JBA consulting

Leigh FSA Expansion Flood Risk Assessment

Final report

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Contract

This report describes work commissioned by the Environment Agency under the Collaborative Delivery Framework, project reference: IMSE100377. The Environment Agency's representatives for the contract were Andy Dellar and James Kennedy. Ben Gibson and James Axton of JBA Consulting carried out this work.

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Purpose

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Executive summary

JBA Consulting was commissioned by the Environment Agency to complete the detailed design of an expansion to the flood storage capacity at Leigh Flood Storage Area (FSA). This work was commissioned under the Collaborative Delivery Framework (CDF) commission reference: IMSE100377 and included the preparation of a Flood Risk Assessment (FRA) of the proposed scheme. The FRA report is one of the pieces of evidence prepared to support the full planning application.

Under the same commission, JBA Consulting are preparing an outline design of a flood embankment at Hildenborough, intended to prevent the upstream ingress of flood water originating from the River Medway into the Hawden Stream valley, which contributes to flooding at Hildenborough. Application for planning for this associated development will be sought via submission of an outline planning application, independent to this detailed application for the works at Leigh FSA, albeit there are linkages between the two schemes discussed in section 1.3. The preparation and submission of the full planning application for the Leigh FSA can progress independently of the outline design/planning intended for submission an embankment at Hildenborough.

Proposed development

The proposed development involves enabling works that will allow the capacity of the Leigh FSA to be increased by raising its maximum operating water level from 28.05mAOD to 28.60mAOD. This change will increase the storage volume from 5,850,000m^3 to 7,250,000m^3, an increase of 24%, and enable greater reduction in peak flow rates during flood events. As is the case for the established Leigh FSA, the proposals will further increase flood storage volumes (and hence flood depths and extents) for a region of floodplain upstream of the FSA embankment, to the betterment of receptors downstream.

Mitigation measures for receptors located within the footprint of the FSA at maximum operating water level form part of the detailed design of the scheme so that potential increased risks to third parties are appropriately mitigated and managed. Existing infrastructure located at land to the south of the railway line at Leigh, which extends from Ensfield Road to a pumping station located 400m to the east, will be protected from elevated water levels in Leigh FSA by the construction and/or enhancement of an existing embankment and wall features. Additional provisions to enable pumping of water from land to the north into Leigh FSA will also be provided.

Planning policy context

The proposed development is 'water compatible' according to the vulnerability categorisation within National Planning Policy and so is deemed appropriate. As required for water compatible development, the development will be designed to

- remain operational and safe for users in times of flood; and
- result in no net loss of floodplain storage

Regarding the third policy requirement that a development should not impede water flows and not increase flood risk elsewhere; although it is accepted that the proposed development will intentionally increase flood depths in the FSA during times of storage, the design event modelling indicates that the risk of flooding to receptors e.g. property is not increased as a result of these activities.

Flood risk associated with the current FSA scheme

Managing fluvial flood risk is the purpose of the FSA and a key consideration for the proposed FSA arrangements from a planning policy perspective. The increase in the flood storage volume of the natural floodplain provided by the Leigh FSA enables the Environment Agency to reduce the peak flow magnitude of downstream flood flows for the design conditions. The effects of climate change are predicted to increase the magnitude and volume of flood flows and this will reduce the effectiveness of the Leigh FSA, resulting in an increase in the frequency and severity of flood risk downstream.

The significance of flood risk from groundwater and surface water on the effectiveness of the proposed development are negligible. The breach failure of reservoirs upstream of Leigh FSA poses a residual risk to the development. However, whilst the potential consequences are not insignificant, the probability of such circumstances is extremely low and hence overall the risk is low.

Proposed development and flood risk

Flood risk within the FSA

Within the FSA, the change in flood extents due to the proposed increase in operating water level from 28.05mAOD to 28.60mAOD is relatively small. The greatest change in depth and extent is in the immediate vicinity of the FSA embankment and the local effect of the change in operation diminishes relatively rapidly along the flooded valley upstream.

At the FSA embankment, the increase in flood depths would be expected to be no more than +0.55m, reflecting the change in the maximum operating water level from 28.05mAOD. However, with increasing distance upstream from the FSA embankment, the increase in flood depths will reduce and become negligible as the influence of the prevailing flood flows from the upstream catchment increasingly dominate the flood mechanism. The duration of time that elevated water levels occurs compared with the current operational regime (storage to a maximum level of 28.05mAOD) will also reduce with distance upstream from the FSA. Design event modelling indicates that no change in flood depths is predicted upstream of circa 1km east (downstream) of Rogues Hill, Penshurst, between the proposed and existing scenarios.

Receptors potentially affected by the proposed increase in water levels stored within the FSA are summarised as follows:

- Railway line to the east of Leigh Station
- Tonbridge Sailing club (note that the deck of the buildings is raised above the normal maximum operating water level)
- Ensfield Road

Note that each of the receptors already lies in the footprint of the FSA at maximum storage level when a flood is passing through the River Medway.

The timing and duration of impoundment at the FSA will vary on an event by event basis, reflecting the nature of flood flows reaching the FSA from upstream, future forecast conditions and therefore the FSA operator's decisions on impoundment. For the purpose of the assessment a large number of flood events has been used to inform the flood risk modelling. This approach allows the following conclusions to be made with respect to the timing and duration of flood water being stored in the FSA in the proposed development scenario:

- The duration of additional impoundment above 28.05mAOD is not predicted until event magnitudes exceed a 10% AEP

- Over the range of results analysed there is a wide variety in the time during which flood water is impounded above 28.05mAOD and the impoundment duration increases or decreases according to the magnitude and characteristics of the event

- On the basis of the range of events considered, the maximum duration that additional water is predicted to be impounded above 28.05mAOD is between 50-60hrs. However, the average duration of additional impoundment is 19 hours for those events where additional impoundment is recorded.

- As event magnitudes increase beyond circa 1% AEP, the duration of time that additional impoundment occurs above 28.05mAOD is reduced. This reflects the fact that for these events the FSA begins to respond in a similar manner as for the circumstances where the storage volume has not been increased.

Flood risk downstream of the FSA

Downstream of the FSA flood extents and flood depths are predicted to reduce in the proposed development scenario for events of circa 5% AEP magnitude and larger, as the additional storage available at the FSA enables the magnitude of outflows from the FSA to be reduced.

The reduced outflows from Leigh FSA results in a contraction in the predicted flood extent which becomes less pronounced downstream of Tonbridge due to the expansion of flow along the floodplain and inflow from other watercourses. Within the Tonbridge, for the 5% AEP event flood depths reduce by up to 0.05m for most regions of flooding. For larger and less frequent events, reductions in flood depths are greater, as a larger storage volume at the FSA enables outflows to be reduced. In the 1% AEP event, the reductions in flood depths are between 0.1-0.2m to the eastern side of Tonbridge, while slightly greater benefit in terms of reduced flood depths are predicted for the 1% AEP +15% flows event. Downstream of Tonbridge, reductions in flood depths are smaller, typically up to 0.1m for the 1% AEP event.

The timing and duration of releases of flood flows from the FSA will vary on an event by event basis, reflecting the nature of flood flows reaching the FSA from upstream, the storage capacity in the FSA and the FSA operator's decisions on impoundment. For the purpose of the assessment a large number of flood events has been used to inform the flood risk modelling (each of which has a different flood magnitude, shape etc). This approach allows the following conclusions to be made with respect to how the duration of outflows released from the FSA are expected to change in the proposed development scenario:

- The occurrence of longer duration releases from the FSA is not predicted until event magnitudes exceed a 5% AEP.
- On the basis of the range of events considered, there is a wide variety in the duration of longer release times and this changes in accordance with the magnitude of a particular event – highlighting that the shape and volume of flood events is also important.
- The predicted maximum duration that higher flow rates would be released in the proposed operational regime is between 40-50hrs. However, the average duration of the longer release times is 16 hours for those events where the time has increased compared with the current operation.

Residual flood risk

The variable nature of flood events mean that events with different characteristics to the design event modelling could occur (e.g. events with multiple peaks or larger flood volumes). For flood events with uncommon characteristics, it is possible that part of the storage volume within the FSA may be utilised through operation of the FSA prior to the main peak of a flood event arriving This operation could result in slightly elevated flood depths to those in the design scenario. In such circumstances the changes in flood depths/levels in the FSA would be relatively small, and the duration of that elevation water levels occurs relatively short. As in the design events, the flood depth in the FSA would decrease the further upstream one is from the main embankment and the changes in depth from this development would diminish in the same manner.

.By increasing the volume of storage that is permitted behind the embankment the proposed development is able to accommodate events with increased severity but maintain the capacity to control the magnitude of the outflows (so reducing flood risk downstream). However, for events that exceed the design capacity of the FSA and would result in a water level which exceeds the maximum operating water level, the operation procedure will remain unchanged: the control gates will be operated so the floodwater in the FSA is maintained at a safe level.

The proposed development, which will enable an increase to the maximum operating water level permitted in the FSA, potentially increases the consequence of breach failure should it occur at the time of maximum permitted impoundment (greater flow rates could be expected due to the larger volume and greater depth of water). However, the proposals include works to further enhance the safety of the embankment during such conditions, so the likelihood of breach occurrence would not be expected to increase. In addition, should the integrity of the embankment be compromised during a flood event, it is considered that there would be opportunity to drawn down water levels in the FSA, by operating the control gates, to reduce the likelihood and consequence of breach failure.

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Abbreviations

AEP	Annual Exceedance Probability
CDF	Collaborative Delivery Framework
CFMP	Catchment Flood Management Plan
FRA	Flood Risk Assessment
FSA	Flood Storage Area
LFRMS	Local Flood Risk Management Strategy
mAOD	Metres Above Ordnance Datum (Newlyn)
MIOS	Measures in Interest of Safety
MMS	Middle Medway Strategy
NMOWL	Normal Maximum Operating Water Level
NPPF	National Planning Policy Framework
PPG	Planning Practice Guidance
SFRA	Strategic Flood Risk Assessment

1 Introduction

1.1 Terms of reference

JBA Consulting was commissioned by the Environment Agency to complete the detailed design of an expansion to the flood storage capacity at Leigh Flood Storage Area (FSA). This work was commissioned under the Collaborative Delivery Framework (CDF) commission reference: IMSE100377.

This commission also included preparation and submission of evidence required to support the submission of a full planning application for the development. This Flood Risk Assessment (FRA) report forms one of the pieces of evidence prepared to support the full planning application.

Under the same commission, JBA Consulting are preparing an outline design of a flood embankment at Hildenborough, intended to prevent the upstream ingress of flood water originating from the River Medway into the Hawden Stream valley, which contributes to flooding at Hildenborough. Application for planning for this associated development will be sought via submission of an outline planning application, independent to this detailed application for the works at Leigh FSA, albeit there are linkages between the two schemes discussed in section 1.3.

1.2 Scope and context of the Flood Risk Assessment

This Flood Risk Assessment is prepared to support the full planning application being sought for the expansion of flood storage at Leigh FSA only.

Unlike most developments being assessed by Flood Risk Assessments, it is known that this proposed development will increase flood storage (and hence flood depths and extents) for a region of floodplain upstream of the FSA embankment, to the betterment of receptors downstream. This proposal adopts the same principle that is already in place and the further increase in the flood storage provides for an additional reduction in flood flows at the peak of flood events downstream of the Leigh FSA. Without consideration of how the increased water levels stored at the FSA could potentially affect third parties, it is possible that the proposed development could have a detrimental effect. However, as presented in the following sections, mitigation measures form part of the detailed design of the scheme so that potential increased risks to third parties are appropriately mitigated and managed.

1.3 Interaction between the Leigh FSA and Hildenborough embankment schemes

The preparation and submission of the full planning application for the Leigh FSA can progress independently of the outline design/planning submission intended for the construction of an embankment at Hildenborough.

However, the development of the embankment at Hildenborough is dependent on the Leigh FSA Expansion development being progressed. The Hildenborough embankment scheme will involve removal of part of the River Medway floodplain from being 'active' during flood events, meaning a proportion of floodplain storage is potentially reduced. Without mitigation for the Hildenborough scheme, flood water levels might be expected to increase elsewhere. The reduction in available floodplain will be more than offset by the increase in storage volume in the FSA.

2 Details of the proposed development

2.1 Overview of Leigh Flood Storage Area

2.1.1 History of the Flood Storage Area

Leigh FSA was built in 1982 in response to significant flooding experienced in 1968. It reduces the risk of flooding to properties and businesses in the town of Tonbridge, Kent, by reducing the flow rate passing through the River Medway downstream. Reduced flood flows extend beyond Tonbridge, with properties downstream also benefitting from its presence, albeit with distance downstream the benefit with respect to reduced peak flows diminishes as additional tributaries contribute flows to the flood flow magnitudes in the River Medway system.

Leigh FSA comprises a 1.3 kilometre-long, five-metre-high earth embankment across the Medway valley. At the FSA embankment, the River Medway passes through a reinforced concrete control structure which houses three radial gates. The radial gates can be moved to either let the river flow normally, or to restrict the flow and hold water in the FSA, to control the amount of water flowing downstream.

Figure 2-1 presents the location of the FSA embankment, and displays the extent of flood water stored upstream in the 1% AEP event, compared with a scenario in which the FSA is not present. This image helps to convey the extent of additional stored water during times of flooding.

2.1.2 Current operation of the Flood Storage Area

The Environment Agency operates the gates at the FSA during times of flood to store flood water and reduce the peak flow rate passing downstream. However, at times of exceptional rainfall, and therefore flood flows, there will still be some flooding downstream, although operation of the FSA should reduce this compared with a scenario in which the FSA was not used to control discharges.

The normal maximum operating water level (NMOWL) of the FSA, which is the top level that water can be stored at the radial gates, is 28.05mAOD. Although the height of the embankment is above this level (circa 29.00mAOD), the level of 28.05mAOD is currently the maximum level to which water can be stored.

The operation of the FSA follows two general procedures, referred to as the 'default' and 'deviate' scenarios. These are described below:

- **'Default' scenario:** Under normal circumstances, if flows associated with the River Medway passing through and downstream of the FSA are forecast to be at or below 75m^3/s then the radial gates at the FSA are not operated to impound flood water and the flow rate upstream is permitted to flow downstream. It is plausible that operation of the gates may occur at lower flow rates, in response to conditions observed in the catchment downstream which could influence flood risk, but this is an exception.
- **'Deviate' scenario:** Under conditions of elevated flow, where flows associated with the River Medway passing through and downstream of the FSA are forecast and/or observed to be above 75m^3/s, then the radial gates may be operated to store water in the FSA and reduce the flow passing downstream. Under this scenario, the Environment Agency use a reservoir balancing system informed by data on the geometry of the FSA, forecast and observed rainfall, inflows and water levels at the FSA and wider catchment, and catchment conditions downstream. Flood water levels can be stored to a maximum water level of 28.05mAOD. If water levels in the FSA are predicted to, or observed to have, risen above the 28.05mAOD maximum operating level, then the radial gates are operated to begin drawing-down water levels so that this permitted level is not exceeded.

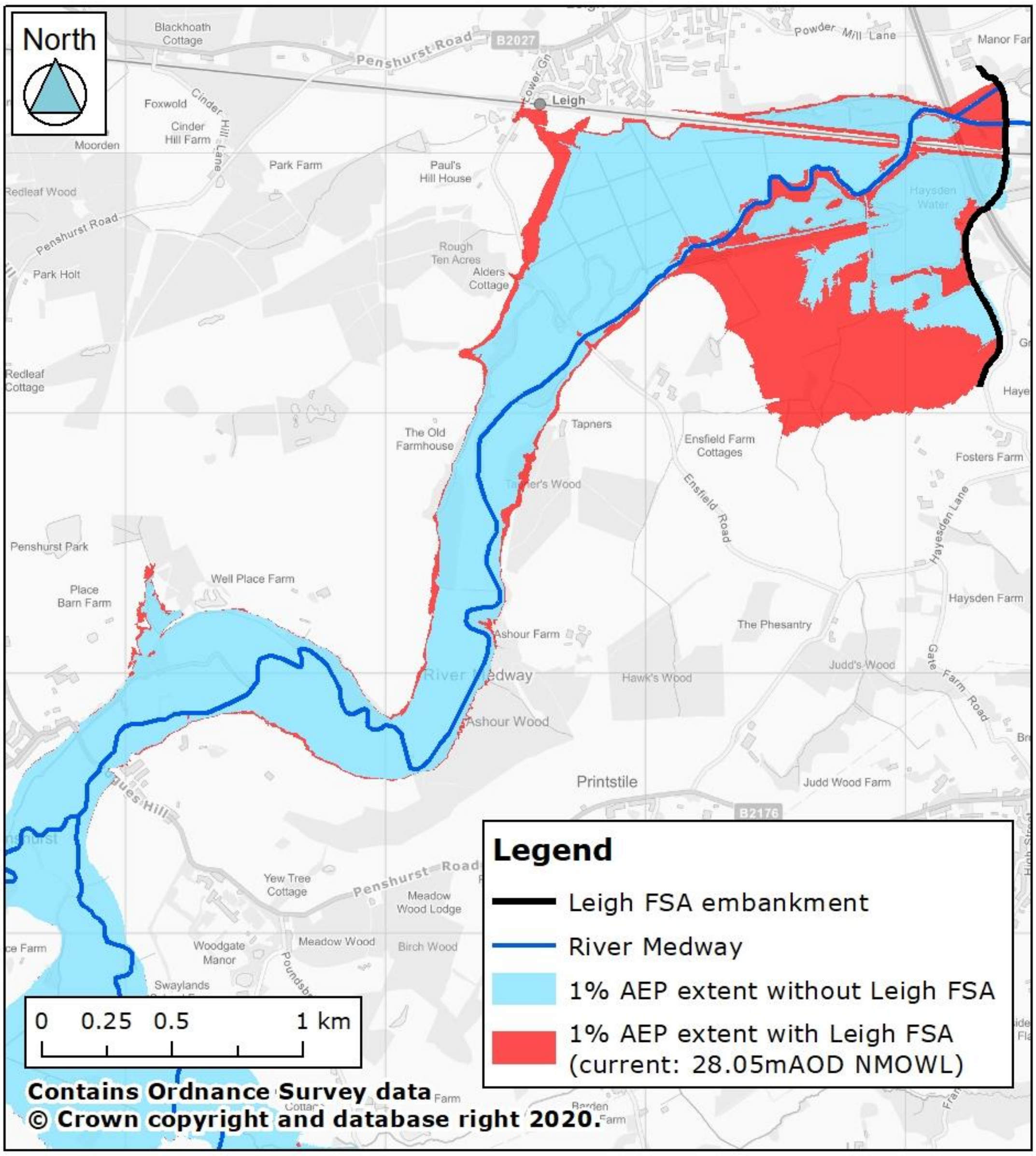

Figure 2-1: Extent of additional impoundment at the FSA (1% AEP event)

2.1.3 Conceptualising the operation of Leigh FSA

Images and the following description describe how changes in water levels and flood flows are brought about by the operation of the FSA during times of flood, and outlines the proposed increase in maximum storage level as a consequence of implementing the application proposals.

Influence of additional flood storage on event-scale: water levels

Figure 2-2 conceptualises the change in water levels expected in the FSA due to an increase in the maximum storage level and shows how the increased volume for storage of flood water is provided. The circumstance presented is one where the capacity of the FSA is not exceeded by the flood event. It should be noted that:

- Increases in water levels, compared with the current storage approach (28.05mAOD NMOWL), will be greatest at the FSA embankment, and decrease with distance upstream. This is because a.) the channel and floodplain gradient results inground levels being lower at the embankment compared with upstream and b.) the magnitude of the upstream flood flows are increasingly influential on the flood water levels as the distance from the FSA increases (until the point where the effect of the elevated storage water level at the FSA ceases to have any influence on the predicted flood level).

- The shape, size and timing of flood events differ and so the shape of the flood presented in Figure 2-2 is indicative only.

Key messages, as presented on the figure, are:

- The water levels in the FSA would be expected to be unchanged from the current 28.05mAOD NMOWL scenario, until the deviate scenario is required.
- Water would be stored to a higher level in the FSA (up to 28.60mAOD).
- Due to the large volume of water stored, water levels in the FSA may take a longer time to reduce to normal levels post-flood.

