>> Dr. Chrissy Henderson: I'm going to go ahead and get us started. Folks will begin trickling in as we go. I would like to welcome you to our Corrosion Webinar Series. I'm Dr. Chrissy Henderson and I will be hosting today's webinar. This event is put on by the Materials and Corrosion Laboratory here at Reclamation's Technical Service Center in Denver. We host up to about four corrosion-related webinars per year to share with you topics in our four disciplines: cathodic protection, coatings, geosynthetics, and hazardous materials. This year, our first three webinars will be a three-part series focusing on the rehabilitation of El Vado Dam. Today's webinar, specifically, will be a summary of the planned modification to El Vado Dam to address seepage and internal erosion risk, focusing on the selection of a geomembrane liner and associated components through research and materials testing in the lab and in the field. Before we get started, let's go over a couple of housekeeping items. We are hosting today's webinar through Microsoft Teams live events and will be recording the presentation. If you don't want to be part of the live recording, you are free to leave at this time. The recording will also be available after the webinar is over through the same webinar link that you received in your email. During the presentation, please ask questions as they come up. There is a live Q&A chat feature. All you have to do is click on the Q&A icon. It looks like a chat bubble with a question mark on the inside. Then you can use this to access that feature. We will monitor all of the questions and hold the Q&A session at the end of this presentation. With that, I would like to go ahead and welcome our guest speaker. Chris Ellis has worked in the geotechnical materials testing and engineering industry for over 20 years. Chris received his Bachelor's and Master's from the University of Colorado, with a focus on geotechnical engineering. He has worked at Reclamation's Technical Service Center for 12 years now, and is currently the supervisor for the Geotechnical Engineering Group #5. He continues to provide, guide, and direct geotechnical services for Dam Safety and other water conveyance projects. Now, I would like to go ahead and hand this presentation over to Chris Ellis.

>> Chris Ellis: Okay. Thanks, Chrissy, for the introduction. I'll jump right into it here. So, I came on board with this project probably about 5-6 years ago. The Dam Safety Office and those responsible for the dam have been monitoring the performance for quite some time and recognize that it has some issues… associated with seepage and internal erosion, which was the focus of the work that I was responsible for. But I'll briefly mention, there's some other work that's going on at the dam. You can see right off the get-go from the picture here, it's very unique. It's a steel face dam. It's one of very few in the country. And it took some unique solutions to address the problems that we have out there. So I can't say this is explicitly coatings, but certainly the geosynthetics came into play. And we got a lot of help from the folks that Chrissy works with in the Corrosion Lab and Materials Lab with the TSC. So, just kind of give a little bit of background of what we're trying to accomplish. But the dam itself is located on the Chama River. It's in north central New Mexico. It was not constructed by Reclamation. It was built by the Middle Rio Grande Conservancy district in the '30s. Ummm, but later transferred to the Bureau of Reclamation in the '50s when they developed some other projects further up the drainage, and that were diverting water out of Colorado. I just want to highlight real quick that the steel—or sorry, the spillway—is also constructed and lined with steel plating. And this is the subject of a separate Dam Safety project that may be touched upon in some of those subsequent seminars that we'll hold. You know, the dam is sizable. It's a steel-faced rockfill. Again, one of very few in the country. It's 175 foot tall and 1,300 feet long. Stores about 185,000 acre-feet of water. And again, the steel plating that I showed in the picture earlier is the sole water barrier. And it works in combination with a concrete cutoff wall and grout curtain that's positioned at the upstream toe on the left side of this figure here. So again, the embankment materials themself are pervious. And anytime we get any flaws through that steel plating, we see seepage rates go up quite a bit. Some interesting pictures from construction. Again, done by folks outside the federal government. We were really lucky to have excellent construction photographs. But generally the process was—as the embankment was being placed, the steel plating that lines the upstream edge at the dam was brought up concurrently. Just another picture a little further along. I do want to highlight—you can see the gap or that space in between the embankment fill and the steel liner. I think that was done purposely to allow the two materials to move independently, but it becomes important for us for the design that we were pursuing later. And you can see that light-colored area, that's some of the original coatings that were placed during construction. A little bit more zoomed-in picture here. This is over on the abutment where this plating is actually covering up part of the shaped abutment materials. Those brackets that you see, kind of projecting up—those were used as kind of framing that were placed against either the embankment or the abutment and were used to form the slope of the dam, which was built at a 1.5 to 1. So, you