| | |
|---|---|
| **In the matter** | of the Resource Management Act 1991 |
| **And** | |
| **In the matter** | a resource consent application by Queenstown Lakes District Council to discharge treated wastewater to land for the purpose of disposal of wastewater from Kingston Township |

# Statement of Evidence of Brian Neil Ellwood

**23 December 2021**

MEREDITH
CONNELL

**Solicitors:**
J Beresford
PO Box 90750, Victoria Street West, Auckland 1142
DX CP24063
T: +64 9 336 7500
Joanna.beresford@mc.co.nz

**Barrister**:
Janette Campbell
PO Box 141, Shortland Street, Auckland 1140
T: +64 9 802 1430
janette@campbell.legal

# Statement of Evidence of Brian Neil Ellwood

## 1 Executive Summary

1.1 The Kingston village and wider QLDC area have the demand for increased housing. This has prompted QLDC to prepare the land treatment feasibility assessment and then the application for discharge consent for wastewater from up to 1,200 new and existing properties at Kingston.

1.2 Currently, there is no reticulated wastewater treatment system and all properties (225) in the Kingston village discharge wastewater to the ground via septic tank systems of various ages.

1.3 The proposed 1,200 lots and businesses able to connect to the wastewater treatment plant (WWTP) and integrated land treatment area (LTA) are forecast to have an average flow of 900 $m^3$/day. The growth in this flow will occur over many years, requiring the WWTP and LTA to be staged to respond in time for the increasing volumes. The initial stage of the WWTP is an oxidation pond, outflow filtration, UV disinfection and application to 5 ha of land via subsurface drip irrigation. The nutrients applied will be further reduced by the growth of grass and lucerne crops on the LTA, with the plant material harvested and used elsewhere on Kingston station for forage.

1.4 When the growth in houses connected to the Scheme reaches between 200 and 450 lots, more intensive WWTP will be required. The future Stage 2 WWTP will be a type of Activated sludge suitable to remove high levels of BOD, Nitrogen and bacteria. The nitrogen concentration and application depth control the LTA area receiving wastewater application. A total load of 450 kg N/ha/yr can be sustainably applied year-round and not increase the catchment nitrogen load. With the connection of the entire village existing septic tanks, a reduction of over 1,116 kg N/yr or 57% of what the Village and farmed LTA currently lose. In addition, phosphorus and bacteria discharge to the Lake due to wastewater treatment will be eliminated.

1.5 Nutrient modelling has shown that the catchment Nitrogen loss could increase by 492 kg N or 23% over what the Village and farmed LTA currently loses if the entire subdivision occurred and no village septic tanks were retired. This scenario is avoided with the restriction of the LTA nitrogen loss while septic tanks remain in service.

1.6 I have assessed the discharge of wastewater to land and have concluded that effects of the application of wastewater at the design loading rates on soil, groundwater due to both pathogens, nitrogen and phosphorus, and the cumulative effects in combination with existing discharges to be all less than minor. The Scheme provides the ability for the cumulative load to significantly reduce for nitrogen and phosphorus entering Lake Wakatipu.

1.7 The alternatives assessment showed that the proposed WWTP and LTA reduce nitrogen load to Lake Wakatipu compared to development occurring under the current ORC RPW permitted activity rules, with the potential for 2,124 kg N/yr, a 200% increase in nitrogen lost to the catchment and ultimately Lake Wakatipu.

## 2 Qualifications and Experience

2.1 My full name is Brian Neil Ellwood. I am a Senior Environmental Engineer with 22 years' professional experience in the fields of wastewater treatment, nutrient management and irrigation. I have been a Senior Environmental Engineer with Lowe Environmental Impact (LEI) for six years. Within my role, I lead the Christchurch office, managing staff across wastewater land application, irrigation development and consenting projects.

2.2 I have a BTech(Hons) Massey University 1996, MApplsc-AgEng (Hons), Massey University 1997 and gained Project Management Professional accreditation from the Project Management Institute in 2013. I also have a Graduate Certificate – Irrigation from Charles Sturt University (NSW) 2006 and a Fertiliser and Lime Research Council FLRC Advanced Certificate in Sustainable Nutrient Management in NZ Agriculture from Massey University 2016.

2.3 I have been provided with a copy of the Code of Conduct for Expert Witnesses contained in the Environment Court's Practice Note 2014. I have read and agree to comply with that Code. This evidence is within my area of expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

## 3 Role in the Project and Scope of Evidence

3.1 LEI was engaged by QLDC to prepare the land treatment application feasibility assessment and then the application for discharge consent to ORC. In a second work stream LEI joined the Jacobs team in August 2019 to undertake the detailed design of the land treatment system for the Kingston Township. Jacobs is assisting QLDC and a developer, Kingston Village Ltd (KVL), to develop the water and wastewater treatment systems.

3.2 My role in the project is Project Manager for LEI, overseeing site investigation work on Kingston Station, preparing a conceptual Land Treatment Area (LTA) design, undertaking an Assessment of Environmental Effects (AEE), and preparing the subsequent report and resource consent application for the discharge of treated community (domestic) effluent into land.

3.3 As part of the work undertaken by LEI on this project, contributions were made by other LEI staff; Terry Hughes (Senior Hydrogeologist), Henry van der Vossen (LEI, Environmental Engineer) and Britt Paton (Environmental Scientist). Mr Hughes provided the detailed assessment of groundwater conditions and flow paths. Ms Paton undertook the site investigation work with Mr van der Vossen and contributed to reporting with regards to investigation findings. I supervised all of this work and am familiar with it. Rob Potts (Senior Environmental Engineer) also reviewed the reports and resource consent application prepared in a peer review role to provide quality control feedback and expert advice.

3.4 Chris Simpson of GWS Limited also provided input to and peer review of the groundwater analysis.

3.5 A number of site visits to Kingston Station have been undertaken. I visited the site on 1 October 2019 to assess the landform, overland flow pathways and proximity of the proposed LTA area to surface waters. A site visit was undertaken by Ms Paton and Mr van der Vossen on 14 and 15 June 2018. The purpose of this visit was to undertake landform and waterway mapping, soil hydraulic testing and soil sampling. Soil testing was taken from representative sites sampling both saturated and unsaturated hydraulic conductivity across the site. Soil composite core sampling was undertaken across the proposed LTA areas to measure soil chemical properties.

3.6 A further site visit was undertaken by Ms Paton, on 17 and 18 June 2020 to measure soil hydraulic properties of LTA Area 1 for the inclusion of a further 7 ha of land treatment area.

3.7 The purpose of my evidence is to provide an overview of the technical aspects of the proposal, outline the environment in which it will locate, and summarise the outputs of the wastewater treatment plant into the environment. I will also respond to matters raised by the submitters and the Council planner insofar as they relate to my area of expertise.

## 4 Site Characteristics

4.1 The LTA is proposed to be located on farmland within Kingston Station. The landform slopes towards Lake Wakatipu and is actively farmed with sheep, beef and winter grazing activities undertaken. The available area for the LTA is approximately 25 ha. The LTA is proposed to be developed in several stages to allow flexibility and to match the number of properties serviced by the treatment system. The land treatment area required at full development is a minimum of 15 ha within the full 25 ha that is available.

4.2 The LTA is proposed to be managed as a cut and carry system. This is where the crop grown (lucerne or pasture) is harvested and exported off the LTA for use as stock feed. The existing land use is predominately pasture with some forage crops planted previously. However, winter grazing of dried-off dairy cows occurs from the beginning of June each year for 2 – 3 months on up to 170 ha of winter crops (such as kale and swede) and grass pasture across the wider station landholding. The remainder of the large run property is grazed by sheep and beef on pasture at relatively low intensity.

4.3 The average nitrogen loss from the current farming systems on both the LTA area and the subdivision area is modelled with Overseer FM to be 16 kg N/Ha/yr

4.4 Hot dry summers and cold winters are the general climatic characteristics for the Kingston District. In winter, snow can cover the LTA and reach the Lake Wakatipu shoreline. During times of heavy rainfall or rapid snowmelt, flooding around the shores of Lake Wakatipu can occur, approximately 1.3 km to 1.5 km from the LTA. The prevailing wind comes from the NW or SE, channelled between mountains and along the valleys.

4.5 There is limited recent weather information from weather stations near Kingston. The closest weather station (Kingston AWS: Station Number 5467) is 4.5 km away from the LTA and only has weather recordings from 2012. The average annual rainfall calculated for Kingston from NIWA's weather station network data is 944 mm and the average annual soil moisture deficit is 208 mm.[1] it is important to note from the soil moisture deficit data that drainage is usually expected from May to September. With the addition of wastewater, this drainage will increase and is expected to occur every month.

4.6 There are no soil temperature monitoring sites within a 30 km radius of Kingston. Cromwell Electronic Weather Station (EWS) is the nearest site with recent data over 10 years and is located approximately 50 km to the northeast. It has been used to give an approximation of the likely Kingston LTA 10 cm soil depth temperatures (for the period 1996 – 2018), as summarised in Table 1.

**Table 1: Cromwell EWS 10 cm Soil Temperature (2004 – 2015)**

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Average ºC** | 20 | 19 | 15 | 11 | 6 | 3 | 2 | 3 | 7 | 10 | 15 | 19 |

4.7 The GrowOtago maps (2015) suggest a winter soil temperature range of 3.6 $^{O}$C to 4 $^{O}$C at the proposed LTA zone, which is comparable with the average recordings shown in the Cromwell EWS data for June, July and August.

4.8 Based on this information and my experience in the region, I consider that the average winter 10 cm soil depth temperature will be within the range of 2 $^{O}$C and 4 $^{O}$C and it is unlikely that the temperature will fall below 0 $^{O}$C for any extended period.

**Soils and Geology**

4.9 The Kingston Township sits within a steep sided glaciated valley at the southern end of Lake Wakatipu. Valley deposits comprise glacial till, lacustrine alluvial (beach) deposits and alluvial glacial outwash deposits. Basement rock beneath the alluvial soil deposits is comprised of Schist and this Schist extends up into the mountains that lie either side of the valley floor. The township extends approximately 1 km on land underlain by lake deposits (beach gravel/sands etc). Further to the south, a glacial till mound (terminal moraine) extends across the valley, essentially cutting off any lake flow that could potentially flow to the south, thus creating a catchment divide. The till mound is the proposed location of the LTA and sits approximately 30 m to 60 m higher than the township to the north, and 20 m to 40 m higher than the pastureland to the south.

4.10 The soils and subsoils within the LTA area have been extensively assessed by Hadley Consultants in addition to the work undertaken by LEI.

