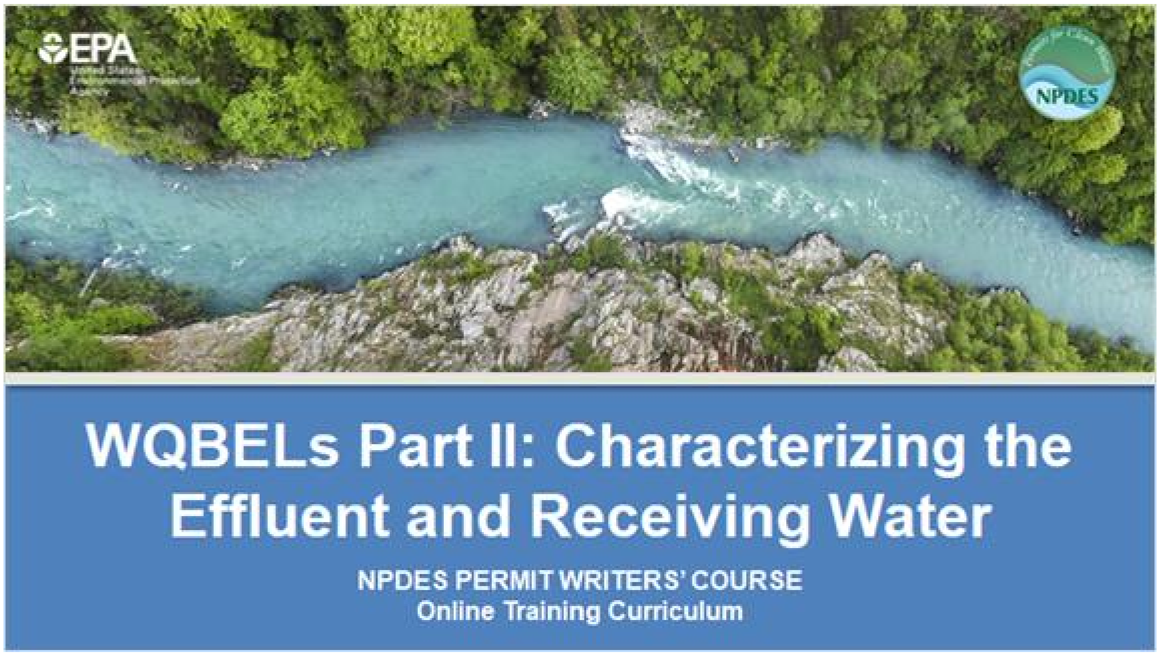
WQBELs Part II: Characterizing the Effluent and Receiving Water

1. NPDES Permit Writers’ Course Online Training Curriculum

1.1 WQBELs Part II: Characterizing the Effluent and Receiving Water



Notes:

Hello, and welcome to Part II of this four-part series of presentations on Establishing Water Quality-based Effluent Limitations in NPDES Permits.

This presentation addresses the topic of characterizing the effluent and receiving water when developing water quality-based effluent limitations.

Before we get started with the presentation, I want to introduce our speakers and take care of a housekeeping item.

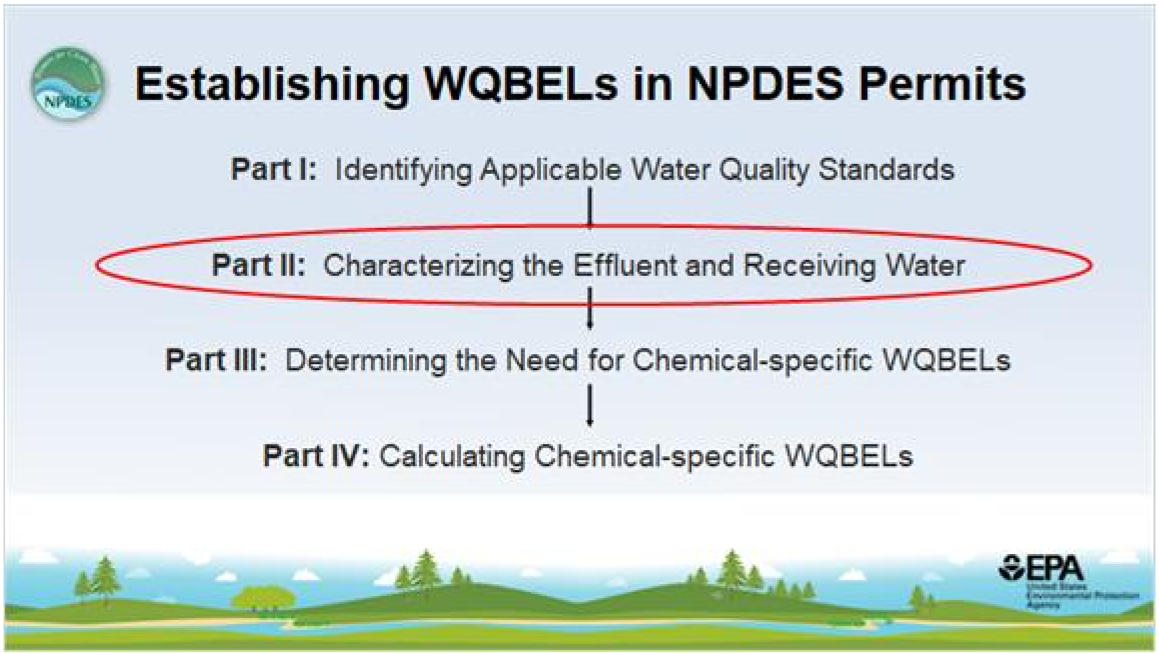
1.2 Presenters

Notes:

Your speakers are David Hair, an environmental engineer with the Water Permits Division of USEPA in Washington, DC, and me, Greg Currey, an environmental engineer with Tetra Tech, Incorporated in Fairfax, Virginia.

In addition to introducing our speakers, I need to let you know that the materials used in this presentation have been reviewed by USEPA staff for technical accuracy; however, the views of the speakers are their own and do not necessarily reflect those of USEPA. NPDES permitting is governed by the existing requirements of the Clean Water Act and USEPA's NPDES implementing regulations. These statutory and regulatory provisions contain legally binding requirements. The information in this presentation is not binding. Furthermore, it supplements, and does not modify, existing USEPA policy, guidance, and training on NPDES permitting. USEPA may change the contents of this presentation in the future.

1.3 Establishing WQBELs in NPDES Permits

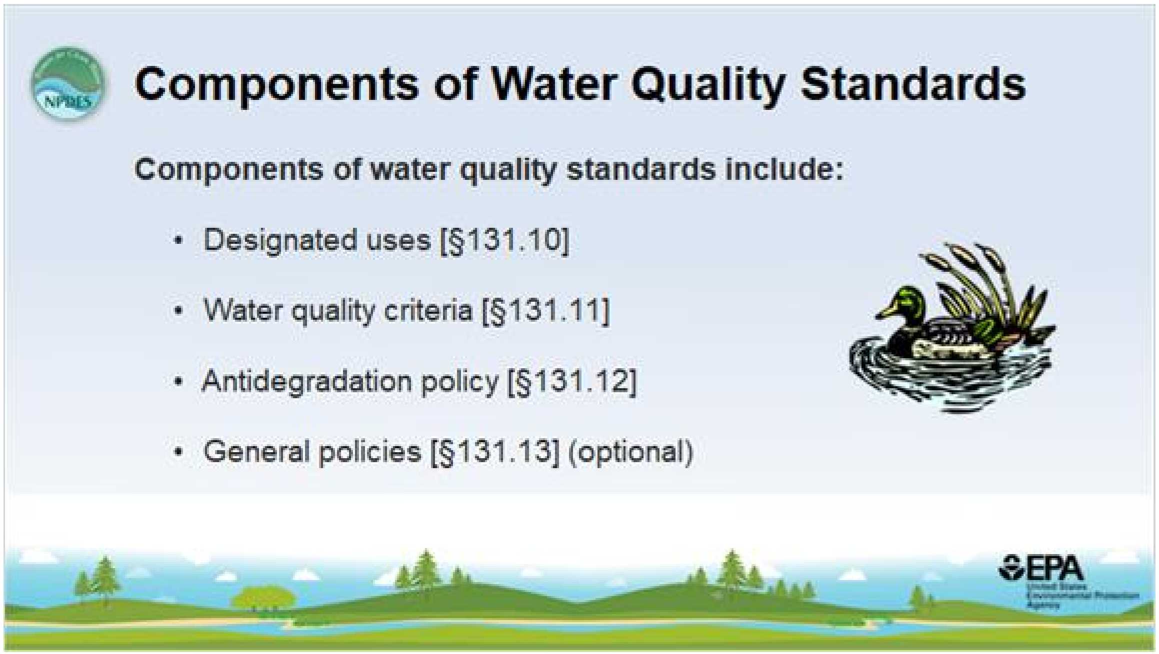


Notes:

As I mentioned before, this presentation is Part II of a four-part series on establishing water quality-based effluent limitations in NPDES permits.

You can find all of the presentations in this series on the "Training and Meetings" page of USEPA's NPDES Web site.

1.4 Components of Water Quality Standards



Notes:

In Part I of our series, we discussed the components of water quality standards, including: designated uses, criteria that support those uses, antidegradation policies, and general policies related to implementation of the standards.

1.5 WQS Implementation Procedures

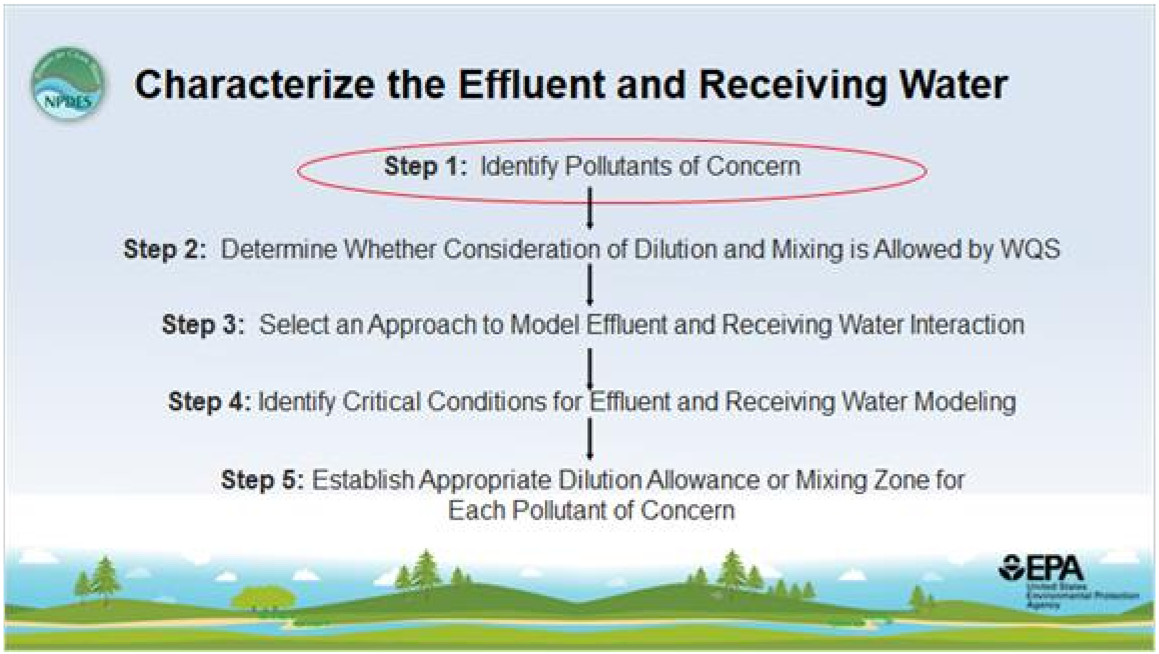
Notes:

At the conclusion of Part I, we noted that the permit writer's role is to understand the state water quality standards and the implementing procedures for those standards, which can be found in the state's regulations, water quality management plans, or guidance, and in USEPA guidance.

As we move into Part II of the presentation, we'll discuss the first step in the implementation procedures, which is to collect and analyze the data necessary to apply the state's water quality standards through water quality-based effluent limits in NPDES permits.

Dave, why don't you get us started with Part II?

