Renewable Energy 71 (2014) 351–360

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Acoustics of weirs: Potential implications for micro-hydropower noise

Neil Johnson [a,*], Jian Kang [a], Elizabeth Abigail Hathway [b]

[a] School of Architecture, The Arts Tower, Western Bank, University of Sheffield, Sheffield S10 2TN, UK
[b] School of Civil and Structural Engineering, Sir Frederick Mappin Building, University of Sheffield, Sheffield S1 3JD, UK

ARTICLE INFO

Article history:
Received 8 October 2013
Accepted 21 May 2014
Available online

Keywords:
Weirs
Micro hydropower
Noise
Renewable energy
Environmental impact

ABSTRACT

There is great potential for the expansion of the small or micro scale hydropower network. Of the 43 thousand weirs in the UK there are only 500 consented hydro schemes. Planning applications for such schemes require a noise assessment. Noise evaluation of a proposed renewable scheme is often complicated by the turbine sites having distinct noise characteristics in the first instance, which are often caused by the weirs themselves. Three types of weir were studied: Broad Crest weirs were studied in detail; this is complimented by further studies in Flat V and Crump weirs. Flow data was collected for ten sites from the Environment Agency and the National Rivers Flow Archive to assess the collected Sound Pressure Level (SPL) and calculated Sound poWer Level (SWL) in relation to various river flows. Weir head height, width and meteorological data were also collected. It has been shown that the SPL data collection method used was the right choice, as the greatest amplitudes at the water impact interface at all weir types was recorded. SPL and SWL were found to be within a 36–82 dBz and 45–86 dBz range respectively for all weir types. These values can be used in computer simulations of sound propagation. The mean SPL and SWL difference between the weir types are 6.1 dBz and 6.3 dBz. Head height has the greatest effect on SPLs. Attenuation with distance was found to be similar to that of a free field line source in general.

© 2014 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/3.0/).

1. Introduction

Energy security and an increasing understanding of environmental awareness have and are continuing to lead a trend into the diversification of energy supplies [1–3]. According to the Department of Energy and Climate Change [4], 1.5% of the United Kingdom's (UK) energy was generated from hydroelectric schemes in 2011. This department indicates that whilst the development of further large-scale hydro is limited, there is ample opportunity to develop sustainable small-scale hydro resources. Such schemes are usually "run of river" and constructed on existing barriers to the flow, usually manmade weirs [5]. Studies by Driscoll and others [5–8] indicate that there are 20–30 thousand weirs in the UK alone. Micro-hydropower is one of the energy supplies which are gaining in popularity in the UK, particularly hydrodynamic screws. This type of machine is perceived by many as having few environmental impacts in a water environment [4,9,10]; however this is contested by Ref. [11]. Globally only 5% of the small hydro potential has be utilised [12]. China has the largest installed capacity of small hydro power schemes (SHP), with some 100,000 schemes, and Europe has the second highest level of SHP installations [11]. In contrast, in the UK for example, by end of 2012, there were only some 500 consented hydro schemes [10]. Planning applications for hydro schemes have increased rapidly in recent years within the UK. Full applications more than doubled between 2009 and 2012 and pre applications increased by 1500% in the same period [10].

In addition to the Town and Country Planning (Assessment of Environmental Effects) Regulations 1988 (where an Environmental Impact Statement (EIS) including an assessment of noise levels would be required in sensitive areas [13]), previous studies have shown that along with concerns related to fish [10], there is some public concern related to the noise that these turbines will produce [14]. However, some community schemes, Torrs Hydro, believe that having turbines unenclosed is seen as positive for educational purposes [15]. Resulting in a risk of increased noise in such locations even with the masking effect of the water [16–18]. Noise evaluation at the planning stage is often complicated by the turbine sites having distinct noise characteristics in the first instance, usually caused by the weirs themselves [19]. Further to this, remembering how perceptibly loud a source is when away from

* Corresponding author. Tel.: +44 7530618394.
E-mail address: n3iljohnson@aol.com (N. Johnson).

http://dx.doi.org/10.1016/j.renene.2014.05.049
0960-1481/© 2014 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/3.0/).

that sound, or shown images in a public meeting for instance, may be distorted by the absence of that source [17,20–23]. Baseline data of weir sounds for comparison with that of combined weir and micro-hydropower installations is essential to accurately assess the relative contribution or detraction of the turbine to the sound environment.

The acoustic environment of water features has been studied for a variety of types, often in order to assess the benefits for masking intrusive sounds from roads [16–18]. Many of these features display similarities to weirs. Fastl [24], Al-Musawi [22] and Galbrun & Tahrir [25], indicated that increasing flow does not easily generate low frequency sounds in cascades and sloping surfaces in small to medium water features. Al-Musawi [22] continues by indicating that low frequencies can be generated by waterfalls by increasing flow, especially if they have a plane edge and that larger amounts of water produce more bubbles [22,25,26]. Extensive works by Leighton [26] examines bubbles in-depth and bubble generation at the hydraulic jump is shown in Ref. [27], which is relevant as weirs create differing amounts of bubbles and have a variety of hydraulic jump size. Al-Musawi, Galbrun & Tahrir [22,25], and Watts et al. [17] also found that the sound generation from all water features studied were mid to high frequency dominant. Width has been shown to have a small effect on Sound Pressure Level (SPL) whereas the head had a significant effect [22,25]; though changes in SPL become less and less significant with flow and height. Materials at the impact point also affect the frequency component [22,25]. For example, impact onto water increases the mid-low frequencies and impact onto hard materials (stone or concrete) or combined water and stone for example increases the higher frequency ranges. Fastl [24] conducted studies on stepped and sloped waterfalls, finding a near linear relationship for stepped waterfall in SPL, with increasing flow, whereas flow did not significantly affect the loudness of sloped waterfalls. Studies have also been carried out in terms of perception of water sounds, relating to the masking effects of traffic sounds, for example [16].

