



Shannon Callows Pinch Point Study

Office of Public Works

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Executive Summary

The Shannon Callows Pinch Point Study has been carried out in order to estimate the possible benefits of a number of measures to potentially reduce summer flood levels while maintaining the navigation channel between Athlone and Meelick Weir.

The proposed measures included removal of the weir boards at Meelick Weir, modification to the existing Keelogue sluices and Marlborough sluices and in-channel maintenance works consisting of the provision of a trapezoidal navigation channel from Athlone to Meelick Weir.

The study uses the existing Shannon CFRAM Study N10 hydraulic model and new survey data acquired by the Office of Public Works (OPW) and Waterways Ireland since the previous CFRAM study.

The existing model was updated as detailed within this report and model runs undertaken to verify the impact of the updates against the previous model calibration. The impact on peak water levels was less than 160mm in the model verification phase, and updates to the operating rules of water level control structures enabled increased confidence in the model results in lower magnitude flood events.

The proposed maintenance works have the potential to reduce water levels throughout the catchment in comparison to the Current scenario. This impact varies depending on location and magnitude of flood event, but is up to 280mm at Athlone, and up to 310mm downstream of Banagher. Constriction of the river channel in the vicinity of Shannon Harbour to Banagher limits the reduction in water levels associated with the maintenance works upstream.

It has been estimated that a flow of 190m³/s is required at Meelick Weir to enable the minimum statutory navigation level at Banagher and Meelick Weir to be retained when the sluices at Keelogue and Marlborough are in the fully closed position.

In flow conditions below 190m³/s, the proposed maintenance works have a far greater impact at Meelick Weir as the boards remain in during the Current scenario (whereas they are removed in the Maintenance scenario) due to insufficient flow to retain minimum water levels.

It is recommended that further detailed bathymetry survey be undertaken if the proposed maintenance, or a variety of, is to be developed in any greater detail with a view to implementation. This should include specification of new survey at pre-defined model cross sections to improve model accuracy.

In addition, the operation of water level control structures in lower magnitude events will need to be refined in the hydraulic model to greater ascertain how operating regimes should be amended in conjunction with the proposed maintenance.

Important note about your report

The sole purpose of this report is to assess the potential benefits of removing the weir boards at Meelick Weir and adopting an in-channel maintenance programme to potentially lower summer flood levels while preserving the navigation channel along the River Shannon between Athlone and Meelick Weir.

This study builds upon previous work undertaken for the Shannon Callows Summer Flooding Report, which was undertaken as part of the Shannon CFRAM Study. New survey data acquired by the Office of Public Works (OPW) and Waterways Ireland has been used to update a hydraulic model and is relied upon and presumed accurate in preparing this report.

The report should be read in full with no excerpts to be representative of the findings. The report has been prepared exclusively for the OPW and no liability is accepted for any use or reliance on the report by third parties.

Glossary

AEP	Annual Exceedance Probability (%)
AMAX	Annual Maxima
ARTDRAIN2	% of the catchment river network included in drainage schemes (catchment descriptor)
CFRAM	Catchment-based Flood Risk Assessment and Management
cSAC	candidate Special Areas of Conservation
DEM	Digital Elevation Model (retains elevations of structures, vegetation, etc.)
DRAIN2	Drainage Density (catchment descriptor)
DTM	Digital Terrain Model (also referred to as 'Bare Earth Model', excluded elevations of structures, vegetation, etc.)
EPA	Environmental Protection Agency
EV1	Extreme Value Type 1 distribution (also referred to as Gumbel distribution)
FARL	Flood Attenuation by Reservoirs and Lakes (catchment descriptor)
FRM	Flood Risk Management
fse	factorial standard error
FSU	Flood Studies Update
HEFS	High-End Future Scenario
HEP	A location along a watercourse (MPW and HPW) at which flood flows are estimated for a range of flood events of different frequencies.
HPW	High Priority Watercourse
IRR	Individual Risk Receptor
LN, LN2	2-parameter Log Normal distributions
Mannings 'n'	An empirical value used widely in hydraulic modelling to describe the hydraulic roughness of an area. Higher values indicate a "rougher" surface.
mOD	Metres above Ordinance Datum Malin
MPW	Medium Priority Watercourse
MRFS	Mid-Range Future Scenario
NDHM	National Digital Height Model
NTCG	National Technical Coordination Group
OPW	Office of Public Works
OSi	The base mapping (ortho aerial imagery, vector data and raster data) used throughout the study owned by Ordnance Survey Ireland and is reproduced under a licence agreement.
PEAT	% of land area covered by peat bogs (catchment descriptor)
PFRA	Preliminary Flood Risk Assessment
QMED	Median Annual Flow (median of long-range annual maxima)
RBD	River Basin District
SAAR	Standard Annual Average Rainfall (mm) (catchment descriptor)
SPA	Special Protected Areas
WFD	Water Framework Directive
1D Domain	The part of a hydraulic model which is defined by flow in 1 dimension.

- The “Current” scenario, referring to the updated model and corresponding assessment of existing flood risk in a variety of flood events; and,
- The “Maintenance” scenario, referring to the proposed removal of weir boards at Meelick Weir and associated in-channel maintenance works.

The two scenarios were run for the design events detailed in Table 1.2 below.

Table 1.2 Summer design flows to be used for Shannon Callows pinch point study

Summer AEP	Summer Growth Factors	Summer Design flows (m ³ /s)
N/A	N/A	25
N/A	N/A	50
N/A	N/A	75
N/A	N/A	100
N/A	N/A	125
50%	1.00	162.7
20%	1.45	236.6
10%	1.73	281.7
5%	2.00	324.9
2%	2.34	380.8

The Shannon CFRAM study included a detailed hydrological analysis associated with these flows. An update to this hydrological analysis was outside the scope of this study.

1.2 Report Outline

This report is structured to meet the requirements of the project brief and clearly set out the methodology and findings of the study as follows:

- Section 1** Provides an introduction to the report and sets the context and scope of the study.
- Section 2** Provides an overview of the hydrometric and hydrological information used in the fluvial hydraulic model and describes the approach to hydraulic model verification.
- Section 3** Presents the findings of the model runs undertaken for the Current scenario.
- Section 4** Presents the findings of the model runs undertaken for the Maintenance scenario.
- Section 5** Summarises the conclusions of this report.

2. Hydraulics

2.1 Hydraulic Model Update

2.1.1 Survey Data and Base Mapping

The development of the existing hydraulic model is detailed within the Shannon CFRAM Study Hydraulics Report for UoM 25/26¹. For the purpose of this study, an overview of the model build is detailed below. The key updates made as part of this study are summarised in bold text with further detail regarding the model update included within Section 2 of this report.

DTM for 2D Model domains:	1D only model was sufficient for this study as there is no urban areas, offline lakes or complex floodplain flow paths.
River channel/Structures survey	<p>General information on the topographic survey of the river channel and structures is included in the Shannon CFRAM Study Hydraulics Report for UoM 25/26.</p> <p>New data obtained from bathymetric surveys undertaken by Waterways Ireland and the OPW was used to update cross sections where data was available.</p> <p>No additional survey data was gathered for the update of the Shannon Callows hydraulic model.</p> <p>Number of cross-sections included in the original model: 744</p> <p>Number of cross-sections updated in the new model: 98</p> <p>A comparison of cross-sections at the identified pinch points between the previous model and the updated model is provided in Appendix A and discussed in further detail in Section 2.1.2.</p>
<u>Athlone Sluice Control:</u>	<p>Generally, the Athlone sluices are operated during the Summer period to ensure that the water level at Lough Ree is between 35.09 and 34.48 mOD.</p> <p>During Summer flooding periods, the sluices are closed when the level downstream of Athlone weir rises above 33.41mOD.</p> <p>The sluice openings at Athlone have been represented in the model based on the above operating procedures and also on sluice opening data obtained from Waterways Ireland.</p>
<u>Weir Boards at Meelick Weir, Keelogue Sluices and Marlborough Sluice Control:</u>	<p>The routine operation of the Weir Boards at Meelick Weir, Keelogue Sluices and Marlborough Sluice has been amended in line with the project brief and subsequent clarifications.</p> <p>In the previous model, these structures were operated to keep the water level at Banagher between 32.71 to 32.61 mOD. During low flow weir boards are normally placed in position at Meelick Weir to maintain the navigation depth upstream of the weir. As the flow increases the weir boards are gradually removed.</p> <p>The impact of this is that, in lower flow conditions, the model would result in a period of turbulence as the impact of removing the weir boards would reduce water levels at Banagher below the lower limit of 32.61mOD and trigger immediate replacement (see Section 3).</p> <p>To improve accuracy and stability in lower flow conditions, the operating regime was amended in the new model to ensure a single operation of weir board removal was undertaken as and when flow and water level conditions dictate.</p> <p>As well as the above constraint at Banagher, this was designed to be consistent with the requirement to retain a statutory navigational level of</p>

¹ Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study, Hydraulics Report – Unit of Management 25/26, Draft Report (October 2013)

	32.33mOD at Keelogue Sluices (as detailed within the Regulations and Guidelines for the Control of the River Shannon (ESB November 2003) and Water Level Control on River Shannon between Athlone and Meelick (Waterways Ireland, March 2011).
Defence Asset Survey Data	<p>No formal defences are located within the Shannon Callows Study area.</p> <p>No amendments have been made to the existing representation of the structures at Meelick Weir, Keelogue Sluices, and Marlborough Sluice.</p> <p>The representation of Meelick and Victoria Canal and Lock was amended in the model to improve calibration during low flow events (prior to removal of the Weir Boards).</p>

2.1.2 Updated Model Cross Sections

The production of the current model was made using the existing Shannon CFRAM N10 model updating a total of 98 cross sections with the bathymetric surveys carried out by Waterways Ireland and the OPW. The purpose of these new surveys was to identify pinch points on the River Shannon between Athlone and Meelick Weir.

Ten potential pinch points were identified in the study area, the location of which is presented in Figure 2.1.1 below.

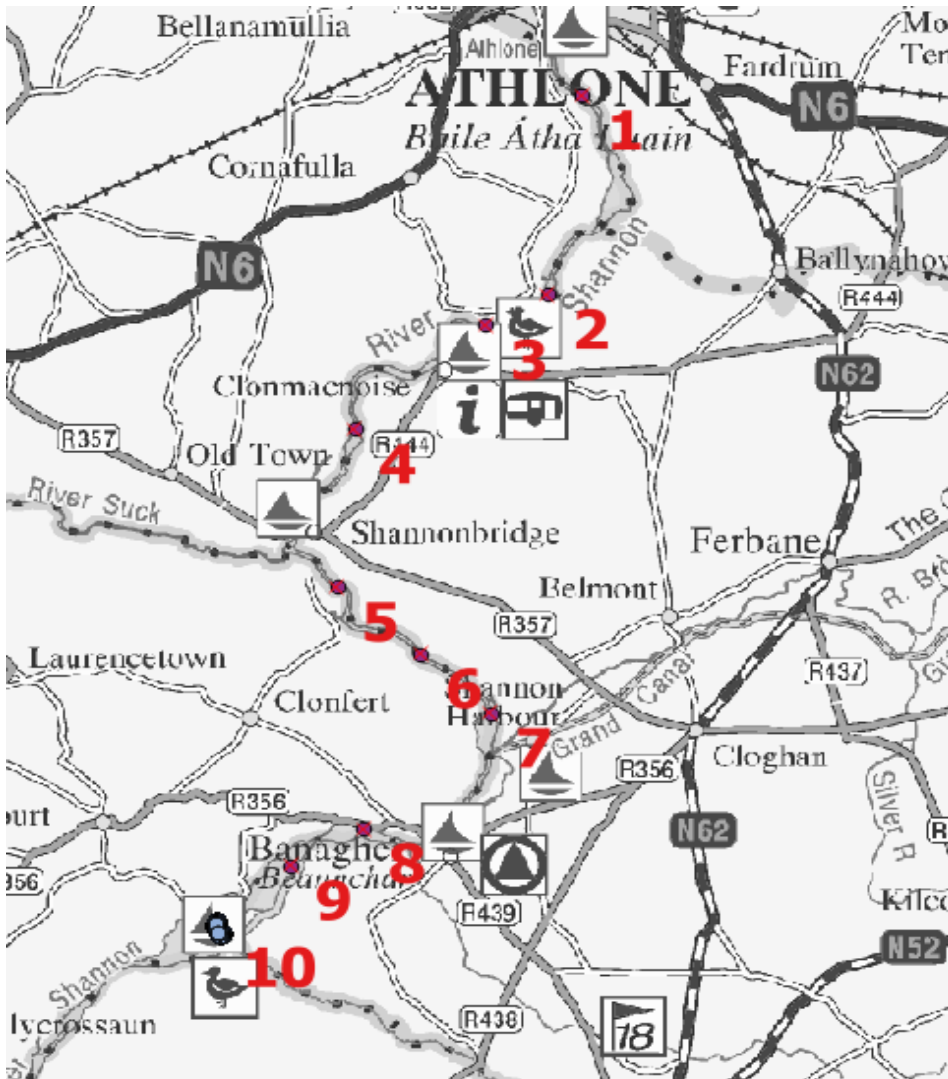


Figure 2.1.1 Location of pinch points as provided in the project brief

The ten pinch points were identified by the OPW and represented locations where individual survey points extracted from the new survey data were compared against corresponding survey in the CFRAM survey data. Pinch points were identified where a discrepancy of 400mm or greater was evident between the recent topographic survey and original CFRAM survey.

Survey data was provided in point cloud format and was presumed accurate for the purpose of updating the model as detailed in this report. Where new survey data was made available, this was used to update the existing model. This enabled full delineation of the pinch points as well as any other significant hydraulic features identified within the survey data.

The survey data was transcribed into a grid format to enable triangulation of the data points and interpolation of bed level between data points. All existing cross section locations coinciding with this grid were updated enabling a like for like comparison with the original CFRAM model.

Typical cross sections at the location of each identified pinch point are provided in Appendix A.

2.2 Verification of Model

2.2.1 Calibration of CFRAMS Model

The existing Shannon Callows hydraulic model was calibrated successfully as part of the CFRAM study. The 1993 Summer flood event was the only event of significance for which flow data was available at the required gauges on the River Shannon at Athlone Weir (Gauge 26027), at Banagher (Gauge 25017) and on the major tributaries of the River Suck (Gauge 26007) and River Brosna (Gauge 25011). These gauging station locations are shown on Figure 2.2.1.

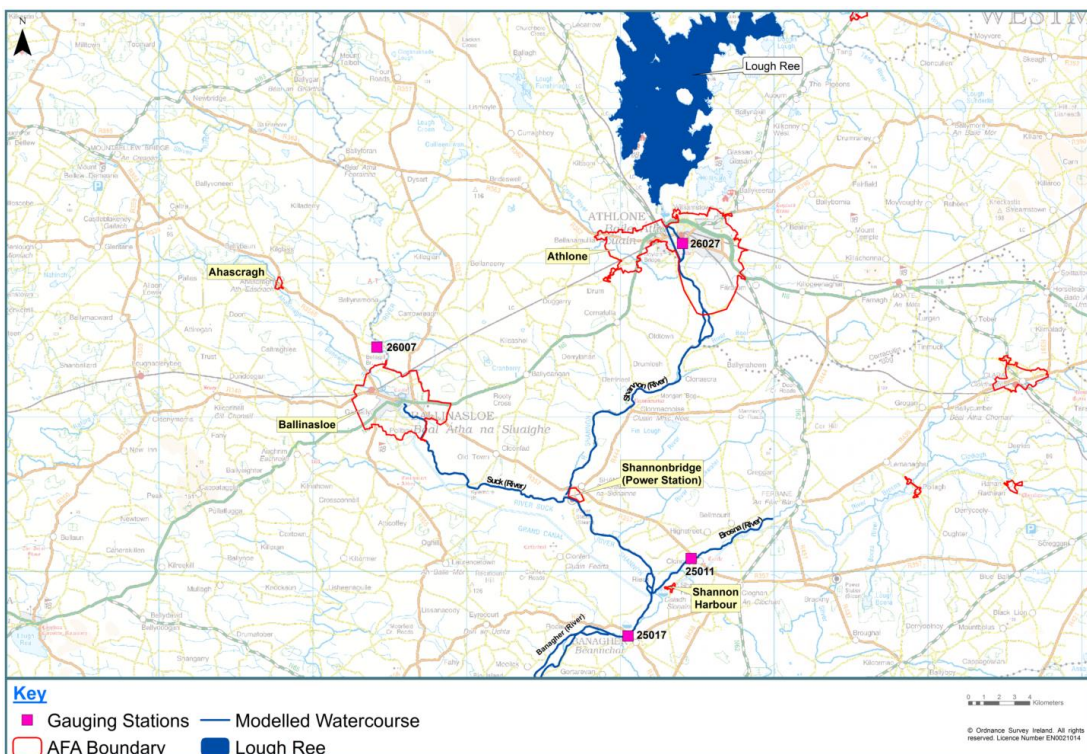


Figure 2.2.1 Shannon Callows Hydraulic Model – Map of Gauging Stations and Modelled Watercourses

Measured flows were applied to the model at Athlone Weir (Gauge 26027), the River Brosna (Gauge 25011) and the River Suck (Gauge 26007).

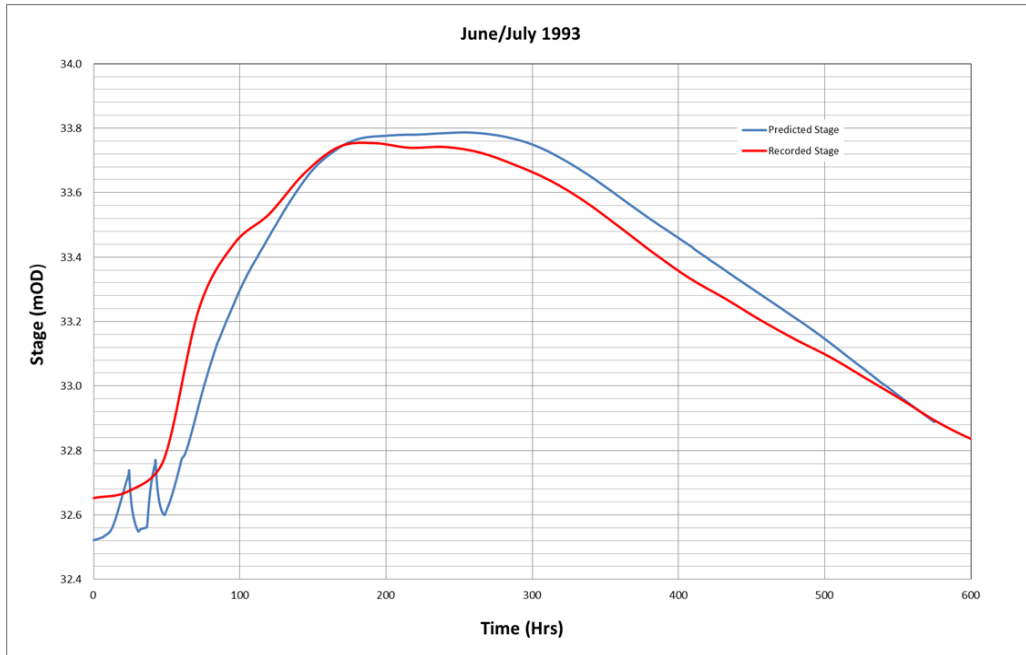
The River Suck Gauge (Gauge 26007) is located outside the modelled extent. The Suck catchment also increases in size significantly between Gauge 26007 and its confluence with the River Shannon. The flow used in the model was scaled up to reflect this additional catchment area between the modelled extent and the gauging station. A lateral inflow was also used to represent the increase in catchment size between the upstream modelled extent and the River Shannon. Similarly, the Shannon catchment increased in size significantly between Athlone Weir (Gauge 26027) and the point in which the River Suck flows into the River Shannon. On the River Shannon a lateral inflow was applied to the model between these points to represent additional flow from the catchment to the river. This additional flow was estimated as a percentage of the initial inflow relative to the increase in catchment size.

The peak water level predicted by the Shannon Callows hydraulic model at Banagher (Gauge 25017) was then compared to the recorded stage. The results of the calibration are presented in Table 2.1 and Figure 2.2.2.

Table 2.1 Historical Flood Events at Banagher (Gauge 25017)

Historical Flood Event	Model maximum stage (m OD*)	Observed maximum stage (m OD*)	Difference (m)
June - July 1993	33.79	33.75	-0.03

(* Datum is taken from Malin Head)

**Figure 2.2.2 Modelled and observed water levels at gauging station 25017 for the June/July 1993 event**

The stage results in Table 2.1 indicate that the peak water level predicted by the Shannon Callows hydraulic model compares well with the recorded levels at Banagher (Gauge 25017) for the 1993 Summer event. There is a difference of 0.03m between the observed and predicted peak water levels. The results would suggest that the channel cross section geometry and roughness parameters set in the Shannon Callows hydraulic model provide a reasonable representation of the hydraulics in the river channel along this reach. There is also a good fit on the time to peak with no time difference between the observed time to peak and the modelled time to peak, as illustrated in Figure 2.2.2.

The model was successfully calibrated with a 0.03m difference between the modelled and observed peak water level, along with a good match on time to peak. Therefore, it is considered that the Shannon Callows hydraulic model adequately represents the conditions within the River Shannon and is suitable for use in this study.

2.2.2 Verification of Model Updates

The calibration of the existing Shannon Callows hydraulic model was not revisited as part of this study as no hydrological update was undertaken, and the amendments to the existing hydraulic model were relatively minor in nature. In addition it is not appropriate to use new survey data to recalibrate a flood event dating back to 1993, particularly in relation to the siltation of a channel bed.

Instead, a verification exercise was undertaken to compare the peak water level predicted in the previous model with the equivalent peak water level predicted in the Current scenario in the updated model. A comparison of rating curves was also undertaken.

This exercise was undertaken for the 20% AEP and 2% AEP summer design flows. The results of the verification exercise are presented in Figures 2.2.3 and 2.2.4 and Table 2.2.

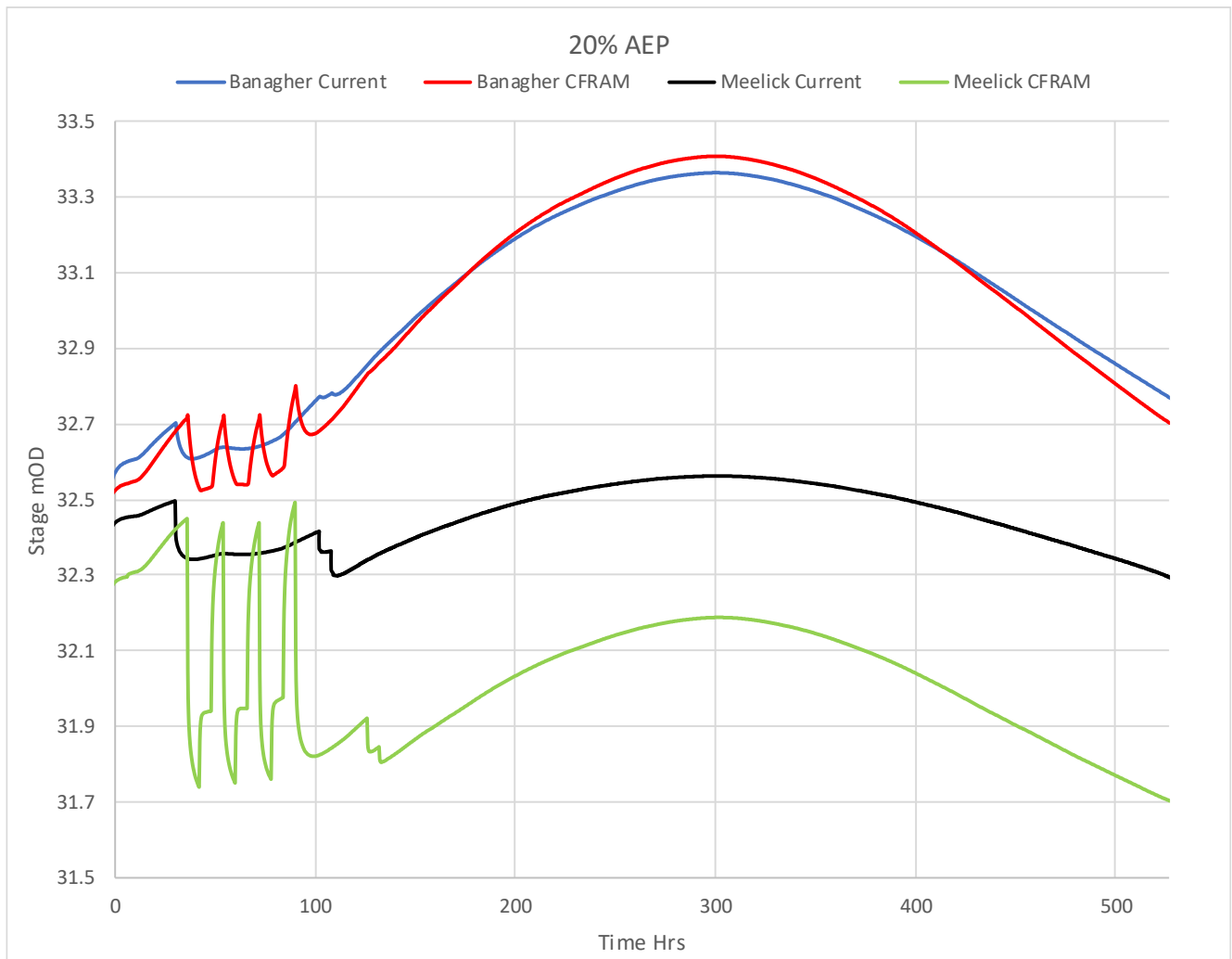


Figure 2.2.2 Comparison of water levels between the previous CFRAM model and the updated model (20% AEP) at Meelick Weir and Banagher

The most notable differences between the two different models for the 20% AEP flood event are:

- In the previous model, the removal of the weir boards at Meelick Weir was based on the water level at Banagher. When the level rose above 32.71mOD, the boards were removed; if it dropped below the minimum level of 32.61mOD, the boards were reinstated. To improve stability in the lower magnitude flood events not considered in the previous study, and to avoid the open/close nature of the rule in lower flows, the new model was used to estimate the flow required to maintain minimum statutory navigation level with the boards removed. This was subsequently used as the trigger point for removal of the weir boards, coupled with the assumption that the boards would not be replaced until after the flood event.
- The impact of this can be seen in Figure 2.4 through the reduction of turbulence (previously consistent with removal and immediate replacement of the boards). In the updated model a sharp decrease can be observed at Hour 15 when the Keelogue Sluice and Marlborough Sluice open, and a second less sharp decrease at Hour 120 when the weir boards at Meelick Weir are removed.
- The peak water level at Meelick Weir has increased by approximately 370mm, with a reduction of 50mm in peak water levels at Banagher. This change in water level can be attributed to the amendment of cross sections to reflect the identified pinch points, particularly between Banagher and Meelick Weir. The channel conveyance has reduced in this area, compared to the previous model, and as such the impact of the board removal at Meelick Weir is less pronounced.

- Other than the points raised above, which are to be expected given the model updates, the homogeneity is maintained in the continuity of the graph, giving confidence in the updated model. In addition, the change in water level is not significant given the size of the study area under consideration.

