RIVER MEDWAY (FLOOD RELIEF) ACT 1976

Inquiry into the Environment Agency's revised Scheme for the Leigh Flood Storage Area, Kent

Proof of Evidence by Andrew Irvine

1 April 2021

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Glossary

The 1975 Act	The Reservoirs Act 1975
The 1976 Act	The River Medway (Flood Relief) Act 1976
AEP	Annual Exceedance Probability. A flood event may be referred to as having a 1% probability of being equalled or exceeded in any one year, also referred to as an Annual Exceedance Probability (AEP). This chance of the event occurring is present each and every year.
The Application	The Environment Agency’s application for the Revised Scheme
CFMP	Catchment Flood Management Plan
COW	Critical Ordinary Watercourse. A watercourse that is not designated as a Main River but which the Environment Agency and other operating authorities agree are critical because they have the potential to put at risk from flooding large numbers of people and property.
Defra	Department for the Environment, Food and Rural Affairs

Drawdown	The phase of FSA operation where the reservoir is emptied in a controlled manner using the radial gates.
Eden	River Eden
FCERM	Flood and Coastal Erosion Risk Management
Flood risk	A combination of the statistical probability of a flood event occurring and the scale of the consequences if it does. So high risk can include circumstances that might not occur very frequently but have very substantial consequences, such as a dam failing and also circumstances that occur relatively frequently and have more moderate consequences, causing relatively frequent but less severe harm.
Freeboard	A safety margin added to give a high degree of confidence that an embankment is not overtopped.
FRA	Flood Risk Assessment This is a document that assesses the flood risk to and from a proposed development or scheme. Flood Risk Assessments are prepared to accompany a planning application submitted to the local planning authority. An FRA reviews a proposed development or scheme against the risk of flooding from all relevant sources (e.g. river (fluvial), surface water (pluvial), groundwater etc) and understands any changes in flood risk to or from the development compared with the current (baseline) position.
FSA	Leigh Flood Storage Area
GOC	Gate Opening Calculator
Hydrograph	A graphical record of river flows and /or river level set against a timescale. The record is for a given point in a river system.
Impounding	Diverting the flow of any inland waters in connection with the construction or alteration of any dam, weir or other works.
LFSAO	Leigh Flood Storage Area Operator. A LFSAO is on duty 24 hours a day, 365 days a year.
m^3/s	cubic meters per second – measurement of flow
Main river	Main river means all watercourses shown as such on the statutory main river maps held by the Environment Agency and Defra, and can include any structure or appliance for controlling or regulating the flow of water into, in or out of the channel. Main rivers are usually larger rivers and streams, and the Environment Agency has permissive powers to carry out works of maintenance and improvement on these rivers.
m AOD	metres Above Ordnance Datum
Medway	River Medway
MFP	Medway Flood Partnership
MFAP	Medway Flood Action Plan
MMS	Middle Medway Strategy
Model	River Medway Food Forecast Model
Operating Procedures	The procedures by which the FSA is operated
Partnership	Medway Flood Partnership
Probability of flooding	The likelihood of a flood event happening is usually expressed in terms of its predicted frequency. This is most

	often communicated in terms of a percentage. For example, a flood event may be referred to as having a 1% probability of being equalled or exceeded in any one year, also referred to as an Annual Exceedance Probability (AEP). This chance of the event occurring is present each and every year.
Revised Scheme	The proposed variation to the Scheme
RBS	Reservoir Balance Sheet
The Scheme	The scheme approved under the 1976 Act which sets out key parameters of how the Leigh Flood Storage Area radial gates can be operated (see Appendix D of the Application)
SMD	Soil Moisture Deficit A measure of the effective rainfall which would theoretically be necessary to saturate the soil. When the SMD is 0, the soil can accept no more rain and the rain will run off the land into rivers faster. Flood conditions and use of the FSA are more likely when there is a low SMD.
Specified Interests	Named organisations and “such other persons representative of interests likely to be substantially affected by the scheme as the Minister may direct” (see section 17(3)(d) of the 1976 Act) to be consulted in the event the scheme is varied, replaced or revoked.
SWA	Southern Water Authority

1. Personal details and introduction

1.1. My name is Andy Irvine. I have a BSc (Hons) in Geography and Ocean Science and an HNC in Civil Engineering.

1.2. I have worked for the Environment Agency for 15 years. I have held several roles within the field of flood and coastal risk management during this time. I have specifically worked in flood asset management, capital project delivery and planning and regulation with respect to the Environment Agency's flood risk functions.

1.3. My current role at the Environment Agency is Team Leader, Partnerships and Strategic Overview. I manage a multi-disciplinary team specialising in Flood and Coastal Risk Management. The principle functions of my team are to promote and deliver new or revised flood alleviation schemes; maintain a strategic overview of flood risk evidence working with risk management authorities; provide statutory planning advice to local planning authorities and determine applications for flood risk activity permits under the Environmental Permitting Regulations (England and Wales) Regulations 2016.

1.4. The Environment Agency is a Category 1 responder under the Civil Contingencies Act 2004. Therefore, in addition to my primary responsibilities set out in paragraph 1.3, I also hold a standby duty role for responding to flooding incidents. I am the lead operator for the Leigh Flood Storage Area (FSA). I have held the role of FSA operator for approximately 10 years and acted as the lead operator for the past 4 years.

1.5. My proof of evidence covers an overview of how the FSA functions, the decision-making role of the operator in how it is operated and examples of operation for context in relation to the modelling presented in the Environment Agency's statement of case.

2. Description of the FSA and how it works

2.1. The FSA is an online flood storage reservoir and it is regulated under the Reservoirs Act 1975 (the 1975 Act). It has a storage capacity of 5.56 million cubic metres (m3). The FSA consists of a 1.3km long earth and clay core embankment and associated flow control structure which consists of three radial gates spanning the River Medway (the Medway). The impounding area covers 278 hectares stretching from Leigh upstream to the village of Penshurst. The FSA reduces flood risk in combination with the flood walls on the banks of the river in Tonbridge. The location and layout of the FSA is given in Figure 1 below.

