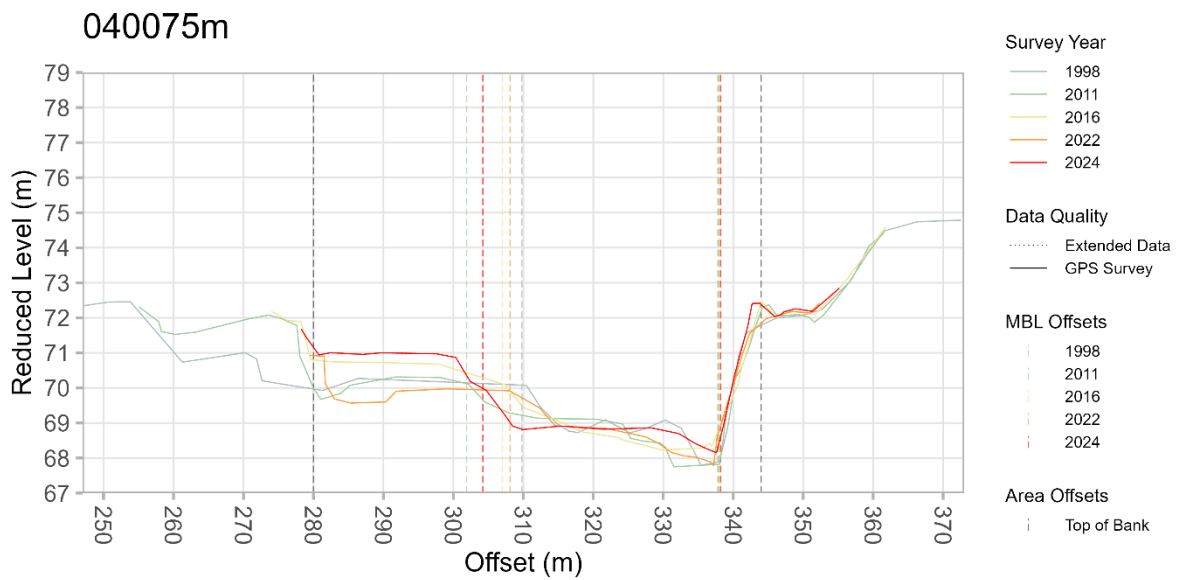
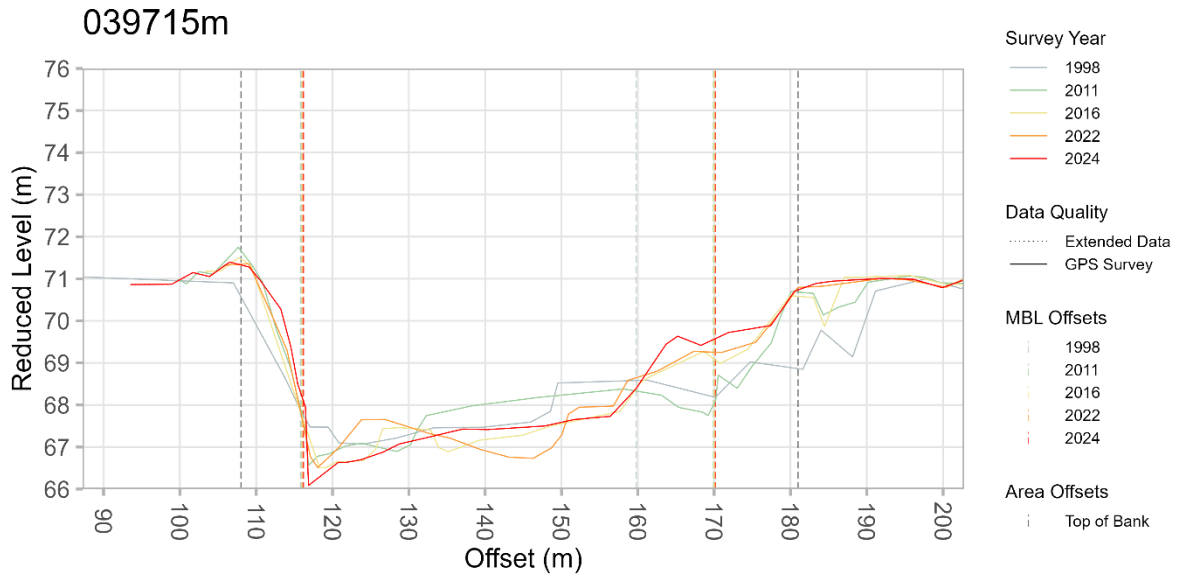




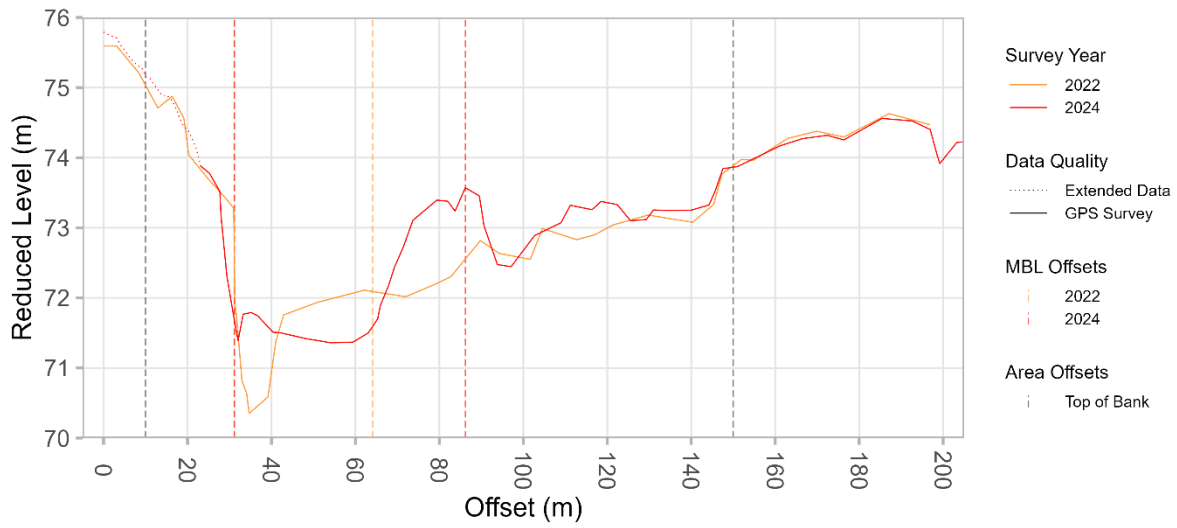




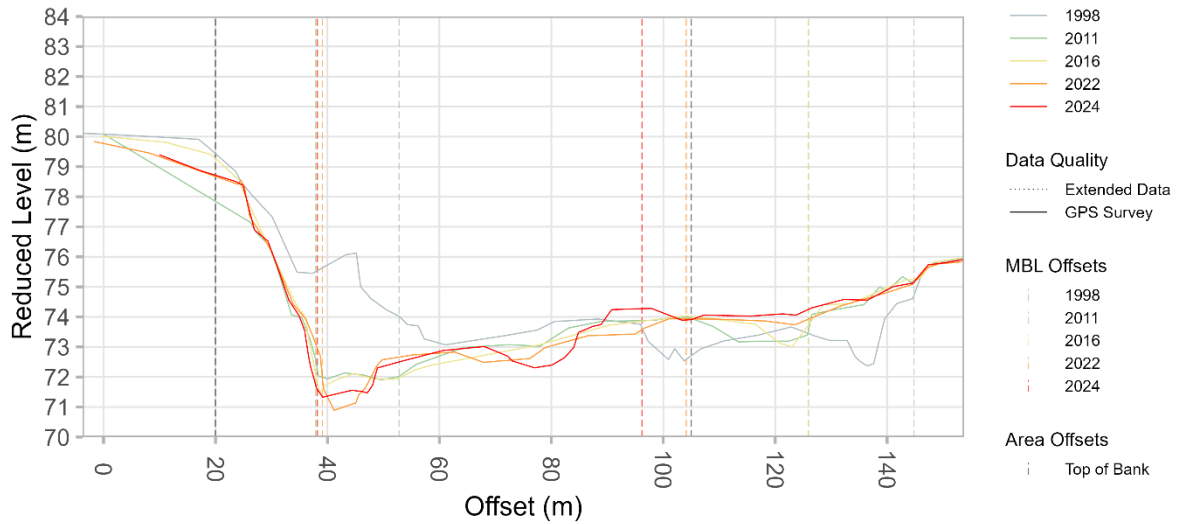




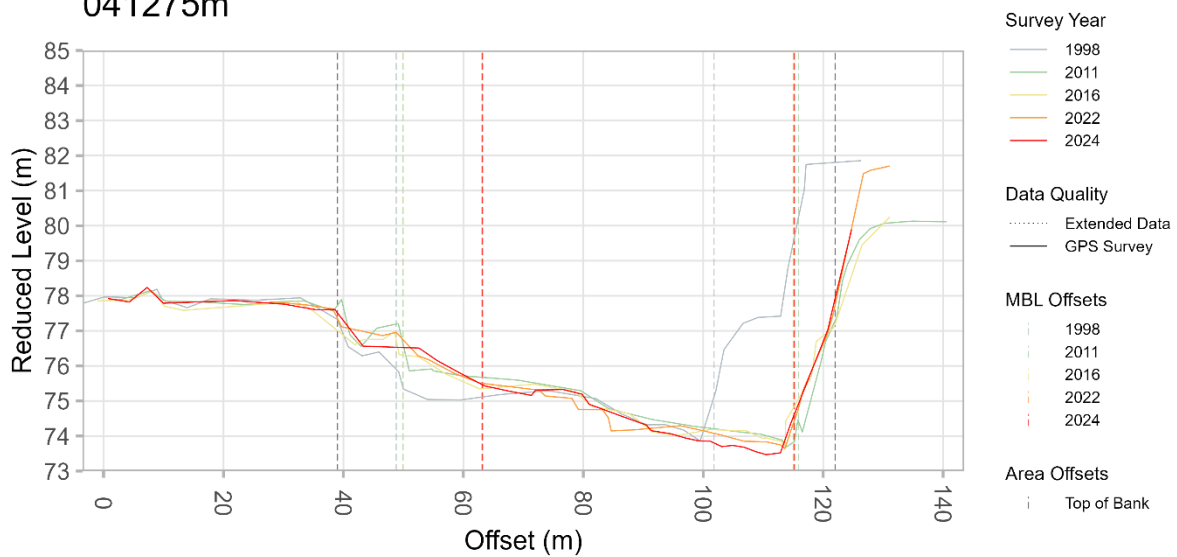
040700m - 9

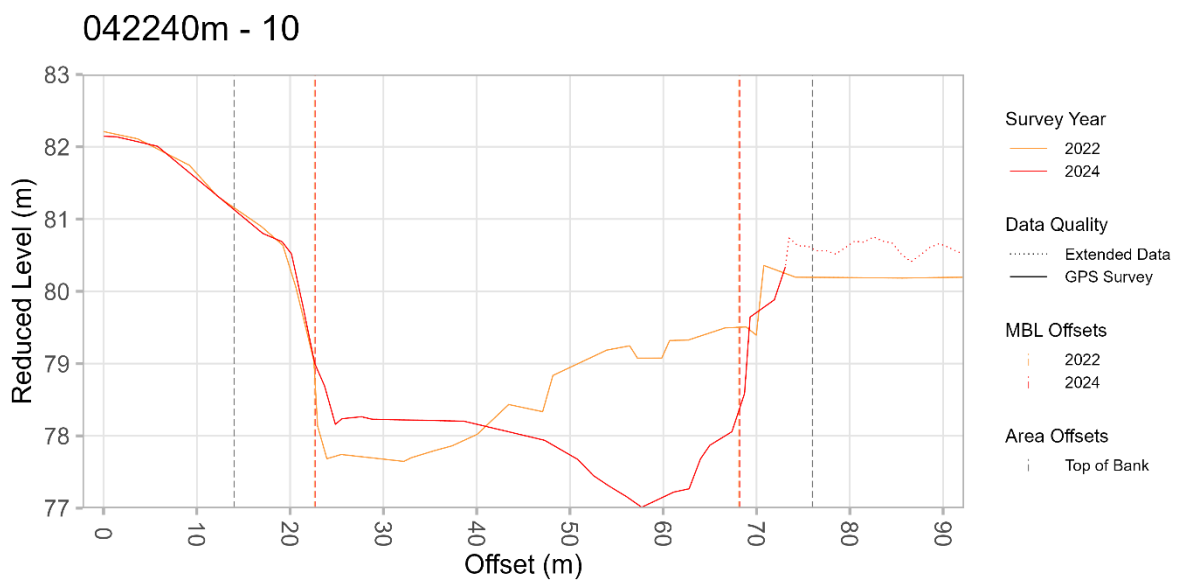
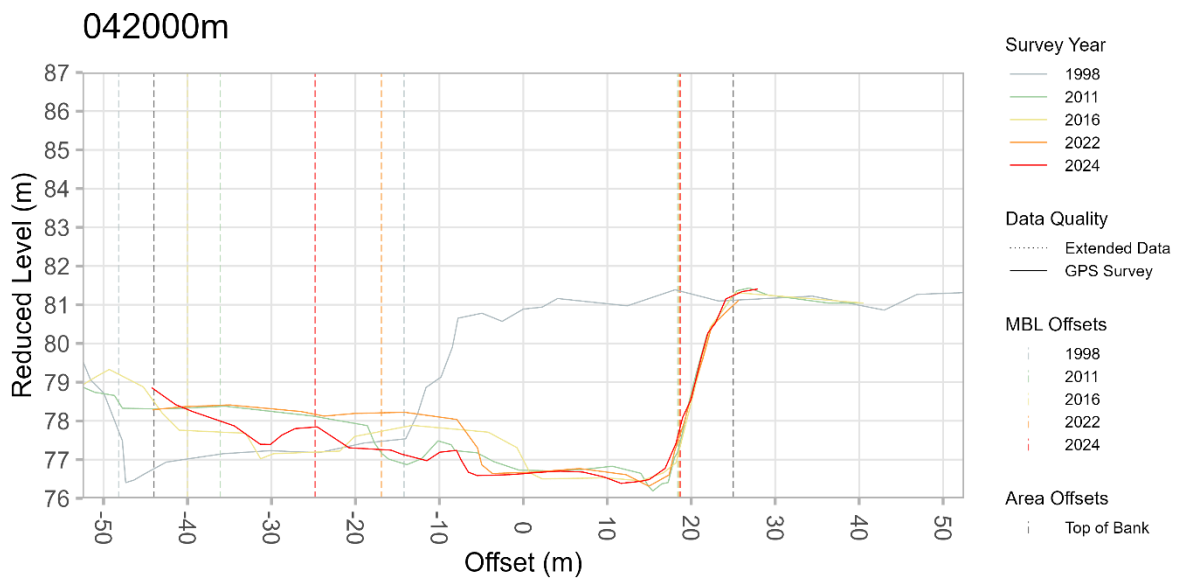
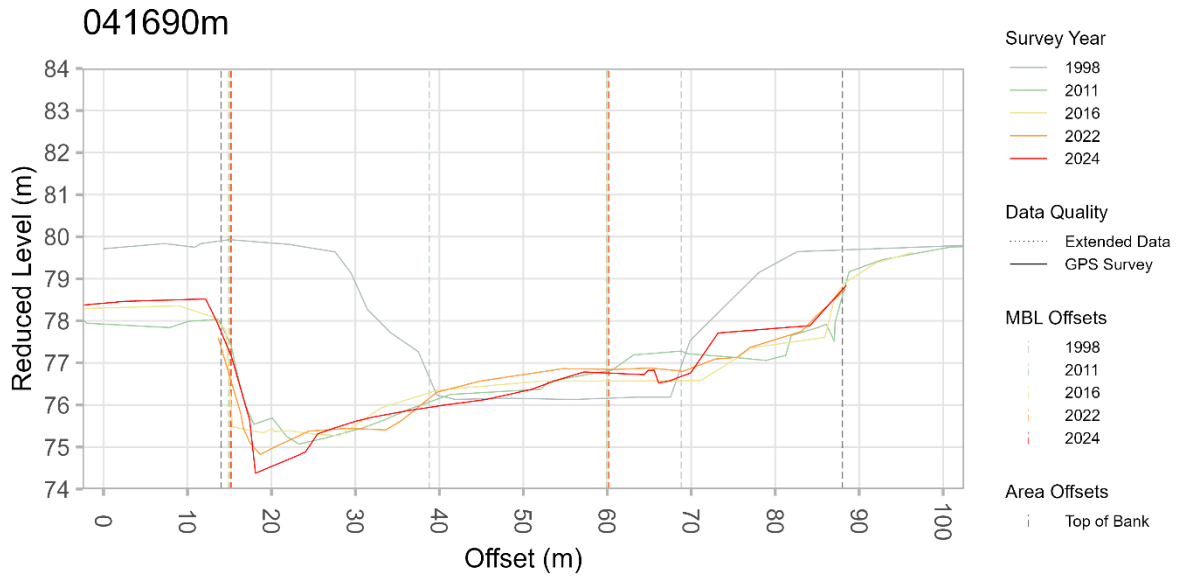


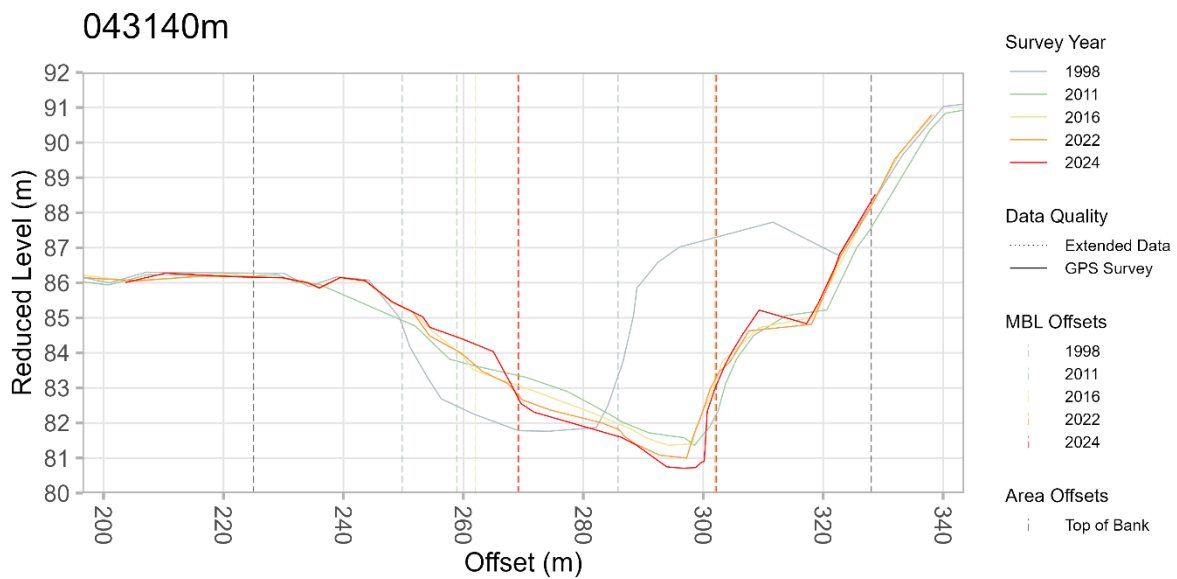
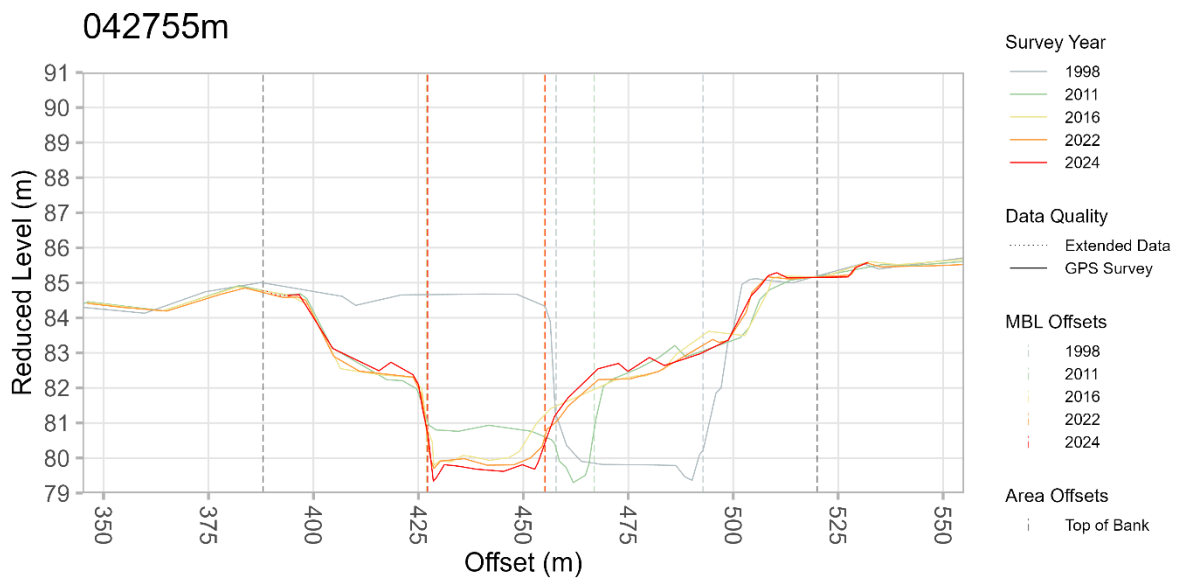
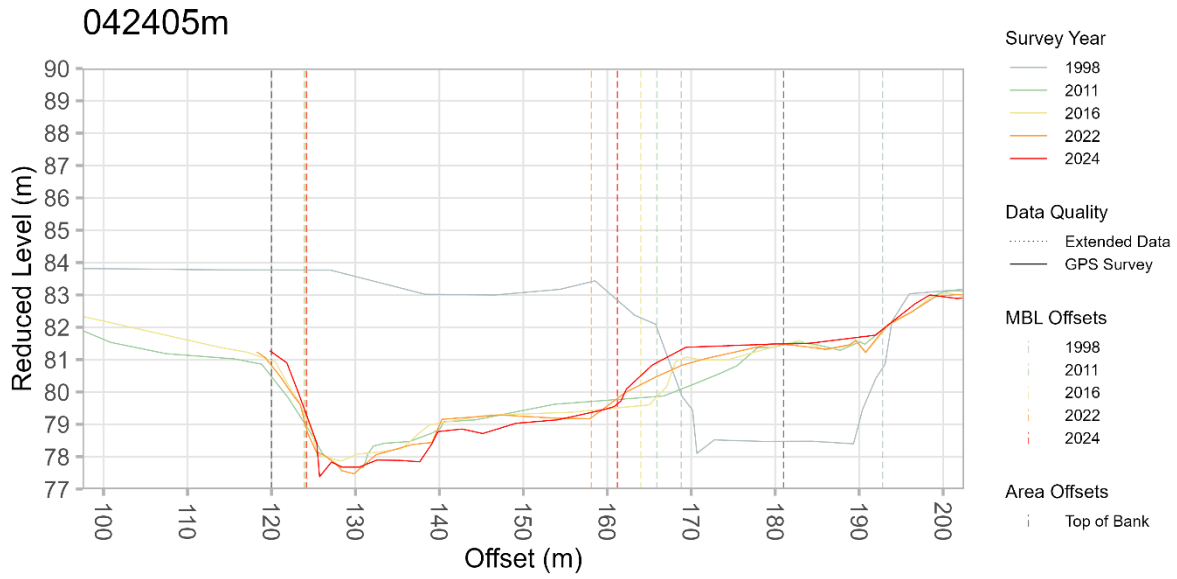
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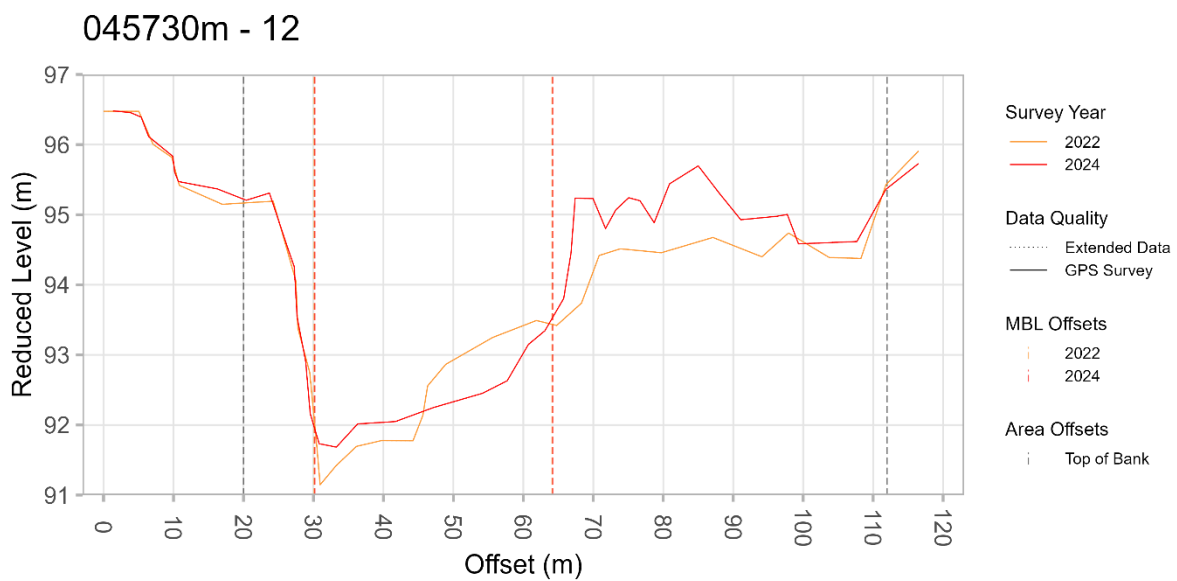
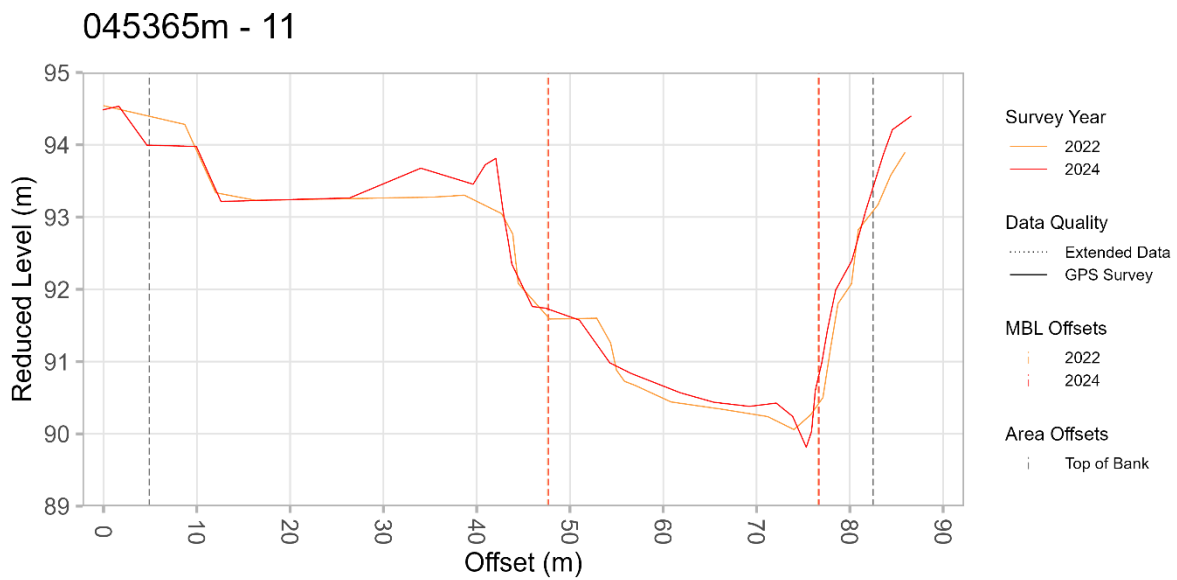
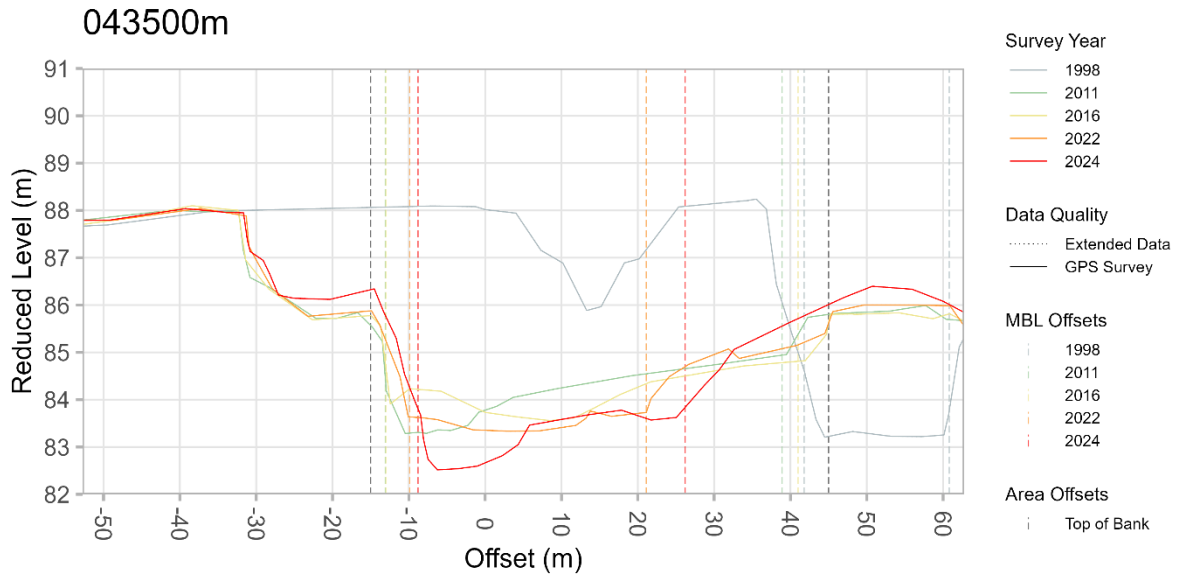