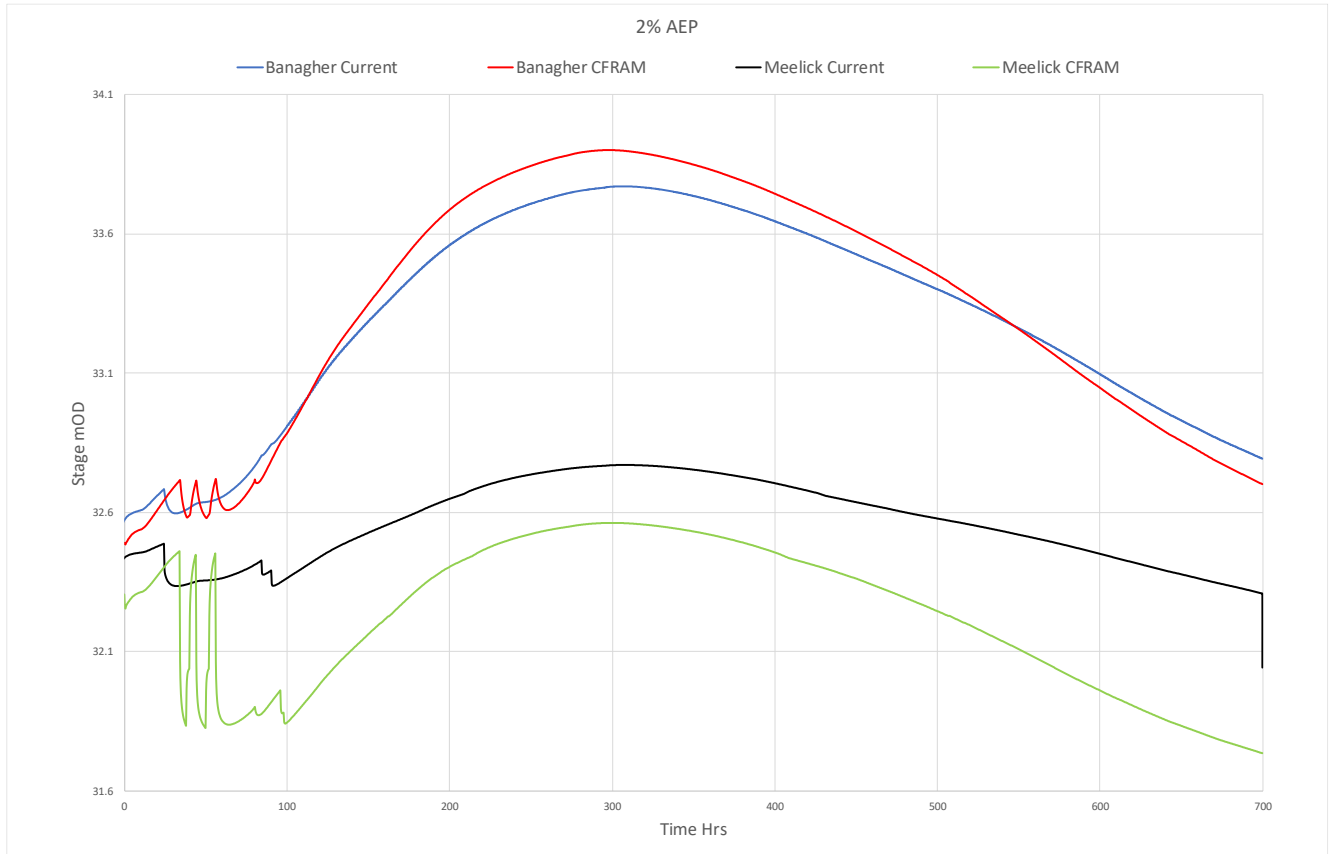


Figure 2.2.4 Comparison of water levels between the previous CFRAM model and the updated model (2% AEP) at Meelick Weir and Banagher

The most notable differences between the two different models for the 2% AEP flood event are:

- As detailed previously in relation to Figure 2.4, the same observation related to the amended rule for operation of weir boards at Meelick Weir can be observed. This provides a more realistic simulation of the removal of the weir boards in lower magnitude flood events.
- The peak water level at Meelick Weir has increased by approximately 210mm, the impact of the pinch points being less pronounced in higher magnitude flood events. A reduction of 130mm in water level is observed at Banagher. The change in water level can again be attributed to the amendment of cross sections to reflect the identified pinch points, particularly between Banagher and Meelick Weir. The channel conveyance has reduced in this area, compared to the previous model, and as such the impact of the board removal at Meelick Weir is less pronounced.
- The homogeneity of the graph is again consistent between the models.

A summary of the difference in peak water levels is detailed below in Table 2.2.

Table 2.2 Comparison of peak water levels between the previous CFRAM model and the updated model

Flood Event	Location	CFRAM (mOD)	Current (mOD)	Difference (m)
20% AEP	Meelick	32.19*	32.56*	+0.37*
2% AEP	Meelick	32.56	32.77	+0.21
20% AEP	Banagher	33.41	33.36	-0.05
2% AEP	Banagher	33.90	33.77	-0.13

**Note: peak water level is taken at the peak of the hydrograph. A higher water level is observed in the early stages prior to sluice gates being opened and weir boards removed.*

2.2.3 Key Modelling Assumptions

For more detail of the model build, the reader is referred to the Shannon CFRAM Study Hydraulics Report for UoM 25/26. The key assumptions made in relation to the hydraulic model are detailed below.

- The Keelogue Sluices could not be surveyed at the time of the CFRAM study for safety reasons. The sizes of the sluices were estimated from photographs.
- There are 18 sluice gates at Marlborough Sluices. It is assumed that the sluices are operated in threes meaning 6 sluice gates units are used to represent all 18 sluice gates. Similarly, the 12 sluice gates at Keelogue Weir have been represented using 4 sluice gates units in the model. At Athlone Sluices, the 15 sluice gates are represented with 5 sluice gate units. Following review of the operation of the sluice gates, it was found that it was appropriate to represent three gates as one sluice unit within the model as it broadly reflected the sluice operations as water levels rise.
- There are also 115 weir boards at Meelick Weir which are represented in the model as six gated or tilted weir units. In practice, all weir boards are removed at once. It is assumed that the Weir Boards will not be reinstalled once removed and as such they are only removed once fluvial flows are sufficient to retain statutory navigation levels at Meelick Weir and Banagher (as detailed within the Regulations and Guidelines for the Control of the River Shannon (ESB November 2003) and Water Level Control on River Shannon between Athlone and Meelick (Waterways Ireland, March 2011)).
- The new survey data provided was presumed to represent to be accurate and to represent best available information. Where obvious discrepancies were identified in the interpolation of data points, these were removed from the dataset prior to updating the model.

2.2.4 Model Limitations

The updated model is considered appropriate to meet the project brief. The survey data has been incorporated and an increase in channel bed levels compared to the previous model can be observed which is broadly consistent with the preliminary analysis of data undertaken by the OPW.

It should be noted that, whilst the updated model is suitable to meet the project brief, the model results and any associated reduction in peak water levels must be looked at in the context of modelling uncertainties. This is particularly the case when studying low flow conditions in a watercourse which is subject to such an extensive operational regime.

3. Model Results

3.1 Determination of flow for current summer conditions

Prior to running the design flood events, an iterative process was undertaken to determine an estimated key flow value (QA) which provides a minimum water level of both 32.33mOD at Meelick Weir and 32.62mOD at Banagher, consistent with statutory navigation levels. This flow value corresponds to the current summer conditions to ensure that these navigation levels are maintained.

It should be noted that the operation of Keelogue and Marlborough sluices has a significant impact upon the estimated QA value. For the purpose of this report, the QA flow has been estimated on the basis of all sluices at Keelogue and Marlborough being in the fully open position.

Figure 3.1.1 and Figure 3.1.2 below illustrate the Stage (mOD) at both Meelick Weir and Banagher for a peak flow at Meelick Weir of 116m³/s (Hour 300). The peak water level at Meelick Weir is 32.33mOD (equivalent to the minimum statutory navigation level). Under the same flow conditions, the peak water level at Banagher is above the minimum required level of 32.62mOD indicating the flow required to retain minimum navigation level is driven by the water level at Meelick Weir.

The QA flow value is estimated at 116m³/s with both Keelogue and Marlborough sluices open.

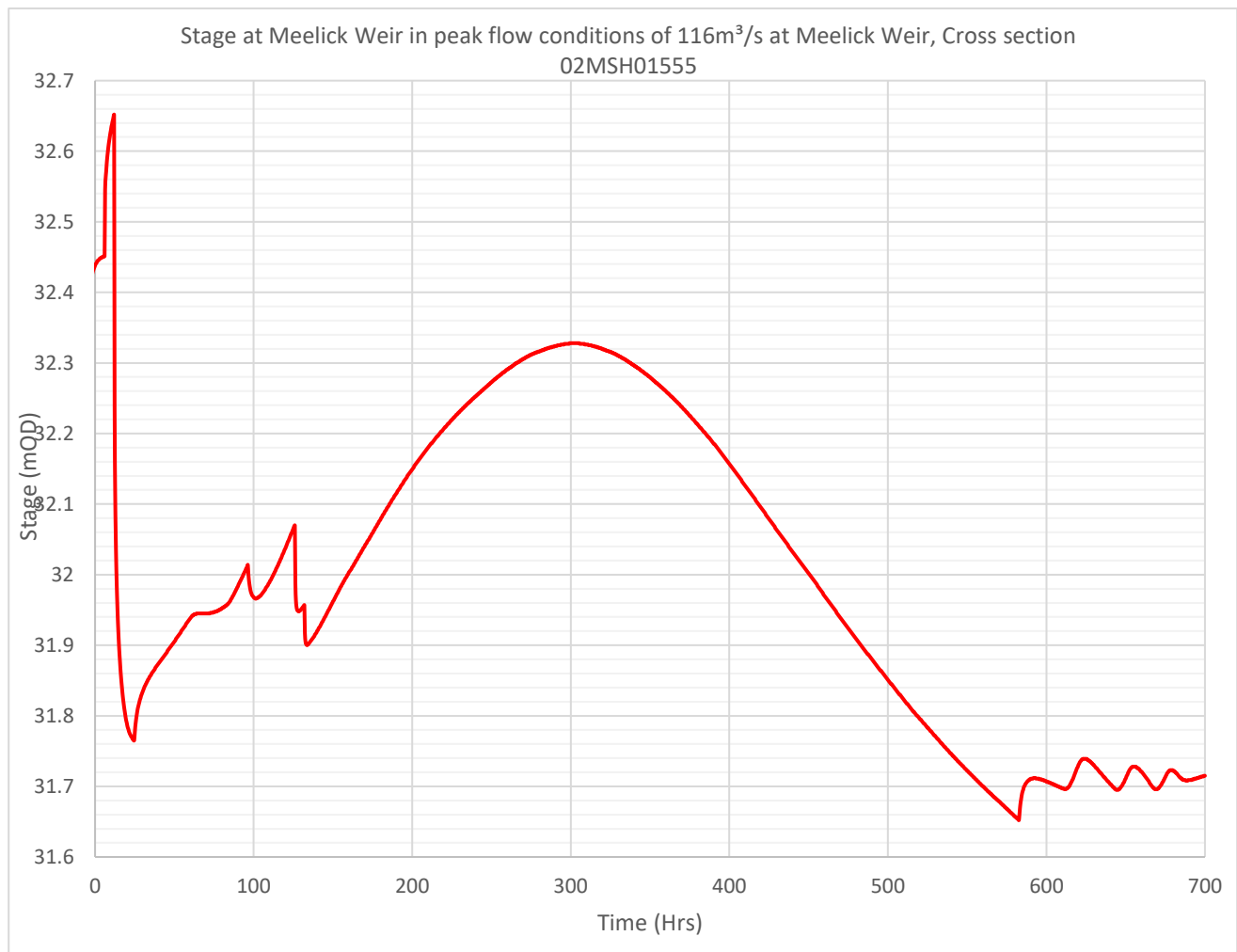


Figure 3.1.1 Stage at Meelick Weir in peak flow conditions of 116m³/s at Meelick Weir

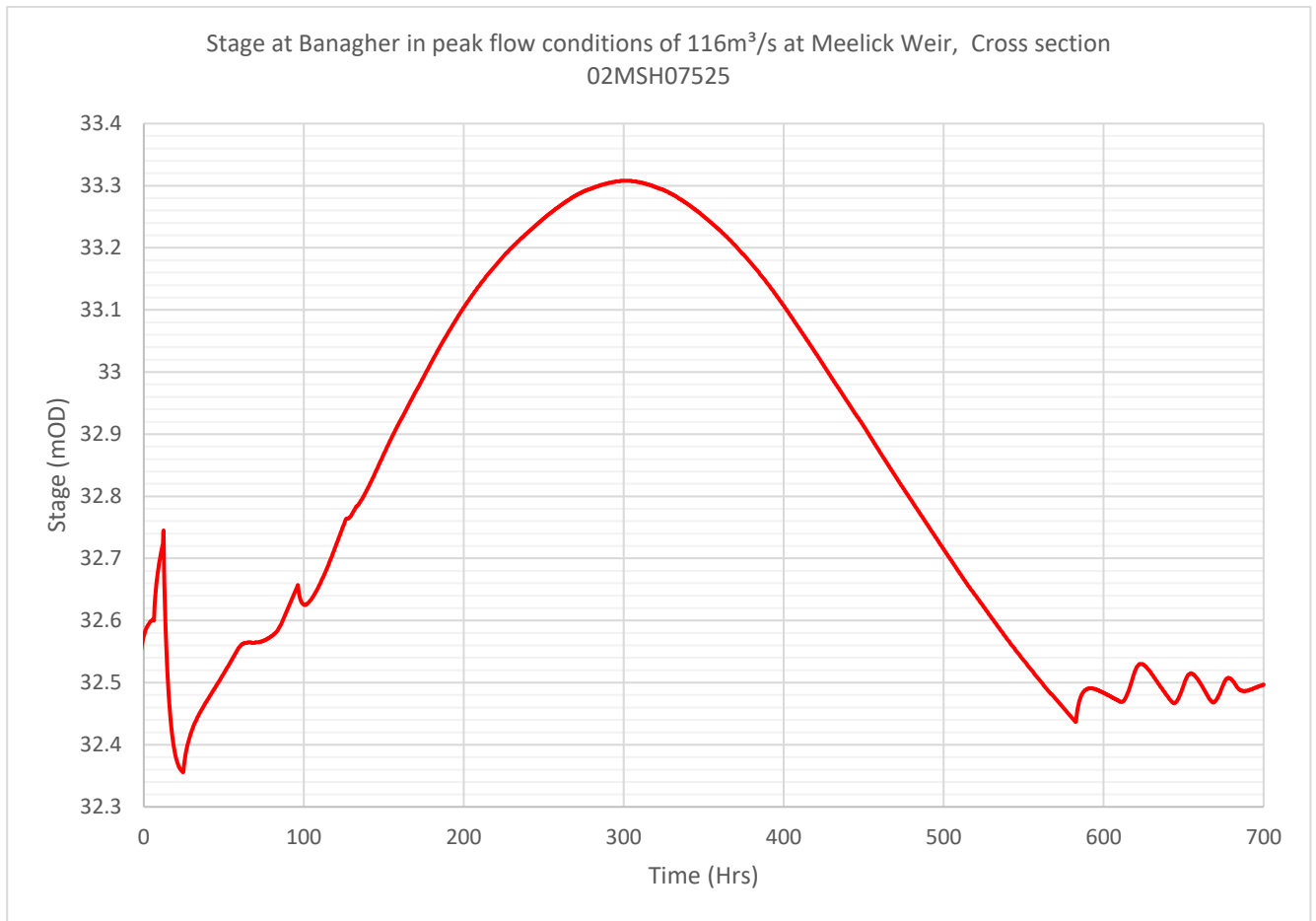


Figure 3.1.2 Stage at Banagher in peak flow conditions of $116\text{m}^3/\text{s}$ at Meelick Weir

3.2 Construction of Maintenance Scenario

In order to assess the impact of the proposed Maintenance Scenario, the updated cross sections and operating regime were modified in line with the project brief and subsequent clarifications.

Three different Maintenance Scenarios have been developed to assess the potential impact on water levels. The proposed measures associated with each Maintenance Scenario are set out below.

Scenario B – excavation of pinch points and removal of weir boards

- Meelick Weir set to a crest level of 32.270m OD, replicating the condition of **no weir** boards in place;
- Keelogue and Marlborough Sluices to be operated as per existing regime to maintain minimum statutory navigation levels;
- A trapezoidal navigation channel from Athlone to Meelick Weir, 30m wide at its base, with side slopes of 1:1, and 10 identified existing pinch points excavated to the level of the adjoining channel.

The revised operating regime at Meelick Weir was incorporated into the model through the removal of the existing Weir Boards in the starting condition. This replicates the scenario where the weir boards are removed in the day to day scenario, rather than specifically in response to a flood event.

The new navigational channel was designed to be largely consistent with the existing channel, with no in channel maintenance to be included outside of the identified pinch points. A design bed level was interpolated from the modelled sections upstream and downstream of the proposed maintenance (or the extent of the pinch point).

A comparison of the typical Current and Maintenance Scenario cross sections at each pinch point is provided in Appendix C, with a comparison of the long sections evident in the model results provided in Appendix D.

Scenario C – excavation of channel to 30.195m OD Malin GSM02 and removal of weir boards

- Meelick Weir set to a crest level of 32.270m OD Malin GSM02, replicating the condition of **no weir** boards in place;
- Keelogue and Marlborough Sluices to be operated as per existing regime to maintain minimum statutory navigation levels;
- A trapezoidal navigation channel from Athlone to Meelick Weir, 30m wide at its base, with side slopes of 1:3, and a maximum bed level of 30.195m OD Malin GSM02 along its length;
- A trapezoidal navigation channel on the New Cut to Marlborough Sluices, 20m wide at its base, with side slopes of 1:3, and a maximum bed level of 30.6m OD Malin GSM02 along its length.

The revised operating regime at Meelick Weir was incorporated into the model through the removal of the existing Weir Boards in the starting condition. This replicates the scenario where the weir boards are removed in the day to day scenario, rather than specifically in response to a flood event.

The new navigational channel was designed to be largely consistent with the existing channel, with no in channel maintenance to be included where the existing bed level was above the identified maximum bed level for the proposed channel width.

Scenario D – modification of Keelogue Sluice and Marlborough Sluice

- Keelogue and Marlborough Sluices and Meelick Weir boards operated as per existing regime to maintain minimum statutory navigation levels;
- Each set of three sluices (approximately 2.0m height x 2.1m width) at Keelogue and the New Cut (approximately 2.0m height x 2.66m width) replaced with a single sluice.

3.3 Comparison of Scenario A1: Current and Scenario B: Maintenance

The updated model was run for each of the design flow events and results generated. The cross section reference and approximate geographic location of each pinch point is detailed in Table 3.3.1 for convenience. In each case, the pinch point extends beyond a single cross section in the model, but the section detailed has been identified as being representative of each individual pinch point.

Table 3.3.1 Geographic location and cross section reference of identified pinch point locations

Pinch Point	Location	Cross Section Reference
1	Downstream Athlone	05MSH02473
2	Clonown	04MSH12228
3	Upstream Clonmacnoise	04MSH10729
4	Clonmacnoise	04MSH04412
5	Downstream Suck confluence	03MSH07952
6	Blackwater confluence	03MSH06273
7	Shannon Harbour	03MSH01096
8	Downstream Banagher	02MSH07525
9	Corclough	02MSH04413
10	Upstream Meelick Weir	02MSH01555

It should be noted that the peak water level is significantly influenced by Athlone, Keelogue, and Marlborough Sluice Control in all scenarios. No proposals have been identified to amend the operation of these structures as part of the Maintenance scenario.

During initial model runs, in certain flood events, the reduction in water levels in the Maintenance scenario resulted in Keelogue and Marlborough sluices remaining closed. Whereas in the corresponding current scenario, the higher water level resulted in these sluices opening. Whilst this result is somewhat intuitive, a comparison of peak water levels would mean the water levels in the Maintenance scenario are higher than the Current scenario due to the different sluice operation.

To ensure a like-for-like comparison in the Current and Maintenance scenario, the rules and sluice operation were adjusted in each flood event so the operational philosophy in the Current scenario matched the Maintenance scenario:

- For all flow conditions up to a peak flow of 116m³/s at Meelick Weir (see Section 3.1) it was assumed that these sluices would remain in the fully closed position. This was based on there being insufficient flow to ensure the minimum navigation level at Meelick Weir was maintained in a scenario where Keelogue and Marlborough sluices are fully open;
- For all flow conditions at or above peak flow of 116m³/s at Meelick Weir, it was assumed that these sluices would be in the fully open position. This was based on there being sufficient flow to ensure the minimum navigation level at Meelick Weir was maintained in the same scenario.

The impact of this assumption is that the water levels in the lower magnitude flood events are artificially high in the Current scenario. In practice, the sluices would likely be partially open in these conditions, as they are operated to maintain the minimum navigation level.

A comparison of peak water levels and flow for each of the design events, at each pinch point, is included in Tables 3.3.2 to 3.3.12 below.

Table 3.3.2 Comparison of peak water levels and flows for 2% AEP design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	35.20	35.13	-0.07	207.8	210.0	+2.2	+1%
2	35.08	35.00	-0.08	205.7	207.7	+2.0	<1%
3	35.05	34.98	-0.07	205.4	207.2	+1.8	<1%
4	34.99	34.91	-0.08	204.5	206.3	+1.8	<1%
5	34.74	34.66	-0.08	303.4	305.5	+2.1	<1%
6	34.61	34.52	-0.09	303.2	305.0	+1.8	<1%
7	34.29	34.22	-0.07	231.0	256.5	+25.5	+10%
8	33.77	33.63	-0.14	371.2	373.6	+2.4	<1%
9	33.60	33.47	-0.13	371.0	373.6	+2.6	<1%
10	32.77	32.80	+0.03	269.4	286.8	+17.4	+6%

Table 3.3.3 Comparison of peak water levels and flows for 5% AEP design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	35.02	34.94	-0.08	180.2	182.3	+2.1	+1%
2	34.90	34.81	-0.09	178.0	180.3	+2.3	+1%
3	34.87	34.78	-0.09	178.1	180.0	+1.9	+1%
4	34.81	34.72	-0.09	177.4	179.4	+2.0	+1%
5	34.57	34.49	-0.08	261.7	263.8	+2.1	<1%
6	34.43	34.34	-0.09	261.5	263.6	+2.1	<1%
7	34.12	34.05	-0.07	205.8	228.2	+22.4	+9%
8	33.62	33.47	-0.15	320.8	322.9	+2.1	<1%
9	33.47	33.33	-0.14	320.8	322.9	+2.1	<1%
10	32.69	32.72	+0.03	239.9	256.2	+16.3	+6%

Table 3.3.4 Comparison of peak water levels and flows for 10% AEP design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	34.86	34.76	-0.10	160.5	162.8	+2.3	+1%
2	34.74	34.64	-0.10	159.1	161.2	+2.1	+1%
3	34.71	34.61	-0.10	158.8	160.7	+1.9	+1%
4	34.66	34.56	-0.10	158.4	160.2	+1.8	+1%
5	34.43	34.33	-0.10	231.4	233.2	+1.8	<1%
6	34.29	34.18	-0.11	231.3	233.1	+1.8	<1%
7	33.98	33.89	-0.09	187.1	207.0	+19.9	+9%
8	33.50	33.34	-0.16	283.4	285.0	+1.6	<1%
9	33.36	33.20	-0.16	283.4	285.1	+1.7	<1%
10	32.62	32.65	+0.03	217.7	232.8	+15.1	+6%

Table 3.3.5 Comparison of peak water levels and flows for 20% AEP design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	34.66	34.54	-0.12	139.9	140.9	+1.0	<1%
2	34.55	34.41	-0.14	138.7	139.8	+1.1	<1%
3	34.52	34.39	-0.13	138.4	139.7	+1.3	<1%
4	34.48	34.34	-0.14	138.0	138.7	+0.7	<1%
5	34.26	34.12	-0.14	199.1	200.3	+1.2	<1%
6	34.11	33.97	-0.14	198.9	200.2	+1.3	<1%
7	33.81	33.69	-0.12	166.6	182.2	+15.6	+8%
8	33.36	33.17	-0.19	243.5	244.8	+1.3	<1%
9	33.23	33.05	-0.18	243.4	244.7	+1.3	<1%
10	32.56	32.58	+0.02	192.6	204.1	+11.5	+5%

Table 3.3.6 Comparison of peak water levels and flows for 50% AEP design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m ³ /s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m ³ /s)	Maintenance (m ³ /s)	Difference (m ³ /s)	Percentage Increase
1	34.16	33.96	-0.20	98.2	97.1	-1.1	-1%
2	34.07	33.86	-0.21	98.3	97.3	-1	-1%
3	34.04	33.84	-0.20	98.1	97.2	-0.9	<1%
4	34.01	33.80	-0.21	98.1	97.3	-0.8	<1%
5	33.82	33.63	-0.19	140.4	139.8	-0.6	<1%
6	33.65	33.47	-0.18	140.3	139.8	-0.5	<1%
7	33.38	33.23	-0.15	123.7	130.8	+7.1	+6%
8	33.02	32.82	-0.20	172.8	172.4	-0.4	<1%
9	32.91	32.74	-0.17	172.8	172.3	-0.5	<1%
10	32.42	32.43	+0.01	139.6	144.9	+5.3	+3%

Table 3.3.7 Comparison of peak water levels and flows for 125m³/s design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	33.91	33.68	-0.23	76.1	76.2	+0.1	<1%
2	33.84	33.60	-0.24	77.8	77.0	-0.8	<1%
3	33.83	33.59	-0.24	76.7	77.0	+0.3	<1%
4	33.80	33.56	-0.24	76.9	77.2	+0.3	<1%
5	33.66	33.42	-0.24	109.5	109.9	+0.4	<1%
6	33.53	33.31	-0.22	109.5	109.9	+0.4	<1%
7	33.34	33.13	-0.21	96.7	103.1	+6.4	6%
8	33.13	32.88	-0.25	135.7	136.3	+0.6	<1%
9	33.07	32.83	-0.24	135.7	136.3	+0.6	<1%
10	32.88	32.65	-0.23	108.9	122.8	+13.9	12%

Table 3.3.8 Comparison of peak water levels and flows for 100m³/s design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	33.66	33.42	-0.24	61.6	61.6	+0.0	<1%
2	33.61	33.36	-0.25	62.7	62.7	+0.0	<1%
3	33.60	33.34	-0.26	62.6	62.7	+0.1	<1%
4	33.57	33.32	-0.25	63.0	63.1	+0.1	<1%
5	33.46	33.21	-0.25	89.1	89.2	+0.1	<1%
6	33.34	33.11	-0.23	89.0	89.2	+0.2	<1%
7	33.19	32.97	-0.22	79.0	84.0	+5.0	6%
8	33.03	32.77	-0.26	111.2	111.4	+0.2	<1%
9	32.99	32.74	-0.25	111.1	111.4	+0.3	<1%
10	32.84	32.60	-0.24	88.7	101.0	+12.3	13%

Table 3.3.9 Comparison of peak water levels and flows for 75m³/s design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)*			Peak Flow (m ³ /s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m ³ /s)	Maintenance (m ³ /s)	Difference (m ³ /s)	Percentage Increase
1	33.46	33.21	-0.25	47.2	47.2	+0.0	0%
2	33.43	33.17	-0.26	48.4	48.4	+0.0	<1%
3	33.41	33.16	-0.25	48.4	48.4	+0.0	<1%
4	33.40	33.14	-0.26	48.8	48.9	+0.1	<1%
5	33.31	33.05	-0.26	74.3	74.4	+0.1	<1%
6	33.21	32.98	-0.23	74.3	74.4	+0.1	<1%
7	33.09	32.87	-0.22	65.9	70.1	+4.2	6%
8	32.96	32.70	-0.26	95.0	95.1	+0.1	<1%
9	32.93	32.68	-0.25	95.0	95.1	+0.1	<1%
10	32.81	32.57	-0.24	75.4	86.7	+11.3	14%

Table 3.3.10 Comparison of peak water levels and flows for 50m³/s design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	33.28	33.00	-0.28	33.4	33.4	+0.0	<1%
2	33.26	32.97	-0.29	34.7	34.7	+0.0	<1%
3	33.25	32.96	-0.29	34.7	34.7	+0.0	<1%
4	33.24	32.95	-0.29	35.2	35.2	+0.0	<1%
5	33.17	32.89	-0.28	60.7	60.8	+0.1	<1%
6	33.10	32.83	-0.27	60.7	60.8	+0.1	<1%
7	33.01	32.74	-0.27	53.9	64.2	+10.3	19%
8	32.90	32.60	-0.30	81.4	81.5	+0.1	<1%
9	32.88	32.58	-0.30	81.4	81.5	+0.1	<1%
10	32.79	32.49	-0.30	64.2	76.1	+11.9	18%

Table 3.3.11 Comparison of peak water levels and flows for 25m³/s design event (Current vs Scenario B: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	33.11	32.83	-0.28	20.6	20.6	+0.0	<1%
2	33.10	32.81	-0.29	22.1	22.1	+0.0	<1%
3	33.10	32.81	-0.29	22.1	22.1	+0.0	<1%
4	33.09	32.80	-0.29	22.6	22.7	+0.1	<1%
5	33.05	32.76	-0.29	48.3	48.3	+0.0	0%
6	33.00	32.72	-0.28	48.3	48.3	+0.0	0%
7	32.93	32.65	-0.28	42.8	45.6	+2.8	6%
8	32.85	32.54	-0.31	68.9	69.0	+0.1	<1%
9	32.83	32.53	-0.30	68.9	69.0	+0.1	<1%
10	32.77	32.46	-0.31	54.0	64.9	+10.9	20%

3.4 Comparison of Scenario A1 and A2: Current and Scenario C: Maintenance Scenarios

The updated model was run for each of the design flow events and results generated. All existing cross sections were reviewed to check compliance with the design profile. A total of 35 cross sections were identified in the model which would require some level of excavation to achieve the design profile, covering a total length of 6.5km of river channel. These are detailed in Table 3.4.1 below.

It should be noted that the peak water level is significantly influenced by Athlone, Keelogue, and Marlborough Sluice Control in all scenarios. No proposals have been identified to amend the operation of these structures as part of the Scenario C: Maintenance scenario.

To assist in evaluating the impact of the proposed maintenance on the ability to retain minimum navigation water levels, the results were compared against two Current scenarios for the lower magnitude flood events – with and without boards removed:

- Scenario A1 (boards in, sluices closed) compared to Scenario C (boards removed, sluices closed) enables an evaluation as to whether minimum navigation water levels can still be retained if the boards are removed and the proposed maintenance undertaken.
- Scenario A2 (boards removed, sluices closed) compared to Scenario C (boards removed, sluices closed) enables an evaluation of the impact of the proposed maintenance alone on peak water levels and flows in lower magnitude events.

A comparison of peak water levels and flow for each of the design events is included in Tables 3.4.2 to 3.4.16 below.

