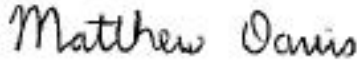
Auckland
Regional Council
TE RAUHĪTANGA TAIAO

A Review of Definitions of "Mixing Zones" and "Reasonable Mixing" in Receiving Waters

August 2010 Technical Report 2010/045

Auckland Regional Council
Technical Report No.2010/045 August 2010
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-927135-01-3

Technical Report, first edition.

Reviewed by:	Approved for ARC publication by:
	
Name: Judy-Ann Ansen	Name: Matthew Davis
Position: Project Leader, Stormwater Action Team	Position: Manager, Partnerships Community and Programmes
Organisation: Auckland Regional Council	Organisation: Auckland Regional Council
Date: 28 August 2010	Date: 28 August 2010

Recommended Citation:
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.

A Review of Definitions of "Mixing Zones" and "Reasonable Mixing" in Receiving Waters

J. Cooke (Beca)
P Milne (Simpson Greirson)
K Rutherford (NIWA)

Prepared for
Auckland Regional Council

Contents

1 Executive Summary

The Auckland Regional Council (ARC) Proposed Air, Land, and Water Plan (ARC: PALWP) defines reasonable mixing as:

The point where the mixing of the contaminated discharges and the receiving water is assumed to have occurred. Assessment of compliance with the reasonable mixing requirement is undertaken at the point downstream, which is 30 times the receiving water channel width at the point of discharge, and one third of the channel width across.

The ARC has recognised that this definition is uncertain, technically deficient, and does not effectively address coastal and estuarine receiving waters. In addition the use of channel morphology to determine the size of the mixing zones does not suit many Auckland streams. The other difficulty identified is that this definition is not always appropriate for stormwater discharges.

This report aims to assist ARC with reconsidering the definitions of mixing zone and reasonable mixing to make it more encompassing and to achieve a better fit with the region's receiving waters. Any new definition needs to be defensible from both scientific and legal standpoints.

The approach we have taken is as follows:

(i) review the role of reasonable mixing under the Resource Management Act (1991) RMA and its predecessor;

(ii) consider the circumstances and purpose of defining a reasonable mixing zone;

(iii) review New Zealand examples of how mixing zones, and in particular "reasonable mixing ", is applied by Regional Councils, and interpreted in case law;

(iv) review contemporary international definitions and usage of mixing zones, analyse the essential elements of usage in each jurisdiction, and compare their application with that in New Zealand;

(v) discuss the merits of some possible approaches; and

(vi) propose some possible definitions.

2 New Zealand Perspectives

2.1 Role of Reasonable Mixing under RMA

The concept of reasonable mixing arises under the RMA in the following contexts:

- The statutory minimum standards in section 70 (permitted activities) and section 107 (discharge permits to discharge to water) require that point source discharges should not on their own or in combination with other contaminants, cause various specified narrative standards to be breached *after reasonable mixing* (e.g. no conspicuous change to colour or clarity).
- Section 69(3) provides that: *Subject to the need to allow for reasonable mixing of a discharged contaminant…..a regional council shall not set standards in a plan which result, or may result, in a reduction of the quality of the water in any water at the time of the public notification of the proposed plan unless it is consistent with the purposes of the Act to do so.*
- A note to the standards in the third schedule states that these standards apply after reasonable mixing and allowance for natural perturbations.
- There are various guidelines referenced in plans, which apply after reasonable mixing. Whilst there is no statutory requirement to apply reasonable mixing to these guidelines, if they are translated into standards in a plan or into consent conditions, or if they are used to assess an application, then reasonable mixing should be allowed for if referred to in the guidelines. That is because the guidelines have been developed on that basis and it would be a misuse of them if they were applied without allowance for reasonable mixing. (For example, the water quality guidelines contained in the Greater Wellington Regional Freshwater Plan for the Wellington Region.)
- Except for the section 70 and 107 minimum standards and the section 69 there is no express requirement for other (non third schedule) water quality standards to incorporate an allowance for reasonable mixing.
- The requirement in sections 70 and 107 does not necessarily require that the conditions of the permitted activity or the conditions of a discharge permit need to include the narrative standards in those sections. The requirement is simply that the council be satisfied that the standards will not be breached after reasonable mixing. It is common, but not essential, to incorporate the standards into permitted activity rules and into consents.

Some Relevant Points

Before one attempts to define reasonable mixing the following points need to be appreciated:

- One needs to distinguish between *standards* (rules) and *guidelines* (which may be reflected in standards or may be incorporated into policy but in some cases are not referenced at all in a Regional Plan.)
- Non compliance with *standards* will usually mean that an activity will fall into a different class. For example if permitted activity standards are not met, the activity may become controlled or discretionary. If discretionary activity standards are not

met the activity will become non-complying or (less often) prohibited.

- Accordingly, actual or likely non compliance with standards does not necessarily mean that consent cannot be granted. (The exception is the section 107 standards and any standards which make a discharge prohibited).
- Non compliance with permitted activity standards in a plan will mean that the discharge is unlawful unless a discharge permit has been obtained to allow that non compliance.
- If conditions on permitted activities or on discharge permits make reference to *reasonable mixing* they should specify the reasonable mixing zone in a manner that is clear and objectively ascertainable, otherwise the rule may be void for uncertainty (permitted activity rules cannot leave a discretion to councils).
- The same is true for conditions on resource consents. If they include an allowance for mixing (whether or not reasonable mixing) then the mixing zone and monitoring point must be clearly specified.
- If a council pursuant to section 69 classifies waters for management as one of the classes specified in the third schedule and if it includes water quality rules, the rules must require the observance of the standards in the third schedule or more stringent or specific standards.
- Section 69 appears to allow for a different type of standard from that discussed above. It appears that a plan may specify water quality standards, which do not impact on the classification of a discharge, but which must be reflected in permitted activity conditions and consent conditions.
- The standards in the third schedule do not themselves make any reference to reasonable mixing. Accordingly it is arguable that those standards can be applied as end of pipe standards with no allowance for reasonable or indeed any mixing. However, there is a note in the third schedule, which states that the standards apply after reasonable mixing and disregard the effect of any natural perturbations that may affect the water body.
- The preferable interpretation is that the effect of section 69(3) is that where a plan incorporates the third schedule standards they must make allowance for reasonable mixing. Even where the plan utilises a different standard, it may be argued that the effect of section 69(3) is that it was intended that those standards also make provision for reasonable mixing.
- However, it is possible that if it was consistent with *sustainable management* (and properly justified in terms of section 32) a council may be able to set end of pipe standards or allow for a fixed (specified) mixing zone which is less than what is required for the discharge to be considered *reasonably* mixed.
- Even with the third schedule standards it can be argued that in some cases reasonable mixing (in terms of what is required for sustainable management) is minimal and is less stringent than what is required for the contaminant to be reasonably well mixed. However, that approach is untested and in our view is somewhat risky.
- Section 21(3A) of The Water and Soil Conservation Act (WSCA) 1967 provided that in relation to classified waters, water rights to discharge must be granted with conditions sufficient to *ensure that …after allowing for reasonable mixing of the discharge with the receiving water, the quality of the receiving water does not as a result of the*

discharge fall below the standards specified in the classification of that water. There is a strong argument that the same was intended to apply under the RMA, at least in relation to the classification standards set out in the third schedule which have their origin in the WSCA classification standards.

- As discussed above, where a Regional Council has different classes than those in the third schedule it may be able to dispense with the notion of reasonable mixing, provided that the end result is that there is no deterioration in water quality after reasonable mixing.[1]
- Even where a plan sets receiving water quality standards, conditions of discharge permits do not need to incorporate those standards. It is acceptable and often preferable, for the discharge permit to only have effluent standards, but for these to be designed to ensure that the receiving water standards (or relevant guidelines) are met.[2]
- Guidelines do not have the effect of standards unless they have been incorporated into standards or as conditions of consent.
- Where a plan does not have receiving water standards incorporated into rules, but instead has policies that refer to guidelines, those guidelines are not standards. They will be relevant to the assessment of consent applications but have no statutory basis to be complied with.
- Guidelines may be incorporated into discharge permits either by being translated into a receiving water condition, or by way of effluent standards that allow the guideline to be achieved after reasonable mixing.
- If a receiving water standard (or guideline) is incorporated into a condition of consent, then the condition will need to specify the point at which the standard must be achieved. There will usually be some allowance for mixing, however some conditions will require compliance prior to reasonable mixing (that approach would however need to be justified by the consent authority).
- For discharge permits which do not have receiving water standards as conditions, reasonable mixing will only be relevant in terms of modeling and monitoring to ascertain whether the receiving water standards are likely to, or are being achieved.
- A discharge should not cause relevant receiving water standards/guidelines (including section 107 standards) to be breached in circumstances where they would not otherwise be breached.
- Point source discharges should not, on their own or in combination with other contaminants, cause the relevant standards to be breached.

---

1 In other words there should be no deterioration from what existed prior to the standards. There is however no requirement that a discharge not cause a deterioration of water quality after reasonable mixing as compared to the upstream situation

2 Effluent standards are usually standards reflected in consent conditions, but could also be reflected by standards in plans.

- If a river or stream would not meet relevant standards at a particular time or flow (e.g. because of upstream contamination or natural perturbations) then the additional discharge is not in breach of the standard because the standard would not be met in any event (i.e. the discharge is not causing the standard to be breached). Whether the cumulative effects of the additional discharge are acceptable is a question of fact and judgement to be made in each case.
- On the other hand, where a receiving water standard/guideline would be met "but for" the additional discharge, then the discharge would cause the standard to be breached or the guideline to be not achieved. For example, if background contamination from diffuse sources is not such as to cause a standard to be breached, but the discharge for which consent is sought pushes water quality over the edge after reasonable mixing, then the discharge would be in breach of the standard. Depending upon how the rules are drafted this may make the discharge non complying or prohibited.

2.2 In What Circumstances is Reasonable Mixing Relevant?

The concept of reasonable mixing (and hence the need for a definition) will arise in the following circumstances:

- When assessing whether a permitted activity rule or a discharge permit will meet the statutory minimum standards specified in sections 70 and 107 respectively.
- Where a plan incorporates the third schedule standards.
- Where receiving water quality standards in a plan allow for reasonable mixing.
- Where policies in a plan require applications to be assessed in terms of guidelines which incorporate reasonable mixing.
- Where conditions of a discharge permit require compliance after reasonable mixing.
- Where the discharge permit has effluent standards rather than receiving water standards, but requires monitoring in relation to guidelines, which are based on reasonable mixing (i.e. the monitoring point will be at the end of the reasonable mixing zone).

2.2.1 Why Define Reasonable Mixing?

For the purpose of permitted activity standards (conditions), it is necessary to define reasonable mixing, or at least the size of the RMZ (Reasonable Mixing Zone), so as to provide certainty as to what is required in order to be permitted. Usually such certainty will be provided by way of a definition or formula which allows the size of the RMZ to be calculated.

