Bullard Wash
MANNING'S 'n' VALUES DETERMINATION REPORT

Loop 303 Corridor/White Tanks
Area Drainage Master Plan Update
Contract FCD 99-40

Prepared for

Flood Control District of Maricopa County

URS

URS Job No. E1-00001526

November 4, 2002

MANNING'S 'n' VALUE DETERMINATIONS REPORT

I. INTRODUCTION

An initial field reconnaissance investigation was conducted on June 27, 2001 to visit study areas, evaluate field conditions, and prepare a preliminary photographic log. Photographic documentation was also collected by the survey crew during their field work at representative cross sections and road crossings. Other site visits conducted to evaluate flooding conditions and direction of flow were also used to verify 'n' values estimates, such visits include a visit to Perryville Wash on January 7, 2001, and another to Camelback Wash on January 22, 2001. Photographic documentation for the estimation of Manning's 'n' values was done for these areas in, and adjacent to, I-10 Culvert Wash, Perryville Wash, Bullard Wash, and Camelback Road Wash.

II. METHODOLOGY

Manning's 'n' values were assigned based on field observation using the methodology described in ***Estimated Manning's Roughness Coefficients for Stream Channels and Flood Plains in Maricopa County, Arizona***, a manual prepared by the U.S. Geological Survey for the FCDMC. A base 'n' value (n_b) was assigned according to the bed material. In accordance with the manual, adjustments to the base value were then made to account for factors affecting the roughness characteristics such as degree of surface irregularity (n_1), effects of obstructions (n_2), and vegetation (n_3). The composite value of n was computed using the following equation:

$$n = n_b + n_1 + n_2 + n_3$$

Typical photographs and calculations for the 'n' values for the areas are included in this report.

III. PHOTOGRAPHS AND 'n' VALUE ASSIGNMENTS

Along with the calculations for the 'n' value assignments, photographs are provided to illustrate typical conditions that exist in four different study areas, which are Bullard Perryville Wash, Bullard Wash, Camelback Wash, and I-10 Culvert Wash. Base n values used in all four study reaches are listed in the following table.

Channel Material	'n_b' Value
Undisturbed Desert or Agricultural Lands	0.022 – 0.028
Asphalt	0.016

Registered Professional Engineer (Civil) CERTIFICATE NO. 21674 ROBERT L. DAVIES Date Signed 11-04-02 ARIZONA, U.S.A.

Robert L Davies

Examples of Manning's 'n' estimates at representative locations of the four washes are included in the next few pages, followed by a detailed listing of 'n' values and corresponding pictures at each cross section for the washes covered by this study.

LOCATION: **Perryville Wash Cross Section 33**

CROSS SECTION DESCRIPTION: **Undisturbed Desert** (Photographs 1 - 3).

'n' VALUE CALCULATION

Portion of Cross section	Components	Composite Values
Channel	$n_b = 0.024$	
	$n_1 = 0.005$	
	$n_2 = 0.002$	
	$n_3 = 0.005$	**n = 0.036**
Left Overbank	$n_b = 0.024$	
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	**n = 0.043**
Right Overbank	$n_b = 0.024$	
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	**n = 0.043**

Photo 1. Perryville Wash from Cross Section 33 looking downstream.

Photo 2. Perryville Wash Left Overbank from Cross Section 33.

Photo 3. Right overbank area at Cross Section 33.

LOCATION: **Bullard Wash Cross Section 27**

CROSS SECTION DESCRIPTION: (Photographs 4 - 6).

'n' VALUE CALCULATION

Portion of Cross section	Components	Composite Values
Channel	$n_b = 0.024$	
	$n_1 = 0.003$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	**n =0.04**
Left Overbank	$n_b = 0.024$	
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.015$	**n = 0.045**
Right Overbank	$n_b = 0.024$	
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.015$	**n = 0.045**

Photo 4. Bullard Wash from Cross Section 27 looking downstream.

Photo 5. Left overbank area at Cross Section 27.

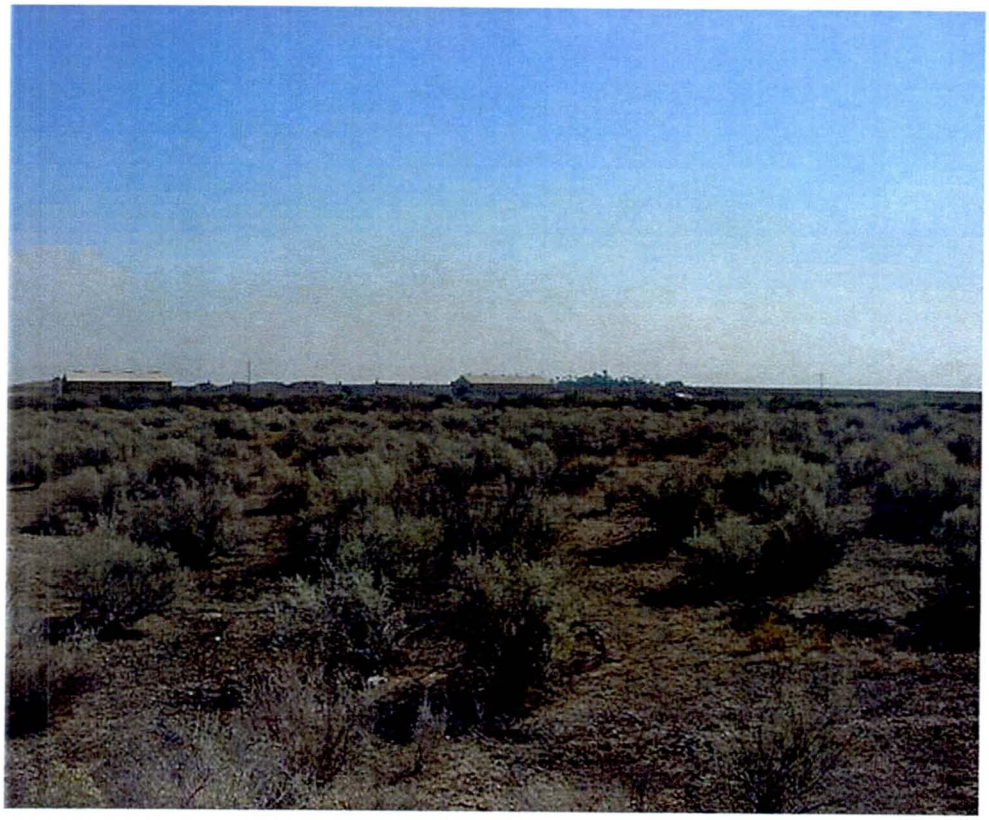


Photo 6. Right overbank area at Cross Section 27.

LOCATION: **Camelback Wash Cross Section 36**

CROSS SECTION DESCRIPTION: (Photographs 7 - 9).

'n' VALUE CALCULATION

Portion of Cross section	Components	Composite Values
Channel	$n_b = 0.016$	
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.001$	**n = 0.021**
Left Overbank	$n_b = 0.24$	
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.03$	**n = 0.06**
Right Overbank	$n_b = 0.024$	
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	**n = 0.03**

Photo 7. Camelback Wash from Cross Section 36 looking upstream.

Photo 8. Left overbank area from Cross Section 36.

Photo 9. Right overbank area from Cross Section 36.

LOCATION: **Beardsley Wash Cross Section 10**

CROSS SECTION DESCRIPTION: (Photographs 10 - 12).

'n' VALUE CALCULATION

Portion of Cross section	Components	Composite Values
Channel	$n_b = 0.024$	
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	**n = 0.03**
Left Overbank	$n_b = 0.024$	
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.005$	**n = 0.032**
Right Overbank	$n_b = 0.024$	
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.005$	**n = 0.032**

Photo 10. Beardsley Wash from Cross Section 10 looking downstream.

Photo 11. Left overbank area from Cross Section 10.

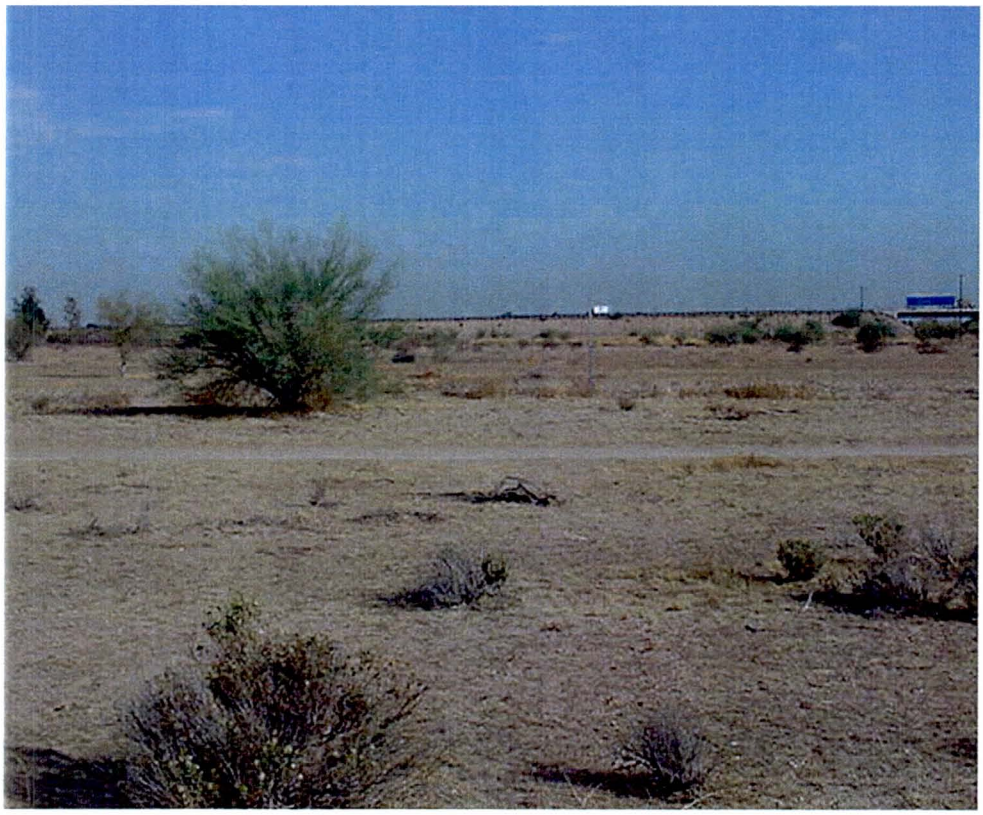


Photo 12. Right overbank area from Cross Section 10.