1.6 Characterize the Effluent and Receiving Water



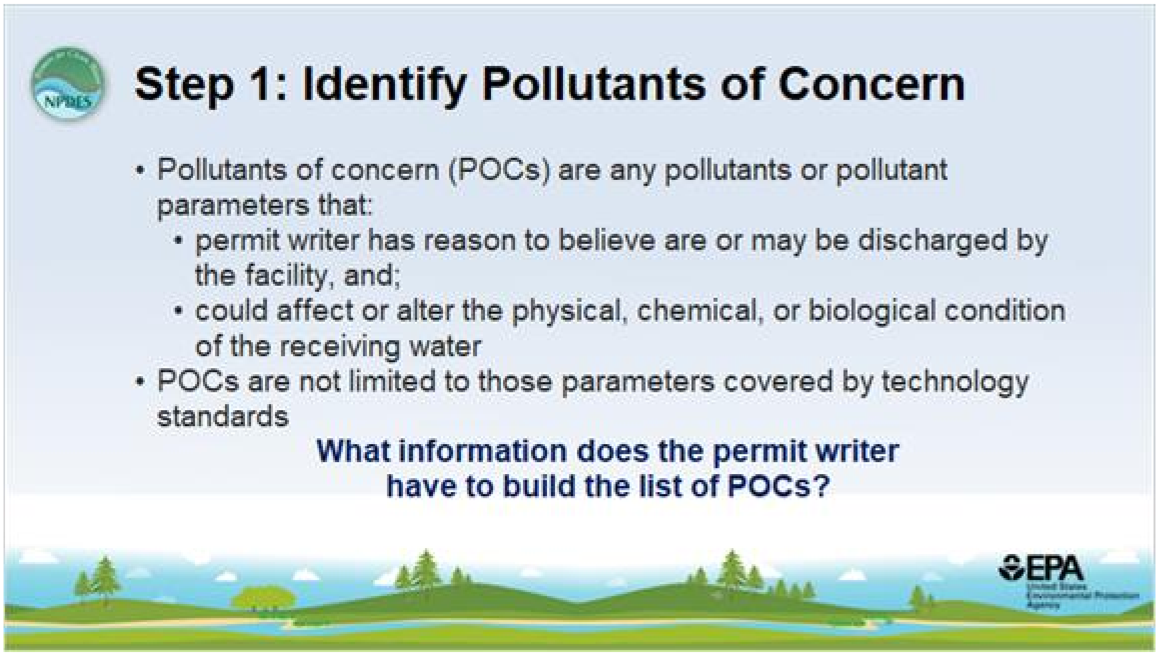
Notes:

Thanks Greg.

In this module we'll be covering a five-step process to characterize the effluent and receiving water in preparation for assessing the impact of a particular discharge to a specific water body. Since both the discharge and receiving water are unique, we need to gather all the information that we can to help feed our analyses.

The first step in our process is to gather information about the discharge that we are permitting and identify the pollutants of concern.

1.7 Step 1: Identify Pollutants of Concern



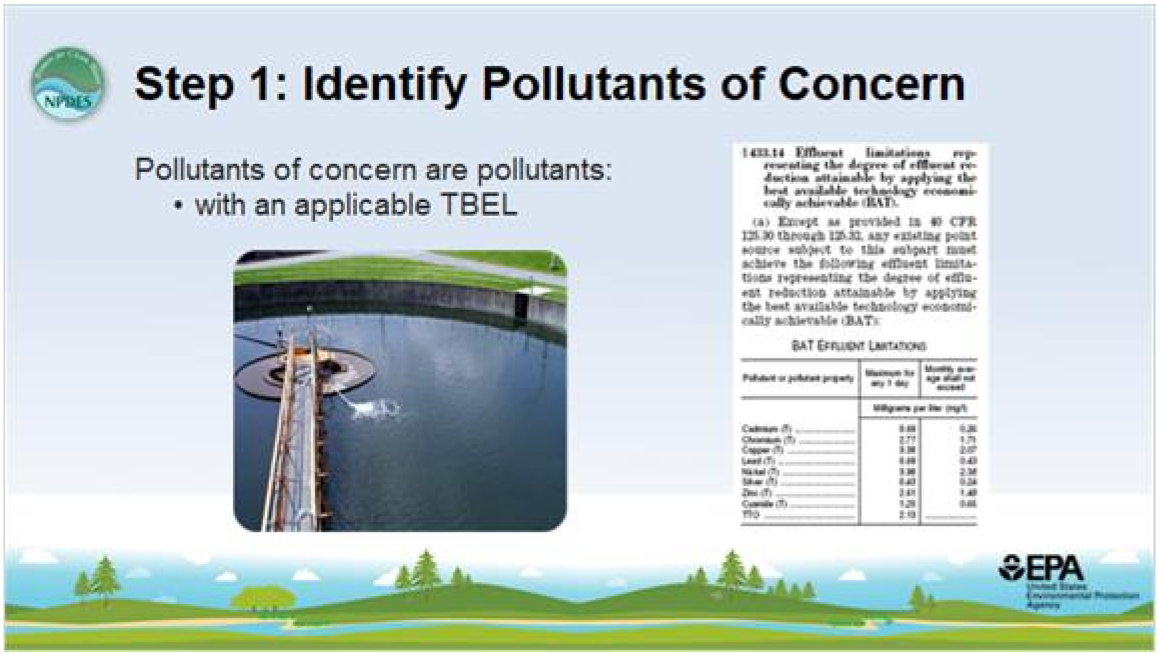
Notes:

What do we mean by pollutants of concern? Well, we can't possibly develop permit limits for every element, or chemical compound, or pollutant parameter in existence. There are hundreds of thousands of things that could be present in water.

Instead, we need to learn all we can about our particular discharge and limit our assessment to those pollutants and pollutant parameters that are relevant. Think of this first step as creating our "master list" of pollutants for further evaluation.

We'll build our list by looking at categories of pollutants that we have some reason to believe are associated with our discharger.

1.8 Step 1: Identify Pollutants of Concern



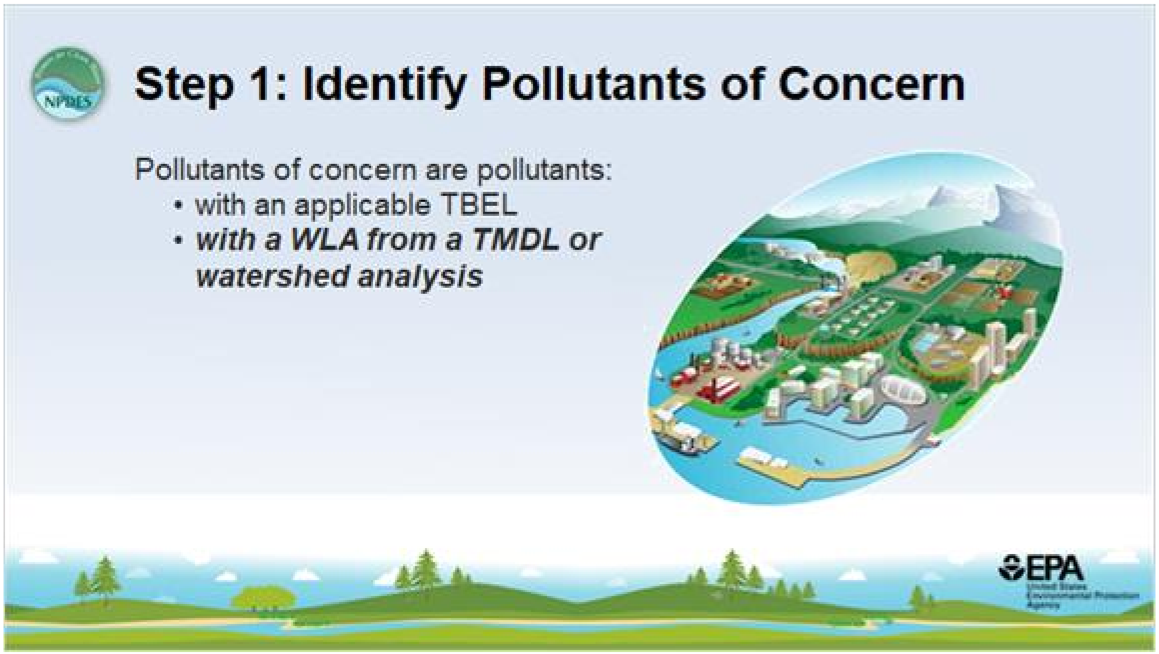
Notes:

The first category of pollutants of concern are those pollutants for which we have already developed technology-based effluent limitations derived from national or state technology standards or on a case-by-case basis using best professional judgment.

By developing technology-based effluent limitations for a pollutant, we have already determined that there will be an effluent limitation for that pollutant in the permit.

These same pollutants are “pollutants of concern” for water quality-based effluent limit development because, having developed a technology-based limit, we must determine whether that limit alone would be protective of water quality. If not, then the Act and regulations require that we include limitations more stringent than the technology-based effluent limitations to prevent an excursion above water quality standards in the receiving water.

1.9 Step 1: Identify Pollutants of Concern



Notes:

The pollutants of concern we will consider next are those pollutants for which a wasteload allocation, or WLA, has been assigned to the discharge through a total maximum daily load, or TMDL.

We just introduced some new terms into our discussion-wasteload allocation and total maximum daily load. So, let's take a moment to define them.

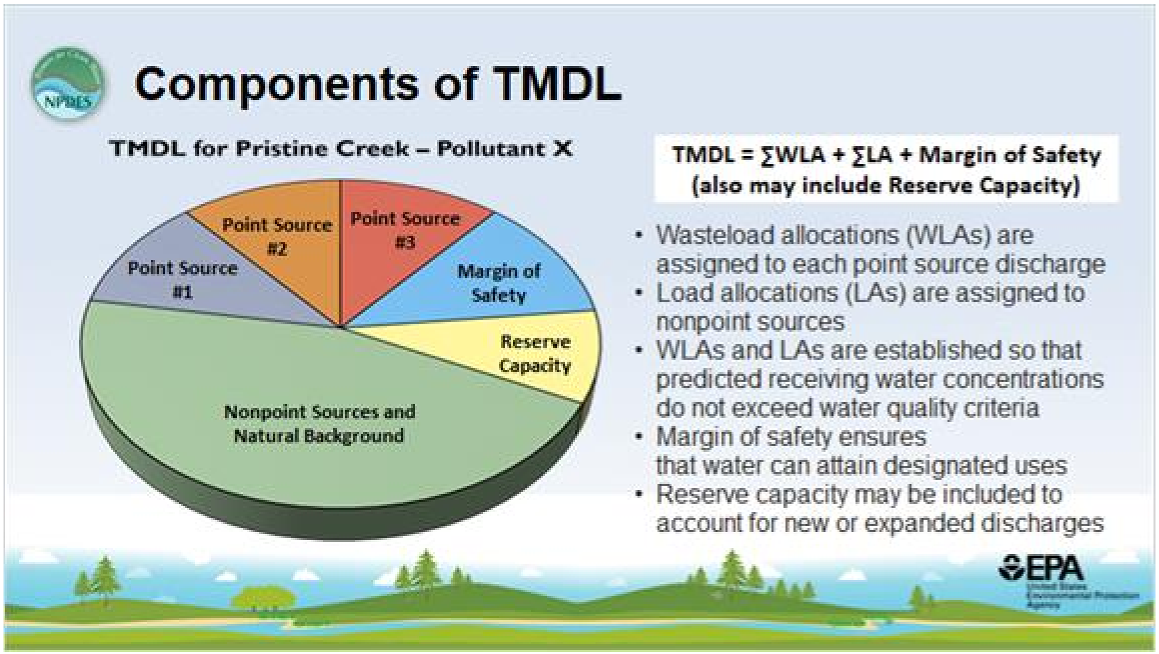
1.10 Total Maximum Daily Load (TMDL)

Notes:

Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. Impaired waters are those that will not meet applicable water quality standards, even after implementation of all technology-based requirements. The law requires that States establish priority rankings for waters on their Clean Water Act section 303(d) list and develop TMDLs in accordance with this priority ranking.

Simple enough, but what is a TMDL?

1.11 Components of TMDL



Notes:

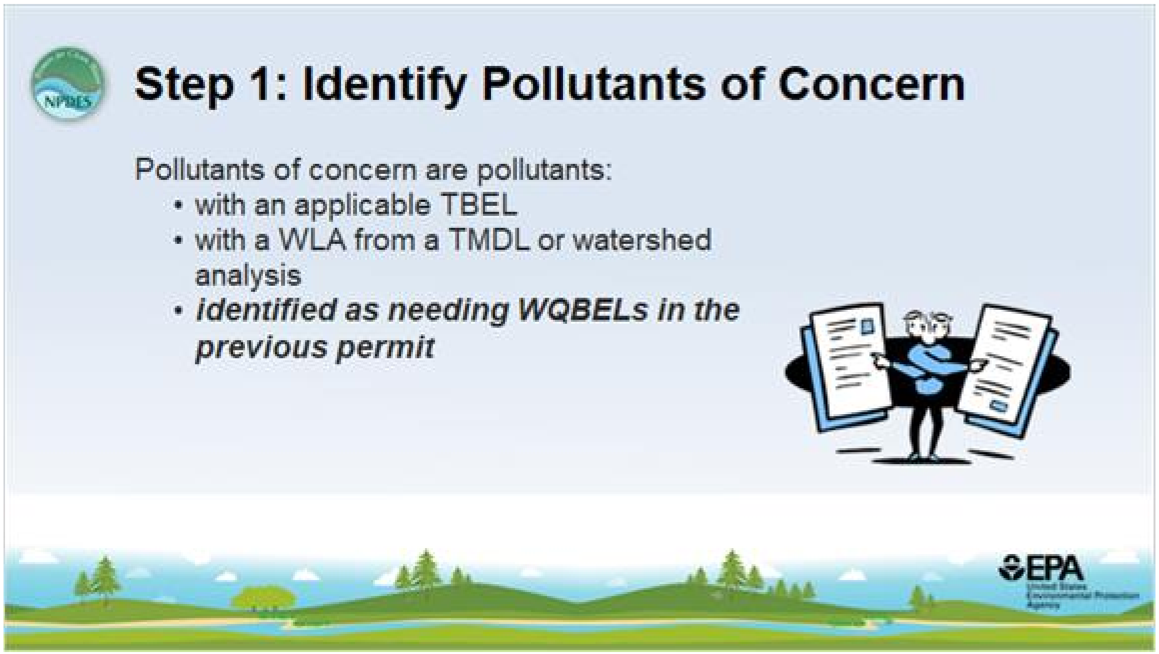
A total maximum daily load, or TMDL, is a calculation of the maximum amount of a single pollutant that a water body can receive and still meet water quality standards. The TMDL then provides allocations of that total allowable load to the pollutant sources. The allocations to point sources are referred to as Wasteload Allocations, or WLAs, and the allocations to nonpoint sources are referred to as Load Allocations, or LAs. The TMDL must also include an allocation reserved as a margin of safety to account for issues such as modeling uncertainty. Some TMDLs also include an allocation reserved for future growth or expansion; however, this is not a required component.

