Sun Valley

Area Drainage Master Plan

Step 2

Proposed Alternatives
Report

Volume 1

Flood Control District of Maricopa County

September 2006

SUN VALLEY AREA DRAINAGE MASTER PLAN

STEP 2 PROPOSED ALTERNATIVES REPORT
VOLUME 1

Flood Control District of Maricopa County

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ENCLOSED DATA CD INCLUDES:

- **Digital Copy of Report in PDF Format**
- **GIS Shapefile Coverages of Project Elements**

1 ABSTRACT / EXECUTIVE SUMMARY

Structural and non-structural alternatives were developed and evaluated as part of Step 2 of the Sun Valley Area Drainage Master Plan (SVADMP). This is the second of a three-step process to develop a drainage master plan for the Sun Valley area. Four flood control alternative strategies were identified in Step 1 of the ADMP process. Those four strategies were further refined in Step 2. The refined alternatives included both non-structural and environmentally friendly, aesthetically compatible structural flood control measures.

In order to achieve this refinement, the area was divided into seven geographic sub-areas based on the type and nature of flooding and the distribution of alluvial fan landforms in the study area. Seven different flood control alternatives were developed and evaluated including apex strategy variations including avoidance, on-line and off-line detention basins, and conveyance. Earthen and concrete excavated channels were also compared with a leveed natural corridor for the downfan conveyance structures. Multiple corridor alignment alternatives were also investigated for four of the six piedmont sub-areas. Non-structural approaches were incorporated wherever possible.

Figure 1 Sun Valley Piedmont

Figure 2 White Tanks Mountain Range

Engineering and landscape compatibility enhancement costs were estimated for all of the proposed alternatives piedmont sub-areas. The proposed alternatives were evaluated for their flood control function, economic costs, environmental impacts, permitting issues, visual and aesthetic characteristics, and recreation and multiple-use opportunities. Preference for natural leveed corridors downstream of on-line detention basins along multiple alignments was expressed by the project team, stakeholders, and the public for the piedmont sub-areas.

For the area north of the CAP, a number of flood-related issues were identified and recommendations made. In particular, stock tanks and the flood control facilities associated with Luke Auxiliary Field No. 4 should be removed or improved to current engineering standards before development occurs downstream. In addition, floodprone areas including some small alluvial fans should be avoided or at a minimum addressed in detail before development plans are approved in this area.

The recommended alternatives will be carried forward for further refinement of the engineering elements and the cost estimates in Step 3. Special attention will be given to maximizing non-structural, floodplain management approaches along the preferred leveed corridor alignments. Stakeholders and the public will continue to be consulted as to their feedback in attempt to incorporate existing and imminent developer plans into the drainage master plan for the Sun Valley area.

2 INTRODUCTION

2.1 Report Organization

The Step 2 Proposed Alternative Analysis Report is presented in seven (7) volumes. Volume 1 provides an overview of the ADMP, explains the ADMP process and the alternatives analysis, summarizes the Step 2 evaluation and results, and provides recommendations for the Step 3 refinements to the recommended alternative. Volume 1 also provides a discussion of general area-wide flood control issues and potential solutions as well as specific issues and potential solutions for the area north of the Central Arizona Project Canal. The so-called North of CAP sub-area is included in Volume 1 for two reasons: first, the sub-area is not dominated by large alluvial fans like the piedmont sub-areas in the remainder of the study area; second, the recommendations for the North of CAP sub-area are predominantly non-structural in nature.

Volumes 2 through 7 present the proposed alternatives for the piedmont sub-areas as follows:

2) CAP (Volume 2),

3) Wagner Wash (Volume 3),

4) Hassayampa River (Volume 4),

5) White Tanks Wash (Volume 5),

6) FRS #1 (Volume 6), and

7) FRS #2 & #3 (Volume 7).

The alternatives presented in Volumes 2 though 7 are primarily structural in nature. Therefore, the discussion of design methods, calculations, and results are more involved, and require additional information in their presentation. Volumes 2 through 7 also include site specific data, hydraulic analyses, and cost estimates for each of the proposed alternatives.

It is intended that each Volume of the Step 2 report be able to stand alone so that a reader, such as an interested stakeholder, unfamiliar with the ADMP, or uninterested in other sub-areas, can understand the overall study as well as the details of an individual sub-area of particular interest to them. Excessive detail associated with the design calculations are left out of Volume 1 in order to provide a more digestible document for the reader interested in the Proposed Alternatives Analysis as a whole. The advantages of this type of report organization are:

- The reduction of reproducible materials required for interested users or stakeholders.
- It provides a condensed overview of the ADMP process and Proposed Alternatives Analyses.
- It narrows the focus to a specific sub-area while still providing an overall comprehensive summary of the Step 2 process and Alternatives descriptions.

2.2 Project Background

The Sun Valley area, located in western Maricopa County, Arizona, is presently experiencing the first stages of accelerated urbanization (Figure 3). Future development is anticipated to occur on the largely undisturbed alluvial fans and piedmont surfaces comprising the western slope of the White Tank Mountains (Figure 4). The upland areas and adjacent watershed drain to the Hassayampa River to the west and the Buckeye Flood Retarding Structure (FRS) Numbers 1, 2, & 3 along Interstate 10 to the south.

The purpose of the SVADMP is to develop a conceptual drainage plan to serve as a roadmap that jurisdictional authorities and developers can use in planning flood control measures to mitigate flood hazards up to the 100-year event. The SVADMP incorporates development plans for the area and jurisdictional drainage policies to develop a preferred regional flood control solution.

The major objectives of the project include the following:

- Plan regional flood hazard mitigation;
- Preparation of approximate alluvial fan floodplain delineations, meeting Federal Emergency Management Agency (FEMA) and Flood Control District of Maricopa County (District) standards, for those alluvial fans in the study area not previously delineated;
- Coordination between the ADMP regional flood control measures and the design of drainage features within the master planned community developments within the study area;

- Preparation of preliminary design of flood control facilities in areas not within master planned communities; and
- Design of landscape aesthetics and visual character in accordance with the District's *Landscape Aesthetics and Multi-Use Consultant Handbook (April 2003).*

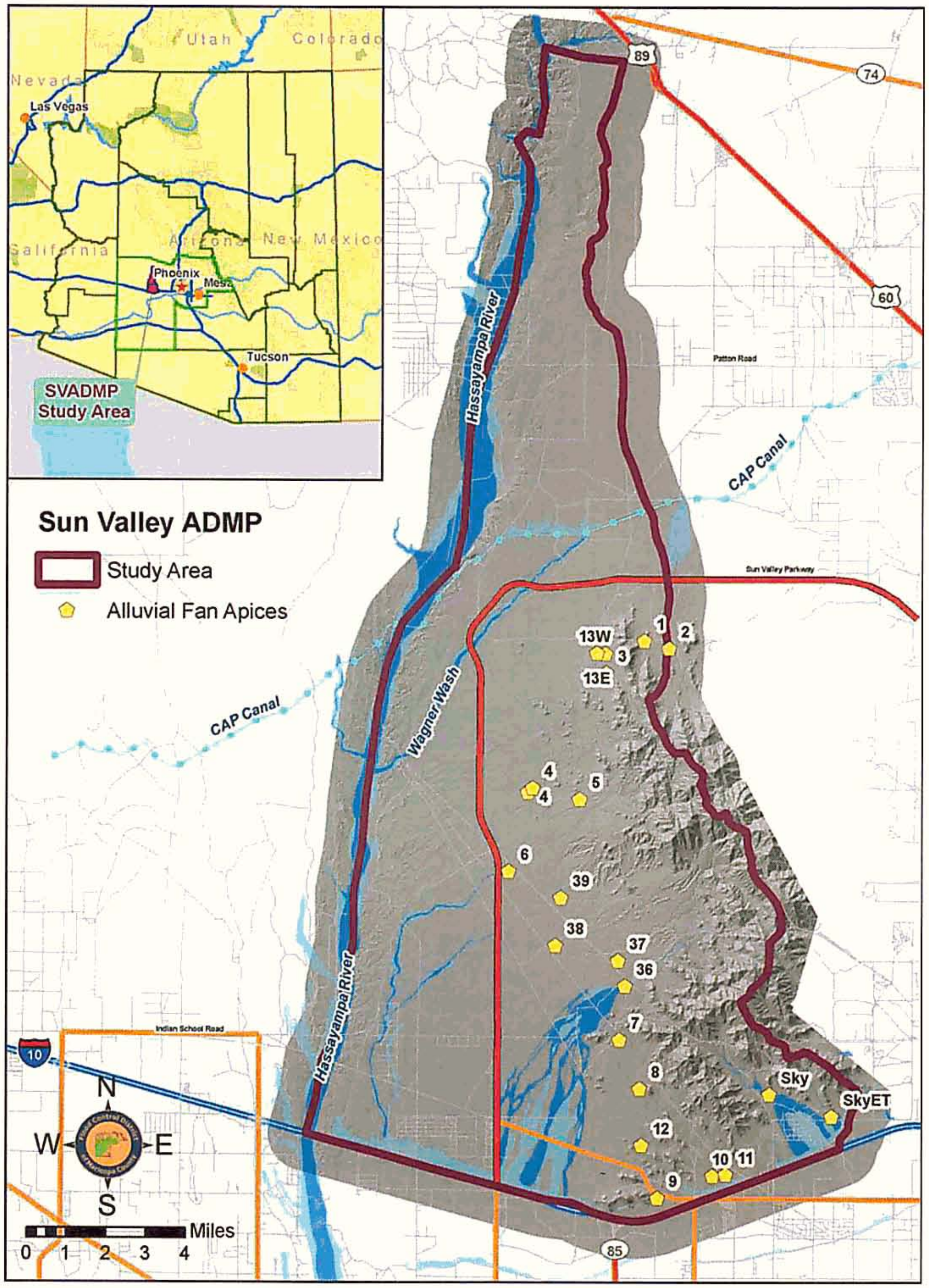

Figure 3 Location of Study Area

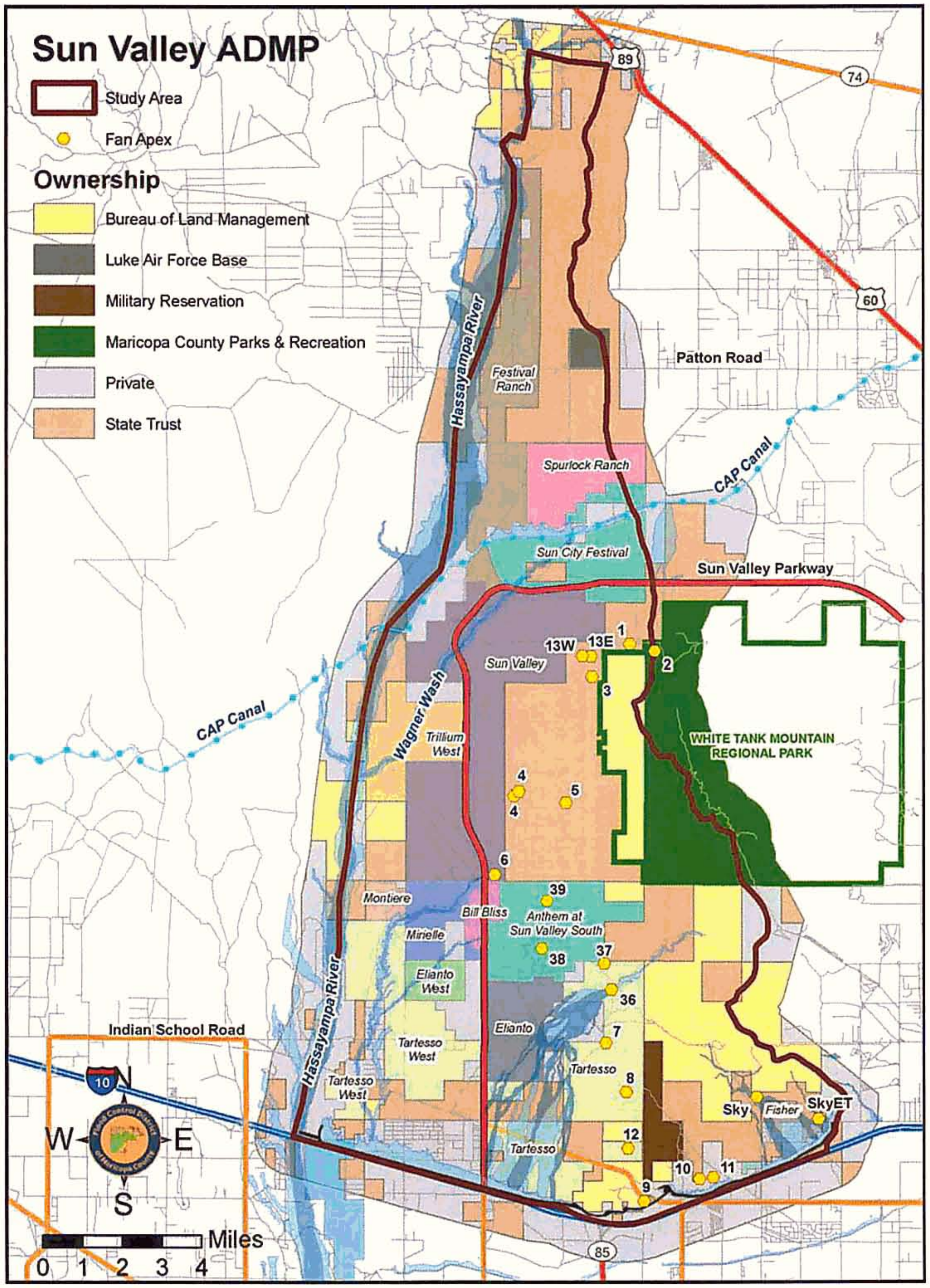

Figure 4 Future developments in the ADMP study area

Previously, the Phase I Buckeye/Sun Valley Area Drainage Master Study (ADMS), conducted by PBS&J, documented and analyzed existing conditions and identified drainage and flooding problems in the study area for the purpose of initial formulation of flood protection alternatives. The Phase II Sun Valley Area Drainage Master Plan builds on the Phase I findings by employing a 3-step process with the goal of developing a Recommended Alternative, consisting of both structural and non-structural measures, to address flood hazards in the study area. Figure 5 shows a flowchart illustrating the SVADMP alternatives development process.

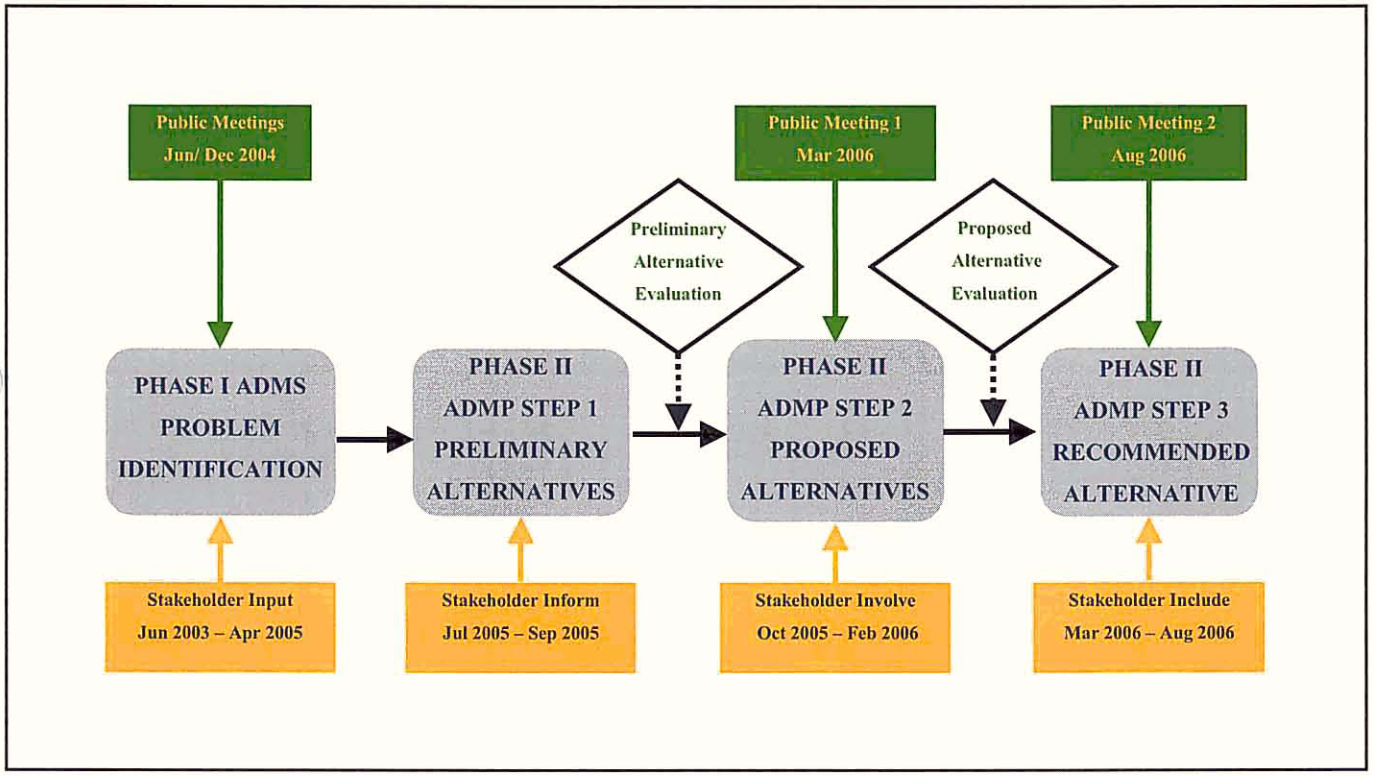

Figure 5 Alternatives development process

This report is part of the Phase II ADMP Step 2 Proposed Alternatives formulation process which focuses on further development of the recommendations of the Step 1 Preliminary Alternatives. The purpose of this study is to evaluate the Step 2 Proposed Alternatives in support of the SVADMP. The Step 2 Proposed Alternatives Report outlines the alternatives development, evaluation, and selection of the Recommended Alternative. The Recommended Alternative will be further evaluated and refined in Step 3 of the ADMP formulation process.

Based upon the recommendations resulting from Step 1, further evaluation of the Preliminary Alternatives was performed at Step 2 to determine engineering feasibility and approximate costs. The Step 1 Preliminary Alternative measures are combined to formulate the conceptual design of regional, whole-fan Step 2 Proposed Alternatives. The concept designs of the Step 2 Proposed Alternatives are presented as part of this study along with cost estimates. The cost estimates include engineering design, major construction items, right-of-way acquisition, major utility relocations, landscape compatibility aesthetic improvements, and maintenance cost for a 50-year design life.

2.3 Authority for Study

The current study was authorized by the Flood Control District of Maricopa County (District) under contract FCD 2004C049 as part of the scope of services for the SVADMP. The Town of Buckeye, Arizona was a project participant. The ADMP was performed by JE Fuller/ Hydrology & Geomorphology, Inc., with subconsultants C.L. Williams Consulting, Inc., Logan Simpson Design, Inc., AMEC Earth & Environmental, EDAW Inc., and Richard H. French, Ph.D., P.E.

2.4 Location of Study Area

The study area is located in western Maricopa County, Arizona and includes a total watershed area of 183 square miles. Figure 3 shows the location of the study area. Most of the study area is located within the Town of Buckeye. The study area is bounded by the White Tank Mountains and Trilby Wash on the east, the Hassayampa River on the west, the Buckeye Flood Retarding Structures on the south and Gates Road to the north. The watercourses within the study area are all tributaries to the Hassayampa River or the Buckeye Flood Retarding Structures, except Fan 2 which is a tributary to Trilby Wash.

3 ADMP PROCESS

3.1 Process Overview

The highly dynamic nature of alluvial fan flooding presents significant challenges for the design of engineered flood control measures. The designed drainage infrastructure must effectively and efficiently convey 100-year discharges without creating unwanted sediment aggradation or degradation. Further complexity is added as flood hazards change in type and severity with geographic position on the fan whether the area of interest is located at the apex, mid-fan, or near the outfall; and if the flood event is less than the 100-year event.

Known problems associated with alluvial fan flooding include spatial uncertainty of the flow distribution, lack of containment within the relatively flat topographic relief laterally across the fan, avulsive movement of defined flow paths, flooding along undefined flow paths, sheet flooding, distributary flow, scour, and landform aggradation (Figure 6). In addition, steep channel slopes between fan apices and fan toes result in high flow velocities with enough energy to move significant volumes of sediment and debris during large floods (Figure 6).

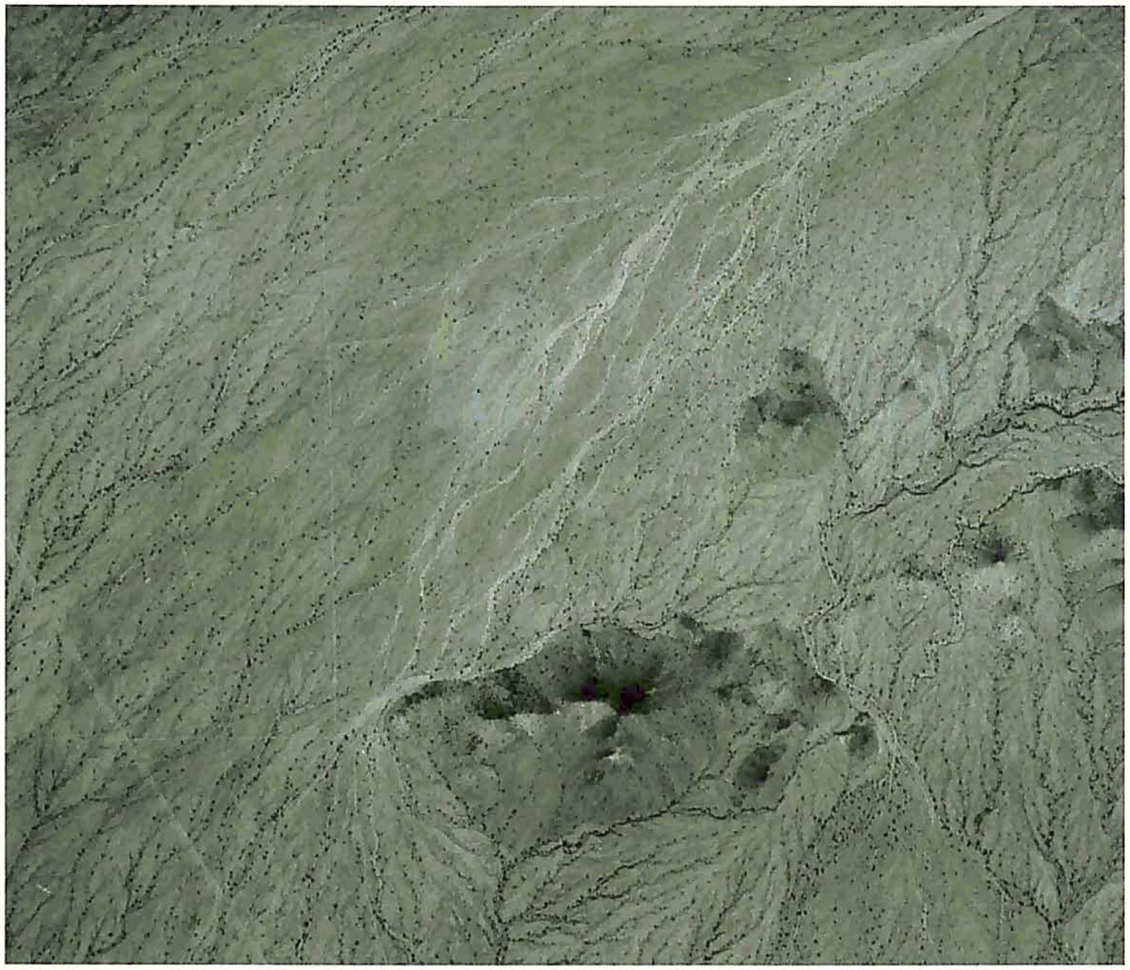

Figure 6 Aerial view of active portion Fan 36 in the FRS 1 Sub-area dated 1954

The Step 1 Preliminary Alternatives Evaluation presented the outline for the alternatives to be analyzed as part of the Step 2 Proposed Alternatives Evaluation. The Step 1 Preliminary Alternatives Evaluation process identified five areas within each fan starting from upstream to downstream: 1) Apex, 2) Up Fan 3) Parkway 4) Down Fan and 5) Outfall (Figure 7). Flooding and drainage characteristics vary for each of these component areas of the alluvial fan landform. This classification permits the design process to identify potential flood control measures specific to each of these areas which, in combination, comprise a whole-fan solution. The whole-fan solution provides a regional flood control system which acts as a major trunk drainage system for the adjacent watersheds. The trunk system is designed to convey runoff and sediment inflows from the apex plus that generated from the fan surface itself. Note that most, but not all, of the alluvial fans considered in this study have all the five component areas (Figure 8). However, the overall design considerations are similar for all the fans.

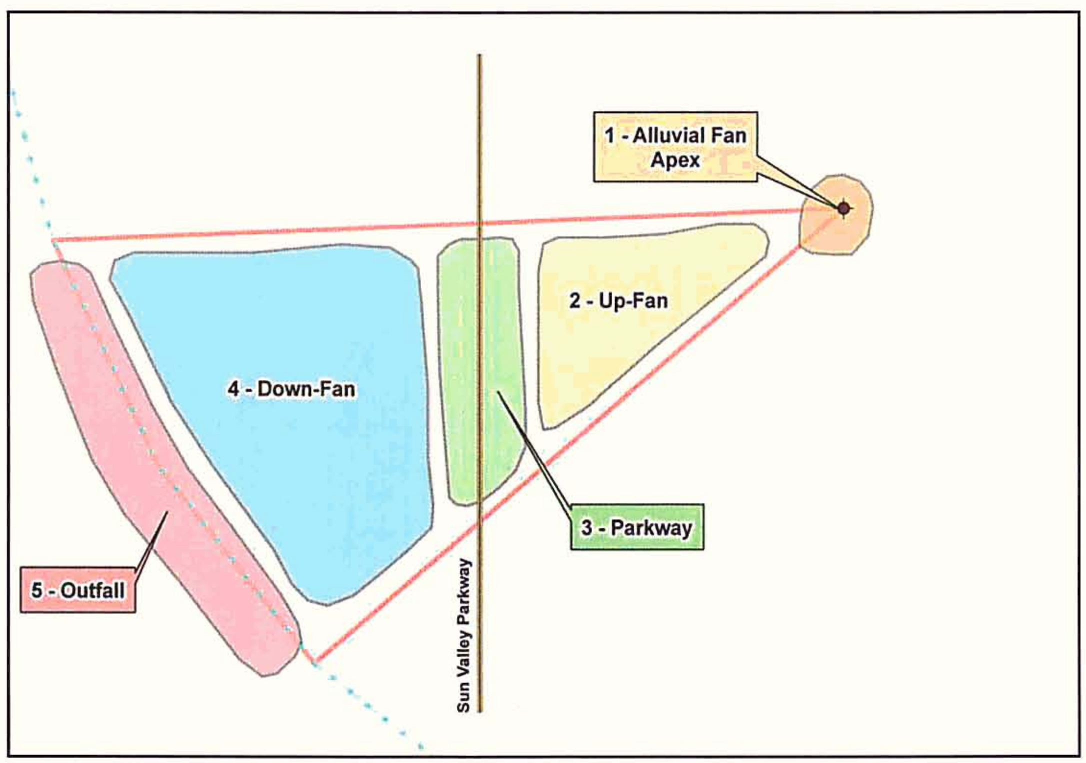

Figure 7 Fan Area Classification

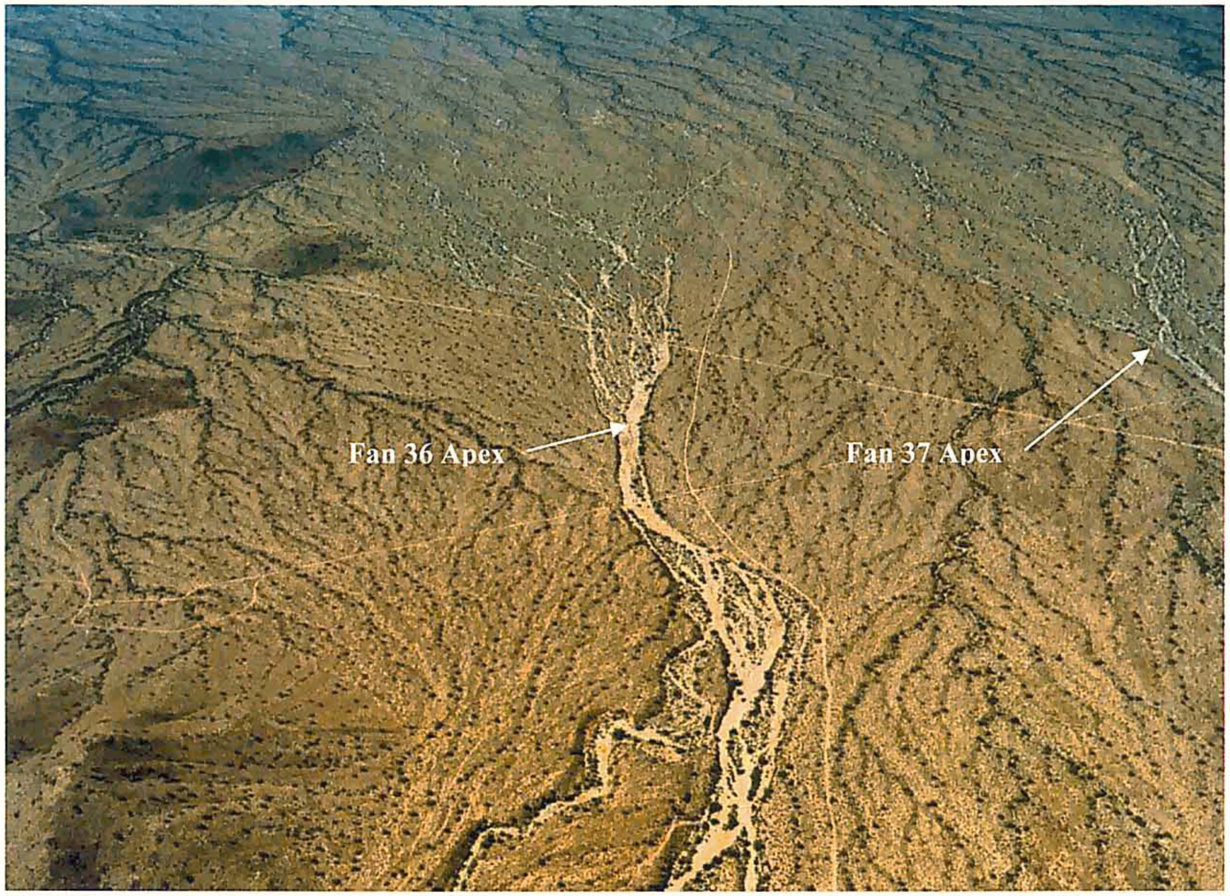

Figure 8 View downstream of Fan 36 (center) and 37 (on right)

The Step 1 process also identified the following design strategies: 1) Conveyance, 2) Storage, 3) Management, and 4) No Measure. These strategies apply to each of the five areas starting from apex to the outfall and form the basis of the Preliminary Alternatives. Four major alternatives were identified based on these strategies: Alternative A, Alternative B, Alternative C, and Alternative D. These four alternatives consist of different combinations of strategies for each of the different areas from apex to outfall. Each alternative can be described as a particular set of strategies applicable to different areas of the fan. In this study, these four alternatives are considered as part of the Step 2 Proposed Alternatives Evaluation process through refinement of the Step 1 concepts.