4.11 In determining the area of the LTA that is needed to sustainably receive and treat the wastewater, soil hydraulic testing was used to determine the maximum design irrigation rates. Table 2 in Appendix BNE1 provides a summary of the results. The difference between $K_{sat}$ and $K_{-40mm}$ indicates that saturated flow is substantially higher than unsaturated flow.

**Soil Phosphorus Storage Capacity**

[1] A report by NIWA *Climate and Weather of Southland* (2nd edition) (2013) summarised the data from its weather station network, with the Kingston mean monthly rainfall for the period 1981 – 2010 and mean monthly soil moisture deficits for the same period shown in Table 1 in Annexure BNE1.

4.12 In 2018, soil samples were collected at the same time as LEI carried out hydraulic conductivity testing across the proposed Kingston LTA, the locations of the 2018 soil testing is presented in Figure 1 in Appendix BNE2. At three sites, phosphorus storage capacity was assessed to determine the likely long-term retention of phosphorus. Soil analysis results show the soil had a capacity over a 1.5 m depth to store 9 to 11 tonnes of phosphorus per ha. Storage beyond these levels would likely see phosphorus migrate lower in the soil/glacial till matrix.

**Hydrogeology**

4.13 The LTA area is located on the northern side of the catchment boundary between the Wakatipu and Mataura catchments. The LTA location on the saddle between the catchments means there is likely to be little groundwater movement across the site. Groundwater was not encountered in any of the test pits across the potential LTA during soil testing, indicating that groundwater is at least 2.5 m or more below ground level at the LTA site.

4.14 Following lodgement of this application, LEI staff under my supervision undertook further investigative and monitoring bores were installed. The location of the 2020 soil investigation is presented in Figure 2 in Appendix BNE2 and the Groundwater Investigation/Monitoring Bores in Figure 3 in Appendix BNE2. The results of that monitoring showed:

(a) The regional occurrence of groundwater is relatively flat within the topographical highs of the terminal moraine and outwash terraces.

(b) This groundwater then falls away to the north, flowing to Lake Wakatipu.

(c) Water within the valley fill deposits could also be sourced from the high relief valley sides (Hector and Eyre Mountain Ranges) and evidence for this is in the sub-artesian nature of water struck within GW5, GW6 and F42/0143 (see Figure 1 below) with chemical signatures (contains arsenic) unlike the overlying perched water.

(d) Evidence for water perching above low permeability sediments is present within all bores along the toe of the terminal moraine.

4.15 Figure 1 presents the conceptual hydrogeological flow model developed following the groundwater bore and water level investigations.

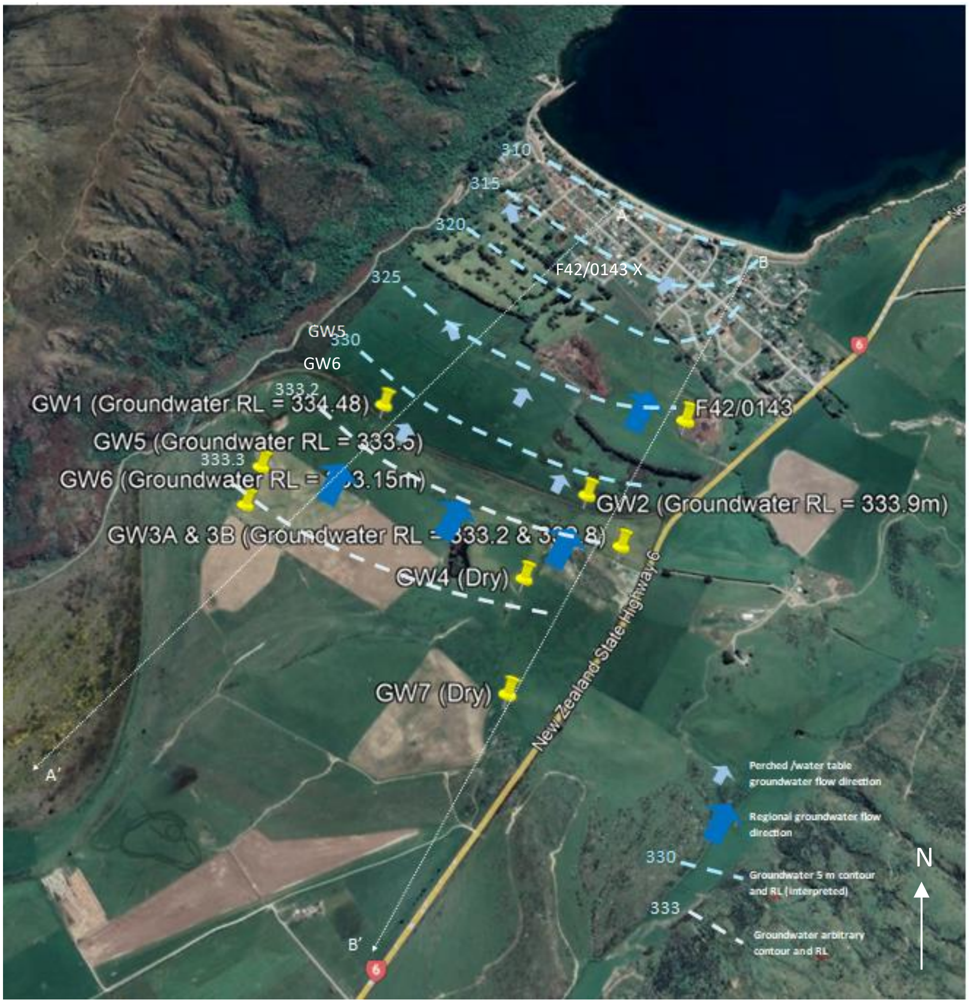


**Figure 1: Conceptual Hydrogeological Flow Model**

4.16 This steep groundwater gradient to the north will likely drive groundwater flow and flow direction. Some examples of groundwater following topography within the outwash terrace and gully features are also present and it is considered that groundwater within the Kingston Valley is likely to be somewhat topographically driven. The proposed LTA is situated on the northern slopes of the terminal moraine and therefore any recharge is likely to flow downwards in the unsaturated zone to the groundwater table and then north to the lake edge or terrace tributaries.

**Surface Waters**

4.17 The LTA is approximately 60 m above Lake Wakatipu (at the lowest LTA elevation), with the closest point being approximately 1.5 km from the Lake Wakatipu southern shoreline. Within the Kingston area, there is an unnamed tributary on the western side of the Village and Kingston Stream, which is located approximately 650 m to the north/ north-east of the LTA. There are also two small artificial ponding areas on Kingston Station.

4.18 To the south of the LTA area beyond the terminal moraine, the surface flow drains south into the Mataura River catchment.

**Groundwater – Surface Water Interaction**

4.19 To assess the potential transport pathway between the groundwater beneath the LTA and surface waters and gain an understanding of possible connections to groundwater, instream flow gauging of the tributaries was undertaken. NIWA measured the losses and gains along the unnamed tributary and Kingston Creek, which are surface water tributaries of Lake Wakatipu. Flow losses or gains along these streams provide a mechanism to estimate the potential discharges from groundwater to these environments.

4.20 This data suggests that flows along the unnamed tributary are gaining from approximately the location of golf course to the lake margin by roughly 10 L/s. The situation within the Kingston Creek appears to be more complicated, with gains of approximately 15 L/s occurring in places and losses of the same order in others. The drain that exists along the railway, near the railway station, appears to discharge roughly 1 L/s, which is sourced from groundwater with no specific spring or surface water source apparent. I therefore consider that groundwater does discharge to these streams within their lower reaches and the amount is similar to what would be recharged from rainfall in the general area.

**Water Take Consents**

4.21 There are three existing water take permits in Kingston. One groundwater take (RM17.100.01), a surface water take (2004.926), as shown in Figure 2, and a registered drinking water supply for the Kingston Motel and Holiday Park (TPO2552) shown in Figure 3 below.

4.22 The groundwater take (RM17.100.01) is for the take and use of water for community supply for up to 57 households as part of a recent development area (Lakefield Estate) that is serviced from a shallow bore adjacent to Kingston Creek. The bore is 4 m deep from an unnamed aquifer. This reticulated supply serves as a supplementary supply to onsite rainwater collection and tank storage, as every site is required to have 30m$^3$ of storage.

4.23 The surface water take (2004.926) is for the purpose of irrigation of a golf course and club house supply. The water is sourced from a spring-fed unnamed tributary of Lake Wakatipu, with the take point located approximately 400 metres south-west of the Kingston Railway Station.

4.24 The registered drinking water supply for the Kingston Motels and Camping Ground (TPO2552) is located on the Motel property and services the Motel and camp visitors. The source is from a groundwater bore mapped to be located on the southern side of Kingston Creek. No bore depth details are provided, with the owners indicating that it was shallow. It is noted that the supply is approximately 30 m down or cross gradient of the Motel and Camping ground wastewater disposal field.

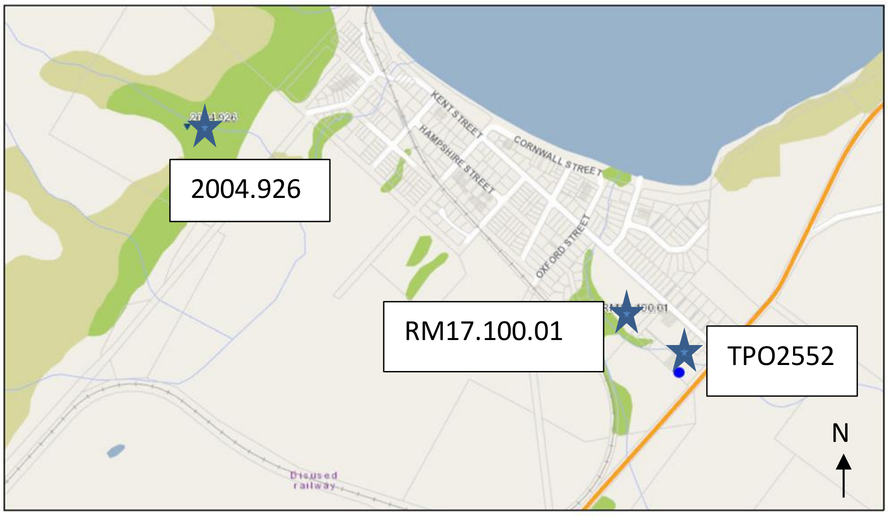


**Figure 2: Current Water Take Permits in Kingston**


**Figure 3: Kingston Holiday Park Limited Water Supply (Blue) and Disposal Field (Green Shaded area) (Source ORC S42 RM18052)**

4.25 In addition to the three water takes, a small number of existing houses rely on bore water supply. The majority of the existing Kingston township collects and stores rainwater for potable use (pers comm QLDC).