If the permitted activity standards are not met then consent is required and may of course be granted if that is consistent with sustainable management. Permitted activity water quality standards are not intended to be a basis for declining consent, rather they are a trigger for a consent application where the effects of the discharge are assessed in full. (However the section 70 permitted activity standards are the same as those in section 107 which prohibit the grant of consent if those standards are breached except in limited circumstances).

In the case of standards which change the classification of an activity from say controlled to discretionary or discretionary to non complying or non complying to prohibited, it is also necessary for people to be able to determine what reasonable mixing is in a particular context.

In other words, in our view, what is reasonable should not be a matter of discretion for such standards.

In the case of standards which do not change the classification of an activity but which are intended to be incorporated into consent conditions, it is not necessary (and arguably not permissible) to define reasonable mixing in quantitative terms. This is because what is reasonable in the circumstances can be assessed in the context of the application and then size of the RMZ can be fixed in the consent conditions if required.[3]

An example of this type of standard is the section 107 standards. Section 107 provides that discharge permits must not be granted where the discharge after reasonable mixing is likely to *give rise to* (cause) any of the listed effects. There is no need to define reasonable mixing in this context and it may be ineffective to do so. The consent authority is to determine what is reasonable in the particular circumstances of the discharge that is being considered and the sensitivity of the receiving environment.[4]

In the case of these types of standards, it is still highly desirable to provide policy guidance as to how the RMZ will be determined in practice. If this is not done, there will be unnecessary debate and sometimes litigation over what is reasonable.

Finally, we observe that if there are no receiving water quality rules, but only guidelines, there is no need for the reasonable mixing to be defined (or at least no need for it to be defined in formulaic objective terms).

There is tension between the need to provide certainty and the desirability of retaining flexibility when considering consent applications and imposing conditions. The Courts have said that reasonable mixing is to be determined on a case by case basis and accordingly, in the consent context, a definition may not be binding. That is because it is open for an applicant or a submitter to argue that the definition in the plan is not *"reasonable"* in the circumstances.

In view of this, it is arguable that any definition of reasonable mixing should allow for discretion to be exercised (except in the context of permitted activity conditions and standards which define an activity class).

It is important to appreciate, that the form of the definition may depend upon what it is being used for. Indeed there is the potential to use different definitions for different purposes. For example, in relation to standards that define an activity class, a definition must be clear and certain and must not reserve discretion. On the other hand, a definition, which is being used for the purposes of policy or assessment criteria to allow the RMZ to be determined in the context of consent hearings, may incorporate a degree of discretion.

---

[3] This will not be necessary if there are effluent standards in conditions rather than receiving water quality conditions.

[4] As discussed below there is at least one decision that implies that a consent authority should always look beyond any definition in the plan and decide what is reasonable in the circumstances.

If a plan defines reasonable mixing, then that may override a case by case approach. We say "may" because this will depend upon how the definition is used in the plan. If a plan includes a definition and the defined words are used in ***standards,*** then that is the standard, there is no discretion (which should be the case for standards). However, if the term is used in a policy then it will not necessarily be determinative. Applicants will still be able to argue that a larger mixing zone is *reasonable* in the circumstances.

Whether or not a definition of reasonable mixing is binding on the consent authority will depend upon its use. If used in the context of activity standards it will be binding. If however the standards are to be used for assessing consent applications and if the consent is granted, they are to be translated into consent conditions, then the definition may not be binding.

One option is to have a definition, which is certain for the purposes of permitted activity conditions and activity standards, but which only provides guidance for situations where discretion is required.

Another variation that achieves the same purpose is to have a clear and certain definition for the purpose of standards, which require this certainty, and to have a *policy*, which guides how reasonable mixing will be determined in other circumstances.

2.3 Approaches to Reasonable Mixing in New Zealand

2.3.1 Case Law

The RMA does not define the concept of reasonable mixing. Previous case law under the WSCA 1967 suggested that what is reasonable mixing *will be a question of fact and degree in each case*. In our view that is still the position if a plan does not define reasonable mixing and may still be the position for resource consents, even where there is a definition.

There is a common misconception that mixing is only "reasonable" once it is complete. However, there is nothing in the legislation or case law to support this notion. "Complete mixing" occurs once the effluent is completely dispersed through the receiving waters. Furthermore, in unbounded flows (such as lakes and the oceans) mixing continues more or less indefinitely. In our view reasonable mixing will usually be less than full mixing and seldom if ever more than full mixing.

In *Mahuta v NWSCA* (1973) 5 NZTPA 73 it was held that the intention of the reasonable mixing zone allowance in the WSCA was that the mixing of the discharge with the receiving waters should occur as quickly as possible in order to ensure that the intention of maintaining the classified water quality is not frustrated. This approach was followed in later cases, including *Freezing Co (Southland) Ltd v Southland Catchment Board* (1977) 6 NZTPA 247 and *Kerikeri Properties Ltd v Northland Catchment Commission* (1977) 6 NZTPA 344.

Under the rather different regime of the RMA, it was decided in *Paokahu Trust v Gisborne DC* (2003) 9 NZED 47 that definitions adopted under transitional and proposed regional plans are not determinative of what is reasonable mixing for the purpose of section 107. As in the case law developed under the WSCA 1967, it was held that reasonable mixing is a question of fact in each case.

It remains to be seen whether this will also apply where there is definition in an operative (or at least beyond appeal) plan. In those circumstances, it may be that the definition will apply and that there will be no room for discretion unless the definition provides for such.

The case by case approach was also adopted in *Southland Regional Council v New Zealand Deer Farms Limited* (2004) 9 NZED 630, which related to a prosecution for disturbance of a river bed (section 13) in contravention of permitted activity standards. The Plan defined the RMZ for the purposes of the standards as being 200m downstream. The Court indicated that

"a zone of reasonable mixing will vary depending on the size of the waterway, velocity of the water, tributaries and the like."…"I have concluded that in order to properly interpret these provisions it is clear that the question of reasonable mixing will be dependent on site specific factors."

The Court concluded that NZDF, either deliberately or by failing to check on the stock, permitted the deer to enter the paddock next to the watercourse over several days prior to the inspection by the Southland RC. The disturbance of the bed of the waterway led to the release of contaminants into the tributary to the Moss Burn, which was unacceptable in environmental terms. Although the downstream sample was not taken at 200m as specified for reasonable mixing, the water discharge still did not comply with the turbidity and clarity requirement 600-800m downstream as required by Rule 3 of the Proposed Plan.

The approach adopted by the Court in this case in the context of a permitted activity standard is debatable. In our view where a permitted activity standard defines reasonable mixing that definition applies. Particularly in the context of a prosecution, previous case law has not allowed any room for discretion as to whether a standard applies or not. Indeed as discussed earlier in our view a permitted activity standard must not leave reasonable mixing to be determined as a matter of discretion. That would invalidate the rule[5].

[5] The comments were in any event non binding since this point was not relevant to conviction in this case. The Court had concluded that the clarity standard was not met after 600 m so clearly it was not met after the 200 m specified for reasonable mixing

2.3.2 Regional Council Approaches

The following tables contain excerpts from relevant planning documents to illustrate how a selection of regional councils have approached the issue of reasonable mixing.

Table 1:
Regional Councils that have adopted quantitative definitions in relation to reasonable mixing

Council	Definitions of Reasonable Mixing
Auckland *Proposed Air, Land and Water Plan*	The point where the mixing of the contaminant discharges and the receiving water is assumed to have occurred. Assessment of compliance with the reasonable mixing requirement is undertaken at the point downstream which is 30 times the receiving water channel width, at the point of discharge, and one third the channel width across. (page 12-21)
Hawke's Bay *Regional Resource Management Plan (operative 2006)*	After reasonable mixing: (a) In relation to flowing surface water bodies, for the purposes of rules in this Plan, means the mixing of contaminants in surface water at whichever of the following is the least: (i) a distance 200 metres downstream of the point of discharge, or (ii) a distance equal to seven times the bed width of the surface water body, but which shall not be less than 50 metres, or (iii) the distance downstream at which mixing of contaminants has occurred across the full width of the surface water body, but which shall not be less than 50 metres. (b) In relation to lakes, for the purposes of rules in this Plan, means the mixing of contaminants in lake water at a distance 15 metres from the point of discharge. (c) In relation to groundwater bodies, for the purposes of rules in this Plan, means the mixing of contaminants in groundwater at whichever of the following is the least: (i) a distance 100 metres from the point of discharge, or (ii) the boundary of the subject property. Alternatively, for activities that are subject to resource consents, "reasonable mixing" may be determined on a case by case basis through the resource consent process. (page 214)

Council	Definitions of Reasonable Mixing
Manawatu – Wanganui (Horizons) *Proposed One Plan (2007)* *Land and Water Regional Plan (operative 2003)*	Reasonable mixing, in relation to the discharge of contaminants into surface water, means either: (a) a distance downstream of the discharge that is the least of: (i) the distance that equals seven times the width of the river at the point of discharge when the flow is at half the median flow, or (ii) 200 metres from the point of discharge or, for discharges to artificial watercourses including farm drainage canals, 200 metres from the point of discharge or the property boundary, whichever is the greater, or (iii) the point at which mixing of the particular contaminant concerned has occurred across the full width of the body of water in the river, or (b) a distance for reasonable mixing determined as appropriate for a consent application where special circumstances apply. (Proposed One Plan, Glossary page 8) Reasonable mixing is the length of a river reach downstream of a discharge point, or an area around a discharge point in a lake, where standards are allowed to be exceeded without compromising overall policy objectives. Note that reasonable mixing does not necessarily equate with full mixing; or with waste assimilation through natural treatment within the receiving water. (page 182) Policy 4: Distances allowed for reasonable mixing To require compliance with any water quality conditions specified in a discharge permit within a distance downstream of the discharge which is either: (a) in the absence of special features or circumstances relevant to the site, the least of: (i) the distance that equals seven times the width of the river when the flow is at half the median flow; or (ii) 200 metres from the point of discharge or, for discharges to artificial watercourses including farm drainage canals, 200 metres from the point of discharge or the property boundary, whichever distance is the greater; or (iii) the point at which mixing of the particular contaminant concerned has occurred across the full width of the body of water in the river; or (b) in the presence of special features or circumstances relevant to the site, a distance determined as reasonable for the specific receiving environment. (Land and Water Regional Plan, page 50)
Taranaki *Regional Fresh Water Plan for Taranaki (operative 2001)*	Reasonable mixing in relation to a permitted activity means a zone seven times the width of the channel at the point of discharge. (page 14)

Table 2:
Regional Councils that provide guidance in relation to reasonable mixing