know, there are many, many hundreds of those frames that are present underneath the plating that kind of hold it in place. And then in the center of the picture you can see the welder—you know, '30s era welder—fabricating many, many thousands of square feet of plating to construct this liner. Umm… Geologic setting—I would say if they had Google Earth back in the '30s, they might not have chosen this spot to build a dam. It's positioned right in the center of a landslide, which is a major contributor to some of the foundation seepage issues that we've experienced. They made efforts to cut that off during original construction. But they've had to come out and do some remedial work. And even still, there's still a need to do some additional remedial work to the foundation. So if you go out in the right time of day, typically early in the morning as the sun's coming up, you can see these deformations and bending of the steel plating, which is pretty remarkable. If you get a sample of that 1/4-inch thick steel, it's hard to imagine it bending as much as it does. But there's quite a bit of deformation and faceplate distress. Particularly on the left-hand side of the dam, or even the left third of the dam. You can kind of see in the picture here. So, early on when Reclamation took over, they felt, well geez, you've got this landslide. Aha. The landslide must have moved, compressed the dam, and explained a lot of those deformations. But as we really dug into the information, it isn't the case. We don't have any evidence that the landslide has moved. But the landslide was a contributor. There's some pretty compressible materials beneath the dam on the left side of the embankment. And if you go out and survey the dam today—there's a little animation here. Originally, it was built horizontal across the crest. Today—if you can see that green line—it's kind of exaggerated, but there's some pretty substantial differential settlement. And you can see the differential settlement profile pretty easily explains those reflections, the displacement reflections we see in the plate today. But those displacements and bending forces are causing a lot of stress and the formation of cracks that have been dealt with over the decades that the dam's been there. Little zoomed in here. You can see this top left—pretty substantial bulging where that settlement is of the greatest magnitude. The other thing I want to point out is, every 25 feet there's these expansion joints for expansion and contraction of the plates in between. And they're basically like a V-shaped channel that accept the expansion and contraction of the plates in between. So these expansion joints have been moving inwards and outwards for 80 years now. And what we see is, we see the formation of these cracks in the base of those expansion joints. And you can kind of see—in this lower left picture and even the one in the lower right—some places where historically these cracks have formed. And specifically, when they happen underneath the water level, you get this jetting of water. And we've actually experienced erosion of materials underneath the embankment. So you get these low points or these settlements that's reflected in the steel. And they've just—there's kind of a patch that it's shown up there—they've been putting steel bandaids and patches on the dam. Or welding these cracks up as they've formed for many decades now. But it's kind of becoming almost too burdensome. Here's just a zoom-in on some of those cracks that form in the base of those expansion joints. Again, it's—in my layman terms—it's the "paper clip effect." If you bend the paper clip in and out enough times, eventually it's going to crack. And we're experiencing this more and more often. And some more types of flaws or other cracks that have formed. Top left—some of the horizontal joints between the panels. We see some localized corrosion and those joints coming apart. You see a lot of other bending stresses or expansion joints tearing apart. Or you just generally see corrosion pit holes, locally. So, all of these flaws, particularly the big ones, when they pop up, we see a sudden increase in seepage. We have done some inspections and so on out there. We've done some… We've taken samples of the plating. We've done some evaluations of the embankment materials underneath the steel. Some of these pictures show that void that we saw during original construction is still present, for the most part. That a lot of the steel plating is kind of elevated above the embankment. And again, that void is going to be important for the design. But overall, they've done some ultrasonic thickness testing and some pit gauge measurements and so on. For the most part, the steel plating is still very—hasn't lost much of its section. It's still about 1/4 of an inch thick. We see just a lot of corrosion where the joints are made, or isolated areas that the corrosion is, for whatever reason, more likely to occur. I mentioned that. So, again, we've got this seepage. It's going through the embankment. That's causing erosion. We've also got the seepage that's going through the foundation. My role was to lead a team to evaluate a bunch of options to solve that problem. And there's a whole gamut listed here. You know, we looked at things like putting a membrane over the liner. We even looked at rehabilitation of the steel itself. Basically a new steel liner. Other ways of putting a geomembrane liner on the dam, such as remove the steel and build some sort of a geomembrane liner that would be exposed. Or a geomembrane that would be covered by other products like