BULLARD WASH
Manning's n Summary Table
Area D/S of LAFB

Cross Section #	LOB	Channel	ROB
1	0.031	0.032	0.031
2	0.03	0.032	0.03
3	0.03	0.032	0.031
4	0.03	0.048	0.031
5	0.029	0.038	0.031
6	0.029	0.031	0.031
7	0.029	0.031	0.031
8	0.029	0.031	0.031
9	0.029	0.032	0.031
10	0.03	0.031	0.031
11	0.033	0.032	0.031
12	0.03	0.031	0.03
13	0.03	0.03	0.03
14	0.03	0.031	0.03
15	0.03	0.031	0.03
16	0.03	0.031	0.03
17	0.03	0.032	0.03
18	0.03	0.049	0.03
19	0.038	0.043	0.039
20	0.038	0.043	0.039
21	0.038	0.043	0.039
22	0.039	0.043	0.039
23	0.039	0.043	0.039
24	0.039	0.043	0.039
25	0.039	0.043	0.039
26	0.039	0.043	0.039

Cross Section 1

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.004$	
Channel	$n_b = 0.024$	0.032
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.004$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 2

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.003$	
Channel	$n_b = 0.024$	0.032
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.004$	
Right Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.003$	

Cross Section 3

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.032
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.004$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 4

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel*	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Fill has been placed in the channel. Need to verify with FCD and reduce n_2 if fill will be removed.

* Verified with Michael Duncan of FCDMC that fill will be removed and n value was reduced.

Cross Section 5

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.029
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.01$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 6

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.029
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 7

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.029
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 8

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.029
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 9

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.029
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.032
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.004$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 10

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 11

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.033
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.005$	
Channel	$n_b = 0.024$	0.032
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.004$	
Right Over Bank	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	

Cross Section 12

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	

Cross Section 13

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Right Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	

Cross Section 14

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	

Cross Section 15

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	

Cross Section 16

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.031
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	

Cross Section 17

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.032
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.003$	
Right Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	

Cross Section 18

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	
Channel	$n_b = 0.024$	0.049
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.02$	
Right Over Bank	$n_b = 0.024$	0.03
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.002$	

channel n3 value of .02 is based on photo #335 from the June 27 field visit.

Cross Section 19

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.01$	
Channel	$n_b = 0.024$	0.043
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	
Right Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	

channel n3 based on photos A4 and A5 of survey data.

Cross Section 20

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.01$	
Channel	$n_b = 0.024$	0.043
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	
Right Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	

Cross Section 21

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	
Channel	$n_b = 0.024$	0.043
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	
Right Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	

Cross Section 22

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	
Channel	$n_b = 0.024$	0.043
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	
Right Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	

Cross Section 23

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	
Channel	$n_b = 0.024$	0.043
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	
Right Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	

Cross Section 24

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	
Channel	$n_b = 0.024$	0.043
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	
Right Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	

Cross Section 25

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	
Channel	$n_b = 0.024$	0.043
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	
Right Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	

Cross Section 26

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	
Channel	$n_b = 0.024$	0.043
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.015$	
Right Over Bank	$n_b = 0.024$	0.039
	$n_1 = 0.002$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	

Bulldog Wash D/S of LAFB

A1

577 - X-section 15 ROB looking north

A2

578 - X-section 15 ROB looking south

579 - X-section 15 ROB looking east

A3

580 - X-section 15 channel looking north

A4

A5

581 - X-section 15 channel looking south

A6

582 - X-section 15 LOB looking north

583 - X-section 15 LOB looking south

A7

584

A8

A9

585

A10

586

587

A11

588

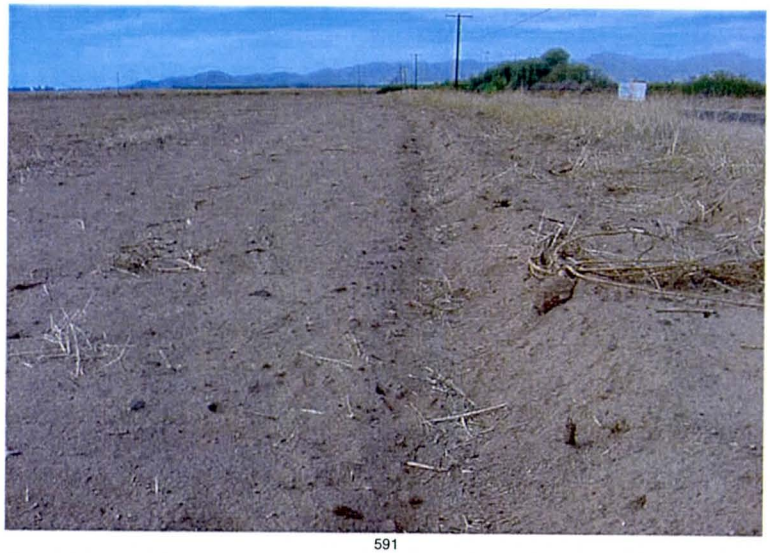
B1

B2

589

B3

590



591

B4

592

B5

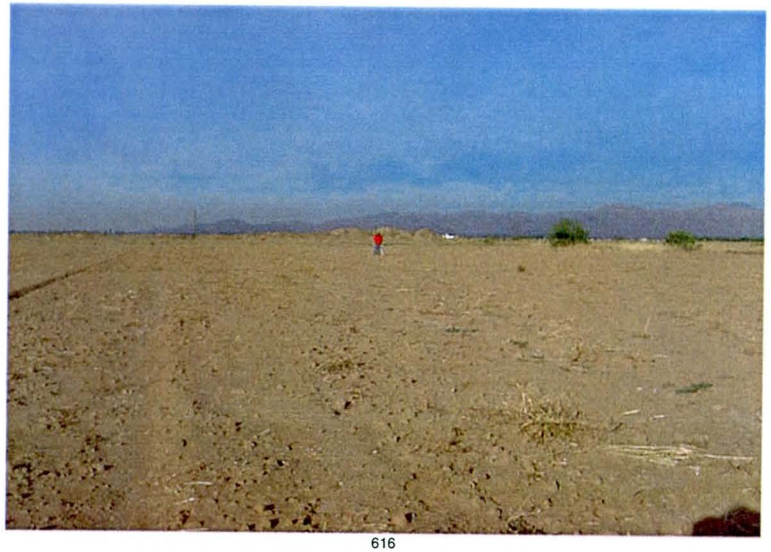
B 6

593

B7

614

615



616

B 8

B 9

B10

617

B11

618

619

B12

620

B13

B14

621

B15

622

623

C1

624

C2

C3

625

C4

626

627

C5

628

C6

C7

629

C8

630

631

632

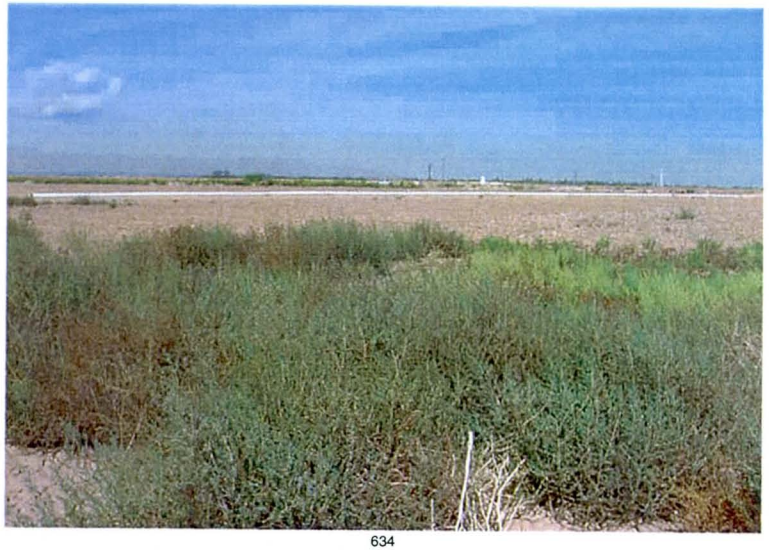
C9

C10

C11

633

C12



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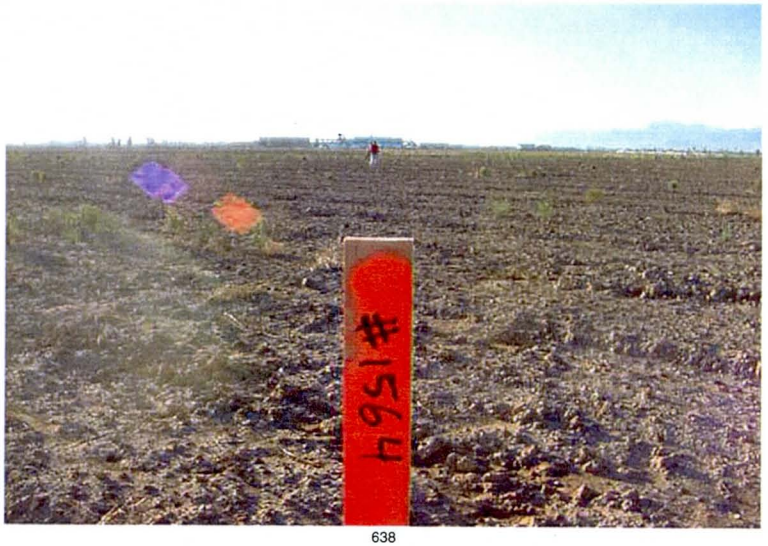

