BEFORE INDEPENDENT COMMISSIONERS APPOINTED BY THE SOUTHLAND REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND IN THE MATTER	of various resource consent applications for periodic openings of Waituna Lagoon Waipārera by Te Rūnanga o Awarua, the Department of Conservation and the Southland Regional Council (Environment Southland) [the Applicants]
Application No.	**APP-20242456**

Evidence of Marc Schallenberg - Limnologist

on behalf of the Applicants

Dated: 10 July 2025

Department of Conservation | *Te Papa Atawhai*
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Executive Summary

A. Waituna Lagoon is a coastal lagoon. It is noteworthy because it is in a somewhat natural condition, with persistent healthy aquatic plant communities, unlike other intermittently open and closed coastal lakes/lagoons on the east coast of New Zealand, which are generally more degraded.

B. Waituna Lagoon is part of an internationally recognised wetland under the Ramsar Convention. It has a variety of ecological values and it provides substantial ecosystem services to Southland communities.

C. Numerous studies have indicated that the lagoon ecosystem is under threat from high nutrient loads and from an opening regime that does not adequately account for ecological values and services. The aquatic plant/macrophyte communities, and especially the seagrasses (*Ruppia* sp.), play a key role in maintaining ecological health; however the aquatic plant communities seem to be in decline in recent years. Although intermittently open and closed coastal lakes/lagoons are vulnerable to rapid degradation (i.e., ecological tipping points), the cumulative stressors have not yet resulted in persistent de-vegetation and a transition to a persistent degraded state.

D. Previously to 2017, the opening regime resulted in frequent openings to maintain low water levels in the lagoon, with no regard to ecological values. Since 2017, the opening regime has been modified slightly to bring it closer to an inferred "natural" opening regime. After 5 years of a modified opening regime with slightly higher water level trigger values, it was found that the new trigger values had little effect on the opening regime.

E. A further modification to the opening regime conditions is sought which would increase the water level trigger value towards a more natural opening regime while also providing mechanisms to alleviate potential ecological stressors that could eventuate, such as extended periods of opening during spring and summer, prolonged periods of closure (e.g., greater than 2 years), and algal blooms in the lagoon.

F. The proposed opening regime is designed to shift the lagoon towards a more "natural" opening regime while safeguarding the lagoon's diverse ecological values. This is part of an adaptive management process toward a clear goal, requiring the monitoring of early warning indicators of degradation, repeated reassessment of conditions and trends, and the flexibility to open the lagoon for enhanced flushing and fish passage, if required.

Introduction

1. My full name is Marc Schallenberg.

2. I have been asked by the Applicants to provide expert evidence on their application for resource consents to periodically open Waituna Lagoon to the sea.

Qualifications and experience

3. I am the Director and Principal Scientist of Hydrosphere Research Ltd, a small environmental consulting company. I founded the company in 2011. Since then, it has completed 93 contracts from central government departments and ministries, regional councils, crown research institutes, as well as industry and community groups. While heading Hydrosphere, I have gained experience in the application of environmental science to resource management and in providing policy advice on freshwater and estuarine science. I have also written numerous lake restoration plans.

4. I am also employed part-time by the University of Otago as an Associate Research Professor. I have worked for the University of Otago since 1994. Over my career, I have accumulated experience working on approximately 150 lakes and lagoons from Northland to Steward Island, Campbell Island and Antarctica. My main areas of research include the impacts of eutrophication, invasive species, climate change on lakes and lagoons, and the use of palaeolimnology to infer environmental history from sediment cores.

5. From 1993 to 1994 I worked for the National Institute of Water and Atmospheric Research based in Christchurch, where I participated in a research programme on Lake Coleridge (Canterbury).

6. I gained my PhD in 1993 from McGill University, Canada. My dissertation focused on the microbial ecology of lakes.

7. I have been an expert witness in three environment court hearings and in numerous regional council resource consent hearings. I've been a member of numerous technical advisory groups assisting the Ministry for the Environment draft different iterations of the National Policy Statement for Freshwater Management where I provided expertise on lakes and lagoons. I've been a member of three technical advisory groups that provided scientific input specifically for the management of Waituna Lagoon. I've also been employed by the Otago Regional Council, Environment Canterbury, Greater Wellington Regional Council, and Hawkes

Bay Regional Council to provide advice on intermittently closed estuaries/lagoons in those regions.

