Alluvial Fan Task Force

California Department of Water Resources Project

DRAFT AFTF LOCAL PLANNING TOOL KIT

For Flood Managers, Local Governments, Developers and Public Stakeholders

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Introduction to Alluvial Fans

Alluvial fan lands are managed by riverine flood standards that are inadequate to address the specific behavior of floods and debris flows on alluvial fans. A flood is not merely a flood. The characteristics of *alluvial fan* flooding differ from the traditional *riverine* flooding paradigm and the approach to analyzing alluvial fan flooding potential is decidedly different from analyzing riverine flooding. It is imperative for floodplain managers to consider the

existence of alluvial fans and their unique behavior when developing measures required for protection of life and property. The following Alluvial Fan tools are designed for floodplain managers to use during the course of an alluvial fan flood hazard study.

One of the major sources of confusion related to alluvial fan flooding is the definition of the term. There are two commonly accepted working definitions of alluvial fan flooding. The Federal Emergency Management Agency (FEMA) published the first definition. The National Research Council (NRC) Committee on Alluvial Fan Flooding Water Science and Technology Board Commission on Geosciences, Environment, and Resources published the second, with the purpose of clarifying the meaning of the term and describing the intricacy of alluvial fan flooding phenomena.

The FEMA definition, found in Section 59.1 of Chapter 44 of the Code of Federal Regulations (CFR), is: "…[F]looding occurring on the surface of an alluvial fan or similar landform which originates at the apex and is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and, unpredictable flow path." The CFR describes the apex as "…the point on an alluvial fan or similar landform below which the flow path of the major stream that formed the fan becomes unpredictable and alluvial fan flooding can occur."

The definition in the 1996 NRC report on Alluvial Fan Flooding restricts the occurrence of alluvial fan flooding to alluvial fans. The NRC definition is:

> *Alluvial fan flooding is a type of flood hazard that occurs only on alluvial fans. It is characterized by flow path uncertainty so great that this uncertainty cannot be set aside in realistic assessments of flood risk or in the reliable mitigation of the hazard. An alluvial fan flooding hazard is indicated by three related criteria: (a) flow path uncertainty below the hydrographic apex, (b) abrupt deposition and ensuing erosion of sediment as a stream or debris flow loses its competence to carry material eroded from a steeper, upstream source area, and (c) an environment where the combination of sediment availability, slope, and topography creates an ultrahazardous condition for which elevation on fill will not reliably mitigate the risk.*

This second definition was meant to identify the processes that are specific to alluvial fans and make alluvial fan flooding unique from other types of flooding. Figure 1 depicts the convergence of the criteria mentioned in the NRC definition of alluvial fan flooding. While different types of flooding may occur when one or two of these criteria are met, the definition of alluvial fan flooding

presented in the NRC report requires that all three of these criteria be met simultaneously.

The FEMA document, *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping April 2003* (hereinafter referred to as Appendix G) suggests that FEMA has accepted the definition of alluvial fan flooding proposed in the NRC report. However, the CFR does not yet reflect a change to the definition of the term.

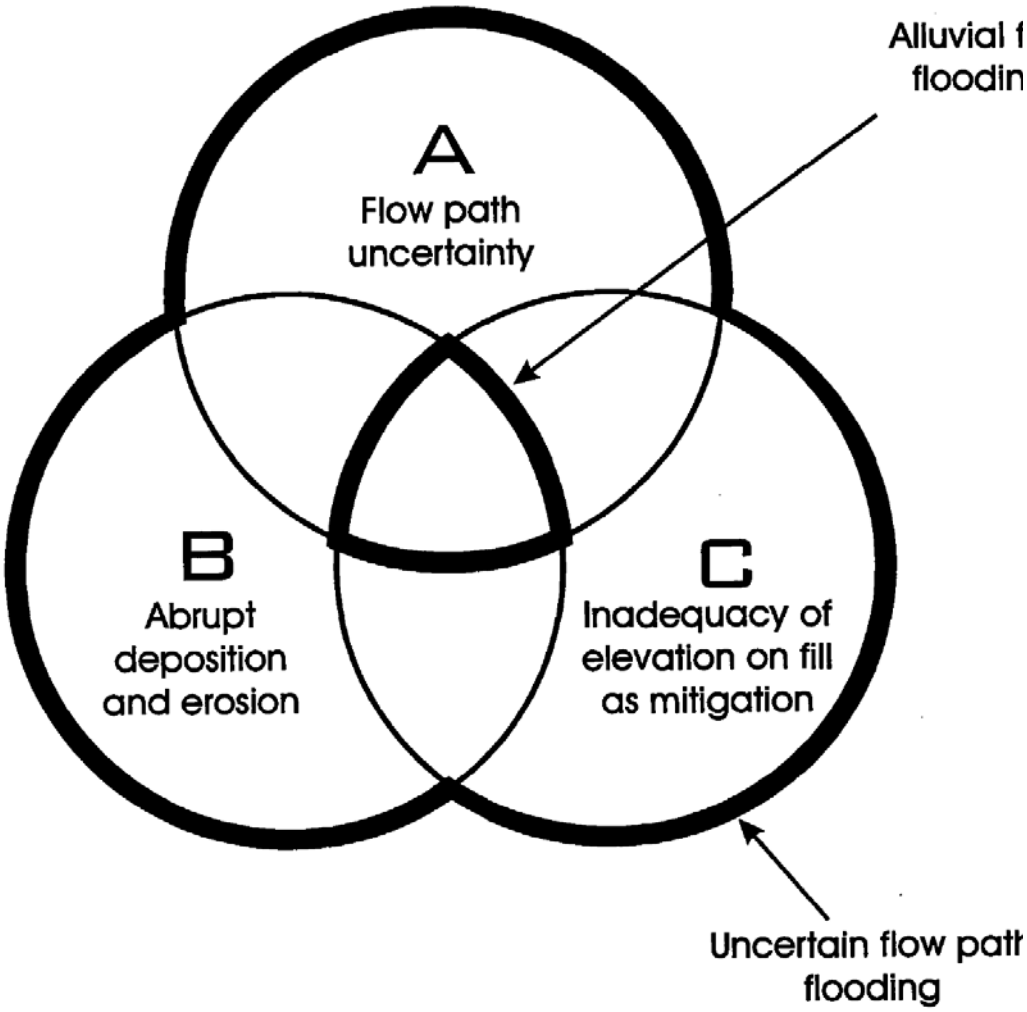

Figure 1. Figure 1-7 taken from the 1996 NRC Alluvial Fan Flooding report, which depicts the three criteria of the NRC definition of alluvial fan flooding.

The **Tools** introduced below are meant to be suggested considerations that can be applied sequentially in a study of flooding on an alluvial fan. Full discussion, including suggested protocols can be found in the Implementation Report in Appendix 2.

AF1: Preliminary Inspection of 10-County Study area and DFIRM data (formerly FM1 and GIS1)

The objectives of this tool are: To determine whether a study area resides in a region of known or suspected alluvial fans; and to assess the first-order degree of flood risk for a particular study area.

To aid in this process, the AFTF provides two sets of maps. **The AFTF 10-county study area maps,** and the **2007 Preliminary DFIRM (Digital Flood Insurance Rate Maps)** will help the researcher determine whether proposed development may be in a location potentially containing alluvial fans or in the footprint of a particular zone, respectively.

Procedure:
1. See Alluvial Fan Task Force 10-County map showing areas potentially containing alluvial fans (dataset created for DWR by PBS&J)
2. See Individual County maps showing 2007 preliminary DFIRM data.

The Individual County 2007 Preliminary DFirm and 10-county Study Area Maps and discussion of the protocol can be found in the Implementation Report, Appendix 2

AF2: Identify and map the presence of an alluvial fan and determine flood hazards (originally part of FM1, FM2 and GIS1)

The objectives of this tool are: To identify areas associated with study site that display the requisite geomorphic and geologic characteristics of an alluvial fan; and to map the lateral boundaries and aerial extent of individual alluvial fans.

Floods on an alluvial fan behave with more uncertainty and introduce risks that are substantially different from flooding that occurs in an area subject to traditional riverine flooding. It is inadequate to analyze a site that would be subject to alluvial fan flooding as though it is in an area subject to the traditional flooding paradigm. Prior to initiating an analysis of flood hazards, it is important to define whether or not a locale is subject to alluvial fan flooding.