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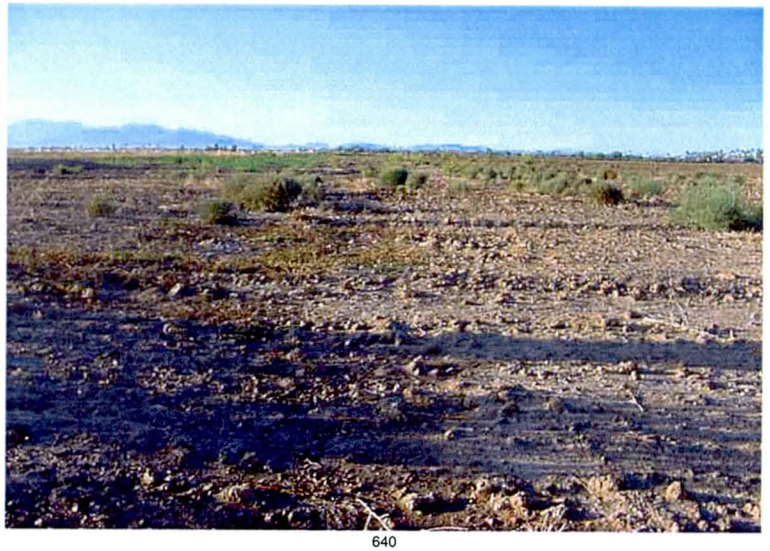

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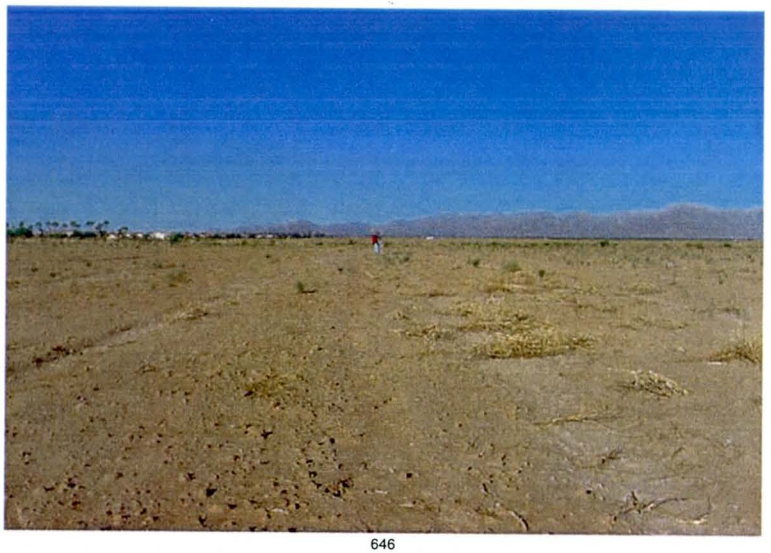

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Channel

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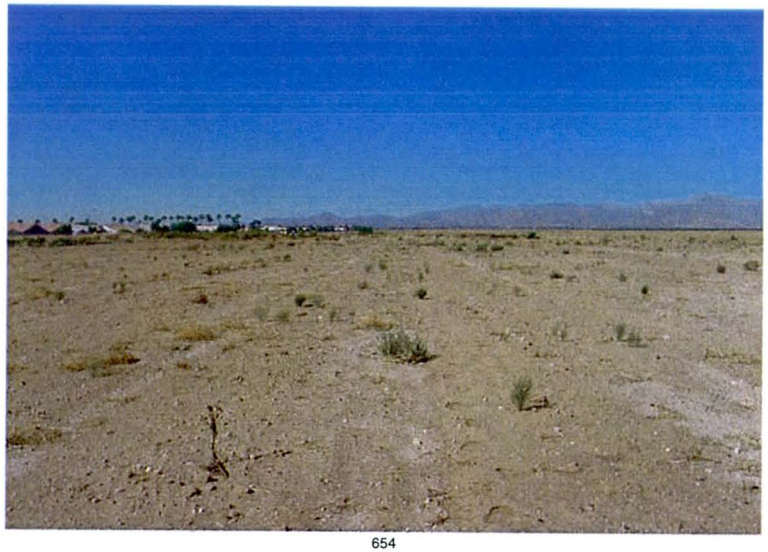

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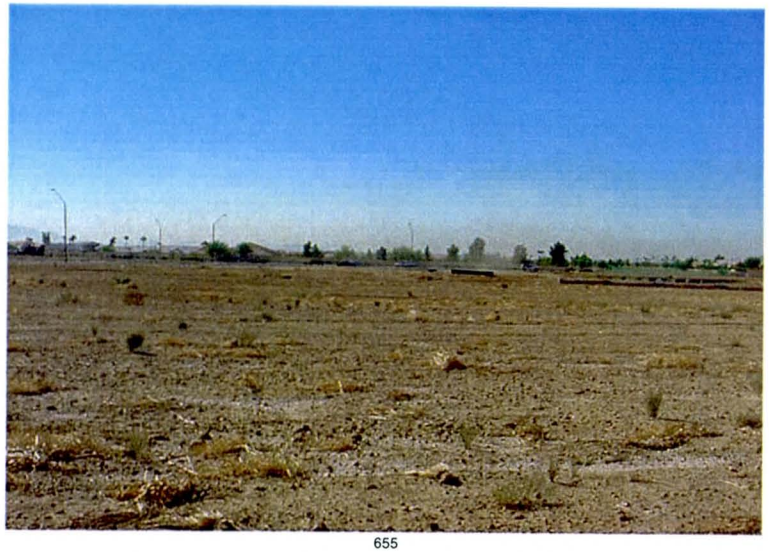
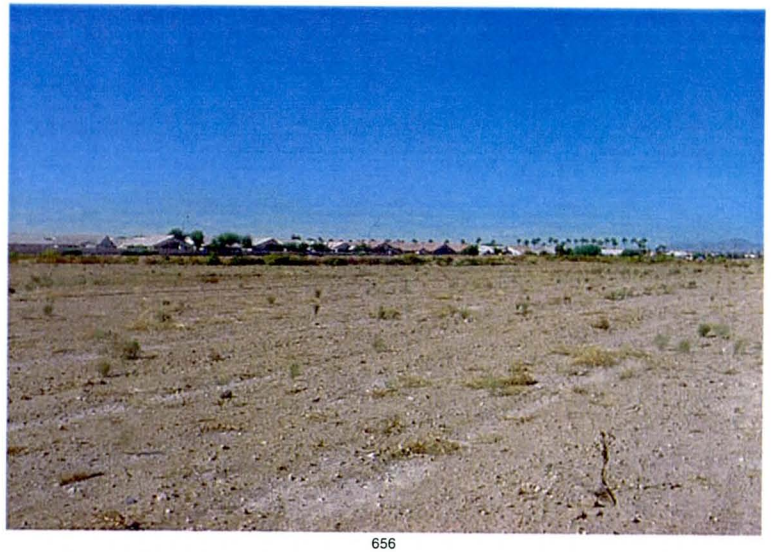


655

D17



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BULLARD WASH
Manning's n Summary Table
Area U/S at LAFB

Cross Section #	LOB	Channel	ROB
27	0.045	0.04	0.045
28	0.045	0.04	0.045
29	0.06	0.055	0.042
30	0.032	0.055	0.047
31	0.047	0.055	0.047
32	0.047	0.055	0.047
33	0.053	0.055	0.053
34	0.048	0.055	0.048
35	Road profile used in culvert modeling		
36	Horizontal variation in n values		
37	Horizontal variation in n values		
38	Horizontal variation in n values		
39	Horizontal variation in n values		
40	Horizontal variation in n values		
41	Horizontal variation in n values		
42	Horizontal variation in n values		
43	Horizontal variation in n values		
44	Horizontal variation in n values		
45	Horizontal variation in n values		
46	Horizontal variation in n values		
47	0.063	0.063	0.063
48	0.063	0.063	0.063
49	0.063	0.063	0.063
50	0.063	0.063	0.063

