Lower Thames Hydro, Teddington Weir

Non-technical Summary and Review

On behalf of **Teddington & Ham Hydro Cooperative Limited**

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Executive Summary

Peter Brett Associates LLP (PBA) has been instructed by Teddington & Ham Hydro Cooperative Ltd to provide additional support documentation and clarification of work previously carried out in relation to potential noise issues from the proposed hydropower scheme at Teddington Weir, Richmond.

The purpose of this report is to provide a non-technical narrative for the planning committee summarising and explaining the work to date in order to provide;

- the necessary reassurance that all possible and practical measures have been taken in previous work, to ensure that the results and representations are reliable.
- a review of data from existing schemes.
- a summary of new work undertaken, i.e. additional baseline sound surveys and re-modelling, demonstrating confidence that the current assessment is robust in its methodology and results, and
- general responses to objections raised regarding previous work.

While the main objective of this report is to address previous and present new work in relation to the proposed hydro scheme, it is important not to forget the planning context surrounding the scheme, both on a national level and in relation to local authority requirements in order to interpret the assessment and understand the results. The aims set out in NPSE (Noise Policy Statement for England) are to avoid "*significant adverse impact*"; in other words it is recognised that developments in some circumstances result in changes in noise level and this, in itself should not form grounds for the refusal to grant consent. Any level change below 3 dB is in principle an indication of "*NOEL (No Observed Effect Level)"* for long-term impact, and anything below 10 dB as an indication of "*LOAEL (Lowest Observed Adverse Effect Level)"*. Any change of less than 10 dB would therefore normally be considered acceptable and with no adverse effect and impact. A planning condition of a level difference below 5 dB as set out by the local authority could therefore be seen as more onerous than what is required by national planning, and the intention / purpose of the NPPF (National Planning Policy Framework).

The dominant source of noise appears to be the water flowing over/through the weir causing a steady state noise. New measurements carried out at Teddington Studio confirm that previous measurements of the existing sound climate at and around the site for the proposed hydro scheme are consistent and reliable.

The methodology of using measured noise source data from another location or installation in a noise impact assessment is not unusual and sometimes necessary when not enough information is available, i.e. there is no laboratory information or the information provided is insufficient. Manufacturers do not measure or provide general noise data for their turbines as they are all bespoke. It is therefore necessary to obtain noise source data in an alternative way. The de-facto standard way of obtaining noise source data for noise impact assessments for hydro schemes are therefore to find a similar existing, i.e. operating, hydro schemes and carry out in-situ measurements of the noise source(s) and use these data in the assessment. The key is to find an existing scheme as similar as possible to the proposed scheme and to obtain the data as close to the source as possible in order to reduce influences from the surrounding topography. While there are some differences between the hydro schemes, the Romney Weir scheme is still the most similar to the proposed scheme in Teddington in terms of type (Archimedean screws), size, capacity and location (i.e. at the Thames). The overall methodology used in the original noise impact assessments for Teddington is therefore considered appropriate and the only practical method that can be applied in terms of a robust assessment.

It should be noted that uncertainties are a measure of how good a model and/or method is. It gives the assessor an indication of whether the data is reliable or not. Uncertainties should NOT be added or subtracted or in any other way be a incorporated in end result. The new uncertainty budgets calculated provide an overall uncertainty for the whole method and calculations of 8 dB with a confidence level of 95%. This indicates that the end results are reliable even with all the various factors influencing the results.

There are drops in the background sound level (L_{A90}) approximately every 12 hours and it has been confirmed that these correlates to the tides. It should be noted that typical drops in background sound levels are around 5 to 8 dB, but can be up to 15 dB. The tides create differences in the water levels in addition to the upstream and downstream water levels. When the available head (the height that the water falls over the weir) for the scheme falls below 1.2 m the scheme will shut down. In effect this means that the scheme will not be operating during the tides, i.e. in periods when low background sound levels occur.

The minimum sound reduction required to mitigate noise from the scheme in order to comply with local authority planning has been established. The proposed mitigation measures (i.e. metal enclosures for the gearboxes and Plexiglas enclosures for the screws) have been evaluated in relation to the required minimum mitigation, and it has been found that the proposed materials in our opinion will achieve the required minimum sound reduction. This should be further verified during detail design.

A new noise impact assessment report (ref. 28307/005 dated 20 July 2015) has been provided, and includes the additional baseline sound survey carried out at the Teddington Studio grounds in order to verify that previous baseline sound surveys provide reliable data. The noise impact assessment provides a new assessment using computer noise modelling with the noise software SoundPlan ver. 7.3. Various scenarios were built and simulated in order to provide the assessment. The results show that the hydro scheme with proposed mitigation complies with local authority planning requirements. As part of the additional work to provide confidence in the new noise impact assessment a model of the existing sound climate at and around the proposed site has been modelled in SoundPlan and calibrated to the measured background sound pressure levels for night time. For comparison the results from the proposed hydro scheme with mitigation measures have been superimposed onto the existing background sound levels. The results show very little difference between the existing background sound levels and the site with the hydro scheme including the proposed minimum mitigation measures. The difference can be found, as expected, close to the scheme.

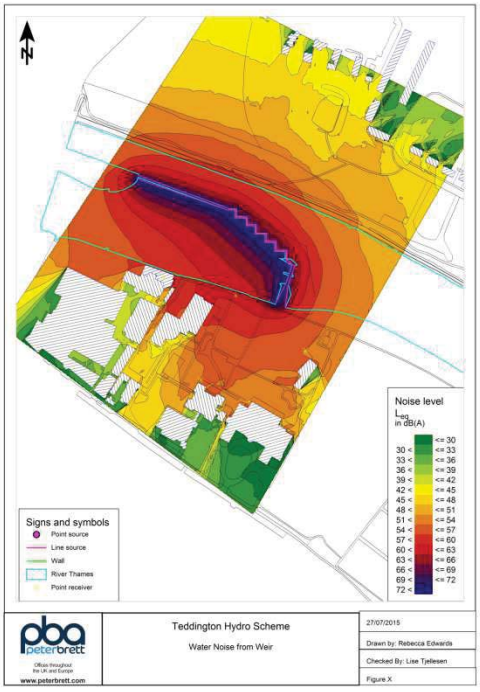
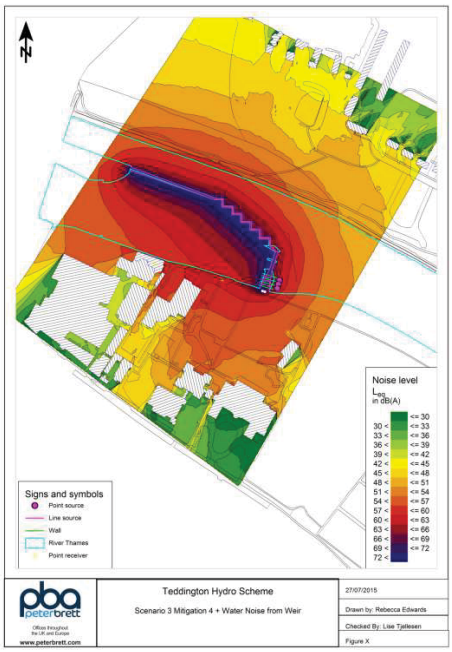
The current report has provided a review and summary of the work done to date, including reviewing and verifying the methodologies, measured data (both baseline and noise source) and presenting the results from the new noise impact assessment. The conclusions can be summarised as follows;

- Results from previous baseline sound surveys are valid and representative of the existing sound climate at and around the site for the proposed hydro scheme.
- The methodology applied to the noise assessments (both previous and current) is the only practical method available.
- Review of the available noise source data show that the data from the Romney Weir scheme provide the highest levels, thus aiding the worst case approach.
- The uncertainty calculated for the current noise impact assessment indicates that results are reliable.

Results from the new noise impact (as shown in the table below) show that the proposed hydro scheme including mitigation measures comply with local authority requirements, and that the long term impact compared to the existing situation can be considered as minor.

Location	External Criterion, dBA	Rating Level (Predicted sound level + adjustments for characteristics), dBA	Level difference, dBA
North-western façade of Riverside Pavilion / Garden (MP1)	Rating Level < 57	43	- 14
North-eastern edge of Clubhouse roof / Clubhouse (Rear façade of the Lensbury Club Hotel) (MP2)	Rating Level < 45	38	- 7
North-eastern edge of Conference Centre (MP3)	Rating Level < 46	41	-5
Burnell Avenue (MP4)	Rating Level < 36	35	- 1
Lensbury Club – Riverside Path (MP5)	Rating Level < 57	51	- 6
Teddington Studios (MP6)	Rating Level < 57	40	- 17

Also as illustrated by the two figures below, the change in ambient sound levels with the scheme including mitigation is negligible.

Existing Sound Climate	Sound Climate with proposed scheme including required minimum in-situ mitigation
	

This Executive Summary contains an overview of the key findings and conclusions. However, no reliance should be placed on any part of the executive summary until the whole of the report has been read.

1 Introduction

1.1 Report Structure

1.1.1 Peter Brett Associates LLP (PBA) has been instructed by Teddington & Ham Hydro Cooperative Ltd to provide additional clarification and support documentation in relation to potential noise issues from the proposed hydropower scheme at Teddington Weir, Richmond.

1.1.2 **Sections 1** to **6** can be read as a standalone non-technical document.

1.1.3 **Appendices A** to **I** cross referenced through the report, should not be required in order to understand the essence of the report, but they contain more detailed information for those, who require or are interested in a more in depth discussion of the various elements.

1.2 Background and Objectives

1.2.1 The proposed hydro scheme (see **Appendix B**) has been subject to a number of noise assessments and reviews of these. The relevant documents are listed in **Table C1** in **Appendix C** with references used throughout this report.

1.2.2 The previous noise assessments have been subject to intensive scrutiny and objections with successive amendments and additional technical notes provided to convey further information.

1.2.3 The latest response to the reports was provided by Adrian James Acoustics (AJA) as a full review report [AJA5] in October 2014.

1.2.4 The purpose of this report is to provide a non-technical narrative for the planning committee summarising and explaining the work to date in order to provide;

a. the necessary reassurance that all possible and practical measures have been taken in previous work, to ensure that the results and representations are reliable.

b. a review of data from existing hydro schemes.

c. a summary of new work undertaken, i.e. additional baseline sound surveys and re-modelling, demonstrating confidence that the current assessment is robust in its methodology and results, and

d. general responses to objections raised regarding previous work.

1.2.5 A new noise impact assessment report (ref. 28307/005 dated 23 July 2015) has been provided. It is a direct response to some of the specific concerns raised. While the noise impact assessment is a standalone document, it is recommended that it is read in conjunction with this non-technical report.

1.2.6 While this report should be self-explanatory and is kept in as non-technical terms as possible, the inherent nature of the subject, there may be some technical terms, so to assist the reader further a Glossary of Acoustics Terms is provided in **Appendix A**.

2 National and Local Planning

2.1.1 While the main objective of this report is to address issues with previous work in relation to the proposed hydro scheme, it is important not to forget the planning context surrounding the scheme, both on a national level and in relation to local authority requirements in order to interpret the assessment and understand the results.

2.1.2 A full list of relevant standards and their meaning is provided in **Appendix D**. The following sections provide a brief summary in order to provide a planning context for the noise impact assessment.

2.2 National Planning

2.2.1 The national planning guidance now consists of the National Planning Policy Framework (NPPF) and the Noise Policy Statement for England (NPSE).

2.2.2 Their aim is to;

- *avoid significant adverse impacts on health and quality of life;*
- *mitigate and minimise adverse impacts on health and quality of life; and*
- *where possible, contribute to the improvement of health and quality of life.*"

2.2.3 The explanatory note for the NPSE contains explanation and definition of terms in relation to assessing noise impact as follows;

> *NOEL (No Observed Effect Level) - The level below which no effect can be detected. In simple terms, below this level, there is no detectable effect on health and quality of life due to the noise.*
>
> *LOAEL (Lowest Observed Adverse Effect Level) - This is the level above which adverse effects on health and quality of life can be detected.*
>
> *SOAEL (Significant Observed Adverse Effect Level) - This is the level above which significant adverse effects on health and quality of life occur.*

2.2.4 It is clear that consideration of acceptable noise levels cannot include "in-audibility", as the aims as set out in NPSE is to avoid "*significant adverse impact*"; in other words it is recognised that developments in some circumstances result in changes in noise level and this, in itself should not form grounds for the refusal to grant a consent.

2.2.5 The NPSE recognises that it is not possible to have single objective noise-based measures that define the NOEL, LOAEL and SOAEL, that are applicable to all sources of noise in all situations. The levels are likely to be different for different noise sources, receptors and at different times of the day. The NPPF and associated NPSE provide the concepts for defining various levels of effect, but do not translate these into actual noise levels. Instead, it is up to individual local authorities to interpret the concepts in the NPPF and NPSE, and translate them into noise level criteria for development to be applied in their area and for a particular type of development.

2.2.6 Institute of Environmental Management and Assessment (IEMA) and Institute of Acoustics (IOA) issued the document "Guidelines for Noise Impact Assessment" on 6th October 2014.

2.2.7 The intention of that document is to help acoustic consultants to interpret the national planning guidelines of NOEL, LOAEL and SOAEL, and to provide indications of what level differences means in terms of impact. **Table 1** below is taken from the guidelines and summarises the long and short term impact in relation to sound level differences.

Table 1 – Impact from the Change in Sound Levels

Long-term Impact Classification	Short-term Impact Classification	Sound level change dB $L_{Aeq, T}$ (positive or negative) T = either 16hr day or 8 hr night
Major	Major	≥ 10
Moderate		≥ 5 and < 10
Minor	Moderate	≥ 3 and < 5
Negligible	Minor	≥ 1 and < 3
	Negligible	≥ 0 and < 1

2.3 Local Planning

2.3.1 The local authority (LBRUT) has set out requirements for both external and internal sound levels. External levels uses terminology from standard BS4142:2014, and the internal levels are in accordance with guidelines in standard BS8233:2014.

