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Te Puru Stream flood protection scheme - service level review

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Abstract

A service level review of the flood protection assets on the Te Puru Stream was completed in October 2019 (Grant, 2019). The process included a reassessment of catchment hydrology and design flows, a complete rebuild of hydraulic models based on available topographic datasets, and a comparison of revised flood profiles against surveyed asset crest levels. The review indicated the scheme could convey the design flow but shortfalls in freeboard were identified in the lower scheme, possibly associated with sediment aggradation near the mouth. Recommendations of the review included re-survey of the channel to compare with past datasets, reassessment of the flood protection assets, and determination of appropriate bed levels in the lower scheme to maintain freeboard.

This July 2020 supplementary report documents the actions taken from the Grant (2019) recommendations. The findings of the supplementary report are that whilst the freeboard-shortfalls in the flood protection assets have improved naturally with fluvial and coastal processes, freeboard shortfalls still exist in the lower 80m of the scheme assets on both banks. At present the assets retain over half of the 600mm freeboard (Performance Grade 2), but the lower channel near the mouth will require further excavation to achieve 600mm freeboard. Excavation of the channel is preferred given the fixed nature of the assets - primarily floodwalls or stopbanks within confined areas. Excavation requirements have been suggested based on modelling of channel reshaping near the mouth. It is acknowledged that this area is subject to relatively quick morphological change at the fluvial/coastal boundary, and that channel works are a frequent requirement in this area.

1 Introduction

1.1 Purpose

In 2019 a service level review of the Te Puru Stream flood protection assets was undertaken (Grant, 2019). Whilst it was found the scheme could convey the 1%AEP design flow, there were shortfalls in the 600mm freeboard in the lower flood protection assets. It was found that these shortfalls were likely a function of aggradation of sediment in the lower stream and the topography of the mouth present at the time of survey capture.

Recommendations from the 2019 service level review and the purpose of this supplementary report are to:

- capture more recent survey (undertaken May 2020),
- reassess whether the scheme is meeting the service level and freeboard requirements,
- determine whether channel excavation from the lower stream and mouth should be undertaken,
- determine extent of excavation required to achieve freeboard requirements in lower scheme assets.

2 Flood protection scheme

The flood protection scheme is comprised of various components having an agreed service level equivalent to the present climate 1%AEP design discharge. During the design phase the present climate 1%AEP design discharge was estimated at Q_p315, and following reassessment (Grant, 2019) is to be retained.

Freeboard allowance at Te Puru is predominantly 600mm but there are exceptions detailed below. Commonly predicted future climate flows (as outlined in Grant 2019) and the associated increase in water levels can be contained within the freeboard but this will be reassessed as part of this analysis. The freeboard allowance also allows for some uncertainty associated with hydrology and hydraulic model uncertainty, super-elevation in water levels, stream wave-action, and mobile debris and bed load.

The scheme assets are comprised of stopbanks and floodwalls with a spillway designed to take some over-design flows to protect the bridge structure. The assets are shown in Figure 1 and described below. The main components of the flood protection scheme are:

Left bank downstream of State Highway

- *Te Puru Left Below State Highway Floodwall* - 463m, 1%AEP, 600mm freeboard

Left bank upstream of State Highway

- *Te Puru Left Above State Highway Floodwall* - 168m, 1%AEP, 600mm freeboard

Right bank downstream of State Highway

- *Te Puru Right Below State Highway Stopbank* – 134m, 1%AEP, 600mm freeboard
- *Te Puru Right Below State Highway Floodwall* – 199m, varying service level[1] :
    - Service level downstream of XS 11 is 1%AEP + 600mm freeboard – 68m
    - Service level upstream of XS 11 (floodwall extension) is future climate 1%AEP + no freeboard – 131m

[1] XS 11 is the break point between the standard of service based on doc #1937518. The difference between the two service level profiles determined during Grant (2019) was 100-200mm.

Right bank upstream of State Highway

- *Te Puru Right Above State Highway Floodwall Spillway* - 62m, 1%AEP, 300mm freeboard[2]

Various other features included in the flood protection scheme include retaining walls, rock rip rap, and floodgates:

Rock rip rap

- *Te Puru Stream LB Rock Rip Rap Upstream of Bridge* (250m)
- *Te Puru Left Rip Rap Below State Highway* (196m)
- *Te Puru Right Below State Highway Rip Rap* (178m)

Floodgates

- *Te Puru Right Floodgate 1* (900mm) downstream State Highway
- *Te Puru Right Floodgate 2* (2 x 375mm) downstream State Highway
- *Te Puru Right Floodgate 3* (1200mm) downstream State Highway

Retaining walls

- *Te Puru Left Retaining Above State Highway*
- *Te Puru Left Campsite Retaining Wall*

The retaining walls are located at the toe of embankments where insufficient space was available for the full embankment profile. Rock rip rap was used to improve the stability of the channel and protect the other works associated with the flood protection scheme such as stopbanks and floodwalls. The floodgates are associated with the SH25 Bridge upgrade. These features are inspected at regular intervals associated with river maintenance schedules. Hence the primary focus of the service level review was the comparison of design discharge floodwater levels and scheme asset crest levels.

Figure 1 Location of Te Puru flood protection scheme assets.

[2] The scheme design report (Wood, 2014) describes 300mm freeboard and is incorrectly assigned 600mm in the Conquest database.

3 Survey

As part of this supplementary report, a survey was undertaken of the stream channel cross-sections and topography at the stream mouth in May 2020. The 2020 survey and past survey datasets are described below along with the various datum and offsets.

3.1 Datum and offsets

The horizontal datum used throughout this report is New Zealand Transverse Mercator (NZTM). Several vertical datum are discussed and used in this report. The most relevant datum is the Hauraki Catchment Board Te Puru Local Datum. The 'Local Datum' is relevant to historic ground surveys, including channel cross-sections (2004, 2014, and 2020) and as-built data for the flood protection scheme (2014).

Three other vertical datum are also commonly used in the area in relation to various data sources. These include Moturiki Vertical Datum 1953 (MVD-53), Tararu Vertical Datum 1952 (TVD-52) and Auckland Vertical Datum 1946 (AVD-46). The relationship between the three datum is shown in Figure 2. The exact offset between Local Datum and these other three datum was assessed as part of the May 2020 survey. It was found that Local Datum was -0.26m in relation to TVD-52, i.e.: *Level (TVD-52) = Level (Te Puru Local Datum) - 0.26m*.

For example and to clarify the offsets, 10.26m (Local Datum) would be equivalent to:

- 10.00m (TVD-52)
- 10.12m (MVD-53)
- 10.13m (AVD-43)

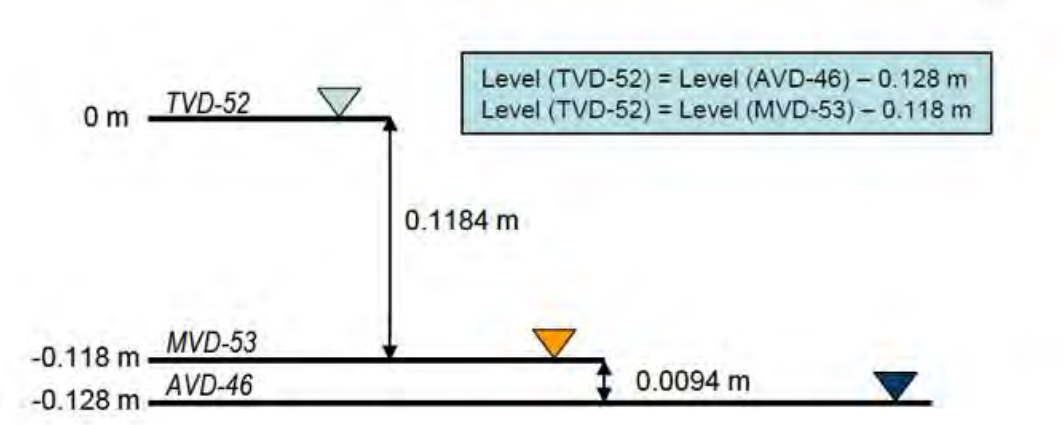

Figure 2 **Relationship and conversions between the three local vertical datum of Tararu (TVD-52), Moturiki (MVD-53) and Auckland (AVD-46).**
(Source: Goodhue, 2012.)

3.2 Ground survey 2004, 2014 and 2020

To date three WRC ground surveys have been completed of the Te Puru Stream (2004, 2014 and 2020). These three surveys have all included 15 channel cross-sections at approximately 50m intervals of the Te Puru Stream from the mouth to a distance upstream of the State Highway (see Figure 3 and Figure 4). These channel cross-sections have all been surveyed on the same alignment and all three relate to the Te Puru Local Datum.

The 2004 survey was prior to construction of the flood protection scheme, and so the channel, banks, and flood protection assets vary significantly to the surveys of 2014 and 2020.

The 2014 survey also includes significant detail on the flood protection scheme, with the addition of longitudinal profiles along the asset crests.

The most recent ground survey was undertaken in May 2020. This survey was captured to reassess shortfalls in freeboard in the lower scheme as determined the 2019 service level review. The survey included the 15 channel cross-sections but also captured more detailed topography around the stream mouth.

3.3 LIDAR 2013

LIDAR coverage of the Coromandel Peninsula coast was captured between 1 January and 12 March 2013. At Te Puru this data is available in terms of the vertical datum AVD-46. Flood protection works at Te Puru including the new bridge were completed at the time of the LIDAR survey.

In theory to place the 2013 LIDAR DTM surface (AVD-46) on the Local Datum it needs to be raised by approximately +0.13m. This agrees with a comparison of 2014 ground survey points (numbering 1577) which were found to be on average +0.10m (median +0.14m) above spatially comparable LIDAR points. It is noted that the LIDAR also has an accuracy of +/- 0.15m.

Comparison of slices from the 2013 LIDAR DTM (adjusted to Local Datum) and the 2014 cross-sections are comparable showing mostly good representation of the channel as shown in Appendix A.

4 Hydraulics

4.1 Revised MIKE11 model July 2020

The MIKE11 1D model used to assess the flood protection scheme was reconfigured with the May 2020 channel survey data.

4.1.1 MIKE11 model development

4.1.1.1 Model network domain and datum

The MIKE11 model network covers a river reach of 710m between surveyed cross-sections. The model domain extends from a southwest origin at NZTM 1823600 5896240 to a northeast corner at NZTM 1824900 5897740 (1300m x 1500m) as shown in Figure 3. Note also as in Grant (2019) the model chainage (Table 1) differs from the asset change (Table 2). The model vertical datum is Te Puru Local Datum which is described in detail relevant to other datum in Section 3.

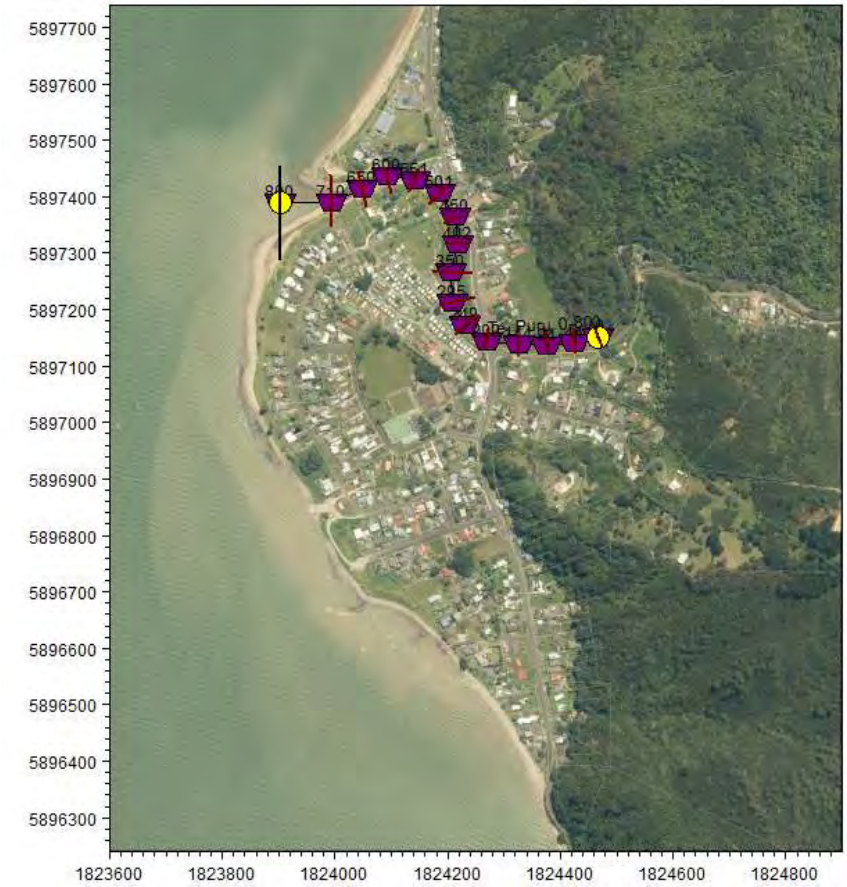

Figure 3 Extent of MIKE11 model network at Te Puru.

4.1.1.2 Model cross-sections

The Te Puru Stream is represented by the cross-sections surveyed in May 2020. These cross-sections have also been checked and adjusted to include the asset crest (floodwall or stopbank) as surveyed in May 2020 and checked against that recorded in 2014. The location and extent of these cross-sections in the model is shown in Figure 4.

Figure 4 **Location and extent of 2020 ground survey cross-sections as shown in MIKE11 model. Note model chainage is shown in image but cross-sections are XS 1 (upstream - right) to XS 15 (downstream - left).**

4.1.1.3 MIKE11 model boundaries

The design discharge estimate was applied as a flood hydrograph at the upstream limit of the MIKE11 model, approximately 200m upstream of the State Highway Bridge (see Grant, 2019 for full details).

At the tidal boundary a static 'mean high water spring' (MHWS) tide for the present climate was used. This was adjusted from RL 1.76m (Grant, 2019) to RL 1.89m based on the difference determined between TVD-52 and Local Datum. For future climate scenarios the MHWS tide plus 1m sea level rise was used at RL 2.89m.

Low tide testing (MLWS assumed at RL -1.49m) was also undertaken but given the scale of the flood flows was found to produce very little difference in 1%AEP flood levels at the flood protection assets (approximately 10 - 40mm between XS 13 and XS15).

4.1.2 MIKE11 model results - 2020 simulation

Predicted water levels at each of the channel cross-sections were extracted from the MIKE11 model incorporating the May 2020 cross-sections. This was undertaken for the present climate 1%AEP design flow (Q_p315), and the two more conservative future climate scenarios (RCP 6.0 and RCP 8.5) having respective peak flows of Q_p375 and Q_p414 plus the effects of 1m sea level rise. The predicted water levels are detailed in Table 1 with flood profiles in Figure 5.

The assumptions include those described in the model build, and the use of the 2020 cross-sections and associated bed levels recorded at the time. There is no allowance for sediment deposition, debris, blockage, or super-elevation of water levels.

Observations from the MIKE11 modelling, surveys, LIDAR and historical aerial imagery are that:

- The original design flood profile is mostly higher than the revised design flood profile. This is more prevalent upstream of the bridge and reduces downstream to less than the revised flood profile (Figure 5).
- Minimum bed levels have lowered through the entire reach between the 2004 and 2020 cross-section surveys. Minimum bed levels at the mouth in 2020 have lowered since 2014 likely as a function of excavation, natural scouring, and the timing of the surveys.
- Comparison of channel cross-section area between 2004 and 2014 indicates channel capacity has been increased with the raising of flood defences and channel works. Channel capacity has not changed markedly between 2014 and 2020, although there is a slight increase in capacity at the mouth associated with excavation, natural scouring, and the timing of the surveys.
- MIKE11 modelling suggests there is sufficient capacity to contain the present climate 1%AEP design flow through the entire river reach however there is insufficient freeboard (<600mm) in the lower stream near the mouth (i.e. downstream of XS 13). See Table 2 highlighted cells for reduced freeboard levels downstream of XS 13.
- MIKE11 modelling suggests that 600mm freeboard is sufficient to allow for increases in flood level associated with the future climate events, however future climate events would currently overtop the banks in the lower reach near the mouth under the current channel geometry as surveyed May 2020.
- The spillway commences activation in the future climate Q_p414 event, but not in the present climate 1%AEP design flow in which approximately 480mm freeboard has been modelled similar to the design freeboard condition of 300mm.

These elements are described in more detail in the following sections.

Table 1 MIKE11 model results for the various design events (all levels in terms of Te Puru Local Datum).

XS	Design Report (#3243546)		Minimum bed levels:					2018 MIKE11 model results:				2020 MIKE11 model results:			
	Model Ch. (m)	1%AEP design flood level (RL m)*	2004 (RL m)	2014 (RL m)	2020 (RL m)	Δ in min. bed level 2004-2014	Δ in min. bed level 2014-2020	Model Ch. (m)	Q_p315 (RL m)	Q_p375+ 1mSLR (RL m)	Q_p414+ 1mSLR (RL m)	Model Ch. (m)	Q_p315 (RL m)	Q_p375+ 1mSLR (RL m)	Q_p414+ 1mSLR (RL m)
1	0	10.92	6.99	6.57	6.56	-0.42	-0.01	0	10.27	10.59	10.78	0	10.33	10.65	10.84
2	50	10.32	6.26	5.97	6.20	-0.29	+0.23	44	9.72	10.03	10.23	44	9.72	10.04	10.23
3	100	9.85	5.82	5.58	5.49	-0.24	-0.09	94	9.19	9.52	9.72	94	9.15	9.48	9.68
4	150	9.06	5.18	4.99	4.92	-0.19	-0.07	144	8.56	8.88	9.08	144	8.51	8.84	9.03
US BRG	200	8.50	4.38	-	-	-	-	192	8.03	8.35	8.54	192	8.01	8.37	8.57
5	210	8.02	4.25	4.16	3.94	-0.09	-0.22	202	7.94	8.26	8.45	202	7.97	8.30	8.49
DS BRG	220		4.13	-	-	-	-	211	7.82	8.13	8.32	211	7.85	8.18	8.37
6	250	7.60	3.82	3.00	2.55	-0.82	-0.45	249	7.26	7.58	7.78	249	7.30	7.63	7.83
7	300	7.01	3.24	3.05	2.99	-0.19	-0.06	295	6.79	7.11	7.30	295	6.81	7.12	7.31
8	350	6.53	2.85	2.32	2.39	-0.53	+0.07	350	6.29	6.60	6.79	350	6.26	6.57	6.75
9	400	6.21	2.18	1.99	1.75	-0.19	-0.24	402	5.92	6.23	6.42	402	5.87	6.19	6.38
10	450	5.52	1.66	1.38	1.00	-0.28	-0.38	450	5.37	5.67	5.84	450	5.32	5.62	5.79
11	500	5.05	1.52	1.02	1.00	-0.50	-0.02	501	4.91	5.19	5.36	501	4.80	5.09	5.25
12	550	4.47	1.11	1.19	0.86	+0.08	-0.33	551	4.50	4.77	4.93	551	4.33	4.62	4.77
13	600	3.92	0.72	0.18	0.18	-0.54	0.00	600	4.08	4.31	4.44	600	3.83	4.08	4.22
14	650	3.41	0.48	0.64	0.10	+0.16	-0.54	650	3.78	3.99	4.09	650	3.51	3.77	3.87
15	700	2.50	0.52	0.48	0.38	-0.04	-0.1	710	2.94	3.20	3.27	710	2.70	3.06	3.13
FIRTH	-	-	-	-	-	-	-	800	1.76	2.76	2.76	800	1.89	2.89	2.89

*Taken from construction issue design drawings in Design Report (Wood, 2014).

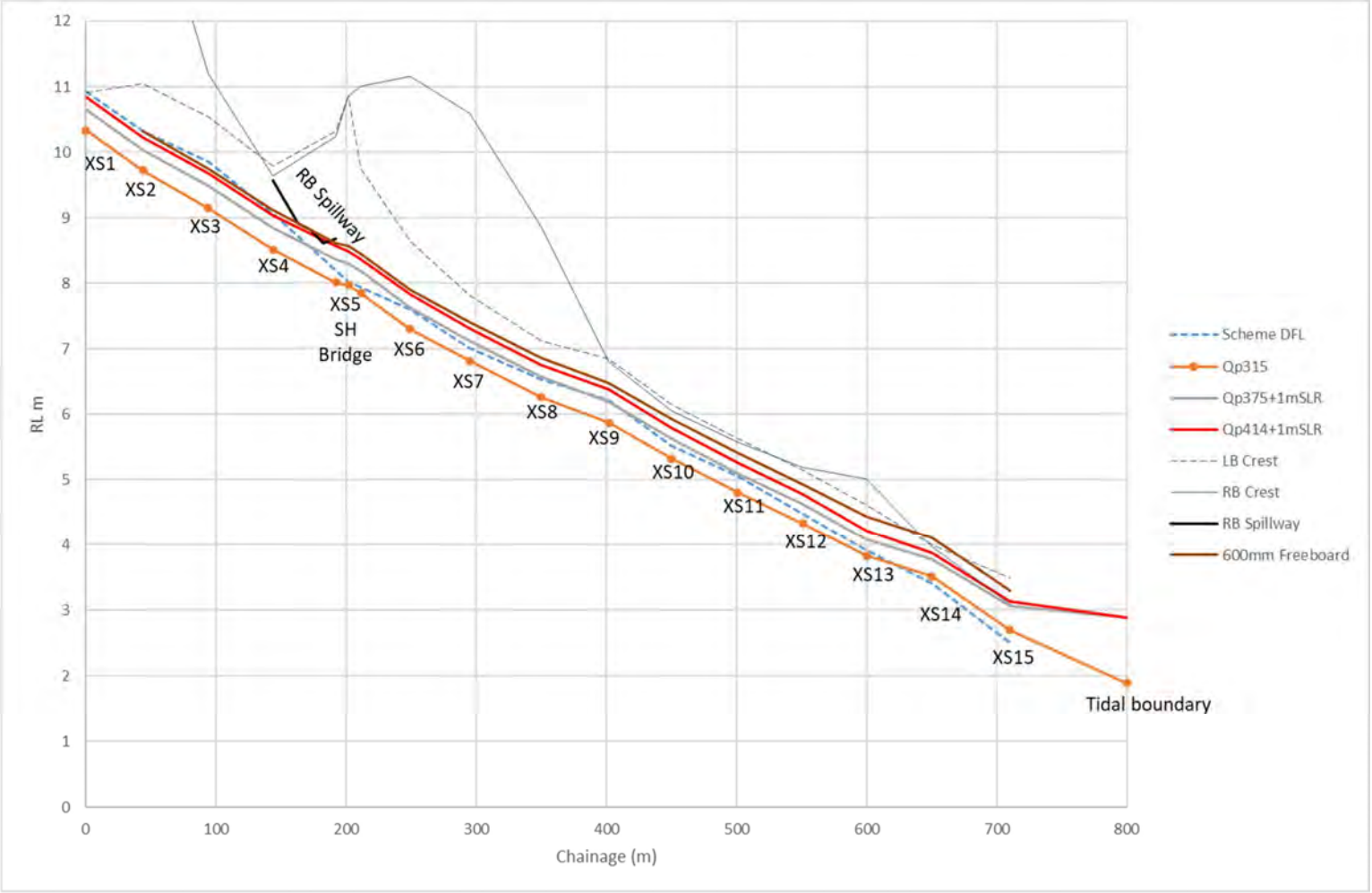

Figure 5 Modelled 2020 flood profiles compared with original design flood levels and left and right bank assets (levels are shown in Table 2).

4.1.2.1 Bed levels

Comparison of the 2004, 2014 and 2020 channel cross-sections indicate that the minimum bed level has typically degraded and was on average -0.27m lower between 2004-2014, and -0.42m lower between 2004-2020 (Figure 6).

Changes upstream of the bridge are typically less than those downstream of the bridge. Some of these changes in the lower stream can be attributed to channel works undertaken during scheme construction and channel maintenance work to remove sediment.

From 2004-2020 the minimum bed levels upstream of the bridge were -0.06m to -0.43m lower; immediately downstream of the bridge (XS 6) -1.27m lower; and further downstream towards the mouth the average was -0.40m (range -0.16m to -0.66m). Minimum bed levels are lower around the stream mouth in 2020 than in 2014, likely owing to both excavation, scouring during high flow events, and the timing of surveys.

