Lower Thames Hydro, Teddington Weir

Noise Impact Assessment

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

Project Ref: 28307/005 | Rev: A | Date: July 2015

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Contents

Figures

Tables

Appendices

Executive Summary

Peter Brett Associates LLP (PBA) has been instructed to prepare a noise assessment of the proposed hydropower system at Teddington Weir, Richmond to support the planning application for the scheme. The proposed scheme will involve the demolition of a section of the weir, and the installation of three Archimedean Screw turbines which will generate hydro-electricity.

The noise impact assessment presented in this report uses previously measured baseline sound surveys carried out by ZBP Acoustics and the London Borough Richmond upon Thames in 2011 and 2013 respectively, together with a new baseline survey by Peter Brett Associates carried out at Teddington Studios in June 2015. The survey locations and methodology have been agreed with the London Borough of Richmond Upon Thames's Environmental Protection Team.

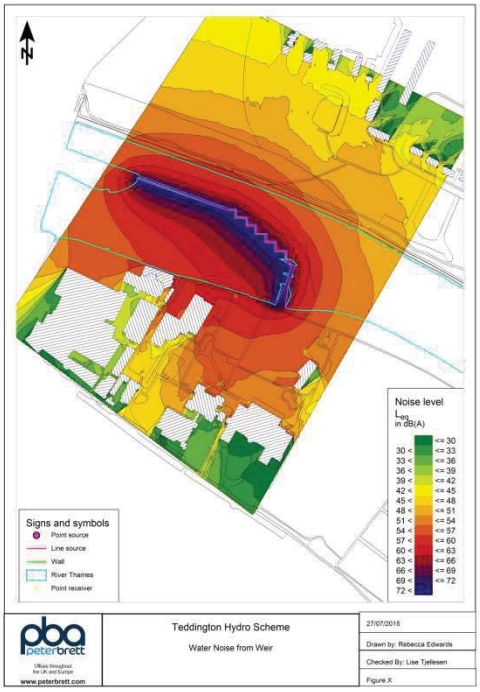
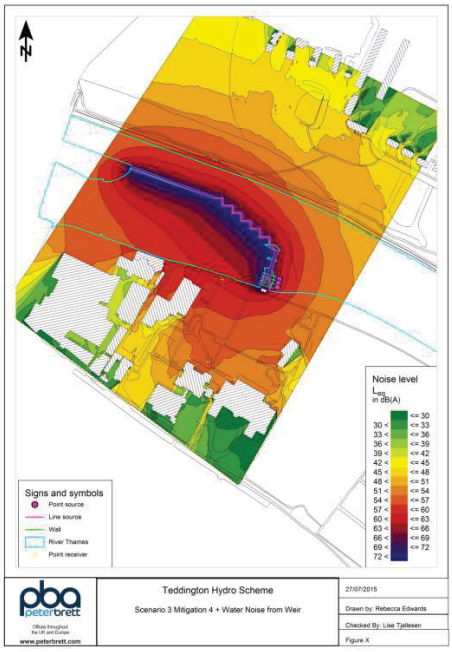
As there is no exact duplicate of the proposed scheme in existence, it has been necessary to use noise source data measured at an existing hydropower scheme at Romney Weir in 2013 to inform the assessment; this is a standard and widely recognized practice in such situations.

A number of measures have been put into place to ensure that this approach is robust and conservative, such as adapting a worst case scenario approach throughout the assessment, taking account of the Lensbury Club Hotel Facility as if it is residential, adjusting for specific noise characteristics and calculating uncertainty budgets, which indicates that the results are reliable.

New sound survey has been carried out at Teddington Studio grounds.

Computer models using the noise modelling software SoundPlan ver 7.3 have been created and used for the noise impact assessment.

The scheme with proposed require minimum in-situ mitigation measures complies with the agreed local authority planning requirements, and therefore the potential for noise from the proposed scheme, as illustrated on the two figures below, should not be a constraint to the development proceeding.

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 Background

1.1.1 Peter Brett Associates LLP (PBA) has been instructed to prepare a noise assessment of the proposed hydropower system at Teddington Weir in Richmond for inclusion with planning application. The proposed application will involve demolition of a section of the weir, and the installation of three Archimedean screw turbines which will generate hydro-electricity, provision of a fish pass and sluice gate, cable route and construction of a plant room.

1.1.2 Noise assessments with successive amendments have previously been undertaken by both ZBP Acoustics (ZBP) and PBA and reported in various documents as listed in **Table 1** below. Additional noise measurements in relation to the proposed scheme have also been carried out by London Borough of Richmond upon Thames (LBRUT).

Table 1 - Previous Noise Assessments and Noise Measurement Report

Reference	Title
[ZBP1]	"Ham Hydro CIC project, rev. C" (ref. 3207) dated 15th November 2011 from ZBP acoustics
[ZBP2]	"Ham Hydro CIC project, Teddington, Richmond – Revised Noise Impact Assessment" (ref. 3207-R01) dated 18th January 2013 from ZBP acoustics
[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
[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
[PBA4]	"Modelling of Teddington Hydropower Scheme" (ref. 28307-004/ESP N2) dated 22nd July 2014 from Peter Brett Associates LLP

1.1.3 The above noise assessments have been subject to intensive scrutiny and objections. This is discussed in more detail in the non-technical report (ref. 28307/006) dated 24th July 2015, as this report is not a review or discussion report.

1.1.4 This current noise impact assessment report can be read as a standalone document, but it is highly recommended that the report is read in conjunction with the associated non-technical document, which provides additional background information, validation, context and discussion of the work undertaken previously, thereby providing "context" to the technical report. The aim therefore is to keep this report as simple and factual as practical possible without compromising the overall noise assessment.

1.1.5 The main purpose of this noise assessment is to provide a new noise assessment for the proposed hydro scheme using computer noise modelling with the software SoundPlan, including revisiting any necessary noise mitigation measures in order to comply with the criteria set out by the local authority.

1.1.6 The assessment is technical in nature, so to assist the reader a Glossary of Acoustics Terms is provided in **Appendix A**.

1.2 Site Description

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

1.2.2 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 Studios grounds. Please refer to **Figure 1** in **Appendix B** for a site plan.

1.2.3 After consultation with the local planning authority of LBRUT and based on their comments on previous reports, it is proposed to have the assessment locations listed in **Table 2** below as noise sensitive receptors. It is attempted to keep the naming from previous reports as far as practically possible. Please see **Figure 2** in **Appendix B** for a mark-up of the receptor locations on the site plan.

Table 2 – Assessment Locations

Location	Description	Surveyed by
MP1	North-western façade of Riverside Pavilion / Garden	ZBP / LBRUT
MP2	North-eastern edge of Clubhouse roof / Clubhouse (Rear façade of the Lensbury Club Hotel)	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

1.3 Proposed Scheme

1.3.1 The proposed hydrodynamic scheme is to include three Archimedean screws, each measuring 6.08 m in length and 4.0 m in diameter, installed in parallel on the southern section of the weir as indicated on initial drawings provided by eWaterpower Ltd, please refer to **Figure 3** in **Appendix C**.

1.3.2 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 scheme.

1.3.3 It is further understood that additional noise mitigation measures comprise covering the screws and gearboxes. This will be further reviewed in **Section 6**.

2 Legislation, Policy and Guidance

2.1 National Planning Policy

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

National Planning Policy Framework (NPPF)

2.1.2 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).

2.1.3 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 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."*

2.1.4 The above is the overruling national guidance with the main goal of avoiding noise from having significant adverse impact on health and quality of life.

2.1.5 Paragraph 14 and 15 of the NPPF further states:

> *"At the heart of the National Planning Policy Framework is a* ***presumption in favour of sustainable development****, which should be seen as a golden thread running through both plan-making and decision-taking.*
>
> *For* ***plan-making*** *this means that:*
>
> - *local planning authorities should positively seek opportunities to meet the development needs of their area;*

- *Local Plans should meet objectively assessed needs, with sufficient flexibility to adapt to rapid change, unless:*

  - *any adverse impacts of doing so would significantly and demonstrably outweigh the benefits, when assessed against the policies in this Framework taken as a whole; or*

  - *specific policies in this Framework indicate development should be restricted*

*For **decision-taking** this means:*

- *approving development proposals that accord with the development plan without delay; and*

- *where the development plan is absent, silent or relevant policies are out-of-date, granting permission unless:*

  - *any adverse impacts of doing so would significantly and demonstrably outweigh the benefits, when assessed against the policies in this Framework taken as a whole; or*

  - *specific policies in this Framework indicate development should be restricted.*

15. Policies in Local Plans should follow the approach of the presumption in favour of sustainable development so that it is clear that development which is sustainable can be approved without delay. All plans should be based upon and reflect the presumption in favour of sustainable development, with clear policies that will guide how the presumption should be applied locally."

Noise Policy Statement for England (NPSE)

2.1.6 The Noise Policy Statement for England (NPSE) was published in March 2010 by DEFRA. It relates to environmental noise and neighbour noise (both from inside and outside people's 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.*"

2.1.7 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.*"

2.1.8 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.

2.1.9 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*."

2.1.10 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 receptors due to noise is acceptable.

2.1.11 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.

2.1.12 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.

2.1.13 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.

2.1.14 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".

