N Value Determination Report

RAINBOW WASH

FLOOD INSURANCE STUDY

FCD 90-66

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N Value Determination Report

RAINBOW WASH

FLOOD INSURANCE STUDY

FCD 90-66

Submitted to:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
2801 West Durango Street
Phoenix, Arizona 85007

FCD 90-66

Submitted by:

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Registered Professional Engineer (Civil) CERTIFICATE NO. 24999 JEFFREY R. MINCH DATE SIGNED 4-23-92 ARIZONA, U.S.A.

Registered Professional Engineer (Civil) CERTIFICATE NO. 21560 DENNIS L. RICHARDS Date Signed 4-23-92 ARIZONA, U.S.A.

April, 1992

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I. INTRODUCTION

This report was prepared by Simons, Li & Associates, Inc., as part of the Flood Insurance Study (FIS) of Rainbow Wash (Contract No. FCD 90-66) for the Flood Control District of Maricopa County. Rainbow Wash is a tributary of the Gila River and is located approximately 10 miles southwest of Buckeye, Arizona. The study limits for the Rainbow Wash FIS begin at the Gila River floodplain and continue along the main channel for approximately 3 miles upstream of State Route 85; and along the tributary of Rainbow Wash for approximately 1 mile upstream of State Route 85. A site map showing the limits of the Rainbow Wash FIS is provided on Figure 1.

The purpose of this report is to present the results of a detailed analysis to define Manning's roughness coefficients for Rainbow Wash and is intended to provide supplementary technical documentation for the development of a detailed hydraulic model.

The "Hydrologic Design Manual" (9) states that precipitation in Maricopa County can typically be divided into two seasons: summer and winter. The summer precipitation season occurs approximately from June through October, whereas, the winter precipitation season occurs from December through March. Major storms generally occur during these two seasons.

The manual categorizes storm patterns into three generalized types: general winter storms, general summer storms, and local storms. General winter storms are characterized as "low intensity, long duration, and large areal extent "(9). General summer storms "consists of a band of locally heavy rain cells within a larger area of light to moderate rainfall" and "are more localized along a southeast to northwest band of rainfall" (9). Local storms more frequently occur during the summer months and are associated with intense, local downpours with lightning and thunder.

The implication of precipitation season and storm type in regards to determination of Manning's coefficients will be presented in Section III.

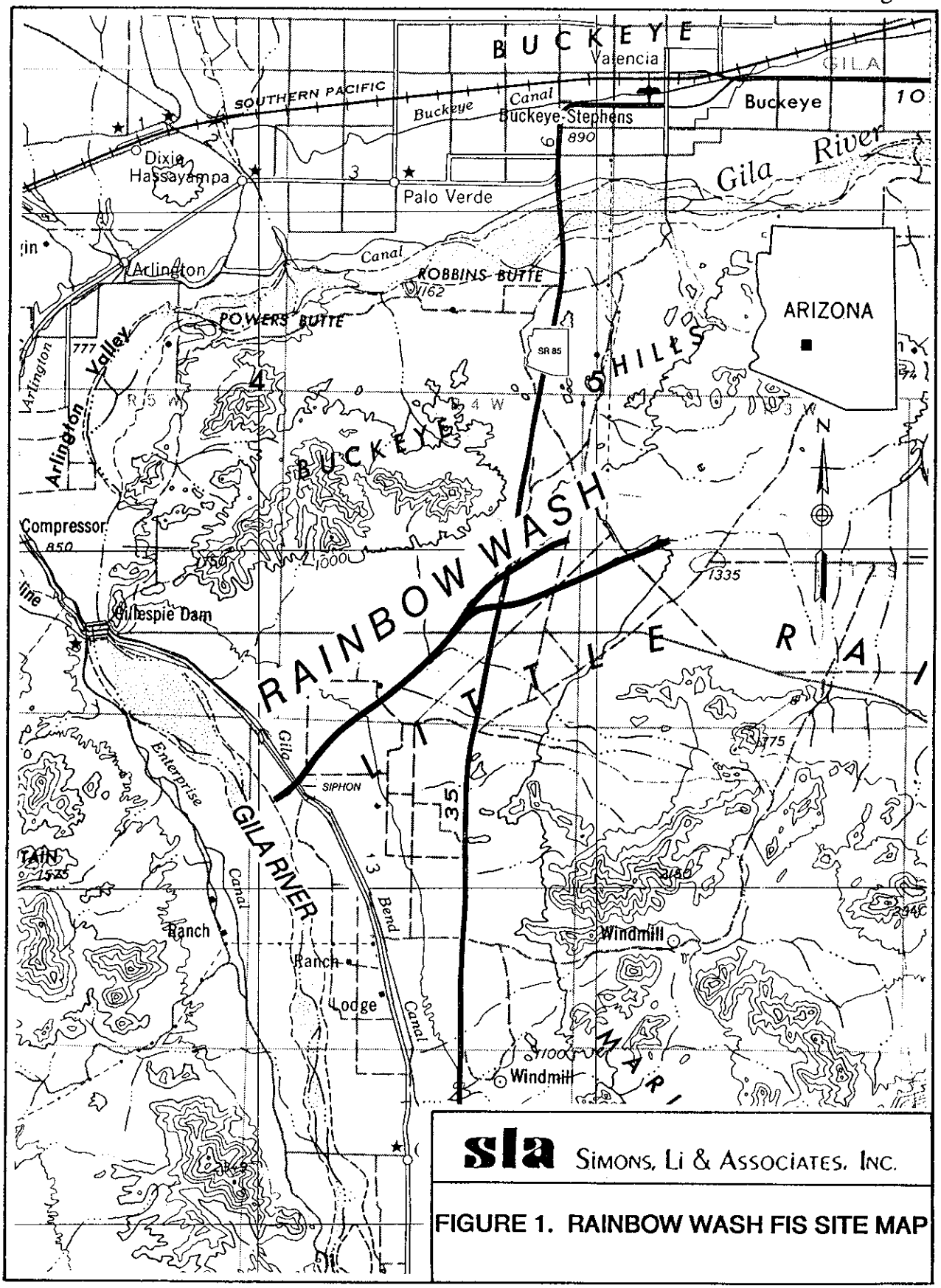

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FIGURE 1. RAINBOW WASH FIS SITE MAP

II. METHODOLOGY

Values for the Manning's roughness coefficient, "n", may be assigned for conditions that exist at the time of a specific flow event, for average conditions over a range in stage, or for anticipated conditions at the time of some future flow event. The Manning's "n" values developed in this study for the Rainbow Wash FIS were developed for the 100-year peak flood discharges (1).

Several sources of data were utilized to develop the "n" values presented in this report. The information available included: 1) two separate sets of aerial photo contact prints (Cooper Aerial - December, 1990; Kenney Aerial - October, 1991); 2) ground level photographs; and 3) video tape of the study reach. The ground level photographs and video tape were obtained during a field reconnaissance trip conducted January 15, 1992. The photographic documentation presented in this report were taken during the field reconnaissance trip.

The "n" value assigned to a stream reach should represent the factors that tend to impede flow. Two procedures will be used to develop the "n" value for the detailed hydraulic model. The first procedure assigns a base "n" value that represents the surface roughness for a straight uniform channel of a given bed material (2). Vegetation, channel shape and irregularity, stage, discharge, and other factors that increase roughness are accounted for by a multiplication factor or by adding increments of roughness to the base "n" value.

The second procedure assigns an "n" value horizontally for the subdivided segments of a specific cross section. The hydraulic model (HEC-2) then computes the average "n" value for the specific section (3). This procedure was utilized to define the average "n" value where vegetation or other obstructions significantly effect the conveyance of a defined portion of a cross section.

Once the composite "n" values were assigned for the various reaches using one or a combination of the methods stated above, the "n" values were compared with channels having

similar characteristics. Several references (4,5,6) were used to verify the range of "n" values that were developed for the Rainbow Wash FIS.

Rainbow Wash is a sand bed channel which transports significant sediment load during flow events. Resistance to flow varies greatly in sand bed channels because the bed material moves easily and assumes different bed configurations or bed forms. The channel bed form is a function of flow velocity, grain size and other variables. Photograph 1 illustrates remnants of bed forms that existed during recent flows. However, Photograph 1 may not represent the bed forms that would be present during the 100-year peak flood discharge. The base "n" values developed for sand bed channels assume the natural channel to be in the upper flow regime. If the natural channel is in the lower or transitional flow regime, the base "n" value will be much larger as a result of the bed form roughness. Therefore, the flow regime was estimated for representative reaches to confirm the applicability of the base "n" values.

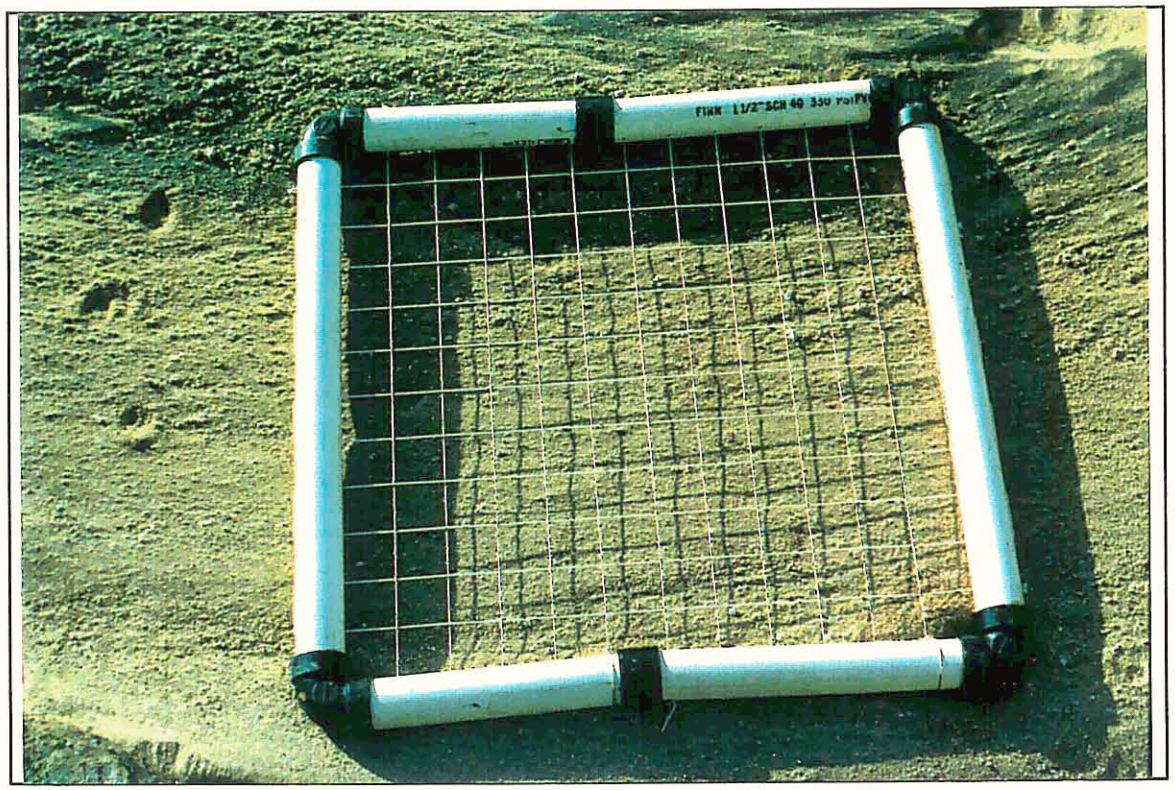
PHOTOGRAPH 1. Remnants of Bed Forms.

III. BASE VALUE DETERMINATION

The base "n" value for Rainbow Wash was assigned for flood flows in sand channels with moveable beds. Photograph 2 illustrates typical bed material found in the main channel of the mainstem and tributary of Rainbow Wash. The bed material can be characterized as medium to coarse grain sand. Close-up photographs of the bed material of Rainbow Wash were compared with a detailed example in reference 2, Waterman Wash above Eagle Mountain Road. Waterman Wash and Rainbow Wash are located in the same general area of Maricopa County. Close examination of the bed material photographs indicate a representative base "n" value for Rainbow Wash would be 0.025.

To check the applicability of the base "n" value, single section hydraulic models of the 100-year peak discharge were developed for 11 cross sections to represent the mainstem and tributary of Rainbow Wash. The hydraulic parameters calculated by these single section models were utilized to determine stream power for the reaches which the cross sections represent. A median bed material size of 0.8 mm was used for the comparison. The computed stream power was compared with the value necessary to cause upper regime flow by entering Figure 1 of reference 4. It was estimated that a minimum stream power of 1.7 foot-pounds per second would be necessary to maintain upper regime flow conditions for the 100-year peak discharge. When the hydraulic conditions for the representative reaches approached the minimum stream power threshold, a minimum overall "n" value of 0.035 was applied to the main channel (7) to account for bed form roughness.

The base "n" values for the overbanks were assigned considering stable channels conditions (2). Review of photographs of the overbanks provide little evidence of bed material movement except in locations where small channels have formed in the overbank. Comparison of base "n" values for the overbanks of Waterman Wash with the overbanks of Rainbow Wash indicate that the bed material can be considered "firm soil." Therefore, a base "n" value of 0.025 was assigned to the overbanks for Rainbow Wash.



PHOTOGRAPH 2. Typical Bed Material

Significant lengths of overbank along Rainbow Wash are wide active and inactive cultivated fields. The field reconnaissance indicates that these fields are planted with cotton. Since it is impossible to predict the time of year when a 100-year flood might occur, it was assumed for the purposes of this study that the 100-year flood would occur during the growing season for cotton at a time when the cotton fields were fully mature. The single section hydraulic analyses indicate that the depth of flow for inactive cultivated overbank areas would generally be shallow (i.e. 1 to 2 feet). A value of 0.040 was selected for inactive cultivated overbanks due to the depth of flow and orientation of the cotton field with respect to the flow lines. A value of 0.15 was selected for active cultivated overbanks (see page 18, Section V).

IV. ADJUSTMENTS TO THE BASE VALUE

The base "n" value (n_b) must be adjusted accordingly for factors such as depth of flow, channel irregularities, obstructions, vegetation, changes in channel shape, and degree of meandering. An accepted method of arriving at the overall "n" is to add increments of roughness to the base "n" for each condition that increases the roughness (2). The base "n" values used in this study generally apply to average conditions rather than the smoothest reach attainable for a given bed material (4). Therefore, the base values require smaller adjustments than do the base values defined in other procedures (5).

Channel irregularity can have a great impact on the overall "n" when the width to depth ratio is small. The width of the main channel of Rainbow Wash is relatively large in comparison to the depth. Therefore, only minor adjustments have been applied to the base "n" value to account for channel irregularity (n_1). Several overbank reaches include small channels parallel to the main channel. Under these conditions a minor increase to the base "n" was included as a component of the overall "n". A minor adjustment due to channel irregularity was also included for the Rainbow Wash tributary.

Obstructions are physical objects which disturb the flow pattern and increase the "n" value. The amount of increase depends upon the channel slope, shape of the obstruction, the size in relation to the cross section, and the number, arrangement, and spacing of obstructions. Engineering judgement and experience was applied when assigning adjustments to the base "n" value for obstructions so as not to duplicate conditions considered for other adjustment factors. The adjustment for obstructions (n_2) was considered to be relatively small throughout the Rainbow Wash study reach.

Several factors impact the extent to which vegetation affects the base "n" value. The percentage of wetted perimeter covered by vegetation, the density of vegetation below the high water line, the degree to which the vegetation is flattened by high water, and the alignment of vegetation relative to the flow all impact the value assigned to the vegetation adjustment factor

(n_3). Vegetation is the primary factor that affects "n" for portions of a number of reaches of Rainbow Wash. Therefore, some parts of the channel or flood plains were assigned "n" values for the vegetation rather than for the material in which it is growing. A majority of the main channel which remains in a natural state had a large growth of trees (e.g., palo verde, mesquite) along the banks. The density of vegetation in the overbanks varied from relatively dense growths of tall brush (e.g., creosote) and trees to sparse brush and weeds.

