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Red John Pumped Storage Hydro Scheme

Volume 5, Appendix 9.2: Water Resource Assessment

ILI (Highlands PSH) Ltd.

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Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
1	November 2018	Submission	CA	Catherine Anderson	Associate Director

Distribution List

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Appendix 9.2 Water Resources Assessment

9.1 Introduction

Objectives

9.1.1 The objective of this report is to assess the following issues in relation to water resources:

- Major water resource demand within the Development proximity;
- Potential impact on water resources as a result of the Development; and
- Appropriate mitigation measures to reduce the impact of the Development on water resources.

Sources of data

9.1.2 To inform this study, information has been obtained from the following sources:

- River Ness Flood Scheme - Details of Hydraulic Modelling undertaken for Development of Preferred Scheme - The Highland Council / Mott MacDonald October 2011;
- Water Control Manual - Caledonian Canal - Version 9.0 - Scottish Canals;
- Dochgarroch Lock water levels - Scottish Canals;
- River Ness flow data - National River Flow Archive;
- Elevation Discharge curve for Loch Dochfour – extract from Loch Dochfour Reservoirs Act Section 10 Inspection 1987; and
- Inverness & Nairn Water Resource Zone (WRZ), Hydrology & Water resource Assessment for Scottish Water – 2011.

Basis of Assessment

9.1.3 Full details of the development are included in Chapter 2: Project and Site Description (Volume 2). The operational regime of the Development is governed by both water resource availability and the electricity market. The Development has the total volume of 5,000,000 m^3 capacity and a working volume of 4,900,000 m^3. Based on assessing the maximum impact the assessment has been carried out on the basis of a full cycle being used, i.e. 5,000,000 m^3.

9.1.4 In the event that the full recharge and generation cycle is undertaken in a single day, the net impact on water resources in Loch Ness is zero impact within that time step (24 hours). The assessment has therefore been undertaken on the basis of a full recharge cycle being undertaken only with no generation cycle. Water is therefore stored in the Headpond and the Development is in a primed state. The impact of generation flows on flood risk in Loch Ness and further downstream has been assessed in the supporting Flood Risk Assessment report, Appendix 9.1.

9.1.5 The water bodies identified in Figure 9.1 (Volume 3) have been assessed to determine the impact of the Development on the water resource:

- Loch Ness / Loch Dochfour;

- River Ness;
- Caledonian Canal; and
- Loch Ashie.

9.2 Loch Ness

Development

9.2.1 The Development consists of a Headpond on Ashie Moor, on the boundary between Loch Ashie catchment, Loch Duntelchaig catchment and the Loch Ness catchment.

9.2.2 The Headpond temporarily removes the small proportion the contributing area of the Ness catchment by attenuating direct rainfall on the Headpond surface area and then releasing during generation cycles. The surface are of the Headpond is however immaterial compared to the overall contributing area of Loch Ness and therefore does not impact on water level and pass forward flows from Loch Ness.

9.2.3 The Headpond also will permanently remove a small proportion the contributing area of the Ashie and Duntelchaig catchment, approximately 2.6 % and 0.1 % of their overall catchment respectively. Therefore it is considered that there is a negligible effect on either catchment.

Existing Water Resource regimes

9.2.4 Water levels are controlled within Loch Ness in order to ensure that water supply into the Caledonian Canal is maintained and minimum flows are maintained in the River Ness.

9.2.5 These are regulated based on the following parameters as set out in the *Caledonian Canal Water Manual, Version 9* which was provided by Scottish Canals.

In drought conditions, SSE is required to release water from upstream catchments and reservoirs to provide minimum 'compensation' flows and maintain minimum navigational depths over lock upstream cills as follows;

- Loch Dochfour (& Loch Ness) – SSE is required to pass a minimum (compensation) flow to the River Ness of 28.3 m^3/s (1000 ft^3/s). This is achieved by opening the two control gates at the western end of the Ness Weir. Furthermore, SSE is required to maintain a minimum water level of 15.27 m A.O.D. i.e. 5.1 m water depth over Dochgarroch Lock upstream cill, measured on the Dochgarroch Lock upstream depth gauge.

9.2.6 No drought plan is included in the Water Manual, it states that:

- *Whilst this section should normally be read in conjunction with a canal Drought Plan, the security of water supply to the Caledonian Canal is such that there is no requirement for a Caledonian Canal Drought Plan.*

9.2.7 A minimum draft of 5.15 m at the cill of Dochgarroch Lock is required for the canal to allow the passage of crafts. This equates to a water level of 15.27 m AOD at Loch Dochfour and Loch Ness.

9.2.8 The normal operating level in the canal within the reach between Dochgarroch Lock and Muirton Basin is set at 15.328 m AOD with a level 1 trigger at 50 mm below and second trigger at 100 mm below this level.

9.2.9 No operational regimes were provided by SSE for Loch Ness and their hydro operations. The assessment has therefore been carried out on the basis of the above operational regimes only.