2.1.15 The NPSE recognise that noise exposure can cause annoyance and sleep disturbance both of which impact on quality of life. In paragraph 2.14 NPSE further states:

> "*It is also agreed by many experts that annoyance and sleep disturbance can give rise to adverse health effects. The distinction that has been made between „quality of life" effects and „health" effects recognises that there is emerging evidence that* ***long term*** *exposure to some types of transport noise can additionally cause an increased risk of direct health effects*."

2.1.16 The key is to avoid significant "health" effects and thus on the "quality of life" from long term exposure to noise.

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

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

2.1.18 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 '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').

2.1.19 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.

2.1.20 The guidance provided by PPG can be summarised in **Table 3** below;

Table 3 – 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

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

2.2.1 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.

2.2.2 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.*"

2.2.3 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*

2.2.4 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."

2.3 World Health Organization Guidelines for Community Noise 1999 (WHO)

2.3.1 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.

2.3.2 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 guideline 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."

2.3.3 Table 1 in Chapter 4 of the WHO guidelines summarises the above statements and provides guideline values for community noise in specific environments as shown in **Table 4** below :

Table 4 – 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

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

2.4.1 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.

2.4.2 Table 4 of Section 7.3 of BS8233:2014 outlines the internal ambient noise levels for dwellings as summarised in **Table 5** below;

Table 5 – Indoor Ambient Noise Levels for Dwellings

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 $L_{Aeq, 8hr}$

2.4.3 For external noise BS8322:2014 provide the design criteria of 50 dB LAeq, T with an upper guideline value of 55 dB LAeq, 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*."

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

3 Noise Surveys

Previous measurements of existing ambient sound climate

3.1 Results of Baseline Surveys

3.1.1 Measurements of the existing ambient sound climate at and around the location of the proposed hydro scheme have been carried out on several occasions and the results are summarised in **Table 6** below.

Table 6 – Ambient and Background Sound Levels

Location	Surveyor	Time	$L_{Aeq, T}$ (dB)	L_{Amax} (dB)	$L_{AF10, T}$ (dB)	$L_{AF90, T}$ (dB)
MP1	ZBP	Day	57	79	57	52
		Night	53	65	54	52
	LBRUT	Day	57	85	57	52
		Night	53	72	54	52
MP2	ZBP	Day	54	77	54	52
		Night	52	59	53	50
	LBRUT	Day	55	79	54	52
		Night	53	59	54	51
MP3[4)]	ZBP	Day	57	74	58	53
		Night	54	72	54	50
	LBRUT	Day	57	83	58	51
		Night	53	73	55	41
MP4	ZBP	Day[1)]	-	-	-	-
		Night	42	60	42	41
	LBRUT	Day	49	63	53	45
		Night	41	53	42	41
MP5	LBRUT	Day[2)]	70	-	-	-
MP6[3)]	PBA	Day	65	68	65	64
		Night	63	66	63	62

1) See comment 3.1.3 2) See comment 3.1.4 3) See comment 3.1.5 & 3.1.6 4) see comment 3.1.7 & 3.1.8

Comments to Table 6 above

3.1.2 Full details on the surveys carried out by ZBP and LBRUT can be found in their respective reports referenced to as [ZBP1], [ZBP2] and [LBRUT] as per **Section 1.1.2**.

3.1.3 ZBP Acoustics did not measure the day time values at measurement location MP4 (Burnell Avenue), as it was assumed that night time would provide the lowest background sound levels.

3.1.4 The single number value reported for measurement location MP5 is a "snap-shot" value measured by LBRUT illustrating the potential high levels that can occur occasionally and which are not considered to be a LAmax value. No value for the background sound levels has been provided.

3.1.5 Full details and results for the survey carried out by PBA at Teddington Studio grounds can be found in **Appendix D**.

3.1.6 The higher sound levels measured at the Teddington Studio grounds could potentially be attributed to the fact that it is measured downstream from the weir.

3.1.7 It should be noted that during high tides the background sound levels can drop up to 15 dB. It is proposed that the turbines are shut down during those periods of high tides, i.e. when this coincides with low background sound levels. This noise assessment therefore only provides an assessment of the hydro scheme under normal/typical operation and typical background sound levels not related to the tides.

3.1.8 The difference in measured LA90 levels between the ZBP and LBRUT measurements be due to the tide. In order to undertake a worst case assessment, regardless of whether the lower value is due to the tide or other differences in the acoustic environment, the lower values are used in the assessment.

3.2 Baseline Surveys – Summary

3.2.1 From **Table 6** in **Section 3.1.1** the following data in **Table 7** have been extracted and linked with each assessment/measurement location and approximate distance between the locations and the proposed hydro scheme site.

Table 7 – Ambient and Background Sound Levels

Location	Approximate 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

3.2.2 It should be noted that the Lensbury Club Riverside Path runs the entire length of the grounds along the south bank of the river. The perpendicular distance from the riverside path to the proposed hydro scheme site is approximately 5 m. The proposed assessment location MP5 (Lensbury Club - Riverside Path) is located approximately 50 m from the proposed site in the opposite direction of MP1.

3.2.3 Despite the fact that assessment location MP5 being located downstream and therefore expected to show higher levels of background sound, in the assessment it is assumed that location MP5 has similar background sound levels to assessment location MP1, thus providing a more stringent limit along the entire riverside path.

3.3 Source Data Survey

3.3.1 No manufacturer noise source data exists for any type of hydro plant. Manufacturers do not measure or provide noise data for their turbines. It is therefore necessary to obtain noise source data in an alternative way.

3.3.2 The de-facto standard way of obtaining noise source data for noise impact assessments for hydro schemes or in similar situations generally is to find a similar existing, i.e. operating, hydro scheme and carry out in-situ measurements of the noise source(-s).

3.3.3 Noise source data was previously measured at an operational hydro plant located at Romney Weir using the general guidelines set out in 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”. Details on the noise source data survey can be found in **Appendix E**.

3.3.4 The sound power levels are calculated based on the measured sound pressure levels in general accordance with BS9613-2:1996 “Acoustics –Attenuation of sound during propagation outdoors – Part 2: General method of calculation”. The measurement results and calculations were originally presented in the noise assessment report [PBA1] dated July 2013. The main measurement results and conversion to sound power levels are shown in **Appendix F**.

3.3.5 The results in terms of sound power levels after calculation and conversion to levels at 1 m from the source are summarised in **Table 8** below.

Table 8 – Noise Source Data for 1 (one) Turbine at 1 m

Measurement Location	L_{WA} per octave band frequency (dB, Hz)								Overall L_{WA} (dB)
	63	125	250	500	1k	2k	4k	8k	
Between turbines	82	74	75	81	74	70	65	62	80
Downstream	107	100	97	102	99	97	96	95	105

Uncertainty related to survey measurements

3.4 Introduction to uncertainty

3.4.1 According to BS4142:2014 the level of uncertainty in data and associated calculations should be considered. It further states:

> “*Where the level of uncertainty could affect the conclusion, take reasonable practicable steps to reduce the level of uncertainty.*”

3.4.2 Estimation and calculations of uncertainty for environmental noise surveys in the UK is currently usually done using 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.

3.4.3 The above guide provides guidelines for providing an uncertainty budget. However, those guidelines only take into account one measurement scenario, i.e. source, transmission path and receiver. It does not cover the usage of measured noise source data and transferring it to another location. There are no published guidelines to address this scenario.

3.4.4 In order to provide a full uncertainty budget for the assessment it would be required to provide uncertainties for each part, i.e. uncertainty related to baseline surveys, uncertainty related to noise source data measurements, uncertainty related to the calculation / modelling method and finally combine them all. **Appendix G** provides an estimated uncertainty budget based on known data and information.

3.4.5 The total uncertainty is 8 dB with a confidence level of 95%. All practical means have been taken to reduce the uncertainties. With the long range of various factors that can influence the uncertainty in this type of noise impact assessment, the calculated uncertainty can be considered to be an indication of reliable results.

3.4.6 It should further be noted that the assessment take a general worst case scenario approach.

4 Planning Criteria

4.1 Local Authority (LA)

4.1.1 After discussions with the local authority the planning criteria is based on BS4142:2014 with an additional condition and BS8233:2014 and as summarised in **Table 9** below;

Table 9 – Local Authority Criteria

Receptor	External LA condition based on terms from BS4142:2014	LA Internal criteria based on BS8233:204	
		Day 07:00 – 23:00	Night 23:00 – 07:00
Residential	Rating Level minus Background Level no greater than -5 dB	35 dB(A) $L_{Aeq, 16hr}$	30 dB(A) $L_{Aeq, 8hr}$
Commercial	Rating Level minus Background Level no greater than +5 dB	n/a	n/a

4.1.2 It should be noted that the above criteria set out by the Local Authority is more stringent than national planning policy.

4.1.3 It is in this assessment assumed that the external levels are proposed for 1 m from the façade of the receptor (i.e. for MP2, MP3, MP4 and MP6) or in the amenity areas (i.e. for MP1 and MP5).

4.1.4 While the Lensbury Club is considered to be commercial premises by the local authority, internal criteria for residential receptors are applied due to the nature of the hotel facility.

4.1.5 This assessment has further chosen to adopt the more stringent residential external criteria for the assessment locations close to the Lensbury Clubs main building containing the hotel facilities, i.e. for MP2.

4.1.6 In order to consider a worst case scenario it has been chosen to assess against the night time values, as these provide the lowest background sound levels.

4.1.7 The above criteria can be converted to sound level limits, which the proposed hydro scheme should comply with based on the measured background sound levels. The limits for each assessment location as set out in **Table 2** in **Section 1.2.3** are shown in **Table 10** below.