In order to address alluvial fan flooding hazards in the Sun Valley study area, regional whole-fan alternatives consisting of a suite of structural and non-structural measures will be required. The major structures considered in the Step 2 design approach are detention basins and open channel conveyance corridors. Detention basins reflect the Step 1 Storage strategy, while the channel corridors reflect the Step 1 Conveyance strategy.

Non-structural measures are also considered for the SVADMP alternatives. The Step 1 Management strategy includes development guidelines, floodplain delineation studies, flood detection network recommendations, and/or voluntary flood-prone property acquisition to mitigate impacts to current downstream private landowners and to prevent/mitigate impacts of future development. Management strategies are addressed in the Step 2 Proposed Alternatives Report.

The Step 1 process also defined the No Measure strategy including enforcement of existing regulations and the permitting process, allowing developers to address flood control issues within their parcel footprints in a manner compliant with existing regulations and approved by the District through permitting process. Thus, the No Measure strategy represents a non-structural solution in that no regional flood control solution is a part of this strategy.

The Alternatives A, B, C, and D formulated in the Step 2 process consist of particular combinations of detention basins, conveyance corridors, developer-planned drainage improvements, and 'no measure' options applied to different areas of the alluvial fan starting upstream at the apex to the downstream outfall. The formulation of the alternatives in terms of the specific combinations of structural and non-structural measures selected for the various portions of the alluvial fans are driven by the selection of the measures at the fan apices. For example, Alternative B includes a detention basin located at the fan apex to control flow and sediment discharges to downfan areas. Open channel corridors along multiple alignments contain and convey design discharges through the up-fan area. Off-line detention basins are considered as part of cross and/or lateral drainage improvements at Sun Valley Parkway, outletting through culverts to the down-fan area conveyance corridors to outfall structures.

During the Step 2 process, Alternative B was further subdivided into five similar, but unique alternatives named B1, B2, B3, B4, and B5. This was done primarily to evaluate the following: 1) influence of size of the apex detention basin on the design of the downfan system; 2) different channel cross-section types; and 3) various channel alignments. Further details on each alternative are presented in Section 4.4.

3.2 Additional Process Background for Step 2 Alternatives Formulation

During the initial Step 2 analyses, multiple stakeholder and team meetings were held to discuss the alternatives development. Stakeholders included in the process are listed in Table 1. The stakeholder process included two Stakeholder Workgroup meetings as well as numerous individual meetings with stakeholders and the project team. Specific input was received about the potential challenges to direct impacts to existing riparian areas as a result of implementation of the alternatives. In addition, concerns were raised about the scale of proposed facilities. As a result, the so-called 'companion channel' and 'leveed corridor' alternatives were generated for evaluation in Step 2. These alternatives are described further in Section 4.4. Another result of these meetings was to limit detention basin depths to no greater than 11 feet to reduce concerns about relative scale of the basins to neighboring developed features like houses.

Table 1 SVADMP Stakeholders

Meeting No.	Date	Agency	Purpose
1	3/7/2005	MCDOT	Sun Valley Parkway Corridor Study
2	7/14/2005	Fisher/ Williams	Skyline Wash coordination
3	8/10/2005	MCDOT	Sun Valley Parkway Corridor Study and culvert analysis
4	8/16/2005	Agency and Private Sector Stakeholders	Stakeholder Working Group Meeting 1
5	8/25/2005	MCDOT	Sun Valley Parkway Corridor Study
6	8/31/2005	Town of Buckeye	Project coordination, implementation, maintenance
7	9/7/2005	AZ Game & Fish	Project coordination, implementation
8	9/28/2005	CAP	Project coordination, implementation
9	9/30/2005	FRS #1 Sub-area Developers/ Engineers	Project coordination, data collection, implementation
10	10/3/2005	Area 4 N of CAP Sub-area Developers/ Engineers	Project coordination, data collection, implementation
11	10/18/2005	Hassayampa Sub-area Developers/ Engineers	Project coordination, data collection, implementation
12	10/19/2005	Town of Buckeye	Project coordination, implementation, maintenance
13	10/24/2005	ASLD/ Consultant	Project coordination, data collection, implementation
14	11/9/2005	ASLD/ Consultant	Project coordination, data collection, implementation
15	11/9/2005	Town of Buckeye	Project coordination, implementation,

Meeting No.	Date	Agency	Purpose
			maintenance
16	11/22/2005	Fisher/ Williams	Skyline Wash coordination
17	11/29/2005	Public and Private Sector Stakeholders	Stakeholder Working Group Meeting 2
18	12/16/2005	Pulte/CMX	Fan 38 coordination
19	1/26/2006	Developers/ Engineers	Feedback regarding Step 2 alternatives
20	1/26/2006	Town of Buckeye	Project coordination, implementation, maintenance
21	2/8/2006	Town of Buckeye	Project coordination, implementation, maintenance
22	2/9/2006	ASLD/ Consultant	Project coordination, data collection, implementation
23	2/28/2006	Vistoso/ Carter Burgess	Project coordination, data collection, implementation
24	3/8/2005	General Public	Public Meeting 1
25	3/23/2006	Vistoso/ Carter Burgess	Project coordination, data collection, implementation
26	3/23/2006	Lennar/ CVL	Rec Alt coordination, data collection, implementation
27	3/23/2006	Capitol Pacific Homes/ CVL	Rec Alt coordination, data collection, implementation
28	3/28/2006	Stardust/ DEA	Rec Alt coordination, data collection, implementation
29	3/30/2006	Pulte/CMX	Rec Alt coordination, data collection, implementation
30	4/5/2006	Communities Southwest/ WRG	Rec Alt coordination, data collection, implementation
31	4/12/2006	Town of Buckeye	Rec Alt coordination, data collection, implementation
32	4/20/2006	ASLD/ Consultant	Rec Alt coordination, data collection, implementation
33	4/20/2006	MCDOT/ Consultant	Rec Alt coordination, data collection, implementation
34	5/1/2006	Stardust/ DEA	Project coordination

3.3 Landscape Character Assessment

The scope of work for the ADMP specifically states that the alternatives to be developed for the ADMP in Step 2 "are environmentally friendly and blend with the natural landscape of the area following the District's *Policy for the Treatment and Landscape of Flood Control Projects*". The alternatives presented in Section 4.4 all include enhancement elements to ensure that the proposed alternatives meet these objectives. In addition, the cost estimates also include the costs associated with these landscape enhancements.

3.4 Stakeholder and Public Involvement

The District and ADMP project team conducted an extensive stakeholder and public involvement process as part of the ADMP in general, and Step 2 in particular. Numerous group and individual meetings were held with the impacted parties in the area (Table 1). Input was received and two-way communication conducted to ensure clear understanding by the project team and the stakeholders as to the nature of the proposed alternatives and project progress. Ultimately, the close interaction of the project team and stakeholders had a significant impact on the nature and the evaluation of the proposed alternatives for the SVADMP.

4 DESCRIPTION OF ALTERNATIVES

Flood control alternatives for the SVADMP area included both structural and non-structural solutions. Given the landscape compatibility assessment, non-structural solutions are generally preferred whenever possible. However, for the areas impacted by active alluvial fans, the degree, extent, and uncertainties associated with the flood hazards are considered too extreme to make fully non-structural alternatives feasible. Therefore, for the areas impacted by large active alluvial fan flooding, structural measures are central to the proposed flood control alternatives evaluated in Step 2 of the ADMP.

The study area was divided geographically into sub-areas to focus attention on appropriate structural or non-structural flood control alternatives for each sub-area. The area north of the Central Arizona Project (CAP) Canal is not impacted by large, widespread alluvial fan flooding and was therefore addressed separately. Most of the remainder of the study area south of the CAP is impacted by large active alluvial fans along the White Tank Mountains piedmont. This area south of the CAP was the focus of most of the ADMP alternatives development and evaluation tasks. In addition to the sub-area specific flood control alternatives, be they structural or non-structural, other general flood hazard related issues exist across the study area. These issues are addressed through a category called "areawide" issues.

The following sections describe the structural and non-structural flood control alternatives evaluated in Step 2 of the SVADMP. The North of CAP sub-area is addressed in this volume. Additional details on the piedmont sub-areas south of the CAP are provided in Volumes 2-7 of the Step 2 Proposed Alternatives Report.

4.1 Areawide

A number of general, or areawide, flood hazard-related issues were identified and addressed in the Step 2 portion of the ADMP. Again, non-structural flood control alternatives are preferred. Therefore, many of the areawide issues are addressed with a non-structural approach. In other cases, areawide issues are related to existing or potential future structural flood control measures. The following areawide items were noted:

Piecemeal solutions – Engineers do not recommend piecemeal construction of flood control projects (except for construction phasing) due to potential for conflicts in design and construction practice, inability to tie in to previously constructed sections, and the potential for permanent gaps. Other concerns with piecemeal flood control solutions include reflective scour, flanking of partial systems, first-come, first-serve inequities, landscape aesthetics, timing issues or other unplanned phasing complications, and potential changes in the regulatory environment whether it be FEMA, Section 404 Clean Water Act, or local ordinance changes. Piecemeal flood control solutions apply to any system including floodway fringe encroachments and channelization. Therefore, whenever structural solutions are proposed to address localized flood or erosion problems in the area, special attention should be paid to address the incompatibility concerns arising from piecemeal solutions.

Stock tanks - Stock tanks present several potential challenges and issues for future development in the area. Though stock tanks are structural flood control facilities of a sort, they are rarely engineered and pose a potential hazard in the event of an embankment failure. The failure of a stock tank can create a larger magnitude flood wave than had the tank not been present. Seventeen stock tanks were identified in the area. Thirteen of those are located north of the CAP Canal (see Section 4.3.4). As part of the SVADMP, it is therefore recommended that stock tanks be removed whenever possible as an area develops.

Other floodprone areas (i.e. non-alluvial fan floodplains) – It should be remembered that while much of the area is dominated by alluvial fans and their associated flood and sedimentation hazards, other locations within the study area are subject to riverine or sheetflooding conditions. It is recommended that floodplain management be the preferred approach to address future development in areas not specifically impacted by the large active alluvial fans in the area.

ADMS Development Guidelines – The Development Guidelines from the Buckeye / Sun Valley ADMS were reviewed as part of the ADMP proposed alternatives development. The review revealed that the suggested guidelines were focused on single lot development and were not especially applicable to master planned community development as they generally promote application of non-structural flood control measures. The SVADMP study area will be almost exclusively developed as a series of large master planned communities many directly impacted by large active alluvial fans. Therefore, the majority of the development guidelines from the ADMS are not recommended for application to the ADMP. However, the Development Guidelines from the Buckeye / Sun Valley ADMS do specifically identify a goal for flood control features for the area that provides a regional solution, controlling the apex of the active alluvial fans and conveyance of flow through the entire fan. The structural solutions in the Step 2 proposed alternatives for the piedmont sub-areas all achieve this objective.

Flood warning – Another areawide flood hazard mitigation measure could be the development of a flood warning system for the area. Instead of, or in addition to, other structural or non-structural flood control measures, flood detection technologies could be deployed in the study area to warn existing and future residents of the forecast or occurrence of severe weather. Recommendations for the placement of flood detection equipment and/or the development of a flood response plan are part of the Step 3 Recommended Alternative for the ADMP. However, a detailed flood response plan is not part of this project.

4.2 Sub-Areas

To aid the Step 2 alternatives development and evaluation beyond the areawide issues, seven sub-areas within the SVADMP study area were identified:

1) North of CAP (this volume)
2) CAP (Volume 2),
3) Wagner Wash (Volume 3),
4) Hassayampa River (Volume 4),

5) White Tanks Wash (Volume 5),

6) FRS #1 (Volume 6), and

7) FRS #2 & #3 (Volume 7).

The sub-areas are based on the outfall locations and the fans discharging to a particular outfall location. For example, fans that drain to Wagner Wash are included in the Wagner Wash sub-area. The sub-areas also represent the hydrologic watershed for the particular outfall location. The sub-area boundaries and fan apices are shown in Figure 9.

This report provides an overview of the Step 2 Proposed Alternatives for the entire study area. Additional details for the six alluvial fan sub-areas south of the CAP Canal are presented in separate companion reports (Step 2, Volumes 2-7).

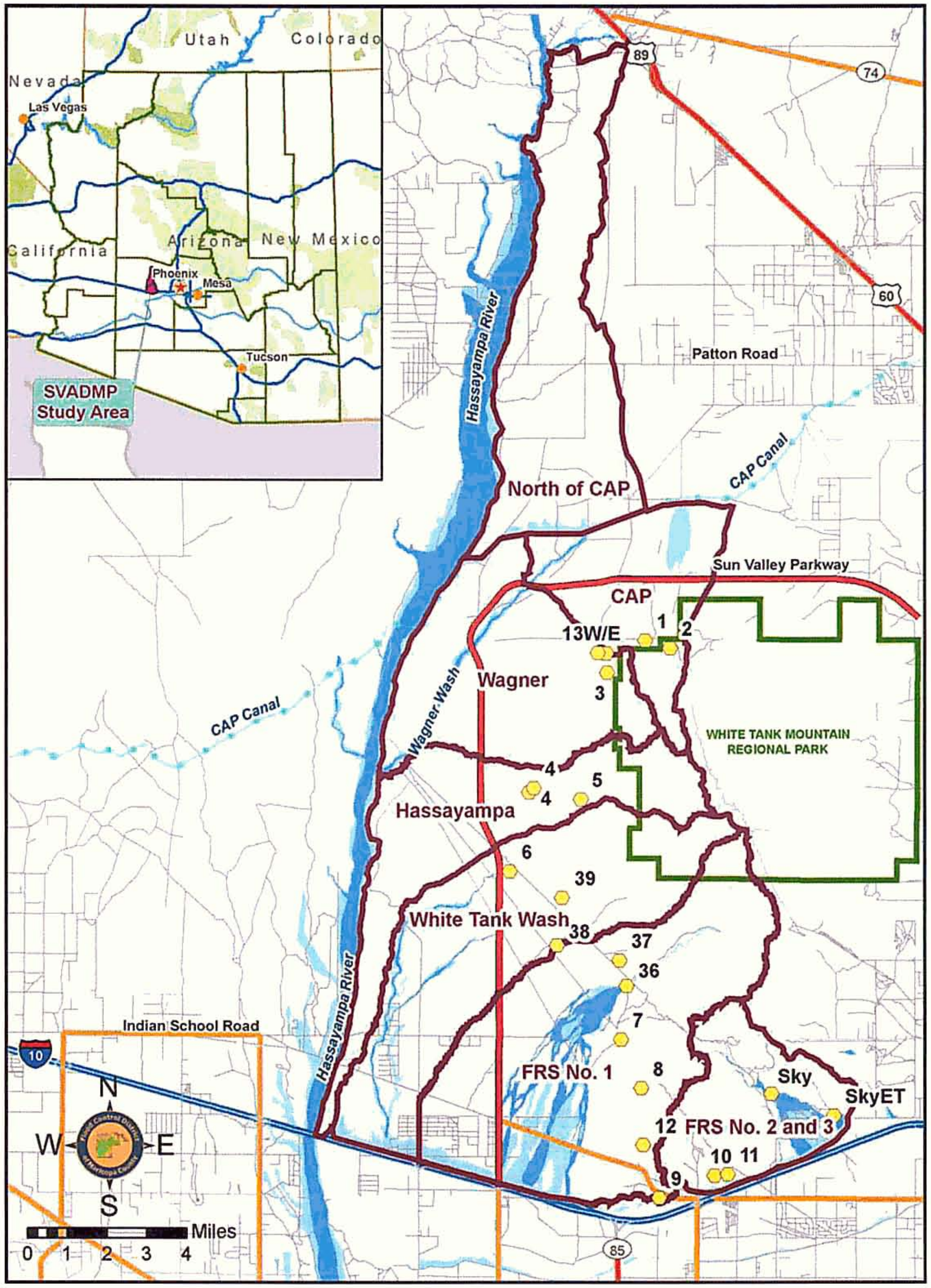

Figure 9 ADMP Sub-Areas

4.3 North of CAP Sub-Area

4.3.1 Description of Area

The North of CAP sub-area is a long narrow area located north of the CAP Canal parallel to the Hassayampa River. The area is bounded on the north by Gates Road, on the west by the Hassayampa River floodplain, on the south by the CAP Canal, and on the east by the drainage divide to the Trilby Wash watershed. The sub-area is about 28 square miles in area. The majority of the area drains directly to the Hassayampa River. The remaining area drains to a detention area along the CAP Canal. About 25 percent of the area is composed of potentially floodprone areas. The identification of those areas and the issues for the ADMP associated with those areas are discussed below.

4.3.2 Floodprone Areas

Potentially floodprone areas in the North of CAP sub-area were delineated based on examination of the 2005 color digital orthophotography (Figure 15) and the countywide 10-foot topographic contour data (Figure 16). The specific frequency of flooding was not evaluated and probably varies from place to place for the delineated areas.

Three types of flooding were recognized in the sub-area:

- Riverine flooding
- Small alluvial fans along Hassayampa River
- CAP pool area

Most of the floodprone areas in the sub-area are subject to riverine-type flooding. That is, flood water is collected and concentrated within tributary watersheds into individual channels. Riverine floodprone areas are identifiable based on vegetation patterns and surficial geologic indicators such as surface texture, color, and composition. Figure 10 shows an example of an area subject to riverine flooding. Note the larger, darker vegetation and the browner sediment colors surrounding that vegetation. Close examination also reveals small channels within and immediately adjacent to the areas of browner sediments.

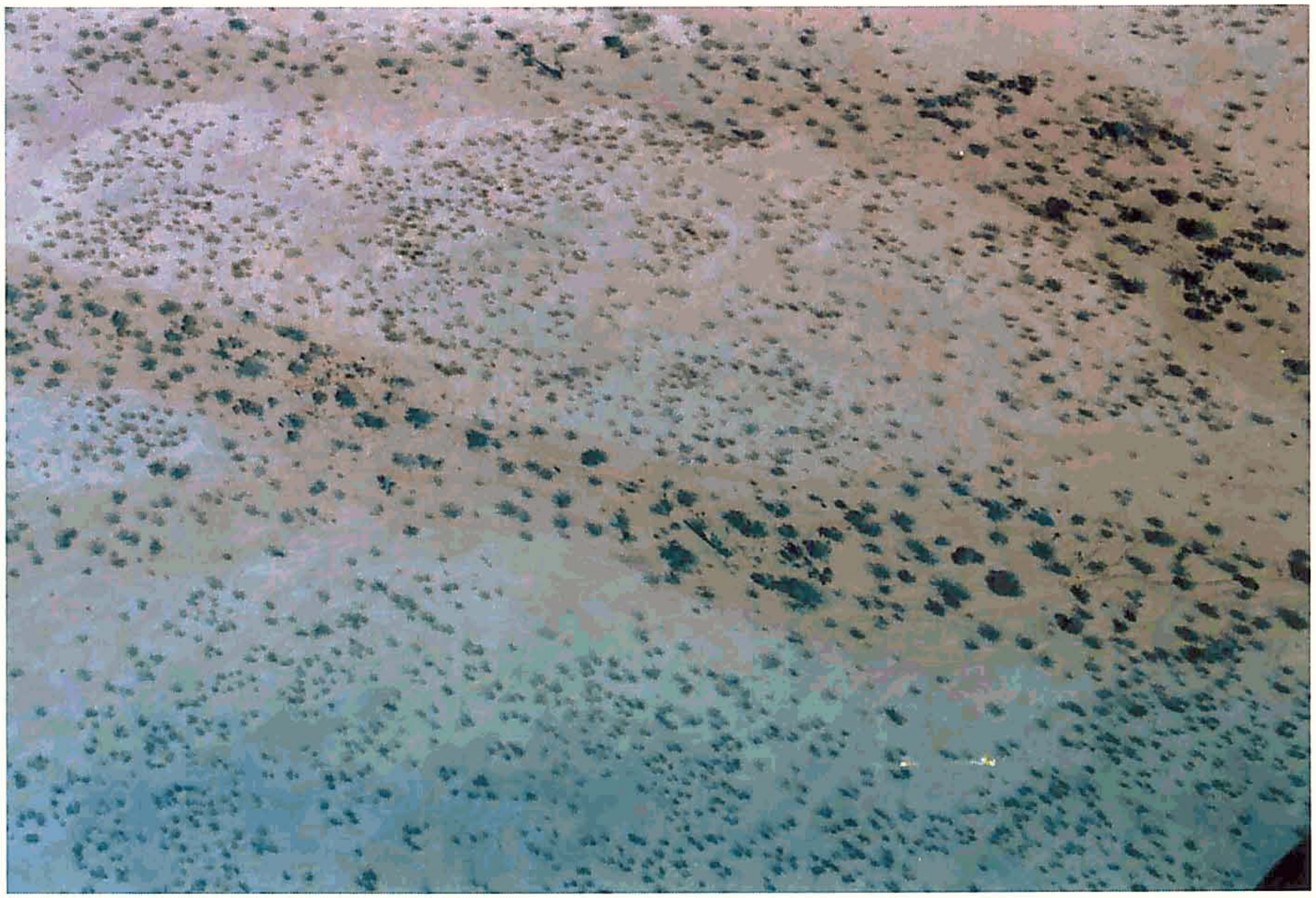

Figure 10 Example of riverine floodprone area North of CAP

A number of the tributary drainages exit onto the Hassayampa River floodplain within the sub-area (Figure 11). The abrupt change in slope from the tributary watershed to the Hassayampa floodplain creates a sudden loss of sediment transport capacity. The result is the development of an alluvial fan. Several small alluvial fans are found along the southwest portion of the sub-area. Compared to the alluvial fans in the rest of the study area, these fans are small, steep, and very active. Slopes on these fans are on the order of 5 percent.

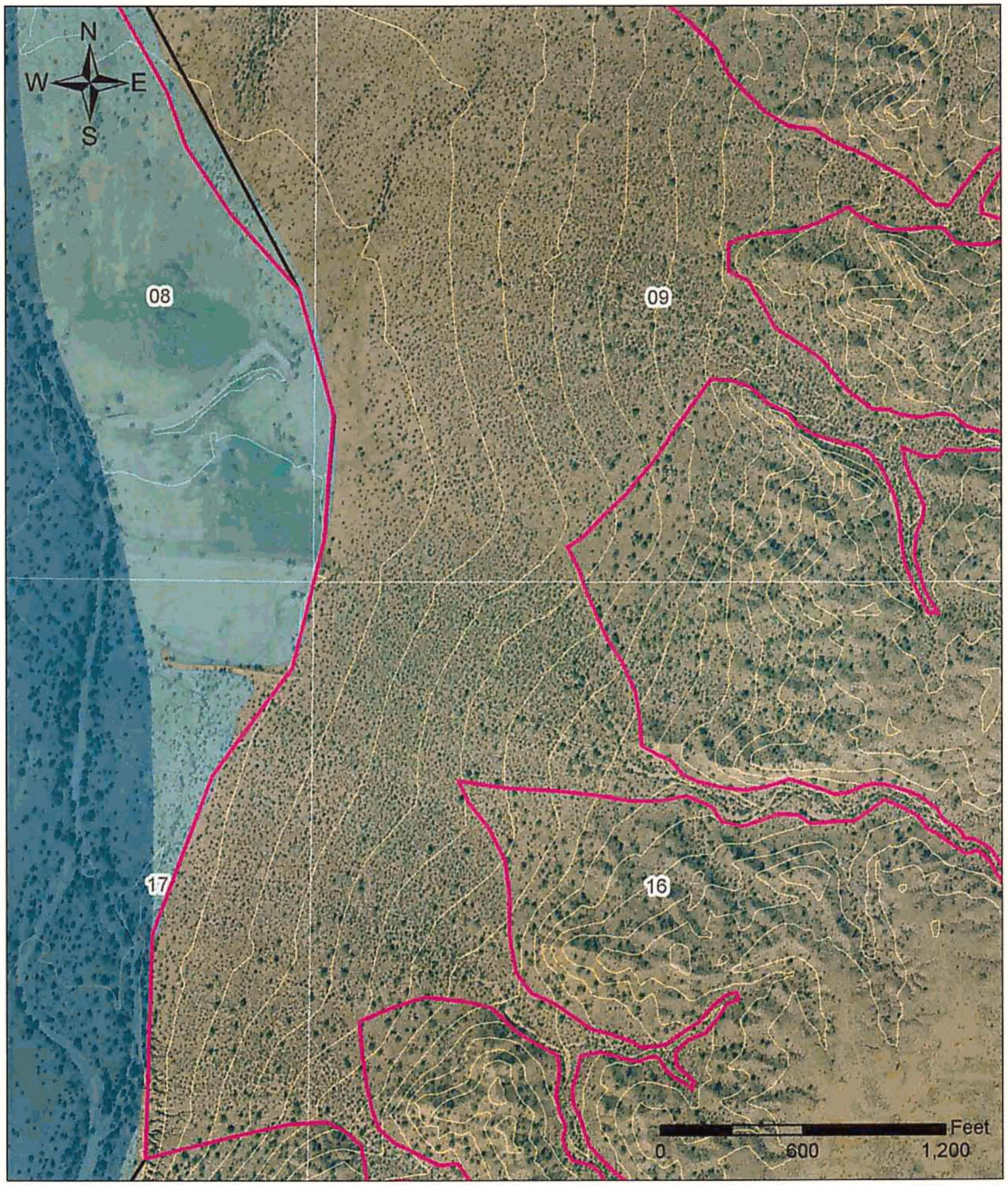

Figure 11 View of area of small alluvial fans along the Hassayampa River in North of CAP Sub-Area

Another floodprone area is the detention pool north of the CAP Canal. The detention area significantly reduces the flow that crosses the canal. Outflow occurs through one of two 18-foot wide concrete overchute structures in CAP Reach 8 – one located at Sta. 181+00 and the other at Sta. 248+00 (Figure 12). The peak discharge is reduced from about 7,800 cfs to 150 cfs in the 100-year 24-hour event (JEF, 2005). This area needs to be reserved, preserving detention capacity, to prevent failure of the overchutes or overtopping of the CAP Canal.

Figure 12 View downstream of CAP overchute at Sta. 248+00.

4.3.3 Luke Auxiliary Air Field No. 4

An abandoned auxiliary air field, Luke Auxiliary Field No. 4, is located just north of Patton Road. The air field is protected by a dike and channel system that diverts flow around the abandoned runways (Figure 13). The future disposition of the airfield and its neglected drainage facilities will need to be addressed as the area develops.

