Oxford FAS

Residual Uncertainty Analysis

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1. Introduction

Since the Oxford Flood Alleviation Scheme (FAS) project began in 2016, the Environment Agency have provided an updated guidance to calculate fluvial freeboard, now called accounting for residual uncertainty. Jacobs will be required to update the freeboard allowance based on this new guidance.

Any flood risk management interventions need to include an allowance for residual uncertainty in estimated water levels, this provides confidence that the scheme will perform as required during a design flood event.

The minimum height of a linear flood defences is derived from two components:

1) Water elevation adjacent to the defence for a flood event of a given rarity. This is usually calculated using a hydraulic model.
2) A freeboard allowance above the water elevation comprising of;
   a) Allowance for uncertainty in calculated water level;
   b) Allowance for other areas of uncertainty (e.g., settlement in embankments, wave action).

The freeboard allowance can be revised during design as risks or uncertainties are mitigated or change (e.g., uncertainty in design water levels can be reduced through collection of observed flow data to improve hydrological estimates).

The latest guidance: SC120014 - "*Accounting for residual uncertainty: updating the freeboard guidance*"[1] outlines three methods for freeboard calculation:

1) First Order Error Analysis (FOEA) - re-stated in SC120014 and referred to as Tier 1 approach
2) Composite Exceedance Probability – re-stated in SC120014 and referred to as Tier 2 approach.
3) Monte Carlo Simulations - re-stated in SC120014 and referred to as Tier 2 approach.

This document details the updated Tier 1 method to quantify the freeboard for the Oxford FAS using the updated hydraulic model developed for the detailed design project phase. The previous assessment (Oxford FAS: Proposed Freeboard Allowances) is no longer valid due to changes in guidance and the hydraulic model updates undertaken since the Outline Business Case (OBC). Drawing IMSE500177-CH2-00-00-VS-PL-0027 attached in Appendix A presents the design areas for the FAS, freeboard is to be assessed throughout the new proposed channel reaches associated with each area, recognising the spatial variation in residual uncertainty

[1] Robinson, A, F Ogunyoye, P Sayers, T van den Brink, and O Tarrant. 'Accounting for Residual Uncertainty: Updating the Freeboard Guide'. Environment Agency, February 2017. https://www.gov.uk/government/publications/accounting-for-residual-uncertainty-an-update-to-the-fluvial-freeboard-guide

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2. Freeboard assessment method

This assessment has adopted the Tier 1 / FOEA method, of the current guidance SC120014, to determine freeboard, the data and analysis tools available are suitable to support this method. The Tier 1 method requires the identification of the secondary variables (for example, peak river flow and channel roughness) which influence the primary variable (predicated river water level through the study area). The influence of change in each secondary variable is assessed in isolation for a given confidence interval. The freeboard associated with uncertainty in the primary variable is quantified by summation of the secondary variable uncertainties. The method assumes a linear response of the primary variable to small changes of the identified secondary variables, this assumption is suitable for linear defences schemes such as the Oxford FAS design.

River systems often behave non-linearly to large changes in secondary variables (e.g., an increase in water level associated with an increase flow will be linear when water remains in channel, with a change in response as floodplains activate and attenuate flows). However, for a small change in variable (e.g., 2% increase in flow) a linear response can be assumed. In the Tier 1 method, the user calculates the linear system response to a small change of the secondary variable, then weights this by the likely uncertainty in the variable (e.g., range of values encompassed by the 95% confidence interval) using the following equation which is reproduced from SC120014 and W187.

$$R_{unc} = \sqrt{\left[\left(\frac{\partial \mathrm{R}}{\partial x}\right) X_{unc}\right]^2 + \left[\left(\frac{\partial \mathrm{R}}{\partial y}\right) Y_{unc}\right]^2 + \left[\left(\frac{\partial \mathrm{R}}{\partial z}\right) Z_{unc}\right]^2}$$

Where R is the total uncertainty in water surface elevation, $\left(\frac{\partial \mathrm{R}}{\partial x,y,z}\right)$ are partial derivatives which represent the relationship between a small change in variable and the resulting change in water surface (the linear response) and $X_{unc} y_{unc}\ Z_{unc}$ are the likely range of uncertainty in the secondary variable within a given confidence interval.

Freeboard is sensitive to the secondary parameters selected, the system linear response and the confidence in secondary variable values. Secondary variable confidence is normally expressed in terms of confidence interval (CI), Table 2.1 defines the confidence intervals considered for this analysis and the equivalent standard deviations.

Table 2.1: Confidence interval and standard deviation equivalents

Confidence interval	Standard deviation ($\boldsymbol{\sigma}$)
38.2% confidence	$\pm \frac{1}{2}$ standard deviation (0.5 σ)
55% confidence	$\pm \frac{3}{4}$ standard deviation (0.75 σ)
68.3% confidence	± 1 standard deviation (σ)
95.5% confidence	± 2 standard deviations (2σ)

When accounting for residual risk in flood defence design, it is important to understand the level of confidence a selected freeboard provides. For a defence constructed to protect against a given design Annual Exceedance Probability (AEP) flood, Table 2.2 summarises the probability of the design water level lying above defence crest when incorporating freeboard calculated using 38%, 55%, 68% and 95% confidence intervals.

