Rio Verde Area Drainage Master Plan
FCD 2001C056

Part 2 - Alternatives Formulation

November 2004

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Flood Control District of Maricopa County

Prepared by:

DIBBLE & ASSOCIATES
CONSULTING ENGINEERS
Since 1962

In association with:

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC

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FCD 2001C056
PART 2 – ALTERNATIVES FORMULATION

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I. INTRODUCTION

The Part 1 *Existing Conditions* Report describes the existing watershed characteristics and the impacts of development within the Rio Verde area. The study area is described in terms of four distinct geologic zones. These zones are grouped into two areas according to whether they exhibit one-dimensional or two-dimensional flow characteristics. Evidence of erosion, sediment deposition, and flow re-distribution is found in two-dimensional flow areas where residential and equestrian related improvements have been made. The potential for these types of impacts to be compounded with future development has been described. Impacts that may seem minimal on an individual lot scale may become extreme when consideration is given to the cumulative impacts resulting from complete development of the Rio Verde area.

This Part 2 *Alternatives Formulation* Report presents the consideration of various alternatives that could be employed within the Rio Verde area to mitigate the increase in flood and erosion hazards that could result from development of the watershed. The purpose of this report is to determine if feasible, implementable, alternatives exist and to identify alternatives for further evaluation in Phase 2 of the project.

A. Opportunities & Constraints

An Existing Constraints Map was developed based on the data collected in the Existing Conditions analysis. Among the items depicted on the map are: existing and planned developments, existing major utilities, mapped floodplains and existing stock tanks. The Existing Constraints map is shown as **Figure I-1**. In addition to the physical constraints depicted on Figure I-1, a broader list of opportunities and constraints was identified to help guide the selection of alternatives. The following opportunities and constraints are identified.

1. Opportunities

- To impact development patterns in a relatively undeveloped area.

  Although development is occurring at a rapid pace, there are still significant areas within the Rio Verde watershed that are natural and undeveloped. This provides an opportunity to influence development of these areas in a manner that is more in harmony with the natural landform and drainage characteristics within the area, which could avoid the need for future drainage structures.

- To preserve the area's scenic value.

  Since the Rio Verde area is not built out, there is still an opportunity to adopt regulatory measures to direct development in a way that will mitigate flood hazards and thus avoid unsightly drainage structures and maintain the natural scenic value of the area.

- To maintain large lot zoning restrictions.

  It is common for rural zoning designations to move toward denser zoning designations as development pressure begins to occur. To date, the one-acre minimum rural zoning has remained intact in the Rio Verde area. There is still an opportunity to retain the rural zoning and preclude the adverse impacts of a denser zoning designation.

- No city to restrict implementation in unincorporated areas.

  Although not having a partner City in the Rio Verde area is considered a constraint in terms of sharing the cost of

improvements, since the area is all unincorporated Maricopa County, there is an opportunity to implement approaches that may not otherwise be possible due to partner Cities with divergent views or objectives that could restrict the District's ability to implement the plan.

- Developable area limited by McDowell Mountain Park, Tonto National Forest, and Scottsdale Preserve areas.

  These areas are protected and will be preserved in their natural state and will therefore not be subject to residential development. This will limit the area threatened by increases in flood hazard from development.

- To consider drainage impacts in development of the transportation system. Perhaps deviate from sectional alignment of roads.

  Rio Verde Drive is one of few County roads in the Rio Verde area. Most of the existing roads are unimproved with no County right-of-way. As a result, there is an opportunity for the County to develop a transportation plan for the Rio Verde area that includes consideration of drainage patterns. The plan could then be implemented with roadway improvements that become County roads and meet County standards.

- Form partnerships between county agencies (P&D, MCDOT, FCDMC)

  Since the area is unincorporated Maricopa County, there is a unique opportunity for cooperation between County agencies to implement and enforce development and drainage requirements using a unified approach.

2. *Constraints*

- Public acceptance of solutions

  The residents of Rio Verde prefer the rural lifestyle and value the natural beauty of the area. As a result, they are vocal in their objection to certain forms of government regulation and would likely object to unsightly structural measures.

- Highest land cost within unincorporated Maricopa County

  The high cost of land in the Rio Verde area will result in high right-of-way costs for structural measures. The high cost of right-of-way could make retention or detention concepts cost prohibitive.

- Low value of existing structures to protect

  Although the cost of individual homes can be very high in the Rio Verde area, there are large areas that do not have homes. As a result, the low aggregate value of all structures in the Rio Verde area would likely yield a low flood protection benefit as compared with the high cost of required drainage improvements. The primary beneficiary of structural drainage improvements would be future residents who have not yet built homes.

- Rectilinear alignments of streets and property boundaries

  The north-south and east-west orientation of streets and property boundaries is not consistent with the drainage patterns. Channel alignments that follow the natural flow path would be skewed with the streets and property boundaries creating difficulties with right-of-way acquisition and street alignments.

- Little County right-of-way due to extent of private roads

  Most of the roads in the Rio Verde area are private. MCDOT has very little road right-of-way in the area. As a result, there is little opportunity to combine flood control improvements with existing County right-of-way.

- Agricultural exemption for Drainage Regulations
  Rural lots that are used for agricultural purposes are exempt from the drainage regulations. As a result, the District cannot regulate agricultural parcels except through the Floodplain Regulations.

- Can't increase discharges into Tonto Verde and Rio Verde communities
  These existing communities have pass through channels designed for a specific discharge. Runoff cannot be concentrated as part of a District project in a way that increases this peak discharge unless costly improvements are made within the communities to provide the needed capacity.

- Fill for elevating lots
  If homebuilders are required to elevate lots without excavating the needed fill material from within their parcel, the cost for importing the fill would be high.

- No City to cost share with.
  Since there is not a local sponsor City for this project, the full cost of implementation would need to be born by the County or developers.

- Distributary flow with braided channels creates a large areal distribution of flooding
  The distributary nature of flooding in the Rio Verde area would increase the cost of collecting runoff into a drainage system. Additionally, localized drainage improvements would benefit only a small area. As a result, drainage improvements would need to be relatively widespread to provide a uniform level of flood protection.

- Variability in flow distribution
  The distribution of flows between the numerous braided channels may change from one storm event to the next. Natural occurring debris may be trapped within the flow path diverting runoff into an adjacent braid. As a result flow distribution cannot be reliably predicted over a period of time.

- Terrain that has hydraulically steep slopes
  The piedmont within the Rio Verde area is steep. Steep slopes create sedimentation and erosion problems and present significant design challenges for channel improvements. The desire to limit the high velocity flow conditions must be balanced with the need to convey the sediments that are naturally transported through the system during flow events.

- "Kinder and gentler" design constraint limits use of concrete for channels
  Due to the steep, high velocity nature of the runoff, concrete channels would be a reliable means to prevent erosion and minimize the right-of-way for drainage improvements. The District's mandate for "kinder and gentler" designs requires use of softer, more natural materials for channel designs, which would be difficult to implement in the Rio Verde area.

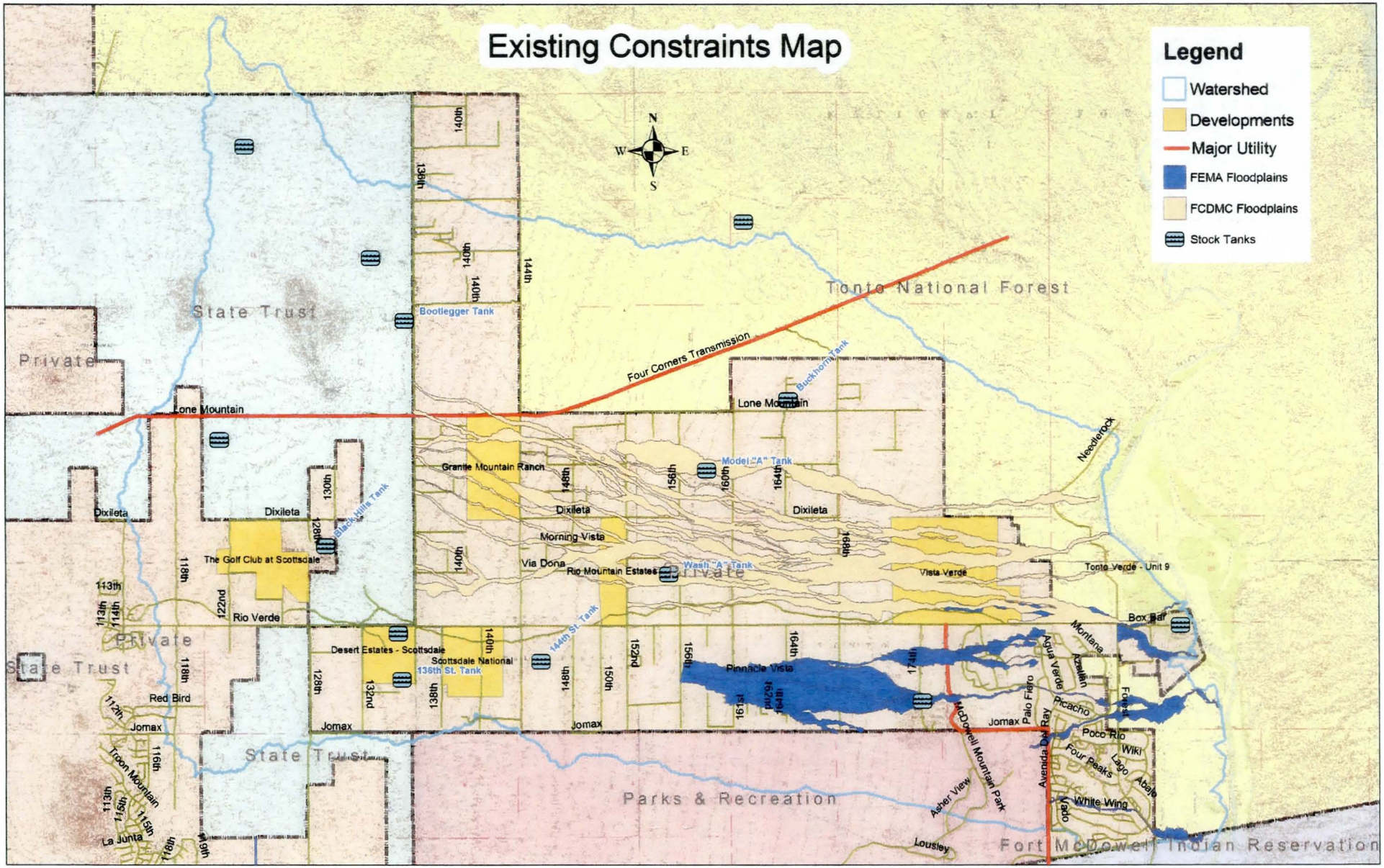


FIGURE I-1 – Existing Constraints Map

II. ALTERNATIVES FORMULATION

A. Introduction

There are many issues to consider in developing a regional solution for the drainage issues which face the Rio Verde Area. Presented below are some of those issues and objectives considered by the consultant team and the review committee in developing the alternatives.

1. Issues

- Physical characteristics of the Piedmont

  The physical characteristics of the piedmont create issues relating to the hydraulics of flow and sediment transport. The piedmont is characterized by hydraulically steep slopes with fine-grained erosive soils. Within the two-dimensional flow areas this results in broad, shallow, unconfined flow characteristics in a distributary flow network of braided channels. The flow paths within this network are uncertain and may vary from one storm event to the next. The sediment transport characteristics complicate the flow conditions due to erosion and the potential for changes in location of the braided channel network. The one- and two-dimensional flow areas are shown on **Figure II-1**. Human induced changes to the natural system can have a dramatic impact on the sediment continuity and erosion potential.

- Land development patterns

  Many of the new residential structures being constructed in the Rio Verde area are being developed on a single-lot basis. Larger parcels are being split into smaller single-lots in a way that avoids the subdivision development regulations. As a result, it is more difficult for the District to regulate the development on a regional basis. The homebuilders may not understand the drainage characteristics and hazards within the area and therefore not give adequate consideration to these issues in preparing their site plans.

- Floodplain management

  The floodplain delineations that have been performed in the area have resulted in extensive land area within floodplains. The extent of floodplain coverage can make it difficult for landowners to find a suitable location within their site that is outside of a floodplain to locate their home. The floodplain mapping results may over state the hazards since much of the floodplain area is very shallow. Additionally, there are still floodplain areas that have not yet been delineated. The "no-build" implications of floodway designations must be weighed against the consequences of encroachment to find a suitable balance between the need for developable land and mitigation of flood risks associated with encroachment.

- All weather access

  Although it is desirable from a drainage standpoint to minimize disruption to the natural system of braided washes through the use of dip crossings at roadways, the issue of access during storm events is an important safety concern.

2. Objectives

- Ensure public safety

  A critical part of the District's mission is to ensure the public safety by identifying flood hazards and taking steps to mitigate them. This is the highest level objective of this plan.

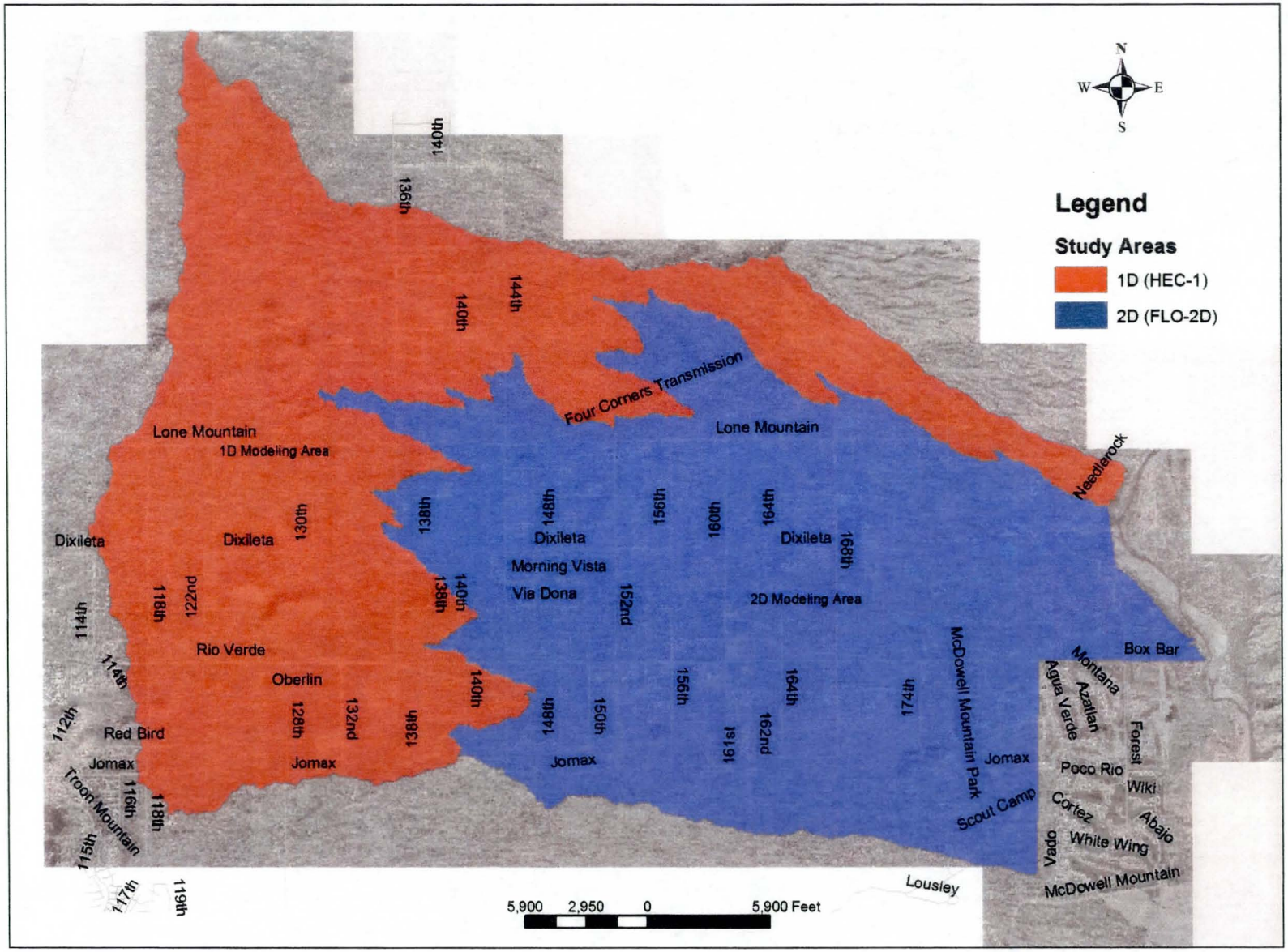


FIGURE II-1 – One and Two Dimensional Flow Areas

- Minimize flood control costs
  The FCDMC is striving to get out ahead of development in areas that are not yet fully developed. Flooding problems avoided through good planning and management cost the residents of the County significantly less than the cost of fixing flooding problems after the area is developed.

- Mitigate adverse land development impacts
  To prevent or minimize the creation of new flood hazards from land development activities. This applies to existing and new developments. This objective must be balanced with private property rights, including the cost to the property owner of the required flood mitigation measures.

- Preserve the natural scenic value of the study area
  The natural vegetation and landform give the Rio Verde area its unique beauty and attraction for residents choosing to live in the area. Flood protection measures should not detract from the natural beauty of the area.

B. Major Considerations in Developing Alternatives

Numerous choices are available in developing drainage alternatives; many more than can be realistically analyzed in detail. The goal of this report is to develop four possible alternatives which are feasible based upon a number of factors. The major considerations used in developing alternatives are summarized below.

1. Alignment

The location of drainage facilities is often along the historic flow path. This may result in the most economical alignment and when the structure capacity is exceeded, the flow will return to its historic path. However, there are times when diverting runoff along a new alignment may be more economical. This may occur when additional land can be made available for development or when channels can be aligned adjacent to roadways to share right-of-way.

2. Spacing of Storm Water Facilities

Storm drain or channel improvements can be planned at many different spacings such as every city block, 1/2-mile, 1-mile, 2-mile or more. Increasing the spacing increases the size of the facilities but may achieve a lower overall cost. In most cases, the existing roadways dictate the spacing of facilities.

3. Type of Storm Water Facility

The type of storm water facility will generally be dependant on the magnitude of the flows, cost, and environmental considerations. Available choices include detention or retention basins, channels, and pipes. For each of these conveyance methods there are several materials that are available including earth, concrete, riprap, concrete pipe, and corrugated metal pipe.

4. Detention vs. Conveyance

Retarding the rate of flow through detention basins allows downstream conveyance facilities to be smaller. The degree to which detention is pursued in a plan is another alternative. It may be economical to detain the flows to reduce the required outfall capacity. Conversely, the cost of land may make detention unfeasible.

5. Nonstructural Plan

In some cases, it may be more economically, politically, or environmentally beneficial to restrict development in flood prone areas. Benefits of restricting development may include preservation of open space, maintenance of existing vegetation and wildlife habitat, overbank storage, avoidance of the cost of drainage improvements and reduced damage to property and structures.

6. *Acceptance of Risk*

The level of risk accepted by the community is another choice that may be considered. Acceptance of additional risk by downsizing improvements results in lower initial costs, but may result in increased long term costs to society in terms of maintenance and repairs of damaged property.

C. Alternatives Formulation Meeting

Storm water management alternatives were identified through an Alternatives Formulation Meeting held with the Review Committee on March 30th, 2004 at the Flood Control District of Maricopa County (FCDMC). The purpose of the session was to identify flooding problem areas and alternative concepts for solutions to the drainage problems.

The Alternatives Formulation Meeting was intended to be a creative brainstorming session to generate possible alternatives. To help stimulate ideas, the consultant team generated several "seed" alternatives prior to the meeting.

D. Potential Alternatives

The following four approaches to flood control were used in the Alternatives Formulation Meeting to develop potential alternatives for further screening:

- No-Action
- Structural Conveyance
- Structural Detention
- Regulatory

Various alternatives were identified for each flood control approach. The alternatives are referred to as Potential Alternatives to differentiate them from the alternatives that will be identified through the screening process. The screening process will identify a single alternative for each flood control approach to be carried forward for more detailed alternatives analysis during Phase 2 of the project. The potential alternatives are described in the following sections.

1. *Evaluation Criteria*

Evaluation criteria were established to be used as the basis for evaluating the merits of the potential alternatives as part of the alternative screening process. The performance of each alternative is measured on a scale of 1 to 5 for each criterion. The evaluation criteria with their performance measurements are described below:

a) **Flood Protection**

5= Major structural or acquisition protection for 100yr. Event.
4= Major flood protection for 100yr (administrative methods)
3= Significant structural protection for less than 100yr.
2= Minor protection, less than 100yr (administrative methods)
1= No significant flood protection

b) **Cost**

5= No initial cost (non-structural)
4= Low regulatory administrative cost (non-structural)
3= Low initial construction cost
2= Medium initial construction cost.
1= High initial construction cost

c) **Environmental Impacts**

5= No mitigation required
4= Some mitigation required
3= Significant mitigation required
2= Major mitigation required
1= Complete EIS possibility

d) **Maintenance**

5= No maintenance required
4= Low frequency, light maintenance
3= High frequency, light maintenance
2= Light frequency, heavy maintenance
1= High frequency, heavy maintenance

e) **Hydraulic Performance**

5= Laminar, non-erosive flows
4= Minor turbulent flow with some erosion protection
3= Significant turbulence, major erosion control
2= Turbulent flow with energy dissipator
1= Natural, high velocity, erosive conditions

f) **Safety**

5= No safety hazard associated with project
4= Possible unsafe features during high flows
3= Possible unsafe features during dry conditions
2= Significant safety problems during wet and dry conditions
1= Major safety hazards inherent in project

g) **Constructability**

5= No hindrance to contractor and local access
4= Minor hindrance to contractor and local access
3= Significant difficulty for contractor and local access
2= Major difficulty for contractor and adjacent property owners
1= High degree of difficulty for contractor, and/or extensive access closures

Minimum performance standards are established for two of the listed criteria. An acceptable project must receive a score of 3 or higher for Flood Protection and 4 or higher for Safety.

