Glen Earrach PSH

Technical Annex
Response to NatureScot Advice on Urquhart Bay Wood SAC

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Quality information

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1. Introduction

1.1.1 This technical annex responds to NatureScot's advice of February 2026 on Urquhart Bay Wood Special Area of Conservation (SAC), issued in response to the Additional Information submission provided in February 2026 (AECOM, 2026). The qualifying interest is alluvial alderwood (Annex I H91E0 Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae), comprising NVC community W7 *(Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland*)* on lower wetter ground and W9 (*Fraxinus excelsior-Sorbus aucuparia-Mercurialis perennis* woodland) on drier ground, the W7 occupying a naturally dynamic river delta and lacustrine margin on Loch Ness. This technical annex provides the detailed mechanistic and evidential basis for the conclusions presented in the accompanying Summary Note.

1.1.2 NatureScot requested additional clarification on whether the proposed operational water level regime could plausibly lead to the development of a persistent unvegetated drawdown zone at the woodland–loch margin, or otherwise alter habitat distribution in a manner relevant to site integrity. The clarification sought relates to the combined effect of: (i) a transition from longer-period seasonal fluctuations towards higher-frequency cyclic water level movement associated with pumped storage operations, and (ii) a modest upward shift in median summer level associated with operation of the seasonal variable weir. NatureScot's advice identifies the need to consider effects both throughout the year and in combination with the elevated median water level during the weir operating season.

1.1.3 NatureScot's supporting annex to their advice highlights particular attention on the lower parts of the mapped loch-margin bands. Within the 15.7 m to 16.5 m AOD elevation range, the AECOM mapping indicates a cumulative area of 7.49 ha, representing 16.2% of the SAC, with habitat recorded within these bands including W7, with local S28 and other wetland elements at the lowest levels. The annex also describes potential pathways involving drainage lag relative to loch level recession, prolonged or near-permanent root-zone wetness in lower bands, and consequent shifts in vegetation suitability. However, NatureScot note changes between woodland community types, including development of wetter communities, fall within the range of acceptable within-feature change, and that some changes from woodland to swamp communities could also be acceptable, since swamp is part of the wider ecosystem, but wider-scale loss of woodland to swamp would be considered an adverse effect on site integrity. NatureScot additionally confirm in their advice that a shift in the W7 to W9 transition, including in the 16.7 m and 16.9 m AOD bands (comprising 2.95 ha and representing 6.4% of the SAC), with potential swamp elements, would represent acceptable change.

1.1.4 This note addresses the requested mechanistic clarification on drawdown-zone risk and associated abiotic and ecological processes. It adopts a mechanism-led approach consistent with Habitats Regulations Appraisal principles, applying established physical and ecological principles to the site-specific context, and testing whether a credible causal pathway exists from the proposed operational regime to persistent de-vegetation and margin instability. For the purposes of this assessment, persistent de-vegetation refers to sustained loss of continuous vegetative cover sufficient to expose substrate to direct and repeated wave attack across a contiguous elevation band at the woodland–loch interface, such that biogenic reinforcement is removed and erosional processes become self-maintaining. Where reasoning relies on analogy from other settings, the governing mechanism is identified and its applicability to this site is stated. The conclusions of this technical note are synthesised in the accompanying Summary Note, which also addresses the conservation-objective and site-integrity implications and the separate grazing and browsing management commitment.

1.1.5 The assessment draws on:

- the quantified hydrological modelling and event-duration and drying-interval analyses provided in the AECOM (2026) Additional Information submission, including elevation-band mapping (15.7 m to 17.5 m AOD) and seasonal subsets relevant to weir operation;
- geomorphological theory relevant to time-integrated wave exposure, shoreline energy distribution and edge formation;
- published evidence on inundation tolerance and redox dynamics in temperate wet woodland soils and vegetation;
- recognised principles of bank stability, drawdown behaviour and root reinforcement in riparian and lakeshore systems; and

- professional judgement grounded in comparable regulated-lake, lacustrine and riparian literature.

1.1.6 This technical note does not introduce new primary survey or modelling outputs. It should be read alongside the EIAR and the February 2026 Additional Information submission (Glen Earrach Energy, 2026; AECOM, 2026), which provide the underlying evidence base, including terrestrial ecology surveys and NVC mapping, LiDAR-derived shoreline topography, quantified water level modelling with event-duration and drying-interval analysis, and long-term Loch Ness level time-series data. The assessed scenario is that defined in the Additional Information submission, namely operation of the seasonal variable weir in combination with all consented and proposed pumped storage schemes (the Proposed Development, Loch na Cathrach, Loch Kemp and existing Foyers). The baseline comparison includes existing Foyers operations.

2. Methods

2.1 Structure of the analysis

2.1.1 The analysis is organised around five sub-questions (SQ1 to SQ5), each addressing a distinct mechanism relevant to the drawdown-zone question, followed by a thematic assessment on alder *Alnus glutinosa* condition and a concluding synthesis.

- SQ1 assesses whether the proposed cyclic regime could concentrate wave-driven forcing and erosion at a fixed elevation band, including interaction with a modestly higher median summer level.
- SQ2 assesses whether the modelled pattern of inundation and recovery intervals is compatible with the tolerance of the mapped woodland communities at the margin, including implications for soil aeration and redox behaviour.
- SQ3 assesses whether stage change rates in the order of centimetres per hour introduce a distinct erosive or geotechnical instability mechanism, including rapid-drawdown type loading.
- SQ4 assesses the stabilising contribution of the composite root–soil matrix and the conditions under which reinforcement could be materially reduced.
- SQ5 assesses whether drainage and pore-water response could plausibly lag loch stage recession to an extent that repeated events lead to persistent or cumulative root-zone wetness within the mapped substrates.

2.1.2 These sub-questions correspond to the five mechanistic themes summarised in Section 2 of the accompanying Summary Note.

2.1.3 Following SQ5, Section 3.7 provides a thematic assessment of alder condition and waterlogging sensitivity, including consideration of the potential pathway for *Phytophthora alni* and the conditions under which alder mortality is reported in the literature.

2.1.4 NatureScot's advice also indicates that an unvegetated drawdown zone would be considered an adverse effect on site integrity, as would wide-scale development of open swamp, but that changes between woodland communities, including wetter communities would be acceptable, as would some change from woodland to swamp, which is part of the wider ecosystem. This is acknowledged in this document.

2.2 Transferability of literature

2.2.1 Much of the available literature on shoreline erosion, bank retreat and vegetation response to water level fluctuation derives from marine, riverine or reservoir settings. These contexts differ from the present case in respects relevant to transferability. Marine and estuarine studies involve open-sea wave exposure, tidal variation and salinity effects. Riverine studies are dominated by lateral current-driven scour absent in lacustrine settings. Reservoir studies, while hydrologically more analogous, commonly address margins without established woody vegetation and therefore without the stabilising contribution of a mature root–soil matrix.

2.2.2 The Urquhart Bay Wood SAC woodland margin differs in important respects. The loch is freshwater with no salinity or tidal influence. The shoreline is primarily exposed to lacustrine wave action rather than fluvial current. The woodland is long-established, with a mature alder–willow canopy and associated W7 ground flora providing a composite root–soil matrix. Urquhart Bay occupies the north-western shoreline of Loch Ness, whose principal axis trends south-west to north-east along the Great Glen. The predominant wind direction is broadly aligned with this axis, so that maximum wind fetch is directed along the central loch corridor rather than directly into the bay. For winds blowing directly from the east, representing the orientation that generates the greatest open-water fetch towards the bay, the effective fetch distance to the woodland margin is approximately 5 km, compared with approximately 35 km along the loch's principal axis. This geometric constraint on wave development is relevant to the assessment of erosion potential at the woodland–loch margin.

2.2.3 Where this assessment draws on analogies from other settings, the governing physical or ecological mechanism is identified and its applicability to the site-specific context is assessed in each sub-question. The available evidence base generally describes settings subject to greater hydrodynamic energy, more aggressive chemical or hydraulic conditions, or less vegetative reinforcement than the woodland–loch margin at Urquhart Bay.

3. Analysis

3.1 Central question

3.1.1 The central question addressed is whether the proposed regime introduces a new, or materially intensified, mechanism capable of causing persistent de-vegetation and consequent habitat loss at the woodland–loch margin, beyond the range of natural or baseline variability.

3.2 Mechanistic Formation of Concentrated Erosional Edges Under Static vs Cyclic Water Levels (SQ1)

Question

3.2.1 Is sustained hydrodynamic pressure at a fixed elevation a strong enabling condition for the development of a concentrated erosional attack line at a lacustrine woodland margin? Does redistribution of exposure across a broader elevation band through irregular predominantly sub-daily operational water-level movement reduce the likelihood of concentrated edge formation? Does the introduction of a modestly higher median summer water level materially alter this mechanism?

Governing physical principle: time-integrated wave exposure

3.2.2 The geomorphological literature establishes that the intensity of wave-driven erosion at a shoreline is governed not simply by wave height, but by the cumulative duration of wave attack at a given elevation.

3.2.3 Trenhaile (2000) formalised this relationship through modelling of wave-cut platform development, demonstrating that erosion rate at a contour is proportional to the time that contour lies within the active wave zone. Where water level is stable, hydrodynamic energy is repeatedly applied at the same elevation, allowing progressive undercutting and formation of a defined erosional feature.

3.2.4 Trenhaile (2015), in a comprehensive review of coastal notch morphology, further demonstrated that as vertical variability in water level increases, erosional forms become broader and less sharply defined. The controlling variable is therefore the distribution of time spent at level, not merely wave climate.

3.2.5 The transferability considerations set out in the Introduction apply here: Trenhaile's formulations derive from marine wave climates and rock-coast morphodynamics, and are used for the direction of effect of residence-time distribution rather than quantitative prediction at the Urquhart Bay margin. The key mechanism relevant to this assessment is the relationship between time-at-elevation and erosional concentration. That relationship applies equally to large freshwater lochs subject to wind-wave processes.

3.2.6 The implication for the present question is that sustained residence of the still water level at a particular contour is a strong enabling condition for concentrated hydrodynamic work at that contour over seasonal timescales.

3.2.7 Hofmann et al. (2008) similarly distinguish between short-term water-level fluctuations, such as wind waves operating at sub-daily timescales, which provide the energy for erosion, and long-term fluctuations driven by hydrological processes, which determine which section of the shoreline is exposed to that energy. In this framework, the operational water-level position governs which elevation band is presented to wave attack. Prolonged stability at a fixed level therefore repeatedly exposes the same contour, whereas continuous movement redistributes cumulative exposure across a broader vertical range.

3.2.8 This principle is further supported by reservoir-specific erosion prediction methods. Elçi and Work (2003) developed and calibrated a shoreline erosion model for Hartwell Lake, a USACE hydropower reservoir, in which recession rate is calculated as a function of water level, wind climate, fetch and shore profile geometry. Their framework explicitly recognises that the erosion mechanism operating at the shoreline depends on the position of the water surface relative to the shore profile, and that cumulative erosion is obtained by integrating instantaneous recession over time. Accordingly, the total erosive work at any given elevation is proportional to the duration for which the water surface occupies the configuration that generates shear stress at that elevation. Under a cyclic operating regime, the water surface passes through these configurations sequentially rather than remaining fixed at a single contour, distributing integrated erosive work across a broader vertical band. The Elçi and Work framework therefore provides reservoir-specific support for the directional conclusion that sustained residence at a fixed elevation concentrates erosion, whereas cycling attenuates that concentration. The study is cited for its mechanistic structure rather than for quantitative transfer, as the Hartwell Lake shorelines examined were exposed, cohesive bluff margins rather than sheltered, vegetated alluvial deposits.

3.2.9 Hiles et al. (2023), analysing 2,021 shoreline reaches on a regulated freshwater lake with a forested catchment and gravel, cobble and bedrock margins, formalised this relationship through an "action of water" framework in which effective wave exposure at any contour is defined as wave power conditional on the water surface being at or above that elevation. Their results show that boundary position is governed by the frequency and duration of exceedance at each contour rather than by wave climate alone, and that a change in regulation redistributes the vertical zone of cumulative wave action by altering residence patterns. They further note that in sheltered, low-fetch embayments, the statistical relationship between wave power and boundary elevation weakens substantially, indicating attenuation of a sharply defined wave-driven attack line where incident wave energy is limited.

Static Summer Level vs Irregular Operational Water-Level

3.2.10 With movement under a quasi-static summer regime:

- Wind-wave energy is repeatedly focused at a narrow vertical band;
- Hydrodynamic loading is concentrated at that elevation;
- Progressive development of a defined attack line is mechanically consistent with the governing principle above.

3.2.11 For clarity, the proposed operational regime does not involve a fixed daily oscillation. Water levels change at irregular predominantly sub-daily intervals in response to pumping, generation and idle operating states, superimposed on the broader seasonal hydrological trajectory of Loch Ness governed by catchment inflows and regulated outflow at Dochfour Weir. Under an operationally variable regime characterised by irregular predominantly sub-daily water-level movement:

- The water surface moves continuously through an elevation band;
- No single contour experiences prolonged, repeated residence;
- Hydrodynamic loading is redistributed vertically rather than concentrated at a fixed level.

