Bill Bouley: I am one of the steering committee members and also one of the co-authors of this technical manual, which is FEMA 534. We were called in to help the Association of Dam Safety officials to publish this document, so we had federal representation; also, the state Dam Safety Organization furnished different people to assist us on it. So, it's not just a federal write-up that's shoved down everybody's throat, and it's pretty much meant to be a manual that owners can use to give them the information to help do a better job with their facility.

This is the steering committee. We had North Carolina State University, Maricopa County Flood Control in Arizona, obviously the Bureau of Reclamation, Association of State Dam Safety Officials, Bruce Tschantz is a professor at the University of Tennessee at Knoxville, University of Georgia was representing us from the forestry side, Stanford University with their National Performance of Dams Program, USDA with their Natural Resources Conservation Service, and also their other research stations, and Wright State University.

So, the question that probably impacts on this audience, levees are different from dams, so how does this even apply to the levee situation? A general perception is a dam holds a permanent pool of water and levees just have a periodic loading. But then there's cases where the Corps of Engineers has dams that are dry most of the time until a big flood hits; levees sometimes have permanent river loading against them, and then you've got delta levees as well as lake levee sites as well. So, I threw this in for the non-engineers; I'm a graphical kind of guy. A lot of your levees and dams that were built in the old days were homogenous; pretty much all the same material all the way through it, no pervious zone to drain the water safely out of the structure so it just flowed right through.

And then they modified it with a little bit of drainage system over at the toe of the dam, and then we have the more modern designs where we have the impervious core and then the outer shell material to protect

against erosion. On rock fill structures we might have an impervious zone on the river side or the water side of the structure, and this is also what we have in our canal structures as well. We'll have a concrete lining or some other kind of membrane on the water side of the canals as well. And then with rock fills we also have the impervious core as well.

And then for those of you engineers in the audience, the Corps guys gave me this nice detailed sketch of all the different levee designs and dam designs, so this will be in your session notes, I guess, so that you can review it online later on. The objectives of FEMA 534 was to increase awareness on dam safety issues involved with having trees and woody vegetation growth on embankments. Also provide a level of understanding that these trees and woody vegetation things are somehow addressed in most of the state dam safety policies. And then we were also trying to provide state of practice guidance on how to remediate with design on structures that already have problems that we have to mitigate. And then a rationale for state of practice techniques for managing this vegetation in the future.

So, at the time of our publishing, 48 states responded to the questionnaires that were sent out; the only two that didn't respond were Alabama and Delaware, but I think Jill Biden would probably answer that question now if we asked them. Responding to the seven question survey, so just seven questions, and they all considered trees and plant growth to be a problem on these structures. And you can see this picture here shows where the embankment in the picture and it's under all the vegetation.

Other dam safety problems that were identified; the uprooted trees will reduce your cross-sectional area on the embankment once they come out, and that reduces your freeboard, also affects your stability, the decaying roots can create seepage valves and internal erosion problems because of the root rot it will shrink in diameter. It interferes with the effective dam monitoring for seepage tracking, sinkhole slumping, settlements,

deflection of just about anything you're trying to view visually, a tree or brush is going to obscure, so that you have trouble finding those areas. And it also hinders the growth of desirable vegetative coverage. Some trees will not allow grass cover below the shade of their canopy, so we want to make sure that those trees especially aren't growing on the embankment, and then they'll clog your embankment underdrain system, which are critical for lowering the freeeatic surface in the embankment, and if it's plugged up with tree roots, then that drainage system's not working effectively.

And this is just a photo from one of our video cameras that went into one of our tow drain systems on one of our embankment dams. I'm hoping this one's another agency's dam, but you can see how the tree roots have plugged up almost the entire area. And this is just a slide that I took off the internet showing the different between a live root and a dead root system, and how much they do reduce in diameter with time.