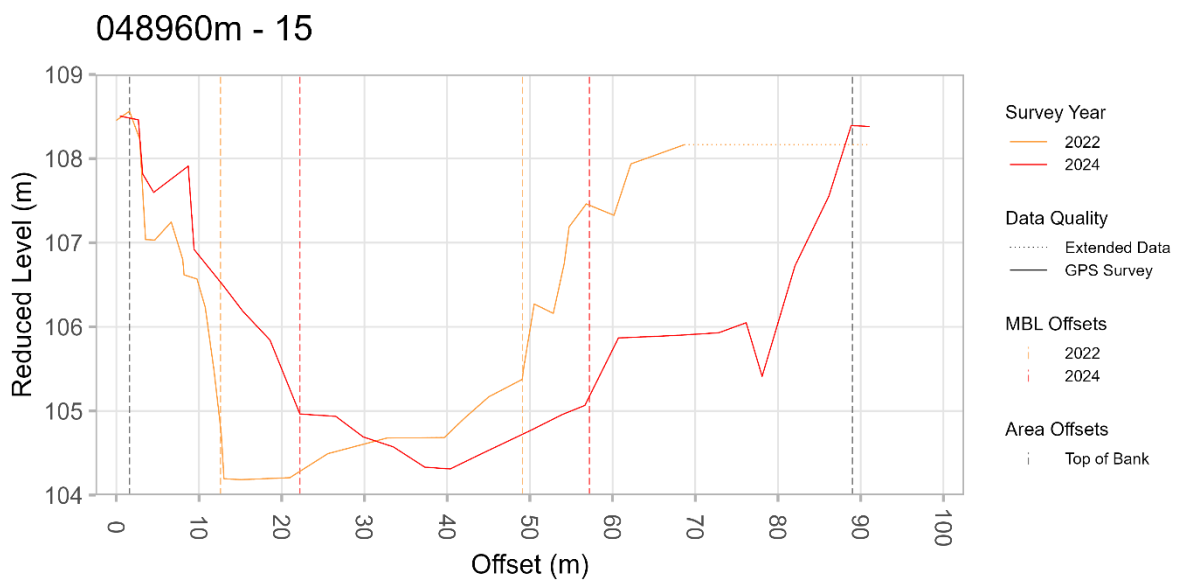
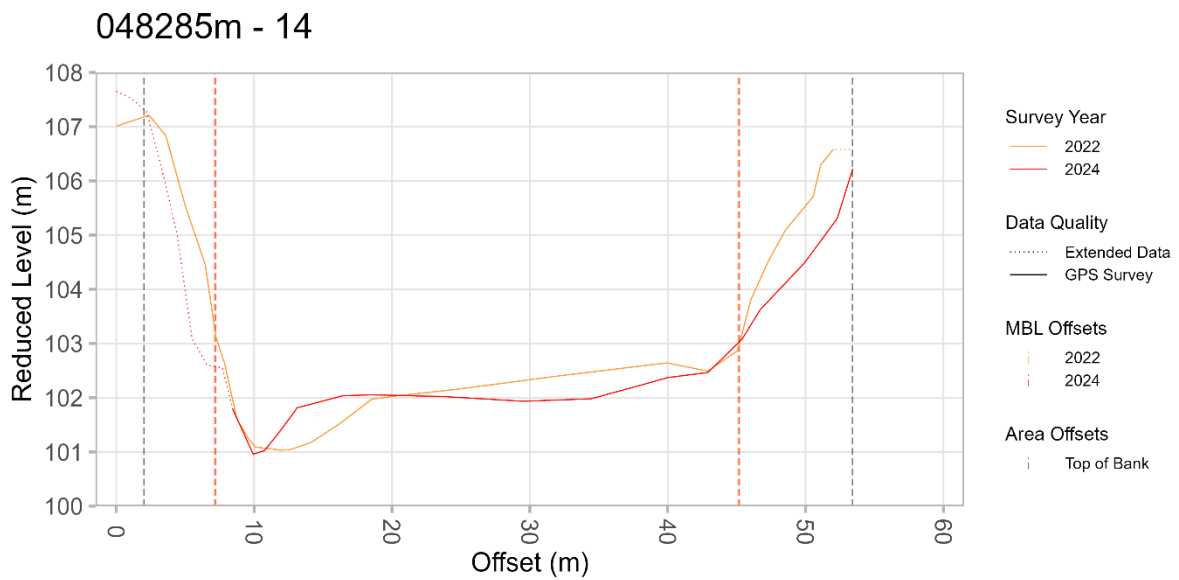
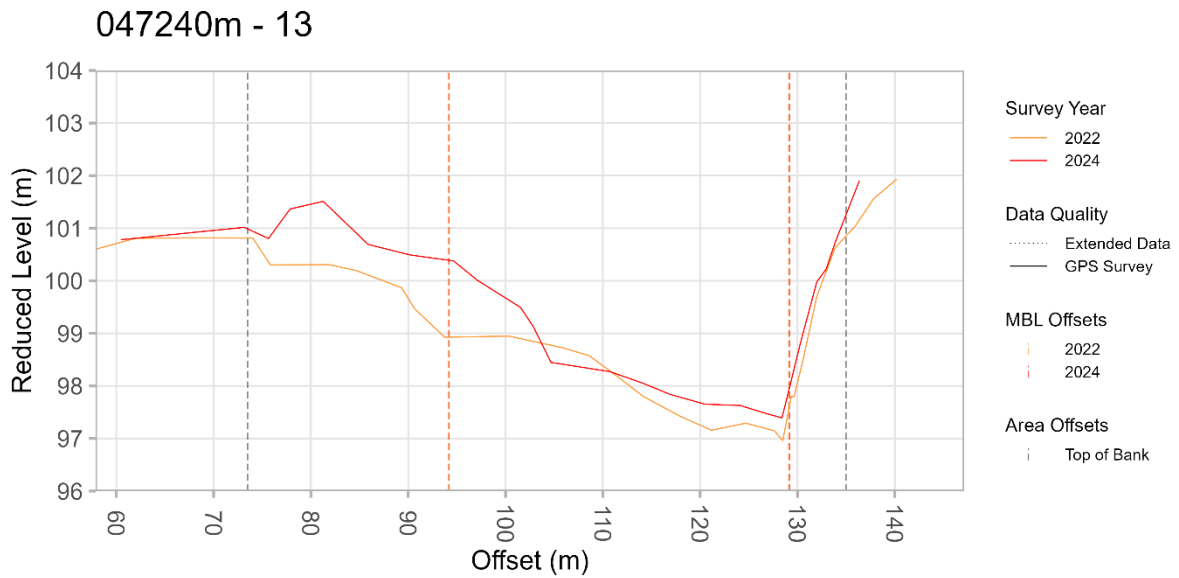
041275m



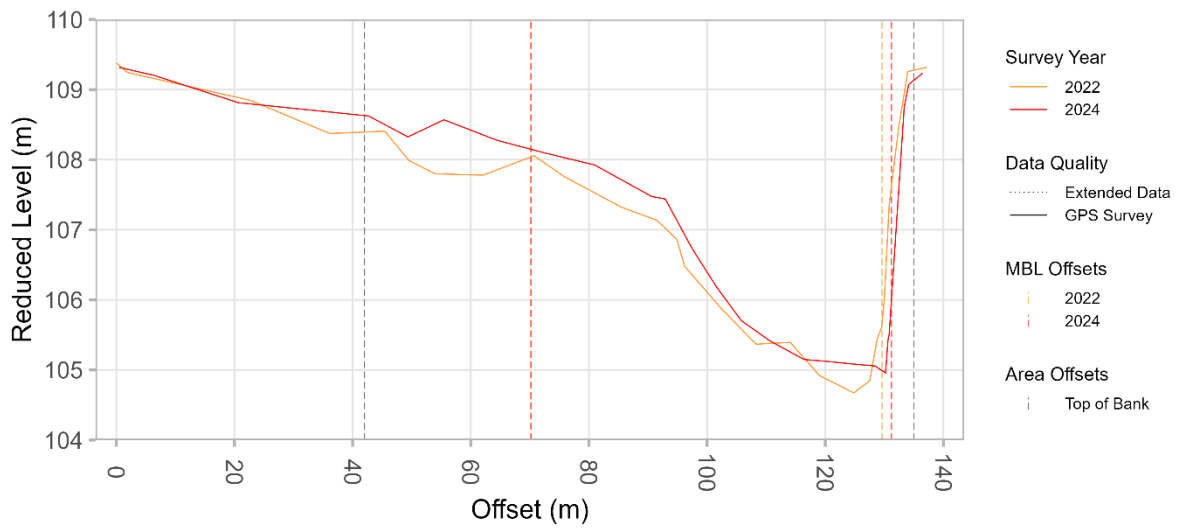




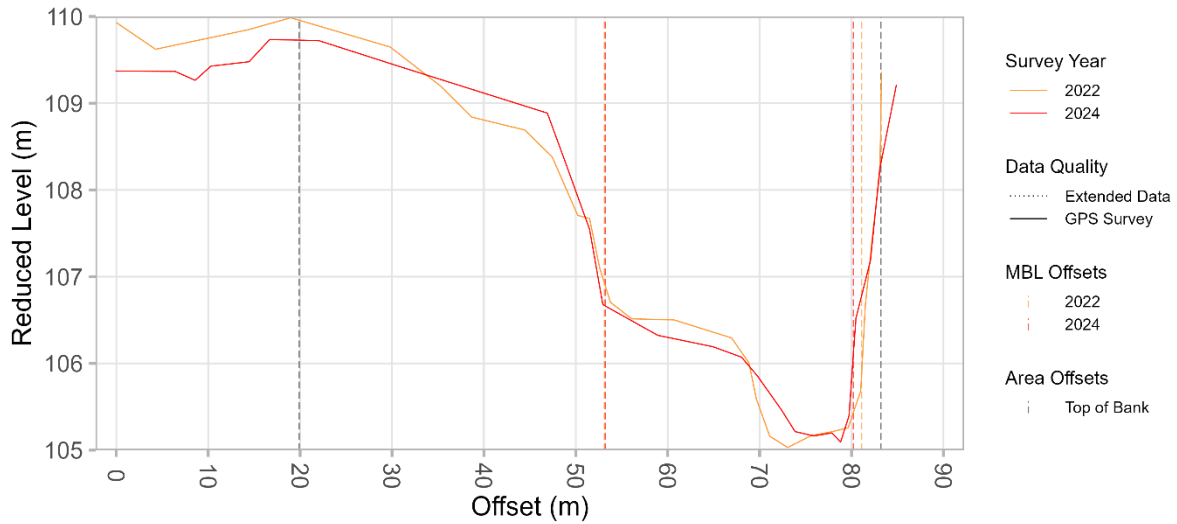




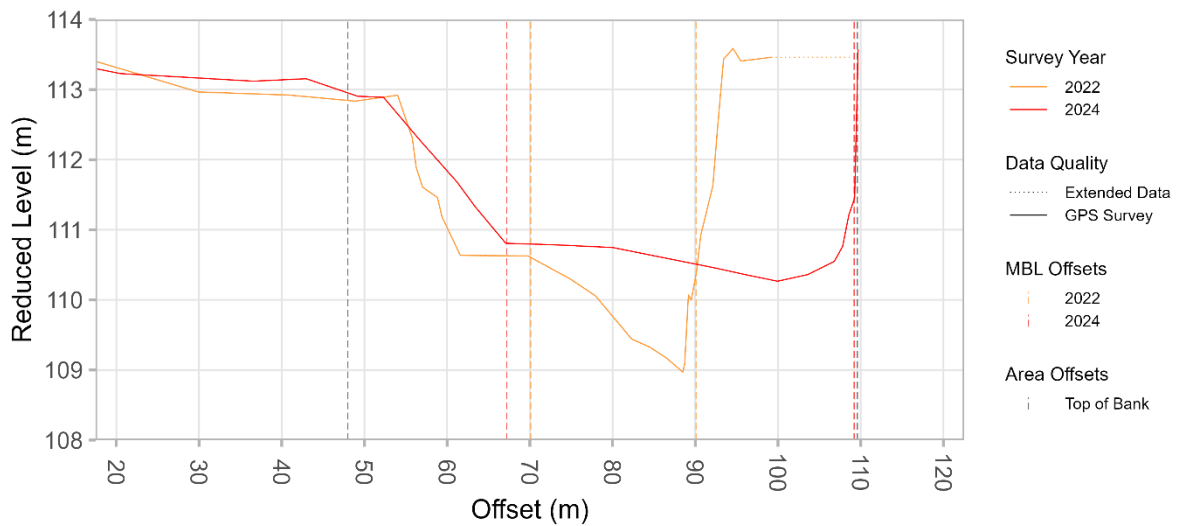
049105m - 16

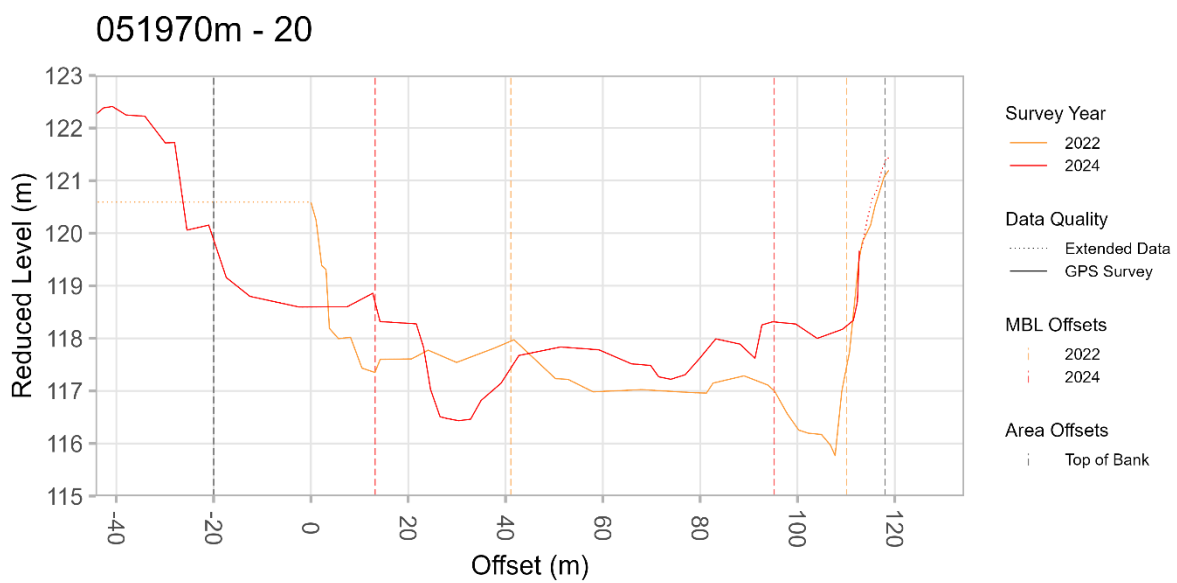
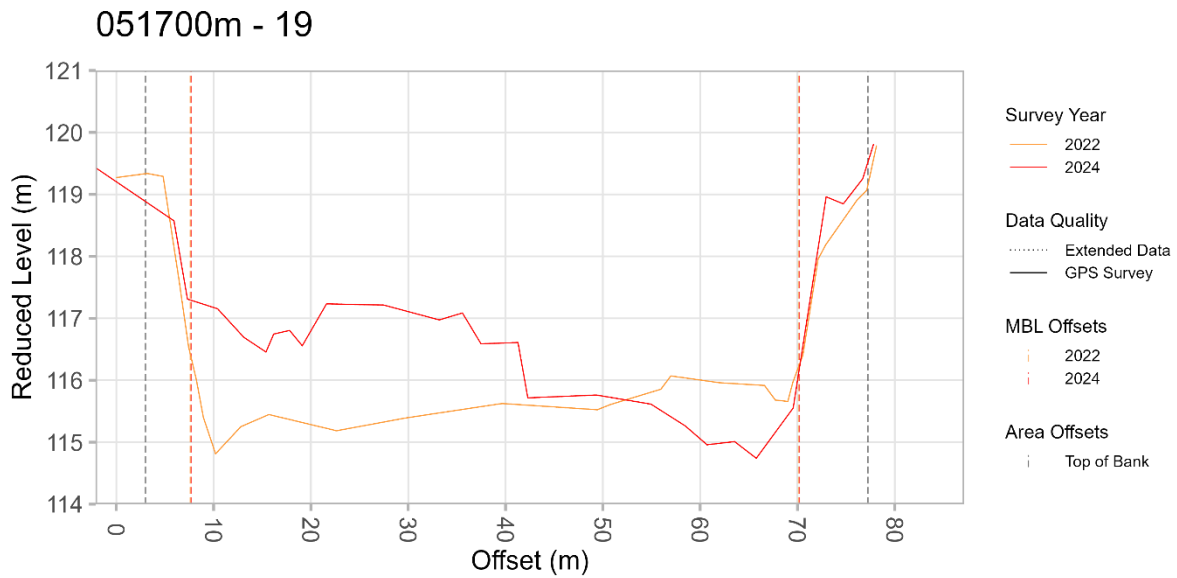