4.26 The bore associated with the proposed reticulated community supply (Kingston HIF) was installed in June 2020 as detailed in evidence from Mr. Court-Patience.

The bore number is F42/0147 and it is not located in aquifers downgradient of the LTA.

**Existing Environment Summary**

4.27 The land treatment areas have been selected for their compatibility with existing farming activities, surface water catchment topography and distance to groundwater and surface waters. The soils on the site are suitable for irrigation. The potential land treatment available area has been broken into two areas. This is to ensure the land treatment area is on the most suitable topography and to fit in with appropriate buffers to existing farm features

# 5 Proposed Wastewater Treatment Scheme

**Projected Wastewater Flow Rates**

5.1 The wastewater flows and influent characteristics from Kingston are based on knowledge and data of similar townships and with direction from QLDC engineering design requirements. The Jacobs wastewater treatment plant design and staging have been based on the typical domestic influent strength. Flows assume:

(a) 3 people per household;

(b) each person generates 250 L/d of wastewater; and

(c) there are 1,175 households (225[2] existing, 200 "infill" dwellings on vacant sections and subdivided sections within the existing township, and the remaining 750 new households in new areas consented for development).

5.2 This results in an average dry weather wastewater flow of approximately 900 $m^3$/d with an allowance of twice that for peak wet weather flow. Capacity to convey, treat and discharge twice the average dry weather flow is a requirement of QLDC Land Development and Subdivision Code of Practice[3]. I consider that this is conservative design standard as the reticulation network will be newly installed and dominated by small bore pressure sewers.

5.3 The majority of wastewater flows will be ordinary strength domestic wastewater from individual households as the current zoning limits the area available for non-residential purposes. There will be some higher strength contributions of wastewater from restaurants, cafes and tourist facilities (toilet/bathrooms). It is estimated that commercial activities will make up approximately 10% equivalent population connected to the WWTP.[4]

---

[2] Within the AEE reference was made to a ORC report (Leslie. S. 2015) that noted there was 270 septic tanks discharging to the Kingston aquifer. This included addition rural properties. The correct number of dwelling is 225, source from Statistic new Zealand 2018 survey data. https://www.stats.govt.nz/tools/2018-census-place-summaries/kingston

[3] QLDC Land Development and Subdivision COP (2018 revision as downloaded from https://www.qldc.govt.nz/planning/resource-consents/land-developments-and-subdivisions/ on 08/11/2019).

[4] Plan Change 25, Kingston Village Special Zone. Preliminary Infrastructure Report.

5.4 The expected raw wastewater quality and the average effluent quality from the WWTP is summarised in Table 3 in Annexure BNE1.

**Proposed Wastewater Treatment Plant (WWTP):**

5.5 The treatment plant will provide primary, secondary and tertiary treatment in a staged manner to align with the number of properties connected to the Scheme.

5.6 4 presents the conceptual layout of the treatment plant during the initial Stage 1 of development when connections are less than 450 lots. The design is based on efficient use of infrastructure with an initial system based on oxidation pond technology that has ability to handle the initial low flows better than the more mechanical technologies. As the number of connections increase, the oxidation pond function for providing wastewater treatment changes to a calamity pond/emergency overflow storage system necessary to accommodate short periods of treatment system outages in the more mechanised future Stage 2 system.

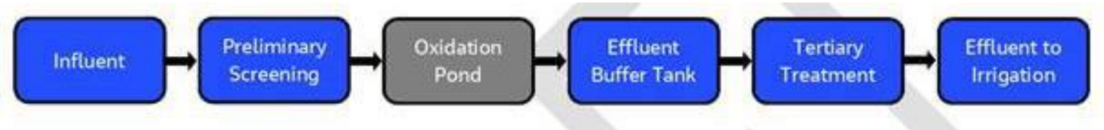


**Figure 4: Process Flow Diagram for the Stage 1 Treatment**

5.7 For Stage 2, there are a number of different activated sludge type treatment processes available that can meet the proposed final treatment standards (e.g. [5]MBR, SBR, SAF and rtPBR). Jacobs' preferred design is a Sequencing Batch Reactor (SBR) because this system is flexible to operate, and the design is simple with all functions occurring in one tank per SBR unit. The units are modular allowing for additional stages to be added as flows increase. SBR do not produce a waste stream that requires further treatment and/or clarification and it is a system that is already used in the district with very good results.

5.8 Figure 5:3 shows the structure of a WWTP to treat the wastewater from a fully developed Kingston of up to 1,200 lots with a SBR. The system includes the oxidation pond repurposed as a calamity pond for times that treatment plant is inoperative or to avoid an uncontrolled discharge. This very infrequent discharge is indicated by the red arrows in Figure 5:3, with water directed to the calamity pond. Water that is discharged to the calamity pond would be returned to WWTP head works and the start of the treatment sequence as shown by the green arrow. The normal sequence of treatment is shown by the black arrows.

5.9 Other activated sludge treatment systems could also be used to produce the same quality of effluent and would also repurpose the oxidation pond from Stage 1 to a calamity pond for Stage 2.

---

[5] Activated Sludge treatment system types: MBR = Membrane bioreactor, SBR = Sequencing Batch Reactor, SAF = Submerged Aerated filters, rtPBR = rotating Packed Bed Reactor

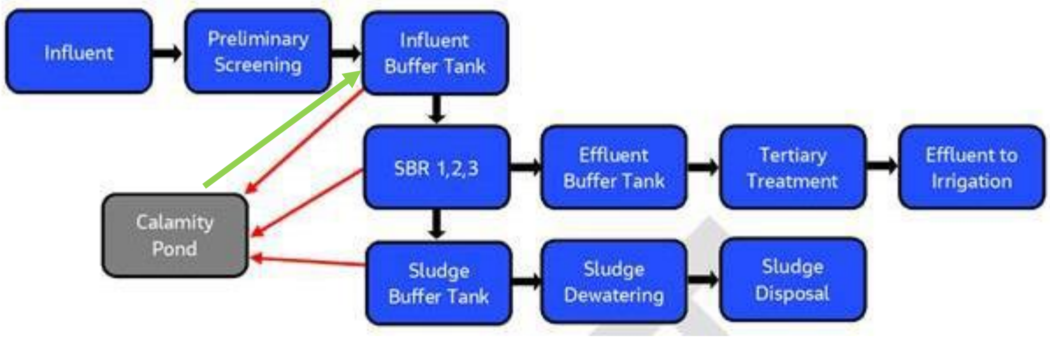


**Figure 5:3 Process Flow Diagram for Stage 2 Ultimate Plant Design**

**Treatment Standards from the WWTP**

5.10 The treatment plant and LTA are an integrated treatment train for the wastewater. The proposed conditions allow QLDC to secure environmental outcomes by either lowering nitrogen concentrations exiting the WWTP or reducing nitrogen loading rates by increasing the size of the LTA. This type of flexibility is important to service a community like Kingston where growth is anticipated but the timing of that growth is unknown, and non-linear. Some management interventions and treatment plant upgrades take longer than others, and it is important for the Council to be able to respond in the most effective way to development as it occurs.

5.11 Stage 1 proposes a lower treatment standard for the main parameters of biological oxygen demand (BOD) and total nitrogen (TN). This is to accommodate the much lighter loading of the WWTP. It would not be possible to effectively operate the Stage 2 activated sludge (mechanical) treatment system with less than 50% design capacity compared to its final expected load. It is proposed to cap N discharges from the LTA at 450 kg N/ha/yr to ensure the same expected environmental outcomes in terms of nitrogen loss below the root zone would be achieved for all stages. Fine filtration following the pond treatment system will be installed to protect the LTA infrastructure from blockage of the drippers with algae.

**Land Application Method**

5.12 The proposed land application method is subsurface pressure compensating drip irrigation to be buried at a depth of around 200 mm below ground. For conceptual design and effects assessment purposes, a drip irrigation spacing of 1 m between lines and a 0.6 m spacing between emitters has been adopted. However, the exact requirements will be determined during the detailed design and procurement phase. Placing the dripper lines beneath the surface protects the lines form freezing and damage from machinery.

5.13 The fact that saturated flow is substantially higher than unsaturated flow in these soils is an important consideration when designing an irrigation regime. In addition to accounting for the ability of water to enter the soil, consideration needs to be given to the effect of wastewater constituents, as opposed to clean water effects which are typically observed during field measurements. Organic material, solids and nutrients in the wastewater can allow the development of microbial growth, which in turn can result in a 'clogging' effect of the soil pores, particularly near the irrigation line outlets. This reduces the soil's infiltration capacity. In addition, the salt concentration will influence the soil wetting by altering water tension.

5.14 Crites and Tchobanoglous (1998) recommend a value of 10% - 30% of the $K_{sat}$ to provide Design Irrigation Rates (DIR). I have adopted the more conservative 30% of $K_{-40mm}$ as a maximum design standard to avoid excessive drainage occurring and maximise contact with the soil. The design takes the lower infield measured unsaturated flow to base a conservative maximum irrigation rate of an average of 20 mm/d on. I consider this suitable for long term application on the site with regard to absorbance, infiltration and adsorption. I also note that the irrigation application rate is further reduced so that the total nitrogen loading rate is not exceeded.

5.15 The wastewater application can be applied as a peak wet weather application depth of 36 to 48 mm to a block, with a 3 to 4-day return period to average 12 mm/d. Normal dry weather depth of application is approximately 6 mm/d and up to 24 mm per 4-day return period. The exact irrigation scheduling and daily and weekly dose rate is a matter of detailed design.

5.16 Table 2 summarises the required effluent land application rate. These are included as proposed conditions.

**Table 2: Effluent Land Application Rate**

| Parameter | Value |
|---|---|
| Peak Dry Weather Daily Discharge ($m^3$/day) | 900 |
| Available land area for irrigation (ha) | 15 |
| Average dry weather application rate (mm/day) | 6 |
| Maximum Wet weather Daily Discharge ($m^3$/day) | 1,800 |
| Maximum wet weather application rate (mm/day) | 12 |

5.17 The proposed dry weather application rate of 6 mm/d is significantly lower than the topsoil unsaturated capacity. It is within this topsoil profile that the majority of effluent soil treatment will take place. The low application rate will allow the topsoil to assimilate the irrigation demand via plant uptake and evapotranspiration, without exceeding the soil's capacity to absorb and adsorb contaminants during normal conditions. Plant uptake will inevitably be determined by the grass or crop species grown within the LTA, while evapotranspiration will be dependent on the seasonal climatic conditions, as well as cropping species, growth stage and density.

