APPLYING FEMA

ALLUVIAL FAN FLOOD HAZARD THREE STAGE DELINEATION APPROACH

FOR FLOOD PROTECTION PLANNING / DESIGN

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Presentation Program Outline

1. Background Countermeasures Planning & Design Considerations
2. Alluvial Fan Floodplain Hydraulics for Countermeasure Design
3. Alluvial Fan Flow Path Uncertainty
4. CASE STUDY
   Palm Creek Ranch (Thousand Palms, CA)
5. CASE STUDY
   Flood Protection System Design Program / Specialized Features
Background Countermeasures
Planning & Design Considerations
Alluvial Fan Hazards & Design Issues for Design

- Uncertainty of flow depths (R&U analysis)
- Inundation extents / flow direction / impingement
- Sediment deposition
- Scouring and undermining
- Impact forces
- Channel avulsions and entrenchments
- Hydrostatic and buoyant forces
- High velocities
- Unpredictable flow path (R&U analysis)
- Flooding from both debris and water flows
“Whole Fan” Solutions vs. Localized Protection – Structural Countermeasures
Structural Countermeasures for Alluvial Fans – Basic Building Blocks

**Primary Building Block Category**

- **Collection / Diversion**
  - BASINS
  - LEVEES – TRAINING
  - COLLECTION CHANNELS
  - GROINS
  - DEBRIS BARRIERS

- **Conveyance**
  - CHANNELS
  - GRADE CONTROL STRUCTURES
  - GUIDE BANK / CONFINING LEVEES

- **Dispersion**
  - SPREADING CHANNELS
  - BASINS / LATERAL WEIRS
  - DISPERSION STRUCTURES
Standard Alluvial Fan Structural Countermeasures

- Debris / Detention Basin
- Levees / Flood Walls
- Channelization
- Drop Structures
- Dike (Storage)
- Elevation Structures
- Debris Barriers
- Street Orientation
Effectiveness of Alluvial Fan Structural Countermeasures for Different Hazards

<table>
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<th>MANAGEMENT TOOLS</th>
<th>Inundation</th>
<th>Sediment Deposition</th>
<th>Scour / Undermining</th>
<th>Impact Damages</th>
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Basic Countermeasure Planning and Design Process

Data Collection
- Sediment
- Mapping
- Geology
- Historical Geomorphic Data

Baseline Technical Analysis
- Watershed Hydrology
- Sediment Delivery / Transport
- Sediment Yield
- Bulking Factor

Field Investigation
- Sediment Data Collection
- Geomorphic Mapping

Alluvial Fan Floodplain Analysis
- FEMA 3 Stage Delineation Process
- Floodpath Uncertainty
- Hydrologic Analysis
- 2-D Hydraulic Modeling Alternative Floodpath Scenario

Concept Alternative Formulation
- Alternative Countermeasures
- Layout / Geometry
- Maximum Flowrates
- Existing Baseline Inflow/Outflow Hydraulic
- Sediment Delivery
- Facility Sizing
- Sediment Transport Capacity

Alternatives Assessment/Evaluation
- Freeboard
- Scour Protection
- Armoring
- "NO" Hydraulic Impacts Validation
- Drainage Law
- Maintenance/Access Features

Recommended Alternative Refined Analysis
- Hydraulic Performance
- Impacts Analysis
- Sediment Transports
- Armoring / Scour
- Costs
Alluvial Fan Floodplain Hydraulics for Countermeasure Design
Conventional Alluvial Fan Floodplain Mapping Approaches

FEMA - FIRM ALLUVIAL FAN HAZARDS PROBABILISTIC APPROACH

FRENCH - MODIFIED FEMA METHODOLOGY - PROBABILISTIC

APPLICATION OF APEX FLOW
Issues with Application of Conventional Analytical Solutions
Background FEMA 3-Stage Approach

STAGE 1
Recognizing and Characterizing Alluvial Fan Landforms
- Is the landform a sedimentary deposit composed of alluvium or debris-flow deposit?
- Does the landform have the shape of a fan?
- Is the landform located at a typographic break?
- Where are the lateral boundaries of the fan?

STAGE 2
Defining Areas of Active Erosion and Deposition on Alluvial Fans
- What parts of the alluvial fan are still active?