There are three major indicators that establish whether or not a landform is an alluvial fan. These indicators relate to the composition of the land surface, its morphology, and its location. An alluvial fan surface is covered with alluvial sediments and/or debris flow deposits. Confirmation of the composition of the land surface can be made through review of geologic maps, Natural Resources Conservation Service (NRCS) soil maps, field borings, site inspections, and other information sources.

These methods are provided not for Flood Managers familiar with alluvial fans but for counties or cities where Public Works personnel have little knowledge about alluvial fan developments. It is not the purview of the AFTF to determine which department or staff is responsible for review and implementation of the Model Ordinance; it will depend on the local agency's established system.

To identify areas associated with study site that display the requisite geomorphic and geologic characteristics of an alluvial fan and to map the lateral boundaries and aerial extent of individual alluvial fans, consider the following procedures:

1. Acquire pertinent data resources and FEMA guidelines.
2. Analyze topography.
3. Analyze aerial photographs and/or satellite imagery.
4. Analyze available geologic maps.
5. Map the extent of alluvial fans identified in 2, 3, and 4 above onto a standard topographic base with a minimum of four geo-registration points.
6. Produce a standardized multi-layer GIS map with accompanying geo database, scale, and legend.

More detailed discussion of this protocol is found in the Implementation Report, Appendix 2

AF3: Research and acquisition of pertinent data resources

To acquire pertinent data resources (Internet downloads or hard copies) necessary to accomplish tasks of the various planning tools and mapping protocols in a particular alluvial fan study area consider:

- GIS data bases
- FEMA Guidance for Alluvial Fan Flooding Analysis and Mapping
- 1:24,000 scale topographic maps
- Aerial Photographs and Satellite Imagery
- Geologic Maps

- Surface Fault Rupture Hazards (Alquist Priolo Earthquake Fault Zones)
- Earthquake-Triggered Ground Failure Hazards
- Precipitation Data
- Stream Flow Data
- Groundwater Data
- Dams and Reservoirs
- Statistical Methods for 100-Year Flood Determination
- Mineral Resource Classification and Designated Zones
- Rare, Threatened, or Endangered Species
- California Drinking Water Standards
- California Environmental Impact Assessment Reports
- Table 3-1 in Appendix 8 of 1996 National Research Council report
- Need More Ecology and Biology References

Much data relevant to alluvial fan analysis has been compiled by scientists or municipal agencies but is not posted on websites. This is commonly the case for remote areas with low population density. Diligent research (email requests, phone calls, regular mail, etc.) may yield valuable information that could negate the need for future expensive studies. Many agencies compile archives and obscure publications in libraries or private collections that may be accessed by special request. Types of data sets to search for include, but are not limited to:

- rainfall records from discontinued or remote, non-automated gauges
- historical stream flow records from discontinued gauges
- water well data from municipal or private wells
- city planning reports
- published scientific articles or abstracts
- unpublished theses available from universities
- Environmental Impact Reports
- internal reports from the DWR, USGS, CGS, MWD, DPW, U.S. Forest Service
- data archives from the DWR, USGS, CGS, MWD, DPW, U.S. Forest Service
- maps of burned areas compiled by the US Forest Service or involved fire-suppression agencies
- geotechnical reports (produced by industry consultants) that focus on geology, soils, seismic hazards, and slope stability)

Introduction to Flood Hazard tools

FH1: Map hazardous upstream catchment areas (formerly MH2)

There are two objectives to this tool: to analyze important physical aspects of upstream catchment areas that may influence flooding or debris flows on an

alluvial fan; and to rank the degree of risk for flooding and debris flows on alluvial fan based on upstream catchment parameters.

The severity of flooding on an alluvial fan will be depend largely on characteristics of the upstream drainage basin (catchment area) that supplies stream runoff to the apex of the fan. Important factors include size of catchment area, presence of land denuded by wildfires, magnitude and intensity of rainfall, and historical nature of runoff. Utilizing historical precipitation and stream-flow data, it is possible to estimate the magnitude of maximum expected flood in two ways.

A preliminary assumption is that alluvial fan flood risk is greatly minimized by dams that regulate flow from the upstream drainage basin. Flood control dams are usually situated on the trunk stream near the fan apex or farther upstream in a mountain canyon. Smaller debris basins or check dams may be constructed below drainages of less extensive area. Therefore, the risk analysis process should evaluate the capability of existing flood-control structures to handle maximum expected flood events.

Consideration of weather patterns and climate factors that control the frequency and magnitude of storm events in a particular geographic area may also be important. For example, storms derived from the Pacific Ocean will have more severe impact on upslope areas that face the storms, particularly those at high elevations. Summer thunderstorms with high precipitation tend are much more common in Imperial County and the eastern portions of San Bernardino and Riverside Counties than in San Diego, Orange, Los Angeles, and Ventura Counties.

An overview of the procedures follows:

1. Acquire pertinent data resources.
    A. 1:24,000 scale topographic maps
    B. Aerial Photographs and Satellite Imagery
    C. Precipitation data
    D. Stream Flow data
    E. Flood-control dam and reservoir parameters
    F. Wildfire Records
    G. Statistical Methods for 100-Year Flood Determination
2. Identify trunk streams with non-existent or inadequate flood-control dams or debris basins
3. Measure area of upstream drainage basin
4. Map upstream burned areas subject to accelerated erosion

5. Analyze historical precipitation data to determine maximum expected rainstorm that might affect upstream catchment area
6. Analyze historical stream flow records to determine magnitude and frequency of upstream floods
7. Estimate stream discharge and volume of maximum expected flood event
8. Rank the probability or potential for flash-flooding and/or debris flows
9. Compile results of flood and debris flow hazard analysis onto a 1:24,000 or larger scale topographic base map with a minimum of four geo-registration points.
10. Produce a standardized multi-layer GIS map with accompanying geo database, scale, and legend.

Complete discussion of the protocol for this tool is in the Implementation Report, Appendix 2

FH2: Map areas demarked by active stream channels (formerly first part of WS3, FM2 and FM3)

There are two objectives to this tool: to map active and inactive areas on the alluvial fan; and to determine existing hazards on the alluvial fan.

In this step, we provide protocol to identify the existing hazards on the fan for purposes of understanding the possible behavior of an alluvial fan during a flood event. The hazards can include or be a consequence of an assortment of elements related to the natural environment, including vegetation type (or presence of vegetation), lithology, geology, topography, climate, and temporary landscape changes, such as those that occur as a result of wildfire. The characteristics of the hazards dictate the mitigation strategies required.

Procedures for this tool are:

1. Acquire pertinent data resources.
   A. Appendix G of 2003 FEMA report "*Guidelines and Specifications for Flood Hazard Mapping Partners*."
   B. 1:24,000 scale topographic maps
   C. Aerial Photographs and Satellite ImageryD. Geologic Maps
2. Identify fan-shaped drainage network on the topographic map.
3. Utilize aerial photographs and/or satellite imagery to deduce truly active segments of the alluvial fan drainage network.
4. Analyze geologic maps of the area (if available).
5. Delineate segments of active channels that have been channelized or otherwise modified by human activity.
6. Conduct detailed field check of features identified above

7. Map the active channels identified in 2, 3, 4, 5, and 6 above onto a standard topographic base with a minimum of four geo-registration points.
8. Produce a standardized multi-layer GIS map with accompanying geo database, scale, and legend.

Complete protocol for this step can be found in the Implementation Report, Appendix 2

FH3 Map Areas Already Disturbed Areas (new tool)

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Step Two: Assess Multiple Hazards and Benefits

Introduction

By this point in the process, it should be clear whether an alluvial fan is present, and what fan-related hazards exist. In this step, the analysis turns to existing non-flood hazards as well as the watershed benefits of the fan area.

Just as the potential hazards on alluvial fans cannot be dismissed, neither can the myriad ecological benefits. Alluvial fans serve vital ecological functions, including sand delivery, groundwater recharge, movement corridors for wildlife and native plants, and nutrient and sediment transport that sustains habitat for sensitive species. The tools in this step highlight those ecological functions and allow planners to place them within the context of the hazards to create a true picture of the costs and benefits of a potential development. Identifying potential public safety hazards associated with development on alluvial fans during the initial planning phase will assist developers, regulators, and the public in minimizing post-development risks and the costs associated with their mitigations.