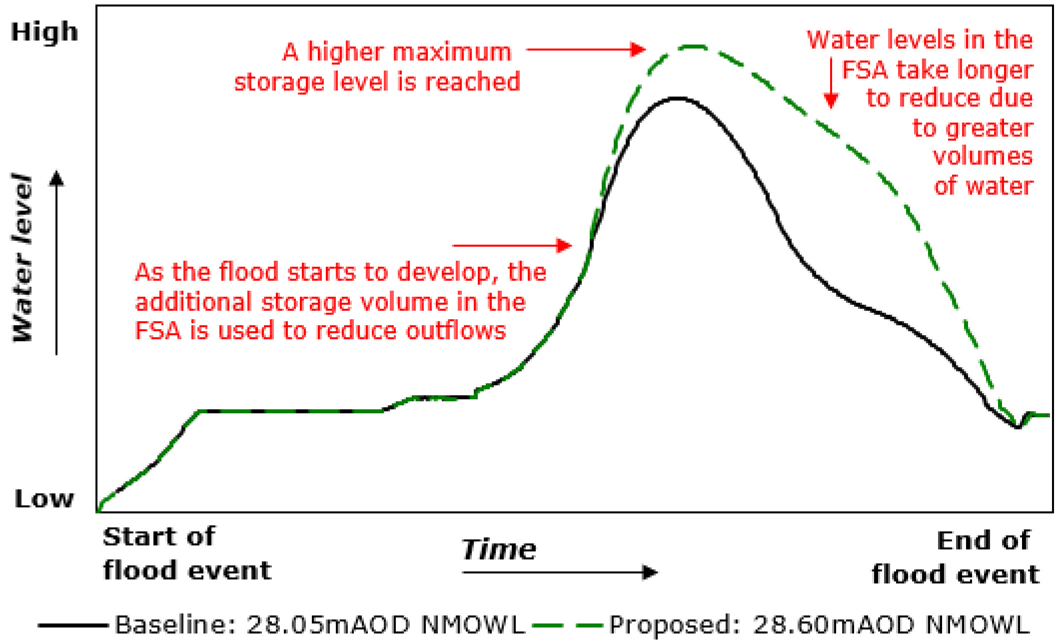

Figure 2-2: Change in water levels at Leigh FSA embankment for a single flood event

Influence of additional flood storage across all event magnitudes: water levels

Figure 2-3 conceptualises the change in peak water levels in the FSA across a large number of flood events, each of which has different peak inflows, with floods associated with larger peak inflows being of larger magnitude but less frequent.

The graph, referred to as a flood frequency curve (in this case focusing on water levels rather than flows) shows that:

- For smaller events, which reflect the ‘default’ operation scenario, there is no change in peak water levels stored in the FSA between the 28.05mAOD and 28.60mAOD NMOWL scenarios, because the gates are not operated to manage flows downstream
- For a relatively large range of flood magnitudes, the peak water levels stored in the FSA increase, up to the 28.60mAOD maximum water level, reflecting the utilisation of the additional storage volume to reduce peak flows passing downstream (this is shown as the green line being above the black line in the figure).

- Should the capacity of the FSA be forecast to be exceeded, the radial gates are operated to limit the increase in water levels in FSA. This results in little or no change in peak water level stored between the 28.05mAOD and 28.60mAOD NMOWL scenarios in these events.

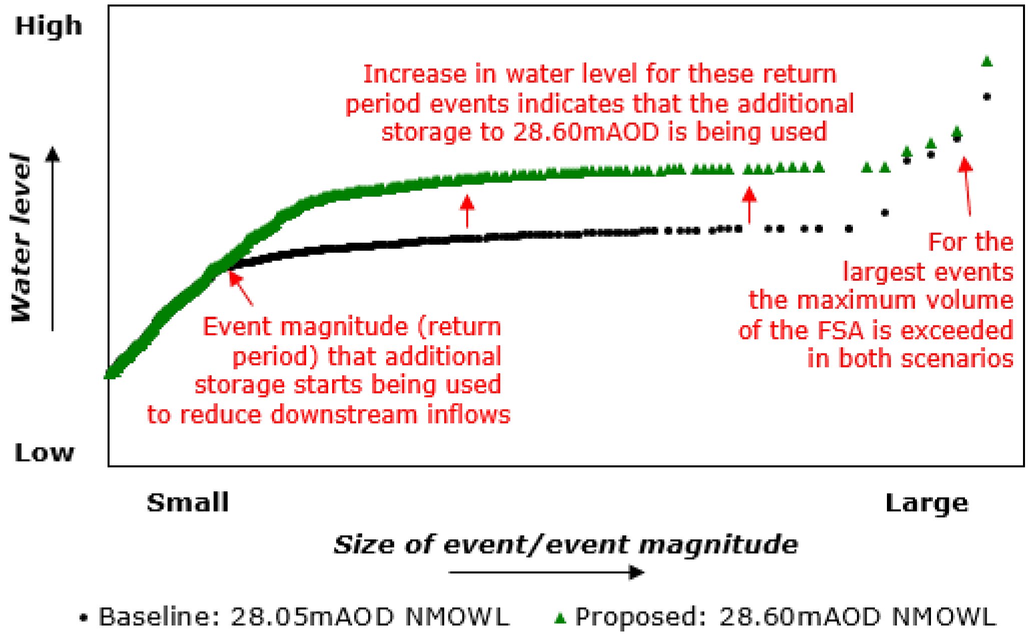

Figure 2-3: Change in peak water levels at Leigh FSA embankment across a large number of event magnitudes

Influence of additional flood storage on event-scale: outflows from Leigh FSA

Figure 2-4 conceptualises the change in outflow expected from the FSA due to an increase in the maximum storage level, which provides increased volume for storage of flood water.

It should be noted that the shape, size and timing of flood events differ and so the shape of the flood presented in Figure 2-4 is indicative only. The circumstance presented is one where the capacity of the FSA is not exceeded by the flood event.

Key messages, as presented on the figure, are:

- Outflow magnitudes from the FSA would be expected to be unchanged from the current 28.05mAOD NMOWL scenario, until they exceed 75m^3/s.
- Above 75m^3/s, the flow rate that reductions in flow occur would change according to the magnitude, shape, timing etc of the flood event, all of which influences how much flood storage is used up.
- The peak outflow in the 28.60mAOD NMOWL scenario would be reduced compared with the current 28.05mAOD NMOWL operation
- Due to the large volume of water stored in the FSA, outflows from the FSA may be released over a longer period of time, albeit at a flow rate that is lower than the peak flow that would have been released in the 28.05mAOD NMOWL scenario.

In summary, the increased volume of storage makes it possible to more frequently reduce the magnitude of peak flows experienced downstream of the Leigh FSA and this is the principal benefit afforded by the proposed scheme. It should be noted that whilst the magnitude of peak flows is reduced, the duration of the controlled discharges is potentially increased. However, this effect is predicted to be more pronounced immediately downstream of the Leigh FSA but will be less evident as the distance downstream of the FSA increases.

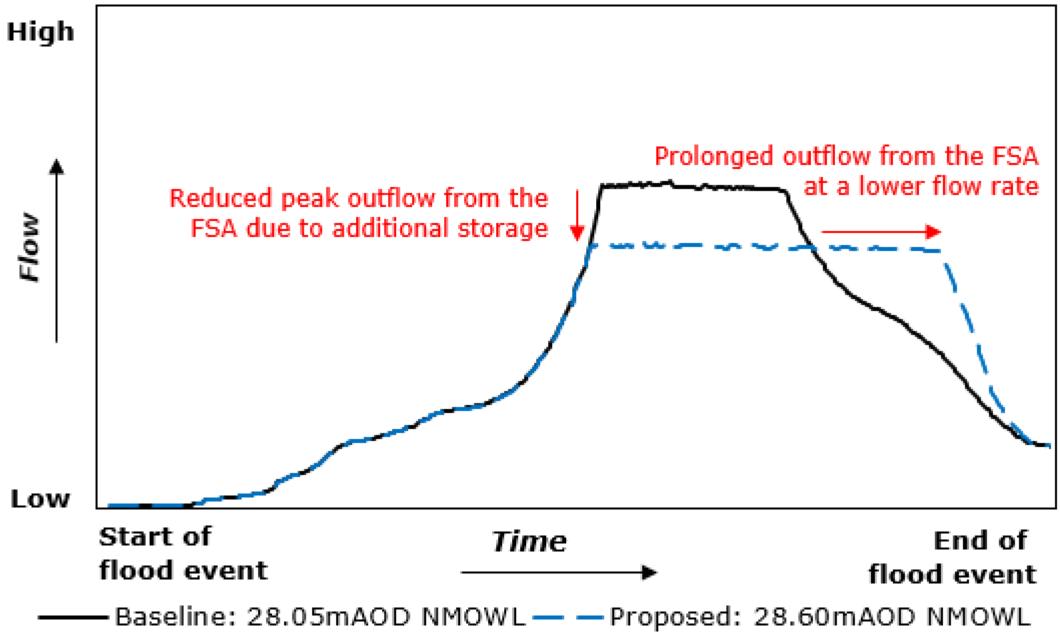

Figure 2-4: Change in outflows Leigh FSA for a single flood event

Influence of additional flood storage across all event magnitudes: outflows from Leigh FSA

Figure 2-5 conceptualises the change in peak water levels in the FSA across a large number of flood events, each of which has different peak inflows, with floods associated with larger peak inflows being a larger magnitude and less frequent.

The graph, referred to as a flood frequency curve, shows that:

- For smaller events, which reflect the 'default' operation scenario, there is no change in outflows from the FSA between the 28.05mAOD and 28.60mAOD NMOWL scenarios for a given event frequency/rarity because the gates are not operated to manage flows.
- For a relatively large range of flood magnitudes, the peak outflows from the FSA decrease for a given event frequency/rarity in the 28.60mAOD NMOWL scenario, reflecting the utilisation of the additional storage volume to reduce peak flows passing downstream.
- Should the capacity of the FSA be exceeded, in spite of the expansion of storage volume, the radial gates are operated to limit the increase in water levels in FSA . This results in little or no change in peak outflows from the FSA between the 28.05mAOD and 28.60mAOD NMOWL scenarios.

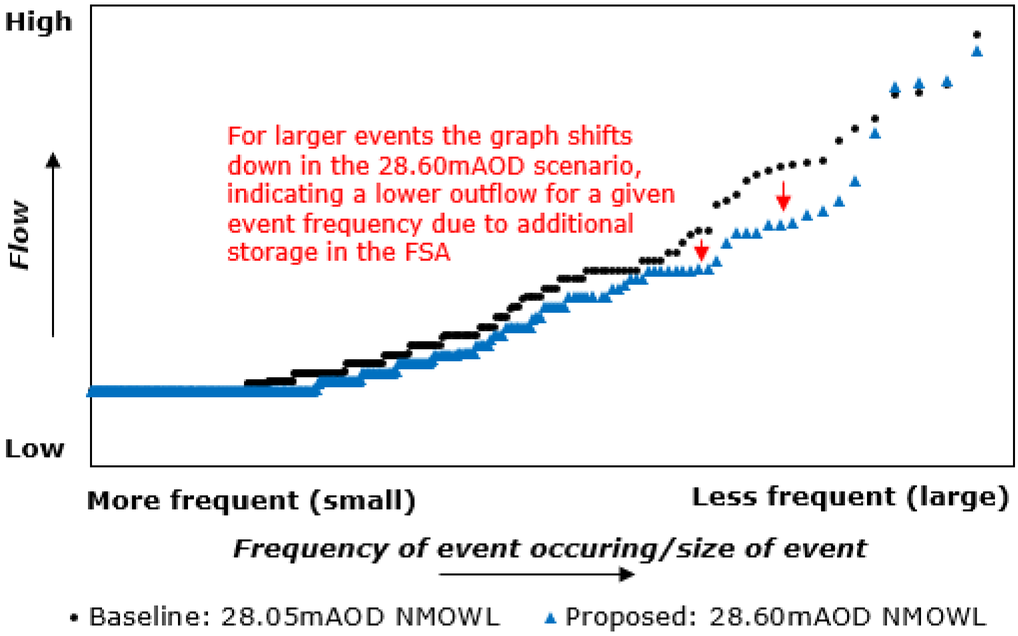

Figure 2-5: Change in peak outflows from Leigh FSA across a large number of event magnitudes

2.2 Overview of the proposed development

The proposed development can be summarised as: works to expand the capacity for storage of flood water at Leigh FSA which, subject to approval, will enable the normal maximum operating water level to be raised from 28.05mAOD to 28.60mAOD. This change will increase the storage volume from 5,850,000m^3 to 7,250,000m^3, an increase of 24%. The increased storage volume would enable greater reduction in peak flow rates and help to reduce the risk of flooding to over 1,400 homes and 100 businesses (these figures are correct when the proposals at the FSA are combined with the proposed embankment at Hildenborough).

In practice, there are numerous elements to the proposed development, including engineering (electrical, mechanical, structural etc), environmental, flood risk and safety related which are all required for the development to be brought forward. However, this Flood Risk Assessment only focuses on aspects of the development which contribute to, or are affected by, flood risk within the River Medway catchment.

Under the development scenario, the geometry of the embankment itself and the radial gates are to remain largely unchanged. Although adjustments resulting from refurbishment of engineering elements or reinforcement of the embankment may result in minor alterations to the form of such features, they are not considered material to the flood risk performance of the proposed development and whether this is acceptable from a flood risk perspective.

The existing principles used to define the regime for operating the FSA will remain consistent. Although the forecasting tools, operating systems and so on for the FSA will need to be updated to reflect the greater capacity for storage at the FSA, the overarching methodology for operation will remain. This will continue to involve using a reservoir balancing approach, informed by forecasts and observations of rainfall, flows and levels in the River Medway catchment, in addition to any observations/reports of flooding in the wider catchment.

As noted in section 1.2, unlike most developments being assessed by Flood Risk Assessments, it is known that the proposed development will increase flooding for a region of floodplain upstream of the FSA embankment, to the betterment of receptors downstream by reducing flood flows at the peak of flood events.

In light of this, it has been important for the development to include the provision for mitigation measures so that increased water levels associated with the expansion of flood storage capabilities does not adversely affect third parties.

The individual elements of the scheme are discussed and mapped in section 2.3.

2.3 Specific details of the development proposals

Figure 2-6 presents the location of specific elements of the development and the red line boundaries associated with these, while Table 2-1 describes each element.

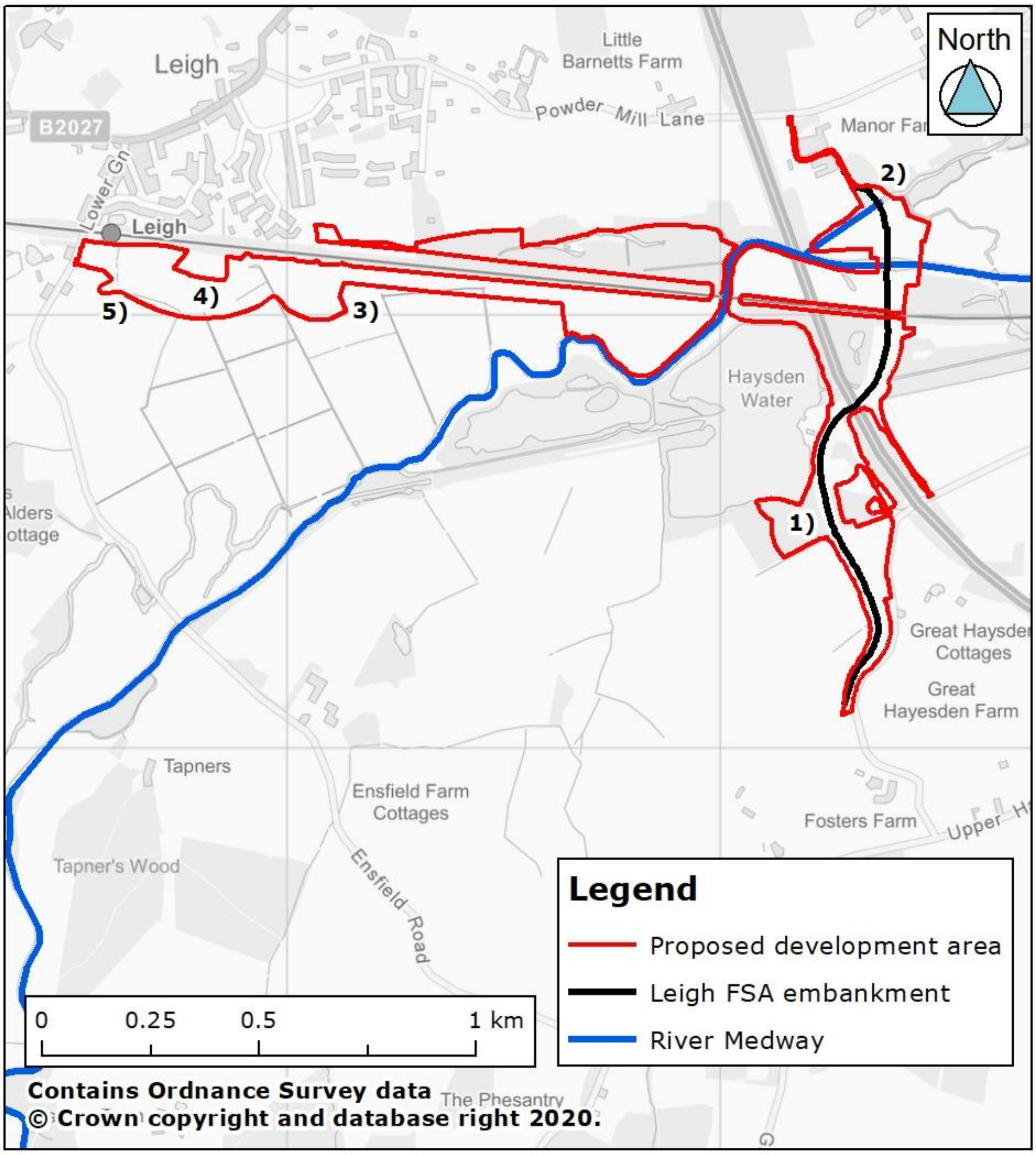

Figure 2-6: Location of specific red line boundaries for elements of the scheme

Table 2-1: Description of the various elements of the proposed development

Element of the proposed development	Description	Benefit in terms of flood risk
1) Leigh FSA Embankment	• Reinforcement of the crest and downstream face of the embankment. The materials will extend up to 6m beyond the embankment toe drain • An existing bridleway across the embankment will be resurfaced • Embankment raising is not required as it is high enough to accommodate proposed raising of the NMOWL	• Enables raising of the NMOWL to 28.6mAOD, increasing the capacity of water that can be stored to reduce the flood flows released downstream. • Improves safety as the embankment surface should be able to withstand the velocity/volume of water predicted to pass over. • Reduces the likelihood of residual risks occurring e.g. breach failure
2) Leigh FSA control structures	• Refurbishment and modifications to Leigh FSA control structures • Includes strengthening and increasing the height of the gates to 28.6mAOD when closed • Replacement and repairs to existing FSA gates and drive equipment • Installation of an eel pass	• Enables raising of the NMOWL to 28.60mAOD, increasing the capacity of water that can be stored to reduce the flood flows released downstream • Improves on present reliability/safety of existing control structure.
3) Cattle Arch Embankment	• Raising of the existing embankment up to 29.52mAOD with earth fill • Installation of 300mm vertical 'gravel board' wave return wall on front shoulder of embankment • Existing ramp for a public footpath and access over the embankment will also be raised to extend over the new crest, with the ramp footprint increased (eliminating the need for a flood gate)	• Reduces the likelihood and risk associated with overtopping of the embankment by wind driven waves when the NMOWL of Leigh FSA is raised. • If this mitigation measure is not adopted, the Leigh FSA Expansion may result in increased flood risk to third party land.
4) Southern Water pumping station and Archimedes screw	• A new raised defence will be constructed comprising a combination of; raising an existing earth embankment, installing a new low level concrete wall, road raising and a new length of earth embankment. • The raised defence will be constructed along the crest of existing earth embankment south of the pumping stations, extending towards Ensfield Road along southern edge of an existing access road. • Before Ensfield Road the defence will turn southwest across a	• Mitigates flood risk to the pumping station and Archimedes screw, located to north of proposed embankment, associated with raising the NMOWL of Leigh FSA. • In conjunction with item 5 below, and the deployment of additional pumping during times of flood, this reduces the likelihood and magnitude of flooding to an area behind the embankment, including at Ensfield Road. • If this mitigation measure is not adopted, the Leigh FSA

Element of the proposed development	Description	Benefit in terms of flood risk
	small channel and tie into high ground in the form of a new embankment • Installation of 300mm vertical 'gravel board' wave return wall on front shoulder of embankment	Expansion may result in increased flood risk to third party land.
5) Leigh Embankment pumping platform	• Hardstanding platform installed for operation of temporary pumps with a footprint of approximately 10 x 15m • Flap valve enabling water from the small watercourse to flow through the embankment into Leigh FSA, but not permit water in Leigh FSA to flow northwards to land behind the embankment	• Pumps will be deployed at the pumping platform and operated in an extreme flood event if needed when a.) the FSA is impounded and b.) water needs to be pumped from the small fluvial system north of the embankment into the FSA to reduce water levels • The flap valve will prevent impounded water from the FSA flowing in the area north of the embankment • If this mitigation measure is not adopted the Leigh FSA Expansion may result in increased flood risk to third party land.