2.3.2 While the Lensbury Club is considered as commercial premises by the local authority, internal criteria for residential receptors are applied due to the nature of the hotel facility, i.e. as stringent internal criteria as for residential dwellings.

2.3.3 It has been chosen in the new noise impact assessment to assess against the night time values, as these provide the lowest background sound levels, and with the assumption that if the scheme will work for night time values, it is likely to work for day time values as well, and this is a worst case approach.

2.3.4 Notwithstanding the above the local planning conditions could be considered more stringent that national planning. From the above **Table 1** any level change below 3 dB is in principle an indication of NOAEL for long-term impact, and anything below 10 dB as an indication of LOAEL. A change of less than 10 dB would normally be considered acceptable and with no adverse effect and impact.

2.3.5 A planning condition of a level difference below 5 dB could therefore be seen as more onerous than what is required by national planning, and the intention / purpose of the NPPF.

2.4 Changes in Sound Levels

2.4.1 The above mentioned level changes or differences put into context of perception the following **Table 2** provides typical sound levels in terms of dBA for common situations;

Table 2 – Sound Pressure Levels and Perception

Approximate Noise Level, dBA	Example of Perception
120	Threshold of pain
100	Pneumatic Drill
80	Vacuum cleaner
70	Inside a moving car
60	Normal conversation
50	Quiet Office, no machinery
40	Public Library
30	Rural area at night, still air
0	Threshold of hearing

2.4.2 It should further be noted that Decibels are not an absolute unit of measurement, but an expression of a ration between two quantities expressed in logarithmic form. This means that relationships between numbers do not work in the same way as ordinary numbers.

2.4.3 **Table 3** below shows the connection between changes in sound levels and the human perception;

Table 3 – Changes in Sound Levels and Human Perception

Change in Sound L:evel	Perception
1 dB	Just noticeable in perfect laboratory conditions
3 dB	Just noticeable
10 dB	Perceived as a doubling or halving

3 Assessment Locations and Existing Sound Climate

3.1 Assessment Locations

3.1.1 The question about which planning criterion to apply relates closely to the definition of the type of the nearest noise sensitive receivers.

3.1.2 In the report from LBRUT [LBRUT] the following is stated:

"There are existing residential and commercial users in relatively close proximity to the proposed scheme, with Burnell Avenue properties and the Lensbury Hotel at approximately 200 & 125 meters from the proposed development site respectively. The Lensbury also has grounds which are used by guests which extend to the edge of the river. Figure 1 above presents the location of the proposed development site and the locations of the closest residential and commercial noise sensitive receptors."

3.1.3 The above statement could be interpreted as nearest residential receiver is located at Burnell Avenue and that the Lensbury Club and Hotel is considered as being a commercial receiver. It is our understanding from discussions with the EHO, that it should be interpreted that way. This has been confirmed in recent discussions.

3.1.4 Notwithstanding the above the current assessment locations are set out in **Table 4** below based on what now has been generally agreed as being reasonable assessment locations.

Table 4 – Assessment locations

Location	Description	Surveyed by
MP1	North-western façade of Riverside Pavilion / Garden	ZBP / LBRUT
MP2	North-eastern edge of Clubhouse roof / Clubhouse	ZBP / LBRUT
MP3	North-eastern edge of Conference Centre	ZBP / LBRUT
MP4	Burnell Avenue	ZBP / LBRUT
MP5	Lensbury Club – Riverside Path	LBRUT
MP6	Teddington Studios	PBA

3.2 Existing Noise Climate

3.2.1 In the original noise assessment report [ZBP1] by ZBP Acoustics only measured the ambient and background sound levels in location MP4 (Burnelle Avenue) and only over a short period of time during the night. The successive critique from AJA [AJA1] led to additional measurements at the Lensbury Club. The results were reported in the updated version of the assessment [ZBP2] and confirmed by measurements carried out by LBRUT and reported in [LBRUT].

3.2.2 Access to the Lensbury Club was sought in 2014 by PBA, but was not obtained.

3.2.3 PBA has tried again to gain access to the Lensbury Club and grounds to carry out new surveys in order to provide additional data for verification in relation to the current (*June 2015*) work. However, due to various practical issues raised by the Lensbury Club, it has not yet been possible to carry out the additional surveys. However, it is the intention to do so at the soonest available opportunity depending on the Lensbury Club granting the necessary access.

3.2.4 The dominant source of noise at and around the site appears to be the water flowing over/through the weir causing a steady state noise.

3.2.5 New measurements carried out at Teddington Studio confirm that previous measurements of the existing sound climate at and around the site for the proposed hydro scheme are consistent and reliable.

3.2.6 From the measurements at Teddington Studio it can be seen that there were drops in the background sound levels due to the tides occurring twice a day. Apart from these drops the background sound levels appeared to be very steady and consistent with no or little difference between day and night time periods. This is illustrated by the sound level data measured at Teddington studio shown graphically in **Figure E3** and E**4** in **Appendix E.**

4 New Assessment

4.1 Introduction

4.1.1 As a result of the objections to the original noise impact assessments this non-technical summary has been commissioned in order to provide clarification of the potential noise impact from the proposed scheme.

4.1.2 Part of the new additional work carried out in in relation to this is further background sound level measurements at Teddington Studios and a new noise impact assessment using SoundPlan modelling.

4.2 New Assessment

4.2.1 The new noise impact assessment still relies on previous baseline surveys; however, a new noise survey at Teddington Studios has been carried out in order to provide additional information on the existing acoustic environment surrounding the site for the proposed hydro scheme. Graphical representation of the results can be seen in **Figure E3** and **E4** in **Appendix E**.

4.2.2 The new baseline sound survey confirms that previous measurements carried out by ZBP and LBRUT are reliable, and that the data can be used with confidence.

4.2.3 While the new noise impact assessment also still rely on previous noise source data obtained at the Romney Weir hydro scheme, it has been verified that the data is valid as part of the work undertaken for this report as discussed in **Section 5.3** .

4.2.4 A new noise impact assessment has been carried out using the noise modelling software SoundPlan ver. 7.3. Results were calculated for each assessment location predicting the sound pressure levels for the proposed scheme without mitigation and with the minimum required in-situ mitigation.

4.2.5 The results show that the proposed hydro scheme with the mitigation measures complies with Local Authority requirements for both external and internal levels. Full noise maps from the SoundPlan models are shown **in Figure F1** and **F2** in **Appendix F**.

4.2.6 As part of the additional work to provide confidence in the new noise impact assessment existing sound climate at and around the proposed site has been modelled in SoundPlan and calibrated to the measured background sound pressure levels for night time. The results are shown in **Figure 1** below.

4.2.7 For comparison the results for the proposed hydro scheme with the proposed minimum mitigation measures have been superimposed onto the existing background sound levels and the result can be seen in **Figure 2** below.

4.2.8 There is very little difference between the existing background sound levels and the site with the hydro scheme including the proposed minimum mitigation measures. The difference can be found, as expected, close to the scheme.

Figure 1 – Existing sound climate

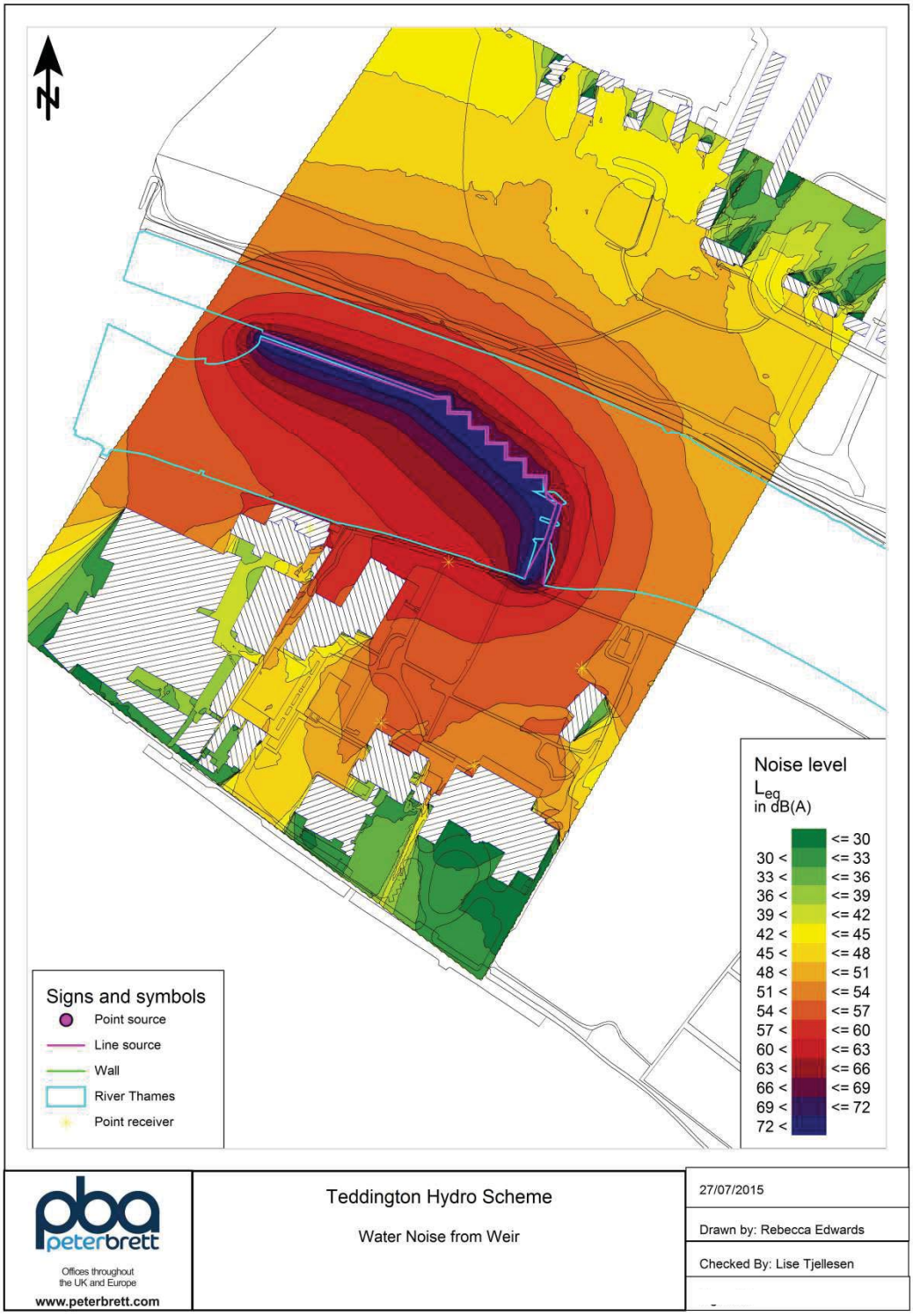
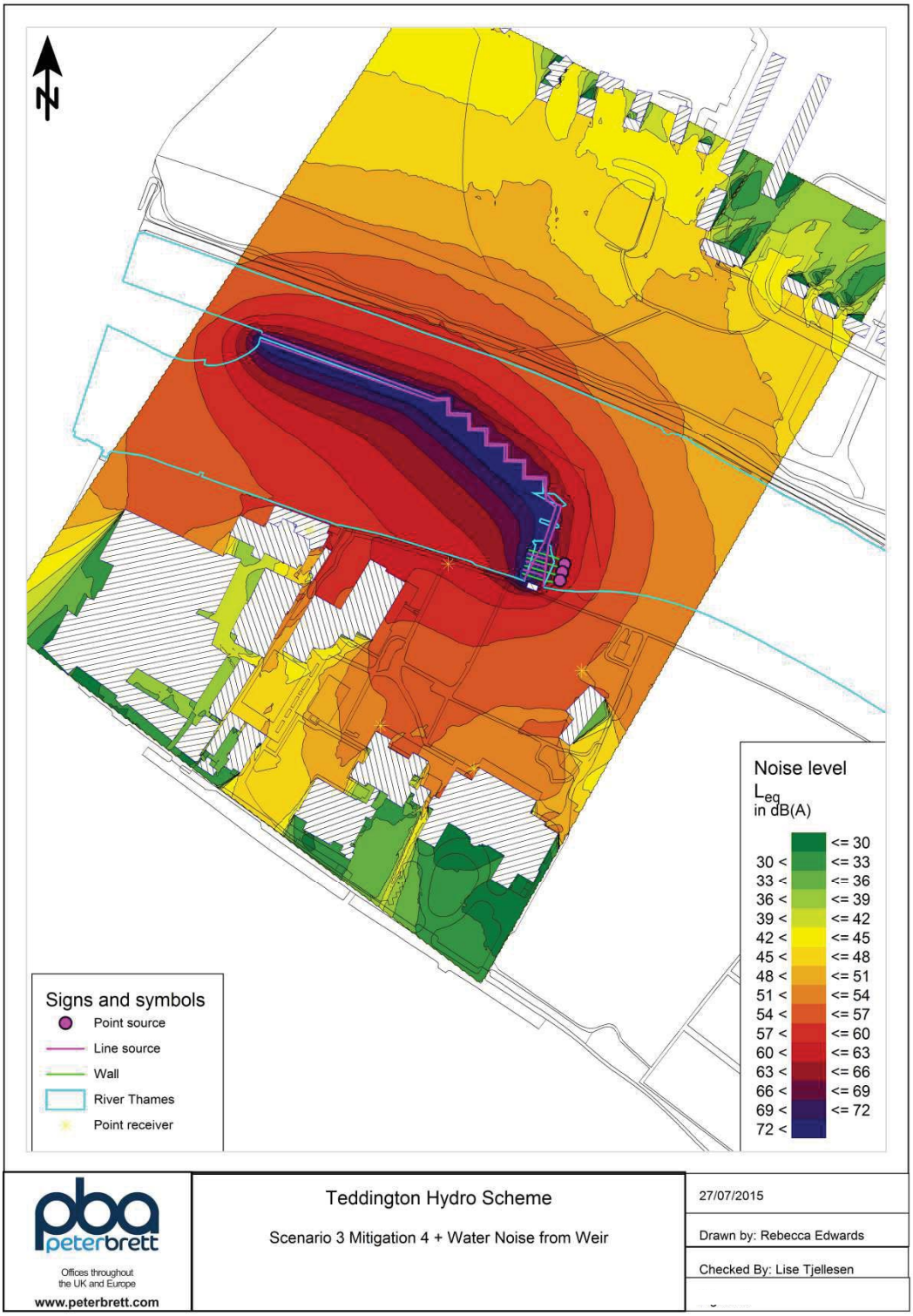


Figure 2 – Existing sound climate and proposed hydroscheme with minimum required mitigation



5 Review and Discussion

5.1 Introduction

5.1.1 Hydro plant installations are well known throughout Europe and to some extend in Scotland, but they are a relatively less known entity in the rest of the UK. However, the later years have seen an increase in hydro plant installations.