The alluvial fans of Southern California function as important parts of watersheds. The ecology of alluvial fans is a delicate balance among the varied and often extreme forces that these landscape features are exposed to. Alluvial fans can go through long periods of relative quiet, and then be subjected to dramatic changes caused by floods, debris flows or earthquakes. They are exposed to long periods of dry weather and short periods of often heavy rains. Critical ecological features can exist at very fine scales or across regional zones. Important time frames can be hours to decades. This makes capturing an understanding of this ecology difficult. It is clear however, that the ecology of an alluvial fan is at risk as lands are developed and the landscape changed. And as

the ecological balance is altered the risk to public safety and community sustainability can also be challenged, changed dramatically, or compromised.

Below is a table that lists possible sources of data for identifying non-flood hazards and watershed benefits on an alluvial fan. This is a high-level example of data available; for a detailed listing of resources, see the protocol for AF3 in the Implementation Report in Appendix 2.

Table 1. List of Possible Data Sources Useful in Identifying Alluvial Fan Hazards and Benefits

Data Type	Possible Sources of Data
Topographic Maps	Local, USGS
Surficial Geologic Maps	USGS, California Geological Survey
Soils Maps	NRCS
Aerial Imagery	Local aerial photo archives, on-line aerial imagery archives
Historical documents	Local agencies, Newspapers, town records, personal accounts
Rainfall Data	Local agencies, State Agencies, NWS, etc.
Hydrologic Data	Local Agencies, State Agencies, USGS, etc.

(While the tools in this step identify those factors to consider; full protocols are found in the Implementation Report, Appendix 2)

MH1: Map zones prone to surface rupture of active faults (formerly MH3)

There are two objectives to this tool: **t**o identify surface fault rupture hazard zones near alluvial fans as defined by the Alquist Priolo Act; and **t**o distinguish the 100 ft-wide "no-build" zone from the encompassing 1000 ft-wide "Earthquake Fault Zone" in which further earthquake fault investigations are required before building structures for human occupancy

The Alquist Priolo Earthquake Fault Zoning Act of 1972 was designed to mitigate surface fault rupture hazard by avoiding the placement of human-occupied structures across traces of hazardous faults. The law requires establishment of "Earthquake Fault Zones" encompassing hazardous faults, which are specified as those faults that are "sufficiently active" and "well-defined." A sufficiently active fault exhibits evidence of Holocene displacement

(i.e., movement during the last 11,000 yrs). A well defined fault has a surface trace detectable by a trained geologist.

The Alquist Priolo Act bears on alluvial fan development because many alluvial fans owe their existence to uplift of the adjacent highlands by incremental displacement on an active fault (or faults). Most commonly, such active faults occur at the topographic break and thus transect the upper reaches of a fan near its apex. However, it is not unusual for active fault traces to transect the mid-fan or toe region.

The basic rule is one cannot build within 50 ft of an active fault (structures built prior to 1972 are exempt from this, however). There is a straightforward procedure for identifying active fault traces and locating the 1000 ft-wide "Earthquake Fault Zones" that require further investigation for potentially hidden active fault traces. Simply consult the appropriate 7.5 minute Alquist Priolo Earthquake Fault Zonation map produced by the California Geological Survey.

Procedures for this tool follow:

1. Acquire pertinent data resources and guidelines.
    - A general description of California's Alquist Priolo Earthquake Fault Zoning Act (1972)
    - A detailed PowerPoint presentation explaining the Alquist Priolo Act and methodologies used by CGS geologists to create Alquist Priolo Fault Zonation maps is available
    - Special Publication 42, "Fault-rupture Hazard Zones in California
    - An index to official 7.5 minute Alquist Priolo Earthquake Fault Zonation maps published by the California Geological Survey through 1999, included in Special Publication 42
    - Official Alquist Priolo maps
    - California Geological Survey CDs 2002-01, 2002-02 and 2002-03: Fault Evaluation Reports Prepared Under the Alquist-Priolo Earthquake Fault Zoning Act
    - Technical Guidelines for Evaluating Surface Fault Rupture Hazard (CGS Note 49)
    - Technical Guidelines for Reviewing Geologic Reports (CGS Note 41)
    - A description of the Seismic Hazards Mapping Act (1990)
    - 1:24,000 scale topographic maps (standard base maps for plotting Alquist-Priolo fault zones)
2. Locate study area on the index of official 7.5 minute Alquist Priolo Earthquake Fault Zonation maps
3. Zone all active faults located in study area

4. Map the features identified in step 3, above onto a standard topographic base with a minimum of four geo-registration points.
5. Produce a standardized multi-layer GIS map with accompanying geo database, scale, and legend.

Complete protocol for this step can be found in the Implementation Report, Appendix 2

MH2: Identify unstable soils or sediment prone to amplified seismic shaking, liquefaction, differential settling, or swelling (new tool with parts of MH3)

There are two objectives to this tool: **t**o identify those alluvial fans whose bedrock source areas are likely to yield concentrations of fine-grained sediment (clay, mica, or silt); and to map areas of alluvial fans underlain by fine grained soil or sediment prone to amplified seismic shaking, liquefaction, differential settling, or swelling.

The natural flooding process that drives alluvial fan sedimentation tends to produce thick deposits of sand and gravel with relatively minor proportions of fine-grained particles. This is because a natural sorting or winnowing action associated with high-energy stream flow transports fine-grained clay and silt out to the valley floor, while gravel and sand are deposited closer to the mountain front within the apron of sediment that forms the alluvial fan. Typically, particle size ranges from boulder size at the fan apex to fine gravel and course sand in the mid-fan region to fine sand at the fan toe. Such gravel-sand sediments intrinsically have significant porosity and permeability and therefore drain well. Finer-grained sediments and soils that drain poorly tend to accumulate beyond the toe of the fan in playa lake beds. These localities are notorious for seismic shaking hazards and differential swelling or settling.

However, certain alluvial fans may contain significant accumulations of clay or mica minerals and silt-sized particles. These fans correspond to geologic settings where an upstream bedrock source is composed of shale, siltstone, or mica schist. Alluvial fan sediments eroded from these rock types will contain a higher proportion of fine-grained minerals. Soils developed on undisturbed surfaces of the fan between active stream channels may be very rich in unstable clay minerals.

Procedures for this tool follow:
1. Acquire pertinent data resources.
   A. Guidelines for protecting the public safety from the effects of earthquake-triggered ground failure

B. Seismic Hazards Zone maps, created by the California Division of Mines and Geology, display liquefaction zones and earthquake-induced landslide zones

C. Geologic Maps:

D. Local Geotechnical Reports:

2. Read CDMG Special Publications 117 and 118.
3. Note all zones of potential liquefaction displayed on the appropriate Seismic Hazards Zone map (if this is available for study area)
4. Analyze available geologic maps and seismic hazards zone maps
5. Analyze available geotechnical reports
6. Conduct a detailed field check of potentially hazardous soils identified in 3, 4, and 5
7. Compile results of soil hazard analysis onto a 1:24,000 or larger scale topographic base map with a minimum of four geo-registration points.
8. Produce a standardized multi-layer GIS map with accompanying geo database, scale, and legend.

Complete protocol for this step can be found in the Implementation Report, Appendix 2

MH3: Map Landslide Potential (new tool with parts of former MH4)
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MH4: Map Hazardous Materials (new tool with parts of former MH4)
Placeholder for text to come from Boykin

MH5: Determine Groundwater Quality (new tool)
Placeholder for text to come from Boykin

MH6: Map Wildfire hazards (parts of former MH1-MH4 tools)
Placeholder for text to come from Boykin

MB1: Determine geometry, quantity, and quality of existing groundwater resources (new tool)

There are five objectives to this tool:

- To determine the subsurface geometry of water-saturated gravel and sand aquifers associated with an alluvial fan
- To determine present-day water well levels that demarcate elevation of the water table
- To quantify volume of recoverable groundwater stored in alluvial fan aquifers

- To obtain quantitative aquifer parameters useful for future management of the groundwater resource
- To survey groundwater quality of existing wells, and develop a sense for its special variation

Alluvial fans are preferred environments for groundwater development because their thick gravel and sand deposits are porous and very permeable; hence they are capable of storing large quantities of pore water and transmitting it efficiently to wells. Thicknesses of water-saturated sand and gravel aquifer systems typically range from tens to hundreds of meters. High-energy floods associated with alluvial fan deposition tend to winnow out fine-grained clay and silt particles that generally inhibit the groundwater transmission in unconsolidated sediments. The cumulative effect of this natural fluvial process is to produce a systematic particle size gradation from boulders and cobbles near the fan apex to medium gravel and coarse sand in the mid-fan region to fine sand near the toe **(see illustration)**. All of these sediments provide good aquifers when water-saturated.

