Design of "Natural" Flood Control Channels in an Urbanizing Area

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Introduction

- Design a cost effective and aesthetically pleasing "natural" channel within the wash corridor(s) identified during the US Army Corps of Engineers' 404 permit process

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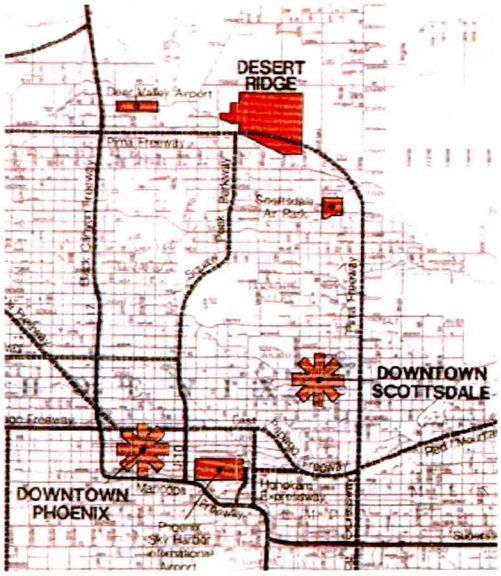

Location

- **Desert Ridge residential area and Wildfire Golf Course in NE Phoenix**

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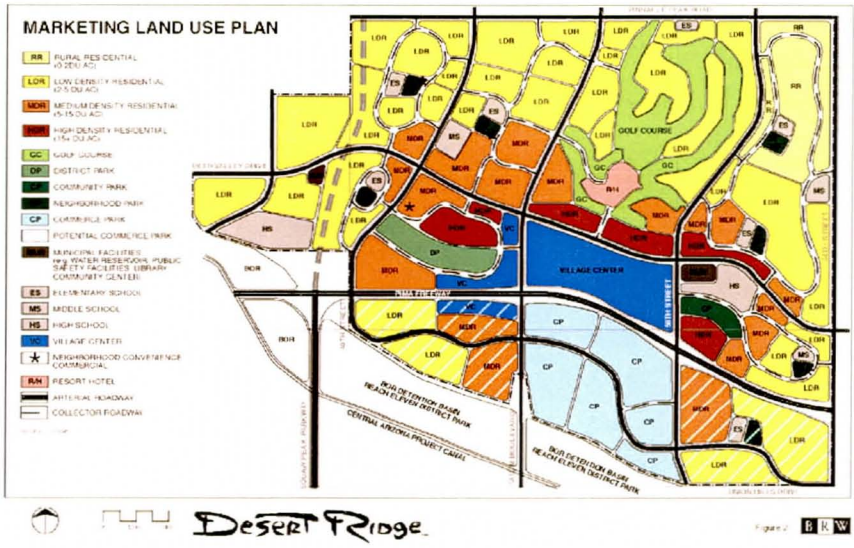

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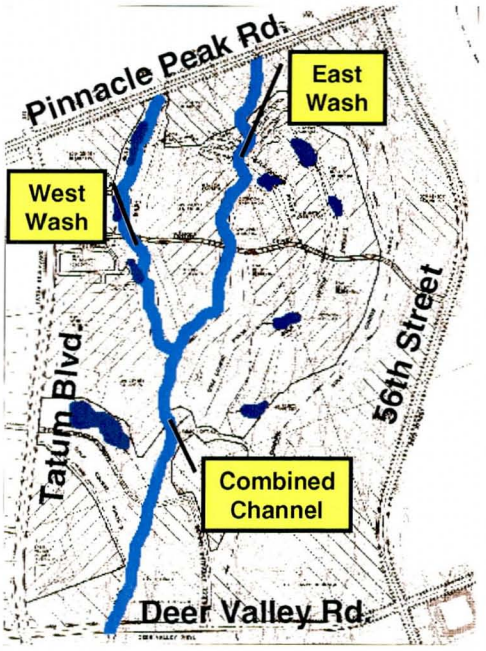

"Natural" Flood Control Channels Location Map

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Key Elements of a Successful Watercourse Design Project

- Upfront Planning by a Multi-disciplined Team
- Substantive and Rigorous Hydraulic, Scour and Sediment Transport Analysis and Design
- Environmentally Sensitive Landscape Design with Recreational Component
- Multi-disciplinary Interaction
- Client and Review Agencies Input
- Regulatory Agencies Coordination
- Public Participation