5.1.2 At the time of the original planning application and thus the original noise impact assessment for the proposed hydro scheme at Teddington Weir, it was a relatively new and uncharted installation in terms of both size and type of turbines, i.e. 6 m long Archimedean screws. Hydro plants have long been seen in Scotland, though on a much smaller scale and typical a different type of turbines, i.e. not Archimedean screws.

5.1.3 Finding precedence for methodology and planning guidance for a scheme of this size has therefore not been readily available. Only very few hydro plant schemes of a similar nature and size are currently either operational or at planning stage.

5.1.4 There have been many objection points to the original assessments *([ZBP1 & ZBP2], [PBA1, PBA2 & PBA3]*) carried out by both ZBP and PBA. Some of these points have been either rectified and/or clarified specifically in the last technical note [PBA4].

5.1.5 In response to the last technical note [PBA4] from PBA, AJA provided a full report [AJA5]. The main objections that remain relates to the following issues;

a. Noise Source Data and thus the entire methodology
b. Uncertainty, i.e. how reliable is the assessment?
c. Tides, i.e. what happens during the tides with regards to noise?
d. Mitigation, i.e. is the proposed mitigation reliable and/or achievable?

5.2 General Methodology

5.2.1 One of the main objections for the previous noise impact assessments has been the transfer of the measurements of noise source data from one hydro scheme used to provide data to another location, i.e. the application site. Both Professor Kang [Kang] and AJA [AJA3, AJA4 & AJA5] point out the challenges of using measured noise source data and transferring them to another scheme, as there are a wide range of factors which can influence the validity of this transfer, such as topography and physical dimensions and design of the turbines.

5.2.2 However, the methodology of using measured noise source data in a noise impact assessment is not unusual and sometimes necessary when not enough information is available, i.e. there is no laboratory information or the information provided is insufficient. Nor is it unusual to make various qualified assumptions in order to even make an assessment. But these obviously need to be based on available facts and not the least experience.

5.2.3 Manufacturers do not measure or provide noise data for their turbines as they are each unique. It is therefore necessary to obtain noise source data in an alternative way. The de-facto standard way of obtaining noise source data for noise impact assessments for hydro schemes are therefore to find a similar existing, i.e. operating, hydro scheme and carry out in-situ measurements of the noise source(s) and use these data in the assessment. This approach is the only way to do a noise impact assessment for a hydro plant scheme, due to lack of general manufacture data.

5.2.4 The key is to find an existing scheme as similar as possible to the proposed scheme and to obtain the data as close to the source as possible in order to reduce influences from the surrounding topography.

5.2.5 The following noise impact assessments from other acoustic consultants for various hydro schemes can be seen as a few examples of this procedure;

[1] "Proposed Hydropower Archimedean Screw – Mill Island, Sonning Eye RG4 6TW" (ref. 185559 R1) dated 8th April 2014 from SoundSolution Consultants

[2] "Proposed Hydropower Archimedean Screw – Osney Lock and Weir, Oxford" (ref. 14024 R1) dated 28th September 2012 from SoundSolution Consultants

[3] "Assessment of Environmental Impact of Noise at Proposed Archimedean Screw Turbine (AST) at Pitcastle, Gandtully" (ref. R13.7794/1/RK) dated 6th September 2013 from Vibrock

[4] "Determination & Evaluation of Noise Emissions & Noise Pollution in the Environment of the Hydrodynamic Screw located in Dittigheim" (ref. 90503/1) dated 14th August 2009 by TechnAk

5.2.6 All of the above noise impact assessments have used measured noise source data from an existing and operational hydro scheme to assess the potential noise impact from new proposed schemes.

5.2.7 The overall methodology used in the original noise impact assessments for Teddington is therefore considered appropriate and the only practical method that can be applied in terms of a robust assessment.

5.3 Review of Noise Source Data

5.3.1 As mentioned no manufacturer provides noise source data for their turbines. In practice that means having to measure sound from an existing and operating hydro scheme in order to obtain the necessary data.

5.3.2 The general guidelines of ISO 3746:1995 "*Acoustics – Determination of sound power levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane*" are applied to obtaining relevant noise source data from an operating hydro plant with certain allowances for practical restrictions depending on the site location and considerations to health and safety measures.

5.3.3 The noise source data used in the ZBP assessments [ZBP1 & ZBP2] came from German test measurements (from Birkenau and Dittgeheim) carried out by Technak and measurements from Mapledurham carried out by LBRUT. Based on available documents all measurements seem to be carried out in general accordance with national (German DIN) and international measurement standards from standard series ISO 3740.

5.3.4 The noise source data used in the PBA report [PBA1] were measured at Romney Weir, Windsor in June 2013 after the general guidelines set out in BS 3746:1996.

5.3.5 It is understood that the chosen hydro plant at Romney Weir, at the time of the noise impact assessment [PBA1] by PBA, was and most likely still ise the only operating hydro scheme with screws of a similar size, capacity and location (i.e. at the river Thames) as the proposed plant at Teddington Weir.

5.3.6 Of the available noise source data reported in [ZBP1, ZBP2, PBA1 and referred reports in section 3.2.5], the data from the Romney Weir hydro plant provided the highest levels. Using them in the noise impact assessment will therefore be a worst case approach as well as providing data from the most similar operational scheme.

5.3.7 Further details can be seen in **Appendix G**.

5.4 Uncertainties

5.4.1 An essential discussion / critique point has been the application of (or perhaps lack of) uncertainties. Uncertainties were not addressed in detail in the first noise assessments ([ZBP1] & [ZBP2]). This was pointed out by AJA [AJA2]. However, the discussion shows a general misconception of what uncertainties are.

5.4.2 It should be noted that uncertainties are a measure of how good a model and/or method is. It gives the assessor an indication of whether the data is reliable or not. Uncertainties should NOT be added or subtracted or in any other way be a incorporated in end result.

5.4.3 In order to do assess how good a model is, it is required to look at uncertainty budgets for each element on its own, i.e. one uncertainty budget for the baseline survey, one uncertainty budget for the noise source measurements, one uncertainty budget for transferring the noise source data and one uncertainty budget related to the modelling. The combination of this provides the overall uncertainty.

5.4.4 The new uncertainty budgets calculated provide an overall uncertainty for the whole method and calculations of 8 dB with a confidence level of 95%. This indicates that the end results are reliable even with all the various factors influencing the results.

5.4.5 Further information on uncertainties and their calculation can be found in **Appendix H**.

5.5 Mitigation

5.5.1 There are three main parts that contributes to the overall sound levels produced by a hydro plant;

a. The hydrodynamics of the screw

b. The gearbox(es)

c. The transformer(s)

5.5.2 There appear to be a general consensus in the previous noise impact assessment reports that some means of noise mitigation is required in order for the scheme to comply with local authority requirements.

5.5.3 Professor Kang further provided the following comment in his report [Kang]: "…*if the noise level from the renewable energy installation at the site of Teddington Weir could be controlled at the source side, achieving the noise-limit targets at other receivers, it is likely that the noise level along the riverside path would also achieve the noise-limit targets, although sound propagation path to the riverside path should be carefully considered*…"

5.5.4 The sound pressure levels of screws are the result of the hydrodynamics, i.e. how the screw and water interacts at both inlet and outlet. The sound characteristics for the hydrodynamic interaction would usually comprise of "splashing", "whooshing" and/or "thumping" sounds. The variance in sound levels is further influenced by the water levels and how the turbines are run, i.e. at what speed, and what the angle that screws hits the water.

5.5.5 The key is to mitigate noise at the source, i.e. at the screws, gearboxes and transformers. This has been proposed by enclosing the screws and gearboxes. The transformer(s) are proposed to be located in separate housing.

5.5.6 The originally proposed mitigation measures in previous reports consisted of metal enclosures for the gearboxes and Plexiglas enclosures for the screws.

5.5.7 The minimum sound reduction required by these enclosures in order for the scheme to comply with local authority planning has been established. The proposed mitigation measures have been evaluated in relation to the required minimum mitigation, and it has been found that the proposed materials are likely to achieve the required minimum sound reduction. This should be further verified during detail design.

5.6 Tidal Influence

5.6.1 One of the major discussion points were the periods of tides and the potential noise impact during these periods. It has been confirmed that timings of the high tides correlate closely with the drop in background sound levels observed during measurements at several receptors.

5.6.2 The drops in the background sound level (L_{A90}) of up to 15 dB occur approximately every 12 hours and are due to the tides. It should be noted that typical drops in background sound levels are around 5 to 8 dB.

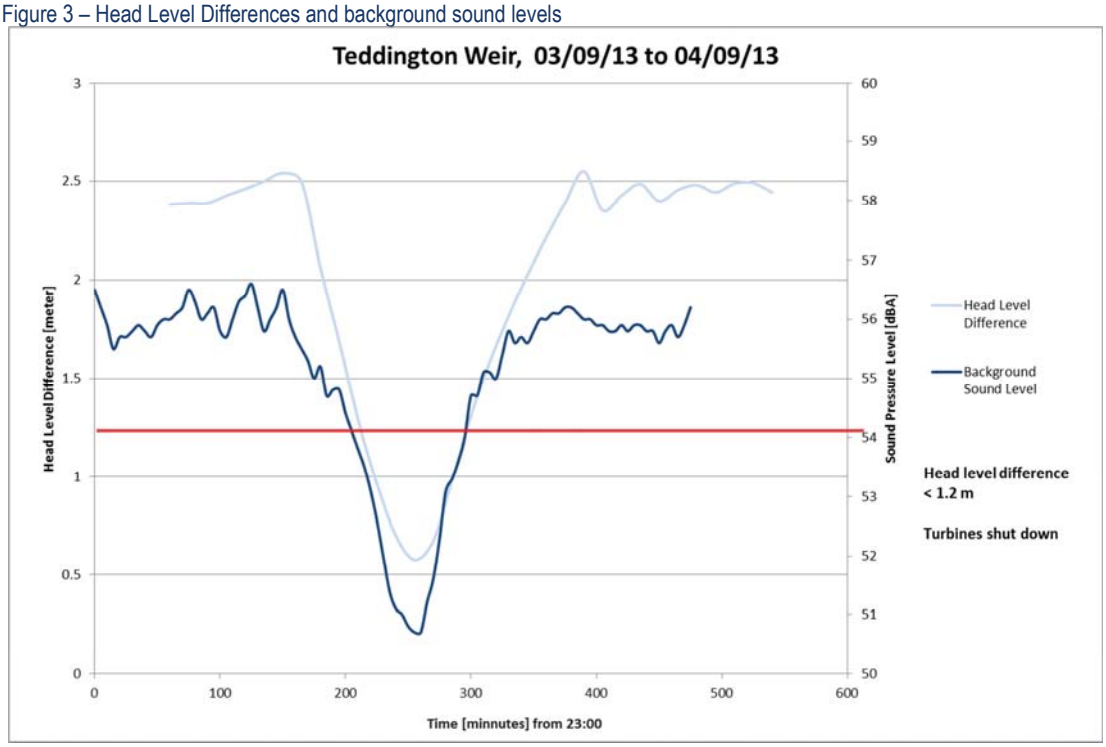
5.6.3 The tides create differences in the water levels in addition to the upstream and downstream water levels. When the available head (the height that the water falls over the weir) for the scheme falls below 1.2 m the scheme will shut down.

5.6.4 In effect this means that the scheme will not be operating during the tides, i.e. in periods when low background sound levels occur. It would therefore not be reasonable to assess against at the lower background sound levels.

5.6.5 For illustrative purpose see **Figure 3** below. The figure shows the variation of the tide as a function of the time, as well as the sound pressure levels as a function of the time. That illustrates how the tide and drop in background sound levels correlates. It further shows that when the head level difference drops below 1.2 m, i.e. in periods with tides, the turbines will be shut off.

5.6.6 For further details see **Appendix I**.

Figure 3 – Head Level Differences and background sound levels



6 Conclusions

6.1.1 Peter Brett Associates LLP (PBA) has been instructed by Teddington & Ham Hydro Cooperative Ltd to provide additional clarification and support documentation in relation to potential noise issues from the proposed hydropower scheme at Teddington Weir, Richmond.

6.1.2 The current report has provided a review and summary of the work done to date, including reviewing and verifying the methodologies, measured data (both baseline and noise source) and presenting the results from the new noise impact assessment.