Gravel-sand aquifers in alluvial fans are bounded at the top by a gently sloping water table extending from the apex region to the playa lake or valley floor that bounds the toe of the fan **(see illustration)**. The highest point on the water table usually occurs where the trunk stream exits the mouth of the mountain canyon at the fan apex. The water table level is maintained by recharge from surface water, the primary source of which is periodic flooding focused in the primary active channel and its distributary channels. A secondary (but generally minor) source of groundwater recharge is infiltration of rainwater into the surface area of the fan (see also MB2). In areas of long term, extensive groundwater development, the water table may be dramatically lowered due to "drawdown" effects associated with pumping wells (see case study of Borrego Valley, cited below).

Evaluation of groundwater resource in an alluvial fan requires three-dimensional analysis of subsurface data acquired during the drilling and subsequent monitoring of water wells. Available information may be quite limited, with sparse geographic coverage, but it is worth pursuing all potential sources of well data (see below) because each well provides crucial information needed to constrain the subsurface geology and location of the water table. An ideal data set will allow one to generate contour maps showing elevation of the water table and elevation of the bedrock surface that forms the basement of an alluvial fan. From these maps it is straightforward to derive an estimate of the total volume of water saturated sediment. Another important procedure is to construct cross sections (if possible) that display the configuration of gravel and sand deposits. It is not unusual to encounter layers of clay and silt interstratified

with sand and gravel. This is most common in the region between the mid fan and toe, where water table tends to occur at the shallowest depths

Of crucial importance for future management of the groundwater resource is the determination of a representative average value for Specific Yield. This aquifer parameter, usually obtained through pump tests of individual water wells, is the best measure of water volume that one could expect an aquifer to yield. Effectively, one multiplies the total volume of water-saturated aquifer material by the percent value of Specific Yield to obtain the theoretical recoverable groundwater volume. Specific Yield is also a key parameter for predicting the amount of "drawdown" (water table lowering) caused by pumping an individual well or multiple wells at a known discharge rate.

Procedures for this tool are:

1. Acquire pertinent data resources.
   A. 1:24,000 scale topographic maps
   B. Information on specific groundwater basins:
   C. Water well data, including groundwater levels, drilling logs, well completion reports, and pump tests.
   D. Additional information on groundwater levels, drilling logs, well completion reports, and pump tests may be available from local municipal water agencies.
   E. A recent DWR groundwater study of Borrego Valley provides examples of groundwater elevation maps and the variation of water table elevation over a 50 year period.
   F. Examples of the types of geologic information from drilling logs and well completion studies are available in reports on three recent wells drilled by DWR in Borrego Valley:
   G. California drinking water standards:
2. Determine location of study area relative to regional designated groundwater basins
3. Analyze existing groundwater reports and data sets.
4. Utilize contouring methods to map water well data onto topographic base map
5. Construct hydro-geologic cross sections to illustrate aquifer geometry
6. Estimate volume of existing recoverable groundwater resource
7. Estimate the effects of future pumping on lowering of the water table
8. Estimate existing groundwater quality
9. Map the various units identified in, Steps 3, 4, 5, and 8 above onto a standard topographic base with at least four geo-registration points.
10. Produce a standardized multi-layer GIS map with accompanying geo database, scale, and legend.

Complete protocol for this step can be found in the Implementation Report, Appendix 2

MB2: Map Areas Critical to Water Supply Recharge (originally WS5)

There are two objectives to this tool: to identify areas of alluvial fans with greatest groundwater recharge capacity; and to map and rank zones of variable recharge capability on an alluvial fan.

Because alluvial fans are composed of relatively young, coarse sedimentary deposits, they typically allow for rapid infiltration of surface waters that recharge local groundwater basins. In an area with a limited water supply, such as southern California, capturing storm runoff on alluvial fans presents a significant water supply potential. The water recharge capacity is generally greatest at the alluvial fan head, where alluvium is coarse grained; recharge capacity typically decreases toward the distal parts of the fan due to a general decrease in sediment grain size. Recharge is typically limited to direct infiltration of rainfall on fan areas that are topographically higher than adjacent active channels that convey flows from the upland basins. Additionally, groundwater recharge capacity on inactive fan surfaces generally decreases with increasing fan surface geologic age, as the deposits become progressively more consolidated through time. This tool provides a method for evaluating the relative capability of alluvial fan surfaces for groundwater recharge.

Procedures for this tool follow:

1. Acquire pertinent data resources.
   A. 1:24,000 scale topographic maps
   B. Aerial Photographs and Satellite Imagery
   C. Geologic Maps
2. Identify areas of enhanced groundwater recharge.
   A. Analyze the topographic map to identify a fan-shaped drainage network.
   B. Utilize aerial photographs and/or satellite imagery to deduce which segments of the fan-shaped drainage network are truly active.
   C. Study geologic maps of the area (if available) to confirm that the active alluvial channels identified in 2A and 2B are mapped as such.
3. Delineate areas of lesser or zero recharge capability.
   A. Identify areas of the fan covered by moderately to well-consolidated old alluvial fan deposits.
   B. Utilize aerial photos or satellite imagery to subdivide the old alluvial fan deposits into:
      A. areas of sparse vegetation
      B. areas of moderate or dense vegetation.

C. Delineate areas of the fan that have been modified by human activities.

4. Carry out field checks of map units delineated in 2 and 3 above.

5. Rank the Recharge Capability of the mapped zones and apply specific zoning values.

Zone 4: Highest Recharge Capability--Active Holocene alluvial or stream wash deposits

Zone 3: Medium Recharge Capability--Old alluvial fan deposits with sparse vegetation

Zone 2: Low Recharge Capability—moderately to densely vegetated portions of old alluvial fan deposits

Zone 1: Very Low Recharge Capability—graded portions of residential lots or other properties not covered by man-made structures

Zone 0: Zero Recharge Capability—impervious zones covered by paved roads and man-made structures

6. Map the various units identified in 2, 3, 4, and 5 above onto a standard topographic base with at least four geo-registration points.

7. Produce a standardized multi-layer GIS map with accompanying geo database, scale, and legend.

Complete protocol for this step can be found in the Implementation Report, Appendix 2

MB3: Map Risk Reduction Methods (originally WS6)

The objective of this tool is to map where engineered mitigation features such as dams, catchment basins and culverts exist and to determine what jurisdictions are already in place.

Placeholder for procedures

MB4: Map Ecological benefits (replaces WS1, WS2, WS3, WS4, WS8)

There are four objectives to this tool: to identify areas of transition from one ecological setting to another; to identify areas of known habitat for state or federally listed threatened or endangered species; to identify areas of important ecological patterns; and to identify areas supporting important corridors for migration, transit or dispersal for native species of plants, animals and sediments critical to sustain habitat

Alluvial fans provide important ecological functions to the immediate and larger regions of southern California, including sand delivery, aquifer recharge, flood control, and nutrient and sediment transport for riparian habitats. They offer critical connectivity between lowlands and uplands, provide habitat for

sensitive species, while still providing economic and recreational benefits to local and regional communities (AFTF 2007). This tool allows a planner to add the ecological benefits of an alluvial fan into the decision-making process, making the development's true costs and benefits to the entire watershed clearer.

To assist planners, developers and others, AFTF recommends an approach that seeks to map key ecological features that can be combined with mapped flood and multi-hazard layers created from FH and HM tools . This can lead to a composite map that highlights areas on fans where avoiding the risks of hazards may be combined with protecting the beneficial functions of alluvial fans when development is proposed.

