Thank you, Holli. Today's webinar will be brought to us, today, by Richard Weber. He is the Wetland Hydraulic Engineer on the National Wetlands Team. Our topic today is *Wetland Restoration Hydrology and Design Overview.* We will have a couple of spots where we'll take a pause for questions at about the midway point and, then again, at the end. So without any delay, let's go ahead and turn it over to Rich for the presentation.

Thanks, Bill, and thanks, Holli. And without further ado, let's go ahead and get started. If I could get presenter, I'm going to spend a little bit of time telling you what I'm going to tell you. And we're going to talk about wetland hydrology in terms of inputs and outputs, and put magnitude, and vector, and some time scale on those inputs and outputs. And we're going to talk about the relationship between individual types of wetlands, and the way to determine differences between wetlands, and how that relates to those inputs and ouputs. And we're going to talk about wetland types in terms of the hydrogeomorphic classification system.

Many of you may have heard of HGM and rightly associated it with wetland functional assessment. But that is hard. HGM is a landscape classification system that works very well with hydrologists and engineers. Because it's largely abiotic. It ties directly to parameters of landscape, soil, and water.

We're going to talk about different sources of hydrologic data so that we, at least in broad terms, know what kind of data we need to describe those inputs and outputs. And, finally, we're going to talk about individual practices, and planning alternatives, and where certain practices are or are not appropriate based on those wetland classes. A key term is wetland hydroperiod. And what hydroperiod is is the term that describes the period of time in an average year that a site has wetland hydrology.

Not all wetland landscapes are wet all the time. In fact, most aren't. And some wetland hydroperiods are very short, like that's indicated in the aerial photo with the Playas in the Texas panhandle. Those are fairly short-term hydrographs. But that wetland-- well, the type is a very high level of function. It depends on that hydroperiod being what it is.

Well, it's like the one down in the lower right-hand corner in Upstate New York. Those are wet virtually all year long. Sometimes the water on them is deeper than others. But in general, that surface, or that wetland site, is saturated nearly continuously.

And in the lower left hand corner, we've got a beautiful slide of a headwater close to the Continental Divide in Colorado. And we can still see a little rendered snow up on the tundra. So that snow melt hydrograph will basically, when it's gone, it will start ending the hydroperiod for that wetland type.

Next key term, hydrologic regime. And we need to think of regime as a range. It's a range in depth. And that depth might be surface ponding, or it might be depth to groundwater, or the range might go from ponding depth down to a lower groundwater level.

In the photo in the left-hand side, we've got three separate regimes in existence, at this particular point in time, in the hydroperiod in this wetland. We've got service ponding. That ponding actual range might be from 12 to 18 inches. And it's probably closer to 12", has a surface saturated regime.

And then, in the foreground, we have a wet metal regime with groundwater at some distance below the surface. The point is that these three separate regimes respond to three separate functional types for wetland plant communities in the associated wildlife habitats. And, finally, regime and hydroperiod go together, in hydrologic terms, to create hydrologic diversity. And hydrologic diversity means variation in those regimes and hydroperiods.

In general rules-- I just threw a few high points down at the bottom-- try to get deep water and shallow water. That's kind of the target for a highly functioning wetland system. So we have more than one regime in existence. At least after the capability of that landscape to maintain different regimes which means certain parts of that site will have a longer hydroperiod than others.

If we're doing a constructed project, or we have the ability to physically move earth to modify the landscape, the flatter the slope, generally, the higher the diversity. And the reason for that is very flat slopes create a large spatial extent change, what's a relatively small depth change. And as hydrologists, or those working with hydrologists, we need to be aware that there are tools available that will allow us to make some really good decisions about matching calculated regime areas spatially with vegetative establishment techniques.

So water budget is composed of parameters. And, right now, these parameters are just described in terms of quantities. But later, I'm going to start putting deckers on those. But this is all the water budget parameters in general terms, except for tidal areas which have tidal inflow and outflow.

So all wetlands, obviously, receive direct precipitation. Evaporation, especially in our wetland context, is loss of water off of a ponded water surface or a wet bare soil surface. And transpiration is the loss of water through plant stems and leaves. We, typically, consider those together as ET.

But it's important to recognize that evaporation off of open water or bare soil is not the same as plant transpiration. And especially in wetlands, that distinction can be important. Groundwater out of the wetland, that's G subscript o. Groundwater inflow into the wetland is G subscript i. And likewise, for surface runoff inflows and outflows.

When we put algebraic signs on these vectors, we can compute a change in storage in the wetland. And this is basic water budgeting. Not all wetlands can be water budgeted. But many can. And it's also important to remember that that storage is storage of ponded water on a wetland substrate as well as storage within that wetland's soil profile.

And in many wetlands, that soil moisture storage in the profile is as important, or as large, as that surface water. OK. The hydrogeomorphic wetland classification system puts all wetlands generally, basically, all wetlands on earth into one of seven separate, broad HGM classes on the basis of these three parameters.

Number one, landscape position, and all that means is that certain wetland types, with certain functions and surface water budget parameters, only exists in certain landscapes and do not exist in others. All wetlands have a dominant water source, not the only water source. And again, obviously, all wetlands receive direct precipitation. But in some wetlands, the dominant water source is groundwater which makes a wetland with drastically different functions than a wetland that has a surface water runoff dominant water source.

And hydrodynamics is a term that describes a water budget vector in terms of direction. And those directions are described as horizontal or vertical. And water does move in to verticals into-- excuse me-- into wetlands with the vertical vector with groundwater discharge.