6.1.3 The conclusions can be summarised as follows;

a. Results from previous baseline sound surveys are valid and representative of the existing sound climate at and around the site for the proposed hydro scheme.

b. The methodology applied to the noise assessments (both previous and current) is the only practical method available.

c. Review of the available noise source data show, that the data from the Romney Weir scheme provide the highest levels, thus aiding the worst case approach.

d. The uncertainty calculated for the current noise impact assessment indicates that results are reliable.

e. Results from the new noise impact (as shown in **Table 5** below) show that the proposed hydro scheme including mitigation measures comply with local authority requirements, and that the long term impact compared to the existing situation can be considered as minor.

Table 5 – Assessment of Scheme with proposed mitigation – External Levels

Location	External Criterion, dBA	Rating Level (Predicted sound level + adjustments for characteristics), dBA	Level difference, dBA
North-western façade of Riverside Pavilion / Garden (MP1)	Rating Level < 57	43	- 14
North-eastern edge of Clubhouse roof / Clubhouse (Rear façade of the Lensbury Club Hotel) (MP2)	Rating Level < 45	38	- 7
North-eastern edge of Conference Centre (MP3)	Rating Level < 46	41	-5
Burnell Avenue (MP4)	Rating Level < 36	35	- 1
Lensbury Club – Riverside Path (MP5)	Rating Level < 57	51	- 6
Teddington Studios (MP6)	Rating Level < 57	40	- 17

Appendix A Glossary of Acoustics Terms

The following glossary of terms has been produced from BS 8233:2014 and BS 4142:2014. In addition, PPG 24 (HMSO, 1994) has been used for some definitions; although PPG 24 has been revoked by the NPPF, the daytime and night-time periods defined in it are typically still used. This Glossary provides explanations of the terms used within this document.

Ambient sound	Total encompassing sound in a given situation at a given time, usually composed of sound from many sources far and near.
Background sound	In BS 4142 this is defined as the A weighted sound pressure level of the residual sound at the assessment position that is exceeded for 90% of a given time interval, T ($L_{A90,T}$)
Daytime	Defined in PPG 24 as the period 07:00-23:00 hours.
Decibel (dB)	A unit of level derived from the logarithm of the ratio between the value of a quantity and a reference value. It is used to describe the level of many different quantities. For sound pressure levels the reference quantity is 20 uPa. The threshold of normal hearing is in the region of 0 dB and 140 dB is the threshold of pain. A change of 1 dB is only perceptible under controlled conditions.
dB(A), L_{Ax}	Decibels measured on a sound level meter incorporating a frequency weighting (A weighting) which differentiates between sounds of different frequency (pitch) in a similar way to the human ear. Measurements in dB(A) broadly agree with people's assessment of loudness. A change of 3 dB(A) is the minimum perceptible under normal conditions, and a change of 10 dB(A) corresponds roughly to halving or doubling the loudness of a sound. The background noise in a living room may be about 30 dB(A); normal conversation about 60 dB(A) at 1 metre; heavy road traffic about 80 dB(A) at 10 metres; the level near a pneumatic drill about 100 dB(A).
$L_{A10,T}$	The A weighted sound level exceeded for 10% of the measurement period, T. It gives an indication of the upper limit of fluctuating noise such as that from road traffic. $L_{A10,18h}$ is the arithmetic average of the 18 hourly $L_{A10,1h}$ values from 06:00-24:00.
$L_{A90,T}$	The A weighted sound level exceeded for 90% of the measurement period, T. This is defined in BS 4142 as the background sound level.
$L_{Aeq,T}$	The equivalent continuous sound level – the sound level of a notionally steady sound having the same energy as a fluctuating sound over a specified measurement period (T). $L_{Aeq,\ T}$ is used to describe many noises and can be measured directly with an integrating sound level meter.
$L_{Amax,}$	The highest A weighted sound level recorded during a noise event. The time weighting (slow or fast) should be stated.

Night-time	Defined in PPG 24 as the period 23:00-07:00 hours.
Rating Level, $L_{Ar,Tr}$	The specific sound level plus any adjustments for the characteristic features of the sound. Used in BS 4142:2014.
Residual Level	The ambient $L_{Aeq,T}$ remaining when the specific noise source is not present or is suppressed to a degree such that it does not contribute to the ambient noise.
Sound Power Level, Lw	An absolute parameter widely used for rating and comparing sound sources. Sound power is a physical property of the source alone, independent of any external or environmental factors[1].
Specific Noise Level, $L_{Aeq,Tr}$	The equivalent continuous A-weighted sound pressure level at the assessment position produced by the specific noise source over a given reference time interval
Specific Noise Source	The noise source under investigation for assessing the likelihood of complaints

[1] Hassall, JR; Zaveri, K "Acoustic Noise Measurements" Brüel and Kjær 1988

Appendix B Proposed Hydro Scheme

B.1.1 The proposed hydrodynamic scheme is to include three Archimedean screws, each approximately measuring 6.0m in length and 4.0m in diameter, installed in parallel on the southern section of the weir as indicate on initial drawings provided by eWaterpower Ltd, please refer to **Figure B1** below.

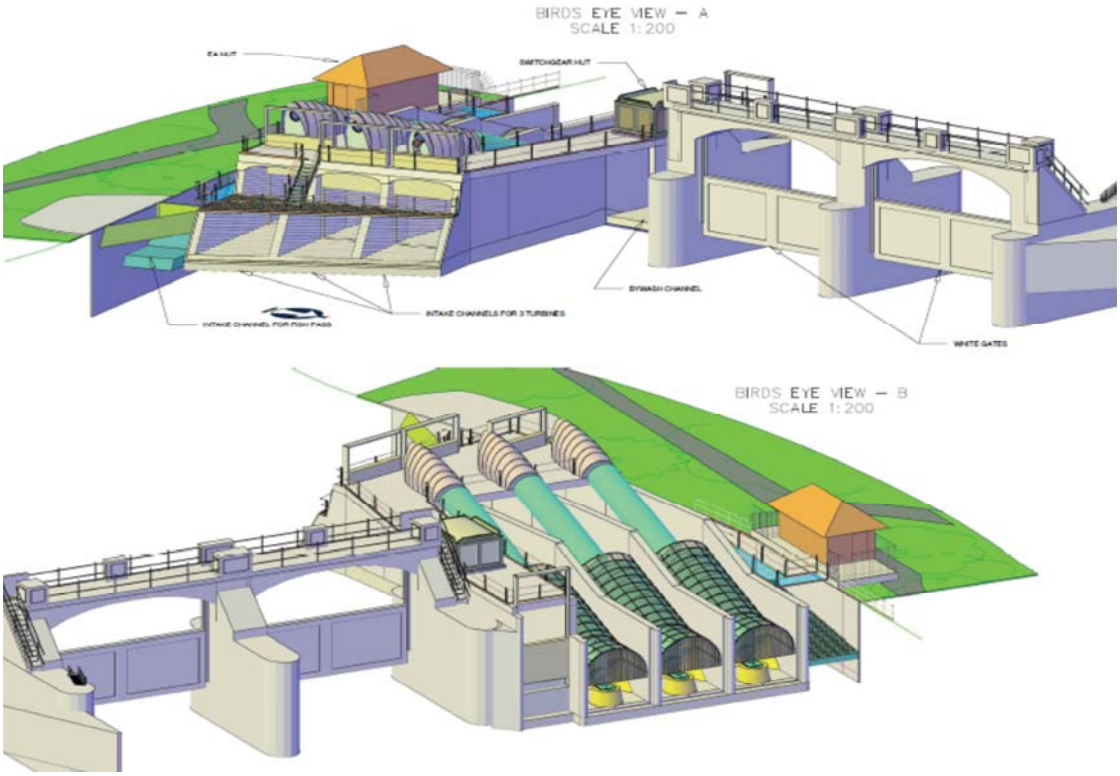
B.1.2 It is understood that the anticipated overall power generation is approximately 164 kW of power output per turbine, with a total of 492 kW estimated from the overall installation.

B.1.3 The physical dimensions of the proposed scheme are summarised in **Table B1** below.

Table B1 – Physical dimensions proposed Teddington scheme

Item	Dimension / description
Gearbox Housing	Length: 3.0 m Width: 2.5 m Height: 2.0 m
Screw length	6.08 m
Screw diameter	4.0 m
Material of encasement	Steel trough set in concrete
Bearing	Fully submerged
Number of blades per screw	4
Numbers of screws	3

Figure B1 – 3D view of the proposed hydro scheme, ref. eWaterpower Ltd drawing DWG-TW-P4 dated 27/08/14



Appendix C Background & History

C.1.1 **Table C1** below provides the noise reports and responses in relation to the Teddington & Ham Hydro power scheme. The reports are listed in chronological order.

Table C1 – Previous noise assessments and reports

Reference	Title
[ZBP1]	"Ham Hydro CIC project, rev. C" (ref. 3207) dated 15th November 2011 from ZBP acoustics
[AJA1]	"The Lensbury Club – Comments on noise impact of Ham Hydro Project" (ref. M001/10633 The Lensbury Club, Teddington) dated 12th January 2012 from Adrian James Acoustics
[ZBP2]	"Ham Hydro CIC project, Teddington, Richmond – Revised Noise Impact Assessment" (ref. 3207-R01) dated 18th January 2013 from ZBP acoustics
[AJA2]	"Ham Hydro CIC – AJA comments on revised noise impact assessment" (ref. M003/10633 The Lensbury Club, Teddington) dated 13th February 2013
[LBRUT]	"Ham Hydro CIC-Renewable Energy Installation Teddington Weir – Environmental Noise Impact, Non-Technical Summary" dated February 2013 from London Borough of Richmond upon Thames
[PBA1]	"Hydropower Scheme at Teddington Weir – Noise Assessment" (ref. 28307-004) dated 9th July 2013 from Peter Brett Associates LLP
[AJA3]	"Ham Hydro CIC – AJA Comments on Peter Brett Associates Noise Assessment" (ref. M004/10633) dated 23rd July 2013 from Adrian James Acoustics
[Kang]	"Ham Hydro CIC – Renewable Energy Installation Teddington Weir, Environmental Noise Impact – Further review of the consultancy reports" (ref. Report 2) dated 1st September 2013 from Professor Jian Kang, PhD (Cantab.), CEng, FIOA, FASA
[PBA2]	"Hydropower Scheme at Teddington Weir – Noise Assessment" (ref. 28307-004 rev: 003) dated 11th September 2013 from Peter Brett Associates LLP
[PBA3]	"Results of the Teddington Weir Hydropower Scheme" (ref. 28307-004/ESP N1) dated 4th October 2013 from Peter Brett Associates LLP
[AJA4]	"Ham Hydro CIC – AJA Comments on Peter Brett Associates Technical Note ESP N1" (ref. 10633/M005) dated 28th October 2013 from Adrian James Acoustics
[PBA4]	"Modelling of Teddington Hydropower Scheme" (ref. 28307-004/ESP N2) dated 22nd July 2014 from Peter Brett Associates LLP
[AJA5]	"Ham and Teddington Hydro – Review of noise assessment and related documents, technical report" (ref. 10663/1) dated 9th October 2014 from Adrian James Acoustics

C.1.2 The original noise assessment was carried out and reported by ZBP Acoustics in 2011 [ZBP1]. Initial review by Adrian James Acoustics (AJA) in January 2012 [AJA1] led to an updated noise assessment report by ZBP Acoustics issued February 2013 [ZBP2].

C.1.3 More intense objections from the Lensbury Club expressed via memo from AJA [AJA2] in February 2013 with additional response for clarification from London Borough of Richmond upon Thames (LBRUT) [LBRUT] in February 2013 led to the engagement of Peter Brett Associates LLP (PBA) providing a new noise assessment of the proposed scheme in July 2013 [PBA1].

C.1.4 The report from PBA [PBA1] led to additional comment from AJA [AJA3] as well as from an independent acoustic expert, Professor Jian Kang [Kang]. Based on the comments PBA issued a revised report [PBA2] in September 2013 followed by a technical note [PBA3] in October 2013 covering the SoundPlan modelling of the noise propagation from the proposed hydro scheme.

C.1.5 Further questions and objections were voiced in the review provided by AJA [AJA4]. The noise modelling was further updated and another technical note [PBA4] was issued in July 2014. In response a full review report was provided by AJA [AJA5] in October 2014.

Appendix D Legislation, Policy and Guidance

D.1 National Planning Policy

D.1.1 The national planning guidance now consists of the National Planning Policy Framework (NPPF) and the Noise Policy Statement for England (NPSE).

National Planning Policy Framework (NPPF)

D.1.2 The Department for Communities and Local Government published the National Planning Policy Framework (NPPF) on 27 March 2012 and upon its publication, the majority of planning policy statements and guidance notes were withdrawn, including Planning Policy Guidance 24 'Planning and Noise' (PPG24).

D.1.3 With regards to noise the NPPF outlines four aims, which are detailed in paragraph 123 in Section 11 of the document, titled "Conserving and enhancing the natural environment", which states:

"*Planning policies and decisions should aim to:*

- *avoid noise from giving rise to significant adverse impacts on health and quality of life as a result of new development;*
- *mitigate and reduce to a minimum other adverse impacts on health and quality of life arising from noise from new development, including through the use of conditions;*
- *recognise that development will often create some noise and existing businesses wanting to develop in continuance of their business should not have unreasonable restrictions put on them because of changes in nearby land uses since they were established; and*
- *identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason*."

Noise Policy Statement for England (NPSE)

D.1.4 The Noise Policy Statement for England (NPSE) was published in March 2010. It relates to environmental noise and neighbour noise (both from inside and outside peoples homes, and noise arising from within the community, such as industrial and entertainment premises, trade and business premises, construction sites and noise in the street). The vision of the policy is to:

"*Promote good health and a good quality of life through the effective management of noise within the context of Government policy on sustainable development.*"

D.1.5 And the aim is to:

"Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

- *avoid significant adverse impacts on health and quality of life;*
- *mitigate and minimise adverse impacts on health and quality of life; and*
- *where possible, contribute to the improvement of health and quality of life.*"

D.1.6 The long term policy vision and aims are designed to enable decisions to be made regarding what is an acceptable noise burden to place on society.

