

Laura Kaplan: Good morning, folks. If you could please take your seats, we will begin. I'd like to welcome everybody to the Vegetation Challenge. My name is Laura Kaplan, and I'm a facilitator for the Center for Collaborative Policy. I am filling in this morning for Emir Macari, who is running a bit late. But we have established a rule for this conference, and that is that we start on time and we end on time, and the train waits for nobody, including our moderator. So, I'm filling in. And luckily enough, I prepared the speaking notes for Emir this morning, so hopefully I'll do a good job.

I want to start by just emphasizing how hard the state, the Army Corps of Engineers, and the local agencies have worked to create a truly collaborative symposium for you today, based on science and engineering. I was lucky enough to facilitate the planning meetings, and we've meeting for about three months, trying to get everybody together to do an honest and thorough evaluation of the policy, the science, getting everybody to be able to speak about this very challenging and complex issue in an open format today. And I want to thank all of our sponsors for their willingness to participate in that kind of collaborative environment.

So, our theme for this morning is about this vegetation issue; what is it and why is it so important, especially here in California? And I'm going to leave it up to our speakers, our first speakers, to set the tone for that. I'd like to thank the Planning Committee who worked so hard for three months, especially Peter Buck, who I believe is also running late with a migraine this morning. But Peter Buck at SAFCA really put his heart and soul into being the driving force behind organizing this symposium. So, thank you Peter wherever you are.

I'd like to emphasize that we are running on extremely tight timeframes today, so we ask our speakers to please start and end on time. They will have a timecard countdown, and speakers, I want you to know in case there's any confusion, that that countdown includes any Q and A that you are able to include in your presentation. We leave that up to you to moderate for yourself. This symposium will be videotaped and it will be available on the Internet for the public, and there may be media presence. We wanted everyone to know that. And please, if you have a cell phone or pager on you, this is a good time to turn it off or turn it to silent so that is not what appears on the videotape and up on the Internet for everyone to see.

With that, I would like to introduce our first person today -- is Mayor Fargo here? Okay, we will start then with Steve Stockton from the Corps of Engineers.

Steve Stockton: I don't know about you all, but when I told people I was coming to the Levee Vegetation Symposium, they went, "What?" Sounds pretty exciting. Good morning, everybody. I would like to thank the Department of Water Resources, SAFCA, and Reclamation Board for their leadership in bringing the symposium together.

What I'd like to do this morning, no slides, which will allow me to stay on schedule, I'd like to provide a little context for today's discussion. Katrina was a wake-up call for the nation, the Corps, and other agencies involved in flood risk management. After Katrina, we performed extensive engineering and decision-making forensics to determine what factors led to the tragedy in New Orleans. Key findings of these forensics: the system. It was a system in name only; we need better system-wide risk-

based planning and design methodologies. Changes. We need to consider changes in the hazard, the system, and the consequences over time. Lifecycle. We must better consider lifecycle performance of systems; we need to incorporate concepts such as resiliency, redundancy, and adaptive management to accommodate change -- both expected change and unexpected change. Policy and practice. We must enhance technical competence and evolve guidance and methods to integrate new technology and knowledge. That's the reason we're here today at this conference.

In response to these findings, we developed an action plan to institutionalize changes that we needed to focus more energy on. Here are these key actions. We need to employ integrated, comprehensive system approach; we need to employ risk-based concepts in planning, design, construction, operation and maintenance of Flood Damage Reduction projects. We need to continuously reassess and update our policy, employ dynamic independent review of our policies, employ adaptive planning, focus on sustainability over time - not just good enough - to build something, and not just expect it's going to stay that way forever. We need to review and inspect completed works more thoroughly and rigorously. We need to assess and modify our organizational behavior, effectively communicate risks to all stakeholders, establish public involvement risk reduction strategies, manage and enhance technical expertise, and invest in research and development.

Bottom line to all this: the Corps and our partners must be diligent in exercising our shared responsibilities in reducing flood risk to the public. Public safety is paramount and will remain as the primary focus of our efforts. However, we understand the sensitivity of environmental

concerns and other issues of concern in California, and we'll seek to develop sustainable and compatible solutions. Public safety can be compatible with environmental concerns; we are committed to making this happen.

The Corps of Engineer's goals go beyond seeking compatible solutions to vegetation management. Our broader goals and our focus is to, (1) have a safe and informed public that's empowered to take responsibility and a role in their own public safety, (2) establish and administer clear national policy and standards, not just for operation and maintenance of levees but in all areas of flood risk management, (3) have sustainable flood risk management systems that support public safety in a robust manner and provide a healthy environment. This symposium and round table activities are California-centric. That said, our goals are to share factual engineering and scientific engineering, identify substantive information gaps, and identify areas of commonality; listen, learn, and understand other stakeholders' perspectives.

We're seeking to move forward in a collaborative manner to develop mutually agreeable solutions without compromising public safety or environmental values. The Corps existing regulations provide for the allowance of vegetation and small trees on levees and are consistent with our flood risk management environmental missions and responsibility. Trees can exist, providing they do not prevent the proper functioning and operation of the levee system. Dave Pezza will go into more detail on this during his presentation.

One last thing I would like to remind everybody: it's not just about the vegetation. Levees are one component of a flood management system

which can be composed of levees, pump stations, flood walls, dams, channels, and numerous other components. Each of these components must be properly designed, built, operated, and maintained and work together as a single system in order to reduce risks to the public. Trees may be the subject of the symposium; however, it's important to not lose focus or divert attention away from the fundamental mission of the flood management agencies, which is to ensure that the system as a whole is reducing the flood risks to the communities living and working behind the system.

Laura Kaplan: Thank you, Steve Stockton. As he walked off the podium, he asked me, "How'd I do time wise?" So, I think we've got the right idea going here. I would like to invite first Les Harder from DWR and then Stein Buer from SAFCA up to the podium, and I'm not going to come back up in between you two, just to save a little time.

Les Harder: Thank you. Good morning all of you; it's quite an impressive turnout, obviously a lot of concerns about this issue. So, on behalf of the state of California, I'd like to welcome you. This is a very important symposium to us. We at the Department of Water Resources and the State Reclamation Board view this levee vegetation policy and issues associated with it as extremely important, and of course we have various concerns about the implementation of this policy. We really want to thank the Sacramento area Flood Control Agency for organizing this and setting this up. We are happy to co-sponsor it and we are very appreciative of the Corps co-sponsoring as well.

In the interest of time I'm going to try to be brief, but I would like to leave you with a basic theme for you to think about during these next two days,

and then touch on three thoughts associated with that theme. The theme is this: we are all concerned about public safety, and that's going to be our primary focus; our highest priority. But we have very limited resources, and associated with the fact that we have limited resources, these are the three thoughts I'd like to leave you with. First of all, the Corps' approach currently uses risk and uncertainty, and this is based on the premise that we do have limited resources and we cannot do everything, and we have to apply them to the most critical areas first.

Now, I don't think any one of us in this room would disagree that we need to have a levee vegetation management policy, and that we have to focus on safety elements. But we need to be careful that we do not unnecessarily spend our very limited resources in areas that do not significantly reduce risk. These resources must be carefully conserved and applied to the most critical things that affect public safety.

Second, with regard to limited resources, our levees are founded on and commingled with natural levee systems and the habitat that's currently on them and the habitat that was left there when the projects were completed by the Corps. This habitat, the vegetation and the trees, are the last remnants of the Great Riparian forests in the Central Valley. Now, there's less than about 5 percent of that left, and they provide critical habitat to numerous endangered species, and it will not be acceptable to resource agencies, environmental stakeholders, or the general public to simply eliminate all that habitat and have basically all the impacts to the endangered species.

In addition, related to that is that one of the lessons from Katrina was that degradation of environmental systems -- the wetlands and the barrier

island -- actually aggravated the flood surge and the flooding that resulted and the loss of life that resulted. So, here, there may be several benefits to the habitat, particularly on the water side, that we don't fully understand yet -- such things as erosion protection in an area that we have pervasive erosion problems. We should not necessarily eliminate that without fully understanding what we're doing.

And finally, the third thought I would leave you with related to limited resources is we cannot afford to do this without being collaborative; we have to work together with our main goal of protecting the public. Now, historically the state has had just an extraordinarily excellent relationship with the Corps, particularly here with the Sacramento district, and we're looking forward to continuing that relationship and being collaborative. We were greatly encouraged when we talked with General Reilly and he agreed to co-sponsor this very important symposium, and last month when General Van Antwerp was out here and he agreed to pursue a flexible policy that would leave some of the vegetation in place.

So, with all of that, thank you all here for coming, coming here to listen, to learn, and to work collaboratively to solve this issue. Thank you very much.

Emir Macari:

Good morning. My name is Emir Macari, I'm the Dean of Engineering and Computer Science here at Sacramento State. I'm sorry that I had to be a little bit late; kids being dropped off in the morning and then traffic coming into downtown. But it is a great pleasure to be here with you today. It is very important that throughout this symposium, we stress the fact that it is a collaborative meeting; it is a dialogue that we want to have between the federal government, the state government, and local

government, to find a solution that best fits our population. And throughout the meeting we will try to make that emphasis, because it is important that we work together to solve local problems, thinking nationally but looking at things locally.

Our next speaker now brings, then -- after our first two speakers brought the national perspective and the state's perspective, our next speaker brings out the local perspective, and that is Mr. Stein Buer, Executive Director of SAFCA, the Sacramento Area Flood Control Agency.

Stein Buer:

Good morning. This is an awesome turnout, this is wonderful. I want to start by thanking Steve Stockton for coming here late last night to spend time with us; I promise you, Steve, this Vegetation Symposium will grow on you. And I want to thank all the rest of you as well for coming; it's your time, your energy, and your knowledge freely shared that will make this symposium a big success. I want to thank our partners, the Corps of Engineers, the State Department of Water Resources, and the State Reclamation Board for co-sponsoring this event, and for allowing a large number of your talented staff to be here this morning. It's very important that a lot of us hear what goes on today and contribute to the symposium.

Our partnership is a long-standing, deep, and wide partnership in California, extending over 100 years in planning, designing, constructing, maintaining, flood-fighting, forecasting, operating, recovery and rehabilitation. We have worked together on all these fronts over all these years. We look to our distinguished partners and we see a lot of strength. In the Corps of Engineers, we see an organization deeply rooted in the nation's history with a global reach, a national perspective, powerful, determined, and accomplished. In the state of California, the Reclamation

Board and the Department of Water Resources, we see a great talent pool as well; an organization capable of rapid mobilization under strong leadership, as we have seen play out in 2006 when the state declared an emergency and mobilized to spend about 300 million dollars in the season. It was a fantastic accomplishment, a great credit to this state.

So, what is it that local agencies such as SAFCA can bring to this partnership? And there are many of us up and down the Valley who work directly with the state and the Corps to move forward on these projects. Well, being small, SAFCA has 13 full-time employees; that's our full extent. But we have, because we're small, agility, creativity, and a passionate commitment to our community, and we have the support of a truly remarkably talented group of consultants; we can reach into the consulting world and get the very, very best the nation and the world has to offer. We can bridge gaps, we can solve problems, we can quickly move unencumbered to fill the gaps where the larger agencies may be held up by contacting regulations, funding limitations, or decision-making processes.

But our greatest strength is the fact that our nerve endings are deeply embedded in our local communities. This is America up close, and our citizens ask us on a daily basis -- we get thousands of phone calls, emails, and at public meetings we're in direct contact with our constituents, day in, day out throughout the year, during the day and in evening meetings. And our constituents ask us over and over again, how are you spending our hard-earned money? Do you have your priorities straight? Are you being efficient? Are you considering all of the consequences of your actions? Are you using the best available science? Those questions, which

guide us on a daily basis, I think can guide this symposium as well, and I look forward to the proceedings and report. Thank you very, very much.

Now, it is my great pleasure and honor to introduce the mayor of this great city of Sacramento, a veteran of flood fights and battles to win improvements for Sacramento over 16, 17 years now. Please welcome Mayor Heather Fargo.

Heather Fargo:

Good morning to everyone and welcome to Sacramento. How many of you are not from Sacramento? Very impressive. Thank you so much for joining us today. This is such an incredibly important subject to us here in our city, in our community, and in our region. There are approximately 400 or 500 of you that have come from as far away as Holland to discuss the important issue of vegetation as it relates to flood protection. Many of us were very stunned the day we read our local paper, which said that the Corps had a new policy to remove all vegetation on the levees in our region. We were stunned for two reasons -- actually, for one main reason, and that is that we didn't want to see it happen. We do admit to having a love-hate relationship with our rivers here in Sacramento; we love them in the summer and we begin to fear them and sometimes hate them in the winter, and I think that's true for a lot of communities, although some communities tend to flood in the summer, as opposed to those of here who tend to look towards flooding more in the winter when it's colder and, frankly, more difficult to survive.

We take flood control very, very seriously in Sacramento. I have been on the Sacramento Area Flood Control Agency since it was formed; I first got appointed in December of 1989, and I've been doing it ever since. And even after becoming mayor, I kept myself on SAFCA because I

believe that flood protection is the most important public safety issue facing Sacramento, and it's incredibly complicated and can be very divisive at times. So, we have a community that has gone beyond what I call denial; we just had a recent assessment district vote here in the community of Sacramento, beyond the city as well, and we received an 82 percent vote to assess ourselves again for flood protection. That's how seriously we take it here.

Well, we also take our parkways seriously. We take the option of being close to nature here seriously. There's a lot of recreation that takes place along our parkways; we think that our parkways here in Sacramento along the American, along the Sacramento, are two of the most beautiful urban parkways anywhere in the nation, and we don't want to lose them. That's part of why people came here, and as some of the previous speakers mentioned, that vegetation is historic; that vegetation was frankly placed here by Mother Nature, in some cases, and we don't like to argue with Mother Nature here. We tend to think that she knows a lot about what is right, and as we look forward to making improvements in our natural system and in our urban system, we feel a need to meld those here in Sacramento, to blend those.

And so I am incredibly grateful to all the sponsors and those of you that envisioned this symposium that you would hold it here in Sacramento, because we take this issue of what to do about vegetation as a very serious issue. We take as both a threat as well as an opportunity. We recognize that if we're going to be the largest metropolitan area at risk of flooding in the United States that we need to do all that we can to protect people. But we don't want to lose our quality of life while we do that, and we don't think we have and we hope that through your proceedings over

the next couple of days that you will come forward with some resolutions, some opportunities, some suggestions that hopefully will recognize the uniqueness of different parts of the United States.

National policy is important, but you can't always apply it evenly throughout a system as diverse as the United States, and we've found that in California and even in Sacramento, that you can't apply policy broadly into local situations. Rivers are important in our nation; they're certainly important in our region, and so is vegetation. We are, after all, known as the City of Trees, which hopefully you will get a chance to explore our city while you're here, enjoy the tree canopy, visit some of our great night spots, some of them not too far away, within easy walking distance. We have a number of great restaurants; we like people to come here and enjoy themselves, so I expect to see a lot of conversations over beer and wine this evening where you will really find the solution to what you are looking for.

I really encourage you to do that. I, on the other hand, will be at the City Council meeting tonight, so if you are feeling a little bit missing that kind of direct government activity, we're just going to be down the street at I Street; you're more than welcome to come. But we're not talking about flood control tonight, we'll be doing that today and tomorrow.

There are over two million people within the Sacramento region, and fully 25 percent of those people rely upon levees, and that is a significant number of people. We have 400 to 500 thousand people that rely upon levees every day, so we understand how important it is. But we also want to be able to walk under a tree canopy, we want to be able to maintain habitat; SAFCA has put a lot of energy into working on the lower

American River through a forum that we've put together that has allowed us to improve fisheries and improve habitat. And that's what our community is looking for, is a balance, and that's difficult; I realize it's a stretch to really try to figure out the nuances and the balances that have to take place to preserve a natural habitat and to offer shade and vegetation, and at the same time make sure that our levees are strong. We don't want to lose more and more people.

So, in conclusion I want to thank U.S. Army Corps of Engineers, I want to thank the State Reclamation Board, the California Department of Water Resources, and in particular, the Sacramento Area Flood Control Agency staff. Now, that I know they have 13 staff members to equal the 13 board members, that's a very interesting number. But that's good. We have a very creative staff, we have a very dedicated board, and we have a community which is paying attention to what you are doing. I think there are other communities that probably are as well, but this particular community is very interested in the outcome of this symposium. I see a lot of very alert and creative people in the audience and I really hope you do your best so that we can continue to maintain our quality of life while at the same time making strides in providing additional flood protection.

Thank each and every one of you for being here, and best of luck to you.

Emir Macari:

Thank you very much, Mayor Fargo. This meeting, as the mayor mentioned, was something that came about very, very quickly. In April, the white paper was published; it reached our newspapers, people started wondering, what is this all about? And at that time, SAFCA, along with its partners in Water Resource, the Reclamation Board, and the Army Corps of Engineers started a dialogue to see how to provide more

information not only to our local community but throughout the state, and as far away as Holland and Germany.

So, this meeting, this symposium was put together very, very quickly, and I would like to acknowledge the Planning Committee, whose efforts have been tremendous. And if you look in the second page of your agenda, the Planning Committee is listed there, and I would like to ask for everyone in the Planning Committee to please stand up and be recognized. Among all these great colleagues, there is one that stands out, as well, because he has dedicated the past three months exclusively to this symposium, and I know many of you have been in touch with him. He has made phone calls, run around the state, run around the country, trying to put together this symposium, so I would like to recognize Peter Buck. Is Peter here? Thank you very much, Peter, for bringing us all together. This is going to be a great dialogue, and that is the way we have envisioned it to be.

The theme of this morning is what is the issue and why is it important. The mayor mentioned that this white paper and this news came about without many of us knowing what it was all about. And this meeting gives us this opportunity to learn something behind the recommendations that have been made and to be able to have this dialogue on a basis of science, but as well as policy. Today most of the meeting will be dedicated to the science. We have asked members of our greater community -- engineering, sciences -- to come in and make presentations on their perspective on the issue of vegetation and levees. However, we need to start from the beginning. What is this white paper that we keep talking about? Where did it come from, how was it developed, and what is the plan for implementation?

And for that, I would like to ask Mr. David Pezza from the U.S. Army Corps of Engineers to make a presentation titled, "The Corps New Draft: White Paper on Levee Vegetation Management Guidelines and the Driving Factors." This presentation will set the stage, along with a couple of other presentation that will be this morning, set the stage to have this dialogue.

David Pezza:

Thank you for the introduction, Dr. Macari. Mayor, fellow participants, I appreciate the opportunity to be with you -- I've got a little bit of logistics here; things don't always work out like you planned. Mayor, the Corps certainly understands the challenge that you have with your Riparian and aquatic life. We recognize and understand that it's precious. Our challenge has been finding a way to integrate public safety within such habitat in a way that's best for both.

You know, there is a saying that we pay for the sins of our fathers. You are not going to find much about the early development of this nation where we took sustainability into consideration. Our forefathers focused on, what, evacuating flood waters as fast and as cheaply as possible. And assume that we're having to live with this, the environmental degradation as a result of those actions. Guess what, today we are the fathers, and we're certainly going to leave plenty of sins for our sons and daughters. However, one sin we can strive to avoid is failing to find a safe way to incorporate sustainability into our infrastructure. We need a way that enhances both public health as well as public safety. In this presentation, I'm going to briefly go over the white paper, why the Corps talks about systems and risk-informed decisions, and what the future holds for our [unintelligible].

Many people realize that Sacramento is a tough spot. This article that you say was in the American Society of Civil Engineers civil engineering magazine back in November 2005. It posed a question: "Is your levee system vulnerable to a disaster far greater than the one that hit New Orleans?" The criticism on the system in the southeast of Louisiana was on the quality of the standard of care that was applied to planning, designing, constructing, operating and maintaining systems. The system itself in Sacramento is really an amalgamation, a hodgepodge, and when we look at it we see a system that's very fragile.

Why all the fuss about levees? Well, failure in New Orleans drew a lot of attention, as you all know. Southeast Louisiana, 1300 people died. That's a lot of families. More than 100 billion dollars has been spent on the recovery and reconstruction efforts. And you know what, there's over a quarter of a trillion dollars worth of lawsuits. What's a quarter of trillion dollars? A quarter of a trillion dollars is equivalent to one highway bill, which is a six-year bill that's partially covered by taxes. Our federal budget for FY08 is three trillion dollars, and when you subtract out all of the mandatory expenses for entitlements and defense and so forth, Congress is left with a discretionary income of about half a trillion dollars. This lawsuit consumes more than half what they have for discretionary income.

The administration and Congress wants to know, what is the risk for floods in this nation? And I asked the Corps to do an inventory, and if what you hear and read in the papers and the press is true, Sacramento -- the risk here is incredibly high. The Corps is responsible for public Law 8499; the Corps completed its initial inventory of all its federal projects and those within the Rehabilitation Inspection Program. This is just a

sample of what we found. Here's one levee, two districts, different standards of care. Now, we have -- the Mayor referred to new policy, and actually it's existing policy. We've had it in place for well over 30-some odd years. We also have, in response to Werter 96, Congress asked us to develop a regional variance, which we did, and we must meet four criteria in order to grant a variance.

Now, I want to point out two key ones: structural integrity and accessibility. The Corps has long allowed vegetation on levees as long as we designed those levees to accommodate it through overbuilding or containment. We will grant a variance, provided it meets those four criteria that we already showed in the previous slide. Now, the earliest I could find historically any guidance by the Corps was in 1968; man, it was your brick, sod cover levee. But in the early 1970s with the emergence and the nation demanded that we treat our environment as a national resource. Well, the Corps developed guidance to accommodate that, and here it is in December of 1972 and it includes recommendations for integrating landscaping in our flood control projects to enhance systems, providing it doesn't impact the stability, maintenance, and flood fighting.

The white paper. Why does the Corps write the white paper? Believe me, it wasn't my idea. If the Corps has policy and guidance, why is vegetative encroachment so prevalent in our systems? The white paper, a 34-page thinking paper, that examines the issue at a policy level. This simple paper listed over 1000 comments, and yes, we read each comment. I found it absolutely fascinating. It was a great Miller beer commercial, really; "Tastes great, less filling." Many comments challenged the Corps' assessment of the effects of vegetation on the reliability of our levee.

Many comments challenged the science that we used as the basis for our policy, and many more comments pointed out the recommended actions required for environmental consultation. We know, or we understand the federal law, and we understand that that's important. But one thing the white paper pointed out to us, from our perspective, is that the Corps needs to do a better job of clarifying and communicating its requirements. We see these requirements as absolutely essential to reducing our nation's risk of floods.

Why is the Corps so excited about having vegetation on levees? Well, we have responsibilities under the code of federal regulations. The Corps is going to be looking at, as Mr. Stockton said, levees from a system perspective. By system we mean the entire project over its lifecycle. We're looking at all the components that make up a levee or a flood control system. A system can consist of structural components as well as non-structural components. Vegetation is just one small part of the system, and actually it's just one part of our O and M component.

The Corps has adopted a four-step inspection assessment process in support of this CFR. For a system like yours that provides protection for 100 years or greater, the Corps will conduct four steps. One, it will do an annual inspection, routine inspection, to assess and rate the condition of your levee. And every five years we'll conduct a periodic inspection to verify proper maintenance and evaluate the overall safety of your system. In conjunction with the very first periodic inspection, we will do a periodic assessment, which will look at failure modes and consequences.

Now, each component, we'll rate it as one of these three categories, and an unacceptable rating has one or more deficiencies with that particular

component that may impair the component's ability during a flood. Then we'll roll up all those components and we'll look at your system, and an unacceptable rating is when one or more components rated as unacceptable prevents the system from performing. Now, a project can have one component rated as unacceptable and still receive a minimally acceptable for your system, but that's going to depend on your component. If it's a gate, it may not be critical, but if it's a levee, well you can fully expect that your system is going to get an unacceptable rating. Unless your vegetation is incredibly bad, generally what you're going to find is that your vegetation, which is part of the O and M, the O and M probably will get an unsatisfactory or unacceptable, but you'll get a minimally acceptable rating for your system and then the Corps will grant time as part of the implementation process to get that corrected.

Now, if the system proves marginal, we'll take the fourth step. Before we'll do an assessment, they determine the residual risk of your levee system. Well, we'll use this information to communicate to the public how well or how poorly protected you are. This information will help the public judge for themselves what additional measures they may need to do to protect themselves. For example, there is a list of risk reduction measures. Our key point is the Corps will establish a cadre of experts who will travel around the country to do these assessments, and there are two reasons: to ensure that we have consistency and that we offer an independent review.

What is risk? Well, no project is perfect; there is always risk. This is an equation that the Corps has adopted as its process. The probability of the event is what is the flood, or in your case an earthquake -- for example, you'll be asking yourself, what are the chances that this flood's going to

overtop in my levee and cause a failure? Well, that's the second part. The probability of failure, that's a measure of the fragility of your system; what are the chances that your levee can fail? Then the consequences. Consequences are for loss of life, economics, and also loss of habitat. Are you aware that you can lose your habitat two ways? You can lose it in a flood fight, in an emergency. We have to go in there and clear the habitat to fight. You can also lose it in washing away.

Well, the risk equation will help you understand your system and what components or what parts of it are most likely to be a problem, and who's most likely to get wet first. If you want to learn more about risk, I suggest you get this month's issue of the National Geographic. It asks the question, "Should New Orleans rebuild?" and it comes complete with a nice foldout. But it shows what parts of New Orleans have the greatest risk. Are you aware that over 30 thousand people live 10 feet below sea level? That's staggering. You need the same kind of information, and that's one thing the Corps and the state can do working together.

Now, what does it take to design a safe system, or a safe levee, in this example? We have minimum safety requirements, this is a key point. You know, you have a building code. You can do whatever you want with a building like this, but you must meet the minimum safety requirement to ensure that this structure will be safe enough for you to be in here. You can do whatever else you want to it, but it must meet those minimum requirements. So, a system must be structurally stable and must provide unobstructed access. It must meet minimum maintenance and operations standards, and it must be continually evaluated. Because what happens? Things change. Californians know this principle very well; what do you do every time you have an earthquake? You go out and you inspect your

bridges, you go inspect your buildings, you go out and inspect your dams, and then you update your codes. You do this very well. We do the same with levees, and Katrina was our earthquake; it changed the way we look at things.

I want to quickly go over this part. There are four basic forces you've got to consider when you're looking at a levee: gravity, hydraulic forces internal and external, and dynamic forces. In the upper left hand, you've got underseepage; this is very critical in your system. On the bottom left side, you've got scour, that's already been alluded. This is also a critical issue with your system. On the top right side, slope stability. This is particularly an issue when you've got an earthquake; your system is very susceptible. And then the bottom right is seepage through your levee, which I understand happens a lot when you have floods.

This is our guidance relevant to these topics. There were a few comments in the white paper that, well, you know, engineering manuals, they're not requirements, just guidance. It's just suggestions. Well, as some of the kids would say, au contraire. We have a policy and they come in the form of engineering regulations. They're based on law, they're based on our organizational requirement, and they're based on lessons learned. The engineering manual says the technical requirements to support that policy. And so if a manual says you shall a minimum safety factor of 1.5 or you need a minimum setback of 15 feet, they're not suggestions, they are requirements in support of our policy.

Now, one of the things that we're doing is we're converting our guidance to support the periodic and risk assessment. We're first going to use screening guidance to assess how fragile your system is when it's under a

flood. And then ultimately - we're in the process of doing this already - developing what's called a "fragility curve" in engineering to each component. And this is essential to support the risk assessment process. Just to show you, on the left side you see the flood rising, and under the old model the levee didn't show any performance problems, it just went straight up with the flood level on the left side. Then we had instant failure in a straight line across, and then on the right hand side, as you see that black arrow rise, if the river's rising you no longer have a levee in place. And what in reality is more like a curve, not as shaky as that line is itself, but as you apply a load, guess what? It starts to show stress, and depending on the condition of that levee and whether it's overtop, failure may occur at some point.

I'm going to skip through this slide for the sake of time, but in essence, I just wanted to say when you're designing these systems you have very little information. And when you have very little information, guess what, you miss a lot of these spots. And this is a boil, one that's actually deteriorating. Dr. Harder came to Washington and met with General Reilly, and he presented this list. This was educational to me. This slide shows eight issues in order of relative risk, and I can say where vegetation may be the list when you look at it by itself. But vegetation contributes to several of these failure modes and I don't see how you can separate it out.

But this tells the Corps something else -- and this is what's important, how we're seeing this thing within public Law 8499, which we're responsible for. Normally -- you heard about the 122 levees so far that was out in press; well, the only issue we were really dealing with these levees was vegetation. And this slide tells us that your system is incredibly fragile, and what you need to be concerned about is that it can place your system

in an inactive status in public Law 8499 because it's so fragile, regardless of the vegetation issues. The Civil Engineering magazine article that I referenced brought this point up as well, so it's not just us.

You also need to understand that we've got to be smarter about working some things. We've got different people making different decisions, but when you have an agreement that restricts maintenance on a levee because you're trying to protect the habitat, I can understand that. It's important. But if it also prevents us from doing maintenance, it's causing our system to deteriorate, and that interferes with our minimum safety requirements. That's why it's very important to plant vegetation appropriately in the overbuilt places and in contained areas.

What about the science behind showing the beneficial aspects of vegetation? I'm going to leave that to Dr. Maureen Corcoran, who will talk later this morning. I want to make a point about this document because several people referred to it, "The Effects of Vegetation on the Structural Integrity of Sandy Levees." It was a document that our research people did that was specific to Sacramento, and Dr. Donald Gray will be speaking today, and he's one of the authors and can certainly speak for himself. I can't argue with some of the conclusions that vegetation can reinforce a levee, but as an engineer, if I needed to reinforce my levee I would not depend on the random presence of vegetation to make that happen.

Also, those who've referenced this document never mentioned some of the limitations that some of the authors also raised in their document. People like to quote ERDC, our research facility, as if their document is definitive. I like to respond to such quotes as, research is not policy; it

only answers the particular question we use to help build policy. Now, the Corps published this report in 1991. We updated our landscaping guidance in 1993 and again in 2000, so I called my predecessors and asked them, why didn't you consider the research? And their answer was simple, they said it didn't match what they observed in the field, which is what's critical to us.

There were several comments about how brush and trees can mitigate erosion; it can't. But there were a lot of comments also that said that it can cause erosion, and here's a particular case that weren't able to validate, but it was the opinion of the folks in Operations, that water got in here and got behind the trees, caused eddies, and caused this erosion. And this levee is like yours, it's a hydraulic spill which is basically sandy. Now, we also had a lot of comments about the scientific basis for the 15-foot setback. I also had a lot of comments that challenged that 15-foot setback, saying that it should be the dripline of the tree. Roots can extend, depending on the tree, well over 100 feet and can have an impact root-free zones and certainly can impact on a drainage system. Anybody here ever had to clean out your sewer line? Then you'd understand.

Also, there were several comments questioning about the appropriateness of a cement slurry sloop cutoff wall within an area where you have a lot of trees, which is an area we are concerned about and we're going to want to do a little more science on. I'm going to skip much of this, but you know, we went through this debate when we stood up the Dam Safety Program in the 1970s. We had several dam failures at that time that killed a few folks. Common sense taught us that you don't want to have vegetation on dams, particularly small dams that are like levees. One key difference, though -- some people question, well, why were you

referencing guidance that had to do with dams? What's that got to do with levees? Well, you're right, they are different, but in a way that you didn't intend.