So water does actually flow uphill in the ground. And those vectors may be uni-directional, one-way, or bi-directional as water moves back and forth from the wetland to a source. The seven broad HGM classes are riverine, slope, the flats which include mineral and organic soil flats, fringe wetlands along the lakeshores or the ocean coasts-- on lacrustrine and estuarine-- and, finally, depressional.

And, again, these are broad classes which really don't do us a lot of good by themselves. That, for instance, to describe a depressional wetland in South Carolina doesn't say anything about the fact that it's a Carolina Bay and not a High Plains Playa depression or a Prairie Pothole depression. So it's very important, and HGM requires us, to put some local distinctions on those wetland types. It'll make some good categorizations within what we call a reference domain.

But the broad HGM classes are these seven. So let's start with riverine wetlands very quickly. Obviously, they occur, like we might expect, on floodplains. And by floodplains, we mean active floodplains. Floodplains, where the hydrology responds to the stream hydrograph.

The dominant water source is the stream hydrograph. And so the wetland function and the nature of that stream hydrograph are intimately connected. And the hydrograph, depending on what kind of river system we're in, has a big effect on either surface water, as flooding, or in a lot of cases, the groundwater. And that's the instance in the slide shown here of a small, what we call macrotopographic feature which is an old, abandoned remnant channel next to a fairly large river in eastern Wyoming. And we see water in this macro feature. We don't see any evidence of water flowing in or out of this macro feature. And that's because this is groundwater.

And the level of groundwater, at this point in time, is directly connected to the level of the water surface profile in the river. Yeah, water in this feature will go up and down with the stream water surface profile. And the water moves in and out of this feature between the stream and the feature, horizontally and bi-directionally, into an outload.

The key consideration for wetlands and riverine systems is a term called lateral connectivity. And when we restore wetlands and this landscape if we do a good job, of restoring the lateral connectivity of those surface and groundwater flows, then we've largely made our hydrology objectives. So this is what a stream hydrograph looks like.

Hydroperiods are cyclic and repeatable. And we've got a good example of snow melt hydrograph from the Tongue River in, again, Wyoming. And so, in this instance, if we know that our wetland groundwater table approaches the surface that flow rate of about 100 cfs, just in this particular instance, the width of the hydrograph, that starting and ending at 100 cfs, defines our wetland hydroperiod.

Again, because of the snow melt hydrograph, we had two successive years that show peak discharges around May going into June. Also, a good time to point out that if they're fortunate enough to have good soil mapping in this wetland type or any wetland type, it's always a good idea to go to a soil survey. Take a few minutes, and print out the Soil Survey Water Features table. And it'll give you three separate columns. And those columns will correspond to flood, frequency, and duration, and sometimes by mud.

It will also give you a column on ponding. Ponding is separate from flooding. And we're going to talk about that a little bit later. And also groundwater regimes.

So, at least, we'll have the first course interpretation of hydrology that's already incorporated into soil mapping. And, of course, our primary source of data, for riverine wetlands and hydrograph description, is the stream gauge data typically available through the US Geological Survey or other sources. So this is what flooding looks like.

This is a dynamic flooding. This is surface flooding. The floodwater, on this floodplain is there because we're at the high stage of the hydrograph. And when the hydrograph goes down, water is going to go back into the channel. And that flood inundation period will end.

If we have any small surface depressions out of the floodplain, like we see over on the left-hand side of the screen and then toward the top, those areas are capable of ponding. And that is a different regime, different dynamic. And in some cases, where those areas are large enough, we'll have soil mapping that actually have different interpretation.

And so it's got a pretty direct relationship between-- well, water would be our planning objectives and the original features of the total map. And finally, this is an episaturated condition. This water is water on the top. And in a case were floodplain soils are not very capable of moving water through the soil profile, laterally, from the stream and the wetland, we really don't have a groundwater component to that stream hydrograph.

It's all about the surface flooding. And that is episaturation in our water riverine hydrology context. So a shot up close, this is what ponding looks like after the hydrograph recedes. And we still have a fairly large area of ponding.

Again, park on the surface. The water's trying to move, vertically, downward in this situation. And this is episaturation. This is surface water.

Taking a look at a restoration project, we see a, over on the right-hand side of the slide, a straightened channel with the levee on both sides. And in the lower right-hand corner, if you can see my arrow, we have the planners who decided to lower that levee to restore lateral connectivity for that dynamic floodwater to get into and out of the floodplain. And this is one of the primary functions of riverine wetlands is that dynamic flood [INAUDIBLE].

So that restores the lateral connectivity of the flood hydrograph. In the Interior of the wetland, the planners had elected to do some excavations of the ponded surface water features. Again, what we call macrotopography. And the flood hydrograph has receded long ago.

But we still have large areas of residual ponding left over. Let's contrast this with another floodplain that's very different. In the foreground, we have standing vegetation. And we see some surface water evident.

And if we look in the far distance, we can just see the water surface profile of the Tongue River, again, in Wyoming. And the elevation of that water surface profile is not much different from the elevation of this groundwater surface. That's because this is an endosaturated floodplains. These soils are sandy and gravely, capable of transmitting groundwater between the stream and those associated groundwater features, and the macrotopographic features, readily in a direct connection.

And note that we don't really see any evidence of surface flow coming in or out of this feature in the foreground. And in fact, this floodplain does not require surface flooding at all to make it a wet floodplain. So this is a groundwater for-- again, endosaturated.

