FLOOD MANAGEMENT

Reducing Runoff

As floodplain managers, state resource agencies and local communities wrestle with the problems associated with flood-control dams; cities around the country are implementing innovative techniques for managing floods without new dams. While many of these alternatives are not quick fixes, they are real solutions that can be implemented with long-term planning. The following are some alternative approaches to dams for flood management:

- Reducing runoff
- Riparian & in-river flood management
- Separating the people & the threat

REDUCING RUNOFF

The principle behind runoff reduction measures is to increase the proportion of precipitation that infiltrates the soil and decrease the amount that runs off directly into rivers. On undeveloped land, typically less than 20 percent of the volume of rainfall becomes direct surface runoff that drains into rivers.[1] With development of buildings and paved impermeable surfaces, and the use of conventional piped drainage systems, direct runoff can increase to over 80 percent of the volume of rainfall. By reducing the amount of runoff, the streamflow levels during storm events will be reduced, thereby reducing flood risk and the need for structures such as dams.

- In urban areas
- In agricultural areas

IN URBAN AREAS

In urban areas, the types of techniques recommended to reduce runoff include:

- Infiltration trenches, which are rock-filled trenches in which stormwater is stored in the voids of the stones, and then slowly filters back into groundwater;

1. Dunne, T. and L.B. Leopold. *Water in Environmental Planning*. New York: W.H. Freeman and Company, 1978.

- Downspout diversion programs (i.e., allowing domestic gutters to discharge to lawns or other unpaved areas instead of being connected to the sewers);[2]
- Permeable or porous pavements for roads and parking lots;

POROUS PAVEMENT

PERMEABLE PAVEMENT CORPORATION

- Swales (i.e., grass depressions that catch runoff from impermeable surfaces and slowly filter it back into groundwater) or grassed surface conveyance;
- Infiltration and treatment systems which can also serve as landscape features;

STREET SWALE IN SEATTLE

SEATTLE PUBLIC UTILITIES

- Wide filter or buffer strips of natural vegetation: grass or woodland, usually located between paved areas and the watercourse to slow flows and remove pollutants;
- Small detention basins: grassy and vegetated depressions that hold and treat excess surface water for slow release;
- Infiltration basins that hold surface water, allowing it to infiltrate the soil gradually; and retention ponds or permanently wet ponds that retain surface runoff and provide biological treatment through wetland and aquatic vegetation such as reeds.

2. Downspout diversion programs have helped to maintain a consistent flow of higher water quality into urban streams. UNITED STATES studies have shown that downspout diversion programs can reduce mean flow volumes in the sanitary sewer network by 25 to 62 percent (Kaufman and Wurtz, 1997).

Advantages

These strategies are considered preventative measures that reduce the fundamental flood risk by reducing runoff and peak flood flows. Many of these strategies cost relatively little money compared to dams and levees and they can be squeezed into dense urban areas because most do not require large amounts of space.

Disadvantages

One drawback to these strategies is that in order to significantly reduce runoff, these strategies must be implemented in many locations. In addition, the dispersed and incremental nature of this approach poses a challenge to quantify the impacts and maintain the effectiveness of the measures. Although many of the measures listed above require little space, large infiltration or detention basins could be difficult to site within urban areas. In addition, care must be taken to ensure that detention basins do not increase flood peaks.[3]

Costs

Costs will vary greatly depending on the measure chosen, ranging from less than $100 to install downspout diversions to hundreds of thousands of dollars for elaborate infiltration basins. The good news is that many of these techniques cost less than traditional stormwater drain systems. For an additional project cost-savings example, see the case study below.

3. For example, a detention basin in the lower area of a watershed might delay inflow to a creek such that it occurs when the flood wave is arriving from the upper watershed, thereby potentially increasing flood levels.

Case Study, Reducing Urban Runoff

In 1992, the Oregon Museum of Science and Industry (OMSI) relocated to a former industrial site on the Willamette River and in doing so decided to take steps to ensure their impact on the environment was minimal and that they addressed some of the environmental issues plaguing the watershed. In order to reduce runoff and capture stormwater on their 10-acre parking lot, OMSI chose to build 2,300 feet of bioswales rather than the traditional parking lot islands. These bioswales are linear wetlands that contain a variety of native plants and trees. While still not considered inexpensive, these bioswales did cost $70,000 less than a traditional stormwater drainage system and has resulted in little stormwater discharge during a normal storm event.

