Chapter 5.6 Flood Risk Management

(Flood Control & Stormwater Runoff)

Summary

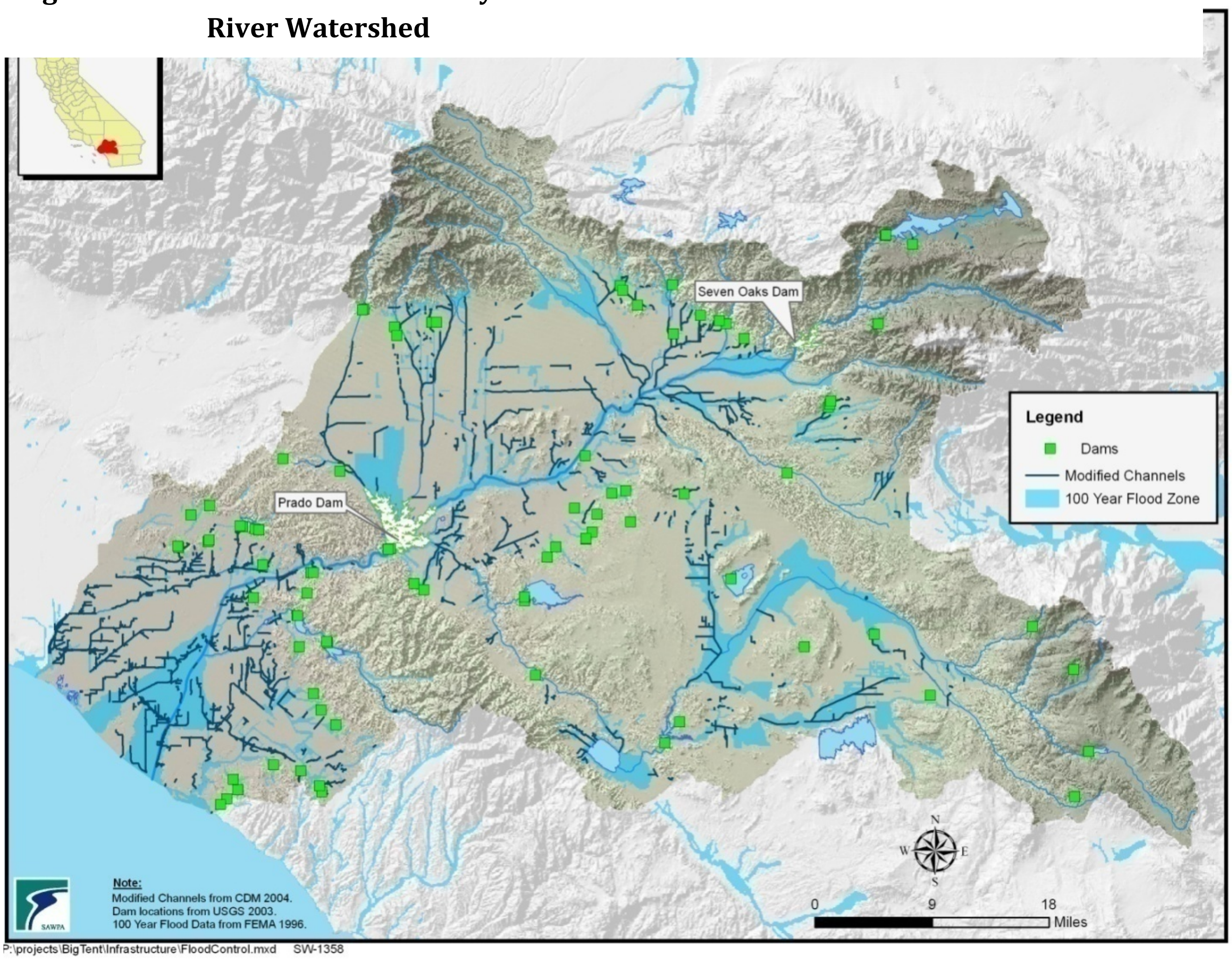
The Flood Control chapter describes the watershed physically, the way that a flood manager or flood control engineer would see it: catchment area, land uses, runoff volumes, and elevation differences or slopes. The chapter also describes the typical types of storms the region experiences, and the volumes and intensity of runoff these storms can produce. The chapter recounts the flood experience of the region and the strategies that have been used to respond to the risk of future flooding, including the ongoing Santa Ana River (SAR) Project. These strategies mainly have consisted of hardening and straightening the stream channels to maximize drainage efficiency and buffering peak flows by providing large flood storage facilities. In general, communities in the SAR Watershed have been effective at reducing flood damage risk, allowing the traditional California urban and suburban development to be maximized. However, some highly populated areas remain vulnerable to flooding even in fairly modest storms. In addition, the current principle strategies are expensive in terms of money, natural resources impacts, and lost water supply. Changing community values are forcing a re-evaluation of the traditional approach to managing flood risk, in effect changing the terms in the "cost-benefit" equation used for the past century.