Take a look at a large endosaturated floodplain. And this is the Central Platte Valley in Nebraska. And that valley, in most places, still has evidence of remnant channel braids from back in the old days when the river really did get a large amount of snowmelt flooding from Wyoming and Colorado. If we go into a feature such as that, and isolate it, and remove material out of it to the point where we expose groundwater, we can express groundwater quite readily, again, in these endosaturated floodplain systems.

There's a very important consideration in systems like this, especially when they get large-scale. The valley slope, in this part of the river is about 10 feet per mile. And so let's say, for instance, we excavate out a long channel braid a mile long, we have an upper end of that excavation that's 10 feet higher than the lower end. And it will tend to lower the groundwater at the upper end, and convert that groundwater flow to surface flow, and run it at the bottom and, essentially, drain a large area of that valley, and again, for the purpose of actually restoring wetland hydrology. And in no instance should we ever take those channel excavations and connect them-- or those braid excavations-- and connect them back with the active channel because that surface runoff will be drained down to the valley and run directly back into the--

So a technique that should be employed is to, if we're contemplating doing this type of excavation to expose groundwater, keep the length of those individual excavations short, and separate them so that we have the remnant material in between, and maintaining those individual, short, discrete pondered elevations, and we will maintain that groundwater elevation in effective sections of the valley.

And I get a little bit detailed here. Riverine hydrology can make use of a specific tool which we can reference in *Engineering Field Handbook,* chapter 19. And it's called, in short terms, the stream inundation tool.

What that tool allows you to do is calculate a probability duration-frequency flow. Yeah, and what we're looking for is-- well, for instance, the definition of a farmed wetland, we know, is 15 days of inundation on the average year, which we interpret to be a 50% chance 15-day continuous inundation during a growing season. This tool will give us inundation duration directly. So it's a direct solution for an episaturated floodplain.

And if we're in the southeastern US or areas in the upper Midwest and northern plains, it gets a lot of long-term snow melt hydrograph. A lot of our floodplains do have inundations of that duration. So those of this outside of those areas, we more than likely do not have wetland areas in our floodplains that will have water on the surface due to direct duration of inundation only.

However, if we can establish a good relationship between stream stage and floodplain groundwater level, we can still use that probability frequency-duration analysis to calculate the duration of high groundwater. And there are methods to do that on a site-specific basis. And finally, to make everybody aware, the HEC Ecosystems Function Model, or HEC-EFM, software has recently been CCE approved. And they will take a long-term period of noon daily flow data as input. And it will accept any combination of probability-duration, or any period of the year you want to select as growing season.

And furthermore, it will not only calculate exceedance flows. But it'll also calculate average and minimum flows as well. It's a very good easy tool to use. And the net result is a flow rate that corresponds to the flow rate that meets the input criteria. Moving up the watershed, out of riverine, we're going to go to slope wetlands. The dominant water source of slope wetlands is groundwater. And this is where water actually moves into the wetland with a vertical upward vector. It is actually hydraulic head in a flow net, starting in the adjacent uplands, that collect precipitation and into these wetlands.

And they're typically found in low water reaches in a watershed network. And in some parts of the country, they're quite ubiquitous. And other parts of the country, they're limited to small seeps, and springs, and headwaters.

Where we have enough groundwater or discharge for a long enough period of time to start to form organic soil layers, these sites are typically called fens. And so fens, the takeaway point here is when you hear the term fen, and used in the correct way, it should be associated with a groundwater discharge wetland. And again, when that groundwater discharge is long enough to maintain organic soils which, by the way, organic soils do not exist without continuous surface, we might be in a fen landscape. But we got a few shots here, upper right-hand corner, the Henry's Fork in southwest Wyoming. Lower right, we've got a small seep in Utah. Actually, this is a spring development site.

And in the lower right, we have a wet meadow in the Nebraska Sandhills that is groundwater discharge wetland. And it's been severely degraded by a gully moving up into the wetland. And this restoration with the sheet pile was meant to raise the groundwater surface back up and restore that groundwater level.

In the map of a watershed network, I apologize for the lack of brightness of the colors. But if we look closely, in that dendritic watershed pattern, we can see in the upper reaches-- in yellow, and orange, and even light blue-- These are low order stream reaches that don't have enough flow accumulation and flow energy to form a channel floodplain system.

And these are the reaches where we had looked for those headwater slope what-- The shape of the landform is concave across the valley, and also concave longitudinally. And with the full site, it's probably concave, concave landscape position in energy and morphic description. And it's just concavity that actually forces water, topographically, to the surface.

Schematically, that's what these landscapes look like with the water budget vectors added in. The GI is groundwater discharge going into that wetland site and this headwater reach. We got a RI vector because, obviously, we're going to get surface run off of the topography. And if the groundwater discharge is strong enough, we'll get a surface runoff discharge in the spring.

The slope wetland boundary does not end when the spring flow emerges. The slope wetland boundary ends when we transition into riverine breach where we have a landscape that's dominated by a true stream hydrograph. So, here, the dominant water source is groundwater even though we get surface water runoff. In a riverine system, the dominant water source is a stream hydrograph even though we might be a little bit of a--

Slope wetlands are unique wetlands, largely unrecognized. And in my opinion, quite underappreciated. And because they have some unique functions that cannot be performed by most of the wetlands, they serve to receive groundwater discharge and hold it for long-term release downstream that has a highly functioning capacity to maintain base flow in our larger stream reaches.