STAGE 3
Defining Areas Affected by the 100-Yr Flood on Active Parts of Alluvial Fans
- On what parts of the active alluvial fan is alluvial fan flooding occurring
Alluvial Fan Flow Path Uncertainty
Alluvial Fan Flowpath Uncertainty
Avulsions Issues Complicating Alluvial Fan Flood Hazard Analysis

- CATCHMENT
- CONFINED VALLEY
- ALLUVIAL FAN
- FORMER CHANNELS
- CURRENT CHANNEL

Development of an Avulsion:
1. OLD RIVER COURSE
2. NEW RIVER COURSE
Avulsions Issues Complicating Alluvial Fan Flood Hazard Analysis

- Uncertain and changing flow distribution downstream of avulsions
- Continually changing channel and overflow topography
- Uncertain and changing flowpath location during floods
- Flooding and sedimentation hazards in areas previously not in active floodplain
- Abrupt change in channel position that is unpredictable and uncertain
Flowpath Uncertainty Modeling using Alternative “Virtual Levees”

- Objective of levee to force flooding in different directions simulating avulsions
- Virtual level scenarios were optimized to direct flow from identified bifurcation point to a different area of the fan because of morphology.
- Lengths of levees varied at each location in order to achieve flow diversion
- Aligned at moderate angles prevent ponding
Case Study – Palm Creek Ranch
Thousand Palms, CA
Alluvial Fan Topographic Features – Multiple Coalescing Fans
Regional Watershed Map to Alluvial Fan Apexes
Mapped Boundary Extents of Different Alluvial Fans

Legend

Fan Boundaries
- CP-10
- CP-11
- CP-12
- CP-13
- CP-14
- CP-15
- CP-21
- CP-8
- CP-9
FEMA FIRM Defining Flood Hazards
Regional 2-Dimensional Hydraulic Model – Coarse Grid

Legend

- Maximum Flow Depth in ft
- 0.0 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 15.0
- 15.0 - 20.0
- > 20
Long Term Regional Flood Protection Master Plan

Reach 1 Levee

Reach 2 Levee

Reach 3 Levee and Excavated Channel (L&C)

Reach 4 Levee and Excavated Channel (L&C)
Results of Stages 1 and 2 Analyses

Stage 1 – Landform – Alluvial Fan Identification

Stage 2 – Active / Inactive
Flow Uncertainty Using Virtual Levees Simulating Avulsions
Examples of “Virtual Levee” Scenario Development

- March 2015
- August 2011
- April 2017
- Sept 2011
2-Dimensional Floodplain Hydraulic Model Extents

**Coarse Grid Model** – Grid Element Size = 10m square

**Fine Grid Model** – Grid Element Size = 2 m square
Scenario No. 1 – Virtual Levee Configuration

Legend
- Concentration Points
- Levees
- Project Boundary
Scenario No.1 – 100-year Max Flood Depths 2D Model Results
Scenario No. 2 – Virtual Levee Configuration

Legend:
- Concentration Points
- Levees
- Project Boundary
Scenario No.2 – 100-year Max Flood Depths 2D Model Results
Scenario No.2 – 100-year Max Velocity

Legend
- Concentration Points
- Levees
- Project Boundary

Fan Maximum Velocity ft/s
- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 5.0
Scenario No. 3 – Virtual Levee Configuration

Legend
- Concentration Points
- Levees
- Project Boundary

Points:
- CP9
- CP10
- CP11
- CP13
- CP14

Boundaries:
- Project Boundary

Map showing the configuration of concentration points and levees within the project boundary.
Scenario No.3 – 100-year Max Flood Depths 2D Model Results
Scenario No. 3 – Virtual Levee Configuration
Scenario No. 4 – 100-year Max Flood Depths 2D Model Results

Legend
- Concentration Points
- Levees
- Project Boundary
- Fan Maximum Depth ft

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 5.0

Points: CP9, CP10, CP11, CP13, CP14
Case Study – Flood Protection System
Design Program / Specialized Features
Primary Design Considerations

**California Drainage Law**
- Flow Distribution
- Mitigate Hydraulic Impacts

**Level of Flood Protection**
- Detailed Water Surface Profile

**Countermeasure Erosion Protection**

**Sediment Transport**
- Scour and Deposition
Detailed Design Process for Local Flood Protection System

1. Regional modified 2-dimensional baseline existing hydraulics conditions model – fine grid model

2. Define flow distribution along all project boundaries – inflows and outflows
   a. Subdivide into small segment based on 2-D depths / flow distribution