8. I've written or co-written nine book chapters, 73 peer-reviewed journal articles, and 72 technical reports. Fifteen peer-reviewed journal articles and 21 technical reports have focused on lagoons and estuaries. Waituna Lagoon was the focus of one of my peer-reviewed journal articles and four of my technical reports.

Code of Conduct

9. Although this is a Council hearing, I have read the code of conduct for expert witnesses as contained in the Environment Court's Practice Note 2023 (the Code). I have complied with the Code when preparing my written statement of evidence.

10. The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence below. The reasons for the opinions expressed are also set out in the evidence below.

11. Unless I state otherwise, this evidence is within my sphere of expertise, and I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

12. For the avoidance of doubt, in providing this evidence as an expert witness in accordance with the Environment Court Code of Conduct, I acknowledge that I have an overriding duty to impartially assist the Commissioners on matters within my area of expertise. The views expressed are my own expert views, and I do not speak on behalf of the Applicants and, in particular, I do not speak for The University of Otago.

Scope

13. I have been asked to provide evidence in relation to coastal lake functioning and ecological processes relevant to Waituna Lagoon.

14. My evidence addresses the following matters:
    a. What are intermittently closed and open coastal lagoons?
    b. How do they differ from permanently open estuaries and freshwater lakes
    c. How do open and closed phases affect water quality and the lagoon biota

d. The importance of aquatic plant/macrophyte communities to the health of Waituna Lagoon
e. Current threats, vulnerabilities and the likelihood of ecological tipping points in the Waituna Lagoon ecosystem
f. Key values and ecosystem services of Waituna Lagoon
g. The influence of the opening regime on the lagoon health
h. What would a "natural" opening regime of Waituna Lagoon be like
i. Aims of the proposed new opening regime
j. Adaptive management of the opening regime: the importance of early warning indicators, monitoring, reassessment, and the flexibility to open the lagoon if required

Material Considered

15. In preparing my evidence I have read and relied upon the following documents:
    a. The technical review of conditions for opening Waituna Lagoon, February 2024
    b. The s42A Council Hearing Report
    c. Technical reports, a peer-reviewed journal article, a PhD dissertation, and a news media article listed under References, in Appendix 1.

16. Since 2006, I have undertaken numerous studies on Waituna Lagoon, including work on aquatic plants, light penetration, macroalgae, water quality, groundwater inputs, and palaeolimnology (environmental history).

Application and supporting documents

17. **Waituna Lagoon is an intermittently closed and open lagoon:** Waituna Lagoon is characterised by having a barrier bar which sometimes blocks the estuary mouth. As a result, there are two distinct hydrological phases:
    a. An open phase, when water in the lagoon is tidal and is able to exchange with sea water; and
    b. A closed phase, when the tidal influence is minimal, the lagoon water level is higher than sea level, and the water in the lagoon reduces in salinity.

    Such systems have been referred to as intermittently closed and open lakes/lagoons (ICOLLs), intermittently closed estuaries, or Waituna-type lagoons. I will use the term ICOLL when referring to Waituna Lagoon and other estuaries with both open and closed phases.

18. **ICOLLs differ in important ways from open estuaries and freshwater lakes:** Due to the two hydrological phases described above, as well as being located along coasts, ICOLLs are dynamic water bodies, with complex ecologies. Table 1 summarises some general differences between the functioning of ICOLLs, open estuaries, and lakes. ICOLLs were only explicitly brought under a policy framework in the NPSFM in 2017, which first provided water quality guidelines for them. The guidelines only applied to conditions when the ICOLLs are closed.

Table 1. Summary of some attributes of ICOLLs, permanently open estuaries, and freshwater lakes. These are descriptions of the general characteristics and some exceptions to these can occur. The principal regulatory domains governing the water quality and ecosystem health of the different systems are also indicated.