The bed lowering recorded over the surveyed reach (2004-2020) increases the amount of available freeboard and helps explain the apparent lowering of design flood levels. The lowering of bed levels since 2014 has also helped improve the shortfall in freeboard noted in Grant (2019), although this remains an issue indicating a potential need for further excavation.

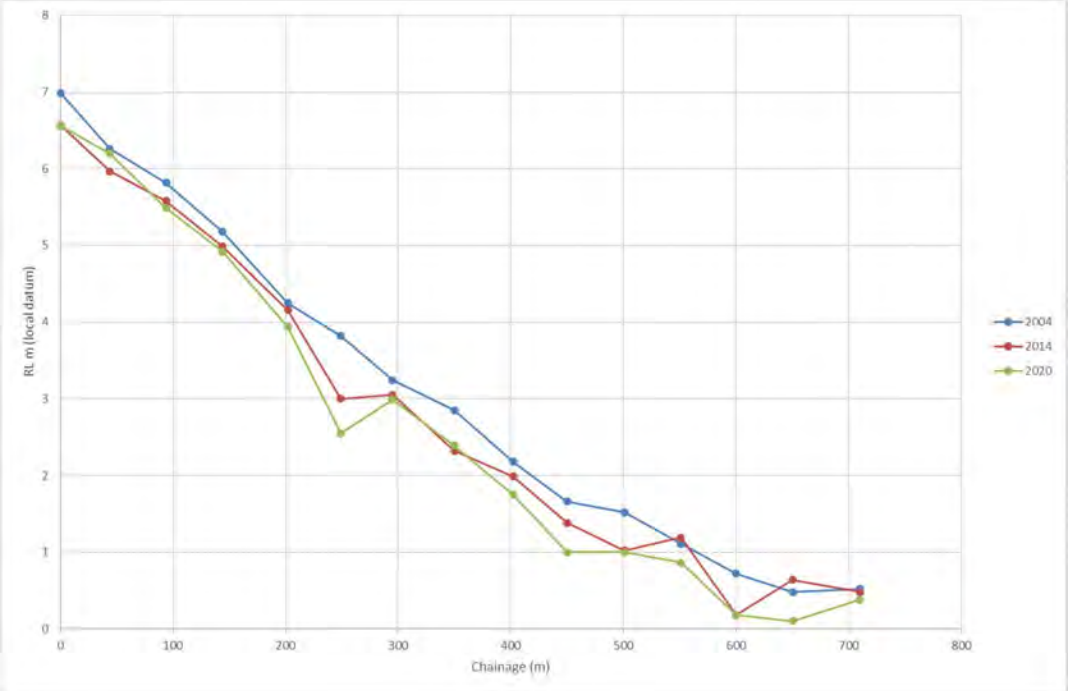

Figure 6 **Minimum bed level profiles from 2004, 2014 and 2020 channel surveys between XS 1 (upstream) and XS 15 (downstream).**

4.1.2.2 Channel capacity

A key function of the scheme design philosophy was to increase stream channel capacity by raising flood defences. A comparison of channel cross-sectional areas was made between the 2004 and 2014/2020 surveys to the level of asset crest overtopping. This indicated that on average channel capacity has increased by a ratio of approximately 1.7 associated with the scheme construction.

Cross-section area is similar between the 2014 and 2020 surveys, although there has been a slight increase in channel capacity at the mouth between the two periods at XS14 and XS15. As discussed in Grant (2019) the mouth was relatively narrow in 2014, and this has likely been improved by subsequent channel maintenance and high flow events. As per the bed levels discussion this has helped improve the shortfall in freeboard noted in Grant (2019), although this remains an issue indicating a need for further excavation requirements.

4.1.2.3 Spillway activation

The spillway design is for the 1%AEP design flow with 300mm freeboard. The modelling suggests there is 480mm freeboard available for the revised MIKE11 model similar to the design condition. Modelling of the future climate Q_p414 event estimated that peak water levels would be just high enough to commence spillway activation.

4.1.2.4 Freeboard and excavation requirements

The freeboard shortfalls in the lower flood protection assets as noted in Grant (2019) have improved with the inclusion of the May 2020 survey but remain an issue. The shortfalls are in the lower 80m of flood protection assets (both banks approximately below XS13) with the freeboard reduced by almost half and affected areas having Performance Grade 2 (see Section 5).

Model testing was undertaken by lowering the channel profile to achieve 600mm freeboard with the present climate 1%AEP flow. If the channel at XS14 and XS15 has a wider trapezoidal base of 15m at RL 0m Local Datum (-0.26m TVD-52), and side slopes are blended back into the upper banks then 600mm freeboard can be achieved. The upper banks have had similar shape through the various survey periods, and the area through XS14 and XS15 is often where a narrowing and sill develops at the stream mouth. Historic side slopes at these cross-sections from the various survey periods indicate that these have not changed significantly

Operations Staff recently undertook excavation around XS14 and the current channel dimensions closely mimic those described above (i.e., wider trapezoidal base), similar excavation around XS15 with a lowering of 300-400mm to the stream bed base width described will be sufficient to cater for the freeboard in the lower reach of the stream.

Based on past surveys minimum bed levels at XS14 and XS15 have been up to 100-500mm higher than this level. It is likely that a sill will be present around this area of the mouth and it will naturally reform between excavations or following larger stream flow events.

4.1.2.5 Freeboard and future climate

The MIKE11 modelling suggests that 600mm freeboard (based on present climate 1%AEP design flows) would be sufficient to cater for increases in flood level associated with the future climate events. The increase in flood levels between the present climate and future climate flows are predicted to be in the range up to 360-560mm. Future climate events would overtop the banks in the lower reach near the mouth under the current channel geometry as surveyed May 2020.

4.1.3 MIKE11 model summary

Remodelling of the Te Puru Stream for the present and future climate 1%AEP flow events has been undertaken using the May 2020 channel cross-section survey and flood protection scheme as-built data. The results indicate:

- The present climate 1%AEP design flow is contained within the scheme assets, however, there remains less than 600mm freeboard in the lower stream near the mouth (i.e. downstream of XS 13 and relating to the lower 80m of assets on both banks).

- Future climate 1%AEP flows are likely to overtop the banks in the lower stream near the mouth as above based on the current May 2020 channel geometry.
- The spillway upstream of the State Highway approximates its design condition that is to activate in events greater than the 1%AEP design flow with 300mm freeboard.
- Analysis of 2004, 2014 and 2020 channel cross-sections showed that bed levels have typically lowered through most of the Te Puru Stream reach over time. Aggradation was noted in the lower stream near the mouth in the 2014 survey but degraded as of 2020. This is a function of excavation, natural processes, and timing of surveys. The modelling suggests that further excavation is required to maintain freeboard and service level in the lower stream assets.

5 Service level review of flood protection assets

A service level review of the flood protection assets described in Section 2 and shown in Figure 1 has been undertaken based on the updated results of the MIKE11 model compared to the 2019 MIKE11 model.

Primarily the service level of the assets is based on the present climate 1%AEP design flood (Qp315) in conjunction with a MHWS tide (RL 1.89m), and a freeboard allowance of 600mm. There are however exceptions to the service level:

- Te Puru Right Above State Highway Floodwall Spillway
    - 1%AEP flood + 300mm freeboard (erroneously recorded in Conquest database as 600mm)
- Te Puru Right Below State Highway Floodwall (floodwall extension only - upper 130m)
    - future climate 1%AEP flood and no freeboard (used RCP 8.5 scenario Qp414)

Profiles have been plotted along each asset crest length showing the actual crest level, revised design crest level and design flood level (Figure 7 to Figure 11). In addition, Table 2 provides full details of the service level data including performance grades at individual survey points along the entire asset length. Performance grades are assessed based on the percentage of available freeboard as shown in Figure 12.

In total there is a linear length of 1027m of scheme floodwalls and stopbanks with:

- 85.5% performance grade 1 (877m)
- 14.5% performance grade 2 (150m)
- 0% performance grade 3 (0m)
- 0% performance grade 4 (0m)
- 0% performance grade 5 (0m)

The performance grades show that most of the scheme is providing the intended service level for the present day climate 1%AEP design flow. The modelling indicates that the main shortfalls in freeboard are in the lower 80m of assets on both banks near the mouth. Excavation requirements to regain freeboard shortfalls have been estimated by modelling channel reshaping in the lower stream as described in the previous section.

The current service level data is provided for import into the Asset Management Conquest Database in Table 3 (Appendix C – Conquest service level data).

5.1 Suggested change in service level for right bank 'floodwall extension'

The Wood (2014) design report indicates that one section of the flood protection assets has a different service level:

- *Te Puru Right Below State Highway Floodwall ('floodwall extension' only - upper 130m)*
    - future climate 1%AEP flood and no freeboard

It is proposed that this service level is changed to the 'present climate 1%AEP flow + 600mm freeboard'. This reasoning for this is:

- All stopbanks and floodwalls would then share the same service level (apart from the spillway which uses 300mm freeboard).

- This proposed change in service level results in design flood/crest levels 160mm higher than those currently assigned to the 'floodwall extension' asset, however the actual crest levels already cater for this condition.

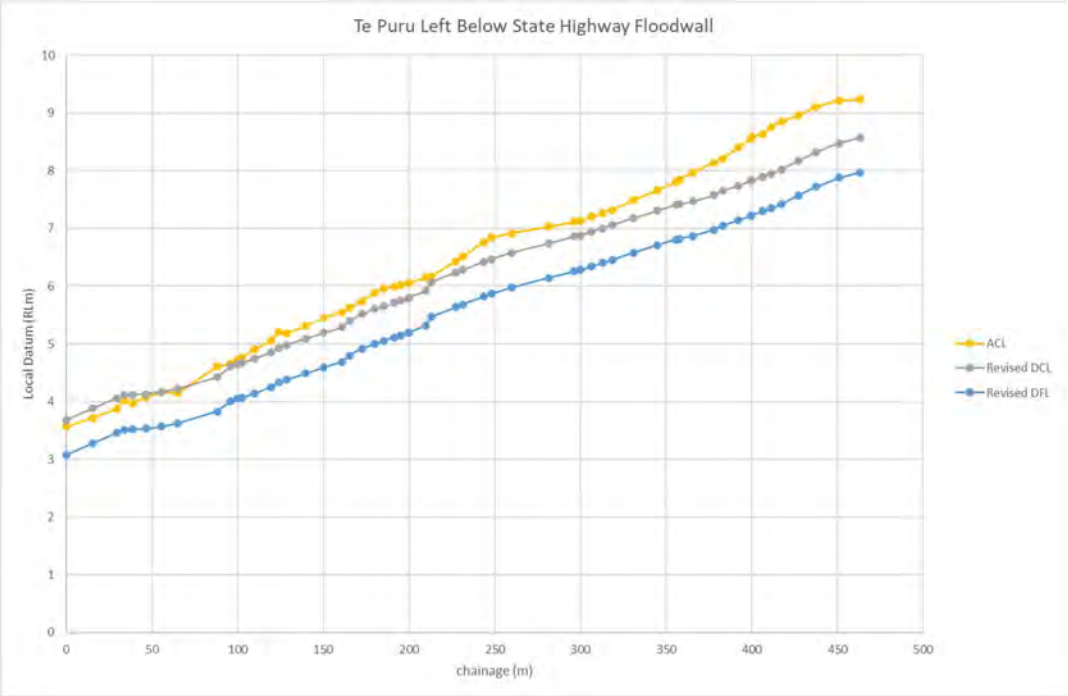

Figure 7 **Te Puru Left Below State Highway Floodwall - profiles for actual crest level (ACL) compared to the revised design crest level (DCL) and design flood level (DFL).**

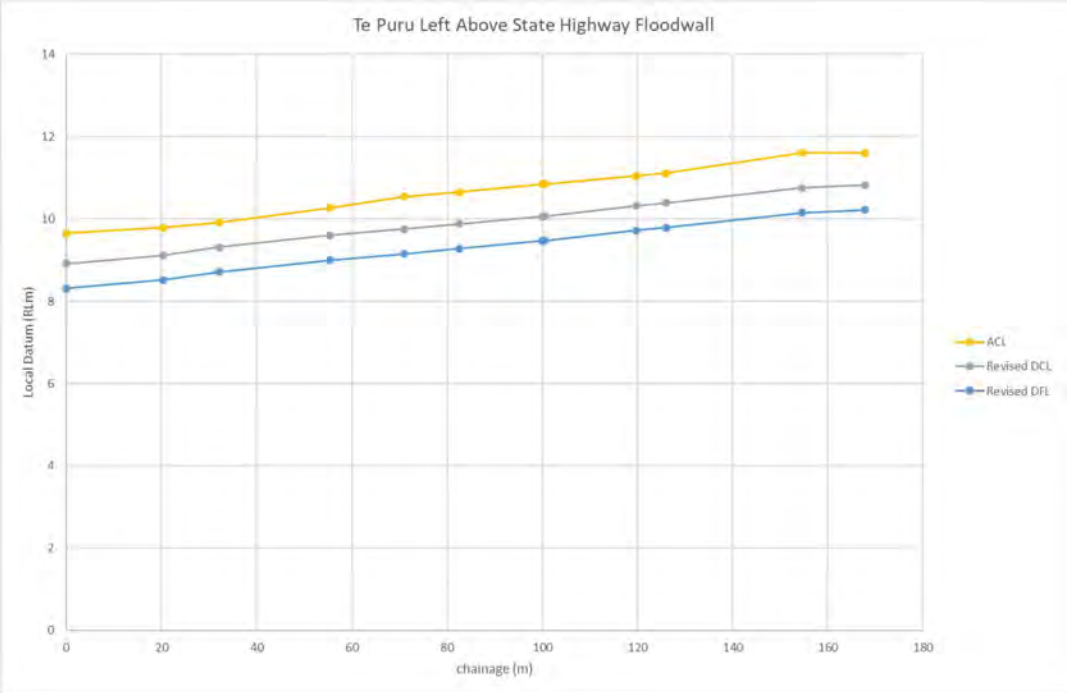

Figure 8 **Te Puru Left Above State Highway Floodwall - profiles for actual crest level (ACL) compared to the revised design crest level (DCL) and design flood level (DFL).**

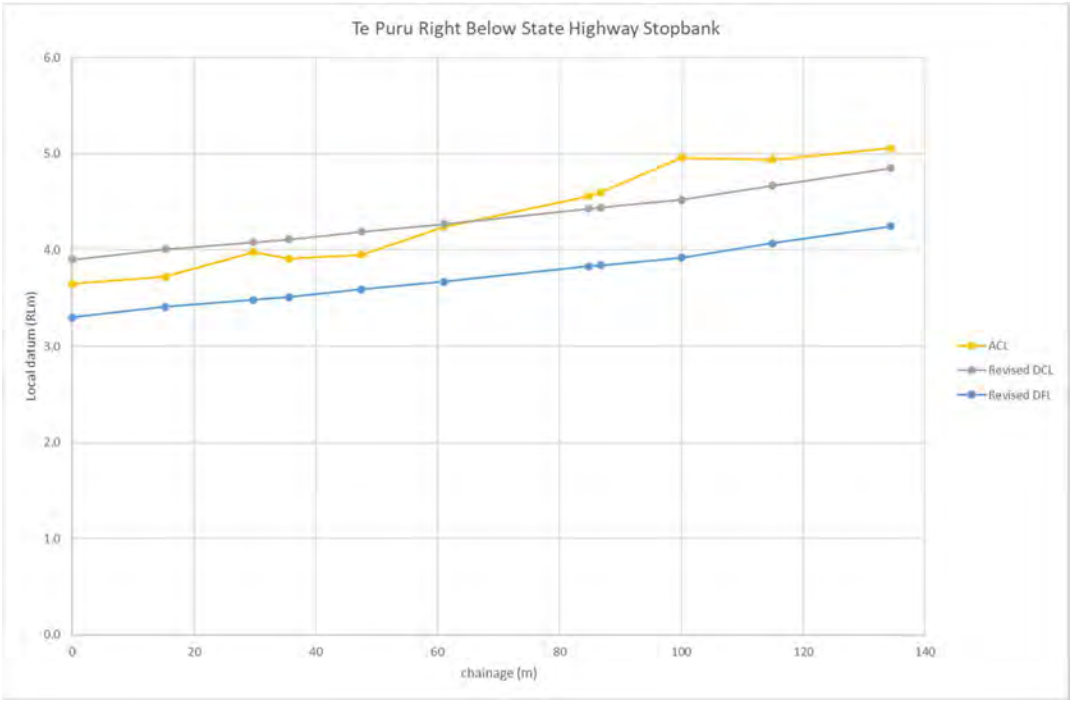

Figure 9 **Te Puru Right Below State Highway Stopbank - profiles for actual crest level (ACL) compared to the revised design crest level (DCL) and design flood level (DFL).**

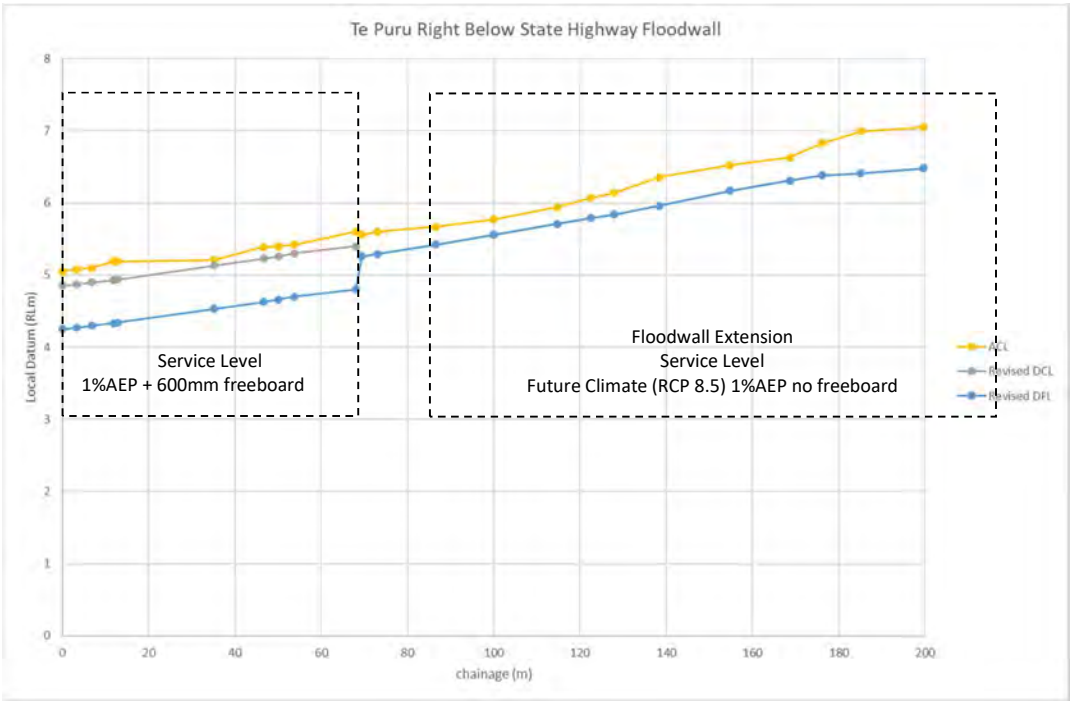

Figure 10 **Te Puru Right Below State Highway Floodwall - profiles for actual crest level (ACL) compared to the revised design crest level (DCL) and design flood level (DFL).**

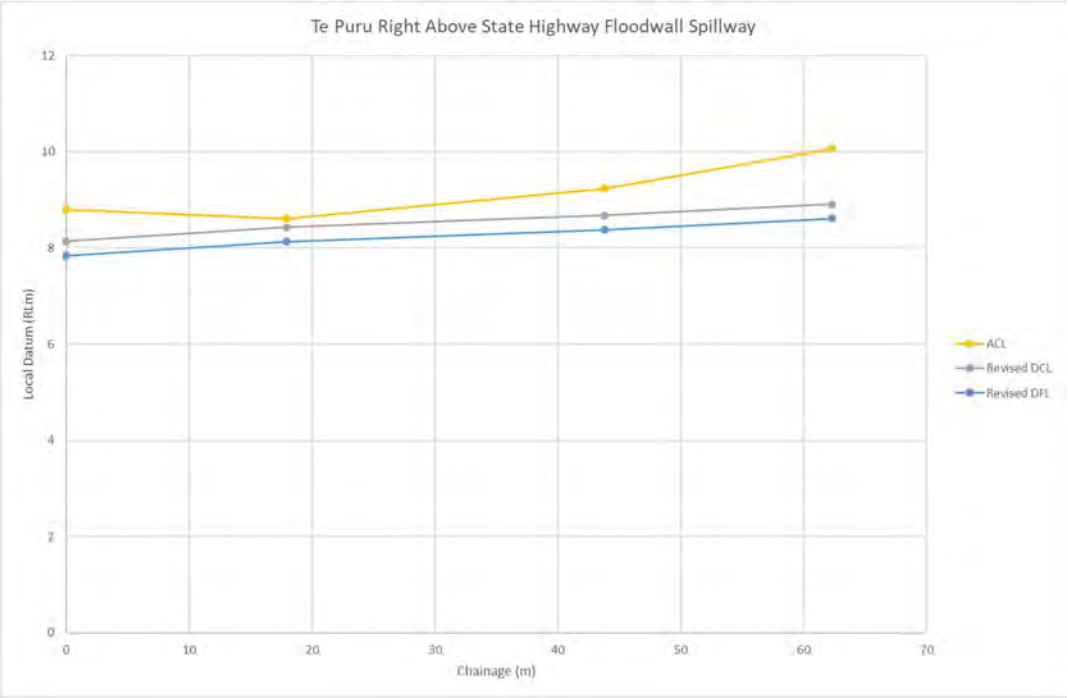

Figure 11 **Te Puru Right Above State Highway Floodwall Spillway - profiles for actual crest level (ACL) compared to the revised design crest level (DCL) and design flood level (DFL).**

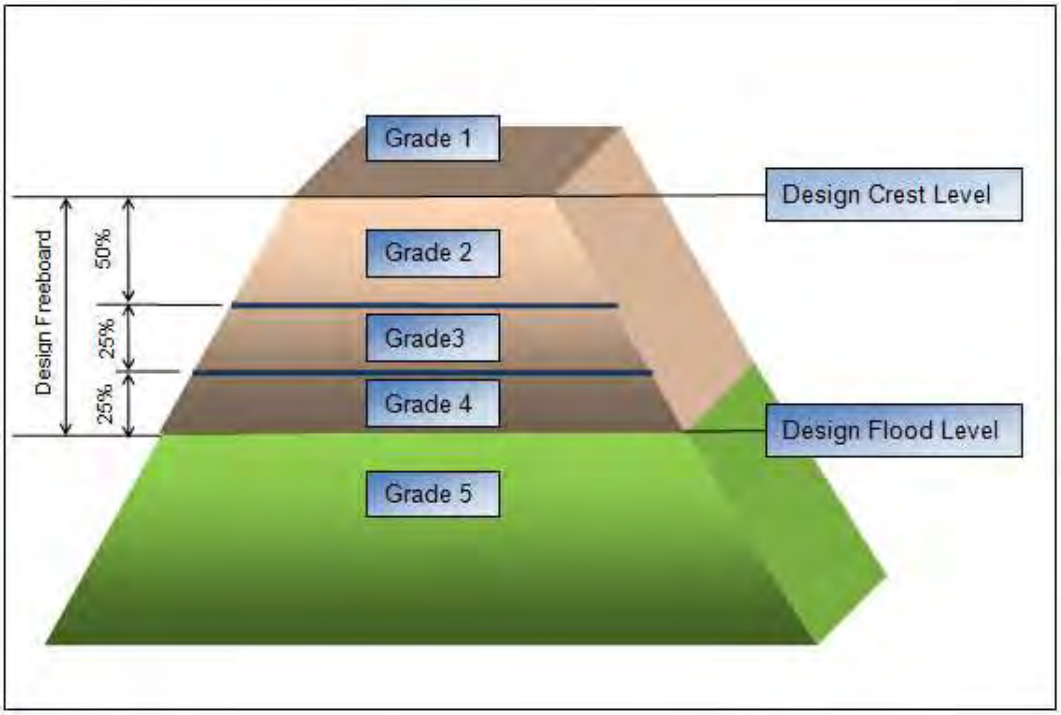

Figure 12 **Diagrammatic representation of stopbank performance grades.**

Table 2 Revised service level review data based on 2020 channel survey data.