Table 10 – Local Authority Criteria per Assessment Location in Terms of External Sound Levels

Location	For External	For Internal BS8233:2014	
		Day 07:00 – 23:00	Night 23:00 – 07:00
MP1	Rating Level < 57 dBA	N/A	N/A
MP2	Rating Level < 45 dBA	50 dBA	45 dBA
MP3	Rating Level < 46 dBA	N/A	N/A
MP4	Rating Level < 36 dBA	50 dBA	45 dBA
MP5	Rating Level < 57 dBA	N/A	N/A
MP6	Rating Level < 57 dBA	50 dBA	45 dBA

5 Assessment

5.1 Noise Modelling

5.1.1 A noise model of the proposed hydro plant scheme and relevant surroundings has been created using SoundPlan version 7.3 noise modelling software. The noise prediction modelling software SoundPlan allows for terrain, meteorological and noise data to be processed in accordance with a wide range of models. The model chosen for this assessment is the ISO 9613-2:1996 “Attenuation of sounds during propagation outdoors, a general method of calculation”.

5.1.2 ISO 9613-2:1996 specifies a method for calculating the attenuation of sound during outdoor propagation in order to predict levels of environmental sound in terms of both instantaneous levels LpA and as time averaged levels LAeq, T at various distances from a number of different sources.

5.1.3 SoundPlan creates noise contour maps using octave band sound power levels (LW). Hence noise data measured at Romney and converted into sound power levels as shown in **Table 8** in **Section 3.3.5** have been used;

5.1.4 Each of the three Archimedean screws has been modelled as a line source with the length of the physical screw, i.e. 6.08 m, and each assigned the sound power level of 105 dBA, Each of the three gearboxes has been modelled as a point source and assigned the sound power level of 80 dBA.

5.1.5 In the assessment a correction for specific sound characteristics according to BS4142:2014 (see **Section 2.2.4**) has been applied as +4 dB for tonality and + 3dB for other sound characteristics, which totals to a +7 dB adjustment. The tonality has been determined by applying the objective one-octave method, and the correction for other sound characteristics has been applied due to the nature of the sound characteristics of the hydrodynamics, which may include “splashes”, “whooshing” and “thumping”, both adjustment values are determined as set out in BS4142:2014.

5.2 Assessment of scheme – no mitigation

5.2.1 **Table 11** and **Table 12** below summarises the results of the baseline assessment.

Table11 – Assessment of Scheme, No Mitigation – External Levels

Location	External Criterion, dBA	Predicted sound levels, dBA	Adjustments for characteristics	Rating Level, dBA	Level difference, dBA
MP1	Rating Level < 57	58	7	65	+8
MP2	Rating Level < 45	51	7	58	+ 13
MP3	Rating Level < 46	56	7	63	+17
MP4	Rating Level < 36	51	7	58	+ 22
MP5	Rating Level < 57	66	7	73	+ 16
MP6	Rating Level < 57	55	7	62	+ 5

Table 12 – Assessment of Scheme, No Mitigation – Internal Levels

Location	Criterion, external levels, dBA 1m from façade		Rating Levels[1)], dBA	Level difference, dB	
	Day	Night		Day	Night
MP2	Rating Level < 50	Rating Level < 45	58	+8	+ 13
MP4			58	+8	+ 13
MP6			62	+ 12	+17

1) The rating levels are for the external sound as listed in Table 10

5.2.2 As it can be seen from the above **Tables 11** and **12** the proposed scheme with no mitigation measures does not comply with the requirements set out by the local authority.

5.2.3 Based on the above it is clear that various mitigation measures are required.

5.2.4 Noise maps from SoundPlan for the baseline calculation, i.e. with no mitigation can be seen in **Appendix H**

6 Mitigation Measures

6.1 Individual sources of noise and their possible mitigation measures

6.1.1 There are three 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)

6.1.2 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.

6.1.3 The gearbox(es) and transformer(s) are usually enclosed in a building or similar. Noise from these elements is therefore more easily controlled. It should be noted that specific characteristics of the sound, i.e. tonality with clear audibility usually comes from gearbox(es) and transformer(s).

6.1.4 In order for the scheme to comply with local authority planning requirements, the required overall minimum in-situ sound reduction of all elements of the plant should be as shown in **Table 13** below.

Table 13 – Minimum Required in-situ Sound Reduction

In-situ Sound Reduction (dB, Hz)							
63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
13	13	16	21	27	21	31	31

6.1.5 It has previously been proposed to provide enclosure of Plexiglas for the screws in order to mitigate noise related to hydrodynamic interaction of the screws. In order to achieve the proposed minimum in-situ sound reduction the Plexiglas should have a thickness of minimum 25 mm, be sealed appropriately and have a minimum laboratory sound reduction, R_W as shown in **Table 14** below;

Table 14 – Minimum Required Laboratory Sound Reduction, R_w for Screw Enclosure Material.

In-situ Sound Reduction (dB, Hz) *)								
63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**R_W**
na	25	29	33	35	38	45	na	33

**) Test data from Fraunhofer Institut Bauphysik (P-BA 115/1999e)*

6.1.6 For the gearboxes in relation to the proposed hydro scheme the enclosures have been proposed to consist of 100 mm panels with 0.8 mm sheet steel outer and inner skin with an acoustic filling with a density of 45 kg/m3. According to the manufacturer (Envirosound) the sound reductions listed in **Table 15** below should be achievable. It should be noted that these are laboratory values.

Table 15 – Sound Reduction Data for Gearbox Enclosure

Sound Reduction (dB, Hz)								
63	125	250	500	1000	2000	4000	8000	R_W
20	21	28	37	49	57	62	64	40

6.1.7 Both the proposed mitigation measures should provide the minimum required in-situ sound reduction as set out in **Table 13** in **Section 6.1.4**. If other materials or enclosure providers are chosen, a review of the material and provider should be carried out.

6.1.8 Noise from the transformer(s) can be effectively mitigated by means of a solid building containing the transformer(s). If air cooling is necessary any louvres or similar will be required to be acoustic and subject to detail design. If water cooling can be applied, the building can be effectively sealed off, allowing no or very limited noise to transfer to the surroundings.

6.1.9 The design of the individual elements should be verified during detail design, once the relevant plant elements, such as transformer (-s) and gearbox (-es) has been chosen. The chosen design and material for the screw enclosure is subject to detail design, and a list of suitable suppliers of acoustic enclosures is shown in **Appendix I**. It should be demonstrated that the designs and materials can provide the minimum required in-situ sound reduction, and thus that the proposed scheme comply with local authority planning requirements.

6.2 Assessment with Proposed Minimum Mitigation

6.2.1 A model has been created in SoundPlan incorporating the above minimum mitigation measures. The results for the assessment locations are shown in **Tables 16** and **17** below. Noise contour maps from SoundPlan can be found in **Appendix J**.

Table 16 – Assessment of Scheme, With Proposed Minimum Mitigation – External Levels

Location	External Criterion, dBA	Predicted sound levels, dBA	Adjustments for characteristics	Rating Level, dBA	Level difference, dBA
MP1	Rating Level < 57	36	7	43	- 14
MP2	Rating Level < 45	31	7	38	- 7
MP3	Rating Level < 46	34	7	41	-5
MP4	Rating Level < 36	28	7	35	- 1
MP5	Rating Level < 57	44	7	51	- 6
MP6	Rating Level < 57	33	7	40	- 17

Table 17 – Assessment of Scheme, with Proposed Minimum Mitigation – Internal Levels

Location	Criterion, external levels, dBA 1m from façade		Rating Levels[1)], dBA	Level difference, dB	
	Day	Night		Day	Night
MP2	Rating Level < 50	Rating Level < 45	38	- 12	- 7
MP4			36	- 14	- 9
MP6			40	- 5	- 5

1) The rating levels are for the external sound as listed in Table 15

6.2.2 As it can be seen from the above **Tables 16** and **17** that the proposed hydro scheme with the minimum in-situ mitigation values set out in **Table 13** complies with the local authority planning requirements.

6.2.3 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. The results are shown in **Appendix K**.

6.2.4 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 **Appendix L**.

6.2.5 There are very small and subtle differences between the site with existing background sound levels and the site including the proposed hydro scheme with the minimum required mitigation measures. The difference can be found, as expected, close to the scheme.

7 Conclusions

7.1.1 Peter Brett Associates LLP (PBA) has been instructed to prepare a noise assessment of the proposed hydropower system at Teddington Weir, Richmond for inclusion with planning application.

7.1.2 A non-technical report (ref. 28307/006) dated 24th July 2015 has been issued, and it is recommended it is read in conjunction with this noise assessment report.

7.1.3 A worst case scenario approach has been applied in the assessment.

7.1.4 The uncertainty budget indicate that the results are reliable, thus making the assessment robust.

7.1.5 The proposed scheme with mitigation measures that provide the minimum required sound attenuation as stated in **Table 13** in **Section 6.1.4** is likely to comply with local authority planning requirements for both external and internal levels.