2. ***No Action Alternative***

a) **Description**

The No Action Alternative documents the likely outcome if no additional action is taken to alleviate flooding. It is based on continuing the same management practices and development requirements that were in effect prior to this project. The No Action alternative forms a basis for comparison of the benefits and costs of other alternatives.

b) **Assumptions & Issues**

The following assumptions and issues form the basis of this alternative:

- The Development guidelines developed as part of this project are not implemented
- The FCDMC will enforce the existing FEMA and District floodplains and the current Floodplain Ordinance
- The existing Rio Verde special drainage rules will continue to be enforced (i.e. Engineer's Report required for each single-lot development)
- Undeveloped areas will develop at 1-acre per lot density as individual lots

c) **Evaluation Criteria**

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of the no-build alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – Since this is a non-structural alternative there are no constructability issues with this project.
- **Safety** – Since this is a non-structural alternative there are no safety issues with this project.

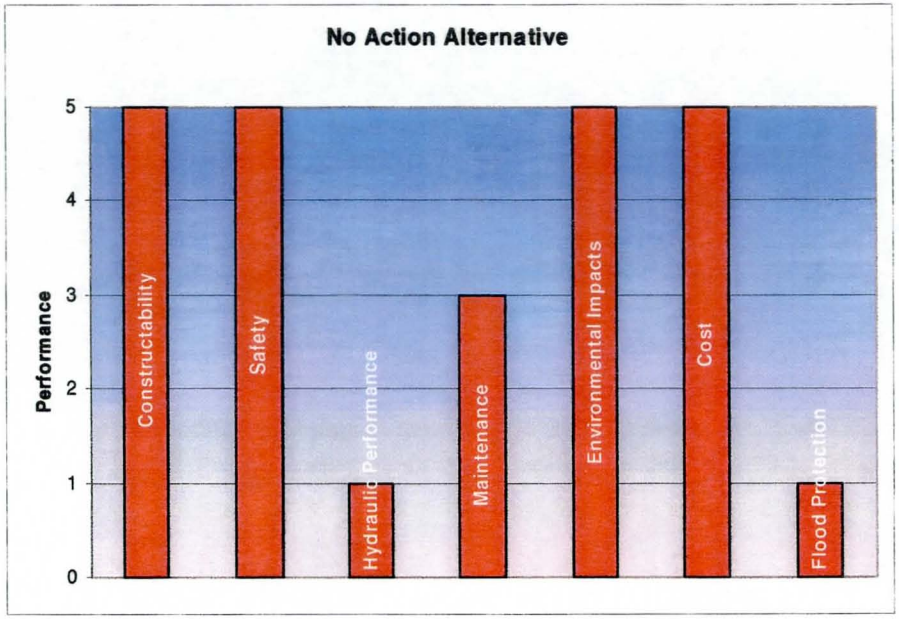
- **Hydraulic Performance** – This alternative will not address the natural high velocity, distributary flow conditions. As a result this alternative has poor hydraulic performance.
- **Maintenance** – Due to limited drainage structures, light maintenance would be anticipated after small, frequent storms to remove sediment and to repair erosion damage.
- **Environmental Impacts** – Since this is a non-structural alternative, no environmental permits or mitigation would be required with this project.
- **Cost** – There is no initial cost with this alternative
- **Flood Protection** – This alternative provides no significant flood protection. Flood protection will need to be addressed by the home builder on a project by project basis.

d) **Advantages & Opportunities**

- No structural improvement CIP cost
- Ease of implementation – no County Board action required
- No U.S. Army Corps of Engineers 404 permit impacts

e) **Disadvantages & Constraints**

- Negative impacts to watershed from limited regulation of development
- Increased potential for litigation
- Public safety concerns associated with impassable roads during flood events.
- Potential damage to the natural environment
- Limitations on ability to regulate development
- Existence of non-FEMA delineated floodplains



3. *Structural Conveyance Alternative*

a) **General**

A total of five structural conveyance (C) alternatives were identified by the project team. These alternatives consist primarily of either open channels or storm drain systems. The conceptual alternatives which follow are shown unmodified with respect to concepts that were developed by the project team at the alternatives formulation meeting. The following assumptions, advantages, and disadvantages apply to all the structural alternatives. Advantages and disadvantages that are specific to a particular alternative are included with the descriptions of each alternative. The approximate land areas receiving flood protection benefits from each project are shown on the exhibits.

(1) Assumptions & Issues

The following assumptions and issues form the basis of the structural conveyance alternatives:

- FCDMC channels in 2-D areas only
  Washes within the one-dimensional flow area will not be improved as part of this plan. Runoff that exceeds the natural channel capacity will be naturally conveyed in the overbank floodplain areas without being diverted into adjacent stream systems. Structural conveyance improvements will be limited to the two-dimensional flow area to establish a certain flowpath and provide discharge and sediment continuity through the area.

- Series of collectors and main channels
  The conveyance alternatives will consist of a series of collectors and main channels. The collectors will be used to collect the broad shallow runoff and concentrate it so it can be discharged into the main channels.

- Once channelized, continue to the Verde River or well incised channel
  Once concentrated into a main channel, runoff will be conveyed to the Verde River or to a well incised outlet channel. Clear water scour would occur if the concentrated runoff is discharged back into the natural drainage network within the two-dimensional flow area.

- Designed for 100-year capacity
  Where channel improvements are made, they will be designed for the full 100-year discharge.

- Feasibility of alignments
  The feasibility of the conveyance alignments identified in the Alternatives Formulation meeting is reviewed and evaluated as part of the alternative screening process. Issues relating to the feasibility of potential alternative alignments are identified with the disadvantages of each alternative.

(2) Advantages & Opportunities

- Establish certain flow paths
  The flow path uncertainty will be eliminated by establishing fixed channel locations.

- Eliminates or reduces floodplains
  By designing the channel improvements for the 100-year discharge, the floodplains will be eliminated.

- Controls flooding and mitigates hazards
  This approach will control flooding and reduce the land area subject to flood hazards.

- Multi-use
  Channel alignments provide opportunities for multiple-use corridors. These corridors could allow development of an equestrian trail network.

(3) Disadvantages & Constraints

- 404 Permit issues
  Channel improvements will likely require a 404 Permit from the U.S. Army Corps of Engineers. The 404 permit process can be quite lengthy and expensive. The Corps may impose harsh restrictions for habitat mitigation and on allowable channel types.

- Increases in peak discharge from lost watershed storage
  The existing broad shallow flow condition results in a significant amount of watershed storage of runoff, which acts to reduce peak discharge rates. Channel improvements will remove the watershed storage resulting in significant increases in discharge rates, which would have to be included in the design channel capacity.

- Cost of construction
  Due to the large areal extent of flooding and the design requirements for steep channels with high sediment loads, a channel system for the Rio Verde area would be very expensive.

- Maintenance requirements
  Channel improvements would require ongoing maintenance to control sedimentation and erosion. Maintenance would likely be required after most storm events.

- Negative visual impact
  Channel improvements, particularly concrete channels, would have a negative visual impact on the area. Man-made channels would disrupt the natural, rural appearance of the area.

- Phasing and implementation challenges
  Once a channel segment is constructed, it would need to be continued to the ultimate outfall location to prevent clear water scour problems. This could be a challenge to implement, since development patterns will not follow such an orderly sequence. As a result, developers may not be able to implement channel improvements on their property until the downstream improvements are completed.

- Sediment issues – convey or capture sediment?
  The naturally occurring sediment transport processes within the area will need to be addressed. Typically, sediment can be conveyed through the system or collected in sediment basins and hauled away. In either case, the cost of managing the sediment is high, and additional hazards are present if sediment deposition occupies needed channel or basin capacity.

- Must cross USFS land to get to Verde River
  Any channel alignment would need to cross Tonto National Forest lands to reach the Verde River. The Forest Service may impose restrictions on channel improvements within the Forest.

- Loss of riparian habitat
  Channel improvements would destroy natural habitat, which may need to be replaced as part of the requirements to obtain a 404 permit

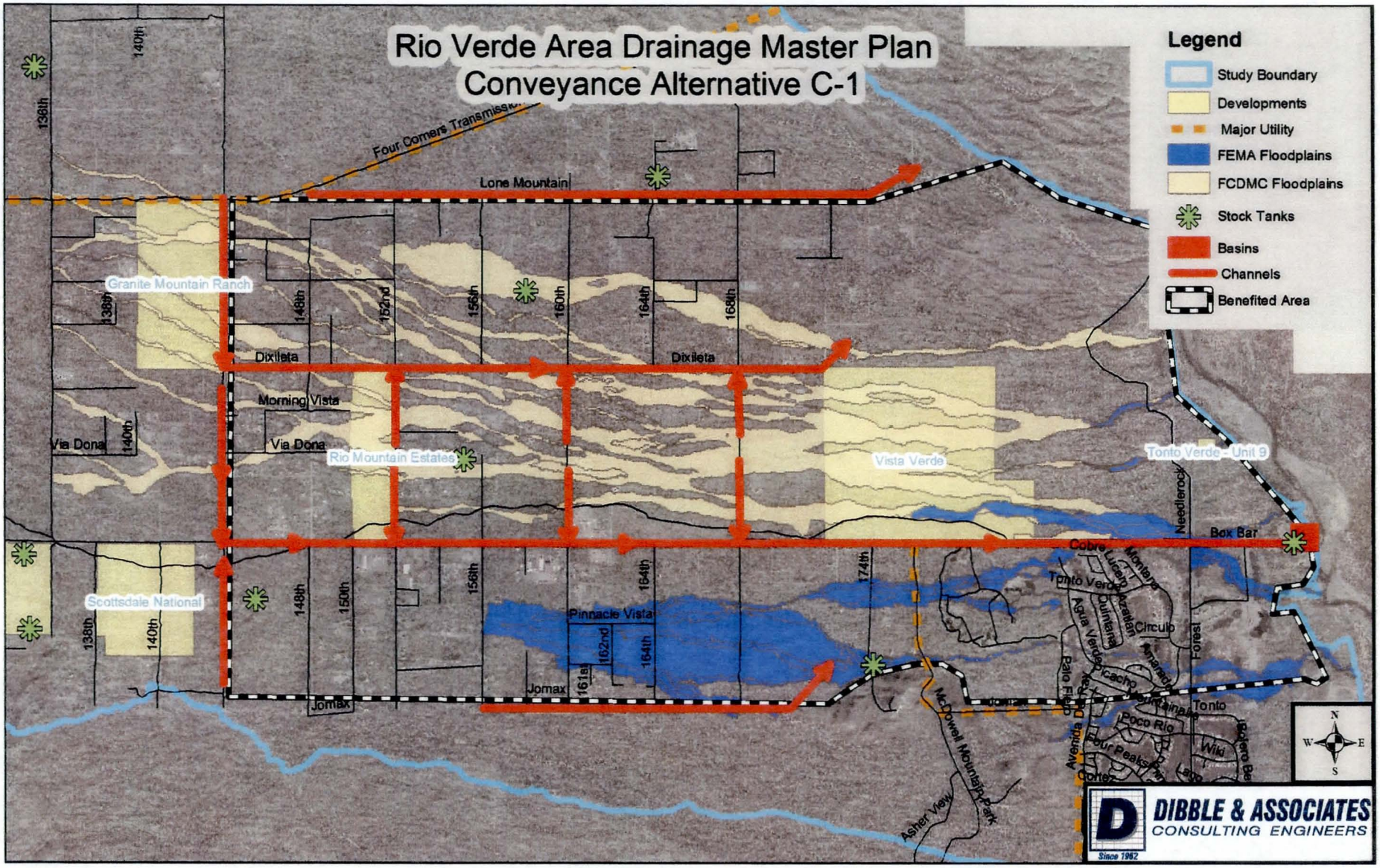


FIGURE II-2 – Alternative C-1

b) **Conveyance Alternative C-1**

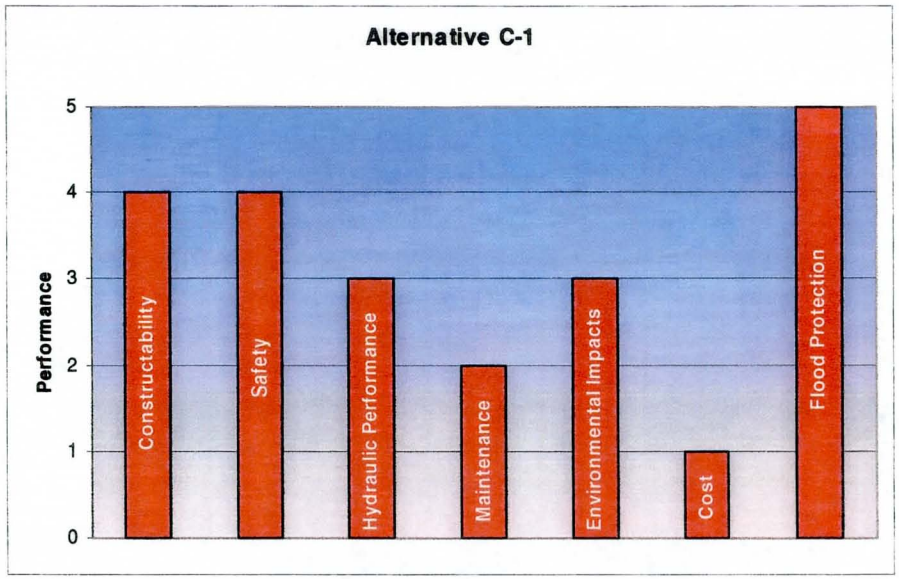
(1) Description

This alternative consists of approximately 21-miles of open channels that are laid-out in a grid configuration. Main-line channels run from west to east with collector channels delivering flow from the south and north as needed. The channels discharge back into the deep incised washes located toward the east end of the study area. There is a water quality basin located at the discharge point near the river.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – Because the channel alignments are in a grid pattern and situated adjacent to road alignments and property lines, this alternative is expected to encounter only minor hindrances to the contractor and to local access during construction by crossing roads and across numerous properties.
- **Safety** – Because of the steep channel slopes, it is expected that channels will have a super critical flow regime during flood events. This type of flow makes it harder to escape if caught in the flow. However, during dry periods, the channels will be relatively safe.
- **Hydraulic Performance** – While this alternative will move a large quantity of water, it is expected that it will require major erosion control measures due to the high expected velocities.
- **Maintenance** – Due to the steep slopes and erosive soils, it is expected that this alternative will require infrequent but heavy maintenance.
- **Environmental Impacts** – This alternative will have significant impacts to the existing natural washes by eliminating much of the flow reaching them. Therefore, significant mitigation measures may be required by the Corps of Engineers.
- **Cost** – This alternative is expected to have a high initial cost.
- **Flood Protection** – This alternative benefits approximately 16 square miles of area and will provide major structural protection for the 100-year event.



(3) Advantages

- If the channel geometrics permit, channels could be designed as multiuse facilities with hiking and horseback riding trails.
- Rectangular grid pattern utilizes existing roadway corridors and allows potential for sharing road ROW

- ROW acquisition will be facilitated since the alignments follow property lines which will minimize bisecting of existing parcels.

(4) Disadvantages

- This alternative provides somewhat restricted access to properties located along conveyance corridors.
- Depending on the channel geometrics, the channel may require fencing
- Concrete channels will be unattractive and will detract from the natural appearance of the area.
- The channel along the Jomax Road alignment wouldn't fully address the floodplain between Jomax Road and Rio Verde Drive.
- Potential sediment transport and erosion problems (especially collectors).

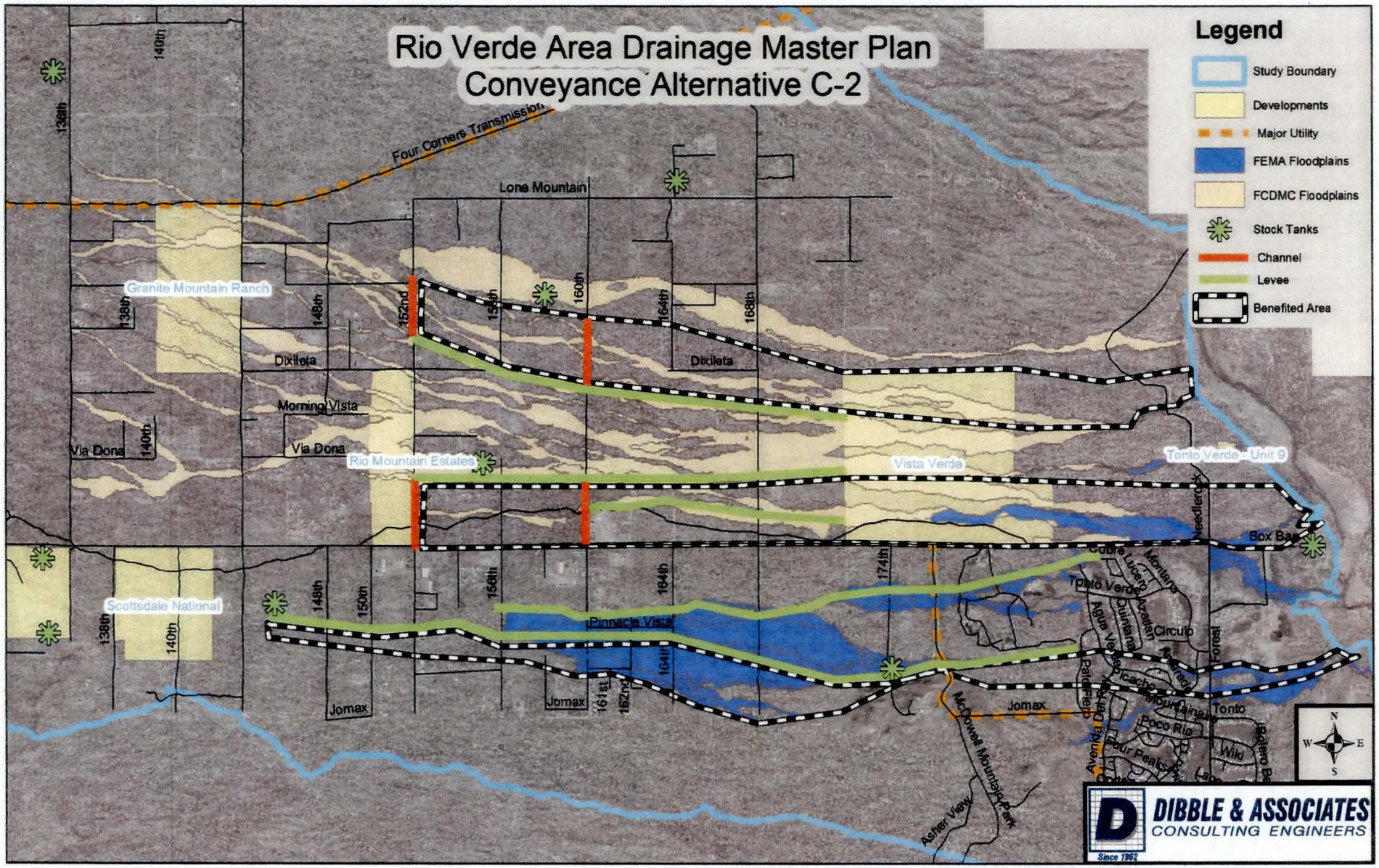


FIGURE II-3 – Alternative C-2

c) Conveyance Alternative C-2

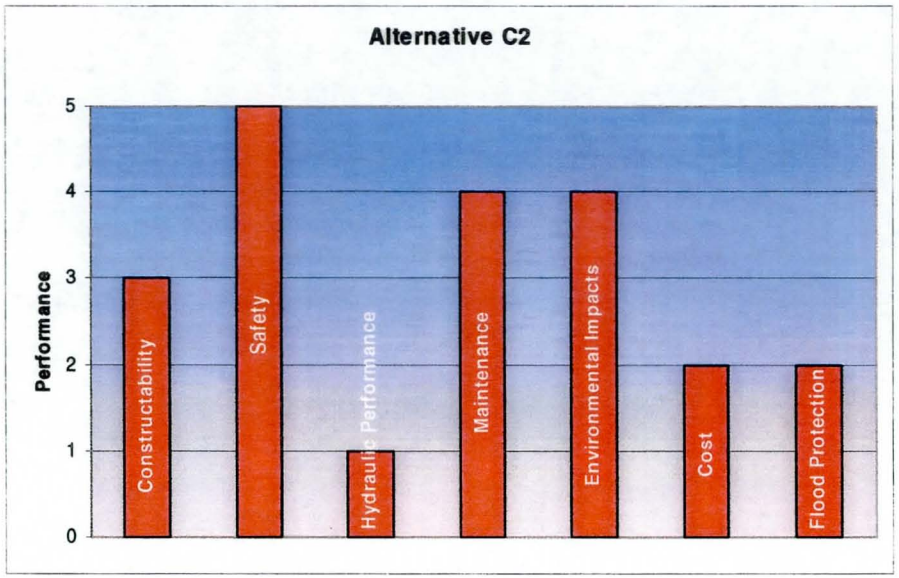
(1) Description

This alternative consists of approximately 13.5 miles of earthen levee and approximately 1-mile of open channels that follow the natural drainage pattern. The north-south collector channels collect flow and route it to within the levees. This alternative does not meet the established minimum performance level for flood protection.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – this alternative is expected to cause significant difficulty for both the contractor and to local access during construction. This is due to the alignment bisecting numerous properties at oblique angles.
- **Safety** – This project is not expected to cause impacts to safety except during high flows from flows along the embankments.
- **Hydraulic Performance** – This alternative would do little to alleviate the existing natural, high velocity, erosive conditions.
- **Maintenance** – It is expected that this alternative will require light maintenance on an infrequent basis.
- **Environmental Impacts** – This alternative will have some impacts to the existing natural washes by eliminating some flow reaching them. Therefore, some mitigation measures may be required by the Corps of Engineers.
- **Cost** – This alternative is expected to have a medium cost.
- **Flood Protection** – This alternative benefits approximately 4 square miles of area. There is still a large area that does not have protection for the 100-year event.



(3) Advantages

- Existing flow corridors are maintained, the runoff is being directed along existing flowpaths.
- The collector channels could be designed as multiuse facilities with hiking and horseback riding trails.
- This alternative preserves the open space and natural vegetation between the levees.

