Otago Regional Council

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MEMORANDUM

To: **Policy**

From: **Rachel Ozanne**

Date: **30 November 2023**

Re: **Mixing Zones and Receiving Water Quality Standards**

Role	Name	Date Completed
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Introduction

ORC science was asked to provide advice on receiving water quality standards to control the quality of the discharge into water, and a formula for determining the size of the mixing zone. The request is specific to permitted activities.

Policy provided a list of discharges, provided in Appendix A, to be considered in the permitted category (with reasonable mixing).

Mixing Zones

The Regional Plan: Water for Otago[1] defines reasonable mixing as 'the process where undiluted effluent disperses through receiving waters. Mixing results in a mixing zone where the concentration of contaminants varies from that in the effluent to that of the fully mixed receiving water. Reasonable mixing may be said to have occurred at some point between the point of discharge and the point at which the effluent is completely mixed with the receiving water. Beyond the reasonable mixing zone, the effluent and water mix comply with any water quality standards for the water body. ORC has not defined mixing zones in previous water plans. Several research publications and technical reports propose different approaches to the definition of mixing zones. Cooke, et al, (2010)[2] provide a review

[1] https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-policies/water

[2] Cooke, J. Milne, P. Rutherford, K A review of definitions of "mixing zones" and "reasonable mixing" in receiving waters Prepared for Auckland Regional Council. Auckland Regional Council Technical Report 2010/045.

of definitions of mixing zones and reasonable mixing in receiving waters and suggested approaches to the application of reasonable mixing zones in New Zealand.

An important concept is that of the 'non-compliance zone' (Rutherford et al., 1994[3]). If water quality standards are defined which apply after 'reasonable mixing' this implies the reasonable mixing zone is a zone of 'non-compliance' in which water quality is below specified standards.

Cooke *et al.,* (2010) suggest two approaches for defining the limit of a mixing zone.

- A 'reasonably well mixed' approach where a contaminant is considered reasonably mixed at the point at which it is mixed with a reasonable percentage of the flow of receiving water.
- A 'specified distance approach', i.e., reasonable mixing in a river is deemed to occur at a particular distance below the outfall.

Cooke *et al.,* (2010) suggests that the 'reasonably well mixed' approach is preferable for rivers and streams and the distance approach may be more practical for lakes (and the coastal marine area). Both approaches require a measurement of flow. Examples of how the approaches work are given in Cooke *et al.,* (2010).

The specified distance approach is the simpler to understand of the two categories, Cooke *et al.,* suggests criteria for the downstream limits of the 'reasonable mixing zone' as follows:

> *The lesser of a distance of X m downstream of the point of discharge or a distance being X times* w*, where* w *is the mean wetted width of the river or stream at median flow, as measured at 10 cross sections downstream of the point of discharge. With the option to carry out a mixing assessment.*

ORC proposes to use a similar specified distance approach, using distances already used in operative regional plans[4] that but without reference to flow:

For *river*, *modified watercourse*, and *artificial watercourse* locations with flowing *water* present at all times:

(a) no longer than 200 m along the longest axis of the zone *or* 10 times the wetted channel width for that location (whichever is the lesser); and

(b) occupies no greater than two-thirds of the wetted channel width for that location; and

(2) For *river*, *modified watercourse*, and *artificial watercourse* locations with intermittent flows, no longer than 20 m at times of flow and 0 m at no flow; or

(3) For *lake* locations:

(a) if the *discharge* location is within 50 m of the *lake water* edge[3] at any time, a circle with a diameter of 50 m; or

(b) if the *discharge* location is greater than 50 m from the *lake water* edge[3] at all times, a circle with a diameter of 100 m; or

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[3] Rutherford, K.; Zuur, R.; Race, P. (1994). Resource Management Ideas. No. 10. A. discussion on reasonable mixing in water quality management. Ministry for the Environment.

[4] https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-regional-plan/canterbury-land-and-water-regional-plan/

Classification system

The River Environment Classification (REC; (Snelder and Biggs 2007)) is used by ORC to classify river segments in Otago. It is either used in its entirety, or modified into fewer management classes using the second (source of flow) level (Snelder and Fraser 2023).

REC (using the second-level REC class; climate by typography) could be incorporated into the permitted activity process and would allow for the use of ANZECC guidelines[5] as receiving water quality standards.

Six of the REC classifications do not occur in Otago. They are: Warm Dry Low-elevation, Warm Wet Hill, Warm Wet Low-elevation, Warm Wet Lake, Warm Extremely Wet Hill, and Warm Extremely Wet Low-elevation.

Receiving Water Standards (met at downstream mixing zone limit)

ANZECC guidelines provide default guideline values (DGVs) for physical and chemical stressors in freshwater in New Zealand which have been developed for the second-level REC classes (climate by typography) using reference conditions[6]. Parameters include ammoniacal nitrogen, clarity, conductivity, dissolved oxygen, dissolved reactive phosphorus, nitrate, pH, suspended solids, total nitrogen, total phosphorus, turbidity.