There are two additional key issues that flood management must address in order to succeed. First, the basic goals of flood control efforts throughout the watershed need to be clarified and reaffirmed. Although there are few formalized rules, the most common planning and design guideline in the region is to design for the 100-year flood. How and why that level of protection became a community standard, and whether or not it is appropriate, is not free from doubt. There have been recent bills in the legislature proposing different standards, e.g. 200-year protection. This should be a watershed-scale community decision based on a balance of risks and economic and environmental costs. To facilitate such an agreement, we need a common vocabulary for the risks and costs associated with flooding and other competing issues, such as water supply and water quality. Additionally, the "100-year" standard is elusive because it is a statistical construct based on historical flows that were a product of past conditions in the watershed. Over time, both the physical conditions of the watershed and the climate itself change, and therefore the flows associated with a 100-year storm change. Thus, the standard that we use for flood risk management is not formally established, not easy to compare to or integrate with other community needs within the watershed, and of dubious predictive strength in any event. This OWOW process should produce more understandable and more universal metrics for the expression of risk, and use them to facilitate the establishment of a flood protection standard.

Second, the reality has been that very early land use decisions have preceded flood management strategies and have severely limited the alternatives that flood managers can consider. Once development has been allowed to encroach into a floodplain, regional storage and hardened, straightened, and levied channels may be the only feasible approaches. Ideally, it would be better to devise a flood management strategy during the original planning of the development of a region, so that flood risk management and other land and water needs could be optimized. Since that has

never been the practice in the region, and since the region is now highly urbanized, the Flood Risk Management Pillar and the Water and Land Use Pillar will need to collaborate to determine what, if any, new approaches would be productive going forward. **Figure 5.6-1** illustrates the built flood control systems, as well as the 100-year flood zones within the SAR Watershed.

Figure 5.6-1 Built Flood Control Systems and 100-Year Flood Zones in the Santa Ana River Watershed



Introduction

A vision of flood risk management in 2030:

Each person in the watershed feels secure that there is a less than one in one hundred chance in any given year that their home will be flooded. No one in the watershed is killed by flood waters, and there is no uninsured property damage due to flooding. Stormwater is managed with the understanding that it is both a potential risk and a valuable resource.

Agencies throughout the watershed manage flood risk in balance with other community goals as part of a common management program. Investment in flood risk management is guided in this way to optimize risk reduction and avoid creating new problems or conflicts.

Stormwater conveyance facilities are used to achieve multiple benefits as much as possible, e.g., recreation, groundwater recharge, pollutant removal, habitat functionality, etc. This occurs because each of the municipal agencies in the watershed ensures that flood risk management strategies are considered early in the general plan process, and the costs and benefits of various strategies are fully described.

The objective of this OWOW planning process most directly relevant to flood risk management is the goal to "manage rainfall as a resource," with its sub-objectives of maximizing beneficial use of rainwater and providing appropriate flood control capacity and other community benefits. Although water is valuable and groundwater recharge is important, the prevailing view within the watershed has been that physical protection from flood damage was of paramount importance, and that efforts to capture and store flood water for beneficial use were generally infeasible, considering the volumes, intensity, and infrequency of such flows. The effect of this prevailing view was magnified by the fact that decisions about land development, water supply, and flood control were based on work done by separate agency staffs, often approved by separate governing boards, and on different timelines. The strategies available for flood risk reduction often have been constrained by development decisions that were made separately and earlier. Changing this trend in the future requires a conscious effort to integrate flood risk reduction into other community needs, both in terms of the weight given to flood risk concerns, and in terms of the timing of decision making.

The Santa Ana River Watershed from a Flood Manager's Perspective

The SAR drains approximately 2,450 square miles. Maximum elevations in the Watershed exceed 11,000 feet, and more than one-third of the watershed area lies within three steep mountain ranges. Most of the rest occurs in lower-sloped valleys formed by a series of broad alluvial fans that extend from the base of the mountain front. The SAR has an average gradient of about 240 feet/mile in the mountains and about 20 feet/mile near Prado Dam. The principal tributaries are significantly steeper.