3 Existing development: Present and climate change flood risk

3.1 Present day and climate change flood risk information for the current operation regime

3.1.1 Information available

Information relating to flood risk within the Leigh FSA and for the catchment downstream is informed by the projects stated in Table 3-1. Each of these has provided modelling and/or mapping that has been used to inform the evidence presented for this FRA.

Modelled flood events for various flood magnitudes, referred to as 'design events', have been used and are presented in this document to evidence the likely changes in flooding brought about by the proposed development. Each design event represents one particular flood condition for a given flood magnitude (which is informed by the peak flow of the event). In reality, different flood conditions (resulting in different timings, shapes etc of the flood hydrograph) could occur and would be managed according to the operational procedures at the FSA. The design event modelling for changes at Leigh FSA focused on single-peaked flood events (e.g. without preceding flood events) as is typical when considering design events. Consideration of potential impacts should atypical events occur is discussed in section 5.3.1.

Table 3-1: Projects informing the understanding of flood risk associated with the development

Project name	Information available
Medway Catchment Mapping and Modelling *(JBA Consulting for the Environment Agency, 2015)*	Flood risk modelling and mapping information for the River Medway catchment upstream and downstream of Leigh FSA, for both defended and undefended scenarios. A suite of flood magnitudes were modelled, including climate change tested for the 1% AEP event with an uplift of +20%.
Medway Scenario Modelling: climate change modelling *(JBA Consulting for the Environment Agency, 2016)*	Flood risk modelling and mapping information for the River Medway catchment upstream and downstream of Leigh FSA, for both defended and undefended scenarios. Modelling/mapping was prepared for the 1% AEP event, with climate change flow allowances of +35% and +70% tested.
Leigh FSA Exceedance Study - MIOS 2017 *(JBA Consulting for the Environment Agency, 2018)*	Flood risk modelling and mapping for various scenarios to inform responses to the Measures in Interest Of Safety (MIOS) points made by Leigh FSA's Inspecting Engineer. The modelling included the simulation of breach failure scenarios from the reservoir.
Leigh Expansion and Hildenborough Embankment Scheme Outline Business Case flood modelling *(JBA Consulting for VBA Joint Venture Limited, 2019 commissioned by the Environment Agency)*	Flood risk modelling and mapping information for the River Medway catchment upstream and downstream of Leigh FSA, for defended case scenarios in which the NMOWL of the FSA is increased. Scenarios tested were 28.60mAOD, 28.85mAOD and 29.00mAOD, although a greater number of scenarios were prepared for the 28.60mAOD at the time of delivery at this NMOWL became the preferred option.

Project name	Information available
Leigh Expansion and Hildenborough Embankment Scheme Outline Business Case *(JBA Consulting for the Environment Agency, current)*	Additional flood risk modelling and mapping scenarios prepared for the River Medway at Leigh FSA. Scenarios focused on the proposed NMOWL scenario of 28.60mAOD.

3.1.2 Change in flood risk if the proposed scheme was not taken forward

Figure 3-1 displays how flood extents through Tonbridge are predicted to change for the 1% AEP event as a result of climate change for the current operation at 28.05mAOD NMOWL. Flow allowances of +20% and +35% are presented, providing context to the Higher central and Upper end change scenarios that the Environment Agency's guidance suggests should be considered within FRAs for flood risk over the 45-year lifetime of development – refer to section 4.1.1 (note: these allowances are included to set the context for risk at residential properties).

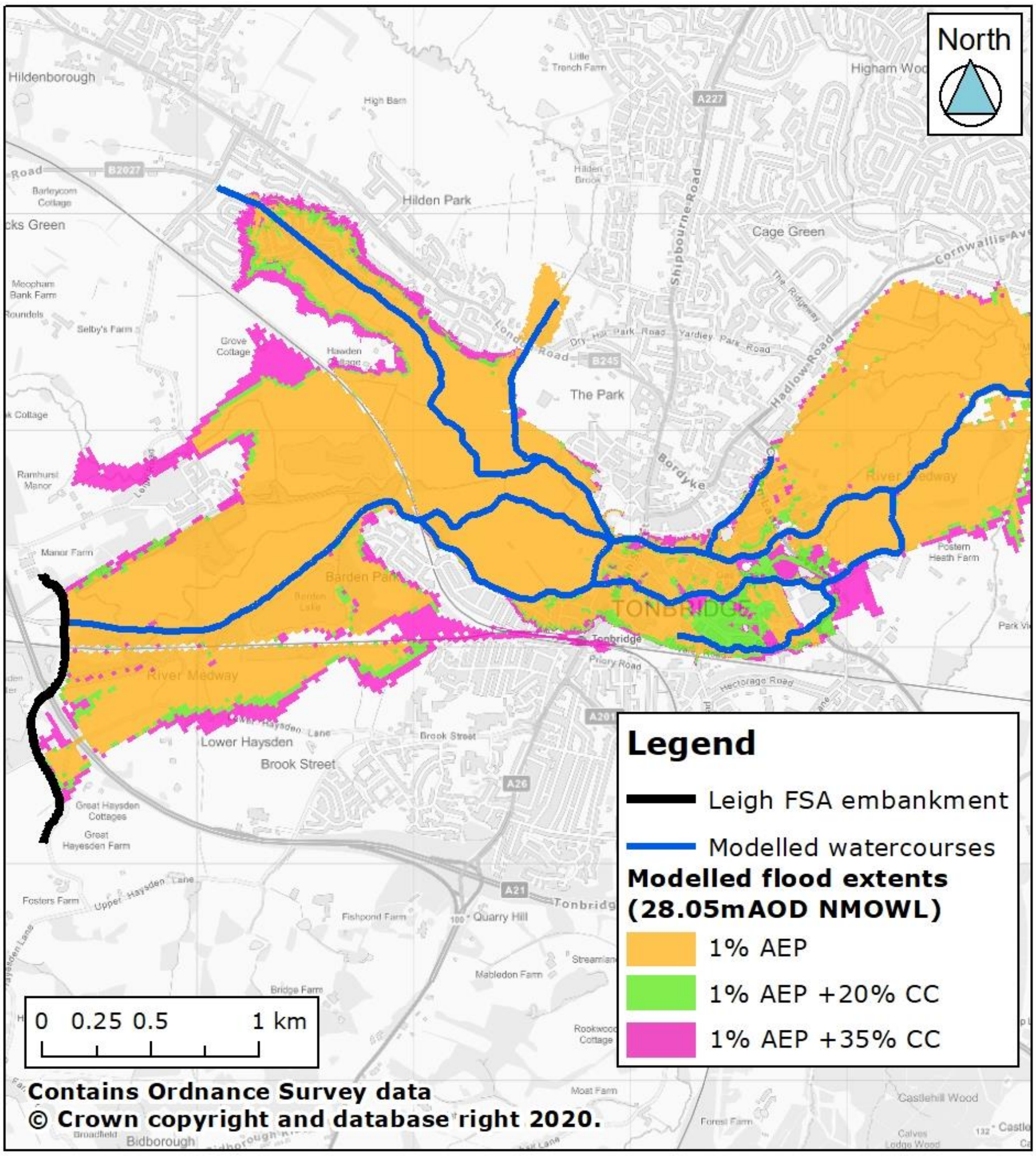

Figure 3-1: Comparison of the present day 1% AEP flood extent and 1% AEP plus climate change flood extents

For both climate change scenarios, flood extents increase considerably through Tonbridge, also in residential areas of Hildenborough, as well as the area immediately downstream of the embankment. Peak water levels in the floodplain immediately downstream of the embankment are predicted to increase by around 0.2m in the +20% flows scenario, with increases of around 0.3m upstream of High Street in the centre of Tonbridge and 0.2m at Hildenborough. For the 1% AEP +35% flows scenario, changes in flood extents are less marked when compared against the +20% flows scenarios, but changes in water levels are more notable. Compared with the present day, peak water levels in the floodplain downstream of the embankment are predicted to increase by circa 0.7m, with increases of circa 0.8m and 0.6m at the High Street and Hildenborough, respectively.

Therefore, without measures to help manage flood risk, the impact of climate change on flood flows is expected to notably increase risk through Tonbridge and beyond.

3.2 Fluvial flood risk

3.2.1 Risk within the Flood Storage Area

The influence of Leigh FSA upstream of the embankment during the 1% AEP event is displayed in Figure 2-1, which compares flood extents from the ‘defended’ scenario representing the FSA at its current operational level of 28.05mAOD NMOWL with extents for the ‘undefended’ scenario where the FSA is not present.

The impounding of water in the defended scenario results in increased flood extents upstream of the FSA embankment. The change in flood extents becomes less marked with distance upstream of the embankment.

For the 1% AEP event, peak flood levels in the channel immediately upstream of the embankment are approximately 3.5m higher for the defended scenario compared with the undefended scenario, reflecting the storage of flood water. For context, at the downstream of Rogues Hill road bridge, Penshurst, the defended case 28.05mAOD NMOWL scenario increases flood depths by only 0.15m compared with the undefended scenario.

3.2.2 Risk from the presence of the Flood Storage Area

The existing impact of Leigh FSA on fluvial flooding during the 1% AEP event is displayed in Figure 3-2. This compares flood extents from the defended scenario representing the FSA at its current operational level of 28.05mAOD with extents for the undefended scenario.

It can be seen that the storage of flood water in the FSA, and corresponding reduction in outflows from the FSA, decreases flood extents across large areas of Tonbridge and Hildenborough. For the 1% AEP event, peak flood levels immediately downstream of the embankment are predicted to reduce by circa 0.4m due to operation of the FSA, with reductions of circa 0.3m predicted in the centre of Tonbridge and Hildenborough.

3.3 Surface water flood risk

3.3.1 Risk within the Flood Storage Area

The Environment Agency Risk of Flooding from Surface Water mapping for an area close to the FSA embankment is displayed in Figure 3-3. Overland flow routes contribute flood water to the FSA, as expected, but overall surface water flood risk within the Leigh FSA and the surrounding area is generally low. Accumulation of surface water is predicted behind some raised infrastructure e.g. the railway line and embankments close to the village of Leigh, some of which form part of the proposed scheme and have works proposed to help manage this risk (refer to Figure 2-6 and Table 2-1).

Given the proposed development is associated with facilitating the storage of flood water, the presence of surface water flood risk to parts of the FSA are is not considered to preclude development and the volumes of surface water flooding are very small compared to the existing and proposed increase to the capacity of the storage area.

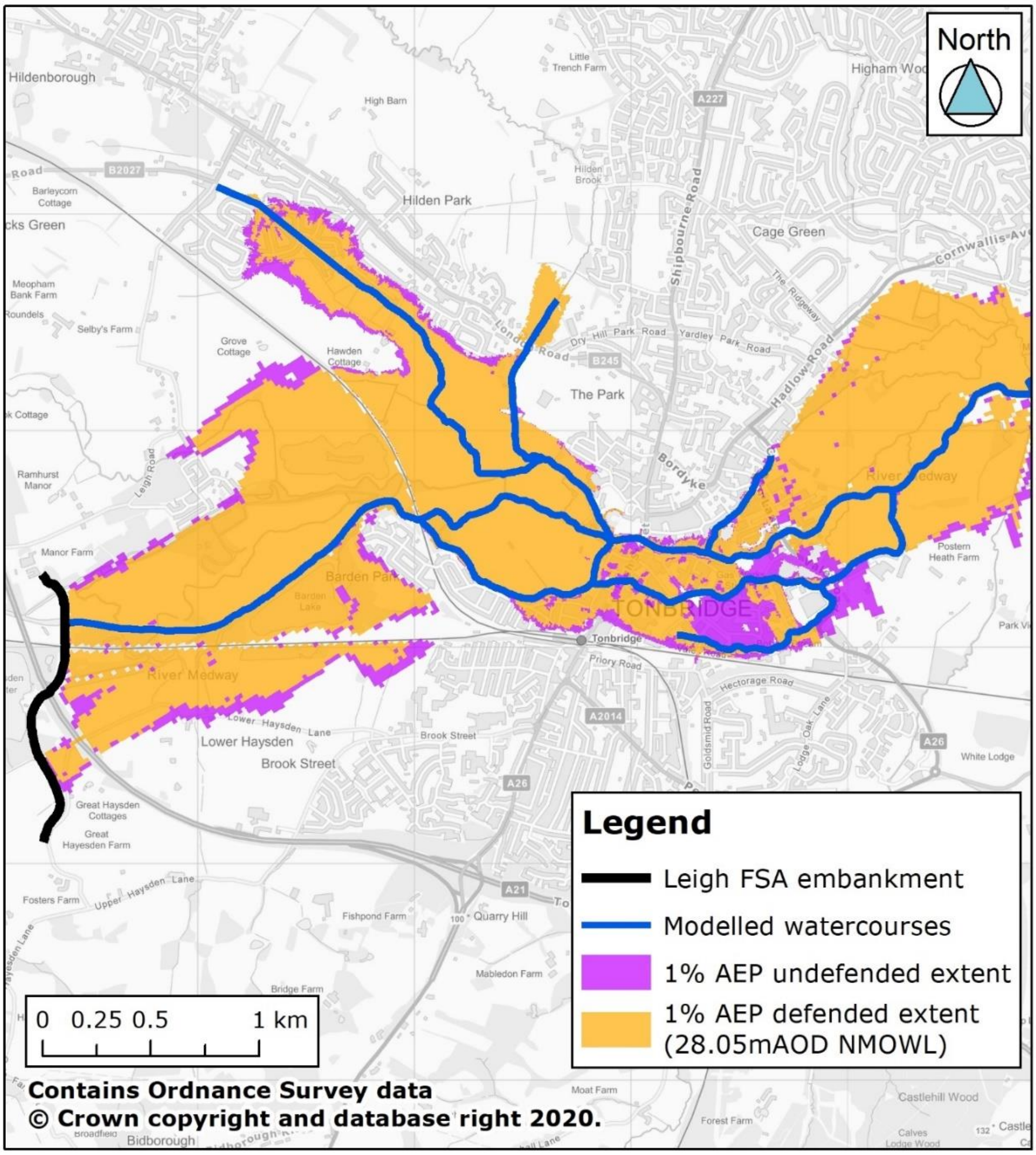

Figure 3-2: Present day 1% AEP undefended vs defended (28.05mAOD NMOWL) flood extents through Tonbridge

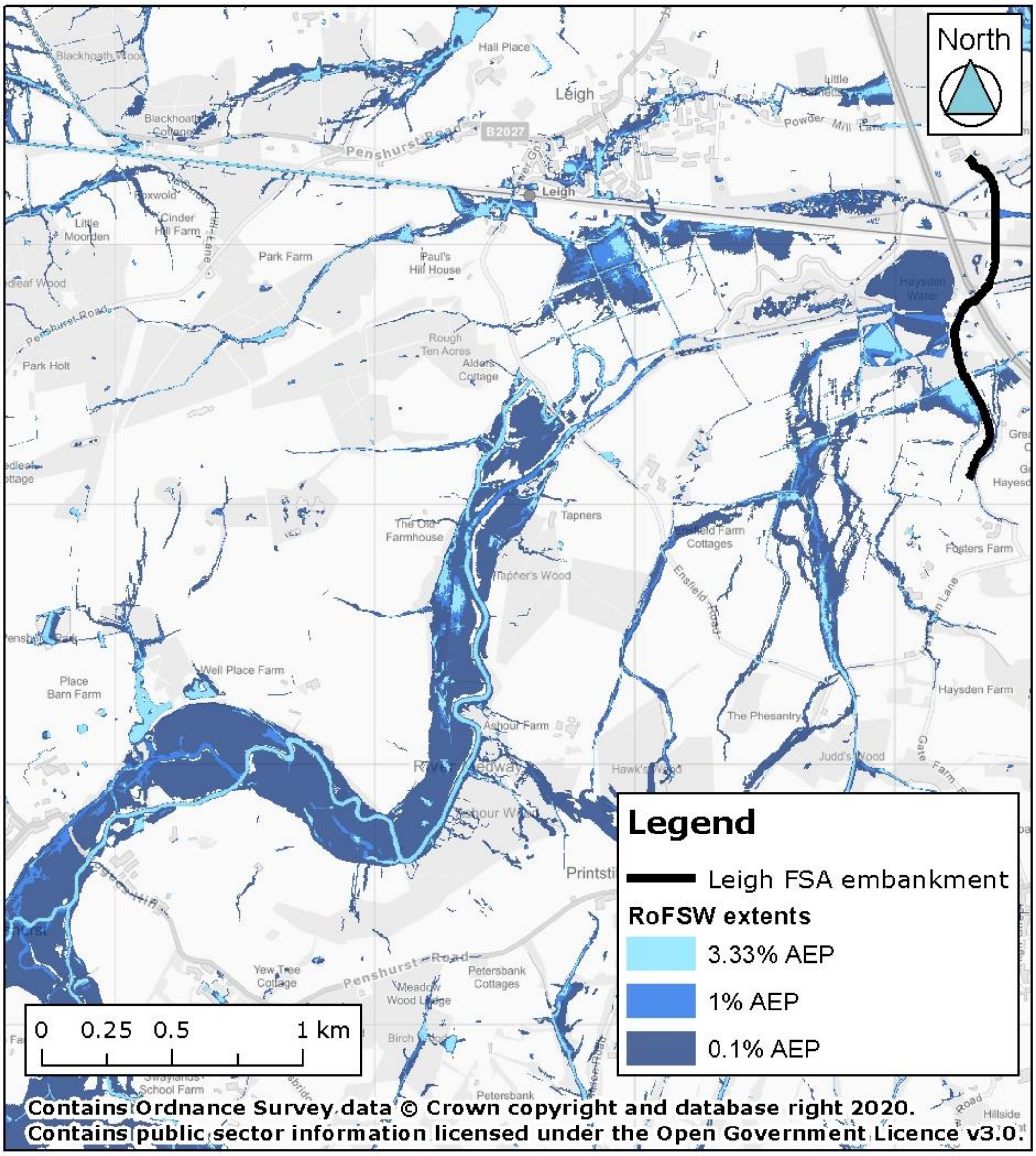

Figure 3-3: Surface water flood risk extents at Leigh FSA

3.3.2 Risk from the presence of the Flood Storage Area

The presence of Leigh FSA is considered to cause little change to surface water flood risk in the surrounding area. If the FSA was not present, then the need for Cattle Arch embankment and associated pumping stations would be removed. However, currently there is infrastructure to manage this risk and the proposed development includes measures to continue for this to be managed in the future. Beyond the potential for very localised runoff of rainfall from the FSA's embankment, downstream of the FSA, its presence does not increase surface water flood risk.

3.4 Groundwater flood risk

3.4.1 Risk within the Flood Storage Area

The risk of groundwater flooding at the Leigh FSA is documented in the Strategic Flood Risk Assessments (SFRAs) for the councils of Sevenoaks District[1], Tonbridge and Malling Borough[2] and Tunbridge Wells District[3]. Mapping in the SFRAs displays the Environment Agency's Areas Susceptible to Groundwater Flooding dataset. The groundwater mapping shows that the proportion of each 1km grid cell that the dataset presents may be susceptible to groundwater flooding typically is categorised as 25-50%, with 50-75% reported for the area immediately upstream of the FSA embankment. The risk in the area is likely to be attributed to presence of waterbodies and the alluvial nature of deposits associated with the river.

If groundwater emergence were to occur within Leigh FSA it would slightly reduce the storage capacity available within the FSA for the storage of flood water. However, the volumes of groundwater flooding are likely to be very small when compared with the total capacity of the FSA. Additionally, the operational procedures and methods used to inform storage within the FSA make use of water levels that are monitored in the FSA, so accounts for this influence.

3.4.2 Risk from the presence of the Flood Storage Area

The presence of Leigh FSA is considered to cause little change to the risk of flooding from groundwater in the surrounding area.

3.5 Reservoir breach failure flood risk

3.5.1 Risk within the Flood Storage Area

Breach failure of reservoir is considered a residual risk. While the consequences of breach failure are typically high, the likelihood of failure is considered low for large reservoirs which fall under the Reservoirs Act 1975, given requirements for inspection and monitoring that are imposed on them.

The Environment Agency's Risk of Flooding from Reservoirs mapping shows that should breach failure of Bough Beech or Weir Wood reservoirs occur, then flood water would be expected to flow into Leigh FSA. Flood depths are predicted to be in excess of 2m, while flood flow velocities would be below 0.5m/s at the FSA embankment located upstream were to breach.

The proposed expansion of storage at Leigh FSA is not expected to change the flooding within the FSA should this residual risk of flooding materialise, given the top level of the embankment and the overall control structure configuration of the FSA is not going to change. Therefore, the potential for upstream breach failure does not preclude progressing with the proposed development.