3.2.12 Importantly, the total wind-wave energy entering the loch system is unchanged. Wind climate, fetch, and basin geometry remain constant. What changes under a cyclic regime is the temporal distribution of exposure at each elevation.

3.2.13 On the basis of the time-at-level principle (Trenhaile 2000; 2015), redistribution of exposure across a broader band is mechanistically less consistent with the formation of a sharply defined erosional attack line than prolonged stability at a fixed elevation. This pattern is illustrated by the modelled residence-time distribution for Loch Ness derived from the water-level time-series discussed above (Figure 1). Under baseline conditions, residence is strongly concentrated, with approximately 49% of the time falling within the 0.1 m bands at 15.7 to 15.9 m; under the operational scenario, that concentration is substantially reduced and time-at-elevation is redistributed across a broader vertical range.

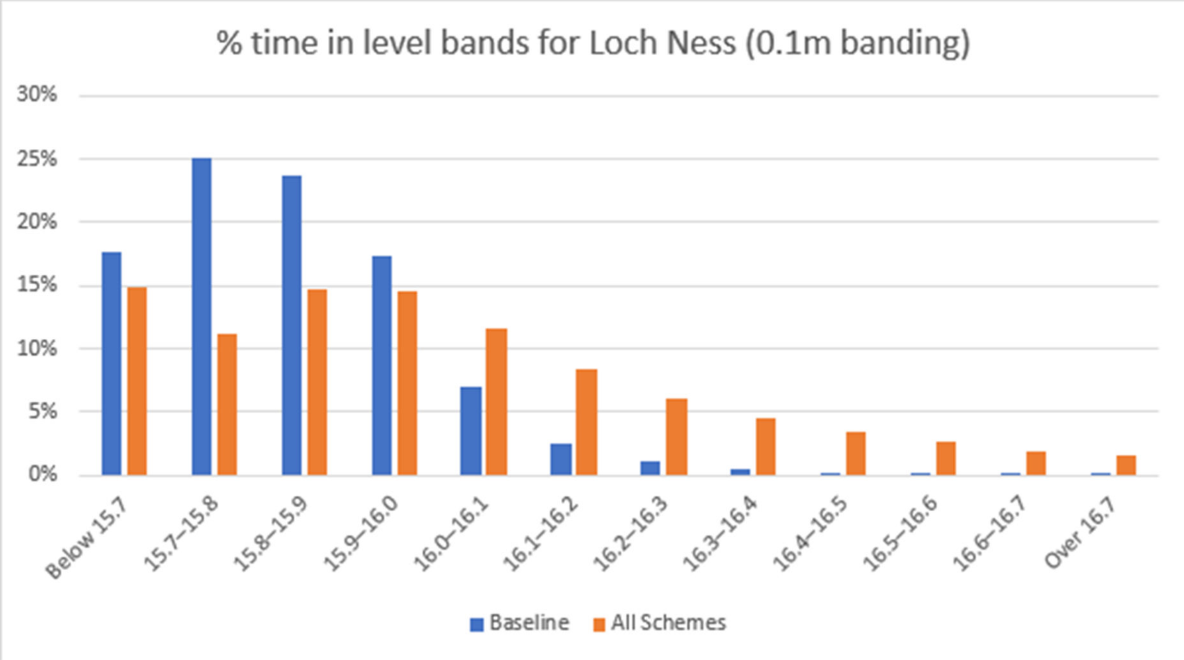

Figure 1 - Percentage of time spent within 0.1 m elevation bands for Loch Ness, for the full year, under baseline conditions and the cumulative operational scenario.

3.2.14 This conclusion relates specifically to the **propensity to form a sharply defined, single-elevation attack line**. It does not, by itself, quantify net erosion or long-term retreat, which also depend on local exposure, sediment properties, vegetation condition, and nearshore geometry.

3.2.15 This does not imply that erosion ceases. Rather, it indicates that the specific mechanism responsible for a concentrated, sharply defined edge – sustained seasonal residence at one contour – is attenuated.

Interaction with a modest higher median summer level

3.2.16 A specific concern raised is whether the combination of irregular operational water-level movement and a modestly higher median summer level could establish a new quasi-stable attack elevation over a seasonal period.

3.2.17 From a mechanistic perspective, a higher median level can only alter erosion risk if it materially increases sustained time-at-elevation at a particular contour. Median level, in itself, is not a driver of erosional concentration. The controlling variable remains duration and continuity of residence at level.

3.2.18 Under the proposed regime:

- The water surface remains mobile, changing in the order of centimetres per hour;
- Elevations within the active band are passed through repeatedly rather than held.

3.2.19 The time series do not indicate prolonged seasonal dwell at the new median level comparable to the quasi-static baseline condition. This inference is supported by the hourly Loch Ness level time-series extracts provided in the Additional Information submission (June 2025; Appendix 2: Water Resources), which show continuous sub-daily variability under multiple scenarios. The extracts include representative windows under: exceptional low-level conditions (2023), typical summer conditions (2021) and a winter scenario (2020, seasonal variable weir not in operation), with traces presented for baseline conditions (including Foyers PSH) and for Glen Earrach operating alone and in combination with other pumped storage schemes (Loch na Cathrach and Loch Kemp). Across these scenarios, the operational traces demonstrate irregular oscillation rather than extended multi-day plateaux at a fixed elevation within the active band. For the purposes of this mechanistic assessment, the time-series extracts provide direct, scenario-based evidence that the proposed operational regime is characterised by frequent reversals and continuous movement within the operating band, rather than sustained seasonal residence at a single contour.

3.2.20 A modest upward shift in median level therefore shifts the vertical position of the active band but does not, of itself, recreate the prolonged seasonal residence that characterises the baseline static regime. The hydrodynamic mechanism required to carve and maintain a sharply defined attack line – repeated, extended exposure of the same contour – is not re-established unless sustained dwell occurs.

3.2.21 The governing variable remains time-at-elevation distribution rather than median elevation per se.

Applied recognition in hydropower practice

3.2.22 Operational guidance within the hydropower sector recognises the same principle.

3.2.23 The International Finance Corporation (IFC, 2018) Good Practice Note: Environmental, Health, and Safety Approaches for Hydropower Projects explicitly identify “time spent at particular operating levels” as a factor influencing shoreline erosion and recommend management of operating levels and ramping regimes to reduce concentrated shoreline impacts.

3.2.24 This operational recognition is consistent with the geomorphological mechanism described above: prolonged residence at a fixed elevation increases erosion risk; reducing sustained exposure at any one contour attenuates concentration of hydrodynamic work.

Conclusion for mechanistic assessment

3.2.25 The available geomorphological theory and operational guidance support the following conclusions:

3.2.26 Formation of a sharply defined erosional attack line is most mechanically consistent with prolonged residence of the water surface at a relatively fixed elevation over extended periods, such that wave work is repeatedly focused within a narrow vertical band.

3.2.27 Under a regime characterised by continuous irregular predominantly sub-daily operational water-level movement, exposure is redistributed across an elevation band and the still-water level does not remain fixed at one contour for extended periods. The hourly Loch Ness time-series extracts illustrate this continuous predominantly sub-daily movement across representative summer and winter scenarios and across operational combinations.

3.2.28 A modest upward shift in median summer level shifts the position of the active elevation band but does not, of itself, recreate the quasi-static condition required for sustained residence at a single contour, unless the time-series shows multi-day plateaux at that elevation.

3.2.29 Accordingly, a cyclic regime is mechanistically less conducive to a single concentrated notch or attack line than a quasi-static summer level concentrated at a fixed elevation.

3.2.30 This does not imply elimination of all erosional processes. Residual erosion risk remains governed by wind-wave climate, substrate characteristics, and vegetation persistence.

SQ1 References

AECOM (2025). Glen Earrach Pumped Storage Hydro: Additional Information Submission (June 2025), Appendix 2 – Water Resources (Water Balance Model Extracts and Hourly Loch Ness Level Time-Series Data). Prepared for Glen Earrach Energy Ltd.

Elçi, S. and Work, P.A. (2003). Prediction of reservoir shoreline erosion. *Proceedings of the 2003 Georgia Water Resources Conference*, University of Georgia, Athens, Georgia.

Hiles, C.E.; Morris, E.; Sutherland, C.; Bazett, D.; Davey, C. (2023). Estimating natural boundary change on a large lake. *Water*, 15(17), 3037.

Hofmann, H.; Lorke, A.; Peeters, F. (2008). Temporal scales of water-level fluctuations in lakes and their ecological implications. *Hydrobiologia*, 613, 85–96.

International Finance Corporation (2018). *Good Practice Note: Environmental, Health, and Safety Approaches for Hydropower Projects*.

Trenhaile, A.S. (2000). Modeling the development of wave-cut shore platforms. *Marine Geology*, 166, 163–178.

Trenhaile, A.S. (2015). Coastal notches: Their morphology, formation, and function. *Earth-Science Reviews*, 150, 285–304.

3.3 Compatibility of the Predicted Cyclic Inundation Regime with Alluvial Woodland including at the Loch Margin (SQ2)

Question

3.3.1 Does the predicted pattern of cyclic inundation at the loch margin (i.e. particularly around and below ~15.9 m AOD), as indicated in the inundation and drying event analyses interpreted by and accompanying AECOM (2026), cause persistent vegetation loss, or is it consistent with retention of vegetation associated with the continued functioning of the alluvial alderwood?

Ecological context and site-specific evidence

3.3.2 AECOM (2026) notes that the alluvial alderwood in the lower parts of the SAC is dominated by NVC type W7 and associated with periodically waterlogged soils. It occupies riverine and loch-margin settings where water levels fluctuate and seasonal flooding occurs. The lower parts of Urquhart Bay Wood SAC already represent a wetter expression of this community type.

3.3.3 The relevant issue is therefore not whether water levels fluctuate in principle, but whether the specific predicted hydrological regime creates sustained growing-season saturation sufficient to cause irreversible vegetation loss (which would also result in associated exposure of the margin to erosion).

3.3.4 AECOM (2026) provides the hydrological quantification of inundation and drying patterns and the ecological interpretation of those outputs for Habitats Regulations Appraisal purposes. This includes:

- Fine-scale LiDAR-based level band mapping in requested 0.2 m intervals from median summer loch level (15.7–17.5 m AOD);
- Event duration distributions by level band;
- Seasonal subsets (including growing season);
- Drying interval analysis quantifying recovery periods between events;
- Updated NVC mapping and habitat sensitivity interpretation.

3.3.5 The inundation analyses set out in AECOM (2026) indicate that:

- The dominant inundation durations in the loch margin area (≤15.9 m), as well as higher elevations, are ≤24 hours;
- Longer events are less frequent, particularly over 1 week duration – e.g. for the growing season at 15.9 m, the modelling predicts averages of 59 inundations of ≤24 hours duration, 11.1 of 1-3 day duration, 7.2 of 3-7 day duration and 2.8 exceeding one week, and the overall growing season exceedance is 63.9% (thus 36.1% of the growing season not inundated to this level). The frequency of inundation events decreases with increasing height, e.g. at 16.1 m the modelling predicts 54 inundation events of ≤24 hours duration, 7.0 of 1-3 day duration, 6.0 of 3-7 day duration and 1.9 of more than one week, with overall growing season inundation dropping to 40.3%, indicating considerable capacity for drying during non-inundated time (59.7% of the growing season at 16.1 m, and more at higher levels).

3.3.6 The assessment of ecological compatibility must therefore be grounded in this quantified duration and recovery pattern, rather than in abstract assumptions about variability.

Soil processes under modelled cyclic inundation

3.3.7 Flooded soils undergo a predictable redox sequence as oxygen is depleted (Ponnamperuma, 1984). Phytotoxic stages associated with root damage arise primarily under prolonged, continuous saturation where reducing conditions are allowed to advance.

3.3.8 Where inundation is short and followed by drainage:

- Early oxygen depletion may occur;
- The redox sequence is interrupted;
- Soil oxygen availability is restored before advanced reducing conditions (e.g. sustained iron and sulphide reduction) become established.

3.3.9 The drying-interval distribution described above demonstrates that the predicted regime is characterised by repeated re-aeration intervals between inundation events. At 16.1 m, this amounts to 59.7% of the growing season (since overall exceedance at this level is 40.3%), and 36.1% at 15.9 m. This distinguishes the modelled hydrological regime from a sustained quasi-static summer water level with a quasi-static level of soil saturation. For the lowest 15.7 m band, the proportion of the growing season not subject to inundation is modelled to be 13.4%, however there are still 51 growing season drying events at this lowest level which, although mostly of less than 24 hours duration, are spread through the growing season and will have an ameliorating effect (given substrate drainage characteristics discussed in SQ5 below).