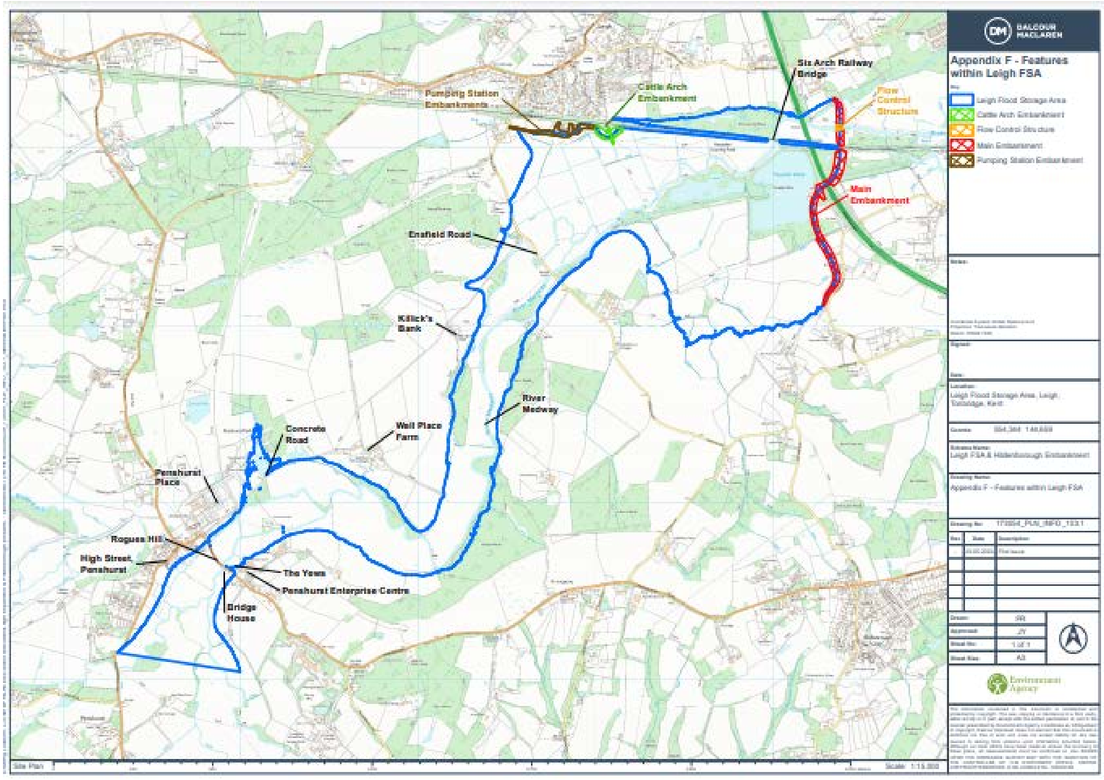

Figure 1. The FSA's layout as shown in Appendix F of the Environment Agency's Application

2.2. The FSA is an online flood storage reservoir. This means that the Medway constantly flows though the FSA and the control structure, unlike a flood barrier where the flow is constrained altogether. This is true both during flood operation and during normal river flows. The control structure influences upstream levels at all times either by automatic gate movement in normal flows or by the intervention of an operator in times of flood flow. The FSA is kept empty until such time that it is used to store flood water. I will expand on how this is achieved and the principles by which it is operated further below.

2.3. The FSA does not prevent all flooding and is only utilised to reduce the risk of flooding to homes and businesses in Tonbridge and Hildenborough.

2.4. During non-flood conditions the FSA is designed to operate automatically without the intervention of an FSA operator. The gates will move automatically to maintain water levels between the range of 24.2-24.4mAOD upstream of the control structure. At this water level it is within bank.

3. Principles of operation

3.1. The FSA is operated in accordance with the Leigh Flood Storage Area Operating Procedures (the Operating Procedures) (see CD 17), which have been written in the context of the Scheme. I attach Appendix A which is an extract of the Operating Procedures relevant to my proof.

3.2. The principles of operation of the FSA, as set out in paragraph 6.1 of the Operating Procedures, are:

- The structure is to be operated to reduce flood risk from the Medway to Tonbridge and Hildenborough only.
- Water to be stored in the reservoir shall not exceed the maximum legal reservoir level (currently 28.05m AOD).
- A minimum impounding flow of $35m^3/s$.
- The outflow must not exceed the maximum rate of flow which will occur naturally in the river upstream of the control structure, i.e. the peak outflow must not be higher than it would be without the Scheme in place.
- The level in the Powdermill Stream must not go below 23.95m AOD.

The Operating Procedures, therefore, ensure effective use of the FSA to reduce the risk of flooding downstream in Tonbridge and Hildenborough and ensure that the FSA storage volume is not exceeded and that reservoir safety is maintained at all times.

3.3. The FSA is not operated below $35m^3s$ and at flows below this figure the FSA remains in automatic as described above. In this mode the FSA gates will maintain an equilibrium between inflow and outflow through the FSA to ensure impounding does not begin. The FSA will notify an FSA operator if this state is exceeded and manual intervention will be instigated. In most flood events this will not instigate impounding, rather a greater degree of monitoring of conditions. This is further explained below.

3.4. Under the 1975 Act the FSA is categorised as a high risk large raised reservoir. This categorisation is applied due to its storage volume exceeding $25,000m^3$ and the risk to life associated with reservoir failure.

3.5. A crucial role of the FSA operator is to ensure that the reservoir is safely operated within the limits of its design. The Operating Procedures deal with this this by explicitly setting a maximum impounding level which allows for additional Freeboard (see explanation in Glossary) before the reservoir embankment height is exceeded.

4. How is the FSA used to reduce flood risk?

4.1. Flood risk reduction in Tonbridge and Hildenborough is achieved by reducing peak flood flows downstream of the control structure to a degree that in the majority of flood events the water is retained within the town food walls. The volume of the FSA is utilised to store only the peak flows of a flood event allowing a reduced flow rate to pass through the control structure. Figure 2 shows conceptually how flood storage reservoirs such as the FSA are operated during a flood to capture the peak flows in the storage area, leading to a reduction in flood flows experienced downstream and thereby reducing flood risk.