A TMDL can be thought of then as a planning and management tool that can be used to ensure that the sum of point and nonpoint loads of a specific pollutant to a specific water body or water body segment will not cause an exceedance of the applicable water quality standards.

As shown in our diagram here, you can think of the TMDL as a “pie” where the sum of all of the slices equals the TMDL-the maximum quantity of the pollutant that can be discharged into the water body while ensuring that water quality standards are achieved.

For our purposes, the important point to remember is that any pollutant for which a wasteload allocation has been assigned to the permitted facility through a TMDL is a pollutant of concern. So, in this case, if we were drafting an NPDES permit for Point Source #1, then Pollutant X would be considered a pollutant of concern.

1.12 Step 1: Identify Pollutants of Concern

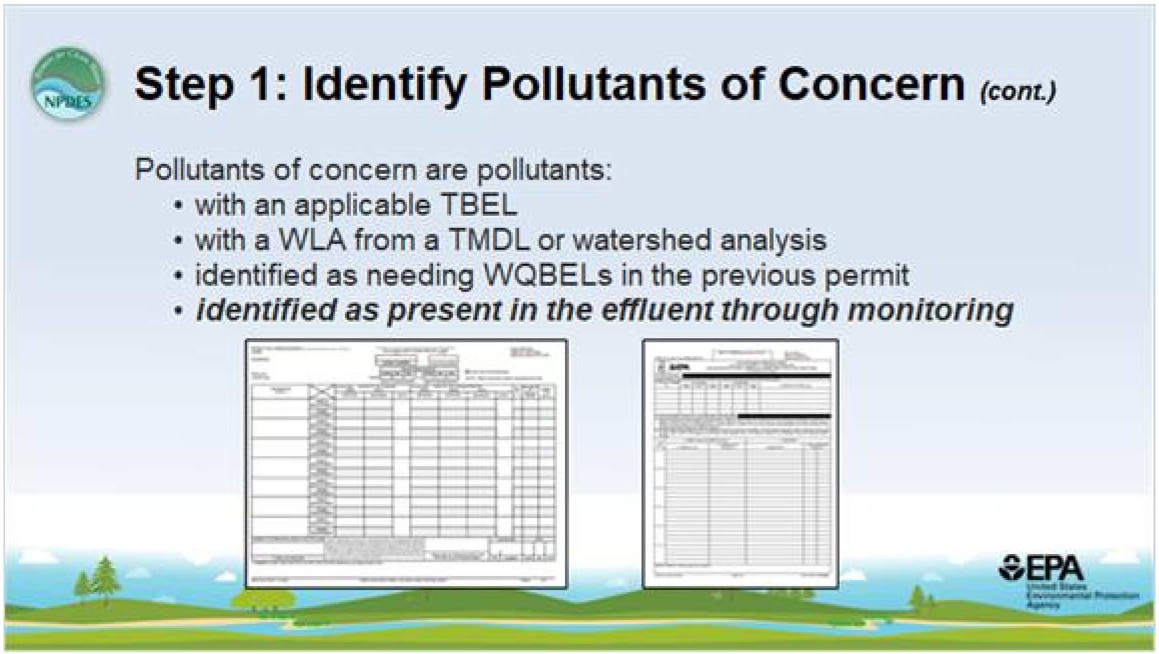


Notes:

A third category of pollutants of concern is pollutants that were identified as needing water quality-based effluent limitations in the discharger's previous permit.

We must determine whether the conditions leading to a decision to include WQBELs for the pollutant in the previous permit continue to apply.

1.13 Step 1: Identify Pollutants of Concern (cont.)



Notes:

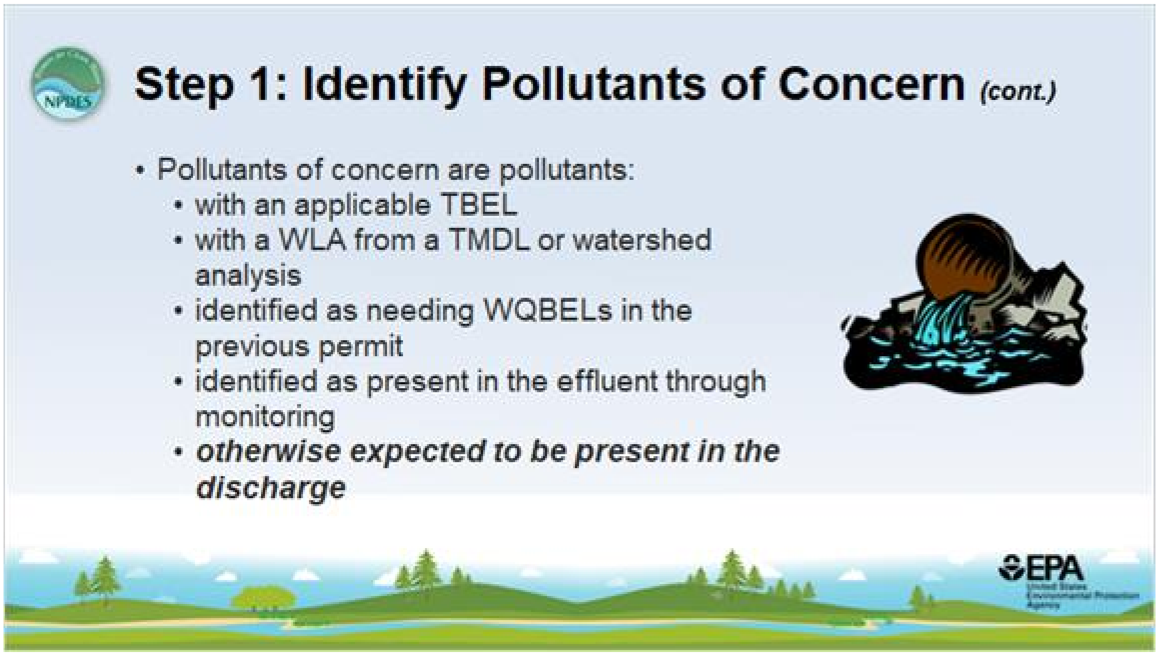
Fourth, pollutants of concern include any pollutants identified as present in the effluent through monitoring.

Effluent monitoring data might be reported in the discharger's NPDES permit application or Discharge Monitoring Reports or through special studies.

In addition, the permitting authority itself can collect data through, for example, compliance inspection monitoring.

We should match information on which pollutants are present in the effluent to the applicable numeric and narrative water quality standards to identify which parameters are candidates for water quality-based effluent limits.

1.14 Step 1: Identify Pollutants of Concern (cont.)



Notes:

Finally, the last category of pollutants of concern is those that do not fit into one of the other categories, but are otherwise expected to be present in the discharge.

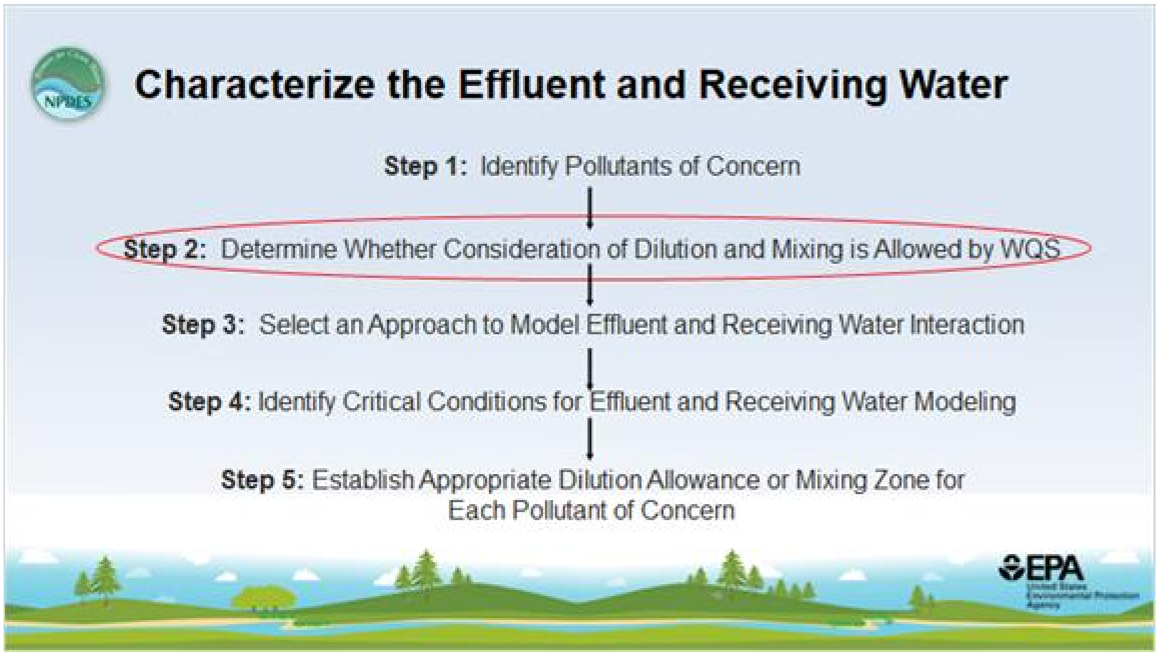
There could be pollutants for which neither the discharger nor the permitting authority have monitoring data, but because of the raw materials stored or used, products or by-products of the facility operation, or available data and information on similar facilities, the permit writer has a strong basis for expecting that the pollutant may be present in the discharge.

Because there are no analytical data to verify the concentrations of these pollutants in the effluent, the permit writer must either generate, or require the discharger to generate, effluent monitoring data before permit issuance or during the term of the permit, or base a determination of the need for water quality-based effluent limits on other information, such as engineering estimates provided by the applicant. A discussion on determining the need for WQBELs without effluent monitoring data is provided in Section 3.2 of USEPA's Technical Support Document.

OK, that gives us our list of pollutants of concern.

Greg, how about taking us on to Step 2

1.15 Characterize the Effluent and Receiving Water

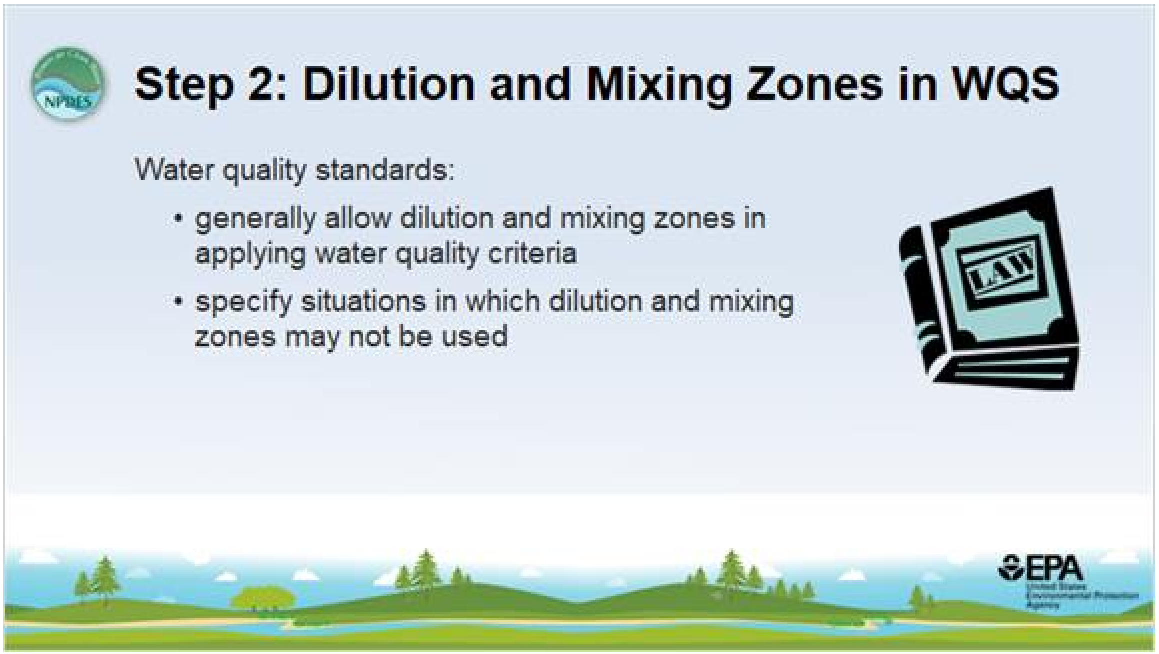


Notes:

Thank you, Dave.