Cross Section 27

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.045
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.015$	
Channel	$n_b = 0.024$	0.04
	$n_1 = 0.003$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	
Right Over Bank	$n_b = 0.024$	0.045
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.015$	

Cross Section 28

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.045
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.015$	
Channel	$n_b = 0.024$	0.04
	$n_1 = 0.003$	
	$n_2 = 0.003$	
	$n_3 = 0.01$	
Right Over Bank	$n_b = 0.024$	0.045
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.015$	

Cross Section 29

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.06
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.03$	
Channel	$n_b = 0.024$	0.055
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.025$	
Right Over Bank	$n_b = 0.024$	0.042
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.015$	

Cross Section 30

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.032
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.005$	
Channel	$n_b = 0.024$	0.055
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.025$	
Right Over Bank	$n_b = 0.024$	0.047
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.02$	

Cross Section 31

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.047
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.02$	
Channel	$n_b = 0.024$	0.055
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.025$	
Right Over Bank	$n_b = 0.024$	0.047
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.02$	

Cross Section 32

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.047
	$n_1 = 0.003$	
	$n_2 = 0.015$	
	$n_3 = 0.005$	
Channel	$n_b = 0.024$	0.055
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.025$	
Right Over Bank	$n_b = 0.024$	0.047
	$n_1 = 0.002$	
	$n_2 = 0.001$	
	$n_3 = 0.02$	

Cross Section 33

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.053
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.025$	
Channel	$n_b = 0.024$	0.055
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.025$	
Right Over Bank	$n_b = 0.024$	0.053
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.025$	

Cross Section 34

Portion of Cross Section	Components	Composite Values
Left Over Bank	$n_b = 0.024$	0.048
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.02$	
Channel	$n_b = 0.024$	0.055
	$n_1 = 0.002$	
	$n_2 = 0.004$	
	$n_3 = 0.025$	
Right Over Bank	$n_b = 0.024$	0.048
	$n_1 = 0.002$	
	$n_2 = 0.002$	
	$n_3 = 0.02$	

Cross Section 35 **Roadway info for culvert. No n estimates necessary**

Portion of Cross Section	Components	Composite Values
Left Over Bank	n_b =	0
	n_1 =	
	n_2 =	
	n_3 =	
Channel	n_b =	0
	n_1 =	
	n_2 =	
	n_3 =	
Right Over Bank	n_b =	0
	n_1 =	
	n_2 =	
	n_3 =	

Cross Section 36

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b =$	0
	$n_1 =$	
	$n_2 =$	
	$n_3 =$	
Right Over Bank (paved)	$n_b = 0.016$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	
Right Over Bank (grass air field)	$n_b = 0.024$	0.036
	$n_1 = 0.002$	
	$n_2 = 0.005$	
	$n_3 = 0.005$	

*Base value of 0.016 based on USDOT pavement standard

no defined channel in urban area

old station	STATION	ELEVATION	n
0	8919.43	1070.35	0.063
0.644	8920.08	1069.9	0.063
2.547	8921.98	1069.83	0.063
12.935	8932.37	1069.95	0.063
28.307	8947.74	1069.81	0.063
28.9	8948.33	1070.24	0.063
33.01	8952.44	1070.12	0.063
33.58	8953.01	1069.59	0.063
63.411	8982.84	1069.1	0.063
95.63	9015.06	1068.7	0.063
97.295	9016.73	1068.58	0.063
98.302	9017.73	1069.18	0.063
103.332	9022.76	1069.26	0.063
152.72	9072.15	1069.11	0.063
193.288	9112.72	1068.7	0.063
250.61	9170.04	1068.38	0.063
298.975	9218.41	1067.8	0.063
307.987	9227.42	1067.57	0.063
313.219	9232.65	1067.4	0.063
313.809	9233.24	1066.96	0.063
315.153	9234.59	1066.96	0.063
337.986	9257.42	1066.51	0.063
472.967	9392.4	1067.58	0.063
548.171	9467.6	1066.7	0.063
587.643	9507.08	1068.51	0.063
635.764	9555.2	1069.33	0.063

703.073	9622.51	1069.47	0.063
793.885	9713.32	1068.92	0.063
895.187	9814.62	1068.75	0.063
898.657	9818.09	1068.68	0.063
908.244	9827.68	1067.78	0.063
909.643	9829.08	1067.84	0.063
925.088	9844.52	1067.89	0.063
1052.185	9971.62	1068.27	0.063
1067.878	9987.31	1067.96	0.063
1069.151	9988.58	1067.89	0.063
1069.738	9989.17	1068.36	0.063
1077.911	9997.34	1066.81	0.063
1080.567	10000	1066.11	0.063
1082.578	10002.01	1066.04	0.063
1085.185	10004.62	1066.82	0.063
1092.191	10011.62	1067.27	0.063
1092.84	10012.27	1066.8	0.063
1094.138	10013.57	1066.87	0.063
1121.97	10041.4	1067.29	0.063
1184.158	10103.59	1068.09	0.063
1219.087	10138.52	1068.84	0.063
1295.109	10214.54	1068.74	0.063
1341.351	10260.78	1068.77	0.063
1369.243	10288.68	1068.77	0.038
1482.217	10401.65	1069.78	0.038
1730.708	10650.14	1069.43	0.038
1874.007	10793.44	1069.02	0.038
2080.145	10999.58	1068.93	0.038
2175.494	11094.93	1067.67	0.038
2283.955	11203.39	1070.79	0.038
2396.771	11316.2	1071.84	0.038
2438.671	11358.1	1071.47	0.038
2453.235	11372.67	1071.13	0.038
2462.16	11381.59	1070.96	0.038
2468.934	11388.37	1071	0.038
2480.344	11399.78	1070.79	0.036
2548.965	11468.4	1069.69	0.036
2741.793	11661.23	1070.01	0.036

Cross Section 37

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (paved air field)	$n_b = 0.016$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	
Right Over Bank (grass air field)	$n_b = 0.024$	0.036
	$n_1 = 0.002$	
	$n_2 = 0.005$	
	$n_3 = 0.005$	

old station	STATION	ELEVATION	n
0	8853.07	1069.96	0.063
28.575	8881.65	1070.13	0.063
45.839	8898.91	1069.95	0.063
46.44	8899.51	1070.44	0.063
50.81	8903.88	1070.43	0.063
51.394	8904.46	1069.92	0.063
85.349	8938.42	1069.63	0.063
120.771	8973.84	1069.51	0.063
120.952	8974.02	1069.23	0.063
125.053	8978.12	1069.39	0.063
179.356	9032.43	1069.58	0.063
252.209	9105.28	1067.61	0.063
297.843	9150.91	1070.22	0.063
298.69	9151.76	1069.63	0.063
300.536	9153.61	1069.61	0.063
309.874	9162.95	1069.6	0.063
383.365	9236.44	1069.62	0.063
410.623	9263.69	1070.08	0.063
423.053	9276.12	1068.04	0.063
428.808	9281.88	1069.38	0.063
465.523	9318.59	1070.56	0.063
488.729	9341.8	1070.9	0.063
506.261	9359.33	1070.76	0.063
613.238	9466.31	1069.63	0.063
639.006	9492.08	1069.7	0.063
662.707	9515.78	1069.84	0.063
704.831	9557.9	1069.93	0.063

708.762	9561.83	1069.88	0.063
710.063	9563.13	1070.39	0.063
742.902	9595.97	1070.39	0.063
765.904	9618.98	1079.86	0.063
766.415	9619.49	1079.36	0.063
767.915	9620.99	1079.36	0.063
795.82	9648.89	1069.49	0.063
824.285	9677.36	1069.27	0.063
827.303	9680.37	1069.22	0.063
828.476	9681.55	1069.72	0.063
850.805	9703.88	1070.04	0.063
873.005	9726.08	1070.02	0.063
874.031	9727.1	1069.51	0.063
876.307	9729.38	1069.59	0.063
941.923	9794.99	1069.45	0.063
1000.358	9853.43	1069.09	0.063
1001.848	9854.92	1068.99	0.063
1002.446	9855.52	1069.64	0.063
1012.797	9865.87	1070.04	0.063
1027.302	9880.37	1069.41	0.063
1028.08	9881.15	1068.88	0.063
1029.424	9882.49	1068.97	0.063
1069.313	9922.38	1068.85	0.063
1145.438	9998.51	1069.06	0.063
1146.932	10000	1069.01	0.063
1147.583	10000.65	1069.52	0.063
1158.975	10012.05	1070.04	0.063
1173.264	10026.33	1069.55	0.063
1173.911	10026.98	1068.99	0.063
1175.269	10028.34	1069.01	0.063
1197.566	10050.64	1069.58	0.063
1198.932	10052	1069.55	0.063
1199.666	10052.74	1070.09	0.038
1238.187	10091.26	1069.91	0.038
1364.702	10217.77	1069.94	0.038
1425.649	10278.72	1069.88	0.038
1435.672	10288.74	1069.33	0.038
1624.806	10477.88	1069.87	0.038
1690.229	10543.3	1071.33	0.038
1700.363	10553.43	1071.66	0.038
1738.018	10591.09	1071.98	0.038
1775.299	10628.37	1071.56	0.036
1824.284	10677.36	1070.89	0.036
1835.75	10688.82	1070.87	0.036
1975.156	10828.23	1070.86	0.036