Dams are built to a much higher standard of care than levees, and I'm going to skip that part, but there is one distinct difference. When we design a dam, we design it so that it can pass the flood through a spillway. We don't do that with a levee. Even though we design for a smaller flood, we don't have any way to accommodate overtopping flows except to survive the flood. Mother Nature doesn't know the difference between a dam and a levee; that's our silliness in trying to make that distinction. She only knows that something is in the way of her flood plane, and guess what, she wants to move whatever's there out of the way. And it's our job as engineers to convince her otherwise, that that flood wall needs to stay there.

As noted, levees do not have any way to pass overtopping flows, therefore -- I just wanted to highlight in this slide that the least desirable construction is a hydraulic spill. In New Orleans, we had 46 of the 50 breaches that were caused by overtopping, and those that were most susceptible were those that were hydraulic built. Dr. Bob Deany, University of California, has made several comments on how susceptible sandy levees are, and that's basically what you have. All the more why flood fighting is a critical feature when we have levees as opposed to dams. With every major flood, we learn the same lesson. Vegetation gets in the way. We have to go in there and clear it, cut it down, just so we can do inspections and look for those boils, and then actually do the flood fight. That's a loss of precious time.

Some comments referred to, well, show me the evidence that vegetation caused a failure. Well, most breaches wash away whatever evidence you can find. Our goal is that we don't want to ever have a need to have evidence; failure is not an option. This was one of those "taste great, less filling" slides; you could make a case either way. I want to talk a little bit -- there was some discussion about using risk to justify or not justify vegetation. We do not trade off a margin -- we have the minimum safety requirements; we do not use risk to trade off or marginalize minimum safety requirements. We'll use them once we've met the minimum safety requirements, same as this building, to make some decisions.

The challenges facing you as a system are that the structural stability of your system is in question, and any agreements in the vegetation that I referred to that prohibit maintenance or impinge upon emergency operations, it's really an issue; it does interfere with our minimum safety requirements. All the more that we should accommodate that in a smart way. The next steps, I'll go through these real quick. We're updating our current policy, we're going to put that out, and we're going to evaluate our existing policy and we're going to issue new, updated policy and implementation concurrent. And others will be talking about that.

I want to just highlight three areas where we need more science. We need to look at the 15-foot setback: is it enough? On the flood side, we need to do a better job of finding ways to integrate the infrastructure within a recurring environment, and then we have some concerns about the slurry wall. Now, my mother-in-law asked me -- oh, one more thing, I want to say that the Corps is developing a comprehensive engineering manual by the exciting name of "Engineering Design of Flood Risk Management Systems." But what it will do is provide guidance to design a system

integrating all the components, so you can see them all; we have the engineering to back that up. It will be based on reliability engineering and used to make risk-informed decisions. You will be able to assess how much risk your design can buy down and whether it's a good investment of your dollars. This is something we don't have right now. But help you make better decisions of just how much level of protection do you need. And our goal is to achieve a standard federal code based on the minimum safety requirements; we believe that by adhering to this code we can improve safety, we can minimize maintenance costs, we can provide a sustainable design, and actually, perhaps lower insurance premiums.

Now, my mother-in-law asked me, "What are you going to California for?" Like Mr. Stockton said, "Well, I'm going to a vegetation symposium." Well, her reaction was, she started reciting this poem, and I thought it was nice. It says, "I think that I shall never see a poem as lovely as a tree" -- well, to save time, you can read that. But I'd like to add a one-line poem of my own. In conclusion: "Levees are made by fools like me, where even God lacks space to plant a tree." I've designed levees, and believe me, they were stark as can be. But we need to get smart; trying to justify the status quo really presents a high risk to life. And ASCE just published [unintelligible] article in last month's issue, the July issue of Civil Engineering magazine titled, "In Harm's Way."

I was in Chicago last week and got to watch CBS evening news, and they were relating about the levee system here. The message is simple: the solution must be sustainable. We agree with that. And it's got to be one, though, where we provide public safety first and we integrate the system in a way that enhances our environment. All of us want a system that can protect us, but also one that we can enjoy and is beautiful. I will highly

encourage you to continue to work with our Sacramento district, the administration, congressional interests, to seek a solution that will help us achieve our mutual goals. I appreciate sharing this time with you.

Emir Macari: Thank you very much, Mr. Pezza. That was a good presentation of the Corps' perspective on the white paper. Now, I would like to ask Mr. Keith Swanson, Acting Chief of the California Department of Water Resources, Flood Management, to make a presentation on the overview of compliance to this white paper. How would California have to deal with this, and how can this white paper or these recommendations be implemented in our local community?

Keith Swanson: Good morning, everybody. I want to start off and thank the authors of the white paper. Some of you might be a little bit perplexed that I would be thanking the authors if you know my personal views on the white paper and you know the state's stance on it. I don't think we have a lot of agreement on the concept of vegetation removal from our levees because of the fact that it will result in destruction of critical habitat, it doesn't appear to effectively reduce flood risk, and it diverts money from more critical issues such as underseepage, erosion, evaluating pipe penetrations through our levees, and from my own personal perspective, if I get involved in removal of vegetation from our levees I'm going to get in trouble with my wife. She's a runner and she's up on the levee every day, and if we destroy that canopy, she's not going to be real happy and so it's going to be a problem for me.

But really, the reason that I applaud the core authors is that I think the white paper stimulates discussion on how we manage our flood control projects. I think we've got huge issues, and this discussion is long

overdue. And I'm excited because this forum has the players that need to work together on solving the issues. So, we have this symposium and then we have a Rec Board sponsor round table on Thursday.

During the early days of the state-federal flood control partnership in the Central Valley, life was good. There was federal money flowing into the state; first it was under the guise of navigation, and then later it was in support of legitimate flood control projects that predominately protected agriculture interests. In retrospect, though, a storm was building and moving toward land. Specifically, here in the Central Valley, levees were constructed without control of the materials that were used, without any kind of control on the compaction that was applied to the materials; levees were constructed with sub-standard cross-section. We have slopes with mature vegetation on them, that maybe a waterside slope of 1.8 to 1 - - probably areas steeper than that. The levee alignments were selected without any consideration for foundation geology, and that's causing huge problems now as we go through FEMA recertification.

The system was designed to erode; we've all heard about that, and that was great when we had mining debris that we needed to wash through the system, but it's really an untenable situation for a lot of our reclamation districts that are financed through agricultural interests. We have areas such as the Tisdale Bypass that don't even function as designed. The only way you can get the design flow through the system is if this other bypass is empty of water, and the system doesn't work that way. When the project was turned over to us, we had mature vegetation on our levee slopes, and that was contrary to Corps policy even back in the 1950s, but that's the system we have. There are a lot of people that would argue that

our system is dead from an environmental perspective because of the fact that we've constrained it so much.

From an operation and maintenance perspective, problems became even more apparent with the passage of Clean Water Act and the Endangered Species Act. Now, there's no doubt as to the importance and the national support for these two key pieces of legislation, but the requirements have a practical effect of restricting operation and maintenance activities. Beginning in the late 1980s, and probably just until a few years ago, should have been a time for action. But actually, I think it was a time of denial. We were all hoping that somehow our storm would stay out at sea. We've had an ineffective inspection program, and that's at the state and the federal level. The state budget cuts occurred periodically, first in the early 1990s, and then later in 2002, that timeframe, we had staff cuts, we had programs like sediment removal programs that were just completely eliminated. I think we had inadequate funding at the federal level also. Vegetation management was reduced. We stopped doing vegetation management in our channels for a number of years. In fact, Sac Bay program that was formulated to deal with this erosion program was brought to its knees due to impasses with environmental compliance issues. And we really have not addressed our ongoing underseepage issues. And I guess the other thing is, during that time we've had continued development of our Valley, so we put more people behind these substandard levees.

The situation got worse when the courts intervened. In 2002 Areola decision, local maintaining agencies were found liable for deferred maintenance. In 2003, Paterno's decision, the state was liable for latent design deficiencies associated with the 1986 break on the Yuba River.

We've had flood control project failures. First we had Jones Track, which was a local event that illustrated that delta fragility and associated risks of the State and Federal Water Project. And then Katrina garnered worldwide attention as we witnessed the catastrophic death and destruction that that storm brought on.

Now, the present time, the question is, are we in the eye of the storm or has the storm passed? If we focus on vegetation removal and only vegetation removal, I think we can expect more foul weather. Agencies aren't going to be working collaboratively together. I think you can expect that there will be lawsuits, poor public relations as the public questions the loss of important habitat and asks, are we really spending our money wisely? Is it resulting in risk reduction? I think you'll see a deterioration of agency relations. Recently, those of you that know about our interagency flood management collaborative program, it's resulted in critical erosion repairs occurring in an unprecedented timeframe. Things like our Tisdale Bypass sediment removal that's ongoing now wouldn't have happened without the cooperation that we've gotten from the Resource Agency.

I think we have a choice for an alternate reality. First of all, I think collectively we do need to agree that public safety is our first priority. Environmental compliance process must allow routine maintenance to occur, and timely repair of flood damages. In the spring after the water recedes, if we see a problem, we need to be able to identify that and get it repaired before the next flood season. Now, having said that, we also need to address our public trust issues. Management of our flood control project must be tied to species recovery, and I think really we're going to need to look at a system redesign to develop a sustainable system, and we

need to maximize habitat quality consistent with conveyance. We have a lot of our channels full of star thistle; we could do a better job of maximizing the habitat values consistent with our public safety needs.

We need a science-based approach, especially true with the vegetation issue. We need to focus on high-risk guidance. At the Levee Conference last month, George Sills said, "Y'all need to pick your risk." To me, that was one of the most profound things that I heard at the conference. And I think we need to move forward in a collaborative fashion. The challenge will be to separate critical needs from agency policy position. I guess, just in conclusion, I want to ask the group, do you think there's a solution out there? I personally think there is, and I think it's the challenge of the group to figure out what that solution is. Thank you.

Emir Macari:

Thank you very much, Mr. Swanson. It's certainly nice to see the Gulf of Mexico satellite today like this. Obviously, two years ago today it was not looking like this. We had Katrina basically bearing down on our coast, and New Orleans was very much affected as a result; Mississippi, Alabama. Prior to coming to Sacramento, I was chairman of Civil and Environmental Engineering at Louisiana State University. We formed the LSU Hurricane Center there, which got very much involved in issues related to evacuation. Evacuations were brought in incredibly as a result of some of the plans that were done from the center. One of the big lessons that we learned there was really one of the main lessons that we're trying to address in this symposium, the collaboration between the federal, state, and local organizations in order to better serve the public. So, I applaud you for bringing these question to the forefront and perhaps right before the break we can ask the audience if they have any comments

or any questions to any one of the speakers that are setting the stage for the discussion later today.

Our next speaker comes from the U.S. Bureau of Reclamation, Mr. Bill Bouley. He will be presenting on behalf of the Army Corps of Engineers and Bureau of Reclamation on the topic "FEMA 534: The Technical Manual for Dam Owners and the Impacts of Plants on Earthen Dams."

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 difference 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 uptaken 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 trunk 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](http://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.

Emir Macari: All right. Well, we are on time, and we have some time for questions from the audience. There are a couple of roving microphones, so please raise your hand if you have a question, and to whom you are addressing it from these first three speakers, please.

Male Voice: I have a question, or I want to echo what Keith Swanson said about system redesign. We really need to take that seriously. Our system is completely under designed and we need to redesign it from the bottom up. Some of the statements from Dr. Buer's talk were a little disturbing, and I'd like to see or ask him which two states have a law that prevents endangered species removal of vegetation? There are only two states with

that law, yet five have an aesthetic criteria. You know, we need to start reexamining these problems. Can I get an answer to that question?

Stein Buer:

At the time, Alabama and Delaware did not have a dam safety program, so I would guess Alabama and Delaware would be the two states that didn't have any criteria at all. So, it's probably been resolved since then. Oh, I couldn't tell you offhand. We'd have to get a hold of Dr. Tschantz, who heads a personal matter come up, and I was runner up number two, I believe, so I'm Miss North Carolina. But it might be in the publication; I can look through there, but I don't think it's that clear. We'd have to really get a hold of Dr. Tschantz from the University of Tennessee at Knoxville.

Male Voice:

Looking at the levees in the Sacramento area up and down the Valley, you notice an enormous number of trees on both sides of the levee, at the toe, large trees, and also on the levee. If those trees are cut down and it leaves roots behind, even if you try to remove some of the roots, what's the long-term effect of decaying roots on both sides of a levee and on the levee? And that could go to all three speakers.

Emir Macari:

I know that we are going to have quite a bit of science presented here in the next session; as a matter of fact, our next speaker, a horticulturalist from UC Davis that can speak specifically to that question. But would any of the speakers like to answer, or give it a shot?

Keith Swanson:

Just a quick comment. To me, that is a major practical issue that would have to be dealt with. I mean, if you're talking about hundreds of miles of levee with trees on them, how do you practically go about that? We're going to get into the mining business and we're going to completely rebuild our levee system. Because we have rough estimates, maybe 400

miles of levee with trees on them, and if you start getting off the toes, it's going to be a huge undertaking. And if you're going to do that, then you really need to start looking at a system redesign and rebuild the system properly to modern engineering standards. If we spend the money chasing roots, we're not going to have a lot to show for it.

Male Voice: A question for Mr. Pezza and/or Mr. Swanson. Part of what we're hoping to learn here is the areas where we have commonality so we can focus on the areas where we don't. It's my understanding that the state of California has regulations that allow vegetation on trees; we saw Mr. Pezza's presentation that allows -- I'm sorry, vegetation on levees -- how do those two regulations compare? And if they do compare fairly closely, why is this an issue in terms of trees being on levees?

David Pezza: Are you talking about title 23, section 131 in the state code? Is that the correct reference? I've read through the state standards, which I understand is title 23, 131, and they're very good standards. The challenge that we're having here is that vegetation has grown happenstance on the system, and there's no engineering applied to it at all, and trying to find a way to achieve the public safety objectives of our flood protection system within a system that is just happenstance is very difficult. The state's requirements are pretty good; I'd have to look at them a little closer to lay them down next to ours, but I was impressed with them. I thought they were comparable to what we would want. I had a couple questions about what they called a "minimum levee section," but other than that, they have it down in 131. But trying to implement that in a system -- you know, starting from new, that would work fine. But if you're trying to do it retroactive it's a challenge.

Keith Swanson: I want to echo the fact that retroactively with the situation that we have is going to be a major challenge. Our system was constructed, it had vegetation on the slopes, it was turned over to us, it had vegetation on the slopes. We've collectively operated and maintained it for the past 50 years and we've allowed additional vegetation on our slopes. And so, I think we can talk about enforcing the existing criteria, but really, again, we need to talk about how we rebuild a system that is sustainable.

Female Voice: I have a question for David Pezza. You had said earlier that you didn't science in the new vegetation policy because science did not match the visual observations that whoever had in the field. I'm just a little concerned about not using science in a policy, and I'm wondering why you don't use performance-based standards rather than technology forcing policy.

David Pezza: I stand to be corrected, but I was referring to the REMA report, that specific report. And that report was prepared by our research lab in the 1980s, and I think Dr. Donald Gray is here and he will talk about it. In his findings, he made some conclusions, and when I asked my predecessor as to why they didn't consider that specific report, they said that report didn't match what they had observed in the field. We have an extensive research facility; we have seven laboratories, we have one that's just environmental. And so we do a lot of research on the order of about 20 to 25 million dollars a year on research and support of our civil works project. So, we use science a lot to answer questions to help us develop policy. But in that particular case, we did not find that that science was relevant to what we were doing.

Female Voice: [unintelligible] has caused levee failure. I couldn't find any evidence in California for that.

David Pezza: Well, someone is probably going to chat on that, but what we have found when we go to do the forensics on a levee failure or a dam failure is that you're going to find very little evidence. It's generally washed away. We can only speculate, and we don't speculate. We can't use speculation for policy of engineering criteria. But we do know from practice, as you saw in some of the presentations this morning, vegetation is very hazardous infrastructure when it's not done in an integrated way. Seeing some of these pictures, I've had trees overturn and rip out my utilities because the roots wrap around the utilities. That's not fun. I've had to clean out my sewer line; that's expensive. That's not fun. I've actually got to replace it.

So, we've got to be, as engineers and all the elements of the team, we need to get smarter about how we integrate these things. Because if we don't, we create a situation where we damage the infrastructure, which is very expensive, and then we're faced with a situation where now we have to go, how do we deal with a habitat that's precious? So, we're faced with the decision of abandoning a certain kind of infrastructure or having to mitigate a certain habitat. And that's only because we as men -- it's a manmade situation, something we didn't give enough thought to.

Now, as for your question about performance base, we use minimum safety requirements. This building is based on minimum safety requirements. And then above those things, we can do whatever we want to do, but you must meet the minimum safety requirements first.

Male Voice: I think this is a question for Mr. Pezza. If in California we have two thousand miles of project levee, maybe 400 or 300 are urban levees, what are the ramifications of not complying with the Corps standards?

David Pezza: Well, the Corps has a responsibility under the code of federal regulations for public Law 8499, and within that program it's our responsibility to advise Congress and whoever else whether a system is in compliance or not. And if it's not in compliance, then we have a responsibility to recommend withdrawing that program. And what that means is, under the Rehabilitation Inspection Program, we would still participate in a flood fight, but we would not participate in the cost to do the repairs.

There's also a secondary risk to that. FEMA makes its own decisions, but if we pull the system out of the RIP, they take that into consideration when they're developing their flood maps. So, the implications can be enormous.

Male Voice: Perhaps, but there's the loss of, in effect, the PL 8499 funds to reconstruct a levee after it fails. If you go back to your definition of risk and you think about the non-urban levees in this state, perhaps that's not out of the question in terms of part of a long-term approach on a system wide basis here. If you're out, can you get back in?

David Pezza: Yes. You're just put in an inactive status and you're granted some time to get back in compliance, and if you exceed that period, you're placed in an inactive status. At some future point, you can go back and reapply; it's there and it's always available to you. The risk, and I think the focus right now is on the urban areas, and if we're going to use risk and prioritize, I'm hoping we're using this to prioritize which systems are the greatest threat

to life. I flew in from Chicago and I didn't see anything, I just saw farms, it was quite beautiful, and the levees. We're not really talking about that environment right now, because we can always replace a crop. It's people that's the biggest thing, and then the economics of an urban area is also more traumatic.

Emir Macari:

Well, thank you all very much. We're going to hold questions for a little while longer. We have a break now, it is a 15-minute break, I ask you to please come back on time. It's not easy to move in and out this great audience, and also if you could leave a little bit of room behind you so people can squeeze in, there's a lot of people standing in the back and I know that there's tables and chairs available. So, let's get back here at 10 after and we'll start promptly. Thank you.

All right. And if you could squeeze in a little bit, there's a lot of people that needed seating. We're going to put up additional tables and seats during our lunch break. Our first speaker of the second session, which will be mostly on the science, is Dr. Alison Berry. Dr. Berry is a professor at the University of California Davis, Horticulture and Plant Sciences, and the topic of her presentation is root architecture, root response to soil conditions, levees, and river hydrology. And I think a lot of the questions of issues that were presented this morning will be answered in this presentation.

Alison Berry:

That's quite an introduction. Thanks, Emir. I'm glad to be here this morning; good morning everyone.

The purpose of this symposium is to talk about vegetation and levees. I think these two photographs depict sort of the key characteristics and the

challenges of the levee systems of Central Valley California. On the one hand, levees afford important protection for our rapidly urbanizing neighborhoods adjacent to levees, and at the same time, the vegetation on the levees is a major riparian forest which provides rich habitat. And to say nothing, of course, of the central resources which is the water system itself. But there are concerns that vegetation on levees poses threats to the integrity of the levee, so I'm going to talk about particularly tree roots. I'm going to talk about some of the issues of tree roots as potential risk factors, and particularly I'm going to focus on how do tree roots grow and how do they grow in relation to levees.

So, the two key questions that I get out of the report, two of the most important factors that are of concern in terms of tree roots is whether they grow into the levees or under the levees and increase seepage or underseepage. So, that's one main issue. Another is windthrow; we saw some slides earlier of trees falling over and root systems uprooting, and those increasing surface erosion. Dr. Chris Peterson is going to be speaking about windthrow later this morning, so in the second part of my talk I'll just focus a little bit on the seepage question, where do roots grow in relation to levees, in relation to this question of seepage. The first part of the talk, though, I just want to have a "roots 101," how do tree root systems grow. And these are the major characteristics; I'll talk about each of these a little bit more in detail in the next few slides.

First of all, tree roots grow horizontally and they grow vertically, they are three-dimensional structures in the soil with a lot of variability and differences in pattern. Secondly, tree roots grow opportunistically. If soil conditions are permissive of tree root growth, trees will grow there -- in your sewer or whatever if they're very vigorous rooters. If soil conditions

are prohibitive to root growth, roots won't grow there. So, that's another characteristic of tree root growth. And thirdly, tree roots grow biomechanically, so they grow in relation to the whole structure of the tree and to the stresses and the symmetries and the weights that are distributed and transmitted to the root system, the structural root system which is supposed to support the weight of the above-ground part of the tree. Then I'll talk a little bit about implications of some of these aspects for tree failures.

So, here's a current classic view of a tree root system shown in this diagram. First of all, you can see that the horizontal direction spread of this root system is enormous in relation to the vertical spread. It's quite common in many growth conditions for the horizontal spread of the root system to extend at least as far as the canopy, sometimes two and three times as far as the canopy. Now, I must say that the root diameter as you get out towards the edge of the canopy usually will decrease greatly, so we're talking about much smaller roots at the edges of the canopy than certainly you have in the center. But nevertheless, the horizontal growth of root systems in many conditions is very expensive. And surprisingly, you can see how shallow, in terms of depth, that tree root system is. It's down to about a meter in depth, so three to four feet is about the maximum extent of, say, 80 percent of the root system of many, many trees. That includes the fine root system, but it also includes those woody roots, so that's kind of a surprise also.

And you'll see there's no taproot in this drawing, and that's because the tap root is part of the juvenile growth of the tree, but usually, in most mature trees, with few exceptions, there is no major taproot. Instead, we have these sort of three different woody systems that make up the mature

architecture of the root system. And all root systems are composed of these different systems in different proportions or combination. So, there are heart roots; you can see there the very thick buttress roots in the center of the diagram that support the main structure of that tree are called the heart roots. The horizontal woody roots that extend out exploring the soil volume, horizontal root system, and then you can see those vertical roots extending downwards, and those are called sinker roots. So, every tree root system has got some combination of these three systems of roots.

Now, let's go on to the second point: roots grow opportunistically. This is a diagram of a tree root system that was excavated painstakingly, cubic soil by cubic soil volume, showing how the root system is growing, where it's growing in the soil profile. So, tree roots are opportunistic. They need moisture, they need nutrients, and they need good aeration, so where they find those three conditions they will grow very well. And that's usually in the top foot or two of the soil. That's why a large fraction of roots are growing in that part of the soil. Mechanical impedance is also an important component of tree root growth; that is, high mechanical impedance will prevent roots from growing.

So, here's just a typical root system of many trees. You can see the central buttress roots there, the woody heart root system; you can see those lateral roots that are tapering in diameter as they go away from the base of the tree. And you note the marker there indicating 40 inches, so that's about three to four feet; most of the root system is located in that three to four feet. These are classic concepts. In the next part of the talk, we will see some differences on that, but this is just sort of basics that you want to know.

Now, I'm going to show a few examples of different kinds of root systems, so variations on these themes. And again, soil conditions are a major criteria determining whether and how root architecture is developed, as well as certain tree species characteristics. So, this is a group of cottonwoods from Cosumnes River, and you can see they've got some buttress roots there; very strong, extremely vigorous horizontal roots. Those are not decreasing in diameter as they go away from the tree. And very strong sinker roots. So, this is a very aggressive root system -- exceptionally aggressive.

On the other hand, this is another example from along the rivers here in California. This was a Valley oak that was excavated by Don Gray and Doug Shields in their study about 15 years ago that has been referred to here, along a levee in the Sacramento River. Very sandy soils, this is a Valley oak, and look at that root system, it's going right down, and you can see the laterals are also very vertical in their orientation. It's unclear whether this could even be a taproot; it's more likely it's more than one root sort of twining around, so these sort of vertical center sinker roots. So, here we have a deep sandy soil; it provides very little mechanical support for a root system and it's probably very dry, droughty soil. So, the roots are growing downwards; they're probably growing along a moisture gradient and they're not spreading laterally due to biomechanical issues.

So, that's a contrasting kind of root system to the cottonwood; certainly not an aggressive root system at this level. Here's another very typical, this sort of root plate. We saw a few images of that earlier in other people's talks. These are usually because of shallow soils, you have a very shallow root system or there's some kind of clay pan or hard pan underneath, so you get this very broad, dense root system. It has very

poor stability; it can be supported -- this was a Douglas-fir growing in a forest, they opened the forest to build houses and so the tree was much larger on the top than its root system could support, so in a storm it uprooted. So, that's a very flat root plate.

Here's another kind of a tree failure. This is a pine, very typical root structure of pines. They have often a very shallow surface plate, then they have some sinker roots, and they may have a deeper plate below. So, this one here had a very large canopy, asymmetric, so the above-ground part was heavy, it was growing into the gap, and when the soil became saturated it just seems to have hinged down. These roots look to me as if they fractured at the base rather than pulling the whole root system, so it's different from the root plate action.

The third point is that trees grow biomechanically, so roots respond to stresses and shifts in weight, bending stress and axial stresses can produce a reinforcement of the wood in areas where there is maximum stress. You can see I-beams or buttress roots and so on. In addition, the whole tree transmits stress to the root system which is supporting the above-ground part, and some asymmetrical force can cause compression on one side and tension on another. This could be wind or this could be other kinds of asymmetry, such as differences in the crown symmetry, sun exposure if the tree's growing on a slope, or if the soil itself is unstable. So, the whole tree has an affect on the architecture of the root system, which compensates to support the weight of the tree.

So, uprooting is a major concern near and on levees, and I just wanted to mention quickly, from the viewpoint of root architecture, there may be different damage levels due to uprooting based on different species,

different conditions of soil, and different root architectural patterns. So, shallow root plates, as we've been discussing, might be one to two feet deep; they uproot, they're unstable, but they create rather a shallow divot. Aggressive root systems, however, can penetrate broadly, can penetrate deeply, and those systems can cause potentially severe damage, in my opinion. Steeply tapered roots like we saw in those buttress roots, those central heart roots, tend to fracture as they go over rather than pulling up the entire root system. So, there are different mechanisms of root system failure, and with different consequences.

Now, we get to the question that was brought up. Do dead roots pose threats? What about root turnover and the formation of channels? I think we need a lot more information on the persistence patterns of dead woody roots, large roots, and their turnover patterns. It has been reported in the literature that large diameter Douglas-fir roots - that is, two-inch diameter roots - persist for 50 years or more. Hardwood roots are more susceptible to decay; they may have a different trajectory - 20 years, 30 years, something like that. In either case, as decay takes place, you get deposition of organic material; it makes a nice channel for roots to grow in. If there are other roots around, they'll be opportunistic and they'll grow in those channels very nicely. But on the other hand, if there are no other roots around, if there's large-scale tree removal, then it's been shown that indeed these lots of killing of the root systems will result in soil destabilization.

Okay, so that's the first part, the primer on root growth. I want to now get into, where do roots grow in relation to levees? Do large roots grow into or under levees and cause increased seepage? I think excavation trench profile method, as has been done in the past, is still the best way to find

out essential information. And we're only just starting this project; we have a trench profile project at Mayhew levee here in Sacramento. We've done just an initial look, and so this is one location and three trees that we've excavated. So, this is an overview of the Mayhew levee; it was constructed in the 1970s as part of establishing this residential neighborhood here adjacent to the levee. You can see the levee road, you can see the 300-foot berm there, running along the American River. There's quite a wide berm before you get to the levee itself. So, the levee is scheduled to be re-graded, so this provided a really good opportunity for us to come see these trees along the slope there, along the berm itself and the toe of levee, provide good opportunity to do some excavations and see where tree roots are growing.

Ones we look at, really, are mature oaks; we just looked at three mature oak trees. You can see here, this is one of them, and this is the one I'll mainly talk about today; the others were very similar results, however. This is 14 feet from the toe of the levee; they ranged from 14 to 30 feet from the levee toe. We did use the trench profile method, so you excavate a backhoe trench, you climb into the trench and you use some acetate sheets, marking grids, to mark where the roots are and what sizes they are. So, the trenches were four feet deep; by contract, we had that restriction, and they were running parallel to the levee, just at the toe of the levee.

The length of this tree crown, from dripline to dripline, is 56 feet, so we have a trench of 48 feet along the length of the tree. So, here's our backhoe excavating the trench. You can see the levee toe there and the tree. It was a big project and it involved a lot of people, a lot of help; SAFCA sponsored the project, Army Corps was there with a lot of help,

and a number of people, scientists were there. We had a lot of help from consultants and other organizations, and we had a great research crew from UC Davis and Sac State who helped us with the excavation.

So, here are some data; that's our full profile of the one tree. You can see the roots look like pepper on that profile. The tree trunk is towards us and the levee toe would be away from us, into the screen. Here's just a chunk of that 12-foot length of what we found. And as I said, we found essentially the same results in all three trees. So, here's our four feet profile. Roots 10 millimeters or less in diameter are black dots, and roots 10 to 19 millimeters are red dots. The black dots, I should say, are most roots below 5 millimeters, so 1 to 2 millimeter roots. We were just recording every root, so most of the root system that you see in the top four feet, 14 feet from the trunk of this tree, were tiny 1 to 2 millimeter roots. The red dots are 10 to 19 millimeters; that's less than an inch diameter, so we had a smattering of those. And essentially we had one root in the entire profile that was over an inch in diameter.

So, very different from the classic concept. Where are the roots? We're down to four feet -- oh, and we're well within the canopy here, and we're well within the dripline. I wanted to show bulk density over there on the far right; we did some bulk density measurements. You can also see there's a zone with almost no roots in it, that's a two to three foot zone, and it was highly compacted, very uniform. It looked like we may have grazed the toe of the levee and there was a compaction zone there. And you can see that's reflected in bulk densities, which increased significantly in the middle of the trench. So, bulk density for this trench at that depth was 1.63, and the critical bulk density for root growth in this soil type is 1.65. So, I just wanted to have that illustration to show you

roots growing in a sandy loam soil at these different bulk densities, 1.6 and above. Basically, we found that roots do not grow in that compacted zone; it was a successful mitigation effort.

All right. So, where are the roots? So, we said, let's just do one scoop of the backhoe below four feet. And so here's the trench floor right across from the trunk, and sure enough, we hit roots. Not very many, but some. You can see it's a two-inch diameter root; there's a couple of one-inch and so forth in that scoop. So, amazingly enough, although there's no roots in the top four feet, we were finding roots at the toe of the levee here at two-inch diameter. We wanted to corroborate that. We are also experimenting with ground-penetrating radar as a way of non-destructively analyzing root systems in soil. In fact, John Lichter shown here has really been a leader in this field, developing a GPR or trying to apply it and other tools, too, to look at root systems of trees.

So, here he's running a scan line; we set up an experiment with five scan lines, shown in this diagram. The tree itself is on the left and you can see the levee slope there, so one, two, three, four, five scan lines running parallel, again to the toe of the levee. The one in the middle corresponds with where we excavated, where our trench profile was. So, five transects three feet apart, two of them on the slope, two of them on the berm. And we did this for the three trees. Again, I'm just going to show briefly one set of data here, and this is very preliminary. It's almost raw data. There are some calibrations that we need to go out there and do in the field; these are just the early glimmerings, and there's a lot of chatter, a lot of artifact, which you can see as these sort of vertical lines in this tree.