**Nutrient Loading Rates**

5.18 Table 3 shows the expected WWTP effluent annual average total nitrogen and total phosphorus concentrations.

**Table 3: Kingston WWTP Effluent Quality**

| Parameter | Stage 1 Development (up to 450 Lots) | Stage 2 Full Development (1,200 Lots) |
|---|---|---|
| Total Nitrogen (mg/L) | 50 | 20 |
| Total Phosphorus (mg/L) | 10 | 10 |

5.19 Plant and microbial removal and the soil cation exchange capacity are the primary mechanisms for assimilation of nutrients and water by land application systems. The total assimilative capacity of the plant system is dependent on the land area utilised, with the loading rate refined, based on the crop type and its management. Table 4 provides nutrient uptake rates for different crop types.

**Table 4: Crop Nutrient Uptake**

| Crop / Land use | N uptake (kg/ha/year) | P uptake (kg/ha/year) | Reference |
|---|---|---|---|
| Pasture – irrigated, cut and carry | **500 - 600** | **130 - 160** | Morton *et al.* (2000) |
| Pastoral – irrigated grazed system | 200 - 240 | 52 - 64 | FLRC (2009), Williams and Haynes (1990) |
| Maize silage | 220 | 40 | FAR (2009) |
| Kale | 380 | 50 | Beare *et al*. (2010) Brown *et al.* (2007) |
| Peas | 106 | 16 | Hanson (2001) |
| Squash | 107 | 20 | Fandika et al. (2011) Hortnet (1995) |
| Sweetcorn | 62 | 9 | Hortnet (1995) |
| Standard Rotation Forestry – Pine | 100 (kg/ha/year) | 30 (kg/ha/year) | Nicholas (2003) |
| Standard Rotation Forestry – Eucalypt | 50 (kg/ha/year) | 10 (kg/ha/year) | Myers *et al.* (1999) |
| Eucalypt or Willow Coppice Systems | 200-300 (kg/ha/year) | 75-125 (kg/ha/year) | NZLTC (2000) |

**Nitrogen Loading Rate**

5.20 The management of the Kingston LTA will be cut and carry. To be conservative, a design annual loading of 450 kg N/ha/yr has been adopted, i.e. less than the maximum plant uptake rate of 500 – 600 kg N/ha/yr reported in Table 4. Therefore, based on a design 12 monthly average Total Nitrogen concentration of 20 g/m$^3$ and an average annual volume of 328,500 m$^3$, the minimum size LTA required to keep the nitrogen loading at or below 450 kg N/ha/yr for a cut and carry system is 14.6 ha.

5.21 A minimum land treatment area of 15 ha is proposed within a wider area of 25ha. The additional 10 ha allows for non-irrigated field headlands for turning harvest equipment and additional irrigation zones to be constructed in the future. Having additional areas within the consented LTA area, but necessarily built at the commencement of stage 2, will allow QLDC flexibility in the management of the infrastructure investment. This flexibility will allow for rotation of the application area, future flexibility to undertake pasture or crop harvesting and replanting, and LTA component renewal when the system is at full capacity.

5.22 During the initial stages as household connections come online, the WWTP has reduced ability to remove nitrogen as set out above. This will be managed by applying higher nitrogen concentration wastewater to the LTA over a larger area, meeting the capped nitrogen load of 450 Kg N/ha/yr. As the number of household connections increases, there will be improved treatment quality with the shift to a SBR or equivalent mechanical treatment process. Once there are 450 connections to the system, the system will be operating at the progressively higher treatment standards and ultimately a treatment quality of a 12 monthly average of 20 mg/L Total Nitrogen, allowing application over the 14.6 ha calculated above.

**Phosphorus Loading Rate**

5.23 Based on a phosphorus concentration of 10 mg/L and the LTA area of 15 ha, I estimate a P loading of 222 kg P/ha/yr. I estimate the plant uptake and export within the harvested material to be between 36 and 160 kg P/ha/yr. Allowing for lower OverseerFM estimated plant uptake and export off the LTA area, the net P loading to the soil matrix is 186 kg P/ha/yr.

# 6 Environmental Effects Assessment

6.1 I have focused on the effects on the groundwater system and the soils in terms of cumulative nutrient loading rates. Effects on surface water quality are presented in the evidence of Dr Goldsmith.

**Effects on Soils**

6.2 The irrigation of Kingston WWTP effluent to land has been designed taking into consideration the hydraulic and nutrient limitations of the soils and climatic fluctuations within the region. I consider that the application of effluent to land has the potential to enhance the soils' nutrient status, allowing for improved plant growth. I also conclude that the proposed hydraulic and nutrient loading rates for a cut and carry regime are within the soil and plant assimilation capacities expected over the life of the consent.

**Biochemical Oxygen Demand ($BOD_5$)**

6.3 A healthy soil environment can assimilate up to 600 kg $BOD_5$/ha/d (NZLTC, 2000). The LTA covers a proposed area of 15 ha which has a capacity to assimilate 9,000 kg $BOD_5$/d. The effluent $BOD_5$ concentration, after treatment, will be on average 20 to 50 g/m$^3$ prior to tertiary filtration and the average flow is estimated as be 900 m$^3$/d. Therefore, the $BOD_5$ in the effluent is on average 18 kg $BOD_5$/d for the fully treated wastewater and 45 kg $BOD_5$/d during the stage 1 treatment via the oxidation pond. Both these loading rates are significantly less than the 9,000 kg/d the soil can assimilate, so anaerobic activity and resultant slime development in the soils is extremely unlikely.

**Effects on Groundwater – Pathogens**

6.4 The effluent discharge will be treated with UV disinfection to an annual geometric mean concentrations of $10^4$ MPN/100 ml *E.coli* prior to application to the LTA,[6]. Further removal of pathogens then occurs within the soil and subsoil matrix through the mechanisms of filtration, absorption and natural attrition.

6.5 Because of the high quality of effluent being discharged and the natural mechanisms within the subsoil, I concluded that there are no adverse effects on downgradient identified drinking water bores or registered water supplies, due

[6] This is less that WHO (2000) guideline limit of $10^5$ faecal coliforms/100ml for spray irrigation and the land has restricted human access.

to the presence of bacteria in the wastewater applied via subsurface drip irrigation.

**Effects on Groundwater – Nitrogen**

6.6 In this section of my evidence I describe the assessment methodology, mass of nitrogen leached from the proposed LTA system and then compare that mass to the current nitrogen leaching from the existing land uses (farming and residential).

*Current N Loss*

6.7 To assess changes in the catchment and Lake's nitrogen load I have used two approaches: OverseerFM modelling and a mass balance approach.

6.8 The current land use of the LTA and the area zoned for subdivision and new residential development is a mixed species pastural farming system. Using OverseerFM, I estimate that the current farming landuse is leaching 16 kg N/ha/yr[7]. This is based on a mix of low nitrogen leaching sheep grazing and high leaching winter forage crop dairy support. The total mass of nitrogen loss from the subdivision and LTA area when used for farming is given in

6.9 Table 5.

**Table 5: Existing Nitrogen Leaching on Kingston Station LTA and KVA Subdivision**

| Landuse | Area (ha) | Nitrogen Loss Rate (kg N/ha/yr) | Nitrogen Mass Leached (Kg N/yr) |
|---|---|---|---|
| **LTA area** | 15 | 16 | 240 |
| **Subdivision area** | 55 | 16 | 880 |
| **Total** | 70 | | 1,120 |

6.10 In addition to the farming landuse, the nitrogen loss from the existing township forms part of the existing total. I calculated the nitrogen loss from the 225 septic tank serviced properties, based on two average occupancy rates; 1.1[8] (to reflect the normally present residential population) and 3 persons (which is the QLDC design guideline value) per household. The N loss per person per year is a commonly accepted figure, allowing for removal of 30% of N discharged by the septic tank. The total mass of nitrogen loss from the existing septic tank serviced dwellings is given in Table 6.

6.11 Table 5

---

7 This rate is the OverseerFM predicted rate for the more intensively farmer flat land, when combined with the wider area available to be farmed, the average property level loss is less than 15 kgN/ha permitted by Plan Chang 6A Rule 12.C.1.3 (a) (iii.

8 Statistics New Zealand Census data 2013 was used in the AEE as 2018 data was not available at that time. The 2013 Kingston normally resident population was 237, increasing to 1.5 persons per dwelling to total 348 residents in 2018.

**Table 6: Existing Nitrogen Leaching from Kingston Village**

| Number of Dwellings | Occupancy (Person per Dwelling) | Nitrogen Loss per Person (kg/yr) | Nitrogen Mass leached (kg N/yr) |
|---|---|---|---|
| **225** | 1.1 | 3.15 | 780 |
| **225** | 3 | 3.15 | 2,126 |

6.12 From my calculations, I therefore predict the total N loss from the study area currently is in the order of 1,900 – 3246 kg N/yr, depending upon the number of residents at each dwelling.

*Predicted N loss from the Project*

6.13 As discussed above, the nitrogen loading rate of 438 kg N/ha/yr is within the range of plant uptake capacity for a cut and carry system. Therefore, nitrogen applied to the soils will provide a beneficial nutrient for plant growth and most will undergo plant assimilation, immobilisation within the soil matrix, and denitrification prior to potential leaching to groundwater of any surplus.

6.14 A cut and carry system involves removing cut pasture off the LTA site as hay, silage, baleage or similar. My nitrogen leaching analysis has assumed a total of 12 t DM/ha/yr of lucerne silage cut and exported off the 15 ha irrigated block. A lucerne yield of 12 t DM/ha/yr is conservative, with published yields of 16 to 28 t DM/ha (Brown *et al* 2005) grown. I used this conservative estimate of production of lucerne as an input into the OverseerFM modelling and prediction of catchment nitrogen loads post development.

6.15 OverseerFM does have limitations and leaching estimates can vary with a change to model version. It has however been used in other wastewater treatment to land applications to help quantify the effects and scale of the likely leaching losses (Foxton WWTP and discharge). The OverseerFM version used during the preparation of the AEE was V3.7. This has now been replaced with version V4.1, which incorporates NIWA monthly climate data from 1991 - 2020. The change in OverseerFM version has reduced the estimated leaching from the project by 3 kg/ha from 142 kg N/ha/yr to 139 kg N/ha/yr. However, for the mass balance calculations presented below I have retained the higher value of 142 kg N/ha/yr.