(Note: Performance grades are based on estimated flood level and actual crest level at each surveyed point along 'embankment link.'

Parent asset ID	Asset ID	Description	Asset chainage (m)	Cross-section	Easting (NZTM)	Northing (NZTM)	Revised design flood level (RL m)	Free-board (m)	Revised design crest level (RL m)	Actual crest level (RL m)	Actual free-board (m)	Perf. Grade at point
Te Puru Left Below State Highway Floodwall – 463m Service level: 1%AEP + 600mm freeboard												
76074	76378	TP Left Below SH Floodwall 00	**0**		1824025.41	5897373.06	3.08	0.60	3.68	3.57	0.49	2
76074	76379	TP Left Below SH Floodwall 01	15		1824039.06	5897379.88	3.28	0.60	3.88	3.72	0.44	2
76074	76379	TP Left Below SH Floodwall 01	29		1824052.70	5897382.49	3.46	0.60	4.06	3.87	0.41	2
76074	76379	TP Left Below SH Floodwall 01	34	XS 14	1824054.07	5897386.77	3.51	0.60	4.11	4.02	0.51	2
76074	76379	TP Left Below SH Floodwall 01	39		1824055.66	5897391.52	3.52	0.60	4.12	3.97	0.45	2
76074	76379	TP Left Below SH Floodwall 01	46		1824059.81	5897398.03	3.53	0.60	4.13	4.08	0.55	2
76074	76379	TP Left Below SH Floodwall 01	56		1824068.31	5897401.40	3.57	0.60	4.17	4.16	0.59	2
76074	76379	TP Left Below SH Floodwall 01	65		1824076.67	5897405.63	3.62	0.60	4.22	4.15	0.53	2
76074	76379	TP Left Below SH Floodwall 01	88	XS 13	1824098.74	5897412.48	3.83	0.60	4.43	4.61	0.78	1
76074	76379	TP Left Below SH Floodwall 01	96		1824106.31	5897414.64	4.01	0.60	4.61	4.66	0.65	1
76074	76380	TP Left Below SH Floodwall 02	**100**		1824110.37	5897415.42	4.05	0.60	4.65	4.72	0.67	1
76074	76380	TP Left Below SH Floodwall 02	103		1824112.85	5897415.90	4.07	0.60	4.67	4.76	0.69	1
76074	76380	TP Left Below SH Floodwall 02	110		1824119.90	5897415.42	4.14	0.60	4.74	4.90	0.76	1
76074	76380	TP Left Below SH Floodwall 02	120		1824129.58	5897413.24	4.25	0.60	4.85	5.06	0.81	1
76074	76380	TP Left Below SH Floodwall 02	124	XS 12	1824133.61	5897411.31	4.33	0.60	4.93	5.21	0.88	1
76074	76380	TP Left Below SH Floodwall 02	128		1824137.62	5897409.33	4.38	0.60	4.98	5.18	0.80	1
76074	76380	TP Left Below SH Floodwall 02	140		1824147.69	5897404.71	4.49	0.60	5.09	5.31	0.82	1
76074	76380	TP Left Below SH Floodwall 02	150		1824156.75	5897398.96	4.59	0.60	5.19	5.45	0.86	1
76074	76380	TP Left Below SH Floodwall 02	161		1824165.65	5897393.27	4.69	0.60	5.29	5.55	0.86	1
76074	76380	TP Left Below SH Floodwall 02	165	XS 11	1824168.69	5897390.18	4.8	0.60	5.40	5.63	0.83	1
76074	76380	TP Left Below SH Floodwall 02	173		1824173.89	5897384.97	4.92	0.60	5.52	5.74	0.82	1
76074	76380	TP Left Below SH Floodwall 02	180		1824178.53	5897379.24	5.00	0.60	5.60	5.88	0.88	1
76074	76380	TP Left Below SH Floodwall 02	185		1824181.44	5897374.83	5.05	0.60	5.65	5.96	0.91	1

Parent asset ID	Asset ID	Description	Asset chainage (m)	Cross-section	Easting (NZTM)	Northing (NZTM)	Revised design flood level (RL m)	Free-board (m)	Revised design crest level (RL m)	Actual crest level (RL m)	Actual free-board (m)	Perf. Grade at point
76074	76380	TP Left Below SH Floodwall 02	191		1824185.33	5897370.15	5.11	0.60	5.71	5.99	0.88	1
76074	76380	TP Left Below SH Floodwall 02	195		1824187.27	5897366.80	5.15	0.60	5.75	6.02	0.87	1
76074	76380	TP Left Below SH Floodwall 02	200		1824190.36	5897363.44	5.19	0.60	5.79	6.06	0.87	1
76074	76381	TP Left Below SH Floodwall 03	**200**		1824190.45	5897363.15	5.20	0.60	5.80	6.06	0.86	1
76074	76381	TP Left Below SH Floodwall 03	210	XS 10	1824193.30	5897353.70	5.32	0.60	5.92	6.15	0.83	1
76074	76381	TP Left Below SH Floodwall 03	213		1824194.24	5897350.82	5.47	0.60	6.07	6.17	0.70	1
76074	76381	TP Left Below SH Floodwall 03	227		1824197.77	5897336.86	5.64	0.60	6.24	6.43	0.79	1
76074	76381	TP Left Below SH Floodwall 03	231		1824197.52	5897332.86	5.68	0.60	6.28	6.51	0.83	1
76074	76381	TP Left Below SH Floodwall 03	243		1824196.75	5897320.75	5.82	0.60	6.42	6.76	0.94	1
76074	76381	TP Left Below SH Floodwall 03	248	XS 9	1824196.50	5897316.27	5.87	0.60	6.47	6.84	0.97	1
76074	76381	TP Left Below SH Floodwall 03	260		1824195.70	5897304.37	5.98	0.60	6.58	6.92	0.94	1
76074	76381	TP Left Below SH Floodwall 03	282		1824194.32	5897282.75	6.14	0.60	6.74	7.03	0.89	1
76074	76381	TP Left Below SH Floodwall 03	296	XS 8	1824192.07	5897268.12	6.26	0.60	6.86	7.12	0.86	1
76074	76382	TP Left Below SH Floodwall 04	**300**		1824191.71	5897264.45	6.28	0.60	6.88	7.13	0.85	1
76074	76382	TP Left Below SH Floodwall 04	307		1824190.78	5897257.98	6.34	0.60	6.94	7.20	0.86	1
76074	76382	TP Left Below SH Floodwall 04	313		1824192.35	5897251.83	6.40	0.60	7.00	7.27	0.87	1
76074	76382	TP Left Below SH Floodwall 04	319		1824193.42	5897246.07	6.46	0.60	7.06	7.32	0.86	1
76074	76382	TP Left Below SH Floodwall 04	331		1824194.42	5897234.10	6.58	0.60	7.18	7.49	0.91	1
76074	76382	TP Left Below SH Floodwall 04	345		1824197.51	5897220.24	6.71	0.60	7.31	7.66	0.95	1
76074	76382	TP Left Below SH Floodwall 04	356	XS 7	1824198.76	5897209.55	6.81	0.60	7.41	7.81	1.00	1
76074	76382	TP Left Below SH Floodwall 04	358		1824199.00	5897207.50	6.82	0.60	7.42	7.85	1.03	1
76074	76382	TP Left Below SH Floodwall 04	366		1824201.95	5897200.26	6.87	0.60	7.47	7.97	1.10	1
76074	76382	TP Left Below SH Floodwall 04	378		1824206.17	5897188.74	6.98	0.60	7.58	8.14	1.16	1
76074	76382	TP Left Below SH Floodwall 04	383		1824208.44	5897184.09	7.05	0.60	7.65	8.21	1.16	1
76074	76382	TP Left Below SH Floodwall 04	392		1824213.23	5897176.15	7.14	0.60	7.74	8.41	1.27	1
76074	76382	TP Left Below SH Floodwall 04	399		1824217.70	5897170.70	7.22	0.60	7.82	8.56	1.34	1
76074	76383	TP Left Below SH Floodwall 05	**400**		1824218.13	5897170.24	7.23	0.60	7.83	8.59	1.36	1
76074	76383	TP Left Below SH Floodwall 05	406	XS 6	1824222.50	5897165.50	7.3	0.60	7.90	8.64	1.34	1

Parent asset ID	Asset ID	Description	Asset chainage (m)	Cross-section	Easting (NZTM)	Northing (NZTM)	Revised design flood level (RL m)	Free-board (m)	Revised design crest level (RL m)	Actual crest level (RL m)	Actual free-board (m)	Perf. Grade at point
76074	76383	TP Left Below SH Floodwall 05	411		1824225.82	5897162.04	7.35	0.60	7.95	8.76	1.41	1
76074	76383	TP Left Below SH Floodwall 05	417		1824229.83	5897157.52	7.42	0.60	8.02	8.85	1.43	1
76074	76383	TP Left Below SH Floodwall 05	427		1824237.16	5897151.02	7.57	0.60	8.17	8.96	1.39	1
76074	76383	TP Left Below SH Floodwall 05	438		1824244.47	5897143.55	7.72	0.60	8.32	9.11	1.39	1
76074	76383	TP Left Below SH Floodwall 05	451		1824254.23	5897134.14	7.88	0.60	8.48	9.22	1.34	1
76074	76383	TP Left Below SH Floodwall 05	**463**	XS 5	1824264.60	5897127.85	7.97	0.60	8.57	9.24	1.27	1
Te Puru Left Above State Highway Floodwall – 168m Service level: 1%AEP + 600mm freeboard												
76084	76387	TP Left Above SH Floodwall 01	**0**		1824307.07	5897116.77	8.31	0.6	8.91	9.65	1.34	1
76084	76388	TP Left Above SH Floodwall 02	20	XS 4	1824327.20	5897118.40	8.51	0.6	9.11	9.79	1.28	1
76084	76388	TP Left Above SH Floodwall 02	32		1824338.96	5897119.36	8.71	0.6	9.31	9.91	1.2	1
76084	76388	TP Left Above SH Floodwall 02	55		1824362.23	5897120.98	9.00	0.6	9.60	10.27	1.27	1
76084	76388	TP Left Above SH Floodwall 02	71	XS 3	1824377.80	5897121.40	9.15	0.6	9.75	10.54	1.39	1
76084	76388	TP Left Above SH Floodwall 02	83		1824389.49	5897121.73	9.28	0.6	9.88	10.65	1.37	1
76084	76389	TP Left Above SH Floodwall 03	**100**		1824406.87	5897122.61	9.46	0.6	10.06	10.85	1.39	1
76084	76389	TP Left Above SH Floodwall 03	100		1824407.36	5897122.64	9.47	0.6	10.07	10.85	1.38	1
76084	76389	TP Left Above SH Floodwall 03	120	XS 2	1824426.50	5897124.00	9.72	0.6	10.32	11.04	1.32	1
76084	76389	TP Left Above SH Floodwall 03	126		1824432.81	5897124.51	9.79	0.6	10.39	11.11	1.32	1
76084	76389	TP Left Above SH Floodwall 03	155		1824461.35	5897125.09	10.15	0.6	10.75	11.61	1.46	1
76084	76389	TP Left Above SH Floodwall 03	**168**		1824470.15	5897115.16	10.22	0.6	10.82	11.6	1.38	1
Te Puru Right Below State Highway Stopbank – 134m Service level: 1%AEP + 600mm freeboard												
76076	76392	TP Right Below SH Stopbank 00	**0**		1824012.45	5897460.34	3.30	0.6	3.9	3.65	0.35	2
76076	76393	TP Right Below SH Stopbank 01	15		1824021.41	5897448.01	3.41	0.6	4.01	3.72	0.31	2
76076	76393	TP Right Below SH Stopbank 01	30		1824035.23	5897443.66	3.48	0.6	4.08	3.98	0.50	2
76076	76393	TP Right Below SH Stopbank 01	36	XS 14	1824041.10	5897443.10	3.51	0.6	4.11	3.91	0.40	2
76076	76393	TP Right Below SH Stopbank 01	47		1824052.82	5897441.50	3.59	0.6	4.19	3.95	0.36	2
76076	76393	TP Right Below SH Stopbank 01	61		1824066.12	5897444.04	3.67	0.6	4.27	4.24	0.57	2

Parent asset ID	Asset ID	Description	Asset chainage (m)	Cross-section	Easting (NZTM)	Northing (NZTM)	Revised design flood level (RL m)	Free-board (m)	Revised design crest level (RL m)	Actual crest level (RL m)	Actual free-board (m)	Perf. Grade at point
76076	76393	TP Right Below SH Stopbank 01	85	XS 13	1824088.50	5897452.00	3.83	0.6	4.43	4.56	0.73	1
76076	76393	TP Right Below SH Stopbank 01	87		1824090.45	5897452.45	3.84	0.6	4.44	4.6	0.76	1
76076	76398	TP Right Below SH Stopbank 02	**100**		1824103.67	5897451.31	3.92	0.6	4.52	4.96	1.04	1
76076	76398	TP Right Below SH Stopbank 02	115		1824118.54	5897450.03	4.07	0.6	4.67	4.94	0.87	1
76076	76398	TP Right Below SH Stopbank 02	**134**		1824137.78	5897452.84	4.25	0.6	4.85	5.06	0.81	1
Te Puru Right Below State Highway Floodwall – 199m. ***Service level varied: downstream XS11 - 1%AEP + 600mm freeboard (68m)*** ***upstream XS11 - %AEP (future climate) + no freeboard (131m) – possible revision for 1%AEP + 600mm freeboard in red brackets***												
76076	76384	TP Right Below SH Floodwall 00	**0**		1824137.78	5897452.84	4.25	0.6	4.85	5.05	0.80	1
76076	76385	TP Right Below SH Floodwall 01	3		1824140.95	5897452.23	4.27	0.6	4.87	5.08	0.81	1
76076	76385	TP Right Below SH Floodwall 01	7		1824144.07	5897450.41	4.3	0.6	4.9	5.1	0.80	1
76076	76385	TP Right Below SH Floodwall 01	12	XS 12	1824148.60	5897448.30	4.33	0.6	4.93	5.19	0.86	1
76076	76385	TP Right Below SH Floodwall 01	13		1824149.52	5897447.81	4.34	0.6	4.94	5.19	0.85	1
76076	76385	TP Right Below SH Floodwall 01	35		1824167.96	5897435.28	4.53	0.6	5.13	5.21	0.68	1
76076	76385	TP Right Below SH Floodwall 01	47		1824177.42	5897428.75	4.63	0.6	5.23	5.39	0.76	1
76076	76385	TP Right Below SH Floodwall 01	50		1824179.34	5897425.87	4.66	0.6	5.26	5.4	0.74	1
76076	76385	TP Right Below SH Floodwall 01	54		1824182.31	5897423.53	4.70	0.6	5.3	5.42	0.72	1
76076	76385	TP Right Below SH Floodwall 01	68	XS 11	1824193.70	5897415.10	4.8	0.6	5.4	5.6	0.80	1
Change in service level as detailed in header												
76076	76385	TP Right Below SH Floodwall 01	69		1824194.81	5897414.28	5.26 (4.81)	0 (0.6)	5.26 (5.41)	5.56	0.30 (0.75)	1 (1)
76076	76385	TP Right Below SH Floodwall 01	73		1824197.18	5897411.45	5.29 (4.84)	0 (0.6)	5.29 (5.44)	5.60	0.31 (0.76)	1 (1)
76076	76385	TP Right Below SH Floodwall 01	87		1824201.76	5897398.79	5.42 (4.96)	0 (0.6)	5.42 (5.56)	5.67	0.25 (0.71)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	**100**		1824208.86	5897387.44	5.56 (5.09)	0 (0.6)	5.56 (5.69)	5.77	0.21 (0.68)	1 (1)

Parent asset ID	Asset ID	Description	Asset chainage (m)	Cross-section	Easting (NZTM)	Northing (NZTM)	Revised design flood level (RL m)	Free-board (m)	Revised design crest level (RL m)	Actual crest level (RL m)	Actual free-board (m)	Perf. Grade at point
76076	76386	TP Right Below SH Floodwall 02	115		1824216.65	5897374.99	5.71 (5.24)	0 (0.6)	5.71 (5.84)	5.94	0.23 (0.70)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	123	XS 10	1824219.80	5897367.80	5.79 (5.32)	0 (0.6)	5.79 (5.92)	6.07	0.28 (0.75)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	128		1824222.02	5897362.91	5.84 (5.37)	0 (0.6)	5.84 (5.97)	6.14	0.30 (0.77)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	138		1824225.58	5897353.02	5.96 (5.48)	0 (0.6)	5.96 (6.08)	6.36	0.40 (0.88)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	155		1824230.58	5897337.45	6.17 (5.67)	0 (0.6)	6.17 (6.27)	6.52	0.35 (0.85)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	169		1824234.44	5897324.15	6.31 (5.81)	0 (0.6)	6.31 (6.41)	6.63	0.32 (0.82)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	176	XS 9	1824235.10	5897316.70	6.38 (5.87)	0 (0.6)	6.38 (6.47)	6.83	0.45 (0.96)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	185		1824235.89	5897307.74	6.41 (5.90)	0 (0.6)	6.41 (6.50)	6.99	0.58 (1.09)	1 (1)
76076	76386	TP Right Below SH Floodwall 02	**199**		1824238.60	5897293.48	6.48 (5.98)	0 (0.6)	6.48 (6.58)	7.05	0.57 (1.07)	1 (1)
Te Puru Right Above State Highway Floodwall Spillway – 62m Service level: 1%AEP + 300mm freeboard												
76086	76390	TP Right Above SH Floodwall Spillway	**0**	XS 5	1824273.69	5897167.53	7.84	0.3	8.14	8.8	0.96	1
76086	76391	TP Right Above SH Floodwall Spillway	18		1824290.95	5897162.81	8.13	0.3	8.43	8.61	0.48	1
76086	76391	TP Right Above SH Floodwall Spillway	44		1824315.72	5897155.26	8.38	0.3	8.68	9.24	0.86	1
76086	76391	TP Right Above SH Floodwall Spillway	**62**		1824334.10	5897152.83	8.61	0.3	8.91	10.07	1.46	1

6 Conclusions

The supplementary report has addressed issues raised in the Grant (2019) service level review of the Te Puru flood protection scheme assets. These issues primarily related to shortfalls in freeboard in the lower scheme assets associated with aggradation of material at the stream mouth.

The stream channel cross-sections and topography near the mouth were resurveyed in May 2020 and the MIKE11 hydraulic model revised to reassess the provision of service. Whilst the situation has since improved through both excavation and natural processes (resulting in lower bed levels) there remains a shortfall in freeboard in the lower 80m of the scheme assets on both banks. This shortfall is typically less than 300mm or half the freeboard, meaning that the assets are currently rated as Performance Grade 2. The remainder of the flood protection scheme is rated as Performance Grade 1.

The flood protection assets with Performance Grade 2 are floodwalls or stopbanks within confined areas and are not easily modified to provide more freeboard. The best solution to meet the service level and improve performance grades in the lower stream is to undertake as-required channel excavation/maintenance to allow sufficient capacity to meet the required 600mm freeboard.

Suggested stream excavation requirements are outlined in Section 4.1.2.4 based on modelling with an excavated trapezoidal channel through the lower stream reach (cross-sections XS14 and XS15). This modelling applied a 15m base width at a minimum level of RL 0m (Te Puru Local Datum) or RL -0.26m TVD-52), with side slopes blended back into the existing upper banks which have been relatively stable throughout the various survey periods.

7 Recommendations

The recommendations based on this supplementary report are:

- Undertake excavation of the lower channel to the stream mouth to improve freeboard in the seaward 80m of flood protection assets on both banks.
- Revise the flood protection scheme asset 'floodwall extension' service level to 1%AEP + 600mm freeboard to be consistent with other stopbank/floodwall assets. This is a higher standard than used at present and is supported by the actual asset crest level.

References

Goodhue N 2012. Tide marks and mean sea-level for Whitianga and Tararu. Prepared by NIWA for Waikato Regional Council. Doc. #3245587

Grant D 2019. Te Puru Stream flood protection scheme service level review. Waikato Regional Council Technical Report 2019/26. Hamilton, Waikato Regional Council.

Wood M 2014. Te Puru flood protection scheme design report. Waikato Regional Council Technical Report 2013/42. Hamilton, Waikato Regional Council.

Appendix A – Comparison of ground survey cross-sections (2014 – local datum) and LIDAR DTM slices (2012 – AVD-46+0.13m i.e. local datum)

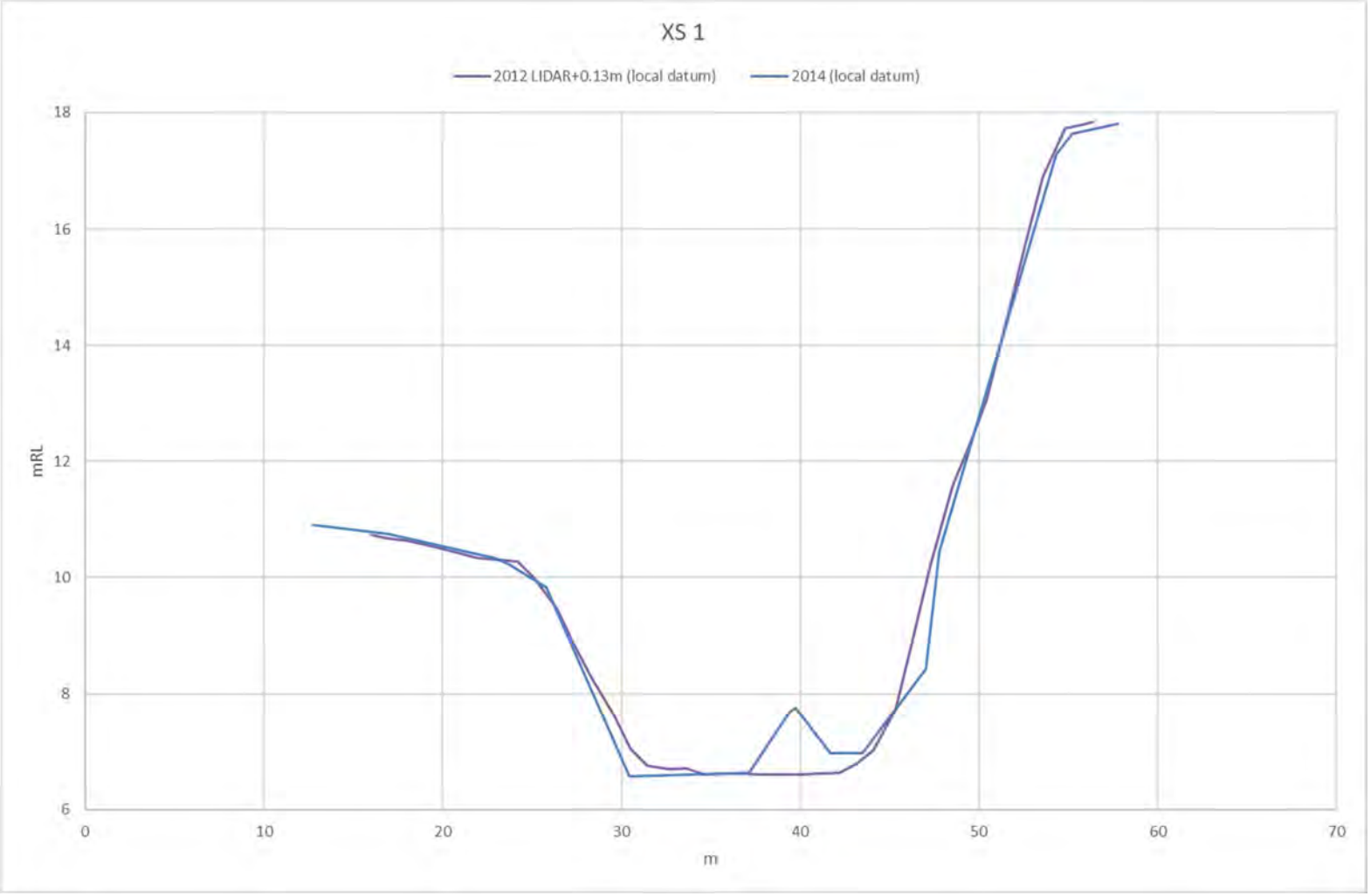

Figure A1 XS 1 (MIKE11 model chainage 0m – location shown in Figure A16)