Table 3.4.1 Geographic location and cross section reference of identified pinch point locations

Cross Section Reference	Location	Increase in Cross Sectional Area (m ²)	Material to be excavated (m ³)
07MSH00161	Downstream Athlone Weir	3.8	554.8
05MSH00716-05MSH00714	Upstream Long Island, Ballygowlan	0.0	2.0
04MSH12228	Curraghnaboll	4.5	2382.6
04MSH04066	Devenish Island	0.7	170.4
04MSH03918	Devenish Island	6.8	1027.6
04MSH03508	Downstream Devenish Island	3.3	716.0
04MSH00747	Downstream Shannon Bridge	16.1	927.4
04MSH00629	Downstream Shannon Bridge	10.1	708.8
04MSH00541	Downstream Shannon Bridge	4.8	416.0
03MSH08641	West Offaly Power Station	0.8	52.1
03MSH08486	Downstream West Offaly Power Station	11.4	622.0

Cross Section Reference	Location	Increase in Cross Sectional Area (m ²)	Material to be excavated (m ³)
03MSH08182	Downstream West Offaly Power Station	1.2	125.8
03MSH07719	Upstream Bishops Islands	2.0	254.2
03MSH07446	Bishops Islands	3.0	392.2
03MSH07200	Bishops Islands	1.4	165.0
03MSH06960	Bishops Islands	0.5	77.8
03MSH01330u- 03MSH01330d	Lehinch	0.2	29.1
03MSH01205	Lehinch	0.3	39.0
02MSH10670	Bullock Island	0.3	46.7
02MSH08884	Upstream Banagher	1.7	310.1
02MSH08762	Upstream Banagher	0.9	113.6
02MSH08641	Upstream Banagher	0.8	107.9
02MSH08255	Upstream Banagher Bridge	42.6	1583.0
02MSH08206	Downstream Banagher Bridge	6.4	248.7
02MSH08078	Downstream Banagher Bridge	6.5	485.9
02MSH07909	Downstream Banagher Bridge	4.6	621.3
02MSH04413	Ballymacoolaghan	7.8	2363.4
02MSH04313d- 02MSH04313u	Ballymacoolaghan	5.0	832.0
02MSH03172	Incherky	1.8	932.1
02MSH02709	Incherky	4.0	1913.6
02MSH01555	Meelick Weir	0.8	356.0
02MSH01223u	Meelick Weir	0.2	11.9
01MSX03484	Gortachallaow	15.2	7263.4
01MSX03184	Gortachallaow	17.8	2841.1
01MSX03144	Gortachallaow	21.9	6356.6
Total			35049.9

3.4.1 Comparison of Scenario A1 (Current, boards in, sluices closed) and Scenario C (Maintenance, boards removed, sluices closed)

Table 3.4.2 Comparison of peak water levels and flows for 2% AEP design event (Current vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	35.20	35.20	0.00	207.8	207.9	+0.1	<1%
2	35.08	35.08	0.00	205.7	205.9	+0.2	<1%
3	35.05	35.04	-0.01	205.4	205.6	+0.2	<1%
4	34.99	34.98	-0.01	204.5	204.7	+0.2	<1%
5	34.74	34.74	0.00	303.4	303.4	+0.0	0%
6	34.61	34.60	-0.01	303.2	303.4	+0.2	<1%
7	34.29	34.28	-0.01	231.0	231.6	+0.6	<1%
8	33.77	33.75	-0.02	371.2	370.6	-0.6	<1%
9	33.60	33.57	-0.03	371.0	370.6	-0.4	<1%
10	32.77	32.75	-0.02	269.4	261.7	-7.7	-2%

Table 3.4.3 Comparison of peak water levels and flows for 5% AEP design event (Current vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	35.02	35.01	-0.01	180.2	180.1	-0.1	<1%
2	34.90	34.89	-0.01	178.0	178.2	+0.2	<1%
3	34.87	34.86	-0.01	178.1	177.9	-0.2	<1%
4	34.81	34.80	-0.01	177.4	177.1	-0.3	<1%
5	34.57	34.57	0.00	261.7	261.7	+0.0	0%
6	34.43	34.42	-0.01	261.5	261.6	+0.1	<1%
7	34.12	34.11	-0.01	205.8	206.0	+0.2	<1%
8	33.62	33.60	-0.02	320.8	320.9	+0.1	<1%
9	33.47	33.43	-0.04	320.8	320.8	+0.0	0%
10	32.69	32.67	-0.02	239.9	232.2	-7.7	-3%

Table 3.4.4 Comparison of peak water levels and flows for 10% AEP design event (Current vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	34.86	34.85	-0.01	160.5	160.7	+0.2	<1%
2	34.74	34.73	-0.01	159.1	159.2	+0.1	<1%
3	34.71	34.70	-0.01	158.8	158.9	+0.1	<1%
4	34.66	34.65	-0.01	158.4	158.5	+0.1	<1%
5	34.43	34.43	0.00	231.4	231.6	+0.2	<1%
6	34.29	34.28	-0.01	231.3	231.2	-0.1	<1%
7	33.98	33.97	-0.01	187.1	187.5	+0.4	<1%
8	33.50	33.47	-0.03	283.4	283.5	+0.1	<1%
9	33.36	33.31	-0.05	283.4	283.3	-0.1	<1%
10	32.62	32.60	-0.02	217.7	208.0	-9.7	-4%

Table 3.4.5 Comparison of peak water levels and flows for 20% AEP design event (Current vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	34.66	34.66	-0.00	139.9	139.9	+0.0	0%
2	34.55	34.54	-0.01	138.7	138.5	-0.2	<1%
3	34.52	34.51	-0.01	138.4	138.5	+0.1	<1%
4	34.48	34.47	-0.01	138.0	138.2	+0.2	<1%
5	34.26	34.24	-0.02	199.1	199.2	+0.1	<1%
6	34.11	34.09	-0.02	198.9	199.2	+0.3	<1%
7	33.81	33.78	-0.03	166.6	167.6	+1	<1%
8	33.36	33.31	-0.05	243.5	243.7	+0.2	<1%
9	33.23	33.16	-0.07	243.4	243.6	+0.2	<1%
10	32.56	32.53	-0.03	192.6	182.2	-10.4	-5%

Table 3.4.6 Comparison of peak water levels and flows for 50% AEP design event (Current vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	34.16	34.13	-0.03	98.2	97.7	-0.5	<1%
2	34.07	34.04	-0.03	98.3	98.0	-0.3	<1%
3	34.04	34.02	-0.02	98.1	97.8	-0.3	<1%
4	34.01	33.98	-0.03	98.1	97.8	-0.3	<1%
5	33.82	33.80	-0.02	140.4	140.1	-0.3	<1%
6	33.65	33.62	-0.03	140.3	140.1	-0.2	<1%
7	33.38	33.33	-0.05	123.7	123.8	+0.1	<1%
8	33.02	32.97	-0.05	172.8	172.6	-0.2	<1%
9	32.91	32.84	-0.07	172.8	172.5	-0.3	<1%
10	32.42	32.39	-0.03	139.6	130.0	-9.6	-6%

Table 3.4.7 Comparison of peak water levels and flows for 125m³/s design event (Current A1 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m ³ /s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m ³ /s)	Maintenance (m ³ /s)	Difference (m ³ /s)	Percentage Increase
1	33.91	33.85	-0.06	76.1	76.0	-0.1	0%
2	33.84	33.78	-0.06	76.8	76.7	-0.1	0%
3	33.83	33.76	-0.07	76.7	76.6	-0.1	0%
4	33.80	33.73	-0.07	76.9	76.8	-0.1	0%
5	33.66	33.58	-0.08	109.5	109.4	-0.1	0%
6	33.53	33.44	-0.09	109.5	109.4	-0.1	0%
7	33.34	33.23	-0.11	96.7	96.9	+0.2	0%
8	33.13	33.00	-0.13	135.7	135.6	-0.1	0%
9	33.07	32.92	-0.15	135.7	135.6	-0.1	0%
10	32.88	32.66	-0.22	108.9	116.6	+7.7	7%

Table 3.4.8 Comparison of peak water levels and flows for 100m³/s design event (Current A1 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m ³ /s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m ³ /s)	Maintenance (m ³ /s)	Difference (m ³ /s)	Percentage Increase
1	33.66	33.59	-0.07	61.6	61.6	+0.0	0%
2	33.61	33.53	-0.08	62.7	62.5	-0.2	0%
3	33.60	33.51	-0.09	62.6	62.5	-0.1	0%
4	33.57	33.49	-0.08	63.0	62.9	-0.1	0%
5	33.46	33.36	-0.10	89.1	89.0	-0.1	0%
6	33.34	33.24	-0.10	89.0	89.0	+0.0	0%
7	33.19	33.06	-0.13	79.0	78.9	-0.1	0%
8	33.03	32.88	-0.15	111.2	111.1	-0.1	0%
9	32.99	32.82	-0.17	111.1	111.1	+0.0	0%
10	32.84	32.61	-0.23	88.7	96.4	+7.7	9%

Table 3.4.9 Comparison of peak water levels and flows for 75m³/s design event (Current A1 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)*			Peak Flow (m ³ /s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m ³ /s)	Maintenance (m ³ /s)	Difference (m ³ /s)	Percentage Increase
1	33.46	33.37	-0.09	47.2	47.1	-0.1	0%
2	33.43	33.33	-0.10	48.4	48.3	-0.1	0%
3	33.41	33.31	-0.10	48.4	48.3	-0.1	0%
4	33.40	33.30	-0.10	48.8	48.7	-0.1	0%
5	33.31	33.20	-0.11	74.3	74.2	-0.1	0%
6	33.21	33.09	-0.12	74.3	74.2	-0.1	0%
7	33.09	32.95	-0.14	65.9	65.8	-0.1	0%
8	32.96	32.79	-0.17	95.0	94.9	-0.1	0%
9	32.93	32.75	-0.18	95.0	94.9	-0.1	0%
10	32.81	32.58	-0.23	75.4	83.1	+7.7	10%

Table 3.4.10 Comparison of peak water levels and flows for 50m³/s design event (Current A1 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m ³ /s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m ³ /s)	Maintenance (m ³ /s)	Difference (m ³ /s)	Percentage Increase
1	33.28	33.17	-0.11	33.4	33.3	-0.1	0%
2	33.26	33.14	-0.12	34.7	34.6	-0.1	0%
3	33.25	33.13	-0.12	34.7	34.6	-0.1	0%
4	33.24	33.12	-0.12	35.2	35.1	-0.1	0%
5	33.17	33.05	-0.12	60.7	60.6	-0.1	0%
6	33.10	32.96	-0.14	60.7	60.7	0.0	0%
7	33.01	32.85	-0.14	53.9	53.8	-0.1	0%
8	32.90	32.72	-0.18	81.4	81.3	-0.1	0%
9	32.88	32.68	-0.20	81.4	81.3	-0.1	0%
10	32.79	32.55	-0.24	64.2	72.0	+7.8	12%

Table 3.4.11 Comparison of peak water levels and flows for 25m³/s design event (Current A1 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m ³ /s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m ³ /s)	Maintenance (m ³ /s)	Difference (m ³ /s)	Percentage Increase
1	33.11	32.98	-0.13	20.6	20.6	+0.0	0%
2	33.10	32.97	-0.13	22.1	22.0	-0.1	0%
3	33.10	32.96	-0.14	22.1	22.0	-0.1	0%
4	33.09	32.96	-0.13	22.6	22.6	+0.0	0%
5	33.05	32.91	-0.14	48.3	48.2	-0.1	0%
6	33.00	32.84	-0.16	48.3	48.2	-0.1	0%
7	32.93	32.76	-0.17	42.8	42.7	-0.1	0%
8	32.85	32.66	-0.19	68.9	68.9	+0.0	0%
9	32.83	32.63	-0.20	68.9	68.9	+0.0	0%
10	32.77	32.52	-0.25	54.0	61.6	+7.6	14%

3.4.2 Comparison of Scenario A2 (Current, boards removed, sluices closed) and Scenario C (Maintenance, boards removed, sluices closed)

Table 3.4.12 Comparison of peak water levels and flows for 125m³/s design event (Current A2 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	33.86	33.85	-0.01	75.9	76.0	+0.1	<1%
2	33.79	33.78	-0.01	76.7	76.7	+0.0	0%
3	33.77	33.76	-0.01	76.5	76.6	+0.1	<1%
4	33.75	33.73	-0.02	76.7	76.8	+0.1	<1%
5	33.60	33.58	-0.02	109.4	109.4	+0.0	0%
6	33.45	33.44	-0.01	109.3	109.4	+0.1	<1%
7	33.25	33.23	-0.02	96.9	96.9	+0.0	0%
8	33.01	33.00	-0.01	135.6	135.6	+0.0	0%
9	32.94	32.92	-0.02	135.6	135.6	+0.0	0%
10	32.66	32.66	0.00	118.5	116.6	-1.9	<1%

Table 3.4.13 Comparison of peak water levels and flows for 100m³/s design event (Current A2 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	33.60	33.59	-0.01	61.6	61.6	+0.0	0%
2	33.54	33.53	-0.01	62.5	62.5	+0.0	0%
3	33.53	33.51	-0.02	62.5	62.5	+0.0	0%
4	33.50	33.49	-0.01	62.8	62.9	+0.1	<1%
5	33.38	33.36	-0.02	89.0	89.0	+0.0	0%
6	33.25	33.24	-0.01	89.0	89.0	+0.0	0%
7	33.07	33.06	-0.01	78.9	78.9	+0.0	0%
8	32.89	32.88	-0.01	111.0	111.1	+0.1	<1%
9	32.83	32.82	-0.01	111.0	111.1	+0.1	<1%
10	32.61	32.61	0.00	97.6	96.4	-1.2	<1%

Table 3.4.14 Comparison of peak water levels and flows for 75m³/s design event (Current A2 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)*			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	33.38	33.37	-0.01	47.1	47.1	+0.0	0%
2	33.34	33.33	-0.01	48.3	48.3	+0.0	0%
3	33.33	33.31	-0.02	48.3	48.3	+0.0	0%
4	33.31	33.30	-0.01	48.7	48.7	+0.0	0%
5	33.21	33.20	-0.01	74.2	74.2	+0.0	0%
6	33.10	33.09	-0.01	74.2	74.2	+0.0	0%
7	32.96	32.95	-0.01	65.8	65.8	+0.0	0%
8	32.80	32.79	-0.01	94.9	94.9	+0.0	0%
9	32.75	32.75	0.00	94.9	94.9	+0.0	0%
10	32.58	32.58	0.00	84.0	83.1	-0.9	<1%

Table 3.4.15 Comparison of peak water levels and flows for 50m³/s design event (Current A2 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	33.17	33.17	0.00	33.3	33.3	+0.0	0%
2	33.15	33.14	-0.01	34.6	34.6	+0.0	0%
3	33.14	33.13	-0.01	34.6	34.6	+0.0	0%
4	33.13	33.12	-0.01	35.1	35.1	+0.0	0%
5	33.06	33.05	-0.01	60.7	60.6	-0.1	<1%
6	32.97	32.96	-0.01	60.6	60.7	+0.1	0%
7	32.86	32.85	-0.01	53.8	53.8	+0.0	0%
8	32.73	32.72	-0.01	81.3	81.3	+0.0	0%
9	32.69	32.68	-0.01	81.3	81.3	+0.0	0%
10	32.55	32.55	0.00	72.5	72.0	-0.5	<1%

Table 3.4.16 Comparison of peak water levels and flows for 25m³/s design event (Current A2 vs Scenario C: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m³/s)			
	Current (mOD)	Maintenance (mOD)	Difference (m)	Current (m³/s)	Maintenance (m³/s)	Difference (m³/s)	Percentage Increase
1	32.99	32.98	-0.01	20.6	20.6	+0.0	0%
2	32.97	32.97	0.00	22.0	22.0	+0.0	0%
3	32.97	32.96	-0.01	22.0	22.0	+0.0	0%
4	32.96	32.96	0.00	22.6	22.6	+0.0	0%
5	32.91	32.91	0.00	48.2	48.2	+0.0	0%
6	32.85	32.84	-0.01	48.2	48.2	+0.0	0%
7	32.76	32.76	0.00	42.7	42.7	+0.0	0%
8	32.66	32.66	0.00	68.9	68.9	+0.0	0%
9	32.63	32.63	0.00	68.9	68.9	+0.0	0%
10	32.52	32.52	0.00	62.0	61.6	-0.4	<1%

3.5 Comparison of Scenario A: Current and Scenario D: Maintenance

This was modelled for a flow of 1.3 times the normal flow required (116m³/s) to retain minimum navigation levels with all sluices open (Section 3.1).

Keelogue and Marlborough sluices allow control over the minimum required navigable water levels upstream of Meelick Weir. Keelogue, located adjacent to Meelick Weir consists of 12 sluices in 4 units, each unit consisting of three sluices in a steel frame with concrete abutments. Marlborough, on the New Cut, consists of a similar arrangement however includes 18 sluices in 6 units.

No amendment was made to any cross section as part of this model. This represents a direct comparison between the modelled sluices. This modification was modelled by amending the sluice dimensions and undertaking a sensitivity test on the coefficient of discharge. The modelled parameters are set out in Table 3.6.1 below.

Table 3.6.1 Input parameters for Keelogue and Marlborough Sluices in Scenario A and D

Scenario	Keelogue (4 sets)				Marlborough (6 sets)			
	Number per set	Height (m)	Width (m)	C _D	Number per set	Height (m)	Width (m)	C _D
Current	3	2.0	2.1	0.7	3	2.0	2.66	0.7
Scenario D	1	2.0	6.3	0.7	1	2.0	7.0	0.7
Sensitivity	1	2.0	6.3	0.8	1	2.0	7.0	0.8

A comparison of peak water levels and flow between Scenario A and D for each of the design events, at each pinch point, is included in Tables 3.6.2 below.

Table 3.6.2 Comparison of peak water levels and flows for 151m³/s design event (Current vs Scenario E: Maintenance)

Pinch Point	Peak Water Level (mOD)			Peak Flow (m ³ /s)			
	Current 3 Sluices (mOD)	Current 1 Sluice (mOD)	Difference (m)	Current 3 Sluices (m ³ /s)	Current 1 Sluice (m ³ /s)	Difference (m ³ /s)	Percentage Increase
1	34.09	34.09	0.00	89.9	89.9	0.0	0.0%
2	34.01	34.01	0.00	90.1	90.1	0.0	0.0%
3	33.98	33.98	0.00	90.0	90.0	0.0	0.0%
4	33.95	33.95	0.00	90.1	90.1	0.0	0.0%
5	33.78	33.78	0.00	129.0	129.0	0.0	0.0%
6	33.64	33.64	0.00	129.0	129.0	0.0	0.0%
7	33.40	33.40	0.00	113.5	113.5	0.0	0.0%
8	33.13	33.13	0.00	159.2	159.2	0.0	0.0%
9	33.04	33.04	0.00	159.2	159.2	0.0	0.0%
10	32.70	32.70	0.00	138.8	138.8	0.0	0.0%

4. Discussion

Discussion of the key findings and conclusion of the study are presented within this section. A high level comparison of results in the CFRAM study is also undertaken when reviewing the results. In particular, in relation to Scenario A of the CFRAM Study (impact of reducing bed level by 0.5m and reducing Manning's coefficient), and in Scenario P of the CFRAM Study (widening the Shannon by 50m on each bank between Banagher and Meelick).

4.1 Impact of proposed Scenario B: Maintenance

4.1.1 Impact of proposed maintenance on peak water levels throughout catchment

A review of peak water levels and flow in the modelled design events identifies a consistent pattern of results in relation to the impact of the proposed maintenance works on peak water levels.

The proposed maintenance works can be seen to have a maximum reduction in peak water level of 0.31m (Table 3.3.11), with the greatest impact being evident downstream of the bridge at Banagher in the lowest design event (25m³/s). This observation is intuitive, as it represents the downstream reach of the catchment and the flow conditions corresponding to the lowest water level (and associated flow area).

In contrast, the smallest impact is evident upstream near Athlone in the 2% AEP flood event, where the reduction in water levels associated with the proposed maintenance works is only 0.07m. Again, this observation is somewhat intuitive given it is at the upper part of the catchment and the highest flow conditions studied.

A similar pattern is evident under Scenario A and P in the CFRAM study, where the greatest impact was evident at Banagher, with the impact reducing closer to Athlone and Meelick.

4.1.2 Impact of proposed maintenance on peak water levels at Meelick Weir (2% AEP to 50% AEP)

Following on from the above, a more specific review of the results was undertaken at Meelick Weir.

With reference to Tables 3.3.2 to 3.3.6, a small water level increase was observed at Meelick Weir. This increase is only evident at this location, as a reduction in water levels is evident further upstream at all pinch points. The increase in water level at Meelick Weir is less than 0.03m which is close to being negligible in relation to the wider catchment and model uncertainties.

This can be explained as the same flow is being conveyed by the newly maintained channel sections at a lower water level than previously (in the Current scenario). This is due to the increase in channel size. The result of this is that at the water level which triggers the operation of the sluices at Keelogue and Marlborough, specifically 32.71mOD, a greater flow is evident in the Maintenance scenario than in the Current scenario.

In practical terms this means that as Keelogue and Marlborough sluices are opened later in the same flood event, and for a shorter duration, the sluices are unable to evacuate the same volume of floodwater as in the Current scenario. This has an impact at all water levels, both above and below the crest level of Meelick Weir. It may be possible to offset this impact locally if the operating regime of Keelogue and Marlborough sluices were amended in conjunction with the wider maintenance proposals detailed in the Maintenance scenario.

In addition, and perhaps more importantly, at the peak of the flood event the boards at Meelick Weir are removed in both the Current and Maintenance scenarios, meaning the control structures are operating in the same way at peak water level in both scenarios. The model results indicate that the proposal to remove the boards earlier in the event has negligible impact on peak water levels in higher magnitude events.

In comparison, a reduction in water level was observed upstream at all locations which is associated with the proposed maintenance of the river channel.

This observation is also consistent with the CFRAM study. In Scenario N of the CFRAM study, the crest level of Meelick Weir was lowered by 0.5m and this had no impact on peak water levels in the 20% AEP or 2% AEP flood event. In comparison, channel works investigated under Scenario A and P had a far greater impact.

4.1.3 Impact of board removal on peak water levels in lower magnitude events (125m³/s and below)

The greatest impact in water levels is evident in the lower magnitude flood events and design flows. This is particularly evident when the peak flow at Meelick Weir is less than 116m³/s. This being the flow required to retain the statutory minimum navigation water level at Banagher and Meelick Weir.

In conditions when the peak flow is less than 116m³/s, the boards at Meelick Weir are not removed in the Current scenario as the flow is insufficient to maintain the minimum navigation levels if the boards were removed.

In comparison, the boards are removed throughout the event in the Maintenance scenario, therefore contributing to a more significant reduction in water levels locally (due to the operation of the boards) as well as throughout the catchment (due to the proposed maintenance of the river channel).

4.1.4 Impact of Shannon Harbour to Banagher

Finally, a noticeable change in the reduction in water levels associated with the Maintenance scenario was observed in all design events between Pinch Point 7 (Shannon Harbour) and Pinch Point 8 (Banagher). In the 5% AEP flood event for example (Table 3.3.3), the reduction in water levels associated with the proposed maintenance is up to 0.09m upstream of Shannon Harbour, and up to 0.15m downstream of this point. Similarly, in the 20% AEP flood event, the upstream impact is up to 0.14m, whereas the downstream impact is up to 0.19m.

This change can be attributed to channel narrowing and bed siltation being greater than elsewhere in the River Shannon. More extensive maintenance may be required here to assist in overcoming this constriction, as it limits the potential benefit of any proposed maintenance in the upstream catchment.

Whilst more extensive maintenance here may assist in overcoming this constriction – for example, going beyond the proposed 30m maintained channel – this has the potential to cause an adverse impact downstream as it may negatively affect the balance of the overall system. Areas of floodplain upstream currently frequently subject to inundation may become less prone to flooding, whereas areas downstream may be inundated far more frequently due to the increased conveyance.

Further evidence of this location being the greatest constriction can be observed through the increase in peak flows at Pinch Point 7. In the Maintenance scenario, an increase in peak flow of between 6% and 19% can be seen at Pinch Point 7 (as well as the reduction in water level) due to the scale of the works required to widen and deepen the navigation channel. In comparison, the increase in flows elsewhere is generally less than 1% (with the benefit manifesting as a reduction in water levels only).

Upstream of Meelick Weir, an increase in peak flow of up to 20% is evident in lower magnitude flood events, however this is associated with the closure of Marlborough Sluices preventing any flow in the New Cut..

It should be noted that in the vicinity of Pinch Point 7, the proposed maintenance is far more significant than at the other locations. The existing bed level is at or above 30mOD, whereas the bed level upstream and downstream is as low as 26mOD. At other sections, this discrepancy is between 1 and 1.5metres (see Appendix B and C). A less extensive design profile for the maintenance at this location may reduce the flow increase currently observed.

4.2 Impact of proposed Scenario C: Maintenance

4.2.1 Impact of proposed maintenance on minimum navigation water levels

It is evident from the model results in Section 3.4.1 that, so long as the sluices at Keelogue and Marlborough are operated appropriately to manage upstream water levels, minimum navigation levels will be retained following the proposed maintenance works.

The lowest water level evident at Meelick Weir and Banagher in Scenario C are 32.52mOD and 32.66mOD (Table 3.4.7), in the design event with 25m³/s. Both of these are above the minimum navigational water level required.

A maximum reduction in water levels of 0.25m can be observed in the lower magnitude flood events, and this reduction is associated with the removal of the boards at Meelick Weir as opposed to the proposed excavation. This is evident by comparing the water levels in the Current A1 and A2 scenarios in Tables 3.4.7 to 3.4.11 with 3.4.12 to 3.4.16, where the only difference is the board operation in the current scenario.

4.2.2 Impact of proposed excavation on peak water levels throughout catchment

A review of peak water levels and flow in the modelled design events identifies a consistent pattern of results in relation to the impact of the proposed excavation works on peak water levels.

The proposed maintenance works give a maximum reduction in peak water level of 0.07m (Table 3.4.6), with the greatest impact occurring downstream of the bridge at Banagher in the 50% AEP flood event. In lower flows, the sluices at Keelogue and Marlborough would remain closed to maintain navigational levels and the impact of the proposed excavation on water levels is negligible (<0.02m).

A far greater reduction in water levels is evident in Table 3.4.7 to 3.4.11, however this is associated with the removal of the boards in lower magnitude flood events.

In contrast, the smallest impact occurs upstream near Athlone in the 2% AEP flood event, where the reduction in water levels associated with the proposed maintenance works is only 0.01m. This observation is somewhat intuitive given it is at the upper part of the catchment and the highest flow conditions studied.

The reduction in the impact on water levels is much less than that observed in Scenario B due to the volume and extent of excavation being far less.

4.2.3 Impact of proposed maintenance on peak water levels at Meelick Weir (2% AEP to 50% AEP)

Following on from the above, a more specific review of the results was undertaken at Meelick Weir.

With reference to Tables 3.4.2 to 3.4.6, the reduction in water levels observed at Meelick Weir is slightly less than upstream at Pinch Point 9. This is associated with the increased excavation of the New Cut. Pinch Point 9 is located upstream of the New Cut.

Additional flow is being conveyed by the New Cut in the larger flood events as a result of the proposed maintenance works. As such, a minor reduction in flow is evident on the River Shannon, but a cumulative increase in capacity as a result of the excavation on the New Cut.

This observation is no longer evident in lower flows as the closure of the sluices at Marlborough negates the additional benefit gained.

4.2.4 Impact of board removal on peak water levels in lower magnitude events (125m³/s and below)

As detailed in 4.2.2, the proposed excavation works have a negligible impact on water levels in lower magnitude events, with a maximum reduction in peak water level of 0.02m.

However, the removal of boards compared to the current scenario with boards retained has the potential to reduce peak water levels by up to 0.25m at Meelick Weir in lower magnitude events. This impact reduces as the magnitude of the flood event increases, with an impact of 0.22m in the 125m³/s design event.

Upstream of Banagher, this reduction in water level reduces to 0.17m and 0.14m respectively for the same design events.

4.3 Impact of proposed Scenario D: Maintenance

Keelogue and Marlborough sluices allow control over the minimum required navigable water levels upstream of Meelick Weir. Keelogue, located adjacent to Meelick Weir consists of 12 sluices in 4 units, each unit consisting of three sluices in a steel frame with concrete abutments. Marlborough, on the New Cut, consists of a similar arrangement however includes 18 sluices in 6 units.

The sluice gates have been modified in the current model by replacing each set of three sluices with a single sluice of increased width (6.3m for Keelogue and 6.1m for Marlborough). Sensitivity testing was also carried out to review the assumed change in coefficient of discharge.

The modelling exercise undertaken found that the impact on upstream levels were negligible.

5. Conclusion

The proposed maintenance works in Scenario B have the potential to reduce water levels throughout the catchment in comparison to the Current scenario. This impact varies depending on location and magnitude of flood event, but is up to 0.28m at Athlone, and up to 0.31m downstream of Banagher. Constriction of the river channel in the vicinity of Shannon Harbour to Banagher limits the reduction in water levels associated with the maintenance works upstream.