Table 2.2: Summary of design exceedance probability for a range of confidence intervals.

Confidence Interval	Probability defence crest is above design water level	Probability (%) defence crest is below design water level
38% (0.5 standard deviation)	69.1 %	30.9 %
55% (0.75 standard deviation)	77.3%	22.7%
68% (1 standard deviation)	84.1 %	15.9 %
95% (2 standard deviations)	97.7 %	2.3 %

Confidence intervals consider a normal distribution centred on the mean (μ) value, standard deviation (σ) is an expression of the distance from the mean value. For example, for peak flow estimation, the design flow for a given flood event (e.g., 0.5% AEP) will be calculated, and the best estimate assumed to equate to the mean value. Upper and lower 95% confidence interval bands from this value are calculated, assuming a normal distribution, allowing the communication that there is 95% confidence that the true 0.5% AEP peak flow lies within this range. Therefore, it can be deduced that there is 97.5% confidence that the peak flow is less than the 95% confidence interval.

3. Tier 1 – First order error analysis

To restate, the Tier 1 method consists of three stages:

- Stage 1 – Identify secondary variables.
- Stage 2 – Calculate linear change in water surface associated with small change in secondary variable using hydraulic model.
- Stage 3 – Calculate freeboard using the equation set out in the previous section.

Work undertaken to calculate freeboard is summarised below for each stage.

3.1 Stage 1 - Identification of secondary variables

3.1.1 Introduction

A review of potential secondary variables which could influence the primary variable (design water levels) was undertaken, nine secondary variables have been identified to inform the Tier 1 analysis, an additional three variables have been identified for sensitivity testing to determine their significance on the analysis.

Secondary variables should be independent of each other, with care taken to identify secondary variables which were distinct from one another. For example, there is uncertainty in the quality of recorded historic flows, stationarity in flow records and performance of hydrological methods, however, each of these components ultimately influences the calculation of design flow, hence were grouped as a single secondary variable.

3.1.2 Notable physical processes not incorporated

In line with the *Accounting for residual uncertainty: updating the freeboard guidance*, only sources of uncertainty have been included in the residual uncertainty assessment. However, notable physical processes have been considered; in case, these need separate allowances as shown in Figure 3.1. The conclusion of the assessment of these processes is as follows:

i. Waves – Wave action residual uncertainty is not considered when calculating the freeboard allowance, for the Oxford Flood Alleviation Scheme, as the River Thames becomes non-tidal at Teddington Lock and Weir and there are limited open areas of water where wind could generate large waves..

ii. Super elevation – On river bends, high velocity water can create a water surface gradient across the channel, with higher water levels on the outer bank. All the structures, with the exception of Old Abingdon Road, which has specific constraints, are designed to be situated away from tight channel bends and the channels are designed to cross existing infrastructure in a perpendicular orientation as much as possible to minimise the span of new structures. Results of the design modelling for the 100yr +30% climate change event show that nodes in the areas which may be likely to produce super elevation, like the structures around and within Area 4E, have a flow velocity of less than 1.2m/s maximum; so super elevation is unlikely to occur. The influence of super elevation is not necessary for to calculate freeboard, for the Oxford FAS.

iii. Settlement – Where earth embankments form part of linear defences, an amount of settlement can be expected. Settlement is not a part of this assessment, as allowance or consideration for embankment settlement has already been considered in detailed design, and so is not required for this analysis.

3.1.3 Climate change

In line with a) *Accounting for residual uncertainty: updating the freeboard guidance* which states that the residual uncertainty should only consider present day parameters and b) *Flood and coastal risk projects, schemes and* *strategies: climate change allowances*[2], the sensitivity to climate change will be tested by using the severe climate change allowance and then discussing with the Environment Agency the additional resilience or mitigation measures to cope with the identified severe impacts.

3.1.4 Notable secondary variables not incorporated

Notable secondary variables which were not incorporated into our freeboard assessment include:

a) LiDAR accuracy - much of the main area of the scheme has been subject to topographic survey as part of the project. Additional survey points were obtained to 'truth' the LiDAR. Whilst some minor local variations were noted the LiDAR in the main areas of flood plain corresponded closely to the topographic checks and is not considered to be a significant source of errors.

b) Fluvial Phasing - has been checked as one of the sensitivity checks during the detailed modelling. This indicated that the peak flows from the main tributaries of the Evenlode, Cherwell and River Ock to the River Thames in the Oxford area pass through and down the River Thames well in advance of the peak flows of the River Thames and are not a concern from an uncertainty analysis perspective.

c) Hydrograph volume-the Oxford area of the River Thames has a relatively long gauge record upstream of the site which has covered a wide range of flows. The model and hydrology have been well calibrated to recent known flood event data. The scheme is not designed to store water but to help facilitate the flow of water around the areas of flood risk. Therefore, hydrograph volume is not considered to be a significant factor in the uncertainty analysis.

d) Variations in channel geometry - during the initial stages of the modelling the channel surveys in the existing models adopted was compared to later channel surveys obtained as part of a wider geomorphological review of the River Thames being undertaken by the Environment Agency. The comparison of these surveys indicated that whilst there were some minor variations the sections on the main channels remained stable. Therefore, significant variations in the channel geometry are unlikely to occur on the mature established channels in the Oxford area and this variable has been discounted.