(4) Disadvantages

- This alternative provides somewhat restricted access to properties located along conveyance corridors.
- This alternative doesn't provide protection for properties within the levee impound area.
- This alternative splits many parcels making ROW acquisition more difficult

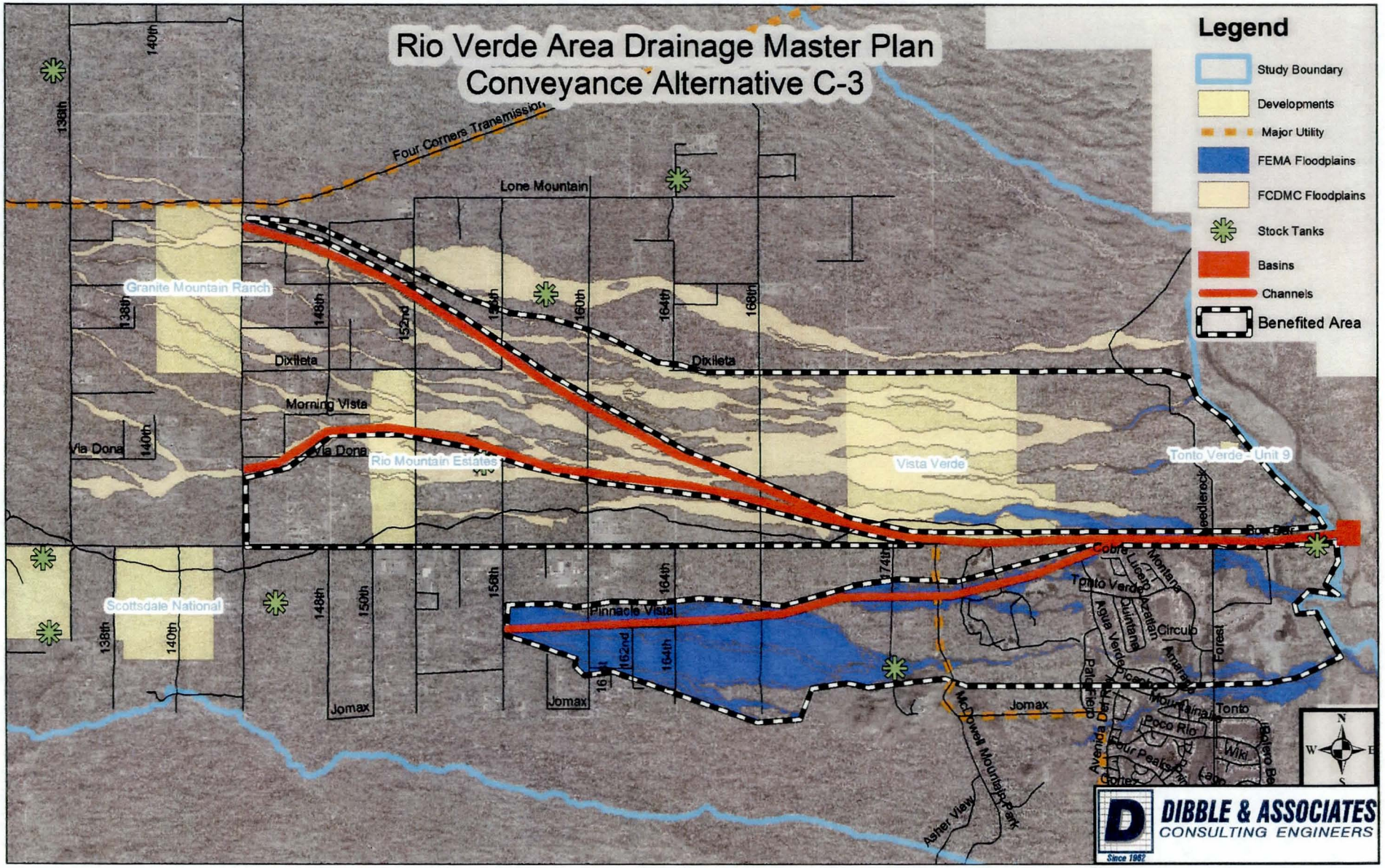


FIGURE II-4 – Alternative C-3

d) **Conveyance Alternative C-3**

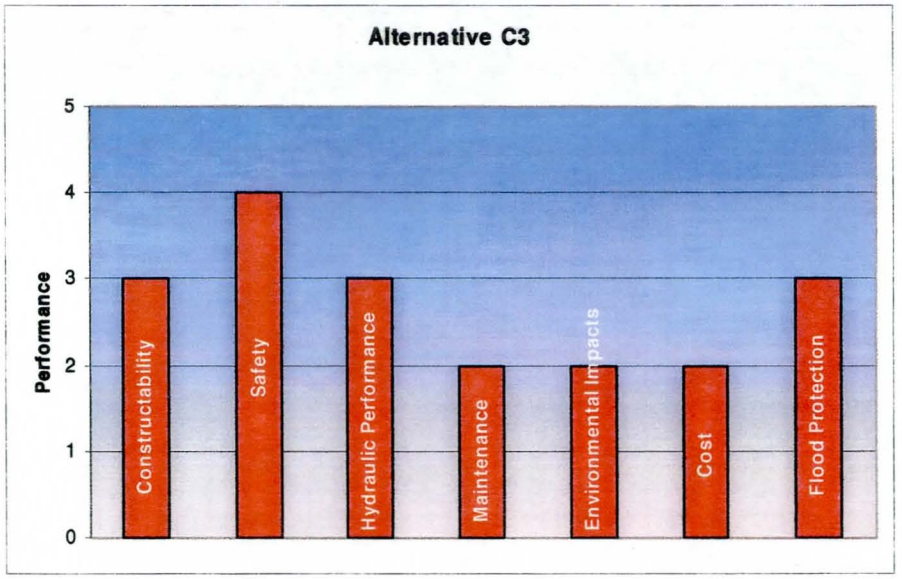
(1) Description

This alternative consists of approximately 14.5 miles of channels along the existing natural alignments. There is a water quality basin located at the discharge point near the river.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – this alternative is expected to cause significant difficulty for both the contractor and to local access during construction. This is due to the alignment bisecting numerous properties at oblique angles.
- **Safety** – Because of the steep channel slopes, it is expected that channels will have a super critical flow regime during flood events. This type of flow makes it harder to escape if caught in the flow. However, during dry periods, the channels will be relatively safe.
- **Hydraulic Performance** – While this alternative will move a large quantity of water, it is expected that it will require major erosion control measures due to the high expected velocities.
- **Maintenance** – Due to the steep slopes and erosive soils, it is expected that this alternative will require infrequent but heavy maintenance.
- **Environmental Impacts** – This alternative will have major impacts to the existing natural washes by eliminating much of the flow reaching them. Therefore, major mitigation measures may be required by the Corps of Engineers.
- **Cost** – This alternative is expected to have a medium initial cost.
- **Flood Protection** – This alternative benefits approximately 7 square miles of area will provide protection for the 100-year flow in some areas and less in others.



(3) Advantages

- If the channel geometrics permit, channels could be designed as multiuse facilities with hiking and horseback riding trails.

(4) Disadvantages

- This alternative provides somewhat restricted access to properties located along conveyance corridors.
- Depending on the channel geometrics, the channel may require fencing.

- Concrete channels will be unattractive and will detract from the natural appearance of the area.
- Due to the curvilinear alignment, there are many impacted parcels at irregular angles. This could render some of the parcels "unbuildable" and complicate right-of-way acquisition.

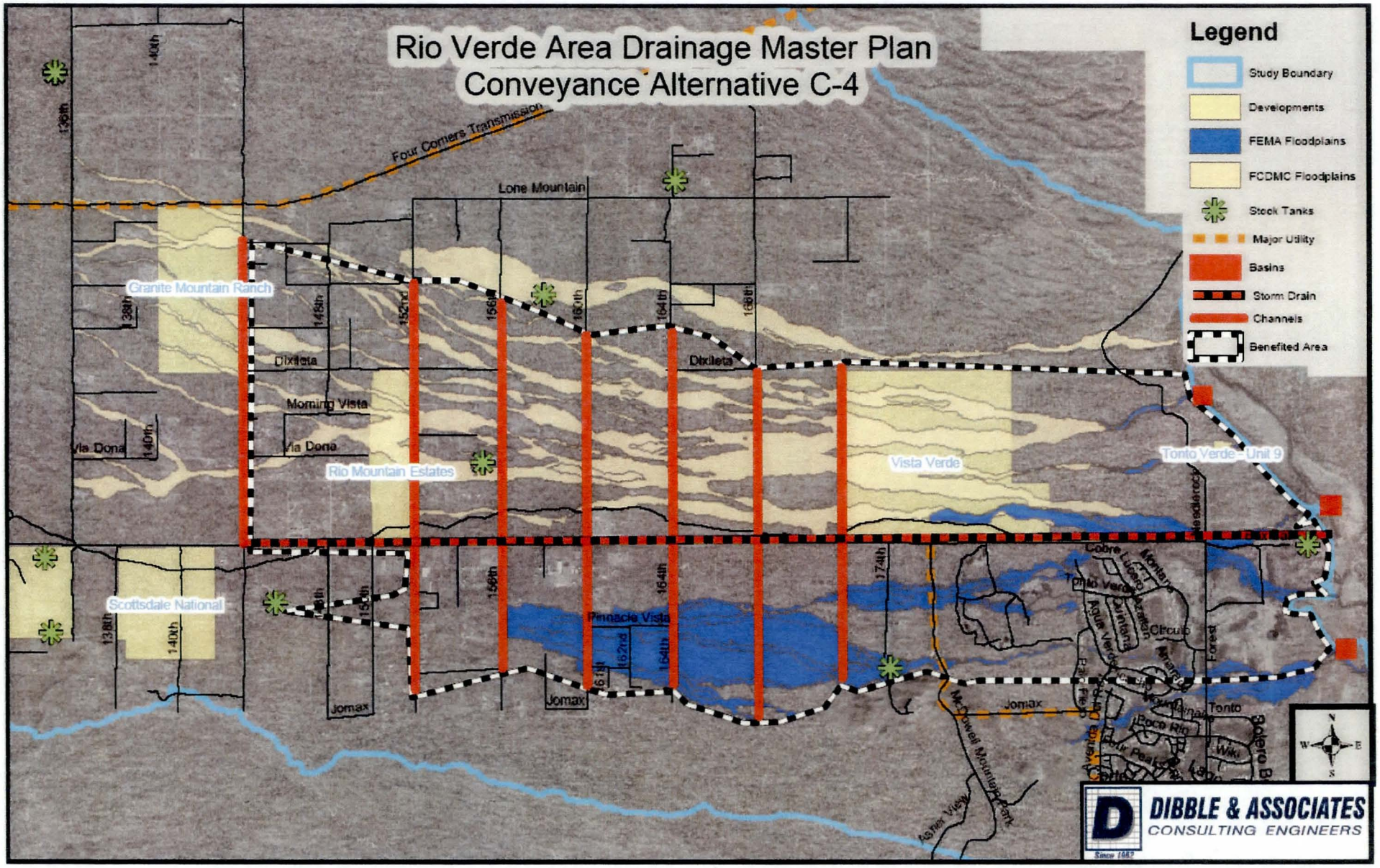


FIGURE II-5 – Alternative C-4

e) Conveyance Alternative C-4

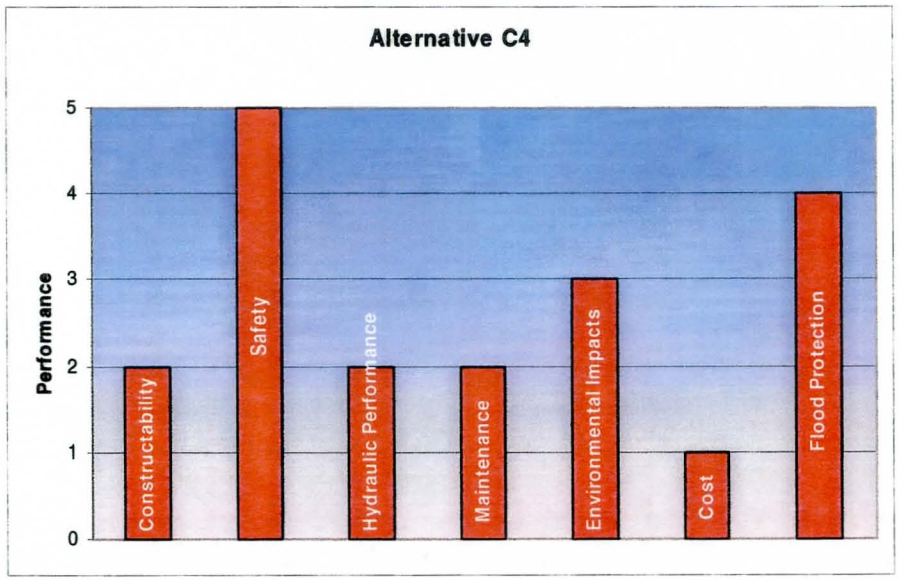
(1) Description

This alternative consists of approximately 14 miles of open channels and 6.5 miles of storm drains. The main-line storm drain lies within Rio Verde Drive and runs from west to east. Open channels are used to collect runoff and route it to the storm drain system. The open channels would route the flow from the south and north as needed along collector roads. The storm drain will discharge into a water quality basin located at the outfall into the Verde River.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – this alternative is expected to encounter major difficulty to the contractor and to local access during construction by crossing roads and across numerous properties. In addition, the storm drain in Rio Verde Road will cause major inconvenience to the public while under construction.
- **Safety** – There are not expected to be any safety hazards associated with this project.
- **Hydraulic Performance** – This alternative is likely to require internal energy dissipators within the storm drain.
- **Maintenance** – This alternative is likely to require infrequent but heavy maintenance due to sedimentation and plugging of the storm drain inlets.
- **Environmental Impacts** – This alternative will have significant impacts to the existing natural washes by eliminating much of the flow reaching them. Therefore, significant mitigation measures may be required by the Corps of Engineers.
- **Cost** – This alternative is expected to have a high initial cost.
- **Flood Protection** – This alternative benefits approximately 11 square miles of area and will provide major structural protection for the 100-year event.



(3) Advantages

- Channels could be designed as multiuse facilities with hiking and horseback riding trails.
- Provides for unrestricted access to individual properties along Rio Verde Drive.
- The storm drain could also serve as roadway drainage for Rio Verde Drive.

(4) Disadvantages

- This alternative provides somewhat restricted access to properties located along the north-south channel corridors.
- Sedimentation could be a problem for the collector channels.
- Could have very high velocities in the storm drain.
- High maintenance cost over time.

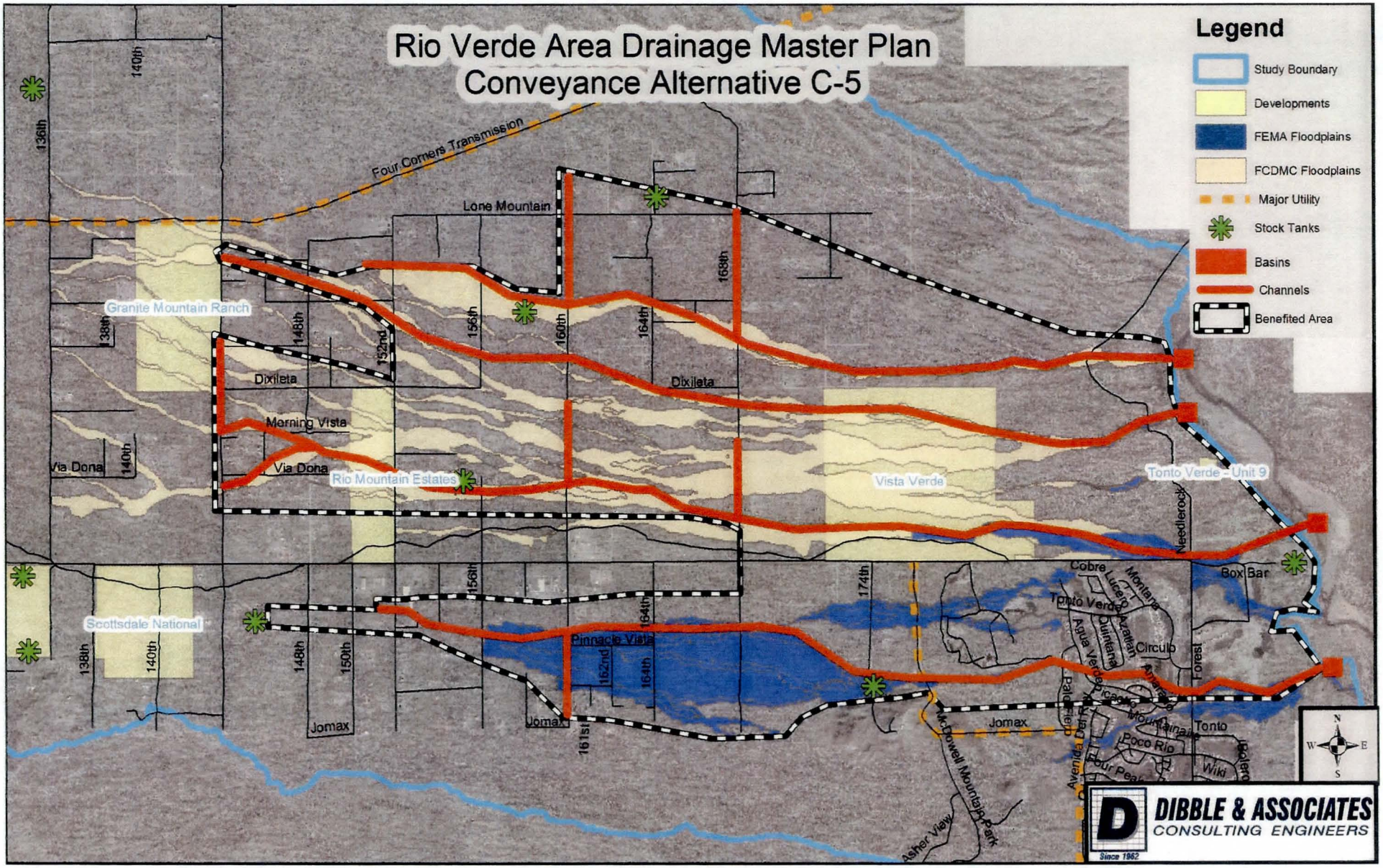


FIGURE II-6 – Alternative C-5

f) Conveyance Alternative C-5

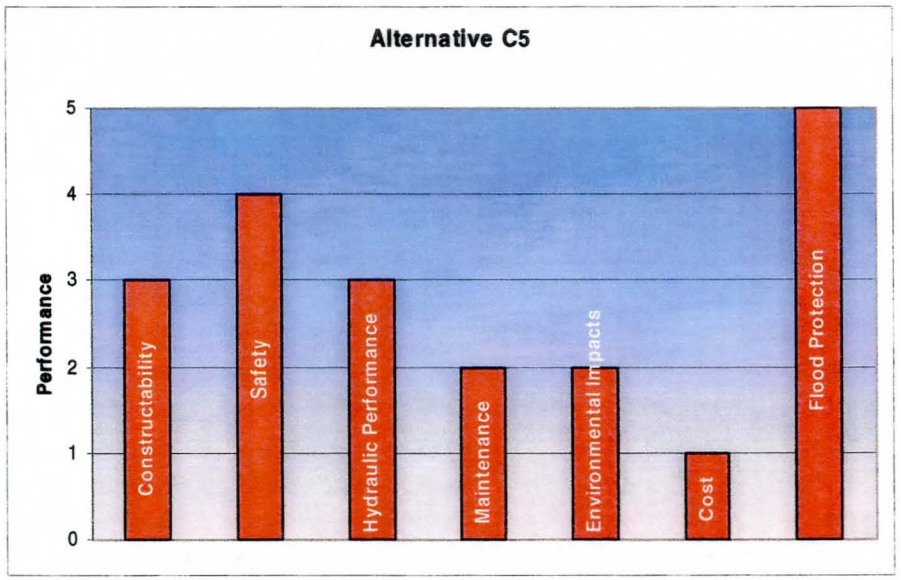
(1) Description

This alternative consists of approximately 26.5 miles of open channels. North-south collector channels are used to intercept runoff along roadway alignments and route it to the main channels that follow the existing washes. Each of the four channel systems discharge into water quality basins located at the outfall into the Rio Verde River.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – this alternative is expected to cause significant difficulty for both the contractor and to local access during construction. This is due to the alignment bisecting numerous properties at oblique angles.
- **Safety** – Because of the steep channel slopes, it is expected that channels will have a super critical flow regime during flood events. This type of flow makes it harder to escape if caught in the flow. However, during dry periods, the channels will be relatively safe.
- **Hydraulic Performance** – While this alternative will move a large quantity of water, it is expected that it will require major erosion control measures due to the high expected velocities.
- **Maintenance** – Due to the steep slopes and erosive soils, it is expected that this alternative will require infrequent but heavy maintenance.
- **Environmental Impacts** – This alternative will have major impacts to the existing natural washes by eliminating much of the flow reaching them. Therefore, major mitigation measures may be required by the Corps of Engineers.
- **Cost** – This alternative is expected to have a high initial cost.
- **Flood Protection** – This alternative benefits approximately 12 square miles of area and will provide major structural protection for the 100-year event.



(3) Advantages

- If the channel geometrics permit, channels could be designed as multiuse facilities with hiking and horseback riding trails.
- Channels are generally improvements to existing natural washes and therefore follow existing flow paths.

(4) Disadvantages

- This alternative provides somewhat restricted access to properties located along conveyance corridors.

- Depending on the channel geometrics, the channel may require fencing.
- Because of the curvilinear alignment, there are many impacted parcels at irregular angles. This could render some of the parcels "unbuildable" and complicate right-of-way acquisition
- Sedimentation transport and scour could be a problem for the channels.
- Due to steep slopes, the channels would have high velocities.

4. *Structural Detention Alternative*

a) General

A total of four structural detention (D) alternatives were identified by the project team. Detention alternatives consist of basins placed at strategic locations throughout the project area. Some basins make use of existing stock tanks and others do not. The conceptual alternatives which follow are shown unmodified with respect to concepts that were developed by the project team at the alternatives formulation meeting. The following assumptions, advantages, and disadvantages apply to all the structural alternatives. Advantages and disadvantages that are specific to a particular alternative are included with the descriptions of each alternative. The approximate land areas receiving flood protection benefits from each project are shown on the exhibits.

