For the attention of the Inspector

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

Additional Evidence

In light of the Environment Agency technical response to our initial representation, we would like to submit the following additional evidence, which bears upon the question of the operational implications of being able to store more water in the FSA, within the legal framework of the River Medway (Flood Relief) Act 1976, and the potential for those operational decisions to cause flooding at Yalding and in other downstream communities that would not occur without the implementation of the revised Scheme, through the additional quantity of water discharged, the timing of such outflows, and the longer duration of such outflows due to the proposed additional storage capacity, if these decisions are to be taken without 'the operational tools [and] confidence in the forecast models [required] to make decisions about how to operate the FSA to reduce risk in Yalding', as well as in all other 'communities past Tonbridge and Hildenborough', which the EA now claims not to possess (see Environment Agency technical responses ID-03 and ID-04, among others), despite the provision of the comprehensive new Medway Flood Model 2015 (CD 1.18 and associated documents):

- the following extracts from the Leigh Barrier Operating Procedures Review - Final Report (June 2005), commissioned by the Environment Agency and produced by Mott MacDonald, variously highlighting the need to re-calibrate the Middle Medway Model in order to improve the FSA operating procedures to adequately manage the barrier's impact on downstream flooding;

- the Environment Agency/National River Flow Archive (NRFA) gauging station details for the River Beult at Stilebridge (<https://nrfa.ceh.ac.uk/data/station/info/40005>), noting the extent to which the level of the River Medway controls the level of the River Beult during severe floods;

- the tables 4.1 and 4.2 from the HR Wallingford Leigh Flood Storage Area Review July 2015 (CD 1.19), comparing the effect of the operation of the FSA on River Medway levels at Tonbridge, Yalding and East Farleigh during the December 2013 flood, as well as comparing the additional reduction in the level of the Medway that might hypothetically have been achieved under optimal operation of the FSA.

Text passages of particular relevance to the inquiry have been highlighted.

Dr John Ackerman and Dr Robin Schuldenfrei

26 April 2021

Table 4.1: Estimated maximum flood level reduction through operation of the Leigh FSA

Location	Peak flood level in the event (m ODN)	Origin	Maximum reduction attributable to Leigh FSA operation (m)
Tonbridge	22.44	Model output for 159 m^3/s	0.6 m
Yalding	11.734	Gauge records	1.0 m
East Farleigh	9.367	Gauge records	0.7 m

Table 4.2: Estimated maximum additional flood level reduction achievable

Location	Peak flood level in the event (m ODN)	Origin	Estimated additional reduction from changed operation (m)
Tonbridge	22.44	Model output for 159 m^3/s	0.2 m
Yalding	11.734	Gauge records	0.4 m
East Farleigh	9.367	Gauge records	0.2 m

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Leigh Barrier Operating Procedures Review

Final Report

June 2005

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1.2 Scope of Work

The assignment is divided into six main tasks:

- Preparatory Work;
- Revision of Existing Operation;
- Revision of Improvements by Operational Staff;
- Development of Revised Rules;
- Assessment of the Impact of Future Climate Change;
- Institutional Review; and
- Production of Report.

This report describes the findings of the Study. The findings do not only relate to the operation of the Leigh Barrier but also to the Medway Flood Forecasting and Warning Model which incorporates the operation of the barrier.

1.3 Modifications to Original Proposal

In consultation with the Agency two major modifications were made to the original proposal:

- A number of options of how to operate the structure were identified. Three options were tested and each option is described in detail. A summary is given for each option describing the particular data requirements, the recommended supporting tools, how the forecasting would work, advantages and disadvantages. Recommendations are given in the report, but it is left to the Agency to decide which of the options to implement.

- The development of the revised rules originally included an assessment of the benefits for communities downstream of Tonbridge. The assessment would have been based on the Flood Forecasting and Warning Model of the Middle Medway and its tributaries. With the identification of serious errors in the water level records downstream of the barrier, used for the calibration of the Middle Medway Model, it became clear that the model will have to be re-calibrated before it will be possible to use it with confidence. It was therefore decided to focus on the optimum protection of Tonbridge. However, recommendations are made on how improvements can be made.