The climate is generally mild, but both temperature and precipitation vary considerably with distance from the ocean and with elevation. Most precipitation falls as rain and occurs from December through March. Rainfall varies from ten inches/year in Riverside to about 45 inches/year in the higher mountains.

Winter storms usually move in from the Pacific Ocean bringing widespread rain, and snow at the higher elevations. Such storms often last for several days. More localized storms associated with frontal systems can occur at any time of the year. They are rare, but can produce high-intensity precipitation over a comparatively small area for up to six hours.

Stream flow is perennial in the canyons of the SAR and in the headwaters of most of its tributaries, but is generally ephemeral in most valley segments. Stream flow increases rapidly in response to precipitation. High-intensity precipitation, especially following wildfire, may result in intense sediment-laden floods, with some debris load in the form of shrubs and trees.

The Watershed has experienced flooding on numerous occasions in the American era, including flood in 1825, 1862, 1884, 1914, 1916, 1927, 1938, 1965, 1969, 1983, and 1995. The critical event in flood management in the Watershed was the 1938 flood. In that event, Orange County experienced California's worst flooding of the 20th century. Anaheim experienced 15 feet of water in some places, and 182,000 acres were inundated. Dozens of people died. In Riverside and San Bernardino Counties, the 1938 flood made it painfully clear that the County governments did not have an adequate program of flood protection. San Bernardino County created its flood control district in 1939, and Riverside County followed the same course in 1944.

Prado Dam had been authorized in 1936, but was not completed until 1941. It was built primarily for downstream flood protection, and 92 percent of the Watershed lies above it. More recently, the dam also has become a vital component of the water supply management program in the region, and has allowed the creation of ecologically important habitat areas behind the dam. According to a mainstem report, when Prado Dam was built, it was to provide protection against flooding in a 200-year event. Because the area has become so heavily populated, that number has decreased to 70 years with downstream channel capacity reduced to approximately 50 years.

The Army Corps of Engineers (Corps) initiated the Santa Ana River Mainstem Project (SARP) in 1964. The Corps completed a survey report in 1975 and the Phase I General Design Memorandum (GDM) for the SARP in 1980. Construction of the SARP was authorized by Section 401(a) of the Water Resources Development Act of 1986. Construction of the SARP was initiated in 1989, and completion scheduled for 2010.

The SARP is located along a 75-mile reach of the SAR in Orange, Riverside and San Bernardino Counties. The plan for flood control improvements includes three principal features:

Lower river channel modification for flood control along the 30.5 miles of the SAR from Prado Dam to the Pacific Ocean.

Construction of Seven of Seven Oaks Dam (about 3.5 miles upstream of the existing Prado Dam) with a gross reservoir storage of 145,600 acre-feet (AF).

Enlargement of Prado Dam to increase reservoir storage capacity from 217,000 AF to 362,000 AF.

The Seven Oaks Dam Watershed comprises 177 square miles, excluding 32 square miles that is isolated by Baldwin Lake. The principal tributary within the Seven Oaks canyon area is Bear Creek, which drains 55 square miles, and has an average gradient of 460 feet/mile. The only existing structure that would affect flood flows in this sub-watershed is Big Bear Lake, which is a water conservation reservoir. It collects water from a 38-square-mile drainage area, and has a surcharge storage capacity of about 8600 AF between the top of the conservation pool and the top of the dam. Aside from Seven Oaks Dam, the only other major flood control dam above Prado Dam is San Antonio Dam.

The Lower SAR Basin from Prado Dam to the ocean comprises about 208 square miles, excluding the 19 square miles behind Carbon Canyon Dam. The river flows about 31 miles from Prado Dam through Santa Ana Canyon and seven Orange County cities before reaching the ocean. About 60 percent of the drainage area to this reach lies in the Santa Ana Mountains and Chino Hills, while most of the rest lies within the broad coastal plain. Of the numerous tributaries, the principal one is Santiago Creek, which drains about 102 square miles. The average gradient of the river mainstem from Prado Dam to the ocean is about 15 feet/mile.

Other smaller flood control improvements exist along Cucamonga, Deer, Lytle, and Cajon Creeks above Prado Dam, and Carbon Canyon Dam and Villa Park Dam in Orange County. These include channelization, debris basins, storm drains, levees, stone and wire-mesh fencing, stone walls or rip-rap along the banks of stream channels, concrete side slope protection, and drop structures. Other improvements not aimed mainly at flood control include spreading grounds, recharge basins, and water conservation reservoirs. There are more than 100 water conservation and recreational reservoirs in the basin, with storage volumes ranging from 5 AF to 182,000 AF in Lake Mathews. These improvements affect the regimen of lesser flood flows, but do not appreciably affect major flood flows. Lake Elsinore can have considerable influence on flood flows depending on its water surface elevation at the beginning of a storm.