Our second step is to determine whether the applicable water quality standards allow us to consider dilution or mixing zones in our analysis.

1.16 Step 2: Dilution and Mixing Zones in WQS

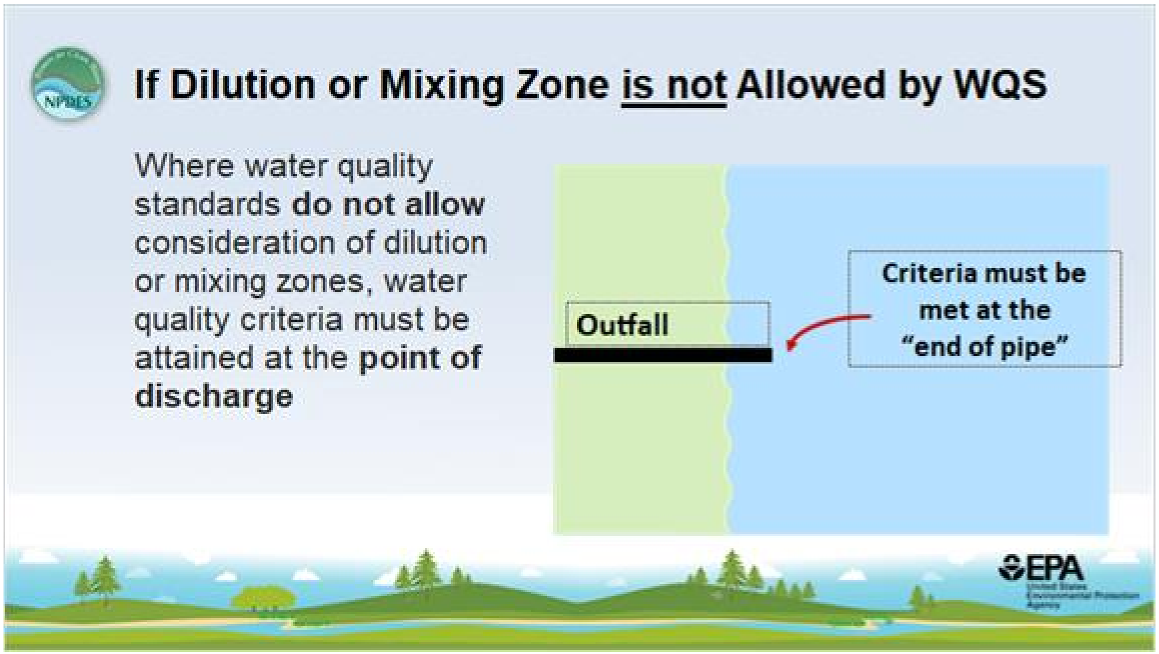


Notes:

Most, if not all, state water quality standards have a general allowance for dilution or a mixing zone to be used in applying the water quality criteria.

However, even where dilution or mixing zones might generally be allowed, most states provide exceptions within the standards where consideration of dilution is not allowed, such as for bioaccumulative pollutants or near areas that are sensitive, like bathing beaches or breeding grounds for aquatic species.

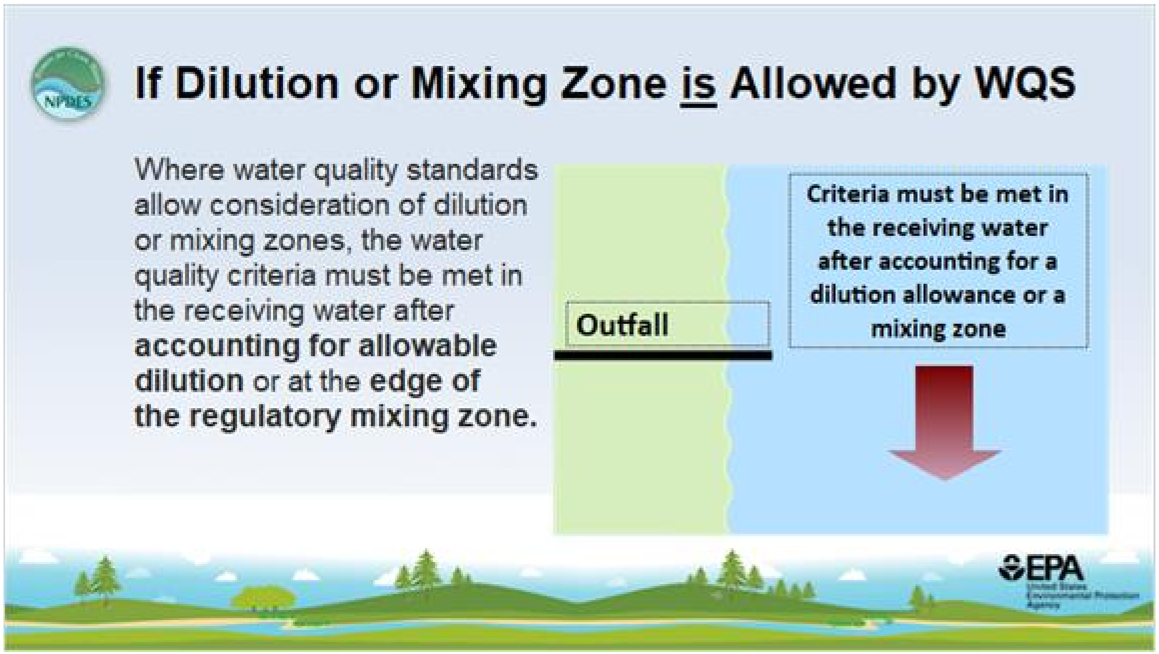
1.17 If Dilution or Mixing Zone is not Allowed by WQS



Notes:

Where no consideration of dilution or a mixing zone is allowed, effluent limitations must be as stringent as necessary to ensure that water quality criteria are attained right at the point of discharge or, as you might hear someone say, at the "end of pipe."

1.18 If Dilution or Mixing Zone is Allowed by WQS

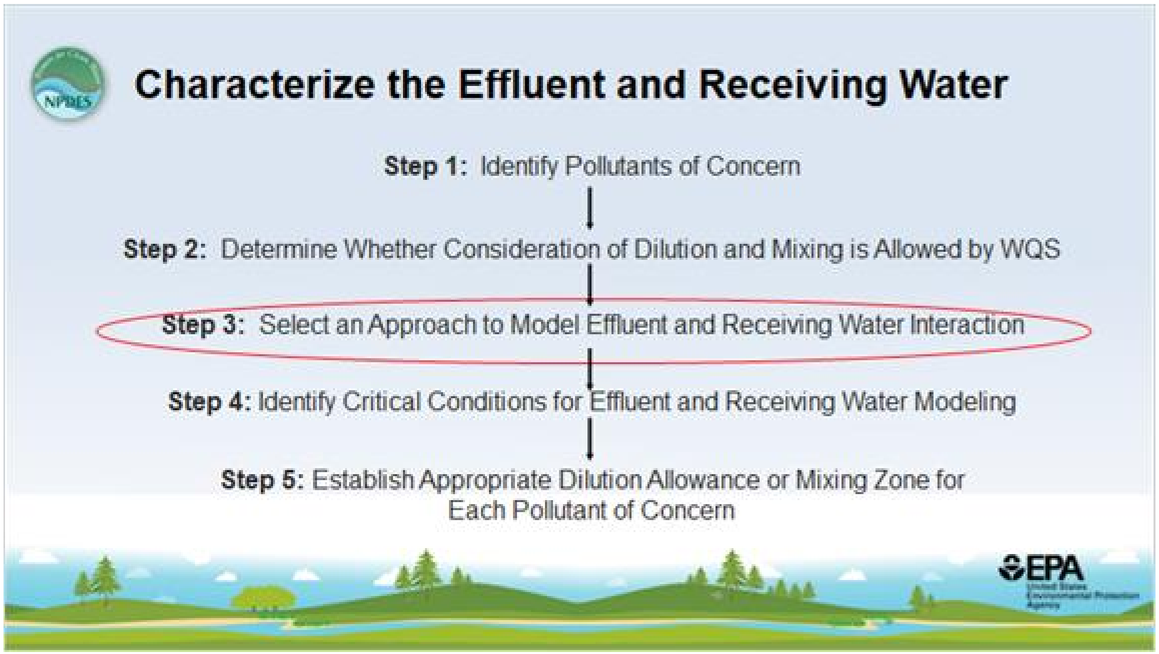


Notes:

If the water quality standards allow consideration of dilution or mixing zones for a pollutant of concern, then the water quality criteria do not have to be attained at the "end of pipe."

Rather, the criteria must be met in the receiving water after accounting for the allowable dilution or mixing zone.

1.19 Characterize the Effluent and Receiving Water

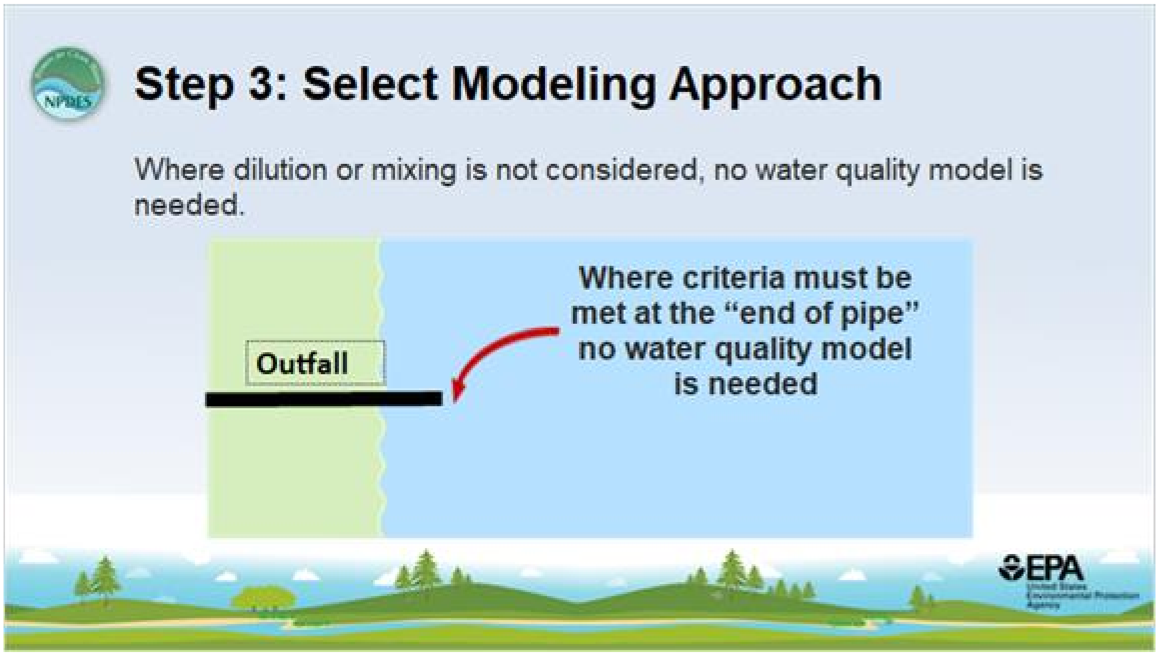


Notes:

On to Step 3, which is to select a water quality modeling approach for modeling the interaction of the effluent and receiving water.

We're going to try to understand how the effluent and receiving water mix together and what impact the effluent has on the amount of the pollutant of concern in the receiving water.

1.20 Step 3: Select Modeling Approach



Notes:

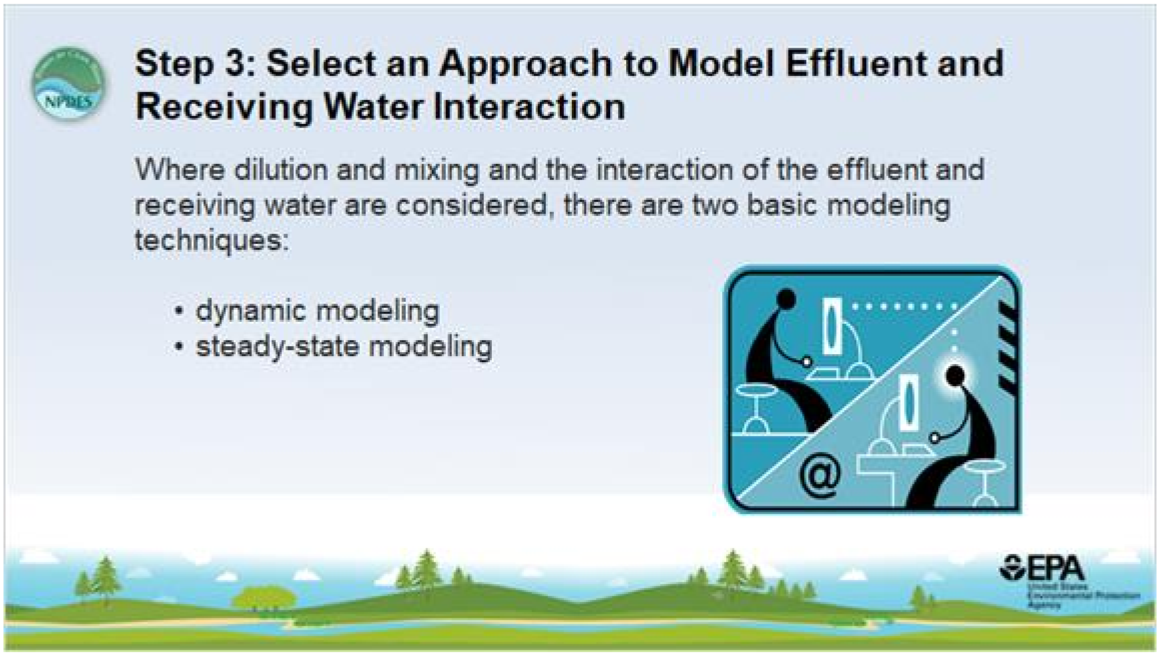
Thinking back to the possible outcomes of Step 2, remember that one possibility is that the applicable water quality standards do not allow any consideration of dilution or mixing zones for the pollutant of concern.