And so, earlier, putting a wetland restoration in a watershed context should focus on making sure that we do what we can to get these slope reaches and these headwaters back to a level of function. Because they can form organic soils, they have a strong potential function to sequester organic carbon. And when the hydrology is lost in these systems, that organic carbon, that was previously formed, will be exposed to oxidation. And all of that soil organic carbon in that soil will be loss to the atmosphere as carbon dioxide-- typically critical. That's when water sources, that don't exist elsewhere, one thing they don't do very well is provide areas of open water for water fowl habitat. But they have a strong function of maintaining the off-site benefits and stream network for fisheries and other aquatic organisms.

This is what a slope wetland looks like in-- this one's in Box Elder County, Utah. And we have an upstream shot of a slope wetland. We've got, actually, a watercourse here. This is spring flow flowing out of this wetland site.

And we don't really have any landscape distinction between a channel and a floodplain. It's just all one single landscape position dominated by groundwater discharge. And downstream we have a gully advance moving up into that wetland. As the gully deepens, the channel ensizes. The groundwater table goes with it.

And that surface saturation, when it's-- here the gully is now, 6 feet or more below the surface. And we can see some remnant willows there. But, there, you don't have much chance of regenerating because the site, at this reach, has been completely converted to upland. When we're looking at a reach like this, we need to be careful when we apply extreme channel morphology principles. Because these sites don't have a watercourse that corresponds with terms like geomorphic bankfull discharge in quite the same way as we do when we actually-- extreme reach with an active channel that gets free from an active floodplain. The surface runoff hydrographs are short-term. But the groundwater discharge is long-term.

In an extreme case, beginning directly to look at the slide in the upper right-hand corner, this is a very large-scale slope wetland, surface saturated. We're at the peak of the hydroperiod in early spring. We've even got the [INAUDIBLE] dominating the site really good highly intact slope wetland taking large amounts of groundwater and releasing it downstream to larger variations in the stream network.

If we misinterpret this landscape is one that should feature an active channel. We may make a decision to do something like we see in the lower left-hand corner where we've constructed a stream channel. Put some sinuosity in it. Use all the techniques that we learn in channel morphology.

But, unfortunately, the net effect is going to be to lower the groundwater table from this channel, which is an effected drainage ditch, And aerate the organic soil layer from the top of the bank down to the flow line of the channel which, over the next several decades, will become aerated, oxidized, and completely caused subsidence in the land surface. And plus the loss is thousands of tons of organic material to the atmosphere.

Slope wetland in the upper reaches of a watershed near the Continental Divide in Colorado, this is a especially interesting case. Because we've got a system that's maintained as a slope wetland by the actions of the North American beaver. And the beaver maintaining the high groundwater table with, certainly, the beaver ponds.

We see spring flow flowing out of this system. The wetland boundary is clearly delineated here by the margin of the Engelmann spruce and the shrub willow. At some point and time, with enough sediment, the beavers will tire of building up those bends, and maintaining ponds, and move out of the system, over the ridge, and into another reach. And at that point in time, likely, we'll see a catastrophic failure of those dams and reversion of their site to something that might look a little bit more like a riverine reach with--

-and this period of time, we'll have the Engelmann spruce, probably, move down close to the channel until the next colony of beavers moves in. And it there starts the system all over again. So in a case like this, we've actually got a temporal context to our landscape function.

Discreet practice, it's very appropriate for wet metal-type slope wetlands, or even small riverine systems, where we think that the active channel is does not maintain a water surface profile high enough to maintain that endosaturation in the adjacent meadows to put in one or more rock check structures solely for the purpose of raising the water surface profile. And if we're doing this in the context of trying to improve the function of the active stream channel and the stream restoration technique, we ought to-- that the associated wetland functions are coming along with that restoration. It's an extreme case of a water surface profile modification practice, in the Nebraska Sandhills, or a large, deep channel has moved up through a wet meadow. And in this case, the seep pile were structured, constructed in a crossvein orientation.

That's right, the water surface about 3 feet, and resulted in a pretty direct response of groundwater. It cost a very large wet meadow. It's very important to approach this type of project with extreme care.

In this case, this was the first of the three of it's structures in theory. And this project will be stable as long as the downstream structuring series provides backwater to that structure during out of bank flows. And there are some very rational ways of doing that with channel hydrology analysis-- always remember when we're raising the water service profile significantly, we almost always need to consider putting structures in series so that they protect each other. And that last structure needs to be appointed confluence to a slighter reach downstream. Or it might even need to be three grade-stabilization structure.

Mineral class, another issue in class. And this is, actually, probably about the simplest one hydrologically. These are on broad, flat landscapes and uplands, and where we've moved out of the watershed network into landscapes described as interfluves. These are the top of ridges.

And in places like Minnesota and northern Indiana, these ridges may be very flat and very wide. The mineral flat wetland hydrology only exists in areas of the country where we have an excess of precipitation. During the wetland hydroperiod, that's enough to actually maintain surface-- across the landscape. Usually mineral flats consist of small, discreet areas of shallow ephemeral depressions separated by other areas that are actually known wetland. But the point is, the landscape is too flat for surface runoff to be directed into them. And it's too flat for ponded water to flow out. And it's, essentially, purge--

Another key point to make if we're familiar with the use of drainage equations, lateral effect equations, or modeling tools like DRAINMOD. The hydrology factors associated with this wetland type, on this landscape, fit perfectly with the assumption of those lateral effect tools. And here's why.

Hydrodynamically, we only have vertical vectors. Direct precipitation falling on the surface of the landscape, water in the soil profile attempting to move downward into soil profile, into a deeper water table. And there are no horizontal vectors. No horizontal runoff going in. No horizontal groundwater inflow going in.