[2] Environment Agency. 'Flood and Coastal Risk Projects, Schemes and Strategies: Climate Change Allowances'. GOV.UK, 20 July 2021. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances

3.1.5 Influence of residual uncertainty allowance, climate change and allowances for other physical processes on final design level

The influence of the residual uncertainty allowance, climate change and allowances for other physical processes on the final design level for a generic project is shown in Figure 3.1 and Figure 3.2.

As discussed in sections 3.1.2 and 3.1.3, not all of these allowances are required on Oxford.

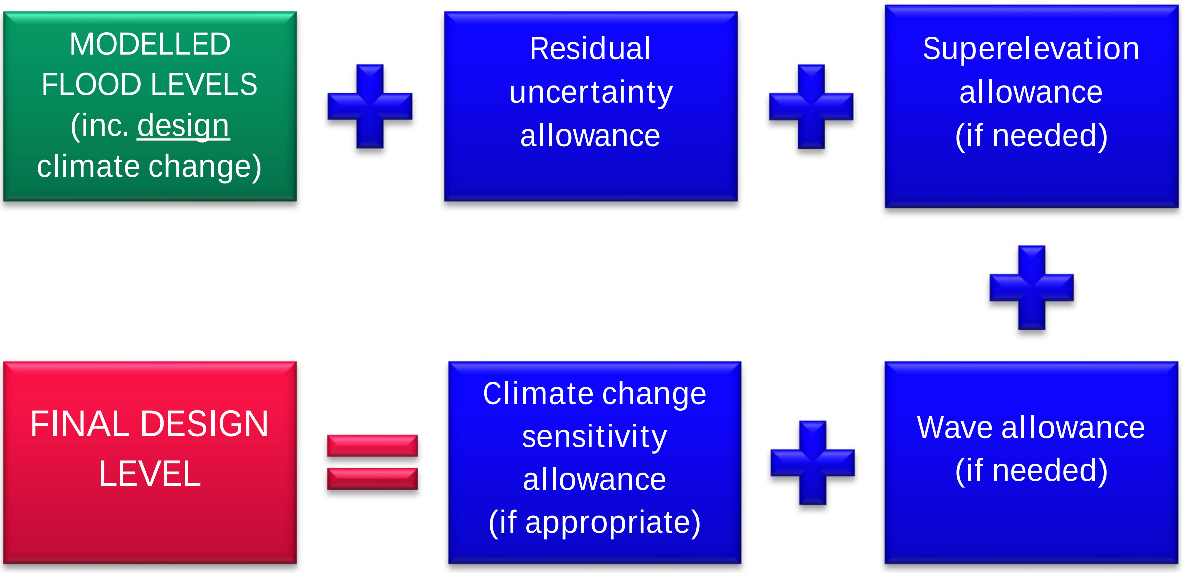


Figure 3.1: Build-up of final design level

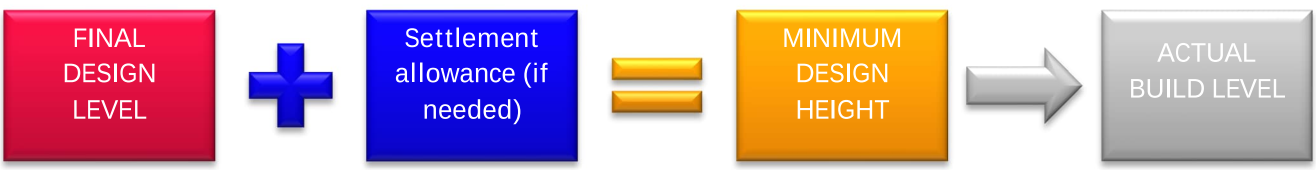


Figure 3.2: Application of settlement allowance

3.1.6 Secondary variables identified

The identified secondary variables are described below in Table 3.1

Table 3.1: Secondary variables identified to determine Tier 1 uncertainty analysis