7.1.6 All mitigation measures should be subject to verification during detail design.

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 Site Plans

Figure 1 – Site Plan

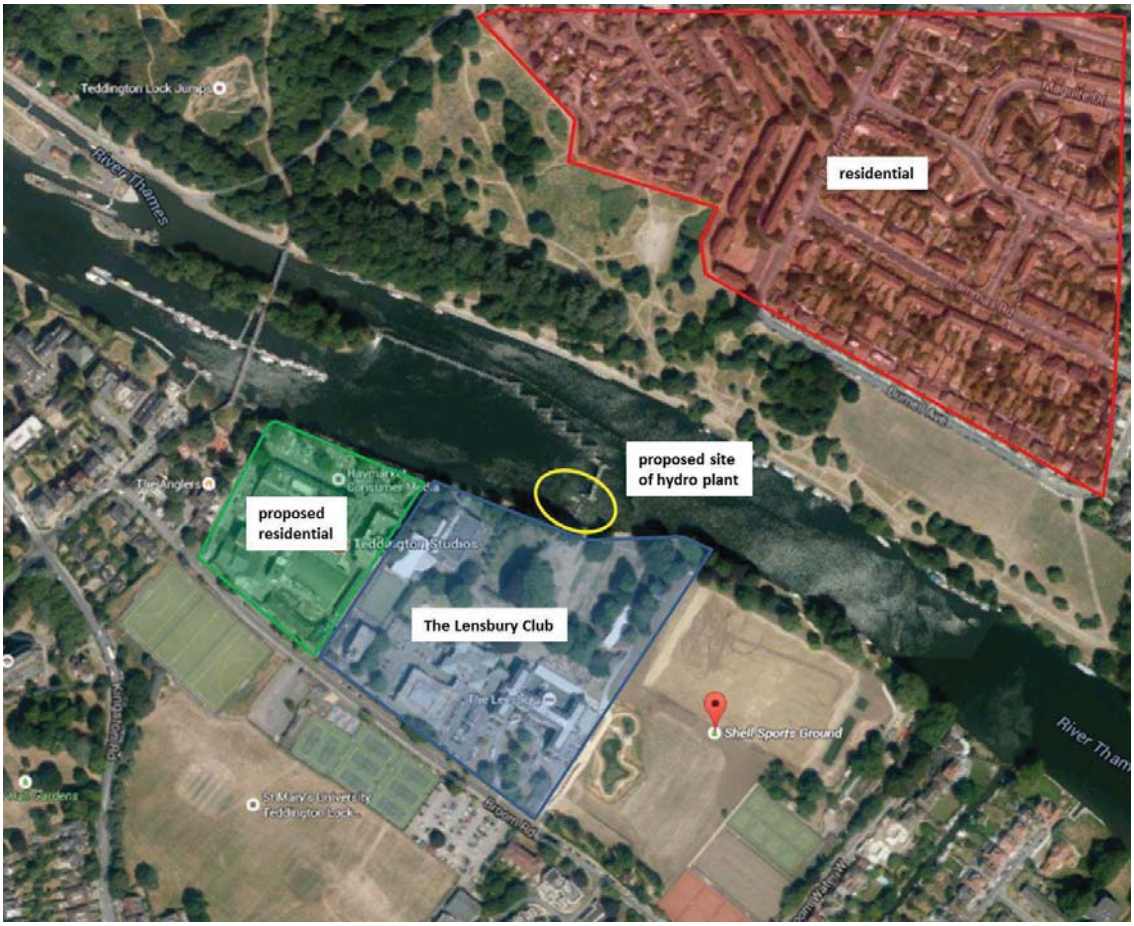
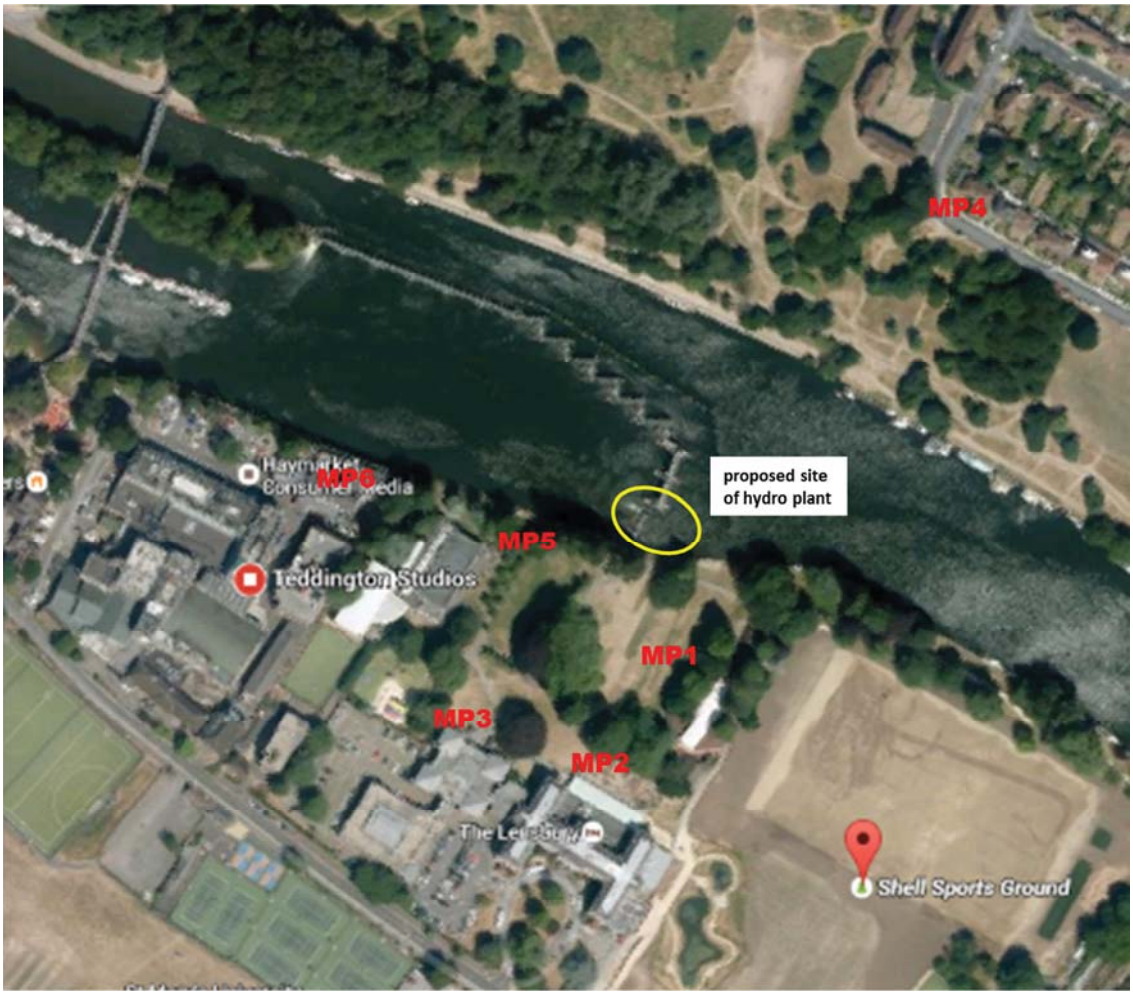
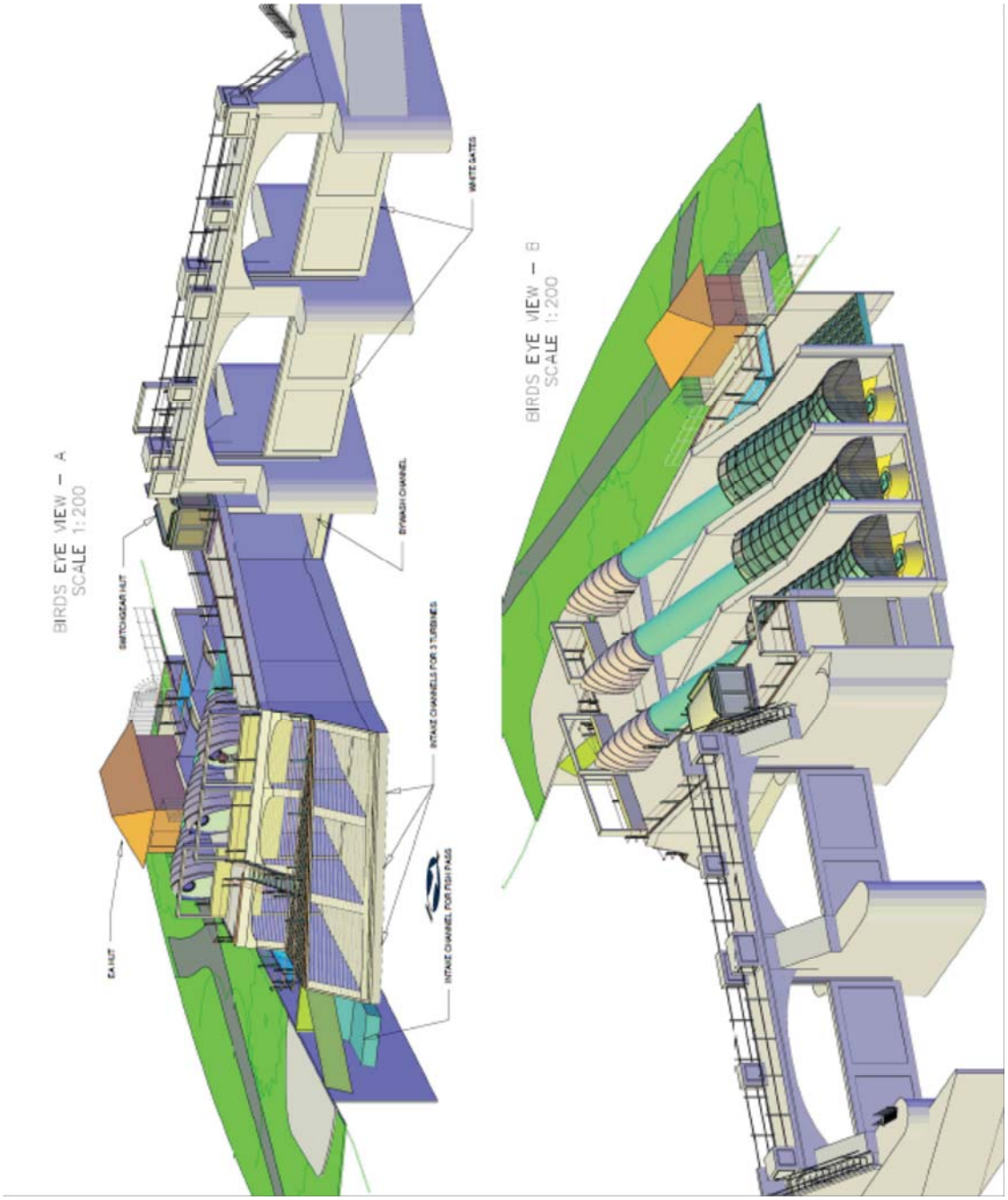