Other dam safety problems; they can reduce turbulence in scouring around the trees in emergency spill ways during the overtopping event. The decaying roots can create a seepage pass and internal erosion problems, like we said before. The other issue, which was mentioned by Mr. Pezza, is they provide cover for burrowing animals, and we'll get a mammal expert up here later. But if you're trying to hide from predators, raptors and stuff, climbing into a root mass is the best protection for you. And they'll also loosen compacted soil. When trees grow, they tend to corkscrew their way into an embankment and that loosens the soil in that area, and typically, the outer shells of the embankment, if it's a rock fill, they have a relative density so they're not compacted as strongly as what a clay or cohesive material would be. And then the root penetration can also affect conduit joints and concrete structures and damage those as well.

And this is kind of a fuzzy slide, but it shows how this tree is uprooting a panel on one of our line canals. Fifty percent of the state has reported having formal policies; this is just a summary of some of those policies. Trees not allowed to grow on the dams or near the tow in abutment areas; some cases where trees and stumps have to be removed but they leave their roots in; other cases where the trees, stumps and roots must be removed, and then on and on. Smaller trees left in, larger trees removed, and then under the direction of a qualified professional engineer.

Some of the other issues of why they have constraints for removing; the unwanted trees and vegetation; there's financial limitations, it's a burden to the owners. You finally have inherited this dam from previous owners, now the trees are all over the place, the state's telling you to remove them. So, that's a major expense. There is environmental regulation in permits that are required. I guess there was an article in the paper not too long ago where Bette Midler in Hawaii was trying to remove some non-native trees off her property and they hammered her for taking the trees down. So, now she's got to plant trees in there to mitigate the tree she removed.

Legal issues in some states; aesthetics were used for the shade on the levees here in Sacramento; you take those trees down, we're going to have to put umbrellas out there or furnish them to the joggers so they can wear them on their head. Threatened or endangered species issues. You know, we've got elderberry bushes out here along our embankments, and the bush may not be a protective thing, but the beetle will. And then there's media issues; we're telling somebody to remove trees on their embankment and it's creating a financial burden, so they call the media and now we're the bad people for requesting them to remove the tree. And then there's sentimental reasons; I guess there are people who grow attached to certain trees. When I put my addition up, I didn't grow too attached to them; I just was grateful that they fell away from the house when I pulled them away.

There's vegetation-caused problems; 29 states reported that there was evidence where the vegetation has either caused the dam failure or negatively affected their safe operation. Several states had no documented evidence and some states didn't even respond to that question. They provided photos and information on tree-caused failures or dam safety problems, and then the publication 534 mentions an Air Force Academy dam that failed in 1999 from root penetration. It affected a couple horses but didn't cause any damage to private homes. And then there's also a case here where decomposed granite embankment along the roots, so that washed out when the tree roots penetrated that area.

At the federal level, and RCS referred to their documented cases where dam failure has been determined to be caused solely by tree and noted that the trees have also masked more serious seepage problems, which was also presented by Mr. Pezza. A recent study in St. Paul district at the time of this publication had identified blow down trees near the downstream tow and also produced potentially dangerous increase in the seepage and also internal erosion.

The cost of trees in removal can range anywhere from one thousand to five thousand dollars an acre, and this is back when we published that in 2005, so I think it's a couple dollars more now. The tree size greatly influences the cost to repair; the embankment slope steepness also affects the cost of repairs, so you've got to rebuild portions of the embankment when you take out these trees. And then the herbicide costs that you might use as well were identified as being as much as 60 dollars an acre. So, they all agreed that trees caused problems in the embankment, and basically trees and dense vegetation hindered the dam inspection. The tree roots can cause structural instability and hydraulic problems, and the trees also attract burrowing animals which in turn can lead to this structural and hydraulic problems as well. So, here's a log jam, well, we have a fire in the West and all of the sudden the next year we have a good runoff

because there's no trees to soak up the water coming down from the heavy runoff, and then we end up with all these things in our reservoir or river.

