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Times are changing – Flood mitigation technology: Proceedings of the 22nd Annual Conference, May 18-22, 1998

Association of State Floodplain Managers

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TIMES ARE CHANGING

FLOOD MITIGATION TECHNOLOGY

PROCEEDINGS OF THE
22ND ANNUAL CONFERENCE

May 18–22, 1998
Milwaukee, Wisconsin
TIMES ARE CHANGING
FLOOD MITIGATION TECHNOLOGY

PROCEEDINGS
Twenty-second Annual Conference of the Association of State Floodplain Managers

May 18–22, 1998
Milwaukee, Wisconsin
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Published 1999.

This volume is available from:

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Institute of Behavioral Science
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Preface

This volume of proceedings represents the technical content of the Association of State Floodplain Managers' 22nd Annual Conference, held in Milwaukee, Wisconsin, from May 17 to 22, 1998. The theme this year was "Times are Changing: Flood Mitigation Technology," and we truly did obtain a glimpse of the increased capabilities that improvements in technology are—and will continue to be—bringing to the field. A record 450 floodplain management professionals crowded the meeting rooms, exhibit areas, breakout sessions, social events, and hallways. They shared ideas and helped each other explore solutions to floodplain issues.

A vivid, fast-moving video opened the meeting by showing different applications of technology, particularly digitized geospatial data and three-dimensional computer modeling for manipulating, applying, and displaying it. The speakers after that described the efforts of forward-looking states, regions, and localities to combine flood mitigation with such other concerns as quality of life, environmental protection, and housing. Later plenary sessions focused on national initiatives with local implications, and then on looking back over 30 years of the National Flood Insurance Program. We also heard presentations on the natural functions of floodplains and techniques to protect and restore them. And in the last plenary session we got down to the business of preparing ourselves for the future by discussing the need (and plans) for a professional certification program for floodplain managers across the country.

Lively small-group presentations and discussions covered a range of technical topics: digitized mapping; advances in modeling; computerized loss estimation; multi-objective management; water quality; disaster recovery; the Community Rating System; wetlands restoration; channel hydraulics and maintenance; coastal flooding and erosion; construction techniques; and a variety of policy issues. Excellent workshops offered training in risk-based analysis, using the new residential substantial damage estimator, among others.

We also visited a rain forest and turned back time to the beginning of the 20th century for at least one evening. It was quite a week of contrasts!

The Association greatly appreciates the efforts of the whole conference team, our host city of Milwaukee, and the exhibitors. And we thank the participants for their enthusiasm, willingness to explore new ideas, and desire to contribute to floodplain management.

We hope to see you next year, in Portland, Oregon!

Terri Miller
Chair, Association of State Floodplain Managers
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Acknowledgements

The annual conference of the Association of State Floodplain Managers would not be possible without the generous contributions of numerous dedicated individuals, and 1998 is no exception. We thank the 150 speakers and presenters, the Board of Directors, the Committee Chairs, session moderators, and room monitors. We particularly thank the following people for devoting their time and talents to the development and conduct of this year's meeting:

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**Local and Regional Agencies:** City of Milwaukee, Milwaukee Metropolitan Sewerage District, Greater Milwaukee Visitors & Convention Bureau, Wisconsin Conservation Corps, South East Wisconsin Regional Planning Commission, Federal Emergency Management Agency Region V

**Registration/Notebooks**—Mike Parker; Lynn Phillips; Amy Koerner; Skala & Associates; Wendy Malamut; University of Wisconsin at Madison; Lucy Sherwood

**Technical Tours**—Gary Heinrichs; Lynn Torgerson; Chris Magruder, Metropolitan Milwaukee Sewerage District; Gordon Rozmus, City of Wauwatosa; Tom Miller, City of Milwaukee; Will Wawrzyn, Wisconsin Department of Natural Resources

**Audio Visual**—Jack Burbank; Roxanne Gray, Wisconsin Division of Emergency Management; Al Lulloff; Dave Fowler, Metropolitan Milwaukee Sewerage District

**Awards**—Jim Wright, The FPM Group; Jean Brown, California; Doug Plasencia, Kimley-Horn; Diane Watson

**Graphics Arts/Printing**—Jennifer & Greg, Insty Prints Madison East; Eric Curl, Wing & A Prayer Graphics; Rob Knight, MATC; Wisconsin Department of Natural Resources

**Conference Signs**—Maggie Mathis, Dewberry & Davis

**Training Workshops**—Carl Cook, FEMA Region X; Mike Buckley, FEMA; Errol Garren, ISO, Inc.; Cliff Oliver, FEMA; Jon Kusler, Association of Wetland Managers; Wil Thomas, Michael Baker, Jr., Inc.; U.S. Army Corps of Engineers

**Special Events**—Sue Josheff; Gary Heinrichs; Lynn Torgerson; Wendy Malamut; Clancy Philipsborn, TMAC; Susan Vancil, Illinois Association of Floodplain and Stormwater Managers; Mike Klitzke; Wink Hastings, National Park Service; Rick Fores, Gray Line Tours; Michael Baker, Jr., Inc.; Dewberry & Davis; Woodward Clyde

**Sponsor Development**—Gary Heinrichs; Lynn Torgerson; Dan Accurti, Diane Watson

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Part 1
National Policy and Programs
The subject of this panel is 30 years of the National Flood Insurance Program. Although turning 30 can be a somewhat sobering experience as you reflect back and look ahead to the things that you ought to be getting serious about, I think in the case of the NFIP there is a lot to celebrate already. It is an exciting time for everyone in this room to be involved in the NFIP, in disaster and emergency management, in environmental issues in general, and in the overall effort of making each and every community in this country disaster resistant. That is a worthy goal and one that we can all be proud to be working toward.

One of the things worth celebrating with regard to the NFIP is your organization itself, the Association of State Floodplain Managers, and the many, many contributions you have made to floodplain management in this country. The ASFPM has had a major impact on national policy through its participation on workgroups and technical committees on elevation certificates, the mapping update committee, the project to revise the Coastal Construction Manual, the Community Rating System Task Force, the Flood Insurance Producers National Committee, the Technical Mapping Advisory Council, and of course through the ASFPM’s own technical committees—Mapping and Engineering, Coastal Issues, Floodplain Regulations, and others—and also the ASFPM’s promotion of multi-objective planning and work to create a certification program for floodplain managers. With all these efforts, along with your consistent advocacy with members of Congress and local and state legislators, the ASFPM can and should be proud of its role in the success today of the NFIP.

Accomplishments for the NFIP

Since 1980 the NFIP has successfully partnered with states through the Community Assistance Program and its predecessor, the State Assistance Program. Largely with your help, over 19,000 communities have joined the nation’s oldest and most effective mitigation program. The changes made in the Performance Partnership Agreement under
James Lee Witt's direction have allowed all of us to be more creative and flexible in solving the needs of the communities. We look forward to continuing those as well.

Since the inception of the NFIP, through the adoption of floodplain management requirements, these 19,000 communities have permitted the construction of over 2.5 million flood-resistant buildings. These are buildings that are 72% less likely to be flood-damaged than those constructed before the program began. That is certainly something of which we can all be proud.

The CRS, which was begun in 1990, now has 900 participating communities that are doing insurance and flood mitigation activities over and above the NFIP standards. These 900 communities represent $7 million in flood insurance discounts going to 66% of all NFIP policyholders annually. These discounts are awarded because it has been proven that floodplain management activities over the long term reduce losses and costs. One aspect of the CRS that you suggested and that is being expanded in the 1999 version is recognition of state laws that require communities to go beyond NFIP standards—state freeboard requirements, floodway standards, hazard disclosure laws. These are just examples of ways in which state leadership is valued and rewarded in the CRS.

We also have local governments adopting disaster-resistant codes, ordinances, and activities. I think joining the NFIP has encouraged local elected officials and policymakers to think about other types of regulations that can promote the sense of being more resilient in the face of disasters.

Certainly partly as a result of the NFIP we have a closer federal, state, and local floodplain manager partnership than we had before the NFIP.

**New Activities that Contribute to the NFIP**

We at FEMA believe that some of our programs, some of the improvements we have instituted, and some of the organizational changes that we are making are going to add to the momentum that has been built over the last 30 years and that is now rising to a crescendo as we go in front of the appropriations committees in Congress. As we travel around the country, we see that even the most conservative members of our society—those who sometimes complain very loudly about personal property rights and government interference—are somewhat flummoxed when it comes to criticizing the NFIP because they also are very concerned about reducing costs and about keeping their families safe. On the one hand they are cautious about the
property rights issue but on the other they see the benefits of effective floodplain management. I think that now many of them are beginning to see the value of some tradeoffs in this arena and we can go ahead and move forward in exciting ways.

The new Flood Mitigation Assistance Program—the idea of targetting vulnerable structures in the pre-disaster environment—is now in its second year. That is something that would not have been possible several years ago but a changed climate and a changed attitude on the part of Congress and the public are now allowing us to look at predisaster mitigation.

Our Project Impact is further illustration of the fact that members of Congress are starting to ask what can be done to spend money on pre-disaster assistance and mitigation. At my recent confirmation hearings it was observed that for the first time we are hearing members of the U.S. Senate say not, "How much is it going to cost to do mitigation?" but "What more can we do to promote mitigation?" That is a huge change; those of you who have been working in the NFIP for many years know that this is not "business as usual."

Project Impact is an attempt on the part of FEMA to create a "seed and magnet" program wherein we catalyze behavioral change, not by putting a lot of money in one community to make it totally "disaster resistant," but to enable, through public-private partnerships and the assistance of state and local governments and other agencies and the nonprofit sector, to have a community momentum build toward doing the right thing in terms of how building is done, where it takes place, and how these decisions are made. Project Impact is now in its second fiscal year. In the first, we received $2 million from Congress; for this year, we received $30 million; and the President has asked for $50 million for next fiscal year.

What are we going to do with this money? There have been presentations about Project Impact this meeting, and our coordinator is very adamant that this is not a money hunt. We are going to resist turning this into a sort of "block grant competition," or a formulaic approach to how you "download" dollars from the federal government. Sometimes we really would prefer that there were no money for this program because in a way the money is sort of a distraction from something that is not really a program at all. It is an initiative. What we are trying to do is accelerate and reward good behavior and do a combination of demonstration projects and public education initiatives that will convince local decisionmakers—planning commissioners, mayors, city council members, building officials, and other boards—that it is okay to make smart decisions regarding management of floodplains and other
hazardous areas and answer other threats such as earthquakes, wind, and fire.

We have seven pilot communities now and we have spent about $5 million in those communities, but we have raised about $10 million from the private sector. That is very significant and important to us, that the private sector contributions for this initiative exceed the federal ones. Because the idea is that mitigation is local. If local decisionmakers, and individual citizens, and the business community together do not value mitigation, it will make no difference that the federal government advocates it. The federal government can only do so much. We can begin the discussion; we can put some money in; we can bring some technical assistance to the table. But it is the citizens in the local community that make the difference, be they small business owners who care about getting their employees to work after a disaster; parents who care about the safety of their children in vulnerable school buildings; or individuals who want to move to a community where they have a sense of peace of mind as they take care of their elderly parents. The whole idea of sustainability—of making a community resilient to the ravages of nature, to fluctuations in the economy, crime, environmental concerns—all those issues are connected, and Project Impact is a part of it.

We are also doing some organizational things that I think will enhance not only the NFIP but also mitigation generally. In the last several months I have created new branches within the Mitigation Directorate. Among them is a new Planning Branch, because I believe that planning as a discipline has to be valued at higher levels within our organization; that we have to have a stronger relationship between planning organizations and professional planners inside and outside the federal government; that we need to do more to encourage planning to be attached to anything else we do; and that while historically FEMA has been largely a response-oriented agency, the pro-active planning culture has to be equally valued for us to effectively accomplish our missions. We have also created an Outreach Branch. I have been concerned that we are still not doing a good enough job of demonstrating why mitigation is the right thing to do, why it has a positive effect, and why it is good public policy. It is important for us to make it easier for people to demonstrate that fact, whether it be in front of a local councilor or a state legislature or wherever. This Outreach Branch is going to be collecting success stories and marketing them through a variety of outlets, like trade journals and professional publications and the media generally; to our disaster workers; to the Response and Recovery Directorate; those who design our curricula at
the Emergency Management Institute; and through those institutes of higher education that are developing graduate degrees in planning and emergency management.

**Challenges and Opportunities for the Future of the NFIP**

Not only should we celebrate what we have done—FEMA as an agency and the ASFPM as an organization and each of you as professionals—but we should also face what I call challenges or opportunities for the future. As much as we have accomplished so far, I would have to say that the NFIP is under fire today. Jo Ann Howard talked a little about this: that we need to do more, for example, to address the problems of repetitive losses. It is frustrating to us because we know how many good stories are out there. It is very enticing to somebody in the media to film someone standing in front of a home saying, "Every year I just file another insurance and I just get new furniture. Year after year after year." What is our counter to that? A shot of a dry house? An open space lot that used to have property on it? The film from our end is not quite as sexy as the material that is available to the critics of the NFIP, so we have to work harder.

We have challenges in looking at sustainability. The idea that many of these programs can and should be connected: for example the Corps' proposed new Challenge 21 program and the new Natural Resources Conservation Service initiatives could be linked up with Project Impact. One of my frustrations and hence a crusade that I'm embarking upon with my colleagues is the idea that right now the Executive Branch isn't coordinating as it should be. As FEMA pursues this kind of floodplain management policy, the Department of Housing and Urban Development or the Department of Agriculture or other departments or agencies are pursuing a different policy. I actually had a discussion with an official from another agency who wanted to debate me on the merits of our position that we would not allow levees to be built in FEMA-acquired open space under our Section 404 program. They thought that such a prohibition was wrong because it was preventing new construction. And I said, "Exactly right!" We do not want new construction under those circumstances in those places; it is bad public policy. And I intend to take every opportunity to talk to my counterparts at the assistant secretary level about this administration's policy toward land use and floodplain management. This administration really is very concerned; you see it with the advent of Challenge 21 and the "greening" effort within the Corps of Engineers; the PATH initiative of HUD (Partnerships Advancing Technology in Housing); the solar roofs initiative and other sustainability projects of the Department of Energy;
and with the Office of Science and Technology Policy's concern about climate change and weather patterns like El Nino.

We are trying very hard in this administration to bring together the collective power and wisdom of these various agencies and efforts to move forward in a smart fashion. I think the President has been quite successful at demonstrating that the environmental concerns and the economic concerns do not have to be at war with each other. A community that is more environmentally sensitive and creative in how it uses its riverine system for recreational purposes and quality-of-life concerns, is more likely to draw more and better teachers; and the more environmentally friendly businesses there are going to be in that community; the more viable and sustainable its economy is going to be; the lower its crime rate is going to be; and the better its housing system is going to be. All of these issues can and should play together. But this is an enormous challenge, because money drives so much of what we do. We have to continue to strive to show how these agendas complement each other.

We also have also the issue of the shrinking federal dollar base. Federal officials are now doing what you at the state and local levels have been doing for almost 20 years: cutting back, streamlining, saying "no," discontinuing programs, reassigning staff, urging people to think outside the box, strategic planning. The Government Performance and Results Act is one tangible indicator of the fact that we are going to be held accountable as federal officials for whether we have done what we said we were going to do. That is a good thing, but it also means that the federal government is not going to be the one with the money in all cases. That is going to put more and increasing pressure on you at the state and local level to come up with creative ways to really become partners with us.

Another opportunity we have is in coming up with some tangible actions to follow up on recommendations in the Galloway Report. We have a small work group reviewing that report now, looking at the idea of a Presidential executive order and other options. We have challenges in the area of compliance. We are renewing our efforts to identify problem areas in this country that are chronically flirting with probation and suspension from the NFIP. I believe in being aggressive about compliance, but I have also told my staff that it is when we look like we are gleeful about enforcement that we have trouble. We need to make sure that we give a community and a state every opportunity to do the right thing. We have to be proactive. We have to be sensitive to different histories, different problems, and different approaches as we push for compliance.
We continue to be vulnerable as floodplain managers in the area of repetitive losses, and in the issue of disaster assistance vs. disaster resistance. We at FEMA are sometimes correctly perceived as being at counter purposes within our own agency in how we distribute disaster aid and in how that encourages or discourages communities from becoming disaster resistant. And that is something that we in the agency need to consider.

We have to look at competing and conflicting policies not only between federal agencies but also between federal, state, and local governments. We have another vulnerability I think in the tendency towards state and local overdependence on the federal government for dollars and for setting policy. We are truly all in this together; and the tax dollar is shrinking at all levels, including the federal government. It is great that we have a balanced budget, but we still have a national debt and we still have challenges in areas other than floodplain management and emergency management. So it behooves state legislators and county commissioners and town managers and others to look at how they are going to invest in floodplain management and mitigation to a greater degree.

We also have a challenge to promote local and individual responsibility as part of the answer. Too often we talk about what government is going to do and how quickly they are going to get there and yet we all know it is in those first few hours after a flood—before anyone can "get there"—that determines whether lives are lost and how badly property is damaged. What kinds of conversations are parents having with their children? What kinds of familiarity does a homeowner or small business owner have with the local emergency management plan or local emergency management officer? What are people doing in their volunteer time, in their roles as citizens, to promote awareness or to help neighbors or coworkers?

We have the whole issue of mapping. The flood maps have evolved from merely helping set insurance rates to being a cornerstone of long-range planning for local governments. Like it or not, that is how those maps are being used. So we can and must do a better job in the area of customer service with regard to mapping. The technology is out there; the talent is out there; the know-how is out there. We now have a mapping modernization proposal on the table. The seminars that our staff have held here at this meeting have been crowded; we want and need to hear your comments about what we are doing now that could be done differently with existing regulations and existing staffing priorities. This is an extraordinarily important challenge. It is one of my three
main priorities, along with streamlining the Hazard Mitigation Program and implementing Project Impact.

Conclusion

We have many advantages today that were not in place 30 years ago when the NFIP began operations. We have a political climate that is much more welcoming to the argument that the time has come to invest money in predisaster mitigation. It used to be that people said, well, we don't know for sure that that disaster is going to happen there again, or that it will be as bad as it was the last time. I use the analogy to immunization. In this country we immunize children against a variety of diseases. If we didn't immunize them, would all of them get sick? Of course they wouldn't. But it is good public policy to protect them anyway. I believe that pre-disaster mitigation is our disaster inoculation policy. It is good public policy to position every community to be disaster-resistant. Because that disaster surely will happen at some point.

We have new technology, not just in mapping but in a variety of other areas. There are breakthroughs every week, and we need to embrace those innovations and what they can do to help make our jobs easier and our output more effective. We have a growing expertise in floodplain management at all levels of government. We have a growing momentum away from structural solutions and toward floodplain management as the primary approach of government. We have the issue of climate change and weather patterns and this helps make our mitigation efforts more urgent. We should seize that moment while the public is engaged.

In conclusion, I think we owe each other three things. We owe each other leadership. We owe each other engagement in our roles as business members, as citizens, and as public sector employees. And finally we owe each other true partnership. On the federal end, we need to become less of a parent and more of a partner. I invite you into this new sense of partnership.
It is a pleasure to be with this group of dedicated professionals today, and to participate in this discussion about and celebration of the 30th anniversary of the National Flood Insurance Program. I want to take this opportunity, as the "rookie player" on this field, to talk with you about five topics that have a direct bearing on the NFIP as we know it today and as we hope to shape it for the future. Those five things are: (1) OPM, (2) teamwork, (3) promises sold, (4) a deal's a deal, and (5) when water wants to, it wins.

OPM

"OPM" is a principle that I have worked with for quite a while, both as an insurance regulator and as a court-appointed liquidator for insolvent insurance companies. I know my colleagues and predecessors at the Federal Insurance Administration and also those involved in other aspects of the insurance industry at state levels and in the private sector also work with this concept every day.

OPM is dealing with Other People's Money. When we are in charge of OPM, we have a heavy fiduciary responsibility. We can never take for granted the fact that the money we are using and the choices we are making involve money that really belongs to someone else. Because of this serious responsibility, the flood insurance program has to be scrupulously managed. We have to make sure that every penny is well spent. We have to be sure that no expenses are higher than they should be. We are doing some things at the Federal Insurance Administration to make sure that that level of conscientious management of other people's money is achieved. Some of these things have been in progress for a while, some are new, and some have been in place but we are pushing even harder on them than before.
• We are examining the issue of expense allowances. This summer a study will be done of the Write Your Own expense allowances.

• We are looking at tighter cash management procedures, reviewing the arrangements between FIA and the Write Your Own companies.

• A call for issues will go out this summer to invite all of our partners and constituents to tell us what they think could be improved within the NFIP. It will take a great deal of resources to sift through and answer each of these, but we intend to do it because we want to use the best and the most workable of all the good proposals and ideas that are out there.

I do not take for granted at all the sacrifices American families make in their budgeting process. When they spend money on flood insurance, they are spending money that they could have used to purchase a new washing machine, or to take the family to the beach, or to pay for day care for a few weeks or a month. So the decision to purchase flood insurance (or the requirement to purchase it) is something we take very seriously at FIA, and we have an obligation to manage the money paid for that insurance in the most effective and efficient way possible. Government has to be meticulous in its handling and accounting. We have to demonstrate and be very open in our procedures. For that reason, in the case of the coming expense allowance review, we will probably have a hearing, rather than just conduct a study and announce what the allowance will be. Some things need to be on the record.

In terms of internal management of OPM, if we could save just 1% in the federal insurance program we would have saved $12 million. I believe we can find a percent or two. For example, we need to look at the lawsuits over insurance claims. We need to look at the management of that litigation and see if the benefits warrant the expense of pursuing those cases. There are several areas like that within the program that the Washington team is going to be examining in an effort to find ways to save money internally. Repetitive losses also fit into this category because what we are trying to do is allocate the best use of the premiums.

**Teamwork**

The NFIP has a great team of professionals surrounding it, and the Association of State Floodplain Managers is a vital player on that team. At the Federal Emergency Management Agency, Mike Armstrong and I
are developing a strong partnership and sense of teamwork and cooperation not just between us but also among the personnel in our respective arenas at the agency. James Lee Witt is a wonderful director and he really fosters that sense of teamwork. If we do not function that way, we are inefficient; we are not promoting the NFIP. But I have found it is easy to work with Mike and with the people in the Mitigation Directorate. It is easy because they are smart folks; they are dedicated; they believe in what they are doing and they do it very well.

I want to emphasize that we also want to work with you at the state and local levels as well. Floodplain management is vital to this country. There is a beautiful symmetry in the NFIP which I am coming to appreciate more and more. It comes from the wisdom of the founders of the NFIP, in balancing the insurance aspects of the program with the floodplain management/mitigation components. I am grateful for the early leaders of the FIA and for the way they developed such a well-balanced program. It makes a perfect circle because the more flood insurance policies that are sold through the NFIP, the more policy fees—those $30 fees—we collect, and then the more funds we have available for important mitigation work around the country. In fact, last calendar year we had about $60 million available for mitigation out of about $83 or $84 million collected, so that is a very strong contribution. I know you recognize this, but we should never forget the advantage of not having to go through an appropriations process every year to get those funds that can go back into the communities for important on-the-ground work that eventually helps to reduce future disaster losses.

Out of that $60 million, about $17 million was for flood mitigation grant money. But there is an exchange operating for that money. As the circle goes around, the communities have to do their part. And that is where the state floodplain managers come in. You form the link between the federal program and the local activity, that base that must not be skipped if we are to get to home plate.

Promises Sold

The intriguing part about insurance to me—and one that is poorly understood in general—is that it is one of the few products that is actually a promise being sold. And once it is sold, you are out there on the hook to keep the other end of the bargain, and of all promises, it is one that really has to be kept. In this case, when the rains come, we have to keep that promise we have sold, and we have to keep it promptly and fairly.

Insurance in general is misunderstood. People do not really understand risk management. They do not understand exactly what they
A Look at the National Flood Insurance Program

are paying for when they pay premiums or why, if they do not suffer a loss, they really have not lost out by having paid the premium. So we have some ongoing education to accomplish. We need to tell people why they need insurance in the first place. And that is why we are spending millions of dollars on Cover America and on Project Impact. These initiatives are about changing attitudes. They are additional ways in which we people from the insurance piece of the program can get down into the community level and talk to the community planners and find out how those local people are responding to the ordinances that they should have in place and find out what is going on. We want to talk to the insurance agents out there as well and find out why, perhaps, they are not convincing more people to buy flood insurance.

We have to have communities adopting comprehensive mitigation programs. The NFIP is a unique program. It is also the largest monoline insurance in the United States; it is enormous. Insurance can function in our society as a major lever for inducing self-protective behavior. It has an additional role in flood insurance because it fosters the sound land use that is a vital piece of this program.

A Deal's a Deal

The federal government made a deal with localities a long time ago in the NFIP. We said, "We won't make you go back and fix all the structures in your community to make them flood resistant. Instead, we'll go ahead and provide flood insurance for the structures that are already built in your community. We'll make it reasonably priced and we'll make it dependable." But that is only half of the deal. The other half is that the community agrees to prevent new buildings from being constructed in a way that makes them susceptible to flood damage. It is in the community's best interest to do this; it is in the best interest of the state; it is in the best interest of the taxpayer. It is a win-win situation all the way around. That deal is the fundamental premise of the NFIP, and it has grown into a complex program indeed.

My hat is off to you because you have the Community Assistance Program, and that is not an easy piece of the program to keep functioning properly and effectively. There are many different influences operating at the community level, as you well know, so it can be extremely difficult to keep a given locality focused on floodplain management and flood insurance issues. Nonetheless, it is a vital effort. We want to help you more with it. For one thing, we want to help you communicate. I believe we at FEMA need to talk with state legislators ourselves, and Mike and I will be discussing ways to do this. How can we better educate state legislators? Because even though money is
coming down from FEMA and coming from policy fees, you are still struggling out there. You have not had enough people or enough money to do what you want to be doing. We need to find some ways to bring some money up from the state level to your offices and under your control. We cannot take on the whole world at one time, but when we have the opportunity we will be speaking to this issue. Because this money does not come from the sky. This is OPM, and we cannot keep raising the premiums and the policy fees incrementally; we can't price people out of the program. It serves us no purpose for them to drop insurance, and then to have to rely on other federal programs. So there is a balance in there—a symmetry—that we have to be careful to maintain. But I am very aware of the struggle you have had and are still having in trying to provide more and better services and assistance with funds that in many cases have not even kept up with inflation. We support you and we are going to find better ways to help you.

Communication is very important, and we are going to be looking for ways to improve the give and take with all of our partners. We are putting some of our information on the Internet and using email more often; we are taking notes and distributing them of our significant conference calls and we are keeping records of our regional meetings. I pledge to you we are finding more and more ways of letting everybody know what is happening, because a job this complex and a program with this many players just cannot be kept going without that.

When Water Wants to, It Wins

Although I strongly believe this statement is true, what distresses me is that it implies that someone loses. We are looking for "win-win" situations. We want water. We need water. Water likely will be one of—if not the most—precious natural resources of the next century. People all over the planet are going to be working to find ways to harness and conserve it. Because water is a dynamic and powerful force, we know that we will always be in business; people in your profession and in mine will always have work to do as long as there is development, and weather, and climate changes.

I do not see Congress ever going back and deciding to use an appropriations process to fund the federal insurance program. And I pledge to you that we will work to strengthen that program to ensure that it stays in place and that it will be respected, efficient, and effective. Next spring no doubt I will be sitting beside Mike Armstrong in front of a Congressional committee. I want to be able to tell the story of the NFIP from beginning to end. I think too many cheap shots have been taken at the NFIP lately—shots that are aimed at a piece of the program
without understanding the whole. We are putting together at FIA documentation to enable us to tell the whole story. I want to be able to approach it from an offensive standpoint rather than a defensive one, because we have a terrific message. And I believe that when we do that we will really be educating people about the value of the program.

**Conclusion**

We have paid out about $8 billion in claims in the NFIP. About $1 billion has been spent on maps. We have borrowed and had forgiven about $1.2 billion and we have about $700 million borrowed from the U.S. Treasury now. But this makes perfect sense. These statistics should not alarm anyone when the costs that have been avoided are taken into account, and when all the local and state planning that has been enabled and encouraged through the program is considered. So in my view that money has been a very good investment indeed.

One of the needs that I immediately noticed when I came to FIA is that documentation of the NFIP does not exist in one place. To remedy that, we are doing a short-term project now to gather together the studies, reports, and other "deliverables" from the last 30 years that tell us what kind of progress has been made in the NFIP, and what impacts the program may or may not have had on external aspects of our society and environment. We have to be able to document our achievements for Congress, and be able to say precisely how we measure progress, and how we know the program is working. Of course we can say intuitively that "x" happens because of "y," but we need to be able to demonstrate that.

As part of this short-term project we also are looking for areas that need new academic study. We want to challenge schools of government and universities to investigate some of these issues and examine or re-examine some of the hard questions, such as, "Does the flood program promote development in floodplains and coastal areas?" There are people who have criticized the program, saying that we are enabling unwise development. To answer that charge fully, we must be able to demonstrate, with facts, what the program does and does not do. I suspect that more information about these issues exists than is readily apparent, and in fact we are finding even within FEMA that there are important studies that have been done, but people have forgotten about them. In addition, we want to determine where there are gaps in our understanding and knowledge about the program, and deficiencies in the actual documentation of what we think we know. We solicit the help of the academic community in determining what needs to be done. For example, I would love to see a study, perhaps a doctoral dissertation, of
the economic impacts of the NFIP after 30 years. It is that kind of information that we are going to try to accumulate.

I want to congratulate you, and thank you for being here in this profession and for the jobs you are doing. Because the work you do helps people. That is one of the ways in which I have been impressed by FEMA and by FIA. The employees at FIA are dedicated and many have spent most of their careers working on this program. The Mitigation Directorate staff at headquarters, likewise, are amazing in their dedication and in forging and maintaining that vital link between our two facets of the NFIP. We are available to you; we work for you. And we are looking forward to the coming year in which can tackle a lot of these important issues together.
Tonight, I announce that this year I will designate ten American Heritage Rivers, to help communities alongside them revitalize their waterfronts and clean up pollution.

—President Bill Clinton

With this one sentence in his 1997 State of the Union message, President Clinton waded into the world of rivers and floodplain management. It was not a huge splash or even a full plunge. But his announcement of the American Heritage Rivers (AHR) initiative set the stage for greater attention to river issues of all kinds, and an historic opportunity to highlight the multi-objective floodplain management approach.

Background

The American Heritage Rivers initiative promises increased federal attention to all rivers and focused assistance to a few. From its inception, AHR has been multi-objective in its purposes. While its focus is on rivers and their associated lands and communities—"cleaning up pollution," "revitalizing waterfronts," and "helping communities," in the President's words—its objectives as laid out by the White House the day after the President's speech are threefold: economic revitalization, historic preservation, and environmental protection. For the last year, a federal interagency committee has been fleshing out these objectives and developing a full-blown program. Communities were asked to nominate their rivers, and the criteria and application process were designed to elicit information about plans communities have developed for their rivers, as well as the breadth and depth of support for these plans. (Communities are self-defined, often including numerous towns, counties, and even states.) By the December 1997 deadline, the President's Council on Environmental Quality had received 126 applications from river communities in 46 states. Since that time, nine
nominations have been dropped due to Congressional opposition. Some of the river segments are as long as 1200 miles (the Rio Grande in Texas), and some as short as six.

In order to select rivers for designation, the White House has recruited a 12-member Presidential Advisory Committee of leading figures in conservation, preservation, economic development, and recreation, to make recommendations to the President. The Advisory Committee was announced April 8, 1998, and is chaired by Dayton Duncan, a film-maker with credits including the recent documentary on Lewis and Clark. Some other members include David Olsen, president of Patagonia, Inc., Donald Sampson, the Watershed Manager for the Columbia River Intertribal Fish Commission, and General Gerald Galloway, Dean of Faculty at the Industrial College of the Armed Forces and author in 1993 of *Sharing the Challenge: Floodplain Management in the 21st Century* (otherwise known as the Galloway Report). The Advisory Committee will meet in May 1998, and it is expected that the President will designate ten rivers shortly thereafter.

AHR differs markedly from two well-known river protection systems, the National Wild and Scenic Rivers System (enacted in 1968) and the Canadian Heritage Rivers System (now in its 14th year). In both these other systems, designations come without extensive community input and generally before any management planning is completed. Further, government entities lead in providing management. In contrast, AHR designation can come only after a broadly supported community nomination. Once a river is designated, the community remains responsible for implementing its plan, with federal agencies "in service to" them (see Table 1).

What has made the initiative attractive are four ideas: (1) federal agencies will concentrate various assistance programs, including grants, on the river areas; (2) a federal employee, called the "River Navigator", will be assigned to coordinate federal assistance and untangle red tape; (3) federal agencies will be expected to conduct their ongoing work and projects to be consistent with the community plan for the river; and (4) designation as one of the first ten American Heritage Rivers will bring enormous publicity.

The initiative has not been without controversy. Fears of federal agencies overreaching their authorities, clamping new restrictions on private property rights, and dictating local land use decisions have caused a vocal minority to challenge the President's initiative in the communities around the country, in press, in court, and in the halls of Congress. However, the opposition to AHR seems to be dissipating in the face of such overwhelming interest from local communities. The
Table 1. Contrasts and comparisons between American Heritage Rivers, Canadian Heritage Rivers, and Wild and Scenic Rivers.

<table>
<thead>
<tr>
<th>Goals</th>
<th>AHR</th>
<th>CHRS</th>
<th>W &amp; S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Economic Revitalization, Historic/Cultural Preservation, Water Quality/Environment</td>
<td>Heritage &amp; Natural Preservation</td>
<td>Preservation of outstandingly remarkable values and free flowing character</td>
</tr>
<tr>
<td>Which Rivers?</td>
<td>Tend to be working rivers</td>
<td>Tend to be historic routes &amp; natural/cultural corridors</td>
<td>Typically less developed rivers, often threatened by some form of development</td>
</tr>
<tr>
<td>Key Criteria</td>
<td>Community support Adequacy of plan (no requirement for resource significance)</td>
<td>Significance of historic &amp; cultural resources</td>
<td>Free flowing and one or more outstandingly remarkable values</td>
</tr>
<tr>
<td>Who Initiates?</td>
<td>&quot;Community&quot; only</td>
<td>Agency (plus community)</td>
<td>Agency, state, or congress (usually at community's request)</td>
</tr>
<tr>
<td>Who Designates/ &quot;Proclaims&quot;?</td>
<td>President</td>
<td>Canadian Heritage Rivers Board</td>
<td>Congress or Secretary of Interior (for state initiated requests)</td>
</tr>
<tr>
<td>Who Prepares Management Plans/ Plan of Action?</td>
<td>1 Step: Community</td>
<td>2 Steps: Agency (Community)</td>
<td>Agency for congressionally designated rivers and state for secretarial designations</td>
</tr>
<tr>
<td>Timing of Federal Support</td>
<td>Federal agencies help only after designation</td>
<td>Federal agencies help only before designation</td>
<td>Federal agencies help both before and after designation</td>
</tr>
<tr>
<td>Sequencing of Designation/ Plan</td>
<td>Plan before designation</td>
<td>Plan after designation</td>
<td>Plan usually follows for congressional designation and precedes for 2(a)(ii) rivers</td>
</tr>
<tr>
<td>Roles</td>
<td>Federal agencies &quot;in service to&quot; communities, provides river navigator</td>
<td>Provinces in lead, federal agencies in cooperation with local/regional authorities</td>
<td>Federal agencies in lead for congressional designations and states for 2(a)(ii) rivers</td>
</tr>
<tr>
<td>Key Tools For Conservation</td>
<td>Local only, non-regulatory</td>
<td>Patchwork (non-regulatory), watershed/basin focus</td>
<td>Section 7 and presence of a land management agency</td>
</tr>
<tr>
<td>Duration of Planning/ Management/ Assistance</td>
<td>3 months for first plans 5 years of assistance</td>
<td>3 years for evaluation 7 years for plan</td>
<td>3 years for planning/ management dependent on federal/state/local management</td>
</tr>
<tr>
<td>Expectations of Measurable Progress</td>
<td>Results are expected/evaluated</td>
<td>Not emphasized</td>
<td>No existing mechanism</td>
</tr>
</tbody>
</table>
volume of nominations received is evidence that communities see the initiative's approach as helpful, rather than threatening (as its opponents would claim).

How AHR Will Work

First, a community gets its act together and nominates its river. In order to apply for designation, communities had to have in hand, or be in the process of developing, a plan of action. In addition, they were asked to demonstrate the extent of support for their plan of action. Many communities documented this support by submitting, along with their nominations, dozens of letters of support for designation, from government officials, local nongovernmental organizations, and other community leaders.

Next, nominations are scored. The nominations were scrutinized by an interagency team of federal employees who had not been involved in the initiative to date. They scored nominations by assessing how well the plan of action addressed the initiative's primary areas of concern—environmental restoration, historic and cultural preservation, and community and economic development—and also by assessing the nature of support for the plan: how many, and what kind of organizations, how much public involvement there was in developing it, and what kind of political support it has.

Third, the Advisory Committee recommends rivers to the President. The Advisory Committee will use the agency scores and the nominations themselves to inform their decisions. They have been asked to ensure that the ten designations, as a whole, represent different kinds of rivers and communities, as well as different parts of the country. The advisory committee may recommend up to 20 rivers to the President, but only ten will be designated this year.

Fourth, the President designates American Heritage Rivers. It's time to celebrate!

Fifth, communities meet with federal agency staff to begin providing assistance, and prepare the "Framework Document." In the first three months after designation, communities with designated rivers will be working with a broad range of federal agencies. Together, they are asked to prepare a Framework Document, which is a partnership agreement that establishes a framework for coordination and cooperation (rather than a partnership agreement that defines how a specific project is implemented). In order to make this process a little easier, AHR will be offering the assistance of experienced, neutral, federal facilitators to the community of each designated AHR.
Significantly, 12 federal departments and councils, and the agencies that report to them, have been instructed by Executive Order to assist the communities of the designated AHRs. While many of the designated communities may have successful working relationships with some federal agencies, it is certain that the partnership opportunities will be expanded once the full complement of federal resources is made available. The Executive Order addresses the following federal organizations:

- Department of Defense;
- Department of Justice;
- Department of the Interior;
- Department of Agriculture;
- Department of Commerce;
- Department of Housing and Urban Development;
- Department of Transportation;
- Department of Energy;
- Environmental Protection Agency;
- Advisory Council on Historic Preservation;
- National Endowment for the Arts; and
- National Endowment for the Humanities.

Sixth, the community hires a federal "River Navigator." Perhaps the most anticipated benefit communities receive with designation is the assistance of a full-time federal employee, the "River Navigator," who will work as a "bridge builder" between the community and the federal agencies, looking for ways the federal government can help the community implement its plan. AHR has committed five years of assistance from a River Navigator for each designation. The River Navigators will have a tough job, but their effectiveness will be augmented by direct communication with, and support from, a federal interagency committee of high-level decisionmakers. This committee will be able to address federal policy problems as they arise in the community.

Seventh, federal agencies begin focussed assistance to communities. Under the agreements set out in the Framework Document, and with the assistance of the River Navigator, federal agencies will enter project-specific partnership agreements with the community to implement specific parts of the plan. This intensive level of assistance will continue for five years. Some projects may outlive this commitment, particularly those that start with extensive planning processes. However, it is expected that the River Navigator will not work in the community
Beyond the five-year mark. This limit is meant to prevent the community from growing too dependent on the River Navigator.

American Heritage Rivers puts communities in the driver's seat, with federal agencies tailoring their services to be of assistance when and where the community suggests. Partnerships are the byword.

**AHR and Floodplain Management**

While the AHR initiative is intended to spur economic revitalization, protection for natural resources and the environment, and preservation of the nation's historic and cultural legacy, it also seeks out and will recognize advances in various river-related fields, highlighting:

- a variety of innovative programs in such areas as historic preservation, wildlife management, fisheries restoration, recreation, community revitalization, agricultural practices, public health and drinking water source protection, and floodplain and watershed management. [emphasis added]

(Source: *Federal Register*, September 17, 1997. The wording on floodplain management was added to the guidance after General Galloway spoke to the interagency working group in the spring of 1997).

Because no rivers have yet been designated, we cannot say exactly how and in what ways floodplain management will receive attention under the AHR initiative. However, the nominees include such well-known, flood-prone rivers as the Mississippi, Illinois/Chicago, Lower American, and Neuse. In the communities' nominations of these rivers, improved floodplain management is one of their primary goals. We can expect that most features of the multi-objective process which the Association of State Floodplain Managers has pioneered will occur in the designated river areas, including:

- community-based, locally driven, decision-making;
- extensive public involvement;
- a broad spectrum of goals, needs addressed, and objectives to be achieved simultaneously through one set of actions (i.e., no more single-purpose projects);
- interagency and interdisciplinary approaches;
- well-coordinated, inter-jurisdictional activities;
- partnerships; and
• creative, innovative approaches, featuring a wide array of alternative actions.

Conclusion
The American Heritage Rivers initiative can be seen as a logical and important testing ground for the multi-objective management concepts that ASFPM has championed for a decade. In fact, in its basic design, the AHR initiative is multi-objective management: community-based, multi-disciplinary, encouraging of entrepreneurial approaches, relying on partnerships, and encompassing a broad range of values...all hallmarks of the MOM approach. As communities move forward with implementing their plans, a host of new ways of responding to flood threats will be highly visible, and the new approaches communities use will be given national attention. It is hoped that watershed-wide solutions are among those employed. The AHR initiative will be a prominent national stage for floodplain management.

The benefits of this initiative go much further than what happens on the ten designated rivers. The initiative is designed to assist all rivers through increased access to information. The initiative has developed an extensive library of programs on the World Wide Web. This catalogue of both federal and non-federal resources should be useful to communities interested in the initiatives' three main objectives, including floodplain-related goods and services. The government has also established a toll-free telephone line to accept requests for this information from people without Internet access.

With 12 federal departments participating and looking for new opportunities to coordinate their work, with its emphasis on access to information, and with the visibility that comes with a Presidential initiative, the AHR initiative promises to give a quantum lift to river conservation—including floodplain management—everywhere.
TIMES ARE CHANGING FOR THE NRCS

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Watersheds and Wetlands Division
Natural Resources Conservation Service

The Natural Resources Conservation Service is not as well known among floodplain managers as is the Corps of Engineers or the Federal Emergency Management Agency, but our accomplishments are nonetheless worthy of mention. The following is a short history of our involvement in flood prevention and the changes that have taken place over time.

Before the Reorganization Act of 1994, the NRCS was named the Soil Conservation Service. Many people are not aware that the NRCS has been involved in flood prevention and watershed protection efforts since the Flood Control Act of 1936. Under that Act the Corps of Engineers was to have primary responsibility for controlling floods through downstream water control methods such as large dams or levees. USDA was authorized to conduct surveys and investigations of watersheds for flood prevention purposes and to install measures to retard water flow and runoff to prevent erosion. Under the Flood Control Act of 1944, USDA was authorized to undertake flood prevention projects, using upstream water control methods for 11 watersheds covering 30 million acres. Funding for flood control efforts was less than balanced. For every $100 appropriated for flood control, the Corps got $96 and the USDA got $4. The money was appropriated to the Department of War and they in turn transferred funds to the USDA. The Corps was less than pleased at having another agency with engineering capability doing work they deemed to be theirs. They were not interested in diverting funds to USDA for upstream projects.

It was not until the 1950s, when Congress passed the Small Watershed Program and funding came through the Agriculture committee, that USDA got funds directly. Supporters of the Corps were successful in limiting the size of projects. The project area was limited to 250,000 acres and no single structure could be built that holds more than 5,000 acre-feet of storage. Although the law has been amended many times over the years, raising the size of structures to 12,500 acre-feet that can be built under this program and adding additional purposes, the maximum project area remains at 250,000 acres.
Since 1948 we have constructed nearly 15,000 structures of various sizes, most being small grade stabilization structures. Over one third of these are over 30 years old now and beginning to need rehabilitation. These structures are not federal projects, but federally assisted projects. USDA cost shared with the local community in constructing them, but the local sponsors are responsible for the operation, maintenance, and rehabilitation. Over time other changes in the watershed have occurred. On a recent trip to Texas I participated in a town hall meeting to discuss issues surrounding two structures that had been built over 30 years ago. When they were built, the land was far from any built-up area. The benefits were for agriculture purposes and the structures were designed as low-hazard structures. Since then, development has surrounded the lake, encroaching on the flood pool and emergency spillway as well as building in the floodplain below the dam. This causes major problems as sponsors try to upgrade the structures from low-hazard to a high-hazard dam. Breaching the structures is not an acceptable alternative. The residents built where they did for the view overlooking the water. We need your assistance in working with communities on these kinds of issues to prevent these situations from happening.

On July 3 of this year, the sponsors of the Cloud Creek Watershed Project in Oklahoma will be hosting a celebration in honor of the 50th anniversary of the construction of the first structure under this program. Historical records indicate that over 10,000 people came to the dedication in 1948. Our first administrator, Hugh Hammond Bennett, was a strong supporter of the program and spoke to the crowd. Let me share the following comments he made as he spoke to the crowd overlooking the reservoir. "This illustrates what I have long felt is the true situation about floods; namely: flood control is a job that begins where the rains fall and runoff starts, and ends only when the runoff has safely reached the ocean. We are tackling this problem at the very beginning, on the small watershed far upstream where the raindrops first begin their journey from the land to the sea. From time to time I have pointed out that floods are no more than raindrops, infinitely multiplied and allowed to concentrate into controlled torrents, which sweep destructively over the banks of streams. Our aim is to hold back as much as possible of the surplus water so as to reduce the height and destructiveness of floods. We do not claim, in setting out on this undertaking, that we can control major floods with this kind of work alone. Some of the peak flow can be cut down, and this will help. But for the heavier floods there will be needed additional controls in the way of reservoirs, levees, and other main channel operations. These major engineering operations are the responsibility of the Corps of Engineers."
It is our belief that a combination of these programs, the main channel program supplemented by the upstream program, can get the job of preventing and controlling floods accomplished."

In the early years of this program, most projects were planned for a single purpose, flood control. Today they are multi-purpose. Last week we presented a project located in Kansas to the Water Resources and Environment Committee for approval. It provides flood protection, recreation, drinking water for the Kickapoo Indian Tribe, erosion control, wildlife habitat, and will reduce the amount of sediment reaching Lake Perry, a Corps of Engineers project. NRCS assisted the local communities and the Tribe in planning the project to meet their needs.

During this same era, the policy of the Department of Agriculture was to maximize production. The government cost shared with landowners to drain the land and bring it into production. It was not until the late 1960s and early 1970s, with the passage of the National Environmental Policy Act and the Clean Water Act, that things began to change.

With the passage of the Food Security Act of 1985, USDA became a major player in the protection of our nation's wetlands. Conversion of wetlands on agricultural lands reduced dramatically and restoration began with the inclusion of restored wetlands in the Conservation Reserve Program. In 1990, USDA became a major player in the restoration of wetlands with the passage of the Wetland Reserve Program. In 1994, USDA became a major player in the restoration of floodplains with the passage of the supplemental appropriations after the flood of 1993, with the creation of the Emergency Wetlands Reserve Program. In 1996, USDA received the authority to purchase easements as a tool in addressing flood recovery efforts. It also initiated the buffer initiative to restore 2 million miles of buffers along streams and in critical areas by the year 2002.

Since 1990 we have enrolled over 600,000 acres of land into the Wetland Reserve Program, most of which are in the floodplain. We enrolled over 80,000 acres into the Emergency Wetland Reserve Program after the flood of 1993. We are in the process of purchasing floodplain easements on approximately 15,000 acres after the floods in the Red River Valley and California. We were recently delegated the responsibility by the Secretary to implement the "debt for Nature" program. It provides landowners with an opportunity to lower their mortgages in exchange for a conservation easement. We are receiving watershed applications calling for the acquisition of floodplain easements as a nonstructural alternative to flood protection, and last, we are reviewing some of our old watershed projects and looking to
substitute floodplain easements for dams and channels that are no longer feasible to construct. In addition to these easement programs, USDA also has the Conservation Reserve Program, which includes a "buffer" initiative. It is primarily under this program that the goal of installing 2 million miles of buffers by the year 2002 was initiated. We are very excited about the benefits this initiative will provide.

In conclusion, the USDA is a major player in floodplain management. We have a "tool box" as we have come to call it, with a wide variety of programs to address nearly every natural resource concern. We have a delivery system with a presence in nearly every county in the United States. We provide our assistance through local conservation districts. We are strong proponents of "locally led conservation," where the local people living in the communities are the key decisionmakers in determining which solutions best fit their needs. USDA is a major player in floodplain management. We have some excellent programs available to help local communities address their natural resource concerns and a trained staff to assist them. Our programs continue to be very popular and demand far exceeds available resources. As an example of the value of our programs, our Small Watershed Program has helped reduce flood damage in four counties in Iowa. The number of requests for disaster assistance in the watershed project area is far lower than in other parts of the county.
Part 2
State and Local Planning, Management, and Projects for Flood Mitigation
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AT THE CROSSROADS: WATERSHED MANAGEMENT, TRANSPORTATION, AND FLOOD HAZARD REDUCTION

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Washington State Department of Transportation

The State of Washington experiences frequent flooding due to climate, weather patterns, steep drainage systems, and other factors. Infrastructure owned and managed by Washington State Department of Transportation (WSDOT) often intersects floodplains. As a result, flooding impacts WSDOT facilities, disrupting services, interrupting the movement of people and goods, and impacting the economy. And, WSDOT facilities have the potential to impact the capacity of floodplain and watershed function, thus having a negative impact on natural resources. Since 1980, Washington has experienced 11 Presidential disaster floods. These floods have caused serious property and environmental damage. Since November 1995, over $377 million in damage has occurred to state highways, county roads, and city streets. Additional damage has been incurred by other public facilities or businesses, industries and homeowners.

The magnitude of the expense and disruption of services is of concern to WSDOT and several activities have evolved to address different aspects of flood management. These activities include participating in interagency work groups and discussions to streamline the environmental review process, improve bank and channel stability, reduce flood hazards in the Chehalis watershed, improve coordination with other agencies and governments on flood hazard reduction and mitigation, and improve coordination with upland landowners and developers. In addition, an intra-agency team is examining ways to improve the emergency contract process.

Historically, road-related flood reduction projects have been confined to the right of way but with the cost of solutions reaching several million dollars, other approaches are being considered. Application of a watershed approach may suggest alternative ways to reduce flood potential for considerably less cost. In order to optimize the effectiveness of agency flood management activities, WSDOT is piloting a coordinated flood management strategy that will network existing work groups and develop a strategic approach to agency flood
management. The strategy will improve the agency's ability to identify, plan, and prioritize flood reduction projects; respond effectively and efficiently to emergency repairs; optimize cost benefit; and meet environmental responsibilities.

**Background**

In 1994, the Environmental Cost Savings and Permit Coordination Study was conducted on behalf of the Washington State Legislative Transportation Committee (LTC). The study addressed several issues related to compensatory wetland mitigation, wetlands banking, and a watershed approach to environmental impact mitigation. A common point among these three issues was the lack of a WSDOT strategy to implement a holistic management approach to the environmental impacts related to transportation facilities. The LTC's evaluation of WSDOT's environmental management programs coincided with the emergence of two major issues confronting Washington State’s natural resource managers: salmon recovery and watershed planning.

The WSDOT has responded by developing a programmatic structure consisting of seven major initiatives: Flood Management Strategy; Wetlands Strategic Plan; Stormwater Grant Program; Capital Budget Coordination; Fish Passage Barrier Removal; Advanced Mitigation Account; and Federal Planning (NEPA). A pilot program has also been established in the Snohomish basin to use the watershed approach in linking mitigation needs with watershed recovery projects. The coordination of these initiatives provides a holistic approach to transportation-related environmental concerns.

The Washington State Legislature has also expressed an interest in flood management through ESHB 3110. This legislation directs WSDOT and the Department of Ecology to convene a committee of state agencies, tribal, and local governments to identify opportunities for improved coordination on floodplain management. As well, the legislature provided $2 million to the WSDOT Advance Mitigation Account to develop mitigation opportunities. This account specifically calls for identification of flood hazard reduction projects. The interagency committee will develop a recommended process to identify appropriate flood hazard reduction projects.
The Flood Management Strategy

The goal of the Flood Management Strategy is to minimize mobility, environmental, and economic losses that occur during an emergency and reduce the likelihood of future flood hazard. Objectives of the Flood Management Strategy are to streamline the state environmental process; streamline the emergency relief contract process; promote watershed-based planning and management; develop an approach to transportation-related floodplain management and impacts; evaluate options for programming flood hazard reduction needs; identify mitigation opportunities to reduce the risk to WSDOT facilities; improve the compatibility and use of different flood-related funding sources; and reduce department damage costs.

The WSDOT Flood Management Strategy comprises four elements: information; technology transfer; outreach and education; and management.

Information

The primary focus of the Flood Management Strategy is to develop a database of WSDOT infrastructure that has sustained damage from flooding. From this data, we will be able to identify and address frequently flooded facilities. We also plan to work with other agencies to develop data layers identifying priority emergency routes, environmental concerns, and economic considerations in order to help program emergency repairs. Information on flood plans in the State of Washington; flood-related laws, policies, and guidelines; and WSDOT flood-related activities will be compiled and made easily accessible.

Technology Transfer

Another primary element of the strategy is the development of a watershed model for flood management. The model is intended to help evaluate the cause and effect relationship between activities in a basin and flooding. Understanding the cause and effect relationships will improve programming decisions and help WSDOT develop partnerships to reduce damage to WSDOT infrastructure. Technology transfer will also include research, monitoring projects for design optimization, and review of literature and programs for new and innovative technologies for flood management.

Outreach and Education

Program awareness and access to information are limiting factors in developing a coordinated approach to flood management. Therefore, a
key component of the Flood Management Strategy is to develop and implement methods to convey information regarding WSDOT’s Flood Management Strategy to agency employees and interested stakeholders. Effective outreach will help develop appropriate connections between WSDOT’s strategic plan and other relevant planning efforts. In addition, understanding the connections between flooding and other watershed issues will improve flood-related decision-making. Toward this end, issue papers will be developed to address flooding and emergency response, project design considerations, data management, opportunities to optimize fiscal and project benefits, and flood hazard reduction needs and objectives. These papers will also discuss community impacts, community involvement, environmental impacts with specific considerations for fish habitat, wetlands, and water quality.

Management
The strategy will assess barriers to a coordinated flood management approach and develop a strategic plan to remove those barriers. Legislation, agency directives, and procedures may need to be altered to incorporate a watershed-based coordinated approach to flood management. Specific areas of review will include project identification, mitigation opportunities, and data management. Significant progress has already been made in streamlining permits for emergency work and developing design guidelines for streambank protection that emphasize bioengineering solutions. And work is already underway to improve our management of bridge scour through understanding the potential risk and developing general permits for maintenance. Performance measures will be developed to assess the effectiveness of this strategy.

Scope of the Flood Management Strategy
A key component of the Flood Management Strategy is the development of geographic information data layers and analytical models that streamline the planning process. The flood management strategy will help address the following questions.

Emergency Work
Which infrastructure has been or is likely to be damaged by flooding?
Which lands are impacted by backwater from WSDOT facilities during a flood event?
Where do emergency repairs need to be done?
Where have emergency repairs been done in the past?
Which repairs need to be conducted first (based on emergency routes, environmental priorities, or economic considerations?)
What are the environmental issues of concern at a project site?
Where are the mitigation, restoration, and protection opportunities in the watershed?
What are the mitigation priorities within the watersheds?
How can WSDOT optimize use of emergency funding?

Project and Retrofit Work
What is the cause of flooding in the basin and with whom does WSDOT need to work to develop flood hazard reduction plans?
What needs to be done to reduce flood hazard from and to WSDOT infrastructure?
Are certain types of infrastructure or designs prone to flooding?
Which flood hazard reduction projects should be conducted first?
Are there opportunities to leverage outcomes or costs?
How can we streamline permitting and maintenance agreement needs?

The WSDOT Flood Management Strategy is being developed by a cross-program committee. The committee is identifying current activities, functional needs, and geographic priorities. A basin will be selected in which to test the new database and flood model. An inter-agency committee is also forming to address the needs identified in ESHB 3110. This committee will consist of a policy work group and a technical work group. The interagency committee will develop opportunities for coordination and develop a process by which to identify priority flood hazard reduction projects. An interagency research partnership is also forming to develop a watershed-based flood model.

Conclusion
The reputation of state transportation agencies is that of a developer and construction agency. Building and maintaining transportation facilities will always be the primary mission of WSDOT. However, the agency also recognizes its responsibility to develop projects in a cost-effective, environmentally responsible manner. Improving environmental performance within the agency does not necessarily have to come at the expense of cost-efficiency. WSDOT has recognized that efficiencies can be obtained by coordinating flood management activities and directing flood hazard reduction expenditures towards sites that are repeatedly damaged. In order achieve this objective, site selection and evaluation must be approached from a watershed perspective. WSDOT has
developed a series of environmental initiatives and pilot projects to integrate a watershed approach into the agency's mission.

WSDOT's effort to improve its own environmental programs can offer enormous benefits to basin-wide flood management recovery efforts. Application of a coordinated watershed approach to flood management will improve the decisionmaking capacity of agencies and local governments in the face of complex choices. WSDOT brings new options and perspectives to the table for financing, constructing, and planning flood management efforts. The foundation is established within WSDOT to begin implementation of its watershed-based flood management approach. The long-term success of the initiatives and the flood management strategy will be measured by a reduction in damage and cost to WSDOT infrastructure. The benefit of the Flood Management Strategy will be in improved understanding and working relationships with other watershed stakeholders.
COLORADO STATEWIDE STREAM REHABILITATION AND FLOODPLAIN MANAGEMENT NEEDS INVENTORY

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Larry Lang and Brian Hyde
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Introduction

Significant floods in 1993 and 1995 caused an estimated $48.3 million in damage and related fatalities in Colorado. In response to this, the Colorado Legislature in early 1997 authorized the Water Conservation Board to "conduct a statewide inventory of river channel restoration and floodplain management needs. The findings of the Needs Assessment will be the basis for a proposal to determine the economic feasibility of establishing a statewide floodplain management and river channel rehabilitation program funded separately from the Colorado Water Conservation Board construction fund. The proposed program would represent a comprehensive approach and source of funds for local governments to better manage mitigation measures, streambanks and channel erosion, loss of channel conveyance capacity, and loss of wildlife habitat areas."

This legislative directive became prophetic a few months later when extreme flooding impacted a 13-county area of eastern Colorado between July 28 and August 17, 1997. An estimated $200 million in flood damage occurred in the Fort Collins/Larimer County area, and an additional $50 million in damage was documented in 12 other counties. Six deaths were attributed to the flooding, and the affected areas received a Presidential disaster declaration.

In October 1997 the Colorado Water Conservation Board (CWCB) retained McLaughlin Water Engineers, Ltd. (MWE) to conduct an inventory of floodplain management and stream rehabilitation needs for the State of Colorado. The results of this inventory would serve as the basis for recommended programs to address those needs.
Assessment Process

The CWCB organized a Steering Committee to provide overview and guidance for the project, bring an expanded level of expertise and perspective, provide comment and endorsement of study findings, and actively participate in recommendations to the CWCB. The 18 Committee members represented city and county officials, state and federal agencies, water user groups, land development/reclamation interests, agricultural landowners, and environmental interests. Periodic meetings were held with the committee throughout the study.

Questionnaire Development and Distribution

To assess the floodplain management and stream rehabilitation problems and concerns across Colorado, a detailed questionnaire was developed by MWE, CWCB, and the Steering Committee. The questionnaire solicited data on the following major subjects.

- Community Profile
- Floodplain Management
  - Floodplain-related issues (flood history; population and structures in floodplain)
  - Floodplain mapping needs (unmapped stream reaches, maps requiring updating)
  - Existing/planned mitigation measures
- Multi-Objective Use of Stream Corridors (Is there a need for a multi-objective management project?)
- Institutional Issues
  - Floodplain regulations (Is community in the National Flood Insurance Program?)
  - Drainage criteria (Does the community have criteria or master drainage plans?)
  - Funding mechanism preferences

Based on recommendations from CWCB staff and the Steering Committee, a second questionnaire was developed for distribution to special districts, environmental organizations, and other water-related groups. On October 23, 1997, the questionnaires were mailed to 63 counties and 268 cities and towns, with a request that they be returned by November 14, 1997. Similarly, questionnaires were distributed to 110 water-related organizations.
Questionnaire Responses

By the initial November deadline, only 10% of the communities had responded. In order to improve the response rate, members of the consultant team made over 200 follow-up phone calls to the non-responding communities. This effort dramatically improved the return rate. By the end of January, approximately 44% of Colorado counties had returned their questionnaires, and approximately 39% of cities and towns had responded. Overall, 135 of the 331 questionnaires (40.8%) have been received. Twenty-four of the 110 organizations (21.8%) also completed questionnaires.

Questionnaire Review

Each questionnaire was reviewed by MWE staff. Completed questionnaires ranged from very brief responses with minimal or incomplete data to extensive documents with detailed responses that included maps, reports, or other supplemental information. Additional follow-up calls were made to fill in blanks on returned questionnaires or to clarify responses. Once all information was verified, the questionnaires were entered into a database model.

Database Analysis

The database model enabled the project team to quantify statewide needs regarding miles of unmapped floodplains, mapping that needs updating, miles of eroded or unstable streams requiring rehabilitation, watershed or drainage master planning needs, flood mitigation project needs, and funding needs. Figure 1 illustrates that over 70% of respondents indicated the lack of a funding mechanism for planning and implementing flood protection or stream rehabilitation improvements. When asked what type of mechanism would be preferred, a significant percentage favored a revolving loan fund, as shown in Figure 2.

The survey responses reflect a keen interest by local community officials to better understand the natural resource functions of stream corridors, so that flood protection can be gained without compromising other beneficial values such as aquatic and riparian habitat, wetlands, water quality, open space, recreation, and water supply.

Identified Needs

Based on a review of the questionnaire responses from the communities, counties, and water-related organizations, needs were identified and grouped under two major categories; stream rehabilitation and flood protection.
Figure 1. Problems identified with flooding.

Figure 2. Funding mechanism preferences.
Stream Rehabilitation Needs

Over 1,200 miles of Colorado streams were estimated to have erosion-related problems as a result of natural processes and human activities. Stream bank erosion and channel aggradation and degradation can harm fish habitat, destroy agricultural land, and damage private property. Rehabilitation measures are needed to stabilize threatened stream corridors, preserve the natural resources and functions of floodplain areas, and increase flood capacity. Such measures can include:

- Channel stabilization measures,
- Riparian habitat improvements,
- Wetland area enhancement,
- Eroded stream bank repair, and
- Open space preservation and conservation buffers.

Flood Protection Needs

Stream flooding remains the greatest hazard to life and property in Colorado. Today, flood-prone areas have been identified in 268 cities and towns, and in all of the 63 counties in Colorado. As many as 250,000 people are estimated to reside in the 100-year floodplain area, with property valued at more than $11 billion.

There is a clear need for improved floodplain management to reduce the at-risk human population’s vulnerability to flooding and prevent further encroachment into flood hazard zones. In Colorado, over 2,000 miles of streams were estimated to require floodplain mapping, and numerous miles of mapped floodplains are not current and require updating. In the area of flood mitigation, the survey enabled the project team to estimate a need for over $1 billion throughout Colorado for flood control or flood mitigation projects. The survey responses also indicated needs in the areas described below.

Planning assistance. A significant percentage of the respondents expressed support for watershed-based master plans that can provide comprehensive, multi-objective solutions for urbanizing watersheds. Most respondents recognize that such plans can provide a broader perspective to issues of aquatic and riparian habitat, flood conveyance, groundwater discharge/recharge, water supply, land use activities, agricultural uses, and recreational, open space, and aesthetic values of stream corridors.

Public information/technical assistance. Community respondents indicated a need for technical assistance in formulating and planning their flood mitigation or rehabilitation projects. In addition, the survey revealed a clear need for a public information/education program.
regarding the natural resources and functions of stream corridors and the role of multi-objective planning as a tool to address existing and potential impacts along stream corridors.

**Policy and criteria needs.** A major percentage of respondents do not have a drainage criteria manual or other adopted drainage criteria. A similar number of communities lacked a stormwater detention policy.

**Funding needs.** Figures 1 and 2 illustrate the survey results regarding the lack of a mechanism for funding the planning and implementation of improvements and the support for a statewide revolving loan program, respectively.

**Recommendations**

The project team has recommended to the State Legislature a program to address the following efforts:

- Provide funding for multi-objective watershed planning studies for Colorado's major river basins, stream rehabilitation analysis for selected stream reaches, and community-based mitigation projects;
- Create a statewide revolving loan fund to enable communities to implement flood protection and stream rehabilitation projects;
- Establish a statewide wetlands bank;
- Expand the ongoing program for floodplain mapping;
- Prepare a statewide model stormwater criteria manual; and
- Set minimum criteria for detention of excess runoff from development.

**Potential Legislative Action**

As of the writing of this paper, there are three possible options for action by the Colorado Legislature during the 1998 session.

1. Establish a statewide revolving loan fund for implementation of stream rehabilitation and flood mitigation projects;
2. Adopt a resolution authorizing the creation of a multi-disciplinary task force to develop policy and funding recommendations for the 1999 legislative session; and/or
3. Authorize funding to develop a proposal to Great Outdoors Colorado (a lottery-funded agency that distributes funds from the state lottery to open space, parks, and recreation projects throughout Colorado) for implementation of a stream rehabilitation and flood mitigation program.
Introduction

Planning has been a significant part of the National Flood Insurance Program's (NFIP's) Community Rating System (CRS) since the program's inception in 1990. In fact, planning is required for those communities in the program who have over a certain number of repetitively flooded structures. The CRS planning process provides a flexible framework that allows communities to undertake planning at different levels of sophistication, depending on the personnel and expertise in the community. The planning process allows communities to learn from the past, assess the present, and prepare for the future. The planning process is based on ten steps, with each step worth a certain number of points under the CRS.

Proactive versus Reactive

In the past, the approach to mitigation planning was reactive. After a disaster, a hazard mitigation plan would be developed addressing the problems that surfaced during the disaster. In essence, mitigation planning was thought of as "now that we have this problem, what do we do about it?" The CRS planning process takes a different approach. A standard planning process is applied in a proactive manner. The community is encouraged to learn from past disasters and to apply that knowledge to the current situation so that a plan for the future can be developed. This is important because there is very little time to plan after a disaster and communities are immediately focused on recovering. Proactive planning can reduce the overall damage that occurs in a future disaster. Most importantly, the CRS planning process helps communities to understand their flood problems and to direct resources and energies toward solving them, before disasters occur.
The Planning Process

The CRS planning process is just that, a process. It is a framework to guide a community into the future by comprehensively evaluating all options or alternatives for addressing the identified flood problems and selecting those most appropriate for implementation. The CRS credits the process that a community follows to arrive at the final plan's recommendations, more so than the plan document itself.

Flexibility is built into the CRS planning process through minimum requirements in each of the ten steps. A community that believes that the planning requirement in the CRS is a mandate rather than a tool can choose to conduct a planning process that meets the minimum requirements. On the other hand, a community that wants to do a more comprehensive, detailed, and thorough job of planning can undertake additional elements from each of the ten steps in the process. A community that chooses this direction will score additional points on its CRS application.

Each of the ten steps in the CRS planning process is worth a certain number of points as described below. Maximum credit for a plan conducted under this process is 210 points. For reference purposes, 500 points on a CRS application entitles a community to a 5% reduction in flood insurance premiums for its residents.

<table>
<thead>
<tr>
<th>Step</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Organize to prepare the plan</td>
<td>10</td>
</tr>
<tr>
<td>b. Involve the public</td>
<td>48</td>
</tr>
<tr>
<td>c. Coordinate with other agencies</td>
<td>18</td>
</tr>
<tr>
<td>d. Assess the hazard</td>
<td>10</td>
</tr>
<tr>
<td>e. Assess the problem</td>
<td>30</td>
</tr>
<tr>
<td>f. Set goals</td>
<td>2</td>
</tr>
<tr>
<td>g. Review possible activities</td>
<td>30</td>
</tr>
<tr>
<td>h. Draft an action plan</td>
<td>50</td>
</tr>
<tr>
<td>i. Adopt the plan</td>
<td>2</td>
</tr>
<tr>
<td>j. Implement, evaluate, and revise</td>
<td>10</td>
</tr>
</tbody>
</table>

One of the cornerstones of the CRS planning process is public involvement. The CRS only credits a planning effort where the public has had the opportunity to sufficiently participate in the process. The CRS encourages a "committee approach" to planning that brings in lay
citizens from the community to work cooperatively with departments and agencies within the community. Often communities resist this type of public involvement because it slows down the process. It has been demonstrated through the CRS, however, that more involvement from the public results in a more effective plan, because those affected most by the flooding problems are those who have a vested interest in solving the problems. Additionally, this type of involvement has been shown to turn citizen adversaries into citizen advocates for the community. Once a citizen fully understands the obstacles, constraints, and issues associated with addressing flood problems and implementing solutions, the more likely he or she is to support the community and its efforts.

Flood problems do not stop at the corporate limits of a community. Therefore, coordination with adjacent and nearby communities is required under the CRS planning process. Coordination is also required between the local jurisdiction and state and federal officials. Most notably, the State NFIP Coordinating Agency, the FEMA Regional Office and the U.S. Army Corps of Engineers as well as regional planning agencies and water management districts are to be brought into the process of developing the plan. Coordination will help communities become aware of available monies or programs that may benefit them. Coordination may help reduce the cost of some projects by sharing the effort with adjacent communities. And, coordination may reduce duplicative efforts.

The only way to solve a flood hazard is to clearly define the hazard. The description of a flood hazard should include discussion of (1) cause of the hazard; (2) source of water; (3) velocities; (4) height of water; and (5) past flood history. Additionally, a picture description (flood hazard map) is also required to supplement the textual definition.

To adequately prepare a plan for the future, an assessment of the present situation is required. It is important to know what is at risk in the unlikely event of a future disaster. The CRS planning process recognizes the importance of this inventory and at a minimum requires a community to include the number and type of structures subject to the hazard. A community that wishes to more thoroughly assess the problem can undertake additional elements, such as addressing critical facilities.

A plan's vision lies in its goals. A community must set basic floodplain management goals as a part of the CRS planning process. The goals serve as a level of achievement for the implementation phase of the plan.
The community must conduct a comprehensive review of all possible mitigation activities. This comprehensive review would include the evaluation of both structural and nonstructural approaches. The discussion of various alternatives requires a community to include in its plan not only why certain mitigation activities are appropriate for implementation, but also why other mitigation activities are not appropriate.

The action plan directs what activities will be implemented, who or what department or agency will implement them, when the activities will be implemented, and how will they will be financed. A plan is valuable only when these questions are addressed in the action plan. By addressing these questions, responsibility is attached to each mitigation activity and the action is more likely to be carried out. The local governing body must adopt the plan. The adoption can be either through a resolution or ordinance.

Annually, the CRS planning process requires a community to review the progress it has made toward implementing the action set forth in the plan. This review will inform the community if it is moving in the right direction and allows the community to redirect its effort if necessary. The annual review requires the community to complete a progress report, which is made part of a community's annual recertification to the CRS program.

**Conclusion**

The CRS planning process takes mitigation seriously by requiring communities to complete pre-mitigation plans. There is no better defense for a disaster than preparation. This is the focal point of the CRS planning process. The process helps a community to define its flood hazards, assess its flood problems, evaluate possible solutions, and select the most appropriate activities for implementation. Parts of the CRS planning process model were borrowed to develop the Flood Mitigation Assistance Program (FMA) planning guidelines.

Because each community is uniquely different, the CRS recognizes that each planning effort will be different. Therefore, the CRS planning process is the framework that allows a community to develop a plan of action that directly addresses and relates to its own unique environment and situation.
Introduction

DuPage County, Illinois, initiated its Stormwater Management Program in the early 1980s with a focus on addressing flooding problems through a watershed-based approach. Watershed planning used advanced technical methods, including continuous simulation hydrologic and one-dimensional, unsteady flow hydraulic modeling. The flood of August 1987 led to state legislation allowing the collar counties of northeastern Illinois to regulate stormwater and floodplain issues on a countywide basis, and to levy a dedicated stormwater tax. Retaining the watershed planning approach, the county adopted the comprehensive Stormwater Management Plan, and the Countywide Stormwater and Flood Plain Ordinance (DPCSFPO) in 1992, which also contains stringent regulations regarding development in wetlands. The Stormwater Management Program also includes elements such as remapping of flood plains and stream maintenance.

Background

The Valley View subdivision of 600 homes is located in unincorporated Glen Ellyn, separated from the East Branch DuPage River by Illinois Route 53 (see Figure 1). The subdivision was built in the 1960s, before the publication of federal floodplain and flood insurance maps. Eighty-seven homes have the potential for inundation from overbank flooding of the East Branch. Groundwater flooding from a high water table is also a problem. The river once flowed through the first two rows of homes before the river was channelized in the 1930s and relocated on the other (east) side of Rt. 53 for agricultural purposes. The roadway and vegetation now obscure the fact that a river with over 30 square miles of drainage area at that point lies just 250 feet from the lowest row of homes.

The Morton Arboretum, a leading arboretum in the United States for plant collections, research, and education, is located directly across from Valley View, on the east side of the river. The Hidden Lake Forest Preserve lies just northeast of Valley View, north of the Arboretum. The East Branch flows within the Preserve, through a wetland site which was
Figure 1. Valley View location map and hydrographic features.
mitigation for construction of the I-355 Tollway, and continues through the Morton Arboretum across from Valley View.

Valley View is the mostly heavily flood-damaged area in the East Branch Watershed, an 82-square-mile watershed centrally located in the county. The subdivision experiences some level of flooding every three years, on the average. Major recent events include the floods of August 1987, July 1996, and February 1997. Simulated damage in the subdivision exceeded $10 million for the 40-year study period of 1949 to 1988 (assuming 1990 land use conditions over the period). Local studies of the flooding problem were performed as early as the 1970s. The U.S. Army Corps of Engineers performed a reconnaissance study for Valley View in the early 1980s. In 1992, an agreement was executed by the county and the Corps for a Section 205 Flood Damage Reduction Feasibility Study.

Technical Methods

A Full Equations (FEQ) (Franz and Melching, 1997) model of the East Branch DuPage River, developed by the DuPage County Department of Environmental Concerns (DEC), was used to establish baseline damage and flood heights, and to assess the effectiveness of alternative strategies for flood damage mitigation. Hydrologic input (runoff files) to the FEQ model were taken from a Hydrologic Simulation Program—Fortran (HSPF) (Bicknell et al., 1993) calibration of the Salt Creek watershed, which borders the East Branch watershed on the east side (Price, 1993). A 40-year record of 65 historical storm events was simulated using HSPF and FEQ.

Independent economic analyses were performed by DuPage County and by the Corps, using the same set of flood peak elevations. The county computed residential damage on an event-by-event basis over the 40-year historical simulation period, while the Corps generated flood frequencies from the simulated flood event data, extrapolated to the 500-year return interval, and used mathematical integration to compute annual and total damage. The Corps also calculated traffic damage, and damage to the Morton Arboretum, based upon data supplied by the Arboretum.

Potential impacts to the Hidden Lake wetland mitigation site were evaluated by developing elevation-duration tables from the FEQ output for both baseline conditions and flood mitigation alternatives.

Planning Process

The Joint Feasibility Study also served as the basis for the county's 1996 Valley View Flood Control Plan, to be included in the future East
The Valley View Flood Control Plan. (The county accelerated the Flood Control Study ahead of the overall Watershed Plan because Valley View is the highest-priority flood damage area in the East Branch Watershed, and because it is isolated geographically and hydraulically from other major damage areas in the watershed.) Noteworthy features of the Feasibility Study include: 1) the Corps's willingness to allow the county to perform all of the hydraulic analyses, using the county's East Branch FEQ model, and 2) to design the project to meet the DPCSFPO.

Steering committees have been formed for numerous county projects, both to satisfy the public input requirement of the Stormwater Management Plan, but also for the following reasons: the major "stakeholders" in the watershed are given an opportunity to become part of the planning process; the committee facilitates communication as well as information-gathering, such as detailed damage data; and allows a forum to discussion of the opportunities to use private land for public flood control, as well as potential negative impacts to each of the major land owners. A Valley View Steering Committee was formed, consisting of representatives of the Valley View Civic Association, major landowners such as the Morton Arboretum and DuPage County Forest Preserve District, DEC, the Corps, utilities, the Illinois Department of Transportation, and Milton Township.

Alternatives Analysis

The Steering Committee was instrumental in developing alternatives for consideration for solving Valley View's flooding problems. The design goal was to address all structural inundation. The alternatives included both nonstructural alternatives (buyout, floodproofing, wetland bank, greenway), structural alternatives (impounded storage, excavated storage, pumped storage, floodwall, levee, diversion channel), and various combinations of the above. In all, 15 different alternatives were considered. Enough analysis was done on each alternative to reach a point of decision about whether the project was viable; if not, the alternative was screened out from further consideration. Factors that rendered a project not viable included inability to meet regulatory requirements, including the DuPage Countywide Stormwater and Flood Plain Ordinance, extremely low flood control benefits, extremely high cost, negative environmental impacts, and failure to meet the goals and objectives of the Stormwater Management Plan. All but two of the 15 alternatives ended up being screened out.

The two lowest cost, feasible alternatives were (1) non-structural buyouts and floodproofing 39 and 48 homes, respectively; and (2) a dam
on the East Branch in the Hidden Lake Forest Preserve with residual buyouts and floodproofing (22 and 25, respectively). The total cost of each alternative was $6,318,480 and $5,227,835. Staff recommended the dam and residual buyouts and floodproofing alternative over the non-structural alternative for three reasons: (1) cost-savings of $1,300,00; (2) flood level reduction by the dam of up to 0.7 ft, which gives (unquantified) benefits including less flooding on Rt. 53, less flooding on the Arboretum, less yard flooding, and associated benefits; (3) Steering Committee discussions suggest that the proposed dam could have environmental benefits. The proposed dam would remove all simulated residential inundation by significantly reducing flow in only 8 of the 65 simulated floods. This fact, along with a hydroperiod analysis of all 65 simulated storm events, indicates that low-flow and frequent storm hydrology will not be significantly changed by the dam. Also, the additional increase in inundation period for the extreme events may kill off undesirable species dominating the mitigation wetland upstream of the proposed dam. The DuPage County Stormwater Management Committee approved the staff's recommendation, along with other plan components such as maintenance and drainage improvements.

Implementation and Status of the Plan
The Valley View Flood Control Plan was under public review when a major flood occurred in July 1996. This event brought rainfall ranging (in a 24-hour period) from 4 inches at the upstream end of the East Branch Watershed to 13 inches at the downstream end (and 17 inches just outside of the county on the west), resulting in a federal disaster declaration. Homes in the lower two rows of Valley View were flooded. Federal funds were made available through the Federal Emergency Management Agency’s (FEMA) Hazard Mitigation Grant Program (HMGP). DuPage County applied for funding, and received a grant in an amount to cover 75% of the cost to buy out all 47 homes that had been targeted for buyout and floodproofing under the Flood Control Plan. (The criteria for buyout under the HMGP is simply occurrence of overbank flooding in the home. Thus, homes that suffered such flooding, but did not meet the more stringent criteria for buyout under the Countywide Buyout Program, were now eligible for buyout rather than floodproofing.) The FEMA HMGP buyout program was initiated in June 1997. As of April 1998, 43 sales contracts have been executed. The acquired property, which covers approximately 14 acres, must remain as open space under public ownership in perpetuity. The county was able to coordinate the demolition of the vacant homes with training exercises by local fire and police departments, and a salvage auction. The county
is currently working with the Valley View Civic Association on a native plant restoration plan, and is considering transferring the property to an open-space agency for long-term management.

The Corps's economic analysis of the dam alone did not show a benefit-cost ratio of 1.0 or less, necessary for federal cost-share in dam design and construction. The Corps, however, was open to the idea of the county performing a "peak-to-volume" statistical (PVSTATS) analysis for generation of flood frequencies (DuPage County, 1994; Bradley and Potter, 1992). Preliminary results are under review as of this writing; however, it does not appear that a 1:1 benefit-cost ratio will be realized.

Lastly, one of the interior drainage projects recommended in the Plan has been constructed.

References


MAKING SECTION 211 WORK FOR YOU

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Introduction

The Water Resources Development Act of 1986 culminated 16 years of stalemate between the Executive Branch and Congress regarding the federal role in water resources projects. The argument had been over how much the non-federal project beneficiaries should have to pay toward the project costs. The 1986 Act is considered to be landmark legislation and just as significant to flood management interests as the 1935 Flood Control Act, which formally and, at least so far permanently, put the federal government in the flood damage reduction business.

Among the many provisions of the 1986 Act was Section 203, an authority for navigation interests to circumvent the standard Corps of Engineers feasibility study process, prepare their own feasibility studies, and submit them to the Secretary of the Army for recommendation to Congress. This section was in response to reforms of the 1986 Act that made the Corps and the non-federal sponsor partners and to a call by navigation interests to provide a mechanism to expedite project studies.

Section 211 of the Water Resources Development Act of 1996 extends the same authority to non-federal flood control interests and presents some great opportunities for them. Non-federal project sponsors for federal flood control projects have seen their role in federal flood control projects evolve during the past few decades from the historic role as essentially a silent partner who provided the local assurances required by the Corps of Engineers (while the Corps did everything else) through one of junior partner to one currently of equal partner financially and substantively.

Section 211 allows non-federal project sponsors to plan, design, and ultimately build flood control projects, subject to review and recommendation by the Secretary of the Army. Upon meeting the review requirements, the non-federal sponsors would be able to recover the federal share of the study cost had the project followed the traditional Corps study process.

Never before have non-federal sponsors had so much flexibility in determining the fate of their projects and their relationship with the Corps. In the Section 211 process, the relative roles of the non-federal
There are three alternative study processes available, the standard Corps process with a 50/50 cost shared study, a Section 211 study with the sponsor leading the study and providing study funds with reimbursement later for the federal share of the study funds, or a combination of the standard Corps process with additional funds advanced by the sponsor under Section 11 of the 1925 River and Harbor Act to expedite the schedule. Regardless of which option is selected, the study elements are essentially the same. They are just carried out in different organizational and management frameworks.

The Administration supports efforts to accomplish project study, design, and construction “better, faster, and cheaper.” In order to do things better, faster, and cheaper, traditional study and design elements must be examined and modified as necessary. By looking for opportunities to reduce costs and accelerate schedules without compromising safety or environmental quality, project sponsors can truly save significant time and money over the traditional Corps process.

**Formation of a Project Organization**

Each project starts with assignment of a program director, someone in the sponsor's organization at the executive level who has overall responsibility for the program under which the project will take place.

**The Technical Team**

The program director would appoint a project manager with enough authority and responsibility to conduct all, with an emphasis on all,
aspects of the study. Fragmentation of authority and responsibility among different disciplines on the project team almost always leads to unnecessary difficulties. The project team must include all disciplines necessary to complete the study and design and must include representatives of the Corps and federal and state agencies with responsibility for resources affected by the project. These agencies are not usually represented directly on Corps project teams, but their early, direct, substantive, and continuing involvement can greatly aid the process and enhance the likelihood of project approval. The technical team would be responsible for all analysis, evaluation, and preparation of the project report and the Environmental Impact Statement.

The Management Team

The program director should also establish a management team comprising the program director, the project manager, a Corps of Engineers executive level representative, the head of the vertical team (described below), and one or two other key individuals having major project technical or policy responsibility. The principal function of the management team is to address and resolve project technical, schedule, resource allocation, and other related issues definitively and expeditiously.

The Vertical Team

In one of the Section 203 studies, the sponsor created a “vertical team.” This team comprised representatives of the sponsor and of each level of the Corps organization—district, division, headquarters, and the Office of the Assistant Secretary of the Army. The vertical team had two main purposes. One was to participate in the process as it was being carried out to ensure that all problems encountered were dealt with expeditiously and resolved in a way the entire Corps could support so there would be no second guessing later. The second purpose was to ensure that the project report, when submitted, would have quick and complete agency support.

Action Items

Scope of Work

The first effort is to develop a scope of work for each element of the project—engineering, economic, environmental, cultural, legal, public affairs, and real estate. The scope of work should be concurred in formally by each organization involved—the sponsor, the Corps, and the resource agencies as well as the management and vertical teams.
There is a range of judgment to be made on how much technical analysis is actually needed to support a feasibility report compared with how much can be deferred until later in the project development process. The feasibility study should include just enough analysis to make judgments about the feasibility of the project, but not so much as to be able to design the project and produce construction plans and specifications. That level of detail should be reserved for later stages of the process after the project has been authorized. A “leaner” feasibility study has several advantages for the sponsor. First, it moves the project to a go/no go decision point faster and cheaper. Second, it would result in an overall savings for the sponsor in that cost-sharing percentages are greater for the feasibility study than for more detailed evaluations in later phases of the project.

The economic analysis has perhaps the most assumptions with the greatest effect on the benefit-to-cost ratio, net benefits, and the plan the federal government could support, i.e., the National Economic Development (NED) Plan. Assumptions must be made about what would happen over the next 50 years if the project is not built and what would happen if one of several alternative projects is built. Extremely careful analysis by experts in the field is critical to obtaining the optimum project from the sponsor’s point of view.