049240m - 17

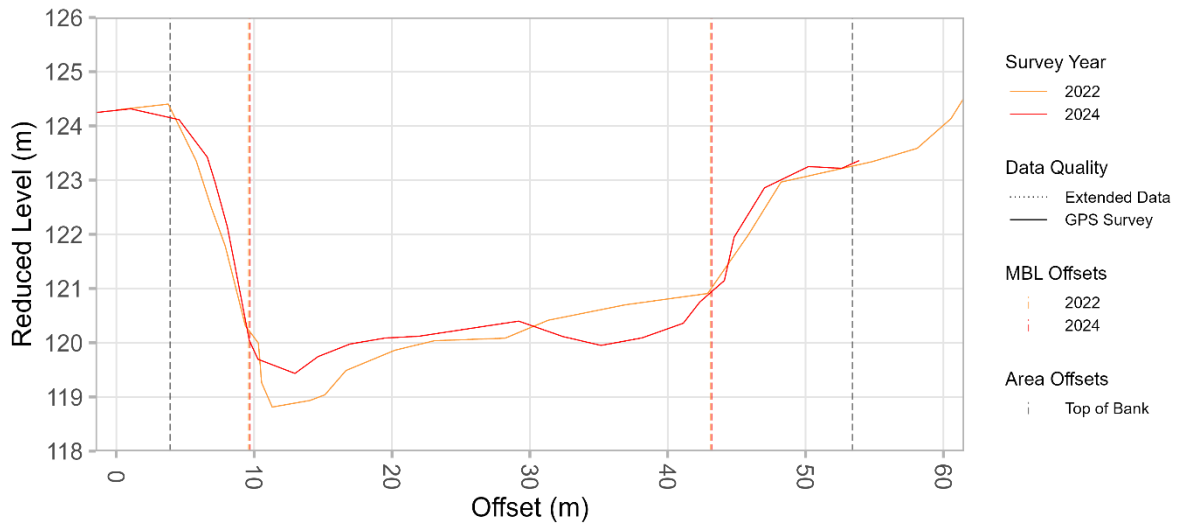


050260m - 18

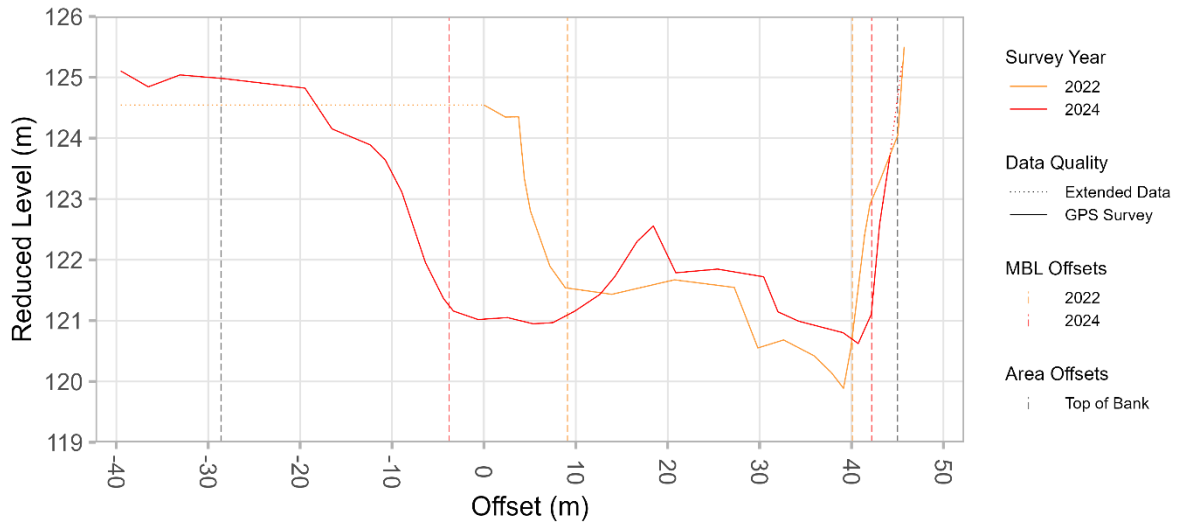




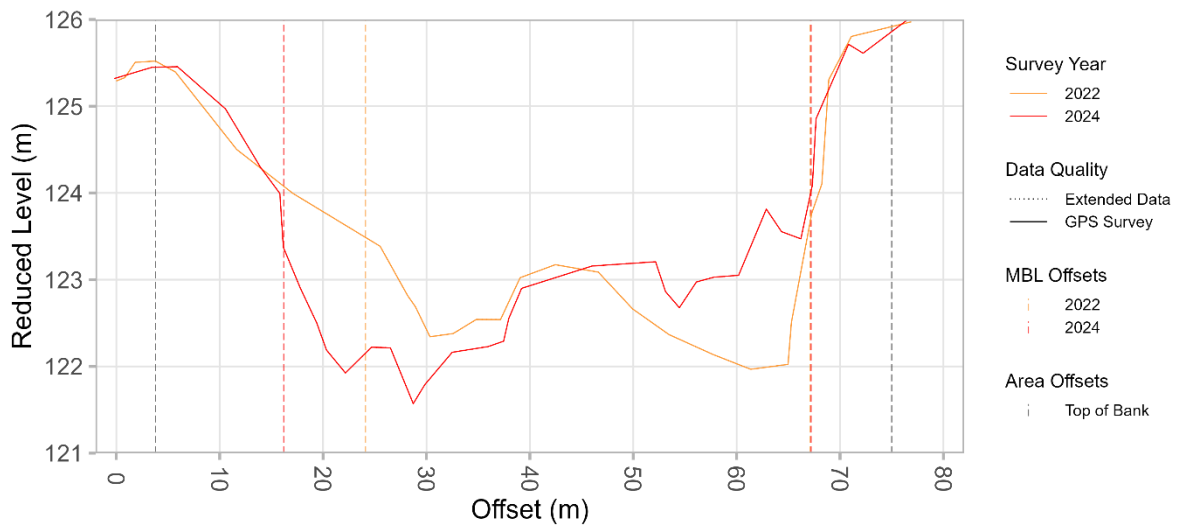
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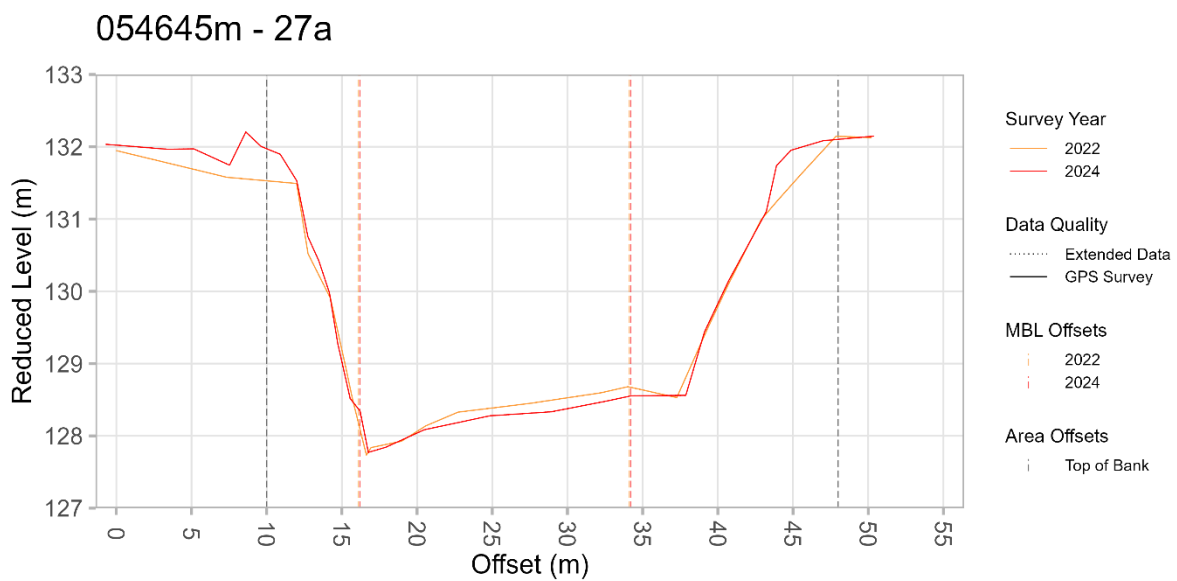
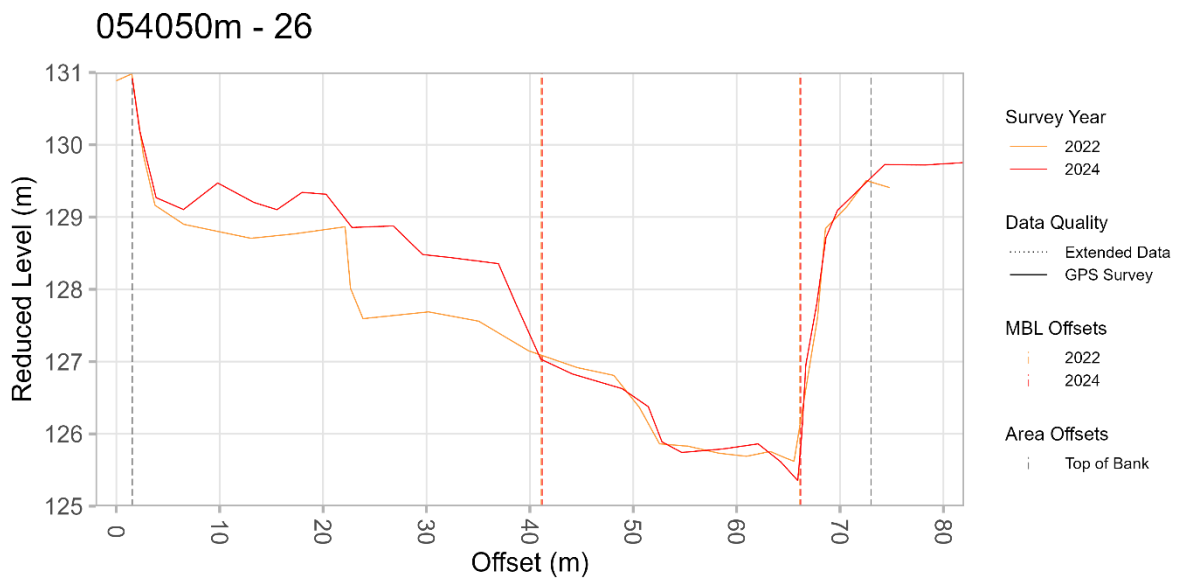
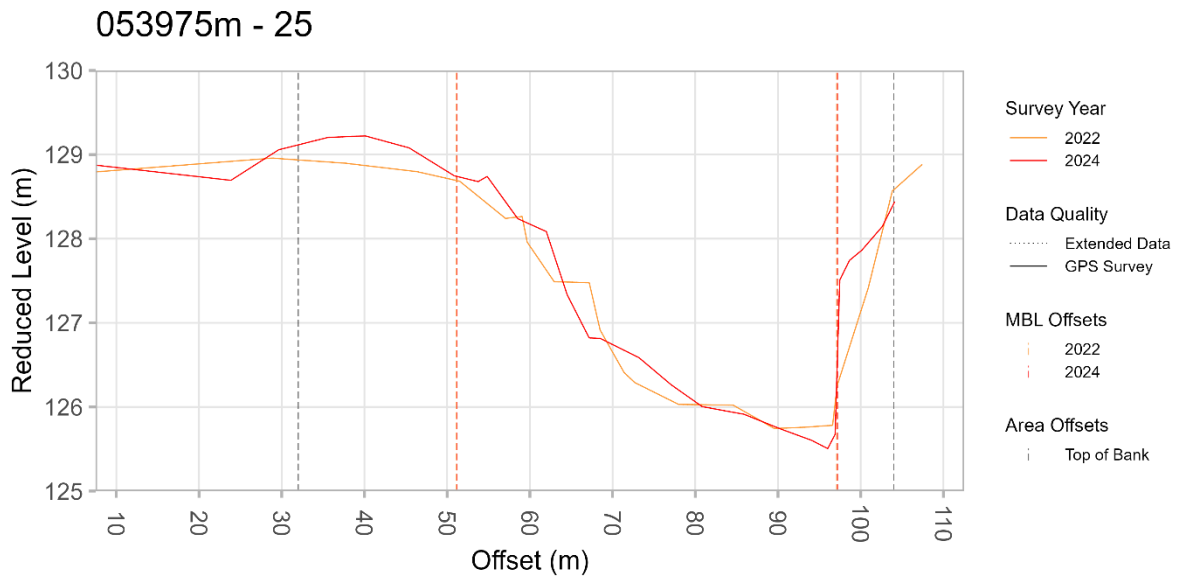


052890m - 23

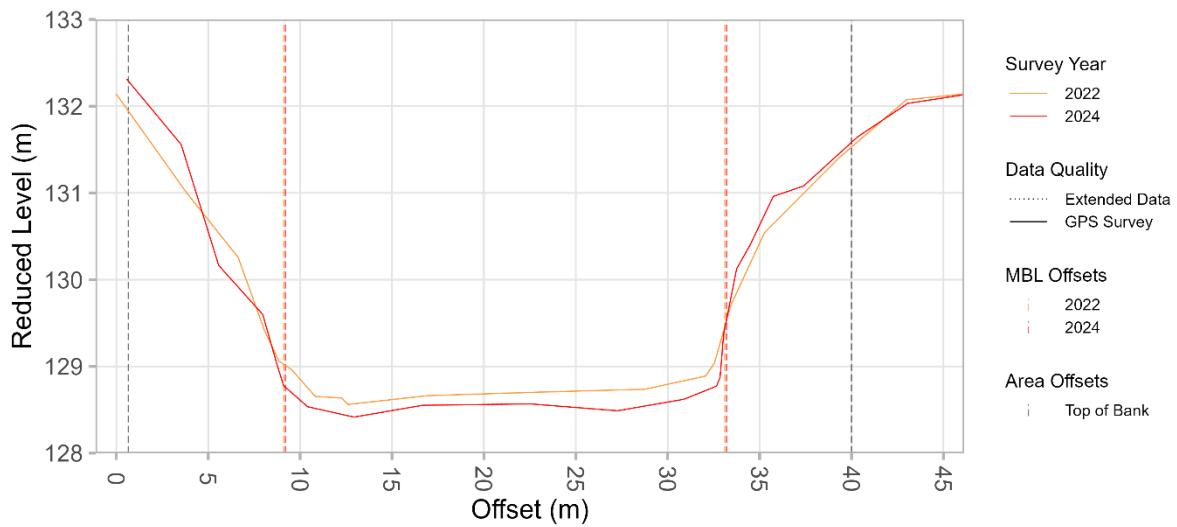


053170m - 24

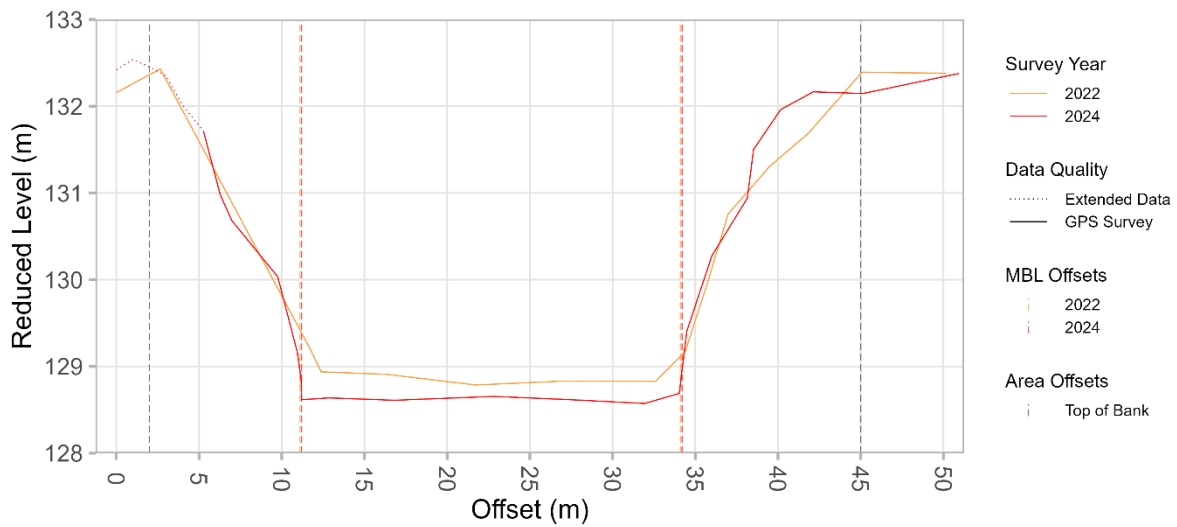




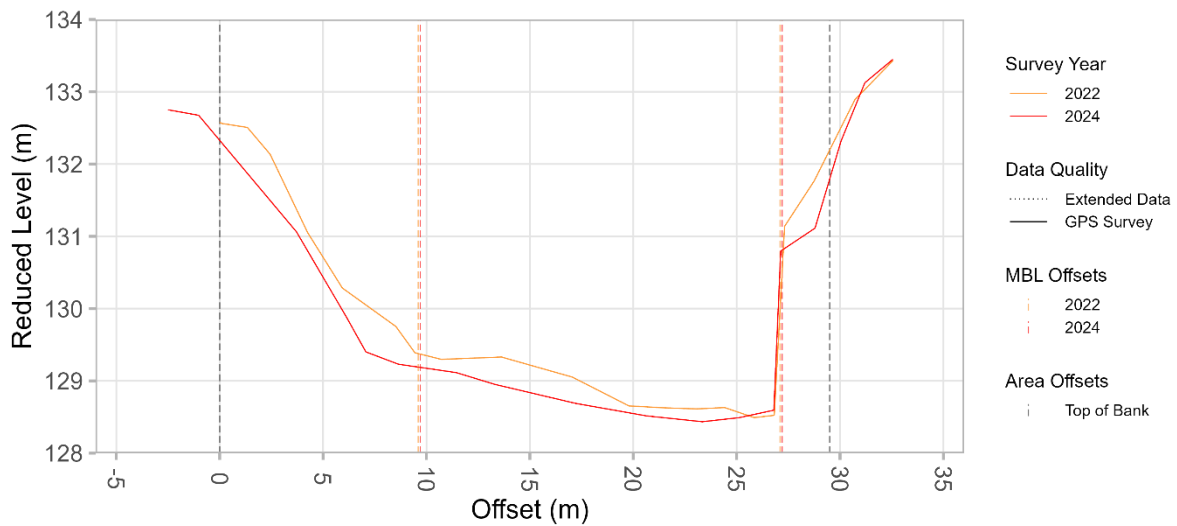
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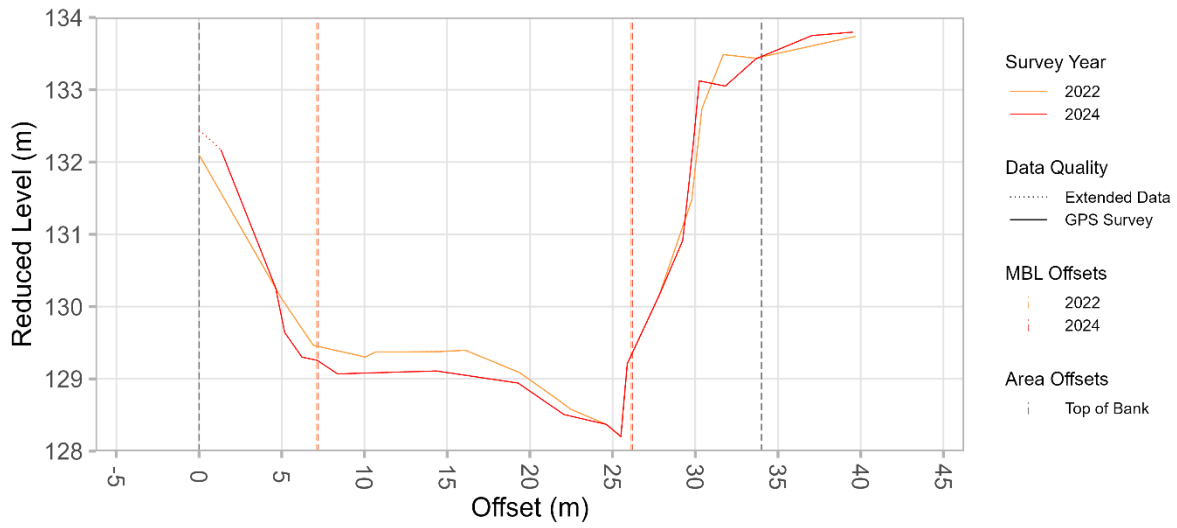
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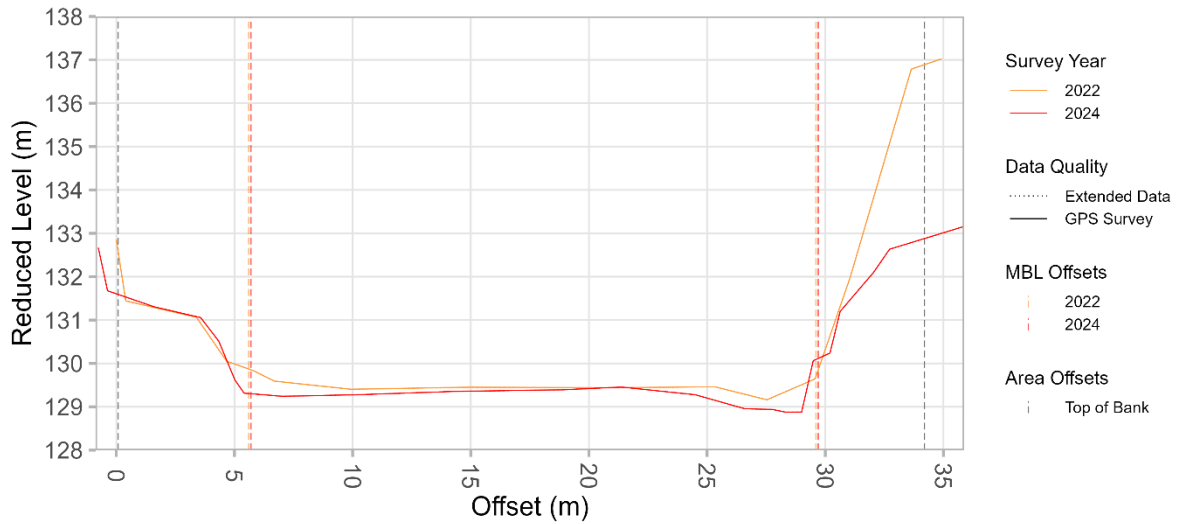
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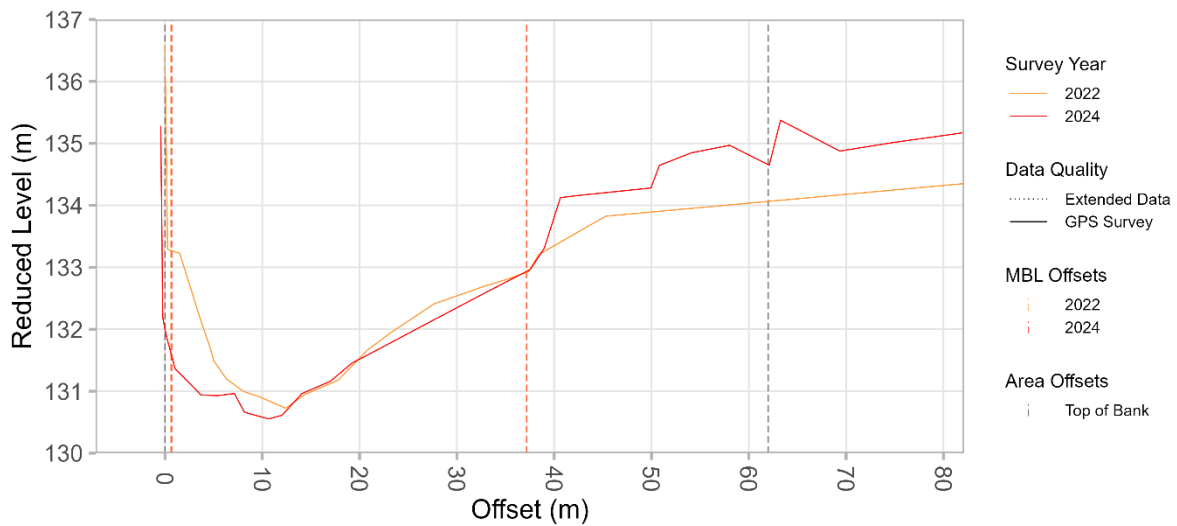
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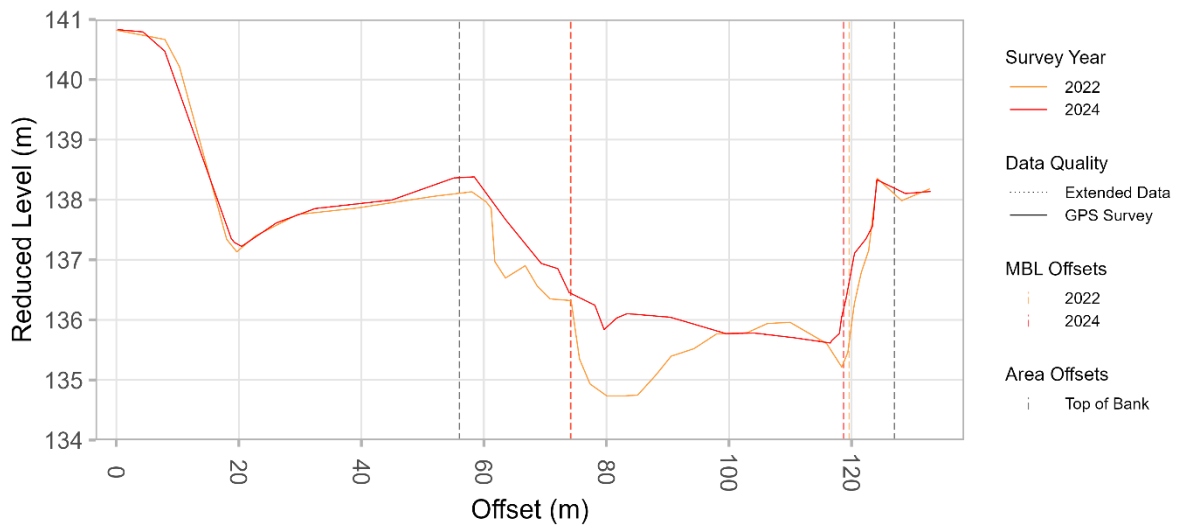
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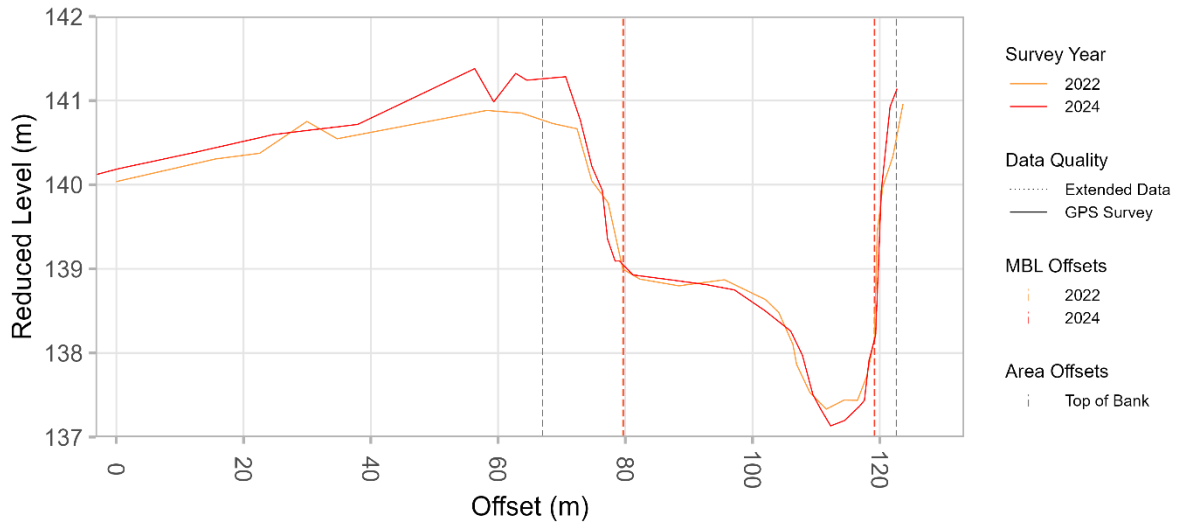
055315m - 28



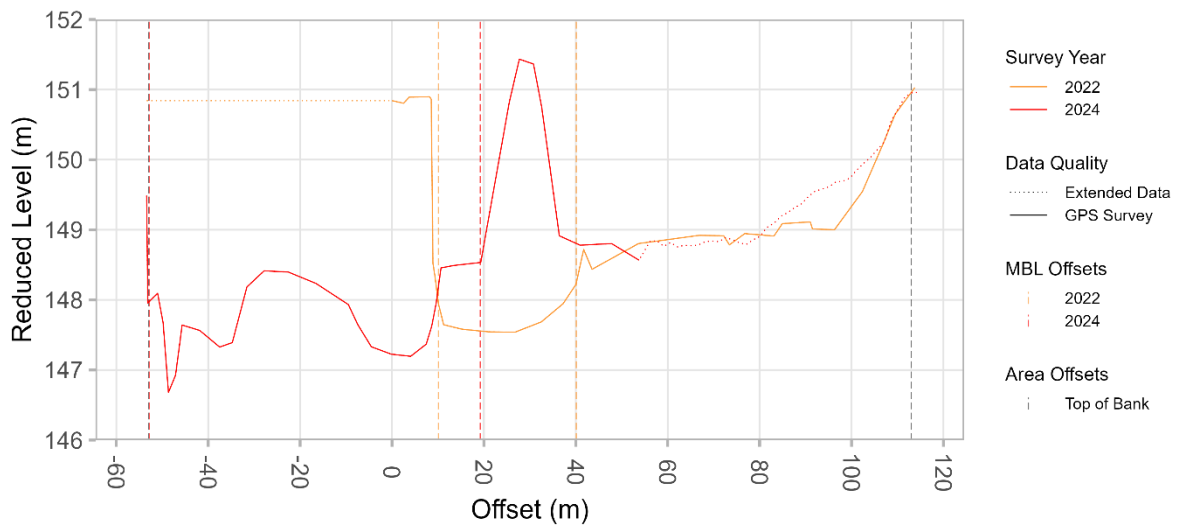
056150m - 29



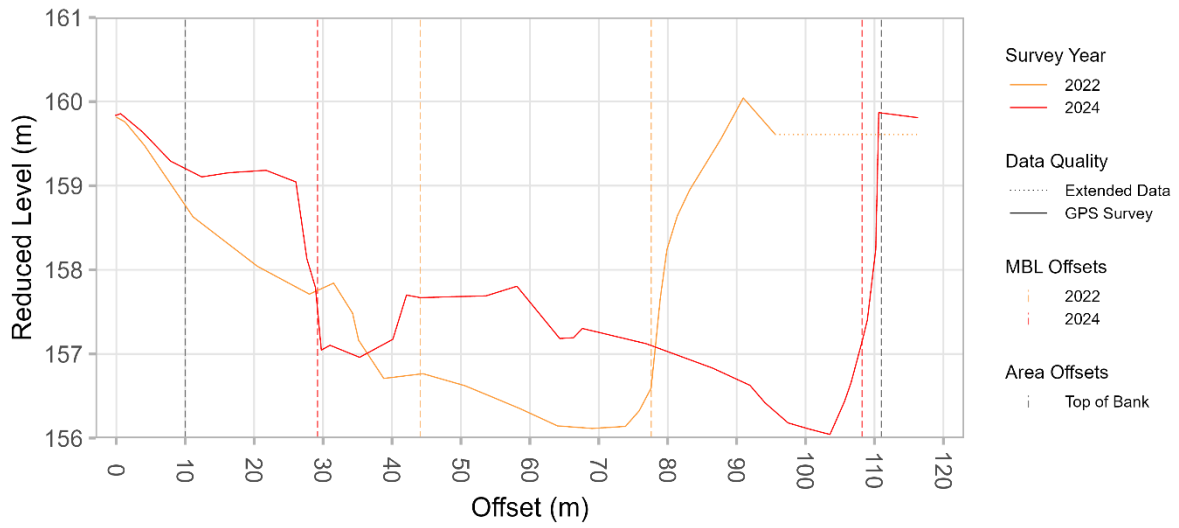
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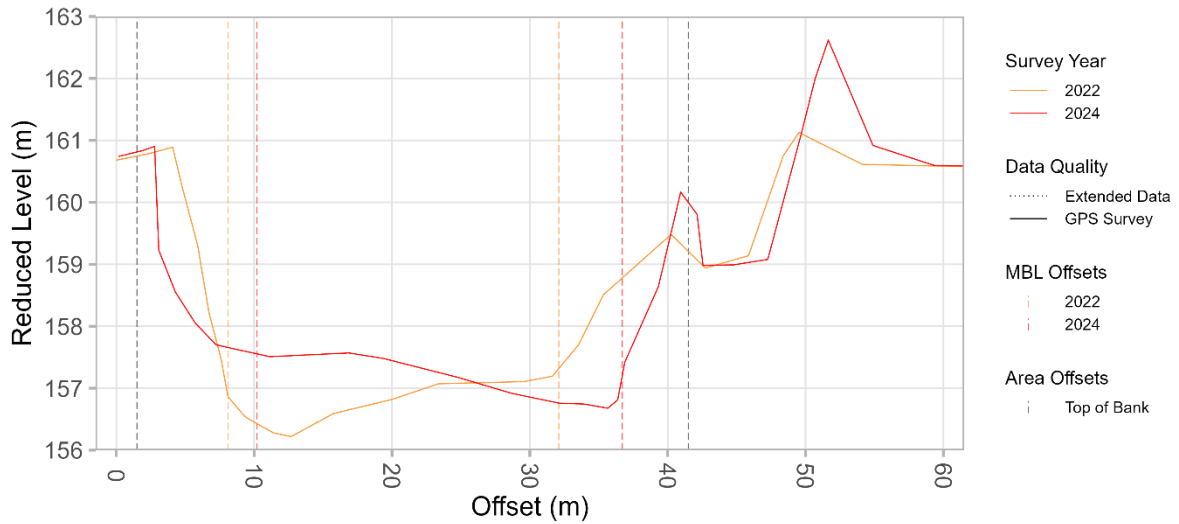
059040m - 31