D.1.7 The explanatory note for the NPSE contains explanation and definition of terms in relation to assessing noise impact as follows;

"*2.19 There are several key phrases within the NPSE aims and these are discussed below.*

"Significant adverse" and "adverse"

2.20 There are two established concepts from toxicology that are currently being applied to noise impacts, for example, by the World Health Organisation. They are:

NOEL – No Observed Effect Level

This is the level below which no effect can be detected. In simple terms, below this level, there is no detectable effect on health and quality of life due to the noise.

LOAEL – Lowest Observed Adverse Effect Level

This is the level above which adverse effects on health and quality of life can be detected.

2.21 Extending these concepts for the purpose of this NPSE leads to the concept of a significant observed adverse effect level.

SOAEL – Significant Observed Adverse Effect Level

This is the level above which significant adverse effects on health and quality of life occur.

2.22 "*It is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times. It is acknowledged that further research is required to increase our understanding of what may constitute a significant adverse impact on health and quality of life from noise. However, not having specific SOAEL values in the NPSE provides the necessary policy flexibility until further evidence and suitable guidance is available*."

D.1.8 It is clear that consideration of acceptable noise levels cannot include "in-audibility", as the aims as set out in NPSE is to avoid "*significant adverse impact*", i.e. some level of impact on residents due to noise is acceptable.

D.1.9 It should be noted that the NPPF and NPSE policy vision refer to '*adverse impacts*' whereas the NPSE Explanatory Note refers to '*adverse effects*'. For the purposes of this assessment '*adverse effects*' is used.

D.1.10 The NPSE recognises that it is not possible to have single objective noise-based measures that define the NOEL, LOAEL and SOAEL, that are applicable to all sources of noise in all situations. The levels are likely to be different for different noise sources, receptors and at different times of the day.

D.1.11 The NPPF and associated NPSE provide the concepts for defining various levels of effect, but do not translate these into actual noise levels. Instead, it is up to individual local authorities to interpret the concepts in the NPPF and NPSE, and translate them into noise level criteria for development to be applied in their area. For the purposes of this assessment the LOAEL and SOAEL have been defined for each relevant potential noise effect. It should be noted that these are based on the specific circumstances of this development and may not be applicable in other situations.

D.1.12 Paragraph 17 of the NPPF states that one of the 12 principles of planning is that it should "*not simply be about scrutiny, but instead be a creative exercise in finding ways to enhance and improve the places in which people live their lives*".

D.1.13 It should be noted that the noise criteria as given in WHO (see **Section D3**) and BS8322:2014 (see **Section D4**) are based on noise levels below which there is negligible effects due to noise and consequently comply with requirements of SOEAEL.

Planning Practice Guidance (Department for Communities and Local Government, 2014)

D.1.14 In March 2014, the Department for Communities and Local Government (DCLG) released its "Planning Practice Guidance (PPG)" web-based resource to support the NPPF.

D.1.15 This guidance introduced the concepts of NOAEL (*No Observed Adverse Effect Level*), and UAEL (*Unacceptable Adverse Effect Level*). NOAEL differs from NOEL in that it represents a situation where the acoustic character of an area can be slightly affected (but not such that there is a perceived change in the quality of life). UAEL represents a situation where noise is

D.1.16 '*noticeable*', '*very disruptive'* and should be '*prevented*' (as opposed to SOAEL, which represents a situation where noise is '*noticeable*' and '*disruptive*', and should be '*avoided*').

D.1.17 As exposure increases above the LOAEL, the noise begins to have an adverse effect and consideration needs to be given to mitigating and minimising those effects, taking account of the economic and social benefits being derived from the activity causing the noise. As the noise exposure increases, it will then at some point cross the SOAEL boundary.

D.1.18 The LOAEL is described in PPG as the level above which "*noise starts to cause small changes in behaviour and/or attitude, e.g. turning up volume of television; speaking more loudly; where there is no alternative ventilation, having to close windows for some of the time because of the noise. Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a perceived change in the quality of life.*"

D.1.19 PPG identifies the SOAEL as the level above which "*noise causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion; where there is no alternative ventilation, having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.*"

D.1.20 The guidance provided by PPG states the following in relation to determining noise impact;

"*At the lowest extreme, when noise is not noticeable, there is by definition no effect. As the noise exposure increases, it will cross the no observed effect level as it becomes noticeable. However, the noise has no adverse effect so long as the exposure is such that it does not cause any change in behaviour or attitude. The noise can slightly affect the acoustic character of an area but not to the extent there is a perceived change in quality of life. If the noise exposure is at this level no specific measures are required to manage the acoustic environment.*

As the exposure increases further, it crosses the lowest observed adverse effect level boundary above which the noise starts to cause small changes in behaviour and attitude, for example, having to turn up the volume on the television or needing to speak more loudly to be heard. The noise therefore starts to have an adverse effect and consideration needs to be given to mitigating and minimising those effects (taking account of the economic and social benefits being derived from the activity causing the noise).

Increasing noise exposure will at some point cause the significant observed adverse effect level boundary to be crossed. Above this level the noise causes a material change in behaviour such as keeping windows closed for most of the time or avoiding certain activities during periods when the noise is present. If the exposure is above this level the planning process should be used to avoid this effect occurring, by use of appropriate mitigation such as by altering the design and layout. Such decisions must be made taking account of the economic and social benefit of the activity causing the noise, but it is undesirable for such exposure to be caused. "

D.1.21 The above statements can be summarised in the following **TableD1**;

Table D1 – Summary of PPG noise impact definitions

Perception	Examples of Outcomes	Increasing effect level	Action
Not noticeable	No effect	No observed effect	No specific measures required
Noticeable and not intrusive	Noise can be heard, but does not cause any change in behaviour or attitude. Can slightly affect the acoustic character of the area but not such that there is a perceived change in the quality of life.	No observed adverse effect	No specific measures required
		Lowest observed adverse effect level	
Noticeable and intrusive	Noise can be heard and cause small changes in behaviour and/or attitude, e.g. turning up volume of television; speaking more loudly; where there is no alternative ventilation, having to close windows for some of the time because of the noise. Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a perceived change in the quality of life.	Observed adverse effect	Mitigate and reduce to a minimum
		Significant observed adverse effect level	
Noticeable and disruptive	The noise causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion; where there is no alternative ventilation, having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.	Significant observed adverse effect	Avoid
Noticeable and very disruptive	Extensive and regular changes in behaviour and/or an inability to mitigate effect of noise leading to psychological stress or physiological effects, e.g. regular sleep deprivation /awakening; loss of appetite, significant, medically definable harm, e.g. auditory and non-auditory	Unacceptable adverse effect	Prevent

D.2 British Standard 4142:2014 "Methods for rating and assessing industrial and commercial sound" (BS4142:2014)

D.2.1 BS4142:2014 sets out a method for determining the level of noise of an industrial nature (e.g. building services plant, factories etc.), together with procedures for assessing whether the noise is likely to give rise to complaints from people living nearby.

D.2.2 The method involves determination of background sound levels and rating levels including adjustment for any characteristic features of the sound. BS 4142:2014 further states:

"*The significance of sound of an industrial and/or commercial nature depends upon both the margin by which the rating level of the specific sound source exceeds the background sound level and the context in which the sound occurs. An effective assessment cannot be conducted without an understanding of the reasons(s) for the assessment and the context in which the sound occurs/will occur. When making assessments and arriving at decisions, therefore, it is essential to place the sound in context.*"

D.2.3 BS4142:2014 further states that:

- *A difference of around +10 dB or more is likely to be an indication of a significant impact, depending on the context.*
- *A difference of around +5 dB is likely to be an indicator of an adverse impact, depending on the context.*
- *The lower the rating level is relative to the measured background sound level, the less likely it is that the specific sound source will have an adverse impact or a significant adverse impact. Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact, depending on the context*

D.2.4 For the adjustment of the rating level due to special characteristics of the sound BS4142:2014 states the following;

"*Certain acoustic features can increase the significance of impact over that expected from a basic comparison between the specific sound level and the background sound level. Where such features are present at the assessment location, add a character correction to the specific sound level to obtain the rating level. This can be approached in three ways:*

a) subjective method;

b) objective method for tonality;

c) reference method"

In relation to the subjective method the following guidelines are given:

Tonality

For sound ranging from not tonal to prominently tonal the Joint Nordic Method gives a correction of between 0 dB and + 6 dB for tonality. Subjectively, this can be converted to a penalty of 2 dB for a tone which is just perceptible at the noise receptor, 4 dB where it is clearly perceptible, and 6 dB where it is highly perceptible.

Impulsivity

A correction of up to +9 dB can be applied for sound that is highly impulsive, considering both the rapidity of the change in sound level and the overall change in sound level. Subjectively, this can be converted to a penalty of 3 dB for impulsivity which is just perceptible at the noise receptor, 6 dB where it is clearly perceptible, and 9 dB where it is highly perceptible.

Other sound characteristics

Where the specific sound features characteristics that are neither tonal nor impulsive, though otherwise can be readily distinctive against the residual acoustic environment, a penalty of 3 dB can be applied.

NOTE 2 Where tonal and impulsive characteristics are present in the specific sound within the same reference period then these two corrections can both be taken into account. If one feature is dominant then it might be appropriate to apply a single correction. Where both features are likely to affect perception and response, the correction ought normally to be added in a linear fashion.

Intermittency

When the specific sound has identifiable on/off conditions, the specific sound level ought to be representative of the time period of length equal to the reference time interval which contains the greatest total amount of on time. This can necessitate measuring the specific sound over a number of shorter sampling periods that are in combination less than the reference time interval in total, ,and then calculating the specific sound level for the reference time interval allowing for time when the specific sound is not present. If the intermittency is readily distinctive against the residual acoustic environment, a penalty of 3 dB can be applied."

D.2.5 It should be noted that the BS4142:1997, which was used for the original assessment, has now been replaced by the current BS4142:2014. The assessment method remains in principle the same. However, there is no longer any correction values for the residual levels and the assessment method of special acoustic features of the source have changed.

D.2.6 BS4142:2014 also emphasises a clear distinction between "sound" and "noise". Sound is typical defined as the physical and sensory perception of sound waves, which can be measured. Noise is defined as unwanted sound. This is in line with the WHO guidelines discussed in Section 2.3. The terms and now for example "ambient sound level" instead of "ambient noise level". This new usage of terms are used throughout the noise assessment (ref. 28307/005) dated 23rd July 2015.

D.2.7 There is further a new section addressing uncertainty. However, there are no numbers to be applied. Thus BS4142:2014 does not provide any guidance as how to calculate or apply the uncertainty.

D.3 World Health Organization Guidelines for Community Noise 1999 (WHO)

D.3.1 World Health Organisation (WHO) published in 1999 the document "Guidelines for Community Noise", which is the outcome of a taskforce meeting held in London 1999. It is further based on the document "Community Noise", which was published in 1995.

D.3.2 The document "Guidelines for Community Noise" states the following;

"*Community Noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic, industries, construction and public work, and the neighbourhood*."

"*In Dwellings. The effects of noise in dwellings, typically, are sleep disturbance, annoyance and speech interference. For bedrooms the critical effect is sleep disturbance. Indoor guidline values for bedrooms are 30 dB L_{Aeq} for continuous noise and 45 dB L_{Amax} for single sound events. Lower noise levels may be disturbing depending on the nature of the noise source. At night-time, outside sound levels about 1 metre from facades of living spaces should not exceed 45 dB L_{Aeq}, so that people may sleep with bedroom windows open. This value was obtained by assuming that the noise reduction from outside to inside with the window open is 15 dB. To enable causal conversation indoors during daytime, the sound level of interfering noise should not exceed 35 dB L_{Aeq}. The maximum sound pressure level should be measured with the sound pressure meter set as "Fast".*

To protect the majority of people from being seriously annoyed during the daytime, the outdoor sound level from steady, continuous noise should not exceed 55 dB L_{Aeq} on balconies, terraces and in outdoor living areas. To protect the majority of people from being moderately annoyed during the daytime, the outdoor sound level should not exceed 50 dB L_{Aeq}. Where it is practical and feasible, the lower outdoor sound level should be considered the maximum desirable sound level for new development."

D.3.3 Table 1 in Chapter 4 of the WHO guidelines summarises the above statements and provide guideline values for community noise in specific environments as shown in **Table D2** below :

Table D2 – WHO guideline values for community noise in specific environments

Specific environment	Critical health effect(s)	L_{Aeq} [dB(A)]	Time base [hours]	L_{Amax}, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening	55	16	-
	Moderate annoyance, daytime and evening	50		
Dwellings, indoor	Speech intelligibility & moderate annoyance, daytime and evening	35	16	-
Inside bedrooms	Sleep disturbance, night time	30	8	45
Outside bedrooms	Sleep disturbance, windows open (outdoor values)	45	8	60

D.4 British Standard 8233:2014 "Guidance on sound insulation and noise reduction for buildings" (BS8233:2014)

D.4.1 BS8233:2014 provide information and guidance on design of buildings that have internal acoustic environments appropriate for their functions. It provides guidance on control of noise from outside the building, noise from plant and services within the building, and room acoustics for non-critical situations.

D.4.2 Table 4 of Section 7.3 of BS8233:2014 outlines the internal ambient noise levels for dwellings as summarised in **Table D3** below;

Table D3 – Indoor ambient noise levels for dwelling

Activity	Location	07:00-23:00	23:00-07:00
Resting	Living room	35 dB $L_{Aeq, 16hr}$	–
Dining	Dining room/area	40 dB $L_{Aeq, 16hr}$	–
Sleeping (daytime resting)	Bedroom	35 dB $L_{Aeq,, 16hr}$	30 dB $L_{Aeq, 8hr}$

D.4.3 For external noise BS8322:2014 provide the design criteria of 50 dB $L_{Aeq, T}$ with an upper guideline value of 55 dB $L_{Aeq, T}$. It further states the following:

"*However, it is also recognized that these guideline values are not achievable in all circumstances where development might be desirable*."