Figure 2 – Site Plan with assessment locations



Appendix C Proposed Hydro Scheme

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

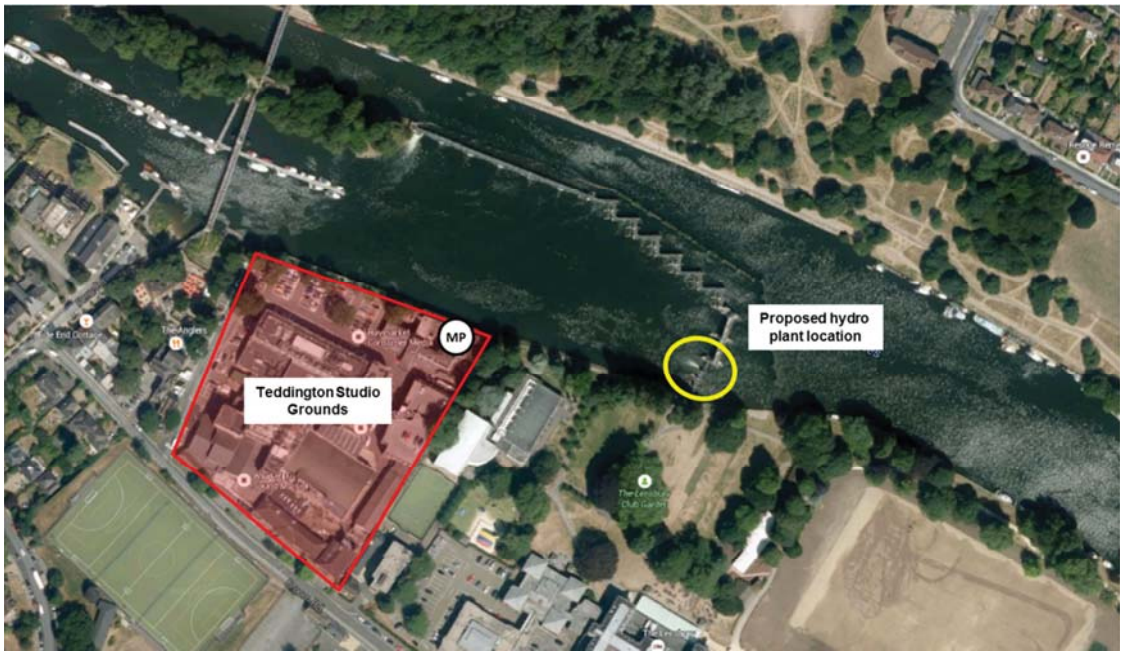


Appendix D Noise Survey – Teddington Studios

D.1 Site Description

D.1.1 The Teddington Studio site is located just south of the Thames and west of the Lensbury Club grounds. To the west of the site are residential properties. To the south there are recreational grounds on the opposite side of Broom Road (see Figure 5 below).

Figure 4 – Teddington Studio site



D.2 Noise Survey Details

D.2.1 Instrumentation:

Rion NL-42 (serial no. 1043458) with Rion preamp NH-25 (serial no. 43487) and microphone Rion UC-59 (serial no. 07233). Instrument including microphone, pream and cabling was calibrated before and after measurement with no calibration drift observed.

D.2.2 Location:

Measurement Position was located on a first floor balcony approximately 5m from the river. Microphone was 1.5m above horizontal surface and more than 2m away from façade of building.

D.2.3 Period:

Automated measurements were carried out between 14:15 on Friday 19th June 2015 to 15:45 on Monday 22nd June 2014 in 15 minutes intervals.

D.2.4 Weather:

Weather conditions prevailing during the survey period were generally clear and dry, except for Sunday 21st June 2015 which had light all-day rain. Wind was generally below 5 m/sec throughout the survey.

D.2.5 Site Noise Characteristics:

The general ambient sound environment was dominated by noise from the water flowing across the weir. It is considered that no unusual events occurred during the survey period, and the data is a true representation of ambient noise levels in the area.

D.2.6 Surveyor:

Sean Graham, MIOA

D.3 Site Sound Levels

D.3.1 The measured sound levels are shown in graphical representation in **Figure 6** and **7** below.

D.3.2 It can be seen that there are dips of up to 15 dB in the background sound levels at the tides twice a day.

D.3.3 The background sound levels appear to be stable and constant with few variations other than the tides.