The environmental analysis is an area of the study more open to public involvement and review than the other portions. Experience has shown that the EIS is much more closely watched and commented on by outside interests than other aspects of the study. The study effort must ensure that the comments of the resource agencies and other environmental interests are fully understood and incorporated into the analysis and the coordination documented with written evidence of concurrence.

Scoping Meeting

The scoping meeting must be taken seriously and care taken to ensure all potential public concerns are addressed thoroughly. Depending upon the type and degree of concern raised, the study team should follow up after the meeting with the concerned parties to inform them how the team plans to address their concerns and get some feedback from them about the adequacy of the proposed response. Projects with unresolved environmental issues later in the process will be very difficult, or perhaps impossible, to have authorized and the longer the issues go unresolved, the more difficult it is to finally settle them satisfactorily.
Periodic Team-wide Progress Checks

The project manager should assemble the entire technical team at least monthly, and perhaps more often, to examine progress, address and resolve issues, look ahead for any potential pitfalls in progress, and raise any issues as necessary to the management team and the vertical team. The synergy developed in a periodic team-wide review is a very valuable tool to achieve the most efficient design, least cost, and most widely supported project.

Comparison of the Alternative Processes

Schedule

The Corps process could be expected to take at least four years, and more likely five, including one year for the reconnaissance phase and three or four years for the feasibility phase. The uncertainty on the timing of the feasibility phase is a result of uncertainty of federal funding to execute the optimum Corps schedule. That schedule is usually three years for a feasibility study, but may well slip to four in the face of budget shortages. As noted earlier, advance of funds by the sponsor under Section 11 of the 1925 River and Harbor Act could serve to accelerate the schedule of a Corps-led study.

A sponsor-led study could be completed in two years or less. The two other sponsor-led studies to date, Oakland and Savannah Harbors, are both on schedule to be completed in less than two years, with Savannah actually being done in 16 months.

Given proper cash flow provided by the sponsor, the sponsor doubtless could complete the study process as much as three years quicker than the Corps.

Financing

The Corps District will budget for funds needed to pursue the project on the schedule it establishes. Whether the Administration would include the requested funds in the President's budget is uncertain. The sponsor would have to contribute 50% of the study costs as the study proceeds. If the sponsor wishes to accelerate the Corps schedule, it can voluntarily furnish an advance of funds to the Corps under Section 11 of the River and Harbor Act. An agreement would have to be signed for the Corps to accept such funds and to credit the sponsor for the advance against the cost sharing required for construction.

For a Section 211 study, the sponsor would have to provide all the study funds. The sponsor could control the cash flow based on whatever schedule the sponsor established.
The questions here are how much control the sponsor wants and whether the sponsor is willing to risk a small potential for non-reimbursement of the federal share of the advance of funds, either under Section 11 or Section 211, to accelerate the study. A sponsor-led study could be done much more economically, perhaps with 75% of what the Corps study would cost. Assuming a 25% cost reduction, the net effect on the sponsor in a sponsor-led study would be a savings of 12.5% of study costs relative to the Corps-led option (50% of 25%).

Feasibility Cost Sharing Agreement/Section 211 Agreement
The Corps has a standard Feasibility Cost Sharing Agreement (FCSA). District offices can sign standard FCSAs without requiring approval from higher headquarters. Any deviations from the standard provisions require approval of the headquarters.

A Section 211 Agreement for a sponsor-led study would be patterned after a FCSA, but because the process is different and there is no standard pre-approved form, headquarters level approval would be required.

A Section 211 Agreement would be more difficult and time consuming to achieve, but would provide the sponsor with more control over the content as compared with the FCSA under a Corps-led study.

Study Execution
Study execution would be directed by the Corps under a Corps-led study. The sponsor would be a partner, but any influence by the sponsor on study execution would be circumscribed by standard Corps practice. The Corps would do the vast majority of the work, but some of it could be done by the sponsor or through consultants.

Under a sponsor-led study, the sponsor could be in full charge of the study and could assign the work to whomever it chose. This could include using sponsor staff, consultants, or the Corps. If this option is chosen, a major role for the Corps is strongly recommended. There are study elements that the Corps can do better than anyone else and it is important to have the Corps develop at least part ownership in the process.

While the Corps study requires a partnership, the partnership is more likely to be weighted in favor of more Corps influence. Because of Corps internal rules and their responsibility to guard federal expenditures, it is difficult to achieve an truly equal partnership. The advantage of following the Corps normal practice is that the Corps knows how to do it and roles, responsibilities, and expectations would be better understood than with a sponsor-led study. On the other hand, a
sponsor study need not involve the Corps at all. However, I believe a sponsor would be ill advised not to include the Corps as a full partner. The key factor in this comparison is the degree of control over schedules, scopes, and costs either partner would have. This degree of control is negotiable in either process, but will never be equal. The Corps would be "more equal" in the Corps process and the sponsor would have more control over a sponsor-led process.

Organizational Options
The organizational structure would look similar for either option except for a management team and the vertical team, which would be used for the sponsor study option. Having said that, even in a Corps study, the functions of a management team and a vertical team should be incorporated, even though there may not be specific organizational elements identified.

Bottom Line
Section 211 provides an outstanding opportunity for project sponsors to accelerate their projects and not lose the federal support necessary for construction funding. They may have to defer complete reimbursement, waiting for the federal appropriations process, but risk assessments can inform sponsors of whether their respective communities should pursue Section 211 projects.
Introduction

Major flooding has been reported in Lafayette Parish, Louisiana, due to storm events and high river stages along the Vermilion River since 1907, and as recently as 1997. Approximately 300 homes experienced water damage as a result of a severe storm in January 1993. Local interests have made structural improvements to the flood control system, but damage continues to occur. In addition to these efforts, Lafayette Parish is in the initial stages of instituting regulations that would require developers to mitigate for additional runoff as a result of residential, commercial, and industrial improvements. As a result of recurring floods and a limited availability of local funds, Lafayette officials requested the federal government to investigate the feasibility of reducing flood damage in Lafayette Parish.

The U.S. Army Corps of Engineers, New Orleans District, initiated a general investigations study in April 1994. As a result of this effort, a reconnaissance report was completed in June 1996 recommending the investigation of several structural and nonstructural flood reduction measures through a detailed analysis called a feasibility study. Structural measures (large pump facilities, levees, retention facilities, etc.) currently under investigation are anticipated to provide flood damage relief to many of the neighborhoods in Lafayette Parish. However, several flood-prone neighborhoods are anticipated to receive minimal flood reduction benefits through the implementation of structural measures. Nonstructural efforts will seek to reduce flood damage in these "high damage" areas. During the initial stages of the feasibility study, Lafayette Parish officials were successful at requesting the federal government to expedite the nonstructural analysis portion of the feasibility study. The current schedule for nonstructural study completion is February 1999 with construction slated for the early part of 2000.
Nonstructural Measures

For the purposes of this discussion, nonstructural flood reduction measures can be described as small-scale structural projects that are typically implemented in areas prone to recurring flood damage. Measures considered for the Lafayette Parish nonstructural effort included small floodwalls with interior flood control improvements, structure raising, and dry floodproofing measures (impermeable improvements around the home perimeter). Although floodproofing measures were considered, these types of improvements can be considered unique and are not the standard types of projects implemented under nonstructural measures.

Study Area

Four areas were identified during the reconnaissance study as being the "worst of the worst" with respect to flood damage as a result of high stages on the Vermilion River and its tributaries. These areas were investigated under the nonstructural analysis and are referred to as areas 1, 2, 3, and 4. Each area has residential land use with limited commercial development in area 4. An estimated 43, 12, 23, and 300 "slab on grade" homes are located within the 100-year floodplain for areas 1, 2, 3, and 4, respectively. Areas 1, 2, and 3 are located along the scenic Vermilion River, which serves as the major drainage artery of Lafayette Parish and has carried a maximum flow rate of 6300 cubic feet per second near each of these areas. Many of the residents reside in these areas have an average value of approximately $105,000. Area 4 is located off the Vermilion River and is separated by a drainage channel that is prone to headwater flooding due to a large upstream watershed. The homes in area 4 have an average value of approximately $86,000 and are not offered scenic views from the drainage channel. As a result of the January 1993 event, approximately a 50- to 75-year frequency, residents reported inundation depths on the order of 2 to 3 feet in each of the four areas and as much as 5 feet in one home located in area 1.

Planning Process

The Corps of Engineers initiated the nonstructural effort by conducting a public discussion with residents from each of the four areas. Overall, residents were receptive to the concepts of small floodwalls and structure raising. The primary concerns voiced at the discussion included costs, scheduling, how the measures would impact a given homeowner,
and what the measures would look like. As a result of the meeting the Corps of Engineers proceeded with the standard planning and engineering process to determine if such projects merit federal participation. If deemed feasible, the federal government would contribute a maximum of 65% and a minimum of 50% total project cost. In addition to the standard planning practices, the Corps utilized computer visualization to address the concerns voiced by the residents concerning impacts and aesthetics.

**Design Process**

With respect to small floodwalls, several types were considered, including 1) concrete wall, 2) earthen levee, 3) earthen levee with a concrete wall, and 4) invisible floodwall. Based upon existing ground elevations, the proposed floodwall would have a maximum height of 6 feet and an average height of approximately 3.5 feet. Earthen structures would be constructed to have typical crown dimensions and side slopes of 1 vertical on 4 horizontal. The largest proposed earthen footprint would be approximately 60 feet. With respect to structure raising, homes were considered to be raised to set the structure slightly above the 100-year flood elevation, as well as elevating on the order of 8 to 10 feet above the 100-year flood elevation. This would provide a usable, yet uninhabitable, area under the original structure.

Although four floodwall types were considered, alignments would be the same for either type of protection. In areas 1, 2, and 3, the proposed alignments would extend along the riverbank for approximately 2700, 2900, and 2700 feet, respectively, behind existing homes and vacant land and would tie back into high ground. A total of 45 homes would be directly impacted as a result of constructing a floodwall in areas 1, 2, and 3. In certain reaches of the alignment, sufficient right-of-way is available and an earthen section would be proposed. In areas of limited right-of-way either a concrete floodwall or a reduced earthen section with concrete wall would be proposed. The invisible floodwall approach calls for installing a permanent foundation and erecting an aluminum wall before a storm. Although this approach is advantageous with respect to maintaining scenic views, it requires human intervention and will probably require special consideration from other parties if selected as a preferred flood reduction plan. Area 4 is not located along the scenic Vermilion River and does not have the constraint of maintaining desired views. Undeveloped lands adjacent to area 4 provide sufficient right-of-way for an earthen levee to extend approximately 20,000 feet around the perimeter of the community. In addition to this protection, interior protection is required as a result of interior flooding caused by
an interior drainage channel extending through the center of the neighborhood. A floodwall would be required along the banks of this channel to confine the damaging flows. Due to limited right-of-way, a concrete structure would be required. In addition, forced drainage improvements would be required on the interior of all four areas to remove confined water as a result of the floodwall and ring levee systems. An economic analysis was completed to generate benefit-to-cost ratios for floodwalls in each of the four areas. This analysis indicated that floodwalls are feasible in areas 1, 2, and 4. Implementation costs ranged from an estimated $250 per lineal foot for earthen levees to $500 per lineal foot for concrete walls. This cost included lands and interior drainage improvements. The results from this analysis were illustrated through the use of computer visualization and are shown on Figure 1.

Structure raising was also considered for each of the four areas. For the given neighborhoods, this technique would involve elevating existing concrete slab homes to or above the 100-year flood elevation. In most cases this would require elevating each home an average of 2 to 2.5 feet. According to structure raising contractors, the cost for raising a home 2 feet versus 2.5 feet or even 8 feet is comparable. The majority of the cost is in the preparation efforts and not the actual elevating process. For this analysis, the costs for elevating structures were not a function of distance to be raised but were based upon an estimated cost of $45 to $50 per square foot. Total construction costs were developed and compared to the estimated benefits. With the exception of a sub-area of area 2 that contained two homes, structure raising was not deemed economically feasible in any of the four areas. The results from this analysis were illustrated through the use of computer visualization and are shown on Figure 2.

Dry floodproofing was also considered for each of the four areas. For the given communities, this technique would involve wrapping each home with an impermeable membrane, thereby eliminating seepage through the structure. In addition to wrapping, closures or flood shields would be required at each of the structures’ openings. This technique provides a valid method of flood protection up to approximately 3 feet of inundation. For this analysis, costs were estimated at $15 per square foot based upon the total square footage of each structure. These estimates are based upon dry floodproofing projects completed in neighboring parishes. An economic analysis indicated that dry floodproofing would be feasible in areas 1 and 4.
Figure 1. Computer visualization showing floodwall implementation, existing and proposed conditions.
Figure 2. Computer visualization for home raising, existing and proposed conditions.
Conclusions

The above planning and design process yielded three economically feasible nonstructural strategies to reduce flood damage in Lafayette Parish, Louisiana, including small floodwalls, structure raising, and dry floodproofing. Although three plans were deemed economically feasible, a preferred plan needs to be developed based upon maximizing net benefits. For the given areas, it appears that small floodwalls and isolated structure-raising for homes subject to depths greater than 3 feet would provide the greatest net benefits. Based upon the public discussions, it was apparent that concerns existed over the appearance and impacts of both floodwalls and structure raising as well as potential costs imposed on residents. Through the use of computer visualization, each of the alternative plans was illustrated so that homeowners could easily envision future aesthetics and appreciate potential impacts. This technique was well received and is expected to be used for future public discussions. With respect to costs, the federal government would potentially fund up to 65% of any of the proposed projects. The remaining funds would be the responsibility of the non-federal sponsor. Lafayette Parish indicated that they would be in a position to fund small floodwalls rather than structure raising, indicating that individual homeowners may be responsible for some costs where structure raising is concerned.
Part 3
Applying GPS, GIS, and Other Technology
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Introduction

The implementation of geographic information system (GIS) technology within a municipal government is a timely and costly endeavor. Many decisions will be made with respect to acquiring the appropriate hardware and software and system configuration. More importantly, however, are the numerous decisions regarding the value and role of the GIS and how it will impact the municipality. Positive impacts can be realized by many departments ranging from engineering to planning to emergency operations to floodplain management. However, GIS implementation introduces operational changes. Will these departments require additional staff or will current staff be provided training? Is the GIS to serve as a means of integrating operations and information flow or is it intended to foster independence among units? Are managers interested in the technology or do they simply want to streamline operations and increase efficiency? Is the expenditure worth the return? Understanding and appreciating the implications of each of these questions and many more are critical to the successful implementation of GIS, or for that matter any other information management technology.

East Baton Rouge Parish, Louisiana, recognized the need for appropriate planning and decisionmaking before undertaking the GIS implementation process and requested planning assistance from the U.S. Army Corps of Engineers, New Orleans District. Departmental GIS requirements were considered for the following 12 departments: Department of Public Works, Planning, Police, Fire and HAZMAT, 911/Emergency Medical Services, Office of Emergency Preparedness, School Board, Recreation, Landscape and Forestry, Downtown Development District, Community Development, and Information Services.
Why GIS?

A GIS is a collection of hardware and software tools used to collect and analyze spatial data in a problem-solving environment. Numerous departments can benefit by accomplishing tasks and activities such as locating addresses, determining ground elevations, defining areas of inundation, locating ideal areas for flood damage reduction facilities, and numerous other tasks through GIS technology. The “power” of the GIS is the information stored in the database linked to the graphical data displayed, queried, and analyzed through various GIS tools. Complementing graphic data (street and flood maps, etc.) with spatial data (fire hydrant specifications, base flood elevations, and culvert dimensions, etc.) provides an extremely powerful and useful tool to the various departmental users. GIS is extremely useful to governmental departments such as public works, 911/emergency, planning, emergency preparedness, fire, and virtually all functions of local government. Numerous Louisiana parishes are in the process of implementing GIS and/or advancing their current systems.

Potential Benefits

The benefits of GIS can be broken into three categories: time, money, and data quality and intangible benefits. Time-related benefits of GIS are simply being able to accomplish current tasks in a timely and efficient manner. Data becomes easier to analyze and may allow for certain analyses that without GIS may be time- and cost-prohibitive to complete. Consolidation of data in GIS technology increases user access to information and processing capabilities. Money-related benefits can be realized by reducing existing and future costs. Productivity improvements are the yield of additional time for additional tasks. Data quality benefits are realized by collecting, storing, and managing highly accurate data with GIS technology. Specific benefits may include access to common base maps shared by all departments and maintained to include updates as well as ease of plotting and generating highly accurate graphics. Specific to floodplain management, parishes may be able to reduce insurance premiums to more efficient management of the floodplain. In addition, GIS technology is expected to improve communication through a networked system that will streamline work flow and assist management in obtaining required information. Many federal, state, and local government agencies are collecting spatial data suitable for GIS technology, and the trend for data collection is anticipated to continue and increase. GIS technology not only allows for accessing the numerous shared resources, but will be essential in the future to obtain and use valuable data sets.
Implementation Planning

Four phases were completed as a result of East Baton Rouge Parish requesting planning assistance from the New Orleans District. Phase one, Needs Analysis, reviewed the organizational and operational requirements of the various parish departments (management and staff personnel) active in the use and management of geo-spatial data, and identified specific GIS functions. Phase two, Conceptual Database Design, developed a logical framework for storing and managing data based upon the departmental needs uncovered during the Needs Analysis. Phase three, Feasibility Analysis, provided the parish with a set of implementation alternatives with associated costs and duration required to implement a parish-wide GIS. Phase four, Logical Database Design, modeled the data requirements described in the Conceptual Database Design phase and yielded a parish-wide database ready for data population.

Through the implementation process, East Baton Rouge Parish personnel identified various data layers or data sets as being used on a regular basis and by numerous departments and should be incorporated into the parish-wide GIS. In addition to the regularly used data sets, parish personnel also identified “unique” or “departmental specific” data sets that should also be incorporated in the GIS. The “unique” data sets included information such as shelter locations, tree inventory, parks and recreation, etc. In order to include these data sets into the parish-wide GIS a recommendation was given to develop a “foundational” GIS into which specific data needs could be incorporated in the future. However, the foundational GIS would include all data sets identified as being used regularly.

Foundational GIS

The foundational GIS would be beneficial to the majority of parish departments and consist of the following data sets:

- **Aerial Photography**—Horizontally controlled, true color photography was developed to produce 1 inch = 100 foot maps, Corps of Engineers Class 2 standards. This data was provided on CD-ROM. This data shall serve as the common raster base map used by all departments to produce line (vector) work.

- **Hydrography and Flood Insurance Rate Maps (FIRMs)**—One of the essential data sets, all rivers, streams, and water bodies shall be compiled from the above aerial photography. Once this is completed, essential data sets like channel maintenance databases, cross sections, etc., can be linked to the hydrography data set. In addition, base flood
elevations and other pertinent Federal Emergency Management Agency data would be linked to the FIRMs. This data set is anticipated to assist parish floodplain managers.

**Digital Terrain Model**—Another data set essential for floodplain management and flood control, this will consist of two-foot contours. The contours would be compiled so that area versus inundation analyses can be done easily.

**Street Centerlines**—This data set will be developed to include address ranges and will be used to identify buildings and structures by address by all necessary departments such as emergency operators.

**Transportation**—Another essential data set, all roads, streets, highways, and railroads would be compiled from aerial photography. Essential data sets such as routing, street closures, pavement maintenance, and signage can be linked to the transportation data set.

**Storm and Sanitary Sewer**—An essential data set, sewer characteristics such as dimensions, type of material, age, invert elevations, capacity, and pump locations, can be linked to the sewer maps. This data set is anticipated to be used by engineers, planners, developers, and floodplain managers.

Additional required data sets included in the foundational GIS include lot and parcel boundaries, zoning, land use, building footprints, and land cover.

**Implementation Schemes**

Three alternatives were investigated to develop the foundational GIS: minimal outside resources, mix of in-house and outside resources, and minimal in-house resources. Minimizing outside sources would allow for parish staff to build and maintain the entire GIS from project initiation. Additional staff would be required to complete this task. Based upon a four-year implementation scheme, 18 additional staff positions would be required. An advantage to this process is that in-house staff would develop capabilities as resources permit and that staff members would become knowledgeable on their own GIS. A disadvantage to this approach is the long-term cost of the additional staff. The cost for building the foundational GIS under this approach is estimated at $3.7 million. Using a mix of in-house and outside resources, East Baton Rouge Parish would be able to develop the foundational GIS for an estimated $3.5 million over 4 years. An additional 9 in-house staff members would be required to complete this approach. An advantage to the second approach is that the implementation schedule is more structured with respect to fewer hardware/software conflicts. Additionally, in-house staff would benefit from working closely with GIS
consultants. A disadvantage to this approach is that in-house staff will not be as close to the development process as in the first option. Minimizing in-house resources to implement the foundational GIS would be completed at an estimated cost of $4.8 million over 4 years. Efforts of in-house resources would be limited to providing hardcopy and digital data to consultants. This effort would require five additional in-house staff. An advantage to this process is that it requires the least amount of new parish staff as well as the least requirement of hardware and software. However, this implementation scheme is the most costly of the three investigated.

Foundational GIS and Floodplain Management

Multiple uses of the GIS would be realized with respect to floodplain management and flood reduction planning. Key data sets for floodplain management include aerial photography, FIRMs, hydrography, two-foot contours, land use and zoning, storm sewer, sanitary sewer, land cover, and addressing. These GIS data sets would be beneficial to floodplain management by providing accurate data and the capability of spatial analyses through standard GIS tools.

Typical Uses

FIRMs would be digitized and incorporated as a separate data layer into the parish-wide GIS. Typically, the floodplain manager requires a descriptive location rather than a street address to identify a specific property. With GIS technology and an address data layer, the location in question can be identified by street address in lieu of perhaps section, township, and range data. In addition, once the GIS user locates the property in question, the user can query for available data such as base flood elevations, nearest base flood elevations, flood zone, and other pertinent data.

Contour data is essential to wise use and planning in the floodplain. GIS technology can be used to generate water surface elevation versus area curves, which would be ideal for determining flood hazard areas. In addition queries can be developed to identify homes (address database) flooded by a given stage. This type of data is ideal for 911 and emergency operators to disseminate storm warnings during times of flooding or other natural disasters. Additionally, hydrologic models and forecast models could be developed to run in conjunction with GIS technology providing floodplain managers, emergency operators, and other key personnel information relevant to flood damage mitigation measures and/or necessary actions to take during a flood.
Aerial photography, land use, and land cover are ideal data layers for floodplain management. Through the use of these data sets, a floodplain manager can retrieve data pertinent to the overall floodplain management plan. Data on environmentally sensitive areas; hazardous areas; and commercial, industrial, and residential areas are also necessary data sets to determine wise use of the floodplain.

The above examples are some typical uses that floodplain managers and other personnel may benefit from through the implementation of GIS technology and the various data sets. These are only a few uses and it is inevitable that future uses will be developed as warranted.

Conclusions

GIS technology is a very powerful tool for data collection, storage, managing, analyzing, and presenting spatial data products. It is inevitable that as more and more federal, state, and local agencies continue to develop data sets using this technology, more and more "new players" must begin to implement their own GIS capabilities to share available data sets. Municipalities would recognize substantial benefits of shared data and realize time and cost benefits from implementing GIS technology. There are numerous benefits to a GIS, typically time, cost, and production benefits. However, until a GIS is implemented for a given community, municipality, or agency, actual benefits will vary and probably not be realized until the GIS becomes an integral part of daily routines. The issue of incorporating a GIS into departmental functions is anticipated to be controversial and not well received by all, but must be overcome during the initial phases of implementation. Municipalities have been known to eliminate old technologies, forcing staff to complete tasks through modern GIS technology. This approach seems crude but the results are indisputable and resulting benefits overwhelming.
CASE STUDIES OF THE USE OF GIS FOR PREPARING DIGITAL FLOOD CONTROL MASTER PLANS IN CLARK COUNTY, NEVADA

Gale Fraser
Clark County Regional Flood Control District

Virginia Valentine
PBS&J Inc.

Introduction
Flood control master plans have traditionally been prepared in hard copy format. The first countywide flood control master plan for Clark County was developed in 1986. That document consisted of five volumes of text and a technical appendix of two bound volumes of computer printouts including the input and output files for the hydrologic modeling. Since then the amount of data available electronically to develop flood control master plans has increased dramatically. The ability of geographic information systems (GIS) to manage, transmit, and manipulate data has proven GIS to be both a more efficient and more comprehensive format than traditional methods for flood control master planning. This case study compares five GIS flood control master plans in Clark County, Nevada, and describes the advantages and disadvantages of GIS planning documents.

Background
In 1988 Clark County created a GIS implementation plan to support the operations and decision-making process and the Geographic Information System Management Office (GISMO) was formed. The GISMO coordinates the acquisition, use, exchange, and dissemination of geographic information between County departments and local entities. Twelve local entities, including Clark County Regional Flood Control District (CCRFCD), have signed an interlocal agreement for this service and pay a yearly fee for GISMO’s administration and consulting services. The participating local entities entered into the agreement for GIS data and cost sharing. The GISMO is the coordinating body for maintaining and disseminating the common database, a central
repository, of countywide GIS data by all participants. The data is shared via magnetic media or on-line if communication links exist. The efforts of Gismo and the other participating entities to actively support and produce GIS data greatly aided in the development and preparation of the flood control master plans. Without GIS data easily accessible, the efforts to produce digital plans may not have been feasible.

The CCRFCD is a relatively new agency. It was created by changes to state legislation in 1985. The first flood control master plan for all of the CCRFCD's service area, Clark County, was completed in 1986. The master plans are updated on a five-year cycle in accordance with state law. The subsequent master plan updates were as voluminous as the first and were also paper copies. Recognizing the trend towards GIS and digital data, the availability of local data in digital format, and advances in technology so that a user of the information could access the information from a desk top application, the CCRFCD elected to pursue the 1996 Las Vegas Valley Master Plan Update in digital format.

Las Vegas Valley Master Plan Update

The washes that traverse the Las Vegas Valley drain approximately 2,000 square miles. It is this same valley that is one of the fastest-growing areas in the nation. The communities studied include the cities of Las Vegas, North Las Vegas, Henderson, and unincorporated Clark County with the Las Vegas valley. The flooding in the valley is similar to that found in other areas of the arid Southwest. Mountain ranges with steep slopes, alluvial fans, desert pavement soils, undefined flow paths, debris, and sediment all contribute to the flooding potential. The information collected to form the foundation for the digital plan consisted of geology, topography, soil types, land use (existing and future), environmental constraints, major infrastructure (existing and proposed), existing drainage facilities, and hydrologic criteria. While considerable digital data existed, it is important to note that the level of effort required to collect the inventories of existing drainage facilities from the impacted communities was quite extensive. However, once the data collection and the various GIS layers were completed, the ability to perform the studies and examine alternatives was greatly enhanced.

The CCRFCD views this document and others as establishing a firm foundation for future studies. Now, for the first time, digital data is shared by all so that everybody understands what the master plan examined and utilized in formulating recommendations. Further, usual research to perform future master plan updates will be minimal. It is important to understand that the flood control master plan assumes certain future conditions such as rim-to-rim development within the Las
Vegas valley. It is prudent planning to assume an ultimate development boundary when sizing and identifying flood control facilities in a master plan. Those assumed hydrologic conditions are a very important GIS layer that needs to be continually updated to account for changing hydrologic conditions and to respond quickly with plan modifications or necessary development mitigation.

**Boulder City Master Plan Update**

Boulder City lies in southern Clark County, along U.S. 93 between Las Vegas and Hoover Dam. The city is approximately 20 miles southeast of Las Vegas and four miles southwest of Lake Mead. The terrain of the study area is steep, with slopes ranging from 3% in the alluvial valleys to nearly vertical in the mountainous areas. Elevations within the study area range from 3,600 feet in the mountains to the north of the city to 1,900 feet in the alluvial valleys to the south and northeast of the city.

The purpose of the MPU for Boulder City was to provide an update to the existing and proposed flood control facilities from those listed in the previous Boulder City Flood Control Master Plan. Since the previous master plan was completed, new drainage facilities have been constructed, the proposed locations of some of the facilities have changed and new residential, commercial, and industrial developments have been completed. Also, for this analysis, the land use plan and the hydrologic model have been revised and updated. This report provided documentation of current conditions within the city and a revised and updated flood control master plan, which can be used as a planning tool as development continues.

The scope of work included collecting all relevant information, such as soils, land use, topography, rainfall, flood hazard mapping, digital air photos, drainage studies and an inventory of all existing flood control facilities greater than 36 inches in diameter, aerial photography and a facility inventory; developing a hydrologic base model; creating an Arc Info Data Base, including layers for rainfall, land use, soils, subbasins, aerial photographs, topography, existing and proposed flood control facilities and the digital Flood Insurance Rate Maps (FIRMs); and performing an alternative analysis for the recommended facilities including the approximate size, depth, storage, configuration, and conceptual cost for each alternative. Both hard copies and digital copies of the final document were prepared and included a graphical inventory of existing and proposed facilities and attributes, a soils data map, a watershed delineation map, cost estimates for proposed alternatives, a description of the recommended plan, and a prioritizing and phasing plan for improvements.
City of Las Vegas Flood Control Facilities Inventory and Citywide Hydrology Analysis

The purpose of the City of Las Vegas Flood Control Facilities Inventory and Citywide Hydrology Analysis was to develop baseline information for future use in neighborhood drainage planning and predesign of local storm drain facilities to provide the city with a complete and comprehensive storm drainage analysis. The study area and watershed consists of approximately 244 square miles in the Las Vegas valley.

The work included digitized orthophotos at five-foot (5') contours; compiling master plans, drainage studies, development plans, land use plans, public improvement plans, and major public utility plans for existing and proposed developments located within and around the study area; updating the hydrologic analysis for existing and future conditions for the 10- and 100-year design flows; providing flows in a 1,320-foot street grid; establishing proposed street profiles; providing a utility inventory; determining street capacities; providing a linked hydrologic model; and preparing a final document displaying all discharges, quantities, and floodplain mapping.

City of Las Vegas Northwest Neighborhood Study

The purpose of the City of Las Vegas Northwest Neighborhood Flood Control Master Plan was to provide a comprehensive hydrologic analysis and storm drain facility plan for the approximately 30-square-mile study area. The project was completed concurrently with the 1997 City of Las Vegas Flood Control Facilities Inventory and City-Wide Hydrology Analysis. Though this neighborhood analysis is more detailed (and considers local proposed storm drains and some revisions to regional proposed flood control facilities) it fully conforms with the City-Wide Hydrology Analysis. This project included re-modeling virtually the entire study area with the HEC-1 parameters calculated with automated GIS methodology.

The scope included work to the Citywide Hydrology Study in addition to developing a program to update lag time attribute tables as changes in basin parameters are developed and preparing a program to determine the composite precipitation value for the subbasin, soils coefficient, density and corresponding runoff coefficient, including macro programs to create a HEC-1 input file from linked GIS layers. The final document was provided in hard copy and CD-ROM formats.
Clark County Southwest Area Development Guidelines

The Development Guidelines were produced under the direction of Clark County Public Works (CCPW). This document is a tool to help ensure coordination, compatibility, and flood mitigation for development in a 26-square-mile developing area of Clark County. These guidelines are intended to be used on a planning level by property owners, developers, and consultants to qualify approximate storm runoff rates impacting specific parcels and to identify requirements for development of those parcels that are consistent and compatible with other existing or proposed improvements in the area.

The work involved in preparing the guidelines included aerial photographic mapping to establish existing condition topography, research to identify existing roadway and drainage features and conflicts, research of previous drainage studies, research of major utilities and planned roadway projects, establishment of proposed street cross sections and slopes, existing and proposed hydrologic and hydraulic analyses, designation of major drainage corridors, and preparation of a storm water management plan and related policies and procedures.

The document includes current topography, an inventory of existing drainage facilities, right-of-way information, 10-year and 100-year existing and future flow rates, street capacities, recommended street grades, proposed drainage facilities, and recommended street sections. The data is also provided in a GIS; each digital layer used in the study may be accessed, utilized and updated. The GIS data is included on a CD-ROM with the Technical Appendix. Digital layers include information pertaining to land use, soil type, hydrologic subbasins, and existing and proposed drainage facilities.

Advantages and Disadvantages

One of the greatest advantages of digital/GIS documents over traditional hard copies is the capacity of digital documents to manage and manipulate large volumes of data. The ability to compress files allows the inclusion of data that otherwise may have been omitted due to space limitations. For example, it was possible to include all the source material for the cost estimates in the Las Vegas valley MPU. The hard copy technical appendices for this document consisted of five 4-inch binders. The cost of the CD-ROM version for the 1996 MPU is approximately 25% of the hard copy version.

There are several advantages of CD-ROM for data manipulation. Because the digital files are stored, it is easier to search for specific information on the CD-ROM version of the plan. Data can be electronically transferred via the Internet. Files may be copied directly
for use by others. Other data, such as major waterlines, beltways, local storm drains, land ownership, and environmental constraints can be overlain on existing and proposed flood control facilities. This capability improves the efficiency and comprehensiveness of alternative analysis.

One other advantage of digital document is the ability to include macro programs, videos, sound, and enhanced graphics. Most of the flood control master plans discussed herein include macros for linking hydrologic data to a hydrologic model. Future updates and amendments will be stored on the CCRFCD's web page. Updates and amendments could then be downloaded by those requiring the information. This should result in a savings of staff time for assimilating the information requested by consultants and other agencies.

Data collection consumes a significant share of the budget for planning projects. The ability to start a planning update with an electronic document should reduce the amount of time and budget spent on data collection. Because they have a digital document, the CCRFCD has the ability to directly utilize data from other sources such as land use, rights-of-way and utilities atlases, which is available electronically.

One of the disadvantages of preparing a digital GIS document is the cost of creating the database. Depending on the state of the existing database and availability of GIS data from other sources, data conversion can be the single most costly task in preparing the updates.

A limitation of the GIS document is the technical level of the end user. To fully utilize the document, the user should have the appropriate hardware and software and should be proficient in the use of ARC INFO or ARC VIEW. Data exchange files to allow AutoCadd users access to the GIS files has been provided on the CCRFCD master plans to make the data accessible to provide a broader base of users.

Although not specifically a disadvantage, a consideration in making the decision to convert to a digital document is the commitment required to maintaining the document and updating the database. Database maintenance then must be an annual budget item.

Summary and Conclusions

In conclusion, the cost of investing in the GIS database for flood control planning is offset by the improved efficiency and utility of the digital document. It is likely that costs will only increase as the amount of information available increases. The ability to share data from other sources to make the data available and to easily manipulate data, results in greater utilization of the master plans. The use of GIS documents should ultimately result in improved planning and coordination for all infrastructure improvements.
USE OF AUTOMATED TECHNOLOGIES IN WATERSHED MANAGEMENT PLANNING

Daniel Cook
Lake County Stormwater Management Commission

Introduction

Lake County, Illinois, is located in the most northeastern portion of the state and is one of the fastest growing counties in the country. The county has 61,000 acres of wetlands and 400 miles of streams and rivers throughout its 480 square miles. The combination of growth and the need to protect our natural resources is driving the Lake County Stormwater Management Commission’s (SMC) comprehensive watershed planning efforts. Plans are currently being developed for urbanizing watersheds between 2 and 23 square miles. These watershed plans involve data collection and collation, problem analysis, alternative solutions identification, and development of an action plan. As part of a watershed management plan, one of our end results is to update floodplain maps and to map depressional storage areas. Other end products of this effort include maps of the location of all the water resources, including wetlands and regional detention sites, and to identify them as needing preservation, enhancement, or restoration. We can then prioritize these areas and determine cost estimates for assisting local governments in implementing an action plan.

With limited personnel and funding, SMC is utilizing in-house computer capabilities and staff technical expertise to save time and money as we increase our flexibility to model and display watersheds. The Squaw Creek Watershed Management Plan will be used as an example of how SMC is currently utilizing automated technology options for watershed planning purposes. SMC is integrating geographic information system (GIS) technology with computer aided design (CAD) and the Army Corps of Engineer’s HEC-1 and HEC-RAS models through a variety of vendor software packages that include ESRI’s ArcView and its Spatial Analyst and Hydrologic Extensions, and Bentley's Microstation software.
Data Collection

It is very important to determine the methods for calculating data early in the automation process. The technique for calculating time of concentration, runoff, stream storage, stream routing, sub-basin boundaries, mapping exhibits, and water surface elevations had to be determined before final data was formatted and collated.

Data availability is a very important part of mapping. Available digital mapped data included land use, hydrologic soil descriptions, and U.S. Geological Survey orthophotos. The Northern Illinois Planning Commission (NIPC) provided the land use map and Lake County Mapping Services provided the map of the Soil Conservation Service (SCS) hydrologic soil groups (HSGs). SMC contracted to collect 2-foot topographic contours, detailed orthophotos, stream cross-sections, and hydraulically significant structures. Stream bridge and culvert information and cross-sections were also delivered digitally from Illinois Department of Natural Resource’s land survey crew using global positioning system (GPS) and conventional surveying. The USGS digital orthophotos were also obtained. Each map covers one quarter of a quadrangle and is 45 MB. The topographic maps were delivered in AutoCad and Microstation format.

Additional hydraulically significant structures, such as road crossings and detention basin outlets, were collected from the county and state highway departments and communities. The townships and communities did not always have detailed mapped information so field investigations were made where necessary using topographic mapping to establish a reference elevation. Photogrammetry and cross-section control points were collected in the field utilizing a GPS with accuracy of 1:50,000 horizontal and +/- 0.03 feet vertical.

Contracted data was delivered by square mile. This created a reasonable size file to transmit data. The cost for the two-foot contours overlaid on an orthophoto varied between $2200 and $3300 per square mile and included:

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<th>Cost Range</th>
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<td>Two-foot topographic contours</td>
<td>1.2 to 3 MB per square mile</td>
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<td>and breaklines</td>
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<td>Orthophotos</td>
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<tr>
<td>Digital Elevation Model</td>
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Creating Hydrologic and Hydraulic Data

Runoff Curve Number

SMC created a method to convert SMC-defined land use categories to SCS runoff curve number (RCN) using ArcView and Excel. RCNs were calculated using the following sequence. First using ArcView, we converted the NIPC land use polygons to SMC land use categories based on land cover using orthophotos as a backdrop. Land cover is impervious, graded and natural grass, graded and natural forest, and agriculture. A SMC land use was created for each calibration year, for the model year of 2000, and for the projected year of 2020. Second, concurrently with the land use conversion, the digitally mapped soil numbers were converted to HSGs using GIS queries. Third, the HSG map was intersected with the SMC land use categories to automatically create a land cover map. Fourth, we joined the land use categories table and a land cover conversion table and in a few seconds we had one RCN for each of the four HSGs.

Sub-basin Delineations

The sub-basin boundary was also completed automatically. A Digital Elevation Model (DEM) was produced from photogrammetry. A DEM is a list of equally spaced data points with a defined easting, northing, and elevation. Spacings of 10 and 30 feet for the DEM points were evaluated. The 10-foot spacing used 10 times the disk storage as the 30-foot spacing. The DEM was loaded into ArcView and converted to a DEM grid using ArcView's Spatial Analyst. Second, in four steps, the flow paths and the preliminary sub-basin boundaries were created using ArcView's Spatial Analyst and Hydrologic Extension along with the DEM grid. Each step took less than 25 minutes. One hundred and eighty preliminary sub-basin boundaries were delineated in 2.5 hours. Third, these boundaries were edited with the digital contour map in the background to better model storage areas and road crossings. This editing entailed splitting basin boundaries and joining basins together mainly to produce more accurate boundary lines. This editing was performed on approximately 50% of the preliminary sub-basins that were automatically created. These edited boundaries were checked against hard copy maps and field investigation of storm sewer and tiles. Incorrect boundaries were found at three locations. ArcView automatically calculates the sub-basin area.
Runoff Data

The HEC-1 data needed to generate runoff for a sub-basin include identification, area, the time of concentration (Tc), Clarks coefficient of runoff (R), and weighted RCN. Area determination was previously described. The weighted RCN is created by intersecting the finalized 140 sub-basin boundaries with the RCN polygons to split the RCN polygons at the sub-basin boundary in just 20 minutes. This table of RCN attributes for each sub-basin is exported from ArcView into Excel where the weighted curve number for each sub-basin was calculated.

In addition, each sub-basin needs a length and slope of travel to generate the time of concentration and Clarks coefficient of runoff. To determine the length and slope, we needed a line and two points, one upstream and one downstream. The line is the direction of runoff from the farthest ridge to the outlet of the sub-basin. We had a consultant, GeoAnalytics, Inc., create a program to automatically generate a 10% and an 85% point in 30 seconds along a digitized line. The point locations along the line are determined by our method used to estimate Tc and R. These points were queried individually with the DEM grid to determine their elevation, which was entered into a table. ArcView calculates all line lengths in less than a minute. The stream line and two elevation points were associated with a sub-basin identification. Next, the sub-basin boundaries and the associated line and two points were joined into one table and exported as a database file. This database file is imported to an Excel spreadsheet where the Tc and R were calculated for each sub-basin.

Reservoirs

For reservoir routing, the reservoir volumes were determined using ArcView and the 2-foot digital contours. First, the smaller reservoirs had one polygon for each contour so the area could be determined by measuring the area of the contour polygon with one click of the mouse and entry into a database table. The larger reservoirs were a series of polygons on the contour map so a single polygon was created by digitizing over the contours. Second, the elevation of the contours is entered into a table. Third, after all the elevation polygons are created, ArcView calculates the area of the polygons with one command. The elevation and area were tabulated and entered into an Excel workbook to calculate the elevation versus storage as the fourth step. This documented the location of every reservoir that was modeled, as not all reservoirs could be modeled within the scope of our project, and allowed us to complete the reservoir modeling expeditiously.
reservoir discharge was calculated on the same spreadsheet as the storage.

**Hydrology Model Development**

All of this data was combined into one Excel workbook to generate the input needed for an HEC-1 file. The sub-basin data entry that was needed included identification, area, weighted RCN, Tc, and R. Most sub-basins also need reservoir or stream routing data. The sub-basin identification was assigned to each sub-basin area for fast reference. A spreadsheet was formatted with HEC-1 formatted column widths so the data could be saved into a correctly formatted ASCII file that HEC-1 FORTRAN program would read. The sub-basin data entry was automatically input by referencing other spreadsheets in the same workbook. Once the first sub-basin referenced the other spreadsheets properly for use as HEC-1 input data sets, this formatted sub-basin data could be copied to create another set of HEC-1 data for the next sub-basin. Once the sub-basin identification is entered for this new HEC-1 input data set, the remaining data is automatically retrieved in the workbook and entered. There were no data translation errors.

**Hydraulic Data**

The stream cross-section data was generated in Microstation. Each section was digitized as a series of connected line segments that were exported to a comma delimited file of easting, northing, and elevation and imported into HEC-RAS Import/Export Files for Geospatial Data. The culvert and bridge data had to be coded in separately. The channel stationing was also determined automatically using Intergraph In-Roads and imported to HEC-RAS. This not only provided data formatted to be used directly in HEC-RAS but also created a 3D map of the channel cross-sections and stream centerline to used to document the model in Microstation and ArcView.

**Floodplain Development**

Stream cross-sections and hydraulic structures are modeled using HEC-RAS and ArcView's Spatial Analyst Extension in the process of delineating the floodplain. Final maps are generated in ArcView. The HEC-RAS generated water surface profiles are exported per HEC-RAS Import/Export Files for Geospatial Data. This data is imported into an ArcView project that uses the earlier developed DEM grid. ArcView needs a line and an elevation that is associated with a cross-section identification for each cross-section to map a floodplain.
using a DEM grid. The cross-section line and its identification were created in Microstation, exported as comma delimited points, and then imported into ArcView to create the cross-section line. The line with its cross-section identification is associated with the water surface elevation. The grid is then "flooded" between the two cross-sections with a linear slope between the appropriate water surface elevations. This creates a grid of the flooded area. For each flood profile that is to be mapped a separate grid of the flooded area must be completed.

Storage areas, such as lakes, ponds, and depressions, that have their base flood elevation determined using HEC-1, are mapped automatically also. The storage areas also had the water surface defined by a line and the water surface elevation. However, the line was created in ArcView rather than imported from Microstation. The water surface elevation is associated with this line and the upstream grid is "flooded".

The above flooded grids are converted to polygons in ArcView. Last the polygons are reviewed against the digital two-foot contours and adjusted as needed before final map production.

**Summary**

It is very important to determine the methods for calculating data early in the automation process. Digitizing the data collection and automating the data calculations and formatting have improved accuracy by reducing data entry errors from one format to another, by improving mapping accuracy and mapping display flexibility, and by reducing calculation time.
Introduction

Lafayette Parish, located in southern Louisiana, has a long history of flooding. The majority of this flooding has occurred along the Vermilion River. With the inception of a real time data collection system along the Vermilion River in coordination with a flood preparedness plan, appropriate actions can be taken to reduce the impact of flooding. With this in mind, a series of digital collection platforms (DCPs) has been installed along the Vermilion River in Lafayette Parish. The platforms utilize satellite telemetry and automatic stage and precipitation recorders. Six locations were identified that would provide the most accurate data compilation of stream characteristics.

The collection of real time stage and precipitation data along the Vermilion River and the ability to access this data on the Internet has provided invaluable data to a multitude of users. Those interested in this data include the emergency operators such as the department of public works and the police department, National Weather Service, local news authorities, residents along the river, and recreational sportsmen. Information that can be retrieved from the Internet include real time river stages, precipitation data, hydrographs, and a record of the aforementioned data.

The following report will present the uses and benefits of the data collection system, data users, and the role in which the Internet serves. Further actions that would improve the data collection system and data dissemination will also be discussed.

Hydrologic Data Collection System

Applications

The data collection system, consisting of six DCP sites along the Vermilion River, were installed to collect river data for hydrologic modeling efforts being conducted by the U.S. Army Corps of Engineers, New Orleans District. Once the gauges were installed, the full benefits of receiving real time stage and precipitation data from the river were
realized. An emergency preparedness plan was developed, a flood­
forecast model is being investigated by the River Forecast Center, and
the recreational benefits of receiving real time stage data are being
encountered.

Local civil and emergency organizations teamed up and developed a
flood preparedness plan. This plan utilizes the real time data collected
from the DCPs to warn the general public of threatening stages and
flooding potential. Each gauge site is programmed to collect data in
both a timed and event reporting mode. The stage will automatically be
recorded at specified times of the day. During a storm event, increased
stage and precipitation data will be collected at a specified increment.
The National Weather Service and U.S. Geological Survey receive the
stage and precipitation data via the GOES satellite, which is expected to
be the most reliable communications option during a flood event. Since
it is cost prohibitive for parish offices to receive information via satellite,
phone modems are used to transfer real time data to each office. The
Lafayette Parish Bayou Vermilion District (BVD) is the recipient of the
real time data through a base station located at its office. The base
station is linked directly to each site via telephone line. The base station
allows the BVD office to collect and archive their real time data in a
user-friendly environment. Ultimately BVD personnel would then
disseminate river stages to the appropriate emergency managers in the
case of a potential flood hazard. These agencies include the office of
emergency preparedness, public works, police, and fire.

With the data provided from the DCPs and the implementation of
the flood recognition system, ample warning time is expected for the
general public to respond appropriately to the flood at hand. Given
early warning time, residents are able to set up temporary flood
mitigation measures. When ample warning times are provided, residents
are expected to complete flood mitigation measures as well as evacuate
from hazardous flood areas with personal property and necessary
personal belongings. With an emergency management plan established,
flood damage can be reduced as well as post flood health hazards
minimized, with the proper flood mitigation activities transpiring.

The data collection system provides automatically recorded stage
and precipitation data along the Vermilion River. This type of data has
not been previously collected for the Vermilion River. With this data
available, a reliable flood forecast model can be developed for the
Vermilion River. At this time, flood forecast tables are used by the
River Forecast Center to forecast the maximum river stage and time of
crest. The forecast is based on NWS's daily flash flood guidance, which
is defined as inches of rainfall for a given duration required to produce
flash flooding. This provides a valid forecast, but should not be
considered as reliable or accurate as forecasts based on numerical models. With a river forecast model, timely, reliable and accurate forecasts can be provided to residents and businesses affected by the river.

Internet Capabilities

Interested parties can receive near real time stage and precipitation data from the Internet. A web site developed and maintained by the U.S. Geological Survey (USGS) provides the information retrieved from the DCPs. The data at each site is collected and stored on the Internet for public use. River stage and precipitation data from the Internet can be used by interested parties and public officials for the following purposes: boating, fishing, agriculture, water quality, high water marks for insurance purposes, engineering analysis, etc. This data is considered near real time because there is approximately a several minute delay. Therefore, for emergency situations, the Internet is not the most reliable means for retrieving data.

Reference information that can be retrieved from the Internet includes station name and description, gauge specifications, and the purpose for and history of the gauge. Hydrologic data that can be retrieved from the Internet include latest stream stage conditions (in feet) referencing the date and time, discharge measurements, a location description (latitude, longitude, and the particular quad map the gauge is located on), drainage area, regulations and/or diversions near the stream gauge, reference marks (datum), extremes for period of record, and flood thresholds including flow and stage data. A link can also be made to connect the user to attain historical stream flow data and peak discharge data for a user-specified period of record.

A hydrograph of the stage, in feet above datum, for about a seven day period of record can be found on the Internet (Figure 1). This table is updated every few hours. Residents near the river can monitor the stages presented on the Internet. Knowing that the river stage is rising can give residents ample time to take flood reduction measures, such as sandbagging and raising furniture. Also with this data, a recreational boater can assess whether or not the river is too high or low for boating and farmers can monitor how much water is available to divert from the river for agricultural purposes. This data is available for the six gauge locations along the Vermilion River.
Historical data located on the Internet include stream flow data and peak discharge. The historical stream flow data can be viewed in graphic format for a user specified time frame. In Figure 2, the stream flow is presented for a one-year time frame for the Vermilion River at Surrey Street gauge location. From this data, a hydraulic modeler can reach several conclusions about the stream characteristics at that location. Combining the represented data with that from the other gauges located along the river, a hydrologic model can be developed to model and predict stream conditions. A particular stream characteristic of the Vermilion River at the Surrey gauge location is that once the channel capacity is exceeded south of the gauge, the flow direction reverses to the north. This flow reversal is represented in the figure as a negative discharge.

Historical peak flow values can be retrieved from the Internet through the USGS gauge reference site. The values are retrieved by water year, which goes from October 1 of the previous year to
September 30. For example, water year 1997 went from 10/1/1996 to 9/30/1997. Peak flow data can be used in conjunction with flood zones to determine at which slab elevation to build a home near the river.

**Further Issues**

Collecting real time stage and precipitation for the Vermilion River proves to be valuable for the various civil servant organizations located in Lafayette Parish. With the direct phone modem hookup going to the BVD office, real time data is transferred to Lafayette Parish. To reap
full benefits from the DCPs, civil servant offices require direct hookup to the base station at the BVD office. This does not occur at this time. The office of public works receives its data from the Internet. Unfortunately, the Internet is not truly "real time"; there is a lag time involved in the data update. The Vermilion River can rise so quickly that flooding can often occur before the stage data is provided through the Internet. In emergency situations, data retrieval is not fast enough through the Internet. To solve this problem, the Department of Public Works requires either a direct link to the gauges or a link to the BVD office base station.

Additional DCP locations are identified that would benefit both flood preparedness and recreation. Recommendations include extending the data collection system to the entire parish and northwest of the parish, with both of these recommendations benefiting the flood warning system. Various streams located in the western portion of the parish also rise quickly and there is presently no real time data collection system set up for this area. DCP gauges located northwest of the parish would provide further warning time for flood reduction activities to occur. For recreational purposes, additional gauges at boat launches along the Vermilion River would be beneficial to recreational boaters and fishermen.
EMERGENCY WARNING AND NOTIFICATION SYSTEMS FOR DAMS

David R. Gilchrist
Federal Signal Corporation

Introduction
At present, the term "dam warning systems" refers to systems that can warn the owner when there is a structural problem caused by floods, earthquakes, design flaw, or material deterioration. These systems are very important, but equally important are systems that can alert and notify the appropriate public officials, emergency personnel, and the affected population of an impending disaster when the emergency becomes critical. This is an area that is often overlooked and has resulted in unnecessary loss of life in the past.

This paper describes the types of devices that are available to provide this emergency alert and notification and how these devices can be integrated to provide an effective system.

There is no one system that can be effective for every dam in the United States. Different approaches are required to solve the alert and notification problems that occur. Some of the factors that affect the type of system used are population density, size of floodplain, degree of threat, terrain, desired effectiveness, and budgetary considerations.

Types of Warning Devices

Outdoor Sirens
These warning devices are designed to provide emergency warning signals over a large area. They are designed to warn a large percentage of the population that is outdoors and a lesser percentage of the indoor population. They are usually activated by remote control by using an FM radio transmitter which, with the use of an encoder, sends codes to the remote siren site where the signal is decoded and the siren activated. Siren systems are easily designed and tested. There are two types of outdoor sirens: mechanical and electronic.

Mechanical sirens produce sound by the use of motors and have the advantages of being economically priced, reliable, requiring very few repairs, are able to be operated on batteries or AC power, and have the
longest lifetime (30-40 years). Their disadvantages are that they produce only three signals and can only sound an alert.

Electronic sirens produce sound by the use of amplifiers and speakers. Their advantages include that they produce multiple signals, can produce public address messages, and are operated on batteries. Their disadvantages are a shorter product life, requiring more repairs, and being more expensive.

**Tone Alert Radios**

These devices provide indoor warning by receiving emergency messages from a centrally located transmission point. The typical tone alert radio will decode the code sent from the central control point, produce an attention-getting signal, and then allow a voice message to be sent. The device will then produce either a sound or a blinking light until it is reset by the user.

These devices have the advantages of being located inside and being able to provide both a warning signal and a notification message. They are adaptable to sparsely populated rural areas. Their disadvantages are that they are difficult to test and maintain, they can be expensive in heavily populated areas, and they are only effective if the user is in proximity to the device.

**Low Power AM Broadcast**

The low power AM station is designed to broadcast on a specific AM frequency on the radio dial, typically either 530MHz or 1610MHz, although any AM frequency can be used. The FCC requires that no more than a 10-watt transmitter be used and that the antenna be a maximum of 49 feet above the ground. With these limitations, a properly installed station will be able to cover a 3-to-5-mile radius or a 25-to-75-square-mile area.

The station is equipped with a digital recorder that will play various pre-recorded messages on command. A typical station will have a telephone dial-in feature that will allow the user to call in and record an emergency message from any touch-tone phone. The message will then be broadcast over and over until the user changes the message or shuts down the station.

The advantage of an AM station is its ability to broadcast an emergency message continuously, which allows more of the residents to tune in and hear it. Anyone with an AM radio has the capability of receiving the emergency message, and the cost per household in large-coverage areas is lower.
The disadvantages of an AM station are the variance of AM radio receiver performance within any broadcast area and the problem of user education, i.e., creating the awareness to tune to the station during potential emergency situations.

**Telephone Systems**

The emergence of digital voice technology has provided the essential means for computerized telephone systems that will systematically call residents in a specified area and deliver a pre-recorded message to the recipient. These systems require several telephone lines over which to make the calls.

The advantage of the telephone dial system is its ability to call an individual and deliver a specific message and verify the receipt of the call. It can also be used to call emergency personnel when an emergency situation is approaching.

Disadvantages include the time to call a large population during an emergency, possible damage to phone lines during a flood, the total cost of the system, and the multiple phone lines required for operation.

**Television Override Systems**

These systems are used to scroll an emergency message across the television screen when an emergency situation occurs. They are considered to be a secondary warning system since the cable reception is unreliable, especially during storms, and broadcast stations cover a large area and are not specific to a floodplain.

**System of the Future**

The use of the RDS technology is becoming one of the most interesting possibilities for warning systems of the future. This system allows emergency personnel to send out a radio message which will automatically turn on an FM radio and deliver the message to the user. The use of this is dependent upon the manufacture of radios that have this capability. Today only a small percentage of radios have RDS capability.

**Emergency Alert System**

EAS is the system that has replaced the Emergency Broadcast System. The EAS uses a digital code called SAME that is broadcast by the National Oceanic and Atmospheric Administration and state and national governments. The system is also used by local government on its local radio channel to broadcast emergency information to alert
radios, cable television, and local radio stations that in turn rebroadcast the message. Since this system is area-specific, it can be used for the areas below dams for warning in case of emergency. Further information on this system can be obtained from state emergency management agencies.

System Design

The design of a warning system for the floodplain should be based on the concept of what is the best solution for the specific area that is being considered. Here are a few examples.

- If the floodplain is several miles long and has only a few homes that will be threatened if gates are opened or the dam fails, the use of tone alert radios with battery backup would be a good choice. This system would be simple and effective and could be accomplished at a relatively low cost. Using sirens or telephone dial systems for this application, although effective, would be cost-prohibitive.

- If the river below the dam is used by recreation boaters and fishers, alert sirens are the best choice. The siren alert could then be supplemented by signs along the river and alert radios for the population. If the area is heavily populated, an AM broadcast system could be used to provide notification after the siren alert.

- If the affected area is long and impossible to cover with sirens, but has a fairly large population, the use of a telephone dial system would be the best choice. This system will notify all of the affected entities and record their responses.

- If a large park was located in the proximity of the dam, the use of electronic sirens with both alert signals in the park area would be best. The siren would produce a warning signal followed by a public address announcement to notify the park visitors of the nature of the situation and the suggested response. This system could be supplemented with alert radios for the rest of the area to be notified.

- At many dams, water is released at regular intervals. In these cases, warning sirens are installed above the dam to warn boaters of the current that is created by the release and prevent them from drifting into the release area.
Designing a System

Once the basic type of design for the system is determined, many factors have to be considered to complete the final design.

To design an effective siren system, design criteria, i.e., ambient (background) noise, topography, foliage, power accessibility, radio frequency availability, and environmental factors should be considered. The Federal Emergency Management Agency's CPG-17 "Outdoor Warning System Guide" is a good resource to use when designing a system. There are many consultants that are available to design systems. However, the best and most economical method is to contact a siren manufacturer. They have the most experience in this field and will provide the most effective design usually at no cost.

The design of a TAR system involves the selection of radio frequency, code scheme, control point, signal, and type of unit. A radio signal coverage study should also be conducted to be assured that the TARs will properly receive the signal.

The design of an AM broadcast system involves selection and licensing of a frequency, selection of system site, and selection of recorder features to fit the system needs. It is important to note that a license for this type of station can only be obtained by a governmental agency. Therefore, if the dam is privately owned, the cooperation of the local emergency management agency will be required to complete the license procedure. The examples in the previous paragraphs are a few for developing a system design for the circumstances of a particular region or area. There are many different combinations of devices that can be used to achieve the goal of effective alerting and notification.

Conclusion

The design and installation of a reliable and effective emergency warning system for the population that could be affected by a dam failure or release can save lives and allow emergency personnel to perform other duties associated with the emergency. An emergency warning system is like fire insurance—we always buy it, but we hope that we will never have to use it.
Introduction

America's global positioning system (GPS) already is the world's next utility system. The Freedonia Group and similar organizations project a meteoric rise in GPS users over the next decade, with communications, automotive, and other applications impacting virtually every American. During the past year, the National Geodetic Survey (NGS) and others have proven that GPS can provide good 3-D positioning, including heights/elevations, and not just 2-D positioning. Airborne GPS, combined with inertial, laser, and radar sensors, also enable America to satisfy its decades-long requirements for accurate digital elevation models (DEM) vital to thousands of federal, state, county, local communities, and private organizations that rely on modern geographic information system (GIS) technology for modern business practices.

The report on the Nationwide Height Modernization Study, prepared by Dewberry & Davis for NGS, presents actions necessary to efficiently revolutionize the way in which America obtains, maintains, and utilizes elevation data, not just for basic mapping, but for modern water resources management; public safety; air, land, and sea navigation; infrastructure and construction management; natural and technological hazard mitigation; precision agriculture; natural resources management; environmental protection; and other nationwide applications.

The NGS study was performed in partnership with the Federal Emergency Management Agency (FEMA) because of FEMA's need for good elevation data for modernization of the National Flood Insurance Program (NFIP), and because of Dewberry & Davis' technological leadership in elevation-related technologies.

Needs Assessments

The needs assessment process began with two NGS-sponsored "user forums" in early 1998, one in Ontario, California, and one in Durham, North Carolina. D&D then proceeded to interview diverse elevation data users from applications requiring elevation data. To document user requirements for height or 3-dimensional data, D&D developed these categories during the study: (1) digital elevation models (DEM) of the
terrain, (2) static survey data for fixed features, and (3) real-time or near real-time positioning of vehicles and other moving features. As suspected, D&I discovered that flood mitigation has one of the most demanding requirements for high accuracy elevation data.

Flood Mitigation

According to a 1997 FEMA study entitled "Multi-Hazard Identification and Risk Assessment, A Cornerstone of the National Mitigation Strategy," there are an estimated 9 million flood prone buildings in America, but only 2.8 million flood insurance policies are in effect. Average annual flood damage to property amounts to $2.15 billion, mostly uninsured, excluding agricultural losses. Because of the unavailability of accurate and affordable elevation data, the NFIP currently relies on horizontal criteria for flood risk determinations and has been unable to perform detailed flood studies for over half of the flood prone areas in the United States. According to a 1997 FEMA progress report, "Modernizing FEMA's Flood Hazard Mapping Program," between one-half and two-thirds of U.S. floodplains are not studied by detailed methods, but use approximate methods in which base flood elevations (BFEs) are not computed. Furthermore, over 2,700 flood prone communities are unstudied. With high accuracy DEMs and GPS elevation surveys, FEMA could (1) establish combined horizontal/vertical criteria for high-accuracy flood risk determinations, (2) automate the hydrologic and hydraulic (H&H) analyses needed to rapidly and cost-effectively produce accurate and complete flood hazard information for the entire nation, (3) implement major portions of the Flood Hazard Mapping Modernization Plan, and (4) yield the full benefits of proactive floodplain management.

The NFIP has been unable to perform detailed flood studies for many of the flood prone communities in the U.S. due to funding limitations and the lack of accurate elevation data. Furthermore, many communities choose to not participate in the NFIP because they do not want to adopt floodplain management measures required by the NFIP; in such communities, owners of flood prone buildings cannot purchase flood insurance. With high-resolution, high-accuracy DEMs produced by LIDAR and IFSAR technologies, legitimate flood risks could be accurately determined; and automated H&H analyses could be used to rapidly and cost-effectively produce accurate and complete flood hazard information for the nation. Consequently, flood insurance studies could be rapidly and efficiently updated as conditions change; at present, Flood Insurance Rate Maps (FIRMs) are rarely updated, and many of them are obsolete, leading to false conclusions as to current flood risks.
By performing high-accuracy GPS surveys of lowest floor elevations for all buildings in or near Special Flood Hazard Areas (SFHAs), these elevations are compared with BFEs for that location, from FEMA's FIRM, to determine the estimated depth of interior flooding from the 100-year (1% annual chance) flood. Combined with the pre-flood replacement value of the building, and the area of the building's "footprint," flood damage models can accurately predict future flood damage, not just for one building, but for every building in or near a community's SFHA.

Knowing the inevitable damage that will occur from future flooding, communities with comprehensive elevation data can effectively (1) convince owners of their legitimate need for flood insurance, based on legitimate (elevation-based) flood risk determinations; (2) identify candidate buildings for retrofitting/floodproofing before actual floods, rather than wait for post-flood mitigation steps to force this action; (3) use the predicted flood damage to determine where it is cost-justified to initiate drainage improvement projects that will lower the BFEs for an area; and (4) rapidly determine depths of interior flooding and estimate flood damage, when floods actually occur, without needing time-consuming surveys of individual buildings. With pre-surveyed elevation data for buildings, flooded communities would merely survey the high water mark at a few key locations in town, model the flood waters, and compute the actual depth of interior flooding for each building. With actual depths of interior flooding, and previously known replacement value and area, it takes very little time to accurately estimate the flood damage to every building in the community in order to expedite funding assistance to those who qualify.

Such proactive floodplain management actions, made possible by differential GPS elevation surveys, could annually save $1 billion in federal assistance to uninsured flood victims if but 50% of flood victims were insured. Insurance premiums, paid by owners who choose to buy and mortgage homes in hazardous areas, would be paid to the NFIP; then the NFIP would provide flood relief to insured victims, reducing the burden on the U.S. Treasury. The intent is to maximize the number of owners of at-risk buildings who would purchase flood insurance.

**Recommendations**

**NAVD 88 Implementation**

The study recommends additional funding for NGS so as to expedite the nationwide implementation of NAVD 88. This is necessary to implement subsequent recommendations and to provide the technical expertise needed to support constituencies (including FEMA and state and local...
governments) about to experience meteoric rises in technical support requirements from NGS. The practical impact of this recommendation is that the United States would obtain a federal base network of high-accuracy (3-D) survey monuments (NAD 83 and NAVD 88), perhaps on a 10 km x 10 km grid, from which all other surveys could be extended.

High-Accuracy Digital Elevation Models

The study recommends nationwide acquisition of high-accuracy (15- to 25-cm), high-resolution (5- to 10-meter) DEMs generated by LIDAR and/or IFSAR. LIDAR data should include first and last returns of laser pulses, in order to quantify timber heights and volumes, estimate surface roughness coefficients for floodplain hydraulic modeling, etc. Current Level 1 DEMs from the U.S. Geological Survey (to be completed nationwide in 1999) have 30-meter point spacing, and elevation errors of 14 meters at the 95% confidence level. These DEMs are unacceptable to most users who need higher-resolution, higher-accuracy DEMs, which are now achievable and which cost a small fraction of the benefits to be realized by the multiple users from virtually every community (including agriculture).

Nationwide Differential GPS System (NDGPS)

The study recommends implementation of the full 120-site NDGPS system, proposed by the Federal Railroad Administration and the U.S. Coast Guard, for completion without delay. This is vital for giving a competitive advantage to American agriculture, reduced transportation costs for all commodities, and public safety advantages to every American. This will enable all Americans to receive differential GPS (DGPS) corrections by nationwide radiobeacons (operated by the U.S. Coast Guard and/or U.S. Army Corps of Engineers) so that individual users do not need to establish and operate their own DGPS base stations.

GPS Satellite Upgrades

The study recommends upgrade to the civil-use signals of future GPS satellites (3 or more coded signals, higher signal strength, etc.), an increase in the number of satellites in the GPS constellation to 30 or more, and immediate removal of selective availability, which deliberately degrades the accuracy of GPS signals. These signal upgrades will allow autonomous positioning with accuracy of 1–2 meters, without the need for differential GPS or NDGPS reference stations.
GPS Elevation Surveys

The study recommends funding for elevation surveys (lowest adjacent grade and lowest floor elevations) of an estimated 10 million insurable buildings in or near floodplains, hurricane tidal surge, and coastal erosion zones mapped by FEMA. This is the most cost-effective way to accurately identify elevation-based risks, to require owners to purchase needed insurance, and to reduce dependence on federal handouts as predictable and inevitable disasters occur.

Summary

The conclusions of the study are clear: (1) NAVD 88 needs to be implemented nationwide as soon as possible; (2) America needs high-accuracy, high-resolution DEMs as part of the National Spatial Data Infrastructure, (3) America needs a Nationwide Differential GPS system, (4) America needs additional GPS satellites, upgraded with additional civil frequencies to improve system performance for everyone, and (5) America needs accurate elevation surveys of all buildings in or near floodplains in order to mitigate flood damage and implement proactive floodplain management.
Introduction and Background

In 1986, the City of Louisville and Jefferson County, Kentucky, decided to transfer stormwater services to one governmental jurisdiction; they gave those responsibilities to the Metropolitan Sewer District (MSD). In response, MSD developed a Stormwater Management Program by creating a stormwater utility that provides a dedicated funding source specifically for stormwater activities. When MSD established the utility in 1987, they inherited approximately 2,000 city and county stormwater customer service requests related to flooding, standing water, obstructions, and erosion conditions.

Due to the extent of stormwater related problems in Jefferson County, the existing service request management system could not adequately meet the needs of MSD or its customers. By August 1996, the backlog of unresolved drainage service requests grew to more than 15,000 for various reasons. Unfortunately, MSD did not have the mechanism in place to communicate to the customer a resolution or a date when the service request would be corrected. It was apparent that MSD needed to resolve the drainage problems and create an efficient system to address service requests.

MSD pooled internal and external resources to develop an action plan that would objectively analyze and evaluate the existing and future drainage service requests and develop a graphical-interface system to address these issues. The team that was assembled included experts in engineering, maintenance, physical assets, customer response, communications, human resources, and information systems. This technology driven project was called the Drainage Request Action Plan (DRAP).
Using GIS to Resolve Drainage Maintenance Problems

DRAP and GIS Technology

The DRAP goals were to systematically address, catalog, and resolve all drainage requests through field reconnaissance and data collection. The challenge for the DRAP team was to use GIS technology in a methodological process that would result in a "user-friendly" customer service interface. Fortunately, the DRAP team had as a resource an award-winning, innovative GIS system.

The team designed the action plan to utilize GIS as a tool to manage and record massive amounts of data and to use a solution-based process to address Jefferson County's drainage issues. By using the Louisville and Jefferson County Information Consortium (LOJIC) GIS system it was possible to connect the locational data to the unresolved customer service inquiry database.

LOJIC is a county-wide GIS consortium with a system built using ESRI's Arc/Info software. MSD is the managing member of the consortium which also includes the City of Louisville and Jefferson County, the Property Valuation Agency, and the Louisville Water Co. LOJIC has the following data layers: topography, watershed and floodplain boundaries, contours, streams, land use, and stormwater infrastructure. More detailed layers include parcels, streets, structures and site addresses, and emergency management facilities. LOJIC also includes soils layers, based upon the Natural Resources Conservation Service soils classifications. Information in LOJIC is updated daily and includes information from all partners.

DRAP used the invaluable LOJIC/GIS system to organize and to manage the solution's effort by dividing the 15,000 open drainage requests into the categories of existing projects or neighborhood areas. Once the existing drainage requests were known, the customer service system database could properly address the problems and find solutions.

Three-Phased Approach

The team decided to develop DRAP by using a three-phased approach that would run parallel and require a structured method to communicate the results clearly. The DRAP-phased goals were to: identify and organize all drainage service requests, find solutions, and link a request to the solution in the customer service database interface. Once a solution was found, setting priorities and scheduling solutions were the next steps toward implementation.

Specifically, Phase 1 initiated the process of data collection and categorization. Phase 2 initiated prioritization, scheduling and programming, and Phase 3 initiated implementation. The resource
commitments to maintain the DRAP process included developing a cross-departmental group and an external resource team to ensure efficiency and prevent duplication of efforts while creating a systematic process to cover all service areas.

To address the drainage requests in the field and collect data directly, 30–40 field inspectors each took a packet of information from the ArcView/Access database into the field. Packets included a detailed LOJIC map of each site, the customer request, surveying equipment, and MSD Level of Service guidance criteria. MSD trained field inspectors to determine a resolution and cost estimates and quantities while at the site. Field inspection results were then entered into the relational database, so further analysis of all solutions by cost and prioritization could begin.

Amazingly, the DRAP-phased process categorized at least three-fourths of the service requests into existing projects, leaving minimal open service requests that would need further office or field review. DRAP categorized many service requests into existing MSD projects, such as Capital Improvement Projects, Sewer Assessments, and Neighborhood Area Studies.

### Integrated Customer Service Interface and Communication

The result of the three-phased project is an innovative and technologically creative customer service interface. The objective of the interactive database was to make it easy for customer service personnel to clearly communicate the status of a drainage request, the priority of a project, and a schedule to customers, management, and maintenance crews.

Today, the customer service interface allows the user to view GIS maps of Jefferson County that show streams, roads, homes, contours, and floodplains. Users also can view drainage request locations, stormwater infrastructure, and drainage solutions. The system also links the map to a database that contains the owner's address, phone number, complaint history, request categories, and solution estimates. Other system data includes queries such as solution quantities, cost per complaint, cost per solution, and the number of service requests per solution (Figure 1).

The Customer Response System (CRS) consists of a relational database in ORACLE and ArcView GIS technology (replacing a mainframe computer complaint system). Using this system, the spatial information products of field maps, complaint information, existing infrastructure maps, floodplain maps, construction mapping, and an ArcView customer service interface were produced. This system
Using GIS to Resolve Drainage Maintenance Problems

REGRADE DITCHES ALONG BOTH SIDES OF CLOVERLEAF DR. FROM 4413 ON E. SIDE & 4412 ON W. SIDE OF STREET TO C/S AT CORNER OF CLOVERLEAF DR & ANNA LN. APPROX 900 FEET. INSTALL D/W CULVERTS AT THE FOLLOWING: D/W 4410, 4409, 4408, & 4407 CLOVERLEAF DR. & D/W CULVERTS. REPLACE D/W APRON AT 4416 CLOVERLEAF.

DRAINAGE INSPECTION INFORMATION

Revised on 2/15/97

Route To: I

Packet No. ML5004

Customer Name: HAGAN, TERRY
Customer Address: 4409 CLOVERLEAF DR

Initial Screening of Drainage Service Requests

Non-Public Water (Which does not involve more than two properties): Yes/No
Public Water: Yes/No

Jurisdiction

Agency Responsible: 1

Observations: ROADSIDE DITCH REGRADE. THERE IS APPROX. 6" TO 10" OF SILT IN THE ROADSIDE DITCH AT BOTH SIDES OF CLOVERLEAF DR. FROM 4413 TO 4412 CLOVERLEAF TO CORNER OF CLOVERLEAF & ANNA LN. APPROX. 900 LF. THERE IS STANDING WATER.

Recommendations: REGRADE DITCHES ALONG BOTH SIDES OF CLOVERLEAF DR. FROM 4413 ON E. SIDE & 4412 ON W. SIDE OF STREET TO C/S AT CORNER OF CLOVERLEAF DR & ANNA LN. APPROX. 900 FEET. INSTALL D/W CULVERTS AT THE FOLLOWING: D/W 4410, 4409, 4408, & 4407 CLOVERLEAF DR. & D/W CULVERTS. REPLACE D/W APRON AT 4416 CLOVERLEAF.

Figure 1. The Customer Service Interface shows a site map, the drainage request information, and the resolution.
currently provides data to more than 50 workstations throughout MSD's administrative, engineering, and maintenance departments.

The ArcView/ORACLE CRS system works by classifying and segregating each drainage inquiry into one of two project categories: maintenance or major capital. Next, the system can further segregate maintenance projects into one of three categories: routine maintenance, emergency maintenance or annual neighborhood programs.

MSD quickly learned from the Customer Service Departments that all systems (the network and the PC) need to be fast and very responsive. Otherwise, the system would not allow Customer Service to view all of the necessary mapping and data while on the phone with the customer. The DRAP team also learned that early training of customer service personnel is imperative to a successful process.

Watersheds, Area Teams, and Drainage Maintenance

Solutions and implementation of the action plan forced the serious consideration of several topics. DRAP needed to develop a method to cover all service areas and determine the role of watershed and stormwater management in the solution process. A large portion of MSD's service area lies within the 100-year floodplain of the Ohio River and its tributaries.

To implement and administer a county-wide drainage program, the bigger issues of watershed and floodplain management became the focus. Similarly, the questions of how to link neighborhoods together, address flooding, and resolve the drainage issues needed to be addressed. MSD had been considering a watershed management program for sometime and DRAP was the catalyst that led management to the idea of a per watershed plan.

During 1997, MSD decided to reorganize the service areas into five watersheds that designated area teams would manage. Currently, MSD has five area team internal managers and five external consultant managers who work in cooperation with one another. Each area team can now provide the best management practices and maintenance per watershed.

Placing the DRAP system under the management of the area teams allows the managers to use the DRAP system as a maintenance management tool. Working together is now easy and convenient for area team leaders, maintenance, and customer service personnel. After Customer Service logs the drainage request into the CRS database, they send the complaint to the appropriate area team managers who then designate a field and maintenance review. After field review, the area
team leaders update the system and determine construction costs that customer service can then easily communicate to the customer.

**Successes and the Future of DRAP**

The Drainage Request Action Plan successfully accomplished its goals before the deadline. Major keys to success for DRAP were existing programs and work efforts, such as LOJIC, the Neighborhood Area Study and the Customer Response Team. DRAP's success also can be attributed to the aggressive team of experts who focused the process by meeting weekly throughout the process. Soon after the first year of the program, DRAP resolved 12,000 service requests and considerably reduced the duplication of efforts by customer service, maintenance, and information services. Additionally, the cost-efficient system causes a shorter response time for actual construction and reduces the cost of field work because the problem goes to an inspector supervisor who works directly with construction management and bypasses the engineering level of service. Projects that formerly took two years, start to finish, are now completed in a couple of months because there is often no need for design, planning, and construction documents.

DRAP developed a watershed-based process that partnered with GIS technology and has changed the way Louisville/Jefferson County approaches watershed and floodplain management, planning, maintenance, and capital project scheduling. The DRAP project became a catalyst to many changes within MSD. Besides the division of the county into watersheds and the development of area teams, there are changes in applications of technology, construction management, and communication. Additionally, because of supporting data from the DRAP process, MSD has a better handle on the size of the county's drainage problems and no longer is looking at a black hole of drainage requests.

**Lessons Learned**

MSD realized that any process the size of DRAP would require an intensive commitment of time, money, and staff. Further, a project of this size takes serious consensus building from all levels of service, including personnel and networking capabilities. Involving key people and services is imperative from the very beginning. In addition, staff must be committed to entering data on a daily basis to keep the system viable and current. For a staff to accomplish this goal there must be extensive training not only in the technical aspects of the project but also during the process of maintaining a large database.
Acknowledgements

The authors thank Louie Greenwell, Alan Castaneda, and Brian Belcher, of Fuller, Mossbarger, Scott & May Engineers, Inc.; Mark Johnson and Andy Meyer, of Presnell Associates, Inc.; Molly Jones, of MC Jones Consultant Engineering; and Dave Schaftlein, Janet McKinley, Julia Price, Julia Muller, Jolyn Colon and Bruce Carroll, of the Metropolitan Sewer District. Thanks also to all the staff who helped DRAP along the way.

A special thanks goes to the commitment and resources of MSD's Customer Response Team: Sharlie Kahn, Kevin Kaufman, Raymond Jeffries, Paul Meyer, Steve Emily, Mike Marling and Cathy Cornish. Credits also go to the following for their support and leadership: Gordon Garner, John Beyke, Trish Burke, James Hunt, David Johnson, Frank Walker, and Craig Avery.
THE ROLE OF GPS ELEVATION SURVEYS IN PROACTIVE FLOODPLAIN MANAGEMENT

David F. Maune
Dewberry & Davis

Introduction

Dewberry & Davis (D&D) started using the global positioning system (GPS) in 1994, for post-flood surveys in Georgia, Florida, Alabama, and Texas. Those "windshield" surveys were reactive in that floods had already occurred, and damage inventories needed to be taken in order to provide individual assistance to flood victims.

We have come a long way since 1994, GPS elevation survey techniques have improved, and GPS elevation surveys now play a vital role in "proactive floodplain management." The evolution from "reactive" to "proactive" happened in part from lessons learned from D&D's GPS surveys tabulated below.

Table 1. GPS surveys conducted by Dewberry & Davis.

<table>
<thead>
<tr>
<th>When</th>
<th>Where</th>
<th>Buildings Surveyed</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>GA, FL, AL, TX</td>
<td>7,963</td>
<td>Floods</td>
</tr>
<tr>
<td>1995</td>
<td>Louisville, KY</td>
<td>1,240</td>
<td>GPS &quot;Shoot-Out&quot;</td>
</tr>
<tr>
<td>1996</td>
<td>Charlotte, NC</td>
<td>2,193</td>
<td>Proactive Plan</td>
</tr>
<tr>
<td>1995 to 1998</td>
<td>Nationwide</td>
<td>2,338</td>
<td>Disasters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9,087</td>
<td>FEMA Studies</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>22,821</td>
<td></td>
</tr>
</tbody>
</table>
1994 Post-Flood Surveys in Georgia, Florida, Alabama, and Texas

What D&D Did

In response to a request by the Federal Emergency Management Agency (FEMA), D&D performed GPS horizontal surveys of nearly 8,000 flooded buildings in Georgia, Florida, Alabama, and Texas. D&D's surveyors recorded the depth of interior flooding to the nearest whole foot, and estimated the area of each building's footprint. Certified flood adjusters made "windshield estimates" of flood damages. D&D produced damage assessment maps of over a dozen flooded communities, produced inventory forms for each flooded building surveyed, and produced a GIS database with geocoded information on each flooded building.

What We Learned

FEMA learned that the "windshield" flood damage estimates were in error by 50-100%, but that FEMA's computerized flood damage models could make accurate damage estimates by knowing three things:

1. the depth of interior flooding to the nearest whole foot,
2. the area of the building footprint, and
3. the pre-flood replacement value for each flooded building.

From this "lesson," D&D recognized that accurate damage estimates for individual buildings and entire communities could be accurately predicted in advance for standard floods (10-, 50-, 100-, and 500-year floods) by geocoding and surveying lowest floor elevations, in advance, and comparing them with base flood elevations (BFEs), and by populating GIS databases with footprint areas and replacement values.

1995 GPS "Shoot-Out"

What D&D Did

With FEMA funding, D&D conducted a GPS "shoot-out" in Louisville, Kentucky, in support of the Metropolitan Sewer District (MSD). The "shoot-out" involved two D&D subcontractors, utilizing competing technologies capable of performing GPS "stand off" surveys. Larry N. Scartz, Ltd. (LNS) used "GPS Back-Pack" technology; and John E. Chance & Associates (JECA) used "GPS TruckMAP" technology.

For cost comparisons, LNS surveyed over 700 buildings with the GPS Back-Pack, and JECA surveyed over 500 buildings with the GPS TruckMAP. For accuracy comparisons, 62 of the 1232 buildings were
independently surveyed twice—by both teams; these buildings were selected as difficult for GPS stand-off elevation surveys for the following reasons: (1) The streets were tree-lined with overhead canopy, foliage was full (June), and the necessary GPS signals were expected to have difficulty in penetrating the tree canopies; (2) the differential GPS base station was on the opposite side of hills from the "rover" units, which were expected to have difficulty receiving RTK differential corrections by radio; and (3) some of these buildings were several hundred feet from the road, making it difficult to accurately "cantilever" elevation differences to those buildings.

What We Learned

Accuracy comparison. For the 62 buildings independently surveyed by both firms, D&D had been prepared to use traditional leveling to resolve discrepancies greater than 6 inches—FEMA’s accuracy goal. In fact, the elevations agreed within 1 inch for 61 of the 62 buildings; one building had elevation differences of several feet because one team had failed to detect the existence of a basement under part of a split-level home. The National Geodetic Survey (NGS) reviewed the procedures used and determined them to be consistent with NGS’s draft guidelines for GPS elevation surveys at the 5-cm accuracy level.

Cost comparison. Under the ideal conditions that existed in Louisville, both LNS and JECA proved that they could mass produce GPS elevation surveys, with elevation accuracy of 5 cm (2 inches) at the 95% confidence level, for approximately $30 per house. However, these were high-density houses in flood prone subdivisions, and approximately six houses could be surveyed from each GPS point established. There were no delays in moving from site to site, and only 5% of the houses (62 of 1,232) were difficult for GPS, as stated above. The costs for deploying the TruckMAP, however, were so high that it would not be cost effective unless there were thousands of high-density buildings to be surveyed.

GPS elevation certificates. Because 3-D coordinates had been surveyed, D&D produced a prototype GPS Elevation Certificate and provided it to FEMA and MSD for review and comment. This GPS Elevation Certificate included all information required by a conventional elevation certificate (FEMA Form 81-31), plus a digital image of the building surveyed; a background map that included the local street network, Special Flood Hazard Area (SFHA), and upstream/downstream BFEs; and additional data describing the building and its estimated depth of interior flooding from a 1% annual chance flood. All comments
from FEMA and MSD were favorable, and most reviewers felt that the GPS Elevation Certificate format would be most effective in convincing home owners of their legitimate need for flood insurance.

**1996 Charlotte-Mecklenburg Storm Water Services**

**What D&D Did**

As a subcontractor to Ogden Environmental, D&D surveyed and produced GPS Elevation Certificates for 2,190 buildings in the SFHA in Charlotte and Mecklenburg County, North Carolina. D&D also produced an ARC/INFO database complete with area, replacement values, etc. requested by the Charlotte-Mecklenburg Storm Water Services.

**What We Learned**

Charlotte-Mecklenburg Storm Water Services proved the value of proactive floodplain management within one year of project completion. In the summer of 1997, Charlotte was hit by a flood that met or exceeded 100-year projections in some areas. Within 24 hours, the Charlotte-Mecklenburg Storm Water Services had used their GIS to compute the depth of flooding for individual buildings and to estimate flood damages to each. Within hours, a complete list of addresses, owners, telephone numbers, pre-flood replacement values, and estimated damages were provided to FEMA in order to expedite the provision of individual assistance.

On the negative side, D&D learned that the unit price for these GPS Elevation Certificates was nearly twice as much as those in Louisville, Kentucky, because of complicating factors that were not originally recognized, i.e., erroneous address lists of buildings to be surveyed, and the low density of buildings, e.g., surveying one or two houses at the bottom on a cul-de-sac (rather than all houses in the cul-de-sac), then relocating perhaps a mile to the next location to survey a few more houses.