(1) Assumptions & Issues

The following assumptions and issues form the basis of the structural detention alternatives:

- Off-line basin approach to reduce sediment impacts
  Once runoff is contained within a basin the sediment being carried by the flow will be dropped out. Discharge from a basin into a natural wash would result in clear water scour. To avoid clear water scour, an off-line basin concept is used. Only discharges above a set rate will be directed into the basin. Discharges below this rate would be left in the wash to maintain the natural sediment continuity and to support native vegetation and wildlife habitat. Off-line basins would typically be drained by small diameter storm drain pipes or through infiltration. As a result, the off-line basins are actually *retention* basins.
- Maximize use of existing natural channel conveyance
  The threshold discharge, above which flow would be directed into the basin will be set according to the capacity of the existing natural wash.
- Use stock tanks where possible
  Existing stock tanks will be considered as potential basin sites, where possible. Existing stock tanks may or may not be good candidates for a retention basin. The tanks will need to be evaluated on an individual basis.
- 100-year design discharge
  The combination of natural wash discharge and basin storage capacity will initially be based on the 100-year storm event.

(2) Advantages & Opportunities

- Reduce extent of floodplains
  The reduction in peak discharge from the basin storage will reduce the extent of floodplains.
- Limited aerial extent of structural impacts
  If basins can be situated at natural flow concentration locations, extensive channel systems can be avoided.
- Easier to acquire ROW (fewer parcels than channels)
  A smaller number of regular shaped parcels can be obtained in their entirety for basin sites rather than partial ROW takes on many parcels required for channel improvements.
- Reduced 404 impacts and can use sites for mitigation
  Smaller areas of impact to waters of the U.S. would result in less mitigation required. Additionally, the mitigation could be provided within the basins themselves.
- Preserve many existing washes

The off-line basin concept will allow many natural washes to remain undisturbed.

(3) Disadvantages & Constraints

- Maintenance requirements due to sedimentation and erosion
  The basins would require ongoing maintenance to remove sediment and repair erosion.
- Difficult to implement in steep slope areas
  The volume that can be achieved in steep areas is limited unless a "dam" type embankment is constructed. This frequently results in large areas of ineffective dead storage within the basin.
- Design challenges for off-line concept
  The design of off-line basins will require hydraulic structures to split the flow above the desired discharge away from the natural wash.
- ROW cost for basins
  ROW costs are high in the Rio Verde area which would drive up the cost for basins

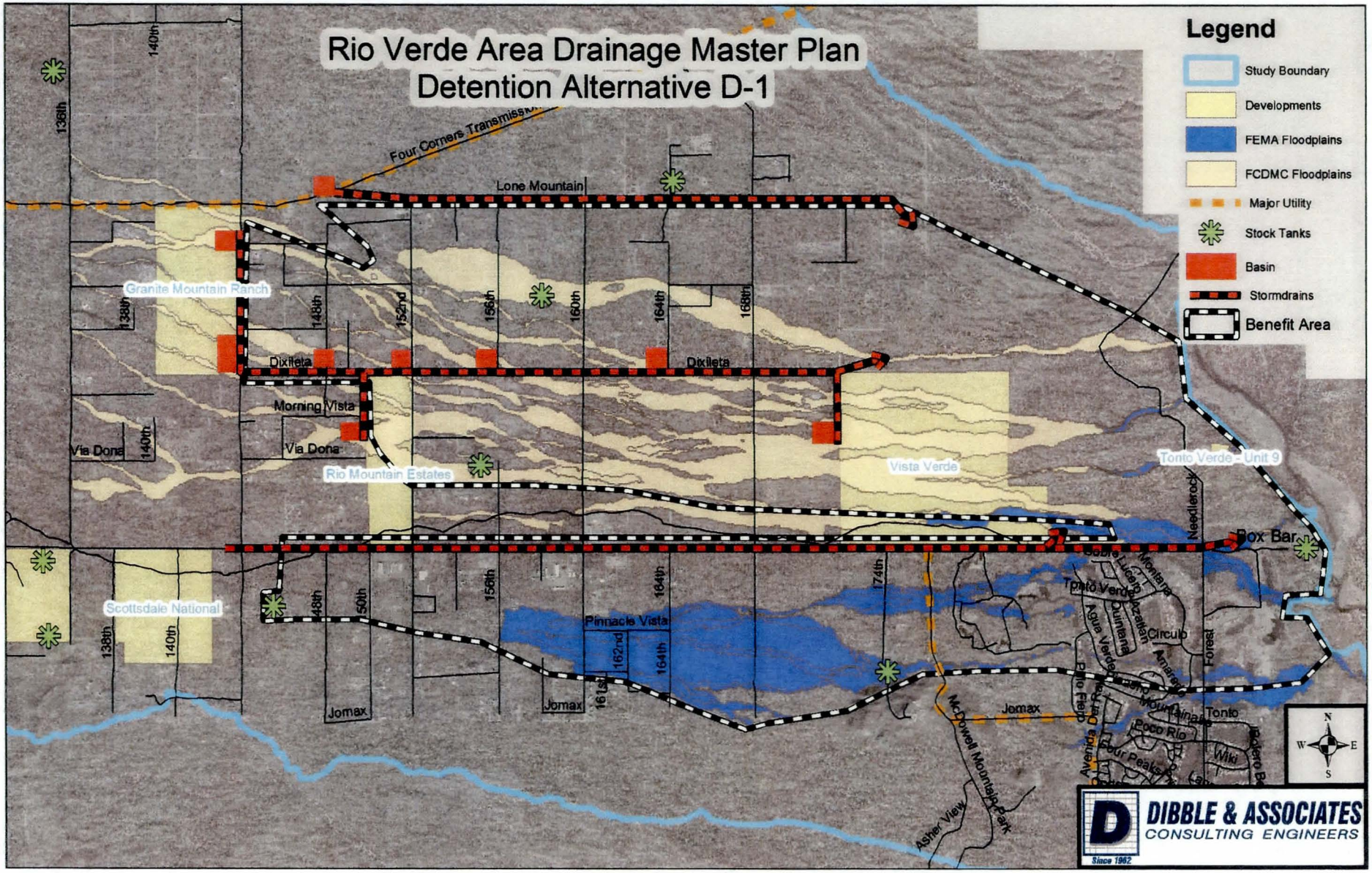


FIGURE II-7 – Alternative D-1

b) **Detention Alternative D-1**

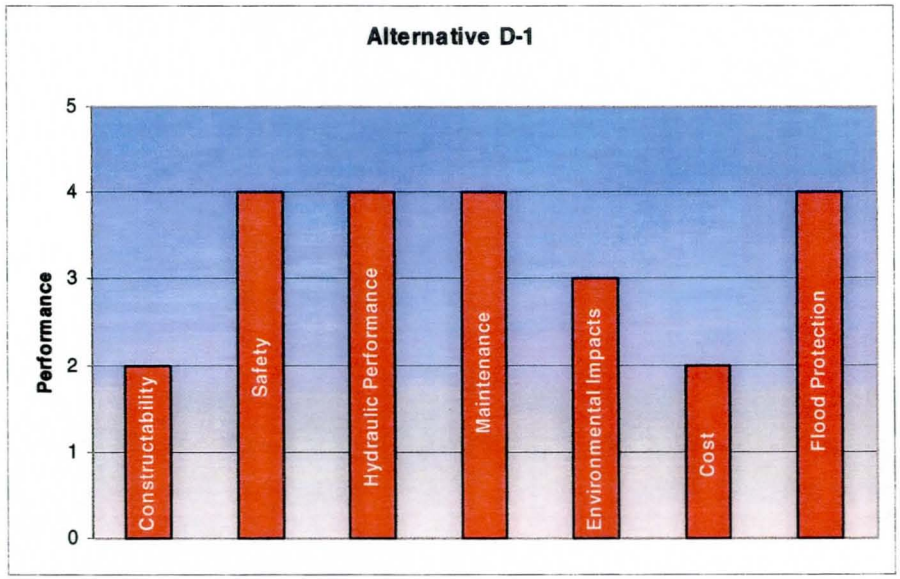
(1) Description

This alternative consists of a system of off-line detention basins and 14 miles of storm drain. The offline basins will allow some base-flow to bypass the basin thus allowing the storage volume in the basin to be maximized for the 100-yr event. The detention basins will intercept and attenuate flow at key locations and discharge into storm drains that run from west to east along major arterials. The storm drains will outfall into the deep incised washes located toward the east end of the study area. The storm drain along Rio Verde Drive is intended to serve as roadway drainage for Rio Verde Drive but could also be used to drain future detention basins as well.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – this alternative is expected to cause major difficulty for both the contractor and to local access during construction. This is due to the location of the storm drains in the three major east-west arterial roads.
- **Safety** – This alternative is considered to be safe in all conditions except during high flow events.
- **Hydraulic Performance** – This alternative is expected to perform well and will require some erosion protection at the storm drain outlets.
- **Maintenance** – Because of sedimentation in the basins, this alternative will require infrequent light maintenance.
- **Environmental Impacts** – This alternative will have significant impacts to the existing natural washes by reducing much of the flow reaching them. Therefore, significant mitigation measures may be required by the Corps of Engineers.
- **Cost** – This alternative is expected to have a medium initial cost and high maintenance cost over time.
- **Flood Protection** – This alternative benefits approximately 13 square miles of area and will provide major structural protection for the 100-year event.



(3) Advantages

- This alternative provides unrestricted access to individual properties located along conveyance corridors (no channel crossings).
- The basins could be designed to integrate parks and other amenities.

- The basins can be deeper than other basin alternatives because they can be drained into a deep underground storm drain pipe rather than back into the existing shallow washes.
- The potential for "clearwater" scour is avoided since the sediment is not deposited into the basins during the more frequent storms and stormwater draining from the basins is contained in the pipe system.
- Reduced potential for impacts to 404 washes as compared to conveyance alternatives.
- Reduced ROW impacts as compared to conveyance alternatives.

(4) Disadvantages

- High construction, land and maintenance cost.
- Potential for basins being filled with sediment during large storm events.
- Nuisance flooding during frequent storms since basins only receive water during larger events.

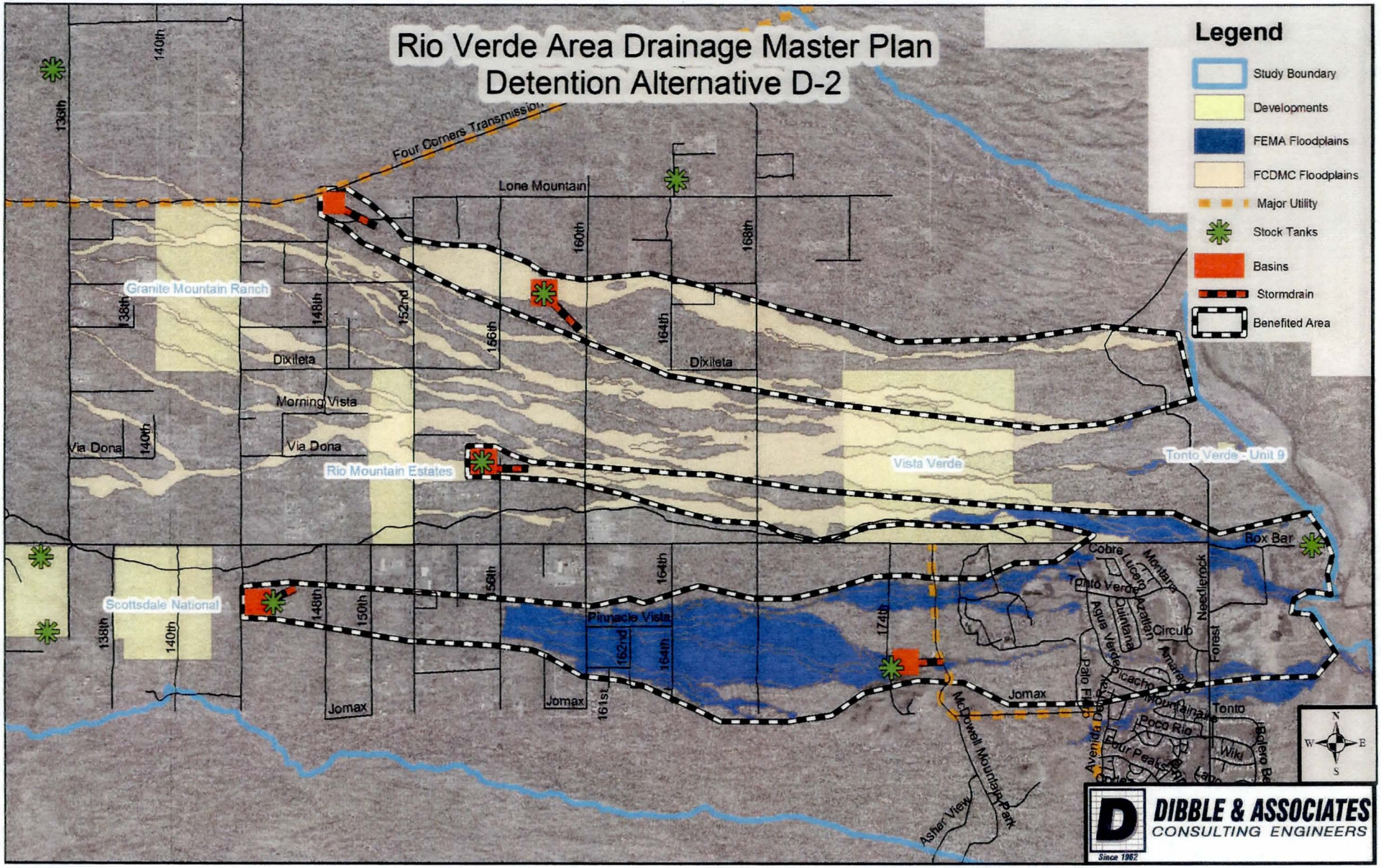


FIGURE II-8 – Alternative D-2

c) Detention Alternative D-2

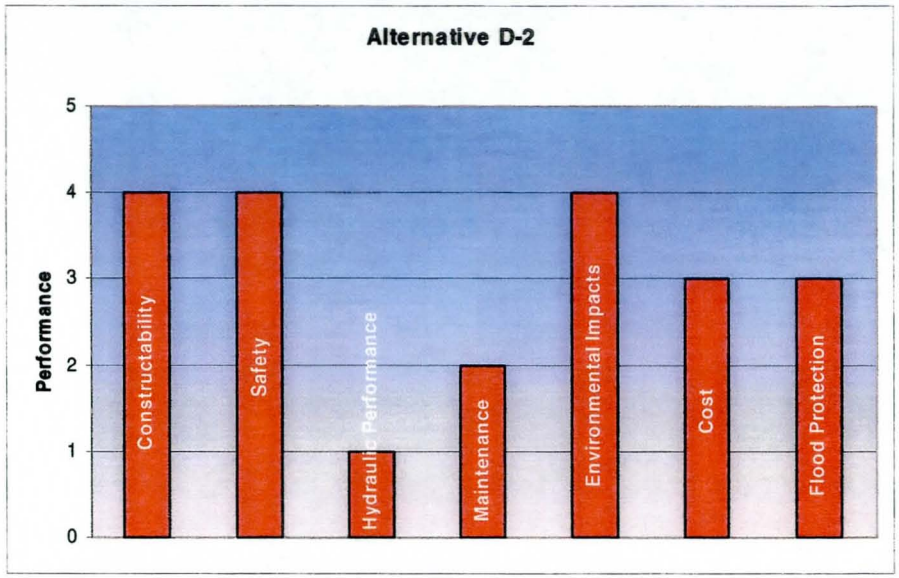
(1) Description

This alternative consists of a system of strategically placed off-line detention basins. The offline basins will allow some base-flow to bypass the basin thus allowing the storage volume in the basin to be maximized for the 100-yr event. Some of the basin locations would be in conjunction with select stock tanks and would drain back into the existing wash, downstream of the basin.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – this alternative is expected to cause minor difficulty for both the contractor and to local access during construction only in the vicinity of the various basins.
- **Safety** – This alternative is considered to be safe in all conditions except during high flow events.
- **Hydraulic Performance** – This alternative will require major erosion control measures due to the high expected velocities in the vicinity of the basin outlets due to Clearwater scour.
- **Maintenance** – Because of sedimentation in the basins and requirements associated with the outlet works, this alternative will require infrequent heavy maintenance.
- **Environmental Impacts** – This alternative will have some impacts to the existing natural washes by reducing much of the flow reaching them. Therefore, some mitigation measures may be required by the Corps of Engineers.
- **Cost** – This alternative is expected to have a low initial cost as compared to other alternatives.
- **Flood Protection** – This alternative benefits approximately 6 square miles of area and will provide localized structural protection for the 100-year event.



(3) Advantages

- Requires no channel crossings for property access.
- The basins could be designed to integrate parks and amenities.
- Floodplains downstream from the basins would be reduced.

(4) Disadvantages

- The offline basin concept operates opposite to existing stock tanks by allowing low flows to bypass the basin. Could not be used if stock tanks are needed to water stock.
- Fairly limited area of benefit.
- Clearwater scour downstream of basin outlets.

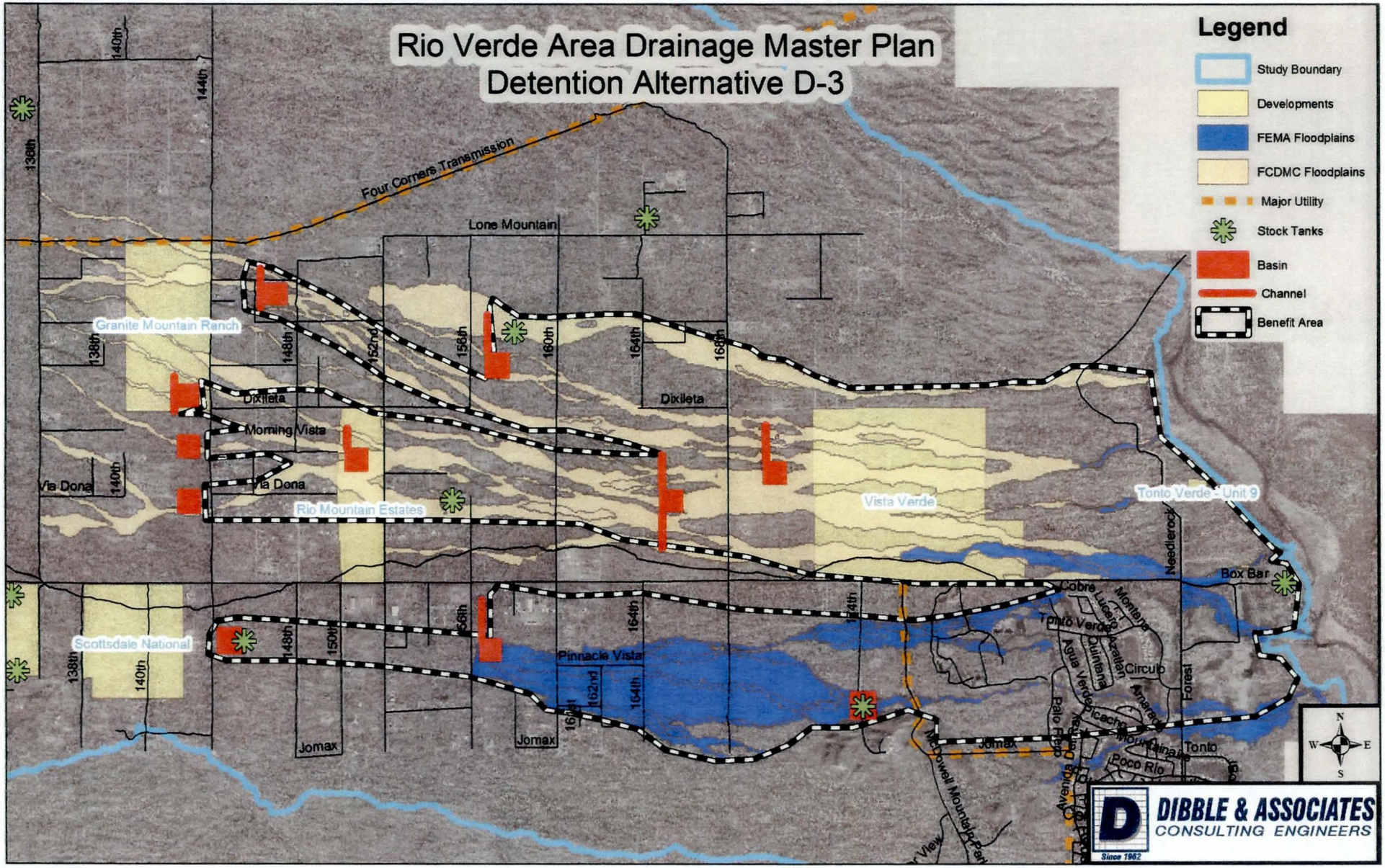


FIGURE II-9 – Alternative D-3

d) Detention Alternative D-3

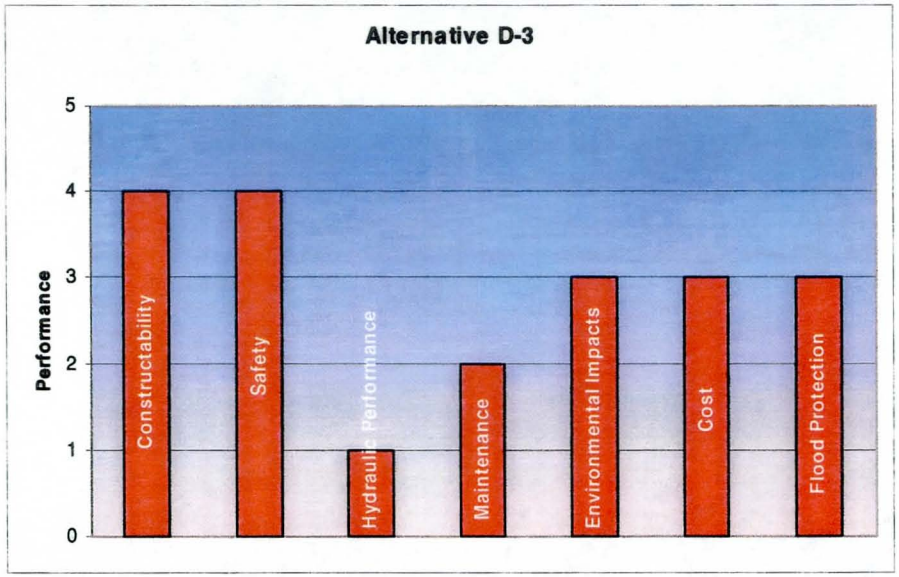
(1) Description

This alternative consists of a system of strategically placed off-line detention basins and uses short collector channels to divert more flow to the basin. The offline basins will allow some base-flow to bypass the basin thus allowing the storage volume in the basin to be reduced for the 100-yr event. Some of the basin locations would be in conjunction with select stock tanks. The basins would drain via small outlet pipes to the downstream channel.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – this alternative is expected to cause minor difficulty for both the contractor and to local access during construction only in the vicinity of the various basins.
- **Safety** – This alternative is considered to be safe in all conditions except during high flow events.
- **Hydraulic Performance** – This alternative will require major erosion control measures due to the high expected velocities in the vicinity of the basin outlets due to Clearwater scour.
- **Maintenance** – Because of sedimentation in the basins and requirements associated with the outlet works, this alternative will require infrequent heavy maintenance.
- **Environmental Impacts** – This alternative will reduce the flow reaching downstream washes. Significant mitigation measures may be required by the Corps of Engineers.
- **Cost** – This alternative is expected to have a low initial cost as compared to other alternatives.
- **Flood Protection** – This alternative benefits approximately 10 square miles of area and will provide localized structural protection for the 100-year even



(3) Advantages

- The basins could be designed to integrate parks and amenities.
- Collector channels increase the benefited area by diverting more natural washes into the basin.