If this is the case, no modeling approach is necessary.

Remember, where no dilution or mixing zone is allowed, the water quality criteria must be met at the point of discharge, or "end of pipe." In other words, the effluent itself must meet all applicable water quality criteria.

Thus, there's no need to model what is happening out where the effluent and receiving water have had a chance to mix.

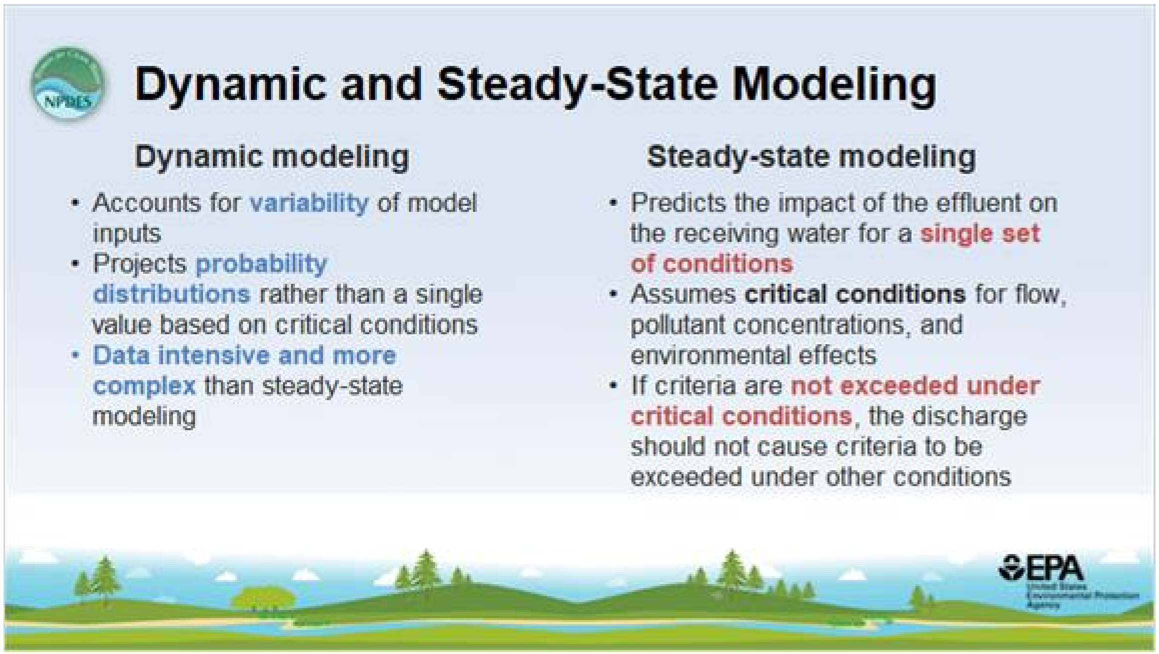
1.21 Step 3: Select an Approach to Model Effluent and Receiving Water Interaction



Notes:

Where we *are* considering dilution and mixing however, we have two basic water quality modeling techniques from which to choose: dynamic modeling and steady-state modeling.

1.22 Dynamic and Steady-State Modeling



Notes:

In some cases, a permitting authority or a discharger may wish to use a dynamic model.

Dynamic models account for variability of model inputs and project a probability distribution rather than a single value based on a single set of conditions.

Because dynamic models can be rather complex and data intensive, they're not used all that often in NPDES permitting.

In most cases, a steady-state model will be sufficient for NPDES permitting purposes.

"Steady-state" simply means that the model will project the impact of the effluent on the receiving water under a single set of conditions.

Because we are only running the model under a single set of conditions, we want those conditions to be what we call the "critical conditions" for protection of receiving water quality.

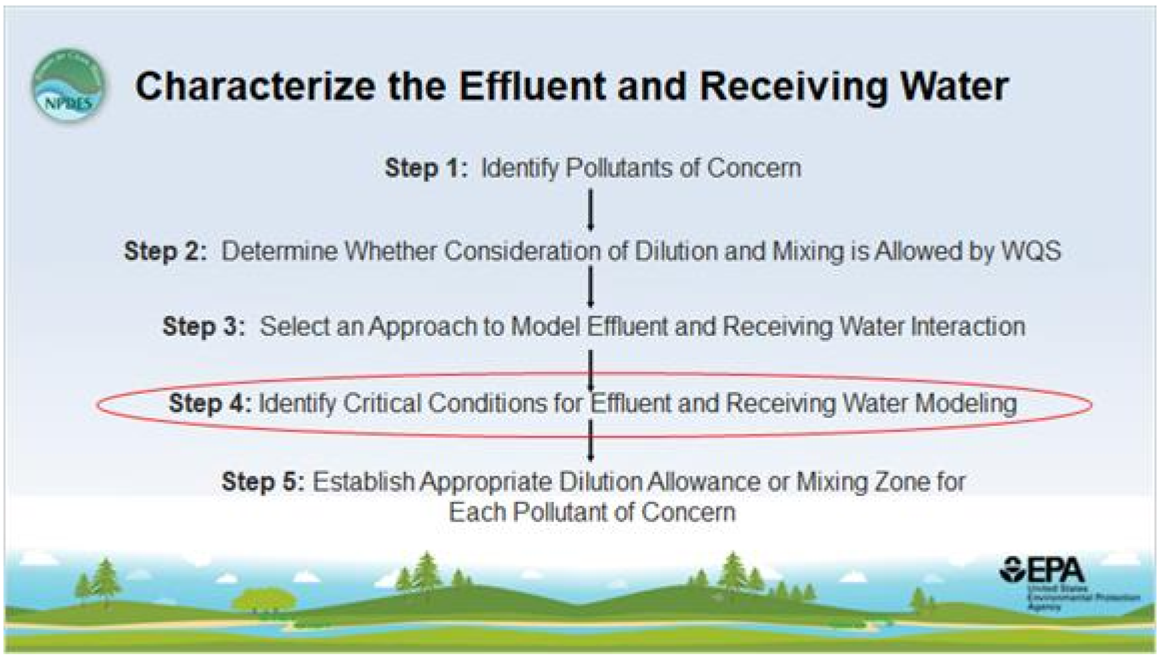
So for example, for a river or stream, we would use in the model whatever flow the water quality standards specify as the critical flow.

We pick critical conditions that allow us to have confidence that if the criteria are not exceeded in the receiving water under those critical conditions, the discharge should not cause the criteria to be exceeded under other foreseeable conditions.

The next obvious question is “What are all of the steady-state model inputs we need to consider?”

Dave, how about taking us through Step 4?

1.23 Characterize the Effluent and Receiving Water

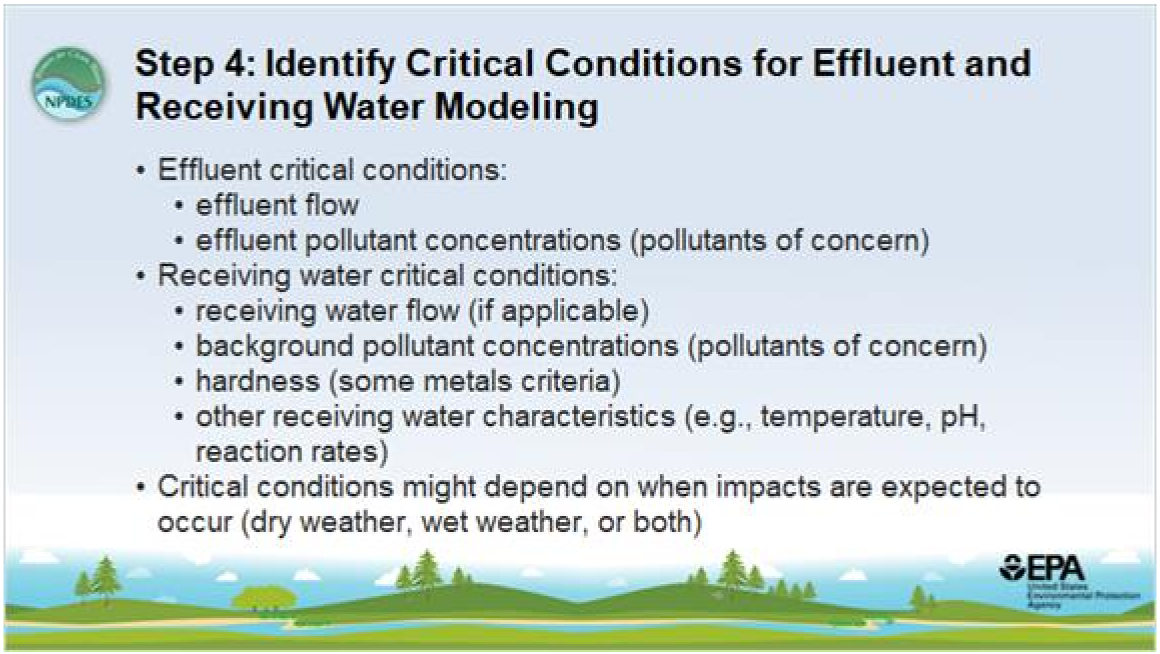


Notes:

Sure, Greg.

In Step 4, if we’re using a steady-state model, we’ll want to identify the critical conditions that we will use in that model.

1.24 Step 4: Identify Critical Conditions for Effluent and Receiving Water Modeling



Notes:

We can divide the critical conditions that are inputs to our model into two categories: effluent critical conditions and receiving water critical conditions.

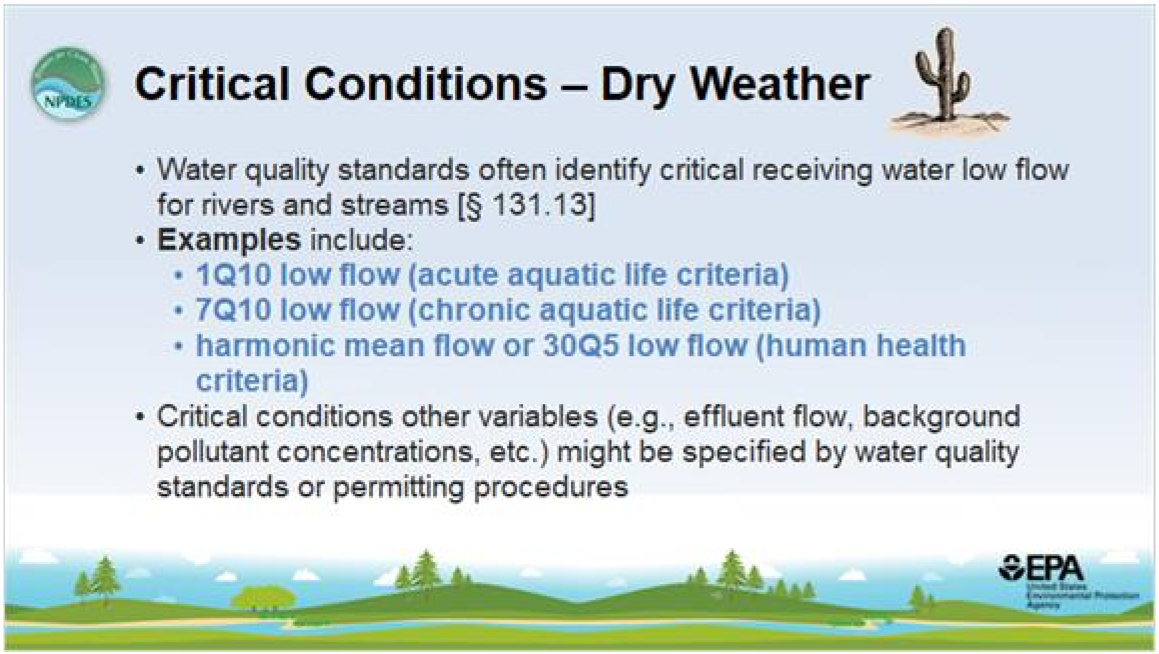
Effluent critical conditions include the flow and the concentration of each pollutant of concern in the effluent.

For the receiving water, critical conditions include the flow and background concentrations of pollutants of concern, but might also include receiving water conditions such as temperature, pH, or reaction rates depending on the particular pollutant of concern.