D.4.4 According to BS8233:2014 internal noise levels for hotels should as a minimum be similar to those for dwellings.

"Guidelines for Noise Impact Assessment" 6th October 2014 from Institute of Environmental Management and Assessment (IEMA) and Institute of Acoustics (IOA)

D.4.5 IEMA and IOA have issued the document "Guidelines for Noise Impact Assessment" on 6th October 2014.

D.4.6 The document distinguishes between the terms 'Noise Impact', 'Noise Effect' and 'Significance of Effect'. 'Noise Impact' is defined as the difference between before and after the implementation of the proposals. 'Noise Effect' is defined as the effect of the noise change. 'Significance of Effect' is defined as the ranking of the noise effect. The document further provides three tables (here reproduced below in Tables D4 to D6) summarising the scale of noise impacts and effects on individuals in dwellings.

Table D4 – Degree of Effect Matrix

		IMPORTANCE /SENSITIVITY OF RECEPTOR			
		High	Medium	Low	Negligible
MAGNITUDE/SCALE OF CHANGE	Large	Very Substantial	Substantial	Moderate	None
	Medium	Substantial	Substantial	Moderate	None
	Small	Moderate	Moderate	Slight	None
	Negligible	None	None	None	None

Table D5 – Effect Description

Effect	Descriptor
Very Substantial	Greater than 10 dB L_{Aeq} change in sound level perceived at a receptor of great sensitivity to noise
Substantial	Greater than 5 dB L_{Aeq} change in sound level at a noise-sensitive receptor, or a 5 to 9.9 dB L_{Aeq} change in sound level at a receptor of great sensitivity to noise
Moderate	A 3 to 4.9 dB L_{Aeq} change in sound level at a sensitive or highly sensitive noise receptor, or a greater than 5 dB L_{Aeq} change at a receptor of some sensitivity
Slight	A 3 to 4.9 dB L_{Aeq} change in sound level at a receptor of some sensitivity
None/not significant	Less than 2.9 dB L_{Aeq} change in sound level and/or all receptors are of negligible sensitivity to noise or marginal to the zone of influence of the proposals

Table D6 – Impact from the change in sound levels

Long-term Impact Classification	Short-term Impact Classification	Sound level change dB $L_{Aeq, T}$ (positive or negative) T = either 16hr day or 8 hr night
Major	Major	≥ 10
Moderate		≥ 5 and < 10
Minor	Moderate	≥ 3 and < 5
Negligible	Minor	≥ 1 and < 3
	Negligible	≥ 0 and < 1

D.4.7 The key is to assess the difference in level between the scenarios before and after the proposed scheme is in place in relation to national planning guidance in terms of LOAEL and SOEAL.

Appendix E Site Description and Plan

E.1 Site Description

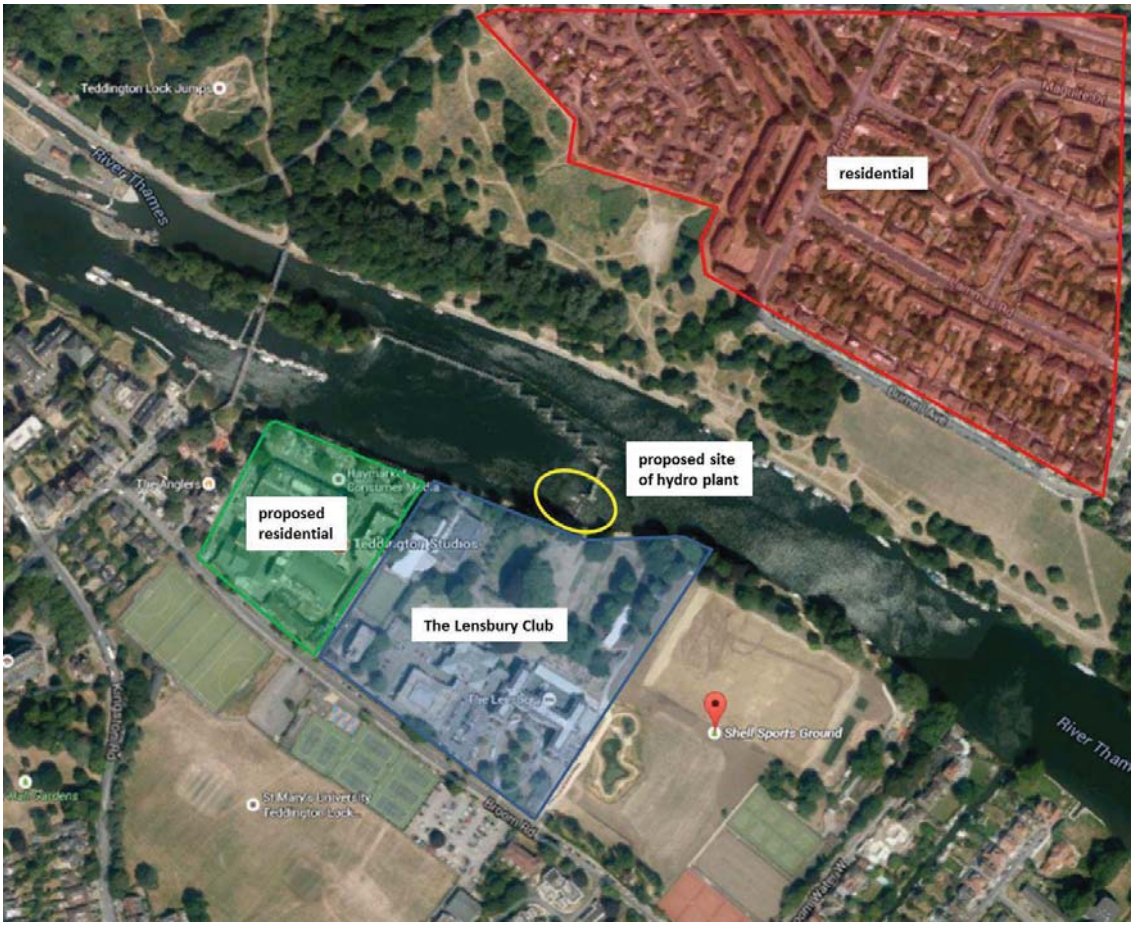
E.1.1 The site of the proposed hydro plant scheme is located at Teddington Weir in Ham, Richmond. Teddington weir is located at the end of the tidal stretch of the river Thames approximately 3.5 km from Richmond Town Centre.

E.1.2 Teddington Weir is surrounded to the north and north east by recreational grounds and residential development. The Lensbury Club and grounds are located immediately to the south of the weir. The Teddington Studios are currently located to the south west of the weir. It is understood that a proposed residential development is planned to be located on the Teddington Studio grounds. Please refer to **Figure E1** below.

E.1.3 It is understood that the land south of the proposed location of the hydro scheme, i.e. the Teddington Studio grounds and the Lensbury Club grounds are relatively flat with no noticeable dips, peaks or height differences, but with several trees and other vegetation on the Lensbury Club grounds.

E.1.4 To the north of the proposed location is the river and an unobstructed view to the residential dwellings on Burnelle Avenue and Bedford Road, with the exception of some trees and low vegetation.

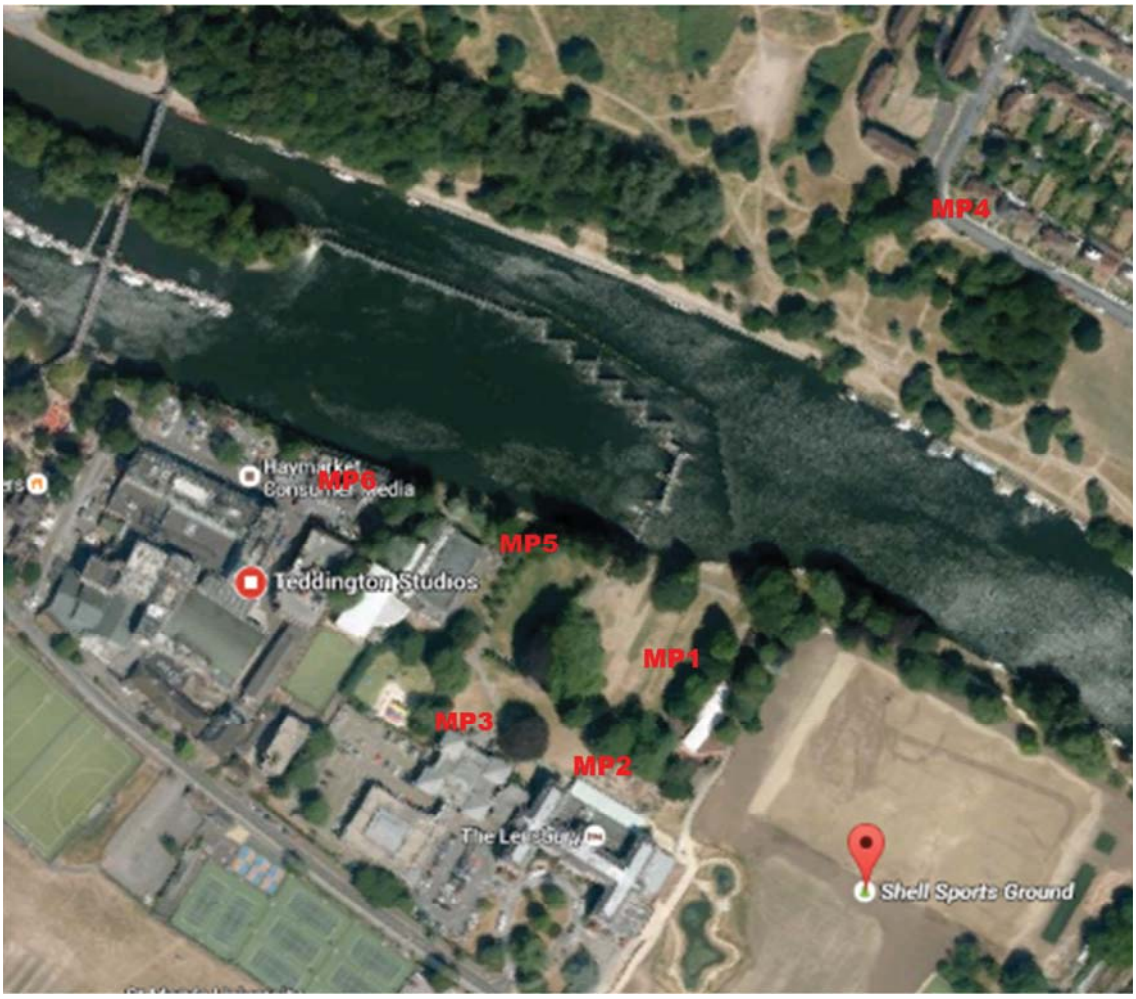
Figure E1 – Site Plan



E.2 Assessment Locations

E.2.1 **Figure E2** below shows the assessment locations.

Figure E2 – Assessment Locations



E.3 Baseline Surveys – Result summary

E.3.1 A summary of the results from baseline surveys are shown in **Table E1** and linked with each assessment/measurement location and approximate distance between the locations and the proposed hydro scheme site.

Table E1 – Ambient and Background Sound Levels

Location	Appoximate distance from proposed plant location	Time	$L_{Aeq, T}$ (dB)	$L_{AF90, T}$ (dB)
MP1	50 m	Day	57	52
		Night	53	52
MP2	125 m	Day	54	52
		Night	52	50
MP3	125 m	Day	57	51
		Night	53	41
MP4	200 m	Day	49	45
		Night	42	41
MP6	150 m	Day	65	64
		Night	63	62

E.3.2 **Figures E3** and **E4** show the survey results from MP6 in graphical form;