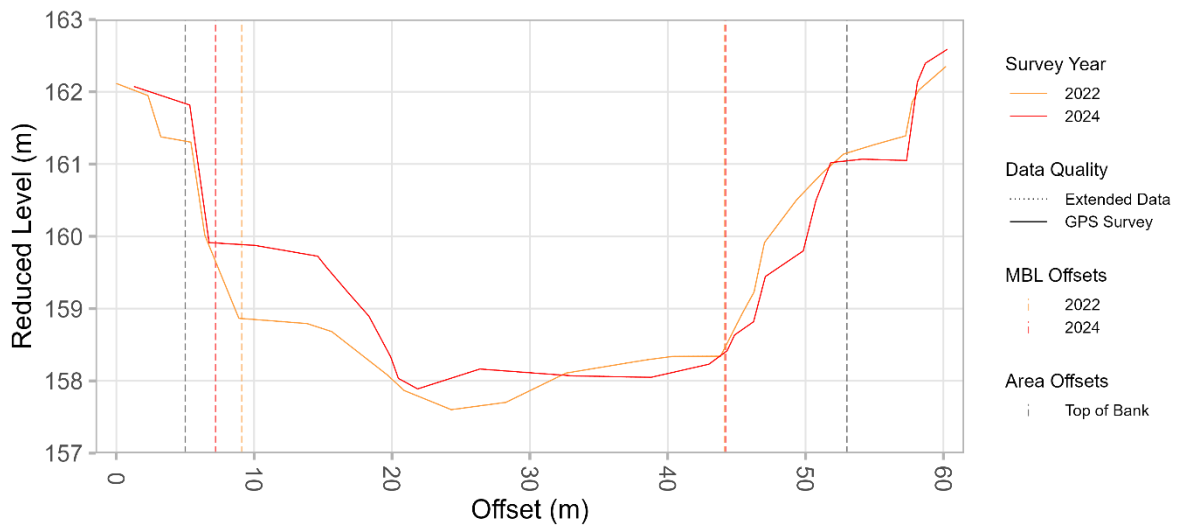
061010m - 32



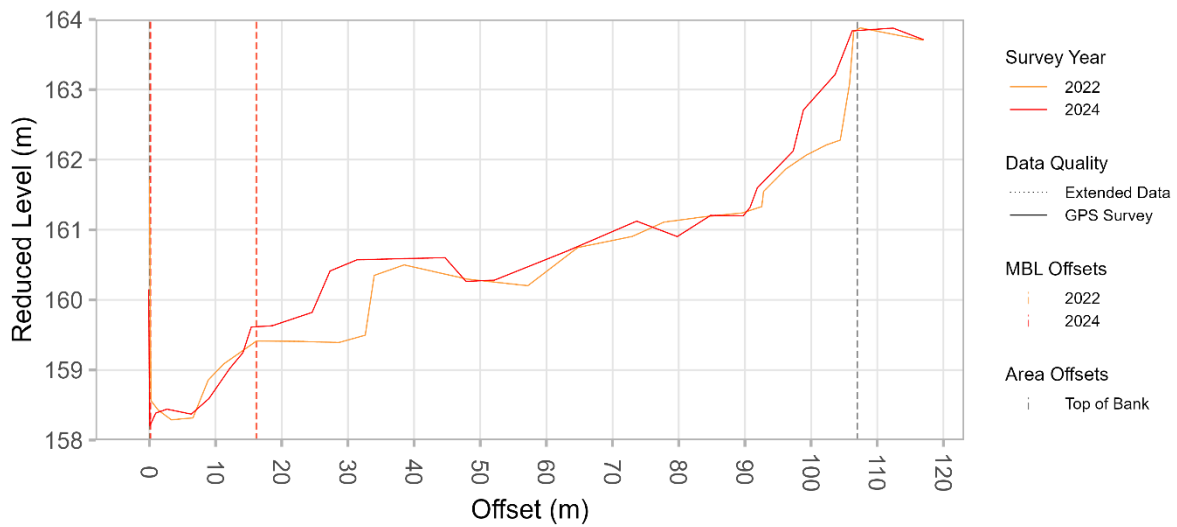
061245m - 33



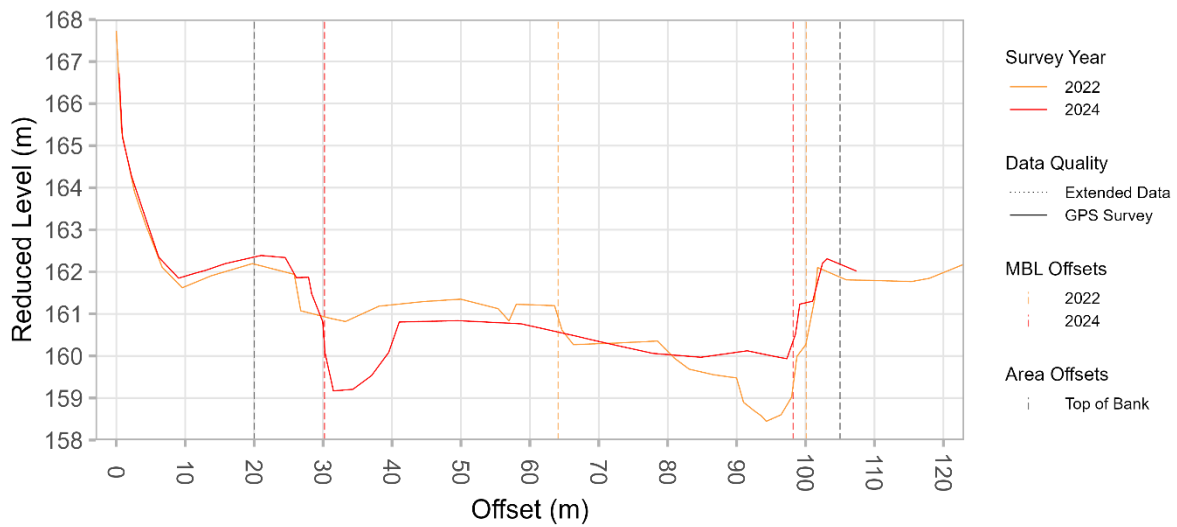
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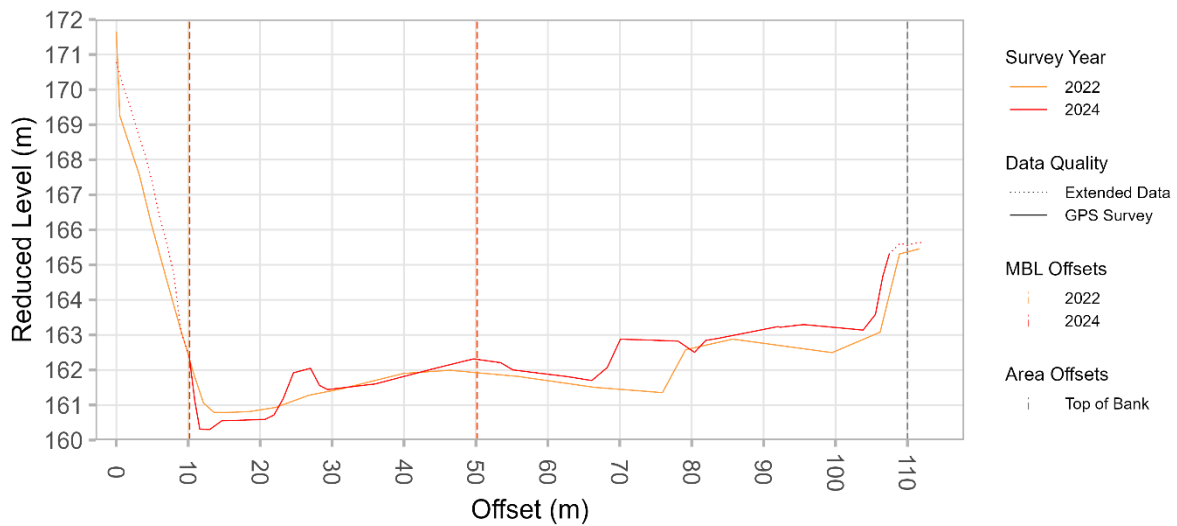
061755m - 35

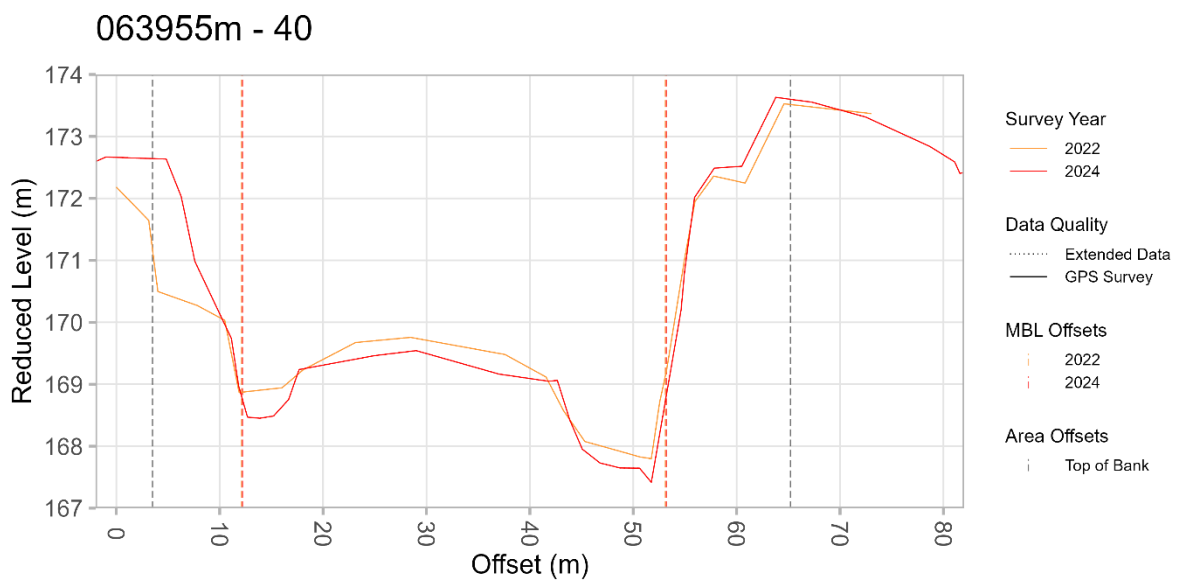
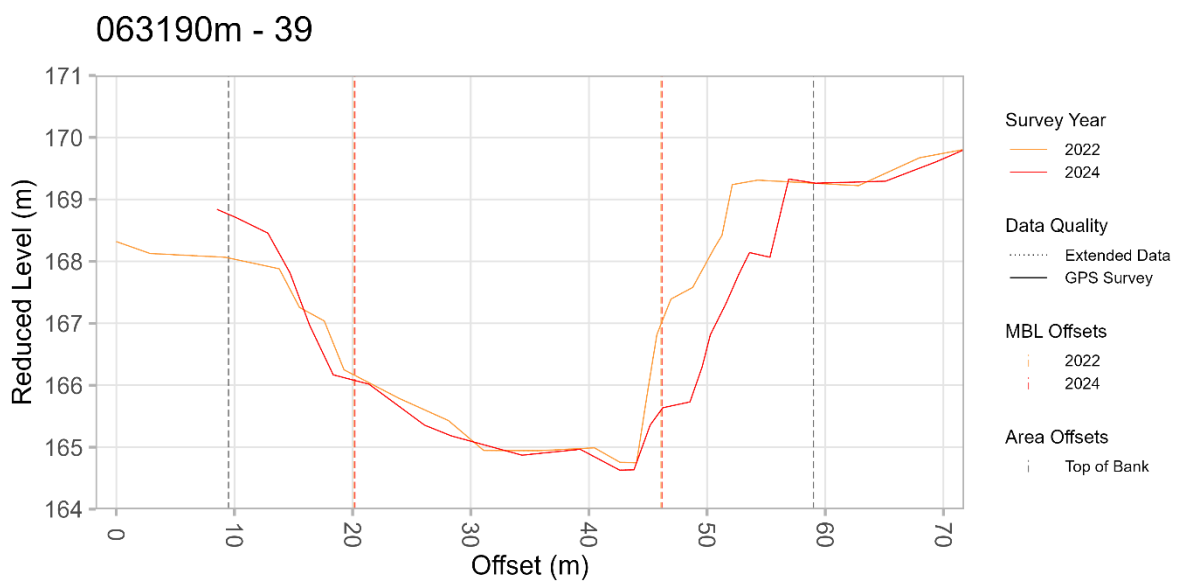
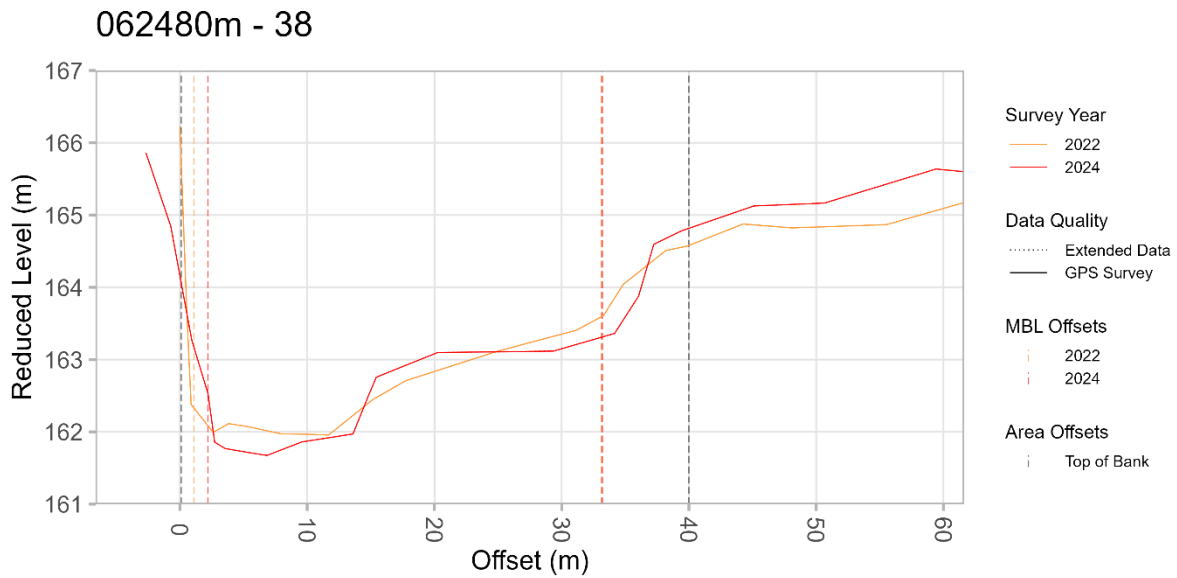