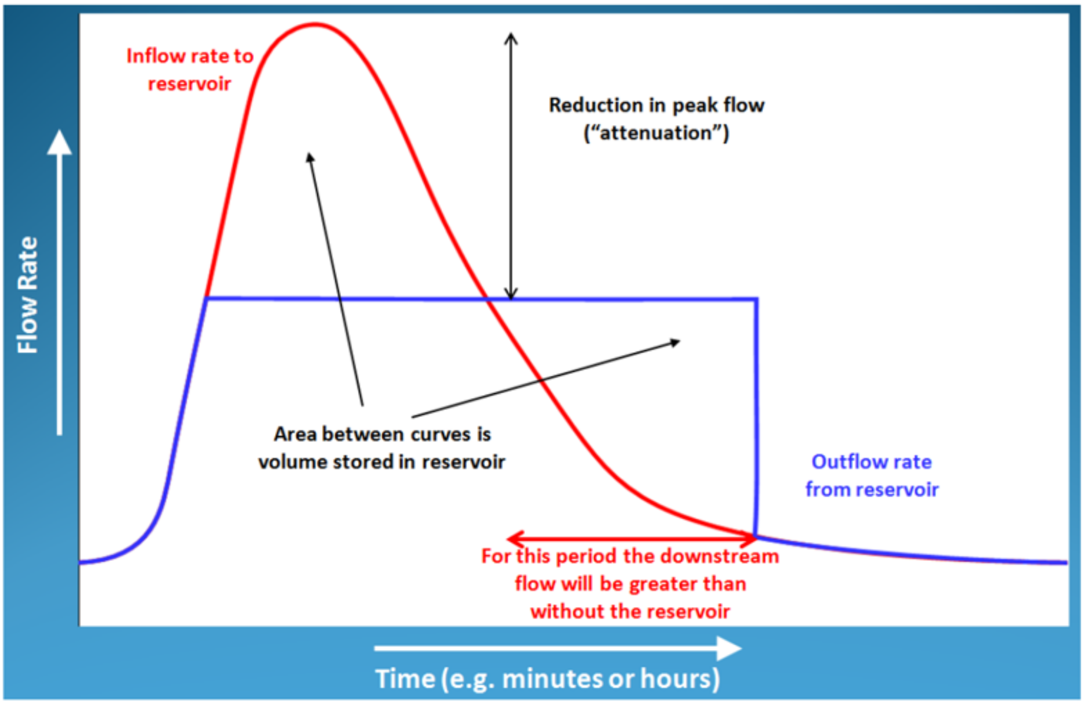

Figure 2. Conceptual hydrograph showing principles of operation of a flood storage area. (Source: fig 6.3 Operating Procedures)

4.2. For the majority of flood events, capturing the peak flows in the FSA is achieved by operating the radial gates to prevent outflow exceeding approximately 75 m^3/s, a flow rate (called a fixed rate of flow) that can be conveyed through Tonbridge and Hildenborough without exceeding the height of the flood walls and so causing flooding to homes and business.

4.3. It is important to note that this fixed rate of flow does not prevent all flooding. For example, areas of the floodplain are allowed to flood such as the recreational sport pitches and other low lying undeveloped land. The exception to this is the Tonbridge Swimming pool site. To prevent this from flooding the FSA operator provides advanced warning to the swimming pool to deploy its flood defences before flows reach a level which would cause flooding. Flooding of these locations occurs at outflows from the FSA above 50m3/s.

4.4. In some floods it is not possible to store enough of the peak flood volume in the FSA. However, flooding downstream would be greater if the FSA did not exist. During this type of flood event, such as one on the scale that occurred over December 2013, the Environment Agency seeks to minimise the amount of water going downstream, whilst ensuring the safety of the reservoir. During larger flood events the FSA operator must take decisions about how the gates are operated and what flows to pass through the structure to optimise the use of the FSA.

4.5. The FSA operator liaises with the Environment Agency flood warning team and provides information on FSA outflows to inform the assessment of the risk of flooding to downstream communities. If outflows cannot be maintained below $75m^3/s$ then flood warnings are issued. Paragraph 10.4 of the Operating Procedures deals with thresholds for flooding impacts downstream. Flows above $80m^3/s$ trigger a flood warning (meaning properties are at risk) for communities such as East Peckham. The threshold to issue a flood warning in Tonbridge and Hildenborough is flows above $100m^3/s$.

4.6. The Revised Scheme will increase the overall storage volume of the FSA. The additional capacity afforded will enable some events that would have previously exceeded the capacity of the FSA to be managed effectively further reducing flood risk downstream.

4.7. The active nature (i.e. the position of the radial gates can be adjusted) of the control structure as opposed to a fixed flow control is a key feature of the FSA. The ability to vary the outflow from the FSA, through operation of the radial gates, during a flood event enables the effective use of the storage volume in the FSA to reduce the impacts of flooding downstream. Experienced operator judgement supported by the Operating Procedures which set out how the FSA should be operated flexibly within set parameters (see the Operating Procedures sections 8, 9 and 10) to store peak flood flows while making effective use of storage volume in the FSA. This flexibility enables operators to store flood water effectively for a wide range of flood event scenarios. I expand on this below (see sections 5 and 6).

4.8. Paragraph 8.1 of The Operating Procedures defines two modes of operation for the FSA during a flood, Fixed Flow and Variable Flow, and are defined as:

- Fixed Flow – An operating plan is developed based on a 'fixed' outflow from the FSA of $75m^3/s$. For these conditions this will provide a safe and effective operation of the FSA and flood risk reduction downstream. This mode of operation is not appropriate for all flood events.
- Variable Flow – An operating plan is developed based on the operator defining an initial outflow and modifying outflow for the duration of the flood event. This aims to maximise the use of the FSA's volume and provide the greatest flood risk reduction based on forecast and real time data.

4.9. Two example flood events which utilise each of the above operating scenarios are set out in section 7 of this proof of evidence.

4.10. There are three fundamental reasons to move to 'variable' flow operation:
- To conserve reservoir capacity;
- To reduce flood risk downstream; and
- The Supervising Engineer has advised that the reservoir must be drawn down for safety reasons.

4.11. Practically, the outflow from the FSA is controlled by operating the three radial gates of the control structure. During a flood event this will see the centre radial gate fully closed and the two side radial gates (North and South gate) opened and adjusted to control outflows as the reservoir level changes in response to impounding the flood flow.