an articulated concrete block to provide some protection. We looked at other lining options like asphalt reinforced concrete or roller compacted concrete. And then to address the seepage issues through the foundation—we looked at an upstream seepage blanket, some foundation grouting, and then embankment cut off wall, which is kind of a twofer. It addresses both through the embankment and the foundation. And then kind of a requirement when we do Dam Safey work, we also look at either draining or abandoning the site. Umm, reservoir restrictions to achieve our risk reduction goals. Or just removing the dam altogether. So, from that long process of about three years, we came out the other end and said: best solution is to put a geomembrane liner over the existing steel liner. And do some remedial—focused remedial foundation grouting. So, this is just an excerpt of some of our drawing packages that we produced. And I want to highlight some things here. That kind of tan highlighted region you see in that profile in the top right. Very important because there's been considerable sediment accumulation at the toe of the dam. It's like 30 or 40 feet thick. And we recognize—if we want to line the entire dam face, that sediment's got to come out. And it presented a ton of challenges for managing the river, mitigating environmental impacts, and so on. So, through a long process, we decided, well, let's just line what we feel is most needed. And basically above that blue line. And what that blue line represents is, that's what we're going to lower the reservoir during construction. And basically install the liner above that elevation. So, some of the first steps involved is filling of that void that's present beneath the steel. So we're going to do some backfill grouting. And we're going to do it in two phases. The phase at the bottom, we're going to do by a tremie method. Basically injecting the grout behind the plate through tremie pipes. And then above the water level we're going to literally drill hundreds and hundreds of holes and directly inject the grout and bring it up in lifts until filled. Once that's done then the geomembrane liner goes in. And again, we'll have the same restriction. Some of the components—and I'll get a lot more into this—There'll be a geonet drainage layer that'll be present across the bottom of the installation in combination with some drain holes that will allow whatever leakage happens through the liner to permeate into that pervious embankment. And then we'll be putting in the liner, generally where that green area is shown. And that represents about 88% of the face of the dam, is what we're going to line when we're all done. And we did a lot of work and we felt that this—lining this portion of the dam will satisfy the seepage reduction goals that we're trying to get at. But there's a lot of bits and pieces to install that membrane over the dam. And that's what was evaluated as part of this project. And we took some unique approaches doing market research, vetting of materials, and ultimately getting to a point where we could… umm… Sole source with a particular contractor and allow them to aid us in designing, or basically doing the design-build—cooperation when we were finalizing the design. And that's very unique for a lot of the Dam Safety work that we do. So this is just a depiction, I've got it in my office here. But when we're done, it's a pretty substantial system. So you'll have the liner that you ultimately see exposed. There'll be a very thick geotextile cushion. There'll be that geonet, where it's required at the bottom to convey whatever leakage. You'll still have the steel plate in place. And then you'll have that roughly 4-8 inches of grout present beneath. So all of these features work together to mitigate seepage through the embankment. The other piece—I won't spend a lot of time on this—but basically, we're focusing on grouting the left third of the dam. And we did a lot of work through dye testing and resistivity testing to really under—to estimate where those… flaws were within the existing seepage cutoff wall and grout curtain. And we're going to focus in on those areas and the area that we believe most of the seepage is occurring is kind of in this region on the right side, or where these lines just appeared. So we're going to be adding actually two rows of grout curtains there. And then we'll have a single wall that will extend out to the breadth of the dam. So, this is kind of where the part gets interesting, is once we decided we wanted to install this exposed geomembrane, we wanted to use a logical process to make sure that we were using the right product and working with the right people to install this material on this dam. So, generally the process involves market research to find viable materials that are available in industry and do some testing as we need—as need be. Umm… We also did queries and what's called an Industry Day announcement where we're looking for vendors and installers to participate in the project. And based on those findings, we leverage that to do some sole source justification, both for materials and installer or the contractor. And once we did that, we engaged in contract for them to Umm… provide some additional design consultations. 