The proposed AFTF mapping procedures serve as a core for ecological assessment that capture most if not all of the critical ecological processes at play on alluvial fans. This mapping approach does replace detail environmental analyses required under CEQA or NEPA but provides geospatial information about areas that are least unsuitable for development that a local agency may wish to avoid for any number of reasons. Using a consolidated mapping approach can streamline and facilitate project development and give planners and developers alike a better understanding of the landscape and the ecology that it supports.

The guidelines presented herein are intended to account for both small parcel scale and larger regional scale features, understanding that alluvial fan ecology includes such values of importance that may span beyond the alluvial fan footprint.

The procedure for this tool is:
A. Map areas of discrete transition from one ecological setting to another
B. Map Areas of known habitat for state or federally listed threatened or endangered species.
C. Map Areas of important ecological patterns not otherwise delineated
D. Map areas supporting important corridors of migration, transit or dispersal for native species of plants, animals and sediments that are critical to sustain their habitats
E. Map riparian adjacent areas

Complete protocol for this step can be found in the Implementation Report, Appendix 2

MB5: Identify designated mineral resource zones and classified mineral resource zones (originally WS9)

There are two objectives to this tool: to map areas of alluvial fans containing economic mineral resources, usually sand/gravel aggregate; and to rank the importance of sand/gravel mineral resources in terms of market accessibility and costs/benefits to local communities.

Alluvial fans often contain large quantities of economic sand and gravel deposits, and significant construction aggregate deposits are classified (MRZ-2) on alluvial fans in many counties under SMARA. Alluvial fan deposits may contain economically significant quantities of construction aggregate, even if the fan is mapped as an area of undetermined mineral significance (MRZ-3) in a mineral land classification report. Well-planned and near-source mineral production on alluvial fans can provide materials for construction. The mined lands may also be used for flood management, parks, and open space, sediment disposal, and groundwater recharge areas. Thus, consideration of SMARA-defined mineral resource zones may benefit the integrated Alluvial Fan Task Force (AFTF) model ordinance.

The California Surface Mining and Reclamation Act of 1975 (SMARA) requires the State Geologist to classify land based on the known or inferred mineral resource potential of that land. Classification is the process of identifying lands containing significant mineral deposits, based solely on geologic factors, and without regard to present land use or ownership. The primary goal of mineral land classification is to ensure that the mineral resource potential of lands is recognized and considered in the land-use planning process (CDMG, 2007).

Procedures for this tool are:

1. Acquire pertinent data resources and guidelines.
   A. California Surface Mining and Reclamation Act (SMARA) Mineral Land Classification Reports and Updates
   B. California State Mining and Geology Board (SMGB) Designation Reports
   C. SMGB Guidelines for Classification and Designation of Mineral Lands
   D. The California Mineral Land Classification System
   E. State Defined Mineral Resource Zone (MRZ) Categories and Nomenclature
   F. 1:24,000 scale topographic base maps for plotting mineral resource zones
2. Determine classified mineral resource zone.
3. Identify regionally significant designated mineral resource zones.
4. Process for mineral resources reclassification
5. Additional considerations for ranking importance or value of mineral resources
6. Map the various Mineral Resource Zones identified in 2, 3, and 4 above onto a standard topographic base with a minimum of four geo-registration points.

7. Produce a standardized multi-layer GIS map with accompanying geo database, scale, and legend

Complete protocol for this step can be found in the Implementation Report, Appendix 2

MB6 Map Cultural Resources (formerly WS7)

The objective of this tool is to delineate areas of particular cultural significance. These areas may include archeological sites, landscapes or particular features highly valued by the community, religiously significant sites, or other areas of important watershed resources. Development in these areas should sustain the key cultural values and, where feasible, the specific cultural icons and images underlying the zone designation.

Procedures for this tool need to be written
Protocol for this tool will be placed in the Implementation Report, Appendix 2, when completed.

MB7 Map Raw Land Capacity (new tool)

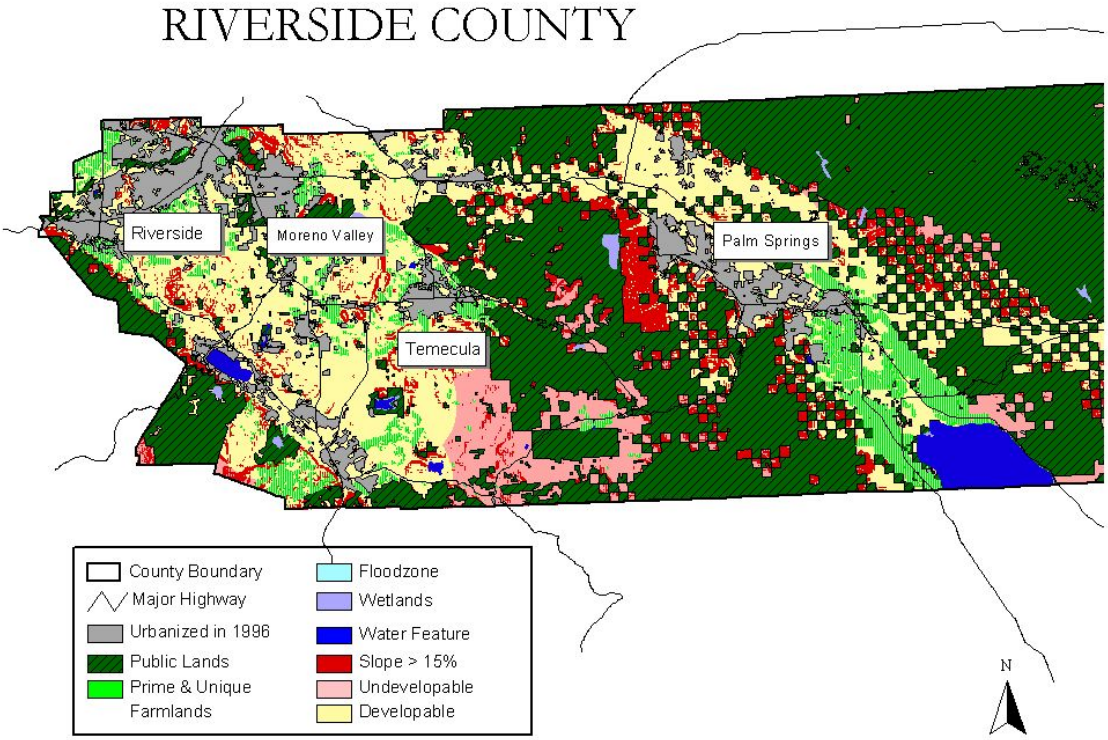
The objective of this tool is to use California Department of Housing and Community Development data to determine development potential.

Developers talk about land that is privately owned, lacks urban services, and has not been previously developed as "raw land." Raw land parcels located at the fringe of existing urban areas are commonly referred to as "greenfield" sites, to distinguish them from "infill sites," which are located within developed urban areas. In theory, California should have ample supplies of raw land. As of 1996, the 35 California counties for which detailed land supply data are available—including all of the state's urban counties—included approximately 3.5 million acres of urbanized land, 32 million acres of public or undevelopable land, and nearly 25 million acres of physically-developable raw land.

To determine how much of these 25 million acres of physically developable land might *realistically* be considered developable, a geographical information system (GIS) and various digital map layers were used to identify and characterize potential development sites. Detailed digital maps and data were obtained from many sources, including the U.S. Geological Survey, the California Farmland Mapping and Monitoring Project (FMMP), the State of California Teale Data Center, the National Wetlands Inventory, FEMA, the U.S. Census Bureau, the California Department of Fish and Game's Natural Heritage Program, and the Gap Analysis Project. The data were assembled for the entire

state, "gridded" into a common system of one-hectare cells, and then separated by county.[3] Because no federal or state agency collects comprehensive data on sites within urban areas, the comparable potential for infill development could not be established.

Sample Map



Protocol for this tool can be found in the Implementation Report, Appendix 2.

Step Three: Pulling it all together for Multi-Objective Outcomes

The object of this step is to combine all the data gathered in the previous steps to create input for the Sustainable Development tool. To illustrate how the four MA tools work together, we use a case study of a developed watershed.