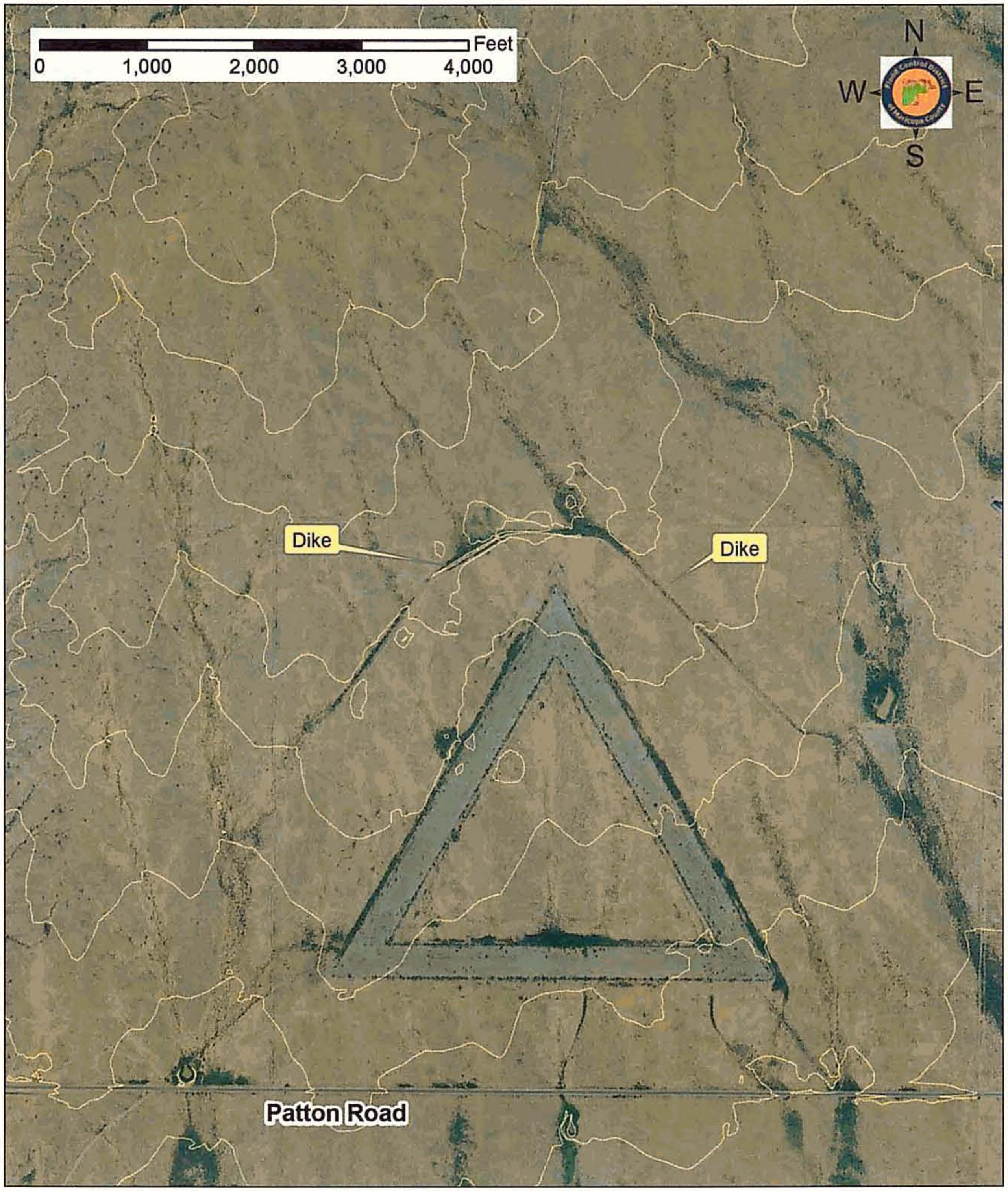

Figure 13 Close-up view of Luke Auxiliary Air Field No. 4

4.3.4 *Stock Tanks*

Thirteen of the 17 stock tanks in the study area are located within the North of CAP sub-area (Figure 15). Stock tanks present several potential challenges and issues for future development in the area. Stock tanks provide some level of protection from flooding to downstream reaches. Property owners downstream of existing stock tanks may perceive some flood control benefit from the tanks. However, these structures are rarely engineered and pose a potential hazard in the event of an embankment failure (Figure 14). Stock tank failure is not uncommon in Maricopa County. The failure of a stock tank can create a larger magnitude flood wave than had the tank not been present.

Figure 14 View upstream into stock tank breach on Skunk Tank Wash (October 2000)

Stock tanks also disrupt sediment transport along the washes in which they are placed. The ponds trap sediment inflowing from the upstream wash and prevent sediment delivery to the downstream reach. In some cases, the sediment trapping effect can result in dramatic channel incision downstream.

Stock tanks also create a locally lush riparian habitat of mesquite, palo verde, and other large trees. This creates a challenge to the selected mitigation of the hazards posed by these tanks. In most cases, removal of a tank is the preferred solution to eliminate the potential hazards associated with a catastrophic tank failure. However, potential habitat mitigation and perceived increased flooding by downstream property owners may create impediments to their removal. Neverless, as part of the ADMP it is recommended that stock tanks be removed as development begins to occur with the area north of the CAP Canal.

4.3.5 Summary

Much of the North of CAP sub-area is subject to some level of flood or sedimentation hazard. These areas have been broadly identified as part of Step 2. It is recommended that future development acknowledge and address these hazards according to existing federal, state, and local regulations. Special issues for the area include legacy issues such as stock tanks and an old abandoned airfield. The drainage impacts of these facilities are best addressed by removing all of them and returning the drainages to their original conditions. Finally, an area of small, but steep and very active, alluvial fans is found adjacent to the Hassayampa River floodplain. Development of these areas should be avoided unless engineered facilities are provided to mitigate the hazards. As will be detailed for the piedmont sub-areas south of the CAP Canal, the preferred structural solutions are generally on-line detention basins at the apices with downstream conveyance to drain the basin and collect local drainage. However, these areas may be small enough that a non-structural avoidance strategy may prove acceptable.

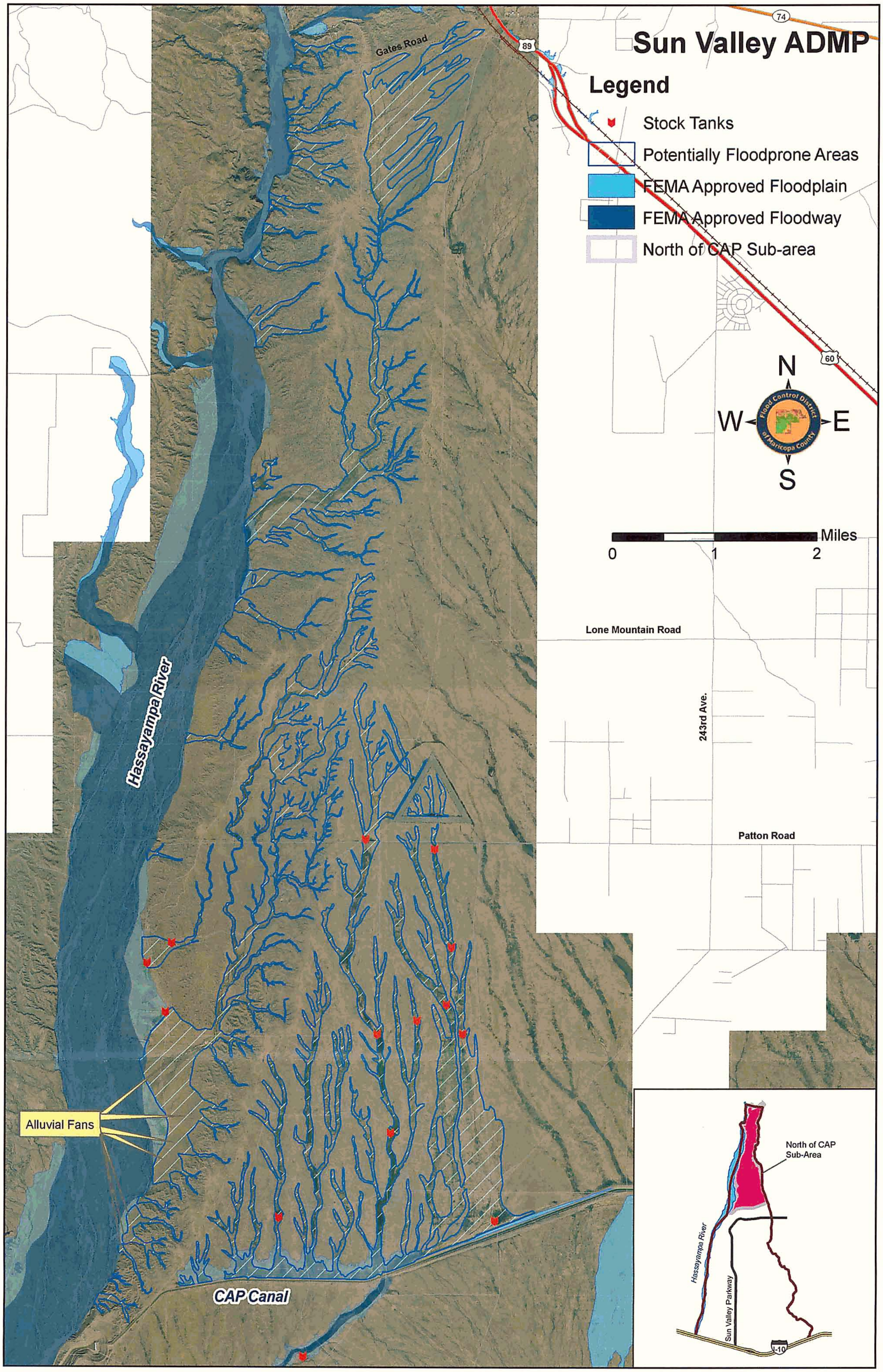

Figure 15 North of CAP Sub-Area Aerial

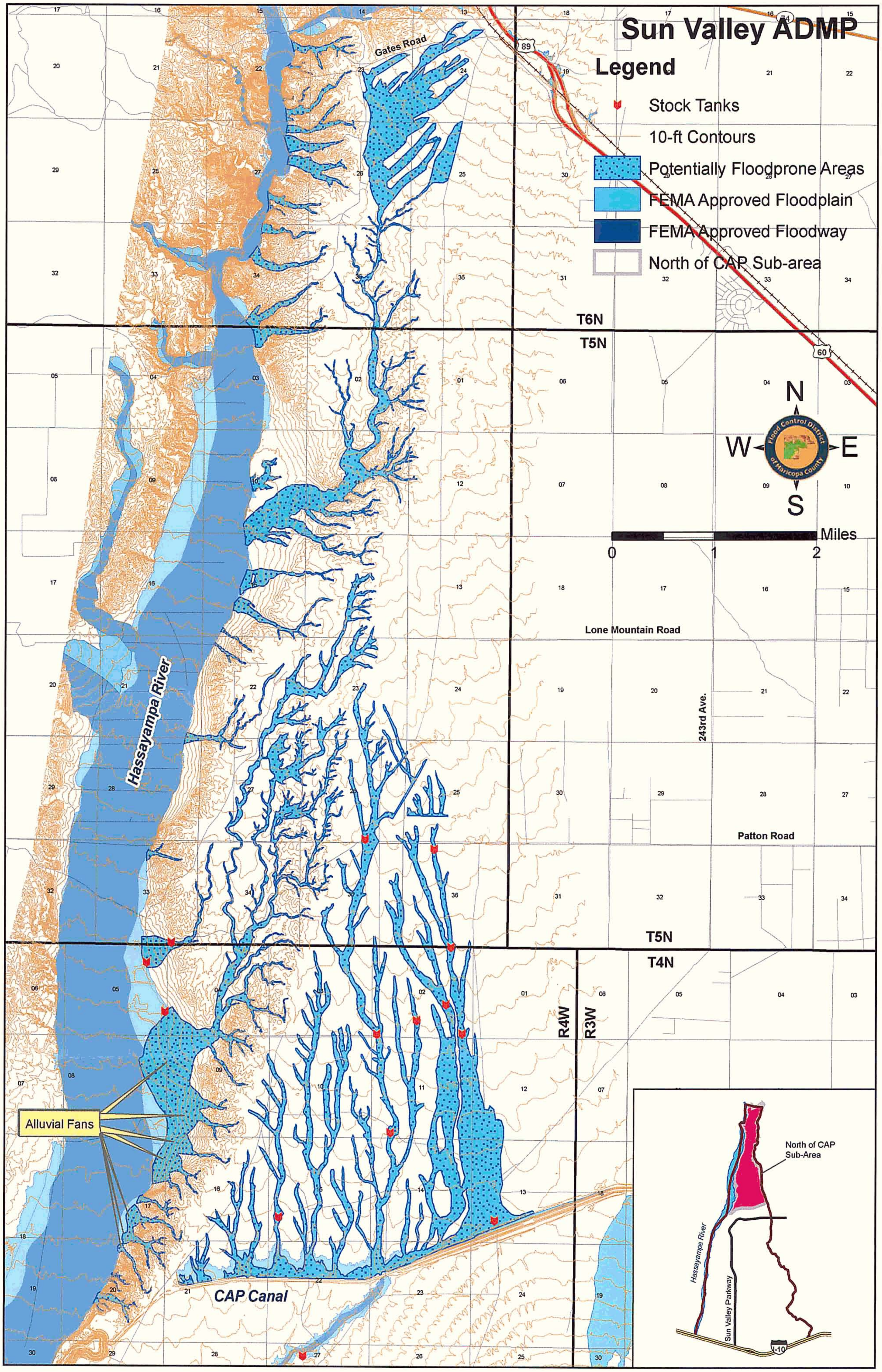

Figure 16 North of CAP Sub-Area Topographic Map

4.4 Piedmont Sub-Areas Alternatives Classification

The Step 1 Preliminary Alternatives Evaluation classified the Alternatives into 4 categories, namely Alternative A, Alternative B, Alternative C, and Alternative D. In this study, the concepts developed during Step 1 process were expanded and refined. Alternative B was further sub-categorized into B1, B2, B3, B4, and B5 as listed below. Table 2 provides brief descriptions of the four alternatives.

Table 2 Descriptions of Alternatives

Alternative	Description
A	No measure at apex / Leveed channel section
B1	Big on-line detention basin / Small leveed channel section
B2	Small on-line detention basin / Big leveed channel section
B3	On-line detention basin / Earthen 'companion' channel
B4	On-line detention basin / Leveed channel section along different alignments
B5	Off-line detention basin / Leveed channel section
C	No measure at apex / Concrete 'companion' channel
D	No measure (Whole Fan)

Again, while the flood control alternatives for the active fans in the piedmont sub-areas focused on structural mitigation of the alluvial fan flood and sedimentation hazards, non-structural elements were included wherever possible. In addition, some of the alternatives have greater or lesser degrees of non-structural elements which varies by sub-area. The following sections provide an overview of each of the types of Alternatives A-D for the piedmont sub-areas south of the CAP Canal. Additional details for all of the individual piedmont sub-areas are provided in Volumes 2-7 of the Step 2 Proposed Alternatives Evaluation Report.

4.4.1 Alternative A

The area downstream of the apex represents a region of significant alluvial fan instability. The alluvial fan instability, in turn, results in the uncertainty of flow paths. The region of significant alluvial fan instability can be identified to a reasonable extent. The Step 1 process defines Alternative A to represent "No Measure" at the apex. The main design objective of this alternative is to allow the natural geomorphic processes to occur within a designated active area downstream of the apex. This provides a largely non-structural approach to the treatment of the alluvial fan hazards near the apex.

Downstream of the region of active fan processes, flows will be controlled by structural means; that is, captured via diversion levees/dikes, and collector channels. Once collected, the flows are routed downstream using leveed channel sections, culverts, and detention basins (if needed) until the flows reach the outfalls. In some cases, like Wagner and White Tanks Wash sub-areas, the outfall is a large existing riverine riparian wash system. In these cases a non-structural, floodplain management approach is inherent to the alternative for these reaches.

Figure 17 shows a spatial layout of the A Alternative for all of the piedmont sub-areas. Included on Figure 17 are the location of the active fan set-aside areas, the collector channels, downstream leveed corridors, detention basins where needed, and the existing FEMA floodplain reaches on Wagner and White Tank Washes.

The advantage of Alternative A is that it minimizes environmental impacts near the apex by preserving existing natural conditions. The main disadvantage is the cost of land set aside to allow for the natural alluvial fan processes.

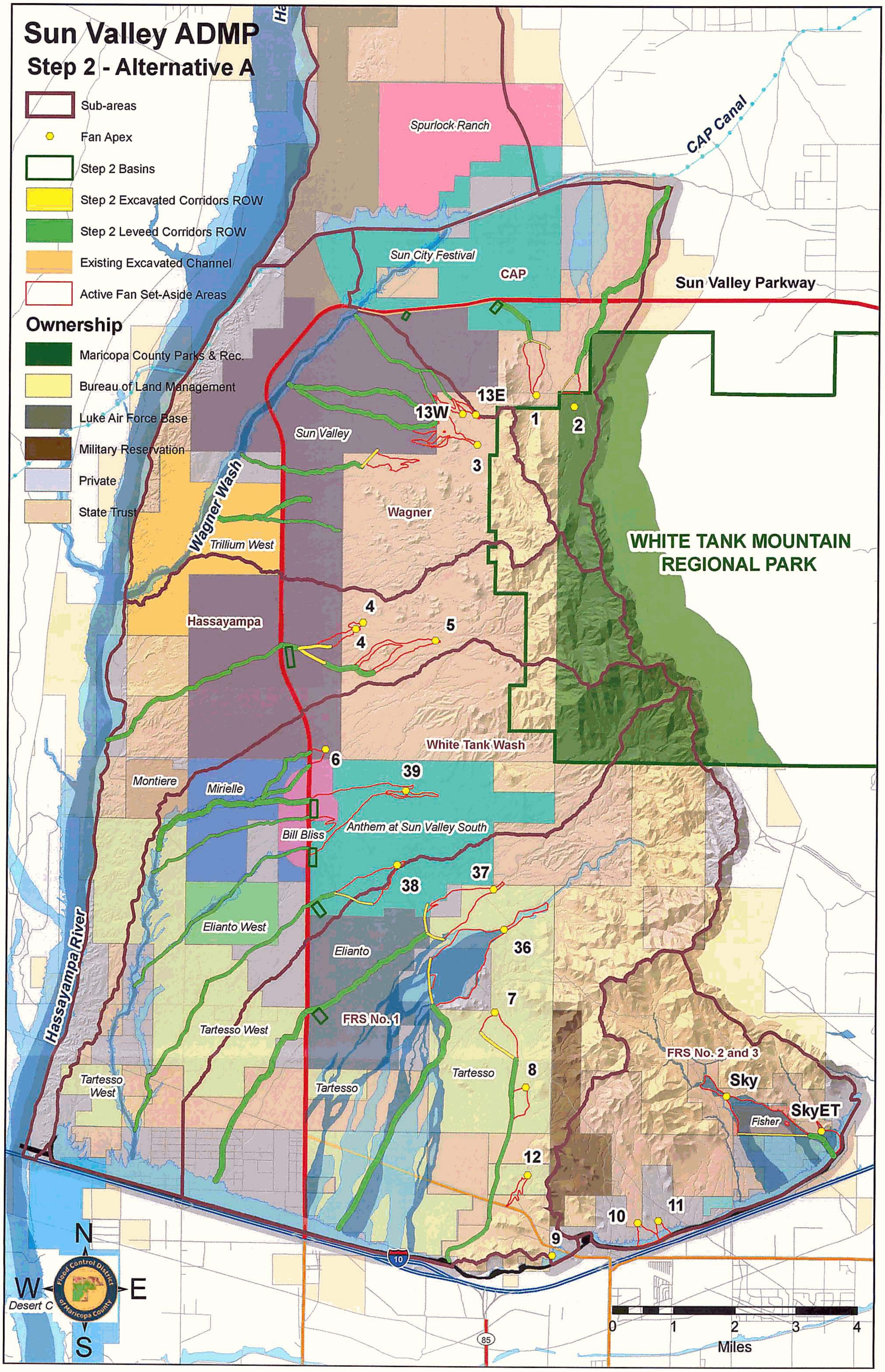

Figure 17 Alternative A

4.4.2 *Alternative B*

Alternative B is based on a structural flood control strategy at the apex. The objective of Alternative B is to capture all of the upstream flow at the apex using on-line detention basins. The presence of a detention basin at the apex eliminates the downstream alluvial fan uncertainties. Once collected into the detention basins, flows are routed downstream using open channels, culverts, and additional detention basins (if needed) until the flows reach the outfalls. Again, for the reaches of Wagner Wash and White Tank Wash within the study area, a non-structural, floodplain management approach is included in the B alternatives for those sub-areas.

This approach increases channel stability by eliminating flow path uncertainty beginning at the apex. This alternative also offers better management of sedimentation issues by capturing incoming sediment directly into the basin. In addition, the alternative provides a continuous, comprehensive flood control trunk system which minimizes the impacts of phasing of developments in the Sun Valley Area.

Alternative B is classified into further sub-categories based on 1) sizing of structures, 2) different channel cross-section types, and 3) different alignment of channels. Alternatives B1, B2, B3, B4, B5 and C represent different combinations of these sub-categories (See Table 2 for details).

Sizing of Basins

The effect of basin size at the apex is evaluated by comparing the effects of a big excavated basin to that of a smaller basin at the apex. The variation in the sizing of the basin at the apex influences the size of the downstream structures. For example, the smaller upstream basin results in a wider channel immediately downstream. The evaluation of basin size is applied to the fans in the CAP and White Tank Wash sub-areas because of their straightforward channel alignment options. Alternatives B1 and B2 represent the big and small basin options, respectively, and a comparison between these two alternatives was performed to evaluate the effects of basin size on the overall design.

Variations in Channel Cross-sections

Leveed Channel Corridor Section – The existing natural corridor is laterally constrained on two sides by a levee. The levee ensures flow containment within the natural corridor while allowing the channel to naturally adjust to the higher discharges resulting from flow concentrations. Figure 18 shows a schematic of the cross-section for the earthen levee natural channel corridor. Walls could also be considered instead of earthen levees to provide flow containment for the natural channel sections. Figure 21 shows the natural channel section with walls as the alternative bank structure. The channels for the A, B1, B2, B4 and B5 alternatives are designed with an earthen leveed natural channel section.

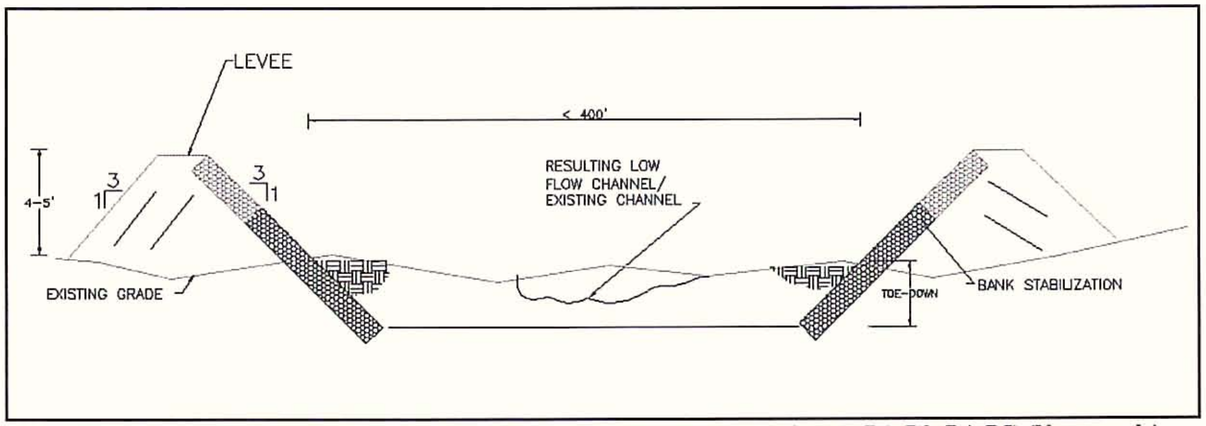

Figure 18 Concept Cross Section for Earthen Leveed Corridor (Alternatives A, B1, B2, B4, B5) (Not to scale)

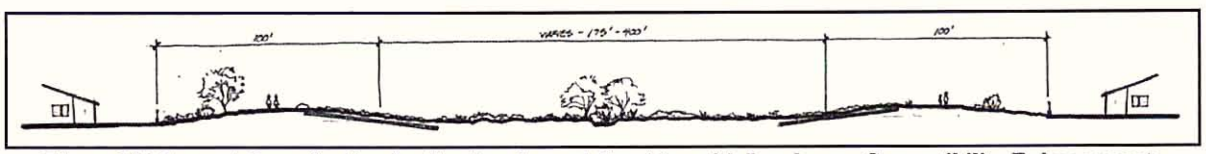

Figure 19 Concept Cross Section for Earthen Leveed Corridor with Landscape Compatibility Enhancements (Alternatives A, B1, B2, B4, B5) (Not to scale)

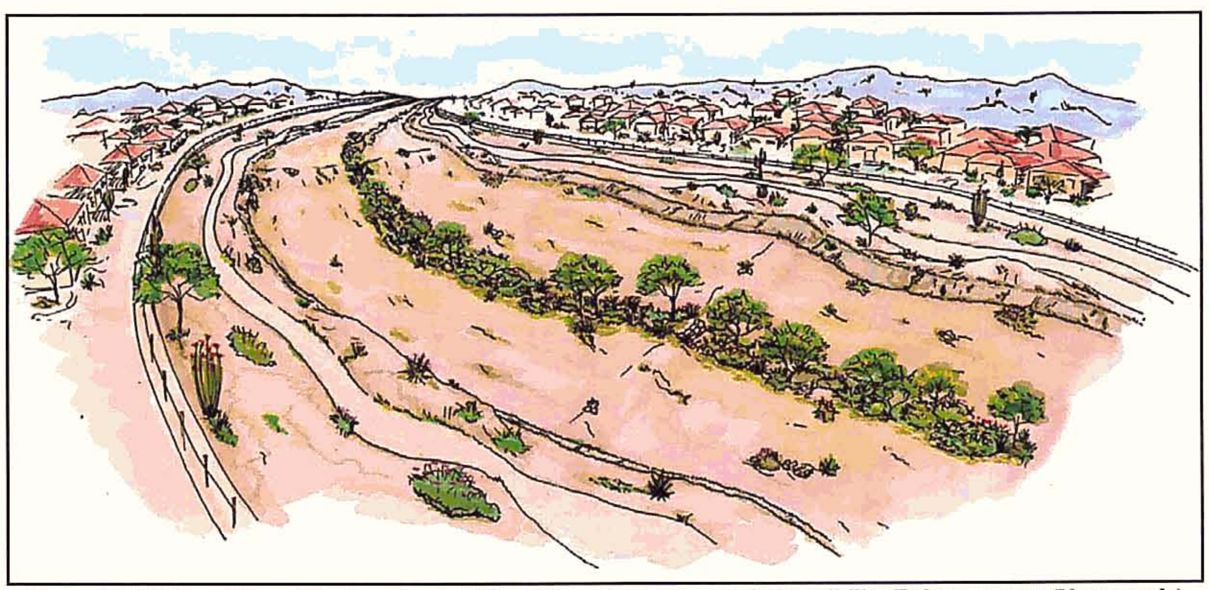

Figure 20 Oblique View of Earthen Leveed Corridor with Landscape Compatibility Enhancements (Not to scale)

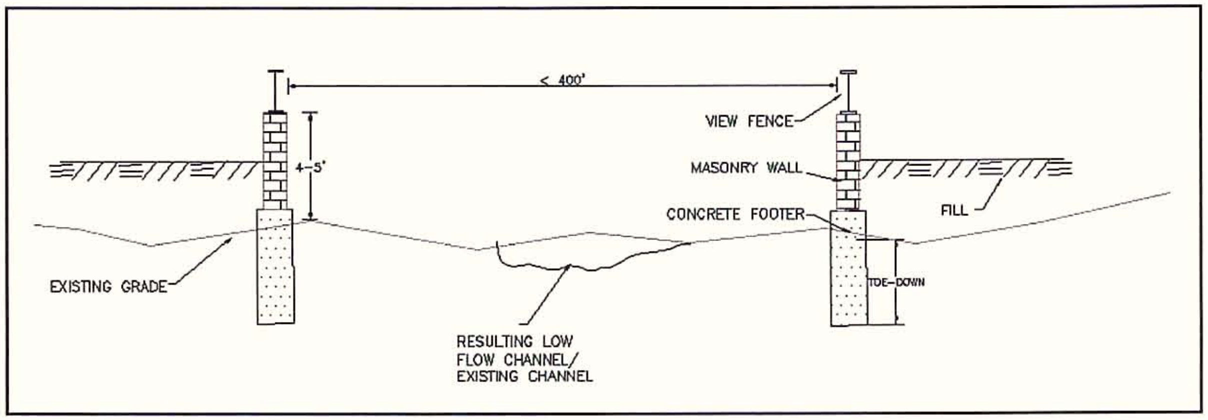

Figure 21 Concept Cross Section for Leveed Corridor with Walls (Alternatives A, B1, B2, B4, B5) (Not to scale)

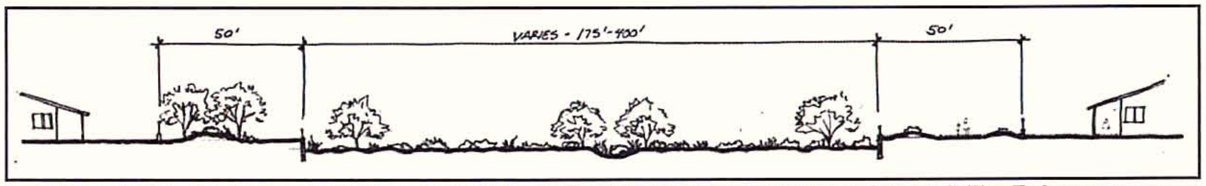

Figure 22 Concept Cross Section for Leveed Corridor with Walls & Landscape Compatibility Enhancements (Alternatives A, B1, B2, B4, B5) (Not to scale)