OMSI also chose to protect and rebuild the banks of the Willamette from erosion by planting native riparian shrubs in the buffer. FEMA cited this project as an excellent example of the use of bioengineering, and during the floods of 1996 and 1997, the bank stabilization survived.

To learn more about the Oregon Museum of Science and Industry's project, visit www.fish.ci.portland.or.us/pdf/pdc1.pdf.

Case Study, Reducing Urban Runoff

As Atlanta, Georgia's population continues to expand, the Big Creek watershed is facing increasing threats from development interests. Presently, the watershed is 16 percent impervious cover; with negative effects from stormwater runoff beginning at about ten percent impervious cover. The resulting impacts from excess runoff include degraded water quality, erosion, increased flood damage and habitat degradation, as well as the construction of

Case Study (cont.)

dams and levees and stream channelization.

A reconnaissance study was undertaken to develop recommendations to reduce the adverse impacts of urbanization on the watershed, which included stormwater management, riparian buffers and restoration. Stormwater management recommendations included the creation of stormwater ponds and natural detention and infiltration facilities that would improve water quality and capture and store runoff and floodwater. The riparian buffers and corridors will also store and extend the discharge of floodwaters, as well as decrease erosion and remove pollutants from stormwater runoff. By allowing runoff to be absorbed into the earth and undergo a more natural hydrologic process, flood impacts could be significantly reduced in the Big Creek watershed and flood management infrastructure, such as dams and levees, could be removed.[4]

To learn more about the Big Creek reconnaissance study in Atlanta, Georgia, visit www.forester.net/sw_0011_assessing.html.

4. Fischenich, J.C., R.B. Sotir, and T. Stanko, "Assessing Urban Watersheds: The Case of Big Creek," *Stormwater: The Journal for Surface Water Quality Professionals*, ‹www.forester.net/sw_0011_assessing.html› (11 June 2002).

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- Stormwater Managers Resource Center: www.stormwatercenter.net/.
- American Rivers, Natural Resources Defense Council, Smart Growth America, *Paving Our Way to Water Shortages: How Sprawl Aggravates the Effects of Drought*: www.amrivers.org/landuse/sprawldroughtreport.htm.

In Agricultural Areas

Where land adjacent to rivers has been developed for intensive cultivation of crops, the volume and speed of runoff usually increases, contributing to the risk of flooding downstream and the possibility of pollution by herbicides, pesticides and agricultural waste products. Possible methods for minimizing these risks include:

- Adopting less intensive agricultural practices (e.g., farming outfits that continually increase production each season with longer growing seasons, using a sand and clay substrate) and controling irrigation rates and contour levels so that water is retained on the land;
- Creating vegetated buffer strips or wetlands between cultivated land and watercourses to slow surface water runoff and remove pollutants; and
- Directing agricultural runoff to infiltration ponds, retention ponds and wetland areas to slow runoff and improve water quality. These may also provide features for wildlife.

LYNN BETTS, USDA NATURAL RESOURCE CONSERVATION SERVICE

VEGETATED BUFFER STRIPS

GARY KRAMER, USDA NATURAL RESOURCE CONSERVATION SERVICE

WETLANDS RESTORED FOR FLOOD MANAGEMENT

Advantages

These measures share the same benefits of those listed for urban areas. Detention basins are usually quite shallow and require a large area to provide significant flood storage. However, because they are normally dry and will not be needed in most years, they can be put to use in the meantime. For example, the detention basins of the Lincoln, Nebraska flood alleviation scheme are farmed, and farmers receive compensation for damage to their crops when the basins are used for flood management. One option considered for the Red River watershed in Canada and the United States was that of micro-storage, using the agricultural fields between the raised roads as flood storage.

Disadvantages

Implementing these measures in rural areas can present challenges similar to those in urban settings, such as the fact that these strategies may need to be implemented in many locations. If the area is composed of many smaller farms, one farmer working to reduce runoff will not impact flooding enough to lead to the removal of a dam. In addition, changing agricultural practices might be impractical for the crops under cultivation or the characteristics of the area.

Costs

The cost of runoff control measures will vary greatly depending on the size and type of measure applied. The cost of detention basins can ranges from $0.10 to $2.50 per cubic foot of detained water.[5] A relatively small detention basin that would hold the volume of a typical backyard pool, 20,000 gallons, would likely cost between $2,000 and $10,000.

5. Schueller, T.R. *Controlling Urban Runoff: a practical manual for planning and designing urban BMPs.* Metropolitan Council of Governments, 1987.