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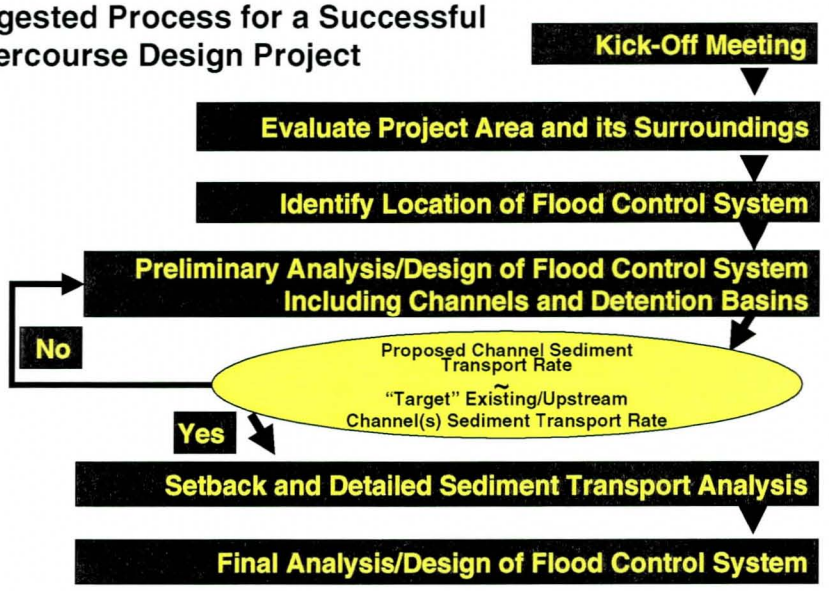
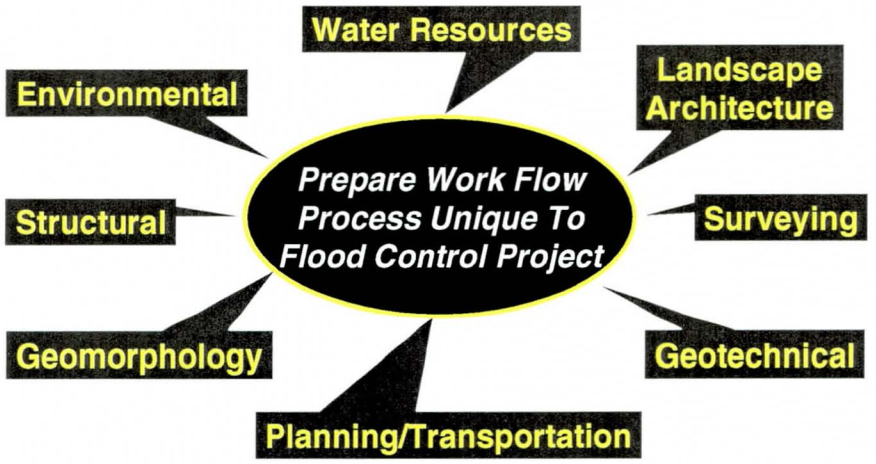
Suggested Process for a Successful Watercourse Design Project



Kick-Off Meeting



Note: All disciplines interact with each other throughout this process

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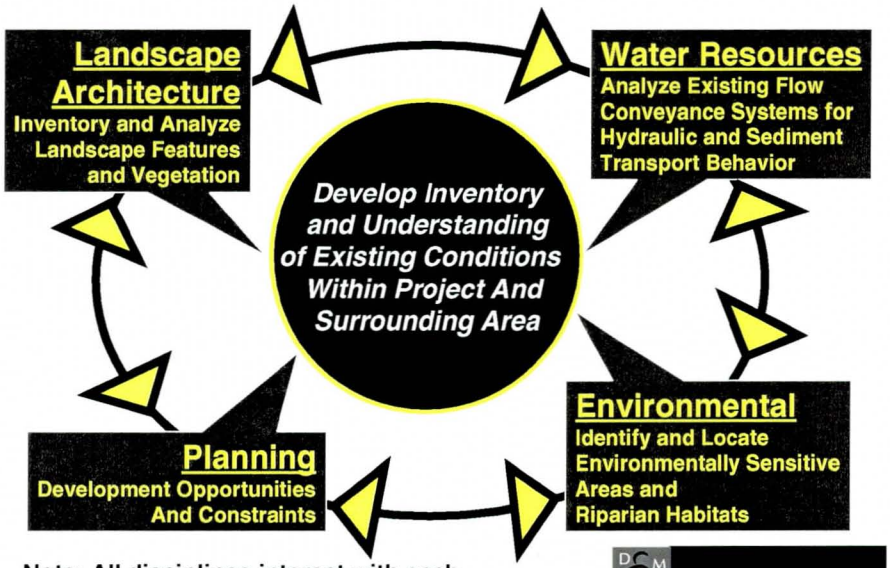
Evaluate Project Area And its Surroundings