4.12. However, the operator's positioning of the gates is determined by following the operating plan (as set out in section 5.3 below) and aiming to achieve a target outflow for any given event. This may be fixed or variable as defined above. The decision-making around which approach is taken is supported by the Operating Procedures.

4.13. As described above, the desired fixed outflow for the majority of flood events is set at a rate of approximately 75 m^3/s, at which property flooding will not normally occur in Tonbridge and Hildenborough. The relationship between outflow and inflow for the flood duration and the interventions made by the FSA operator determines the volume of water stored within the FSA, the duration of flood water storage and the rate of rise of flood water in the impounding area at any given time.

4.14. A flow rate of less than $75m^3/s$ is required to prevent flooding in some circumstances. For example, it may be necessary to reduce the outflow should blockages occur in the river channel downstream such as fallen trees, silt build up or failure of a bridge or other river structure. As an example, this type of operating plan was used in January 2014 following successive flood events causing damage to the river banks through Tonbridge. On 18 January following several weeks of high flows the FSA was operated using a variable flow regime where outflows were reduced from an initial $75m^3/s$ to an outflow of approximately $50m^3/s$. This decision was made following observed flooding to low lying property in Tonbridge at the higher flow rates. I attach Appendix E which contains the RBS record of this flood event including inflow and outflow from the FSA while in use.

4.15. It is vitally important to retain the right to reduce the flow for effective use of the FSA. The above example illustrates how it has been necessary to do so in the past to prevent flooding. It is also necessary should an emergency such as a bridge collapse or major blockage to the river channel occur, such as a boat slipping its moorings and becoming lodged under a bridge.

4.16. It is important to note that the flow rate at which the FSA is operated is not the sole determining factor of the duration of impounding within the FSA. The duration of impounding relates to the volume of FSA storage utilised to effectively reduce flood risk and the operating plan followed. Each flood event is different and that the peak outflow at which the FSA is operated does not uniformly correspond to the duration of impounding.

5. The role of the Leigh FSA operator and operational procedures

5.1. The operation of the FSA is undertaken only by trained Leigh Flood Storage Area Operators (LFSAO) and in accordance with the Operating Procedures.

5.2. An FSA operator is on standby 24 hours a day 365 days a year in readiness to both plan the operation and operate the control structure during a flood event. The operators work within a wider Environment Agency incident response command and control structure. How the FSA is to be operated is recorded in the operating plan during the early stages of a developing flood event. It also informs the wider incident team on matters such as providing a flood warning service and supporting operational response elsewhere in the catchment in managing a flood incident.

5.3. During non-flood conditions the role of the operator is to monitor the catchment conditions and ensure the FSA is operating in automatic mode. Operators will also escalate any faults to the maintenance team so that the reservoir is operationally ready to be used during a flood, and may be called upon to undertake gate movements during planned maintenance activities.

5.4. During a flood event the FSA operator records all decisions and communications made in a log book. Key operational data such as reservoir level and reservoir outflow, as set out in paragraph 10.3 of the Operating Procedures, is also recorded within the Reservoir Balance Sheet (RBS), a computer spreadsheet based tool explained in more detail in paragraph 6.9 below.

6. The decision making role of the Leigh Flood Storage Operator during a flood event

6.1. Whilst the operational decisions taken by an FSA operator are informed by the Operating Procedures the operator also relies upon a suite of forecasting and operational planning tools such as meteorological data and the River Medway Flood Forecast Model (the Model).

6.2. At all times during a flood event the FSA operator is responsible for monitoring the catchment conditions in the Medway. This is ordinarily carried out remotely from the FSA control room in Leigh, Tonbridge. Following periods of rainfall and when the Medway and Eden respond with increased flows the FSA operator will concentrate on catchment conditions in line with the Operating Procedures. The operator will monitor a combination of weather forecasts, real time rainfall, river level and flow data covering the Medway catchment.

6.3. The operator takes on a more active role in managing the FSA when the likelihood of flooding increases. Paragraph 7.2.3 of the Operating Procedures defines triggers for escalation of operational planning and monitoring. The triggers relate to defined thresholds of heavy rainfall and forecast flows into the FSA from the Upper Medway.

6.4. In the early stages of a flood the operator will produce an operating plan. The operating plan (see an example in Appendix D of the Operating Procedures) sets out the likelihood and magnitude of a forecast flood event. It documents how the FSA is intended to be operated to manage the flood using either a fixed or variable flow regime. The plan also gives an estimate of the expected duration of impounding and the FSA capacity that will be utilised. I will go on to describe how this plan is continually refined throughout a flood.

6.5. Figure 3 shows the preceding phases of a flood event and what information the operator will rely upon to prepare and modify an operating plan for the FSA in line with the Operating Procedures. This shows first, that the planning of how the FSA will be operated starts early before the onset of impounding in the FSA and second, how the operating plan is refined using available data throughout an event.

6.6. Forecast rainfall is used as a trigger for more detailed monitoring of catchment conditions such as upstream river level and flow. Early on, the operator will rely on discussions with Environment Agency flood forecasters to determine the likelihood and magnitude of flood flows in the catchment and the need to operate the FSA.