The extent to which the depth of flow, channel shape, and degree of meandering impact the "n" value were evaluated for Rainbow Wash. In general, these factors were considered when assigning adjustment factors for the components listed above. Several main channel reaches of Rainbow Wash are divided at normal and lower flow stages by small in-stream islands. These braided reaches were considered as a single channel for determining the overall "n" values.

V. DETAILED ANALYSES

Eleven cross-sections of the mainstem and tributary were developed from the Rainbow Wash FIS topographic mapping for the detailed evaluation of typical "n" value characteristics. The representative cross sections were then divided into subsections, where applicable, primarily based on major breaks in cross section geometry. Each of these subsections were evaluated in detail to systematically define the "n" value for the subdivided portions of the cross section. The preliminary flow regime models indicate generally shallow, wide flow depths for the 100-year peak discharges. Composite "n" values were computed by using values weighted by wetted perimeter for each segment of a subsection to account for the roughness attributed to low-lying boundary material. Photographs are used to illustrate typical channel and overbank features and characteristics for each of the 11 cross-sections. The channel and overbank features depicted in the photographs can be applied to the particular cross-section as well as to the reach of the stream for a distance both upstream and downstream of the cross-section. Results from the detailed analysis for each of the 11 cross sections follows:

CROSS SECTION 0.19

Location of cross section:

The mainstem of Rainbow Wash at river mile 0.19, approximately 1,000 feet upstream of the confluence with the Gila River and 2,000 feet downstream of the Gila Bend Canal.

Description of channel:

The main channel bed consists of medium to coarse grain sand and has the capacity to convey the entire 100-year peak discharge. Erosion is evident along both banks of the main channel. The flow depth is approximately 4 to 5 feet and the little vegetation existing in the channel would be flattened by the flood flows.

Portion of area or wetted perimeter of subsection from left end	Components	Weighted and composite values
	$n_b = 0.025$	
	$n_1 = 0.003$	
	$n_2 = 0.000$	
	$n_3 = 0.002$	$n = 0.030$

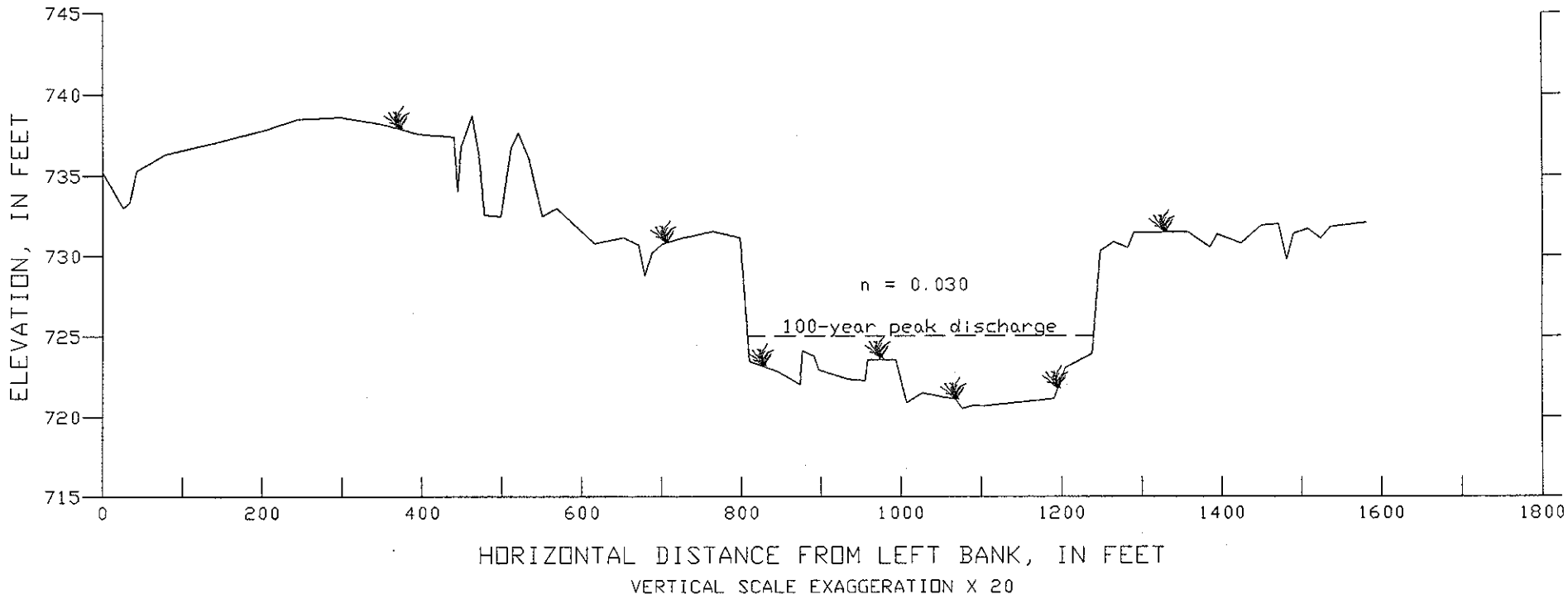


FIGURE 2 Cross section of Rainbow Wash near the confluence with the Gila River

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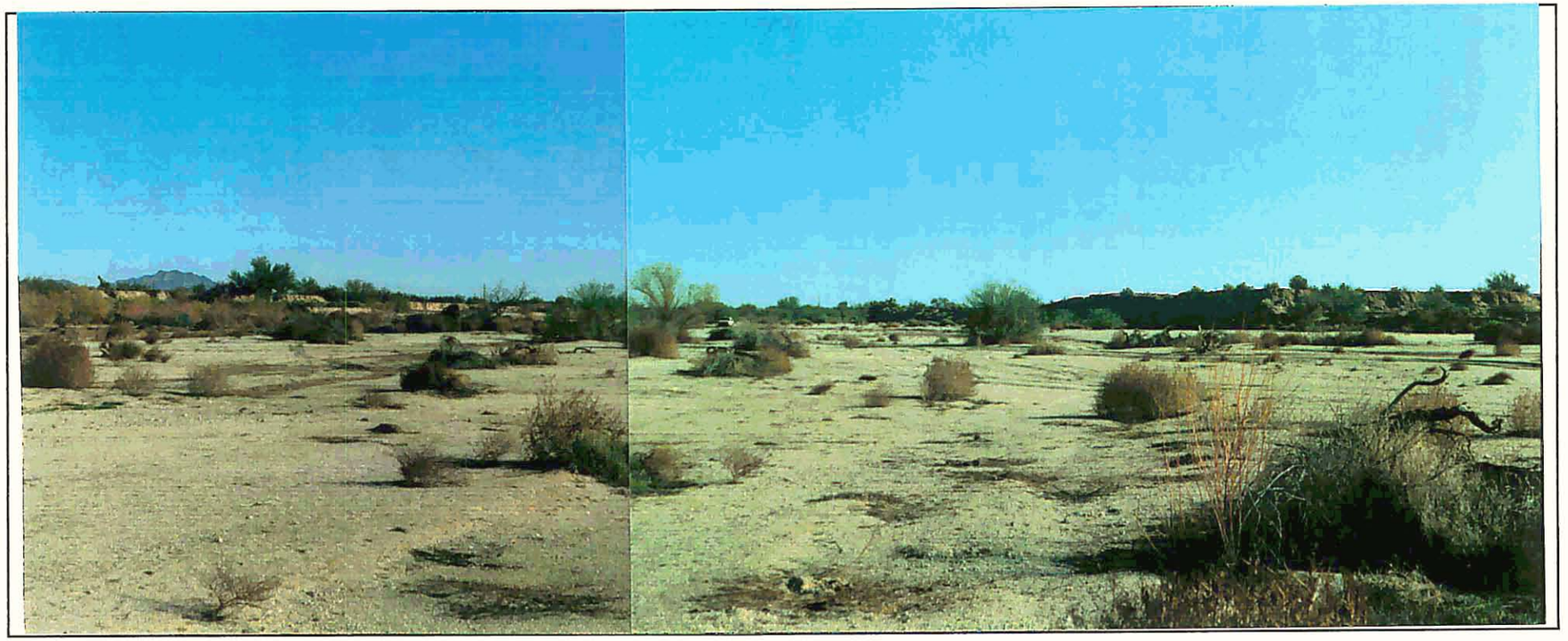

PHOTOGRAPH 3. Looking upstream at Rainbow Wash from the confluence with the Gila River. Selected n = 0.030 due to little vegetation and only small scattered brush.

PHOTOGRAPH 4. Close-up of the finest bed material upstream of the confluence with the Gila River. A base "n" of 0.025 was assigned.

PHOTOGRAPH 5. North bank of main channel near the confluence with the Gila River. Relatively tall eroded banks.

CROSS SECTION 0.38

Location of cross section:

The mainstream of Rainbow Wash at river mile 0.38, approximately 1,800 feet upstream of the confluence with the Gila River and 1,100 feet downstream of the Gila Bend Canal.

Description of channel:

The main channel bed consists of medium to coarse grain sand and has the capacity to convey the entire 100-year peak discharge. Erosion is evident along both banks of the main channel. The flow depth is approximately 6 feet. Vegetation consists of palo verde trees, shrubs and weeds. Five percent of the flow area was estimated to contain significant obstruction by vegetation. Most, if not all, of the smaller vegetation would be flattened by flood flows.

Portion of area or wetted perimeter of subsection from left end		Components		Weighted and composite values
		n_b=0.025 n_1=0.001 n_2=0.002 n_3=0.004		
0.95	x	n =0.032	=	0.030
		n_b=0.025 n_3=0.035		
0.05	x	n =0.060	=	0.003
1.00				n =0.033

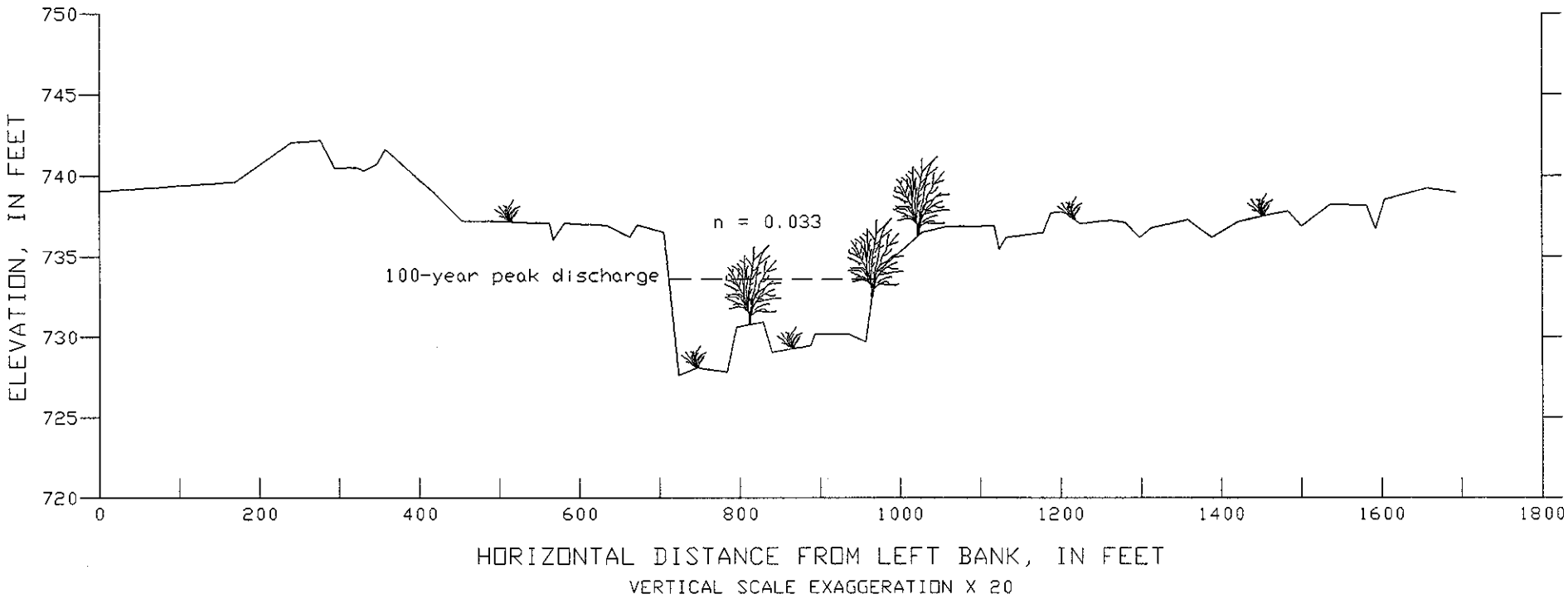

FIGURE 3 Cross section of Rainbow Wash near the Gila Bend Canal

PHOTOGRAPH 6. Looking upstream towards the Gila Bend Canal at the vegetation within the main channel.

PHOTOGRAPH 7. Looking upstream towards the Gila Bend Canal. The vegetation is assigned an overall "n" value of 0.060 for the estimated flow depths.

PHOTOGRAPH 8. Looking downstream towards the confluence with the Gila River. The overall "n" assigned to this reach is 0.033.

CROSS SECTION 1.36

Location of cross section:

The mainstem of Rainbow Wash at river mile 1.36, approximately 4,000 feet upstream of the Gila Bend Canal.

Description of channel:

The main channel consists of medium to coarse sand that has been bulldozed over the banks to increase channel conveyance. The resulting banks are higher than the surrounding overbank areas. Little or no vegetation exists in the main channel. Both overbanks experience shallow flooding (i.e. 1 to 2 feet) and are active cropland planted in cotton. The estimation of the roughness coefficient for the left and right overbanks was based on the recommendations provided in reference 2 (pages 10 and 11). Since the time (seasonality) of a storm event is unpredictable, it was assumed that the overbank areas were fields of fully developed mature cotton plants instead of defoliated cotton. "Fields of mature cotton plants are comparable to dense brush in summer" (ref.2) and were assigned an "n" value of 0.15.

Portion of area or wetted perimeter of subsection from left end	Components	Weighted and composite values
Main Channel	$n_b=0.025$ $n_1=0.003$ $n_2=0.001$ $n_3=0.001$	$n=0.03$
Left and Right Overbanks	$n_3=0.150$	$n=0.15$

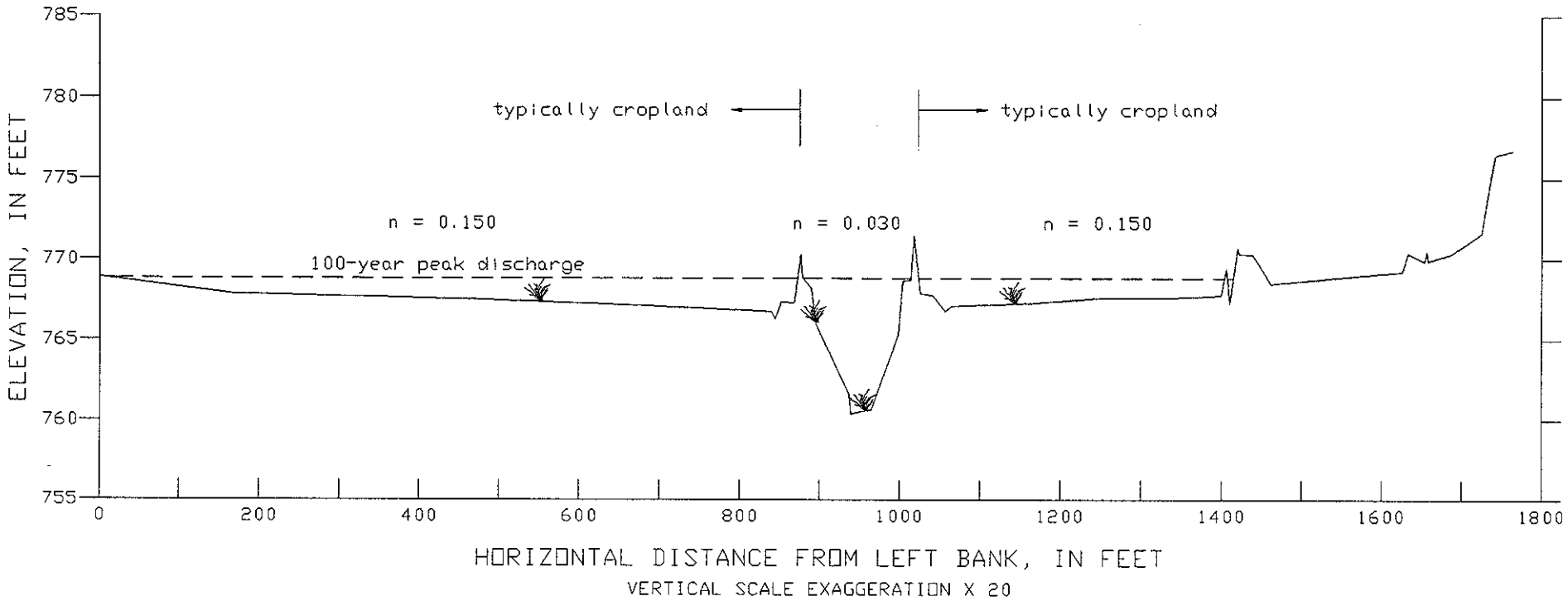

FIGURE 4 Cross section of Rainbow Wash where main channel is graded and the overbanks are cropland

PHOTOGRAPH 9. Looking upstream at the bulldozed banks of the main channel. The main channel was assigned n = 0.03.