Figure 5 – Measured L_{Aeq} and L_{Amax} at Teddington Studio

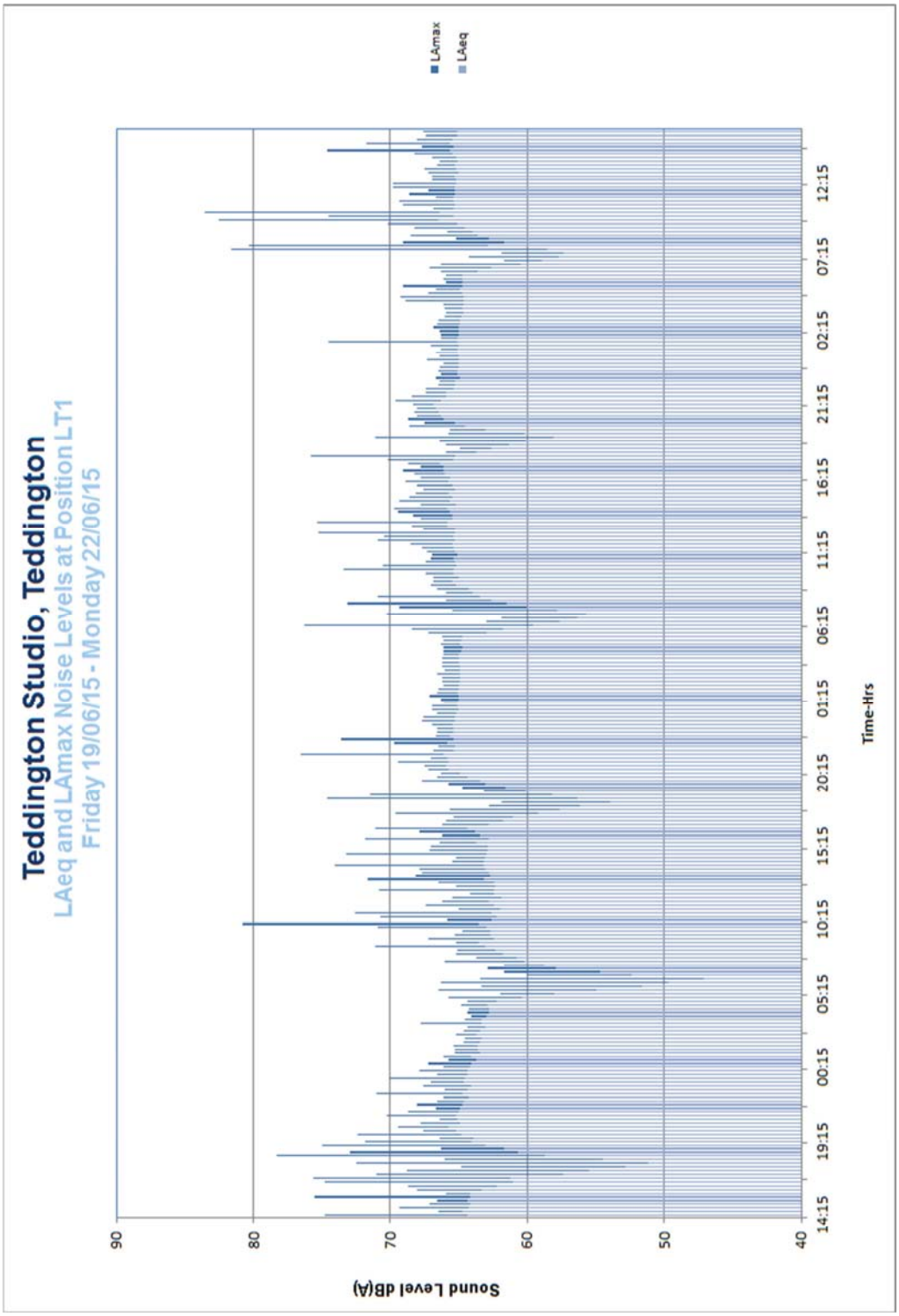
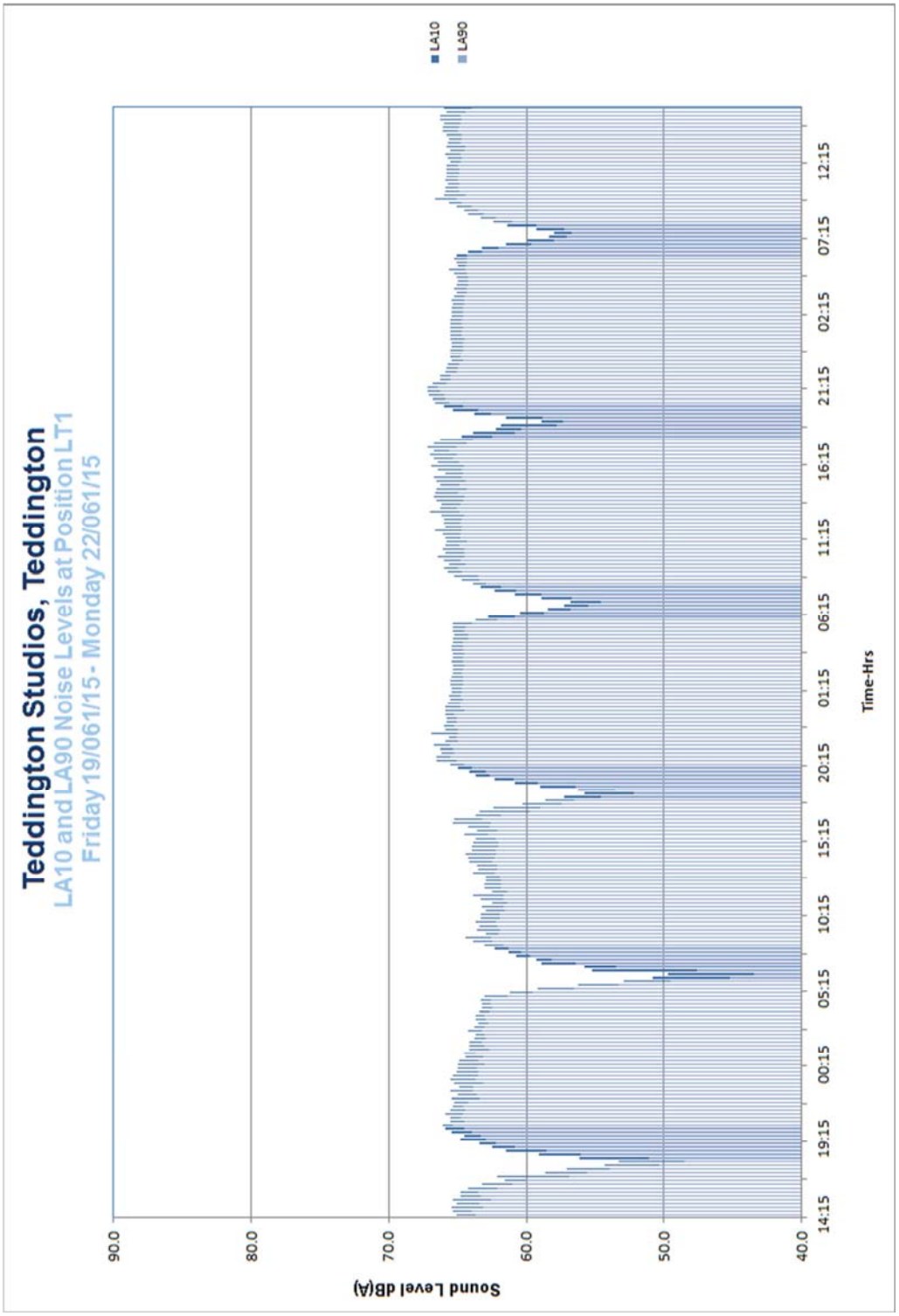


Figure 6 – Measured L_{A90} and L_{A10} at Teddington Studio



Appendix E Noise Source Data, Survey

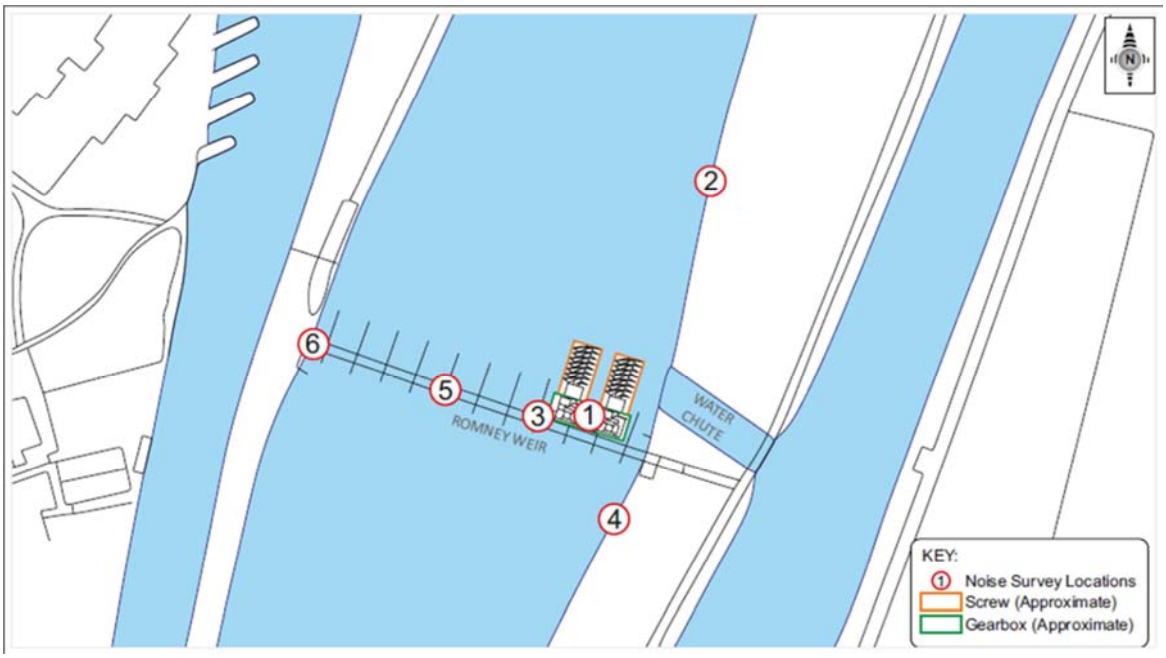
E.1 Site Description

E.1.1 The hydropower scheme at Romney Weir, Windsor was identified as the most similar existing scheme to that proposed at Teddington Weir.

E.1.2 The land between the upstream measurement locations and the weir and top of the Romney Weir scheme is reasonably flat with no significant difference in level between the scheme and measurement location and no sizeable dips or peaks; the same is true for the downstream measurement locations and base of the screws.

E.1.3 **Figure 7** below provides a drawing of the Romney Weir scheme including measurement locations.

Figure 7 – Romney Weir with Measurement Locations



E.2 Noise Survey Details

E.2.1 Instrumentation:

Item	Type	Manufacturer	Serial Number	Laboratory Calibration Date
Calibrator	4231	Brüel & Kjær	2619375	18 January 2013
Hand-Held Analyzer	2250	Brüel & Kjær	2626233	23 January 2013
Microphone	4189	Brüel & Kjær	2621212	23 January 2013

Instrument including microphone, preamp and cabling was calibrated before and after measurement with no calibration drift observed.

E.2.2 Location:

The accessible noise survey locations are provided in **Table 18**. Measurements on land were taken at 1.5 m above local ground level and measurements over the weir were taken 1.5 m above the bridge height.

Table 18 – Measurement Locations

Measurement Reference	Description
1	Between turbines: Approximately 3 m from top of turbines, 1 m to left of gearbox enclosure (looking downstream)
2	Downstream: Approximately 30 m from turbines
3	Left of the turbines: Approximately 5 m from top and 1 m to left the of the left hand turbine (looking downstream)
4	Upstream: By the fishpass: Approximately 10 m from bridge, 12 m from gearbox enclosure, 16 m from turbines
5	Half way across the weir: Approximately 25 m from scheme
6	Completely across the weir: Approximately 50 m from scheme

A windshield was fitted over the microphone at all times during the survey periods to minimise the effects of any wind induced noise and the sound level meter was tripod-mounted for all measurements.

E.2.3 Period:

Noise measurements at the Romney Weir scheme were undertaken on 19 June 2013.

Due to the proximity of Heathrow airport, the noise survey was undertaken between approximately 02:40 and 04:00 hrs as no air traffic is in operation at the airport during this time. No aircraft noise was heard during the survey

E.2.4 Weather:

The weather conditions during the noise survey were mild and calm with a temperature of 19°C, humidity of 82%, atmospheric pressure of 1012 mbar and no wind.

E.2.5 Site Noise Characteristics:

It was advised by the site operator that the turbines were running at 100%, when turned on, and that the weir was closed, apart from the measurements with no turbines running.

The general ambient sound environment was dominated by noise from the water flowing across the weir when turbines were turned off.

When the turbines were turned on, they were the dominant sound source.

It is considered that no unusual events occurred during the survey period, and the data is a true representation of ambient noise levels in the area.