And this matches up directly with the assumptions of classic drainage equations. If we have a landscape like this where we're doing a restoration plan, if we think we need to have a function that incorporates surface ponding or deep depressional areas in a landscape like this with no surface runoff water source, the net result will be able to leave behind unsightly post spoil piles. And our excavated depressions, with a few inches of rainfall in the bottom.

This is not a depressional wetland landscape. And organic soil flats are very similar to mineral flats except where in areas where the net balance between precipitation, and inputs, and circulation, and ET output is very high. And we'll actually build up organic soil on the surface just because of direct precipitation alone. And [INAUDIBLE] extremely common.

But they do exist widely in the New England states. They also exist alongside the Southern Atlantic Coast as pocosins. And they exist in central Florida, especially in large areas south of Lake Okeechobee.

Rainfed means ombrotrophic. So that term is associated with rainfed wetlands. And ombrotrophic organic flat wetlands are commonly referred to as bogs. So we've got a distinction that I'll take the time to point out between fens and bogs. Fens are groundwater fed.

The groundwater, typically, contains nutrients. So fens are, typically, nutrient rich. Bogs are rainfed only. Rain doesn't have any nutrients. And so they're typically, bogs are, typically, nutrient poor which is one reason why bogs, typically, are locations where we find some of our rare and endangered plant species.

Because those are species-- nutrient forces like pitcher plants or Venus flytraps that actually have to eat insects to survive because of the nutrient poorness. And again, these organic flats are different areas where we-- parts of the country where we have a high precipitation to do a ET balance.

Estuarine fringe wetlands, these are wetlands that are simply dominated by the action of ocean tide. That might be the actual tidal fringe itself. Or it might be as far up in a outlet stream that we're getting tidal influence.

But tides are, obviously, very cyclic, twice daily. And one thing to point out with estuarine fringe wetlands is water typically moves in and out of these wetlands in discreet tidal inlet channels. Water rarely moves in and out as sheet flow. We actually have the-- channels that are in equilibrium with the volume of tide which, by the way, is referred to as the tidal prism.

And the flow energy, and whatever sediment that source is coming in. So the equilibrium and it's tidal inlet channels is very similar to a stream channel equilibrium-- -And the tidal inlet channels, also, are very analogous to channels referred to as bayous in the lower Mississippi Valley where water moves back and forth in the channel between the stream and the adjacent landscape. And, Bill, we have any questions we need to take now?

OK. This is a point to remind everybody that if you have questions for Rich, you can enter them into the notes bar at the right. And be sure to address it to All Moderators. Rich, I've got a question for you. You've thrown out an awful lot of terminology so far. Strain channel morphology, HGM classes, episaturation, endosaturation. If somebody wanted to get more information on what you've been talking about today, where would they go for that?

If you go to the Wetland Team website which, I think, now is under the Water tab of the national webpage. And then go to Hydrology. There are a series of tech notes that cover riverine wetlands, as well as restoration planning scenarios, and especially a tech note called Floral Hydrodynamics for Wetlands. And those, especially that tech note, has got all of that terminology in it.

All right. Well, that was all the questions I had at this point. We'll cover the rest of whatever questions come up at the end, Rich. So why don't you go ahead and continue on.

OK. Going to forge ahead. I left off with talking about tidal inlet channels. And there are techniques for modeling the attenuation of tidal flows either through a tidal inlet channel or through a tidal hydraulic structure. And this is a very common scenario along our ocean coastline.

And for those HEC-RAS gurus out there, if access set a type gauge data, a typically hourly data on a 30 day period of record, you can use that hydrograph as the downstream boundary condition for in-study flow model. And run it and see what kind of attenuation you get. The key point is the function of tidal, or one of the functions of the estuarian fringe wetland is the attenuation of the tidal flow, and also the attenuation of storm surge.

There are some techniques that haven't been employed a lot. But there are ways to do that. And if anybody's interested in that, contact myself or, actually, Karl Visser or Jon Fripp at the NDCSMC.

Lacrustrine fringe are similar to tidal fringe except they occur on the shorelines of large lakes. And it's important to remember that lakeshore itself is not a lacrustrine fringe wetland. But a landscape formed by lake action is a lacrustrine fringe-- And that's a pretty-- I'm going to describe the slide over on the right-hand side where we have Yellowstone Lake in the background.

And in the middle ground, we've got a dune. It was actually formed by a lakewave action. And it's dry, Obviously, because it's growing lodgepole pine. And then in the foreground, we've actually got our wetland which is the behind the dune wetland.

And the water that we present in that wetland moves up and down with lake level. And in some extreme cases, large lakes will set up lake faces which are, basically, long-term wind will raise the elevation along one certain shoreline of the lake. And those lakes faces themselves can raise the water level in those lacrustrine wetlands.

So the hydrology analysis of water movement in those wetlands can be done with lake gauge data. And, actually, even perform the same probability duration-frequency analysis with that data as with stream gauge data. And, finally, the default landscape position is depressional. These are out of the watershed network.

They're not in floodplains. They're not in any other wetland landscape. And a closed topographic depressions form depressional wetlands. They exist all over the country in different forms.

You see our Carolina Bay in the lower right. But Playa wetlands, depressional wetlands, it is from the Texas panhandle, actually up into Wyoming and the western Dakotas. And then we have the Prairie Pothole Region wetlands as well. All depressional.