Selection of the appropriate critical conditions might also depend on when impacts are expected to occur (for example dry weather, wet weather, or both).

Let's take a look at these considerations on the next two slides.

1.25 Critical Conditions – Dry Weather



Notes:

The first situation we'll consider are "dry weather" critical conditions. For dry weather, the critical flow conditions for rivers and streams generally are specified in the state water quality standards.

For free flowing rivers and streams, examples of critical dry weather flows include the 1Q10, defined as the 1-day average low flow expected to recur once every 10 years; the 7Q10, defined as the 7-day average low flow expected to recur once every 10 years; the harmonic mean flow, which reflects a mean with larger values discounted and smaller values amplified; and the 30Q5, defined as the 30 day average low flow expected to recur once every 5 years.

The Technical Support Document recommends using the 1Q10 as the critical low flow for application of acute aquatic life criteria, the 7Q10 for chronic aquatic life criteria, and the harmonic mean or 30Q5 for most human health criteria. However, as we noted, permit writers should look to their state water quality standards and implementation procedures to see what their state requires.

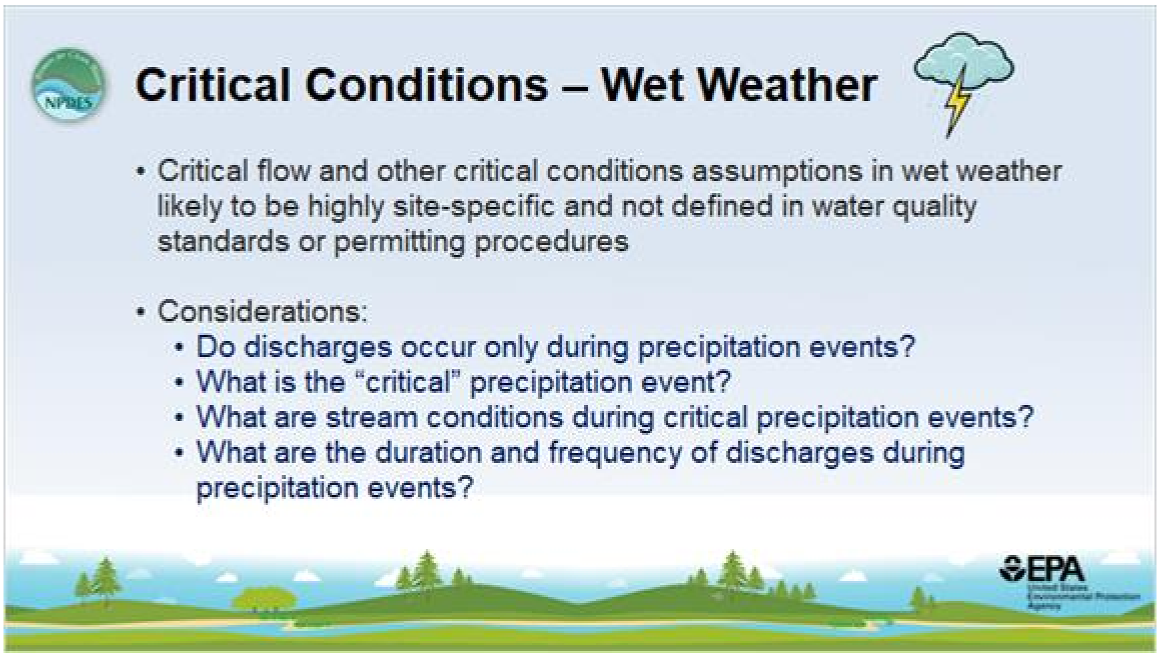
For water bodies that do not flow freely, there might be other environmental conditions that are considered critical conditions, such as season, temperature, or tidal flux. Some of these conditions might be critical conditions for a river or stream as well.

We will focus our attention on rivers and streams for the majority of this presentation.

The water quality standards or permitting implementation procedures should identify appropriate critical conditions for other variables such as the effluent flow or background pollutant concentrations in the receiving water. If the water quality standards or permitting implementation procedures do not specify these critical conditions, the permit writer should look to other permits and follow past practice.

We'll dig into these critical conditions some more in a little while when we consider a simple model for predicting the impact of a discharge on receiving water quality. As part of that discussion, we'll consider EPA guidance for determining the critical concentration of pollutants of concern in the effluent. Your state procedures likely include guidance similar to or based on the EPA guidance.

1.26 Critical Conditions – Wet Weather



Notes:

You'll be less likely to find clear guidance defining critical conditions during wet weather.

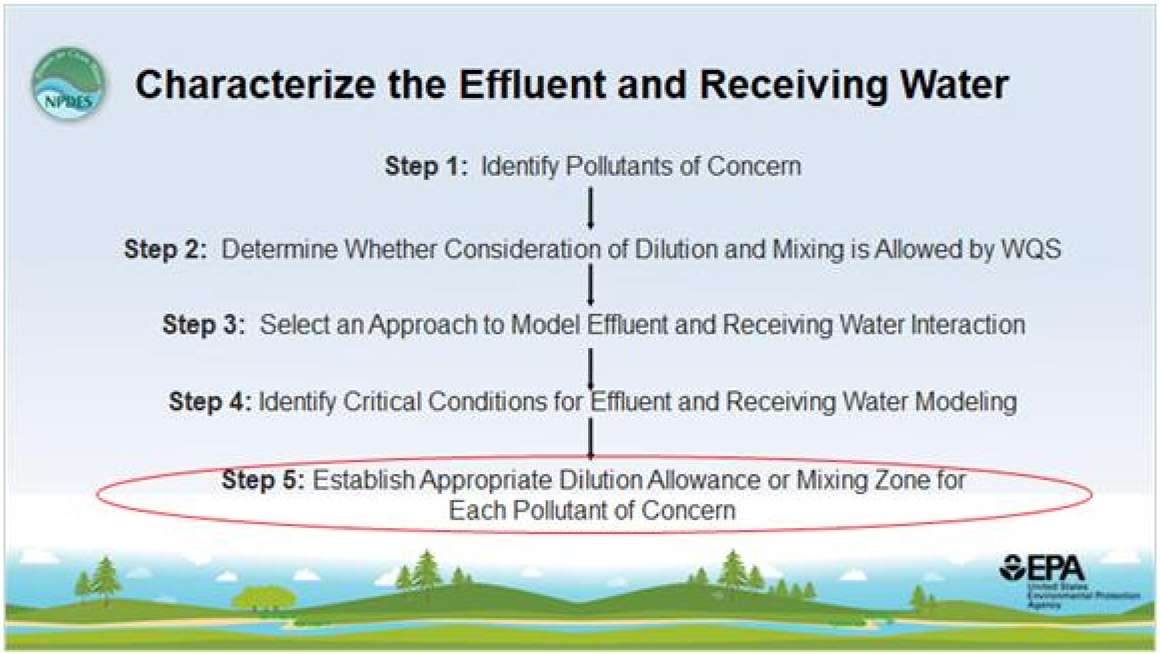
Why would we be concerned with modeling wet weather conditions? Well, many point sources (for example combined sewer overflows or municipal storm sewer systems) only discharge during precipitation events, so modeling dry weather conditions doesn't really work.

Some questions to consider when establishing critical conditions for wet weather events include:

- Do discharges occur only during precipitation events?
- What is the "critical" precipitation event?
- What are water body conditions during critical precipitation events?
- What are the duration and frequency of discharges during precipitation events?

Selection of these critical conditions will likely be highly site-specific, dependent on the type of discharge and receiving water, rather than being defined in the water quality standards or implementation requirements.

1.27 Characterize the Effluent and Receiving Water



Notes:

Alright, now that we've established our critical conditions, our final step is to establish the appropriate dilution allowance or mixing zone, if any, for each pollutant of concern.

1.28 Step 5: Establish Appropriate Dilution Allowance or Mixing Zone for Each Pollutant of Concern

Notes:

In order to understand how much dilution of the effluent by the receiving water we are able to consider as part of our calculations, we need to understand something about how the effluent and receiving water are actually mixing.

In many cases, the amount of dilution we can use in our calculations will depend on whether there is rapid and complete mixing or incomplete mixing of the effluent and receiving water under critical conditions.

1.29 Rapid and Complete Mixing

Notes:

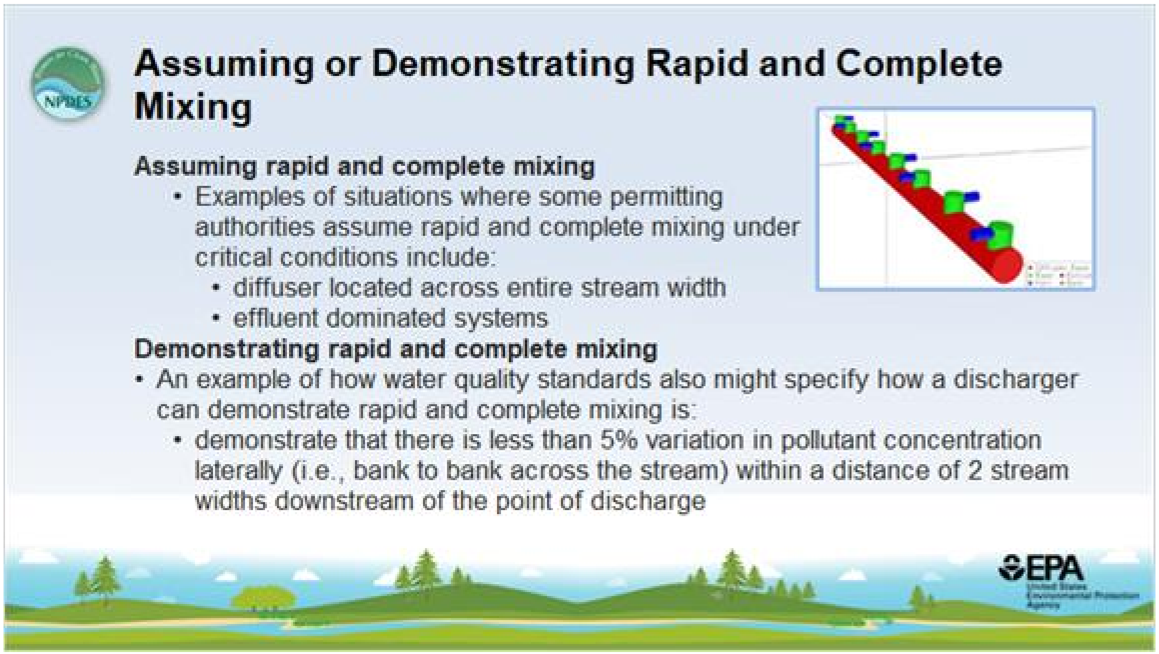
So I guess we first need to answer the question “What is rapid and complete mixing?”

Well basically, rapid and complete mixing is where the effluent and receiving water mix so quickly and thoroughly that you don’t observe any significant plume, or “pockets,” of effluent downstream of the discharge point. A slightly more technical definition is that rapid and complete mixing occurs when the lateral variation in the concentration of a pollutant in the direct vicinity of the outfall is small.

We should note that rapid and complete mixing generally occurs only under certain conditions in rivers and streams. Rapid and complete mixing would not typically occur in the ocean or in a lake. Except possibly for pollutants that exert their effects over months or years, we’ll need to assume incomplete mixing in oceans and lakes.

Let’s take a closer look at this issue to see how we might determine whether rapid and complete mixing is occurring.

1.30 Assuming or Demonstrating Rapid and Complete Mixing



Notes:

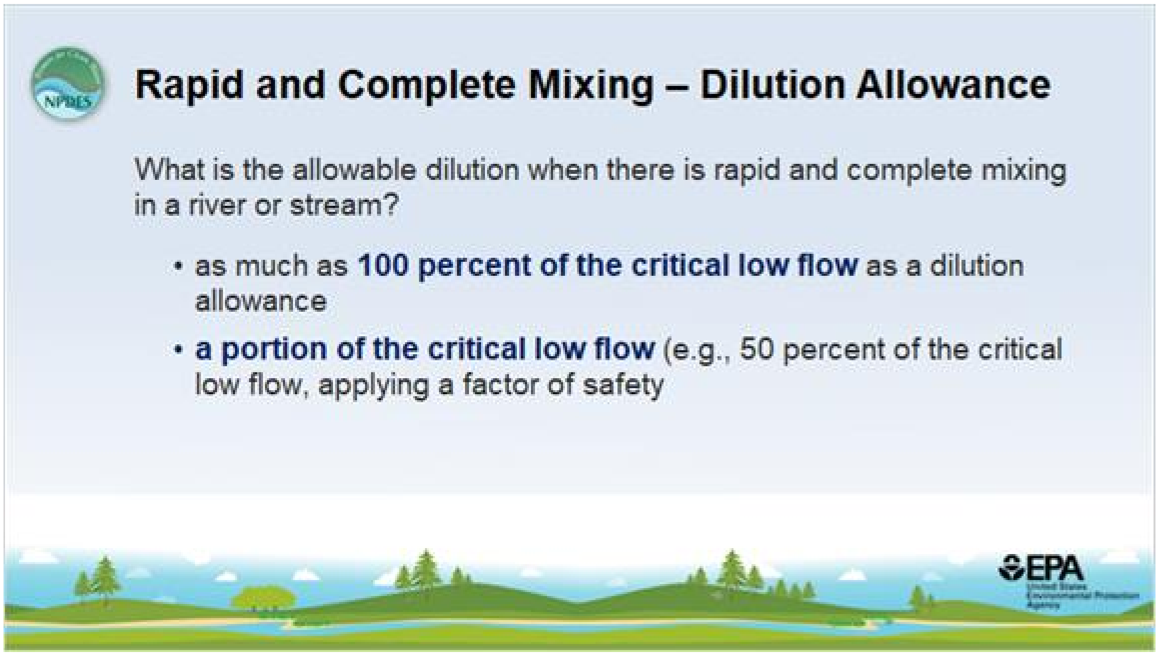
The applicable water quality standards might specify conditions under which we could assume that rapid and complete mixing is occurring,

Such conditions might include, for example, the presence of a diffuser located across the entire stream width or, where the stream is effluent dominated, such as when mean daily effluent flow is greater than the a specified percentage of stream low flow.