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Identify and Analyze Upstream Washes

- Visit site and obtain hydraulic parameters for upstream washes e.g., bottom width, side slopes, depth and roughness
- Obtain soil data for existing washes
- Perform hydraulic and equilibrium slope analysis of existing washes
- Establish target sediment transport rate(s)

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Existing wash upstream from project

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Another existing wash upstream from project

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TABLE 4-1
Equilibrium Slope Analysis (Revised 16 Jul 96)

Drainage Area	Concentration Point/Location	10 yr Peak Discharge cfs	Channel Data: Bottom Width ft	Side Slope horiz/vert	Long Slope ft/ft	Manning's n	Flow Characteristics: Normal Depth ft	Uniform Velocity ft/sec	Mean Depth ft	Unit Sed. Load cfs/ft	Total Sed. Load cfs	Comments
					Proposed East Channel							
SB4.51	C10AR/Pinnacle Peak Rd	118.5	8	8.5	0.0185	0.035	1.870	7.15	1.89	0.104	0.525	Exist. channel 0.65 mi w. of 64th St
		58.1	3	1	0.0185	0.035	1.870	6.16	1.36	0.058	0.283	Exist. channel 0.7 mi w. of 64th St
		57.9	4	8.5	0.0106	0.035	1.870	6.27	1.57	0.060	0.297	Exist. channel 0.85 mi w. of 64th St
		233.5									1.505	Target Sediment Load
		234	10	4	0.0170	0.035	1.955	8.72	1.38	0.084	1.503	
SB4.51	CB4.63/Lakins	239	10	4	0.0155	0.035	2.020	8.54	1.40	0.075	1.202	
	CB4.65/Above Ranger Dr.	239	15	4	0.0157	0.030	1.670	8.80	1.28	0.072	1.655	
SB4.66	CB4.65/Below Ranger Dr.	230	15	4	0.0142	0.030	1.630	8.81	1.25	0.070	1.607	Proposed east channel
					Proposed West Channel							
SB4.11	Pinnacle Peak Rd	120	4	1	0.0167	0.035	2.550	7.16	1.84	0.105	0.675	Exist. channel 0.95 mi w. of 64th St
		120	4	1	0.0167	0.035	2.550	7.16	1.84	0.105	0.675	Exist. channel 1.1 mi w. of 64th St
		315	12	1	0.0186	0.035	2.550	8.49	2.17	0.202	2.554	Exist. channel 1.25 mi w. of 64th St
		120	4	1	0.0167	0.035	2.550	7.16	1.84	0.105	0.675	Exist. channel 1.35 mi w. of 64th St
		575									4.660	Target Sediment Load
		574	25	4	0.0141	0.035	2.480	7.78	1.55	0.143	5.000	Proposed west channel
SB4.11	CB4.12/Ranger Dr.	708	25	4	0.0136	0.035	2.575	7.79	1.59	0.143	5.033	Proposed west channel
SB4.22	CB4.22/Downstream Ex. Subdiv	710	25	4	0.0136	0.035	2.590	7.30	2.07	0.112	3.998	Proposed west channel
					Proposed Combined Channel							
											6.405	Target Sediment Load
SB4.09	CB4.59/Confluence E. & W. Wash	831	30	4	0.0128	0.035	2.640	7.76	2.09	0.138	5.608	
SB4.25	CB4.54/Local St.	848	30	4	0.0128	0.035	2.655	7.84	2.10	0.146	5.875	Proposed combined channel
SB4.31	CB4.31/Deer Valley Dr. (upstr.)	851	30	4	0.0129	0.035	2.660	7.87	2.11	0.147	5.865	Proposed combined channel
SB4.31	CB4.31/Deer Valley Dr. (upstr.)	851	40	4	0.0082	0.020	1.910	9.35	1.85	0.124	5.009	Proposed temporary channel
SB4.31	CB4.4/Deer Valley Dr. (downstr.)	853	30	4	0.0132	0.030	2.540	8.36	2.03	0.147	5.895	
SB5.1	CB5.1/Pima Fwy at Tatum Blvd	860	30	4	0.0132	0.030	2.530	8.38	2.03	0.148	5.647	
											8.791	Target Sediment Load
SB8.3	CB5183/Pima Fwy 300' W. of Tatum	1137	30	2.5	0.0057	0.015	2.530	12.37	2.15	0.229	8.254	
											9.553	Target Sediment Load
SB8.2	CB1823/Pima Fwy E. of 40th St	1421	30	2.5	0.0048	0.015	3.030	12.48	2.52	0.227	8.542	