Type	Variable	Components	Approach and confidence interval
Model Boundary Conditions	Fluvial peak flow estimates	Reliability of gauge record	Confidence intervals calculated as part of statistical analysis following FEH methods to inform standard deviation: Flows are produced from the Oxford FAS flood model River Thames meeting Seacourt Stream upper 95% confidence limits calculated from FEH Vol 3 table 12.4 (Page 94). Modelled flows are taken so no donor assumed No assessment of growth curve uncertainty is included.
		Length of gauge record	
		Assumed stationarity	
		Statistical model used	
	Fluvial hydrograph volume	Hydrograph volume	Analysis of observed events (>QMED) at where River Thames meets Seacourt Stream to determine variability in hydrograph shape and subsequent volume.
Hydraulic Response	Accuracy of hydraulic model representation	Bridge afflux co-efficient.	Model is well calibrated at gauge locations, although there are numerous structures and crossings add uncertainty in relation to bridge afflux Testing within likely ranges based on experience and discussions with Flood Modeller developer. +/- 10% equivalent to 68.3% confidence interval (1.0 σ)
		Weir co-efficient	Weirs on the new channel controls flow downstream, coefficients used within model to calibrate the weir efficiency. Testing within likely ranges based on experience and discussions with Flood Modeller developer. +/- 10% equivalent to 68.3% confidence interval (1.0 σ)
		Channel Mannings' "n"	Model is well calibrated, but uncertainty remains in "n" values selected. Particularly within fluvial and tidal transition reaches. W187 document provides guidance on uncertainty in selected "n" values (Figures 6.4 and 6.5)
		Flood plain Mannings' "n"	Model is well calibrated, but uncertainty remains in "n" values selected. W187 document provides guidance on uncertainty in selected "n" values (Figures 6.4 and 6.5)

3.2 Stage 2 - Calculation of linear change

As outlined in Section 2, the linear change in water level associated with a small change in the secondary variable is calculated using the scheme hydraulic model. For Oxford FAS, a linked 1D/2D Flood Modeller – Tuflow model has been used to calculate design water levels. Details of the model development following the Outline Business Case are reported in IMSE500177-CH2-00-00-RP-HY-0130 – "Detailed Design *Hydraulic Modelling Report*".

Based on the identified secondary variables (Section 0) modelled tests have been identified to determine the partial derivative (Table 3.2) for development of the Tier 1 uncertainty assessment and additional tests (Error! Reference source not found.) to determine the sensitivity of the model to additional variables, and their significance to the Tier 1 assessment.

Table 3.22: Secondary variable partial derivative definitions

Variable	Simulation to define partial derivative
Fluvial peak flow estimates	+ 5% increase in flow
Bridge afflux co-efficient.	+/- 10% in calibration coefficient
Weir co-efficient	+/- 5% in calibration coefficient
Channel & Floodplain Mannings' "n"	+/- 5% increase in Mannings' "n"

3.3 Stage 3 – Calculate freeboard allowance

Freeboard is calculated using the equation set out in Section 2. Partial derivative values $\left(\frac{\partial R}{\partial x,y,z}\right)$ have been calculated using the Oxford FAS hydraulic model as discussed in Section 3.2. Additionally, the calculation requires an estimate of the likely variability in secondary variables ($X_{unc} y_{unc}\ Z_{unc}$). The range in secondary variable values depends on the confidence interval selected. In this assessment, freeboard has been calculated for the 38%, 55%, 68% and 95% confidence intervals (0.5, 0.75, 1.0 and 2.0 standard deviations respectively).

Where possible, likely variability in secondary variables for each confidence interval has been based on published research. Where this is not possible, estimates have been made based on experience and understanding of the system. Adopted values are listed in Table 3.3.

Table 3.3: Uncertainty secondary variable value ranges

Secondary Variable	Source	Modelled Values	Uncertainty in Secondary Variable by Confidence Interval			
			95%	68%	55%	38%
Peak flow - Global (m^3/s)	FEH [3]confidence interval calculation. Section 12.5, FEH Volume 3	183.02	22.21	15.43	11.57	7.71
Weir co-efficient (dimensionless)	Estimated likely range based on experience and discussions with Flood Modeller developer	1.00	0.1	0.05	0.038	0.025
Bridge Afflux (dimensionless)	Estimated likely range based on experience and discussions with Flood Modeller developer	1.0	0.2	0.1	0.08	0.05
Mannings “n” (S2.1) $s/m^{1/3}$	Figure 6.4 of W187.	0.055	0.086	0.055	0.055	0.035

4. Results

4.1 Secondary Variables

Freeboard has been calculated for each model node (Table 4.1 and Table 4.2) for the 95%, 68%, 55% and 38% confidence intervals. The median average freeboard in metres has been calculated for each design area and is summarised in Error! Reference source not found.. There is spatial variation in the calculated freeboard estimates within each area, it is these spatial results which should referred to when freeboard allowances are selected. The table below should not be used for freeboard allowances. Refer to drawing IMSE500177-00-00-VS-C-0027 attached in Appendix A, for the general scheme overview identifying the defence areas.