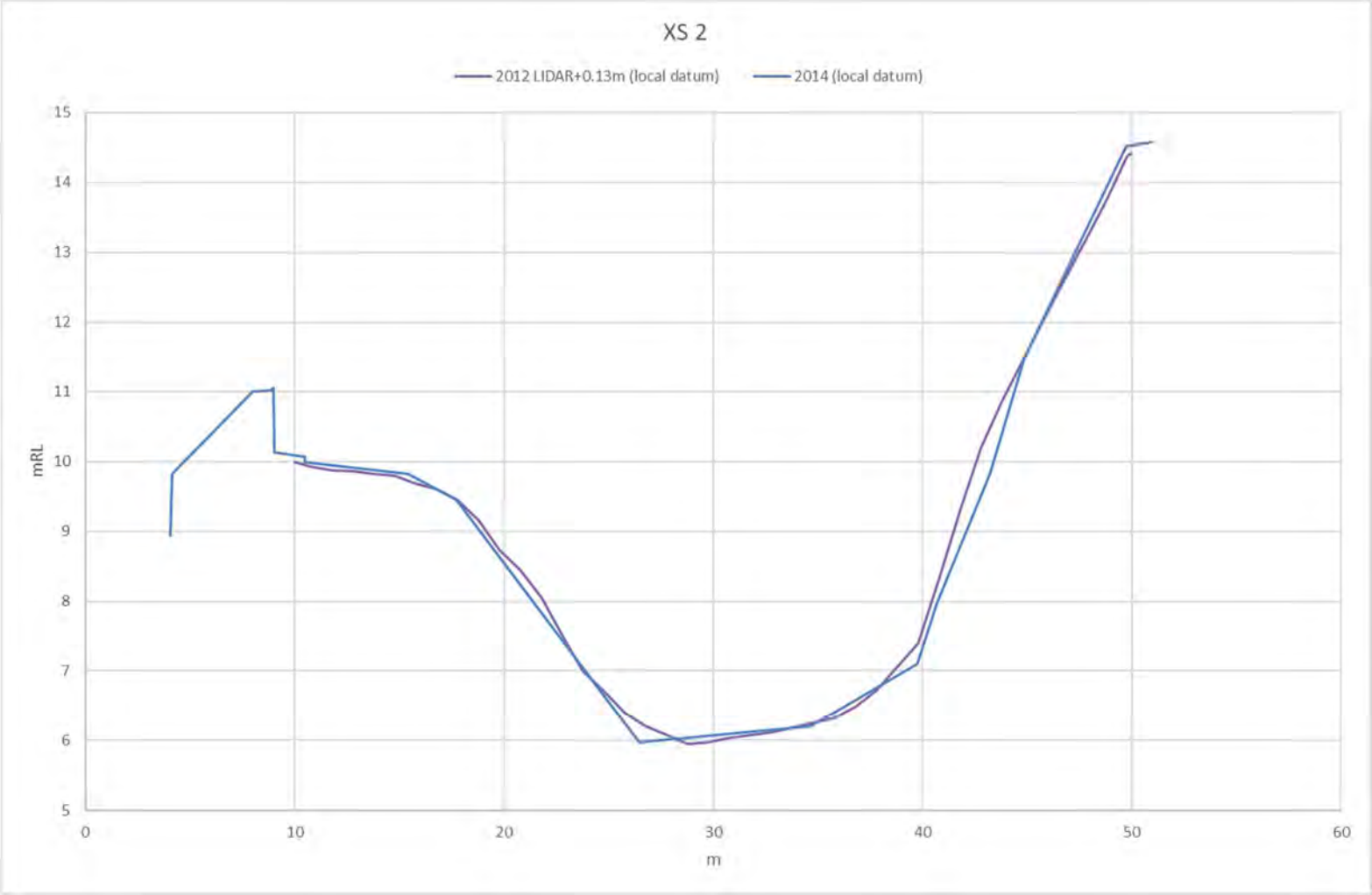

Figure A2 XS 2 (MIKE11 model chainage 44m – location shown in Figure A16)

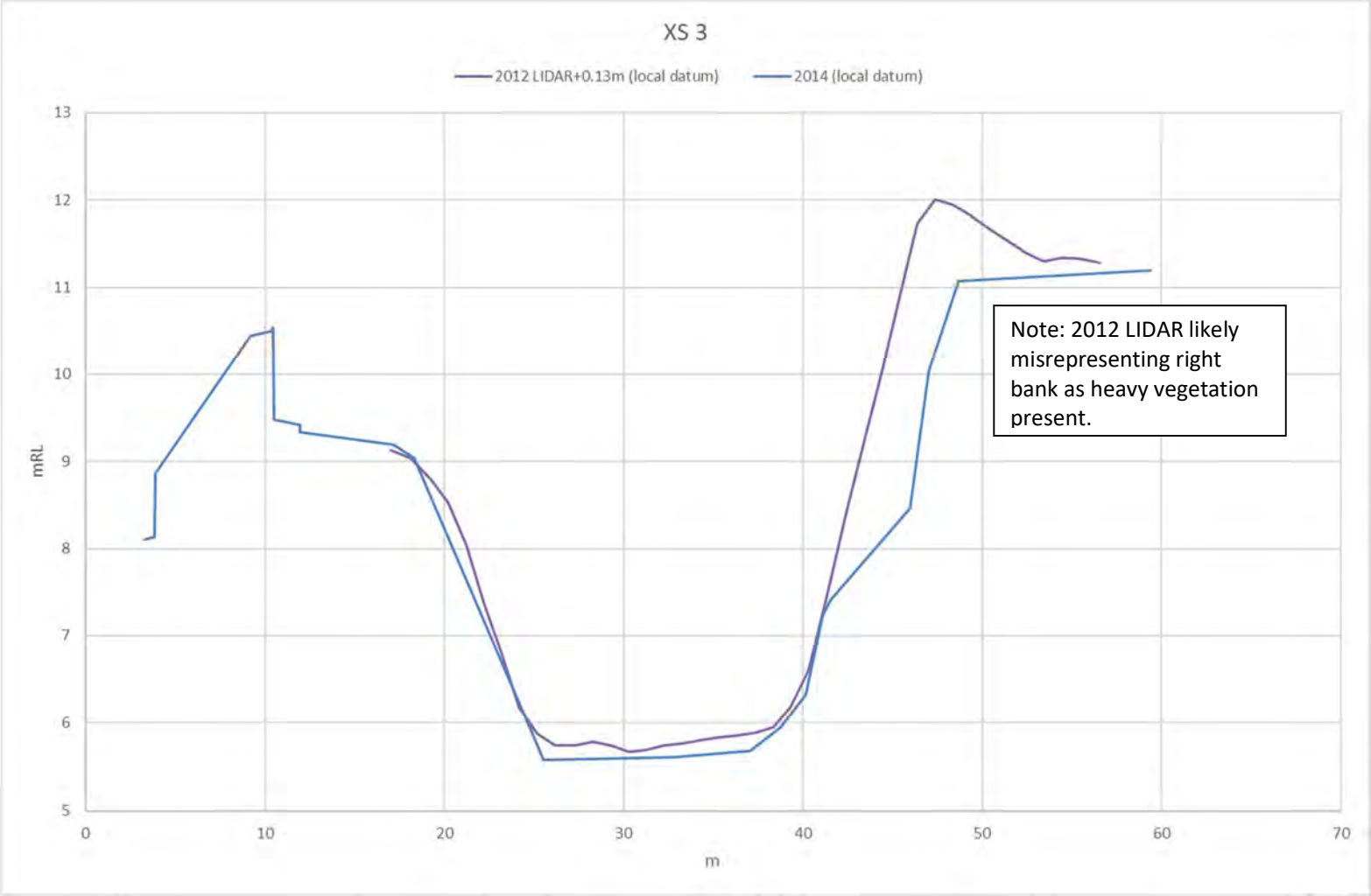

Figure A3 XS 3 (MIKE11 model chainage 94m – location shown in Figure A16)

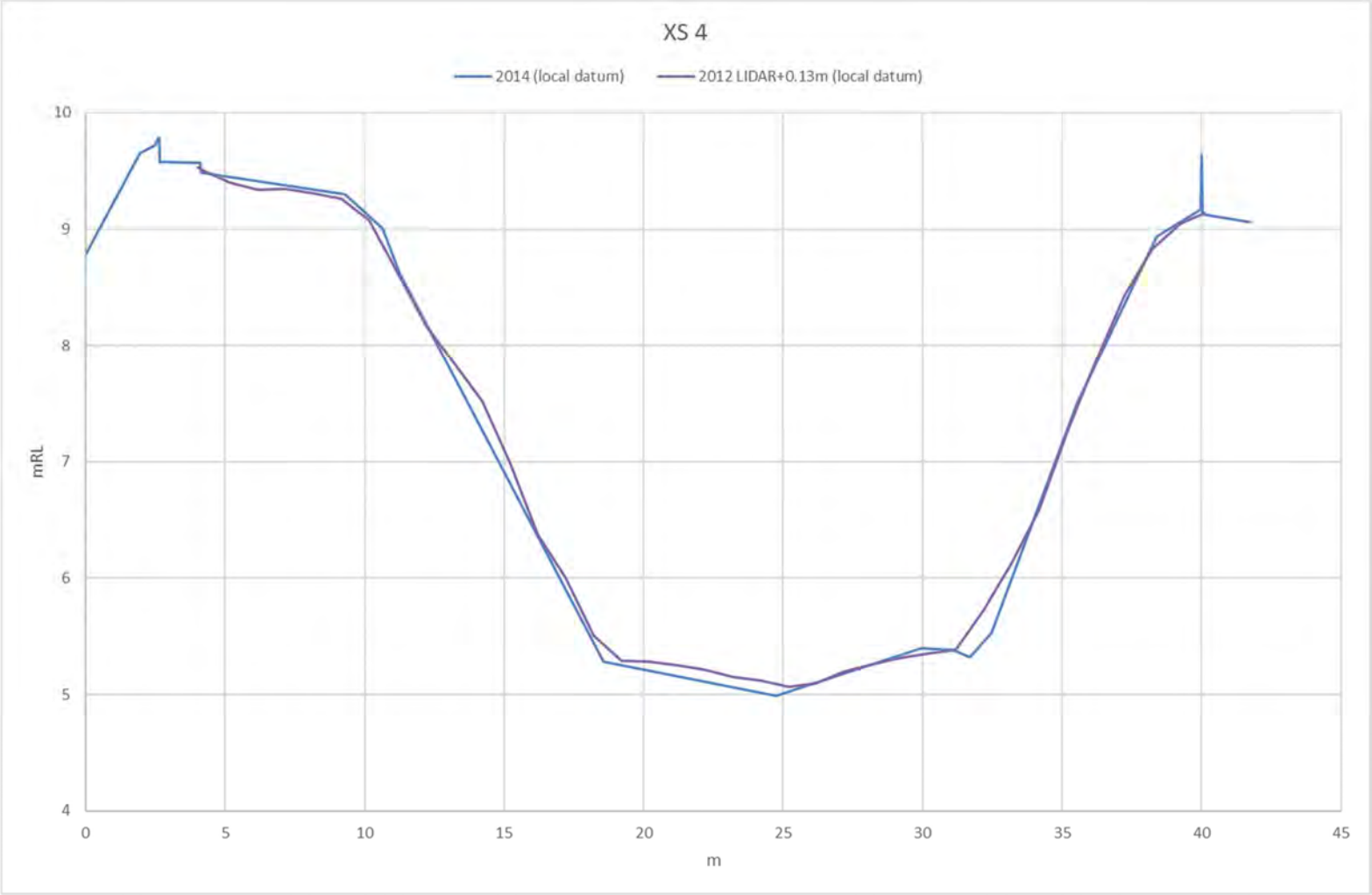

Figure A4 XS 4 (MIKE11 model chainage 144m – location shown in Figure A16)

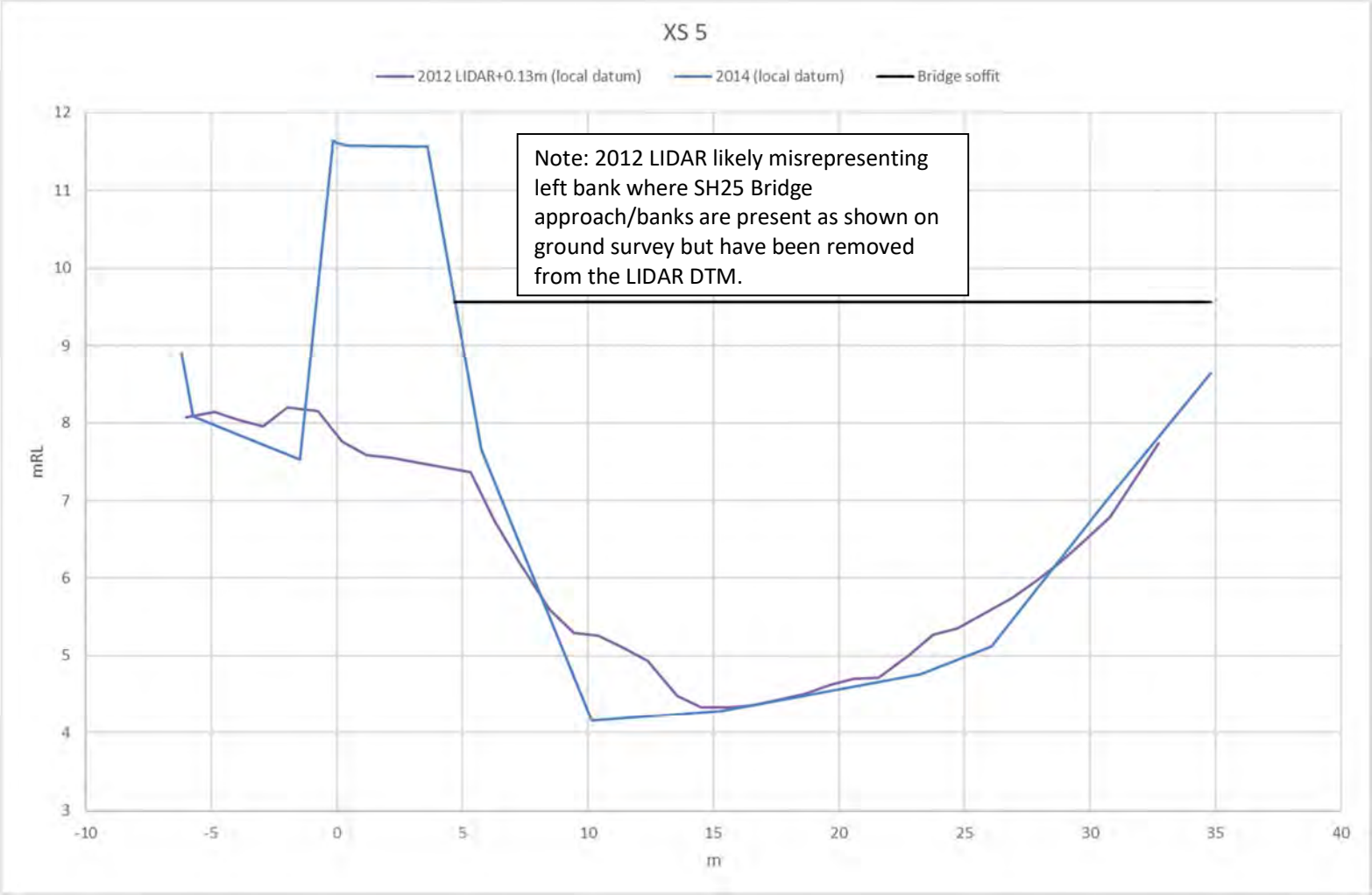

Figure A5 XS 5 (MIKE11 model chainage 202m – location shown in Figure A16)

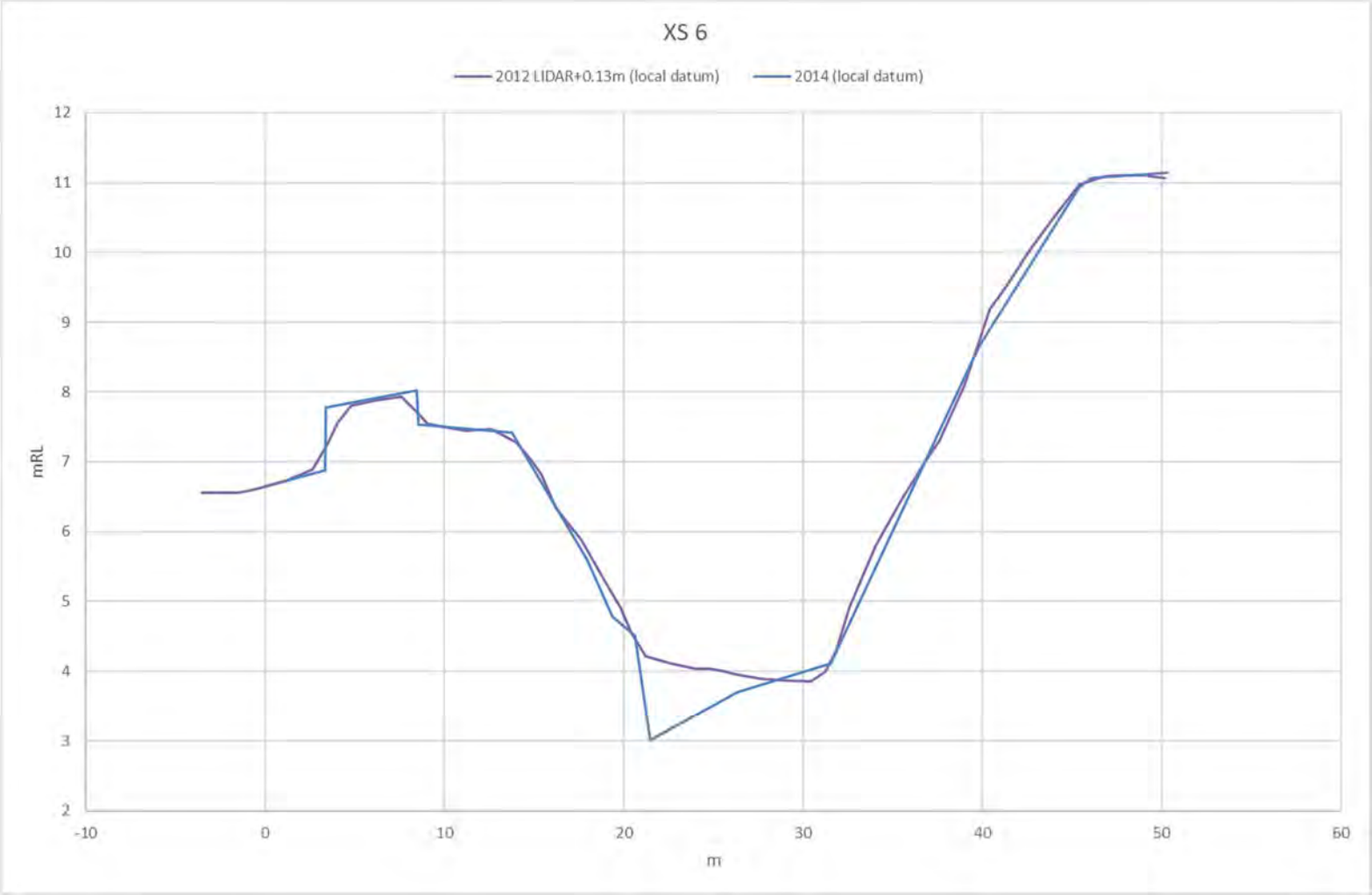

Figure A6 XS 6 (MIKE11 model chainage 249m – location shown in Figure A16)

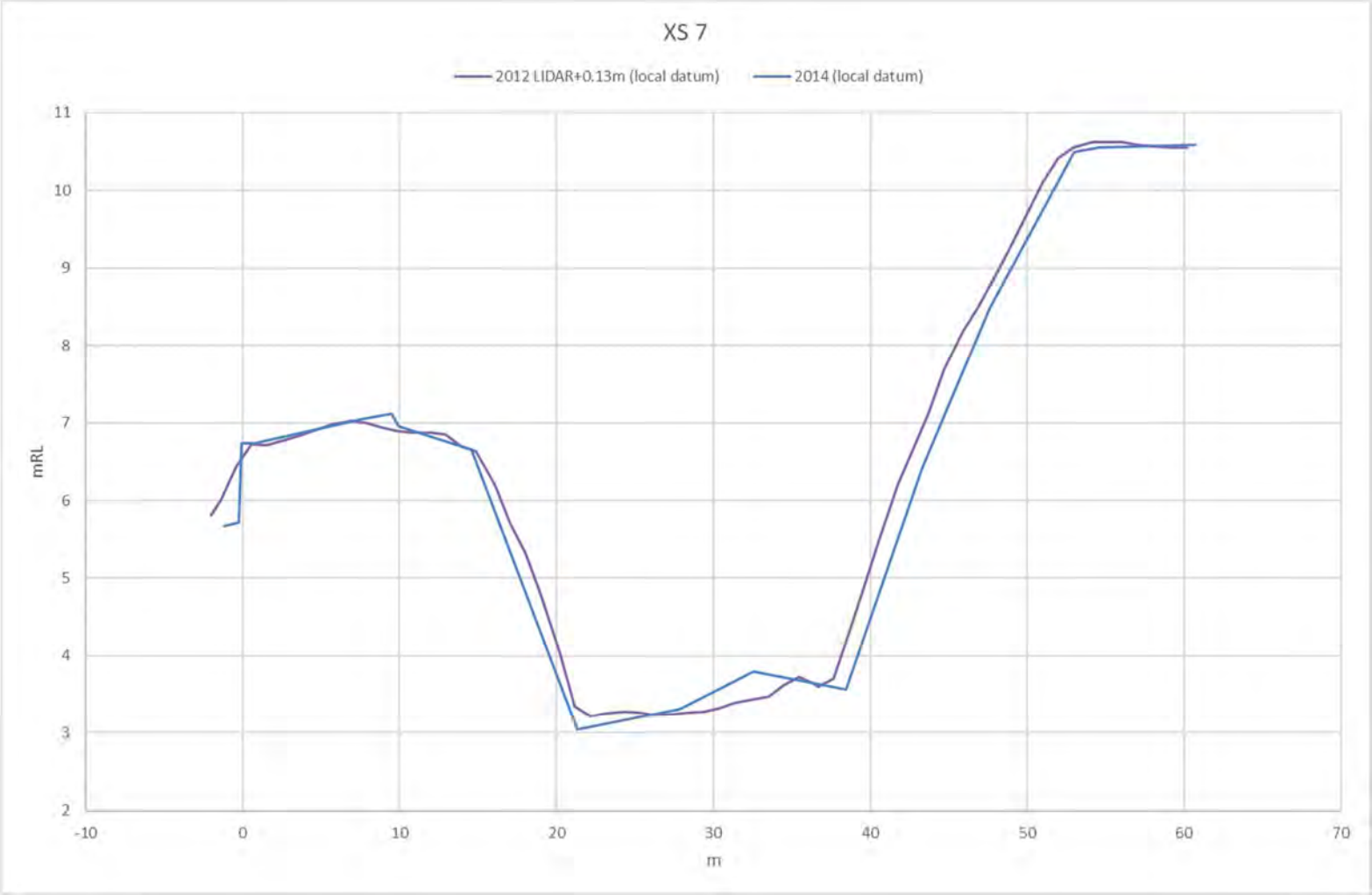

Figure A7 XS 7 (MIKE11 model chainage 295m – location shown in Figure A16)