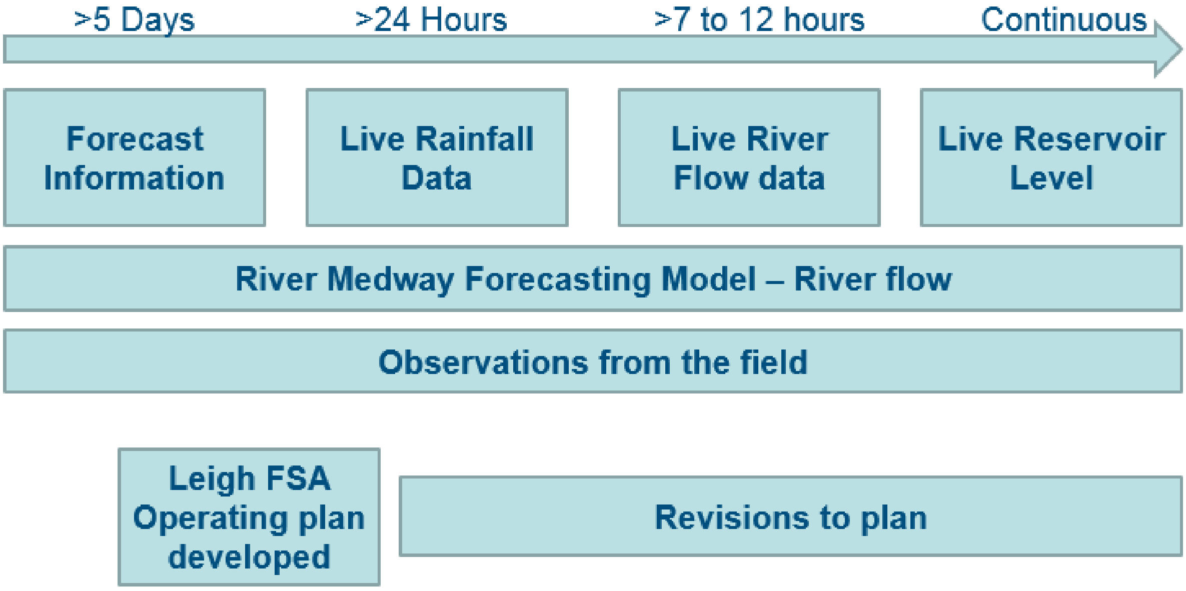

Figure 3. Approximate timeline preceding flood event showing data available to Leigh FSA operators to develop operating plan and make operational decisions

6.7. Following heavy rainfall and when river levels become elevated beyond set thresholds (see paragraph 9.2 of Operating Procedures) in the Upper Medway, the operator will instigate a full operational roster and attend the FSA control room. This shift pattern provides resilience as the operation of the FSA may last several days or longer depending on the scale of flood event. The frequency of monitoring is set out within the Operating Procedures (see paragraph 9.2) and corresponds to the escalating risk of flooding and the need for operation of the FSA. In the preceding days to a flood event, which may be up to a week in advance of potential flooding, the operator will use the Model outputs to estimate flood flows. The Model provides an estimated flow and flood level upstream of the FSA using inputs of both rainfall forecasts and actual rainfall data. In the early stages of a flood the FSA operator uses this forecast flow data to estimate the scale of a flood event. In the early stages of a developing flood this will be presented by Environment Agency forecasters as a range of estimated flood flows with corresponding confidence (i.e. best and worst case estimates) using a range of forecast and real-time rainfall data.

6.8. The operator switches from using forecast information to live data of river flows, river levels and rainfall to modify the operating plan to effectively utilise the FSA storage volume for flood reduction downstream. The operator uses a set of operating tools to continually assess the scale of the flood, the available storage volume and the impact upon the resulting outflows from the FSA.

6.9. The operator uses the RBS to support decision-making. The RBS is used in both forecasting and real time operation. Its main purposes are:

- To record the operation of the FSA;
- To monitor the storage area, upstream and downstream catchment conditions; and
- To support the operator in decision making, in particular when to employ fixed or variable operation.

The RBS is used to monitor reservoir capacity while the FSA stores flood water. Paragraph 10.5 of the Operating Procedures sets out trigger levels for formally reviewing the operating plan as the reservoir fills.

6.10. Any flood forecasting has an element of uncertainty. This is particularly relevant to inflow forecasts which the operator will use to develop an operating plan and target outflow. There is a risk of over-estimating or under-estimating flows and either under-filling or filling the reservoir too quickly, so limiting the storage available to attenuate the most damaging peak flood volume. The operator mitigates these risks by regularly comparing forecast information with real time data to determine the efficacy of the forecasts and adjust any planning assumptions accordingly.

6.11. Once the decision to operate the FSA to store flood water has been made the Environment Agency notify a list of upstream landowners (see Appendix B) firstly with a preliminary warning and then with an onset of impounding warning. These landowners are those which are subject to easements for flooding agreed under the River Medway (Flood Relief) Act 1976 (the 1976 Act). Other actions include the closure of Ensfield Road which becomes inundated as the FSA begins to fill. The road closure is notified to the Kent Highways Authority, Sevenoaks and Tonbridge & Malling Borough Council and to local media traffic news.

6.12. The preliminary impounding warning is given at the earliest opportunity when it is expected that flood water will be stored in the FSA. Where time allows the operator will endeavour to provide this warning with enough notice in daylight hours for the benefit of tenant farmers to move livestock to higher ground for example. The impounding warnings are issued to all those landowners with easements, which includes the Penshurst Estate office and any tenants whom the Environment Agency are advised would benefit from being contacted. This list of recipients is regularly updated. This is followed by a notification prior to the reservoir actually beginning to fill.

6.13. It should be noted that flooding of land or property may already be occurring in the Upper Medway floodplain before the FSA begins to impound. Independent of the FSA operation, the Environment Agency also provides a flood warning service to those who are registered to receive them.

6.14. During impounding the FSA operator is in contact daily with an independent reservoir supervising engineer who provides advice on the operation of the FSA with respect to the structural integrity and reservoir safety. The FSA operators oversee daily inspections of the reservoir embankments while water is being stored. They will also share the live operating plan and current data on river flows and reservoir level with the reservoir supervising engineer to enable scrutiny of safe use of the storage volume. These actions ensure the reservoir embankment is structurally sound while it is storing flood water and that there is no risk of overtopping the reservoir embankments.

6.15. Once the peak of a flood has passed the FSA is drawn down in the same managed way that it is filled, in that the river flow and level data upstream and downstream of the reservoir control structure is monitored and movement of the radial gates made according to the Operating Procedures. The drawdown time of the reservoir will depend on the scale of flood event but will also depend on the outflow used in the given event. Factors as described in 4.1.13 above may require a lower outflow to be sustained for longer to reduce flooding downstream.

6.16. The operational plan is used to communicate the duration of impounding and drawdown of the FSA to the wider Environment Agency incident response command structure. This ultimately informs when we expect river levels to return to normal and impounding ceases when river levels upstream of the FSA structure return to below 24.7m AOD.

6.17. Following drawdown as described above the FSA gates are returned to automatic and LFSAO rosters are stood down.

7. Examples of how the FSA has been operated

7.1. To illustrate the differences in operating the FSA using either a fixed or variable flow regime for flood events of differ magnitudes I have set out below two historic flood events in December 2013 and December 2019 and the considerations made in operating the FSA in each case. Appendix C and D are extracts, respectively, from the RBS record for each flood event.