Notes:

1. Target Sediment Load at CB5183 = Target loads at C10AR, CB4.12A & C8RL = 1.505 + 4.960 + 2.326 = 8.791
2. Target Sediment Load at CB1823 = Target loads at C10AR, CB4.12A & C8RL & C6L = 1.505 + 4.960 + 2.326 + .762 = 9.553
3. It may be noted that the existing grade along the Pima Freeway from Tatum Blvd. to 40th St is approx. .0045 ft/ft. Proposed grade for a concrete lined channel within the same stretch is approx. 0.006 ft/ft. It is within the realm of possibility that the shortfall of approx. 8 feet can be made up by grading upstream and downstream of the proposed channel. A feasibility study is recommended.

NOTES:

1. Equilibrium slope analysis is based on
   - Zeller-Fullerton Sediment Transport Equation for Stepped Channels in Alluvial Rivers (1973)
   - D_{50} sediment size (mm) = 1.5
   - Sediment Gradation Coefficient = 4
2. Sediment Transport Equation is

$$q_s = \frac{0.0084(s^{1.12}Vn)^{2.3}(G)^{0.44}}{y_s^{1.05}D_{50}^{0.61}}$$

where
- q_s = unit width sediment transport rate (cfs/ft/ft of channel, or cfs/ft/ft depth)
- n = Manning's roughness
- V = mean flow velocity (fps)
- G = sediment gradation coefficient
- y_s = hydraulic depth (ft = area/top width)
- D_{50} = diameter of bed material particle of which 50% is greater by 1 lb x ft.

Identify Location of Flood Control Features

Implement Corps of Engineers
404 Permit Process

Note: All disciplines interact with each other throughout this process

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Preliminary Analysis/Design of Flood Control System

Landscape Architecture / Environmental/Planning		Water Resources/Geomorphology Geotechnical/Structural
Visual and Land Use Influences	Channel Meander	Sinuosity and Scour Analysis
Aesthetics and Riparian Consideration	Channel Geometry	Backwater Hydraulic Analysis
Vegetation, Seed Mix, Landscape, Riparian Habitat	Channel Lining	Channel Roughness
Selection of "Natural" Walls Or Boulders	Channel Slope/Grade Control Structures	Sediment Transport and Equilibrium Slope Analysis
Vegetative Buffer Design	Flood Plain	100-Year Floodplain Hydraulic Analysis
Grading/Contouring and Landscape	Detention Basin Shape and Extent	Storage - Routing Analysis
Location, Alignment and Extent of Trail Path and Other Facilities	Trails and Other Recreational Facilities	2 - 10 Year Frequency Storage Below Trails and Recreation Facilities
Mitigation by Enhancing, Restoring and Preserving Riparian Landscape	Riparian Habitat	Channel/Floodplain Roughness

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Channel Lining Matrix

TABLE 5-1
DESERT RIDGE DRAINAGE MASTER PLAN
COMPARISON OF DIFFERENT CHANNEL LININGS

Lining	Description	Application	Cost	Sediment Transport Characteristics	Erosion Protection	Soil Condition
Soil cement	- Designed mixture of soil and portland cement compacted at a proper water content to form a veneer/structure to prevent erosions	- Drop structures - Channel banks - Channel bottoms	- Moderately high	- Excellent	- Excellent	- Arid
Riprap	- Graded dumped riprap to prevent erosion	- Drop structures - Channel banks - Channel bottoms - Channel outlet - Culvert outlet - Spillways	- Moderately high	- Fair	- Excellent	- Arid or wet/irrigate
Armor-flex	- Cellular concrete blocks interlocked and joined with cables to form a mat. 20% of block area is open to allow for vegetation growth.	- Drop structures - Channel banks - Channel bottoms	- High	- Excellent	- Excellent	- Arid or wet/irrigate
Armater	- Semi-rigid geomatrix of hexagonal cells made of polyester fabric and filled with native soil or gravel or other aggregate.	- Drop structures - Channel banks - Channel bottoms	- Moderate	- Good	- Good	- Arid or wet/irrigate
Enkamat	- 3-D geomatrix of heavy nylon monofilaments fused at their intersections. 90% of geomatrix is open space.	- Channel banks - Channel bottoms	- Moderate	- Fair	- Fair	- Wet/irrigated
Nevada Mat		- Channel banks - Channel bottoms	- Moderate	- Good	- Good	- Arid or wet/irrigate
Grass	Irrigated turf continued from golf course into channel.	- Channel banks - Channel bottoms	- Moderate	- Fair	- Fair	- Wet/irrigated
Earth	- Natural excavated earth sides and bottom	- Channel banks - Channel bottoms	- Low	- Good	- Fair	- Arid or wet/irrigate