Cross Section 38

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (paved air field)	$n_b = 0.016$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	
Right Over Bank (grass air field)	$n_b = 0.024$	0.036
	$n_1 = 0.002$	
	$n_2 = 0.005$	
	$n_3 = 0.005$	

station	elevation	n
9035.41	1070.64	0.063
9081	1070.13	0.063
9308.37	1069.01	0.063
9395.51	1069.53	0.063
9596.3	1071.27	0.038
9772.16	1072.87	0.038
10000	1071.21	0.038
10037.67	1072.03	0.038
10074.99	1071.63	0.038
10127.44	1071.44	0.038
10138.92	1071.44	0.036
10316.87	1071.81	0.036
10503	1072.19	0.036

Cross Section 39

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (paved air field)	$n_b = 0.016$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	
Right Over Bank (grass air field)	$n_b = 0.024$	0.036
	$n_1 = 0.002$	
	$n_2 = 0.005$	
	$n_3 = 0.005$	

station	elevation	n
8957.06	1070.64	0.063
8999.19	1070.04	0.063
9208.92	1069.04	0.063
9283.92	1069	0.063
9330.88	1069.4	0.038
9557.86	1071.1	0.038
9811.65	1073.06	0.038
9968.28	1071.25	0.038
10000	1070.58	0.038
10148.15	1071.37	0.038
10190.62	1071.67	0.038
10233.06	1071.31	0.038
10298.4	1071.71	0.038
10311.85	1071.89	0.038
10423.4	1071.93	0.038
10599.34	1072.33	0.036
10863.48	1073.3	0.036

Cross Section 40

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (paved air field)	$n_b = 0.016$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	
Right Over Bank (grass air field)	$n_b = 0.024$	0.036
	$n_1 = 0.002$	
	$n_2 = 0.005$	
	$n_3 = 0.005$	

station	elevation	n
8411.94	1072.16	0.063
8463.31	1072.2	0.063
8490.65	1071.84	0.063
8511.78	1071.54	0.063
8539.45	1072.01	0.063
8646.33	1071.61	0.063
8769.52	1071.51	0.038
9010.16	1071.85	0.038
9207.95	1072.08	0.038
9402.82	1072.54	0.038
9601.44	1073.18	0.038
9710.62	1072.57	0.038
9810.53	1071.42	0.038
10000	1071.18	0.038
10194.42	1071.46	0.038
10372.96	1072.11	0.038
10567.5	1072.51	0.038
10761.36	1073.02	0.038

Cross Section 41

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (paved air field)	$n_b = 0.016$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	
Right Over Bank (grass air field)	$n_b = 0.024$	0.036
	$n_1 = 0.002$	
	$n_2 = 0.005$	
	$n_3 = 0.005$	

station	elevation	n
8640.83	1074.91	0.038
8720.45	1074.55	0.038
8780.45	1073.19	0.038
8814.17	1073.14	0.038
8953.98	1072.33	0.038
9108.31	1072.54	0.038
9286.84	1072.64	0.038
9470.84	1073.79	0.038
9585.28	1073.73	0.038
9733.75	1072.24	0.038
9791.11	1071.81	0.038
9857.62	1071.55	0.038
9970.13	1071.56	0.038
10000	1067.94	0.036
10028.4	1068.18	0.036
10119.34	1071.38	0.036
10145.63	1068.43	0.036
10284.78	1068.38	0.036
10498.96	1068.51	0.036
10516.55	1071.8	0.036
10522.14	1070.87	0.036
10526.31	1071.76	0.036
10566.95	1072.03	0.036
10590.98	1072.05	0.036
10630.43	1072.38	0.036
10670.13	1072.13	0.036

10735.48	1072.39	0.036
10745.29	1072.25	0.036
10759.71	1069.2	0.036
10957.28	1068.7	0.036
11152.99	1068.97	0.036
11362.39	1069.42	0.036
11400.2	1073.07	0.036
11431.66	1073.36	0.036
11623.95	1073.77	0.036
11724.01	1074.23	0.036
11753.14	1074.33	0.036
11806.57	1074.38	0.036

Cross Section 42

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (paved air field)	$n_b = 0.016$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	
Right Over Bank (grass air field)	$n_b = 0.024$	0.036
	$n_1 = 0.002$	
	$n_2 = 0.005$	
	$n_3 = 0.005$	

station	elevation	n
8728.03	1075.1	0.038
8853.09	1074.4	0.038
8996.78	1073.67	0.038
9194.62	1072.67	0.038
9400.82	1072.19	0.038
9601.32	1072.39	0.038
9831.74	1072.42	0.038
9885.89	1072.79	0.038
9891.57	1072.34	0.038
9920.12	1072.17	0.038
10000	1072.12	0.038
10105.08	1072.4	0.038
10126.15	1072.18	0.036
10161.35	1072.3	0.036
10173.47	1072.27	0.036
10347.34	1072.7	0.036
10359.52	1073.27	0.036
10379.4	1073.2	0.036
10488.45	1073.2	0.036
10508.35	1073.22	0.036
10520.33	1072.77	0.036
10687.05	1072.88	0.036
10711.53	1073.03	0.036
10750.59	1073.33	0.036
10789.97	1072.97	0.036
10856.33	1073.24	0.036

10973.06	1073.17	0.036
11030.3	1074.51	0.036
11062.68	1074.45	0.036
11073.57	1074.06	0.036
11085.54	1074.55	0.036
11126.28	1074.47	0.036
11211.78	1073.97	0.036
11326.57	1074.08	0.036
11517.54	1074.25	0.036
11721.21	1075.22	0.036

Cross Section 43

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (paved air field)	$n_b = 0.016$	0.038
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	
Right Over Bank (grass air field)	$n_b = 0.024$	0.036
	$n_1 = 0.002$	
	$n_2 = 0.005$	
	$n_3 = 0.005$	

station	elevation	n
8787.64	1075.09	0.038
8999.41	1076.12	0.038
9179.42	1075.64	0.038
9377.33	1074.66	0.038
9575.44	1073.83	0.038
9775.7	1072.87	0.038
9948.4	1071.96	0.038
10000	1071.68	0.038
10197.43	1071.82	0.038
10397.29	1072.08	0.038
10597.31	1072.29	0.038
10797.18	1072.57	0.038
10997.24	1072.76	0.038
11217.42	1073.05	0.038
11417.27	1073.29	0.038
11617.17	1073.5	0.038
11849.8	1073.84	0.038

Cross Section 44

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	

station	elevation	n
9115.2	1075.2	0.038
9148.4	1075	0.038
9174.3	1074.9	0.038
9175.1	1075.4	0.038
9318.4	1075	0.063
9319.1	1074.3	0.063
9320.8	1074.4	0.063
9370.3	1073.9	0.063
9372.2	1073.8	0.063
9373	1074.3	0.063
9382	1074.2	0.063
9449.5	1074.1	0.063
9458	1074	0.063
9459.2	1073.5	0.063
9461.1	1073.5	0.063
9503.6	1074	0.063
9540.7	1074.3	0.063
9542.6	1074.2	0.063
9543.6	1074.8	0.063
9552.1	1075.1	0.063
9560	1074.8	0.063
9560.8	1074.2	0.063
9562.5	1074.2	0.063
9585.7	1075	0.063
9606.2	1074.6	0.063
9799.8	1073.2	0.063
9983.9	1072.9	0.063
10000	1073	0.063
10015.6	1072.9	0.063
10209.2	1073.1	0.063
10411	1073.3	0.063

10636.2	1073.4	0.063
10650	1073.6	0.063
10664.2	1073.4	0.063
10751.9	1073.5	0.063
10866.1	1073.8	0.063
10879.4	1074.1	0.063
10896.5	1073.7	0.063
10911.2	1073.9	0.063

Cross Section 45

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	

station	elevation	n
8880.4	1077.1	0.063
8957.5	1075.5	0.063
8998.6	1075.8	0.063
9063.9	1075.5	0.063
9067.9	1075.8	0.063
9136.8	1075.4	0.063
9140.8	1075.5	0.063
9264.2	1075.2	0.063
9264.7	1075	0.063
9273.4	1075.1	0.063
9317.2	1074.9	0.063
9318.1	1074.2	0.063
9319.2	1074.2	0.063
9334.4	1074.6	0.063
9365.9	1074	0.063
9511	1073.9	0.063
9758.8	1073.9	0.063
9951.6	1073.7	0.063
9984.1	1073.8	0.063
9999	1073.4	0.063
10000	1073.2	0.063
10000.9	1073.9	0.063
10010.9	1076.5	0.063
10015.5	1077	0.063
10016	1076.7	0.063
10045.8	1076.3	0.063
10071.8	1076.6	0.063
10072.4	1077.1	0.063
10078.4	1077.4	0.063
10090.6	1076.9	0.063
10190.8	1076.1	0.063