7.2. The following is an explanation of Figures 4 and 6 which are hydrographs summarising the RBS record:

7.2.1. Reservoir Level: shown as a black line. This is the height of water measured in mAOD directly behind the FSA control structure. The data is available as a live data feed from a river level gauge immediately upstream of the radial gates.

7.2.2. Outflow: shown as a blue line. This is the calculated flow of water passing through the FSA structure. The outflow is calculated using a spreadsheet tool called the Gate Opening Calculator (GOC). The GOC uses a weir equation specific to each of the radial gates that enables the operator to determine the outflow based on the height of water (reservoir level) being retained behind each gate orifice.

7.2.3. Inflow: shown as a red line. This is the net reservoir inflow (the inflow minus the outflow) into the FSA at a given point in time. It is calculated and recorded in the RBS at 15m intervals.

7.2.4. The change in reservoir level over a given period is known as the rate of rise and is measured in cm/hour. It is omitted in the figures below for clarity.

7.3. The RBS calculates inflow using a mass balance equation, which calculates the change in volume within the FSA. The calculation relies upon operator input of the reservoir level (upstream level) to calculate the rate of rise in the FSA's water level. It then takes account of the calculated outflow through the radial gates over a given time period. In the case of the RBS this is every 15 minutes.

7.4. It should be noted that the 15min inflow reading (the red line in Figures 4 and 6) appears erratic due to the nature of the input data. For example, the reservoir level will be subject to minor error due to surface effects such as wind waves in the FSA. Similarly the timing of reservoir level readings may not be precisely every 15 minutes. Furthermore, the very large surface area of the FSA means that a level change experienced directly at the embankment following a gate movement will not be realised uniformly across the entire FSA instantaneously. For these reasons the rate of rise and corresponding net inflow is best estimated over a 1 hour period. Operators will make this assessment and also compare the calculated net inflow in the RBS to that estimated by the Model and those recorded in the Upper Medway at Colliers Land Bridge and Vexour Bridge flow gauging stations to provide confidence.

7.4.1. To expand on this point it is worth highlighting that the following information on the inflow into the FSA is available to the operator:

- Real time flow and level at Collier's Land Bridge (Medway) and Vexour Bridge (Eden). The inflow to the FSA lags approximately 7 hours behind these gauged inflows.
- Current inflow into the FSA as calculated in the RBS can be averaged over an hour to give a more accurate estimate.
- Forecast flow and level at Collier's Land Bridge gauging station (Medway) and Vexour Bridge gauging station (Eden) from the Model.
- Forecast inflow into the reservoir (Medway and Eden confluence) from the Environment Agency forecaster and the Model.

7.5. The December 2013 flood event was very large in its scale and required the operator to employ the variable flow regime. I will discuss below the considerations in making this decision and the impacts upstream and downstream.

7.5.1. Figure 4 shows the flood hydrograph as represented by the RBS from 24 December to 26 December. Further flood events followed during the following weeks but are not included here for clarity. The hydrograph plots both inflow and outflow from the FSA measured in m^3/s on the left hand axis and overlays reservoir level measured in mAOD on the right hand axis. I will further decribe what this shows below.