3.3.10 Moreover, species such as reed canary-grass *Phalaris arundinacea* and bottle sedge *Carex rostrata*, already present, can grow in water (in this respect, AECOM (2026) notes a study in which fully deoxygenating the roots of reed canary-grass resulted in little if any oxygen stress). It is also important to note that the 15.7 m band occupies 0.3% of the SAC. Given that 36.1% of the growing season is not inundated at 15.9 m, spread across over 80 modelled drying events (see February 2026 Additional Information) allowing for appreciable recovery (see SQ5 regarding substrate drainage), soil saturation would have less impact, although it will likely result in expansion of existing open swamp in and near the 15.9 m band (discussed further below under Regeneration and recruitment). Soil saturation is not by itself considered likely to result in vegetation loss given the aforementioned ability of certain existing species to grow in water. At 16.1 m where 59.7% of the growing season is not inundated, spread across over 65 modelled drying events, and given the tolerance of key species to inundation as discussed in the following section, substrate oxygen depletion would have still less effect (although there would be expected to be some expansion in more flood-tolerant species).

3.3.11 Site-specific redox measurements are not presented in this document; however, SQ5 addresses why the mapped alluvial substrate supports pore-water recession broadly tracking stage change rather than persistent saturation.

Flood tolerance of characteristic species in relation to inundation modelling

3.3.12 The dominant canopy species (alder) of the low-lying alluvial alderwood, and some of the associated W7 ground flora species, are documented as tolerant of considerable degrees of waterlogging. AECOM (2026) sets out evidence of such tolerance for key species present in the low-lying W7 alluvial alderwood (including meadowsweet *Filipendula ulmaria*, soft-rush *Juncus effusus*, tufted hair-grass *Deschampsia cespitosa* and reed canary-grass). Further experimental and synthesis evidence is provided below on relevant species.

3.3.13 Experimental work on alder *Alnus glutinosa* provides direct physiological evidence relevant to the margin conditions identified in the AECOM assessment. Dittert et al. (2006), in controlled experiments on two-year-old alder under waterlogged conditions, confirmed that lenticels at the stem base are the primary site of oxygen entry into the root system, with oxygen transport driven by concentration gradients between aerial tissues and the anaerobic rhizosphere. Net oxygen flux into the root system was inversely related to dissolved oxygen concentration in the rooting medium, meaning that as external oxygen declined, internal oxygen transport increased – indicating an active compensatory response rather than passive tolerance of low-oxygen conditions. Under waterlogging, alder redistributed root biomass towards the upper soil horizons and increased lenticel development, representing morphological accommodation rather than structural failure. While conducted under controlled conditions rather than under a cyclic lacustrine regime, these findings provide species-specific confirmation that alder possesses dynamic structural and physiological mechanisms capable of sustaining root function during episodic anaerobic exposure. In the context of the AECOM analyses, where inundation events are predominantly short and interspersed with shorter but frequent drying intervals, such recovery phases would restore the oxygen gradients on which this transport mechanism depends.

3.3.14 Johansson & Nilsson (2002), in a transplant experiment comparing riparian plant performance across free-flowing and regulated boreal rivers, found that flood duration and frequency under regulation reduced growth rates in some species. Notably, slender tufted-sedge *Carex acuta* and autumn hawkbit *Leontodon autumnalis* showed no consistent difference in performance between free-flowing and regulated sites. Two regulated run-of-river impoundments in this study exhibited very frequent water level fluctuations not dissimilar to the modelled cyclic fluctuations for Loch Ness, at which meadowsweet (a key W7 species at Urquhart Bay Wood) was relatively flood-tolerant, showing a decrease in growth above 200 cumulative days of flooding but with positive growth observed at up to 400 days at one of these sites and approximately 300 days at the other, and partial mortality recorded from approximately 280 days (approximately 61% of the study period from July 1993 to September 1994). For slender tufted-sedge little effect of flooding was observed; although not recorded at the SAC, this species can be seen as representative of medium to large sedges, of which bottle sedge occurs in the SAC at the edge of and shortly inland of Loch Ness in the low-lying north-eastern sector, and more extensively adjacent to the SAC at the south-eastern edge, and is a species that can form swamp in water. These findings indicate that increased substrate wetness would not eliminate larger sedges such as bottle sedge. In the case of the moderately flood-tolerant meadowsweet possible partial loss is unlikely much above 15.9 m (at which growing season exceedance is 63.9%, less for the year as a whole), and around or below 15.9 m such loss would likely be replaced by more inundation-tolerant species that already occur in the low-lying parts of the SAC adjacent to Loch Ness (such as reed canary-grass, already abundant in the north-eastern part of the SAC, and bottle sedge), rather than resulting in structural de-vegetation.

3.3.15 Kozlowski (1997), in a comprehensive synthesis of woody plant responses to flooding, identifies duration of flooding and plant age as primary determinants of flood tolerance, with mature trees substantially more tolerant than young seedlings. Among flood-tolerant woody angiosperms, alder and several willow *Salix* species – including crack willow *Salix fragilis*, present in the W7 at the SAC – are specifically identified as producing adventitious roots in response to flooding, a morphological adaptation that compensates for root decay by restoring water absorption, increasing rhizospheric oxidation, and maintaining hormone supply to the canopy. These adaptations operate alongside hypertrophied lenticel formation and aerenchyma development, providing multiple concurrent pathways for internal oxygen transport and gas exchange under waterlogged conditions. Notably, with regard to willow species this article also cites two studies in which seeds completed germination ‘in water’ (under water) and ‘germinated readily while submerged’.

3.3.16 The duration and recovery framing is further supported by European synthesis evidence. Glenz et al. (2006), reviewing flooding tolerance across 65 Central European tree and shrub species, identify flooding duration, depth, timing within the growing season, and recovery time between events as the principal abiotic determinants of flooding stress response. The review classifies alder and crack willow – both present at Urquhart Bay Wood and alder the principal canopy species – in the highest flooding tolerance class (Class 5, “very high”). Crack willow is additionally recorded as possessing all three principal morphological adaptations to flooding: adventitious roots, hypertrophied lenticels, and aerenchyma (Glenz et al., 2006, Table 1). Glenz emphasises that adverse outcomes are most strongly associated with prolonged, uninterrupted growing-season submergence or with insufficient recovery time between flooding events, allowing cumulative stress to develop. In contrast, where drainage intervals permit physiological recovery, flood-tolerant species are documented as persisting under periodic inundation regimes. In light of the hydrological regime characterisation established above, the quantified inundation and recovery pattern aligns with the conditions identified in the literature as compatible with persistence of such highly flood-tolerant riparian woodland species.

3.3.17 These species-specific findings are consistent with the broader ecological framework for lake-margin dynamics. Wantzen, Junk and Rothhaupt (2008), extending the floodpulse concept to lacustrine systems, characterise periodic inundation at lake margins – the Aquatic-Terrestrial Transition Zone (ATTZ) – as a structuring ecological process that selects for flood-adapted species rather than a perturbation that degrades established communities. Their framework describes flooding as a filter favouring species equipped with physiological and morphological adaptations to cyclic wet–dry conditions, and identifies alder as characteristic of flood-influenced lake margins in Central Europe. The reformulated floodpulse tenets distinguish between predictable, moderate-amplitude fluctuations – to which resident transition-zone species are adapted – and extreme or untimely events that exceed adaptive capacity. The proposed Glen Earrach regime, with shorter duration inundation events most frequent, and with shorter but frequent intervening drainage intervals, is most consistent with the former class of fluctuation. Abrahams (2008) similarly identifies vegetation loss as associated with high disturbance amplitude combined with low substrate fertility, rather than with moderate periodic inundation on fertile alluvial substrates.

3.3.18 The hydrological modelling, as summarised above and set out in more detail in AECOM (2026) and accompanying tables, does include longer-duration inundation events. However, the most frequent inundation events are of short duration. The ecological literature indicates that vegetation loss is most strongly associated with prolonged, uninterrupted growing-season saturation rather than repeated shorter events separated by shorter but frequent drying intervals (for example, as noted above, at 15.9 m 36.1% of the growing season would not be inundated, spread across over 80 drying events, increasing to 59.7% of the growing season at 16.1 m spread across over 65 drying events). The flood tolerance of key species indicated above and in AECOM (2026), in combination with the hydrological modelling, suggests that existing elements of the vegetation in the lowest-lying parts of the SAC are likely to persist under the predicted hydrological regime (although liable to change towards more swampy vegetation around the 15.9 m band and below).

Regeneration and recruitment within the SAC

3.3.19 The physiological tolerance evidence summarised above relates principally to established trees and mature ground flora. Seedlings and saplings are generally more sensitive to flooding duration and timing, and regeneration within alluvial woodland is characteristically episodic rather than continuous, occurring during periods when suitable moisture, temperature and light conditions coincide. However, alder seedlings do appear to exhibit some tolerance to flooding – Glenz et al. (2006) observed that alder seedlings tolerated partial submergence for three months with little effect, with damage observed by four weeks of full submersion.

3.3.20 In AECOM (2026) it was noted that Barsoum et al. (2005) give a 'rule of thumb' for alluvial alderwood of a limit of 40% of the growing season under flood, but for which the available of two cited references did not refer to a 40% limit or indeed discuss habitat tolerances. However, an older study by Gill (1970) may have been the intended reference – this study suggests that whilst established woody species may persist where flooding exceeds 40% of the growing season, colonisation (i.e. seedling establishment) cannot occur; it also suggests that indefinite persistence requires 55-60% of the growing season unflooded. Since at 15.9 m the growing season exceedance is 63.9%, this suggests that regeneration could be an issue at that level. However, this appears somewhat at odds with other studies. An experiment by Siebel et al. (1998) found that unshaded alder seedlings subjected to continuous full submergence in 30-70 cm depth of clear water did not exhibit a reduction in weight until more than three weeks of such treatment (extremely shaded seedlings afforded 1% sunlight, which could be taken as simulating turbid water, fared only slightly worse at three weeks); at six weeks there was a clear weight reduction in unshaded seedlings (less so in shaded plants) but the seedlings were still alive.

3.3.21 For comparison, the predicted hydrological regime at the SAC at 15.9 m is one where the most frequent inundation durations are less than 24 hours, with an average of 2.8 per growing season exceeding one week, and shorter but numerous drying events amounting to 36.1% of the growing season spread across over 80 modelled drying events (AECOM, 2026). At 16.1 m the growing season exceedance is 40.3%, approximately the limit stated in Gill (1970). However, the aforementioned predicted hydrological regime at 15.9 m and the experimental results of Siebel et al. (1998) suggest that alder at the SAC would likely achieve at least some regeneration below the 16.1 m band, particularly given that there is micro-topographical variation within each height band affording local slightly higher ground within each height band (see next paragraph). An incidental recent observation in February 2026 of a budding (i.e. growing) larger alder seedling/small sapling amongst wet vegetation near the SAC/loch edge towards the 15.7 m level lends some support to this assertion (since baseline growing season exceedance in this position would likely exceed 40%). However, should alder regeneration be impeded, it is likely that willows (which already supplement alder in the low-lying parts of the SAC) would expand in cover – as noted above, Kozlowski (1997) cites two studies in which willow *Salix* spp. seeds completed germination 'in water' (under water) and 'germinated readily while submerged', indicating an ability for willow seedlings to germinate in extremely waterlogged conditions including while submerged.

3.3.22 Field survey undertaken for the AECOM assessment confirms that woodland currently extends to the existing loch margin, including alder individuals rooted within the loch-margin substrate at low elevations, a few of the lowest-level individuals growing separately from other vegetation within the loch substrate surrounded by water. Observed canopy vitality at these lowest elevations is consistent with persistence under the existing water-level regime. There is also microtopographic variation within the lower margin and elsewhere, including small areas of slightly raised ground, woody debris accumulations and tussock-forming vegetation, some currently with the dry woodland species greater woodrush *Luzula sylvatica* even at the loch edge. Such micro-elevation heterogeneity provides locally less wet microsites more favourable to seedling establishment. Given also the ability of willow to germinate whilst submerged, it is not considered likely that woody species regeneration would cease around the 15.9 m band or lower, although it cannot be ruled out that willow in this vicinity may replace a proportion of alder, and some expansion of open swamp is also possible (likely to involve further S28 reed canary-grass *Phalaris arundinacea,* already present in an open patch in the north-eastern sector of the SAC, and other species such as bottle sedge and water horsetail *Equisetum fluviatile,* also already present in smaller quantity within the lowest woodland or more extensively beside it to the south-east).

3.3.23 However, it is important to note that the part of the SAC from 15.9 m downwards represents the lowest-lying parts of the SAC, occupying 2.9% of the SAC. Given the discussion in the above paragraphs, there is not considered likely to be loss of vegetation cover in this vicinity (or elsewhere) as a result of soil saturation itself, and although there may be some expansion of existing swamp types that are part of the existing ecosystem, the ability of willow to germinate underwater indicates that there would not be substantial loss of woodland cover, although there may be some replacement of alder by willow, and potentially expansion of open swamp. Such effects would not represent wide-scale change, and not out of keeping with the strongly dynamic nature of the alluvial woodland at this SAC. There is likely to be very limited effect on regeneration above 15.9 m and especially above 16.1 m, where upslope regeneration within the alluvial woodland would be expected to continue similarly to baseline (notwithstanding a likely shift towards more alder and associated W7 species and less ash and associated W9 species in the transition zones between W7 and W9, both of which, as noted in AECOM (2026), constitute alluvial alderwood at this SAC, thus such change does not affect the qualifying habitat extent).