E.2.6 Surveyors:

Angela Lamacraft, MIOA
Gwenc'hlan Tournier, MIOA

E.3 Measurement Results

See **Appendix F** and report [PBA1] dated July 2013

Appendix F Noise Source Data, Calculation

F.1.1 Original data was measured and reported in report (ref. [PBA1]) dated September 2013. The listed values have been corrected for the background noise and are for one turbine only.

Frequency [Hz]	MP1 – Between Turbines, SPL [dB]		MP 2 – Downstream, SPL [dB]	
	1/3 octave	1/1 octave	1/3 octave	1/1 octave
31.5	63.1		60.9	
40	67.5		63.5	
50	68.0		63.8	
63	68.9	72.1	64.6	67.8
80	62.9		59.0	
100	61.8		55.6	
125	56.0	64.5	57.2	60.7
160	59.6		54.6	
200	61.1		45.9	
250	62.4	65.6	52.0	57.9
315	57.9		56.2	
400	70.2		56.4	
500	61.8	71.0	57.5	62.0
630	59.3		57.6	
800	63.2		56.2	
1000	56.8	64.6	54.9	59.7
1250	54.9		53.3	
1600	53.7		53.1	
2000	56.4	60.4	52.2	57.0
2500	56.4		51.3	
3150	52.0		52.4	
4000	50.2	55.5	51.1	56.2
5000	49.6		50.7	
6300	48.7		50.1	
8000	47.0	51.9	48.5	53.4
10000	45.0		46.8	
12500	42.7		44.5	
16000	39.5		41.0	
20000	33.3		34.8	
L_{eq}	77		72	
L_{Aeq}	70		65	

F.1.2 The octave band sound pressure values have been converted to sound power values by calculations in accordance with ISO 9613-2:1996 as shown in **Tables 19** and **20** below;

Table 19 – Between Turbines, One Turbine (NOT A-weighted)

Item	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	Overall
$L_{Aeq,T}$ (dB)	72.1	64.5	65.5	71.0	64.6	60.4	55.5	51.9	
A_{Div}	11	11	11	11	11	11	11	11	
A_{atm}	0	0	0.001	0.003	0.005	0.01	0.02	0.07	
A_{gr}	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	
SWL (dB)	81.6	74.0	75.1	80.6	74.1	69.9	65.0	61.5	86

Table 20 – Downstream, One Turbine (NOT A-weighted)

Item	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	Overall
$L_{Aeq,T}$ (dB)	67.8	60.7	57.9	62.0	59.7	57.0	56.2	53.4	
A_{Div}	41	41	41	41	41	41	41	41	
A_{atm}	0.003	0.009	0.031	0.083	0.155	0.27	0.64	2.06	
A_{gr}	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	
SWL (dB)	107.3	100.2	97.4	101.6	99.3	96.8	96.4	95.0	110

F.1.3 The geometrical divergence (A_{diiv}) is the dominant contributor to the calculations. It should be noted that the ISO 9316-2:1996 assumes the geometrical divergence for spherical spreading in the free field from a point source. In reality this will estimate a much larger attenuation than what is really the case, and thus resulting in a higher sound power level.

F.1.4 It should be noted that attenuation due to barriers and miscellaneous are set to 0, as there is no barriers and no apparent other sources of attenuation.

Appendix G Uncertainty Budget

G.1.1 In order to find more information on uncertainty and uncertainty budgets it is recommended to refer to the PBA non-technical report (ref.28307/006) dated 24th July 2015.

G.1.2 Estimation and calculations of uncertainty for environmental noise surveys in the UK is currently usually done using 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.

G.1.3 They have based their guidelines 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.

G.1.4 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.

G.1.5 In order to do that it is necessary to 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 and one uncertainty budget related to the modelling. The combination of this provides the overall uncertainty.

G.1.6 The baseline survey does not as such involve a specific source. The uncertainty therefore primarily relates to the reproducibility of the measurements, which for the available measurements is 2.3 dB as per the calculation below.

Standard uncertainty for a rectangular distribution (Type B evaluation) is found as:

a/√3, where a is the semi-range (half-width) between upper and lower limit.

a = 2 dB which means the standard uncertainty, u is: $u = \frac{2\ dB}{\sqrt{3}} = 1.2\ dB$

G.1.7 The uncertain budget of the noise source survey in Romney can be calculated as per the guidelines provided by Craven & Kerry and set out in **Table 21** below;

Table 21 – Uncertainty Budget for Noise Source Survey

Source of uncertainty	Notes	Value (half-width)	Conversion	Divisor	Standard Uncertainty, dBA
Source					
Running conditions	Normal	5 dB	-	√3	2.9
environmental	Small	1 dB	-	√3	0.58
Transmission path					
Weather	Max. 30m downwind	1 dB	-	√3	0.58
Ground reflection	Negligible	0.1 dB	-	√3	0.058
Receiver					
Measuring position	Small	1 dB	-	√3	0.58
Instrumentation	Type 1	1.9	-	√3	1.1
Combined uncertainty					3.3 dBA
Expanded uncertainty (95% confidence [k=2])					6.6 dBA

G.1.8 While there are many factors that can influence the "transfer" of the noise source data to the location of the present scheme there is no easy or straightforward way to quantify the various differences.

G.1.9 The proposed uncertainty of 5 dB is based on a number of measurement data for single turbines as described in PBA report (ref. 28307/006) dated 4th August 2015. The uncertainty is calculated as follows in **Table 22** below;

Table 22 – 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**

G.1.10 Uncertainty in relation to noise modelling using commercially available programs such as SoundPlan and CadnaA has been reported in “Acoustical Design Margins: Uncertainty in Prediction and Measurement of Community Noise” by R. Putnam and R. Hetzel in proceedings for Acoustics in Paris 2008 as expected to be between 2 and 5 dB.

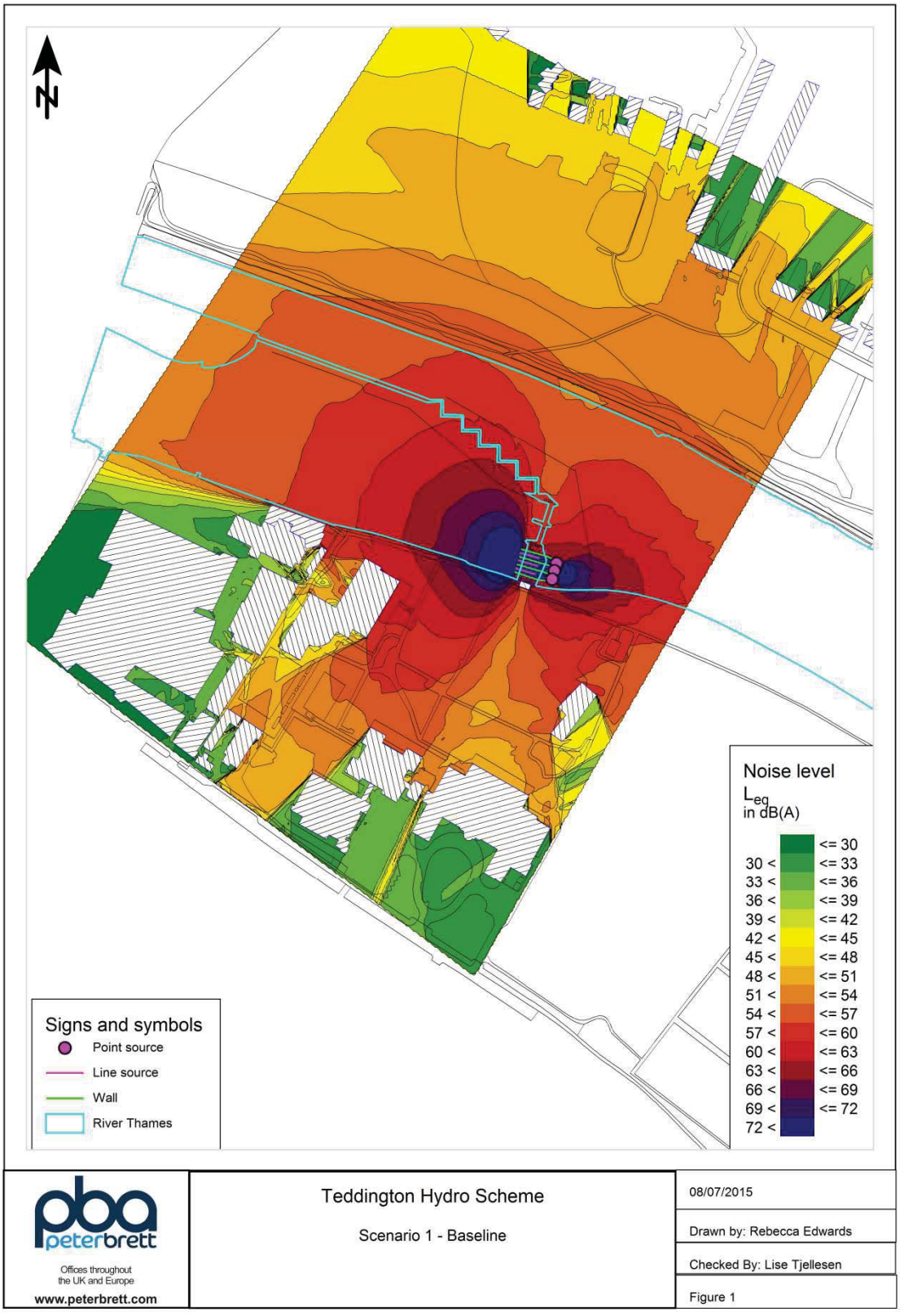
G.1.11 SoundPlan does not provide an estimated uncertainty for its calculations, however it is estimated that a typical uncertainty would be 3.5 dB.