By 1988, the Corps noted that the SAR was uncontrolled for much of its length in Riverside and San Bernardino Counties above Prado Dam. Flooding in 1969 had caused serious damage to sewage treatment plants, sewage lines, and bridges, and had flooded large areas of agricultural land and caused heavy bank erosion along most of the river. Below Prado Dam, the Corps calculated that downstream communities enjoyed about 70-year flood protection, while parts of the channel near Fountain Valley and Huntington Beach could not contain a 50-year flood. A 100-year flood would inundate over 160 square miles of urbanized land in Orange County.

The intent of the SARP was to provide the developed and developing areas in the Watershed with approximately 100-year flood protection through the end of the project life. While this system of infrastructure has been in development, the three counties that comprise the Watershed and the various cities within them, have overseen the growth of the region's population and its conversion, broadly speaking, from agriculture to an urban setting. The population of the three counties comprising the Watershed was less than 400,000 in 1940, and is now more than 7 million, most densely concentrated in the SAR Watershed.

In addition to the mainstem of the SAR, the regional flood control agencies each have extensive plans governing flood management for tributaries. For example, the Upper SAR Watershed is contained within San Bernardino County Flood Control District's (SBCFCD) jurisdiction. There are approximately seven major and three minor mainline flood control systems draining directly into the SAR from San Bernardino County. In addition, two systems flow directly into Prado Flood Control Basin which connects to the SAR. Of these 12 mainline systems, eight are built to their ultimate capacity. The remaining ones are in an interim condition and need upgrading. Many of the regional subsystems that feed these main lines are in interim condition; a few others are merely proposed facilities.

Though most concrete structures typically are designed to have a 50 year lifespan, SBCFCD has a number of facilities that are older than 50 years and still function well. Many of the SBCFCD's facilities were built by the Corps in the 30s, 40s, 50s, 60s and 70s. Most of those facilities still are considered to be stable and secure structures with little or no repair requirements.

From SBCFCD's perspective, the majority of the mainline system is built out to ultimate, but the interim facilities operating within our jurisdiction are in need of improvements. The regional interim subsystems consist of rail and wire revetment or simple rock slope protection. These facilities experience erosion and undercutting on a regular basis. Also, these interim systems do not provide the ultimate capacities and as communities develop, increasing runoff volumes further compromise those capacities. In conclusion, although the mainline systems are complete, the regional subsystems are acceptable at best, and the flood control system as a whole is in need of improvements.

The Traditional Way of Thinking about Flood Protection in Southern California

Flood protection agencies, including the Corps, county flood control districts, and cities are charged with ensuring that floodwaters do not endanger life or property. Historically, efforts to deal with flooding in the region focused on reducing the threat to properties from floodwaters and on damage control. These strategies mainly have consisted of hardening and straightening the stream channels to maximize drainage efficiency, and buffering peak flows by providing large flood storage facilities.

In many ways, these strategies have been a great success; many people and highly valuable economic assets are now protected from a certain level of flooding. A number of significant issues have arisen, however, that warrant consideration in a discussion about a going-forward strategy.

The management of flood risk has been profoundly affected by the sequence of decision-making and the interests of the early decision makers. A typical conversation today about reforming our approach to flood risk management compares the various costs of our traditional strategies against the alternative "softer" approaches of wider floodways, restricted development in floodways, restoration of wetlands, and so forth. The reality, however, is that much of the land use and development in the SAR Watershed preceded systematic flood control planning and implementation. This history of limitations is not unique to this Watershed.

Typically in southern California, the early European settlers established themselves near sources of water. Because of the climate and terrain, the places where water tended to be readily available were lower, flatter areas near streams, where stream flow could be diverted or shallow wells could produce groundwater. Often, stream beds were attractive for land development because of accessibility. Immigrants from wetter climates did not think of the dry stream beds as water bodies. Given the semi-arid climate and the braided-channel form of many of the local rivers, it might be years between rain events that actually produced any significant flow in some of the streambeds. As the population grew very rapidly between the infrequent but significant storms, only a diminishing percentage of the residents had any concept of the physical floodplain for the streams they lived near.