In peak flow conditions exceeding 116m³/s (flood events of 50% AEP and higher magnitude) the boards at Meelick Weir are removed in both the Current and Maintenance scenario at the peak of the flood impact. The corresponding negligible impact of the maintenance at Meelick Weir indicates the proposed maintenance of the river channel has a far greater impact on peak water levels than the proposed amendment to the operation of the boards. This observation is consistent with previous work undertaken for the CFRAM study.

In peak flow conditions below 116m³/s, a far greater impact is evident at Meelick Weir as the boards remain in place in the Current scenario due to insufficient flow to retain minimum statutory navigation water levels with the boards removed. However, in practical terms, it is assumed the sluices at Keelogue and Marlborough would be operated for the purpose of water level control, and as such the change in operation of the boards may be less pronounced.

In Scenario C, excavation of the channel to a bed level of 30.2mAOD (and 30.6mAOD on the New Cut) will have no impact on flow or water levels at or below minimum navigation level of 32.33mOD at Keelogue Sluices. In these conditions, the removal of the boards at Meelick Weir will also have no impact as the level is controlled by the crest of the weir and the Keelogue and Marlborough Sluices.

For flows up to a flood event with a 50% AEP, excavation of the channel has a negligible impact on flow or water levels. Any decision to remove the boards at Meelick Weir in this scenario would result in reduced water levels, having a resultant beneficial impact locally as concluded within the first phase of the study. It should be noted however, that this impact reduces as you move further upstream due to the impact of the pinch points.

Finally, the greater the amount of material which is removed from the pinch points, the greater the impact the board removal will have on water levels in flood events up to the 50% AEP flow. Significant excavation could potentially result in a greater reduction in water levels, particularly upstream (as per the first phase of the study), however this is far greater in volume than the 35,000 cubic metres associated with the excavation of the channel to a bed level of 30.2mAOD (and 30.6mAOD on the New Cut).

5.1 Recommendations

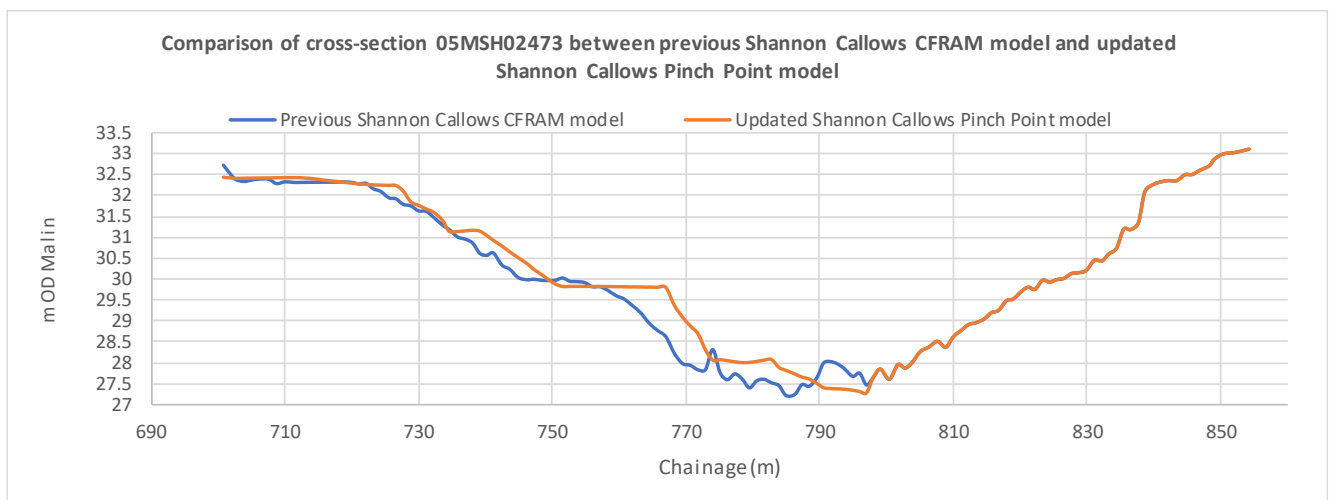
This study provides an indication of the impact of the proposed maintenance on peak water levels and flows throughout the catchment. It should be noted that the existing hydraulic model is designed to simulate real conditions. At lower return periods, the accuracy and certainty associated with model results inevitably reduces due to the complexities of flow dynamics and in-channel features having an increasing impact on model runs. The ability to model these accurately is limited by both technology and the available survey data. Model uncertainty in these lower magnitude events is further compounded by a watercourse which is subject to such an extensive operational regime, the operation of which has to be simplified in order to overcome model stability issues.

It is recommended that a further more detailed bathymetry survey be undertaken if the proposed maintenance, or a variety of, is to be developed in any greater detail with a view to implementation. This should include specification of new survey at pre-defined model cross sections.

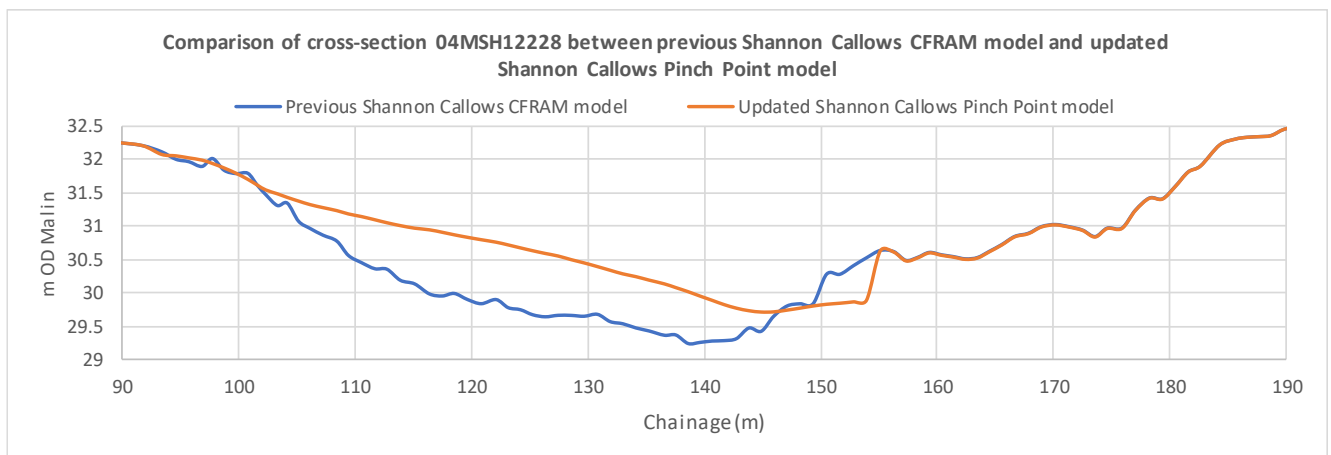
In addition, the operation of water level control structures in lower magnitude events will need to be refined in the hydraulic model to greater ascertain how operating regimes should be amended in conjunction with the proposed maintenance. This may be better undertaken by truncating the existing model and focussing specifically on the operation and management of the water level control structures.

Appendix A. Comparison of cross-sections between previous Shannon Callows CFRAM model and updated Shannon Callows Pinch Point model

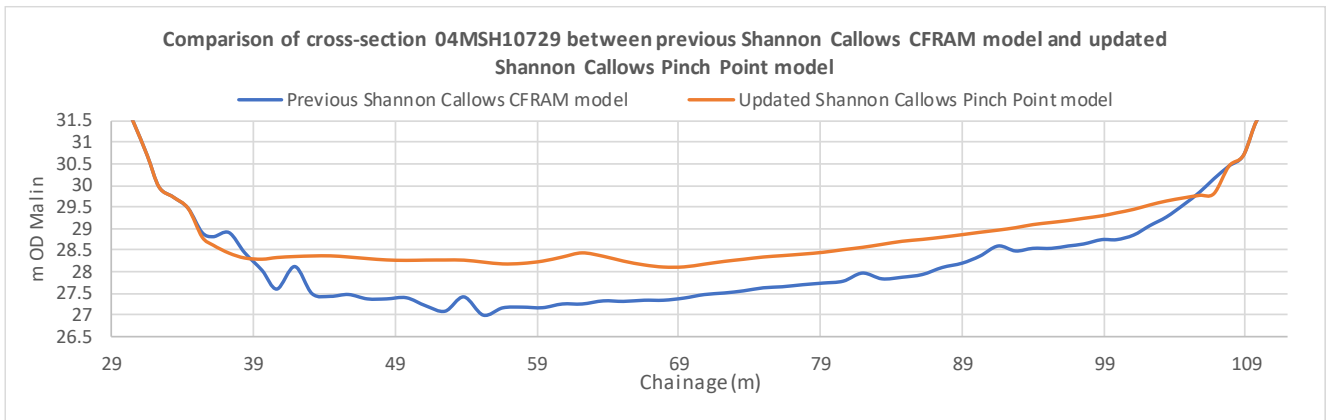
Pinch Point 1, Downstream Athlone. Cross section 05MSH02473



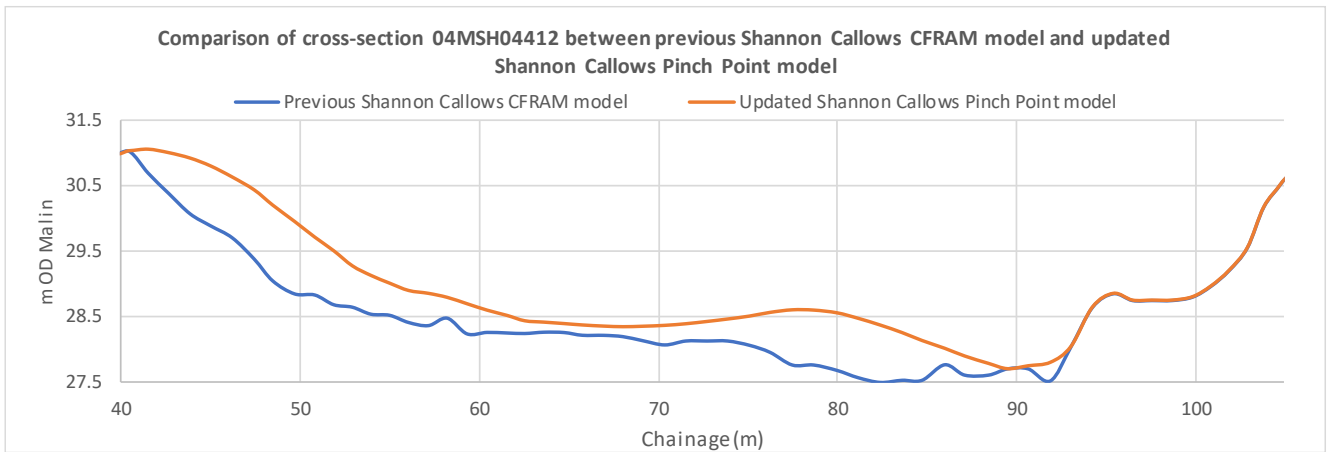
Pinch Point 2, Clonown. Cross section 04MSH12228



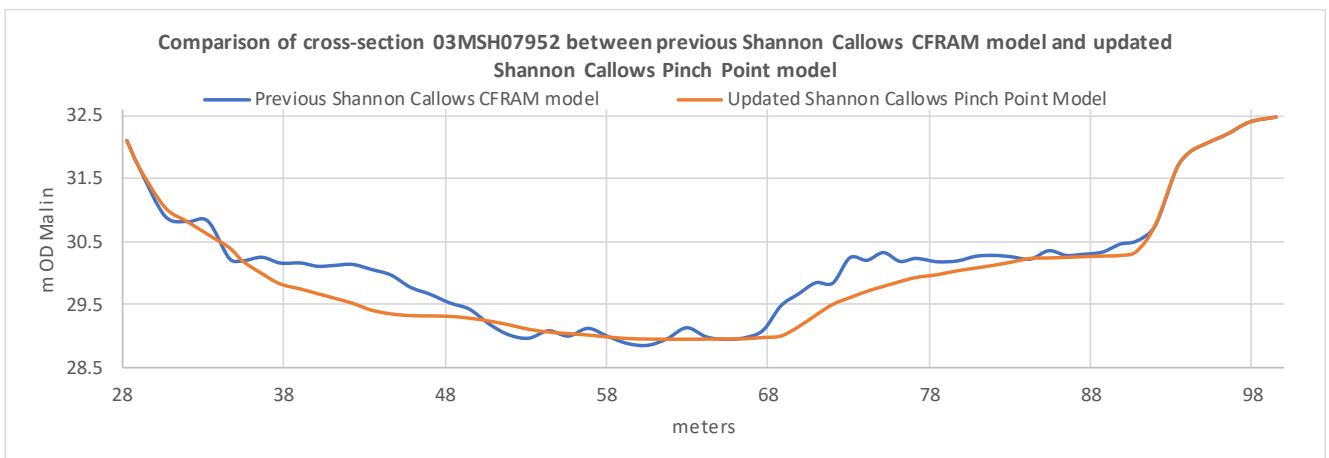
Pinch Point 3, Upstream Clonmacnoise. Cross section 04MSH10729



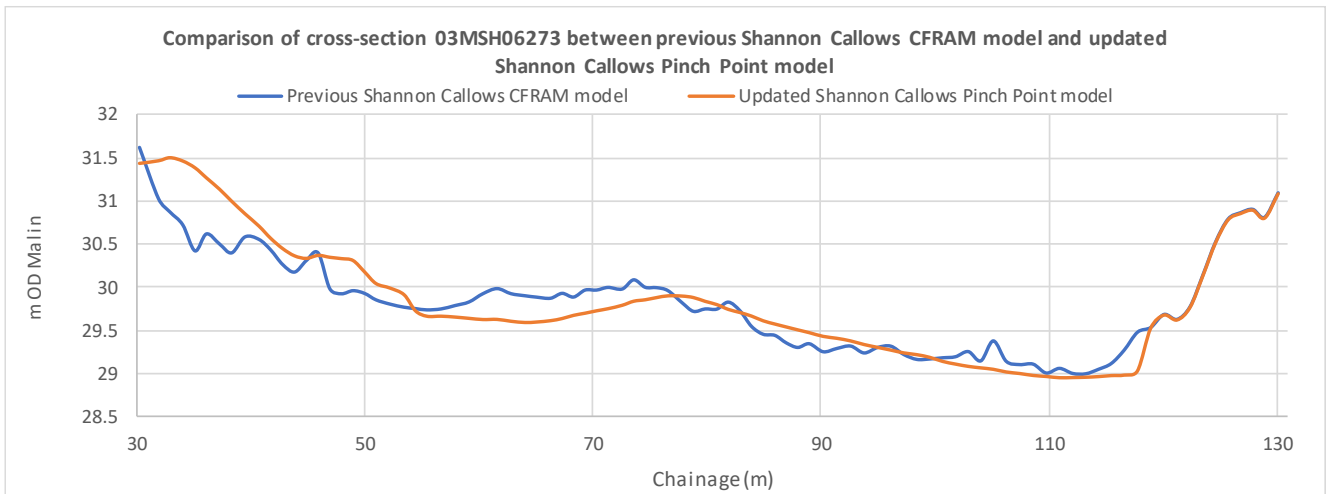
Pinch Point 4, Clonmacnoise. Cross section 04MSH04412



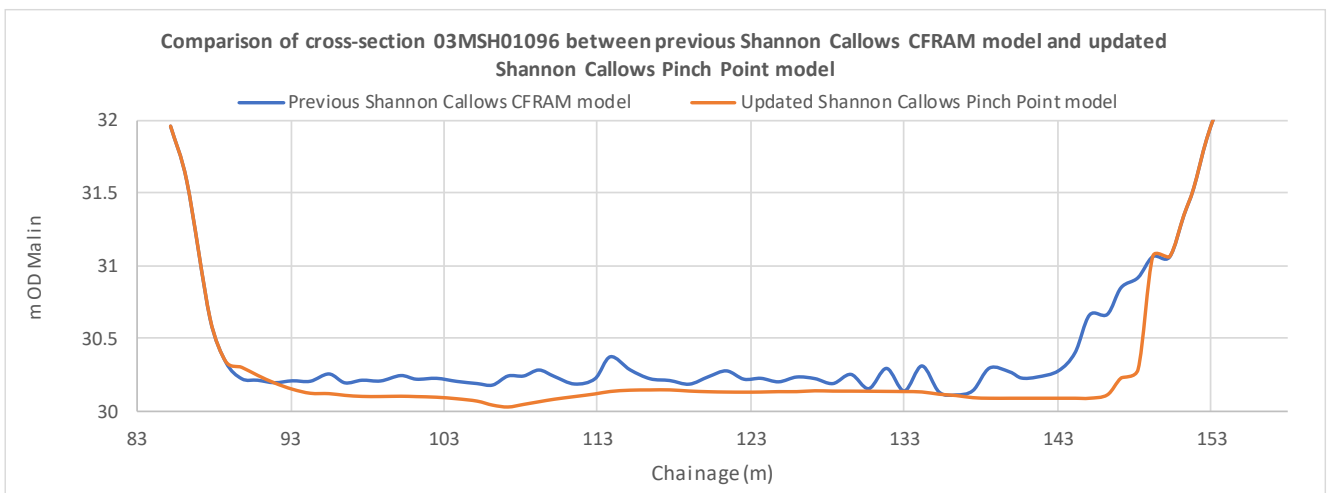
Pinch Point 5, Downstream Suck confluence. Cross section 03MSH07952



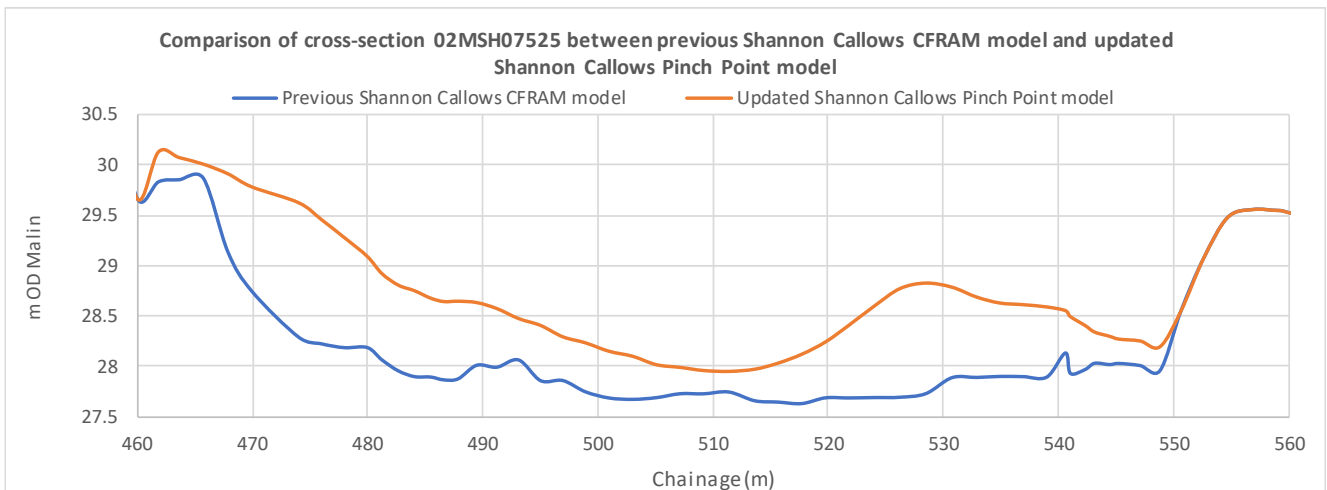
Pinch Point 6, Blackwater confluence. Cross section 03MSH06273



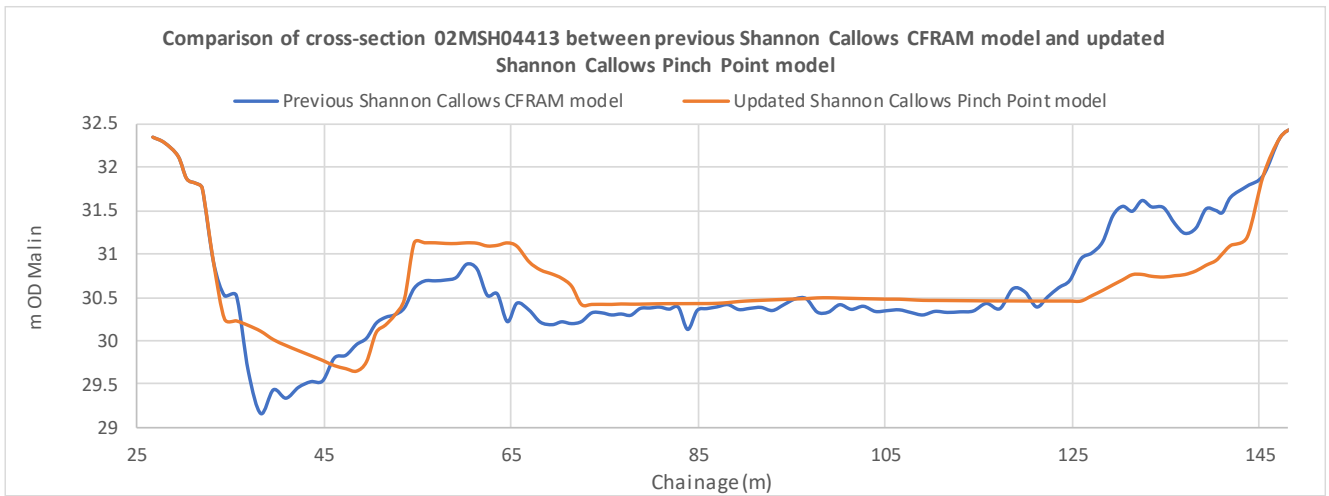
Pinch Point 7, Shannon Harbour. Cross section 03MSH01096



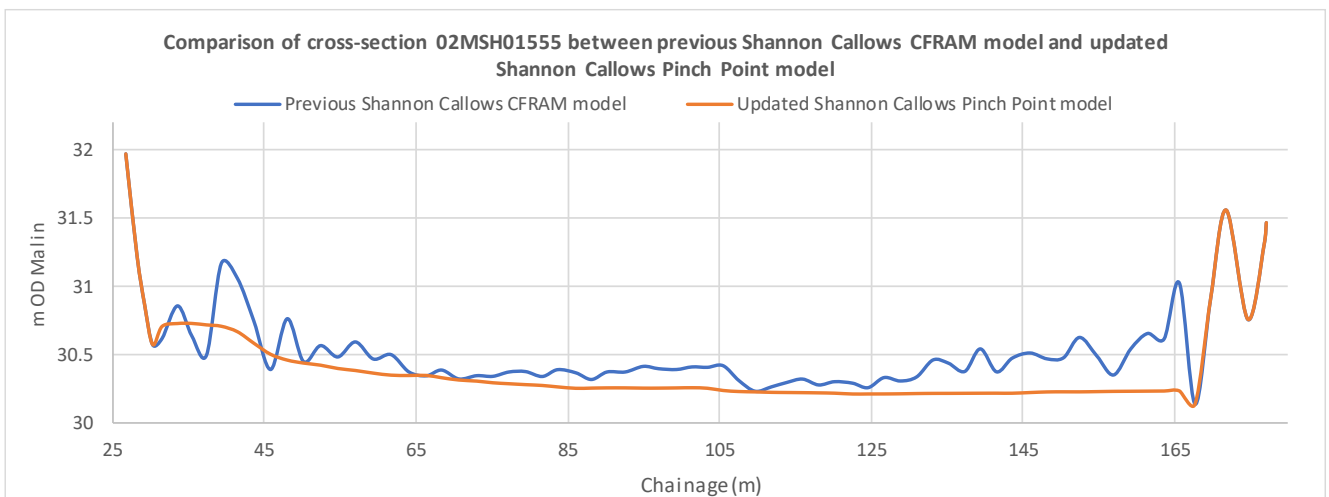
Pinch Point 8, Downstream Banagher. Cross section 02MSH07525



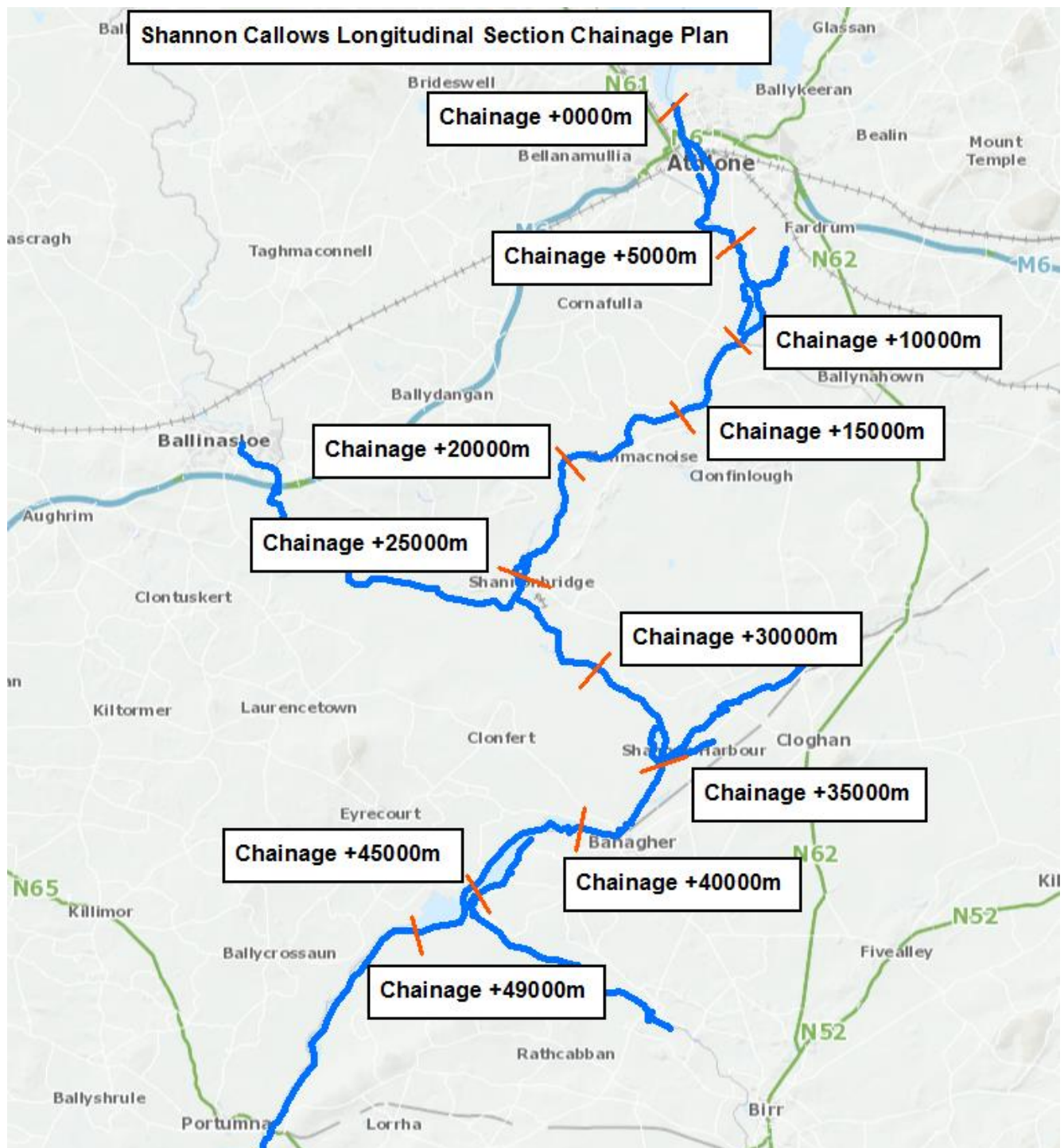
Pinch Point 9, Corclough. Cross section 02MSH04413