Loch Ness water levels and River Ness flow data

9.2.10 Daily water level data was supplied for Loch Dochfour from January 2014 to September 2018 by Scottish Canals. Loch Dochfour water levels coincide with those of Loch Ness during normal and low flow conditions. During events where water level exceed a level of 16.0 m AOD the Bonnar Narrows, a short length of open channel that separates Loch Ness form Loch Dochfour act as a constraint leading to rise in water levels in Loch Ness.

9.2.11 During the period January 2014 to September 2018 the minimum water level experienced was 15.37 m AOD on the 5 July 2018. This is believed to the lowest level on record. The maximum level recorded during this period was 17.02 m AOD at Loch Dochfour. This would equate to 17.4 m AOD at Loch Ness based on the constraint at Bonnar Narrows during extreme events. Analysis of the change in level during extreme events is included in Appendix 9.1.

9.2.12 The maximum drop in daily water level at Loch Dochfour and Loch Ness experienced during normal or low flow conditions is 150 mm in August 2015. Greater changes in water levels have been experienced post wetter periods, for example a drop of 450 mm recorded in March 2015.

Assessment Methodology

9.2.13 The assessment of the potential effect on water resources has been carried out based on ensuring compliance with the current water management regimes for the key receptors.

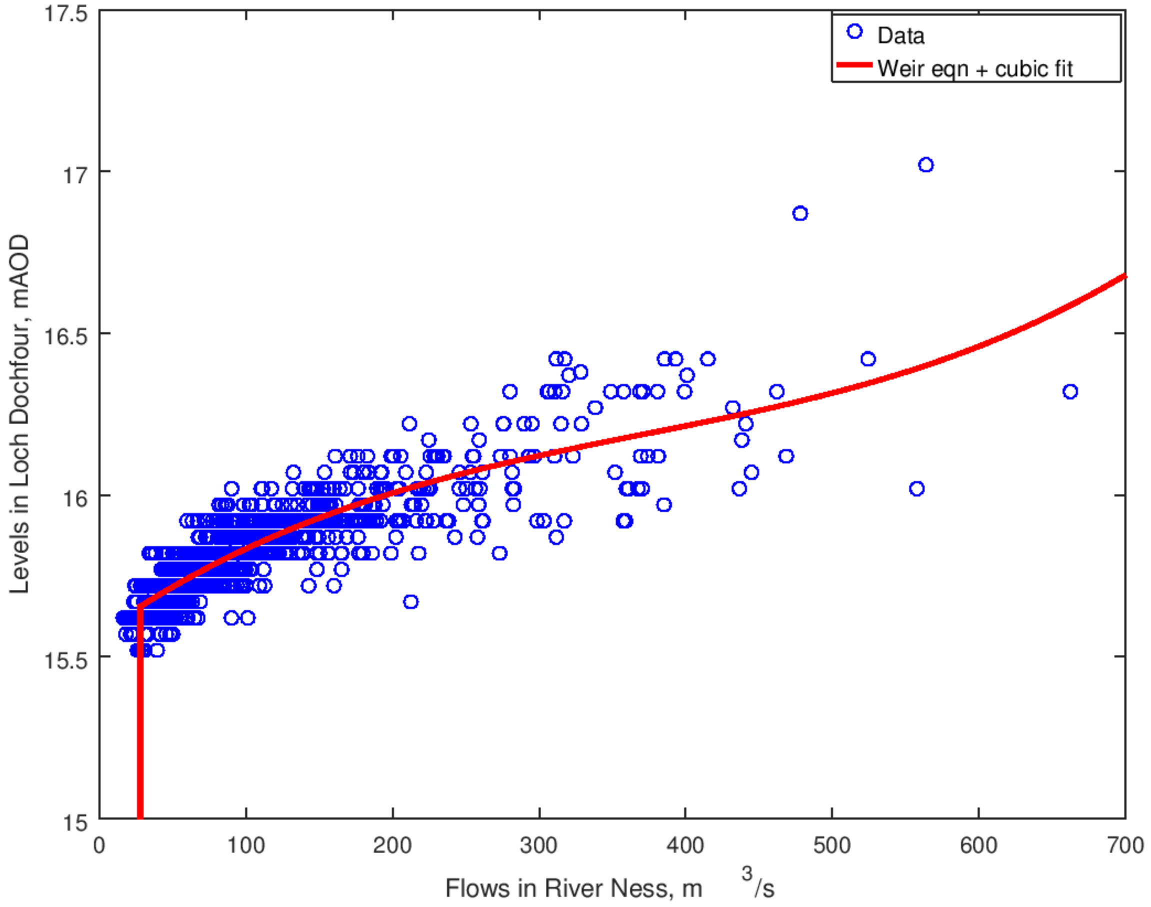
9.2.14 The specific generation / pumping operational regime for the Development is not known at this stage as it will be determined by the energy market. The Development has approximately 4,900,000 m^3 of available raw water storage within the Headpond that can be used in a single cycle. It is likely that only a proportion of this will be used per cycle. However, based on a precautionary approach a full cycle has been used for the purpose of the assessment.