Council	Guidelines for `reasonable mixing and `mixing zone'
Northland *Operative Regional Water and Soil Plan (2004)*	When determining what constitutes a reasonable mixing zone, the Council will take into account: (a) The characteristics of the discharge and the sensitivity of the receiving water; (b) The assimilative capacity of the receiving water body; (c) The proximity and effects of other discharges; (d) The proximity of, and likely effects on, downstream uses; (e) The desirability of keeping the mixing zone as small as practicable; (f) The availability and cost-effectiveness of current treatment technology. (page 50)
Waikato *Proposed Regional Plan – Appeals Version – June 2005*	The zone of reasonable mixing is the area within which a discharge into water (including any discharge that occurs subsequent to a discharge onto or into land) does not need to achieve the standards specified in the water management class for the receiving water body. The size of the mixing zone must be minimised as far as is practicable and will be determined on a case by- case basis, including consideration of the following matters. (page 56)
Bay of Plenty *Proposed Regional Water and Land Plan – Version 9.7 (2007)*	Defines the length or radius of a reasonable mixing zone in the conditions of a resource consent for the point-source discharge of contaminants to a surface waterbody having regard to the following assessment criteria: (a) The best practicable option to minimise the length or radius of the reasonable mixing zone. (b) The water quality classification of the receiving waterbody (refer to the Water Quality Classification Map), and the relevant water quality classification standard in Schedule 10; (c) The flow regime of the receiving water; (d) The ambient concentrations of contaminants in the receiving water; (e) Effluent discharge flow rate and contaminant concentrations; (f) Existing discharge and abstraction consents; (g) Fish migration and aquatic ecosystems requirements; (h) The values and existing uses of the waterbody; (i) Maori cultural values (refer to Policy 34); (j) Proximity to bathing sites, especially those listed in Schedule 11; (k) Adverse environmental effects of the discharge, including cumulative effects in elation to (a) to (j); (l) The location of the discharge and position of the outfall; (m) Outfall diffuser design criteria; (n) Information provided by the applicant; (o) Any other information relevant to the nature of the discharge and the site characteristics. (page 73)

Council	Guidelines for `reasonable mixing and `mixing zone'
Greater Wellington *Regional Freshwater Plan for the Wellington Region (1999)*	Policy 5.2.11 To ensure that any zones allowed on a discharge permit for reasonable mixing of contaminants or water with the receiving water are determined by having regard to: • the purpose for which the receiving water is being managed, and any effects of the discharge on that management purpose; and • any tangata whenua values that may be affected; and • the volume of water or concentration of contaminants being discharged, and the area of receiving water that could potentially be affected; and • the physical, hydraulic and hydrological characteristics of the receiving water. (page 57) Appendix 8 Water Quality Guidelines The plan contains water quality guidelines rather than standards. The guidelines are expressed in terms of reasonable mixing.
Canterbury *Proposed Canterbury Natural Resources Regional Plan*	Policy WQL1(2)(a) establishes criteria for determining the size of a mixing zone so that the discharge does not compromise the values of the water body and the aquatic ecosystem. In the vicinity of an outfall, there will be a zone where the discharge mixes with the receiving water, and the receiving water standards will not be complied with. This is called the "Zone of Non- Compliance". The boundary of the zone defines the point at which reasonable mixing has occurred and the water quality standards are met. In each case, the size of the zone will depend on the flow regime and water quality characteristics of the receiving water body, the type of contaminants, the level of treatment and flow rate of the discharge, and the design of the outfall. (Chapter 4, page 28-29)
Otago *Regional Plan: water for Otago (2004)*	Discharges of contaminants authorised under resource consents must meet any water quality standard set in respect of receiving waters after "reasonable mixing". Reasonable mixing occurs in a mixing zone, an accepted area of non compliance. Matters (a) to (f) of the policy will be considered in the determination of the size of any mixing zone. Where a mixing zone is required for the discharge of contaminants to water, to ensure that it is limited to the extent necessary to take account of: (a) The sensitivity of the receiving environment; (b) The natural and human use values identified in Schedule 1; (c) The natural character of the water body; (d) The amenity values supported by the water body; (e) The physical processes acting on the area of discharge; and (f) The particular discharge, including contaminant type, concentration, and volume. (page 92)

2.3.3 Discussion of Existing Approaches

As described above, the consent process enables discussion about what mixing is 'reasonable' on a case by case basis. A considerable body of material has built up over many consent hearings that helps clarify the important issues and underlying science.

An important concept is that of the 'non compliance zone' (NCZ –see Rutherford et al., 1994)). 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 the specified standards.[6] The question then arises whether this area of non- compliance, and the things that happen inside and outside it, are 'reasonable' in relation to the management objectives of the Plan.

The size of the RMZ will vary depending on the contaminant considered (e.g. water temperature may exceed the temperature standard in a very small zone near the outfall but ammonium may exceed the chronic toxicity standard over a larger zone). In addition the size of the mixing zone will vary with effluent flow, effluent concentration, river flow, background concentration and channel and bed characteristics. This adds to the number of scenarios that may need to be considered when deciding whether or not the RMZ is, in fact, reasonable.

What happens within a proposed RMZ is relevant in terms of whether it is in fact reasonable. If an adverse effect occurs (e.g. a significant decline in fish numbers) which is contrary to the management objectives of the waterbody (e.g. the river is being managed as a fishery) and the effect arises from something that happens *within* the RMZ then the proposed mixing zone may not be 'reasonable'.

In rivers three important considerations are: (1) near-field toxicity, (2) loss of habitat, and (3) blocks to migration. If water quality within the RMZ is such that a significant adverse effect is likely to occur if organisms enter the zone (e.g. fish run a high risk of mortality when they swim through it) this is unlikely to be deemed 'reasonable'. An assessment of near-field toxicity involves comparing predicted contaminant concentrations within the RMZ against acute (short-term) toxicity limits for sensitive, local organisms. For mobile organisms (e.g. fish) it also involves considering the length of time they are likely to spend in the RMZ and whether or not they show an avoidance response to the toxicant.

Fish and other organisms may be excluded from inhabiting the RMZ resulting in a loss of habitat. Assessment involves comparing contaminant concentrations with chronic (long- term) toxic limits and 'no effect' concentrations. If the proportion of habitat 'lost' is small, the non-compliance zone may be deemed 'reasonable'. The USEPA uses similar criteria to define two mixing zones relating to acute and chronic effects for toxic substances (see Section 3.5).

Many New Zealand freshwater fish undertake migrations to and from the sea. Upstream migrations (e.g. whitebait) can be disrupted by poor water quality thereby preventing recruitment to waterways upstream from the outfall. Juvenile fish tend to migrate upstream along the banks where currents are low. To minimise the risk to migration outfalls can be configured to discharge into the centre of the flow and to minimise the likelihood of the plume impinging on the banks. Alternatively the plume can be confined to one side of the river leaving the other side substantially free from effluent. This strategy works provided the fish migrating upstream along the same bank as the outfall, cross the river when they first detect the plume. Clearly the fully-mixed concentration must be below the level that disrupts migration.

---

[6] While the NCZ is valuable conceptually, it is not used in legislation or Regional Council plans. As NCZ is equivalent to the Reasonable mixing Zone, we use RMZ from this point onwards.

In lake, estuarine and coastal waters three factors complicate a mixing analysis: (1) time variations in current speed and direction; (2) time variations in the rates of vertical, transverse and longitudinal mixing; and (3) the unconfined nature of the flow. Notwithstanding, the basic principles for determining what constitutes 'reasonable mixing' remain the same as those outlined above for rivers. What differs is the considerable increase in complexity of the analysis required to estimate the size of the RMZ as it varies over time and the resulting impact on the ecosystem. While this complexity may be justified when setting consent conditions for a small number of major discharges, it poses problems when setting rules covering large numbers of 'minor' discharges, which may or may not be *permitted activities* (e.g. stormwater outfalls).

One approach for such water bodies or for storm water discharges generally, is to define rules based upon effluent standards thereby avoiding the complexity of mixing. Setting such standards involves analysing a range of 'typical' discharge scenarios and generalising the results. Any 'rules' derived from such an analysis need to: (1) err on the side of caution; (2) take account of the volume and composition of the effluent; (3) take account of the mixing characteristics of the receiving water; (4) take account of the sensitivity of the biota in the receiving water and (5) allow for the exercise of discretion where there is uncertainty.

A number of Regional Councils have adopted a different approach and derived rules applicable in rivers (see Table 1 above). Several Plans deem reasonable mixing to have occurred after '…30 times…' or '…7 times…' the channel width. A rule of thumb is that in a straight, uniform channel effluent becomes completely mixed at a distance below the outfall of 100-300 times the width (Rutherford 1994). Thus effluent would not be expected to have mixed completely after 7 or 30 times the width in a straight channel although complete mixing could occur within this distance at a sharp bend. For a bankside outfall, effluent reaches the far bank sooner than it mixes completely and in a sinuous channel this may occur within 30 times the width, and at a sharp bend within 7 times the width. Overall, the '…7 times…' and '…30 times…' rules are likely to result in a RMZ below a bankside outfall that extends part way across the channel, except possibly where there is a sharp bend. This means that water quality standards are unlikely to be breached along the bank opposite the outfall – an important consideration for fish migration as discussed earlier. The '…7 times…' and '…30 times…' rules are often over-ridden by a maximum distance that varies from 50 to 200 m (Table 1). Such provisions are based upon the desire to minimise the extent of the RMZ as required by case law.

It is worth noting that the '…7 times…' and '…30 times…' rules stem from considerations of the degree of mixing. In a section 4 we argue that a method for setting rules based more explicitly upon the degree of mixing which occurs has attractions.

3 International Perspectives

In this section we review how the 'mixing zone concept is applied in other countries. During the course of this review it became apparent that no other country uses the term 'reasonable mixing' within a legislative or policy context. Reasonable mixing is a NZ construct and a function of the RMA, which was carried over from the Water and Soil Conservation Act 1967.

Nevertheless it was clear that in defining 'mixing zones' some of the countries reviewed utilised similar arguments to those used in New Zealand to define a 'reasonable mixing' zone. The zone of 'reasonable mixing' under the RMA is, in effect analogous to the (regulatory) 'mixing zone' in some countries. It is therefore useful to review the use and application of 'mixing zones' in these other countries.

3.1 United Kingdom

The United Kingdom, being a member of the European Community, needs to comply with the EU Water Framework Directive (EUWFD, 2000). The WFD defines strategies to control water pollution and in particular has a policy of a "combined approach" i.e. limitations on pollutant releases at the source (emission limit values –ELV) as well as compliance with a receiving water environmental quality standard (EQS). This "combined approach" combines the administrative simplicity of the "end-of-pipe" (ELV) with a measure (EQS) intended to reflect the ecological significance of the pollutant being discharged within the receiving environment. However the WFD does not provide any information on the spatial specification of the EQS values. Moreover, it does not oblige the national authorities to establish such specification (Jirka et al., 2004). The authorities in the UK responsible for administering the WFD (The Environment Agency - England and Wales, and the Scottish Environmental Protection Agency - SEPA) have recognised that practical enforcement of the EQS requires the definition of a *mixing zone* in order to maximise the benefits of the "combined approach".