6.16 I used the approach of Beggs et. al., (2011)[9] as an alternate tool to predict nitrogen loss rates via leaching from the LTA. Beggs found wastewater applied to land undergoes further biological processes, with research trials indicating that the concentration of nitrogen applied to the soil from wastewater treatment systems via subsurface drip irrigation is not 100% lost via leaching. Soil type is an important parameter. I consider the soils of the LTA to be equivalent to a silt loam soil (Loam). Using Beggs' work, the fate of wastewater nitrogen applied to land via subsurface drip irrigation in a Loam soil is:

- 30 – 32% via root uptake from plants;
- 40 – 62% lost via Denitrification; and
- 8 - 30% lost via leaching.

[9] Beggs, R.A., Hills, D.J., Tchobanoglous, G., Hopmans J.W. (2011) Fate of nitrogen for subsurface drip dispersal of effluent from small wastewater systems. Journal of Contaminant Hydrology 126:19–28

6.17 Using Beggs' approach, applying 438 kg N/Ha/yr to 15 ha LTA, with 8% to 30% leaching below the root zone equates to 35 to 131 kg N/ha/yr of lost nitrogen. The top end of this range is comparable to the OverseerFM estimate of 142 kg N/ha. The congruence of this result with the OverseerFM calculation gives me confidence that they are accurate within a margin.

6.18 OverseerFM modelling presents an annual average nitrogen loss. The nitrogen loss is via drainage below the soil profile and is therefore concentrated during the times when there is limited plant uptake and higher drainage through the soil due to the rainfall in addition the wastewater application. To ensure that I had predicted a worst-case scenario, I also assessed the leaching of nitrogen resulting from a winter increase in population, or a reduction in treatment plant denitrification with an additional OverseerFM model run. This model showed the winter nitrogen applications 50% higher than the original scenario (an increase of 56 kg N/ha). The total annual applied nitrogen remained 437 kg N/ha/yr. This scenario applied 166 kg N/ha over the winter and overall, the system lost 178 kg N/ha/yr, an additional 36 kg N/ha (i.e. 178 vs 1 OverseerFM) for the year.

*Cumulative effects and change in N loss to the environment*

6.19 Table 7 presents seven potential future scenarios. The Kingston Village population's nitrogen contribution is calculated for each scenario, with the first three considering two population densities. These two densities were the historical population density (2013) of 1.1 persons per dwelling and the QLDC design guideline value of 3 persons per dwelling. These populations are used to estimate the nitrogen contribution from each septic tank, which in combination with the nitrogen loss from the subdivision and 15 ha of farmland, represent the catchment load of interest to this application.

6.20 Scenario descriptions

1. Scenario 1: This represents an even application of wastewater from the full subdivision development, village infill and existing dwellings to total 1,200 lots. The wastewater is applied over 15 ha LTA. The nitrogen loss is compared to the nitrogen lost from the village septic tanks (two population densities) along with the land-use of 70 ha (15 ha LTA and 55 ha Subdivision) for grazing.

2. Scenario 2: This is the same as Scenario 1, with the nitrogen application to the LTA being 50% higher in the winter and lower in the summer.

3. Scenario 3: This is the same mass of nitrogen applied to the LTA used in Scenario 2 but is spread over a larger LTA area of 21 ha resulting in a lower nitrogen application rate. The nitrogen loss is compared to nitrogen lost from the village septic tanks and the farmland use of 76 ha (21 ha LTA and 55 ha Subdivision) for grazing.

4. Scenario 4: This scenario is used to show a situation where there are no village septic tanks connected and 27.5 ha (50%) of the subdivision is developed into 370 lots, wastewater applied over 15 ha of LTA and the remaining subdivision area still being farmed. The Village and existing subdivision continues to leach at the same rate pre and post development.

5. Scenario 5: This scenario is the full development of the subdivision with 200 lots of vacant village sections also connected to the WWTP, but no village septic tanks are connected. All properties have a population of three people per dwelling. The Village continues to leach at the same rate pre and post development.

6. Scenario 6: No subdivision is progressed and no WWTP is constructed; however development in the Village continues with the 200 existing vacant sections in Kingston developed under ORC using advanced on-site sewage systems removing 60% of the nitrogen applied, and existing village septic tank properties remain. All properties have a population of three people per dwelling.

7. Scenario 7: Development occurs with new wastewater discharged as a Permitted activity. The Subdivision and village infill continues with 950 dwellings developed using advanced on-site sewage systems removing 60% of the nitrogen. Existing village septic tank properties remain. The scenario is presented with the historical population density (2013) of 1.1 persons per dwelling and the QLDC design guideline value of 3 persons per dwelling.

6.21 The calculation of nitrogen mass (kg/yr) being lost within the Kingston catchment before and post the proposed development is presented in Table 7.

**Table 7: Wastewater Nitrogen Budget Pre and Post-Development Nitrogen Leaching Estimate Land Use Area (ha) N Leached (kg/ha/yr) (kg/yr)**

| Scenario | Persons per Household | Nitrogen Lost from Existing Township plus Grazing Land (kg/yr ) | Nitrogen lost Post-Development (kg/yr) | Catchment Nitrogen Change (kg/yr) |
|---|---|---|---|---|
| 1<br>LTA leaching 142 kg N/ha and 15 ha LTA | 1.1 | 1,900 | 1,853 | 47 kg lower |
| | 3 | 3,246 | 2,130 | 1,116 kg lower |
| 2<br>LTA High Winter Leaching 178 kg N/ha over 15 ha LTA | 1.1 | 1,900 | 2,316 | 416 kg higher |
| | 3 | 3,246 | 2,670 | 576 kg lower |
| 3<br>LTA Leaching set at 135 kg N/ha over 21 ha LTA | 1.1 | 1,996 | 1,654 | 341 kg lower |
| | 3 | 3,342 | 1,877 | 1,465 kg lower |
| 4<br>No community connection, 370 Lots, 27.5 ha subdivision and 15 ha LTA Leaching 43 kg N/ha/yr | 3 | 3,246 | 3,214 | 32 kg lower |
| 5<br>No village connection, 975 Lots, 55 ha subdivision and 21 ha LTA Leaching 88 kg N/ha/y | 3 | 3,342 | 3,834 | 492 kg higher |
| 6<br>Status quo ORC PA rules: Kingston Village and 200 additional new community advanced septic tanks (60% N removal) on existing consented sections, no new subdivision Lots | 3 | 3,246 | 4,326 | 1,080 kg higher |
| 7<br>ORC PA rules: Kingston Village and 950 additional new community advanced septic tanks (60% N removal) on existing consented sections, and subdivision Lots | 1.1 | 1,900 | 2,901 | 1,001 kg higher |
| | 3 | 3,246 | 7,496 | 4,250 kg higher |

6.22 Under Scenario 1, which assumes an enlarged Kingston township, fully serviced by the new WWTP and LTA, I predict a reduction of 47 to 1,116 kg N entering the environment every year. This is as a result of the new proposal compared to the nitrogen loss occurring from the current Kingston Township septic tank systems and current Kingston Station farming.

6.23 The proposed treatment system results in less N being leached from that currently modelled to be occurring. The WWTP and LTA when the community connects provides the potential to remove the leaching from a number of on-site septic tank systems located close to Lake Wakatipu, overall reducing the total nitrogen load and microbiological contamination of groundwater and the Lake.

6.24 With Scenario 2 and 3, the application of nitrogen load is not even across the year with an increase in winter and a decrease in nitrogen application in the summer. The additional leaching predicted under a higher winter application scenario could cause an increase in the catchment nitrogen loss if the Kingston Village population returned to the 2013 census population density as modelled in scenario 2. However, as the population density increases to 3 people per dwelling, the proposed WWTP and LTA reduces the mass of nitrogen entering the catchment over that which could occur from the Village dwellings' septic tanks. Even with the higher winter nitrogen loss I have calculated a net decrease of 576 kg N/yr under this scenario compared to the Kingston Village dwellings retaining septic tanks. The increase in the N discharge with the WWTP and LTA functioning under scenario 2 with the lower density per household but higher winter population numbers, could be managed in a range of ways, including as shown in scenario 3, by increasing the size of the LTA.

6.25 As presented in evidence from Mr Court-Patience, there is some uncertainty with the number of existing septic tanks that may connect to the new treatment system. Scenarios 4 and 5 present the prospect that the new subdivision proceeds, while the existing township remains unconnected to the WWTP. Scenario 4 demonstrates a reduction in the amount of N leached annually if half of the newly zoned allotments are developed, and none of the existing township dwellings move over to the reticulated sewage system. I have calculated the nitrogen balance for the full subdivision development with infill housing to have the potential to increase the cumulative nutrient loss within the catchment by up to 492 kg N/yr.

6.26 Scenario 5 shows an increase in mass N load. It is effectively the worst-case scenario, with the maximum number of residents per dwelling and all new allotments contributing to N discharge through the WWTP and LTA, while none of the existing load to the environment has been reduced by conversion of the existing septic tanks in the township over to reticulated wastewater services.

6.27 To avoid the Scenario 5 situation of additional cumulative nitrogen load, Condition 11 has been offered to limit the loss of nitrogen from the LTA in proportion to the number of Village septic tanks that are connected. This consent condition uses a nitrogen mass balance to equate the surplus nitrogen within the LTA and the nitrogen lost from septic tanks.

*The Nitrogen Mass Balance (Total Nitrogen applied less Total Nitrogen removed) calculated in accordance with Condition 10 shall not exceed:*

*a) 1,050 kg N/yr while existing properties (as at the date of the consent granting) within Kingston Village with septic tanks discharging to the ground (**Existing Property**).*

*Or*

*b) 1,050 kg N/yr plus 5.2 kg N/yr for every Existing Property that has been connected to a communal collection system and conveyed to the WWTP.*

*The results of this Nitrogen Mass Balance calculation shall be presented in the Annual Report, required under Condition 22 of this consent*

***Advice note****: The Total Nitrogen leaching mass when 225 properties are reticulated to the WWTP shall be 1,050 plus 225*5.2 = 2220 kg N/yr.*

6.28 Scenarios 6 and 7 present the situation where development continues to occur with each lot meeting the ORC RPW permitted activity rule 12.A.1.4 at each lot. The scenario has assumed that the future septic tanks are advanced treatment systems which remove 60% of the nitrogen load. Under this development scenario, total nitrogen loads increase in the catchment by 1,001 to 4,250 kg N/yr. This nitrogen is enters the shallow groundwater system between 50 and 1,000m form Lake Wakatipu, in comparison to the nitrogen lost from the LTA which enters the groundwater system 1,000 to 1,500 m from the Lake.