9.2.15 In order to assess the impact of proposed abstraction of 5,000,000 m^3 out of Loch Ness within an 8 hour recharge cycle a behavioural analysis of Loch Ness under current arrangement and with a recharge cycle has been undertaken. The assessment has been carried out based on a full recharge volume. However, during the Development operation, a full cycle recharge cycle is unlikely to occur on a frequent basis and that most cycles will be a proportion of the full volume.

9.2.16 Readily available data was used to generate a stage discharge for the Ness Weir at Loch Dochfour together with a long-term net inflow into Loch Ness.

9.2.17 The available data used were: measured daily flows in the River Ness (record from 6 September 1972 to 30 Sep 2017) and measured daily levels in Loch Dochfour (record from 1 Jan 2014 to 6 June 2018).

9.2.18 Based on the period of overlapping level and flow records (1 Jan 2014 to 30 Sep 2017), a rating curve relating flows in River Ness and levels in Loch Dochfour was derived (Insert 9.1). The rating curve is limited to a minimum level of 15.6 m AOD because of existing constraints on the operation of two radial gates governing flow from Loch Ness into the River Ness. If the flow over the weir at this location drops below 1000 ft^3/s (28.3 m^3/s), the radial gates are required to be opened to maintain an environmental flow of 28.3 m^3/s in River Ness.



Insert 9.1 Ness Weir Stage Discharge Rating Based on Historic Events

9.2.19 Using the full record of flows measured in the River Ness, at Ness-Side gauging station, a corresponding record of levels in Loch Dochfour was developed. Given a lack of recorded inflows into Loch Ness, an estimate of these was made using the assumptions set out in paragraphs 9.2.18.

9.2.20 Loch Ness has an area of approximately 56 km².This area is very similar over the shallower depths of the loch, for which we are interested, ignoring other potential inflows / outflows and evaporation. A section of these estimated inflows are plotted against measured outflows, at the Ness-Side gauging station, in Insert 9.2.

$$\Delta V_{loch} = A_{loch} \times \Delta h_{loch},$$

Where:

ΔV_{loch} is the difference between the daily volume in Loch Ness

A_{loch} is the area of Loch Ness

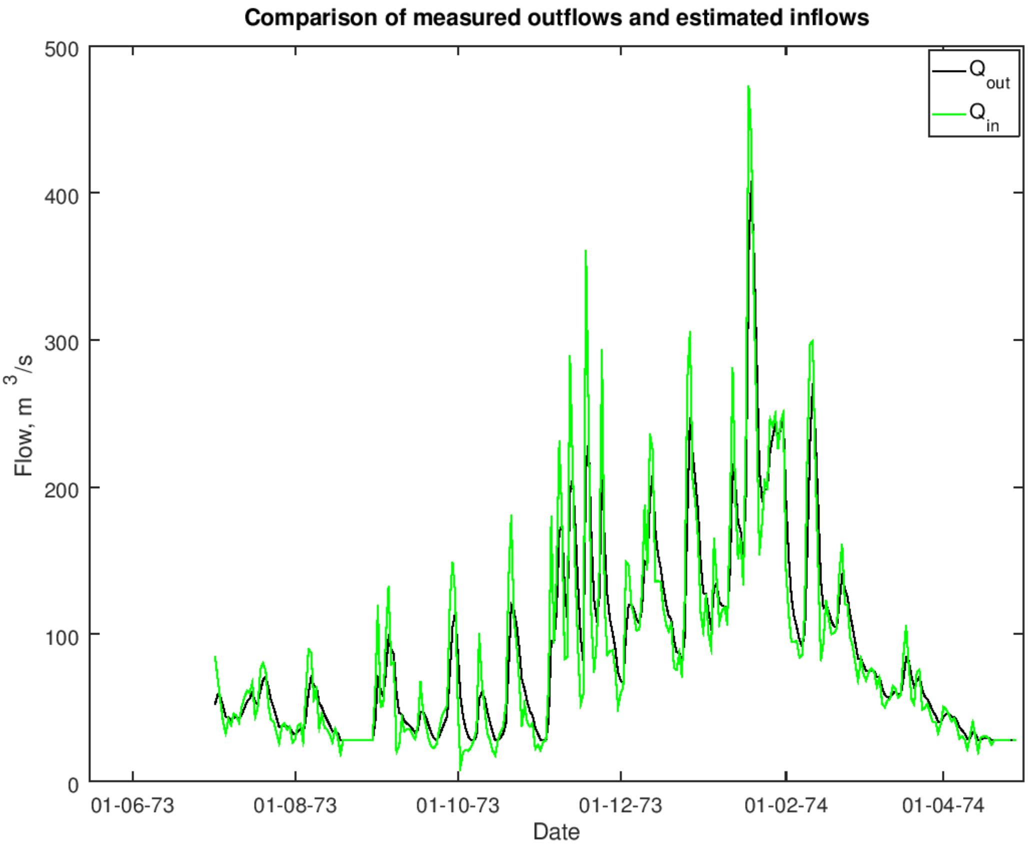
Δh_{loch} is the difference between daily levels in Loch Ness