Sometimes the conditions for assuming rapid and complete mixing are not met, but the water quality standards might still allow a site-specific demonstration of rapid and complete mixing.

The water quality standards or implementation policy or procedures should specify the conditions that must be met to demonstrate that there is rapid and complete mixing. For example, the standards might indicate that rapid and complete mixing occurs where there is a variation in pollutant concentration of less than five percent within a longitudinal distance of less than two stream widths downstream of the point of discharge.

1.31 Rapid and Complete Mixing – Dilution Allowance



Notes:

The allowable dilution for rivers and streams under conditions of rapid and complete mixing should be indicated in the water quality standards or standards implementation policy or procedures and is usually expressed as some percentage of the critical low flow. For example, the state might provide that where there is rapid and complete mixing, the permit writer may use up to 100 percent of the 7Q10 low flow as dilution in reasonable potential and effluent limit calculations.

Allowing up to 100 percent of this critical low flow might make sense for a relatively small stream where there are no other sources discharging that pollutant to the receiving water.

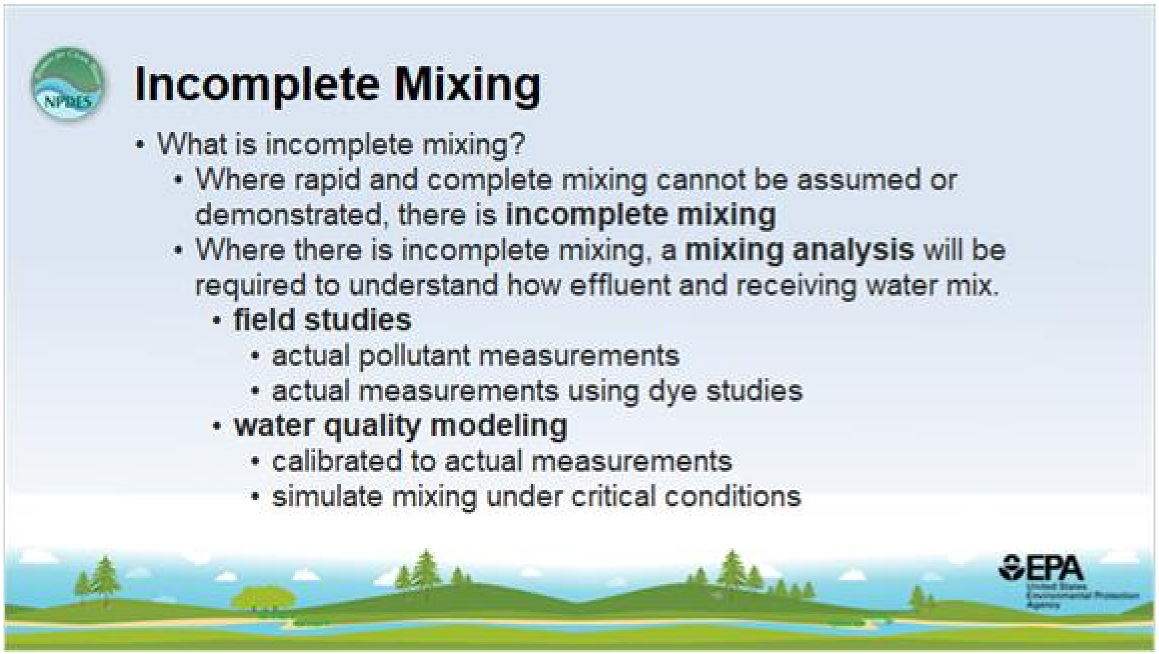
The second bullet indicates that some water quality standards implement a factor of safety, so to speak, by allowing only a portion of the critical low flow to be used as dilution even though there is rapid and complete mixing with the entire receiving stream.

Water quality standards might incorporate such a factor of safety to account for uncertainty related to other conditions in the water body or to ensure that some of the assimilative capacity is retained downstream of the discharger being permitted.

So, we’ve covered how we might account for dilution under a condition of rapid and complete mixing. What about incomplete mixing?

Greg, can you fill us in?

1.32 Incomplete Mixing



Notes:

If we cannot assume or demonstrate that there is rapid and complete mixing, then we have incomplete mixing.

Where there is incomplete mixing, we would need to conduct a mixing analysis to understand how the effluent and receiving water mix with one another.

And, in order to do that, we would first gather the results of, or conduct field studies with, actual measurements of pollutant concentrations under known conditions or dye studies that simulate pollutant mixing and dilution in the receiving water.

The results of these field studies can then be used to calibrate a water quality model, such as CORMIX.

We then would use the model to simulate mixing under critical conditions.

1.33 WWTP Mixing Study: Missouri River–Kansas City, Missouri

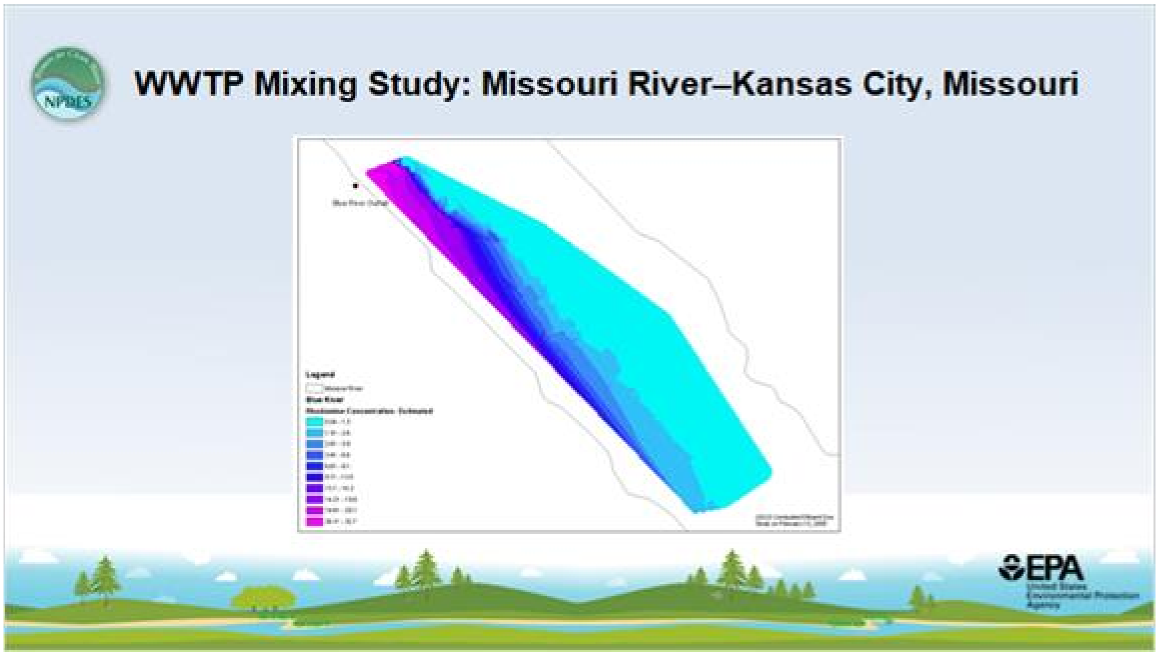
Notes:

Here is a picture of a dye study that was conducted in February 2008 for a municipal wastewater treatment plant discharging to the Missouri River.

You can see the light pink shade of the effluent as it comes out of the pipe. The color is from the dye.

You can tell from the picture that the effluent and receiving water do not seem to be mixing particularly well.

1.34 WWTP Mixing Study: Missouri River–Kansas City, Missouri

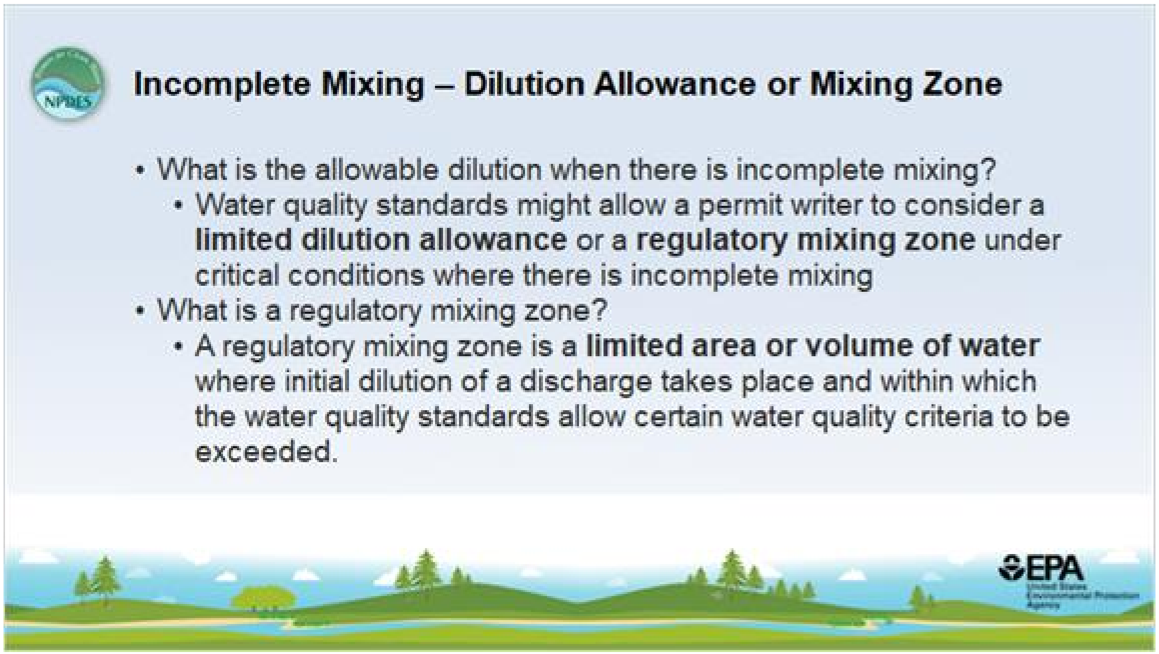


Notes:

When we look at the diagram produced from the study, we can really see that the mixing is nowhere near being considered "rapid and complete."

Concentrations of the dye decrease as the color on the diagram moves from pink to purple to blue, and we see that there is a rather distinct plume downstream of the discharge.

1.35 Incomplete Mixing – Dilution Allowance or Mixing Zone

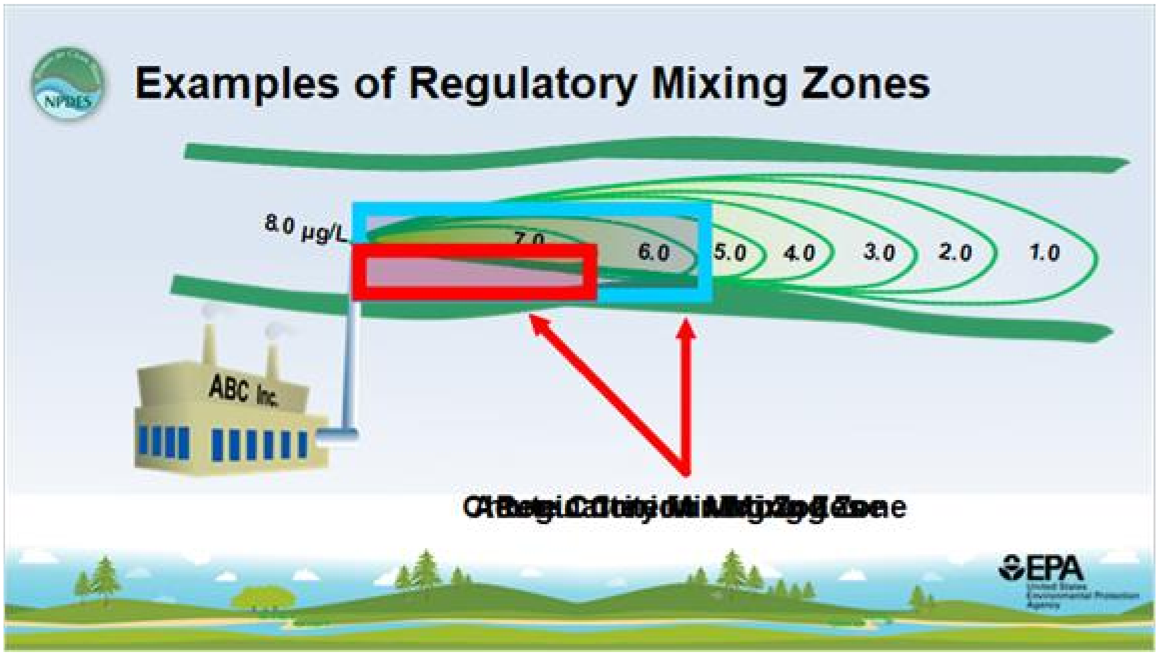


Notes:

If we have an incomplete mixing situation, the water quality standards might still allow us to consider ambient dilution, but rather than allowing as much as 100 percent of the critical low flow, the standards likely will specify a limited dilution allowance, such as a percentage of the critical low flow, or specify the maximum size of what we call a “regulatory mixing zone.”