PHOTOGRAPH 10. Looking upstream at the right overbank. Active cropland planted in cotton with shallow flooding likely. Assigned n = 0.150.

PHOTOGRAPH 11. Looking at the south bank and the channel irregularities caused by bulldozing material out of the main channel.

CROSS SECTION 2.02

Location of cross section:

The mainstem of Rainbow Wash at river mile 2.02, approximately 8,000 feet upstream of the Gila Bend Canal.

Description of channel:

The main channel consists of medium to coarse grain sand with flow depths ranging from 3 to 4 feet. The main channel is in a natural condition with relatively large palo verde and mesquite trees lining the banks. Five percent of the flow width is estimated to be obstructed by vegetation. Both overbanks experience shallow flooding (1 to 1.5 feet) and are cropland, planted with cotton.

Portion of area or wetted perimeter subsection from left end		Components		Weighted and composite values
Main Channel		$n_b=0.025$ $n_1=0.001$ $n_2=0.002$ $n_3=0.002$		
0.95	x	$n=0.030$	=	0.030
0.05	x	$n_3=0.080$	=	0.004
1.00				$n=0.033$
Left and Right Overbanks		$n_3=0.150$		$n=0.150$

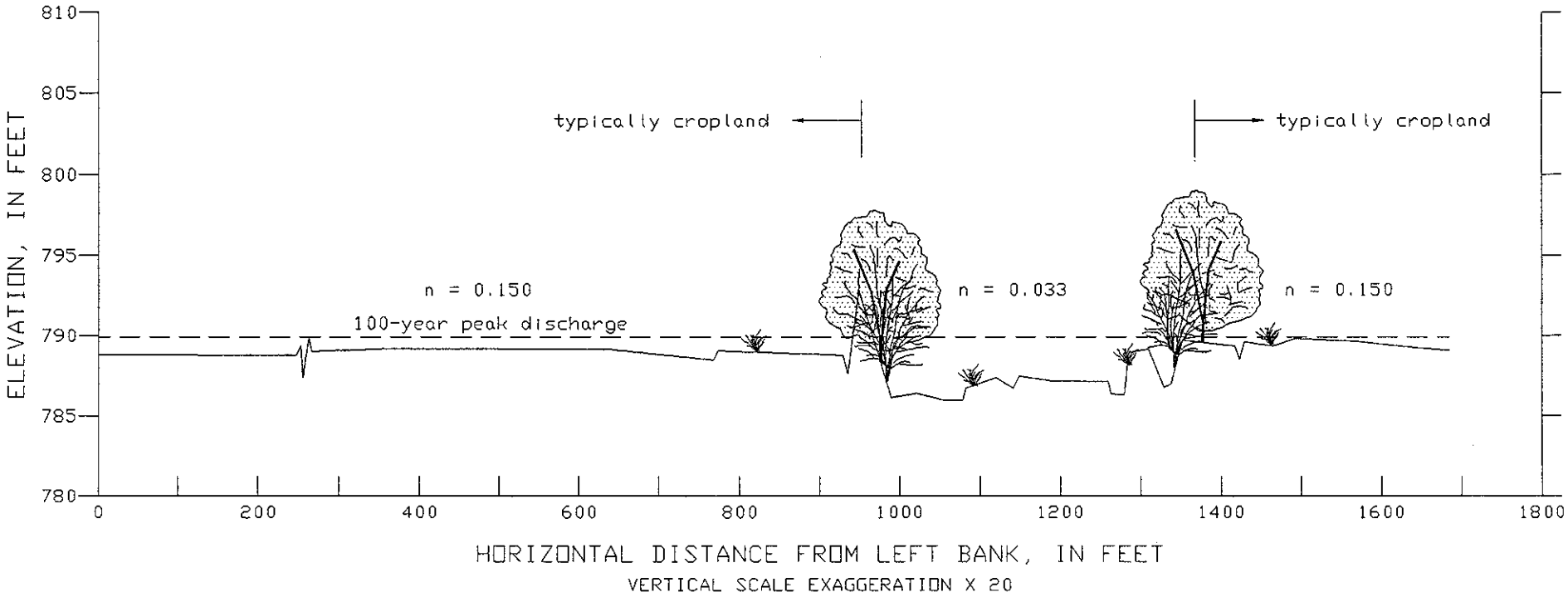

FIGURE 5 Cross section of Rainbow Wash natural main channel and overbanks are cropland

PHOTOGRAPH 12. Typical natural main channel with large palo verde and mesquite lining the banks. Assigned an overall main channel n = 0.033.

CROSS SECTION 2.63

Location of cross section:

The mainstem of Rainbow Wash at river mile 2.63, approximately 11,000 feet upstream of the Gila Bend Canal.

Description of channel:

The main channel consists of medium to coarse grain sand with flow depths ranging from 3 to 5 feet. The main channel remains in a natural condition with relatively large palo verde and mesquite trees lining the banks. Vegetation is estimated to obstruct 5 percent of the flow width in the main channel. Both overbanks experience shallow flooding (ie. 1 to 2.5 feet) and the right overbank is cropland planted in cotton. The left overbank remains in a natural state with a relatively dense growth of creosote, sage, small palo verde trees, and cactus.

Portion of area or wetted perimeter of subsection from left end		Components		Weighted and composite values
Main Channel		$n_b=0.025$ $n_1=0.001$ $n_2=0.002$ $n_3=0.030$		
0.95	x	$n=0.030$	=	0.029
0.05	x	$n_b=0.080$	=	0.004
1.00				$n=0.033$
Left Overbank		$n_b=0.025$ $n_1=0.003$ $n_2=0.002$ $n_3=0.020$		$n=0.050$
Right Overbank		$n_b=0.015$		$n=0.015$

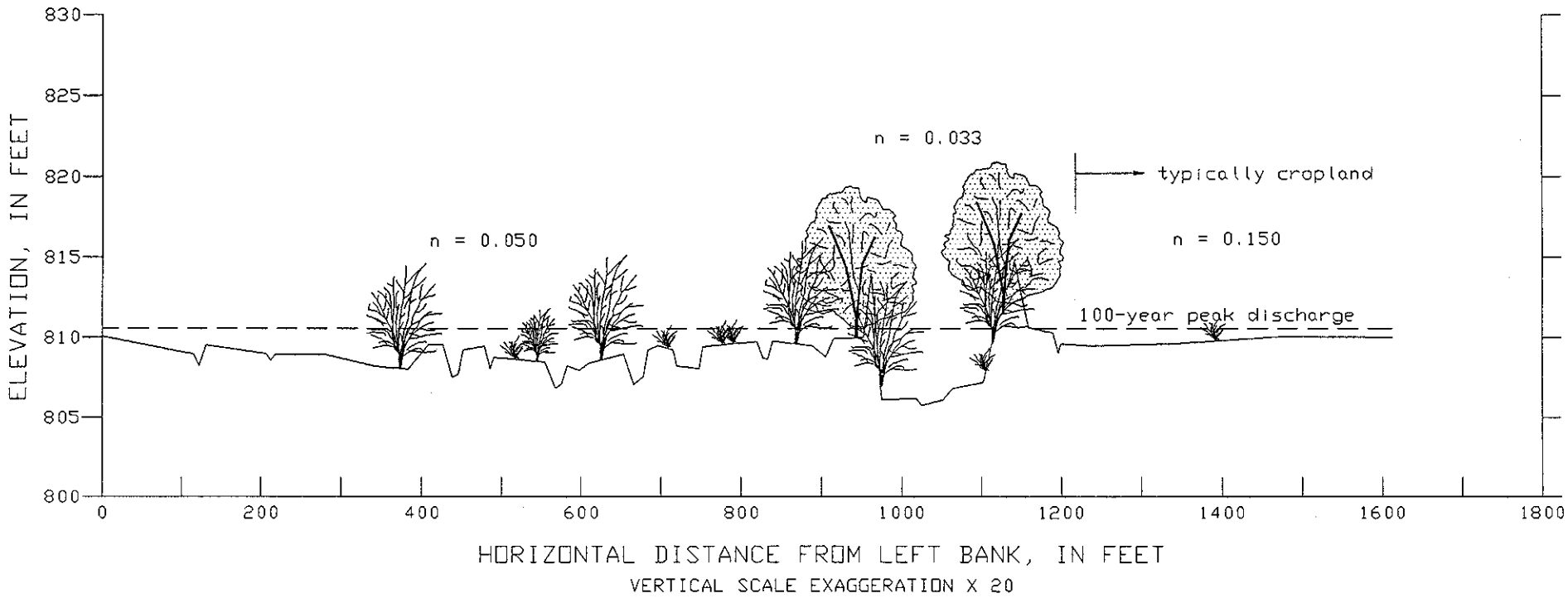

FIGURE 6 Cross section of Rainbow Wash with natural main channel and one overbank, cropland in other overbank

PHOTOGRAPH 13. Relatively dense growth in the right overbank. Assigned an overall n = 0.050.

PHOTOGRAPH 14. Natural main channel with large trees on both banks. Assigned n = 0.033 for the overall main channel.

CROSS SECTION 4.25

Location of cross section:

The mainstem of Rainbow Wash at river mile 4.25, approximately 19,000 feet upstream of the Gila Bend Canal and 10,000 feet downstream of S.R. 85.

Description of channel:

The main channel consists of medium to coarse grain sand with flow depths ranging from 3 to 5 feet. The main channel in this reach of Rainbow Wash is braided with several small islands. Fairly dense stands of vegetation line the banks and stabilize the islands. The subordinate channels of this braided reach were analyzed as a single channel. Therefore, no overbanks were subdivided out of the total cross section.

Portion of area or wetted perimeter of subsection from left end		Components		Weighted and composite values
0.45	x	$n_b=0.025$ $n_1=0.001$ $n_2=0.002$ $n_3=0.002$ $n=0.030$	=	0.014
0.15	x	$n_b=0.025$ $n_3=0.055$ $n=0.080$	=	0.012
0.40	x	$n_b=0.025$ $n_1=0.002$ $n_2=0.003$ $n_3=0.005$ $n=0.035$	=	0.014
1.00				$n=0.040$

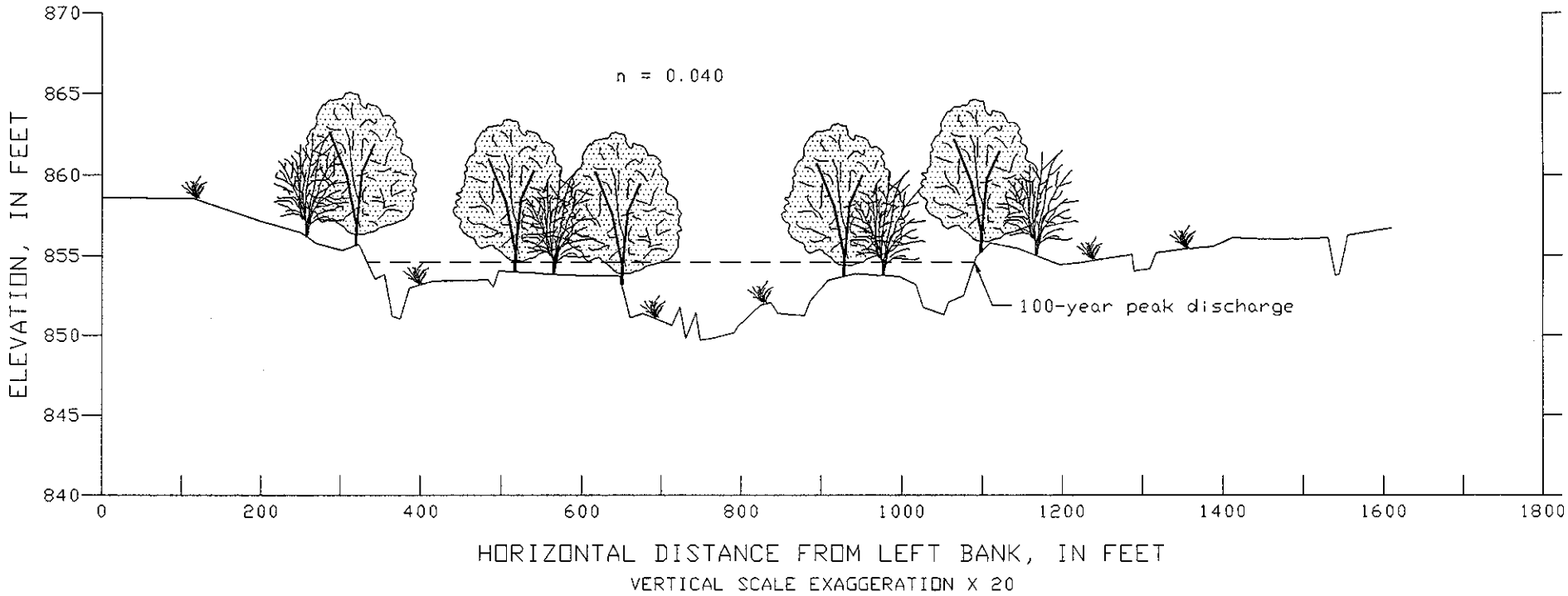

FIGURE 7 Cross section of Rainbow Wash braided channel

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PHOTOGRAPH 15. The subordinate channels of this braided reach were analyzed as a single channel. The overall "n" value assigned is 0.040.

PHOTOGRAPH 16. The subordinate channels of this braided reach were analyzed as single channel. The overall "n" value assigned is 0.040.

CROSS SECTION 4.56

Location of cross section:

The mainstem of Rainbow Wash at river mile 4.56, approximately 21,000 feet upstream of the Gila Bend Canal and 8,000 feet downstream of S.R. 85.

Description of channel:

The main channel consists of medium to coarse grain sand with flow depths ranging from 3 to 5 feet. This reach of Rainbow Wash presents a typical transition between main channel and overbank flow to a braided stream with several small islands. The main channel is generally lined on one side with large palo verde and mesquite trees. Typical flow depths in the overbanks range form 1 to 3 feet. Vegetation in the overbanks generally consist of creosote, brush and cactus.