061915m - 36

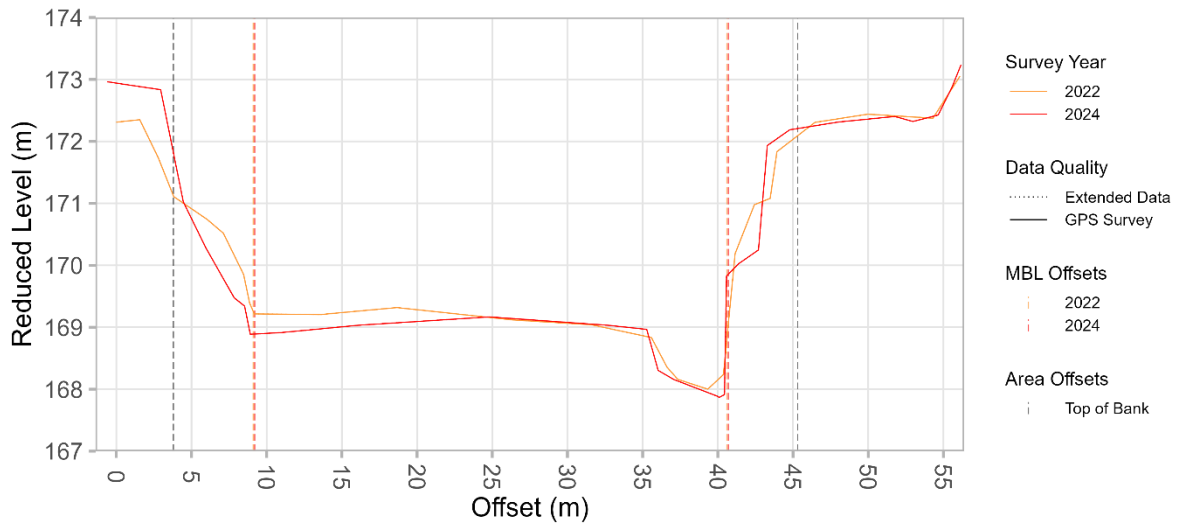


062120m - 37

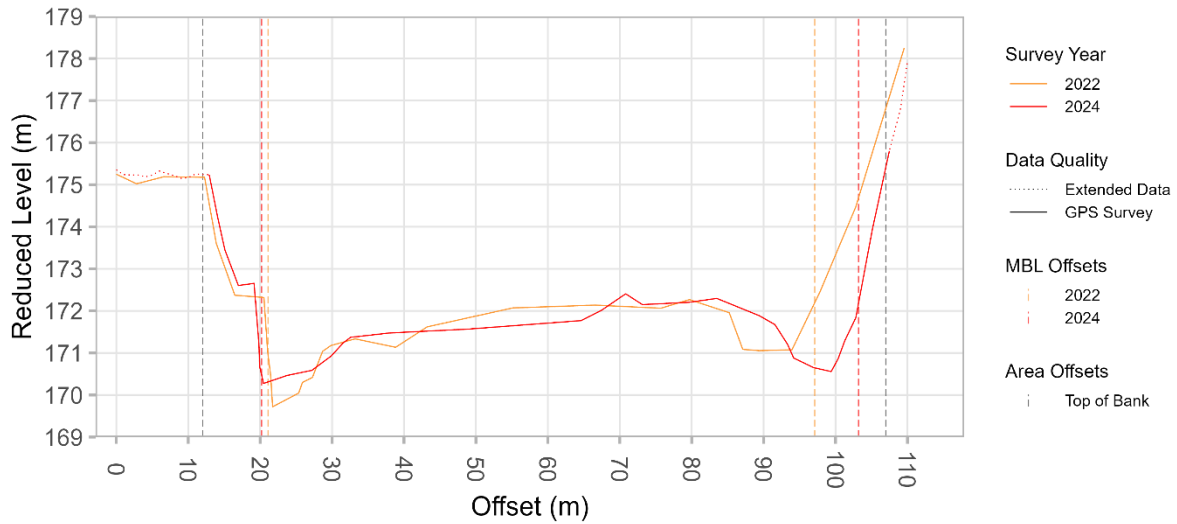




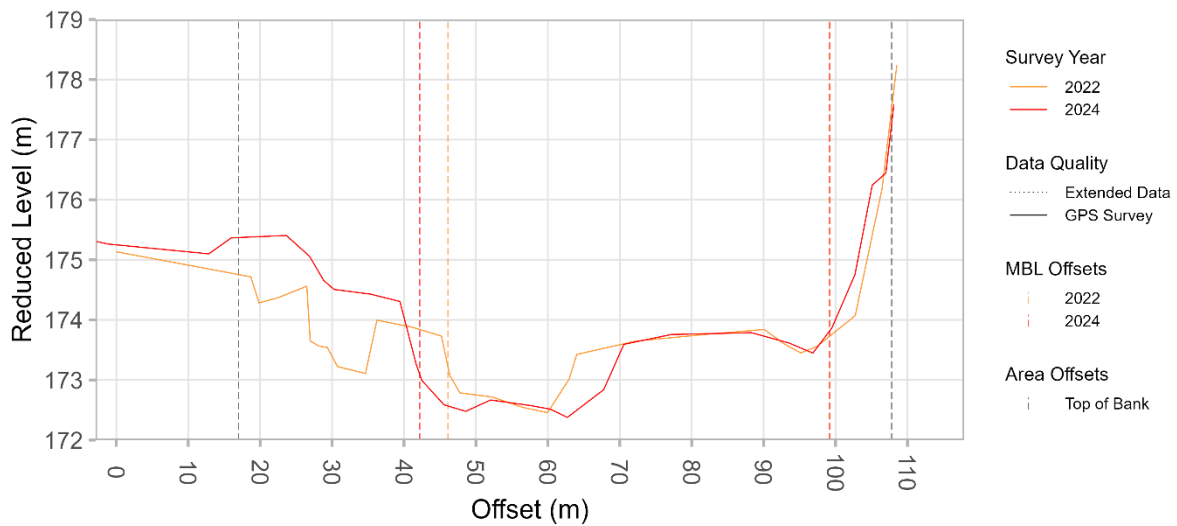
064030m - 41



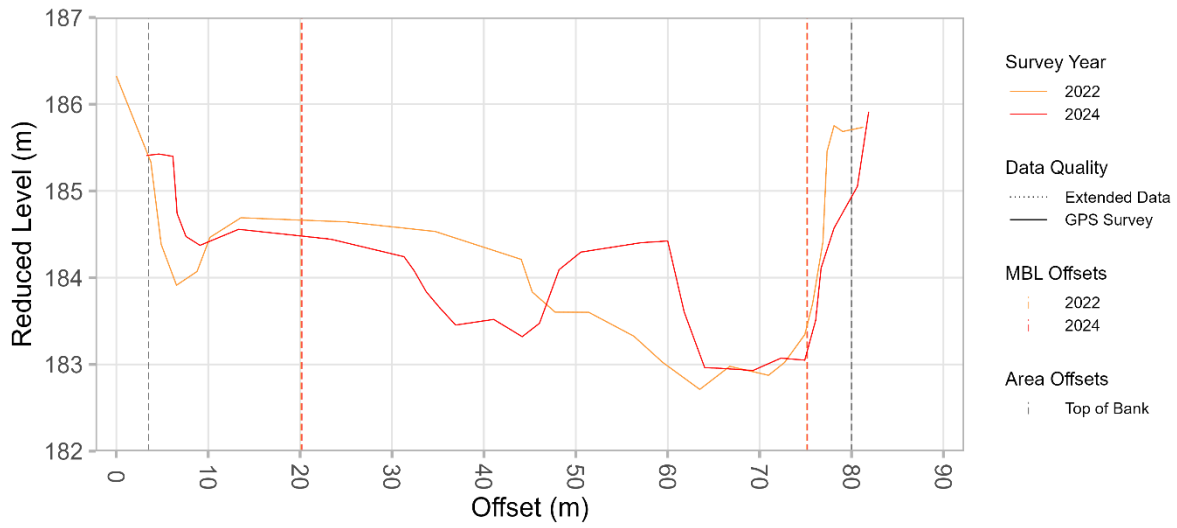
064405m - 42



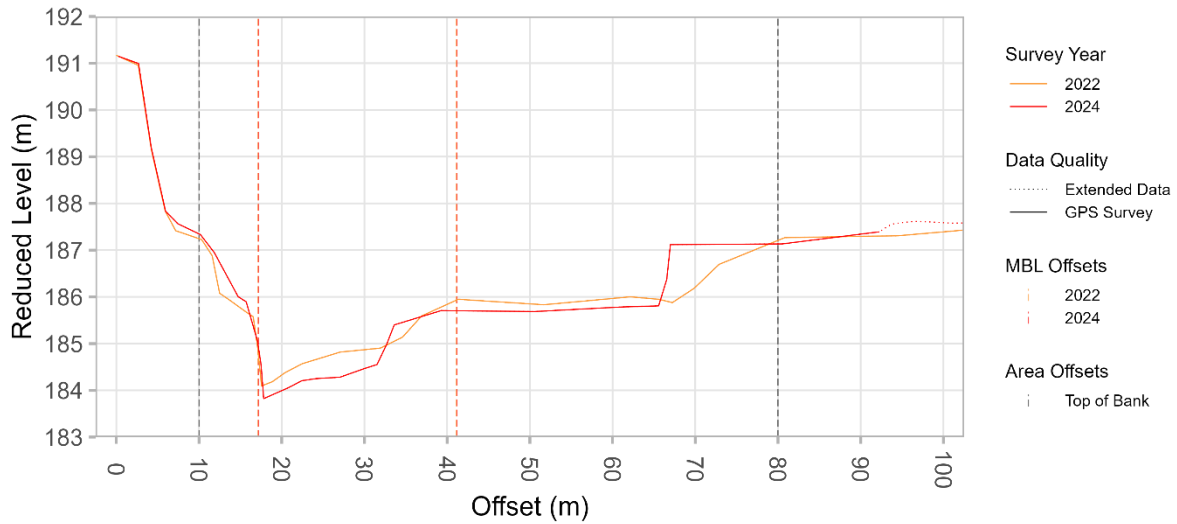
064760m - 43



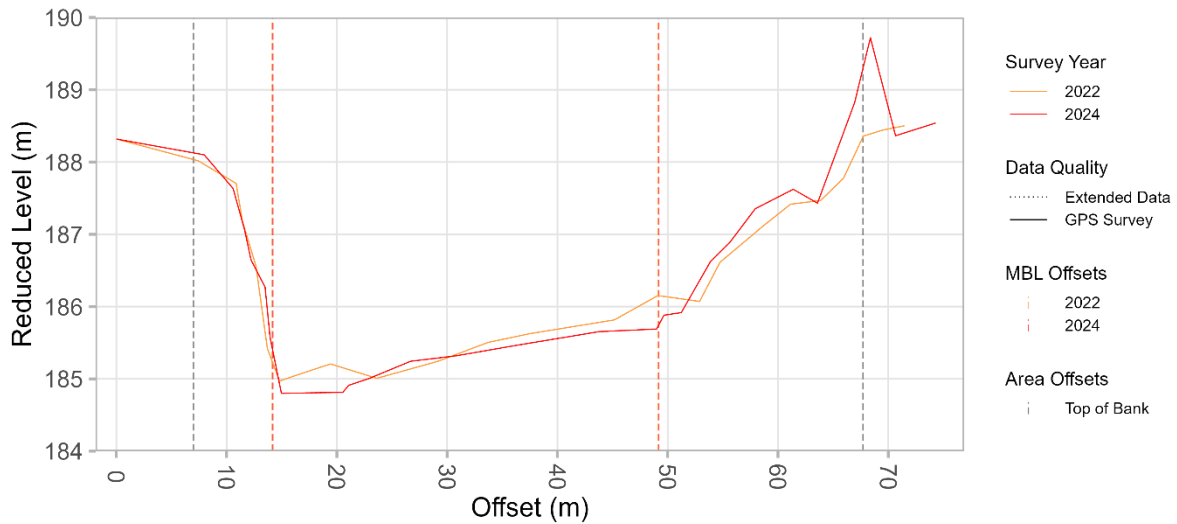
066905m - 44



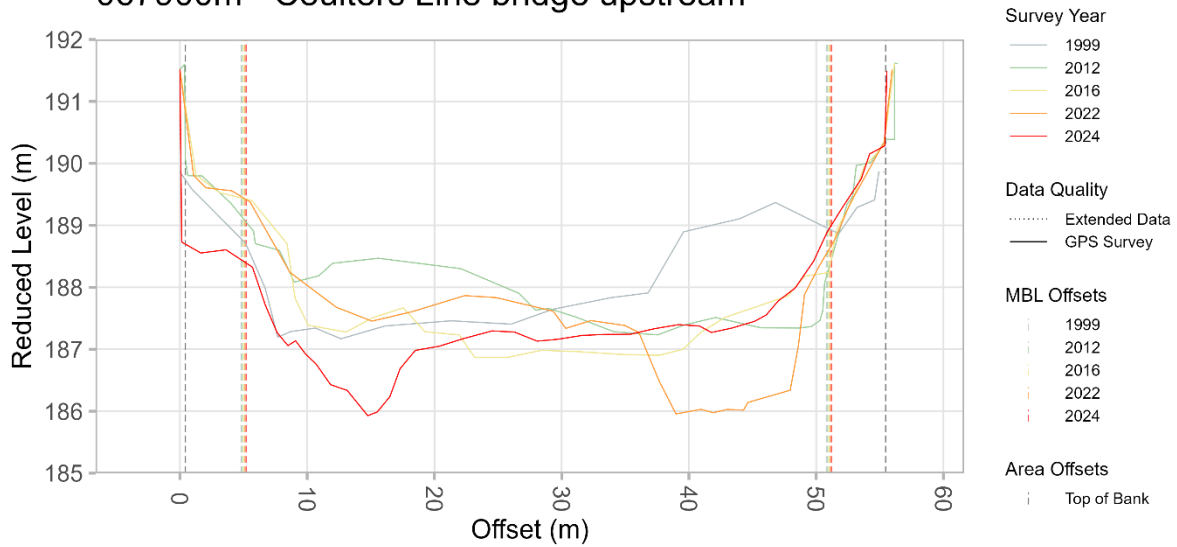
067230m - 45



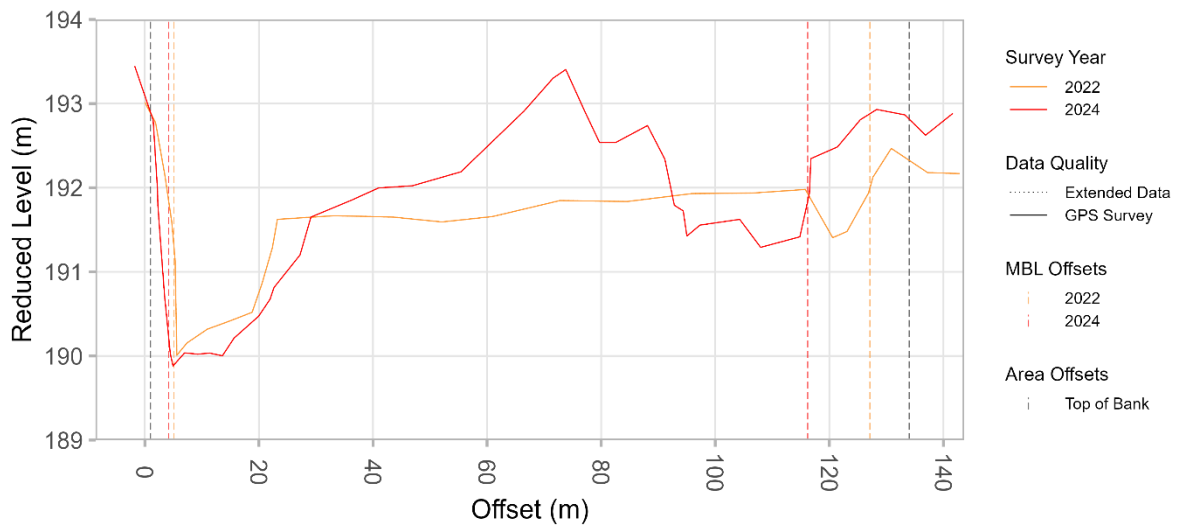
067350m - 46



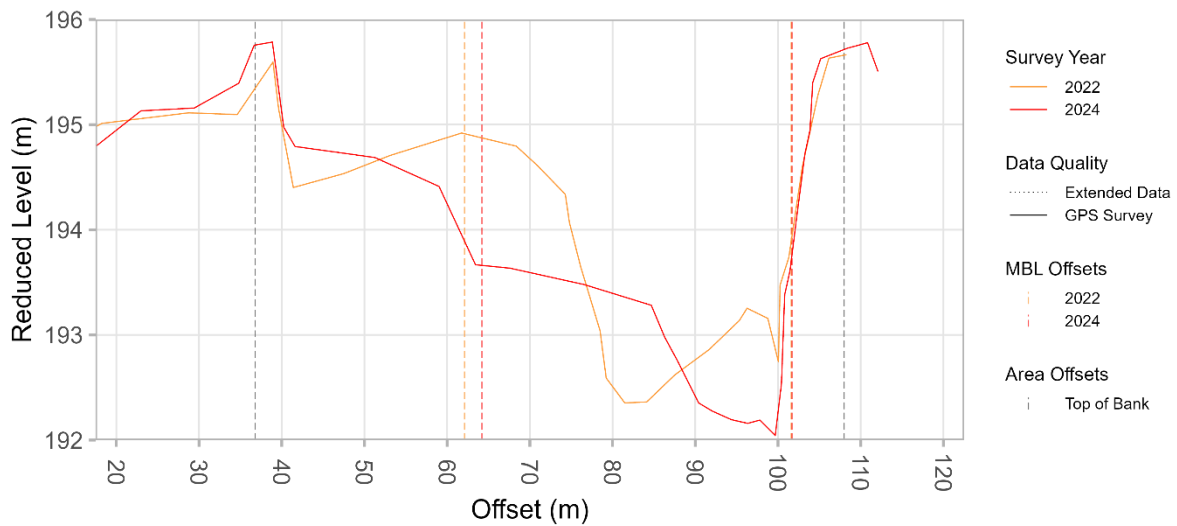
067900m - Coulters Line bridge upstream

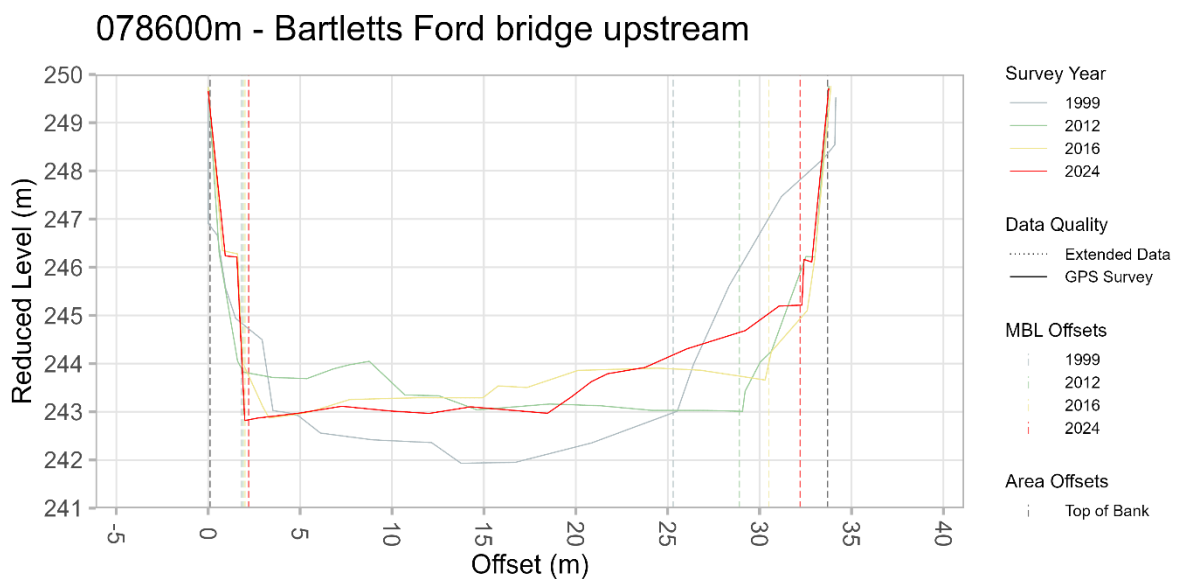
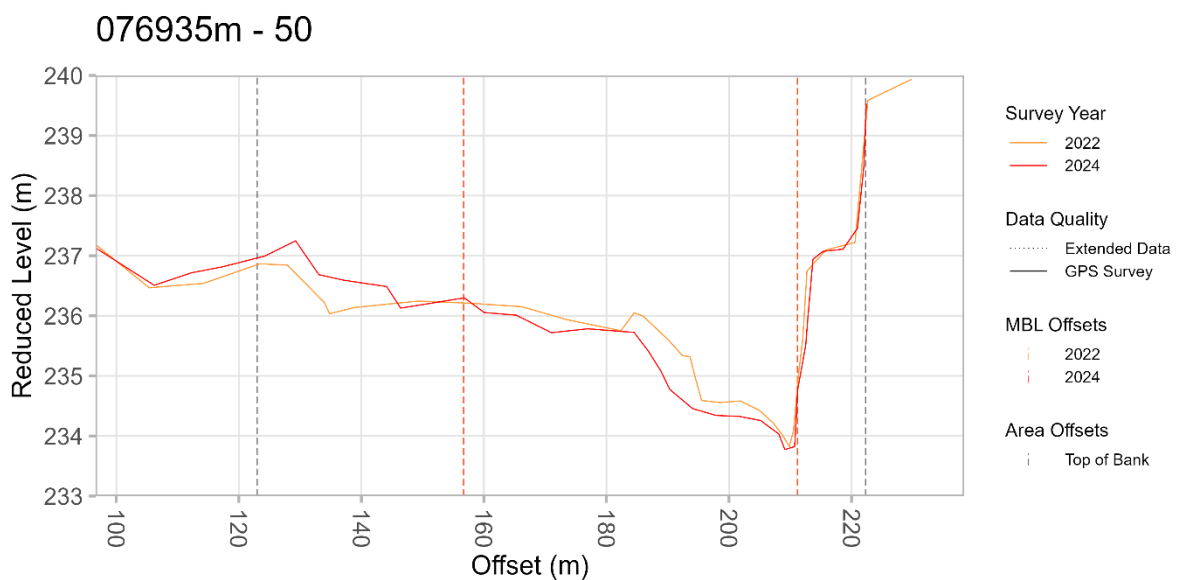
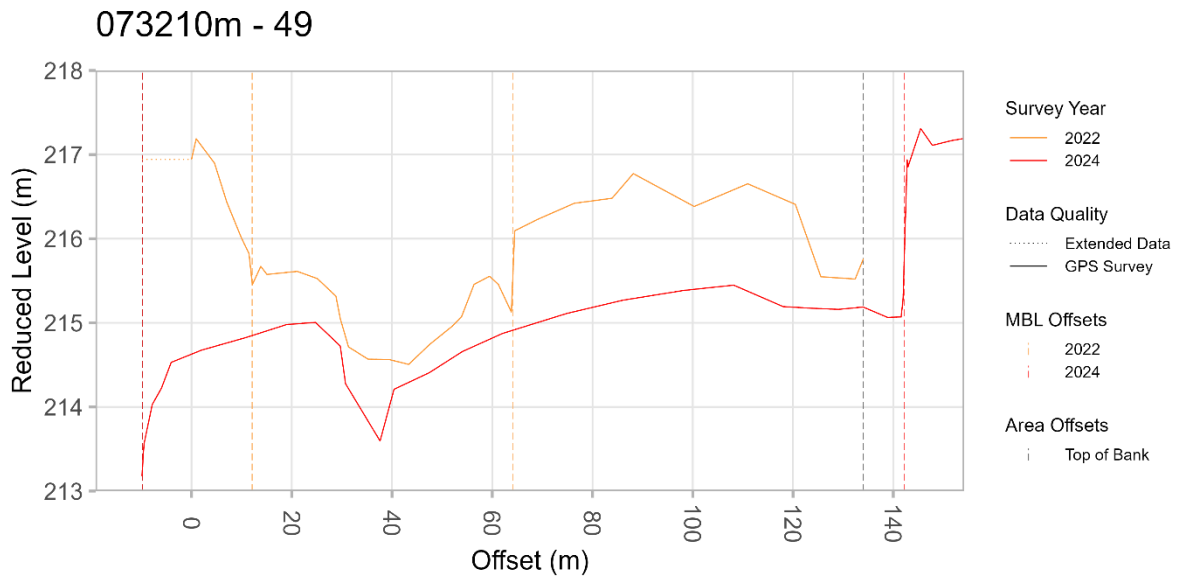


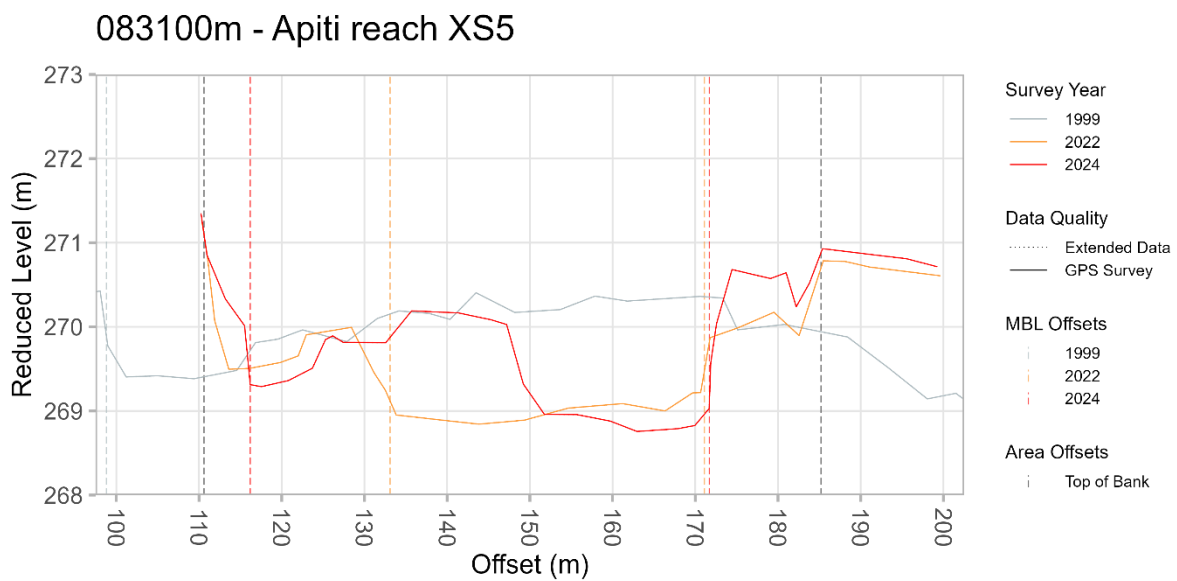
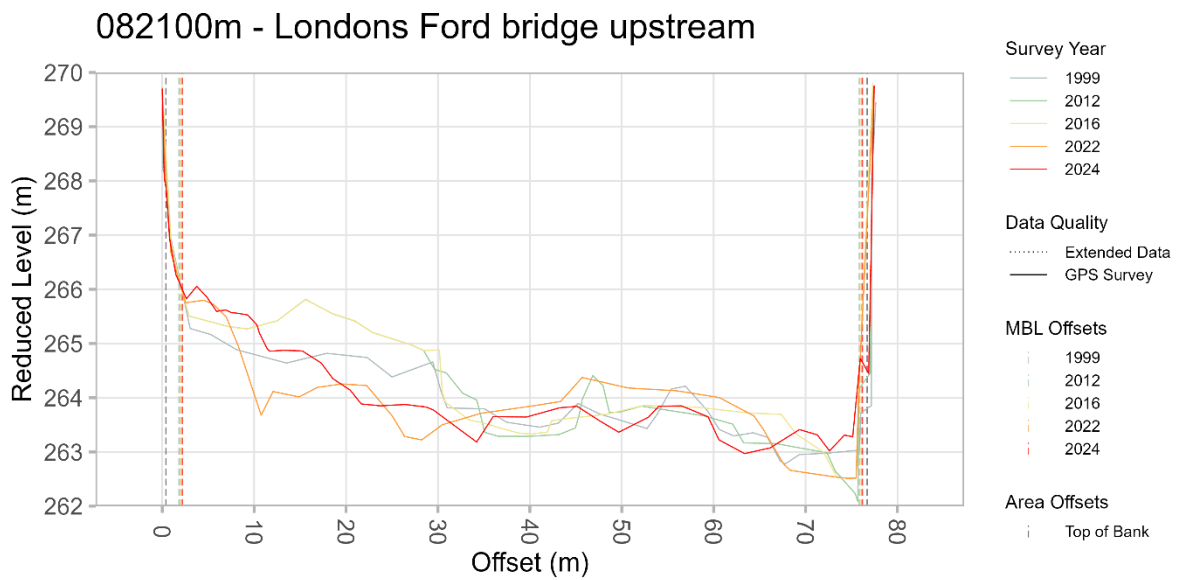
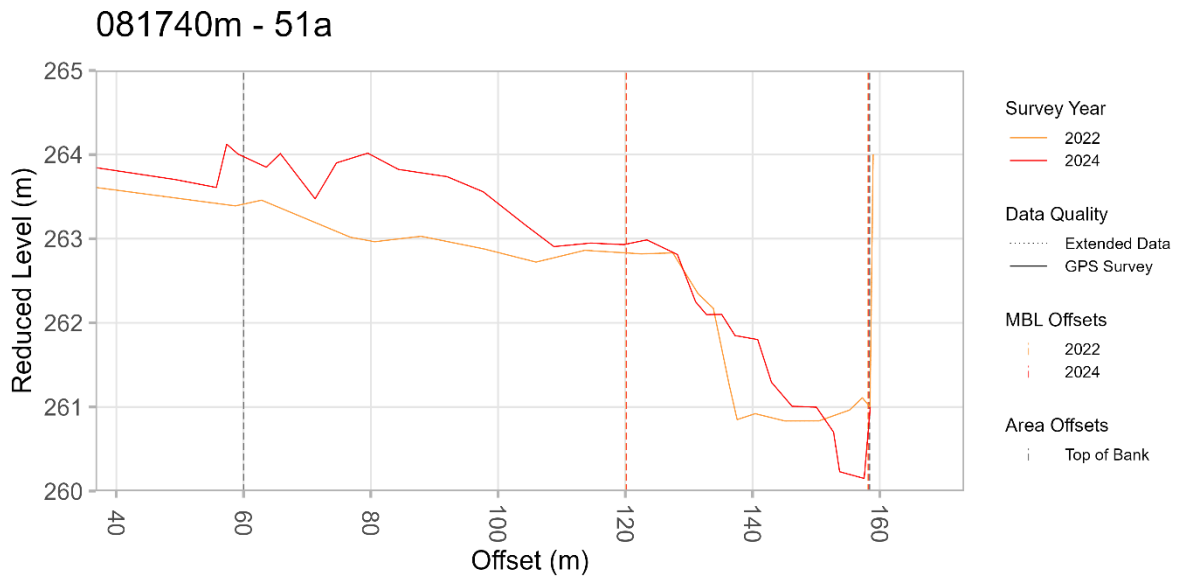
068555m - 47