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[1] Sevenoaks District Council Level 1 SFRA: Appendix F groundwater flood map, Sevenoaks District Council, Sheet 8, 2017. Available: https://www.sevenoaks.gov.uk/downloads/file/1527/env014_strategic_flood_risk_assessment_-_appendix_f_-_groundwater_flooding

[2] Tonbridge and Malling Borough Council Level 1 SFRA: Appendix F groundwater flood map2, Tonbridge and Malling Borough Council, Sheet 23, 2017. Available: https://www.tmbc.gov.uk/__data/assets/pdf_file/0018/241047/SFRA_Appendix_F_AstGWF_part4.pdf

[3] Tunbridge Wells Borough Council Level 1 SFRA: Appendix F groundwater flood map3, Tunbridge Wells Borough Council, Sheet 29, 2019. Available: http://opendatanew-tunbridgewells.opendata.arcgis.com/datasets/twbc-sfra-appendices

3.5.2 Risk from the presence of the Flood Storage Area

The Environment Agency's Risk of Flooding from Reservoirs mapping presents the risk from all reservoirs combined into one dataset. Downstream of Leigh FSA the presence of flood mapping from other reservoirs may influence the extents displayed. Therefore, Figure 3-4 presents the modelled flood extent through Tonbridge predicted from breach failure of Leigh FSA prepared as part of the Environment Agency's Leigh FSA MIOS (2017) project.

The extent mapping shows that large areas of the Medway floodplain, as well as developed areas of Tonbridge and Hildenborough are at risk of flooding from a breach event at the FSA. Downstream of Leigh FSA, much of the River Medway floodplain would be inundated, including parts of Little Mill and East Peckham, including extension to the settlements of Laddingford and Yalding on the River Teise and River Beult floodplains, respectively.

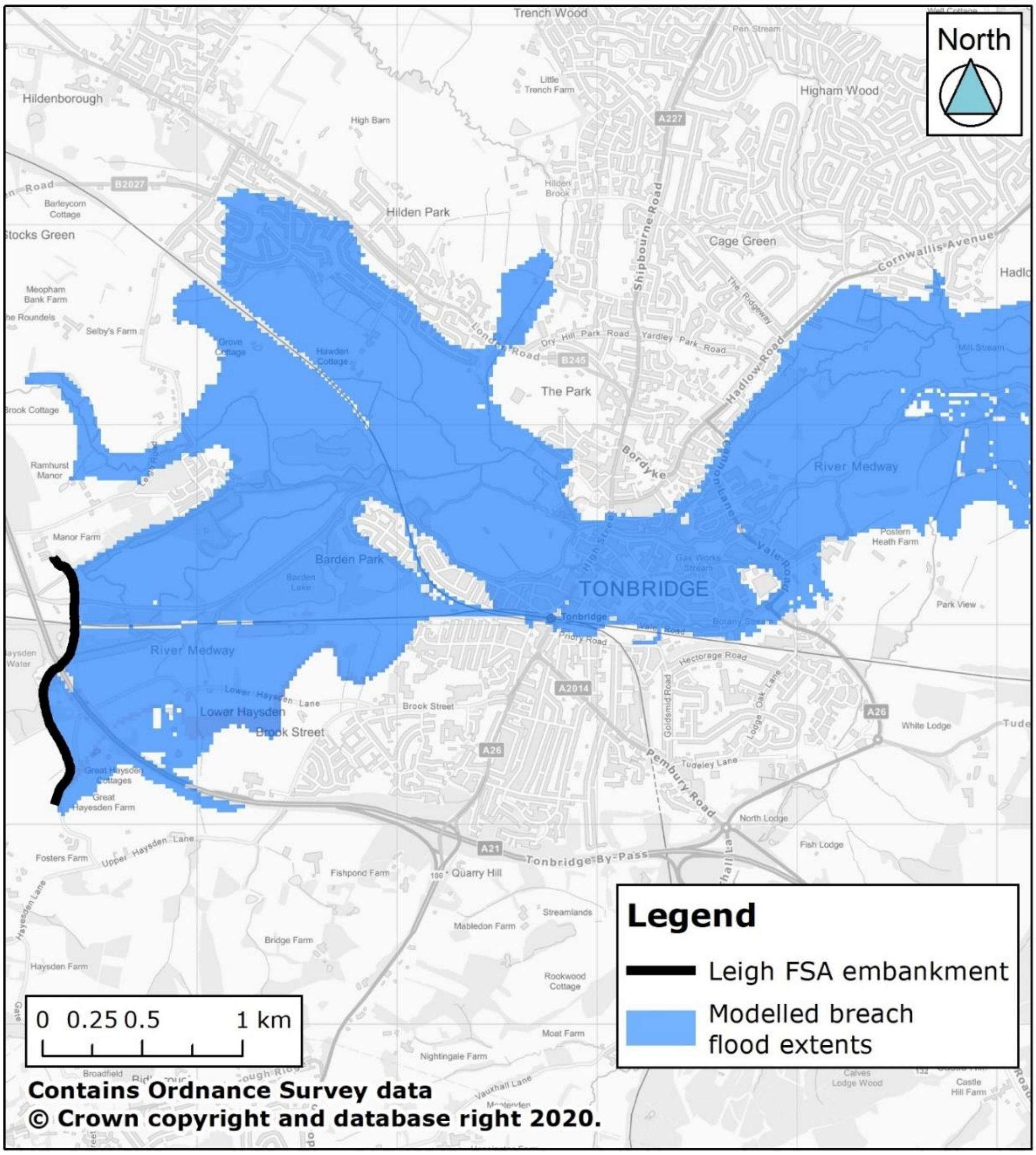

Figure 3-4: Flood extent predicted from breach failure of Leigh FSA

Mapping of reservoir breach failure considers that the water level in the FSA is at the embankment crest level at the time of breach and a large flood event is also occurring upstream. Therefore, given the proposed development is not adjusting the embankment levels of the FSA, the breach mapping remains representative of the residual risk associated with breach failure of the FSA.

4 Planning policy

4.1 Planning context and relevant authorities

4.1.1 Lifetime of the development

The lifetime of the development is taken as 45-years and the appraisal process has been completed on this basis. Following this time-period, the operation approach at the FSA would not be expected to change. However, should predicted increases in flow rates resulting from climate change continue, the benefit provided by the FSA (and therefore the proposed development) may be expected to reduce given that flood volumes may increase meaning peak flow rates cannot be reduced as much as originally designed.

4.1.2 Applicable climate change flow allowances

The Environment Agency's guidance applicable to the appraisal of flood risk management infrastructure developments is: *Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities (2016)*.

The 2050s epoch (covering the years 2040-2069) aligns with the proposed lifetime of the development and indicates that the Higher central flow allowance is +25%, while the Central estimate is +15%. The allowance advised as applicable to the proposed development is +15% flows and the assessment is made on this basis. In practical terms, some of the modelling available for the River Medway focuses on larger climate change allowances (e.g. +20%, +25% and +35%) and some of this information is relied upon to inform this Flood Risk Assessment. Given these larger increases in flow rates present a more worst-case scenario that +15%, this is considered appropriate.

4.1.3 Relevant authorities

A number of authorities operate within, and therefore influence the decisions relating to the proposed development. These are summarised in Table 4-1, with context provided to how they are influenced by, or interact with the proposed development.

Table 4-1: Authorities influenced by, or interacting with, the proposed development

Authority	Influence/interaction with the proposed development
Environment Agency	Applicant and statutory consultee.
Maidstone Borough Council	Local Planning Authority: Located circa 12km downstream of the Leigh FSA. Flood risk is predicted to be reduced in this area due to the proposed development.
Sevenoaks District Council	Local Planning Authority (lead authority dealing with the application): The FSA is partly located within Sevenoaks District. Flooding is predicted to increase in this area as a result of the increased maximum storage level in the FSA.
Tonbridge and Malling Borough Council	Local Planning Authority: The FSA is partly located within Tonbridge and Malling Borough. Flooding is predicted to increase in the FSA as a result of the increased maximum storage level in the FSA. However, much of the borough benefits from reduced flood risk due to the proposed development

Authority	Influence/interaction with the proposed development
Tunbridge Wells Borough Council	Local Planning Authority: The FSA is partly located within Tunbridge Wells Borough. Flooding is predicted to increase in this area as a result of the increased maximum storage level in the FSA.
Kent County Council	Lead Local Flood Authority and Highway Authority
Upper Medway Internal Drainage Board	Watercourses that are the responsibility of the Internal Drainage Board are located within the FSA.

4.2 Development in Flood Zones

For the purposes of applying the National Planning Policy Framework (NPPF), flood risk is a combination of the probability and the potential consequences of flooding from all sources – including from rivers and the sea, directly from rainfall on the ground surface and rising groundwater, overwhelmed sewers and drainage systems, from reservoirs, canals and lakes and other artificial sources. Section 3 identifies that fluvial flood risk is the most influential flood mechanism within and downstream of the FSA (indeed this is what the proposed development intends to improve through the provision of additional storage capacity in the FSA), and consideration of flood risk from other sources would not preclude development. Therefore, the assessment presented below focuses principally on fluvial flood risk.

Table 1, Paragraph 65 of the NPPF Planning Practice Guidance (PPG) for Flood Risk and Coastal Change[4] presents flood risk categorised into a series of Flood Zones. Flood Zones 2 and 3a typically reflect a situation in which flood risk management infrastructure (such as Leigh FSA) is absent. However, given storage of water in the FSA increases the extent of flooding in its footprint, the area is marked as Flood Storage Area on Flood Zone mapping published by the Environment Agency and Flood Zones within the FSA can be considered to reflect the maximum extent of the defended and undefended flood extents combined.

Section 4.3 shows how the Flood Zones relate to a sequential planning response, as advised in the NPPF.

4.3 NPPF and PPG Flood Zones and risk tables

When considering whether a proposed development is appropriate within a given Flood Zone, the vulnerability of the development needs to be considered. The vulnerability classification for development types is presented in Table 2, Paragraph 66 of the NPPF PPG for Flood Risk and Coastal Change[5]. The proposed development at Leigh FSA is considered "Water-compatible development" as it comprises flood control infrastructure.

Table 3[6] of the NPPF PPG identifies Water-compatible development is considered appropriate development for all Flood Zones, albeit for Flood Zone 3b, the development should:

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[4] Table 1: Flood Zones, from the National Planning Policy Framework Planning Practice Guidance, Paragraph: 065 Reference ID: 7-065-20140306. Available: https://www.gov.uk/guidance/flood-risk-and-coastal-change#Table-1-Flood-Zones
[5] Table 2: Flood risk vulnerability classification, from the National Planning Policy Framework Planning Practice Guidance, Paragraph: 066 Reference ID: 7-066-20140306. Available: https://www.gov.uk/guidance/flood-risk-and-coastal-change#Table-2-Flood-Risk-Vulnerability-Classification
[6] Table 3: Flood risk vulnerability and flood zone 'compatibility', from the National Planning Policy Framework Planning Practice Guidance, Paragraph: 067 Reference ID: 7-067-20140306.

- remain operational and safe for users in times of flood;
- result in no net loss of floodplain storage; and
- not impede water flows and not increase flood risk elsewhere.

The Environment Agency as asset owners and operators will be obliged to ensure that the FSA remains operational and safe in times of flood. Their reservoir inspection regime, flood management and operation procedures will help achieve this. No net loss of floodplain storage is associated with the development: the development is increasing the available storage volume in times of flood and making use of this to reduce flooding downstream.

While it is accepted that the proposed development will intentionally increase flood depths in the FSA during times of storage, the risk of flooding to receptors e.g. property is not increased as a result of these activities. This consideration in the context of the proposed development is presented in section 5. The land upstream of the FSA used for flood storage is considered to be functional floodplain.

4.4 Planning Guidance Review

4.4.1 Local Plans

The Leigh FSA is predominantly located within Sevenoaks District, with the existing Sevenoaks Local Plan adopted in February 2011. Within Section 5 outlining strategic policies for the district, the Local Plan states that to adapt to climate change, winter water storage reservoirs and other sustainable land management practices that increase flood storage capacity will be encouraged[7]. At the time of writing the emerging Local Plan for Sevenoaks is yet to be adopted. However, in the proposed Local Plan's discussion of Flood Risk and Sustainable Drainage it is stated that an issue for the district to address will be looking for opportunities to work with natural processes to reduce flood risk, for example, consideration of construction storage schemes to protect urban areas downstream in partnership with neighbouring authorities, organisations and water management bodies[8].

The Local Plans for the other local authorities that are interacting with or affected by the Leigh FSA expansion (see Table 4-10) do not contain policies specific to the proposed development.

4.4.2 Strategic Flood Risk Assessments

The Level 1 SFRAs for Tonbridge and Malling Borough Council[9] and Maidstone Borough Council[10] both identify fluvial flooding from the River Medway as the primary cause of flood risks within their administrative boundaries, with both boroughs located downstream of the Leigh FSA. Both SFRAs highlight the impact of the current Leigh FSA in reducing the flood risk from the Medway, though identify the residual risks of a potential breach from the storage area. The Tonbridge and Malling Borough Council SFRA emphasises the benefits of the Leigh FSA, stating it was instrumental in preventing severe flooding in Tonbridge during the October 2000 floods. However, both SFRAs state that despite 5.5 million cubic metres of water being stored within the FSA in December 2013, there was insufficient capacity to prevent flooding from

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Available:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/575184/Table_3_-_Flood_risk_vulnerability_and_flood_zone__compatibility_.pdf

[7] Sevenoaks District Council, Local Plan Core Strategy, p. 62-63, 2011. Available: https://www.sevenoaks.gov.uk/info/20069129/current_local_plan

[8] Sevenoaks District Council, Proposed Local Plan Submission, p 102, 2018. Available: https://www.sevenoaks.gov.uk/info/20069131/emerging_local_plan/463/local_plan_examination_library_index_including_evidence_base_documents

[9] Tonbridge and Malling Borough Council, Level 1 Strategic Flood Risk Assessment Final Report, 2016.

[10] Maidstone Borough Council, Level 1 Strategic Flood Risk Assessment Addendum Report, 2016.

the Medway downstream. Within Tonbridge and Malling Borough a total of 436 properties were flooded, with Tonbridge, Hildenborough, and East Peckham among the worst affected areas, while 262 properties were flooded in Maidstone, with communities in Laddingford, Yalding, Collier Street, and Maidstone affected.

The Tonbridge and Malling Borough SFRA identifies FSAs as a potential strategic mitigation measure, highlighting the expansion of the FSA as the most likely option for potentially reducing flood risk from the River Medway within the borough.

The Sevenoaks District Council Level 1 SFRA[11] states that the majority of the impounded area within the Leigh FSA is within the Sevenoaks District, reducing the flood risk to neighbouring authorities downstream. The SFRA also identifies the potential for expanding the Leigh FSA to benefit neighbouring authorities, highlighting the council's involvement in a partnership with the Environment Agency, Kent County Council, and Tonbridge and Malling Borough Council to bring forward plans to increase the capacity.

The Tunbridge Wells Borough Council Level 1 SFRA[12] identifies the River Medway and its tributaries as the primary source of fluvial flood risk within the borough, with the capacity of the Medway exceeded in the October 2000 floods resulting in flooding in the area north of Tudeley Hale and Paddock Wood. The SFRA identifies a small area of the FSA located within its administrative area approximately 1.3km north of Bidborough, and states that the FSA currently has an impact on reducing peak flows within the Medway floodplain in the north of the Borough. The SFRA identifies the expansion of the Leigh FSA as a potential strategic mitigation measure to potentially reduce flood risk in the borough, and states that the council have been consulted in plans for its expansion.

4.4.3 Kent County Council Local Flood Risk Management Strategies

Under the Flood and Water Management Act (2010) Kent County Council has developed a Local Flood Risk Management Strategy (LFRMS), in consultation with local partners. This Strategy acts as the basis and discharge of duty for flood risk management co-ordinated by Kent County Council. The Leigh FSA, as well as the areas upstream and downstream of the storage area, is covered by the Kent County Council LFRMS, the latest version of which (2017-2023) was published in 2017[13].

The strategy highlights the significant flood risk to areas within the Medway floodplain, as well as detailing Kent County Council's involvement in a Strategic Flood Partnership for the Medway Valley, led by the Environment Agency. In relation to the Leigh FSA, the 2017-2023 LFRMS details Kent County Council's successful bid for funding for the Leigh and Hildenborough FAS to promote large scale growth in Kent.

4.4.4 Medway Catchment Flood Management Plan[14]

The Leigh FSA is located within sub-area 3 of the Medway Catchment Flood Management Plan (CFMP), 'Upstream of Tonbridge'. This plan identifies that within this area there is currently a minimal risk of flooding to properties, and predicts the risk will still be minimal in 2100. The preferred option for the area is Policy Option 6, where action will be taken to increase the storage of water for benefits for flood risk or the environment, which supports the proposed expansion of the Leigh FSA.

It is worth noting that in the Tonbridge sub-area the flood risk is predicted to increase, despite the protection offered by the Leigh FSA. This highlights the need for flood risk management infrastructure, such as increasing the capacity of Leigh FSA, to manage flood risk.

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[11] Sevenoaks District Council, Level 1 Strategic Flood Risk Assessment Final Report, 2017.
[12] Tunbridge Wells Borough Council, Level 1 Strategic Flood Risk Assessment Final Report, 2019.
[13] Kent County Council, Local Flood Risk Management Strategy, 2012-2023, 2017.
[14] Environment Agency, Medway Catchment Flood Management Plan, 2009.

For the Tonbridge sub-area, the CFMP recommends the action to implement the outcomes of the Middle Medway Strategy. The Middle Medway Strategy (MMS) was completed in August 2005 and investigated flood risk management options for the Middle Medway catchment through modelling, economic and strategic environment assessment[15]. The strategy was intended to guide those involved in flood defence and planning to present a business case to justify future works and investment in flood risk management. The MMS was revised in 2010 to set out options to manage flood risk from the River Medway, the River Beult and the River Teise[16]. One of the options outlined included enlarging the capacity of the Leigh FSA from 5.5 million cubic metres to 8.8 million cubic metres to improve the standard of protection for homes in Tonbridge and along the fluvial River Medway[17].

4.4.5 Thames River Basin Flood Risk Management Plan

Part B of the Thames River Basin Flood Risk Management Plan[18] identifies the Leigh FSA as a major flood storage reservoir, highlighting the role it played in reducing the impact of the December 2013 floods in Tonbridge. The plan also documents plans to increase the capacity of the Leigh FSA, which has the potential to significantly reduce the number of properties at risk of flooding. Additionally, the plan set out the objective to implement schemes within the Middle Medway Strategy to reduce the flood risk to communities, such as the expansion of the Leigh FSA.

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[15] Tonbridge and Malling Borough Council, Level 1 Strategic Flood Risk Assessment Final Report, 2016.

[16] Tonbridge and Malling Borough Council, Level 1 Strategic Flood Risk Assessment Final Report, 2016.

[17] Environment Agency, River Medway Flood Storage Areas Project, 2016. Available: https://www.gov.uk/government/publications/river-medway-flood-storage-areas-fsas-project/river-medway-flood-storage-areas-fsas-project

[18] Environment Agency, Thames River Basin Flood Risk Management Plan 2015-2021 Part B, 2016. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/507140/LIT_10230_THAMES_FRMP_PART_B.pdf

5 Proposed development and flood risk

5.1 Changes in flood risk within the Flood Storage Area due to the proposed development

5.1.1 Change in flood extents

Within the FSA, the change in flood extents due to the proposed increase in operating water level from 28.05mAOD to 28.60mAOD is relatively small. The change in flood extents for the 1.33%, 1% and 1% AEP +20% flows scenarios are displayed in Appendix A.

As would be expected, the greatest change in depth and extent is in the immediate vicinity of the FSA embankment and the local effect of the change in operation diminishes relatively rapidly along the flooded valley upstream for the reasons identified in Section 2.1.3. The limited change in flood extent also reflects the relatively steep sided nature of the valley adjacent to the floodplain and highlights that predicted changes in maximum flood depth resulting from the proposed development will generally not be expected to have significant effects on the predicted flood extent.

5.1.2 Change in flood depths

Within the FSA, as conceptualised by Figure 2-2, the proposals result in a higher peak water level at the FSA embankment (up to 28.60mAOD) than is presently the case during flood events where the FSA is used to store additional water to reduce downstream peak flood flow magnitudes. The maximum water level reached in the FSA and the duration of the impoundment above the currently operation level (28.05mAOD) will vary according to the nature and severity of the flood event. At the FSA embankment, the increase in flood depths would be expected to increase by no more than +0.55m, reflecting the change in the Normal Maximum Operating Water Level. With increasing distance upstream from the FSA embankment, the increase in flood depths will reduce and become negligible, as the influence of the prevailing flood flows from the upstream catchment increasingly dominate the flood mechanism. This is referred to as a "backwater effect" and the modelling analysis prepared to understand the performance of the Leigh FSA fully accounts for the flow, channel and floodplain mechanisms that are influential.

For the purpose of the assessment, model results have been obtained for the change in flood depths between the proposed and existing operation and these are presented in Appendix B for the 1.33% AEP, 1% AEP and 1% AEP +20% flows scenarios.