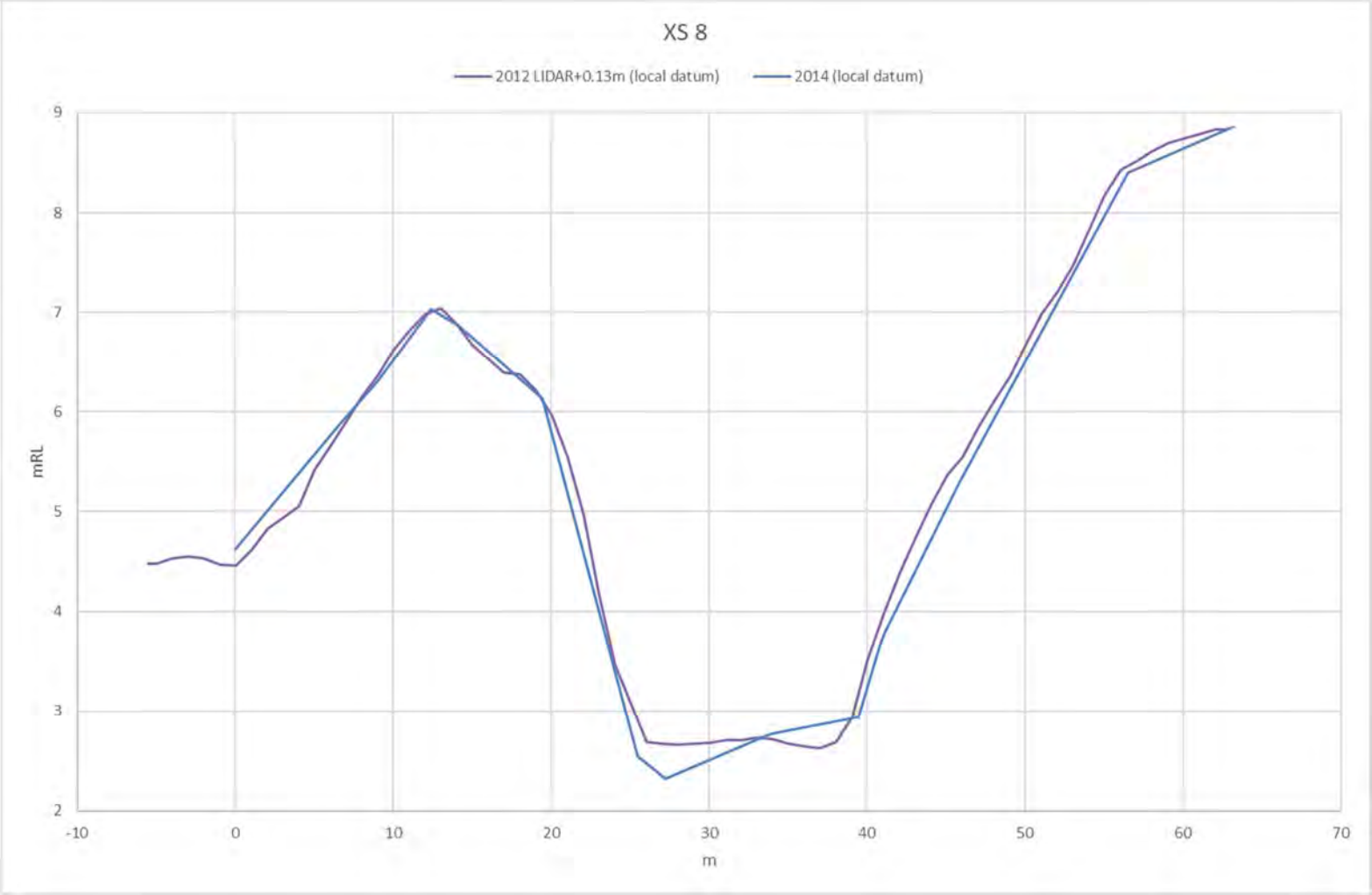

Figure A8 XS 8 (MIKE11 model chainage 350m – location shown in Figure A16)

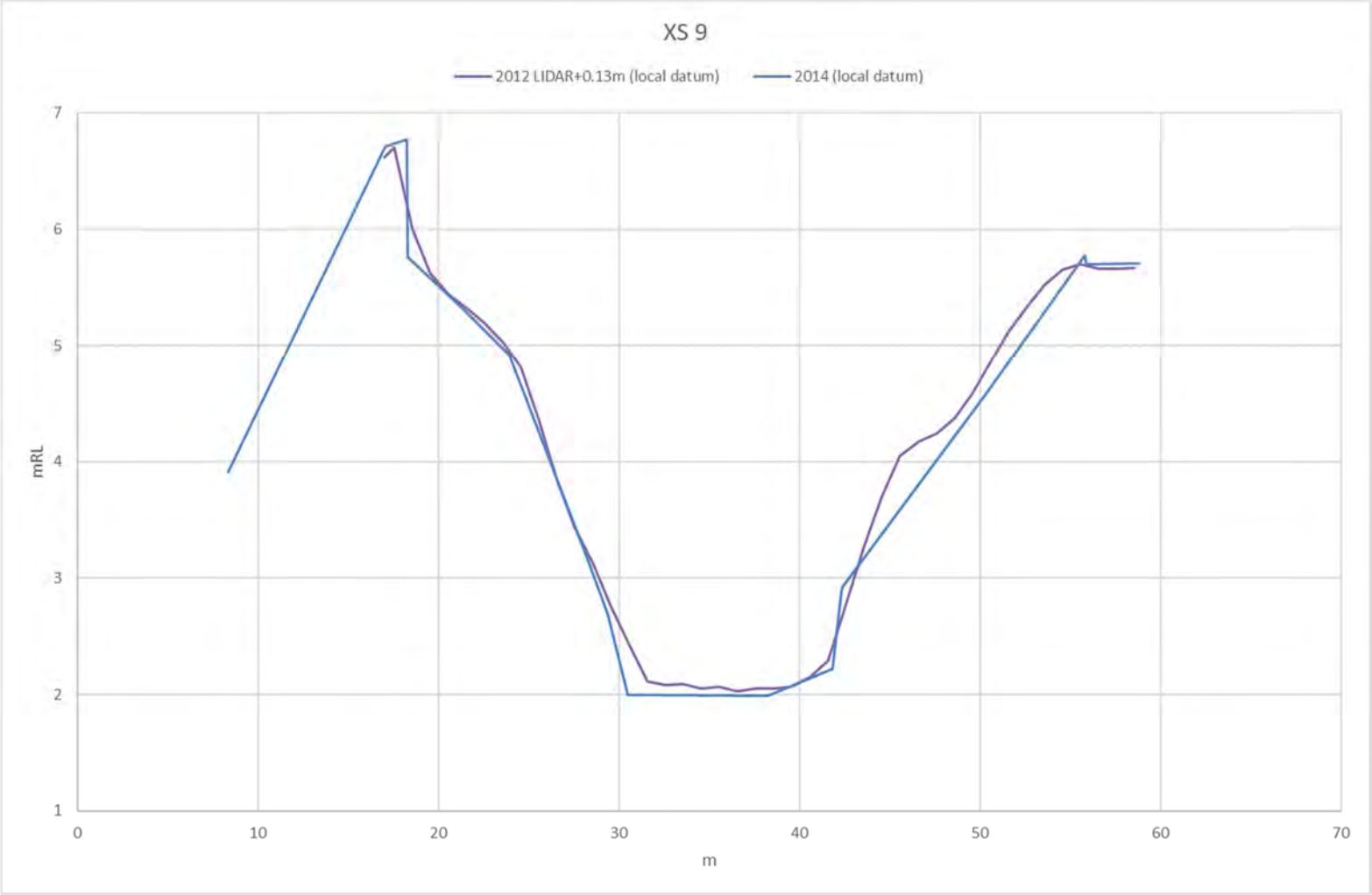

Figure A9 XS 9 (MIKE11 model chainage 402m – location shown in Figure A16)

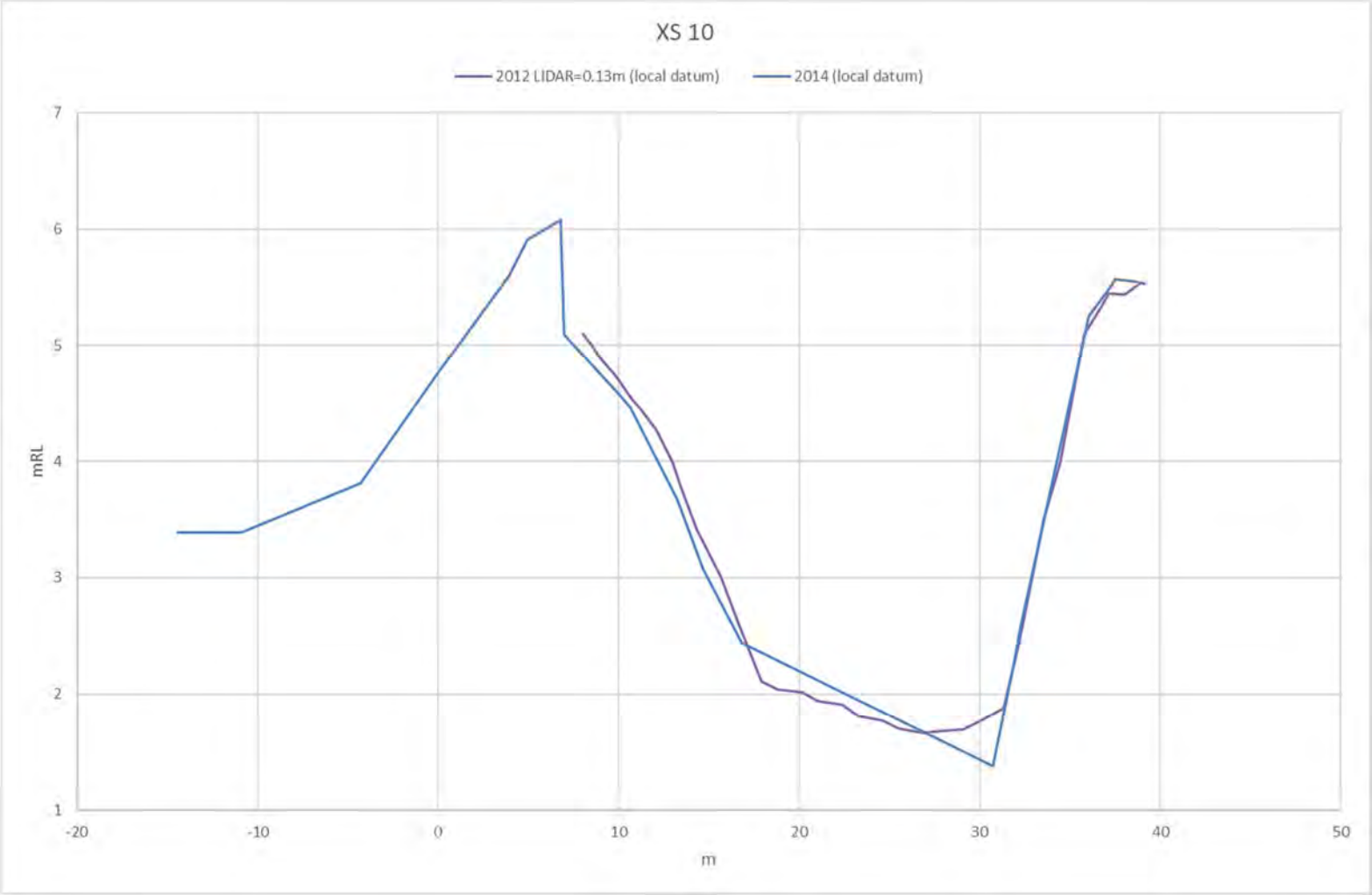

Figure A10 XS 10 (MIKE11 model chainage 450m – location shown in Figure A16)

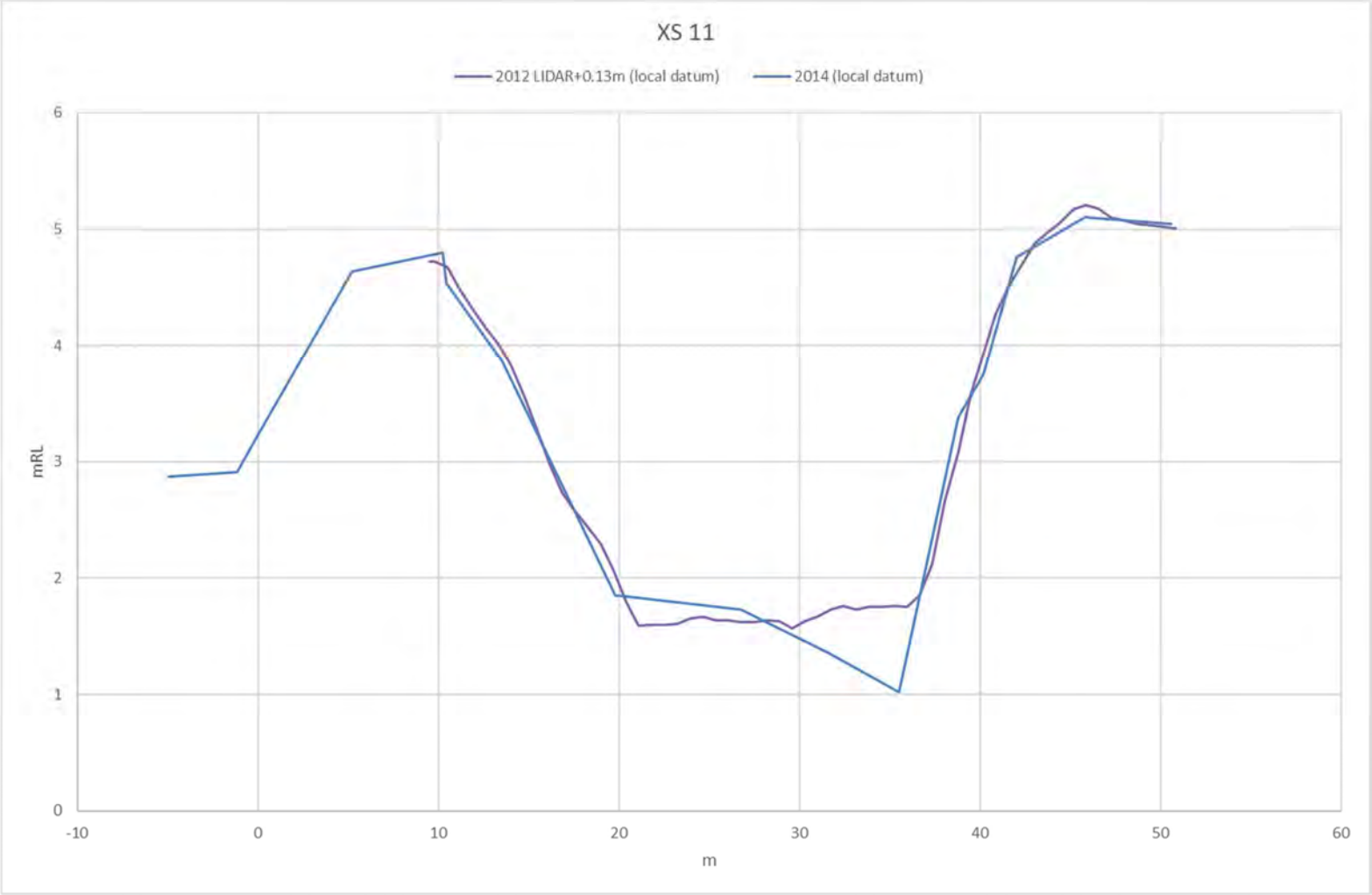

Figure A11 XS 11 (MIKE11 model chainage 501m – location shown in Figure A16)

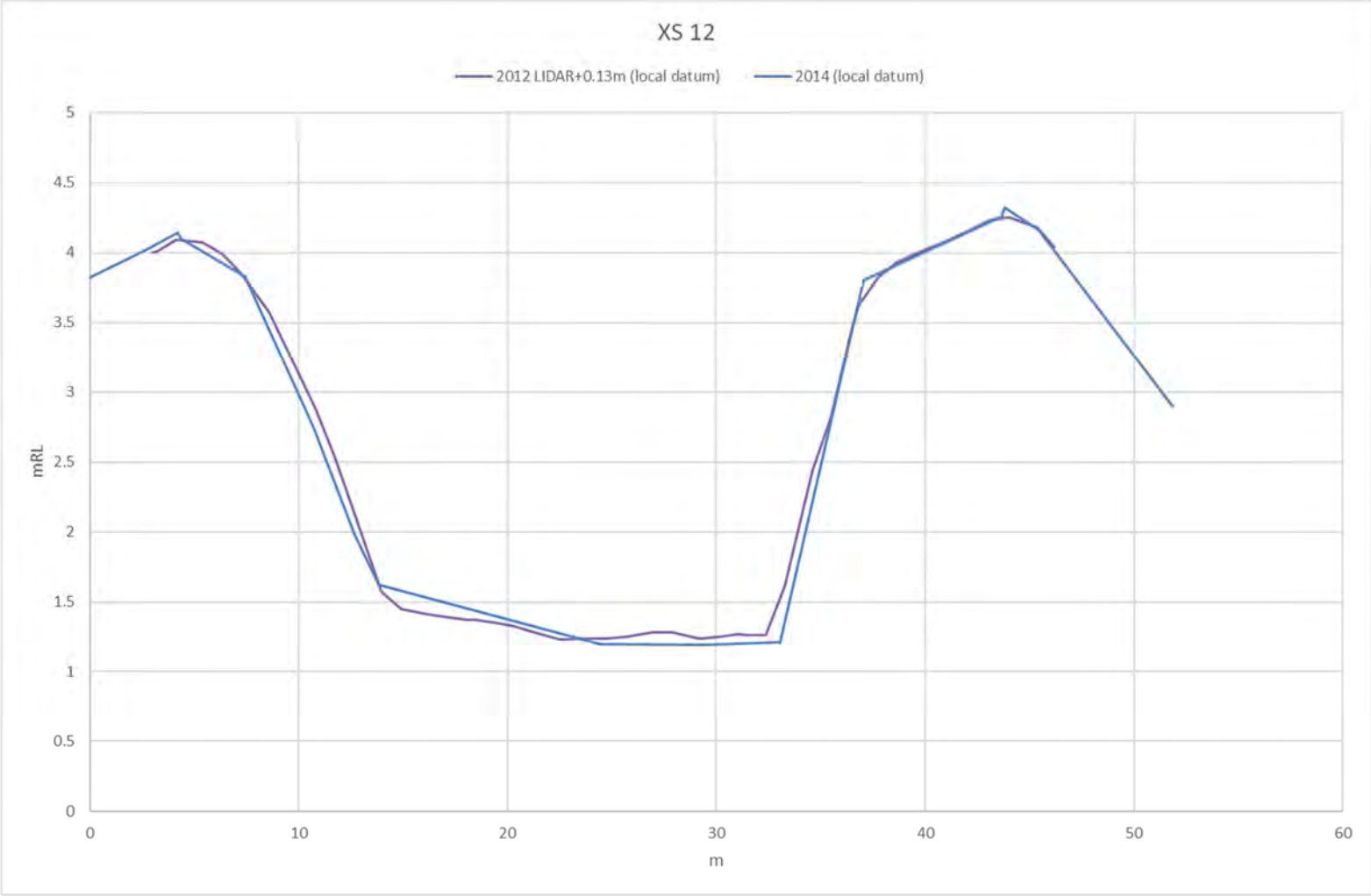

Figure A12 XS 12 (MIKE11 model chainage 551m – location shown in Figure A16)

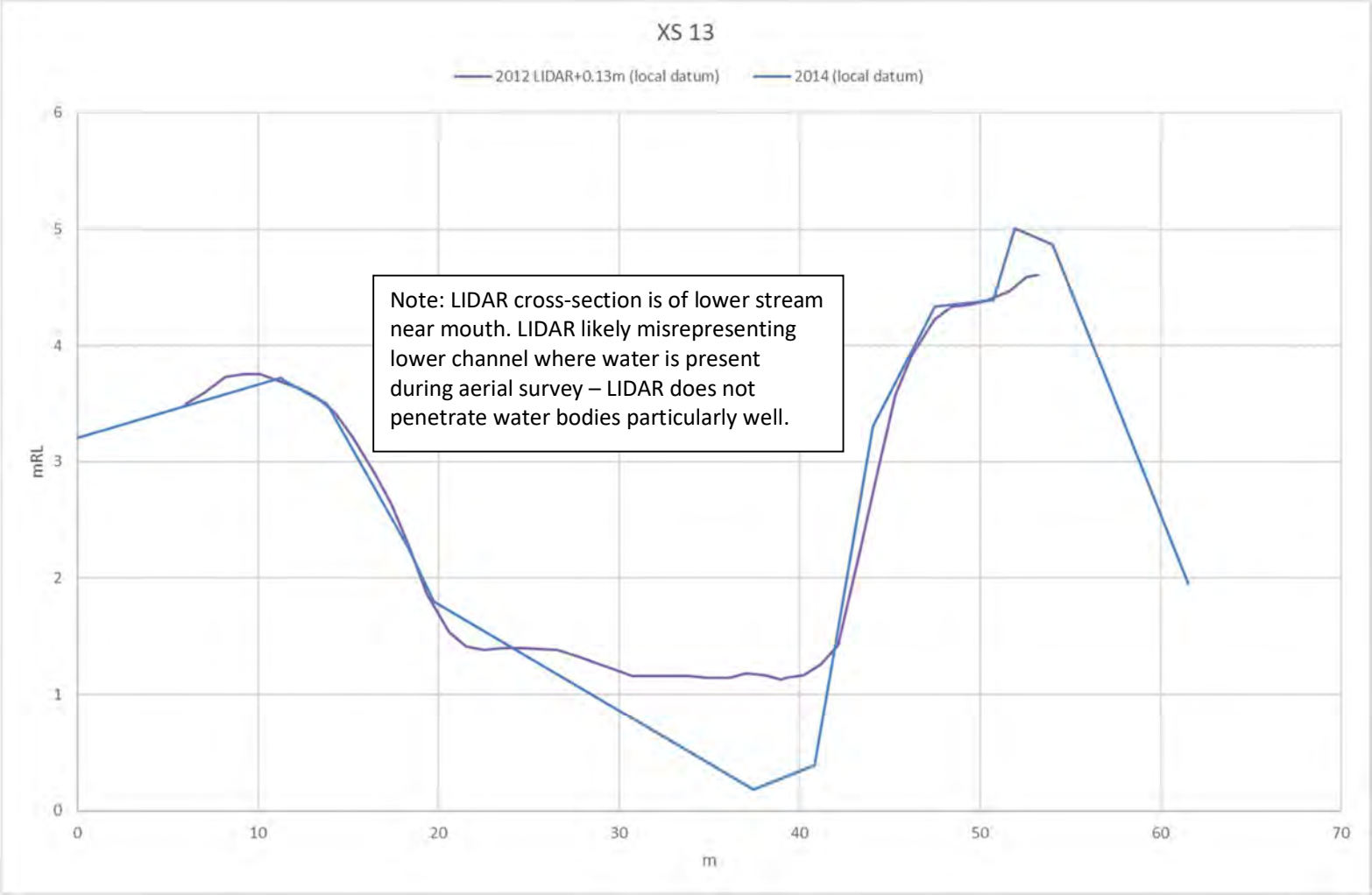

Figure A13 XS 13 (MIKE11 model chainage 600m – location shown in Figure A16)