Implications for the loch-margin (≤ ~15.9 m AOD) and above

3.3.24 At the margin, the question considered here is whether the modelled inundation regime would be expected to reduce vegetation cover through soil saturation and associated effect on flora, and thereby remove habitat from the loch-side margin of the SAC.

3.3.25 As discussed above, the ecological literature indicates that persistent structural de-vegetation in floodplain and lacustrine margins is typically associated with:

- Prolonged continuous growing-season saturation; and
- Sustained reducing soil conditions without opportunity for recovery.

3.3.26 However, the hydrological modelling indicates:

- Dominance of shorter duration inundation events during the growing season (and outside it);
- Frequent intervening drying intervals during the growing season, amounting to 59.7% of the growing season at 16.1 m (since overall exceedance is 40.3% at this level) and 36.1% of the growing season at 15.9 m. For the 15.7 m band, the proportion of the growing season not inundated is only 13.4%, however it is critical to note that this band occupies only 0.3% of the SAC, and is already subject to significant inundation at baseline (total exceedance 70.7%).

3.3.27 Accordingly, and given the above discussion, prolonged soil saturation that could result in plant mortality would be most significant in the 0.3% of the SAC occupied by the 15.7 m band, however existing graminoid species (reed canary-grass and bottle sedge) in and above this vicinity are capable of growing in standing water thus vegetation loss is not indicated by soil saturation alone. There is a general absence of sustained static submergence comparable to a quasi-static summer level – at 15.9 m, 36.1% of the growing season is not inundated spread across over 80 drying events, rising to 59.7% across 65 drying events at 16.1 m, such that soil saturation effects decrease substantially;

3.3.28 Particularly around the 15.9 m zone and below, there will likely be a reduction in smaller less flood-tolerant species, a reduced persistence of certain existing species such as meadowsweet, tufted hair-grass and soft-rush, and as mentioned an expansion of reed canary-grass and other existing swamp species such as bottle sedge and water horsetail;

3.3.29 Wide-scale reduction of woody species regeneration is not suggested by the above evidence, although there may be replacement of a proportion of alder by willow around the 15.9 m band and below. There may also be expansion of existing swamp types in this vicinity, however 97.1% of the SAC lies above 15.9 m, thus wide-scale change of this sort is not predicted, given factors such as micro-topographical variation within each height band and the ability of willow to grow in still wetter habitats than alder and to germinate whilst submerged;

3.3.30 The W7 to W9 transition will likely shift upwards in response to the inundation regime, however this does not change alluvial woodland extent because both constitute the qualifying alluvial woodland at this SAC;

3.3.31 Localised compositional shifts are consistent with dynamic floodplain ecology, and swamp / wetter woodland are part of the existing ecosystem and characteristic of alluvial woodland systems generally.

3.3.32 Such changes are not considered inconsistent with the highly dynamic alluvial woodland at the SAC and generally, and associated conservation objectives. This is consistent with the SAC conservation advice, which recognises considerable variation in the alluvial woodland and the great dynamism of the site, rather than there being a fixed flora. It is acknowledged that NatureScot have identified herbivore pressure also as a factor influencing regeneration dynamics, noting that expanded dominance of willow in wetter vegetation might not occur with preferential deer browsing without deer management mitigation, which is addressed elsewhere in the submission.

3.3.33 It is useful to also consider a temperate reservoir analogue provided by Krolová et al. (2012), who investigated littoral vegetation distribution in Lipno Reservoir (Czech Republic) under a 2–3 m annual water-level fluctuation regime associated with hydropower operation. Across 115 shoreline sites, broadly persistent eulittoral vegetation was recorded within the fluctuation band, dominated by emergent and amphibious species. Vegetation extent was structured primarily by shore slope, fetch and erosion morphology rather than fluctuation amplitude alone. Although this study concerns herbaceous macrophyte communities rather than mature alluvial woodland, it demonstrates that multi-metre seasonal drawdown associated with high-amplitude hydropower-induced fluctuation in a temperate lacustrine setting does not necessarily generate persistent unvegetated drawdown zones. Lipno Reservoir also experiences regular winter ice cover and associated freeze–thaw disturbance, yet vegetated eulittoral zones persisted across much of the fluctuation band. Loch Ness does not typically experience comparable ice scour or prolonged freezing at the margin. The Lipno case therefore represents a system subject to greater winter physical disturbance than occurs at the Urquhart Bay Wood SAC / Loch Ness interface, strengthening the inference that cyclic water-level fluctuation alone is not synonymous with sustained de-vegetation in sheltered temperate embayments.

Conclusion for ecological compatibility

3.3.34 The event-duration distribution with intervening recovery intervals, together with key points such as the ability of existing species such as reed canary-grass and bottle sedge to grow in water, and the ability of willow to germinate underwater, do not indicate a pathway to persistent de-vegetation through substrate saturation. Although some open swamp expansion may occur around the 15.9 m level and below, and possible replacement of a proportion of alder by expansion of willow, this would not be a wide-scale change (given that 97.1% of the SAC lies above 15.9 m); such swamp is part of the existing ecosystem, and this is consistent with the dynamic alluvial woodland ecosystem.

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3.4 Erosion Processes Under Gradual Water Level Change (SQ3)

Question

3.4.1 In a woodland-loch margin systems where water level change occurs gradually (in the order of centimetres per hour) does cyclic stage movement introduce a distinct erosive mechanism relative to a quasi-static summer water level dominated by wind-wave exposure?

3.4.2 Loch Ness is a large natural freshwater loch with a surface area of approximately 56 km², rather than a conventional impounded reservoir. For a given volume exchange, the resulting stage change is governed by this large surface area; the same pumped volumes acting on a smaller reservoir would produce proportionally greater level movements. The theoretical maximum stage change that would occur under complete transfer of all relevant headpond storages in combination to or from Loch Ness is approximately 1.2 m, of which Glen Earrach's full operational storage accounts for approximately 0.5 m. These figures represent physical capacity bounds rather than expected operational movements. The modelled operational regime presented in the February 2026 Additional Information submission indicates stage movements dominated by substantially smaller incremental changes, with frequent directional reversals between generation and pumping phases, such that stage movement alternates rather than progressing continuously in a single direction. The frequent alternation between generation and pumping phases limits the duration of any single-direction hydraulic gradient acting across the bank profile. Under a conservative assumption of simultaneous operation of all schemes at maximum ramp rate, the combined instantaneous rate of stage change could be of the order of 7 cm per hour during drawdown and 8–9 cm per hour during pumping; these represent envelope ramp rates and do not imply sustained full-range transitions (despite its significantly larger generating power, the GEE contribution to these stage changes is less than 3 cm per hour for both pumping and generation due to significantly greater hydraulic head than all other schemes). In geotechnical terms, rapid-drawdown instability is associated with sustained unidirectional lowering of external water level relative to internal pore pressure, where the rate of recession exceeds the capacity of the bank material to dissipate pore pressures. The relevance of the proposed loading characteristics to the site-specific conditions at the Urquhart Bay loch margin is examined below.

Stage change and rapid drawdown mechanisms

3.4.3 Bank instability associated with water level change is most clearly documented under rapid drawdown conditions. The U.S. Army Corps of Engineers (USACE, 2003, EM 1110-2-1902, Chapter 2) identifies "sudden drawdown" as a distinct loading condition requiring specific stability analysis. For analysis purposes, sudden drawdown assumes that the external water level is lowered rapidly and that no drainage occurs in low-permeability soils during the drawdown phase. Under these conditions, pore-water pressures within the bank remain elevated while the confining external water pressure is reduced, resulting in a transient reduction in effective stress and shear strength.

3.4.4 The controlling variable is therefore rate of stage change relative to the soil's ability to dissipate pore pressures.

3.4.5 Zhao et al. (2022), in their review of bank retreat mechanisms, similarly identify pore-water pressure fluctuation and seepage forces as drivers of bank instability where stage changes generate hydraulic disequilibrium between the bank interior and the external water level. Zhao et al. describe the mechanism qualitatively, noting that such instability arises where stage change is sufficiently rapid relative to the drainage capacity of the bank material, or large in amplitude, to prevent progressive pore-pressure dissipation, leading to effective stress reduction and potential mass failure. The review does not identify specific drawdown rate thresholds.

3.4.6 Whether a given rate of stage change constitutes "rapid" drawdown in geotechnical terms is determined by the relationship between drawdown rate and the hydraulic conductivity of the bank material, rather than by the absolute rate of stage change alone. USACE (2003, EM 1110-2-1902) differentiates soil response to drawdown loading by material permeability class, with granular soils expected to drain during drawdown such that drained strength parameters apply, whereas low-permeability clays are assumed to retain excess pore pressures during the drawdown phase. Berilgen (2007), in a parametric finite-element study of drawdown stability, confirmed that identical drawdown rates produce markedly different pore-pressure responses depending on soil permeability, with excess pore pressures developing in low-permeability materials but dissipating readily in granular soils. The published case histories from which the rapid-drawdown instability literature derives consistently involve tall, steep slopes in low-permeability materials – settings that differ fundamentally from the loch margin considered here.

3.4.7 Under the proposed operational regime, stage movement is characterised by frequent alternation between pumping and generation phases. This limits the duration of sustained unidirectional stage lowering and therefore limits the persistence of any single-direction hydraulic gradient acting across the bank profile. The regime does not replicate the sustained, large-amplitude, unidirectional recession that characterises the "sudden drawdown" loading condition defined by USACE (2003), which assumes rapid recession with negligible drainage in low-permeability materials during the drawdown phase.

3.4.8 Rapid drawdown instability further requires bank geometry in which gravitational driving stresses are sufficient to exceed soil shear strength under conditions of reduced effective stress. This failure mode is not commonly reported on low-gradient, low-height vegetated lakeshore margins; the published case histories consistently involve engineered embankments or natural slopes substantially taller and steeper than those present at the Urquhart Bay margin. Reported rapid-drawdown failures typically involve slopes where gravitational driving stresses approach the shear strength of the soil mass under reduced effective stress conditions, a situation associated with tall embankments or steep reservoir margins rather than gently sloping alluvial deltas. The loch margin within Urquhart Bay Wood SAC is a low-lying alluvial delta formed at the confluence of the Rivers Coiltie and Enrick. LiDAR-derived contour mapping submitted in the February 2026 Additional Information pack confirms the shallow deltaic character of this margin, with a typical gradient of approximately 1 m rise over 100 m horizontal distance (approximately 1:100, or less than 1°) across the elevation bands relevant to the assessment. At gradients of this order, gravitational driving stresses are extremely small relative to typical soil shear strength, and the stress conditions required for pore-pressure-driven mass failure are not expected to arise. Where locally steeper sections may exist at the margin, any potential susceptibility would be confined to those limited locations rather than operating across the SAC frontage as a whole.

3.4.9 The remaining precondition for rapid-drawdown instability (soil of sufficiently low permeability to retain excess pore pressures during drawdown) is addressed in SQ5, which describes the mapped substrate at the active loch margin as coarse alluvial sand and gravel expected to be relatively permeable and in hydraulic communication with the loch. The mature W7 woodland root–soil matrix described in SQ4 provides further resistance to any residual shallow shear stresses. The three conditions required for rapid-drawdown instability (low-permeability soils, steep or high banks, and sustained unidirectional drawdown of large amplitude) are not present at the Urquhart Bay loch margin. Accordingly, the proposed cyclic stage change regime is not expected to activate this failure mechanism at this site.

Direct hydraulic forcing and sediment mobilisation

3.4.10 Shoreline erosion in lakes and reservoirs is governed primarily by wave-generated shear stress, substrate characteristics, and exposure-related processes, rather than by gradual vertical translation of the still-water level itself. The studies cited below derive from systems subject to greater fluctuation amplitudes and wave exposure than Urquhart Bay (see Introduction, transferability considerations). They are referenced for the direction of mechanism and response rather than quantitative transfer.

3.4.11 Kaczmarek et al. (2025), in a multi-decadal geomorphological analysis of the Jeziorsko Reservoir in Poland, examined shoreline evolution under an operational regime involving annual water-level fluctuations of up to 6.5 m and wind-generated waves reaching up to 0.82 m in height. The principal mechanisms of shoreline change identified were wave undercutting of cliff bases, sediment redistribution within the periodically exposed littoral zone, and mass slope movements including slumping, toppling and sliding. Additional exposure-related processes, including subaerial weathering and freeze–thaw action in exposed cohesive sediments, contributed to progressive shoreline adjustment in that reservoir setting. These freeze–thaw processes reflect the continental winter climate and exposed cohesive substrates characteristic of Jeziorsko. By contrast, Loch Ness functions as a large thermal mass, moderating nearshore temperature extremes and substantially limiting prolonged freezing exposure at the margin. Freeze–thaw weakening is therefore not expected to represent a material erosive driver at Urquhart Bay.