Attribute	Intermittently closed estuary	Permanently open estuary	Lake
Salinity/Marine influence	Salinity varies; higher when open (but influenced by tides), lower when closed	High and influenced by tides	Low
Tidal flushing	Occurs when open	Continuous	None*
Water level variability	Higher than tidal range; often governed by consents	Determined by tides	Lower
Outflow	Intermittently blocked; often manually opened	Permanent connection to the sea	Permanent outflow to river (unless impounded)
Types of organisms present	Freshwater (itinerants), estuarine and marine (itinerants)	Estuarine and marine	Freshwater (and estuarine, for tidally-influenced lakes)
Principal regulatory domain	National Policy Statement for Freshwater Management (NPSFM) and regional land/water plans (NPSFM provides guideline conditions only for when ICOLLs are closed)	National Coastal Policy Statement and regional coastal plans	NPSFM and regional land/water plans

* excludes tidally-influenced lakes such as Lakes Waihola and Waipori (Otago)

19. **The effects of open and closed phases on water quality and lagoon biota:** Due to the hydrological complexity and the dynamic nature of ICOLLs, water quality can vary greatly over time, especially with regard to salinity, water clarity, nutrient concentrations, dissolved oxygen concentrations, and phytoplankton biomass. When open to the sea, the water quality of those ICOLLs that have strong tidal flushing (e.g., Waituna Lagoon; Schallenberg et al. 2010) and will approximate the water quality of the sea water that tidally exchanges with the lagoon water. For example, under the influence of strong tidal flushing, the salinity will tend

to be higher and nutrient concentrations will tend to be lower, compared to a lagoon with weak tidal flushing. Some ICOLLs, such as Lake Ellesmere/Te Waihora, exhibit less tidal flushing resulting in less marine influence during openings (Schallenberg et al. 2010). Generally, the stronger the tidal flushing, the longer the duration of opening, and the more frequent the openings, the more marine influence an ICOLL will experience.

20. In contrast, when an ICOLL is closed, it will begin to fill with freshwater inputs from the catchment, decreasing the salinity of the ICOLL. The closed barrier bar restricts tidal flushing, which can result in the build-up of nutrients and phytoplankton biomass in the ICOLL, especially if nutrient loads from the catchment are high. This eutrophication process (increase in nutrients and algal biomass) can repeat during subsequent closed phases, as it does in Waituna Lagoon. The proliferation of macroalgae and phytoplankton during closed phases can be such that water clarity can decline and oxygen stress can occur. If anoxic "dead zones" develop, this can have rapid and severe consequences for the plant, invertebrate and fish life in the lagoon. The development of anoxia in the bottom waters (and the development of high pH in the daytime due to high rates of photosynthesis) can also increase the rate of nutrient recycling, causing an ecological feedback to occur, which favours algal blooms at the expense of aquatic plants, fish and invertebrates. Such shifts in lagoon functioning can be persistent and difficult to reverse, as in the case of Lake Ellesmere/Te Waihora (Canterbury).

21. **The importance of the aquatic plant/macrophyte communities in Waituna Lagoon:** Many New Zealand ICOLLs have crossed ecological tipping points, where the beneficial aquatic plant communities have suddenly died out and water quality has subsequently deteriorated. Examples of such ICOLLs are Hawkesbury Lagoon (Otago), Wainono Lagoon (South Canterbury), Lake Ellesmere/Te Waihora (Canterbury), Lake Wairarapa (Wairarapa), Lake Onoke (Wairarapa) and Whakaki Lake (Hawkes Bay). These ICOLLs have been in a degraded state for some time, suffering from algal blooms and low water clarity. Other ICOLLs undergo alternations between a degraded state and a clear-water state, during which aquatic plants temporarily recover. Examples of alternating ICOLLs are the Tomahawk Lagoons (Otago) and Lake Forsyth/Wairewa (Canterbury). These ICOLLs can remain in a devegetated state susceptible to algal blooms for a few years before shifting back to a vegetated state and vice versa.

22. In comparison to the above listed ICOLLs, Waituna Lagoon is exceptional in that it retains its aquatic plants and many of its important ecological values to this day (Schallenberg & Tyrrell 2006; Waituna TAG 2013). The presence of healthy aquatic plant communities is essential for maintaining the ecological health of ICOLLs. Aquatic plants remove nutrients from the water column (reducing the risk of macroalgae and phytoplankton blooms), they dampen wave energy thereby maintaining water clarity, they provide habitat for fish and invertebrates, and they oxygenate the water. For these reasons, the maintenance of communities of aquatic plants, such as the seagrass, *Ruppia* sp., in Waituna Lagoon is critical for maintaining water quality and ecological values. For further information, refer to the evidence of Ms de Winton.