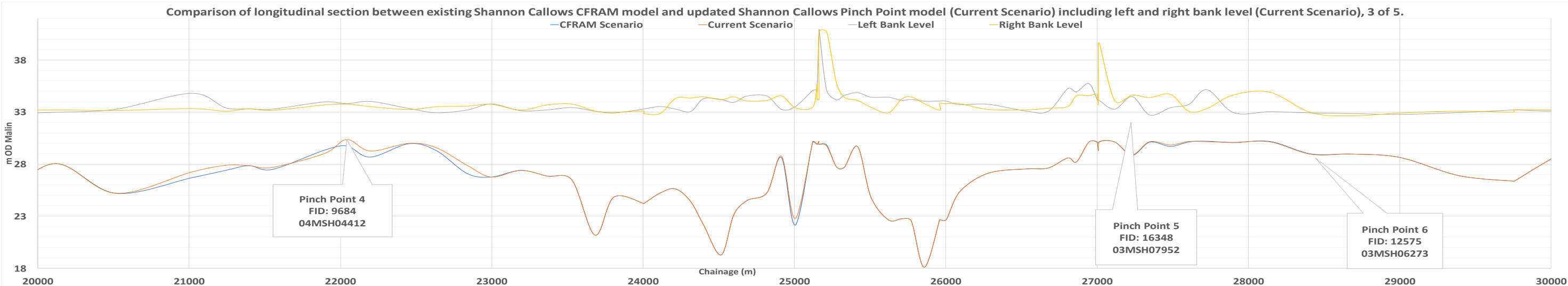
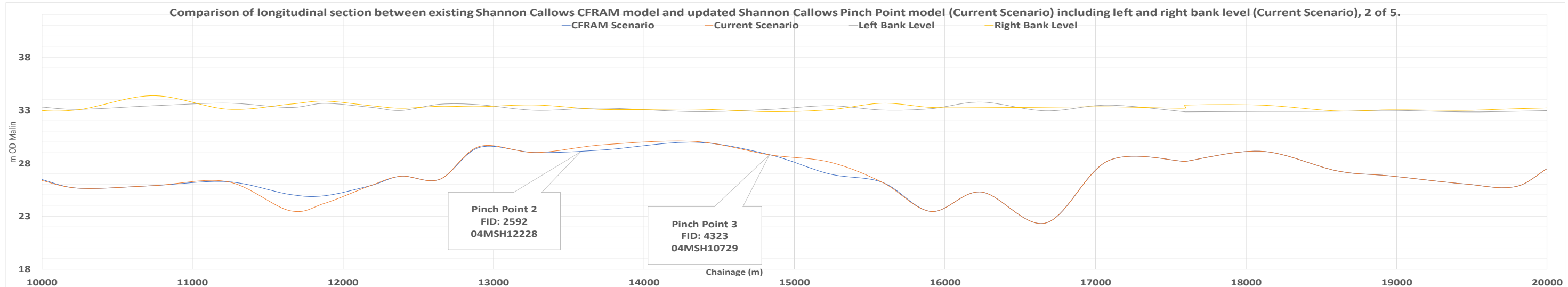
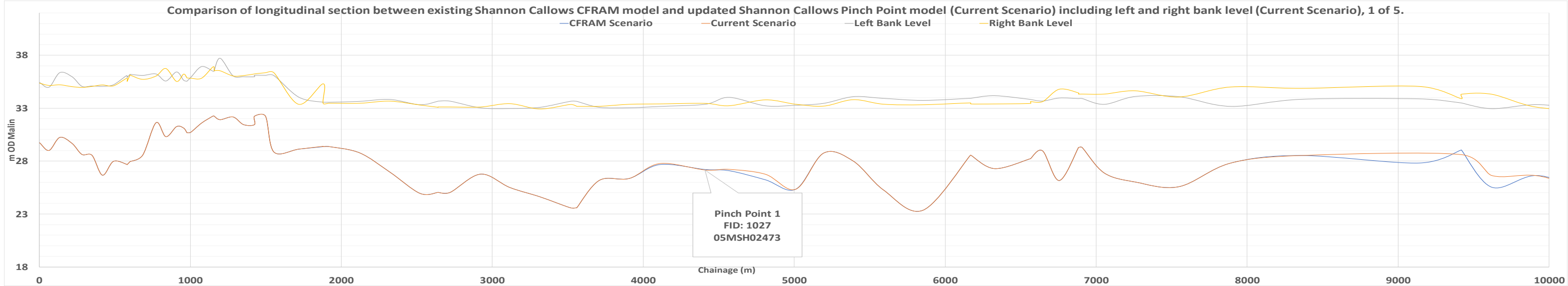


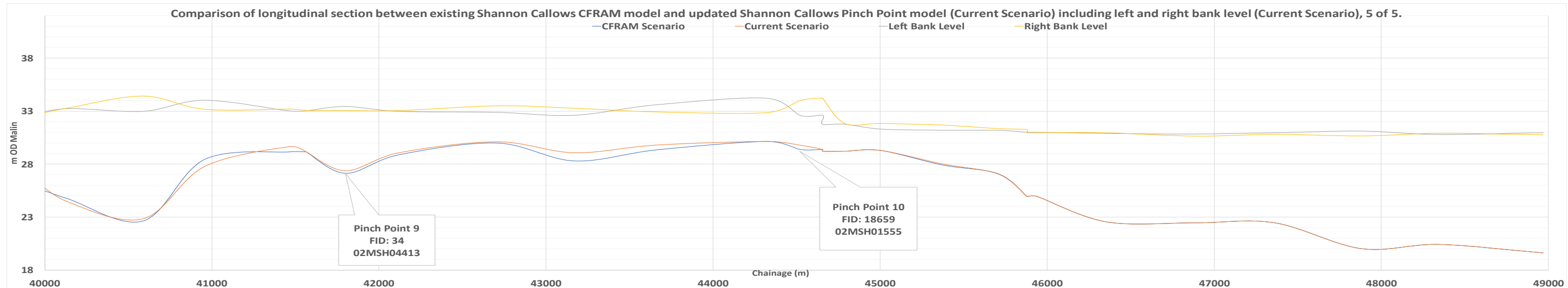
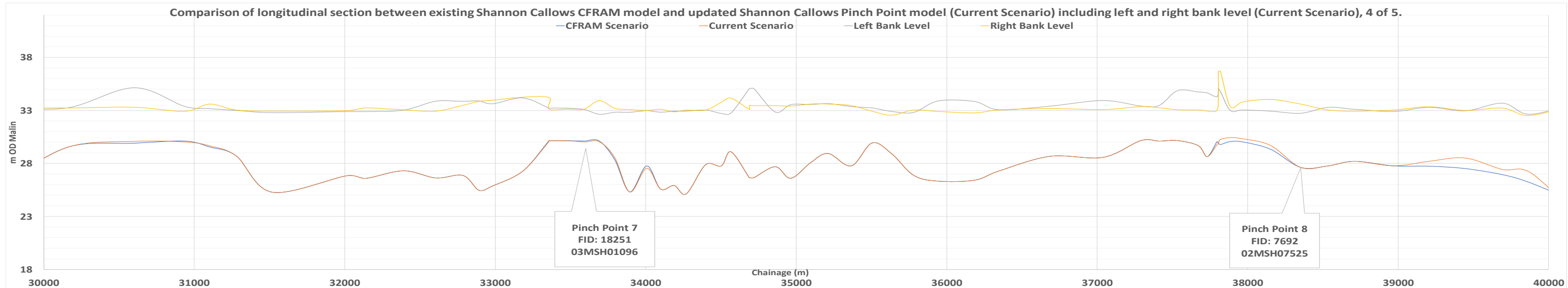
Pinch Point 10, Upstream Meelick Weir. Cross section 02MSH01555



Appendix B. Comparison of longitudinal section between existing Shannon Callows CFRAM model and updated Shannon Callows Pinch Point model (Current Scenario)

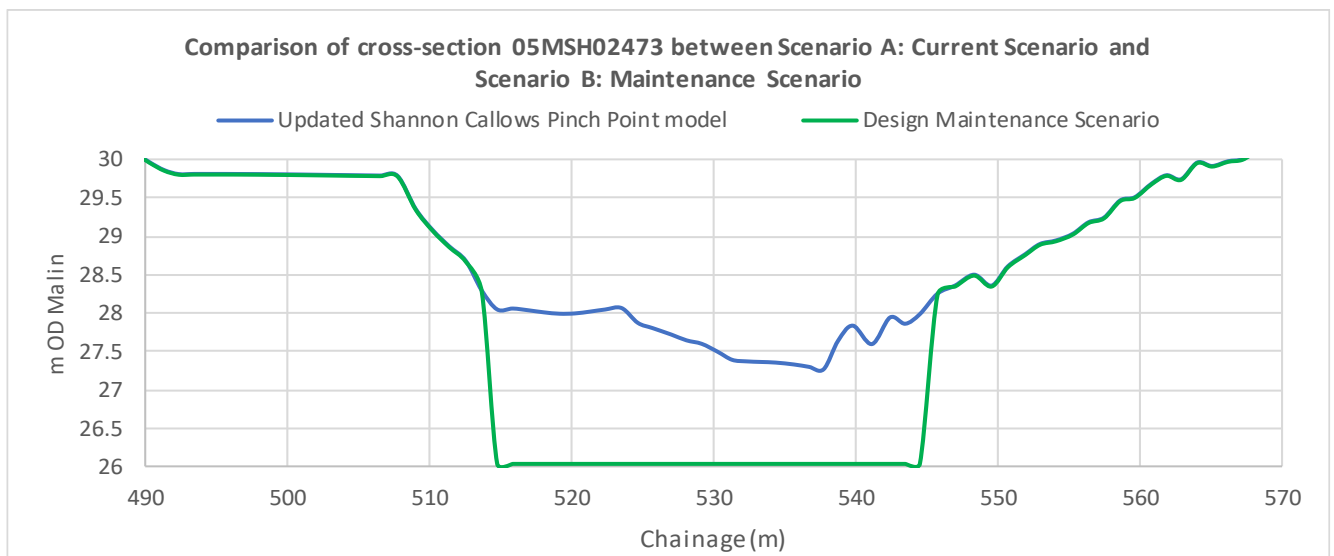
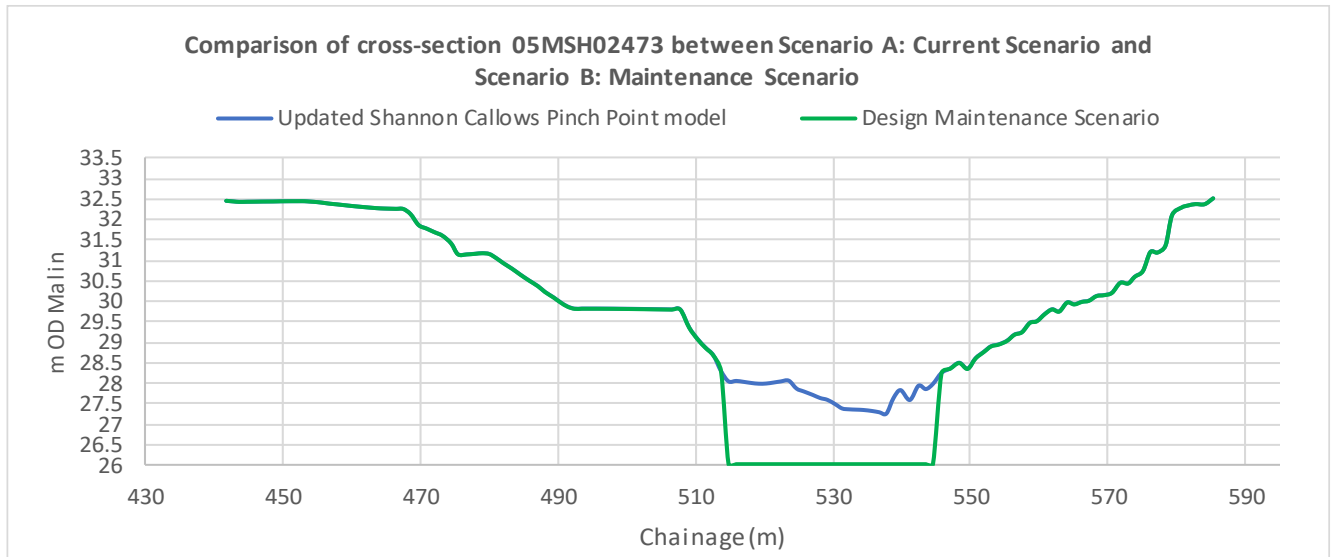




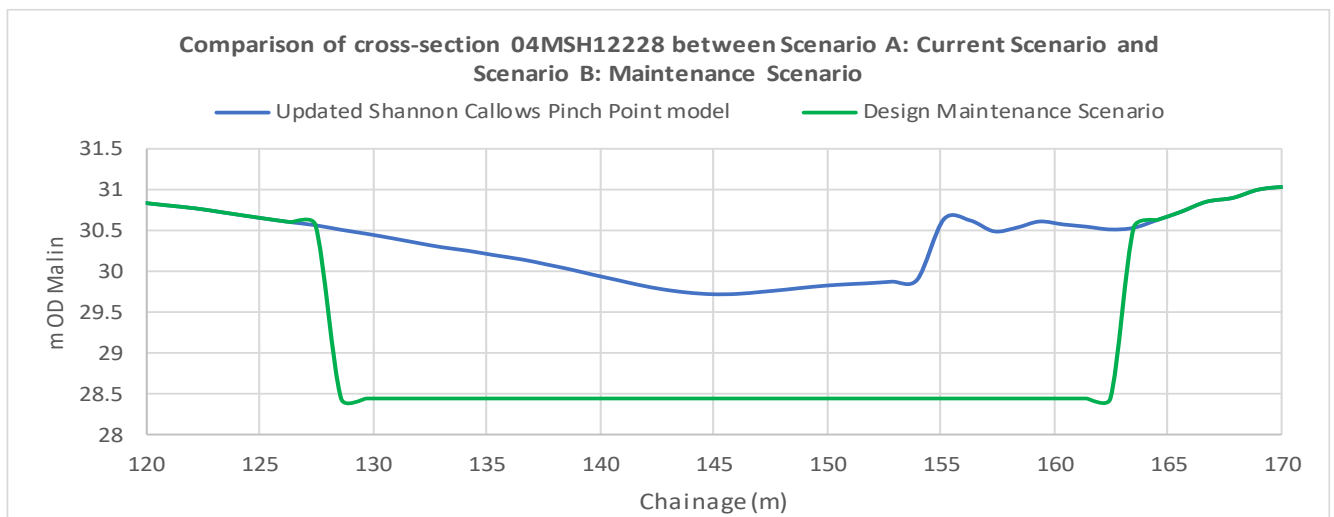
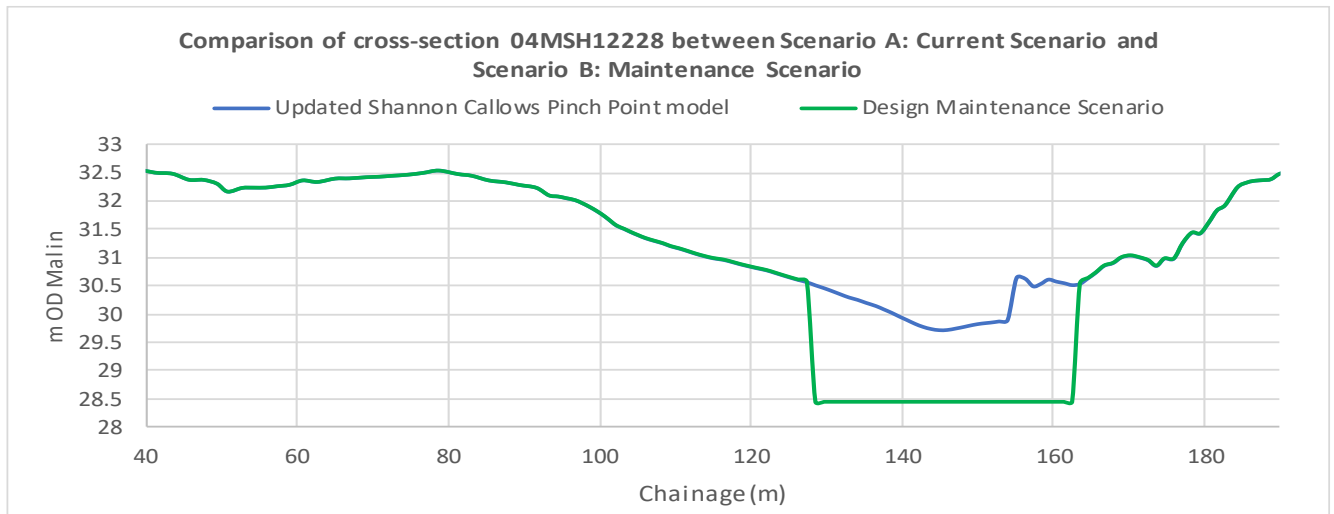


Appendix C. Comparison of cross-sections in Scenario A: Current Scenario and Scenario B: Maintenance Scenario

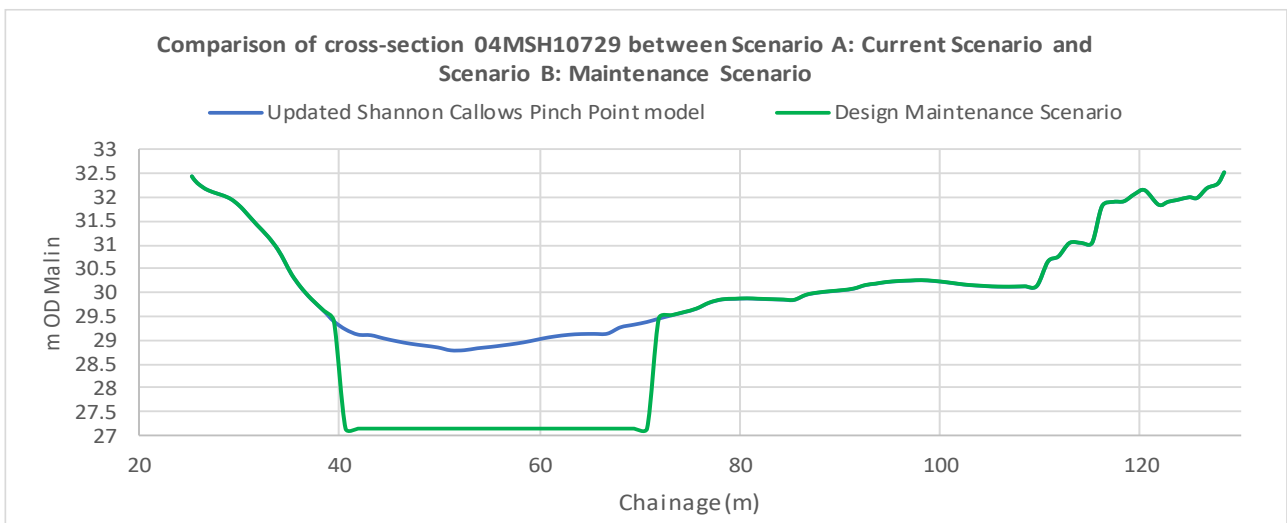
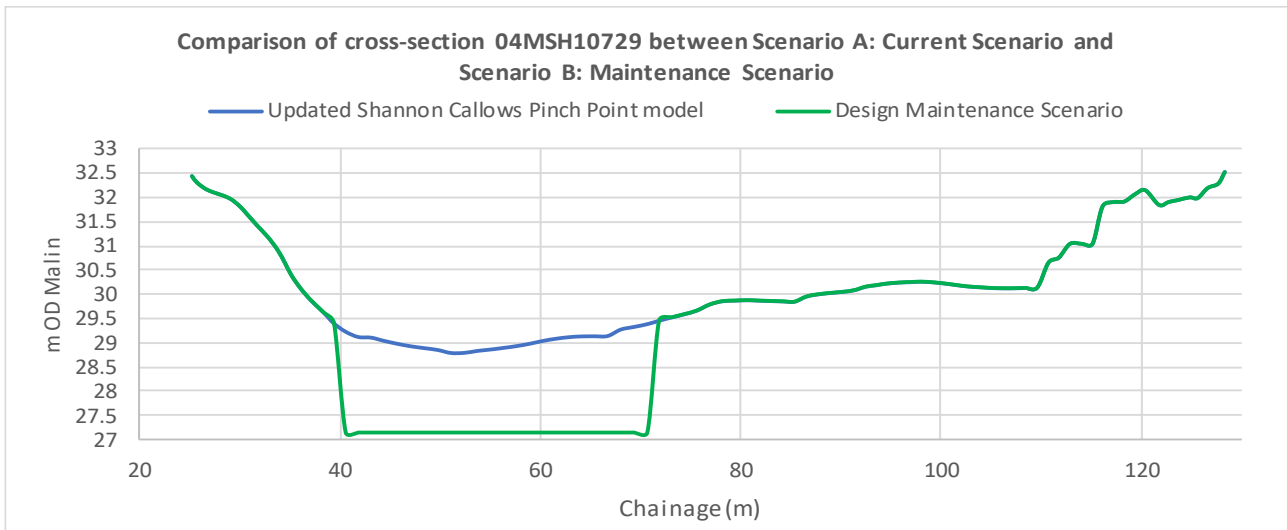
Pinch Point 1, Downstream Athlone. Cross section 05MSH02473



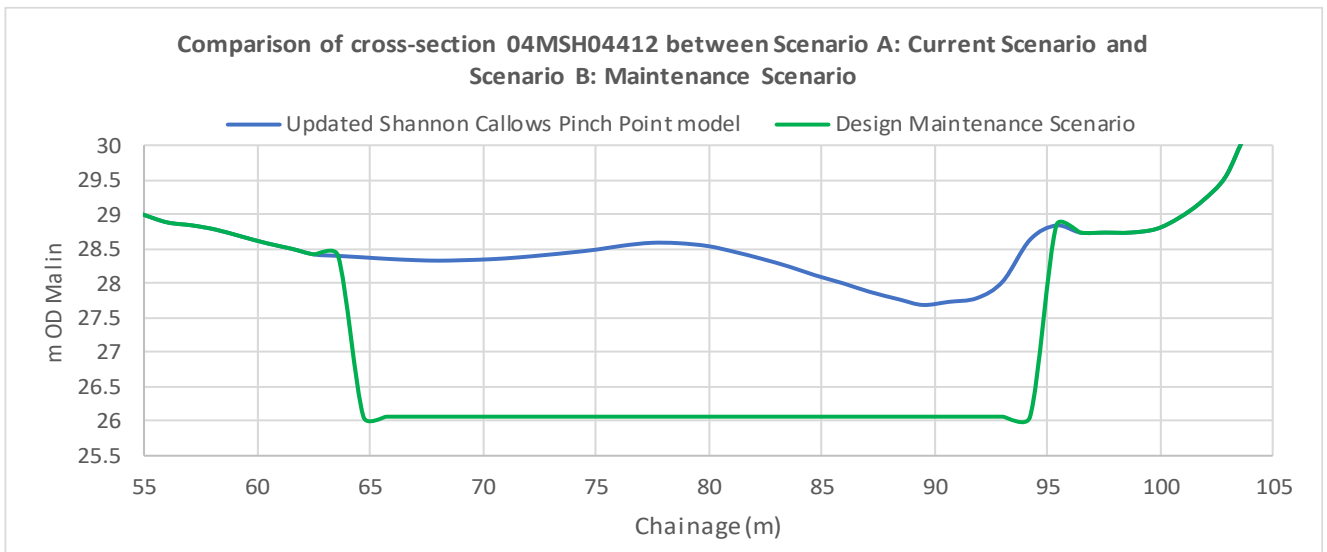
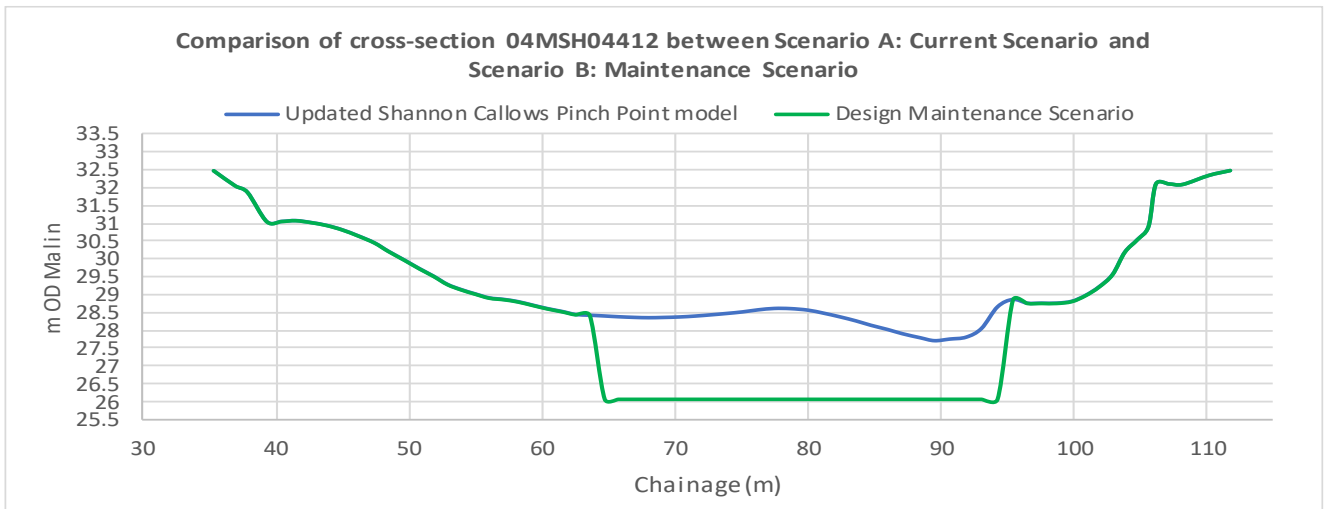
Pinch Point 2, Clonown. Cross section 04MSH12228



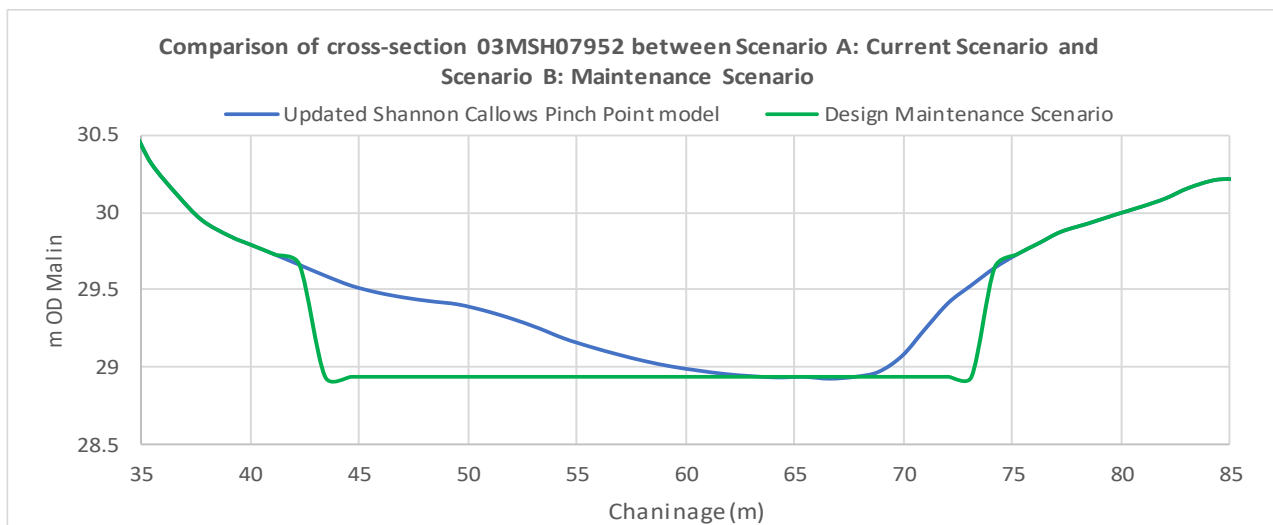
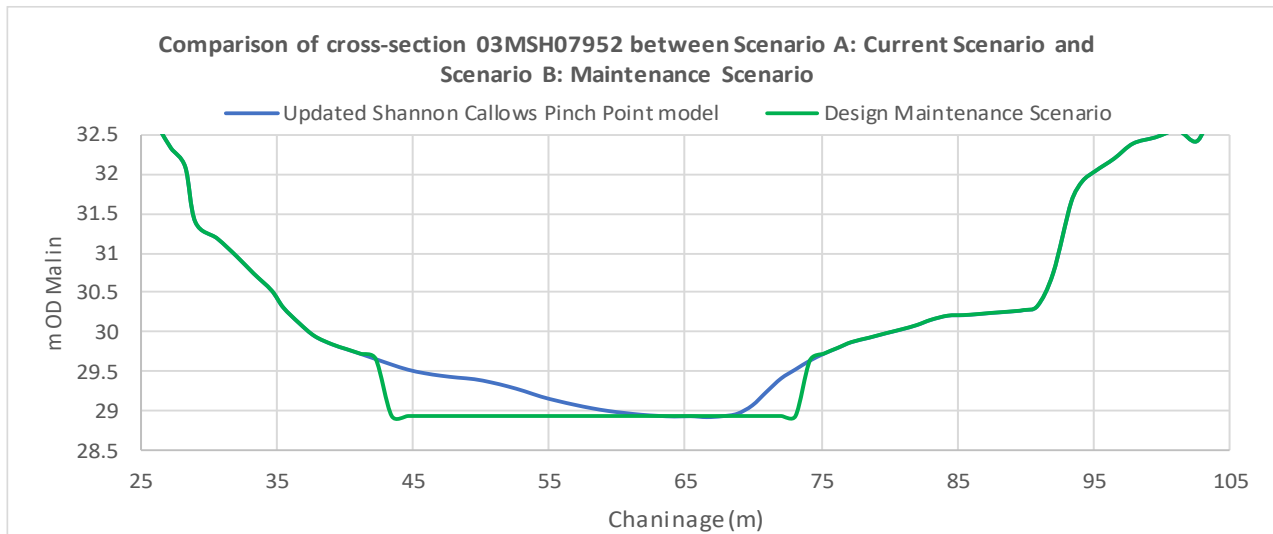
Pinch Point 3, Upstream Clonmacnoise. Cross section 04MSH10729