Eventually, rain fell and the rivers flowed. The resulting damage to property that had been developed in the floodplains prompted initiatives to protect valuable property from flood damage. The available flood management solutions where thus entirely reactive to then-existing development, even though not nearly as dense as development was to become in the future. The alternatives available to flood managers were constrained by existing development and the expense of acquiring urbanizing land for flood control right=of-way. The only feasible solution tended to be to channelize the streams, which increase velocities, so that more flow could be carried in the same narrow channels. To maximize velocity and to avoid erosion, the channels often needed to be engineered with rock or concrete lining.

This approach**,** while effective at managing flood risk, created other environmental, fiscal, and management issues, which must be addressed as we plan for the future. Any opportunity to change the direction of flood management strategy immediately encounters the constraint of available land and the cost of acquiring additional land. It is ironic and true that the land that is too dear now to be acquired reasonably for flood management only has become valuable because of the promise of flood protection.

There already have been some efforts toward more holistic approaches to flood risk management within the Watershed. For example, the San Jacinto River Watershed Council (SJRWC) has led a stakeholder group to develop an Integrated Regional Water Management Plan (IRWMP) for that 770-square-mile sub-watershed. Like all IRWMPs, it addresses a number of water resources issues in an integrated framework, including water supply, water quality, drought-proofing ,and critical habitat protection. The plan also addresses flood risk concerns, and recognizing that the issue is risk management and not purely a matter of engineering, the SJRWC approach frames the issue as "provid[ing] flood protection to existing disadvantaged communities." In that group's view, assisting disadvantaged communities is a particularly important risk to be mitigated, considering all of the needs within the watershed. The plan acknowledges a number of alternative strategies to flood risk management instead of channelization. It remains to be seen how well the plan is implemented and whether or not it is detailed enough to provide decisive support for the innovative approaches is mentions.

Challenges for the Future

Watershed Coordination

For more creative approaches to flood risk management both to flourish and to improve upon the results of traditional approaches, planning and implementation needs to be coordinated at the watershed scale. The three county flood control districts already have developed good working relationships and they coordinate more effectively than, for example, the various land use planning agencies within the Watershed. To firmly integrate flood risk management with other water resources goals, however, will require a quantum leap in the level of coordination and communication between agencies and stakeholders. The Watershed truly needs a culture of communication, where the sharing of information and strategies, and group discussion of costs and benefits, is the norm. In particular, the three county flood control districts should coordinate even more than they do now, and they should develop standard approaches to coordinating with the major land use planning agencies in the watershed, as well as the water districts.

A significant challenge and opportunity for the future is the improvement of risk assessment methods, metrics, and messages. This will be discussed in more detail below, but it can be noted here that this is one kind of action that should be standardized throughout the Watershed to get the most benefit. All agencies and the general public will benefit from clarity and commonality in the way risks are assessed, quantified, and described.

The watershed approach also always raises issues of working or contributing to work that is physically outside of an agency's jurisdiction. This is true for all sorts of water resources efforts that can be the focus of the watershed approach, including flood risk management. The issue cannot be avoided and must be addressed so that resources can be directed at the watershed scale to the most important issues, and with the greatest integration and synergy.

A final example of an aspect of planning and design that relates to stormwater management that would be greatly improved by watershed-scale coordination is the adoption of data standards. For planners, engineers, and managers to collaborate routinely across disciplines and across jurisdictional lines, they need to use the same data, or at least the same kinds of data, as much as possible. This can mean standard protocols for topographic data, hydrologic calculations, rainfall measurement, and quality assurance and quality control for hydrologic data. It is a necessary part of establishing a common language and a common understanding within the watershed.

Water Conservation

The OWOW Steering Committee adopted a sub-objective of maximizing the beneficial use of rainwater. Our historic strategies for flood risk reduction have been directly opposed to this goal. The hardened channels that sped storm water away also prevented the water from replenishing groundwater basins. Even where storage has been used to buffer peak flows, the storage facilities are designed and operated for flood control capacity, and do not provide significant water supply benefit. Soon after flood control projects were implemented, groundwater sources usually experienced shortages, and water importation became a necessity.

Today we face an ever increasing need to be as efficient as possible with our water supply. We have made significant improvements in our approach, by using our facilities on the SAR to increase groundwater recharge, especially in the lower SAR. We have pioneered the reoperation of Prado Dam and the use of Seven Oaks Dam to allow more use of storage capacity for water conservation, without unacceptably diminishing flood protection.