23. **Current vulnerability of Waituna Lagoon:** Waituna Lagoon is the only substantial ICOLL on the east coast of New Zealand with an ecological condition that is somewhat "natural". A key indicator of the health of ICOLLs is the persistence of aquatic plant communities, particularly the health of seagrass community of *Ruppia* sp. While Waituna Lagoon has not flipped to a prolonged devegetated and degraded state, some "alarm bells" have been ringing, pointing to the vulnerability of the aquatic plants. Three key threat indicators include, (1) high nutrient loads from the catchment that exceed a threshold that would safeguard the aquatic plants and the lagoon (Waituna TAG 2013), (2) high year-to-year variability in aquatic plant biomass in the lagoon, with some recent years showing very low aquatic plant abundance scores (de Winton et al. 2023; Table 2 in Robertson et al. 2024), and (3) an unprecedented phytoplankton bloom that occurred in the lagoon in January 2024, which threatened the ecosystem and necessitated an emergency opening of the lagoon (Environment Southland 2024, Figs 1 and 2; Southland Times 2024). These indicators suggest that Waituna Lagoon is poised to cross an ecological tipping point, which would likely result in rapid and persistent degradation, as was documented in Lake Ellesmere/Te Waihora in 1968.

24. **Key ecological values and ecosystem services of Waituna Lagoon:** Because Waituna Lagoon still exhibits a somewhat "natural" state, it still retains many values that other degraded ICOLLs have largely lost (Table 2). Further details on the assessment of the multiple values of Waituna Lagoon is presented in the evidence of Dr Robertson.

Table 2. List of some of the important ecological values and ecosystem services provided by Waituna Lagoon in its current condition.

Ecological values
Migration route, nursery, and feeding area for native fish, including giant kokopu
Integral to high value Awarua Wetlands, with rare plants

Important water bird habitat
Brown trout fishery
Supporting and regulating ecosystem service
Removal of nitrogen (dentirification) and phosphorus (sequestration) from the coastal zone
Aquatic plants maintain water clarity
Flooding of fringing wetlands (when closed) and flood protection (when open)
Biodiversity hot spot
Provisioning ecosystem services
Fishing
Duck hunting
Food basket/mahika kai
Cultural ecosystem services
Boating
Bird watching
Fishing
Hunting
Tourism
Mahika kai gathering
International obligation
Ramsar Wetland of International Importance

25. Together, the ecological values and ecosystem services in Table 2 contribute to Waituna Lagoon's unique natural environment and ecology as well as to its international conservation status as was recognised under the Ramsar Convention on Wetlands in 1976. Supporting and regulating ecosystem services are attributes of the Waituna Lagoon ecosystem that underpin all the other ecosystem services and values. Provisioning ecosystem services include tangible products that are extracted for use, including food and fibre. Cultural ecosystem services represent activities that are of significance to people that use, or live in the vicinity of, Waituna Lagoon.

26. **Main threats to the ecological health of Waituna Lagoon:** In 2013, the Waituna Technical Advisory Group (Waituna TAG) was set up to undertake investigations aimed at (1) determining the current conditions of the lagoon and (2) developing guidelines for the safeguarding of the lagoon's values (Waituna TAG 2013). The TAG identified key ecological values as well as the two main threats to those values, which included nutrient loads from the catchment and the opening regime, which, at the time did not account for ecological values.

27. The TAG gathered multiple lines of evidence to estimate the nutrient load limits that would safeguard the lagoon's values. Calculated actual N and P loads at the time were approximately 50% higher than the estimated safe upper limits for both nutrients. While this

finding stimulated some agricultural mitigations in the catchment, I believe that the nutrient loads have not yet been reduced to the safe recommended guidelines in the TAG report. This indicates that nutrient loads continue to threaten the ecology and values of the lagoon – a conjecture confirmed by the continuing high N and P concentrations measured in the lagoon during closed phases (see Fig. 8a in Robertson et al. 2024).