Table 4.1: Freeboard statistics for defence areas (Median Freeboard values)

Probability defence crest is above design water level	98%	84%	77%	69%
Corresponding confidence interval	95%	68%	55%	38%
All	0.60	0.30	0.25	0.15
Area 1	0.65	0.35	0.25	0.15
Area 2	0.55	0.30	0.20	0.15
Area 3 – A, B & D	0.65	0.30	0.25	0.15
Area 3 – C	0.60	0.30	0.20	0.15
Area 4 – A, B, C, D & G	0.60	0.30	0.20	0.15
Area 4 – E & H	0.95	0.50	0.35	0.25

Table 4.2:Freeboard statistics for defence areas (Maximum and Minimum Freeboard values)

Probability defence crest is above design water level	Maximum (m)				Minimum (m)			
	98%	84%	77%	69%	98%	84%	77%	69%
All	1.15	0.60	0.45	0.30	0.45	0.20	0.15	0.10
Area 1	0.70	0.35	0.25	0.20	0.65	0.30	0.25	0.15
Area 2	0.85	0.45	0.35	0.20	0.45	0.20	0.15	0.10
Area 3 – A, B & D	0.65	0.35	0.25	0.15	0.60	0.30	0.20	0.15
Area 3 – C	0.65	0.30	0.25	0.15	0.55	0.30	0.20	0.15
Area 4 – A, B, C, D & G	0.70	0.35	0.25	0.20	0.55	0.30	0.20	0.15
Area 4 – E & H	1.15	0.60	0.45	0.30	0.70	0.35	0.25	0.15

The first order error analysis median results (Error! Reference source not found.) show the variability of uncertainty within the model in the relation to each of the design areas.

SC120014 does not provide specific guidance on the confidence interval to select when assessing freeboard, however it is noted that the case studies provided using the Tier 1 method, the 95% interval was used.

Table 4.3 outlines the secondary variables which drive the freeboard values for each of the design areas within the Oxford FAS. These results demonstrate that channel roughness is the most important secondary variable throughout the study area.

Table 4.3: Defence area freeboard drivers

Location	Freeboard drivers
Area 1	Mannings “n”, Peak flows
Area 2	Mannings “n”, Peak flows
Area 3 – A, B & D	Mannings “n”, Peak flows
Area 3 – C	Mannings “n”, Peak flows,
Area 4 – A, B, C, D & G	Mannings “n”, Peak flows,
Area 4 – E & H	Mannings “n”, Peak flows,

5. Comparison to previous freeboard

The original design levels used for the flood defence levels were calculated using the previous guidance (Fluvial Freeboard Guidance: Note W187), and the freeboard allowance proposed will be checked in this new guidance for its confidence of success. The ‘simple method’ W187, reviews a range of simulations and scenarios for flow increases based on the climate change guidance from 2018. The proposed freeboard is calculated by providing a freeboard allowance for each physical process separately.

The quick method (W187) previously adopted to estimate freeboard requirements, with a conclusion of 200mm minimum applicable to all Areas within the scheme, does not account for this variability. The results from the first order error analysis shows that a value of 200 mm approximates to a confidence interval of 16% (0.2 Standard Deviations), which relates to a 58% chance that the scheme would not be exceeded. Table 5.2 shows what the previous W187 freeboard (current design levels) would approximate to, in confidence percentage.

Osney Mead defences are overtopped at a low return period (between 5% AEP and 2% AEP), and due to design constraints, the design level cannot be increased above the current design level (produced from the previous freeboard guidance). Area 4H is being allowed to flood as there are no properties nearby, so freeboard is not being considered here.

Area 4E; the floodwall level on the right-side bank is 56.3mAOD with a max stage of 56.097mAOD (1% AEP+30% CC), and so freeboard applied for climate scenario 2080s is 0.2m. Instead, the 2020s climate scenario has been considered for Area 4E, with a max stage of 55.795mAOD (1%AEP+11%CC), and so the freeboard considered is 0.5m. The left-side bank freeboard is not being considered as the design level (updated recently) is adequate.

In comparison to the previous freeboard allowance, all structures reflect a high confidence percentage from the previous freeboard allowance provided, with structures showing at least 69% confidence, with exception to the cases mentioned above.

Table 5.1:Median Freeboard statistics by structures

Probability defence crest is above design water level (%)	98%	84%	77%	69%
Botley Road Raised Defences (area 1C embankment at the end)	0.75	0.30	0.25	0.15
Existing Botley Bridge	0.70	0.35	0.25	0.15
Westway Cycle Bridge	0.55	0.30	0.20	0.15
Willow Walk Bridge	0.55	0.30	0.20	0.15
Osney Mead Defences (Area 3D from 2D results)	0.70	0.35	0.28	0.18
North Hinksey Causeway Bridge	0.65	0.35	0.25	0.15
Devil's Backbone Bridge	0.55	0.30	0.20	0.15
South Hinksey Raised Defences	0.65	0.35	0.25	0.15
New Hinksey Raised Defences	1.00	0.50	0.35	0.25
Bridges at Old Abingdon Rd & Kennington Road	0.65	0.35	0.25	0.15
Area 4 – E	0.80	0.40	0.30	0.20
Area 4 – H	1.00	0.50	0.40	0.25
Embankments near Bridges at Old Abingdon Rd & Kennington Road	0.65	0.35	0.25	0.15

