APPENDIX B
FLOOD CONTROL IMPROVEMENT PROJECT SUMMARY (USACE 1996)

RIO GRANDE CANALIZATION IMPROVEMENT PROJECT

PERCHA DIVERSION DAM, NEW MEXICO, TO AMERICAN DIVERSION DAM, TEXAS

EXECUTIVE SUMMARY

VOLUME 1

JULY 1996

PREPARED FOR:

INTERNATIONAL BOUNDARY AND WATER COMMISSION

UNITED STATES AND MEXICO

UNITED STATES SECTION

PREPARED BY:

US Army Corps Of Engineers
Albuquerque District

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RIO GRANDE CANALIZATION IMPROVEMENT PROJECT
PERCHA DIVERSION DAM, NEW MEXICO, TO AMERICAN DIVERSION DAM, TEXAS

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PREFACE

This volume is part of a multi-volume set prepared for the United States Section of the International Boundary and Water Commission (USIBWC). All documents in the set are listed below.

Volume 1		- Executive Summary
Volume 2		- Hydrology and Hydraulic Analyses
	Appendix A	- Alignment Plan and Cross-Section Locations
	Appendix B	- Fixed-Bed Water Surface Profiles
	Appendix C	- Fixed-Bed Cross Sections
Volume 3		- Sedimentation Analysis of the Rio Grande Tributary Basins
	Appendices A- J	
Volume 4		- Scour and Deposition Analysis of the Rio Grande
	Appendices A - I	(Volume A4.1 of 2)
	Appendices J - N	(Volume A4.2 of 2)

The hydrologic analysis summarized in Volume 2 presents the 100-year flood discharges at selected locations along the Rio Grande computed using standard hydrologic procedures and the U.S. Army Corps of Engineers computer program HEC-1. The hydraulic analysis presented in Volume 2 identifies locations at which the 100-year flood encroaches upon the levee freeboard or overtops the levee and locations at which Caballo Dam low-flow releases overtop the existing low-flow pilot channel. Discharges used in the hydraulic analysis of the low-flow channel were approved by the USIBWC and establish conditions as they exist for standard operation of the Rio Grande below Caballo Dam. The U.S. Army Corps of Engineers computer program HEC-2 computed the water surface profiles. Geometry for the HEC-2 modeling was obtained using digital terrain models with Intergraph's *InRoads* (version 5.1) computer software running in the *Microstation* (version 5.0) environment.

The profiles displayed in Volume 2, Appendix B, show the invert of the Rio Grande, the low-flow water surface elevation, the 100-year water surface elevation, the right-bank elevation, the left-bank elevation, and the existing right and left top-of-levee elevations. The right- and left-bank profiles show limits of the existing low-flow channel.

The cross sections and invert and bank profiles presented in Volume 2, Appendices B and C, show conditions as they existed when the aerial photography was produced (November 1993). No effects of future sediment aggradation or degradation were included in the cross-sectional and profile data.

The U.S. Army Corps of Engineers, Albuquerque District, Hydrology and Hydraulics Section, performed the hydrology and hydraulic analyses for this study. The Albuquerque District produced the plates showing the alignment plan and cross-section locations, the fixed-bed water surface profiles, and the fixed-bed cross sections. Resource Technology, Inc., performed the sedimentation analysis for the tributary arroyos and the main stem of the Rio Grande under contract to the Albuquerque District.

Appendices A, B, and C should be used with this volume to gain a full visual representation of fixed-bed conditions along the Rio Grande.

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INTRODUCTION

The U.S. Army Corps of Engineers, Albuquerque District, evaluated approximately 100 miles of the Rio Grande floodway between Percha Diversion Dam in New Mexico and the American Diversion Dam in El Paso, Texas, to determine the Rio Grande channel capacity and the cause of channel scouring. Channel capacity and scour information is necessary for the United States Section of the International Boundary and Water Commission (USIBWC) to provide adequate flood control protection and channel stabilization in the study reach. The Albuquerque District conducted the study under contract to the USIBWC on a cost-recovery basis under authority of Section 321 of the Water Resources Development Act of 1990.