The results show that with increasing distance upstream, the difference in flood depths is reduced.. The area of land north of Cattle Arch embankment, the Southern Water Pumping Station and Archimedes Screw and embankment pumping station platform is removed from the predicted flood extent due to specific measures implemented at these locations (refer to Table 2-1 and Figure 2-6 for details of these measures).

5.1.3 Change in the duration of impoundment

The timing and duration of impoundment at the FSA will vary on an event by event basis, reflecting the nature of flood flows reaching the FSA from upstream, future forecast conditions and therefore the FSA operator's decisions on impoundment. Figure 2-2 conceptualises the change in the water level stored in the FSA between the current and proposed operational regime for a typical flood event.

By interrogating results from the circa 3,000 flood events which inform the hydrological methods for the flood flow hydrology (each of which has a different flood magnitude, shape etc), it is possible to understand how the water levels in the FSA may be expected to differ between the current and future operation scenarios for many different types of events.

Figure 5-1 presents for a range of flood magnitudes (stated by the annual exceedance probability of the event) the duration of additional time, compared with the current operation, that the proposed development is predicted to result in water levels being stored above the current maximum level of 28.05mAOD at the FSA embankment. Each data point on the graph reflects one of the hydrological events available from the hydrological methods. The analysis is complex and performed so that there is confidence over the performance of the FSA for the likely range of "real world" events that might be encountered, rather than a single "design" event, as would be used for the purpose of formulating the scheme details.

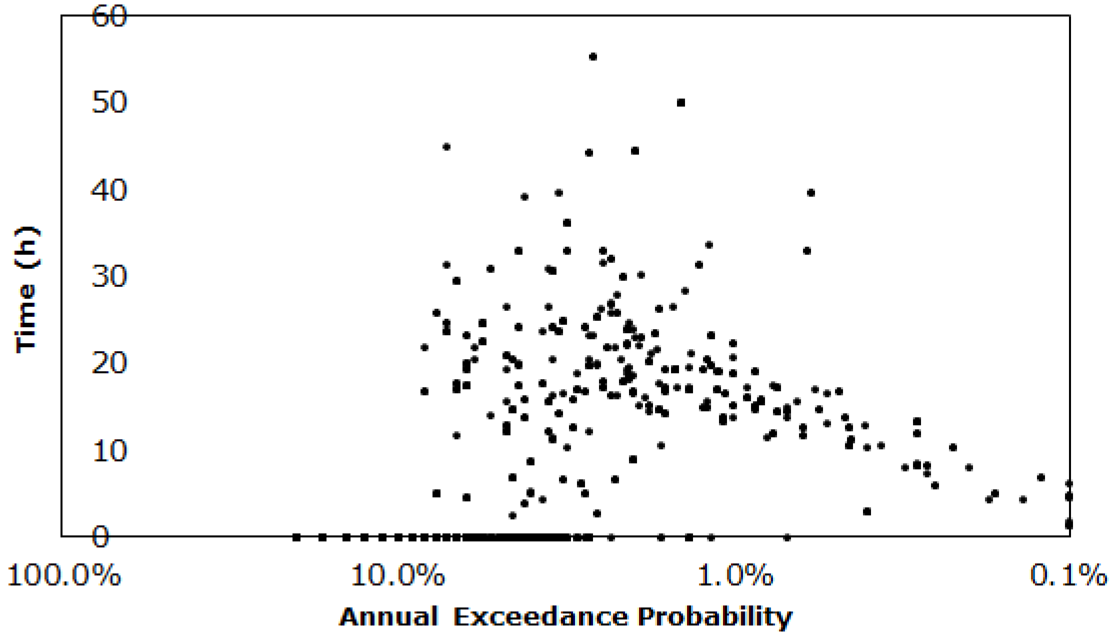


Figure 5-1: Flood magnitude (AEP) plotted against the duration of additional time, compared with the current operation regime, that the proposed development is predicted to result in water levels being stored above the current maximum level of 28.05mAOD at the FSA embankment

Interpretation of the results of this analysis indicate that:

- The duration of additional impoundment above 28.05mAOD is not predicted until event magnitudes exceed a 10% AEP
- Over the range of results analysed there is variety in the time during which flood water is impounded above 28.05mAOD and the impoundment duration increases or decreases according to the magnitude and

characteristics of the event – highlighting that the shape and volume of flood hydrographs associated with different flood events is also important

- On the basis of the range of events considered, the maximum duration that additional water is predicted to be impounded above 28.05mAOD is between 50-60hrs, although the majority of events see additional impoundment above 28.05mAOD for shorter durations of time.
- The average duration of additional impoundment above 28.05mAOD at the FSA embankment is 19 hours for those events where additional impoundment is recorded. Note that this average duration, and the maximum duration noted above, differ from the change in outflow duration discussed in section 5.2.3. This is expected given the elevation vs area characteristics of the FSA and the hydraulics behind the discharge (flow) of water at different water levels.
- As event magnitudes increase beyond circa 1% AEP, the duration of time that additional impoundment occurs above 28.05mAOD is reduced. This reflects the fact that for these events the very large flood magnitude begins to exceed the capacity of the FSA and so benefit of the additional storage is reduced and the FSA begins to respond in a similar manner as for the circumstances where the storage volume has not been increased. For the largest events this will involve operating the radial gates to help more safely manage water levels in the FSA.

5.1.4 Receptors affected by the additional flood depths

Inspection of Ordnance Survey mapping datasets and the National Receptor Database 2014 reveals that the receptors listed below may be affected by the additional depths of flooding and duration of impoundment from the design event modelling. Note that receptors north of the Cattle Arch embankment, the Southern Water Pumping Station and Archimedes Screw, and embankment pumping station platform are not listed as these are removed from the predicted flood extent due to measure implemented at these locations (refer to Table 2-1 and Figure 2-6 for details). Each of the receptors identified below are already influenced by the current flooding within the Flood Storage Area.

Railway line to the east of Leigh Station

Although peak flood levels at the maximum operating level of 28.60mAOD do not exceed the level of the railway, a higher water level would occur adjacent to the railway line during time of additional impoundment.

Tonbridge Sailing club

An increased depth of flooding up to 0.5m is predicted. It is understood that the deck of the structure on which the club house is positioned has a level of 29.4mAOD, so the proposed change would not be expected to adversely impact this building.

The NPPF vulnerability classification table identifies this development type as water compatible.

Ensfield Road

An increased depth of flooding up to 0.5m is predicted.

5.2 Changes in flood risk downstream of the Flood Storage Area due to the proposed development

5.2.1 Change in flood extents

The proposed development reduces flood risk downstream of the FSA and so flood extents are reduced compared with the existing scenario (when the maximum operating water level is limited to 28.05mAOD). Appendix C presents mapping focused on both Tonbridge and the floodplain downstream, and evidences the reduction in flood extents that are predicted for the 1% AEP +15% flows and 1% AEP events, respectively. The reduced outflows from Leigh FSA results in a contraction in the predicted flood extent, albeit the reduction in flood extents becomes less pronounced downstream of Tonbridge due to the expansion of flow along the floodplain and inflow from other watercourses.

Note that the Hawden Stream floodplain is displayed as completely removed from the River Medway flood extent in the proposed development modelling – this reflects the addition of an embankment across the floodplain at this location, which as noted in section 1.3 is not the focus of the planning application which this FRA supports.

For clarity, the modelling used to inform the changes in predicted flooding downstream of Leigh comprises the following components:

- Alterations to the outflows from Leigh FSA, reflecting the proposed operational regime associated with the development. For events associated with a 'deviate' scenario (refer to section 2.1.2), this results in a reduction in the peak outflow from the FSA. The reduced flooding southeast of the Hildenborough embankment (described as follows) i.e. the full extent of the River Medway floodplain upstream, throughout and downstream of Tonbridge is associated with the Leigh FSA Expansion proposals.
- A raised embankment along the Hawden Stream floodplain, near Hildenborough, which prevents the north-westerly ingress of flood water along the floodplain beyond the embankment. This does not form part of the Leigh FSA Expansion scheme for assessment, but was included in the modelling which was prepared to inform the assessment of the two schemes combined. Leigh FSA Expansion alone does not result in the prevention of flood water behind the location of a proposed embankment - the embankment itself is required to achieve this. However, Hildenborough benefits from reduced peak flows due to the existing operation of the Leigh FSA. The reduced peak outflows from Leigh FSA in the proposed development scenario would further reduce the extent of flooding in this region.

5.2.2 Change in flood depths

The proposed development reduces flood risk downstream of the FSA and so flood depths are reduced compared with the existing scenario (when the maximum operating water level is limited to 28.05mAOD). Appendix D presents mapping focused on the Tonbridge area for the 5% AEP, 1% AEP and 1% AEP +15% flows events, and evidences the reduction in peak flood depths predicted. Appendix E presents the same mapping for the floodplain downstream of Tonbridge for the 1% AEP, 0.4% AEP and 0.4% AEP +25% flows events. The differences in levels for the events presented for the two areas reflect the flood risk modelling scenarios that have been used as part of previous modelling projects and illustrate the benefits derived from the development.

Within Tonbridge, for the 5% AEP event flood depths reduce by up to 0.05m for most regions of flooding. Flooding through Tonbridge town centre is limited during this event even in the current operational regime, reflecting the fact that this flood magnitude can be safely managed by the existing storage arrangements at Leigh FSA.

For larger events reductions in flood depths within the proposed development scenario are greater, as a larger storage volume at the FSA enables a reduced outflow from the FSA. In the 1% AEP event, the reductions in flood depths are up to 0.2m immediately downstream of the FSA and for parts of the southern floodplain through Tonbridge, 0.1m on the floodplain upstream of Tonbridge to the High Street and for parts of central Tonbridge, and 0.05m for other areas. Slightly greater benefit in terms of reduced flood depths are predicted for the 1% AEP +15% flows event.

As described above – note that the Hawden Stream floodplain displays notably reduced flood depths, reflecting the addition of an embankment across the floodplain within the flood modelling to inform the assessment of the two schemes combined. While the Hildenborough embankment does not form part of the Leigh FSA Expansion scheme for assessment, its inclusion in the flood modelling does not affect the conclusions evident from the flood risk mapping outputs.

Downstream of Tonbridge, reductions in flood depths are predicted, but the magnitude of change is smaller, typically up to 0.1m for the 1% and 0.4% AEP events, and up to 0.05m for the 0.4% AEP +25% flows event.

5.2.3 Change in the duration of outflows from the FSA

The timing and duration of releases of flood flows from the FSA will vary on an event by event basis, reflecting the nature of flood flows reaching the FSA from upstream, the storage capacity in the FSA and the FSA operator's decisions on impoundment.

Figure 2-4 conceptualises a change in outflow from FSA between the current and proposed operational regime for one flood event.

By analysing and assessing the results from the circa 3,000 flood events which inform the hydrological methods for the flood flow hydrology (each of which has a different flood magnitude, shape etc), it is possible to understand how this response may be expected to differ between the current and future operation scenarios for many different types of events, as will most likely be experienced in "real world" circumstances.

Figure 5-2 presents, for a range of flood magnitudes (stated by the annual exceedance probability of the event), the duration of the time during a given flood event that flow rates released from the FSA under the proposed operational regime are predicted to exceed the outflows from the FSA in the current operational regime. This shows that the release time of flows for the proposed development scenario is longer than for the FSA in its present condition. Note that the magnitude of the peak flows released in the proposed 28.60mAOD scenario are reduced compared with the current operation and the depth difference mapping presented in Appendix E indicates that this would not lead to increases to peak flood depths downstream. Each data point on the graph reflects one of the hydrological events available from the hydrological methods. The analysis is complex and performed so that there is confidence over the performance of the FSA for the likely range of "real world" events that might be encountered, rather than a single "design" event, as would be used for the purpose of formulating the scheme details. Interpretation of the results of this analysis indicate that:

- The occurrence of longer duration releases from the FSA is not predicted until event magnitudes exceed a 5% AEP
- Over the range of results analysed there is a wide variety in the duration of longer release times and this changes in accordance with the magnitude of a particular event – highlighting that the shape and volume of flood events is also important
- The predicted maximum duration that higher flow rates would be released in the proposed operational regime is between 40-50hrs, although the majority of events see higher flows released for shorter durations of time.

- The predicted average duration of the longer release times is 16 hours for those events where the time has increased compared with the current operation. Note that this average duration, and the maximum duration noted above, differ from the change in additional impoundment duration discussed in section 5.1.3. This is expected given the elevation vs area characteristics of the FSA and the hydraulics behind the discharge (flow) of water at different water levels.

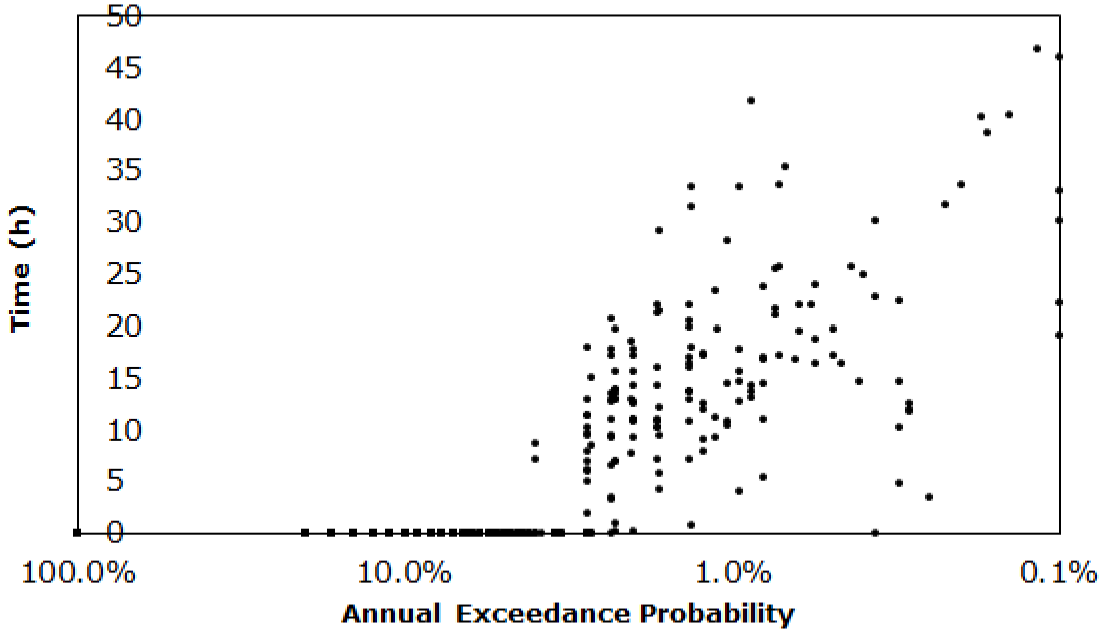


Figure 5-2: Flood magnitude (AEP) plotted against the duration of time that a larger outflow rate is released in the 28.60mAOD scenario compared with the 28.05mAOD scenario (note: the peak flow released in the 28.60mAOD scenario remains lower than the 28.05mAOD scenario)

5.3 Residual risk

5.3.1 Events with characteristics that differ from design event modelling

The design event modelling prepared to inform the assessment of changes in flood risk at Leigh FSA involved consideration of single-peaked flood hydrographs, as is typical for design event modelling. It is plausible that events with different characteristics (e.g. events with multiple peaks or larger flood volumes) could occur and the impact of such events has been considered. The variation of operation that would occur in response to different event characteristics would seek to optimise flood volumes in the FSA to manage water levels upstream and betterment downstream through reduced outflows. The design event modelling will not fully reflect the event-specific refinements that could be made by FSA operators during real events. Under circumstances where flood events occur with uncommon characteristics, it is possible that part of the storage volume within the FSA may be utilised through operation of the FSA prior to the main peak of a flood event arriving. While operations would seek to limit impacts, in these circumstances the area of deeper water levels (compared with the current operation) could extend further upstream. In such an event the changes in flood depths/levels in this region would be relatively small, and the duration that deeper water levels occur relatively short given the distance away from the FSA embankment.

On this basis, the residual risk from the occurrence of such events is considered to be acceptable.

5.3.2 Events of a larger magnitude than that which the development has been designed for

By increasing the volume of storage that is permitted behind the embankment the proposed development is able to accommodate events with increased severity but maintain the capacity to control the magnitude of the outflows (so reducing flood risk downstream). However, for events that exceed the design capacity of the FSA and would result in a water level which exceeds the maximum operating water level, the operation procedure will remain unchanged: the control gates will be operated so the floodwater in the FSA is maintained at a safe level.

On this basis, the residual risk from these larger events is not increased by the implementation of the proposed development.

5.3.3 Breach failure

Mapping for breach failure of the FSA is presented in Figure 3-4 and represents the maximum likely extent of flooding should the FSA embankment fail when water levels are at the embankment crest level - above the maximum operating water level. The prevailing flood conditions in such an event would be very severe.

The proposed development, seeking to increase the maximum operating water level permitted in the FSA, increases the potential consequence of breach failure should it occur at the time of maximum permitted impoundment (greater flow rates could be expected due to the larger volume and greater depth of water). However, the proposals include works to further enhance the safety of the embankment during such conditions, so the likelihood of breach occurrence would not be expected to increase.

Should the integrity of the embankment be compromised during a flood event, it is considered that there would be opportunity to draw down water levels in the FSA, by operating the control gates, to reduce the likelihood and consequence of breach failure.

On this basis, the residual risk of breach failure is considered to be acceptable.

6 Conclusions

6.1 Introduction

A Flood Risk Assessment (FRA) has been prepared to provide supporting information for a planning application describing proposals to increase the storage capacity of the Leigh FSA. The assessment has used computation modelling to understand the effects of the proposed changes, both upstream and downstream of the existing embankment and radial gates. The proposed development involves an increase in the depth of flood water upstream of the Leigh FSA and a reduction in the magnitude of the peak flows experienced downstream.

6.2 Overview of the proposed development

The proposed development involves enabling works that will allow the capacity of the Leigh FSA to be increased by raising its maximum operating water level from 28.05mAOD to 28.60mAOD. This change will increase the storage volume from 5,850,000m^3 to 7,250,000m^3, an increase of 24%, and enable greater reduction in peak flow rates during flood events. The proposals will increase flood storage (and hence flood depths and extents) for a region of floodplain upstream of the FSA embankment, to the betterment of receptors downstream. The proposed scheme is based on the same principle that is already in place and the further increase in the flood storage capacity provides for an additional reduction in flood flows at the peak of flood events downstream of the Leigh FSA.

Mitigation measures form part of the detailed design of the scheme so that potential increased risks to third parties are appropriately mitigated and managed. Existing infrastructure at land to the south of the railway line at Leigh, which extends from Ensfield Road to a pumping station located 400m to the east, will be protected from elevated water levels in Leigh FSA by the construction and/or enhancement of an existing embankment and wall features. Additional provisions to enable pumping of water from land to the north into Leigh FSA will also be provided.

6.3 Planning policy context

The proposed development is 'water compatible' according to the vulnerability categorisation within National Planning Policy and so is deemed appropriate. However, for water compatible development, the development should

1. remain operational and safe for users in times of flood;
2. result in no net loss of floodplain storage; and
3. not impede water flows and not increase flood risk elsewhere.

Regarding points 1 and 2; the Environment Agency as asset owners and operators will be responsible for the FSA remaining operational and safe in times of flood. There is no net loss of floodplain storage associated with the development as the development is increasing the available storage volume and making use of this to reduce flood risk downstream. For the third point: while it is accepted that the proposed development will intentionally increase flood depths in the FSA during times of storage, in an area considered to be functional floodplain, the design event modelling indicates that the risk of flooding to receptors e.g. property is not increased as a result of these activities.

6.4 Flood risk associated with the current FSA scheme

Managing fluvial flood risk is the purpose of the FSA and a key consideration for the proposed FSA arrangements from a planning policy perspective, as the presence of flood flows influences the flood water impounded within the FSA and released downstream of it. The proposed development enhances the current practices in place at Leigh FSA to the betterment of regions downstream. The effects of climate change are predicted to increase the magnitude and volume of flood flows and the current operational regime at the FSA will not be able to provide the same level of flood flow reduction for a given rarity of flood event in the future. For example, in the future, for the existing Leigh FSA it will not be possible to reduce the outflow from Leigh FSA for an event with a 1% annual exceedance probability and so higher flows would be released downstream. The change in flood risk (a reduction) resulting from the proposed development is discussed in section 6.5.

The significance of flood risk from groundwater and surface water on the effectiveness of the proposed development are negligible. The potential for accumulation of groundwater in the FSA or runoff of surface water do not significantly influence the benefits of the scheme (due to very large volumes of flood storage available at a level above which flood water is currently stored), nor does the scheme increase the risk presented by these flood mechanisms. The breach failure of reservoirs upstream of Leigh FSA poses a residual risk to the development. However, whilst the potential consequences are not insignificant, the probability of such circumstances is extremely low and hence overall the risk is low.