Guidance notes for staff at the Environment Agency (Leverett, pers. comm.) note:

- If the level of a substance in a discharge is above the EQS concentration, then the EQS will only be achieved after dilution in the receiving water. Unless this dilution is
- achieved by initial dilution on discharge, there will be a body of water where the EQS may be exceeded. This is similar to freshwater discharges before complete mixing. For tidal waters discharges this mixing zone has been defined as *"the area of water within which we are prepared to accept EQS exceedance"*.
- Further guidance to Environment Agency staff on how to assess existing discharges
- (Appendix A) includes steps for assessing the significance of water uses and ecology in
- the area where EQS are exceeded prior to setting a *defined mixing zone*. This process may be considered analogous to determining reasonable mixing.

The Scottish Environmental Protection Agency (SEPA 2006) discusses mixing zones in relation to dominantly sewage effluents (which can contain treated industrial wastes also) discharged to coastal waters. They identify an area of sea surface surrounding a surface boil and define it as a *mixing zone*. "This zone comprises an early part of the secondary mixing process[7] and is prescribed to ensure that no environmental damage will be encountered outwith its boundaries." An individual mixing zone is only defined with respect to an established environmental quality standard (EQS) for a particular polluting substance. The mixing zone is

the area of sea surface within which the EQS may be exceeded."

SEPA's objective of defining mixing zones is to allow a rational and sound scientific basis for the derivation of marine discharge consent conditions that can be related to readily enforceable end of pipe effluent (effluent limit values - ELV) concentrations and design criteria.

SEPA (2006) provides criteria that must be met (if relevant) within any defined mixing zone (see Appendix A). These include maximum spatial limits, restrictions on shoreline impingement, the blocking of estuaries, and occupancy of special conservation areas.
SEPA also makes provision for incorporating the seabed within a mixing zone, where solids from an effluent are expected to accumulate in the benthic zone.

While both the Environment Agency (EA) (England and Wales) and SEPA are implementing the European "combined approach" (ELVs and EQSs) they are doing so in different ways, with the SEPA approach being more prescriptive than that of the EA. The EA appears to allow tests analogous to 'reasonableness' before setting a defined mixing zone, whereas SEPA does not.

3.2 Australia

Each Australian State has its own environmental legislation and policies. However for the management and licensing of discharges to the aquatic environment all states broadly follow procedures given in the ANZECC (2000) water quality guidelines with a strong emphasis on risk-based assessment. For example in Queensland (Eco-access, 2004), the protection of Environmental Values (EVs) using Water Quality Objectives (WQOs) underpins the procedure, where a discharge is required. Protection of EVs requires a "whole-of catchment" approach and needs to consider catchment-wide pollutant sources to the local and regional aquatic environment. Similar approaches apply in Victoria, (Victorian Government, 2003) where the discharger is required to actively manage the mixing zone to continuously reduce its size and eventually eliminate it altogether. In NSW the Protection of the Environment Amendment Act (2005) defines the environmental values of water as the environmental values of water specified in the ANZECC 2000 Guidelines. State spokespersons on application of mixing zones (Ian Ramsay, QLD; Brett Light (VIC), and Tim Pritchard (NSW)) all referred to the Appendix to volume 2 as the source of definitive explanations on mixing zones.

In the Australian context, ***mixing zones*** are defined as: 'An explicitly defined area around an effluent discharge where effluent concentrations may exceed guideline values and therefore result in certain environmental values not being protected.'

The size of the mixing zone is site specific. The application of a mixing zone in licensing discharges is not mandatory, but where it is proposed ANZECC (2000) give guidance on its application (see Appendix 1). This includes directions on: the size of a mixing zone (small as possible); the applicability (or lack of it) with certain water uses and for particulate substances (contrast with the SEPA guidelines); and, the applicability with respect to toxic substances (invoked in most other guidelines).

The Australian approach (ANZECC) to the management of discharges to the aquatic environment is compatible with the RMA in that it is risk (effects) based. However the application of mixing zones within the management 'toolbox' appears to be based on restrictions (i.e. where and how a mixing zone is not applicable). Where a mixing zone is invoked, it appears to be done on a 'necessity' basis with the objective being to eliminate it altogether over time. There does not appear to be any test for 'reasonable mixing', either actual or implied.

3.3 South Africa

South Africa has specific operational policy governing the discharge of land-derived wastewater to the marine environment (Taljaard et al., 2006). As with other 'wastewaters' when land-derived wastewater is discharged into the sea, the sea must remain fit for use by its other users; therefore discharges should be of such quality that the guideline values as contained in the Water Quality Guidelines for Coastal Marine Waters (Oelofse et al., 2004) will be met outside the predetermined mixing zone of the discharge. South Africa has opted not to go for 'fixed areas' when defining mixing zone, but rather that this area be based on local transport and dispersion processes and the 'Requirements of the Receiving Environment' (Taljaard, pers. comm.).

The approach is therefore first to define and map 'Important Marine Aquatic Ecosystems' and other beneficial uses (e.g. recreation, mariculture) and well as their specific water quality requirements in a particular area. The location of these areas (and their water quality requirements) relative to the location of the discharge (or any other discharge for that matter) then determines the 'allowable mixing zone'. Local transport and dispersion processes are also explicitly taken into account in determining the dimensions of the mixing zone. The approach appears to imply that reasonable mixing is taken into account when setting an 'allowable mixing zone'.

The South African legislation specifically includes stormwater in the definition of land- derived wastewater discharged into the sea. Ostensibly then, there is provision for a mixing zone in licensing stormwater discharges to the coastal environment. In practice, however diffuse sources (including stormwater) are managed and controlled at source through a requirement for 'best practicable treatment options'. Taljaard et al., (2006) defend the decision not to require adherence to a receiving water standard (therefore invoking the possibility of a mixing zone) commenting: "Although there are means of calculating and measuring the volumes and composition of diffuse wastewater inputs, controlling such properties, once the wastewater reaches the marine environment (or any other water resource), is extremely difficult."

3.4 Canada

Canadian states tend to follow US EPA guidance (see below) with respect to mixing zones. The application of a mixing zone rests on the principle that a very small degraded zone can exist without compromising the intent of receiving water standards or significantly affecting aquatic life (Environment et Parcs, Quebec, 2007). In a strategic review of procedures for licensing the discharge of effluents to receiving waters, the Canadian Ministry for the Environment (2006) noted that the concept of a mixing zone where some dilution could take place was worthwhile, but it needed clarification and guidance on its use.

Whilst largely following the US lead, there are some variations in the definition of mixing zone. For example New Brunswick (2002) defines mixing zone as: "*the immediate area within the receiving water of a watercourse, where a contaminant being released into the receiving water is initially diluted, but does not include an area where the contaminant is treated.*" The Saskatchewan Department of Environment (2006) provides guidelines for defining the dimensions of mixing zones based largely on the needs of aquatic life. They define mixing zones as *"… a transitional area within a waterbody in which an effluent discharge is gradually assimilated into the receiving water. At the outer edge of the mixing zone the water quality should not be appreciably different from the water quality prior to the discharge of the effluent."*

We were not able to glean whether the Canadian approach implies a test of reasonableness. It would appear that the degree to which such an assumption can be made varies state by state.

3.5 USA

Much of the development of contemporary mixing zones concepts has occurred in the United States. This has been mainly due to the evolution of water law from the visionary Federal Water Pollution Control Act (FWPC) (1972) that promised elimination of discharge of pollutants to waterways by 1985, to the more pragmatic Clean Water Act (CWA) (1977). The FWPC (1972) Act established the National Pollution Discharge Elimination System of permits (NPDES) and the concepts of Best Practicable Technology (BPT) and Best Available Technology (BAT) for limiting effluent discharges (Doneker, 2006). The Clean Water Act (1977) classified pollutants as conventional (BOD, pH, TSS, faecal coliforms, oil and grease), non-conventional (e.g. COD, ammonia), toxic (e.g. heavy metals such as Cu, Pb, Zn – organic chemicals such as benzene and chloroform), as well as two other classifications for waste heat, and dredge and fill spoils. The Act required that BAT be used for toxic pollutants but that best conventional technology (BCT) is used for conventional pollutants.

The CWA (1977) devolved responsibility to the States for setting Water Quality Standards within their jurisdictions that defined the water quality goals of their water bodies by designating uses. Numeric water quality criteria are then applied to protect aquatic life or human health (e.g. the $\text{copper}_{\text{acute}}$ concentration to protect freshwater aquatic life is 18 µg/L). This approach was the foundation for all subsequent water quality criteria and guidelines internationally including the Canadian, European and ANZECC (although the values promulgated may vary). The setting of national water quality criteria (or standards) is an approach compatible with the recent drive towards National Environmental Standards in New Zealand.

The high marginal costs for industry and municipalities of complying with water quality criteria using BCT and BAT for conventional and toxic pollutants led to the Environmental Protection Agency (EPA) allowing States at their discretion, to include in their State standards, policies generally affecting the application and implementation of NPDES permits, such as mixing zones. It was argued that without mixing zones water quality criteria would have to be met in discharge pipes, not after mixing with, and being diluted by, the receiving waters (Idaho DEQ, 2000). This would result in discharge limits many times more stringent than would result if compliance were evaluated after the effluents were diluted with receiving water. All but two states (Arizona and Pennsylvania) have adopted a mixing zone policy, which has not been without controversy. High profile non-Government organisations (NGOs) such as the Campaign to Safeguard America's Waters (2002) argue that mixing zones are not mentioned in the Clean Water Act, and that States are misusing them as de facto zones for waste assimilation. However the States argue (e.g. Idaho DEQ, 2000) that if effects are limited, physical sizes are small, and the mixing zones do not jeopardize the integrity of the rest of the water body they are considered acceptable.

EPA defines a mixing zone as: '*an allocated impact zone where numeric criteria can be exceeded as long as acutely toxic conditions are prevented. It is a limited area or volume of water where initial dilution of a discharge takes place. Thus water quality criteria apply at the boundary of the mixing zone, not within the mixing zone itself*'.

Each State's water quality standards need to describe a methodology for determining the location, size, shape, outfall design, and in-zone quality of mixing zones following guidelines issued by the EPA (1991,1994 see Appendix A). These guidelines have much in common with

both ANZECC (2000) and SEPA (2006) guidelines, and as they predated both of these documents we can probably assume that both of these sources drew on the EPA experience. However the EPA guidelines go further in that specific guidance is given on how to set the dimensions of 'regulatory mixing zones'. This 'default' procedure appears to be widely used in setting RMZs for NPDES permits.

It was noted above that the CWA (1977) requires that Best Available Technology (B A T) be used for toxic substances. This implies a high degree of treatment and that there should be negligible acute effects on receiving water biota. In keeping with this philosophy the USEPA has special mixing zones for toxic substances. Two water quality criteria apply a spatially restrictive criterion maximum concentration (CMC) to protect against acute effects, and a criterion continuous concentration (CCC) to protect against chronic effects. The CCC is the same as a regular water quality standard and must be met at the boundary of the mixing zone. Normally the acute to chronic ratio (CMC/CCC) is 10 but can be up to 100. In other words the mixing zone to protect against lethal toxicity is one tenth to one hundredth the dimension of the regular(atory) mixing zone. Recent policy changes will phase out (ban) discharge of bioaccumulative chemicals of concern such as mercury, PCBs, chlordane by 2010 (i.e. toxic mixing zones will not be relevant).