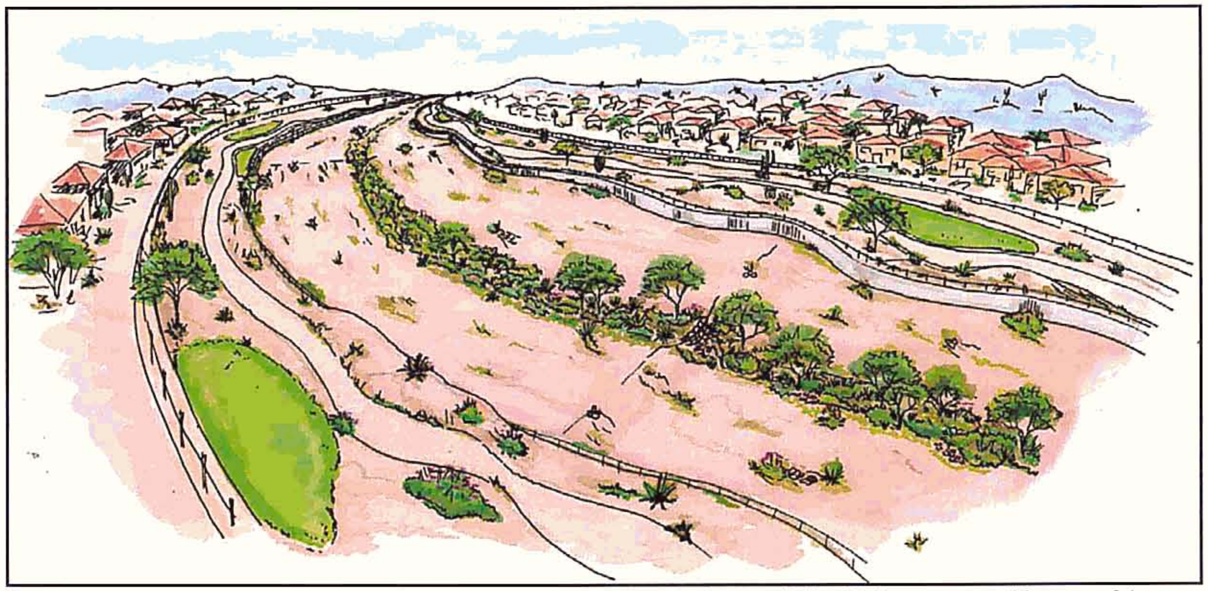

Figure 23 Oblique View of Walled Corridor with Landscape Compatibility Enhancements (Not to scale)

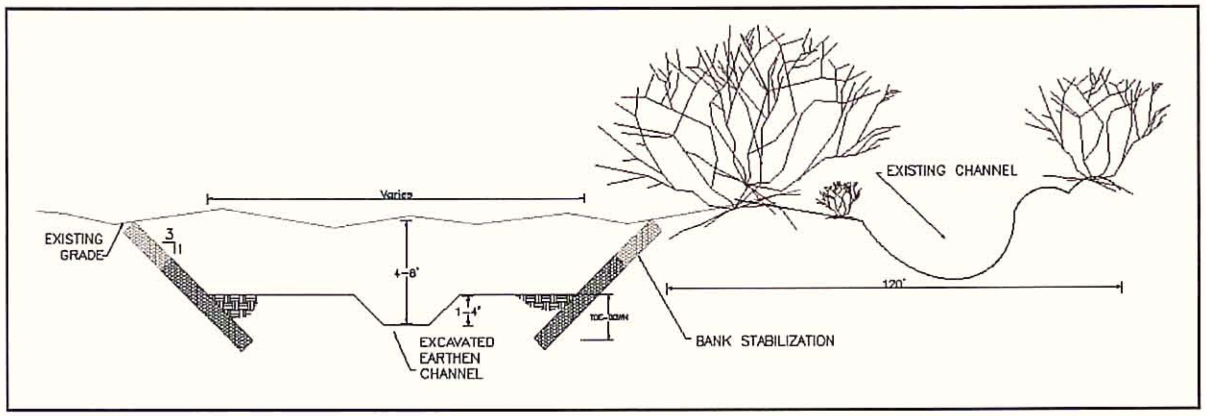

Figure 24 Concept Cross Section for Earthen Companion Channel (Alternative B3) (Not to scale)

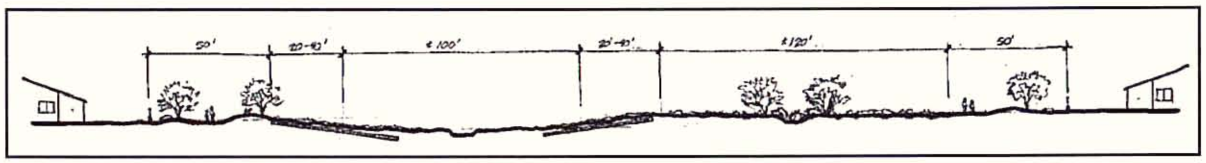

Figure 25 Concept Cross Section for Earthen Companion Channel with Landscape Compatibility Enhancements (Alt B3) (Not to scale)

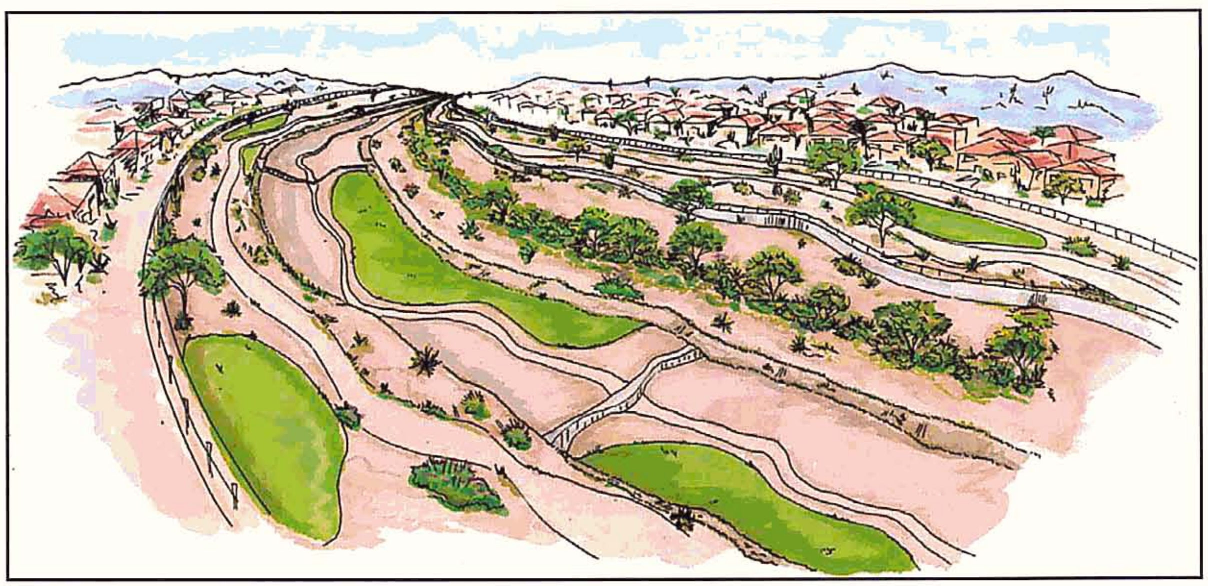

Figure 26 Oblique View of Earthen Excavated Companion Channel with Landscape Compatibility Enhancements (Not to scale)

Earthen Companion Channel – An excavated channel with earthen lining is located adjacent to the existing corridor to convey the flow. The channel is placed adjacent to the existing corridor so that the natural watercourse habitat is not disturbed. Figure 24 shows the concept cross-section for the earthen companion channel. The earthen companion channels are incorporated in Alternative B3.

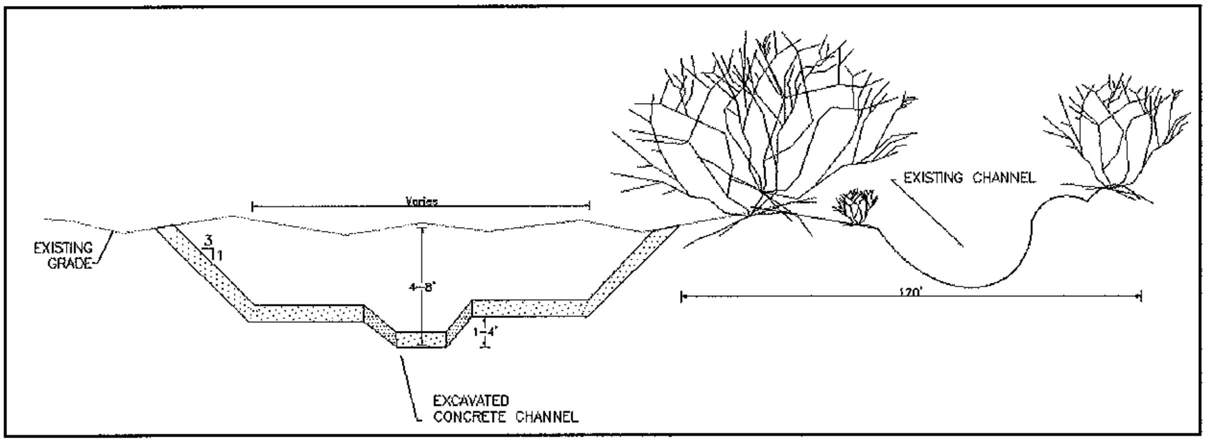

Figure 27 Concept Cross Section for Concrete Companion Channel (Alternative C) (Not to scale)

Concrete Companion Channel – An excavated channel with concrete lining is considered for Alternative C (See Section 4.4.3. for additional information). Figure 27 shows the concept cross-section for the concrete companion channel.

Variations in Channel Alignments

The choice of the channel alignment can significantly influence the cost of the project. Longer alignments are typically more expensive. The evaluation of the different channel alignments was considered for the following areas:

1) Wagner Wash,

2) Hassayampa River,

3) FRS #1, and

4) FRS #2 & #3.

These sub-areas provide clear possibilities for channel alignment variations. To the contrary, multiple channel alignment were not considered for the CAP and White Tank Wash sub-areas because of their straightforward channel alignment options. The evaluation of the variations in channel alignment was considered as Alternative B4 which was subdivided into B4-1, B4-2 and B4-3 to represent three different channel alignment variations. The other design considerations for Alternative B4 are similar to Alternative B1. Table 3 shows the various design options chosen for each piedmont sub-area.

Table 3 Design Options for Alternatives

Subarea	A	B1	B2	B3	B4	B5	C
CAP	SA, LVC	BB, LVC	SB, LVC	BB, EXCEC	N/A	OB, LVC	BB, EXCCC
Wagner Wash	SA, LVC	N/A	SB, LVC	BB, EXCEC	BB, LVC, 3 Alignments	N/A	BB, EXCCC
White Tank Wash	SA, LVC	BB, LVC	SB, LVC	BB, EXCEC	N/A	N/A	BB, EXCCC
Hassayampa River	SA, LVC	N/A	SB, LVC	BB, EXCEC	BB, LVC, 3 Alignments	N/A	BB, EXCCC
FRS #1	SA, LVC	N/A	SB, LVC	BB, EXCEC	BB, LVC, 3 Alignments	N/A	BB, EXCCC
FRS #2 and #3	SA, LVC	N/A	SB, LVC	BB, EXCEC	BB, LVC, 3 Alignments	N/A	BB, EXCCC

LVC - Leveed Channel, EXCEC - Excavated Earthen Channel, EXCCC - Excavated Concrete Channel
SA - Sedimentation Area, BB - Big On-line Basin, SB - Small On-line Basin, OB - Small Off-line Basin
Note: CAP and White Tank Wash have only one alignment.

Alternative B5 considers an off-line basin at the apex instead of an on-line basin. The off-line basin is designed to be a small basin with the main purpose of reducing the peak flow approximately by 10%. This alternative is similar to Alternative B2 with the only difference being the off-line basin at the apex instead of an on-line basin. Alternative B5 was considered for CAP sub-area and provides a means for evaluating the effectiveness of an off-line basin at the apex.

Figures 28 – 34 show the planimetric layout of each of the various B Alternatives for the piedmont sub-areas. Included on each map are the locations of the detention basins at the apices, the downstream leveed corridors, off-line detention basins where needed, and the existing FEMA floodplain reaches on Wagner and White Tank Washes.