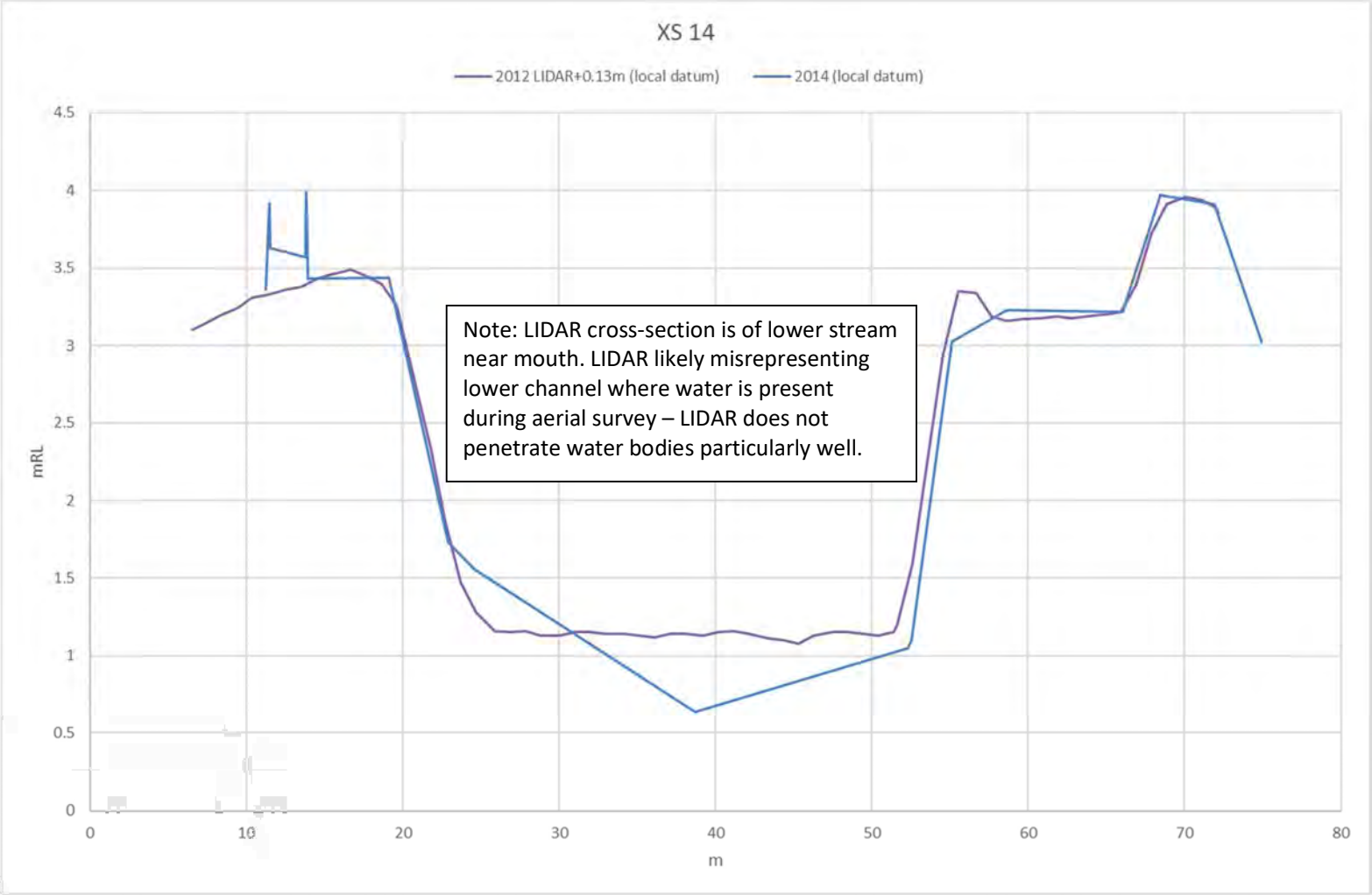

Figure A14 XS 14 (MIKE11 model chainage 650m – location shown in Figure A16)

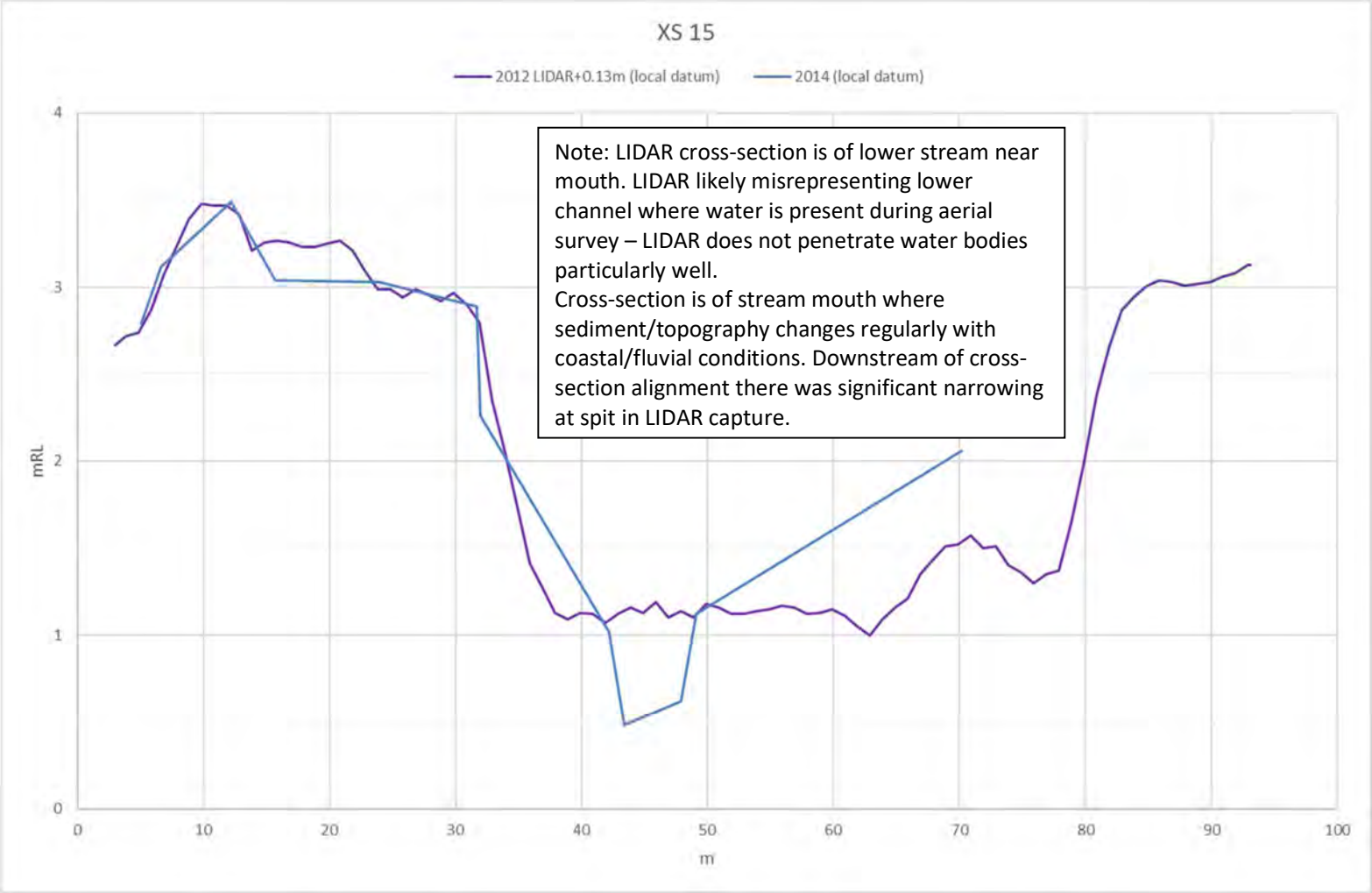

Figure A15 XS 15 (MIKE11 model chainage 710m – location shown in Figure A16)

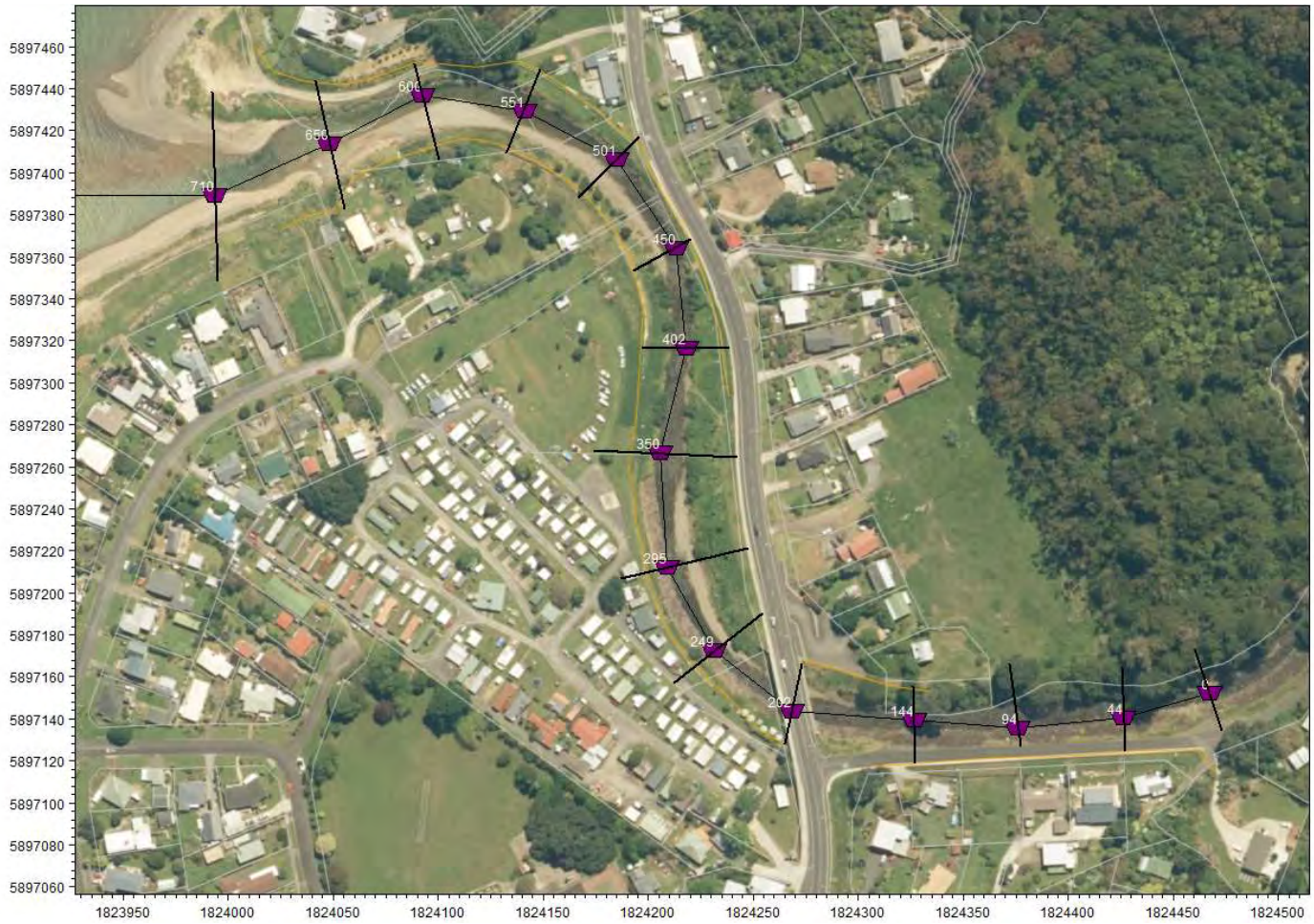

Figure A16 Location of ground survey cross-sections as shown in the MIKE11 model. Note model chainages are shown in image but cross-sections are XS 1 (upstream) to XS 15 (downstream).

Appendix B – Comparison of 2004, 2014 and 2020 ground survey cross-sections

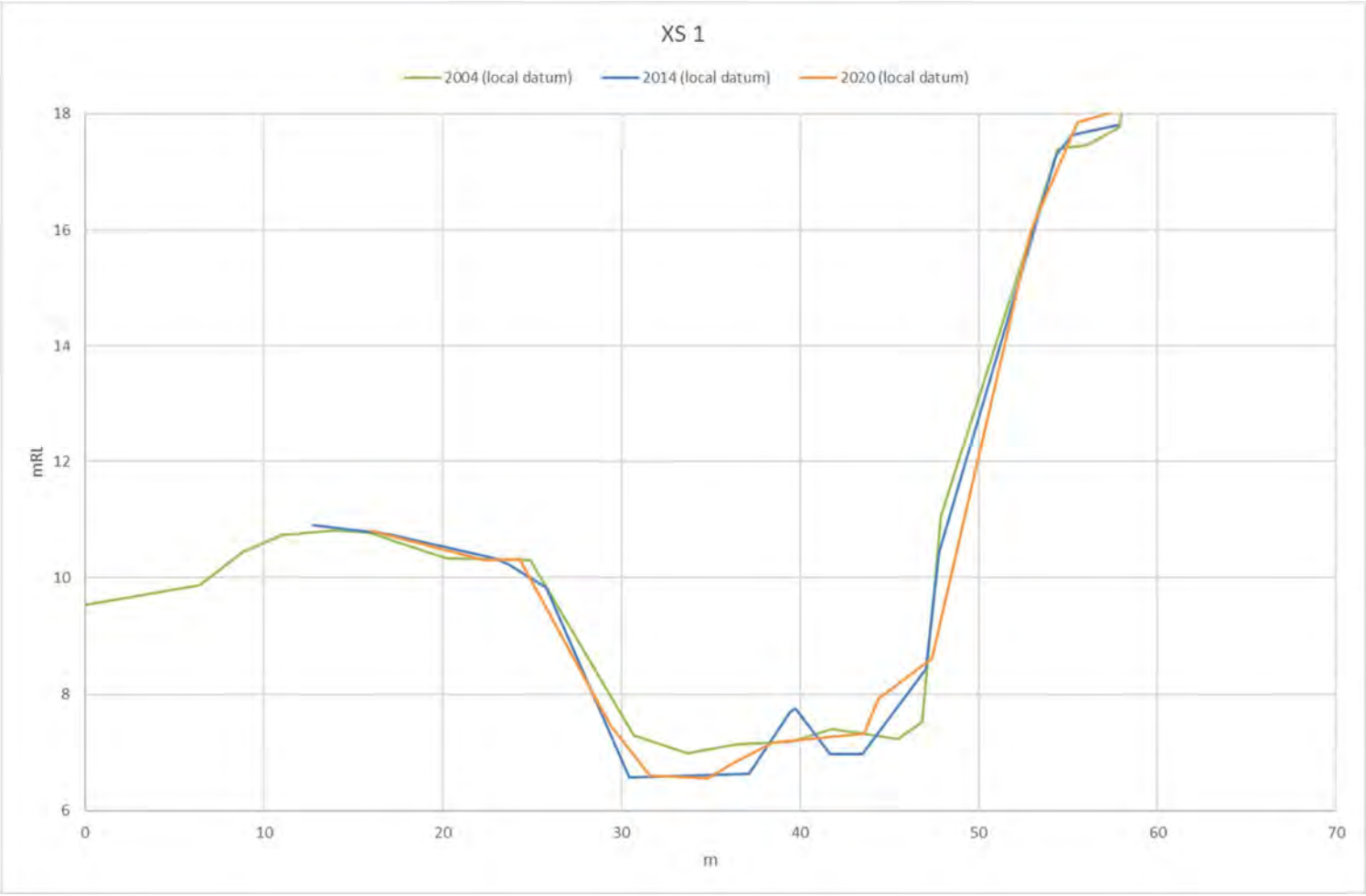

Figure B1 Comparison of 2004 and 2014 survey at XS 1 (MIKE11 model chainage 0m – location shown in Figure A16)

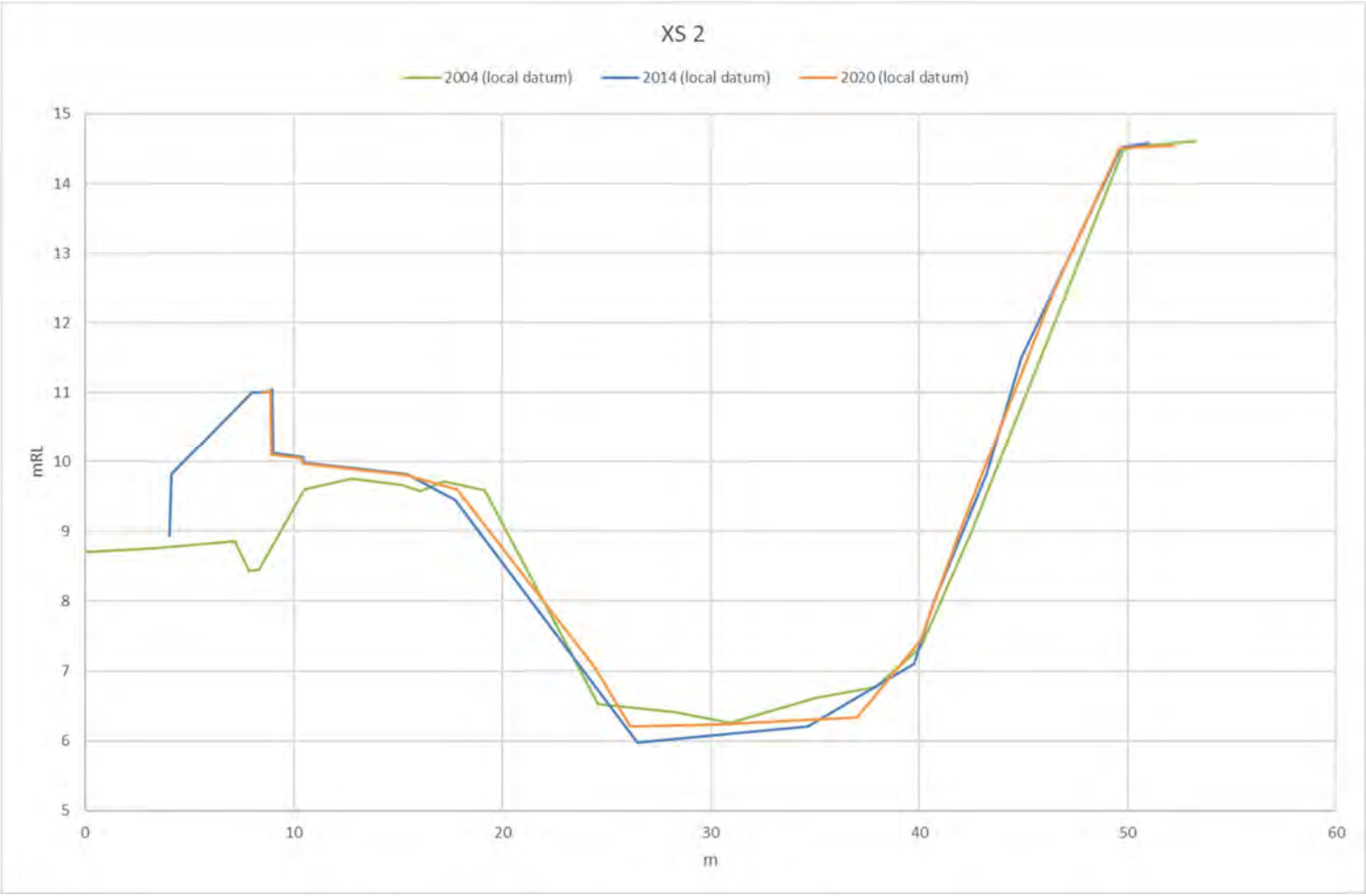

Figure B2 Comparison of 2004 and 2014 survey at XS 2 (MIKE11 model chainage 44m – location shown in Figure A16)

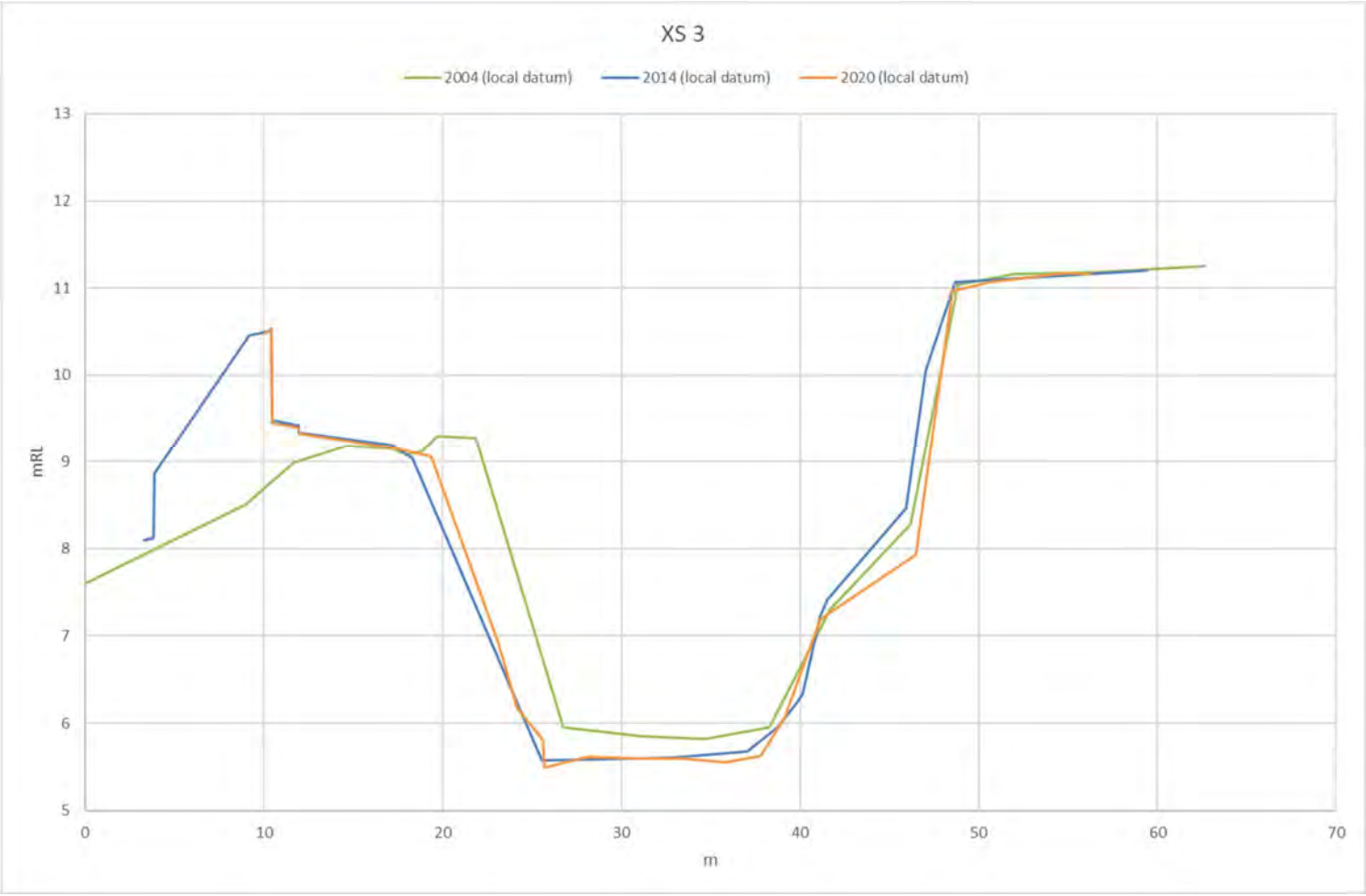

Figure B3 Comparison of 2004 and 2014 survey at XS 3 (MIKE11 model chainage 94m – location shown in Figure A16)

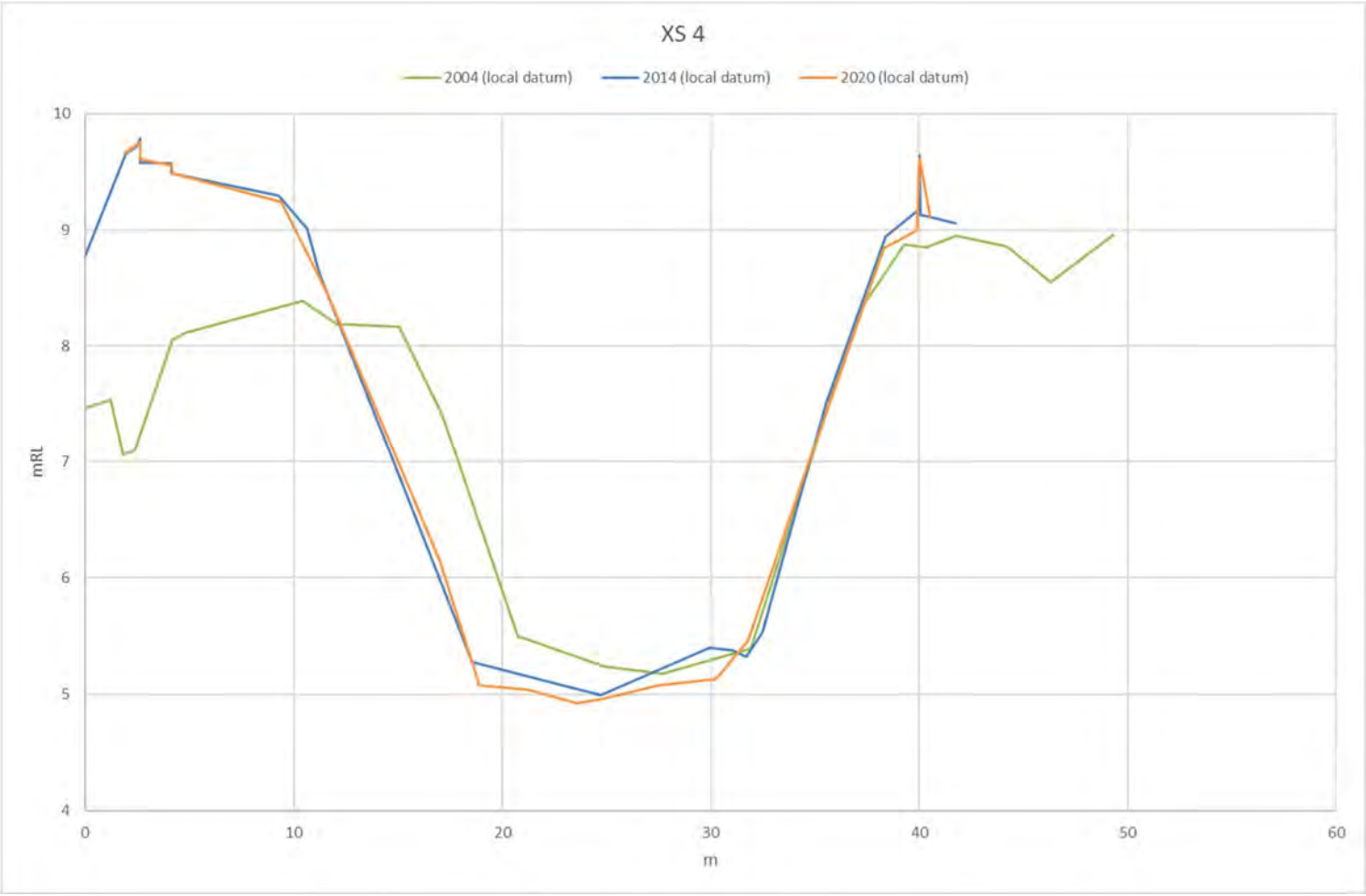

Figure B4 Comparison of 2004 and 2014 survey at XS 4 (MIKE11 model chainage 144m – location shown in Figure A16)