After reviewing a number of NPDES permits (not referenced) we conclude that the application of mixing zones in the US is technically demanding (usually requires the applicant to model or monitor physical mixing characteristics and ecological effects). It is also the subject of considerable debate because of the belief in some quarters that the rules surrounding the allocation of mixing zones is being applied loosely in some States and that unnecessarily large mixings zones are being used to assimilate wastes, thus thwarting the intention of the Clean Water Act (e.g. LaLiberte, 2006).

The USEPA does not explicitly recognise 'reasonable mixing' in a regulatory sense. However the approach of the setting a regulatory mixing zone (RMZ) may effect a similar result in practice, as would a zone of reasonable mixing in New Zealand. A regulatory mixing zone is an administrative construct that has little to do with physical mixing processes (Doneker, 2006). As with the reasonable mixing zone in New Zealand, the limit of the regulatory mixing zone is somewhere between the point of discharge and the point o f full mixing. However setting the boundaries of the RMZ in the US appears a more pragmatic process than does the decision on reasonable mixing in NZ. In most cases the regulatory mixing zone is set by the individual state agencies based on whatever guidelines each state considers appropriate (mostly following EPA precedents). In most cases these are prescriptive (especially with respect to dimensions). However some states allow the applicant for a permit to propose the dimensions and location of the RMZ based on monitoring and/or modelling in which case arguments of reasonableness would at least be considered.

3.6 Elements of Mixing Zone

The purpose of this section is to summarise the essential elements of mixing zone usage internationally that may be useful to consider in developing a workable definition for the ARC:PALWP.

The important elements associated with the use and delineation of mixing zones in each of the jurisdictions reviewed is given in Table 3. A discussion on the specific usage with respect to stormwater discharges follows in the next section.

Table 3
Important elements used in delineation of mixing zones internationally (blank cell indicates no information found to support or refute)

	UK	Australia	South Africa	Canada	USA
An area of volume of water where a receiving water quality standard may be exceeded					
Ecological significance of MZ important					
Limiting determinand sets size of MZ					X[8]
Specific provision for toxic substances		9			
Stochastic approach considered for monitoring exceedance					

	UK	Australia	South Africa	Canada	USA
MZs not permitted for designated water uses					10
Specific provision for benthic environment		X			
Small as practicable					
Configuration important					
Fixed or variable	Either	Variable	Variable		Either
Regulator or applicant proposes	Either		Regulator		Either
Active management of MZ to reduce with time					
Provision for use of MZ with stormwater					

[8] Theoretically mixing zone (MZ) assigned on a parameter by parameter basis

[9] MZ should not be acutely toxic. Specific prohibition of use of MZ where discharge contains substances that bioaccumulate

3.7 Mixing Zones and Stormwater

Of the jurisdictions reviewed, only the USA and South Africa specifically mention stormwater in the context of the application of mixing zones.

In the US, amendments to the Clean Water Act in 1987 required that discharges of storm water from large and medium municipal separate storm sewer systems and discharges of storm water associated with industrial activities be in compliance with NPDES permits (Stormwater Panel, 2006). Theoretically these stormwater discharges may have mixing zones allocated to their discharge permits. In practice, however, there is wide variation among the states[10] in consideration of a mixing zone or level of dilution for determining the impact of a stormwater discharge on a water body (Schafran et al., 1998).

The reason for this variability in application of mixing zones is that, for it to be effective, numeric water quality standards need to be applied, which in the case of stormwater is very difficult to achieve. In California, for example, the State Water Board ruled (1990) that it was not feasible at the time to develop numeric limits for municipal separate stormwater systems and that water quality standards could and should be achieved through the implementation of BMPs (Best Management Practices) (Stormwater Panel, 2006). A similar ruling was made for stormwater from construction activities and industrial sites. Federal court decisions led the State Water Board to convene a panel of experts to reconsider whether numeric limits could now be promulgated. The panel (Stormwater Panel, 2006) recently reported that for municipal stormwater *"It is not feasible at this time to set enforceable numeric effluent criteria for municipal BMPs and in particular urban discharges. However, it is possible to select and design them much more rigorously with respect to the physical, chemical and/or biological processes that take place within them, providing more confidence that the estimated mean concentrations of constituents in the effluents will be close to the design target."* For construction and industrial wastewater the panel recommended that numeric limits could be developed (with reservations), but that to do so will be technically challenging and time-consuming (since it will rely on an evolving database of performance from well-designed and maintained BMPs). Thus it would appear that until such limits are developed mixing zones will not be routinely allocated for stormwater discharges in the US, except for systems combined with municipal or industrial effluent.

The legislation in South Africa treats stormwater in the same way as any other land- derived 'wastewater' discharging to the marine environment (Oelofsee, 2004). Stormwater from industrial areas may be defined as a 'water use', which requires a licence and may therefore be regulated in the same was as other effluents. Although in theory the same policy can also be applied to diffuse urban stormwater runoff into the marine environment, the regulators have found that it becomes a major headache to enforce and have not applied receiving water quality standards. Therefore, as with the US, without such standards the invocation of a mixing zone becomes meaningless. Therefore as with the US, the emphasis is towards controlling urban runoff at source or the point of discharge through insisting on BMPs. South Africa is in the process of developing a wastewater discharge charge system, which may be a potential (incentive) route to encourage local authorities to invest in source-based solutions to improve quality of urban runoff (Taljaard, pers. comm.). In the absence of such incentives, the imposition of BMPs can be ineffective even in highly developed economies because once installed regulators do not monitor the performance of BMPs and therefore developers and dischargers do not maintain them effectively (Stormwater Panel, 2006).

[10] State by state differences

4 Synthesis and Proposed Definitions

4.1 What is Reasonable Mixing?

Although the term `reasonable mixing' was not used explicitly in any of the countries reviewed in the section 3.6, it was apparent that similar concepts were used in defining and giving guidance on ***regulatory mixing zones***, ***allowable mixing zones***, or simply ***mixing zones***, in these jurisdictions. The important points (from the purposes of developing a definition) that consistently arose in definitions or guidelines on mixing zones internationally and are consistent with ***reasonable mixing*** are:

- It is the area of water downstream of, or in the proximity to, a point source discharge
- within which the regulatory authority is prepared to accept exceedance of receiving
- water standards or guidelines.
- The RMZ should be consistent with the management objectives for the waters concerned.
- The size of the RMZ should not be such that the environmental effects within the RMZ are unacceptable.
- The point at which a contaminant is reasonably mixed, is a point or distance which is somewhere between the discharge and the point/distance of full mixing.

There are three alternative ways of viewing the concept, which we now discuss.

The Effects Based Approach

On one view this point/distance is *no more than what is* ***reasonable in the circumstances*** *in order to achieve sustainable management*. In essence this is an effects based approach, and is also consistent with the '…*small as practicable*…' guideline used in Australia and the US, and included in New Zealand case law (e.g. *Mahuta decision* –see Section 2.3).

On this approach, the size/length of the reasonable mixing zone will vary according to the contaminant involved and the sensitivity of the receiving waters. In some instances it may be reasonable to allow the mixing zone to be equivalent to full mixing (e.g. colour and clarity where the impact is felt well downstream from the point of complete mixing) and in other circumstances it may be reasonable to only make a very small allowance for mixing (e.g. toxic contaminants or temperature that may have significant adverse effects on important biota close to the point of discharge).

The difficulty with this approach is that it cannot be used to define reasonable mixing for the purpose of standards in a plan. What is reasonable/sustainable will be different for different contaminants and for different receiving waters.

With this approach, the most a plan could do is set a minimum and perhaps a maximum reasonable mixing zone and for particular contaminants and/or particular receiving waters and leave it to the consent process to determine what is in fact reasonable in the circumstances. The disadvantage of this approach is that it is inherently uncertain and leads to unnecessary and often unhelpful debate at hearings. Furthermore whilst this approach could work for guidelines it is very doubtful whether it is valid for standards that define the activity class of a discharge. There is case law to support the view that this type of standard (including those based on section 70) need to be certain and not leave any discretion to the consent authority.

Accordingly in our view this type of standard needs to define reasonable mixing either in terms of fixed distance or in terms of a formula.

On the other hand, if there are section 69 standards in a plan, which do not define an activity class, then it seems that the definition could (and some would say should) leave the size of the RMZ to be defined by the consent process based on evidence and the nature of the effects involved. However even with this type of standard it will be useful for the plan to provide at least guidance as to how the consent authority will determine what is reasonable. It may also be useful to set out a formula for determining the minimum reasonable mixing zone.

The "Reasonably Mixed" Approach

An alternative interpretation is that a contaminant is *reasonably mixed* at the point at which it is mixed with a *reasonable* percentage of the flow of receiving water. In this approach reasonable mixing is defined by reference to a known or estimable physical parameter (flow) without the need to undertake an argumentative and uncertain analysis of what is reasonable in the circumstances. One might for example specify reasonable mixing to be say mixing at *50% or 75% of a particular specified flow.*

It would be possible to define different percentage mixing figures for different classes of contaminant. For example, when considering contaminants whose effects occur in the far-field (e.g. nutrients that stimulate periphyton growth, colour and clarity) 75% of the flow might be reasonable while for contaminants whose effects occur in the near-field (e.g. toxicants and high temperature) 10-25% of flow might be reasonable.

This approach has the distinct advantage of being clear and certain. It is therefore an approach that can be utilised for standards in a plan, or if necessary, incorporated into conditions of consent. By removing the uncertainty and the requirement for a discretionary judgment, one also avoids debate (which is often marginal to the question of environmental effects).

The Specified Distance/Area Approach

The third approach is similar to the second but defines the RMZ in terms of a distance or area rather than in terms of a percentage of total flow. On this approach, reasonable mixing in a river is deemed to occur at some distance below the outfall specified in the plan. For example the plan might define reasonable mixing as being: *The lesser of 100m downstream of the discharge point or a distance of 7 times the average width of the river or stream (measured at median flow) in the reach to 100m downstream of the discharge point.*

This approach, like the previous one, has the advantage of being clear and certain and can work well in rivers and streams. While it may appear that the choice of the width multiplier (e.g. 7 times the average width) is arbitrary, it does have a rational basis in terms of analysis of the distance required to achieve a certain percentage mixing (see Section 2.3.3.).

In the context of some consent applications it may well be argued that the specified value is *unreasonable* and/or that the contaminants are not reasonably well mixed by this point. Those opposing an application may argue that the particular discharge is more than reasonably mixed at the point in question, and the specified distance should be reduced.

This disadvantage is not necessarily a fundamental problem. If a definition survives the first schedule process and becomes operative, then it will become determinative at least for the purposes of standards that define activity classes. However if this approach is used in relation to policies, guidelines and assessment criteria, there will still be some room for argument by applicants or submitters that the definition should not apply to a particular application.