We talked about common myths when Mr. Pezza was up here; the tap root is thought to be the primary root system for all types of trees. There are different kinds of tap roots, as my next slide will show, but as the roots all develop the tap root becomes less important. Tree roots stabilize soil mass; well, tree roots actually loosen the soil mass as part of their growth pattern. For some people that walk on them or sit on them, it seems like it's more stable than a gravel surface. Ground water penetration by the root system; the trees will intercept the ground water zone to obtain water, but if the roots are inundated for long periods of time, it causes some trees to die. And soil moisture uptake is also not significant; well, that was researched and they found 200 to 300 gallons of water can be uptaked by trees if it's available. Vegetation control versus dam performance; tree roots do not stabilize the soil mass, on the contrary, the tree root penetration loosens the soil, like I said before.

And this is just some of the different types of tree roots. For those of you who have removed trees in the past, you know what this slide is showing. I had a 20-year old pine tree I had to remove when I did my addition, and luckily pine trees form pretty much a hard root so it was easy to get to; it only took a couple months of digging. Cottonwoods would tend to have the flat root. Cottonwoods, willows, my locust tree in the front yard is growing on the side yard, and also I've seen some locust root popping up in the backyard. And that would be the pattern with aspen trees as well. And then you also have trees that have tap roots as well, that sink down significantly and then they have feeder roots going from that.

This came from the University of Georgia, just talks about the different diameters of the tree versus the root ball versus the root system, and Mr. Pezza was talking about that as well, and also minimum and maximum values for growth. And this is just an easier slide to remember, the wine

glass. You've got the crown of the tree, or the dripline, and then the feeder roots go much beyond that, but then you also have your anchoring roots right there within the dripline, so it's all a matter of what diameter root you're trying to remove. And then this is also in there, density of different soil masses; the denser the soil and the compaction level, the harder it is for those tree roots to get in there.

We have saturation zones; some embankments have drain systems that lower that saturation zone, but that's the feeder for the tree roots when they start growing on your embankment. And then we get to mid-life crisis, which several of us in here have approached. You've got other issues that affect the dam; you've got burrowing animals that take advantage of the embankment that they can dig into, you've got fox coyote den here where he's looking for beavers to eat or muskrats or groundhogs, you have blown down trees, you have trees that mature and die along the embankment, and all those are issues that you're dealing with on an older structure.

So, in the publication, they identified five zones as areas to sort of rate the significance or the criticality of which zone to take care of first. We have the zone 1, which is the upstream slope area; zone 2, the dam crest; zone 3, which is the up- or downstream slope; then zone 4, the lower downstream slope; then finally the downstream toe area which is beyond the catch point of the embankment. So, the upstream, zone 1, it starts four feet below your normal water surface and it extends to the center line of the dam or dike crest; it's the most critical to dam or dikes that have a narrow crest width, and I'm just saying, for example, less than 12 feet. So, you get those narrow crest roads, a tree starts growing there, the roots can penetrate to the downstream side a lot easier if there's no positive cutoff on the structure.

It also is affected by wave erosion or rapid drawdown of the reservoir, which might cause a weakening of the soil. And this is an example of one

of our dams - it's not a Reclamation dam - and then that Detroit rip raff is also helping as well. Zone 2, we get into the crest of the dam; there's some overlap that's intentionally done with the zone 1 so it just goes right over the upstream crown slightly. But this is one of the least critical zones to tree and woody vegetation, but you want to make sure that it's maintained free of deep-rooted, bushy growth so that you can identify any tension cracks, slope failures, or other issues that are occurring in the crest. And some of these, if there's trees or brush nearby, they could be aggravating those deficiencies. And this is a dike that we inspected one time; you can see a dead pine tree, you've got plenty of living trees as well, so at least the embankment crest looks fine, we were able to see that.