During the surveys, D&D frequently observed that for every assigned address to be surveyed, there was often one or more neighboring addresses, located outside the SFHA, that had lower elevations and were more likely to be flooded than houses on the assigned address list provided by the client. D&D voluntarily surveyed 839 extra buildings (mostly built after the Flood Insurance Rate Map, or post-FIRM) believed to be lower, even though they were not on the assigned address lists. Of the 839 buildings surveyed by D&D outside the SFHA, only 39 proved to have lowest floor and LAG elevations.
below the BFE, but D&D considered this 39 too many. This points out a dilemma with the horizontal (SFHA) criteria; the NFIP was successful in causing most of the new construction within SFHAs to be elevated above the BFE, but the erroneous SFHA boundaries undoubtedly contributed as well to the construction of new homes at floodprone elevations, merely because they were located on the opposite side of the imprecise SFHA boundary.

Three statistics were especially noteworthy: (1) Half of the pre-FIRM buildings inside the SFHA had lowest floor elevations above the BFE. (2) Forty-four post-FIRM buildings inside the SFHA had lowest floor elevations below the BFE. Most of them flooded in the 1997 flood. (3) Thirty-nine of the buildings outside the SFHA (mostly post-FIRM) were actually floodprone, having lowest floor elevations and lowest adjacent grades below the BFE.

1996 Post Disaster Surveys

What D&D Did

With a short (3-week) deadline, D&D generated GIS databases and GPS Elevation Certificates for 1,137 flooded buildings in 16 West Virginia communities. Subsequently, D&D performed four different types of GPS elevation surveys in response to Hurricane Fran in North Carolina, including the generation of GIS databases and over 2,000 GPS Elevation Certificates.

What We Learned

The lessons here were fourfold: (1) the importance of having pre-approved standard GPS Elevation Certificates used by all FEMA regions; (2) the importance of counties having geocoded tax records, complete with owner names and addresses for all buildings; (3) the importance of gaining information prior to a natural disaster, rather than during post-disaster turmoil; (4) the importance of public information to clarify issues and procedures, and to overcome disinformation that appears to accompany most natural disasters.

FEMA Studies

What D&D Did

For FEMA's 1995 No-Cert Study, D&D performed GPS elevation surveys of 1,459 post-FIRM buildings in 62 communities in eight states. For FEMA's 1997 study of the effects of charging actuarial rates for pre-FIRM buildings, D&D used a list of 15,000 addresses (in 23 communities in 17 states), provided by Price Waterhouse, to identify
buildings that were pre-FIRM and located within SFHAs. The addresses had been identified by Price Waterhouse so as to statistically represent demographic and other criteria specified by FEMA. During the reconnaissance and selection of final addresses, D&D’s GIS personnel took digital images and populated the GIS database for each community, including Marshall & Swift specified data needed to estimate replacement values for each building surveyed. A total of 7,628 buildings were surveyed that satisfied the specified criteria. D&D then produced GPS Elevation Certificates for these buildings and provided FEMA with spreadsheets indicating various statistics.

What We Learned

**Elevation reference marks.** In virtually every community, the GPS teams had difficulty locating elevation reference marks (ERMs) identified on the FIRMs being used. When ERMs were located, they were found to have poor accuracy, falling outside the 1-inch accuracy tolerance with respect to NGS’s "blue booked" benchmarks in the National Spatial Reference System (NSRS). Several ERMs were identical to "blue booked" benchmarks in the NSRS, except that the ERM elevations published on the FIRMs were in error by as much as five feet. All four GPS teams arrived at similar conclusions, i.e., that the ERMs were more trouble than they were worth. NGS already maintained the NSRS accurate and up-to-date on a daily basis (via the Internet), and there was no apparent overriding reason for basing high accuracy GPS elevation surveys on low accuracy ERMs.

**Noncompliance with the NFIP.** Almost every community was found to be in noncompliance to some degree. Some communities were far worse than others. The primary source of noncompliance pertained to elevated buildings with furnished basements and utilities, as opposed to crawl space for storage.

**Pre-FIRM actuarial study.** The overall results of the actuarial study have not yet been released by FEMA. However, the nationwide GPS elevation surveys of 23 communities indicate that the survey results in Charlotte in 1996 were not an aberration, but fairly typical of floodprone communities nationwide.

Summary

GPS elevation surveys are clearly a key to proactive floodplain management.

- If the elevation of the lowest floor and lowest adjacent grade, the footprint area, and the replacement value of each building
are known, flood damage models can accurately estimate the projected damages to be incurred from standard flood events, i.e., 10-, 50-, 100-, and 500-year floods.

• By quantifying the flood damages to be incurred by individual buildings and by a community as a whole, the community can, for the first time, know the magnitude of predictable flood events to individual owners, and to the community as a whole. Such hazard identification and risk assessment would be the first step in flood mitigation.

• The GPS Elevation Certificates themselves can be used to convince reluctant homeowners of their legitimate need for flood insurance. Flood insurance is a major plank in FEMA’s flood mitigation platform.

• The GPS elevation survey data are crucial in benefit/cost studies to determine whether it is justified to spend $X for drainage improvement projects that would lower the BFEs for upstream buildings and prevent $Y in flood damage.

• GPS Elevation Certificates should be used to determine candidates for retrofitting or floodproofing, prior to inevitable flood events, rather than waiting for floods to occur.

• Finally, when floods actually occur, it is no longer necessary to survey individual buildings to determine their depth of flooding. Merely determine the high water marks at several key locations in town, and model the flood water elevations. By knowing the peak flood elevations, and lowest floor elevations, the depth of interior flooding can be quickly determined. Combined with area and pre-flood replacement value, actual flood damage is quickly and accurately estimated for every flooded building in town.
Introduction

Mecklenburg County selected Woolpert to develop GIS applications that would give access to the county's extensive GIS data. Originally, the applications were to be created using ArcView. However, because the GIS services department was certain that it would eventually implement an Internet/intranet network, it was decided that the applications be developed initially in that medium rather than in ArcView. One reason for this decision was that migrating the applications from ArcView to an Internet/intranet could require more than a 70% recoding effort.

The GIS services department's software base consists primarily of packages from Environmental Research Institute (ESRI). Because of its flexibility, the MapObjects IMS (Internet Map Server) was chosen to perform GIS and Internet functions. This software exists as an add-on to MapObjects, ESRI's set of development tools for the PC. Because of the department's familiarity with Visual Basic, the county asked that the applications be written in that development environment. A significant portion of the project consisted of data conversion, and most data to be integrated into the applications existed in AutoCAD format. This data needed to be converted into a format that could be understood by the MapObjects software. Although MapObjects can read both ARC/INFO coverages and shapefiles, displaying shapefiles is significantly faster. Spatial data referenced by the application exists as shapefiles.

In addition to the conversion effort from AutoCAD to shapefiles format, some datasheets had to be altered to be used for certain functions. For example, geocoding requires address attributes to be standardized and properly formatted. Woolpert has written routines in
Background

The development of the applications began with a survey and internal meetings with staff about their needs for a simplified method to access and query spatial data on a desktop computer. A list of wants and needs was finalized and Woolpert was retained to assist in development of the needed applications. Woolpert worked closely with key members of county GIS and Storm Water staff in fine tuning the development of the application. When the project was about 50% complete, a meeting was held with all internal users to obtain their input on comments on the progress of the product being developed. Woolpert then incorporated the comments into the development of the final product. The application will be used by staff for several months to work out any “bugs” and research is now underway to place the application on the Internet.

Application Description

The main application comprises a suite of four separate applications that provide the user with a means to quickly access data and maps associated with determining flood zone proximity, stormwater engineering, land development, and water quality/quantity. Figure 1 shows the intranet application startup screen. The background maps on all the applications can be customized to show features selected by the user. These include such coverages as streets, hydrology, floodplains, political boundaries, planemetrics, and commissioner's districts.

Flood Zone Proximity Determination

It is anticipated that the flood zone proximity application will be the most widely used and provide the greatest benefit for users. Presently, MCSWS receives between 200 and 300 requests per month for flood zone information. This service presently requires about one-half of a staff person’s time. A staff person using the application has reduced this time by about 75%, and when it is available on the Internet we anticipate that this time will be reduced even more.

An address can be researched by entering either an exact address or a street name to search on. There is also the option to enter up to 20 addresses in a batch mode. Once entered, the application searches and then displays the location of the point on a zoomed-in background.
that includes the street centerline with names and the Q3 or digitized floodplain coverage (Figure 2). A 300-foot buffer is placed around the point and a determination is made of the proximity of the point or buffer to a Special Flood Hazard Area.

The address entered is checked against three databases to provide an accurate determination of the flood zone. First, it is checked to see if it matches an address in a database of over 2000 flood-prone structures that have been GPS surveyed. If it matches an address in this database, an exact determination is made and the results are displayed on the screen. If the address is not found in the GPS structure database, it is checked against a database that includes all Letters of Map Revision for Charlotte/Mecklenburg and an exact determination can then be made. If the address is not found in either of these databases, it is then checked against a database of addresses that have been manually researched during previous flood zone determinations using the application.
In addition to showing the location in relation to the floodplain, the application provides a written description of the determination. This information includes the community and panel number, map date, flood zone, watershed name, and determination reason (in by distance, out by distance, in or out by GPS surveyed database, out by Map Revision database, and in or out by previously researched database). If the 300-foot buffer intersects the digitized floodplain, a message is displayed that instructs the user that further research is required by MCSWS and the information will be available at a later time. If the address entered matches an address in the GPS structure database, a digital photograph may be accessed on the screen.

Two forms are available as output in this application. The first is a Flood Zone Determination Letter, which includes all the information needed for an official flood hazard determination. The color GPS elevation certificate is also available as output. The certificate includes all required data from FEMA's form #81-31 as well as additional information and a color image of the structure (Figure 3).
Stormwater Engineering Application

MCSWS has aggressive capital improvement and maintenance programs involving streams and drainage structures throughout the county. Other departments, such as water and sewer, greenways, and environmental protection, also have programs and data involving these same streams. The Stormwater Engineering application provides a means to quickly access maps and data and query on a variety of fields in several of these databases. This allows for rapid and accurate updating of project data and helps eliminate problems caused by different departments planning and constructing projects without other departments' knowledge.

The application allows the user to select an address or street intersection to zoom to in the initial inquiry. Then, a multitude of fields may be queried, including a database of all stormwater service requests, length of project, date of completion, inspector name, type of materials used, location of existing and proposed water and sewer, and existing and proposed greenway parks.

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### GPS Elevation Certificate

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<th>Item</th>
<th>Attribute</th>
<th>Value</th>
</tr>
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<tbody>
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<tr>
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<td>City/State</td>
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<tr>
<td>3</td>
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<td>9</td>
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<td>10</td>
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</tr>
<tr>
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<td>100.3</td>
</tr>
<tr>
<td>12</td>
<td>CR Flood Area on Lower Flood Plain</td>
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</tr>
</tbody>
</table>

---

**Figure 3. The GPS elevation certificate.**
Land Development Application

The Land Development application is similar to the Stormwater Engineering application. Many of the same fields can be queried. In addition, the Land Development application includes some additional coverages like a database of all land development activity, including new subdivisions and commercial sites, inspection reports, and violations. This application also provides for the output of a county map that includes an up-to-date location of all land development activities occurring within a specified time period. This information can then be provided to the newspaper or other media interested in growth patterns around the county.

Water Quality/Quantity Application

This application provides access to the U.S. Geological Survey (USGS) rainfall data, which includes over 40 rain gages and over 15 stream quantity and quality gages. The maps displayed show isohyets of total rainfall or the storm frequency across the county. Individual rain gage stations can also be queried spatially in a number of ways and displayed with attached data. Data to be queried include total rainfall, rainfall threshold amounts, and rain gage station locations. The application automatically zooms to a county-wide map that can be customized. Once the isohyet map is produced the user can zoom, pan, or redraw as in the other applications (Figure 4).

Conclusion

It is anticipated that the use of these applications will greatly improve the efficiency of day-to-day operations for internal staff. The future availability of the applications across the Internet should provide property owners, developers, and others with a wealth of information upon which to base land use decisions.

The flood zone proximity application has already been proven to greatly reduce staff time required to manually look up flood zone information for several thousand inquiries per year. The ability for property owners, lenders, appraisers, realtors, and insurance agents to
access this information over the Internet will further reduce staff time and it will allow outside users to obtain the information more quickly.

Additional GIS coverages may be added to the applications in the future as they become available. It is also anticipated that these applications will provide useful data for the development of a county-wide Watershed Management System that is being developed by Charlotte Storm Water Services.

**Figure 4. Screen displaying rainfall data for a given site.**
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Part 4
Coastal Issues
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Hilton Head Island is a barrier island known as a "Sea Island," located off the southern coast of South Carolina. It occupies an area of approximately 41 square miles 90 miles south of Charleston, South Carolina, and 30 miles north of Savannah, Georgia. The island is 5 miles wide at the broadest point. Broad Creek nearly divides the island with the low lying "Folly" serving as the connection. The land at the southern end of the island consists of low-lying salt marshes and wetlands, while the northern headland rises to a 22-foot-high bluff. Wide sandy beaches line the Atlantic coast. Calibogue Sound separates the island from the mainland, and a single bridge spans it. "The island has been a frontier of Spain, a colony of France and a pivotal strategic base of operations in the Civil War. Indians, Spanish, French and English all agreed on two things: the land was fertile and the water was fresh" (Greer, 1989). Captain William Hilton first surveyed the bluff headland at the northern end of the island in 1663. From this time the island has been referred to as "Hilton's Head." In 1698, the first English development began and by 1733 25 families were living on Hilton Head Island. A new era began in 1950 with the sale of the southern part of the island to the Hilton Head Company, which not only harvested timber but began to sell property and develop land with the goal of preserving the natural beauty. From a small isolated community of 2500 residents in 1969, Hilton Head Island has grown into a world-renowned retirement resort of 28,000 permanent residents. The island hosts over 1.8 million guests annually.

A Category 3 hurricane would flood all but the highest portions of the island's northern headland. Considering Hilton Head Island's vulnerable location it has been historically spared the devastation suffered by its neighbors on the coast. History records storms of catastrophic levels on August 25, 1686, and September 19, 1752, but they had little lasting effect on the largely uninhabited island. On
August 27, 1893, a category 3 hurricane devastated Beaufort County. The 20-foot storm surge drowned 3000 people, sweeping away buildings and spoiling the fields with salt water and mud. Category 2 hurricanes visited the island in 1928, 1945, 1947 and 1952, but their principal damage was to the natural beauty of the land and the crops of the native island families. On September 29, 1959, the south coast of South Carolina received a direct hit from the category 3 Hurricane Gracie. She arrived just north of Hilton Head Island at dead low tide, once again sparing the area catastrophic damage. The 8.6-foot storm surge and 80 mile per hour winds caused beach erosion, shallow flooding, damage to vegetation, and minor property loss. Statewide, 11 lives were lost and $12 million in property damage was recorded.

When Gracie made landfall on the South Carolina coast, fewer than 1000 permanent residents lived on Hilton Head Island. But as the population grew and many more resort guests came during the hurricane-prone months, the Beaufort County emergency preparedness planners realized the need to evacuate the population well before a storm's arrival. Evacuations were ordered 24 hours before the category 2 Hurricane David made landfall on September 4, 1979. County-wide damage was reported at $1.8 million. On the island, damage was limited to beach erosion, dock structures, vegetation, and minor property loss. Again on September 20, 1989, the island was evacuated 24 hours before anticipated landfall of category 4 Hurricane Hugo. At the last moment Hugo swerved north and passed over the Charleston harbor, causing $7 billion damage and taking 25 lives in two states. Damage on the island was limited to beach erosion and minimal wind damage to vegetation and property.

But these catastrophic storms do not represent the island's greatest danger from flood damage. The terrain of Hilton Head Island is very flat, causing storm drainage to be the most critical issue. The island's drainage facilities are not capable of accommodating prolonged rainfall or a storm surge from the Atlantic Ocean. Within the planned communities of the island, the drainage networks consist of a complex arrangement of interconnected lagoons that ultimately discharge into the Atlantic. The capacity of the lagoon system is created by the buildup of storage within each lagoon. This build-up is the driving force that releases water from the system. The water accumulation in each lagoon impoundment creates a driving energy head that forces the flow of water from higher to lower areas. Thus, the interaction between lagoons results in an intricate and delicate drainage network.

The drainage systems of most of the unplanned communities comprise networks of piping, ditching, and detention basins—designed
without attention to comprehensive planning. This evolved drainage network results in ditching and piping with non-uniform longitudinal slopes. The flow of storm drainage is sometimes slowed, stopped, or even reversed as a result. Due to the delicacy of the island's drainage system the ocean's tides and surges have a direct effect on the system's efficiency. For example, if a high tide or a surge coincides with heavy rainfall, the flooding potential is increased.

In the Flood Disaster and Protection Act of 1973, the 100-year flood was specified as the limit of the floodplain for insurance purposes. For construction falling under the jurisdiction of the local governing bodies, Beaufort County and the Town of Hilton Head Island have established the design storm frequency to be 25 years. This design criteria has evolved over time. This evolution is seen in the fact that the initial county design storm requirement was a 10-year, 1-hour storm. This corresponds to a 1-hour rainfall of 2.8 inches. The present requirement is a 25-year, 24-hour design storm frequency. This equates to 8 inches of precipitation in 24 hours. Therefore, a majority of the development done on the island has been constructed using different rating requirements. Most of the construction development on Hilton Head Island was built to the 10-year requirement since the 25-year design was not required until the mid-1980s.

This progressive change in the design storm requirement can create difficulties such as drainage bottlenecks. Generally, the first areas developed were adjacent to the beaches, marshes, and tidal creeks, since these are the most aesthetically pleasing areas. This left the higher inland areas to be developed later. Drainage problems arise when the outfalls are designed for 2.8 inches of rainfall and the inland drainage systems are designed for 8.0 inches of rainfall. However, a large number of lagoons built in the island's residential golf course communities provide a flood protection buffer for storms that exceed a 10-year frequency. With these diverse systems in place, a study of the island's drainage has led the town to develop unique solutions such as the Jarvis Creek Drainage Project to remedy localized flooding.

On October 2, 1994, and October 12, 1994, storms were recorded having 8 and 14 inches of rainfall during a 24-hour period, respectively. These storms equate to the 25- and 145-year rainfall events. Additionally, on the Labor Day weekends of 1987 and 1988, Hilton Head Island experienced severe flooding. The isolated daily storm for both weekends exceeded the 100-year event. For the two Labor Day floods and the October 12 flood, the lagoons and groundwater were high due to spring tides and previous rains. The planned residential subdivision, Hilton Head Plantation, has experienced substantial
flooding during each of these events, specifically in the "Headlands" residential area. The October 12 storm was the most catastrophic not only because of the volume of rainfall but also because the lagoons and groundwater were still high from the October 2 event. The result was widespread structural flooding to single-family homes and commercial structures.

At the request of the town, an inventory and analysis of the island's drainage infrastructure, "The Town of Hilton Head Island, Island Wide Drainage Study," was being completed in 1995 by Thomas and Hutton Engineering Co. The analysis phase of the study made recommendations for areas throughout the island. In the Jarvis Creek watershed it was determined that the stormwater conveyance system downstream from the "Headlands" was undersized. The system consists of two elements: an undersized culvert crossing under U.S. highway 278, and a ditch that runs from the downstream side of the culvert to the tidal discharge into Jarvis Creek. The existing ditch was approximately 8 to 12 feet wide at the bottom and overgrown with a mature stand of vegetation. This ditch section may drain approximately 50 cfs. However, the design storm discharge rate is 440 cfs. To accommodate the design storm requirements, the study recommended that the ditch be increased to a bottom width of 35 feet and a depth of approximately 6 feet with a 3:1 bank slope. A 100-foot-wide canal with maintenance roads on both sides would be required. Additionally, the study recommended that the existing 60-inch diameter culvert at highway 278 be upgraded to a concrete box culvert 5 feet by 12 feet.

When the study was completed in 1995, the upgrades were prioritized against other improvements identified in the study. The prioritization was based on providing relief to the areas suffering most frequent structural flooding and greatest damage. The study and its priorities were adopted by Hilton Head Island Town Council and funded in the 1996-97 municipal budget. Specifically, the Jarvis Creek Ditch and the highway 278 culvert were priorities two and three, respectively, out of 17 drainage improvement projects in the town's 1996-97 Capital Improvements Program. Help was solicited from other governmental agencies, including the South Carolina Department of Transportation and Beaufort County. The SCDOT agreed to provide the necessary drainage structure at highway 278 when the improvements were made downstream.

The Island Wide Drainage Study recommended internal improvements for Hilton Head Plantation. However, they could not be completed until after the box culvert and ditch were installed downstream. The Hilton Head Plantation Property Owner's Association
committed to the drainage improvements as recommended by Thomas and Hutton Engineering. The improvements consist of ditch excavation and widening, lagoon enlargement, removal of any major pipe restrictions, replacement of undersized pipes or bridges, and additional improvements deemed necessary. Funds from property assessments have been placed in escrow for the drainage improvements to the Hilton Head Plantation’s internal drainage system.

Work began in fiscal year 1996-97 on the conceptual design and topographic survey of the Jarvis Creek Ditch Project. Significant wetlands and trees were found within the proposed project location. Therefore, the town began to pursue an option that minimized the impact on the wetlands by rerouting the ditch. Rerouting also meant lengthening and deepening the ditch, which in turn increased the amount of excavation and loss of trees and wildlife habitat. Costs increased from $1.6 million to $3.0 million. It was also during the summer of 1996 that the town was negotiating the purchase of property adjacent to the existing Jarvis Creek Ditch. Town staff began to explore additional design options to solve the drainage problem assuming ownership of the roughly 50 acres of adjacent property. A 13-acre lake capable of storing and conveying the necessary stormwater was envisioned. The majority of the lake could be constructed on already cleared pasture on the site. A stormwater pumping station would be needed to move the water from the Headlands ditch to the lagoon. This would be costly but comparable to the $3.0 million associated with the second ditch option. From the lake water would flow through a spillway that discharged into Jarvis Creek. Additionally, littoral shelves were contemplated along the lake edges to minimize erosion and mitigate wetlands disturbed by other town projects within the watershed. The benefit of the discharge of stormwater detention in the lake was improved water quality into Jarvis Creek. Lastly, once constructed, the lagoon and surrounding land would provide an ideal setting for a passive park. The pump station alternative, although costly, is environmentally friendly since it retains the stormwater runoff and allows for time, sunshine, and earth's natural filters to cleanse the storm water runoff of many pollutants while minimizing flooding. The proposed drainage improvements consist of the construction of a below-ground concrete structure that will house four 43,750-gallon-per-minute stormwater pumps, four bar screens, and a 12’ x 5’ box culvert with flap gate; the installation of four 1,150-linear-foot, 48”-diameter force main pipes from the pump station to the 10-acre Jarvis Lake; and the construction of an electrical station that will house all electrical and pump controls for the pump station. The station will also house a sufficient number of
generators and diesel fuel to provide back-up power to all four pumps for a minimum of three continuous days.

The 50-acre Jarvis Creek Tract was purchased by the town. An agreement for excavation of the lake has been executed with the proceeds from the sale of the dirt funding park construction. The drainage design has been identified and construction documents and permits are in progress. A mining permit has been issued by the South Carolina Department of Health and Environmental Control for the construction of the lake. The town is finalizing the design and specifications for the pumping station and lake. Once the design is complete and all permits granted, the town will pursue, via competitive bid, a contract to install the pump station and force mains. The project is funded in the Town of Hilton Head Island’s 1997-98 Capital Improvement Program Budget. The lake and pump station will be constructed first, followed by the highway 278 culvert. After that, Hilton Head Plantation will complete the recommended plantation improvements. Together, these complementary projects should solve the structural flooding in the Jarvis Creek Watershed.

In June, 1997 the town applied to the South Carolina National Flood Insurance Program Coordinator’s Office for a Flood Mitigation Assistance Project Grant for $800,000 to construct the Jarvis Creek Drainage Project. To be eligible the community must participate in the NFIP, have an approved Flood Hazard Mitigation Plan, and be able to meet the cost-share requirement. Hilton Head Island was able to meet these requirements. The project was confirmed as an eligible flood mitigation activity because it will prevent repetitive flood loss to insured structures and will not duplicate the flood prevention activities of other federal or state agencies. The cost-benefit analysis confirmed that the cost of construction was far exceeded by the cost of flood losses to the 447 residential and 39 commercial structures in the watershed. The project was technically feasible and conformed to all federal and state regulations. In October 1998 funding was confirmed at $256,050 from a South Carolina FMA grant, $520,000 from SCDOT, $3,026,600 from the Town of Hilton Head Island, and $475,000 from Hilton Head Plantation. Construction is in progress with completion scheduled for summer 1999.

References

Greer, Margaret
DEVELOPING SHORELINE RECESSION RATES FOR THE LAKE MICHIGAN COASTLINE

Mark Riebau
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Introduction

Recession of the Lake Michigan shoreline is related to both lake dynamics and upland processes. Wave action in the lake works to move sediment along the shoreline. Varying lake levels expose bluffed areas to direct wave attack during times of high water, while low lake levels uncover and widen beaches so that bluff erosion is temporarily halted. Often, many years are required for the shoreline to re-equilibrate to a new water level so erosion or accretionary effects may not coincide with the present lake conditions.

Geology and development of the shoreline also influence the shoreline recession process. Soil type determines the natural angle of repose and strength of the soil to resist erosion. Groundwater seeping from the side of the bluff can often cause slope failures even when the toe is not being eroded by waves. Surface water runoff, exacerbated by development, can cause bluff edge failures. Erosion control measures placed at the toe of a bluff slope can decrease the recession rate locally while accelerating the rate on adjacent shorelines.

Ideally, the recession of the shoreline should be correlated with the physical processes in order to best describe the shoreline change. However, it is not realistic to allocate portions of the recession to the different physical processes. The only available data is the composite change to shoreline position based on historical records, which do not reveal the cause for recession.

*The Lake Michigan Recession Rate Study was funded by the Wisconsin Department of Administration, Office of Wisconsin Coastal Management Program; Oscar Herrera, Chief*
The approach used to develop recession rates for 30 miles of the Wisconsin shoreline relied on the historical recession rate evidence and avoided use of variable physical factors such as type of failure, variable water level, and geologic formations. Reference and control lines for measuring the recession, and the calculation method employed to determine the rate were selected to be insensitive to these variable physical factors.

All pertinent data were incorporated into a geographic information system (GIS) database compatible with State of Wisconsin computer software. The GIS database includes, in addition to digital orthophotographs of both the most recent (1992 or 1995) aerial photography and the oldest (1952 or 1956) aerial photographs, Digital Elevation Model (DEM), Inventory of Development (IOD), Baseline and Transects, major roads, political subdivisions, 30-year Recession Line, and 60-year Recession Line.

Methodology

The methodology employed in this study is unique, if not unprecedented. Most studies of coastline recession rely on manual interpretation of aerial photographs, but seldom use stereographic pairs. In bluff shoreline areas this study employed automated photogrammatic analysis of stereographic pairs, spatially located in Wisconsin State Plane Coordinates to develop elevation contours. The translation of these contours was then measured using automated computer techniques to develop recession rate relationships. By employing stereographic pairs of photographs, rather than monographic coverage, and measuring the recession of the shoreline at predetermined elevations, errors in photointerpretation were minimized. Use of stereographic aerial photography aids in the clear definition of the top of bluff, toe of bluff, slopes, and makes it possible to define a mid-bluff contour.

To project the recession into the future, past studies conducted by the University of Wisconsin for the Southeast Wisconsin Regional Planning Commission (SEWRPC) were used to determine the stable bluff angle of repose. After the toe of bluff was projected 30 and 60-years in the future, using recession rates from mid-bluff mapping, the stable bluff angle was used to calculate the location of "top of bluff" for each future condition or time frame.

Data Processing

Mapping of the shoreline recession utilized repeatable reference features as erosion indicators. For this study, three reference features were used to assess and map erosion rates. For the majority of the
coastlines, the mid-bluff contour was selected to measure the erosion process. This reference feature was computer-generated from DEMs and lends itself to automated computation and repeatability since no operator interpretation is required to define and locate the feature.

The mid-bluff contour, a point approximately half way between the top and toe of the bluff, is the least sensitive to water-surface fluctuations and is generally the most stable point on a slope during erosion. The mid-bluff contour is generally below the portion of the bluff that slumps downward, but above the associated debris pile. Therefore, its retreat rate should be more constant and less episodic. Because the contour approach does not involve manual determination of a line, which has additive mapping errors due to both human subjectivity in defining a reference position, it is inherently more accurate.

In areas along the coast where vertical relief was small, the stable vegetation line was manually mapped as the reference feature to assess the erosion rates. The vegetation line was identified from the aerial photographs and digitized into the digital elevation model. The last reference features used to map the erosion rates were the break lines, or changes in slope. These included the top of bluff and toe of bluff. These points were not used to calculate the erosion rates, but provided physical features for reference in mapping.

Rate Analyses
Shoreline recession, particularly on bluffed shorelines or shorelines that experience large long-term variations in water level, tends to occur in discrete steps, rather than a smooth continuous process. This is due, in large part, to geotechnical considerations and episodic storm events. To develop a reliable recession rate requires a sufficiently long sampling interval, and a number of recession measurements to encompass and incorporate these episodic events into an equivalent continuous rate.

Calculation of average annual shoreline recession rates for a particular location requires two decisions: 1) selection of an appropriate portion of the historic shoreline record for analysis, tempered by the availability of suitable stereographic aerial photography; and 2) employment of appropriate analysis method(s). Note that the period of record and method(s) employed at one location may not be appropriate for another location. The calculation of shoreline recession rates may be highly site specific, especially in situations where significant spatial and temporal variations in shoreline position exist in the historic record.

For this analysis, the maximum available data set used five historic measurements of shoreline position spanning a period of 40 years in Manitowoc County and 39 years each in Racine and Ozaukee counties.
Calculations were made at 200-foot intervals over the entire 30 miles of shoreline studied.

Recession Rate Calculation Methodologies

The calculation of the rate can be performed using several different techniques, each with particular application given certain conditions. Initial review of mapped shorelines for the study areas revealed most of the shorelines have been receding since the early 1950s, and mostly in a linear or nearly linear fashion. The review made clear that some methods would not be appropriate for this study—the Maxima and Minima Trend method (lack of cyclic shoreline behavior in the record); the Minimum Description Length method (overly complex for the length of record and nature of shoreline behavior observed); Non-Linear Regression method (general linear trends observed, with lack of cyclic shoreline variation).

Hence, four methods were used to calculate recession rates for each station in the study area: the end-point method, ordinary least squares (OLS) regression, the Average of Rates (AOR) method, and the Jackknife method. The Jackknife method makes use of all combinations of linear regression by omitting one data point during each calculation. A comparison of the results obtained from the four methods demonstrates their similarity—a reflection of linear trends in this region, which was generally repeated in other regions as well. Given this tendency the end-point method became the principal method for calculating recession rates. The OLS method was selected as a secondary method to provide rate selection guidance in areas where shoreline histories deviate from linear trends.

Recession Rate Screening and Smoothing

Once end-point recession rates were calculated for each station, longshore variations in rates were examined, particularly those situations where significant rate variations existed between adjacent stations. Such variations usually indicate one or more of the following: actual shoreline behavior resulting from non-uniform shoreline movements; actual shoreline behavior near a shoreline discontinuity (harbor entrance, cape, termination of a long seawall or revetment, etc.), false results attributable to the presence of drainage features or other confounding influences; mapping errors. With few exceptions (usually attributable to shoreline discontinuities) these large variations in rates between adjacent stations cannot be sustained through time and must be removed from the data set. Thus, rate outliers were removed and interpolated rates were substituted at selected stations.
The next step in the calculation of final recession rates was to smooth individual rates using a 13-point optimal smoothing function. The smoothing process removes small-scale variations in recession rates that may be the result of any of the factors described above. Smoothing preserves meaningful longshore trends in recession rates, eliminates small-scale variations, includes shoreline stabilization effects afforded by structures, and results in orderly estimates of setback distances—the technique reflects the nature of the dominant physical processes controlling shoreline recession and advance. The smoothed recession rate line preserves large-scale longshore variations while reducing small-scale variations. The smoothed rates were used to calculate 30-year and 60-year recession line locations.

**Calculated Recession Rates**

The smoothed, and unsmoothed, recession rates for Manitowoc, Ozaukee and Racine Counties are:

**Manitowoc County**—Recession rates (smoothed) range from a maximum of approximately 3.5 ft/yr near the north county line to 0.0 ft/yr at the Point Beach Power Station (due to the presence of the shore protection at the plant). There appear to be some accretional reaches in the dunes area.

**Ozaukee County**—Recession rates (smoothed) between the south county line and a point approximately 3.8 miles north of the south county line, fluctuate between 0.1 and 0.6 ft/yr. From that point north to the north limit of the 10-mile study area, recession rates tend to fluctuate between 0.3 ft/yr and 1.3 ft/yr.

**Racine County**—Racine County was divided into 2-subreaches; the northern 8 miles and the southern 2 miles of the county. The segment between these two subreaches is all within the boundaries of the City of Racine and is heavily armored. Recession rates range from 5.5 ft/yr to 0.0 ft/yr in the northern study area. The southern study area extends from the south county line to a point approximately 2.0 miles to the north of the county line. Recession rates in this region fluctuate between 1.0 ft/yr and -0.5 ft/yr (accretional).

It should be pointed out that the final (i.e., smoothed) rates calculated in this study sometimes differ significantly from rates calculated in previous studies. However, the rates calculated during the present study are believed to be more representative of actual shoreline trends during the past 40 years, and provide improved rates with which to forecast future shoreline positions.
Recession Line
The 30 and 60-year recession distances calculated using mid-bluff recession rates form the basis for projecting future bluff edge locations, but reflect only what is occurring at mid-bluff. To relate these values to a physical recession line or set back, the topography of the site and the geotechnical stability of the bluff must also be factored. Mickelson et al. (1977) studied the stability of the bluffs along Lake Michigan and determined that the soil properties result in a stable slope angle of 22 degrees. To locate the recession line, the toe of bluff break line was recessed the 30- or 60-year amount, then a stable bluff slope was extended upward until it intersected with the top of bluff, defining the recession line.

Mapping of the projected recession line assumed a recession rate of zero in instances where long, substantial shore protection structures existed. Mapping of the projected recession line behind short segments of armored shoreline produced a non-zero erosion rate value due to the smoothing process. This a realistic outcome reflecting, in the long term, lateral flanking of the armor and geotechnical instability of the bluff behind the armor in the shore parallel direction.

Discussion
The present study is predicated upon several important assumptions:

(1) The 39-40 year study period, which includes record lake levels in the 1980s, will yield recession rates that are representative of rates that can be expected in the near term and should yield realistic projections of shorelines 30 years into the future. Extrapolation of calculated and smoothed recession rates 60 years into the future will result in greater uncertainty, but should provide better estimates than previous studies.

(2) Recession rates calculated in the present study reflect the presence and influence of shore protection structures. In other words, shore protection structures that slowed or halted shoreline recession during the study period resulted in recession rates lower than rates that would have been observed had the structures not been built. Projection of calculated recession rates into the future therefore assume the shore protection structures will remain intact and functional. If shore protection structures cease to function, either because they are destroyed during a storm or because property owners fail to maintain them, future shoreline recession can be expected to exceed that predicted from this study. Property owners
and government agencies should take this into account when development decisions are made.

(3) A 22-degree stable slope angle was used to project stable bluff positions throughout the study areas. However, local geology may vary, resulting in steeper or milder stable slopes and greater or lesser stable slope distances (and setbacks). While the consequence of local variations in stable slope angle will not be great in low relief areas, it may be significant in high bluff areas. Property owners and government agencies should take any more detailed geologic information into account when development decisions are made.

The accuracy of recession rates were calculated. Calculations show the recession rates for Racine and Ozaukee counties (0.16 ft/yr) are slightly more accurate than the rates calculated for northern Manitowoc County (0.26 ft/yr) due to the difference in photography scales. Rates calculated in the southern portion of Manitowoc County (0.72 ft/yr), the dunes area, are slightly less accurate than other study areas due to the fact that manual interpretation of vegetation lines was required in areas without bluffs. Nevertheless, the resulting rates calculated for all counties achieve precision of +/- 1 ft/yr.

Conclusions

The use of stereographic aerial photography increased accuracy of the calculated recession rates, as did the determination of the mid-bluff contour, which would not have been possible without the use of stereographic pairs. Calculation of recession rates at 200-foot intervals provided a great deal of detail for the study, but increased both the time and the costs. The incorporation of digital orthophotographs of both the most recent and eldest to depict the movement of the shore that has been affected provide a valuable tool for explaining the impact of the natural processes to the general public. The use of several methods for the calculation of recession rates is important to verify and provides confidence in the rates used to predict future top of bluff position.

References

LUCAS VS. SOUTH CAROLINA
COASTAL COUNCIL, REVISITED

Christopher P. Jones
Christopher P. Jones & Associates

Debra L. Hernandez and William C. Eiser
South Carolina Office of Ocean and Coastal Resource Management

Introduction
The General Assembly of the State of South Carolina passed its Beachfront Management Act in 1988, establishing lines of state jurisdiction and prohibition for construction along ocean shorelines. The lines at the eastern end of Isle of Palms, South Carolina, were drawn landward of two oceanfront lots owned by David Lucas, effectively prohibiting construction on the lots. Shortly thereafter, David Lucas filed suit against the South Carolina Coastal Council (SCCC—now the Office of Ocean and Coastal Resource Management (OCRM)) over provisions of the Act that prevented him from constructing houses on the two lots. Ultimately, Lucas prevailed and the state purchased the lots from him for approximately $1.7 million in 1993 (a similar suit by a nearby property owner was dropped when the state amended its Beachfront Management Act in 1990 to allow construction on the lots).

The story does not end there, however. The state resold the two lots in 1994 (with explicit conditions on the rights of purchasers to build), and a house was constructed on one of the lots in 1994. That house—and several others in the area—have recently been undermined by erosion, resulting in two other suits against the state (see the chronology of events that follows).

Much has been written about the Lucas decision. However, little has been written about the technical justification for the establishment of the baseline in the area, or about subsequent shoreline changes and legal challenges. This paper will (1) review the original foundation and rationale for the establishment of the state's construction setback along the Isle of Palms, (2) summarize shoreline and inlet changes over the past 10 years, which have caused additional property and structures to be threatened by erosion, (3) describe recent challenges to the state's
prohibition on erosion control devices, and (4) provide technical and policy guidance regarding siting and construction in coastal areas adjacent to tidal inlets.

**Chronology of Events**

1944-1977: Subsequent analysis shows at least part of the lots Lucas would buy were on the active beach during the periods 1944-1952 and 1958-1977; the entire lots were on the beach during 1963-1970

Mar 1975: South Carolina Sea Grant published a beach erosion inventory for Charleston County, showing historic shorelines and listing the area where Lucas would purchase lots as "unstable"

1976: Construction began on the Wild Dunes development at the east end of Isle of Palms

1982: Wild Dunes development initiated a beach profile and shoreline monitoring program (as a result of shoreline fluctuations and localized erosion)

1984: The National Oceanic and Atmospheric Administration and U.S. Army Corps of Engineers published historic shoreline change maps for the area

1984: Wild Dunes development produced a brochure for property owners, describing 1982–83 shoreline changes (resulting from an inlet shoal attachment) and erosion control measures undertaken

Aug 1985: Kana and others published a paper documenting 1982–84 shoreline changes and erosion control measures at Wild Dunes (beach scraping, sand bagging, artificial seaweed, rock revetment, and beach nourishment)

Dec 1986: David Lucas purchased two oceanfront lots on Beachwood East at Wild Dunes

May 1987: Williams and Kana published a paper describing a second shoal attachment (1986–87) and associated erosion at Wild Dunes

June 1988: South Carolina Coastal Council adopted "interim" lines of jurisdiction (baseline, no-construction line, and 40-year setback line) landward of Lucas' lots

July 1988: South Carolina Beachfront Management Act became law

Jan 1989: Lucas suit against state initiated

Nov 1989: Suit by Curry against state heard (same grounds as Lucas)

July 1990: State amended Beachfront Management Act, allowing construction seaward of the baseline
July 1990: Curry suit against state dropped
July 1991: State adopted final baseline and setback line for Isle of Palms
Nov 1992: Conclusion of Lucas suit; state ordered to pay damages
July 1993: State paid Lucas $1.7 million ($0.9 million for land and $0.8 million for fees and interest) for his two oceanfront lots
Feb 1994: State resold two oceanfront lots formerly owned by Lucas
Fall 1994: House constructed on western lot formerly owned by Lucas
Fall 1995: Erosion threatens five properties 0.1 miles east of lots formerly owned by Lucas; sandbagging, sand scraping, and beach nourishment with upland fill begin
Jan 1996: Suit against state by five oceanfront property owners (*Jerozal et al.* vs. *OCRM*) over state prohibition on erosion control devices
Nov 1996: Court found in favor of state in *Jerozal vs. OCRM*
1995-1996: Between January 1995 and January 1996, three homes on Summer Dunes Lane (0.8 miles east of lots formerly owned by Lucas) constructed immediately landward of setback line
Fall 1996: Erosion undermines home built on former Lucas lot, adjacent house, and three homes on Summer Dunes Lane; sandbagging, sand scraping, and beach nourishment with upland fill begin
July 1997: Suit by three property owners at Summer Dunes Lane (*Heritage et al.* vs. *OCRM*) over state prohibition on erosion control devices; houses standing on active beach
Apr 1998: Beach under and seaward of Summer Dunes Lane homes recovering; no decision from court on suit against *OCRM*

**Establishment of the Baseline and Setback Line**

The 1988 Beachfront Management Act called for the creation of regulatory lines along South Carolina’s ocean shoreline. These lines—a baseline, a no-construction line (20 feet landward of the baseline), and a 40-year setback line—were established as interim lines by the South Carolina Coastal Council in June 1988 (the final baseline and setback line were adopted three years later) based on a statewide study of local coastal processes, inlet dynamics and historic shorelines (Jones et al., 1988). The Act prohibited any construction seaward of the no-construction line.

The east end of Isle of Palms was classified as an unstabilized inlet erosion zone, and the baseline was established on the most landward shoreline (line of stable vegetation) over the preceding 40 years. At Beachwood East, the most landward shoreline was the 1963 shoreline, which was landward of the oceanfront lots owned by David Lucas. At
Summer Dunes Lane (approximately 0.8 miles east of the lots owned by Lucas, and the site of another legal challenge), the most landward shoreline used to establish the baseline was the 1984 shoreline; although the 1941 shoreline was approximately 70 feet farther landward, it was not used by the state since it was outside the 40-year window specified by the Beachfront Management Act.

The study for the SCCC (Jones et al., 1988) confirmed the findings of earlier studies (Stephen et al., 1975; Kana et al., 1985; Williams and Kana, 1987) that showed the shorelines at Beachwood East and Summer Dunes Lane were highly unstable due to the emergence, migration, and attachment of sand shoals from Dewees Inlet (with documented shoreline advance and recession of up to 400 feet in just a few years). Interestingly, a brochure prepared for Wild Dunes property owners by the developer (Wild Dunes Beach and Racquet Club, 1994) also documented the shoreline history of the area, including a discussion of erosion and shoreline fluctuations resulting from the 1982-83 shoal attachment.

The study for the SCCC also determined that the shoreline exhibited long-term accretion, based on historic shoreline data and on the nature of the shoal attachment process, whereby large quantities of sediment are periodically added to the island's littoral system. Thus, the setback line was established at the minimum distance from the baseline allowed by the Act, 20 feet, in recognition of the long-term accretional trend.

**Shoreline Changes Since 1988**

Not unexpectedly, the ocean shoreline along Wild Dunes has continued to fluctuate since the establishment of the first baseline and setback line in 1988. These fluctuations, like others before them, have resulted from inlet shoal migration and attachment. The latest shoal attachment episode began in 1995 and is not yet fully resolved at this writing (spring 1998). It has threatened or undermined approximately a dozen homes, including one built in 1994 on a lot formerly owned by Lucas, and three built during 1995 and 1996 at Summer Dunes Lane.

**Shoreline Changes along Beachwood East**

At the time the 1988 Beachfront Management Act was passed and Lucas filed his initial suit against the SCCC, the vegetation line was at its most-seaward known location in the previous 47 years (it was the point of attachment for an inlet shoal). Within nine years, however, erosion associated with a subsequent shoal attachment farther east caused the vegetation line along Beachwood East to shift approximately 200 feet landward. The 1997 location was the same as where the vegetation line had existed in the mid 1950s and early 1970s, and was
approximately 200 feet seaward of its 1968 location (the most landward known location since 1941). In other words, the 1997 shoreline that undermined two homes and threatened several others was near the midpoint of its historic excursions during the past 57 years. A review of the historic shorelines in the area shows that the vegetation line on the lots formerly owned by Lucas has been farther landward than its 1997 position over 40% of the time since 1941.

**Shoreline Changes at Summer Dunes Lane**

At the time the 1988 Beachfront Management Act was passed, the vegetation line at Summer Dunes Lane was approximately 150 feet seaward of the baseline and growing toward a point approximately 80 feet farther seaward, which it reached in 1993. However, by 1995 when the homes at Summer Dunes Lane were constructed, the shoreline had begun to erode as a result of a shoal attachment farther west (the same shoal attachment that caused recent erosion along Beachwood East). By 1997 the shoreline had eroded to a point 60 feet landward of the baseline and within approximately 30 feet of its most landward known position since 1941; recovery of the shoreline is slowly proceeding at present. The 1997 shoreline position was approximately 400 feet landward of the 1963 shoreline, the most seaward known shoreline position at Summer Dunes Lane in the past 57 years. Coincidentally, the 1963 shoreline was associated with a shoal attachment that might have been responsible for the most landward shoreline excursion at the Lucas lots on Beachwood East. A review of the historic shorelines at Summer Dunes Lane shows the vegetation line has been farther landward than its 1997 position only 12% of the time since 1941.

**Other Legal Challenges Since Lucas**

Within months after the Lucas case was heard, a second and similar case was argued over a nearby lot seaward of the baseline (Curry vs. SCCC). Like Lucas, Curry challenged the state's prohibition on construction seaward of the baseline; unlike Lucas, however, Curry dropped the challenge when the state amended the Beachfront Management Act to allow construction seaward of the baseline in limited circumstances.

The Curry property was subsequently purchased by Jerozal and became party to a 1995 challenge to the state's Beachfront Management Act (Jerozal et al. vs. OCRM). Five owners of oceanfront property immediately east of the former Lucas lots challenged the state's prohibition on erosion control devices and its 5-gallon size limit on sandbags used for emergency protection (the owners had received local approval to install 500-gallon
sandbags, later denied by OCRM). The Jerozal challenge was rejected by the circuit court, and the beach subsequently began to recover naturally.

In an administrative hearing in October 1997, the Summer Dunes Lane property owners (Heritage et al. vs. OCRM) challenged the state's claim to jurisdiction landward of the setback line and to the state's prohibition on erosion control devices. Like Jerozal, the property owners in Heritage had requested permission to install 500-gallon sand bags on the active beach seaward of their homes; the state had denied the request. At this time (April 1998) no order has been issued by the judge in the case, three piling-supported homes still stand on the active beach, and the shoreline is slowly recovering.

**Construction along Shorelines Subject to Inlet Effects**

The review of shoreline changes and shoreline management problems at the east end of Isle of Palms points to several conclusions. First, construction along an inlet-influenced shoreline—even one that is experiencing long-term accretion—is risky. The state's 1988 attempt to site new construction landward of the most landward shoreline in the past 40 years is clearly justified, given several recent examples of inlet-induced erosion threatening or undermining oceanfront structures. Second, the recent erosion at Summer Dunes Lane demonstrates that even building behind the most landward shoreline of the past 40 years does not eliminate the risk of erosion reaching a structure. Had the state been allowed to use shoreline data from the year 1941 when it established its baseline and setback line, the three houses now standing on the beach might still be on high ground, unaffected by the recent erosion. As future baseline and setback line revisions are made in South Carolina, the potential exists that other landward shorelines will be dropped from usable data sets, and other structures will be built in compliance with the lines but will be subject to future inlet-induced erosion. Finally, while the 1990 amendment to the Beachfront Management Act (allowing construction seaward of the baseline) eliminates takings claims similar to those made by Lucas, it ensures that many other structures will be threatened, and guarantees future challenges to the state's prohibition on erosion control devices. Clearly, property owners and governments faced with these fluctuating shorelines must develop better methods to identify and manage inlet hazard areas.
References


Part 5
Mapping: Program Issues, Applications, and New Technology
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COMPLEMENTING REMOTE SENSING SYSTEMS IN FLOOD MITIGATION AND PREPARATION

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U.S. Army Corps of Engineers Topographic Engineering Center

Stanford T. Hovey
Michael Baker Jr., Inc.

Background
As a result of experience with disasters in the 1990s, the Federal Emergency Management Agency (FEMA) has been directed by the U.S. Congress to place mitigation of future natural hazards as its highest priority in working with state and local governments. The National Flood Insurance Program (NFIP) and its related flood-risk studies and flood hazard mapping are increasingly important mitigation support functions. A current focus is on map modernization to speed up the flood mapping process, lower the cost, and increase the accuracy of the results. A further emphasis is on more mitigation support to the local areas as exemplified by Project Impact.

These initiatives by FEMA, when coupled with the National Mitigation Strategy and one of its objectives of applied research and technology transfer, has precipitated a heightened need to use existing and emerging remote sensing assets to the fullest. Since the information element of "elevation" is so critically important in many flood mitigation planning and preparation scenarios, the collection, processing and use of this set of multi-use information is of high priority. A parallel objective is to evolve a suite of remote sensing system options that can be used during a single flight pass to collect many types of data to be combined to support multi-hazard mitigation and rapid response needs.

The California Condition
In early 1997, the El Nino-related flooding threats were causing serious concern in the San Joaquin and Sacramento Valley areas of California. FEMA was requested to orient some of its flood mitigation efforts
towards producing more accurate elevation data to be used for water flow prediction analysis. Additionally, due to the U.S. Army Corps of Engineers’ downgrading of the levee reliability in the area around Lakewood, California, improved elevation information was needed to guide the evaluations of structures for flood insurance. In response, FEMA decided to employ Interferometric Synthetic Aperture Radar (IFSAR) and Light Detection and Ranging (LIDAR) collection systems to provide for these existing requirements. At the same time, FEMA would evaluate the possibility of these technologies being fused to satisfy the long-term map modernization effort by creating a technology that could be transferred to lower the cost of mapping elevations.

Remote Sensing Options

Over the past decade there has been a significant maturing of many remote sensing collection systems and related data processing subsystems. Many are candidates for full operational use. To evaluate these technologies, FEMA established a Remote Sensing and Emerging Technologies Evaluation Project for technology transfer for multi-hazard mitigation, preparation, response, and recovery—with the emphasis on map modernization at this time. The current, preliminary results from using IFSAR and LIDAR in California are part of this project.

IFSAR

This particular type remote sensing "tool" has emerged as a very useful option for producing elevation information over large geographic areas (entire valleys, counties, etc.). The digital elevation model (DEM) produced from this type system normally has an absolute vertical accuracy in the 1-2 meter range. One of the advantages of IFSAR is that many thousands of square miles can be collected in one day by a high-flying aircraft. One of the disadvantages is that the ground processing is fairly intense and takes significant computing resources to result in a quality-checked DEM within a few weeks.

In the early fall of 1997, a collection mission of IFSAR was accomplished over the central valley areas of California. FEMA transferred funds to the Corps of Engineers Topographic Engineering Center (TEC), which had a contract with the Environmental Research Institute of Michigan (ERIM) who developed IFSAR-Elevation (IFSAR-E) configuration for the mission. ERIM sub-contracted with Intermap to collect the IFSAR-E and produce DEM values at approximately 1.5 meters absolute vertical accuracy. The IFSAR-E and DEM information has been provided to California state government, TEC, and FEMA. It is under evaluation at this time.
LIDAR

This remote sensing technology has been evolving for a number of years. The resultant DEM requires coordinated processing of the laser-lighted ground-spot returns, the global positioning system (GPS) signals along the flight path, and the inertial navigation unit (INU) values at frequent, regular intervals to record the pitch, yaw, and roll components of the aircraft's motion (similar to the coordinated processing performed with IFSAR sensor systems). Processing techniques have been developed so that DEM results can be available within a few days and even a few hours after the time of collection. The relative vertical elevation accuracy of the DEM points are in the range of sub-foot values with absolute vertical accuracies between 1 and 2 feet. Currently, it is most beneficial to use LIDAR for small areas (a few kilometers square) or along extensive, narrow ground tracks where high detail elevation/height information is needed. As a result, LIDAR has historically been employed for obtaining elevation information along ocean coast, waterways, lake shorelines, levees, transmission lines, road networks, etc.

In the fall of 1997, FEMA coordinated with the National Aeronautics and Space Administration (NASA) Wallops Island Flight Test organization performing LIDAR collection along the Oregon and California coastlines. A 10-hour mission was flown by the NASA LIDAR in their fixed-wing aircraft over an extensive section of the levee network in the same central valley areas covered by the IFSAR-E a month earlier. This data has been processed by NASA and is now in the evaluation stage at the TEC. This evaluation will include combining the LIDAR and the IFSAR-E derived DEMs to further refine and attempt to improve the vertical accuracy of many of the IFSAR-E points, as well as provide very accurate elevations for many of the levee tops. A technique of "differencing" will be employed using the LIDAR values similar to how ground control is used in photogrammetric mapping to improve the vertical accuracy of the IFSAR-E derived DEM values near the levees, as well as provide very accurate elevations for the levee tops.

LIDAR and IFSAR-E data sets will be fused as follows: Step 1—Both DEM data sets will be imported into ARC/INFO as Triangulated Integrated Network (TIN) geographic data sets associated with reference control points. Step 2—The IFSAR-E DEM points in the LIDAR regions will be extracted and the differences calculated between them and remaining IFSAR-E DEM points outside the LIDAR regions. Step 3—LIDAR DEM corrections will be applied to IFSAR-E DEM data by calculating the difference between the elevation of the IFSAR-E points and the LIDAR points within the LIDAR boundary areas and applying the difference to all the IFSAR-E points outside the LIDAR
boundary areas. Step 4—Actual data fusion will be performed by generating a TIN file for the mean value of the DEM points and a separate TIN file for the median values. Step 5—The RMS and standard errors of the mean and median values in the overlap areas will then be used to establish the expected accuracy of the DEM data fusing procedure. Step 6—Products will be bare-earth DEMs, DEMs including structures, an overlay of the Letter of Map Revisions (LOMRs) with the structures, and a statistical analysis of the differences between the structures' annotated elevation and the LOMR elevation. Results of this evaluation should be available in the summer of 1998.

A set of LIDAR collections will soon be completed over the currently flood mapped AR Zone near Lakewood, California. The thrust of this series of tasks is to obtain LIDAR collections from a number of LIDAR system configurations (3-4), process the data for DEM and other structure-related locations and heights relative to the topography, and evaluate the results for production operations in the future. This set of LIDAR evaluations will allow a comparison of cost and accuracy for various LIDAR systems, and a determination of how the use of LIDAR can support determining the lowest adjacent grades for structures potentially in flood risk areas. Results from this evaluation should be available in the late summer of 1998.

Summary Considerations

Since time responsiveness, cost reductions, and useability are all key considerations for map modernization planning at FEMA, these considerations provide the basic guidelines for the evaluations of the candidate remote sensing systems. Acquisition factors, processing steps, and the product formats all play important roles in whether a particular remote sensor system or combination of systems should be used or not.

Because DEM information is the objective of IFSAR and LIDAR collections and that particular data element has such pervasive benefits in multi-hazard mitigation—especially flood mapping—these systems warrant concentrated evaluation efforts to establish how to operationally use them at this time. One of the future objectives to which these systems are likely to contribute is the configuration of a single-pass, multiple-use collection capability that can both assist with mitigation and rapid damage assessment requirements. Terrain elevation, structure characteristics, soil permeability, ground cover categorization, and infrastructure conditions may all be derived from one overflight with the proper combination of multi-sensors as they become more miniaturized and less expensive.
Introduction

Flood damage is a significant problem in Lake County, Illinois. The county’s gently rolling to flat topography and an abundance of surface water resources predispose residents to flooding. A high rate of development (and increased run-off) has exacerbated flood damage in recent years. The county’s vulnerability to flood damage became obvious with the floods of 1982, 1986, 1987, 1993, and most recently in the floods of May 1996 and February 1997. Since 1982, Lake County has experienced a level of flood damage that has prompted six state and three federal disaster declarations (Illinois Emergency Management Agency, 1997).

Lake County is a suburban county, strategically placed between Milwaukee and Chicago, and as a result has experienced rapid increases in population and development recently. Lake County is expected to continue to develop, with a population increase of 53% (272,424) and a corresponding household increase of 64% (110,524) projected between 1990 and 2020 (Northeastern Illinois Planning Commission, 1997). Without significant flood hazard mitigation, flood damage and public health risks will increase, based on these development projections. In response to this concern, the Lake County Stormwater Management Commission (SMC) is developing a comprehensive, county-wide flood hazard mitigation plan.

Flood Hazard Mitigation

The county’s need for a flood mitigation plan was apparent after the damage caused by recent floods. The significance of that damage is partially reflected in flood claims and damage reports submitted to the National Flood Insurance Program (NFIP), the Illinois Emergency Management Agency (IEMA) and Small Business Administration (SBA) (Table 1).

1 These forecast estimates represent the average of two regional forecast alternatives considered.
Table 1. Damage estimates and claims.

<table>
<thead>
<tr>
<th>Program/year</th>
<th>Number</th>
<th>Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFIP claims (thru 1996)</td>
<td>1,054</td>
<td>$5,137,248</td>
</tr>
<tr>
<td>IEMA (formerly IESDA) damage reports (1986 &amp; 1993)</td>
<td>1,746</td>
<td>$7,212,499</td>
</tr>
<tr>
<td>SBA verified damage (1993)</td>
<td>208</td>
<td>$3,464,900</td>
</tr>
</tbody>
</table>

Data from FEMA (1997), IEMA (1997), and SBA (1993).

Over $7 million in federal funds came into the county for flood mitigation as a result of the 1993 flood. Efforts to direct the funds to the best projects pointed out the need for prioritizing flood problem areas for mitigation. In response to this need, $60,000 of the post-disaster mitigation funds for the 1993 flood were earmarked for a flood problem areas inventory and to cost-share the development of the Lake County Flood Hazard Mitigation Plan.

Flood Problem Areas Inventory

The flood problem areas inventory was begun in 1995. Forms were developed to record information from municipalities, townships, and citizens (Figure 1). This audience-specific information was then consolidated to standardized flood mitigation "problem areas worksheets," which were used for internal recording and assessment. As problem sites were identified they were assigned to one of the county's 26 subwatersheds and given a watershed and sequence number known as the "Flood Problem I.D." number.

A resident input questionnaire ("problem area input form") was also developed and distributed through community associations to gather additional information on local flooding problems. These forms were added to the watershed and sequence numbering system, and the flood information collected was included in the master inventory. The flood problem area inventory (compiled from all information) was summarized in spreadsheet format to provide a quick reference and index of all the sites, and to allow for easy aggregation and analysis by watershed. The spreadsheet was also used to compare and associate flood problem areas with claim and damage report information from the NFIP, IEMA, and the SBA. All of the inventory and damage/claim information was then incorporated into a "master inventory spreadsheet."

The information collected for the inventory was largely anecdotal. It required significant community outreach and was compiled from
**LAKE COUNTY FLOOD HAZARD MITIGATION STUDY**

**PROBLEM AREAS WORKSHEET**

<table>
<thead>
<tr>
<th>DATE</th>
<th>CB#</th>
<th>Wirshd f-Seq. f-Structure f</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/14/95</td>
<td>10</td>
<td>60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BY WHOM</th>
<th>LCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>T - R - S - 1/4</td>
<td>45-9-18 - NW</td>
</tr>
</tbody>
</table>

**STUDY or CONTACT (Name, Title, Phone)**

<table>
<thead>
<tr>
<th>Name</th>
<th>Jurisdiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charles Smith</td>
<td>Lincoln Township</td>
</tr>
</tbody>
</table>

**LOCATION**

- S. of Flux Lake along RR track @ intersection of Maple @ Lakeview

**Property Owner**

<table>
<thead>
<tr>
<th>Name</th>
<th>Jurisdiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowland Subdivision</td>
<td>Lincoln Township</td>
</tr>
</tbody>
</table>

**Problem Description (Damage-Causing or Nuisance)**

- Low houses on Maple flood periodically. Showhill development contributes to flood. RE: Changed the drainage pattern — flood worse! (Septic or Sewer?)

**DAMAGE POTENTIAL (100-Year Flood)**

- Overbank (lake or river)
- Depressional
- Poor Drainage
- Sewer Backup

<table>
<thead>
<tr>
<th># &amp; Type of Buildings</th>
<th>Critical Facilities</th>
<th>Access, Highways, Bridges</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 residences</td>
<td>No</td>
<td>Maple + Lakeview flood frequently</td>
</tr>
</tbody>
</table>

**REGULATORY RESTRICTIONS**

<table>
<thead>
<tr>
<th>Floodway (elev.)</th>
<th>Floodplain (zone)</th>
<th>Flood Prone</th>
<th>Depressional</th>
<th>Wetlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE (partial)</td>
<td>AE (partial)</td>
<td>AE (partial)</td>
<td>AE (partial)</td>
<td>AE (partial)</td>
</tr>
</tbody>
</table>

**LAND USE**

<table>
<thead>
<tr>
<th>Current Zoning</th>
<th>Natural Features (prot. level)</th>
<th>Adjacent to Public Areas?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Natural Features</td>
<td>Natural Features</td>
</tr>
</tbody>
</table>

**HISTORICAL FLOOD DAMAGE (Confidential Information)**

<table>
<thead>
<tr>
<th>Month/Yr</th>
<th>Depth</th>
<th>Freq./Occur.</th>
<th># Bldgs.</th>
<th>$ Damage</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/6</td>
<td></td>
<td>20 homes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**100-YEAR FLOOD DATA**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Velocities</th>
<th>Warning Times</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PLANS FOR THE AREA**

- Flood Control Projects
  - Township plans to put in larger storm drains — will help
- Community/Neighborhood Plans
  - Flux Lake Assoc. controls lake level

**OTHER HAZARDS**

- Septic failure

**OTHER DATA SOURCES**

- Fix-it + Associates drainage study

*Figure 1. Sample problem areas worksheet.*
personal interviews and follow-up site inspections with municipalities, townships, county agencies, county board members, watershed management board members, and homeowner associations, as well as collecting information during public meetings. Flood problem areas were also identified as a result of individual phone and letter reports to SMC staff during and after subsequent floods.

A total of 339 flood problem areas were identified through this initial inventory. A flood problem area may refer to a single home, business, road location or bridge, but most problem areas include multiple structures subject to flood damage. In several cases whole subdivisions (up to 200 homes) are considered a single flood problem site. As they were identified in interviews, flood problem locations were manually marked on a map and followed up with a field inspection. (Some community representatives provided on-site inspections of problem areas during the interview process.) Field inspections included: verification of the problem area boundary; assessment of the flood problem including the primary and secondary sources of flooding; and identification of potential mitigation solutions suitable for each site. The information gathered during the field assessment was added to the problem areas spreadsheet.

Putting Flood Problem Areas on the Map

In order to map the inventory information, SMC utilized digital map data available from the Lake County Geographic Information System (GIS). "Base maps" were first plotted by township at a scale of 1"=1000' that included parcels, roads, surface water, watershed boundaries, and municipal boundaries. Problem sites were hand drawn on these working maps based on information provided during interviews and tagged with the flood problem I.D. number.

The hand drawn map areas were entered into the GIS via "heads-up" digitizing, that is, by drawing polygons on-screen referenced to the underlying digital base map data. Though parcel level data was available, the intent was not to identify individual parcels that flooded. Effort was made, however, to map the inventoried areas as accurately as possible given the level of information provided. In addition, the staff performed

2 A number of additional flood problem areas have been identified and recorded since the original inventory. A process to add these sites to update the inventory and mapping is being developed. There are currently over 400 sites recorded.
field checking for more than 300 of the initial mapped areas and refinements were made to the mapped polygons as needed.

Mapping was done with two goals in mind. First, to be able to produce a map set for reference and presentation purposes and second, to develop a GIS database. For thematic mapping purposes, the flood problem areas were color coded according to five types or sources of flooding: 1) overbanking of streams and lakes, 2) sanitary sewer backup or septic system failure, 3) local drainage blockages, or runoff exceeding local drainage capacity, 4) depressional storage flooding, and 5) flood-induced erosion. Many areas had more than one source or type of flooding. Any secondary or tertiary flood sources were indicated on the map by a color dot next to the I.D. number labeling the polygon.

The flood problem area I.D. number also serves as the link between the spatial location of the inventory areas and associated attribute information stored in the GIS. In this case the master inventory spreadsheet was converted to a GIS database. The significant information associated with each flood problem area that was collected as part of the inventory, which included addresses, FEMA repetitive loss listings, floodway/floodplain designations, and claim/damage costs, is included in the master inventory spreadsheet. Photographs of flood events may also be linked to a mapped problem area in the GIS database. The unique map sets and data stored within the GIS will prove useful to other county departments for various applications.

**Using the Flood Hazard Areas Maps**

The flood problem areas inventory, corresponding maps, and GIS database are the basis for the problem identification and action plan portions of the flood hazard mitigation plan. The inventory and maps are used for purposes other than flood hazard planning: 1) They are used by county permit staff when reviewing development proposals under the county-wide Watershed Development Ordinance; 2) The clear identification of flood problem areas has focused SMC and county department proposals for flood mitigation projects; 3) The Flood Hazard Mitigation Plan action recommendations and the flood hazard areas map layer are being incorporated into comprehensive watershed planning efforts throughout the county. In addition to their current uses, the maps will be distributed to each municipality, township, and other county and applicable state agencies for their individual uses after official county adoption of the Flood Hazard Mitigation Plan in 1998.
Summary

The flood problem areas inventory provides information in a standardized form for assessing the extent, frequency, and duration of flooding. The degree of flood damage is also considered through use of available information on damage and claim reports. This combined information provides decisionmakers with a tool for prioritizing flood damage sites for mitigation projects.

The flood problem areas inventory and assessment pointed out the need for flood problem site mapping. Forty-five percent of the 339 identified flood problem areas are not located within the 100-year floodplain boundaries mapped by FEMA on the dFIRMs. This points to the likelihood that a large number of the properties that sustain flood damage may not be adequately covered by flood insurance. The flood hazard areas maps can be a useful tool in conveying information to real estate agents and potential buyers, as well as existing property owners, of their potential flood risk.

Mapping flood problem areas in Lake County is anticipated to provide numerous benefits for flood hazard mitigation in Lake County. Maps provide quick and easy locational information and graphically represent the flood sources and concentration of flood problem areas by watershed, subwatershed, and political jurisdiction. The flood hazard areas maps will generate a greater awareness and use of flood damage information for planning, regulatory and property transfer purposes, serving as an integral tool for both promoting and determining the success of flood mitigation in Lake County.

References

Federal Emergency Management Agency
1997 FEMA WYO and Direct Data by State then County, for Illinois.

Illinois Emergency Management Agency

Lake County Department of Emergency Services Office of the Sheriff
1987 Damage Assessment Reports to Illinois Emergency Services and

Small Business Administration Area 2
1993 Disaster Assistance, Lake County Disaster Loan Approvals.

Northeastern Illinois Planning Commission
The goal of the National Flood Insurance Program (NFIP) is to maintain, for floodprone communities, accurate and up-to-date Flood Insurance Rate Maps (FIRMs) that (1) identify the floodprone areas within each community, (2) show information from which insurance rates can be derived, (3) show information to which the flooding information can be referenced, and (4) show information on which sound floodplain management can be based.

**National Flood Insurance Reform Act of 1994, Section 575**

To further the goal of the NFIP, Section 575 of the National Flood Insurance Reform Act of 1994 (NFIRA) mandated that:

(e) **REVIEW OF FLOOD MAPS.** —Once during each 5-year period (the 1st such period beginning on the date of enactment of the Riegle Community Development and Regulatory Improvement Act of 1994) or more often as the Director determines necessary, the Director shall assess the need to revise and update all floodplain areas and flood-risk zones identified, delineated, or established under this section, based on an analysis of all natural hazards affecting flood risks.

(f) **UPDATING FLOOD MAPS.** —The Director shall revise and update any floodplain areas and flood-risk zones—(1) upon the determination of the Director, according to the assessment under subsection (e), that revision and updating are necessary for the areas and zones; or (2) upon the request from any state or local government stating that specific floodplain areas or flood-risk zones in the State or
locality need revision or updating, if sufficient technical data justifying the request is submitted and the unit of government making the request agrees to provide funds in an amount determined by the Director, but which may not exceed 50 percent of the cost of carrying out the requested revision or update.

The Five-Year Map Update Task Force and the Map Needs Assessment Process

Even before the NFIRA was enacted, the Five-Year Map Update Task Force was formed in 1992. Members of the Task Force included FEMA Headquarters and Regional Staff, members of the Association of State Floodplain Managers (ASFPM) Engineering and Mapping Standards Committee, and FEMA’s Technical Evaluation Contractors (TEC), Dewberry & Davis and Michael Baker Jr., Inc. The Task Force developed a study plan for implementing the map update requirements of the National Flood Insurance, Mitigation, and Erosion Management Act of 1991, which became Section 575 of NFIRA. In addition, the Task Force developed a process for identifying map update and restudy needs, and prioritizing those needs against budgetary constraints. The process, outlined in the July 1994 report Federal Emergency Management Agency Mitigation Directorate: A Process for Identifying Map Update Needs for the National Flood Insurance Program, has three major components: (1) an initial screening of communities to identify all needs, (2) a verification process to determine whether the needs identified are valid, and (3) prioritization and ranking of the verified needs.

Screening Mapping Needs Data

The screening process distinguishes between map update needs brought about by changes in flood hazard information and those brought about by changes in reference information. Causes for changes in flood hazard information are generally as follows:

1) Development has occurred and, in order to effectively regulate floodplain development, a study or a change in study type is warranted. For example, a stream studied by approximate methods should now be studied via a detailed engineering analysis to specify base (1% annual chance) flood elevations (BFEs).

2) The floodplain and BFE information on the FIRM is accurate, but a floodway analysis is warranted.

3) The watershed or floodplain characteristics have changed, rendering the information shown on the effective FIRM obsolete. For
example, development in the watershed has caused an increase in runoff or a recent storm has created substantial beach erosion.

4) No significant change has occurred in the watershed or floodplain, but the information on the effective FIRM is incorrect. For example, a new publication from the U.S. Geological Survey supersedes an earlier publication used to determine the 1% annual chance flood discharge value, or flow measurements from a recent flood exceed the 1% annual chance value used to develop the FIRM, but high water marks were surveyed and are less than the 10% annual chance profile values.

Causes for changes in reference information include:
1) New development has occurred in an area that cannot be easily referenced to the existing base map information.
2) Historically, the FIRM has been difficult to interpret because the base map is inadequate or the corporate limits have changed significantly.
3) Elevation reference marks (ERMs) are no longer valid. For example, an ERM has moved vertically as a result of subsidence or frost heave, or an ERM no longer exists because of construction.
4) Few or no ERMs are shown on the FIRM.

Verifying Mapping Needs Data

The verifying process involves determining that, when met, the solution will provide a discernible change in information provided on the FIRM and that the need is an appropriate request for use of FEMA funding. A valid need is one that would result in a change that increases the completeness and accuracy of the flood hazard and/or reference information on the community’s FIRM. For example, adding roads in and near the floodplain would be a valid need whereas adding roads a half-mile away would not. The verification process will also determine how the need should be met. If the need would be more appropriately addressed by a revision under Part 65 of the NFIP regulations, it will be referred back to the community for processing. If a Part 65 revision is not the appropriate response, a more detailed investigation will be undertaken to establish the degree of change expected in the information provided by the FIRM.

Ranking Mapping Needs Data

Because over 19,000 communities have FIRM s and the NFIP mapping budget is finite, map update needs must be ranked and prioritized. Therefore, the process developed by the Task Force ranks communities
based on a need/benefit relationship. Need is measured by the degree to which the completeness and accuracy of the information on the FIRM would be improved by an update. For instance, a 2.0-foot increase in the BFE would be a greater need than a 0.8-foot increase. Similarly, a 1-square-mile change in the Special Flood Hazard Area would be a greater need than a 1-acre change. The screening process will link the need to the economic benefit. A 2.0-foot increase in the BFE in a floodplain that is largely pastureland and expected to remain so will have a lower priority than a 2.0-foot increase in a floodplain with development. However, if future development is expected, the highest priority of economic benefit will be given. This is because, with accurate maps, future construction will be required to conform to the limitations imposed by the flood hazards, and thus, damage to future construction will be limited primarily to those resulting from flooding more severe than the 1% annual chance flood.

A reliable ranking system depends upon accurate measurement of need and economic benefit. While the need (the extent of a change in flood hazard information) can be estimated before the study (and confirmed or not at the end of the study), the economic benefit is more elusive. To determine the economic benefit connected with future development in the floodplain requires projecting and then comparing how much development might take place with and without more accurate, detailed mapping. Similarly, more accurate mapping will have economic benefit for existing development in the floodplain, but quantifying that benefit is difficult. For the ranking process, approximations will be used for the two primary sources of economic benefits: growth and density. The approximation for growth will be based on the change in population between the two most recent decennial censuses and, for density, on the population-per-square-mile for the community. If more accurate site-specific information is available, it will be used.

Current Status of Efforts to Implement NFIRA

Although the NFIRA mandate has never been fully funded, we have established a goal to identify mapping needs by contacting every community in the NFIP by the end of calendar year 1998. Then, by September 1999, prepare and submit a report to Congress that outlines our process and summarizes our analyses of the results. The order in which we contact these communities is based upon a variety of data taken from sources such as: mapping priority lists and comments submitted by our Regional Offices, the Association of State Floodplain Managers, and the TECs, in-house mapping needs files, and oldest map
dates. In 1996 and 1997, we contacted 10% and 20% of the country, respectively. In the spring of 1998, we contacted an additional 35% of the country. Overall, we have contacted 65% of the communities in the NFIP. We are continuing to analyze the data as we receive it. Depending upon the results of our analysis for the 65%, we may contact the final 35% as early as fall 1998 or if warranted we will make adjustments to the process before contacting the remaining 35%.

To capture the collected data, we have developed a computerized system, the Map Needs Update Support System (MNUSS), which is based on the aforementioned July 1994 process report. MNUSS stores the inventory of map update needs and ranks the identified needs. Also, the data in the system provides a community-by-community assessment of funding which is needed to update the maps to show the current flood hazard and reference information. According to MNUSS, of the 30% of the communities contacted during 1996-97, nationwide 56% responded. Of this 56%, 91% stated that they had maintenance needs and/or restudy needs. Nine percent stated that they had no needs. There remain 44% of those contacted communities for which we have received no response. Currently, we are determining how we can further increase the number of community responses through more rigorous involvement of the FEMA Regions, State NFIP Coordinators, and the ASFPM. To date, the states have been involved through the ASFPM representation on the Five-Year Map Update Task Force, responses from the states to a letter and draft priority lists forwarded by FEMA requesting the states to comment and recommend alternative lists, and consultations between FEMA Regions and the states. Ultimately, we will establish a greater role for the states in the process, particularly with regard to data collection and analyses and access to MNUSS. As in the past, we will consult the states on the prioritizing of flood insurance study/restudy starts for each fiscal year. However, for the immediate future, the initial five-year cycle will continue to be managed primarily by FEMA due to the need to complete the process in accordance with the timeframe established by the law.

Challenges

Collecting update needs and supplementing data already entered into MNUSS to create a comprehensive inventory remains one of our challenges. Other challenges include: ongoing refinement of MNUSS to establish an accepted and accurate restudy prioritization tool; enhancing of MNUSS by integrating other components such as the Community Information System (CIS), geographic information systems (GIS),
disaster data, and flood insurance claims and repetitive loss data; obtaining funding for mapping commensurate with the identified needs; and integration of the five-year update process into FEMA's Map Modernization initiative. In order to meet these challenges, we welcome and encourage the ASFPM's continued support and commitment to achieve the common goal of providing communities with accurate, up-to-date and complete flood hazard data.
FEMA'S DIGITAL FLOOD INSURANCE RATE MAP DATA PLANS

Sue Hoegberg
Dewberry & Davis

Introduction

The Federal Emergency Management Agency (FEMA) currently publishes Digital Flood Insurance Rate Map (DFIRM) data in two formats: the Q3 Flood Data product and Digital Line Graphs (DLGs) made from the DFIRMs, also known as DFIRM-DLGs. As part of its Map Modernization efforts, FEMA is proposing to create two new DFIRM products: the DFIRM 2.0 and the DFIRM 2.1. This paper discusses how these new DFIRM products relate to the current DFIRM products and the new features that are planned.

FEMA's Current DFIRM Products

FEMA released the first edition of the Q3 Flood Data product in 1996. This was FEMA's first large scale release of digital data. Data covering almost 900 counties and over half of FEMA's inventory of paper maps were released at that time. The Q3 Flood Data product has been favorably received by users, and demand for additional data has grown. The data are being used by communities, counties, regional, and state agencies for planning purposes. In addition, the private sector has developed products and tools that rely on the flood hazard information provided in the Q3 Flood Data files. Several states, including Georgia and Maryland, have embarked on initiatives to complete state-wide Q3 Flood Data for their states. Since 1996, 383 additional counties have been digitized by FEMA's contractors, primarily in response to Presidential disaster declarations, and a release of these new data is planned for the summer of 1998.

While the release of the Q3 Flood Data product was an important first step, the product has some limitations. These include a limited data content (no elevation information), no accompanying base map, no legal standing (the user must still refer to the paper map for determinations), and the necessity that the user purchase geographic information system (GIS) software.
In addition to the Q3 Flood Data product, FEMA has prepared and distributed a limited number of DFIRM-DLGs. These files accompany a paper FIRM created using digital technology. DFIRM-DLGs contain more data features than the Q3 Flood Data product, including elevation information and cross sections. However, the DLG file format has proven to be confusing to some users. FEMA currently distributes only the thematic floodplain data layers, not the base map data. Base map data in digital format are used to create the paper maps but are not distributed with the DFIRM-DLGs; therefore, the digital files alone have no legal standing for making flood insurance determinations.

Map Modernization

As part of the review proposed by FEMA's modernization of the mapping program, FEMA plans to classify communities in one of four ways regarding their mapping needs: (1) those that require map updates, (2) those that require map maintenance, (3) those that require no revisions, and (4) those that are floodprone but are not presently mapped. Map maintenance needs typically affect base information, such as roads, road names, streamline locations, and community boundaries. Because the accuracy and currency of the base information directly impacts all flood zone assessments based on the FIRMs, the maintenance of these features is crucial. Map update needs are typically necessitated by changes to the physical conditions within a watershed, increased flood insurance rating and floodplain management requirements as a result of new development, development of improved study and mapping methods, and the availability of more detailed or up-to-date information (such as historical flood data).

FEMA is currently surveying communities to assess their mapping needs, and two new DFIRM products are planned to address these needs. The DFIRM 2.0 product is planned for the estimated 40,000 map panels that have adequate floodplain mapping but require map maintenance to improve outdated base maps. Map maintenance updates will include new roads, road names, and changes to community boundaries. The DFIRM 2.1 product is planned for the estimated 25,000 map panels that require map updates as well as the estimated 13,700 new panels required to map the estimated 2,740 unmapped floodprone communities.

During the development of the Map Modernization plan, FEMA reached out to its FIRM user community for input. The development of the two new DFIRM products, DFIRM 2.0 and 2.1, will also be done with input from the user community as prototypes and specifications are developed.
DFIRM 2.0

As envisioned, the DFIRM 2.0 product will build upon the strengths of the Q3 Flood Data, with the addition of features that will allow it to serve as the regulatory document. These features include base flood elevations, cross sections, and most importantly, the base map. FEMA plans to develop a list of base map options that meet the DFIRM accuracy requirements and can be freely distributed to the public. Among the base map options to be investigated more fully are the following public domain data from the U.S. Geological Survey (USGS):

- Digital Orthophoto Quarter Quads (DOQs);
- Digital Raster Graphic (DRG) files, which are scanned images of topographic quadrangles; and
- Vector-based DLG files.

The use of new base map data sources, especially the raster based products, will necessitate changes to the look and feel of the DFIRM 2.0. The use of color and/or distinctive area patterns have been suggested as ways to better distinguish features and reduce the time-consuming procedure of labeling every map element. Prototype maps showing the best of these various options will be developed and evaluated. The evaluations will include user issues, such as ease of use and legibility. Additionally, printing issues, such as cost and publish-on-demand feasibility, will be examined.

The DFIRM 2.0 database will be designed to be readily expandable to the DFIRM 2.1 product. Thus, as the data are captured or processed, additional attribute items will be added for future input of data. Features currently shown on FIRMs and DFIRMs but not currently included in the DFIRM-DLG database will also be added. These include Letters of Map Change outlines, map scale, map size, bridges, and culverts.

In addition to the new map features, the DFIRM 2.0 data format will be designed to be more user friendly than that of the DFIRM-DLG. The formats being considered include MapInfo, ARC/INFO, ArcView, and the new Spatial Data Transfer Standards (SDTS) that all federal government agencies are required to support. Internet distribution will also be factored into the equation. DOQ base maps may make the DFIRM 2.0 files too large for Internet distribution with reasonable download times, so other options will need to be explored.
DFIRM 2.1

The DFIRM 2.1 product will build upon the DFIRM 2.0 as new floodplain analyses are conducted. As with the DFIRM 2.0, the digital product will serve as the regulatory document. The base map needs will be similar to those of DFIRM 2.0, and the same graphic output options, such as the use of color, will apply; therefore, the look of the DFIRM 2.0 and 2.1 will be similar.

New features that will be added to the DFIRM 2.1 include cross section nodes, study reaches, and additional database attributes. The expansion of the database attributes will allow for the integration of the hydrologic and hydraulic modeling data with the mapping data to create a more interactive map product. In addition, the database will be expandable to allow for the future inclusion of new features or additional hazard analyses.

An example of how the new database will provide additional information is that bridges would be identified not just with a symbol, but also with attributes such as their stationing and information about their opening shape, wingwalls, piers, and embankments. An optional attribute would be a photo identification number that would allow a digital image of the bridge to be viewed. This or similar information will be stored and can be accessed for other map features, such as culverts, drop structures, dams, and weirs.

For features maintained by other federal agencies, such as bench marks and stream gages, the attributes would include that agency's identifier so that direct access through the Internet of the ancillary information would be facilitated. For example, adding the USGS identification number to the stream gage would allow a user to look up peak discharge or daily stream flow at that station directly from the USGS Internet site. Adding the National Geodetic Survey's identification number to a bench mark used as an elevation reference mark would serve the same function. Similarly, for features for which separate inventories are kept (such as the Department of Transportation's National Inventory of Bridges and FEMA's National Inventory of Dams), the inventory identification number would be included. Users thus can access the additional data directly from another CD-ROM.

The integration of the hydrologic and hydraulic modeling data into the map would allow a user to generate a cross section of the stream or a profile from the data at hand. This would reduce the need to reference multiple data sources to answer frequently asked queries. In addition, the inclusion of study reaches and stationing numbers will facilitate cross references to the backup Flood Insurance Study data that FEMA currently archives separately on CD-ROM.
The DFIRM 2.1 product will allow the mapping database to act as the linkage between the spatial map features and other relevant information that may or may not be maintained by FEMA. Figure 1 illustrates how the DFIRM 2.1 will tie together these different elements.

![Diagram of DFIRM 2.1 elements](image)

*Figure 1. Elements linked by the DFIRM 2.1 product.*

**Conclusion**

FEMA is looking toward the future with the development of the two new DFIRM data products, DFIRM 2.0 and DFIRM 2.1. Both products will serve to improve FEMA's internal use of its digital data holdings as well as better serve the needs of its data users. Community officials, state and regional planners, study contractors, local engineers, developers, map readers, and map determination companies will all be better served by these new data products.
UPDATING FLOOD INUNDATION MAPS EFFICIENTLY WITH A GEOGRAPHIC INFORMATION SYSTEM

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Background

Existing flood maps, mostly produced around 1980

- are based on flood likelihood estimates that in many cases are now out of date;
- were often hand-drawn on paper maps that were of limited accuracy or poorly registered in real-world coordinate systems;
- used elevation data that have been or will be superseded in the next decade by more accurate data in many places; and
- are too expensive to update as often as necessary.

Updates using geographic information systems (GIS) and modern high-accuracy digital elevation data

- cost about 10-20% of the cost of a re-study using the original procedures in our pilot in Washington state;
- are as accurate and more detailed than existing maps;
- provide depth-of-flood details as a by-product;
- can identify areas where uncertainty in elevations (flood or land) causes uncertainty in flood extent; and
- are easily incorporated with other GIS data for various analyses.

Need For New Flood Maps and an Efficient Mapping Method

Current Maps are Out of Date

Most of the existing flood inundation maps produced under the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) were prepared in the late 1970s and early 1980s. For several reasons, many of those maps are out of date. For many rivers, updates are needed to the estimates of streamflow associated with a 1%-chance flood (also called the 100-year recurrence interval flood), which is the standard, or "base flood," for the determination of inundation areas in NFIP Flood Insurance Studies. (Recurrence interval and
percent-chance likelihood are comparable terms—the use of "recurrence interval" is minimized here because of the tendency for people to assume a 100-year recurrence interval flood occurs only once in 100 years.) Typically, the original estimate was calculated using annual peak stream flows for only a few decades; the additional peak flow data now available provide a more accurate estimate. For example, the original estimate of the 1%-chance flood for our pilot river, the Nisqually River near Olympia, Washington, was 33,000 cubic feet per second (cfs), while the revised estimate is 40,000 cfs.