Case Study, Reducing Agricultural Runoff

The Lake Thompson Watershed, located in southeastern South Dakota, has lost the majority of its wetlands over the years to increase agricultural production, for which 90 percent of the land is now used. As a result of increased agricultural production and the loss of wetlands and other retention space, the region experienced severe flooding around several lakes from 1984 to 1986 that led to crop, property, and road damage. In an effort to reduce the frequency and duration of major flooding, both governmental and non-governmental organizations created a wetland restoration plan within the watershed that included restoring drained wetlands on public lands; acquiring new land to restore wetlands; developing conservation practices on private lands; and offering incentives to prevent further drainage projects. In addition to decreasing the threat of flooding, many of the restored sites once again function as wildlife habitat. [6]

To read the entire Lake Thompson case study, visit www.ramsar.org/lib_wise_18.htm. For more information about this project you may also contact Tom Dahl with the U.S. Fish and Wildlife Service at 608-783-8425.

6. Dahl, Thomas E., "Wetland drainage and restoration potential in the Lake Thompson watershed, South Dakota, USA," *Towards the Wise Use of Wetlands*, 1993, ‹www.ramsar.org/lib_wise_18.htm› (11 June 2002).

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- Dosskey, M.J., R.C. Schultz, and T.M. Isenhart. *Riparian Buffers for Agricultural Land.* Dosskey. USDA Natural Resources Conservation Service: waterhome.brc.tamus.edu/projects/afnote3.htm.
- Buffer Strips: Common Sense Conservation, USDA Natural Resource Conservation Service, www.nrcs.usda.gov/feature/buffers/
- Haeuber, R. and W.K. Michener. "Natural Flood Control", *Issues in Science and Technology*, Fall 1998. 205.130.85.236/issues/15.1/haeube.htm.
- Buffers for Agriculture, Connecticut River Watershed: www.crjc.org/buffers/Buffers%20for%20Agriculture.pdf.

Riparian & In-River Flood Management

Rivers themselves can serve a flood management function by providing "live storage." The open space of floodplains adjacent to rivers and streams store and slowly release floodwaters, reducing peak flood flows downstream. Wetland areas act as large sponges, soaking up floodwaters in addition to filtering water and adding to groundwater supplies.

Many flood management measures constructed in the past reduced the natural live storage capacity of river channels. When engineers cut off meanders to straighten rivers and increase flow velocities, the storage provided by the longer, meandering river channel is lost. Levees constructed to keep rivers within their channels prevent floodplains from storing and slowly releasing flood flows. As a result, in some cases peak flood flows have increased and caused greater flood risk downstream of highly controlled river reaches. This transferring of the flood creates a feedback loop of escalating flood risk and flood management actions that propagates downstream.[7] By restoring the natural flood-carrying capacity of rivers and/or their riparian buffer regions, the need for a new or existing dam is reduced.

In more recent efforts to restore natural river functions, including providing instream storage, the trend has reversed. The most common measures recommended today, which are discussed below, include:

- Breaching levees
- Setting back levees
- Restoring river meanders
- Constructing bypass channels[8]

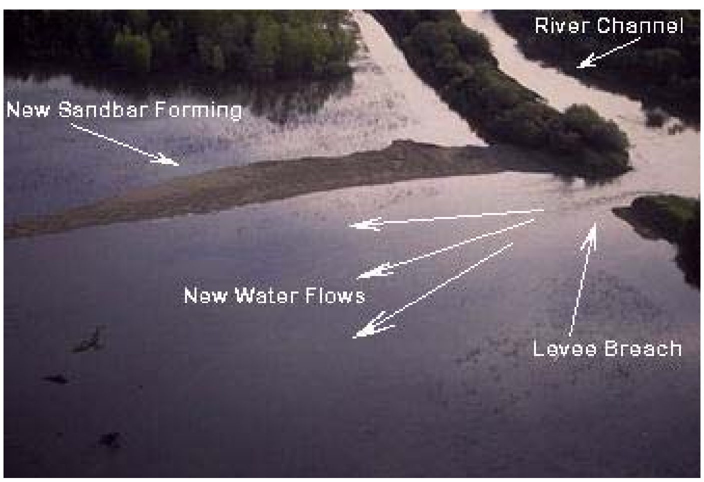
7. Mount, J.F. *California Rivers and Streams: the conflict between fluvial process and land use.* Berkeley: University of California Press, 1995.
8. Interagency Floodplain Management Review Committee. *Sharing the Challenge: Floodplain Management into the 21st Century.* Washington, D.C.: GPO, 1994.

