Discussion Paper #2: Effluent Mixing in Nonflowing Waters

State of Idaho
Department of Environmental Quality

June 2014

Printed on recycled paper, DEQ, June 2014, WQST, 82316. Costs associated with this publication are available from the State of Idaho Department of Environmental Quality in accordance with Section 60-202, Idaho Code.

Problem Statement

Idaho's current rules regarding limitations on mixing zones are focused on discharges to flowing waters such as rivers and streams. The zone of passage, organism drift time, limits on the fraction of width or volume of the receiving water body that a plume may occupy, and specification of low receiving water design flows for applying toxics criteria, all conger up images of a flowing waters and do not transfer well to regulating mixing zones in nonflowing waters. While our current rules do speak to mixing zones in lakes and reservoirs, providing that they should not exceed 10% of the surface area, this can be an exceedingly generous size in a large lake/reservoir and exceedingly limiting in a small lake/reservoir. The Idaho Department of Environmental Quality (DEQ) is struggling with how to improve handling of mixing zones for discharge to waters other than streams and rivers—lakes, reservoirs, or even wetlands. DEQ looked at other states and found considerable variability, from rules that allow no mixing in lakes to rules with a variety of basic limitations, including two states with Idaho's same area restriction, for which we do not know the basis.

Background—Near-Field Versus Far-Field Mixing

Mixing of effluent with a receiving water body can be conceptually divided into near field and far-field regions. Close to the point of discharge (i.e., in the near-field region) mixing of effluent with ambient water is dominated by the momentum and buoyancy of the discharge, in addition to the outfall's geometry. In this region, mixing is largely controlled by the characteristics of the effluent and the discharge structure.

At some distance from the point of discharge, initial momentum and buoyancy of the discharge dissipate and the plume transitions to the far field. In the far field, the characteristics of the receiving water body, turbulence due to ambient flow, and diffusion control further mixing. Relative speed of mixing varies within the two regions, with outfall design being important in the near field and ambient turbulence being key in the far field.

Through engineering design, we can exercise control over near-field mixing; in the far-field, we are at the mercy of ambient conditions. In general far-field mixing is much slower in lakes and other waters of similarly low to no velocity.

What Do We Mean by Nonflowing?

Lakes and reservoirs are characterized in part by low velocity of flow. While some reservoirs may be much like deep slow rivers, others are more lake-like in their characteristics including a low velocity of flow. Wetlands typically have little to no discernable velocity. Collectively lakes, some reservoirs, and wetlands can be ecologically classified as lentic (i.e., sluggish or slow) waters.

Idaho's water quality standards treat reservoirs that have a mean detention time of greater than 15 days as lakes for the purpose of applying aquatic life criteria (IDAPA 58.01.02.250.02.c).

However, the 2014 Idaho water quality standards contain no definitions for the terms lake, reservoir, wetland, or mean detention time.

While flow may not be absent in these types of receiving waters, it is weak and may be dominated at times by tides or wind-induced currents. Furthermore, the direction of flow may shift or even reverse. This weak flow creates little far-field turbulence and thus slows mixing. The result can be a larger area exceeding concentration thresholds, such as acute or chronic criteria, than would occur with more rapid mixing.

Flow reversal can cause a plume to double back on itself. This creates areas of even more limited dilution of the effluent plume with ambient water and locally higher pollutant concentrations than would otherwise exist. These areas of elevated pollutant concentrations are hard to predict and may interfere with beneficial uses.

A further issue is thermal stratification. Thermal stratification is important to mixing because temperature is typically the primary determinant of water density. Thus, the buoyancy of an effluent, relative to the water body receiving the discharge, depends on temperature and the thermal stratification of the receiving water body. In the far field, this can lead to flattening of the plume to a thin layer of like density, which may spread over a large area due to very slow further mixing. Density of the effluent relative to a stratified receiving water is an important consideration in selecting the best depth for an outfall and may even require the ability to vary the depth of discharge with season or water levels.

In lentic waters, careful location of the discharge point (e.g., away from shore) at proper depth, and with a diffuser design that maximizes jet flow at the point of discharge, are key to rapid mixing and minimizing the size of a mixing zone. It may be that some nonflowing water bodies are too small, relative to the volume of effluent to be discharged, to allow mixing without interfering with beneficial uses of the water.

What Do We Know About How Other States Handle Mixing in Nonflowing Waters?

To improve our knowledge of how other states deal with mixing zones in nonflowing waters, DEQ teamed with the Association of Clean Water Administrators to survey to other states asking them the following questions:

1. Does your state allow mixing zones for discharge to nonflowing waters such as lakes, reservoirs and wetlands?

2. If so, how do you distinguish nonflowing from flowing waters, e.g. do you have a definition or a flow velocity threshold?

3. If allowing mixing in lakes and other lotic waters, how is the size of the mixing zone determined, what are the limitations on size?

4. Are these limitations in rule or guidance, and how long have they been in place?

5. If available, please provide a link to your rules/guidance document.

6. Do you have a support document that provides the rationale or basis for the mixing zone limitations you apply to nonflowing waters?

The results of the survey were compiled in a spreadsheet and are summarized as follows:

Twelve states responded: Alaska, Iowa, Kansas, Louisiana, Michigan, Minnesota, Nebraska, New Jersey, North Dakota, Oregon, Utah, and Wyoming.