6.5 Proposed development and flood risk

6.5.1 Flood risk within the FSA

Within the FSA, the change in flood extents due to the proposed increase in operating water level from 28.05mAOD to 28.60mAOD is relatively small. The greatest change in depth and extent is in the immediate vicinity of the FSA embankment and the local effect of the change in operation diminishes relatively rapidly along the flooded valley upstream. The limited change in flood extent also reflects the relatively steep sided nature of the valley adjacent to the floodplain and highlights that predicted changes in maximum flood depth resulting from the proposed development will generally not be expected to have significant effects on the predicted flood extent.

The proposed increase to the maximum operating water level results in a higher peak water level at the FSA embankment (up to 28.60mAOD) where the FSA is used to store additional water to reduce downstream peak flood flow magnitudes. At the FSA embankment, the increase in flood depths would be expected to increase by no more than +0.55m, reflecting the change in the maximum operating water level from 28.05mAOD. However, with increasing distance upstream from the FSA embankment, the increase in flood depths will reduce and become negligible, as the influence of the prevailing flood flows from the upstream catchment increasingly dominate the flood mechanism. The duration of time that elevated water levels occurs compared with the current operational regime (storage to a maximum level of 28.05mAOD) will also reduce with distance upstream from the FSA. With increasing distance upstream, the difference in flood depths is reduced. Design event modelling indicates that no change in flood depths is predicted upstream of circa 1km east (downstream) of Rogues Hill, Penshurst, between the proposed and existing scenarios. As part of the proposed development, the land north of Cattle Arch embankment, the Southern Water Pumping Station and Archimedes Screw and embankment pumping station platform are removed from the predicted flood extent due to specific measures implemented at these locations.

Receptors potentially affected by the proposed increase in water levels stored within the FSA are listed as follows:

- *Railway line to the east of Leigh Station:* Although peak flood levels at the maximum operating level of 28.60mAOD do not exceed the level of the railway, a higher water level would occur adjacent to the railway line during time of additional impoundment.
- *Tonbridge Sailing club:* An increased depth of flooding up to 0.5m is predicted. The existing structure is set above this proposed maximum storage levels, so additional impacts are not anticipated. The NPPF

vulnerability classification table identifies this development type as water compatible.

- *Ensfield Road:* An increased depth of flooding up to 0.5m is predicted.
- Note that each of the receptors is already in the footprint of the FSA at maximum storage level when a flood is passing through the River Medway.

The timing and duration of impoundment at the FSA will vary on an event by event basis, reflecting the nature of flood flows reaching the FSA from upstream, future forecast conditions and therefore the FSA operators decisions on impoundment. For the purpose of the assessment numerous flood events have been used to inform the flood risk modelling (each of which has a different flood magnitude, shape etc). This approach enables the following conclusions to be drawn with respect to the timing and duration of flood water being stored in the FSA in the proposed development scenario:

- The duration of additional impoundment above 28.05mAOD is not predicted until event magnitudes exceed 10% AEP
- Over the range of results analysed there is a wide variety in the time during which flood water is impounded above 28.05mAOD and the impoundment duration increases or decreases according to the magnitude and characteristics of the event
- On the basis of the range of events considered, the maximum duration that additional water is predicted to be impounded above 28.05mAOD is between 50-60hrs. However, the majority of events see additional impoundment above 28.05mAOD for shorter durations of time, with the average duration of additional impoundment being 19 hours for those events where additional impoundment is recorded.
- As event magnitudes increase beyond circa 1% AEP, the duration of time that additional impoundment occurs above 28.05mAOD is reduced. This reflects the fact that for these events the very large flood magnitude begins to exceed the capacity of the FSA and so benefit of the additional storage is reduced and the FSA begins to respond in a similar manner as for the circumstances where the storage volume has not been increased.

6.5.2 Flood risk downstream of the FSA

Downstream of the FSA, reductions in flood extents and flood depths are predicted in the proposed development scenario for events of circa 5% AEP magnitude and larger, as the additional storage available at the FSA is used to reduce outflows released from the FSA.

The reduced outflows from Leigh FSA results in a contraction in the predicted flood extent, albeit the reduction in flood extents becomes less pronounced downstream of Tonbridge due to the expansion of flow along the floodplain and inflow from other watercourses. Within the Tonbridge, for the 5% AEP event flood depths reduce by up to 0.05m for most regions of flooding. For larger events reductions in flood depths within the proposed development scenario are greater, as a larger storage volume at the FSA enables a reduced outflow. In the 1% AEP event, the reductions in flood depths are up to 0.2m immediately downstream of the FSA and for parts of the southern floodplain through Tonbridge and 0.1m on the floodplain upstream of Tonbridge to the High Street and for parts of central Tonbridge. Slightly greater benefit in terms of reduced flood depths are predicted for the 1% AEP +15% flows event. Downstream of Tonbridge, reductions in flood depths are smaller, typically up to 0.1m for the 1% and 0.4% AEP events, and up to 0.05m for the 0.4% AEP +25% flows event.

The timing and duration of releases of flood flows from the FSA will vary on an event by event basis, reflecting the nature of flood flows reaching the FSA from upstream, the storage capacity in the FSA and the FSA operator's decisions on impoundment. For the purpose of the assessment numerous flood events have been used to inform the flood risk modelling (each of which has a different flood magnitude, shape etc). This approach enables the following conclusions to be drawn with respect to how the duration of outflows released from the FSA are expected to change in the proposed development scenario:

- The occurrence of longer duration releases from the FSA is not predicted until event magnitudes exceed 5% AEP.
- On the basis of the range of events considered, there is a wide variety in the duration of longer release times and this changes in accordance with the magnitude of a particular event – highlighting that the shape and volume of flood events is also important.
- The predicted maximum duration that higher flow rates would be released in the proposed operational regime is between 40-50hrs. However, the majority of events see higher flows released for shorter durations of time, with the predicted average duration of the longer release times being 16 hours for those events where the time has increased compared with the current operation.

6.5.3 Residual flood risk

The design event modelling prepared to inform the assessment of changes in flood risk at Leigh FSA involved consideration of single-peaked flood hydrographs, as is typical for design event modelling. It is plausible that events with different characteristics (e.g. events with multiple peaks or larger flood volumes) could occur and the impact of such events has been considered. The variation of operation that would occur in response to different event characteristics would seek to optimise flood volumes in the FSA to manage water levels upstream and betterment downstream through reduced outflows. Under circumstances where flood events occur with uncommon characteristics, it is possible that part of the storage volume within the FSA may be utilised through operation of the FSA prior to the main peak of a flood event arriving. While operations would seek to limit impacts, in these circumstances, the area of deeper water levels (compared with the current operation) could extend further upstream. In such an event the changes in flood depths/levels in this region would be relatively small, and the duration that deeper water levels occur relatively short given the distance away from the FSA embankment. On this basis, the residual risk from the occurrence of such events is considered to be acceptable.

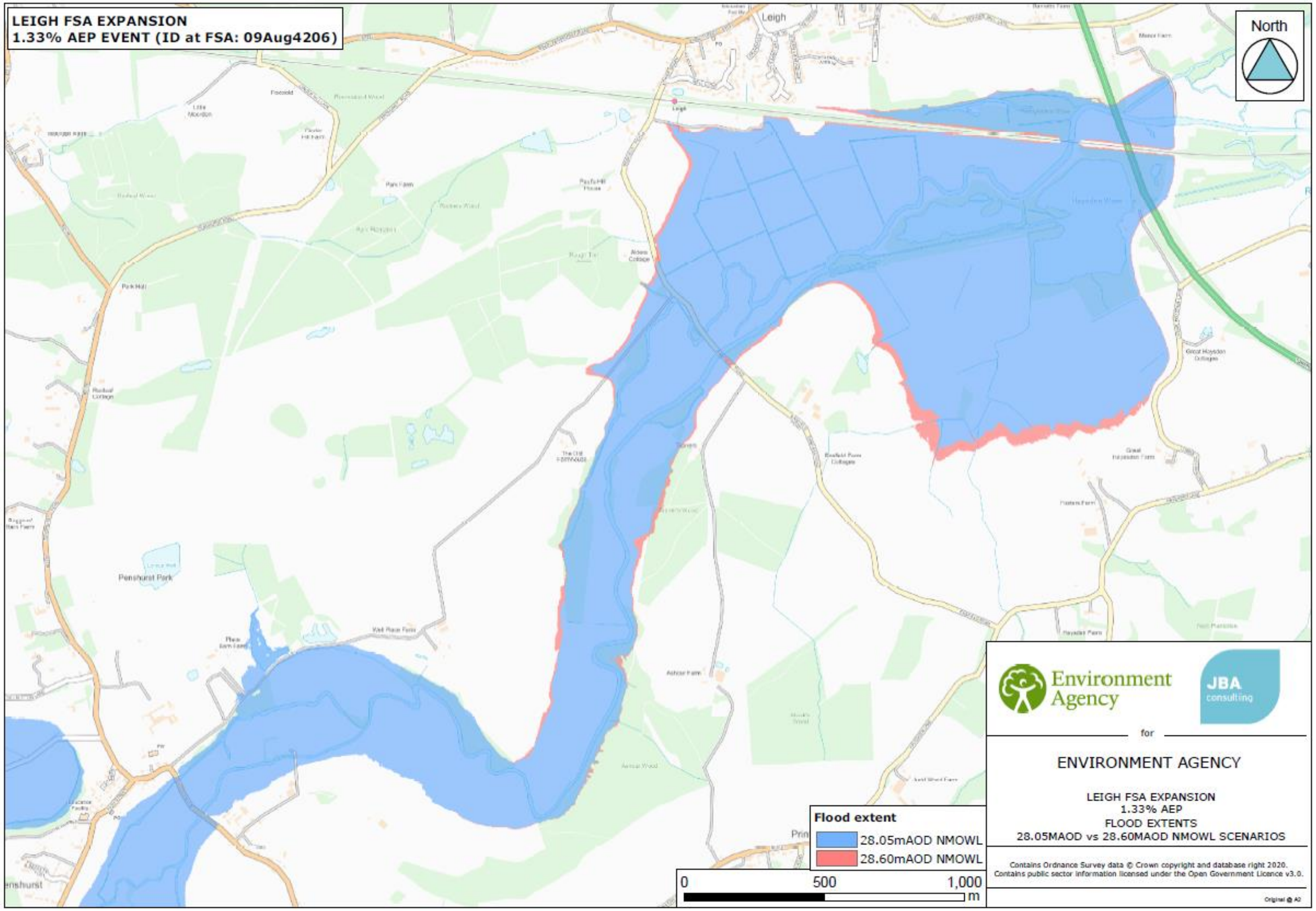
By increasing the volume of storage that is permitted behind the embankment the proposed development is able to accommodate events with increased severity but maintain the capacity to control the magnitude of the outflows (so reducing flood risk downstream). However, for events that exceed the design capacity of the FSA and would result in a water level which exceeds the maximum operating water level, the operation procedure will remain unchanged: the control gates will be operated so the floodwater in the FSA is maintained at a safe level. On this basis, the residual risk from these larger events is not increased by the implementation of the proposed development.

The proposed development, which will enable an increase to the maximum operating water level permitted in the FSA. This potentially increases the consequence of breach failure should it occur at the time of maximum permitted impoundment (greater flow rates could be expected due to the larger volume and greater depth of water). However, the proposals include works to further enhance the safety of the embankment during such conditions, so the likelihood of breach occurrence would not be expected to increase. Should the integrity of the embankment be compromised during a flood event, it is considered that there would be opportunity to drawn down water levels in the FSA, by operating the control gates, to reduce the likelihood and consequence of breach failure. On this basis, the residual risk of breach failure is considered to be acceptable.

Appendices

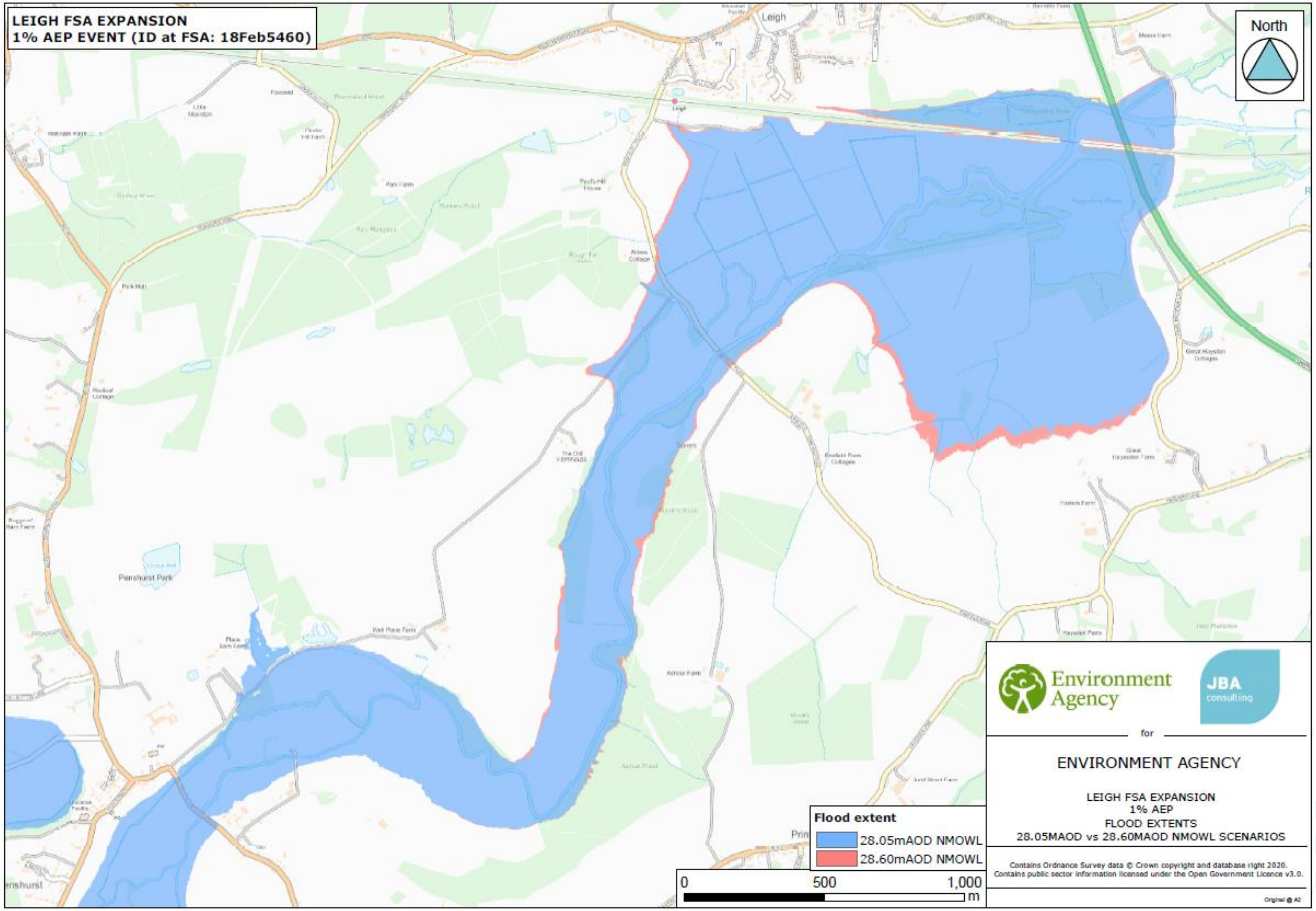
A Change in predicted flood extent within Leigh FSA: Proposed development scenario compared with baseline (current operation)

A.1 1.33% AEP



LEIGH FSA EXPANSION
1.33% AEP EVENT (ID at FSA: 09Aug4206)
North
Leigh
Penshurst Park
Flood extent
28.05mAOD NMOWL
28.60mAOD NMOWL
0
500
1,000
m
Environment Agency
JBA consulting
for
ENVIRONMENT AGENCY
LEIGH FSA EXPANSION
1.33% AEP
FLOOD EXTENTS
28.05MAOD vs 28.60MAOD NMOWL SCENARIOS
Contains Ordnance Survey data © Crown copyright and database right 2020.
Contains public sector information licensed under the Open Government Licence v3.0.
Original @ A2

A.2 1% AEP



LEIGH FSA EXPANSION
1% AEP EVENT (ID at FSA: 18Feb5460)
North
Leigh
Penshurst Park
Flood extent
28.05mAOD NMOWL
28.60mAOD NMOWL
0
500
1,000
m
Environment Agency
JBA consulting
for
ENVIRONMENT AGENCY
LEIGH FSA EXPANSION
1% AEP
FLOOD EXTENTS
28.05MAOD vs 28.60MAOD NMOWL SCENARIOS
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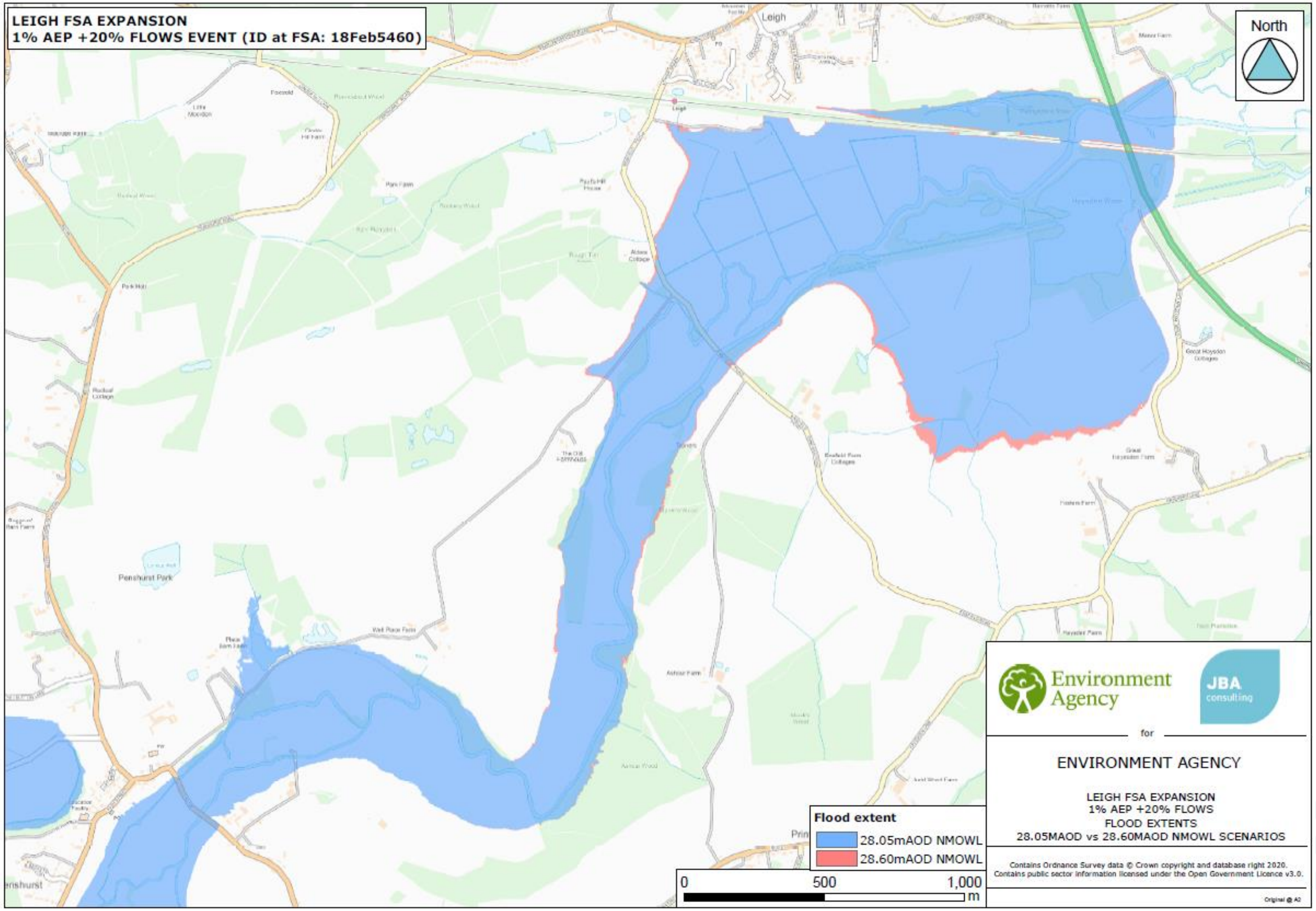
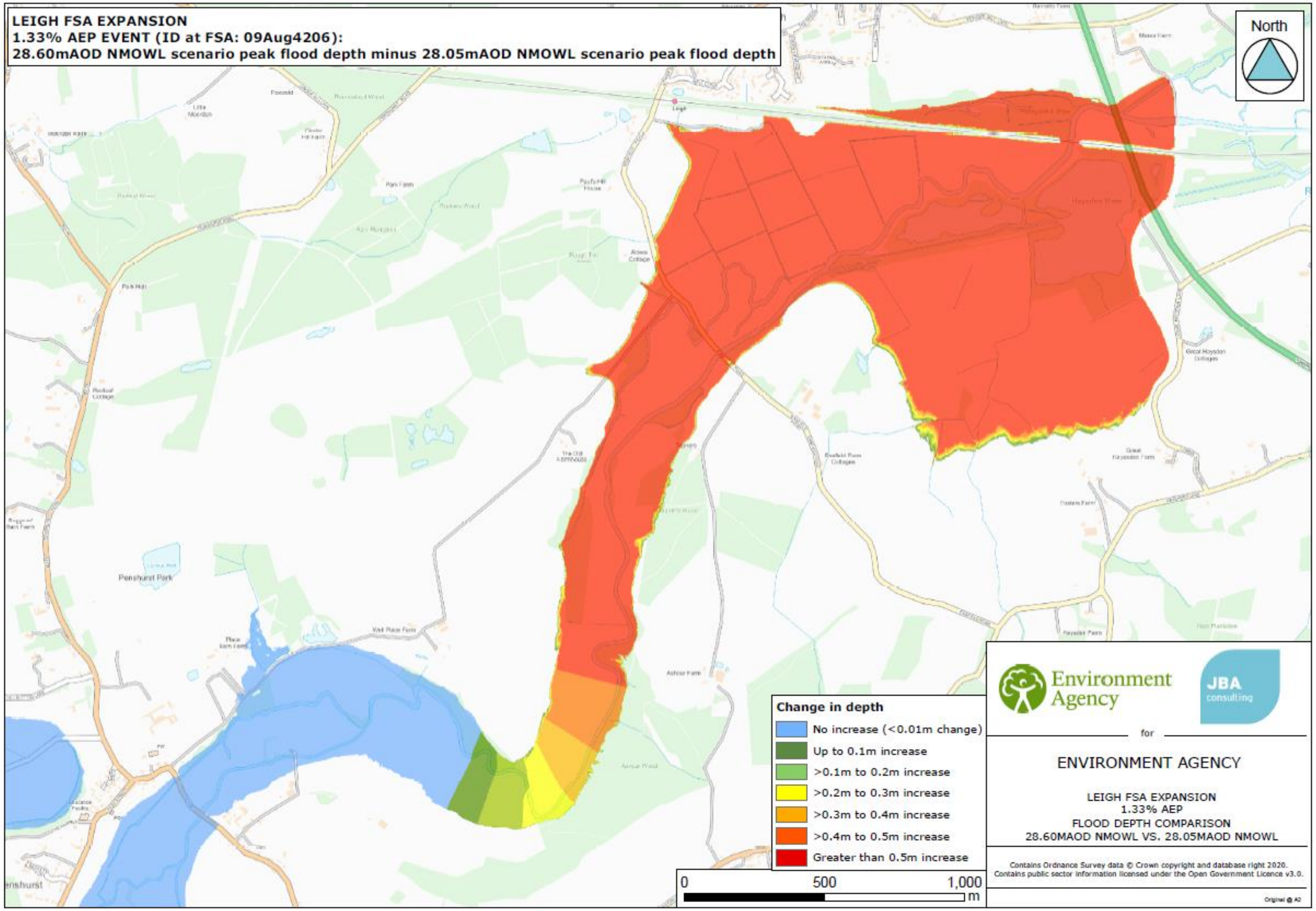
A.3 1% AEP +20% flows event