Breaching Levees

Many river restoration and flood management projects involve breaching or removing portions of levees to allow the river to reconnect with its floodplain, thereby recreating the temporary flood storage function and important floodplain habitat.

Advantages

Breaching levees can be a relatively inexpensive measure in many cases, involving only several hours of operating a backhoe or bulldozer. Temporarily flooding old floodplains will produce many secondary benefits such as increasing groundwater infiltration, improving water quality, restoring natural floodplain forming processes (e.g., sediment transport and deposition) and improving fish and wildlife habitats.



THE NATURE CONSERVANCY

SUCCESSFUL LEVEE BREACH FOR FLOOD MANAGEMENT

Disadvantages

In many cases the area to be inundated again with a levee breach has been developed, requiring other levees to limit the area to be flooded. Many levees today also have secondary functions, such as an active roadbed, that would have to be accommodated somehow before breaching.

Costs

Costs will vary from thousands to millions of dollars depending on the size of the levee, the amount to be removed, whether the opening must be protected with engineered structures, whether the breach is to be open continuously or operated in response to certain events, and whether other measures are needed to control the flooding allowed by the new

Case Study, Breaching Levees

The Cosumnes River Project in California was started in 1987 after The Nature Conservancy (TNC) and its partners established the Cosumnes River Preserve with the goal of restoring and protecting the river system. As part of the project, TNC scientists breached a riverside levee along the Cosumnes River in California during the winter of 1995-6, allowing the river to flow through a 50-foot long gap into a former farm field.[9] More levees have since been breached or have been set back to create a larger floodplain.[10] As a result of the levee breaching, the natural process of flooding has resumed, allowing restoration of plant, fish and wildlife populations, as well as restoring a floodplain for excess water storage.[11]

To learn more about this project, visit The Nature Conservancy at www.tnccalifornia.org/our_proj/cosumnes/ or Cosumnes River Preserve at www.cosumnes.org or contact Ramona Swenson with The Nature Conservancy at 916-684-4012.

9. Consumes River Preserve, *Consumnes River Project and Mission*, ‹www.cosumnes.org/› (11 June 2002).
10. The Nature Conservancy of California, “Cosumnes Preserve Gets New Partners, New Lands—More than Doubles in Size,” *California Newsletters*, 1999, ‹www.tnccalifornia.org/news/newsletters/newsletter_summer_1999.asp› (11 June 2002).
11. ———, *Consumnes River Project and Mission*, ‹www.cosumnes.org/› (11 June 2002).

THE NATURE CONSERVANCY

INITIAL BREACH ON THE CONSUMNES LEVEE IN OCTOBER 1995

THE NATURE CONSERVANCY

CONSUMNES FLOOD ABSORPTION AREA IN 1996

THE NATURE CONSERVANCY

CLOSEUP OF THE LEVEE BREACH

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- Florsheim, J. and J. Mount. *Intentional Levee Breaches as a Restoration Tool.* University of California at Davis: watershed.ucdavis.edu/crg/product.asp?var="06".
- Florsheim, J.L. and J.F. Mount (2002), Restoration of floodplain topography by sand splay complex formation in response to intentional levee breaches, Lower Cosumnes River, California: Geomorphology, v. 44, p. 67-94.

SETTING BACK LEVEES

Many river projects also involve moving levees away from rivers (setting back levees) to provide more floodplain area to store floodwaters and to restore some of the habitat complexity characteristic of natural rivers.

Advantages

Setting levees back can serve the dual purpose of creating more favorable habitat for fish and wildlife and increasing the channel's flood capacity, thereby reducing flood water levels. Depending on the river system and the amount of storage capacity created, this could eliminate the need for new or existing flood management dams.

Disadvantages

The principal drawback of levee setbacks is often the cost, as moving large amounts of the material that makes up levees can become expensive. The planning and engineering design for the reconfigured channel can also be costly. In addition, setting levees back far enough to have a meaningful impact on flood flows can require a significant area, which can conflict with current land uses.

Costs

The cost of levee setbacks will vary from thousands of dollars to many millions, depending on the size of the river and setback to be implemented.

Case Study, Setting Back Levees

The California cities of Marysville and Yuba City are situated near the confluence of the Sacramento, Feather, and Yuba rivers, and, as a result, have experienced numerous devastating floods. Regional stakeholders have developed a plan to set back several miles of levees along both banks of the Feather River, rather than build new dams or other flood management structures. Project modelers predict flood water levels will decrease up to four feet in certain areas once the project is completed.[12] The project is expected to cost more than $20 million.[13]

For more information, contact Janet Cohen with the South Yuba River Citizens League at 530-265-5961.