The challenge for the future is to find additional ways to modify our infrastructure, or at least build new parts of the system differently, to provide flood protection but still capture our local water, particularly in the Inland Empire (water captured in the upper watershed is likely to be available for use two or more times before it flows to the ocean).

Stormwater Quality Management and Flood Risk Management

The area within the watershed is regulated by three area-wide municipal stormwater permits, all of which are in the process of being renewed. The existing stormwater quality programs in each county include the use of site design features and flow-reduction management practices in connection with new development. These elements of the stormwater quality programs are certainly going to be increased in the current round of permit renewals. The new permits will include express requirements to limit the projects change of the hydrograph for runoff from the site, mainly by using "low impact development" (LID) design concepts. These include minimizing impervious surface area, including pervious areas to interrupt flows across impervious areas, maximizing the use of groundwater infiltration basins, and so forth.

It is important to note that these management practices are intended to prevent or minimize water pollution and the deleterious effects on water bodies from the change in flow characteristics resulting from development. The LID concepts and other methods used to avoid changes to the hydrograph will not, however, address flood management issues. As a practical matter, once even natural areas are saturated by the first rains of a big storm or a series of storms, the runoff characteristics of the site become very much the same as that from a traditional development with many impervious surfaces. In any event, it is almost certain that the new permits will mandate certain LID measures and other control measures that are sized to address relatively small and frequent rain events, but not the large events for which flood conveyance facilities have to be sized.

Ecological Impacts

Our flood control system has had dramatic effects on the environment within the Watershed. Natural floodplains perform ecological functions as habitat, water pollutant removal, and groundwater recharge, as well as slowing flows and thereby dampening flood peaks downstream.

Our extensive system of improved channels unquestionably has a significant effect on the region's riparian and wetland habitats, on water quality in the streams and at the beach, and on the aesthetics of our communities.

Channel improvements for flood conveyance and the construction of dams for flood detention have a direct effect on riparian and wetland habitats. New projects of this type have become increasingly unacceptable to the public, and when approved, incur major costs for environmental mitigation. Flood control strategies in new developing areas may well be changed just because of these habitat concerns. Whether retrofitting of existing channelized reaches will ever be found to be feasible is a challenge for the future. The expense—especially of land acquisition—would be great, but the benefit to regional habitat vitality and sustainability also would be significant. An important goal should be to maximize marginal opportunities for gains in habitat functioning within existing rights of way.

A closely related challenge is the regulatory burden on maintenance of flood conveyance channels and basins. Vegetation management such as mowing, sediment removal, and other maintenance activities are often subjected to permitting and mitigation requirements in the name of protecting habitat. The imposition of stricter environmental regulations on existing facilities represents a new cost without increase in flood protection, and often without real habitat benefits either. In fact, regulatory attempts to benefit habitat in man-made or highly modified channels likely will increase flood risk, defeating the goals of the flood management project. In addition, the difficulties associated with habitat regulations are a very real disincentive to any attempts at habitat restoration within existing flood control facilities, illustrating the rubric that no good deed goes unpunished. A goal of this regional planning effort should be to develop a regional consensus on habitat restoration projects and how to keep environmental regulations from defeating them.

Money and Advocacy

Historically, both flood control projects and the often related water supply projects were expensive. The public investment needed for projects of that sort was more palatable if it were spread over a large population. Thus, the idea became ingrained in our regional culture that property protection depended on infrastructure improvements, which depended on growth to be affordable. A challenge for the future is for the Watershed to break the habit of relying on future development to fund infrastructure.

In addition, the evaluation of new flood risk management strategies will take place largely in the setting of an already built environment. No new flood management strategy will achieve a pronounced effect on the Watershed unless it can address both new development and retrofitting in existing developed areas. It will be important to identify incentives for flood management agencies to view programmed repair and replacement projects as significant opportunities to implement new approaches. Changing to a new approach, for example, deciding to widen a right of way and channel to incorporate softer features with more natural functions, is unlikely ever to be found an appropriate investment if it only is evaluated on a project by project or reach by reach basis. Innovative retrofitting projects will make more sense if they are part of a larger plan that is being patiently but consistently implemented.

Flood control infrastructure construction in this watershed often has depended on State and Federal subsidies. This approach necessitates a sustained commitment to advocacy in Sacramento and Washington, DC, that is itself expensive and that has not always been well coordinated. Within the Watershed, different agencies and stakeholders advocate different priorities to State and Federal officials regarding water projects of all types, including flood control projects. The Watershed as a whole, therefore, misses an opportunity to be much more forceful and persuasive in seeking State and Federal funds. A comprehensive, watershed-wide plan for flood management, integrated with other water resources programs, would be the foundation for focused advocacy efforts of all stakeholders and the entire delegation of legislators in the Watershed.