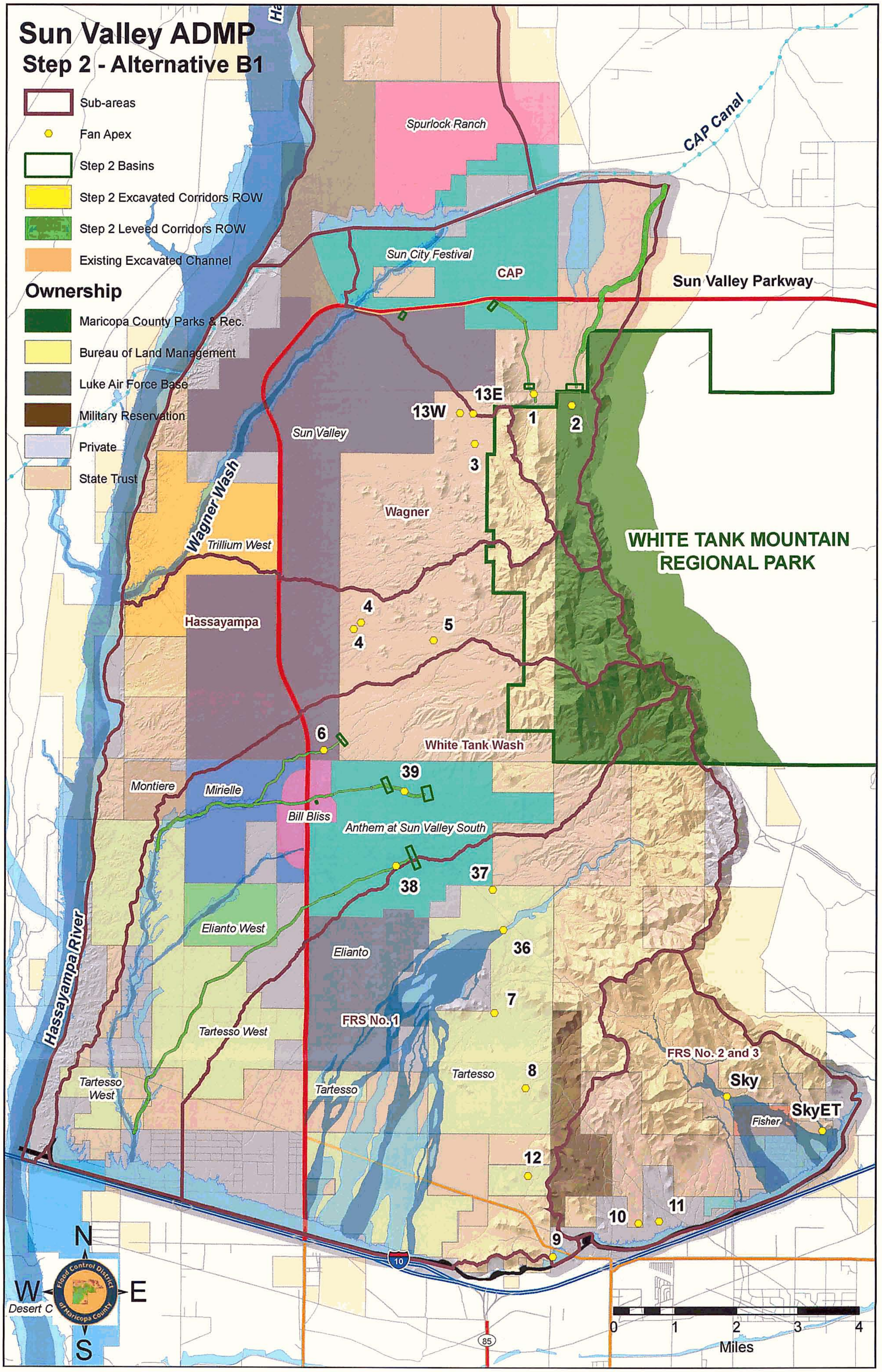

Figure 28 Alternative B1

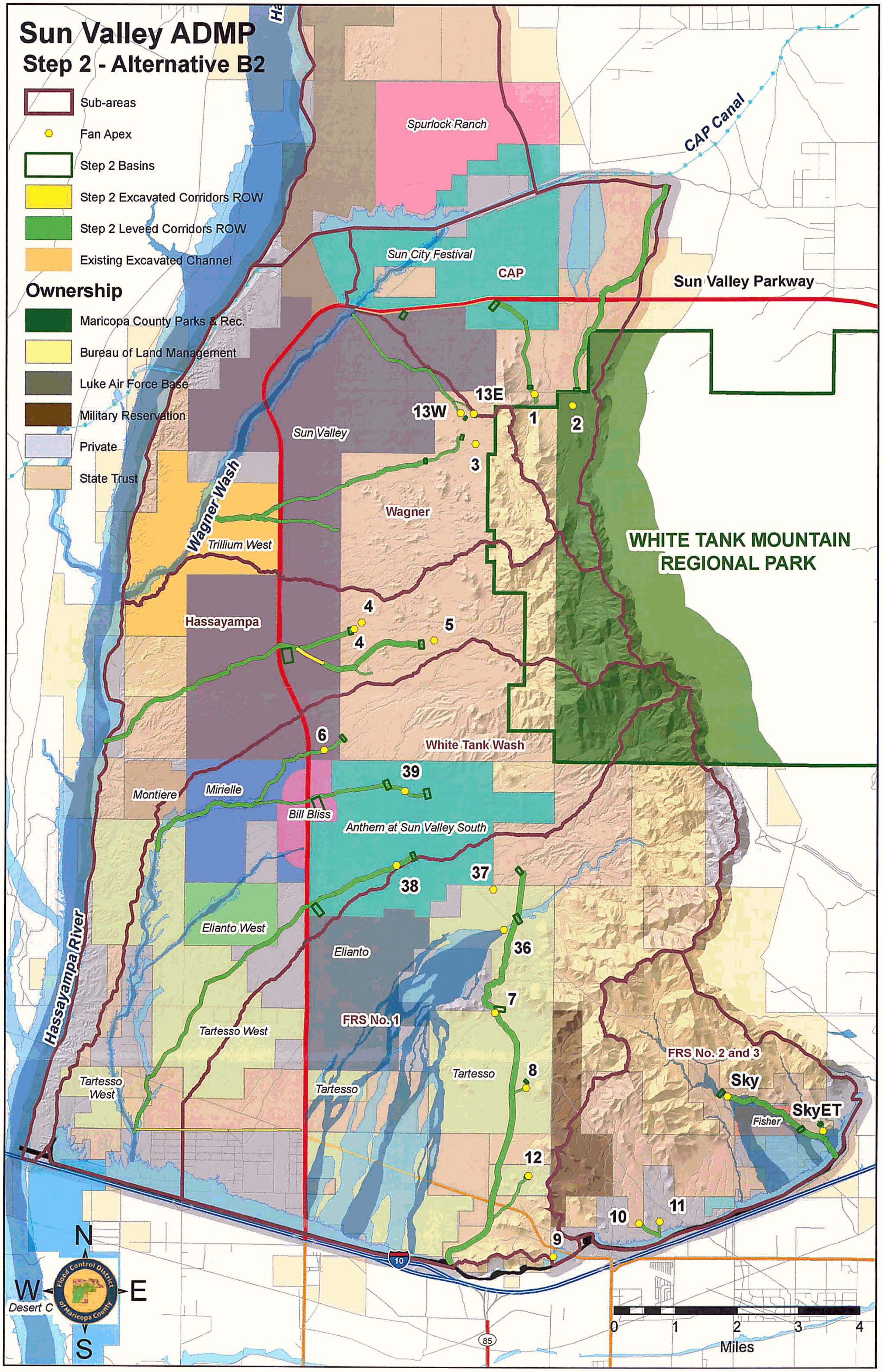

Figure 29 Alternative B2

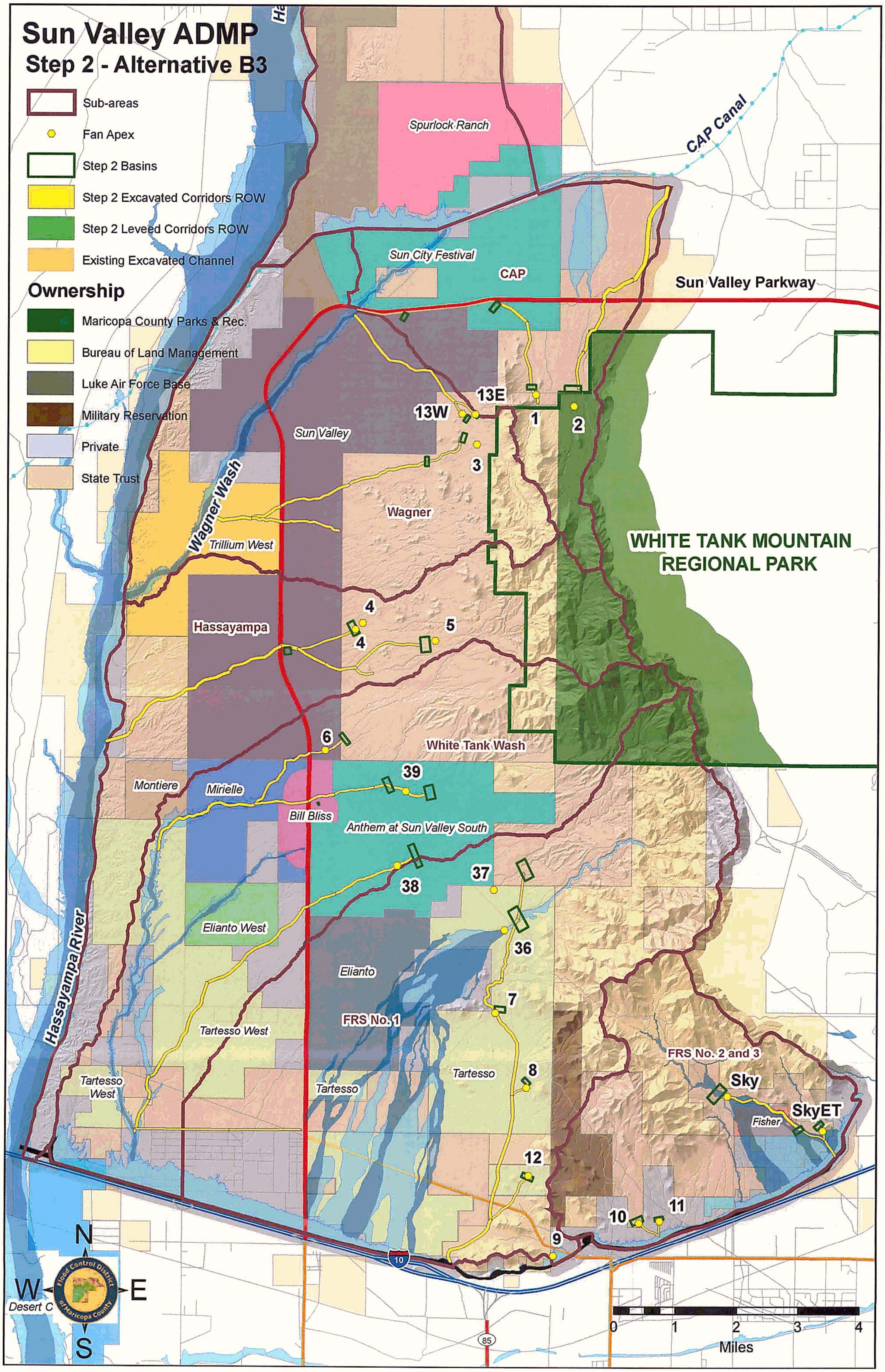

Figure 30 Alternative B3

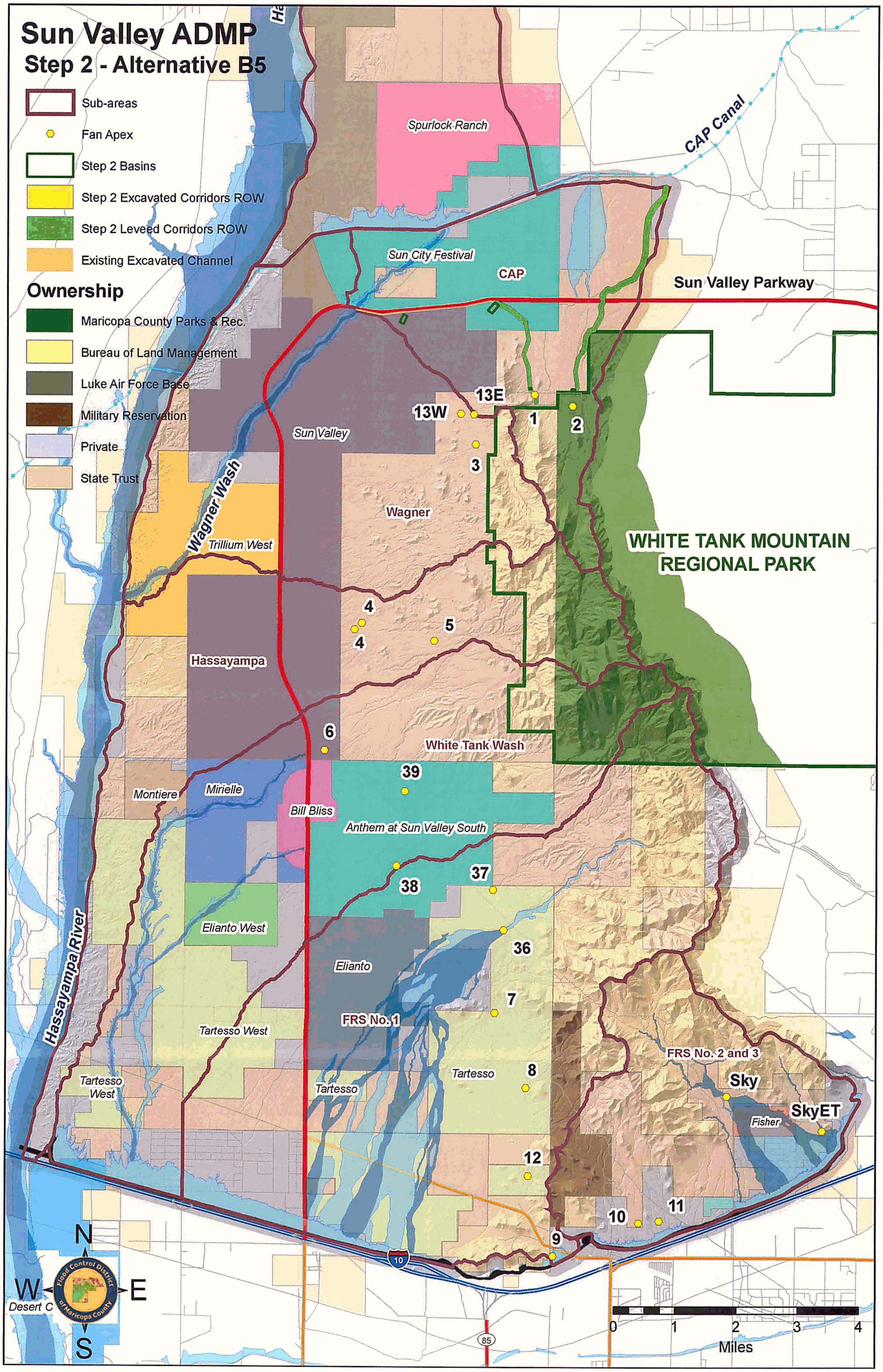

Figure 31 Alternative B5

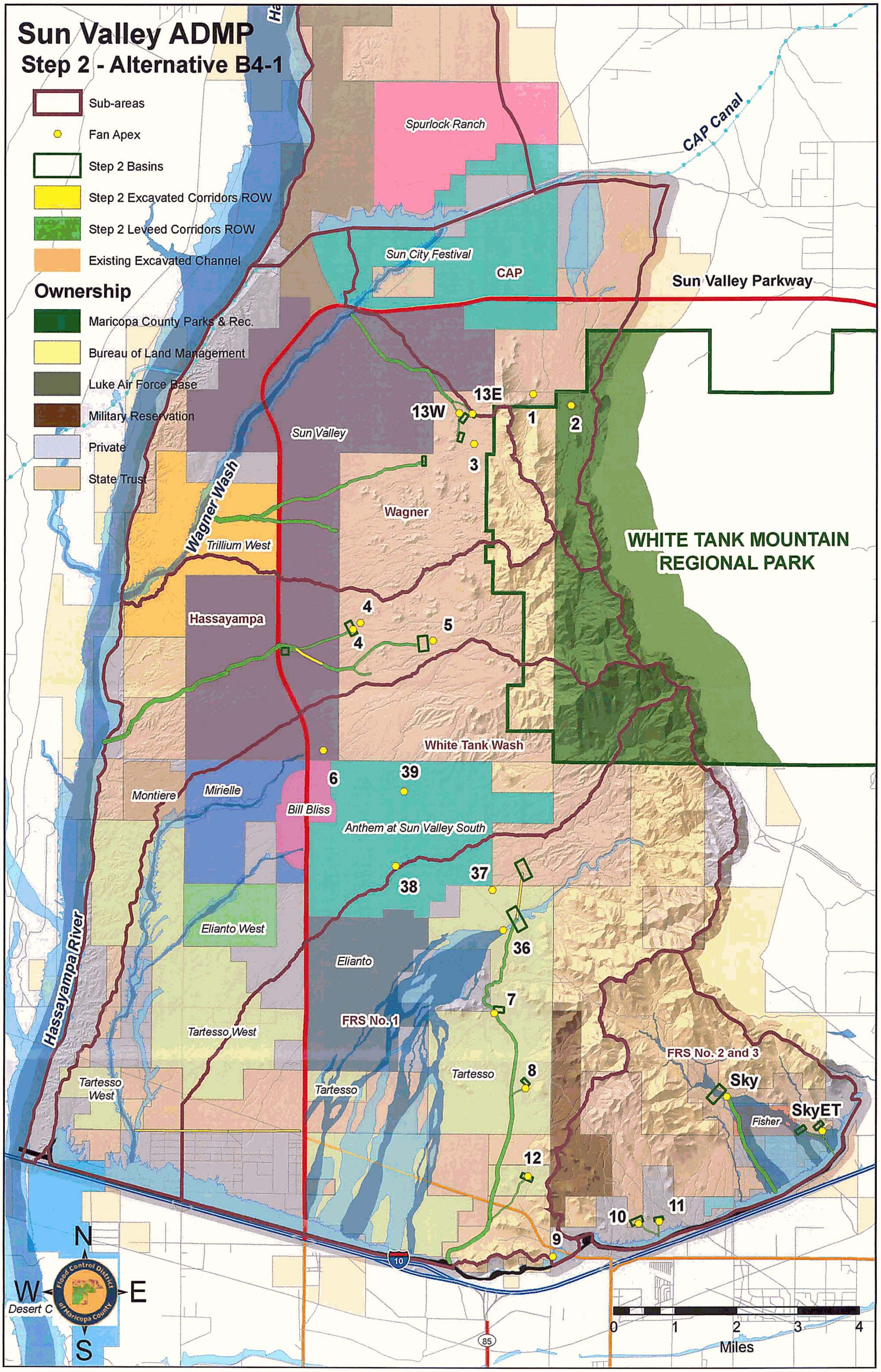

Figure 32 Alternative B4-1

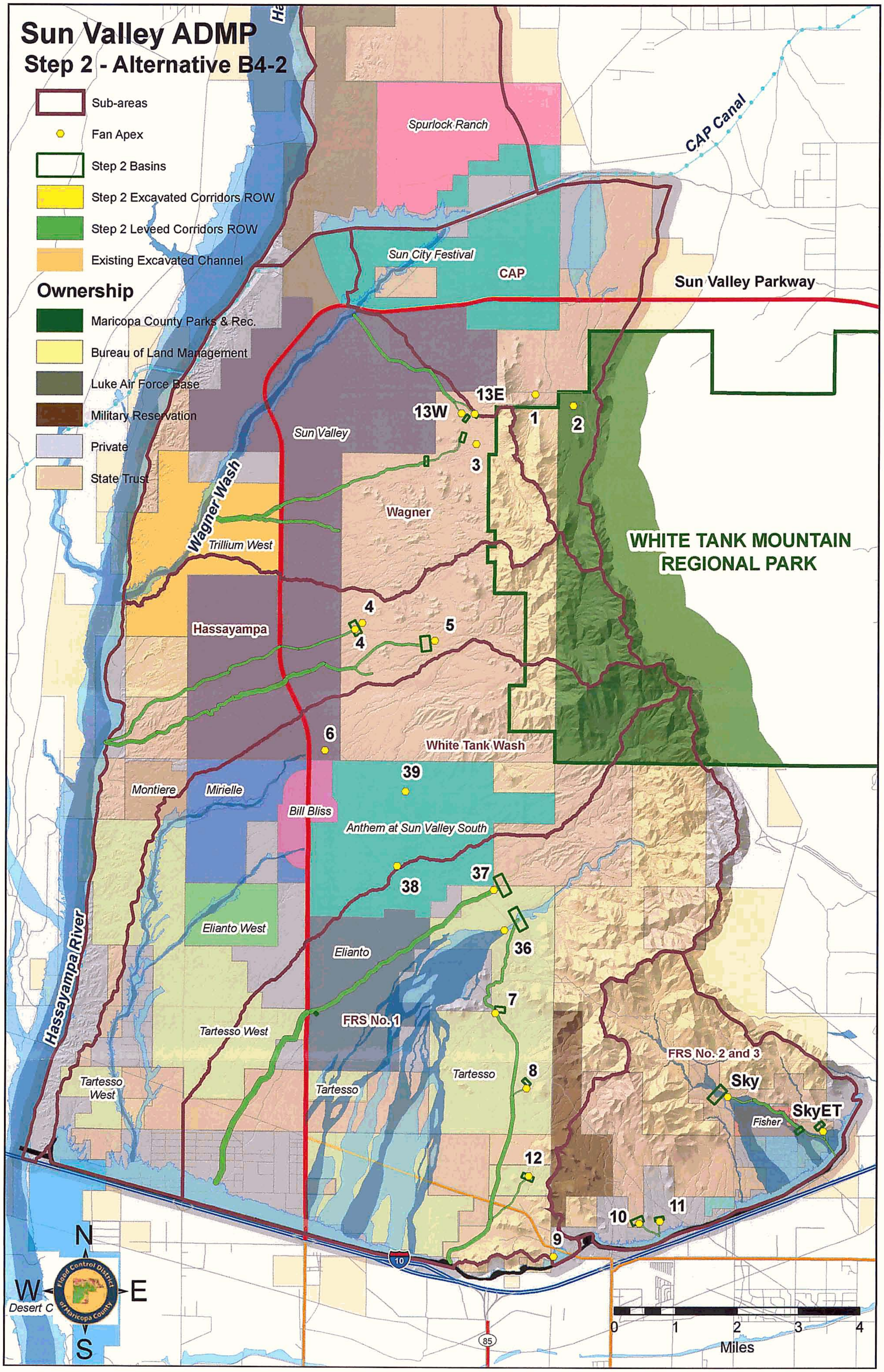

Figure 33 Alternative B4-2

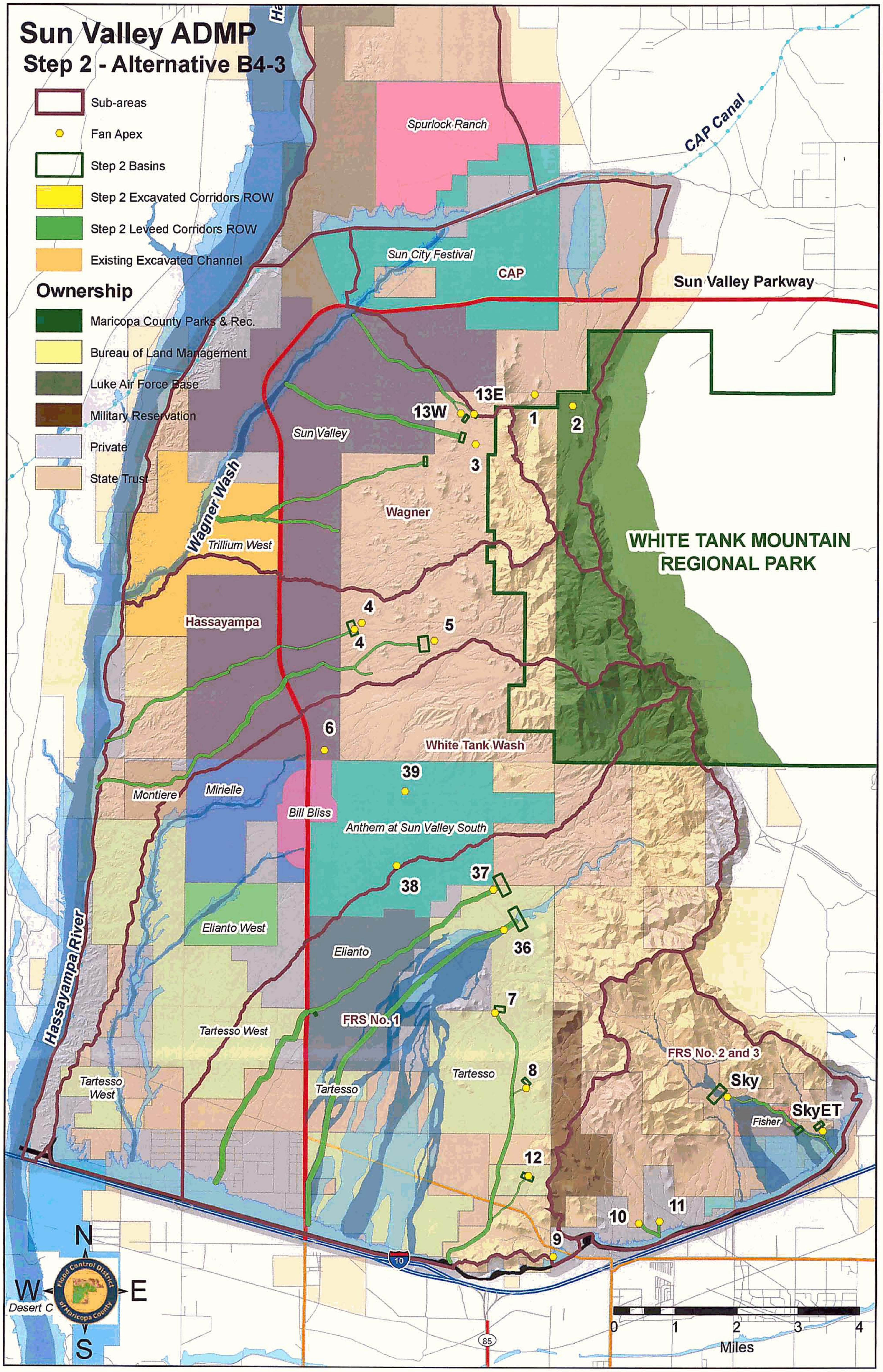

Figure 34 Alternative B4-3

4.4.3 Alternative C

Alternative C is a structural flood control alternative based on the concept of an excavated concrete-lined channel from the apex to the outfall (Figure 27). No detention basin is provided at the apex. Sedimentation basins are provided throughout the system. The advantages of Alternative C include reduced land cost due to lack of a detention basin near the apex and smaller channel land areas. The concrete channels are easier to maintain as well. The disadvantages are that the concrete channels are not as aesthetically appealing and are less amenable for multi-use. Another disadvantage is the high cost of construction due to excavation and concrete lining.

Figure 35 shows the planimetric alignment of the C Alternative companion channels and corridors. While primarily a structural alternative, Alternative C includes the same non-structural, floodplain management approaches for the outfall reaches of Wagner and White Tank Washes.

4.4.4 Alternative D

Alternative D follows the "No Measure" strategy as defined by the Step 1 Preliminary Alternatives Evaluation. This alternative relies on existing drainage facilities or new master planned communities developing their own drainage infrastructure. Current drainage ordinances and floodplain regulations are enforced to ensure adequate flood hazard mitigation measures. Enforcement options can be enhanced by developing new alluvial fan floodplain delineations.

The major advantage of this alternative is that no immediate and expensive action is needed from the District. The main disadvantage compared to the other alternatives is that there will be no regional whole-fan flood control system leading to unnecessary redundancies, unintentional system discontinuities, and/or potential planning problems. This measure is also likely to leave portions of unstable, active alluvial fan areas open and undeveloped.

Figure 36 shows the location of the corridors and basins known to be part of existing master plans for the area. Note how some of the proposed plans contain elements of both the A and B Alternatives. Input from the stakeholder workgroup suggests that many of the corridors are likely to be walled corridor cross sections.

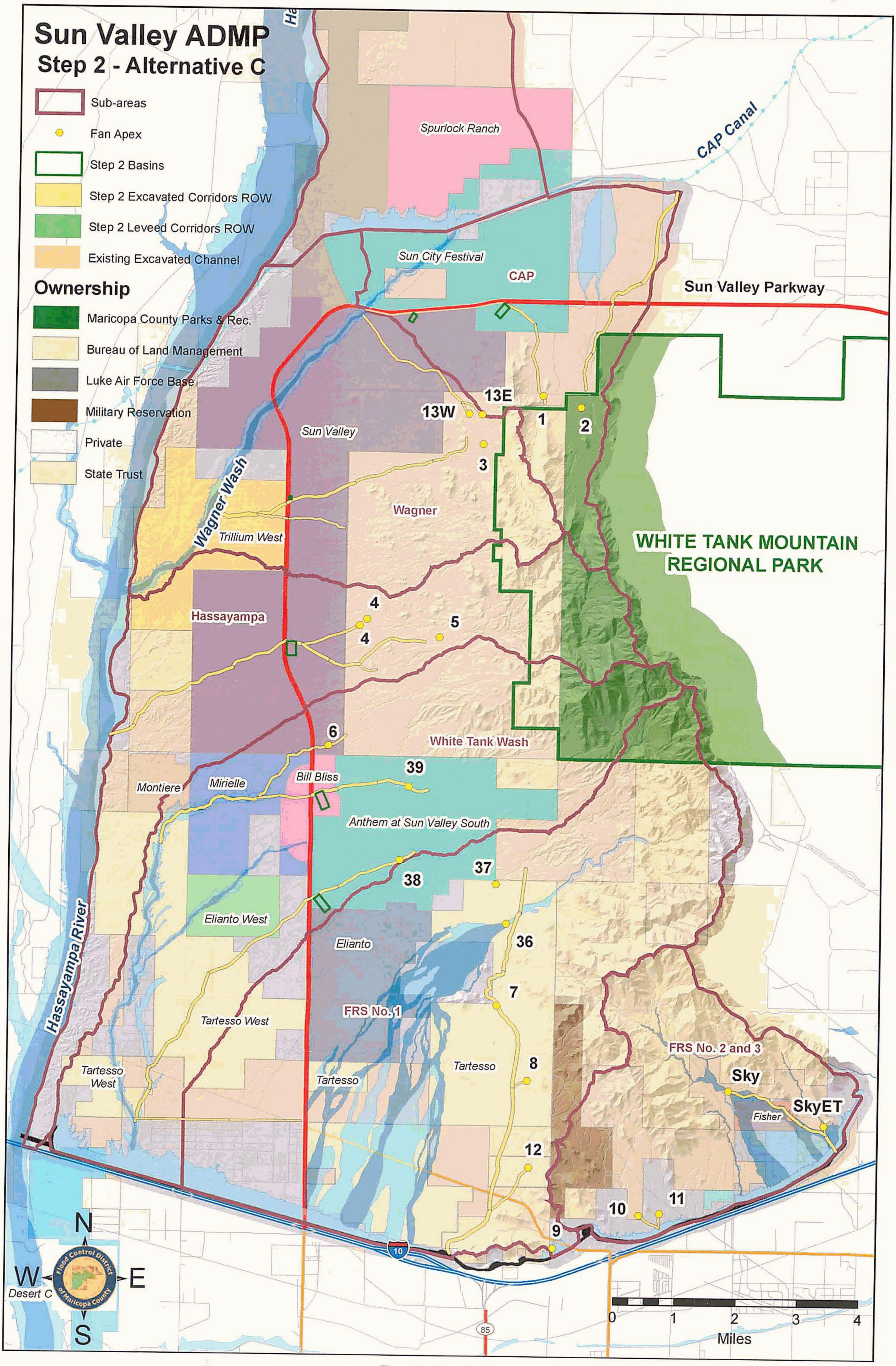

Figure 35 Alternative C

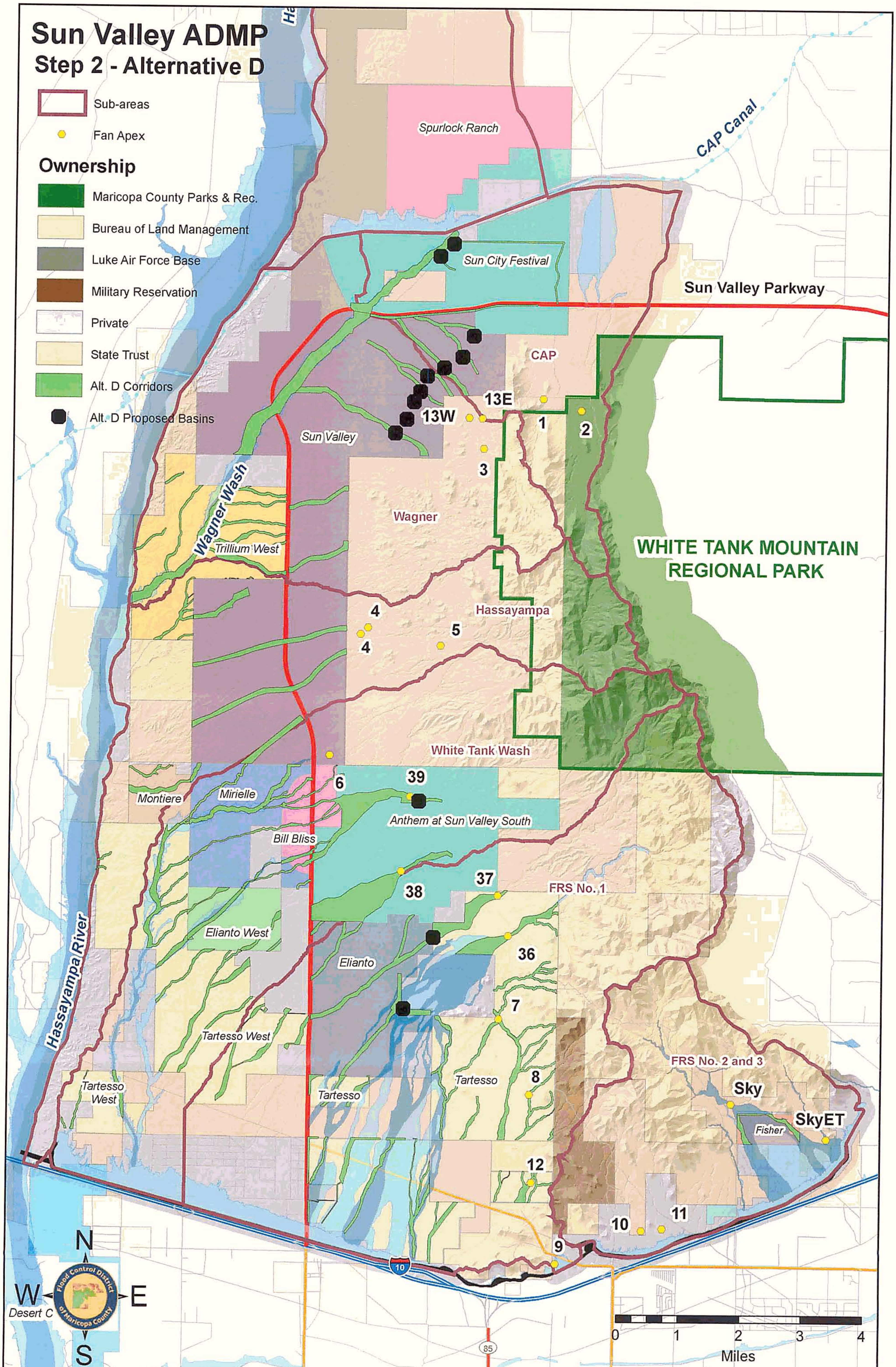

Figure 36 Alternative D

5 STEP 2 APPROACH

5.1 Data Collection

5.1.1 Field Survey Information

Refer to the Flood Control District of Maricopa County (District) for field survey information associated with the 10-foot topographic mapping used in the current study.

5.1.2 Mapping

The District provided 10-foot contour mapping and DTM data for use in the hydrologic and hydraulic calculations. That work was done under separate contract for the District in 2000/2001. The flight dates of that mapping were 12-16-00, 12-17-00, and 12-27-00. A triangulated irregular network (TIN) was developed in ArcGIS software using the 10-ft topographic contours. The TIN and the contours were used to obtain all the elevation data used in this study.

5.1.3 Aerial Photographs

The Flood Control District provided aerial photographs for use in the GIS applications.

5.1.4 Existing Culvert Data at Sun Valley Parkway Crossings

The as-builts for the existing culverts at the Sun Valley Parkway were obtained from MCDOT.

5.1.5 Sediment Gradations

Sediment gradations used in this study are based on data collected by Coe and Van Loo, Consultants Inc (CVL). These are the only set of sediment gradation data available at the time of preparation of this report. Additional sediment samples are being collected as part of this study and will be included in the Step 3 refinements of the alternatives.

5.2 Process Overview and Summary of Design Criteria

The details of the design procedures for the structural elements of all of the alternatives are presented in the companion volumes for each individual sub-area (Volumes 2-7). The following sections provide a brief overview of these design procedures for each structure type and each alternative. The alternatives themselves are described in Section 4.4. The design procedures vary by structure type and alternative. However, there is significant commonality between alternatives. Table 4 shows a summary of the design criteria used for each of the Step 2 alternatives. All structures are designed for the maximum peak flow or volume from the 100-year 6-hour or 24-hour event.

Using the criteria shown in Table 4, the structural elements for each sub-area were designed using the following general approach:

- Identify the fan apex/upstream area location and the preferred channel alignment from the apex to the outfall. For Wagner, Hassayampa, FRS 1 and FRS 2 & 3 sub-areas, the preferred channel alignment is one of the alignments in B4-1, B4-2, or B4-3. The alignments for the CAP and White Tank Wash sub-areas are the same for all alternatives.
- Identify the set-aside area (A) or design the detention basin (B) near apex location
- Route flow from the apex to Sun Valley Parkway by designing a leveed corridor (A, B1, B2, B4, B5) or excavated channel (B3, C) along the preferred alignment.
- Design an off-line basin upstream of the culvert location at Sun Valley Parkway if the culvert capacity is not adequate. Off-line basin capacity is the volume of flow above the culvert capacity.
- Route the flows from Sun Valley Parkway to the outfall by designing a leveed corridor or excavated channel along the preferred alignment.
- Prepare cost estimates (see Section 6) for the land cost, construction cost, landscaping cost, and maintenance cost for the base condition and for the landscape compatibility enhancements.

Sediment is controlled at the apex for all alternatives. For the areas downstream of the alluvial fan apex, sedimentation is controlled in two ways. First, sedimentation basins are provided longitudinally along the channels based on the sediment yield from the contributing area to the design reach. Second, grade control structures are included for the leveed corridors (A, B1, B2, B4, B5) and the excavated earthen channels (B3). All earth bottom corridors also include bank and toe protection from scour.

Table 4 Summary of Design Criteria for Step 2 Alternatives

Alternative	Apex Treatment	Basin Geometry Criteria	Downstream Channel	Hydraulic Criteria
A	Active Area Set-aside	N/A	levee/wall	≈ 4 ft levee height; 4 - 6 ft/s; ≤ 400 foot width
B1	On-line Basin; 10% outflow	Z = 3:1 Function; Z = 6:1 Form; D < 12 ft	levee/wall	≈ 4 ft levee height; 4 - 6 ft/s; ≤ 400 foot width
B2	On-line Basin; 90% outflow	Z = 3:1 Function; Z = 6:1 Form; D < 12 ft	levee/wall	≈ 4 ft levee height; 4 - 6 ft/s; ≤ 400 foot width
B3	On-line Basin; 10% outflow	Z = 3:1 Function; Z = 6:1 Form; D < 12 ft	excavated earthen channel	≈ regime w, d, v
B4	On-line Basin; 10% outflow	Z = 3:1 Function; Z = 6:1 Form; D < 12 ft	levee/wall	≈ 4 ft levee height; 4 - 6 ft/s; ≤ 400 foot width
B5	Off-line Basin; 90% bypass flow	Z = 3:1 Function; Z = 6:1 Form; D < 12 ft	levee/wall	≈ 4 ft levee height; 4 - 6 ft/s; ≤ 400 foot width
C	Sediment Basin Only	N/A	excavated concrete channel	Fr < 0.86; 2-year < 2 ft or 5 ft/s
Note: All channels include longitudinal sediment basins based on sediment yield from contributing area.				

Additional details regarding the design considerations associated with each structural element are discussed briefly in the following sections. Again, Volumes 2-7 contain additional details of the methodologies, calculations, and results for each piedmont sub-area.

5.3 *Open Channel Design Considerations*

Open channels are used for the "conveyance" strategy as recommended by the Step 1 Preliminary Alternatives process. The channels are aligned along existing natural watercourse corridors in order to preserve the existing natural habitat. Most of the alternatives use the existing channel contained within the earthen levees for conveyance. The exceptions to this are the two alternatives where channel excavation is considered. These are Alternative B3 (Earthen excavated channel) and Alternative C (Concrete excavated channel) which are located approximately parallel and adjacent to the natural corridor. In these cases, a portion of the flows in the excavated channel may have to be diverted into the existing watercourse corridor to preserve the natural habitat.

The channel types are classified into 1) Leveed channel corridor, 2) Excavated channel, and 3) Existing channel. The leveed channel corridor uses the existing watercourse corridor with levees on both sides to contain the flow. The excavated channel can have an earthen or concrete lining and is designed to be excavated below existing ground. The existing channel is any existing channel that is used as part of the design alternative.

The channels are designed to act as a regional flood control trunk system and are sized to convey local drainage as well as sediment from the adjacent watershed area. As part of the Step 2 design process, four discharge values are analyzed to ensure the applicability of the design to a range of flows. The four flows are simply ratios of the 100-year peak flows: 10%, 25%, 75% and 100%. The 10% flow can be expected to approximately represent the 2-year flow, the 25% represent the 10-year flow, and 75% represent the 50-year flow.

Per the District's Hydraulics Manual, minimum freeboard for the open channel is set as the greater of 1 foot or $0.25\ (y + V^2/2g)$. For channels with levees, the FEMA freeboard requirement of 3 feet is applied for the concept designs.

Excavated channels are designed for subcritical flow with Froude numbers less than 0.86. Subcritical design results in flows with lower velocity and are favorable from a public safety point of view. The design slopes are flatter than the existing slopes to achieve the subcritical flow.

Velocity in the leveed channel corridors is designed to be 4 to 6 ft/sec. This velocity range is expected to adequately move sediment downstream without being so large as to cause excessive erosion. The width of the leveed natural channel is also restricted to 400 ft. Flow depth in the leveed channel is restricted to 1-2 ft unless the velocity and/or width requirement could not be met simultaneously.

A side slope of 3H:1V is assumed for both the main channel as well as the low flow channel for the base design.

5.4 Inline Sedimentation Basin and Drop Structure Design Considerations

Drop structures and inline sedimentation basins are included to control sedimentation issues. The on-line detention basins collect both sediment and flow volume while the off-line basins collect only the flow volume. As a result, the on-line detention basins also function as sedimentation traps near the fan apices. Inline sedimentation basins are placed within the channels acting as sediment traps to collect any additional sediment influx exceeding the capacity of the designed channel. Excessive sediment influx is possible at all the tributary confluences as well as at confluences of any other inflow that may occur in the future. Sediment yield from the upstream reach as well as adjacent watershed provides estimates of sediments entering the channels and is used to size the inline sedimentation basins. Sedimentation basins/traps are distributed along the reach to avoid serious sedimentation problems at any specific location.

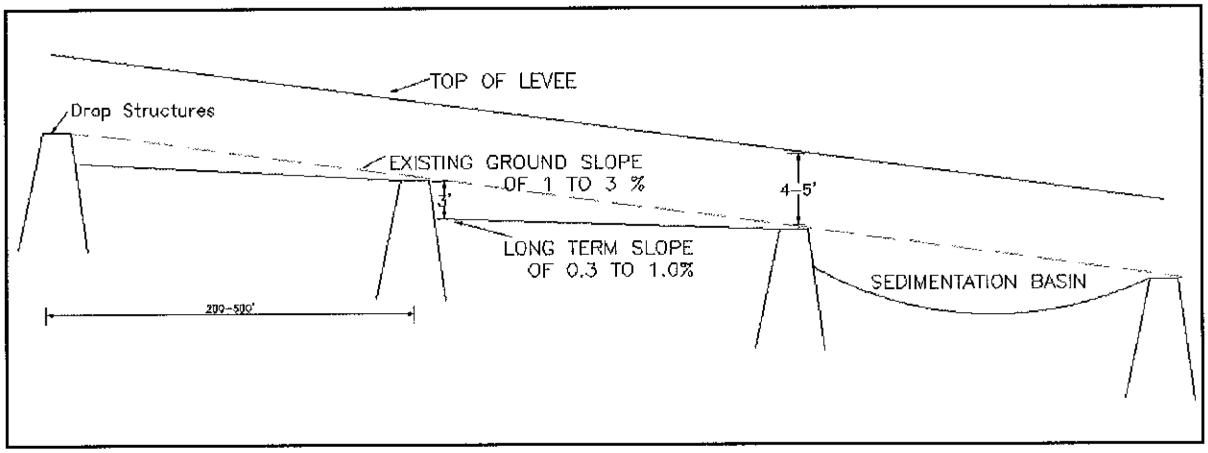

Figure 37 Concept Profile View of Leveed Channel Corridor (Alternatives A, B1, B2, B4, B5) (Not to scale)

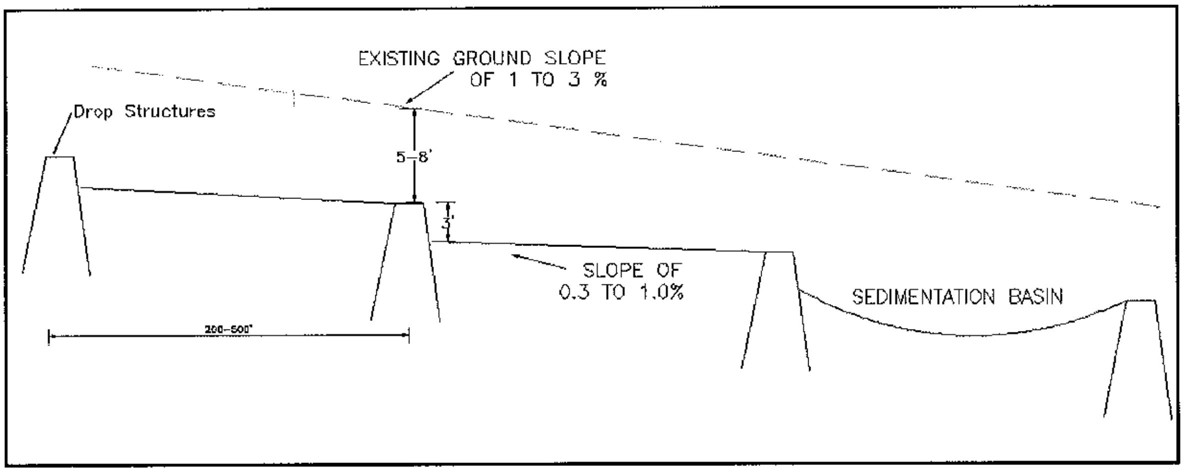

Figure 38 Concept Profile View of Excavated Channel (Alternatives B3 and C) (Not to scale)

The drop structures are designed to be 3 feet high and are spaced accordingly. The 3-foot drop provides a reasonable height from a multiple-use point of view. For the purpose of comparing alternatives considered in the Step 2 process, grade control structures for all alternatives except the concrete excavated channel were assumed to be made of riprap. The riprap is assumed to be buried. The number of drop structures was determined by using the difference between the existing slope and the design slope for excavated channels or anticipated long-term slope for the leveed corridors. The drop structures were spaced to achieve the elevation difference caused by the difference between the existing slope and the design or long-term slope. Figure 37 shows the concept profile view of the leveed channel corridor which is part of A, B1, B2, B4 and B5 alternatives. Figure 38 shows the concept profile view of the excavated channel which is part of the B3 and C alternatives.