Setback Analysis Based on Sediment Transport Deficit Volume Distribution

- Sediment-Transport Relationships
- Water Discharge v. Sediment Discharge
- Analysis of Sediment Volumes
- Erosion Hazard Potential as a Function of Sediment Volume Deficit
- Results

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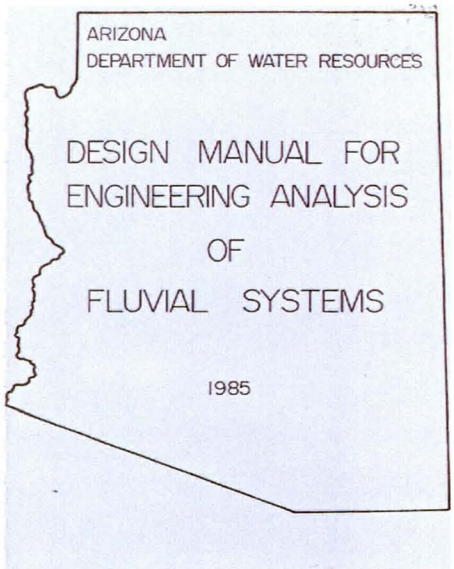

Sediment Transport Criteria and Guidelines - by ADWR

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	COMPARISON OF PREDICTED 100-YEAR SINGLE EVENT AND 100-YEAR ANNUALIZED SETBACK DISTANCES TO OVERBANK WIDTHS		
STUDY REACH	100-YEAR SINGLE-EVENT SETBACK DISTANCE	RECOMMENDED 100-YEAR "ANNUALIZED" SETBACK DISTANCE	OVERBANK WIDTH†
WEST WASH	50 feet	60 feet	51 feet
EAST WASH	55 feet	75 feet	36 feet
OUTFALL CHANNEL	60 feet	65 feet	(N/A for Temporary Channel)

†From: Preliminary Drainage Report for Desert Ridge, Phase 2, Superblock 4 (BRW, March 1996)

Setback Analysis Results

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Final Analysis/Design of Flood Control System

Landscape Architecture / Environmental/Planning	Refinement of Preliminary Design	Water Resources/Geomorphology Geotechnical/Structural
Final Contouring	Final Grading Plan	Final Backwater Analysis
Aesthetic Design Of Superstructure	Bridges/Culverts and Grade Control Structures	Structural and Hydraulic Design
Placement of Hardy "Native" Vegetation	Localized Reinforced Turf	Erosion/Scour Protection with Geosynthetic Fabric Below Ground
Shaping and Vegetative Treatment	Berms/Levees at Fringes Of Floodplain	Cut Off Walls Below Ground
Compatibility of Softer Features with Structural Elements	Construction Plans And Specifications	Structural Design Amenable to Landscape Treatment
Consideration of Planting Times and Riparian Issues	Construction Sequencing	Infrastructural Construction
Ecological, Archaeological, Cultural and Biological Study	Environmental and Other Permits	Backup Engineering Analysis