**Complete Re-studies Cost Too Much**

Largely due to the burdens of flow modeling and surveying cross-section elevations, complete re-studies are very expensive and available funds are sufficient for only a handful per year. Hundreds of maps need updating, but at the current rate of revision the average time between updates is proving inadequate in many cases.

**Most Maps Used Elevation Data of Varying Detail and Accuracy**

Many of the inundation maps produced in the 1970s used elevation data that are inferior to high accuracy data sets that are available now, or will be in most developed areas in the next decade. Local governments are developing elevation data with accuracy estimates on the order of 1 foot, whereas older maps, such as the U.S. Geological Survey (USGS) 7.5-minute quad maps, are only accurate to one-half contour interval (usually 20 feet). While many of the hydraulic models used in the older maps used relatively accurate elevation data for floodplain elevation cross-sections, such as photogrammetrically derived 5-foot contour maps or on-the-ground surveys, inundation areas were frequently mapped using lower accuracy maps. Consequently, the accuracy of the resulting inundation maps is highly variable.

Elevation data now or soon to be available are more accurate than many on-the-ground survey data due to lack of horizontal control available for some surveys. These new data are expensive to produce—about $1,000 per square mile; however, because local governments need these data for a variety of reasons, many have already acquired them. As the cost decreases and the usefulness of the data becomes more apparent, these data will become commonly available, likely including most developed areas in the next decade.
Inundation Maps for Supplemental Flood Levels are Needed

Many government agencies, particularly local agencies, need flood inundation maps for other than the 1%- or 0.2%-chance floods (100-year or 500-year floods). Decisions regarding land use planning and the acquisition of high-risk properties are better guided by maps of more likely flood levels, such as the 4%-chance or 25-year flood.

GIS and High-Accuracy Digital Elevation Data Provide An Efficient Way To Revise Flood Maps

A GIS can be used to greatly reduce the cost and time required to produce flood maps by streamlining the most expensive and time-consuming steps of flood delineation. The savings come from building on the results from previous studies' flow modeling and from using the GIS to do the actual delineation of inundated areas at different flood levels. The resulting maps are more accurate and detailed, include depth information, and can be incorporated with other digital GIS maps like property locations and values for assessment of potential flood damage.

Building on Existing Studies

Updating the streamflow estimate for a selected flood likelihood is comparatively simple and quick, and is the same for both the traditional and the GIS methods. The most tedious and time-consuming steps of producing flood inundation maps using the traditional method are the determination of the flood elevation profile (the elevation of a flood along the length of the stream) using a hydraulic model and the delineation of the inundation area associated with that flood profile. The GIS method produces updated flood profiles either by using an existing hydraulic model, or by interpolating from the flood-flow/flood-height relation generated at each cross-section by the earlier hydraulic calculations—in either case, greatly reducing the time required by building on previous work.

In most cases the new 1%-chance flood will be less than the 0.2%-chance streamflow for which a previously computed flood profile is usually available—allowing interpolation. In the case where the 0.2%-chance flood profile is not available, care must be taken not to extrapolate beyond a reasonable degree. Our initial pilot of this estimation method showed very good agreement between interpolation and re-running the hydraulic models with new flood flow estimates. The updated 0.2%-chance streamflow in our pilot area was above the original 0.2% flow estimate, so extrapolation was required, but there was still good agreement with re-running the hydraulic model with the new
flow. An additional alternative being investigated elsewhere is the use of high-accuracy elevation data to generate cross-sections for input to a revised hydraulic model (personal communication with Charles Berenbrock, U.S. Geological Survey, Boise, Idaho).

**GIS-derived Flood Maps Include Depth Information**

GIS can create and manipulate elevation grids (called digital elevation models) of both the land surface and the flood profile, although care must be taken to assure the quality of these data. For example, the elevation grids of floods through sinuous reaches of rivers need to be inspected for undesired extrapolation of water elevation information across the dry land where streams double back on themselves (as at oxbows). The determination of the inundated area is a simple calculation—subtracting the flood elevation from the land elevation at each grid point results in negative values everywhere the flood elevation is larger than the land elevation. A valuable by-product of the subtraction is flood depth. This method does not lend itself to the identification of floodways, but it is possible that the floodway (or a devised substitute) could be estimated using some combination of information on depth and distance from the channel as a surrogate.

**Mapping Uncertainty**

Another desirable aspect of using GIS is the ability to map zones of uncertain flooding—those areas along the periphery of the inundated area where uncertainty in the flood or land elevations translates into uncertainty about the extent of inundation. It is a simple matter to adjust the elevations in the flood elevation grid by estimates of uncertainty or error, thereby producing maps of the areas of lower confidence that flooding will occur. Both the digital land elevation grid used to define channel geometry and inundation areas, and the hydraulic models that are used to create the flood elevation grid have error estimates associated with them.

**Advantages of Digital Maps**

The large-scale paper maps currently used to display inundation areas are difficult to store and distribute. These maps frequently lack information about roads, buildings, and other features that users would want to identify as being inside or outside of a given flood area. These maps are problematic to digitize because they are not geographically referenced and usually lack sufficient detail to manually reference. Digital inundation maps produced with GIS allow users to easily overlay
additional digital information such as roads and highways; buildings and other cultural features; and critical facilities—allowing quick assessment of the potential impacts of a given flood level. Map storage and distribution are greatly simplified as well, because each map can be prepared at any desired scale and stored and distributed electronically, probably over the Internet with Web-based geographic searches.
VERTICAL MAPPING TECHNOLOGIES:
LIDAR AND IFSAR VS. PHOTOGRAMMETRY

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EarthData Technologies

Introduction

Although the global positioning system (GPS) has revolutionized our ability to navigate and position ourselves easily and accurately, a whole host of related technologies has been simmering in the background just waiting to be used. These technologies are now reaching a maturity that allows them to revitalize the survey and mapping industry. For floodplain managers, we have a brand new "toolbox" with which we can efficiently collect geospatial data for accurate and efficient hydrologic and hydraulic (H&H) modeling for flood studies. These technologies allow mapping scientists to obtain data from many parts of the electromagnetic spectrum, increasing the volume of information exponentially.

Technological advancements include active sensors such as Interferometric Synthetic Aperture Radar (IFSAR) operating in the microwave band, Light Detection and Ranging (LIDAR) operating in the near infrared and visible spectrum, and digital CCD arrays operating across the infrared bands through the visible spectrum to the ultraviolet range. Of course, driving these systems are fantastic leaps in portable computing power and data storage capacity, along with the tightly coupled integration of GPS and inertial measuring units (IMU).

Advancements in softcopy photogrammetry, digital orthophotography, and airborne GPS have meant greater automation of the entire spatial data production process without sacrificing quality or accuracy, while reducing unit costs. These capabilities, combined with emerging technologies, have set the stage for the future of the mapping profession. The next generation "GIS laboratory" will use an interchangeable sensor suite that allows mapping scientists to meet their clients' mapping and GIS needs by developing accurate map products and collecting source data simultaneously. Ground-based operations will fuse, reformat, and provide automated feature extraction from the georeferenced sensor data. The implication is that a number of traditional photogrammetric operations such as aerotriangulation and digital terrain model (DTM) surface development will eventually be
relegated to the history books. By developing spatial data in real time from a range of commonly georeferenced sensors on both air- and space-borne platforms, the mapping industry will deliver spatial data knowledge about the earth, rather than an old-fashioned "digital flat map."

**Inertial Measuring Units (IMUs)**

At the heart of this sensor fusion is the integration of differential GPS on board the aircraft with an IMU on each sensor to provide orientation parameters for all sensors and to position them precisely. While an airborne sensor is collecting data, the position and orientation of the sensor are typically unknown. Classical procedures require surveying points on the ground and using advanced mathematical adjustments to compute the position and orientation of the sensor. This process, referred to as "airtrig" (aerial triangulation) consumes a significant part of the mapping process and is a requirement for the successful use of imagery for further compilation and extraction of elevations and features. Furthermore, many remote sensing projects using digital or multispectral camera systems simply forego this process, resulting in compromised spatial accuracies.

Recent studies have shown that the accuracy required for the position of the sensor varies with the scale of the desired map products, ranging from five to 110 centimeters for map scales from 1:600 to 1:7,200. The required accuracy of the orientation parameters (pitch, roll, and heading), however, remains constant at all scales. To generate accurate map products, with the various images rectified to each other, requires the sensor's angular orientation to be measured to an accuracy of 10 arc seconds. During the past several years, differential GPS has been documented to provide the stated positional accuracies. Using GPS to position the sensor itself, without orientation parameters, has allowed a reduction in ground control of 90 to 95%. At the same time, the mathematical airtrig process has become more complex. Installing an IMU on the sensor and measuring the orientation of the platform to 10-second accuracy renders the requirement to install ground control and the airtrig process unnecessary to rectify the imagery accurately for the map compilation process.

**Digital Cameras**

Digital camera technology actually covers a host of emerging capabilities. Remote sensing scientists have known for many years that natural and human-made features of the earth have unique responses to discrete areas of the electromagnetic spectrum. The ability of sensors to
discriminate these responses allows the creation of knowledge such as biologic diversity and vegetative stress about the mapped area.

Digital sensors, specifically CCD arrays, offer an alternative to conventional photogrammetric camera systems. With no film processing, the digital camera systems offer speed of data turnaround that can be valuable to many clients, especially in emergency response situations. However, the CCD array cameras do not have as great a geometric and radiometric quality as conventional film cameras. Furthermore, the digital cameras are smaller in format than conventional film cameras. A standard aerial mapping film camera has a negative image area of about nine inches by nine inches, which corresponds to roughly 20K by 20K pixels on a CCD array. Currently digital cameras exist as large as 4K by 4K pixels, with systems as large as 9K by 9K on the drawing board.

The size of the CCD array also directly affects the quantity of data transmission and storage, which can rapidly approach terabits of data per mission. Nonetheless, the potential speed and simplicity at which the digital imagery could be handled, with rapid evolution of computing power, transmission, and storage, is driving a number of groups to develop camera systems, calibration procedures, and system administration to replace the conventional aerial photography film process with digital imaging systems.

Digital cameras also provide a relatively inexpensive method of creating a multispectral sensor. Simply put, a multispectral camera is nothing more than a series of cameras, typically four, mounted in a single housing with a different filter mounted on each camera. To date, the systems in use are relatively small format, about 1K by 1K pixels, and are set up to provide the same bands as Landsat images, thereby providing an airborne alternative to Landsat, with spatial resolution similar to conventional film imagery. The airborne systems also cover a much smaller ground area than satellite systems, but can be flown on demand, as opposed to relying on satellite availability. In fact, the satellite-based data, including the new 1-meter satellites, is expected to increase the demand for more and more accurate airborne data.

**Light Detection and Ranging (LIDAR)**

Airborne laser systems have been in use for many years to measure points on the earth's surface. As with so much of America's technology, LIDAR grew out of the defense industry. By the early 1980s, a second generation of systems was in use around the world; however, these were expensive and had limited capability and were generally restricted to use by federal agencies. The single largest concern was the ability to geolocate the sensor in the aircraft. Furthermore, improvements to
aircraft positioning and altitude subsystems were required to facilitate application to the mapping community. As discussed throughout this article, with the enhanced computer power currently available, and with the latest positioning and orientation systems, LIDAR systems have become a commercially viable alternative for development of digital elevation models (DEM) of the earth's surface.

Airborne LIDAR is simply an aircraft-mounted laser system designed to measure the 3-D coordinates of a passive target. This is achieved by combining a laser with positioning and orientation measurements. The laser measures the range to the ground surface, or target, and, when combined with the position and orientation of the sensor, yields the 3-D position of the target.

The laser range subsystem operates differently than a surveyor's laser distance measuring unit. A surveyor's "distance meter" measures the phase shift of a laser pulse, modulated through a series of frequencies to resolve finer and finer units until the total distance is measured to a high degree of precision. For LIDAR applications, the laser generates the range to a passive target by measuring the time of flight for a single laser pulse to make the round trip from the laser source to the target and return to the laser receiver. LIDAR systems typically use a single frequency, about 1064 or 532 nanometers, corresponding to the infrared and green areas of the electromagnetic spectrum, respectively. The electronic circuits measure this time to an accuracy of about 1/3 nanosecond. This measurement accuracy correlates to a distance resolution of about five centimeters (2 inches).

**LIDAR Ranging Limitations**

The ranging depends primarily on the ability of a system to detect the peak points of the transmit and receive pulses. This ability is a function of the pulse width and the "steepness" of the rising and falling edges of the pulse. The ability to detect a return signal from targets with weak reflective signatures, and from targets at a great distance, is a function of the laser power. Finally, the number of laser spots hitting the ground, and consequently the density of the resulting DEM, is a function of the pulse rate of the laser. Unfortunately, these three characteristics (pulse width, laser power, and pulse rate) work against each other in the selection of the best laser source. As the pulse rate increases to produce a DEM with greater density, the power decreases and the pulse width increases. The lower power results in fewer target returns, and the increased width results in a lower range resolution.

Positioning of the final point on the ground is derived by adding the range to the position and orientation information from the aircraft.
positioning system. This is typically achieved through the use of differential carrier-phase GPS and an IMU. Some systems have included the positions of ground targets to aid the orientation process because of the limited accuracy of low-cost inertial units and to help solve the GPS ambiguity problem.

Early systems simply shot the laser downward, normal to the aircraft, in a profile along the flight path. Current systems use a scanning mechanism to scan a path beneath the aircraft, yielding a pattern of points on the ground. These points then become the basis for a DEM, after a minimal amount of processing.

A key component of all systems currently operating is the scan width, or ground footprint. Current systems provide a footprint of roughly 20 to 30% of the ground coverage of a conventional aerial mapping camera. The most recent developments will operate at altitudes and swath widths to match the footprint of conventional camera systems, yet remain tunable to allow the ground to be "painted" with data for engineering applications.

**LIDAR Applications**

The most direct application of LIDAR technology is the creation of a DEM for application to mapping products. This technique is much faster than conventional photogrammetric techniques, and the data is easily combined through many commercial software products to numerous mapping applications. As an active device, the laser pulse is less susceptible to shadows and sun angle. The timing and recording units may also record multiple returns from a single laser pulse indicating canopy height or vegetation density (relevant to determination of surface roughness coefficients—Manning’s n-number—in hydraulic modeling). For each laser pulse, the first return provides vegetation height, and the last return provides terrain height.

For topographic applications, the data is easily contoured. Because each data point is georeferenced, the data is also easily merged with other feature data or imagery sources. LIDAR data is typically three or more times denser than photogrammetrically captured elevation data and provides an ideal DEM for the rectification of orthophoto images. Whereas photogrammetric elevation accuracy is a direct function of the flying height, LIDAR is relatively insensitive to height, yielding similar accuracies from any height. One of the most exciting applications of LIDAR data is its value to aid automated feature extraction. LIDAR’s ability to discriminate the heights of nearby features easily yields valuable data for the automated interpretation and extraction of these features. The characteristics of the laser frequency may also play a role
in this process. For example, infrared laser light provides excellent discrimination along water boundaries. LIDAR data can also be collected to "see" discrete features, such as power lines, providing a unique opportunity for engineering applications.

Bathymetric LIDAR systems are similar to their topographic cousins with laser power much greater for water penetration and processing techniques much more rigorous to account for refraction and attenuation of the laser pulse traveling through two distinct mediums (air and water). The vertical accuracy of the bathymetric systems is three to five meters with one exception. A system operated by the U.S. Army Corps of Engineers (Scanning Hydrographic Operational Airborne LIDAR System [SHOALS]) has implemented differential carrier phase GPS positioning and new processing algorithms for refraction, and they report vertical accuracies of 15 centimeters. To support the higher laser power necessary for water penetration, the bathymetric systems also operate at a slower repetition rate. This translates to lower density of points on the "ground" or slower aircraft speed and lower flying height to increase the density.

**Interferometric Synthetic Aperture Radar (IFSAR)**

Another of the new mapping tools is IFSAR. Radar interferometry relies upon a coherent combination of radar measurements made by two antennas displaced by a small distance. The phase difference between two backscatter measurements is used first to compute a range difference between the two antennas and then to compute the position and height of the target. Furthermore, depending on the relative geometry of these antennas, the combined measurements can be used to derive surface topography, topographic change, and displacement over time. IFSAR is also an all-weather system, allowing operations to occur when conventional mapping would not be possible. The technology provides a wide range of resolutions, from one to 100 meters, and covers large geographic areas rapidly. Systems are flown on spacecraft or commercial aircraft at speeds in excess of 300 knots, with ground swaths of 25 to 300 kilometers. Once again, advances in measuring sensor position and motion, along with developments in computing power, have led to a dramatic improvement in the overall capability of radar interferometry systems. In fact, data processing has been automated to a greater degree than classical photogrammetric stereo imaging.

The U.S. government has conducted much of the IFSAR development activity; however, several systems are available for commercial use. In fact, "civilian" systems are in use in at least 12 countries around the world. The latest development appears to be a
system currently under construction by the GeoSAR consortium (the National Aeronautics and Space Administration, California Department of Conservation, and Calgis, Inc.). This system is a dual band system that, when complete, will have the ability to penetrate foliage to depict "bare ground" to a vertical accuracy of one to three meters.

Summary

Each of the technologies discussed, GPS/IMU integration, digital cameras, multispectral cameras, LIDAR, and IFSAR, are currently operational. With these sensors, mapping scientists have the opportunity to develop and deliver not only maps, but also knowledge about the earth and its resources, whether natural or synthetic, at resolutions, speeds, and accuracies not previously obtainable. GPS was simply the beginning of the leap forward in mapping capabilities and is serving as a catalyst for a host of tools to continue the revolution.
RELATING HEC COMPUTER PROGRAMS TO FEMA MAPS

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Introduction

This paper provides an overview of the relationship between the technical data, predominately Hydrologic Engineering Center (HEC) programs, that is generated for flood insurance studies (FIS) and the final Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) that are distributed to the public. The paper is aimed primarily at city or county floodplain administrators who need only a cursory knowledge of these programs, but could utilize a better understanding of the technical basis of the mapped data. The basic content of this paper was used for a training session for city and county floodplain administrators at the 1997 Texas Floodplain Managers Association Annual Texas Flood Conference in Lubbock, Texas.

Basic Technical Programs Used in Flood Insurance Program

A brief overview of the various hydrologic and hydraulic models that are being used by FEMA technical contractors is presented below. How the technical elements of those programs become the information shown on a community FIRM, in a conditional or final Letter of Map Revision (LOMR), or in a FIS will be described.

Hydrologic Models

HEC-1, Flood Hydrograph Package (Hydrologic Engineering Center, 1990a), is the predominant hydrologic computer program used by FEMA technical contractors. HEC-1 is used to generate the 10-, 50-, 100-, and 500-year peak flood discharges for each stream in a FIS. Version 1.0 of the recently released Hydrologic Modeling System (HEC-HMS) is a "new-generation" software package for precipitation-runoff simulation, that will supersede HEC-1 (Peters and Feldman, 1998). Other hydrologic models that are commonly used for computing flood discharges include the Department of Agriculture programs TR-20, TR-55, and HYMO. More complex or less often used programs include MITCAT, AHYMO, DR3M, and HSPF.
Hydraulic Models

The most common hydraulic models used for FIS include WSPRO (USGS/FHA), WSP2 (USDA), and the HEC programs HEC-2 (Hydrologic Engineering Center, 1990b) and HEC-RAS (Hydrologic Engineering Center, 1997a). More complex or less used models include DAMBRK, SWMM, DWOPER, UNET, TABS2, and FESWMS. This presentation will concentrate on the HEC-2 and HEC-RAS programs.

HEC-2—The Standard Bearer for 30 Years

HEC-2 has been the most widely used hydraulic model since its introduction in 1968 and is used internationally as well as throughout the United States. A majority of the riverine flood insurance studies in the United States have been prepared utilizing the HEC-2 program. It has undergone major revisions and advances through the years and the HEC-2 floodway computations have been the standard of the industry since the early 1970s.

HEC-RAS (River Analysis System)—The New Kid on the Block

HEC-RAS is the windows-based river hydraulics program of HEC's "Next Generation" (NEXGEN) engineering software. It is widely anticipated to be the replacement for the "classic" backwater program HEC-2. One important feature of the HEC-RAS program is the ability to import HEC-2 models from previous studies. Some "cleanup" or modification is usually needed, especially around bridges. Version 2.1 of HEC-RAS was released in October 1997. The ease of hydraulic modeling, especially with the addition of GIS/CAD input of data, combined with the powerful graphics package, makes HEC-RAS a future tool that every floodplain administrator should become familiar with as the program is used for new studies and LOMRs.

FEMA Flood Insurance Rate Maps (FIRMs)

FIRMs are the insurance and floodplain management maps issued by FEMA that identify, based on detailed or approximate analyses, the areas of 100-year flood hazard (floodplain) in a community. In areas studied by detailed analyses, the FIRM shows base flood elevations (BFEs), and on many maps, the 500-year floodplain, and floodway boundaries. Flood insurance studies and the resulting maps have evolved since about 1968 into standardized products that include street and city boundary information with flood-related data superimposed upon the base maps. Many of the currently effective FIRMs are based on 10-foot contour interval, 7 ½ minute, USGS quadrangle maps, although the
elevation contours are rarely shown. The current trend for flood insurance mapping is to digital FIRMS, useful for GIS applications, for transferring data, and for updating easily.

**Relating HEC Hydraulic Models to FEMA Flood Insurance Rate Maps**

Figure 1 is a portion of a City of Grand Prairie, Texas, November 1996 FIRM. This map will be used to demonstrate the correlation between the HEC-2/HEC-RAS hydraulic models and FEMA maps. The scale of the map is 1"=1000', a common scale on FIS. It shows only a few of the numerous hydraulic cross sections that are included in the HEC-2 model of Fish Creek. It also shows the limits of the 100-year and 500-year floodplains, the floodway limits, flood insurance zones, reference marks (bench marks for surveys), and BFEs for the 100-year flood. Often the technical work maps, prepared by FEMAs technical contractors, for flood insurance studies, as well as for Letters of Map Revision (LOMR)
are usually more detailed than the FIRM, showing detailed information, such as 1-, 2-, or 5- contours, all hydraulic cross-sections, and floodplain elevations and limits, and floodway data.

**Technical Elements**

**HEC-2 model input.** Using the cross section geometry along the creek in combination with other parameters such as Manning’s ‘n’ values (roughness coefficients), channel bank (left and right side of channel), reach lengths (distance between cross sections), bridge and dam geometry, coefficients of expansion and contraction, starting water surface conditions, flood discharges (from HEC-1), ineffective flow areas, and encroachment stations or targets (for floodways), a hydraulic model is developed. Although in a different type of encoding format (Windows GUI), HEC-RAS has essentially the same basic input data as HEC-2.

**Cross sections.** To demonstrate the technical relationships of the hydraulic models with the work map and FIRM, the cross section “G” on Figure 1 will be used. Section “G” is located at Fish Creek river station 179+85 (or 17,985 feet upstream of the mouth of the creek). See the plotted cross section “G” in Figure 2. The view is looking downstream. This cross section was obtained from 2’ contour topography.

**HEC-2 model output.** After the HEC-2 or HEC-RAS hydraulic model is completed, calibrated, and refined, the final runs are made and results plotted and printed. For the example problem, the Fish Creek HEC-2 model from a submittal to FEMA for a final letter of map revision for the City of Grand Prairie is used. The detailed computations are voluminous and not shown in this paper. Note that the model had floodway encroachments that are delineated on the map. Additional output in the form of standard HEC-2 FLOODWAY tables can be requested, are very convenient to read, and are also included in the Flood Insurance Study report.

**Flood profiles.** Flood profiles along each river or stream depicting the computed flood elevations versus the stations along the stream are shown in Flood Insurance Studies. These profiles include the 10-, 50-, 100-, and 500-year floods, as well as the bottom profile, locations of bridges and dams.
Relating Technical Elements to Each Other and the FIRMs

The cross section and flood profile plots are most helpful in visualizing the results of the HEC-2/HEC-RAS analysis and in correlating the data to the final product, the FIRM. In addition to the visualization, the graphical representation can be used to check the floodplain and/or the floodway width on the maps and in the printout. The HEC-RAS program is much more graphical and therefore is easier to use for examining and comparing results.

Using the computer printouts, plots of cross sections and profiles, and the various tables, the technical results such as flood elevations, floodplain and floodway dimensions, velocities, and bridge/culvert/dam analyses can be correlated, checked, and transferred to the topographic maps (Lovell, 1997). With GIS/CADD technology, much of this
laborious effort is being automated (Hydrologic Engineering Center, 1997b).

With the HEC-2 or HEC-RAS output files, a reviewer or floodplain administrator can correlate and check the information shown on FIRM or proposed LOMRs. In addition, as users get familiar with the process and data, they can provide more accurate floodplain data to the citizens of their community. A reviewer or user of the HEC-2 /HEC-RAS output can utilize this information to verify important data such as the actual widths of floodways that are shown on maps, the channel and overbank velocities, for erosion and other hazard purposes, reasonableness of roughness values used, excessive encroachments, actual encroached flood elevations at specific locations, other than those shown in the standard Floodway Table, and differences in elevation between various frequency floods.

Conclusions

A cursory knowledge of the HEC-2 and/or HEC-RAS programs input and output data is a valuable tool for the floodplain administrator or city engineer responsible for the federal flood insurance program in a community or county. Although a strong working knowledge and experience with these hydraulic programs would be beneficial, it is not mandatory in order to be able to review and verify most FIS models. The advent of the HEC-RAS program with its graphical and user-friendly options, will probably be an even more effective floodplain management tool for the local administrator. As more and more creeks are studied using the HEC-RAS program, the need for familiarity with its options will increase.

No matter what program is being used for the floodplain and floodway determinations, care must be exercised in transferring the computed elevations and dimensions to the base maps. This is being automated to a certain extent with the GIS/CADD technology that is available. However, again caution should used and visual checks of the automated delineations should made for consistency and practicality.

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GIS APPLICATIONS IN SUPPORT OF WATERSHED PLANNING IN DUPAGE COUNTY, ILLINOIS

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Introduction
The Stormwater Management Division (SWMD) of the Department of Environmental Concerns (DEC) of DuPage County, Illinois, is responsible for watershed planning and floodplain development in DuPage County. Because of the complex urban nature of its jurisdiction and the need for up-to-date information, several GIS applications have been developed. One of the most significant is the tool that allows rapid floodplain map development. Two GIS application elements of this method are described in this paper: stream cross-sections may be constructed into a database from which, in combination with flood routing elevations, floodplains may be delineated.

Overview
GIS software has the ability to represent and allow description of objects in geographic space. It can also produce new geo-spatial information by its ability to maintain topologic relationships among the members of a given GIS dataset. The SWMD, with assistance from the GIS consulting firm GeoAnalytics, Inc., of Madison, Wisconsin, has created a pair of GIS computer program applications that capitalize on these virtues to produce floodplain maps. The Stream Cross-section Construction, Manipulation, and Output application (XSEC) is an inventorying type of activity that allows users to represent and fully describe all stream cross-sections for a modeled watershed in the form of a GIS database. Besides the 3-D location of each part of a cross-section, staff can attach a variety of descriptive information to these parts, including a select storm event's flood elevation as predicted by a flood analysis program. With such a fully described set of cross-sections and the corresponding topography for a modeled watershed, the Floodplain Delineation Application (FPD), can perform the task of producing a rendering of the extent of flood waters for it. This rendering is a plan view of a 3-D
depth surface, where positive depth below the water surface implies flooded areas.

**Cross-section Database Development and Management**

**Traditional Method of Data Management**

The SWMD utilizes the unsteady flow analysis program called Full Equations (FEQ) and statistical analysis program PVSTATS to predict flood elevations for a modeled stream. The FEQ program requires the expression of stream cross-sections in a tabular format within its text based data files. These 'flat files' have been the de-facto database of stream cross-sections for the SWMD simply because that was where they were utilized the most. However, from a data management perspective, this method is lacking because of various editing styles, inconsistent geo-referencing (FEQ does not need geographic coordinates to operate; it is a 1-D program), and potential interpretation ambiguities. Moreover, the identifiers for these flat file tables need only be unique per program run; they were not necessarily surviving the propagation of the datasets into other computer programs or even returning unchanged for other iterations.

**Motivation to Use GIS**

While FEQ is rigorous for its modeling requirements, its flat file formatting was never intended to serve as a repository, or database, of information for stream cross sections. With the prospect of thousands of flat files to manage and for the reasons cited above, the SWMD concluded that its GIS engine could be customized with an application to create and maintain a digital database dedicated to stream cross sections. Such a GIS database would allow consistency in geographic referencing, both for scale and accuracy, consistency in data management and access, if it could only be accessed and changed via software meant for that purpose, and would allow better means to visualize, interpret, and maintain the cross-sections as more intuitive geographic objects.

**GIS Data Sources**

A database of stream cross-sections can be built from a variety of sources. For the SWMD, the obvious choice is the cross-section tables within the FEQ flat files themselves. Another is the recently sanctioned use of survey files produced by global positioning systems (GPS) surveying equipment. Another is creating cross-sections from scratch from the information available from related GIS datasets. The SWMD
currently uses all of these methods, although each has its drawbacks. FEQ flat files typically lack or have some geographic coordinates, have only a local system's coordinates, or a blend of all of these. GPS survey files, while obviously rich in coordinates, lack the descriptive information that will be needed for later FEQ processing. Cross-sections created within the XSEC GIS application will have elevation values only as good and timely as the accuracy of the corresponding topographic map. Nonetheless, because the XSEC application can be and is more than just a data translator, all of these sources, and potentially others, can be utilized as is and be refined or updated to meet modeling objectives.

**GIS Data Structure**

The SWMD uses ARC/INFO GIS software, which in its native form has all of the capabilities required for the XSEC application, including the relational database called INFO, which, for the foreseeable future, is adequate for this application.

**Stream cross-sections.** One of the elemental topologic objects that ARC/INFO uses is called an arc. It is a set of line segments connected end-to-end where the whole set has the property of being 'directed', i.e., one end of the set is logically called the FROM and the opposite end is called the TO. These ending vertices are modeled internally as nodes, hence the ends are called the FROM and TO nodes. Arcs may be chained together at these nodes. The data structure that was chosen by the SWMD to best represent a stream cross-section is a chain of arcs with the following restrictions: a) each arc is limited to one segment only (no shaping vertices between nodes, thus 'simple'), and b) all arcs in the chain are directed uniformly so that the chain may be deemed to possess a 'START' end and a 'FINISH' end. Since this data structure is a composite of an elemental one and does not correspond to a composite that is recognized by the GIS, it existence must be maintained by the XSEC application itself. This user-defined, composite object is further constrained to have all of its parts, whether singular or corporate, identified in a strict enumeration and coding scheme. Thus, a SWMD XSEC cross-section is componentized; each part has a name and can be found in relation to other components. Arc nodes represent the location of a survey setup, arcs themselves represent the path of the cross-section transect, and a chain of arcs represents a single stream cross-section. All of these are located geographically by the coordinates of the nodes. All of these components may have attributes in the form of various descriptions, including groups of cross-sections.
Stream network. Naturally, stream cross-sections are associated with streams, or more particularly, with selected reaches within stream networks. The SWMD maintains a dataset that is a network of non-simple arcs where reaches that are modeled are amplified into ARC/INFO composite objects or features called routes. Routes are measurable. As with stream cross-sections, these routes are identified by a coding scheme. Therefore, with all elements structured and identified, the XSEC application can ascertain for a given cross-section which stream it crosses and what are the measures for the crossing point along both the cross-section transect and the stream reach.

Database Attribution
For all features within a dataset, ARC/INFO maintains an INFO database table to include required descriptive information. These tables are in addition to the geometry files that the GIS maintains in proprietary format. The GIS user may augment these Feature Attribute Tables to house other attributes that apply to elemental and composite features. Moreover, ARC/INFO allows the use of User Attribute Tables for both spatial and aspatial data. The XSEC application uses both methods to maintain descriptive information about the various components of a stream cross section, which includes GIS identifiers, FEQ model data, and flood elevations. In fact, the majority of the application is dedicated to updating and synchronizing the set of INFO tables that house all but the geometry of a given stream reach's set of cross-sections.

Data Processing Steps
The creation of a portion of the Stream Cross-section Database follows three fundamental processing steps. The first is to assess the source data for clarity. This is especially true for FEQ flat files that were prepared perhaps years ago when the notion of using them as a GIS data source was not relevant. The next step is called, overall, bulk processing since whole sets of cross-sections, segregated per select stream reaches within the DEC's watershed planning areas (WPA) called tributary areas, are processed in two steps. (The DEC's WPAs are planning and modeling units where river basin watersheds comprise tributary watersheds, which in turn are composed of catchment or sub-basin, watersheds.) The first is to simply induct the cross-section data into the GIS dataset form called a coverage, where checkpoints will inform the user of lack of required clarity. The second is to manipulate the geometry of the raw cross-sections according to the intelligence from the source file into a possible fit against the current stream reach. Again, this step has
checkpoints, as well. The next basic step is to allow the user to access the processed cross-sections and refine them with the Cross-section Database Interface.

The Cross-section Database Interface

The Cross-Section Database Interface (XDI) is the part of the XSEC application that allows all SWMD staff ready access to the ARC/INFO coverages that constitute the DuPage County stream cross-section database. It is designed to let users call for a stream reach set of cross sections for a given tributary watershed and manipulate the user aspects of any component of any given cross-section. The extensible XDI is a shell around the ARC/INFO module called ARCEDIT, with calls to module ARCPLOT.

**Selection status.** The XDI main menu always displays which cross-section in the active cross-section set is available for subsequent edit updates. The XDI is predicated on manipulating one cross-section at a time.

**Component manipulation.** The heart of the XDI is a set of tools allowing the user to manipulate and examine one of the components of the currently selected cross-section. Manipulation in this tool set implies creating a geometric (and thus a geographic) change to a component of the arc chain. This is effected by first performing the geometric alteration, then pursuing an appropriate litany of database table changes that may include any of these: stream information, annotation, station point/segment IDs, station point measures, and map coordinates. The elevation values are only updated by the user, however, since the SWMD has assumed that, by and large, source flat files contain survey elevation values that are inherently more accurate than callouts from the corresponding topography coverage. The user may verify and alter the user descriptions of any of components via the so-called inspection tools.

**Control tools.** This tools set is for non-geometric changes to cross-sections. For example, the GIS code name for a cross-section may be changed to any other one not in use in the finite name set, or the chirality of a cross-section may be reversed.

**Reporting tools.** In the most general sense, reporting is any view of a database. For the XDI, this includes changing the editing display to include contextual themes of data such as topographic contours or known planimetric features, displaying a profile graph of any cross-section, or most importantly for SWMD's sake, generating an FEQ ready flat file for use in a modeling run.
**System tools and messages.** This part of the XDI main menu provides feedback to the user to let him/her know that a process is still active, provide instructions, or provide small reports. Typical buttons are provided, but none are casual since they implement actions and safeguards that would be otherwise time consuming for the user.

**Automated Floodplain Delineation**

**Traditional Method of Data Management**

The flood elevation results of SWMD's flood analyses have traditionally been drafted onto hardcopy topographic maps or their softcopy equivalent. Not only is this time consuming and subjective, it is generally not repeatable, particularly if source documents, personnel, and processes change.

**Motivation to Use GIS**

An automated approach to floodplain delineation utilizing GIS will overcome virtually all of the drawbacks of posting floodplains by hand. Furthermore, automation allows relatively rapid scenario analyses and defensible products.

**GIS Data Sources**

By the time the XSEC application is exercised for a given tributary watershed, all that is needed to pursue the FPD one is to post the flood analyses elevation results as attributes of its cross-sections. Thus any given cross section in the plan view becomes, effectively, a flood elevation contour. The same topography dataset used for the XSEC application is already available, and other datasets possessing elevation values might be utilized as well.

**GIS Data Structure**

The FPD application uses a raster, or grid, representation of the local topographic and flood elevation surfaces to determine a flood depth surface. A grid cell size is chosen, preferably comparable to the spatial resolution of the contour spacing and to the cross-section separation, and its orientation is fixed to the geographic coordinate system. The respective surfaces are then sampled at each grid cell center and an average elevation value is posted as an attribute of the grid cell.
Data Processing Steps

The objective of the FPD application is to demarcate the geographic areas of positive flood depth. First, the grids that represent the topographic and flood elevation surfaces are produced. Since these grids are exactly registered, a new dataset may be produced from them, likewise exactly registered. The algebraic difference between the two grids is computed, cell-by-respective-cell. Where the difference is positive (assuming the relation \( \text{flood grid} \) - \( \text{topo grid} \)), then the flood waters exist above the topographic surface. The collection of contiguous, positive valued grid cells constitutes the extent of the floodplain for the set of flood elevations of a given modeled storm event. However, because of the paucity of cross-section station points as compared with the abundance of points in the topographic map, with its contours and spot elevations, the above depth grid likely needs editing to capture nuances of the floodplain like backwater areas. These can be accomplished with the FPD application merging user defined, area-of-interest depth grids. An acceptable floodplain grid can then be converted into an ARC/INFO coverage, have that dataset's grid-cell following edges smoothed through a splining routine, and the coverage merged with other, neighboring floodplain coverages to produce a floodplain of chosen watershed extent.
Introduction

Efficient response to customer inquiries is a critical role of government agencies. Quality customer service has been identified as a top priority for the City of Tallahassee, Florida. The city's Stormwater Management Division (SMD) is using a geographic information system (GIS) to provide customers with flood-related information.

The SMD began implementing a GIS program six years ago. The first efforts were focused on data collection and entry. The first significant use of the GIS program came with the need to comply with the U.S. Environmental Protection Agency's National Pollutant Discharge Elimination System Part One Permit Application. The program has since seen many uses, from simple mapping efforts to major project facilitation. The most recent utilization of the program has been the enhanced customer support efforts in coordination with updates to the Federal Emergency Management Agency's Q3 data.

Application Development Environment

The population of Tallahassee is 140,700. The city covers approximately 96 square miles including three major lake basins. It is the major one of only two incorporated areas in Leon County, Florida. The urban electric, water, sewer, natural gas, solid waste, and stormwater utilities are all owned and operated by the City.

Tallahassee has charged city utility customers a 'stormwater fee' through utility bills since 1986. The Streets & Drainage Division of the Public Works Department originally used the revenue mainly for stormwater maintenance activities. The SMD has been in operation

The author acknowledges the assistance and input of Ken Jones, Project Manager for PBS&J, Inc.; Michelle Morin, Application Development/Programming at PBS&J, Inc.; and Ana McGuiness, City of Tallahassee's Stormwater Management Division.
since 1992, as part of the City Public Works Department, but functions as a utility using the stormwater fee income for its operating budget.

There are currently 60,000 residential city utility customers billed based on a ‘residential unit,’ and 8,600 commercial utility customers, billed per square feet of impervious surface. Average annual revenue is approximately $8.9 million. The SMD uses the major portion ($5.9 million) for planning, studies, and customer support activity. The Streets & Drainage Division uses the balance of $2.8 million for maintenance.

This area of north Florida averages 64.59 inches of rainfall annually. A tropical storm or hurricane passing through the area can create serious flooding conditions. Rainfall is highest in the months of July and August. The ground remains fairly saturated through this period, which coincides with hurricane season.

Phase I—The Original ArcView Project

The FEMA Floodplain Flood Problem Area Overlay Application was originally developed as a simple Environmental Systems Research Institute, Inc. (ESRI) ArcView project. It was created in response to a need for timely and efficient access to stormwater-related GIS data. Developed in-house, it was mainly used by a few SMD staff to determine if a property parcel and/or building footprint fell within the 100-year floodplain as designated on the FEMA map. It quickly became apparent that some automated enhancements could improve its usability.

Modifications to the application were made implementing user ideas. This streamlined several of the software’s query capabilities as well as providing the ability to automatically generate a standard plot of the data. This enhanced version was developed in coordination with the Tallahassee-Leon County Inter-Local GIS (TLC-GIS) Project staff. Users of the application expanded to additional SMD staff, city engineering, and Leon County Stormwater staff.

A preliminary or draft version of the FEMA data was overlaid on the base GIS layers. Graphically the user could determine if the selected property parcel and/or building footprint was in or out of the 100-year floodplain. The user could get the property owner's name and address along with additional property tax-related information. A similar determination could also be made regarding the flood problem areas.

Data

Data used in the application came from four sources. The TLC-GIS Program manages base or background data layers. This data was generated from aerial photography at 1:200 scale by several mapping
consultants. The layers used in the FEMA application include (1) building footprints, (2) hydrologic features, (3) city limits, and (4) section/township/range. These layers are only graphic data and have no real associated attribute information. A layer of street centerlines, created by a mapping consultant for the Leon County Emergency Management Agency, was used as the base for the geo-coded address layer. These layers have attribute data and are used to perform the address match queries.

The Leon County Property Appraiser maintains a layer of property parcel boundaries, which includes attribute data. This layer can also be linked to associated property information databases. These databases include the property appraiser’s name, address, and legal file where property ownership and tax-related data is stored. Digitizing the existing paper property parcel maps created this layer. It is undergoing a major quality control and update effort by the TLC-GIS. This layer provides the property ownership and address information for the application.

SMD staff created basin, watershed and catchment layers that are a hierarchical breakdown of the drainage hydrography. These polygon layers contain associated data including name, number, and acreage for each area. In addition to the hydrographic layers, the SMD GIS created a layer that identifies “local flood problem areas.” These areas have been observed by City staff over the years and charted manually on a paper map. This layer includes associated data pertaining to each flood problem area, including area name, number, and whether it is classified as a hazard or nuisance flooding problem. It also includes detailed information regarding any SMD projects taking place for each area.

FEMA provided the floodplain layer that includes 100-year and 500-year floodplains and floodways. The 100-year floodplain was the only category used in the first and second phases of the application.

**Phase II—Automated Query Enhancements**

In efforts under the National Flood Insurance Program’s Community Rating System, over 4,000 letters were mailed out to property owners notifying them that all or a portion of their property fell within the 100-year floodplain. This list was generated in ArcInfo using the GIS data. Over 120 phone calls were received from concerned property owners.

The Flood Overlay Application was used by SMD staff to quickly identify the customer’s property, answer any questions by viewing the GIS data used to generate the mail-out list, and plot a map of the data if requested. During this period of intense use the user group expanded and identified several additional enhancements that could be made. A consultant was hired to work with SMD staff to implement the ideas.
The user could query the application for a property parcel by typing in the street address, the property tax identifier, or the intersection of two streets. When a match was made, the application zoomed in on the map, highlighted the selected area, and popped open a box including the database tables showing property address and ownership information. Additional automated queries were added, including query by watershed name, query by flood problem area, and query by section/township/range. These queries were facilitated through pull-down lists so the user could scroll through existing names and numbers and therefore did not have to memorize the lists. These areas were also zoomed into and highlighted when the match was completed. The user could use the software's 'identify' tool to access database tables associated with the basin, watershed, catchment, and flood problem areas layers.

Plotting was enhanced to include two sizes, 8.5 x 11 inches and 11 x 17 inches. A plot preview window was also added, allowing the user to view the layout before sending it to the plotter or printer. The property owner's name and address are now automatically included on the plot.

The ArcView Graphical User Interface (GUI) was customized, limiting the user's access to the software's capabilities but making the application more 'crash proof.' The main ArcView GUI could be switched off or on with a password.

**Phase III—Additional Enhancements**

Once again through user input a list of further enhancement suggestions was compiled. The final approved and adopted version of the FEMA floodplain data was delivered to the City. Included with the floodplain layer was a text file containing the elevation data for the floodplains and floodways. In addition, a set of stream cross section profiles for the major drainage system was delivered. These new data sets offered new opportunities for enhancements to the application.

The list of desired enhancements was contracted out to a consultant for development. Requirements were detailed out and data sources provided. The major upgrade covered determination of stream reach flood elevation using the FEMA floodplain elevation and cross-section profile data. SMD wanted the ability to access this data graphically within the existing application and view the associated tabular data.

The first task in implementing the enhancements was to get the FEMA floodplain elevation, stream reach, and cross section profile data into usable formats. A script was written to extract the floodplain elevation data from the provided text file into Dbase (.dbf) format. The .dbf file includes data for 25-, 50-, 100- and 500-year floodplains.
The stream reaches were digitized into a graphic layer using ArcView. The base hydrologic and hydrographic layers were used as a base for the creation of this arc layer. The arcs were split at points corresponding to the cross section profile locations. Once this was completed the arcs were attributed with "to" and "from" nodes at the split points. This layer was then geo-coded so those location queries could be performed on it. The associated floodplain .dbf data was linked so that when a stream reach was queried the resulting match contained the floodplain data.

A new query tool has been added that includes the floodplain elevation data. Once a parcel is selected the user can 'find the nearest stream reach from the selected parcel' or 'find the nearest stream reach from a user entered point'. The search will not cross a watershed boundary. If no stream reach is located within the query area, a message is sent back to the user. If a stream reach is found, the flood elevation data for 25-, 50-, 100-, and 500-year floods is shown in a pop-up window.

A locator extension was included in this phase. The locator window shows a simple view of the study area; in this case the city limits. As the user zooms and pans around the main view a red highlight rectangle shows the relative location on the reference window map. This function was actually developed as a free standing extension to the ArcView software and can be imported into any ArcView project or application.

All six of the queries from the previous application phase (owner address, property parcel tax identifier, street intersection, watershed, flood problem area, and section/township/range) are now combined on one pop-up dialog box. The user enters owner address or a property parcel tax identifier after choosing the corresponding radial button. The user can now choose from a pull-down list to create the street intersection query. The watershed, flood problem area, and section/township/range pull-down lists are at the bottom of the match query box. The address and ownership information is now shown in a neat inset box on the view. This version will have most of the native ArcView GUI removed. The graphic and tabular data will be stored on a server and called from the application.

Future Development

Plans for the future include posting to the Internet for customer access to the application. To facilitate this, the application will be converted from ArcView to MapObjects. Although this will require a considerable programming effort this is a much more efficient format for Internet deployment. The application can be made much faster and somewhat more 'user friendly' through the MapObjects environment.
Part 6

Acquisition
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A NEW URBAN REVIVAL: FLOODPLAIN ACQUISITION IN LAWRENCE, MASSACHUSETTS

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Acquisition in Lawrence?
A foot of rain in 24 hours floods cities and towns throughout eastern Massachusetts and southern New Hampshire and Maine. Local and state emergency managers are on the scene along with the Federal Emergency Management Agency for rescue, response, assessment, and recovery. Just before the Interagency Hazard Mitigation Team meeting, a professor from a small Massachusetts college calls FEMA in Boston with a question. Can the City of Lawrence get help in acquiring and demolishing structures that were flooded? The FEMA staffer asks for clarification. Lawrence? Yes, Lawrence, a small city with a depressed economy, struggling businesses, problems with arson and other crime, and a school system on its way to losing accreditation. Yes, the idea is to tear down buildings in the Arlington District, a densely developed, tightly knit, low-income neighborhood where more than half the residents are minorities, most Spanish-speaking. Yes, it's true that this flood didn't destroy or "substantially damage" most buildings, but it has flooded repeatedly in this neighborhood, forcing evacuations and causing health hazards from floating debris and sewage-contaminated flood waters. Yes, that's the neighborhood where a homeless shelter lost all its supplies and food stored in the basement during the flood. Oh, some of the residents are blaming upstream neighbors for the flood due to release of dams. Don't FEMA and the state deal with this kind of thing?

The City and the Flood
Lawrence is a small, densely developed post-industrial mill city about 26 miles north of Boston, with a population of about 67,000 within its 6.5-
square-mile jurisdiction. Economic patterns in the past 50 years have resulted in loss of local industry and the collapse of associated commercial sectors, high unemployment, and a spreading decay in housing stock. While recent redevelopment, economic revitalization, and historic preservation successes have provided hope for the future, Lawrence has been left reeling from its transformation from a vibrant retail and manufacturing center to a stagnating urban residential community with limited commercial and manufacturing opportunities. In 1995, Lawrence had the highest incidence of lead poisoning in Massachusetts, and more than a quarter of the population was at or below the poverty line. From 1990 to 1995, there was a 40% decrease in the assessed value of housing. One of the city's largest employers, Malden Mills, was nearly destroyed in a fire in late 1995. And in October 1996, only 9 years after a 100-year flood in the spring of 1987, the city was hit with a major flood on the Spicket River.

The Spicket River flows south from its headwaters in New Hampshire through the towns of Salem, New Hampshire, and Methuen and Lawrence, Massachusetts, until it joins the Merrimack River in the center of Lawrence. It flows through rural fields on into densely populated neighborhoods within the cities. In Lawrence, the floodplain and the riverbed itself have become more and more constricted as a result of channelizing and straightening done at the turn of the century.

On October 22-23, 1996, the Spicket, along with many other small rivers in northeastern Massachusetts, was sent over its banks by heavy rainfall resulting from a slow-moving Northeaster that had started to affect New England on October 20. The heavy rainfall resulted in 8- to 13-inch rainfall totals across eastern Massachusetts, southeastern Maine, and New Hampshire. The damage caused by the 1996 flooding was extensive throughout these areas, but the heaviest rainfall and greatest damage in Massachusetts occurred in Essex County, where Lawrence ranks as both the largest and most densely populated city. Losses in Lawrence were estimated at $9.3 million with 1,860 residential units and 100 businesses damaged. Over 2,000 residents were forced from their homes. At the height of the flood, over 13 city blocks were under water. In comparison, the flood of 1987, which included flooding from both the Merrimack and Spicket Rivers, caused an estimated $8.6 million in losses for public and private property. Other areas hard hit were neighboring Methuen and Salem, New Hampshire.

The October flooding was especially damaging to an area of the city known as the Arlington District, a neighborhood of older structures comprising both owner-occupied and rental units. The District had suffered severe damage in 1987 and was often affected by smaller, more frequent events. Most of the buildings in the area were deteriorated as a
result of the frequent flooding, the increase in absentee landlords, the reduced numbers of owner-occupied units, and the general downturn in the local economy.

**Scoping a Proposal**

Many neighborhood residents were frustrated by the repeated flood damage, and felt that the problem was not being adequately addressed by the local, state, or federal governments. The Merrimack River Watershed Council held a public forum called "Discover the Spicket" shortly after the flood in November 1996. What was intended as a meeting to discuss clean-up ideas and riverfront uses ended up as a "venting" session for angry residents, who showed up in force to complain that their long-term well-being and safety was in jeopardy. Latino residents in the audience speculated that the politicians did not care about Arlington District. Charles Tontar of the Urban Resource Institute at Merrimack College was in attendance, and immediately contacted U.S. Representative Martin Meehan's office to notify them of the issue. His discussion with June Black of Meehan's office and his awareness of FEMA's mitigation efforts (via a presentation on joint Housing and Urban Development/FEMA mitigation for Hurricane Andrew) led him to call Michele Steinberg at FEMA with the idea of an acquisition project, and helped the city create a proposal. In December 1996, the city applied for $3 million in Hazard Mitigation Grant Program funding to acquire structures in the Arlington District.

What convinced the city and the state that acquisition was viable for Lawrence? The Arlington District is subject to frequent low-level flooding, which has resulted in repetitive damage to the structures, but has never caused them to be substantially damaged as defined in the existing National Flood Insurance Program regulations. However, the need for evacuation of large numbers of residents, the long periods of dislocation, the contamination from raw sewage in standing flood waters, and the floating debris (including derelict vehicles) all contributed to the District's distress over the repetitive flood problems. Added to this was the existence of vacant lots and abandoned buildings that had become an attractive nuisance for vandals and a backdrop for illegal activities such as drug dealing and prostitution. The increasing decay of the neighborhood meant a constant struggle by the District's residents, city police and building officials to meet public safety needs.

This pervasive blight, along with the dense development and lack of open space, meant that city community development officials were proactively seeking systematic demolition of damaged and abandoned buildings before the October 1996 flood. While any loss to the property
tax base was a consideration for Lawrence, the costs of policing a neighborhood dotted with abandoned structures, and the increasing number of landlords abandoning buildings encumbered with back taxes, offset the issue and made demolition a realistic, cost-effective option.

In May 1997, the Commonwealth of Massachusetts recommended a total funding package of $1 million to FEMA, about 20% of the total HMGP funds allocated to Massachusetts at that time. Mitigation staff from the Massachusetts Department of Environmental Management Flood Hazard Management Program (DEM-FHMP), the Massachusetts Emergency Management Agency (MEMA), and FEMA Region I Mitigation Division worked closely with city officials, URI-MC, the state Department of Housing and Community Development (DHCD), and the Arlington Neighborhood Association, meeting almost weekly from May to September 1997, to narrow the scope of the original proposal. This proposal had included channel improvements, bridge repairs, and other items, but was eventually reduced to a workable, straightforward acquisition/demolition project that could meet FEMA's cost-benefit and environmental review requirements and could be accomplished within existing funding and staffing constraints. The fact that the project clearly met multiple objectives for the community, however, was never overlooked as the "Lawrence Project" team coordinated with the many partners at the local, state, and federal level to ensure success.

Unique Challenges

Acquisition of floodprone properties in a densely developed urban area presents unique challenges for FEMA and its state, local, and other partners. The challenges to achieving the goal of reducing hazard losses in the Arlington District included: the high percentage of low-income residents; the fact that many homeowners and landlords bought their properties at the height of the real estate market in the late 1980s and now carried outstanding liens or "upside-down" mortgages; the language barrier in the ethnically mixed neighborhood; and mistrust of government. In addition, the New England regional office of FEMA had undertaken very few acquisition projects in the past 10 years, none as large or complex as the proposed Lawrence project. The strong neighborhood commitment to improving the situation, however, along with the determination of a number of city and state officials to end the damage-repair-damage cycle, made the difference between a good idea in theory and a workable acquisition project in reality.

The demographics of the Lawrence Project area are quite different from other areas where acquisition has become a primary mode of mitigation, e.g., most places in the Midwest. The Arlington District is
classified as low-to-moderate income, with more than half the residents renting rather than owning. The neighborhood is in a census tract of 60-80% minority population, with a large proportion of new immigrants from Central and South America and the Caribbean, and many of the rental properties have absentee landlords. In terms of FEMA project review, careful review of environmental issues was necessary to ensure that public input was considered, that structures proposed for demolition were not historically significant, and that the effect of the project on the neighborhood would not constitute an adverse and disproportionate impact on minority populations.

A number of homes in the area were purchased in the mid 1980s when the New England real estate market was booming. The collapse of the real estate market in the last decade has created a number of upside-down mortgages. Other structures are nearly worthless due to unpaid taxes and excessive liens. Although housing values have started to rise in the area over the past year as part of a general improvement in the economy statewide, city officials were concerned at the outset of the project that offering even pre-flood value for the structures would not be enough to help property owners find comparable housing elsewhere. FEMA, the state, and the city are working out a provision for compensation to help owner-occupants relocate, which should provide added incentive for homeowners to agree to be bought out.

Language barriers and cultural differences were an additional challenge. Public informational meetings required English-to-Spanish translation, as did a questionnaire sent out to gauge residents’ interest in acquisition. While none of the state or federal staff involved spoke Spanish, Arlington Neighborhood Association leaders Ana and Robert Silvera and Jose Chavez were instrumental in providing this vital service, as well as helping maintain the flow of information to local residents and keeping rumors to a minimum. Their knowledge of the community’s working life and culture also facilitated communications. Meetings were announced at the neighborhood church, and the local Catholic high school was involved in hosting the meetings, which were scheduled on Sunday evenings to allow those who worked the third shift at local factories to attend. The Silveras and Chavez pointed out such concerns as the need for careful thought on what to do with open space, since the few city parks tended to attract drug dealing and prostitution.

While involvement of neighborhood leaders helped the Lawrence Project gain credence with residents and reduce their mistrust, political issues and cross-jurisdictional squabbling surfaced periodically during the scoping process. City officials had many competing priorities for their time and energy during 1997, including the loss of state accreditation of the high school following a turbulent political battle over school system
management problems. When the incumbent mayor, who had signed the HMGP application, lost to a newcomer, state and FEMA officials began to be concerned about whether or not Lawrence could carry out an expensive and complex project. As with all such projects, rumors, communication failures, and misconceptions were all part of the challenge.

In a city with myriad departments with potential interest in the project, communication becomes difficult. The strong state mitigation team provided a good example of how to work together, as DEM-FHMP, MEMA, and the DHCD presented a united front at meetings large and small. While there was some struggling to get needed assistance from a few other state agencies and other partners, on the whole the state and federal team concept worked well. The challenge was to strike a balance between involving all possible parties and, while limiting the working group to the minimum necessary to get the job done, still maintaining reasonable coordination and communication.

**Expectations**

Now, in the spring of 1998, the City of Lawrence is preparing to sign a contract with the Commonwealth of Massachusetts and begin the process of actual implementation. FEMA reviewers found the proposal cost-beneficial and by its nature did not require a full environmental assessment. The Lawrence Project is expected to result in 20 to 50 structures acquired, with open space along the Spicket River set aside for recreational or other passive use. The City of Lawrence committed some of its HUD small-city entitlement funds to help match the HMGP dollars, and has also received additional HUD funds from the recent Disaster Recovery Initiative, which may help stretch the project further.

Community leaders have made renewed commitments to ensuring the project's success. URI-MC is already working with a local group, Groundworks Trust, on ways to ensure that whatever open space is created is used well. Other partners in the process will include the Environmental Protection Agency, the National Park Service, the Merrimack River Watershed Council, and the state Department of Fisheries, Wildlife and Environmental Law Enforcement. The Commonwealth of Massachusetts and the State of New Hampshire, along with representatives from communities along the Spicket River, continue to meet with federal partners to address other solutions to the flood problems in the watershed. The Lawrence Project is expected to engender new partnerships that will last long after the demolition is completed, and to reinforce existing ones that will further community goals in creating safe, livable, disaster-resistant neighborhoods.
Illinois has one of the largest inland systems of rivers, lakes, and streams in the entire nation. While a blessing to the state's natural resources, it also creates another more dubious distinction of making Illinois one of the nation's most flood-prone states. Under natural, undeveloped conditions, flooding causes little or no damage. Flooding is a natural cycle. In fact, many plants and animals in the state depend on the flood cycle for survival. As Illinois developed, our waterways served as the focal point for growth and commerce. Homes, businesses, and even entire communities now occupy floodplains across Illinois. This floodplain development has resulted in continual and often severe damage as well as loss of life. Over 14% of the total land area in the state is subject to flooding. Over 250,000 structures are located in flood-prone areas. Yet fewer than 10% of these buildings have flood insurance, leaving many flood victims to rely on state and federal disaster assistance. In some places, flood depths have been known to reach almost 30 feet, entirely submerging buildings. Flood damage in the state now exceeds $300 million every single year.

Flooding in Illinois has caused increased concern in recent years. Since the great flood of 1993, there have been six successive federally declared flood disasters in Illinois. Seventy-four of the state's 102 counties have been declared federal disaster areas at least once in this four-year period, with some declared four times in four years. Most susceptible to flooding are areas where rapid urbanization is occurring. Floods are commonly referred to as a "100-year" flood. Although a "100-year" flood sounds remote, it must be kept in mind that a "100-year" flood can occur any year (in some cases, twice a year). The "100-year" or "base" flood is nothing more than a flood with a statistical probability of having a 1% chance of occurring in any given year. Maps produced by the Federal Emergency Management Agency (FEMA) that delineate the base flood have been produced for every county and nearly every community in the entire state. These maps can be viewed in any city hall or county courthouse.
Illinois Department of Natural Resources, Office of Water Resources (IDNR/OWR) is the state agency with the difficult task of addressing the state’s flood problems. Both structural and non-structural projects have been used over the years to meet these goals. Levees, berms, reservoirs, and diversions have existed for many years along most of the state’s major waterways. However, in 1993 as levees and other structural systems failed, a hard lesson was learned: Mother Nature can beat our best efforts to control flooding. Structures to “stop” or control floods can be very expensive to build and maintain; take a long time to plan, fund, and build; and can cost more than the value of the property they would protect. They may also adversely affect other properties and damage the environment. As a result, voluntary buyout programs have become increasingly popular in recent years as floodplain residents chose to leave flood prone areas and seek “higher ground.”

One approach to addressing flooding is a concept called “multi-objective management” or “MOM.” There is nothing magical about MOM. It simply means bringing together everyone who has a concern about flooding and building a common solution. MOM planning teams can include engineers, farmers, stormwater managers, biologists, historians, bicyclists, canoeists, and flooded citizens. It requires communication between these different parties, and it capitalizes on the assistance offered by government agencies and private organizations. The solution is often more effective, more sensitive to the environment, has broader support, and is part of a comprehensive plan meeting several objectives.

At the request of flood-ravaged communities across the state, IDNR/OWR, the Illinois Emergency Management Agency, the Department of Commerce and Community Affairs, and the Federal Emergency Management Agency have worked together and made great strides towards reducing the degree of flood damage in Illinois. Using a MOM approach since 1993, nearly 2,500 flooded structures have been or soon will be removed from the state’s floodplain areas to create open spaces.

Across the state, areas once prone to frequent flood damage have now been converted to more appropriate uses. One example is Grafton, which sits at the confluence of the Illinois and Mississippi rivers and has a reputation as perhaps the state’s most flood prone community. In 1993, well over 100 of Grafton’s homes were damaged or destroyed, 48 businesses were under water, and revenue from tourism, the staple of Grafton’s economy, was non-existent. After the 1993 flood, residents chose to rebuild a large portion of the structures and public buildings at
a new flood-free location high on the bluff. When Grafton flooded again in 1995 damage was at a minimum.

Today, the areas that were once a flood problem are now an asset to Grafton's booming tourist economy. Where floodprone homes once stood in harm’s way, a new bicycle path and open green space have been created. A large, new marina is planned for the riverfront. Cyclists riding along the Mississippi River bicycle path between Alton and Pere Marquette State Park now have an open view of the river.

Buyout properties across the state are being used to benefit the public. In Shorewood, 40 structures are being acquired along the DuPage River in order to create a park for its residents. The Village of Keithsburg has proposed a marina and a wetlands restoration for their large buyout area. Along the Illinois River, Peoria County's long-running buyout program has been used to restore wetlands and create wildlife areas. A large parcel of buyout property in Peoria County has been turned over to the Chillicothe Park District for the development of a future park. In East St. Louis, floodprone property acquisitions have been used to create open space and greenbelts. Parks and playgrounds are in the planning stage. Near Valmeyer, where nearly the entire town has moved up on the bluff, a golf course is proposed for the site of the old town.

Farther south along the Mississippi River, a cooperative arrangement has been established among several agencies and the U.S. Forest Service in the Shawnee National Forest. The Forest Service's "Inageh" project endeavors to secure all unprotected bottom lands between the Shawnee National Forest and Mississippi River for possible preservation and inclusion in national forest lands.

Where flood damaged and destroyed homes once littered the view, city parks now exist. Where disaster assistance once paid for repetitive flood losses, natural areas exist. Egrets and great blue herons now calmly wade along the shorelines, wood ducks fly among the cottonwoods, and red tail hawks and turkey vultures once again ride the air waves along the bluffs above open floodplains.
Introduction

The Harris County Flood Control District was established by the Texas Legislature in 1937 for the purpose of "the control, storing, preservation, and distribution of storm and flood waters; and the waters of the rivers and streams in Harris County and their tributaries for domestic, municipal, flood control, irrigation, and other useful purposes; the reclamation and drainage of the overflow land of Harris County; the conservation of forests; and to aid in the protection of navigation on the navigable waters by regulating the flood and storm waters that flow into said navigable streams."

The Mission of the Harris County Flood Control District is to provide flood control and stormwater management for Harris County through the planning, implementation, and operation of necessary flood control facilities. It accomplishes its mission through the use of five major operational tools: (1) watershed management (planning and permitting); (2) capital improvements (channels, storage, and levee facilities); (3) interagency coordination (with local, state, and federal stakeholders); (4) maintenance; and (5) environmental services. More than 1,400 miles of channels comprising 23 watersheds draining some 3,000 square miles make up the jurisdiction of the Flood Control District.

The flat topography of Harris County, and proximity to the Gulf of Mexico and Galveston Bay, result in comparatively wide, shallow coastal floodplains. The floodplain in Harris County totals approximately 387 square miles, or roughly 22% of the county area. Harris County is also the most urbanized county in Texas, with a population of more than 3 million, including a major portion of the City of Houston, the fourth largest city in the United States. Much of the development that occurred in Harris County happened before the community's participation in the
National Flood Insurance Program (NFIP) in 1973. As a result, many homes are at risk of flooding during major storms.

In mid October 1994, rainfalls approaching 30 inches fell over virtually the entire southeast Texas area over a four-day period. In Harris County the resulting runoff contributed to more than 3400 reported structures being flooded, and more than $20 million in NFIP insurance damage and $7 million in privately covered insurance losses. As an aftermath to the event, some 44 residences were purchased through cooperative funding under the Federal Emergency Management Agency's Section 1362, and 108 residences were purchased under the Section 404 program. The acquisition of structures after the 1994 event was not unique, but it was the first time that such an activity was coordinated to such a degree in Harris County. In an effort to implement its strategies with its five operational tools, the Flood Control District has often identified and proceeded with structure acquisition on a localized level, using local funds.

The October 1994 event, however, highlighted a fact that had been recognized but not clearly conceptualized. That is, in some cases, acquisition of structures is a more cost-effective alternative to structural improvements, but that an effective acquisition program must be directed by formal guidelines and rules for participation. Ideally the program would be in place before a disaster, so that the information could complement the post-disaster efforts, but could also act on its own before or in between disasters. With this concept, the Flood Control District is embarking on a Pre-Disaster Floodplain Buyout Program.

In creating the Buyout Program, the Flood Control District has the vision that it will expand the District's toolbox by interfacing with each of the five major operational tools the Flood Control District currently uses. The goals of the Buyout Program are to:

- Provide a cost-effective alternative to flood damage avoidance;
- Enhance public safety;
- Be prepared to respond in a storm aftermath; and
- Be more responsive to citizen needs.

At the outset, the Buyout Program will not supersede the FEMA post-disaster assistance program nor will it prohibit the acquisition of property under one of the other District programs. The information available in the Buyout Program database will be available to assist these other programs if appropriate. The basic premise of the Buyout Program is that it will complement these other programs and provide information on critical areas as needed. Several distinct aspects of the program will be that it will apply to all structures at risk and not just those with flood...
insurance. The program will also address the issues of the surrounding community once the structure is acquired. Such issues could include the impact of resultant loss of tax base or the ultimate use of the property once the structure is removed. It is also anticipated that the Buyout Program will have a defined annual budget from which to implement its activities. By having its own budget, the program can operate independently from the other five operational tools at the District.

Several important issues have to be determined for the program to be successful. Not the least of these issues is, Who and what property will be eligible? Will the program be voluntary or involuntary? Will the program be homeowner initiated, Flood Control District initiated, or both? If the program is successful, and the number of applicants exceeds the annual budget for acquisition, how will the priorities be established for which homes are purchased first? These questions bring to realization that the most important aspect of the Buyout Program is that it is a formal process. The information used to make the decisions is the kernel of the decisions, but adherence to the process will ultimately result in the success or failure of the program.

The Buyout Program process is envisioned as comprising six major elements:

- Floodplain Inventory
- Relationship to Capital Programs
- Setting Priorities
- Eligibility Issues
- Procedural Matters
- Community Issues.

**Floodplain Inventory**

The inventory phase of the project allows the District to characterize what exists and to estimate relative risk of properties. Logical thinking is that the more information gathered, the better the program. However, there are practical limits on the cost of acquiring some data versus the actual value of the data. One of the conditions of the Buyout Program is to recognize that the program must be cost effective to set up and maintain. Money from the program is intended to purchase structures, not to maintain data. Initially, the inventory phase will include information from available sources. These will include floodplain limits from FEMA DFIRMs; structure locations from available digital orthophotography; political subdivision, ownership, and property value from tax appraisal records; and risk of flooding either from repetitive loss data or slab elevations. The cost of acquiring this data will determine how the final data set should be compiled in the future.
Relationship to Capital Programming

Major planned capital projects could alter significantly the flood risk of the property. If a capital program is to be constructed in an area, the following questions need to be answered: What does the program cost? What is the schedule for improvements and when will they be completed? What is the probability the structure will flood before the capital project is in place? What is the anticipated damage? How does that damage compare to the cost of acquisition?

Setting Priorities

Setting the priorities for acquisition could encompass many factors. At the current time, the Buyout Program is considering risk assessment, financial capability of the program to complete the purchase, the program schedule for when the program may be able to complete the purchase, the geographic distribution and social equity of purchases, and post-flood versus pre-flood activity. As an example, a likely scenario would be 10 homes in a single subdivision with a combined value of $2 million. If this amount substantially used the available funds in the program, it would mean that other properties across the county would not be eligible for another year.

Eligibility Issues

The eligibility issues could be the most difficult part of the Buyout Program. Key questions could be whether or not the program should include only those residents that volunteer to have their homes purchased. Another consideration could be whether or not the property was developed in compliance with county and city permits, or was undertaken without compliance. If a property floods as a result of an event, and is eligible for acquisition from the FEMA post-disaster assistance program, and chose not to participate, would that affect its eligibility and priority in the pre-disaster program? One factor that has been determined is that initially, all structures would be eligible for the program, regardless of whether or not they had flood insurance. This is important so that insurance can still be encouraged, but lack of insurance would not be punitive to those residents that cannot afford it. Another factor likely to be included is the historical flooding trend of the property. Does flooding occur frequently, or only during a severe event?
Procedural Issues

The Buyout Program will be designed with specific instructions on how the homeowner should proceed with a homeowner-initiated buyout. A similar procedure will be defined for a District-initiated buyout. Within each procedure, it must be clearly defined what the responsibilities of the homeowner and the District are once an agreement to enter the program is reached. The responsibilities would likely include the ability of the homeowner to sell any assets, or the timetable for the District's completion of the assessment and acquisition of the property. As the procedure is going forth, the level of coordination with other agencies and groups as to the ultimate use of the property must be defined, whether it remains with the homeowner, whether it reverts to the community, or whether it remains with or is assigned by the District.

Community Issues

The coordination with other agencies and groups include the local community. In addition to the property disposal issue, questions need to be addressed on the residual economic impacts. Public education of the risk of floodplains, and understanding of the procedures of the Buyout Program are key issues of concern to residents affected by flooding.

Project Status

The project is currently in its developmental stages. These initial concepts were introduced to a stakeholder group that included representatives of the City of Houston and County Floodplain Administrator's Office. Attending the same meeting were representatives from environmental concerns and residents who had been through the FEMA post-disaster program. At the meeting, the participants were asked to answer questions that they felt were important to consider in the program development. A pilot program on one watershed in Harris County is scheduled to be in place by June 1998. Full implementation of the program is scheduled for December 1998.
Part 7
Stream Protection and Restoration
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MULTI-OBJECTIVE MANAGEMENT CRITERIA FOR STREAMBANK PROTECTION

Robbin B. Sotir
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Introduction

Although hydraulic, hydrologic, and geotechnical goals must be met, the requirements to meet environmental goals have also become major issues in most aspects of stream work. Streambank protection designs that consist of riprap, concrete, or other inert structures alone are being accepted less frequently because of their lack of environmental benefits. Consequently, there is greater interest in designs that combine vegetation and inert materials into living systems that can meet mechanical goals of erosion reduction while providing environmental benefits. Soil bioengineering designs that employ woody vegetation as the major component are especially attractive because of the habitat and water quality benefits that they can provide.

Soil Bioengineering Benefits

Soil bioengineering is based on sound engineering practice and ecological principals. Typically, soil bioengineering systems for streambank protection consist of several soil bioengineering and structural engineering components combined into an integrated system that provides protection for the entire streambank reach. There may be several soil bioengineering components capable of providing erosion protection for a given site, depending on the type of problem. The specific design chosen may depend on several factors, including the level of risk that is acceptable, cost, and environmental and aesthetic objectives (Table 1).

Table 2 further summarizes the major environmental benefits of the most common soil bioengineering and conventional engineering methods employed in streambank protection that utilize woody vegetation. Such a table can be useful in helping to select soil bioengineering methods that can be incorporated into streambank protection designs to maximize specific environmental benefits. For example, the scour holes that develop around the noses of live booms (dikes composed of woody vegetation and soil) make them an excellent choice as part of a bank protection system on streams where pool habitat is scarce. There may be
Table 1. Evaluating streambank protection alternatives.

<table>
<thead>
<tr>
<th>Method Type</th>
<th>Habitat Benefits</th>
<th>Water Quality Benefits</th>
<th>Recreation Benefits</th>
<th>Aesthetic Benefits</th>
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<tr>
<td>Live Stakes</td>
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<td>negligible, except on small streams</td>
<td>fair to good</td>
<td>good</td>
</tr>
<tr>
<td>Live Fascines</td>
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<td>fair to good on small streams</td>
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<td>good to very good</td>
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<td>Branchpacking</td>
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<td>negligible</td>
<td>fair</td>
</tr>
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<td>Brushlayer</td>
<td>good to very good</td>
<td>good to excellent</td>
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<td>good to excellent</td>
</tr>
<tr>
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<td>fair</td>
<td>negligible</td>
<td>good to very good</td>
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<tr>
<td>Joint Planting</td>
<td>good</td>
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<td>fair to good</td>
<td>good</td>
</tr>
<tr>
<td>Brushmattress</td>
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<td>fair to good</td>
<td>good to excellent</td>
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<tr>
<td>Conventional Vegetation</td>
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<td>negligible</td>
<td>fair</td>
<td>good</td>
</tr>
<tr>
<td>Tree Revetment</td>
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<td>negligible</td>
<td>none</td>
<td>fair</td>
</tr>
<tr>
<td>Conventional Riprap Revetment</td>
<td>none</td>
<td>none</td>
<td>fair to none</td>
<td>none</td>
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</table>

other constraints that affect the choice, however. For example, live booms should generally be avoided on deep, narrow streams where they might cause too much flow constriction or might cause erosion of the opposing bank. Table 3 provides a summary of the hydraulic and geotechnical constraints on and benefits of the use of the soil bioengineering methods listed in Table 1. All soil bioengineering methods have a common geotechnical benefit of providing root reinforcement in the soil mantle. The more deeply installed methods positively affect the direction of seepage. Hydrologically, these methods serve as horizontal drains converting parallel flow to vertical flow, which improves the safety factor.
Table 2. Environmental benefits of soil bioengineering for streambank restoration.

<table>
<thead>
<tr>
<th>Method</th>
<th>Create or Preserve Scour Holes</th>
<th>Shade and Overhang Cover</th>
<th>Riparian Habitat</th>
<th>Recreation</th>
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</thead>
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<td>Vegetated Geogrid</td>
<td>good</td>
<td>excellent</td>
<td>fair to good</td>
<td>very good</td>
</tr>
<tr>
<td>Live Cribwall</td>
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<td>excellent</td>
<td>fair to good</td>
<td>very good</td>
</tr>
<tr>
<td>Live Boom(s)</td>
<td>excellent</td>
<td>very good</td>
<td>fair to good</td>
<td>n/a</td>
</tr>
<tr>
<td>Live Sedimentation</td>
<td>n/a</td>
<td>excellent</td>
<td>n/a</td>
<td>good to very good</td>
</tr>
<tr>
<td>Brushmatress</td>
<td>n/a</td>
<td>good to very good</td>
<td>very good to excellent</td>
<td>good to very good</td>
</tr>
<tr>
<td>Live Fascine</td>
<td>n/a</td>
<td>good</td>
<td>good to very good</td>
<td>good</td>
</tr>
</tbody>
</table>

Table 3. Hydraulic and geotechnical constraints and benefits.

<table>
<thead>
<tr>
<th>Method</th>
<th>Constraints</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetated Geogrid</td>
<td>none</td>
<td>may be constructed vertically where space is a constraint</td>
</tr>
<tr>
<td>Live Cribwall</td>
<td>restricted to streams with maximum 8 ft. high banks</td>
<td>may be constructed vertically where space is a constraint</td>
</tr>
<tr>
<td>Live Boom(s)</td>
<td>should not be used on streams with width-depth ratio less than 10; may raise water surface profile in small flood channels</td>
<td>none</td>
</tr>
<tr>
<td>Brushmatress</td>
<td>restricted to slopes flatter than 1.5H:1V</td>
<td>Banks may be cut back - allows channel to be opened where space is not a constraint</td>
</tr>
<tr>
<td>Live Fascine</td>
<td>restricted to slopes flatter than 1.5H:1V</td>
<td>Banks may be cut back - allows channel to be opened where space is to a constraint</td>
</tr>
</tbody>
</table>

The species of woody vegetation selected for inclusion in soil bioengineering systems can have a significant effect on the habitat benefits. Various species of willow are the most common woody plants used in soil bioengineering because of their excellent rooting ability and availability. While willow can provide good overhanging cover and shade for streams, good nesting habitat for some species of birds, and some cover for mammals, it is not noted as an excellent food source for land
animals. There are other plants that may be better choices for accomplishing specific habitat objectives. Such plants can be incorporated into soil bioengineering designs to provide benefits for target species. Table 4 gives information about growth habits, habitat value, and rooting characteristics for a short list of plants adapted to various regions of the United States.

**Table 4. Soil bioengineering plant species.**

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Habitat Value</th>
<th>Size/Form</th>
<th>Root Type</th>
<th>Rooting Ability for Cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alnus rubra</em></td>
<td>NW</td>
<td>excellent</td>
<td>large tree</td>
<td>shallow</td>
<td>spreading</td>
</tr>
<tr>
<td>Red alder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Baccharis viminea</em></td>
<td>W</td>
<td>very good</td>
<td>medium shrub</td>
<td>fibrous</td>
<td>good</td>
</tr>
<tr>
<td>Malefat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Betula pumila</em></td>
<td>N, E &amp; W</td>
<td>very good</td>
<td>medium shrub</td>
<td>fibrous</td>
<td>poor</td>
</tr>
<tr>
<td>Low birch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cornus sericea</em></td>
<td>N, NE &amp; NW</td>
<td>very good</td>
<td>med-small shrub</td>
<td>shallow</td>
<td>very good</td>
</tr>
<tr>
<td>ssp. Stownifera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red osier dogwood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Populus deltoides</em></td>
<td>MW, E</td>
<td>good</td>
<td>large tree</td>
<td>shallow</td>
<td>very good</td>
</tr>
<tr>
<td>Eastern cottonwood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rubus spectabilis</em></td>
<td>SW</td>
<td>good</td>
<td>small tree</td>
<td>fibrous</td>
<td>fair-good</td>
</tr>
<tr>
<td>Salmonberry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sambucus canadensis</em></td>
<td>NE &amp; SE</td>
<td>very good</td>
<td>medium shrub</td>
<td>fibrous</td>
<td>good</td>
</tr>
<tr>
<td>American elderberry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Symphoricarpus albus</em></td>
<td>N, NW &amp; E</td>
<td>good</td>
<td>small shrub</td>
<td>shallow fibrous</td>
<td>good</td>
</tr>
<tr>
<td>Snowberry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Viburnum dentago</em></td>
<td>S &amp; SE</td>
<td>good</td>
<td>large shrub</td>
<td>shallow</td>
<td>fair-good</td>
</tr>
<tr>
<td>Nannyberry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Viburnum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


**Johnson Creek Realignment, Stabilization, and Habitat Restoration**

Johnson Creek drains a heavily industrialized watershed in the Portland, Oregon, metropolitan area. Although water quality is severely degraded, there is a great deal of local interest in cleaning up the stream and
restoring the anadromous fishery that once existed. When the Oregon Department of Transportation (ODOT) relocated and shortened a short reach of Johnson Creek to construct a new bridge and interchange at McLoughlin Boulevard in Milwaukie, the Johnson Creek Corridor Committee insisted that ODOT ensure the stability of the relocated section and restore aquatic and riparian habitat. Live siltation constructions were installed along the channel margin on the inside of the bend to provide overhanging cover, and brushmattress was installed on the inside bank to provide erosion protection and riparian habitat. Outside banks were protected with low vegetated geogrids installed above a rock toe that extended to the ordinary high water elevation. Subsequent monitoring has shown the new reach to be heavily used by waterfowl, songbirds and small mammals.

**Kenai River Bank Stabilization and Habitat Restoration**

The Kenai River in Alaska is a world-class sport fishing stream noted for its trophy Chinook salmon fishing. In heavily used public access areas such as Soldotna Creek Park and Centennial Park, bank vegetation had been destroyed by foot traffic and the streambank was eroding rapidly. Because of potential impacts on rearing habitat and movement of young Chinook, Alaska Fish and Game would not permit dikes of any kind or hard structures such as bulkheads. A 650-foot section of streambank at Soldotna Creek Park was stabilized using soil bioengineering methods. Overhanging cover was provided by live siltation constructions and live cribwalls. In wet areas, native sod rolls and live fascines were used to stabilize the bank line and reestablish vegetation. Large rocks placed randomly in the shallow water in front of the live cribwalls and small rootwads anchored further out were used to create additional fish cover. The soil bioengineering installations survived the 1995 flood, the largest on record, with minimal damage. This project continues to develop well.

**Long Leaf Creek Flood Control, Stabilization, and Aesthetic Enhancement**

This stretch of Long Leaf Creek is located in a residential neighborhood known as Long Leaf Hills Subdivision. Streams in the Wilmington area, including Long Leaf Creek, have been altered by accepting increased stormwater runoff due to urbanization. Increased flooding and high peak discharges have caused significant bank erosion with deepening and widening of the channel. Compounding the increased stormwater problem are bank seepage and uncontrolled overbank runoff, which also contribute to bank failure. Finally, the creek has been used as a dump
site for organic garden debris, which kills the bank vegetation and is exacerbating erosion. These mechanical, hydrologic, and hydraulic problems have caused degradation of the aesthetic and riparian corridor values. Public meetings illuminated the desirable past conditions, the poor existing conditions, and the interest in stabilization and restoration in terms of how the people wanted to use and enjoy the creek.

Six conceptual alternatives, which included a simple intermediate action for cleanup and stabilization, grass, riprap rock and concrete liners, box convert, and soil bioengineering, were presented to the neighborhood. The soil bioengineering approach was selected as it fulfilled all the criteria. The project is proceeding into final design.

**Summary**

Streambank protection projects, by their very nature, involve multiple objectives. In addition to controlling erosion in a cost effective manner, people are increasingly concerned with water quality, habitat, aesthetics, and other environmental objectives. Soil bioengineering designs that employ woody vegetation meet these environmental objectives better than other types of streambank protection. Maximum benefits are derived by choosing soil bioengineering methods and selecting the vegetation to achieve specific environmental objectives. The success of soil bioengineering on Johnson Creek and the Kenai River and the interest in its use on Long Leaf indicates that this approach to streambank protection is growing.

**References**

Natural Resources Conservation Service
CONSERVATION CORPS AS A PARTNER FOR MULTI-OBJECTIVE MANAGEMENT

Andrew O. Moore
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Milwaukee Community Service Corps

Mark Shupp
Wisconsin Conservation Corps

Colin Weaver
Lake County Forest Preserve Youth Conservation Corps

Introduction
Floodplain managers could benefit from greater knowledge of, and partnerships with, state and local youth conservation corps. Youth corps are increasingly becoming trained and involved to carry out a range of labor-intensive approaches to stream and waterway restoration. These include controlling erosion by stabilizing streambanks, floodproofing residences and other buildings, educating community members and schoolchildren, establishing or restoring wetlands, and removing exotic species. Such approaches can benefit habitat and recreation, increase channel capacity to handle peak flows without significant erosion, and improve wetlands’ ability to serve as a “sponge” at times of high water. Corps are also uniquely well-positioned to assist in efforts to floodproof buildings and homes in floodplains through low-tech strategies. In addition, youth corps frequently assist in flood response efforts.

Youth Corps And Restoration
Stream and Wetland Restoration Projects
In recent years, state and local youth conservation corps have conducted a wide range of projects in floodplains. Corps generally undertake these projects by deploying crews of 6 to 10 young adults, ages 16–25, along with a trained adult leader, for a specified period of time. A natural
resource agency provides technical supervision. Many corps receive state and federal funding that permits them to share the cost of projects. Many corps enjoy strong linkages with citizen restoration groups through the national Coalition to Restore Urban Waters for the identification, development, and maintenance of projects important to local communities. Typical floodplain management and restoration projects that youth corps undertake include the following.

**Erosion control.** Corps can carry out projects involving bioengineering for bank protection, native plant propagation and planting, tree planting, crib walls, mulching, exclusionary domestic animal fencing, and installation of check dams.

**Floodproofing.** Corps can assess buildings in floodplains to determine the need for floodproofing, and can follow up with the appropriate steps to prepare those buildings to withstand flooding.

**Fisheries management.** Corps can remove log barriers, install in-stream structures for fish cover, place boulder weirs, assess fish populations under the direction of local biologists, rear native fish species, and carry out data entry of fish population information.

**Community and school education programs.** Corps can develop and make presentations of interactive K-12 environmental education programs on subjects such as used motor oil recycling, watershed stewardship, water conservation, and tree planting. Corps members can make presentations to classes and can also lead students in wetlands service projects. Youth corps work in partnership with other environmental and service organizations to coordinate and sponsor wetlands projects and environmental clean-ups.

**Wetland establishment.** Corps are able to work with local agencies and their staff to re-establish wetlands in new locations as mitigation for highway construction or local development projects, or for flood control purposes. Many corps can remove existing plant species from areas of development, place them in temporary care and storage, then plant them in the new wetland location. Some corps have the ability to use light- to medium-duty grading equipment needed in the development of new wetlands.