The dominant water source of depressional wetlands is may be surface runoff, or it may be groundwater, or in some cases, it may be both. But the point for a depressional wetland to have meaning in terms of wetland hydrology and the hydrology tools, we have to have a relatively well-defined catchment area. In other words, depressional wetlands have an associated watershed which we can analyze for surface runoff or even groundwater runoff calculations or groundwater discharge calculations.

And, again, I'm going to repeat. Shallow ephemeral depressions in mineral flats have to be treated as mineral flats. And the reason is because we cannot define a surface watershed. And so the, again, the lateral effects and drainage equations techniques that we use to analyze mineral flats are appropriate for those.

They are not very appropriate for analyzing the change in hydrology of a true depression. We can separate the depressional wetland hydrologically as we recharge or discharge. And a recharge depression is one where the dominant water source is surface runoff, and the water in the ponded area is attempting to recharge a deeper underlying groundwater level. So this is a classic recharge wetland.

Surface runoff and then groundwater [INAUDIBLE] moving out the wetland to recharge the groundwater table. A discharge wetland is one where groundwater is discharging into the wetland. And so that's the primary distinction. And in technical terms, if the ground water outflow is greater than the groundwater inflow, it's a recharged wetland.

And the reverse is true for discharge wetland. And in certain cases that the groundwater essentially flows through a wetland, like occurs in quite a few wetlands in the Prairie Pothole Region, it's referred to as a flow through. But mainly remember recharge and discharge. And that extinction is profound enough that the actual evidence in soil survey and soil features can determine whether that site is a recharge or a discharge wetland.

SPAW model, moving into a specific tool, SPAW model works relatively well for recharged depressions. And the reason is because SPAW model allows us to put a lot of detail in defining these surface runoff conditions of the contributing watershed. So the same principles that allows SPAW model worked very well for analysis of the pond or an [INAUDIBLE] storage structure.

Also, let's it work relatively well for recharged depression. Again, groundwater is not much of an effect here, not much of a water source. The groundwater loss, in most of these cases, isn't that high.

One caveat, SPAW model tends to work better in more humid climates. And that's because of the complexity of the calculation of surface runoff within a rainfall data. So those in the Arid West need to, I guess, be aware that more challenging, SPAW model's more challenging tool to use in parts of the country.

We can do a simplified water budget, again, in recharged depressions especially, on a monthly time stamp if we have a good data source for monthly precipitation. Then we can calculate monthly runoff, monthly [INAUDIBLE] aspiration and the percolate. And so, basically, this is a spreadsheet-- not too old-- starting from a hand calculation. And we go through September of one year through August of-- or through September of that same year.

And, basically, the wetland hydroperiod is a checkbook type analysis. And this is classic wetland water budgeting. It's typical to find recharged depressions with agricultural landscapes. And, in most cases, that agricultural landscape has charged that wetland with an excess of sediment from soil erosion.

And a common restoration technique is to remove that sediment to restore the original depth of the pondered depression. Perfectly rational approach. One thing to keep in mind, in situations like this, is that recharged wetlands typically, not always but very typically, have a shallow perching layer.

If you're into soil profile descriptions, look for a Bt horizon. That's a translocated horizon that often makes a perching layer. And if you excavate out that perching layer, you may drain out the entire wetland down to the recharged groundwater table underneath.

Also, consider leaving the original A horizon, which might be buried by sediment intact, solely for the reason that that A horizon has got an elevated organic matter content which can't perform or serve as a energy source or some important biological chemical functions in the wetland. Data source for direct precipitation, especially on a monthly time stamp, for those of you-- I think everybody in the country has the links working now.

And actually, anybody in the public, to go to eFOTG, select your county. Go to Section 2, Climate Data. And then click on the Ag CIS tab. Assuming that county has active NOAA climate stations, you will get a wet table.

And wet is not an acronym for anything. It's just a wet table. And they'll give you your average-- monthly-- rainfall as well as 30% chance wet and dry departures from average-- well as the wetland growing season. So this is the best direct source for monthly precipitation in a monthly water budgeting technique.

Also, want to talk a little bit about groundwater monitoring. Groundwater monitoring wells are direct way to keep track of groundwater levels and wetlands assuming we have enough time to collect that data. Hopefully, at least you're when wetland hydroperiod. And a monitoring well by itself will give us direct evidence of the pre-open groundwater surface.

However, if we have the time and expertise to install a nested piezometer immediately adjacent to that open groundwater well, and put a slotted interval in that piezometer at depth, if we have groundwater inflow under vertical hydraulic gradient, we will see a water level in the piezometer higher than the water level in the groundwater well. And this is direct evidence of groundwater discharge. And, in certain cases, we can come up estimates of the actual rate of water movement using some soil hydrodynamic and saturated hydraulic connectivity calculations.

But the qualitative knowledge of whether or not the water is discharging or not, conversely if the nested piezometer with, again, a slotted interval at depth, if the water level in that piezometer is lower than the water level in the monitoring well, that means groundwater is moving downward. And so this nested well piezometer device can put direction on that groundwater effect or-- Moving into a typical stream restoration technique.

I just want to point out that if we put in something like this rock crosslink structure, and it has the net effect of raising the stream water surface profile. We have, whether we intended or not, increased the lateral connectivity between the stream and it's adjacent floodplain. And if this is an endosaturated floodplain, we've also raise the adjacent floodplain groundwater level.

So the techniques of fluvial geomorphology, in this landscape, are highly appropriate to wetland restoration. And again, the two slides I showed you earlier, in a different context. But usually on a riverine or on a small water course on a slope wetland, techniques, that tend to raise water surface profile, restore that lateral connectivity.