I'm not going to go into detail on this. I'll be happy to talk about methods with you if you like, but essentially, the take home is that those red dots, except where you see the vertical lines, can be interpreted as roots. The antenna we used detects roots only one inch in diameter and greater, so we're not picking up any of those small roots that we saw in the trench. It can penetrate eight to ten feet. Essentially, the GPR data indicated that any large roots present were between four feet and six feet in depth, which is just where we actually did see them in that single scoop that we did. So, if we take a sort of overhead view of the transect, and again, you've got the tree and then the five transects - you can see the two on the levee slope there - the X's mark what can be interpreted as roots. Or they could be rocks. But that's the beauty of the transect method; if you have parallel lines and you can see the roots going from one to another, then that suggests it may be a root rather than a rock. In fact, we found very few rocks in these soils anyway. And the squares are artifacts, probably due to the way we were rolling the cart or something like that.

These are things we have to sort out, so I'm almost hesitant to present these, but it confirmed our data so nicely that I just thought it gives you a hint, and it has some promise as a methodology, I think. Again, this is the depth range between four feet and six feet; 41 inches to 72 inches. And if you squint and use your imagination, you can sort of trace some roots, potentially, from one transect to another. I think we need to repeat this with a slightly more dense array, but it looks as though there are quite a few roots close to the tree, or some roots, and this is the entire scan. This is the entire 50 feet of the canopy, so we're scanning from one end to the other; this is the sum and substance of the roots in this tree. But you can see some do extend - maybe - this is what we call "virtual trenching," so we have to call these "virtual roots." But we'd like to go back and confirm

it. But it's potentially possible that there's a root or two in this zone, 41 inches to 72 inches that might be getting into this part of the toe of the levee. Now, they're not into the compacted zone so they're probably going underneath the levee.

So, take-home messages to wind it up. First of all, some roots, anyway, could be growing under the Mayhew levee from nearby trees. However, the roots avoided well-compacted fill. They were not growing into that toe region of the levee. So, that suggest that some mitigation measures such as keyhole trenches or the slurry walls or deep protection trenches may be effective in coping with these root systems. Again, they are opportunistic; they can only grow where they are able to grow. However, there are many unanswered questions raised by just this much data.

Where are those roots in the top four feet of soil? Is it because it was an oak species, it had some particular characteristics of this species? Is it because of California Mediterranean climate, we have a droughty soil? Is it because of that relatively high berm? These are some very good questions that I think we need to get at. Are their species differences, are there differences in rooting patterns in different soils or regions in the country? We need more information combining trench excavation and other methods such as GPR, if we can get it standardized, to determine the real picture of roots and levees.

Now, just as a final point, as I was preparing the biomechanical part of roots 101 and thinking about rootshoot consideration, it occurred that crown asymmetry is a high risk factor, and also crown size. Pruning, while it may be a very expensive route, could reduce risk of root damage considerably, both from blowovers and reducing the overall vigor of the tree. With that, I'll conclude and turn it over.

Emir Macari: We have time for two questions.

Female Voice: Cheryl Blichester. So, as I remember it, Mayhew levee had eight Heritage oak trees between 250 and 450 years old that were off the toe of the levee. If the Corps of Engineers had elected to explore other designs other than their standard design and had come up with a slurry wall or something, I don't remember what you said at the beginning in your primer about the roots breaking off, at what size they break off, but what is the likelihood that any of those trees, had they remained, would have toppled and ripped up a levee in a way like what's being described?

Alison Berry: Well, we did an excavation along the toe opposite one of those Heritage oaks, and we also did not find roots in the top four feet. But without going further and figuring out where the root system is in relation to the levee using GPR or some other excavation method, I think it's new enough in terms of this as a root system configuration that we really need to do more work on it before speculating on whether the whole system could tumble over. In terms of the breakage potential, yeah, there are a number of papers and publications on root strength decreasing diameter. I can't quote you off the top of my head, but I'd be happy to find those for you. The larger diameter roots are reinforced because of stresses placed on them. That's why they're larger. And the smaller diameter roots are much weaker.

Male Voice: I'm hopefully not going to put you on the spot, but I noticed some similarities between your talk and the talk on the FEMA paper in terms of root structure. But one thing that was kind of troubling me was that in the FEMA paper, they noted that roots can actually cause destabilization of

the soil, and you're saying at the same time, if you have compaction, it's not going to occur. So, I'm trying to make sense of that, and hopefully you can make some sense of that and my comment in terms of, what do you see happening in cases? Do roots actually destabilize soil or not?

Alison Berry: I think Don Gray and Doug Shields may be going to comment on that a little more in terms of there is definitely literature, despite what was shown in the slide, there is definitely a literature suggesting that root systems can stabilize soil. So, there is more than one approach out there, perhaps, but I think Don Gray and Doug may address this more than I can.

Male Voice: Hi. Collin Clark, Water Resources. I just want to point out that particular area right there -- I don't know how you came up with your OG for where your roots are, but out there I can guarantee there's at least two extra feet of dirt on top of that. Some of it's sloughed off of the levee, and a lot of it was put on that particular tree by the guy who owns the house behind it.

Alison Berry: Well, I'd like to say that we did excavate the root flare, and actually the soil line is right above the root flare. So, there's not much of a fill soil on that particular tree.

Emir Macari: Thank you very much, Alison. Our next speaker is Dr. Donald Gray, who has been mentioned a couple of times already. He is a professor of Geotechnical Engineering from the University of Michigan, Ann Arbor, and he has been working on this issue for a number of years now -- over 20 years. Now, his presentation, though, will show some perfect example or analogy to what we're trying to do. He's trying to put in a presentation from Apple Mac into a PC, and the people will not be perfectly served.

So, what we're trying to do here is have the federal government, the local government and state government work together so that people get served perfectly. So, here with go with the presentation. It's not that bad.

Donald Gray:

The best-laid plans. . .As a mere mention, I'm a geotechnical engineer who has spent the past few decades investigating the influence of woody vegetation on the stability of slopes and the consequences of removing that woody vegetation. Together with my colleague Doug Shields, whom you will hear from after lunch, we spent a summer in the late 1980s investigating the influence of woody vegetation on stability and structural integrity of a levee along the Sacramento River. And this study has already been alluded to by a previous speaker. Doug Shields will describe the results and findings of that study, and I think you will have a slightly different take on the conclusions that were reached from that study.

At any rate, during the next half hour I will be reviewing the factors that affect levee performance, the damage mechanisms - some of which have already been mentioned - and the role of vegetation. And I hope to convince you that, by and large, woody vegetation - tree - have a positive or beneficial influence on stability of levees, and by implication on their safety as well. So, I'd like to begin my presentation by showing a photograph that shows a failed levee with trees growing on it. And this is one of the reasons that trees get a bum rap, these types of photographs. It's called "Guilt by Association." If trees are growing on a levee and the levee fails, then the trees must have caused the failure -- or at least, so the reasoning goes. And I'm afraid to say that this type of logic is seriously flawed. The fact of the matter is that levees can fail for a host of reasons, most of which have nothing, or at least very little, to do with either the presence or absence of trees.

So, these are the three major categories of damage or failure mechanisms, which have already been mentioned; mass stability failures; superficial erosion; and hydraulic forces. Well, let's take a look at these in a little more detail. Mass stability failures, slope instability, this can include varying capacity failures, lateral translation failure, shallow sloughing failure -- although in the case of shallow sloughing failures, the presence of woody fibers in the soil can actually help prevent the failure. And finally, deep-seeded rotational failures, and even in this case, the presence of woody vegetation can have a beneficial effect.

Structural failures of walls and sheet piles, dynamic structural impact; that is, if you have barges which knock into a levee during a flood time. Superficial erosion; this includes overtopping. In the case of overtopping, again, this is an instance where the presence of vegetation actually has beneficial effects. Jetting, which is a form of waterfall erosion, when you have water run off the top of the flood wall, impinging on the levee slope below. Lateral tangential surface erosion; again, woody vegetation - particularly supple woody vegetation, where you have stems which bend over in the flow and protect or armor the slope - can have a beneficial influence.

Wave impacts, which include notching, scalloping; here are some cartoons showing overtopping failure or damage mechanism. Wave erosion; these are taken from the Independent Levee Investigation Team Report in 2006. There were two major reports following the Katrina hurricane and the failure of many of the levees, but the first was called the IPET Report - the Interagency Performance Evaluation Team - and then

there was a subsequent investigation called the Independent Levee Investigation Team. So, these cartoons are taken from that second report.

So, when you have waves that impinge on a levy, you can get scalloping or crenulations shown here on the levee prow. Now, hydraulic forces; this is a major concern and also a major cause of levee failure. It includes foundation under seepage instability, bottom-heave or blowout where you have upward flow of water the landward side of the levee, and if this upward flow of water is at a critical gradient, then the soil loses all its bearing capacity and its shear strength and you have serious failure problems. Seepage erosion and piping, exit seepage erosion; this occurs when the phreatic surface - that's the seepage line at the top of the saturation zone - intersects the inboard or landward levee face. And internal seepage, sometimes referred to as through-seepage erosion, where soil particles become entrained in the seepage flow and are just simply washed out.

So, here's another cartoon showing these damage mechanisms, both water seepage - water going under the levee and emerging on the landward side beyond the levee toe - and through-seepage, or internal erosion and piping. Now, if you have underseepage emerging at the levee toe or beyond the levee toe, you can get what's called a critical gradient condition, or "quick" condition -- that's when you get out of there quickly. Under these conditions, the soil loses all its shear strength and bearing capacity; the critical gradient -- this is a Physics 101 typical final exam question, what's the typical critical gradient in the soil? And it turns out the critical gradient is on the order of one, and you can calculate that critical gradient by this simple formula here: the saturated density of soil minus the density of water divided by the density of water. The typical

saturation of soil - sandy soil, at least - is 125 pounds per cubic foot. So, you put those numbers in there and you get a critical ingredient of one. So, upward flow of water and critical gradient conditions, you have lots of bearing capacity and lots of shear strength; in that case, you could lose part of your embankment slope.

Now, the difference between levees and earth dams was discussed earlier this morning. In the case of earth dams, we normally have a permanent reservoir or reservoir surface, and you have so-called steady state conditions, you develop a flow net, the seepage line or phreatic surface. This seepage line up at the top, the flow net would intercept the downstream face of the dam, and that's not good, so different types of drains are put in to prevent that seepage line from intercepting the downstream face of the dam.

Now, in the case of a levee - you see the cartoon over on the right hand side - levees, for the most part, are high and dry. We took a tour of the levee system in the Sacramento area yesterday, and they're all sitting high and dry right now. So, there is no phreatic surface in those levees, and the phreatic surface only occurs during flood times. The time for that phreatic surface to develop and extend across the levee and intercept the downstream flow is a function of the height of the flood stage, the geometric properties of the levee, and the permeability of the levee. In this particular simulation here, it took 12 hours for that phreatic surface to fully develop and reach the downstream flow.

Now, causes of internal or through-seepage; you don't need a pre-existing void -- void volume defect or crack or fissure in order to have internal seepage erosion. This can occur when you have unstable soil gradation,

so-called gap-graded soils, which the fines can actually travel through the network or framework or larger, coarser particles. Unfavorable stratification; not all levees are homogeneous; you might have layers or strata in the levee which permit through-seepage. Hydraulic fracturing; we don't hear a lot about that, but hydraulic fracturing can lead to preferential seepage paths without the need for a pre-existing crack or fissure or void volume defect. I'll say a little more about that in a second. Rodent burrow tunnels are being mentioned as a possible source of through-erosion or seepage, and finally, relic tree root holes.

Now, hydraulic fracturing is an interesting phenomenon; it was discussed at length in a very important paper by James Girard, he is a geotechnical engineer back in 1986, who looked at hydraulic fracturing in earth dams. Hydraulic fracturing occurs when you have internal stress distribution within the levee or the dam which leads to soil arching effect, and this means that you can have surfaces within the levee or dam in which the vertical stress, the confining stress or compressive stress, is extremely low. And that allows hydraulic pressure then to jack open the crack in the levee that allows through-seepage.

Levees are more susceptible to this type of problem because they're generally low structures, so you start out initially with much lower vertical stresses. In addition, levees are susceptible to differential settlement, and differential settlement introduces soil arching effects, which produces, in turn, the stress distribution within the levee structure. This is just an example; in this case they're not river levee, they're delta levees, which shows the amount subsidence which has occurred over the years, and it's this type of subsidence and the differential settlement associated with it that can lead to hydraulic fracturing.

Now, this is the study which has been alluded to several times. This is the report of investigations of this study that Doug Shields and I worked on many years ago. It was a study looking into the effects of woody vegetation on the structural integrity of the Sacramento River levee system. I would mention to you that this report was vetted by all the core districts before its publication; this report was sent to every core district in the United States. They had an opportunity to comment on it before it was published.

One of the things we do in this study, and Doug Shields will be talking in much greater detail about this, is we trenched through the levee and we did so in order to study the architecture and distribution of roots. We used the profile wall method that Alison mentioned previously, but in addition to the distribution and type and depth of roots, we were also interested in perforation features that appeared in the trench. And here's two types of perforation features -- I would mention that we saw quite a few rodent tunnels in this particular trench, only one or two rootholes; all these tunnels or rootholes were filled with sand, producing what's referred in the literature as a pedotubule. You can see on the left a former rodent tunnel is being infilled with finer sand which has washed into the tunnel over time. And this happens in the same way with roots when they decay and rot, the sand gradually fills in the tunnel that's left behind.

Now, this was one of the problems with transferring my Apple presentation to a PC, but these are just the cover page from the two agency reports that I've already referred to, and they observed all the same types of levee failure mechanisms, damage mechanisms, that I've already discussed. They also talked about the influence of trees, but the

interesting thing, both reports had very little to say about the influence of trees. In fact, the IPET report did not even mention trees as an important cause of failure in their findings and conclusions. And in the ILET report, this is all I could find, just a short paragraph describing the effects of trees in which they are referring to two figures where they showed tree toppling. And this is one of the figures, it was a tree toppled next to a levee on the London Avenue canal. Well, they were not able to determine whether the tree toppled and that caused the breach, or whether the breach occurred and that had caused the topple.

Another interesting thing about this picture is look how close those houses are to the levee toe. Again, on our trip around Sacramento yesterday, we were looking at levees and I was struck by how many houses literally butt right up against levee toes, and I'd be quite concerned about how many of these houses have basements or swimming pools, because basements and swimming pools next to a levee are not a good idea. Well, this is how they explain the tree topple phenomena; this happened to be a cartoon of one of the New Orleans' levee with a floodwall on top of it, and you can see the flowline underseepage coming up beneath the tree. However, it doesn't make any difference whether there's a tree there or whether there's not a tree there. If you have underseepage, upward flow, and a critical gradient, you're going to get lots of bearing capacity, loss of shear strength, and you're going to get a failure. So, it'll topple a tree, certainly, but this problem would have occurred regardless of whether there was a tree there or not.

One of the interesting things about the effect of levee vegetation was this photo, which appeared in the ILET report, showing a vegetated levee, there's only grass on the levee structure itself but there's plenty of woody

vegetation growing right next to the toe. And they cited this levee as an example of a levee which performed exceptionally well and was not eroded during Hurricane Katrina or the earlier Hurricane Rita.

The main cause of levee failures in the New Orleans system was the composition of the levees. The levees that failed tended to be very sandy, and when you look at a plot of erosion rate as a function of velocity for samples of the levee material, you can see that samples with very high erodability, i.e. sandy levees, tended to have erosion rates even at relatively low velocities. Whereas levees that were more clay had very low erosion rates even at high velocities.

I'd like to talk a little bit in general about the influence of woody vegetation on the mass stability of slope. There are two main mechanisms by which woody vegetation influences mass stability, and that is hydrologic and mechanical. And there are indeed, beneficial and adverse influences of the vegetation. This is one of my slides that did not transfer over very well, but all it is is just a listing of all these different mechanisms - hydrologic and mechanical - and whether or not they're adverse or beneficial. About two to one in favor of beneficial mechanisms and even some of the adverse mechanisms can be mitigated or eliminated by management technique, which I'll get to in just a second.

Well, here's an example of an adverse mechanism. This is a poor choice; this tall, rigid tree is not a good choice to be going on a levee for a variety of reasons. You can get scour and erosion around the base of the tree, and because it's a high tree with a big sail effect, it's liable to blow down and overturning, which has already been discussed. But this blow down or overturning hazard can be eliminated by a practice known as coppicing,

and in coppicing you just simply prune the tree at breast height and bring the crown way down so it's no longer subject to windthrow or overturning, but you still preserve the advantages of the root system.

So, these are the main protective mechanisms of vegetation in preventing mass erosion: root reinforcement, soil moisture depletion, soil buttressing and arching effects, and even surcharge, the weight of the vegetation under certain circumstances can be beneficial. Root reinforcement is the most intuitively obvious way in which woody vegetation promotes soil stability. You cannot explain the existence of this structure in the absence of woody root fibers. The presence of these root fibers in the sand transfers shear stresses, soil salient shear; the transfer of shear stresses in the soil through tensile resistance in the root.

We have seen the effects of root reinforcement in both laboratory and field studies. This is just the laboratory study showing the influence of increasing numbers of fibers in a fan, and so it's a plot of shear stress versus horizontal displacement; these are just stress strain curves showing increase in peak stress or shear resistance with increasing numbers of fibers. Field studies have corroborated this effect; this is an in situ direct shear test performed on a root-permeated soil pedestal, and you can see that as you increase the concentration or number of fibers in the shear cross-section, you also increase the shear resistance. These increases in shear resistance can be substantial, and if you have some way of determining what is the biomass of roots per unit volume of soil, and you take the results of these shear tests, you can then factor in this increase in shear strength into soil stability. And my colleague Doug Shields will be getting into this later on after lunch.

Lastly, what happens when you remove vegetation from hillsides? Most of the research here is focused on hillsides in which trees are being removed in clear-cutting operations. And it's being observed that somewhere around 10 to 15 years after you clear-cut the vegetation is when all the slope failures start, and that seems to coincide with the period when the tree roots have rotted and before new roots have colonized the slope. So, the question that was raised earlier here is certainly a good one; what are you going to do with all the trees that you cut down and leave roots behind in the levee?

So, the thought that I'd like to leave you with before closing is that woody vegetation can provide multiple benefits, including improved stability against slope failure, and I think we need to shift the discussion away from removal, per se, and towards maximizing benefits and minimizing the liabilities. And there a number of strategies and techniques that can be implemented to obtain these goals, and they include such things as selection of the proper plant species, placement and removal strategies, and management strategies that would include things like pruning and coppicing. Alison's already mentioned that.

So, I'd like to end there, and also respond to the poem that Mr. Pezza gave us earlier today by quoting my Scottish mother, who was fond of saying that "there are better ways to kill a little buggie than boiling him in water." And I would say that there's better ways to fix levees than cutting all the trees down. Thank you.

Emir Macari:

Thank you very much. Obviously we see a very different perspective in Dr. Gray's presentation, and this allows us to have a dialogue again. So, any questions from the audience please raise your hand.

Male Voice: Dr. Gray, your two closing points were maximize benefits, minimize the liabilities. You did a good job of discussing the potential benefits; please enumerate what you've identified as the liabilities.

Donald Gray: Well, I think I already mentioned potential liabilities. One of them is the overturning and blow down threat, but I suggested a way that that could be addressed. Another potential liability is the -- this is an issue that I'm sure is going to come up, and that is the inspection issue. But there are ways of planting trees and pruning trees in such a way that you can provide viewing alleys or inspection alleys to facilitate inspection. And even if you have to remove trees, the worst thing you can do is to just come in and clear-cut all the trees on the levee.

British Railroads was faced with this problem of having to remove some trees from their right-of-ways along their railroad tracks on their cuttings and embankments -- and I think I have a slide here. They went to a phased vegetation clearance scheme where they removed vegetation in chevron pattern so that they never had a clear line downslope with no trees in it. So, this is just an example of yet another strategy that could be invoked to minimize liabilities and maximize benefits of vegetation.

Male Voice: One of the presentations earlier today suggested that at least from the perspective of priorities, deficiencies in the flood control system in California, vegetation removal or vegetation management seem to one of the more low priority problems. I'm curious if the Katrina researchers identified tree-related failure mechanisms as one of the failure mechanisms in Katrina. And for that matter, what's the experience been

more broadly in core districts or in the academic community in describing these things as causing levee failure?

Donald Gray: Well, I'm not sure that I can answer your question, but I did read the two reports very carefully, and as I mentioned, trees did not loom large as a cause of failures in the New Orleans levee system. I don't know what else I can say beyond that.

Male Voice: Perhaps this question is best asked at the end of today or even tomorrow, we already see these differences of views and observations, and maybe this is more of a sociological question than the realm of science. But why is it in so many other branches of natural resource management the positive values and slope stability erosion control are so much in evidence, yet on the other hand in our classic flood control engineering community an almost opposite view has come to light? Do you have any observations on the history of why these diverse views have come about?

Donald Gray: I don't know that I have a good explanation, but I can say that in my own training as an engineer, I was not really exposed to the influences and effects of vegetation on slope stability. I can't remember any course or mention of it during my years at university.

Male Voice: Just when I think I've begun to understand underseepage, I get confused again. The soil profiles in the Valley in many cases the upper layer is silty clay or fine silt, which tends to confine the hydraulic gradient that's in the coarser sand. Now, in that situation, is it likely that the toppling of the tree, the removal of a root ball that removes part of that overburden that's confining that, would allow it to become critical? Or is that an

imagination that comes about from an engineer's overactive desire to create problems?

Donald Gray: In order to get underseepage, you have to a flow root or flow path, and so that means a soil that has some permeability so that the groundwater can flow underneath the levee or the dam and pop up on the other side. So, if you have a clay cap, a total impermeable clay cap, that couldn't happen; it would force the flow somewhere else. Or if the hydraulic pressure was great enough, I guess you could actually get forcing up.

Male Voice: I know there is a great deal of information from Aubrus down in the New Orleans area, large parks, Audubon and City Park down there, concerning flow down and high winds of trees by type of tree and so forth. Have you collected any of that information?

Donald Gray: No, I've not collected information on blowdowns, but one of the next speakers will be addressing the whole blowdown issue in some detail. So, perhaps he will answer your question.

Male Voice: Okay, so he might have looked into that, taken advantage of that information that is available down there?

Donald Gray: I can't speak for him, I assume he might be able to.

Emir Macari: I believe that that will be discussed, and perhaps at that time you can ask the same question. Blowdown rather than induced by levee underseepage or seepage through the levee is mostly the topic here. But, yes, certainly blowdown should be addressed.

Male Voice: We heard earlier this morning that we all have a common goal of protecting public safety. Do you think we have the information available now to characterize whether vegetation and when vegetation is either increasing public safety or decreasing public safety as a function of levee stability?

Donald Gray: I believe we do. I think we have the means now to determine whether woody vegetation growing on a slope is increasing slope stability. If there are limitations associated with that vegetation, what are some of the techniques we can use to mitigate or decrease problems with the vegetation. Yes, I think the science is out there now to manage the force resource on the levees intelligently.

Emir Macari: Thank you very much, Dr. Gray. As we said before, this is an equal opportunity symposium, so our next speaker comes from the Army Corps of Engineers, Engineering Research and Development Center -- I want to call it still WES, but it's ERDC. It is Dr. Maureen Corcoran, and the title of her presentation is "Literature review of vegetation in flood control."

Maureen Corcoran: Good morning. I want you to notice that my title on my presentation differs just a little bit from what you see on the agenda, and I want to make note that it is a preliminary assessment. Recently, one of our technical directors down at ERDC called me into office and said headquarters wants us to do an expensive literature review on vegetation on levees. So, my first thought was, I can't say no to headquarters; that's like saying no to my mother, and my mother's from New York. So, sure, and then my second thought was how difficult can this really be? So, I left the office after telling Dr. Sharp, sure, I'll do it, and I get back to my office minutes later, I look at my email, I have one from Dr. Sharp, and it

says, "Did I tell you this has to be done in two weeks?" So, keep that in mind that we have assembled a lot of data, but there still perhaps is more that we need to look at.

First, I'd like to recognize my colleagues that helped with this literature assessment. Pam Bailey is a botanist at our environmental lab at ERDC; Charlie Little and Freddie Pinkard -- and I have to apologize, Jim Leach, I left his name out, and he's the only one here of the group that is here to support me. I'm sorry Jim. And they're hydraulic engineers. I'm a geologist and as we say in the South, none of us have a dog in this race. So, we are presenting this is an unbiased format.

The objective of the literature review is to collect and summarize the literature that's pertinent to vegetation on levees and to identify data gaps as defined in the reviewed literature. Now, with the literature review, like I said, we wanted to do an extensive review, an extensive data gathering. So, of course, that everybody's heard today, we look toward the guidance in government documents, and of course journal articles, the proceedings and transactions, newspaper articles, Gray literature, which of course, in the scientific community that usually does mean the government documents. But thanks to the worldwide web, everybody has access to those today.

So, really we included memorandums that you find that for some reason would appear in different formats, but not something that's easy for the public to access. And also personal communication, and by that I don't mean the people that came by my office - and believe me, there were plenty - that had an opinion on this. But these were emails that I received that I felt came from people with experience in this area that I did want to

include. Well, unfortunately, as they say, the book is better than the movie, so in this case the document is better than the presentation. I can really not do justice to the document that we reviewed. So, look forward to the book coming out.

Well, when we started getting into this, we realized that we had to come up with different considerations when we were reviewing the literature. We've heard about some of these already this morning; from Dr. Berry, we have to include all types of vegetation, and that includes brush, grasses, trees, the different types, and understand each document and report's research focus and objectives. Also to identify the soil properties, any observations, recommendations that the researcher had made. And here comes the clincher: we had to separate the literature that deals directly with vegetation on levees from literature that may offer an insight or provide us a background, but perhaps did not focus just on levee vegetation.

Well, - and I warn you, I may sigh a lot during this - of course, with a standard format on a literature review, you usually have the title and the abstract. Well, because I thought, we're dealing with so many documents, how can we let the person know that we're trying to get this across to to give them a faster look instead of doing the abstract? So, I thought, okay, let's pull out the objectives, the methodology, the soil properties, the study location, the results, the recommendations, and put those in our literature review. Obviously I don't have much life outside of ERDC. Then also we needed to note that perhaps the newspaper articles did not pull as much weight, or maybe should not be given as much weight as a peer-reviewed journal article. So, we also make note that when a journal article or document is peer-reviewed.

So, we came up with this really neat coding system, and at first, I thought, I'll make it simple; I'll come up with a two-letter coding system. Well, unfortunately, that made bank stabilization BS. So, I had to extend that a little bit more to come up with a better code. As you can see, we have more letters. Well, this is some information that we did not really use in our assessment, but if the research continues - which I really believe and hope it will - these are documents that are out there that we already have that are going to be very useful to this research. Well, for levee veg, we gathered those documents, well still, it included so many documents that perhaps did not answer the issue that we were looking for. So, then, we included the P for pertinent documents.

To give you a little bit of an idea, we reviewed close to 200 documents, and I think we have about 140 that are actually in the literature review. From that, we only had about 18 that were what we felt were pertinent literature documents that dealt with vegetation on levees. Also, keep in mind that we're looking at 18 documents, but eight of those documents may be from the same research. We may have research that was published in one journal that was also published in several proceedings. So, what it narrows down to, we really don't have that much information on the issue that we're looking at.

Well, I'm not going to cover, like I said, the guidance documents which you've heard a lot about this morning from Dave and others. But I would like to point out some of the international guidance documents that we were able to acquire. One from the United Kingdom in 2003 is "Environmental Options for River Maintenance Work," and when we called Dr. Colin Thorne with the University of Nottingham to see if he had

any such document - he's effluvial geomorphologist, very well-published in that area - we mentioned that, gosh, Colin, we're having a little bit of trouble finding literature to vegetation on levees. Well, his answer kind of said it all. He said, "It's not supposed to be here." I can't do an English accent, but it's much better than that.

So, I thought okay, point taken. From Japan, we were able to acquire a manual for river works in Japan. We don't have a date on that, but there is a section 5.2, Aforestation of Rivers, and that was listed as a draft document. So, apparently there is another report that perhaps exists that we don't have our hands on yet. You will hear this afternoon from the Netherlands and also from the German documents; I'm not going to cover those. My Chinese is a little scratchy now, so we weren't able to translate the article that we have, but we're hoping to do so.

Let me move on to the UK guidelines. They used what they refer to as environmental options, or EOs, to address the vegetation and environmental concerns on embankments, and they go through a little process - or I should say a well-thought out process - where they take these EOs, which are a series of cross-sections and long-section drawings that provide a visual picture of the desired environmental outcome. And they balance each EO with the flood defense needs of the water course, keeping in mind that the flood protection, of course, is the primary objective of the area, and the safety issues with that. They have an area called the Flood Defense Operation, and I'm sorry but I had to spell defense like we do in America; I chance the C to the S. They had the Flood Defense Operation that actually decides the standards required, but then when they agree on that, they meet the standards with what's called the FRB team, or the Fisheries, Recreation, and Biodiversity team.

I have a few examples from their guidelines, and this is their EO on the raised flood embankment. And as you can see, on the bottom of it they say "All trees and bushes removed from embankment." Now, keep in mind that, of course, some trees do grow - do grow, I'm sure, at a very fast rate - so they are faced with the fact that some trees have grown on these embankments, and now what do they do? So, they look at the trees, and if they're over 25 centimeters - and any branches too - they are trimmed or cut. But anytime a habitat, like an otter hole or a bat habitat is encountered during this time, the FRB team is called in and they reevaluate the EO.

Now, the Japanese guidelines, I don't have the photos from this, but they do believe that aforestation is allowed, which of course is the replanting of trees and vegetation, it is allowed as long as it does not obstruct river control measures. Well, that doesn't give any definite information on that, but in other words they do not allow trees if they influence the primary purpose of the dikes and levees. And also, there is a list available in the manual where they have listed the types of trees and shrubs and vegetation that they do allow to grow on their levees and dikes.

Well, when I was trying to come up with a way to present this to you all today, I have to say, I probably did four different presentations to come up with the best way to present this. So, I decided that probably doing this in a chronological order may be the best. I didn't want to put a lot of information on each document, so I pulled out what we did in our literature review - or some of it, a subset - where we listed the objectives and some methodology and recommendations. Well, one in 1967, a pilot levee maintenance study, the objective was to test for alternate methods

of levee maintenance. They did realize that the trees and shrubs were allowed in open patterns, something that was seen earlier by Dr. Gray, I believe, and the recommendation is that the timely repair of any erosion and berms can head off any major reconstruction work, such as removal of vegetation.

In 1984, the role of vegetation in integrated pest management approach to levee management, brings to us an environmental aspect of it, and that is to keep in mind that the sensitive habitat of different plants and animals and to incorporate these into our levee maintenance program. This is similar, I believe, to what the EOs are with the UK guideline. In 1987, the environmental consideration for levees was really a data review on existing guidelines of the U.S. Corps of Engineers, and they left us with some very good questions. Can current levee maintenance standards be revised to allow more woody vegetation without increasing hazard? And of course, that is the million dollar question and why we all are here today.

And this one you've heard of in every presentation that's been given today, and that's the famous REMA report, 1991, by Dr. Gray and others. The objective was to investigate the relationship between the vegetation and structural integrity of the river levees. And at the time, they did state that the U.S. ACE guidelines were adequate based on the lack of science. Well, on the conclusion that they found, that Dr. Gray did mention in the previous presentation, was that it appears that woody vegetation does not adversely affect the structural integrity of the levee.