You get to zone 3, that's the upper third of the dam height on the downstream face, and it includes also the downstream half of the dam crest; it's the least critical zone for tree and woody vegetation growth because it is furthest from the phreatic surface coming through the dam. Major tree removal may not require a reservoir-river drawdown because you're up so high out of the water surface area. Then we get to inspection evaluation zone 4, which is the lower two-thirds of the dam to the toe of the embankment; it's the most critical zone to tree and woody vegetation removal because your phreatic surface comes through the embankment and starts intercepting either the downstream slope or a chimney drain that goes into a tow drain system, and if those trees are growing right there, they're choking off all those structures. Major tree removal may require a reservoir-river drawdown, but it definitely should be performed under the direction of a qualified engineer so that when you guys go to court, that engineer can testify what happened when.

Inspection and evaluation zone number 5; this goes from the toe of the embankment, or from mid-height of the dam on the downstream slope to that same distance beyond the toe of the embankment. And it could extend into areas that are beyond your property line, so that gets real

sensitive when you start knocking down somebody's fence and tearing out their oak tree. It's the second most critical zone to tree and woody vegetation, and it's also very close to where the phreatic surface starts exiting sometimes through the foundation. And the major tree removal would require probably a reservoir or river drawdown and the dewatering, also performed under the direction of a qualified professional engineer.

Then this is what a nice embankment slope should look like, denude of most vegetation, a few trees growing further downstream to where they don't affect our structures, and obviously these are pine trees, so they don't have the root penetration that cottonwoods or willows or everything else would. So, basically the four rules for dam or dike owners: remove existing trees, and they shouldn't be allowed to mature on embankments, abutment growings, or water conveyance structures; the trees and shrubbery should not be planted on or around new or existing dams, unless you've got cute little planters that the landscape architects provide; areas around existing trees should be closely watched until they're removed, because there could be dam safety problems developing right around those; then fine grasses and shallow-rooted native vegetation that's more desirable for that area to provide the surface covering to prevent erosion on the downstream slopes of the dam and dike.

This is one of the dams we looked at back in '87, and then we refined our vegetation removal criteria after that. But the irrigation district had allowed trees and brush to grow to significant heights on the embankment. And you can see down near the downstream toe, those trees are much higher in height, just like that one slide I showed earlier. And tree root elongation management and control methods; these are some of the methods you may have to employ, and they'll be in the PowerPoint slides that are made available on the internet site. Other methods of management and control also listed, and then Dan Marks put in the publication several design remediation methods that you could consider; this one's up near the zone 1 area, there's the zone 2 and 3. You may not

agree with leaving the stumps, but he's got that in some cases. And then zone 4, what you do there; he shows them digging out a portion of the embankment to recompact it as well. And then zone 5, things you do there.

And then through the life of your dam, the first year you try to keep a close eye on it, make sure you're mowing it on a regular basis so that trees and brush don't start growing. If you get some small trees, remove them when they're four inches or less, keep them flush with the ground. Treat the stumps, if possible, with something to kill them off. Second year, all trees in zone 1 through 4 that have larger stump diameters would be removed; third year, fourth year, and fifth year. So, different methods of control.

And this is a slide that kind of clarifies, Reclamation's got a 25-foot distance that we try to enforce, and we tell that to our dam operators and irrigation districts that operate our facilities. And then on the reserve works we do it as well. It gives us a nice cleared area that we can do our visual inspections, and also protects the tow drains and other devices that are installed in those areas. And this is a slide from my Katrina experience; I was down there for 30 days. And you can see the root ball here, it's sheared off completely from the high winds. The soils are very sandy and silty in the area I was in, and then the actual tree truck diameter is barely 18 inches, but this root ball is well over 10 feet.

You can get a free download of the publication from FEMA's website, just go into fema.gov and there's a click over in the corner on the left side that says "Request the publication number." You click on that, you type in 534, and you can just save a copy to your desktop or My Documents; whatever's good for you, and then you can print it out for yourself. So, it's free.