(4) Disadvantages

- The offline basin concept operates opposite to existing stock tanks by allowing low flows to bypass the basin. Could not be used if stock tanks are needed to water stock.
- Because of the necessity to drain the basins to the downstream channels, there is a limitation to the depth of the basin. This could make the basins less effective.

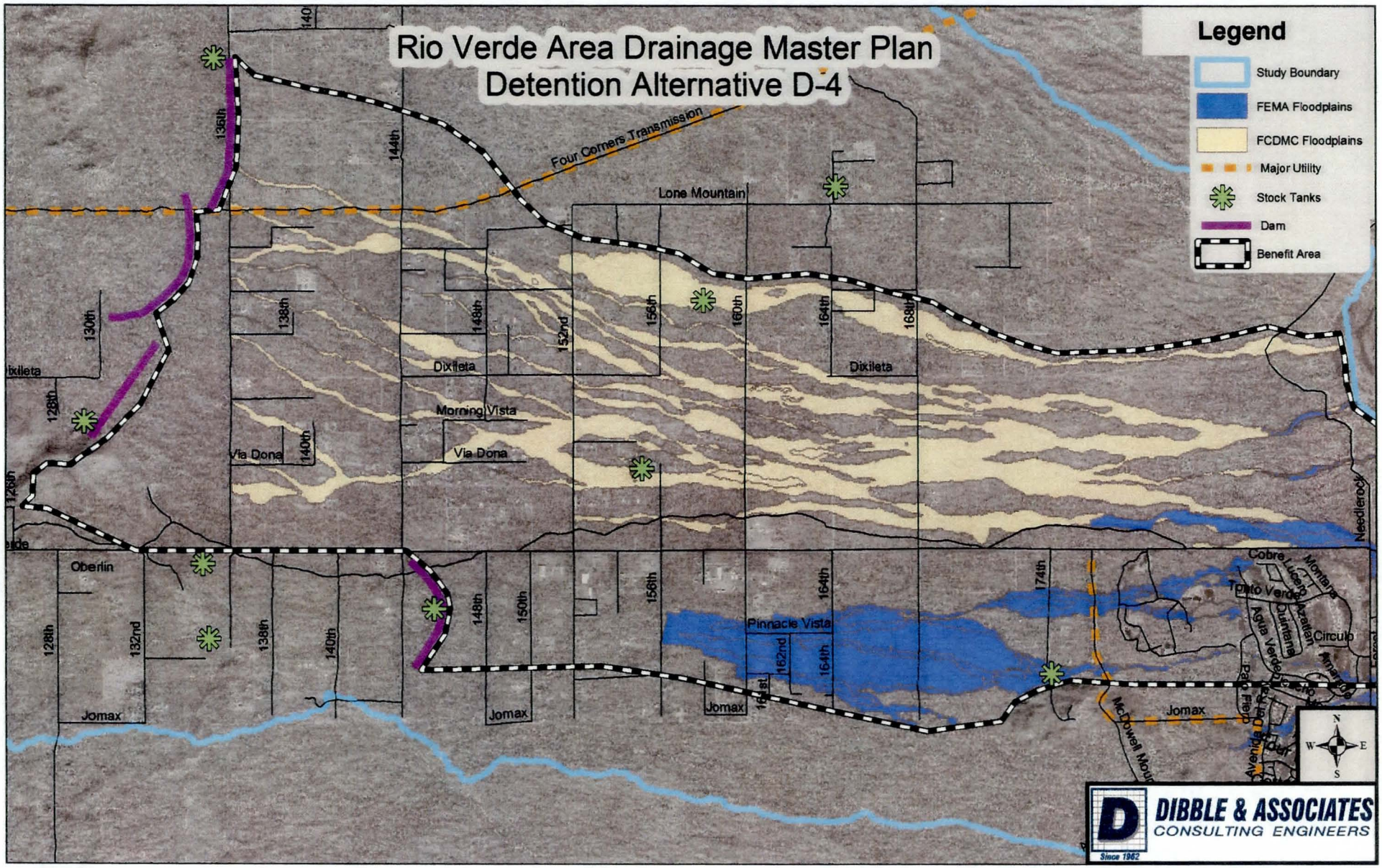


FIGURE II-10 – Alternative D-4

e) **Detention Alternative D-4**

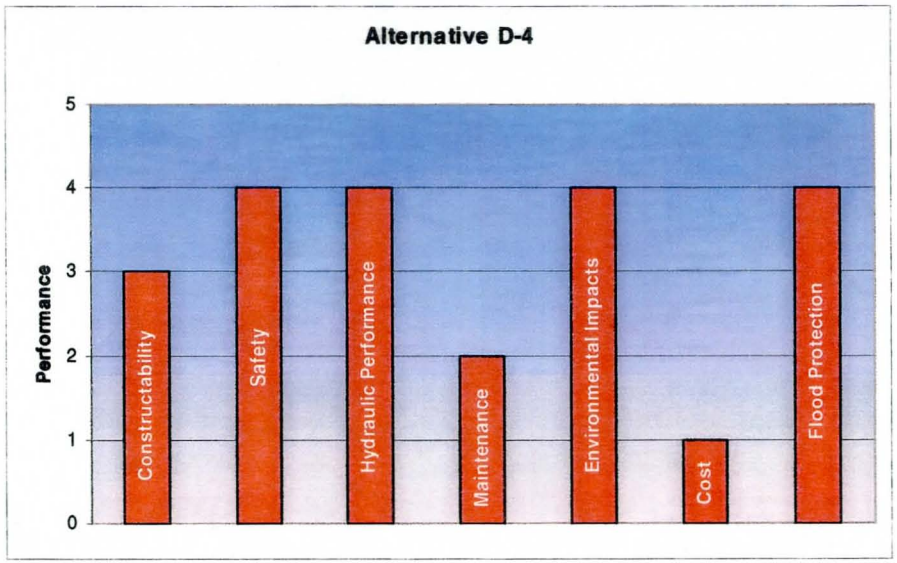
(1) Description

This alternative consists of Dams to capture runoff upstream of the 2-dimensional flow area eliminating runoff that currently flows through the study area to the Verde River. Potential Dam sites are identified at Black Hills Tank (210 AF), at Bootlegger Tank (220 AF), at the southwest corner of 136th Street and Lone Mountain Road (100 AF) on the Scottsdale Sonoran Preserve land, and at 144th Street Tank (370 AF) south of Rio Verde Drive. The volumes reported are for 100% interception of the runoff hydrographs at the dam sites.

(2) Evaluation Criteria

Each alternative is evaluated based on its expected performance according to the evaluation criteria. A brief explanation of the evaluation of this alternative is presented below. The scores are shown graphically on the accompanying figure.

- **Constructability** – this alternative is expected to cause significant difficulty for both the contractor and to local access during construction in the vicinity of the dam.
- **Safety** – This alternative is considered to be safe in all conditions except during high flow events.
- **Hydraulic Performance** – This alternative will require major erosion control measures in the vicinity of the principal and emergency spillways.
- **Maintenance** – Because of sedimentation behind the dam and additional requirements associated with the outlet works, this alternative will require infrequent but heavy maintenance.
- **Environmental Impacts** – This alternative will impact the existing natural environment. Some mitigation will likely be required.
- **Cost** – This alternative is expected to have a high initial cost.
- **Flood Protection** – This alternative benefits approximately 17 square miles of area and will provide major structural protection for the 100-year event. Residual floodplains will exist some distance downstream from the dams.



(3) Advantages

- Reduction in peak discharges in washes downstream from the structures. This would also reduce the extent of floodplains.

(4) Disadvantages

- The high hazard potential resulting from a dam failure should be avoided in favor of safer approaches in developed areas.
- Ongoing operation and maintenance requirements, including required inspections and documentation for ADWR would present higher long term costs.

- Properties further downstream in the watershed would not receive the full 100-year level of protection. There is a large downstream area that would continue to generate runoff and related hazards downstream of the dam.

5. *Regulatory Alternative*

a) **General**

The Regulatory Alternative is a non-structural approach that is based on developing and enforcing drainage guidelines for development combined with managing floodplains to restrict development in the primary conveyance areas. The drainage guidelines would apply to all development within the Rio Verde area. The guidelines would discourage concentration and diversion of sheet flow and would limit the amount of disturbance allowed on the parcel. Floodplain management techniques would be used to identify special flood hazard areas used for conveyance of runoff through the watershed and would restrict development in those areas.

The alternatives identified in this section are various tools that could be used to regulate development. A combination of alternatives may ultimately be selected.

(1) Assumptions & Issues

- Must fit within existing drainage & floodplain regulations
  It is assumed that the existing drainage and floodplain ordinances will not be changed for this project. Therefore, regulatory measures must fit within the existing ordinance structure.
- Zoning density will not be increased
  Emphasis must be placed on not allowing the zoning density to be increased beyond the current zoning. It is assumed that this will be achieved.

(2) Advantages & Opportunities

- No public infrastructure and related cost
  An advantage to any regulatory approach is the cost savings of not constructing physical drainage improvements. These savings would also extend to ongoing maintenance costs and the reduced potential for liability.
- No adverse visual impact
  Drainage structures displace the natural vegetation and landform creating a visual impact wherever they are constructed. Despite context sensitive designs with good landscaping, the visual impact of structures cannot be prevented.
- No maintenance cost
  Regulatory approaches to flood control have no direct maintenance costs.
- No 404 impacts
  Since there is no construction activity with regulatory approaches, a costly U.S. Army Corps of Engineers 404 Permit is not required.

(3) Disadvantages & Constraints

- Doesn't fix existing problems
  Regulatory measures will only impact new projects. Existing drainage problems will not be addressed.
- Public opposition to regulations that limit development
  The public will frequently resist special regulations that would limit their ability to develop a parcel. If regulations are too restrictive, the plan risks not being adopted.
- Difficulty in enforcement. Additional staff required
  Residents may not be aware of regulations and the need for permits and may proceed with improvements without proper review and approval. To maintain adequate enforcement, the District would likely be required to retain additional staff.

- Some lots will be unsuitable for residential structures
  Due to the widespread flood hazards, without structural improvements some lots will be unsuitable for residential structures.

- Doesn't address issues of access during flooding
  Access to residential areas during flooding events in some cases would need to be addressed separately from the regulations through MCDOT projects. Access issues could be addressed for new subdivisions within the regulatory framework.

b) **Regulatory Alternative R-1**

(1) Description

This alternative is to develop and enforce **Drainage Guidelines** for development.

(2) Engineering Considerations

The guidelines would need to be evaluated to ensure that, if implemented, the guidelines would in fact mitigate the increase in flood hazards from development.

(3) Advantages

- The guidelines would promote good development practice.
- The cost of implementing the guidelines would be borne by development. The only cost to taxpayers would be the cost of enforcement.

(4) Disadvantages

- Enforcement has been difficult in the past. Additional inspectors may be required to ensure that the guidelines are adhered to.
- The guidelines would need to be adopted by the County Board of Supervisors to be enforceable.

c) **Regulatory Alternative R-2**

(1) Description

This alternative is to delineate **floodplains and floodways** and use the standard FEMA process and the County floodplain regulation to manage development within the floodplains.

(2) Engineering Considerations

- In the 2-dimensional flow area, the FLO-2D analysis would need to be approved by FEMA. An approach would need to be established to set the floodplain limit at a reasonable location to avoid large areas of floodplain with very shallow depths that don't really constitute a flooding hazard for structures.
- Methods to delineate floodway limits would need to be developed for the 2-D area. The methods would need to be accepted by FEMA.

(3) Advantages

- Other than gaining acceptance of the FLO-2D modeling, the process for enforcement is standardized and well established. The County staff, engineers, and residents will be able to anticipate the development requirements.
- Construction of structures within floodways is not allowed. This tool would provide a stronger protection for critical flow corridors.

(4) Disadvantages

- To meet the FEMA criteria for the 1-percent flooded area, an excessively large portion of the watershed may need to be designated as floodplain, which could overstate the actual

hazard and impose costly requirements on the resident community with minimal actual benefit.

- Some lots will be unsuitable for residential structures
- There is less flexibility for District staff to accommodate special situations within floodways.

d) **Regulatory Alternative R-3**

(1) Description

This alternative is to develop and enforce **Conveyance Corridors** for development, using a methodology similar to one already developed for the Rio Verde area as part of a previous floodplain delineation project. The corridors could be shown on the FEMA maps as locally administered floodways.

(2) Engineering Considerations

A method would need to be adopted to define conveyance corridors.

(3) Advantages

- Factors other than flow depth, such as erosion or lateral migration potential could be included in developing the corridors.

(4) Disadvantages

- Conveyance corridors are not consistent with standard FEMA methods. The force of the floodplain regulation and nationwide standardization of FEMA floodplains could result in difficulty in enforcement and public acceptance.

e) **Regulatory Alternative R-4**

(1) Description

This alternative is to develop **flood and erosion hazard mapping** as a tool to regulate development. Similarly to alternative R-3, factors other than flow depth could be used to identify hazard areas. Flow velocity is considered an important parameter for identifying flood hazards within the Rio Verde area and could potentially be used in combination with flow depth as a tool to measure the hazard from flooding and from erosion potential.

(2) Engineering Considerations

Criteria would need to be developed to identify what conditions constitute a hazard. A method would also be needed to define and map the hazards.

(3) Advantages

- The criteria and approach could be customized to address the specific hazard conditions within the Rio Verde area.
- Could allow areas with shallow flooding to be excluded from the hazard area.

(4) Disadvantages

- The methodology may not be applicable outside the Rio Verde area.
- A non-standard approach would cost more to develop and to maintain.
- This type of mapping is not consistent with standard FEMA methods. The force of the floodplain regulation and nationwide standardization of FEMA floodplains could result in difficulty in enforcement and public acceptance

E. Screening of Alternatives

1. Introduction

The potential alternatives were screened and evaluated against the evaluation criteria to identify the most promising alternatives for further consideration according to the 4 approaches to flood control. Phase 2 of the ADMP will evaluate the screened alternatives in more detail and select a Recommended Alternative.

The purpose of the screening effort was to select the *best* combination of alternative features for each approach to form a comprehensive plan for the entire study area.

The potential alternatives were reviewed in the field with available mapping and aerial photos. The relative flow rates and existing wash size were considered to determine which alignments would provide the most benefit based on the existing storm flows in the study area. The potential alignments were traveled by vehicle where possible, noting any potential obstructions or difficulties on a study area map.

A map showing preliminary results from the two-dimensional analysis was reviewed to determine which alignments were most feasible from a right-of-way, constructability, and drainage viewpoint. Existing ground profiles were plotted along the conveyance alignments to evaluate the natural ground slopes as a means to test the feasibility of the alignments. Once all of the feasible alignments were identified, the most promising alignments were grouped together to determine which ones would work with the others to form a complete regional drainage solution.

The Screened Alternatives are shown on **Figure II-11 - Conveyance Alternative,** on **Figure II-12 - Detention Alternative,** and on **Figure II-13 - Regulatory Alternative**.

2. Alternatives Evaluation Matrix

The FCDMC Evaluation Matrix was used to rate the potential and screened alternatives against the criteria described in Section II.D. The matrix evaluation process facilitates evaluation of the effectiveness of various alternatives and measures the aggregate effect of the alternatives relative to the project specific baseline performance expectations. The matrix evaluation technique establishes weighting factors between 1 and 10 for each of the criteria based on a comparison of the importance of the criteria as compared with each of the other criteria. The weighting factors for each criterion are as follows:

- Constructability 1
- Safety 10
- Hydraulic Performance 9
- Maintenance 2
- Environmental Impacts 3
- Cost 3
- Flood Protection 8

Safety, hydraulic performance, and flood protection received the highest weightings. The No Action alternative is evaluated as a baseline for comparison with the other alternatives. The evaluation was then performed with the potential and screened alternatives for the conveyance alternative to identify the best conveyance alternative. The process was then repeated with the detention alternatives to identify the best detention alternative. A description of the matrix evaluation process and the completed forms for the conveyance and detention alternatives are contained in the Appendix.

3. *No Action Alternative*

a) Description

The No-Action alternative is what would result if development were to continue in much the same manner as that of the present time. The alternative assumes that development guidelines are not in place and there are no legal recourses beyond existing County ordinances (such as the Drainage and Floodplain Ordinances) and the laws of the National Flood Insurance Program. Any floodplain that is delineated but not submitted to FEMA would be utilized as best available information. This would include District Floodplains and FLO-2D models. Existing special drainage rules will be enforced, such as requiring an Engineer's Report for all development within the Rio Verde study area. It is further assumed that the smallest lot size will be one acre.

b) Evaluation Criteria

The No Action alternative is evaluated in Section II.D.2. The Flood Protection criteria received a score of 1, which is below the minimum established standard of 3. This alternative is therefore considered to be not acceptable.

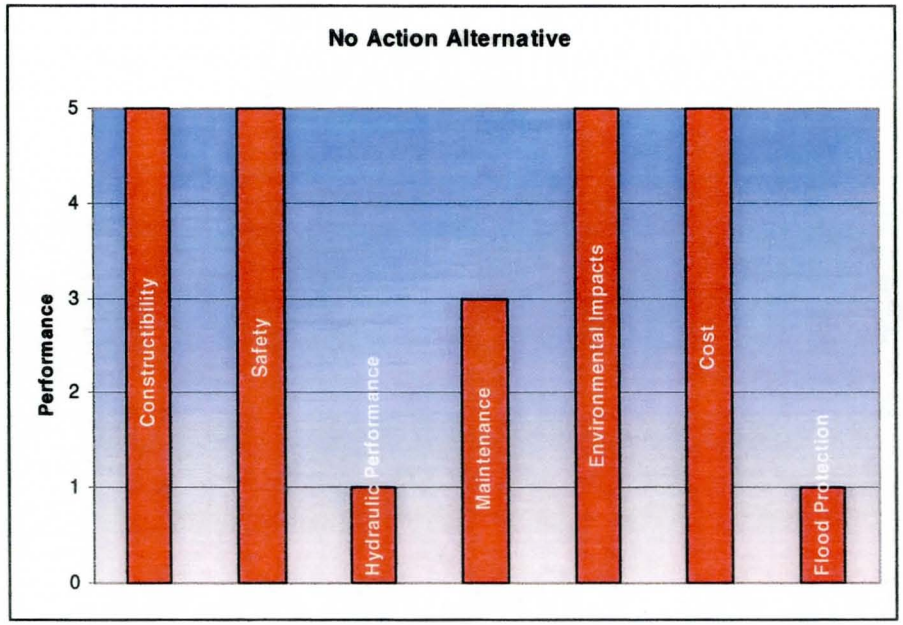
c) Advantages and Opportunities

The advantages are summarized from Section II.D *Potential Alternatives* to be specific to the screened alternative and are repeated here for completeness and convenience of the reader.

- No structural improvement CIP cost.
- Ease of implementation – no County Board action required
- No U.S. Army Corps of Engineers 404 permit impacts

d) Disadvantages and Constraints

- Negative impacts to watershed from limited regulation of development
- There is the increased potential for litigation between adjacent property owners and against the District.
- It does not address public safety concerns associated with minimal or unsafe access during flood events. This includes fire, ambulance and police access.
- Potential damage to the natural environment
- There is the potential for increased flood-related property damage.