3.4.12 The spatial distribution and persistence of erosion at Jeziorsko were controlled primarily by wave exposure, slope morphometry, and substrate composition: steep, wind-exposed shores remained actively erosional over multiple decades, while sheltered shallow-gradient margins stabilised progressively through sediment accumulation and vegetation colonisation. Water-level fluctuation amplitude determined the vertical extent of the active shore zone, but the erosional and depositional processes themselves were consistently linked to wave action and exposure of sediments, rather than to the rate of water-level change as a direct hydraulic forcing mechanism.

3.4.13 Notably, sheltered shallow-gradient shores in the Jeziorsko Reservoir – a morphological analogue to the Urquhart Bay margin, sharing gentle inclination, shallow nearshore bathymetry, and reduced exposure to dominant wind-wave directions – were progressively colonised by woody vegetation (principally *Salix* spp.) and emergent macrophytes within the first two decades of reservoir creation, despite the large fluctuation amplitude. By the third decade of operation, biogenic shoreline dominated these margins, constituting up to 77% of the shallow-gradient bank length (Kaczmarek et al., 2025, Section 3.3d: fourth mapping, 2022). This colonisation occurred on initially bare, newly inundated substrates – former floodplain, former neutral shore, and in some cases former artificial shore – with no pre-existing root matrix. Conditions were therefore substantially less favourable to vegetation persistence than those at Urquhart Bay, where mature W7 alluvial woodland with an established root–soil system is already present. The documented trajectory on these sheltered shallow-gradient margins was progressive stabilisation towards biogenic dominance; no return to persistent bare erosional condition on these margins was recorded during the 31-year monitoring period, notwithstanding annual water-level fluctuation amplitudes averaging 4.51 m.

3.4.14 A further observation from the Jeziorsko study reinforces this pattern. In 2014, the maximum operating water level was reduced by 0.5 m. This modest reduction in the duration of direct wave exposure at the upper margin led to accelerated vegetation encroachment onto the near-shore part of the coastal platform, including on formerly erosional shore sections (Kaczmarek et al., 2025, Section 3.4). This demonstrates that even small reductions in sustained high-water residence time can materially accelerate vegetation colonisation – a finding directly relevant to a regime in which residence time at any single contour is reduced through continuous redistribution across an elevation band.

3.4.15 The fluctuation regime examined by Kaczmarek et al. involved substantially greater amplitude and wave exposure than the sheltered loch-margin conditions considered here. The relevance of this evidence lies in demonstrating that even under large-amplitude fluctuation regimes, shoreline erosion is governed by wave energy, exposure duration, and substrate response rather than by rate of stage change. The vegetation colonisation findings further demonstrate that sheltered, shallow-gradient margins – analogous in form to Urquhart Bay – are characterised by progressive stabilisation and biogenic succession even under substantially more aggressive hydrological regimes than those proposed at Loch Ness. The available geomorphological evidence does not indicate that a fluctuation regime of materially smaller amplitude would be expected to remove established woodland from an analogous sheltered margin.

3.4.16 The Kaczmarek et al. findings are consistent with the broader pattern identified in a recent global review of vegetation dynamics on hydroelectric reservoir shorelines. Matthes et al. (2025), reviewing 103 peer-reviewed studies across multiple continents, report that persistent vegetation loss along reservoir margins is most consistently associated with large-amplitude fluctuation regimes, often involving multi-metre seasonal drawdowns, anti-seasonal inundation patterns, and the abrupt conversion of formerly terrestrial land to periodically inundated shoreline. These conditions differ materially in scale and character from the proposed Loch Ness regime. The review further identifies adventitious rooting, lenticel development, rhizomatous growth and flexible root systems as traits associated with survival within water-level fluctuation zones – traits already documented for alder and willow species established at Urquhart Bay. The Matthes et al. review is cited here to corroborate that vegetation loss on reservoir shorelines is linked to extreme and disruptive fluctuation regimes rather than to moderate, periodic cycling of the type assessed in this document.

3.4.17 Vertical stage movement in the order of centimetres per hour, distributed across the loch surface, would be expected to generate negligible horizontal flow velocities at the margin and therefore negligible additional boundary shear stress relative to that generated by wind-wave action. Wind forcing, fetch, and basin geometry are not altered by the proposed operation. Accordingly, gradual cyclic stage change modifies the vertical position of wave interaction with the margin but does not introduce a distinct hydraulic forcing mechanism beyond the existing wind-wave regime.

Conclusion

3.4.18 The proposed operational regime, assessed against the site-specific conditions at the Urquhart Bay loch margin:

- Does not activate rapid drawdown instability mechanisms, for the reasons set out in paragraphs 3.4.6 to 3.4.9;
- Does not generate significant additional hydraulic shear stress;
- Does not constitute a distinct erosive forcing mechanism.

3.4.19 The dominant erosive drivers at the loch margin remain wind-wave exposure, substrate characteristics, and vegetation condition. Cyclic stage movement modifies the vertical position of the waterline but does not independently intensify bank erosion relative to a quasi-static summer regime.

3.4.20 Evidence from the Jeziorsko Reservoir – a single case study, but one involving substantially greater fluctuation amplitude and less favourable initial conditions than those at Urquhart Bay – indicates that sheltered, shallow-gradient margins can undergo progressive vegetation colonisation and stabilisation under large-amplitude regimes, particularly within the upper and middle eulittoral zones. The lower, more frequently inundated zones remained sparsely vegetated or bare. This is consistent with the expectation that vegetation response at the Urquhart Bay margin would be spatially differentiated by elevation rather than uniform, but does not support a pathway to widespread de-vegetation of the established woodland margin under a regime of materially smaller amplitude.

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3.5 Root Cohesion, Ground Cover Contribution, and Substrate Stability (SQ4)

Question

3.5.1 Do the root systems of alder, willow and associated W7 graminoid and forb species provide meaningful structural reinforcement to the loch-margin substrate under a cyclic inundation regime? How does this reinforcement interact with wave-driven erosion risk?

Tree Root Reinforcement: The Composite Alder–Willow System

3.5.2 Vegetation increases apparent soil cohesion by adding tensile resistance across potential shear planes, an effect quantified through field measurement, controlled shear testing, and numerical stability analysis (Simon & Collison, 2002; Pollen-Bankhead & Simon, 2009).

3.5.3 Simon & Collison (2002), in field-based bank-stability analyses on incised streambanks, report root-derived increases in apparent cohesion of approximately 2 to 8 kPa for tree species averaged over the upper metre of the soil profile. Grass roots contributed 6 to 18 kPa, reflecting the effect of dense fine-root networks rather than individually stronger roots. These values are of the same order as, or greater than, the intrinsic effective cohesion of many sandy alluvial soils, which may itself be only a few kilopascals. Root reinforcement at this magnitude is therefore mechanically meaningful in controlling shallow shear initiation and surface detachment, even though it does not prevent failure where external hydraulic forcing exceeds soil strength.

3.5.4 Pollen-Bankhead & Simon (2009) report a β value for alder of 0.902, corresponding to approximately 95% of root biomass concentrated within the upper 30 cm, with deeper structural roots present at lower densities. Alder's primary reinforcing contribution is therefore a dense, shallow root plate reinforcing the zone most susceptible to surface scour and shallow shear failure – consistent with the site geomorphology: a flat, sandy, low-lying delta where shallow failure modes, not deep-seated rotational instability, are the relevant concern.

3.5.5 Mickovski et al. (2009), in controlled direct-shear tests on osier *Salix viminalis* roots grown in Scottish sandy soil (71% sand, 19% silt, 10% clay – a substrate comparable in texture to the Urquhart Bay delta sediments), demonstrated shear-strength increases of two- to eight-fold depending on depth. Reinforcement correlated linearly with root area ratio. Failure mode was strongly diameter-dependent, with smaller roots more prone to tensile breakage and larger roots more prone to stretching and pull-out under shear, subject also to confining stress conditions. This progressive, ductile failure mode maintains residual strength beyond peak loading. Although the study used juvenile plants (90-day growth), the mechanisms – tensile resistance, frictional root–soil interaction, and progressive mobilisation – are transferable to established *Salix* spp. at Urquhart Bay.

3.5.6 Bibalani et al. (2008) recorded pull-out forces of 450–860 N for alder (*Alnus glutinosa*) roots in alluvial soils at a riparian site in northern Iran. These values are site- and soil-specific and cannot be transferred quantitatively to Scottish alluvial sediments, but corroborate that alder root systems provide mechanically significant anchorage in alluvial substrates.

3.5.7 The Urquhart Bay Wood loch margin supports a multi-species riparian assemblage. In canopy terms, alder dominates the wetter ground, with willows (including grey willow *S. cinerea* and crack willow) also observed at the shoreline and in the lower-lying parts of the SAC (with other woody species becoming more frequent at higher levels such as ash, gean *Prunus avium*, bird cherry *Prunus padus*, rowan *Sorbus aucuparia*, wych elm *Ulmus glabra*, hazel *Corylus avellana* and blackthorn *Prunus spinosa*). This creates a composite root system spanning shallow fibrous networks and larger structural roots at varying depths. In mechanical terms, this produces overlapping reinforcement across the upper soil profile rather than reliance on a single rooting architecture, increasing resistance to shallow shear and surface detachment relative to a single-species stand.

Ground flora and turf-mat reinforcement

3.5.8 The ground flora in the loch edge area – including meadowsweet, tufted hair-grass, soft-rush, reed canary-grass and in places bottle sedge – concentrates fine-root density in the upper 10–30 cm, directly reinforcing the zone most susceptible to wave scour initiation.

3.5.9 The combination of alder's dense root plate with a fine-root network including graminoids creates a composite reinforcing layer in the uppermost soil horizon. Simon & Collison (2002) found that grass root reinforcement (6–18 kPa from Wu equation estimates) exceeded tree root reinforcement at the immediate surface, driven by high root area ratios rather than individual root strength. This composite system, where tree and graminoid root networks overlap in the upper 30 cm, provides overlapping reinforcement contributions from multiple species and growth forms. Note that likely vegetation change in the loch edge vicinity (see above) includes persistence and likely expansion of the relevant graminoids reed canary-grass and bottle sedge.

Saturation, failure mode, and root integrity

3.5.10 Under saturated conditions, matric suction is reduced and stability depends more heavily on mechanical root cohesion. Simon & Collison (2002) found that even when hydrologic effects were adverse under wet antecedent conditions, mechanical root reinforcement consistently offset the deficit: at the most adverse point monitored, hydrologic effects reduced the factor of safety by 11%, while net mechanical effects increased it by 25%. In some monitored cases under dry antecedent conditions, hydrologic effects of tree cover increased factor of safety by up to 71%.

3.5.11 The interaction between root reinforcement and soil moisture operates through the failure mode of roots. Tensile breakage – governing failure of larger structural roots – is largely independent of soil moisture. Pull-out resistance – more relevant for finer roots with lower surface area (such as those of the existing graminoid species reed canary-grass and bottle sedge, that can occur in swamp and are likely to increase nearer the loch, as discussed above) – declines under saturation as soil shear strength is reduced (Pollen-Bankhead & Simon, 2009; Mickovski et al., 2009). Under the proposed cyclic regime, with the possible exception of the 15.7 m zone (0.3% of the SAC), saturation is relieved by appreciable drying intervals (as noted above, at 15.9 m, 36.1% of the growing season is not inundated, spread across 80 modelled drying events, rising to 59.7% spread across 65 drying events at 16.1 m) allowing partial recovery of matric suction, periodically restoring pull-out resistance.

3.5.12 The existing woodland has developed under a regime of "frequent inundation by floods, changes in channel and accumulations of woody debris" (SSSI citation). The proposed operational regime introduces more frequent but smaller-amplitude wetting cycles – a less severe hydrological disturbance than the existing regime.

Time-lagged vulnerability following vegetation loss

3.5.13 Root cohesion does not disappear immediately upon vegetation death. USACE ERDC (2010) notes that root strength declines progressively as roots decompose, with the rate dependent on species and conditions. Substrate destabilisation requires: vegetation mortality from sustained stress; multi-year root decay; and subsequent exposure of unreinforced soil to erosive forces. This pathway is contingent on prior vegetation removal (addressed under SQ2 and which is not predicted), not on cyclic stage movement alone.

Limits of vegetation protection under wave attack

3.5.14 Feagin et al. (2009), in controlled flume experiments on shallow-rooted smooth cord-grass *Spartina alterniflora* saltmarsh edges, found no statistically significant reduction in lateral wave-induced erosion relative to unvegetated plots ($P = 0.569$), with soil properties acting as the dominant control. The significant breaking wave height in the laboratory was approximately 7 cm, and field conditions were reported as broadly comparable, though occasionally exceeding the tested range.