Figure E3 - Teddington Studios (MP6), LAeq & LAmax

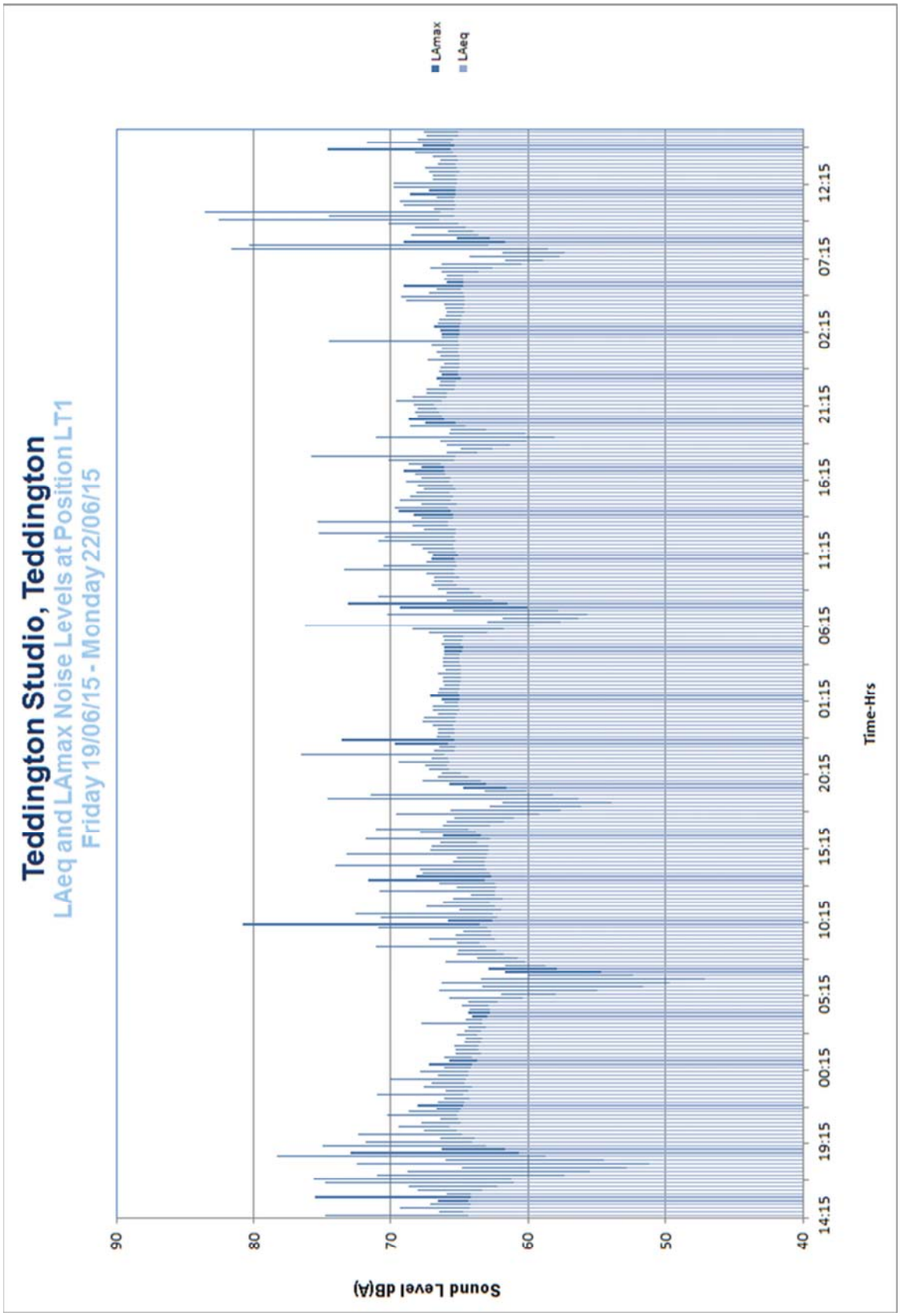
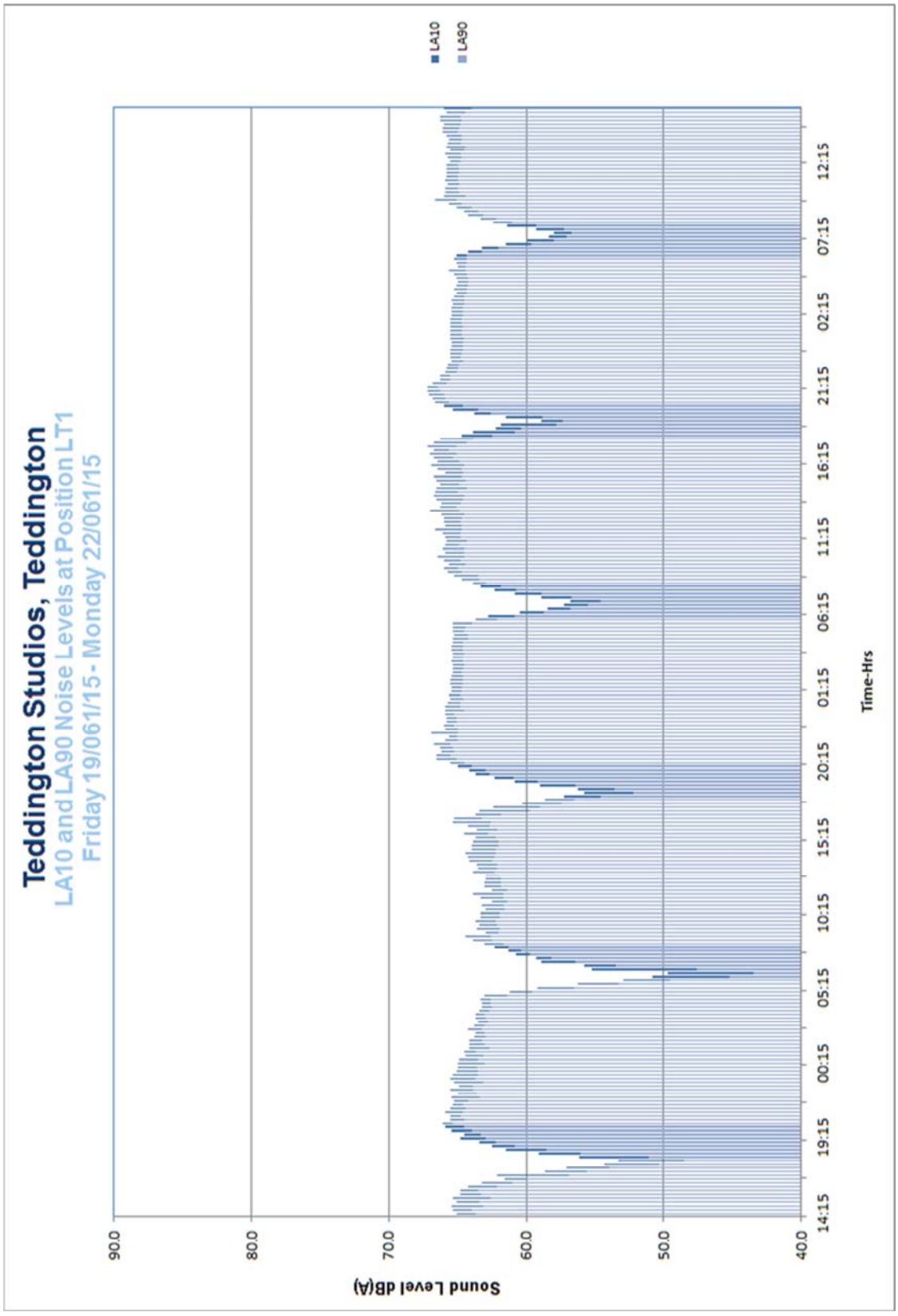


Figure E4 - Teddington Studios (MP6), LA90 & LA10



Appendix F Noise Maps

Figure F1 - Baseline, no Mitigation

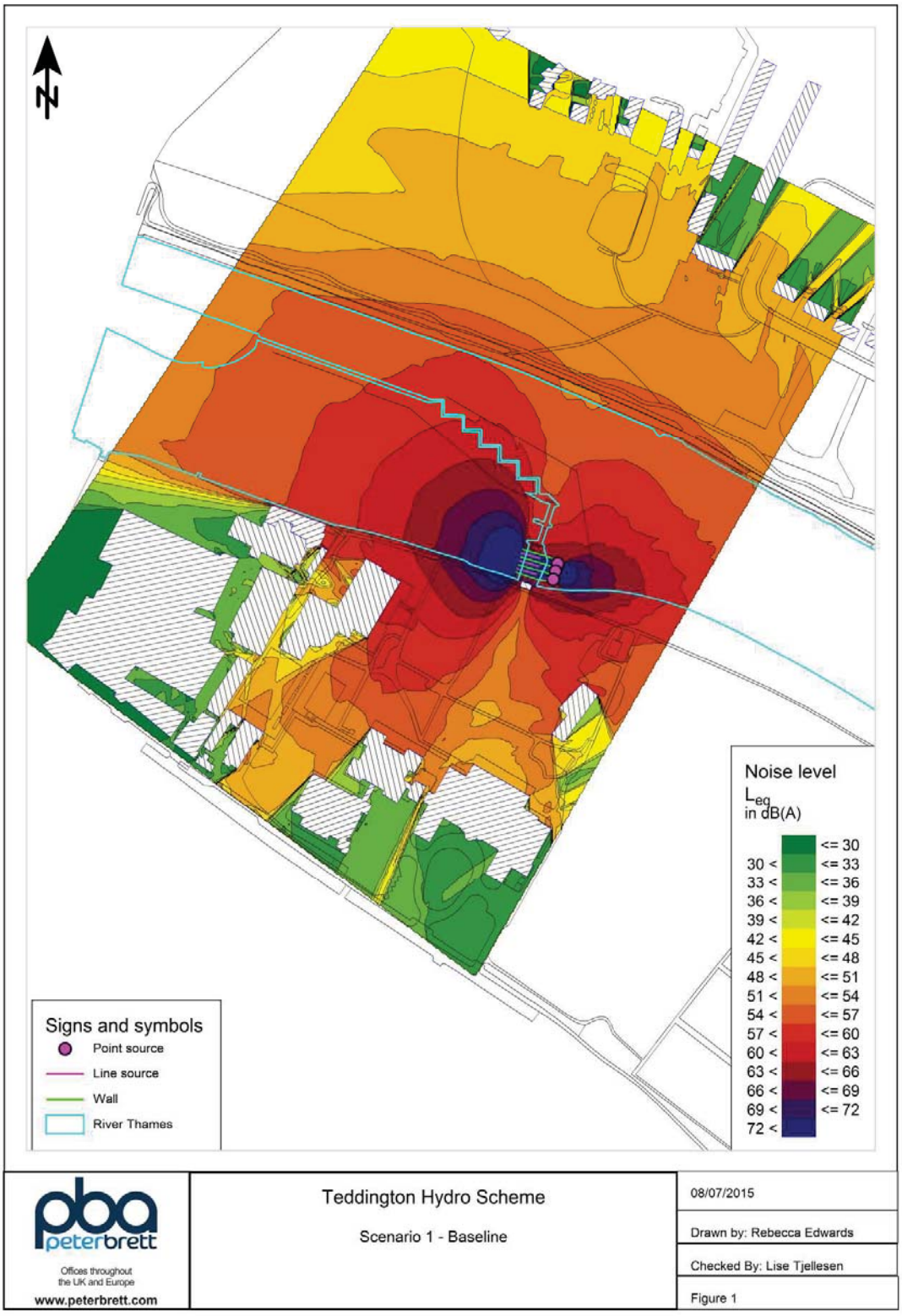
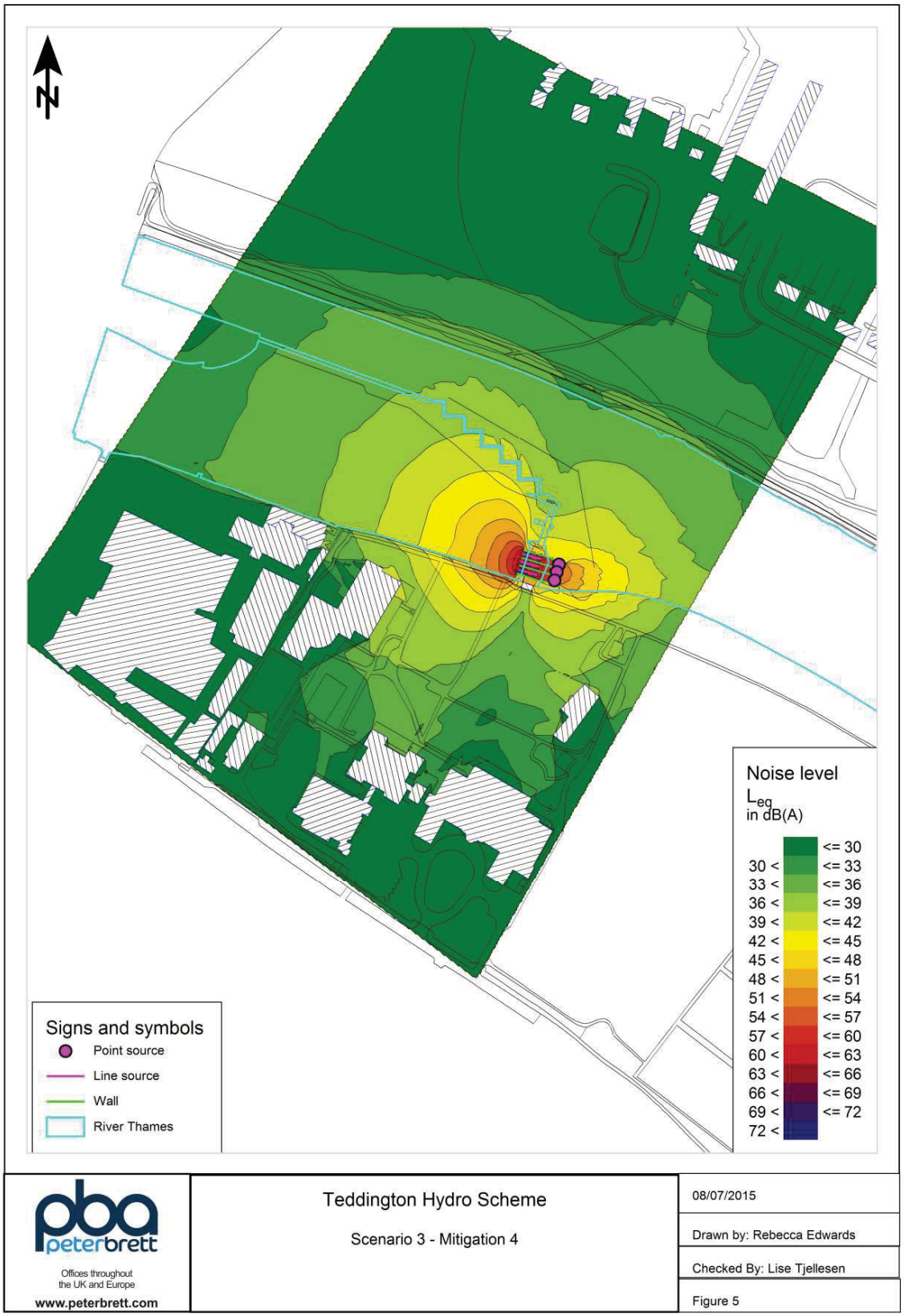


Figure F2 - Scheme with Mitigation



Appendix G Noise Source Data Review

G.1.1 No manufacturer provides noise source data for their turbines. In practice that means having to measure sound from an existing and operating hydro scheme in order to obtain the necessary data.