1.4 This Report

This report has been set out with a logical progression through the chapters as described below:

- Chapter 1 gives a short introduction to **the background** of the study and its **scope of work**. It describes the modifications made to the original proposal. Chapter 1 also contains a glossary explaining some terms used in this report and a list of abbreviations.
- Chapter 2 discusses the **data requirements** for the study, particularly in respect of flood events, but also operation of the barrier, hydrometry and environmental data.
- Chapter 3 briefly describes the available **models** relevant to this study.

7 Development of Revised Operation Procedures

7.1 Option 1 - Automatic Rules

7.1.1 Introduction

Investigations were carried out to assess whether the original rules could be modified to provide an effective means of operating the Leigh Barrier in flood conditions.

The advantage of such an approach is that the operation would be controlled only by the upstream and downstream levels, thereby avoiding the risks related to the uncertainties in other hydrometric data such as flow. As the operation would only be based on the actual observed water levels, there would be no need for any element of forecasting.

7.1.2 Option 1 - Automatic Rules Varying Downstream Control Levels

(i) Tests on Design Events – Optimised Downstream Control Levels

A number of scenario tests were carried out during the S105 Flood Risk Mapping Study to help to provide a better understanding of the effect of the operation of the hydraulic control structures, particularly the operation of the Leigh Barrier, on flood water levels through the river system. Some of the tests were repeated with the re-calibrated model and additional tests carried out.

The scenario tests carried out are based on the original automatic rules described in Chapter 5. The downstream trigger water levels (gate raising and gate lowering level no 4 and 5) were modified for a number of design flood events. The downstream trigger water levels were optimised to reduce the outflow without greatly extending the duration of high flows through Tonbridge.

Table 7-1: Summary of Scenario Tests on Optimised Downstream Trigger Level

Return Period	Peak Flow (m^3/s)	Optimised D/S Trigger Level	Max Outflow (m^3/s)	Max Reservoir Level reached?
100	194	23.42	144	Yes
50	180	23.34	128	Yes
25	161	23.18	105	Yes
10	115	22.5	55	Yes
5	95	22.1	41	No
2	71	22.1	41	No

The results of these scenario tests are shown in Figure 7-2 to Figure 7-4. The following main conclusions were drawn from the test results:

- For floods of high return periods, use of the original downstream trigger levels causes the reservoir to be filled before the flood peak arrives. When the reservoir is full, the operators have no choice but to open the gates to allow the inflow to pass through without attenuation. This can make flooding downstream worse.

- Attenuating the flood peak, or effectively attenuating the top part of the flood hydrograph, by adopting higher downstream trigger levels, can reduce the peak discharge through the barrier significantly. However, such operation may increase water levels further downstream of Tonbridge, particularly downstream of the confluences of the Teise and Beult, due to the prolonged peak flow coming down the Medway, which is more likely to coincide with the peak flows from the tributaries. This needs to be investigated.
- The peak flow reduction through the Leigh Barrier varies from event to event. The amount of peak flow reduction through the barrier is not only affected by the peak flow upstream of the barrier, it is also heavily affected by shape and duration of the flow hydrograph, most importantly, the volume of flood water from the Upper Medway and the Eden. Owing to the limited storage capacity in the reservoir, the longer the storm duration and the higher the flood peak and the bigger the volume of flood water, the smaller the peak flow reduction would be through the barrier, and vice versa.

The optimal trigger levels vary from event to event. They were developed by looking at the operation in terms of the entire event. Considering the information available to the operator it is impossible to define an appropriate trigger level at the start of an event. It is only possible to do this with hindsight (see Section 7.1.2(iii) below).

(ii) Test on Design Events – Constant Maximum Outflow 55 m^3/s

According to Appendix X of the Operating Manual flooding occurs when the flow from the barrier exceeds 57 m^3/s. Tests were carried out for all return periods to assess for what event size the barrier could be operated to avoid any flooding in the Tonbridge area. It has to be noted that the flow from the tributaries joining the Medway in the Tonbridge area were not considered. Details related to the flooding thresholds are discussed in more detail in Section 12.3.3, 12.3.5 and Appendix C .

The results show that for the 100, 50 and 25 year design events the outflow could not be kept at 55 m^3/s as the reservoir would fill up to the operational limit at a time when the inflow still exceeds 55 m^3/s significantly. This flow passes through the gates without any attenuation.