There are, however, only a very limited number of studies investigating the acoustics of micro-hydro turbines. Johnson et al. [19] examined both the Sound poWer Level (SWL) and the SPL of a micro-hydro turbine and Broad Crest weir. Other data are from manufacturers but rather limited. The limitation of such data often cause great difficulties in estimations of acoustic impacts during planning stage (e.g. Ref. [14].)

This paper will provide information on the existing sound environment around weirs, essential for evaluating the alteration due to the installation of a hydro power turbine. The evaluation of the sound environment around micro-hydropower turbines is essential to assessing a scheme's viability.

With this and the aforementioned in mind, this paper, as part of a larger research project, aims to evaluate several weir types in order quantify the SPL and SWL characteristics, which are important for the understanding of the acoustic effects of weirs, given that existing work has been very limited. It is important to calculate SWL data, for comparison of pre and post development, whether physically or computer simulated, as SWL data is used to determine SPL at a given source-receiver distance in any environment and hence the level of nuisance from the sound [28]. This paper will examine the SWLs and spectral analysis of ten weirs at various river flows and examine the near field environment in order to help to understand the acoustic environments around weir sites. The spatial distribution of several weirs will be shown. Overall, the following questions will be answered: What are the SPLs and SWLs of different weir types? What effect do flow, head, width and type of weir have on SPLs? Are there any correlations between these parameters and SPLs by frequency? What are the spatial distribution characteristics of noise around the weirs?

2. Methods

2.1. Case study sites

A weir, in this paper manmade, is a dam where there is little or no storage, and the water flows continuously over the crest; it can be described as a run of river feature which does not exceed the height of the river banks, but traverses the entire width [27]. There are many types of weir and some of the most common ones can be found in the literature [29,30] along with idealised sketches. Three main types of weir from these were chosen, namely Broad Crest (BC), Crump (CR) and Flat V (FV). The ten weir sites (A-I) and (Z) studied are shown in Figs. 1 and 2. These were chosen as they are reasonably common on UK rivers [29]. The National Rivers Flow Archive (NRFA) [31] from the Centre for Ecology and Hydrology (CEH) and the Environment Agencies (EA) HiFlows pages [32] were used to identify gauged weir sites and flow data.

Table 1 shows the summary widths, water head height and flow ranges [33] of the nine main weirs (A-I). The table also shows ten year flow data for river mean, 95 percentile and 10 percentile flows [34].

2.2. Measurement method

2.2.1. Near field sound pressure level

The methodology for SPL data collection was tested at three sites, B, C & Z; one Flat V, one Broad Crest (stepped) and one Crump weir, as shown in Figs. 1 and 2. This was to develop and ensure that the method used to measure the greatest source of sound at the weirs, in subsequent data collection periods at the nine main sites, was taken from the loudest point. The measurement points were arranged at 2 m intervals starting at 4 m above the weir crest and ending at the last white water turbulence river interface. As expected, the greatest sound generation is at the water impact point, as annotated in Fig. 2. Therefore, extra measurement points at the water impact point from the falling water into the weir pool were taken. For the stepped Broad Crest weir a change in the sampling method was utilised as there were numerous water impact points, measurement points were taken at 1 m, 3 m and 4 m.

The main study SPL measurements were taken from a suspended microphone receiver, (receiver B in Fig. 2) at an average of 1.6 m above the water's surface, depending on the hydraulic wave position. The distance from the river bank was between 2 and 4 m, which was dependent on river bank height and the angle of inclination. A reference receiver point was on the bank in line with the weir crest (receiver A in Fig. 2) approximately 1 m from the bank top. This was to test that the suspended microphone at a height of 1.6 m above the main water impact point was producing higher amplitudes than possible extraneous sounds at site. At each of the nine sites, three, 30-s samples were recorded on four days at four different flows; these samples were then divided into three 5-s samples, excluding the beginning and ends of the clips and any noted external noise periods.

Sound was recorded using class 1 microphones on the Symphonie and NetdB systems (01 dB- Metravib, France) [35]. The SPL, un-weighted (dBz) in 1/3 octaves, was measured at the nine main sites (sites A-I).

Temperatures on the sampling days were between 17 and 23 °C on the first three sampling days and 12–20 °C on the fourth. Wind speeds were <5 ms^{-1}on all sampling days and generally tended to zero with gusts up to 5 ms^{-1}. Wind direction had a south, south-west tendency on the sampling days.

SPSS 20 was utilised to perform statistical analysis on the SPL data presented in the results [36].

Download English Version:

https://daneshyari.com/en/article/6768116

Download Persian Version:

https://daneshyari.com/article/6768116

Daneshyari.com