'Cause these guys know best at how to install this stuff. And we wanted to incorporate that in our design and then we got a chance to go out to the field and actually try these attachments and other surface preparation and so on to kind of incorporate that into the design. And then ultimately roll that into construction. So again, this is pretty unique. We don't get to do this a lot in the government—to do these last three steps here. So, the geomembrane research. Again, our objective was to find a suitable geomembrane product for an exposed installation, right. So, this material is going to be left exposed to the water and the sun. And people. So, at the time a lot of this was happening—you know, three, four years ago—and we leveraged a lot of publications and information that was out there. And the materials that kind of got to the short list were: HDPE. And some of the information we had at the time is that it had a design life in excess of 50 years. A linear low-density polyethylene, LLDPE. It had a reported life somewhere in that 20-40 years. Polyvinyl chloride, or PVC, specifically formulated for exposed can have a design life in the 75-100 years. And when I say design life, it's a—kind of a service life, that it's retained about 50% of its original engineering properties at these years that I'm presenting here. Then you've got EPDM, another good product. Design life on the order of about 50 years. And then flexible polypropylene. And we didn't have near as much information on that. We did wind up removing LLDPE and FPP pretty early on. It had, you know, again, shorter design lives and limited exposed installation examples for projects of the magnitude of El Vado. Another reason for doing so—within Reclamation, we have these design standards that anytime we're doing modifications to our infrastructure, we lean on that heavily. And it has some guidance for exposed geomembranes and it kind of pointed us towards pursuing PVC, HDPE, and EPDM for a number of reasons. Umm… But also, part of this involved, you know, this market research. We were spending time doing paper research, consulting with the TSC's Materials Lab. Jay Swihart—if you've heard the name, he was around at the time. He facilitated some conversations we had with the Geosynthetic's Institute, the Koerner's. We did some site visits. There's an asphalt lined—asphalt dam that was lined with geomembrane near Breckenridge. Went and looked at that. And then we did a lot of phone calls with vendors and installers to see who's out there and who could do this kind of work. We also leaned on this manual from ICOLD, specifically for geomembrane sealings for dams and mostly in exposed applications. And it has some really good information, specifically from case studies in Europe. And it starts to break down, you know, of the materials that are used in industry, you can see that PVC, HDPE, and EPDM—they represent 70 plus percent of the industry. And, uh… When we're about to spend this many millions of dollars to address Dam Safety issues, we don't want to get into a case where we're doing something that's unproven or trying something brand new. We want to use something that's proven in industry. Umm… Once we started the shortlist, these products—again, PVC, EPDM, and HDPE—like any vetting, you kind of feel like you're obligated to do some sort of testing or evaluation. But we saw that a lot of the engineering properties have been well established. Uh, you know… elongation, rupture, tensile, brittleness, even UV testing is being done pretty exhaustively by the Geosynthetics Institute. So we didn't want to touch that. So we felt something that we could contribute was kind of looking at the relative damage or impact resistance. And during the design we recognized, well, the things that could damage an exposed geomembrane liner—one could be floating debris or logs. We could have boats that could break loose or be driven into the liner. Well, those are really addressed by installation of a log boom. And that will be done once this membrane's installed. We already have all the materials at the site, we just need to install it. From an ice loading perspective, we had a couple different vendors share us case histories of exposed geomembrane installations where there's freezing conditions even more severe than El Vado. And, um… They've had favorable results. And even the Canadians have done some pretty good research on this. And it's really not so much an issue. So we really felt that most of the damage, if it were to occur, it would come from vandalism. So I got little Johnny in the picture here, throwing a rock at the membrane. So, our approach was to, again, look at this relative resistance to impact. And what we wanted to do was look at some reasonable impact forces. We had kind of some apparatus that we could apply 10- and 15-pound drop weights. And then we wanted to look at different temperature ranges. And what we looked at was 70, 32, 0, and -40 degrees Fahrenheit. And, again, kind of the performance of these shortlisted materials would kind of help us select which one we ultimately wanted to go with. So, here's some pictures. Hopefully it's got good enough resolution on your end. Kind of two different apparatus. This one on the left, this vertical drop—pretty straightforward. It's got a series of weights and an impact head that can be dropped from different heights to impart different forces. This was something from Europe that we found an example of. There's no ASTM for that one. The one on the right is an ASTM. It's kind of more made for evaluation of roofing materials. But it did the job for what we needed to do. And it also allows you to vary the impact force by adjusting the fall hammer weights. So the ASTMs were kind of lacking in what we needed to do, so we developed our own damage classification categories. And I don't want to read through all these, but basically there were five increments where you'd impart