But they do point out, too, that their study does not include other aspects such as flood fighting and inspection. And also in the recommendations

from the REMA report, they had some very good research, and with good research you always have future recommendations. And that is to conduct similar field studies in levees made of cohesive soils. Their study was conducted in Sacramento, where most of it is sandy levees. Well, down by the river levees on the Mississippi River, we have a lot of clay and a lot of silt, so a different type of material altogether. And also to conduct studies in regions where climatic conditions are different.

In 2007, we've talked about Katrina quite a bit; there was a document that did analyze tree root extending behavior along the levees and flood walls in the New Orleans district. They did collect data through root extensions, from photographs and doing root profile wall mapping, which was discussed by Dr. Berry and Dr. Gray. They did say that while the root may bind the soil together, reducing erosion, that overturning trees may accelerate the loss of levee integrity. So, they still leave us with some questions; does root extension change when encountering a levee? Their recommendation also was to develop a physical model to do a more in-depth study of this.

On the data gaps, we do recognize that further research to recognize the interaction of vegetation with individual components of the levee is needed, and to address levees not as an entire unit, but as separate environmental communities and establish specific yet different guidance for these areas. And also to extend future research to a system-wide -- and what we mean by system-wide in this note is that the levee system is not just the levees. We have the slurry walls, the pump houses and everything, and also the communities. We have the river communities, channel communities -- to recognize all those and to connect those

scientifically, and to answer the questions that we're asking today and during this symposium. And that's all I have.

Emir Macari: This presentation obviously brings out a lot of work that was done very quickly to try to update the state of knowledge on issues related to vegetation and levees. I would think that this is a live document that is going to continue to be enhanced as more science and more reports come about, perhaps as a result of this symposium there may be folks out here that could send additional information, if there is more pertinent information, to Dr. Corcoran. She will be participating in the panel discussions tomorrow, so that can be brought about now.

Male Voice: You talked about rejecting documents that you didn't feel as pertinent. I wanted to know what your criteria to define what is pertinent, and maybe give an example of what you rejected.

Maureen Corcoran: Sure. I probably should have been clearer on that. We didn't reject any of them -- in fact, the document now is probably two inches thick. What I showed today were peer-reviewed articles and those articles that are cited more with the scientific and engineering community. But no, we included anything, and that's why I also included emails from people that I thought were important. So, we did try to include everything.

Female Voice: What's the basis this policy was made; were there any assessments before they made this important decision for the vegetation management levee? Because I was surprised that you made decisions as assessments, a study, we base our study on assessment. But it seemed to be when you said that you were asking to make assessment, I was surprised why you make an assessment after decision. I want to know the process, what's going on.

Maureen Corcoran: Okay, I think you're talking about why we were doing an assessment now, following the white paper? Well, like I think Dave mentioned, I don't think it was expected that that would generate as much interest - and he might be able to elaborate on this - as was generated. Now, when they recognized that perhaps there was that need to do an extensive literature review, then that's when they asked us to do this. And it may sound like it's putting the cart before the horse, but that white paper, I believe, is something that is still in a draft final format.

Emir Macari: Yes, we should keep that in mind that this is a working document and it is being sent for discussion purposes. This is the reason for this symposium, so obviously when the Corps of Engineers received comments from folks, they decided to go about doing a comprehensive literature review, which I applaud that effort, and hopefully it will add to the scientific knowledge.

Male Voice: From the documentation, what was the ratio from the East coast to the West coast? Such as using the Rockies as a medium for the documentation.

Maureen Corcoran: Most of the work that I found seems to be in the West. There has not been -- and that's in the area of vegetation on levees.

Emir Macari: As I said, Dr. Corcoran will be here tomorrow, as well, in the panel discussions, and that would be a great opportunity for folks to be able to address direct questions. By the way, if you look at the last page in your agenda, you will find a form that you can fill out your questions. I recommend that you would do as the presenters are speaking, because

most of these presenters will be included in the panel discussions tomorrow.

Our next speaker is Dr. Dirk Van Vuren. He's a professor and chair of Wildlife, Fish and Conservation Biology, University of California at Davis. He will be addressing one of the issues that has been discussed quite a bit here; I believe in Mississippi they call them "critters," ground squirrels and other mammals' relationships, interactions with vegetation on levees.

Dirk Van Vuren: My background is in mammalian ecology, but it's also in wildlife damage management. And the issue of the kinds of impacts that mammals might have on levees is really one of wildlife damage management, in addition to being an ecological issues.

Now, there are several species of mammals around Sacramento that live on or near levees, and some of these have the potential to displace levee soil through their burrowing or digging activities. Mammals often have, or sometimes have, specific habitat requirements; consequently, the manipulation of levee vegetation may affect their distribution and abundance. What I'd like to do today is to briefly summarize or review the species of mammals that live on levees around Sacramento, on or near levees, to assess their habitat relations, to also assess their potential for soil disturbance on levees, and to try to forecast the consequences of wholesale removal of woody vegetation from levees in Sacramento.

Okay. Habitat basically provides the necessary resources for a species. Because resource requirements vary from species to species, habitat requirements may vary as well. Habitat, for mammals, provides three

basic resources: cover, food, and water. Now, cover is defined as the physical structure of the habitat that provides protection from predators and from environmental extremes such as cold or heat. There's a popular misconception that cover means, says, shrubs or trees. Actually, it doesn't. Cover is the physical structure that provides that protection, and for some species, cover is an absence of features such as shrubs and trees.

Now, cover requirements vary from mammal to mammal; some are very generalized, some are relatively specialized, and it's those relatively specialized species that are especially vulnerable to habitat change. Like cover, food requirements vary from species to species from relatively generalized to more specialized. And again, the more specialized species are more vulnerable to habitat change.

The final component is water. All mammals require water, but not all mammals require free water for drinking. I basically won't be dealing with water at all in this talk for the simple reason that in our arid Mediterranean climate, the mammals that live here are pretty well adapted to dealing without free water for part or all of the summer; also, levees tend to be built near sources of permanent water, so animals that live at long levees oftentimes have water available nearby, so it's not really an issue.

Let's take a look at some of the mammals that live along California levees. First of all, a very common species, the black-tailed jackrabbit; cover requirements for jackrabbits are open habitats. Basically, the lack of a structured habitat; they require openness, and there's two reasons. One is their primary food is grasses and forbs, which occur in grasslands, open habitats; but also, their main protection from predators is early detection

and speed. They achieve early detection by visual detection at a distance, so jackrabbits almost never occur in shrubby habitats where that visual detection is impaired. And then, of course, their escape - as I'm sure you've all seen - is speed and agility. They basically outrun their predators. Their burrowing potential really is minimal; when they nest, the female will scrape a very shallow scrape in the soil, and that's about it. Obviously, black-tailed jackrabbits will probably benefit from removal of trees and shrubs and conversion to grassland, but impact on levees I would say would be minimal.

Their cousin, the cottontail rabbit - and we actually have two species here, I'll just call them both cottontails - they have a very different cover requirement. They do require dense shrubs, and that's in part because they have a much higher shrub component in their diet than do black-tailed jackrabbits, but also because dead shrubs are their cover, their protection from predators. That's where they run when they're threatened. Now, also unlike black-tailed jackrabbits, cottontail rabbits do use underground burrows. However, they don't dig them; what they use is an existing burrow dug by another species. So, their burrowing potential is minimal to non-existent because they use existing burrows and don't create their own. They would probably be greatly reduced in abundance by elimination of trees and shrubs, but not much impact on levees because they have very little burrowing potential.

Now, California voles do have some burrowing potential; it's not much, but some. Their favorite habitat is grasslands, and there's two reasons they're found in greatest density -- they occur in a variety of habitats, but at very low densities; it's really grasslands that they prefer. The reason is their cover is the dense grass. They build runways through the dense

grass, they're very much a surface animal and they can achieve relatively high densities. They don't do much burrowing, but they do do some. They're not great diggers and they'll dig relatively short burrows for nest chambers, but at high densities that could amount to a minor impact in displacing levee soil. So, I would consider their burrowing potential minor. Obviously they will greatly benefit by removal of trees and shrubs from levees.

Now, carnivores. We have several carnivores, and I'll just go through them quickly. As a group, most carnivores are very generalized in their habitat requirements - the ones we have here - and they're also very generalized in their food requirements. So, for most of them, I wouldn't expect overall much of an impact of conversion of levee vegetation from woody vegetation to more grassy communities. But let's just quickly run through them

The coyote is the ultimate generalist, it will live anywhere and eat anything. Even though the canids - it's the largest member here of the canid family - as a group are pretty good diggers, you've all seen your dog in the backyard going after a bone or whatever, they actually don't dig very much. In fact, most of their excavation consists of using a nest burrow, a den, once a year. So, they may excavate that, but they usually use an abandoned burrow or the burrow that they dug last year. So, considering the rather large home ranges and relatively low densities of coyotes around here, if you figure in one burrow maybe six feet deep once every two or three years, the overall impact on a levee, I would say, would be very minimal.

Same with the red fox, the smaller cousin. For a long time it was believed the red foxes here in the Sacramento Valley were exotic; there's some recent information in the case that they may be native. Variable habitat requirements; can occur in a variety of locations. Do like some shrub cover but are also seen in grasslands, so I wouldn't expect much of an impact on abundance. Again, they are pretty good diggers, but they usually don't dig their own burrow; for a nest chamber they capitalize on an existing structure so the net impact on displacing levee soil I would think would be very, very minimal.

And then finally, the grey fox, a little more oriented toward shrubby tree vegetation than the two larger canids, but again, highly variable in its habitat requirements. Like the other two canids, very variable in dietary requirements, so I wouldn't expect much of an affect in removing trees and shrubs from levees. And again, they usually use an existing burrow and only occasionally dig their own. So, minimal impact in terms of burrowing potential.

Now, raccoons are a little different from the canids in that they do make regular use of a burrow; they'll den once a day. But interestingly enough, they rarely dig their own. They almost always use an existing structure like an abandoned burrow dug by something else, a cavity in a tree, or that space under that shed in your backyard. And they are a little more oriented toward aquatic systems; their densities are often a little higher in riparian zones, but they're still very generalized in their habitat requirements, and eat a variety of things as well. So, no major impact on removing levee vegetation, and only a minimum burrowing potential.

Now, the skunk actually are excellent diggers, and they do have some burrowing potential. Again, very highly varied in their habitat requirements, both cover and food, so I wouldn't expect much of an impact on skunks. A little bit, maybe; probably a little more common in riparian systems than elsewhere with a shrubby vegetation. They are good diggers and they are more likely to dig their own dens than some other species, but again, they usually don't. They usually use an existing structure. So, the overall impact in terms of soil displacement is really pretty small.

Now, the final carnivore we're talking is rather different than the rest of them. This is the badger. This is the famous digger; it can excavate large amounts of soil very quickly. However, even though badgers occur in this area, they are very uncommon and their presence is really sporadic, hit or miss. Now, if you do get a badger in your area, it's probably going to be most abundant in grassland communities because badgers especially like to dig out gophers and ground squirrels, which, as we'll find out in a minute, are most abundant in grassland communities. So, they may benefit from conversion of tree and shrub communities to grassland communities, especially if that leads to an increase in gophers and ground squirrels. Their burrowing potential is substantial if you have one, but their occurrence is very localized and very sporadic.

A more aquatic animal that we have here in Sacramento, an exotic species, the muskrat. For a muskrat, cover is water. That's escape from predation and escape from environmental extremes. Their food is primarily aquatic plants, consequently they are closely associated with water. Their burrowing potential is substantial; they do dig burrows into the bank, some can be fairly long. And oftentimes the entrances are

underwater. Impacts of conversion of levee vegetation would probably be pretty minor for muskrats, simply because they rarely leave water and they rely almost entirely upon aquatic vegetation.

In some measure is a similar species, the beaver, is also highly aquatic; cover is water. But food is very different than muskrats, a much higher woody component, and also beavers will range much farther from water than muskrats will. Substantial burrowing potential; beavers can excavate large diameter burrows some distance into a bank, and they'll either build a stick house or they'll burrow into the bank -- either one, same species of beaver. And by the way, beavers are native in this area, sometimes I get asked that. Their food is primarily shrubs and trees. They do some grazing of grasses and forbs on the bank, but it's primarily shrubs and trees. And again, their burrowing potential is substantial.

The pocket gopher, major burrowing potential; that's how they live. They're a subterranean species, they build underground tunnels and those tunnels are their cover; their protection from predation and environmental extremes. They feed mostly, in this area, this particular species, largely on forbs and somewhat on grasses; a little bit on shrubs. Consequently, they are most abundant in grasslands. And again, their burrowing potential is substantial; they maintain extensive systems of underground tunnels.

And then finally, the California ground squirrel lives basically in open habitats. You can see them in a variety habitats; they'll live in oak savannah, grassland with scattered oak, a little bit in shrubland, but not much; really it's grasslands where they reach high densities. There are two reasons; one is their food is primarily grasses and forbs, green when it's

wet, seeds of these species when it's dry. But also, they rely almost entirely on visual detection of predators and then escape into a burrow; consequently, they rely on open habitats. Their burrowing potential is substantial; they live in burrows, they're good diggers, they excavate burrows and maintain these tunnel systems.

Let's take a look, then, at those species with some burrowing potential and some potential for displacing levee soil. To get an idea of which ones may increase or decrease, voles with some burrowing potential will probably increase because they are most abundant in grasslands. Muskrats, probably no effect because they rarely go very far from aquatic habitats and they're almost entirely aquatic. Beaver, it depends on how the trees and shrubs are removed. If the trees and shrubs are completely removed and replaced entirely with grassland vegetation, if you don't have some sort of a tree or a shrub food source, you usually don't have very many beavers, so that will probably have a negative impact on beaver numbers. However, if the trees and shrubs are simply cut down and sprouts allowed to regrow, that actually is an excellent food source for beavers; they especially like those new sprouts from, say, willows and cottonwoods. So, that could actually increase the food source for beavers depending upon how the vegetation change occurs.

Gophers, there will probably be an increase in the conversion from tree and shrub vegetation to grassland vegetation. Ground squirrels, almost certainly an increase. And badgers, it's hard to tell. They are so uncommon and so localized and unpredictable, maybe there would be an increase. Again, they are so sporadic in their activity, it's hard to say.

I'd like to conclude by saying that tree and shrub removal from levees will almost certainly have a substantial impact on at least some of the resident mammals. This will be a really drastic change in habitat structure, and for some species, in terms of food supply. And this will affect many of the resident mammals and some of these have substantial burrowing potential. But what I'd like to emphasize is that to say an animal has substantial burrowing potential is not the same thing as saying that it will have a negative impact on levees, at least to an extent that we might care about. We have to be very careful, as mentioned earlier today, about making the mistake of guilt by association. I think it would be safe to say that every levee that has ever failed in this country had at least one mammal burrow in it. That doesn't mean that that burrow caused that failure, because you could also say that every levee that has not failed had a mammal burrow in it.

In the field of wildlife damage management, this guilt by association has been commonly used for a long time. I run into it mostly in agricultural situations; you'll see a flock of birds or a herd of deer in a field and, geez, there's deer in my field, they must be doing damage, something needs to be done. This was a common perspective for a long time. In wildlife damage management, that perspective has changed dramatically in the last several decades, and the reason primarily is scientific research showing that there is not necessarily a link between the presence of an animal in a commodity and the actual damage being done.

And so let's not make the same mistake here; just because there is a burrowing mammal on a levee does not necessarily mean that that animal is doing damage. What we really need is science-based research on the

magnitude of the damage in order to conduct basically a risk analysis in order to guide management efforts. Thank you very much.

Emir Macari: We have time for a couple questions. Obviously, this is an area from a civil engineering perspective that I'm very ignorant on, so I appreciate the expertise here, and perhaps that creates a few questions from the audience.

Male Voice: I just want to support one thing you said because it seemed so counterintuitive to me when I first discovered it. I went out and did some inspection of the inside a levee after a failure had occurred there and the water had gone down, and as it washed all of the grass and everything off the face of the levee. And I never saw so many burrowing holes in my life. There were literally hundreds to thousands along a sand line in there. But there wasn't a tree anywhere; this was an area where there were no trees, no brush, it was just grass. And I'd always thought before that time that those animals really thrived where there was heavy vegetation. So, at least that one observation supports what you're saying there.

Dirk Van Vuren: Some do, some don't. It's species by species and it really requires a knowledge of the natural history of the species in order to forecast what the consequences of habitat change will be.

Male Voice: Based on behavior of a gopher or a ground squirrel and just plain old physics, is it possible for either of these animals to burrow completely through the levee, from one side and come out the other side?

Dirk Van Vuren: That's a really good question and something that I think needs to be addressed. I was interested to see the work on root structure, and there's

not much of it done because of the work required. Same thing with burrow architecture and burrowing animals. It's such a huge amount of work, we don't know that much about it. But it is doable, and some of the work that has been done indicates that there are various factors for gophers and ground squirrels, and these factors differ for the two species that influence the depth and direction of burrows.

And I think some research on that subject that would allow us to predict burrow architecture of these two well-known diggers in levees would be very helpful. One aspect is soil consistency influences the direction of burrowing. The purpose of the burrow; for a gopher, one purpose of the burrow is to reach food. Well, the food is the roots of forbs, which is only about that deep at most. So, most gopher burrows are not very deep; the nest chamber can be, and so forth. And so we know something about the factors that influence burrow architecture in these species, but it is doable research and I think we need more of it to help predict how these animals will influence levee integrity.

Male Voice: Can you talk a moment about how monitoring burrows takes place, how intimately do you have to be on the ground, are there remote monitoring capabilities for burrows, and can you assess the size of a burrow from the outside? How do you tell what the risk to the levee is from the presence of a burrow, and how do you discover the presence of a burrow in the first place?

Dirk Van Vuren: That's a good question that I can only partly address. I think some of that is actually unknown, and some of it may be known, but I don't know it myself. But I can tell you for, say, the two big burrowers, gophers and ground squirrels, there are a variety of techniques to determine whether or

not a gopher burrow is occupied; one is called the open hole technique, where you look for fresh dirt that's been removed from the burrow. Open the hole, come back a specified period of time later, and if it's closed that means there's an occupant. And then once you've done that, there are some fairly standard dimensions of gopher burrow systems; quite a few have been excavated, and so you could probably come up with an estimate of the extent of the active systems that you've got in that area, and the density of active burrows. And since they are often solitary and territorial, it can actually give you an idea of gopher density.

With ground squirrel burrows, that's harder to tell because an entrance will lead to multiple chambers, and a chamber may have multiple entrances. And also, ground squirrel burrows are a little more durable than gopher burrows; they do collapse in a period of time. One of my graduate students looked at this and found out that they lasted, if they were maintained, about 18 months - one year to a year and a half - after they were last maintained by the occupant. So, an unoccupied ground squirrel burrow can look occupied for awhile, so it's a little trickier for estimating whether or not it's occupied or not.

As far as monitoring efforts go, I think there are some going on, but I'm not closely familiar with them.

Male Voice:

Department of Water Resources has a grouting program for levees, and we have found that the grout can actually meander through inter-tunnel systems from the ground squirrels, which are generally the major burrowing problem that we find. And we've done some excavations to see where the grout's going, and it's generally consistent with what was reported by Dr. Terry Salmon from UC Davis some years ago, where he

had done a number of excavations and found that the ground squirrels generally burrowed to a depth of about five feet, didn't go deeper. But what that leads to is a veneer of the outer slopes of the levee and the crown having tunnel systems to a depth of five feet, which could actually be quite dangerous when you get high water.

And we have seen, during high water events, water exiting from one side of the levee out through burrows on the land side of the levee. So, in answer to a question earlier, you can get connected holes that go right through the levees.

Emir Macari:

Just a couple of bookkeeping things. We are breaking for lunch right now; we have 40, 45 minutes for lunch. It is feeding 500 or 600 people, so please try to get down to the hall right away. If you take the escalators or the stairs down all the way --

This afternoon's presentations are broken down into two different sections, both of them having four scientists. We will have a break between 3 and 3:20, and obviously depending on the speakers' adherence to their time and whether we can get the folks to sit down on time, that cuts into the break. So, I'm sure that we all want to get going here.

Our first presentation this afternoon is one that has been talked about quite a bit during the morning sessions, and it is from Dr. Gray's colleague, whom he mentioned. Our speaker is Dr. Doug Shields, formerly with the Corps of Engineers for a number of years; currently he is at USDA National Sedimentation Laboratory. The topic of the presentation will be about that report from the late '80s, early '90s, and

the presentation is titled, Roles of Vegetation and [unintelligible] Stability and Revetment.

Doug Shields:

Well, my presentation today is basically going to be three presentations in one. The first thing I'm going to talk about is the levee study in the late '80's, then I'm going to follow that up with a little extension of that work that we've just done recently. I've done this with my colleagues at the sedimentation laboratory, where we've taken some of the information from that study and incorporated it in a computer model we have of bank stability, or slope stability. And then I'm going to come back and talk about another study we did in the late '80's out here on the Sacramento River revetments and the vegetation on the durability revetment.

Let me go back for just a second and say that, the 1980's studies are both documented in core technical reports and in the referee literature papers published in the Water Resources Bulletin, which is now the Journal of the AWRA, in 1991 and 1992. So, since the work has been published, I'm going to cover it rather rapidly and rather briefly, and I'll allow some time for your questions. But the work is documented in writing.

First of all, the levee study. This involved collection of field data in the summer of 1987; I was about 14 years old at that time. We looked at sites that were a reach along a 10 kilometer reach here near Sacramento, on the west side of the Sacramento River proper. We were looking at the effect of vegetation on the riverside levee embankment slopes, and within this 10 kilometer reach we identified six sites that were characterized by different types of vegetation. The veracious site had not been burned, it was covered primarily with California Rose and different kinds of [veges] and grasses, a dead oak stump and then a cluster of two rather large valley

oaks, a stand of willows, some elderberry shrubs, because of their significance to endangered species, and black locus, and you see how they were arrayed there along the reach. Just right across the river from the Sacramento Airport.

At each one of these sites we excavated L-shaped trenches using the profile wall method that Allison discussed earlier. We dug down about four feet. The trenches ran parallel and perpendicular to the levee crest, and where we were working around woody species, we tried to dig the trenches where they coincided with the drip lines of the trees, thinking this was a more or less typical condition for a vegetative levee slope. However, at the elderberry site, to kind of max things out, we dug the perpendicular trench right through the center of the cluster of -- or the clump, of bushes.

And so this is what our field site looked like, one of our field sites. This is the perpendicular trench at the valley oak site. So, you see the two valley oaks there in the middle and the people are actually mapping roots on a clear acetate overlay with a grid there. Different colors were used to map different sizes of roots, different size classes were identified. So, basically, just a day at the beach there, they're having a good time. Ann McDonald, who's now with URS Corporation in Portland, led this effort, did a terrific job.

In addition to the botanic data, both above ground and below ground, we collected pretty standard information about the levee geometry and about soils. We used our bore hole shear test device to get shear strength parameters [unintelligible]. We found that the levees were overbuilt slightly on the riverside, they were not quite as steep as 3H on 1B. The

levees were sandy, pretty uniform, medium sand, not very well compacted at all, and very little cohesion. We did see some inclusions of clay balls and just occasionally we'd find some [unintelligible] material, more about that later.

I'm not going to talk about the above ground botanical results because of time. But below ground we worked very carefully, we had to wet down the soil to get that trench space to hold a vertical slope, so it wouldn't just crumble off. And in addition to the root locations and sizes, we also mapped things like voids, [unintelligible], mineral inclusion and stratigraphic features.

We used the root information to compute root area ratios. If you're not conversant with this term, RAR, root area ratio, basically you get the cross-sectional area of the roots, the white spots here, and divide by the total area over which you're mapping. So, it's the white area divided by the brown area. The summation of the area roots divided by the total area, and we did this in 10 centimeter depth increments so that we could calculate the vertical distribution of root area ratio.

Again, I'm just going to let you kind of peruse the above ground results, but I'm going to talk about the below ground results. The root area ratios were pretty low numbers. Yes, that is three zeros one percent, to two percent, which is really kind of an out there, because our mean was only about .2%. Pretty large coefficient variation you see here. The root numbers declined exponentially with size, there were a lot more small roots than big roots, not much of a surprise there, and that's consistent with what Allison presented earlier.

The root frequency and the root area ratio declined with depth, and so here, this is depth below surface, up here at zero is the surface of the ground, and we're showing our data down about a meter, and that's about as far as we were able to go down. And, you know, based on what Allison showed this morning, the question is, well, did you miss some roots because you didn't go deep enough? And I'd have to say, well, probably so, because we didn't go all the way to -- we didn't get all the way to the zero with the root area ratio down here.

This is the average, or the control, or the veracious site, right here, and this is the average with the wooden grip line sites right here. So, you see, we're pretty much in that .2 to 0 range. Important point though, is we found no significant difference in root area ratio at depths greater than 20 centimeters. Above 20 centimeters, a lot of veracious roots up there. Below 20 centimeters, based upon analysis of variants, and one reason we were unable to detect a significantly significant difference, is because of the wide range of variants from site to site.

However, if we take those data and we plot a cumulative frequency distribution, like a grain site curve here, on the vertical axis, of course we have the depth of the soil surface, and here the percent of roots above a given depth. So, the dark green is the woody sites and we can see that about half of the roots, about half the root area ratio, is above 25 centimeters. This is depth below the soil surface in centimeters, not meters. But anyway, you see the curves lie pretty close to each other, we got more herbaceous roots at shallow depths and then more woody roots at what I'll call the mid-range depths, and then they kind of come here together close to a meter.

These results are consistent with findings about others -- no, well, Bill Gates is trying to ruin my life again. Up here, bound curves from Jackson, et al 1996, this publication right here that appeared in the *Ecologia*, they reviewed 250 studies of roots from all over the world and plotted these kinds of curves for different species and different biomes. And what we found is that temperate grass land is up here, it has its roots concentrated near the surface, a desert is back here. So, our herbaceous site is close to - - kind of close to desert, the woody sites hit the temperate deciduous biome right on top of the money.

So, we may have missed a few roots at depth, but I think all in all, we're very consistent with the findings that have been published in the literature about the vertical distribution of roots. That's the takeaway message that I'm trying to show on this slide.

Okay. A few qualitative observations and then we'll go to the data. I think Dr. Gray talked about seeing these [tubules] that were filled with different kinds of sand. We didn't see very many voids, the density of voids greater than 5 millimeters in diameter range from only 0 to 10 per square meter, and average 1.65 per square meter. Not many holes in the levee. Also, I think Allison, or Dr. Barry, showed a picture of our -- Allison showed a picture of our dead oak stump and we see these lateral roots in a non-orthodox, non-classical way. Instead of radiating outward, it actually angled downward and we interpreted this as an adaptation to our extremely [unintelligible] site.

Okay, so those are qualitative observations, and I'll slow down here long enough to say this is the only thing I have to tell you about root induced

findings. There's nothing else in this study that really gives us much information about root inducing findings in these qualitative observation.

We did do some analysis on seepage, but instead of looking at root induced piping and its effect on seepage, here we were looking at the modification of surface permeability's due to vegetation. Normally we expect vegetation to increase the surface permeability of the soil, but what we did is kind of a sensitivity analysis where we look at the existing permeability and then we increase that by a factor of 10 and decreased it by a factor of 10. And the idea is under steady state extreme hydraulic loading, where you've got a water surface elevation that's, like, 90 percent of the levee height on the riverside, and if the surface foot of the levee has a change in permeability, what are the implications for seepage? And so here are findings. This is the flow net that we got with a phonic difference relaxation technique for a homogenous levee. The flow net for a levee with more permeable skin, what we'd expect from the vegetation, really isn't affected very much. A less permeable skin, say the vegetation possibly may be trapped some vines or something, and that's kind of hard to conceive of, but it's a kind of a what-if analysis here, elevates the discharge point, and so it increases the discharge area here on the land side of the levee. So, a negative indication as far as the effect of vegetation permeability, if it makes the skin less permeable.

The main analysis we did, though, was a slope stability analysis. We did two kinds of slope stability analysis, and I refer you to a publication for the details. We did a infinite slope analysis, which is appropriate for sandy soils subject to shallow sluffing, and we also did a circular arc analysis, and really, the findings of these two were confirmatory or complimentary.

The way we treated the vegetation, and this is the only link, really, between all that digging in the field in 1987 and the stability analysis, was we assumed a relationship between soil cohesion and the root area ratio. And I say we assumed this, this was actually based upon the experimental work that Dr. Gray did. He showed you a picture of it, where they isolated a soil block, root permeated sand, and did a direct shear test on it. They did tests with field samples and with lab samples and this relationship is an empirical relationship here. .233 times the root area ratio for the additional cohesion, due to roots, is based upon that work. He showed a slide that had the -- in different units, 3.2 instead of .23, but it's the change of units to PSI to get the 3.2.

Well, what's the effect on soil cohesion? Very conservative, based on measurements published by others. This increased our soil cohesion only about 50%, using the mean value of root area ratio and the mean value of soil cohesion we measured in the field. But it had a major effect on factor of safety. Now, here I've plotted three curves where we have the factor of safety on the Y axis and root area ratio in a log scale on the X axis. The different curves represent the different depths to the failure surface.

As to the one that appears to be most critical is this one down here at 40 centimeters, and you see a major increase in factor of safety as we move from minimal root area ratio up to a higher value, decreasing the factor of safety from an unstable to a pretty stable value. To get this kind of relationship we're looking at a very steep slope, this is one that was -- I assumed it was measured from the land side slope, very low friction angle, zero cohesion in the soil, and the seepage angle is equal to the slope angle. So, we're really pushing things here to be conservative. We

assumed a constant root area ratio that was not varied with depth for this particular analysis.

How does this root area ratio, this X axis, play out in terms of what we observed? The green line that just suddenly appeared here, is the mean for the herbaceous sites, and the box represents plus or minus a standard deviation. This burnt green is the mean that was observed for the woody drip line sites, plus or minus a standard deviation, and so, you can see that the vegetation is having a significant positive impact on slopes that go up with these assumed conditions.

Okay, so we're ready for the key findings of this particular study. The roots were concentrated near the surface, the large lateral roots that we observed from the stump angled downward, the vegetation made an important contribution to slope stability. Apparently roots did not create void, we found no evidence and we found evidence to the contrary. The voids we did see were associated with animal activity, both insects and rodent. We concluded that maintenance standards should favor woody shrubs and small trees.

There are several limitations here and I want to just stress these. There was no quantitative analysis of piping potential, root induced piping, one way or another. There was no analysis of wind throw issues, obviously no analysis of conveyance flood site or inspection, either. That's what we found out on that study.

So, let's shift gears. If you were listening closely here -- let me go back to this, if you were listening closely, I was able to show that vegetation is good for slope stability. I did not show what kind of vegetation is good

for slope stability. I showed you that we found no significant difference in the average root area ratio deeper than 20 centimeters in the soil under a herbaceous site, or under a woody drip line site. No significant difference. So, vegetation is good, but what kind of vegetation we really weren't able to show that.

Shifting gears, up to the present date, from 1987 up to today, we -- I got one of my colleagues in the sedimentation lab, Dr. Natasha Collin, who works with Andrew Simon, to spend a great deal of time looking at the effect of vegetation on screen bank stability, on bank stability. Andrew, with a lot of folks that work with him, have come up with a numerical model called the ARS Bank Stability Model, and it is intended to model screen banks, it simulates a wedge type slope failure. You can have five different soil layers with different soil property. You give it the phreatic surface within your screen bank, it is based upon static 2D conditions, this is the input screen for the model, and it is a free download.