The results show that for a 10 year design event with a peak flow of 115 m^3/s the outflow would still exceed 55 m^3/s but for a relatively short time and would stay below 71 m^3/s only causing flooding of some agricultural land downstream of Tonbridge. The automatic rules would cause a peak outflow of about 105 m^3/s. The reservoir would be filled up to its maximum for about 30 hours.

The 5 and 2 year design events with a peak flow of 95 m^3/s and 72 m^3/s respectively were not tested as by using the original rules the outflow stays well below the 57 m^3/s. The maximum reservoir level would not be reached, but for the 5 year event the level would come close to the limit for about five hours.

(iii) Tests on Historic Events – Optimised Downstream Trigger Levels

As described above the optimal trigger levels vary from event to event. They were developed for design events with particular characteristics such as the volume and the shape of the hydrograph. In order to assess whether and how the optimised trigger levels could be applied to the operation of the barrier the trigger levels were analysed and applied to some historic events.

12 Recommendations

12.1 Introduction

This chapter summarises a number of recommendations based on the findings of this study. The recommendations do not only relate to improvements in the operation of the Leigh Barrier but take a wider view on other issues related to the operation of the structure. There is a close link to the Medway Flood Forecasting and Warning Model currently being implemented into the NFFS and being tested. The operation of the barrier was set up as a forecasting tool within the model suite. Any changes made to the operations would have to be incorporated into the tool bearing in mind the limitations in NFFS.

12.2 Operation of the Barrier

12.2.1 Operational Rules

(i) Staged Outflow Calculation Based on Reservoir Level

From the three options tested Option 3, the staged outflow calculation based on reservoir level, shows the best results. Details are described in Section 7.3 and Chapter 8.

The method is simple and robust. Only measurements of the reservoir level would be required which can be readily obtained even in the event of systems failure (by reading the gauge board).

The calculation can be carried out in an Excel spreadsheet together with the determination of the corresponding gate openings.

(ii) Threshold Flow 55 m^3/s

As it is very unlikely that a reliable forecast of the full flood event will ever be available, the operation of the barrier will always primarily be based on real time data. Forecasts would provide no more than supportive information to the operator. It is therefore important to define priorities. The barrier was constructed in order to provide flood alleviation for Tonbridge, and not to reduce the extent or frequency of flooding of farmland or recreational land. As discussed in Chapter 6 and 7, the premature filling of the reservoir represents a significant risk. The safest approach would be to have a policy that discourages any retention in the reservoir until after the onset of flooding of agricultural and recreational land downstream.

In terms of effective operation of the barrier, having a higher threshold for the commencement of impounding will reduce some of the pressure on operational staff during the early stages of a developing flood.

Due to the uncertainties involved in the definition of flooding thresholds, there is some hesitation to recommend a higher trigger flow than the 35 m^3/s described in the Blue Book. However, based on the findings of this study considering the safe and effective operation of the structure, it is suggested that the Agency considers a higher threshold for the commencement of impounding of 55 m^3/s.

(iii) Forecasting

As the suggested procedure is simple it can easily be incorporated into the existing Medway Flood Forecasting and Warning Model in NFFS.

The ISIS model of the Upper Medway and Eden would provide the inflow into the storage area based on the flow forecasts from PDM at the upstream gauging stations. The outflow would be calculated based on the reservoir level. A mass balance calculation would be used to re-calculate the reservoir level for each time step.

12.2.2 Institutional Considerations

The Agency has well established procedures for the management of flood risk nationwide, and the Medway catchment is no different in this respect. However, there are relatively few large flood storage facilities in England, so operation of the Leigh Barrier is inevitably somewhat of a specialist activity. Recent changes to the structure of flood risk management in the Agency, together with the rehabilitation of the barrier control system, and the recent experience of major floods, all suggest that the time is right for a major review of operating procedures.

The following recommendations are made following a review of the operational procedures in the institutional context.

- The numbers of staff qualified to operate the barrier should be increased to ensure that there are no problems providing full cover in a major flood event.
- A formal training programme for existing and new operating staff should be developed and delivered.
- The hierarchy of decision-making in flood events should be reviewed and formalised.

The operating manual for the barrier should be completely rewritten to reflect experience gained over the past 25 years, and the recent change referred to above.