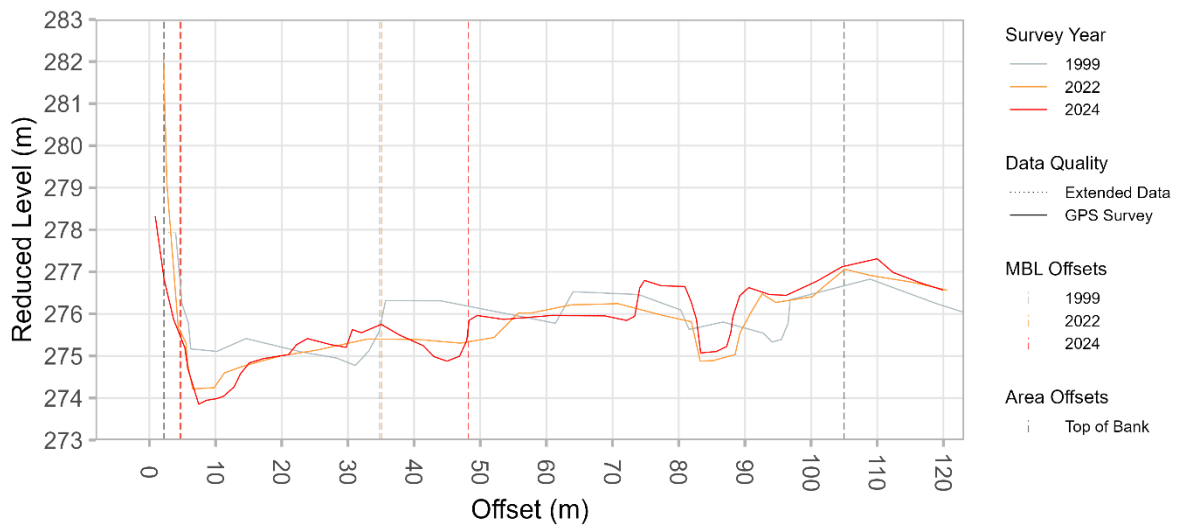
069060m - 48



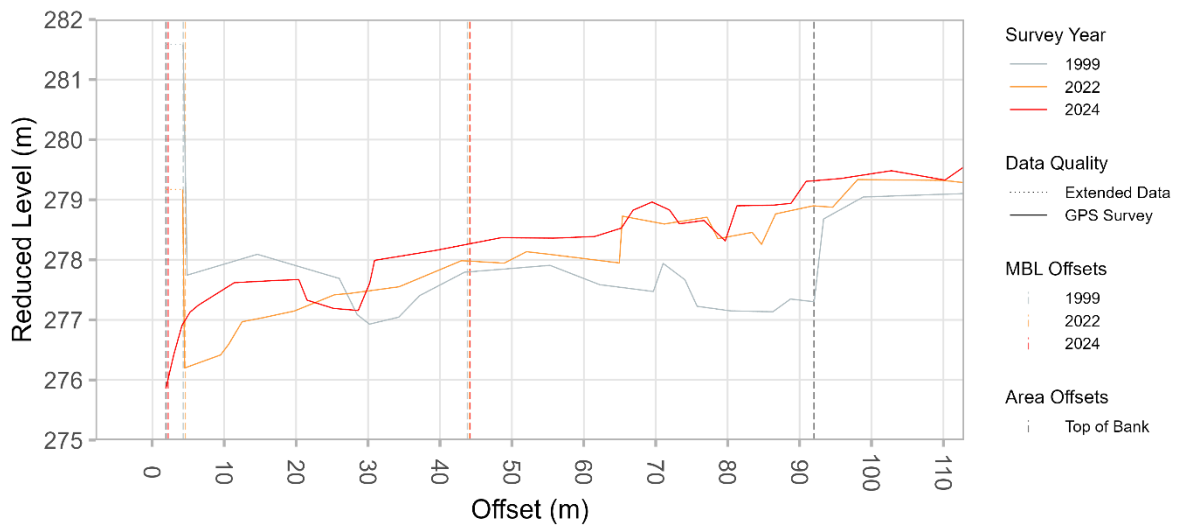




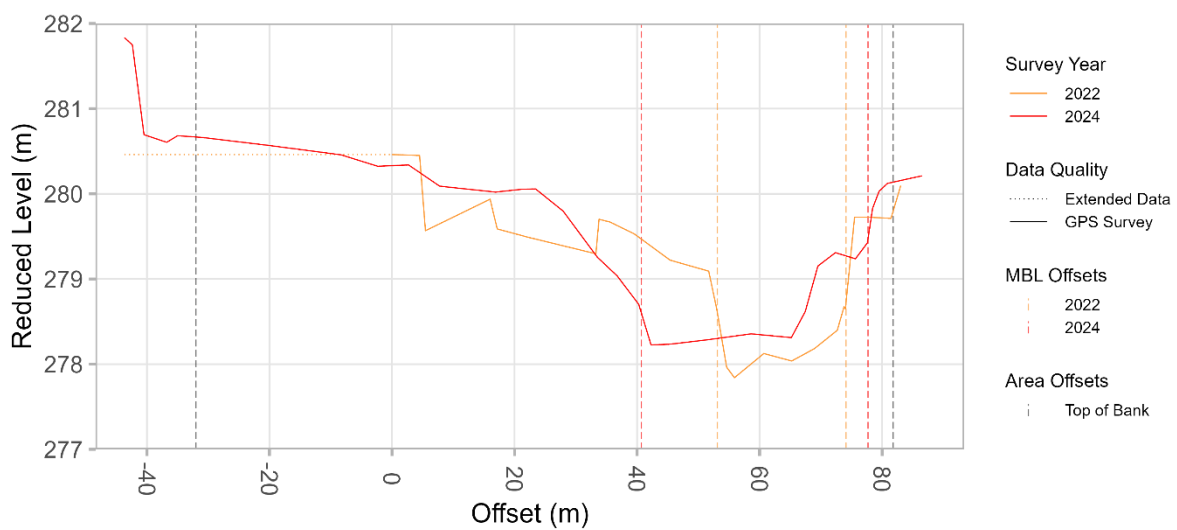
084100m - Apiti reach XS10



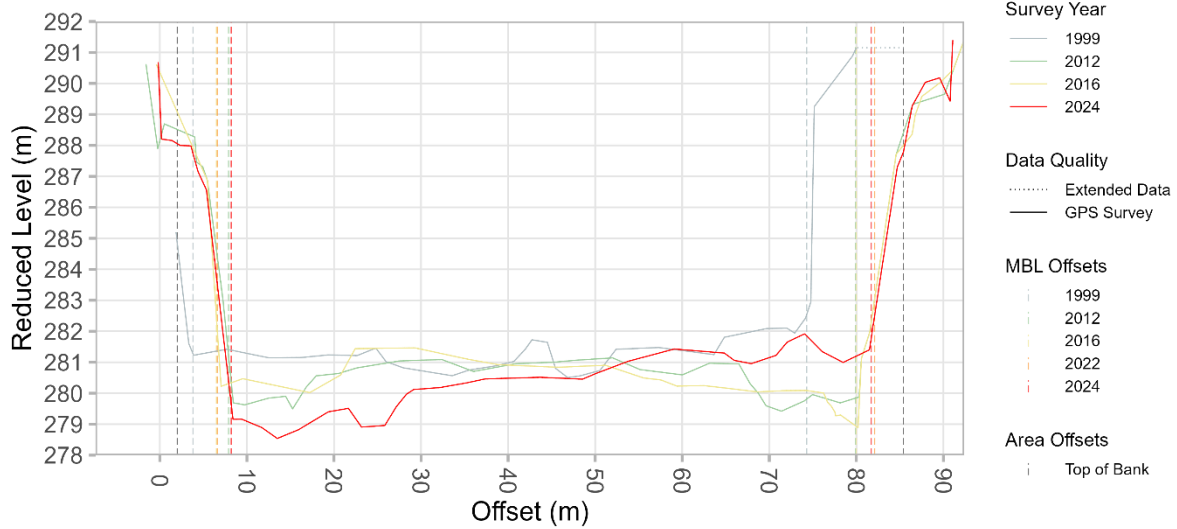
084500m - Apiti reach XS12



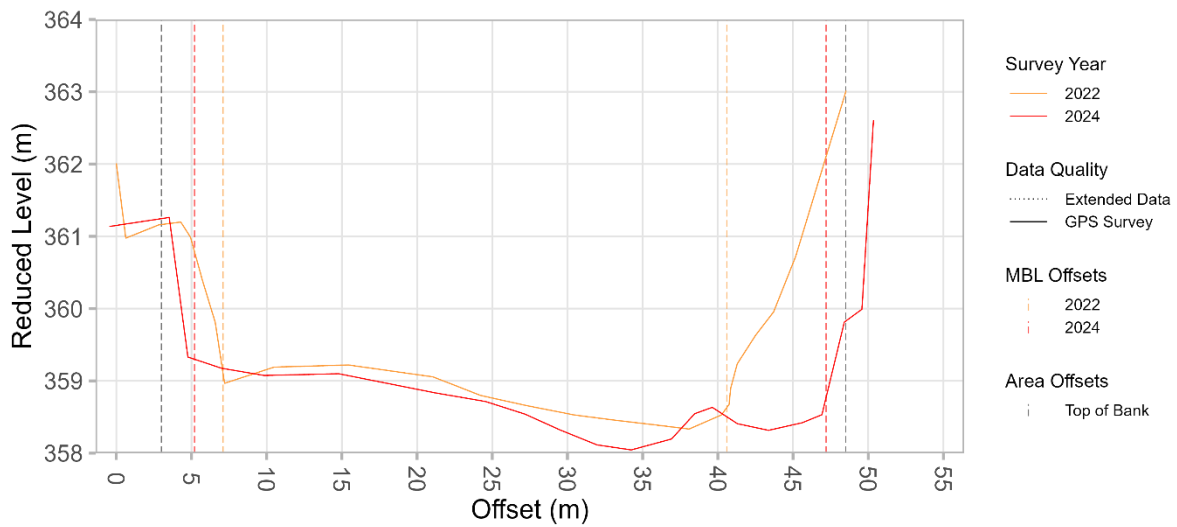
084680m



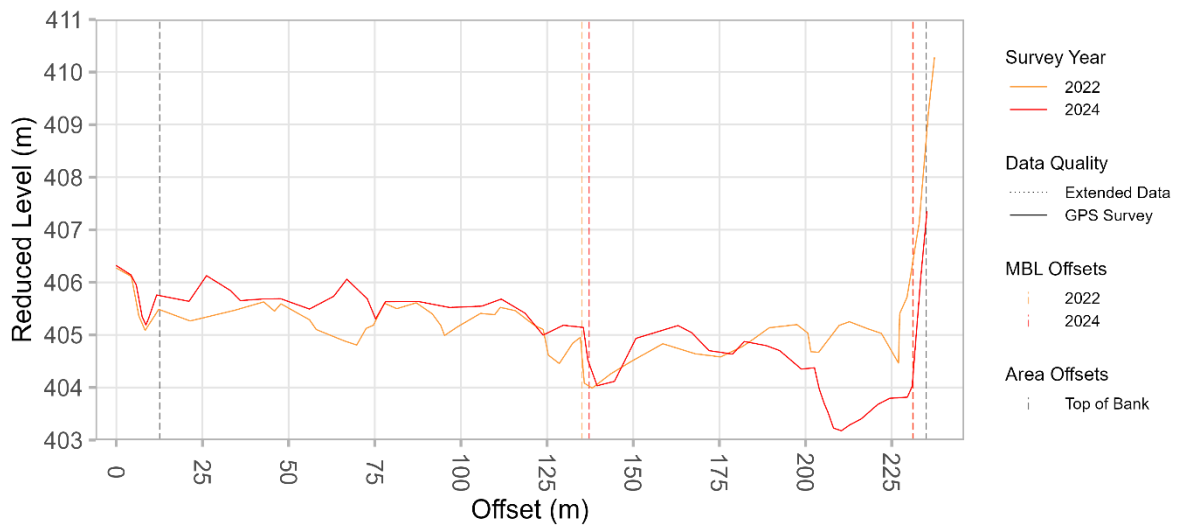
084900m - Apiti Rd bridge upstream



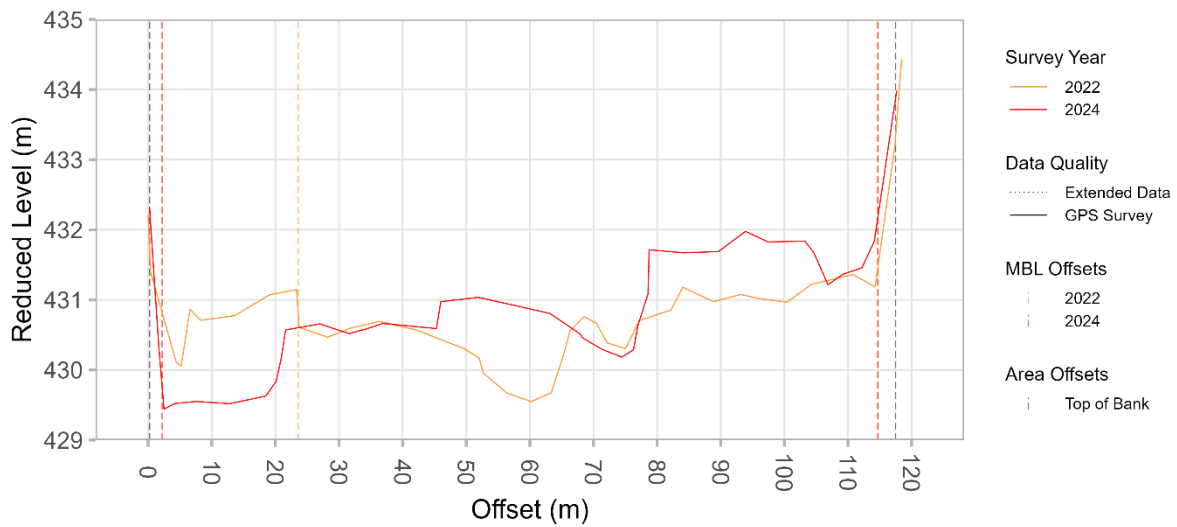
096440m - 52



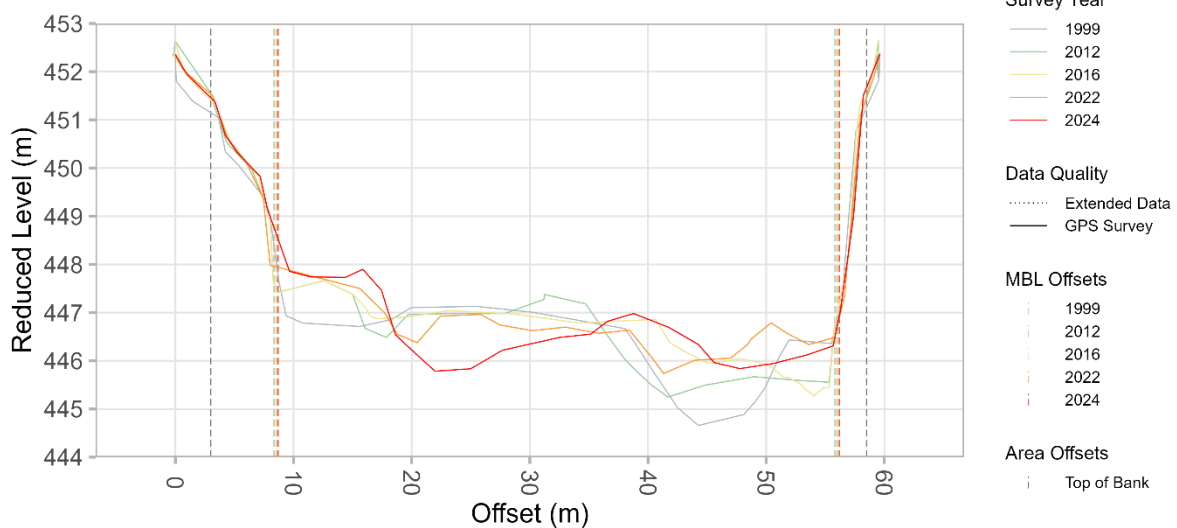
101975m - 53



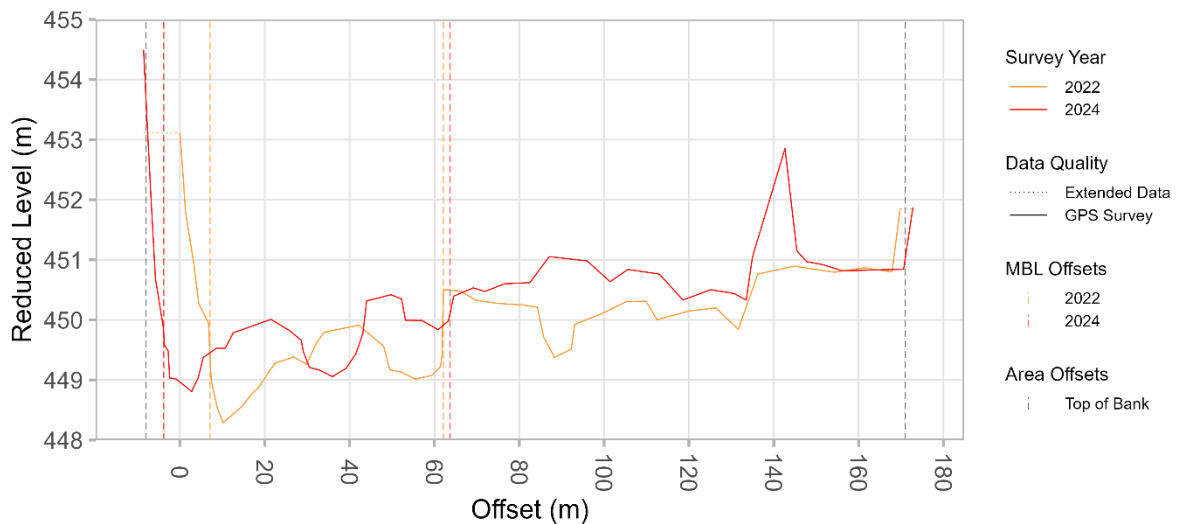
105455m - 54

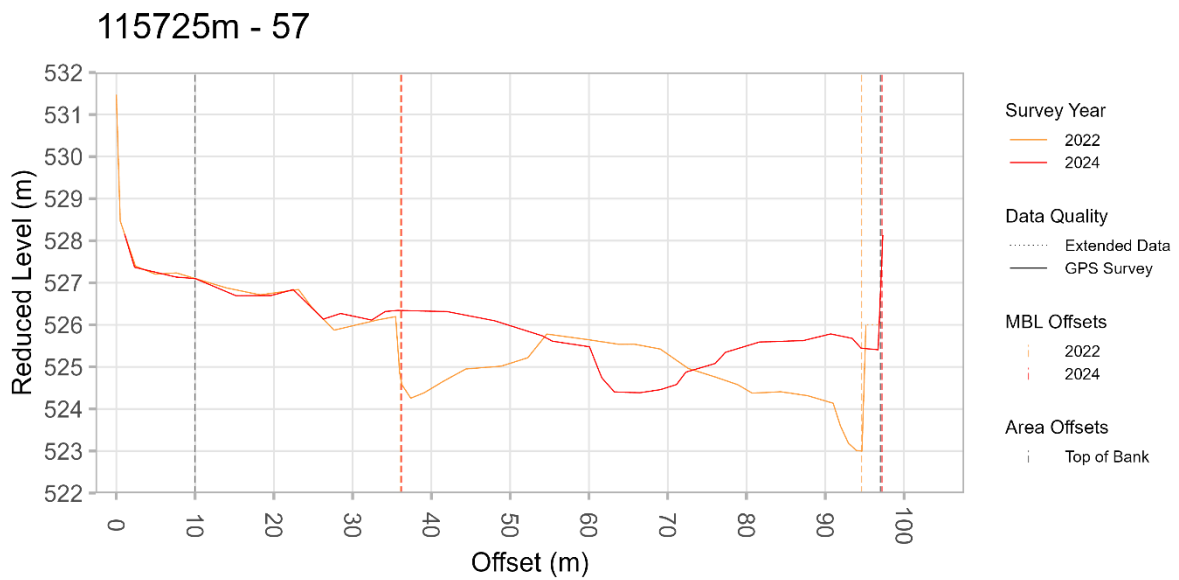
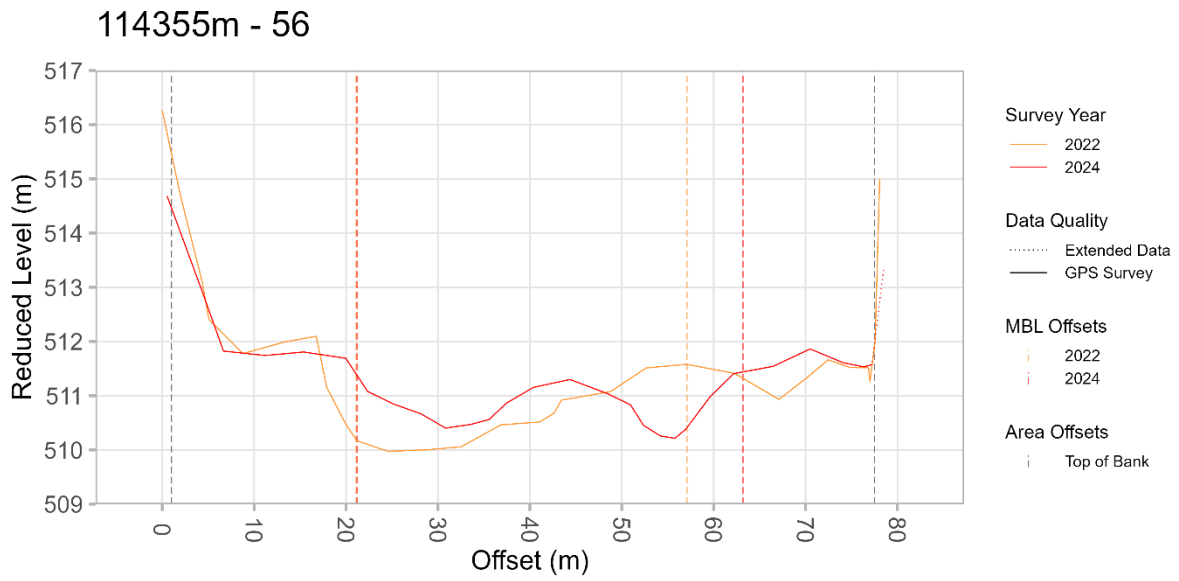


107695m - Apiti Gorge bridge upstream



108035m - 55





Appendix B

Area under the section and volume raw results using 2022/2024 active channel offsets. Cross-section sites with missing values in any of the years of interest (1998/1999, 2011/2012, 2016, 2022, 2024) were not used in the long-term analysis. Left and Right Offsets indicate the distance in metres along the cross-section from the true left as stored in Hilltop used to calculate the area under the section in square metres. Blanks indicate no data was available/appropriate for use. Volume was not calculated for the upper Ōroua above cross-section 69060m, as above this point the cross-section spacing is too coarse (>4 km) to reasonably estimate volume changes between cross-sections.

Site	Offset (m)		Area under the Section (m²)					Long-Term Analysis						Short-Term Analysis		
	Left	Right	1998/1999	2011/2012	2016	2022	2024	Distance	Volume (m³)					Distance	Volume (m³)	
									1998/1999	2011/2012	2016	2022	2024		2022	2024
Silt Phase																
000000m	0	56.21	279	286	301	303	305	1150	615,250	637,905	659,065	633,018	651,993	1150	633,018	651,993
001150m	10	120	791	823	845	798	829	350	550,078	573,895	570,273	548,660	561,278	350	548,660	561,278
001500m	17	297	2,352	2,456	2,414	2,338	2,378	625	1,248,781	1,302,625	1,295,844	1,271,063	1,288,156	625	1,271,063	1,288,156
002125m	27	229	1,644	1,712	1,733	1,730	1,744	475	650,394	664,858	673,384	676,923	683,074	475	676,923	683,074
002600m	10	140	1,094	1,087	1,102	1,121	1,132	400	402,200	403,880	408,440	416,360	418,120	400	416,360	418,120
003000m	15	128	917	932	940	961	959	535	497,470	501,910	504,666	518,201	522,963	535	518,201	522,963
003535m	12	124	943	944	947	976	997	430	284,639	287,950	290,293	297,367	303,215	430	297,367	303,215
003965m	2.081	53.35	381	395	403	407	414	535	349,837	356,203	364,148	367,839	375,089	535	367,839	375,089
004500m	7	114	927	936	958	968	988	470	716,257	730,803	741,402	712,426	734,352	470	712,426	734,352
004970m	11	225	2,121	2,174	2,197	2,064	2,137	550	817,795	839,685	848,733	813,670	839,163	550	813,670	839,163
005520m	9	105	853	880	889	895	915	480	527,952	546,816	552,984	556,536	567,480	480	556,536	567,480
006000m	18	159	1,347	1,399	1,415	1,424	1,450	575	776,624	809,456	820,899	830,616	843,008	575	830,616	843,008
006575m	14	152	1,354	1,417	1,441	1,465	1,483	1910	2,198,792	2,298,017	2,327,908	2,359,041	2,375,181	450	562,905	568,508
007025m	12	114	958	1,024		1,037	1,044							475	476,401	478,111
007500m	11	106	916	946		969	969							485	496,664	496,446
007985m	-18	78	1,090	1,089		1,079	1,078							500	520,900	520,625
008485m	16	109	948	989	997	1,005	1,004	515	660,874	685,826	673,234	685,800	692,057	515	685,800	692,057
009000m	9	154	1,619	1,674	1,617	1,658	1,683	420	583,002	608,412	578,571	599,088	609,651	420	599,088	609,651
009420m	10	117	1,158	1,223	1,138	1,194	1,220	380	537,415	552,235	535,477	549,328	554,895	380	549,328	554,895
009800m	29	169	1,671	1,683	1,681	1,697	1,701	350	481,250	490,088	478,800	486,045	488,093	350	486,045	488,093
010150m	7	103	1,079	1,117	1,055	1,081	1,089	350	367,150	378,140	358,663	364,613	365,610	350	364,613	365,610
010500m	11	100	1,019	1,044	994	1,003	1,001	360	345,006	360,234	346,104	349,686	349,902	360	349,686	349,902
010860m	27	107	898	958	929	940	943	720	1,505,412	1,568,088	1,552,536	1,558,116	1,568,448	340	567,256	571,285
011200m	17	205		2,460	2,350	2,397	2,417							380	1,099,207	1,107,871
011580m	10	258	3,284	3,398	3,384	3,388	3,414	420	1,010,856	1,051,806	1,043,826	1,047,753	1,057,287	420	1,047,753	1,057,287
012000m	12	132	1,530	1,610	1,587	1,601	1,621	290	566,022	588,512	580,841	587,729	593,369	290	587,729	593,369
012290m	23	200	2,374	2,448	2,419	2,452	2,471	350	914,498	942,270	932,050	940,783	949,690	350	940,783	949,690
012640m	17	222	2,852	2,936	2,907	2,924	2,956	460	1,084,703	1,114,258	1,094,317	1,107,588	1,121,043	460	1,107,588	1,121,043
013100m	13	149	1,864	1,909	1,851	1,892	1,918	400	615,900	631,800	615,420	626,820	633,300	400	626,820	633,300
013500m	11	102	1,215	1,251	1,226	1,242	1,248	350	442,068	451,010	448,088	454,353	458,290	350	454,353	458,290
013850m	13	110	1,311	1,327	1,334	1,354	1,371	365	475,066	480,778	484,611	490,943	495,853	365	490,943	495,853

Site	Offset (m)		Area under the Section (m²)					Long-Term Analysis						Short-Term Analysis		
								Distance	Volume (m³)					Distance	Volume (m³)	
	Left	Right	1998/1999	2011/2012	2016	2022	2024		1998/1999	2011/2012	2016	2022	2024		2022	2024
Silt Phase (cont.)																
014215m	10	104	1,292	1,308	1,321	1,336	1,346	335	661,005	679,062	683,249	684,656	693,752	335	684,656	693,752
014550m	7	187	2,654	2,746	2,758	2,752	2,796	450	1,197,968	1,238,963	1,243,620	1,243,665	1,259,123	450	1,243,665	1,259,123
015000m	10	188	2,670	2,760	2,769	2,776	2,801	325	663,065	686,936	688,464	692,689	698,555	325	692,689	698,555
015325m	15	112	1,410	1,467	1,468	1,487	1,498	375	661,050	676,894	681,038	679,275	687,338	375	679,275	687,338
015700m	11	149	2,116	2,143	2,165	2,136	2,168	375	776,719	787,294	797,925	789,619	801,113	375	789,619	801,113
016075m	15	145	2,027	2,056	2,091	2,075	2,105	425	1,112,735	1,146,990	1,161,695	1,161,844	1,169,749	425	1,161,844	1,169,749
016500m	14	219	3,209	3,342	3,376	3,392	3,400	400	1,351,540	1,394,580	1,402,080	1,375,640	1,363,460	400	1,375,640	1,363,460
016900m	13	229	3,548	3,631	3,635	3,486	3,418	325	1,325,756	1,348,506	1,360,239	1,336,286	1,331,671	325	1,336,286	1,331,671
017225m	15	292	4,610	4,667	4,736	4,737	4,777	400	1,492,200	1,523,040	1,543,340	1,546,100	1,558,300	400	1,546,100	1,558,300
017625m	12	187	2,851	2,948	2,981	2,993	3,014	375	860,888	877,875	892,294	899,400	908,250	375	899,400	908,250
018000m	13	120	1,741	1,734	1,778	1,804	1,830	340	631,601	641,529	652,358	657,237	665,703	340	657,237	665,703
018340m	11	129	1,975	2,040	2,059	2,063	2,086	385	1,487,159	1,522,521	1,536,073	1,545,178	1,566,219	385	1,545,178	1,566,219
018725m	10	332	5,751	5,870	5,921	5,964	6,050	400	1,655,440	1,689,360	1,706,280	1,717,980	1,742,140	400	1,717,980	1,742,140
019125m	17	160	2,526	2,577	2,611	2,626	2,661	375	825,488	845,194	852,131	857,438	864,375	375	857,438	864,375
019500m	10	115	1,876	1,930	1,934	1,947	1,949	250	569,600	584,713	589,550	595,438	599,963	250	595,438	599,963
019750m	14	162	2,681	2,747	2,783	2,816	2,850	350	1,071,175	1,091,283	1,106,298	1,119,073	1,134,298	350	1,119,073	1,134,298
020100m	14	197	3,440	3,489	3,539	3,579	3,631	300	823,455	841,455	850,755	858,690	870,435	300	858,690	870,435
020400m	12	123	2,049	2,121	2,133	2,146	2,172	325	642,704	663,569	667,355	673,465	681,233	325	673,465	681,233
020725m	14	115	1,906	1,962	1,974	1,998	2,021	275	796,923	822,058	829,538	830,541	841,995	140	330,799	334,908
020865m	10	148				2,727	2,764							135	456,921	463,496
021000m	14	213	3,890	4,016	4,059	4,042	4,103	100	305,775	315,780	319,735	319,740	324,210	100	319,740	324,210
021100m	7	122	2,226	2,299	2,336	2,353	2,381	235	516,401	532,604	543,191	545,165	549,689	235	545,165	549,689
021335m	12	123	2,169	2,233	2,287	2,287	2,297	215	570,900	591,465	599,538	600,269	604,935	215	600,269	604,935
021550m	10	168	3,141	3,269	3,290	3,297	3,330	285	832,086	864,134	873,012	876,746	886,564	190	538,555	543,495
021740m	9	124				2,372	2,391							95	248,302	250,881
021835m	11	146	2,698	2,796	2,836	2,856	2,891	315	707,884	733,934	741,542	744,392	749,322	315	744,392	749,322
022150m	3	92	1,797	1,864	1,872	1,871	1,867	350	650,388	670,233	677,215	665,595	668,115	350	665,595	668,115
022500m	9	102	1,920	1,966	1,998	1,933	1,951	310	751,471	760,833	771,342	768,816	773,621	310	768,816	773,621
022810m	13	150	2,928	2,943	2,979	3,028	3,040	275	766,508	780,629	789,305	799,411	804,279	275	799,411	804,279
023085m	13	139	2,646	2,734	2,762	2,786	2,810	310	873,813	896,040	909,075	920,235	928,993	310	920,235	928,993
023395m	9	149	2,991	3,047	3,103	3,151	3,184	305	1,004,762	1,035,262	1,045,998	1,058,670	1,074,439	305	1,058,670	1,074,439
023700m	11	179	3,597	3,742	3,756	3,792	3,862	300	1,069,305	1,089,405	1,098,540	1,111,815	1,129,815	300	1,111,815	1,129,815
024000m	-1	157	3,531	3,521	3,568	3,621	3,671	325	920,514	918,629	921,749	935,513	949,666	325	935,513	949,666
024325m	4	97	2,133	2,132	2,105	2,136	2,174	440	784,168	768,636	763,906	772,156	785,048	440	772,156	785,048
Lower Gravel Phase																
024765m	60	122	1,431	1,362	1,368	1,373	1,395	285	474,782	456,128	460,475	463,866	471,989	285	463,866	471,989