The USIBWC constructed and maintains the Rio Grande levee system between Percha Diversion Dam and American Diversion Dam as part of the Rio Grande Canalization Project. The levees are generally continuous, except where the river runs against the base of rising ground or bluffs. A sizable unleveed section exists near Canutillo, Texas, where the Atchison, Topeka, and Santa Fe Railroad embankment serves as the east river levee. The low-flow pilot channel within the floodway carries the normal irrigation releases from Caballo Dam.

HYDROLOGIC ANALYSIS

The hydrologic analysis, presented in Volume 2, involves only the watershed area that contributes directly to the Rio Grande. The flat river-bottom land between the bluffs and the Rio Grande provides a large amount of valley storage where arroyo flood peaks dissipate before flowing to the river via irrigation ditches in the Canalization Project levees. The hydrologic analysis provides the 100-year peak discharges for selected stations on the Rio Grande between Percha Diversion Dam and American Diversion Dam. The Albuquerque District assumed that the existing levees contain the flood flows without overtopping for the entire study reach. Table 1-17 in Volume 2 lists the 100-year flood peak discharges at selected locations on the Rio Grande.

The irrigation canals drain into the Rio Grande by gravity through ungated openings (wasteways) in the levee. Many of the wasteways have closure devices; however, thirty-two in the study reach do not. A majority of these large wasteway openings, with mild invert slopes, would allow Rio Grande flood waters to flow backward through the levee openings and cause localized or generalized flooding behind the levee. Irrigation returns are minimal compared to the 100-year flow in the Rio Grande; therefore, the wasteways have ample capacity to store non-conveying flow. The wasteway diversion and storage of these flood waters in the irrigation canals cause a significant attenuation of the flood peaks on the Rio Grande; consequently, the Albuquerque District modeled the ungated wasteways within the study reach to determine their effect. Table 1-17 in Volume 2 identifies the wasteways where the Rio Grande discharges are reduced to reflect flow diversion and storage in the wasteways.

Computed flood discharges, based on or supported by frequency-discharge relationships developed from local stream gage records, constitute a desirable situation in any hydrologic analysis. The Albuquerque District recommends that the concerned agencies begin recording instantaneous annual peak discharges, as well as mean daily discharges, at the existing stream gages on the Rio Grande. Furthermore, support of cooperative stream gaging programs on the tributary arroyos will provide additional information to further the understanding and interpretation of hydrologic conditions in the watershed.

HYDRAULIC ANALYSIS

The hydraulic analysis presented in Volume 2 details the hydraulic evaluation of approximately 100 miles of the Rio Grande floodway between Percha Diversion Dam in New Mexico and the American Diversion Dam in El Paso, Texas. These analyses include: (1) identification of the areas which do not adequately convey the maximum annual irrigation releases from Caballo Dam within the channel banks (low flow) of the Rio Grande; (2) identification of the levee areas where the 100-year computed water surface elevation encroaches upon the freeboard or overtops the levee; and (3) analysis of all ungated wasteways to determine if backwater effects of the Rio Grande, during the 100-year flood, exceed the wasteway bank elevations. General recommendations are provided for containment of the 100-year flood within the levees and in the Canutillo, Texas, area where the Atchison, Topeka, and Santa Fe Railroad embankment forms the east river levee.

The results of the HEC-2 analyses for both the low-flow condition and the 100-year flood condition are listed in Tables 2-3, 2-4, and 2-5 in Volume 2. Table 2-3 lists the centerline station, the HEC-2 section number, the low-flow discharge, the computed water surface elevation, and the left and right low-flow channel bank elevations. Table 2-3 also identifies the cross sections where the computed water surface elevation overtops the bank elevation. Table 2-4 summarizes Table 2-3. Table 2-5 lists the centerline station, the HEC-2 section number, the 100-year discharge, the computed water surface elevation, and the left and right top-of-levee elevations. Table 2-5 also identifies the cross sections where the computed water surface elevation encroaches upon the levee freeboard or overtops the levee. A separate HEC-2 model was created for each ungated wasteway to determine if the backwater effects of the 100-year flood would exceed the wasteway embankments. Table 2-6 in Volume 2 lists the results of the wasteway analysis.