6.29 I also note that the nitrogen load onto the LTA is restricted to a maximum of 450 kg N/ha/per year. This load will be calculated based on daily WWTP flows, monthly treatment nitrogen sampling and the area of the LTA the water is applied to. In my experience this system of accounting for LTA nitrogen load means that if the wastewater flows or strength increases at certain times of the year due to population changes or seasonal impacts on the WWTP effluent quality, the treatment plant and LTA effectiveness can be managed and improved to ensure that the overall loading per ha remains within consented nitrogen limits.

6.30 As an example, if population increases are seen in the summer holidays, the additional nitrogen application that is being applied over summer is being applied when there is a high plant uptake. To remain within the 450 kg N/ha/yr limit, the nitrogen loading per ha for the reminder of the year would have to decrease. This can be achieved by increasing the land treatment area used or increasing the nutrient removal achieved at the WWTP by increasing aeration to nitrify the effluent and anoxic time for denitrification.

6.31 The regular monitoring of flows to the WWTP, the WWTP system’s performance and the LTA area capacity will give QLDC advance warning that the system is approaching the need for an upgrade with either an additional WWTP stage required or the construction of additional LTA.

6.32 To provide a sense of scale and to put the nitrogen leaching mass into context for this rural farmed environment, my experience using OverseerFM is that one ha of winter forage crop would typically leach between 80 and 150 kg N/ha/yr. Kingston Station regularly has 170 ha of winter forage crops in rotation around its flat productive area. Using an average figure of 115 kg H/ha/yr, that would generate a mass N load of 19,550 kg/year with a proportion in the Kingston aquifer system. The differences presented in the scenarios’ mass balances in Table 7 is small in the scale of the total catchment load. The proposed wastewater leaching from the LTA is equivalent to adding or subtracting between 4 to 14 ha of winter cattle grazed forage crops in the existing catchment of over 300 ha in area. It is my opinion that a change of this area of winter grazed forage crop area in the catchment is a plausible scenario for this catchment.

6.33 With regards to a permitted future modelled in Scenario 6, I have accounted for no nitrogen from the newly subdivided allotment, but the development of the existing 200 additional Kingston Village lots occurring using onsite sewage systems. In this situation the catchment total nitrogen loading is expected to increase by 1,080 kg/yr compared to the existing situation. This can be avoided with the development of a community WWTP and LTA and appropriate conversion of existing dwellings from septic tanks to the community scheme.

6.34 Scenario 7 also assumes an enlarged Kingston township, as enabled by the zoning provisions, but without the construction of the WWTP and LTA. That scenario shows that the proposal reduces the amount of nitrogen discharged annually from that full scale of development by 1,048 to 5,367 kg N/yr when compared to Scenario 1.

6.35 My conclusion for nitrogen losses is that under the likely development scenarios presented, the proposed WWTP and LTA area will reduce the nitrogen loading entering Lake Wakatipu when compared to the Village without the community wastewater treatment system.

**Effects of Phosphorus**

6.36 The proposed application rate will be approximately 222 kg P/ha/yr. This rate is greater than the suggested phosphorus plant uptake capacity of 130 kg P/ha/yr – 160 kg P/ha/yr (Morton, *et al*, 2000) for a cut and carry regime.

6.37 To assess the fate of the surplus P, I investigated the soil's P retention properties. Phosphorus is not very mobile within the soil profile. The soil test analysis shows that the proposed LTA soil profile can retain large amounts of added phosphorus before it migrates further down the soil/subsoil profile.

6.38 The phosphorus retention analysis I have undertaken shows that phosphorus supplied over 54 years can be stored within the first 1.5 m of the soil profile before there would be significant phosphorus migration to lower subsoils. This storage potential is much greater than the proposed consent duration of 35 years.

6.39 I have recommended a soil sampling programme in the proposed Conditions to identify and measure of the phosphorus levels in on soil.

6.40 The risk of adverse effects from phosphorus occurs when it enters surface water. This may occur via either overland flow entrained in sediment/particulate matter or, leaching from the soil once soil sorption sites are nearing saturation.

6.41 The risk from overland flow has been managed through sub-surface application of phosphorus containing wastewater and setback distances, as given in the proposed Condition. Additionally it has been managed by there being no direct surface water flow paths off the LTA areas.

6.42 The risk of leaching down the soil profile is monitored as part of the detailed measurement of soil conditions at depth. This is intended to detect movement of phosphorus through the soil profile.

6.43 To the extent that phosphorus is moved from septic tanks, close to the lake foreshore to the LTA, I expect the leaching and runoff of total phosphorus and DRP to decrease, thereby reducing the total catchment phosphorus loss.

**Summary of Effects**

6.44 In conclusion, it is my experience that the modelled current farming nitrogen and phosphorus losses are realistic and with the LTA area proposed and condition 11 constraining the mass of nitrogen lost from the LTA area, the proposed treatment system will likely result in less nitrogen and phosphorus being leached from that currently permitted and occurring due to the farming and Kingston Village septic tank discharges.

6.45 The community WWTP and LTA provides the opportunity to remove the leaching from a number of on-site systems located close to Lake Wakatipu should landowners wish or are required to connect. This will significantly reduce the total nutrient load and microbiological contamination of groundwater and the Lake.

**Operation and Maintenance**

6.46 Monitoring is proposed to ensure compliance with the proposed volume and nutrient loading limits, and to monitor the impact of the proposed activities on the environment. A flow meter will be installed to monitor the volume of effluent discharged to the land treatment area. Monitoring results from the proposed sampling will be reported annually to the Regional Council, or for the soil sampling, within 6 months of testing.

# 7 Submissions

7.1 Two submissions were received; Southern District Health Board and Kingston Community Association Inc (KCA). In this evidence I have addressed issues raised that relate to my area of expertise.

7.2 Southern District Health Board have raised concerns with the effects of a lack of connection of septic tanks to the system and monitoring conditions. Both concerns are addressed with the conditions proposed. The cumulative effects of the proposed discharge and existing septic tanks is managed by limiting the leaching mass prior to the retirement of Village septic tanks (Paragraph 6.27) of my evidence and proposed Condition 11) and baseline and regular monitoring of groundwater and surface waters is proposed in Conditions 16 and 19 for the duration of the consent.

7.3 The submission from KCA raises a number of technical matters with the application. These principally relate to the capacity of the LTA to treat the applied wastewater volume and nutrient loading rates. KCA proposes a data collection period and assessment prior to implementation of the Scheme.

7.4 The principal issues all manifest via the effects on groundwater and are dominated by nitrogen leaching. Nitrogen leaching is driven by a combination of nitrogen loading rate, hydraulic loading rates, climatic conditions and LTA management. In paragraphs 6.1 to 6.436.45, I address these matters and conclude that the proposed system will have a reduced nitrogen and phosphorus loading rate when compared to the current system.

7.5 Other specific concerns raised are covered via the following comments:

(a) Available climate data. The Cromwell soil temperature data is used to demonstrate that the soil at 200 mm is not likely to be frozen at any time in the winter, allowing the discharge of water to occur all year around. This is the most relevant data**.**

(b) Rainfall data within OverseerFM was based on the period 1981 to 2010 and now revised to 1990 to 2020. Changing the rainfall data within OverseerFM from a 30-year annual average to a updated 30 year monthly average data reduces estimated leaching losses by 3 kg N/ha.

(c) While OverseerFM's usefulness has been challenged within a MfE peer review, a separate mass balance approach has also been used to calculate nutrient losses. The higher estimate loss predicted using OverseerFM has been used. Nutrient uptake via lucerne and dry matter production rates were derived from Pioneer Brand Lucerne Manual 2008 and Brown *et al* 2005, Village septic tank catchment load data was source from ORC report (Leslie, 2015).

(d) The soil's assimilative capacity to absorb the hydraulic loading is explained in paragraph 6.2, the BOD loading rate and its suitability is explained in paragraph 6.3. As explained in both paragraphs, the proposed loading is below sustainable limits for the soils.

(e) Nitrogen leaching rates. The proposed LTA system utilising cut and carry of lucerne has less nutrient loss than the current losses within the catchment as explained in paragraphs addresses nitrogen application and leaching. A net reduction in catchment nutrient levels is achieved when considering the current landuse farming and Village septic tanks being converted.

(f) Wastewater characteristics flowing into the WWTP. The zoning limitations that constrain development in the township support the assumption that the inflows will be normal domestic strength influent. The more important factor relevant to this application are the wastewater strengths of the applied effluent to land. Limits for the key parameters are proposed in Conditions 8, 18 a, and 18 b of consent. These conditions must be complied with regardless of the influent strength.

(g) Pathogens' effect on surface water. The effects of pathogens on groundwater is addressed in paragraph 6.4, furthermore, soil based treatment systems have been shown to greatly reduce pathogen transport to groundwater and then surface waters. In addition, there is no direct surface water connection that links the LTA to the tributaries of Lake Wakatipu.

(h) Surface emergence of treated wastewater. The placement of the dripper lines at 200 mm depth and low hydraulic loading rates of 6 mm/day are design factors that reduce the potential for surface emergence of treated wastewater. Any surface water that did emerge has no direct flow path and would need to re-enter the groundwater system to then contribute to surface water flows.

(i) Alternatives. In selecting the treatment system and location for the LTA, the proposed community wastewater treatment system and 15 ha LTA on Kingston Station was favoured due to support of the land owner, the large depth to groundwater, lack of surface water catchment connections and distance to the Lake Wakatipu. The use of the golf course or Glen Nevis Station are still within the same catchment and have the same or greater issues to that of Kingston Station. In addition, the golf course area, while identified by KRA, is not supported by KRA. Neither site has superior advantages over the use of Kingston Station. There are no significant effects from use of the Kingston Station site that would warrant its abandonment in favour of one of these other options.

7.6 Overall, it is my opinion that typical and appropriate design standards have been used to design the WWTP and LTA treatment train. The level of treatment will not result in any adverse effects on soils or groundwater.

## 8 Section 42A report

8.1 I have reviewed the s 42A Report and additional technical memorandum from PDP.

8.2 The Council Planner and technical advisors from PDP raised a number of issues and points that are appropriate for response in the following section.