Table 5.2: Maximum and Minimum Freeboard statistics by structures

Probability defence crest is above design water level (%)	Maximum (m)				Minimum (m)			
	98%	84%	77%	69%	98%	84%	77%	69%
Botley Road Raised Defences (area 1C embankment at the end)	0.75	0.40	0.30	0.20	0.60	0.30	0.25	0.15
Existing Botley Bridge	0.70	0.35	0.25	0.15	0.70	0.35	0.25	0.15
Westway Cycle Bridge	0.55	0.30	0.20	0.15	0.55	0.30	0.20	0.15
Willow Walk Bridge	0.55	0.30	0.20	0.15	0.55	0.30	0.20	0.15
Osney Mead Defences (Area 3D from 2D results)	0.80	0.40	0.30	0.20	0.60	0.30	0.25	0.15
North Hinksey Causeway Bridge	0.65	0.35	0.25	0.15	0.65	0.35	0.25	0.15
Devil's Backbone Bridge	0.55	0.30	0.20	0.15	0.55	0.30	0.20	0.15
South Hinksey Raised Defences	0.75	0.35	0.30	0.20	0.65	0.30	0.25	0.15
New Hinksey Rasied Defences	1.00	0.50	0.40	0.25	0.95	0.50	0.35	0.25
Bridges at Old Abingdon Rd & Kenninton Road	0.70	0.35	0.25	0.15	0.65	0.30	0.25	0.15
Area 4 – E	1.00	0.50	0.40	0.25	0.70	0.35	0.25	0.15
Area 4 – H	1.15	0.60	0.45	0.30	0.95	0.50	0.25	0.25
Embankments near Bridges at Old Abingdon Rd & Kenninton Road	0.65	0.35	0.25	0.15	0.65	0.35	0.25	0.15

For some structures, the levels are reduced in the proposed design levels, however, have a higher confidence with its freeboard allowance.

There are a number of local locations where the previous design levels were set at the original 1%AEP design levels due to topographic and infrastructure constraints in the locality resulting in achieving the full freeboard was not feasible. These local low points in the defence levels would be the first to overtop in an exceedance event and be the focus of emergency response teams. These locations are;

- Seacourt Park and Ride area along the access road to the park and ride site.
- Osney Allotments just north of Botley Road adjacent to West Oxford Community Centre
- Eastwyke Stream at Eastwyke Lane where the defence ties into Abingdon Road
- Southern end of Wytham Road in New Hinksey

It is not feasible to raise these local areas, and these will remain the first points where flooding will commence in an exceedance event. With the scheme adopting the latest climate change guidance flows for the 2020s as baseline condition flows these local areas will provide less than a 1% AEP level of protection.

Table 5.3: Comparison of freeboard

	Structure	Previous freeboard allowance (1)	Design crest/soffit levels (mAOD) (2)	1% AEP +30% Climate change design water level (mAOD) (3)	Freeboard achieved (m) (4) = (2) –(3)	Confidence percentage for proposed crest/soffit levels (5) looks up from previous table based on (4)
Area 1	Botley Road Raised Defence	0.5m for bunds 0.3m for walls	58.15 for bunds 57.95 for walls	57.63	0.32	>84%
	Existing Botley Bridge	Existing freeboard: 100yr = 0.25m 100yr +35%CC=-0.6m	N/A	57.55	X	X
Area 2	Westway Cycle Bridge	0.30m	57.51	57.23	0.28	>77%
	Willow Walk Bridge	0.20m	57.12	56.87	0.25	>69%
	Osney Mead Defence	N/A	56.70***	56.86	X	X
Area 3	Monk's Causeway Bridge	0.20m	56.98	56.77	0.21	>69%
	Devil's Backbone Bridge	0.30m	56.92	56.57	0.35	>84%
Area 4	South Hinksey Raised Defence	0.5m for bunds 0.3m for walls	57.15 for bunds 56.95 for walls	56.58	0.37	>84%
	New Hinksey Raised Defence	0.5m for bunds 0.3m for walls	56.80 for bunds 56.58 for walls	56.21	0.37	>77%
	Bridges at OAR & Kennington Road	None	*54.95	56.38	X	X

*Lowest soffit elevations on both bridges

**Freeboard above 1% AEP level only

***Flood defence levels constrained by surrounding topography

X values indicate the structure is surcharged

6. Conclusions and recommendations

Analysis, in accordance with the Tier 1 first order error analysis, has been undertaken to determine the secondary variables for consideration. The conclusions and recommendations from this analysis are summarised below:

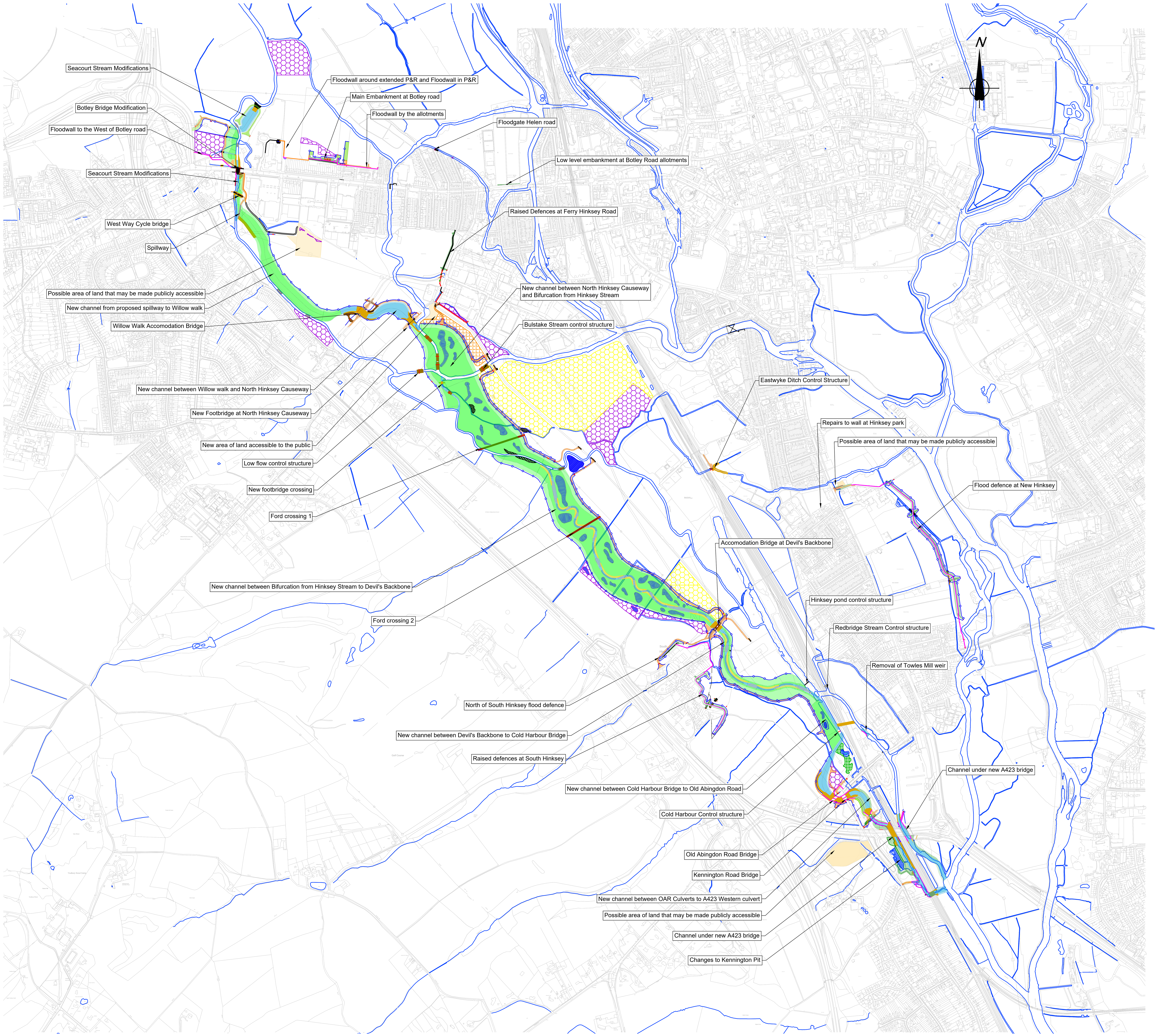
- The Tier 1 assessment approach has been identified as the most suitable approach to determining the level of uncertainty in design water levels. This assessment method is applicable to the data and tools available to the project. The method assumes a normal distribution of uncertainty for each secondary variable, with a small change in secondary variables resulting in a small linear change in the primary variable. This method is deemed suitable for linear defence schemes such as the Oxford FAS design. Should a different distribution be deemed more appropriate, a Tier 2 approach (SC120014) should be considered.
- The previous uncertainty assessment undertaken at the OBC stage of the Oxford FAS (Oxford FAS: Proposed freeboard allowances) has been updated due to a number of model updates undertaken and to reflect the latest climate change guidance.
- The analysis has identified five secondary variables and has defined the confidence intervals and partial derivate tests for each.
- Analysis of available topographic survey throughout the study area has not been undertaken.
- The assessment has identified channel roughness to be the most important variables in relation to the calculated freeboard. The complexity of the modelled system creates significant variability in the importance of secondary variables on freeboard estimates.
- Freeboard values have been calculated for the 1% AEP flood event (present day including climate change allowance for the 2020s).
- The freeboard applied depends on the confidence interval chosen. SC120014 provides no guidance on this beyond stating that the same confidence interval is used for all secondary variables considered. The previous W187 suggests 0.5 or 1 standard deviation, that is, 38% or 68% confidence.
- Further variables (superelevation, settlement and sensitivity to climate change) were identified where additional separate allowances might be necessary at specific locations.
- The design levels proposed in the previous freeboard allowance report have been checked and deemed acceptable for all structures, and so, the current design levels should be kept.