Portion of area or wetted perimeter of subsection from left end		Components		Weighted and composite values
Main Channel		$n_b=0.025$ $n_1=0.001$ $n_2=0.002$ $n_3=0.002$		
0.90	x	$n=0.030$	=	0.027
		$n_b=0.025$ $n_3=0.055$		
0.10	x	$n=0.080$	=	0.003
1.00				$n=0.035$
Left Overbank		$n_b=0.025$ $n_1=0.004$ $n_2=0.001$ $n_3=0.015$		$n=0.045$
Right Overbank		$n_b=0.025$ $n_1=0.002$ $n_2=0.001$ $n_3=0.012$		$n=0.040$

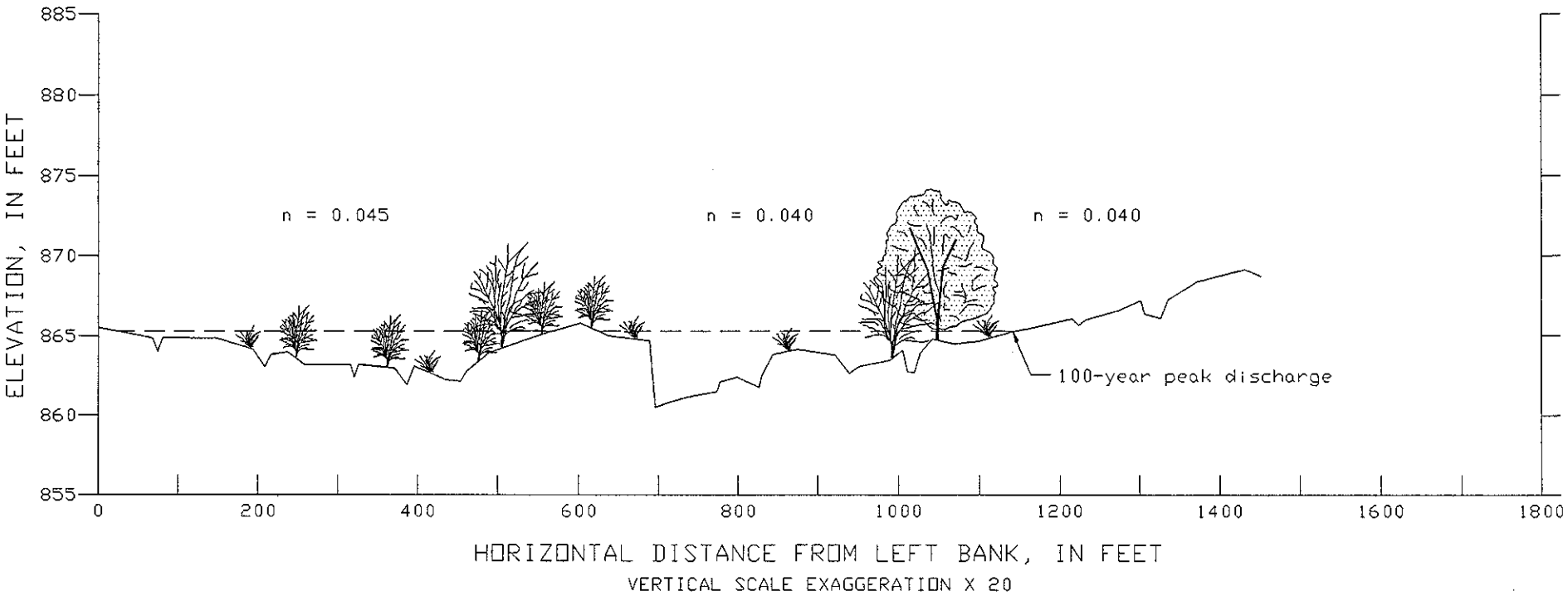
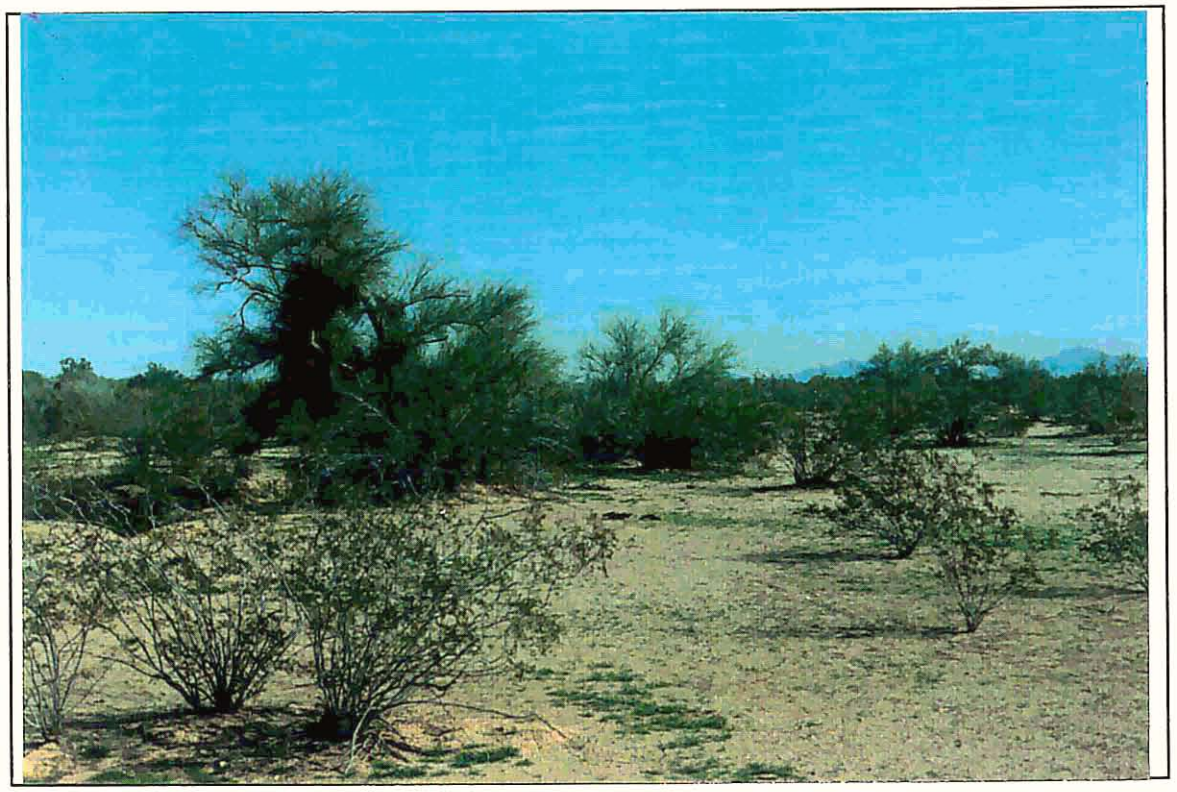


FIGURE 8 Cross section of Rainbow Wash transition from overbank to braided channel

PHOTOGRAPH 17. Main channel of Rainbow Wash looking upstream towards the left bank. Typical transition reach from overbank and main channel flow to a braided stream. Assigned n = 0.040.



PHOTOGRAPH 18. Left overbank looking upstream. Assigned n = 0.040.

PHOTOGRAPH 19. Left overbank looking upstream. Assigned n = 0.040.

CROSS SECTION 4.48

Location of cross section:

The mainstem of Rainbow Wash at river mile 4.48, approximately 6,500 feet downstream of S.R. 85.

Description of channel:

The main channel consists of medium to coarse grain sand with flow depths ranging from 4 to 5 feet. The banks of the main channel are lined with large, dense palo verde trees and shrubs. Vegetation is estimated to influence around 10 percent of the main channel flow width. Flow depths range between 1 and 3 feet in the overbanks. The density of vegetation in the left overbank is substantially greater than the right overbank. Vegetation in the overbanks generally consist of creosote, palo verde, and brush.

Portion of area or wetted perimeter of subsection from left end		Components		Weighted and composite values
Main Channel		$n_b=0.025$ $n_1=0.001$ $n_2=0.002$ $n_3=0.002$		
0.90	x	$n=0.030$	=	0.027
0.10	x	$n_3=0.080$	=	0.008
1.00				n=0.035
Left Overbank		$n_b=0.025$ $n_1=0.002$ $n_2=0.003$ $n_3=0.030$		n=0.060
Right Overbank		$n_b=0.025$ $n_1=0.002$ $n_2=0.001$ $n_3=0.002$		n=0.040

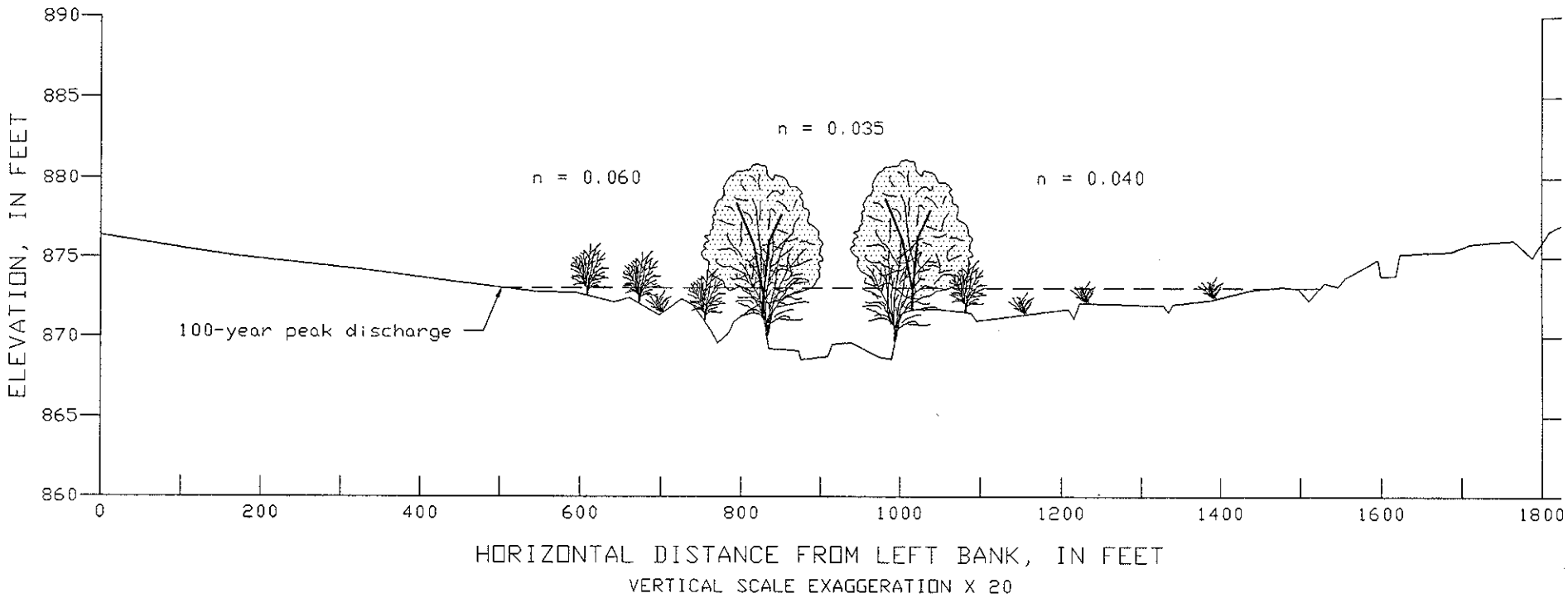


FIGURE 9 Cross section of Rainbow Wash with substantial vegetation in the left overbank

PHOTOGRAPH 20. Main channel looking upstream and downsteram. Assigned n = 0.035.

PHOTOGRAPH 21. Main channel looking upstream and downstream. Assigned n = 0.035.

CROSS SECTION 7.02

Location of cross section:

The mainstem of Rainbow Wash at river mile 7.02, approximately 5,500 feet upstream of S.R. 85.

Description of channel:

The main channel consists of medium to coarse grain sand with flow depths ranging from 6 to 8 feet. The banks of the main channel are lined with large, dense palo verde trees and shrubs. Vegetation is estimated to influence around 10 percent of the main channel flow width. Flow depths range between 1 and 3 feet in the overbanks. The density of vegetation in the left overbank is greater than in the right overbank. Vegetation in the overbanks generally consist of creosote, palo verde, brush and cactus.

Portion of area or wetted perimeter of subsection from left end		Components		Weighted and composite values
		n_b=0.025 n_1=0.001 n_2=0.002 n_3=0.002		
0.90	x	n =0.030		0.027
0.10	x	n =0.080	=	0.008
1.00				n =0.035
Left Overbank		n_b=0.025 n_1=0.004 n_2=0.001 n_3=0.015		n=0.045
Right Overbank		n_b=0.025 n_1=0.002 n_2=0.001 n_3=0.012		n=0.040