the damage from where it was basically unnoticeable to some slight, you know… Umm… Bending or impact dents that you could see exposed in the membrane, to some small holes or leakage—apparent leakage, to pretty severe damage, like you see in the bottom corner. We went through the process of evaluating five different products, four different temperatures, and a range of impact weights, and two different apparatus. And really the process was, we would apply or assign a numeric rating based on what we saw happen. And we summed up the values. That was kind of our simplistic approach. And it became apparent that the PVC materials kind of performed best. And one particular vendor performed even better than all the others. You can see, even—if I back up a slide here—this is one of the PVC materials that if you get it very, very cold, -40 degrees, it actually becomes brittle, whereas the HDPE and the EPDM didn't. So we spent some time talking to the vendors. They can actually make them perform even better at ultra low temperatures, but you lose some of the UV resistance performance when they start messing with the resin. So, we felt UV resistance was more important than having a liner that performed really good at -40 degrees Fahrenheit, which very rarely happens. Then we engaged into these field trials. And the vision was to have multiple vendors or installers participate to inform that market research. And we wanted to use that opportunity to see, how are we going to secure this membrane to a steel substrate or create these watertight seals. And then, from that, we would use that information to inform the design and specs. So we wanted to have about five contracts to come out and each install about a 30 by 30 foot size panel. And would include basically all the features, or nuts and bolts, to install the geomembrane. And it was advertised, put out on the street, and we only got interest from one particular company—Carpi USA. So, based on working with them, they're heavy in installing the PVC materials. And we gave them some guidance on the material that we wanted demonstrated. It would be—they would show us how they would utilize the geonet drainage layer, how they would utilize the geotextile cushion. And we actually found out that we had to go quite a bit heavier than what we first started with. And then we wanted for them to demonstrate their relatively thick PVC geocomposite geomembrane. And it's 120 mil PVC and it has a geotextile cushion fused to the back of that material. So, we contracted with them and they came out with all the supporting subs that would make the job happen. And what you're seeing here in the picture is the stainless steel components that are used to create the perimeter seal. It's like a batten strip system of stainless steel batten strip with the hardware prefabricated. And then that's kind of sandwiched in with a gasket material to create the watertight seal. And you'll also see these tensioning profiles, which is pretty unique to what Carpi does. It's somewhat proprietary. It's done twofold to… Umm… provide additional support throughout the installation to resist downdrag of the material… resist wind loads, material flopping in the breeze. But these tensioning profiles are pretty unique, is it actually pulls the panels taut so that you don't have any of those wrinkles, which is typically where you get a lot of the flaws to develop later on. Here's just a picture of that geomembrane composite that's put along the base. It's kind of held in place with an adhesive, initially. Here's some more on those tensioning profiles. Basically there's this C-shaped channel that's initially attached to the dam. The liner is kind of teepeed up and over that C channel. And then there's this top cap that goes in. And when that top cap goes in, it pulls the adjacent panels nice and taut. And then they actually put another fused geomembrane that goes over the top of that steel feature, so that when you're done, this is what you see. Those tensioning profiles are covered with membrane and are all watertight as well. But again, this is that completed field trial that we did initially. And it gave them an opportunity to show all the pieces that would be required to attach to the steel, to the concrete at the bottom, and so on. But we learned a lot from this. One, we recognized the cushion that we initially selected wasn't thick enough. There's all these rivets and bolts that are present on the dam, and we don't want these poking through. So we went with the thicker cushion, actually 2,000 grams per square meter, which is almost like a 1/2-inch thick. We found that the PVC liner is a good material for conforming to the irregular surfaces at the dam. We found out that surface prep and removal of scale and hazardous coatings is going to be important. It needs to be planned for so that we can perform those welds. We recognized that we were going to be using stainless steel components to hold the membrane in place and attaching them to a mild steel baseplate. And we needed to consider some of the cathodic protection. And some of those other presentations that Chrissy mentioned will dive into this more. And I already mentioned the heavier cushion. So, after that field trial, we did what's called an Industry Day. And again, we put it out on the street saying—hey, contractors, vendors, we have this project coming up. Come participate in this Industry Day and show us that you are interested in the job and could support us in this project. Again, Carpi was the only company that really showed up that seemed qualified for this type of work. But it did