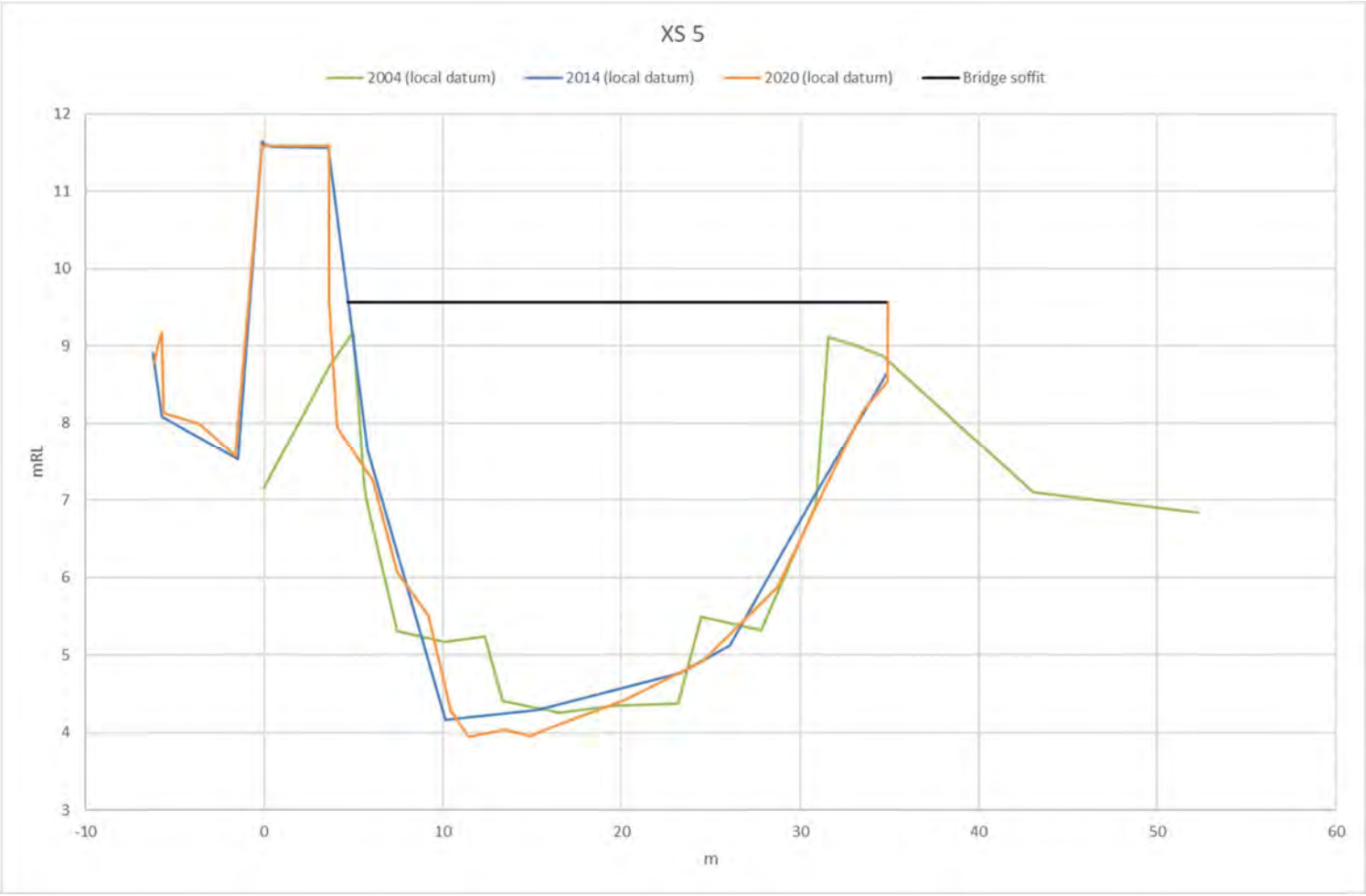

Figure B5 Comparison of 2004 and 2014 survey at XS 5 (MIKE11 model chainage 202m – location shown in Figure A16)

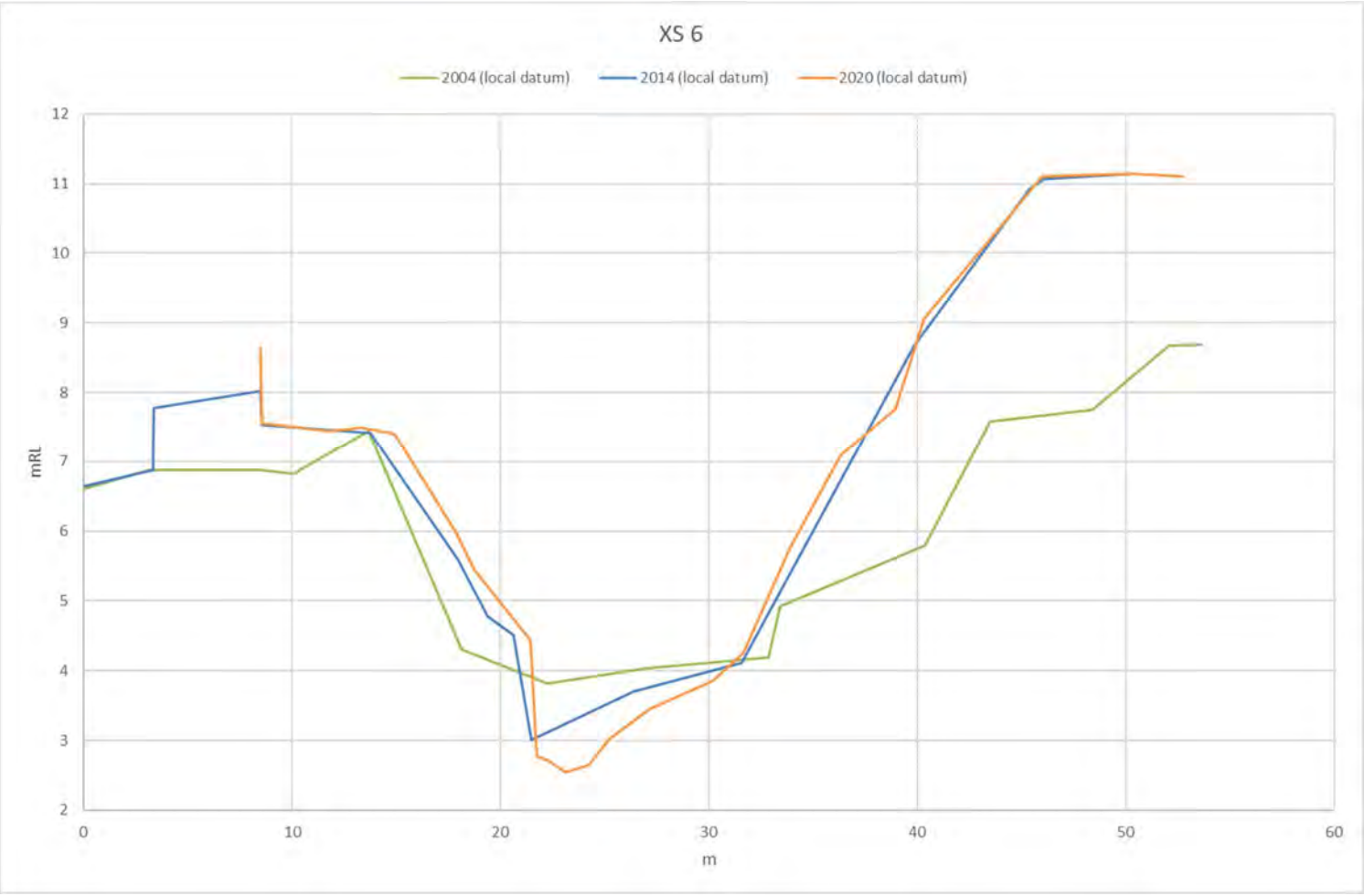

Figure B6 Comparison of 2004 and 2014 survey at XS 6 (MIKE11 model chainage 249m – location shown in Figure A16)

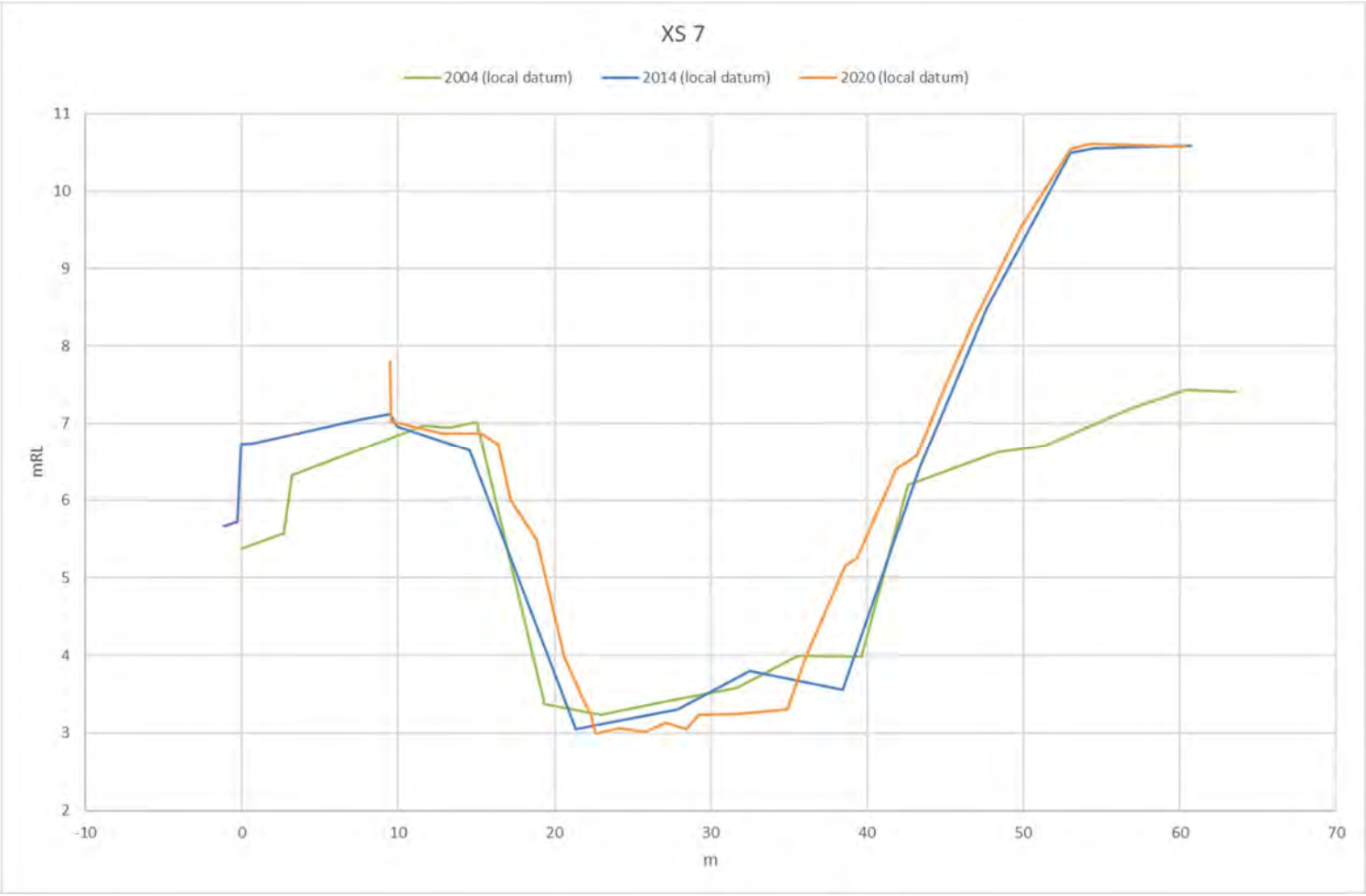

Figure B7 Comparison of 2004 and 2014 survey at XS 7 (MIKE11 model chainage 295m – location shown in Figure A16)

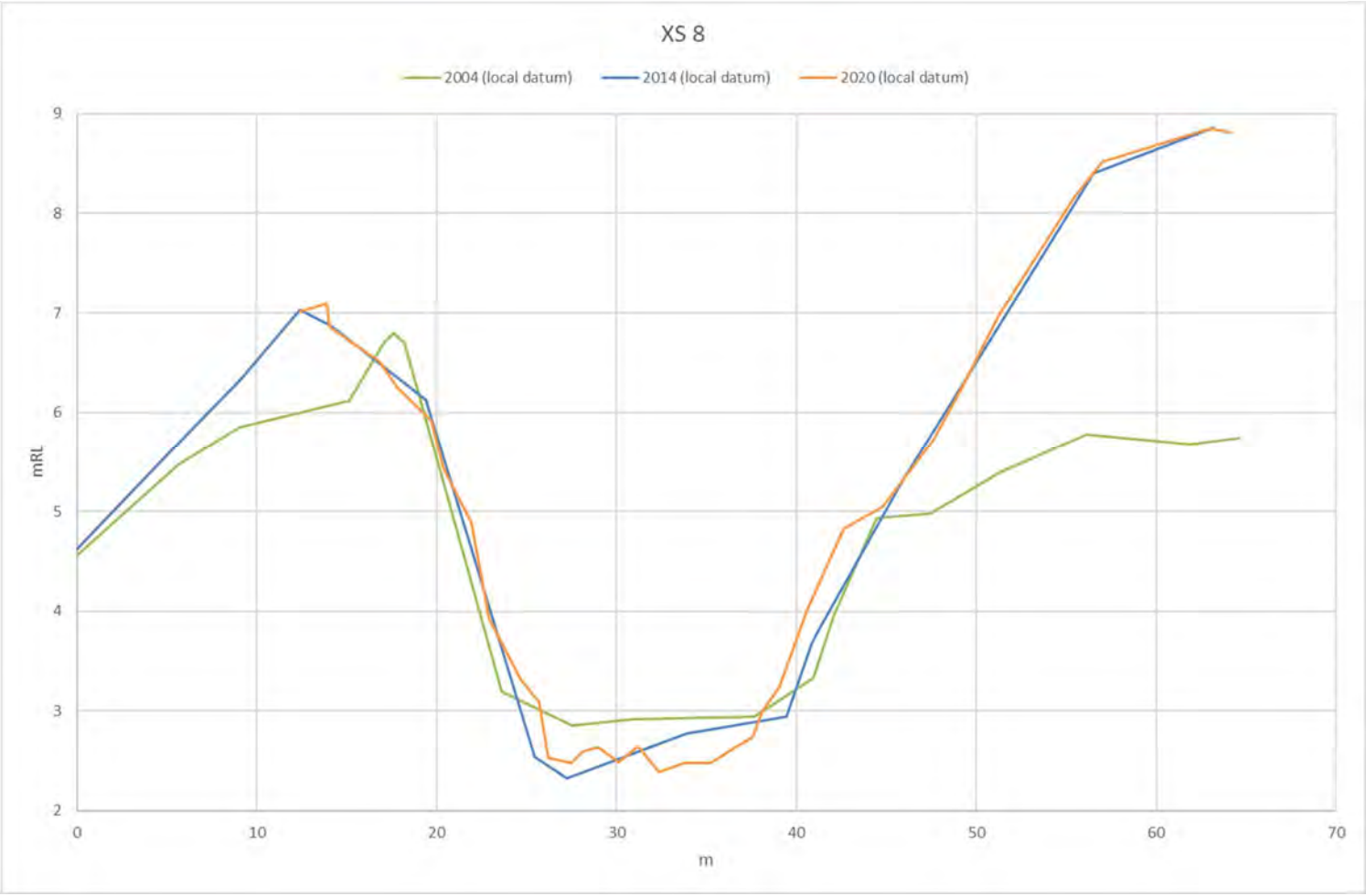

Figure B8 Comparison of 2004 and 2014 survey at XS 8 (MIKE11 model chainage 350m – location shown in Figure A16)

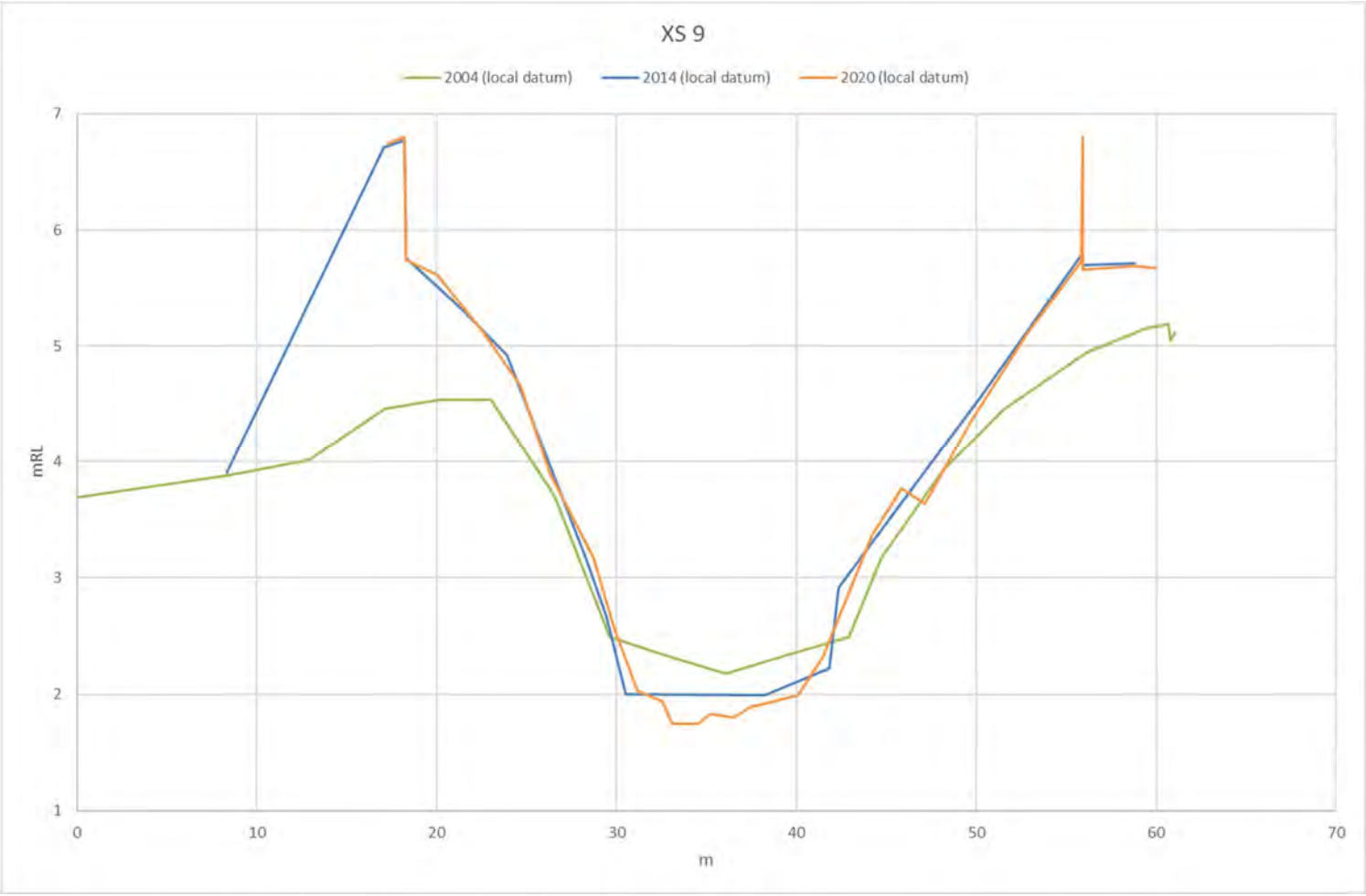

Figure B9 Comparison of 2004 and 2014 survey at XS 9 (MIKE11 model chainage 402m – location shown in Figure A16)

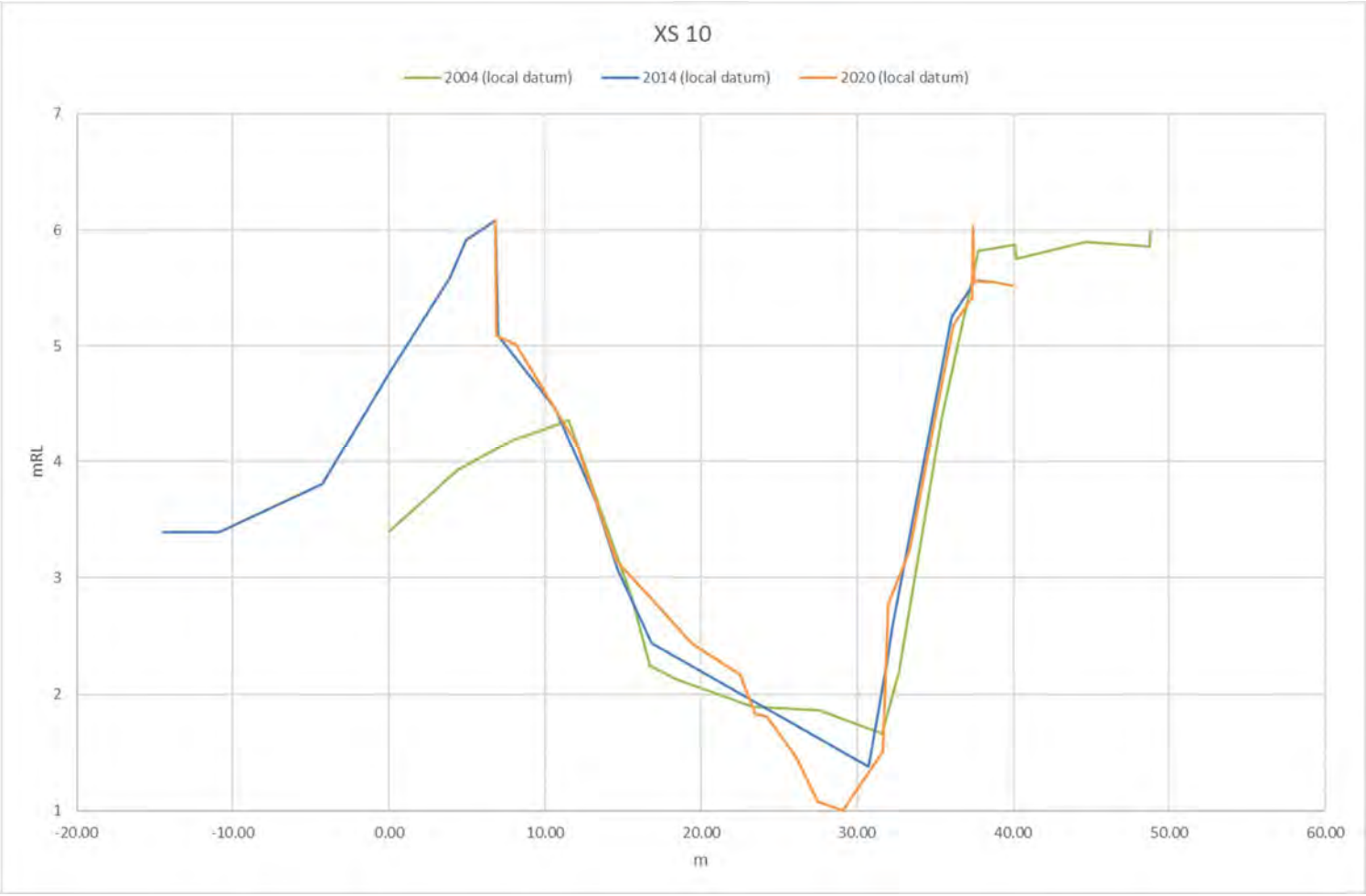

Figure B10 Comparison of 2004 and 2014 survey at XS 10 (MIKE11 model chainage 450m – location shown in Figure A16)