Don't forget to consider installing these structures in series, again. And, also, remember that the effect, depending on the wetland type, whether it's endo- or episaturated, will be more focused on surface flooding or groundwater influences. Ditch plugs are a very common technique used in wetlands around the country. And they're appropriate everywhere where a ditch has been installed to drain that wetland except ditches that are large enough to actually be a active stream channel.

I know we need to think about some-- if the net effect, again, is to reduce the groundwater outflow water budget vector and, also, the surface water out flow water budget vector, and increase that wetland storage parameter. Sharp crested weir, talk about those a little bit. They're appropriate, like in this case, in a degraded slope wetland where we actually had a gully advance through the system and drain, lower that groundwater table.

They're a good alternative to ditch plugs in sandy soils where we have high permeability. They're also very effective in organic flats where it's hard to actually fill material on an organic soil and expect it to stay. But if that organic layer is shallow enough, we can drive a sheet pile into a deeper substrate of, usually, sand in those landscapes and--

This is what a sheet pile weir looks like in cross section. All weirs need a appropriate bed key. They need an appropriate bank key. And they need a control section.

And sheet pile wears, especially, most of the installation is below the surface, sort of analogous to an iceberg. So when the sheet pile engineer that's designing the install properly, most of what's out there is below the surface. Don't forget that hydraulic structures are buoyant. And, especially, in a wetland landscape where our objective is to increase that saturated surface, or saturated condition after the surface, buoyant forces are especially strong.

The large picture on the right with that broken tube, that tube was submerged and flowing partially full at the time it failed. And because it was flowing partially full under inlet control, there was enough buoyancy to float it to the surface. The lower right is a typical Agri Drain stoplog structure. And those structures are subject to buoyant forces that is largely unrecognized.

And the reason they don't fail any more than they do is because they, typically, are held in place by a drawdown tube and a principle stairway. That buoyant force is putting stress on those connections that we typically don't anticipate. Conversely, here we have a stoplog structure out of precast concrete.

Obviously, very little problem with buoyancy. But they're heavy. And wetland soils are typically pre-consolidated saturated. And so we also have settlement and consolidation of those foundations. And with that, Bill, I can take whatever questions we've got.

Thanks, Rich. We've got a few. And I'll give you a couple here. We got a question. Could you go over the difference again between a depressional wetland and a mineral flat. They seem to be quite similar.

OK. Yeah. Honestly, it's nuanced. And I don't know where the questioner came from. But if they're from Minnesota, I can kind of sympathize with you.

Because we have a certain limited toolbox to analyze hydrology. And we can't apply the same tools across the board to both of them. But in general, if we have a depression that's-- and I'm just going to say that has a depth up to 12 inches-- and we've got a defined watershed where we know that water's flowing into that depressional wetland, we need to think about water budgeting, SPAW model analysis type tools to analyze that.

If that depression is really shallow, and really broad, and not very deep, and on a really flat landscape-- so flat that we can't define a contributing watershed, the drainage equation tool-- the model groundwater drawdown-- are, basically, pretty appropriate for that. Because we're really not drawing down deep depressional storage. And frankly, we don't have another method.

And I hope that was a little clearer than mud. I know it's kind of problematic. And, actually, that's the subject of some discussions going on in the Prairie Potholes right now.

All right. I've got another one for you here. Can you please explain how to calculate groundwater recharge? And to some of these, you spent some time talking about groundwater [INAUDIBLE] data wetlands. How would we account for that recharge into those wetland types?

Yep.

And is there a equation or reference that you'd go to for that?

I struggle with that myself. And I'm going to answer that question in two separate components. If we know the direction of water movement of groundwater, in other words, if we actually know the groundwater is physically discharging under hydraulic head, we've got a qualitative assessment of the hydrology of the wetland.

Don't have any quantitative assessment. Coming up with the actual volume of inflow is extremely difficult and requires, probably, more investigation than we can afford to do. And I'm sorry that's the answer. But that is.

However, if we really wanted to quantify groundwater inflow, and we had the head differential between the open standpipe piezometer and the groundwater well, and we knew the elevation difference between the slotted intervals, we had a good idea of the saturated hydraulic connectivity we could solve Darcy's equation for that. And If we had enough wells to characterize that across the wetland perimeter, we actually could quantify it. But the level of intensity is usually not worth it.

And frankly, the qualitative knowledge of whether that water's actually discharging in your head is enough. And by the way, any wetland that's got strong groundwater discharge is almost always a almost nearly continuous groundwater discharge anyway. So we've almost always got excess water that flows out of the site is spring flow.

But that quantity of groundwater can change over time through the seasons too. That's one thing I would have mentioned is that over time, it's one thing to go in and measure groundwater inflow. But that groundwater inflow can change over time. So it's a pretty intense study that you've have to do involving nested piezometers. And it's not something, like you said, Rich, that we typically do.

No.

At this point, Holly wanted to interject something for us here real quick. Holly?

Yeah. Thank you, Bill. And, Rich, you've not necessarily seen the participation. But we've had really big numbers today. Close to 500 people have been in the webinar.

And I know many of you are going to want to go back to conservationwebinars.net to complete step two to get your CEUs. And I just wanted to mention that as long as you have that webpage open that offers you-- you don't have to click it right away. You could give it a few minutes.

Or you can try to jump in early one way or the other. But if you leave that webpage open, that link is still going to function for you in the next several minutes. So if everybody's trying to hit the site at the same time, we can slow that down just a bit.