12.3 Issues

As briefly discussed above, not all issues identified during the Study directly relate to the operation of the barrier. However, they cover a number of problems all related to flooding problems on the Medway and its tributaries ranging from data problems to new studies which could provide more reliable data and useful information for further improvements.

12.3.1 Improvement of Flow Measurements at Key Locations

The problems identified at Collier's Land Bridge and Vexour with regard to the reliability of the flow data in particular for high flows were described in the Appendix of the Proposal for this Study.

Some improvement could be made to the rating curve at Collier's Land as described in Chapter 4. However this improvement requires cross checking against spot gauges. Whereas some information was available at Collier's Land, at Vexour the data situation did not justify a rating review. Spot gaugings would be required to improve the rating curve for high flows.

The Agency recently bought two new high-flow acoustic gauging units (ADCPs), one of which is solely dedicated to support the operation of the barrier. The equipment is easy to handle and robust. Flow measurements could be carried out relatively quickly which would help to ensure that the flow close to the peak can be captured.

Whereas the equipment is available, the Kent FMD (Hydrometry and telemetry) team is not on a standby/callout rota at the present. It is likely that the flow peaks would be missed if they occurred outside the working hours. It is therefore recommended that a rota should be in place to ensure the required measurements can be carried out to support the Barrier operations. This would also enable the pending calibration of the newly installed flow gauging station at Lucifer Bridge, to be completed at an earlier date.

The gauging stations at Collier's Land and Vexour are known to be bypassed during large flood events. The flood plain is very wide and it is therefore difficult to correctly measure the flood plain flow. In order to apply the new technique successfully and to obtain the required information it should be checked whether the measurements could be taken at a location further upstream where the flood plain is better defined. The existing S105 model, aerial photographs of the flooded areas in 2000 and the DTM could provide supporting information.

12.3.2 Frequency Analysis

The frequency analysis carried out for the S105 study to define the design peak flows for six return periods was carried out based on the data provided at the beginning of the study in 2000. The frequency analysis did not include any of the large flood events experienced in May and autumn 2000. It is therefore recommended that the frequency analysis should be updated.

12.3.3 Monitoring Tributaries

In order to optimise the operation of the barrier not only with regard to the truncation of the flow but also the timing taking into account the inflow from the tributaries further downstream such as the town streams and also the major tributaries Teise and Beult, more reliable information on event characteristics would be required.

There was no information available on the inflow from the town streams which would have allowed a further optimisation of the operation. It is likely that due to the difference in catchment size the timing of the peaks from the tributaries and the outflow hydrograph from the barrier can be optimised. Information would be needed to assess the catchment reaction of the tributaries and to take the travel time into account for the operation of the barrier. Additional telemetry on the town streams linked to the barrier is recommended.

The extent of flooding further downstream of Tonbridge, in particular at Yalding where the Medway, the Teise and the Beult all contribute to the flooding, is affected by the operation of the Leigh Barrier. More reliable flow measurements would be needed to incorporate the inflows from these tributaries into the optimisation of the operation. Recommendations were already made based on the findings of the Medway FF&W Study [1].

12.3.4 Medway Flood Forecasting and Warning Models

Improvements to the hydrodynamic ISIS model were made during this study in particular to the channel immediately downstream of the barrier where new cross section survey was provided. The model was updated using the information and re-calibrated. It is recommended to update the MFF&W model accordingly.

With the identification of serious errors in the water level records downstream of the barrier up to 2002, used for the calibration of the Middle Medway Model, it became clear that the model has to be re-calibrated before it can be used with confidence. The log book records of the water levels taken from a different data source were considered reliable and could be used to re-calibrate the model[1)].

[1)] Mott MacDonald has been commissioned by the Agency to carry out the required update to the Medway Model. The work will start in July 2006.

As recommended in the MFF&W Study, more data downstream of Stonebridge and Stile Bridge would be needed to calibrate the at present un-gauged sub-catchments with confidence.

Mott MacDonald is currently undertaking a Flood Risk Mapping Study of the Teise and Beult using 2d modelling techniques. This study could provide useful information on flood characteristics such as travel time, flood attenuation and timing of peak flows. It is recommended to use the results to improve the understanding of the interactions between the main river and the tributaries and to take them into account to refine the operation of the barrier if possible.