10202.2	1076.3	0.063
10202.4	1077.2	0.063
10203.4	1075.6	0.063
10255.9	1074.8	0.063
10320.5	1075.4	0.063
10344.5	1074.5	0.063
10345.2	1074	0.063
10347.1	1074.1	0.063
10367.3	1074.4	0.063
10382.9	1074.8	0.063
10384.9	1074.4	0.063
10385.5	1075.1	0.063
10388.9	1075.1	0.063
10389.5	1074.8	0.063
10391.3	1074.6	0.063
10416.4	1074.7	0.063
10441.1	1074.8	0.063
10443	1074.8	0.063
10443.6	1075.2	0.063
10535.8	1075.3	0.063
10542.8	1075.3	0.063
10550.2	1075.1	0.063
10550.9	1074.6	0.063
10552.8	1074.7	0.063
10579.3	1075	0.063
10604.5	1074.7	0.063
10606.5	1074.6	0.063
10607.1	1075.1	0.063
10626.5	1074.1	0.063
10630.3	1074.1	0.063
10638.4	1073.8	0.063
10639.3	1073.4	0.063
10640.4	1073.4	0.063
10655.3	1074	0.063
10670.1	1073.9	0.063
10688.3	1073.9	0.063
10689.7	1073.9	0.063
10690.3	1074.4	0.063
10695.4	1074.4	0.063
10722.4	1074.4	0.063
10818.4	1074.9	0.063
10845.7	1074.6	0.063
10850.6	1074.7	0.063
10851.4	1074.2	0.063
10852.6	1074.2	0.063
10870.5	1074	0.063
10885.8	1074.4	0.063
10902.1	1073.7	0.063
10917.9	1074.2	0.063

Cross Section46

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	

station	elevation	n
9307.34	1076.73	0.063
9308.04	1076.19	0.063
9309.41	1076.26	0.063
9320.32	1076.21	0.063
9349.34	1076.26	0.063
9350.74	1076.2	0.063
9351.36	1076.7	0.063
9366.6	1075.87	0.063
9367.37	1075.33	0.063
9368.46	1075.34	0.063
9383.58	1075.75	0.063
9415.61	1075.24	0.063
9611.06	1074.73	0.063
9813.17	1074.35	0.063
10000	1074.09	0.063
10017.46	1074.14	0.063
10032.87	1074.4	0.063
10048.27	1074.34	0.063
10049.27	1074.38	0.063
10050.17	1074.88	0.063
10073.5	1074.93	0.063
10092.86	1075.51	0.063
10095.61	1075.01	0.063
10098.45	1075.01	0.063
10124.84	1074.71	0.063
10154.59	1074.74	0.063
10155.9	1074.73	0.063
10156.57	1075.22	0.063
10186.55	1075.29	0.063
10222.97	1074.85	0.063
10226.8	1074.74	0.063

10279.16	1074.55	0.063
10285.1	1074.49	0.063
10354.4	1074.46	0.063
10411.27	1075.6	0.063
10497.36	1075.97	0.063
10555.1	1075.01	0.063
10609.4	1074.99	0.063
10609.95	1074.51	0.063
10668.81	1074.4	0.063
10669.38	1074.88	0.063
10677.16	1074.5	0.063
10680.89	1074.46	0.063
10691.07	1073.81	0.063
10691.65	1073.2	0.063
10692.97	1073.25	0.063
10708.05	1073.94	0.063
10723.43	1073.64	0.063
10724.85	1073.72	0.063
10725.48	1074.21	0.063
10733.51	1074.28	0.063
10737.33	1074.24	0.063
10822.61	1074.33	0.063
10909.48	1074.41	0.063
10913.31	1074.36	0.063
10921.44	1074.12	0.063
10922.03	1073.77	0.063
10923.53	1073.95	0.063
10938.13	1074.48	0.063
10953.95	1074.1	0.063
10969.46	1074.02	0.063

Cross Section 47

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	

Cross Section 48

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	

Cross Section 49

Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	

Cross Section 50

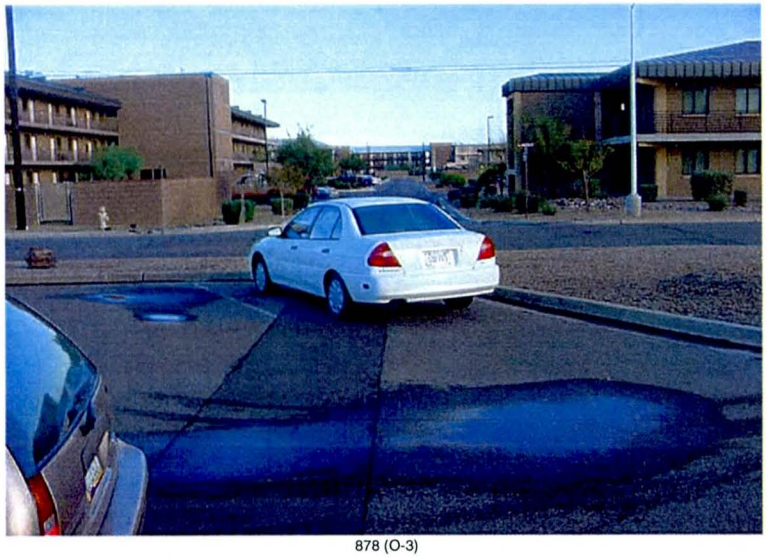
Portion of Cross Section	Components	Composite Values
Left Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Channel	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.045$	
	$n_3 = 0$	
Right Over Bank (Urban area)	$n_b = 0.016$	0.063
	$n_1 = 0.002$	
	$n_2 = 0.02$	
	$n_3 = 0$	

876 (O-1)

XS 47 REP looking S ROB

877 (O-2)

XS 47 LFP looking N LOB



878 (O-3)

XS 46 LFP looking N

LOB

879 (O-4)

S. Side

Harris & Mustang

XS 46 mid point

N

Typ of Both

R & LOB

880 (O-5)

XS 46 midpoint looking N

881 (O-6)

Same as O-5 looking S

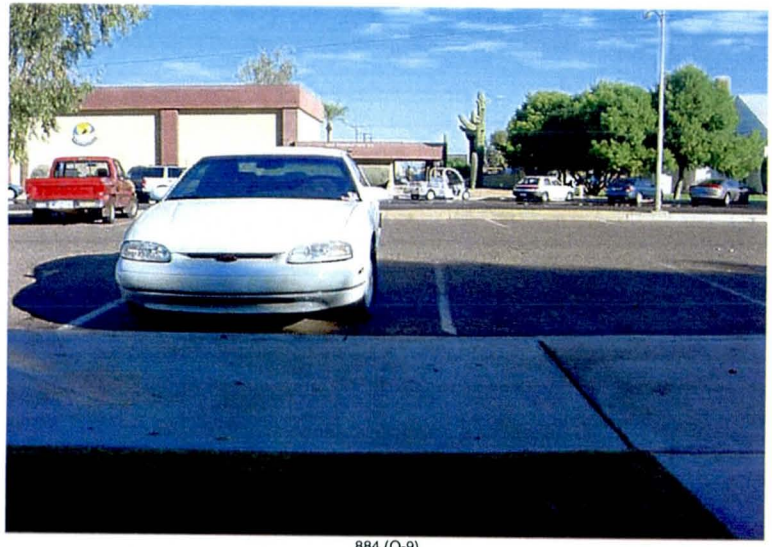
882 (O-7)

XS 46 REP looking S.

ROB

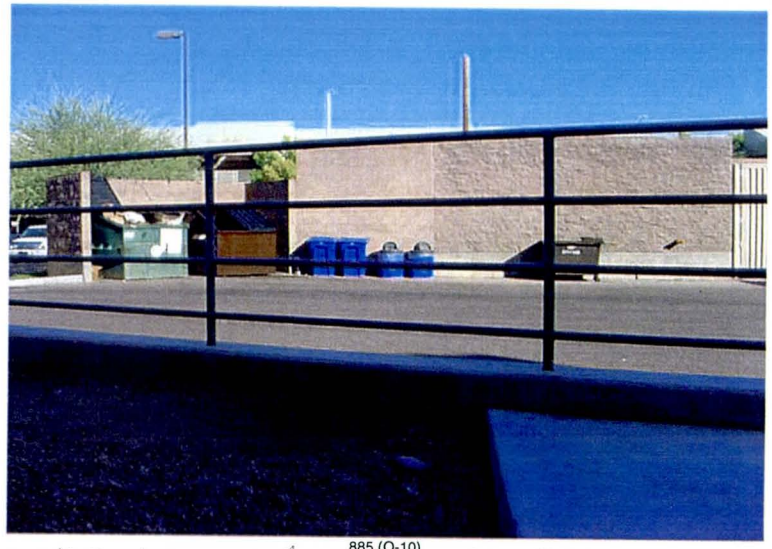
883 (O-8)

XS 45 mid XS N ROB



884 (O-9)

XS45 mid xs looking S ROB



885 (O-10)

XS 45 mid xs N ROB

886 (O-11)

XS45 mid xs N ROB

887 (O-12)

XS45 mid XS S ROB

888 (O-13)

XS 44 midXS N LOB

889 (O-14)

XS 44 REP S ROB

890 (O-15)

XS 37 LEP NW

LOB

891 (O-16)

XS 37 midXS NW LOB

892 (O-17)

XS 37 mid xs SE ROB

893 (O-18)

XS 37 mid xs - NW ROB

894 (P-1)

XS 36 LEP W LOB

895 (P-2)

XS 36 mid xs E LOB

896 (P-3)

XS 36 - mid XS W LOB

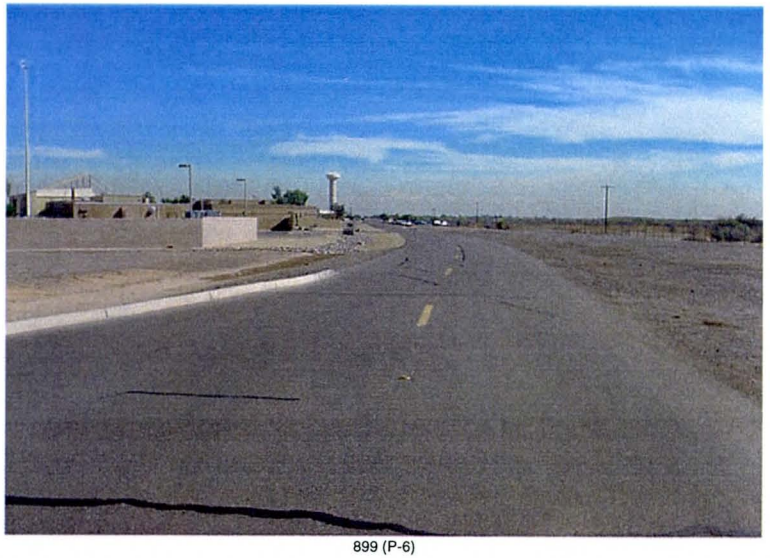
897 (P-4)

XS36 mid XS W LOB

898 (P-5)

XS 35 near LEP looking W.