12. Sacramento River Portal, *Sacramento River Project Reports*, ‹www.sacramentoriverportal.org/modeling/hydro_index.htm› (19 June 2003).
13. Janet Cohen, Executive Director, South Yuba River Citizens League, personal communication, 14 March 2003.

Restoring River Meanders

Restoring meanders to impounded and/or straightened streams is becoming an increasingly accepted choice in flood management across the

USDA NATURAL RESOURCE CONSERVATION SERVICE

NATURAL FLOOD MANAGEMENT:
RIVER MEANDERS AND VEGETATED BUFFERS

country. Many rivers have been so altered by flood management projects that significant restoration work may be required. The University of Mississippi, in conjunction with the U.S. Department of Agriculture, has conducted successful research using vegetation of specific densities and patterns to encourage streams to alter their courses and sediment deposition, recreating "natural" meanders. Once a dam or other flood management project is removed, however, many rivers will naturally recreate an appropriate meandering channel relatively quickly without any assistance. Either way, increasing the natural capacity of the river can decrease the need for an existing or new dam.

Advantages

Restoring meanders to rivers that have been straightened not only restores river habitat degraded by past flood management projects, but also increases the in-stream storage capacity and slows the downstream propagation of the flood peak, thereby decreasing downstream flood risk and the need for flood management dams.

Disadvantages

Restoring meanders often requires large areas of land adjacent to the river, which could inhibit or eliminate existing uses of that land. In addition, it may be difficult to convince members of the community that flooding will not increase when a dam is removed. This is often the case, even when the dam provides no meaningful flood protection.

Costs

As discussed above, restoring rivers and stream meanders can cost anywhere from several thousand to many millions of dollars depending on the size of the project. For example, a project to restore natural meanders on the Soque River in Georgia cost $55,000 and involved the use of rock vanes and strategically placed vegetation.[14] On the other end of the spectrum, restoring the Omak Creek in Washington State to its original stream was more complex. The total project cost was $788,000, which included moving the stream back to its original channel, creating instream habitat, revegetation, and more.[15]

14. Environmental Protection Agency, *Natural Restoration on the Soque River, Georgia*, ‹www.epa.gov/region4/water/wetlands/projects/soqueepa.html› (15 March 2004).
15. Alvarez, S.M. and B. Ridolfi, *Omak Creek Relocation Project: Forming a Stream Team to Rebuild Steelhead Runs*, ‹www.ridolfi.com/omak/› (15 March 2004).

Case Study, Restoring River Meanders

North Richmond, California was established on the floodplains of Wildcat and San Pablo creeks on San Pablo Bay near San Francisco. Although this was a suitable location for the shipbuilding industry, the community frequently suffered from flooding in the winter months. After years of costly and ineffective flood management projects that damaged the environment, the County Board of Supervisors approved a community supported alternative flood management plan in 1985. The goal of the plan in this highly developed watershed was to use the creek's natural character as much as possible to handle 100-year flood flows, and to properly manage environmental stressors from these flows in order to allow the functioning of the ecosystem.

Restoration techniques included restoring a meandering channel pattern that mimicked natural streams and riparian tree planting. The natural channel provides various aquatic habitats with its designed pools, riffles and glides while also transporting sediments away from vulnerable marshes and accepting higher flows onto floodplains. Trees were planted along the stream to guide channel formation, to prevent erosion, to lower the water temperature and to provide woody debris beneficial to river organisms. Not only was flood management achieved and riparian and habitat restored, but the project provided public education and aesthetic enhancement.[16]

To learn more about the North Richmond alternative flood management plan, visit www.epa.gov/OWOW/NPS/Ecology/chap6wil.html.

16. Environmental Protection Agency, *Ecological Restoration: A Tool To Manage Stream Quality; Wildcat Creek, California*, July 2002, ‹www.epa.gov/OWOW/NPS/Ecology/chap6wil.html› (17 July 2003).

Where you can go for help

- For more information, contact your state natural resources agency, such as Department of Natural Resources or Department of Environmental Protection.
- U.S. Department of Agriculture: www.usda.gov/stream_restoration/newlnk.htm.
- Rinaldi, M. and P.A. Johnson. "Characterization of Stream Meanders for Stream Restoration." *Journal of Hydraulic Engineering* 123(6): 567-570.
- Shore, D. and P. Wadecki. "Born Again River: Remeandering the Nippersink." *Chicago Wilderness*. Winter 2001: chicagowildernessmag.org/issues/winter2001/bornagainriver.html.
- National Technical Information Service. *Stream Corridor Restoration - Principles, Processes, Practices*: www.ntis.gov/products/bestsellers/stream-corridor.asp?loc=4-2-0#order.