28. **The importance of the opening regime:** As part of the TAG's assessment (Waituna TAG 2013), it discussed some changes to the opening regime that could improve the ecological values of the lagoon. This initiated ongoing discussions which have culminated in modifications to the opening regime consented in 2017 and to the current resource consent application supported by my evidence. While the opening regime is an important attribute influencing the ecological values and services of the lagoon, it is also a key mitigation tool for preventing excessive nutrient buildup in the lagoon. Therefore, an optimal opening regime under the current nutrient load scenario must also consider the threat of eutrophication due to the nutrient issue.

29. Lagoon openings alleviate nutrient build up and resultant algal blooms in the lagoon. Openings also allow for fish migration. However, frequent openings and prolonged low water levels have negative consequences for other lagoon values. For example, *Ruppia* sp. benefit from periods of decreased salinity (e.g., between c. 3 and 10 ppt) in spring and early summer, when the germination of new plants occurs (Gerbeaux 1989; see also Ms de Winton's evidence). Therefore, the health of the seagrass community is improved when the lagoon is closed during the spring and early summer. Furthermore, summer openings at Waituna Lagoon are often associated with blooms of macroalgae (e.g. sea lettuce), which negatively impact *Ruppia* and other aquatic plants. This occurs when macroalgae proliferations smother aquatic plants, intercepting light and impeding water flow and oxygenation. Therefore, the health of the seagrass community benefits two ways from lagoon closure in spring and summer: lower salinity facilitates germination of young plants, and a deeper, closed lagoon inhibits macroalgal blooms. Furthermore, when the lagoon is full, there is more habitat for fish and invertebrates and the fringing wetland also benefits because flooding of the soils inhibits terrestrial plants, which could invade the wetland if it remains dry for extended periods of time. A full lagoon in summer also benefits other values, such as boating, fishing, as well as cultural values that Mr. Whaanga discusses in his evidence.

30. **Inferring the "natural" Waituna Lagoon opening regime:** One approach to determining a more ecological opening regime is to infer what the opening regime would be like if the lagoon were not opened manually. Under this scenario, the maximum water level would rise, and it is likely that the durations of open and closed phases would change. The durations of closed phases would likely increase as the lagoon's filling height would increase. Eventually, natural runoff would overtop, and then cut through, the barrier, creating break out. The increased hydraulic head of a fuller lagoon could make deeper cuts through the barrier bar, especially if sea conditions were calm at the time of the breakout. Deeper cuts would probably take longer to close, resulting in longer durations of opening (compared to current opening phases). However, if sea conditions were not ideal for a good cut during the breakout, then cuts through the barrier bar might not be deep, resulting in more rapid closures (shorter open phases). Currently, when opened manually, the digger operators will open the lagoon only during favourable sea conditions as this provides a deep cut, a longer duration of opening, and better drainage of soils. Under a "natural" opening regime, breakouts would likely happen regardless of sea conditions. So, under such a scenario, both deep and shallow cuts are likely to occur and, therefore, durations of openings could be more variable (shorter and longer) than they currently are, when the lagoon is opened manually.

31. In summary, my best estimate of a natural opening regime is that it would have the following characteristics, in relation to the current opening regime:

    a. Maximum water levels: higher than current (greater depth of the lagoon than current)
    b. Maximum size of the lagoon: greater than current
    c. Minimum water levels: more variable than current
    d. Duration of closures: longer than current
    e. Duration of openings: more variable than current
    f. Frequency of openings: less frequent than current
    g. Tidal flushing: more variable than current; stronger after deep cuts, weaker after shallow cuts
    h. Salinity variations: greater than current

32. **Towards a more "natural" opening regime, while balancing the diverse values of Waituna Lagoon:** A "natural" opening regime may be considered a desired endpoint for long-term ecological restoration of the system if seeking to restore the natural character of New Zealand's indigenous ecosystems. Such an opening regime would be driven solely by the geomorphology of the barrier bar (dependent on local ocean energy), seepage through the

barrier bar, and by the hydrological dynamics of runoff from the catchment into the lagoon. Under a "natural" opening regime together with the current nutrient load scenario, longer periods of closure would lead to a greater threat of algal blooms, such as the one that occurred in January 2024. Furthermore, less frequent openings would reduce opportunities for migratory fish to move into and out of the lagoon. However, the move towards a more natural opening regime would benefit the fringing wetlands by providing more frequent flooding, benefitting wetland plants over terrestrial invaders.