G.1.12 **Table 23** below shows the combined uncertainty and the expanded uncertainty with a confidence level of 95% for the results of the noise impact assessment. This can be considered an indication of reliable results.

Table 23 – Total Combined Uncertainty

Source of uncertainty	Value, ±	Divisor	Standard Uncertainty
Baseline survey	1.2 dB	√3	0.7 dB
Noise source survey	3.3 dB	√3	1.9 dB
Transfer of noise source data to current location	5 dB	√3	2.9 dB
Computer modelling	3.5 dB	√3	2.0 dB
Combined uncertainty			4.1 dB
Expanded uncertainty (95% confidence [k=2])			8.2 dB

Appendix H Noise Maps – Baseline, no mitigation

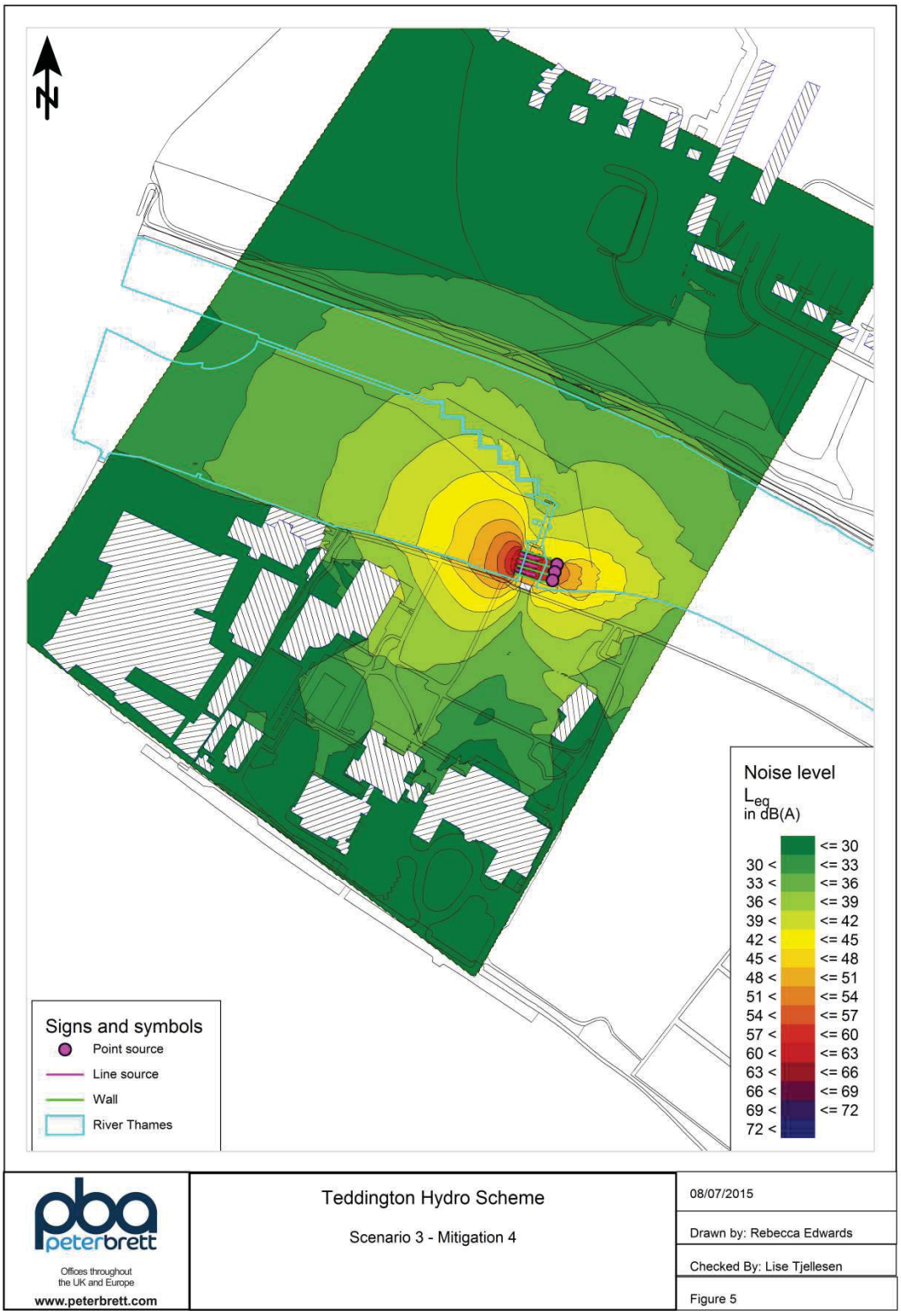


Appendix I Suppliers of Acoustic Enclosures

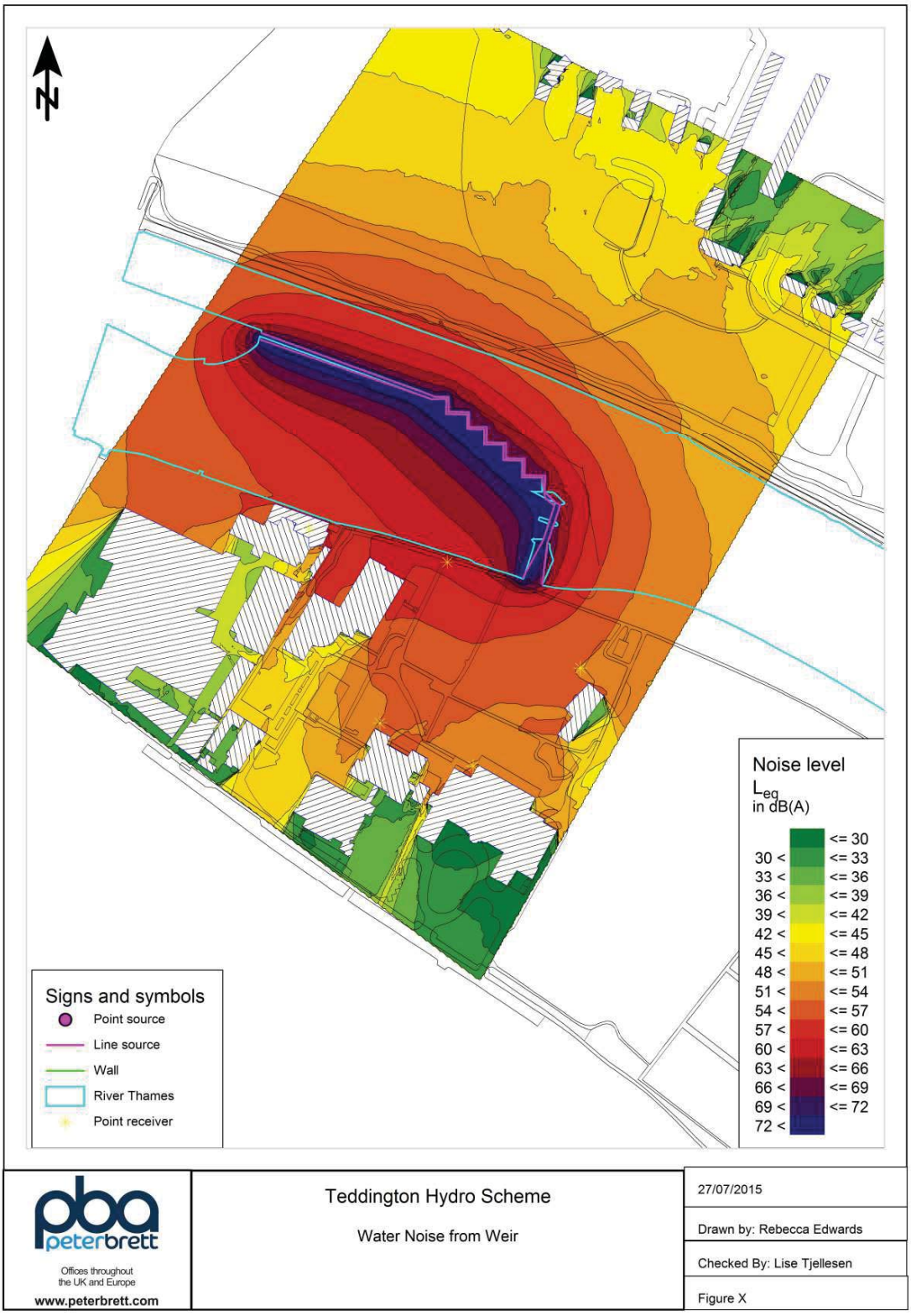
Name & Address	Telephone Number	Contact
Industrial Acoustic Company IAC House Moorside Road Winchester Hampshire SO23 7US	01962 873000	Scott Simmons
Allaway Acoustics Ltd 1 Queens Road Hertford SG14 1EN	01992 550825	Jim Grieves Roger Wade
Acoustic Engineering Services Ltd 78 High Road Byfleet Surrey KT14 7QW	01932 352733	Barry Austin Mark Stagg

I.1.1 Please note that the above are not recommendations or endorsements and the appearance of these organisations in this list does not imply any warranty on the part of PBA on the products produced by these suppliers.

Appendix J Noise Maps – Scheme with mitigation



Appendix K Existing Sound Climate



Appendix L Sound Climate with Hydro Scheme with mitigation