give an opportunity for other supporting subcontractors like grouters, earthworkers, welding companies, and so on, to show interest in the job and kind of rub shoulders with Carpi, who ultimately was chosen to be our prime for this project. So, again, this kind of—that unique part is doing this market research, the Industry Day—that gave us the ability to pursue sole source. And even some Buy America deviation. Some of the products that Carpi's pursuing—this Sibelon CNT 4400 material is made in Europe. And… Our preference is to use that material. But we recognize that some of the geonet and geotextile cushion materials, they can be obtained in the US. And we couldn't pursue any sole source on those. So, now we're at a point where we've selected Carpi. We have justification to work with them. And we engaged in a contract that was kind of three phases. It was design consultation meetings to kind of finalize the design. And while that's being done, do some additional lab testing and another follow-up field trial to reflect those meetings. Umm, Carpi is unique in that they have a big facility in Italy to kind of evaluate all the unique requirements for them to install their products on all kinds of different dams. So we wanted to leverage their experience and abilities. And then once all that was done, we would roll into the actual construction phase. So, the consultation meetings. These were extremely valuable to the designers. We got to kind of work out all the issues. I hope. And I really hope that this is going to make the ultimate construction go so much better. But we talked about faceplate preparation, talking about how we're going to create the watertight seals, use of those tensioning profiles, refined the drainage system to accomplish what we want, let them inform the specifications and drawings, talk about long-term instrumentation. And then they facilitated calls with other prospective grouters to help us with the grouting drawings and specs as well. And then they provided a construction schedule, which was helpful. So, this is just some pictures from Carpi's laboratory. And again, these consultation meetings were really—I mean, they paid for themself. They offered attachment details that we hadn't thought of that had considerable cost savings. This upper left picture—there are certain areas that are going to be a temporary attachment until other parts of the Dam Safety project are done. And there was an opportunity to simply just glue the membrane directly to the steel. So they did some bond testing and peel and shear test for us. We also recognize those expansion joints that—the seal goes across the bottom of the dam—has to cross like 17 or 18 of these expansion joints. And it was really important to figure out a way that we could bridge those expansion joints and create a watertight seal. So they were advocating for, like this elastomeric material that could be formed within the—it's like a liquid that forms and sets within the expansion joint. And then they could compress it later with those batten strips. So, you can see here in this upper right, they formed it in that channel. And then they basically strain the thing almost 50, 60%, and they can show that that material adheres to the steel very well. The other thing that Carpi had that's really unique is they have a pressure vessel. And here that material is—in the bottom right—formed within that expansion joint. And then they create that seal that bridges that expansion joint. And then they pressurized it to pressures that are like well in excess of what we'll ever experience from reservoir loading. And it showed that it worked. I won't touch on this a whole lot 'cause it's going to be touched on in those other presentations, but we also looked at different surface preparations. Simply a hand brush or a grinder with a disc, or a grinder with a brush. Umm… And then we even looked at some sandblasting methods with containment to inform how we're going to prep the steel to successfully weld the attachments. There are areas where the coatings are still present and we looked at some chemical products to remove that. And again, that'll be touched on more by others. Ultimately, Carpi was tasked with developing shop drawings. Basically, everywhere that an attachment or some sort of a seal was to be made, they produced shop drawings. And we used these to inform our design drawings. Or noted that it was to be done by others. And we had a good sense of what they were going to be presenting to us once we got to the construction phase. There were some new details that we'd developed from the first field trial. And I'll start with the upper right. When we first did it, we were welding this stainless steel batten strip directly to the mild steel. And the welder was having a hard time getting that—a good connection. Just, the heat that was required to connect those two materials was so different that he kept burning through the lower mild steel. So what we felt we wanted to do was, okay, we're going to weld the stainless steel product to the mild steel in the shop. We'll bring out these prefabricated pieces. And then in the field, you'll weld… mild to mild. Well, that worked, but it's extremely time consuming. And you can see for every linear foot of these connections, you've got 4 feet of weld. So it's costly and takes too long. So, Carpi suggested, why don't we just weld these stainless steel bolts directly to the plate? And we came up with this stud gun approach and this actually worked very well. We came up with some quality control procedures where we would torque test those to make