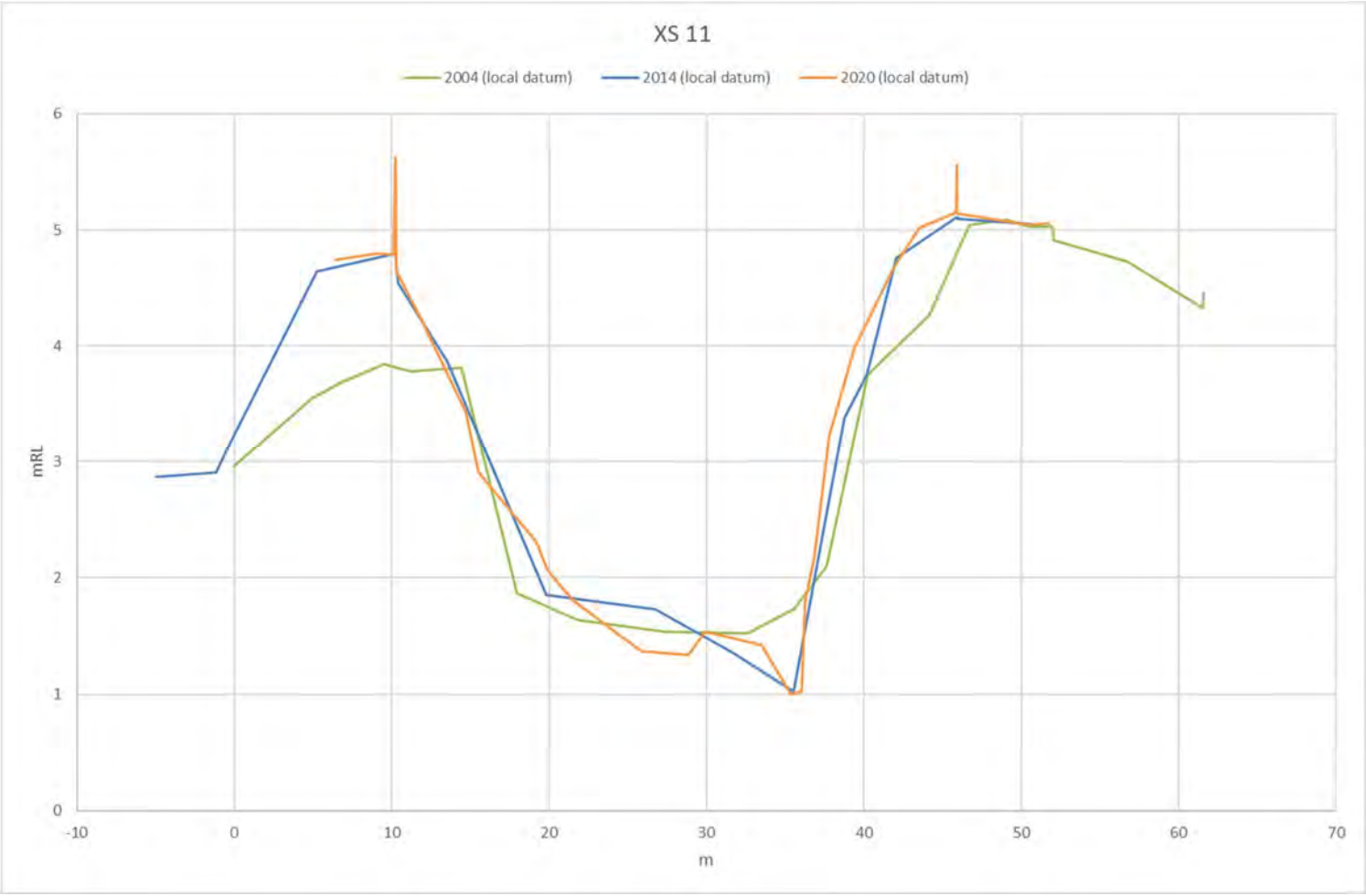

Figure B11 Comparison of 2004 and 2014 survey at XS 11 (MIKE11 model chainage 501m – location shown in Figure A16)

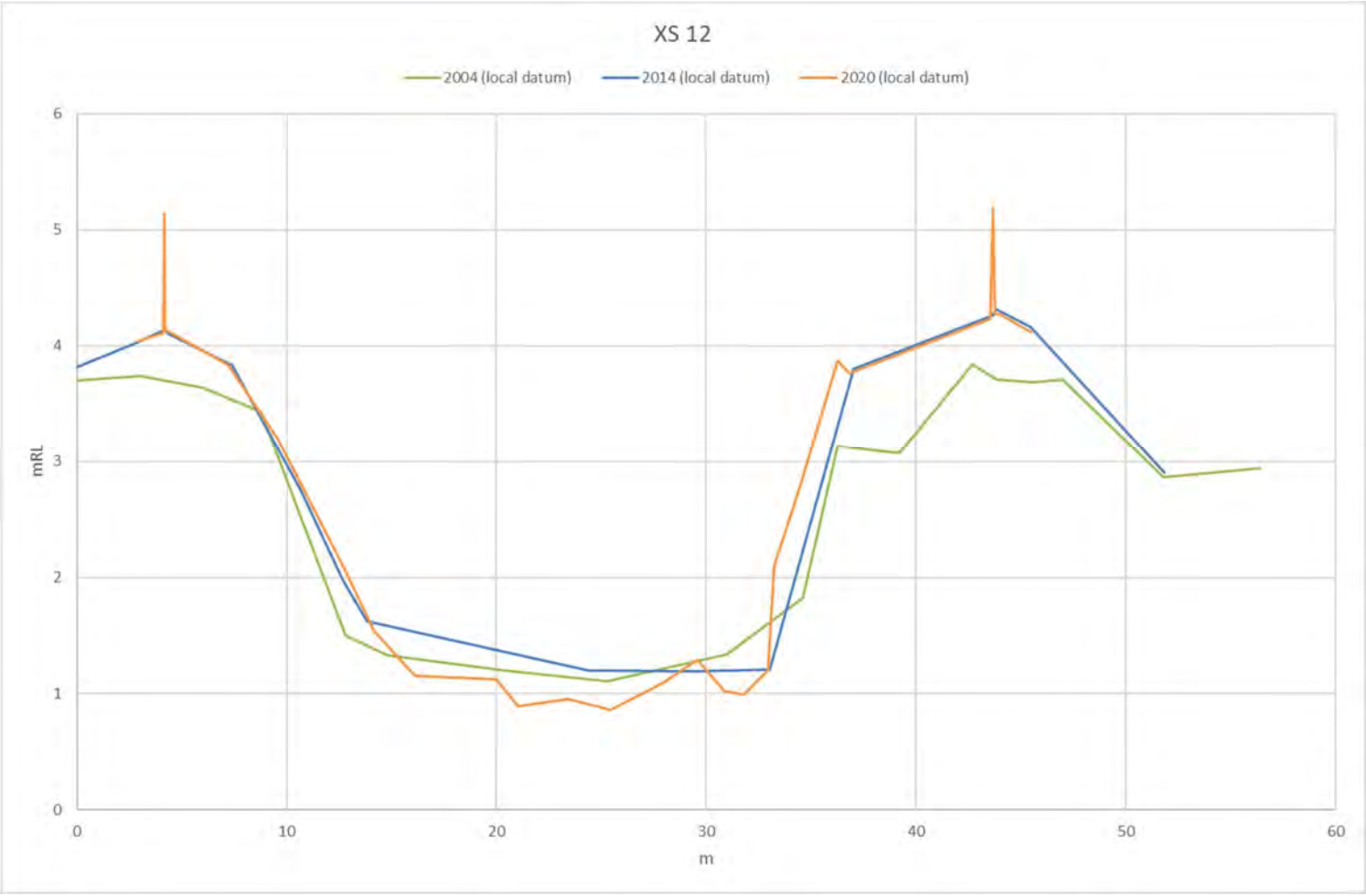

Figure B12 Comparison of 2004 and 2014 survey at XS 12 (MIKE11 model chainage 551m – location shown in Figure A16)

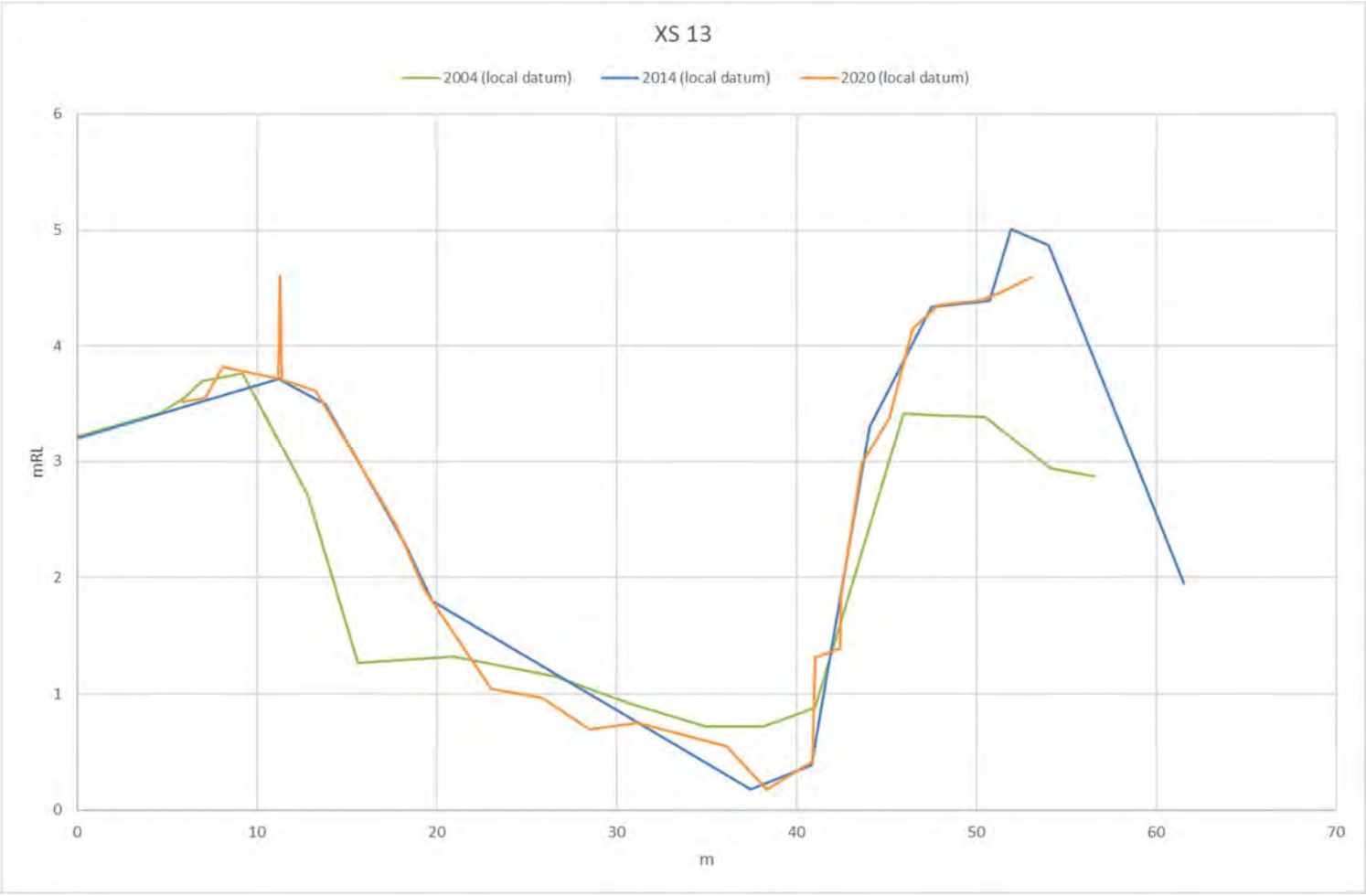

Figure B13 Comparison of 2004 and 2014 survey at XS 13 (MIKE11 model chainage 600m – location shown in Figure A16)

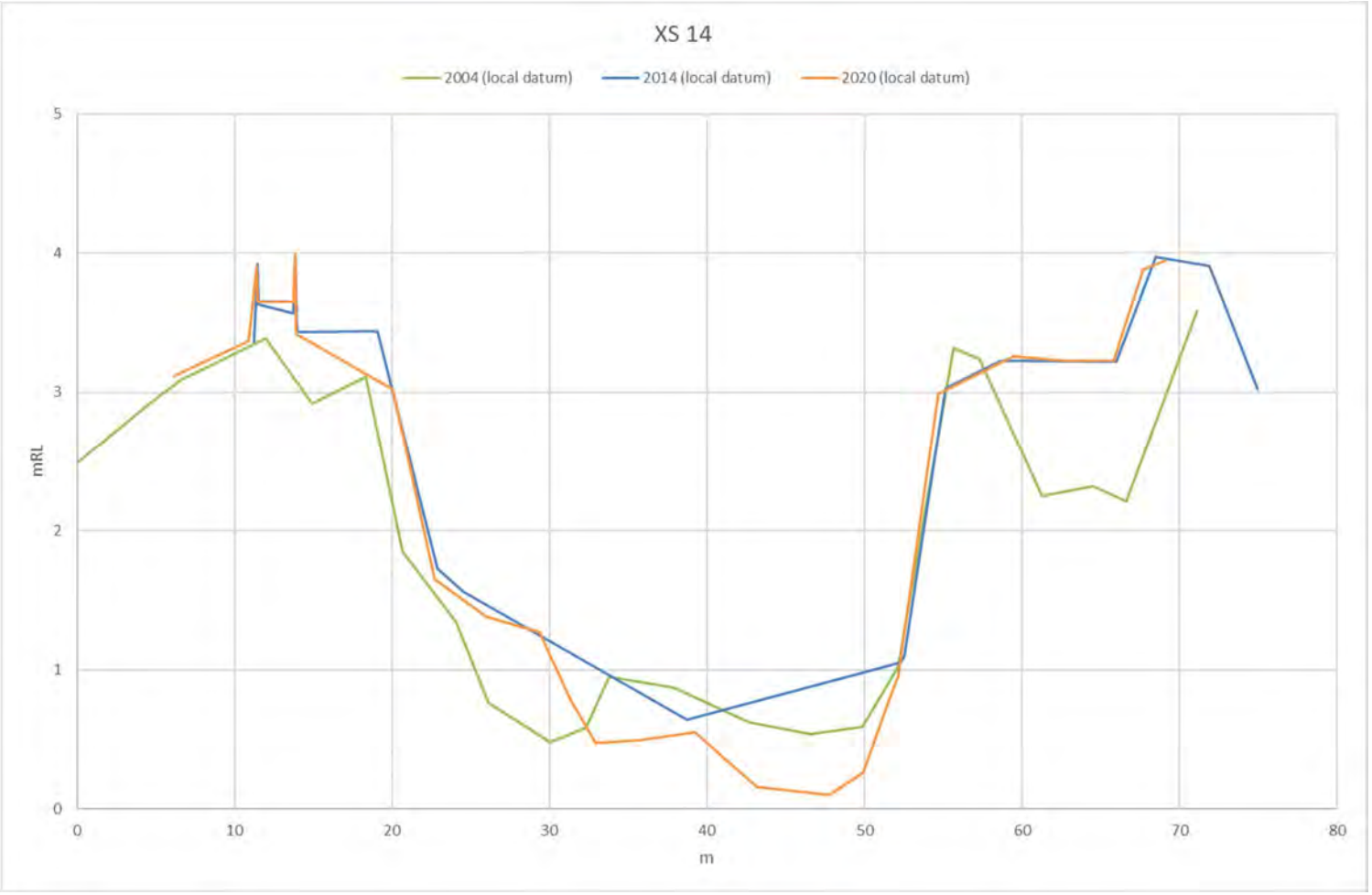

Figure B14 Comparison of 2004 and 2014 survey at XS 14 (MIKE11 model chainage 650m – location shown in Figure A16)

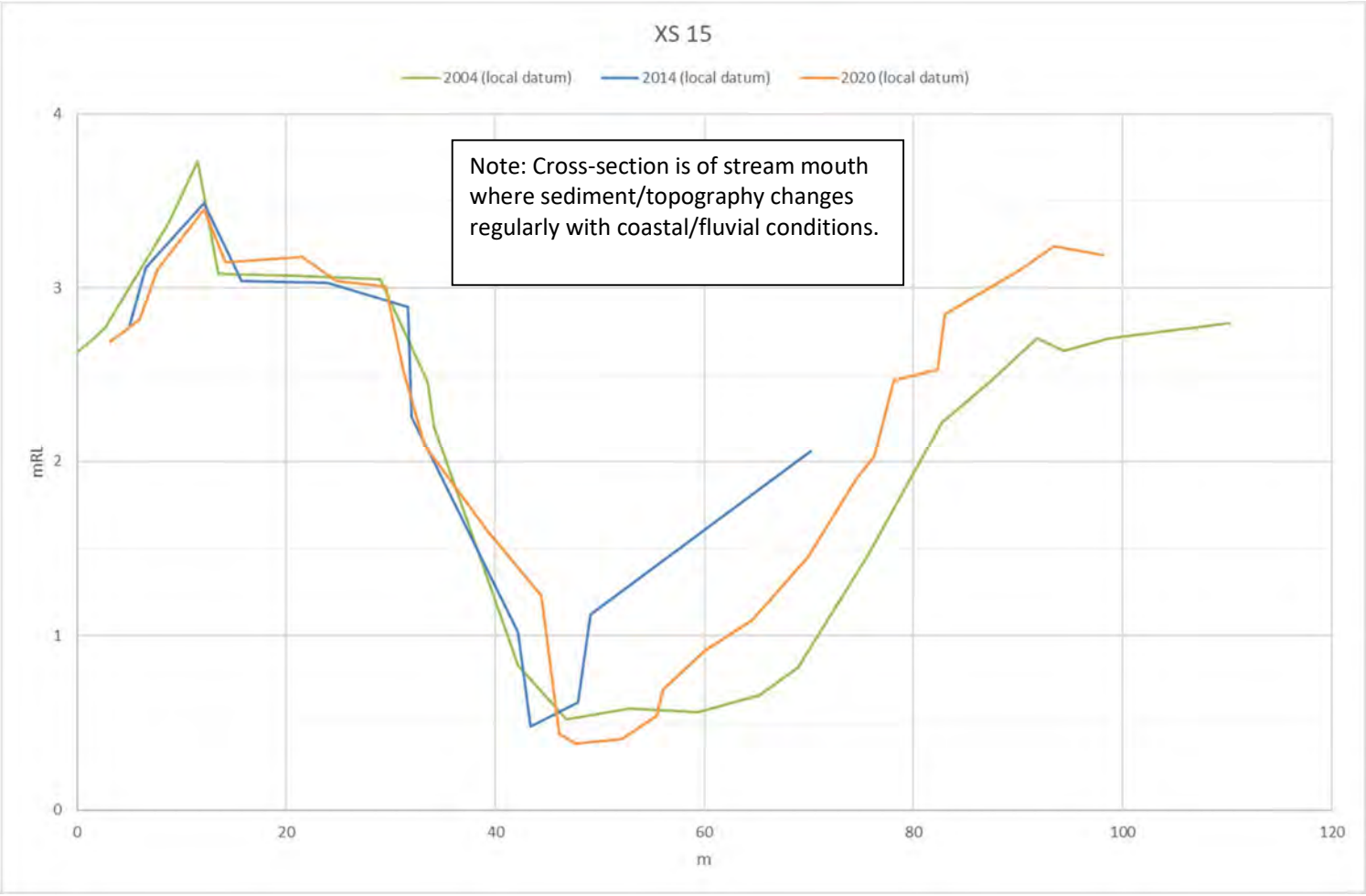

Figure B15 Comparison of 2004 and 2014 survey at XS 15 (MIKE11 model chainage 710m – location shown in Figure A16)

Appendix C – Conquest service level data

Table 3 Conquest service level review data table based on 2020 channel survey data.

(Note: more detailed information is provided in Table 2)

Parent asset ID	Asset ID	Description	Asset chainage (m)	Cross-section	Easting (NZTM)	Northing (NZTM)	Revised design flood level (RL m)	Free-board (m)	Revised design crest level (RL m)
Te Puru Left Below State Highway Floodwall – 463m Service level: 1%AEP + 600mm freeboard									
76074	76378	TP Left Below SH Floodwall 00	**0**		1824025.41	5897373.06	3.08	0.60	3.68
76074	76380	TP Left Below SH Floodwall 02	**100**		1824110.37	5897415.42	4.05	0.60	4.65
76074	76381	TP Left Below SH Floodwall 03	**200**		1824190.45	5897363.15	5.20	0.60	5.80
76074	76382	TP Left Below SH Floodwall 04	**300**		1824191.71	5897264.45	6.28	0.60	6.88
76074	76383	TP Left Below SH Floodwall 05	**400**		1824218.13	5897170.24	7.23	0.60	7.83
76074	76383	TP Left Below SH Floodwall 05	**463**	XS 5	1824264.60	5897127.85	7.97	0.60	8.57
Te Puru Left Above State Highway Floodwall – 168m Service level: 1%AEP + 600mm freeboard									
76084	76387	TP Left Above SH Floodwall 01	**0**		1824307.07	5897116.77	8.31	0.60	8.91
76084	76389	TP Left Above SH Floodwall 03	**100**		1824406.87	5897122.61	9.46	0.60	10.06
76084	76389	TP Left Above SH Floodwall 03	**168**		1824470.15	5897115.16	10.22	0.60	10.82
Te Puru Right Below State Highway Stopbank – 134m Service level: 1%AEP + 600mm freeboard									
76076	76392	TP Right Below SH Stopbank 00	**0**		1824012.45	5897460.34	3.30	0.60	3.90
76076	76398	TP Right Below SH Stopbank 02	**100**		1824103.67	5897451.31	3.92	0.60	4.52
76076	76398	TP Right Below SH Stopbank 02	**134**		1824137.78	5897452.84	4.25	0.60	4.85
Te Puru Right Below State Highway Floodwall – 199m. Service level varied: downstream XS11 - 1%AEP + 600mm freeboard (68m) upstream XS11 - %AEP (future climate) + no freeboard (131m)									
76076	76384	TP Right Below SH Floodwall 00	**0**		1824137.78	5897452.84	4.25	0.60	4.85
76076	76385	TP Right Below SH Floodwall 01	68	XS 11	1824193.70	5897415.10	4.80	0.60	5.40
Change in service level as detailed in header									
76076	76385	TP Right Below SH Floodwall 01	69		1824194.81	5897414.28	5.26	0.00	5.26
76076	76386	TP Right Below SH Floodwall 02	**100**		1824208.86	5897387.44	5.56	0.00	5.56

Parent asset ID	Asset ID	Description	Asset chainage (m)	Cross-section	Easting (NZTM)	Northing (NZTM)	Revised design flood level (RL m)	Free-board (m)	Revised design crest level (RL m)
76076	76386	TP Right Below SH Floodwall 02	**199**		1824238.60	5897293.48	6.48	0.00	6.48
Te Puru Right Above State Highway Floodwall Spillway – 62m Service level: 1%AEP + 300mm freeboard									
76086	76390	TP Right Above SH Floodwall Spillway	**0**	XS 5	1824273.69	5897167.53	7.84	0.30	8.14
76086	76391	TP Right Above SH Floodwall Spillway	**62**		1824334.10	5897152.83	8.61	0.30	8.91