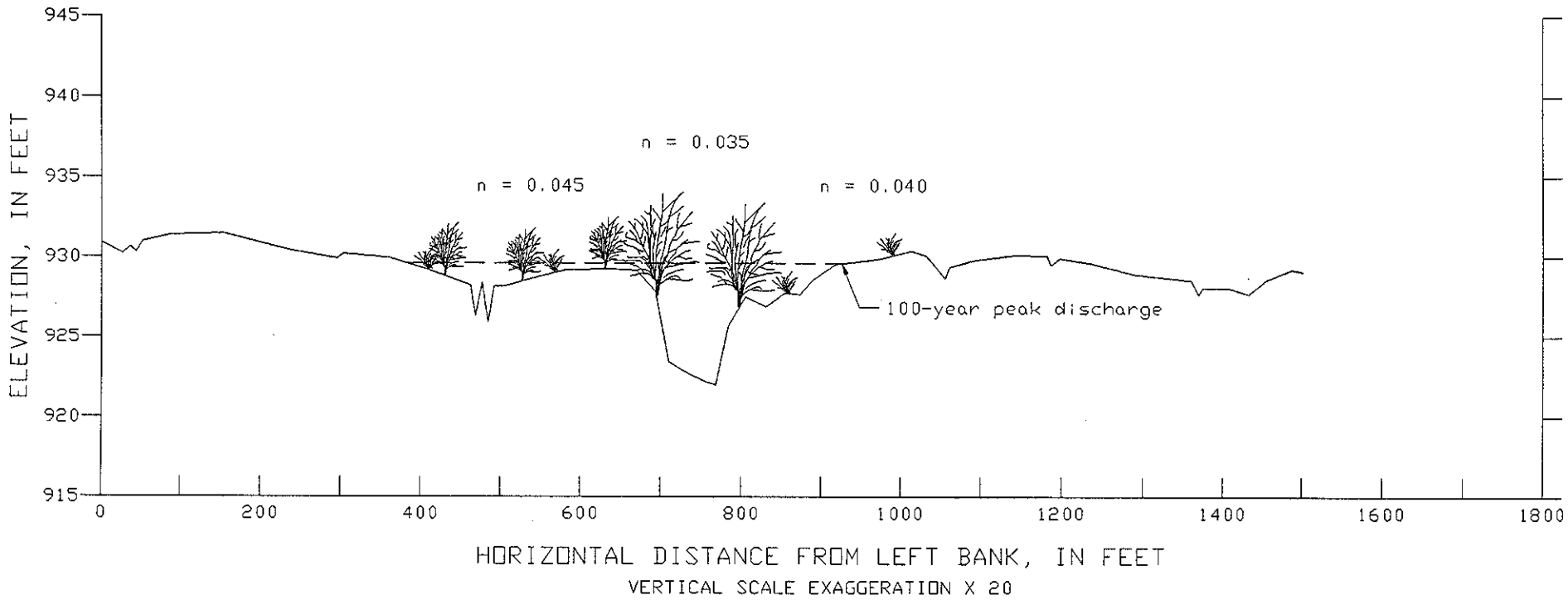


FIGURE 10 Cross section of Rainbow Wash upstream of S.R. 85

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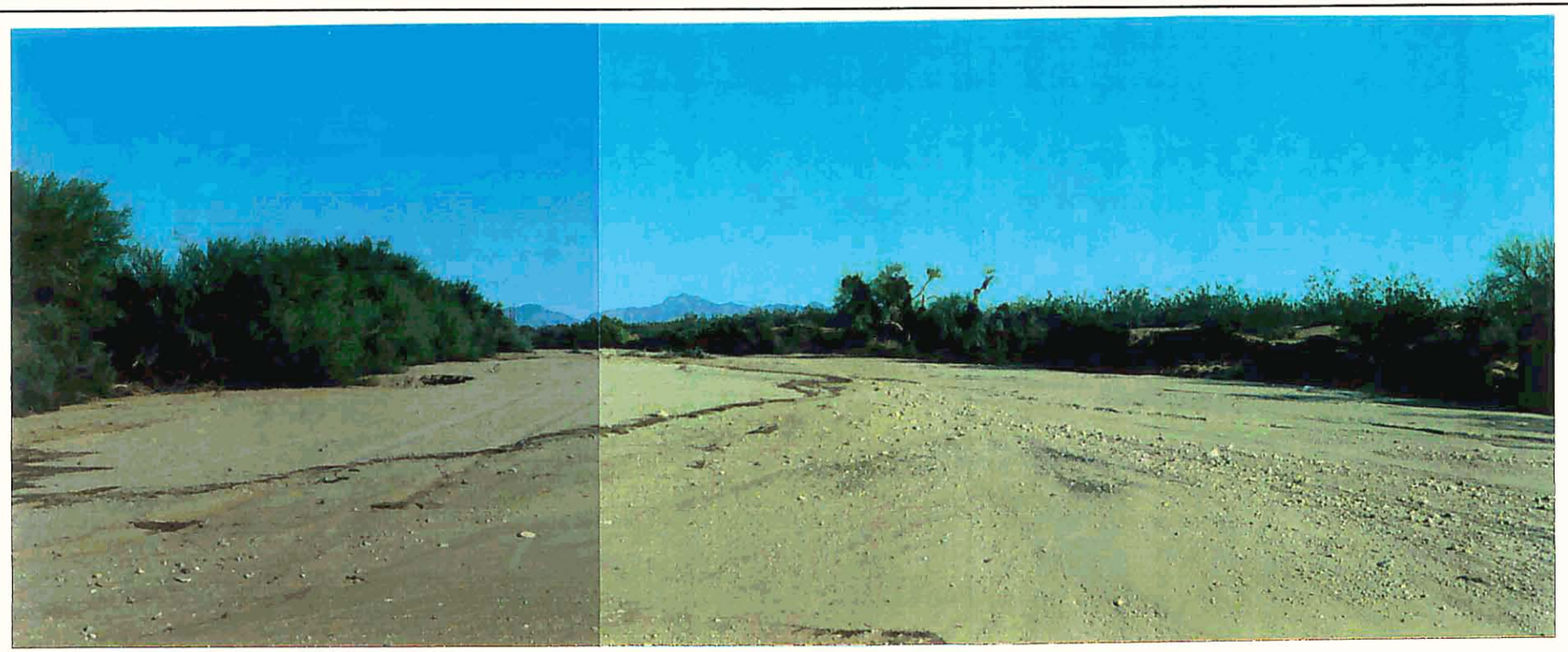

PHOTOGRAPH 22. Main channel of Rainbow Wash upstream of S.R. 85. Banks lined with palo verde and brush. Assigned n = 0.035.

PHOTOGRAPH 23. Left bank erosion and vegetation.

PHOTOGRAPH 24. Right bank vegetation is relatively dense.

CROSS SECTION 0.29

Location of cross section:

The tributary of Rainbow Wash at river mile 0.29, approximately 1,600 feet upstream of the confluence with the mainstem and 2,100 feet downstream of S.R. 85.

Description of channel:

The main channel is medium to coarse grain sand with flow depths probably limited to the top of the left bank elevation. The maximum flow depth within the main channel is approximately 5 feet. A normal depth analysis indicates that the main channel does not have the capacity to convey the 100-year peak flood flows. The width of the main channel ranges from 50 to 80 feet. The banks are generally densely lined with brush and palo verde. The left overbank falls away from the main channel indicating potential split flow conditions. Flow in the right overbank may be non-existent.

Portion of area or wetted perimeter of subsection from left end	Components		Weighted and composite values
Main Channel	$n_b=0.025$ $n_1=0.003$ $n_2=0.002$ $n=0.010$	=	0.040
Left and Right Overbanks	$n_b=0.025$ $n_1=0.003$ $n_2=0.002$ $n_3=0.015$	=	0.045

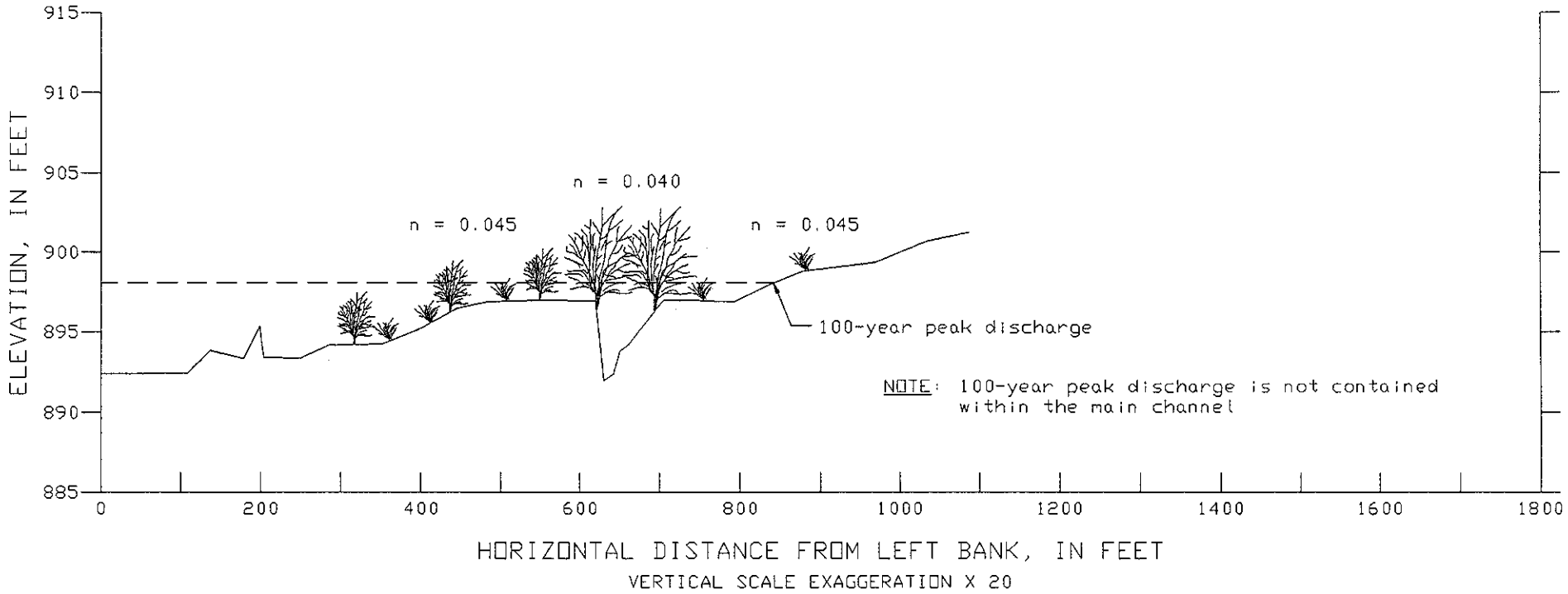

FIGURE 11 Cross section of Rainbow Wash tributary downstream of S.R. 85

PHOTOGRAPH 25. Rainbow Wash tributary looking upsteam from the confluence with the mainstem.

PHOTOGRAPH 26. Rainbow Wash tributary looking upstream. Banks are typically lined with vegetation.

PHOTOGRAPH 27.

Rainbow Wash tributary main channel showing remnants of bed forms.

PHOTOGRAPH 28. Rainbow Wash Tributary typical bank vegetation. The main channel was assigned n = 0.040.

CROSS SECTION 0.88

Location of cross section:

The tributary of Rainbow Wash at river mile 0.88, approximately 1,000 feet upstream of S.R. 85.

Description of channel:

The main channel is medium to coarse grain sand with fine material intermixed. The main channel is relatively narrow with a dense growth of palo verde and brush lining the banks. Main channel flow depths range from 2 to 7 feet. Overbank flow depths vary from 1 to 3 feet. Creosote and brush typically cover the overbanks.

Portion of area or wetted perimeter of subsection from left end	Components		Weighted and composite values
Main Channel	$n_b=0.025$ $n_1=0.003$ $n_2=0.002$ $n_3=0.010$	=	0.040
Left and Right Overbanks	$n_b=0.025$ $n_1=0.001$ $n_2=0.002$ $n_3=0.012$	=	0.040

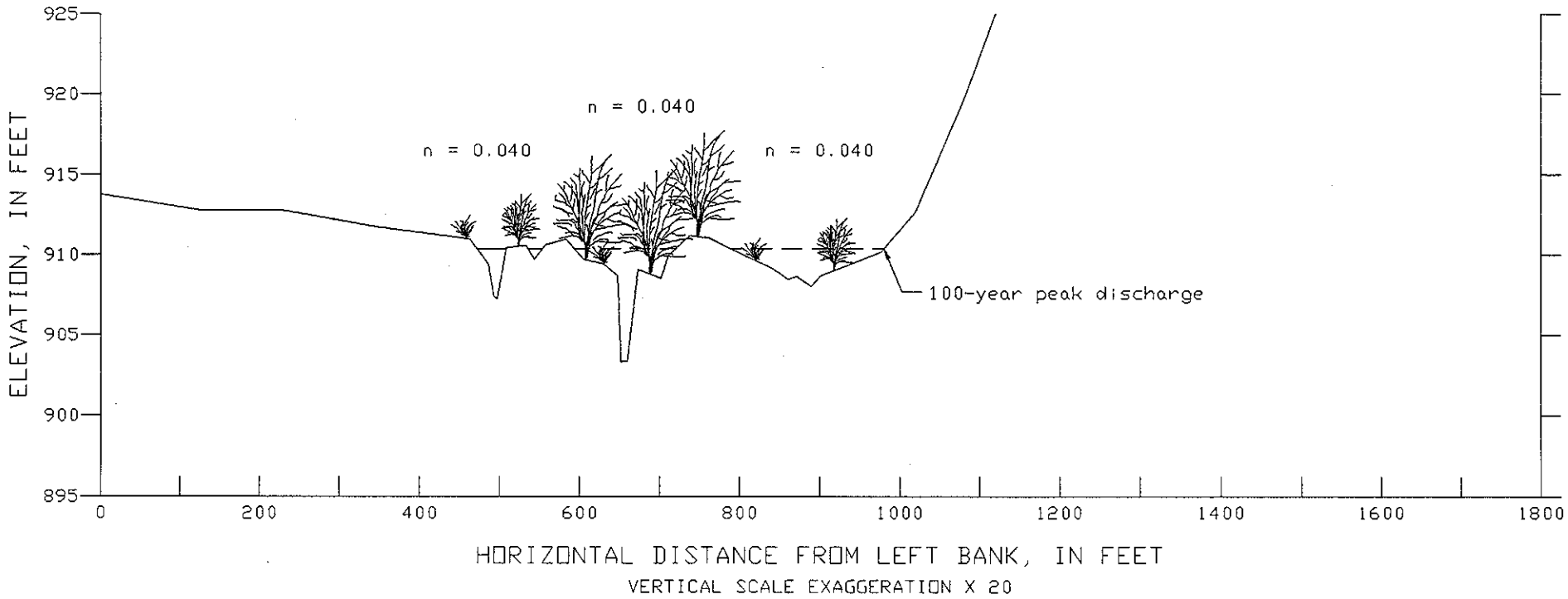

FIGURE 12 Cross section of Rainbow Wash tributary upstream of S.R. 85

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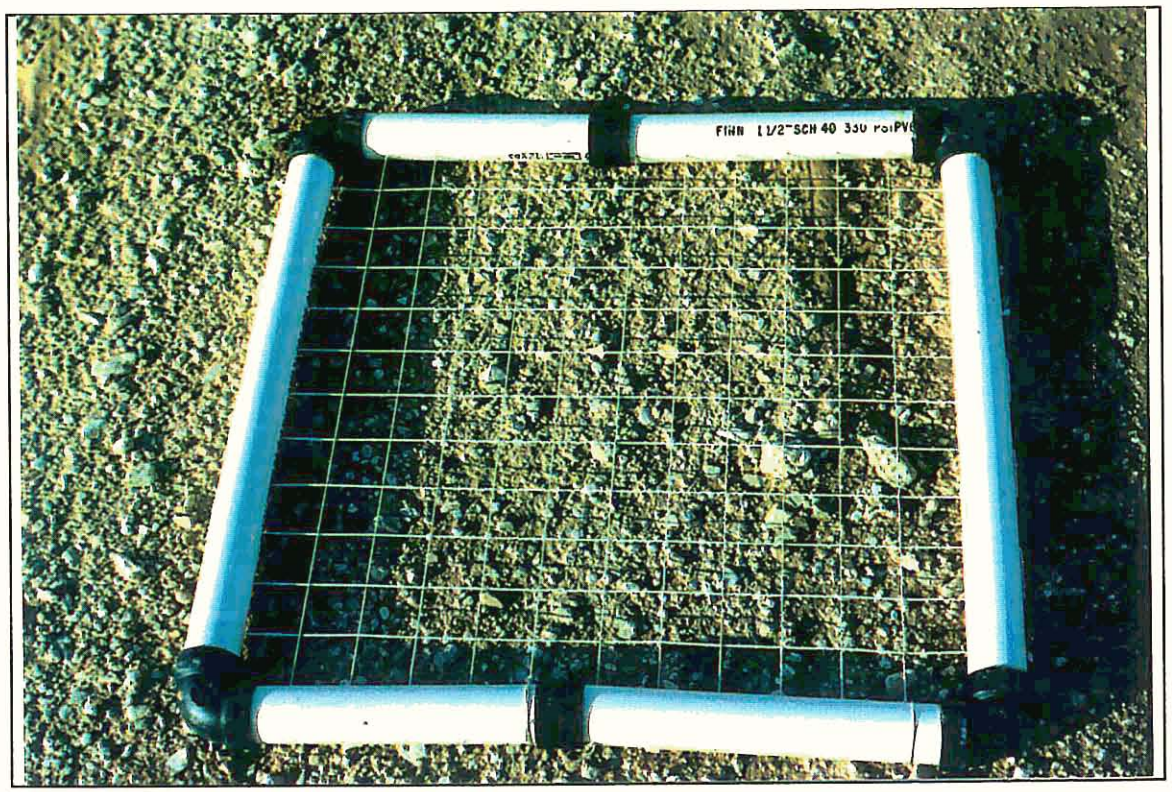
PHOTOGRAPH 29. Rainbow Wash tributary upstream of S.R. 85. Large bushes and trees line the banks. Assigned n = 0.040.

PHOTOGRAPH 30. Rainbow Wash tributary upstream of S.R. 85. Large bushes and trees line the banks. Assigned n = 0.040.



PHOTOGRAPH 31. Close-up of the Rainbow Wash tributary bed material. Fine material intermixed with sand. Assigned base n = 0.025.

VI. SUMMARY

Results from the "n" value analysis were used to define "n" values for the cross sections incorporated in the detailed hydraulic model. The assignment of "n" values for subsections of each individual cross section was accomplished utilizing aerial photographs and the "n" values established in the detailed "n" value analysis. The location of each cross section and the factors which affect the overall "n" value were compared on the aerial photographs with the cross-sections developed in the detailed "n" value analyses.

The contraction and expansion coefficients assigned to each cross section were typically 0.1 and 0.3, respectively (3). Contraction and expansion coefficients for braided portions of the study reach were assigned values of 0.2 and 0.4, respectively, to account for the small in-stream islands in the channel. At bridges and culverts values of 0.3 and 0.5 were assigned to the contraction and expansion coefficients (3).

The channel reach lengths were measured along the channel thalweg developed from the digital terrain model. The channel thalweg is defined as the hydraulic baseline for the Rainbow Wash Flood Insurance Study. The overbank reach lengths were measured along the anticipated path of the center of mass of the overbank flow (3).