sure that we had a good bond and that we were going to be able to compress those gasket materials. And this is what we went with, and had considerable cost savings. And then, that upper left corner, that's trying out some of those adhesive—temporary adhesive connections. And you just got a guy yanking on them there. Umm. There were some other… So, they tried that elastomeric plug material in the field and it didn't go well. So, it left some doubt in the designers' minds if that's truly the approach that we wanted to go with. So, we also had them fabricate—in this left side—a more rigid plug that would be used to bridge those expansion joints. And that would be supplemented with stiffener plates that are shown up in this upper-right corner. And the idea was, locally where the batten strip would go across these expansion joints, we would constrain that expansion joint from moving. Umm. That seemed to work. We've been monitoring these welds for a couple years now and they haven't broke. So, we can't actually constrain that joint, but in true "belt and suspenders" fashion, we chose to do both. So, in the end, what you're gonna see is the top seal where the batten—that lower seal goes across—that's where that rigid plug'll go. And then in the bottom, we're still going to pursue that flexible seal that Carpi had proposed. So we'll really—we'll have redundancy for water not being able to leak up underneath our liner installation. So you'll see these little square or rectangular projections every time we cross those expansion joints during construction. So, last slide here is where we're at. We're all done with the design. Umm… Mobilization is scheduled for next spring, and it roughly is going to take about two years to do. A lot of the grouting activities and surface prep will happen next year. We'll do some foundation grouting through the fall and winter. And then the bulk of the geomembrane installation will happen spring, summer of '23. Just acknowledge—it took a lot of folks to help with this. I'm not gonna read through all these names. These may not mean anything to folks outside of Reclamation. But, got a lot of help from the designers within TSC's—Technical Service Center—on the design side and the laboratory. And couldn't have done it without everybody. And I'll leave it here for Chrissy.

>> Dr. Chrissy Henderson: Alright, thanks Chris. To our audience members, if you have any more questions you would like to submit, go ahead and use that Q&A box. And you can start doing that at this time. Before we begin our Q&A session, I would like to mention briefly the capabilities we have regarding geosynthetics here in our Materials and Corrosion Lab. Brian Baumgarten is our contact person that does the geosynthetics in our lab. So, if you would like to get ahold of him or reach him, you can contact him. Brian Baumgarten's email, I didn't put it up here, but it's B, as in Brian. Baumgarten. At USBR dot gov [bbaumgarten@usbr.gov]. So, we're going to go ahead and start with questions. And if… They start showing—uh, I don't know if we're seeing any yet. We do have a couple—go ahead and present to Chris here. So, first question—so, damage and vandalism is probably not as likely at very low temperatures. You mentioned the UV resistance was more important than the low temperature performance. Was that actually used as part of a weighting of your impact results, or was it pretty clear that your chosen material outperformed at all temperatures?

>> Chris Ellis: Yeah, the PVC materials performed best over the temperatures that it's going to be exposed to a majority of the time. There may be very rare instances that you have these cold temperatures, but is that going to occur at the same time that someone's doing vandalism? So, that kind of came into our mind. Umm… There are going to be other pretty extensive security features as part of the two projects. Again, there's the seepage reduction project that I led, but there's also a spillway and dam crest modification project that's coming down the pipe. So, there's going to be a lot of security—fencing, signage, other barriers—to keep people from accessing the geomembrane. Either from tossing materials from the crest or accessing directly from the abutments. So we're trying to do what we can to mitigate that damage. And then the other the other impact things are really addressed by the log boom—presence of that log boom. There's just no way to get to the liner.

>> Dr. Chrissy Henderson: Alright, thank you. Here's another question—did you do any grouting in your field testing?

>> Chris Ellis: We have not. Um… We had a good vision of what we want to do. You know, the way Reclamation does a lot of our grouting specs, it's kind of organized as time and materials. So we're going to be heavily involved with directing a lot of those grouting work. Umm… We did have consultations with a number of grouters. And it was so beneficial where we got to take time and really talk through it. And each of them had different perspectives and suggestions. Things that we hadn't thought about—way to install the tremie pipes or sizing of the hoses to deliver the rate of grout to meet the schedule—construction schedule. Access. All those kinds of things were extremely beneficial. Sure, we would have liked to have gone out and demonstrated them. But… Having that opportunity to kind of pick their brain during the design process was invaluable. And again, we don't get to do that a lot. So, it was really unique here that they got to kind of weigh in on what was ultimately included in the solicitation package, or the drawings and specs.