<u>The Multi-Objective Analysis Tools</u>

Introduction

The multi-objective analysis tools consists of two sets of tools:

- Spatial Data Analysis Tools
    - MA1
    - MA2
    - MA3
    - MA4
- Internet Query and Download Tool
    - SDT

Spatial Data Analysis Tools

The MA1-MA4 multi-objective analysis tools allow for all of the considerations developed in Steps 1 and 2 to be used to help determine which specific practices are most suitable for distinct areas on an alluvial fan. The primary objectives of the multi objective analysis tools MA1-MA4 are to simplify and synthesize the spatial relationships between known fan related hazards, other hazards and benefits found on the fan. The resulting Alluvial Fan Land Classification can then be used with the Sustainable Development Table (SDT) to review a range of suitable practices specific to a unique set of land classifications.

Internet Query and Download Tool

The SDT tool contains the design guidelines, BMP's, findings and flood related ordinances (collectively referred to as practices) gathered from various specific plans, LHMP's FMP's etc. The primary goal of the SDT is to organize and carry forward the practices for reuse and repurposing by providing a method for searching for and reporting on relevant practices for a specific fan based on the land classification resulting from MA1-MA4. An important feature of the SDT is that it will return a range of optional practices for a given land classification system allowing local jurisdictions to incorporate local values into the development to a draft ordinance.

Tool Details
MA1

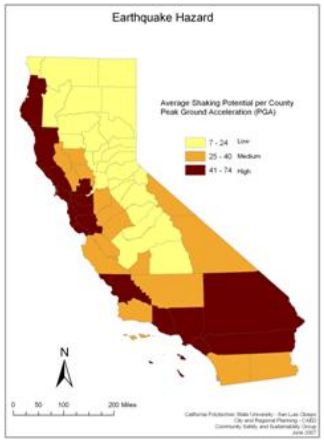
The MA1 tool will simplify and synthesize the results from Tools AF1-AF3 and FH1-FH3. The objectives of the MA1 tool are to create a set of two GIS map layers that define the footprint and context of the alluvial and the known and perceived hazards directly related to the alluvial fan. The foot print layer will display the best known location of the fan footprint and geologic / surface conditions of the fan as well as upland and down stream context for the fan. The known hazards layer will display the active and inactive zones on the fan and other flood / debris flow hazards related to the fan.

The procedures include simplifying the feature classes from the source data organized in steps AF1-AF3 and FH1-FH3 including remotely sourced data, existing GIS data layers, field observations and measurement and the results of hydrologic modeling into high medium and low hazard zones on the fan using GIS spatial analysis tools. A series of metrics are then used to combine the simplified GIS layers into the two final GIS layers.

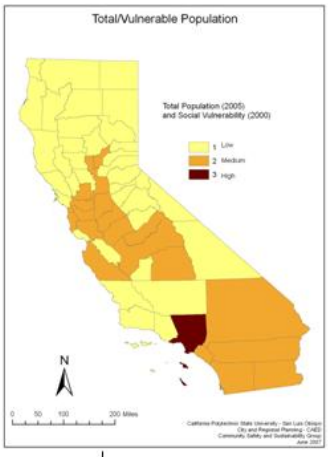
Diagram 6 and metric is and example of how the GIS software combines the individual simplified layers. This example is from the CA State OES 2007 Multi-Hazard Mitigation Plan. This diagram and metric are a typical example of the procedure used in MA2, MA3 and MA4.

6. Map 5.4.8. Earthquake Hazard Risk and Total/Vulnerable Population Evaluation

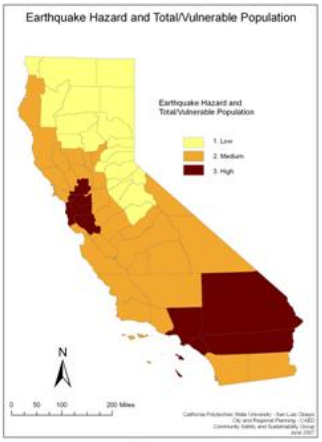
Map 5.4.4. Earthquake Hazard



Map 5.4.3. Total/Vulnerable Population



Map 5.4.8. Earthquake Hazard and Total/Vulnerable Population



Weighted combination		EQ Haz 50%		
		1	2	3
Vuln Pop 50%	1	1	2	2
	2	2	2	3
	3	2	3	3

MA2

The MA2 tool will simplify and synthesize the results from tools MH1-MH6. The objectives of MA2 is to develop a single GIS data layer that displays the multi-hazards found on the fan in a high medium low classification. The high ranking indicating that multiple types of hazards are present in a single

location. Low indicating none or perhaps a low degree of a single hazard for example.

The procedures include simplifying the feature classes from the source data organized in steps MH1-MH6 including remotely sourced data, existing GIS data layers, field observations and measurement into high medium and low hazard zones on the fan using GIS spatial analysis tools. A series of metrics are then used to combine the simplified GIS layers into the final GIS layer.

MA3

The MA3 tool will simplify and synthesize the results from tools MB1-MB7. The objective of MA3 is to develop a set of two GIS data layers that describe the resource, ecological, cultural and aesthetic beneficial values of the fan and locations that are conducive and beneficial for development.

The procedures include simplifying the feature classes from the source data organized in steps MB1-MB7 including remotely sourced data, existing GIS data layers, field observations and measurement into high medium and low hazard zones on the fan using GIS spatial analysis tools. A series of metrics are then used to combine the simplified GIS layers into the two final GIS layers.

MA4

The MA4 tool will simplify and synthesize the results from tools MA1, MA2 and MA3 into a single GIS data layer. The MA4 GIS data layer will display the compound and complex relationships of the combination of known fan hazards (MA1), other hazards (MA2) and know benefits (MA3) associated with the alluvial fan. The MA4 GIS data layer will display these combinations as a polygonal land class unit (LCU) in a range of 1-5 based on capacity, suitability and hazard constraint.

A series of metrics are then used to combine the simplified GIS layers from MA1, MA2 and MA3 into the final MA4 GIS layer. The resulting five land classification units will be cross referenced to each practice contained in the SDT database.

Case Study: Developed Watershed with Alluvial Fans Study (South Orange County)

The case study will illustrate the consequences of flood management on alluvial fans that does not incorporate measures that sustain alluvial fan

watershed functions. Full discussion of the case study can be found in the Implementation Report, Appendix 2.

Once this exercise is complete, the planner uses the Sustainable Development Tool to look at a range of practices applicable to the specific site.

Introduction to the Sustainable Development Tools

Incorporating multiple objectives into the mitigation measures designed to safeguard life and property can provide solutions to more than one regional problem or provide added benefits beyond flood protection. For example, devising a retention or detention area that would contain peak flows on an alluvial fan could simultaneously serve as a groundwater recharge area and/or a debris basin. There have been land development projects that have incorporated facilities such as golf courses that have the dual use of serving as channels that can convey or attenuate peak flows and/or serve as areas that can collect sediments or capture debris during storm events. Other measures may be developed to preserve habitat or migratory pathways for wildlife, while providing flood protection. Defining the boundary between Holocene and Pleistocene deposits with a structure (e.g., a wall) can serve to restrict channel migration and help direct flow in a preferential direction that improves the design of a mitigation measure.

It is valuable to consider ways by which multiple objectives can be integrated with flood protection measures. The possibility of addressing the needs or interests of various parties that may be concerned or impacted by developing a strategy to address multiple objectives in a mitigation measure can improve the land development process. Evaluation of the costs and benefits of the construction and long-term maintenance of a mitigation measure is important at the outset of design.

SDT: Sustainable Development Tool

The primary goal for the AFTF model ordinance is to reduce the loss of life and property caused by the unique risks associated with development on alluvial fans in Southern California. The secondary goal for the model ordinance is to promote ordinances that address multiple objectives.

The protocol for using the Sustainable development tool is:

1. Input data collecting from MA1-MA4 tools into SDT to find preliminary categories of ordinances/BMP's/guidelines that define development practices in alluvial fans.

2. Use SDT Evaluation Guide to rank for its potential for meeting a specific sustainable development objective, as defined by the AFTF
3. Consult the Data Dictionary for definitions of the major and sub types of guidelines available.