33. The proposed opening regime primarily aims to safeguard the beneficial but vulnerable aquatic plant communities of the lagoon, which are under threat due to deteriorated water quality due to high nutrient loads from the catchment. However, moving too far toward a "natural", unregulated opening regime at this time could threaten the aquatic plants. For example, under such an opening regime, deeper water would decrease the amount of light penetrating into the lagoon, potentially stressing aquatic plants in the deeper parts of the lagoon (Schallenberg & Robertson 2017).

34. Given that current constraints don't favour a "natural", unregulated opening regime at this time, the applicant's proposed opening regime attempts to shift from the current one towards a more "natural" opening regime, while balancing and safeguarding the diverse ecological values and ecosystem services of the lagoon. At higher water levels, the barrier bar seeps water to the sea. For this reason, the increase in the maximum trigger threshold from 2.0 m to 2.2 m in the 2017 short term consent did not reduce unwanted summer openings during the 5-year period when the consent was active.

35. To mitigate against adverse effects, the technical guidance underpinning the current proposed opening regime (Robertson et al. 2024) incorporates some modifications to the 2017 short-term consent to allow openings of the lagoon for water quality and ecosystem health benefits. Robertson et al. (2024) recommend the following modifications to the opening regime:
    a. An increase in the maximum opening trigger level to 2.5m (above MSL) to restore ecological health and cultural values
    b. Inclusion of new opening conditions to facilitate fish passage at least every two years
    c. Refinement of conditions for emergency lagoon openings to mitigate risks of algal blooms on ecosystem health

36. Hydrological modelling done by Environment Southland, which was calibrated with historical data from Waituna Lagoon, indicates that the raising of the trigger level to 2.5m will result in substantially fewer openings per year and longer durations of high water levels (see Table 6 in Roberston et al. 2024), which are the goals sought for improvement of ecological health of the lagoon.

37. In recognition that the proposed water trigger level would reduce the frequency of openings, the proposed opening regime incorporates a condition allowing the opening of the lagoon at least every two years to facilitate fish passage. This safeguards values associated with fish migration into and out of the lagoon. Also in recognition of the lower frequency of lagoon openings under the proposed regime, a condition is sought to allow emergency openings of the lagoon when algal biomass is high. This condition safeguards the water quality and ecological health of the lagoon while nutrient loads from the catchment remain high.

38. Thus, the proposed opening regime aims to nudge Waituna Lagoon toward a more "natural" opening regime while also providing mechanisms to avert potential adverse effects due to elevated nutrient concentrations under closed conditions and due to less frequent connections between the sea and the lagoon, which would restrict fish passage.

39. **Summary:** Waituna Lagoon is a rare coastal lagoon/lake ecosystem because it retains many of its natural values thanks to the persistence of aquatic plants/seagrasses in the lagoon. However, studies have indicated that the ecological health of the system is at risk from high nutrient loads and an opening regime that doesn't properly account for the lagoon's diverse ecological values. Studies carried out on other similar lagoons indicate that ecological tipping points could likely manifest in Waituna Lagoon and that once tipping points are breached, degradation can be rapid and the system can become recalcitrant to restoration.

40. The technical advice underpinning the proposed opening regime was developed by a diverse group of experts who accounted for a diverse range of ecological values and ecosystem services provided by the healthy lagoon. An overarching goal of an optimised opening regime was identified as one that shifts the system toward a more "natural" opening regime while protecting the aquatic plant/*Ruppia* communities, which support many of the values of the lagoon. However, constraints exist on how far and how rapidly a more "natural" opening regime should be achieved. Furthermore, to safeguard all of the diverse values, consent conditions to allow the opening of the lagoon to facilitate flushing and fish passage are

proposed – two ecological functions that could be adversely affected by a higher trigger level and longer durations of closed phases of the lagoon.

41. Managing this system through a transition of its opening regime requires careful monitoring of early warning indicators, which have been identified by Robertson et al. (2024). The proposed consent is an example of adaptive management toward a clear ecological outcome. As such, the opening regime is both a key determinant of the ecological condition of the lagoon and also a useful tool for flexible, adaptive management toward the desired ecological outcome.

Section 42A Report

42. I have read the s42A report and have nothing further to add.

10 July 2025

Appendix 1

References

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