Site	Offset (m)		Area under the Section (m²)					Long-Term Analysis						Short-Term Analysis		
								Distance	Volume (m³)					Distance	Volume (m³)	
	Left	Right	1998/1999	2011/2012	2016	2022	2024		1998/1999	2011/2012	2016	2022	2024		2022	2024
Lower Gravel Phase (cont.)																
025050m	21	101	1,901	1,839	1,864	1,882	1,917	390	604,773	590,577	594,809	600,522	609,044	390	600,522	609,044
025440m	130	180	1,201	1,189	1,187	1,198	1,206	60	84,612	84,147	83,658	84,654	85,512	60	84,654	85,512
025500m	60	127	1,620	1,616	1,602	1,624	1,644	175	323,199	319,410	316,925	321,895	325,456	175	321,895	325,456
025675m	13	96	2,074	2,035	2,020	2,055	2,075	405	612,927	603,977	599,258	607,399	614,446	405	607,399	614,446
026080m	135	173	953	948	939	945	959	290	299,860	293,828	293,872	296,699	300,672	290	296,699	300,672
026370m	185	228	1,115	1,079	1,087	1,102	1,114	240	273,612	265,140	266,328	270,588	274,812	240	270,588	274,812
026610m	69	113	1,165	1,131	1,132	1,153	1,176	270	295,151	288,050	286,943	291,303	295,448	270	291,303	295,448
026880m	77	115	1,021	1,003	994	1,004	1,013	120	125,274	122,094	121,974	123,078	124,188	120	123,078	124,188
027000m	50	89	1,067	1,032	1,039	1,047	1,057	250	357,550	344,788	347,438	349,563	353,563	250	349,563	353,563
027250m	280	343	1,794	1,726	1,740	1,750	1,772	325	528,856	512,298	516,133	519,545	523,851	150	276,428	279,233
027400m	127	196				1,936	1,952							175	296,074	297,833
027575m	200	251	1,461	1,427	1,436	1,448	1,452	260	354,848	348,699	350,480	353,457	355,394	260	353,457	355,394
027835m	141	185	1,269	1,256	1,260	1,271	1,282	280	338,436	333,900	335,244	338,282	340,998	280	338,282	340,998
028115m	221	260	1,149	1,129	1,135	1,145	1,154	385	506,256	503,638	506,853	507,526	511,453	385	507,526	511,453
028500m	117	166	1,481	1,487	1,498	1,492	1,503	250	424,488	424,100	425,513	424,000	427,988	250	424,000	427,988
028750m	136	197	1,915	1,906	1,906	1,901	1,921	375	623,344	617,250	617,156	617,231	622,950	375	617,231	622,950
029125m	167	211	1,410	1,386	1,386	1,391	1,401	275	550,248	546,370	546,631	544,390	548,254	275	544,390	548,254
029400m	106	184	2,592	2,587	2,590	2,568	2,586	300	672,495	670,155	667,830	668,070	673,440	300	668,070	673,440
029700m	270	326	1,892	1,880	1,862	1,886	1,904	300	618,810	609,765	609,090	611,910	617,730	300	611,910	617,730
030000m	72	137	2,234	2,185	2,198	2,193	2,215	250	609,463	605,663	608,338	603,913	609,963	250	603,913	609,963
030250m	22	98	2,642	2,661	2,669	2,638	2,665	350	1,329,335	1,345,820	1,337,648	1,337,088	1,342,355	100	246,080	248,620
030350m	1.5	67				2,284	2,307							100	228,395	231,035
030450m	12.5	77.5				2,284	2,313							150	546,510	548,918
030600m	425	564	4,954	5,030	4,975	5,003	5,006	450	1,963,328	1,972,440	1,961,303	1,968,975	1,974,128	120	474,750	475,650
030720m	27	107				2,910	2,922							330	1,098,620	1,103,916
031050m	120	220	3,772	3,737	3,742	3,748	3,768	450	1,157,108	1,150,898	1,149,615	1,152,698	1,158,210	450	1,152,698	1,158,210
031500m	133	169	1,371	1,379	1,368	1,375	1,379	325	636,513	628,599	629,606	630,354	635,635	325	630,354	635,635
031825m	243	307	2,546	2,490	2,507	2,504	2,532	335	930,647	921,066	918,168	921,686	929,123	335	921,686	929,123
032160m	73	147	3,010	3,009	2,975	2,998	3,015	400	1,088,740	1,090,980	1,084,800	1,090,240	1,094,600	400	1,090,240	1,094,600
032560m	306	365	2,433	2,446	2,449	2,453	2,458	440	1,136,102	1,143,010	1,145,474	1,142,966	1,148,092	440	1,142,966	1,148,092
033000m	103	167	2,731	2,750	2,758	2,742	2,760	315	1,000,661	1,004,551	1,011,749	1,009,874	1,016,773	315	1,009,874	1,016,773
033315m	65	148	3,623	3,628	3,666	3,670	3,696	485	1,769,814	1,774,494	1,786,522	1,789,480	1,796,004	485	1,789,480	1,796,004
033800m	200	281	3,676	3,689	3,701	3,710	3,711	360	1,337,760	1,338,336	1,342,692	1,346,706	1,349,172	360	1,346,706	1,349,172
034160m	240	320	3,757	3,746	3,759	3,772	3,785	340	1,303,339	1,295,451	1,301,112	1,302,982	1,306,841	340	1,302,982	1,306,841
034500m	58	138	3,910	3,874	3,895	3,893	3,903	475	1,762,915	1,755,244	1,760,730	1,761,443	1,764,245	250	932,938	938,088
034750m	109	182				3,571	3,602							225	798,176	801,889
034975m	215	285	3,513	3,516	3,519	3,524	3,526	340	1,393,201	1,392,164	1,392,436	1,392,708	1,394,391	340	1,392,708	1,394,391

Site	Offset (m)		Area under the Section (m²)					Long-Term Analysis						Short-Term Analysis		
								Distance	Volume (m³)					Distance	Volume (m³)	
	Left	Right	1998/1999	2011/2012	2016	2022	2024		1998/1999	2011/2012	2016	2022	2024		2022	2024
Lower Gravel Phase (cont.)																
035315m	223	314	4,683	4,673	4,672	4,668	4,677	310	1,298,590	1,296,033	1,298,125	1,297,567	1,298,420	310	1,297,567	1,298,420
035625m	373	443	3,695	3,689	3,703	3,703	3,700	375	1,120,200	1,113,281	1,117,013	1,117,706	1,118,119	195	708,835	708,825
035820m	77	144					3,567	3,570						180	524,268	524,925
036000m	45	87	2,279	2,249	2,255	2,258	2,263	290	1,022,134	1,008,954	1,012,332	1,012,492	1,015,464	290	1,012,492	1,015,464
036290m	380	465	4,770	4,709	4,727	4,725	4,740	480	2,805,912	2,768,808	2,774,832	2,774,520	2,777,496	480	2,774,520	2,777,496
036770m	350	469	6,921	6,827	6,835	6,836	6,833	290	1,424,335	1,407,515	1,409,110	1,410,546	1,409,792	290	1,410,546	1,409,792
037060m	436	486	2,902	2,880	2,883	2,892	2,890	440	1,494,372	1,487,244	1,489,202	1,491,578	1,492,854	440	1,491,578	1,492,854
037500m	9	74	3,891	3,881	3,886	3,888	3,896	285	970,653	965,680	967,903	968,416	970,112	285	968,416	970,112
037785m	7	55	2,921	2,896	2,906	2,908	2,912	335	1,516,126	1,497,819	1,502,023	1,505,138	1,505,540	335	1,505,138	1,505,540
038120m	10	108	6,131	6,046	6,061	6,078	6,076	455	3,013,875	2,969,671	2,977,065	2,982,957	2,983,276	455	2,982,957	2,983,276
038575m	29	139	7,117	7,008	7,025	7,034	7,037	425	2,528,474	2,487,801	2,491,159	2,495,876	2,498,851	425	2,495,876	2,498,851
039000m	-29	43	4,782	4,700	4,698	4,711	4,722	350	1,340,833	1,321,898	1,321,635	1,325,415	1,327,480	350	1,325,415	1,327,480
039350m	145	188	2,880	2,854	2,854	2,863	2,864	365	1,433,209	1,430,161	1,428,829	1,431,348	1,432,479	365	1,431,348	1,432,479
039715m	108	181	4,973	4,983	4,975	4,981	4,986	360	1,697,022	1,696,662	1,698,444	1,696,248	1,701,540	360	1,696,248	1,701,540
040075m	280	344	4,455	4,443	4,461	4,443	4,467	425	2,424,264	2,413,936	2,419,738	2,417,018	2,420,566	425	2,417,018	2,420,566
040500m	2	99	6,953	6,916	6,926	6,931	6,924	365	2,425,900	2,404,474	2,406,317	2,405,861	2,405,186	200	1,711,010	1,712,510
040700m	10	150					10,179	10,202						165	1,355,533	1,357,703
040865m	20	105	6,339	6,259	6,259	6,252	6,256	410	2,592,574	2,563,894	2,563,177	2,561,086	2,561,229	410	2,561,086	2,561,229
041275m	39	122	6,307	6,248	6,244	6,241	6,238	415	2,504,069	2,471,284	2,469,395	2,469,997	2,468,731	415	2,469,997	2,468,731
041690m	14	88	5,760	5,662	5,657	5,662	5,659	310	1,739,643	1,708,069	1,705,744	1,709,883	1,705,636	310	1,709,883	1,705,636
042000m	-44	25	5,463	5,358	5,348	5,369	5,345	405	2,121,370	2,066,756	2,065,662	2,069,753	2,064,933	240	1,231,908	1,225,560
042240m	14	76					4,897	4,868						165	804,235	801,933
042405m	120	181	5,013	4,848	4,853	4,852	4,852	350	2,800,735	2,754,273	2,755,585	2,754,115	2,755,410	350	2,754,115	2,755,410
042755m	388	520	10,991	10,891	10,894	10,886	10,893	385	3,803,685	3,764,376	3,766,917	3,763,606	3,765,319	385	3,763,606	3,765,319
043140m	225	328	8,768	8,665	8,675	8,665	8,667	360	2,520,792	2,471,004	2,471,526	2,468,826	2,468,070	360	2,468,826	2,468,070
043500m	-15	45	5,236	5,063	5,056	5,051	5,044							1865	11,381,069	11,380,883
Upper Gravel Phase																
045365m	4.9	82.5					7,154	7,160						365	2,879,047	2,883,956
045730m	20	112					8,621	8,642						1510	11,100,237	11,140,025
047240m	73.5	135					6,081	6,113						1045	5,943,072	5,951,275
048285m	2	53.4					5,293	5,277						675	4,922,843	4,899,791
048960m	1.6	89					9,293	9,241						145	1,394,509	1,392,239
049105m	42	135					9,942	9,963						135	1,130,780	1,132,367
049240m	19.9	83.2					6,811	6,813						1020	6,976,698	6,964,152
050260m	48	109.6					6,869	6,842						1440	11,146,464	11,159,352
051700m	3	77.25					8,612	8,657						270	3,359,840	3,368,156

Site	Offset (m)		Area under the Section (m²)					Long-Term Analysis						Short-Term Analysis		
								Distance	Volume (m³)					Distance	Volume (m³)	
	Left	Right	1998/1999	2011/2012	2016	2022	2024		1998/1999	2011/2012	2016	2022	2024		2022	2024
Upper Gravel Phase (cont.)																
051970m	-20	118				16,276	16,292							310	4,027,396	4,032,589
052280m	13	94.5				9,708	9,725							380	2,981,043	2,985,128
052660m	3.9	53.4				5,982	5,987							230	1,727,622	1,723,632
052890m	-28.6	45				9,041	9,002							280	2,496,158	2,490,432
053170m	3.8	75				8,789	8,787							805	7,228,900	7,232,321
053975m	32	104				9,171	9,181							75	685,725	687,004
054050m	1.55	73				9,115	9,139							595	4,173,836	4,180,976
054645m	10	48				4,915	4,915							35	175,173	175,137
054680m	0.65	40				5,095	5,093							30	160,214	160,124
054710m	2	45				5,586	5,582							100	470,755	470,130
054810m	0	29.5				3,830	3,821							40	165,036	164,796
054850m	0	34				4,422	4,419							55	243,818	243,397
054905m	0.08	34.2				4,444	4,432							410	2,596,879	2,595,034
055315m	0	62				8,224	8,227							835	7,466,737	7,481,266
056150m	56	127				9,661	9,692							550	4,780,270	4,789,538
056700m	67	122.6				7,722	7,724							2340	38,068,290	37,923,795
059040m	-53	113				24,815	24,689							1970	40,142,395	39,984,696
061010m	10	111				15,939	15,904							235	2,614,070	2,609,781
061245m	1.5	41.5				6,308	6,307							315	2,193,329	2,194,542
061560m	5	53				7,618	7,627							195	2,416,089	2,419,160
061755m	0	107				17,163	17,185							160	2,465,512	2,466,784
061915m	20	105				13,656	13,650							205	3,056,581	3,059,154
062120m	10.2	110				16,164	16,195							360	4,079,700	4,084,956
062480m	0.1	40				6,501	6,499							710	5,235,576	5,229,044
063190m	9.5	59				8,247	8,231							765	7,162,619	7,156,460
063955m	3.5	65.2				10,478	10,479							75	656,618	656,434
064030m	3.8	45.3				7,031	7,026							375	4,382,156	4,377,338
064405m	12	107				16,340	16,320							355	5,699,401	5,698,158
064760m	17	107.8				15,769	15,783							2145	32,010,479	32,024,421
066905m	3.5	80				14,077	14,077							325	4,400,305	4,400,094
067230m	10	80				13,001	13,001							120	1,457,934	1,457,862
067350m	7	67.7				11,298	11,297							550	5,948,140	5,944,703
067900m	0.43	55.46	10,356	10,354	10,335	10,332	10,320							655	11,730,886	11,738,288
068555m	1	134				25,487	25,522							505	9,924,790	9,929,512
069060m	36.8	108				13,819	13,803									
073210m	-9.8	134				31,054	30,901									

Site	Offset (m)		Area under the Section (m²)					Long-Term Analysis						Short-Term Analysis		
								Distance	Volume (m³)					Distance	Volume (m³)	
	Left	Right	1998/1999	2011/2012	2016	2022	2024		1998/1999	2011/2012	2016	2022	2024		2022	2024
Upper Gravel Phase (cont.)																
076935m	123	222.3				23,429	23,422									
081740m	60	158.4				25,825	25,862									
082100m	0.4	76.7	20,147	20,162	20,167	20,143	20,145									
083100m	110.6	185.2	20,149			20,098	20,120									
084100m	2.2	105	28,362			28,335	28,341									
084500m	1.9	92	25,021			25,038	25,060									
084680m	-32	81.8				31,814	31,820									
084900m	2	85.4	23,558	23,453	23,449	23,446	23,434									
096440m	3	48.5				16,348	16,324									
101975m	12.6	235				90,097	90,089									
105455m	0.25	117.5				50,501	50,520									
107695m	3	58.5	24,803	24,807	24,817	24,817	24,811									
108035m	-8	171				80,582	80,623									
114355m	1	77.5				39,109	39,117									
115725m	10	97				45,707	45,746									

Appendix C

Mean Bed Level (MBL) raw results. Cross-section sites with missing values in any of the years of interest (1998/1999, 2011/2012, 2016, 2022, 2024) were not used in the long-term analysis. Left and Right Offsets indicate the distance in metres along the cross-section from the true left as stored in Hilltop used to calculate the elevation in metres (NZVD16) of the MBL. Blanks indicate no data was available/appropriate for use.

Site	1998/1999				2011/2012				2016				2022				2024			
	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL
		Left	Right			Left	Right			Left	Right			Left	Right			Left	Right	
Silt Phase																				
000000m	05/05/1998	21.0	39.0	1.2	20/01/2012	21.0	39.0	0.9	02/02/2016	21.0	39.0	1.1	11/04/2022	24.0	39.0	0.8	22/10/2024	24.0	41.5	1.3
001150m	05/05/1998	44.0	56.0	1.7	25/01/2012	44.0	56.0	1.1	02/02/2016	44.0	56.0	1.2	11/04/2022	44.0	58.0	1.1	22/10/2024	44.0	58.0	1.5
001500m	05/05/1998	233.0	254.0	1.6	25/01/2012	238.0	249.0	1.6	02/02/2016	232.0	246.0	1.3	11/04/2022	225.5	245.0	1.3	22/10/2024	220.0	239.0	1.6
002125m	01/05/1998	113.0	129.0	2.2	25/01/2012	113.0	127.5	1.8	02/02/2016	113.0	127.5	1.7	06/07/2022	113.0	127.5	1.8	22/10/2024	113.0	127.5	1.9
002600m	05/05/1998	43.0	55.0	1.8	25/01/2012	47.0	56.0	1.4	02/02/2016	47.0	55.0	1.6	06/07/2022	47.5	57.0	2.4	22/10/2024	49.0	57.0	1.7
003000m	05/05/1998	65.0	79.5	2.3	25/01/2012	65.5	78.0	2.1	02/02/2016	67.0	77.0	2.1	06/07/2022	64.5	76.0	3.0	22/10/2024	64.5	76.5	2.6
003535m	05/05/1998	87.0	100.0	2.5	25/01/2012	89.0	100.0	2.0	02/02/2016	88.0	99.0	2.3	06/07/2022	90.0	100.0	2.4	22/10/2024	91.0	100.0	2.1
003965m	05/05/1998	17.0	32.0	3.3	29/02/2012	17.0	32.0	3.7	02/02/2016	17.0	32.0	3.7	04/07/2022	20.0	32.0	3.5	23/10/2024	20.0	32.0	3.6
004500m	05/05/1998	37.0	51.0	3.1	26/01/2012	37.0	51.0	3.5	02/02/2016	37.0	51.0	3.5	05/07/2022	37.0	53.0	4.0	23/10/2024	40.0	53.0	3.8
004970m	01/05/1998	185.0	197.0	3.7	26/01/2012	185.0	197.0	3.3	02/02/2016	185.0	197.0	3.5	05/07/2022	180.0	199.0	4.2	23/10/2024	180.0	199.0	4.3
005520m	01/05/1998	59.0	79.0	4.3	26/01/2012	64.0	79.0	4.0	02/02/2016	65.0	79.0	3.8	05/07/2022	66.0	79.0	4.3	23/10/2024	67.0	79.0	4.2
006000m	21/04/1998	123.0	145.0	4.5	26/01/2012	123.0	140.0	4.3	02/02/2016	123.0	140.0	4.3	05/07/2022	125.0	140.0	4.7	23/10/2024	123.0	138.0	4.5
006575m	01/05/1998	84.0	103.0	4.6	26/01/2012	90.0	103.0	4.3	02/02/2016	92.0	103.0	4.3	05/07/2022	92.0	103.0	5.1	23/10/2024	92.0	103.0	4.5
007025m													05/07/2022	53.0	62.5	4.8	23/10/2024	53.0	62.5	4.8
007500m													05/07/2022	57.0	72.0	5.7	23/10/2024	57.0	75.0	5.6
007985m													05/07/2022	20.0	36.0	5.8	21/10/2024	20.0	36.0	5.7
008485m	01/05/1998	68.0	82.0	5.1	27/01/2012	70.5	81.0	5.1	04/02/2016	70.5	81.0	5.3	05/07/2022	70.5	82.0	5.7	21/10/2024	68.0	79.0	5.6
009000m	01/05/1998	65.0	82.0	5.8	27/01/2012	66.0	80.0	5.8	04/02/2016	59.0	78.5	6.3	05/07/2022	63.5	77.0	6.2	21/10/2024	63.5	77.0	6.0
009420m	01/05/1998	59.0	75.0	6.1	27/01/2012	59.0	72.0	6.2	04/02/2016	59.0	72.0	6.3	05/07/2022	55.0	70.0	6.5	21/10/2024	55.0	67.0	6.4
009800m	01/05/1998	128.0	145.5	6.1	31/01/2012	128.0	146.0	6.2	04/02/2016	128.0	141.0	6.6	01/07/2022	128.0	139.0	6.2	21/10/2024	128.0	139.0	6.2
010150m	01/05/1998	27.0	40.0	6.1	31/01/2012	27.0	40.0	6.5	04/02/2016	27.0	40.0	7.0	01/07/2022	27.0	37.0	6.3	21/10/2024	28.0	40.0	6.7
010500m	01/05/1998	26.0	38.0	5.8	31/01/2012	26.0	38.0	6.9	04/02/2016	26.0	36.0	6.6	01/07/2022	26.0	40.0	6.8	21/10/2024	26.0	40.0	6.5
010860m	01/05/1998	71.0	85.0	6.7	31/01/2012	71.0	85.0	7.4	04/02/2016	71.5	85.0	7.2	01/07/2022	71.0	82.0	6.9	21/10/2024	71.0	81.0	6.4
011200m	01/05/1998	78.0	93.0	6.9	31/01/2012	79.0	90.0	7.4	04/02/2016	79.0	90.0	7.5	01/07/2022	79.0	91.5	7.5	21/10/2024	80.0	94.0	7.7
011580m	01/05/1998	123.0	143.0	7.5	31/01/2012	130.0	142.0	7.5	04/02/2016	130.0	142.0	7.9	06/05/2022	130.0	143.0	7.5	21/10/2024	130.0	142.0	7.5
012000m	01/05/1998	91.0	107.5	7.8	01/02/2012	93.0	104.0	8.1	04/02/2016	93.0	104.0	8.1	06/05/2022	90.0	104.0	8.2	21/10/2024	90.0	102.5	8.3
012290m	01/05/1998	138.0	159.0	8.1	01/02/2012	139.0	152.0	8.5	04/02/2016	139.0	154.0	8.5	06/05/2022	138.0	152.5	8.5	21/10/2024	135.0	149.0	8.5
012640m	01/05/1998	55.5	75.0	8.4	01/02/2012	55.5	68.0	8.5	04/02/2016	55.0	66.0	8.5	06/05/2022	55.5	67.0	8.4	21/10/2024	55.5	67.5	8.5
013100m	01/05/1998	69.0	83.0	8.2	02/02/2012	69.0	83.0	9.1	15/02/2016	69.0	83.0	9.0	06/05/2022	69.0	83.0	9.3	16/08/2024	69.0	83.0	9.3
013500m	01/05/1998	73.0	92.5	9.0	02/02/2012	72.0	90.0	9.6	15/02/2016	65.0	86.5	9.9	06/05/2022	64.0	83.0	9.9	16/08/2024	62.0	82.0	9.7
013850m	01/05/1998	29.0	50.0	9.4	02/02/2012	31.0	47.0	9.4	15/02/2016	32.0	47.0	9.5	06/05/2022	34.0	47.5	9.3	16/08/2024	34.0	49.0	9.7
014215m	01/05/1998	26.5	44.0	9.4	02/02/2012	28.0	44.0	9.9	15/02/2016	28.0	44.0	10.1	05/05/2022	28.0	44.0	10.0	16/08/2024	28.0	44.0	10.1