3.5.15 This study provides a useful boundary condition: vegetation cover does not inherently prevent wave erosion, particularly where rooting depth is shallow and reinforcement is confined to a thin surface layer. Accordingly, claims of vegetation-mediated protection should be evaluated with reference to root architecture, tensile strength, and soil–root interaction rather than assumed from cover alone.

3.5.16 The Urquhart Bay Wood loch edge margin differs qualitatively from the cord-grass saltmarsh system tested by Feagin et al. The species composition is different, it is not marine, and it does not comprise a single species but multiple species. It includes woody species providing reinforcement through deeper tensile root networks, progressive load-sharing under deformation, and evapotranspiration-mediated soil drying during non-inundated periods (Simon & Collison, 2002; Mickovski et al., 2009). These mechanisms increase resistance to shallow shear and undercutting relative to herbaceous turf alone (although as noted above, Simon & Collison (2002) found that graminoid root reinforcement exceeded tree root reinforcement at the surface). However, such mechanisms do not confer immunity where wave power exceeds soil resistance.

Interaction with the proposed cyclic regime

3.5.17 Under the inundation and recovery regime characterised in SQ2: vegetation persistence is predicted; structural root reinforcement remains operative; and fine-root reinforcement is periodically restored during drainage phases. The cyclic regime distributes wave exposure across a vertical band rather than concentrating it at a single contour (see SQ1), reducing the likelihood of sustained undercutting at any one elevation.

Conclusion

3.5.18 The Urquhart Bay Wood loch margin presents a multi-species W7 woodland community whose root systems provide measurable and mechanically significant reinforcement concentrated in the upper 30–50 cm of the substrate. Tree roots contribute additional cohesion of 2 to 8 kPa for individual species under the Wu equation, with fibre-bundle corrections reducing these by approximately one-third (Simon & Collison, 2002; Mickovski et al., 2009). Graminoid ground flora contributes 6 to 18 kPa in the upper soil horizon through dense fine-root networks and their reinforcement exceeds that of tree roots at the surface (Simon & Collison, 2002). In the composite W7 system, where tree root networks overlap with those of multiple ground flora species including graminoids, these provide cumulative reinforcement contributions across a range of depths. Structural root reinforcement from larger-diameter roots is largely independent of soil moisture state; fine-root reinforcement fluctuates with saturation but is periodically restored during drying intervals.

3.5.19 Loss of this reinforcement requires prior vegetation mortality and subsequent root decay over a period of years. The existing community has developed and persisted under frequent flood inundation on this substrate, and compositional changes likely in the most frequently inundated zone around 15.9 m and below include expansion of species that are already present and capable of growing in standing water, such as reed canary-grass and bottle sedge (see SQ2 above). It is therefore not indicated that there would be significant reduction in substrate stability through removal of vegetation cover and root reinforcement.

SQ4 References

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3.6 Substrate Permeability and Soil Drainage Response at the Loch Margin (SQ5)

Question

3.6.1 In a deltaic woodland–loch margin underlain by mapped alluvial sand and gravel deposits, would a cyclic water-level regime characterised by predominantly short-duration inundation events and intervening drying intervals be expected to generate persistent root-zone saturation through drainage lag, or would pore-water levels be expected to track loch stage recession?

Hydrogeotechnical context

3.6.2 The potential for cumulative soil saturation under a cyclic regime depends primarily on:

- The hydraulic conductivity of the superficial deposits;
- The thickness and continuity of any low-permeability horizons;
- The degree of hydraulic connectivity between the shallow groundwater system and the adjacent surface water body.

3.6.3 Drainage lag sufficient to produce season-long elevation of pore-water levels typically requires cohesive, low-permeability soils capable of maintaining pore pressures independently of external stage conditions. In coarse, unconfined alluvial systems, groundwater levels are generally strongly influenced by adjacent surface water boundaries.

3.6.4 The question is therefore whether the loch-margin substrate at Urquhart Bay Wood exhibits characteristics consistent with sustained hydraulic disequilibrium.

Site-specific substrate evidence

3.6.5 Multiple independent sources describe the superficial deposits at Urquhart Bay Wood as deltaic alluvium dominated by sand, gravel and shingle.

- British Geological Survey mapping records the superficial deposit across the SAC as Alluvium (ALV), classified within Fluvial Deposits (FLUV) (BGS Lexicon of Named Rock Units and BGS online mapping);
- The Woodland Trust Management Plan (Woodland Trust, 2023, Section 2) describes the site as situated on “alluvial sand and gravel deposits between the deltas of the Rivers Coiltie and Enrick”, with thin soils and active gravel deposition at the loch margin. The compartment description for the loch-margin area (sub-compartment 1c) records a “flat, sandy, low-lying area of very uneven and disturbed ground forming the delta of the River Enrick at the lochside”, periodically reworked by flooding (Woodland Trust, 2023, Appendix 1);
- The SNH Site Management Statement records channel migration, gravel accumulation and periodic reworking as intrinsic elements of site functioning, including “occasional removal of accumulated gravel” and the presence of “areas of gravel hardstand adjacent to the Drumbuie Burn” (SNH, 2009).

The Natura 2000 Standard Data Form identifies the site geology as "alluvium, sand, shingle" and the geomorphology as "lowland, island, floodplain" (JNCC, 2015).

3.6.6 Collectively, the available site descriptions consistently characterise the active loch-margin as a coarse-grained deltaic substrate dominated by sand, gravel and shingle, rather than a clay- or silt-dominated floodplain deposit. While finer sediment pockets and organic accumulations may occur within redundant channels and interior depressions, no site documentation or management record identifies a laterally extensive, cohesive low-permeability horizon at the current active loch-facing margin.

Hydraulic behaviour of coarse alluvial deposits

3.6.7 Hydraulic response to falling stage is governed by permeability and hydraulic gradient.

3.6.8 In hydrogeological literature, coarse sands and gravels are consistently characterised as highly permeable relative to silts and clays (Freeze & Cherry, 1979). In unconfined alluvial aquifers:

- Shallow groundwater levels typically respond to changes in adjacent surface water level;
- Pore-water pressures dissipate progressively as stage declines;
- Sustained internal pore-pressure elevation independent of boundary conditions is not characteristic unless permeability is low.

3.6.9 At the loch margin below approximately 15.7 m AOD, the substrate is directly exposed to the loch, with no vegetated peat mat or cohesive barrier separating the soil column from open water. This configuration indicates direct hydraulic communication between the loch and the shallow alluvial deposits.

3.6.10 This does not imply instantaneous equilibration, nor does it preclude local variability associated with fine sediment lenses. However, it indicates that the substrate characteristics at the active delta-front margin are consistent with hydraulic connectivity rather than confinement.

Implications under a cyclic inundation regime

3.6.11 Under the modelled regime characterised in SQ2, the potential for cumulative soil saturation depends on whether drainage between events is materially impeded.

3.6.12 On a permeable sand–gravel substrate in hydraulic communication with the loch:

- Groundwater levels would be expected to track stage recession;
- Residual saturation above the declining water table would be limited to capillary retention within the soil matrix;
- Progressive drainage would occur under the hydraulic gradient toward the loch unless inundation frequency exceeded the soil's dissipation capacity.

3.6.13 As noted above, although the 15.7 m band (0.3% of the SAC) would experience 13.4% of growing season uninundated, at 15.9 m 36.1% is not inundated spread across over 80 drying events, rising to 59.7% at 16.1 m. In the context of a permeable alluvial substrate, the physical mechanism required to generate season-long, persistently elevated root-zone water tables at the loch margin is therefore constrained.

3.6.14 Localised slower drainage may occur within fine-sediment swales or organically enriched depressions. Such micro-topographic features are characteristic of interior floodplain areas rather than the actively reworked delta-front loch margin that forms the focus of the drawdown-zone analysis.

3.6.15 In addition, the SAC delta is influenced not solely by loch stage but by independent fluvial inputs from the Rivers Coiltie and Enrick. These tributaries provide a continuous freshwater supply to the deltaic margin that is not governed by operational stage movement in Loch Ness. This independent hydraulic input constrains any drying-stress pathway by maintaining groundwater and soil moisture inputs from upstream even during periods of lower loch level.

Consistency with observed site function

3.6.16 Documented site behaviour includes frequent inundation, gravel redistribution and periodic drying associated with flood recession. Both the Woodland Trust management plan (Woodland Trust, 2023, Section 4.2) and the SNH site documentation (SNH, 2009) describe dynamic wetting and drying as intrinsic to the woodland's ecological context. There is no evidence of persistent waterlogging at the loch margin following flood events as causing structural woodland decline. In this regard it is relevant that median inundation duration is longer at baseline at all levels than under the modelled regime with the pumped storage schemes operating (owing to more fluctuation).

3.6.17 The continued persistence of W7 alluvial alder woodland at the lowest elevations under existing hydrological variability is consistent with a substrate that drains between inundation events rather than retaining prolonged saturation independent of loch level.

3.6.18 Freeze–thaw processes can contribute to surface loosening of exposed substrates during severe winter conditions. However, at the woodland margin the canopy, litter layer and the thermal buffering effect of the loch limit frost penetration at the waterline, and the proposed regime does not materially alter the elevation band exposed to air during winter relative to natural seasonal low-water conditions.

Conclusion

3.6.19 The mapped and described superficial deposits at Urquhart Bay Wood indicate a permeable, hydraulically connected deltaic alluvial substrate at the loch margin.

3.6.20 In such a setting, shallow groundwater levels would be expected to respond to loch stage recession rather than remain persistently elevated through drainage lag. The available substrate evidence does not indicate the presence of extensive low-permeability soils capable of sustaining cumulative pore-water elevation between inundation events.

3.6.21 Accordingly, the hydrogeotechnical characteristics of the loch-facing margin constrain the likelihood that cyclic operational stage movement would generate season-long root-zone saturation sufficient, in itself, to drive structural woodland loss.

SQ5 References

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3.7 Alder Condition and Disease Susceptibility

Scope and framing

3.7.1 NatureScot's February 2026 advice raises two related concerns regarding alder at the loch margin. The first is that altered wetting and drying dynamics under the proposed regime could increase the susceptibility of alder to *Phytophthora alni*, potentially causing dieback and tree death. The second is that where willow may replace alder, but willow regeneration is simultaneously suppressed by herbivore pressure, a reduction in woodland area could result. This section addresses the first concern through a mechanism-led assessment of whether the proposed operational hydrological regime could plausibly create the conditions that the published literature associates with harmful waterlogging stress and elevated *P. alni* susceptibility. The second concern is addressed through a proposed Grazing and Browsing Management Plan discussed in the accompanying Summary Note.

3.7.2 This section draws on peer-reviewed and agency literature reviewed specifically for mechanistic evidence on the conditions under which waterlogging causes physiological damage to alder and predisposes trees to *P. alni* infection, and on the role of water temperature, oxygen content, duration, continuity, and seasonality in determining outcomes. It additionally draws on Hendry and Elliot (2024), the most recent systematic field investigation of alder mortality in Scotland, commissioned by Scotland's Centre of Expertise for Plant Health. That study surveyed alder health across multiple sites in northern Scotland, including riparian stands in the Spey catchment, and examined the distribution and relative contribution of damaging agents including *P. alni*, waterlogging, fungal dieback pathogens, *Armillaria* spp., and competition from invasive species.

3.7.3 NatureScot's February 2026 advice notes that alder "is intolerant of submersion during the growing season and of subjection to stagnant/anoxic conditions." This is drawn from the Scottish field literature on alder decline. This section addresses whether the proposed operational regime creates those conditions, and therefore whether the potential risk pathway identified by NatureScot is engaged.

The harmful waterlogging envelope

3.7.4 Alder is widely documented as tolerant of periodic flooding and of permanently wet but well-oxygenated conditions. Glenz et al. (2006), in a synthesis of flooding tolerance across 65 Central European tree and shrub species, place alder in the highest tolerance class (Class 5, "very high"), alongside crack willow, which is also present at Urquhart Bay. This does not imply unlimited tolerance of any inundation state.

3.7.5 The literature is consistent and specific about the conditions under which tolerance is exceeded. Three lines of evidence converge on the same harmful envelope.

3.7.6 Vyhlídková et al. (2005), examining alder decline along the Lužnice River following the August 2002 flood, distinguished between tolerated spring inundation and damaging summer flooding. They report that during the August event, water temperatures were high, flow velocity declined after peak stage, and in some locations water stagnated for up to four weeks. Under these conditions, trees exhibited root mortality, crown wilt, and subsequent dieback. The authors interpret the decline as polyetiologic, but attribute a marked role to abiotic stress associated with prolonged summer waterlogging and reduced oxygen availability in the root zone. *Phytophthora* was not isolated in their study.