**Climate Change**

8.3 Climate change is identified as having a potential to change the effectiveness of the LTA over time. QLDC commissioned Bodeker Scientific in 2019[10] to assess the implications of climate change for the Queenstown Lakes District. The overall conclusions from this report are:

> *As a result of climate change, the Queenstown Lakes District (QLD) is likely to warm by several degrees by the end of the 21st century, with some parts of the District potentially warming by up to 7°C under a high greenhouse gas (GHG) emissions scenario. While total annual precipitation is not projected to change much across the District, the distribution and intensity of rainfall is likely to change, with a greater likelihood of more extreme rainfall events.*

8.4 Based on the Bodeker's analysis, I conclude that climate change is likely to enhance the potential for plant growth and lengthen the growing season. Higher temperatures will enhance the WWTP performance during winter and improve the efficiency in nutrient removal. This is slightly countered by additional high intensity rainfall that may increase the potential for drainage and leaching. By 2040-2049 it is predicted there will be 0.7 to 1.9 additional rainfall days/yr[11], with greater than 10 mm of rainfall for the most extreme RCP8.5 climate change scenario.

**Groundwater Monitoring**

8.5 The Council's Planner has queried the groundwater sampling locations and frequency. As part of the groundwater investigations seven bores were drilled[12]

---

[10] https://www.qldc.govt.nz/media/tjgdjtuc/24-4-19_bodeker_final_report_qldc.pdf

[11] Queenstown is predicted to see an increase in the number of heavy rainfall days (from 26 to 31 days per year) by 2090, which corresponds to a trend of 0.80±0.39 days/decade.

[12] Appendix BNE2 Figure 3 shows the bore locations and water levels

to confirm the groundwater flow direction and to establish the geological model. The work concluded that groundwater was topographically controlled predominantly following the ground contours and is draining towards the north and Lake Wakatipu .

8.6 Monitoring of Bores GW1 and GW2 is proposed, along with the nested bore GW3a/3b (located at the same location but in separate aquifers). Bores GW4 and GW7 on the southern side of the LTA were dry when drilled to 60 m depth. The casing for GW7 was not installed and no bore now exists. GW5 (59 m) and GW6 (58 m) were drilled to the south of LTA 2. These bores showed that groundwater direction is to the north. I do not recommended sampling these bores for water quality parameters due to the difficultly of gaining a representative sample at a depth to groundwater of over 40 m. QLDC has contracted Watercare services lab to undertake quarterly sampling of the bores, however they have not been able to reliability abstract water from these 50 mm bores. Given the difficulties in reliability of monitoring of the deep groundwater bores, and the LTA being located near the top of the catchment divide, it is my opinion that monitoring of these bores is not necessary to identify the potential for effects from groundwater on surface water bodies of interest to this application.

8.7 The three bores that are proposed to be monitored are down-gradient of the LTA and will provide baseline and long term monitoring data to support the management of effects from the LTA. Appendix BNE2, Figure 1 (attached), contains a map showing the monitoring bore locations along with the LTA areas and surface water monitoring sites.

**Wastewater Nitrogen Concentration**

8.8 PDP have raised that it is possible that a SBR WWTP can achieve a wastewater nitrogen concentration below 10 mg/L during winter. I agree with this statement, but this level of treatment in the SBR is not needed when considered in the context of the integrated WWTP and LTA system proposed. The treatment of wastewater to this higher standard would require a significantly increased treatment plant size due to the increased hydraulic residence time. It would also require an increase in operational costs from the need to providing heating, alkalinity dosing during nitrification, additional aeration and then carbon dosing for during the dentification stage. The increased treatment level would increase sludge production and disposal needs, along with an increase in the WWTP overall carbon emissions.

8.9 The proposed Nitrogen limits are consistent with other QLDC-operated plants and reflect that further treatment occurs in the soil/plant system of the LTA. The concentration and volume are important in achieving the 450 kg N/ha/yr limit to the LTA; wastewater with a higher concentration will require a correspondingly larger LTA to ensure the 450 kg N/ha/yr limit is achieved.

8.10 As shown by the hydraulic analysis of the soils presented earlier in my evidence, the infiltration capacity of the soil at 20 mm/d is higher than the average design loading rate of 6 mm/d. This lower rate is needed to match the higher nitrogen concentration, resulting in a greater area needed to achieve the loading rate of 450 kg N/ha/yr.

**Nitrogen form and concentration**

8.11 The 50 mg/L limit proposed during Stage 1 is in my opinion appropriate, it makes pragmatic use of a future overflow storage pond as an oxidation pond while flows to the WWTP are low. The oxidation pond treatment system is a passive treatment system appropriate when the plant may only be receiving flow from a small number of connected properties. The low flows make it difficult to build and operate a SBR that then has suitable capacity for Stage 2. With Stage 2 connecting to a SBR, an overflow pond has been designed to manage unforeseen events by allowing the controlled release of water to a storage pond.

8.12 The Stage 1 level of 50 mg/L is consistent with the effluent quality of the Lake Hawea oxidation pond[13]. The oxidation pond adds an additional benefit as the form of nitrogen will predominately be ammoniacal nitrogen. 62% of the Lake Hawea pond effluent is in the form of ammoniacal nitrogen, with the remaining nitrogen being a nitrate or organic nitrogen.

**Nitrogen gaseous losses**

8.13 Further information has been sought in the s 42A Report to explain the nitrogen form and the potential for gaseous losses. In Stage 1, I expect the nitrogen form to be similar to that at the Lake Hawea oxidation pond, with a high proportion of ammoniacal nitrogen and nitrate nitrogen concentration similar to the future Stage 2. However, in Stage 2, the nitrogen form will be dominated by nitrate, with the Stage 2 treatment system achieving a 60 to 70% reduction in nitrogen. Within Stage 2, most of the ammoniacal nitrogen will be nitrified, and then 70% to 90% will be denitrified[14].

8.14 The simple nitrogen mass balance incorporates 15% of the applied nitrogen as lost. This is nominally described as being via gaseous losses of volatilisation to ammonia gas and denitrification to $N_2$ gas but will also include soil immobilisation which has not been separately accounted for. Beggs *et al* (2011) reported denitrification losses of 40 to 62 % for drip irrigation of wastewater. The 5% of ammonia volatilisation loss is less than the 22% observed by Saez *et al* 2012 for spray irrigation and less that 15% loss used within the Lake Hawea nitrogen balance, while 10% is allowed for denitrification losses within the Lake Hawea Balance. The losses of 15% also align with combined gaseous loses estimated by de Klein *et al* 2010 for a dairy pastural system soil mineral N of 570 kg N/ha.

8.15 It is my experience that the use of a 15% loss, in addition to the mass of nitrogen harvested but not leached, is conservative when compared to the published literature, and existing non leaching loss factors within mass balances for other consented discharges of wastewater in the region. Overall, whether the nitrogen gaseous losses are by ammonia volatilisation, which will occur more from Stage 1, or denitrification, which will occur following Stage 2, the 15% loss factor used is very conservative.

[13] QLDC monitoring data, Lake Hawea Oxidation pond monitoring data: Totals Nitrogen 2017 to 2021 average monthly mean 52 mg/L. Ammoniacal 32 mg/L.

[14] (NZLTC, 2000) – Potts, R. and Ellwood, B. 2000. Sewage Effluent Characteristics. Chapter One in New Zealand Guidelines for Utilisation of Sewage Effluent on Land. Part 2: Issues for Design and Management. (Edited by L.J. Whitehouse, H.Wang and M. Tomer). Pp. 180. Joint publication of the New Zealand Land Treatment Collective and Forest Research. Rotorua, New Zealand

8.16 The simple mass balance is supported by the OverseerFM modelling to establish the load limits of the pastoral equivalent system and incorporated published nitrogen content from human effluent. The mass balance is simple and efficient to administer and is not subjected to future version changes or obsolescence like is possible with reliance on a predictive model. Furthermore, the environmental monitoring of groundwater immediately down gradient of the LTA and the extensive network of surface water sites will allow effects greater than those predicted to be identified.

8.17 The PDP December review raised a new issue of the potential for phosphorus losses causing an adverse environmental effect on surface water bodies. Within my evidence I have described the measurement and assessment of the phosphorus storage potential of the upper horizons of the soil and glacial till and the likely loss pathway.

8.18 I consider that the conditions of consent and the design of the LTA mitigate the risk of phosphorus runoff and monitoring will detect phosphorus leaching down the soil profile.

8.19 The Council Planner has indicated that there is an uncertainty with the total nitrogen leaching mass and in combination with other discharges this could cause a decline in the surface water quality of Lake Wakatipu. As explained in Paragraphs 6.1 to 6.35 above, the Council Planner's concerns are able to be addressed. The staged development of the subdivision and the connection of Village septic tanks and linked nitrogen mass discharged, along with annual accounting of the nitrogen mass applied (WWTP and Septic Tanks), and the mass of nitrogen harvested via the cut and carry will ensure adverse effects of the discharge can be identified and reduced from that currently occurring. These factors in combination with proposed monitoring of water quality parameters will contribute to a reduction in adverse effects and further monitoring or mitigation can be conducted as mentioned below.

8.20 Should groundwater monitoring, as an early water trigger, indicate greater leaching is occurring than currently observed, the applicant has further mitigation measures that can be implemented, such as improved treatment at the treatment plant or increasing the size of the LTA.

**Conditions of Consent**

8.21 I have the following comments to support changes to the consent conditions recommended in the s 42A Report.

8.22 Condition 2 (b): I have amended this condition back to that in the application in order to retain flexibility to apply irrigation with a return period greater than one day during peak flow and two days during average dry weather flow. Providing an average over 7 days allows irrigation to be efficiently applied, giving operators options around application time during harvest and rest periods to avoid machinery trafficking on recently irrigated soils for example.

8.23 Condition 3 (a)(ii) and (iii): the level of prescription to lot sizes is unnecessarily restrictive. I interpret the condition as written restricting Stage 1 to an oxidation pond up to 450 lots, but precludes the use of Activated Sludge type treatment before 450 lots are connected. The specification of lot numbers precludes the option of managing the oxidation pond for longer in combination with a larger

LTA or SBR earlier. While the condition provides certainty to ORC, this is not necessary. Certainty of the treatment standard is provided with the WWTP effluent limits contained within Condition 16 and Condition 18 capping for all stages the total nitrogen application rate to 450 kg N/ha. The nitrogen loading rate and the residual nitrogen loss within Condition 23 are the key factors limiting the potential scale of effects to that assessed.