$$\frac{\Delta \mathrm{V_{loch}}}{\Delta t} = \frac{A_{loch} \times \Delta h_{loch}}{1\ day} \times \frac{1\ day}{86400\ s}$$

$$Q_{in} - Q_{out} = \frac{\Delta V_{loch}}{\Delta t},$$

Therefore;

$$Q_{in} = \frac{\Delta V_{loch}}{\Delta t} + Q_{out}$$

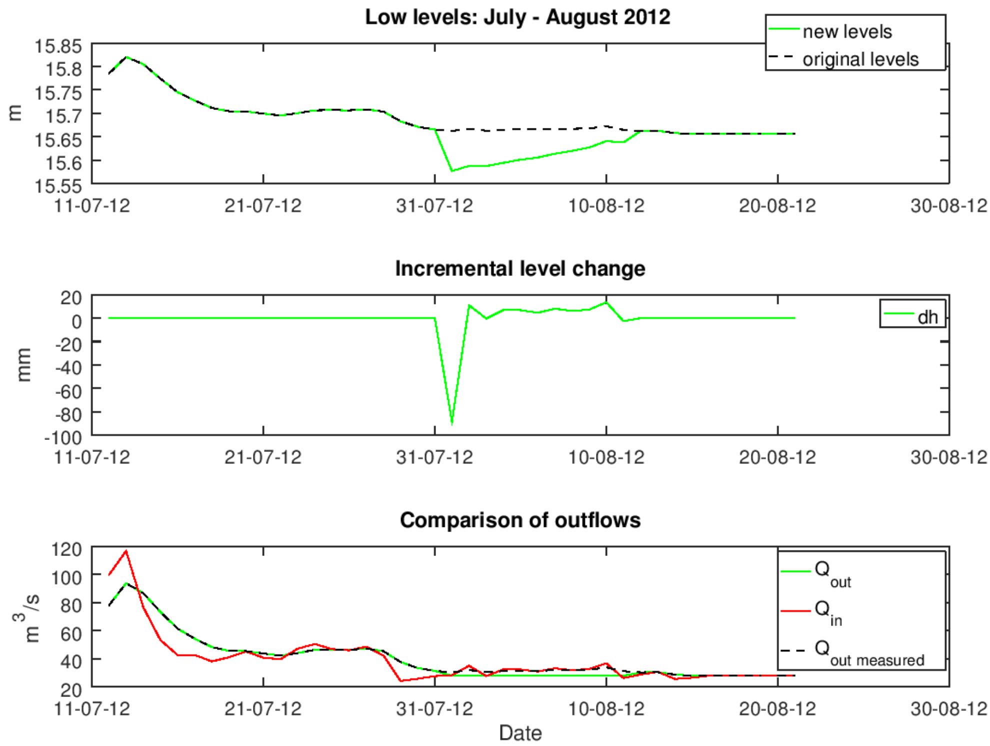


Insert 9.2 Measured River Ness flows against generated Loch Ness flows

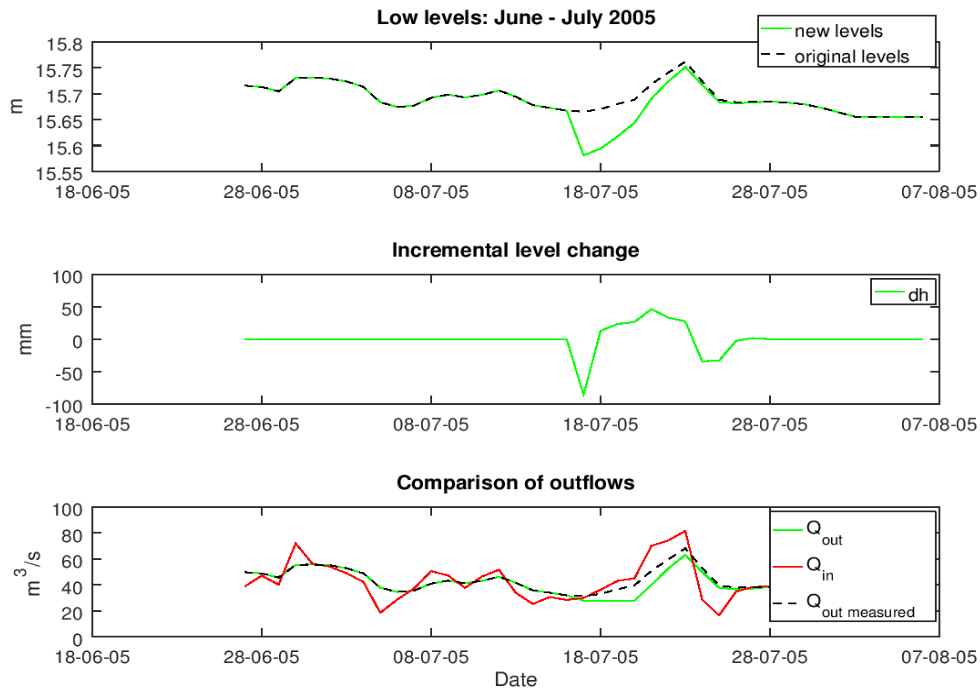
9.2.21 Using the net inflow into Loch Ness the behaviour of Loch Ness with and without the 5 million m³ of water removed from the system (simulating a pumped hydro scheme holding a full upper reservoir) was carried out. The method is outlined below.