The other thing I was going to mention that Rich made mention of the webpage for the Wetland Team. And I have put a link up to get people to that site at conservationwebinars.net for the webpage that has the information for this particular webinar. And somebody, also, asked a question about whether or not there was going to be a replay available.

And, yes, the replay will be put back at the conservationwebinars.net in about a week, the same page. So instead of joining for the live event, you actually view the replay. And those are my comments. And I'll turn it back over to you, Bill.

-Thanks, Holly. We got a couple more questions. I'll go through here, Rich. Somebody was asking a question about-- if you could address this, Rich-- some farmers are adjusting their calcium levels, in their soils, to increase infiltration. And could this process be impacting wetlands due to that modification of permeability in sealing clays that are dominated by sodium?

I have heard--

Yeah, I--

That's fascinating.

When surface--

I guess if it's got the property to deflocculate the clay, yeah, it definitely could. Especially if you're in a episaturated ponded wetland type where that water's trying to move out through a substrate, and anything you can do to increase that case sat will, yeah, reduce the hydroperiod.

Here's another one. Somebody asked if you could add a little bit more with this question. Estuarine fringe and the Great Lakes Coastal areas, you got siege effects, storm surge, wind surge, riverine, flows that all contribute to estuarine hydrology. Aside from the obvious solidity differences between the Great Lakes and tidal-- your coastal tidal-- any other considerations for freshwater estuarine systems?

There are probably a limitless number considerations. What we can analyze with the toolbox we have is going to be based on the combination of lake gauge data, tide gauge data, stream gauge data, and whatever hydraulic structures or pathways we can model. And that's about the best we can do. That coupled with evidence, we can gain either from an on-site soils investigation or soils mapping. Hopefully, it'll be enough to get us going down the right direction.

How about any freeze-thaw type of situations that we need to be aware of or thinking about, Rich?

Freeze-thaw, I think of that more in terms of wetland structures and structure function. I have the facts on stoplog structures or freeze-thaw effects on compaction of material in a saturated substrate. But in general, when we model wetlands like in the Northern Plains, we tend to be able to get away with modeling based in terms of rainfall and data for runoff and without having a whole lot of trouble with freeze-thaw cycles. That being said, if you get into really intense hydraulic modeling procedures for the appropriate landscape, like DRAINMOD, there are some parameters in here where you can allow for frozen ground and its affect on water infiltration into a soil profile. And I know that wasn't a very clear--

Could you talk a minute, Rich, about the NEDS course on wetlands hydrology and wetland restoration?

Sure. Yes. Good plug, Bill. Bill is on the Wetland Hydrology Tools [INAUDIBLE] along with myself and some other highly qualified hydrologists.

And that course specifically addresses the use of hydrology tools. It's a hydrology-based course. And it's been taken successfully by non-hydrologists very well.

But all the techniques that are currently available, for modeling well and hydrology are covered in that. The wetland restoration and enhancement course is a week-long course that, actually, I'm the [INAUDIBLE] leader on that one. And we cover wetland science from soils to well and plant communities, to wetland hydrology, to wetland habitat restoration techniques, and that sort of thing.

So it's a broad-based course on wetland science appropriate for all disciplines. And the hydrology tools course is a detailed course appropriate for those interested in actually doing well and hydrology modeling.

So those are two NRCS employee courses. I got one more question for you here, Rich. What do you think? Could depressional wetlands in the Prairie Pothole Region be a source of recharge for the "Olagalla"? And I probably messed it pretty good.

Ogallala.

That aquifer.

Yeah, the Ogallala aquifer, the true Ogallala aquifer, plays out at pretty much the southern South Dakota border. And the wetlands in the Nebraska Sandhills-- that's part of the aquifer-- and those wetlands are basically fens. They're groundwater discharge well is-- as you get out of that landscape into the Dakotas, if we have depressional wetlands up there, most of those, I think, are recharged depressions. And I don't think they have a significant connection with the Ogallala.

And in Prairie Potholes, a lot of those are pretty low hydraulic connectivity. There wouldn't be much getting through those. I guess if they were wet for long periods you could.

Yeah. It's interesting. Those Prairie Potholes, they are evenly divided between recharge and discharge.

And as a matter of fact, the [INAUDIBLE] in South Dakota have got a pretty good handle on what soil mappings correspond to whether they're recharged wetlands that actually perch water and discharged wetlands where groundwater flows into them. And, generally, the recharge wetlands-- well, actually, I'll throw it out there-- the Tonka and Tahtonka soil series, those are classic recharge map units. And the [INAUDIBLE] series that there are discharge. And they never discharge because they have a calcic horizon and some other indications of a mineral rich groundwater discharge that is left behind by that. And the recharge wetlands tend to be smaller and shallower.

We had a question. Somebody was asking about access to the NRCS employee courses by some of our partner agencies out there. And I'll just go ahead and answer that one.

That access to the NRCS courses is on a space available kind of relationship. We've had some folks, outside NRCS folks, who have attended those in the past. And in fact, the Wetland Hydrology Tools course, originally, was a course that was Corps of Engineers, NRCS, and Fish and Wildlife Service all attended that course pretty regularly.

Yeah, well, the--

Well, Rich, that's the last question that I'm seeing here. I want to say thank you for presenting the topic today. And your contact information is there on the last page for those who may have some questions that you'd like to talk to Rich personally about. I'd encourage you to do that.

Yep, feel free.

Any final words, Rich?

No. Appreciated the opportunity. And, yeah, anybody who has any follow-up questions, feel free to drop me a note on my email address. And I'm looking forward to it.

All right. Thank you very much. That brings today's webinar to a close.