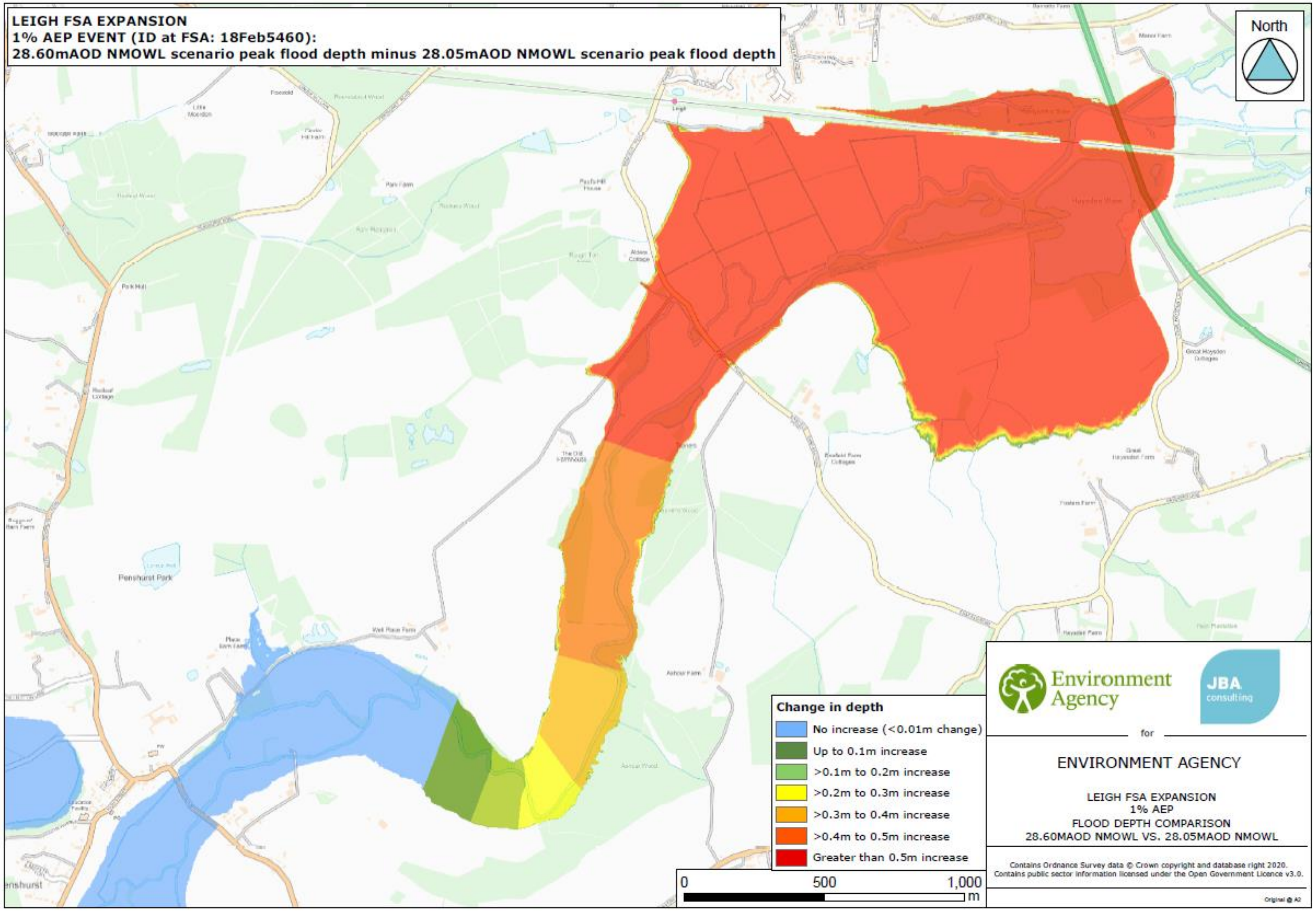


B Change in predicted flood depths within Leigh FSA: Proposed development scenario compared with baseline (current operation)

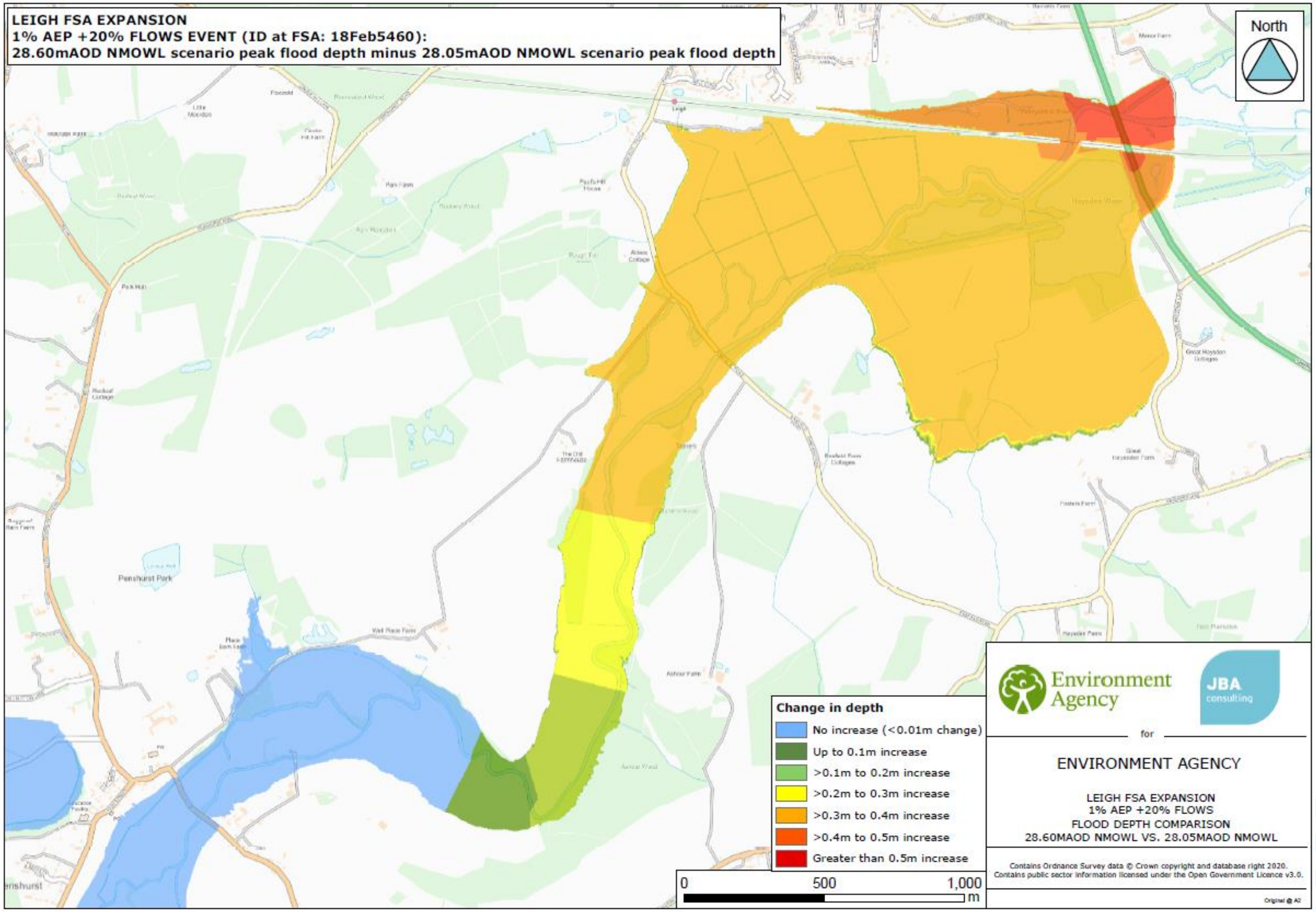
B.1 1.33% AEP event



B.2 1% AEP event

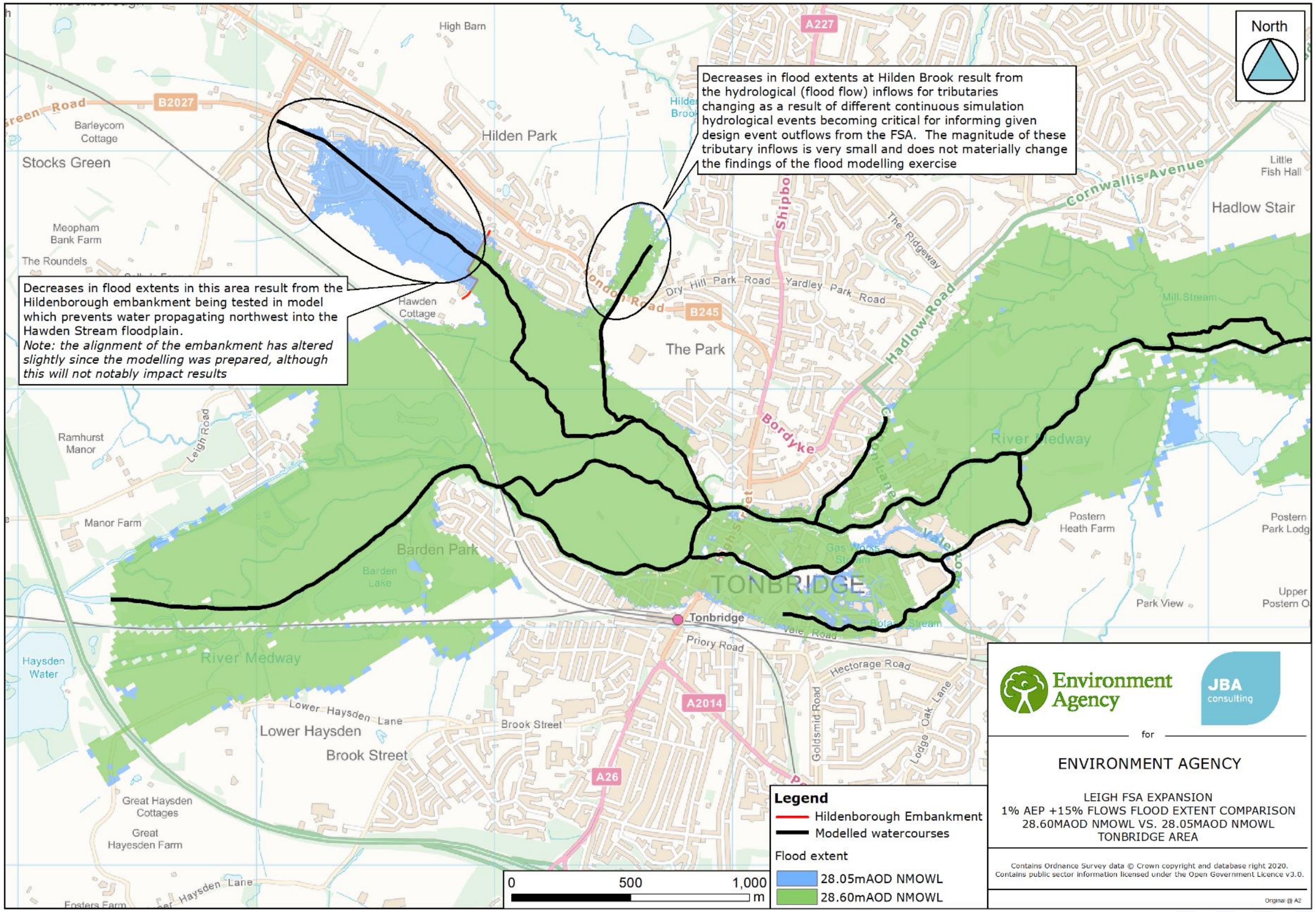


B.3 1% AEP +20% flows event

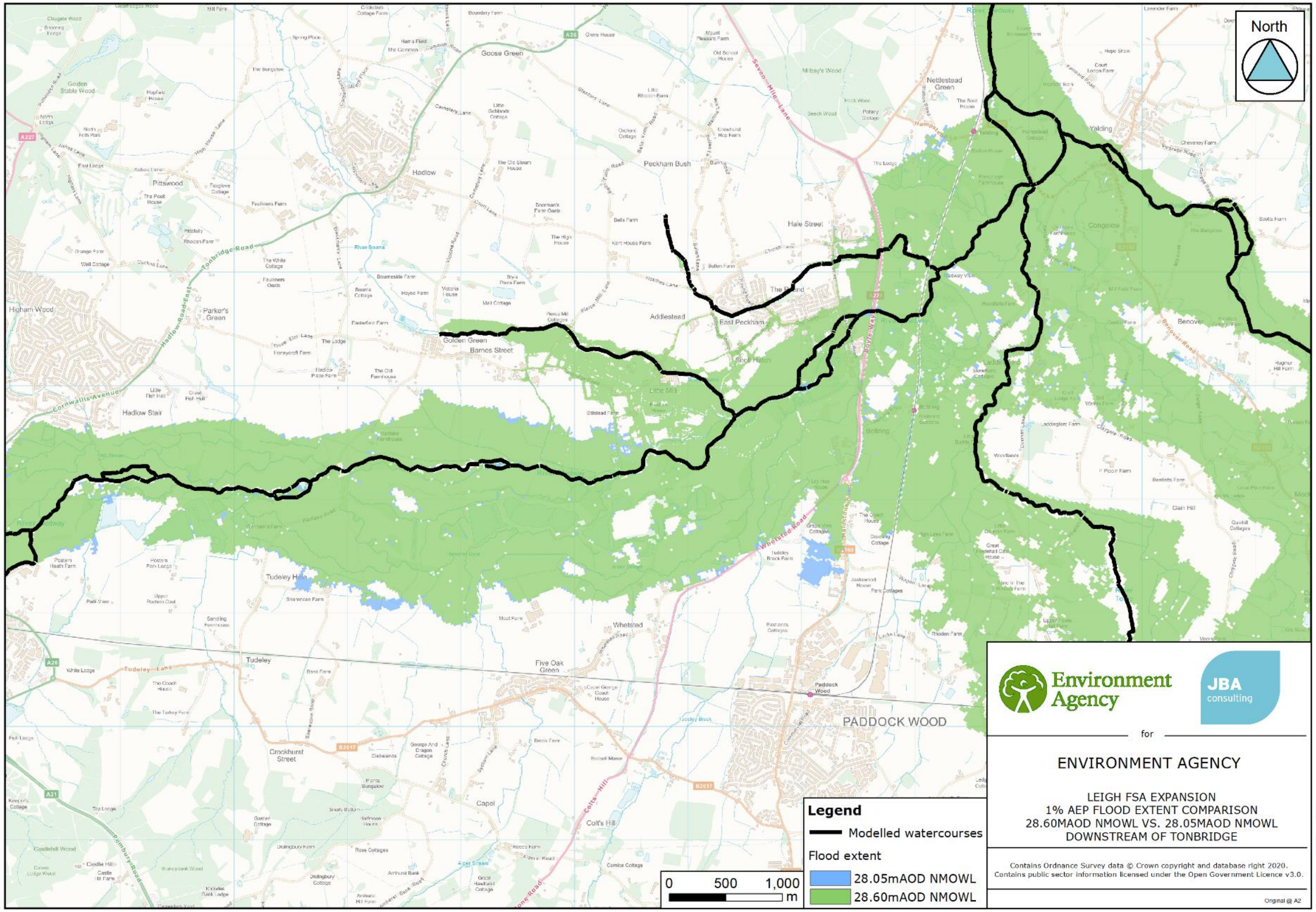


C Change in predicted flood extent downstream of Leigh FSA: Proposed development scenario compared with baseline (current operation)

C.1 1% AEP +15% flows event (Tonbridge)

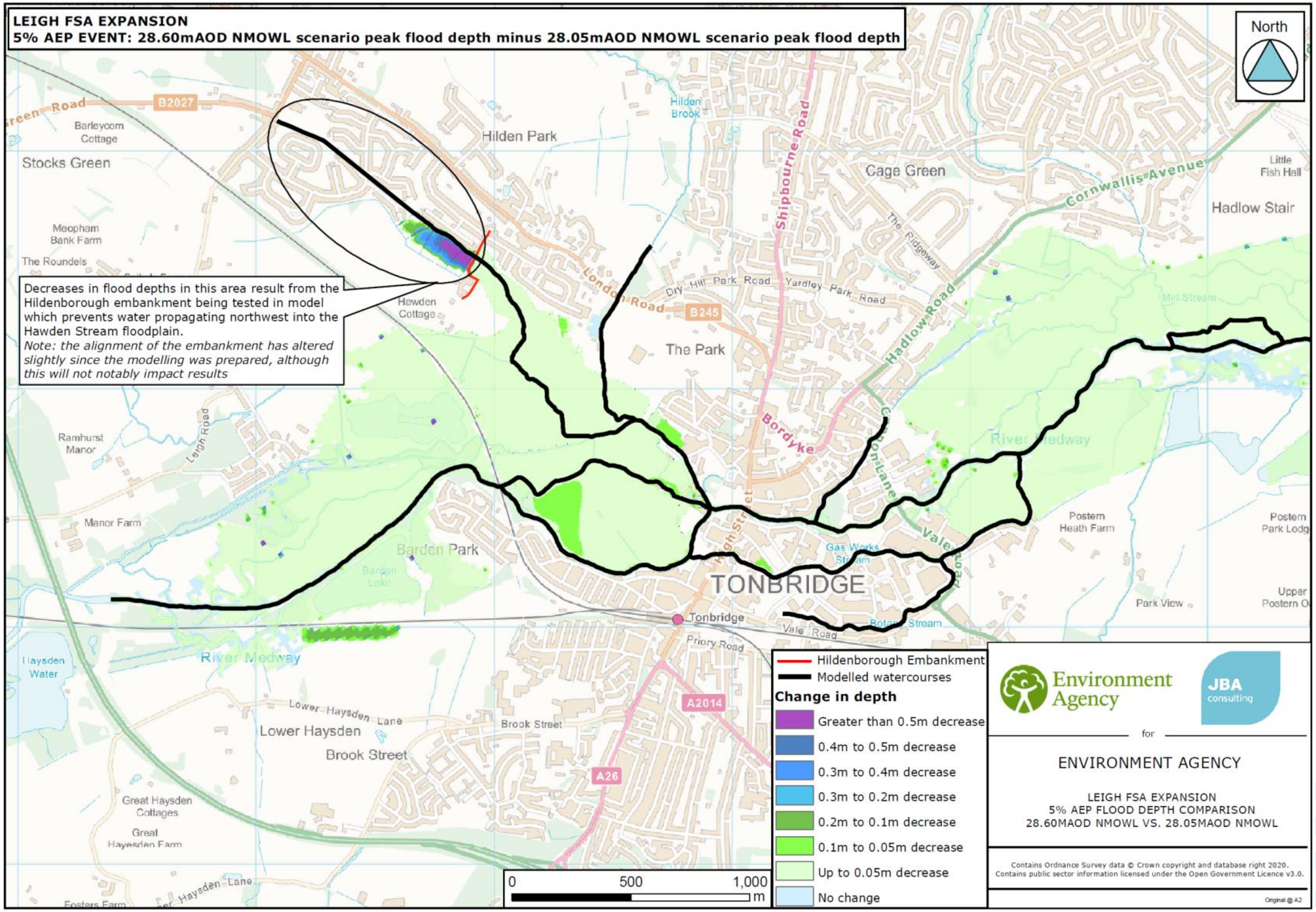


C.2 1% AEP event (downstream of Tonbridge)