The Albuquerque District originally developed the HEC-2 hydraulic model of the Rio Grande using a channel roughness coefficient (Manning's "n" value) of 0.020 and an overbank roughness coefficient of 0.030. Based on the hydraulic analysis conducted by the Albuquerque District, Resource Technology, Inc., the study contractor for the sediment investigation, also used "n" values of 0.020 and 0.030 for the channel and overbank areas, respectively. Closer examination of the overbank areas, conducted jointly by the Albuquerque District and the USIBWC, revealed that the overbank "n" value should be increased in several areas, particularly in the Selden Canyon region where dense vegetation is present. Consequently, the final HEC-2 model uses a channel "n" value of 0.020 and overbank "n" values that range from 0.030 to 0.080.

The Albuquerque District compared the HEC-2 models developed with the original and revised "n" values. The results of the comparison showed that the computed water surface elevation with the revised "n" values varied by more than 0.5 foot for only 73 of the 1,159 cross sections in the model; a variation in the 1- to 2-foot range occurred at only 18 cross-section locations, and none varied by more than 2 feet. The channel velocity changed by more than 10% at isolated locations at 46 of the 1,159 cross sections. Based on the variations indicated by the comparison, the HEC-6 sediment model was not adjusted to reflect the revised "n" values; the HEC-6 model incorporates the original "n" values of 0.020 for the channel and 0.030 for the overbank areas. If the HEC-6 model were modified to include the revised "n" values, the HEC-6 results would change. However, because the sediment analysis should be used to identify trends as opposed to magnitudes, the Albuquerque District considers the differences based on the revised "n" values insignificant to the analysis. The current HEC-6 model is acceptable to identify areas of scour and deposition.

GENERAL RECOMMENDATIONS

All closure devices along the levee should be inspected to insure that they will operate correctly in case of flood emergencies. Several existing closure devices in the study reach have been tampered with such that they remain permanently open.

There are three bridges (Brickplant, Courchesne, and Canutillo) at which the 100-year flood overtops the roadway elevation. These bridges should be replaced in order to pass the 100-year flood without overtopping. The Tonuco Bridge is an abandoned bridge in the northern reach of the study area and should be removed from the floodway.

CANUTILLO, TEXAS, GENERAL RECOMMENDATIONS

Flooding in Canutillo, Texas, is currently prevented by the Atchison, Topeka, and Santa Fe Railroad embankment which acts as the east river levee. As denoted by asterisks in Table 2-5 of Volume 2, the railroad embankment extends from Station 575+00 (HEC-2 Section Number 117) to Station 865+00 (HEC-2 Section Number 175); however, the protection is discontinuous due to uncontrolled openings in the railroad embankment. To successfully contain river flood stages within the levee section, the openings must be eliminated. This can be accomplished on an emergency basis by sandbagging the openings or by building stop-log structures at each opening. Both of these methods require extensive manual labor and coordination during an emergency situation; therefore, the measures are not considered viable solutions unless an extensive flood warning system was to be implemented.

A recommended structural solution would involve both an earthen levee and a concrete floodwall. The floodwall, beginning approximately at Station 525+00 and extending to Station 600+00, is necessary due to the constricted flow area that exists; the levee-to-levee width in this reach is only 310 feet to 350 feet. This river section currently represents the hydraulic constriction in the study reach, and the levee-to-levee width cannot be reduced by a new earthen levee section without adversely increasing the water surface elevation upstream. The recommended 7,500-foot floodwall would vary in height from 8 to 10 feet, without freeboard, and the structure would be located riverside and immediately adjacent to the Atchison, Topeka, and Santa Fe Railroad embankment (the existing east river levee). To accommodate local drainage, the floodwall must tie into the drainage control structures at appropriate locations. Downstream of Station 525+00 and upstream of Station 600+00, the levee-to-levee width expands to approximately 500 feet, thus allowing the floodwall to transition to an earthen levee.