The "n" values, contraction and expansion coefficients, and reach lengths assigned to the cross sections for use in the detailed hydraulic model are presented in Tables 1 and 2 for Rainbow Wash and it's tributary, respectively. Slight adjustment to the values presented in Table 1 and Table 2 may be required during the detailed hydraulic analysis of Rainbow Wash.

SECNO	Distance (miles)	Distance (ft)	XLOBL (ft)	XLOBR (ft)	XLCH (ft)	XNL	XNR	XNCH	CCHV	CEHV	Remarks
0.02	0.02	95	0	0	0	0.030	0.030	0.030	0.1	0.3	
0.11	0.11	574	460	280	479	0.030	0.030	0.030	0.1	0.3	
0.15	0.15	790	140	250	216	0.030	0.030	0.030	0.1	0.3	
0.19	0.19	1015	160	250	226	0.030	0.030	0.030	0.1	0.3	
0.29	0.29	1525	475	480	510	0.033	0.033	0.033	0.1	0.3	
0.34	0.34	1774	200	240	249	0.033	0.033	0.033	0.1	0.3	
0.38	0.38	2014	150	185	240	0.033	0.033	0.033	0.1	0.3	
0.47	0.47	2476	470	440	462	0.033	0.033	0.033	0.1	0.3	
0.55	0.55	2884	490	300	408	0.033	0.033	0.033	0.1	0.3	
0.57	0.57	2990	130	95	106	0.033	0.016	0.016	0.1	0.3	Old U.S. 80
0.58	0.58	3045	45	55	55	0.033	0.033	0.033	0.1	0.3	
0.59	0.59	3115	150	60	70	0.033	0.033	0.033	0.3	0.5	
0.60	0.60	3159	30	40	44	0.033	0.033	0.033	0.3	0.5	Gila Bend Canal
0.61	0.61	3205	40	40	46	0.033	0.033	0.033	0.3	0.5	
0.66	0.66	3478	440	230	272	0.033	0.050	0.033	0.3	0.5	
0.70	0.70	3701	230	170	223	0.033	0.050	0.033	0.1	0.3	
0.79	0.79	4193	300	560	493	0.033	0.040	0.033	0.1	0.3	
0.89	0.89	4690	515	480	496	0.033	0.040	0.030	0.1	0.3	
0.98	0.98	5190	560	465	501	0.150	0.150	0.030	0.1	0.3	
1.08	1.08	5682	430	440	491	0.150	0.150	0.030	0.1	0.3	
1.17	1.17	6183	300	650	502	0.150	0.150	0.030	0.1	0.3	
1.26	1.26	6678	450	520	494	0.150	0.150	0.030	0.1	0.3	
1.36	1.36	7177	560	450	500	0.150	0.150	0.030	0.1	0.3	
1.45	1.45	7674	515	480	497	0.150	0.150	0.030	0.1	0.3	
1.55	1.55	8179	530	480	505	0.150	0.150	0.030	0.1	0.3	
1.61	1.61	8507	330	330	328	0.150	0.150	0.030	0.1	0.3	
1.64	1.64	8670	160	165	162	0.150	0.150	0.030	0.1	0.3	
1.67	1.67	8833	170	170	164	0.150	0.150	0.030	0.1	0.3	
1.74	1.74	9168	300	340	335	0.150	0.045	0.033	0.2	0.3	

TABLE 1. Rainbow Wash Reach Lengths, Roughness, and Loss Coefficients

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SECNO	Distance (miles)	Distance (ft)	XLOBL (ft)	XLOBR (ft)	XLCH (ft)	XNL	XNR	XNCH	CCHV	CEHV	Remarks
1.83	1.83	9666	520	460	498	0.150	0.045	0.033	0.1	0.3	
1.88	1.88	9935	250	280	270	0.150	0.045	0.033	0.1	0.3	
1.92	1.92	10162	220	220	227	0.150	0.045	0.033	0.1	0.3	
2.02	2.02	10652	475	490	490	0.150	0.045	0.033	0.1	0.3	
2.11	2.11	11150	490	490	497	0.150	0.058	0.033	0.1	0.3	
2.21	2.21	11652	400	530	503	0.040	0.045	0.033	0.2	0.3	
2.30	2.30	12154	470	490	502	0.045	0.045	0.033	0.1	0.3	
2.39	2.39	12644	490	470	490	0.045	0.045	0.033	0.1	0.3	
2.49	2.49	13136	490	490	493	0.050	0.045	0.033	0.1	0.3	
2.58	2.58	13639	500	500	503	0.050	0.045	0.033	0.1	0.3	
2.63	2.63	13860	215	230	221	0.050	0.045	0.033	0.1	0.3	
2.68	2.68	14133	270	275	273	0.050	0.045	0.033	0.1	0.3	
2.73	2.73	14435	320	275	301	0.050	0.040	0.033	0.2	0.3	
2.77	2.77	14623	210	180	188	0.050	0.050	0.033	0.2	0.3	
2.86	2.86	15120	460	530	497	0.050	0.050	0.033	0.2	0.3	
2.96	2.96	15628	500	470	508	0.045	0.050	0.033	0.1	0.3	
3.05	3.05	16121	520	430	493	0.040	0.050	0.033	0.1	0.3	
3.15	3.15	16620	495	505	499	0.040	0.050	0.033	0.1	0.3	
3.24	3.24	17116	425	510	496	0.040	0.045	0.033	0.1	0.3	
3.34	3.34	17613	450	520	497	0.040	0.040	0.033	0.1	0.3	
3.43	3.43	18113	500	495	500	0.040	0.040	0.033	0.2	0.3	
3.52	3.52	18605	525	440	492	0.040	0.045	0.045	0.1	0.3	
3.62	3.62	19100	470	520	495	0.040	0.045	0.045	0.1	0.3	
3.71	3.71	19598	480	510	498	0.040	0.040	0.033	0.1	0.3	
3.81	3.81	20104	515	485	506	0.040	0.045	0.033	0.2	0.3	
3.90	3.90	20582	515	475	478	0.040	0.045	0.035	0.1	0.3	
4.00	4.00	21101	550	420	519	0.040	0.045	0.040	0.2	0.4	
4.09	4.09	21599	480	520	498	0.040	0.045	0.040	0.2	0.4	
4.15	4.15	21889	300	275	290	0.040	0.045	0.040	0.2	0.4	

TABLE 1. Rainbow Wash Reach Lengths, Roughness, and Loss Coefficients (Cont.)

SECNO	Distance (miles)	Distance (ft)	XLOBL (ft)	XLOBR (ft)	XLCH (ft)	XNL	XNR	XNCH	CCHV	CEHV	Remarks
4.18	4.18	22094	195	215	205	0.040	0.045	0.040	0.2	0.4	
4.28	4.28	22597	480	510	503	0.040	0.045	0.040	0.2	0.4	
4.33	4.33	22845	230	250	248	0.040	0.045	0.040	0.2	0.4	
4.37	4.37	23083	160	270	238	0.040	0.045	0.040	0.2	0.4	
4.47	4.47	23583	280	600	500	0.040	0.045	0.040	0.1	0.3	
4.56	4.56	24076	400	510	493	0.040	0.045	0.036	0.1	0.3	
4.65	4.65	24573	550	370	497	0.040	0.045	0.035	0.1	0.3	
4.75	4.75	25069	570	380	496	0.040	0.045	0.047	0.1	0.3	
4.84	4.84	25571	490	505	503	0.040	0.045	0.034	0.1	0.3	
4.94	4.94	26068	490	510	497	0.040	0.045	0.031	0.1	0.3	
5.03	5.03	26570	540	430	502	0.040	0.045	0.029	0.1	0.3	
5.13	5.13	27062	470	500	492	0.040	0.045	0.045	0.2	0.4	
5.22	5.22	27564	430	485	503	0.040	0.045	0.045	0.2	0.4	
5.31	5.31	28058	480	480	494	0.040	0.045	0.045	0.2	0.4	
5.41	5.41	28559	450	580	500	0.040	0.045	0.045	0.2	0.4	
5.50	5.50	29057	330	540	499	0.040	0.045	0.040	0.2	0.4	
5.54	5.54	29269	160	160	212	0.040	0.045	0.040	0.2	0.4	
5.60	5.60	29549	140	250	280	0.040	0.045	0.040	0.2	0.4	Tributary
5.67	5.67	29947	170	470	398	0.040	0.045	0.040	0.2	0.4	
5.75	5.75	30355	260	420	408	0.040	0.045	0.040	0.2	0.4	
5.83	5.83	30758	300	370	404	0.040	0.045	0.040	0.2	0.4	
5.90	5.90	31153	280	360	395	0.040	0.045	0.040	0.2	0.4	
5.94	5.94	31372	190	225	219	0.040	0.045	0.035	0.2	0.4	
5.97	5.98	31565	185	210	194	0.040	0.045	0.025	0.3	0.5	
5.99	5.99	31622	45	45	45	0.040	0.045	0.025	0.3	0.5	State Route 85
6.04	6.04	31867	260	210	244	0.040	0.040	0.035	0.3	0.5	
6.08	6.08	32115	250	240	248	0.040	0.040	0.035	0.1	0.3	
6.18	6.18	32614	560	420	500	0.040	0.040	0.035	0.1	0.3	

TABLE 1. Rainbow Wash Reach Lengths, Roughness, and Loss Coefficients (Cont.)

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SECNO	Distance (miles)	Distance (ft)	XLOBL (ft)	XLOBR (ft)	XLCH (ft)	XNL	XNR	XNCH	CCHV	CEHV	Remarks
6.27	6.27	33114	560	430	500	0.045	0.040	0.035	0.1	0.3	
6.37	6.37	33611	590	390	497	0.045	0.040	0.035	0.1	0.3	
6.46	6.46	34105	490	500	494	0.050	0.040	0.035	0.1	0.3	
6.55	6.55	34605	480	510	501	0.050	0.040	0.035	0.1	0.3	
6.65	6.65	35104	500	480	498	0.050	0.040	0.035	0.1	0.3	
6.74	6.74	35597	460	530	494	0.050	0.040	0.035	0.1	0.3	
6.84	6.84	36096	520	480	499	0.050	0.040	0.035	0.1	0.3	
6.93	6.93	36585	475	500	489	0.050	0.040	0.035	0.1	0.3	
7.02	7.02	37086	480	510	501	0.045	0.040	0.035	0.1	0.3	
7.12	7.12	37581	430	520	495	0.045	0.040	0.035	0.1	0.3	
7.21	7.21	38087	465	480	506	0.045	0.040	0.035	0.1	0.3	
7.30	7.30	38568	560	400	482	0.045	0.040	0.035	0.1	0.3	
7.40	7.40	39076	490	520	508	0.045	0.040	0.035	0.1	0.3	
7.45	7.45	39329	250	255	253	0.045	0.040	0.035	0.1	0.3	
7.49	7.49	39573	240	255	245	0.045	0.040	0.035	0.1	0.3	
7.59	7.59	40070	480	505	496	0.045	0.040	0.035	0.1	0.3	
7.70	7.70	40661	620	575	592	0.045	0.040	0.035	0.1	0.3	
7.78	7.78	41066	420	380	404	0.045	0.040	0.035	0.1	0.3	
7.82	7.82	41305	230	255	240	0.045	0.040	0.035	0.1	0.3	
7.87	7.87	41557	240	260	252	0.045	0.040	0.035	0.1	0.3	
7.97	7.97	42059	430	510	502	0.045	0.040	0.040	0.1	0.3	
8.01	8.01	42299	260	200	240	0.045	0.040	0.040	0.1	0.3	
8.06	8.06	42564	300	215	265	0.045	0.040	0.040	0.1	0.3	
8.15	8.15	43053	550	430	490	0.045	0.040	0.040	0.1	0.3	
8.25	8.25	43544	480	495	491	0.040	0.040	0.035	0.1	0.3	
8.34	8.34	44044	450	530	500	0.040	0.040	0.035	0.1	0.3	
8.43	8.43	44535	450	530	491	0.040	0.040	0.035	0.1	0.3	
8.53	8.53	45042	400	600	507	0.040	0.040	0.035	0.1	0.3	
8.62	8.62	45534	475	505	492	0.045	0.040	0.035	0.1	0.3	

TABLE 1. Rainbow Wash Reach Lengths, Roughness, and Loss Coefficients (Cont.)

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SECNO	Distance (miles)	Distance (ft)	XLOBL (ft)	XLOBR (ft)	XLCH (ft)	XNL	XNR	XNCH	CCHV	CEHV	Remarks
8.72	8.72	46034	650	380	500	0.045	0.040	0.040	0.2	0.4	
8.81	8.81	46526	480	470	492	0.045	0.040	0.040	0.2	0.4	
8.91	8.91	47028	490	495	502	0.050	0.040	0.040	0.2	0.4	
9.00	9.00	47515	510	485	487	0.050	0.040	0.035	0.1	0.3	
9.09	9.09	48010	530	465	495	0.050	0.040	0.040	0.2	0.4	
9.19	9.19	48505	450	505	494	0.050	0.040	0.040	0.2	0.4	
9.28	9.28	49005	440	540	500	0.045	0.040	0.035	0.1	0.3	
9.38	9.38	49504	410	515	499	0.045	0.045	0.035	0.1	0.3	
9.47	9.47	49996	500	480	492	0.045	0.045	0.035	0.1	0.3	
9.56	9.56	50500	420	540	504	0.045	0.050	0.040	0.2	0.4	
9.66	9.66	51003	530	390	503	0.045	0.050	0.040	0.2	0.4	

TABLE 1. Rainbow Wash Reach Lengths, Roughness, and Loss Coefficients (Cont.)

SECNO	Distance (miles)	Distance (ft)	XLOBL (ft)	XLOBR (ft)	XLCH (ft)	XNL	XNR	XNCH	CCHV	CEHV	Remarks
0.06	0.06	335	320	300	335	0.050	0.040	0.040	0.1	0.3	Confluence
0.14	0.14	728	250	480	394	0.050	0.045	0.040	0.1	0.3	
0.18	0.18	939	250	160	211	0.050	0.045	0.040	0.1	0.3	
0.21	0.21	1129	235	160	190	0.045	0.040	0.040	0.1	0.3	
0.29	0.29	1527	370	405	398	0.045	0.045	0.040	0.1	0.3	
0.36	0.36	1925	230	420	398	0.040	0.045	0.040	0.1	0.3	
0.44	0.44	2338	420	400	413	0.040	0.040	0.040	0.1	0.3	
0.52	0.52	2731	415	380	393	0.045	0.040	0.040	0.2	0.4	
0.59	0.59	3125	455	325	394	0.040	0.040	0.040	0.2	0.4	
0.67	0.67	3533	110	550	409	0.040	0.040	0.040	0.2	0.4	
0.68	0.68	3610	80	75	77	0.040	0.040	0.013	0.3	0.5	
0.70	0.69	3661	47	47	47	0.040	0.040	0.013	0.3	0.5	State Route 85
0.79	0.79	4146	580	320	485	0.040	0.040	0.040	0.3	0.5	
0.88	0.88	4652	520	420	506	0.040	0.040	0.040	0.1	0.3	
0.93	0.93	4884	240	235	233	0.040	0.040	0.040	0.1	0.3	
0.98	0.98	5150	280	250	266	0.040	0.040	0.040	0.2	0.4	
1.03	1.03	5423	200	250	273	0.040	0.040	0.040	0.2	0.4	
1.07	1.07	5655	195	220	232	0.040	0.040	0.040	0.1	0.3	
1.17	1.17	6161	530	490	506	0.040	0.040	0.040	0.1	0.3	
1.26	1.26	6650	490	500	489	0.040	0.040	0.040	0.1	0.3	
1.31	1.31	6897	240	255	247	0.040	0.040	0.040	0.1	0.3	
1.35	1.35	7144	220	260	248	0.040	0.040	0.040	0.1	0.3	
1.45	1.45	7639	500	490	494	0.040	0.040	0.040	0.1	0.3	
1.52	1.52	8006	400	340	367	0.040	0.040	0.040	0.1	0.3	

TABLE 2. Rainbow Wash Tributary Reach Lengths, Roughness, and Loss Coefficients

Simons, Li & Associates, Inc.
Water Resources & Civil Engineering Consultants

VII. REFERENCES

1. Donohue & Associates, Inc., "Hydrology Report, Gila Bend Canal Flood Plain Delineation Study, Gillespie Dam to Gila Bend," prepared for the Flood Control District of Maricopa County, September 1991.