Dissolved oxygen (below point source) and *E. coli* are variables included as an attribute in Appendix 2A of the National Policy Statement for Freshwater Management (NPS-FM) (MfE, 2020).

The DGVs have two percentiles calculated based on stressor. For physical and chemical (PC) stressors (indicators) that are harmful at high values (e.g., nitrate) the 80th percentile is used and PC stressors that are harmful at low values (e.g., clarity) the 20th percentile is used. Beyond the reasonable mixing zone, the effluent and water mix comply with any water quality standards for the water body.

It is reasonable to use the ANZECC PC DGV's for all parameters, apart from dissolved oxygen, pH and clarity (which are discussed further below).

ANZECC guidelines also provide an extensive list of DGVs for toxicants in freshwater[7]. Unlike the physical and chemical stressors, toxicant DGV's are not based on REC classes rather the level of species protection (80%, 90%, 95% and 99%).

It is suggested that the level of species protection to be used varies according to REC: Mountain 99%, Hill 95%, and Low 80%, which reflects the ANZECC recommendations i.e., high conservation or ecological value (Upper Lakes), slightly to moderately disturbed (all other Rohe/FMU) and highly disturbed (i.e., urban streams). The Lake REC will differ depending on the rivers feeding them. The recommendations are to use the following: 80% for Cool Dry Lake, and 99% for both Cool Wet Lake and Cool Extremely Wet Lake.

It is reasonable to use the ANZECC toxicant DGV's.

[5] https://www.waterquality.gov.au/anz-guidelines/resources/previous-guidelines/anzecc-armcanz-2000
[6] https://www.waterquality.gov.au/anz-guidelines/your-location/new-zealand
[7] https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/search

Parameters not considered by ANZECC Guidelines, or alternatives to using ANZECC Guidelines

Chlorophyll a, temperature, and *E. coli* are not considered by the ANZECC guidelines. Alternative criteria for visual clarity, pH, dissolved oxygen, sediment cover and suitability for consumption are also discussed.

a) Chlorophyll a. It is recommended to use the RMA condition of no undesirable biological growths because of any discharge of a contaminant into the water. This standard should apply within the zone of reasonable mixing.
b) Temperature. Retain RMA condition - the discharge does not increase the natural temperature of the receiving water, after reasonable mixing, by more than 3°C, and does not cause the temperature of the receiving water, after reasonable mixing, to rise above 25°C.
c) E. coli. Table 9 of the NPS-FM is for the human contact value which uses *Escherichia coli (E. coli)* as the attribute unit. Attribute band A is the state with the least risk [8] with attribute bands B and C having increasing risk. It is suggested that the attribute band required for E. coli should vary according to REC and that the 95th percentile should be used. The draft LWRP contains Target Attribute States for each of the FMU/rohe, which includes target bands for the *E. coli* 95th percentile based on REC class. These targets vary depending on the FMU/rohe. For consistency, it is recommended that the receiving water standard for *E. coli* should be the same as the target band set for the FMU/rohe.
d) Clarity – The aim is to prevent any conspicuous change in the colour or visual clarity. A narrative change is preferred (the approach taken in the RPW) as opposed to using the ANZEEC DVGs., A narrative approach will be locally nuanced, which will help eliminate risk in those waterbodies with naturally higher clarity. The narrative change should consider the REC, with Mountain REC class allowing up to a 10% change (as the condition of the waterbody is considered reference or near pristine condition), Hill 20% change and Low 33% change [9]. For lakes the recommendation is 33% change for Cool Dry Lake, and 10% change for both Cool Wet Lake and Cool Extremely Wet Lake. Outside the mixing zone there should be no noticeable difference in clarity.
e) pH. pH in Otago is influenced by geology and landscape. The 20th percentile for pH (ANZECC PC DGV) will be breached in areas sourced from swamps/tussock i.e., upland areas in central Otago including the Upper Taieri, and the 80th percentile for pH will be breached in areas originating from alkaline geology i.e., some Waitaki region rivers. It is suggested to retain the RPW condition - the discharge does not change the pH of the receiving water, after reasonable mixing, by more than 0.5 pH units.
f) Dissolved Oxygen. Table 7 of the NPS-FM is for dissolved oxygen (below point source) and gives a 7-day minimum and 1-day minimum for dissolved oxygen. The NPSFM uses mg/l as the dissolved oxygen unit. The alternative would be to use ANZECC which provides a DGV table for dissolved oxygen with percent saturation, however by using a percentage of maximum saturation, the threshold dissolved oxygen concentration decreases as water temperature increases (i.e., 80%

[8] For at least half the time, the estimated risk is <1 in 1,000 (0.1% risk). The predicted average infection risk is 1%.