**Specialty services.** Corps can remove a wide variety of exotic species, provide soil stabilization services in the aftermath of emergencies such as fires and floods, collect environmental data as a part of geographical information system projects, restore abandoned mine landscapes, and provide data entry services for environmental
projects. Still other corps conduct snagging and clearing projects in streams and channels.

**Highlights of Recent Midwestern Youth Corps Restoration and Floodplain Management Projects**

Youth corps in Illinois and Wisconsin are quite active in stream and wetland restoration projects. Specific examples may prove instructive in understanding the variety of ways floodplain managers could apply corps labor to a specific situation. For example, the Prairie Wolf Slough Wetlands Demonstration Project in northern Illinois is a wetlands restoration and monitoring and flood control project with a wide range of partners including the Youth Conservation Corps, Lake County Forest Preserve District, U.S. Environmental Protection Agency, Friends of the Chicago River, and Highland Park Conservation Society. In its second season working on the Slough, the Youth Conservation Corps planted over 5000 native species, removed 10 acres of exotic species including European Buckthorn, Purple Loosestrife, Garlic Mustard and Sweet Clover, installed educational signs, and removed trash and flood debris from the river/wetland.

Nearby, the Milwaukee Community Service Corps has been preparing for a major role in local restoration projects that will follow on removal of dams in local rivers, and from a state commitment to develop a stronger urban trail and greenway system. Also, for the past several years, the Wisconsin Conservation Corps has worked closely with state and local emergency management staff to carry out flood recovery projects in the Mississippi River and Red River basins. The Wisconsin Corps and the neighboring Minnesota Conservation Corps have cleaned up flood debris for local, state, and federal agencies; provided primary sandbagging assistance to communities; and also assisted with rescue and evacuation operations.

**Stream Restoration Training**

A strong commitment to training undergirds and in fact precedes these projects. The National Association of Service and Conservation Corps, along with a host of other partners, is conducting regional training sessions in bioengineering of wetlands and stream banks for the staff of state and local youth corps. Trainees depart equipped to train fellow staff members and corps members, and to work with state and local agencies, to accomplish restoration and erosion control objectives. In addition, some corps have received special training in in-stream fish habitat restoration. A pilot stream restoration training session took place on Minnehaha Creek in Minneapolis in 1994; plants and other
restoration techniques installed there in only three days have greatly increased bank stability on a 100-yard stretch of creek.

**Background On Youth Corps**

The youth corps that stand to be such a helpful resource to floodplain managers are unique organizations (sometimes community-based non-profits, sometimes arms of state or municipal agencies) that marshal the energy and idealism of the young to carry out a wide range of conservation projects. Each crew undertakes, and completes to specifications, highly visible and measurable projects such as those described above. Corps members, as the participants are known, receive payment or stipends of about minimum wage for their full-time work with the corps. Corps also provide basic education, life skills classes, and job preparation services for their members, many of whom are educationally or economically disadvantaged.

State and local corps have grown and thrived over the past 20 years because they offer great community benefits—in fact, a four-fold return on investment. Corps members gain valuable work skills, and use those skills for the benefit of themselves, their families, and their communities. Corps provide temporary employment, and participants and staff spend their wages in local stores and businesses. Corps accomplish and leave behind tangible, visible work projects that often improve recreational facilities and the environment simultaneously. Also, corps focus on improving basic skills through work-based learning, so corps members have the reading, writing, and critical thinking abilities that employers demand. A recent study by Abt Associates confirmed these benefits.
The Mississippi/Rhine exchange program was conceived in the wake of the 1993 and 1995 floods on both the Mississippi and Rhine rivers. Like so many floods before them, these events were marked by two prominent characteristics. First, the flood damage experienced by the affected communities resulted largely from the failure of static flood control approaches. These approaches, which are predominantly structural in nature, are based on an assumption of a relatively constant environment predicted on the basis of extremely limited historic data. Second, the response to the floods was reactive in nature, and involved relatively little concern for future events.

Static approaches to flood damage reduction carry with them two major sets of risks. One set comprises the economic risks to communities that rely on these approaches. This set includes the probability that the projects were designed on based on inaccurate or misleading climate and flow data; the dismissal by floodplain residents of residual risk from flood events that exceed design standards ("false sense of security"); and the unanticipated increase in risk that results from changing conditions in the river channel, floodplain, watershed, and regional climate. The second set of risks are the risks to the integrity of the environment. These risks result from physical habitat alterations in the channel and floodplain, changes in the flow regime of the river, and degradation of water quality that can result from these changes.

These shortcomings in traditional approaches to flood damage reduction have become increasingly apparent to river managers on both continents over the past few decades and have triggered a search for new approaches to flood damage reduction and other river management objectives that are more robust and environmentally sustainable. The purpose of the Mississippi/Rhine exchange was to give each side of the ocean a glimpse of the strategies used on the other side that integrate economic and environmental objectives in river management.

The first stage in the Mississippi/Rhine exchange was a September 1996 tour of the Rhine River by 15 people involved in river
management from the United States. American participants came from seven Mississippi basin states and the District of Columbia. They included representatives of environmental groups, agriculture, regional commissions and federal, state, and local government agencies.

The Rhine trip took us from the Port of Rotterdam on the Dutch coast up the river to Germany and France. Along the way, we discussed issues of coastal erosion and sea level rise, dredged material disposal, water quality, floodplain management, forestry, hydrology, navigation, and environmental restoration.

**Historic Alteration of the Rhine Channel and Floodplain**

The channel of the Rhine River has been significantly altered for flood control in France and Germany since the middle ages. The Dutch initiated the construction of dams and dikes along the river and distributaries in the 17th century. These measures caused silt to accrete in the river forelands, filling in meander scars and oxbows. The German Engineer J.G. Tulla developed a program on the upper Rhine between 1817 and 1874 for flood control and to fix the border between Germany and France. Through this plan, the river branches in the braided zone of the southern upper Rhine were concentrated into a single channel and shortened the river by one-fourth between Basel and the border of Hesse.

Channelization, dam construction, constriction of the river by dikes, and loss of floodplain storage capacity has significantly increased flood risks along the upper Rhine. The loss of roughly 60% of the floodplain retention area contributed to an increase in flood peaks and velocity. Before 1955, it took 65 hours for the flood peak on the Rhine to travel from Basel to Karlsruhe. Since the end of Rhine development in 1977, only 30 hours are required for the peak to travel the same distance. The higher stage and faster flow of the river, combined with dense floodplain development, have significantly increased flood damage over the past few decades.

**New Approaches to Flood Damage Reduction on the Rhine**

In response to increasing flood risks and to the environmental impacts caused by dam and dike construction, the Rhine basin nations are diversifying their approach to flood damage reduction. New approaches include flood warning and evacuation systems and restoration of secondary channels and floodplain ecosystems.
Flood Warning and Evacuation

The lack of sound evacuation plans exposed floodplain communities in the Netherlands to an unnecessarily large risk during the Rhine River floods of 1993. In response to these floods, the Dutch water boards created Calamity Action Plans for the main river area. Simulations of dike breaks under various inundation scenarios indicated that within 24 hours—a period of time too short to complete an evacuation—the diked areas would be flooded with water 2 to 3 meters deep. The water boards concluded that evacuation in advance of the arrival of the flood crest would be the only way to avoid fatalities. During the floods of 1995, therefore, the Dutch government instituted a "preventative evacuation" of 200,000 inhabitants and tens of thousands of farm animals in advance of the flood crest to reduce the risks posed by the rising water levels and weakening dikes.

In France, Switzerland, and Germany, the international Upper Rhine Forecast system provides flood forecast services for large portions of the river system. During the late 19th century, flood warnings were passed downstream via telegraph. Now, sophisticated electronic networks transmit information virtually instantaneously, gauging stations monitor water levels constantly, and rainfall measurement networks have been expanded. The entire monitoring system is now fully automatic. Computer modes calculate expected water levels over a series of days. Regional conditions, such as impervious surfaces, topography, soil saturation, and precipitation, are incorporated into flood forecasts. Computers automatically make the results available after they have been checked by experts, and the results are transmitted via online computers, phone, and fax. When flows reach a target level, pedestrians are evacuated from riverside polders (dry detention basins), which are then used to store flood water.

Restoration of Secondary Channels and Floodplain Ecosystems

World Wildlife Fund offices are working with the Dutch and German governments to give some of the floodplain land back to the river. In the Netherlands, WWF proposed a "Living Rivers" program to reduce flood damage while restoring floodplain ecology. This strategy involves mining the deposited silt from the old oxbows and meander scars on the floodplain, and using the resulting clay to manufacture bricks for the construction industry. The recreated floodplain areas are then stocked with native grazing animals to prevent the encroachment of woody vegetation, and managed as nature reserves.

In Germany, WWF's Floodplain Ecology Institute is working to set back dikes so that natural floodplain plant communities can be
established. WWF works with the International Flood Protection Commission for the Rhine, which has set a goal of achieving the same level of flood protection as existed in 1955 in the middle and upper Rhine. Achieving this objective would require between 210 and 220 million cubic meters of additional retention volume. The Commission is using three types of flood retention measures to create this storage: special operation of the hydropower plants on the Rhine, construction and operation of retention weirs, and construction and operation of polders.

WWF’s approach to restoration of floodplain communities requires modifications in the design and operation of polder areas. Specific requirements for an ecologically healthy floodplain detention area include that prolonged inundation take place almost every year; that the tolerance limits of flooding depth and inundation for a given natural community not be exceeded; that the water level and groundwater table be allowed to fluctuate in a relatively natural pattern; that adequate water quality is maintained; that as many connections as possible between the river and floodplain be maintained; and that water flow constantly through the system so that cool temperatures and high dissolved oxygen levels are maintained.

Phase Two: Tour of the Mississippi

The second phase of the exchange involved a trip by 18 river managers from six European countries to the Mississippi River basin in September 1997. River managers from Hungary, the Czech Republic, and Slovakia came to the United States along with the Rhine riparian countries of Holland, Germany, and France. The central Europeans were seeking fresh perspectives on flood damage mitigation after the 1997 floods on rivers such as the Odra and Elbe. The Mississippi River trip featured many of the same issues discussed in Europe the previous year, including coastal management, navigation, water quality, and environmental restoration. Highlights of the trip included a tour of the relocated town of Valmeyer, Illinois, and visits to current and former floodplain farms. The U.S. visit also emphasized public participation, data management and decision support frameworks, and watershed conservation.

Post Script and Next Actions

The Mississippi/Rhine exchange helped to build working relationships between people of very different backgrounds. Communication barriers were broken down not only between different countries, but between ecologists and engineers. Approaches to floodplain management and
other water resources issues that provide benefits to a wide range of interests were highlighted.

We are hoping that the spirit of exploration and cooperation developed during this project will continue through further joint ventures between the U.S., European countries, and others. WWF will continue to collaborate with our colleagues around the world to develop and disseminate sustainable approaches to river management.
DEVELOPING A MODEL FOR
MULTI-OBJECTIVE WATERSHED PLANNING OF A
DEGRADED URBAN RIVER

Sean S. Wiedel
Lake County Stormwater Management Commission

Introduction

The North Branch of the Chicago River watershed is a largely urban watershed covering approximately 100 square miles in northeastern Illinois. The three tributaries of the North Branch, the West and Middle Forks and the Skokie River, originate in Lake County and flow into Cook County where they ultimately join to form the Chicago River in the city. The North Branch watershed is split evenly between both counties, is long and narrow and, like many urban watersheds, its drainage is defined by "stormsewersheds" rather than tributary areas. The Lake County Stormwater Management Commission (SMC) is developing a multi-objective watershed management plan for the Lake County portion of the North Branch watershed.

Problems in the Watershed

There are considerable problems in the North Branch watershed. The water quality has been degraded by a number of sources over the years, while properties throughout the watershed have suffered substantial flood damage, and significant losses and degradation of natural resources have occurred. All of these obstacles together have led to a negative perception of the North Branch.

Water Quality

The Illinois Environmental Protection Agency (1996) classified the water quality in North Branch as fair; that is, the water partially supports all uses. The causes and sources of the water quality problems in the river are primarily urban in nature: channelization for improved drainage, first for agricultural purposes, and more recently for urban and suburban land uses. The ditching and draining have resulted in trapezoidal channels with high and steep, severely eroded banks that contribute large amounts of sediment to the river. In addition, the river absorbs
urban runoff from 850+ outfalls in Lake County alone that carry pollutants from a wide variety of urban and suburban land uses.

**Flooding Problems**

In 1995 and 1996, SMC conducted a flood problem areas inventory for the entire county (Lake County Stormwater Management Commission, 1996). In the North Branch, 35 flood problem sites were identified with 19 in the Skokie River subwatershed, 13 in the Middle Fork, and 3 in the West Fork. Almost 50% of the flooding problems are due to overbank flooding in areas adjacent to the three forks and 63% of the problem sites are in mapped floodplains. In response to past and present flooding problems, approximately $20 million has been spent on three single-objective flood control reservoirs. Two of these reservoirs are located on the West Fork, while one is on the Middle Fork. The large number of flood problem sites in the Skokie River subwatershed is exacerbated by the lack of flood control projects on that fork.

**Natural Resources Degradation**

The greatest impacts on natural resources in the North Branch watershed have been due to the degradation and loss of habitat for both plants and animals. Decreases in terrestrial habitat have resulted from the on-going urbanization and suburbanization of the watershed. Based on 1990 land use data from the Northeastern Illinois Planning Commission (1995), 75% of the West Fork, 50% of the Middle Fork, and 60% of the Skokie River subwatersheds are developed.

"Development" refers to the conversion of land to intensive uses such as residential, commercial, industrial, transportation, and others. Development reduces habitat by changing natural land cover to streets, sidewalks, and buildings. A less obvious loss occurs with the decreases in aquatic habitat due to urbanization. Aquatic habitat is lost as a result of sediment deposition in the stream channel that buries the natural substrates upon which many aquatic creatures depend. This sediment comes from erosion on building sites in areas that are still developing and from erosion of highly-channelized streambanks in the three forks.

In addition to urbanization's effects on habitat, invasive and exotic species have substantially reduced habitat as well. The most prevalent exotic species in the North Branch include European buckthorn, Tartarian honeysuckle, reed canary grass, purple loosestrife, and garlic mustard. These species often outcompete native species especially in disturbed areas and may worsen existing problems, such as erosion. For example, buckthorn is extremely common on the streambanks of all three forks. Buckthorn shades out and kills off native plants, leaving a
monoculture of buckthorn behind. Unfortunately, buckthorn's root systems do not effectively hold soil in place and this leads to increased erosion from the banks and further degradation of aquatic habitat.

Wetland losses are a good illustration of the habitat degradation that has occurred in the North Branch. Based on the presence of hydric soils, there were approximately 9,800 acres of wetlands covering about 30% of the watershed before European settlement (Lake County Department of Map Services, 1997). As of 1992, only 14% of the watershed (4,400 acres) was still wetlands (Northeastern Illinois Planning Commission, U.S. Environmental Protection Agency, and Lake County Stormwater Management Commission, 1992). This means that 5,400 acres of wetlands (or 55% of pre-settlement wetlands) were converted to other uses.

**North Branch Watershed Project**

In order to address the problems in the North Branch watershed, the Lake County Stormwater Management Commission (SMC) has joined with the Friends of the Chicago River (Friends) and Northeastern Illinois University in a unique partnership to develop a multi-objective watershed management plan for the Lake County portion of the watershed. This watershed planning effort is one component of the North Branch Watershed Project (NBWP). The NBWP is an overall watershed restoration strategy for the river that was funded by a Clean Water Act Section 319 grant to the Friends from the Illinois Environmental Protection Agency (IEPA) as well as by local cost-share match. The NBWP has four primary components: the watershed plan for Lake County, a how-to handbook for urban watershed planning efforts, a series of BMP demonstration projects, and an education program for schools in the watershed. The IEPA intends to use the North Branch project and the Lake County planning process as a model for future urban watershed planning efforts in the state.

**Multi-Objective Management in the North Branch**

**Applications to the North Branch Watershed Project**

The multi-objective management (MOM) approach has six basic elements. The first is to keep efforts locally based. The NBWP started as a grass-roots, stakeholder-driven initiative. The project began at a series of stakeholder meetings called "Voices of the Stream" organized by the Friends in the early 1990s. This informal structure has, over time, developed into the current NBWP.
Second, the North Branch partners have tried to understand flooding and other problems and their relationships to the watershed. SMC did a comprehensive watershed assessment and a stream inventory that examined and documented channel characteristics, hydraulic structures, point discharges, stream corridor land use, substrate, water quality, and wildlife habitat. In addition to collecting new information, SMC compiled and summarized existing reports and raw data from numerous sources. This information has been used to determine how all of the problems relate to each other and to the watershed.

The MOM approach required project partners to think broadly about possible solutions to watershed problems. The NBWP used a number of different techniques to identify watershed problems and opportunities including an assessment and strategy (A&S) working group made up of experts from the Natural Resources Conservation Service, consulting firms, forest preserves, and others. Identified problems were categorized and utilized to develop a draft goals and objectives statement for the project. The NBWP also held a meeting called the “River-Rap” where stakeholders were asked to identify problems and opportunities in the watershed. These problems and opportunities were then ranked using a weighted voting process; this ranking is being used to prioritize the action plan for Lake County.

North Branch partners attempted to identify other community goals and concerns. SMC conducted interviews with representatives from all of the municipalities, townships, drainage districts, and other stakeholder groups to determine this information and to incorporate these issues into our planning efforts.

The NBWP obtained expert advice and assistance from the A&S working group. The A&S group was made up of experts from various agencies with many specialties. The A&S working group was the primary source of expertise for the NBWP; if they did not have the information they were usually able to steer project partners towards useful resources.

Finally, SMC has worked to build a partnership among public and private groups and individuals. The NBWP has held several meetings that were open to the general public. SMC convened monthly meetings of the planning committee (formerly A&S), and three times a year it hosts meetings of the North Branch Watershed Management Board.

Challenges to MOM
Planning for the North Branch watershed has been complicated by a number of factors. First, to coordinate and communicate between numerous jurisdictions and stakeholders has proven to be difficult. In Lake County, there are 14 municipalities, 7 townships, 11 county board
districts, 4 drainage districts and many other stakeholders that have jurisdiction over, or interest in, the North Branch watershed. As part of the planning effort, SMC has performed a considerable amount of outreach to potential stakeholders through personal interviews and open meetings to generate interest and participation in plan development. Although outreach efforts have been substantial, participation in the North Branch project has only been moderate. Second, throughout the project, it has become apparent that different stakeholders often have very different priorities and interests for the watershed. Multi-objective planning is the most effective way for SMC to incorporate this wide variety of interests and concerns into a meaningful and useful product. Third, the subwatersheds of the North Branch are highly developed which means that, in many cases, land to do large projects does not exist. In addition, the remaining undeveloped land is often very expensive, making projects cost-prohibitive and project siting difficult.

A final challenge faced by the NBWP is a lack of awareness and poor perception of the river throughout the watershed. Many residents in watershed communities are unaware of watershed issues and problems and how their actions can affect the river. Residents also have a tendency to view the river as a ‘ditch’ or as a liability rather than an asset. This lack of education and awareness is an important obstacle that still needs to be overcome. If the river is viewed as an asset, this will help to increase support from stakeholders and residents during the implementation phase of the project.

**North Branch Action Plan**

To address watershed problems, the North Branch plan includes an action plan that recommends projects that provide multiple benefits and incorporate best management practices (BMPs). Some of the benefits include improved water quality, reduced flooding, new recreational opportunities such as greenways and trails, and protection and enhancement of wetlands and other plant and animal habitats. In addition, educational and recreational components, such as signs and trails, may be included in project designs. Multi-objective wetland restoration projects are proposed in the plan that were identified by overlaying a geographic information systems (GIS) hydric soils layer with a GIS layer of all remaining public and private open space.

The focus of BMP projects is on remediation and retrofitting of existing problems. Projects will also seek to incorporate innovative design methods into new developments, particularly in undeveloped areas of the watershed. One example of a retrofit project is a detention basin that the City of North Chicago intends to construct in an existing
subdivision. The initial proposed project was a dry bottom detention basin with a concrete low-flow channel that had no water quality benefits, was aesthetically unappealing and had few benefits other than flood reduction. SMC and the NBWP partnership were able to persuade the city engineer to substantially improve the design of the detention basin by making project funding contingent on the design improvements. The revised design includes deep water settling basins with wetland vegetation, native vegetation throughout the basin, and a recreational trail with a boardwalk and educational signs.

Innovative design methods have been used in some newer developments in the watershed. One such technique is the clustering of housing in less sensitive areas to preserve natural resources. A good example is the Mellody Farms project on the Middle Fork in Lake Forest. The Lake Forest Open Lands Association (LFOLA) formed a partnership with a developer that allowed the developer to build on the perimeter of the site while LFOLA was able to preserve sensitive savanna, wetland, and prairie habitat in the interior. When the Middle Fork was ditched in the early 1900s, the spoils were deposited on the banks at the river’s edge. As part of the project, LFOLA pulled the spoil piles and banks back to create more natural conditions. The streambank slopes were substantially reduced and the banks were planted with native vegetation. The bank re-contouring had several benefits. First, the project provides substantial new and improved habitat for both plants and animals. The bank re-contouring allows the floodplain to function more naturally so that as the river level rises, the water can spread out onto surrounding lands. Finally, the project helps to re-connect the river to the land and to assist in changing peoples’ perceptions of the North Branch. Before the Mellody Farms project was completed, the Middle Fork was in a deep ditch visible only from the streambank.

Summary

The Lake County Stormwater Management Commission is developing a multi-objective watershed management plan for the North Branch of Chicago River. SMC has found that while using the MOM approach presents many challenges throughout the planning process, it has many benefits that will result in more and better solutions to solve problems and to manage the North Branch in the future.
References

Illinois Environmental Protection Agency
Springfield, IL: Illinois Environmental Protection Agency.

Lake County Department of Map Services
1997 North Branch Hydric Soils Map. Waukegan, IL: Lake County Department of Map Services.

Lake County Stormwater Management Commission
1996 Flood Problem Area Maps. Libertyville, IL: Lake County Stormwater Management Commission.

Northeastern Illinois Planning Commission

Northeastern Illinois Planning Commission, U.S. Environmental Protection Agency, and Lake County Stormwater Management Commission
Part 8
Flood Damage Estimation
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THE RESIDENTIAL SUBSTANTIAL DAMAGE ESTIMATOR

Clifford Oliver and Mark Vieira
Federal Emergency Management Agency

Daniel E. Deegan
Woodward-Clyde Federal Services

Introduction

Communities participating in the National Flood Insurance Program (NFIP) often have difficulty determining whether structures are substantially damaged. This is particularly true after a major flood or other disaster in which large numbers of buildings have been damaged and there is a need to provide timely substantial damage determinations so that reconstruction can begin. Structures located in a Special Flood Hazard Area (SFHA) that are determined to be substantially damaged or substantially improved must be brought into compliance with the minimum requirements of the respective community's NFIP-compliant floodplain management laws or ordinances. The regulations may require a residential building to be elevated, resulting in additional repair/reconstruction costs for the homeowner. Such costs may be covered under the Increased Cost of Compliance (ICC) coverage of the NFIP. Information regarding the ICC may be found in FEMA Publication No. 301, Interim Guidance for State and Local Officials on Increased Cost of Compliance.

The "Residential Substantial Damage Estimator" (RSDE), a computer program (FEMA Publication No. 311), has been developed by FEMA to assist state and local officials in estimating building value and damage costs for both single family and manufactured homes. This application is based on regulatory requirements of the NFIP and is intended to be used in conjunction with an industry-accepted residential cost estimating guide. It is anticipated that this approach will be used by the local building officials or other persons knowledgeable about residential construction costs and practices. The RSDE guidance document provides a "how-to" approach to the application that will help users understand the software program and the relationship between the various computer screens in the software program. In communities participating in the NFIP, a residential structure located in an SFHA
that is determined to be substantially damaged must be brought into compliance with NFIP regulations (44 CFR 59.1) (i.e., elevated to or above the base flood elevation). According to the NFIP regulations, substantial damage or improvement is the ratio of the cost to repair or improve a building over the market value of the building:

\[
\text{Percentage damaged/improved} = \frac{\text{Cost of repairs/improvements}}{\text{Market value of building}}
\]

Additional information about substantial damage may be found in FEMA Publication No. 213, *Answers to Questions about Substantially Damaged Buildings*. This publication is a guidance document on NFIP regulations and policy governing substantially damaged buildings. The RSDE software program provides a consolidated application to estimate substantial damage of residential buildings. The tool can assist state and local officials in using FEMA-accepted approaches to estimate the value of a structure and determine cost to repair/reconstruct a structure. From this information, a percentage of damage/improvement can be calculated to make a substantial damage/improvement determination for each residence. The software program is a valuable tool since, according to FEMA Publication No. 213, the "enforcement of the substantial improvement requirement as defined in the NFIP regulations frequently becomes a major concern for local officials after a community has experienced serious damage as a result of a flood or other disaster." The RSDE application is designed to accommodate both single family residences and manufactured (mobile) homes. This application does not account for structures designated by the state or federal entities as "historical structures."

**Data Collection and Field Inspections**

Damaged buildings must be evaluated and important data collected in order to properly make a determination of substantial damage. The Damage Inspection Worksheet, included in the RSDE User's Guide, suggests information state and local building officials should obtain while inspecting a building in order to determine substantial damage. The following are suggested procedures in performing substantial damage inspections.

State and/or local officials should take these supplies in the field when performing the inspection: Flood Insurance Rate Map (FIRM) for the community, address map that shows individual lots or an assessor's map for the community, a camera (preferably one that provides instant photographs so that notes may be made on the photograph—alternatives
include a 35-mm or digital camera and possibly a video camera), stenographer's pad to record notes, sufficient copies of Damage Inspection Worksheets, measuring tool (e.g., tape measure) to record building dimensions and to help determine depth of flooding over the lowest floor, hard hat, and steel-toed shoes.

The following information should be obtained while conducting the inspection: the location of flooded buildings on the map, a list of all flooded structures by address (the list should include the depth of flooding and a brief description of any exterior/interior damage observed), an exterior/interior visual inspection for each structure (exercise extreme caution when entering damaged buildings), a photograph(s) of the structure showing any damage (of particular interest is a photograph identifying a water line and the address should be noted on each photograph as well as whether the structure is located in or out of the SFHA).

While in the field, the following activities should be completed: the approximate location of the SFHA should be drawn on the address map or assessor's map in order for the state or local official to determine which damaged structures are in the SFHA, and the data required on the Damage Inspection Worksheet should be recorded (this includes the percentage damage of each building component). The percentage of damage for each building component should be determined based on a visual inspection of each component. Where more than one inspector is present in the field, a consensus percentage should be mutually agreed upon. The proper completion of the Damage Inspection Worksheet is essential for using the RSDE software program effectively and the information will assist the state or local official in calculating the values used for substantial damage determinations.

Two main values used in calculating substantial damage are the cost of repairs and the value of the building. To determine the cost of repair/reconstruction, the following approaches have been identified; computed damage (using the RSDE software), contractor's estimate of repair/improvement (this must be a detailed estimate that includes repairing the building to its pre-damaged condition), and the community's estimate of repair/improvement (this may include information such as the building code valuation tables published by the major building code groups).

Remember, when determining the cost of repair, donated or discounted materials must be at their full market value estimated as though they were bought during a normal market transaction. When determining the cost of labor, self or volunteer labor must be estimated at prevailing wages for the appropriate type of construction wage scale. The only costs that may be excluded are those for plans, specifications,
survey and building permits. To determine the value of the building, the following approaches have been identified: a detailed estimate of the actual cash value as determined by the RSDE or a detailed estimate of the market value using (a) property appraisals used for tax assessment purposes, (b) independent appraisals by a professional appraiser, and (c) qualified estimates based on sound professional judgment made by the staff of the local building department or local or state tax assessor’s office. The RSDE application begins after the field inspection has been performed and the Damage Inspection Worksheet has been completed. Descriptions and clarifications of terms used in the Damage Inspection Report, the Manual Computation Worksheet, and this application can be found in this document as well as an industry-accepted residential cost estimating guide.

Documentation

It is important that sufficient documentation concerning the substantial damage determination on each impacted structure be prepared and safely stored. Documentation is critical for the following reasons: it may be required by applicable state and/or local law or ordinance; it may be critical in defending a substantial damage determination during an administrative and judicial appeal; it is often necessary to demonstrate to FEMA that the community has enforced its floodplain law or ordinance in accordance with the minimum requirements of the NFIP; and it is often extremely useful in developing mitigation plans, including preparing applications for grants under FEMA’s Hazard Mitigation Grant Program and Flood Mitigation Assistance Program; and it is required to adjust a flood insurance claim under the NFIP Increased Cost of Compliance coverage.

Documentation can take many forms, but can be broken down into three major categories: field recognizance; substantial damage analysis and determination; and administrative and judicial appeals. For the three categories, the following types of documentation are often collected and stored:

1. Field Recognizance: including field assessment worksheets such as the Damage Inspection Worksheet, field notes, and photographs (including digital, film, and video).
2. Substantial Damage Analysis and Determination: including computer software printouts and hand computation worksheets.
3. Administrative and Judicial Appeals: administrative or judicial hearing minutes or decisions; alternative data used in calculating substantial damage such as professional appraisals, adjusted tax
### RESIDENTIAL SUBSTANTIAL DAMAGE ESTIMATOR

<table>
<thead>
<tr>
<th>Subdivision</th>
<th>Community Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Address</th>
<th>Mailing Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Name</td>
<td>1st Name</td>
</tr>
<tr>
<td>Last Name</td>
<td>Last Name</td>
</tr>
<tr>
<td>Address</td>
<td>Address</td>
</tr>
<tr>
<td>City</td>
<td>City</td>
</tr>
<tr>
<td>State</td>
<td>State</td>
</tr>
<tr>
<td>Zip</td>
<td>Zip</td>
</tr>
<tr>
<td>Phone</td>
<td>Phone</td>
</tr>
</tbody>
</table>

Date Damage Occurred: 
Residence Information: 

<table>
<thead>
<tr>
<th>Types</th>
<th>Single Family Residence</th>
<th>Quality</th>
<th>Low</th>
</tr>
</thead>
</table>

Inspector: 
Inspector's Phone: 
Date of Inspection: 
Est. Flood Depth: 
Above Lowest Floor: 

<table>
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<tr>
<th>NFIP Community ID#</th>
<th>Firm Panel #</th>
<th>Suffix</th>
<th>Date of Firm Panel</th>
<th>FIRM Zone</th>
<th>Base Flood Elev-Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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### OUTPUT SUMMARY

<table>
<thead>
<tr>
<th>Replacement Cost</th>
<th>Computed Damages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depreciation %</th>
<th>Repair/Reconstruction %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Per FEMA Publication 213, Actual Cash Value may be used as Market Value.

### OPTIONAL USER ENTERED DATA

<table>
<thead>
<tr>
<th>Professional Appraisal</th>
<th>Contractor's Estimate of Repair/Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.00</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tax Assessment</th>
<th>Community's Estimate of Repair/Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.00</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percent Factor</th>
<th>Adjusted Tax Assessed Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

### DETERMINATION OF SUBSTANTIAL DAMAGE IN ACCORDANCE WITH STATE/LOCAL FLOODPLAIN MANAGEMENT REQUIREMENTS

<table>
<thead>
<tr>
<th>Value of Building</th>
<th>Cost of Repair/Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Actual Cash Value</td>
<td>☐ Computed Damages</td>
</tr>
<tr>
<td>☐ Adj. Tax Assessed Value</td>
<td>☐ Contractor's Estimate</td>
</tr>
<tr>
<td>☐ Professional Appraisal</td>
<td>☐ Community's Estimate</td>
</tr>
</tbody>
</table>

Percent Damaged: 

Authorized Signature: 
Date: 

---

Figure 1. The summary page of the RSDE software.
assessment, contractor's estimate of repairs/improvements, and the community's estimate of repairs/improvements.

How to Use the RSDE Software Program

This application has been developed in Microsoft Access Version 2.0. The disks provided include the Access software required to run the RSDE in a run-time module. This module contains a modified copy of Microsoft Access, which does not permit users to modify applications provided with the run-time software. The module is a self-contained application and does not require the user to purchase the Access software. Also, since the RSDE module is self contained, it should not interfere with any existing versions of Access that may already be loaded on the computer.

If the default selections are chosen during the installation process, the software will be installed onto your hard drive in a directory called C:\RSDE. In addition, the setup utility provided will create a separate Program Group in Windows 3.x® or a separate folder in Windows 95/NT® called Substantial Damage Estimator. This group or folder will contain only one icon.

Reports Generated by the RSDE

The RSDE software generates both a full report on each evaluated structure as well as a summary page. The summary page (Figure 1) contains all the pertinent results and findings for each structure. The summary page includes a field that contains language that changes, depending on whether the structure is, in fact, substantially damaged. In the event that the structure is substantially damaged, language appears that informs the property owner that the structure must be brought into compliance with the community's floodplain ordinance or law. Additionally, the summary page includes space for the local floodplain administrator to sign and date the findings contained in the report.

NOTE: To order FEMA publications, call 1-800-480-2520. Some FEMA publications can be downloaded from the FEMA Website at http://www.fema.gov.
ANTICIPATING NON-RESIDENTIAL FLOOD DAMAGE:
FINDINGS OF A SURVEY OF BUSINESSES IN THE WYOMING VALLEY OF PENNSYLVANIA

Jack C. Kiefer
Planning and Management Consultants, Ltd.

Stuart Davis
U.S. Army Corps of Engineers Institute for Water Resources

Introduction
Flood damage to non-residential buildings and businesses constitutes a major portion of the total damage from flooding. The wide assortment of business activities in the sector presents unique challenges in computing content values, content to structure ratios, and depth-damage functions—three key relationships used for estimating damage from flooding and for projecting hypothetical damage avoided as a result of flood control projects. In such circumstances, it is often necessary to conduct surveys to collect data that can be used to develop these relationships and anticipate damage from flooding.

This paper relates the findings of a survey of businesses conducted in 1992 in the Wyoming Valley of northeastern Pennsylvania. The original purpose of the survey was to obtain flood damage data for a proposed levee-raising project. However, since the time the survey database was established, supplemental data have been gathered and additional analyses have been conducted that are pertinent to estimating non-residential flood damage (see Kiefer and Willett, 1996).

Geographic Setting
The Wyoming Valley lies in Luzerne County in northeast Pennsylvania, approximately 110 miles northwest of New York City and 90 miles northeast of Harrisburg, Pennsylvania. The study area is formed by a system of levees protecting eight townships, all in Luzerne County, which had a 1990 population of 328,149. An additional 406,026 live in the four surrounding counties. Approximately 115,000 people resided in the Wyoming Valley levee area in 1990.
The valley has a long history of flooding. During the 100-year period 1891-1991, the valley experienced 56 floods that exceeded channel bank capacity. The frequency of flooding resulted in construction of the levee system during the 1930s. Thus, since the 1940s, flooding in the area has been the result of levee overtopping. Historically, levee overtopping in the area has been associated with precipitation from hurricanes and tropical storms moving up the coast. This region experienced record flooding in 1972, when Tropical Storm Agnes produced an extended period of rain sufficient to exceed the design capacities of the levees in the Wilkes-Barre area. Several shopping centers and high value industrial properties still reside in the levee-protected floodplain areas resulting in high flood damage potential.

**Sampling Approach and Survey Design**

A preliminary inventory of Wyoming Valley businesses affected by Tropical Storm Agnes was conducted in 1979 to gather data on expected annual damage (EAD). Individual business EADs were calculated using 1979 stage damage information and 1991 rating curve and discharge-frequency information. An examination of the flood damage revealed that the level of EAD for each non-residential business would be the appropriate variable to consider for sample selection for the development of flood damage models. All high damage (EAD > $10,000) properties were sampled, while relatively low damage (EAD < $10,000) properties were sampled randomly.

Non-residential flood damage information was gathered using a field survey. Respondents were asked to estimate flood damage in dollars that would occur to both building structures and contents at four discrete flood depths (1 foot, 4 feet, 8 feet, and 12 feet). The value of the major components of building content damage, equipment, inventory, business records, and vehicles, were also estimated. These data were combined with variables identifying the standard industrial classification codes and standard land use codes for each respondent. In addition, the survey sought to identify building characteristics having a potential impact on flood damage, such as building size in square feet, number of stories, and the existence of a basement. Measurements were also collected for variables affecting the level of damage that occurred 20 years earlier during Tropical Storm Agnes. Respondents were asked to recall damage mitigation measures used, if any, the amount of warning time they had, and the length of time their businesses were closed as a result of the flooding. Standard data screening procedures resulted in 449 complete records for which these key variables were computed: (1) content value (defined as the sum of three components: values for equipment and
supplies left inside, inventory and raw material kept inside, and business records); (2) content-to-structure value ratios (C/S ratios); and (3) damage-to-value ratios (i.e., percentage damaged) for 1-, 4-, 8-, and 12-foot flood depths for contents, structure, and vehicles and other outside property.

Table 1. Selected survey statistics.

<table>
<thead>
<tr>
<th>Survey Characteristic</th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total floor area (sq ft)</td>
<td>16,174</td>
<td>5,000</td>
<td>3,109</td>
<td>446</td>
</tr>
<tr>
<td>Number of employees= full-time + part-time</td>
<td>23.9</td>
<td>6.0</td>
<td>61.2</td>
<td>424</td>
</tr>
<tr>
<td>Years at location</td>
<td>28.1</td>
<td>19.0</td>
<td>28.8</td>
<td>425</td>
</tr>
<tr>
<td>Warning time required to remove all items (hours)</td>
<td>51.77</td>
<td>24.00</td>
<td>99.13</td>
<td>429</td>
</tr>
<tr>
<td>Depreciated structure replacement value (thousands of 1992 dollars)</td>
<td>685.2</td>
<td>184.4</td>
<td>1,911.7</td>
<td>449</td>
</tr>
<tr>
<td>Value of contents (thousands of 1992 dollars)</td>
<td>1,056.0</td>
<td>165.0</td>
<td>4,980.7</td>
<td>397</td>
</tr>
<tr>
<td>Content to structure value ratio</td>
<td>2.66</td>
<td>0.85</td>
<td>18.09</td>
<td>397</td>
</tr>
</tbody>
</table>

Summary of Survey Results

Table 1 provides some statistics on the general characteristics of the surveyed businesses. At the time of the survey, the typical establishment had been in operation at the same location for approximately 28 years. The number of employees working at the sample facilities ranged from 1 to 530 people, with a mean number of employees per business of 24. The median of responses concerning the amount of warning time required to remove all transportable contents from the threat of flood damage was 24 hours. This is in contrast to the sample mean of warning time required of 52 hours. The sample distributions of nearly all of the variables related to replacement costs were characterized by wide dispersion. Replacement costs ranged from typical values in the hundreds of thousands of dollars to maximum values in the tens of millions. The sample mean content-to-structure value ratio is 2.66, with a sample median of 0.84, which is indicative of the large degree of heterogeneity in the business sector. Although not listed, nearly 70% of respondents had flood insurance at the time of the survey.

Table 2 reports the experience that surveyed businesses recalled having with Tropical Storm Agnes. Approximately 72% of the survey sample recalled being flooded in 1972 during the torrential
Table 2. Recalled experience of the 1972 flood.

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Percent</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Was your business flooded in 1972?</td>
<td>71.8</td>
<td>440</td>
</tr>
<tr>
<td>Did business take any actions to prevent damage in the 1972 flood?</td>
<td>33.3</td>
<td>324</td>
</tr>
<tr>
<td>Did your business try to prevent damage by raising items?</td>
<td>24.9</td>
<td>321</td>
</tr>
<tr>
<td>Did business try to prevent damage by sandbagging?</td>
<td>5.0</td>
<td>322</td>
</tr>
<tr>
<td>Did business try to prevent damage by moving items?</td>
<td>17.1</td>
<td>322</td>
</tr>
<tr>
<td>Percent of potential damages prevented:</td>
<td>Mean = 6 %</td>
<td>Sample Size</td>
</tr>
<tr>
<td>Days closed due to 1972 flood:</td>
<td>Median = 0 %</td>
<td>Std. Dev. = 0.2 %</td>
</tr>
<tr>
<td>Depth of 1972 flood relative to 1st floor:</td>
<td>Mean = 9 ft</td>
<td>Std. Dev. = 6 ft</td>
</tr>
<tr>
<td></td>
<td>Median = 8 ft</td>
<td>Std. Dev. = 72 days</td>
</tr>
</tbody>
</table>

The Wyoming Valley survey provided information that was used to construct and estimate statistical models for predicting content value. A non-residential content valuation function was estimated using ordinary least squares regression and natural log transformations of content value and independent variables representing building square footage, number of employees, and structure replacement value. The model explained approximately 58% of the variation among the sample, which should be considered quite adequate given the cross-sectional nature of the data. Interestingly, an independent 10% increase in either building square footage, number of employees, or structure value was found to result in only a 3.5 to 3.6% increase in building content value.
Table 3. Estimated damage by flood depth.

<table>
<thead>
<tr>
<th>Survey Characteristics</th>
<th>Hypothetical Water Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Foot</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Estimated Damages (in thousands of 1992 dollars)</td>
<td></td>
</tr>
<tr>
<td>Structural Damage</td>
<td>174.2</td>
</tr>
<tr>
<td>Content Damage</td>
<td>305.0</td>
</tr>
<tr>
<td>Vehicle and Outside Property (VOP) Damage</td>
<td>16.1</td>
</tr>
<tr>
<td>Clean-up costs</td>
<td>53.7</td>
</tr>
<tr>
<td>Total Damage</td>
<td>462.8</td>
</tr>
</tbody>
</table>

| Percent Damages (decimal fraction) |        |         |        |         |        |         |        |         |
| Structure Damage/Structure Value | 0.27   | 0.26    | 0.53   | 0.31    | 0.67   | 0.30    | 0.71   | 0.30    |
| Content Damage/Content Value    | 0.16   | 0.19    | 0.30   | 0.27    | 0.46   | 0.33    | 0.58   | 0.36    |
| VOP Damage/VOP Value            | 0.11   | 0.26    | 0.45   | 0.41    | 0.51   | 0.42    | 0.51   | 0.42    |
| Total Damage/Total Value        | 0.18   | 0.17    | 0.39   | 0.23    | 0.52   | 0.25    | 0.60   | 0.27    |

Depth-damage functions for structures and building contents were also estimated using survey data. A general nonlinear negative exponential growth specification was selected for the depth-damage relationships, which were estimated using nonlinear least squares. Variants of this general model were specified to include particular building characteristics, such as the existence of a basement and number of stories in the building. Figures 1 and 2 illustrate and report two of the models that were developed. As shown, damage to structures and contents (with and without the presence of basements) converged at approximately 72.0% of structure value with complete inundation (i.e., 24+ feet above the first floor).

Conclusions

Two key components of estimating potential flood damage are valuation of contents and structure and identification of applicable depth-damage relationships for both structure and contents. The Wyoming Valley survey and its subsequent analyses have demonstrated the usefulness
Anticipating Non-residential Flood Damage

Figure 1. General model of structure depth-damage function.

of and degree to which sample data can be used to predict damage from flooding. Properly targeted non-residential business surveys offer the greatest potential for providing the data necessary to develop robust models of depth-damage relationships. The Wyoming Valley survey should be considered only the first step in a larger non-residential data collection process. Finally, the timeliness of any flood damage survey should be considered critical, and the 20-year period that had elapsed in this study since the flooding of Tropical Storm Agnes should be considered far too long. Surveys targeting cities/regions that have been flooded within the past 5 years will result in respondents having an easier time remembering more recent events, and will likely provide more accurate information on damage and other important information that can be used to establish statistical relationships.
Figure 2. General content depth-damage for single-story buildings.

References

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Part 9
Post-Flood Activities
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DATA TRANSFER AMONG MULTIPLE GROUPS DURING POST-DISASTER RESPONSE

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Introduction

After a major disaster, various groups from federal, state, and local agencies, private industry, and academia collect data and other needed information for many purposes in response, building reconstruction, research, and planning. All of these areas address issues that assist in the mitigation effort to avoid or reduce future devastation. Because there is such a high level of interest in data collection and analysis, there needs to be data transfer among the various groups and agencies to ensure that the appropriate data is collected and funds are not used in duplicating the various efforts.

Although there are several agencies that are key in the recovery effort after a major disaster, the Federal Emergency Management Agency (FEMA) is the lead agency. Among FEMA's many responsibilities are the initial response to identify opportunities to reduce disaster-related damage through mitigation. Hurricane Fran allowed FEMA the opportunity to illustrate that data transfer among multiple groups—both private and public—can be accomplished.

Coordination of Data Collection

Hurricane Fran, which struck the Carolina coast September 5, 1997, required a significant effort in disaster response and provided an opportunity to collect valuable data and information for different purposes. In supporting the on-going effort of mitigation, FEMA coordinated this effort by the utilization of cooperative agreements and mission assignments among federal and state agencies as well as existing engineering contracts, including the Hazard Mitigation Technical Assistance Program (HMTAP) contract. Utilizing these contracts with various federal and state agencies that have the appropriate expertise in the mitigation effort enabled FEMA to streamline the initiative and start
work immediately. Having the engineering contract(s) in place allowed for additional technical support and provided a built-in mechanism for communication and coordination among the engineering firms as well as with the federal and state agencies. The coordination was critical for recovery efforts and was achieved because there was a common goal among the various groups and improved the working relationship among the parties involved.

Data Collection

In determining the type of data to be collected, each agency evaluated its needs, including potential mitigation projects.

Aerial Photography

One such project was to evaluate the flood hazards and determine if the Flood Insurance Rate Maps (FIRMs) should be revised to better reflect the actual flood risk. In order to revise the FIRMs, it was determined that air photos of the coastal areas should be taken to assist in this evaluation and analysis. To take the air photos and allow the data to be easily available for other agencies, FEMA entered into a cooperative agreement with the North Carolina Department of Transportation. The air photos that covered over 175 miles of coastline were processed within two months and provided to an engineering consultant to develop topographic data with 2-foot contours. This topographic data was then used to perform the wave height and erosion analysis as well as provide valuable information in mapping the flood hazards that would be shown on the revised FIRMs for North Topsail Island and Bogue Island. Also used in the analysis was the National Oceanic and Atmospheric Administration data for the assessment, evaluation, and calibration of the coastal flood models for the FIRMs.

The FIRMs were provided to the communities within six months of the disaster to assist them in the rebuilding process. The maps would provide a better assessment of the flood risks and encourage building homes at higher elevation, which would reduce future losses. In addition, the following groups used the FIRMs:

- The Coastal Areas Management Agency, to better identify the pile embedment requirements for homes built in A Zones and V Zones;
- Local building departments, to provide better and more updated information of the flood risks; and
- The National Park Service, to better assess risk to relocate the lighthouse.
The aerial data was not only used by FEMA in the development of the FIRMs to better assess the flood risk, but also by the following groups:

- North Carolina State University, to assess the erosion and develop a geomorphologic history of the North Topsail Island; and
- FEMA in conjunction with North Carolina Sea Grant, to study pile foundations for structures built along the coastline of Topsail Island.

**High Water Mark Studies**

In response to the immediate disaster, high water mark data is collected in collaboration with public and private interests. Based on the response time necessary to identify high water marks, the marks are "tagged" by personnel from various agencies including the Corp of Engineers, and U.S. Geological Survey as well as staff from an engineering firm(s). FEMA coordinates the effort since so many groups are interested and the resources are limited. The following groups used the high water mark information:

- Private insurance companies, to assess damage;
- The Federal Insurance Administration, to assess damage and determine cause of damage (flood versus wind);
- FEMA, to assess the damage and evaluate the FIRMs; and
- The Corps, to calibrate and run the evacuation models.

**Geographic Information Systems/Global Positioning Systems**

To facilitate the amount of data to be processed, analyzed, stored, and utilized, the information was developed using geographic information system (GIS) technology. This information was utilized by multiple users for a variety of purposes as described above. The following data was collected and prepared using GIS/GPS technology:

- Damage assessments/elevation certificates,
- Topographic maps,
- Air photos,
- Flood Insurance Rate Maps,
- Flood inundation maps, and
- COBRA zone and flood hazard maps.

To assist the users in the reconstruction effort and future planning activities of North Topsail Island, this data was developed with GIS
using different formats including ARCINFO and MAPINFO and provided to the community, the state, and the many federal agencies.

Summary

This data transfer effort was successful and possible for the following reasons:

- Shared data through built-in contract mechanism;
- Increased coordination and awareness with multiple users; and
- Elimination of duplicate efforts, to reduce overall costs.

This coordination and data collection process should be continued for future recovery efforts.
LOCAL FLOODPLAIN ADMINISTRATOR TRAINING
DURING POST-FLOOD RECOVERY

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Dewberry & Davis

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Introduction

The March 1997 flooding in the Ohio River valley resulted in Presidential disaster declarations in 13 southern Indiana counties. As flood waters receded, the Federal Emergency Management Agency (FEMA) and the Indiana Department of Natural Resources (IDNR) recognized that many of the communities were not prepared to comply with federal, state, and local regulations governing floodplain management. Because failure to comply with these regulations could affect a community's participation in the National Flood Insurance Program (NFIP), FEMA decided to provide local officials with training in the application of floodplain management regulations to disaster recovery activities.

The training was provided by two-person teams who visited the affected communities and met with community officials to discuss their floodplain management responsibilities. The teams, which consisted of personnel experienced in the NFIP, floodplain management, and property casualty adjustment, were provided to FEMA by Woodward-Clyde Federal Services under the Hazard Mitigation and Technical Assistance Planning (HMTAP) contract.

Objective

The training program was implemented to ensure that community officials were aware of their floodplain management responsibilities under the NFIP for floodplain management, and that they had the tools to fulfill these responsibilities during flood recovery. To achieve this objective, the program was designed to:
(1) Disseminate information on FEMA and IDNR floodplain regulations;
(2) Clarify NFIP floodplain management requirements, such as determinations of substantial damage;
(3) Recommend permitting and documentation methods; and
(4) Answer questions and note local concerns.

Scope

There were 54 communities participating in the NFIP in the 13 declared counties. The IDNR identified 13 of these communities as priorities, and the training teams visited them first (Clarksville, Corydon, Dearborn County, Floyd County, Grandview, Hanover, Harrison County, New Albany, Switzerland County, Poesy County, Sellersburg, Utica, and Warrick County). To ensure that the participating communities received NFIP and floodplain management information, the training teams also visited 15 additional communities that showed interest but were not on the priority list. Meetings were scheduled with the official having responsibility for permits in each community. The training team scheduled one-day visits with each priority community and follow-up visits for those communities where additional time was needed to complete the training. Visits to the non-priority communities were generally shorter in duration; however in some cases these communities required as much time and information as the priority communities.

Problems Facing Local Officials

Each community participating in the NFIP is required to adopt and enforce the minimum floodplain management regulations of the program as part of the community’s zoning ordinances. The State of Indiana had required additional regulations through a model floodplain ordinance that each participating community adopted. When floods damage insurable structures, the combined federal and state regulations require that (1) substantially damaged structures in the 100-year floodplain be elevated two feet above the 100-year or base flood elevation (BFE) if that structure is repaired, and (2) substantially damaged structures in a floodway cannot be repaired or rebuilt (per Indiana law).

The communities in the declared counties faced significant problems with enforcing their own floodplain management ordinances and, in turn, federal and state requirements. These problems included:

(1) Most of the affected communities were small and did not have large staffs.
Many had no standard permitting process in place.
Community officials had little or no background in the NFIP, floodplain management, the IDNR coordination requirements, or in recovering from a flood.

Team Operations

Each team consisted of a civil engineer with NFIP and floodplain management experience and a property casualty insurance adjuster who provided information on substantial damage determinations and procedures for elevating structures. The teams developed information packages for each community that included:

1. A four-page job aid describing flood hazard mapping terminology, floodplain management regulations, and criteria for determining substantial damage. For uninformed officials, the job aid provided a simplistic approach to the primary floodplain management issues related to the disaster recovery. Though simplified, it was also a useful summary for more experienced floodplain managers.

2. Estimating tools (i.e., procedures) for checking substantial damage determinations. These tools included worksheets for estimating market values and itemized unit cost lists for verifying repair estimates. The cost estimating tools provided a simple approach to determination of substantial damage, if more accurate or reliable information was not available.

3. FEMA publications on substantially damaged buildings (FEMA-213), elevating residential structures (FEMA-54), and installation of manufactured homes in flood hazard areas (FEMA-85); and copies of the FEMA elevation certificate and the IDNR model floodplain management ordinance. Additionally, the teams carried copies of the Flood Insurance Rate Map, Flood Boundary and Floodway Map (if available), and IDNR floodway map (if available) to each community.

Methodology

The teams used the same basic format in approaching each community. This format consisted of the following elements:

1. Verification that each official had copies of the FIRMs, the FEMA or IDNR floodway maps, and the community's floodplain ordinance.
(2) Determination of responsibility for ordinance enforcement, particularly for new construction, substantial damage, or substantial improvement.

(3) Review of the community's permitting process (if one existed).

(4) Discussion of the NFIP and state floodplain management regulations pertaining to disaster recovery.

(5) Application of the NFIP substantial damage criteria during the recovery process.

(6) Discussion of IDNR involvement in the permit process.

With few exceptions, the 13 communities on IDNR's priority list were receptive to the training. Community officials were accommodating with schedules and willing to show the teams their permit files (if they existed). Similarly, the teams were generally well-received by communities that were not on IDNR's priority list.

The information presented by the teams was appropriately basic in most cases. While some of the communities had effective permitting processes in place, the majority of the community officials needed advice on how to proceed, had questions, or sought validation of their efforts. In most cases, the officials were concerned about their responsibilities but were frustrated because they were unsure how to proceed during the period immediately after the flood.

Several community officials expressed the opinion that the timing of the visits was too late. Because the teams were deployed more than two weeks after the flood had receded, many residents had completed repairs to their homes before community officials could assess damage or issue permits. This delay may have compromised the efforts of these officials to ensure that their communities were complying with all regulations. Deployment of the training teams in the hardest-hit areas within a week of the flooding would greatly enhance the effectiveness of the program.

**Additional Problems Identified During Visits**

The teams noted problems faced by community officials in enforcing their ordinances and reported these problems to FEMA and IDNR. These problems included the following:

(1) Residents rebuilding without permits.

(2) Pressure to allow rebuilding from residents receiving FEMA disaster aid or flood insurance settlements.

(3) Lack of real enforcement capabilities.

(4) Inability of the community and IDNR to challenge a resident's estimate of the cost of repairs.
(5) Unclear authority for permitting (i.e. county vs. community).
(6) Proper use of floodway maps.
(7) NFIP regulations pertaining to commercial structures.
(8) Application of regulations for historic structures.
(9) Moving mobile homes before the flood and replacing them afterward.
(10) Problems with the elevation of mobile homes (such as general hazard insurance implications).
(11) Regulations pertaining to travel trailers and recreational vehicles.
(12) Lack of adequate survey data in rural areas.
(13) Authority for permitting construction along the U.S. Army Corps of Engineers levees.
(14) Rumors of buyouts using FEMA and state funds.

Results

Table 1 presents the communities' abilities to administer the NFIP and the IDNR floodplain management programs as determined through the training team visits.

Table 1. Capabilities of the communities.

<table>
<thead>
<tr>
<th>State of Readiness</th>
<th>Effective</th>
<th>Marginal</th>
<th>Unprepared</th>
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<tbody>
<tr>
<td>Priority Communities (13)</td>
<td>Excellent understanding of regulations; pro-active process in place</td>
<td>Some confusion about regulations; process has problems or is being developed</td>
<td>Little or no understanding of regulations; no process in place</td>
</tr>
<tr>
<td>Non-Priority Communities (15)</td>
<td>4</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7</td>
<td>6</td>
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As the table shows, most of the communities visited either had problematic floodplain management processes or did not have a process at all. The follow-up training efforts were targeted at these communities. While the effectiveness of the team meetings with these communities...
cannot be quantified, it is significant to note that two of the priority communities initiated permitting activities between the teams' initial and follow-up visits. Two additional communities stated their intentions to initiate a permitting process as soon as possible. Given the positive response of most of the community officials to the training, the program achieved the desired objectives. The fact that several of the priority communities initiated permitting processes, or stated their intentions to do so, as a result of the training reinforces this conclusion.

Recommendations

The success of the training effort suggests that this process could be used in future disasters in other states. However, some aspects of the process could be enhanced to improve the delivery and impact of the training.

(1) The timing of the field deployment of the training teams is critical to their success. Communities requiring NFIP and floodplain management training need it quickly during the recovery process. Because flood victims are likely to begin rebuilding their residences as soon as floodwaters recede, community officials should be prepared to initiate permit activities immediately.

(2) The process needs to incorporate state-specific criteria to ensure that the teams are providing a comprehensive package of relevant data to the communities visited. This will require some advance coordination between FEMA and the state.
WHY CAN'T I REBUILD?
EMERGENCY PUBLIC EDUCATION FOR MECKLENBURG COUNTY FLOOD VICTIMS

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Introduction

The enforcement of local flood damage prevention regulations as well as other requirements of the National Flood Insurance Program can be a tedious and sometimes controversial endeavor. Citizens and the development community are being told what they can and cannot do with their property simply because there is a creek on or near the property and a floodplain has been depicted on an official flood map of the area. Floodplain property owners may become antagonistic, as they perceive that government restricts their ability to gain maximum benefit from the use of the property.

This antagonism is increased many fold following a major flood that has caused substantial damage. Distraught and sometimes destitute flood victims suddenly find out that they must not only deal with the emotional and physical losses caused by the flood, but they now may not even be able to repair and move back into their homes and quickly return to a normal lifestyle.

Proper public education of floodplain property owners as well as the general population is the key to reducing antagonism and building an understanding of the need for proper flood damage prevention regulations. An aggressive public information program that is updated regularly can go a long way in preparing flood-prone property owners for the inevitable damaging event that is bound to happen over time.

Unfortunately, much of this information is not fully comprehended until the occurrence of a damaging flood and then flood victims must be given a crash course on the requirements of local flood damage prevention regulations.

This paper describes the emergency public education effort that occurred as a result of a flood in Charlotte and Mecklenburg County, North Carolina, in July 1997. The effort had both successful and not so
successful results. It is anticipated that Mecklenburg County Storm Water Services (MCSWS) and others may learn from both the successes and shortcomings.

Background

Tropical Storm Danny brought massive rainfall to Charlotte and Mecklenburg County on July 22 and 23, 1997. The storm produced all-time record rainfall, discharge, and flood heights to many areas of the county and elevations approached the 500-year level on some streams. Over 300 homes and businesses experienced flooding and damage exceeded $12 million dollars.

For the first time since joining the NFIP, Charlotte/Mecklenburg had to face the possibility of dealing with substantially damaged buildings. Therefore, flood-damaged property owners as well as staff had to be educated on the requirements of the local flood damage prevention regulations. In addition to educating flooded property owners and staff, a concerted learning effort took place about the methods of dealing with the substantial damage effort for the first time.

Mecklenburg County Engineering and Building Standards issues approximately 3400 building permits annually for remodeling or upfitting of buildings. All addresses are normally checked against tax maps (which show the Federal Emergency Management Agency (FEMA) floodplains) to determine if a hold is required on the certificate of occupancy to assure that the upfit or remodel complies with the local flood regulations.

Efforts after the July 1997 Flood

After the July 1997 flood, it was recognized that this process may not catch all permits for potentially damaged buildings. Meetings were held with permitting and inspection staff instructing them about the substantial damage requirements. MCSWS requested that "substantially damaged" holds be placed on the computerized permit tracking system when the proposed construction cost approached 50% of the tax value of the building. Any questions were to be directed to MCSWS staff. The county geographic information system produced a list of all streets where flood damage may have occurred. This list served as the "first line" check for potential substantial damage.

Signs describing the substantial damage requirements were placed at the permitting counter to tell contractors and others coming in for permits about the substantial damage requirements. The signs served as
a buffer and helped the permit staff explain the substantial damage requirements to contractors and property owners as they arrived.

**Education of Floodplain Management Staff**

As mentioned earlier, the July 1997 storm event was the first in the history of our participation in NFIP where substantial damage requirements had come into play. As we found out, the requirements look good on paper, but actually making them come to fruition can be challenging.

MCSWS employed two methods to detect substantial damage and guarantee that the issue be addressed in the reconstruction process. These are described below.

**Building permit data.** As mentioned earlier, construction information from building permit applications in the flooded areas was checked against the tax value of the buildings. Holds were placed on the occupancy permits where the construction values on the permits approached 50% of the tax value of the building. When a question arose concerning the validity of the cost estimate, the contractor was required to submit an affidavit of the itemized costs for repair and reconstruction. This accounted for the vast majority of our substantial damage determinations.

**Flood insurance claims data.** FEMA Region IV provided Preliminary Damage Assessment Reports from Write Your Own insurance companies. The data included the building damage assessment as well as the building replacement cost value from the flood insurance policies for covered homes in the affected areas. Those instances where the damage assessment value exceeded 50% of the building replacement cost value were included on the list. Holds on the occupancy permits were immediately placed on these addresses. The main drawback with this data was that the information was not available until several weeks after the flood.

**Education of Flood Victims**

MCSWS employed several methods to educate flood victims about the requirements of the Flood Damage Prevention Ordinance, especially with regard to the substantial damage requirements. These methods are described below.

**Neighborhood visits.** MCSWS staff went door-to-door in the most affected neighborhoods distributing leaflets that described the substantial damage requirements. The leaflets included information on the benefits of elevating homes and information describing loans and assistance
offered by the Small Business Administration. The leaflets were left on the homes or given to contractors or homeowners if available.

**Mailing to all floodplain residents.** MCSWS recently completed a project that provided global positioning system (GPS) elevation certificates for all floodprone structures in the FEMA-regulated floodplains. These elevation certificates are cross-referenced to a larger tax database that includes the mailing addresses of the property owners. After the July 1997 flood, information describing the substantial damage requirements and available disaster assistance was mailed to all 2200 property owner addresses in the database.

**Local media.** The local media was contacted in order to disseminate information about the substantial damage requirements and the benefits of retrofitting houses. Interviews were conducted with the local newspaper, a local television station, and a local talk radio program.

**ICC information.** The Increased Cost of Compliance provisions for flood insurance policies took effect after June 30, 1997, so the possibility existed that some of the flood victims could benefit from this additional coverage. FEMA Region IV quickly provided MCSWS with a list of all flood insurance policies that could possibly qualify for the ICC benefits. MCSWS in turn mailed information to these policyholders describing the ICC program and informing them that they may qualify.

**Lessons Learned and Recommendations**

The July 1997 flood was a learning experience to everyone affected by the storm. Never before had Mecklenburg County been faced with substantially damaged buildings and we have learned from our successes as well as our mistakes.

The County went through a property revaluation only five months after the storm. Because of this, the existing tax values on the old system were outdated. The majority of the homes that we determined to be substantially damaged obtained appraisals which, in every case, indicated that the reconstruction costs were well below 50% of the appraised value of the building. In fact, one home that would have qualified for the ICC benefits, obtained an appraisal to reduce the repair costs to less than 50%.

Another major problem is that much work has been completed without permits. A recent comparison of NFIP claims data and local permit data indicate that several claims were issued for over $20,000 but no building permits have been issued.
MCSWS has learned from the July 1997 flood and will approach future flood situations differently. The staff will make house-by-house surveys of the damaged areas, noting the depth of water and probable needed repairs. This information will be provided to the building inspection department to assure that required permits are obtained. Also, buildings where potential substantial damage has occurred will be included in a database to track repair costs and other information throughout the permitting and reconstruction process.
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Part 10

Building Performance and Standards
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Background

In 1995, committee work to prepare a new national consensus standard dealing with flood-resistant design and construction was initiated by the American Society of Civil Engineers (ASCE). The committee was guided by an ASCE prestandard document whose preparation was funded in 1993 by the Federal Emergency Management Agency (FEMA). The prestandard document was prepared by a group of consulting engineers under the direction of a steering committee of consultants, educators, public officials, and ASCE staff members.

Responsibility for the development of this new standard, ASCE 24-98, is with the Structural Engineering Institute (SEI) of ASCE, and it is expected that the standard will be published for the first time in 1998. This standard was prepared in accordance with ASCE's procedures as an American National Standards Institute (ANSI) accredited standards developing organization and it will be submitted for adoption by reference into the International Building Code (IBC) being developed by the International Code Council (ICC).

ASCE's Consensus Standards Process

Standards documents, which are prepared by volunteer members and non-members of ASCE, are consensus documents requiring balloting by the balanced standards committee and review by the public in accordance with ASCE's Rules for Standards Committees. These rules have been reviewed and approved by the American National Standards Institute and ASCE is hence accredited by ANSI. Standards may be:

(1) Mandatory, which are for adoption by reference in building codes, purchase specifications, contracts, laws or other obligatory purposes; or
(2) Non-mandatory, which are intended for use as guides or recommended practices.

ASCE Standard 24-98, Flood Resistant Design and Construction, has been developed as a mandatory standard. Balloting began in September 1996 and the public balloting, after the resolution of all comments received in prior ballots, was conducted early in 1998. After the public ballot, it will be submitted to the ICC for adoption into the IBC, which is expected to be published in 2000.

International Building Code

In a vast, complex effort to simplify the model building code system, thus allowing the U.S. building industry to become more competitive, the three national model code organizations—Uniform Building Code (UBC) from the International Conference of Building Officials (ICBO), Standard Building Code from Southern Building Code Congress International, Inc. (SBCCI), and Building Officials and Code Administrators International National Building Code from Building Officials and Code Administrators International, Inc. (BOCA)—joined together in 1994 to form the ICC. The goal was to develop one set of documents that would provide regulations for building, mechanical, plumbing, and fire features to the building industry, replacing the many codes now used by regulatory officials throughout the country.

To date, the ICC committees have developed and published the International Plumbing Code, International Private Sewage Disposal Code, and the International Mechanical Code. The International Building Code is in draft form, with public hearings in progress. It is expected that it will be adopted by the ICC and published in 2000.

ASCE Standard 24-98, Flood Resistant Design and Construction

This new standard provides minimum requirements for flood-resistant design and construction for structures located in flood hazard areas, and its provisions are applicable to all new structures and work classified as substantial repair or substantial improvement to existing structures that are not classified as historic structures. The table of contents discloses the areas addressed by the new standard:

<table>
<thead>
<tr>
<th>Section</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1</td>
<td>General</td>
</tr>
<tr>
<td>2</td>
<td>Basic Requirements for Flood Hazard Areas</td>
</tr>
<tr>
<td>3</td>
<td>High Risk Flood Hazard Areas</td>
</tr>
</tbody>
</table>
Flood loads and load combinations have been previously developed and are presented in ASCE 7-95, Minimum Design Loads for Buildings and Other Structures, which ASCE 24-98 adopts by specific reference for these items. Work is ongoing to refine the load factor for flood loads and the load factors to be used when wind and flood occur together. This project, funded by FEMA, is expected to be completed in the spring of 1998 and the results will be presented to the ASCE 7 Standards Committee for consideration.

Some of the salient provisions addressed in the ASCE 24-98 sections are important to note.

Section 1—General

Contained in this section are precise definitions for more than 100 words and terms used in the standard, and whose understanding is critical for the application of this document. Few portions of the standard required more work to develop than the definitions, but this underlined their importance to an understanding of the provisions.

This section identifies flood hazard areas that are subject to the provisions of the standard as:

1. those lands within a floodplain subject to a 1% or greater chance of flooding in any year
2. those lands designated as a flood hazard area on a community's flood hazard map, or otherwise legally designated if a community regulates to a higher standard than 1% or base flood.

This section further classifies structures into categories (I, II, III or IV) by the nature of their occupancy in accordance with the classifications defined by ASCE 7-95.
Section 2—Basic Requirements for Flood Hazard Areas

This section establishes minimum elevation requirements for a structure's lowest floor relative to the base flood elevation (BFE) or design flood elevation (DFE) according to a structure's category for those structures in flood hazard areas not subject to high velocity wave action.

Also addressed in this section are foundation requirements, including provisions for the use of both structural and non-structural fill, the use of load-bearing walls and required openings in same, and openings in enclosures below the DFE.

Section 3—High Risk Flood Hazard Areas

Special requirements are established for structures located in high risk areas subject to alluvial fan flooding, flash flooding, mudslide, erosion, high velocity flows, high velocity wave action (subject to the requirements of Section 4), and damage-causing ice or debris.

Section 4—Flood Hazard Areas Subject to High Velocity Wave Action

This section establishes design and construction requirements for structures located in areas designated as being subject to high velocity wave action on a community's flood hazard map or:

1. where the stillwater depth of the design flood above the eroded ground is greater than or equal to 3.8 feet, i.e., sufficient to support a wave height equal to or greater than 3 feet, and where conditions are conducive to the formation and propagation of such waves, or

2. where the eroded ground elevation under design flood conditions is 3 feet or more below the maximum wave runup elevation.

It further establishes minimum elevation requirements for the bottom of a structure's lowest supporting horizontal structural member of the lowest floor relative to the BFE or DFE according to a structure's category for those structures in flood hazard areas subject to high velocity wave action.

Specific requirements are also established for the use of pile foundations, columns, grade beams, bracing, enclosed areas below DFE, erosion control structures, and decks, concrete pads, and patios.
Section 5—Design

The major portion of this section is devoted to design and installation requirements for pile foundations. The requirements address timber piles, HP-sections, concrete-filled steel pipe piles and shells, precast (including prestressed) concrete piles, and cast-in-place concrete piles. Specific requirements for pile capacity, capacity of the supporting soil, minimum penetration, pile spacing, pile caps, connections, and splicing are presented.

Section 6—Materials

This section presents the requirements for flood-damage-resistant materials to be used for construction in flood hazard areas. It covers metal connectors and fasteners, including protective coatings; structural steel in both corrosive and non-corrosive environments; concrete; masonry; wood and timber.

The section also establishes minimum elevation requirements relative to the BFE or DFE, below which flood-resistant materials shall be used, based upon a structure’s category, location (with respect to high velocity wave action), and orientation of lowest horizontal structural member relative to the general direction of wave approach for structures located within areas of high velocity wave action.

Section 7—Dry and Wet Floodproofing

Requirements and restrictions for dry and wet floodproofing based upon structure category are presented, including minimum elevation requirements for floodproofing relative to the BFE or DFE for structures located outside of high risk flood areas.

Also included in this section are requirements/restrictions for active floodproofing, where human intervention before or during a flood is required.

Section 8—Utilities

Requirements and restrictions for utilities and equipment (electrical, plumbing, HVAC, and elevators) are contained in this section, including minimum elevation requirements for the location of utilities and equipment relative to the BFE or DFE based upon a structure’s category, location (with respect to high velocity wave action), and orientation of lowest horizontal structural member relative to the general direction of wave approach for utilities and equipment located within areas of high velocity wave action.
Section 9—Means of Egress
This section presents some general design requirements for stairs and ramps in order to ensure that their functionality will not be impaired during flooding.

Section 10—Accessory Structures
Design requirements for decks, porches, patios, garages (attached and detached), chimneys, and fireplaces are contained in this section. The intent is to provide minimum requirements for these accessory structures in order to reduce the likelihood that they will become damage-causing waterborne debris during floods.

Section 11—Applicable Documents
This section contains a list of all documents referenced in this standard, and the commentary to Section 11 contains a list of all documents referenced in the commentaries for each of the standard's sections. These source documents provide a wealth of technical information that has been drawn upon for use in the standard.

Conclusion
The new ASCE 24-98 Flood Resistant Design and Construction Standard provides essential minimum criteria to be used for the design and construction of structures located in flood prone areas, either coastal or riverine. Written as a mandatory standard, it is suitable for use by reference in all state and local codes, and the information contained in this new document will be of valuable and significant help to all individuals engaged in the design and construction of flood-resistant structures.
Introduction

Documentation of product performance has become an issue of paramount importance in the erosion and sediment control industry. End-users and designers are more frequently requesting this information to provide the basis for construction project designs, specifications, and installations. Performance data is also valuable to manufacturers, so that they can provide realistic expectations to end-users, designers, and installers. This information is also central to product research and development; sales and marketing activities; installation guidelines; and product certification. With the development of a more sophisticated sediment and erosion control market, it is imperative that advancements in product performance testing be pursued.

Currently, information on performance is often difficult to secure or is of questionable accuracy. A few universities offer facilities for testing erosion control materials and methods. However, comprehensive testing programs conducted at these facilities require a considerable amount of capital and often run into the tens of thousands of dollars. In addition to the high cost, university facilities are also typically scheduled many months in advance, making rapid testing of erosion control products difficult. And there are no commercial organizations or test labs available at present to do performance testing of erosion control best management practices (BMPs).

Informal field testing has therefore been the primary source of information on product performance. While actual field results amassed over a number of years may provide valuable insight on performance, it is often difficult to translate the results from one site to another. Job site conditions, such as soil, topography, weather, and treatments, are
often undocumented in field studies, yet can vary dramatically from site to site. And the quality of materials and installation, also typically undocumented, can have a significant effect on the field performance of erosion control solutions.

**The ErosionLab, Rice Lake, Wisconsin**

In order to provide timely and reliable information on the performance of erosion and sediment control BMPs, American Excelsior Company has recently sponsored the development of an in-house test facility near its manufacturing plant in Rice Lake, Wisconsin. The decision to construct this facility, known as "The ErosionLab," was based on three primary factors: 1) the need to evaluate conventional BMPs (blown straw, loose-placed, rip-rap, silt fence, and hay bale checks); 2) the need for documentation on manufactured alternatives, including installation methods; and 3) the drive to develop new solutions.

Although the company has successfully furnished erosion control products to countless projects over the past 30 years, the need for carefully quantified data on performance in typical applications was determined to be a top priority. Since the mid 1980s, many competitive materials have entered the erosion control market, each with its own claims on performance—some realistic and some not. Aside from the materials themselves, it was decided that related work, such as soil preparation, anchor patterns, and termination details, should also be evaluated. There is currently very little, if any, data available on these related topics which, in all likelihood, have a significant effect on performance. And finally, the desire to improve existing solutions and to innovate new solutions for erosion control applications was a major objective.

The ErosionLab is tasked with determining the capabilities of a wide variety of products and methods to determine performance as related to two basic criteria: 1) the ability to control erosion and reduce sediment loss prior to the establishment of vegetation, and 2) the ability to accelerate seed germination and enhance the establishment of vegetation. As discussed later in this paper, generally accepted scientific principles are applied to the test protocol, including documentation of existing conditions, use of control cases, certification of the materials/methods being applied, documentation of the test itself, and collection of data.

The ErosionLab site comprises a portion of the American Excelsior Company's 46-acre wood storage yard located near its manufacturing facility in western Wisconsin. A 2 hectare (5-acre) human-made pond is located on the site. The pond has no surface outlet, receives inflows only
from adjacent stormwater runoff (overland flow) and maintains its surface at the natural groundwater level. The on-site soil is predominantly Chetek sandy-loam, a fine- to medium-grained non-cohesive soil that exhibits rapid infiltration rates. Forested buffer strips several hundred feet wide separate the property from adjacent lands and from the nearby Red Cedar River. The on-site pond offers a ready source of clear water for conducting both rainfall and channel erosion studies. Erosion mechanisms for hillslopes and channels are evaluated using the Rainfall Erosion Facility (REF) and Channel Erosion Research Facility (CERF) areas of The ErosionLab, respectively.

After a thorough research activity, the best elements of several existing research facilities were incorporated in the design of The ErosionLab, including the Construction Industry Research and Information Association's Jackhouse Reservoir Research Laboratory in England (1987), the Simons, Li & Associates facility in Colorado (Clopper and Chen, 1988), the University of Hawaii (Sutherland, 1996), Utah State University's Water Research Laboratory, the University of Minnesota's St. Anthony Falls Hydraulic Laboratory, and Texas A&M University's facility (Texas Transportation Institute).

Construction of the laboratory required approximately 1,800 m$^3$ (2,400 yd$^3$) of cut and 1,725 m$^3$ (2,300 yd$^3$) of fill, exclusive of the 30-cm (18-inch) thick “veneer” material required for the hillslope and channel test surfaces. Equal quantities of the three veger materials (loam, clay and sand) were installed, totaling approximately 2,100 m$^3$ (2,800 yd$^3$).

The development concept for the REF involved simulation of rainfall to approximate the kinetic energy and erosive power of “typical” raindrops impacting fairly steep hillslopes. The development concept for the CERF centered around a water recycling theme where highly erosive flows are pumped from the pond through supply, test, and return channels, and ultimately through a sedimentation basin where excelsior logs further filter the water, before being returned to the pond. Figure 1 provides a plan view of the site showing the locations of the major features of The ErosionLab; Figure 2 is an air photo of the site.

**The Rainfall Erosion Facility**

To construct the Rainfall Erosion Facility (REF), excavated material from the channel area was placed in 15-cm (6-in) lifts and compacted using conventional earthmoving equipment on a 3H:1V slope. Twelve separate plots, delineated with heavy-duty landscaping edging to control run-on, were located on the embankment, each 8 ft wide by 12 ft long) long. The REF area construction was completed with the installation of a 20-cm (8-inch) diameter polyvinylchloride (PVC) pipe to convey water
from the portable pump up to the top of the berm. A manifold with 7.5-cm (3-in) diameter PVC risers was then constructed to distribute water to the top of each test plot.

Eleven sprinkler risers, each 3 m (10 ft) tall with throw heights of approximately 1.2 m (4 ft), were positioned around the desired test plot to provide a 4.2-m (14-ft) fall height and simulate natural rainfall. Valves on sprinkler risers enable uniform intensities of 64, 128, 190, and 254 mm/hr (2.5, 5.0, 7.5, and 10.0 in/hr) to be delivered onto the test plots at drop sizes typical of natural rainfall. At the maximum intensity of 254 mm/hr (10 in/hr), a flow rate of about 3.8 l/s (60 gallons per minute) is required, considering test plot area and overspray requirements, which ensure uniform rainfall coverage. For a 20-minute test, a maximum REF "event" uses about 2,600 liters (700 gallons) of water.

Runoff rates and sediment yields were measured by collecting all the runoff output from each plot at intervals during the entire test. The performance parameters of the REF are comparison of the infiltration, runoff, and erodibility to the corresponding bare soil control (baseline).

This embankment design is representative of many "real world" construction project requirements, including landfill caps, highway embankments, and levees. A variety of slope protection materials are
slated for investigation at the REF, including dry-blown straw, hydraulic mulches, erosion control blankets (ECBs) and turf reinforcement mats (TRMs).

The Channel Erosion Research Facility

To construct the Channel Erosion Research Facility (CERF), twin vertical-lift pumps, with a combined maximum discharge of 1.7 m³/s (60 ft³/s or 27,500 gpm), were mounted on pre-cast concrete sumps and driven by 6-cylinder, 200 horsepower diesel engines. By varying the speed of the engines, a smooth range of discharges up to a total capacity of 1.7 m³/s (27,000 gpm) can be achieved. Water is pumped to the inlet control structure, which feeds the supply channel where pre-cast 23 headgates, each weighing 8,600 kg (19,000 pounds), direct the flow into the desired test channel. Test channels were excavated using a trapezoidal cross-section with a 0.6 m (2-foot) bottom width and 2H:1V side slopes, and 5 and 10% bed slopes (6 each). The CERF capabilities allow velocities and shear stresses to reach about 4.2 m/s (14 ft/s) and 480 N/m² (10 lb/ft²), respectively, depending on system roughness.
Centerline flow depth and velocity are measured at nine cross-sections located in the middle 40-ft-long reach of the test channel. Pre- and post-test contour maps of the channel boundary (soil surface) are developed using total station field measurements downloaded into CAD-compatible earthwork software. This method allows accurate quantification of channel degradation or aggradation along the entire test reach. The primary performance indicators for the channel tests are the Clopper Soil Loss Index (CSLI), which divides the total "cut" volume by the total wetted surface area of the test reach to determine an average erosion depth, and subjective material observations, such as elongation, tearing, loss of material, etc.

The CERF channel designs are representative of many "real world" construction project requirements, including highway ditches, landfill drainageways, and stormwater management facilities. A variety of channel lining materials are slated for investigation at the CERF, including loose-placed rip-rap, ECBs and TRMs.

Data Analysis and Evaluation

Strict adherence to documentation and reporting procedures, including a thorough description of pre-test versus post-test conditions, is critical to the success of the program. This fundamental precept pertains to control runs, as well as tests of specific BMPs, and to channel tests, as well as hillslope rainfall simulations. Conditions to be documented include soil properties, subgrade preparation and geometry, meteorological conditions, product/material properties, application rates for mulches, and installation details for other materials.

To improve the quality and assure the accuracy, the Procedures Manuals for both the REF and CERF were developed and then reviewed informally by a number of independent, third-party agencies, including several universities, departments of transportation, and other relevant organizations. Comments and suggestions received as a result of these reviews have been incorporated into the manuals. These protocols have been re-formatted and are currently undergoing balloting in the American Society of Testing and Materials (ASTM).

To assure accurate and reliable performance assessment, the testing methods, data collection procedures, and analysis techniques for studies performed at The ErosionLab adhere to accepted scientific and statistical principles. Multiple independent tests are performed for control plots and for specific treatments in order to assess the reproducibility of measured results. Comparisons are then made between control and product to quantify the degree of erosion control provided by the given BMP.
Summary

The ErosionLab represents a significant investment in the development of reliable technical information on product performance for the most typical applications: hillslope erosion due to rainfall and channel erosion due to concentrated flows. The data generated should be invaluable in the development of performance-based standards within industry recognized organizations, including the International Erosion Control Association and ASTM. As important as detailed standards and specifications are, perhaps the most significant contribution of this state-of-the-art facility will be to offer the erosion control industry the ability to establish realistic expectations of performance that can be translated and applied to problem sites throughout the world. By maintaining an end-user perspective, the most economical erosion control solutions can be selected, based on an appropriate level of protection to eliminate both overkill and shortcuts.

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Sutherland, R.A., and Ziegler, A.D.
PERFORMANCE OF BASEMENTS IN EXCEPTION COMMUNITIES AS A RESULT OF FLOODING IN THE RED RIVER VALLEY

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Greenhorne & O'Mara, Inc.

Paul Tertell
Federal Emergency Management Agency

S. Bruce Langness
Ulteig Engineers Inc.

Introduction
The Federal Emergency Management Agency (FEMA) has been interested in gathering information about residential basement performance in areas where it has regulatory authority. One of these areas includes the "basement exception" communities (44 CFR 60.6 (b,c)). When specific flood characteristics and construction requirements are met, a community may request an exception from minimum National Flood Insurance Program (NFIP) regulations to build residential basements in the Special Flood Hazard Area (SFHA). Twenty-one communities in North Dakota and Minnesota have been granted basement exceptions and have adopted floodplain management regulations that allow residential basements in SFHAs.

History of the Basement Exception
In the early 1970s, the real estate and building industries in North Dakota sought relief from the requirements that prohibit the construction of basements in the SFHA. Some of the reasons given for these requests include:
- The tornado history in the area; basements provide a shelter.
- The local building code requires that foundation footings be extended down to a frost depth of 5 feet below grade. Under these circumstances, a basement can be constructed at a small increased cost.
- Flood waters in the area rise very slowly; residents have adequate warning in advance of impending floods.
FEMA responded by allowing communities in North Dakota and Minnesota to enact floodplain management ordinances that permitted the construction of residential basements. Communities that petitioned FEMA were allowed hardship under 44 CFR 60.6(b). In 1986, FEMA established regulations that allowed communities to propose standards for the construction of floodproofed residential basements. These regulations specify technical and administrative requirements that must be met for floodproofed basements to be allowed. Some of the technical requirements are described below:

- **Flood Conditions**—Flood depths must be not greater than 3 or 5 feet depending on the lot; flood velocities must be 5 feet per second or less; flood warning times must be at least 12 hours.

- **Structural Design Conditions**—The basements must be designed to resist hydrostatic and hydrodynamic loads; the basements must be watertight without human intervention; and the floodproofed design level must be 1-2 feet above the BFE depending on flood elevations.

A Professional Engineer must also review and certify the structural design, specifications, and plans to ensure that they are consistent with the accepted standards of practice. These engineered basements are also inspected by a community official.

**Why Study Basements in the Red River Valley?**

The April 1997 flooding in the Red River Valley provided a unique opportunity for FEMA to learn about the performance of basements in SFHAs in the basement exception communities. A Building Performance Assessment Team (BPAT) was deployed by the Mitigation Directorate of FEMA to gather information about the factors that affect the type and amount of damage, and to study the structural performance of engineered basements. The BPAT was also interested in the overall performance of basements and the corresponding damage to both pre- and post-FIRM structures.

The BPAT consisted of engineers from Greenhorne & O'Mara, Inc., FEMA, and Ulteig Engineers of Fargo, North Dakota. Ulteig Engineers was familiar with the design and construction of basements placed in the basement exception communities.

**Technical Approach**

FEMA deployed the BPAT in June 1997 to study and collect data in several communities affected by the April 1997 flooding in the Red River Valley. The communities studied were Fargo, North Dakota;
Moorhead, Minnesota; Breckenridge, Minnesota; Grand Forks, North Dakota; and East Grand Forks, Minnesota. Of the five communities studied, only East Grand Forks, Moorhead, and Fargo were granted residential basement exceptions under the hardship provisions of 44 CFR 60.6(b). Communities without basement exceptions were studied to analyze pre-FIRM basements.

To meet the goal of obtaining statistically significant results from this study, the BPAT chose a sample of 111 single-family houses to inspect. The sample was intended to represent the total population of approximately 30,000 single-family houses in the five-community study area. The BPAT attempted to choose representative numbers of pre- and post-FIRM structures as estimated from the 1990 Census data.