- Calculate the daily inflow volume from $V_{in} = Q_{in} * 86400\ s$
- The change in the volume in the loch is now $\Delta V_{loch} = V_{in} - V_{abstracted} - V_{out}$
- Convert the change in volume to a change in level assuming that the area of the loch is constant at any level we are considering: $\Delta h_{loch} = \frac{\Delta V_{loch}}{A_{loch}}$
- The new level of the loch after the abstraction is then $level_{mod} = level + \Delta h_{loch}$
- Use the rating curve to estimate a modified outflow ($Q_{out\ mod}$) that corresponds to the new loch level
- Calculate again the change in daily inflow volume, but using the modified outflow: $\Delta V_{loch\ mod} = V_{in} - V_{abstracted} - Q_{out\ mod} \times 86400\ s$
- If $\Delta V_{loch\ mod} \neq \Delta V$ then iterate using $\Delta V_{loch\ mod}$ to generate a new Δh_{loch} until an acceptable tolerance is reached
- Carry out this iteration for each day after the abstraction until the modified levels approach the pre-abstraction levels.

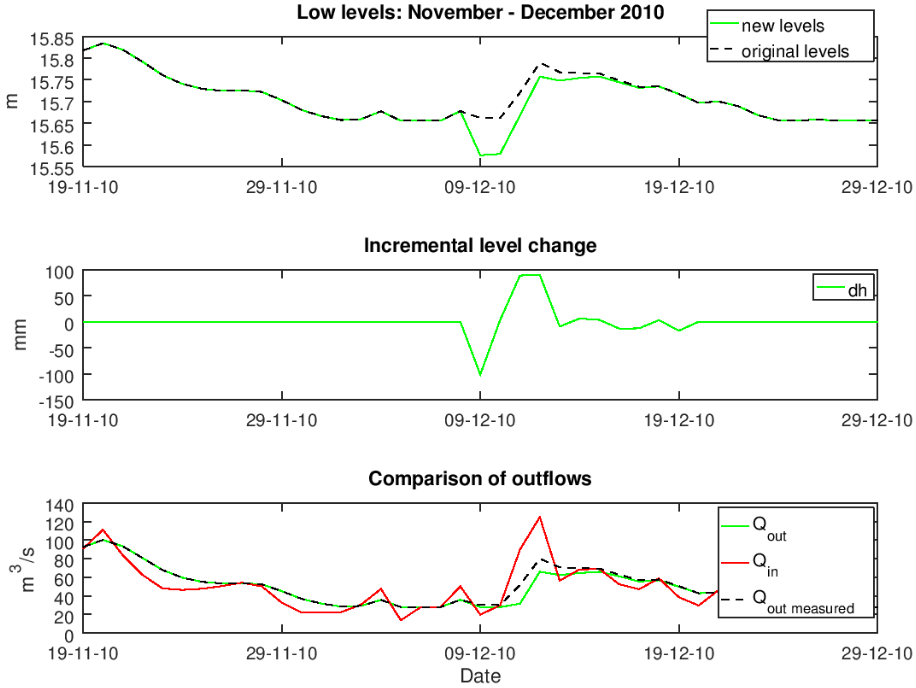
9.2.22 Examples of the results of this analysis for low water and normal water level in Loch Ness are provided in Insert 9.3 to Insert 9.8.



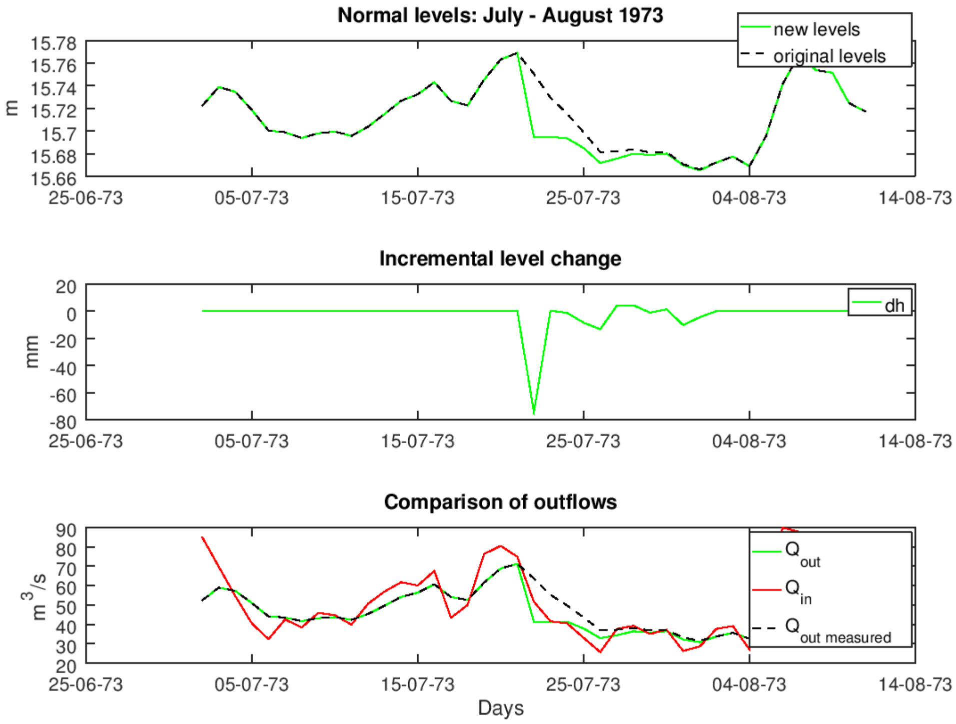
Insert 9.3 Loch Ness Recharge Abstraction Behaviour Analysis July - August 2012 Conditions