Question 1: Most states do allow mixing zones in either lakes (8 of 12) or reservoirs (9 of 12), while most states do not allow mixing in wetlands (7 of 10, 2 unclear). New Jersey grandfathers in existing discharges with mixing in nonflowing waters (lakes, reservoirs, and wetlands) but does not allow mixing zones in these waters for new discharges. Kansas does not allow mixing zones in certain designated lakes (Outstanding Resource Waters) but does in others. Oregon allows mixing zones in reservoirs but not in lakes or wetlands. The table below summarizes the responses that were received:

Allowance for mixing zones in nonflowing waters.

State	Lakes	Reservoirs	Wetlands
AK	Yes	?	?
IA	No	No	No
KS	Yes, with exceptions	Yes	Yes
LA	Yes	Yes	Yes
MI	Yes	Yes	No
MN	No	No	No
NB	No	No	No
NJ	NJ, existing only	NJ, existing only	?
ND	Yes	Yes	No
OR	No	Yes	No
UT	Yes	Yes	No
WY	Yes	Yes	Yes

Question 2: Most states (8 of 12) replied that they did not have definitions for lakes, reservoirs, or wetlands, or at least not in terms of flow.

Alaska defines a lake as “an inland water body of substantial size that occupies a basin or hollow in the earth's surface and that might or might not have a current or a single direction of flow.”

Michigan defines lotic as waters that exhibit flow but sets no minimum flow threshold.

Minnesota defines lakes, reservoirs and wetlands, as well as shallow lakes, but the definitions do not refer to flow limits. Their reply indicated that they do not allow mixing in waters with a 7Q10 (i.e., lowest 7-day average flow that occurs, on average, once every 10 years) less than zero, and their rules specifically preclude calculation of a 7Q10 in lakes.

Nebraska replied they have lakes defined, but their definition is not based on velocity of flow.

Question 3: If allowing mixing in lakes and other lotic waters, how is the size of the mixing zone determined, and what are the limitations on size?

Size limitations are quite variable and reference either fraction of area or a fixed dimension, sometimes both, with a “not to exceed X % or Y dimension” construction.

Alaska and Iowa limit mixing zones in nonflowing waters based on area only; limiting size to 10% of the surface area, which is the same as Idaho’s current rules.

New Jersey limits mixing zone size in lakes and reservoirs to 5% of surface area or 100 meters (approximately 328 feet) at design flow, but this is for existing (as of 2002) discharges. New discharges are not allowed in lakes.

North Dakota and Wyoming limit mixing to 5% of the surface area or 200 feet radius, but for North Dakota, this applies only to lakes and reservoirs. No mixing is allowed for discharges to wetlands.

Kansas limits the size to 1% of the surface area or 50 meters (approximately 164 feet) from point of discharge.

Utah and Louisiana limit mixing zone size based on fixed dimensional limits only. For Utah, this is 200 feet for a chronic mixing zone and 35 feet for an acute mixing zone, with no mixing in wetlands. Louisiana is a more restrictive at 100 feet for the mixing zone as a whole and 25 feet for the zone of initial dilution. Louisiana also indicated a “case-by-case” departure from the values in rule is allowed.

Question 4: Are these limitations in rule or guidance, and how long have they been in place?

All 12 states replied they had size limitations in rule, most going back many years.

Examination of the rules, at the web links the respondents provided, indicated a vast range in the specificity in rule. Wyoming is on the terse end with a one paragraph rule that has no specific size limitation mentioned. Utah’s rule is also quite terse but does have numbers for size limitations. Michigan had the lengthiest, perhaps most detailed rules, followed closely by North Dakota.

Questions 5 and 6: Refer to the online spreadsheet at “MZs in nonflowingwaters_state query.xlsx.”

Other Interesting Observations

The majority of the states responding (7 of 12) have language to the effect of keeping mixing zones as small … as possible, as practicable, as feasible, or similar language to minimize their size. These states are Alaska, Louisiana, Michigan, Minnesota, Nebraska, North Dakota, and Oregon.

A different majority (7 of 12 again) call out bioaccumulative compounds in some way for special limitation on mixing. In Minnesota, this limitation is specific to waters draining to the Great Lakes. In New Jersey, it is for a specific list of 17 compounds—mostly banned pesticides. Other states with specific language regarding bioaccumulative compounds are Alaska, Michigan, North Dakota, Utah, and Wyoming. For the most part, the restriction is just a simple statement that mixing may be further limited based on “bioaccumulation in fish tissue or wildlife.” This would seem to acknowledge that while bioaccumulation is factored into calculating water column criteria for protection of human health, site-specific bioaccumulation rates may differ from those used in broadly applicable criteria.

Conclusion

Far-field mixing is comparatively slow in lakes and other *nonflowing* waters or waters with sluggish flow. The limitations outlined in the rule for receiving *streams* (e.g., fraction of low flow, width, and fish passage) do not easily lend themselves to application on nonflowing waters, and a fixed fraction of the area of a lake or other lentic water body seems too arbitrary given the broad range in size of such waters from small ponds to Lake Pend Oreille. Collectively, these factors present a compelling argument for different restrictions than would apply in rivers and streams.

The size of a lentic water body—lakes, lake-like reservoirs, and wetlands—could be a factor in mixing zone size limitations for such waters. It may make more sense to use a fixed size limitation, like Utah and Louisiana do, than a fraction of the surface area of the lake or reservoir. Design of outlet structures, such as diffusers, which promote rapid mixing in the near field, thus mitigating to some degree more limited mixing further from point of discharge, could be another important requirement.