But what I got Natasha to do was to modify the model so it considers vegetation along the bank slopes, or bank base. The one that you can download for free just considers vegetation at the top of the bank. In addition, the latest version of the model incorporates certain advances over that .23 times the root area ratio that Natasha has made. First of all, we think that approach may have overestimated the contribution of vegetation because it assumes that all the plant roots break simultaneously. That when you load the root permeated soil, the root saturated soil, that all of the roots contribute to resisting the load that's been placed on the soil at the same time.

And, in fact, the roots rip, they break one or two at a time, and this is found -- this is represented by a fiber bundle type model, and it's more realistic. Also, the root contributions to soil strength are very based upon the vegetation species that age the soil type and the moisture content. A much more sophisticated look at the vegetation and this is in the bank stability model, what they call the rip root algorithm.

So, the conditions that we assumed for our simulation exercise, basically we just pulled the conditions from our field study back in the late '80's and fed them into the model, and we -- the bank stability model makes you assume a horizontal phreatic surface, definitely a worse case condition as far as a levee. And so we kept that at 80% of the levee height, and so she looked at a lot of different scenarios, in the interest of time, I'm just going to present a few here. I am going to show three different kinds of vegetation and you see that the rooting depth assumed there and their contribution to soil cohesion.

We're just going to look at the impact of vegetation on a one on three -- one horizontal, three vertical river side slope, and we're going to look at a condition where we have a low river state, like a rapid drawdown, 80% of the levee height, but a high phreatic surface, up here at 80% of the levee height, so kind of a worse case condition as far as the hydrologic loading's concerned.

So, here's what we found out. The red dash line at the bottom of the bar chart, the factor of safety of one, the vertical axis is factor of safety, and so you see the vegetation free bank, or vegetation free levee is -- factor of safety of only .54, unstable without root reinforcement. Bunch grass

comes up here pretty good, mature -- young trees not quite so good, small trees and immature trees are best of all. So, positive impact.

So, quickly, key findings under worst case assumptions of riverside slope is unstable without vegetation, and as far as factor of safety goes, mature trees are better than bunch grass, are better than young trees. Maintenance standards should favor bunch grass or trees based upon this little study here. [Unintelligible] large trees because this has nothing to do with wind throw. So, I'm not going to say large trees, but bunch grass or trees.

Several important limitations. We only analyzed wedge type slope failure, the effect of vegetation on soil permeability and the seepage was not considered, wind throw not considered, piping potential not considered, and it's a minor point, but since we're talking about physics, I will mention that the surcharge, the additional weight of the vegetation on the river slope is not considered in this modified model. It is considered in the downloadable bank stability model, [unintelligible] vegetation [unintelligible].

Well, let's go back in time, back to 1989, and now we're in the third phase of my presentation, we're going to talk about the revetment study. The reason to talk about revetment is, and you folks that live out here know this, but I preface my remarks by saying the revetments coincide with the river [unintelligible] or the river slope of the levee in some cases. In other cases they're very approximate to the levee, the revetments are key as far as protecting the levees go. They may be within that 15 foot vegetation free zone that the white paper is talking about, so that is one reason for the interest in this work.

This study in comparison, I've already presented, is purely empirical. We simply took one reach of the Sacramento River and we said, how did woody vegetation affect the durability of revetment during the project flood -- not project flood, the flood of record, during the flood of record. So, we calculated damage rates for vegetated and unvegetated revetment, allowing for the type of stone and construction date and bank curvature, and then compared these with past [unintelligible] statistics.

First of all, the study reach was from Sacramento River mile 84.5 to river mile 119, this is between the Freemont [unintelligible] and the [unintelligible]. There are no major inflows or outflows in this group. These are annual peak discharges that I just downloaded the USGS for the [Gage] and [Wilkins] slew, and when we did the work in 1989, the 1986 flood was the flood of record, and apparently it still is, and there's an interesting positive trend here which [unintelligible] you that.

What we did was, we said, okay, what revetments were damaged during the flood, and were they vegetated before the flood? We found only five instances of revetment damage that resulted from the flood and we got these from request under the [PL849]. Only five cases, none of them supported vegetation before or after the flood. So, well that makes for a very short research project, so we said, why don't we do this? Why don't we look at inspection records and aerial photographs, and just find out where the vegetation was before and after the flood, and then let's get in a boat and go out and see where the vegetation is today, because it had only been two or three years since the flood.

And so, we built a series of overlays, clear material, about three by five, that could be overlaid on base map. This was back in the day before

everybody had a GIS and a GPS, so that's how we did, and so, we were able to look at the relationship between revetment damage and these other variables. To have a database that we could actually analyze, we divided the revetments into 30 meter long segments, and for each segment we recorded in the database, this suite of information, bank curvature, construction date, revetment material, usually your cobble or rip rap, and then the vegetation conditions from different sources, and whether or not the revetment was actually damaged or not when we inspected it in 1989.

We did a very simple classification as far as vegetation types go. One was bare rocker soil, or just a little grass or herbaceous material. Type two was this sort of vegetation here, woody vegetation less than 12 feet high, and then if you had more than that, that was a type three. An important point here is, to be very conservative; we did our classification based on the largest individual plants growing on each segment. So, this right here's a type three revetment, even though there's only one tree in that 30 meter segment.

What were our results? Well, about two-thirds of the bank line of our reach was revetted, a lot of rock out there. Only about 10% of the revetment supported some type that is two or three, of woody vegetation. The state inspection records underreported revetment vegetation by 80%, relative to aerial photos. I've already mentioned that only five sites were reported as damaged, during that '86 flood event. We classified about 3% of the revetted bank line as damaged in the September '89 visual inspection, and this was right on top of what Mike Harvey and his associates did, when they did the same thing just before we did. Mike Harvey was retained by the Sacramento District to do a series of geomorphic studies.

And most of the damage was what Mike called threading, here. This is an old cobble revetment and there's been a vertical displacement at this point, exposing its cohesive bank, and the reason he called threading, is these failures appear periodically down the bank, and was able to relate this to the alluvial [unintelligible] of an area and selective removal of fine material.

So, what we did is, we took our database and we said, well, let's just calculate the damage rate based upon, you know, all these segments for vegetated versus unvegetated, and use [Chi-square] statistics to see if they're significantly different. And so this is what we found for vegetation, about 3% of the unvegetated segments were damaged, 5% of the vegetated, but that was not significant, according to chi-square, bank curvature almost exactly the same damage rate, based upon spray convex, or concave. The material, again, about the same damage rate for cobble and rip rap, but we did find a very significant difference. The older revetment tended to show more damage and, again, most of the damage was that threading on the cobble revetment, not as much tow protection or special tow trench design on that cobble revetment, and perhaps that's why it slid down the way it did.

However, when we lump all the data like this, we were concerned that we might've been comparing apples with oranges. So, we did another analysis where we split things into some smaller categories. First of all, based upon the construction date, three different dates you see here across the X-axis, and then for each construction date, we looked at bank curvature, straight, concave and convex. This led to some categories that had only a very few revetments, for example, it stands out kind of like a

sore thumb, we've got a 60% damage rate for vegetated revetment recently constructed on convex banks, but this represented 3 out of 5 revetments. At any rate, if you look at all of them, the damage rates were higher for unvegetated in 6 out of -- 6 categories, only 3 categories were vegetated [unintelligible].

We look at rip rap revetments, previous was cobble revetment, we had several categories where there were no revetment segments found. But when we count up the score, the damage rates were higher for unvegetated revetments in three categories; only one category was the vegetated damage rates higher. There were two times where both rates were zero.

Okay, and I'm trying to get through here where you can have a chance to talk a little bit. The damage rates for revetments supporting woody vegetation tended to be lower than unvegetated revetments, when you compared apples with apples. The Chi-square test indicated that older revetments were more likely to show damage. During the 1986 flood, vegetation did not adversely impact revetment ability. This is an empirical study, any time you have an empirical finding, to transfer those findings elsewhere must be done with great care. Very low damage rates, and that's why we had to do our statistics the way we did, and, again, there's no assessment here of vegetation impacts on flood [unintelligible] or inspection.

Okay, somebody else can talk.

- Emir Macari: Okay. We have time for a few questions. Certainly quite a bit of information related to stability and vegetation. We have one question right there, please.
- Male Voice: Thank you. A question for you based on critical erosion sites from 2006, and the utilization of PL8499 money. I'm trying to understand that as we grow this into the future, vegetation, large woody debris, issues of trees toppling over in the river and causing erosion sites, basically on the Sacramento River. Utilizing that PL8499 funding, how in the future will you not allow us to use that same funding source when it was an issue of vegetation larger than 2 inches, huge trees, huge root balls breaking loose, and causing --
- Doug Shields: I live in Oxford, Mississippi. I work for US Department of Agriculture, I don't have any funds to help people in California. I don't have anything to do with it. I used to work at the Waterways Experiment Station, I haven't worked for the Corp of Engineers since 1990, god bless them. I can't answer those kinds of questions.
- Male Voice: You sound like me. You sound like a farmer. No, can I -- can we answer that in some way, if possible?
- Emir Macari: Would anybody from, perhaps the Corp of Engineers, I guess, is that question being --
- Jeff [Chence]: My name's Jeff Chence and I work at the Corp headquarters, and let me make sure I restate question, so I understand it. You're referring to the Sac. bank erosion project and the maintenance that goes on to repair erosion sites? The project that he's referring to is a specifically authorized

project. It is not funded out of Public Law 8499, so the funding authorization is different authorization than 8499, and as a result, that authorization will continue regardless of what happens with 8499 eligibility, based on maintenance or other effects, and that eligibility will continue as long as that project authorization receives appropriation to continue.

Emir Macari: Any other questions? Well, perhaps, my question would be, where do you think we should move on to in the area of research for vegetation and stability of levees, having seen that this is taking us back 20 years to when the study was started. Have we learned anything new, can we add to the knowledge base from research that some of the agencies could be doing?

Doug Shields: Well, I hesitate to make a lot of comments outside my expertise and experience. One of the recommendations out of research though is that every effort be made to replace the existing piles of sand that you have with engineered levees. And if you can set these back -- I know there's a program of setback, but if you can set these back, then the environment wins and flood control wins.

And that may mean taking really hard courses of action with landowners. There are a lot of people in the 9th Ward of New Orleans that they've had a very hard course of action taken with them now, too. So, that's a worthwhile, long-term goal. In the short term, I think that, frankly, when somebody called me up and asked me about this meeting, I was thinking that the work we had done 20 years ago must surely be irrelevant by now. I mean, it's been 20 years, who, you know, who would care about research that is that old. So, a lot of different experiments can be run and

every university professor you get up here has a wealth of ideas, and things they would like to be funded to do.

It seems to me that you could have field science with different maintenance practices and look at all sorts of practices. Let's have woody species that you go in and [copious] every five years and just see what that does to a levee section. Let's have, you know, an area with big trees, let's have an area with bunch grass, let's see what it takes to get different vegetation in patterns started on a levee. That -- to propagate some kinds of vegetation on these droughty levees is difficult.

So, there are lots of different things that I think could be done. It might be worthwhile to have a large test facility where you have an earthen embankment and you can load it hydraulically. But it's hard to simulate blood and guts, so you might have to build that in prototype scale with some coffer down type structures where you could do that. But that kind of money that you guys are slinging around out here, I don't see why you wouldn't want to do that.

Emir Macari: We have a question right over there. Certainly, we'll be hearing from the perspective in Holland this afternoon and I don't know, maybe something out of this symposium, we could develop a white paper that says the first 10 row of homes next to -- does anybody live near a levee?

Male Voice: In this study, did you have any sense of how sick the revetments were, and was there any particular growth patterns in the vegetation that were correlated with different types of revetment?

Doug Shields: Say that one more time.

Male Voice: So, did you have any sense of how sick the revetments were? In other words, how much rock was on top of the levees at these sites that had damage associated with them? And the second thing was, did that seem to -- did the revetments seem to affect the growth pattern of the vegetation? Were you able to see, you know, a particular type of growth or a --

Doug Shields: Okay. The revetments were constructed, more or less, to standard Sac. bank standards and there were two main kinds. There were the older, cobble revetments and the newer rip rap revetments, and they're documented in the West Technical report and in the referee publication.

As far as the effect of the revetment on vegetation patterns, the main effect was that once you revetted a bank, and laid that slope bank to -- laid the slope back to lay the rock on it, you would frequently induce deposition of sediments in a prism, or a wedge, that was then colonized by woody species and that was the main effect. And so you had this nice, heavy wedge of sediments that supported all kinds of vegetation, some quite small and some becoming quite large, and there's a sketch of that in the paper. It's also described in 1991 Federal Inter-Agency Sedimentation Conference by Karen Fisher.

Seemed like there was one other aspect. Oh, I was going to say, there's a very liberal definition of damage. When we got out in the boat and we started going around and saying, 'Well, this is damaged, that's not.' One square meter of displaced stone was damaged, okay? So, we took a very liberal definition of what is damaged.

And while I have the podium, or the floor, I will say that there were a lot of people that contributed to these efforts, and I don't have time to call out all the names. I've mentioned the names that are here on the screen, except for Terry Waller. I want to make sure that I do give acknowledgment to all these folks.

Emir Macari: One question right here, please.

Male Voice: Thank you. I noticed that you had a plot that showed -- a slope stability plot where you showed those factors of safety and how the factor of safety increased versus the ratio of root mass, or root area. If you believe some of the things we heard earlier, that the soil has actually loosened, or weakened, do you think it's appropriate to show factors of safety for dead vegetation? In other words, your baseline condition was with no vegetation, do you think you should also show a condition in how might it change for vegetation that is dead and decayed, and the soil has been loosened and it's lost its strength?

Doug Shields: Well, I don't have any data, and I don't know of anybody that has any data. You know, that would be a good field experiment, but I don't think you have any data either when you said that dead -- that soil that has dead roots in it is looser and weaker, you know? But it has been alleged.

It is a fact that there are many measurements that show that roots do contribute to soil strength. You know, that -- there's lots of data and the earliest data, of course, is due to Dr. Gray, but there's plenty of data on that. Dead roots, you know, I don't know of any information on that.

Emir Macari: All right. Thank you. I've been asked to request three people to go to the back of the room. There's a media consultant here that would like to interview Ed Wallace, Ken Rude and Michael Stout. If you could make yourselves available, I think that they're trying to write an article regarding this symposium.

Okay. Our next speaker is Chris Peterson. Dr. Peterson is a professor of Forest Ecology in the Department of Plant Biology from the University of Georgia, and his presentation is on Tree Wind Throw and contributing factors. Hopefully the question that arose this morning regarding trees and Audubon parks being blown as part of the hurricanes may be addressed in this presentation. Dr. Peterson.

C. Peterson: Okay. So, kind of following the theme that Alison used this morning, this will be Tree Fall 101, I suppose, and unfortunately, I can't talk to you for three hours, but I'd like to, but we'll try to fit it into 20 or 25 minutes. And so this is the outline of what I'll be saying. Just say a little bit about geography of windstorms, compare the Central Valley area to other parts of the US. Then, move into a little bit about the biomechanics of windthrow. I do that with some trepidation. I know all the engineers in this audience and I'm not. So, I'll do that with quite a bit of care.

And then talk a little bit about the influences on windthrow, tree characteristics, characteristics of the sand or the other vegetation, if you will. I hesitate to say forest because we're usually not talking about a real forest on the levees here. Plate characteristics are topographic or soil non-biotic characteristics of a particular location, and then of course storm

characteristics are an influence, as well, and I'm not going to address those so I'll just concentrate on the first few, and to kind of follow-up with something somebody said a few minutes ago, there's some great research opportunities here so, in terms of trying to answer some questions.

And the first thing I'll mention is just some preliminary comments, just basics. There's a whole lot more I can go into. Most of the existing and maybe all the existing data that I know of come from [Porid], okay, and so I was really clear when folks contacted me about coming out here and said well, look, I don't -- I'm not aware of any study anywhere that has been published on tree fall from levees. So, we're extrapolating a little bit, and I ask you to kind of bear that in mind.

Also, none of the information that I could find bears on the particular species that we're probably mostly talking about here today, the cottonwood and sycamore and live oak and valley oak here. I've been unable to find any tree fall information on these particular species. That said, most of the trends that I'll mention are pretty well established. A lot of it comes from my own work, and so I'll show you some real data, and they've been developed across a number of studies, and then finally as I mentioned, there are great research opportunities. Foresters in windy places such as Scotland are very concerned about tree stability, and have made great strides in developing mechanistic models to predict when a tree is likely to fall over or blow over or not. So, it strikes me as this is a situation where such models could be directly applicable to trees on levees.

So, geography of wind, you can -- probably this is no surprise to anybody. Okay. So, this is showing the distribution -- geographic distribution of tornados in the US. Of course, we've all heard of the tornado alley in the Great Plains area, and tornados decrease sort of slowly to the east. There's a little bit of an oddball or anomaly in Florida. There are lots of very weak tornados in Florida, and then, of course, the bigger issue for this audience is that there are very few out here, right. So, that's something that one need not worry about.

A type of windstorm you may not be so familiar with are [unintelligible]. The meteorological community has become much more aware of these. These are quite large storms. They may be 20 to 30 percent the size of a hurricane, but they occur in the middle of continents, and typically we see one or two per year in North America. Maybe one every couple of years in Europe, and they can be quite large. This map here shows the distribution of forest damage. Anybody here ever heard of the Boundary Waters Canoe Area? Okay, wonderful place. You should go there if you can. A 30 mile by 10-mile damage area here shown in the red from this windstorm, so 400,000 acres from a single storm. So, these are large-scale events. Happily for the Central Valley, they don't occur here, either, and the same thing is true of hurricanes, although we've heard a lot about Katrina today so I need to show this.

And as you're all aware, hurricanes form over the ocean. The ones that we're mostly concerned about with in America are the ones that come off the Atlantic and strike the East Coast or the Gulf Coast. Although, they also do form in the Indian Ocean and in the Pacific Ocean and so, Japan and China and other areas of Southeast Asia are affected. Here in

Sacramento, I'm sure there are many people in this audience that could say a whole lot more than I could about the wind climate here.

One good way of getting an idea of what the wind climate is, is to look at wind [unintelligible] And so here we see some from December and April and this is quite a long time span from 1961 to 2000 or something like that, and they show the direction that winds are coming from in a particular time period. And the different colors show what percentages of the winds are of different wind speeds, and so the dark green on the outer edge are the highest wind speeds. So, not an extreme wind climate here, compared to a lot of other parts of the US. So, that's maybe the underlying take-home message in terms of wind climate relative to other areas for the Central Valley.

All right. So, what happens when wind damage happens somewhere? I've picked the most extreme example that I could find. This is the result of an F4 tornado in Pennsylvania. We can see a lot of different things have happened. Of most concern here are the two most severe types of damage, trees either breaking off or uprooting. Of course, they have very different consequences, particularly in light of the issue of vegetation on levees. Uprooting, presumably, would have a much more dramatic and important effect on levee integrity.

Trees seem to fall in the direction of the wind blowing. That's probably no great surprise. You can see in the photograph here, the wind was blowing from the right towards the left, and of course the trees are all leaning over towards the left, and this illustrates, also, a -- it's a good illustration of the root ball idea that we've heard talked about. Allison talked about that. We've heard a number of other people speak to that.

Okay. So, a little bit about the biomechanics of windthrow. So, it occurs when there is a turning moment -- in engineering terminology, that exceeds either the strength of the trunk or the strength of what we call the root-soil plate. Okay. And that turning moment can be sort of approximated or modeled in the simplest way by just thinking of the tree being a lever arm, which is more or less the trunk, with a force at the end of that lever. Okay, the force is the wind pushing against the crown of the tree, and I think Don this morning was using the term sail area and sometimes the book -- people use the word sail to talk about the crown area of the tree that's exposed to the wind.

Okay. For the engineers in the audience, so the drag force on a tree crown can be calculated, and so I'm using just the letter  $D$ . Calculated from air density. Usually, in the most calculations I've seen, that's assumed to be constant. The things that we're more concerned with are the drag coefficient, which is the dimensionless number, the wind velocity, of course in meters per second, and the frontal area of the crown. So, this gives you an immediate idea of what sort of factors are going to be important in influencing tree vulnerability to windthrow. Larger trees because they have a larger crown are more likely to be wind thrown, even though they are bigger and have stronger trunks and stronger root-soil plates, the impact in terms of high wind -- the impact on the sail area increases faster as the tree gets large. It increases faster than the trunk strength does.

And the turning moment at the base of the stem, you simply multiply the drag times the length of the lever arm or the length of the -- which is more or less the height of the tree. So, another prediction is that trees with --

that have a crown mass concentrated near the top are more vulnerable because the lever arm is out at the end of the trunk, rather than at some lower point, and we'll come back to a few things like that in a second.

What I just told you is sort of the static picture. Of course, when trees are blown on by wind, they are dynamic entities and things change. They're not just static. There are a number of things that do change. I'll just mention a couple of them. The frontal area changes because twigs and branches will -- in fact, the whole crown will bend and present a smaller area to the wind. All right. This is called streamlining. So, that increases the value of A in this equation right here, and at the same time, the drag coefficient will change, as well, because leaves and needles and twigs are going to become more streamlined, as well.

So, drag coefficients and the area changes dynamically at increasing wind speeds, and the diagram here on the side is meant to demonstrate also that once a tree is deflected from being vertical in addition to the drag induced by the wind, itself, you have actually the weight of the crown of the tree that is off-centered. And that's going to tend to pull the tree in whatever direction its leaning. It's more or less an extension of what Allison was saying earlier about if you have an asymmetric crown that's leaning or loading a trunk and root plate in a certain direction.

All right. So, I just said this. So, this is the idea of streamlining.

Streamlining can be pretty important, okay. So, one calculation that was done with cottonwood is that a frontal area -- if you've got a 20-meter per second wind, is only 28 percent of the frontal area of the tree in still air, right. So, the streamlining can be pretty significant. As a result, this power that we saw back here in this slide, the  $U^2$  actually is not quite

accurate, and the more accurate number is drag increases with the power of 1.8 rather than 2.

And of course as you might imagine, as with everything else I'll say here, it differs from specie to specie, okay. So, we can talk a lot about the sizes of trees, but species are important in almost any kind of calculation in terms of windthrow. Species are different. They have different properties. Okay, trunk breaks -- it occurs if the bending moment exceeds the strength of the trunk, and here's the formula for the critical bending moment for a knot-free trunk, meaning a clear wood with no knots in it. And the main factor is the module could rupture, which is highly correlated with wood density, which was an easier thing to measure, and it increases with the cube of the diameter. Deviates is the forestry or ecology terminology for diameter [breath] type. That's the diameter of the trunk at one point for meters, and, of course, trees are weakened if there are defects in the wood. So, in reality this formula is applied with a knot factor as part of the formula, which decreases the wood strength.

Anchorage is comprised of four factors: The weight of the root plate, and we've heard a little bit about that already here today. So, the root plate or the root ball is the soil plus the roots -- the large root. The soil sheer strength -- the tensile strength of the windward roots, which is what this diagram is trying to illustrate, and then the resistance to bending and compression of the deep roots in the leeward group. All right. So, those are the four major components.

And people that have calculated this have found it very difficult to get accurate data on the second, third and fourth factor, and so they've come up with sort of a fudge, and that's what this formula is here. The critical

[unintelligible] used in field measurements is just number one here, but it's assumed -- and empirical studies actually bear this out, it's assumed that that's a constant component of the total turning moment -- or the critical turning moment. So, we have the first part of the formula, and that's just divided by the FRW, which is sort of the fudge factor.

Okay. So, three different categories of influence on types of damage. The biggest issue with trees is the size, right. So, this graph shows the probability of tree fall from some of my studies, as a function of tree diameter, 1.4 meters, and in almost all cases, the probability increases with size. That's no surprise. The more important thing is that it increases at different rates and different places. Okay. So, in some places it increases very dramatically from very small to not-so-small trees, such as the Cathedral pine, the diagram here. The other one, the [unintelligible] to a 1994 shows a very gradual increase, so it's a very sight specific . . .

As trees get bigger, a bunch of things are happening. The trunk is getting stronger, generally. The root plate weight increases. But the overpowering issue is that this sail area or the crown area increases, typically faster than those other things can keep up with, and also trees that get bigger tend to be more exposed. Okay, so if you're bigger than your neighbor -- regardless of your absolute size, if you're bigger than your neighbors, you're going to be more likely to blow over than your neighbors are, all right.

And then find larger trees tend to be older, and so therefore there's more likely decay or knots or some other sorts of defect in the roots or the trunk and so that will make the tree more likely to go down. Of great interest to this group, of course, is the fact that if a tree uproots, it creates this hole in

the ground, which is what some of us call the root pit, and there is the strong relationship between size of tree and size of root pit, and this increase differs with species. I've only shown one pulled sample here, but it differs from species to species.

Other species' influences are -- think characteristics of the wood of species. As you might imagine, species with weaker wood are more likely to break off, all other things being equal. So, we've got some pictures of aspens from Northern Minnesota, some pines in Southern Sweden, and you can see that not very many of these uprooted. The overwhelming pattern in both of these cases was trunk breakage, rather than uprooting because these are weak-wooded species.

Another species of fact is, as we've already heard, species differ in wooding depth. Okay, so a more shallowly rooted species are more vulnerable to uprooting. So, things such as Spruce, which is the Latin name as picea shown here in the right-hand side of the -- right-hand photograph, and, in general, conifers tend to be more shallowly rooted than a broadleaf tree. All right. So, therefore, they are more vulnerable for both uprooting and trunk breakage.

One of the frustrating things is that the relationship between vulnerability and size changes among species, all right, and it is also site-specific. So, there's a lot of difficulty in making really broad generalizations here. So, species differ in vulnerability for a particular size, so if you look at the upper two lines, they're showing -- from one particular site, we're comparing Hemlock and Beech in the east, and you can see that the

Hemlock is more vulnerable in the size range from about 15 to 30 centimeters than the Beech is.

If you look at the diamond symbol line, you see a very different sort of story. These are the same two species across the same size range, but a different storm that was only about 5 kilometers away. All right. So, the relationship of species to each other and vulnerability to size can be very site and storm-specific. So, that creates us -- gives us a real difficulty in making -- sweeping a broad generalization.

What about stand characteristics? There's a number of stand characteristics that influence vulnerability. The two ones -- two that I'll mention the most here are the density and presence of edges. So, low-density stands allow more wind to penetrate in amongst the trees. Trees that are at low density do not have mutual support with each other. When you have a high-density stand, the trees actually bleed off some of the energy that might knock them over by crashing into their neighbors, okay. You have a low-density stand where the trees are far enough apart when they wave back and forth, they can't run into or lean on anybody else, okay. So, at lower density, trees are more vulnerable.

Now, the flip side of that is that trees are adaptive organisms, and I think Allison mentioned something about this, this morning. Trees that have been growing in an open circumstance will do their best to develop a wind firm root structure and trunk, as well. All right. So, there are some complexities there, as well.

And then the other sort of stand effect I'll mention is related to this, and that is trees on edges are more vulnerable than trees that are further into a

stand. Again, because the leaning on each other effect and because the trees on the edge are attenuating. They're taking the brunt of the wind, if the wind is coming off of an open area.

Fight characteristics, there's a whole bunch of them, as many as you undoubtedly realize. Topography is a big one so damage is usually greater at higher elevations. I spent a semester in Finland on sabbatical a couple of years ago and heard a lot about the winter storms they have other there, which are kind of like temperate hurricane, and so in 1999, they had Hurricane Lothar or what they called hurricane. And it caused an immense amount of damage across France, Germany, Austria, very large areas, and so this picture is from there.

And this had wind speeds of, you know, 150 to 160 miles an hour or kilometers per hour in the valleys, but up on the mountaintops was 230 kilometers per hour. So, there's a very strong topographic effect. Windward sides of hills and ridge tops are the most vulnerable topographic positions. And so here's just a little cartoon that illustrates that. If you've got a hill that's perpendicular to the flow of the wind, the wind tends to speed up over the crest of the hill. You typically get turbulence if it's steep enough on the leeward side, and that turbulence can, itself, be a major cause of windthrow, as well.

Now, one key question that's in my mind, which I'm not enough of an airflow person to know this, is whether the levees in this particular area are big enough to sort of qualify for this sort of scenario. They may just be too small to have this sort of thing happen, and then, of course, there's soil characteristics as we've heard a little bit about from various people today. The two key factors are depth of root penetration and saturation.

So, saturated soils have much lower shear strength and so roots can pull out of them and soils that restrict root growth, that cause you to have a very shallowly rooted tree of course are going to increase the vulnerability to wind throw as well. Okay, so those are some of the major factors. There are a whole bunch of other ones we can go into if we want to talk more later, but I do want to mention that there are some great research opportunities, especially after I heard things just a few minutes ago, you know, about what are the questions that we can address -- well, there are mechanistic models that have been developed by foresters, particularly in England and Scotland and Northern Europe that take all these factors into account. So, there's a couple of them -- one is called Forest Gales and one called H Wind and these are models that calculate the critical turning moment needed to overturn or break off particular trees if you know characteristics of the tree, so the size, diameter and so on. What the next step is after doing that is to merge those models with site features like soil conditions and topography to get a site specific estimate of wind speed -- the wind climate in a particular location, and then finally overlay that in a GIS sort of context to sort of bring all these factors together and this could be done of course in levee context and come up with particular predictions for particular stretches of levee if you know the site characteristics of soil, topography, exposure and the trees that are on it.

So, there is a great research opportunity. And then finally, I'll just make a few of my suggestions. These sort of echo what Don was saying earlier. There are things that can be done if one is concerned about wind throw that aren't maybe as drastic as completely removing all of the trees. So, removing part of the crown area reduces the length of the lever arm if you cut off the top 20% of the tree. Many trees will survive it. Some certainly

will not, but many of them certainly will. You can reduce the wind velocity on your Heritage Oaks or whatever by having additional upwind trees or you can deflect the wind upward by having sort of a stepping stone of small shrubs, large shrubs, small trees, that will just push that wind up over the trees that one might be concerned with saving. And, then down the road, there is certainly the opportunity if the public desire for it is to have trees on the levees, is to have species that are much less vulnerable. Okay, so, there is a great deal of variety among species and their wind firm in planting. Wind firm species as opposed to weak species would be the solution for 20 or 30 years down the road. Thank you very much.

Emir Macari: Okay, we have time for a couple questions. One and two back there.

Male Voice: I have two questions -- your research. One is, did you look in any of your research or others at the difference in slope angle of the landform to tree fall? And my second question is you talked about the group plate dimensions in terms of diameter. Did you also -- do you have data on the typical size, depth rather, of the root pits -- not the root system, but the root pits?

Chris Peterson: No and yes. It would be feasible certainly to do the measurement at the function of slope, but to my knowledge, neither myself nor any of my colleagues have that data incorporated into the field measurements unfortunately. The question about depth of root plate, I certainly have information on that from some of my studies. Not all of them. Typically, ecologists and foresters are more interested in the aerial extent, so we tend to concentrate on sort of the length and width rather than depth. But, at least in some of my studies, at least we have depth information as well.

Really, quite a bit like what Alison was saying earlier. So, we might see root plates that are 10 or 15 in diameter and 2 or 3 feet deep. I have rarely seen anything more than probably three feet deep and that's pretty unusual. Most of the root pits that I've seen are two feet or less.