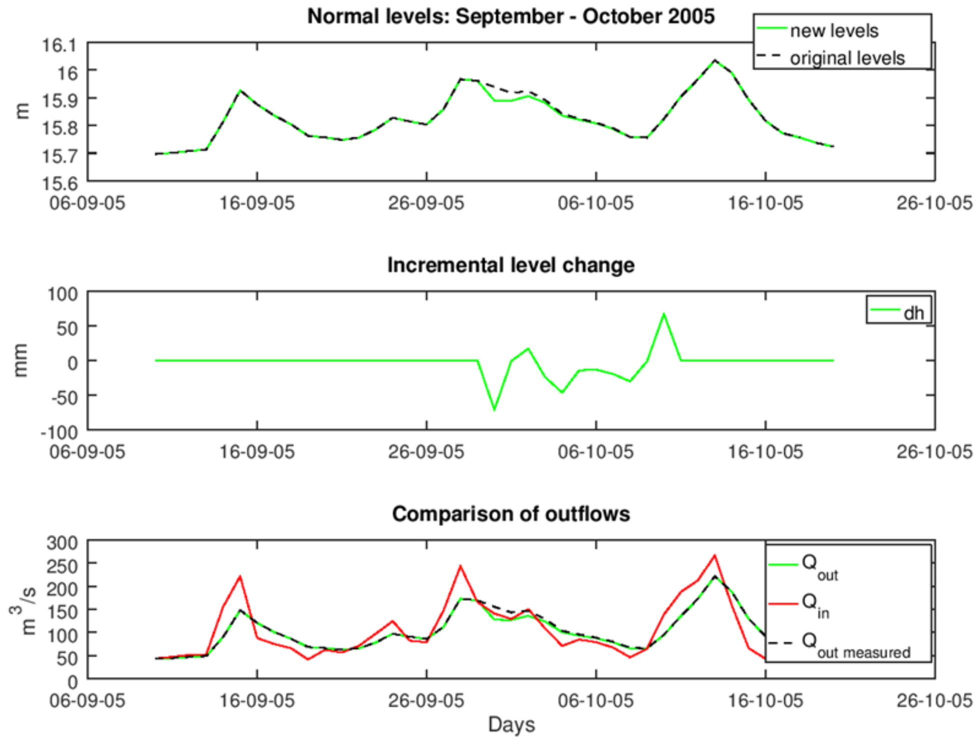
Insert 9.4 Loch Ness Recharge Abstraction Behaviour Analysis June - July 2005 Conditions