LOB



899 (P-6)

X 35 Near REP looking E

ROB

900 (P-7)

Culvert on XS 35 looking S
upstream end of culvert

901 (P-8)

Down stream end
Culvert XS 35

902 (P-9)

XS 34 LEP looking W

LOB

903 (P-10)

XS 33 mid XS N

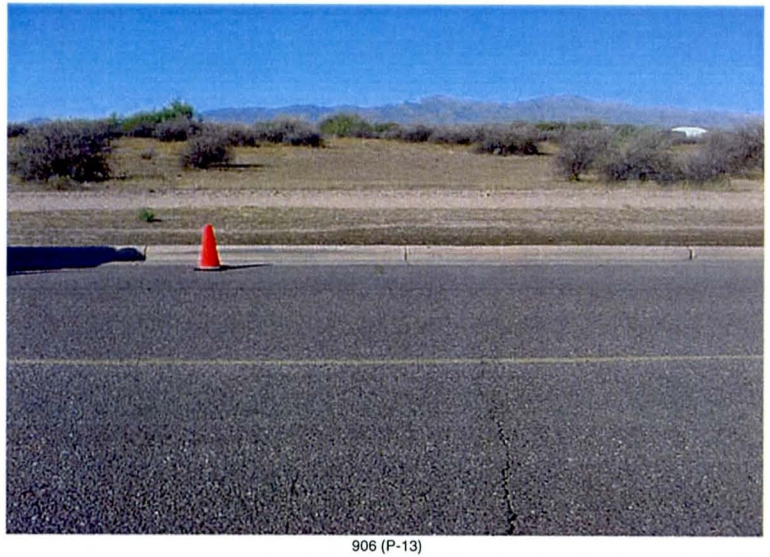
Typ of ~ LOB

904 (P-11)

XS 33 mid XS E Typ of LOB

905 (P-12)

XS 33 mid XS S Typ of LOB



906 (P-13)

XS 33 mid XS W typ L&ROB

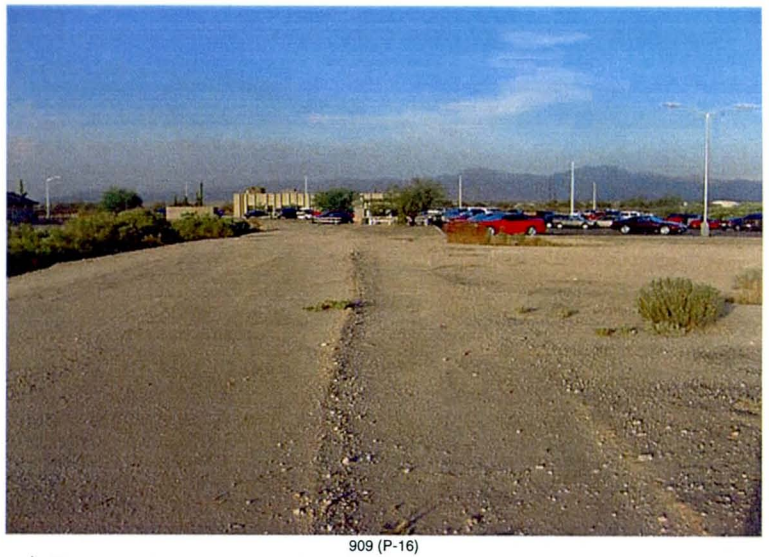
907 (P-14)

Culvert near XS 35 LEP

N

908 (P-15)

Culvert near XS 35 LEP looking S



909 (P-16)

XS 32 LEP looking W LOB

910 (P-17)

XS 32 REP looking W

ROB

911 (P-18)

XS 31 REP looking W

ROB

912 (P-19)

XS 31 mid XS looking W @ Bullard Ave

001 (Q-1)

XS 30 looking E from Bullard Ave

002 (Q-2)

XS 30 REP looking E

ROB

003 (Q-3)

XS 29 REP looking E

ROB

004 (Q-4)

XS 29 Thalweg N

005 (Q-5)

XS 29 Thalweg S

006 (Q-6)

XS 29 Culvert view of east end (looking SW)

007 (Q-7)

XS 29 view of west end of culvert (looking NE)

008 (Q-8)

Between xs 29 & 30 West side of culvert looking NE

009 (Q-9)

Between xs 29 & 30 E. side of culvert looking NE

010 (Q-10)

Between xs 32 & 31 Upstream end of culvert looking S

011 (Q-11)

Between xs 31 & 32 Downstream end of culvert looking N.

012 (Q-12)

XS 28 NW from Bullard Ave LOB

013 (Q-13)

XS 28 REP looking SE ROB
XS 27

nb = 0.024
n1 = 0.002
n2 = 0.004
n3 = 0.015

014 (Q-14)

XS 27 - Thalweg N

015 (Q-15)

XS 27 Thalweg S

nb = 0.024
n1 = 0.003
n2 = 0.003
n3 = 0.01

$n_b = 0.024$
$n_1 = 0.002$
$n_2 = 0.004$
$n_3 = 0.015$

016 (Q-16)

XS 27 LEP looking NW LOB

024 (R-1)

XS 36 - MID XS NW TYP ROB

025 (R-2)

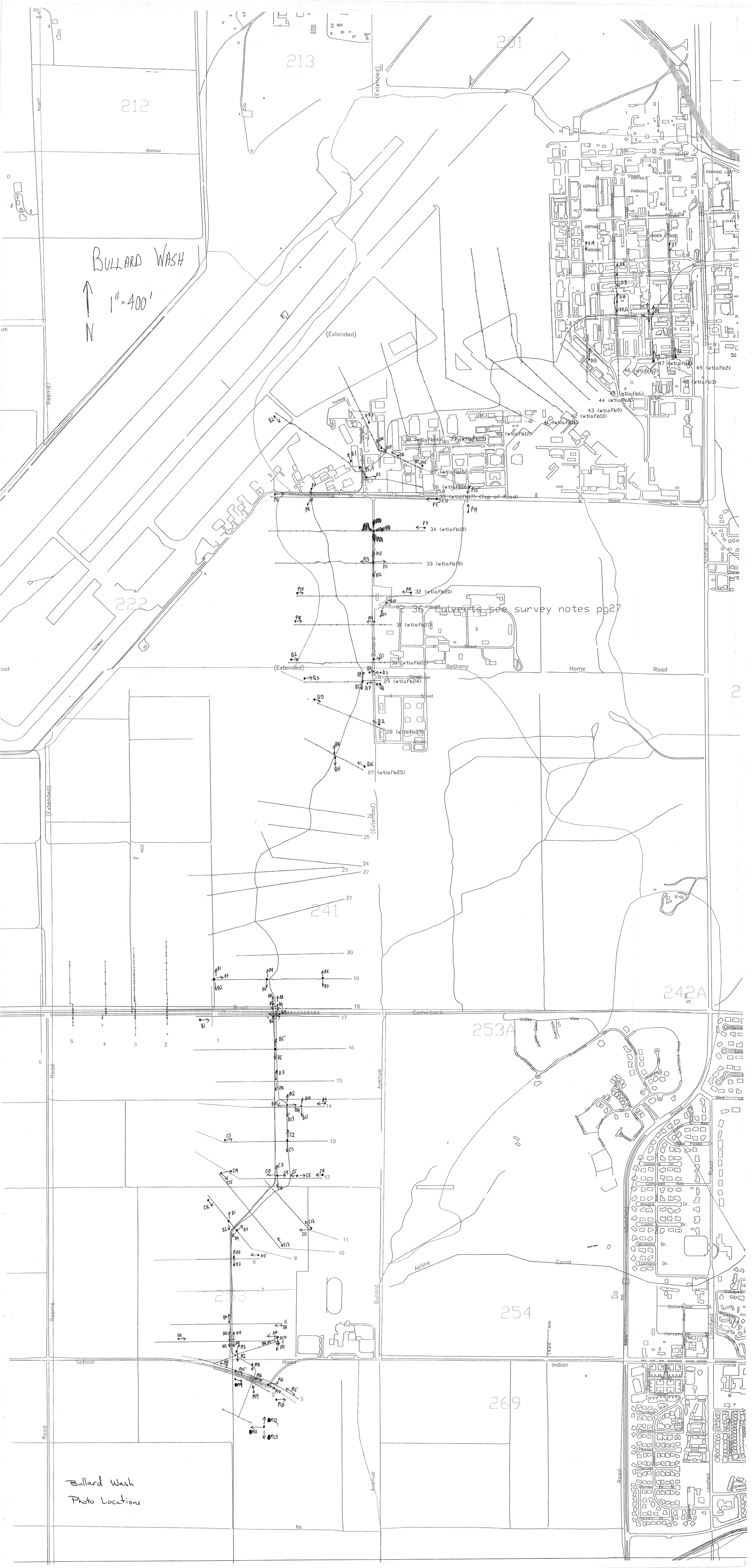
XS 36 REP looking SE

Typ ROB

026 (R-3)