Male Voice: You've used the term wind throw and I could be wrong, but at least in my observation in our area, I don't really see from my own experience wind fall. I see a lot of trees that fall over, but it's often associated with when the river comes down and you just have the whole slope failure and the tree comes with it. Now, on those areas with riprap, it's less likely to have the trees growing in with the rocks. But, generally speaking, from what I see, after the high crest of the flood, the water goes down super saturated vertical bank. The tree tends to fall over. I'm not saying that the tree is causing the bank failure because in fact, there could be a lot of cases where without any vegetation you have more mass failure. So, I think tree fall is perhaps a more generic term and I don't know if all the tree falls are really due to wind fall or not around here.

Chris Peterson: I'm sure that you are absolutely right and I certainly didn't want to imply any thing differently other than you know, Peter asked me to come and talk about trees blowing over in the wind, so that's what I talked about, but I certainly agree that there are a whole bunch of other causes that may be a major factor here as well.

Emir Macari: Okay, one last comment here.

Dick Marshall: Dick Marshall with the California Central Valley Flood Control Association. Have you done any calculations -- you know we mostly have deciduous trees along our rivers and on our levees here -- what the

reduction in a wind sail is from loss of the leaves in the winter time when the levees are first subject to the saturation and high winds?

Chris Peterson: Yeah, actually people have looked at that and the reduction and drag on a tree after it loses its leaves for a deciduous species typically can be down around 20 or 30% in the winter compared to what it was in the summer. So, there is a dramatic change in that area that's presented to the wind, whether you've got leaves or not. So, the same wind in two different seasons could have very, very different effects on whether trees blow over or not.

Emir Macari: Thank you very much Chris. Our next speaker is Joe DeVries. Dr. DeVries is a hydraulic engineer with David Ford Consulting Engineers here in Sacramento and the title of his presentation is Vegetation Effects on River Hydraulics.

Joe DeVries: We're going to take a little bit of a look at hydraulics here and what I'd like to start out with is looking at some levees and I've got a variety of pictures. One of them came from DWR of different types of conditions along levees. So, this is up at river mile 99 on the Sacramento River -- some rock along the water, some vegetation above it. Here at river mile 6.4, highly vegetated -- hard to see where the bank is actually. Again, a little less dense vegetation but pretty highly vegetated levee bank and 44.7 again on the Sacramento River. A picture from the Feather River where there is sort of mixed vegetation but shrubs and some trees. Another picture from the Feather River where there is some really good sized rock on the right hand side here and it sort of goes into a little less dense vegetation into highly dense vegetation along the river bank. I was looking for places where I could really identify riprap along the

Sacramento River and it took me a little bit of work to find a place I could get a picture. This is on the main stem of the Sacramento left bank, some place below hood and what's interesting I think is that vegetation is trying to get itself established here in the rock along the riverbank. And, I thought I ought to put this one in because this is sort of an unusual condition along here. It looks like it was a riverbank that had essentially concrete lining along it that is becoming flexible lining now due to probably settlement of the levee, but it's changing its characteristics there a little bit.

So, I would like to talk about what happens in terms of floodway conveyance -- the capacity of the river to carry flow with vegetation effects, implications for near bank erosion, the effects of vegetation free areas is next to levees. I found some information about erosion around trees and suppression of waves in areas that were vegetated and I don't want to steal anything from the next speaker who will talk about primarily boat wakes, but there is some information about wind wave and boat wake waves and how they influence what happens on the levee. Well, basically, and some of you are hydraulic engineers -- you know this -- but, water flows down hill so gravity is the driving force and basically the resistance to flow is what happens along the boundaries of the conveying system, the river bed and banks and hydraulic engineers use Manning's equation along with an empirical coefficient we call Manning's N to express this boundary surface roughness. Manning's equation is the thing we use to characterize resistance and in its simplest form, it involves relating the discharge -- cubic feet per second -- to this empirical coefficient the Manning's N, along with some of the physical characteristics of the cross section. Hydraulic radius, which is the cross

sectional area, the flow area divided by the wetted perimeter, that part of the channel that's in contact with the water.

So, we have the hydraulic radius and we have the flow area again in this equation and then we multiply that by the square root of the energy slope, which is approximately the same as the water surface slope in the river and that's the relationship that relates roughness characteristics, geometric properties and the energy loss in the system. And, one of the things when I've looked at river sections is that we typically don't do a very good job of showing what they really look like because most rivers are really quite shallow and very wide. They are very wide with respect to the flow depth and the riverbed itself makes up most of the wetted perimeter, the boundary that the flow is going along and the banks, including the levees, comprise just a small fraction of the wetted perimeter. And, if we look at the effects of vegetation on levees, we're really looking at a small contribution to the overall flow resistance. So, I tried to plot a picture of what an undistorted plot -- if we keep the vertical dimension the same as the horizontal dimension for this particular section of the Sacramento River, it is really very wide and not very deep, even at flood stage, which is basically what I'm showing here. In the typical way, at least hydraulic engineers like to look at pictures and cross sections where we distort the plot so we can actually see all the points in the cross section and get an idea of what the depth looks like. But, it is really this little area -- let's see if I can get the cursor up here -- maybe not. Oh, there it is. Up along the edges here where we have resistance due to vegetation on the levees on each side and really the whole width, the whole bed has a much larger effect on the hydraulic resistance. And, being an engineer, I wanted to find some way to quantify this.

I didn't really have the opportunity to run large scale models so I picked out some typical cross sections for a central valley river. So, I've got a cross section that I took and had levees and basically a reasonable looking cross section of the Bear River and the Yuba River and again, I'm plotting these with a 4 to 1 distortion so I can get them into a recognizable plot here and read the scales. And, I also looked at the Feather River cross section -- a Feather River cross section and a cross section from the Sacramento River and I pulled off a cross section of the Feather that's part of I think a levee setback area. So, in this case, it is very wide relative to the depth and I plotted the upper plot of the Feather River cross section at a 20 to 1 distortion so I could get it on a plot so I could see the values quite easily. The Sacramento River, which as you go past Sacramento, is more like a canal than a river. It is roughly trapezoidal and cross section has really uniform slopes in the levee and looks less like a natural levee. Fortunately, we have the yellow [unintelligible] passage or the flood plain but it is basically more like a big conveyance canal. Okay, now I want to look at what the effect of vegetation on levees -- I got this paper by one of our speakers here today. Dwyer is co-author on this -- where they looked at various types of vegetation at levees and I wanted to consider a fairly high density of vegetation on the water side over to the left side there in contrast to then with a situation where there would be a low roughness coefficient on that area next to the levee itself.

And, I did this analysis sort of using the standard program for river analysis, the Hydrologic Engineering Center River Analysis System, a program called HECRAS, sort of the general purpose tool for river analysis. I made some runs with these four typical cross sections with and without vegetation on levees, so represented that by or high end values with the vegetation on the levee in that particular area and low in values

with no vegetation or basically grass type of surface. And, I looked at what the difference in the conveyance capacity would be for the typical river section at capacity -- how much flow it could carry. I also looked a little bit -- because HECRAS provides some way to evaluate velocity distribution and I took a little look at that as well. And, for my computations on the Feather River, which was that very wide section, whether or not we had high vegetation on the levees, really produced a very small reduction of the conveyance, so I had really only 1.6% reduction on the conveyance, where we went up 5 on the Bear, 3 on the Yuba, 2 on the Sacramento River. One of the things of course that is going to happen if we remove vegetation or dense vegetation next to levees, is we are going to increase the velocity in the banks and we'll have potential for additional scour and you can see some of the effects from this sketch I stole from [unintelligible] on velocity profile. So, if you have low vegetation, you get low velocity right at the bed surface.

If you have trees with no low limbs, you get a higher velocity through there and lower velocity above and mixed vegetation gives you that sort of glass shape there. So, in my HECRAS analysis, I looked at an end value for the low roughness of being .035 the banks and the velocities in that calculation were about 1.5 feet per second. If we look over on the right side with a high end value, .08 velocities were reduced down to .6 feet per second and so it was contrast between two different types of banks -- low roughness in the previous one and high roughness in this one. I'll go through these slides of some wave run up fairly quickly here but one of the major factors affecting erosion on levees is the fact that we get wind waves that when they impact the levee, will run up the levee surface of the slope -- same thing happens with boat wakes. Different types of surfaces respond differently and grass levees are basically like a

smooth or concrete surface. The runoff is the highest and is not attenuated at all. Shrubs and trees attenuate the trees to some degree. Vegetation also provides additional erosion protection. Rock and riprap provide the greatest degree of protection. The Dutch have done some studies of this and it is quoted in a Corps paper, that you can knock the waves down to about half their height, an attenuation of about .5 to .6. You are going to hear about grass mats and using grass on levees. Grass mats provide high erosion resistance and this is due primarily to the structure of the root layer and not the thickness of the layer of the grass or the leaves or the stems above the ground. And, the consensus primarily of the Dutch experience, plant roots are important in keeping the particles of soil together. A well rooted grass mat can resist one to two days of sand exposure, to flood velocities.

Poorly rooted mats may fail within a few hours and I think what's important from a California perspective is that you need an actively growing perennial grass and I think what works well with grass levees in Holland is that it rains every month in Holland and you get good irrigation. I've got one minute so I'm going to move through this and basically you'll hear about this. There is a study done by the Corps of Engineers on the effects of tree stand for protecting levee embankments, primarily from winds and wakes. If you don't have branches down in the water, the wave reduction is small, maybe 9 or 15 % of the wave height. If you have tree stems that have branches down in the water, the maximum wave attenuation is about 45%. Since I'm out of time, I'm going to skip over this case study. It's an interesting study. You can find it on the internet -- the Williams River in Australia and they've revegetated the river where they were restoring vegetation -- I'll go back one here -- to provide bank resilience and roughness to stabilize the banks. They

recognized that vegetation along the river would increase the hydraulic resistance during flood events and this could potentially increase flood heights and reduce flood protection. So, to wrap this up, basically my pros and cons relative to hydraulics with vegetation on levee, is that levee armoring with properly designing woody material and vegetation will slow flood water velocities near the banks, dissipate weight energy, reduce scouring potential, increase soil strength and the con of course, is you are going to have minor decreases in the river conveyance capacity on the wide channels. On narrow channels, the decrease is going to be a little more significant. Thank you.

Emir Macari: We have time for a couple of questions. Anybody in the audience?

Joe Devries: I guess we all agree.

Emir Macari: Well, they do agree with you. That's very good. Okay, we have a question.

Male Voice: I have a question. I would like to know why engineers use such low manning end values to design conveyance channels in the first place.

Joe Devries: I don't know if they do. For example, I think we have a pretty good database now on like the main stem of the Sacramento Feather River. People have been doing analyses and calibrating models from major flood events, like the 97 flood event and for example, we've got some of the models that were developed initially by the Corps and also modified the [unintelligible] and they've adjusted end values slightly but have had good correlation to get reproduction of observed flood events. So, it's possible to I think home in and get good measures of these roughness coefficients.

Emir Macari: Okay, question right here.

Female Voice: Yes, I have a question also. You said before that vegetation on [unintelligible] would reduce the velocities. Did you study how much is the increasing water elevation upstream due to the reduction of the velocity in the water?

Joe Devries: Could you ask her the first part of the question please.

Emir Macari: The first part of the question again please.

Female Voice: Yes. You said that the vegetation on the river bank would reduce the velocities in the water, yes?

Joe Devries: Yes it will, yes.

Female Voice: And how much is the increasing water elevation upstream of the area vegetated?

Joe Devries: It could be -- if you had unvegetated levees and you added vegetation, possibly 10 foot a mile, something like that.

Female Voice: Is this not against the FEMA violation that does not accept an increase in water velocities to everything --

Joe Devries: I think that maybe we'd be looking at more than -- seeing increases is the fact that there is a fair amount of vegetation and if we would be removing it, we would be reducing the water surface. I don't know what FEMA

really does if you have increases in vegetation growth and they can't regulate that very well and you are going to get increases in the water surface elevation.

Female Voice: No, but if you intentionally bear the vegetation, it's a violation. If it is a vegetation that is natural --

Joe Devries: Yeah, if it's natural, yeah. You may have to look at your free board or your risk analysis to ascertain whether or not you are encroaching too far up on the levy.

Emir Macari: Thank you very much Joe. Our last presentation in this section is by Dr. Doug Sherman. Dr. Sherman is Department Head and Professor in the Department of Geography at Texas A&M University and the title of his presentation is Assessing Mechanisms in Race of Levee Erosion in the Sacramento and San Joaquin Delta. Dr. Sherman.

Douglas Sherman: Please let me begin by thanking the organizers for the great job they've done putting this event together. This is pretty spectacular. I want to say how privileged I feel to have been invited and also to be able to represent my co-authors on the science team. I want to note that particularly because this is part of the record, that almost all of us were at the University of Southern California when this project began and in particular the listing of NASA and East Bay Mud have current affiliations with two of our former students, does not represent in any way an endorsement of these findings. I am going to summarize very quickly about ten years of research in different phases. The first three parts of this project have been sponsored primarily by the California Department of Boating and Waterways. The last two projects listed here were also

sponsored by CALBO and partially underwritten by Hart, Incorporated, a consulting firm in Walnut Grove, proprietor Jeff Hart is somewhere over here. Thank you Jeff. I appreciate that. What we've been trying to do over the years is get a good handle on how much bank erosion is occurring in the Delta out of a variety of locations and how much of that erosion might be the result of boat wake activity. When we first undertook this project, we did so with the proviso that we are allowed to make conservative estimates of boat wake impacts wherever possible and by conservative, I mean in our context, to maximum potential impacts of boat wakes. So, I'll run through this quickly.

First, our long term monitoring program. We'll talk about our efforts to monitor boat traffic, particularly with the inventory of boat sizes and speed, characteristics of wakes in terms of the energy in individual boat wake and their ability to mobilize and remove sediments from the banks. We'll talk about our project to map and characterize eroding water lines and we'll talk about the last two topics which are probably most germane to this symposium and that is to model the effects of surrogate vegetation, i.e., brush bundles and real vegetation and in this case, non-woody vegetation [unintelligible] stems. I do have a pointer here but I'm not sure I'm going to use it yet. We established an erosion pin network that comprises 44 sites scattered throughout the Delta and here we sort of put the sites on this map in three categories. One are those on maintained levees, a second set are unmaintained levees. Unmaintained levees in this case are those that surround some of the drowned islands for reasons that I don't understand are still called islands. Mildred Tract, Mildred Island, for example, and others and then a set for mid-channel islands. We have 4 to 12 erosion pins on each one of these sites. They are all monitored four times per year. We have ten years of data for the oldest sites. Some of our

newest sites which are replacements for reclaimed sites only have two years of data and we measure vertical and horizontal change on each of these. We try to distribute these across the Delta and we've also distributed them according to the [unintelligible] of environmental processes that we think are most likely to be controlling bank change at those sites. I'll talk more about that in a second.

This is the erosion pin concept. It's pretty simple. They don't actually look as pin-like as this. These are just iron rebars, little yellow caps pounded into the bank. When we go back to visit these sites, if the pins are sticking out, we measure how far they stick out and we pound them down flat again. If they are buried, we have metal detectors to find them. We dig a hole and measure how deeply buried they are and fill the hole back up again. When we picked the sites, and this is part of our conservative approach to this, we picked sites that were visually, actively, and rapidly eroding. So, we have picked a cross section of some of the most rapidly eroding sites in the Delta and across the slough here, you can get a sense of what some of those sites look like. When we saw a site like that, we got to it, put the pins in. You can notice at the upper part of the site up here, someone has actually planted trees as an attempt to stabilize that. For some of the process distribution, we also put a series of sites in some of the Delta backwaters where there is minimal to no boat traffic, there is minimal river flow and there are minimal wind waves and so we have several sites, I think four or five in the vicinity of [Railroad Cut] -- this is near Walnut Grove for those of you who are familiar with the area -- and this is kind of the background rate of Delta levee changes where there is a slow rise and fall of water due to tidal exchanges and some discharge and it's just the slow dissolution of mud banks. We have others where we have strong currents, boat wakes, wind waves, medium tide.

We have a whole number of these sites. This is a location on the Sacramento River a few miles below Walnut Grove. This is south where Georgiana Slough splits off from the Sacramento River. You get a sense of what a typical site looks like. Along here, we went by boat and we saw bare earth exposed between the trees and we put pins in there. And, so this is what it looks like. For the most part, the location to the left hand side of this diagram, are the older ones. The ones to the right hand side are the newer ones and we can see that for a Delta wide statistical look at this, we are averaging about .13 meters per year of horizontal bank erosion and about .03 meters per year of vertical erosion. We see one site in particular where there have been very, very rapid horizontal accretions, about 50 centimeters a year for the duration of this study. That is on the inside of a meander bend. It's an over seeping meander bend and so that there is accretion going on there as part of the Georgiana Slough tries to round off the corner. If you exclude that site, all the erosion values go up by about a centimeter a year. We can see that we have a number of sites where the horizontal erosion rate exceeds 20 centimeters per year, about 8 inches. Because we go back four times a year, we've been able to put some seasonal signatures on these data and this is a bit more tenuous but we think we're starting to get a pretty good signal here. And, the typical characteristic we see here is that there is usually a reduction in the erosion rate or a slight accretion during the winters followed by a little bit more erosion than in the summers. So, here we can see summer erosion, summer erosion, summer erosion. These half stripes represent each summer season bracketed by Memorial Day in May and Labor Day in the fall. What's going on here are two things that cause that wintertime erosion. One are the flood deposits of poorly consolidated muds, which we do measure. Also, if we get bank collapse in the wintertime, that

shows up in our summer measurement as accretion because material has fallen across our pins, which are all put in the lower part of the profile.

I want to give you a tale of two sites and I 'm sorry I'm going through this quickly. It's hard summarizing it. You can ask me questions later if you are interested. Sites 5 and site 17 which are on opposite side of Georgiana Slough. This is what site 5 looked like in September of 2000. We've instrumented this site to actually measure boat wakes. This site is unusual in that there is a relatively wide mud platform unvegetated in a low cut bank behind that. On the opposite sit of Georgiana is site 17. we can see two large unvegetated scallops. If you look carefully, you can see that these have been modified. Jeff Hart had been here putting his brush bundles, basically ruining the site for us -- thanks Jeff. On this side, you can see the coloration slightly different. This had been a demonstration project by the Corps of Engineers where they put in broken gravel and then planted it with small trees. If you look at this site today on both sides, it is heavily vegetated, partly because of the effects of the brush bundle and partly because of the tree plants there. If you look how they behave through time, we've got site 5 here and we can see relatively steady erosion through time until we get to this point in the summer of 2004, when the bank collapsed. We had a large bank failure burying our pins. Of course we measured this again as accretion and slightly after that, Jeff Hart put a brush bundle here where the vertical green bar is and we can see that after that point when the brush bundles are involved, we start to get fairly rapid response, dramatic accretion at this site. Across the slough at site 17, we can see that between the summer of 1998 and 1999, we had dramatic erosion. That's the removal of the unconsolidated gravels. Once the gravels are out of that scallop, the erosion rate slows

down substantially. We can see brush bundles installed in 2000 and we have kind of a tapering off of the erosion rate.

At this site there were also some large woody debris put in there and plantings and the site began to revegetate itself and by about the summer of 2005 and continuing, we started to get accretion at this site. I point these sites out because by picking sites where obvious and dramatic erosion is occurring, none of our sites by definition were then vegetated and this is one of the very few sites that has revegetated itself during this study period. We've also been trying to actually find out how much erosion can be caused by the boats per se and there are several ways we've approached this. Over several summer holiday weekends, we videotaped radar gunned boat traffic. We counted all the boats, measured the impact of the wake using pressure transducers to measure wake height, current meters to measure the loss that's associated with them, optical back scattering sensors to measure sediment concentration and from these data, which we've not finished yet, we are trying to sort of develop an atlas of boat impact on the bank. We've also done two experiments. In one case, we drove a boat past one point 500 times -- that was kind of fun -- so then we did it 1000 times. It's not as much fun as it sounds, really. The novelty wore off after about ten times, but we had to do it this amount to actually try to drive some kind of bank change that we can measure so we can get a sense of what does this do. In all these cases -- and I don't have a picture of this -- we loaded the back of the boat with graduate students and concrete blocks to try to get the boat to mush through the water to generate the largest waves that we could. These are some sample data. Up here, we see a current meter record. This is the period leading up to the passes of the boat. Here we see the velocity fluctuations caused by the wake itself. Here we have the record from the

optical back scatter and sensor. This is measuring the increase in suspended sediment concentration caused by the impact of that boat wake on site 5, one of the locations that I showed you earlier.

The main photograph -- this is site 5, you can just see the probe of the top of the current meter there and the suspended sediment that had been stripped off of this bank. We have published one paper on this that discusses the impact of 7 particular boat wakes that were controlled by us and now we're trying to span this to be more genetic. For a couple of summers, we measured boat traffic, in some cases with and without the measurements. Labor Day 2000, Memorial Day, Fourth of July and Labor Day 2001. The N equals the number of boats that went by. A couple of anomalies here -- Fourth of July, 2001 was in the middle of the week so we had unusually low traffic and for those of you who have been around for awhile, you may remember Labor Day 2001 -- it was a really crappy weekend. It was cold and it rained. So, those are anomalously low values. So, we can convert based on our profile measurements about how much erosion occurred and we can see that for all of those studies, we get between a little bit less than one-hundredth of a millimeter, up to about .2 millimeters per boat passage. For our 500 and 1000 boat passage experiments, we get erosion rates of .03, 01 and .05 millimeters per boat passage. These are fairly broad scale numbers and the variance is because for each one of these sites, we have numerous micro profile and we get different values depending on which stuff we look at, so we are still trying to agglomerate those data. To couple this with those weekend boat counts and those impacts and trying to find out and get some sense of what the total boat traffic is like, I'm going to show you a video if this works.

I've been pretty stressed about this. We have a video camera set up on Georgiana Slough. It monitors from sunrise to sunset everyday. It has a motion detector in it so that when it detects the motion of a boat going by, it saves the preceding and the succeeding -- the preceding 10 seconds and the succeeding 20 seconds and so we can see what happens here if this works. That didn't work. I'll try it again. Here we go. Watch the wake bounce off the far bank. One of the problems here in the Georgiana Slough in particular is that the channel is so low, there is substantial wave reflection off both sides of this. The far bank is vegetated and we can see that waves are reflecting off that vegetated barrier. And, so I have graduate student who spends all his free time going to this video trying to characterize the size of the boat, the direction of the boat, the type of the boat. And we are developing algorithms that will let us estimate the boats speed from these videos so we can compare it to our other data sets. This is what the boat traffic has looked like since October 1, 2006. Our goal here is to try to get one year of data. We are about five weeks away and we're hoping that camera doesn't get taken in the meantime. We can see the effects of holiday traffic here. This is the Columbus Day weekend. This is Memorial Day, Fourth of July and we're ramping up now. This is through last weekend -- and hopefully we'll get a nice turnout for Labor Day weekend this year. We'll see. Passages so far of 2833. We read online it was something on the order of the 3000 boat passages per year. Now, another one of our fun activities was to map the characteristics of the water line for 800 miles of levees in the Delta. This maze of orange indicates the levees that we've mapped. They are all categorized as 9 different bank types and we use these as one indicator of potential erosion vulnerability. I want to say a few things about this again. This is a very conservative estimate. We don't actually know what these levees are

made out of.

What we did was categorize what we could see at the water line. These are some of the categorizations -- partial rock, partial concrete, unprotected, which means we can see bare exposed bank with little or no vegetation, trees or vegetation. Now, if you have blackberry bushes that are growing down across the riprap -- and we can see no riprap at the water line, we categorized that as vegetation, so that in all of our cases, we have made conservative estimates of what the bank type is. If there is rock underneath that and we don't see it, we don't categorize it as rock. This is an overview of the Delta that we've mapped. If you see colors here that are in red or blue, that means that they are protected by some combination of rock or concrete. Those have minimal susceptibility to boat wake erosion and we're not talking about overall levee integrity -- water line susceptibility to boat wake erosion. We've done a breakdown on the bank types. We have about -- of the 800 miles that we've categorized, 75 miles that are unprotected -- this is bare exposed soil or sand that does include a few beaches -- 65 miles that are vegetated. This is non-woody material usually. And, 50 miles of what we call trees. Now, for us, trees include three different things. One, where the branches and leaves of the tree are down into the water, two, where the water line comprises the root masses of the trees, or if there are down trees in the water and the down trees provide a substantial barrage of boat wakes, we also consider that to be a treed water line. This map shows the distribution of the 5's, 6's and 7's. 5's are trees, 6's are vegetated and 7's are unprotected. This is a fairly good snapshot of the areas that are most vulnerable to boat wake and I guess by extension wind wave erosion in

the Delta. You can see that the central core area is pretty well protected. It's mainly some of these fringe areas.

Many of these, in fact, are not really amenable to boat traffic. We had to only go a few miles an hour to try to get through the snags and about the only boats we saw were some hardy bass fisherman. This is Georgiana Slough. Just to give you an example, Georgiana Slough is probably the highest boat traffic area with the least protection. This site here where our tract departs from the curve, this is the meander bend where we are getting all the accretion and we couldn't get closer to the bank because of shoreline. This mapping project just finished this July. When we quality control these data, we'll kind of stretch that path out to match the shoreline better. The last two parts -- brush bundles and Tule stems. We had two students with master [unintelligible] trying to look at some of the effects of shore protection and boat wake, and mitigation structures. The brush bundles -- I don't know if Jeff Hart invented these but he's put I don't know how many miles along parts of the Delta. This one is notable because it is a relatively small section. It's anchored between two trees where there is a large v shaped scallop behind those, behind the trees -- that's what it looks like from the land side. We put a series of pressure transducers and current meters here -- a set inside the brush bundles and a set outside the brush bundles to measure how efficiently the brush bundles can reduce the transmission of boat wake energy to the banks. We have a control for the data. We were able to put those pressure transducers in before the brush bundles were in place so our control site is that location without brush bundle. I have drawn two red lines on here. The vertical red line is the normalized water depth. That is the water depth relative to the crest elevation of the brush bundle plus the height of a typical boat wake and so that at  $H=1$ , the average boat wake will not

have any water come across the top of that. The horizontal red line is an energy ratio.

That is the ratio of the energy measured at pressure transducers near the bank divided by those measures outside of the bank. And so that if the values are scattered around 1, that means there is no attenuation and if the values are less than 1, that means there has been attenuation. We can see for the control there is no real pattern there for -- oh, I've lost the cursor again. Where we have the brush bundles in place, we can see that under all water levels, there is a reduction in boat wake energy. So, only about 50 % of the energy is transmitted through the bundle even with water well over that, and when we have low water levels, somewhere in the order of only 10 or 15% of the boat wake energy gets through. Now, this has important implications for vegetation. We don't really have tree root systems that behave like brush bundles in terms of the transmission of energy through them. However, what we do have are root bundles that have the same kind of wave reflective capability as the brush bundles. And, so most of the energy that is lost here is not turbulent dissipation through the brush bundle per se, it's reflection back off of the outer surface into open water. We think that is a reasonable surrogate for how root bundles at the water line behave. The Tooley stem experiment was designed exclusively to see how valuable the self-conscious planning [unintelligible] might be to reduce boat wake energy -- by extension, wind wave as well -- the same principles are involved here. This is based on some of the concepts first noted by Markel and Dean. In their studies, they weren't looking at flexible vegetation. They were looking at woody vegetation, but it was the best hand we had to get this process started. Where dissipation should be a function of the stem size, the stand at

density and the width of the stand. I won't spend a lot of time on these equations.

There are only a couple of variables here that are critical.  $H_0$  is the wave height outside of the vegetation stand,  $H_x$  is the wave height at any given location  $x$  within the stand, the variable  $x$  itself is how far you are within the stand from the outside.  $A$  is a little more complicated. It represents CD drag coefficient of the stems themselves,  $D_s$  is stalk diameter, so we basically have a common drag coefficient here  $3\pi$ ,  $F^2$  (squared) is the spacing between the stalks and  $H$  is the water depth. Now, Dean's model was originally designed for tsunami modeling and storm surge modeling across through forests, but we tried to apply it here. This is what Dean's model predicted. We did 10 data runs of five boat passes each. We measured the wake height through the stand at two meter intervals over a 10 meter distance total. Between each set of runs, we send out the Tules. We did a methodical reduction in Tule density. When we cut them we measured their stem diameter. This spray of red line represents 10 % decreases so that at this point, we have about 50% stem density and up here we have no reeds left in our stand. Then, we compared these with Dean's predictions. This is our observers that predicted wave heights. Our score was 51%. There is a lot of variability here but still, this is a bit better than a shotgun blast. I've drawn the red lines in here to show that we actually measured, observed a little more attenuation than Dean's model predicted. So, where we had an observed wave height of .15 meters, Dean's model predicted we should see .24 and so we actually have a bit more dissipation by the reeds that his model would predict. So, to kind of summarize these findings -- and I do want to emphasize these are preliminary findings because we still are involved in this project and some of these numbers are going to change as we wrap this up.

The average erosion rates for the unprotected sites in the Delta are about 13 centimeters a year for horizontal erosion, 3 centimeters a year vertical erosion. Those are again conservative toward the high side. The boat wake erosion averages about 9 centimeters a year. That number we got at by taking the average of all of our per boat passages and multiplying them by 3000. Now, this is a good number and a bad number. I mean it's good in the sense that for the sites on the Georgiana Slough we don't actually measure that much erosion anywhere and so it's a good number because we've actually overestimated the erosion caused by boat wakes. It's a bad number because we are not getting a realistic number yet but we're still working on that. There are about 200 miles or less of levees in the Delta we think are vulnerable to some degree to boat wake erosion. Brush bundle dissipated about 60% of wake or wind wave energy and the tooley stems -- this is a relatively thin stem, a thinly populated stem, not very thick -- dissipates between 15 and 30% of the wake energy. So, thank you very much.

Emir Macari: Okay, we have time for a few questions. My understanding is that from the data then that you are saying to people, do not ride their boats on the river and that's not good news, but then again, you look at it and say, well you can ride it but in the winter because that's apparently where there was less erosion.

Douglas Sherman: I think people should ride boats wherever they want. Understand this -- that when we count these boats, a 40 foot cabin cruiser going at 10 miles per hour and throwing up a phenomenal wake counts exactly as much as an aluminum fishing boat going by at 2 miles per hour. And this is part of what we still have to figure out from these data and so that's kind of our

atlas of size, speed and impact. So, we have a way over estimate of the impact, but certainly boat waves do erode the bank.

Emir Macari: We have a question right here.

Male Voice: Well, he might just have addressed it. Is there an attempt to correlate the boat speed, size and also width of channel on your erosion problem?

Douglas Sherman: We haven't focused on width of channel yet because our main effort has been in Georgiana Slough and in our study sites there's not a whole lot of width. One of the things we are doing is where we have the detailed measurements of individual boats is to try categorization. So, we have 30 foot boats at 5 to 10 miles an hour, 30 foot boats at 10 to 15 miles an hour and so forth, to see what the energy component of that group of boats in like and then we can break down the annual counts into those same classes. But, we're not done with that yet. I've got a PhD student who is working that out for his dissertation now. Hopefully, he'll finish pretty soon.

Emir Macari: Any more questions? I think folks are looking forward to this break. Alright, well thank you very much Doug. We are taking a break then -- a 15 or so minute break. There are some refreshments and things in the back I assume, so please be back and we'll complete the marathon, the last 10 kilometers this afternoon.

Okay, so here we come. Okay, so here we go. Alright, just a minute or two more to get everybody in their seats. Great. Because this next set of presentations are really from foreign dignitaries, [unintelligible] Louisiana being considered foreign to the republic of California.