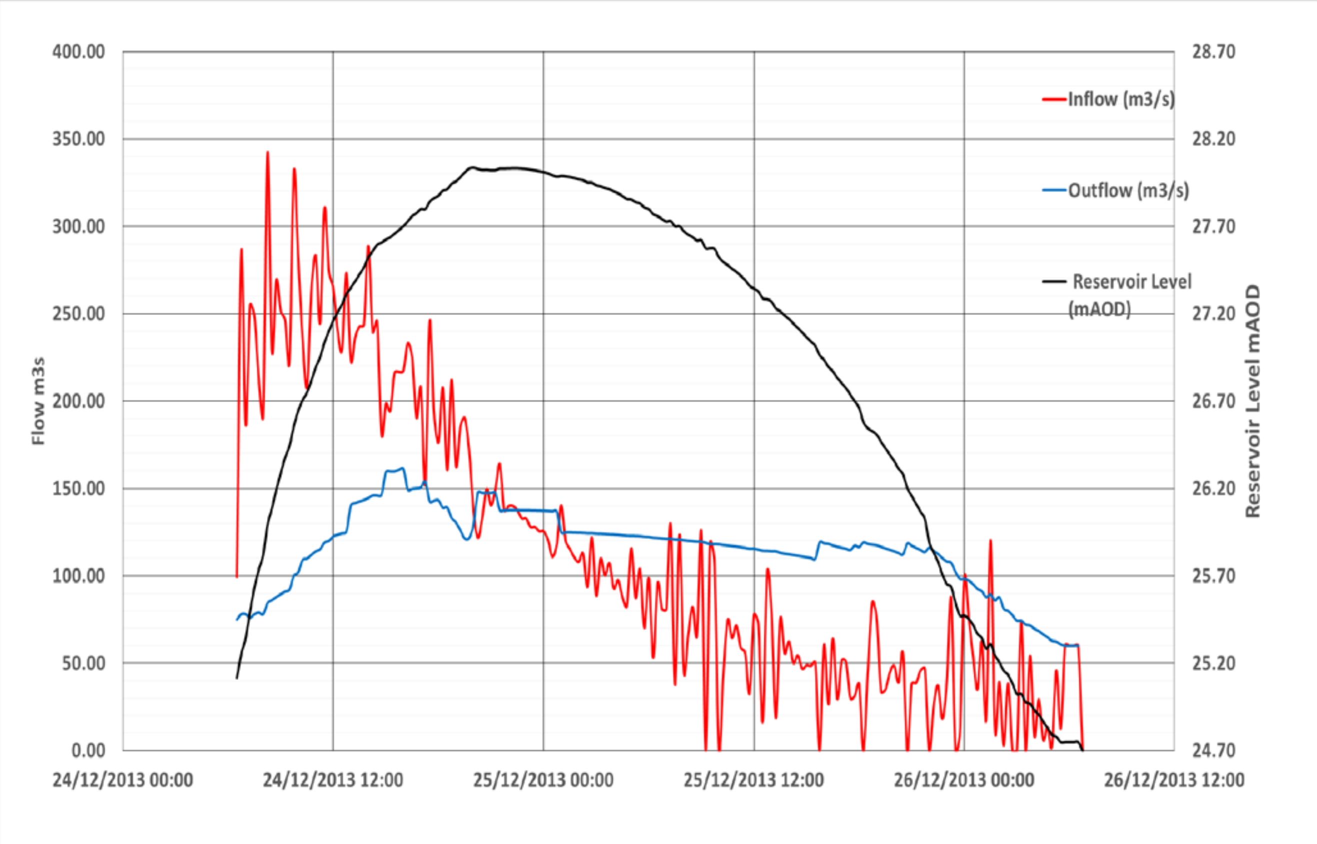

Figure 4. Flood hydrograph produced from RBS data December 2013

7.5.2. This event illustrates why it may be necessary to vary the outflow from the FSA to effectively store peak flood flows without exceeding reservoir capacity. Had the operator not have varied the outflow from the fixed flow rate of $75m^3/s$ the reservoir would have overtopped. Following this flood event the 48 hour flood volume was calculated as $21,837,280m^3$. The volume of the FSA is $5,600,000m^3$. This is four times the volume of water that can be stored in the FSA so the operator had to plan when to begin storing water and what outflow to pass through the FSA to make effective use of the storage volume without exceeding capacity.

7.5.3. The decision to operate in variable flow regime is arrived at by first establishing an operating plan and reviewing this as the understanding of the developing flood becomes more certain. In this event the flow forecasts from the Model gave operators an indication that the event was very large. Using the RBS to assess the impact of these inflows it was established that a higher outflow was required to manage the flood effectively.

7.5.4. Figure 4 also plots the reservoir level (black line) for the duration that the FSA was being utilised to store flood water. It illustrates that there was the rapid rate of rise in level of the FSA as flows were attenuated from passing downstream and the FSA fills.

7.5.5. While it was not possible to store the entire flood volume in this event it was still possible to make effective use of the storage volume and reduce the risk downstream. In this event there was, unfortunately, some flooding of property in Hildenborough and Tonbridge. However were it not for the operation of the FSA it is estimated further properties in this area would have flooded. The reduction in peak flow and associated reduction in flood risk resulting from the use of the FSA can be seen by contrasting the peak inflow to the FSA (the red line) with that of the peak outflow passing downstream (the blue line) as shown in Figure 4.

7.5.6. Figure 4 illustrates how the FSA storage volume was used during this event and is a representation of the RBS record of operation given in Appendix C. It shows that on 24 December 2013 the FSA began storing flood water from 05:15 reaching a peak flood storage volume at 20:00. Water was stored for approximately 36 hours with complete drawdown of the reservoir by 06:45 on 26 December. The operator's decision to use a variable outflow greater than $75m^3/s$ can be seen early in the event. The outflow (the blue line) was increased gradually in the early stages of the event as the operator gained certainly in the real time inflows (the red line) coming into the FSA. Each decision to modify the FSA outflow was supported by a combination of revised forecast inflows and the real time inflows being recorded. The RBS was used to determine how a given outflow would influence the effective use of the FSA without exceeding its capacity. The FSA operator regularly tests these planning assumptions and makes adjustments to the plan having considered actual inflow data and reviewing confidence in forecasts with the Environment Agency forecasting team.

7.5.7. You can also see how drawdown is conducted gradually in a controlled manner.

7.5.8. The hydrograph and RBS record are useful when referenced against the photograph on the first page of Mr Storey's Joint Statement of Case which shows flooding at Rogues Hill Bridge at 9am on 24 December. Figure 4 demonstrates that when that photograph that the FSA water level was 26.29m AOD, just 35% full.

7.5.9. Flooding at Rogues Hill prior to the FSA reaching capacity reflects how the FSA can fill from upstream before the influence of the radial gates impounding water are realised. This occurs as the flood water from the

Medway propagates across the floodplain where it has come out of bank upstream of the FSA.

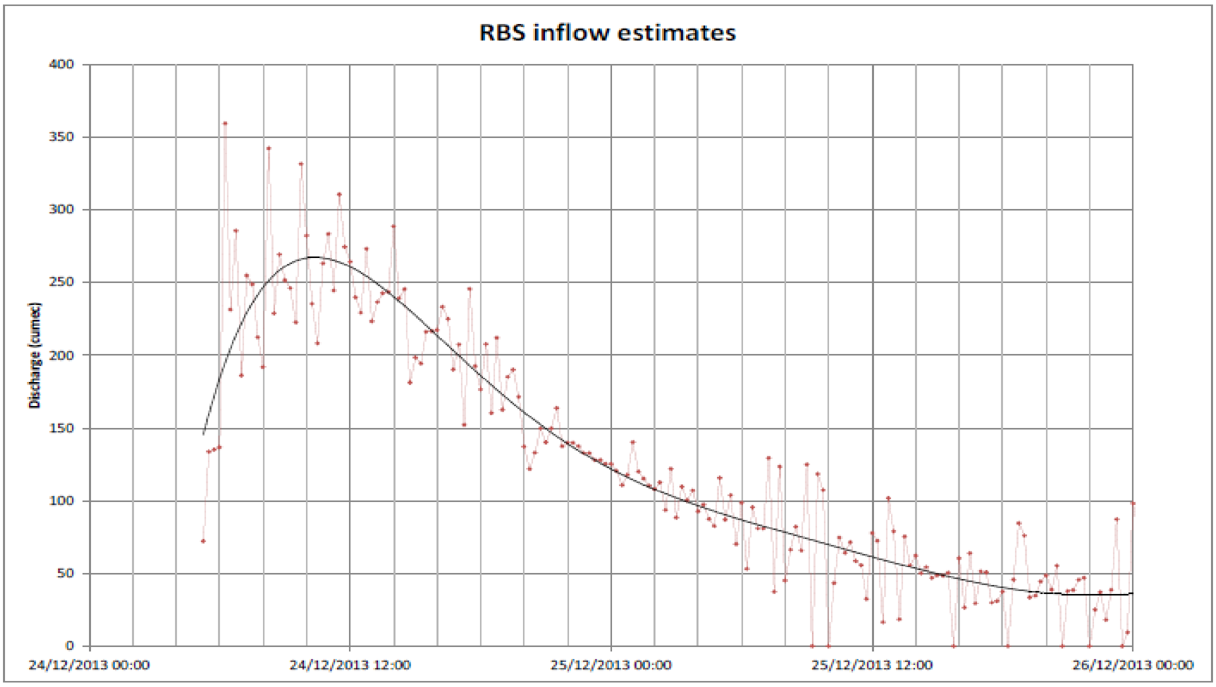

Figure 5. Averaged 15 minute inflow readings at the FSA 24/12/13 to 26/12/13

7.5.10. Figure 5 also presents the inflows to the FSA recorded by the RBS during the flood event on 24 December 2013 (the red line). This graph also incorporates a smoothed average inflow (the black line) for clarity.