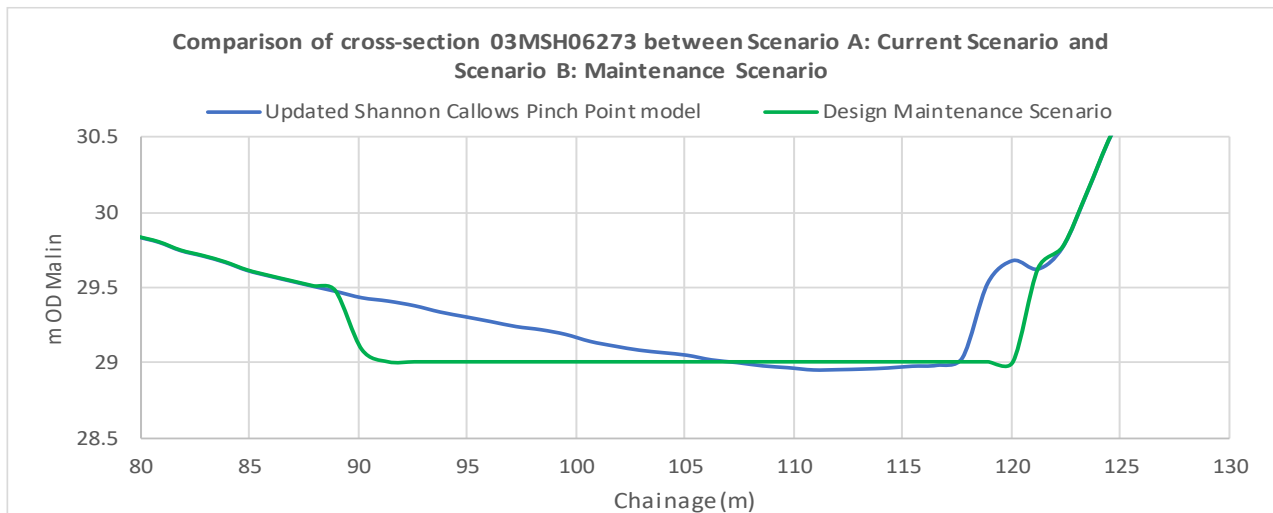
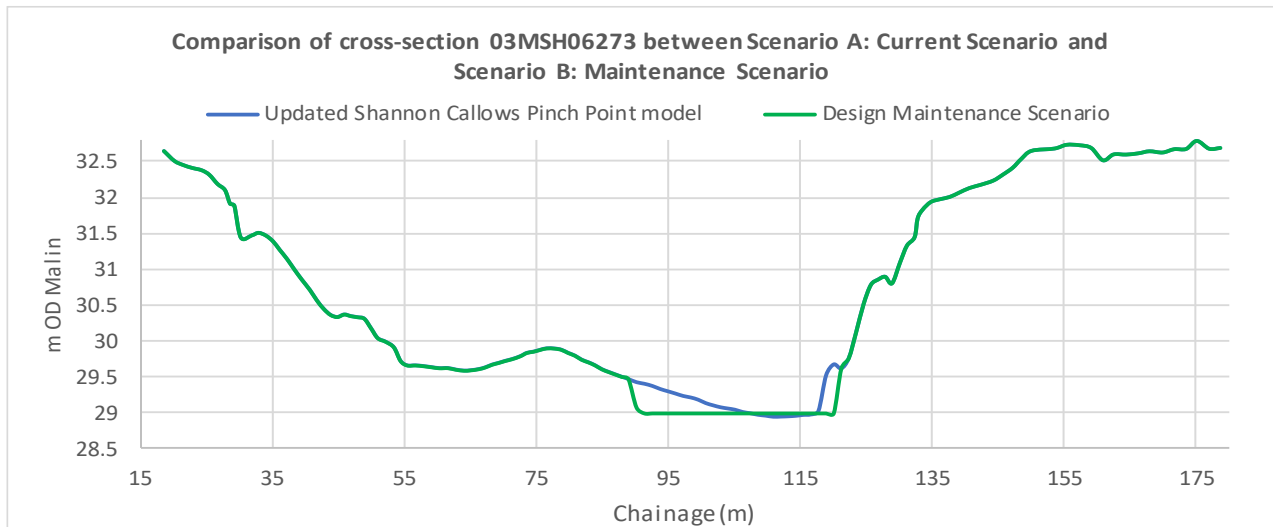
Pinch Point 4, Clonmacnoise. Cross section 04MSH04412



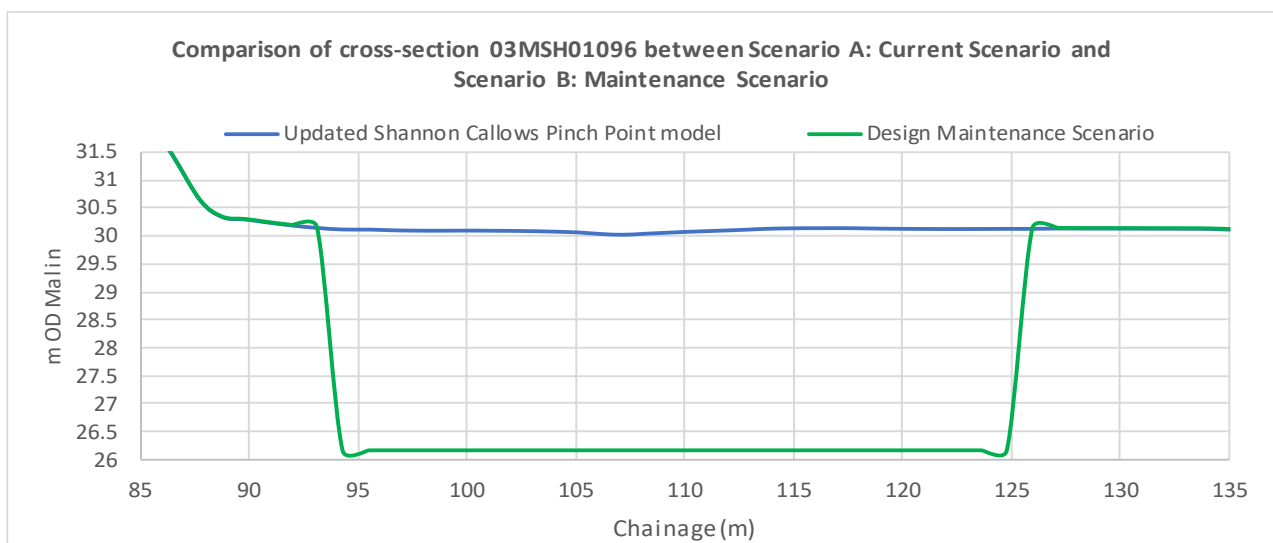
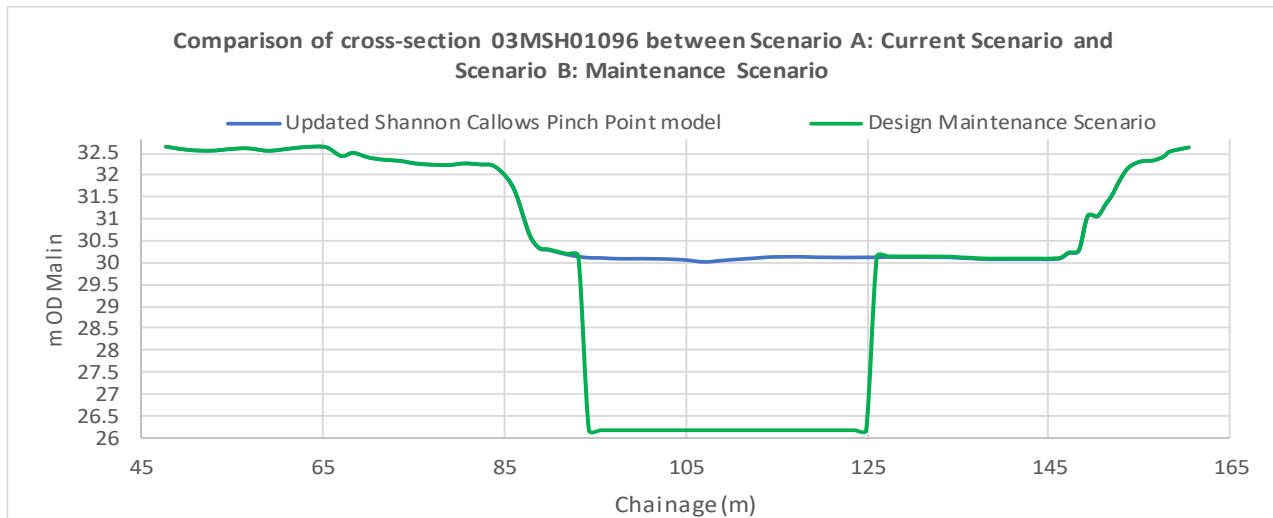
Pinch Point 5, Downstream Suck confluence. Cross section 03MSH07952



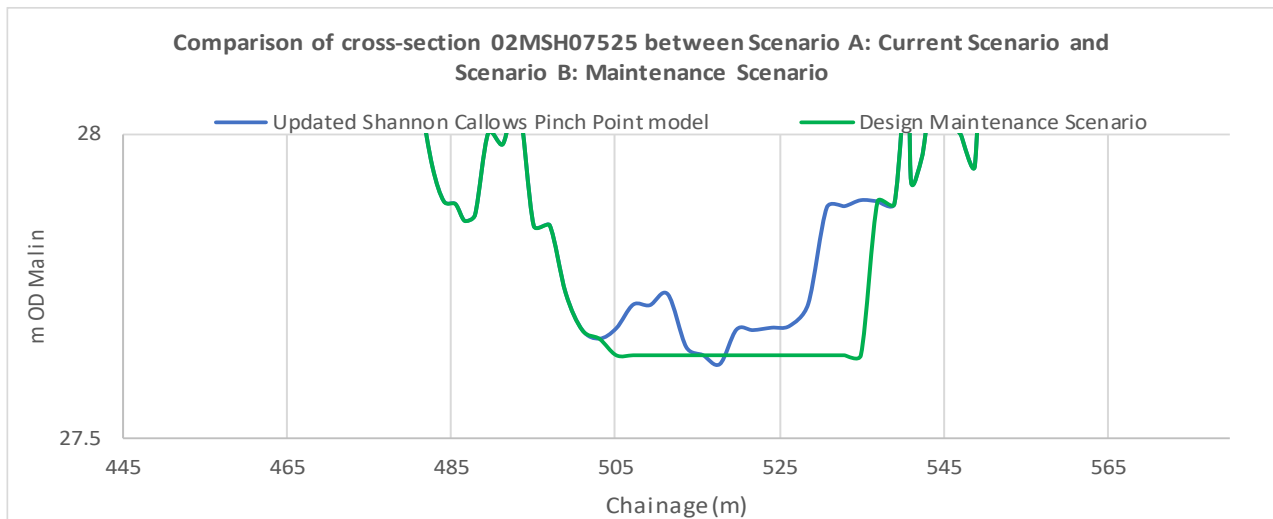
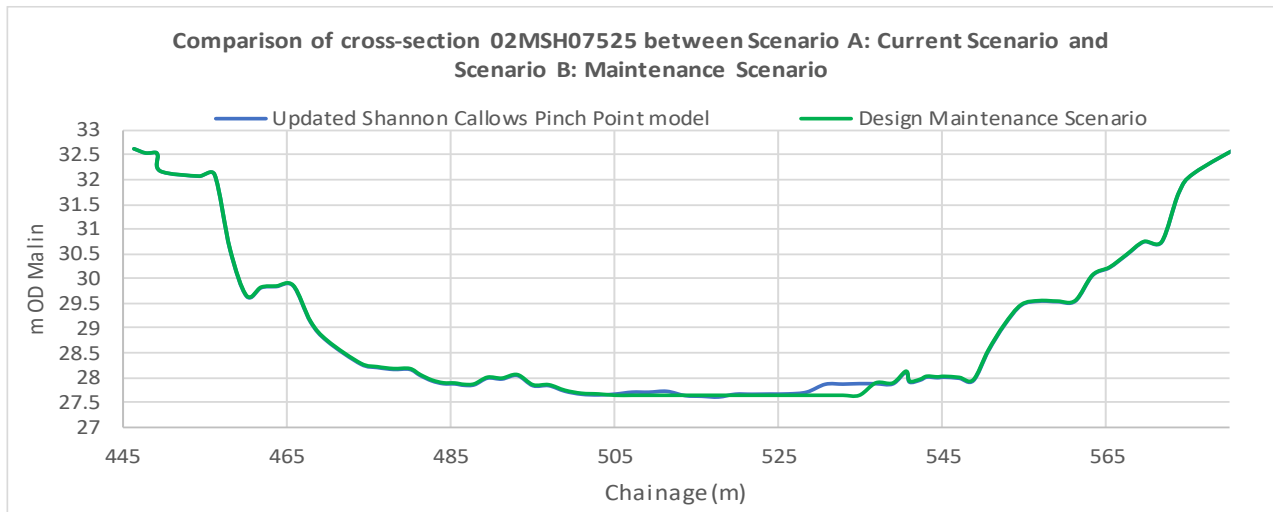
Pinch Point 6, Blackwater confluence. Cross section 03MSH06273



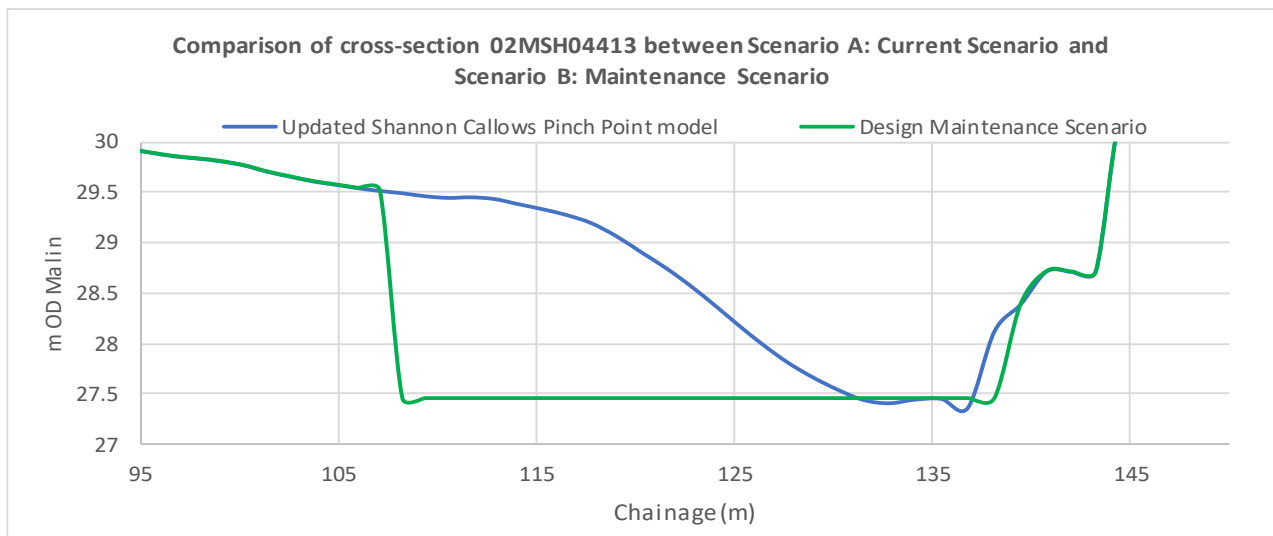
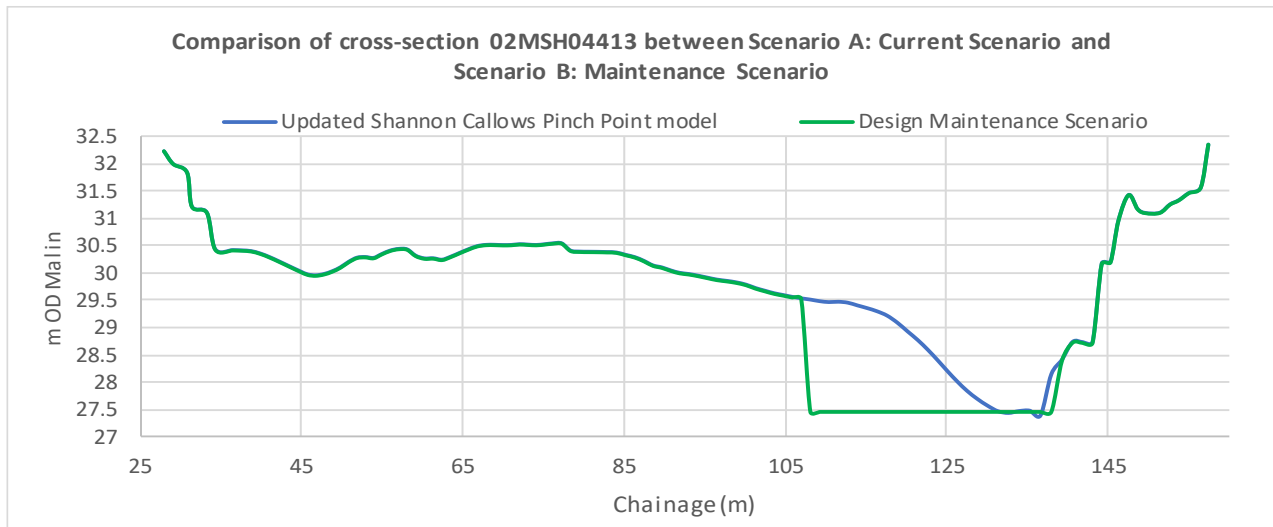
Pinch Point 7, Shannon Harbour. Cross section 03MSH01096



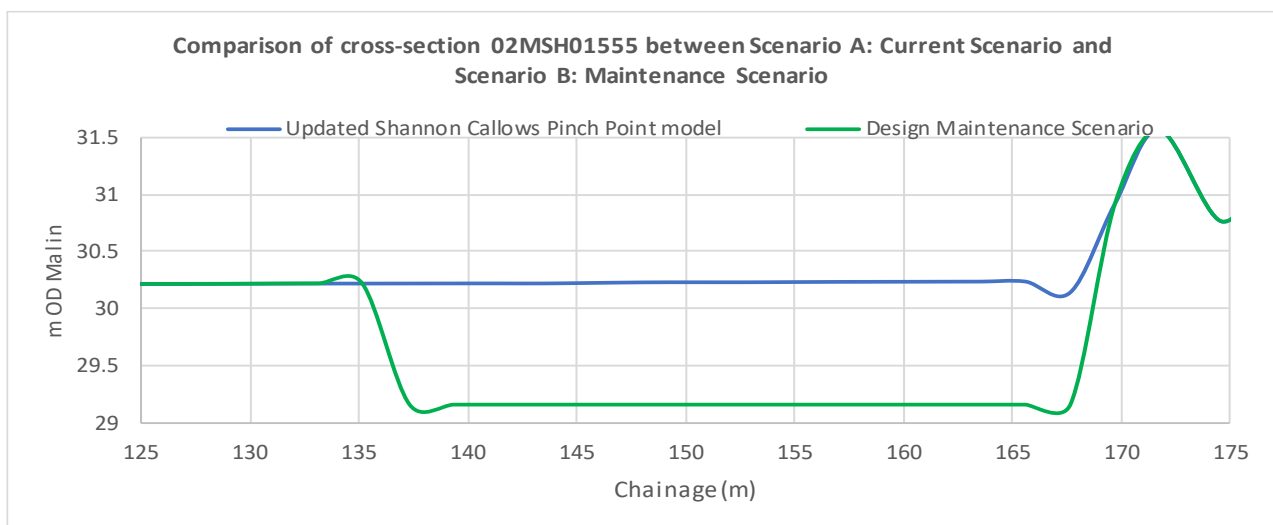
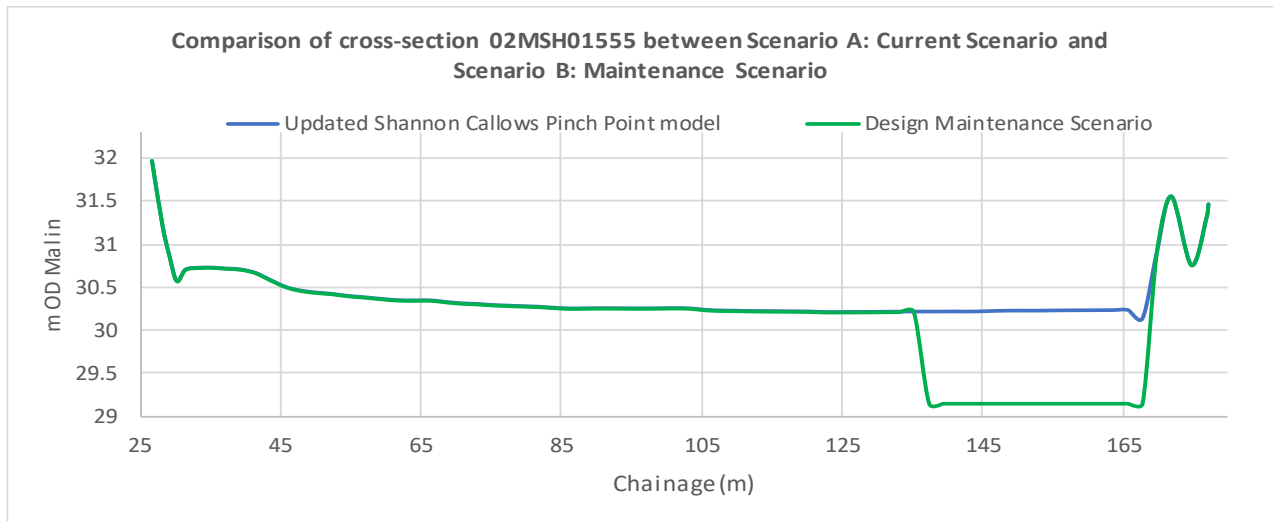
Pinch Point 8, Downstream Banagher. Cross section 02MSH07525



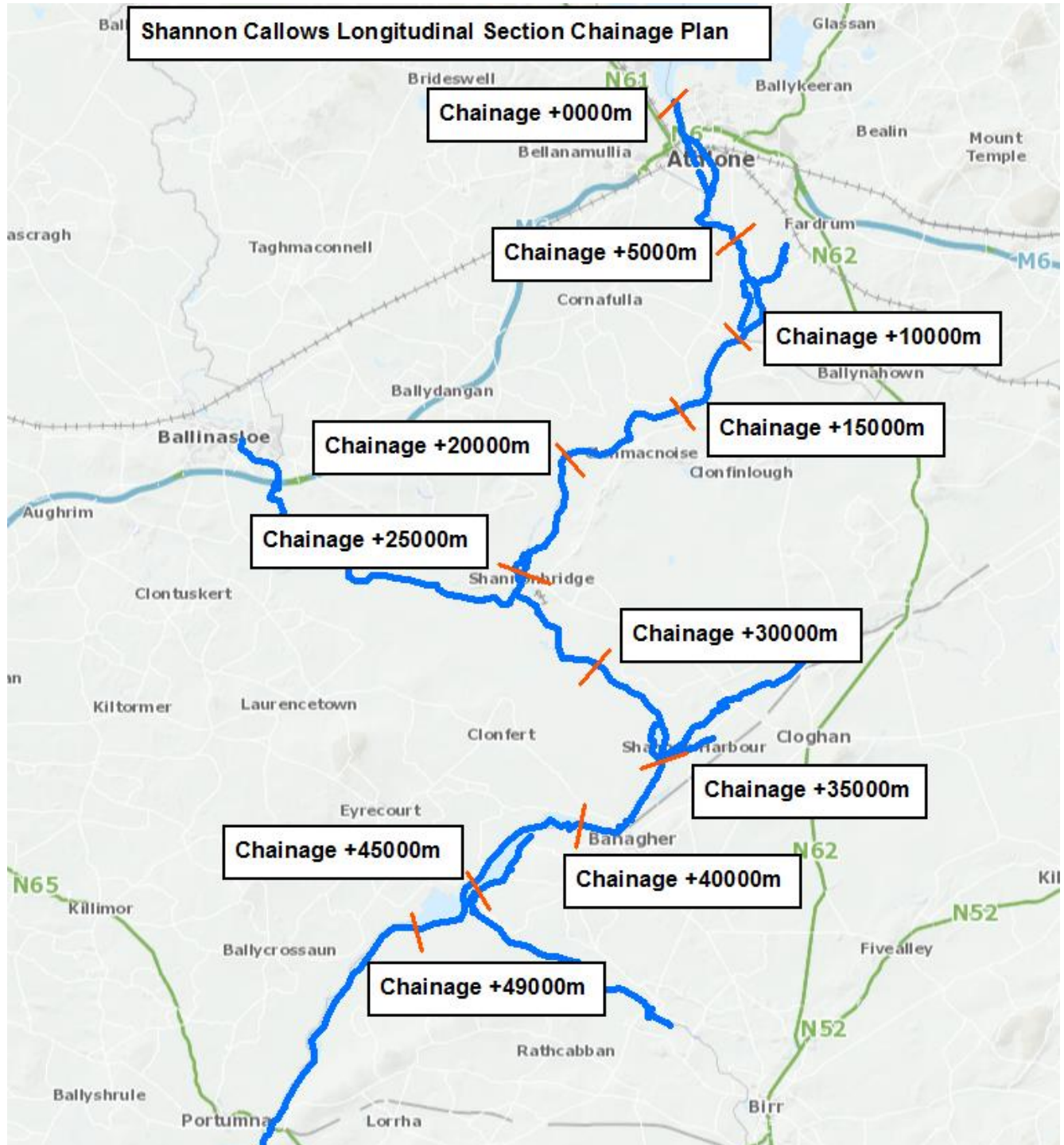
Pinch Point 9, Corclough. Cross section 02MSH04413