5.5 On-line Detention Basin Design Considerations

The on-line detention basins are located mostly at the apices to control the flow and sediment arriving at the fan apices. The basin volume is provided entirely through excavation and is designed to be entirely below existing ground. Raised embankments are not used to provide basin storage volume. Rectangular basins with constant side slopes are considered for the purpose of the base design analyses and sizing. In reality, these would be shaped differently to better fit into the natural setting depending on landscaping and other requirements. The adjustments and cost estimates for these landscape compatibility enhancements are described in Section 6.2. The rectangular basins provide an approximate idea of the required size of basin in terms of storage volume and the minimum land footprint needed to obtain that volume. Figure 39 shows the concept plan view of the on-line basins and Figure 41 shows the concept profile view. Figure 40 and Figure 42 show the on-line basins with landscape compatibility enhancements.

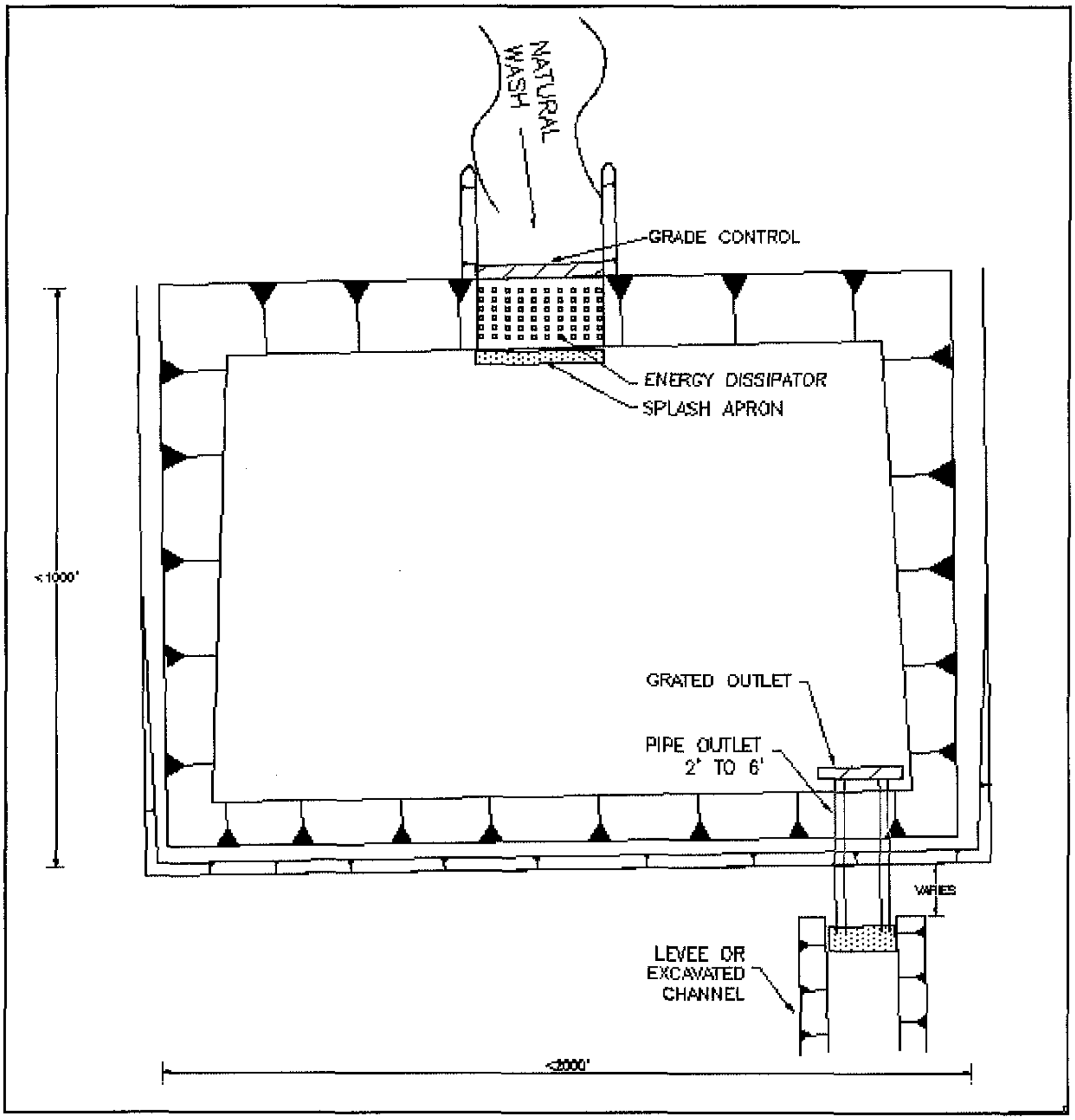

Figure 39 Concept Plan View of On-line Basins for B Alternatives (Not to scale)

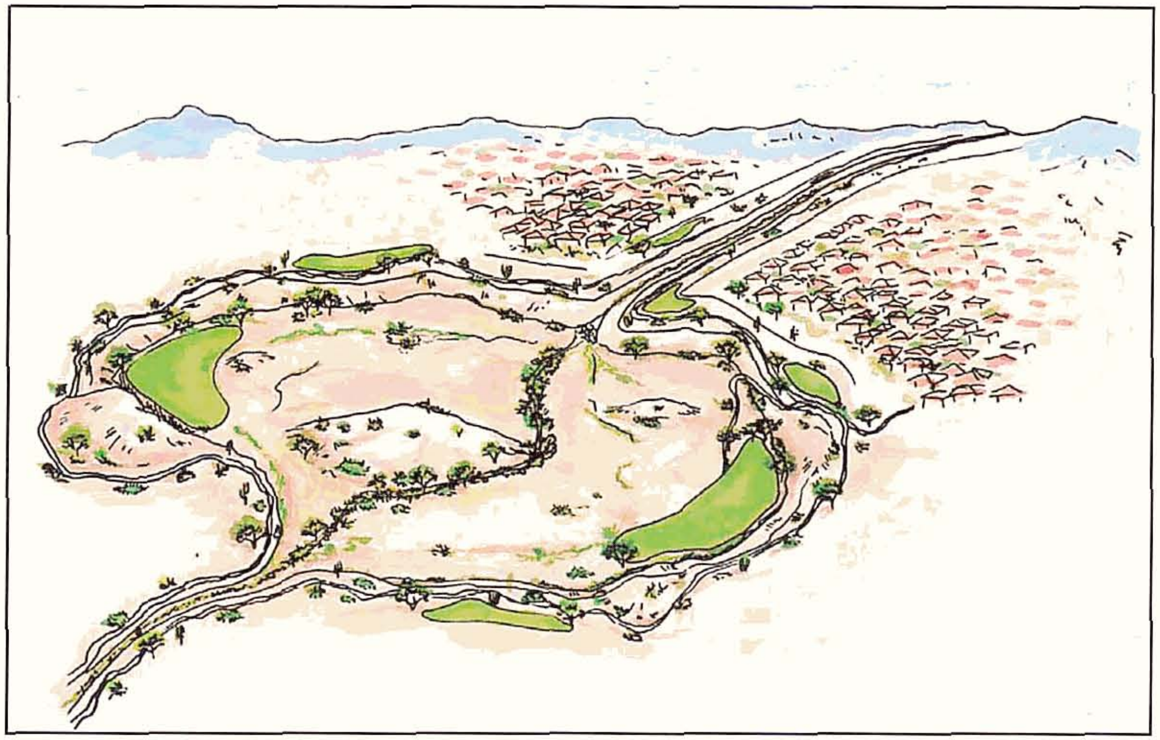

Figure 40 Concept Plan View of On-line Basins for B Alternatives with Landscape Compatibility Enhancements (Not to scale)

The big basin option is designed to have a peak outflow of approximately 10% of the peak 100-year design inflow, representing approximately the 2-year flow. The small basin option is designed to have a peak outflow of approximately 90 % of the peak 100-year design inflow.

Pipe outlets are designed to drain the basins. Multiple pipes are needed when the basins are small compared to the total flow volume entering the basins. Appropriate hydraulic equations are used to determine the stage–discharge relationships. Sediment yield from the upstream watershed is used to estimate inflowing sediment volume.

The existing topographic slope was determined from the 10-ft topographic mapping contours. The existing slopes near the apices are approximately 2-3%. These steep slopes result in considerable elevation differences between the upstream and downstream ends of the basins. Basins are designed to have longer dimensions perpendicular to flow direction to minimize the cut-slope exposure on the upstream side of the basins. This gives a minimum basin dimension along the topographic slope and reduces the visual impact of the basins.

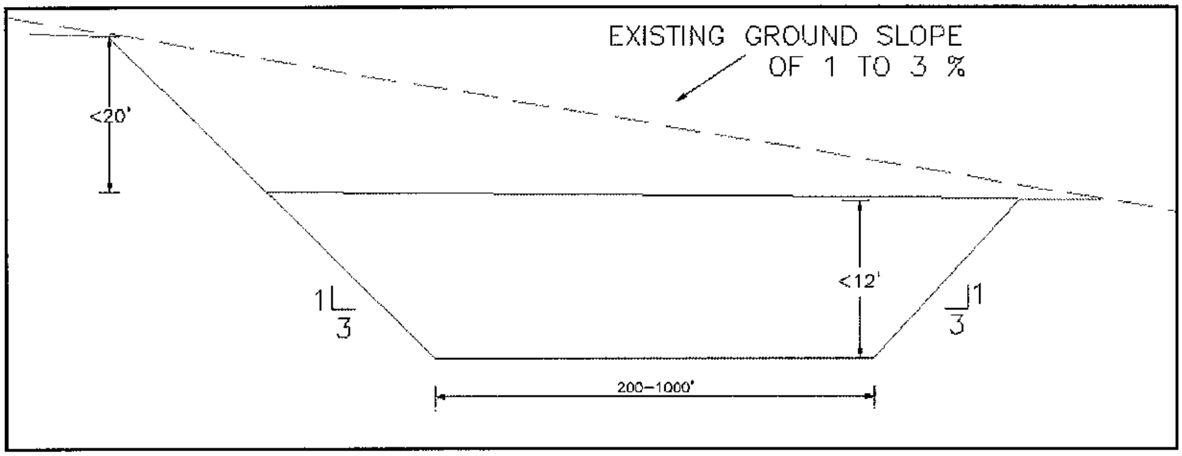

Figure 41 Concept Profile View of On-line Basins (Not to scale)

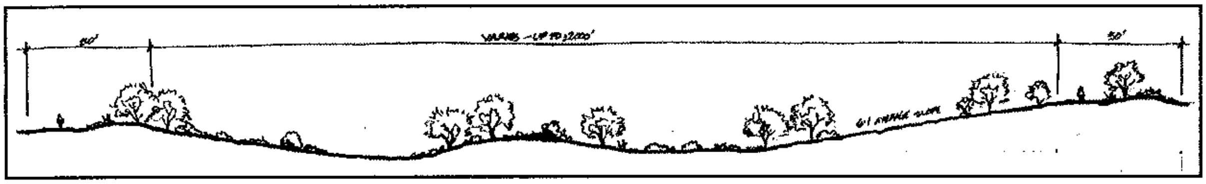

Figure 42 Concept Profile View of On-line Basins with Landscape Compatibility Enhancements (Not to scale)

The basins are designed to be up to 12 feet in depth. This depth includes a freeboard of 1 ft. An initial side slope of 3H:1V is assumed for the base design. Shallower side slopes are included in the landscape compatibility enhancements.

5.6 Off-line Detention Basin Design Considerations

Off-line detention basins are provided in locations where there is a need to reduce peak flows. These locations include: a) upstream of culverts to reduce flow to culvert hydraulic capacity, b) tributary confluences, and c) at the downstream end at outfall locations. Most of these basins will be located downstream of the apices except for Alternative B5 where an off-line basin is located near the apex.

The flow from the open channel will enter the off-line detention basins via a weir. Figure 43 shows the concept plan view of the off-line basins. Figure 44 shows the off-line basin with landscape compatibility enhancements. The Step 2 design process estimated the volume to be diverted using an inflow-outflow diversion relationship. The weirs were not sized in the Step 2 design process.

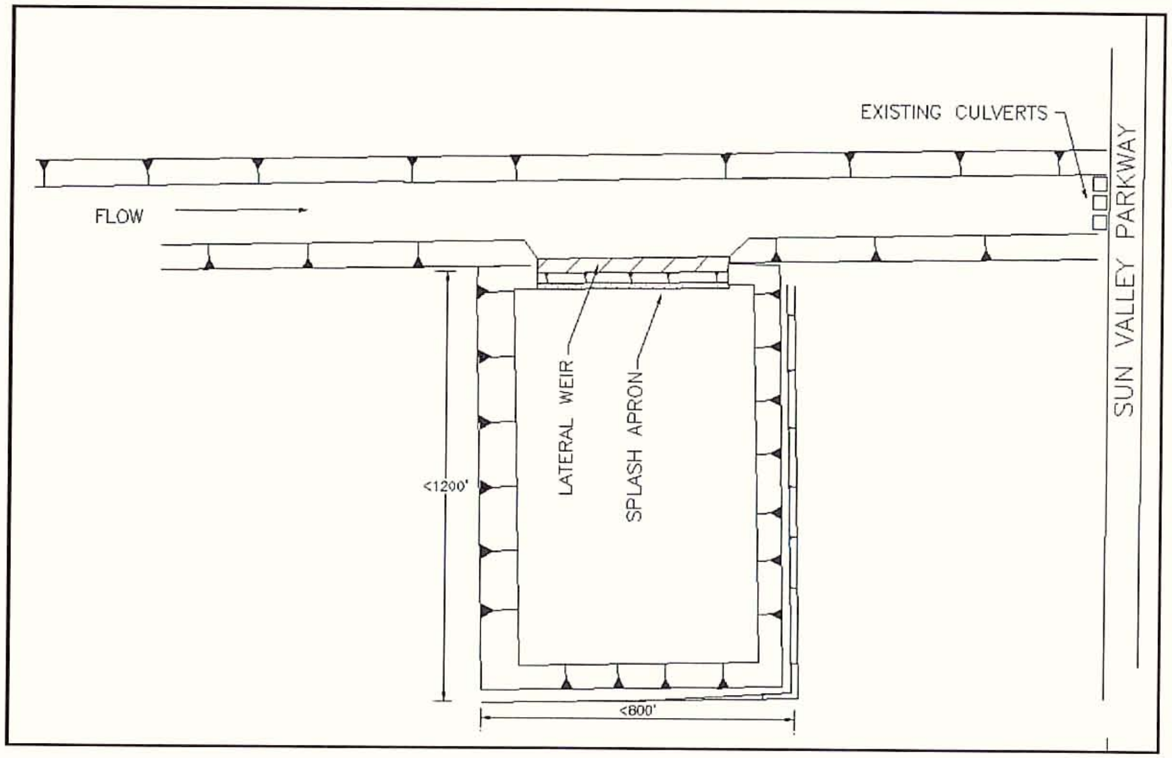

Figure 43 Concept Plan View of Off-line Basins (Not to scale)

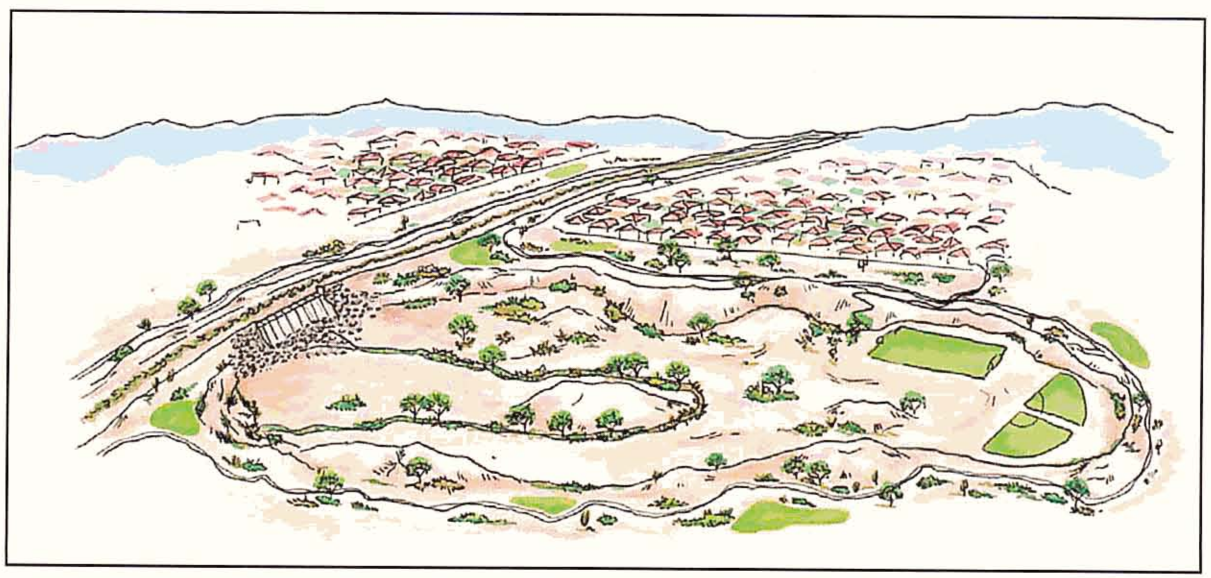

Figure 44 Concept Plan View of Off-line Basins with Landscape Compatibility Enhancements (Not to scale)

5.7 Hydrology

The design of the open channels as well the detention basins are based on the 100-year peak discharges. HEC-1 modeling is used to determine the peak discharges as well as the flow volume passing through the designed structures. The existing conditions hydrology model is used for the estimation of the peak discharges used in the design. The flows computed from existing conditions model are higher than the future conditions model due to retention requirements. Thus, using the flows computed from the existing conditions model represents a more conservative design approach. In addition, the phasing of the developments is unknown. As a result, it is prudent to be conservative and use the existing conditions hydrology to ensure effective continuous functioning of the flood control system.

A separate HEC-1 model was developed for each sub-area for the 100-year 24-hour and 100-year 6-hour storms for each alternative. For the purpose of the design, the maximum of the values obtained from the 24-hour and 6-hour results were used to ensure adequate functionality under 6-hour and 24-hour storm scenarios. This means that the design analyses sometimes use the 6 hour value and vice-versa depending on whichever is larger.

The procedure to estimate peak flow and flow volume was iterative in nature: The iteration steps can be briefly described as follows:

- Change in structure design dimensions affect HEC-1 model
- Change in HEC-1 model affects discharges/volumes
- Change in discharges affect structure design dimensions

The HEC-1 models used here are based on the Area 3 HEC-1 model by PBS&J (2005) and Area 4 HEC-1 model by JE Fuller/ Hydrology & Geomorphology, Inc (2005). The HEC-1 models were not refined at Step 2 to provide design peak flows at every location for all the design elements. Long open channel sections were treated as a single routing in HEC-1. In addition, some of the subasin are large providing only a single downstream concentration point. In such situations, the design discharges and volumes were estimated using an area-ratio between the actual area affecting the design element and the entire subasin modeled in HEC-1. This simplified procedure facilitates a more refined design of multiple channel segments within a large subasin without the need for refining the HEC-1 model. Future HEC-1 model modifications at Step 3 will address the need for additional concentration points to generate peak flow data for concept design refinements.

5.8 Sediment Yield

Sediment contributions from the watershed adjacent to the design element were estimated using sediment yield. The sediment yield was estimated assuming a 3-year maintenance period plus a single 100-year event. An annual sediment yield of 0.3 ac-ft/sq. mi./year and a 100-year event sediment yield of 1 ac-ft/sq. mi. was assumed for this purpose. These values were derived based on examination of numerous previous studies conducted throughout Maricopa County. The total sediment volume was estimated as the sum of 3 average years' sediment volume and one 100-year event volume. The estimation of the contributing watershed area was performed using GIS. The sediment volume entering a particular design element was then estimated using the sediment contributing area and the sediment yield estimates.

5.9 On-line Detention Basin Analyses

The design considerations for the on-line detention basins are described in detail in Section 5.5. The analyses use rectangular basins with constant side slopes (3H:1V). The sediment yield estimates were used to estimate incoming sediment volume. One foot of freeboard was applied to accommodate the flow volume as well as the sediment volume. A stage-storage-discharge relationship was calculated and this relationship entered into the HEC-1 model using SE-SV-SQ records. The stage-storage relationship was determined from the basin design dimensions. The stage-discharge relationship was determined from pipe outlet equations. The HEC-1 model was then run to estimate the peak volume stored in the basin. The basin dimensions were then resized to hold this maximum volume at peak flow as predicted by HEC-1. In addition, the designed basin depth should be larger than the peak stage as predicted by HEC-1. The estimated sediment yield was added to the depth required to evaluate the adequacy of the basin design. The process was repeated in an iterative fashion until a satisfactory design was achieved.

5.10 Open Channel Analyses

5.10.1 Hydraulics

The hydraulic analyses for open channel design were performed using Manning's equation (normal-depth assumption). An 8-point cross-section was used to represent the channel cross-section dimensions. A Manning's n-value of 0.045 was used for all the alternatives except Alternative C where the designed channel has concrete lining. In places where the existing channel is used, analyses were performed to ensure adequate conveyance and freeboard for the estimated flows entering the channels.

It is anticipated that within the leveed conveyance corridors, a low-flow channel will form between the levees in the long-term. The low-flow channel dimensions were estimated using regime theory described in Section 5.10.2. Calculations were also performed to evaluate the hydraulic conditions expected to occur after the leveed corridor develops a low-flow channel. The earthen excavated channels (Alternative B3) were also sized to approximate the estimated regime dimensions.

5.10.2 Regime Theory

Regime theory was used to arrive at approximate estimates of gross dimensions as a function of discharge, d50 etc. The regime theory was specifically used to estimate the dimensions of the low-flow channel. The low-flow channel is expected to form in the long-term for the leveed corridors over time.

In addition, regime theory was used to design the main channel as well as the low-flow channels for the excavated earthen channels (Alternative B3). The main parameters evaluated by regime theory are: width, depth, and velocity. The design approach aims to match the regime value estimates approximately and does not match all three parameters exactly. The values estimated by regime theory were used as guidance/starting point for the design dimensions and are interpreted as the dimension the channel wants to be or will evolve into in the long-term. The main goal is to not deviate too much from regime theory wherever possible.

5.10.3 Equilibrium slope

The equilibrium slope is defined as the slope at which the channel bed is in equilibrium. It is interpreted as the slope the channel would evolve into, provided continuous flows for a long period of time and provides an idea as to what the design slope should be.

The following equations were computed:

- Schoklitsch
- MPM

- Shields
- Lane's Tractive Force
- Average BUREC
- Bray
- Henderson
- BUREC
- Simplified AMAFCA

Equilibrium slope[1] is defined as the slope which causes the channel's sediment transport capacity to equal the incoming sediment supply (ADWR, 1985). If the slope is too steep, channel velocities will be high and net erosion will occur. If the slope is too flat, channel velocities will be low and net deposition will occur. The equilibrium slope is the slope that the undisturbed, natural channel will tend towards over the long term. While there are philosophical and practical problems with applying equilibrium slope concepts to ephemeral streams with variable channel geometry and high flash flood potential, or streams where the natural hydrology has been altered by urbanization, equilibrium slope equations provide a useful order-of-magnitude assessment of the likelihood of vertical channel adjustments.

Design reach-averaged data required for application of equilibrium slope equations to the study area were derived from the following sources:

- Hydraulic data – normal-depth computations
- Hydrologic data - HEC-1 modeling and area weighting
- Topographic data – 10-foot contour data and DTM

Most equilibrium slope equations are based on the mean annual flood, the "channel-forming," or "bankfull" discharge. On many perennial alluvial streams, particularly in humid climates, the mean annual flood and the channel-forming and bankfull discharges are nearly equivalent. However, on ephemeral streams where flow events are rare, the channel-forming discharge is often difficult to determine. To account for the discrepancies in what flow rate is appropriate for equilibrium slope analyses, and to assess the trend of expected slope adjustments during floods, a range of discharges

[1] Equilibrium slope is also referred to as stable slope or limiting slope.

were used in the equilibrium slope equations to assess the expected slope adjustment over a range of discharges. Four ratios of the 100-year peak discharge estimate were examined: 10%, 25%, 75%, and 100%. The 10% flow was assumed to approximate the 2-5-year flood. The 25% flow was assumed to approximate the 10-year event. The 2-year event approximates the mean annual flood calculated on a probability-weighted basis. The 10-year event better approximates bankfull conditions in many ephemeral stream reaches.

5.10.4 Scour and Toe Protection

The toe-down for the levee and other bank protection were estimated using general scour estimates. It was assumed that the bend scour is negligible as most of the designed channels have somewhat straight alignments. The long-term scour was estimated from equilibrium slope and local scour was defined as the low flow channel depth.

Scour calculations were performed using procedures outlined in the City of Tucson's *Standards Manual for Drainage Design and Floodplain Management* - Chapter VI - Erosion and Sedimentation (1989; hereafter, "the COT Manual"). The following equation for depth of scour in a stream was used:

$$Z_t = 1.3\,(Z_{gs} + \tfrac{1}{2}\,Z_a + Z_{ls} + Z_{bs} + Z_{lft})$$

where:

Z_t = Design scour depth, excluding long-term degradation or aggradation (ft)

Z_{gs} = General scour depth (ft)

Z_a = Anti-dune trough depth (ft)

Z_{ls} = Local scour depth (ft)

Z_{bs} = Bend scour depth (ft)

Z_{lft} = Low-flow thalweg depth (ft)

1.3 = Safety factor to account for non-uniform flow distribution

Scour depth below drop structures was estimated using the following equation from Schoklitsch (1935):

$$D_s = 4.75\ h^{0.2}\ q^{0.57}\ /\ d_{90}^{\ 0.32}$$

where:

D_s = Scour depth below downstream water surface (m)

h = Drop height (m)

q = Unit discharge (m^3/s/m)

d_{90} = Bed material size for which 90% of the sample is finer (mm)

5.11 Off-line Detention Basins Analyses

Off-line detention basins were included in situations where the flow needs to be limited to accommodate downstream capacity of existing channels, culverts or delineated floodplains. These basins are modeled as diversions in HEC-1 using the DI/DQ records. At the culvert locations along Sun Valley Parkway, the purpose of the off-line basin is to reduce the flow capacity to the maximum capacity of the culvert. The maximum capacity of the culvert was determined using HY8 results as the flow rate that occurs when the upstream water surface elevation is 1 foot above the culvert top elevation. At other locations, flows higher than certain desired values are diverted and the inflow/outflow relations are the design parameters.

5.12 Summary

The design criteria applied to the hydraulic design of the structural elements of the Step 2 Proposed Alternatives were given in Table 4. Through feedback from project team meetings and the stakeholder involvement process, the scale and approaches for each element were constrained. Importantly, basin depths were limited to 12 feet and levee heights to about 5 feet. Additionally, preservation of the existing riparian corridors was a paramount characteristic of each alternative. All of the alternatives designed and for which cost estimates were made meet these objectives. Moreover, the alternatives achieve safe, effective 100-year regional flood protection for the SVADMP area.

6 STEP 2 COST ESTIMATES

Costs for all of the proposed alternatives for each sub-area were estimated for the minimum engineering requirements (called here the "base" cost estimates) as well as the costs associated with the landscape compatibility enhancements. The elements were computed separately so that the difference or additional costs associated with meeting the landscape compatibility requirements could be assessed. The following sections describe the base and landscape compatibility enhancement cost estimate procedures and results.

6.1 Base Cost Estimates

Base costs for each alternative were estimated by establishing unit costs for the various design components. The total cost for each component was obtained by multiplying the quantities involved with the unit costs. The cost components considered in the design are: 1) Land Cost, 2) Construction Cost, 3) Landscaping Cost, and 4) Maintenance Cost.

For the channels, the cost estimates are categorized into the following: (a) Levee (Alternatives A, B1, B2, B4, B5), (b) Levee Lining (Alternatives A, B1, B2, B4, B5), (c) Channel Excavation (Alternatives B3, C), (d) Channel Lining (Alternative C), (e) Toe Protection, (f) Drop Structures (Alternatives A, B1, B2, B3, B4, B5), (g) Sedimentation Basins, and (h) Other. The "Other" category is included for the purpose of including any other miscellaneous cost. Table 5 summarizes the channel materials selected for the purpose of cost estimation of the alternatives.

Table 5 Cost Estimate Categories for Channels

Channel Type	Channel Lining	Toe Protection	Levee Fill	Levee Lining	Drop Structures	Sedimentation Basins
Leveed Natural	None	Riprap	Yes	Riprap	Riprap	Yes
Earthen Excavated	None	Riprap	No	None	Riprap	Yes
Concrete Excavated	Concrete	None	No	None	Concrete	Yes

Similarly for the basins, the costs are categorized into: (a) basin, (b) inlet, (c) outlet, and (d) other.

The four cost components are estimated for all the cost categories. A summation of all cost components provides the total cost for the particular channel or basin. The costs for all design elements (channels and basins) are totaled to provide the total cost for the particular alternative in a sub-area.

The procedures adopted in estimating the cost for each component are presented below. The details of the calculations performed are presented in Volumes 2 - 7. The summary of the unit costs for all the components is presented in Table 6.