[9] The RMA Sections 70 and 107 standards set out that discharges of contaminants into water shall not give rise to "any conspicuous change in the colour or visual clarity in the receiving waters". The Ministry for the Environment Water Quality Guidelines No. 2 (MfE, 1994) provide guidance as to what degree of water clarity change constitutes a "conspicuous change": 20% change in waters where visual clarity is an important characteristic of the water body, and 33% to 50% in other waters.

saturation at 10°C is 9.0 mg L-1 and at 25°C is 6.6 mg L-1)[10]. The preferred option is to use the NPSFM table, which is specifically targeted at below point source, and uses mg/l. The NPS-FM Table 7 has four 'bands', attribute band A is considered to be of a standard equivalent to achieving reference or near-pristine status[11]with attribute bands B and C moving further away from reference state with attribute band D being below the national bottom line. It is suggested that at the end of the mixing zone the dissolved oxygen should achieve an attribute state depending on REC class. The REC 'Mountain' classification should achieve the A band, 'Hill' should achieve the B band and 'Low' should achieve the C band.

g) Sediment cover. If ORC were to include a change in sediment cover, it would be reasonable to use a narrative condition like that of Southland and Taranaki, i.e., no increase in the deposition of matter on the bed of the water body if it has an adverse effect on aquatic life.

h) Suitability for consumption. If ORC were to include the suitability for consumption, it would be reasonable to use a narrative condition like that of Taranaki, i.e., the contaminant must not cause the water to be rendered unsuitable for treatment (equivalent to coagulation, filtration, and disinfection) for human consumption by the presence of contaminants.

Modified watercourses

The proposed definition of 'modified watercourse' is:

' a water body that has been modified, channelled, or straightened for land drainage or other purposes.'

Given these watercourses are natural waterways that have been modified, these can be treated the same as other rivers, and the same receiving water standards can be applied.

Artificial watercourses

The proposed definition of 'artificial watercourse' is:

> *'a watercourse that is deliberately created by human action (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, farm drainage canal, drain, or duck pond) provided that it is not part of a water body or a modified watercourse.'*

The definition spans a range of waterbodies which are likely to have variable water quality. Rather than apply the same regime as natural waterbodies (DGV's or ANZECC based on REC), it is suggested that at the end of the mixing zone the discharge will simply have a 'no more than minor' effect on water quality.

[10] https://environment.govt.nz/assets/Publications/Files/national-objective-framework-temperature-dissolved-oxygen-ph.pdf

[11] https://environment.govt.nz/publications/national-objectives-framework-temperature-dissolved-oxygen-and-ph/

Recommendations

- Use mixing zone distances specified in operative regional plans.
- Use ANZECC DGV's to populate table of receiving water quality standards, using the second-level River Environment Classification classes (climate by typography) (where applicable) for all parameters, except for dissolved oxygen, E. coli, clarity, and pH.
    - For dissolved oxygen use the NPS-FM (Table 7).
    - For E. coli, use the NPS-FM (Table 9), 95th percentile, and the attribute band set for target attribute state for the relevant FMU/rohe.
    - For clarity, classify according to REC with a maximum specified % change.
    - For pH, the discharge does not change the pH of the receiving water, after reasonable mixing, by more than 0.5 pH units, for all relevant water bodies.
- Use RMA or RWP to populate parameters not covered by ANZECC (chlorophyll a, temperature), for all relevant waterbodies.
- Narrative conditions should be used for sediment cover and suitability for consumption, for all relevant waterbodies.
- Discharges to modified watercourses to be treated the same as a discharge to a river.
- Discharges to artificial watercourses to have a 'no more than minor' effect after the mixing zone.

Appendix A

Policy provided list: Types of discharge to water.

All Discharges
Discharge of construction-phase stormwater
Discharge of agrichemicals
Discharge of tracer dye (excluding visual clarity)
Discharge of water used for holding live organisms
Discharge of stormwater (excluding from a reticulated stormwater network)
Any discharge associated with earthworks
Any other discharge not specifically managed elsewhere
Constructing a wetland
Maintaining an in-stream dam or weir
Placement of a weir
Removing an in-stream dam or weir
Maintaining flood protection and drainage infrastructure (excluding drains)
Maintaining, altering, or placing small structures in the bed
Maintaining, altering, or placing single span bridges and fords
Maintaining any other lawful structure in the bed
Demolishing or removing any structure in the bed
Placement of a culvert or passive flap gate
Vehicle access in the bed
Post-flood debris removal
Rebattering or reshaping of banks
Reinstatement of banks
Gravel extraction
Removal or clearance of vegetation in the bed (excluding via agrichemicals)
Vertebrate toxic agents
Emergency firefighting training
Passive discharge from contaminated land – this currently refers to DWS 2005 and ANZECC given the likely contaminants in the discharge