4.2 Which Approach is Preferable?

In our view, where reasonable mixing is defined for the purpose of a *standard in rules* that classify discharges into activity classes, the first approach above is unhelpful and probably invalid (i.e. leaving it to discretion to determine whether an activity is permitted or which activity class it comes within).

Either of the alternative approaches is workable, but in our view, the "reasonably well mixed" approach is preferable for rivers and streams at least in conceptual terms. The distance approach may be more practical for lakes and the coastal marine area.

Both the percentage mixed, and specified distance/area approaches requires the Council, through its definition, to make decisions about what is reasonably well mixed for different classes of pollutant (e.g. 25%, 50% or 75% of full mixing) or the distance downstream of the discharge that will be allowed. Scientific analysis of the parameters needed for either approach should lead to essentially the same result (i.e. they are interchangeable in the case of rivers and streams) although the percentage mixing approach is conceptually easier to grasp.

In practice both the distance based approach and the percentage of full mixing approach are based upon endeavouring to allow for reasonable but not full dilution. In our view, there is merit in an approach that explicitly focuses on percentage dilution rather than on surrogates for that.

If a percentage dilution rule is adopted then that obviates the necessity for complex modelling and mixing studies. We set out an example of such an approach below (section 4.3). We emphasise, however, that this approach might require different reasonable mixing zones for different parameters. Furthermore, like other quantitative approaches it would need to be a default definition. It would apply directly to *permitted activity* standards and standards which classify an activity. However, it could also apply as a means of assessing reasonable mixing for the purpose of considering consent applications whilst leaving the applicant to make a case that a larger zone is reasonable in the circumstances.

As discussed earlier, a discharge does not ***cause*** a breach of a water quality standard if the standard would have been breached in any event. So for the example if an upstream concentration of the target contaminant already exceeds the standard, then the standard is inapplicable to the proposed discharge. The discharge will make the situation worse, however it cannot be said that the discharge ***causes*** a breach of the standard. The question of whether the discharge should be allowed in these circumstances is something that will need to be addressed by policies in the relevant plans and/or by the consent process. This will also depend upon the contaminant involved and the purpose for which the receiving waters are being managed.

A potentially different approach could be applied in relation to reasonable mixing where that term is used in the context of *guidelines/policies* or assessment criteria. The options would appear to be any of the following:

1. Only have a definition for permitted activity conditions, but otherwise have no definition and leave reasonable mixing to be determined in the context of consent applications.
2. Have a definition for permitted activity conditions, and also have a general definition or policy which defines the intention of reasonable mixing but which leaves the point of reasonable mixing to be determined on a case by case basis in the context of consent applications.

3. Have a definition for permitted activity conditions, and also have a general definition or policy which defines the intention of reasonable mixing but which leaves the point of reasonable mixing to be determined on a case by case basis in the context of consent applications, but use the objective definition to define a default or minimum reasonable mixing zone which will apply unless the applicant establishes that a larger mixing zone is reasonable.

In our view the first option is unsatisfactory and inevitably leads to uncertainty as to what the policy is. The second option is an advance on that but is still uncertain. In our view the third option is preferable.

For an objective/quantitative approach we consider three possible approaches.

- Distance approach
- Proportion of distance to full mixing
- Concentration at a proportion of a specified flow

Of these three approaches we prefer the latter as being more rigorous/less arbitrary than the first approach.

4.3 Proposed Use of Reasonable Mixing for the Purposes of Standards

We now develop the approaches outlined above into a possible definition for use in assessing permitted activities and then apply this definition to a particular example.

Concentration Based Approach

We first provide an example, of how this approach works.

If the rule says that a certain standard must be complied with (e.g. concentration <= 10 g/m^3) after reasonable mixing (e.g. defined as being mixing at 50% of full dilution at minimum annual low flow (MALF) then it is simple to determine

(a) the discharge flow (say 0.1 m^3/s)

(b) the concentration of the particular contaminant in the effluent (say 100 g/m^3);

(c) determine the MALF (say 1 m^3/s)

(d) 50% of MALF (0.5 m^3/s).

After mixing with 50% of MALF the contaminant concentration is 0.1 m^3/s x 100 g/m^3 / 0.5 m^3/s = 20 g/m^3. This exceeds the standard of 10 g/m^3 and so is deemed to not to comply with the standard after becoming reasonably mixed.

The key to this approach working is that a RMZ comprising 50% of the flow in which contaminant concentration exceeds 10 g/m^3 must not be inconsistent with the objectives of the plan in regard to water quality. The Plan would define a receiving water standard, expressed as a concentration, which must be complied with after reasonable mixing.

We note that it is important that the standard/mixing combination is sensible (e.g. it might not be sensible to allow 50% mixing for an acute toxicity standard, but it might be sensible to allow 50% mixing for a chronic toxicity standard)

We now develop this into a rule and definition.

Permitted activity rule

The discharge shall not (either by itself or in combination with the same, similar, or other contaminants) cause the receiving waters to fail to achieve the standards set out in ??? after ***reasonable mixing****:*

Provided however, that a standard shall not be deemed to be caused to be breached by a discharge or proposed discharge, if as a result of upstream contamination which is likely to occur during the term of the proposed discharge, the standard would not be met after reasonable mixing if the proposed discharge was not occurring at that time.

Definition

Reasonable mixing *in relation to a particular contaminant, means the calculated "reasonably mixed concentration" of that contaminant in the receiving waters at a flow of y times the mean average annual 7 day low flow (*or some other measure*) in that stream or river, where such concentration is calculated in accordance with the method set out below and where* ***y*** *is a multiplier less than 1 as specified in the standards set out in ??*

The ***reasonably mixed concentration*** *(Crm) will be calculated in accordance with the following formula:*

$C_{rm} = \{(Q_e * C_e) + (Q_r \; C_a * y)\} / (Q_r * y + Q_e)$

where Q_e *= effluent flow rate* (m^3/s);

C_e *= effluent concentration* (g/m^3),

C_a *= ambient concentration just above the discharge* (g/m^3); Q_r *= river flow* (m^3/s);

C_{rm} *= reasonably mixed concentration* (g/m^3)

and y =proportion of river flow (0 < y < 1).

Example of calculation of reasonably mixed contaminant concentration

Receiving water standard for this contaminant Crws = 20 mg/L. MALF = 250 L/s and the 'reasonable mixing' multiplier y = 0.5

4.3.1.1 Step 1

Is the standard already being breached at the mean annual average low flow?

Where applicable determine (measure or estimate) the upstream or existing ambient upper 95 percentile concentration (C_a) of the contaminant in the receiving waters at the mean annual average 7 day low flow

Say C_a= 10 mg/L

As $C_a < C_{rws}$ then the standard applies to this particular discharges

4.3.1.2 Step 2

Determine the maximum flow[11] and maximum concentration of the contaminant 95 percentile summer conditions. For example:

Actual or proposed contaminant concentration (95%ile summer values) Ce = 100 mg/L. Actual

or proposed effluent flow (95%ile summer flow rates) Qe = 10 L/s,

4.3.1.3 Step 3

Calculate the contaminant concentration in the river at **y** times MALF (C_{50}) in accordance with the formula above. C_{rm}= {(Q_e*C_e)+(Q_r **Ca***y)}/(Q_r *y + Q_e)

In this example:

C_{rm} = {(250*10*.5+10*100)}/(250*0.5 + 10) = 16.7 mg/L.

4.3.1.4 Step 4

Does or will the discharge/proposed discharge cause the standard to be breached?

If $C_{rm} < C_{rws}$ the standard is met

If $C_{rm} > C_{rws}$ and $C_a < C_{rs}$ the discharge is causing the standard to be breached

A Distance Based Approach

An *alternative definition* could be based upon the specification approach that defines a reasonable mixing *zone* as follows:

That area of water downstream of the point of discharge within which the discharge is not reasonably mixed and the specified water quality standards are not required to be met.

The downstream limit of the reasonable mixing zone is the distance at which the discharge is deemed to be reasonably well mixed (but not fully mixed) with the receiving waters.

The downstream limit of the reasonable mixing zone shall be ***either****:*

- *The lesser of a distance of 100 ?m downstream of the point of discharge* ***or****; a distance being* ***? 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. The first cross section shall be at the point of discharge and the subsequent cross sections shall be at 10m intervals downstream of the point of discharge;* ***or***
- *Where a mixing assessment has been carried out in accordance with the methodology in schedule ?, a distance downstream of the discharge point which is 75%*[12] *of the distance to the point of full mixing determined in accordance with schedule?*

We note that a judgement call would need to be made as to whether to include the "lesser of" clause. It may be sufficient to simply base it on some multiplier of the width. Obviously the smaller the multiplier is, the smaller the RMZ will be, and consequently the standards will be harder to achieve. If you adopt this approach, the size of the multiplier will need to be justified as not being unreasonably small (restrictive) or unreasonably large (generous).

[11] How to measure maximum flow and concentration of the discharge will also need to be defined (e.g. upper 95%ile).

The advantage of having the alternative approach is that if one makes the multiplier moderately conservative, then applicants can still obtain a more generous RMZ if they are prepared to carry out a mixing study. This approach is also used by USEPA (section 3.5). The methodology or at least parameters for such a study would however need to be set out in the plan. (This mixing study approach has been adopted by Masterton District Council for its current waste water discharge applications).

In our view this approach of specifying alternative means of determining the RMZ is practical and is in accord with the concept of reasonable mixing. Most importantly, it is sufficiently certain to enable it to be incorporated into standards. The size of the parameters is a matter which can be determined initially on the basis of scientific advice, but will ultimately be the subject of submissions and possibly appeals.

Which Approach?

There are advantages and disadvantages with each of the above approaches. The first approach (concentration based) is somewhat complex and would also need to have different multipliers (y) for different parameters[13] depending upon their effects. It does however accord quite well with the notion of reasonably well mixed and does allow for effects to be taken into account when setting the multiplier. Furthermore, whilst appearing complex it is in fact a relatively straightforward calculation. It could either be used just for activity standards or it could be used as a default minimum RMZ for consent applications in conjunction with guidance as to how reasonable in the circumstances will be determined where the default is not suitable.

This approach is not, however, applicable to lakes estuaries and the sea and is not workable for standards that can not be converted to concentrations (e.g. conspicuous change to colour and clarity).

The second approach (distance) is somewhat more arbitrary but is also somewhat easier to apply in practice. It does not require different multipliers for different parameters but can if necessary be modified for particular contaminants (near field versus far field). The approach we have set out uses three alternatives but that is not essential. One or two may suffice. The approach also has the advantage that it can be modified to apply to lakes estuaries and the sea.

We do not consider either approach to be appropriate as anything other than a default position in relation to consent applications. Hence we think that any such quantitative definition should be used in conjunction with guidance as to how reasonable will be determined where the default is not reasonable.