3.7.7 Strnadová et al. (2010), in a controlled greenhouse experiment on four-year-old alder saplings, subjected plants to continuous seven-week inundation during May and June at air temperatures of 20–30°C using pond water with dissolved oxygen below 4 mg/L. The experimental design was explicitly intended to replicate conditions in problematic flooded stands. Even without pathogen inoculation, flooding under these conditions caused significant reductions in height growth, leaf length, foliar biomass, and chlorosis through hypoxia-induced impairment. Adaptive morphology was observed (adventitious roots, hypertrophied lenticels, aerenchyma formation) but did not prevent measurable decline, demonstrating that the species' considerable adaptive capacity has limits when the harmful envelope is met in full.

3.7.8 Hendry and Edwards (2012), investigating alder dieback at the Mound Alderwoods SAC in Sutherland (the most northerly site at which *P. alni* disease has been recorded in Britain) identified two spatially distinct causal pathways operating simultaneously at the same site. In the northern part of the site, *P. alni* was definitively isolated from bark and root lesions, with classic disease symptoms. In the southern part, extensive root mortality with progressive crown dieback was diagnosed in the absence of any detectable pathogen: the evidence pointed firmly to waterlogging damage. Crucially, the authors identified the diagnostic conditions as a permanently high but fluctuating water table, gleyed and anaerobic soil below approximately 30 cm, malodorous anoxic subsoil, and restricted rooting depth confirmed by both soil profile and the depth of ground vegetation roots. They concluded that alder, while tolerant of prolonged dormant-season submersion and permanently wet oxygenated conditions, is intolerant of submersion during the growing season and of sustained exposure to stagnant and anoxic conditions. Dendrochronological analysis confirmed that growth decline had begun in the early 2000s across the site, consistent with a management change in 2001 that replaced proactive flood prevention with reactive flood response, increasing both the frequency and the duration of inundation. The management recommendation was to reinstate flood prevention, specifically to reduce the frequency and duration of inundation rather than eliminate it.

3.7.9 A further strand of evidence is contributed by Tulik et al. (2020), who found measurable deterioration in wood anatomy and hydraulic conductivity in alder exposed to high groundwater levels specifically during the vegetation period, and explicitly noted that short-term waterlogging may be tolerated while repeated or uninterrupted inundation causes serious damage.

3.7.10 The literature therefore indicates that damaging conditions are associated with prolonged growing-season inundation, particularly where warm water and stagnation combine to impair root oxygen status. It does not identify predominantly shorter-duration, repeatedly interrupted inundation of oxygenated loch water as an equivalent stress state.

Does the proposed regime create the harmful waterlogging envelope at Urquhart Bay?

3.7.11 This question is addressed through the combined conclusions of SQ2 and SQ5, applied to the specific physical character of the inundating water.

3.7.12 SQ2 establishes that the predicted inundation pattern at the loch margin is characterised by predominantly short-duration events (the majority at and below 15.9 m AOD being 24 hours or less in duration) separated by repeated drying intervals, including during the growing season. This pattern is distinct from prolonged, continuous, growing-season saturation that the literature identifies as the harmful state. The event-duration analysis demonstrates that even at the lowest elevations, the regime is not one of unbroken inundation. The median inundation duration at 15.9 m AOD under the full in-combination scenario is approximately 10 hours, substantially less than at baseline (25 hours), owing to greater fluctuation with the pumped storage schemes operating, with on average over 80 drying events including over 14 exceeding 24 hours during the growing season at that elevation. Although at the lowest 15.7 m (the 15.7 m band occupying 0.3% of the SAC, and with baseline growing season exceedance already high at 70.7%) 86.6% of the growing season would be inundated, even at this lowest level there are 51 drying events. Moreover and importantly, SQ5 establishes that the mapped deltaic sand–gravel substrate at the loch-facing margin is in hydraulic communication with the loch, such that pore-water levels would be expected to track stage recession rather than remain persistently elevated through drainage lag.

3.7.13 Together, SQ2 and SQ5 constrain the likelihood of the sustained, continuous anoxic saturation at rooting depth that the literature identifies as causally associated with waterlogging damage. The pattern of repeated shorter inundations with intervening drainage intervals on a permeable substrate is physically and physiologically distinct from the conditions that produced damage at the Lužnice River (August 2002: four-week stagnant summer flooding), in the Strnadová experiment (seven-week continuous warm, anoxic inundation), and at the Mound Alderwoods (permanently elevated water table with consistently anoxic subsoil, following effective cessation of drainage management).

3.7.14 The character of the inundating water is a further material distinction. Loch Ness is a large, deep, thermally buffered freshwater body. The water entering the loch margin at Urquhart Bay is loch water subject to wind mixing, thermal exchange and continuous turnover. It is not analogous to the warm, stagnating, oxygen-depleted floodwater in an enclosed floodplain hollow or managed lowland catchment that characterises the high-risk scenarios in the literature. No evidence has been identified to suggest that loch water at the Urquhart Bay Wood margin routinely approaches the dissolved oxygen threshold (below 4 mg/L) used to simulate the harmful stand condition in the Strnadová experiment. This does not preclude localised oxygen depletion within fine sediment pockets or sheltered organic deposits, but such microsite conditions differ qualitatively from a systematic site-wide reduction in root-zone oxygen availability.

3.7.15 Site-specific observational evidence lends support to this assessment. Field observations recorded in AECOM (2026) noted a few mature alder trees at the loch margin growing with root systems fully surrounded by loch water at a level of 15.5 m (below the median summer level) while showing active bud development. This is direct evidence of continued physiological activity and tolerance of the existing hydrological regime at the lowest elevations of the SAC, consistent with the literature's characterisation of alder as tolerant of cold, oxygenated, loch-margin inundation.

3.7.16 The proposed regime alters the frequency and median level of inundation at the margin relative to baseline, but does not cause prolonged static submergence. On the contrary, AECOM (2026) notes that median inundation durations under the full in-combination operational scenario are shorter than at baseline at all elevation bands, because cyclic pumped storage operation creates more frequent reversals and therefore shorter individual inundation events. The concern that soil drainage may lag stage recession such that soils remain continuously saturated is addressed in SQ5, which concludes that the permeable deltaic substrate does not exhibit the hydrogeotechnical characteristics associated with this failure mode.

The *Phytophthora alni* risk pathway

3.7.17 *P. alni* risk involves a sequence of distinct components, each of which is necessary to the causal pathway. The literature does not indicate that increased water contact is a proxy for elevated disease risk.

3.7.18 Jung and Blaschke (2004), examining the distribution of *P. alni* across Bavarian river systems, found that in 58 of 60 river systems with diseased riparian stands, infested nursery plantations or other inoculum sources were identified upstream or within the catchment. They found higher disease incidence where alders had permanent contact with river water or where floodwater was retained for extended periods in floodplains, oxbows, and carrs. Their findings emphasise inoculum presence and hydrological connectivity as primary drivers of distribution, rather than water-level variation as a general condition.

3.7.19 Schumacher et al. (2006), examining epidemic dynamics in the Spreewald, found that winter flooding did not promote spread (pathogen activity was largely suppressed between December and March) and that high infection rates were associated with growing-season flooding where floodwater persisted for extended periods. Trees established on raised banks were rarely infected. Single or episodic infections could be overcome by healthy trees; it was frequent or permanent contact with infectious water during the growing season that led to acute decline.

3.7.20 Bjelke et al. (2016), reviewing the distribution and ecology of *P. alni* across Europe, note that high incidence can occur in non-flooded stands, confirming that flooding is not a necessary condition for pathogen activity. They identify water temperature as a material modifier of pathogen dynamics: cold winters suppress pathogen activity, particularly for certain *P. alni* complex variants, while sporulation increases with temperature. Very high summer temperatures may also limit incidence. The relevant window for elevated risk (warm growing-season conditions with sustained water contact) is consistent with the harmful waterlogging envelope identified in the wider literature.

3.7.21 The Forestry Commission Information Note (Webber, Gibbs and Hendry, 2004) notes that while *P. alni* zoospores are waterborne, they are rarely isolated from river water or soil in the absence of infection events, indicating that successful infection requires particular conditions rather than simply the presence of water.

3.7.22 Applying this evidence to the proposed regime: an increase in the frequency of predominantly shorter-duration loch-margin inundation events does not, of itself, imply elevated *P. alni* risk. The causal pathway requires inoculum presence in the system, exposure of susceptible host root and collar tissue to water carrying active zoospores, conditions suitable for zoospore production and infection (specifically warm growing-season temperatures and prolonged contact with infectious water) and host stress sufficient to reduce resistance. The proposed regime increases the frequency of contact between loch water and the margin, but does not increase the duration of individual growing-season inundation events (which, as noted above, is reduced relative to baseline including at the loch margin), and does not create the sustained warm, anoxic, growing-season root-zone conditions under which host susceptibility is materially elevated.

3.7.23 The status of *P. alni* within the Urquhart Bay catchment and the upper Coiltie and Enrick catchments is not known from the information available for this assessment. This is a residual uncertainty that exists independently of the proposed scheme and is considered further under Section **Residual uncertainties**. An independent line of evidence further constrains *P. alni* risk at this site: the thermal biology of the pathogen itself, which imposes limits on overwinter survival and epidemic potential under cold, thermally buffered conditions.

3.7.24 An important and independently documented dimension of *P. alni* risk is the thermal biology of the pathogen itself. Brasier et al. (2004), in the formal taxonomic description of the pathogen, established through controlled growth tests on carrot agar that *P. alni* subsp. *alni* has an optimum growth temperature of approximately 23–25°C and an upper limit of approximately 29°C. The study also confirmed that the pathogen does not produce chlamydospores and that oospore viability is relatively low (approximately 31–36% for morphologically normal oospores). While oospores are present, their reduced viability compared with many other *Phytophthora* species, together with the absence of chlamydospores, indicates limited development of persistent resting structures. This biological profile is consistent with reduced resilience under sustained cold conditions and supports the conclusion that winter temperature exerts an important constraint on pathogen persistence.

3.7.25 Aguayo et al. (2014) developed and validated an epidemiological model of *P. alni*-induced alder decline across two contrasting climatic regions of France, using six years of monitored crown health data and concurrent soil inoculum measurements. Their analysis identified mean winter temperature and mean summer temperature as the principal climatic drivers of temporal variation in disease prevalence. Low winter temperatures were associated with reduced disease progression and increased likelihood of tree recovery, while milder winters were associated with greater persistence of infection. The authors attribute this pattern to reduced overwinter survival of the pathogen under cold conditions, noting its low oospore viability and absence of chlamydospores. Soil inoculum monitoring demonstrated substantially lower viable inoculum in spring following colder winters relative to milder winters.

3.7.26 The study therefore provides quantitative, field-validated evidence that winter temperature exerts a primary control on pathogen persistence and epidemic dynamics. Aguayo et al. characterise *P. alni* as “a thermophilous organism with relatively high optimal growth temperatures of 22.5–25°C,” reinforcing the mechanistic basis for this climatic sensitivity.

3.7.27 These findings are directly relevant to the assessment of *P. alni* risk at Urquhart Bay. The Aguayo model demonstrates that winter temperature is a principal limiting factor on pathogen persistence and inoculum accumulation. The winter climate of the Great Glen and Loch Ness catchment is colder than the north-eastern French sites examined in that study, where winter conditions were already sufficient to produce recurrent reductions in disease prevalence. In addition, Loch Ness is a large, deep, thermally buffered water body whose surface temperatures remain below the pathogen’s documented thermal optimum for much of the year. These characteristics are consistent with environmental conditions that are less favourable to sustained pathogen growth and inoculum amplification relative to the warmer continental systems examined in France3.7.14.

3.7.28 Independent distributional evidence from Redondo et al. (2015) supports this climatic interpretation. In a systematic survey of sixteen river systems in southern Sweden, the probability of detecting *P. alni* subsp. *alni* was strongly and positively correlated with mean February temperature and negatively correlated with the duration of heavy frost periods. The more pathogenic subspecies was confined to the milder end of the winter temperature gradient, whereas colder locations were associated predominantly with *P. alni* subsp. *uniformis*. The authors attribute this distributional pattern to the greater sensitivity of subsp. *alni* to sustained frost conditions. These findings provide field-scale evidence, at a northern European latitude comparable to Scotland, that colder winter regimes act as a significant ecological constraint on establishment and persistence of the most aggressive member of the *P. alni* complex.

The synergistic pathway

3.7.29 The experimental evidence for a combined waterlogging–*P. alni* effect is principally provided by Strnadová et al. (2010), whose controlled experiment demonstrated that the combined flooding and inoculation treatment produced substantially worse outcomes (including greater necrosis extent and reduced biomass) than either alone. However, the experimental conditions are the critical qualification: the flooding treatment was specifically designed to replicate the harmful stand condition – warm, continuously stable, low-oxygen, seven-week growing-season inundation. The synergistic amplification of pathogen impact was demonstrated under that specific stress state, rather than under periodic predominantly shorter-duration inundation with intervening drainage.

3.7.30 Bjelke et al. (2016) note that summer flooding can exacerbate *P. alni* impacts by stressing trees and creating physical damage facilitating pathogen entry, and that flood events facilitate zoospore dispersal from infected bark. These operate through the preconditions already discussed — prolonged growing-season exposure, inoculum presence, and host stress sufficient to impair resistance — rather than through water-level variation alone.