6.1.1 Land Cost

The land cost is the major cost component in most of the alternatives. The land cost is estimated using a unit cost of $100,000 per acre except for one design reach through existing homes in sub-area FRS #1. A land cost of $250,000 per acre was applied to that reach. The land areas considered in the estimates are: 1) on-line basin footprint, 2) off-line basin footprint, 3) channel area between the levees (A, B1, B2, B4, B5), 4) excavated channel area (B3, C), 5) adjacent natural preservation corridor (B3, C), 6) area occupied by levee and/or access road (A, B1, B2, B4, B5), and 7) area set-aside for natural active fan processes to occur (A).

6.1.2 Construction Cost

The construction costs are estimated based primarily on unit costs for materials and excavation costs. The unit material cost includes all costs associated with material fully constructed in place. For example, a unit cost of $75 for riprap drop structures includes the cost of material as well the cost of constructing the drop structure. A contingency cost of 25% is applied to the estimated base construction cost. Similarly, the cost for the engineering design is set at 5% of the base construction cost. The sum of the base construction cost, contingency cost, and the design cost provides the total construction cost.

6.1.3 Landscaping Cost

Landscaping costs are also applied as unit costs for the cost categories where landscaping is needed. The landscaping costs are mostly based on "per area" unit cost with the areas estimated using the design parameters. A landscaping cost of $1 per square foot was assumed based on an assumption of 60 percent of the area landscaped at $1.50 per square foot and 40 percent of the area naturally seeded at $0.06 per square foot. Landscaping costs were applied only to the disturbed areas impacted by the structural elements of the alternatives. For example, the surface area of the excavated earthen channels (B3) was assumed to require landscaping. Similarly, the external slopes of the levees were assumed to require landscaping. This landscape cost is for basic reestablishment of vegetation on disturbed areas. It does not include the cost of landscape enhancements required for compatibility of the structural flood control measures with the future landscape character of the area. Landscape compatibility enhancement costs are discussed in Section 6.2.

6.1.4 Maintenance Cost

The maintenance costs are based on a 3-year maintenance cycle. The costs are estimated for a design life of 50 years.

Table 6 Summary of Unit Costs

	Construction Units	Construction Cost	Landscape Units	Landscape Cost	Maintenance Units	3 Year Maintenance Cost
Levee						
Fill	cu. Yd	$ 7.00	sq. Yd	$ 9.00	sq. Yd	$ 0.70
Wall	sq. Yd	$ 215.00	sq. Yd	$ -	sq. Yd	$ 4.50
Toe Protection						
Riprap	cu. Yd	$ 75.00	sq. Yd	$ -	sq. Yd	$ 1.50
Gabions	cu. Yd	$ 85.00	sq. Yd	$ -	sq. Yd	$ 1.70
Soil Cement	cu. Yd	$ 50.00	sq. Yd	$ -	sq. Yd	$ 1.50
Concrete	cu. Yd	$ 155.00	sq. Yd	$ -	sq. Yd	$ 2.35
Levee Lining						
Riprap	cu. Yd	$ 75.00	sq. Yd	$ -	sq. Yd	$ 1.25
Gabions	cu. Yd	$ 85.00	sq. Yd	$ -	sq. Yd	$ 1.50
Soil Cement	cu. Yd	$ 75.00	sq. Yd	$ -	sq. Yd	$ 1.80
Concrete	cu. Yd	$ 155.00	sq. Yd	$ -	sq. Yd	$ 2.00
Channel Lining						
Riprap	cu. Yd	$ 75.00	sq. Yd	$ -	sq. Yd	$ 2.00
Gabions	cu. Yd	$ 85.00	sq. Yd	$ -	sq. Yd	$ 2.25
Soil Cement	cu. Yd	$ 75.00	sq. Yd	$ -	sq. Yd	$ 3.00
Concrete	cu. Yd	$ 155.00	sq. Yd	$ -	sq. Yd	$ 2.50

	Construction Units	Construction Cost	Landscape Units	Landscape Cost	Maintenance Units	3 Year Maintenance Cost
Drop Structure						
Riprap	cu. Yd	$ 75.00	sq. Yd	$ -	sq. Yd	$ 2.00
Gabions	cu. Yd	$ 85.00	sq. Yd	$ -	sq. Yd	$ 2.25
Soil Cement	cu. Yd	$ 75.00	sq. Yd	$ -	sq. Yd	$ 3.00
Concrete	cu. Yd	$ 155.00	sq. Yd	$ -	sq. Yd	$ 2.50
Basin Inlet						
Riprap	cu. Yd	$ 75.00	sq. Yd	$ -	sq. Yd	$ 2.00
Concrete	cu. Yd	$ 155.00	sq. Yd	$ -	sq. Yd	$ 2.50
Pipes						
24" RGRCP	LF	$ 55.00	sq. Yd	$ -		$ 0.55
30" & 36" RGRCP	LF	$ 82.00	sq. Yd	$ -		$ 1.20
42" & 48" RGRCP	LF	$ 160.00	sq. Yd	$ -		$ 2.40
54" & 60" RGRCP	LF	$ 183.00	sq. Yd	$ -		$ 2.75
Channel						
Excavated Channel	$ 10.00	cu. Yd	sq. Yd	$ 9.00	sq. Yd	$ 0.50
Sedimentation Basin						
Sedimentation Basi	$ 10.00	cu. Yd	sq. Yd	$ -	sq. Yd	$ 0.50
Basin						
Excavated Basin	$ 4.00	cu. Yd	sq. Yd	$ 9.00	sq. Yd	$ 0.50
Outlet Cost	Based on 100' x12' Weir					
None	EA	$ -	sq. Yd	$ -	sq. Yd	$ -
Concrete Weir	EA	$ 15,000.00	sq. Yd	$ -	sq. Yd	$ 2.50
Riprap Weir	EA	$ 10,000.00	sq. Yd	$ -	sq. Yd	$ 2.00
Pipe	LF	$ 160.00	sq. Yd	$ -	sq. Yd	$ 1.00

6.2 Landscape Compatibility Enhancement Costs

In order to ensure that the proposed structural flood control measures are compatible with the future landscape character of the area, some enhancements to the base engineering design concepts were required. In particular, the engineering structures require modifications to blend them into the landscape (e.g., non-rectilinear form). Adjustments to the concept design of flood control features included decreasing average side slopes for channels and basins from 3:1 to 6:1. A one-foot height adjustment to earth and walled levees was added to vary to the profile of these structures, so as to create an undulating form on the landscape. Additional buffer area was added parallel to all channels and around all proposed detention basins. Land buffers of 50 feet were added to each side of the walled corridor channels. The top with of earth levees was increased from 14 feet to 20 feet. Buffers of 50 feet were added around the perimeter of all detention basins. Additional enhancements for landscape compatibility included additional length for drop structures and architectural treatments to walls and basin inlet structures.

6.3 Results

Cost estimates including the landscape compatibility enhancement elements for the alternatives are presented in Table 8. Cost estimates are not provided for Alternative D because of insufficient detail regarding the drainage infrastructure improvements planned by the developers within the master planned community footprints. The cost estimates reveal the following information from the alternative comparisons.

Sizing alternatives – The large on-line basin (B1) alternative is approximately the same cost as the small on-line basin (B2). In addition, the off-line basin (B5) is a similar cost to the small on-line basin. The reasons for this result are: 1) the downstream reach peak discharges are driven by the on-fan runoff, 2) land cost is the largest portion of the total cost for the leveed corridor alternatives, and 3) smaller apex basins lead to larger off-line basins at the Sun Valley Parkway.

Alignment alternatives – The longer or greater the number of corridors, the greater the cost. The B4-3 alternatives are generally the longest, and therefore, most expensive of the B alternatives.

Other apex or conveyance strategies – The A alternative and excavated channel alternatives (B3 and C) are the most expensive alternatives; even more expensive than the multiple leveed corridors with apex basins. In the case of the A alternative, the land cost associated with the active alluvial fan area makes this approach much more expensive than the apex basin B alternatives. For the B alternatives, the active fan area is recovered for potential development. For the excavated or so-called companion channel alternatives (B3 and C), the construction costs are much greater than the land area saved. Additionally, the 'companion' channel alternatives include a 120-foot preservation corridor, comprising the adjacent existing watercourse corridor, as part of the land cost which offsets some of the potential cost savings.

Landscape compatibility enhancements – The landscape compatibility enhancement costs include costs for additional land requirements, construction requirements (excavation and fill), increased landscaping area, and increased maintenance (due to the larger areas requiring maintenance). The increased costs for landscape compatibility enhancements average about 40 percent for all alternatives, ranging from about 25 to 55 percent. The increased costs are greatest for the longest earthen levee alternatives (B4-3) and least for Alternative A.

Wall versus earth levee corridor containment structures – The relative cost differences for the walled corridor versus the earthen levee corridor were also evaluated. A comparison of the per unit channel length was performed for an example reach. Table 7 shows the results of this comparison. The costs for the wall do not include any fill behind the wall. That is, the flood wall itself serves to provide lateral corridor containment without any backfill upland of the wall. The walled levee ranges from about 45 to 80 percent less expensive than the earthen levee option depending on levee height. The cost differential increases with levee height. The differences in cost are due to additional construction costs, landscape compatibility enhancement costs, and land costs associated with the earthen levee. The primary reason the cost difference increases with levee height is related to the size of the levee footprint. The earth levee footprint grows with increasing height whereas the wall footprint (and 50-foot landscape enhancement buffer) does not. The larger levee footprint results in larger construction, land, landscaping, enhancement, and maintenance costs.

Table 7 Walled vs. Earth Levee Cost Comparison

	Levee			Wall			
Levee/Wall Height (ft)	Base Cost per foot	LC Enh. Cost per foot	Total Cost per foot	Base Cost per foot	LC Enh. Cost per foot	Total Cost per foot	Percentage Difference
3.5	$ 611	$ 672	$ 1,284	$ 381	$ 512	$ 893	44%
4	$ 675	$ 734	$ 1,409	$ 421	$ 512	$ 932	51%
4.5	$ 725	$ 814	$ 1,539	$ 460	$ 512	$ 972	58%
5	$ 795	$ 876	$ 1,671	$ 499	$ 512	$ 1,011	65%
5.5	$ 847	$ 975	$ 1,822	$ 539	$ 512	$ 1,050	73%
6	$ 915	$ 1,045	$ 1,960	$ 578	$ 512	$ 1,090	80%

6.4 Summary

Engineering cost estimates for the Step 2 Proposed Alternatives were computed. The apex basin alternatives with leveed corridors (B1, B2, B4, B5) are generally the least expensive alternatives compared to the excavated channel alternatives (B3, C) or apex avoidance strategy (A). The results also show that the longer corridor alignment alternatives are more expensive than the shorter ones.

The additional costs associated with meeting the landscape aesthetic requirements were also estimated. The results indicate that the landscape compatible alternatives are about 40 percent more expensive than the base engineering costs. In addition, the costs of the earthen levee were compared those estimated for a flood wall levee. Those calculations showed that the walled levee approach is significantly less expensive compared to the earthen levee.

Table 8 Cost Summary Including Landscape Compatibility Enhancement

			Costs (in $1000)					Cost Percentage				Increase Over Base Costs					
Sub-Area	Alternative	Land Area (acres)	Land Cost	Constr. Cost	Lndscp Cost	Maint. Cost	Total Cost	Land Cost %	Constr. Cost %	Lndscp Cost %	Maint. Cost %	Total Cost Difference	Land Cost %	Constr. Cost %	Lndscp Cost %	Maint. Cost %	Total Cost
CAP	A	477	$ 47,750	$ 23,971	$ 5,894	$ 13,711	$ 91,326	52%	26%	6%	15%	$ 22,050	10%	59%	75%	83%	32%
CAP	B1	341	$ 33,940	$ 27,869	$ 7,416	$ 16,218	$ 85,443	40%	33%	9%	19%	$ 26,401	18%	61%	72%	89%	45%
CAP	B2	363	$ 36,190	$ 25,292	$ 6,296	$ 14,997	$ 82,775	44%	31%	8%	18%	$ 24,328	14%	64%	84%	91%	42%
CAP	B3	328	$ 32,610	$ 105,637	$ 8,146	$ 8,664	$ 155,057	21%	68%	5%	6%	$ 29,481	31%	22%	22%	19%	23%
CAP	B5	354	$ 35,410	$ 25,296	$ 6,000	$ 14,711	$ 81,417	43%	31%	7%	18%	$ 24,037	14%	64%	89%	93%	42%
CAP	C	304	$ 26,590	$ 100,850	$ 5,690	$ 12,385	$ 145,514	18%	69%	4%	9%	$ 36,365	34%	32%	27%	49%	33%
Wagner Wash	A	938	$ 93,810	$ 53,694	$ 12,161	$ 32,333	$ 191,998	49%	28%	6%	17%	$ 51,330	10%	67%	100%	90%	36%
Wagner Wash	B2	390	$ 38,930	$ 36,266	$ 8,517	$ 21,329	$ 105,041	37%	35%	8%	20%	$ 36,784	18%	74%	103%	108%	54%
Wagner Wash	B3	369	$ 37,030	$ 119,071	$ 7,202	$ 7,880	$ 171,183	22%	70%	4%	5%	$ 37,332	35%	26%	28%	24%	28%
Wagner Wash	B41	361	$ 36,030	$ 35,597	$ 8,860	$ 20,712	$ 101,198	36%	35%	9%	20%	$ 35,681	21%	69%	91%	103%	54%
Wagner Wash	B42	367	$ 36,740	$ 37,018	$ 9,223	$ 21,882	$ 104,863	35%	35%	9%	21%	$ 37,669	22%	72%	93%	105%	56%
Wagner Wash	B43	518	$ 51,830	$ 47,342	$ 11,233	$ 27,049	$ 137,455	38%	34%	8%	20%	$ 46,786	18%	70%	96%	106%	52%
Wagner Wash	C	338	$ 33,860	$ 142,114	$ 6,031	$ 15,676	$ 197,681	17%	72%	3%	8%	$ 54,945	36%	37%	34%	59%	38%
Hassayampa	A	510	$ 51,070	$ 27,776	$ 6,603	$ 13,663	$ 99,113	52%	28%	7%	14%	$ 23,045	10%	51%	67%	84%	30%
Hassayampa	B2	446	$ 44,540	$ 33,745	$ 8,512	$ 18,461	$ 105,259	42%	32%	8%	18%	$ 30,222	15%	57%	72%	88%	40%
Hassayampa	B3	361	$ 36,160	$ 96,487	$ 8,269	$ 8,634	$ 149,550	24%	65%	6%	6%	$ 31,004	32%	25%	24%	21%	26%
Hassayampa	B41	376	$ 37,490	$ 34,807	$ 9,074	$ 18,631	$ 100,002	37%	35%	9%	19%	$ 30,948	20%	55%	68%	88%	45%
Hassayampa	B42	481	$ 47,990	$ 49,121	$ 12,105	$ 27,368	$ 136,584	35%	36%	9%	20%	$ 46,331	20%	64%	83%	101%	51%
Hassayampa	B43	506	$ 50,430	$ 50,778	$ 12,616	$ 28,616	$ 142,440	35%	36%	9%	20%	$ 48,562	20%	66%	84%	101%	52%
Hassayampa	C	335	$ 33,530	$ 133,944	$ 7,300	$ 16,306	$ 191,080	18%	70%	4%	9%	$ 46,180	33%	30%	27%	54%	32%
White Tank Wash	A	1505	$ 150,600	$ 79,462	$ 19,741	$ 47,685	$ 297,487	51%	27%	7%	16%	$ 79,805	10%	73%	86%	102%	37%
White Tank Wash	B1	550	$ 54,920	$ 61,574	$ 16,548	$ 37,376	$ 170,418	32%	36%	10%	22%	$ 61,139	25%	67%	76%	96%	56%
White Tank Wash	B2	706	$ 70,680	$ 59,574	$ 16,097	$ 37,920	$ 184,271	38%	32%	9%	21%	$ 61,082	18%	72%	78%	95%	50%
White Tank Wash	B3	616	$ 61,590	$ 121,591	$ 13,018	$ 14,626	$ 210,825	29%	58%	6%	7%	$ 44,224	33%	24%	25%	20%	27%
White Tank Wash	C	607	$ 60,670	$ 171,118	$ 12,842	$ 28,921	$ 273,552	22%	63%	5%	11%	$ 64,595	32%	28%	25%	50%	31%
FRS #1	A	2087	$ 208,750	$ 82,315	$ 17,170	$ 42,085	$ 350,320	60%	23%	5%	12%	$ 67,897	6%	54%	79%	86%	24%
FRS #1	B2	640	$ 63,690	$ 50,131	$ 12,326	$ 26,946	$ 153,093	42%	33%	8%	18%	$ 44,405	18%	53%	69%	84%	41%
FRS #1	B3	545	$ 54,260	$ 125,833	$ 13,972	$ 15,124	$ 209,189	26%	60%	7%	7%	$ 44,334	36%	24%	25%	21%	27%
FRS #1	B41	523	$ 52,070	$ 56,602	$ 15,225	$ 26,944	$ 150,841	35%	38%	10%	18%	$ 43,847	28%	40%	51%	69%	41%
FRS #1	B42	822	$ 82,210	$ 75,125	$ 18,597	$ 40,250	$ 216,182	38%	35%	9%	19%	$ 66,356	18%	56%	72%	92%	44%
FRS #1	B43	1180	$ 117,930	$ 96,389	$ 23,032	$ 52,011	$ 289,363	41%	33%	8%	18%	$ 86,273	15%	58%	78%	95%	42%
FRS #1	C	469	$ 47,000	$ 217,113	$ 11,348	$ 28,666	$ 304,127	15%	71%	4%	9%	$ 71,191	35%	28%	27%	51%	31%
FRS #2 & #3	A	538	$ 53,770	$ 20,209	$ 2,016	$ 3,801	$ 79,796	67%	25%	3%	5%	$ 9,182	4%	32%	58%	77%	13%
FRS #2 & #3	B2	185	$ 18,640	$ 14,665	$ 3,378	$ 8,366	$ 45,049	41%	33%	7%	19%	$ 13,264	15%	58%	84%	85%	42%
FRS #2 & #3	B3	182	$ 18,220	$ 24,166	$ 4,623	$ 5,194	$ 52,204	35%	46%	9%	10%	$ 9,558	35%	16%	22%	18%	22%
FRS #2 & #3	B41	193	$ 19,340	$ 21,465	$ 6,037	$ 10,594	$ 57,436	34%	37%	11%	18%	$ 15,825	27%	36%	48%	63%	38%
FRS #2 & #3	B42	155	$ 15,480	$ 18,548	$ 5,647	$ 9,577	$ 49,252	31%	38%	11%	19%	$ 14,391	33%	38%	47%	62%	41%
FRS #2 & #3	B43	146	$ 14,500	$ 16,720	$ 4,794	$ 8,777	$ 44,792	32%	37%	11%	20%	$ 13,598	28%	44%	54%	71%	44%
FRS #2 & #3	C	113	$ 11,360	$ 33,321	$ 2,070	$ 7,477	$ 54,229	21%	61%	4%	14%	$ 15,142	37%	35%	36%	66%	39%

7 ALTERNATIVES EVALUATION

7.1 Evaluation Criteria

Criteria to evaluate the Step 2 alternatives were developed though a series of meetings with the project team. Table 9 shows twenty-three criteria in three broad categories that were selected for evaluation of the Step 2 alternatives.

Table 9 Step 2 Alternative Evaluation Criteria

Public Safety Criteria (Function)	
1) **Public Safety Enhancement** • Improve Public Infrastructure • Reduce Flood Level • Number of People Impacted	2) **Level of Damage Reduction** • Dollar Costs Saved/Reduced • Flood Frequency Impacted
3) **Transportation Impacts** • Collector or Arterial Roadway • Only Access • Number of People Impacted	4) **Upstream/Downstream Impacts** • Stand Alone • Systematic Solution
5) **Relative Risk of Failure** • Lower than average • Average • Greater than average	6) **Eliminates Flood Problem** • Partial Solution • Whole Solution
7) **Design Certainty** • Captures apex flow •	8) **Constructability** • Excavation excess •
Economic Criteria (Common)	
9) **Comparative Benefit Cost** • Dollars • Number of People • Regional Solution • Recoverable Flood Plain	10) **ROW Acquisition Necessary** • Existing ROW Available • Amount Needed • Private or Public Land
11) **Condemnation Required** • Yes • No	12) **Cost of Implementation (in $1,000)** • < than $50,000 • < than $500,000 • < than $1,000,000

13) Maintenance Cost • Lessened • Increased • Neutral • Comparative to Other Measure	**14) Potential Cost Sharing Partner** • Already Contacted • Already Willing • Possibly
Social/ Environmental/ Aesthetic/ Multi-Use Criteria (Form)	
15) Public Support • Known • Anticipated • Unknown	**16) Public Acceptance** • Known • Anticipated • Applicable • Unknown
17) Addresses Public Complaint/Concern • Response From Public • Unknown	**18) Private Acceptance** • Known • Anticipated • Applicable • Unknown
19) Environmental Impacts • Habitat • Hazmat • Cultural • 404	**20) Complexity of Environmental Permitting** • Minimal • Average • Significant
21) Visual Resource Impacts/ Aesthetic Compatibility • Incompatible • Partially Compatible • Fully Compatible	**22) Multi-Use Opportunities** • Minimal • Average • Significant
23) F.C. Method Consistency with Buckeye Recreation Master Plan • Incompatible • Partially Compatible • Fully Compatible	

7.2 Evaluation Results

Table 10 through Table 13 present the scored results of the evaluation meetings held with the project team. Table 13 presents a summary of the recommended alternatives resulting from the process.

The alternatives evaluation process was divided into two steps: 1) strategy evaluation and 2) evaluation by sub-area. In each of the two steps, the evaluation criteria listed in Table 9 were used to assign a lumped score for each of the three primary categories (Public Safety, Economic, and Social/Environmental/Aesthetic/Multi-use).

7.2.1 Strategy Evaluation

The relative merits and disadvantages of the alternatives are discussed in this section without considering any sub-area specific issues. The evaluation criteria are presented for the type of treatment at the apices as well as the type of channel cross-section.

Alternative A - Sedimentation Area at Apex

The main design objective of Alternative A is to allow the natural geomorphic processes to occur within a designated active alluvial fan area downstream of the apex. This designated active alluvial fan area is the highlight of this alternative and distinguishes this alternative with other alternatives where basins are used at the apices to control alluvial fan uncertainties. Therefore, the discussion below focuses mainly on the designated alluvial fan area. Most of the downstream impacts are expected to be similar to that in other alternatives.

Public Safety:

- The lack of basins could result in no significant reduction in the peak discharges. Thus, the risk of failure in the downstream is not reduced due to lack of reduction in the peak discharges.
- Area set aside in the active alluvial fan area could be a potential hazard to public if access is not adequately restricted.
- Sediment deposition will occur in the area. Deposition within the collector channels must be handled through maintenance. If proper maintenance is not performed, channel capacity may be reduced leading to overflow.
- Area set aside may be used for other purposes. This might include transportation; though roadways are not recommended within the set aside area.

- The designated active area is not available for development. Therefore the land costs for Alternative A can be significant, especially for the larger alluvial fans. In addition, the risk of impacts to downstream areas is higher (compared to other B alternatives with the basins at the apex) due to uncertainties associated with the designated sedimentation area.

Economics:

- The set aside land area is usually large enough to significantly impact the land costs, especially for the larger alluvial fans.
- The construction cost will be significantly less compared to the basin-based alternatives where large excavation volumes can be expected to result in larger costs.
- The area required is large when compared to other alternatives.
- The peak discharges downstream of the apex region are larger compared to other alternatives where the presence of basins reduces the peak flows. The larger peak flows result in the need for larger structures downstream increasing the cost of the project.
- The lack of basins near the apex means that the fill material available from excavation is minimal. Therefore, the opportunity to balance the excavated dirt as fill material is not present in this alternative.

Social/ Environmental/ Aesthetic/ Multi-Use Criteria

- The designated alluvial area is set aside to allow natural sedimentation process to occur. As a result, this area is not conducive for all types of recreational multi-use.
- This alternative is favorable from a habitat preservation perspective since the existing natural corridor is mostly preserved in the designated sedimentation area. The collector channels require some disturbance to the natural habitat. However, they are not significant compared to the area of disturbance in the basin-based alternatives.
- This alternative may fair better in 404 permitting process.
- Preservation of the existing corridor as well as lack of major engineered structures provides minimal visual resources impacts. Since the existing corridor is preserved, the aesthetic compatibility is better compared to the basin-based alternatives. Cultural and hazmat impacts are also expected to be minimal applying a similar reasoning.

Alternative B - Big Basin/Small Basin/Off-line/On-line

The main objective of Alternatives B1, B2, and B5 is to evaluate the effectiveness of basins at the apices as flood control measures. The B1 alternative represents the big-basin option while the B2 represents a smaller basin. Both are on-line basin options. The B5 Alternative is a small off-line basin for water and an in-line sediment only basin. The basin at the apex is the highlight of these alternatives and distinguishes them from other alternatives where basins are not used at the apices to control alluvial fan uncertainties and/or reduce peak discharges. Therefore, the discussion below focuses mainly on the basins at the apices. Most of the downstream impacts are expected to be similar to that in other alternatives.

Public Safety:

- The basin alternatives provide design certainty from the flood control point of view by capturing the flows at the apices and metering them downstream in a controlled fashion.
- The on-line basins are generally preferred to off-line basins as they provide a higher degree of certainty with respect to the control of the active alluvial fan.
- The presence of the basin results in lowered peak discharges. Lower peak discharges correlate to lower risk of failure and public endangerment downstream. However, flows will last longer resulting in increased duration of flood exposure to the public. Lower peak discharges also reduce the number of people potentially impacted by a flood event.
- The failure of the basin itself could be more dangerous than a conveyance-only strategy because of reduced conveyance downstream. Significant development can be anticipated to occur near the washes that carry the outflow from the basins and hence more at risk in the event of a basin failure or discharges in excess of the basin design. However, the possibility of failure of the basin is considered low. As a result, the presence of the basin at the apex can be, in overall, considered as a reduction in potential downstream flood related risks.
- The large basin (B1 Alternative) can be expected to influence the bigger flood events with significant reduction in the peak discharges. The presence of the basin may not influence smaller events and the smaller flows could go through the basins relatively unhindered. The significant reduction in the peak discharges will potentially benefit a larger area.
- For the small basin (B2 Alternative), the reduction of peak discharge at the apex is not as high as in large basins (B1 Alternative). The downstream peak flows can still be quite large compared to upstream peak flows. As a result, the potential downstream risks in terms of area of benefit as well as number of people benefited are also larger. However, a small basin will be more beneficial when compared to Alternatives A and C where there are no basins at the apices.
- Sedimentation is expected to occur within the basins requiring regular maintenance. However, if unusually high sedimentation occurs during a large flood event, the storage capacity of the basins can be reduced causing a flooding problem for the downstream properties. Risk of failure due to reduced sedimentation capacity is greater for the off-line basin.
- There is a potential risk exposure to the public if the basins are designed to accommodate recreational uses. Flood water will enter at least a portion of the basin during even smaller floods posing a potential danger to recreationists within the basins.

Economics:

- The big basins (B1) cover a larger area compared to B2 and B5 alternatives. However, the right of way (ROW) area needed will be smaller when compared to that of the A alternative where a much larger area is designated as the sedimentation area.
- The basins can be designed as multi-use recreational facilities. The land area set aside for the construction of the basins could also act in lieu of the open space requirements. These multi-purpose uses of the land may reduce the apparent cost of the land.
- The land area at the apices is not presently developed. Therefore, condemnation of existing developed properties may not be needed to facilitate the construction of the basins.
- Excavation is the major part of the construction of the basins. Given the long period of deposition at the apices, the excavation process may be relatively easy. However, construction of the basins could become difficult if significant bed rock is encountered during excavation.
- The excavation excess can be potentially spoiled as fill material for the levees. The big basin (B1) alternative will produce more excess material compared to the B2 alternative. The availability of fill material for the construction of levees can be a significant benefit in terms of construction costs.
- The big basin (B1) alternative has larger maintenance costs compared to the smaller basin (B2 or B5) alternatives. The differences are directly related to the size of the basins and volume of flows captured.

Social/ Environmental/ Aesthetic/ Multi-Use Criteria

- The basins provide considerable opportunity for recreational and other multiple-uses.
- Significant excavation will be needed to construct the basins. The basins will be larger for the B1 alternative and will have larger impact on the visual and aesthetic compatibility. The basins will have to be enhanced to achieve compatibility with the landscape of the area which will require additional expenditures.
- The basin excavations can be expected to impact the natural habitat.
- The excavations may also have cultural implications and exact excavation locations may have to be determined if cultural impacts are anticipated. However, the cultural resources assessment found that native people's activities in the area were generally limited to hunting and gathering. No known habitations exist in the area.
- If developed recreational facilities are not part of a basin, the larger basins provide potential open space area for future wildlife habitat.
- Hazmat impacts at the basin locations are mostly unknown, but are not expected to be a significant limitation.
- The disturbance to the existing corridor is likely to play a key role in the 404 permitting process. Mitigation of the environmental impacts must be planned and designed to aid in the approval of the 404 permits.

Alternative B – Leveed Corridors

The leveed corridor is designed as the flow conveyance from the upstream apex to the downstream outfall. Existing washes are laterally contained between engineered earthen levees and/or walls on both sides to provide adequate conveyance.