Missouri, the show me state as well. Okay. Basically, this next section in the agenda presents some practices of the past, what has happened and provided some experience that folks have had in different parts of the country as well as abroad. Our first speaker is Michael Stout. He comes to us from New Orleans District. He's an urban planner. New Orleans District of the US Army Corps of Engineers and obviously having been there and experienced what has happened over the last two years, urban planning -- it's a very, very important part of this issue that we're discussing.

Yesterday, we visited several levees around the area and we saw many multi-million dollar homes -- the California Ninth [Wards] basically on the other side of levees, and it brings the reality of what these regions could be affected by, especially in their flood plain. My office is Sacramento State University, California State University, Sacramento -- which is right across from the Guy West Bridge right next to the American River, we are under 25 feet of water if those levees fail, so it is very much a reality that we live with. So, the presentation is New Orleans, current vegetation removal activities, driving factors and technical basis. Michael.

Michael Stout:

It's not unusual to have Louisiana referred to as something other than the United States, so I'm fine with that introduction, basically a banana republic. But anyway, yes I am an urban planner, my background, so I'll preface with that and go ahead and get started here. I just want to make one comment -- a lot of references to Katrina today. Obviously, those of us in New Orleans have a pretty firsthand feel for that, so you'll see some of the work we've done since Katrina. One of the many themes that the Corps of Engineers stood up in the wake of Katrina was this tree removal

theme and I was volunteered -- I mean I volunteered to lead this team and so knowing that it would be well received by the population in New Orleans. So, anyway, our scope includes three tasks, the Lake Pontchartrain and vicinity projects of which I'll show you a graphic in a few minutes is the project that protects New Orleans -- the east bank of New Orleans. It's the project that was heavily damaged during Katrina.

And so, our main focus of my team has been involved in removing trees that lower the -- I mean that induce risk to the system of this project and it's done under the repair and rehabilitation work after Katrina, that was authorized. So, that involves removing trees and fences and I'll get to fences. I haven't heard that come up today but I wanted to share that with you because I think this is an issue elsewhere. But, removing trees and fences within 15 feet of levee or burn sections or flood walls and that though is limited by where we have right-of-way available or preexisting right under state law, and I'll cover that. Another task that we had were to get inventories of encroachments of other levee systems in our district. We have about 1300 miles in the New Orleans district and so we have gotten a lot of that inventoried as far as GPS locations of trees and fences and other encroachments. And, then another one of our responsibilities is within the organization to champion, to be an advocate for the Corps' vegetation management policy so that we don't -- as we go about the repair and enlargement of the hurricane protections system in New Orleans and in the region -- that we not get back in the same situation we were in pre-Katrina, with a lot of encroachments that we believe are harmful for the system.

This graphic illustrates the project. The red lines are the Mississippi River okay. So, the other colors here on the right hand and top side and I'll see if

I can get the pointer here -- these represent the levees that protect the urbanized areas of New Orleans, okay. And, if you are familiar with Katrina, the damages -- the heavy damages were to the MRGO, the levee that goes along the Mississippi River Gulf outlet here in green, some of the levees here in New Orleans East and then some of the spectacular levee breaches occurred on these outfall canals as well as the industrial canal right here. So, a lot of these levees since Katrina have been repaired. Other sections were not so heavily damaged and that's where our work is focused. We're -- there was not active repair work going on because the trees that were a problem there were being taken care of as part of the repair work. So, this is the status of our work. It really got underway a little more than a year ago and all we're showing you here is that it started in April of last year as far as the actual removal of trees and it continues.

The area we are focused on right now is along the 17th Street Canal which is one of the outfall canals that I illustrated there. The total cost estimate for what we're doing as far as removing trees from the Lake Pontchartrain project is about 5.3 million. To date, we've spent 3.2 million. Just a plan map to help you orient the outfall canals you know. Here is first St. Bernard and lower Ninth Award is here. These areas were heavily devastated by levee break. New Orleans East is this area. I'm looking at -- the work we've been doing is mostly focused here in New Orleans proper and then this is Jefferson Parish over here and these are the three outfall canals. One thing I want to illustrate for you is this is the London MU Canal. It's residential on both sides of the canal. The Orleans Avenue Canal is the middle one and you might be able to see that on one side it's a city park, on the other side there's a roadway and then the canal furthest to the west is the 17th Street Canal which is residential on both

sides. Okay, so a lot of this has been covered. I'll go through this quickly and then I have illustrations. Why are trees a problem? We get asked this all the time and we've covered these things. I know some of these things, these points may have been disputed by some of the previous speakers and so obviously there is still work to be done here. But, tree roots and levees provide pathways for seepage especially when the trees or the roots are dead.

The root balls of blown over trees can create critical voids during a storms, worsening seepage and weakening stability. Large overturned trees can fall on and damage flood walls or other features. The shading from trees can result in erosion of the levee embankment and poor turf establishment and I've got some illustrations of that. Trees too close to the levees impair maintenance, inspections and flood fighting activities. And for all the science I heard today that spoke to levees increase, you know, slope stability, the caveat I seem to hear very frequently is well we didn't address maintenance or we didn't address inspection. Well, I've got to tell you that we have to live with that so we're addressing it. Fences. I haven't heard fences come up but this came up early in our mission because initially, our goal was to simply -- where trees that were behind fences that were a problem, remove the section -- if there was a gate, we go through the gate, remove the tree and leave the fence alone. But, what we came to realize is we did more inspections of encroachments were that in many ways fences were a big part of the problem. One of those being that fences are where trees -- volunteer trees -- are going to grow up. In our environment, it's largely hack berries or sugar berries and Chinese Tallow. These trees will -- anytime there is a fence that's not well maintained, these trees are going to grow and they're going to get large pretty quickly. The fence lines that are on the slope or at the toe cause a

problem in terms of doing levee inspections, especially say, a privacy fence at the toe.

There's no way when you are doing your levee inspections from the levee you see problems that may exist in the toe area. They also impair maintenance of the levee in terms of cutting the grass -- you may not be able to get down to the toe to cut the grass. The vegetation is coming up. It can also hinder flood fighting. We found that out in the immediate days after Katrina and we had to build roadways in because there was too much development close to some of the levee break. This is an illustration we use at some of our public meetings to try to illustrate why a blown over tree, especially along the outfall canals in New Orleans could be a major problem during a storm. And, I'll point out a few things here. One is that even in -- I know we've made the distinction between levees and dams, that there is a higher standard of care for dams and we understand that. In this case, these structures are essentially dams year around because the adjoining neighborhoods are below sea level. Now, I heard somebody say 10 feet below sea level and there are very few areas in New Orleans that are that low to be quite frank.

There are a lot of parts in New Orleans that are two or three or four feet below sea level and if -- these canals are open to Lake Pontchartrain and the typical water elevation plus one. So, you have a four foot head maybe along a lot of the outfall canals. So, these levees are essentially dams and they are -- and as I'll show you an illustration, there are lots of trees -- there were lots of trees at the toe. Tree falls near levees. Okay, we can say this is hypothetical or impossible. Here's a couple of illustrations of where they actually occurred. This is on the 17th Street Canal within a few thousand feet of where the major breach occurred and here's a large tree

right at the toe. I don't know if you can tell but this fence is actually a few feet up on the slope. The toe is about where the tree has uprooted, removing a lot of -- creating a large void there right at that critical spot along the levee. This is on the London Avenue Canal also near one of the breach sites, again showing a large tree. This one has fallen sort of toward the flood wall but still right at the toe and you can see the fence section that was lifted up and the problem that creates. Here's some other views along London Avenue.

The toe is about basically where the bricks are and you can see trees, large trees on the slope, as well as fencing climbing the slope. Another area along London Avenue Canal with trees right at the toe and getting to the issue in vegetation and fences, getting to the issue of inspection, there is no way to see the toe area you know, in this kind of setting. And this is a portion of the London Avenue Canal after we had removed the tree. In this case, we removed the trees, we cut them off and then we removed the stumps as well as dug out the root, down to half inch in diameter. So, it was essentially a levee repair job and then brought in clay and compacted the fill. And, this is before the grass has taken seed but this is after the job has been finished along the stretch of the London Avenue Canal. And, you can see the improvements in terms of removing the trees and the fences and now we can inspect that area and it can be maintained properly. This is along the Orleans Avenue Canal which is along City Park and you can this is a large live Oak that was unfortunately was actually killed by the salt water that sat for weeks, but what you may not be able to see in this slide too well is the fact that due to the heavy canopy over the levee slope, there was no grass establishment in this area and the embankment had eroded and there was actually like a pretty good divot in

the side of the levee there holding that flood wall up. 17th Street Canal which is the one furthest west.

There we have fences and trees coming right up to the crown of the levee and this kind of illustrates it from somebody's backyard. Most of New Orleans is flat and if you are one of the few property owners along the outfall canals, you might have a hill in your backyard, unfortunately a levee. The fences went up to the property line and then you had all kinds of features in the levee section to include steps, retaining walls, structures, even swimming pool. And, this is the other side of the 17th Street Canal, the Jefferson Parish side and again you can see trees right at the toe and you might be able to see that there is no grass growing in the shade of these trees. There is gravel that's been put down by the levee district but obviously the preferred surface cover is grass, and then fences again that prevent inspections in the toe area. Some of the challenges we face -- obviously in a storm like Katrina, we lost a lot of our urban tree cover and now on the heels of that, here is the Corps of Engineers removing more. So, that has not been very popular because some of the areas we've worked in have been public parks. There are many trees in backyards and behind fences and that work has been done under authority that's in the Louisiana State law and it's covered here.

The footprint of the levee is covered by the Doctrine of Unopposed Use and then there is an additional state law that says levee districts can remove obstructions within six feet of that levee. So, under this, we are actually going on to private property to remove trees and you can be sure that's not popular. Okay. We took advantage of the fact that we were going to remove hundreds of trees to get a tree root study underway. We got with LSU Forestry Department through an AE contractor, Dr. Jim

Chambers, Dr. [unintelligible], developed a methodology very similar to the study that Dr. Berry represented. In fact, it's a little eerie hearing her talk about her study. It's almost exactly what we did. Okay, one thing that I want to point out here is we looked at trees of various sizes and distances from the levee and then we tried to be specific to speed the [unintelligible]. This illustration shows three different trees actually being studied. In the foreground there was a pecan tree about 25 feet away where we did trenches looking at its root extent and that hole is being backfilled and compacted. Then, in the middle ground, there were some cypress trees that we were studying that were maybe about 6 feet from the toe and then in the background, there is a large water oak tree that we were studying.

So, this is just a good illustration of the kind of areas we were looking at. And, then again, it was a similar type profile wall method to the other study. 79 trees studies, 8 species common to Louisiana, 217 trenches and again, we were restricted to shallow depth. On average, one of our findings were that the edge of the crown or the canopy, pretty much defines the extent of roots that are half inch or larger in diameter. However, we did find there was variation by species. This table summarizes the results looking at the radial extent of roots of these different species and in this table we are showing the roots that are larger than half inch and then the roots that are larger than one inch, accounting for 50% of the roots that we counted in the profile. So, you can see, it starts out cypress sugar berry about 10 and one-half feet, sycamore and pecan for roots that are half inch apart. If we want to account for 95% of the accounted roots then we have to go much further and we have some species where the distance is around 18 feet but when you get to sycamore and pecan, we found much greater distances. If your concern is

about roots half an inch or larger, then you know, the 15 foot guideline may need to be examined, at least in the soil that we were working with. Okay, I'll summarize real quickly here. Our trenches were shallow.

We did document that tree roots climb the levee slope. However, because of the shallow trenches, there's more work needed to determine what their behavior is into levee sections and below levee. I think others have pointed out that that's a significant data to get. Then, we think there's some research needed in looking into preexisting trees, those that have established root systems before the levees were built and those trees that have grown since the levee was there because we think there are differences. And, again, deeper roots need -- we noted some during some exploratory trenches, they have concern and this additional study definitely needed to document that. I'll just close and say that we've been focused on the Lake Pontchartrain levees around New Orleans. We've got about 900 miles of other levees and we've got lots of tree encroachments along the Mississippi River and the [unintelligible] Bay, so we have lots of work ahead of us. Thank you.

Emir Macari: Okay, we have time for a couple questions. One here and one here.

Male Voice: Yes, I was in New Orleans last week and was riding around and was looking at the areas that you are talking about -- around the outfall canals and the property lines of course, as you pointed out, go up to the levees around those canals. You know, this 15 foot right-of-way I guess there is an issue there about the access, having the right-of-way or a roadway next to the levees, which then goes deeply into the property and in some cases the houses there. What are you all going to do about that?

Michael Stout: That's a big challenge for us on the outfall canal because residential development does go right up to the toe and sometimes up the slope of the levee. We are working right now -- our interim guidance within the core is out to 15 feet of to the extent of whatever right-of-way you have and in this case we are limited to the outfall canal to the actual footprint plus six feet out, but we are not achieving the 15 feet in most cases, but we are clearing that six foot zone. We do have one reach where even the footprint plus six feet actually goes into peoples' homes, so we are still struggling with that.

Male Voice: You said you had a contract for 5.3 million dollars to remove trees?

Michael Stout: Not one contract. That's our total estimate for tree removal from that project.

Male Voice: How many miles is that?

Michael Stout: I don't have that number off the top of my head. The total levee system is like 350 miles, but the tree removal doesn't cover that full extent. It's probably less than 100 miles of that extent.

Male Voice: Is that all urban or rural or mixed or what is that?

Michael Stout: It is a mix. I mean the areas we've been working in on the outfall canals are primarily residential. We've also done work along the lake front levees where it's mostly a public park setting. And, then there are other areas that we are going to be working on that are more rural, more remote type settings. It's a mix.

Emir Macari: There was some issue of the old cypress swamp that was out there. As the city started growing and then water was being brought into the canals, a lot of these trees were just simply cut at the base and levees were built on top of -- because it was for agricultural purposes at the time. Can you comment on that because what we saw on some of these pictures from the report was really that the stumps from those cypress trees being pushed over as well. Okay. We'll talk about it a little bit later then.

Michael Stout: I'm not really sure of that. I will say that the outfall canal levees started out as foil banks from the 1800's and then became local levees and actually the Corps never built those levees. We installed flood walls into those, but they are definitely not poor standards as far as material or compaction. There is no doubt about that but I don't know about the cypress stuff. I've not seen that myself.

Emir Macari: Obviously, a lot of the levees, not just in New Orleans but also here, they were grandfathered in. They were not built engineering building, so that will be interesting. Question?

Male Voice: When one hears of the issues with Katrina and Louisiana, does Louisiana engage in all of this just as we do in California with the Department of Water Resources in Louisiana and something like a State Board of Reclamation -- is there that same type of format that proceeds all projects within the State of Louisiana?

Michael Stout: Yes, and that has changed since Katrina also. Before Katrina, we were mostly dealing with local levee districts and they still exist but those levee districts have been consolidated as well as the State has established additional oversight state wide and region wide. So, that has changed. It's

still evolving, but the Department of Transportation and Development at the state level is now more heavily involved than prior to Katrina -- more oversight of the local levee districts as well as trying to work issues out with the Corps on a statewide basis, so that has changed.

Emir Macari: Okay, we have a question in the back.

Male Voice: Good afternoon. Quick question. We heard this morning several speakers that impugned this notion of dead roots leave pathways or opportunity for seepage path, that they shrink as they decay, and I'm curious what science is the Corps using because I've heard two Corps speakers that's the facts and that's the way it is and we've heard two others with more recent studies it sounded like that say, well we don't find any evidence of that. So, curious what the Corps' position is based on in saying that the roots create pathways, particularly dead roots.

Michael Stout: I think it would be outside of my realm to say what the Corps' position is. It's obvious in our technical manuals and in our guidebook that it is a concern. I've heard that, you know -- and before this symposium -- I'm aware that the science may not support that, so I think that's an area that definitely needs more research. As far as the Corps' position, I would let one of our folks in headquarters probably answer that.

Emir Macari: And certainly that will be an area that we will be examining in the panel. Make sure to please write that as a question for the panel tomorrow because I know a lot of these folks will go this evening rather than going out to dinner to go do research on these issues so they can go and answer them. We have a question over there and the last one over here.

Male Voice: My question is just about cost. Do you have a sense of the relative cost of what you've expended so far? 3.2 I think you said million, of structural removals versus tree removals and the proportionate cost to repair the levee structure to a current standard after the trees were removed? Can you segment those three costs?

Michael Stout: In general, and I could get the figures exactly, I just don't have them with me, because we actually develop our cost estimates that way, and there have been certain segments where all we did was cut the trees under one contract and came back later and dug up the stump and the roots, so I've got -- I would say in general, the greatest cost by far is in removing the stumps and being careful about getting the roots out and then bringing in clay and backfilling and doing the levee repair. That's by far the greatest cost -- the heavy equipment, the clay, the compaction, the tests, that's by far and then followed next by the tree cutting itself. As far as fences -- all we've removed is fences, so that's relatively cheap. So, it would be in that order, you know, the levee repair is by far the most, then the tree cutting and removal and then the fences are the minor part of it.

Emir Macari: Last question over here.

Male Voice: Thank you. We heard that -- I guess my question is that in the areas where you had trees growing roots up into the levees, were those also the levees that had where essentially dams had water on the backside all the time?

Michael Stout: That had water where?

Male Voice: Water -- or on the water side, was it up against the levee year around?

Michael Stout: It was in all the levees that we tested where we had trees within 10 or 15 feet. Normally, our trenches would start -- we had a narrow right-of-way we were usually working with so usually about six feet out from the toe and the next trench would be at the toe, as illustrated in the other study, and then we would work our way up the slope until we ran out of roots and often, that was not until we almost got to the flood wall. I mean well up the slope the roots were tracing up. What we don't know is were the roots also, you know, below our trenches because as we went up the levee --

Male Voice: Sure. One of the troubling things I think for us in the Sacramento Valley is the one size fits all approach that the Corps appears to be applying here and really the lack of justification for it that's been given to us so far. The climate in Louisiana is very different than it is in Sacramento where we don't get rain for months at a time.

Michael Stout: And we get rain all the time.

Male Voice: Yeah, everyday, and so the roots of course will follow or take after the water but we don't have that here. So, have there been any discussion on sort of regional variations in the approach?

Michael Stout: I think current Corps policy has already, I discovered this morning, you know, provisions for regional variation and I'm sure that's why we are here at the symposium is to explore this further. I mean I can tell you in New Orleans district we have 1300 miles of levees but in different situations, we don't think there is one size fits all just within our own district. I mean I think there is clearly a distinction between the coastal levees that are subject to hurricane wind forces as opposed to river

[unintelligible] situations. So, I don't think there is one size fits all and I don't think -- that may have been the impression of the Corps' policy but it seems to me we are headed toward something that is more, you know, adapted to local conditions.

Male Voice: Okay, thank you.

Emir Macari: So, as we hear, yes that is the reason for this symposium, is to have that dialogue to look at where things can be applied to a local condition and hopefully by the end of our symposium tomorrow and then into Thursday when there is executive meetings taking place, a lot of these things will be ironed out, but it's great to see this type of interaction. Our next speaker comes from the Netherlands, Clara Spoorenberg works for DHV Consultancy in Holland. She is a geotechnical engineer and the topic of her presentation is The Dutch experience - Scientific basis for the Dutch levee vegetation policy. The Dutch groups have been doing quite a bit of work in New Orleans and were also brought by Congresswoman [Matsui] here about five or six months ago to have a dialogue with our local agencies to establish best practices. Clara.

Clara Spoorenberg: Thank you. Good afternoon. I am going to tell you about vegetation on Dutch levees and practices. As has been made clear several times this morning in the US, a levee is not just a soil structure providing strength to withstand high water stress and a tree is not just a foreign element within a levee. Both levee and tree are considered to be part of a larger system in directing elements on various scales that provide safety against flooding as a whole. Change one thing and you risk complete system changing in order to adapt to the new situation. In the Netherlands, this approach is similar. Trees can be considered as part of the system and I'd like to tell

you about vegetation on Dutch levees in this respect. After a small introduction on the location of the Netherlands on this planet and the size of our country and the amount of levees we maintain, I will tell you that according to Dutch national legislation, no trees on levees are permitted. However, trees are not an unusual sight on Dutch levees.

Nevertheless, we claim to meet our required safety levels regardless of the presence of these levee trees. By means of a couple of practical examples, I will explain how we manage this by using either a levee, a tree or a combined approach. Furthermore, I will shortly mention some complimentary properties of trees near or on levees including some Dutch [unintelligible]. For those who are not familiar with [unintelligible] so you will know what we are dealing with. The Netherlands is situated in Western Europe and measures roughly 120,350 kilometers. Two-thirds of the service is up to 7 meters below mean sea level. Our country is threatened by high water level from the North Sea, from large rivers from Germany and Belgium and a couple of big lakes. It is secured against flooding by more than three and a half thousand kilometers of levees, dikes, dams. Some of them are over 1,000 years old. In addition to these primary levees, we maintain 14,000 kilometers of secondary levees along canals, small streams, brooks, creeks and smaller lakes. Only the primary levees are shown on this map. 24 water boards are responsible for the quality and performance of all our water retaining structures.

By law, they are obliged to perform a safety review on the primary levees every five years. The results are reported to our government. Safety reviews contain all but retaining aspects of our levees, including foreign objects [unintelligible]. In the near future, the same review frequency will be compulsory for secondary levees as well. In practice, most water

boards have consultants such as myself to perform the review for them. Consequently, as a consultant, you have the benefit of seeing, understanding, reviewing and designing a lot of different systems for a lot of different water boards. Firstly, I'll go into different policies. From a [unintelligible] point of view, Dutch water boards have a various approach regarding their policy toward trees on levees. In practice, we can distinguish between a toleration policy with or without licensing, extinction policy to remove and replant outside the water retaining closed structure and construction measures. Most water boards allowing trees on their levees pay extra attention to their trees during high water.

I'll demonstrate two different policies based on practical examples. Secondly, I'll mention some events resulting in national legislation. In the past, a couple of events have been [unintelligible] related to trees on levees. These events include uprooted trees during their 1995 storm, and stability problems which may be related to the presence of trees. From these events, the Dutch Levee Advisory Board published new national legislation regarding our trees on levees in 2000 and 2001. By brief consideration, I will point out our Dutch policy based on these reports. Finally, I'll include public opinion in the tree discussion. A lot of trees have been removed from levees in the name of safety. Only recently, public opinion has turned against this policy. The Dutch are attached to our trees. They value their natural beauty and I think Americans do not differ from the Dutch in this respect. The water board I live in is called [unintelligible]. This water board looks after 200 kilometers of primary levees. In the last five years safety review, no less than 21,000 trees were assessed only within the influence of these levees. But the removal of 179 trees that did not meet the minimum required vitality, the safety level of

the [unintelligible] levees is guaranteed. Later on in my presentation, I'll come back on the applied tree assessment technique.

One water board down on the other hand, there's hardly a tree to be seen from on any levee. This water board has never tolerated any tree on or near their levee. Maintenance of the strict policy is the keyword to levees free of trees. Such big differences, although we do only have one national legislation regarding our levees. But who is right and in which one would you live? Or are these levees equally safe? As this slide demonstrates, trees may be a burden during a storm, causing damage to the water retaining source that they are part of. But also because of blown branches and damage due to dynamical tree motions during storm conditions, I use this argument for the tree removal policy. Obviously, this is not the first storm that has caused trees to be tipped over on levees. The ability of levees is affected by several aspects such as soil strength properties [unintelligible]. Trees might influence their stability in either a positive or a negative manner. Dependent on the location within the levee profile, the [unintelligible] weight of trees might increase or decrease total stability. If [unintelligible] occurs due to tree motion, this is considered a negative influence. Lowering of the [unintelligible] level on the inland side of the levee might influence stability in a positive way, by the drainage effect or negatively, by the supplement [unintelligible] induced.

This slide shows indications of supplements caused by water withdrawal caused by trees during an extreme dry summer. Whether or not this will cause a stability problem will be found on the local situation regarding [unintelligible] properties. In Dutch levee design, the lists of positive properties of trees are not taken into account. We cannot be certain the tree will be present at the place and the time we need it. Weight can no

longer be counted in stability calculations after the trees have been uprooted. And, during winter conditions, no tree induced drainage will occur during high weather conditions. Furthermore, the presence of trees might be random and therefore of limited use in levee design. On one Dutch levee, seepage was discovered during high water conditions. By the looks of it from the outside, deep tree roots were held responsible for the problem. Once the levee was excavated for investigation, [unintelligible] and burrows were exposed and related to the seepage. One Dutch study points out even decaying roots contribute to the total [unintelligible] of strength and should not be taken out after the tree died for safety reasons. Obviously, this slide shows signs of bank erosion caused by the presence of trees.

This is considered a negative influence on levee safety. Later on, I will mention some study results regarding slow reduction properties of different types of vegetation. As opposed to the ocean picture, trees can be valued for their ability to retain sediment. Apparently, whether or not erosion will occur will depend on local conditions. Trees on levees have long been a discussion issue in the Netherlands. In the first place, there is no argument on [unintelligible] involved. What situation is to be considered the worst case? The situation where the tree is uprooted or the situation where the trees are [unintelligible], but also applying an additional dynamic load to the levee. And how will [unintelligible] either of these situations? We do have some ideas for this. I would exceed my time going into these. As for the decaying tree roots issue, specialists wouldn't agree either. Decaying roots tend to create hollow spaces in the levee including the permeability of root soil [unintelligible]. Small burrowing animals like worms work their way through this leveling of the

[unintelligible]. Planting of new trees could reduce the problem by new roots replacing the hollow spaces to form new roots.

I think this slide and the next one will speak for themselves. They show inhabitants pointing out additional functions of trees on levees and demonstrating against the removal of the trees. The value of the presence of a tree to the public can actually be calculated. This is showing a 9 million dollar oak tree that was maintained in the middle of a new highway due to the public influence. I've went through the details of two practical cases, the last one being rather commonly used in the Netherlands, the first one being a suitable solution for a specific situation. This concerns a special case. The levee had to be improved for safety reasons. The responsible water board planned to take all trees out in order to be able to perform the important work. Action groups demonstrated against this and a judge decided another technique was to be used. Only the necessary trees were to be taken down. A few were cut back. A complete [unintelligible] was installed in order to gain sufficient strength to withstand high water levels and of course to spare the trees. All that I mention is based on the assumption that a tree, including its roots, does not take part in the levee strength. Neither the uprooting nor the dynamic loading situation tree fill will influence the calculated safety level.

All that I mention may include special methods such as [unintelligible]. From a tree's point of view, a lot can be done to improve levee safety with trees. I'll mention an assessment technique and some measures to be taken. A special tree assessment contains tree health condition and tree stability properties. The assessment is performed by a specialist and based on biological characteristics such as crown form, number of branches, length of new branches, etc. The stages of fungus may indicate group

mortality. [Unintelligible] of my mechanical defects reaction [unintelligible] may indicate an increasing [unintelligible] risk. It would be [unintelligible] to mention all characteristics used in the assessment technique and you can ask me for more detail if you're interested. If a VTA results in uncertainty about the tree vitality, further investigation is possible. Internal tree degradation can be measured using a [unintelligible] or a penetration measurement. The results will show that the tree is in a critical state regarding the acceptable risk. In addition to cutting down of trees, for levee safety purposes, some tree saving techniques might be applied. Measures include limiting crown dimension in order to reduce the sensitivity to wind, improvements of the growing circumstances for better rooting and therefore, anchoring, or replanting on a less sensitive location. Cutting back of trees will affect their root system and will reduce wind loads.

The previously mentioned negative influence on some trees on levees, a couple of positive properties can be measured. Trees outline the landscape. Moreover, Dutch levees with trees are considered a cultural heritage. Their function may be valued for recreational purposes. The same is applicable to trees and natural resources that may govern levees. In this respect, the complete levee system, vegetation affects water transportation properties. Changes in vegetation from grass to trees or the other way around will result in different resistance to flow and therefore may influence the upstream or downstream flow ravine. In a detailed Dutch study, the flow pattern for different kinds of vegetation was calculated in order to model the system's resistance to flow characteristics of the complete system. Despite the contradicting specialists' opinions, based on the study results, we might conclude that trees may contribute to levee stability in both a positive or a negative manner. Counting only the

negative aspects that occur and neglect the positive influence might be a too conservative approach for the design of levees, resulting in a legislation stating no trees on levees are allowed.

From the Dutch experience, it is clear that under certain circumstances, trees can be tolerated on or near levees using both methods from the levee, the tree and a combined approach. All mentioned measures have to be designed to take out or compensate a negative effect of trees on levee safety. Coming back to what I said in my introduction and what has been mentioned several times today, in levee design, all aspects, including trees, should be taken into account. So, before removing all trees from the levees, for example, for wooden shoe production purposes, all possible systems, consequently, have to be studied. Thank you for your attention.

Emir Macari: Okay, we have time for one question, and I should mention that the next speaker will present points of view from Germany and different types of settings -- one being coastal, the other one being inland, and with the river flowing a little bit perhaps closer to what the Sacramento region is. One question. We can also hold it for the next speaker. We have one question over there.

Male Voice: Yes, my question is to come to this type of balanced view, what would you recommend we do? Would this require a lot of public involvement, or what's the model here? Is this the [Puldar] Model you call it, or what should we do?

Clara Spoorenberg: I do not think there is just one solution. I think you have to look at the specific case you are studying and then look at all the aspects and all the

functions you want to have on the levee and then find specific solutions for every case.

Emir Macari: So, yes, it's obvious that Clara is not only a good engineer, but she's also a very good politician. Thank you very much Clara. Our next speaker comes from Bavaria. Dr. Ronald Haselsteiner is a geotechnical engineer with RMD Consult in Munich, and the title of his presentation is Dykes with Wood Vegetation in Bavaria, Germany, Design, Experiences and Research. Ron.

Ronald Haselsteiner: Thank you Emir. Good afternoon. First of all, I have to point out two advantages for you that I am not a native speaker. First of all, I will speak so slowly that you can follow me and the second is that I will only use words that you know. Maybe you will understand it, but okay. I stand here as a representative of our responsible ministry of the State Department of Water Resources and last but not least for our Institute of Hydraulic and Water Resources Engineering of the University of Technology in Munich and I hope I can give you and grant you an insight how we care or how we don't care for our protection dykes in Bavaria, Germany. First of all, I want to give you an outline of my presentation after a little bit longer introduction where I want to tell you about two programs that are let's say the arms to the flood threat, or the arms of the local authorities to the flood threat in Bavaria. I want to go on to the experiences, particularly during floods with woody vegetation on dykes.

Then, I will tell you about our technical standards and we Germans, we've got a lot of technical standards, so we even do not know how to build something that is differing from the standards. And, before I end with a few research topics, I want to give you some structural solutions, how we

can ensuring with the ability of a dyke even allowing some trees on dykes. So, as my fore-speaker, my Dutch colleague gave you an overview of Dutch, of Holland, you see here Germany -- on the west side you see Holland, on the right side you see Poland, and France on the west side borders Austria and you see the major three river systems -- the Rhine on the west of Germany, the Danube on the south of Germany and the Elbe in the east of Germany. Yes, okay, the Rhine, the Danube and the Elbe. Each of these river systems suffered from floods in the recent years, as maybe you know. 2002 there was a very devastating flood incident at the Elbe region, Elbe River, as you see here. Maybe some of you were on vacation in Germany. You see the [unintelligible] in Dresden that was flooded and on the right side you see the winter flood at the Rhine, in [unintelligible], maybe some of you know.