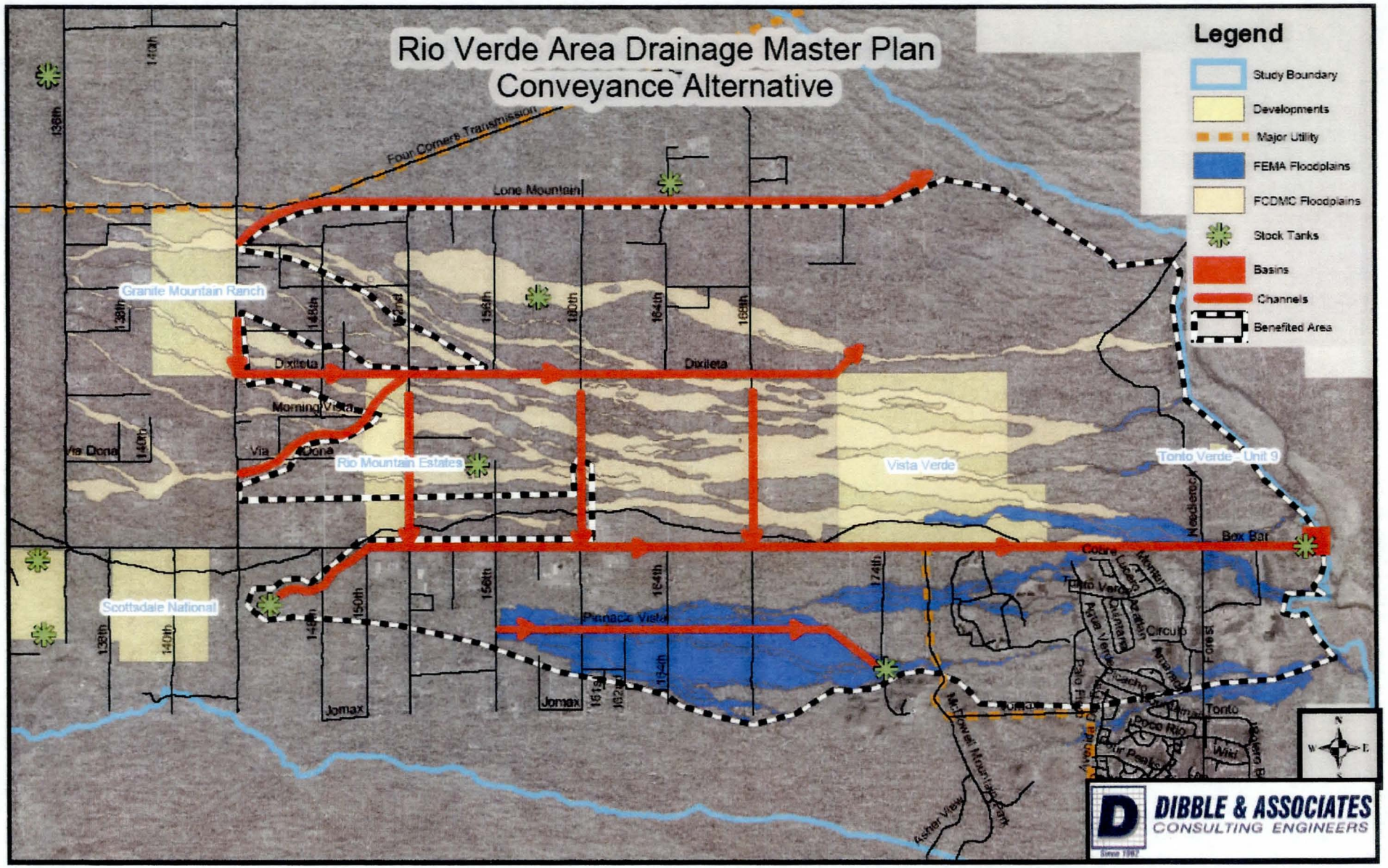


FIGURE II-11 – Conveyance Alternative

4. *Conveyance Alternative*

a) **Description**

Four main easterly-flowing conveyance channels with laterals would intercept and carry runoff to the Verde River, as shown in **Figure II-11**. The channels would provide a defined path for runoff to travel to the Verde River. The approximate total length of channels is 20 miles.

The cost of the conveyance alternative would be in the range of 100 million dollars if concrete channels are used. The cost for other channel types could be higher due to additional right-of-way costs for wider channels and special steep slope design requirements.

One drainage channel is placed along the Lone Mountain Road alignment. A local access road would be placed on either the north or south channel side. The upstream end of the Lone Mountain Road conveyance channel begins at a large wash just as it crosses the Four Corners Transmission line. The channel follows the roadway alignment until 174th Street, where the channel turns northeasterly to flow into an incised natural wash. The outfall point is just upstream of the Tonto National Forest boundary.

Another major channel would begin at Dixileta Drive and 144th Street. An interceptor channel along 144th Street, from 0.5 miles to the north, would intercept and convey runoff to Dixileta Drive.

The upstream portion would follow the existing alignment of a major wash that crosses 144th Street just south of Via Dona Road. At about 150th Street, the channel would trend northeasterly towards Dixileta Drive. Along Dixileta Drive, a local access road would be placed on either the north or south channel side. The channel follows the roadway alignment until 172nd Street, where the channel turns northeasterly to flow into a large natural wash. The channel improvements are not continued all the way to the Verde River because the natural wash from this point downstream is well incised and crosses National Forest Lands. Tonto National Forest property begins about 0.5 miles downstream of the interceptor channel outfall point.

A third major channel in the conveyance system would follow the Rio Verde Drive alignment. The upstream portion would start south of Rio Verde Drive at the 144th Street Tank. The channel would follow the existing wash alignment until 152nd Street, where it would turn northeasterly to Rio Verde Drive. The channel would flow into a water quality basin that drains into the Verde River. Laterals would be constructed between Rio Verde Drive and Dixileta Drive to divert runoff into the channel. There is a natural slope from north to south in this area that would make this channel design feasible.

The fourth channel would be located about 0.5 miles south of Rio Verde Drive starting at 156th Street. At about 172nd Street the channel would turn southeasterly to drain into an existing stock tank at 174th Street. The stock tank would be modified as a water quality basin to treat the runoff. The water quality basin may need to be enlarged to act as a retention basin to ensure that the 100-year peak discharge entering the Tonto Verde development is not increased. The runoff would then be returned to the natural channel as it enters Tonto Verde.

b) **Matrix Evaluation Results**

The total weighted scores for the conveyance alternatives are as follows:

Alternative	Score
• No Action (Baseline)	108
• Alternative C-1	127
• Alternative C-2	104

- Alternative C-3 110
- Alternative C-4 118
- Alternative C-5 123
- Screened Alternative 127

The screened alternative shares the highest score with Alternative C-1. This is no surprise since the screened alternative is based on a refinement of Alternative C-1 to improve the alternative. However, the refinements are not substantial enough to change the score.

c) **Engineering Considerations**

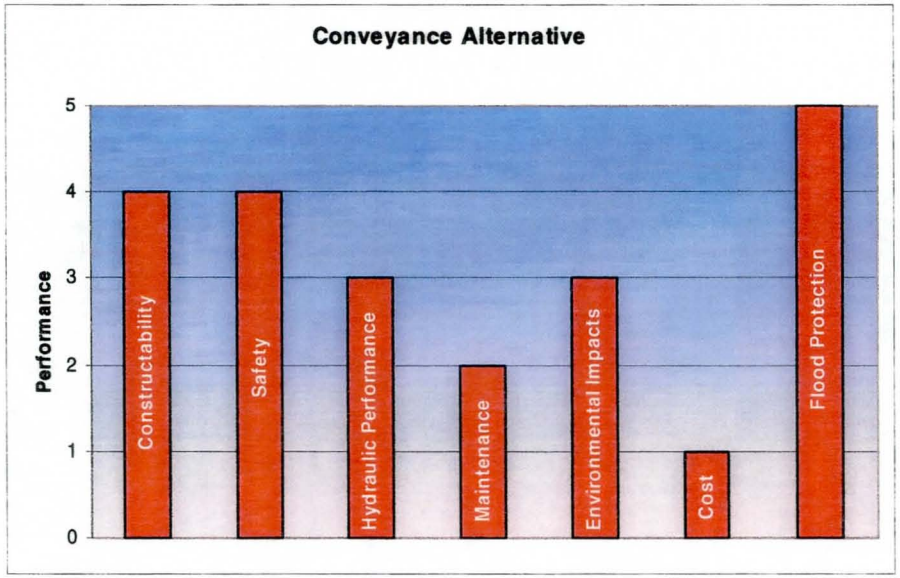
The topography of the study area is evaluated with digital terrain modeling software to evaluate the slope of proposed improvements. Based on this analysis, the laterals are oriented to drain from north to south. The area between Dixileta Drive and Rio Verde Drive has a north-south slope. As stated in the Part 1 Report on page 15 "the maintenance of sediment transport continuity even for small events is very important to the preservation of fluvial system form and function." Therefore, the interceptor channels should be designed to transport sediment.

When necessary for local property access, the conveyance alternative includes a local access road parallel to the channel. Property access for one side of the channel can be achieved through the main roadway. Property access for the other side of the channel can be achieved through the local access road. Culverts or bridges crossing the wash would likely be placed at public roads every one mile or every one-half mile. The crossing design should provide all-weather access during the 100-year flood. Driveway access for private parcels would be via the access road.

Outlet protection would be required at the outfall point into the existing washes. The outfall should mimic the existing conditions of the wash. This could be incorporated into the water quality basins.

Another common design element would be to minimize erosion. Drop structures may be needed to flatten channel slopes, thereby reducing flow velocity. The entire channel length would need erosion protection on the banks or on the banks and bottom. Due to the steep natural slopes channel flow in the super-critical regime is expected unless the slope is flattened with drop structures or alignment change.

The local access road would require additional Right of Way, because the existing Right of Way would probably be insufficient to accommodate the channel, the roadway and the local access road.



d) **Advantages:**

The advantages are summarized from Section II - D – Potential Alternatives to be specific to the screened alternative and are repeated here for completeness and convenience of the reader.

- Areas downstream of the interceptor channels would benefit from reduced runoff and a reduction in the flood damage potential.
- The roadways could be improved because of the parallel interceptor channel and the roadway would not experience a decrease in traffic capacity during frequent flood events.
- Culvert crossings at the interceptor channels would greatly improve accessibility during a storm event.
- The channels could be designed to be aesthetically pleasing to some degree, even if a concrete channel is used.
- There is the opportunity for multi-use facilities such as an equestrian / pedestrian trail running along it.

e) **Disadvantages:**

The disadvantages are summarized from Section II - D – Potential Alternatives to be specific to the screened alternative and are repeated here for completeness and convenience of the reader.

- Property upstream of an interceptor channel would not benefit from the channel, and there would not be a decrease in flow rates.
- Vegetation health and density may be affected, due to the diversion of water that sustains the current vegetation.
- The erosion potential of the outfall wash may increase due to an increase in runoff.
- Each interceptor channel may require fencing if the flow characteristics are unsafe for people. If fenced, provision must still be made for wildlife migration.
- There may be aesthetic concerns for a concrete-lined channel.
- The high cost of conveyance channels is a disadvantage.
- The Tonto National Forest may resist any structural plan that modifies the rate or volume of runoff through forest lands.
- A structural improvement would have associated up-front costs not found in the No-Action Alternative.
- The loss of overbank storage would result in an increase in peak discharge rates.

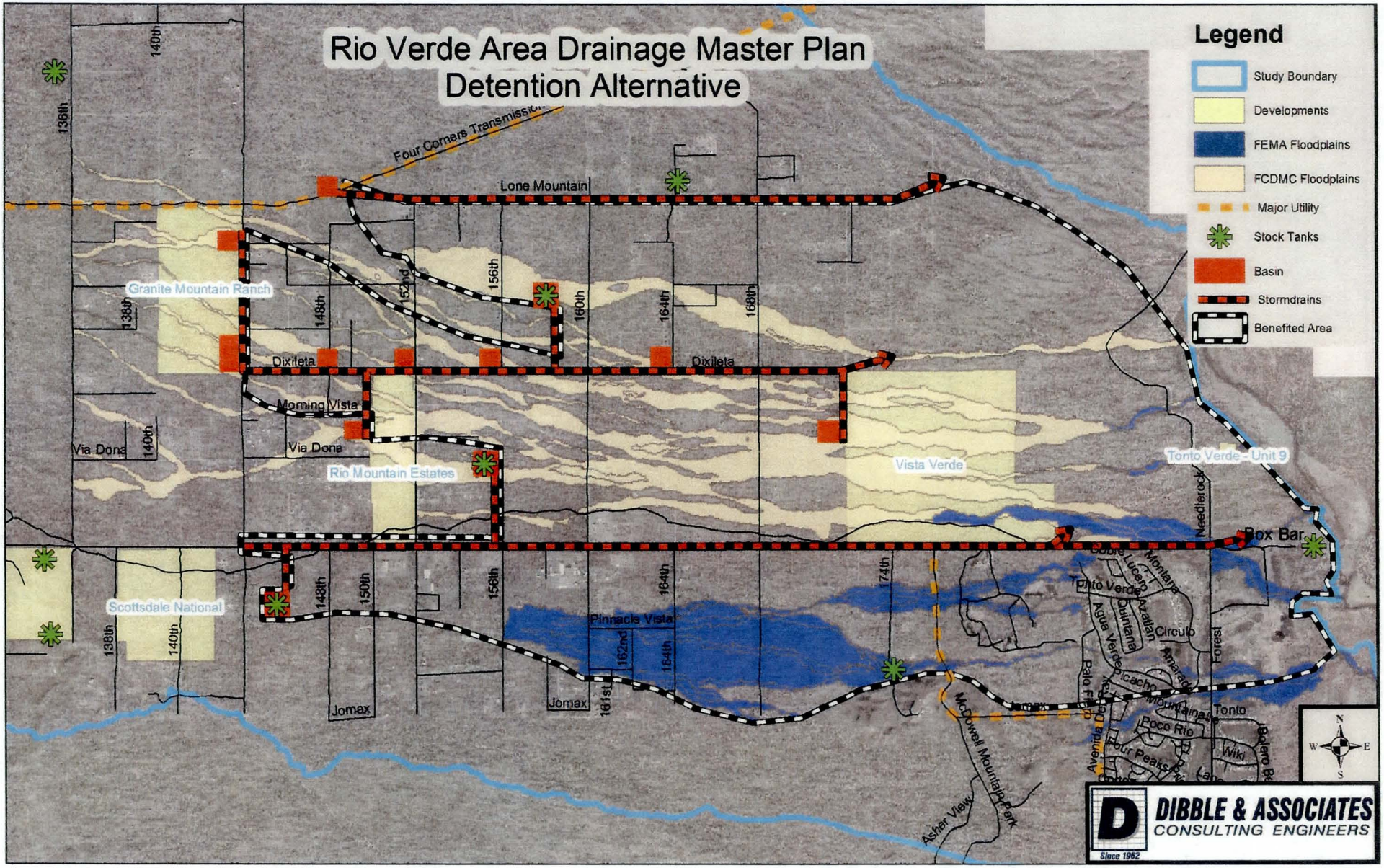


FIGURE II-12 – Detention Alternative

5. *Detention Alternative*

a) **Description**

Twelve detention storage basins are placed at appropriate locations within the study area, as shown on **Figure II-12**. Three of these basins utilize existing stock watering tank sites. The tanks would need to be modified and improved for this purpose. The outfall from each is in a storm drain to mitigate the clearwater scour problems identified by this ADMP project, and to provide additional storage volume. The approximate length of storm drain is 16 miles.

The cost of the detention alternative would be over 50 million dollars.

The northernmost basin is located near 148th Street and the Four Corners Transmission line. A large natural wash flows through this area, as identified by preliminary 2D model results and the conveyance corridors, which are not shown on Figure II-10. The point where the wash crosses the transmission line is located within the Tonto National Forest. Unless agreements could be made with the Tonto National Forest, to locate the basin on forest land, the basin would be located south of Lone Mountain Road. A storm drain would take the attenuated flow from the basin about 3.5 miles to the east. The storm drain would be turned northeasterly to flow into a deep incised wash with a shallow floodplain that covers the entire wash bottom. The wash drains into the Verde River.

The second basin would be located west of 144th Street and about 0.25 miles south of Lone Mountain Road. The parcel within the Granite Mountain Ranch subdivision houses a water tank and two horse exercise arenas. The basin would be designed to fit around the portable exercise arenas, or they could be relocated and incorporated in the area around the basin.

The third basin is located west of 144th Street at Dixileta Drive. The most promising basin location is within the Granite Mountain Ranch subdivision, and would require purchase of two lots.

The next four detention basins would be located along Dixileta Drive. They are located to accept runoff from natural washes that flow southeasterly towards the Verde River.

Feeding the Dixileta Drive storm drain system are three lateral basins, two located to the south and the other one located to the north of Dixileta Drive. One of the southern basins is located near 150th Street and between Morning Vista and Via Dona. This basin could be sited within the Rio Mountain Estates subdivision. The other southern basin is located about 0.5 miles south of Dixileta Drive and could be sited within the Vista Verde Subdivision. The basin to the north of Dixileta Drive is located at the site of an existing stock tank. Storm drains from each of these two lateral basins would drain into the main line.

A storm drain under Rio Verde Drive would serve two detention basins. Both basins would take advantage of existing stock tanks. The storm drain outfall would be to Wash A, a natural wash. The distance from the outfall point to the Verde River is about 0.5 miles. An alternative outfall location would be to Wash A at the 182nd Street alignment. The attenuated runoff would flow in the natural wash for about 1.5 miles before flowing into the Verde River.

b) **Matrix Evaluation Results**

The total weighted scores for the detention alternatives are as follows:

Alternative	Score
• No Action (Baseline)	108
• Alternative D-1	133
• Alternative D-2	102

- Alternative D-3 99
- Alternative D-4 138
- Screened Alternative 141

The screened alternative has the highest score. The screened alternative is based on a refinement of Alternative D-1 to improve the alternative. In this case the refinements were substantial enough to change the score.

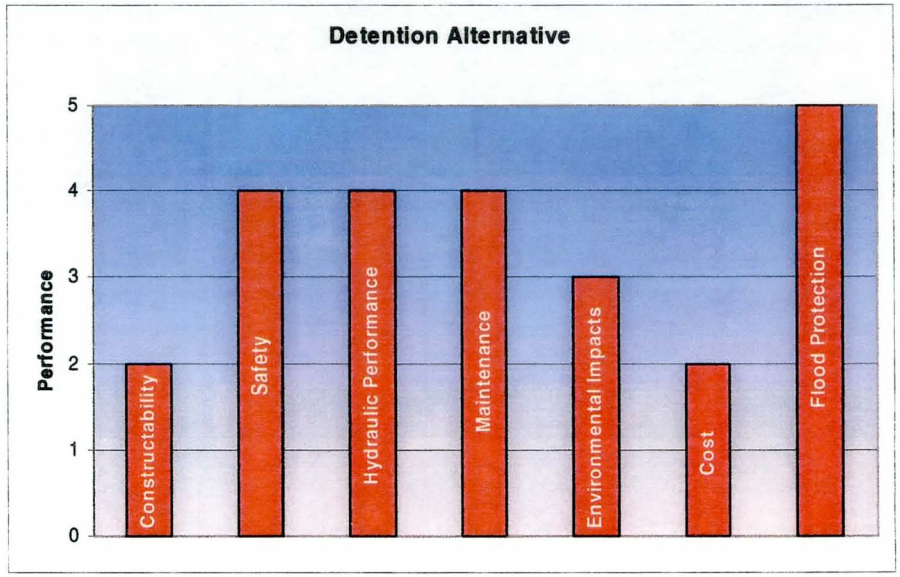
c) **Engineering Considerations**

The most economical configuration would be for an off-line basin. With this type of basin, the lower more frequent flows would bypass the basin. The bypass flows would help maintain the natural vegetative diversity. Higher, less frequent flood waters would be deep enough to spill over a side channel weir into the basin. One tremendous benefit of off-line basins is they require less storage volume than an on-line basin that accepts all wash runoff.

Stock watering capabilities could be addressed by running the bypass flows into a stock tank at any point downstream of the detention basin.

The outfall of each storm drain would need energy dissipation to reduce the pipe discharge to a velocity and flow configuration (depth and width) that would not cause damage to the natural wash.

The basins could be designed to be multi-purpose basins, as a recreational benefit to the community. The engineering design could provide grading sufficient for a trail system through or around the basin or equestrian system, or perhaps some playground areas or athletic fields.



d) **Advantages and Opportunities**

The advantages are summarized from Section II - D – Potential Alternatives to be specific to the screened alternative and are repeated here for completeness and convenience of the reader.

- The bypass flows would maintain the existing and necessary sediment transport functions of the wash. The storm drain would not typically carry sediment with an off-line detention basin.
- The storm drain alignment would use Public Right of Way.
- The storm drain system could be enlarged to incorporate roadway drainage features such as catch basins along Lone Mountain Road, Dixileta Drive and Rio Verde Drive.
- It may be possible to widen Rio Verde Drive with the storm drain construction and this major roadway would receive new pavement.

- Smaller storm drain structures are possible than with the channel conveyance option.
- Less Right of Way would be required as compared to the channel conveyance option.
- Property access would be better than with the channel conveyance option.
- The storm drain would be buried and not visible to property owners.
- It may be possible to add a basin at the existing stock tank near Lone Mountain Road and 164th Street.
- Planned subdivisions such as the Vista Verde subdivision and the Rio Mountain Estates subdivision may be able to revise lot and street layouts to accommodate the basin, especially since the basin would reduce the cost of drainage facilities through the subdivision, or would add developable lands by reducing 100-year floodplain widths

e) **Disadvantages and Constraints**

The disadvantages are summarized from Section II - D – Potential Alternatives to be specific to the screened alternative and are repeated here for completeness and convenience of the reader.

- Would require purchase of private property for the basins, some of which may have new houses, which would increase the cost.
- Individual property owners may be unwilling to sell their property to accommodate the structural solution.