Constructing Bypass Channels

Bypass channels, which are alternate channels that a river or stream will utilize above certain flow levels, have been constructed to increase the discharge capacity of many rivers where flooding has been a problem. In the past, these were frequently no more than concrete-lined canals designed to carry flows with the least frictional resistance. More recently however, bypass channels are being designed to mimic natural channels and provide seasonal or permanent habitat for fish and wildlife. In some cases, rivers are being allowed to reclaim secondary channels that had been converted to agriculture or other uses.

CA DEPARTMENT OF FISH AND GAME

THE YOLO BYPASS

Advantages

Whereas a dam is constructed to "catch" or impound floodwaters, a bypass channel replaces this function by creating an alternative overflow or "storage" channel for floodwaters. In addition to increasing flood capacity of a system, bypass channels can provide temporary fish and wildlife habitat. They can also serve other functions, such as providing additional farmland or parkland, when not needed to convey floodwaters.

Disadvantages

Bypass channels often require a large amount of land, a challenge in many areas. In addition, if the channel must be constructed or greatly improved, such projects can become expensive. In situations where farmland is to be used, it might be difficult to purchase the land or obtain a flood easement to allow occasional flooding. Finally, the potential exists for designing a project that is over engineered and does more harm to the environment (i.e., creation of concrete box channels or culverts).

Costs

Depending on the type of bypass project, costs vary widely and can reach into the millions of dollars. Along the Guadalupe River in San Jose, California, a 3,000-foot long bypass channel will be constructed to double the flood capacity in a heavily developed stretch of river at a cost of $225 million. This cost is on the high end of the spectrum because it includes relocating numerous businesses and residences.[17]

17. "Flood control project to resume in San Jose." *San Jose Mercury News*. 21 June 2002.

Case Study,
Constructing Bypass Channels

Constructed in the early 1930's, California's Yolo Bypass serves to convey floodwaters for the Sacramento and Feather Rivers. The Army Corps of Engineers developed a network of weirs and bypass channels that would mimic the natural hydrology of the Sacramento River. As soon as the combined flow from the Sacramento River and Feather River reach a certain trigger point, floodwaters are diverted to the Yolo Bypass. While the maximum flow capacity for the main channel of the Sacramento River is 110,000 cfs, the Yolo Bypass can

Case Study (cont.)

convey 490,000 cfs. Though the Sacramento River has exceeded its flow capacity every other year on average from 1956 to 1998, the Yolo Bypass has yet to exceed its capacity. In addition to its flood management benefits, the bypass and area wetlands serve as critical habitat for migrating fowl, steelhead, chinook salmon, and delta smelt.[18]

To learn more about the Yolo Bypass, contact Ted Sommers with the Department of Water Resources at 916-227-7537 or tsommer@water.ca.gov or Elizabeth Soderstrom with the Natural Heritage Institute at 530-478-5694 or esoderstrom@n-h-i.org.

18. Sommer, T. and others, "California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture," *Fisheries* 26, no. 8 (2001), ‹www.fisheries.org/fisheries/F0108/F0801p6-16.PDF› (5 July 2002).

NATURAL HERITAGE INSTITUTE

THE YOLO BYPASS WILDLIFE AREA

Flood Management

Separating the People & the Threat

Regardless of the risks involved, people do and will continue to live in the floodplain, both upstream and downstream from dams. And, as scientists and river managers have discovered, many of the dams constructed for flood management are no longer or have never fully achieved that objective. Floodplain management encompasses a wide variety of regulatory, planning and structural measures aimed at reducing the risk of loss of property and human lives in the event of a flood. Flood management measures include zoning, flood proofing, building standards, and warning systems.

An important component of floodplain management is controlling the development of floodplains to place people and flood intolerant land uses in areas with relatively lower flood risk (*i.e.*, land at higher elevation or greater distance from the river). Land with greater flood risk is used for more flood tolerant activities, such as agriculture, parks and parking lots. This type of zoning or resettlement has the biggest impact on the need for an existing or new dam aimed at flood management.

If property and people cannot be located out of flood prone areas, flood proofing or some of the "natural" flood management measures discussed above can prevent floodwaters from reaching areas at risk. While it is not likely that flood proofing alone will lead to the removal of a dam designed for flood management or delay a proposed flood management dam, it can be a useful tool when used in conjunction with the alternatives discussed above.