Decision-making

The common perception in the community is that the flood program managers are responsible for achieving their flood control mission and for the economic and environmental impacts of those actions. But this has not been true, practically speaking, in the history of the region, where flood management alternatives have been constrained by land development decisions that occur first.

From a land use perspective, the three counties and the cities all have adopted General Plans, which are intended to guide planning and development. In the past, General Plans often made little mention of water supply, and flood control discussion focused on the need to make improvements to contain flood flows. The Riverside County General Plan reflects a more modern sensibility, with a balanced statement of the tradeoffs involved in addressing flood protection, as shown in the following excerpts.

Since 1965, 11 Gubernatorial and Presidential flood disaster declarations have been declared for Riverside County. State law generally makes local government agencies responsible for flood control in California.

Riverside County has experienced severe flooding many times throughout its history, resulting in the loss of lives and millions of dollars in property damage. Floods are caused by rivers and creeks overrunning their banks, and most property damage has occurred where development has been allowed without regard for flood hazard. If urban development continues to encroach onto the floodplains without major structural improvements, Riverside County will face an ever-increasing flood hazard, and potential losses will escalate.

The tremendous capital investments made in dikes, channels, levees, and dams over the last half century have not eliminated all flood hazards, and in some instances, the protective facilities may be unable to accommodate the 100-year flood. In recent years, the idea has become increasingly accepted that, while it is essential to protect existing development, the provision of massive flood control facilities merely to permit new development over major floodplains may be unwise. It is often more effective and less costly to locate development outside of hazard areas than to attempt to control the hazard itself.

Furthermore, consistent with the intent and policies of the Multipurpose Open Space Element, the Safety Element recognizes the need to protect watercourses in their natural state. Flood and inundation policies limit the alteration of floodways and channelization when alternative methods of flood control are not technically feasible.

Policies:

S 4.4 prohibits alteration of floodways and channelization unless alternative methods of flood control are not technically feasible or unless alternative methods are utilized to the maximum extent practicable. The intent is to balance the need for protection with prudent land use solutions, recreation needs, habitat requirements, and as applicable, to provide incentives for natural watercourse preservation, including density transfer programs as may be adopted (AI 25, 60).

Risk Assessment

Recent environmental legislation and improved understanding and analysis of flood hazards in arid environments have resulted in new approaches to flood hazard mitigation implementation. Nationwide, there is a move to leave nature in charge of flood control. The advantages include lower cost, preservation of wildlife habitat, and improved recreation potential. However, this type of flood mitigation is difficult to implement in areas where development already has occurred, as well as in regions susceptible to sheet flow. Where water spreads across broad areas, mitigation without channels or culverts is more difficult. Flood control structures often have been built piecemeal over the years, and new development may funnel water into older systems with insufficient capacity. These issues have been mitigated in recent years by the preparation of Master Plans by local public works agencies.

The communities within the watershed have invested enormous resources in creating the existing built environment, including urban development, roadways, channel improvements, pipelines, treatment plants, basins, dams, and levees. It is vitally important that decisions going forward favor multiple benefit projects, but also that we maximize the use that can be made of our existing infrastructure to achieve more benefits. In the past, multiple benefit projects were not emphasized because flood control, water supply, and development decisions were handled by different governmental entities at different times. This planning effort aims to reach agreement on a governmental decision-making process that naturally encourages multiple benefit projects and watershed scale master planning of facilities and strategies.

Quantification of Risk

The Steering Committee adopted a sub-objective of providing appropriate flood control capacity and other benefits to the community. Determining what flood control capacity is appropriate is no easy task. Decisions about flood management were, and are, driven by flood risk, which is a commonly misunderstood concept. Early in the development history of the watershed, flood protection decisions were made based on local notions of what was reasonably or adequately safe. Over time, a community standard has evolved of planning to provide protection from the 100-year flood. This has become somewhat formalized now, driven largely by the Federal government's use of the 100-year probability threshold for insurance and subsidy programs. In theory, at least, a local community should make its own decision about the level of flood protection that is adequate for its local circumstances. But that does not happen in practice, and essentially all communities in California, including the SAR Watershed, default to using the 100-year protection standard for planning purposes. This should not be accepted as a given; however, it is proven by the fact that there has been advocacy in Sacramento recently about creating a statewide standard for a higher level of protection, meaning 200-year or even 500-year protection.