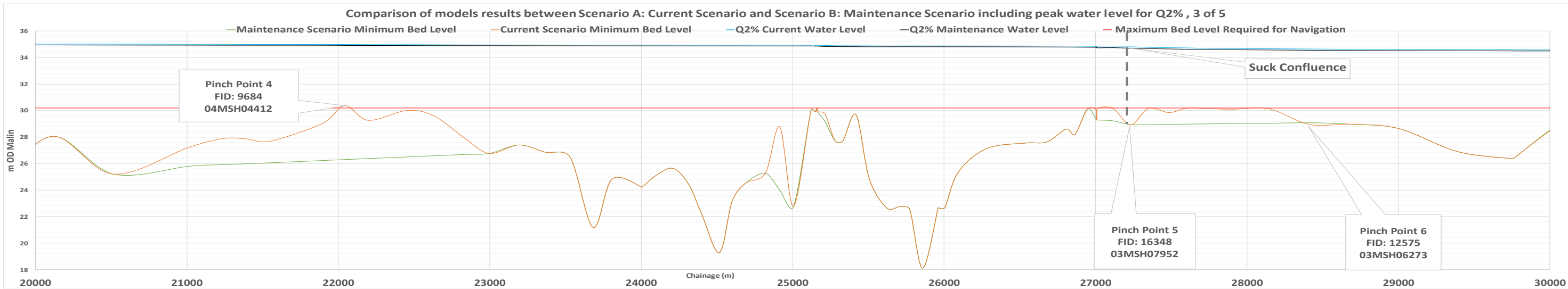
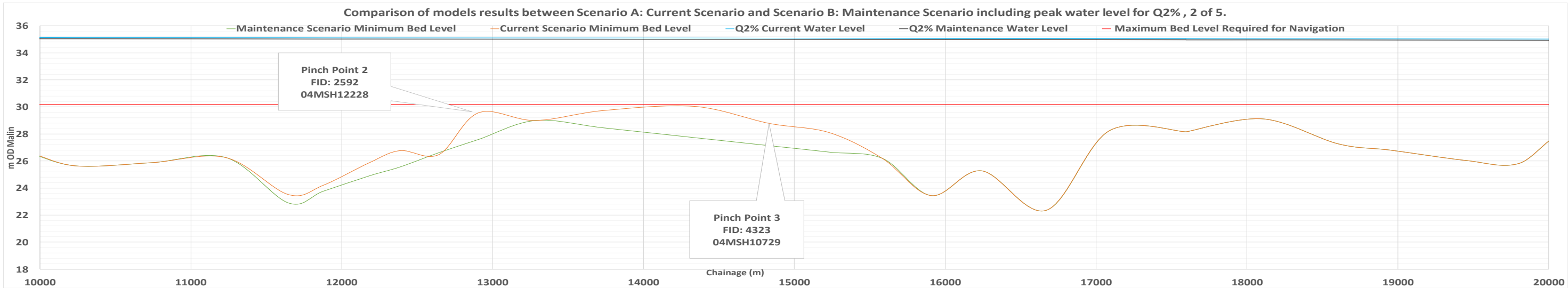
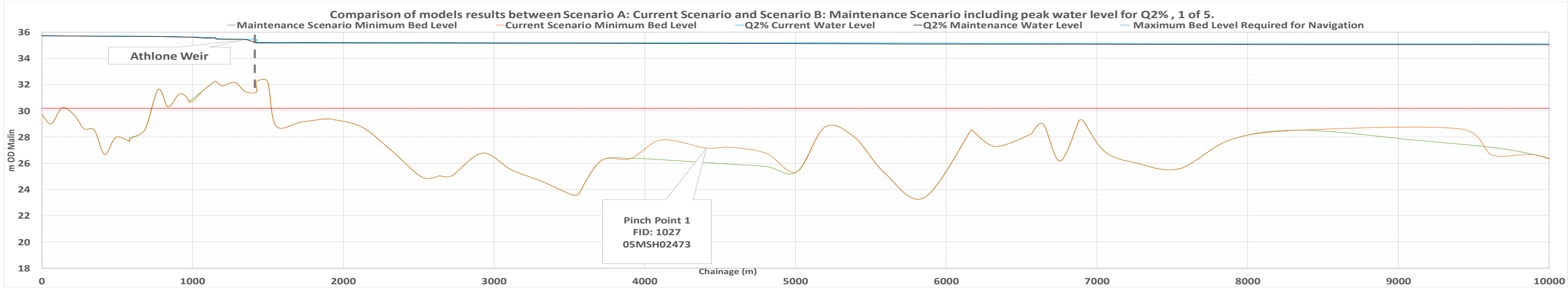
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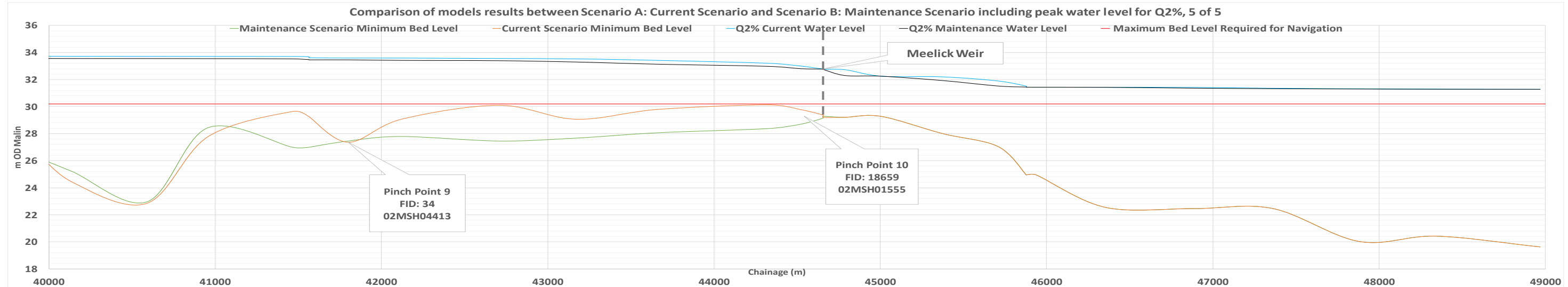
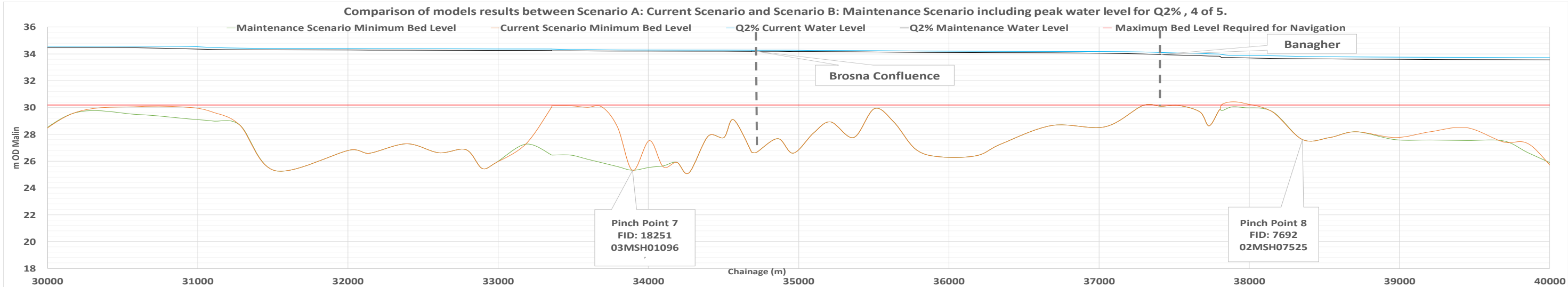


Appendix D. Comparison of model results between Scenario A: Current Scenario and Scenario B: Maintenance Scenario



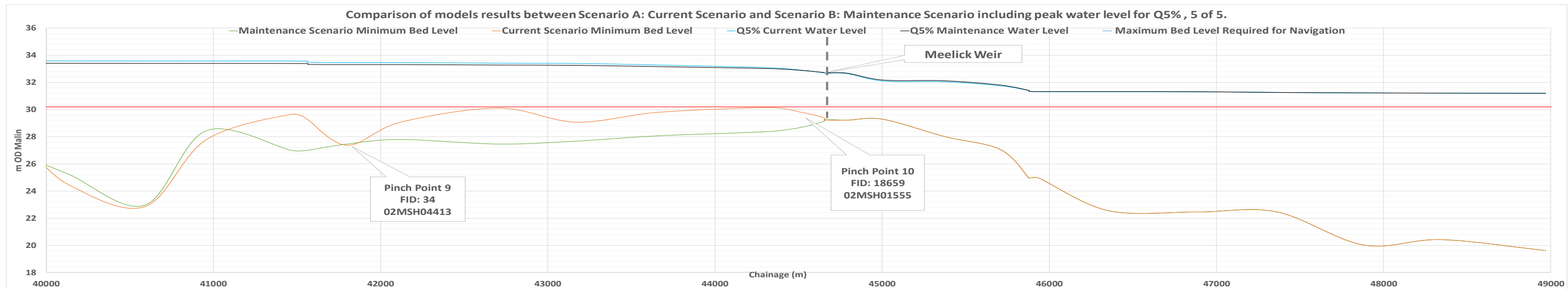
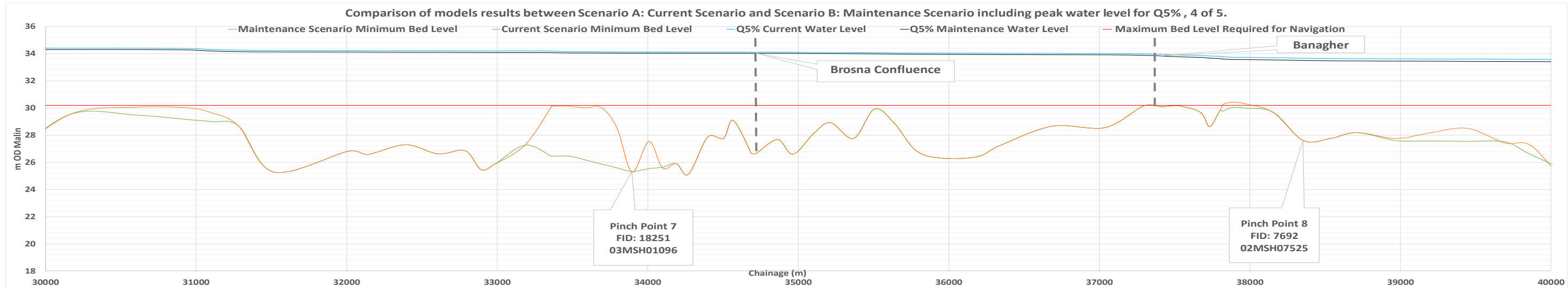
2% AEP Flood Event



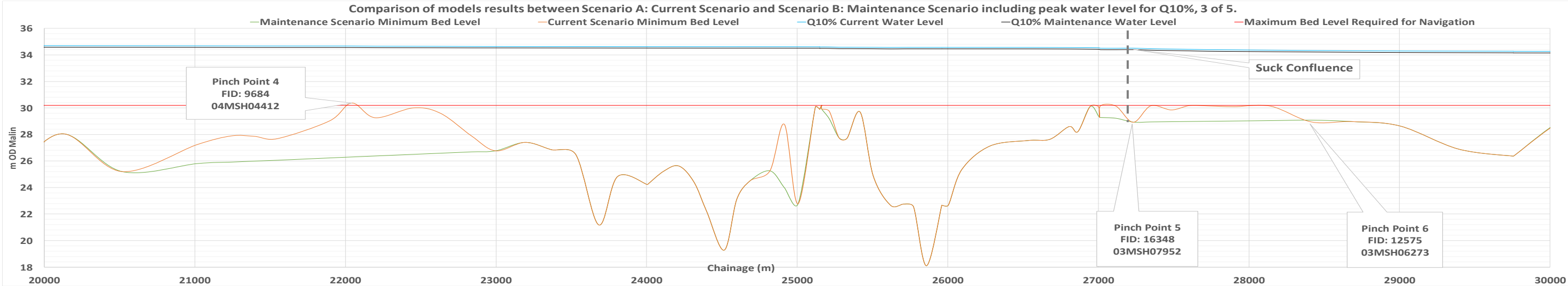
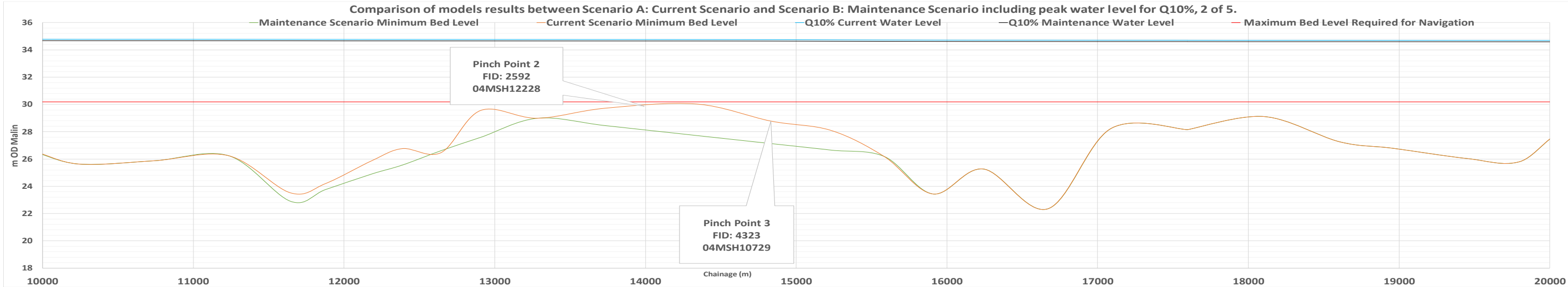
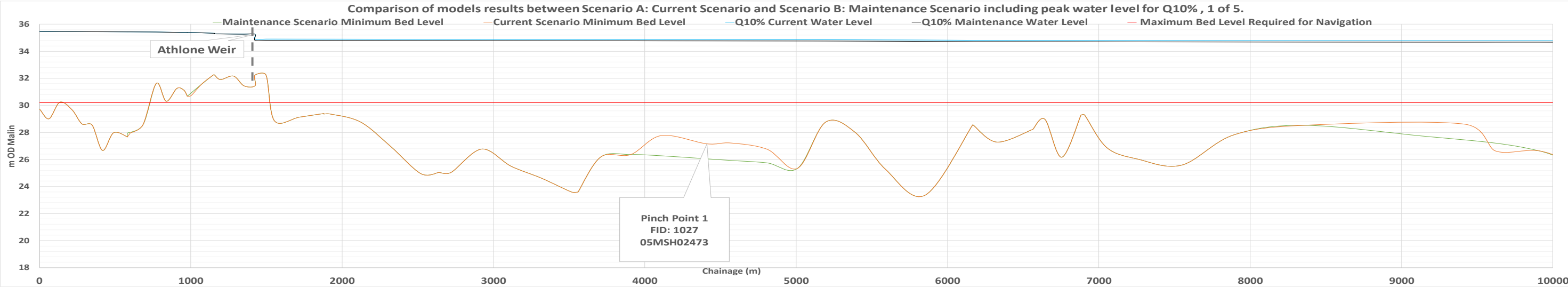


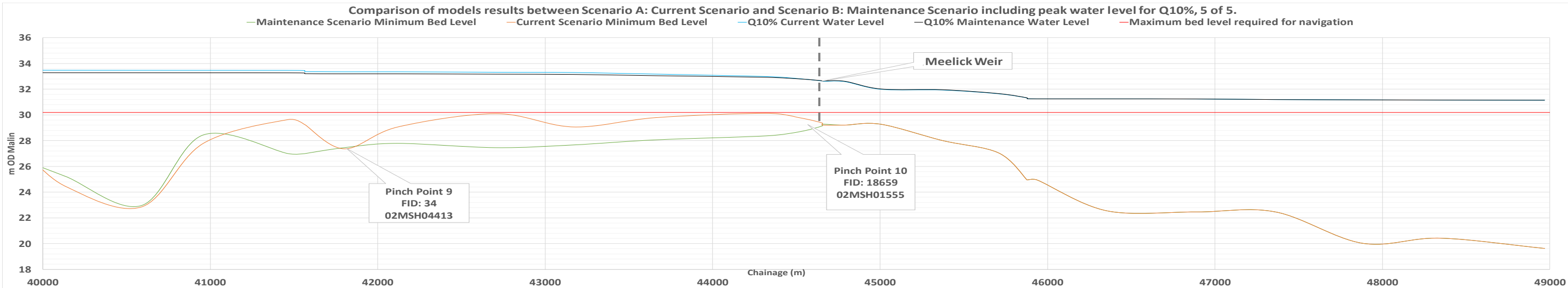
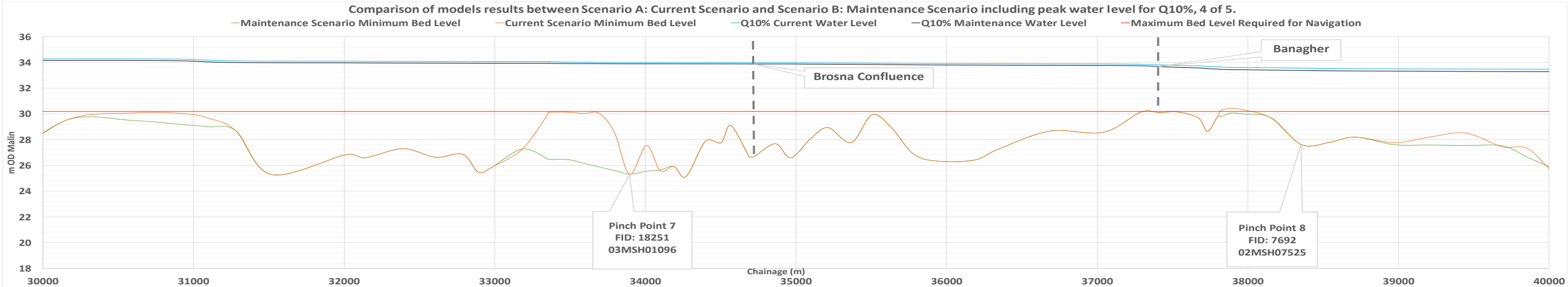
5% AEP Flood Event



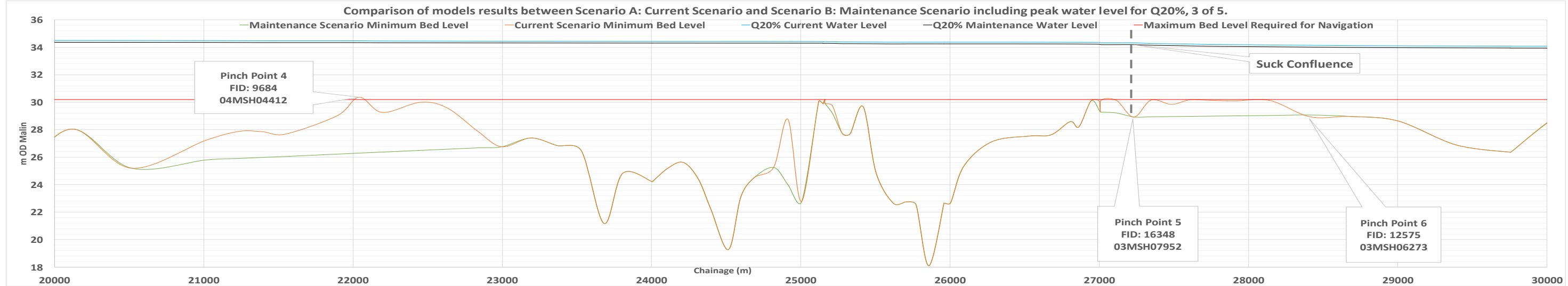
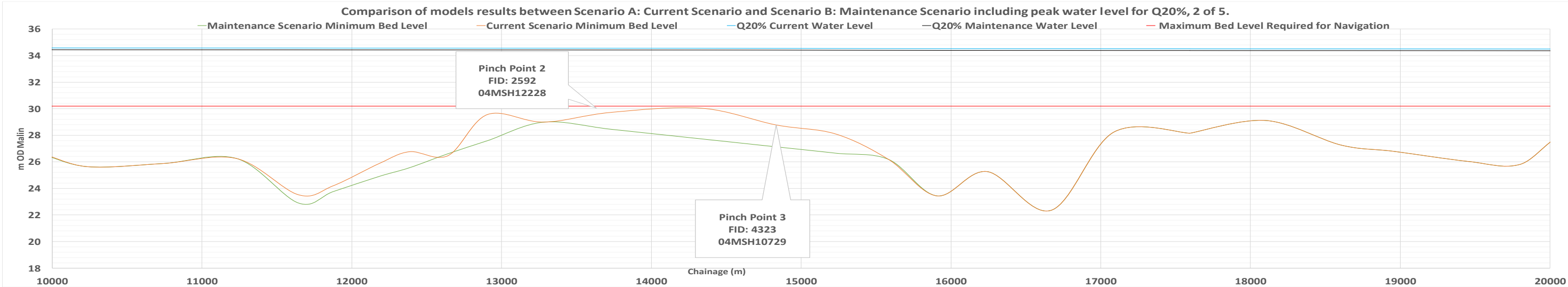
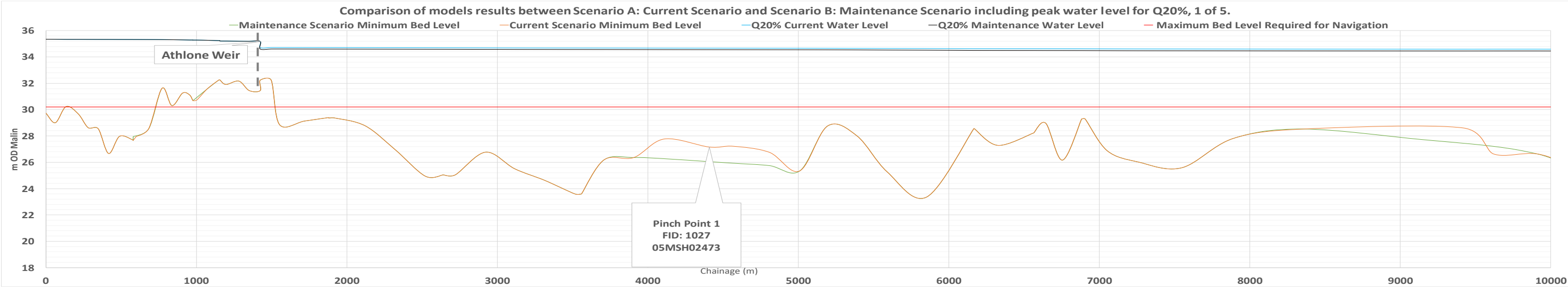


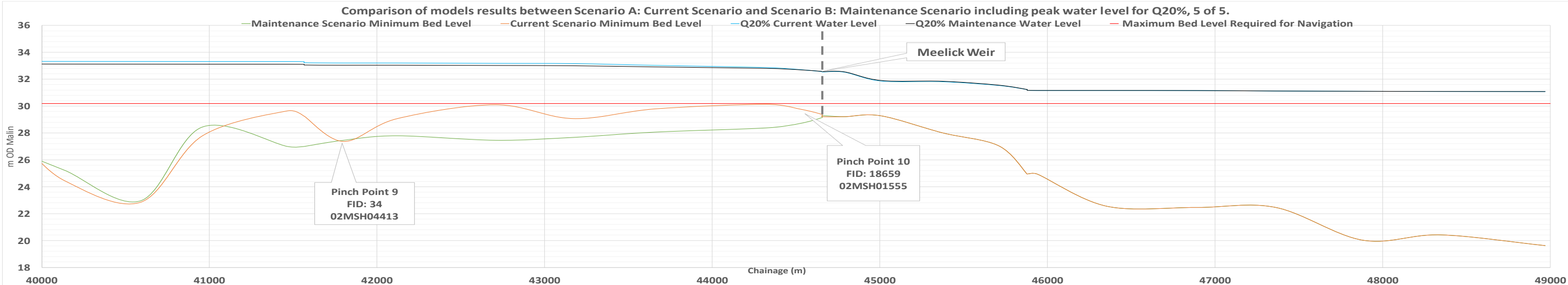
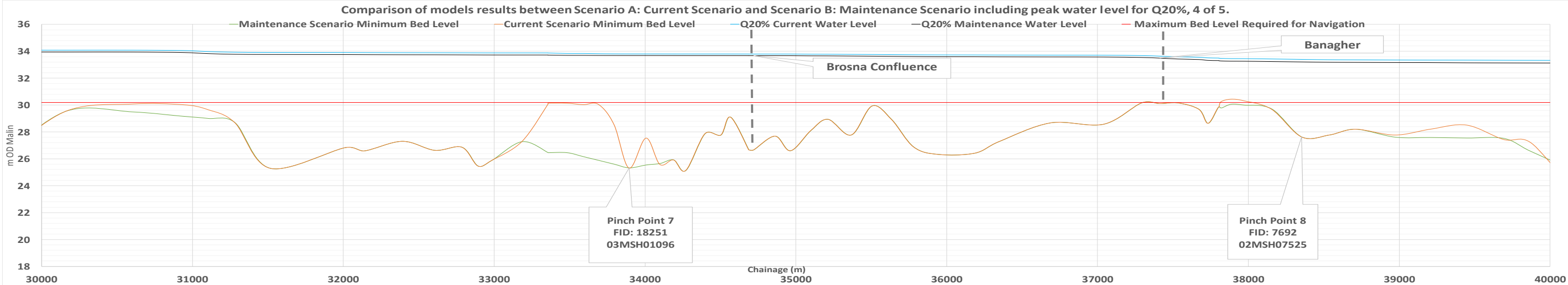
10% AEP Flood Event



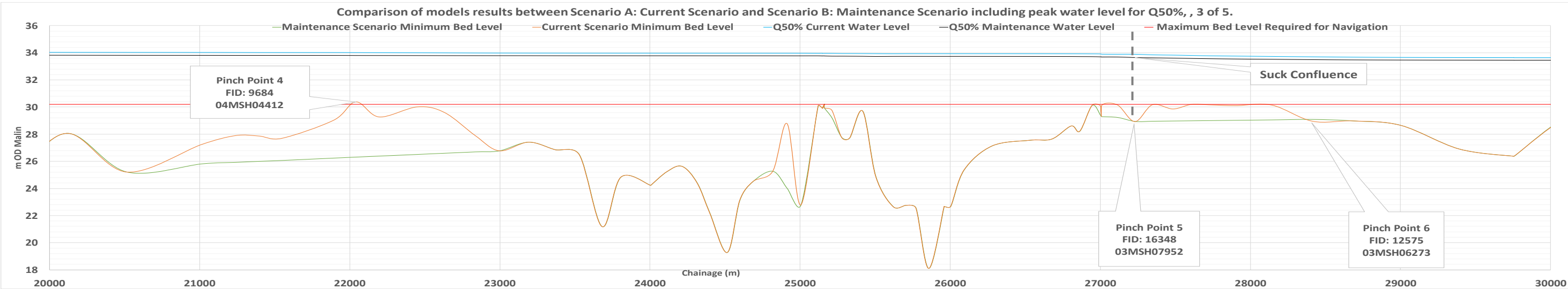
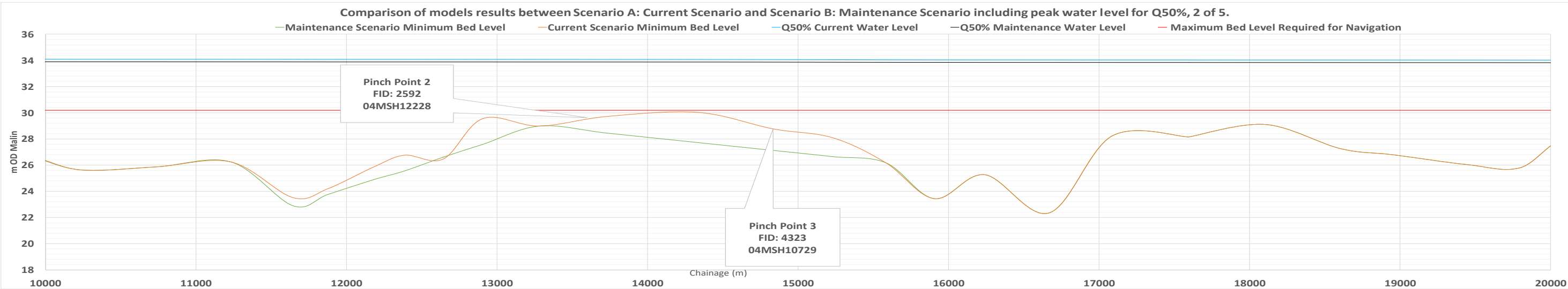
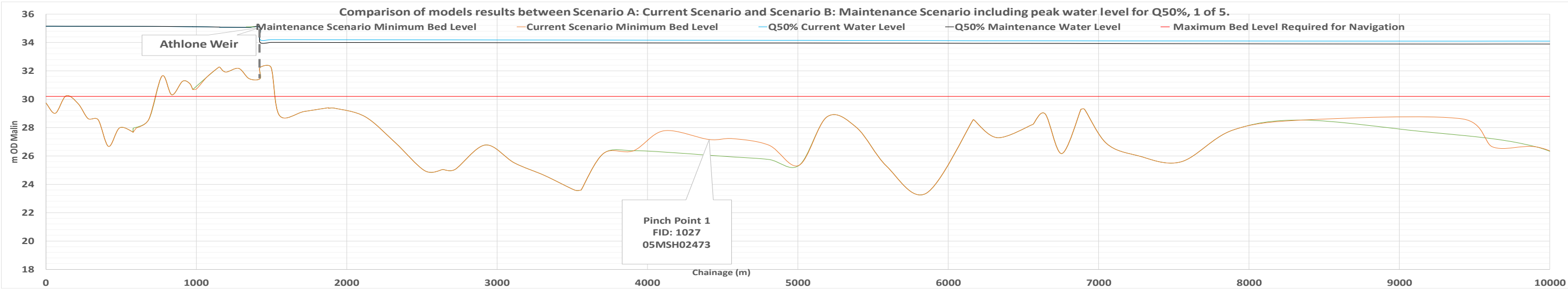


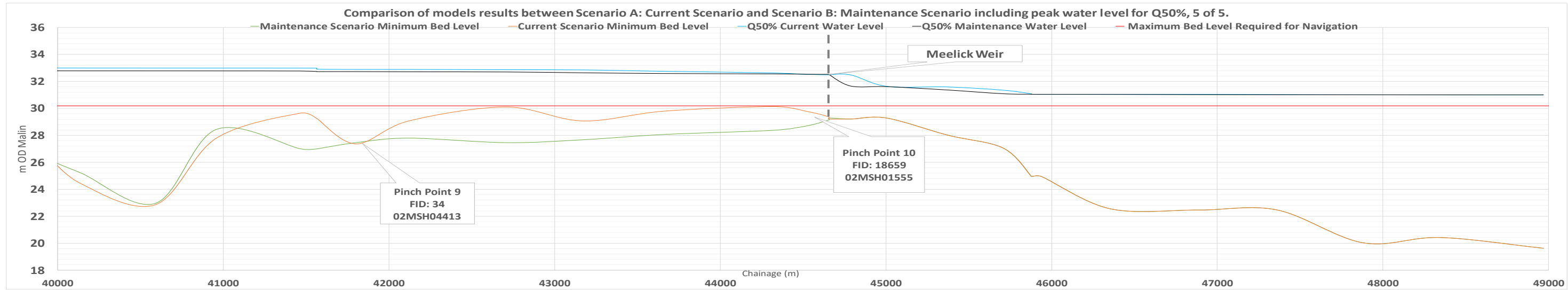
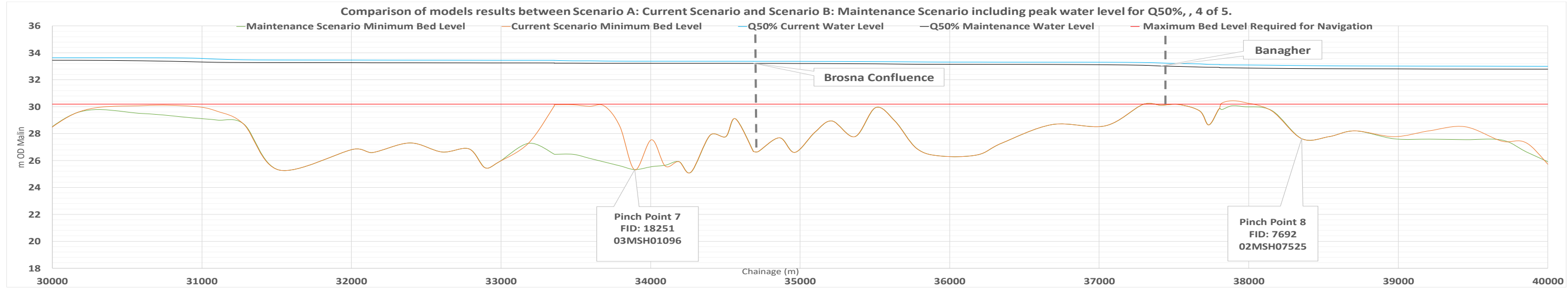
20% AEP Flood Event