AFTF Sustainable Development Tool Evaluation Guide Table omitted—will be in the Implementation Report in Appendix 2. CS: It should be footnoted that the criteria may not be weighted equally by the local jurisdiction.

AFTF Sustainable Development Tool (served in Google Docs) omitted
DRAFT Data Dictionary omitted

Phase Two –Design tools

Introduction

At this point in the process, the sequence of steps required of the local agency and the developer diverge somewhat. For clarity, the AFTF has split Phase Two into considerations of the local planner, and those of a potential developer.

Local Agency planner workflow

The local agency planner using the information gleaned from the Sustainable Development Tool after completion of Step 1-3, is now prepared to draft a site-specific ordinance that integrates sustainable development practices with local values. For example, if the proposed development falls into a hazardous zone on the fan, the existing sustainable development practices may be more restrictive to property rights than the local agency is comfortable with. Nevertheless, the SDT will offer a range of options from which to choose and the local agency can determine which are best for its purposes. From those options, the local planning agent would pick the one most aligned to the agency's values.

Once the local agency planner uses the SDT tool to write a site-specific plan, she will need to consider how a potential development will affect local government, and will move to the Design and Construction tools: Asset Management of Flood Facilities (DC1) and Establish Procedures and Protocols for Evaluating Evacuation Routes (DC2). At this point, the local agency planner's workflow is complete. Once this is done, the agency will need to consider who will be responsible for implementing the guidelines, based on the agency's existing permit review process.

Developer workflow

A developer will have used the same process to query the Sustainable Development database to gather information needed for a better design and will have all the information needed for a rational design with the added confidence that the guidelines have already been vetted.

At this point, the developer needs to determine whether the design requires major flood management engineering. If it does require major engineering, a set of eight Economics tools is listed below to help them consider long-term funding options. If the development does not require major flood management engineering, the developer will use only a subset of those tools. After the engineering evaluation and funding options are considered the developer should consider the Design and Construction tools for long-term financing options.

DC1: Asset Management of Flood Facilities (formerly DC2)

The object of this tool is to evaluate the potential impact to local government from substantial new development on an alluvial fan.

Local governments will be responsible for providing Public Works to new developments in alluvial fan areas. Among the greatest drawbacks of alluvial fan development is the potential for serious flooding, even from relatively minor isolated storms. Alluvial or high-velocity debris flows are unpredictable and can cause great damage from the amount of debris they carry. Other potential hazards of alluvial fans include: wildfires, debris flows, erosion, seismic issues, and liquefaction.

The process recommended by the AFTF to evaluate the potential local government impact from a substantial new development in an alluvial fan area is listed below. It is based on the U.S. Environmental Protection Agency's work in regards to Asset Management of water systems.

An outline for the process follows:

1. Identify current and proposed state of the flood management system.
2. Establish Appropriate Service Levels for the Facilities.
3. Determine Critical Levels of Facility Performance.
4. Establish Minimum Life Cycle Activities and Associated Costs.
5. Establish Long Term Funding Strategy.

The protocol for this step can be found in the Implementation Report, Appendix 2

DC2: Establish Procedures and Protocols for Evaluating Evacuation Routes (formerly DC3)

Local governments will be responsible for providing Public Works functions within new developments in alluvial fan areas. Among the greatest drawbacks of alluvial fan development is the potential for serious flooding, even from relatively minor isolated storms. Alluvial or high-velocity debris flows are unpredictable and can cause great damage from the amount of debris they carry.

Those potential hazards require various response strategies and management approaches at the local level. Most evacuation plans focus on moving residents safely out of an affected area and moving emergency personnel in. These plans often do not take into consideration the movement of public works personnel and equipment into the affected area to remove debris, clear roadways, and to install temporary protection measures around threatened properties to prevent additional loss. The lack of planning for this part of the evacuation process can leave local governments unprepared logistically, and financially.

The process recommended by the AFTF to incorporate local debris management in master planned projects is listed below:

1. Identify and assess all proposed roadways and access areas for adequacy.
2. Review Locations of Adjacent Facilities.
3. Determine Conflict Points or Areas that May Need Special Attention.
4. Ensure Appropriate Traffic Flow Patterns for Debris Removal.
5. Identify Potential Diversion Routes for Debris Flows.

The protocol for this tool can be found in the Implementation Report, Appendix 2

Introduction to the Economics tools

Economic history and long-term economic issues regarding development on alluvial fans

- Flood damage costs are increasing, not only on alluvial fans but downstream alluvial floodplains.
- Flood damage costs in Southern California have increased commensurate with new development.
- While new developments contribute to flood management facilities, property tax revenues are the only reliable source for operations, maintenance & replacement.

- Property tax revenues are outpaced by rising construction costs for operations, maintenance & replacement
- There is a consistent pattern of periodic flooding on alluvial fans and downstream alluvial floodplains (developed and undeveloped).
- Large amounts of rain in a given year do not necessarily trigger flooding on alluvial fans.
- Very damaging floods have been triggered by small isolated rain events.
- High high-debris- velocity, debris laden flows on alluvial fans are more often triggered by a series of storms following wildfires at higher elevations than alluvial flooding events.
- Costs of debris removal must be adjusted to current dollars and assume rapidly escalating energy costs over time. It should be assumed that debris removal costs will inflate much faster than the inflation rate from rapidly escalating energy costs and increasing demand for debris storage space.
- Flooding on fans has contributed to major damage to structures not only on fans but also on downstream alluvial floodplains.

The economics tools include:

- Econ1 Establish appropriate level of hazard protection (formerly FM4)
- Econ2 Benefit analysis of development vs. public safety risks (formerly Econ1)
- Econ3 Estimate long-term costs of alluvial fan development (formerly Econ2)
- Econ4 Evaluate flood risk (formerly Econ3)
- Econ5 Financial strategies for long-term maintenance of flood management facilities (formerly Econ4)
- Econ6 Identify local land use planning tools (formerly Econ5)
- Econ7 No Adverse Impact planning tools (formerly Econ6)
- Econ8 Apply for bond funding for regional alluvial fan projects (formerly Econ7)

The developer will use Econ1 tool to determine if major engineering of structures is needed for flood protection. If it is, she will use the Econ 2-8 tools to learn about the range of long-term financing options available. If there is not major structural engineering required, the developer will use only Econ1, 2, 4, 6, 7 and 8.

ECON1: Establish appropriate level of hazard protection (formerly FM4)

The objective of this tool is to determine what mechanisms are required in the design to protect from the one-percent-chance flood.

The 100-year peak flow (or the flood with a 1 percent probability of occurring in a given year) is the minimum flow that needs to be considered in developing flood protection measures. There are circumstances where flows greater than the 100-year peak flow may need to be considered. The NRC Alluvial Fan Flooding report states "…for regulatory purposes alluvial fan flooding is a flood hazard that on active parts of alluvial fans has a 1 percent chance of occurrence, and it is identified by flow path uncertainty and deposition and erosion below the hydrographic apex." In that light, the appropriate level of hazard protection would incorporate mechanisms that consider these elements. Establishing whether debris flows may occur on an alluvial fan is also a major consideration to formulate the appropriate level of hazard protection.

The procedure for this tool is:
Needs developing

ECON2: Benefit analysis to weigh development benefits against public safety risks (formerly Econ1)

The objective of this tool is to give developers and local agency planners a clear idea of a proposed developments potential disaster clean-up costs versus its housing benefits.

The key benefit of alluvial fan development is increased housing services and the attendant economics benefits. However, these benefits should be weighed against the costs that may be incurred such as: flood protection infrastructure cost, decreased groundwater recharge, the costs of increased fire protection, loss of ecosystem function affecting critical habitat and open space lost in the closest proximity to the built environment that has a particularly high value to residents.

Because these costs are usually incurred several years after development, they may not be immediately obvious at the time of the decision-making over development on alluvial fans. A net benefits analysis, even a qualitative analysis, can help identify the areas of an alluvial fan that are not likely to yield net benefits to society. We recommend that localities use the flood, fire, and ecosystem area delineations contained in the other local planning tools and conduct a qualitative net-benefit analysis for the different delineated areas.

A key objective of an economic study, or net-benefit analysis, is the identification of elements of the development plan, usually corresponding with specific areas on the alluvial fans, where these costs may outweigh the benefits. An economic net-benefit analysis should examine the separate components of the development plan to identify where changes can be made that preserve the majority of the benefits of development while reducing costs.