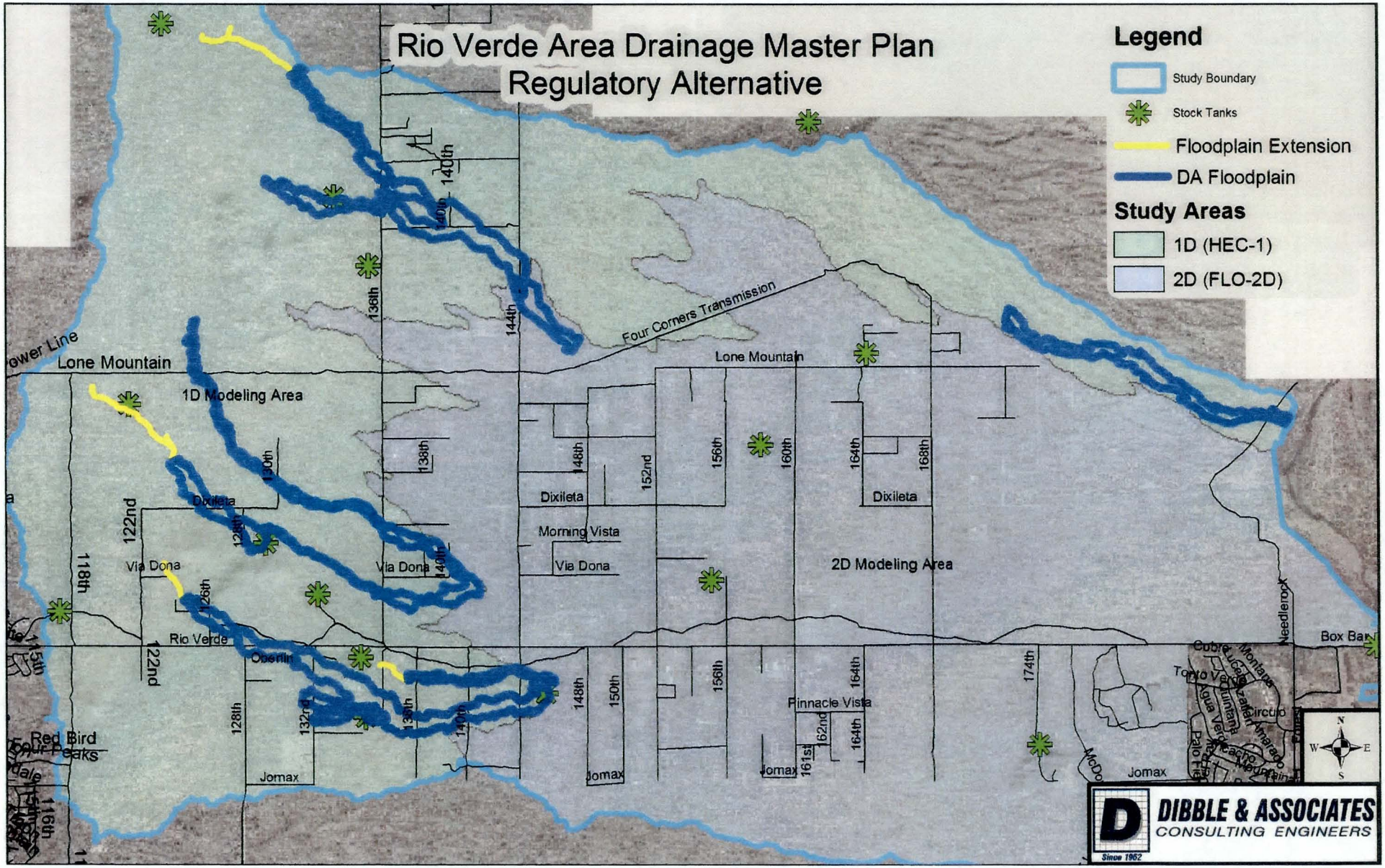


FIGURE II-13 – Regulatory Alternative

6. *Regulatory Alternative*

a) **Description**

The Regulatory Alternative utilizes a combination of three tools to manage development within the Rio Verde area. FEMA floodplains with no-rise floodways are used outside of the 2-dimensional flow area combined with administrative floodways based on a relationship of depth and velocity within the 2-dimensional flow area. The Drainage Guidelines will be in effect for areas outside of floodplains. The administrative floodways would be developed within the 2-dimensional flow area using a relationship of depth and velocity to identify flood hazard areas. Once the flood hazard areas are identified, conventional floodplains would be delineated along the flood hazard alignments. The Regulatory Alternative is shown on **Figure II-13** showing the one- and two-dimensional flow areas and the 1-dimensional floodplain limits.

b) **Engineering Considerations**

(1) Conventional Floodplain Considerations

The FLO-2D model would be used to delineate the floodplain and administrative floodways in the 2-dimensional flow area. Recognizing that FLO-2D has not been widely used for floodplain delineations, and to minimize the use of administrative floodways, the use of conventional floodplain and floodways for the entire study area was investigated. There are fairly well defined channels at the upstream and downstream ends of the study area, which could be delineated using 1-dimensional methodologies; however, the 2-dimensional flow area between those limits is not well defined. An attempt was made to delineate logical connection corridors between the upstream and downstream limits that could be used for the delineations. Through this attempt it became clear that if a corridor were selected, a neighboring corridor could just as easily have been selected. The selection process became somewhat arbitrary with little physical justification for choosing one corridor over another. The braided, distributary channel network does not support such an approach. Additionally, if a single corridor were selected, the flood hazards outside of the selected corridor would not be mapped. For these reasons, the effort was abandoned in favor of the depth and velocity relationship just described.

(2) Administrative Floodways

Since depth and velocity both contribute to the flood hazard a relationship that uses both parameters will be developed and tested as a means to identify the flood hazard areas. Areas exceeding a threshold value will be designated as no-build administrative floodways. This will avoid the problem of managing extensive very shallow floodplain areas which have a questionable hazard. The depth, velocity relationship will more accurately identify areas of true hazard.

(3) One-dimensional floodplains

The extent of FEMA floodplains within the 1-dimensional area is based on performing the floodplain delineations on washes with a minimum 100-year peak discharge of 500 cfs with a minimum length of 1 mile.

For Phase 2, it is recommended to perform detailed floodplain delineations for the Phase 1 floodplains, and to extend certain floodplains. The floodplain extensions are based upon a minimum flow rate of 500 cfs as the selection criteria. Some Phase 1 delineations begin at flow rates greater than 500 cfs but no extension is possible since the upstream limit is already located where two or three washes join to form 500 cfs or more. The Phase 2 detailed delineations should also refine the confluence floodplains where tributaries join the main wash. These confluence areas appear on the

Phase 1 floodplain maps with a limit of study note. The Phase 1 floodplain delineations maps contain 19.8 river miles, and the recommended Phase 2 floodplain extensions contain 3.2 river miles, for a total of 23.0 river miles.

(4) Tonto Verde Discharge Comparison

A comparison is made for the peak flow rate summation from the FLO-2D results at the cross sections utilized for the FEMA floodplains. This comparison is only for the area south of Rio Verde Drive to the southern watershed boundary. The FEMA washes in this area are Washes 9 through 12, which flow through the communities of Rio Verde and Tonto Verde. Two-dimensional flow grids are selected along the floodplain (HEC-RAS) cross sections. The grid outflow discharge for each selected grid (RDISCHARGE in the 2D results) is summed and then compared to the peak flow rate used for the floodplain analysis. Table 1 presents the comparison results, using the FEMA flow rates as the comparison base. For example, a negative percentage difference means that the 2D model indicates a lower peak discharge than the FEMA model.

Table II-1
Comparison of 2D results to FEMA floodplain discharges

Wash At River Mile	2D sum, cfs	FEMA Discharge, cfs	Difference, Per Cent
WASH 9 (RM n/a)	109	660	-84%
WASH 10 at RM 1.337	629	1,430	-56%
WASH 11 at RM 2.109	92	740	-88%
WASH 12.0300 at RM 1.544	247	387	-36%
WASH 12.0375 at RM 0.462	53	186	-72%
WASH 12.0500 at RM 0.893	102	107	-5%
WASH 12.0600 at RM 0.082	17	107	-84%
WASH 12 at RM 1.816	259	151	+72%
WASH 12 at RM 1.846	135	151	-11%
Eastern boundary	3,888	4,054	-4%

The table also includes the outflow from all of the 2D grids at the eastern boundary of the 2D model compared to the summation of all the FEMA peak flow rates. The results compare closely, with only a 4% difference. The eastern boundary FEMA discharge in the table is that reported near the western edge of the development, which may not be located at the same location as the 2D model boundary or even the tabled cross sections and may not include smaller Subbasins not flowing into FEMA washes. However, the 2D sum at the eastern boundary represents the total flow leaving the 2D model and flowing into the developments.

When viewing the individual wash comparisons, one main conclusion can be drawn. The 2D model identifies that more runoff flows in the smaller non-FEMA washes, since the individual wash comparison typically shows less runoff in the FEMA washes. This means that the smaller washes play a larger role in carrying runoff to the existing developments (Rio Verde and Tonto Verde) than can be identified by viewing the FEMA floodplain maps. This can readily be seen when viewing the 2D model results and noting the numerous grids with flows greater the direct rainfall runoff and not within a designated floodplain. It would be important, therefore, to retain the existing smaller washes.

The two locations reported for Wash 12 exemplify the flow variations identified by the two dimensional model. The cross sections at RM 1.816 and RM 1.846 are only 150 feet apart (6 grids), yet the 2D flow at the FEMA cross sections varies greatly from 259 cfs and 135 cfs. It should be noted that the FEMA flow at RM 1.765 (another 270 feet downstream) is 370 cfs.

c) Advantages and Opportunities

The advantages are summarized from Section II - D – Potential Alternatives to be specific to the screened alternative and are repeated here for completeness and convenience of the reader.

- No public infrastructure and related cost.
- No adverse visual impact.
- No maintenance cost.
- No 404 impacts.

d) Disadvantages and Constraints

The disadvantages are summarized from Section II - D – Potential Alternatives to be specific to the screened alternative and are repeated here for completeness and convenience of the reader.

- Public education will be required to educate property owners on flooding hazards within a piedmont.
- Does not fix existing drainage or flooding problems.
- Does not control uncertain flow paths.
- Public opposition to regulations that limit or restrict development.
- Difficulty in enforcement. Additional District staff required for development reviews.
- Some lots will be unsuitable for residential structures.

III. INTERIM DRAINAGE GUIDELINES

Existing landforms within the Rio Verde area generally consist of small, shallow, braided washes with overland sheet flow that is easily influenced by changes in vegetation coverage and surface grading. Such changes could result in concentration of flows that could dramatically increase rates of erosion, modify channel flow paths, and cause damage to downstream and adjacent properties. The strategy employed in the drainage guidelines is to minimize disturbance of existing natural washes, native vegetation, and landform to protect the processes and interactions that currently exist between storm water runoff and sediment transport.

> *The strategy employed in the drainage guidelines is to minimize disturbance of existing natural washes, native vegetation, and landform to protect the processes and interactions that currently exist between storm water runoff and sediment transport.*

A. Single Lot Development

The *Drainage Guidelines for Single-Lot Development* is contained in the Appendix and is posted on the FCDMC website. The guidelines address the following:

- Existing washes
- Disturbance envelope
- Walls and fences
- Site grading

The guidelines were developed based on a review of the *Maricopa County Zoning Ordinance* and the current zoning designation within the Rio Verde area. The densest zoning currently in effect is Rural-43 which requires a minimum lot size of 1-acre. The main questions posed during the guidelines development were:

- What size washes should be regulated, and when should exceptions to the regulation be allowed?
- How much of the lot should remain undisturbed?
- What type of fences should be allowed and where should they be allowed?
- How should the building envelope be graded and how high should structures be raised?
- Should retention be required? When and how much?

As each of these questions was considered, it became clear that in each case there was a trade-off between what the engineers felt was necessary to limit the adverse impact of development and what the regulatory staff felt could reasonably be imposed on and accepted by the residents. The final guidelines represent a compromise between these two perspectives. Preliminary hydrologic modeling performed after the guidelines were completed suggest that the compromises that needed to be made for public acceptance may have negated much of the benefit that was hoped to be gained. This should be investigated further in the next phase of the project.

1. Existing Washes

The objective is to leave existing washes intact and undisturbed. The combination of many small washes forms a network that functions to convey runoff from the upper watershed through the piedmont to the Verde River. It is important to maintain the total conveyance capacity through the watershed.

From an enforcement perspective, it was decided that small washes with small tributary areas could be modified if necessary to be able to

build on the lot. These washes are called secondary washes and were originally defined as washes with a sandy bottom width less than 2 feet, but were subsequently increased to a minimum of 5 feet in width. The justification for selection of a minimum 2 foot width is based on the results of the geomorphic field investigation and is as follows (JE Fuller Memorandum, January 15, 2003):

- Much of the drainage in the study area is conveyed in stream corridors with small bottom widths. If the District wishes to avoid the need for structural flood control measures in the future, these small washes should be preserved.
- Interim guidelines probably should be conservative. It will be easier to relax the guidelines than to raise the level of enforcement and scrutiny once the final development guidelines are established.
- The minimum size of the secondary wash should probably have some technical basis, such as the size of wash required to convey a 2- to 10-year event at bankfull that would correspond to the District's 100-year 50 cfs threshold of regulation (e.g.,~10cfs). However, note that if we assume a velocity of 5 ft/sec and an average bankfull depth of one foot that would yield a minimum channel width of about two feet.
- We believe the two foot criteria would conform more closely to the Corps' rule of thumb for jurisdictional streams.

Due to the potential for lateral movement of washes, a setback requirement is also established. The requirement is based on the Arizona State Standard 5-96, *Lateral Migration Setback Allowance for Riverine Floodplains in Arizona*, except that due to the small size of typical washes in the Rio Verde area, the minimum setback is reduced from 20 feet to 15 feet.

2. *Disturbance Envelope*

Recognizing that vegetative cover and the natural stability of the undisturbed ground surface reduces erosion from overland sheet flow, a disturbance envelope concept was developed to protect existing vegetative cover and minimize soil disturbance. The geomorphic field investigation concluded that "...local increases in peak discharge and discharge frequency would have significant impacts on the channel network, such as headcutting." (JE Fuller Memorandum, January 15, 2003). The intent is to create an "oasis" area for the home, pool, and outbuildings with the potential for a small grass area. The rest of the parcel should remain in its natural state. The maximum size of the disturbance envelope was initially set equal to the maximum lot coverage per the applicable zoning district, which varies from 5 to 15 percent in the Rio Verde area. Due to the extensive equestrian population within the area, and the need for corrals and pens for horses, the maximum disturbance envelope size was increased to 25 percent of the lot area, and was eventually increased to 40 percent. Recognizing that there may be circumstances where even the 40 percent restriction would be onerous, provision was added to allow the disturbance envelope to be increased beyond 40% if on-site retention were provided to reduce the impact of the disturbance.

3. *Walls and Fences*

Field observations and reports from FCDMC inspectors have shown that walls and fences can be a significant cause of flow concentration and diversion. The practice of fencing a resident's entire lot with fence-types that restrict flow cannot be allowed. Consistent with the "oasis" concept, solid walls are only allowed around the home and courtyard or pool area. Acceptable fence types for property fences are those that are open at the bottom of the fence and will not collect debris or block sheet flow. Recent FLO-2D modeling has shown that block fences, even those with every other block removed, cause flow

diversions and concentration which has a substantial impact on the flow conditions on adjacent properties.

4. Site Grading

Flooding within the Rio Verde area is widespread in aerial extent, but is relatively shallow. Most flooding problems can be avoided by selecting an appropriate location on the lot by placing the home away from washes and on topographically high spots, such as ridges. Elevating the finished floors above these shallow flow depths will protect the structure during storm events. The Floodplain Regulations require that finished floors be elevated one foot above the flood depth in shallow flooding areas. Consistent with this requirement, for areas outside the floodplain, the Guidelines include raising the finished floor 1.5 feet above the highest natural adjacent grade which would be adequate for shallow overland flow depths up to 0.5 feet. Flow depths would not be expected to exceed 0.5 feet in areas outside of washes within the Rio Verde area. Additionally, for areas adjacent to a major wash, the structure finished floor should be raised 2.0 feet above the 100-year water surface elevation for the wash. This is consistent with the requirement in the Floodplain Regulations for structures in a Zone A area with no floodway. Grading around the home should slope away from the home and direct runoff around the home and re-distribute the flow on the down slope side of the home to prevent flow concentration or diversion, which could cause damage to adjacent properties.

B. Roads

The drainage guidelines for single lot development should be applied to each lot within a subdivision. In addition to the single lot guidelines, the following guidelines are also recommended for roadways and culvert crossings within subdivisions and for County roads within the Rio Verde area.

Roadway alignments and profiles should be designed to minimize the impact on existing drainage patterns. It is preferable for roadway alignments to be either parallel or perpendicular to the natural flow pattern. Parallel alignments are best if they are on a topographic high point or ridge with no drainage crossings. Alternatively, when crossings are required, they should be perpendicular to the wash and designed to prevent flow diversions and to minimize the length of the crossing. Diagonal roadway alignments can cause flow diversions and should be avoided.

Existing culverts within the area were oversized for the 100-year storm and were increased in size to include a bulking factor to provide additional capacity for the sediment contained in the flow. To fit the culverts under the roadway, the roadway profile was not designed with a dip for overtopping flows. The result of the oversized culverts has been to concentrate flow and to cause the flow velocity to drop as the water ponds at the culvert inlet. Sediment is then deposited on the upstream side of the culvert, plugging the culvert and the culvert inlet area. The natural broad sheetflow condition prior to construction of the culverts has been replaced by diversions along the upstream roadway embankment and concentrated flows at the culverts. This concentrated flow causes additional downstream scour.

Roadway drainage crossings should be designed to maintain the storm water and sediment continuity for a full range of discharges. Dip crossings without culverts have the least impact. Where culverts are required they should be designed to pass the "bank-full" discharge at near the natural channel velocity with minimal upstream ponding. This will help maintain sediment continuity through the structure. The 50-year peak discharge should pass through the culvert and will likely produce some upstream ponding. Discharges in excess of the 50-year discharge should pass over the road in a dipped crossing that directs the overtopping flows back into the downstream channel. The 100-

year discharge should pass over the road with no more than 6-inches of depth. Culverts should not be oversized due to the potential for sediment deposition. Diversion of flows to combined crossings should be avoided.

C. Stock Tanks

1. Introduction

There are a number of existing stock tanks in the Rio Verde area. The tanks were constructed by ranchers for watering cattle. The tanks are typically constructed by excavating a basin. The excavated material is placed on the downslope side of the basin to form a berm to contain the runoff. Larger tanks are in-line and capture all the flow in a wash. These tanks typically have a spillway to direct overtopping flows back to the channel when the tank capacity is exceeded. Smaller tanks function in an off-line manner. A diversion berm is typically constructed to divert stream flows into the tank. When storm events generate higher wash flows, the excess flow overtops the diversion berm and continues in the natural wash.

As the Rio Verde area develops, large homes and barns are being constructed downstream of stock tanks. This presents a hazard that was not envisioned when the tanks were originally constructed. The damage that could result from a tank failing when it is full of storm water is significantly higher than what would have occurred if the natural wash had been left in its natural state. Further aggravating the hazard is the false sense of security that may be felt by the presence of an earthen embankment.

Due to the variety of stock tank sizes and types, and the variation in downstream development, a single approach for dealing with stock tanks is inadequate. The District does not have authority to regulate stock tanks. Unless legislation is enacted to give the District this responsibility, the District can only provide information and recommendations to stock tank owners. It is recommended that a range of actions be identified based on the site specific conditions at a tank. The possible actions for a stock tank are:

- Obtain a permit from ADWR to operate the tank as a dam,
- Remove the structure,
- Maintain and rehabilitate the structure.

Taking no action for a tank is not considered a long term solution. The possible actions may perhaps be deferred until development pressure forces action, but one of the above actions will eventually be required. These actions are discussed in the following sections.

2. ADWR Jurisdiction

Stock tanks that have an embankment height of six feet or greater, or have capacity for 50 acre-feet or more are classified as dams by the Arizona Department of Water Resources (ADWR). Impoundments of this size fall under the jurisdiction of ADWR and are required to have a permit. ADWR oversees all jurisdictional dams and enforces their own set of rules and regulations to ensure the safe operation of the dam. The dam owner must work with ADWR to determine the proper action to be taken with the dam as part of the permit process.

3. Hazard Assessment

Stock tanks that do not fall within the ADWR dam safety criteria are basically unregulated and are the responsibility of the dam owner. In the interest of protecting downstream landowners, a Hazard Assessment should be conducted by each stock tank owner or by the District to identify the magnitude and urgency of the hazard. The Hazard Assessment should also consider the potential impact and cost of the remedial actions identified in the following section. The District could send letters to all tank owners advising them of the potential hazard and encouraging them to take action to undertake the hazard assessment. Alternatively, the District could conduct the Hazard

Assessments on behalf of the owners as part of Phase 2 of this project. The Assessments could then be presented to the stock tank owners to help them understand the potential hazard associated with the structure as well as possible actions that they could take to control their liability exposure.

4. *Remedial Actions*

It should be the District's preferred approach to have the property owners remove embankments that pose a long-term potential for downstream hazards. The structure should be removed if the hazard assessment determines that existing downstream structures would not be harmed by removal of the embankment. Excavation of a retention area with storage below the natural ground elevation should be considered with this approach.

If the tank is still required for stock watering, or if the hazard assessment determines that removal of the embankment would cause an increased hazard to an existing structure, then the owner of the tank should rehabilitate the embankment and maintain it in a safe condition to protect downstream property. This should include embankment stability and routing of overtopping flows or identification of other measures to protect downstream property.

Specific criteria for the Hazard Assessment and for rehabilitation and maintenance can be developed in the next phase of the project.

5. *Interim Measures*

The District is faced with the question of what to require of residents who desire to construct homes downstream from existing stock tanks, potentially within harms way of an embankment failure. Since the stability of the embankments is unknown, until Hazard Assessments can be completed, the District should take a conservative approach to protect the downstream homebuilders.

The critical design scenario could be an embankment failure under a full impoundment condition, or if the embankment is ultimately removed, a 100-year flood with no embankment in place. The embankment should only be assumed to provide flood protection if it is a jurisdictional dam with a current permit with ADWR or if adequate rehabilitation and maintenance are demonstrated to be in place.

Consistent with the recommendation to ultimately have the stock tanks removed downstream property owners should, at a minimum, design for the full discharge with the dam not in place. Failure to do this could force the structure to ultimately be rehabilitated and maintained.

REFERENCES

Dibble & Associates, *Rio Verde Area Drainage Master Plan, Part 1 – Existing Conditions*, May 19th, 2004.

Flood Control District of Maricopa County, Digital Orthographic Aerial Photography, Flight dates December 19 and 27, 2001 and February 21-22, 2002.

U.S. Geological Survey, Digital Orthographic Quarter Quadrangles, GeoTIFF format, 1 meter resolution, UTM, NAD83 projection, 1992.

APPENDIX

Flood Control District of Maricopa County

Drainage Guidelines for Single-Lot Development

April 18, 2003

Revised July 14, 2003

These drainage guidelines are established to help property owners minimize adverse impacts to land areas characterized by the following:

Significant slopes,
Erodible soils,
Desert vegetation, and
Shallow braided channels and/or sheet flow,

which can lead to surface and channel instability.

The drainage guidelines presented herein are in addition to the Drainage Regulations and the Floodplain Regulations.