3.7.31 An additional observation from the Strnadová experiment is relevant to the characterisation of risk: under the most extreme anaerobic conditions at depth in the experimental treatment, *P. alni* was less able to infect deep roots, as the strongly reducing conditions were hostile to pathogen activity at that depth. The experiment thus demonstrated that at the extreme end of the anoxic waterlogging envelope, direct hypoxic damage to the root system and suppression of pathogen activity at depth can co-occur. This observation reinforces the principle that the disease risk and waterlogging damage pathways are not simply additive functions of water contact: they have distinct physical requirements and do not both increase monotonically with inundation frequency or duration.

3.7.32 The synergistic risk pathway is therefore contingent on the establishment of the specific stress state documented in the literature (sustained warm, anoxic, growing-season saturation at the rooting zone) as the predisposing condition for elevated susceptibility. As SQ2 and SQ5 conclude, that stress state is not established by the proposed operational regime.

Contextual comparison with the Mound Alderwoods

3.7.33 The Mound Alderwoods case (Hendry and Edwards, 2012) is directly instructive as a Scottish analogue, and merits explicit comparison with the Urquhart Bay context.

3.7.34 At the Mound, waterlogging damage occurred following a management change that effectively ceased proactive drainage management of a lowland floodplain site at the mouth of an estuary. The site occupies a flat alluvial plain at sea level, regulated by sluices whose failure to operate preventively resulted in increasing frequency and duration of inundation that the management history suggests was materially greater than the long-term baseline the woodland had occupied and tolerated. The substrate in the affected southern areas was described as showing gleying throughout the sandy layer (evidence of persistent seasonal saturation) with malodorous anaerobic subsoil, restricted rooting depth, and hypertrophied lenticels indicating chronic high water tables. The water table was elevated and effectively static rather than rapidly cycling.

3.7.35 The Urquhart Bay situation differs in each of these material respects. The margin is on a hydraulically active deltaic substrate with independent fluvial inputs maintaining soil moisture connectivity. The proposed regime introduces more frequent inundation events but the median duration is less relative to baseline, with modelled drying intervals throughout the growing season. The loch water is thermally moderated and mixed rather than static and warming. The substrate drains between events rather than remaining in a state of chronic saturation. And the existing alder population is already established at the loch margin under current hydrological variability, including the existing Foyers scheme operations, with no reported evidence of systematic condition decline of the type documented at the Mound.

3.7.36 The Mound case illustrates in a Scottish context that the pathway from hydrological change to waterlogging damage and *P. alni* amplification runs through persistent, chronic, growing-season anoxia at the root zone – and that where those conditions are not established, the causal pathway is not engaged.

Residual uncertainties

3.7.37 The preceding analysis identifies no pathway by which the proposed regime would establish the harmful envelope documented in the literature. The following residual uncertainties are acknowledged in the interests of completeness and proportionate risk assessment.

3.7.38 *Pathogen presence and inoculum pressure*. Whether *P. alni* is present in the local catchment (including the upper Coiltie and Enrick catchments and any reaches flowing through or near previously affected woodland) is not known from available information. Hendry and Elliot (2024) confirm that Scottish records of the pathogen are concentrated in east coast river systems including the Rivers Avon, Dee, Deveron, Duirinish and Spey; no records from the Great Glen or Loch Ness catchment are identified in that survey or in any other source examined for this assessment. This does not confirm absence, but it is consistent with the thermal and hydrological characteristics of the catchment discussed above. Hendry and Elliot further note that where *P. alni* has been present in a Scottish catchment over an extended period — including at a site on the River Avon where infection was confirmed in 1997 and a monitoring plot established in 1998 — the majority of alder stools remained present at resurvey, with only a small proportion showing recent decline and a younger regeneration cohort in good health. This evidence of long-term stand persistence in a historically infected catchment is relevant to the characterisation of risk: pathogen presence does not automatically equate to progressive stand failure, and outcome is substantially mediated by site conditions and host stress loading. If inoculum is present in the Urquhart Bay Wood catchment, hydrological connectivity is already a relevant factor under the existing regime. The additional exposure pathway introduced by increased predominantly shorter-duration loch-margin inundation is incremental relative to pre-existing connectivity through active fluvial channels. A targeted environmental DNA survey of catchment water or pathological survey of upstream riparian stands would reduce this uncertainty.

3.7.39 *Localised microsite conditions.* Oxygen depletion within sheltered organic deposits, fine-sediment swales, or debris accumulations at the margin cannot be excluded, and such features may exhibit conditions approaching the harmful envelope even where the wider substrate drains efficiently. These microsites, where they exist, are present under baseline conditions and are not introduced by the proposed regime.

3.7.40 *Current alder condition.* Background root health and any existing stress loading on the stand (from sources including herbivore browsing, wind throw, bank disturbance, or undetected subclinical infection) could influence susceptibility thresholds. A field pathological survey of current tree condition at the margin would provide baseline data relevant to assessing this uncertainty.

3.7.41 *Thermal-biology evidence base.* The thermal constraint argument in Sections 3.7.24–3.7.28 is supported by Brasier et al. (2004), Aguayo et al. (2014) and Redondo et al. (2015). Additional experimental evidence is provided by Chandelier et al. (2006), who reported that *P. alni* did not produce sporangia in river water at 8 °C and that sporulation increased with increasing water temperature in seasonal river conditions. This finding supports the temperature-limitation mechanism discussed above and is consistent with the interpretation that cold, thermally buffered freshwater conditions constrain epidemic potential.

Conclusion

3.7.42 The published literature on alder decline in Europe consistently identifies a specific and well-characterised harmful waterlogging envelope: sustained warm, stagnant, anoxic, growing-season inundation generating persistent anaerobic conditions at the rooting zone. This is the condition under which both direct waterlogging damage and elevated *P. alni* susceptibility are documented. The conditions under which alder is harmed by flooding are described with sufficient precision in the literature to distinguish them clearly from the conditions associated with tolerance, that distinction turning on temperature, oxygen status, stagnation, and the continuity and seasonality of saturation at root level, rather than on water-level variation as a general property.

3.7.43 The proposed operational regime at Loch Ness does not replicate that harmful envelope. SQ2 demonstrates that the modelled inundation pattern is characterised by predominantly short events with repeated growing-season drying intervals, and that median inundation durations are shorter than at baseline at all elevation bands due to cyclic operation. SQ5 demonstrates that the permeable deltaic substrate at the loch-facing margin drains between events rather than sustaining chronic elevated pore-water levels. The physical character of the inundating water (large, deep, thermally buffered, oxygenated loch water rather than stagnant, warming floodwater) is materially different from the conditions documented in the primary harm scenarios.

3.7.44 The risk pathway of increased susceptibility to alder phytophthora under wetter conditions is contingent on the establishment of persistently elevated and anoxic growing-season soil moisture conditions. That precondition is not established by the proposed regime on the basis of the mechanistic evidence presented in SQ2 and SQ5. On the basis of the reviewed literature applied to the site-specific context, a mechanistic pathway from the proposed operational regime to materially elevated waterlogging damage or *P. alni* susceptibility at Urquhart Bay Wood has not been identified.

3.7.45 Residual uncertainties including pathogen presence in the catchment and localised microsite behaviour remain and should be addressed through targeted survey and monitoring proportionate to the planning determination process.

Section 3.7 References

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4. Concluding Synthesis

4.1.1 Taken collectively, the analyses under Sub-Questions 1–5 do not support a mechanistic pathway by which the proposed operational regime would be expected to generate a persistent de-vegetated drawdown zone at the Urquhart Bay Wood SAC margin. The assessment explicitly considers the combined effect of the elevated median summer level and the higher-frequency cyclic variation across the 15.7–16.5 m AOD elevation bands identified in the Additional Information mapping.

4.1.2 For the purposes of this assessment, "persistent de-vegetation" refers to sustained loss of continuous vegetative cover sufficient to expose underlying substrate to direct and repeated wave attack across a contiguous elevation band at the woodland–loch interface, such that biogenic reinforcement is removed and erosional processes become self-maintaining. This corresponds to the "unvegetated drawdown zone" described in NatureScot's February 2026 advice.

4.1.3 First, SQ1 concludes that under the proposed cyclic regime wave exposure is redistributed across an elevation band rather than concentrated at a single fixed contour over seasonal timescales. The modest upward shift in median summer level alters the vertical position of the active band but does not recreate prolonged seasonal dwell at a fixed elevation comparable to a quasi-static summer condition.

4.1.4 Second, SQ2 concludes that prolonged saturation would not alone cause de-vegetation (although the modelled inundation regime would induce changes in floristic composition). There is a general absence of sustained static submergence (including during the growing season, with 36.1% of the growing season not inundated at 15.9 m, spread across over 80 drying events, rising to 59.7% across 65 drying events at 16.1 m). On the basis of the event-duration and drying analyses, and in combination with SQ5, a pathway to progressive, long-term elevation of root-zone wetness independent of loch stage is not supported. Expected floristic changes include expansion around and below 15.9 m of graminoid species that exist at and near the existing edge, such as bottle sedge and reed canary-grass that are capable of growing in water, and possible replacement of some alder by willow in this vicinity. Additionally, the transition between W7 wet woodland and W9 dry woodland will shift upwards as a result of increased wetting, however both constitute the qualifying alluvial alderwood at this SAC. Such changes are not inconsistent with the highly dynamic nature of the alluvial woodland.

4.1.5 Third, SQ3 concludes that the site-specific conditions at the loch margin: a shallow deltaic gradient of approximately 1:100, permeable alluvial substrates, and frequent operational reversals limiting sustained drawdown duration, do not support the geotechnical preconditions for rapid-drawdown instability under the proposed stage change regime. The dominant erosive driver remains wind-wave action. Cyclic vertical translation of the waterline modifies the elevation at which wave exposure occurs but does not introduce an additional hydraulic forcing mechanism.

4.1.6 Fourth, SQ4 concludes that the composite soil–root matrix formed by alder, willow and ground flora provides significant near-surface reinforcement, and that the graminoid contribution is appreciable and exceeds that of tree roots at the surface. Destabilisation through loss of root cohesion requires prior vegetation mortality and removal which is not indicated by SQ2. It is therefore not indicated that there would be significant reduction in substrate stability through removal of vegetation cover and root reinforcement.

4.1.7 Fifth, SQ5 concludes that the mapped and described deltaic sand–gravel substrate at the active loch margin supports hydraulic connectivity with the loch and progressive drainage between inundation events, rather than confinement consistent with season-long drainage lag. The hydrogeotechnical setting therefore constrains the likelihood of cumulative pore-water elevation between repeated inundation episodes.

4.1.8 3.7**Error! Reference source not found.**In relation to the SAC conservation objectives, NatureScot's advice indicates that transitions between woodland types including development of wetter types is acceptable within-feature change, and that some change to open swamp would also be acceptable if not wide-scale, since swamp is part of the ecosystem. Floristic changes towards wetter vegetation are likely at the lower elevations, particularly around the 15.9 m band and below, such that existing wetter woodland would likely develop increased open swamp of the same baseline types, and willow may replace a proportion of alder in this vicinity. However, the majority of the SAC (97.1%) lies above the 15.9 m band, thus such floristic change, involving species already present in the alluvial woodland ecosystem, would not be wide-scale, and is not inconsistent with the highly dynamic nature of the ecosystem. The conditions required to drive sustained woodland dieback and wide-scale conversion to persistent open wetland are not indicated by the modelled hydrological regime.

4.1.9 NatureScot's advice notes that where conditions become more suitable for willow but herbivore pressure suppresses willow regeneration, this mechanism could result in woodland reduction. This is acknowledged, herbivore pressure being a known management concern in the SAC, and given that willow may expand in the lowest parts of the SAC. A commitment to a proposed Grazing and Browsing Management Plan is therefore made, which is discussed further in the separate Summary Note.

4.1.10 The assessment remains sensitive to site-specific factors including wave exposure characteristics at Urquhart Bay, local substrate heterogeneity within the deltaic margin, vegetation recruitment dynamics, in-combination operating patterns across all consented and proposed pumped storage schemes including ramping behaviour, and background disease pressures including alder phytophthora susceptibility under altered moisture regimes.

4.1.11 On the basis of established geomorphological, ecological and hydrogeotechnical principles applied to the site-specific context as defined in this Additional Information submission, the available evidence does not support a mechanistic pathway by which the proposed operational regime would be expected to give rise to persistent de-vegetation of the Urquhart Bay Wood SAC margin. Floristic changes would constitute acceptable change within the alluvial alderwood ecosystem and consistent with its dynamic nature, and would not be wide-scale. As such, it is concluded that there will not be an adverse effect on site integrity of Urquhart Bay Wood SAC, either by the Proposed Development alone or in-combination with other plans and projects. The integrity determination under the Habitats Regulations remains however a matter for the competent authority, informed by the combined evidence presented within the full submission.

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