>> Dr. Chrissy Henderson: Okay. Next question, will you be able to apply your findings to other BOR structures? Or is this work limited to application at El Vado because of the unique steel faceplate spillway and skinplate?

>> Chris Ellis: Uh, certainly for all of the mechanical connections, the details that it's going to take to attach it to the faceplate are pretty unique to El Vado. Carpi and others' use of concrete anchors and batten strips with the gasket materials, that's pretty common in the industry. So, we may see that. I can think of projects I've been involved with—installing other membranes that were canal liners coming into connection with a headworks or a turnout or something like that. We're utilizing those details elsewhere. The materials, certainly—umm, umm—were not bold. And the PVC liners, uh… the product that we are using, is admittedly very expensive. It is being imported from overseas. But for this application, it was the best suited. For other applications—canals. I can think of sealing of expansion joints for some of our concrete dams. I've heard of other projects in the past that have looked at geomembranes to seal those, either construction joints, expansion joints, or other lifts that seem to be leaking. And I think we can leverage what we learned here, materials and installation, for those other projects.

>> Dr. Chrissy Henderson: Alright, we have another one. Will the steel be tied to the grout or will the steel float on top of the grout as it expands and contracts?

>> Chris Ellis: Yeah. So, umm… What I envision—I pointed out those brackets, those braces, that are present beneath the plate. And those are all either bolted or welded beneath the steel plate. And those are all going to become encased in the grout. So the steel, effectively, is going to be locked in. Umm… And intimately tied to the grout. So it will be constrained much more than it is currently. A consideration we had is—we're putting this light-colored material—basically, this material that Carpi utilizes is this very light gray material. So, the thermal impacts are going to be much less. And in a perfect world, we're going to be able to fill the reservoir up a whole lot more than it is currently. So, the variation in temperature from the reservoir water is gonna be much less than exposed to the climate. But what was brought up was thought about. We acknowledge that… The ability for the plates to move will be diminished. It'll be kind of locked in. We even talked about, umm… Defining the temperature at which the grout needs to be placed and set to kind of constrain the—or lock in the expansion joint in a particular, you know, position. We ultimately didn't pursue that 'cause it would have resulted in a lot of constraints. But what's brought up was thought through quite a bit.

>> Dr. Chrissy Henderson: It looks like we have time for one more question. So, you mentioned a lot of good reasons to fill the voids under the dam. Do you wanna elaborate a little bit more into why you'd use it for the—to keep the faceplate from pressing into the voids? Also, umm… Are you just filling with grout or are you gonna do some more rockfill as well so you don't have to use as much grout?

>> Chris Ellis: Good point, I skipped right over that. I started highlighting that and then I Skipped right over it. Let me go back here and show these pictures. Okay, so this void that's present underneath the steel. So, the intent is primarily to provide support. And it's going to be a very low strength grout. It's going to be high bentonite blended cement grout. And, um… what we envisioned is that once you put this geomembrane over the steel, which is practically impermeable, and you've got these large hydrostatic pressures, you can see that… there's going to be more propensity for the reservoir pressures to press that steel down into that void. And there's all kinds of cobbles or those steel supports that you can see—would have a possibility to, over time, poke up through the steel and cause abrasion or damage to the liner beneath. So… We feel that it was important to fill that void up to prevent that mechanism from happening. But the grout also is kind of a secondary seepage reduction feature for water that makes it past the membrane, past the steel. You've got a little bit more seepage reduction. Sorry I missed that. Thanks.

>> Dr. Chrissy Henderson: Alright, well that is all the time that we have for questions. So, if you have any remaining questions, please go ahead and reach out to Chris or myself. Keep an eye out also for our next webinar in our three-part series on hazardous materials mitigation at El Vado Dam. And then…. Umm… Yeah, the third one will then be on coatings and CP. So, we're kind of covering them all in the three-part series. And I wanna thank you, everyone, for joining us today.