I. Applicable Regulations

A. Drainage Regulations for Maricopa County, September 26, 1988, 1994 Revision

1. Authority

Article IV, Administration, Section 403, Discretionary Powers: *"The Drainage Administrator may adopt drainage design standards, guidelines, administrative rules, procedures and policies to implement and effectuate the purposes of this Regulation."*

Article XI, Area Drainage Master Study, Section 1101, Adoption: "Whenever an Area Drainage Master Study authorized under this regulation has been completed, such plan including uniform rules for development may be submitted to the Board of Supervisors for adoption as an Area Drainage Master Plan. If adopted by the Board of Supervisors, the District shall enforce the Area Drainage Master Plan under this regulation."

B. Floodplain Regulations for Maricopa County, August 4, 1986, 2000 Revision

Washes in designated floodplains are governed by the Floodplain Regulations.

I. Single-lot Development in the Rio Verde Area

A Drainage Clearance is required from the Flood Control District of Maricopa County for all single-lot development including **all structures, walls, fences, and site grading** within unincorporated Maricopa County per Sections 601 and 604 of the *Drainage Regulations.*

Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009

A. Purpose

The purpose of these *Drainage Guidelines for Single-lot Development* is to promote and protect the health, peace, safety, comfort, convenience and general welfare of the citizens of Rio Verde by regulating drainage to limit the adverse cumulative impacts of single-lot development within the Rio Verde area and to minimize unnecessary loss from erosion and flooding.

The existing landforms within the Rio Verde and other areas generally consist of small, shallow, braided washes with overland sheet flow that is easily influenced by changes in vegetation coverage and surface grading. Such changes could result in concentration of flows that could dramatically increase rates of erosion, modify channel flow paths, and cause damage to downstream and adjacent properties. The strategy employed in these guidelines is to minimize disturbance of existing natural washes, native vegetation, and landform to protect the processes and interactions that currently exist between storm water runoff and sediment transport.

B. Applicability

The requirements set forth in these *Drainage Guidelines for Single-lot Development* are in addition to existing requirements contained in the Drainage Regulations and the Floodplain Regulations. These guidelines shall in no way be construed to relieve the developer of any development requirements already in existence. These guidelines should be applied to all new construction on single-lots within the unincorporated areas of the Rio Verde or similar watersheds. **Improvements that have already been permitted as of May 2003, or were completed before permits were required may not follow the guidelines, because the guidelines were not available. However, if new improvements are proposed for a lot with existing improvements, new retention, perimeter wall modifications, or other measures may be needed to minimize the impact of potential flooding or erosion on this lot or adjacent lots.**

C. Drainage Guidelines for Single-lot Development

1. Engineered Plans have been and will continue to be required for most development in the area.

2. Existing washes

The site plan should identify any existing natural washes, drainage tracts, easements, or drainage channels located on the lot, or bordering the lot, that may involve or affect the drainage of the lot to be developed. The intent of these guidelines is to minimize the impacts to the numerous washes that flow throughout the area. These washes are vital to the balance of soil erosion and sediment deposition that occurs.

<u>Wash Definition:</u> Existing natural washes to be managed by these guidelines include major washes and secondary washes and are defined as follows:

a) Major Wash - An existing natural wash that has a discernable sandy bottom width of five (5) feet or greater or as determined by the Drainage Administrator.

b) Secondary Wash - An existing natural wash that has a discernable sandy bottom width less than five (5) feet or as determined by the Drainage Administrator.

Major washes should not be disturbed, which includes grading, grubbing or relocating. An at grade driveway crossing may be permitted if no other access is available.

Any disturbance of secondary washes is discouraged. There may be instances where the only option for constructing a house on a lot is to relocate a secondary wash. In these cases the new channel design must be designed by an engineer and must maintain the original wash bottom elevation; the

original width/depth ratio or at least the original cross-sectional area in order to avoid excessive erosion and deposition due to changes in channel character. Erosion protection for the disturbed wash will be required.

Wash Setback Requirement: The distance a structure must be setback from a wash is defined as a "setback distance". The setback distance for both major washes and secondary washes should follow State Standard 5-96, Guideline 1, *Lateral Migration Setback Allowance for Riverine Floodplains in Arizona*, except that the minimum setback is reduced to fifteen (15) feet. A structure may be set closer to a wash, if the foundation footing is set lower than the wash invert scour potential and/or erosion protection for the structure is provided.

3. Disturbance of Area

Grading of lots should be limited to the minimum area required to develop the site, up to a maximum of 40 percent of the total lot area. Removing vegetation and disturbing the soil increases the amount of runoff (water) leaving the site as well as increasing water velocity and erosion potential of the property. All new lots resulting from a lot split will be required to meet these disturbance area limitations following the lot split.

The site plan must outline the areas to be disturbed, which includes any kind of grading, grubbing, or vehicle traffic. The percentage of disturbed area should be stated on the site plan. If an area of disturbance greater than 40 percent is required, then retention will be needed to minimize the increase in flow that is generated from the removal of vegetation and disturbance of the soil. The engineered plans and report should show that the increased amount of disturbed area will not increase erosion or deposition on downstream or adjacent property owners.

Improvements that have already been permitted as of May 2003, or were completed before permits were required may not follow the guidelines, because the guidelines were not available. However, if additional improvements are proposed for a lot with existing improvements, that increases the area of disturbance to greater than 40 percent then the criteria mentioned above should be followed and retention provided.

4. Retention Requirement

Retention should be provided if the disturbed areas exceed the percentage allowed in Section II.C.3 above. Basin(s) should be constructed to retain the first 0.65 inches (0.054 ft) of runoff from the entire disturbed area. The runoff from disturbed areas should be directed to the retention basin(s), and be sized according to the contributing area.

Volume of Basin(cf) = 0.054(ft) x (Total Disturbed Area (sf))

The retention area must be shown on the site plan and be preserved and maintained by the property owner in perpetuity.

5. Walls and fences

Solid walls, wrought iron, or mesh fences should not be used as a perimeter fence due to the sheet flow characteristics of runoff in this area unless specifically approved by the Drainage Administrator. Acceptable perimeter fence types include pipe rail, split rail, barbed wire, or other open fencing. Mesh fencing on the bottom of open fencing should not be used.

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Closed fencing (solid walls or mesh fencing) may be used around pools and as 'courtyard' type enclosures, which are located on the down slope side of the house, protected from sheet flow by the house. 'Courtyard' type fencing may need to have drainage openings to allow water to pass through the yard or to drain the yard.

6. Finished Floor Elevations

For lots **not** located in a District regulated floodplain, building finished floors will be elevated a minimum of 1.5 feet above the highest adjacent natural grade or two (2) feet above the 100-year water surface elevation of a major wash located on the property, whichever is greater.

For lots located in a District regulated floodplain, the floodplain regulations apply for the building's finished floor.

Finished floors may be stepped down to form a multi-level structure to reduce down slope fill heights as long as all points along the foundation meet the elevation requirement. Stepping down of finished floors is only allowed in the down slope direction. The perimeter of the building pad should be graded to direct surface runoff around the building and to disperse the flow back to a sheet flow condition down slope from the structure. Erosion protection may be required around the building pad.

For lots located **within** a District regulated floodplain, the finished floor elevation will be set according to the floodplain regulations.

7. Driveways

Driveways are to be included as part of the disturbance area. Driveways crossing major and secondary washes will be limited to the minimum number of crossings required to access the lot and outbuildings, will be the minimum width necessary for the intended use, and will minimize changes to the channel cross-section. The preferred crossing type is an at grade dip crossing. Culvert crossings, when required, will be designed to minimize changes to the sediment transport continuity of the reaches upstream and downstream of the culvert and will require erosion protection. A registered civil engineer must design proposed culvert crossings.

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Rio Verde Area Drainage Master Plan

Factsheet for Drainage Guidelines for Single-Lot Development

Current Requirements

In Maricopa County, when you buy property and wish to build a structure on it, there are certain requirements that must be met. The same is true if you want to make changes to your existing structure. You must abide by the County Drainage or Floodplain Regulations when developing your property.

The Maricopa County Department of Planning and Development is responsible for processing applications for land-use approvals, zoning and land-use permits, construction and building permits, and engineering and subdivision permits in unincorporated Maricopa County.

Drainage Clearance

As part of this permitting process, a Drainage Clearance must be obtained from the Flood Control District of Maricopa County (District). A drainage clearance must be obtained for the construction of any structure, wall or fence and before any grading occurs on a lot or parcel. The District reviews each permit/drainage clearance application to make sure that it complies with the County drainage and floodplain regulations and to determine if the District has any flood-related concerns.

About Drainage Guidelines

These guidelines were developed to help property owners minimize drainage and flooding problems occurring in the Rio Verde area due to the cumulative impacts of single -lot development. Rio Verde is characterized by steep slopes, erodible soils, desert vegetation, shallow braided channels, and sheet flow – all of which contribute to flooding, erosion, and drainage problems.

These guidelines, when followed along with the County Drainage Regulations and Floodplain Regulations, will help Rio Verde develop naturally and reduce the number of drainage problems. The guidelines will be used as a tool by District staff when reviewing sites for a drainage clearance. As the District develops more technical data in the Rio Verde Area Drainage Master Plan (ADMP), these guidelines will move towards policy and regulation. The drainage guidelines have been attached for your convenience.

Grandfathered Improvements

Improvements that have already been permitted as of May 2003, or were completed before permits were required are "grandfathered" in and are not required to meet these guidelines. However, if new improvements (structures or fences) or additional grading is proposed for a lot with existing improvements, new retention, perimeter wall modifications, or other measures may be required to prevent or minimize drainage problems from occurring on that lot or adjacent property.

Engineered Plans

The Drainage Regulations require a registered Arizona Civil Engineer to prepare engineered plans if there is extensive grading, an encroached upon or rerouted wash, or a finished floor elevated less than one-foot above adjacent grade.

Because of the numerous washes, sheet flow conditions, and highly erosive soil all development in the Rio Verde area should have engineered plans in order to obtain a Drainage Clearance from the District.

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Disturbing Washes

The washes in Rio Verde are vital to the natural balance of the area. The disturbance of washes causes significant soil erosion and deposition in the area. Major washes (5 feet or greater in width) should not be disturbed. This includes grading, grubbing, or relocating. Disturbance of secondary washes (less than 5 feet in width) should be avoided if possible.

Disturbance of Area

The District recommends minimal grading and grubbing (removal of vegetation) of lots. When the ground is graded and the vegetation removed, the water runoff increases and the potential for soil erosion also increases. The District recommends property owners limit the amount of disturbed areas. The maximum amount of disturbed area should be 40 percent of the total lot size. If a property owner grades or grubs more than 40 percent of a lot, then retention should be provided to decrease the amount of flow and/or the velocity as the water exits the lot.

Walls and Fences

Although the County Department of Planning and Development only requires a building permit for walls and fences over the height of six feet, the District currently requires a Drainage Clearance for all walls and fences constructed in unincorporated Maricopa County. Fences often divert stormwater flow onto other people's properties and are one of the main sources of nuisance flooding and drainage problems.

In the guidelines, solid walls and wire mesh type fences should not be used for perimeter fencing. The guidelines offer more detailed information on what is and isn't allowed.

Finished Floor Elevation

For lots not located in the floodplain, finished floors of all structures should be elevated to a minimum of 1.5 feet above the highest natural adjacent grade. For lots located in a District regulated floodplain, the floodplain regulations still apply for the building's finished floor.

Contact Us

If you have questions on the Rio Verde Drainage Guidelines for Single-lot Development, contact:

Felicia Terry, P.E., C.F.M., Project Manager,

602-506-8111 or email: fet@mail.maricopa.gov

Matrix Analysis

Criteria

Criteria Scoring Matrix

How Important
4 - Major Preference
3 - Medium Preference
2 - Minor Preference
1 - Letter/Letter
No Preference - each scored one point.

A. FLOOD PROTECTION
B. COST
C. ENVIRONMENTAL IMPACTS
D. MAINTENANCE
E. HYDRAULIC PERFORMANCE
F. SAFETY
G. CONSTRUCTABILITY

Alternatives

Analysis Matrix

	G	F	E	D	C	B	A	
Raw Score	6	44	39	14	17	16	37	
Weight of Importance (1-10)	1	10	9	2	3	3	8	Total
1. NO ACTION	5/5	5/50	1/9	3/6	5/15	5/15	1/8	108
2. ALT. D-1	2/2	4/40	4/36	4/8	3/9	2/6	4/32	133
3. ALT. D-2	4/4	4/40	1/9	2/4	4/12	3/9	3/24	102
4. ALT. D-3	4/4	4/40	1/9	2/4	3/9	3/9	3/24	99
5. ALT. D-4	3/3	4/40	4/36	2/4	4/12	1/3	5/40	138
6. DETENTION ALTERNATIVE	2/2	4/40	4/36	4/8	3/9	2/6	5/40	141
7.								

Excellent - 5; Very Good - 4; Good - 3; Fair - 2; Poor - 1

Matrix Analysis

Criteria

Criteria Scoring Matrix

How Important
4 - Major Preference
3 - Medium Preference
2 - Minor Preference
1 - Letter/Letter
No Preference - each scored one point.

A. FLOOD PROTECTION
B. COST
C. ENVIRONMENTAL IMPACTS
D. MAINTENANCE
E. HYDRAULIC PERFORMANCE
F. SAFETY
G. CONSTRUCTABILITY

	G	F	E	D	C	B	A	
Raw Score	6	44	39	14	17	16	37	
Alternatives Analysis Matrix — Weight of Importance (1-10)	1	10	9	2	3	3	8	**Total**
1. NO ACTION	5/5	5/50	1/9	3/6	5/15	5/15	1/8	108
2. ALT. C-1	4/4	4/40	3/27	2/4	3/9	1/6	5/40	127
3. ALT. C-2	3/3	5/50	1/9	4/8	4/12	2/9	2/16	104
4. ALT. C-3	3/3	4/40	3/27	2/4	2/6	1/3	3/24	110
5. ALT. C-4	2/2	5/50	2/18	2/4	3/9	1/3	4/32	118
6. ALT. C-5	3/3	4/40	3/27	2/4	2/6	1/3	5/40	123
7. CONVEYANCE ALTERNATIVE	4/4	4/40	3/27	2/4	3/9	1/6	5/40	127

Excellent - 5; Very Good - 4; Good - 3; Fair - 2; Poor - 1

Performance Criteria and Use of Evaluation Matrix

Objective:

The FCD has adopted a set of techniques for identifying key performance criteria; determining the hierarchy of importance for these criteria relative to the overall success of the project; establishing a baseline for project performance expectations of our project Partners, Customers and Stakeholders, and Technical Experts. The technique allows us to evaluate and rate the effectiveness of various alternatives and measure the aggregate effect of the alternatives relative to the project specific baseline performance expectations.

Technique:

The technique developed to measure the performance of FCD projects, includes the following steps:

- Define Criteria
- Determine Hierarchy
- Establish Baseline
- Evaluate Alternatives
- Compare Concepts

Define Criteria

The first step in the process is to identify the criteria that will be used to measure the performance of the project. This is best accomplished using a team approach that includes representation from the project management staff, design team, and other project stakeholders. The group identifies what they feel to be the project's primary objectives and requirements. When the group is satisfied that they have developed a comprehensive list, the group decides which of them are essential to the project's overall success. Many of the items on the list can then be consolidated, or even eliminated. (It is advisable to limit the criteria to no more than eight.) Each of these is given a formal definition that everyone can refer to during subsequent evaluations. These criteria should provide a well rounded "yard stick" for measuring how well a concept meets the project's objectives and requirements. They will be referred to as the project's "performance criteria."

Example

A flood control project proposing the construction of a new channel and the replacement of an existing dike might include the following performance criteria:

Hydraulic Performance - How does the project rate with regard to the project's overall hydraulic requirements?

Local Access - How does the project rate with regard to local traffic access across the new channel?

Project Schedule - How does the project rate with regard to the overall project schedule including design and construction?

Compliance with Design Standards - How does the project rate with regard to its compliance with established design standards?

Construction Impacts - How does the project rate with regard to noise, vibration, dust, detours and traffic delays during construction?

Environmental Impacts - How does the project rate with regard to its effect on the environment including wetlands and wildlife?

Determine Hierarchy of Performance Criteria

Once the group has agreed upon the project's performance criteria, the next step is to determine their relative importance in relation to each other. This is accomplished through the use of an evaluative tool the "Performance Criteria Matrix." This matrix compares the performance criteria in pairs, asking the question: "Which one is more important to the project?" A letter code and a number between 4 and 2 (e.g., "a-3") is entered into the matrix for each pair, identifying which of the two is more important, and how much more important over the other. If a pair of criteria is considered to be of essentially equal importance, both letters (e.g., "a/b") is entered into the appropriate box and each receives 1 points. This, however, should be discouraged as it has been found that in practice a tie usually indicates that the pairs have not been adequately discussed. When all pairs are discussed, the numbers of "votes" for each are tallied and a weighting number (between 1 and 10) derived from the raw number of "votes", which will be used as weighted multipliers later in the process. It is not uncommon for one of the criterion to not receive any "votes." If this occurs, the criterion is given a token "vote", as it made the list in the first place and should be given some degree of importance.

Note: It is important to know, that as we evaluate each pair of criteria, think of performance trade-offs in hypothetical terms. For instance: if we were considering a concept during the design, that would improve hydraulic performance, but at the expense of causing greater environmental impacts, which criterion would take the priority? Remembering that these performance criteria will be used to evaluate the merits of alternative concepts generated during the course of the study. As such, we should keep an open mind and base our evaluation on what is possible rather than what exists in terms of the current conditions.

How to fill out Matrix:

1. ***List Criteria*** *- List the candidate criteria in the left part of the form*

2. ***Discuss Pairs*** *- Compare criterion A with criterion B asking, "Which is more important to the project? "Enter "a" in the intersecting box and a "number" indicating "How important" (in the box where A and B designators meet). Continue for all pairs until matrix is completed.*
3. ***Total Raw Scores*** *- Add the number of times each criterion was selected. 1-1 points results from ties, where criteria are judged to be of equal importance.*

4. ***Normalize Scores*** *- Assign weighting factor of 10 to the highest "vote" and 1 to the lowest "vote". Then proportionately assign numbers between 10 and 1 to the rest.*

Establish Baseline:

The next step in the process is to establish how well the project will need to address the performance criteria. This step establishes a "baseline" to which the design concepts will be compared against. The Performance Rating Matrix is used to assist the design Consultant in determining the performance ratings for the various alternative design concepts.

We need first to establish the performance of the existing, or "no build", condition. The performance criteria, and their relative weights, are first entered into the matrix. Next, the group should identify the unit of measurement for each of the performance criteria.

It is generally advisable to first evaluate the "no build" condition in order to establish a relative baseline then assign the "Expected Performance" requirements for the project. The procedure is accomplished by assigning a 1 to 5 rating for each of the criteria, with a 1 being low and 5 high.

Once the ratings for the various criteria have been established, their total performance should be calculated by multiplying the criteria's weight by its rating. Once the total performance for each of criteria has been determined, the concept's total performance can be calculated by adding all of the scores for the criteria. The projects total "performance requirement" and the "no build" condition's totals will be used in the selection of the preferred alternative.

Suggested Evaluation Criteria and Performance Measurements (for Flood Control Projects):

- **Flood Protection**
  5 = Major structural or acquisition protection for 100yr. Event.
  4 = Major flood protection with administrative methods for 100yr.
  3 = Significant damage reduction with structural protection for less than 100yr.
  2 = Minor protection with administrative methods for less than 100 yr.
  1 = No significant flood protection

- **Public Acceptance**
  5 = Expressed public support
  4 = No known public opposition
  3 = Minor public opposition
  2 = Organized opposition
  1 = Threat of Legal Challenge

- **Environmental**
  5 = No mitigation required
  4 = Some mitigation required
  3 = Significant mitigation required
  2 = Major mitigation required
  1 = Complete EIS possibility

- **Cost (Life Cycle)**
  5 = Low initial cost and no maintenance
  4 = Low initial cost and low maintenance
  3 = Medium initial cost and low maintenance
  2 = Medium initial cost and high maintenance
  1 = High initial cost and high maintenance

- **Hydra. Performance**
  5 = Laminar, non-erosive flows
  4 = Minor turbulent flow with some erosion protection
  3 = Significant turbulence, major erosion control
  2 = Turbulent flow with energy dissipater
  1 = Natural, high velocity, erosive conditions

- **Partnering**
  5 = Financial partner - Committed
  4 = Financial partner - Possible
  3 = Non-financial partner - Committed
  2 = Non-Financial partner - Possible
  1 = No Partnering Possibility

- **Construtibility**
  5 = No hindrance to contractor and local access
  4 = Minor hindrance to contractor and local access
  3 = Significant difficulty for contractor and local access
  2 = Major difficulty for contractor and adjacent property owners
  1 = High degree of difficulty for contractor, and/or extensive access closures

- **Multi-use**
  5 = Trails and structural recreation venues
  4 = Trails and some structural features
  3 = Trails and minimal facilities
  2 = Trails and no facilities
  1 = No multi use opportunities

- **Safety**
  5 = No safety hazard associated with project
  4 = Possible unsafe features during high flows
  3 = Possible unsafe features during dry conditions
  2 = Significant safety problems during wet and dry conditions
  1 = Major safety hazards inherent in project

- **Project Schedule**
  5 = Construction completion in 1 to 3 months
  4 = Construction completion in 4 to 6 months
  3 = Construction completion in 8 to 12 months
  2 = Construction completion in 13 to 16 months
  1 = Construction completion in over 17 months

- **Maintenance**
  5 = No maintenance required
  4 = Low frequency, light maintenance
  3 = High frequency, light maintenance
  2 = Light frequency, heavy maintenance
  1 = High frequency, heavy maintenance

- **Compatibility**
  5 = Complete compatibility with local/regional plans
  4 = Major compatibility with local planning
  3 = Significant compatibility with local planning
  2 = Minor conflict with local planning
  1 = Incompatible with local planning

Matrix Analysis

Criteria

Criteria Scoring Matrix

How Important
4 - Major Preference
3 - Medium Preference
2 - Minor Preference
1 - Letter/Letter
No Preference - each scored one point.

A.							
B.							
C.							
D.							
E.							
F.							
G.							
	G	F	E	D	C	B	A

Alternatives Analysis Matrix	Weight of Importance (1-10)	G	F	E	D	C	B	A	**Total**
	Raw Score								
1.									
2.									
3.									
4.									
5.									
6.									
7.									

Excellent - 5; Very Good - 4; Good - 3; Fair - 2; Poor - 1

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