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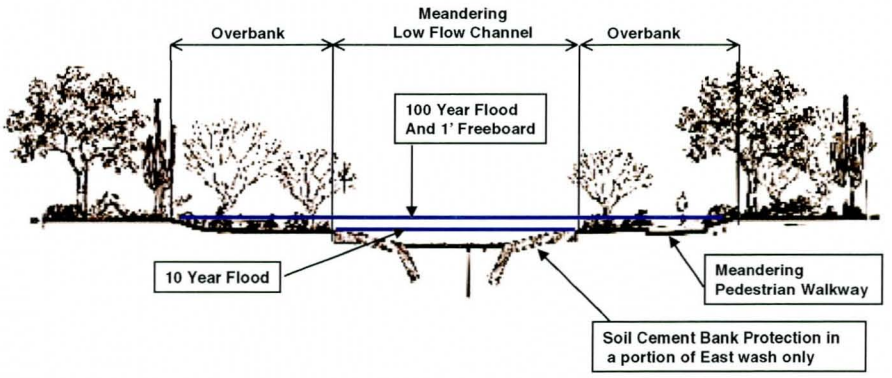
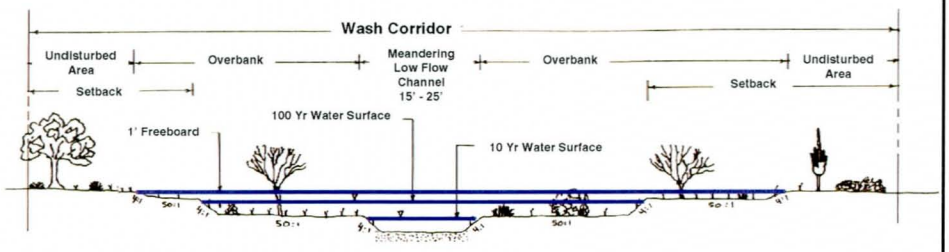


Pseudo "Natural" Wash Corridor - Typical Section



Natural Wash Corridor - Typical Section

West wash

- View of the meandering channel
- Golf course trails and other recreational use

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West Wash
- A more or less straight reach
- Setback provided by vegetated buffer / mitigated area to right

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An island in the wash
- Split flows

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Sediment from the McDowell Mountains
- **A size 7 1/2 shoe vs. grain size**

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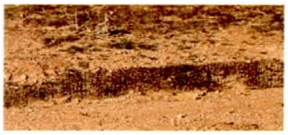

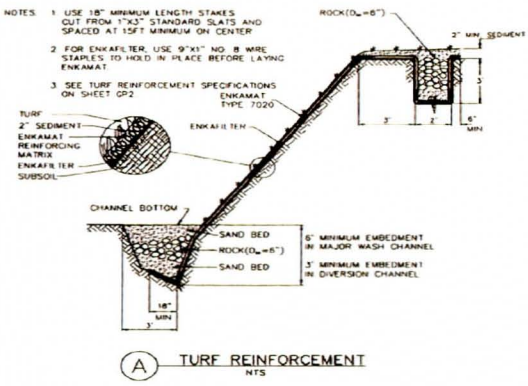

Protection of Washes

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Preservation of Natural Washes With Non-Structural Measures e.g. setbacks

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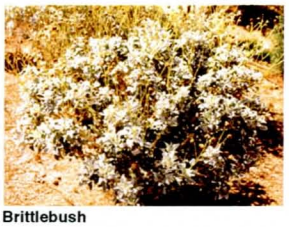
Creosote Bush

Curly Mesquite

Saltbush



Brittlebush

Desert Marigold

Provision of Native Grasses, Shrubs,Trees and Cacti

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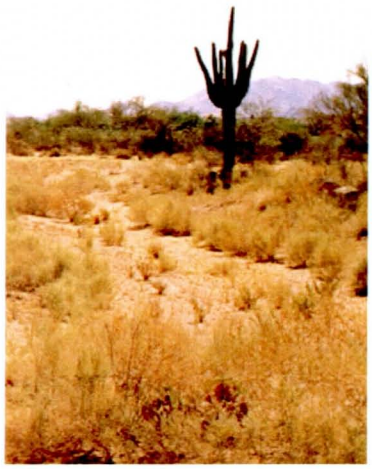

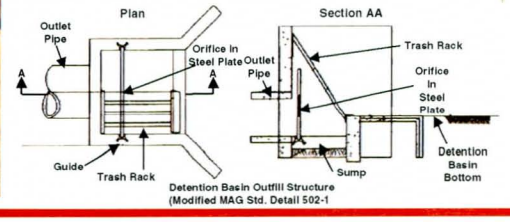

Typical detention basin and inlet/outlet off the wash corridors

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Downstream of the split flow culvert

- **Energy dissipater below culvert**
- **Turf reinforcement on left bank**

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Upstream of split flow culvert
- **Grade control structure above culvert**
- **Split flow keeps underpass dry**

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Summary

- A rational, cost-effective and aesthetically pleasing design blends in with the existing/proposed land development scheme
- Unique features of the design approach:
  - Analysis of existing washes
  - Equilibrium slope analysis
  - Interactive design with resources engineers, planners landscape architects and biologists
  - Setback analysis using a detailed sediment transport procedure to take advantage of golf course and vegetative buffer areas
  - Ease of acceptance by city and other reviewers

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