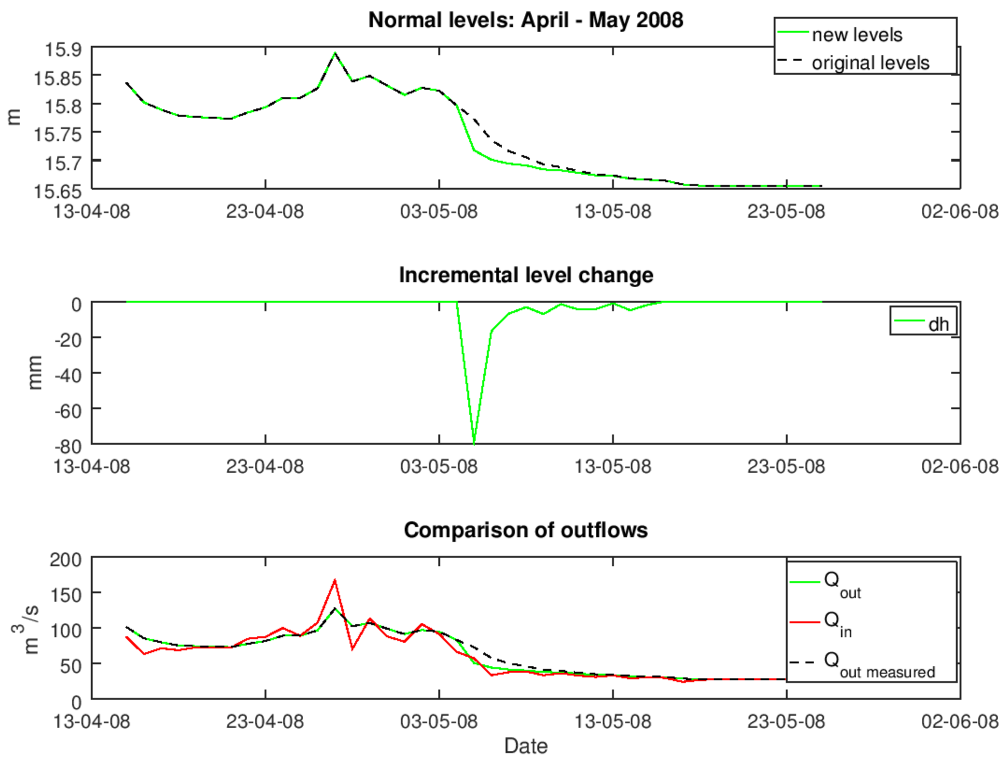
Insert 9.5 Loch Ness Recharge Abstraction Behaviour Analysis November December 2010 Conditions



Insert 9.6 Loch Ness Recharge Abstraction Behaviour Analysis July - August 1973 Conditions



Insert 9.7 Loch Ness Recharge Abstraction Behaviour Analysis September October 2005 Conditions



Insert 9.8 Loch Ness Recharge Abstraction Behaviour Analysis April - May 2008 Conditions

9.2.23 The analysis suggests that the duration required for the loch to return to pre-abstraction levels varies primarily depending on the inflows entering the loch and the level of the loch at the time of abstraction. The rating curve illustrates that at low levels, the flow leaving the loch and entering the River Ness reduces more rapidly with a unit level change than for the same level change when the starting level is higher.

9.2.24 However, this effect is smaller than that of the inflows and can be observed in the low loch level scenarios modelled, where the average time for the loch to return is relatively short compared to similar inflows for a higher starting loch level. Because of this dependence on inflows, several different time periods at which the level was appropriate (15.77 m AOD for normal levels and 15.66 m AOD for low levels) were examined to generate results with a range of inflows. Overall, the time period required for the loch to rebound to pre-abstraction levels varies from 2 days to 12 days. The results are summarised in Table 9.1.

Table 9.1 Loch Ness drawdown and recharge duration summary

Date	Starting loch level (mAOD)	Event No.	Cumulative inflow percentile	Duration of recharge (days)
07/06/1974	5.650	Normal level 1	Q60 (9 day)	9
04/01/2012	5.650	Normal level 2	Q51 (4 day)	4
15/08/2006	5.650	Normal level 3	Q13 (3 day)	3
20/03/2009	5.650	Normal level 4	Q44 (6 day)	6
15/04/1975	5.542	Low level 1	Q81 (10 day)	10
16/06/2013	5.542	Low level 2	Q80 (12 day)	12
01/06/2006	5.542	Low level 3	Q83 (7 day)	7

9.2.25 The peak variation in water levels is during the abstraction day. The total volume equates to 87 mm over the area of Loch Ness. The variation in baseline reduces during the recharge period. Based on the analysis carried out the re-charge period ranges between 3 and 12 days for the 7 simulations undertaken.

9.2.26 The fluctuations in water level are lower than those experienced under natural conditions. The modelled recharge period for Loch Ness is of short duration based on a full recharge of the Headpond. However, during normal operation the recharge volume per cycle is likely to be shorter than those modelled based on a partial recharge.

<u>Abstraction Operational Rules</u>

9.2.27 To ensure that the canal system is fed and that flows in the River Ness can meet the compensation flow of 28.3 m^3/s (1,000 ft^3/s) through the operation of the Ness Weir gates a minimum level for abstraction is required.

9.2.28 Based on ensuring a minimum depth in canal post abstraction plus a further 60 mm to account for a discharge from Loch Ness of 28.3 m^3/s with no inflow into Loch Ness for a period of 12 days will allow the water levels re-charge to natural levels. This is based on the assumption that inflow will meet any loss from evaporation. This is a conservative estimate that will, therefore, provide a robust operational regime and a precautionary cut off level to protect the operation of the canal and other users.

9.2.29 Abstraction of large volumes of water from Loch Ness during periods of low water levels could impact on the ability to maintain navigation within the Caledonian Canal. It would also compel others to supplement inflows from other parts of the catchment into Loch Ness as set out in the Caledonian Canal water manual.

9.2.30 In order to abstract the full 5,000,000 m³ water levels within Loch Ness should be in excess of 15.43 m AOD at the commencement of the abstraction cycle. Water levels in Loch Ness did not fall below this level during the period 2014 – 2017. During the summer of 2018 water level fell below this level for a total of 12 days.