Then, here you see a famous picture that's been around the world -- this is [Regenstein], a little town with a monastery located in the center of the [unintelligible] and this is the River [Mulde] that's making a bend through the village there. And, maybe you do not remember this picture, maybe you remember this picture where there's four humpty dumpty's on the wall. They are quite relaxed and I do not know whether I will be [unintelligible] but you can relax now. They were safe by helicopter and the wall then broke down. Okay, then in Bavaria, we suffered from several floods in 1999, 2002 and 2005. You will see the monastery of Edinburgh flooded at the Danube and at the other side, you will see a village in the [unintelligible] area flooded. The monastery got a mobile protection measures or devices shortly after the flooding. The village was flooded twice, two times after in 2002 and 2005 and then they got their flood protection devices. So, about damages -- what would that cost after the flood incidents? The Rhine in 1993, and the Rhine 1995 they were

quite huge floods, but why should I talk around? The Elbe was outstanding. The damages about 9 billion euros you can flood protect all Germany. So, the answer of the Bavarian authorities -- one program called the Flood Protection Action Program 2020 -- 2020 because in 2020 it will be finished.

Something about Bavaria -- you see Bavaria -- this is located in south of Germany, Austria in the south, the Czech Republic in the East and the Danube is reaching from west to east. Maybe you know Munich, Oktoberfest -- [unintelligible], then you know where you are. We have got 12 million inhabitants and average precipitation about 600 to 2000 millimeters per year and we've got dykes in our larger rivers, at our larger rivers of about 1,200 kilometers. In our minor rivers, there are additionally about 400 kilometers. This program is divided up in three sectors -- natural retention, technical measures provision, and as it was passed in 2001, we will have expenses about 2.3 billion euros until 2020. That means about an average of 120 million a year and after the flood incident in 2005, it was up to 150 million a year. What do we have to do with this money? I think everything about flood management distance, the [renaturation] of rivers is a big topic in Germany this time. Relocation of dykes of course or flood retention with detachment area. Then we do a lot of controlled [unintelligible] and of course we ought to refurbish our dykes and provision -- we try to improve our forecast of our system, for example.

There are 115 million euros per year subdivided in the water bodies or in the torrents, as you see here, as I mentioned this. [Unintelligible] lies on the water board' first order, that means Danube and the [unintelligible] rivers like

So, even within these funds, we have to conduct our refurbishment of dykes. We see here the sum down below. It's about 1200 kilometers of dykes. We refurbished 240 kilometers of our dykes and we still have about 100 kilometers to either refurbish or to explore and therefore we estimated about 600 million euros that will be taken. Another program that was started was the [unintelligible] Program. This involved three countries -- Germany, Austria and Hungary. Each of these countries are related to the Danube and it was co-financed by the European Union and the aim was to create a vegetation management along the Danube. You see here the flood plain, there is a lot of vegetation and we have got no high discharge capacity -- this was all about simply shown by the sections here, the historical floods across in a system where dykes worse and little woody vegetation on the shoreline of the river and therefore, the flood discharge capacity within this flood planes were very high.

And, today it is like this woody vegetation is steep and between the woody vegetation the agricultural use in the form of corn fields dislocated. Though the water never rises, discharges and going down, the water never rises. And in future, we want to have something like a controlled vegetation with a higher discharge in this area. This is the vegetation management along the Danube clearing of critical existing vegetation, the limitation of agricultural use. There are no corn fields in summer -- winter it is possible, but no corn fields in summer. And, you see here a little map downstream of the town of Staubing and you see all the red little things -- there, the woods had to be cleared. If you want to see more, you can read under [www.\[unintelligible\].org](http://www.[unintelligible].org). When we talk about woody vegetation, I think we have three topics. One is the woody vegetation to protect our river banks or our [unintelligible] for erosion or

for shore protection and anywhere in the [unintelligible] section where woody vegetation occurs. We've got [unintelligible]. There are different topics but I will concentrate now on the woody vegetation in dykes and the effects on the stability of dykes.

We've got standards, they are quite strict as the USA for years, but nevertheless, we don't care I think and we have got 35% of our dyke length wooded on the water side and 50% on the landslide slope, so we've got about 1000 kilometers sloped with wood, trees or brushes in Bavaria. [Unintelligible] of the possibility we've got a lot of experience and we have a lot of assessment work to do. So, my fore-speaker, Michael Stout, mentioned all the negative effects of woody vegetation, so I will shortly summarize the positive effects. They've got natural reinforcement, they've got a drainage effect, they've got a protection against surface erosion and maybe or probably they have got something like a root cohesion. The negative effects that were mentioned several times before, but I think they are overwhelming. I mention here 11 and now too from experiences. So, we have got here two examples. On the left, you see a dyke. You have to trust me, there is anywhere a dyke and a nature protection zone, and on the right side you have got something like a trample pass.

I had to believe my professor who took this picture and you have to believe me. This is a dyke rest. There are some positive effects. You've got nice fauna, you've got nice flora, the landscape is very nice. I think it's nice, and you've got minimum cost for maintaining -- there's no maintaining. That's quite good. The negative -- you have not the possibility to inspect it properly, you cannot conduct flood fighting measures, you cannot assess the stability of the dyke and you have got in this case the high cost for refurbishment. So, our statement is that this is

not flood safe. We've got a lot of -- 1000 kilometers I told you. We've got a lot of examples for wooded dykes, the Alme River, [Munkefal] River, a smaller river. But, it began about 50 years ago or in the ancient years in the landscape, engineers started to plant poplars on the dyke toe, on the land dyke tow. Now, they have to remove it and refurbish the dyke again. So, this is from shortly -- taken pictures from a dyke located at the River Loisach and the right example you see, this is what I call the [unintelligible] to the nature authorities because it's a single tree, it's technically not okay, but this was a compromise to conduct the rehabilitation works. So, we have got started I think 30 years ago, a program to excavate trees on dykes.

Here we've got an example of a birch tree that was located on a dyke at the River Leche and the roots were extending all over the slope, all over the water side slope. The next example is a maple tree. The roots were extended in the top soil layer exceeding up to the water side and even exceeding down through a gravel layer to the fine sediment soil. A similar example is here shown by a poplar that even extends its roots toward the water side through the surface, the nature surface ceiling and even through the gravel layer, the gravel dyke body, to the fine sediment sand. We had a lot of dyke breaches because we had a lot of floods, and whether the dyke breaches were caused by trees or not, that is not clear. But, I think the trees or the tree roots in dykes were not able to stop them from breaching. The tree related damages -- here we see again a dyke breach. This picture always arise the question -- where has all the soil gone? There are only roots left. The next picture you see a wind throw at the water side and there was some over-topping, a local over-topping of the dyke and here you see an over-topped dyke with some trees on the crest. Here you have to trust me again. Here are some wind throw

examples, here left of the land side dyke toe, [unintelligible] thrown by wind. On the right side this is a roadway example -- of a few poplars that were thrown by wind. Even at the land side dyke toe in 1999, after the flood took place in 1999, a row of poplars were thrown even by wind forces. So, more damages. Perhaps you see here on the left, this was the over-topped dyke with the trees on the crest.

Even here you see a cable in the crest zone which is not allowed standard, but it is very easy to use a dyke because it is the only way that goes straight through the city or through the town and on the right side you see some top soil layer that's sliding, maybe caused by lack of rooting. So, this is on the right -- we have got an example where a tree root is sticking in the dyke and it's rotting. Maybe it's still alive -- I don't know -- but it's rotting, and when you look at it very close, you see that stones of I think a diameter of one or two centimeters are eroded through this hole. So, I think the question is clear that rotting roots may provoke some erosion or not. This is an example here for it. But for German standards, we have got the National Standard Organization. This is the basic team only referring to flood protection dykes at the rivers and it was called 19,712 and it is now actually revised and will be finished I think in five years. The special thing on this standard is that normally in German standards they are always very technical content. They've got only technical content, but here, even vegetation issues are contained. And we've got the command on these standards, the standards itself has got about 30 pages.

The command will have about 150 pages, where we regard all the scientific things and all of the experiences. Then we've got the old commands and then we have got technical specification or guidelines especially dealing with vegetation on dykes. We have got other guidelines

referring to vegetation on river shores, vegetation along rivers, vegetation to erosion protection, whatever. But, this is only a technical guide for vegetational dykes. Besides, I have to mention that we even have got guidelines for digging animal on dykes regarding beaver, nutria or muskrat. Okay, then we've got different guidelines even very special, like referring to dealings in dykes, dealings in water resource management and [unintelligible]. But, there is one big cost or one big force that is only bad for you because you cannot talk German -- we have no English translation for that and so we can look at your standards report and get all the information you have researched or you gained, but you cannot -- even the Dutch succeeded in translating the standards or some of the standards and so we can look. I actually do not know why we do not translate it, but I think there is not enough time besides work. So, what is in the standards?

Here, we see a dyke section -- how it should be, the minimum specifications. The dyke crest should be wider or larger than 3 meters. The inclination of this load should be 1 to 3 and we have got a berm on the land side and on this berm there should be a roadway that should be higher than the [unintelligible] and we have got the specifications for compaction, for permeability of soils and on and on and on. But, we have even some specific specifications for vegetation on dykes. So, this is a typical dyke system. We've got a berm, we've got a 3 meter crest and normally, the brushes or woody vegetation is only allowed in a distance of 5 meters from the dyke toe. This is 5 meters and large trees are allowed 10 meters from the dyke toe. When you have got here, like I've drawn here, an oversized addition to the dyke body, you can there plant something like small brushes or something like that. But, the lower third of the land side slope has to be clear for inspection because somewhere

there should be the exit of the vegetation and even the water side slope should be free from woody vegetation. What we care a lot for is grass vegetation because this is our erosion protection.

But, you have the need to differ from the standards, landscape issues, natural issues, population, and then you have to think about what can we do not directly according to the standards, but with the same security level. And, we reinvented some new vegetation concepts regarding vegetation types of trees or certain protection measures. You see here the protection measures are very simple -- none. Land side oversized section, land side water side oversized section and those are [unintelligible] aesthetic function in the middle of the dyke. Then, you have to justify the trees or the woody vegetation. We are here introduced to risk class 1-4. Risk class 1 is very risky, so you have got here your Ash Chestnut or Common English Oak and risk class 4 is not very risky. Those are the little brushes like thorn or rock berry. Then you have to subdivide the dyke section in different zones as you did in your standards. We have got a little more zone, but the land side zone subdivided into 6 zones and water side zone into 5 zones and the crest zone and regarding to the protection measures, you can allow some trees where you want it. When we see line 1, this is the normal dyke standards referring to the standards. There is no vegetation within 5 meters distance, 5 meters [unintelligible], but when you see line 4 with the aesthetic feeling element, you can even plant some little brushes on the water side and the land side slope.

There are a few hints that must given when you are using that scheme. There are 11. I here quoted just 8 or 7 and there's always some from [unintelligible] intrusion of roots to [unintelligible] must be excluded, but I will not [unintelligible] this topic. So, maintenance and inspection is

very hotly discussed in Germany because we've got 1000 kilometers with woody vegetation, so we cannot know it and we cannot do nothing with that. But, in the standards it is written flood protection dykes have to be maintained in such a way that their stability can be permanently guaranteed. So, when warm grounds grow digging a hole in your dykes, is then the stability permanently guaranteed? So, we concentrate our maintenance when we have [unintelligible] grass sort to keep the stems, to keep this mowed, and that our erosion protection is ensured, and we have to do it minimum once a year. Five minutes? are you sure? I'm too long, so I have to hurry up and we have to have a dyke book, we have to have a yearly status report, where we have to write down experience during flooding, for example. So, what I have to mention is what I found in some paper of text passage out of a law 700 BC. I will read it for you. If somebody neglects to keep his dyke in good shape and if this dyke fails and all has flooded, then that one who was responsible for this [unintelligible] shall be sold for money and the money shall be taken to compensate the corn that was lost to flooding.

So, I think a few of you guys are quite glad that we are living in this age. Even like in Bavaria, they are very glad too. So, I have to hurry. The structural solution -- you can read it later on my presentation -- we only just want to avoid the seepage through the rooted soil. We use root barriers, we use non-corrosive soils, we use [unintelligible] filling, but you know it on your own. This is a [unintelligible] and you can allow some trees on the slopes or not and these are our typical sheet pile fillings that are applied in Bavaria: there are some milled cut off boards, some boards -- cut off boards, [unintelligible] and a thin wall and the planting of the lower three methods is that you can reinforce it with a [unintelligible] and the other two are the cut off boards that you can

reinforce it. So, you see here reinforced [unintelligible] wall that you have taken from sheet pile. So, for an oversized dyke with a root barrier or some single tree protection measure. Like you see here, left is a dyke within the urban area of Munich. Left there is a reinforced milled slurry wall in it and right is the single protection of a tree. So, research. We research a lot of salts. We don't even research on bushes or something like that or woody vegetation. That is done actually by the University of Vienna. They try to protect the dykes in case of overtopping with bushes or trees and I'm very looking to their results. I think I can imagine what they will be and we are researching some salts or some crest layers that are reinforced [unintelligible]. We will conduct the last test next week after my jet lag.

Then, we researched the [unintelligible] hydraulic behavior of rooted soil. You see here the [unintelligible] potential or the saturation and you see a few of these section curves of soils and what we researched -- what we found out is that with rooted top soil that has protection behavior of silt or loam but the permeability of sand. So, maybe for [unintelligible] page calculations can be worthy. Then, windthrow -- I leave this out and go to the root system of filling elements. We have researched or assessed 6 filling elements -- natural clay silt filling, [unintelligible] the clay liner, sheet pile wool, cut off wool, mitt, thin wool and reassessed it by 5 criterion -- clay systems, protection measures, chemical [unintelligible] systems, imperfections, and the result is in here -- that the surface ceilings are quite in danger by rooting except you apply some protection measures and the [unintelligible] ceilings are quite okay. They are quite good for system except the thin wall that is really very thin, maybe judged for the assessed case. So, thank you for your attention.

- Emir Macari: Okay, we have time for one question. I think they are starting to drop as the afternoon goes by. But, any one question about Bavaria? Okay, Oktoberfest.
- Male Voice: I'd like to hear more about the slurry wall and your experiences in using the slurry wall as a cutoff.
- Ronald Haselsteiner: The flood incident -- the last 2005, we've got one of these milled slurry walls, reinforced slurry walls over top and in the hole, land slide dyke body where the water eroded and it was no problem. The slurry was tough. We have got very good experience with that and this is one of the filling elements that is quite pricey, or whatever you say, good price.
- Emir Macari: Okay, well thank you very much Ronald. The last presentation this afternoon is by Dr. John Dwyer. He is Professor of Forestry Management, University of Missouri Rolla and the topic of his presentation is on the 1993 floods in the Missouri River and woody vegetation on levees and woody corridors.
- John Dwyer: Well, good afternoon ladies and gentlemen. It's a real pleasure for me to be here today and I want to thank Peter Buck for inviting me. I'd like to present some information that I and other researchers at University of Missouri discovered concerning the role that woody corridors played in the protection of levees during the great flood of 1993. Unfortunately, I'm not going to be speaking today about woody vegetation on levees. I'm going to confine my remarks to the data that I have on woody corridors. The devil made me do that. I didn't really put that sign up. This slide was taken of a large billboard which is located on Interstate 370 as one approaches the Columbia Bottoms from the west. The Columbia Bottom

is a large bottom land that is highly developed, much like Sacramento, in which lies adjacent to the confluence of the Missouri and the Mississippi Rivers just north of St. Louis. It is an ominous warning of what could happen and did happen during the 1993 flood. For the time I have today, I want to focus my presentation on the result of a study that was completed in 2003 in which focused on a previous study that followed the flood of 1993. The initial study involved a 39 mile stretch in the Missouri River between Jefferson City, Missouri -- our capital, and Rocheport, Missouri.

The primary reason for this study I present today was to validate the original work over a 353 mile segment, to collect scientific information, to demonstrate the protective value of trees and specifically of woody corridors in the highly dynamic floodplains of the lower Missouri River. The 353 mile segment of the Missouri River between river mile 0 at the confluence with the Mississippi River just north of St. Louis, and river mile 353 near Independence, Missouri was selected as the area for this study. For the symposium I am presenting the entire 353 mile segment, but I do want you to understand in reality there were two sets of shorter river segments derived basically because of geomorphic differences in the river valley that were noted in the literature and were also investigated in this study. This figure represents a good example of a non-existent to narrow woody corridor displaying flood damage along the Missouri River. You have a typical example of an entry break which is identified by B, and an exit break which is identified by C. Also as evident to the primary levee located just adjacent to the river and that's identified by D. Numerous blue holes or scour holes are evident as well, indicated by E.

The flow here is from left to right and the light-toned areas really don't do justice. You could almost discern sand depth by the shading of the

texture. This is an example of a woody corridor A which did exceed 300 feet in width along the Missouri River. The primary levee is shown at B on the north side of the river. Steep limestone bluffs which make real good levees are shown at C on the south --they never fail by the way -- on the south side of the river and we have a protected plain as shown by D and that's a lighter colored sand, less sand deposit than what came in -- probably came in from a break above or a failure above. River flow from this scene is from right to left. I'll give you a little bit of information on our study designs and methods. Coverage of the Missouri River boundaries, river miles, the levee locations, levee failures and riparian woody corridors were taken from a geographic information system database developed in the wake of the 1993 flood by the Scientific Assessment and Strategy Team, which the acronym is SAST, in 1994. This data set was utilized to obtain the measurements that we used in this study. Coverage's of the levee breaks and riparian woody corridors were redigitized from geometrically corrected US Geological Survey, digital Orthophotoquarter quad rails. Try to say that real quick five times.

To improve the special accuracy of these features, the new coverage's were then joined with the attribute data from the original SAST coverage's and the SAST coverage's from the river boundaries, the river miles and levee locations were not modified for our study. The levee break inventory data set included information on all levee failures in the study area, the 353 mile study segment. The following data were collected. We collected flood plain width, measured perpendicular to the river channel, length of levee failure parallel to the levee system, woody corridor width measured perpendicular to the river, distance from the levee to the woody corridor and the type of levee failure, whether it be entry or exit failure. And, following the 2003 manuscript that was

submitted and accepted to the American Water Resource Association Journal, we looked at the length of the woody corridor to help expand somewhat our understanding of that particular dimension on levee protection. Well, we also had a river characterization data set as well. In order to compare the failed levees versus levees that did not fail, we sampled the entire 353 segment on both sides of the river at half mile intervals. The following data were collected.

We collected the river mile number, the side of the river it was on, woody corridor width, flood plain distance, distance from the levee to the woody corridor, presence or absence of failure of type and length of levee failure if applicable. We excluded bluff exit failures and on unlevied flood plains from our study. This figure is just to give you an idea of the woody corridor for this study was defined by the tree canopy zone between the bank of the river channel and the primary levee. The width of the woody corridor was measured perpendicular to the river bank. Flood plain distance was the perpendicular distance from the river bank to the primary levee and we had all configurations of that with flood plain distance with woody corridor involved. We also took a look at levees that may qualify - that did qualify for repair assistance through the Army Corps of Engineers Maintenance Program, Public Law 8499 and I'm sure in this case they were ten year -- five year flood standards for ag levees and ten year for urban protected levees. Our results, just to give you a summary -- statistics taken from the levee failure inventory.

On the average, levee failure occurred about every .78 miles along that 353 mile stretch. The mean levee failure was about 833 feet in length. Woody corridor width averaged 327 feet. The flood plain distance from river to the levee system averaged about 966 feet and distance from the

levee to the woody corridor was about 235. Well, do trees provide protection to the primary levee system and is there some minimum width that would minimize damage? The levee failure inventory -- the 100% inventory showed a total of 396 failures in the 355 study mile segment. Of this total, 276, or about 70% were entry failures and about 30% were exit failures. This figure illustrates how the inventory of levee failures is distributed by woody corridor width. For the entire 355 mile study reach, about 41% of all levee failures occurred when no woody corridor was present and this is indicated by the zero in this figure. Levees with woody corridors less than 300 feet in width accounted for 78% of all failures and levees with woody corridors less than 500 feet accounted for 83% of all failures. So, essentially with a woody corridor width of 300 feet or more the chance of levee failure were reduced by 75% or more.

Was the extent of levee failure significantly greater with the presence or absence of a woody corridor? Well, the median levee failure length for levees that did not have a woody corridor was significantly longer than failure lengths for a woody corridor that was present. Median failure lengths with a woody corridor present were about, almost a little over 50% shorter than the median failure lengths with no woody corridor present. And, these are significant differences between these two median failure lengths. I think I may have scrolled up too much here. Well, that's alright. The next question we had was, was the impact of the woody corridor -- what was the impact of the woody corridor on whether the levee failed or not, and, was the flood plain equally important? So, to look at that question and the results that we show here in this table, we can see that analysis of the data indicated that the width of the woody corridor and length of the levee failure were not independent. In fact, the data show there was an inverse relationship which indicated that as the width

of the woody corridor was increased, the length of the levee failure actually decreased.

Was this reduction in levee failure an artifact of the flood plain distance and not the woody corridor width? Well, the coefficient for this parameter was a negative .072 and that's not -- and while it does indicate a negative correlation but with much weaker inverse relationship than the woody corridor itself. So, what was the impact of the woody corridor? Well, we looked at the median corridor width and the median flood plain distance from levees that did not fail versus those that did and the median woody corridor width for levees without failure was this figure, 217 feet, or a full 140 feet greater than the median woody corridor width for levees that did fail -- in this case, 77. The difference between the woody corridor width and whether or not the levee failed was highly significant. Although the median flood plain width for levees that did not fail was 95 feet greater than the median flood plain width when levees did fail, this difference was not significant. So, what this told us was the impact of the woody corridor width and not the flood plain width was a significant factor in whether or not the levee failed.

We use the word discontinuity here to describe the fact that woody corridors are not continuous belts of woody vegetation, but they often have gaps. And, to better understand this parameter, we looked at the distribution of failures associated with these different discontinuities. There were a total of 76 failures due to the discontinuities in the woody corridor. These discontinuities accounted for about 27 and one-half percent of the total levee failures that occurred in the 353 mile study segment. Of the total of 76 failures, 46% or 35 of these failures, occurred at gaps in the woody corridor. Gaps in this case are where woody corridor

ends and then begins again within a short distance. Additionally, 36% of the 76 occurred at the beginning of the woody corridor and about 18% occurred at the end. But did eligibility for the Corps of Engineers Levee Maintenance Program play a significant role in reducing levee damage? Levees in this case were equally likely to fail regardless of their status, [unintelligible] 0.10, but in all fairness, this was a 500 year flood folks and you know, what else can you say? For example, along the 39 mile stretch of our original study sight, of the 47 entry breaks, 29 or about 62% occurred in levees that were in the program, while 18 or about 38% occurred in levees that were not in the program. And, when we looked at the total levees, 10 of the 17 levees along this stretch of the river, or about 59% were 8499 eligible, while 7 were not.

While these percentages were very close to the levee failure percentages based on their status with the public law 8499, which indicated to us that levees were equally likely to fail in proportion to their PL8499 status. PL8499 status did not play a significant role in whether a levee failed or not. How important was it to have a woody corridor upstream of a levee, looking at another dimension, looking at this length rather than depth dimension? Well, when a woody corridor was present upstream of a levee, the median failure length of the levee was about 341 feet. If, however, the woody corridor was not present upstream of the levee, then the median failure length was 787 feet and this was highly significant. Was the woody corridor length important in whether or not the levee failed? For those levees which did not fail, the median woody corridor length was 4,882 feet. Whereas for those levees that did fail, the median woody corridor length was 2,946 feet. Having a long woody corridor upstream from a levee was highly significant in whether or not that levee failed. And, I might mention a couple of other studies here that I think

were appropriate for the time. Dr. [Gayer] at K State in his work in 2000, found that sandy soils experienced three times as much lateral erosion, 57 feet versus 19 of silty soils during the flood of 93, and he also found that vegetation played a more significant role than soil type in reducing bank stability.

We really didn't look at bank stability. We looked at levee damage so I thought that would be interesting to point out. There was also some work done by Marsh in 2002 looking at different soils and I think these are things that we would all sort of expect with different soil textures. There's probably nothing new here, except that I think that one of the other things that needs to be investigated are these old channels -- these old historic flood channels are very important in knowing where they were because oftentimes, we don't retain that body of knowledge and that history in our restoration. So, we build across these old channels and they are just, in our case, rift with sand and they don't really hold up very well. Well, I thought I'd throw this in here because I don't have analytical data or anything. I did spend a lot of time looking at levees and I thought this was a good one. We talked just a little bit about levee armoring and I had a proposal set to go to the Corps for an extensive study looking at levee armoring. Unfortunately, they were more interested in some other wildlife aspects associated with the flood and I didn't get funding on that. But, living roots -- and we know this now -- do create channels in the soil.

Roots continually die off or slough off and are regenerated and this is an interesting levee. It is an agricultural protection levee and you can actually see -- I hope you can see -- but, there are roots crossing the top here and you can see these roots crossing the top of the levee here. This levee was in the bend of a creek and bore the brunt -- a 90 degree angle --

bore the brunt of flood waters during the 93 flood. It was a major contributory creek to the Grand River, which ends up in the Missouri. The roots in this case actually kept this levee in tact and functioning. I guess we've learned today in a flood zone where static load is delivered against the levee as is the case with the New Orleans situation. Those pose really serious engineering questions that have to be carefully explored. Well, this is what some people do on their own levees. This was in Thompson Bend, which almost looks like an oxbow when you look at it, along the Mississippi River in the boot heel of Missouri. I took this -- this was actually cottonwood planted by the landowner and I think he intends to harvest some of these trees for bio mass, so there was some rationale there, but I took it because I found it interesting that these areas provide wonderful opportunities to track all the debris. And, I can tell you for a fact that when the Missouri River floods, you can almost walk across that River on the debris that is coming down. That's how bad it is. So, I think those kinds of opportunities are there.

Now, I got to get back -- how do I get back here? There you go. Well, just to mention a few directions in terms of research, woody corridor width and length is an important factor in levee protection. I think you have a wonderful opportunity as you think about redesigning your levees here. I'm in awe of your challenges but I'm also heartened by the fact that you have got a wonderful opportunity to make things right in places. So, I think the woody corridor width should be considered in your deliberations. However, I think we need to know more about the structure and function of these woody corridors in this protective role -- how these forested woody corridor respond in flood situation is of course dependent upon flood discharge and energy in association with the biological structure of the zone. So, I'm talking -- by biological structure, I'm talking

about size and density, or stalking as we would call it in forestry. I think at least along the Missouri River we need to explore other things and we could develop a risk assessment model I think quite easily from the work that we've already done, but I want to take into consideration channel morphology -- looking at inside and outside bends where there is a lot of energy generated versus straight channels. I think we are going to have to try to micro-manage these levee situations and we need all the best available information we can get.

I also think that based upon what we said today that, you know, when we look at these things, we can't look at it in isolation. These problems are too large now and you know, if the Corps sponsors a program, sponsors a grant, I think a Corps individual ought to be assigned to that grant to work directly with those researchers in a research mode because we all have a vested interest in those findings if everybody participates. So, I think they ought to be comprehensive and integrative and look at all the factors, risk factors, vegetation, wildlife, physical that affect levee stability and structure. That's all I've got.

Emir Macari: I did tell John that I'm a big New York Yankees fan and the Red Sox are visiting New York -- right now the game is started, so thank you for being on time. We have time for a couple questions. There is a microphone over here please. Two questions right there.

Male Voice: If you could help clarify to make sure I understood your data correctly, you had one slide where you showed a number of failures where there was no vegetation corridor and then failures where there were various widths of vegetation corridors. If I understood the slide correct, can I summarize that there were more failures behind a vegetation corridor as

compared to the number of failures where there was not a vegetation corridor?

John Dwyer: That's correct. Where we had a woody vegetation corridor -- and these are all in front or on the river side of the levee, we not only had fewer failures, but when they did fail, the failure length was much reduced.

Male Voice: No. I think if you take the graph, you said there were 41% of the failures were where there was no vegetation, which then means 59% of the failures were behind a vegetation corridor. Is that correct?

John Dwyer: That's an accumulative distribution is what I should have said maybe. The bar chart represents an accumulation of --

Male Voice: We can talk off line then.

John Dwyer: Okay. That's fine.

Emir Macari: Right next to you if you could pass the microphone.

Male Voice: An observation. You said -- if you could throw up your slide on PL99 participation or eligibility and those that were not eligible or participated in PL99, you said that more that were in the PL99 program failed than did not. The question is what level, if I may use this incorrect term right now, level of protection or what elevation or flood event were those levees designed to? Because that's a 500 year event and if those were -- we have a lot on the Missouri that have less than 100 year or .1% protection design level. So, if you've got a 500 year event, the levees didn't fail. They were overtopped and that's not a failure.

John Dwyer: No. Yeah, I know. Well, I am saying levee failure where it broke. In other words, where it broke. I understand that all the levees were overtopped. There's no question about that. So, when I say a levee failure, I'm talking about a levee break -- a break in the levee.

Emir Macari: We have a question right here.

Male Voice: I had two questions but it was just asked by the last gentleman. The first one was what was the failure modes and we understand that it was overtopping. So, my second question is, what is the significance to flood plain managers that a breach developed from overtopping is smaller where there is woody vegetation? That isn't entirely clear to some folks involved in public safety issues.

John Dwyer: Well, I can't really address the public safety aspect of it because most of the levees that we looked at were for agricultural protection.

Emir Macari: We have a question right here. At the bottom. If you could just push it once.

Male Voice: Did you also look at the type of soils where the trees are growing and where they are not growing? It could be that there's more fine grain cohesive materials where the trees are growing and not where they are not growing. So, that could be another correlation that needs to be looked at.

John Dwyer: Right. I would tell you that most of those soils range anywhere from silty clay loams to sandy clay loams and there could be a wide range. We did not look at that no.

Emir Macari: Any more questions? Do I see a hand up there? Okay.

Female Voice: The levee that were not [unintelligible] PR 8499 [unintelligible], they were non-[unintelligible]. They had about five year flood protection, level of protection and the event was 500. So, you realize that most of the levees were overtopped and breached by overtopped and had nothing to do with the corridor or no corridor. Besides that, most of the failure that happened there, it was part of the soil condition that would not allow even a [unintelligible] corridor to happen or vegetation corridor to happen between the levee there because of the sandy soil. Another big problem was that the levees -- they weren't wooded corridor -- were setback. They marked from the levee, from the [unintelligible] back. So, a setback levee is unlikely to fail but a levee that is just [unintelligible] will fail much easier. This again has nothing to do with a wooded corridor or not wooded corridor. So, I don't know -- your conclusion was that you show us a levee that is covert and up to the crest with vegetation on the land side and the water side. Again, I'm not sure that this is the right conclusion if we want to take it from this discussion that we've had so far.

John Dwyer: Well, all I would say is that I think if you are going to set levees back, I think you should consider the woody corridor as part of that system and I think it can help ensure levee stability if you do that.

Emir Macari: Okay. Any more questions? Well, I believe that today the dialogue has started. We will be going into a little bit more discussion tomorrow. Thank you very much John. So, to conclude this then, somebody out there in the campaign for presidency, once said, it takes a village to protect a levy, so hopefully tomorrow we will get onto that working together and I

look forward to the next set of discussions. I would like to ask all of the speakers for tomorrow, both in the morning session as well as the panelists to come up for a second so we can chat a little bit about what's going on and tomorrow promptly at 8:00 am, we will start whether I'm here or not. And, we have a reception starting right away just outside. I see some bottles of different beverages out there, so I look forward to seeing everybody out there. Thank you.

**End of recording.**