Twenty-two houses of the 111 structures that were surveyed had "engineered" basements. Some pre- and post-FIRM reinforced concrete basements were classified as "engineered" when in fact they may not have been designed by a registered professional engineer or architect.

During field inspections, the BPAT gathered over 40 pieces of information for each structure. To determine the performance of various construction techniques, structures were inspected both inside and outside the SFHA.

The majority of the data was collected in two broad categories of basement damage: structural damage and interior non-structural damage. Structural damage to the basement was estimated by determining the severity of structural distress to each wall of the basement. Interior non-structural damage was estimated in two parts: major utilities and "finishes and furnishings." The major utilities included items such as furnace, hot water heater, and washer/dryer. The "finishes and furnishings" value was determined by dividing the assessed value of each house by the number of floors to arrive at a rough "value per floor." The damage to the finishes and furnishings in the basement was calculated by multiplying the "value per floor" by the visual estimate of the percent the basement was furnished. For example, the total damage to the basement of a structure may be calculated as follows:

Basement Wall Structural Damage = $4,000 ($1,000 per wall)
Major Utilities = $2,500
Finishes and Furnishings: Assessed value of house (3 floors) = $90,000, Basement value = $30,000. The basement inspected was 30 percent furnished, therefore 0.30 x $30,000 = $9,000.
Total damage to the basement = ($4,000 + $2,500 + $9,000) = $15,500.
### Table 1. High water mark elevations within the communities.

<table>
<thead>
<tr>
<th>Location</th>
<th>High Water Elevation (NGVD)</th>
<th>Elevation Difference: High Water - 100-year (Feet)</th>
<th>Elevation Difference: High Water - 500-year (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USGS Gaging Station</td>
<td>962.1</td>
<td>+1.6</td>
<td>-0.9</td>
</tr>
<tr>
<td>Fargo / Moorhead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>County Highway 20</td>
<td>894.4</td>
<td>+1.2</td>
<td>-0.2</td>
</tr>
<tr>
<td>Main Avenue</td>
<td>900.1</td>
<td>+1.1</td>
<td>-2.4</td>
</tr>
<tr>
<td>Interstate 94</td>
<td>902.3</td>
<td>+1.5</td>
<td>-2.5</td>
</tr>
<tr>
<td>Rose Coulee</td>
<td>905.0</td>
<td>+2.2</td>
<td>-1.3</td>
</tr>
<tr>
<td>Grand Forks / East Grand Forks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confluence with English Coulee</td>
<td>829.0</td>
<td>+0.4</td>
<td>-2.7</td>
</tr>
<tr>
<td>USGS Gaging Station</td>
<td>833.1</td>
<td>+4.1</td>
<td>+1.0</td>
</tr>
<tr>
<td>US Highway 2</td>
<td>~ 831.9</td>
<td>+2.1</td>
<td>-3.8</td>
</tr>
<tr>
<td>Minnesota Avenue</td>
<td>~ 833.6</td>
<td>+1.2</td>
<td>-5.5</td>
</tr>
</tbody>
</table>

**Observations**

During the field data collection, much of the damage to the structures had not been repaired. Most homeowners met the inspection team and provided invaluable detail about how the structures were flooded and the amount of damage. Many high water marks were apparent.
Return periods for the floods varied between the 3 study areas of Breckenridge, Fargo/Moorhead, and Grand Forks/East Grand Forks. The difference in the high water elevations at the houses inspected within each of the communities indicated that the return period was between the 100-year and 500-year event. Using river gage data, the 1997 flood was closer to a 500-year event in Grand Forks/East Grand Forks and near a 100-year event in Fargo/Moorhead. As shown Table 1, the return period varied significantly within each of the communities.

Several factors contributed to the calculated total damage for each structure. The most significant factors were the amount the basement was finished (Table 2), the return period of the flood event in each community, and FIRM classification. The average total damage of the basements for each community was calculated (Table 3). Of the 111 structures inspected, the average percent finished of basements was over 50%. The average total damage of "engineered" and non-engineered basements was $17,600 and $20,315, respectively.

As indicated by Table 2, the amount of finishing of the basement in each of the study areas was similar. Approximately 50% of the basement was finished in both pre-FIRM (higher risk) and post-FIRM (lower risk) structures. The extent to which the basement area was finished was not related to the degree of risk of flooding.

Table 2. Percentage of basements finished by FIRM classification.

<table>
<thead>
<tr>
<th>Community</th>
<th>Pre-FIRM</th>
<th>Post-FIRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fargo/Moorhead</td>
<td>69% (n = 36)</td>
<td>48% (n = 14)</td>
</tr>
<tr>
<td>Grand Forks/East Grand Forks</td>
<td>52% (n = 36)</td>
<td>43% (n = 16)</td>
</tr>
</tbody>
</table>

Table 3. Total basement damage by FIRM classification.

<table>
<thead>
<tr>
<th>Community</th>
<th>Pre-FIRM</th>
<th>Post-FIRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fargo/Moorhead</td>
<td>$19,600</td>
<td>$6,900</td>
</tr>
<tr>
<td>Grand Forks/East Grand Forks</td>
<td>$24,300</td>
<td>$24,700</td>
</tr>
</tbody>
</table>
Conclusions

Analysis of the data yielded the following conclusions about the structures studied:

(1) Of the 22 engineered basements inspected in the basement exception communities of Fargo, Moorhead, and East Grand Forks: In East Grand Forks (where flooding based on river gage data was approximately a 500-year event), only one structure became buoyant and floated, resulting in the complete failure of this building. In Fargo and Moorhead (where flooding based on river gage data was approximately a 100-year event), the engineered design of basements succeeded in preventing structural damage to the basement. No damage was found or reported to the post-FIRM basements in the SFHA in Fargo/Moorhead.

(2) The return period of the flood event had a significant impact on basement damage. However, for the extreme event experienced in Grand Forks/East Grand Forks, there was little difference in average basement damage between pre-FIRM and post-FIRM structures. In Fargo/Moorhead, where the 1997 flooding was closer to the 100-year event, damage to post-FIRM construction was considerably less than for pre-FIRM construction.

(3) The use of the basement, the "finishes and furnishings" drove the overall damage in basements. Of the total damage, over 80% was a result of the use of the basement. Damage to major utilities and structural distress to the basement walls was not a significant factor in the overall damage. With one exception (the basement that floated), engineered basements in East Grand Forks were not structurally damaged; however, because of use and finishes, owners of these engineered basements suffered as much financially (from damage associated with using the basement area) as their neighbors with traditional non-engineered basements.

(4) Basement use (finish) caused increased damage. Finishing a basement inside the 100-year floodplain is normally not a substantial improvement under minimum NFIP requirements. However, basements in pre-FIRM houses in the SFHA were routinely finished, leading to greater damage. Much of the damage in the basements is not eligible under a standard insurance policy.

(5) Significant damage in basements based on their use occurs outside the 100-year floodplain. These basements that are usually less regulated may require additional engineering attention.
Foundations, such as reinforced block walls, outside the SFHA that are not designed to resist infrequent flood loads can fail in such events. If the strict construction requirements for engineered basements in the SFHA had been used for structures just outside the 100-year floodplain, the structural failures that were observed could have been avoided. In some cases houses across the street from one another on relatively flat terrain were built to different construction requirements, but were equally affected by the flood.

**Recommendations**

The purpose of floodplain management is to reduce the impacts from flooding to acceptable levels. This includes both the modest damage from frequent flooding and the larger damage from infrequent events. Some flood-prone communities in North Dakota and Minnesota have decided to allow basements in areas that are subject to infrequent floods. These communities have decided that the value of the basement to the homeowner should be balanced against the risk of infrequent flood damage. However, when a community allows basements in its floodplain, it is left with three approaches to reduce damage:

1. **Engineering**—require strict engineering and construction requirements for basements. The engineering solution (with use not restricted) provides the greatest use to the homeowner of a valuable basement area. However, when the design flood level is exceeded, there may be substantial damage to the basement.

2. **Control the use of the basement**—control how the basement area is used (such as by restricting plumbing). Controlling the use of the basement is difficult and prevents the homeowner from the full use of the basement for some uses such as bedrooms or recreation rooms. However, restricting the use of a basement will greatly reduce flood damage from infrequent floods.

3. **A combination of engineering and control of use of the basement area**—Communities can practically eliminate damage by requiring both strict engineering and construction standards combined with practical control of the use of basements.

The 1997 Red River Valley flood provided a rare opportunity to learn, or re-learn, valuable lessons on how both the engineering of basements and their use affect flood losses to the homeowner. A community can make more informed floodplain management decisions if it understands the limits of both engineering and/or controlling the use of basements in reducing basement damage.
Part 11
Program and Policy Evaluations and Issues
ROADBLOCKS FOR EVALUATING FLOOD MITIGATION PROJECTS UNDER FEMA'S HAZARD MITIGATION GRANT PROGRAM

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Introduction

Hazard mitigation is defined as an action intended to reduce repetitive losses from future natural disasters. Repetitive loss refers to life, injury, and property damage where the loss results not only in personal suffering, but also local, state, and federal government expenditures for disaster preparedness, response, and recovery operations. A project is a hazard mitigation project if it is directed towards reducing future disaster relief expenditures for the repair or replacement of public and private property, and expenditures for the relief of personal loss, hardship, and suffering (FEMA, 1992).

The Hazard Mitigation Grant Program (HMGP) was established by the Federal Emergency Management Agency (FEMA) to provide funding to states for disbursement to individual communities for mitigation projects to reduce or eliminate damage. In order to be eligible for funding, a proposed project must be cost-effective, in compliance with the National Environmental Policy Act (NEPA), the National Flood Insurance Program (NFIP) and HMGP regulations, and be a technically feasible project that solves a problem or potential problem and reduces the risk of future damage.

Although the HMGP can fund a wide variety of projects, including coastal, hurricane, and seismic projects, this paper focuses only on riverine (i.e., inland flood) projects since these are considered to be the largest category of funded projects. Applicants should know that the tool used to determine cost-effectiveness is the FEMA Riverine Benefit-Cost Analysis module. Therefore, the support data requirements for flood
frequency information, damage, project costs, project life, and level of protection discussed here are the same as for the module.

FEMA regional offices are responsible for providing guidance to applicants and evaluating state recommended projects to ensure that they are in compliance with the HMGP criteria. In many instances, applications for HMGP funding are incomplete or lack sufficient detail to provide an accurate overview of a proposed project. Other data deficiencies include a misunderstanding or inappropriate use of the NEPA, NFIP, and cost-effectiveness criteria. These applicant errors can result in extended delays in project review or denials of funding requests for potentially eligible projects due to poor or incomplete support data.

During 1996 the co-authors reviewed and evaluated over 250 HMGP flood mitigation applications submitted by California communities through the state Office of Emergency Services (OES) to FEMA Region IX. Many of the data deficiencies were consistent with the problems mentioned above and encountered nationwide for HMGP applications. The deficiencies force the state or FEMA to either return the applications for revisions or, in the role of reviewers, to make broad assumptions on project locations, frequency of flooding, recurrence intervals of flood events, level of protection for the proposed project, pre-damage market values of structures to be protected, damage costs, or depths of flooding above the first floor. These assumptions may yield a project evaluation based on an inaccurate assessment of the proposed mitigation project.

**Eligibility Criteria**

To be eligible under the HMGP, a proposed project must meet the minimum requirements under 44 CFR Section 206.434(b). The project must therefore:

1. Conform with a State Hazard Mitigation Plan.
2. Provide a beneficial impact upon a disaster area.
3. Conform with environmental regulations (NEPA, NFIP, Executive Orders 11988 and 11990, and the National Historic Preservation Act).
4. Solve a problem (either independently or as a functional part of a solution).
5. Be cost-effective.
6. Address repetitive problems or those of significant risk.
7. Use information and data to perform a benefit-cost analysis.
8. Provide an economic benefit.
9. Consider a range of alternatives.
10. Contribute to a long-term solution.
Consider long-term changes and remain manageable in terms of maintenance and modifications.

**Review Guidance**

Each application for HMGP funding must meet and fully address the above eligibility criteria. Often applicants either do not address some of the criteria because they believe they are not relevant to their project, or do not provide adequate support data, particularly for the cost-effectiveness determination. As part of their hazard mitigation plans, most states have developed procedures and a format that communities are required to use when applying for HMGP funds. Failure to follow the state-requested procedures can lead to extended delays at the state level or the return by the state of the application with a request to provide additional information.

Applicants and the states are responsible for knowing and understanding the HMGP eligibility criteria. Applicants must also understand that they are responsible for the presentation (i.e., description and mapping) and technical support of proposed HMGP projects. State and federal reviewers must be able to adequately evaluate a project against all of the eligibility criteria. It is in the best interests of the applicant that they fully address every eligibility issue, whether or not the applicants believe these apply for their projects. If an applicant feels that an eligibility issue is not relevant, it should be addressed as “Not applicable because . . . “, with an explanation. In addition, projects either partially or fully constructed before submittal and approval of an HMGP grant are not eligible for funding.

Applicants are neither required nor expected to hire outside consultants such as planners, surveyors, or engineers to obtain the proper support data. However, certain types of projects may require either engineering data or an analysis to justify technical feasibility. In these instances, the applicant should explore potential data or technical assistance from regional planning authorities, the county, the state, or federal agencies such as the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Natural Resources Conservation Service, or the U.S. Fish & Wildlife Service. Attempts to obtain data from these sources should be documented in the application. Reviewers may be able to work around data deficiencies if the applicant presents information that certain data is not available.

The following are the minimum items recommended to be provided to the state and FEMA as part of an applicant’s submittal package:

1. Full, written project description that states the type of project proposed (elevation of buildings, acquisition, culvert
replacement, etc.), the type and source of historical and repetitive damage, damage that occurred in a federally declared disaster, unit quantity (i.e., number of homes to be elevated, etc.), the estimated level of protection, and the planned project life. Sketches of the proposed project or photographs of similar projects are not required but could be useful for reviewers. The project description should also discuss the beneficial impact upon the disaster area, the impact on repetitive flood losses, the partial or full solution to flood problems, the long-term impact of the project, and potential maintenance issues.

(2) The description of the project should contain an assessment of the technical feasibility of the project. The feasibility of standard items such as streambank erosion protection or the size of a replacement culvert do not need to be supported in detail, but the governing state or county specifications (if applicable) should be cited.

(3) Project location map, referenced to both the effective Flood Insurance Rate Map (FIRM) or a USGS topographic quadrangle. The map should contain a north arrow, the community and county names, location and name of the flooding source, and the project boundaries. The above-requested map annotations do not need to be prepared by a surveyor or engineer, but should accurately reflect the information and data in the vicinity of the project. Due to scale limitations on both the FIRM and the USGS quadrangle, an additional photo enlargement of the project area is beneficial.

(4) Floodplain and wetlands mapping information for both the site and all areas potentially impacted. This should include the FIRM, Flood Boundary and Floodway Map for projects located within a regulatory floodway, state or local floodplain maps for areas not included on the FIRM, and National Wetlands Inventory (NWI) maps. It should be noted that the NWI maps are considered to be only a guide and not the definitive answer on the presence or absence of wetlands. Applicants may need to consult with local or state agencies to make a wetlands determination. Maps from data sources other than FEMA should include copies of the report pages that describe the flood conditions, flood frequency tables, or plots of flood profiles. If the applicant believes that the FEMA or NWI data is incorrect or has been superseded, the reason and data source should also be provided. The project location and estimated impact areas should be shown on all mapping data.
(5) Historic flood data, flood return frequency vs. elevation data, and depth of flooding above the first floor (for the benefit-cost module). The more complete this data (i.e., more data points), the more accurate the damage vs. depth of flooding relationship in the benefit-cost analysis will be, particularly for the elevation at which damage begins. For some situations where this data is not available, flood frequencies may be used from other locations along the flooding source either upstream or downstream of the project site or from adjacent watershed areas. Again, the source of the data and how it was used in the community's application should be cited. The benefit-cost analysis is based on depth of flooding above the first floor, and not the total depth of flooding above grade. It should be noted that cost-effectiveness is determined based on the entire project cost and not just the federal share of the project cost requested under the HMGP.

(6) Lowest floor, 100-year or base flood elevation (BFE), adjacent grades and freeboard requirements (if applicable) for building elevation or acquisition projects.

(7) Project costs and benefits (i.e., damage prevented). This data is obviously critical for determining cost-effectiveness. Often, zero or unsupported dollar amounts are provided with an application. Since the cost-effectiveness of a proposed project is one of the key HMGP evaluation criteria, the absence of dollar amounts or weakly supported information will probably result in the application being denied or, at a minimum, returned for more data. Weakly supported damage or project costs become important when reviewers determine, based on experience in evaluating similar projects, that damage is too high for the conditions described or project costs are extremely low. There may be good reasons for amounts that are either higher or lower than expected. However, unless the application contains sufficient support information, a reviewer may find the information unacceptable.

(8) Conformance with NEPA, NFIP, and Protection of Wetlands. Projects funded under the HMGP may not adversely impact either the environment or adjacent property owners without their consent. The 8-Step Decision-Making Process for Executive Orders 11988 (floodplains) and 11990 (wetlands) must be addressed. Information provided by the applicant should include an assessment of the potential impact on land use,
socioeconomic issues, air and water quality, natural resources, and archeological and historic resources. The application should also provide details for all alternatives considered. Applicants are strongly encouraged to evaluate these issues first, since they are extremely important to project eligibility and usually require the most time to evaluate and address within an application.

(9) The applicant should provide a single, designated point of contact.

**Top 10 Most Common Application Deficiencies**

(1) Lack of flooding information—historic flood data, flood frequency data, flood frequency vs. damage data, depth of flooding above the first floor.
(2) Failure to adequately address or document NEPA, NFIP, wetlands, and historic preservation issues.
(3) Unsupported flood damage, project costs or incomplete total project cost.
(4) Inadequate project description.
(5) Nature of repetitive flood problems.
(6) Lack of technical feasibility.
(7) Incorrect benefit-cost analysis.
(8) Lack of the proposed level of protection or project life.
(9) Proof that project will solve a problem.
(10) Information regarding the alternatives considered.

**References**

Federal Emergency Management Agency

Federal Emergency Management Agency
FLOODPLAIN MANAGEMENT AND FLOOD HAZARD MITIGATION—TIME TO TAKE A NEW LOOK

Thomas D. Fayram and Michael J. Parker
Santa Barbara County Flood Control and Water Conservation District

Introduction

In the 1990s, many businesses have been forced to change the way they do things. Several factors can drive change, including the need to stay competitive. In government, these forces are often not felt until the demand for change becomes an over-reaction. Many times we fail to look at programs midstream to see how we could do better. So often the need for change is recognized only after a program failure.

For several years the Federal Emergency Management Agency (FEMA) has urged local communities to step up floodplain management programs to limit flood losses. However, FEMA has failed to look at the federal government’s role in the process and the problem. Conflicting laws and increased regulation of floodplain management activities have created hurdles to the betterment of floodplain management. Failure to recognize local considerations also results in ineffective programs.

This paper focuses on three areas that deserve a critical look to ensure that fairness, efficiency, and overall program effectiveness are being achieved by these programs and the people they regulate. These areas are the Community Rating System (CRS), the mapping process, and the federal regulatory climate.

The Community Rating System

The CRS, started in 1990, was seen as a way to get communities more involved in flood loss mitigation. A CRS manual was published detailing the "activities" for which one could receive credit. Once it could be verified that the activities the community applied for were done in accordance with the guidelines, the community would receive a rating and a commensurate flood insurance premium reduction.

Our community believes that the CRS program is a worthwhile endeavor and a service to policyholders, however, there are some inequities, stemming from National Flood Insurance Program (NFIP)
regulations that do not address the severity or frequency of flood hazards region by region as they relate to insurable damage.

For example, flooding in the Midwest is a frequent event. In some parts of the arid West, on the other hand, flooding is neither frequent nor severe. In both cases flood insurance premiums can be the same.

The CRS program picks up from there, e.g., a community in the Midwest, along the Mississippi River, decides to buy undeveloped property located in a Special Flood Hazard Area and preserve it as open space. For this activity, the community can receive as many as 375 CRS points. Technically speaking, this community has not mitigated flood losses, but has simply kept them from occurring at this location. On the other hand, when a community constructs channel improvements that effectively remove several homes from the 100-year floodplain, this reduces flood losses significantly, saving taxpayer dollars and possibly lives. This community would receive zero points under the CRS. The fact is that some of the activities do little to reduce flood losses locally.

The nonstructural solution to a flood hazard situation offers more points than a structural solution even if the structural project produced more effective flood loss mitigation. Perhaps the money spent buying up these properties would be better spent on actual flood protection for the pre-FIRM homes presently located in the floodplain.

These activities may produce better results in other parts of the country. That leads one to conclude that a possible flaw of the CRS program is that it assumes that all flood losses are of the same nature everywhere in the country, and can be mitigated in the same manner with the same results.

An answer to this inequity might be to reexamine flood hazards across the country, develop a profile of different flood hazards, and assign worthwhile solutions to flood characteristics unique to each area of the country, i.e., the arid West, Mississippi Valley, etc. It could also be argued that even the likelihood of flood damage is drastically different from one geographical area to another, therefore insurance premiums should be adjusted from area to area.

Admittedly, constructing flood control structures in areas where future development is the only beneficiary may not be a good idea. Those who build in these areas may be at risk from failure of the control facilities. However, the construction of flood control devices to protect existing homes in the floodplain is worthwhile and economical and should be rewarded under the CRS.

The CRS focuses on FEMA-approved activities for local communities across the country. Certain regions, however, may implement activities that are highly effective at flood loss prevention, but receive no credit due to FEMA's strict criteria of "one size fits all."
The Mapping Process

Many people agree that flood hazard mapping by FEMA is not without certain deficiencies. Some of these deficiencies lie with the method used, some are due to poor geographic information, and others stem from simple mistakes in hydraulic calculations. Whatever the reason, the outcome is the same: inaccurate mapping.

Inaccurate mapping can include structures in the floodplain that are completely free from any flood hazard, forcing homeowners to spend thousands of dollars on unnecessary flood insurance. It can also omit structures from the Special Flood Hazard Area, causing disastrous results for unprepared residents, forcing homeowners to spend thousands of dollars on uninsured losses.

In the past, a study contractor hired by FEMA determined a community's flood hazards. Study contractors are picked based on their qualifications as demonstrated to FEMA. FEMA normally determines which contractor gets the job. This process sometimes results in unfamiliarity between the community and the contractor, which can result in delays in the progression of the mapping project.

The contractor's preliminary study is passed on to the community for review and, it is hoped, to correct any errors in the analysis. After community review and concurrence, the study is sent to FEMA's technical contractor for final review and mapping. In California, this would be Michael Baker Jr., Inc. After processing by the technical contractor, the map is made "official" and released to the community along with an updated Flood Insurance Study.

This process can be very lengthy. A study for the Maria Ygnacio Creek, for example, was started in 1991 and has yet to reach the community review stage. Another example involves an error in hydraulic analysis of the Montecito Creek floodplain. The error was found to be in the cross sections used in the hydraulic model being truncated rather than carried out to a point where the ground elevations met the water surface elevation. This error produced a "wall" of water at the edge of the floodplain over eight feet high and flood depths approximately six feet higher than actual flood depth.

A solution to problems like the ones cited here would be to involve the community on a more technical level—providing funding for the study directly to the community, once the community has demonstrated its technical qualifications in the same way study contractors do to FEMA. Communities can likely shorten the mapping process through a better understanding of local geography, thereby removing the community review period and producing a more accurate map in a more timely manner.
Federal Regulatory Climate

As the key entity responsible for floodplain management, local communities have found it increasingly difficult to perform their functions due to new regulations and conflicts. While the federal government increased its call for better floodplain management, the same federal government increased its regulatory authority and caused serious conflicts without any attempt to resolve key issues.

The single largest example of this is the evolution of environmental regulations. The federal government has passed many environmental laws over the years, and has extended their applicability through more aggressive policy interpretations. Today, local flood control agencies are regulated under the Clean Water Act, the Rivers and Harbors Act, the Endangered Species Act, and other laws. Now, activities of flood control agencies are controlled by the Corps of Engineers, the Fish & Wildlife Service, the Environmental Protection Agency, National Marine Fisheries Service, and other state agencies. These agencies review and issue (or do not issue) permits for construction of improvements and maintenance of existing facilities and stream corridors.

While these federal agencies increasingly asserted jurisdiction over key activities such as channel maintenance, no federal oversight was asserted as to the impacts of this regulation. As a result, serious conflicts now exist that not only threaten environmental protection, but the effectiveness of floodplain management.

Three examples illustrate this conflict in Santa Barbara County. They focus on conflicts in the County Flood Control District's Channel Maintenance Program.

Example #1—Santa Ynez River

The Santa Ynez River has been the subject of debate for almost ten years. The Flood Control District had conducted channel maintenance to remove obstructive vegetation for decades. With a cleared channel capacity of 40,000 cfs and estimated 100-year flow of 100,000 cfs, channel maintenance is critical to protecting valuable agricultural land. Recently, however, environmental concerns have restricted maintenance activities. The Corps of Engineers has been unwilling to issue permits for the necessary work, citing impacts to the environment including several endangered species. The EPA has threatened to use its veto authority over any Corps permit that may be issued.

The irony of the issue revolves around suggested alternatives to channel maintenance. After the 1993 floods in the Midwest, most environmental groups and the federal government began to question the wisdom of using levees along rivers. Catastrophic failure of levees often
causes a more hazardous condition than the hazard they are designed to prevent. But in the case of the Santa Ynez River, the EPA has called for the use of levees to offset the conveyance improvements offered by channel maintenance. Discussions that point out the cost and increased flood threat of levees have been ignored by EPA.

Today, the Santa Ynez River is a prime example of the product of regulation without oversight and decisionmaking at the federal level.

Example #2—Santa Maria River

The Santa Maria River forms the northern boundary between Santa Barbara and San Luis Obispo counties. Forming a very broad floodplain, the river lacks definitive banks, resulting in wide meandering over time.

The Corps of Engineers completed construction of a levee system on the Santa Maria River in the early 1960s. This confined the river to a narrower floodplain between the levees. As a result, the City of Santa Maria and thousands of acres of prime farm land were protected from the river's meandering. As with any federal project, the local sponsor is required to provide assurance that the project will be maintained. The Corps completed an Operations and Maintenance Manual for the project. The County agreed to keep the river free of vegetation.

In pursuing this end, the District must now obtain permits from the regulatory branch of the Corps. Rather than cite the District for improperly maintaining the river, the Corps regulations restricted the District's clearing to only a fraction of the river width. Again, there is no oversight or decisionmaking on these important issues. Regulatory concerns prevail over concerns about the levee or flooding impacts.

Example #3—Atascadero Creek

Atascadero Creek traverses a residential area of the Goleta Valley. The channel was constructed by housing developers in the early 1960s. Historically kept clear of obstruction, the creek became grossly overgrown with vegetation due to the environmental permit process. Ultimately, the District was forced to purchase property and create mitigation lands. The clearing project cost approximately $50,000; the mitigation costs are approaching $1 million.

Faced with leaving over 100 homes subject to flooding, the District had no choice but to provide the mitigation. Perhaps making the process even more frustrating, the area of clearing was simply restored to its historical condition. There were no “losses” of wetlands. The process viewed this project only as an impact to the environment but failed to consider the adjacent homes and families. Again, there was no oversight or decisionmaking process.
Conclusions

As these conflicts continue, there is no leadership or conflict resolution process at the federal level. FEMA calls for improved floodplain management at the local level while conflicting programs at the federal level are out of control. It has been pointed out for years the need for FEMA to engage in this dilemma. FEMA continues to ignore this situation. This condition must change.

It is not the intent of this paper to blame FEMA for all of the problems of local communities. Some of the problems originated completely outside of FEMA. Local communities must also share in the responsibility of all of the problems at the local level. FEMA, however, does play a crucial role in assisting local communities in flood hazard reduction. For a breakthrough in flood hazard reduction we believe a stronger federal-state-local partnership is needed.

Clearly what is needed is an improved interest in some of these issues on the part of FEMA. Regulations at the federal level play a key role in impacting flood damage across the country. There are three key steps FEMA can take to provide dramatic reductions in flood losses: (1) utilize local experience; (2) provide federal leadership; and (3) initiate regional implementation of standards and criteria in federal programs.

In terms of the CRS and flood mapping, local experience can make vast improvements to these programs. Regional issues must be considered when looking at mitigation projects, CRS points, or other policies that affect local communities.

Perhaps one of the most important improvements that FEMA could make is to take a strong leadership role in terms of conflict resolution. Across California, flood control districts have faced a tremendous conflict between pursuing the flood control mission and complying with federal environmental regulations. The result of this conflict is no resolution and a process that breeds indecision. Currently, there is no federal agency that has chosen to emerge as a champion for the cause of flood control needs, thus flood hazards mitigation suffers. We believe it is in FEMA's interest to re-evaluate some of its programs and step forward to provide the essential leadership at the federal level. It is time to take a new look, or in some cases, to take the first look.
COMMUNITY PROFILING OF THE NATIONAL FLOOD INSURANCE PROGRAM: A QUANTITATIVE ANALYSIS OF LOCAL PROGRAMS

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Introduction

As part of post-flood mitigation activities, National Flood Insurance Program (NFIP) specialists with the Federal Emergency Management (FEMA), Region IV, have routinely visited flooded communities. They have repeatedly observed problems at the local level in administering effective floodplain management programs. How widespread was, and is, this problem? Without systematic documentation, this question could only be answered in subjective terms.

Region IV has undertaken a study to measure the ability of local communities to administer and enforce local floodplain management. The study involved interviewing local administrators and questioning them on the basic elements and requirements of the NFIP. Their responses were recorded and used to develop a profile of the community. From this profile a variety of information can be ascertained (e.g., strengths and weaknesses, trends, correlation of related elements, independent elements, training needs, etc.). The data were also tallied and scored to provide a comprehensive overview of the program by state.

Purpose and Need for Study

As NFIP participants, community officials have adopted floodplain management ordinances and have agreed to enforce them as part of their voluntary entry into the NFIP. This study had two primary objectives:

- To develop profiles of communities in terms of their current ability to effectively administer a floodplain management program as part of the NFIP; and
- To develop from the community profiles, specific long-term, follow-up initiatives to address identified program deficiencies.
The results are being used to help FEMA and state NFIP coordinating agencies use limited resources more effectively and efficiently in supporting local municipalities in floodplain management.

A secondary objective was to provide technical assistance to local floodplain administrators. The administrators were also given an opportunity to identify what types of assistance would be useful to them. The study findings will also serve as a baseline against which to measure the effectiveness of follow-up assistance and initiatives.

Method

The initial step for this study was developing a survey that contained questions addressing the major elements of floodplain management. Four major elements were identified: mapping and ordinance, program knowledge, technical knowledge, and enforcement and compliance. The intent of the mapping and ordinance section was to determine if communities had these basic NFIP tools and were familiar with them. Program and technical knowledge questions served as indicators of the local administrator’s level of knowledge relative to key floodplain management terms and basic NFIP requirements and procedures, i.e., floodway/floodplain, base flood elevation, lowest floor, best available data, and substantial improvement computation. The enforcement and compliance portion of the survey was designed to assess if the community was responsibly administering and enforcing the requirements of its local ordinance. Questions focused on processing permits, ensuring compliance, correcting violations, and requiring and maintaining elevation.

Background questions were also included that dealt with the status of floodplain management as it related to the individuals’ jobs and responsibilities. Was floodplain administration their primary job duty? Had the current administrator received any training as a floodplain administrator? What impeded their jobs and which aspects of their local program were the most difficult to administer? Questions related to internal support and external difficulties were also included. Local administrators were also asked to assess the knowledge and performance level of peripheral professionals such as lenders, insurance agents, surveyors and architects/engineers.

Within a state, communities were divided into groups based on flood insurance policy counts. Representative samples were selected from the groups, and one-on-one meetings between the local floodplain administrator and a FEMA representative were scheduled. Personal contact was important not only to gain additional insight, but also to initiate a positive relationship between the local administrator and
FEMA. The community was advised that the information gathered through the profile reports would be used to determine the type of assistance needed to improve floodplain management.

The accuracy and validity of the community profiles were cross-checked with Community Assistance Visits (CAVs). A CAV is a scheduled visit to an NFIP community for the purpose of conducting a comprehensive assessment of the community's floodplain management program in relation to NFIP participation requirements. Since the CAVs provided a more in-depth look at a program, they were compared to the profile results in order to determine if the profiles provided an accurate depiction of the community's floodplain management program. In over 80% of the cases, the results were comparable. This was considered an acceptable indicator of the overall validity of the community profiles.

Observations and Findings

The data collected were recorded and tallied for each community. The questions were also categorized by program element, and aggregate totals were used to assess the strengths and weaknesses within the program at the state and local levels. Additional internal and external factors affecting program administration were also evaluated but not as part of the individual community assessment and profile. These findings were used as indicators of systematic problems facing administrators, such as political and public support and the knowledge level of key players.

In addition to the specific data collected from the community profile, Region IV floodplain management specialists have reported other general observations about local programs. This information was gleaned from a variety of sources such as CAVs, community meetings, phone conversations with residents, questions from insurance agents and lenders, and discussions with state and local officials. These observations generally support the community profile findings. A wide range of issues and problems were identified by the findings, but some patterns and trends were noted in the administration of local programs.

In the more densely populated and developing areas, administrators are more knowledgeable about requirements for floodplain development and have generally effective programs. Fortunately, these areas account for a major portion of the population. Communities with high policy counts generally have an adequate knowledge level and have effective local programs. Communities with building codes also have a greater understanding of floodplain permitting . . . regardless of policy count.

In communities where floodplain issues rarely surface, knowledge is limited. Many of the smaller communities experience frequent turnovers
in administrators, and knowledge about the program is minimal at best. Smaller communities were not always aware that they even participated in the NFIP. Administrators in small communities are typically responsible for a wide range of duties, most of which are not related to their floodplain management responsibility. In many small and some large communities, the person designated as the floodplain administrator was not the person actually managing the program. County executives and mayors listed as administrators, for example, frequently assigned these duties to their support staff. The individuals are sometimes designated or delegated without regard to their capabilities or training. Daily operational duties consume the majority of their time, and floodplain issues are rarely discussed. Major floods leave many in confusion as to their responsibility for issuing permits before structural repairs could begin.

Many local officials regard NFIP participation as a federal mandate, and as a result, they have a general lack of understanding of their local ordinances and a lack of commitment to enforce these ordinances at the local level. Evidence of this includes development in the floodplain that has not been properly permitted and noncompliant with minimum floodplain management requirements. Without this program knowledge, local administrators are unaware of when enforcement actions should be taken. In many smaller NFIP communities, floodplain management has become almost optional—only done if and when a permit application is submitted.

Effective administration at the local level depends not only on program knowledge, but also the quality of the tools available. A frequent complaint of floodplain administrators is the poor quality of the floodplain mapping, which in many cases shows no base flood elevations (BFE) or reference marks in the community. In these cases, no detailed hydraulic analysis has been performed and no backup data exists to support the designated Special Flood Hazard Area on these maps. The limited federal funding available for flood insurance studies has stymied efforts to update and produce accurate Flood Insurance Rate Maps.

Calculating substantial damage was one major issue communities struggled with during post-flood recovery efforts. Procedures for making a substantial improvement/damage determination were not always in place. Another major issue was manufactured home requirements in a floodplain. There are frequent misunderstandings and misinterpretations of the regulations for repair, placement and replacement of these units.

Flood damage in many communities could have been reduced if more effective floodplain management had been in place before the flood. A local commitment is needed if future flood losses are to be
lessened and expenditures of federal disaster funds reduced. Without this commitment, losses will continue to increase at a time when they should be declining.

**Recommendations**

The long-term strategy for improving the management includes a series of actions by FEMA in partnership with the state NFIP coordinators and local communities. Some of the actions proposed are:

- Floodplain management starter kit,
- Community support and visits,
- Training sessions for administrators, lenders, insurance agents, and surveyors,
- Follow-up CAVs with communities,
- Mapping, based on available funds, and
- Monitoring communities' actions.

The strategy calls for a commitment of time and resources at the federal and state level to work with local communities to improve their local programs for effective floodplain management. The intent is to save lives, minimize the disruptions caused by severe floods, and reduce property damage, flood losses, and federal expenditures.

Follow-up studies are planned as part of this overall strategy for improving floodplain management. Smaller representative samplings of the communities will be used, and the questionnaire will be refined to better address the most pertinent elements. A comparison will be made with the results of the earlier profiles as an indicator of what has been accomplished by the measures instituted. The follow-up studies should also identify what measures were most effective in correcting deficiencies.

Two goals were identified for this study. The first, an evaluation of floodplain management in several states, has been compiled by FEMA, Region IV. The second and ultimate goal was to develop a strategy for improving the effectiveness of floodplain management. The success of the strategy needs to be measured on a long-term basis. If successful, future floods will not be as devastating. This will be the true measure of success.
AN ASSESSMENT OF FLOODPLAIN MANAGEMENT IN GEORGIA'S FLINT RIVER BASIN

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Introduction

On July 3, 1994, Tropical Storm Alberto made landfall on the Florida panhandle below Dothan, Alabama, and proceeded northeast toward Atlanta, Georgia, before it stalled just south of that metropolis near Peachtree City on July 4th. As the storm lingered and then slowly retraced its steps to the southwest over the next six days, it dumped more than 20 inches of rain over large parts of the Flint River Basin and adjacent areas. The runoff overtopped agricultural dams, swelled tributaries, and precipitated flooding of the cities of Montezuma, Albany, Newton, and Bainbridge. The storm ultimately caused over $1 billion in damage, making the flood the most damaging ever recorded in the Flint or any southwestern Georgia river basin.

This study was initiated by the Federal Emergency Management Agency (FEMA) and the Association of State Floodplain Managers (ASFPM) to assess floodplain management in Georgia's Flint River Basin after the floods caused by Tropical Storm Alberto (see Mittler, 1997 for a full report). The assessment focused on four broad areas:

- An evaluation of previous Flint River Basin studies to understand the context in which flood mitigation policies were judged in relation to other river basin goals, such as economic development, recreation, and environmental concerns;
- An evaluation of the political setting to understand the institutional capacity of the local, state, and federal governments related to floodplain management in which institutional capacity was defined as the sum of the policymaking abilities of the different governmental units; the research included examining historic precedents, jurisdictional claims and constraints, and the existence of experts within the government on such bodies as agencies, commissions, and legislative committees;
- An evaluation of the federal, state, and local responses to the disaster, concentrating on recovery plans and the employment of hazard mitigation programs to reduce future flood losses;
specific attention was paid to the actions of the cities of Albany and Montezuma;

- A detailed analysis of the National Flood Insurance Program (NFIP) to understand whether this program was instrumental in reducing flood losses and whether the availability of flood insurance reduced federal disaster assistance payouts.

Findings and Conclusions

From the assessment, twelve specific conclusions were drawn from which four general findings can be made.

First, it was found that the federal government, the state of Georgia, and the cities of Albany and Montezuma all worked successfully at implementing policies and programs that will reduce future flood losses. There were several reasons for this positive outcome, including:

1. the implementation and enforcement of pre-existing federal recovery and mitigation policies, including the buyout and removal of flood-prone structures from the floodplain, a process initiated immediately after the presidential disaster declaration was issued;

2. the adoption by the State of Georgia of the federal policies as the main elements of its recovery plan and the subsequent efforts by the state to establish state guidelines for acceptable local recovery plans and then to manage and monitor local efforts to achieve their plans;

3. the provision of trained building inspectors by the state to local governments to ensure that statewide building codes would be implemented and enforced during rebuilding and recovery.

Second, it was found that several unforeseen problems associated with the implementation of the federal programs arose at the local level.

In the city of Albany, a neighborhood with approximately 20,000 low-income minority residents (about 30% of the city’s population) was devastated by the flood. Much of this neighborhood was located within the boundaries of the 100-year floodplain. When individual policies such as the buyout and relocation programs were implemented, it was found that these programs could not comprehensively address the complex set of problems that the flood exposed. The city ultimately developed its own long-term recovery plan employing federal flood programs where local officials believed they could do the most benefit for the city.

Furthermore, controversies arose when federal and state agencies worked independently with the city of Albany and other local political entities on problems whose solutions affected the entire city. According
to city officials, there was no attempt to coordinate local and regional programs by federal or state officials.

Finally, an analysis of the buyout data indicated that the procedures employed by the City of Albany to determine which buildings (constructed before the city joined the NFIP) were substantially damaged (for which damage exceeded 50% of fair market value) were flawed. It appeared that the method employed by the city to determine fair market value (the unadjusted tax assessment) undervalued the true market value of the structures and that the estimated cost to repair provided to the homeowners by licensed contractors they hired was often purposely kept below 50% of the assessed value so owners could qualify for a building permit and rebuild their structures without meeting floodplain management regulations.

Third, it was found that flood insurance was not widely purchased in the Flint River Basin; those who purchased it tended to be underinsured; and disaster assistance was the primary source of federal funds to individual victims.

An analysis of flood insurance data, mainly from the City of Albany, indicated that approximately 10% of the owners of flood-damaged structures carried flood insurance. Those who carried flood insurance typically carried only building coverage on the amount of the outstanding loan, as required by law, and no contents coverage. In all of Georgia, only 977 flood insurance claims were filed, totaling $34.5 million. In comparison, FEMA disbursed $31 million in Individual and Family Grants to 12,489 recipients and $22 million in disaster housing assistance to more than 16,000 recipients, and the Small Business Administration (SBA) provided loans of over $183 million to 4,367 applicants. FEMA also made $35 million available for buyouts, and the Department of Housing and Urban Development (HUD) provided $132 million in supplemental Community Development Block Grant (CDBG) funds, most of which was earmarked for housing projects.

Fourth, it was found that federal, state, and local officials were prone to make less than optimal decisions because they did not share important data or effectively use data collected by others. During this investigation, it was found again and again that agencies responsible for making critical decisions did not have access to or attempt to collect data that would have helped them make optimal decisions. It was obvious that decisions were being made by time-pressed officials to meet deadlines using whatever data was available, rather than following an orderly process of data collection and analysis.
Recommendations

In light of the findings and conclusions, to concentrate attention on what might be done to improve floodplain management in the country, 10 recommendations in the form of questions were posed. The questions focused on the relationship among the federal, state, and local governments and the effectiveness of current programs.

Among the ten questions were five that addressed specific problems found in the assessment and five that addressed the current status of disaster assistance, recovery, and mitigation programs in the country. While all ten questions are discussed in Mittler (1997), only the questions addressing the status of the current programs are presented below.

The first two questions are concerned with the responsibilities of different government jurisdictions. Presently, the Stafford Act as amended presumes that the federal government will provide disaster aid supplementary to state and local aid. However, as occurred in Georgia, both the state and local governments rely heavily on the availability of federal programs and assistance. Therefore,

If state and local governments do not develop or implement comprehensive floodplain management policies and programs that could be employed to guide recovery and mitigation after floods, should the federal government continue to play the leading role in the development, implementation, and enforcement of responsible floodplain management practices?

In order to clarify the roles and responsibilities of the federal, state, and local governments in floodplain management and allocate responsibility, should Congress enact a National Floodplain Management Act, and what will it accomplish?

In a similar vein,

Should a federal task force consisting of representatives from at least FEMA, the U.S. Army Corps of Engineers, HUD, the SBA, the Department of Agriculture, the National Oceanic and Atmospheric Administration, and the Economic Development Administration be established to jointly determine data requirements for postdisaster decisions, evaluate the usefulness of the data each agency currently collects, determine what additional data should be collected, and then determine a mechanism to exchange data so better decisions can be made?
Because it was found that only 10% of all damaged structures were covered by flood insurance and those that were covered were underinsured,

Should a more complete analysis of the National Flood Insurance Program now be undertaken?

Finally,

Should the federal government fund additional studies to gain a greater appreciation of how its policies and programs work in order to develop proposals for improvements in the nation's floodplains?

References

Mittler, Elliott
Nearly everyone agrees that the Federal Emergency Management Agency (FEMA) provides a much-needed source of flood insurance for owners of property that is at risk of damage from flood waters. However, in the case where a home with a basement is constructed in an area that has been filled with compacted material and the property, although reconfigured to be above the base flood elevation (BFE), is still designated as being located in a flood zone, FEMA’s mandate that the homeowner purchase this insurance is not easily understood and, in fact, has become a contentious issue.

Historically, construction of the subsurface area in houses has been tied to economics and to the practical need for protection from winter weather. A basement provides a homebuyer with 30 to 33% more useable space for an increase in building cost of only 10%. Therefore, it is financially desirable from the perspective of both the developer/builder and the homebuyer that the house be constructed with a basement.

As for winter weather, since frost penetrates the soils of the central and northern states to depths of between four and six feet, a sound foundation for a residential unit should always be established below this frost line. Therefore, housing foundations have long been placed 10 to 12 feet below grade and the house built over the excavated area. In the Midwest, other uses were found for this usually dark, damp area under the house, such as a coal bin when that was the primary heating fuel, a root cellar for winter storage of vegetables and fruit, a cistern to store rainwater for domestic laundry use, and as a place of safety when a tornado approached.

With the advent of gas furnaces, water softeners, and refrigerators, the excavated foundation space became available for other family uses such as recreation, laundry, or workshops. However, at FEMA, the subsurface section of a residence became a determiner of the premium for flood insurance where the house was constructed with fill used to elevate the first floor of the residence above the surrounding property.
The difficulty occurs when the BFE divides a property into two specific portions, one of which has a ground surface elevation above the BFE and the other below the BFE. From an engineering point of view, the most practical solution is to reconfigure the topography of a lot in a manner that places all or a major portion of the parcel involved, be it one acre or 100 acres, at an elevation somewhat above the BFE.

In contrast, current FEMA directives clearly state that (1) the flood elevation assigned to the particular filled property may change, (2) new information may supersede FEMA's determination of a BFE, or (3) the property could be inundated by a flood with a magnitude greater than the 1% probability. In addition, according to FEMA, localized flooding not shown on the effective National Flood Insurance Program (NFIP) Flood Insurance Rate Map (FIRM) could inundate this property. These directives are seen by some engineers, developers, builders, and homebuyers as unrealistic, especially in light of stormwater management regulations adopted by most local governing agencies that are applauded by the Community Rating System (CRS).

Many governmental agencies restrict such earthmoving or reconfiguring programs, insisting that the stormwater storage potential of the area that is filled below the BFE be compensated for by replacing the volume of stormwater displaced with a similar volume of overbank stormwater storage, sometimes at a ratio of 1.5 to 1.0. Even when none of the property is located below the BFE, governmental agencies in many localities require additional facilities to regulate the amount and rate of stormwater flow that can be conveyed to servient property. The requirements of such ordinances have actually eliminated or significantly reduced the flooding potential for numerous urban and suburban homes that formerly were subject to some degree of flooding potential.

What effect does the mandate to purchase flood insurance have on the average homeowner or homebuyer? Added to the monthly mortgage payment of principal and interest and the usual escrowed amounts for taxes and property insurance premiums, a monthly flood insurance premium payment of as much as $100 translates as a devaluation of the owner's property and as a discouraging factor for the prospective buyer. Where the structure is actually at risk for flood damage, the premium payment is warranted to guarantee the value of the loan. In those instances, the property should not be valued as highly as a similar property with a lesser potential of flooding. However, the inequity of the mandate for flood insurance is evident where adjacent homes are identically constructed with basements at comparable elevations below the established BFE, and one homeowner is required to purchase flood insurance while the other is exempt, despite the fact that the surface of
both lots exists at an elevation that is as much as three to four feet above the established BFE.

The reasoning for this apparent discrimination by FEMA seems to be based on the amount of fill placed on the original ground surface prior to the construction of the structure. If the soil imported for use as fill is of sufficient structural capacity to support the imposed loads and is compacted in a manner that meets the required density, it seems reasonable that the Letter of Map Revision (LOMR) that would exempt the homeowner from flood insurance should be issued based on the existing certified topographic conditions, regardless of whether a structure exists on the property or it is vacant. If no structures exist, then a request for a map revision is usually approved by FEMA. However, if a structure has been constructed with a basement below the BFE, the LOMR request is rejected.

In rejecting the request for a map revision in a particular case FEMA states:

the structures on lots would be inundated by the flood having a 1-percent chance of being equaled or exceeded in any given year (base flood) and are correctly shown on the effective NFIP map as being located in a SFHA, designated Zone A2.

The problem with FEMA's response is that the approved and established BFE of the lot/property in question is 712.1, while the elevation of the lowest portion of the lot that contains the structure is verified by FEMA at 716.0, and the lowest elevation adjacent to the structure is 711.0; however, the basement is located at an elevation of 711.3 (see Figure 1).

Even when the owner of this home (with a basement constructed on a lot that has been filled) purchases flood insurance, an occasion when he or she could collect on this insurance policy will never arise where best management practices for stormwater have been implemented. This is because the entire parcel of ground on this lot is four feet above the BFE and the tributary watershed is less than one square mile in area.

The NFIP has made insurance available to policy holders whose property is at risk for the damage sustained from devastating floods. However, where property has been revised so that it no longer is at risk of flood damage, it is FEMA's current policy not to change the FIRM to reflect the existing topographical conditions. It is my opinion, and that of many others, that that this FEMA policy should be assessed to allow revision of the NFIP maps to accurately reflect the current topographic conditions. Where the established topography coincides with the certified BFE, the FIRM should be revised to agree with the actual existing topography. The condition of the property that existed in the
Figure 1. Example of elevations of adjacent homes.
past when the map was published some 20 years earlier (utilizing topographic information that was five to 10 years out of date at that time) is no longer relevant. Outdated maps erroneously show a condition that does not exist in cases where the topography has been reconfigured and the BFE certified, and the use of these erroneous maps places an economic burden on both the developer and the homeowner.

The site design engineer is challenged to provide a trouble-free environment for the future property owners in the most economical manner possible. The availability of recorded rainfall data, topographic data and maps, and computer modeling programs enable the design engineer to calculate the frequency at which surface stormwater will reach a specific elevation in a specific place. In addition, the FEMA Special Flood Hazard Area (SFHA) information provided on the FIRM is very helpful in planning land uses. However, when the flood frequency information provided by the FIRM is used in the design of sites for housing that will never be subjected to damage by flood water (in the event of a 1% probability storm event), the future property owners are placed at risk of having to purchase a flood insurance policy. This is insurance on which they can never collect a penny because of the current policy not to change the maps.

FEMA has no authority to establish regulations concerning the construction of structures with basements. It does, however, regulate the information that is published on the FIRM documents. Its unwillingness to modify these documents to accurately designate the SFHAs when structures are involved enables FEMA to collect insurance premiums—but the homeowner will never collect for damage to the structure that cannot occur. In one instance, a homeowner on the fifth floor of a condominium was told by his mortgage holder that he would have to pay a flood insurance premium for the entire building at a cost of over $1,000! The flooding potential was re-established and an exemption was given in the form of a LOMR.

Make no mistake, FEMA is in the insurance business. You have noticed the advertisements on television and radio and in newspapers and magazines that a $25,000 policy is available for as little as $85 per year. The agency also offers preferred risk policies for those properties located in low to moderate flood risk zones. Why then is a homeowner whose property is located in a no risk zone required to pay as much as $2,400 per year because his or her home was constructed with a basement as opposed to a slab or crawl space? Further, this premium purchases insurance just for the structure. Coverage for contents of the structure demands even higher premiums.
It is commendable that some entire flood-prone communities, such as those along the Mississippi River which suffered extensive flood damage from the flood of 1993, are relocated to a higher elevation with funds from FEMA. It is also encouraging that FEMA purchases the property of homeowners in cases where payment for damage is determined to exceed the income from flood insurance premiums over a given period of time. The success of these buyout programs, however, should be measured against the cost of floodproofing by the citizens of the community at their own expense. The residents of the 1997 Red River flooding incident in Grand Forks, North Dakota, are capable of assessing their losses, as were residents of the Johnstown, Pennsylvania, flood who were damaged by a dam failure, and the Illinois residents of western DuPage, eastern Kane, and northern Will counties who experienced losses from the July 1996 storm. Risk analysis is often performed for lending institutions by individuals who are not properly trained to interpret FIRMs. When they interpret maps that have not been updated to illustrate the topography that actually exists in an area designated as a Special Flood Hazard Area, the end result is that homeowners must purchase insurance that will never benefit them!

It is my opinion that the reason FEMA requires that the basement elevation be the lowest habitable floor elevation for purposes of insurance and that that agency will not revise the FIRM is not to protect the homeowner against losses from flooding but to increase the number of policies sold where damage (and loss payments) will be the least likely to occur. The lender of the federally insured home loan requires that the homeowner insure against many of the risks that would diminish the value of the property such as wind, fire, earthquake, theft, vandalism, and now flood damage. The federal government protects a lending institution against losses on mortgage loans and the mortgagee pays additional insurance on the property to ensure against the same financial losses. Where a flood hazard actually exists, the opportunity to purchase this insurance constitutes a great benefit to all parties.

However, I believe that a serious, economically burdensome problem exists where the flood damage coverage promised in exchange for the premium paid will never be fulfilled because the risk of flooding with a 1% annual probability simply does not exist (or is no greater than the next door neighbor's who pays no flood insurance and is not required by a lender to obtain flood insurance). This situation, in my opinion, must be changed.
Part 12
Professional Activity in Floodplain Management
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NEWSLETTERS AS AN OUTREACH TOOL: NEW ENGLAND’S EXPERIENCE

Michele Steinberg
Federal Emergency Management Agency Region I
New England Floodplain and Stormwater Managers Association

Creating an organization newsletter is not an undertaking to be entered into lightly. A successful periodic publication requires dedication, creativity, and flexibility. There are some very good reasons to publish a newsletter, just as there are very good reasons to have a pet. Neither activity, however, is as simple to do as it may seem on the surface. Once a newsletter is circulating, there are high expectations of the publishing organization to continue to provide relevant and timely information. It is important to recognize the long-term commitment a newsletter represents. If your organization is ready to take the plunge, here are some things to think about.

Should We or Shouldn't We?

The New England Floodplain and Stormwater Managers Association, Inc., or NEFSMA, was established in 1991 by a core group of the region’s state flood insurance coordinators. Modeled after the national Association of State Floodplain Managers, the organization sought to educate interested parties about floodplain and stormwater management issues and promote sound practices throughout New England. By 1993, it became apparent that an organization spanning six states and multiple disciplines needed a forum for communicating its common goals, and so NEFSMA News was born. The primary purpose of NEFSMA's semi-yearly newsletter is to share information, but it serves to meet other needs as well. These include publicity (getting our name out there); a chance for members to publish articles (getting my name out there); a tangible and useful product to give to our members in return for their membership fee and loyal support; a way to announce upcoming events; a way to educate; and a forum for debate and discussion.

If your organization is large and/or covers a wide spread geographically, a newsletter may be a good choice for you. If you meet only once or twice a year, a newsletter can help bridge the gap between conferences and keep members’ interest alive. If your organization is full
of opinionated and/or knowledgeable people who can write reasonably well, you are on your way to an excellent publication.

**Basic Needs**

The primary necessity for a successful small newsletter is a person or people willing and able to take on the responsibility for coordinating, assembling, and distributing the newsletter. If members of your group love the idea of a newsletter but aren’t prepared to dedicate time and effort, put the idea on the back burner for a while. Key skills for a newsletter producer include strong organizational ability, reasonable writing/editing skills, computer knowledge, and the ability to cajole, beg, and plead for articles to be turned in by deadline. Convincing others to help with assembling and mailing out the newsletter is another important ability. *NEFSMA News* is a desk-top publication, but other small organizations have been able to leverage assistance from a state agency or university.

A user-friendly computer software program to lay out the newsletter helps immensely. *NEFSMA News* is created on Microsoft Publisher, which includes newsletter layout templates. These templates (called "Page Wizards" in the Publisher lexicon) allow the user to choose from a range of tried-and-true formats for newsletters, brochures, calendars, and other types of publications.

Important organizational issues include how to get articles, and how to get them by deadline. NEFSMA decided a couple of years ago to rotate the responsibility for "scouting" articles among board members—the designated scout is responsible for calling or e-mailing members to remind them of deadlines and ask for articles or items of interest. Reprinting articles is one way to go, but there are caveats: decide whether the reprint is relevant to your audience, and make sure you get permission to reprint before doing so. Most small publications ask only that you notify them, usually in writing, and that you send a copy of the newsletter containing the reprint. Larger publications may have other restrictions and may not respond as quickly, so factor in potential delays when requesting reprints from such organizations. NEFSMA’s experience is that our diverse audience appreciates some reprints (such as nationwide NFIP information) but is most interested in local news from their peers and regional experts in the field.

**Keeping it Simple**

A newsletter needn’t be glossy or include lots of graphics or photographs, although if you can afford it, a good-looking publication captures attention. Even on a small budget, your organization can still
create a newsletter with good design elements. A simple design with black and white bold graphics and consistent fonts throughout the publication makes a newsletter easy to read and saves you money (it's usually cheaper to print/photocopy using white paper). The Microsoft Publisher software and other publication software (such as PageMaker) includes tips on design for those who failed cutting and pasting in elementary school (this author included). Pictures and graphics are helpful but should not be included at the expense of important information and articles. Neither should they overwhelm the newsletter and contribute to a messy appearance. Keeping the newsletter to a consistent length (NEFSMA’s is 8 pages) also helps you budget for printing and mailing costs.

Another way to save on costs is using a format that is easy to photocopy and mail. *NEFSMA News* is photocopied onto both sides of two sheets of 11" x 17" paper which are folded in half to create eight 8 1/2" x 11" pages. Half of the back page is set aside for the mailing label and includes the name of the newsletter and the return address. By folding the newsletter in half again, the folded pages can be sealed and are within the size and weight limits for first-class postage (39 cents per newsletter). NEFSMA uses Kinko's, a national chain, to copy newsletters, and we usually pay the cost to have them folded. If the newsletter producers or organization members are willing to fold as well as address, seal, and stamp the newsletters, you can save the cost of having your printer do it for you.

**Content and Politics**

To keep a newsletter fresh, vary the content. With NEFSMA’s diverse membership and audience, repeated reprints of such items as NFIP regulatory information would become boring quite quickly. Content derived from your members is the best way to ensure their interest. You may choose to have a theme for a particular newsletter and to only include articles that fit within the theme. Seeking input from members on what’s important to them is vital to maintaining interest in the newsletter (if not the organization itself). Providing information on who to contact with more questions is also key to helping educate your audience on a particular subject.

NEFSMA has decided to use an "editorial board" to guard against potential dissatisfaction, misunderstanding, or conflict of interest. Since many NEFSMA members are state or Federal Emergency Management Agency employees, an article containing controversial opinions or material could cause problems for a lone editor or newsletter producer. The NEFSMA Board of Directors serves as the editorial board, not so
much for grammar and format (although many of them are excellent proofreaders) as for the general acceptability of the content of the newsletter.

Finally, to avoid strife, be sure always to credit authors, get permission for reprints, include acknowledgements, and provide any needed caveats or disclaimers (especially if you get state or federal funding to produce your publication). A draft of NEFSMA News is faxed to the authors in that particular issue as well as the editorial board to ensure that the layout editor has everything just right.

Costs and Budgets

Newsletters are a reasonably inexpensive way to reach out to your desired audience, but be sure to think of all the costs involved before starting out. Time spent scouting for articles, laying out, and editing the newsletter, and faxing, copying, and mailing it must also be budgeted. If you don't have volunteers for these activities, what will it cost to pay someone to do these things? If there is not a computer and/or appropriate software available, this is a significant cost to be factored into the equation. Regular costs include mailing labels, sealing labels, printing/photocopying, and postage. As mentioned above, newsletter format and choice of paper can also save money on printing and mailing costs.

NEFSMA News is supported by member fees and does not charge a subscription fee. The Board of Directors has debated whether to send the newsletter out to a wider audience than just the membership. To a limited degree, it makes sense to do so, since the newsletter is a benefit that might attract new members, and there is a lot to be said for publicizing your organization through a newsletter. NEFSMA sends its newsletter to all the National Flood Insurance Program coordinators in the nation, all the State Hazard Mitigation Officers, and a limited number of interested parties who are non-members.

One avenue that NEFSMA has not yet pursued is printing paid advertisements from members. The group held a successful conference in October 1997 and managed to get several private sector sponsors to support the cost of the meeting. It seems only to be a matter of time and coordination to get paid sponsorship of our newsletter.

Future Possibilities

In addition to finding financial leverage via subscription fees, advertisements, or sponsors, NEFSMA members are thinking of other ways to improve the newsletter and outreach in general. NEFSMA is incorporated as a non-profit in Massachusetts, but is not yet a "private
non-profit" as defined by the Internal Revenue Service. One benefit of becoming an official non-profit would be the ability to pursue grants to fund education and outreach, including the newsletter.

The NEFSMA web site (www.seacoast.com/~nefsma) is frequently and prominently mentioned in the newsletter. In turn, the website features current events from the newsletter and particular items of interest. Individuals browsing the website are provided with information on how to become NEFSMA members and how to get copies of the newsletter. The web site may be used in future to report on more short-term issues or to gauge interest in different types of articles. Future possibilities also include short profiles of individual board members and their activities, or a "floodplain manager of the year" feature. As our organization grows, so do the ideas and directions for improving outreach to our members in pursuit of our goals.
STATE ASSOCIATION WORKSHOPS: 
THE PERSONAL TOUCH WORKS BEST

Rodney E. Emmer 
Louisiana Floodplain Management Association

Introduction

In 1995, the Louisiana Floodplain Management Association (LFMA) inaugurated a program on professional development for its members. Volunteers from the LFMA planned the workshops in the belief that innovative solutions to common problems remain unreported, costing all in Louisiana time and money. Workshops provided a forum for the exchange of information and creative ideas among the local constituency. The first year included three half-day workshops in Rayne, Thibodaux, and Natchitoches (Emmer, 1996). During 1996 and 1997, the LFMA offered six additional workshops in West Monroe, Gretna, DeRidder, Marksville, Hammond, and Bossier City, and chose two communities for 1998 (Tallulah and Morgan City). The LFMA followed an established process for organizing and presenting programs throughout the state. This paper describes this method, summarizes participants' reactions to the workshops, and offers recommendations for others considering a similar project.

Louisiana Floodplain Management Association Workshops

The LFMA Board of Directors examined the potential for a series of workshops throughout Louisiana that would help its membership, parish (county) and municipal decisionmakers, and other parties better achieve the goals and requirements of the National Flood Insurance Program. After assessing topics important to local coordinators and decisionmakers such as themselves, the Board authorized quarterly workshops focusing on practical information that makes the regular duties of floodplain managers easier, more efficient, and less costly to local governments.

The basic 2.5-hour morning program shown in Figure 1 allowed time for participant travel within the work day. Volunteer speakers, most of whom were LFMA members, arrived approximately 45 minutes early to set up projectors, screens, tables for registration packets, visit with attendees and local officials, and complete the many small tasks that
Louisiana Floodplain Management Association, Natchitoches Parish Police Jury, & City of Natchitoches

Practical Information on the National Flood Insurance Program

Wednesday, October 8, 1997, 8:30 am
Barksdale Room, Bossier City Civic Center
Bossier City, LA

AGENDA

8:30 Coffee and Donuts
How to Read a FIRM Pam Sturrock, Calcasieu Parish Police Jury
9:00 Welcome George Dement, Mayor, Bossier City
9:05 Introduction Rod Emmer
9:15 How to Get a New FIRM Rodney E. Emmer & Associates
Ted DeBaene, Vice President
Owen & White Engineering, Inc.

9:45 LOMA vs LOMR EZ Form Pam Sturrock, Assistant Planning Director, Calcasieu Parish Police Jury

10:00 Floodplain Mitigation Mark Howard, Mitigation Officer, Floodgard, Inc.

10:20 BREAK Alyson Rodriguez, Permit Office Manager Tangipahoa Parish Council
10:30 CRS Participation Rodney Smith, Building Official, Ouachita Parish Police Jury
10:45 FEMA the Untold Story

11:00 Discussion & Questions Rod Emmer & Panel
11:30 Adjourn

Other participants included: Derhyl Hebert, Morgan City; Julie Pellegrini-Jenkins, Floodgard, Inc.; Windell Curole, South Lafourche Levee District; Wayne Berggren, Mandeville; Richard Arceneaux, Welsh; Mike Brown, Louisiana Office of Emergency Preparedness; and Dan Hawkins, formerly with the Louisiana Department of Transportation and Development.

Figure 1. Typical agenda for each workshop, 1995–1997.
result in a successful workshop. A maximum of seven speakers made concise, but informative, presentations using 35mm or overhead slides, computer graphics, and/or printed materials. The workshops began and closed on schedule, although the team answered questions from those who remained after adjournment for a more in-depth discussion. To recognize those attending, framed certificates were awarded at the conclusion of the program. Finally, a post-workshop questionnaire asked the audience to evaluate the proceedings, provide recommendations for improvements, and suggest additional topics of interest that the LFMA should consider for future outreach efforts.

The program evolved as a result of teamwork and cooperation. Each speaker developed his or her part based on personal insights and experiences. Before traveling to the first workshops in 1995, participants practiced together, giving their material as it would appear during the program. As a team, the speakers reviewed and critiqued each presentation to assure substance within a coherent format, to eliminate overlap, and to fill gaps in information. The extra time and effort required by this internal review proved most beneficial and contributed to insightful information that flowed from one speaker to the next. A typical registration packet included the agenda, a recent article from *News & Views* on floodplain management in Louisiana, an announcement of the LFMA annual conference, a brochure about the LFMA with a membership application, a fact sheet on floods, FEMA publications, and supplemental materials provided by the speakers or the community. To maintain the high quality of speakers, to select timely issues, and to coordinate logistics with the local sponsor, one LFMA member assumed the responsibility of workshop facilitator. In this case, Pam Sturrock, Calcasieu Parish Police Jury, accepted this important role.

When the Association announced the potential for workshops, several members immediately offered to host one. Thus, the team goes where invited and when a LFMA member acts as liaison. Sponsors arrange for meeting accommodations (a locally known facility with sufficient free parking) and audiovisual equipment, provide coffee and donuts (optional), ask a parish or municipal official to welcome the workshop participants, distribute written invitations, and call interested parties in the vicinity of the host city/parish who may benefit from attending. To advise everyone in Louisiana about the workshop, the Floodplain Management Section, Louisiana Department of Transportation and Development, prints a notice of the meeting in *Louisiana Floodplain Management Factsheet*, its quarterly newsletter.
Workshop Results

Attendance totaling 288 exceeded the most optimistic expectations. Forty-seven individuals registered in Rayne; 17 in Thibodaux; 22 in Natchitoches; 11 in West Monroe; 47 in Gretna; 20 in DeRidder; 43 in Marksville; 49 in Hammond; and 32 in Bossier City. Review of registrations from this and similar technical workshops in Louisiana suggested that people would not travel over two hours or about 90 miles. The LFMA workshops confirmed this generalization as most of the participants came from parishes and municipalities adjacent to the host site. However, organizers should anticipate individuals making much longer journeys. For example, at the earliest three meetings some travelled several hours. In Rayne (southwest Louisiana), signatures show registrants drove approximately four hours from Jefferson and Terrebonne parishes in southeast Louisiana. In Thibodaux, representatives traveled from Sulphur, near the Texas border, about four hours. And in Natchitoches, in northwest Louisiana, they journeyed from New Orleans and Plaquemine, necessitating overnight lodging. At the 1996 and 1997 workshops, fewer people drove long distances, suggesting potential attendees realized the LFMA workshop would appear in a town near them.

A review of the post-workshop evaluations revealed the audiences' appreciation of the effort. Participants thought the workshop met their expectations and included comments such as: "Really good format!"; "Very informative"; and "Well informed panel, pleasant." Only 11 of 181 who returned the forms suggested modifying the format. The length of the presentations were judged either about right or not too long for the topic. Only in Bossier City, where the audience included representatives from lending institutions, was the program judged too technical. LFMA should continue this form of outreach (141 yes vs 14 no). Opinions on the frequency of workshops ranged from quarterly to annual. Most preferred that the program travel to them on a regular basis. Future workshops could focus on a number of proposals, some beyond the scope of the LFMA, such as wildlife control and erosion. Many topics, however, were appropriate for the team, for example, V-zones; flood insurance; public education; code enforcement; the Community Rating System; ordinances and implementation; and elevation certificates. Participants in Natchitoches suggested that extending the program to four hours may qualify it for continuing education credit from other organizations. The Board investigated this potential and concluded the demands and requirements for different professional associations exceeded the benefits to the LFMA membership. Finally, participants gain information in several ways:
Newspapers = 82  Luncheon Speakers = 44
Brochures = 105  Radio = 22
Meeting Speakers = 57  Television = 35
Other = newsletters, fact sheets, video tapes, website,
technical session at other conferences.

The most important avenues for disseminating information are
brochures and newspapers. Speakers at either luncheons or meetings are
a distant third. Radio, television, and other methods may reach some
potential participants.

Recommendations

An assessment of the evaluation forms and discussions with participants
and speakers confirmed the lessons learned from the initial three
workshops (Emmer, 1995) and added to an understanding of
procedures. To those considering outreach through workshops, the
LFMA shares the following.

- Recruit dedicated members to form the core of the workshop team.
  Six or seven speakers keep the program varied and interesting but
  prevent one issue or speaker from monopolizing the proceedings.
- Identify several substitutes who can participate for the regular team
  when conflicts cause absences.
- The team approach requires workers, not talkers. Be selective and
  choose interesting speakers with something to say who will work as a
  team.
- Have a volunteer facilitator coordinate that year's workshops and
  serve as the point of contact with the local sponsors.
- An essential ingredient is the local sponsor from within the
  association. They arrange for meeting facilities, get a welcome
  speaker, and most important, contact potential audiences from the
  surrounding region. Our local contacts built on their existing
  network of individuals in adjacent parishes and municipalities. They
  first sent written invitations and then telephoned. We cannot
  overemphasize the personal telephone call a week to ten days before
  the workshop.
- Presentations must focus on practical information that the
  registrants can readily use in their daily operations. LFMA
  approaches the workshop as people sharing information and ideas
  with people on a personal basis. Speakers make limited references
  to theory, but instead direct their comments to current issues
  everyone regularly faces and discuss practical, proven solutions.
• Informal presentations within the context of an established format seem most effective. The moderator asked that questions be held until after the individual completed her/his discussion, but this was not enforced. The LFMA was more interested in sharing and receiving ideas than lecturing.

• The speakers tried to relate to the audience by frequently referring to local parishes and municipalities. This was especially important in the introduction where we tried to bond with the audience by demonstrating a knowledge of the region and that their area and problems were important to us.

• Speakers should avoid irrelevant topics. For example, coastal flooding and storm surge were barely mentioned in north Louisiana, but emphasized in the south.

• Handouts should supplement the presentations. Always give them something to take home.

• Slides or other visual aides make for a more interesting presentation, but should be used only when they are effectively integrated into the discussion.

• Time is essential to the participants because they are the interface between the flood program and the public. Start on time and end on time. Those who have pressing site-specific questions will wait after the workshop.

• Framed certificates really mean something. Give them, but have a quality product.

• Learn from each workshop. We enhanced our registration package after the second meeting. In 1997, in response to numerous questions, Pam Sturrock volunteered to begin the program by discussing how to read a FIRM. Her review of the basics of reading a FIRM has proven very successful and this or a similar topic will be built into future workshops.

• Avoid acronyms. Some in the audience are new to floodplain management and insurance and may not know them. This was especially true when the audience included representatives from the lending institutions.

• If limited by time and costs for distributing information about floodplain management, the emphasis should be on brochures, newspapers, and speakers.

• Finally, have fun. You can learn much from the audience.

The personal touch characterizes a LFMA workshop. A member accepts the responsibility for organizing the workshops, contacting potential presenters, and coordinating activities with local affiliates. Everyone
agrees on the date and place of the workshop. Local sponsors use the mail and telephone to contact potential participants in their area to advise them of the workshop and invite them to attend. Speakers arrive early to set up the room, but just as important to meet and talk with participants. After the program, speakers remain to answer questions. The workshop team reviews the evaluation forms in order to modify the next agenda in response to suggestions from the audiences. The more personal the contact, the better the workshop and the more information gets exchanged and used.

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NEFSMA'S HOME PAGE
ON THE WORLD WIDE WEB

Peter A. Richardson
New England Floodplain and Stormwater Managers Association

Introduction

Many professional organizations are using the Internet as a means of promoting themselves and providing information to members and the general public. At the New England Floodplain and Stormwater Managers Association, Inc. (NEFSMA) 1996 annual meeting, the membership agreed that developing a "home page" on the Internet and having e-mail capability would be a good way for the association to gain notoriety and to communicate with others in today's computer-oriented society. At the meeting, NEFSMA formed a web site subcommittee to investigate the cost of developing a web site on the Internet.

Searching for an Internet Service Provider

In order for NEFSMA to have a home page or web site on the World Wide Web, the association needed to have access to the Internet and space on an Internet network server. The web site subcommittee contacted a number of ISPs in the Boston area and found that a corporate Internet access account that included web space would cost approximately $500 to $600 per year. In addition, it would cost another $100/year if NEFSMA wanted to register its own domain name such as "www.nefsma.com".

Besides the cost factor, the group also had to decide who would be responsible for maintaining the web site (in other words who would be the webmaster). The webmaster would need a local access phone number to the ISP in order to avoid costly long distance phone calls when working "on line".

A Contribution to NEFSMA

Realizing that a corporate Internet access account was going to be a significant burden on NEFSMA’s budget, I investigated the possibility of using my own personal Internet access account as a means for NEFSMA to develop its web site. Because AT&T, my ISP at that time, did not offer personal web space with their accounts, I investigated some
Internet web sites that offer free space for home pages. These free sites seemed to be more suited to personal interest groups and had too many restrictions for NEFSMA (not to mention long and complicated addresses). This being the case, I contacted a number of local ISPs to see if NEFSMA could use the web space provided with a personal Internet access account since this would be less expensive than a corporate account.

After speaking with a number of local ISPs, Networx, Inc., of Newburyport, Massachusetts, said they would allow NEFSMA to develop a web site using a personal access account because the association is a non-profit corporation and the web site would provide useful information to the public.

I switched my personal access account from AT&T to Networx and offered to donate my time and network space to NEFSMA for a web site. NEFSMA's Board of Directors was pleased with this arrangement, especially our treasurer. And now, for the same cost as AT&T ($19.95/month), I receive unlimited Internet access and 10 MB of space on Networx's server. Actually, I pay Networx $5 more per month in order to have an additional personal e-mail address.

The best part of the deal, however, is our web site address. Networx is based in a coastal community and uses the following domain name for their personal web site accounts: "www.seacoast.com/~ (user name)". I was able to use "nefsma" as a user name so that the web site address is "www.seacoast.com/~nefsma," which sounds water-related and saves us the cost of registering our own domain name.

**Developing a Home Page and Web Site for NEFSMA**

Once the space for NEFSMA's web site was established, the next step was to go to my office and recruit the help of Green International's computer guru, Erik Atkins. Erik, a young and ambitious civil engineer with an interest in water resources, helped me set up the framework for our home page and taught me how to "put" files on the site using File Transfer Protocol (FTP). For his help, NEFSMA's Board of Directors gave Erik a free membership for one year.

Now that the site has been developed, I try to keep it current by editing and creating new "pages" in html format using Microsoft Word 97. I do have a life, however, so the site is not updated on a daily basis. At present, the web site contains a page describing the history and purpose of the group, a page with membership information and an application form, and a schedule of upcoming events. In addition, there is a page with links to government agencies and other related web sites, information and pictures from our 1997 annual conference, information
about the National Flood Insurance Program, and a "Flood Happens!" page for posting new information. We also play cool, stormwater related music in the background.

**Conclusions**

The web site is one year old and is still under construction. So far, NEFSMA has received a lot of positive feedback. Developing the web site has given NEFSMA some notoriety and has provided an additional tool for the group to perform its mission of promoting sound floodplain and stormwater management.

As NEFSMA's webmaster, I have enjoyed developing pages for the site and have learned a great deal in the last year about using the Internet. The web site has not been "hit" as much as I would have hoped, but I am still e-mailing Internet search engines and other professional organizations to make them aware that the site exists. Check us out at www.seacoast.com/~nefsma and please feel free to e-mail us your comments. It is NEFSMA's hope that the site will become a useful tool for both our members and other floodplain and stormwater managers.
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Part 13
Stormwater Management and Watershed Management
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Introduction
The Pinellas Park Water Management District (PPWMD) was created in 1976 by the Florida State Legislature and operates as a special district to manage the primary drainage system for a portion of central Pinellas County, Florida (Figure 1). The PPWMD is divided into five drainage basins, each with a primary channel system draining it (Figure 2). The PPWMD’s jurisdiction covers 38.2 square kilometers (14.75 square miles). The PPWMD is responsible for the management of the primary drainage system within its jurisdictional boundaries. Secondary public drainage systems, such as curb and gutter inlets and associated conveyance systems, are the responsibility of other agencies, including Pinellas County and the City of Pinellas Park. The PPWMD’s primary drainage system is fundamentally composed of open channels with some culverted systems. The open channel systems vary from improved concrete lined channels to unimproved naturally vegetated channels.

The PPWMD’s engineering consultant, Camp Dresser & McKee Inc. (CDM), updated stormwater master plans for each of the five basins. The intention of the stormwater master plans was to develop alternative drainage improvement plans to meet PPWMD’s design criteria where possible. This criteria includes containing the 25-year/24-hour flood event within open channel banks with 0.3 meters (1.0 foot) of freeboard; minimizing head loss at culverts and bridge crossings to maintain clearance above the 25-year/24-hour flood event; providing adequate capacity within the primary drainage system to accommodate a 10-year/24-hour flood event design capacity in secondary drainage systems; and limiting flooding during the 100-year/24-hour flood event to streets and yards where possible.
Figure 1. Location of the Pinellas Park Water Management District.
Figure 2. Pinellas Park Water Management District basins.
Incremental Modeling Analysis

In an effort to identify those drainage improvement projects of greatest priority, PPWMD directed CDM to perform an incremental modeling analysis. The purpose of this task was to incrementally model the proposed improvements in each of the five basins; identify those projects that would address the level of service criteria; review the benefits of improvements associated with the 10-, 25-, and 100-year/24-hour recurring storm event; and make recommendations of priority and eliminate those projects that would not result in a significant flood reduction benefit. Five reports, one for each drainage basin, were developed. This work began in August 1997 and concluded in January 1998.

The results of the incremental modeling varied for each basin, but overall the results indicated that the analyses were beneficial to the community. Those projects that reduced flooding most significantly were identified, and will be incorporated into the 1998-2003 Capital Improvement Program. These analyses gave the PPWMD a tool for determining how to budget priority projects for the next five years.

Capital Improvement Program (CIP)

The results of the incremental modeling identified those projects that should be constructed by the PPWMD. The PPWMD incorporates the priority drainage improvement projects into a five-year CIP. In its opinion, it would not be prudent to provide a schedule for a "complete build-out" of the district, since variables such as construction and land costs, and availability of lands would be difficult to predict beyond a five-year period. The PPWMD has an annual budget of approximately $3.3 million. Sixty percent of the budget is used for design and construction of new improvements. Since a large percentage of money is allotted to new projects, a five-year budget has been projected to dovetail with the CIP.

Maintenance Program

The PPWMD maintains improved and unimproved channels and culverts. They utilize various means including manual labor and specialized equipment. Maintenance activities include dredging, erosion control, undesirable plant removal, top of bank and slope cutting, removal of dumped and naturally occurring debris, and maintenance of flow. Currently, the maintenance of the primary channel systems is managed with the use of various equipment.
Four major pieces of equipment are used by PPWMD. These include a Kaiser Spyder, Kutkwick slope mower, Alamo slope mower, specially constructed aquatic vegetation sprayer, and some smaller maintenance equipment. The Spyder is an articulating vehicle that can be used for excavation, vegetation removal, and cutting. The Kutkwick can only be used to mow the tops of banks and slopes on which it can maneuver. The Alamo slope mower has a 28-foot boom that can be used to mow slopes that could otherwise only be cut by hand or with the Spyder. The sprayer is specially designed to deliver herbicide to wide ditches with limited access on the tops of banks.

For major dredging operations, the PPWMD employs the services of Pinellas County, which provides a drag line to remove sediment from areas that are accessible to the large equipment. The improved channels that consist of concrete-lined systems require minimal maintenance other than periodic dredging of sediment and removal of vegetation.

Permitting Preferred Design
In an effort to reduce naturally vegetated slope maintenance and ease the environmental permitting process, the PPWMD has begun to design and construct concrete-lined side slopes with naturally vegetated bottoms. The "open" bottoms of this design have satisfied the two surface water management agencies that are responsible for permitting—the Southwest Florida Water Management District (SWFWMD) and the Florida Department of Environmental Protection (FDEP). Although these permitting agencies would prefer that channel side slopes be vegetated, they recognize that the concrete side slopes offer a reduced friction factor for hydraulic conveyance of stormwater, and provide a more stable bank, thus reducing the turbidity involved in bank failures.

The naturally vegetated bottoms of this design offer the desired treatment potential for water quality during normal and low flow periods. The PPWMD and the permitting agencies recognize that treatment potential is substantially reduced during periods of high flows in the channels, and therefore allow for the design of the concrete side slopes.

Recently Completed Drainage Improvement Projects
Recently completed drainage improvement projects include a flood control pond, culvert replacement, and approximately 600 meters (2,000 feet) of stabilized grass-lined channel. These projects were planned in the CIP and implemented on schedule. Having experienced frequent
street and yard flooding for many years, local residents have expressed their pleasure at PPWMD's accomplishments and progress in drainage improvement.

**Current Construction Activities**

The PPWMD has taken an aggressive approach in implementing those priority projects identified in the CIP. Currently, two drainage improvement projects are active. They include the Channel 3—Concrete Liner project that consists of the concrete lining of approximately 1,200 meters (4,000 feet) of stormwater channel, with two in-line sedimentation areas, and utilities relocation. The second project, Channel 1A—North/South, consists of widening and deepening of approximately 600 meters (2,000 feet) of stormwater channel. These improvements include slope stabilization and culvert replacement.

**Conclusion**

The PPWMD has divided its efforts into three phases. They are concrete lining at main outfalls, construction of detention facilities, and the stabilized widening of upstream channels. The PPWMD is now moving into the phase of stabilized widening of upstream channels. Due to right-of-way constraints, future investigations will include new methods to construct grass-lined slopes with minimal impacts to the homes on both sides of the channels.
STORMWATER QUALITY ENHANCEMENT ASSOCIATED WITH WIDENING OF THE TRI-STATE TOLLWAY

John T. McCarthy
Graef, Anhalt, Schloemer and Associates, Inc.

Introduction

The Illinois State Toll Highway Authority (ISTHA) is beginning construction on the Tri-State Tollway to remove the Deerfield Toll Plaza and widen 3.5 miles of the roadway. The West Fork of the North Branch of the Chicago River runs parallel to the roadway for about two miles, crossing beneath the Tollway at one location. Citizen groups and the Lake County Stormwater Management Commission (SMC) have expressed concerns about the impact of Tollway runoff to the river. This paper describes the design efforts undertaken to mitigate impacts from the roadway widening on the quality of stormwater runoff.

Description of the Project

ISTHA operates a system of toll highways as part of the Interstate Highway System in Illinois. The Deerfield Toll Plaza is one of the busiest locations on the Tri-State Tollway system. After a lengthy study to find ways to relieve congestion around the toll plaza, ISTHA decided to eliminate the Deerfield Toll Plaza and to widen the Tri-State Tollway to four lanes, from Lake-Cook Road to Half-Day Road.

This segment of the Tri-State Tollway passes through a developed suburban corridor, with the West Fork of the North Branch of the Chicago River adjacent to the right-of-way at several locations. It was decided that the roadway widening, interchange work, and the relocation of existing roadside drainage ditches would have to be accomplished within the existing right-of-way, due to the high cost and potential delay of obtaining additional right-of-way. Local groups such as the Friends of the Chicago River are working to improve the water quality in the river and have expressed concerns about the quality of stormwater runoff. Design elements that are not included in traditional roadway design were incorporated into this project, because of impacts by the roadway widening to floodplain storage volumes and the concerns about the quality of stormwater runoff.
Regulatory Issues

The project is located within Lake County and is subject, by an interagency agreement, to the requirements of the Lake County Watershed Development Ordinance, as administered by SMC. The ordinance addresses all aspects of stormwater and floodplain management, strictly regulating development within the regulatory floodway, and requiring mitigation of floodplain storage impacts at a ratio of 1.2 to 1. Stormwater quality is also regulated by the ordinance, with a requirement that the first one-half inch of runoff be retained, or that equivalent stormwater treatment be provided.

Stormwater Quality Enhancement

Studies have shown that highway runoff contains significant amounts of pollutants (Barrett, 1997). The pollutants include heavy metals, oils, deicing chemicals, sand, and grit (Pitt, 1992). Storm sewers convey these materials directly to receiving waters with no pollutant removal. Grass-lined roadside ditches can provide a significant reduction in pollutant loads from roadway runoff, however, steep side slopes reduce the pollutant removal effectiveness of the vegetation (Barrett, 1997). Dry detention basins generally used for roadway projects do not provide the water quality benefits achieved by wet ponds (Pitt, 1993). Enhancements to storm sewers and standard ditches are needed to achieve significant water quality improvements for this project.

ISTHA is concerned about impacts to adjacent waterways resulting from runoff from the Tollway. It has agreed to work with SMC to address their concerns regarding runoff water quality. To achieve this objective, three quality enhancement elements were included in the design for Tollway widening: extended dry detention basins, stormwater quality check dams, and stormwater treatment units.