A net benefits analysis, even a qualitative analysis, can help identify the areas of an alluvial fan that are not likely to yield net benefits to society. We recommend that localities use the flood, fire, and ecosystem area delineations contained in the other local planning tools and conduct a qualitative net-benefit analysis for the different delineated areas. General estimates for the cost of additional flood protection, loss of water resources, loss of ecosystem values, and loss of open space can be compared with the net real estate value generated by development to identify those areas where development benefits clearly outweigh the costs, and vice versa. This qualitative analysis should be sufficient to identify those areas of fans that are clear development winners and clear development losers.

Thus, local agencies should accurately identify, either quantifiably or qualitatively, the different types of benefits and costs that will occur as a result of additional fan development, taking into account:

- Public safety
- The incidence of benefits and costs among different parties, including:
- Property owners
- Local government
- State government
- The timing of benefits and costs, including:
    - Short-term
    - Long-term

Costs are to be broadly defined to include not only those directly associated with the development, but also the "opportunity costs" of foregone uses and benefits of the alluvial fan, including:

- Habitat values
- Ground water recharge values
- Open space/recreational values
- Flood management values
- Etc.

ECON3: Estimate long-term costs of alluvial fan development (formerly Econ2)

A variety of facilities and managed areas are likely to need continuing funding for operations and maintenances on a developed alluvial fan. Flood control and water quality infrastructure will need maintenance and periodic rehabilitation. Open space, fire breaks, and trails will also need oversight and maintenance. There may also be other geologic hazards due to faults or erosive terrain that necessitate oversight, monitoring, and maintenance on facilities. Finally, if the development includes area to preserve habitat then there will be a need for funding to maintain that habitat. Here we provide information to help local communities and developers plan for those continuing costs.

Estimation of continuing costs should be conducted for each separate area of the alluvial fan development (as described in accompanying materials). By examining the life-cycle costs of developing on the different areas of the fan, stakeholders can determine whether the development of one portion of the alluvial fan is responsible for a disproportionate share of the costs.

Complete discussion of this tool can be found in the Implementation Report, Appendix 2

ECON4: Evaluate flood risk based upon hydrologic, hydraulic, geotechnical and economic inputs (formerly Econ3)

Software models are available for evaluating flood risk based upon hydrologic, hydraulic, geotechnical and economic inputs. Although most of these have been developed for riverine or coastal analyses, some should be adaptable for evaluating alluvial fan flood risks.

The recommended procedures for this tool are:

1. Consult the FEMA HAZUS-MH (Multi Hazard)
   Flood Loss Estimation Model
   Earthquake and hurricane wind assessment models
2. Consult FEMA Mitigation BCA Toolkit (Version 3.0, July 2006).
3. Consult Flood Rapid Assessment Methodology (FloodRAM)
4. Consult Army Corps of Engineers' Hydrologic Engineering Center Flood Impact Analysis (HEC-FIA) to estimate flood event damage and casualties.
5. Use GIS models for flood assessments

A complete discussion of this tool can be founding the Implementation Report, Appendix 2.

ECON5: Identify financial strategies for long-term maintenance of flood management facilities (formerly Econ4)

Continuing financial support for upkeep, maintenance, and evaluation of facilities and safety practices is critical for maintaining public safety on alluvial fans.

Development on alluvial fans should provide a vehicle for the long-term financing of upkeep and maintenance of the capital projects that ensure public safety. In addition, because of the uncertainties inherent in development on alluvial fans, it should be recognized that either new capital projects or significant changes to original projects may eventually be necessary. Financial and governmental structures should be set up at the time of original development to facilitate continuing evaluation of public safety concerns on the alluvial fan.

Fee levels should reflect the costs generated by particular parcel. Different areas of alluvial fans may generate differing levels of operations and maintenance costs. For example, developments on inactive portions of alluvial fans may need relatively low operations and maintenance expenditures to ensure their safety, while development on more active portions of the fan may need considerable expenditures. The fee levels should de differentiated so that developed parcels on areas of the fan that need significant infrastructure (and therefore have high O & M costs) are higher than parcels that need less O & M expenditures to ensure their safety.

The developer shall assist in setting up a local funding structure that covers the estimated future costs of maintenance on flood control and other public safety practices.

Funding structure alternatives are:

1. Geologic Hazard Abatement Districts (GHADs),
2. Assessment Districts
3. Mello-Roos Community Funding districts (CFDs).

More complete discussion of these financing options can be found in the Implementation Report in Appendix 2

ECON6: Identify local land use planning tools (formerly Econ5)

Many areas on alluvial plains have significant water, open space, ecological, or public safety uses. However, it may be prohibitively expensive to purchase these areas directly and downzoning these areas to prohibit or restrict

development may unduly limit private ownership rights. In these cases, tools such as transferable development rights or purchase of development rights allow protection of the land at lower cost to public agencies and without curtailing private ownership rights. Markets in development rights may also enhance cooperation between public and private entities in the preservation of areas that provide a number of benefits in their undeveloped state.

Transferable Development Rights (TDRs) allow landowners sell the development rights to their property in perpetuity. These rights are purchased by other landowners to allow development above typical zoning development limits. A number of counties and cities have developed programs for transferable development rights that successfully protect open space, aquifers, and ecologically valuable areas. In California, the Lake Tahoe and Santa Monica areas have successfully implemented transferable development rights.

Purchase of Development Rights (PDRs) can be implemented on its own or in conjunction with TDR programs. In a PDR program public agencies (and occasionally private institutions) buy development rights from landowners in areas where development is to be limited. This can be less expensive than outright buying parcels, especially where other uses of the land, such as agriculture, are compatible with open space, water supply, or other values.

More detailed discussion of these options is in the Implementation Report, Appendix 2

ECON7: No Adverse Impact planning tools (formerly Econ6)
Editing Note from Plenary 7

- ECON6 (p 89)

Monitoring
"Actions to be taken"
1. If fully mitigate, cannot fully afford project
2. Absorption losses
3. Ability to realistically build has to be taken into account. (Rick 32)

As discussed in planning tool ECON 1, the key benefit of alluvial fan development is increased housing services and the attendant economic benefits. However, these benefits should be weighed against the costs that may be incurred not only on-site, but also on adjacent properties and others further downstream. Any development that is approved on alluvial fans should be done so with the objective of reducing adverse impacts upon other properties.

The Association of State Floodplain Managers (ASFPM) has proposed a series of No Adverse Impact (NAI) strategies to reduce adverse consequences of floodplain development. The objectives of these strategies are to:

- Ensure that the actions of any community or property owner do not adversely impact others and
- Incorporate multi-objective and watershed planning principles.

NAI does not mean "no development" but rather that any adverse impact caused by a project must be mitigated, preferably based on a community or watershed-based plan.

The ASFPM has identified basic, better and NAI (i.e., the "best") strategies for these categories:

- Hazard identification,
- Education and outreach,
- Planning,
- Regulations and development standards,
- Mitigation,
- Infrastructure, and
- Emergency services.

The benefits of adopting these strategies include:

- Reduce flood losses over time in your community,
- Reduce likelihood of your actions increasing flood damage to others,
- Reduce challenges and lawsuits,
- Receive recognition through the Community Rating System,
- Incorporate multiple objectives and
- Protect natural resources and values of floodplains.

For more information on the ASFPM NAI strategies, visit the ASFPM website at: http://www.floods.org/home/default.asp or the California Department of Water Resources Economics website (Comprehensive Floodplain Management Workshop) at:
http://www.economics.water.ca.gov/studies.cfm.

ECON8: Apply for bond funding for regional alluvial fan projects

Bonds are time sensitive, so discussion of specific bonds is impractical in this report. However, to help the planner consider the range of options available generally, we provide examples of current bond fund opportunities. They include:

- Proposition 1E Flood Corridor Protection Program
- Proposition 84 Chapter 3 Flood Protection Corridor Projects

Funding
- Regional Flood Management Planning
- Urban Streams
- Subventions
- Local Levee Assistance

More complete discussion of the funds available currently, as well as key agency web sites to consult for possible funding, can be found in the Implementation Report, Appendix 2.

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