- Flood proofing
- Resettlement

Flood Proofing

Structures may be modified in a variety of ways to reduce the risk of floodwater penetration and damage, including: waterproofing walls, fitting openings with permanent or temporary doors, gates or other closure devices, fitting one-way valves on sewer lines and building boundary walls around the house structure.

The internal design of buildings may also be altered to reduce flood damage. For example, electrical circuits and sockets may be permanently routed and located at high rather than low levels.

DAVE PALMER

FLOOD WALL BEING ERECTED FOR PRIVATE LANDOWNER

In extreme cases, buildings may be raised on piers and occasionally buildings will be built on raised mounds or with important areas above likely flood levels. Further measures may include sump-pumps that begin operating in basements when water levels rise, and contingency plans for when a flood is anticipated.

EXAMPLE OF FLOOD PROOFING THROUGH ELEVATION

FEDERAL EMERGENCY MANAGEMENT AGENCY

Advantages

The benefit of flood proofing is that it allows existing or new structures to be located within an area prone to flooding if the structure cannot be moved or located in a flood-free area. Flood proofing could also allow areas that are now prevented from receiving floodwaters to flood in the future, providing all the benefits of re-flooding areas described above. Also, depending on the area, these practices can replace a dam, levee, or other traditional flood management structure.

Disadvantages

Retrofitting homes and other structures to protect them from flood damage can be expensive and disruptive to families or businesses. In addition, although a structure might be protected from flood damage, a degree of risk and inconvenience remains for the people or operations occupying the structures sitting in floodwaters.

Costs

Costs for flood proofing vary depending on the combination or complexity of tactics pursued.

- Lifting a house to install a taller foundation or piers could cost as little as $30,000 or more than $200,000.[19]
- Preventive measures for sewer pipes and the flooding of basements or first floors include installation of back-up valves or gates, standpipes, sewage ejector pumps, and overhead sewers and can range anywhere from $100 to $6,000.[20]

19. Mack Construction, *Homepage*, ‹www.stevemack.com/lifting.html› (19 March 2003).
20. City of Hammond, Indiana Sewer Department, *A Property Owner's Guide to Flood Proofing*, ‹hmdin.com/sewer/FloodProofingGuide.htm› (16 March 2004).

- The average price range for materials, labor, and installation of a Floodguard flood wall is $100 to $140 per lineal foot.[21] A flood wall can also be incorporated into the actual wall of the house by retrofitting the structure with a waterproof veneer (appropriate in areas where flood depth is generally two feet or less). The average cost for retrofitting a house or building with waterproof veneer is $10 per square foot of exterior wall.[22]

21. Chehalis River Council, *Personal Flood Wall Facts*, ‹www.crcwater.org/issues/fludwall.html#90› (16 March 2004).
22. City of Wood River, Illinois, *Protecting Your Property from Flooding: Exterior Walls*, ‹www.woodriver.org/FloodInfo/ProtectProperty/ExteriorWalls.htm› (16 March 2004).

Case Study, Flood Proofing

Mandeville, Louisiana, has a number of old homes and businesses of historical value on the shore of Lake Pontchartrain in Louisiana. Southerly winds and tidal influence back up water into these developed areas, with occasional strong winds and heavy rainfall responsible for the majority of flooding. For many citizens relocating out of the floodplain or elevating their homes is not an option, and flood proofing has been used to prevent excessive flood damage. To flood-proof their homes and businesses, Mandeville citizens sealed all openings below flood level on building exteriors and covered walls, doors, windows, vents and other building openings with waterproofing compounds and impermeable sheeting. Due to the pressure from the water on the structure, flood proofing only protects buildings when flood depths are no more than three feet.

Case Study (cont.)

Two historic area restaurants, Bechac's and RIP's, had experienced flooding problems in the past and faced restrictions on what could be done to the structure by the State Historic Preservation Office. Bechac's, valued at $1.5 million, had a total of $35,175 in flood damage from four past floods, and RIP's, valued at $700,000, had $94,055 in flood damage from eleven past flood events. Final costs of dry flood proofing came to $190,000 for Bechac's restaurant and $200,000 for RIP's restaurant. Since then, both businesses have avoided damages during at least two floods.[23]

To read the complete Mandeville case study, visit www.fema.gov/pdf/fima/performance.pdf.

23. Association of State Floodplain Managers and Federal Emergency Management Agency, "Louisiana: City of Mandeville, Louisiana," *Mitigation Success Stories*, 4th ed., January 2002, ‹www.http://www.floods.org/MSS_IV.pdf› (11 June 2002).