Extended Dry Detention Basins

Stormwater quality enhancement features were incorporated in the project's four detention basins. The basins are sized to provide for a reduction in the peak rate of runoff, and include additional features to provide for water quality improvements for more frequent storms. These features will improve water quality through velocity dissipation to improve settling, extended storage times, and retention of pollutants by vegetation (Price, 1993). Figure 1 shows a cross-section of an extended dry detention basin.
Stilling Basins

Major inflow points to the detention basins were provided with stilling basins, to reduce flow velocities and capture large sediments. The stilling basin inlets will have soil reinforcement grids to prevent erosion from the concentrated flow. Rip rap will line the bottom and sides of the stilling basins, and a berm around the basin will facilitate velocity dissipation and sediment deposition.

Hydrophytic Vegetation

The vegetated area of the detention basins will be seeded with water-tolerant vegetation, to assure vigorous growth in a wet environment. A seeding mixture that includes a variety of wetland plant species will be used in the vegetated area between the stilling basin and the micropool. The vegetation will enhance sediment capture and provide nutrient uptake to break down captured pollutants. Beneath the vegetation will be an underdrain system, consisting of a perforated pipe in a stone bedding, to drain the remaining surface water into the micropool after a rainfall event. It is anticipated that total suspended solids (TSS) removals greater than 80% will be achieved by this portion of the basin. A small berm detains water within the vegetated areas, after a storm event, for infiltration to the underdrain system.

Figure 1. Cross section of extended dry detention basin.
Micropool
A 5-foot-deep pond will be built around the detention basin outlet structure, to enhance sediment capture. The micropools are sized to have a normal water volume of at least one-half inch of runoff from the tributaries, as suggested by SMC. Normal water elevations within the micropools are controlled by the detention basin outlet structure.

Water Quality Check Dam System
Runoff from some areas of the project could not be directed to the detention basins. The combination of limited right-of-way and roadway widening precluded the designs of conventional detention facilities in the roadside ditches. Conventional check dams, with an inlet along the upstream face of the dam, would not have provided significant water quality benefits because of the lack of residence time. To improve water quality in these areas, a water quality check dam system was developed.

The check dams will effectively retain the first one-half inch of runoff from the tributary area. An underdrain system will slowly drain the water stored behind the check dam to the downstream watercourse after a rainfall event. It is anticipated that improvement to the runoff water quality will be achieved by settling sediments behind the check dams and by filtering stored water through the vegetation and topsoil layer, to the underdrain system. Testing has indicated that both long detention times and filtering through soil are effective at removing 80% of TSS and have a significant effect on other pollutants (Barrett, 1997).

The slopes and crest of the check dams will be lined with an eight-inch deep soil reinforcement grid, filled with topsoil, to prevent erosion during dam overtopping. The bottom of the storage area upstream of each check dam will also be lined with the soil reinforcement grid, to prevent erosion, facilitate vegetative growth, and support the ditch bottom during wet periods when maintenance and mowing vehicles enter the area. Beneath the soil reinforcement grid will be a fabric-wrapped underdrain system that discharges downstream of the check dam. Figure 2 shows a typical check dam.

Stormwater Treatment Units
Runoff from one segment of the roadway could not be conveyed to a detention basin and could not be handled effectively by a water quality check dam system. This segment, between Deerfield Road and Lake Eleanor, included additional roadway widening and conveyed the treated outflow from two detention basins in the Deerfield Road Interchange. This combination of minimal right-of-way and additional flow precluded
using check dams. But concerns about Lake Eleanor, which received this segment's runoff, dictated that water quality could not be ignored.

The water quality improvements will be achieved by the use of inline stormwater treatment units. The units will be installed beneath the roadway shoulder, just before discharge by the roadway storm sewer system. The units will utilize swirl concentration technology, and a series of weirs and baffles to capture and retain sediments and oils, for later removal by Tollway maintenance personnel.

The use of stormwater treatment units has become more common recently, with a number of manufacturers supplying them. Design capacities are generally based on high frequency storms, e.g., 2-year, with minimal treatment or bypassing of larger events. Since ISTHA requires that the roadway storm sewer systems be designed to convey the runoff from a 50-year storm, it was decided that the stormwater treatment units should also handle the 50-year flow. The Vortechs (TM) Stormwater Treatment System by Vortecnics, Inc. was found to have

Figure 2. Water quality check dam system.
sufficient capacity to handle the 50-year flow, using multiple units with limited tributary areas. The manufacturer's testing shows an average 80% removal rate for TSS commonly found in roadway runoff, over the full range of anticipated flows (Vortechnics, 1995a, 1995b, 1996).

The storm sewer network for this segment was divided into small systems, with a treatment unit sized for each system. A design was developed for the treatment units, with the access manholes located close to the curb, to allow maintenance vehicles to service the units without endangering the traveling public. It is anticipated that cleaning of the treatment units by vacuum truck will be required on an annual basis. A bypass manhole and pipe will be provided just upstream of each unit, to allow for bypassing of runoff in excess of the 50-year storm.

Near the end of the roadway design process, an alternative to the Vortechs (TM) system was suggested by another manufacturer. After review, it was decided to include the alternative stormwater treatment unit, called the V2BI Stormwater Treatment System (TM) by Environment XXI, as an approved "or equal" in the specifications.

It is anticipated that the stormwater treatment units will provide an enhancement to the quality of runoff from the Tri-State Tollway while not impacting the floodplain storage volume within the roadside ditches.

References


GREGG'S LANDING SUBDIVISION:
CASE STUDY IN
LARGE-SCALE STORMWATER MANAGEMENT

Donald R. Dressel
Christopher B. Burke Engineering, Ltd.

Introduction
The development of a 1,000-acre parcel within the Village of Vernon Hills, Lake County, Illinois, provided many challenges in the preparation of a integrated comprehensive stormwater management plan. The challenges included development constraints such as wetlands, floodplain, floodway, and strict detention storage, and best management practices (BMP) requirements.

Pre-project Conditions
The 1,000-acre parcel on which the Gregg's Landing Subdivision is being constructed was part of the large Cuneo Estate. The project site is located between Butterfield Road and Milwaukee Avenue and north of Route 60. The Cuneo Mansion, which has been converted to a museum, and the surrounding 80 acres of grounds and gardens will not be impacted by the proposed development. The land parcel was being farmed at the time of development and portions had been used previously for the production of poultry. The project is divided into northern and southern portions by the Eastern, Joliet & Elgin Railroad (EJ&E).

Drainage
Seavey Ditch, a tributary to the Des Plaines River, flows north to south through the project site. The ditch drains a 5-square-mile urbanized watershed that includes portions of the Village of Mundelein, Village of Libertyville, and the Village of Vernon Hills. The primary pre-project drainage was towards Seavey Ditch. The eastern portion of the project site drains eastward into the Des Plaines River. The ditch flows into Lake Charles, which lies in the middle of the project site. Lake Charles has a surface area of 42 acres and has sufficient water depth to support a wide variety of aquatic life. The lake provides an attractive habitat for a variety of birds and animals, including white deer. The normal water
level of the outflow of the lake was controlled by a concrete notched ogee spillway. An abandoned farm bridge was located over the spillway. The southwest corner of the site adjacent to the Cuneo Museum drains to the 14-acre Harvey Lake.

**Floodplain/Floodway**

The Seavey Ditch 100-year floodplain inundated 148 acres or almost 15% of the total parcel. Within the 100-year floodplain are 60 acres designated by the Federal Emergency Management Agency (FEMA) and the Illinois Department of Natural Resources–Office of Water Resources (IDNR-OWR) as regulatory floodway. In the State of Illinois, the allowable floodway surcharge is only one tenth (0.1) of a foot. In addition to the Seavey Ditch floodplain and floodway there was a floodplain associated with Harvey Lake since its watershed is greater than 100 acres. In Lake County, Illinois, all watercourses or lakes that have a watershed greater than 100 acres must have a 100-year flood elevation determined for regulatory purposes.

**Wetland**

In accordance with the U.S. Army Corps of Engineers Wetlands Delineation Manual, dated January 1987, a wetland assessment and delineation was performed on the project site by Christopher B. Burke Engineering, Ltd. Wetland Specialists. A total of 16 separate wetlands or "waters of the U.S." were delineated with a total surface area of 74 acres. Of this total, the "waters of the U.S." encompassed the 42-acre Lake Charles. The Harvey Lake 22-acre wetland area was determined to be a high functional wetland as identified in the Lake County Stormwater Management Commission (LCSMC) ADID study.

**Project Conditions**

**Project Components**

The Gregg’s Landing Subdivision includes the construction of 2,100 single-family and multifamily residential housing, the 18-hole championship White Deer Run Golf Course, and park land. The breakdown of the land use is 355 acres for the single-family housing, 177 acres for the multifamily housing, and 479 acres of open space. The open space will consist of the 230-acre golf course, 126 acres of park land, the 42-acre Lake Charles and the 22-acre Harvey Lake. Due to the enormity of the project it will be completed in phases over many years.
Stormwater Management Plan

The stormwater management plan developed for the Gregg’s Landing subdivision involved countless hours of close coordination among the developer (G.A.Z, Inc.), the land planner (Allen Kracower & Associates), the site civil engineer (SPACECO, Inc.), the golf course architect (Dick Nugent & Associates), the Village of Vernon Hills and their review consultant (James Anderson & Associates), LCSMC, and Lake County and Department of Transportation (LCDOT). A plan evolved that preserved a significant portion of the forested wetland areas located adjacent to Seavey Ditch, Lake Charles, and Harvey Lake and avoided the regulatory floodway since the IDNR-OWR Part 708 Floodway Construction rules only allow the permitting of "appropriate uses" of the floodway such as excavation, recreational features, but no filling or construction of buildings.

The Lake County Watershed Development Ordinance (WDO) provided the requirements for detention storage and compensatory storage. The WDO requires detention storage be provided for ground disturbances (including the construction of the golf course) based a 2-year design storm release rate of 0.04 cfs/acre and a 100-year design storm event release rate of 0.15 cfs/acre. The 100-year Illinois State Water Survey (ISWS) Bulletin 70 24-hour rainfall depths were utilized in conjunction with the allowable release rates. The 2- and 100-year design storm event rainfall depths were 2.8 inches and 6.6 inches, respectively. The Natural Resources Conservation Service (NRCS) TR-20 hydrologic model was used to develop the 2- and 100-year runoff hydrographs for the project area tributary to each detention basin and to route the inflow hydrograph through the basin. Each basin was provided sufficient detention storage volume in order for the allowable 2- and 100-year release rates to be met.

A total of 31 wet bottom detention basins were designed providing 210 acre-feet of storage. A majority of these basins were located within the golf course and serve as water hazards in addition to providing stormwater management and promoting water quality improvements. All the basins were designed as wet bottom basins in order to provide a water quality benefit to the receiving waters: Seavey Ditch, Des Plaines River, Lake Charles, and Harvey Lake. The basins have sufficient depth to promote aquatic habitat and provide sufficient sediment storage. The number of inlet storm sewers was minimized for each basin and inlets were submerged to provide a pleasing shoreline. The inlet and outlet points were designed to be located as far apart as possible to prevent short circuiting.
The basins were also designed to work in series if possible. By cascading the stored stormwater from one basin downstream to another basin the water quality is enhanced. Instead of directly outleting the stormwater from the last basin in the series to the watercourse or lake, the outflow is directed into a vegetative swale that gently meanders the outflow towards the watercourse or lake, further filtering the stored stormwater. Due to long storage times that result from discharging the 2-year design storm event at a 0.04 cfs/acre rate, the basins have sufficient time to cause the settling of the larger particle sediment. The basins all have 4:1 side slopes and a 5-foot safety ledge located just below the normal water level. The first two feet of the side slope above the normal water level elevation are armored with native river stone brought to the site from nearby quarries. The stone provides adequate toe stabilization in the zone that will experience frequent fluctuation of the water surface. The side slope above the river stones will be planted with appropriate native prairie grasses that will provide a maintenance-free zone in addition to providing a suitable buffer between the residential homes and the golf course.

**Wetland Mitigation**

The project only requires the filling of 4.42 acres of small isolated pocket wetlands located within the farm fields and only 1.73 acres of the forested wetland located along Seavey Ditch and Lake Charles. No wetland disturbance will be made around Harvey Lake. The forested wetland disturbance was required to allow for the construction of the project site's major thoroughfare, Gregg's Parkway and the construction of certain portions of the golf course. In order to provide suitable mitigation for the disturbed wetland areas, 10.4 acres of new higher quality wetlands will be established south of the Lake Charles spillway on both sides of Seavey Ditch. This wetland mitigation area was integrated with the location of the tees and fairways of the 17th and 18th holes on the golf course. In addition, the wetland mitigation area also provides compensatory storage for the minor floodplain filling. The hydrology for the wetland mitigation area will be provided by Seavey Ditch through two weirs. In two areas within the project site, stormwater storage will be integrated with wetland preservation and wetland mitigation. During the construction of the detention basin 2, located by golf holes 11 and 12, groundwater was encountered preventing the construction of a wet bottom basin similar to the other detention basins. This afforded the project team a design challenge that was solved with a creative solution of converting the proposed wet bottom basin to a wetland area. The hydrologist and wetland specialist worked together to
determine the appropriate wetland plants and the appropriate planting elevations that would work with the anticipated basin water level fluctuation. From the air the basin looks very similar in shape to a giant starfish.

The second challenge was the preservation of a 1.88-acre wetland area that will also be surrounded by single family homes and also function as a detention basin. The design involved the creation of a wet bottom sedimentation basin located upstream of the preserved wetland. All the stormwater runoff from the residential development is conveyed to the sedimentation basin before being slowly released to the preserved wetland area. The preservation of this forested wetland provides a suitable aquatic and wildlife habitat.

Floodplain/Floodway Impacts

The development plan was designed to minimize impact to the Seavey Ditch and Harvey Lake floodplain/floodways. The floodplain filling includes only five detention storage basins, portions of six golf holes, roadways, and the rear yards of 67 residential lots. The WDO requires that hydraulically equivalent compensatory storage be provided for all floodplain fill at a 1.2 to 1 ratio. The compensatory storage required for this project was integrated within the wetland mitigation area, along several of the golf holes and within the golf course driving range.

In order to provide vehicle access through the development two roadway crossings of Seavey Ditch were required. The regulatory WSP-2 hydraulic model was used to determine the required waterway opening to allow conveyance of the 100-year flood flow without causing a headloss. The resultant waterway crossings consisted of a triple celled 6' high by 12' wide reinforced concrete box culvert (RCBC) and a triple-celled 9' high by 9' wide RCBC.

The existing Lake Charles spillway, which was classified by the IDNR-OWR Dam Safety Section as a small-sized Class I dam, was required to be replaced by the Village of Vernon Hills. The new concrete-notched spillway duplicated the existing condition rating curve while providing the foundation for a new golf course bridge between the 17th and 18th holes.

Permitting

As with all large projects, permits and approvals were required from many federal, state, county, township, and local regulatory agencies. Specific to the stormwater management plan, a Corps of Engineers nationwide permit was received for the filling of 6.15 acres of wetland and the creation of 14 acres of higher quality wetland mitigation. A
watershed development permit was received from the LCSMC and the Village of Vernon Hills for the detention storage, compensatory storage, and the culvert crossings. A dam safety permit was received from the IDNR-OWR for the Lake Charles spillway replacement. A Conditional Letter of Map Revision (CLOMR) was received from FEMA for the proposed floodplain boundary revision.

Conclusion

The preparation of the Gregg’s Landing Subdivision comprehensive stormwater management plan was the accumulation of the talents of the project team, which included water resources engineers, wetland specialists, land planner, site civil engineer, golf course architect, Village staff and consultant, and the regulatory agencies. The pre-project condition was characterized by the non-point source runoff of approximately 1,000 acres of agricultural fields into Seavey Ditch, Des Plaines River, Lake Charles, and Harvey Lake. This condition resulted in sedimentation and water quality degradation of the receiving watercourses. The stormwater management plan, which utilizes several BMP techniques, will provide sedimentation and filtering of the stored stormwater before its discharge to the receiving watercourses. The natural environment, including the forested wetland and floodplain, were minimally disturbed in order to preserve the existing wildlife and aquatic habitats. Large tracts of open spaces including the golf course, preserved riparian and wetland buffers, and the creation of passive use park land provide a buffer between the new residential areas of the preserved wetland and floodplain areas. The Gregg’s Landing Subdivision is a large-scale illustration on how development can coexist, preserve, and enhance the natural environment.

This project was the result of many long hours put forth by hundreds of dedicated professionals. The construction of the project completes the vision of two gentlemen: Gregg Zale and Jerry Hoskins, whose untimely deaths prevented them from enjoying the fruits of their labor.
Overview

One of the largest challenges facing rapidly growing communities is regulating and managing the stormwater infrastructure system. As a community continues to grow, changes to the drainage infrastructure occur daily. Many communities will develop a traditional "master plan" that will outline significant improvements needed in a watershed, intended to be constructed in a priority order over many years or even decades as funding allows. However, these recommendations are based on a snapshot of conditions that existed at a particular time, and cannot consider ever-changing conditions including continued development, new planning strategies and goals, etc. The master plan becomes more and more out of date as time passes and conditions change, and the large amount of engineering resources invested in its preparation are largely lost. The City of Charlotte and Mecklenburg County have developed an alternative to the traditional master plan that would allow for a continuous "living" master plan, designed to minimize the up-front cost and maximize the usefulness and flexibility of the planning process over time. As the City began the early phases of the watershed modeling effort, it quickly became clear that the manual effort of creating the model input files and the ongoing effort of model updates based on physical changes in the watershed were too time-consuming.

Goals of the Watershed Management System

The city decided to pursue the development of a fully integrated modeling and GIS system that would reduce the effort involved in developing hydrologic and hydraulic models, allowing for more frequent updates and assessing development impacts early in the planning stages.
Hayes, Seay, Mattern & Mattern (HSMM) was selected by the city to develop a fully integrated WMS to be used by the City of Charlotte and Mecklenburg County. The system is being developed to assist the city and county in performing the following tasks:

1. Automatically create hydrologic and hydraulic model input files from existing GIS data sets.
2. Run hydrologic and hydraulic models and link results to existing GIS coverages.
3. Perform "what-if" scenarios for assessing new development impacts for the review re-zoning petitions and site development permits.
4. Automate the revision of maps of altered floodplains.
5. Develop existing and future conditions floodplain delineations for use in floodplain management.
6. Integrate updates to the storm drainage infrastructure GIS coverage from new development plans and completed storm drainage projects.

**Project Approach**

Ultimately, the WMS will provide an automated system that will integrate customer service, floodplain management, work orders, watershed modeling capabilities, and system maintenance. The project team's approach to the project is divided into three major phases:

- **Phase 1** Establishment of Goals and Objectives
- **Phase 2** Software Development
- **Phase 3** Software Testing

The first step in Phase 1 in the development of the WMS was to identify the potential stakeholders involved with the project. Stakeholders are groups or individuals who may have an interest in the WMS, including those who might seek information from the WMS, as well as those who might provide information to the WMS. On January 24, 1997, a meeting was held to discuss the potential stakeholders in the WMS. During the meeting, representatives from the city, county, and HSMM "brainstormed" and compiled a list of groups and organizations who might be stakeholders to the WMS. This list included such diverse groups as city and county staff, insurance companies, surveyors, private engineering firms, and developers. The stakeholders were divided into four main groups:
Access Users Organizations who may seek information from the WMS. This group includes insurance companies and financial institutions.

Data Suppliers Organizations who may have data useful to the WMS. The data could include rain gauge data, zoning, and impervious coverages. This group includes the National Weather Service and the University of North Carolina at Charlotte.

Power Users Organizations who will use the WMS to perform hydraulic and hydrologic calculations. This group includes Storm Water Services and private engineering firms.

Regulatory Users Organizations who only have a regulatory interest in the WMS, such as the Federal Emergency Management Agency and the U.S. Army Corps of Engineers.

During the discussion, 56 potential stakeholder groups were identified and classified. Although some organizations fell into two or more categories, the classification of each group was based upon the organization's primary association with the WMS. Each stakeholder group's primary association in the WMS was determined by listing its goals, or wants and needs from the WMS. During the meeting, 124 different goals or needs from the WMS were identified. These goals helped the city and the county to begin shaping the overall goals and objectives of the WMS and to identify the potential data sets which may be needed to meet those goals.

A questionnaire was developed and sent to all identified stakeholders. A cover letter was included with the questionnaire, providing a brief explanation of the WMS project. The questionnaire requested information about data that could be provided to the WMS from each group as well as a list of data that each would like to obtain from the WMS. After the questionnaires had been returned and compiled, meetings were scheduled with the various stakeholder groups on May 14 and May 15, 1997. During these meetings, additional information concerning data available to the WMS, data wanted from the WMS, and a list of desirable features of the WMS was compiled. The meetings also promoted a higher level of involvement from the stakeholder groups. The input received at these meetings indicated a tremendous amount of support for the goals, which had been outlined by the city and county, and resulted in some additional data and goals previously unidentified.
The next step of Phase 1 was to identify all of the data sets and information that are available to the WMS. All of the data sets identified during and after the stakeholder meetings were obtained and reviewed. In order to facilitate the review and assessment of the existing data structures, the data sets were divided into the following three broad categories:

- Storm Water Services Databases—Databases currently maintained by City and County Storm Water Services. It is anticipated that changes to the database structure of these databases will be possible;
- City and County Databases—Databases outside the direct control of City and County Storm Water Services, but within direct control of another city or county department. It is anticipated that changes to these databases are possible but unlikely;
- Other Databases—Databases maintained outside the direct influence of the city or county. It is anticipated that there will be no changes to these databases.

Phase 2 of the project will establish parameters for various methods of creating a WMS. This aspect of the project will develop a strategy for automating and linking many time consuming tasks. Many different methods and procedures can be performed that will have the same final result. Phase 1 will result in a decision on how each task should be automated. For instance, a program for the creation of data input might be performed with an AML in ARC/INFO, with LISP in AutoCAD or with an outside program such as Visual Basic, Delphi, or C. Each method of implementation will have advantages and disadvantages on usability, ease of maintenance, portability and cost of development. All of these factors must be considered for each aspect of the WMS. The final WMS very well may have features that require programming AML's in ARC/INFO, AutoLisp in AutoCAD, Avenue in ArcView and the use of "true" programming languages of Visual Basic, Delphi and C.

Specific tasks which will be accomplished for this phase of the project include:

1. Review of existing "raw" data procedures,
2. Review of existing data formats,
3. Review of previous engineering studies,
4. Creation of input data files for hydrologic and hydraulic modeling,
5. Quality control checking,
6. Launching of hydrologic and hydraulic models,
7. Graphical selection and review of modeled data,
8. Modification of hydrologic and hydraulic models,
9. Exporting input files for use outside of the WMS platform,
10. Export input/output models to other agencies and engineering firms,
11. Facilitate floodplain mapping from model output to meet specifications of the Federal Emergency Management Agency, and

The next step in Phase 2 of the development of WMS is the integration of data collection and storage, maintenance of computerized hydrologic and hydraulic models and current GIS data, and provision of user interfaces for various levels of users. All of the data sets were reviewed for specific usefulness related to the WMS. Over 170 data sets, comprising over 2,100 fields were reviewed. The Storm Water Services Databases were reviewed in detail and changes were recommended to the data structure for 14 data sets to meet the goals of the WMS. The City/County and Other Databases were also reviewed in detail. This review focused on identifying specific fields in these data sets which could be useful to the WMS. No specific structure changes were recommended to these data sets since they are not under the direct control of the City or County Storm Water Services Divisions.

As part of the evaluation of existing Storm Water Services Databases, a detailed evaluation was done of over 75 data sets. These data sets ranged from ARC/INFO coverages and shape files to spreadsheets and ASCII text files. Each of the fields was evaluated to determine the usefulness of the data to the WMS. In many cases, it has been recommended that specific fields be removed due to the fact that they have not been utilized in the current data set. A large portion of the Storm Water Services data sets are directly related to the possible modeling features that may be included in the WMS. In most cases this recommendation is based on the fact that new or completely revised databases are being proposed to meet the goals for the WMS.

Evaluation of the coverages from Storm Water Services involved an examination of both its spatial properties and its attributes. Each coverage and its attributes were viewed in ArcView.

The coverage characteristics that were examined include:

1. Type of coverage, whether it was point, line, polygon, or other.
2. Format of the coverage, whether it is ARC/INFO, shape file, or both. It is assumed that all coverages will be maintained in ARC/INFO format.
3. Data field name's clarity and use.
4. Contents of the attribute table. Unpopulated and incorrectly formatted fields were noted. Some field widths are not long enough to hold the data in them.

5. Similarity to other coverages in the Storm Water Services database. For those coverages that are similar to others, the recommendation is either to use one coverage and delete the similar ones or combine the coverages into one new coverage.

An evaluation of commercially available programs and computer applications is underway concurrently. The evaluation will entail a detailed description of the flow of data through the WMS and a list of the programs and computer applications that will meet the goals of the WMS. This evaluation will include for each program:

- ease of accessing or moving data from the program to the WMS,
- ease of transferring results from the commercial application to the WMS,
- ease of user interface and customization,
- willingness of the program's developers to modify the program to meet the city's needs,
- accuracy of calculations with respect to the needs of the city.
- cost of the applications including the associated hardware, maintenance, and training, and
- determination of FEMA's acceptance of the program.

After the evaluation of commercially available programs and computer applications is completed, the programs and computer applications that best meet the needs of the WMS will be selected and scheduled for implementation. During the implementation phase, the best methods for obtaining, managing, and distributing the data for the WMS will be determined. Specifications also will be developed for those applications selected for the WMS. Those specifications will concentrate on the user interfaces and will identify areas of programming needed to meet the needs of the WMS that cannot be addressed by commercially available programs and applications. One of the city's long-term goals is the implementation of a Work Order Management System (WOMS) that will be integrated into the WMS. The WOMS will provide a means to track customer complaints from the initial phone call or service call to the initial field inspection and finally to the actual resolution of the request. In addition, the city is investigating the hardware and software requirements for establishing a real-time link to the U.S. Geological Survey stream and rainfall gages located in Mecklenburg County.
Summary

The final phases of the project will involve testing and fine tuning of the WMS. Software and documentation will be modified and finalized. When complete, the city will have a comprehensive Watershed Management System in place that will allow for ongoing modeling and model upkeep to be done by in-house staff on a routine basis. The system will also provide an interface to allow non-modelers to access and utilize the results for use in planning and design of drainage improvements.
ALONG THE MASON-DIXON LINE IN DELAWARE AND PENNSYLVANIA

Gerald J. Kauffman
Water Resources Agency for New Castle County

Over the last year the Water Resources Agency conducted Phase I of the Christina Basin Water Quality Management Strategy. The objective of the 5-year program from 1995 through 2000 is to identify sources of non-point pollutants, assess existing water quality, prioritize subwatersheds for stormwater monitoring, and implement best management practices to reduce pollutants entering streams.

The Christina River Basin includes parts of Pennsylvania, Delaware, and Maryland. Based on long-standing disagreements between Delaware and Pennsylvania on some of the water quality standards in the watershed, the Delaware River Basin Commission (DRBC) recommended establishing a committee of the two states and local agencies to manage the Christina Basin Water Quality Management Program. The committee includes the States of Delaware and Pennsylvania, the Chester and New Castle Conservation Districts, the Water Resources Agency for New Castle County, the Chester County Water Resources Authority, the U.S. Geological Survey, the Environmental Protection Agency, and the DRBC.

The 565-square mile interstate watershed contains four major subwatersheds—the Brandywine, the Red Clay and the White Clay creeks, and the Christina River (Figure 1). The watershed is situated along the Mason-Dixon line in the rolling hills of the Piedmont province. Surface water uses include water supply, recreation, fish and aquatic life, wildlife, and exceptional value designations in the three states. The water quality strategy is part of a multi-agency, watershed-based program designed to improve the quality of Christina Basin waters, which provide 75% of the drinking water for New Castle County, Delaware, and 40% of the water supply for Chester County, Pennsylvania. The basin provides drinking water to over 0.5 million people in both states. Water quality problems include high levels of sediment, bacteria, nutrients, metals, and organics, which have caused fish consumption advisories. Nonpoint source pollutants are thought to come from construction, development, septic systems, erosion, agriculture, and industrial-commercial uses.
Figure 1. Base map for the Christina River Basin Strategy Plan.
The Water Resources Agency (WRA) is serving as the local watershed coordinator for the Delaware portion of the basin and the Chester County Conservation District is serving as the coordinator for Pennsylvania. To date, the WRA has compiled a watershed inventory of 17 GIS maps on the Agency's ARC/INFO AERI II system that depicts geology, soils, land use, zoning, wetlands, and other environmental indicators of watershed health. Using the maps, the WRA has estimated pollutant loads, percentage impervious, forested, open space, and agricultural area data that will be used to prioritize watersheds for clean-up and BMP implementation actions. Water quality assessment maps prepared by the WRA indicate that many stream segments are stressed due to fish consumption advisories (PCBs) and toxic pollution.

The following GIS maps were prepared as part of the Watershed Inventory:

- **Base Map**—The base map includes the fundamental framework of watersheds, streams, roads, and state/county/municipal boundaries for the 565-square mile Christina Basin.

- **Map 1, Geology**—The geology map summarizes the subsurface bedrock characteristics that affect surface and groundwater quality.

- **Map 2, Soils**—The soils map provides indications of permeability and drainage necessary to estimate groundwater recharge, erodability, and stormwater runoff.

- **Map 3, Outfalls/Intakes/Discharges/Monitoring Sites**—The outfalls/intakes map summarizes the physical water supply and water quality management infrastructure needed as input data for water budgets and the Total Maximum Daily Load (TMDL) models for the Christina Basin.

- **Map 4, Topography**—The topographic map is used to define land contours for the Christina Basin and identify steep slopes and estimate runoff and sediment loads.

- **Map 5, Land Use**—Land use is a fundamental indicator of stormwater and impacts of receiving water quality.

- **Map 6, Zoning**—The zoning map provides a delineation of future land uses and estimated pollutant loads for future land use scenarios.

- **Map 7, Floodplains/Wetlands/Groundwater Protection Areas**—The floodplain/wetlands/groundwater protection area map delineates the sensitive water resources features of the Christina Basin.
• **Map 8, Parks and Open Space Areas**—The parks and open space map delineates the potential lands that can contribute to improved quality of ground and surface waters.

• **Map 9, Hazardous Waste Sites**—The hazardous waste site map identifies the superfund sites and other potential sources of pollutants in ground and surface water in the basin.

• **Map 10, Existing Best Management Practices (BMPs)**—This map identifies the location of existing stormwater and agricultural best management practices that have been installed in the Delaware and Pennsylvania portions of the Christina Basin.

• **Map 11, Stream Water Quality**—The water quality map illustrates stream segments with good, fair, and poor water quality.

• **Map 12, Fish Consumption Advisories**—Portrays the stream segments in the Christina Basin with fish consumption advisories.

• **Map 13, Total Suspended Solids (TSS) Loads**—Categorizes the predicted annual total suspended solids (TSS) loads for each of the 38 subwatersheds in the Christina Basin.

• **Map 14, Percent Impervious Cover**—Delineates the percentage impervious cover in the basin as a key indicator of potential watershed and stream health.

• **Map 15, Agricultural Area**—Depicts the extent of agriculture in the subwatersheds that can affect stream water quality in areas without effective conservation practices due to high sediment, nutrient, and bacteria loads.

• **Map 16, Wooded Area**—Portrays the highly wooded subwatersheds that usually exhibit good stream health.

The WRA has also assisted the City of Newark with the installation of a demonstration stream bioengineering project along the Upper Christina River in Rittenhouse Park. In Chester County, the Conservation District has conducted a storm sewer stenciling program and installed clean-up projects at a mushroom farm, a dairy farm, a reforestation effort, and an innovative stormwater recharge project at a local municipal building. A stormwater monitoring effort is intended to characterize representative stormwater pollutant loads entering the streams. Once the quality of runoff is known, a computer model that houses stormwater loadings will be used to evaluate the total impact of point and nonpoint pollutants on the streams and waterways of the Christina Basin.
The Christina Basin Water Quality Management Program has already provided several benefits after the first year. High Schools, civic associations, and environmental organizations are using the GIS watershed maps for water quality education programs. Residents of New Castle County utilize the maps to further understand the impact of contamination on their water supplies. State park agencies are using the maps to identify parcels for open space acquisition. Public and investor-owned utilities identify contamination sources with the maps to protect the quality of water supplies and comply with the source water protection provisions of the Safe Drinking Water Act. Overall, these beneficial results point toward the need to protect the quality of Christina Basin streams that ultimately provide most of the drinking water for New Castle County residents and businesses.
HARRIS COUNTY FLOOD CONTROL DISTRICT
CHANNEL ASSESSMENT PROGRAM

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Harris County Flood Control District

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Introduction

The Harris County Flood Control District in Harris County, Texas, comprises some 2,500 square miles with a population of more than 2.8 million, including the major portion of the City of Houston, the fourth largest city in the United States. Overall operations of the county are managed by four publicly elected Precinct Commissioners and a County judge. Drainage for this metropolitan area is provided by a series of 23 major bayous and the associated tributary channels. The Harris County Flood Control District owns or maintains easements on the majority of these channels and is responsible for operating and maintaining more than 1,300 miles of open channels. In performing its duties of flood management, the Flood Control District relies on five major tools: (1) planning; (2) capital improvements; (3) interagency coordination with federal, state, and local communities; (4) environmental mitigation, and (5) channel operation and maintenance.

The Flood Control District has an annual operations and maintenance budget of approximately $34 million. Of that amount, major channel maintenance activities account for approximately $8 million. Maintenance funds often are expended in reaction to visual inspection of the channels from obvious locations (street crossings, etc.), input received from residents along the channel, or equitable distribution of funds within the four county precincts. Often significant channel damage had occurred before the Flood Control District was made aware of the problem, which conversely results in more expensive maintenance and continued budget pressures, limiting the projects that could be selected each year. The Flood Control District was seeking a more proactive approach to maintenance whereby problems could be
identified for correction under normal maintenance before they became serious. This approach would extend maintenance dollars and improve customer service. The solution was a channel assessment program that attempts to categorize all of the channel segments according to a level of service, and to prioritize where maintenance dollars should be spent.

The Level of Service Concept
The level of service concept, which is adapted from similar concepts used throughout the transportation industry, attempts to measure the quality of service that a particular facility provides to the public. The measurement of the quality of service is assessed through qualitative and quantitative measurement of key parameters that define the purpose of the channel segment, and comparing those parameters to an established standard of service, and to other segments. Those channels or channel segments that show the most departure from the desired value of the key parameters, have the highest priority for repair.

As an example, assume that desired channel roughness is based on vegetative cover being six inches high and free of trees. Visual inspection shows the vegetation on one channel segment to be 24 inches high in a relatively rural area, whereas another segment has 12 inches of vegetation in a reach adjacent to a subdivision. If the purpose of the channel is a defined roughness, then the channel with the higher grass has a higher priority. However, if the objective is flood avoidance or complaint avoidance, then it is more effective to pursue the channel with only 12 inches of grass before it becomes 24 inches.

Similarly, if a structural section is being examined on two separate channels, one has failed and one is indicating initial signs of erosion that will lead to failure, which should be repaired first? In the definition of level of service, it depends on how the respective channel segments affect the overall objective of the channel system.

The principal aspects of the level of service concept is to define the objective or standard of service of the facility and then to establish the key parameters by which the facility will be measured against this objective. Each parameter should then be given a weight of importance relative to the other parameters. The composite score of a channel segment is the sum of the parametric weight multiplied by the relative weight of the individual parameter. Channels that exhibit the highest score are given a higher priority for maintenance.

The Channel Assessment Program
The Channel Assessment Program (CAP) consisted of three phases: (1) a design phase, including program definition and conceptualization; (2)
a development phase, including necessary computer database programming; and (3) a pilot study phase to test implementation.

Design Phase

At the outset, a consensus-building meeting was conducted among members of departments of the Flood Control District and representatives of the four county precincts. The objective was to develop a definition of the CAP and to establish the key parameters. From this meeting the general objective of the CAP became defined to provide a proactive, simple-to-use, well-managed database that provides system solutions based on need, justifies responses to citizen requests, and includes a self-monitoring process for channel maintenance.

Under this definition, need is defined as the protection of property and human safety from flooding and flood-induced damage. From the meeting a consensus was reached on nine key parameters to define a channels relative priority for maintenance: jurisdiction and ownership, degree of development, channel characteristics, channel condition, channel history, flooding history, economic feasibility, environmental characteristics, and safety. Within each of the key parameters a series of measurement indicators was defined, as shown in Table 1.

A key aspect of the implementation of the CAP is the availability of information and the cost for its acquisition. Therefore, it was decided to attack the project by considering only one of the nine key parameters, channel condition, and use this parameter as a method for establishing the process by which a broader CAP can be developed. Consideration would also be given to whether a channel was urban or rural and whether it was a main or lateral channel.

The CAP program is not intended to be a draw on the limited maintenance funds that exist. After the general meeting, individual meetings were conducted with 18 of the department representatives to discuss how they currently do the business of assigning maintenance projects and what information exists to compile the indicators listed in Table 1. They also prioritized the top parameters important to their particular department or function. The purpose of identifying the current method is to examine shortcomings of the system and to reinforce the important parameters to consider. The purpose of identifying available information is to approximate the cost and importance of that information relative to the cost of its acquisition. With this information compiled, a conceptual design of the CAP was formulated, addressing primarily the channel condition.
Table 1. Consensus of key parameters to evaluate level of service.

<table>
<thead>
<tr>
<th>Jurisdiction &amp; Ownership</th>
<th>Watershed Development Characteristics</th>
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</thead>
<tbody>
<tr>
<td>ownership</td>
<td>upstream population density</td>
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<tr>
<td>FEMA channel</td>
<td>downstream population density</td>
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<tr>
<td>precinct</td>
<td>population within reach</td>
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<table>
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<tr>
<th>Channel Reach Characteristics</th>
<th>Channel Capacity</th>
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<tr>
<td>unit designation</td>
<td>channel “n” value</td>
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<tr>
<td>key map page</td>
<td>actual “n” versus design “n”</td>
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<tr>
<td>main or lateral</td>
<td>bottom width</td>
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<tr>
<td>earthen or concrete</td>
<td>depth</td>
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<tr>
<td>age of channel related to its life</td>
<td>bank full capacity</td>
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<td>visual record available</td>
<td>related storm frequency</td>
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<tr>
<td>field surveys available</td>
<td>ratio capacity (actual / design)</td>
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<td>field maintenance issues</td>
<td>proximity to houses</td>
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<td>constraint due to culvert</td>
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<th>Channel Condition</th>
<th>Public Support for Project</th>
<th>Environmental Issues</th>
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<td>condition of backslope drainage system</td>
<td>registered requests</td>
<td>permitting requirements</td>
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<td>erosivity of soils</td>
<td>value added opportunities</td>
<td>past EAs performed</td>
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<tr>
<td>channel accessibility</td>
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<td></td>
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<tr>
<td>trees along berm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>channel vegetation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>steepness of side slopes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>condition of side slopes</td>
<td></td>
<td></td>
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<tr>
<td>condition of channel bottom</td>
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<th>Safety Issues</th>
<th>Economic Feasibility</th>
<th>Previous &amp; Current Projects</th>
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<td>sinkhole / safety concerns</td>
<td>cost estimate for project</td>
<td>historical work performed</td>
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<tr>
<td>side slopes too steep</td>
<td>opportunity for joint cooperation</td>
<td>capital projects planned</td>
</tr>
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</table>

Development Phase
The CAP relies on a computer database software to store the channel inventory information and to compare the information to other channel segments based on an algorithm written to reflect the weighting.
program. FoxPro version 2.6 was used as the database engine. Special programming using Visual Basic was used to develop the parameter weighting and project priority algorithms.

The weighting of the parameters was accomplished by asking each of the representatives what he/she thought was the relative importance of each parameter. A questionnaire was provided to each representative. Their responses were used to develop a relative weight for each parameter. After the main parameters were ranked, the specified attributes related to the channel condition were ranked. A second form, intended to be a comprehensive and objective survey form was provided to field maintenance personnel. They were asked to fill out the form as part of their daily activities in the field. Based on the responses from the first few days of activity, revisions to the form were made in order to make sure data could be collected, and would be collected consistently.

To populate the database, it was necessary to define a logical geographic limit for each channel maintenance project. This meant some segmentation of the channel according to practical descriptive limits of a project, and the ability to acquire data about the project to complete the data set. Initially the geographic designation of these channels was performed by Key Map. Data was collected from approximately 300 channel segments. However, this type designation created some confusion and did not lead to obvious definition of channel maintenance activity to field personnel. It was decided that the Flood Control District would have to predefine channel segments to facilitate easy location in the field. This was done by segmenting each channel by street crossings and confluence with other channel segments. This allowed the channel segments to be broken into concise, well-defined reaches that could be located in the field and could be described to maintenance personnel.

Because Harris County is so metropolitan, the 1,300 miles of channels became 5,500 channel segments, each characterized by an upstream and downstream point referenced by street name or a channel confluence. A field inventory form was designed that responded to the identifier parameters for channel condition. This form, which simulated the data input form for the CAP database, was placed on hand-held data loggers for developing a test case for data acquisition.

**Level of Service Algorithm**

The weighting algorithm is designed to assess the channel inventory data and, by applying the appropriate weighting, develop a priority for that channel level of service. The general procedure used to compute the level of service associated with a channel reach was:
(1) Translate the qualitative data acquired by field personnel about the channel condition into quantitative data. For example, if one of the characteristics (i.e., bank erosion) on the survey form allowed three possible answers (none, some, substantial), these would be translated by the algorithm to mean 0, 1, or 2 (or other appropriate weighting).

(2) The attributes within each category are multiplied by the respective weight. The sum of the respective weights is then computed for each category and the sum is divided by the maximum possible sum, resulting in a number between 0 and 1.

(3) The normalized values for the berm, side slope, and channel bottom categories are multiplied by their respective weights. This sum is again divided by the maximum value to get a value between 0 and 1.

(4) The normalized value in step 3 is then multiplied by the weight for channel condition.

(5) Similarly, weighted parameters are obtained for two other parameters: degree of development and type of channel.

(6) The sum of the weight in steps 4 and 5 is computed. This value is then adjusted for a 100 scale. The number that results from this adjustment is the level of service measurement for this particular channel segment. The higher the score, the higher the priority for maintenance.

**Pilot Study**

To test the algorithm, a pilot study was conducted on some 300 channel segments in southeast Harris County. One of the objectives of the study was to identify alternative methods of data collection, and the level of automation that should be considered. Some of these alternatives included utilizing existing field maintenance personnel to fill out the survey forms, using contractors for the same purpose, relying on the knowledge of office personnel to fill out the forms, using data loggers to fill out the data sets in the field, and using low-level photography or video tapes and have office personnel view the tapes to fill out the forms. The cost of these alternative methods of data collection ranged from $29,000 to $220,000. The most cost-effective alternative appears to be the use of experienced office personnel. However, this is not believed to be the most accurate.

For the pilot study, field maintenance personnel were used. The data collected on the 300 channel segments was entered into the database and subjected to the level of service algorithm. The results were compared to the conclusions of actual office personnel for the same area. The results indicated a surprisingly strong correlation. This indicated the project could be expanded to county-wide implementation.
For county-wide implementation, field personnel were equipped with data loggers that program the survey form directly into the level of service algorithm. The field data acquisition aspect of the project is now in progress. This process has been ongoing for approximately 8 months. It is anticipated that continued updating of the database will occur throughout the year.

Conclusions

The level of service concept has been applied to the Harris County Flood Control District channel maintenance program. Although the program considered primarily one of the key parameters, the method by which data was objectively weighted provided a strong correlation to projects that had been previously identified as high priority for maintenance activity. This also substantiates the program's correlation to the needs of the users. Because the program is ongoing, no conclusions can be made as to its success on the county-wide channel system. However, the level of service concept seems to be applicable for this case and could be expanded with the addition of data as funding and program requirements allow.
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Part 14
Hydrology and Hydraulics
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A COMPARISON OF STEADY-STATE VS. FEQ ANALYSES

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Introduction
The floodplain of the 52-square-mile Upper Salt Creek watershed—located in northeastern Illinois, about 30 miles northeast of Chicago—was recently restudied and remapped by the State of Illinois Department of Natural Resources-Office of Water Resources (IDNR-OWR). The watershed contains six major flood control structures, none of which is reflected on the current effective Flood Insurance Rate Maps. FEQ vs steady-state comparison was required during the Federal Emergency Management Agency (FEMA) review of this study.

Background
IDNR-OWR began the remapping process in 1988. Their initial plan was to use the Full-Equation (FEQ) model (Franz, 1995). An initial model development and debugging took place. However, FEQ acceptance by FEMA did not appear to be imminent. Therefore, in 1990, IDNR-OWR made the decision to switch to a steady-state model.

Steady-State Model Development
A traditional HEC-1, HEC-2 model was therefore prepared. However, since FEQ models had been developed for the flood control structures, it was decided to retain the FEQ models of the six flood control structures. It was felt that the FEQ models of those structures—some on-line, some off-line—could be more accurately represented using FEQ. Therefore, a hydrologic/hydraulic model was developed that utilizes HEC-1 to simulate the rainfall-runoff and channel routing relationships that flow into the flood control structures. FEQ was used to route these hydrographs through these structures. HEC-1 was used to pick up the FEQ output and continue down the watershed. The HEC-DSS program was used as a linking tool to connect the HEC-1 output with the FEQ input and vice-versa. An eight-step iterative procedure was developed to run the HEC-1/FEQ hydrologic model.
This model was successfully calibrated and verified and was used to determine regulatory flow rates throughout the watershed for input to HEC-2. The regulatory flood profiles were run, floodplain was mapped, and all backup data was sent to FEMA in February 1997 for incorporation into the new Cook County Flood Insurance Study.

**FEMA Review**

FEMA has recently conditionally accepted FEQ pending a check of culvert rating curves, where applicable. FEMA has concerns regarding FEQ handling of Type 5 culvert flow. Therefore, at flood control structures in which culverts affect the overall structure rating curve, a comparison of the FEQ and steady-state rating curves was required. Three of the six structures were determined to have rating curves affected by culvert flow. These three structures are known locally as Tom T. Hamilton, Margreth Riemer, and Twin Lakes.

Tom T. Hamilton and Margreth Riemer are similar structures, as follows:

- Off-channel storage (537 acre-feet in Tom T. Hamilton; 572 acre-feet in Margreth Riemer) with pump back after the flood recedes;
- In-bank channel flow is allowed as bypass flow. A culvert under the access road to the pump house acts as a control structure, which controls the flow rate at which side spill flow occurs into the storage area;
- In response to flooding in August 1987 (in which these structures did not fill significantly), cover plates were installed over the top half of these structures, which effectively reduces the bypass flow and causes the reservoir to fill more frequently.

Twin Lakes is essentially a modification of an existing culvert. A concrete drop overflow structure, with low flow openings, was constructed on the upstream end of the extended Route 53 box culvert. In a practical sense, the culvert flow probably has insignificant effect on the overall structure rating. However, these three comparisons were carried out. HEC-2 was used at Twin Lakes and WSP-2 was used at Tom T. Hamilton and Margreth Riemer.

**Results**

The results, shown in Figures 1, 2, and 3, show the following:

1. Excellent comparisons result at Tom T. Hamilton and Margreth Riemer. Each rating curve passes through several flow regimes.
Figure 1. Steady-state/FEQ comparison for Hamilton Diversion Structure.
Figure 2. Steady-state/FEQ comparison for Riemer Diversion Structure.
Figure 3. Steady-state/FEQ comparison for Twin Lakes.
(2) Acceptable comparison resulted at Twin Lakes. FEQ elevations were somewhat lower than steady-state. One explanation is as follows:

Steady-state methodology used nomographs for computations. These nomographs were developed by the Federal Highway Administration (FHWA) for culvert design and were probably intended to be somewhat conservative. FEQ uses the full St. Venant equations solution to determine its rating curve and would be expected to produce slightly lower elevations than the culvert design nomographs.

Conclusion

FEQ is a powerful, effective computation tool used widely by engineers throughout the United States and internationally. It compares well with steady-state methodology. Where appropriate, it should be used for hydraulic analyses for floodplain mapping for the National Flood Insurance Program.

References

Franz, Delbert
SEDIMENT DEPOSITION BEHIND LEVEES

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The design of a diversion dike on an alluvial plane must account for the effects of sediment depositing on the upslope side. As flood waters are diverted perpendicular to the unobstructed flow path, much of the accompanying sediment loads may be deposited against the dike. As flood waters continue to follow paths over previously deposited material the deposit grows. Such deposits can jeopardize the dike's ability to function properly by resulting in too much load on the upslope face causing sliding or overturning or, eventually, overtopping (Figure 1).

![Figure 1. Deposition on the upslope side of a dike.](image)

Rather than embarking on an expensive modeling effort to determine deposition characteristics well beyond the capabilities of the
state of the art, this paper presents a straightforward, inexpensive, and reasonable approach to estimating design depths of deposits formed under the aforementioned conditions. In particular, we ask, “What is the worst that can happen?” That is, we define an upper limit on the depth that a deposit could have at the upslope face of a diversion dike. The approach is to define a physical constraint (or set thereof) and investigate the ramifications. If we can argue that, given certain design criteria such as flow values up to a 100-year flood magnitude with sediment loads as high as 10% (by volume) of the flow value, a diversion dike need not be higher than 8 feet, it seems unnecessary to insist on further analyses to “determine” that the “true” design height should be 7.283 feet.

Flood depths on alluvial planes are typically less than a couple of feet, on the average. At such shallow depths it may seem unlikely that the depth of sediment deposited would exceed a foot. A deposit cannot increase in depth unless flood waters take paths over material already deposited by the flood. However, as a deposit builds, the slope of future paths over the top of the deposit decreases, making such paths less likely. It seems much more likely that flood waters would follow paths to the right and/or left of the sediment already deposited.

If we approach the problem of defining the shapes of potential deposits by assuming flood waters and accompanying sediment loads will take the steepest path to the diversion structure, we see that deposits with depths exceeding those of the flood waters can form on an alluvial plane. In fact, if enough sediment is available and flood waters follow the steepest path, deposits will necessarily grow in depth at the upslope face of the diversion structure. For example, consider a point on a plane at a given slope from horizontal. The steepest slope a line on the plane can have is that of the plane itself. That is, the steepest path from the reference point to a line of equal elevation or contour, somewhere below the reference point is perpendicular to the contours of the plane.

Lines at angles 30 degrees or less with the contours (60 degrees or more with the line of steepest slope) have slopes one-half or less of that of the plane. Thus, on an alluvial plane with a constant slope, the angle defined by the right and left sides of a deposit at and upslope of a diversion dike aligned parallel to the contours will not exceed 120 degrees until the depth of the center of the deposit is one-half the height that the most upslope point of the deposit is above the toe of the dike. On a plane with a slope of 0.02, for the opening of a deposit 500 feet long to exceed 120 degrees the depth at its center would have to exceed 5 feet. At that depth and length the volume of the deposit would be approximately 54 acre-feet.
The shape of a deposit (the surface of) which has constant slope, s, is that of a "wedge" defined by the surface of a cone with slope s, cut through the apex by a plane with a slope, s₀ equal to the slope of natural ground (alluvial plane) and cut with a plane parallel to and at a distance, L₀, from the axis. The distance L₀ is the (shortest) distance from the upper-most point of the deposit to the diversion dike. The shape of the surface of such a deposit against the diversion dike (plane parallel to the cone's axis) is hyperbolic. Exploiting the idea that the surface has a constant slope, we can calculate the volume of the deposit. The cross section of the deposit at the face of the dike has an area,

\[ A = 2H L₀ \int_0^{θ₀} \sec^2 \theta \, dθ - 2s L₀ \int_0^{θ₀} L(θ) \sec^2 \theta \, dθ \]

\[ = 2s_0 L₀^2 \tan θ₀ - 2s L₀^2 \int_0^{θ₀} \sec^2 \theta \, dθ \]

where H is the height of the upper-most point of the deposit above the toe of the dike; L₀ is the shortest distance from that point to the dike; θ₀ is one-half the angle between the right and left boundaries of the deposit; s is the slope of the surface of the deposit; L(θ) is the distance between the upper-most point and a point on the dike L₀ tan(θ) from the center of the deposit; and s₀ is the slope of the alluvial plane. The variables are show in Figure 2. Integrating over the distance between the upper-most point of the deposit and the diversion dike yields the volume. Letting \( l \) denote the distance from the upper-most point of the deposit and writing the appropriate variables as functions of \( l \), we have

\[ V = \int_0^{L₀} A(l) \, dl \]

\[ = 2s_0 \tan θ₀ \int_0^{l^2} dl - 2s \int_0^{l^2} dl \]

\[ = \frac{2}{3}H L^2 \tan θ₀ - \frac{2}{3}(H - D) L^2 I(θ₀) \]

where

\[ I = \int_0^{θ₀} \sec^2 \theta \, dθ = \frac{1}{2} \tan θ₀ \sec θ₀ + \frac{1}{2} \ln |\tan(\frac{π}{4} + \frac{θ₀}{2})|. \]
Thus, for a given volume of sediment in a deposit we can investigate the length, depth, and "angle-of-opening" \((2\theta_0)\) of the deposit. The relationship between length and depth defined above are shown on Figure 3 for several size deposits on a plane with a slope of 0.02.

Through those relationships we can, for example, investigate the difference between designing a diversion dike to withstand a deposit (of given volume) with the maximum depth and designing a dike to withstand a deposit of a given slope. The difference between the maximum depth and the depth associated with a deposit with a slope of 0.01 on an alluvial plane of slope 0.02 is less than 10% for deposits of up to 70 acre-feet. Alternatively, we can determine the maximum depth to which a deposit can form against a diversion dike with a given length. If we wish to provide protection to a development which has an upslope exposure of 1500 feet on an alluvial plane with a slope of 0.02, we would not expect the depth of a deposit against the diversion dike to exceed 3.4 feet. After a deposit reaches a depth of 3.4 feet there are paths to the right and/or left of the diversion dike steeper than paths on top of the deposit.

\[
\begin{align*}
    s &= \frac{(H-D)}{L_0} \\
    s_0 &= \frac{H}{L_0} \\
    \frac{x}{L_0} &= \tan(\theta) \\
    dx &= L_0 \sec^2(\theta) \, d\theta \\
    A &= 2 \int h(\theta) \, d\theta
\end{align*}
\]

\textit{Figure 2. Variables.}
The maximum depths evident in Figure 3 are associated with a 144-degree ($4\pi/5$) angle-of-opening. At that angle, the maximum depth is:

$$D = 0.562 \left\{\frac{3}{\sqrt{\frac{V}{S_0}}}\right\}.$$  

The maximum depth varies as the cube root of the volume. Therefore, doubling the sediment volume estimate for design purposes increases design height by approximately 25%. The difference between maximum depths given sediment yield estimates of 3 and 4% of the volume of the design hydrograph is less than 8%. The width, $w$, of such a deposit is:

$$w = 5 \left\{\sqrt[3]{\frac{V}{S_0}}\right\} = 8.91 \frac{D}{S_0}.$$
Because the width of the deposit is proportional to the maximum depth it may prove more effective to allow for flow through a development than to divert flow around it. If the upslope exposure in the aforementioned example was 3000 rather than 1500 feet, the corresponding depth of the deposit would be 6.8 feet. Adding an additional couple of feet for the flow (flowing on or over the deposit) and some freeboard could result in a prohibitive design height. Allowing for flow to pass through the center of the diversion reduces the height needed by approximately 3.5 feet. The savings would, of course, have to offset any channel design considerations.

Caution should be exercised when using this approach. We must be certain that site specific deviations from the ideal geometry used to derive the relationships presented do invalidate the notion of an upper limit on the "worst it could be." In those situations it may be an easy enough exercise to add the additional physical constraints and investigate the ramifications of taking the steepest path given the additional constraints. Contrary to the assertion of the depth-width relationship given above, a 1.5-foot high wall 891 feet long perpendicular to the natural flow paths on an alluvial plane with a slope of 0.01 will probably be overtopped by sediment some day. In that case, the land form cannot be approximated as a plane plus or minus 0.5 foot for purposes of defining "following the steepest path." If however, we can define a maximum deviation from a plane we can add that deviation to the "worst case."

In summary, searching for upper limits (and, in other cases, lower limits) may be wiser than embarking on detailed, data intensive modeling efforts the accuracy of which may be unknown. Although the approach may be unfamiliar to many engineers, one feels much more comfortable if he or she can say the deposition cannot exceed the design height rather than explaining the model or, more likely, the combinations of models and methods used to arrive at a design height. We should understand that, although more precise, it is less accurate to say the answer is 8.34 plus or minus 1.5 than to say the answer can be no less 8 and no more than 9. The approach is not always simple but when it can be applied the approach yields quick, reliable and easy-to-understand results. If those results are reasonable from the design perspective then more detailed, time-consuming, expensive analyses do not seem warranted.
Traditional one-dimensional floodplain mapping techniques have proven to be inadequate for flood hazard management in the city of Sumas, Washington. Subject to extreme periodic flooding when the Nooksack River, eight miles southwest, overflows its banks, the city has found that existing mapping approaches cover too limited an area; fail to provide essential information on flow direction, velocity, and water depth; and cannot be coordinated easily with land use, topography, and other details commonly available in geographic information systems (GIS). An alternative mapping approach was taken to enhance the city’s flood hazard management efforts. This approach used two-dimensional flow modeling over an area extending beyond the city limits and integrated the modeling results with GIS data.

Background
Sumas, Washington, is an 850-acre city of 950 residents on the U.S.-Canadian border. Eight miles southwest of the city, the Nooksack River makes a sharp bend westward near the city of Everson. This bend is very near the boundary between the Nooksack and Sumas River basins, and Nooksack River flows that overtop the right bank at Everson enter the Sumas River basin, heading downstream from there to the city of Sumas. These floodwaters generally follow the corridor of Johnson Creek, a tributary to the Sumas River that flows through the center of the city. Topography of the overflow corridor is such that the risk is high
of an avulsion that would redirect the entire Nooksack River from its existing westward path to a new corridor through the center of Sumas.

Further concentrating the flood flows through the city are two raised railroad embankments that come together in Sumas. These embankments funnel the flow to a narrow corridor, resulting in fast, deep flows during severe floods. The only outlet for floodwaters from between the two railroad lines is the Johnson Creek culvert under one of the lines. Limited to this outlet, floodwaters during severe flood events overtop both railroads to continue to the city.

In the last 65 years, the Nooksack River has overflowed at Everson 13 times. Five of those occasions led to severe flooding and damage in Sumas. Of those five, two were in 1990 and one in 1989. One of the floods of 1990 caused more than $7.4 million in damage along the overflow corridor, which extends from Everson to the Fraser River in British Columbia. The overflow damage represented a significant portion of total damage along the Nooksack River during that flood ($21.8 million).

**Previous Mapping Efforts**

The Federal Emergency Management Agency last created floodplain maps for the city of Sumas in 1985. The 1985 FEMA maps included a typical 100-year floodplain boundary, as well as a floodway boundary. The floodway boundary, however, was never adopted. Instead, the city mapped and adopted a "Special Flood Risk Zone." The SFRZ was similar to a traditional floodway boundary, but it took into account the density of development, and as such allowed greater flexibility. Allowable development in the SFRZ, for example, included replacement of existing structures and new construction on pilings or on foundation walls oriented in the direction of flow.

The traditional FEMA and SFRZ mapping posed several problems. Because the mapping did not define flow direction, the allowance for foundation walls oriented to the flow direction was difficult to use in practice. The mapping also lacked information on flow velocity and water depth, making it difficult to define varying levels of flood hazard. Also problematic was the fact that the maps did not extend beyond the city limits as of 1985. Not only has the city expanded since then, but Washington State has since established rules giving cities planning authority for "urban growth areas," which include unincorporated areas adjacent to incorporated cities. The existing maps provided no assistance for flood hazard management in the urban growth area outside the old city limits. Beyond these problems inherent in the old approach to mapping, the 1985 mapping was found to have mapped water surface
elevations incorrectly, based on measurements of high-water marks from the major 1990 flood.

New Mapping Techniques

To address the shortcomings of the traditional mapping, new floodplain mapping for the Sumas urban growth area was undertaken in the mid 1990s. A key difference in the new approach was the use of two-dimensional hydraulic modeling rather than the one-dimensional analysis used to create the 1985 FEMA Flood Insurance Rate Maps. The model used for the updated analysis was the FESWMS model. This model provided three key enhancements over the 1985 one-dimensional mapping: it produced a more accurate delineation of the 100-year floodplain boundary; it gave more accurate definitions of water surface elevations; and graphical output from the model divided the mapped area into a grid of small cells, with a vector in each cell indicating both flow direction and flow velocity.

The next step in the updated mapping procedure was to integrate the results of the two-dimensional modeling with data from a GIS mapping of the city. Key to this process was combining topography from the GIS with water surface elevation from the hydraulic modeling to create a map showing contours of floodwater depth. These contours were color-coded, and the direction/velocity vectors from the two-dimensional modeling were superimposed on the map of water depth. The map thus generated is a powerful tool for depicting flood hazards. With the integration of the GIS mapping, it is very simple to superimpose the detailed flood hazard map on maps of parcel lines, streets, structures, railroads, and other features of concern for flood hazard management.

The final map generated in the new approach was a map showing conveyance capacity, which was calculated as the product of flow velocity and water depth. The use of this parameter recognizes the importance of both velocity and depth as factors in flood hazard analysis. A color-coded contour map of conveyance capacity clearly designated parts of the city conveying the most water, and thus subject to the highest flood risk (Figure 1). This map was used to define new flood-hazard zones called "special flood corridors."

Results of the Analysis

The new approach to flood mapping for the city of Sumas yielded a wide range of new or improved tools for use in the city’s flood hazard management. The first of these was a new FIRM that extends to the boundary of the Sumas urban growth area and that includes more
Figure 1. Conveyance capacity map of Sumas, Washington, indicating areas of greatest flood hazard based on flow velocity and water depth.
Figure 2. Two-dimensional flood map of Sumas, Washington, indicating water depth, flow direction, and flow velocity.
accurate water surface elevations than the 1985 FEMA map. Second is a new SFRZ map. Although the boundaries of the new map are similar to those previously created, the new map provides such additional information as flow velocity, depth, and direction within the zones (Figure 2). Finally, the GIS created for the analysis is now resident on the city’s computer and can be used for extensive and diverse planning uses in the future.
Introduction

The Stormwater Management Division of the Department of Environmental Concerns of DuPage County, Illinois, is utilizing an innovative procedure for developing floodplain maps in the county. The process relies on geographic information system (GIS) application tools used in conjunction with continuous hydrology, dynamic wave routing procedures, and the peak-to-volume statistical approach to develop flood elevations. The procedure uses the Hydrologic Simulation Program-FORTRAN (HSPF) to develop the hydrologic inputs for the hydraulic analysis. The hydraulic routing process uses the model full equations (FEQ) (Franz and Melching, 1997a and 1997b) to dynamically route the hydrologic inputs through the system. The determination of flood elevations is based on the peak-to-volume approach (Bradley and Potter, 1992). Each of these components will be described. This method is currently being applied to watersheds in DuPage County.

Rationale of the DuPage County Approach

The methods used by DuPage County to map floodplains differ significantly from traditional mapping methods with respect to the hydrologic, hydraulic, and statistical analysis. Traditional floodplain mapping techniques face several problems when applied to conditions in DuPage County. Implicit in the methods recommended in Water Resource Council's Bulletin 17-B (USWRC, 1981), are many assumptions that do not apply to most DuPage County streams. For example, storage added through various flood control projects and the county's detention requirements impose severe flow regulation throughout the watersheds. In Illinois, design storm methods have been implemented to address the shortcomings of Bulletin 17-B. Thus, the assumption typically used by the traditional approaches, that the 100-year rainfall produces the 100-year runoff, has also been accepted and is
being used by the State of Illinois. Analysis by DuPage County comparing flows produced by the design storm approach and from continuous simulation have suggested that design storms are not appropriate in DuPage County. These concerns with the design storm approach have led DuPage County to develop its HSPF/FEQ/PVSTATS approach.

Advantages of the DuPage County Approach

DuPage County's hydrologic, hydraulic, and statistical procedures have several advantages. First, the continuous simulation hydrologic model utilizes seven long-term precipitation gages (1949 to the present) to capture the effects of antecedent moisture on runoff volumes and peaks, and to account for the spatial variability of precipitation over the watersheds. These factors are difficult to deal with in the design storm approach. Secondly, the effects of backwater, floodplain storage, and complex urban stream systems have a significant impact on the hydraulics of DuPage County streams. Additionally, there are several gated structures, diversions, and pump processes on many of the streams. Thus, an unsteady flow computer model has been adopted for use in DuPage county watershed studies. Finally, to address the statistical aspects of the floodplain mapping process, the "peak-to-volume" approach is utilized. This approach derives relationships between peak discharge and runoff volume and peak stage and runoff volume. The statistical distribution of flood volumes is less likely to have severe discontinuities often found in the distribution of peak flows in urban streams. The peak-to-volume approach also recognizes that the rating curve sometimes is poorly represented by a single line, and to compensate, the relationship between flood volumes and peak flows and stage is derived separately using locally weighted regression. The HSPF/FEQ/PVSTATS approach eliminates design storm and steady-state assumptions; represents variable effects of backwater, floodplain storage, and flow regulation; and utilizes local historical storm data. This approach has been reviewed by the Federal Emergency Management Agency and the Illinois Department of Natural Resources, Office of Water Resources, and has been approved by both agencies for development of floodplain maps in DuPage County, Illinois.

Hydrologic Calibration

The HSPF model is used to create the hydrologic inputs necessary for hydraulic analyses. The model simulates continuous runoff for various land cover types for a continuous precipitation record. The model
incorporates infiltration, interflow, depressional storage, soil storage, snowmelt, overland flow, evapotranspiration, and changes in soil moisture in determining the runoff. The necessary meteorologic data information for the model is obtained from National Oceanic and Atmospheric Administration (NOAA) stations in or adjacent to DuPage County. A network of seven long-term precipitation gages is utilized to represent the temporal and spatial distribution of precipitation throughout DuPage County for hydrologic calibration. Six of these gages are maintain by NOAA and one by Argonne National Laboratory. Measured meteorologic and precipitation data have been compiled for the period of water year 1949 through water year 1995.

Parameters for the HSPF model were initially set based on values used the 208 water quality studies in DuPage County during the 1970s. These parameters represent the characteristics of the soil, vegetation, and land slopes for six land cover types. These land cover types are: hydraulically connected impervious, flat sloped grassland (<25 ft/mi), moderately sloped grassland, steeply sloped grassland (>200 ft/mi), forest/lowland, and agriculture. For each precipitation gage and land cover combination, a runoff time series of land surface runoff (LSRO) was developed using HSPF. Prior to calibration of the HSPF model, the county’s zoning land use was broken down into the basic land covers. All land uses are composed of varying proportions of the six land cover types. The county’s GIS (ARCINFO) is used to convert land use to land cover and aggregates the totals to any point of interest in the watershed. Set percentages for the six land cover categories for each land use are used by the GIS along with slope information and precipitation gage assignment to convert land use to land cover. Typically the points of interest are the various stream flow gages throughout the county.

Continuous streamflow data is used to calibrate the HSPF model. In DuPage County, each of the four major watersheds has at least one stream gage record. Land cover areas are calculated for each of LSROs tributary to the stream gage. The result is the continuous unrouted hydrograph that would result from the precipitation record above the stream gage. Parameters are adjusted to provide the best match between the simulated and recorded records at all stream gages. Once the calibrated parameters set is developed, HSPF is run to obtain a final LSRO to be used as the hydrologic inputs to the hydraulic models.

Hydraulic Calibration

The FEQ unsteady flow model is used to represent the hydraulics of the stream system. This model is based on the Saint-Venant equations and accurately handles complex urban hydraulic situations. Inputs to the
FEQ model include cross-section information, two-dimensional flow tables for structures, and hydrologic inputs developed by HSPF. The cross-section information inputs are created by GIS using survey and topographic map data.

Time series files (TSF) for selected runoff events derived from the calibrated LSROs are used as the hydrologic inputs for the FEQ model. FEQ allows the user to specify the amount of area for each LSRO segment tributary to the stream along its length. Thus, lateral inflows due to tributary area runoff enter the channel diffusely along its length. In order to better calibrate the FEQ model, the county has developed a local precipitation network (93 gages) to improve the spatial representation of precipitation. Event specific LSROs, based on local gage precipitation records are developed from HSPF for the hydraulic calibration. Tributary areas are assigned to the precipitation gages based on Theissen polygons. In order to represent the spatial variation of precipitation across the watershed, each subbasin has a precipitation factor assigned in the FEQ input. The factor for each subbasin is computed as the ratio of the precipitation amount at the centroid of the subbasins based on the isohyetal map, to the precipitation amount for the gage to which the subbasin is assigned via the Theissen polygons. This technique incorporates both the spatial and temporal distribution of precipitation, and should best represent the watershed hydrology so calibration of the hydraulic model can be achieved. The process of developing factors is completely automated and is achieved through the use of GIS application tools. The hydraulic model is calibrated to stream gages and high water marks obtained from residents and public agencies in the watershed. Between two and four events are used to perform the hydraulic calibration. Initially, this calibration was performed on the four major (parent) watersheds.

Final Calibration Evaluation

Once reasonable results have been obtained through the initial hydrologic and hydraulic calibration of the parent watersheds, a hydraulic evaluation of the hydrologic calibration is accomplished. Using the calibrated HSPF and FEQ models, individual storms are simulated and checked at gages where a continuous record of stream flow data is available. At these points the simulated stage and flow hydrographs are compared with recorded stage and flow records. Modifications to the hydrologic and/or hydraulic calibrations are made until the results are reasonable. This process uses a minimum of 18 events and as many as 24 events to check for reasonableness. This helps ensure the model accurately simulates flows over a wide range of storm duration, intensity,
and flow conditions. At this point the HSPF parameters can be used for planning or mapping purposes. In tributaries where there is no stream gage information, the parent watershed hydrology is used.

**Floodplain Map Development**

For statistical analysis of simulated flows and stages, a long-term record of runoff is needed. One-hundred-fifteen (115) of the top precipitation events recorded between 1949 through 1993 were selected to be routed in the FEQ for statistical analysis. The time series file created for this purpose is called TSFLONG. For floodplain mapping, it is assumed that the actual spatial and temporal distribution of precipitation during a storm event is not as critical as it is during calibration; the emphasis is on predicting a series of events that may reasonably be expected to occur in the future. For mapping purposes, it is crucial that the precipitation gage assigned to the watershed represent the statistical characteristics of the region. Thus after analysis of all NOAA gages, two gages were selected to represent precipitation for floodplain mapping work.

Typically, Bulletin 17B would be used to compute the frequency estimates of the streamflows developed by the FEQ model for floodplain map development. In DuPage County, many of the assumptions inherent to Bulletin 17B do not apply. The most common violation of the 17B assumptions in DuPage County is flow regulation. There are numerous areas in the county that have severe flow restrictions, large flood control projects, significant backwater effects, and even flow reversals. An alternative statistical technique called the "peak-to-volume" approach was chosen develop the flood frequency estimates. The idea behind the peak-to-volume approach is to estimate both the probability distribution of flood volume and the regression relationship between flood peaks conditioned on flood volume.

At the site of interest, a partial duration series of flood peaks (stages or flows) is extracted from the resulting output along with their storm volume. A probability distribution is then fit to this series of volumes, yielding frequency estimates of volume. This step exploits the fact that flood volumes often conform to commonly assumed probability distributions, even when flood peaks are affected by flow regulation. The next step is to develop a relationship between flood peaks (stage or flow) and flood volumes. Since the extracted peak flows, stages, and volumes do not contain enough extreme values to define the relationship for less frequent events, precipitation data for 28 extreme storms that have occurred in the Midwest were obtained from the Army Corps of Engineers. These events were applied to the event version of HSPF to
produce TSFs for input into FEQ. A time series event file, "TSFBIG" was created that included all LSROs for the 28 extreme events for three different antecedent moisture conditions. The TSFBIG is applied to FEQ and the results along with the TSFLONG results are used to establish the relationship between volumes and flows or stages for the full range so extrapolation is no longer necessary. A best fitting technique is used to define the regression relationship between flood peak and volume. The peak-to-volume curve is then integrated with the frequency estimates of volume curve to produce the stage and/or flow at selected cross-sections for different recurrence intervals. This process is achieved through the use of a computer program called PVSTATS. Frequency estimates are determined for every cross-section in the FEQ model. Once the elevations are determined, a GIS application tool is used to apply the flood elevations to their respective cross-sections and create a flood grid surface. The floodplain boundary is set at the boundary where the difference between the flood surface grid and the topologic surface grid is negative, indicating that the flood surface is below the topologic surface. The grid boundary is then smoothed and the floodplain boundary is established.

Summary

The Stormwater Management Division of the Department of Environmental Concerns of DuPage County is utilizing an innovative procedure for developing floodplain maps in the county. The process relies on GIS application tools used in conjunction with continuous hydrology, dynamic wave routing procedures, and the peak-to-volume statistical approach to develop flood elevations. The HSPF model is used to develop the hydrologic inputs for the hydraulic analysis. The hydraulic routing process uses the FEQ model to dynamically route the hydrologic inputs through the system. Flood frequency elevations are based on the peak-to-volume approach. This method is currently being applied to watersheds in DuPage County with good results and success. While the technique is a dramatic departure from traditional floodplain mapping techniques, it addresses several problems that could not be handled with traditional methods.

References

Bradley, A.A. and K.W. Potter
Franz, Delbert D. and Charles S. Melching

Franz, Delbert D. and Charles S. Melching

United States Water Resources Council
Introduction

Estimates of the 1% annual chance discharge at ungaged locations are needed to define Special Flood Hazard Areas as part of the National Flood Insurance Program. Basically, two approaches are used to estimate the magnitude and frequency of base flood discharges at ungaged locations: (1) methods based on the statistical (regression) analysis of data collected at gaging stations; and (2) methods based on rainfall characteristics and deterministic watershed models that convert rainfall excess to flood runoff. Within the plains region of Colorado and Kansas, several watershed models and regional regression equations have been used to estimate 1% annual chance discharge, and these models often provide varying results. In response to requests for Flood Insurance Rate Map revisions in this region, we evaluated the regional variation in 1% annual chance discharge in the plains region of Colorado and Kansas. A major objective in our analysis was the evaluation of the effect of basin shape on flood discharge.

Flood Insurance Study Guidelines and Specifications for Study Contractors (FEMA, 1995) recommends that statistical analyses of gaging station data and regional regression equations be used to estimate discharge where feasible. This recommendation is based in part on results of a study by the U.S. Water Resources Council (1981). Therefore, our approach for evaluating the effect of basin shape on flood characteristics of ungaged watersheds in the plains region was to (1) update flood-frequency curves at gaging stations in the plains region using Bulletin 17B, Guidelines for Determining Flood Flow Frequency (Interagency Advisory Committee on Water Data, 1982); and (2) develop regression equations that relate the 1% annual chance discharge to watershed and climatic characteristics.
Compilation of Data Base

The gaging stations that were used in the regional analysis were primarily those used in previous regional flood-frequency studies by McCain and Jarrett (1976), Livingston and Minges (1987), and Clement (1987). An evaluation of available data identified 42 gaging stations that had 10 or more years of unregulated annual peak flow data in the plains region. Flood-frequency analyses were updated for these 42 gaging stations using data through 1993 and Bulletin 17B guidelines. The watershed and climatic characteristics and the 1% annual chance discharge from the updated frequency analysis are given in Table 1 for the 42 gaging stations. Most of the gaging stations are located in Colorado and Kansas, but seven of the 42 stations are located in the plains region of Nebraska, New Mexico, Oklahoma, and Wyoming.

Gaging stations from Livingston and Minges (1987) were eliminated if the effective and total drainage areas were not approximately equal, or if there were less than 10 years of observed peak-flow data available for flood-frequency analysis. Frequency estimates based on rainfall-runoff modeling as developed by Livingston and Minges (1987) were not used in our analysis. Gaging stations from McCain and Jarrett (1976) were eliminated if watershed length, which is required to compute the shape factor, was not readily available, or if several gaging stations were located along one drainage way (such as the Purgatoire River).

The watershed and climatic characteristics selected for the regional analyses were those readily available in published flood-frequency reports. These watershed and climatic characteristics are drainage area (DA) in square miles; a dimensionless basin shape factor (SF) defined as the channel length squared divided by the drainage area; channel slope (SB) in feet per mile; and the 100-year, 24-hour-duration rainfall (I_{100}) in inches. Of particular interest in our study was the effect of the shape factor on the 1% annual chance discharge. Although Clement (1987) determined that the shape factor was significant in estimating flood discharge in Kansas, regional regression equations published for the plains region of Colorado do not include a shape factor (McCain and Jarrett, 1976; Livingston and Minges, 1987).

The updated 1% annual chance discharges shown in Table 1 are plotted versus drainage area in Figure 1. Even though the data are plotted on logarithmic axes, the data indicate a curvilinear pattern. This suggests that a nonlinear transformation of drainage area may be appropriate in the regression equations for estimating 1% annual chance discharge.
Table 1. Watershed characteristics and 1% annual chance discharge for gaging stations in the plains region of Colorado and Kansas that were used in the regional analysis.

<table>
<thead>
<tr>
<th>Station ID</th>
<th>Drainage Area</th>
<th>Shape Factor</th>
<th>Channel Slope</th>
<th>Contributing drainage area (in square miles)</th>
<th>Channel length squared divided by drainage area</th>
<th>Basin or Channel Slope (in feet per mile)</th>
<th>100-year, 24-hour-duration rainfall (in inches)</th>
<th>100-year, 12-hour-duration rainfall (in inches)</th>
<th>51 I-percent-annual-chance discharge (in cubic feet per second)</th>
<th>41 I-percent-annual-chance discharge (in cubic feet per second)</th>
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<td>4.4</td>
<td>8.9</td>
<td>370anton</td>
<td>370anton</td>
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</tr>
</tbody>
</table>
Regional Analysis

The development of regional regression equations included the following steps: (1) identification of watershed and climatic characteristics to be included in the regression equations; (2) development of linear regression equations (including nonlinear powers of drainage area) based on the applicable explanatory variables; and (3) computation of prediction limits for the regional regression equations. Using the data in Table 1, stepwise regression techniques were used to determine the explanatory variables that were statistically significant in explaining variance in 1% annual chance discharge.

Of the four explanatory variables in Table 1, all variables are statistically significant in estimating 1% annual chance discharge except channel slope. Channel slope and shape factor are moderately correlated (correlation coefficient of -0.73) and explain much of the same variability in 1% annual chance discharge. Shape factor is more significant; therefore, channel slope is not statistically significant at the 10% level when shape factor is included in the regression equation.
Linear regression techniques were used in the analysis by first transforming all variables to their logarithms and determining the best fit linear model. As indicated by Figure 1, the logarithms of the 1% annual chance discharge tend to be a nonlinear function of the logarithms of drainage area. A logarithmic linear model that includes drainage area, shape factor, and the 100-year, 24-hour-duration rainfall had a standard error of estimate of 59%, and the residuals plotted versus drainage area indicated a slight trend. Therefore, a nonlinear term in drainage area of the form \((DA^c \log(DA))\) was included in the linear regression analysis. An optimal value of \(c = -0.10\) was determined by varying \(c\) to determine the minimum standard error. The following three regression models resulted from this analysis:

\[
Q_{1\%} = 734.8DA^{1.132}DA^{-0.10}
\]

\[
Q_{1\%} = 224.1DA^{1.106}DA^{-0.10} I_{100}^{0.767}
\]

\[
Q_{1\%} = 218.8DA^{1.148}DA^{-0.10} I_{100}^{0.937} SF^{-0.176}
\]

All explanatory variables are significant at the 10% level in the above equations. The best one-, two- and three-parameter equations are shown to illustrate the decrease in the standard error of estimate as additional variables are added to the equation. Although the reduction in standard error is small between the one- and three-parameter equations, the three-parameter equation should provide more accurate estimates for those watersheds where the shape factor and 100-year, 24-hour-duration rainfall differ significantly from the mean value for the gaging stations used in the analysis. The nonlinear relation between the 1% annual chance discharge and drainage area is consistent with previous U.S. Geological Survey regression analyses in Wyoming (Lowham, 1988), Kansas (Clement, 1987), and Colorado (Livingston and Minges, 1987).

**Computation of Prediction Limits**

Several regression equations and watershed models are available and have been used to estimate 1% annual chance discharge in the plains region. Prediction limits about regression equations are one approach for evaluating if there are significant differences between previously developed model estimates and the regression equation estimates. The computation of prediction limits for regression equations is well
documented in the statistical literature (Montgomery and Peck, 1982; Helsel and Hirsch, 1992). The prediction limits for a future single prediction define an interval that will enclose the true flood discharge a given percent of the time. For example, there is a 50% chance that the true flood discharge will lie between the upper and lower 50% prediction limits about the regression equation.

The standard error of estimate is the standard deviation of the differences between the data and the regression equation and is a constant value (usually expressed as a percentage) throughout the range of the explanatory variables. However, prediction limits provide estimates of uncertainty for data (gaging stations) not used in the regression analysis. Furthermore, the differences between the prediction limits and the regression estimate increase as the explanatory variables deviate from the mean values used in the regression analysis.

The use of prediction limits is illustrated in Figure 1 for evaluating flood estimates developed by the Urban Drainage and Flood Control District using the Colorado Urban Hydrograph Procedure (CUHP) for the Willow Creek watershed near Denver, Colorado. Estimates of 1% annual chance discharge are shown in Figure 1 for seven ungaged locations in the Willow Creek watershed ranging from 1.37 to 13.2 square miles. Also shown in Figure 1 are the corresponding estimates from the three-parameter regression equations and the 50% prediction limits for these equations.

From Figure 1, one can determine that the Willow Creek estimates from the CUHP model are slightly greater than the three-parameter regression estimates and are within the 50% prediction limits of the regression equations. Prediction limits provide a mechanism for determining whether model results, such as those from the CUHP model, are reasonably close to the regression estimates. The choice of the appropriate prediction limits (50%, 68%, etc.) for evaluating and comparing different model results needs further evaluation.

Summary

The use of regression equations is recommended in FEMA 37 for estimating flood discharges for ungaged watersheds. These equations are easy to develop using standard statistical packages, are based on gaging station data, and have associated measures of uncertainty such as the standard error of estimate and prediction limits. The development of regression equations for estimating 1% annual chance discharge for ungaged streams in unregulated watersheds in the plains region of Colorado and Kansas was illustrated using existing data for 42 gaging stations. Drainage area; 100-year, 24-hour-duration rainfall; and a
dimensionless basin shape factor were shown to be statistically relevant explanatory watershed and climatic characteristics for estimation of 1% annual chance discharge. Simplified procedures for incorporating nonlinear terms in a linear regression model were illustrated. Prediction limits about the regression equation were suggested as one useful statistical procedure to quantify the “closeness” of a 1% annual chance discharge estimated by other methods.

References


TWO ASSUMPTIONS USED IN THE DEVELOPMENT OF EINSTEIN'S BED-LOAD FUNCTION

Jeffrey N. King
Michael Baker Jr., Inc.

Introduction
Einstein assumed in Technical Bulletin 1026 that kinematic viscosity is independent of sediment concentration and von Karman's 'universal constant' of turbulent energy exchange is constant and equal to 0.4 within a sediment-laden flow. These assumptions are examined in this paper. The method presented in Bulletin 1026 is modified to incorporate variability in kinematic viscosity and von Karman's universal constant. Observations on the Mississippi and Missouri rivers are used to compare the accuracy of the original method presented in Bulletin 1026 with modified methods that incorporate variability in kinematic viscosity and von Karman's universal constant.

Theory
Viscosity describes the internal friction within a fluid. Dynamic viscosity relates shear stress to velocity gradient. Kinematic viscosity, $v$, incorporates density effects into dynamic viscosity (Munson et. al., 1990). The kinematic viscosity of clear water is a function of temperature—colder water is 'thicker' than hot water; 'thick' water is capable of exerting more resistance to motion than 'thin' water. Abdel-Aal (1969) reports that the kinematic viscosity of a sediment-laden flow is a function of the concentration of sediment within the flow, where sediment and water together make up the 'fluid.' Abdel-Aal presents the findings of investigations that quantify the relationship between kinematic viscosity and sediment concentration for laminar flows. One of these relationships,

$$v_{\text{eff}} = v \left(1 + \frac{2.5C_{\text{sed}}}{2(1-1.35C_{\text{sed}})} \right)^2,$$

will be used in this analysis, where $v_{\text{eff}}$ is the effective kinematic viscosity, $v$ is for a clear water flow at the same temperature, and $C_{\text{sed}}$ is the concentration of sediment within the flow.
Von Karman derived the log-velocity distribution for turbulent flow in a pipe,

$$\frac{u_{\text{max}} - u_y}{u_*} = -\frac{1}{K} \left( \ln \left( 1 - \sqrt{1 - \frac{y}{r}} \right) + \sqrt{1 - \frac{y}{r}} \right)$$

where $r$ is the radius of the pipe, $y$ the position within the velocity distribution measured from the pipe wall, $u$ the velocity, and $K$ a representative 'universal constant' of turbulent energy exchange within the flow (Abdel-Aal, 1969). Nikuradse found that von Karman's $K$ is constant for clear water flow in a pipe, and found it equal to 0.4 (Keulegan, 1938). Keulegan solved von Karman's log-velocity distribution for open channel flow, and adopted Nikuradse's constant value of 0.4 for $K$.