G.1.2 The normal way to obtain noise source data by measurements are standardised in the ISO 3740 "*Acoustics – Determination of sound power levels of noise sources – Guidelines for use of basic standards*". ISO 3740 covers a series (ISO 3741 to 3747 & ISO 9614) of measurement standards for obtaining noise source data covering various scenarios and locations of the noise source under test. The majority of the standards refer to laboratory conditions. Hence why these cannot be directly applied to in-situ conditions.

G.1.3 However, the general guidelines from standards ISO 3746:1995 "*Acoustics – Determination of sound power levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane*" and ISO 3747:2009 "*Acoustics – Determination of sound power levels of noise sources using sound pressure – comparison method in situ*" could be applied to obtaining relevant noise source data from an operating hydro plant with certain allowances for practical restrictions depending on the site location and considerations to health and safety measures.

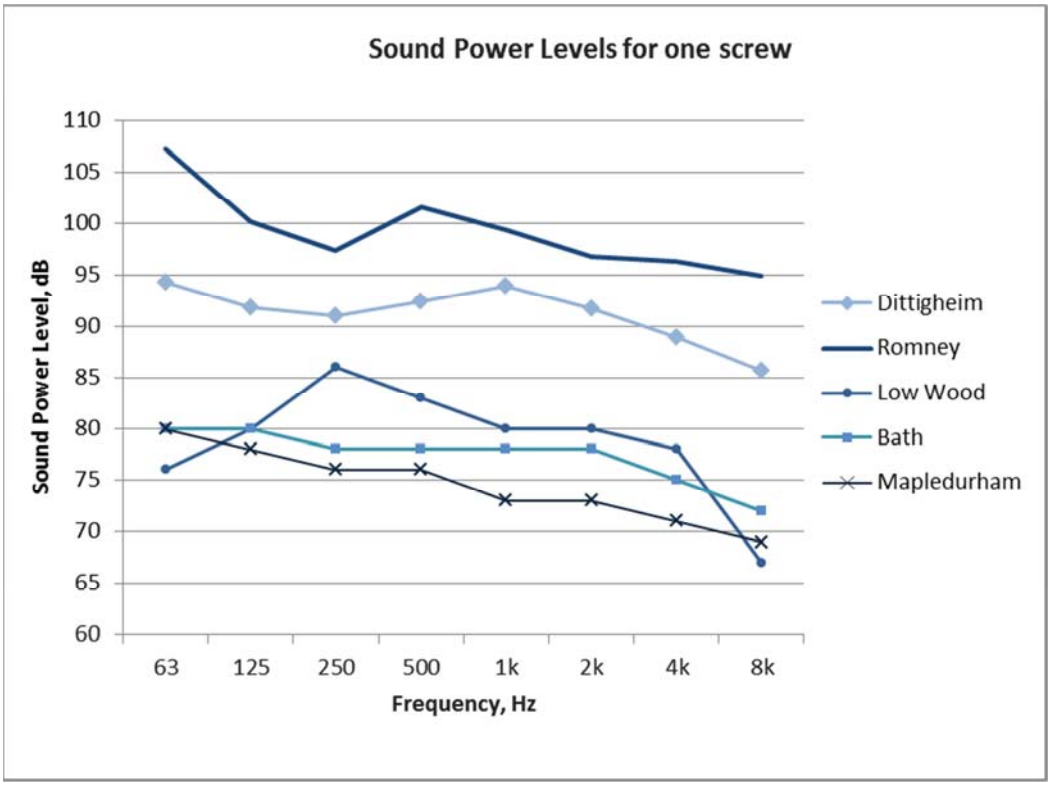
G.1.4 The noise source data used in the ZBP assessments [ZBP1 & ZBP2] came from German test measurements (from Birkenau and Dittgeheim) carried out by Technak and measurements from Mapledurham carried out by LBRUT. Based on available documents all measurements seem to be carried out in general accordance with national (German DIN) and international measurement standards from standard series ISO 3740.

G.1.5 The noise source data used in the PBA report [PBA1] were measured at Romney Weir, Windsor in June 2013 after the general guidelines set out in BS 3746:1996.

G.1.6 BS3746:1996 "Acoustics – Determination of sound power levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane) provides guidelines as to how sound power levels can be obtained using sound pressure level measurements, but theses relates to a source above a reflecting plane. As an alternative the guidelines from BS3747:2009 "Acoustics – Determining sound power levels of noise sources using sound pressure – Comparison method in situ" could have been applied. However, while general guidance can and should be taken from the above standards, neither fully covers the very specific situation of obtaining noise source data from a working hydro plant.

G.1.7 The question whether it is reasonable to use the data measured at Romney Weir still remains an issue according to AJA. The noise impact assessments (see **Section 5.2.5**) provide measured sound power levels for one turbine/screw, and the spectra are shown graphically in **Figure G1** below.

Figure G1 – Sound power levels for one Archimedean screw



Dittgeheim [4], Romney [PBA1], Low Wood [3], Bath [1] & [2], Mapledurham [ZBP2]

G.1.8 When looking at the available sound power level data above, the general shape of the spectra follow the same form. In terms of levels, the measurements at Romney appear to provide the highest levels. The uncertainty of these measurements will be addressed in **Appendix H**.

G.1.9 It is understood that the chosen hydro plant at Romney Weir, at the time of the noise impact assessment [PBA1] by PBA, was and most likely still are the only operating hydro scheme with screws or a similar size, capacity and location (i.e. at the river Thames) as the proposed plant at Teddington Weir.

G.1.10 Assuming that it is the case, it would probably be unwise to choose a different (i.e. smaller plant) to measure source data at as the levels appear to be at lower levels. Further the plant at Romney Weir is apparently currently the only other operating hydro plant located along the river Thames, providing similar conditions for operation as for the proposed plant at Teddington Weir.

G.1.11 If a more identical hydro plant can be identified in the UK, additional source data can obviously be measured when optimal conditions are available. Also for further validation purpose this would be of value.

Appendix H Review of Uncertainties

H.1.1 An essential discussion / critique point has been the application of (or perhaps lack of) uncertainties. Uncertainties were not addressed in detail in the first noise assessments ([ZBP1] & [ZBP2]). This was pointed out by AJA [AJA2].

H.1.2 Various values for the uncertainty have been thrown into the discussion by LBRUT and PBA in [PB1, PBA3] and need for an estimation of the uncertainty has been emphasised by AJA [AJA4 & AJA5].

H.1.3 The discussion show a general misconception of what uncertainties are, and this has been rectified in the current work.

H.1.4 It should be noted that uncertainties are measure of how good the model is. It gives the assessor an indication of whether the data is reliable or not. Uncertainties should NOT be added or subtracted or in any other way be a part of end result.

H.1.5 Estimation and calculations of uncertainty for environmental noise surveys in the UK is usually done according to the guidelines provided in “A Good Practice Guide on the Sources and Magnitude of Uncertainty Arising in the Practical Measurement of Environmental Noise” by N. J. Craven and G. Kerry (School of Computing, Science & Engineering, University of Salford) from May 2007.

H.1.6 Craven & Kerry have based their ‘good practice guide’ on work by Stephanie Bell published in “A Beginner’s Guide to Uncertainty of Measurement, Measurement Good Practice Guide No 11” from NPL in 1999.

H.1.7 The above mentioned document by Craven & Kerry provides guidelines for providing an uncertainty budget. However, the uncertainty budget at set out in the guide by Craven & Kerry only applies to measurements involving source (-s), transmission path (-s) and receiver (-s). They do not take account for this specific case, where uncertainty relating to loads of various elements should be taken into account.

H.1.8 In order to do that it is necessary to go back to basic and apply the method (-s) outlined by Stephanie Bell. This means looking at uncertainty budgets for each element on its own, i.e. one uncertainty budget for the baseline survey, one uncertainty budget for the noise source measurements, one uncertainty budget for transferring the noise source data and one uncertainty budget related to the modelling. The combination of this provides the overall uncertainty.

H.1.9 The baseline survey does not involve a specific source. The uncertainty therefore primarily relates to the reproducibility of the measurements, which for the available measurements can be calculated to 1.2 dB based on the available data.

H.1.10 The uncertainty for the noise source data can for the purpose of the evaluation of the quality of the data be divided into looking at 1) the uncertainty relating directly to the Romney Weir measurements and 2) the uncertainty relating to the various measurements of sound from one Archimedean screw at different locations.

H.1.12 A new uncertainty budget has been calculated for the noise source data measurement at Romney Weir according to the method provided by Craven & Kerry. The calculation is presented in the new noise impact assessment (ref. 28307/005 dated 24th July 2015) and results in an extended uncertainty of 6.6 dB at 95% confidence, which can be considered to be a reliable assessment.

H.1.13 The uncertainty for the various measurements reported in the noise impact assessments mentioned in reports [PBA1, ZBP2] by PBA and ZBP can be calculated as follows in **Table F1** below;

Table H1 – Uncertainty of Noise Source Data Measurements at Different Locations

Location	Sound Power Levels, SWP (dB) per Octave Band Centre Frequency (Hz)								SWL Total (dB)
	63	125	250	500	1000	2000	4000	8000	
Dittigheim	94	92	91	92	94	92	89	86	101
Romney	107	100	97	102	99	97	96	95	110
Low Wood	76	80	86	83	80	80	78	67	90
Bath	80	80	78	78	78	78	75	72	87
Mapledurham	80	78	76	76	73	73	71	69	85
Mean Value	88	86	86	86	85	84	82	78	94
Estimated Standard Deviation, s	13	10	9	11	11	10	10	12	11
Estimated Standard Uncertainty, u	6	4	4	5	5	4	5	5	**5**

H.1.14 The above total estimated standard uncertainty as calculated per the guidelines by NPL indicates that one Archimedean screw are likely to provide an overall sound power level of 94 dB ± 5dB providing a level of confidence of approximately 95%, which for reproducibility uncertainty can be considered good.

H.1.15 It should further be noted that the data measured at Romney Weir are significantly higher than the estimated average level. This indicates that choosing the Romney Weir data is not unrealistic and not an underestimate of the noise source data.

Appendix I Tidal Influence

I.1.1 The drops in the background sound level (L_{A90}) of up to 15 dB occur approximately every 12 hours and are due to the tides. It should be noted that typical drops in background sound levels are around 5 to 8 dB.

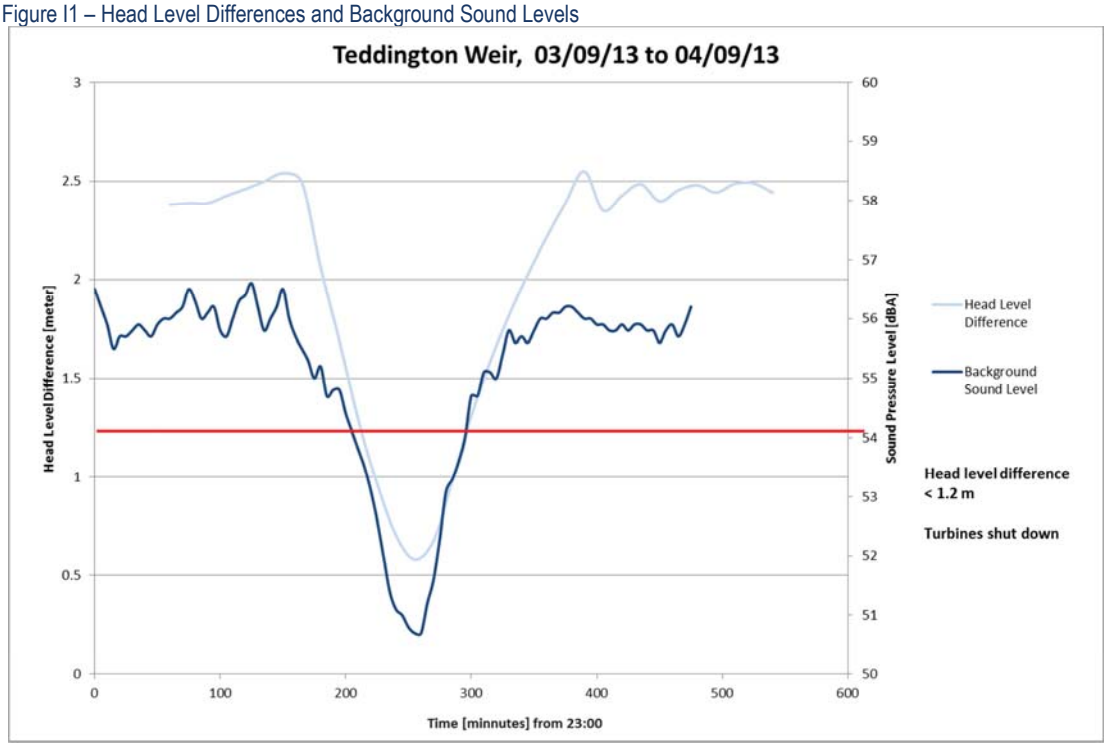
I.1.2 The tides create differences in the water levels in addition to the upstream and downstream water levels.

I.1.3 In order to prevent noise occurring at the periods of tides, it is proposed that the screws are slowed down as the head level difference drops, and stopped completely when the head level difference drops below 1.2 m.

I.1.4 In effect this means that the scheme will not be operating during the tides, i.e. in periods with low background noise levels.

I.1.5 For illustrative purpose see **Figure I1** below. The figure shows the variation of the tide as a function of the time, as well as the sound pressure levels as a function of the time. That illustrates how the tide and drop in background sound levels correlates. It further shows that when the head level difference drops below 1.2 m, i.e. in periods with tides, the turbines will be shut off.

Figure I1 – Head Level Differences and Background Sound Levels



I.1.6 It should be noted that the above graph in **Figure I1** is only a short snapshot of a particular tidal situation from 3rd and 4th September 2013 to illustrate the principle.