8.24 Condition 3 (a) (iv): The design provides for 900 $m^3$ of storage within the calamity pond which is equivalent to the 24 hr average daily flow. I consider this volume is sufficient for the following factors:

(a) It allows time for operations and maintenance staff to get to the site, and implement emergency response measures;

(b) Peak flows significantly higher than the average flow are not anticipated due to the new reticulation network and pressure sewage reticulation system avoiding stormwater and groundwater infiltration; and

(c) The overflow pond is required only for a WWTP disruption because the community wastewater is required to be pumped to the WWTP and a regional wide power outage will cause the influent to stop. Storage and contingencies for the pump stations are not within the scope of this application.

8.25 Condition 3 (b) (ii): I recommend that the minimum depth of dripper line is 150 mm to increase root zone contact with the dripper lines. In practice the installation of the lines to achieve 150 mm will mean that they are installed slightly lower so that this limit is achieved. The slightly shallower depth will not cause the dripper lines to freeze based on my analysis of the climate data.

8.26 Condition 6 (e) I recommend that sheep grazing be precluded on the LTA so that nutrient export off the site is maximised. I do note that sheep grazing of the fence line edges and in non-irrigated areas used as headlands and for valves and water delivery mains will be beneficial to maintain a tidy site.

8.27 Condition 7(a) as discussed in my response to the s 42A Report, I recommend that the groundwater monitoring be restricted to the downgradient Bores GW1, GW2, GW3a and GW3b. GW7 was dry and no longer exists, GW4 is dry and GW5 and GW6 are not able to be reliably sampled due to the depth of the groundwater. Groundwater monitoring is sentinel monitoring for what could potentially arrive in the surface water bodies.

8.28 Condition 10(a); I recommend if triggers are established from the baseline date, they are limited to surface water stream for Nitrate-nitrite Nitrogen, Dissolved reactive phosphorus, Ammoniacal Nitrogen and Escherichia coli.

8.29 Condition 16. I recommend that the concentration of Nitrogen discharged from the WWTP be retained at 50 mg/L while the wastewater is treated with an oxidation pond system and not reduced to 30 mg/L as recommend by the Council Planner in the S 42A report text. This higher Nitrogen concentration in the irrigation water does not increase the Nitrogen load to the LTA as this is controlled by the 450 kgN/ha/yr. The effects of this loading rate forms the basis of the effects assessment. I agree that when the SBR is operational the applied Nitrogen concentration is able to decrease to 30 mg/L.

8.30 With all of the parameters in Condition 16, I recommend that compliance with be based on a rolling 12 month mean, or 8 out of 12 samples within a 12 month period must be below the limit to achieve compliance. The reason for a flexible limit is to improve the operability of the WWTP by allowing for some season variation in treatment quality. Overall this flexibility does not change the Nitrogen loading cap of 450 kgN/ha/yr. All monthly samples would be used in the calculation of the loading rate as presented in the loading examples in paragraph 6.24

8.31 I also recommend the unit of measurement for the *E.coli* be Most Probable Number (MPN) and not Colony Forming Units (CFU) so that the monitoring algins with the most commonly available testing method. There is very little difference in the results and the NPS-FM 2020 does not specify a test method, with LAWA reporting under one category.

8.32 Conditions 19 and 20. I recommend that these conditions be deleted. As discussed in my evidence, soil testing and analysis shows that there is sufficient phosphorus sorption capacity within the soil profile to retain the mass of applied nutrient for the full life of the consent. The sampling programme given as Condition 25 provides a more useful measure of the impact of P on soil and the risk from excessive P loading. The risk of leaching is monitored through Condition 25 which details measurement of soil condition. This is intended to detect movement of P through the soil profile. This allows remediative actions to be taken which are specific to the potential effect, as required by Condition 26e.

8.33 I consider that an Olsen P limit to be a less effective control since the value proposed does not relate to an effect and may unnecessarily limit the operation of the discharge.

8.34 In the event that an Olsen P limit is retained, then monitoring of Olsen P in the 30-50 and 50-100 cm range has no additional value and should be excluded as the duplication of effort places an unnecessary burden on the consent holder. If an Olsen P limit is retained, then I do not consider 40 mg/L an appropriate limit. This value relates to plant response (from yield response curves) not to environmental risk. An appropriate limit would be 100 mg/L.

8.35 Condition 21. This condition establishes the mass of nitrogen removed with the harvested material for use in the nitrogen mass balance calculation in Condition 22. Testing for Total phosphorus in not required for this mass balance and is an unnecessary additional cost.

8.36 Condition 22(b). I recommend that the condition retains the percentage loss that is attributable to factors other than harvesting and leaching, as discussed in my response to the s42 a report.

8.37 Condition 25 (a). I recommend this condition is amended to a frequency of every two years due to the slow response of the soil to change due to applied constituents. A higher sampling frequency will not provide an increased resolution to the changes.

8.38 Condition 25 (b). The measurement of Olsen P is not recommended for the lower sampling depths as movement of phosphorus will be identified with Total phosphorus. The testing of Total Carbon, Organic matter and available nitrogen, while interesting from a soils point of view are not typically tested as they do not contribute to the identification of adverse effects.

8.39 Condition 25 (c); I recommend deleting the reference to Ksat, as this is just one method of measuring soil infiltration. As a replacement for 25 (c) ii and iii, a Visual Soil Assessment would provide a comprehensive assessment of the soil's physical structure and its ability to support a productive pasture. Sheppard 2000[15] provides a detailed methodology to undertake the assessment.

8.40 Condition 34 (c); I recommend deleting the "within or" in relation to seeps occurring within the LTA area. As presented in the AEE, it possible for there to be some lateral movement as well as vertical drainage through the soil profile given the sloping nature of the LTA. Surface emergence of any applied wastewater is very unlikely due to the soil matrix and the 150 mm depth of the emitter lines. For those surface water features that are located within the LTA, a 10 m buffer has been provided to distance the subsurface irrigation from the surface waters.

# 9 Conclusions

9.1 I conclude that the Kingston WWTP and integrated LTA has been designed to provide a high level of treatment removing biological and chemical contaminants from the water and avoid adverse environmental effects.

9.2 The proposed method and scale of treatment is appropriate for the catchment and will at no time increase cumulative nutrient load entering Lake Wakatipu. While at full capacity provide the community with a key component necessary to reduce the nutrients entering Lake Wakatipu when they upgrade the existing septic tank wastewater treatment systems.

9.3 The development is able to be staged to respond to increases in population density and the development of new dwellings connected to the Scheme. A combination of increasing the LTA and the WWTP capacity are available to the community to affordably manage these changes over time.

**Brian Neil Ellwood**

**23 December 2021**

[15] Shepherd, T.G. 2000: Visual Soil Assessment. Volume 1. Field guide for cropping and pastoral grazing on flat to rolling country. horizons.mw & Landcare Research, Palmerston North. 84p

## Appendix BNE1

**Table 1: Kingston Monthly Mean Rainfall and Soil Moisture Deficit (mm)**

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rainfall** | **88** | **61** | **74** | **75** | **84** | **85** | **70** | **79** | **79** | **87** | **67** | **96** | **944** |
| **Soil Moisture Deficit** | **62** | **45** | **20** | **4** | **0** | **0** | **0** | **0** | **0** | **3** | **23** | **46** | **208** |

**Table 2: Field and Laboratory Measurement Hydraulic Conductivity Results**

| Location | Saturated ($K_{sat}$) (mm/hr) | Unsaturated ($K_{-40mm}$) Field test (mm/hr) | Unsaturated ($K_{-40mm}$) LandCare (mm/hr) |
|---|---|---|---|
| Site 1 | 60 | 3.82 | 12 |
| Site 2 | 156 | 2.96 | 50 |
| Site 3 | 90 | | 19 |
| Site 4 | 45 | 4.52 | 27 |
| Site 5 | 25.5 | 1.10 | 10 |
| Site 6 | 122.5 | 1.78 | 7 |
| **Average** | **83.17** | **2.83** | **20.13** |

**Table 3: Expected Raw and Final Effluent Quality**

| Parameter | Typical Domestic Raw Wastewater | Stage 1 Effluent Quality[(1)] | Full Design Treatment Plant Effluent[(1)] |
|---|---|---|---|
| Biochemical Oxygen Demand (BOD, mg/L) | 200 - 400 | 50 | 20 |
| Total suspended Solids (SS, mg/L) | 200 - 350 | 30 | 30 |
| Total Nitrogen (TN, mg/L) | 40 - 85 | 50 | 20 |
| Total Phosphorus (TP, mg/L) | 8 - 15 | 10 | 10 |
| Faecal Coliforms (cfu/100 ml) | $10^4 – 10^7$ | $10^4$ | $10^4$ |

(1) Effluent quality is based on a 12 month rolling mean.

**Appendix BNE2**

**Site Sampling Map**


**Kingston Station Soils Testing Locations by LEI, 2018**

**Figure 1: Soil testing locations 2018**


**Figure 2: Soil testing locations 2020**


**Figure 3: Groundwater Investigation Bores**

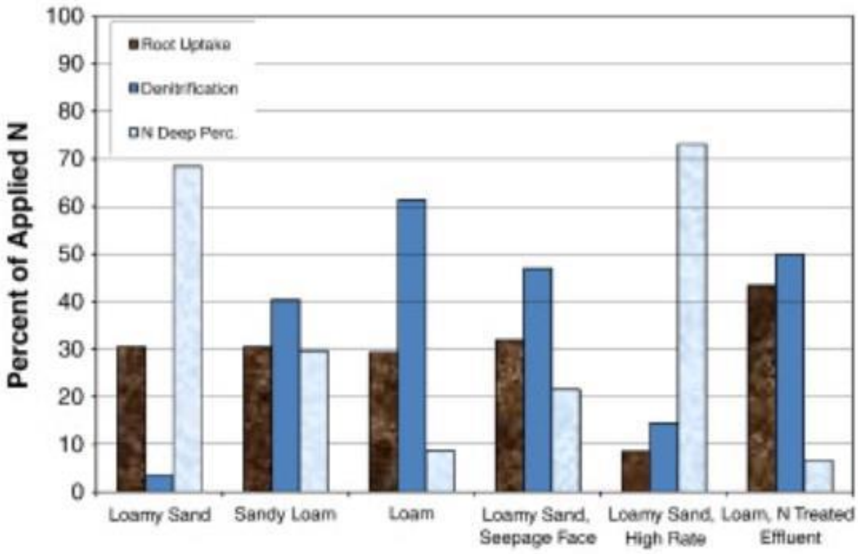


**Figure 4: Fate of Nitrogen in Wastewater Effluent Applied to Land (Beggs, et. al., 2011)**

**Appendix BNE3**


**Figure 1: LTA and Monitoring Locations**