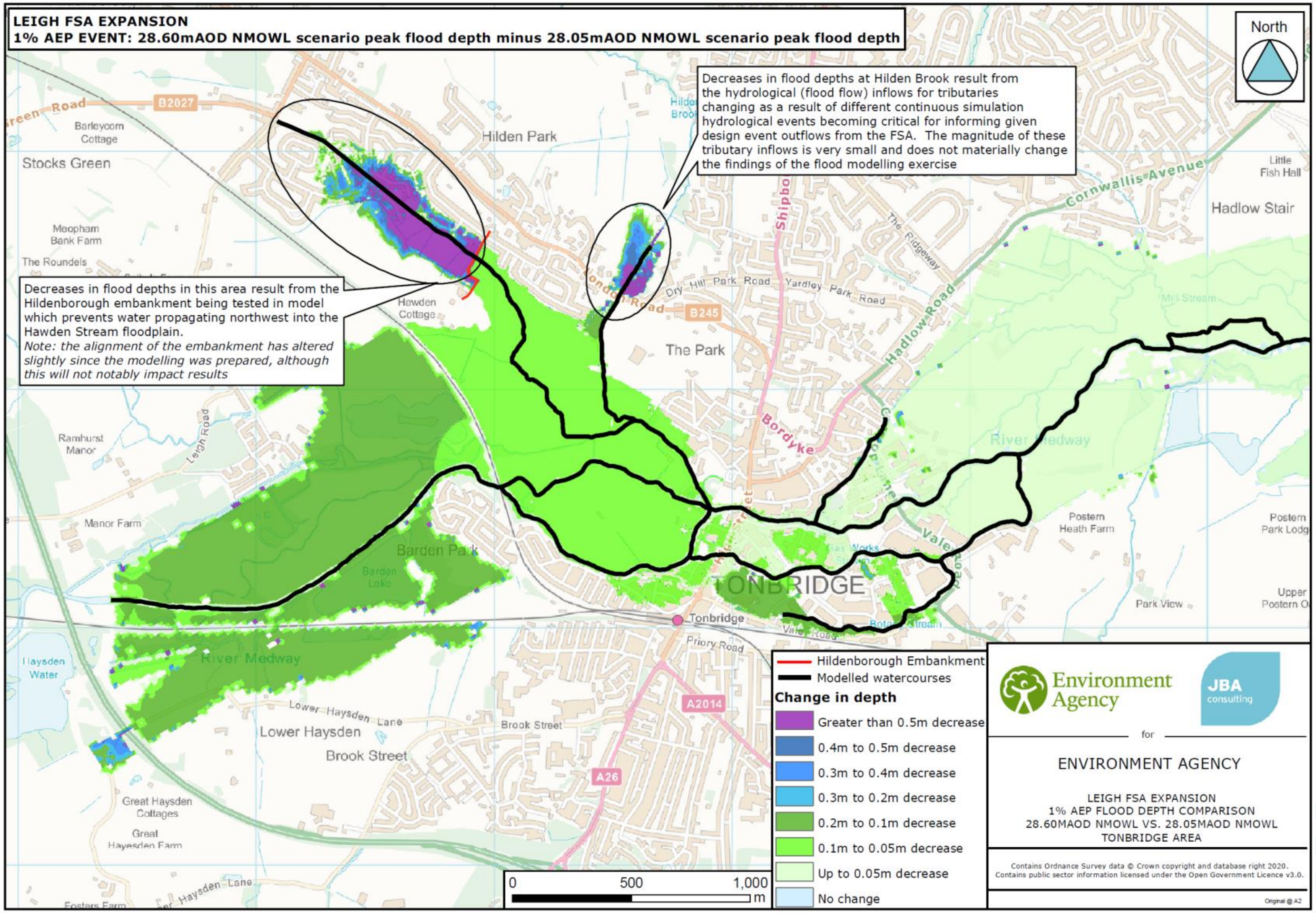


D Change in predicted flood depths through Tonbridge: Proposed development scenario compared with baseline (current operation)

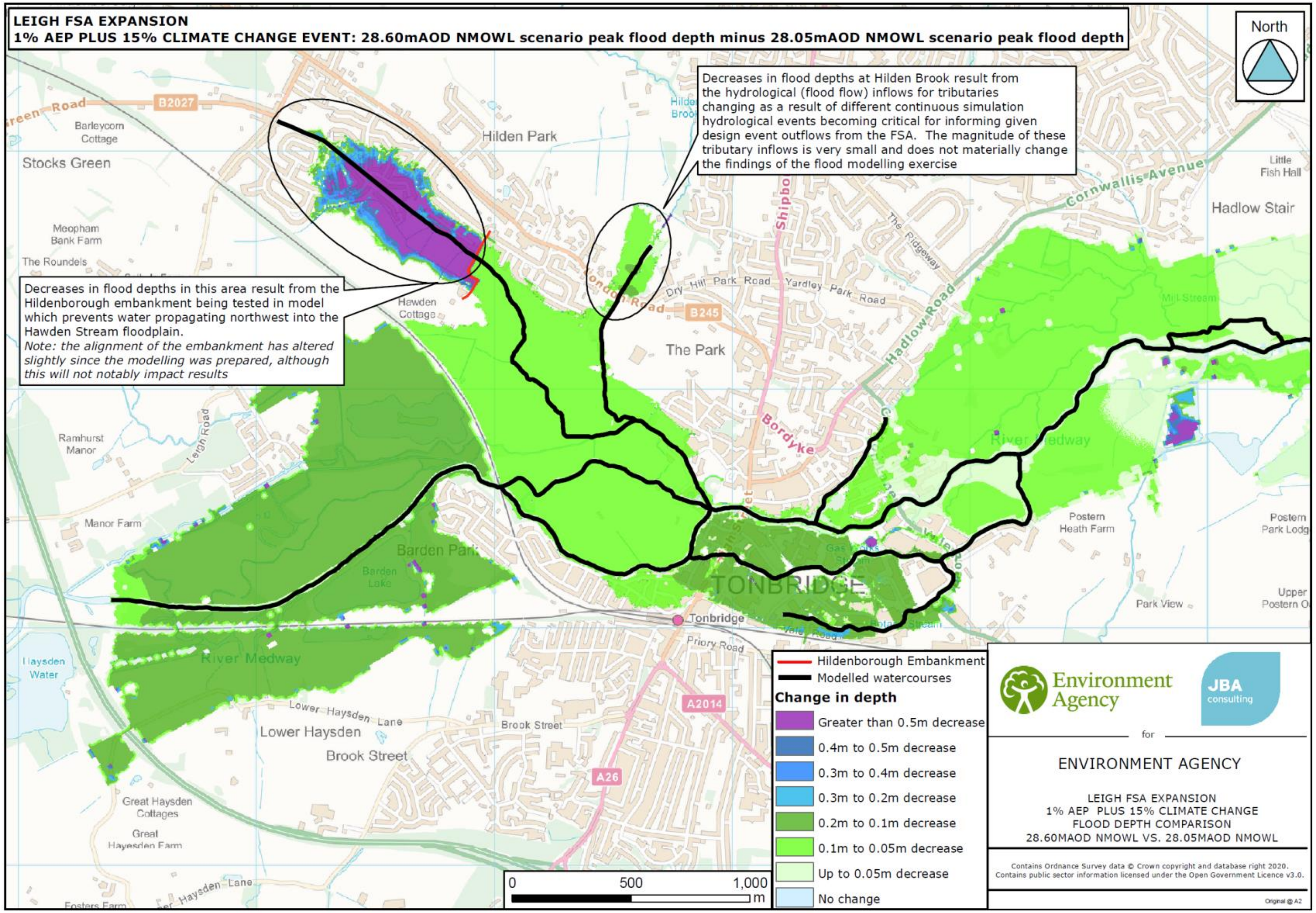
D.1 5% AEP event



D.2 1% AEP event

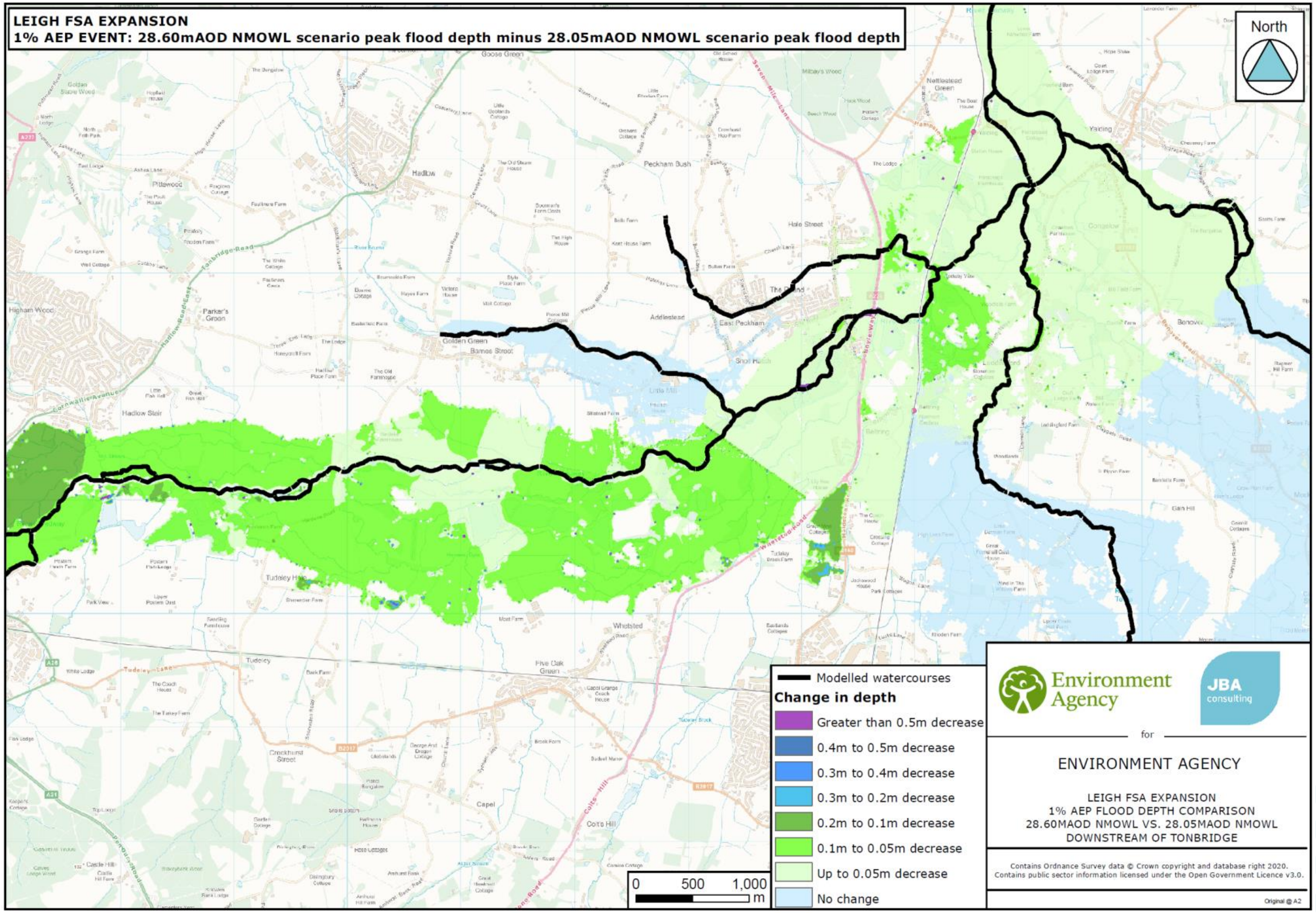


D.3 1% AEP +15% flows event

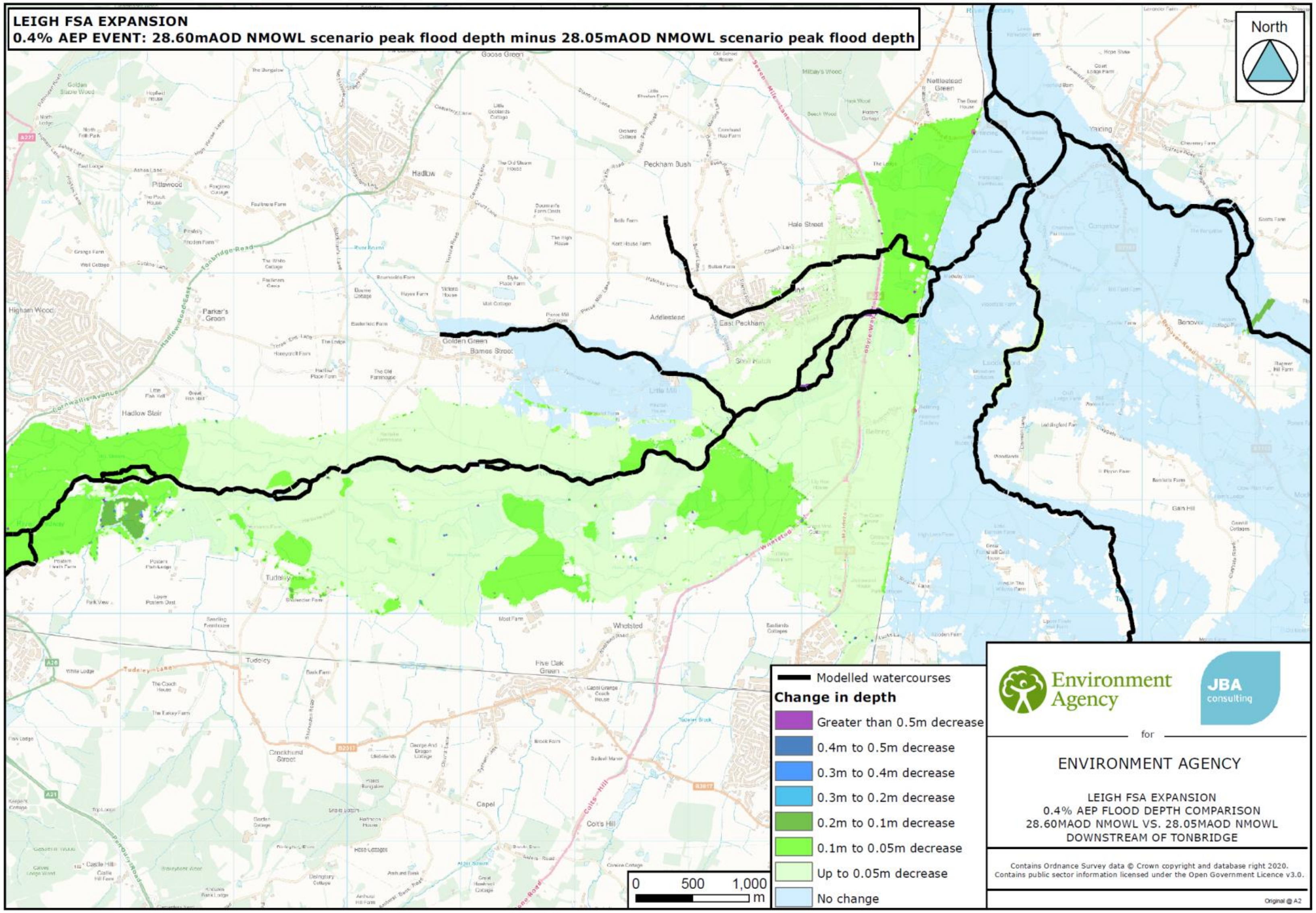


E Change in predicted flood depths downstream of Tonbridge: Proposed development scenario compared with baseline (current operation)

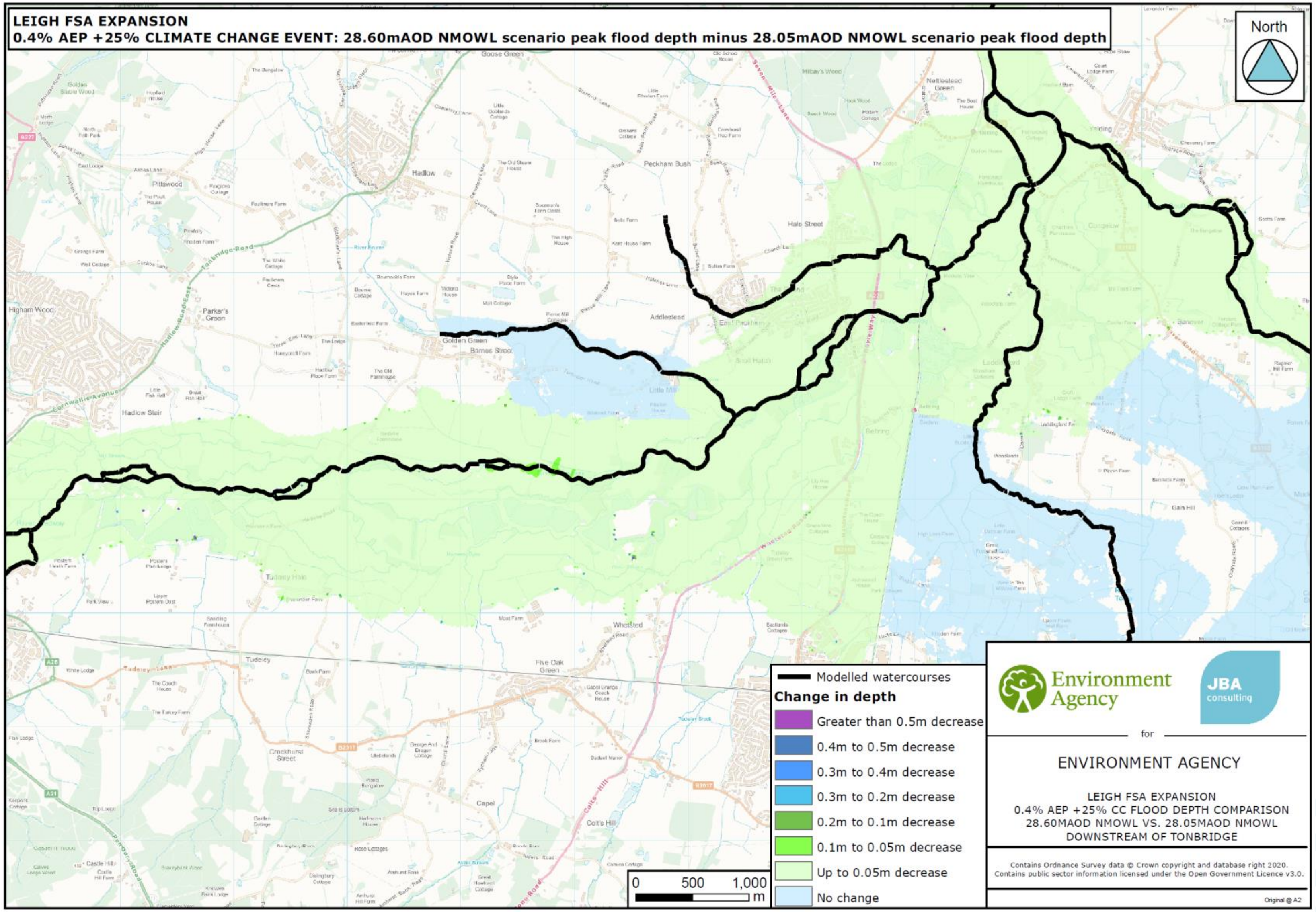
E.1 1% AEP event



E.2 0.4% AEP event



E.3 0.4% AEP +25% flows event



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