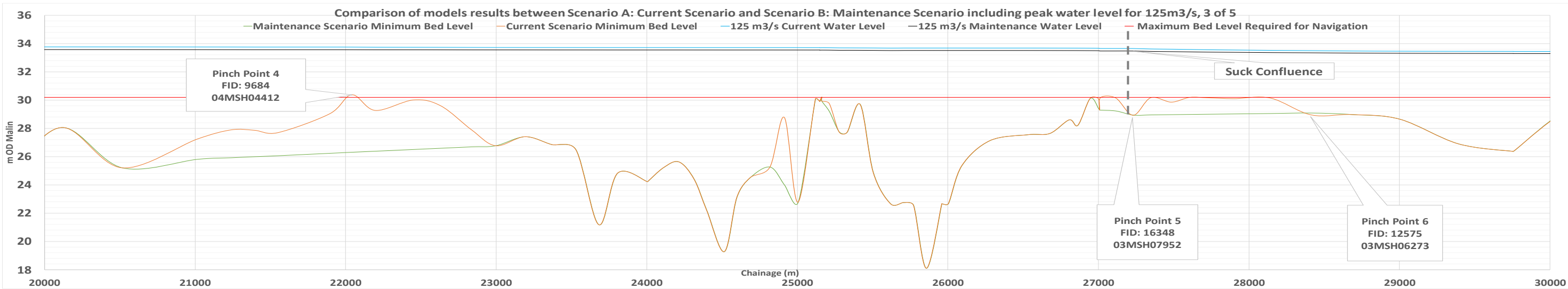
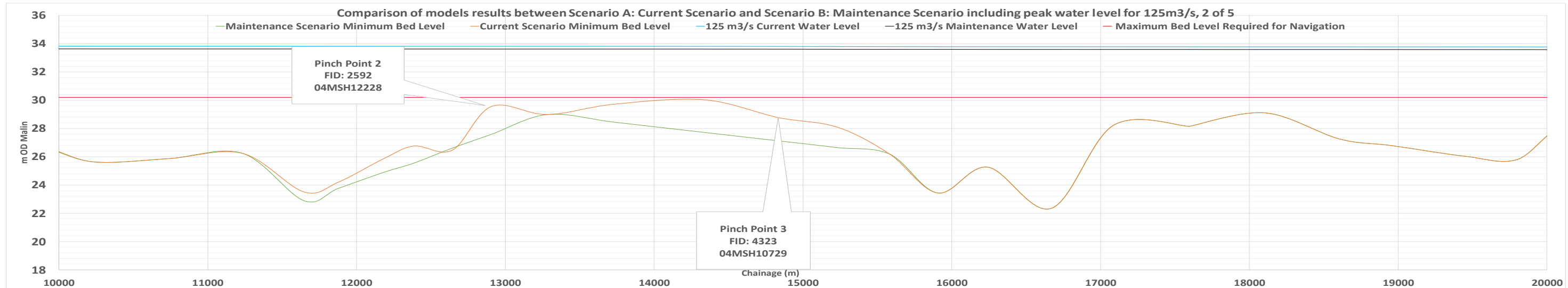
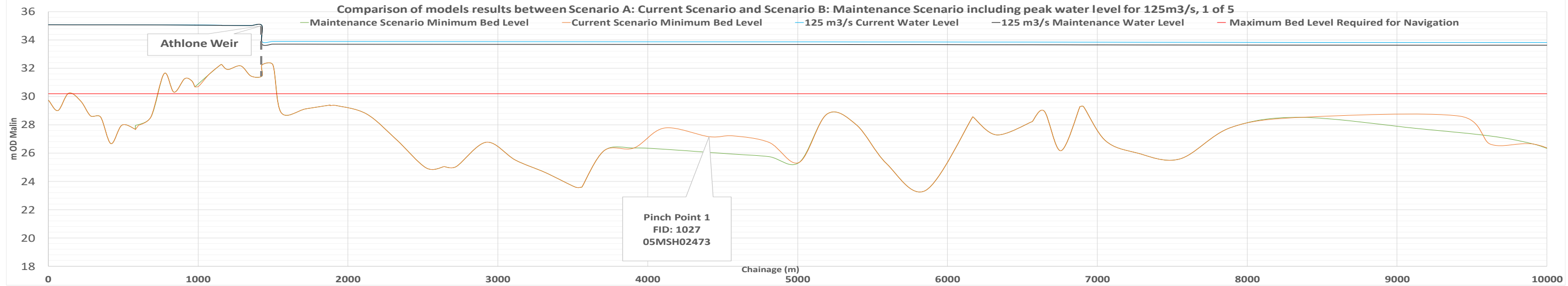


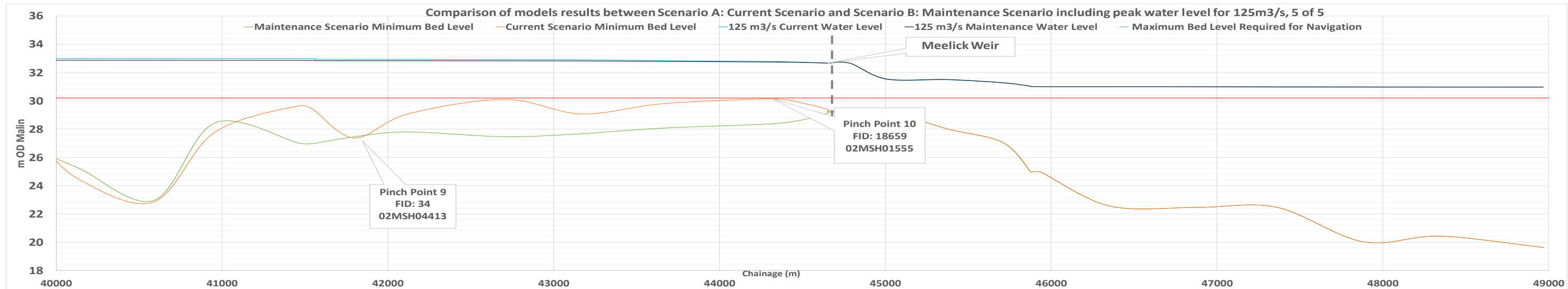
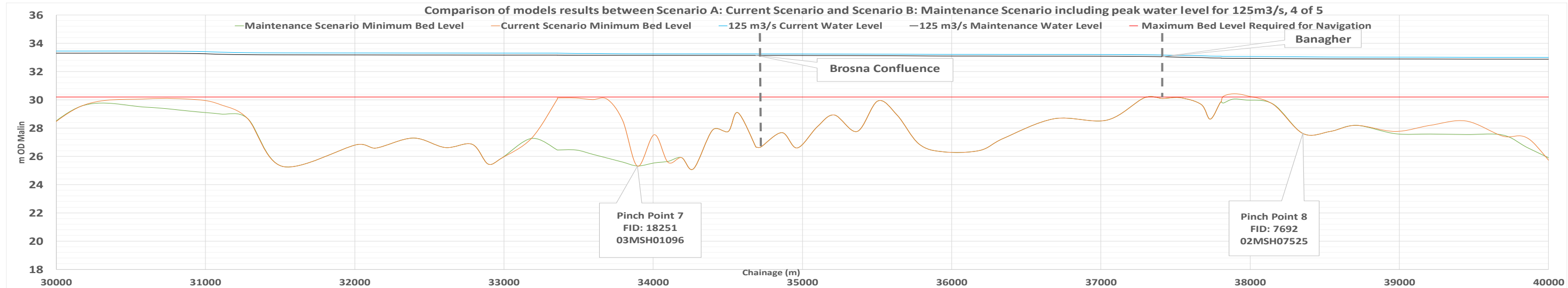
50% AEP Flood Event



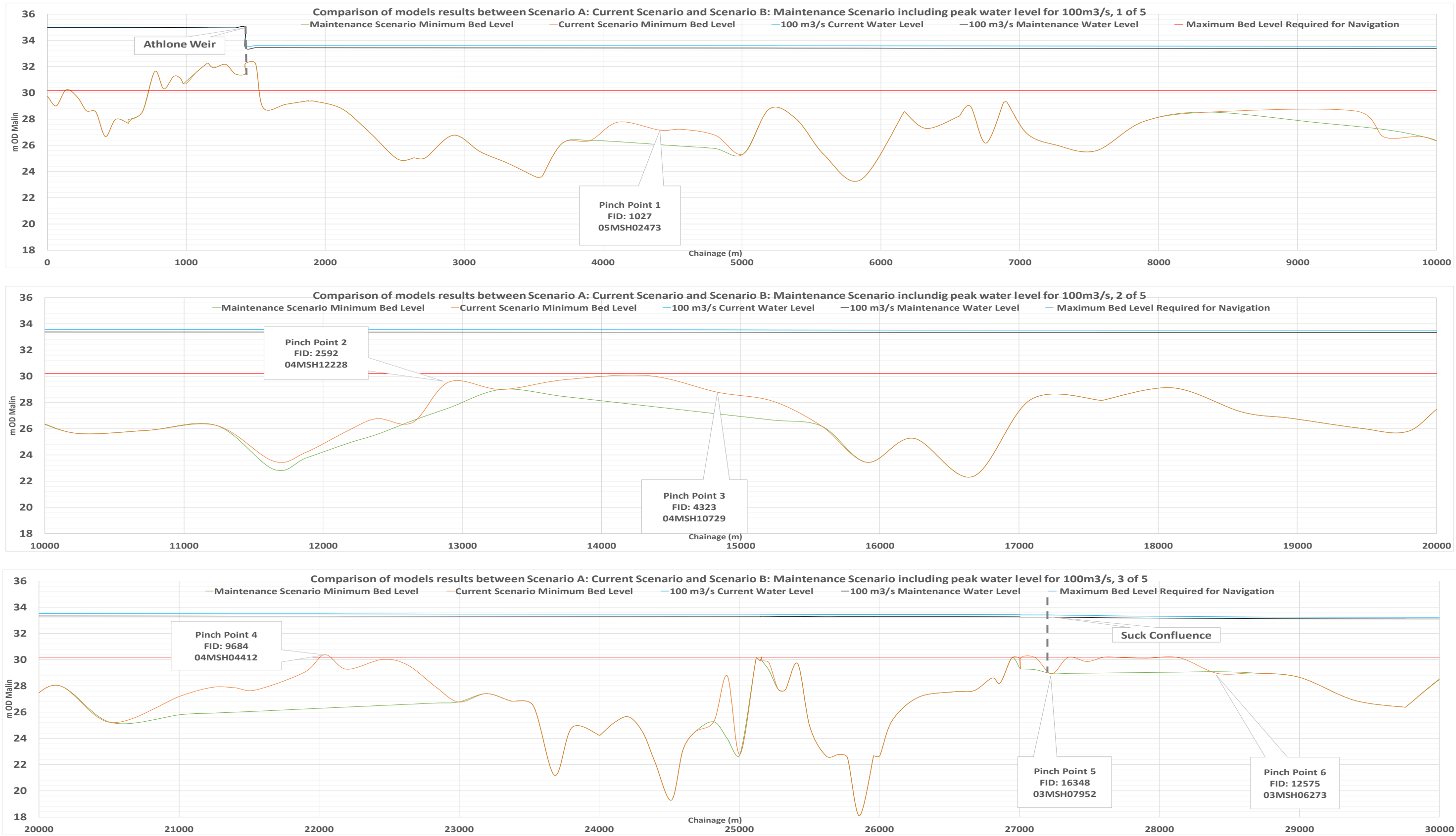


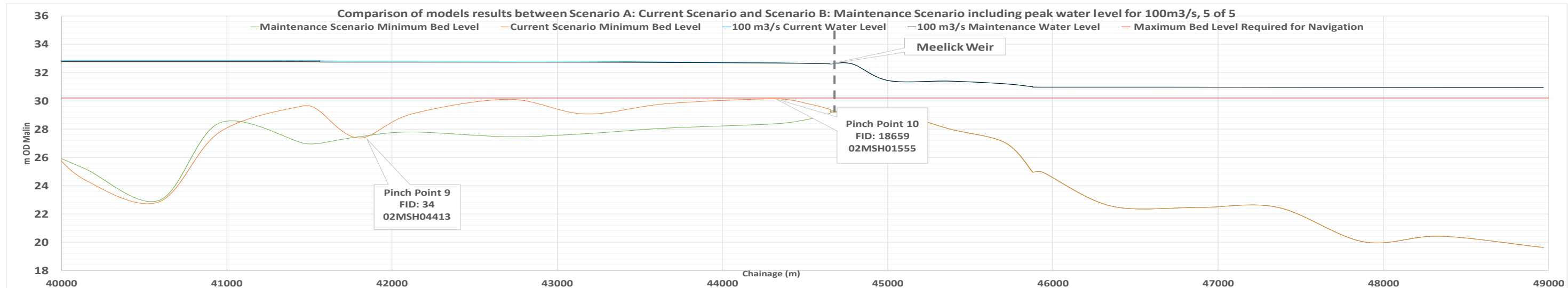
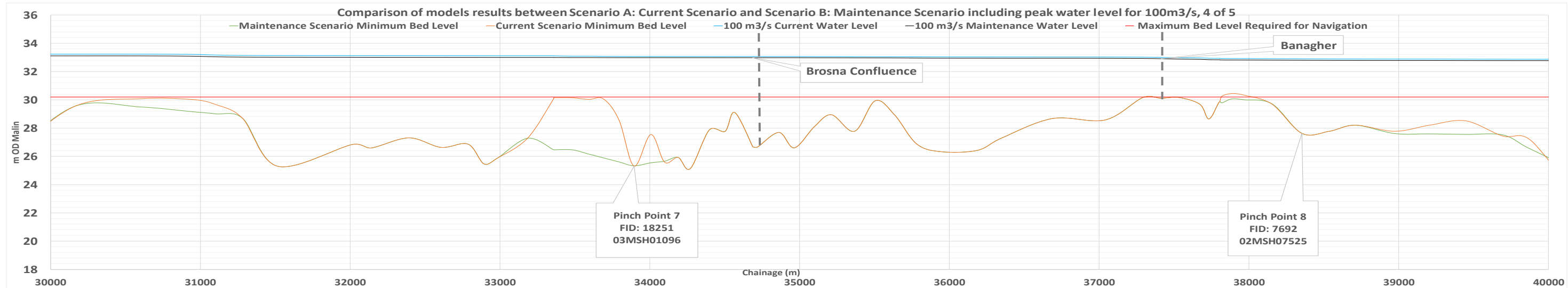
125 m3/s Flood Event



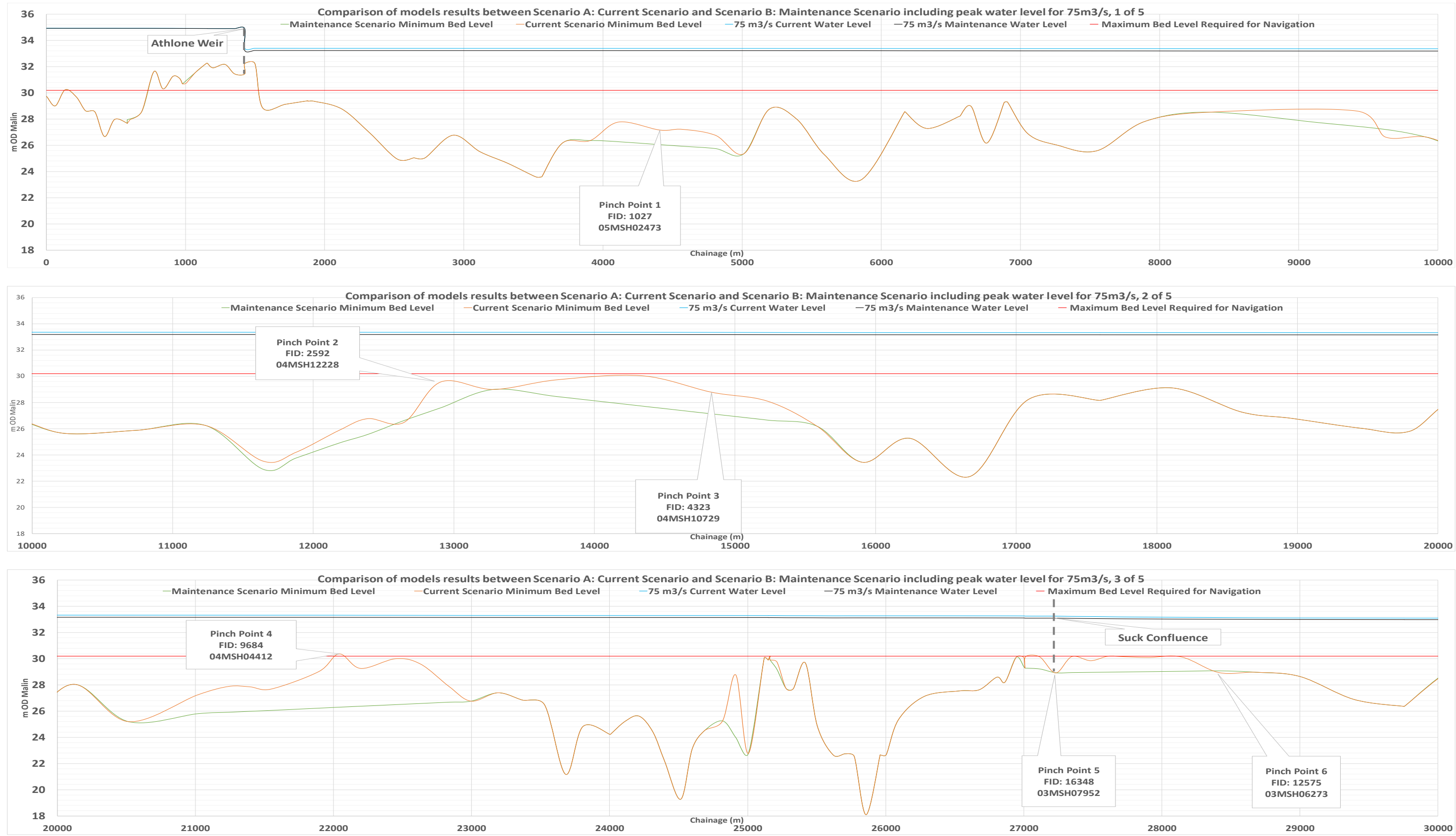


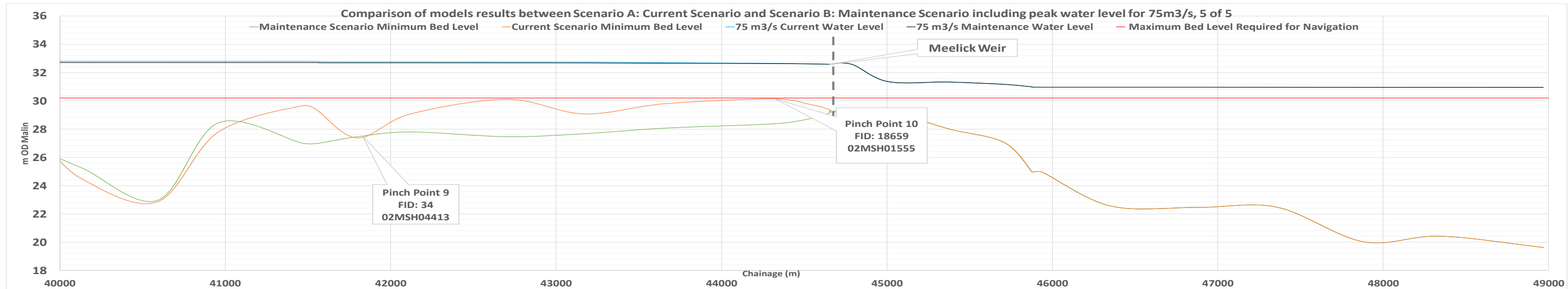
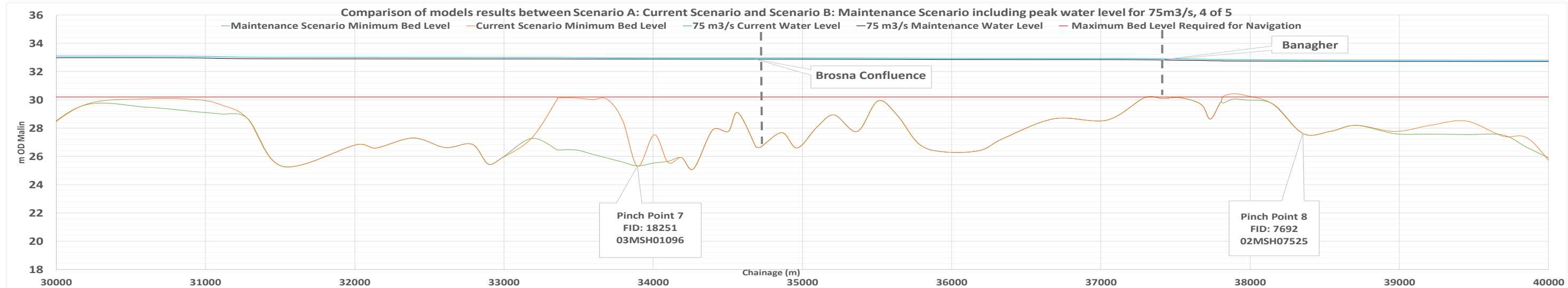
100 m3/s Flood Event



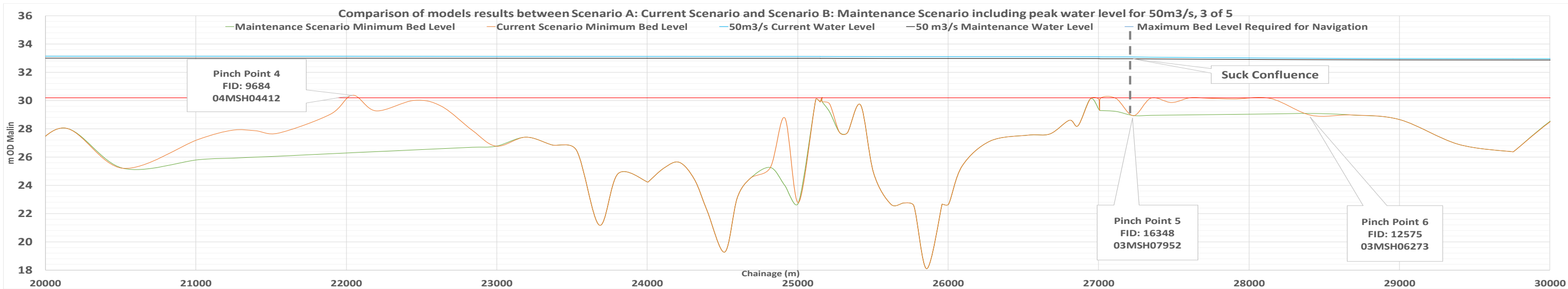
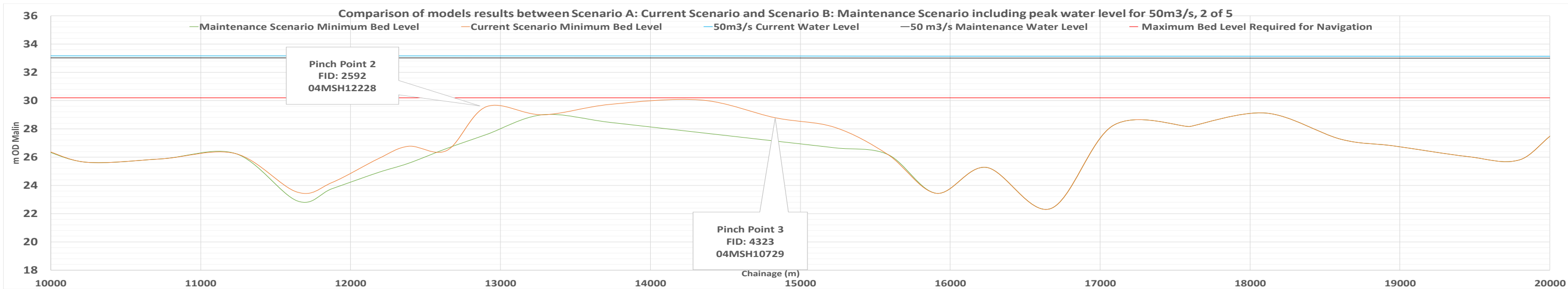
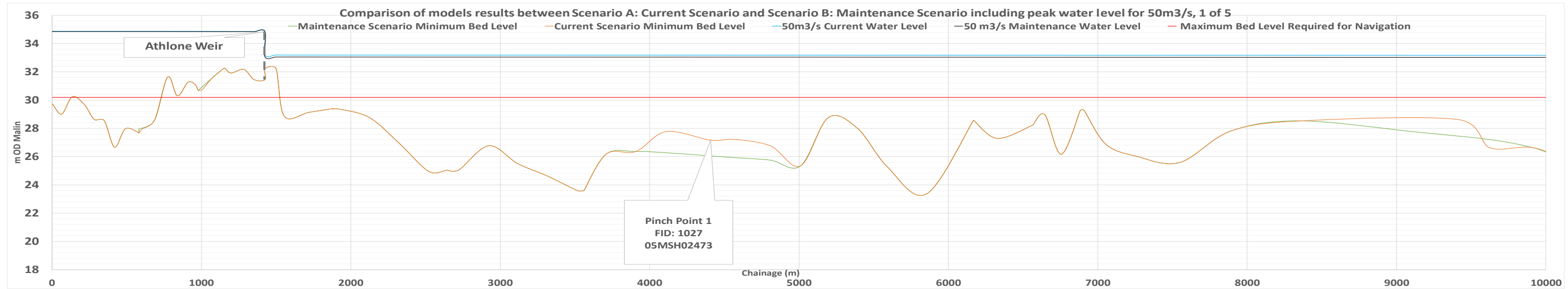


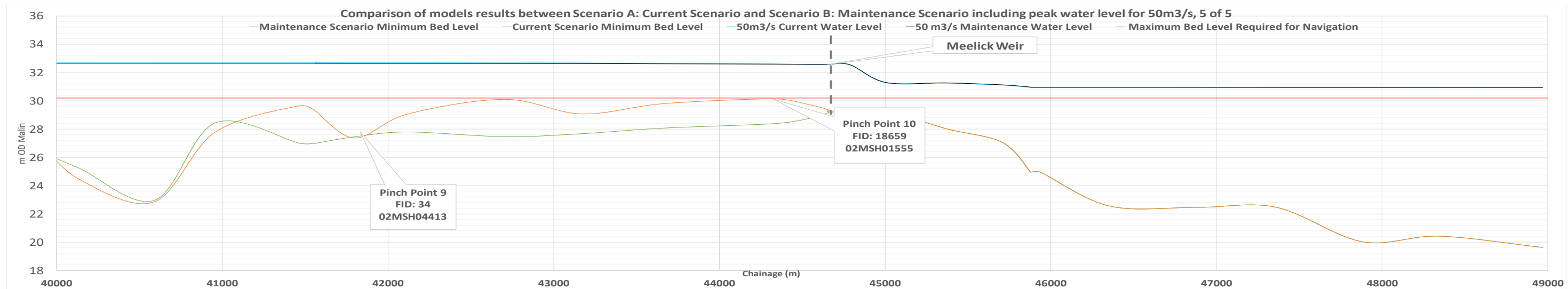
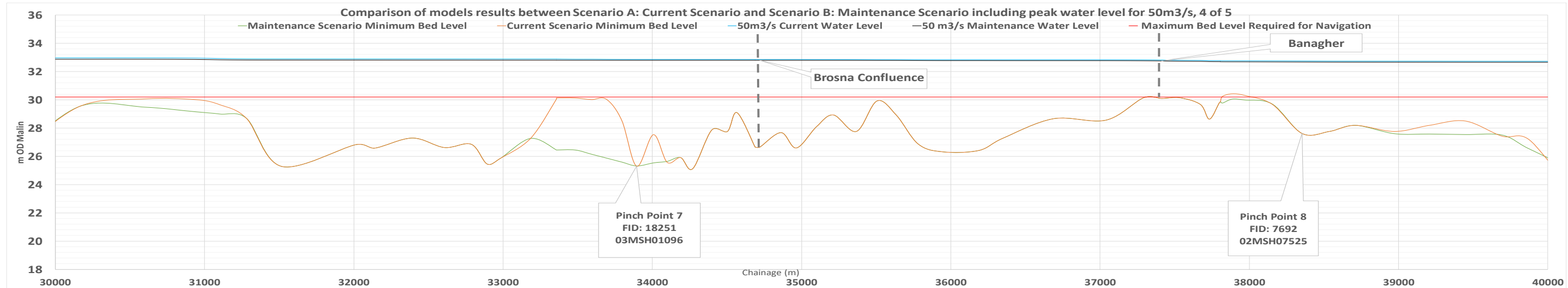
75 m3/s Flood Event





50 m3/s Flood Event





25 m3/s Flood Event