12.3.5 Threshold Review

It became clear during the study that the refinement and optimisation of the operation of the Leigh Barrier would require more updated and reliable information on flooding thresholds in the Tonbridge area. An initial threshold review was carried out based on the six Section 105 design events. As described in detail in Section C.2 the results are based on certain assumptions made for the S105 flood risk mapping. More information has become available since the S105 FRM Study was carried out in 2002/2003.

A S105 Flood Risk Mapping Study of the two Medway tributaries Hildenbrook and Hawden Stream was carried out by Mott MacDonald. The updated FEH technique was used to derive the design inflow hydrographs. The information is available and would provide more reliable information on design inflows than previously available.

This study would provide excellent information to improve the modelling of the operation of the sluice gates for the design events. Incorporating newly defined rules into the S015 design models would provide more reliable information on the likely extent of flooding.

It is understood that Tonbridge and Malling Borough Council is commissioning a Strategic Flood Risk Assessment which would include the Tonbridge area. This study would also provide more updated information on the extent of flooding in this area.

All information available should be used to improve the definition of flooding threshold in the Tonbridge area. Further improvements of the operations procedures would depend on the availability and accuracy of the information on flooding threshold in Tonbridge.

40005 - Beult at Stilebridge

Station info | Daily flow data | Live data | Peak flow data | Trends | Catchment info | Photo gallery

Grid Reference:	TQ758477	Hydrometric Area:	40 - Kent Rivers Group
Catchment Area:	277.1 km^2	Measuring Authority (local station number):	Environment Agency - Kent, South London and East Sussex (453210001)
Station Level:	11.5 m AOD	Station Operating Period:	01/1958 - N/A

Station Summary Description:
Flat-V weir with high flow rating. Ultrasonics used to validate high flow rating. Predominantly clay catchment on the largest tributary of the Medway.

NHMP Index Site: No
FEH indicative suitability: Pooling

General Description:
Flat V-weir with high flow rating and single-path ultrasonics installed to help validate high flows. The station is located on a long and reasonably straight reach of the River Beult approx. 110m downstream of the Stile bridge, 12 km upstream of the Medway confluence. Constructed in 2001 to replace existing weir ~30m d/s, a compound broad-crested structure, with the central flume separated by short divide piers (which could trap debris) from the broad-crested flanking sections. The ends of the dividing walls caused disturbance of flow, although modelling showed a negligible overall impact. Regarded as full range aside from largest exceptional events.

Hydrometric Description:
Flat V weir is primary flow calculation. Flood banks confine flows, the floodplain beyond this is approx. 300-400m wide and water now seeps through into adjacent field due to rabbit burrowing. Out-of-bank flows can be significant but are accounted for in the rating. Stepping boards in place on upstream bridge in summer to maintain levels; their insertion and removal is managed separately so the time of adjustment of levels in unknown. But they are far enough upstream to not affect the gauge. Heavy upstream weed growth causes issues with lower ultrasonic paths during summer months. Regular maintenance required but difficult due to depth of channel. Upper ultrasonic paths function well despite this meaning that portion of flow calculated through this method is reliable. The Medway may control the levels in severe floods. Station calibrated by model tests and cableway gaugings (79 cumecs gauged during Oct 2000 flood), though cableway no longer in place.

Station Type: Flat V/Ultrasonic
Sensitivity: 11.4 %

Factors Affecting Runoff:
E: Runoff increased by effluent returns.
I: Runoff reduced by industrial and/or agricultural abstraction.

Environment Agency

Flow Record Description:
Peak flow data pre-2001 are from the weir site. Post-2001 are from weir and ultrasonics. Drop out in daily flows in April 2015 confirmed by the EA, pattern also seen at upstream station. Full period of record peak flow data reviewed and released in September 2019 (WINFAP Files v8).

Flow Regime Description:
Small overall impact of artificial influences - all abstraction is agricultural (and therefore very variable). Runoff increased by effluent returns. Some upstream temporary summer weirs and sluices in past. Minor baseflow (from the Lower Greensand) but very responsive regime.

40005 - Beult at Stilebridge

Station info | Daily flow data | Live data | Peak flow data | Trends | Catchment info | Photo gallery

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