7. Limitations

- A Tier 1 first order error analysis has been undertaken to estimate the residual uncertainty associated with the hydrodynamic model developed for Oxford FAS to determine suitable freeboard. This method has the below key limitations:
- The method assumes a linear increase in water level for the scaling of modelled results to the required confidence intervals. The method does not account for dynamic changes within the system which could occur at these extremes.
- The method adopts a normal distribution for the determination of confidence intervals. The method does not account variation within the distribution as a result of the population skew, kurtosis, asymmetrical.
- Confidence intervals for each secondary variable considered within the calculation have been defined based on the best available data or theoretical guidance. Should further data, or updated guidance, become available the accuracy of these intervals should be re-assessed. The primary drivers are identified as Manning's roughness and Peak flows (Table 4.3), limitations in the confidence interval derivations of these two variables are:
    - Manning's Roughness – confidence intervals have been defined from W187 (Figure 6.4); these values define the intervals associated with Manning's roughness estimates. As the modelled roughness values have been used to calibrate the model to fluvial and tidal dominant events at three gauges the considered range could be assumed to be smaller than that defined from this figure.
    - Peak flow estimates – confidence intervals have been determined following the recommended method for sites with long data records (> 10 years) from the Flood Estimation Handbook (FEH Vol 3 table 12.4). Other methods for peak flow confidence intervals are available and may give rise to different values. The method does not account for the uncertainty associated with growth curves, used to increase QMED estimates to the required peak flows of defined AEP events.
- This document has been prepared on behalf of, and for the exclusive use of Jacobs' client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this document by any third party.

Appendix A. General Scheme Overview

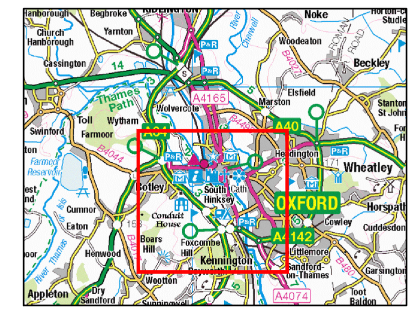
General Scheme Overview - IMSE500177-CH2-00-00-VS-PL-0025



PLAN

NOT TO SCALE

Key Plan:



General notes:

1. All dimensions are in millimetres unless otherwise stated. All levels are in metres above Ordnance Datum (mAOD) Newlyn.

Notes:

1. This drawing is to be read in conjunction with the Red Line Boundary drawing, IMSE500177-CH2-00-00-VS-PL-0028.
2. This drawing is to be read in conjunction with the overview locations of new telemetry stations drawing, IMSE500177-CH2-IAM-ZZ-VS-PL-0031.

Legend:

- Existing Watercourses
- New / Modified First-Stage Channel
- New Second-Stage Channel
- New Maintenance track
- Wetland Features (Scrapes, Backwaters)
- Mitigation areas - Woodland creation
- Mitigation areas - Habitat creation
- Mitigation areas - Shrub tree planting
- Mitigation areas - MG4 grassland
- Mitigation areas - Possible areas of land that may be made publicly accessible

P04	RM	PS	PJM	26/01/22	UPDATED FOR ES ADDENDUM
P03	MBA	PS	PJM	11/01/21	UPDATED FOR ES ADDENDUM
P02	VHJ	CJM	PJM	25/09/18	UPDATED FOR ES ADDENDUM
P01	MM	ZO	PJM	09/03/18	PLANNING APPLICATION
Rev	By	Chkd	Apprvd	Date	Description

Client

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Project
WEM LOT 3 - OXFORD FLOOD ALLEVIATION SCHEME DETAILED DESIGN
684232

Drawing

FIGURE 1
SCHEME OVERVIEW

Drawn by: P.SEGIT Date: 30/01/18
Checked by: C.MORGAN Date: 05/03/18
Approved by: P.MARSH Date: 07/03/18

Drawing No.: IMSE500177-CH2-XX-ZZ-VS-EN-1025
Revision: P04

Document Suitability: S0

Drawing file path & name : C:\pw_workdir\lon002\jegintl_miahr\dms44046\IMSE500177-CH2-XX-ZZ-VS-EN-1025.dwg Layout: 1010
User and Plot Date : Miah, Razuan : Jan 31, 2022 3:59:22 pm Plot Style Table: C:\Program Files\AutoCAD 2000i\Plot Styles\colour A3.ctb