Where you can go for help

- Protecting Your Home From Future Flood Damage: www.fema.gov/nwz97/prothom.shtm.
- Above the Flood: Elevating Your Floodprone House: www.fema.gov/hazards/floods/fema347.shtm.
- Homeowner's Guide to Retrofitting: Six Ways to Protect Your House from Flooding: www.fema.gov/hazards/hurricanes/rfit.shtm.
- Federal Emergency Management Agency and the Federal Insurance Administration. *Guide to Non-Residential Floodproofing—Requirements and Certification for Buildings Located in Special Flood Hazard Areas: Guide to Non-Residential Floodproofing.*

RESETTLEMENT

In many cases, because floodplains are largely developed, separating people and property from flood risk requires resettlement. The relocation of property either from high-risk to low-risk floodplain land, or from floodplain to flood-free land, is a strategy that is used when frequent and severe flooding occurs. Given that the threat to life and/or property is the driving reason many dams are built for flood management, eliminating both of these from the floodplain has the largest impact on the need for new or existing dams.

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AERIAL PHOTO OF GREAT MISSISSIPPI FLOOD

Advantages

The main benefit of resettlement is that the resettled people and property are removed from flood prone areas permanently, eliminating the risk of flood damage. Once a community is resettled, the dam or other flood management structure could be removed or avoided and the river reconnected to its natural floodplain.

Disadvantages

The drawbacks to resettlement include the great cost and inconvenience of moving families and businesses. In addition, adequate and affordable high ground might not be available in an area acceptable to the community to be resettled.

Costs

Resettlement is an expensive proposition in the short term, but often is less expensive when the costs of future floods avoided are considered. For example, in Arnold, Missouri, the total amount of federal disaster assistance granted after the 1993 floods was close to $1.5 million dollars. After the floods of 1995, the fourth largest flood in Arnold's history, the damage was less than $72,000 as a result of non-structural mitigation—the acquisition of flood-prone or flood-damaged properties and relocation of structures. [24]

24. Federal Emergency Management Agency, *Success Stories from the Missouri Buyout Program*, 2002, ‹www.fema.gov/mit/cb_aqres.htm› ‹19 February 2002).

Case Study, Resettlement

The Great Midwest Flood of 1993 resulted in $15 billion in damages, including the displacement of tens of thousands of families, loss of life and demonstrating the failure of traditional flood management measures, such as levees.[25] Rather than face the threat of continued flooding, some citizens chose to resettle on higher ground. Approximately 20,000 Midwesterners decided to move out of the floodplain, resulting in the relocation of more than 8,000 homes and business. This is the largest voluntary relocation after a flood in U.S. history. Furthermore, farmers voluntarily converted more than 50,000 acres of flooded farmland to wetlands.[26] Relocation efforts in a town near St. Louis led to a 99 percent drop in federal disaster relief costs, dropping from $26.1 million in 1993 to less than $300,000 in 1995. This is in stark contrast to another town near St. Louis that chose a more structural flood management approach, enlarging its levees in order to permit development of the floodplain. Despite the upgrades, this town suffered more than $200 million in damages, one of the highest bills for flood-related damage, as a result of the 1993 floods.[27]

To read more about the Great Midwest case study, visit www.greenscissors.org/water/floodcontrol.htm.

25. Larson, L.W., "The Great USA Flood of 1993," Presented at the International Association of Hydrological Sciences Conference, Anaheim, CA, June 1996, ‹www. nwrfc.noaa.gov/floods/papers/oh_2/great.htm› (5 July 2002).
26. "Wetland Destruction Leads to Devastating Floods," *Affinity*, 15 April 1997, ‹www.greenlink.org/affinity/41597/flooding.html› (11 June 2002).
27. Taxpayers for Common Sense, "Rotten to the Corps: Army Corps of Engineers Flood Control Construction $1.25 billion," *Greenscissors: Cutting Wasteful and Environmentally Harmful Spending*, 2002, ‹www.greenscissors.org/water/floodcontrol.htm› (11 June 2002).

Where you can go for help

- Federal Emergency Management Agency, *Hazard Mitigation Grant Program*: www.fema.gov/fima/hmgp/.
- American Rivers, *Programs to Help You Restore Your Floodplain*: www.amrivers.org/floodplainstoolkit/programs.htm.
- The Trust for Public Land, *Flood Control/Hazard Mitigation*: www.tpl.org/tier3_cdl.cfm?content_item_id=1102&folder_id=72.