XS 37 MID XS looking NW

ROB


BULLARD WASH
1" = 400'
N
212
213
201
222
241
242A
253A
253
254
269
Avenue
Road
Reems
Bullard
Camelback
Indian
School
Bethany
Home
Street
Taxiway
TAXIWAY
(Extended)
Airline
Canal
Litchfield
Rd.
36 culverts see survey notes pg27
Bullard Wash
Photo Locations

Estimated Manning's Roughness Coefficients for Stream Channels and Flood Plains in Maricopa County, Arizona

By B.W. Thomsen and H.W. Hjalmarson

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375 South Euclid Avenue
Tucson, Arizona 85719

Prepared for the
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of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009

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A common method of selecting the roughness coefficient, *n*, is to first select a base value of *n* for the bed material (table 1). The base values of *n* are for a straight uniform channel of a given bed material. Cross-section irregularities, channel alignment, obstructions, vegetation, and other factors that increase roughness are accounted for by adding increments of roughness to the base value of *n*. Ranges of adjustments for the factors that may add to channel roughness are shown in table 2.

Many alluvial channels in Maricopa County have bed material that moves during floodflow. In addition to the changing channel geometry of these channels, the roughness coefficient may change during floodflow because of the changing form of the channel bed in parts of the channel cross section (Davidian, 1984). Bedforms, such as dunes, antidunes, and plane bed have been observed during large floods. Within a few minutes, dunes can appear, disappear, and reappear at different locations across a large stream channel. The Manning roughness coefficient can double or triple when the bedform changes from plane to dunes. A method of defining reliable values of Manning's *n* for unstable alluvial channels is not available. A plane bedform is common during large floods, and for this report, plane-bed conditions are assumed where the roughness coefficient is related to the size of the channel material and not the form of the channel bed. Plane-bed conditions were assumed for nearly all indirect measurements of peak discharge where the slope-area method was used.

Table 1.--*Base values of Manning's n for stable channels*

[Modified from Aldridge and Garrett, 1973, table 1]

Channel material	Size of bed material		Base *n* values	
	Millimeters	Inches	Benson and Dalrymple (1967)[1]	Chow (1959)[2]
Concrete.....	-------	--------	0.012-0.018	0.011
Rock cut.....	-------	--------	----------	.025
Firm soil.....	-------	--------	.025- .032	.020
Coarse sand.....	1-2	--------	.026- .035	-----
Fine gravel.....	-------	--------	----------	.024
Gravel.....	2-64	0.08-2.5	.028- .035	-----
Coarse gravel.....	-------	--------	----------	.028
Cobble.....	64-256	2.5-10.0	.030- .050	-----
Boulder.....	>256	>10.0	.040- .070	-----

[1]Straight uniform channel.
[2]Smoothest channel attainable in indicated material.

Table 2.--*Adjustment factors for the determination of overall Manning's n values*

[Modified from Chow, 1959]

Channel conditions	Manning's n adjustment[1]	Example
Degree of irregularity: n_1		
Smooth	0.000	Smoothest channel attainable in given bed material.
Minor	.001- .005	Channels with slightly eroded or scoured side slopes.
Moderate	.006- .010	Channels with moderately sloughed or eroded side slopes.
Severe	.011- .020	Channels with badly sloughed banks; unshaped, jagged, and irregular surfaces of channels in rock.
Effects of obstruction[2]: n_2		
Negligible	.000- .004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
Minor	.005- .015	Obstructions occupy 5 to 15 percent of the cross-sectional area and the spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved smooth-surfaced objects than are used for sharp-edged angular objects.
Appreciable	.020- .030	Obstructions occupy from 15 to 50 percent of the cross-sectional area or the space between obstructions is small enough to cause the effects of several obstructions to be additive, thereby blocking an equivalent part of a cross section.
Severe	.040- .060	Obstructions occupy more than 50 percent of the cross-sectional area or the space between obstructions is small enough to cause turbulence across most of the cross section.
Vegetation: n_3		
Small	.002- .010	Dense growths of flexible turf grass, such as Bermuda, or weeds where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrow weed, or saltcedar where the average depth of flow is at least three times the height of the vegetation.
Medium	.010- .025	Grass or weeds where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemmy grass, weeds, or tree seedlings where the average depth of flow is from two to three times the height of the vegetation; moderately dense brush, similar to 1- to 2-year-old saltcedar in the dormant season, along the banks and no significant vegetation along the channel bottoms where the hydraulic radius exceeds 2 feet.
Large	.025- .050	Turf grass or weeds where the average depth to flow is about equal to the height of vegetation; small trees intergrown with some weeds and brush where the hydraulic radius exceeds 2 feet.

See footnotes at end of table.

Table 2.--*Adjustment factors for the determination of overall Manning's n values*--Continued

Channel conditions	Manning's n adjustment[1]	Example
Vegetation—Continued:		
Very large	.050- .100	Turf grass or weeds where the average depth of flow is less than half the height of vegetation; small bushy trees intergrown with weeds along side slopes of dense cattails growing along channel bottom; trees intergrown with weeds and brush.
Variations in channel cross section:		
Gradual	.000	Size and shape of cross sections change gradually.
Alternating	.001- .005	Large and small cross sections alternate occasionally, or the main flow occasionally shifts from side to side owing to changes in cross-sectional shape.
Alternating	.010- .015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross-sectional shape.
Degree of meadering[3]:		
Minor	1.00	Ratio of the meander length to the straight length of the channel reach is 1.0 to 1.2.
Appreciable	1.15	Ratio of the meader length to the straight length of channel is 1.2 to 1.5.
Severe	1.30	Ratio of the meander length to the straight length of channel is greater than 1.5.

[1]Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base n value (table 1) before multiplying by the adjustment for meander.

[2]Conditions considered in other steps must not be reevaluated or duplicated in this section.

[3]Adjustment values apply to flow confined in the channel and do not apply where downvalley flow crosses meanders. The adjustment is a multiplier.

For floodflows in sand channels with moveable beds, roughness mainly is a function of the size of the bed material as shown in the following table (Benson and Dalrymple, 1967, p. 22).

Median grain size, in millimeters	Manning's *n*	Median grain size, in millimeters	Manning's *n*
0.2	0.012	0.6	.023
.3	.017	.8	.025
.4	.020	1.0	.026
.5	.022		

The above *n* values are for upper-regime flow that is common during floods. Where these *n* values are used, the assumed flow regime should be confirmed (Benson and Dalrymple, 1967, p. 24). Stream channels in Maricopa County commonly are sandy in the low-flow part of the channel where flows are common. Higher parts of the channel beds and the channel banks commonly are stabilized by gravel, cobbles, and boulders, and (or) to some extent by vegetation.

Depth of flow must be considered in selection of *n* values. The effects of roughness elements on and near the channel bottom tend to diminish as the depth of flow increases. The effect of vegetation on *n* values depends greatly on the depth of flow and to some extent on the flexibility of the vegetation. If the flow is of sufficient depth to submerge and (or) flatten the vegetation, *n* values will be lowered. Density of vegetation below the high-water level and the alignment of vegetation in relation to direction of flow also affect *n* values. If the vegetation is aligned in rows along the direction of flow, less vegetation is in contact with higher velocity flow. The roughness of aligned vegetation tends to be less than the roughness of nonaligned vegetation.

Generally an *n* value is selected for a cross section that is representative of a reach of channel. If two or more cross sections are being considered, the reach that applies to a given section extends halfway to the next section. In this study, channel data including maps showing cross-section locations were furnished by Maricopa County Flood Control District. A cross section for each of the 16 sites was selected on the basis of the following criteria: (1) cross section should be located so that visual inspection is reasonably convenient; (2) cross section should be within a reach that is minimally affected by roads, bridges, and other structures that may obstruct floodflow; and (3) cross section should contain roughness elements typical of the reach. Widths of the cross sections range from a few hundred feet to a few thousand feet. Some sections have a distinct main channel and overflow areas; others are one large trapezoidal section.

Components of Manning's n

The general procedure for determining *n* values was to first select a base value of *n* for the bed material (table 1) followed by selection of *n*-value adjustments for channel irregularities and alignment, obstructions, vegetation, and other factors (table 2). In this procedure, the value of *n* was computed by

$$n = n_b + n_1 + n_2 + n_3, \tag{7}$$

where

n_b = base value of *n* for a straight uniform channel,

n_1 = value for surface irregularities,

n_2 = value for obstruction, and

n_3 = value for vegetation.