7.5.11. By reviewing this record of inflows into the FSA it can be demonstrated that the peak flood inflows directly upstream of the FSA were experienced at approximately 10:00. This timing corresponds very closely with the photographs presented within Mr Storey's evidence. Since Figure 5 shows that peak flood inflows at the FSA occurred at 10:00 it supports the conclusion that flooding at Rogues Hill was driven by flooding upstream of Penshurst and not water being stored in the FSA. The peak inflow was experienced at this location some 10 hours before the FSA was filled to maximum impounding level.

7.6. By comparison, during a more recent flood event in December 2019 the FSA was operated under the fixed flow regime. This example shows how the FSA storage volume was used effectively to prevent flooding to homes and businesses in Tonbridge and Hildenborough with a maximum outflow of 79.9m^3/s. On this occasion it was only necessary to store flood water to a level of 27.08m AOD, approximately 60% capacity, to achieve a reduced risk of flooding to downstream communities.

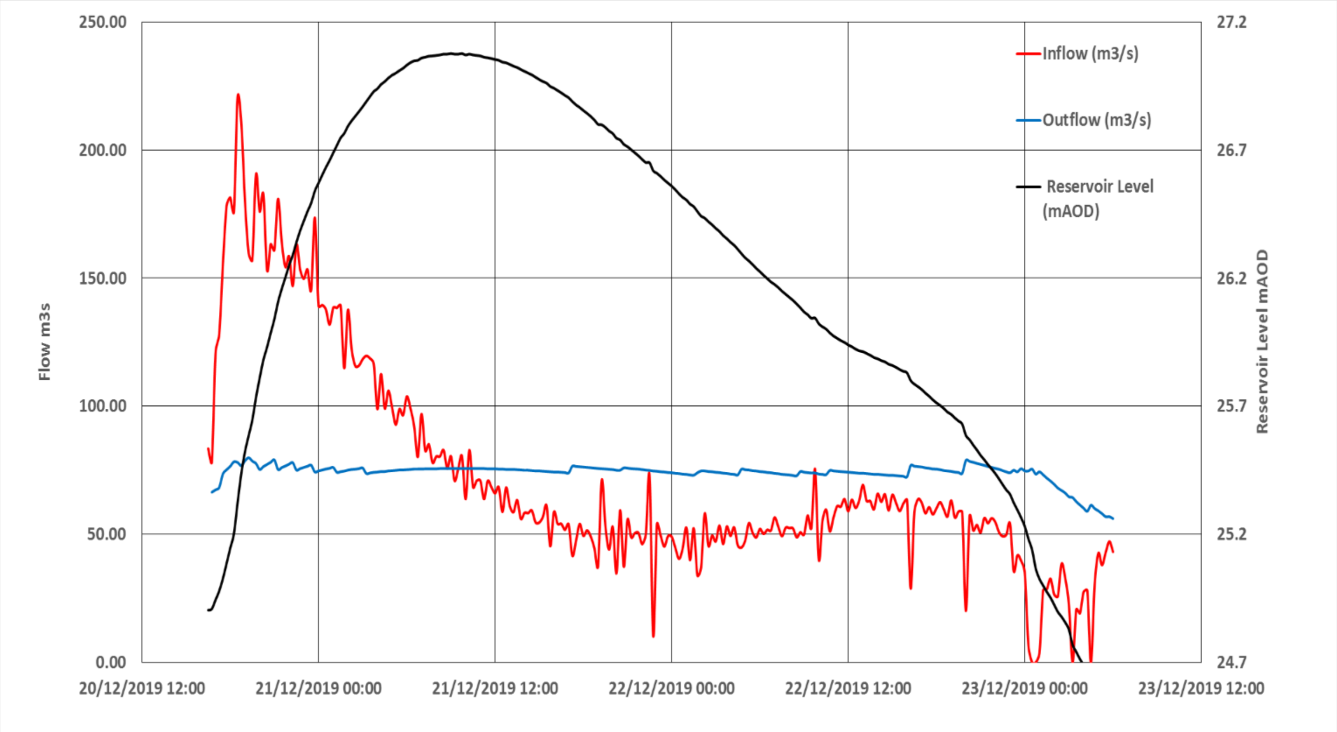

Figure 6. Flood hydrograph produced from RBS data December 2019

7.7. Figure 6 is reproduced from the RBS record given in Appendix D. What is similar to the 2013 event is that the peak of flooding upstream of the FSA was experienced considerably earlier than when the FSA was storing water to its peak for the event. On this occasion the peak inflows to the FSA were approximately 200m^3/s at 18:30 on 20 December 2019.

7.8. Appendix C of Mr Storey's objection to the Application states that water levels at Bridge House reached their maximum at 19:00 on 20 December. Once again referring to the RBS record in Appendix D, it can be shown that at this time the FSA was storing water to a level of 25.52m AOD, which is just 18% of the FSA volume. This is some 14 hours before the FSA reached its peak impounding level for this event. This again shows that the onset of flooding at Bridge House and Rogues Hill is primarily from flood flows directly from the Medway in the flood plain and not as a consequence of peak storage in the FSA.

8. Conclusion

8.1. I have demonstrated here how the FSA is effectively operated under the existing Scheme using the well-exercised Operating Procedures in a range of flood events scenarios.

8.2. The Revised Scheme will not change the overarching operational principles but will require minor updates to the Operating Procedures and the operating tools such as the RBS to incorporate a revised maximum impounding water level. This will enable FSA operators to effectively use the new FSA volume to manage flood events that would previously have resulted in greater flooding in Tonbridge and Hildenborough.

Andrew Irvine