Site	1998/1999				2011/2012				2016				2022				2024			
	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL
		Left	Right			Left	Right			Left	Right			Left	Right			Left	Right	
014550m	01/05/1998	20.0	42.0	10.1	02/02/2012	23.0	37.5	9.8	15/02/2016	23.0	34.5	9.8	05/05/2022	23.0	40.5	9.7	16/08/2024	23.0	42.0	10.5
Silt Phase (cont.)																				
015000m	01/05/1998	37.0	56.0	10.1	02/02/2012	38.0	50.0	10.0	15/02/2016	37.0	50.0	10.2	05/05/2022	41.0	53.0	10.1	16/08/2024	38.5	54.0	10.0
015325m	01/05/1998	66.5	82.0	10.4	02/02/2012	69.0	82.0	10.5	15/02/2016	69.0	82.0	10.6	05/05/2022	67.0	82.0	10.7	16/08/2024	69.0	80.0	10.2
015700m	01/05/1998	33.0	50.5	10.8	02/02/2012	38.0	52.0	11.1	15/02/2016	38.5	51.5	11.2	05/05/2022	45.0	67.0	11.5	16/08/2024	49.0	71.0	11.5
016075m	01/05/1998	24.5	43.0	11.0	03/02/2012	28.0	44.0	11.4	15/02/2016	34.0	44.5	11.3	05/05/2022	31.0	47.0	11.4	16/08/2024	33.5	49.0	11.4
016500m	01/05/1998	41.0	74.0	11.7	03/02/2012	54.0	81.0	11.9	15/02/2016	51.5	71.0	11.9	05/05/2022	58.0	76.5	11.8	16/08/2024	52.0	72.0	11.8
016900m	01/05/1998	185.0	205.0	11.8	03/02/2012	185.0	205.5	12.4	15/02/2016	185.0	205.5	12.5	05/05/2022	156.0	204.0	12.2	16/08/2024	115.5	188.0	13.2
017225m	01/05/1998	70.0	90.0	12.3	03/02/2012	77.0	93.0	12.9	15/02/2016	78.0	92.5	12.6	03/05/2022	80.0	95.0	12.5	07/08/2024	80.0	97.5	12.7
017625m	01/05/1998	49.0	69.0	12.7	03/02/2012	51.0	68.0	13.1	22/02/2016	52.0	67.0	13.0	03/05/2022	51.5	67.0	13.0	07/08/2024	52.5	68.0	12.9
018000m	01/05/1998	54.5	73.0	12.8	03/02/2012	47.0	65.0	13.4	22/02/2016	46.0	65.5	13.7	03/05/2022	50.0	66.0	13.3	07/08/2024	50.0	65.0	13.1
018340m	01/05/1998	45.0	60.0	12.9	03/02/2012	49.0	60.0	13.0	18/02/2016	49.0	60.0	13.0	03/05/2022	49.0	60.0	12.8	07/08/2024	49.0	60.0	12.9
018725m	01/05/1998	21.0	41.0	13.7	03/02/2012	25.0	40.0	14.0	18/02/2016	26.0	40.0	13.9	03/05/2022	29.0	44.5	13.9	07/08/2024	29.0	46.0	13.9
019125m	01/05/1998	70.0	86.0	13.7	09/02/2012	71.0	86.0	14.3	18/02/2016	72.0	84.5	14.1	03/05/2022	72.0	85.0	14.3	07/08/2024	72.5	86.0	14.2
019500m	01/05/1998	52.0	67.0	14.1	09/02/2012	50.5	64.5	14.4	18/02/2016	53.0	65.0	14.2	03/05/2022	50.5	65.0	14.7	07/08/2024	49.0	63.0	14.6
019750m	01/05/1998	39.0	60.0	14.8	09/02/2012	48.0	61.5	15.1	18/02/2016	47.0	61.0	15.1	03/05/2022	46.0	60.0	14.9	07/08/2024	46.0	61.5	15.0
020100m	01/05/1998	168.0	181.0	14.3	09/02/2012	171.0	184.0	15.0	18/02/2016	171.0	183.0	15.1	03/05/2022	171.0	183.0	14.8	07/08/2024	170.0	183.0	14.9
020400m	01/05/1998	46.0	67.0	15.5	09/02/2012	48.0	62.0	15.7	18/02/2016	47.0	62.0	15.7	03/05/2022	51.0	67.0	15.8	06/08/2024	51.0	69.0	15.8
020725m	01/05/1998	53.0	68.5	15.5	22/02/2012	54.0	69.0	15.9	18/02/2016	53.0	67.0	15.9	02/05/2022	56.0	68.0	15.6	06/08/2024	54.5	67.0	15.9
020865m													09/09/2022	24.0	51.0	16.7	24/10/2024	24.0	42.0	16.4
021000m	01/05/1998	84.0	98.0	15.9	21/02/2012	85.0	98.0	16.0	18/02/2016	84.0	98.0	16.3	02/05/2022	84.0	109.0	16.8	06/08/2024	86.0	108.0	16.7
021100m	01/05/1998	55.5	77.0	16.2	21/02/2012	61.0	77.0	16.4	18/02/2016	61.0	77.0	16.4	02/05/2022	59.0	75.5	16.5	06/08/2024	59.0	75.5	16.5
021335m	01/05/1998	61.5	78.0	16.3	21/02/2012	57.5	70.5	16.2	18/02/2016	58.5	70.0	16.4	02/05/2022	59.0	73.0	16.9	06/08/2024	55.0	73.0	17.1
021550m	01/05/1998	135.0	150.0	16.6	21/02/2012	142.0	149.0	16.1	18/02/2016	134.0	145.0	16.6	02/05/2022	136.0	145.0	16.0	06/08/2024	140.0	153.0	17.1
021740m													09/09/2022	52.0	79.0	17.9	24/10/2024	52.0	82.0	17.9
021835m	01/05/1998	81.0	103.0	17.3	21/02/2012	98.0	113.0	17.4	18/02/2016	90.0	112.0	17.7	02/05/2022	94.0	110.0	17.5	06/08/2024	94.0	110.0	17.5
022150m	01/05/1998	16.0	30.0	17.0	21/02/2012	16.5	31.0	17.4	18/02/2016	16.5	31.0	17.5	02/05/2022	17.0	35.0	17.6	06/08/2024	17.0	32.0	17.7
022500m	01/05/1998	28.5	44.5	17.6	23/11/2011	30.0	46.0	18.0	18/02/2016	31.0	45.0	18.0	02/05/2022	31.0	65.5	18.5	06/08/2024	31.0	71.0	18.8
022810m	01/05/1998	115.0	133.0	18.1	23/11/2011	116.0	131.0	18.0	23/02/2016	117.5	131.0	17.9	02/05/2022	115.5	130.0	18.1	06/08/2024	115.0	136.0	18.8
023085m	01/05/1998	37.0	72.0	19.1	23/11/2011	46.0	71.0	19.1	23/02/2016	53.0	72.0	18.9	21/04/2022	54.0	72.0	18.7	06/08/2024	54.0	72.0	18.9
023395m	01/05/1998	82.0	108.0	19.5	23/11/2011	84.5	105.0	19.3	23/02/2016	86.0	103.5	19.2	21/04/2022	85.0	102.5	19.2	06/08/2024	85.0	101.5	19.3
023700m	01/05/1998	100.0	143.5	20.3	23/11/2011	85.0	141.0	20.1	23/02/2016	88.0	132.0	20.1	21/04/2022	94.0	130.0	19.9	06/08/2024	94.0	121.0	20.3
024000m	01/05/1998	11.0	42.0	20.7	23/11/2011	12.0	42.0	20.2	23/02/2016	12.0	42.0	20.4	21/04/2022	13.5	42.0	20.4	06/08/2024	13.0	42.0	20.5
024325m	01/05/1998	15.0	48.0	21.4	23/11/2011	21.5	57.0	20.8	23/02/2016	21.5	45.0	20.8	21/04/2022	22.0	44.0	20.6	06/08/2024	23.0	45.0	20.8
Lower Gravel Phase																				
024765m	01/05/1998	96.0	115.0	21.8	26/10/2011	74.0	116.0	21.5	23/02/2016	81.0	116.0	21.4	26/04/2022	64.5	116.0	21.9	06/08/2024	67.0	110.0	21.9
025050m	01/05/1998	60.0	81.0	22.3	26/10/2011	51.0	81.5	22.1	23/02/2016	38.0	77.0	22.2	26/04/2022	42.0	75.0	22.4	06/08/2024	41.0	74.0	22.6
025440m	01/05/1998	142.0	170.0	23.3	26/10/2011	142.0	174.0	22.7	23/02/2016	141.0	174.0	22.9	26/04/2022	141.0	172.0	22.9	05/08/2024	143.0	172.0	23.2
025500m	01/05/1998	70.5	103.0	23.5	26/10/2011	72.5	104.5	22.9	23/02/2016	72.5	104.5	22.8	26/04/2022	70.5	104.5	23.1	05/08/2024	72.5	104.5	23.3

Site	1998/1999				2011/2012				2016				2022				2024			
	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL
		Left	Right			Left	Right			Left	Right			Left	Right			Left	Right	
Lower Gravel Phase (cont.)																				
025675m	01/05/1998	19.0	40.0	23.6	31/10/2011	20.5	42.0	23.0	23/02/2016	20.5	39.0	22.6	26/04/2022	23.0	41.0	23.0	05/08/2024	23.0	40.0	23.2
026080m	01/05/1998	143.0	163.0	24.4	31/10/2011	146.0	168.0	23.7	23/02/2016	144.5	168.0	23.6	26/04/2022	145.0	167.0	23.7	05/08/2024	145.0	167.0	24.2
026370m	01/05/1998	190.0	215.5	25.1	01/11/2011	195.0	223.0	24.4	23/02/2016	195.0	223.0	24.4	26/04/2022	201.0	223.0	24.4	30/07/2024	201.0	223.0	24.7
026610m	01/05/1998	74.0	97.0	25.5	01/11/2011	75.5	97.0	24.7	23/02/2016	76.5	97.0	24.6	26/04/2022	75.5	97.0	24.9	30/07/2024	76.5	97.0	25.1
026880m	01/05/1998	80.0	104.0	26.2	01/11/2011	82.0	106.5	25.4	24/02/2016	83.0	111.0	25.5	27/04/2022	84.5	110.0	25.7	30/07/2024	85.5	109.0	25.9
027000m	01/05/1998	56.0	76.0	26.2	31/10/2011	56.0	81.0	25.7	24/02/2016	56.0	82.0	25.7	27/04/2022	56.0	80.5	25.8	30/07/2024	57.0	80.5	26.1
027250m	01/05/1998	302.0	319.5	26.6	31/10/2011	289.0	322.5	26.1	24/02/2016	290.0	321.5	26.3	27/04/2022	296.0	327.0	26.5	30/07/2024	299.0	324.0	26.7
027400m													09/09/2022	146.0	185.0	27.3	24/10/2024	152.0	185.0	27.3
027575m	01/05/1998	223.0	246.0	27.2	31/10/2011	211.0	241.0	27.0	24/02/2016	209.0	238.0	27.1	27/04/2022	211.0	239.0	27.3	30/07/2024	213.0	239.5	27.3
027835m	01/05/1998	152.0	170.0	27.8	31/10/2011	150.0	165.0	27.4	24/02/2016	150.0	165.0	27.4	27/04/2022	150.5	168.0	27.4	30/07/2024	150.5	168.0	27.7
028115m	01/05/1998	229.0	252.0	28.6	31/10/2011	229.0	254.0	28.0	24/02/2016	229.0	252.0	28.0	27/04/2022	228.5	247.0	28.0	30/07/2024	228.5	249.5	28.3
028500m	01/05/1998	125.0	152.5	29.3	02/11/2011	126.0	151.5	28.8	24/02/2016	125.0	149.0	28.8	28/04/2022	127.0	149.0	28.8	18/07/2024	127.0	149.0	29.1
028750m	01/05/1998	149.5	176.5	30.1	02/11/2011	148.0	167.0	29.4	24/02/2016	145.5	167.0	29.3	28/04/2022	147.5	167.0	29.4	18/07/2024	150.0	167.0	29.5
029125m	01/05/1998	177.0	199.5	30.8	02/11/2011	171.0	202.0	30.7	24/02/2016	174.0	202.0	30.6	28/04/2022	175.0	202.0	30.6	18/07/2024	175.0	202.0	30.8
029400m	01/05/1998	146.5	173.5	31.4	31/10/2011	116.0	137.0	31.2	24/02/2016	116.0	137.0	31.2	28/04/2022	116.0	135.0	31.0	18/07/2024	117.5	140.0	31.4
029700m	01/05/1998	282.0	295.5	32.1	03/11/2011	280.0	303.5	32.1	24/02/2016	280.0	303.5	32.1	28/04/2022	284.0	303.5	31.9	18/07/2024	285.0	303.0	32.3
030000m	01/05/1998	109.0	138.0	33.1	03/11/2011	76.5	125.0	33.3	24/02/2016	79.0	128.0	33.3	28/04/2022	79.0	124.0	33.3	18/07/2024	82.0	114.0	33.1
030250m	01/05/1998	31.5	60.0	33.9	16/11/2011	31.5	60.0	33.4	16/03/2016	31.5	62.0	33.6	28/04/2022	31.5	62.0	33.2	18/07/2024	31.5	62.0	33.8
030350m													09/09/2022	7.0	33.0	33.8	05/08/2024	7.0	40.0	34.2
030450m													09/09/2022	27.0	67.0	34.4	05/08/2024	27.0	67.0	34.8
030600m	01/05/1998	492.0	553.5	35.0	16/11/2011	512.0	554.0	35.2	25/02/2016	477.0	561.0	34.8	12/05/2022	477.0	560.0	35.1	17/07/2024	481.0	557.5	35.1
030720m													09/09/2022	46.0	93.5	35.6	05/08/2024	46.0	93.5	35.7
031050m	01/05/1998	133.0	162.0	36.3	17/11/2011	143.0	185.0	36.4	25/02/2016	145.0	185.0	36.4	12/05/2022	145.0	185.0	36.2	18/07/2024	150.0	185.0	36.5
031500m	01/05/1998	150.0	168.0	36.9	17/11/2011	147.0	166.0	37.2	25/02/2016	146.0	166.0	37.1	12/05/2022	150.0	167.0	37.1	18/07/2024	148.0	167.0	37.5
031825m	01/05/1998	252.0	277.0	38.3	17/11/2011	252.0	307.0	38.6	25/02/2016	259.0	305.0	38.7	12/05/2022	257.0	305.0	38.7	18/07/2024	280.0	305.0	38.7
032160m	01/05/1998	104.0	126.0	39.2	18/11/2011	108.0	156.0	39.8	25/02/2016	85.0	124.0	39.7	12/05/2022	78.0	101.0	39.5	17/07/2024	76.0	101.0	39.6
032560m	01/05/1998	320.0	354.0	40.6	18/11/2011	333.0	360.0	40.7	25/02/2016	333.0	360.0	40.8	12/05/2022	333.0	363.0	41.0	17/07/2024	333.0	364.0	41.0
033000m	01/05/1998	116.0	153.0	41.8	18/11/2011	119.0	156.0	42.0	25/02/2016	119.0	156.0	42.2	12/05/2022	120.0	155.0	42.1	17/07/2024	116.0	155.5	42.5
033315m	01/05/1998	77.0	150.0	43.5	22/11/2011	78.0	120.0	43.1	25/02/2016	77.0	116.5	43.4	12/05/2022	79.5	120.0	43.5	16/07/2024	79.5	106.0	43.5
033800m	01/05/1998	213.0	272.0	45.0	22/11/2011	211.5	258.0	44.9	29/02/2016	209.0	255.0	44.9	12/05/2022	216.0	254.0	44.9	16/07/2024	216.0	272.0	45.3
034160m	01/05/1998	243.0	300.0	46.5	22/11/2011	258.0	305.0	46.0	29/02/2016	258.0	305.0	46.1	11/05/2022	261.0	303.0	46.2	16/07/2024	261.0	303.0	46.3
034500m	01/05/1998	91.0	117.0	47.4	23/11/2011	76.0	96.0	47.0	29/02/2016	76.5	96.0	47.1	11/05/2022	76.0	96.0	47.3	16/07/2024	76.0	96.0	47.4
034750m													12/09/2022	112.0	173.0	48.7	24/10/2024	132.0	173.0	48.9
034975m	01/05/1998	224.0	264.0	49.3	08/12/2011	224.0	262.0	49.2	29/02/2016	224.0	260.0	49.3	11/05/2022	225.0	260.0	49.3	16/07/2024	227.0	260.0	49.3
035315m	01/05/1998	284.0	358.0	51.0	13/12/2011	241.0	306.0	50.8	29/02/2016	241.0	306.0	50.8	11/05/2022	243.0	312.0	50.9	16/07/2024	244.0	310.5	50.9
035625m	01/05/1998	387.5	434.0	52.2	08/12/2011	387.5	428.0	51.9	29/02/2016	394.0	427.0	51.8	11/05/2022	394.0	425.0	51.7	16/07/2024	389.0	425.0	51.8
035820m													12/09/2022	95.0	135.0	52.7	12/11/2024	95.0	135.0	52.6
036000m	01/05/1998	40.0	81.0	54.1	11/12/2011	48.0	83.0	53.3	29/02/2016	48.0	83.0	53.4	11/05/2022	51.0	81.0	53.4	16/07/2024	51.0	81.0	53.5

Site	1998/1999				2011/2012				2016				2022				2024			
	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL
		Left	Right			Left	Right			Left	Right			Left	Right			Left	Right	
Lower Gravel Phase (cont.)																				
036290m	01/05/1998	428.0	457.0	54.6	09/12/2011	415.0	459.0	54.4	29/02/2016	415.0	455.5	54.5	13/05/2022	415.0	455.5	54.5	16/07/2024	415.0	453.0	54.5
036770m	01/05/1998	414.0	453.0	56.5	09/12/2011	389.0	455.0	56.3	01/03/2016	394.0	460.0	56.4	13/05/2022	397.5	462.0	56.4	16/07/2024	397.0	462.0	56.4
037060m	01/05/1998	439.0	471.0	57.2	09/12/2011	439.0	480.0	57.3	01/03/2016	440.0	481.0	57.3	13/05/2022	442.0	477.0	57.4	16/07/2024	441.0	477.0	57.4
037500m	01/05/1998	18.0	61.0	59.2	12/12/2011	16.0	60.0	59.0	01/03/2016	16.0	57.0	59.0	13/05/2022	16.0	56.0	59.0	15/07/2024	16.0	56.5	59.1
037785m	01/05/1998	16.0	46.0	60.1	12/12/2011	15.5	50.0	59.6	01/03/2016	16.0	50.0	59.8	13/05/2022	18.5	49.0	59.7	15/07/2024	18.5	48.0	59.8
038120m	01/05/1998	54.0	100.0	61.4	12/12/2011	21.0	103.0	61.4	01/03/2016	20.0	98.0	61.5	13/05/2022	19.0	94.5	61.7	15/07/2024	19.0	95.0	61.6
038575m	01/05/1998	35.0	103.0	63.9	13/12/2011	37.0	113.0	63.3	01/03/2016	37.0	134.0	63.7	14/04/2022	37.0	134.0	63.8	15/07/2024	37.0	105.0	63.6
039000m	01/07/1998	12.5	39.0	64.6	13/12/2011	-23.0	17.0	64.7	01/03/2016	-23.0	17.0	64.6	14/04/2022	-23.0	17.0	64.7	15/07/2024	-23.0	17.0	64.7
039350m	01/07/1998	145.0	170.0	65.7	13/12/2011	149.0	178.0	65.6	01/03/2016	149.0	180.0	65.6	14/04/2022	152.0	179.0	65.7	15/07/2024	152.0	181.0	65.7
039715m	01/07/1998	116.0	160.0	67.7	13/12/2011	116.0	170.0	67.8	01/03/2016	116.0	170.0	67.6	14/04/2022	116.0	170.0	67.7	15/07/2024	116.0	170.0	67.7
040075m	01/07/1998	310.0	338.0	68.8	19/12/2011	302.0	338.0	68.8	08/03/2016	307.0	338.0	68.7	19/04/2022	308.0	338.0	68.7	11/07/2024	304.0	338.0	68.9
040500m	01/07/1998	20.0	91.0	71.2	19/12/2011	14.0	91.0	70.8	08/03/2016	15.0	88.0	70.9	19/04/2022	17.0	89.0	70.9	03/07/2024	16.0	83.0	70.7
040700m													01/09/2022	31.0	64.0	71.6	03/07/2024	31.0	86.0	72.0
040865m	01/07/1998	53.0	145.0	73.4	19/12/2011	38.0	126.0	73.1	08/03/2016	38.0	126.0	73.1	20/04/2022	39.0	104.0	72.8	05/07/2024	38.0	96.0	72.7
041275m	01/07/1998	49.0	102.0	74.9	21/12/2011	50.0	116.0	74.9	08/03/2016	50.0	115.0	74.9	20/04/2022	63.0	115.0	74.5	05/07/2024	63.0	115.0	74.5
041690m	01/07/1998	39.0	69.0	76.2	21/12/2011	15.0	60.0	76.0	08/03/2016	15.0	60.0	76.0	20/04/2022	15.0	60.0	76.0	05/07/2024	15.0	60.0	75.9
042000m	01/07/1998	-48.0	-14.0	77.1	21/12/2011	-36.0	18.5	77.3	08/03/2016	-40.0	18.5	77.2	20/04/2022	-17.0	18.5	77.1	05/07/2024	-25.0	18.5	76.9
042240m													12/09/2022	22.5	68.0	78.5	11/07/2024	22.5	68.0	77.9
042405m	01/07/1998	169.0	193.0	78.7	19/12/2011	124.0	166.0	79.0	09/03/2016	124.0	164.0	78.9	20/04/2022	124.0	158.0	78.7	11/07/2024	124.0	161.0	78.6
042755m	01/07/1998	458.0	493.0	79.9	19/12/2011	427.0	467.0	80.5	09/03/2016	427.0	455.0	80.2	20/04/2022	427.0	455.0	79.9	11/07/2024	427.0	455.0	79.7
043140m	01/07/1998	250.0	286.0	82.3	19/12/2011	259.0	302.0	82.6	09/03/2016	262.0	302.0	82.4	20/04/2022	269.0	302.0	81.9	11/07/2024	269.0	302.0	81.6
043500m	01/07/1998	42.0	61.0	83.3	19/12/2011	-13.0	39.0	84.2	09/03/2016	-13.0	41.0	84.2	20/04/2022	-10.0	21.0	83.5	11/07/2024	-9.0	26.0	83.3
Upper Gravel Phase																				
045365m													01/09/2022	47.5	76.5	90.7	09/08/2024	47.5	76.5	90.7
045730m													01/09/2022	30.0	64.0	92.5	09/08/2024	30.0	64.0	92.3
046400m	11/11/1999	15.0	35.0	95.2	30/03/2012	15.0	35.0	95.4	14/03/2016	15.0	35.0	95.3								
047240m													01/09/2022	94.0	129.0	98.1	10/07/2024	94.0	129.0	98.5
048285m													01/09/2022	7.0	45.0	102.1	10/07/2024	7.0	45.0	102.0
048960m													01/09/2022	12.5	49.0	104.6	10/07/2024	22.0	57.0	104.7
049105m													01/09/2022	70.0	129.5	106.3	10/07/2024	70.0	131.0	106.5
049240m													01/09/2022	53.0	81.0	105.9	10/07/2024	53.0	80.0	105.9
050260m													01/09/2022	70.0	90.0	109.8	10/07/2024	67.0	109.0	110.6
051700m													31/08/2022	7.5	70.0	115.6	09/07/2024	7.5	70.0	116.3
051970m													31/08/2022	41.0	110.0	117.0	09/07/2024	13.0	95.0	117.6
052280m													31/08/2022	30.0	58.0	117.8	09/07/2024	30.0	58.0	118.1
052660m													26/08/2022	9.5	43.0	120.1	09/07/2024	9.5	43.0	120.1
052890m													26/08/2022	9.0	40.0	121.1	09/07/2024	-4.0	42.0	121.4

Site	1998/1999				2011/2012				2016				2022				2024			
	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL
		Left	Right			Left	Right			Left	Right			Left	Right			Left	Right	
Upper Gravel Phase (cont.)																				
053170m													26/08/2022	24.0	67.0	122.6	09/07/2024	16.0	67.0	122.7
053975m													26/08/2022	51.0	97.0	126.8	18/06/2024	51.0	97.0	126.8
054050m													26/08/2022	41.0	66.0	126.2	18/06/2024	41.0	66.0	126.2
054645m													26/08/2022	16.0	34.0	128.3	18/06/2024	16.0	34.0	128.2
054680m													26/08/2022	9.0	33.0	128.7	18/06/2024	9.0	33.0	128.6
054710m													26/08/2022	11.0	34.0	128.9	18/06/2024	11.0	34.0	128.6
054810m													26/08/2022	9.5	27.0	128.9	09/07/2024	9.5	27.0	128.7
054850m													26/08/2022	7.0	26.0	129.1	09/07/2024	7.0	26.0	128.9
054905m													26/08/2022	5.5	29.5	129.4	09/07/2024	5.5	29.5	129.3
055315m													31/08/2022	0.5	37.0	131.8	09/07/2024	0.5	37.0	131.6
056150m													31/08/2022	74.0	119.5	135.5	25/06/2024	74.0	118.5	135.9
056700m													31/08/2022	79.5	119.0	138.4	25/06/2024	79.5	119.0	138.3
059040m													19/09/2022	10.0	40.0	147.7	25/10/2024	-53.0	19.0	147.8
061010m													25/08/2022	44.0	77.5	156.4	08/07/2024	29.0	108.0	157.1
061245m													25/08/2022	8.0	32.0	156.8	08/07/2024	10.0	36.5	157.2
061560m													25/08/2022	9.0	44.0	158.2	08/07/2024	7.0	44.0	158.6
061755m													25/08/2022	0.0	16.0	158.7	08/07/2024	0.0	16.0	158.7
061915m													25/08/2022	64.0	100.0	159.8	08/07/2024	30.0	98.0	160.3
062120m													25/08/2022	10.0	50.0	161.4	08/07/2024	10.0	50.0	161.4
062480m													25/08/2022	1.0	33.0	162.6	08/07/2024	2.0	33.0	162.6
063190m													25/08/2022	20.0	46.0	165.3	08/07/2024	20.0	46.0	165.2
063955m													25/08/2022	12.0	53.0	169.1	08/07/2024	12.0	53.0	168.9
064030m													25/08/2022	9.0	40.5	169.0	08/07/2024	9.0	40.5	168.9
064405m													25/08/2022	21.0	97.0	171.6	08/07/2024	20.0	103.0	171.5
064760m													25/08/2022	46.0	99.0	173.3	08/07/2024	42.0	99.0	173.2
066905m													24/08/2022	20.0	75.0	183.8	01/07/2024	20.0	75.0	183.8
067230m													24/08/2022	17.0	41.0	184.9	01/07/2024	17.0	41.0	184.7
067350m													24/08/2022	14.0	49.0	185.4	01/07/2024	14.0	49.0	185.3
067900m	11/11/1999	5.0	51.0	188.0	19/04/2012	5.0	51.0	187.9	14/03/2016	5.0	51.0	187.5	24/08/2022	5.0	51.0	187.4	13/06/2024	5.0	51.0	187.2
068555m													24/08/2022	5.0	127.0	191.6	01/07/2024	4.0	116.0	191.8
069060m													24/08/2022	62.0	101.5	193.5	01/07/2024	64.0	101.5	193.0
073210m													19/09/2022	12.0	64.0	215.1	04/07/2024	-10.0	142.0	214.9
076935m													16/08/2022	156.5	211.0	235.5	04/07/2024	156.5	211.0	235.2
078600m	11/11/1999	2.0	25.5	242.5	19/03/2012	2.0	29.0	243.3	14/03/2016	2.0	30.5	243.5					04/06/2024	2.0	32.0	243.5
081740m													15/08/2022	120.0	158.0	261.6	04/06/2024	120.0	158.0	261.7
082100m	30/09/1999	2.0	76.0	264.0	19/03/2012	2.0	76.0	264.2	14/03/2016	2.0	76.0	264.2	15/08/2022	2.0	76.0	263.9	04/06/2024	2.0	76.0	264.0
083100m	30/09/1999	99.0	208.0	269.9									15/08/2022	133.0	171.0	269.0	04/06/2024	116.0	171.5	269.5
084100m	30/09/1999	5.0	35.0	275.2									15/08/2022	4.5	35.0	274.9	13/06/2024	4.5	48.0	275.0

Site	1998/1999				2011/2012				2016				2022				2024			
	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL	Survey Date	Offset		MBL
		Left	Right			Left	Right			Left	Right			Left	Right			Left	Right	
Upper Gravel Phase (cont.)																				
084500m	30/09/1999	4.5	44.0	277.6									15/08/2022	4.5	44.0	277.4	13/06/2024	2.0	44.0	277.6
084680m													15/08/2022	53.0	74.0	278.1	13/06/2024	40.5	77.5	278.6
084900m	30/09/1999	4.0	74.5	281.3	19/03/2012	8.0	80.0	280.6	14/03/2016	6.5	80.0	280.6	16/08/2022	6.5	82.0	280.7	13/06/2024	8.0	81.5	280.4
096440m													05/09/2022	7.0	40.5	358.8	12/06/2024	5.0	47.0	358.7
101975m													19/07/2022	135.0	231.0	404.8	12/06/2024	137.0	231.0	404.4
105455m													19/07/2022	23.5	114.5	430.6	12/06/2024	2.0	114.5	430.8
107695m	11/11/1999	8.5	56.0	446.4	19/03/2012	8.5	56.0	446.5	14/03/2016	8.5	56.0	446.7	19/07/2022	8.5	56.0	446.7	12/06/2024	8.5	56.0	446.6
108035m													19/07/2022	7.0	62.0	449.2	10/05/2024	-4.0	63.5	449.7
114355m													18/07/2022	21.0	57.0	510.6	07/06/2024	21.0	63.0	510.8
115725m													18/07/2022	36.0	94.5	524.9	07/06/2024	36.0	97.0	525.5



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