Einstein showed that the hydraulic radius, $R$, can be partitioned based on the representative source of resistance to flow: such as the bed, wall, sediment grains, or channel irregularities. Einstein showed that in a wide river, the portion of $R$ contributed by the wall is insignificant with respect to the portion contributed by the bed. Therefore,

$$R = R_b = R_b' + R_b''$$

describes the partitioning of the hydraulic radius into portions representative of sediment grains within the bed, $R_b'$, and channel irregularities within the bed, $R_b''$.

A very thin, laminar flow exists between a turbulent flow and its confining boundary. The thickness of this laminar sub-layer, $\delta'$, is a function of the shear velocity of the sediment grains within the bed, $u_*'$. The thickness of the laminar sub-layer is calculated by

$$\delta' = \frac{11.6v}{u_*}, \quad \text{where} \quad u_*' = \sqrt{gR_b' S_e},$$

g is gravitational acceleration, and $S_e$ the slope of the energy grade line.

Einstein adopted Keulegan's log-velocity distribution for use in Technical Bulletin 1026. Einstein accepted Keulegan's log-velocity distribution, and therefore Nikuradse's conclusion that $K$ is constant and equal to 0.4; adopted the grain diameter which is greater than 65% of the sediment mixture in the bed, $D_{65}$, as the representative grain diameter for friction, $k_s$; and incorporated a correction factor, $\chi$, which accounts for the transition from hydraulically smooth to hydraulically rough boundaries, as a function of $\delta'$ and $k_s$. Einstein's version of the log-velocity distribution for any point a distance $y$ from the bed is

$$\frac{u_y}{u_*} = 5.75 \log_{10}\left( 30.2 \frac{v\chi}{k_s} \right), \quad \text{where} \quad \chi = \phi \left[ \frac{k_s}{\delta'} \right], k_s = D_{65}, \text{ and } K = 0.4.$$
For the depth-average velocity
\[
\bar{u} = \frac{5.75 \log_{10} \left( 12.27 \frac{R_b'X}{k_s} \right)}{u_*}
\]

Subsequent to Einstein, Abdel-Aal reports that a number of investigators concluded that \( K \) varies in natural, open channel systems. Abdel-Aal showed that
\[
K = \phi \left[ \frac{Re_{sed}}{v_s} \frac{k_s}{v} \right]
\]
where \( v_s \) is the settling velocity for the representative grain diameter for size, \( D_x' \), and \( Re_{sed} \) the Reynolds Number for \( D_x \). The settling velocity for \( D_x \) is calculated with Ruby’s equation, as reported by Abdel-Aal:
\[
v_s = \frac{2}{3} g (S_r - 1) D_x^2 + 36 \nu^2 - 6 \nu
\]
Abdel-Aal incorporated variability of \( K \) into Einstein’s log-velocity distribution:
\[
\frac{\bar{u}}{u_*} = \frac{2.3}{K} \log_{10} \left( 12.27 \frac{R_b'X}{k_s} \right)
\]
The graphical relationship between \( K \) and \( Re_{sed} \) is shown in Figure 1 for both flumes and rivers. The regression equation shown in Figure 1 was developed for this analysis with data from Abdel-Aal.

**Methods**

The kinematic viscosity of the flow directly manifests in three relationships required by Bulletin 1026: \( \delta' \), \( v_s' \), and \( Re_{sed} \). However, \( \nu \) is omnipresent—it indirectly affects the calculation of numerous variables that are shown later to be integral to the calculation of the bed load.

Shen reports that various investigators assume different relative diameters for \( D_x' \). These range from \( D_{35} \) to \( D_{65} \). For this analysis, \( D_{35} \) is arbitrarily chosen.

Abdel-Aal’s log-velocity distribution is solved by iteration for \( R_b' \). Integrals
\[
I_1 = 0.216 \frac{A^z-1}{(1-A)^z} \int_0^1 \frac{1-y}{y} dy \quad \text{and} \quad I_2 = 0.216 \frac{A^z-1}{(1-A)^z} \int_0^1 \left( \frac{1-y}{y} \right)^z \ln(y) dy,
\]
where \( z = \frac{v_s}{K u_*} \) and \( A = 2 \frac{D_{35}}{R_b} \).
Two Assumptions in Developing Einstein's Bed-Load Function

Figure 1. Von Karman's "universal constant" of turbulent energy exchange, $K$, vs. the Reynold's Number $Re_{sed}$, for the grain diameter that is greater than 35% of the sediment mixture in the bed. Data for rivers and flumes are from Abdel-Aal (1969). The idealized nature of flume experiments minimizes sources of turbulent energy exchange and provides an upper bound for $K$.

are solved with Simpson's Rule, as described in any elementary calculus text. The bed load is calculated in tons per day:

$$bed \ load = 43.1P_b \Phi_s s_g^{1.5} D_{35}^{1.5} (S_g - 1)^{0.5} (P_1 + 1),$$

where $P_b$ is the portion of the total wetted perimeter assigned to the bed, $S_g$ the specific density of the sediment particle, $P_1$, the parameter of total transport:
\[ P_1 = \left( \frac{0.4}{K} \ln \left( \frac{30.2 \chi R_h}{k_s} \right) \right) I_1 + \frac{0.4}{K} I_2. \]

\( \Phi_\ast \), the intensity of transport on the representative particle as a function of the intensity of shear on the representative particle, \( \Psi' \):

\[ \Phi_\ast = \phi \left[ \Psi' = \frac{s_s - s_f}{s_s} \frac{D_{35}}{R_h S_x} \right]. \]

\( s_s \) the density of the sediment, and \( s_f \) the density of water.

Data shown in Table 1 reported by Abdel-Aal on the Missouri River at Omaha, Nebraska, and the Mississippi River at St. Louis, Missouri, are used to justify variation of \( v \) and \( K \) in the method presented in Bulletin 1026. The concentration of sediment within the flow was not available in the Abdel-Aal data set. As this value is required to calculate \( v_{eff} \), it is assumed to be 10% by volume. The sensitivity of the \( C_{sed} \) assumption was tested by varying \( C_{sed} \) for the Mississippi River at St. Louis on June 7, 1961, by ±5%.

**Results**

The results are shown in Table 2. The June 7-Run 3 and 4 data clearly illustrate that while the \( C_{sed} \) assumption does not cause the bed-load estimate to vary given a constant \( K \), when \( C_{sed} \) is permitted to influence \( K \), the estimate varies significantly and is improved.

The importance of accounting for variation in \( K \) is shown by the November 1 data. Unaltered, Bulletin 1026 overestimates the observed bed load by over 1000%. Comparison of the November 1-Run 1 and 2 shows that the poor estimate is due to the false assumption that \( K \) is constant. The effects of grain size on \( K \), and the subsequent effect of \( K \) on the bed-load estimate, are significant.

Run 2 produces the most accurate bed-load estimate for all three observations. Comparison of the \( K \) estimates from the three Run 2 dates shows that the influence of \( v \) on the \( K \) estimate is subordinate to the influence of \( D_x \) and \( k_s \). The input data for the June 7 and April 19 runs share common location and grain size while they differ with respect to temperature. Estimates of \( K \) differ by approximately 10% given sediment gradation in the bed, which differs by approximately 15%, even though \( v \) for these runs differs by 30%. The input data for the April 19 and November 1 runs share common temperature, while they differ with respect to location and grain size. Estimates of \( K \) differ by approximately 40% given sediment gradation in the bed which differs by approximately 75%, while \( v \) for these runs only differs by 5%.
Two Assumptions in Developing Einstein's Bed-Load Function

### Table 1. Input data.

<table>
<thead>
<tr>
<th>Mississippi River @ St. Louis, Missouri (June 7, 1961)</th>
<th></th>
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### Table 2. Results.

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<td>12.44</td>
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Comparison of the April 19-Run 2 data to the November 1-Run 2 data also show that the influence of the hydraulic input is subordinate to the turbulent effects evident in $K$. The discharge on the Mississippi River at St. Louis on April 19, 1962 is one order of magnitude greater than the discharge on the Missouri River at Omaha on November 1, 1967. The top width on the Mississippi is 138% larger, while the hydraulic radius is 285% larger. However, the measured bed-load in the Mississippi is only 75% larger than that in the Missouri. Because the smaller grains in the Missouri are influenced more by turbulence in the flow than those in the Mississippi, as shown by a $K$ value that is
approximately 40% smaller, the Missouri bed-load estimate is larger relative to the discharge.

**Conclusion**

The qualitative, comparative conclusion is more powerful than the quantitative. Substantiation of the assumed sediment concentration in the bed layer and justification of the choice of $D_{35}$ as representative of the sediment mixture are not necessary. It is shown that very minor variation of the Bulletin 1026 assumptions has significant effects on the bed-load estimate. Similar investigations of other methods of calculating bed load may yield similar conclusions. Additional data collected with more sensitive instrumentation than was available in the 1950s and 1960s may improve the estimation accuracy for $K$. The robust influence of $K$ on the bed-load estimate and the variability in the observed, riverine $K$-$Re_{sed}$ relationship warrants further investigation into the cause and effect of turbulent energy exchange and its relationship to bed load.

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FLOODPLAIN MANAGEMENT OF INTERIOR AREAS USING HEC-IFH

Martin J. Teal
WEST Consultants, Inc.

Introduction

Management of interior areas is a difficult task for floodplain administrators. (An interior area is defined as an area where local precipitation runoff and/or other flows are blocked from reaching an exterior stream by a barrier, usually a levee or floodwall.) Typical questions to be answered include, "How do I determine the 100-year floodplain?" and "What combination of pumps and gravity drains is economically justified by the reduction in flood damage?" The Federal Emergency Management Agency (FEMA) requires that:

Where credit will be given to levees providing 100-year flood protection, the adequacy of interior drainage systems will be evaluated. Interior drainage systems associated with levee systems usually include storage areas, gravity outlets, pumping stations, or a combination thereof (FEMA, 1995).

The author has performed interior flood studies in California, Missouri, and Arkansas—all of these studies relied heavily on use of the computer program HEC-IFH (Interior Flood Hydrology) (U.S. Army Corps of Engineers, 1992). This program, created by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers, is largely unknown among floodplain professionals but is a very useful tool for floodplain management. This paper will first briefly describe the HEC-IFH computer program. The latter part of the paper will then describe an interior flood study performed for the City of Clarendon, Arkansas, where the program was utilized.

Brief Overview of HEC-IFH

This computer program can simulate rainfall-runoff processes, streamflow routing, auxiliary inflow, diversions and seepage and complex combinations of gravity outlets and pumping facilities. Interior elevation-frequency relationships can be determined for various alternative plans by using continuous simulation or hypothetical storm event analysis.
Typical System Layout

The HEC-IFH model is used to analyze areas protected by levees or floodwalls. The area protected is called the interior area, and is separated by a line of protection (levee, floodwall, or high ground) from the exterior area. The exterior area is most often a river, but could also be a lake or the ocean. The line of protection prevents high exterior water levels from reaching the interior area, but can also prevent interior drainage from reaching the exterior water body. Typically, measures such as gravity drains (usually equipped with valves or flap gates) and pumps convey interior runoff to the exterior, and sometimes interior ponds or diversions are constructed to minimize water levels during runoff events.

Water may enter the interior area by two methods. The primary method is runoff from basins tributary to the interior area. When the exterior water surface elevation is higher than the interior water surface elevation, water may also enter the interior area by seepage through or under the line of protection.

Hydrology

The HEC-IFH model uses essentially the same algorithms as the HEC-1 hydrologic model (U.S. Army Corps of Engineers, 1990) for rainfall-runoff computations. However, for computations performed within HEC-IFH, a limitation of two sub-basins (called upper and lower) is imposed. Auxiliary flows are allowed, however, within the model such that more complex hydrologic modeling may be performed exterior to HEC-IFH and the resulting inflow hydrographs read in during the simulation. Like HEC-1, HEC-IFH requires rainfall data, loss rates, and rainfall-runoff transforms (e.g., unit hydrograph). If an upper sub-basin is defined, channel routing is allowed by one of several methods from the upper sub-basin to the lower sub-basin.

Other Data Needs

Interior pond. A pond elevation versus surface area table must be entered by the user and is very important in the analysis results. This information is typically obtained from local ground or aerial surveys.

Gravity outlets. HEC-IFH will compute or read in gravity outlet rating tables for culverts and pipes. Rating table computations will only be performed for box or circular culverts. For the computations to take place, the user must enter a culvert length, roughness (Manning's 'n') value, loss coefficient, interior and exterior invert elevations, exterior elevation for gate closure, and tabulation intervals.
Pumps. A head/capacity/efficiency curve must be entered for each pump unit in the analysis. This information is typically supplied by the pump manufacturer. Pump start and stop elevations are defined by the user and may vary from month to month. Variable speed pumps are not currently supported by the program.

Exterior elevations. Exterior water surface elevations can either be specified by the user or calculated using rainfall-runoff calculations with a user-supplied rating curve.

Clarendon, Arkansas, Study

This study was performed by WEST Consultants for the U.S. Army Corps of Engineers, Memphis District. The purpose of the study was to analyze both existing conditions and a scenario where additional pumping capacity would be added to the single existing pump. The Memphis District would take the study results, calculate benefits resulting from decreased flooding with new pumps added, and compute a benefit/cost ratio to see if the project would be feasible from the federal point of view. For the purpose of this particular project a continuous simulation using historical data was used. For a floodplain delineation a single (base flood) event could be modeled using various exterior conditions to arrive at an interior water surface elevation. The components needed for either continuous or single-event analyses (pumps, drains, etc.) are identical.

General

Using the HEC-IFH computer program, hydrologic continuous simulation analyses (CSA) were performed for the City of Clarendon, Arkansas. Two system configurations were compared: one with a single pump to relieve interior flooding (the 1980 condition) and the other with the addition of two more pumps for a total of three pumps (the 1994 condition). An interior elevation frequency analysis was performed for each of the conditions.

Period of Record

Hourly rainfall data and daily exterior stage data for the study area in HEC-DSS format (U.S. Army Corps of Engineers, 1995) were provided by Memphis District ("the District"). The stage data covered the period January 1965 through December 1992, while the rainfall data covered the period May 1948 through December 1990. Therefore, the period where the records overlap, January 1965 through December 1990, was
used for the CSA. This 25-year period of record was deemed sufficient for the purposes of the study.

**Exterior Stage Data**

The stage data consisted of gage heights for the White River at Clarendon taken at 0800 hours daily. The provided DSS file was modified in two ways. First, the elevation corresponding to zero gage height, 139.91, was added to the original stage values to obtain elevations above mean sea level. Second, the time series data was shifted so that the exterior stages would correspond to daily values at 2400 hours. These two modifications were necessary in order for the computer program to function correctly.

**Hydrology**

The rainfall data provided by the District was not modified in any way. The total interior area as marked by the District on a USGS quadrangle map was measured by planimeter and found to be 2.92 square miles. The District's WSS program was used to determine a Snyder's watershed lag value ($T_p$) of 3.33 hours. Because of the small basin size, as well as the small basin lag time, no further subdivision of the interior area into sub-basins was deemed necessary.

Because of the interior basin's quick response time, the 24-hour unit hydrograph provided by the District was not appropriate to the study and was not used. Instead, a unit hydrograph produced by HEC-IFH using Snyder's $T_p$ and $C_p$ as input parameters was used. The input $T_p$ value was 3.33 hours, and the $C_p$ value was 0.55 (taken from a previous hydrologic study in the same area). Loss rates were also taken from the previous study, and were set to 1.0 inch initial loss and 0.09 inch/hr uniform loss; 3% of the drainage area was estimated to be impervious.

**Interior Pond Storage**

HEC-IFH requires that a pond elevation (ft) vs. surface area (acres) relationship be entered. These values were provided by the District. The program calculates a pond elevation vs. storage volume (acre-ft) relationship from the elevation-area values. The bottom elevation for the pond was assumed to be at elevation 163.6. For both the 1980 and 1994 condition program runs the starting pond elevation was set at 164.0.

**Gravity Drains**

Information on the drain sizes was provided by the District: one 36-inch corrugated metal pipe (CMP), two 48-inch CMP's, and one 60-inch
CMP. Each drain was assumed to be 130 feet long, have a Manning's 'n' value of 0.02, and an entrance loss coefficient of 0.8 (corresponding to a CMP projecting from fill with no wing walls). The invert elevations were assumed to be 163.6 in the interior area and 162.3 outside of the levees, with the drain on a one percent slope. For the CSA runs, it was assumed that the drains would be functioning if the interior water surface elevation minus the exterior water surface elevation was 0.01 foot or greater. The exterior water surface elevation at the drain outlets was assumed to be the same as that indicated on the river stage record.

Seepage

The value for seepage into the interior area was provided by the District as six cfs per foot of head differential (exterior minus interior water surface elevations).

Pumps

Pump performance curves were provided by the District, and were entered into the computer program. The estimated pump head loss, for each pump considered, was 1.0 foot. For the 1980 condition, a single 18,000 gallons per minute (gpm) pump was used. Pump start and stop elevations used were 167.0 and 166.0 respectively. For the 1994 condition, two additional pumps were added: a second 18,000 gpm pump, and an 8,000 gpm pump. The pump start/stop elevations used were 167.7/166.5 for the 8,000 gpm pump, and 168.7/166.9 for the 18,000 gpm pump. For both the 1980 and 1994 condition program runs the gravity outlets and pumps were allowed to operate simultaneously.

Program Time Step

The computational time interval selected for the computer runs has a great influence on the computed pond inflow, outflow, and storage volumes, which in turn affect the results of the frequency analysis. As a rule of thumb, the selected time step should, as a maximum, be one-fifth of the drainage basin's time of concentration, $T_c$. For quick response basins, such as the one under consideration, $T_c$ can be taken as roughly equal to $T_p$. The maximum time step is then: $3.33 \text{ hours/5} = 40 \text{ minutes}$. HEC-IFH allows time steps of 5, 10, 15, 30, and 60 minutes. In theory one would like to use the smallest time step possible to obtain the most accurate results. However, computer memory and runtime considerations, especially when dealing with large amounts of data such as in the present study, prohibit exceptionally small time steps. A time step of 15 minutes was used for the final program runs.
Results

Figure 1 shows results for a typical year during the existing conditions simulation. Events over the interior basin increased water surface elevations for a short period of time until the water surface was lowered by gravity drains or pumps. However, twice during the water year in Figure 1, high exterior elevations prevented rapid drawdown of the interior area.

Figure 1. Interior and exterior elevations for a typical water year—existing conditions.

Figure 2 shows the comparison of elevation-frequency curves for the existing conditions (labeled BP1T15R) and the increased pump capacity scenario (labeled 1994T15R). One can see that the increased pump capacity lowers interior water surface elevations up to an approximately
Figure 2. Comparison of elevation-frequency curves for existing conditions (BP1T15R) and increased pump capacity scenario (1994T15R).

50-year recurrence interval (frequency of 2%). However, for a 100-year interval (frequency of 1%) the increased pump capacity does not alter expected water surface elevations.

References

Federal Emergency Management Agency

U.S. Army Corps of Engineers


Introduction

In March 1997, areas along streams in Kentucky were devastated by floodwaters as a result of record rainfall. In many areas of Kentucky this was the worst flooding in more than 30 years, and initial damage estimates were as high as $400 million for the entire state as reported by the U.S. Geological Survey (USGS). The governor declared a state of emergency during the floods, and 87 of the 120 counties in Kentucky were subsequently declared federal disaster areas. As a result, local officials requested that the Federal Emergency Management Agency (FEMA) provide approximate 100-year or base flood elevations (BFEs) along 42 creeks/streams/rivers in 30 Kentucky counties.

Woodward-Clyde Federal Services (WCFS) was tasked with developing the BFEs within an expedited time frame. The traditional approaches to developing BFEs were too costly and time consuming to meet the needs of FEMA and the local officials. It was necessary to use an approach that would take less time than a detailed study, but at the same time provide results that, while approximate, would serve the needs of the local officials. After discussions with FEMA Region IV, it was determined that the FEMA QUICK-2 hydraulic computer program would be used to develop the approximate BFEs.

Traditional Detailed Studies

Traditionally, the U.S. Army Corps of Engineers (USACE) HEC-2 or Natural Resources Conservation Service (NRCS) WSP2 hydraulic computer models are used in order to develop detailed BFEs for areas along streams not previously studied. In order to develop a hydraulic model, three types of data must be obtained: floodplain geometry, channel and overbank roughness coefficients, and flood discharges.
Typical methods of obtaining or calculating the data required for the development of a hydraulic model will be discussed below.

**Floodplain Geometry**

Field surveys are used to obtain the most accurate floodplain geometry data. Channel cross-sections along the reach to be studied are surveyed at locations where changes exist in channel characteristics (i.e., slope or roughness) and discharge. Additional cross-sections just upstream and downstream of road crossings are also obtained.

At times, field surveys are not necessary because detailed topographic mapping exists. If the map scales and contour intervals of existing maps are adequate, elevations along cross-sections can be obtained directly from the topographic maps.

**Roughness Coefficients**

Site visits are required in order to determine roughness coefficients of the reaches to be studied and their overbanks. Many references exist that supply roughness coefficients based on channel type and surface cover. The reach to be studied should be observed, with special note being taken when a change in channel or cover type exists. Good aerial photographs may also be used to determine roughness coefficients.

**Discharge**

There is a wide variety of acceptable methods that can be used to determine discharges. Methods vary from the use of state- or region-specific regression equations to the development of a detailed hydrologic model using computer models such as the NRCS TR-20 or USACE HEC-1.

The USGS has developed regression equations that can be used to determine the discharge required for BFE calculations. These equations are based on actual stream gage data and extrapolated for ungaged streams. Generally the following type of data is required in order to use a regression equation: drainage area, rainfall amount, land cover type, and stream slope. Certain limitations do exist when using regression equations. The use of a regression equation may be restricted if a high percentage of impervious area exists in the watershed or if a control structure is located within the watershed. Other limitations based on the size of the drainage area or stream slope may also exist.

The NRCS TR-55, "Urban Hydrology for Small Watersheds," is also often used to determine flood discharges. A simple method for calculating discharge is outlined in TR-55. Data including soil type,
cover type, and rainfall amount and distribution is needed if TR-55 is to be used. TR-55 should not be used for drainage areas greater than 2,000 acres (XX square miles).

Computer models such as NRCS TR-20 and USACE HEC-1 are used to perform detailed hydrologic calculations to determine flood discharges. These models generate runoff hydrographs for watershed subareas, which are added together and routed through stream reaches or control structures. These models require the same type of data as TR-55, as well as additional data if routing through stream reaches or structures are necessary. Since many assumptions may be made when developing these hydrologic models, the model should be calibrated against an actual storm event to insure accuracy.

**Hydraulic Calculations**

The data discussed above (floodplain geometry, roughness coefficients, and discharge) are used to develop hydraulic models, such as USACE HEC-2 or NRCS' WSP2, to determine BFEs along a stream reach. Additional data is required if bridges or culverts are located along the reach. Bridge and/or culvert data can either be obtained from government agencies such as the county or state department of transportation or data through a field survey.

Standard hydraulic models such as HEC-2 or WSP2 are used to prepare Flood Insurance Studies (FIS) and the floodplain delineations shown on a Flood Insurance Rate Map (FIRM). However, in certain situations (i.e., for subdivisions with 50 lots or fewer or 5 acres or fewer), normal depth calculations may be used to determine approximate BFEs. FEMA's QUICK-2 program can be used, rather than performing the calculations by hand.

**QUICK-2**

Once flood discharges are determined, the simple QUICK-2 program can be used to calculate both normal depth and critical depth. Manning's equation is used by QUICK-2 to calculate the normal depth at a cross-section. Key assumptions are that flow is uniform, steady, and one-dimensional. In addition, it is assumed that the flow is not affected by downstream obstructions (i.e., bridges or culverts) or flow changes. The program can also be used for step-backwater computations if BFEs at more than one cross-section are required.

In order to use QUICK-2 for normal depth calculations, the following input is required: channel geometry, roughness coefficient, channel slope, and discharge. The output provided includes water depth,
velocity, top width, Froude number, and flow type. If the flow is subcritical (i.e., the normal depth is greater than the critical depth), the normal depth is used for the BFE. If the normal depth is less than the critical depth, supercritical flow exists, and the critical depth should be used for the BFE.

Step-backwater computations will take backwater effects into account when calculating water surface elevations. For step-backwater computations, topographic data is needed along each cross-section to be used in the computations. Left and right channel banks must be identified for each cross-section, and the distance between cross-sections must be provided. Discharge, roughness coefficients, channel expansion and contraction coefficients, and a starting water surface elevation are also required as input. Either a known starting water surface elevation may be used, or the channel slope at the farthest downstream cross-section can be input and a normal depth calculation used to determine the starting water surface elevation.

QUICK-2 is a fast, simple, and inexpensive alternative to the development of a detailed hydraulic model; however, the program does not model the effects of bridges, culverts, or supercritical flow.

**WCFS Approach—Developing BFEs in Kentucky**

Site visits and field surveys were outside the scope of work and time constraints for this project; therefore, an attempt was made to obtain as much existing data for the study areas as possible.

Approximate BFEs were calculated upstream and downstream of cities, at locations where there were significant changes in the topography, and at the confluence of major tributaries. FEMA's QUICK-2 computer program was used to determine the approximate BFEs. The necessary input for QUICK-2 included 100-year flood discharges at the locations of interest, cross-sections at these locations, and roughness coefficients. USGS regression equations for Kentucky were used to calculate the 100-year flood discharges at the points of interest. There was some existing cross-sectional data obtained from the Kentucky Department of Transportation (KDOT); however, the majority of the cross-sections required for the analysis were scaled off of USGS 7.5-minute topographic quadrangle maps with 10- to 40-foot contour intervals. Roughness coefficients were estimated based on information from floodplain permit applications obtained from the Kentucky Department of Natural Resources and Environmental Protection Cabinet, USGS topographic maps, County Soil Conservation Surveys, and data obtained from the KDOT.
Results

The results obtained were presented on USGS topographic maps. Cross-section locations and floodplain boundaries were shown on the maps, and the calculated BFEs were presented at each cross-section. The BFEs were also presented in tabular format.

Although the BFEs developed can only be considered as approximate values, the effort satisfied the local officials' need for BFE data and a quick turn-around. The approximate BFEs can be used as a tool for identifying locations in need of flood mitigation. The local floodplain administrators were given these maps to use as a floodplain management tool and the best available data for the streams that currently have no flooding information. With limited time, resources, and funding, the simplified method of determining BFEs proved to be a viable alternative to a traditional, more costly, detailed flood insurance study.
THE RELATIONSHIP BETWEEN PEAK RATE FACTORS AND WATERSHED CHARACTERISTICS

Moe Khine
Dewberry & Davis

Introduction

The practicing engineer has been using the unit hydrograph method to transform rainfall excess into a discharge hydrograph since Sherman introduced the method in 1932. There are two parameters in unit hydrograph method: lag time and peak rate factor (prf). This paper discusses the origin of prf and its shortcomings, and covers the systematic application of the kinematic wave and Muskingum-Cunge methods for hydrograph simulation using physical characteristics of the watershed. An equivalent prf is also calculated to compare the methods and to gain confidence in making engineering judgements.

The Origin of the Peak Rate Factor

The rising and receding limb of a discharge hydrograph may be approximated by different curves. The hydrographs from steep streams may be approximated with convex parabolas, mild streams with straight lines, and flat streams with concave parabolas. The volume of hydrograph with convex parabolas can be computed by the relationship:

\[ V = \frac{1}{3} Q_p T_p + \frac{1}{3} Q_p T_r \]

However, \( V_p/V = \frac{1}{3} Q_p T_p / (113 Q_p T_b) \); or, \( Q_p = 3 (V/T_p) (V_p/V) \)

where \( V = \) volume of hydrograph in cubic feet, \( Q_p = \) peak discharge in cubic feet/second (cfs), \( T_p = \) time from start of hydrograph to peak in seconds, \( T_r = \) time from peak to end of hydrograph in seconds, \( V_p = \) volume of rising limb in cubic feet, \( T_b = \) base time of hydrograph = \( T_p + T_r \). The volume of hydrograph, \( V \) is equal to the product of precipitation excess, \( P_e \) and the drainage area, \( A \). If \( P_e \) is in inches, \( A \) is in square miles, \( T_p \) is in hours, and \( Q_p \) is in cfs, the equation for \( Q_p \) can be written as:

\[ Q_p = 645.33 \times 3 \times (V_p/V) \times (A P_e/T_p) \]

or \( Q_p = 645.33 \times K \times (A P_e/T_p) \)

and \( T_b = T_p / (V_p/V) \); where \( K = \) peaking coefficient and \( F_p = \) peak rate factor.
If the hydrograph is approximated by a triangle, the peaking coefficient is \( K = 2 \times (V_p/V) \). If the hydrograph is approximated by concave parabolas, the peaking coefficient is \( K = 1.5 \times (V_p/V) \). Previous studies (U.S. Army Corps of Engineers, 1963) have shown that \( V_p/V \) ratio is highly dependent upon the rainfall duration and distribution. According to Table 1, the same watershed can have different prfs depending upon different \( V_p/V \) ratios. However, this table cannot provide prfs based on the shape of the watershed, such as pear-shaped or elongated. The standard Natural Resources Conservation Service dimensionless curvilinear unit hydrograph is based upon the properties of an equivalent triangular unit hydrograph with \( V_p/V \) ratio of 0.375 and therefore the prf is equal to 484. The Snyder's unit hydrograph requires a peaking coefficient, but proper guidance is not available to obtain the value. It is obvious from Table 1 that different hydrograph shapes and \( V_p/V \) ratios will produce different prf values.

**Table 1. Relationship between \( V_p/V \), \( T_b/T_p \), peaking coefficient, and peak rate factor.**

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<td>3.000</td>
<td>1936</td>
<td>2.00</td>
</tr>
</tbody>
</table>

**Determination of Peak Rate Factor \( F_p \)**

Several attempts were made to estimate \( F_p \) for different watersheds from observed hydrographs at gaging stations. The usual procedure is to find \( F_p \) from Equation 1 after obtaining \( Q_p \), \( V \) (\( Pe \)), and \( T_p \) values from an observed hydrograph for known drainage area \( A \). \( F_p \) values obtained from previous studies range from 80 to 637 (U.S. Army Corps of Engineers, 1963). The variation in \( F_p \) may be due to different watershed characteristics, rainfall duration and distribution, and accounting for main channel storage and storages due to swamps and ponds within the studied watersheds. The size of the watersheds in the previous studies
varies from 3 to 875 square miles (U.S. Army Corps of Engineers, 1963) and the determination of Fp was performed only at single gaging stations.

**Proposed Method**

One promising approach is to develop hydrographs based on the physical characteristics of a watershed that can respond to any type of rainfall duration and distribution. The kinematic wave method combined with the Muskingum-Cunge routing method from the HEC-1 program (U.S. Army Corps of Engineers, 1990) may be used to transform excess rainfall into the discharge hydrograph. One or two overland flow elements, one or two collector channels, and one main channel may be used to represent a basin. The results may then be compared to an equivalent prf to gain engineering judgement on the basin response to rainfall. This paper analyzes two typical watersheds, one pear-shaped and the other elongated. Engineering judgement must be used in the application of this method when selecting representative overland flow elements, collector channels, and main channels. However, this paper explains in detail how to consistently make this judgement. The following procedure should be followed when applying this method.

1. Use a USGS 7.5-minute quadrangle map with contour intervals of 10 feet or greater to delineate the drainage boundary. In flat areas the 7.5-minute USGS quadrangle map will often use a 5-foot contour interval. Even a 5-foot contour may not be adequate to locate collector and main channels, in which case one should attempt to use a 1-foot or 2-foot contour topographic map.

2. Trace all blue line streams from the USGS quadrangle map. These represent main channel(s) and some collector channels.

3. As recommended by the NRCS (1986), assume that the overland flow length is no greater than 300 feet. Overland flow will drain into a collector channel from both sides. Think of an open book: the middle of the book represents the collector channel and the open pages on either side represent the overland flow. The total width flowing into the collector channel should not be more than 600 feet. However, if the contours do not allow the engineer to delineate collector channels within 600 feet, the total width may be increased to 1000 feet.

4. Draw the collector channels on the map based on the contours and the overland flow width criteria as described above.

5. Draw lines perpendicular to the collector channel. These represent the flow path of the overland flow element. Find the upstream and downstream ground elevations along the flow path. The slope is determined by dividing the difference between the elevations by the
length of the flow path. Determine the slope of the overland flow element at two or more points along the collector channels. Find the average length and slope of the overland flow element. The Manning's roughness coefficient for the overland flow element can be obtained from Table 3.5 of HEC-1 user's manual (U.S. Army Corps of Engineers, 1990) after reviewing the aerial and ground photographs or land use maps.

6 Select the main channel or channels depending upon whether the basin is pear-shaped or elongated. A pear-shaped basin will have more than one main channel, while an elongated basin will have one main channel.

7 Determine the length of the collector channels flowing into the main channel(s). Determine the average length of the collector channels. Select the collector channels with lengths that are close to the average length. Determine the ground elevations at the confluence with the main channel and at the end of the overland flow element for selected collector channels. Determine the slope of the collector channels. Find the average slope of the collector channels for the basin. Use only one collector channel to represent the basin unless the basin is large.

8 If the collector channel represents a single-line stream, use a triangular section as the shape of the channel. If it represents a double-line stream, use a trapezoidal section as the shape of the channel. The width of the double-line stream can be used as the base width of the trapezoid. Draw perpendiculars to the selected collector channels. Determine the horizontal scale of the side slopes of the collector channels by dividing the width between the same contour lines on each side of the channel by twice the contour interval. This width should be measured at several locations along the collector channel where the contour line crosses the channel. Then determine the average side slope for the collector channel. The Manning's roughness coefficient of the collector channels may be selected from hydraulics textbooks by reviewing the aerial and ground photographs.

9 The average contributing drainage area to each collector channel is equal to the total drainage area divided by the total number of collector channels.

10 Find the invert elevation of the main channel at the outlet of the basin. Find the invert elevation of the main channel(s) where the most upstream collector channel joins. Find the length of the main channel between these two points. Determine the slope of the main channel(s). Determine the average length and slope of the main channel for a pear-shaped basin. Determine the parameters of the shape of main channel the same as the collector channel. The Manning's roughness
coefficient for the main channel may be selected from hydraulics textbooks after reviewing the ground photographs.

(11) After obtaining the parameters for the overland flow element, collector channel, and main channel, select the design storm and loss rate method to compute the discharge hydrograph.

To have a feel of the discharges computed by the proposed method, an equivalent prf should be computed using one of the unit hydrograph methods available in HEC-1. HEC-1 has only one peak rate factor of 484 for the NRCS unit hydrograph method. Therefore, one of the other two HEC-1 unit hydrograph methods, Snyder or Clark, should be used. The NRCS peak rate factor \( F_p \) can be related to the Snyder peaking coefficient by the relationship:

\[
F_p = 645.33 \frac{K}{L} = 640 \times \left(\frac{0.5D + L}{L}\right) \times C_p
\]

where \( D \) = computation time interval, \( L \) = NRCS Lag time, and \( C_p \) = Snyder peaking coefficient.

Two parameters, \( L \) and \( C_p \), are needed when using the Snyder unit hydrograph method (US record in HEC1). HEC-1 provides velocity for the overland flow, collector channel, and main channel, when computing with kinematic wave and Muskingum-Cunge methods (UK/RD records in HEC-1). As an initial estimate, the travel time for each segment is obtained by dividing the lengths by the corresponding velocity. The summation of all travel times is assumed as the time of concentration, \( T_c \). Multiplying \( T_c \) by 0.6 gives the Lag time. Assume \( C_p \) until the computed discharge from Snyder's method is equal to the computed discharge from UK/RD method. The corresponding NRCS prf may then be determined from \( C_p \) and Equation 2. If the computed peak time from the Snyder method is different from that of UK/RD method adjust the lag time on US record. The computed prf should not be considered as the true prf because it is also dependent upon the time-area assumption used in the computation of the Snyder's parameters in HEC-1 analysis. The computed prf should only be used to understand the response to rainfall by different types of watersheds.

Simulations were run on basins with differing shapes and channel slopes to evaluate how peak discharges and hydrograph shapes respond to the proposed method. The slopes of the overland flow element, collector channel, and the main channel for the example problem may be categorized as steep slopes. These slopes are reduced by one magnitude to represent mild slope and reduced by another magnitude to represent flat slope. Tables 2a and 2b show the basin characteristics for pear-shaped and elongated basins. The computed hydrograph shapes were sensitive to basin characteristics and showed a convex curve for steep slope, a triangle for mild slope, and a concave curve for flat slope.
Different dimensionless unit hydrographs may need to be established to reflect different hydrograph shapes with prf other than 484 when using NRCS unit hydrograph method. However, the UK/RD method does not require predefined unit hydrograph shapes, and appears to be capable of producing the correct shape from basin characteristics.

**Table 2a. Basin characteristics.**

<table>
<thead>
<tr>
<th></th>
<th>Pear-shaped basin</th>
<th></th>
<th>Elongated basin</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length feet</td>
<td>Flat Slope</td>
<td>Mild Slope</td>
<td>Flat Slope</td>
</tr>
<tr>
<td>Overland</td>
<td>300</td>
<td>.000333</td>
<td>.00333</td>
<td>.0333</td>
</tr>
<tr>
<td>Collector</td>
<td>1675</td>
<td>.000355</td>
<td>.00353</td>
<td>.0353</td>
</tr>
<tr>
<td>Main</td>
<td>7600</td>
<td>.000149</td>
<td>.00149</td>
<td>.0149</td>
</tr>
</tbody>
</table>

**Table 2b. Basin characteristics.**

<table>
<thead>
<tr>
<th></th>
<th>Pear-shaped basin</th>
<th></th>
<th>Elongated basin</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overland</td>
<td>0.40</td>
<td></td>
<td></td>
<td>.09</td>
</tr>
<tr>
<td>Collector</td>
<td>0.20</td>
<td>0.0</td>
<td>15</td>
<td>.09</td>
</tr>
<tr>
<td>Main</td>
<td>0.10</td>
<td>0.0</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows total discharges by UK/RD and Snyder methods for 100-year 24-hour rainfall using U.S. Army Corps of Engineers hypothetical rainfall distribution, assumed lag time for Snyder's method, and equivalent NRCS peak rate factors. The drainage area of the pear-shaped basin is 2.74 square miles (sq mi), and that of the elongated basin is 2.15 sq mi. The discharges from UK/RD method demonstrate that the flatter the slope of the overland element and the channels, the smaller the discharge is. This table illustrates that the discharges obtained from UK/RD method is within the range of normally accepted lag and prf values for different watershed slopes.
Table 3. Comparison of discharges, lag times, and peak rate factors.

<table>
<thead>
<tr>
<th></th>
<th>Flat Slope</th>
<th>Mild Slope</th>
<th>Steep Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>uk/rd Q</td>
<td>us Q</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>cfs</td>
<td>cfs</td>
<td>hours</td>
</tr>
<tr>
<td>Pear</td>
<td>737</td>
<td>734</td>
<td>7.00</td>
</tr>
<tr>
<td>Long</td>
<td>431</td>
<td>429</td>
<td>8.75</td>
</tr>
</tbody>
</table>

Conclusion

The proposed kinematic wave and Muskingum-Cunge (UK/RD) hydrograph simulation method is capable of producing peak discharges and hydrograph shapes from easily measurable and commonly known basin parameters. This method is a viable alternative to the standard NRCS dimensionless unit hydrograph method that assumes a constant prf of 484 for all basins. It is unlikely that a method can be developed to modify the standard prf to accommodate different watershed characteristics and variability of rainfall duration and distribution. The proposed procedure should be tested on the sensitivity of the parameters to the discharges by recreating the observed hydrographs from known storms. With the advent of GIS programs the measurement of the length, slope, and shape of the channels and the drainage area of the watershed can be automated. We should prepare ourselves for the twenty first century with a better understanding of the response of the watershed to rainfall based on a physically realistic, scientific, and systematic approach.

References

Natural Resources Conservation Service

U.S. Army Corps of Engineers

U.S. Army Corps of Engineers
RECORD EXTENSION AND AUGMENTATION FOR FLOOD FREQUENCY ANALYSIS

Arifur Rahman and Wilbert O. Thomas, Jr.
Michael Baker, Jr., Inc.

Introduction
Annual peak flow data at gaging stations are used to define the base (1% annual chance) flood discharge for floodplain management as part of the National Flood Insurance Program. As recommended in Bulletin 17B, *Guidelines for Determining Flood Flow Frequency* (Interagency Advisory Committee on Water Data, 1982), a minimum of 10 years of record is required to estimate the base flood discharge. However, the standard error of the base discharge is large if only 10 years of record are used in the analysis. This paper describes techniques for extending and augmenting the annual peak flow records at gaging stations that provide more reliable estimates of base flood discharges.

Record extension involves actually estimating additional years of record at a short-term gaging station by using long-term data from a nearby gaging station and then performing a frequency analysis on the extended record. To ensure the extended record has the same variability as the observed record, a technique known as Maintenance of Variance Extension (MOVE.1) (also known as the Line of Organic Correlation) is used to estimate the extended record (Hirsch, 1982). The MOVE.1 technique is more appropriate than ordinary least squares (OLS) regression in estimating the extended record.

Record augmentation involves obtaining improved estimates of the mean and variance of the annual peak flow data at the short-term gaging station using data at a nearby long-term gaging station. This approach is known as the Two-Station Comparison, and the methodology is described in Appendix 7 of Bulletin 17B.

Analysis Approach

Introduction
OLS regression, MOVE.1, and the Two-Station Comparison techniques are described and illustrated, using the following notation: \( N_1 \) is the years of record concurrent for the two gaging stations, \( N_2 \) is the additional years of record available at the long-term station, \( M_y_1 \) and
Sy₁ are the mean and standard deviation of the short record, Mₓ₁ and Sₓ₁ are the mean and standard deviation of the long record for the N₁ concurrent years, and Mₓ₂ and Sₓ₂ are the mean and standard deviation of the long-term record for the N₂ years of nonconcurrent record.

**OLS Regression**

OLS regression is one of the most frequently used statistical techniques in hydrology. The objective is to minimize the sum of the squared vertical distances from the data points to the regression line. The resulting regression equation can be written as

\[ Y_{\text{ols}} = M_y + r \left( \frac{S_y}{S_x} \right) (X - M_x) \]  

where \( Y_{\text{ols}} \) are the N₂ years of extended record at the short-term station estimated from X, the values at the long-term station, \( r \) is the correlation coefficient between the short- and long-term records for the N₁ concurrent years, and the other variables are defined earlier.

Assuming a linear form of the model is correct and the dependent and explanatory variables are measured without significant error, the OLS regression line yields unbiased and minimum variance predictions. Thus, OLS is the preferred method of predicting a particular value of Y given a value of X.

However, it can be shown that the variance of the predicted values of Y, \( S^2 (Y_{\text{ols}}) \), from Equation 1 is equal to

\[ S^2 (Y_{\text{ols}}) = r^2 \left( \frac{S_y}{S_x} \right)^2 (S_x)^2. \]  

However, \( S^2 (Y_{\text{ols}}) = r^2 (S_y)^2 \), which is less than \( (S_y)^2 \) for \(|r| < 1\). Therefore, the predictions \( Y_{\text{ols}} \) from Equation 1 will have less variability than the observed values of Y. This loss of variance associated with OLS regression raises questions about the utility of OLS regression in record extension if the objective is to maintain or preserve the variance of the extended record.

**MOVE.1**

The loss of variance problem associated with OLS regression can be avoided by using MOVE.1. The objective of MOVE.1 is to minimize the sum of the geometric means of both the horizontal (H₁) and vertical (V₁) distances from the data points to the MOVE.1 line. As illustrated in Figure 1, this is equivalent to minimizing the area of a triangle formed between a given data point and the MOVE.1 line.

The MOVE.1 line resulting from this minimization can be written as

\[ Y_{\text{move}} = M_y + (S_y/S_x) (X - M_x) \]
Figure 1. Definition of procedure for fitting the MOVE.1 line.

where all the terms are as described above except that the $Y_{\text{move}}$ values are MOVE.1 estimates of the extended record at the short-term station from the $N_2$ values of $X$ at the long-term station. Note that the only difference between Equation 3 and Equation 1 for OLS regression is that the slope of the MOVE.1 line is $(S_{y1}/S_{x1})$ rather than $r(S_{y1}/S_{x1})$ for the OLS regression line. In the MOVE.1 analysis, the slope of the line is $(S_{y1}/S_{x1})$ if $r > 0$ and $-(S_{y1}/S_{x1})$ if $r < 0$. This is an important difference for preserving or maintaining the variance of the extended record. The variance of the predicted values ($Y_{\text{move}}$) from Equation 3 is $S^2(Y_{\text{move}}) = r^2(S_{y1})^2$, which is equal to $(S_{y1})^2$ for the MOVE.1 equation because $|r| = 1$. Therefore, there is no loss of variance with the MOVE.1 method because the variance of the predictions is, on average, equal to the variance of the observed values. This suggests that MOVE.1 is a viable technique for record extension.

Two-Station Comparison

The Two-Station Comparison is a method for adjusting the mean and variance of a short record on the basis of OLS regression with a nearby long-term record (Interagency Advisory Committee on Water Data, 1982). As discussed above, a loss of variance is associated with predictions from OLS regression and therefore, OLS regression results must be modified to obtain unbiased estimates of the mean and variance of the extended record.

Matalas and Jacobs demonstrated (1964) that an unbiased estimate of the mean and variance can be obtained by adding a random noise
component to Equation 1, consisting of normally distributed independent variables with zero mean and unit variance. Adding independent noise to OLS regression estimates is not too appealing, because independent studies of the same sequence of X and Y by several investigators will lead to different estimates of the extended mean and variance as a result of a different set of random components used in the analysis (Matalas and Jacobs, 1964). Therefore, Matalas and Jacobs determined equations for estimating the mean and variance of the extended record that could be used in lieu of adding a random noise component to Equation 1. The equation for the mean of the extended record is

\[ M(Y) = M_Y + \left[ N_2/(N_1+N_2) \right] \left[ r \left( S_{Y_1}/S_{X_1} \right) \right] [M_{X_2} - M_{X_1}] \]  

(4)

where \( M(Y) \) is the mean of the extended record, and the other terms are previously defined. For reference, Equation 4 is equivalent to Equation 7-5a in Appendix 7 of Bulletin 17B. The equation for the variance of the extended record is

\[ S^2(Y) = \left[ 1/(N_1+N_2-1) \right] \left[ (N_1-1) S^2_{Y_1} + (N_2-1) r^2 \left( S^2_{Y_1}/S^2_{X_1} \right) S^2_{X_2} + \left( N_2 (N_1-4) (N_1-1) \right)/(\left( N_1-3 \right) (N_1-2)) \left( 1-r^2 \right) S^2_{Y_1} + \left( N_1 N_2 \right)/(N_1+N_2) r^2 \left( S^2_{Y_1}/S^2_{X_1} \right) (M_{X_2} - M_{X_1})^2 \right] \]  

(5)

where \( S^2(Y) \) is the variance of the extended record, \( S^2_{Y_1} \) is the variance at the short-term station, \( S^2_{X_1} \) is the variance at the long-term station for the concurrent period (\( N_1 \) years), \( S^2_{X_2} \) is the variance at the long-term station for the nonconcurrent period (\( N_2 \) years), and the other terms are previously defined. For reference, Equation 5 is equivalent to Equation 7-10 in Appendix 7 of Bulletin 17B.

An extension of MOVE.1, called MOVE.2, is to substitute the values of \( M(Y) \) and \( S(Y) \) from the Two-Station Comparison in Equation 3 in place of \( M_Y \) and \( S_{Y_1} \), respectively. Hirsch (1982) describes the motivation for this approach and evaluates the performance of the MOVE.1 and MOVE.2 techniques.

**Application of Techniques**

**Background**

Data for the Pit River Basin in northeastern California (Figure 2) are used to illustrate the OLS regression and MOVE.1 techniques for record extension and the Two-Station Comparison for record augmentation. Estimates of the base flood discharge are needed for a Flood Insurance Study (FIS) for the North Fork Pit River near Alturas, California. Annual peak flow data are available for the North Fork Pit River for 30 years from the period 1930-95 at gaging station 11344000 near Alturas. Annual peak flow data are also available for the Pit River
near Canby, California (gaging station 11348500) for 75 years from the period 1904-94. The North Fork Pit River near Alturas is a 212-square-mile watershed that is a tributary to the Pit River, which has a drainage area of 1,431 square miles at Canby. Because the three largest floods at Canby occurred outside the period of record at Alturas, the shorter record at Alturas was extended and augmented using the techniques described above. Concurrent record is available for the North Fork Pit River and Pit River gaging stations for 28 concurrent years between 1932 and 1994. These data were used in applying the OLS regression, MOVE.1 and Two-Station Comparison.

Record Extension
Both the OLS regression and MOVE.1 techniques assume a linear relation between the dependent and explanatory variables. For the Pit River analysis, the logarithms of the annual peak flows for the North Fork Pit River and the Pit River are more linearly related than the annual peak flows. Therefore, all subsequent computations were performed on the logarithms of the annual peak flows.

The logarithms of the 28 years of concurrent data were used to compute the OLS regression equation that is expressed below in terms of the annual peak flow data

\[
NFPIT_{ols} = 1.193 \cdot \text{PIT}^{0.894}
\]  

(6)

where \(NFPIT_{ols}\) is the estimated value of the annual peak flow in cubic feet per second (cfs) for the North Fork Pit River and \(\text{PIT}\) is the observed value of the annual peak flow in cfs for the Pit River. The
correlation coefficient between the logarithms of the data for the North Fork Pit and the Pit rivers is 0.911, implying that 83% \((0.911^2 = 0.83)\) of the variation in the North Fork Pit River annual peak flow data is explained by the Pit River data. Equation 6 and the observed annual peak flows for the Pit River near Canby (PIT) for the nonconcurrent period were used to estimate 37 years of additional record for the North Fork Pit River to give an extended record of 67 years.

The logarithms of the 28 years of concurrent data were also used to compute the MOVE.1 line expressed below in terms of the untransformed data

\[
\text{NFPIT}_{\text{move}} = 0.620 \cdot \text{PIT}^{0.982}
\]

where NFPIT\(_{\text{move}}\) is the estimated value of the annual peak flow in cfs for the North Fork Pit River and PIT is the observed value of the annual peak flow in cfs for the Pit River. Equation 7 and the observed annual peak flows for Pit River near Canby (PIT) for the nonconcurrent period were used to estimate 37 years of additional record for the North Fork Pit River to give an extended record of 67 years.

To illustrate the difference in variability of the estimates from Equations 6 and 7, the three highest and lowest estimated peak flows in cubic feet per second (cfs) for the North Fork Pit River from the OLS regression and MOVE.1 relation are summarized below.

<table>
<thead>
<tr>
<th>Year</th>
<th>NFPIT(_{\text{ols}}) (Eq. 6) (cfs)</th>
<th>NFPIT(_{\text{move}}) (Eq. 7) (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest</td>
<td>1904</td>
<td>5,680</td>
</tr>
<tr>
<td></td>
<td>1986</td>
<td>4,160</td>
</tr>
<tr>
<td></td>
<td>1938</td>
<td>3,770</td>
</tr>
<tr>
<td>Lowest</td>
<td>1987</td>
<td>405</td>
</tr>
<tr>
<td></td>
<td>1955</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td>1934</td>
<td>67</td>
</tr>
</tbody>
</table>

The MOVE.1 estimates for the higher flows are larger than the OLS estimates, and the MOVE.1 estimates for the lower flows are smaller than the OLS estimates. This is consistent with the previous discussion of the loss of variance associated with OLS estimates.

Record Augmentation

The Two-Station Comparison method was applied to the same data as the OLS regression and MOVE.1 techniques. Using Equations 4 and 5, the mean of the extended record, \(M(Y)\), and the standard deviation of the extended record, \(S(Y)\), are estimated as 2.9946 log units and 0.38920 log units, respectively. As recommended in Bulletin 17B, the station
skew for the 30 years of record at Alturas was weighted with the
 generalized skew from Plate I in Bulletin 17B to give a weighted skew
 for estimating the base flood discharge for the Two-Station Comparison.

**Flood Frequency Analyses**

Flood frequency analyses were performed for the 67 years of record
from the OLS regression and MOVE.1 analyses and using the
augmented mean and standard deviation from the Two-Station
Comparison. The base flood discharge from these analyses was
compared to an estimate of the base flood discharge based on the 30
years of observed record for the North Fork Pit River near Alturas
(gaging station 11344000).

<table>
<thead>
<tr>
<th>Method</th>
<th>Base Flood Discharge (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 years of observed record</td>
<td>5,560</td>
</tr>
<tr>
<td>OLS regression</td>
<td>5,810</td>
</tr>
<tr>
<td>MOVE.1</td>
<td>6,670</td>
</tr>
<tr>
<td>Two-Station Comparison</td>
<td>6,680</td>
</tr>
</tbody>
</table>

**Conclusions**

The MOVE.1 and Two-Station Comparison analyses give similar
estimates of the base flood discharge and higher values than the 30
years of observed record or the OLS regression analysis. The base flood
discharge based on 30 years of observed record is lower because the
three largest floods in the last 90 years occurred outside the observed
period of record for the Alturas gaging station (station 11344000). The
OLS regression estimate is lower because the loss of variance for the
extended record results in a lower standard deviation of the annual peak
flows. The most accurate base flood discharge to use for an FIS study
for the North Fork Pit River near Alturas is the value estimated from
either the MOVE.1 analysis or the Two-Station Comparison.

**References**

Hirsch, Robert M.

Interagency Advisory Committee on Water Data

Matalas, Nicholas C. and Barbara A. Jacobs
METHOD TO ESTIMATE FLOW-INDUCED CHANGES IN VEGETATION CONDITIONS FOR STREAM CHANNELS IN ARIZONA

Jeff V. Phillips and Anne Tillery
U.S. Geological Survey

Introduction

Proper estimation of Manning's roughness coefficient, $n$, in open channels is necessary to reliably estimate channel conveyance—an important element of an open-channel hydraulic study. Proper estimation of $n$ values, however, is difficult in the arid to semiarid southwestern United States because floods can dramatically alter the roughness characteristics of the channel by flattening or laying over vegetation, which acts to increase conveyance (Figure 1). The ability of flows to substantially alter vegetation characteristics and the lack of guidelines to assess these changes can result in uncertainties and erroneous channel-conveyance calculations (House and Pearthree, 1995).

Figure 1. View of a 15-foot-tall willow in a prone position after flow at Vekol Wash near Stanfield, Arizona.
In 1991, the U.S. Geological Survey (USGS), in cooperation with the Flood Control District of Maricopa County (FCDMC), began a 6-year study of flow-induced vegetation changes for streams in central Arizona. Because accurate calculation of channel conveyance is critical for the study of open-channel hydraulics, a major objective of this study was to develop a relation to quantify the effects of flow-induced vegetation changes on channel conveyances and computed water-surface elevations. To accomplish this objective, data collected before and after 22 peak flows at 17 sites were used to develop a semiempirical relation to estimate $n$ values for sites where flow-induced changes in vegetation are significant. This study focused on vegetation growing in the main channel of streams; however, the effect of flow on overbank vegetation was evaluated at two of the study sites.

The information in this report can be used for a wide range of hydraulic applications that require assessment of channel and vegetation conditions during peak flow. Potential applications include indirect measurement of peak discharge, step-backwater computations to delineate floodplain boundaries, capacity computations for hydraulic structures, and determination of the effect of reservoir releases on downstream vegetation conditions. The information and relations presented in this report should only be applied on the basis of sound engineering judgment.

Data Collection and Analysis

Stream Power

The determination of discharge is essential for many hydraulic studies; however, the actual power of the flow is a better indicator of flow-induced changes in vegetation conditions. A fundamental assumption of this investigation is that a critical stream power exists for specific vegetation conditions and that vegetation will begin to bend when this stream-power threshold is exceeded. Stream power is a measure of energy transfer in an open channel and is used in the form presented by Simons and Richardson (1966). Stream power is defined as

$$SP = 62.4RS_wV$$

where

- $SP$ = stream power, in foot pounds per second per square foot,
- 62.4 = specific weight of water, in pounds per cubic foot,
- $R$ = hydraulic radius, in feet,
- $S_w$ = slope of the water-surface profile, in feet per foot, and
- $V$ = average velocity, in feet per second.
Water surface profiles and channel conditions were surveyed following flow to obtain characteristics necessary to compute stream power for each of the 22 peak flows that were studied.

**Vegetation Data**

During this investigation, it was determined that a combination of four vegetation characteristics could effectively model flow-induced changes to vegetation: (1) the flexural strength of specific types and sizes of vegetation, (2) the cross-sectional area of the vegetation that is blocking the flow, (3) the distribution of vegetation, and (4) the depth of flow relative to vegetation height.

The vegetation characteristics that were determined for each site are incorporated into a single component called the vegetation-susceptibility index. The vegetation-susceptibility index, \( K_v \), is defined by

\[
K_v = V_{\text{flex}} C_{\text{blocking}} C_{\text{dist}} C_{\text{depth}}
\]

where

- \( K_v \) = vegetation-susceptibility index, in foot-pounds;
- \( V_{\text{flex}} \) = vegetation-flexibility factor, in foot-pounds;
- \( C_{\text{blocking}} \) = vegetation-blocking coefficient;
- \( C_{\text{dist}} \) = vegetation-distribution coefficient; and
- \( C_{\text{depth}} \) = flow-depth coefficient.

Information obtained from the study sites was used to select values for \( C_{\text{blocking}} \), \( C_{\text{dist}} \), and \( C_{\text{depth}} \). Values assigned to the three coefficients generally were weighted according to engineering experience gained during the course of this investigation (Table 1).

**Vegetation-flexibility factor.** The vegetation-flexibility factor \( V_{\text{flex}} \) (eq. 2) is the most significant factor in determining whether vegetation will bend or remain in a generally upright position when subjected to the power of flow. The unique characteristics of many types of vegetation enable them to bend to extreme angles when force is applied. The flexural strength or stiffness of different species of vegetation is not constant, and the degree of bending varies for a given applied force. The force required to bend or lay over vegetation, therefore, was quantified in order to obtain the flexural strength of different vegetation types. For the purposes of this report, laid over is defined as a condition in which vegetation is bent more than 45° from the vertical.

Dynamometers, mechanical devices that measure the magnitude of tension in cables, were used to determine the force required to lay over four types of vegetation. The vegetation included saltcedar, willow, mesquite, and palo verde and ranged in height from 3 to 18 ft.
Table 1. Vegetation attributes and coefficients required to compute the vegetation-susceptibility index

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saltcedar</td>
<td>$BM = V_{flex} = 10^{6.102H + 0.880}$</td>
</tr>
<tr>
<td>Willow</td>
<td>$BM = V_{flex} = 10^{6.122H + 0.581}$</td>
</tr>
<tr>
<td>Mesquite</td>
<td>$BM = V_{flex} = 10^{6.128H + 0.535}$</td>
</tr>
<tr>
<td>Palo verde</td>
<td>$BM = V_{flex} = 10^{6.171H + 0.548}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amount of vegetation blocking flow, in percent</th>
<th>Vegetation-blocking coefficient, $C_{blocking}$, dimensionless</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 30</td>
<td>1</td>
</tr>
<tr>
<td>30 to 70</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 70</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orientation of vegetation to flow</th>
<th>Vegetation-distribution coefficient, $C_{devel}$, dimensionless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel</td>
<td>3</td>
</tr>
<tr>
<td>Random</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ratio of hydraulic radius to average vegetation height, dimensionless</th>
<th>Flow-depth coefficient, $C_{depth}$, dimensionless</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.4</td>
<td>60</td>
</tr>
<tr>
<td>.4 to .6</td>
<td>20</td>
</tr>
<tr>
<td>.7 to .9</td>
<td>5</td>
</tr>
<tr>
<td>1.0 to 1.5</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 1.5</td>
<td>1</td>
</tr>
</tbody>
</table>

Bending moments were determined by computing the product of the moment arm (distance from base or pivot point to the location where force was applied) and the force required to bend the vegetation to 45° from the vertical. Equations of the bending moment with height were developed for each of the four vegetation types. The vegetation-flexibility factor, $V_{flex}$, can be estimated from the equations for bending moment.

**Vegetation-blocking coefficient.** The flexural strength of vegetation was obtained by considering the force required to lay over the main stem of the vegetation. Consequently, the actual percentage of the flow area that is blocked by vegetation is required to adequately account for the total resistant force associated with the vegetation. The $C_{blocking}$ value was determined for pre-flow vegetation conditions for each site by assigning a weighted value to the estimated percentage of the cross-sectional area of peak flow blocked by vegetation.

**Vegetation-distribution coefficient.** Observed and measured data for this report suggest that the spatial distribution of riparian vegetation in natural and constructed channels could substantially influence the effect of flow on the vegetation. Vegetation aligned parallel to the direction of flow generally is the result of consistent base flow. The
parallel alignment can result in the redistribution of velocities across the channel section because of the combined resistant effect of the vegetation. The combined resistance causes a decrease in the velocities at the immediate location of the vegetation and mitigates the effects of flow on vegetation conditions. For vegetation conditions categorized as randomly distributed, flow-velocity profiles are assumed to remain fairly constant across the channel. Dimensionless vegetation-distribution coefficients ($C_{\text{dist}}$; eq. 2), therefore, were determined primarily on the basis of two categories—vegetation aligned parallel to the flow and vegetation distributed randomly throughout the main channel.

**Flow-depth coefficient.** Because the bending moment or flexural strength generally depends on the height at which force is applied to the vegetation, effect of flow on vegetation can depend on flow depth relative to vegetation height. In general, greater depths and velocities result in decreased ability of the vegetation to resist the power of flow. Dimensionless flow-depth coefficients ($C_{\text{depth}}$; eq. 2) were determined for four different categories that are defined by the ratio of hydraulic radius to vegetation height. The hydraulic radius is assumed to approximate the mean flow depth as well as the approximate depth of flow at the immediate location of the vegetation.

**Relation Between Stream Power and Vegetation-susceptibility Index**

Stream power and the vegetation-susceptibility indices were calculated, and the stream power was plotted against the vegetation-susceptibility index for each studied flow (Figure 2). If the vegetation-susceptibility index is high and computed stream power is low, the vegetation is not substantially affected. As stream power increases, however, the ability of the flow to lay over vegetation increases. The line shown in Figure 2 represents a vegetation-susceptibility threshold. Generally, for flows that plot above this line, the vegetation can be expected to be laid over assuming that the values for vegetation and flow characteristics are within the range of values presented in this report. As indicated by the number of data points in Figure 2, more than one type of vegetation was studied for several of the sites.

This relation can be used in hydraulic studies for which channel vegetation conditions must be assessed for a given magnitude of flow. For example, if application of the relation for specific channel and vegetation conditions for a given site indicates that vegetation will lay over for the 10-year flow, it can be assumed that computed stream power will be larger for the 100-year flow at the same site, and the
Figure 2. Vegetation conditions resulting from 22 flows at 17 sites, as a function of stream power and the vegetation-susceptibility index. The equation for the vegetation-susceptibility threshold is $SP = 2.054 K_v^{0.231}$. More than one type of vegetation was studied for several of the sites.

vegetation index will be smaller. The vegetation will most likely lay over before the 100-year peak flow, and the peak-flow channel conveyance will be greater than conveyance computed for fully weighted pre-flow vegetation conditions.

**Summary and Conclusions**

In 1991, the USGS in cooperation with the FCDMC, began a 6-year study of flow-induced vegetation changes and the effect of these changes on channel conveyances. Data for 22 flows at 17 sites in central Arizona included surveyed water-surface profiles and channel cross-section characteristics and measured or estimated velocity. Vegetation conditions, such as average height, density, and other characteristics
were measured and described before and after peak flows. A semiempirical relation was developed to estimate the effects of flow on vegetation conditions. The data and relations can be used for a wide range of hydraulic applications that require assessment of channel and vegetation conditions during peak flow. Potential applications include indirect measurements of peak discharge, step-backwater computations to delineate floodplain boundaries, capacity computations for hydraulic structures, and determination of the effects of reservoir releases on downstream vegetation conditions.

References

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Simons, D.B., and Richardson, E.V.
DISCUSSION OF TECHNIQUES FOR ANALYSIS OF ICE-JAM FLOODING

Wilbert O. Thomas, Jr., and Kira L. Crockett
Michael Baker, Jr., Inc.

Alan A. Johnson
Federal Emergency Management Agency

Introduction

In northern regions of the United States, the hydrologic and hydraulic aspects of ice-jam flooding should be evaluated in determining base (1% annual chance) flood elevations for Flood Insurance Studies (FISs). An ice jam is an accumulation of ice that restricts flow and may cause much higher flood stages than the high-water stages of open-water floods.

Direct Analysis of Stage Data

If sufficient data exist at the site, an ice-jam stage-frequency curve can be established directly by analyzing the historical ice-stage data. If the study reach for the FIS includes a gaging station where ice jams have historically occurred, a stage-frequency analysis can be performed using stage data at the gaging station, which can be obtained from streamflow records published by the U.S. Geological Survey (USGS) and other agencies. An example of the stage data available from the USGS for the Platte River at North Bend, Nebraska (Station No. 06796000), is shown in Table 1. Stage data are available through 1994, for a total of 45 years.

The annual maximum stage can occur as the result of a free-flow event or an ice-jam event. In Table 1, the peak stages marked with footnote “a” are annual-maximum peak stages that resulted from free-flow events, and those marked with “b” resulted from an ice-jam event. In ice-jam events, the annual-maximum peak stage can occur at a different time than the annual-maximum peak discharge. These events are denoted in Table 1 with an entry in the column “Annual Peak Stage (ft).” Only two annual-maximum stages, 1960 and 1969, that occurred during the ice-jam season were not affected by backwater from ice.

If sufficient stage data are available, two approaches for the direct analysis of stage data are possible: annual-event series using a maximum peak stage for each season (ice-jam or free-flow) for each year (two
Table 1. Example of annual peak discharges and stages available for the Platte River at North Bend, Nebraska (Station No. 06796000).

<table>
<thead>
<tr>
<th>Date</th>
<th>Annual Peak Discharge (cfs)</th>
<th>Stage for Annual Peak Discharge (ft)</th>
<th>Date</th>
<th>Annual Peak Stage (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949/06/02</td>
<td>21000</td>
<td>7.05*</td>
<td>03/07</td>
<td>8.00*</td>
</tr>
<tr>
<td>1950/07/12</td>
<td>25000</td>
<td>7.30</td>
<td>02/24</td>
<td>7.80*</td>
</tr>
<tr>
<td>1951/05/31</td>
<td>30800</td>
<td>7.65</td>
<td>02/13</td>
<td>10.17b</td>
</tr>
<tr>
<td>1952/03/28</td>
<td>18000</td>
<td>6.65</td>
<td>02/08</td>
<td>7.14b</td>
</tr>
<tr>
<td>1953/05/11</td>
<td>20900</td>
<td>7.05</td>
<td>02/08</td>
<td>7.14b</td>
</tr>
<tr>
<td>1954/06/18</td>
<td>22800</td>
<td>7.33*</td>
<td>03/09</td>
<td>8.20b</td>
</tr>
<tr>
<td>1955/03/10</td>
<td>12700</td>
<td>7.65</td>
<td>03/12</td>
<td>8.23b</td>
</tr>
<tr>
<td>1957/06/17</td>
<td>44200</td>
<td>8.06*</td>
<td>03/12</td>
<td>7.55b</td>
</tr>
<tr>
<td>1958/02/26</td>
<td>29100</td>
<td>7.59</td>
<td>03/12</td>
<td>7.55b</td>
</tr>
<tr>
<td>1959/08/02</td>
<td>21700</td>
<td>7.04</td>
<td>03/12</td>
<td>7.55b</td>
</tr>
<tr>
<td>1960/03/29</td>
<td>112000</td>
<td>10.04*</td>
<td>02/16</td>
<td>6.93b</td>
</tr>
<tr>
<td>1961/05/23</td>
<td>15700</td>
<td>6.02</td>
<td>03/23</td>
<td>8.78b</td>
</tr>
<tr>
<td>1962/03/26</td>
<td>39000</td>
<td>7.78</td>
<td>12/24</td>
<td>8.53b</td>
</tr>
<tr>
<td>1963/06/24</td>
<td>37300</td>
<td>7.78</td>
<td>12/24</td>
<td>8.53b</td>
</tr>
<tr>
<td>1964/09/17</td>
<td>30200</td>
<td>7.35*</td>
<td>12/24</td>
<td>8.53b</td>
</tr>
<tr>
<td>1965/06/29</td>
<td>35800</td>
<td>7.84*</td>
<td>12/24</td>
<td>8.53b</td>
</tr>
<tr>
<td>1966/08/14</td>
<td>72500</td>
<td>9.01*</td>
<td>12/24</td>
<td>8.53b</td>
</tr>
<tr>
<td>1967/06/16</td>
<td>75200</td>
<td>9.56*</td>
<td>12/24</td>
<td>8.53b</td>
</tr>
<tr>
<td>1968/06/25</td>
<td>29200</td>
<td>7.52*</td>
<td>12/24</td>
<td>8.53b</td>
</tr>
<tr>
<td>1969/03/22</td>
<td>42100</td>
<td>8.23*</td>
<td>12/24</td>
<td>8.53b</td>
</tr>
<tr>
<td>1970/02/25</td>
<td>12000</td>
<td>5.94</td>
<td>02/24</td>
<td>7.66b</td>
</tr>
<tr>
<td>1971/03/11</td>
<td>28000</td>
<td>8.27</td>
<td>02/20</td>
<td>12.24b</td>
</tr>
</tbody>
</table>

*Annual maximum peak stage resulting from a free-flow event
*bAnnual maximum peak stage resulting from an ice-jam event

values per year); and annual-maximum series using only the annual-maximum peak stages for each year. In both approaches, separate frequency curves are developed for both the ice-jam and free-flow events and then combined to determine the percent chance that a given stage will be exceeded in a year. Weibull plotting positions are recommended for determining individual stage-frequency curves. However, when more than 10 years of ice-jam or free-flow stage data exist, a frequency distribution such as the Pearson Type III could be fit to the stage data to help define or extend the stage-frequency curve based on plotting positions.

Annual-event Series

In the annual-event series, peak stages are developed for both the ice-jam and free-flow seasons for each year of record. For example, to use the annual-event series approach with the 45-year record available for the Platte River at North Bend, the highest stages in the ice-jam and free-flow seasons for each of the 45 years of record must be identified.
However, a review of the data in Table 1 shows insufficient data to develop the annual-event series, because some years have only a single peak stage. To develop the annual-event series for these years, the peak stage for the missing season must either be estimated or, preferably, determined through a search of the historical streamflow records.

For the annual-event series, the stage-frequency curves are computed for each season and combined using the following equation:

\[ P(s) = P(si) + P(sq) - P(si) \times P(sq) \]  

(1)

where

- \( P(s) \) = probability of the annual-maximum stage exceeding a given stage "s" in any year, by either type of event,
- \( P(si) \) = probability of the annual-maximum stage exceeding a given stage "s" in the ice-jam season,
- \( P(sq) \) = probability of the annual-maximum stage exceeding a given stage "s" in the free-flow season, and
- \( P(si) \times P(sq) \) = joint probability of the annual-maximum stage exceeding a given stage "s" in any year from both types of events.

Equation 1 is not appropriate if the two populations are not independent, if an annual-event series cannot be compiled, or if it is impossible to segregate the peak stages into populations of distinct hydrologic causes. In these cases, an alternative approach is to use only the annual-maximum peak stages in the frequency analysis.

**Annual-maximum Series**

In the annual-maximum series, the annual peak stage in each year is identified as resulting from an ice-jam or a free-flow event. A stage-frequency curve is developed using all annual-maximum stages that are ice-jam events, and a separate curve is developed using all annual-maximum stages that are free-flow events. Each of the frequency curves is called a "conditional-frequency curve." For example, the ice-jam conditional-frequency curve is "conditioned" in the sense that only annual-maximum peak stages that are ice-jam related are used in the frequency analysis. To calculate the probability of an ice-jam event exceeding a given stage "s" in any year, the exceedance probabilities from the conditional-frequency curve must be multiplied by the fraction of time that ice-jam events produce annual-maximum peak stages. The same approach is used for free-flow events.

For the annual-maximum series, the stage-frequency curves are computed for each season and combined using the following equation:

\[ P(s) = (P(s) \mid s = \text{free-flow event}) \times P(s = \text{free-flow event}) + (P(s) \mid s = \text{ice-jam event}) \times P(s = \text{ice-jam event}) \]  

(2)
where P(s) is the probability of the annual-maximum stage exceeding a given stage "s" in any year, by either type of event,
(P(s | s = free-flow event) is the conditional probability of the annual-maximum stage exceeding a given stage "s", given only free-flow events that are annual-maximum peak stages are in the analysis,
P(s = free-flow event) is the fraction of years for which the annual-maximum peak stage was a free-flow event, and
(P(s | s = free-flow event) * P(s = free-flow event) is the joint probability of the annual-maximum stage exceeding a given stage "s" in any year and the seasonal free-flow event is an annual maximum,
(P(s | s = ice-jam event) is the conditional probability of the annual-maximum stage exceeding a given stage "s", given only ice-jam events that are annual-maximum peak stages are used in the analysis,
P(s = ice-jam event) is the fraction of years for which the annual-maximum peak stage was an ice-jam event,
(P(s | s = ice-jam event) * P(s = ice-jam event) is the joint probability of the annual-maximum stage exceeding a given stage "s" in any year and the seasonal ice-jam event is an annual maximum.

Figure 1 shows the results of stage-frequency analyses performed using the annual-maximum stage data for the Platte River at North Bend, Nebraska, for the ice-jam and free-flow seasons. The analyses included use of Weibull plotting positions and fitting a Pearson Type III frequency distribution to the annual-maximum stage data. The stage-frequency curves represent the probability that the annual-maximum stage will exceed a given stage "s" in any year for each type of event, because the conditional-frequency curves were adjusted for the fraction of time that each event is an annual maximum.

Comparison of Direct Approaches
Stage-frequency analyses were also performed on the annual-event series using data provided by the U.S. Army Corps of Engineers (USACE), Omaha District, for the Platte River at North Bend, Nebraska. Stage-frequency estimates for the annual-event and annual-maximum series are summarized in Table 2. The combined stage-frequency estimates computed for the two annual series for the 45-year record for the Platte River at North Bend are comparable. For example, the 1% annual chance stage is 14.6 feet using the annual-event series and 14.7 feet using the annual-maximum series. The differences in the estimates for the various percent-chance floods are attributed to a time-sampling error inherent in the finite 45-year record. As the record length increases and the time-sampling error decreases, the two approaches will converge to the same stage-frequency estimates.
Indirect Analysis of Stage Data

Often sufficient data are not available for direct analysis, or the hydraulic conditions in the FIS reach are different from those at gaging stations upstream or downstream of the study reach. In those instances, an indirect approach for determining the stage-frequency curve is needed. In the indirect approach, a discharge-frequency curve is determined first, and water-surface profiles are established for those discharges using standard hydraulic modeling and a computer program such as HEC-2. For the ice-jam season, the ice-cover option in HEC-2 is used to determine water-surface profiles (See "Modeling Ice-Jams with HEC-2," below.)

Ice-Jam Locations, Types, and Formations

Ice jams are likely to form whenever the ice transport capacity of a river or stream is exceeded. Historical records are the best indicator of potential ice-jam locations. One of the more common causes, especially of freezeup types, is a change in slope from steep to mild. Channel bends or other changes in alignment or cross-sectional shape or depth
Table 2. Summary of stage-frequency estimates for the annual-event and annual-maximum series for the Platte River at North Bend, Nebraska (Station No. 06796000).

<table>
<thead>
<tr>
<th>Percent Chance Exceedance</th>
<th>Annual-Event Series*</th>
<th>Annual-Maximum Series*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ice</td>
<td>Free</td>
</tr>
<tr>
<td>50</td>
<td>7.7</td>
<td>6.95</td>
</tr>
<tr>
<td>20</td>
<td>9.65</td>
<td>7.9</td>
</tr>
<tr>
<td>10</td>
<td>10.9</td>
<td>8.45</td>
</tr>
<tr>
<td>5</td>
<td>12.1</td>
<td>9.1</td>
</tr>
<tr>
<td>2</td>
<td>13.5</td>
<td>9.55</td>
</tr>
<tr>
<td>1</td>
<td>14.6</td>
<td>9.95</td>
</tr>
</tbody>
</table>

*In feet

may also lead to ice jams. Like sediment deposition, ice jams may form when velocity decreases. Islands, sand bars, and gravel deposits are potential ice-jam sites. Natural or built obstructions such as bridges or fallen trees reduce the cross-sectional area of a river and lead to decreased ice-transport capacity. The confluences of tributaries with large rivers, lakes, or reservoirs are also prime locations for ice-jams.

Ice jams can be classified in two categories based on formation: freezeup and breakup. Freezeup jams, consisting mostly of accumulated frazil ice formed in turbulent and supercooled water, eventually form a continuous ice cover. Breakup jams consist mostly of fragmented ice, and may be thermal or mechanical in origin. Increased temperatures may result in ice thaw, leading to a thermal breakup, or increased flow may increase stress on the existing ice cover, leading to a mechanical breakup. Breakup jams are associated with sudden surges in stage and high velocity. Because of their high discharges, velocities, and stages, more attention is given to modeling breakup jams in an FIS.

Modeling Ice Jams with HEC-2

The USACE HEC-2 hydraulic modeling program includes an ice-cover option. The user enters the ice thickness for the channel and the left and right overbanks, a Manning's "n_t" value for the ice, a Manning's "n_p" value for the streambed, and the specific gravity of ice (default is 0.916). HEC-2 calculates the water-surface profile by using standard step-backwater calculations assuming open-water conditions but makes allowances for the increased wetted perimeter, W_p', the decreased cross-sectional area, A, and the composite Manning's "n_c" value adjusted for the ice cover. The pertinent parameters are shown in Figure 2.
The open-flow area under the ice is determined by:

\[ A = A_t - (s_i)(t)(B) \]  

where 
- \( A_t \) = the total area under the free-water surface,  
- \( s_i \) = the specific gravity of ice,  
- \( t \) = the ice thickness, and  
- \( B \) = the width of the ice.

The hydraulic radius, \( R \), is determined by:

\[ R = \frac{A}{(W_p + B)} \]  

A composite Manning’s "n" value (\( n_c \)) for the combined ice-cover and streambed roughness is computed based on the Belokon-Sabaneev formula:

\[ n_c = \left( \frac{1}{2} \right) \left( n_i^{3/2} + n_b^{3/2} \right)^{2/3} \]  

where \( n_i \) = the Manning’s "n" value for ice, and \( n_b \) = the Manning’s "n" value for the channel.

HEC-2 treats the ice-cover option as a "floating" bridge in normal open-water conditions. It calculates a low chord by subtracting the ice-specific gravity multiplied by the ice-cover thickness from each trial water-surface elevation during the standard step-backwater calculations.

In addition to the standard output selected for open-water conditions, HEC-2 returns the composite Manning’s "n_c" value, Chezy's coefficient (C), the wetted perimeter (\( W_p \)), the depth of flow (H), the ratio of ice thickness to depth, and an ice-stability variable for each cross section where the ice-cover option is used. The ice-stability variable is based on criteria of Pariset and others (1966) that are applicable for conditions with cohesionless ice and deep-water and wide channels.

The HEC-2 ice-cover option assumes a wide stream, a floating ice cover, and a Manning’s "n" value that does not change as the ice melts. Because of the limited field data available for ice-jam thickness, it is often a difficult parameter to obtain. If thickness data are not available, one may use ice-stability criteria of Pariset et al. (1966) or a trial-and-error procedure while calibrating to known high-water marks. For the
Platte River analysis, the USACE ICETHK program was used with the HEC-2 model to produce ice-roughness and -thickness values.

**Additional Numerical Modeling Alternatives**

Beltaos (1983) has developed a dimensionless depth, \( \eta \), versus dimensionless discharge, \( \xi \), curve for breakup jams. The curve is based on the following equations:

\[
\xi = \left(\frac{q^2}{g S_0}\right)^{1/3} / S_0 B \tag{6}
\]

and \( \eta = H / S_0 B \tag{7} \)

where \( q \) = the discharge per unit width,
\( g \) = the acceleration of gravity,
\( S_0 \) = the channel bed slope,
\( H \) = the total water depth, and
\( B \) = the effective width.

Use of the curve produces approximate estimates of the highest water level of an ice jam at a given site. Given slope, equilibrium ice-jam width, and discharge, \( q \) and \( \xi \) may be calculated. Using the curve, \( \eta \) can be determined, and \( H \) can be calculated. This method assumes that the ice jam is in an equilibrium state; is floating; occurs on a wide, rectangular prismatic channel; and has no constraints such as obstructions, bypass channels, or low overbank areas.

Several other computer models, some of which are still in the development stage, provide more comprehensive modeling alternatives for ice-covered streams. The next version of the USACE HEC-RAS computer model, Version 2.2, will include an ice-cover option. This option will consist of a fixed ice-cover option (similar to the current HEC-2 version) and a dynamic ice-cover option that allows the ice cover to increase based on empirical data. Petryk (1995) outlines several Canadian ice-jam models that are primarily one-dimensional, steady state, and provide comprehensive modeling methods for such processes as water cooling, ice generation, ice transport, ice-cover formation, thickening, shoving, erosion and deposition, melting, and breakup.

**References**

Beltaos, Sypridon

Pariset, E., R. Hauser, and A. Gagnon

Petryk, Sylvester
Related Publications of Interest from the Natural Hazards Center

All items can be ordered from the Natural Hazards Research and Applications Information Center
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Monograph Series


MG58  *Disaster Evacuation Behavior: Tourists and Other Transients.* Thomas E. Drabek. 1996. 370 pp. $20.00.

Special Publications


Working Papers in Print


Quick Response Reports in Print


QR72  *Immediate Emotional Response to the Southern California Firestorms.* E. Allison Holman and Roxane Cohen Silver. 1994. 23 pp. $5.00.


Documents on the World Wide Web

In addition to the printed documents listed above, the Natural Hazards Center has numerous working papers and Quick Response Reports on our World Wide Web. They can be found at [http://www.colorado.edu/hazards](http://www.colorado.edu/hazards). In addition, the center’s library database, HazLit, is now on-line and can be reached at [http://www.colorado.edu/hazards/litbase/litindex.htm](http://www.colorado.edu/hazards/litbase/litindex.htm).

Among the full-text items available, net surfers can find:


QR77  *Psychophysiological Indicators of PTSD Following Hurricane Iniki: The Multi-Sensory Interview.* Kent D. Drescher and Francis R. Abeug. 1995. $5.00 for printed copy.

QR78  *Self Organization in Disaster Response: The Great Hanshin, Japan Earthquake of January 17, 1995.* Louise K. Comfort. 1996. $5.00 for printed copy.

QR79  *Transition from Response to Recovery: A Look at the Lancaster, Texas Tornado.* David M. Neal. 1996. $5.00 for printed copy.

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QR88 Response to Severe Winter and Blizzard Conditions in Grundy and Buchanan County, Virginia in 1996: A Focus Group Analysis. Joseph B. Perry, Duane Dukes, and Randall Norris. 1996. $5.00 for printed copy.

QR90 Tornadoes in the Districts of Jamalpur and Tangail in Bangladesh. Thomas Schmidlin and Yuichi Ono, 1996. $5.00 for printed copy.

QR102 First Aid Response to the Kobe Earthquake, January 17, 1995 (12K),
Sharlene Adamson, 1997. 2/24/98

QR103 Children's Response to Exposure to Traumatic Events (19K), Richard D.

QR104 Dissociative and Posttraumatic Reactions to the Northern California Flooding of 1997 (18K), Lynn C. Waelde, Cheryl Koopman, and David Spiegel, 1998. 7/6/98


QR106 Risk Factors for Death in the 22-23 February 1998 Florida Tornadoes (23K),
Thomas W. Schmidlin, Paul S. King, Barbara O. Hammer, and Yuichi Ono,
1998. 7/26/98


Hurricane Damage to Residential Structures: Risk and Mitigation (147K), Jon K. Ayscue, 1996. 11/13/96

A Case Study of Florida's Homeowners' Insurance Since Hurricane Andrew (88K), Elliott Mittler, 1998. 5/22/98


What Hazards and Disasters are Likely in the 21st Century—or Sooner? (26K), Claire B. Rubin, 1998. 7/8/98

Network Without Center? A Case Study of an Organizational Network Responding to an Earthquake (52K [text] + graphics), Aldo A. Benini, 1998. 9/18/98


The Boulder Creek Flood Notebook—research plan to study and report the causes of an upcoming disaster—the next great flood of Boulder, Colorado

The Natural Hazards Center’s electronic newsletter, Disaster Research.

Topical Bibliographies


The **Natural Hazards Observer**

The Natural Hazards Center publishes a bimonthly newsletter, the *Natural Hazards Observer*, which covers disaster management, mitigation, and education programs; information sources; research and findings from completed projects, recent legislation; applications of research at federal, state, and local levels and by private organizations; recent publications; and future conferences. Subscriptions to the printed version of the *Observer* are free within the U.S., and foreign subscriptions cost $15.00 per year. Beginning with Volume XX, No. 4 (March 1996), back issues of the *Observer* are also available at the Hazards Center's Web site: [http://www.colorado.edu/hazards](http://www.colorado.edu/hazards).

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