We can define “regulatory mixing zone” as a limited area or volume of water where initial dilution of a discharge takes place and within which the water quality *standards* allow certain water quality *criteria* to be exceeded.

1.36 Examples of Regulatory Mixing Zones



Notes:

Here is a very simple diagram of incomplete mixing that we can use to describe the concept of a regulatory mixing zone. The rectangles in the diagram depict regulatory mixing zones.

These rectangles do not characterize *how* mixing actually occurs. The plume in the illustration, which we would have determined through field studies and a water quality model, shows how mixing actually occurs.

So what do the shapes and boundaries in this diagram mean?

Remember we have two different types of aquatic life criteria. Therefore, we potentially have two regulatory mixing zones for aquatic life criteria.

The water quality standards would indicate the maximum dimensions of the blue rectangle, which is the chronic criterion mixing zone. The water quality standards would indicate that the chronic aquatic life criterion may be exceeded within the chronic criterion mixing zone. The mixing zone could be smaller than the maximum allowed by the standards depending on the pollutant or site-specific circumstances.

Within the red rectangle, the water quality standards would allow the acute criterion to be exceeded. Again, the standards would indicate the maximum dimensions of this rectangle-the acute criterion mixing zone-but the actual mixing zone for a specific discharge could be smaller than the maximum size permitted.

1.37 What Are the Limitations on Mixing Zone Size?

Notes:

So, are there any rules for how large a mixing zone can be?

There are no federal regulations that establish a maximum mixing zone size. Criteria for establishing mixing zones are found in state water quality standards or NPDES regulations or state water quality standards implementation policies.

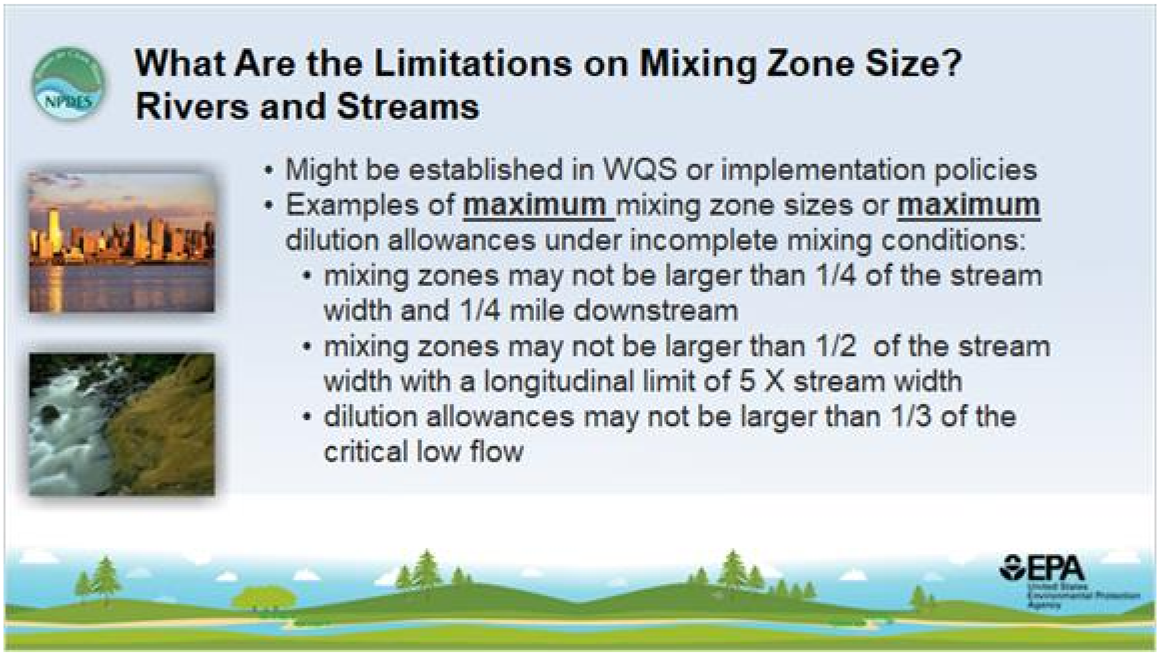
Mixing zone size limitations could include:

- maximum areas or volumes of water;
- limitations on the size of dilution ratios or dilution allowances; and
- narrative constraints that might further limit the size of a mixing zone to something less than the absolute maximum allowed, based on site-specific conditions.

Let's look at these size limitations more closely.

1.38 What Are the Limitations on Mixing Zone Size?

Rivers and Streams



Notes:

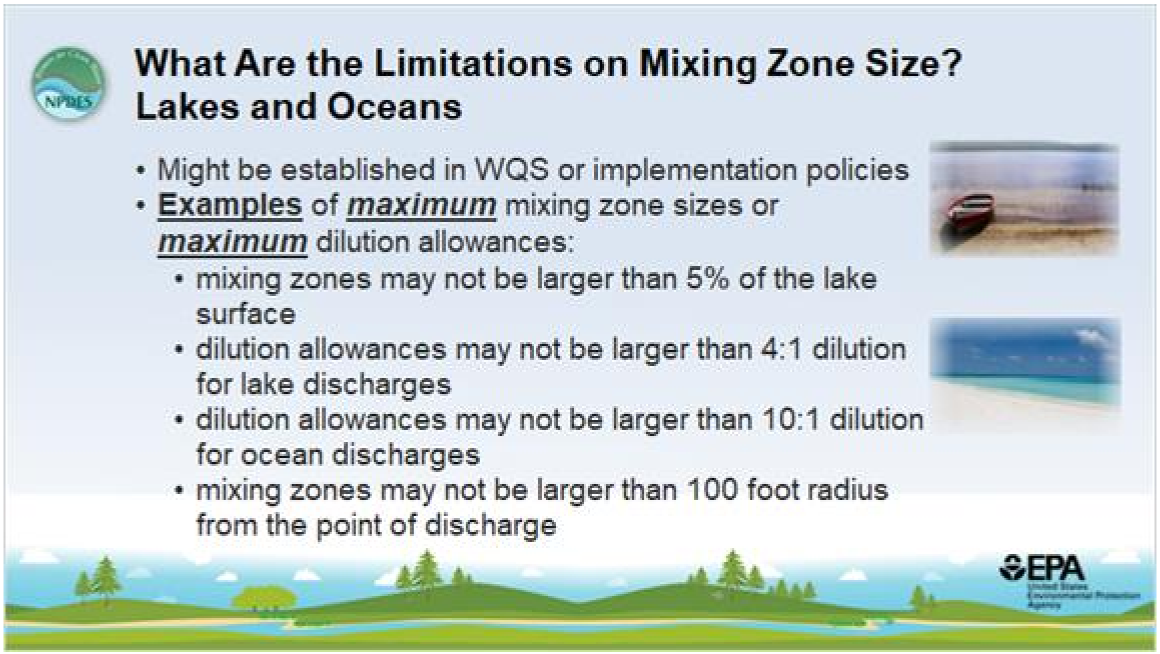
First let's consider some examples of the maximum size of regulatory mixing zones for rivers and streams based on actual water quality standards from various states.

Notice that in two of these examples the maximum mixing zone size is specified as a rectangle with a certain width (across the stream) and length (downstream of the discharge).

The third example is one where a state has chosen to limit dilution under incomplete mix conditions by simply using a fraction of the critical low flow.

1.39 What Are the Limitations on Mixing Zone Size?

Lakes and Oceans



Notes:

Water quality standards or implementation procedures also should give maximum dilution or mixing zone sizes for other types of water bodies.

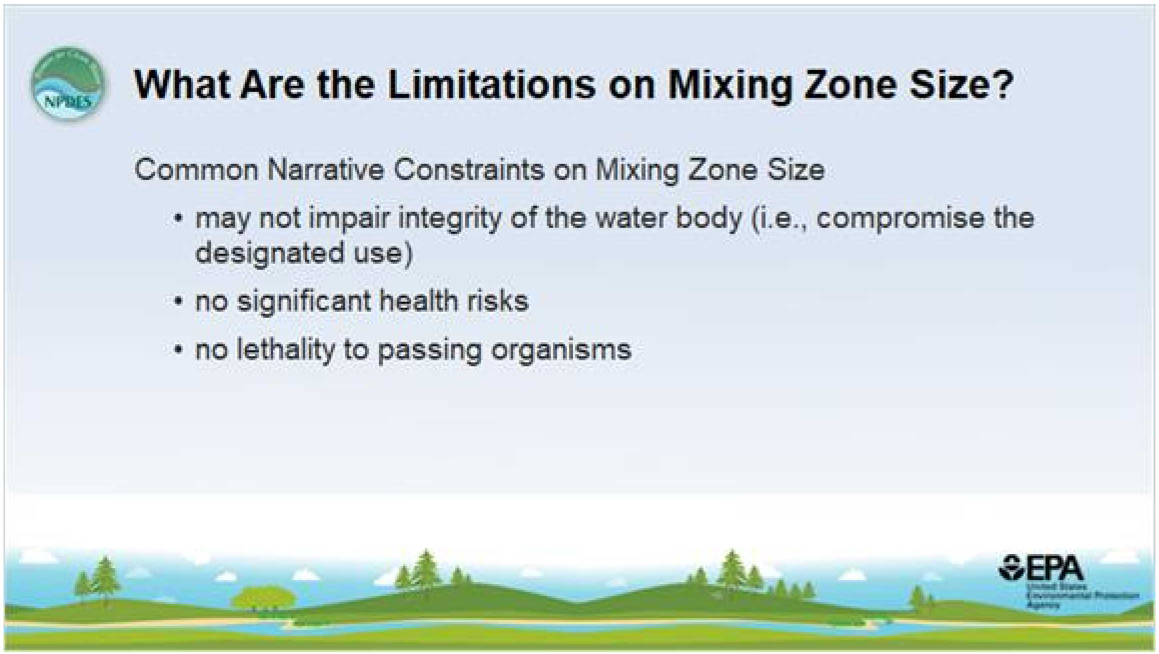
We noted previously that for water bodies other than rivers and streams we almost always have incomplete mixing.

Here are some examples from state water quality standards of the maximum dilution or mixing zone sizes for discharges to lakes or the ocean.

Notice that these mixing zones may be based on a percentage of the total surface area of the water body, distance from the discharge, or a dilution ratio.

Again, it is important to always check the applicable water quality standards to see whether mixing zones are permitted and the maximum size allowed.

1.40 What Are the Limitations on Mixing Zone Size?



Notes:

Finally, it's important to remember that dilution allowances and mixing zone sizes provided in the water quality standards, under both rapid and complete mixing conditions and incomplete mixing conditions, generally state that dilution or the mixing zone size could be "no larger than" or "up to" a certain size.

The water quality standards might also include constraints that further limit the available dilution or mixing zone size to less than the absolute maximum allowed.

On a case-by-case basis, the permitting authority can further restrict dilution or mixing zone size or not allow any consideration of dilution for a particular discharge based on site specific conditions.

Possible restrictions on dilution and mixing zone size include preventing impairment to the integrity of the water body as a whole and preventing significant risks to human health. For example, a permitting authority should consider restricting the size of a mixing zone for a human health criterion to prevent the mixing zone from overlapping a drinking water intake.

One restriction on the size of the acute mixing zone could be that it must be small enough that the potential time of exposure of aquatic organisms to a pollutant concentration above the acute criterion is very short, and organisms passing through this acute mixing zone will not die from exposure to the pollutant. Such a restriction might lead the permitting authority to give a particular discharger an acute mixing zone that is smaller than the maximum size that would be allowed by the water quality standards.

1.41 What's Next?

Notes:

As we come to the end of this presentation, let's see where we are and where we're headed.

In the first two presentations of this series on water quality-based effluent limitations we have:

- identified the applicable water quality standards and
- characterized the effluent and receiving water, which included:
  - identifying pollutants of concern,
  - determining whether the water quality standards allow dilution or mixing,
  - selecting a modeling approach,
  - identifying critical conditions to use in a steady-state model,
  - determining the type of mixing that occurs under critical conditions and
  - determining the allowable dilution or mixing zone.

In Parts III and IV, we'll use the information we've gathered on water quality standards, the effluent, and receiving water to:

- model the interaction between the effluent and receiving water under critical conditions,
- determine whether water quality-based effluent limits are needed and
- calculate water quality-based effluent limitations where they are needed.