9.2.31 Based on a limiting abstraction volume of 2,500,000 m³, 50 % of the total Headpond volume, minimum water levels within Loch Ness at the commencement of the abstraction cycle can be reduced to 15.38 mAOD based on the reduced drawdown and the 60mm buffer level. Water levels in Loch Ness did not fall below this level during the period 2014 – 2017. During the summer of 2018, water level fell below this level for a total of 1 day.

9.2.32 Based on a limiting abstraction volume of 1,250,000 m³, 25 % of the total Headpond volume minimum water levels within Loch Ness at the commencement of the abstraction cycle can be reduced to 15.36 mAOD based on the reduced drawdown and the 60mm buffer level. . Water levels in Loch Ness did not fall below this level during the period 2014 – 2018.

9.2.33 When water levels in Loch Ness reach the lower limit of 15.33 mAOD all abstraction must stop, this is the 'hands off level'. This includes the allowance for the 60mm buffer level.

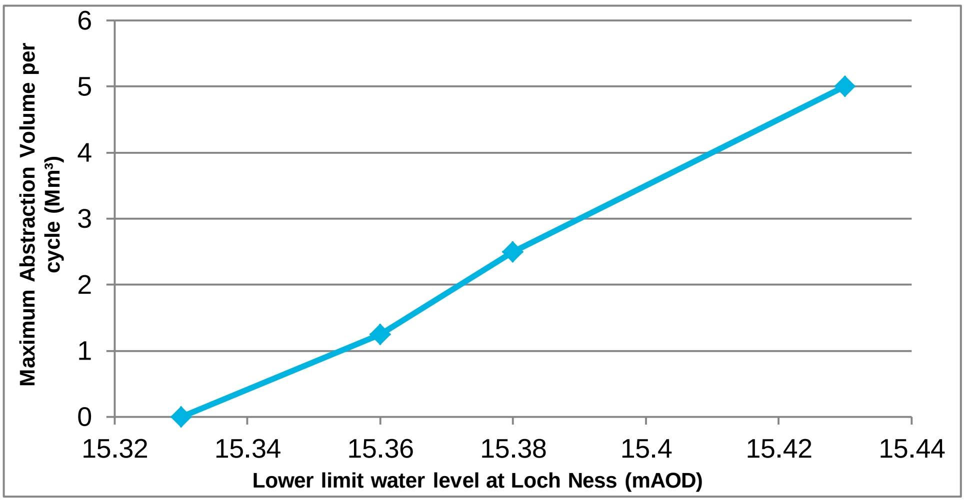
9.2.34 The above assessment is based on current operations of Loch Ness by other users (e.g. SC, SSE) being maintained once the Development is in operation.

9.2.35 Water levels within Loch Ness should be monitored through the abstraction cycle and measures will be in place to prevent abstraction when loch levels fall below the hands off level.

9.2.36 The operational rules for abstraction from Loch Ness are summarised in Table 9.2.

Table 9.2 Development Abstraction Operational Rules

Lower limit water level at Loch Ness at the start of the abstraction cycle (mAOD)	Maximum Abstraction Volume per cycle (Mm³)
15.43	5
15.38	2.5
15.36	1.25
15.33	0 (hands-off)



Insert 9.9 Graph of Loch Ness abstraction operational rules

9.3 Loch Ashie and Duntelchaig

9.3.1 Loch Duntelchaig and Loch Ashie are the raw water supplies to Inverness Water Treatment Works (WTW) and fall with a Drinking Water Protected Zone, these are shown on Figure 9.1 (Volume 3).

9.3.2 The lochs feed the works on a 80:20 ratio of Loch Duntelchaig and Loch Ashie raw water based on prescription by Scottish Water operators based on treatment requirements.

9.3.3 Under current arrangements, the works has a shortfall in the safe yield based on demand and growth. The modelling undertaken of the system by Scottish Water shows that when Loch Duntelchaig fails to meet raw water demand Loch Ashie still holds a significant volume of water within the drawdown limits. Loch Duntelchaig is therefore regarded as being the critical raw water source with regard to the safe yield available.

9.3.4 Scottish Water is developing a scheme that will supplement raw water to the works via a rising main from Loch Ness. The proposed pumping station and rising main has been sized to meet all future demand predictions. This, therefore, secures raw water supply irrespective of yield from Loch Duntelchaig and Loch Ashie. The project has committed capital funding and therefore addresses any water resource issues form the two lochs in question.

9.3.5 The Headpond falls on the boundary between the Ness catchment, the Duntelchaig catchment and the Ashie catchment. The majority of the area of the Headpond falls in the Ness catchment. A small proportion falls within the Loch Ashie and the Loch Duntelchaig catchments, approximately 2.6 % and 0.1 % respectively and are therefore considered negligible.

9.3.6 Direct rainfall on this part of the Loch Ashie catchment will be attenuated in the Headpond and discharged into Loch Ness during a generation cycle. Under the current arrangement, a significant proportion of the available storage in Loch Ashie is not utilised and therefore is available to supplement the yield.

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