[12] Or other agreed %age of full mixing

[13] These could be 'grouped' by common effects as with the US approach (section 3.5). e.g. conventional , non-conventional, and toxic contaminants

4.4 Proposed Definition of Reasonable Mixing for the Purpose of Guidance on Consent Applications

As discussed earlier, there is a good argument that any rules and definitions should be drafted in such a way as to leave a discretion to the consent authority to determine what is reasonable in the circumstances of a particular consent application. In our view however, this approach is not appropriate where the plan has standards that define an activity class because it is too uncertain.

This approach would however be workable for plans that have water quality guidelines rather than standards or which have standards, which do not define activity classes. (The plan would simply provide that conditions will be imposed to ensure that the standards will be met and that consent will not be granted if the conditions can not be met.)

The definitions above can be adapted to be applied to this situation as follows:

Rule

The waters listed in schedule x are classified as Class CR to be managed for contact recreation purposes.

Except for permitted discharges described in rule?, any discharge of contaminants or water to Class CR waters, shall be a discretionary activity.

Policy/assessment criteria

In assessing whether to grant consent and in determining appropriate receiving water quality and/or effluent standards, the consent authority will amongst other matters, consider the extent to which the discharge (either by itself or in combination with other contaminants or water) is likely to cause any of the guidelines set out in schedule ? to not be achieved beyond the reasonable mixing zone:

Definition

For the purposes of rules and policy, ***reasonable mixing zone*** *means:*

(the rest remains as above)

The alternative approach in relation to guideline/policy

Reasonable mixing zone means:

That area of water downstream of the point of discharge within which the discharge is not reasonably mixed and the specified water quality standards are not required to be met

The reasonable mixing zone may be set at different lengths for different contaminants depending upon their mixing characteristics, and the nature of the effects of that particular contaminant.

The downstream limit of the reasonable mixing zone is the distance at which a particular contaminant is deemed to be reasonably well mixed with the receiving waters, and shall in all cases be upstream of the point at which the contaminant is fully mixed.

The minimum length of the reasonable mixing zone shall be as set out (refer to whichever quantitative definition is used) however a greater mixing zone may be used where that is reasonable in the circumstances.

Where an applicant seeks a different mixing zone from that specified in ?? the following will apply:

The length of the reasonable mixing zone for each contaminant shall be determined on a case by case basis having particular regard to the following:

- *The purposes for which the waters are to be managed (where specified)*
- *the nature of the likely effects of the particular contaminants in the context of the particular receiving waters*
- *The mixing characteristics of the receiving waters (behaviour of the contaminant plume and distance to full mixing).*

In all cases the reasonable mixing zone shall be sufficient to allow the discharge to be reasonably well mixed but not fully mixed.

As stated earlier, we do not favour this approach on its own. Firstly, it cannot be applied to standards (including section 70 and possibly section 107 standards) because it reserves discretion and is too uncertain.

Combined Approach

The option that we favour and as outlined above would be to have a combination of these two approaches. The plan would include a quantitative definition for the purposes of permitted activity conditions including section 70 standards (and perhaps section 107 standards) but would leave reasonable mixing to be determined on a case by case basis in relation to guidelines and perhaps section 69 standards. This approach would only work in relation to the latter, if those standards do not define activity classes. Accordingly, the suitability of this type of approach will depend upon whether the plan uses standards or guidelines and upon how any standards in the plan are drafted.

This option does have the distinct advantage of leaving a degree of discretion/flexibility to the consent process. Although there would remain a degree of uncertainty this can be minimised by way of a clear policy, which sets out the matters that will be considered when determining a RMZ on a case by case basis. This approach is also consistent with the case law, which suggests that an RMZ should always be determined on a case by case basis.

4.5 Reasonable Mixing in Relation to Lakes and the Sea

The approaches outlined above can be adapted to be applied to discharges to the sea, estuaries and lakes. However if a quantitative approach is adopted, one would need a separate definition for streams and rivers and for lakes and the sea.

4.3.1.5 For example:

Definition

For the purposes of rules reasonable mixing zone means:

That area of water around the point of discharge within which a particular contaminant is not reasonably mixed and the specified water quality standards for that contaminant are not required to be met.

The outer limit of the reasonable mixing zone is the distance at which the contaminant is deemed to be reasonably well mixed (but not fully mixed) with the receiving waters.

The minimum size of the reasonable mixing zone shall be ***either****:*

- *A distance of 100?m from the point of discharge;* ***or***
- *Where a mixing assessment has been carried out in accordance with the methodology in schedule ?, a distance from the discharge point which is 75%*[14] *of the distance to the point of near complete l mixing determined in accordance with schedule?*

4.3.1.6 Policy for Determining RMZ for Consent Applications

When determining the extent of the reasonable mixing zones for the purposes of determining consent applications and imposing conditions to ensure receiving water standards are met [guidelines are achieved]

The council will have particular regard to the following:

The reasonable mixing zone is that area of water around the point of discharge within which the discharge is not reasonably mixed and the specified water quality standards are not required to be met.

The reasonable mixing zone may be set at different distances for different contaminants depending upon their mixing characteristics, and the nature of the effects of that particular contaminant.

The limit of the reasonable mixing zone is the distance at which a particular contaminant is deemed to be reasonably well mixed with the receiving waters, and shall in all cases be no greater than the distance at which the contaminant is fully mixed.

The minimum size of the reasonable mixing zone shall be as set out (refer to whichever quantitative definition is used) *however a greater mixing zone may be used where that is reasonable in the circumstances.*

Where an applicant seeks a different mixing zone from that specified in ?? the following will apply:

The size of the reasonable mixing zone for each contaminant shall be determined on a case by case basis having particular regard to the following:

- *The purposes for which the waters are to be managed (where specified)*
- *the nature of the likely effects of the particular contaminants in the context of the particular receiving waters*
- *The mixing characteristics of the receiving waters (behaviour of the contaminant plume and distance to near full mixing).*

In all cases the reasonable mixing zone shall be sufficient to allow the discharge to be reasonably well mixed.

[14] Or other agreed %age of full mixing

4.6 Reasonable Mixing in Relation to Stormwater Discharges

ARC has asked us to consider the applicability of any definition to stormwater discharges. Ideally, any definition and/or policy for determining reasonable mixing would apply to all point source discharges. However stormwater, while it may be seen to discharge from a pipe is in fact a diffuse source arising from the effects of rainfall on streets, yards, roofs etc. It is a distributed source channeled to a point, rather than a point source arising from a single activity (as is the case with a municipal or industrial wastewater). As discussed in Section 3.5 the US has classified stormwater as a point source; but only to allow it come under the NPDES permit system. Having classified as a point source, it would appear that US Authorities have not been able to apply mixing zones concepts to NPDES stormwater permits (section 3.7) because of the difficulty in predicting both the concentration and volume at the 'point' of discharge to the receiving environment. Similar problems have been encountered in South Africa. Both countries tend to use BMPs rather than regulatory approaches for stormwater, though the difficulty of monitoring their effectiveness as a control cannot be underestimated (Section 3.7).

For the reasons outlined above, the international community has not resolved the use of mixing zones for stormwater discharges. As can be seen from the preceding discussion, the issue becomes even more complex when "reasonable mixing" is considered. If an approach is adopted which leaves the RMZ to be set via the consent process guided by policy, and if stormwater discharges require consent at least as a controlled activity, then discretion can be exercised when determining the size of the RMZ in relation to stormwater discharges. For example, it might be determined that in the case of stormwater, it is reasonable to allow the mixing zone to extend to the point of full mixing. On the other hand that would not usually be appropriate in relation to sewage discharges/overflows.

In the case of permitted activity standards for storm water, or if the plan has water quality standards which are part of the activity classifications, the above approach will not be appropriate because it is too uncertain and probably invalid. This will also be the case with the section 70 standards. For example in relation to permitted discharges of stormwater, they must meet the section 70 standard of no conspicuous change to colour and clarity after reasonable mixing.

If the Council wishes to permit some stormwater discharges it will need to address section 70 by way of a RMZ definition, which ensures that the standard can be met. It may perhaps be appropriate for there to be a separate definition of reasonable mixing in relation to storm water.

One option is to have a generous definition of RMZ for the purposes of permitted stormwater discharges and then rely on a guiding policy (as above) in relation to discharges that require consent as controlled or discretionary activities. Again however, we caution that if the rules are drafted in such a way that the boundary between controlled and discretionary or any other activity class is defined by reference to compliance with standards after reasonable mixing, then in our view the council cannot retain a discretion to fix the RMZ via the consent process.

Our recommendations in terms of stormwater discharges are as follows:

- Where possible use effluent/end of pipe standards rather than receiving water quality standards to deal with stormwater discharges;
- These could be used in conjunction with BMP or BPO requirements, with the end of pipe standards being a back up;
- Consider exempting storm water discharges from receiving water standards provided that the discharge meets certain specified end of pipe standards;

- For the purposes of sections 70 and 107 consider a specific definition of "conspicuous change to colour and clarity" and/or a specific definition of *reasonable mixing,* which will allow stormwater discharges either as a permitted or controlled activity; or
- Do not convert the narrative standards in sections 70 and 107 to quantitative standards if that is likely to render storm water discharges unlawful.

We note that generally it is only turbidity standards in sections 70 and 107 that cause a difficulty in terms of stormwater. However if a plan includes pathogen standards, careful thought will need to be given to how these apply to stormwater and how reasonable mixing should be defined for that purpose.

5 Conclusions

This review of the use of `mixing zones' internationally and `reasonable mixing' in New Zealand has shown that the issue is complex and one approach does not fit all situations. Thus we have been unable to provide a single definition for use in the ARC:PALWP that covers all contingencies. For permitted activities and for point sources discharging to streams or rivers we have derived a definition based on either a "concentration" approach (essentially the percentage dilution which one considers reasonable for a certain category of contaminant) or a specified distance approach, which is essentially the same approach used in the existing ALWP. Either approach can be used for screening permitting activities although the concentration approach is preferred because it is easier to apply and understand.

For activities other than permitted activities, case law indicates that there should not be a fixed definition of reasonable mixing. There could however be a minimum or default definition and there should, in our view, be policy guidelines to provide more certainty for resource consent applicants. In this case either the concentration or specified distance approaches could be used, but with discretion to determine what is reasonable in the circumstances.

For discharges to lakes or the coastal zone only the specified distance approach is applicable, and this needs to be modified to introduce the concept of 'area' around the point of discharge.

Stormwater discharges arise from diffuse sources and therefore peak concentrations of contaminants and discharge rates are very difficult to predict. For this reason, they are not amenable to a concentration approach and therefore the specified distance/area approach is preferable in instances where a definition of reasonable mixing is required (e.g. if they are permitted activities). In common with international precedent, we recommend that the stormwater discharges be controlled through rules relating to the use of BMPs (or BPO's) and where necessary end of pipe standards, rather than receiving water standards. Where adherence to such standards is mandatory, then a generous reasonable mixing zone (approximating to full mixing) should be applied.

Finally, we note that if the ARC was to utilise any of the suggested approaches above, the proposed definition would require further policy, legal and scientific review.