The 100-year flood standard does not imply a frequency of occurrence, but denotes a likelihood of occurrence in any given year. It is based on hydrology, and therefore on the information about rainfall and stream flow that we have collected in the past. Our period of record for rainfall and flow information is relatively short in southern California, and for both flood and water supply purposes, we are beginning to see the problems that might arise from relying on a dataset that may not accurately represent a very long-term condition. Moreover, the weather itself is changing with time due to global climate change, whether human induced or natural. This means that the likelihood of a particular storm is a moving target, making it problematic as a design standard. Additionally, the stream flow experienced in a 100-year event at a given point along a channel is affected, often dramatically, by changes in upstream land use.

The Corps has noted, regarding the SAR Watershed, that while the mountainous areas of the Watershed remain largely undeveloped, the valley areas are approaching complete urbanization. Urbanization in the valley areas of the SAR Basin has tended to make the basin more responsive to rainfall. Hence, the same rainfall occurring over an urbanized segment of the basin will result in earlier and higher peak discharges, with greater volume than had it occurred over a natural basin without urbanization.

The SARP is designed to provide well over 100-year protection to Orange County through the life of the project. The reality is that no one really knows where that massive investment will leave Orange

County, because the development that actually has occurred upstream is almost certainly different from the assumptions in the original SARP design. The same uncertainty affects flood management decisions in the upper watershed, albeit with less land area above them. Climate change will affect flood protection throughout the Watershed.

Flood risk is documented in FEMA flood insurance rate maps, and the maps are used to determine who can, or who must, obtain flood insurance, and who can receive certain government services. However, the FEMA maps are inaccurate for the reasons discussed here, and are generally out of date, meaning that insurance premiums are assessed inappropriately.

Another consequence of the uncertainties in determining flood risk is that the benefit-cost calculations done to determine the feasibility of flood control projects or to determine whether or not Federal subsidies will be available, are highly imperfect.

The uncertainty in the degree of flood protection provided can be reduced by having strong, clear policies in General Plans, and by favoring flood management strategies that are not as sensitive to changes in upstream conditions. The uncertainty can never be eliminated; however, in any event, the whole notion of flood risk is a statistical construct, never a guarantee. What is more important is for the risks to be articulated understandably.

First, it is important to express flood risk in a way that makes it relatively easy for elected officials to compare that risk to other needs faced by the community, or even other water resources needs. There is no widely used metric for a similar statistical analysis of the risk of water shortage, or of poor water quality, or of the risk of habitat loss, or species impacts, for example. Moreover, flood managers do not provide elected officials with comparative evaluations of flood damage risk and the impacts of crime, traffic, poverty, or earthquake.

Second, it is important for the public to understand more readily what 100-year flood protection means. Currently, the only significance of the term to the average citizen is whether flood insurance premiums are required, and whether the local flood manager is doing his or her job well.

Conclusion

Regional flood protection professionals have faced a series of increasingly difficult challenges. The costs associated with acquiring rights of way and constructing infrastructure have climbed steadily over the years, while dedicated funds for flood control infrastructure have not kept pace. Environmental review processes and budgetary controls have become more complicated so that the development, funding, design, and permitting of projects have become a cumbersome process that can take decades. Environmental regulations related to water quality and habitat have seriously affected the financial and technical capabilities of regional flood agencies to operate and maintain their systems.

More recently, professionals from many disciplines that relate to water resources and urban policy have begun to see that flood management cannot be managed separately from other important decisions about land use, water supply, environmental risks, public safety, and quality of life within the urban landscape. However, the legal and bureaucratic processes through which urban government takes place have not changed, and flood management decisions still are not integrated with land use decisions, water supply decisions, and the like.

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Keith	Linker	City of Anaheim
Khanh	Chu	City of Anaheim
L.F. (Sandy)	Caldwell	City of Riverside, Public Works Dept.
Lance	Natsuhara	County of Orange
Larry B.	McKenney	RBF Consulting
Maria Elena	Kennedy	Kennedy Communications
Mark	Seits	HDR
Melissa L.	Walker	San Bernardino County, Dept. of Public Works
Michele	Hindersinn	City of Corona Public Works Dept.
Rocky	Welborn	Inland Empire Utilities Agency
Steve	Stump	Riverside County Flood Control & Water Conservation District
Thomas	Field	City of Riverside
Vana R.	Olson	County of San Bernardino, Dept. of Public Works
Wes	Hylen	Pacific Summits Consultants, Ltd.