2. U.S. Geological Survey, Water Resources Division, "Estimated Manning's Roughness Coefficients for Stream Channels and Flood Plains in Maricopa County, Arizona," prepared for the Flood Control District of Maricopa County, April 1991.

3. U.S. Army Corps of Engineers, Hydrologic Engineering Center, "HEC-2 Water Surface Profiles User's Manual" September 1990.

4. Aldridge, B.N. and Garrett, J.M., "Roughness Coefficients for Stream Channels in Arizona," U.S. Geological Survey Open-File Report 78-3. prepared for the Arizona Highway Department, February 1973.

5. Chow, V.T., Open-Channel Hydraulics, New York: McGraw-Hill, 1959.

6. Barnes, Harry H., Roughness Characteristics of Natural Channels, U.S. Geological Survey Water-Supply Paper 1849, Washington: U.S. Government Printing Office, 1967.

7. Simons, Li & Associates, Inc., "Design Manual for Engineering Analysis of Fluvial Systems," prepared for the Arizona Department of Water Resources, March 1985.

8. Simons, Li & Associates, Inc., Engineering Analysis of Fluvial Systems, Simons, Li & Associates, Inc., 1982.

9. "Hydrologic Design Manual for Maricopa County, Arizona", Flood Control District of Maricopa County. September, 1990.

10. U.S. Department of Agriculture. Agricultural Stabilization and Conservation Service. Maricopa County ASCS office. Maps depicting cropland areas along Rainbow Wash.

APPENDIX A

Photographic Record of Hydraulic Structures

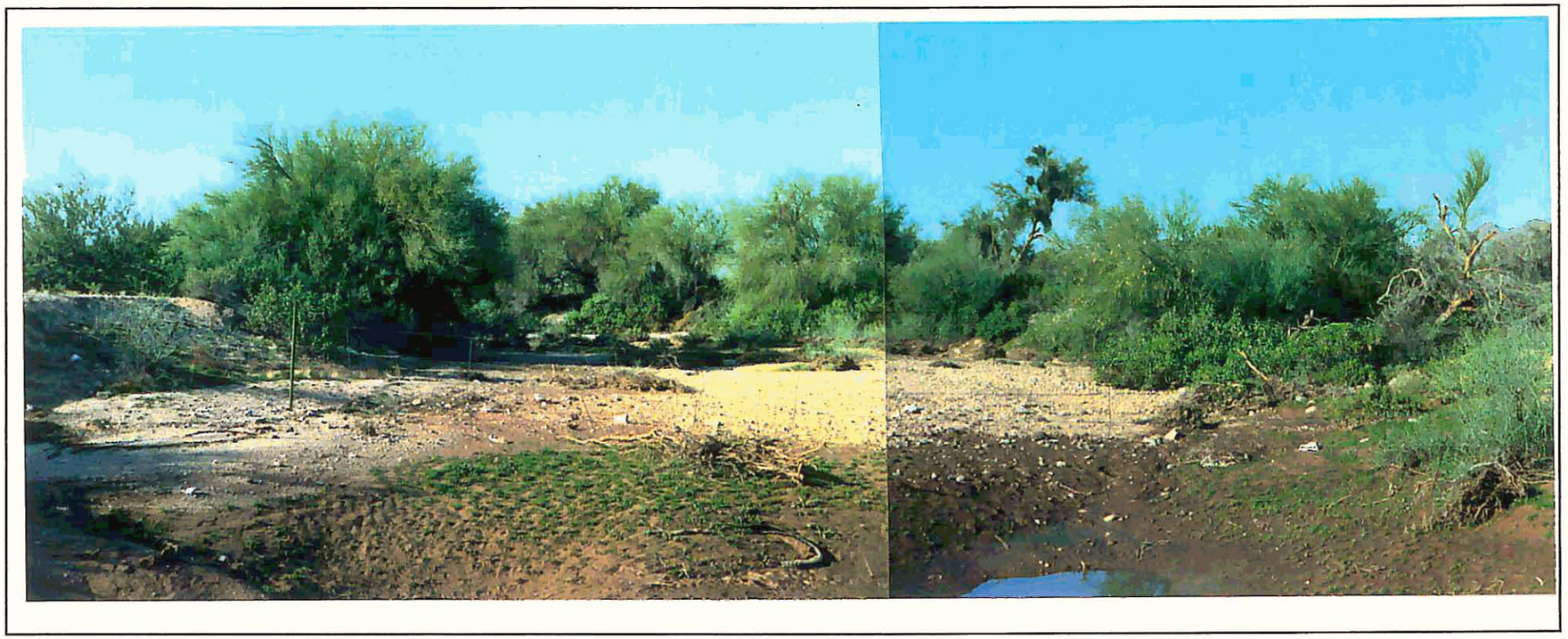
PHOTOGRAPH 32. Looking upstream at the S.R. 85 bridge over the mainstem of Rainbow Wash.

PHOTOGRAPH 33. Looking downstream at the S.R. 85 bridge over the mainstem of Rainbow Wash.

PHOTOGRAPH 34. Looking downstream at the main channel of Rainbow Wash from S.R. 85.

PHOTOGRAPH 35. Upstream photos of the Rainbow Wash tributary triple box culvert.

PHOTOGRAPH 36. Downstream photos of the Rainbow Wash tributary triple box culvert.



PHOTOGRAPH 37. Looking downstream at the Rainbow Wash tributary from the box culvert at S.R. 85.

APPENDIX B

Cropland Mapping by A.S.C.S

H15-B1

(4W-25)

T-2658

② HEL 86.9

SIS solid 84.3 net

3537

③ 75.8 HEL

T-2659

⑦ HEL 36.6 T-2659

Barley 75.8

Barley 36.6

3537

32

① 87.9 HEL T-2659

④ HEL 92.4 T-2659

⑤ HEL 123.9 T-2659

⑧ HEL 143.7 T-2659

ACR Tallow 87.9

SIS solid 84.6 net

3537

SIS solid 120.2 net

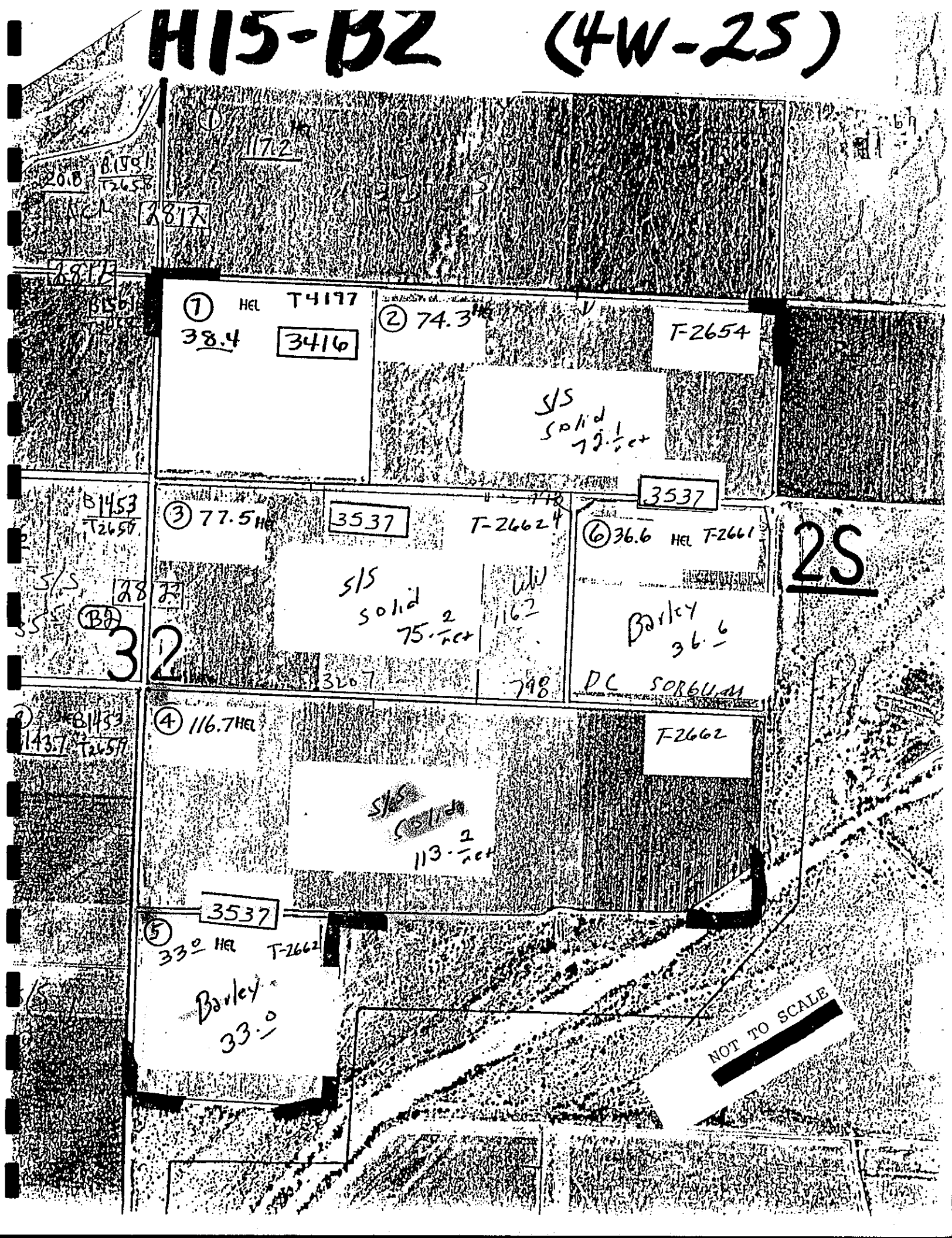
3537

SIS solid 139.4 net

NOT TO SCALE

4W

H15-B2 (4W-2S)


① 117.2 HEL
20.8 B1398 T2658
KCL
28 17
28 18
B1561
① HEL T4197
38.4
3416
② 74.3 HEL
T-2654
S/S
solid
72.1 net
3537
B1453 T2657
③ 77.5 HEL
3537
T-2662
S/S
solid
75.2 net
Wh
116.2
3207
798
⑥ 36.6 HEL T-2661
Barley
36.6
DC SORGUM
2S
28 22
S/S
BB
3
2
B1453
143.7 T2657
④ 116.7 HEL
T-2662
S/S
solid
113.2 net
3537
⑤ 33.0 HEL T-2662
Barley
33.0
NOT TO SCALE

H16-A1 (4W-25)

NOT TO SCALE

(A-1)

28

①

NOT CROPLAND '89

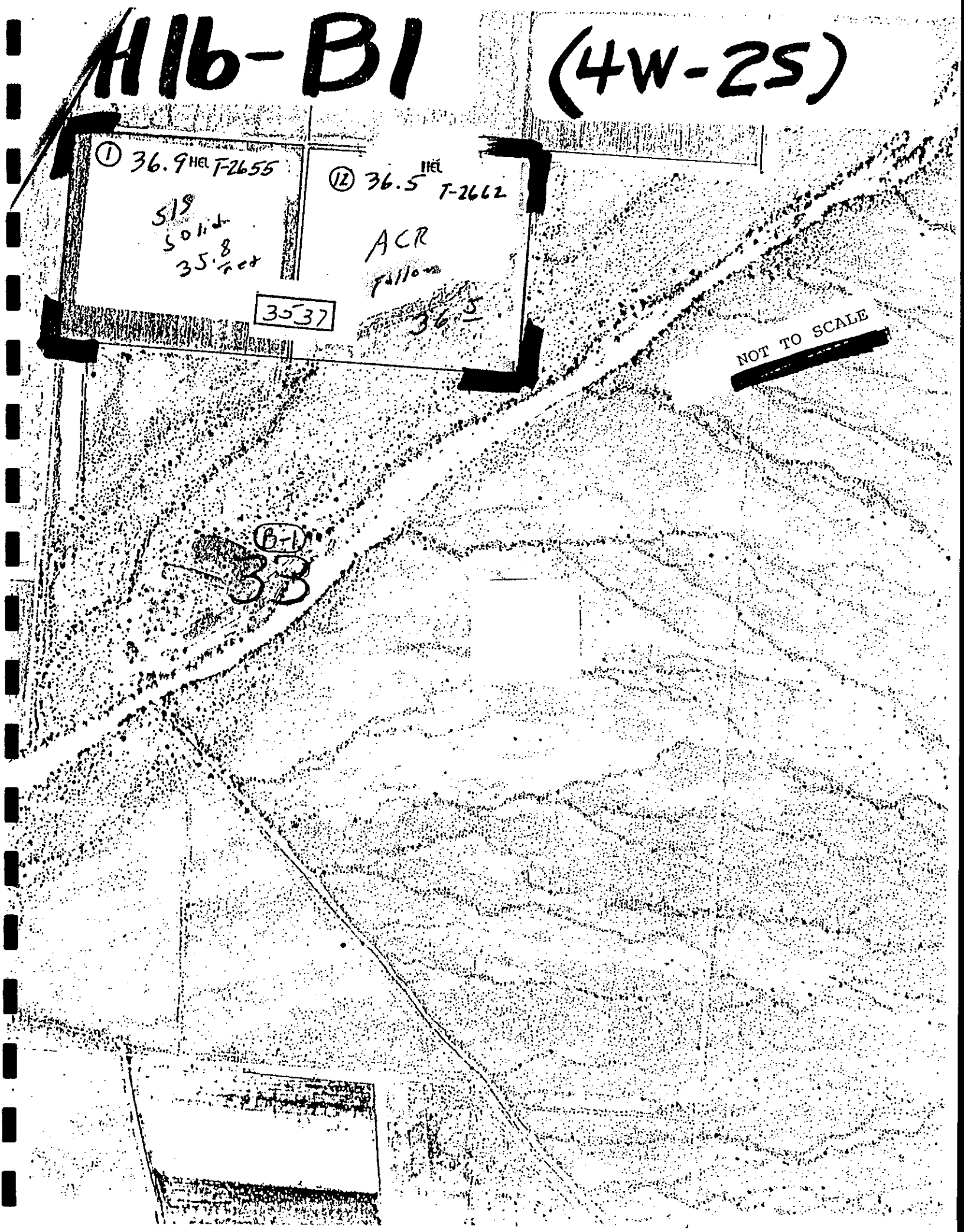
② 73.5 HEL 3537 T-2662

SIS
solid
71.3 ac+

B474
T2655

⑫ 36.5 HEL 10 Most
T2662

H16-B1 (4W-25)


① 36.9 HEL T-2655
519
Solid
35.8
Net
3537
⑫ 36.5 HEL T-2662
ACR
Fallow
36.5
NOT TO SCALE
B-1
33

H18-A2

(4W-3S)

NOT TO SCALE

(10) 24.9 HEL T-2165

(Fallow)

3321

B479

T-2165

(11) 39.9 HEL T-2165

3321

66.4 HEL

(13)

SLS-

(A2)

5

T2164

(12) 60.9 HEL T-2165

(1A) 30.0 HEL

24.3

(1B) 5.2 T-2657 ACR 5.2

3537

110.4 HEL

(2)