6 References

ANZECC (2000) Australia and New Zealand Environment Council (2000) Guidelines for fresh and marine water quality. Appendix to Volume 2 - aquatic ecosystems -Rationale and background Information
http://www.mincos.gov.au/pdf/anz_water_quality/vol2/gfmwq-guidelines-vol2-apps.pdf

Campaign to Safeguard America's Waters (2002) Petition to USEPA Administrator Christine Todd-Whitman.

Canadian Ministry for the Environment (2006) Canada-wide strategy for managing municipal wastewater effluent.
http://www.ccme.ca/assets/pdf/web_posting_consultation_summary.pdf

Department of Environmental Quality - Oregon (2006) Regulatory Mixing Zone - Internal Management Directive

Doneker, R.L. (2006) Mixing zones. Presented at the Workshop on Mixing Zones, Salem Oregon March 31, 2006. Department of Environmental Quality - Oregon http://inr.oregonstate.edu/download/deq_doneker_part1.pdf

Environment et Parcs, Quebec, (2007) Evaluation and recommendation result from the water quality defined for 300 contaminants (in French)
http://www.mddep.gouv.qc.ca/eau/criteres_eau/index.htm.

European Water Framework Directive 2000 http://ec.europa.eu/environment/water/water-framework/index_en.html

Idaho Department of Environmental Quality (2000) Evaluation of Proposed New Point Source Discharges to a Special Resource Water and Mixing Zone Determinations. Thompson Creek Mine Facility, Upper Salmon River subbasin, Idaho.

Jirka, G.H. Bleninger, T; Burrow, R and Larsen, T (2004) Environmental Quality Standards in the EC Water Framework Directive. Consequences for Water Pollution Control of Point Sources. http://ewpca.de/journal-01h.pdf

LaLiberte, D (2006) Review of draft general permit for Cook Inlet Alaska Oil and Gas Operators.

Leverett, D. (2006). Guidance on the use of Direct toxicity Assessment in PC Impact Assessments. E. A. (UK), Environment Agency**:** 43pp.

New Brunswick Government (2002) http://www.gnb.ca/0062/regs/2002-13.htm

Oelofse, S.; Viljoen,P; Taljaard, S; and Botes, W (2004) discharge of water containing waste from land to the marine environment. A water quality management perspective. Water SA Vol. 30 (4).
http://www.wrc.org.za/archives/watersa%20archive/2004/No5-special/92.pdf

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.

Saskatewan Department of Environment (2006) Surface Water Quality Objectives - Interim Edition. http://www.se.gov.sk.ca/environment/protection/water/surface.asp

Schafran, G.C. ; Winfield, J.G.; Pommerink, P.; Akan, A.O.; Mizelle, L. & Fox, T.J. (1998) Stormwater collection, treatment, recycling and reuse in a shipyard. CASRM Old Dominion University.

Scottish Environmental Protection Agency (2006) Supporting guidance (WAT-SG-11) Modelling coastal and transitional discharges. http://www.sepa.org.uk/pdf/wfd/guidance/pointsource/sg11.pdf

Schnurbusch, S (2000).A mixing zone guidance document prepared for Oregon Department of Environmental Quality. Portland State University.

Stormwater Panel Recommendations to the California State Water Resources Control Board (2006) The Feasibility of Numeric Effluent Limits Applicable to Discharges of Stormwater associated with Municipal, industrial and Construction Activities.

USEPA (1991) Technical Support Document for Water Quality-based Toxics Control -web address.

USEPA (1994) EPA Region VIII Mixing Zones and Dilution Policy Website address.

Victorian Government Gazette (2003) Variation to State Environmental Protection Policy Waters of Victoria) http://www.craftpress.com.au/gazette/Gazettes2003/GG2003S107.pdf

Appendix 1: Guidelines for Setting Mixing Zones in England and Wales, Scotland, Australia, and the United States

6.1.1 A1. Environment Agency (England and Wales) (Leverett, pers. Comm.)

1. Check the data to determine whether EQS is exceeded in the discharge. If the EQS is not exceeded in the discharge, then no further assessment against EQS is required.
2. If EQS is exceeded in the discharge then model the effect of initial dilution[15]. This should take account of the range of initial dilutions across the tidal cycle and should be based on the expected flow distribution at the consented design horizon. If the EQS is not exceeded after initial dilution then the EQS should be reported as not being exceeded. If EQS is exceeded after initial dilution, then a further stage of assessment will be necessary.
3. If the EQS is exceeded after initial dilution, then it will be necessary to assess the zone of EQS exceedance in the receiving water before further dilution reduces the concentration below EQS. In most cases, this will require an appropriate level of monitoring of the dispersion of the discharge. If necessary, advice should be sought on appropriate techniques.
4. When you have defined the zone within which EQS exceedance is likely then it will be necessary to assess the significance of the zone. An appropriate assessment of the potential impact of the EQS exceedance on the local water interests should be undertaken. If the zone of exceedance includes ecologically sensitive areas or if the zone is large in absolute or local terms then it will be unacceptable and should be regarded as an EQS exceedance. The maximum acceptable area of the zone of exceedance should be defined (the defined mixing zone) and an appropriate maximum consent limit calculated to achieve that.
5. If the zone is considered acceptable then it should be recorded as the defined mixing zone for the discharge and any future calculation of consent limits should respect the zone and allow no deterioration in quality within the zone or increase in zone size. If more than one determinand results in a zone of exceedance in the receiving environment then normally the same defined mixing zone should be used for all determinands.

---

[15] As the effluent discharges, it usually forms a buoyant plume, which rises to the surface. Sea water becomes entrained and mixing occurs, diluting the plume as it rises to form a surface "boil". The degree to which this occurs varies considerably as the tidal cycle alters both the depth of the outfall below the surface and the ambient velocity of the water past the end of the outfall. The dilution which the plume receives as it rises from the point of discharge is known as the initial dilution.

6. Toxic substances require a mixing zone that is substantially less than the defined mixing zone. A suggested limit is when the determinand mixing zone is less than 10% of the defined mixing zone.

6.1.2 A2. SEPA (2006) Guidelines

The mixing zone needs to meet all of the following criteria that are relevant (summarised from the original):

1. The mixing zone around the effluent surface boil would normally be set at a maximum distance of 100m in any direction (that the plume may travel) from the centre of the boil. The dilution this allows must be calculated for each site.
2. The concentration of dispersing effluent must be such that no established relevant E Q S is breached outside the mixing zone. This must take account of the individual standards, which may be expressed as annual mean values, or percentile exceedance values, or maximum allowable concentrations.
3. Where an effluent requires control through toxicity-based criteria then the concentration of dispersing effluent must be such that there is no residual toxicity outside the defined mixing zone i.e. the residual concentration of the toxic substance shall comply with the Predicted No Effect Concentration (PNEC) lethal or sub-lethal, acute or chronic, determined from an approved toxicity test. After initial dilution there should no point within the mixing zone where the residual concentration of effluent exceeds the 3 hour acute No Observed Effects Concentration (NOEC) for any approved lethal or sub-lethal test.
4. Two or more mixing zones from different neighbouring outfalls must not merge or take up all the diluting capacity of any receiving water body. The edges of the mixing zones should be at least 100m apart. If, for any reason, this criterion cannot be met, then the toxicity of the mixed effluents must be considered.
5. Normally no mixing zone would be expected to impinge on the MLWS shoreline.
6. A mixing zone should generally not plug an estuary, or small bay. It is expected that a mixing zone in such a situation should take up no more than a half of the narrowest dimension.
7 A mixing zone should not jeopardise the integrity of any statutory designated sites (e.g. Special Area of Conservation) and consideration should be given to applying the same criteria for other sites with recognised conservation values.
8. The mixing zone should not give rise to any significant visible slicks or other aesthetic problems.
9. Where solids are present in the effluent, and where these solids are expected to accumulate on the seabed, a similar approach to that used for the liquid dispersal will be utilised, i.e. the 100m mixing zone is retained but the toxicity criteria must recognise the extended exposure times possible for the resident benthic organisms. The seabed sediment must meet standstill clauses for appropriate EC dangerous substances outside the mixing zone. Build up of

other potentially toxic substances must also be avoided but no formally accepted quantitative standards currently exist. No solids will be permitted to accumulate on the seabed within the identified mixing zone in quantities, which would give rise to acute toxicity. 1 Subsequent, or secondary, mixing with the receiving water occurs away from the boil and is generally slower, the rate depending on hydrographic conditions. If the initial effluent is buoyant then this secondary mixing will normally be restricted to the upper layers of the sea until the relative densities are such that mixing can take place throughout the water column.

6.1.3 A3. ANZECC (2000) Guidelines on Mixing Zones

The size of the mixing zone must be as small as practical and should not occupy a significant proportion of the receiving waters.

- Mixing zones are not applicable to certain waters where values or characteristics are not compatible with the existence of a plume of water, which does not meet ambient management goals. Examples include waters with significant and regular use for primary contact recreation, aquaculture, and high conservation values and near potable water intakes.
- Mixing zones are generally designated to manage the controlled discharge of soluble toxicants that do not bioaccumulate. Mixing zones are also not appropriate for managing the discharge of nutrients or particulate substances.
- The-mixing zone should not be acutely toxic to fish or other aquatic vertebrates or cause significant irreversible harm, or growth of undesirable aquatic life or dominance of nuisance species (such as algal blooms).

6.1.4 A4. Summary of USEPA Guidelines on Setting Regulatory Mixing Zones

Size: The area or volume of an individual zone or group of zones shall be as limited to an area or volume as small as practical that will not interfere with the designated uses or with the established community of aquatic life

Shape: The shape of a mixing zone should be a simple configuration that is easy to locate in a body of water and avoids impingement on biologically important areas. Shore hugging plumes should be avoided.

In-zone quality: A mixing zone should be free of the following:

1. Materials in concentrations that will cause acute toxicity to aquatic life;
2. Materials in concentrations that settle to form objectionable deposits;
3. Floating debris, oil scum and other matter in concentrations that form nuisances;
4. Substances in concentrations that produce objectionable colour, odour, taste or turbidity, and;
5. Substances in concentrations which produce undesirable aquatic life or result in a dominance of nuisance species.

In addition some States will not allow mixing zones to apply for certain designated uses.

E.g. Oregon does not allow mixing zones in waters designated for human health (i.e.

bacteria standards have to apply at end of pipe – Schnurbusch, 2000). Theoretically, mixing zone allowances are made on a parameter-by-parameter basis (USEPA, 1994).

Typically the States limit mixing zones for rivers and streams by width or cross section excess (usually <25% -33% cross-sectional areas) and determine lengths on a case-by-case basis. For lakes, estuaries and coastal waters some states specify the surface area affected by the discharge (including the water column and benthic area).

Additional regulations apply to disposal of municipal wastewaters into coastal waters. In such cases the mixing zone is deemed equivalent to the zone of initial dilution and must:

1. Be regularly shaped (circle or rectangle);
2. Surround the discharge structure; and
3. Encompass regions exceeding standards under design conditions.