3. Preliminary layout of concept & facilities
   a. Achieves all desired primary objectives
Detailed Design Process for Local Flood Protection System

4. HEC-RAS water surface profile model all channels detailed hydraulic parameters
   a. Subdivide into small segment based on 2-D depths / flow distribution

5. Trial and Error adjustments of channel geometry and lateral channel weir elevations to match outflows / unit flow at boundaries

6. Analyze sediment delivery and sediment transport of channels for potential deposition
An upper landowner is entitled to discharge surface water from his land as the water naturally flows. If he modifies the natural flow, he is liable for any damage done to a lower landowner unless the lower landowner had acted “unreasonably” in altering the natural drainage over his land. The determination of reasonable or unreasonable is a question of fact to be determined by the court in each case

• No diversion of flows to adjacent or downstream property owners
• Cannot increase level of flooding to adjacent property owners
• Cannot increase erosion downstream
• Must return flows at the downstream end of property to same as the existing conditions (both depth and velocity)
Flow Distribution Analysis – Scenario No.1

Q-Inflow = 2,378 cfs
Q-outflow = 2,236 cfs
Flow Distribution Analysis – Scenario No.2

Q-Inflow = 3,307 cfs
Q-outflow = 3,303 cfs
Flood Protection Design Concept

ALLUVIAL FAN INFLOWS

CONVEYANCE CHANNEL

COLLECTIVE CHANNEL

DISPERSION CHANNEL

RETURN OUTFLOWS
Initial Hydraulics Designed to Achieve Outflow Flow Distribution

Flow Distribution Channels

HEC-RAS Systems Models

Legend
- Project Boundary
- Maximum Flow Depth (ft)
  - 0.0 - 0.25
  - 0.25 - 0.5
  - 0.5 - 0.75
  - 0.75 - 1.0
  - 1.0 - 1.5
  - 1.5 - 2.0
  - 2.0 - 2.5
  - 2.5 - 3.0
  - 3.0 - 3.5
  - 3.5 - 4.0
  - 4.0 - 4.5
  - 4.5 - 5.0
  - > 5.0

EFFECTIVE DISCHARGE
A to B = 285 cfs
S to T = 1491 cfs
R to S = 224 cfs
R to Q = 1322 cfs
per 10/5/2016

= 100 yr Scenario 2
Existing Condition
10/5/2016
Analytical Engineering Planning Tool for Weir Hydraulics / Flow Balance

**CHANNEL SIZING / WEIR PLANNING TOOL**

<table>
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<th>Flow Rate (Q)</th>
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- TOP CHANNEL FREEBOARD
- LATERAL WEIR (OUTFLOW)
- CONVEYANCE DISPERSION CHANNEL

**FLOWRATE MATCHING (Q)**

**HYDRAULIC MITIGATION (D,V)**

**2-D FLOODPLAIN MODEL HYDRAULICS**

**FLOODPLAIN FLOW DISTRIBUTION**

**HEC-RAS MODEL HYDRAULICS DATA**
Complex Channel Layout Solution to Achieve Flow Distribution Objective
Collection / Conveyance / Distribution
Channel Design Considerations

Bank Revetments Only (earthen bottom)
• Hydraulic shear resistance and abrasion resistance at invert
• Abrasion resistance
  • Sacrificial wearing surface (additional concrete thickness)
  • Wear cones (measures)
• Stable channel slope
• Critical depth for supercritical flow

Fully Lined Channels & Partially
• Freeboard for “conveyance” channels only, depth matching for collection / dispersion channel
• Abrasion resistance
  • Sacrificial wearing surface (additional concrete thickness)
  • Wear cones (measures)
• Super-elevation of curves
• Confluence hydraulics junction

TYPICAL CHANNEL SECTION WITH ARMORED SIDES
1. Ability to address flowpath uncertainty using “virtual levees” addresses fan geomorphology

2. Provides effective sensitivity analysis to more realistically provide hydraulic parameters for flood control facility design

3. Conservative design data since “virtual levees” provide 100% diversion/blockage of flows

4. Urban development layouts on alluvial fans must recognize need to meet drainage law requirements as part of the initial planning and cannot be an afterthought.