3537

SLS

solid

107.1 ACT

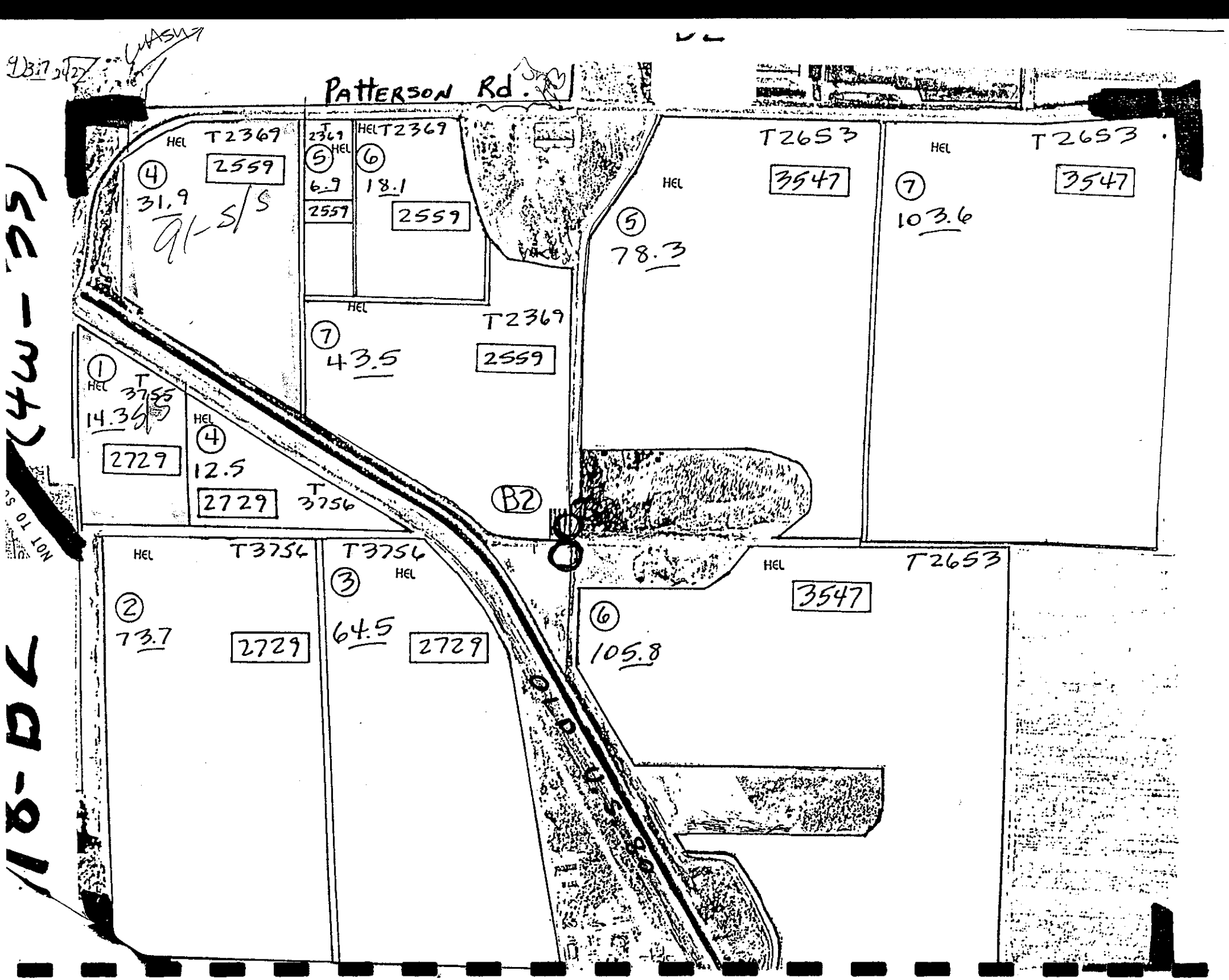
(9) 46.6 HEL T-2165

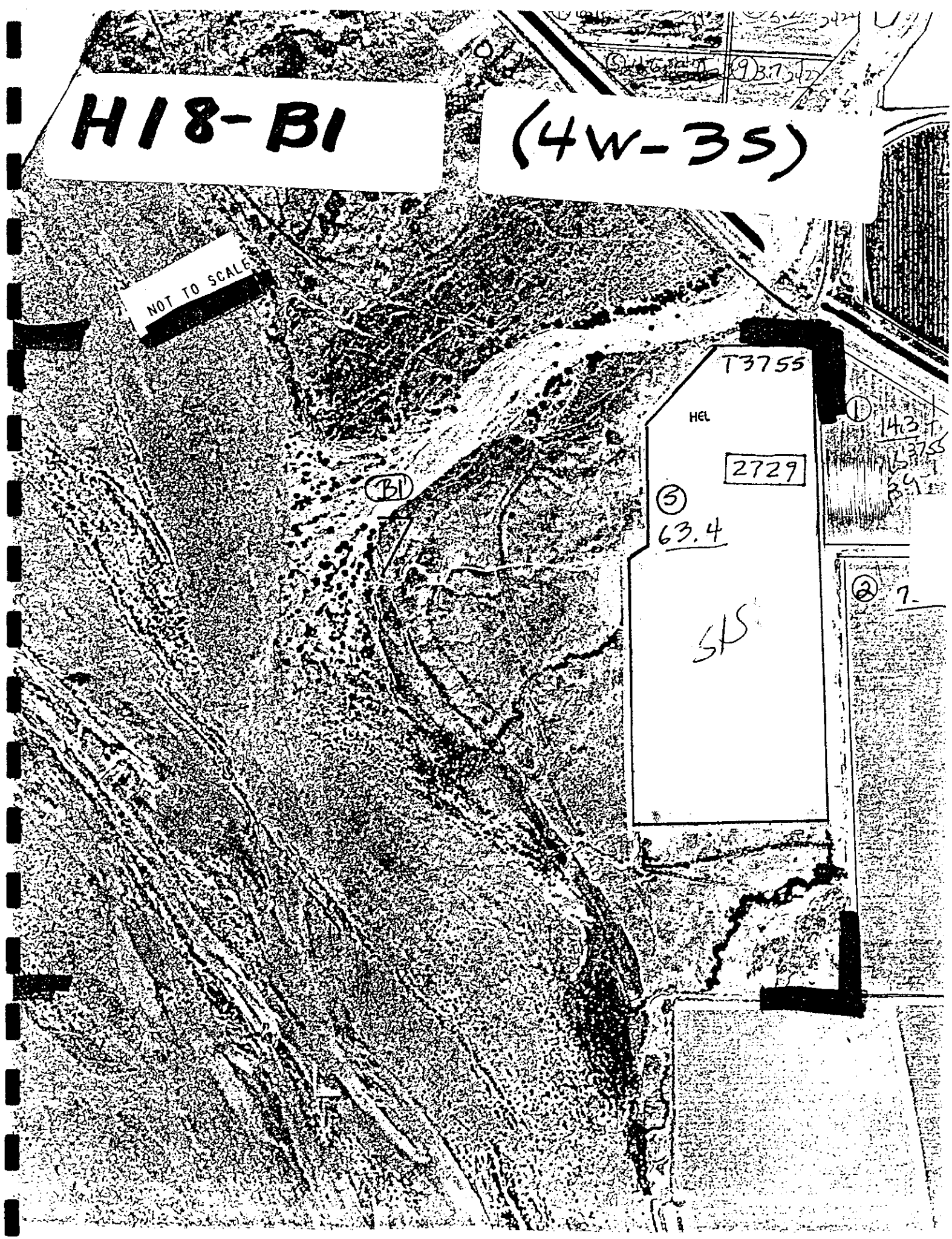
3321

10'

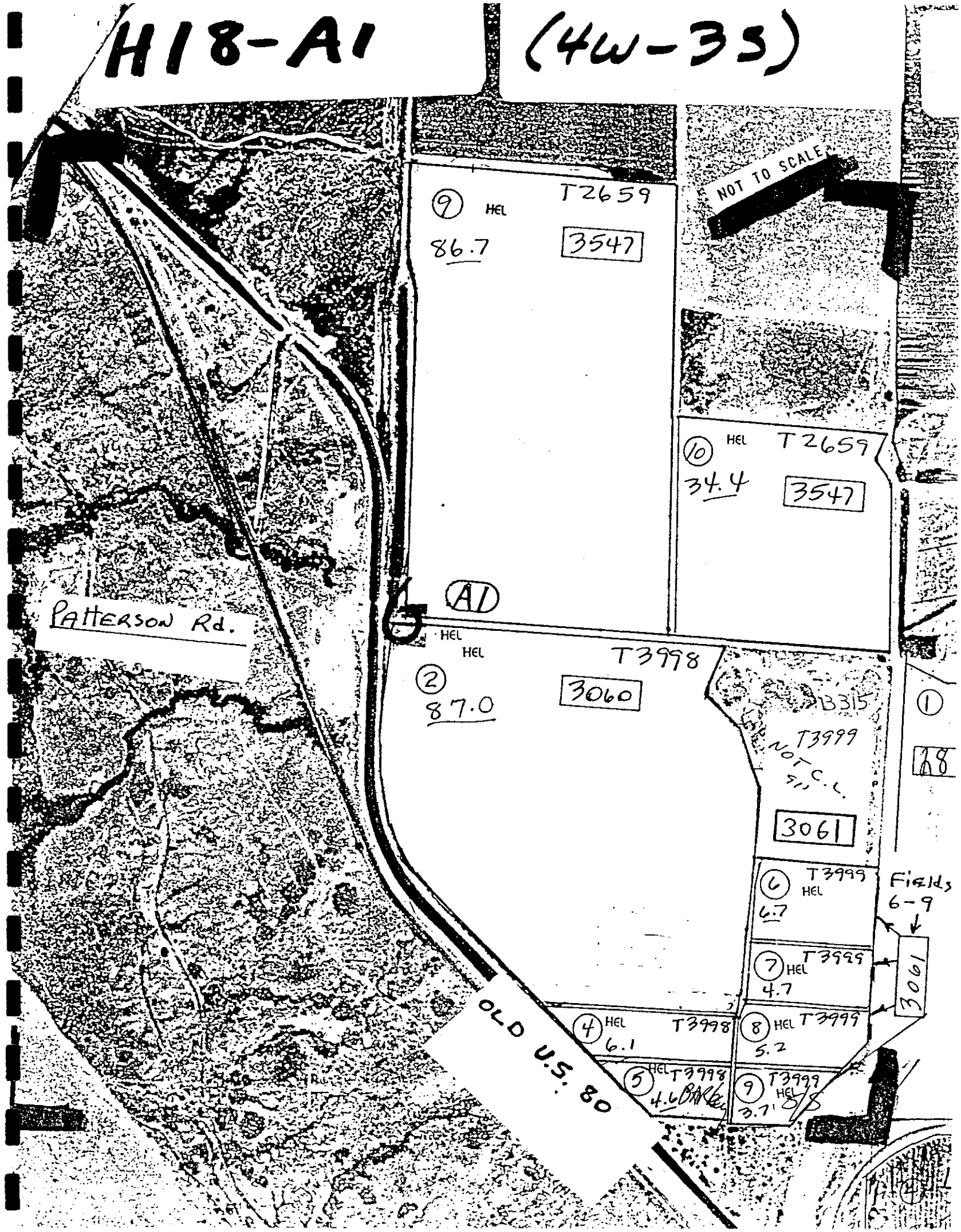
(5) 78.3 HEL B1462 P2653

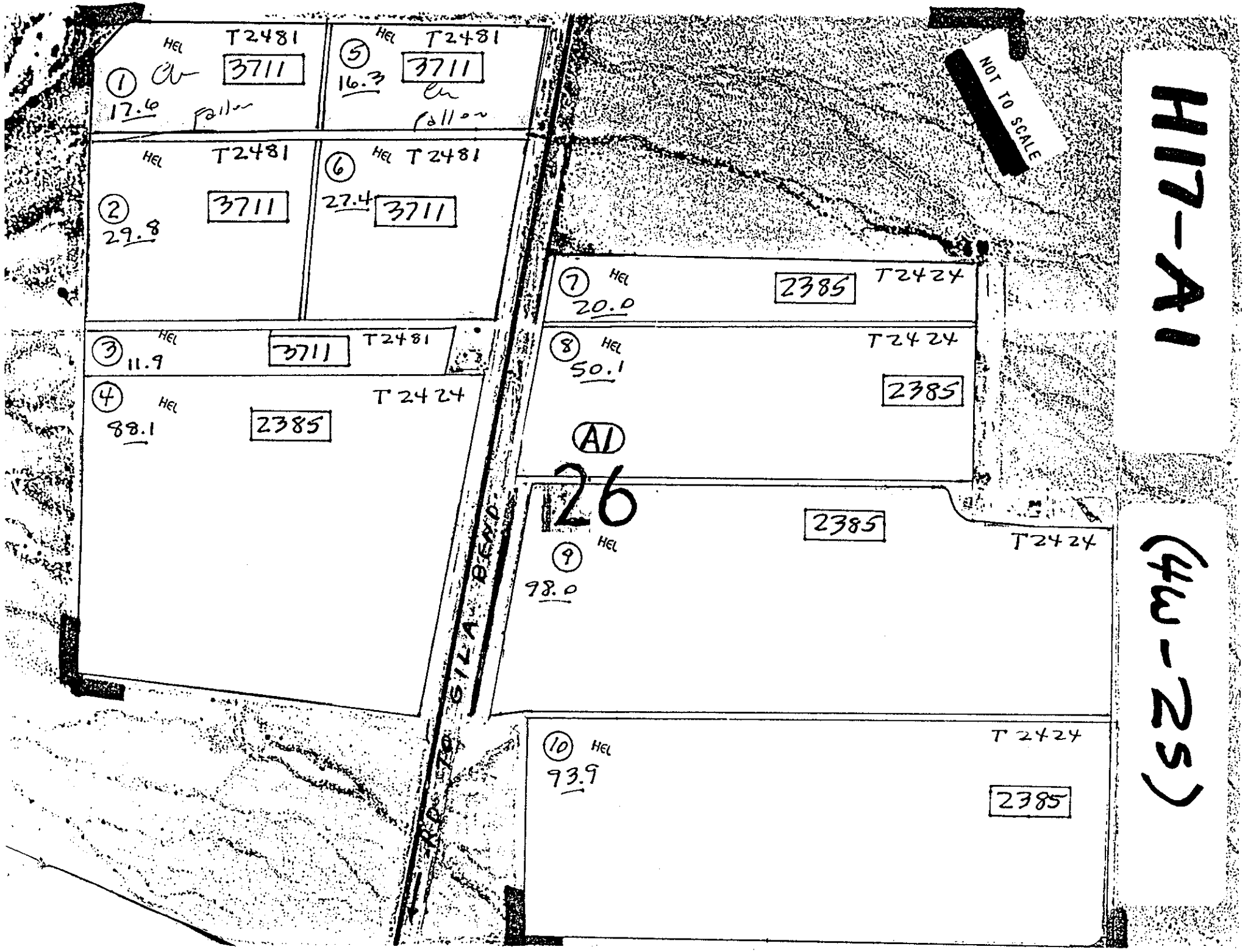
(7) 103.6 HEL


PATTERSON Rd.
T2369
HEL
2559
4
31.9
5
6.9
6
18.1
7
43.5
T2653
3547
5
78.3
7
103.6
1
14.35
2729
4
12.5
T3756
B2
2
73.7
3
64.5
6
105.8
OLD DIXIE
NOT TO SCALE
(4W-25)
JA-81


H18-B1
(4W-3S)
NOT TO SCALE
T3755
HEL
2729
B1
5
63.4
SIS
1
143
2
7

H18-A1 (4W-3S)


NOT TO SCALE
9 HEL T2659
86.7
3547
10 HEL T2659
34.4
3547
A1
PATTERSON Rd.
HEL
HEL
T3998
2
87.0
3060
B315
T3999
NOT C.L.
3061
1
18
6 T3999 HEL
6.7
Fields 6-9
7 HEL T3999
4.7
3061
4 HEL T3998
6.1
8 HEL T3999
5.2
5 HEL T3998
4.6
9 HEL T3999
3.7
OLD U.S. 80


H17-A1
(4W-25)
NOT TO SCALE
HEL
T2481
3711
1
17.6
fallow
5
16.3
fallow
2
29.8
6
27.4
3
11.9
T2424
2385
4
88.1
7
20.0
8
50.1
A1
26
9
98.0
10
93.9
GILA BEND

AZ-MC-14
RAINBOW FIS
Rec'd 4/16/92
from FCD
J. Opstein

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