Public Safety:

- The levees/walls provide engineered means of flow conveyance. The inclusion of adequate freeboard ensures the design certainty for flows up to the 100-year flow event. In other words, the flows (up to the 100-year event) can be expected to be conveyed from the apex to the outfall in a predictable controlled fashion as long as the levee/walls function as designed. This flow containment provides an improvement in public safety compared to existing conditions where the naturally existing banks may or may not provide adequate flow containment or erosion protection.
- The 100-year event design flow could be significantly higher than the flow capacity of the existing channel. While the levees will contain flow within the designed channel corridor, changes can be anticipated in the channel cross-section due to the change in the flow rates. The smaller events could lead to a meandering channel as well as a flatter low flow channel slope. While the channel configuration can be expected to transform due to changes in flow conditions, flow containment will still be achieved through levees and the freeboard. The designed levees/walls satisfy the FEMA freeboard requirement of at least 3 feet above the 100-year water surface elevation.
- Drastic events such as levee failures could result in catastrophic impact to the properties adjacent to the selected conveyance paths. The conveyance relies on the successful functioning of the levees unless adequate conveyance capacity already exists.
- The presence of levees at road crossings requires an elevated bridge over the corridor to facilitate transportation requirements while in the case of excavated channels bridges need not be elevated above existing ground. A bridge could be avoided if the local topography allows for easy crossing of the levees. In such cases, a dip crossing could be used. Dip crossings can provide considerable cost savings compared to bridges. However, from public safety point of view, dip crossings are not preferred because of the risk they pose to motorists during flooding. Bridges provide higher certainty of transportation access during flood events.

Economics:

- The excavation excess material generated by basin construction can be used to construct the levees. This presents an opportunity to avoid hauling away the excavated material as well as hauling in fill material. This can potentially lead to significant cost savings.

- The selected conveyance paths are located along existing wash corridors with existing flood hazards. Therefore, at least part of the area may have been located in a floodway with limited development options potentially reducing land acquisition costs.
- It is possible that adequate conveyance is available based on existing topography at several locations along the selected conveyance paths. This could eliminate the need for a levee while providing the necessary flow containment. In such situations, there would be a considerable cost savings as well as reduction in risk. Channel banks may still require erosion protection, but flow containment will likely be not compromised.
- The structures such as levees, walls, grade control structures, and sedimentation basins will require regular maintenance to ensure continuous and proper functioning. Sedimentation basins shall be located where significant deposition is expected. Any deposited material should be removed on a periodic basis or after a significant flood event. Erosion can be expected to be contained by the grade control structures and bank protection. However, localized erosion problems may still arise, requiring monitoring and repair as needed.
- It is possible that the land set aside for the leveed corridor can also be used to satisfy the open space requirements. This could result in significant cost savings.

Social/ Environmental/ Aesthetic/ Multi-Use Criteria

- The leveed corridor leaves most of the existing watercourse corridor undisturbed. The construction of the levee and the grade control structures can be expected to disturb only parts of the corridor. Typically, the levees are less than 5 ft tall and 200 to 400 ft apart. This makes this option visually compatible with the existing surrounding landscape and also quite favorable from the environmental permitting and cultural point of view.
- The top of levees presents the possibility of use as a trail. Other multi-use opportunities will be very limited in nature since the existing corridor is relatively not influenced by the design.
- The walled corridor option includes parallel buffer areas that could also provide multiple use opportunities adjacent to the conveyance area.

Excavated Channel – Earthen (B3) and Concrete (C)

The excavated channel is designed as a companion channel to the existing wash corridor which is preserved. Two types of excavated channels were evaluated: an earthen excavated channel (B3), and a concrete excavated channel (C).

Public Safety:

- The entire flood conveyance channel is below ground and is designed to have a freeboard of at least 1 foot for the 100-year event. The channel, thus, has adequate conveyance for all flows up to the 100-year flow. The conveyance as designed could be reduced by significant deposition or increase in vegetation. However, these changes must be quite dramatic to pose a significant risk of overflow.

- The excavated channels will deliver flow faster than the channel with natural cross-section. Faster flows pose a more serious public safety problem if people or animals get caught in the flow.
- The banks of the earthen excavated channel (B3) are protected from failure through bank and toe protection. In the event of bank protection failure, the channel may shift location and cause damage to adjacent property. While this scenario represents a structural failure, flow is likely to be still contained. Therefore, such a potential failure does not pose a widespread, significant public safety problem.
- The concrete channel (C) could also experience a lining failure, but is considered less likely than for an earthen channel.
- The channel is designed to a slope that is flatter than the existing slope. The designed slope is maintained by grade control. Grade control failure could lead to similar channel location changes as in B3. Another consequence of failure could be damage to underground utilities. Again, the concrete channel would be expected to have a lower chance of experiencing drop structure failure.

Economics:

- The excavation volume is exorbitantly high and represents a significant portion of the total cost of the excavated channel alternatives. Hauling away of the excavated excess could be major obstacle. Concrete channels, in addition, require concrete lining of the entire channel cross-section. The concrete lining is also very expensive and could form a significant portion of the total project cost.
- The land needed for the excavated channel and the adjacent existing corridor is generally similar to the levee/wall corridor needs. Therefore, the excavated channels do not significantly lower land costs.
- The excavated channels provide the opportunity to avoid the construction of the bridges at road crossings. The conveyance is below ground and could be handled by structures such as box culverts. The adjacent preserved wash would also need to be crossed in some fashion.
- Sedimentation basins will be located in places where significant deposition is anticipated. Periodic maintenance is needed to clear the collected sediment deposits.
- The earthen excavated channel may encounter localized erosion while this is not a problem in concrete channels. Monitoring and erosion maintenance of the excavated channels will be needed to ensure long-term functionality of the channels.

Social/ Environmental/ Aesthetic/ Multi-Use Criteria

- The excavated channel is located adjacent to an existing wash corridor. This will leave the existing corridor completely undisturbed. This is favorable for habitat preservation. The visual impacts can be significant since the excavated channel, particularly with concrete lining, is considered less aesthetically pleasing than the levee/wall corridor.
- The environmental impacts could be minimal since the channel is located separately from the corridor. However, the existing corridor must be provided with an irrigation mechanism to

ensure sustainability of the natural habitat. Flow could come from the flood channel or adjacent tributary areas.

- The excavated channel provides possibilities for multiple-use such as trails.

Alternative D

The "No Measure" alternative relies on existing drainage and floodplain regulations to manage the alluvial fan flood and sedimentation hazards. Individual developments would provide flood hazard mitigation measures for their own properties.

Public Safety:

- Hazards will be addressed entirely by future development. Local communities will have to review and approve all proposed drainage facilities.
- The potential for a discontinuity of solutions across development boundaries exists.
- Long-term maintenance of any constructed facilities is potentially less certain.

Economics:

- Developers would pay for their own improvements. Costs are likely to be passed on to the individual residential and commercial property buyers.
- Because of the distribution of land ownership and the timing/phasing of individual development, there exists the potential for some unnecessary redundancies in future flood control solutions.
- Long-term maintenance assurances needed for some facilities may require public expenditures.
- Depending on the phasing of development and the selected flood control solutions, the potential exists for large areas of development to be constructed within FEMA floodplains.

Social/ Environmental/ Aesthetic/ Multi-Use Criteria

- Continuity of trails and other multiple-use elements of flood control facilities is not assured.
- Aesthetic treatment will be left to individual developments.
- The cumulative impacts of development may not be recognized in environmental permitting or mitigation requirements.

Outcome

Public Safety

Alternative A has a designated sedimentation area at the apices compared to other alternatives which have basins. The presence of the basins provides design certainty aiding in the control of the flows coming down the hills at the apices. This key advantage makes the basin-based B alternatives more preferable over Alternative A. Alternative C represents the concrete channel option without any detention at the apex. This alternative is favored slightly better compared to Alternatives A and D as it would have higher design certainty due to the concrete channels starting all the way from the apex. Alternative B5 represents the off-line basin option at the apex. This alternative ranks lower than the on-line basin alternatives. This is mainly due to uncertainties related to the functionality of the side-weirs/gates to split and let the larger flows enter the off-line basins. The on-line basins, on the other hand, have a well defined inlet taking the flow into the basins. In addition, the longer dimension of the on-line basins is perpendicular to the flow direction. This reduces the uncertainty of flow not entering the on-line basin.

For the purpose of discussing public safety aspects, the types of channel cross-sections can be categorized as leveed corridors or excavated channels. The excavated channel can have earthen or concrete lining. All the alternatives except C and D are ranked similarly. Alternative C represents the concrete channel option is ranked lower. The concrete channels tend to be narrower and deeper than the other alternatives with higher velocities. The higher velocities have negative influence on public safety with the possibility of larger damage when some type failure occurs. In addition, there is higher probability of people getting stuck in the flood waters. These factors resulted in a lowered ranking for the concrete channel.

Alternative D comprises flood control measures and drainage infrastructure as provided by developers within the footprints of the master planned communities. This alternative has a considerable uncertainty over the implementation of regional, whole-fan flood control as it leaves the development of solutions to third parties. The continuity of the design certainty from an upstream development and the immediately downstream development may not be well determined due differences in developer priorities, phasing, and other issues. Discontinuities are likely to occur. As a result, Alternative D ranks lower than the leveed corridor while it still ranks higher than the concrete channel alternative (C). In conclusion, the leveed corridor arises as the preferred alternative from the channel cross-section point of view.

Economics

The cost estimates for the various alternatives were used to determine the relative merits of each alternative in terms of economics. Land cost, excavation cost, levee-fill cost, and the channel-lining cost represent the major cost contributors. Alternatives B3 and C represent excavated earthen and concrete channels. The channel excavation costs for these alternatives are significantly higher than the levee-fill costs for the leveed-corridor alternatives. This is a direct result of the large lengths of the channels to convey the flow from the apices to the outfall. This makes the excavated channel alternatives less favorable compared to leveed corridor alternatives from the cost perspective. In addition to the excavation costs, Alternative C also involves the channel lining cost even though Alternative C has only a sedimentation basin at the apex. The motivating notion behind Alternative C is to avoid having a basin at the apex and, instead, conveying the flow quickly through the concrete channel. Due to large lengths of the channels, lining the channel with concrete is significantly more expensive than placing a basin at the apex. These factors makes Alternative C economically less favorable compared the earthen excavated channel or the other alternatives where a basin is present at the apices.

Alternative A represents the non-structural solution at the apex with the designated sedimentation area. As the designated sedimentation area is not amenable for any other use, the cost of land set aside is not subsidized by additional usage. The designated sedimentation areas are significantly large due to hydraulic and sedimentation uncertainties at the apices. As a result, Alternative A fairs unfavorably with regards to cost. In conclusion, the alternatives with basins at the apices and leveed-corridors as the means of conveyance represent the preferred alternative in terms of cost.

Social/ Environmental/ Aesthetic/ Multi-Use Criteria

The on-line basins and the excavated channel alternatives scored lower than the other alternatives for the social, environmental, aesthetic, and multi-use criteria. Excavation was viewed as having a greater environmental and aesthetic impact than the alternatives without excavation. The D Alternative was viewed as having a relatively higher score because of the perception that a greater number of corridors would be provided than compared to the regional facilities proposed in the other alternatives. However, this scoring did not reflect the fact that the "extra" corridors would be required for preservation as part of the development plan with or without the regional facility.

Summary

Table 10 shows the weighted scoring results from the strategy evaluation process. The result was a clear preference for the basin alternatives at the apices with the levee/wall corridors as the conveyance mechanism downstream (Alternatives B1, B2, B4, & B5). The B4 alternatives represent the alignment variations which were evaluated in the sub-area specific evaluation described in Section 7.2.2 and are strategically similar to the B1 alternative. The B5 alternative, though scoring the same as B1 and B2, is considered less preferable due to the potential public safety and performance concerns. Therefore, the sub-area specific evaluation focused on the B1 and B2 options with an emphasis on the relative strengths and weaknesses of the various alignments. The D Alternative was carried forward to the sub-area evaluation as a requirement of the ADMP process.

Table 10 Strategy Selection Matrix

Strategy Selection Matrix - Area Wide					
Alternative Measure		Evaluation Criteria			Ranking
Alternative Measure	Alternative	Public Safety	Economic	Social/Environmental	Total Score
Example (Rank each alternative from 1 to 3 with 1 being the least preferred alternative)	A	3	2	1	6 out of a possible 9
APEX	A	1	1	3	5
	B1/B2	3	3	2	8
	B3	3	1	2	6
	B4	3	3	2	8
	B5	2	3	3	8
	C	2	1	1	4
	D	1	2	3	6
CROSS SECTION	A	3	1	2	6
	B1/B2	3	3	2	8
	B3	3	1	2	6
	B4	3	3	2	8
	B5	3	3	2	8
	C	2	1	1	4
	D	2	2	3	7
Combined Score for Apex and Cross Section	A				11
	B1/B2				16
	B3				12
	B4				16
	B5				16
	C				8
	D				13
Primary Preferred Alternative	B1/B2/B5/B4				
Secondary Preferred Alternative	D				

7.2.2 Sub-area Evaluation

The sub-area specific evaluation was performed for the B1/B4, B2, and D alternatives. Because the B4 alternatives were similar to the big basin (B1) alternatives (except for the alignment), the sub-area specific evaluations embodied many of the same strengths and weaknesses discussed in the strategy evaluation (Section 7.2.1).

The relative merit of each alignment alternative was evaluated for each of the three lumped evaluation criteria. During the sub-area evaluation process, the nine "Form" criteria were lumped into four related categories: Environmental, Permitting, Visual/Aesthetic, & Recreation/Multiple Use which were used to assess the preferred alternative for each sub-area . Table 11 shows the results of the social, environmental, aesthetic, and multi-use criteria evaluation using the four "Form" categories. Table 12 shows the results of the public safety and economic criteria evaluation. Table 13 shows the results preferred alternative for each sub-area based on the outcome from the evaluation of both "Form" and "Function" by the project team.

The following sections describe additional specifics of the evaluation and results for each piedmont sub-area.

<u>CAP Sub-area</u>

The B1 alternative was selected as the preferred alternative according to the Form criteria. The important merits were the larger basin size and connectivity opportunities to the Regional Park. A larger basin was felt to provide greater recreational or habitat opportunities than the smaller basin alternatives. The B1/B2 alternatives were preferred according to the Function evaluation. The reason both alternatives were indicated was in order to reflect the suggestion by the Function evaluation group to emphasize the importance of balancing cut and fill the project. That is, the design of the recommended alternative should endeavor to balance the volume of material excavated for the detention basins with the volume of fill required for the levees.

<u>Wagner Sub-area</u>

For the Wagner sub-area, the Form evaluation found the B4-3 alternative the most preferred while the Function evaluation preferred either the B4-1 or B4-2 alignment. The B4-1 or B4-2 alternative were preferred to the B4-3 alignment by the Function evaluation primarily due to the additional cost of the third alignment in B4-3. When the Form and Function evaluators discussed the different preferences, it was noted that the B4-1 alternative delivers more water to Wagner Wash further upstream than B42 and was hence more environmentally preferred in terms of potential impacts to the existing riparian habitat along Wagner Wash. In addition, the discussion revealed that functionally a third alignment would provide easier access for local drainage systems to the regional trunk system. Therefore, the B4-3 alternative was identified as the recommended alternative for the Wagner sub-area. A non-structural, floodplain management approach to most of Wagner Wash is also a component of the recommended alternative for this sub-area.

Hassayampa Sub-area

The preferred alternative for the Hassayampa sub-area was the B4-3 alignment alternative. The reasons were advantages and preferences from both a form and a function point of view. The B4-3 alternative provides multiple paths for connectivity from the Hassayampa River to the White Tank Mountain Regional Park. In addition, the alignment takes best advantage of the existing culvert capacity at Sun Valley Parkway. Local drainage facilities will also have a shorter distance to provide connection to the regional trunk channel corridors.

White Tank Wash Sub-area

The evaluation of the White Tank Wash sub-area is similar to the CAP sub-area. While the B1 alternative was preferred, the project team noted the need to balance excavation volumes with fill requirements. The recommended alternative for this sub-area may also be able to take advantage of imminent development drainage facilities as part of the ADMP system. In particular, the Anthem at Sun Valley South development is planning a large set-aside area for Fan 39 downstream of an off-line detention facility (see Figure 36). This system will provide the opportunity for an additional downstream corridor along an existing tributary of White Tank Wash with and effective FEMA floodplain. Some, if not all of this corridor may be able to be addressed with a non-structural floodplain management approach. A non-structural, floodplain management approach to most of White Tank Wash is also a component of the recommended alternative for this sub-area.

FRS No. 1 Sub-area

The preferred alternative for the FRS No. 1 sub-area was the B4-3 alternative. Again, the multiple, separate paths from each alluvial fan apex to the FRS was preferred due to the multiple corridors for wildlife habitat and/or recreational multiple-use connectivity from FRS and the Hassayampa River to the mountainous areas and the Regional Park. Proximity of the regional trunk systems to future local drainage facilities was also identified as a strength of the B4-3 alignment alternative.

FRS No. 2 & 3 Sub-area

The Form and Function evaluation resulted in different preferences from the initial evaluation. In the recommended alternative resolution meeting, the group recommended that both the eastern and western alignments on Skyline Wash Fan be investigated with the potential for inclusion of both corridors. In addition, due to the relatively short distance from the apex to FRS No. 2 and the belief that significant existing channel capacity may be available along these corridors, the small basin (B2) alternative was recommended for further evaluation in Step 3. For Fan 10 and 11 a non-structural approach was recommended. The reason was the relatively small active fan area. Moreover, much of the active fan area for Fans 10 and 11 lies on property already owned by the Flood Control District. A recommendation to delineate the active area with FEMA floodplain/floodway was made in order to ensure the hazards on the property are communicated to the County so that potentially "excess" land is not sold at public auction without the hazard information.

Table 11 Alternative Evaluation Matrix by Sub-area (Form)

Alternative Evaluation Matrix by Sub-Area									
Alternative Measure		Function Criteria	Economic Criteria	Form Criteria				Ranking	
Alternative Measure	Alternative	Public Safety	Economic	Environmental	Permitting	Visual/ Aesthetic	Recreation/ MU	Total Score	Preferred Alternative
Example (Rank each alternative from 1 to 3 with 1 being the least preferred alternative)	A	3	3	3	2	1	1	7 out of a possible 12	Select one preferred alternative for each sub-area
CAP Sub-Area	B1/B2			3	1	3	3	10	B1
	B5			3	1	3	3	10	
	B4			N/A	N/A	N/A	N/A	N/A	
	D			3	1	1	2	7	
Wagner Wash Sub-Area	B4-1			2	1	2	2	7	B4-3
	B4-2			2	1	2	2	7	
	B4-3			3	1	3	3	10	
	B5			3	1	2	2	8	
	D			2	3	2	2	9	
Hassayampa Sub-Area	B4-1			2	1	1	1	5	B4-3
	B4-2			2	1	2	2	7	
	B4-3			3	1	3	3	10	
	B5			3	1	3	2	9	
	D			3	3	1	1	8	
White Tank Wash Sub-Area	B1/B2							0	Large basins More corridors
	B5							0	
	B4			N/A	N/A	N/A	N/A	N/A	
	D							0	
FRS 1 Sub-Area	B1/B2							0	Large basins More corridors
	B5							0	
	B4							0	
	D							0	
FRS 2 & 3 Sub-Area	B4-1			2	1	2	2	7	B4-3
	B4-2			2	1	3	3	9	
	B4-3			2	1	3	3	9	
	B5			3	1	3	2	9	
	D			3	3	1	1	8	

Table 12 Alternative Evaluation Matrix by Sub-area (Function)

Alternative Evaluation Matrix by Sub-Area						
Alternative Measure		Function Criteria	Economic Criteria	Form Criteria	Ranking	
Alternative Measure	Alternative	Public Safety	Economic	Social/Environmental	Total Score	Preferred Alternative
Example (Rank each alternative from 1 to 3 with 1 being the least preferred alternative)	A	3	2	1	6 out of a possible 9	Select one preferred alternative for each sub-area
CAP Sub-Area	B1/B2	3	2		5	B1/B2
	B5	3	2		5	
	B4	N/A	N/A		N/A	
	D	1	3		4	
Wagner Wash Sub-Area	B2	2	3		5	B4-1/B4-2
	B5	1	3		4	
	B4-1	3	3		6	
	B4-2	3	3		6	
	B4-3	3	2		5	
	D	1	1		2	
Hassayampa Sub-Area	B2	1	3		4	B4-1/B4-3
	B5	1	3		4	
	B4-1	2	3		5	
	B4-2	3	2		5	
	B4-3	3	2		5	
	D	1	1		2	
White Tank Wash Sub-Area	B1	3	3		6	B1
	B2	2	2		4	
	B5	1	2		3	
	B4	N/A	N/A		N/A	
	D	2	2		4	
FRS 1 Sub-Area	B2	1	3		4	B4-3
	B5	1	3		4	
	B4-1	1	3		4	
	B4-2	2	2		4	
	B4-3	3	1		4	
	D	1	2		3	
FRS 2 & 3 Sub-Area	B2	2	2		4	Non-structural (A) at Fan 10 & 11; B4-1
	B5	1	2		3	
	B4-1	3	1		4	
	B4-2	2	1		3	
	B4-3	1	1		2	
	D	1	3		4	

Table 13 Alternative Evaluation Matrix by Sub-area (Combined)

Alternative Evaluation Matrix by Sub-Area				
Alternative Measure		Preferred Alternative		Recommended Alternative
Alternative Measure	Alternative	Form	Function	
CAP Sub-Area	B1/B2 B5 D	B1	B1/B2	B1/B2
Wagner Wash Sub-Area	B2 B5 B4-1 B4-2 B4-3 D	B4-3	B4-1/B4-2	B4-3
Hassayampa Sub-Area	B2 B5 B4-1 B4-2 B4-3 D	B4-3	B4-1/B4-3	B4-3
White Tank Wash Sub-Area	B1 B2 B5 D	Large basins More corridors	B1	B1
FRS 1 Sub-Area	B2 B5 B4-1 B4-2 B4-3 D	Large basins More corridors	B4-3	B4-3
FRS 2 & 3 Sub-Area	B2 B5 B4-1 B4-2 B4-3 D	B4-3	B2 B4-1	B2 B4-3

7.3 Summary

The outcome of the evaluation process was a preference for large on-line detention basins at alluvial fan apices with multiple downstream corridors. This conclusion was the same for all sub-areas with alignment options. The alignment variation alternatives preferred more corridors over fewer corridors because of the environmental benefits, the additional multiple-use opportunities, and the proximity for connections for local tributary drainage. In addition, it was emphasized by the evaluation team that any "for sure" elements of developers systems (Alternative D) be incorporated into the final recommended alternative. Non-structural elements also comprise portions of the recommended alternative. These include the delineated floodplains of Wagner Wash and White Tank Wash. In addition, other non-structural recommendations are the delineation of the active fan area for the small Fans 10 and 11 which flow into the FRS No. 2 pool area. Finally, the incised reaches upstream of the alluvial fan apices area also recommended for a non-structural, floodplain management approach.

Figure 45 shows the spatial summary of the recommended alternative components for each of the piedmont sub-areas. The incorporation of the "for sure" developer features are not shown but will be included in the recommended alternative refinement in Step 3. Other elements of the Step 3 refinements to the recommended alternative are discussed in Section 8.

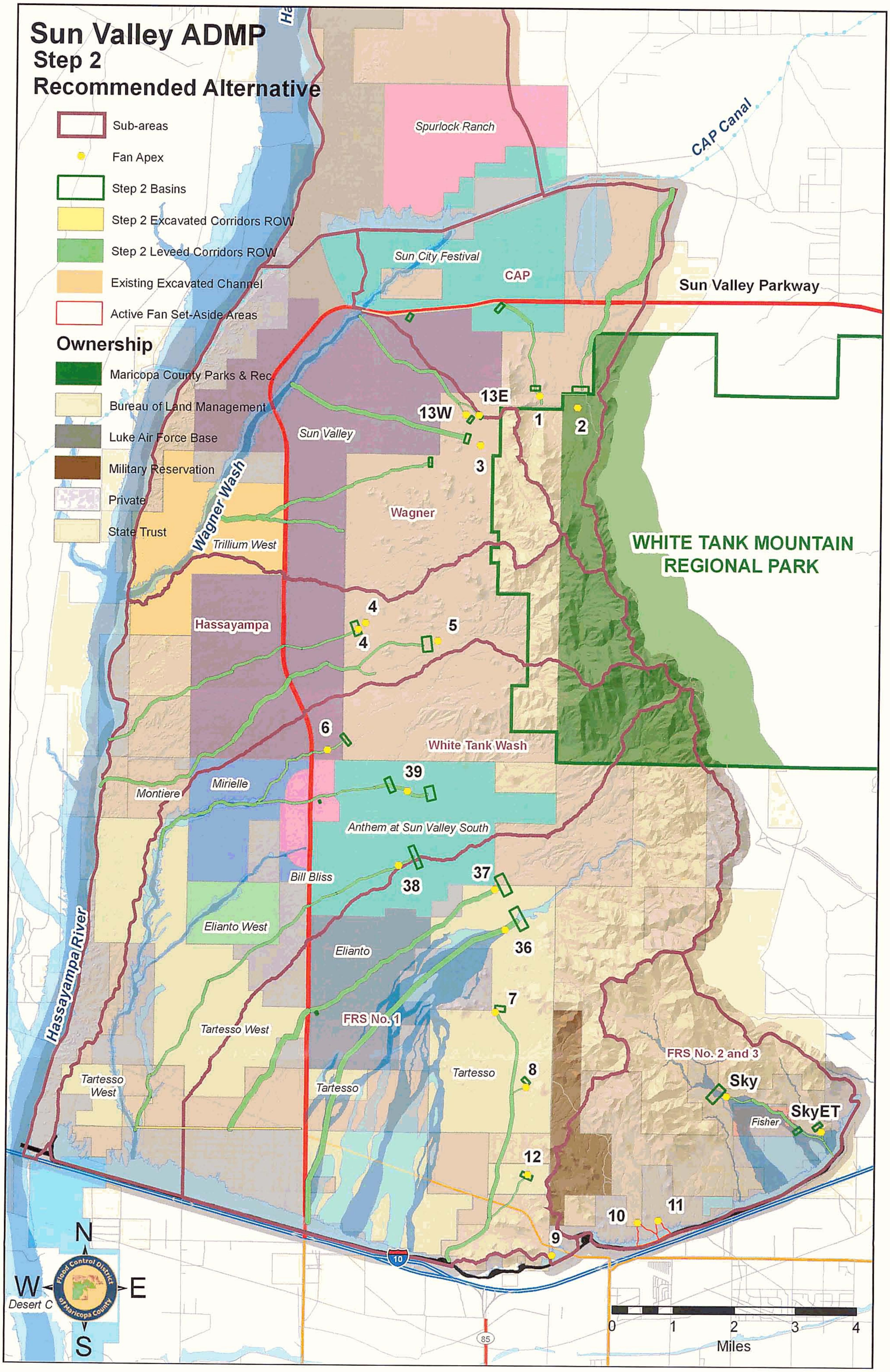

Figure 45 Step 2 Recommended Alternative

8 RECOMMENDATIONS FOR STEP 3

Based on the outcome of the Step 2 alternatives evaluation, a number of items for consideration in the refinement of the recommended alterative are suggested for Step 3 evaluation. These recommendations are based on input received during the development of the proposed alternatives, the team evaluation process, and input from stakeholders and the public.

- On-line big basins are the preferred solution to control alluvial fan uncertainties at the apices.
- Multiple downstream levee/wall corridors are preferred whenever possible.
- The "for sure" developers' drainage features should be incorporated into the ADMP recommended alternative.
- There is a need to balance earthwork by project. For Step 3, a project will be considered the apex-to-outfall system for an individual alluvial fan (or fan complex if hydraulically connected).
- Existing channel conveyance should be quantified and incorporated into the recommended alternative designs. This could result in the elimination of some levee/wall reaches where the existing conveyance is adequate or natural lateral containment exists on one or more sides of the corridor. This will also maximize the use of non-structural or nearly non-structural reach management elements.
- The required landscape compatibility enhancements should be included explicitly in the hydrologic and hydraulic design.
- Enhancement to the existing Sun Valley Parkway channel should be investigated and incorporated into the recommended alternative for Fan 1.
- Incorporate the specific sediment data collected in the study area during Step 2 into the design calculations.
- Identify the area benefited using the Stage 3 delineations.
- Refine the design details including riprap sizing calculations and the evaluation of basin inlet structures (e.g., energy dissipaters, collection dikes/ ditches, off-line basin outlet structures, etc.).
- Refine the hydrologic models to include more HEC-1 subreaches, ideally one subreach per design reach.

- Discretize the quantities and costs by individual fan system (by "project") rather than by sub-area as was done in Step 2.

9 SUMMARY

The proposed alternatives for the SVADMP study area were developed and evaluated in Step 2 of the ADMP process. The alternatives included both non-structural and environmentally friendly and aesthetically compatible structural flood control measures. Engineering and landscape compatibility enhancement costs were estimated for all of the proposed alternatives piedmont sub-areas. The proposed alternatives were evaluated for their flood control function, economic costs, environmental impacts, permitting issues, visual and aesthetic characteristics, and recreation and multiple-use opportunities. Preference for natural leveed corridors downstream of on-line detention basins along multiple corridors was expressed by the project team, stakeholders, and the public. For the area north of the CAP, a number of flood-related issues were identified and recommendations made. In particular, stock tanks and the flood control facilities associated with Luke Auxiliary Field No. 4 should be removed or improved to current engineering standards before development occurs downstream. In addition, floodprone areas including some small alluvial fans should be avoided or at a minimum addressed in detail before development plans are approved in this area.

The recommended alternatives will be carried forward in Step 3 for further refinement of the engineering elements and the cost estimates. Special attention will be given to maximizing non-structural, floodplain management approaches along the preferred leveed corridor alignments. Stakeholders and the public will continue to be consulted as to their feedback in attempt to incorporate existing and imminent developer plans into the drainage master plan for the Sun Valley area.

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