The west-side levee should incorporate a floodwall extension for the same constricted area (Station 525+00 to Station 600+00). The floodwall would consist of a vertical wall partially embedded in the existing levee crown. A floodwall extension is possible on the west side because, unlike the east-side levee, the west-side levee does not serve the dual purpose of railroad embankment and flood control levee. The economics of the recommended plan must be investigated before determining whether the floodwall extension should be considered downstream of Station 525+00 or upstream of Station 600+00 or both. The existing levee section should be checked for through seepage and underseepage and for embankment and foundation stability. Some methods of controlling seepage and improving embankment stability could eliminate the economic advantage of the floodwall in comparison to an earthen levee enlargement. The U.S. Army Corps of Engineers Manual EM 1110-2-2502, Engineering and Design of Retaining and Floodwalls (dated 27 September 1989), provides guidance for the safe design and economical construction of floodwalls.

SEDIMENTATION ANALYSIS - RIO GRANDE TRIBUTARY BASINS

The purpose of this phase of the project is to determine sediment yield estimates from all tributary basins in the study reach between Percha Diversion Dam, New Mexico, and American Diversion Dam, Texas. Detailed hydraulic and sediment analyses were conducted to quantify the sediment yield from twenty selected tributary basins to the Rio Grande within the study reach. The analysis procedure, assumptions, and results are described in Volume 3; the supporting data and calculations are included in the Volume 3 Appendices A through J.

The total drainage area of all tributary basins contributing to the Rio Grande within the study reach is 922 square miles. Fifty-two contributing subareas and many non-contributing subareas were initially delineated by the Albuquerque District. Resource Technology, Inc., (RTI), the study contractor for the sediment analysis, selected twenty of those subareas for detailed hydraulic and sediment analyses. These study basins were selected to represent the entire range of subareas with respect to drainage area, basin slope, and outfall location within the study reach. The reason for selection of twenty study basins was to complete a detailed hydrologic, hydraulic, and sediment yield and transport analysis for each of those basins in order to develop sediment yield prediction equations to be applied to the remaining unstudied contributing subareas. Therefore, the total sediment yield from all tributary arroyo basins could be computed.

The hydrologic analyses for all arroyo subbasins were completed using the HEC-1 computer program. The Albuquerque District developed and provided the 100-year hydrologic model to RTI. The Albuquerque District and RTI jointly developed models for the 2-, 5-, 10-, 25-, and 50-year return period storms. Using surveyed cross sections and the HEC-2 computer program, RTI computed hydraulic data for a short channel segment within each study basin. The peak discharges developed from the HEC-1 models for all return periods were input into the HEC-2 models of each channel segment.

For each of the twenty study basins, RTI computed the sediment yield (wash load) and sediment transport (bed material load) which together equal the total sediment load. The analysis for the total sediment load was completed for the 2-, 5-, 10-, 25-, 50-, and 100-year return period rainfall events for existing watershed conditions. Subsequently, RTI computed the average annual event total sediment load. The representative annual storm is based on the probability of storms of various return periods occurring in any given year.

The total sediment load results for the twenty study basins were then used to develop prediction equations to compute the total sediment load from all tributary basins not studied. To account for the reduction of sediment contribution to the Rio Grande by existing reservoirs, RTI assumed a trap efficiency of 90% based on review of available data for these reservoirs. The total sediment load prediction equations were applied to all subareas, and the results are included in Table 5-10 in Volume 3 which lists subareas which produce the greatest sediment loads descending to the subareas which produce the least sediment loads. RTI used the results of this effort as input into the scour and deposition analysis on the Rio Grande (Volume 4). In addition, Volume 3 results were important in developing the recommendations presented in Volume 4.

SEDIMENTATION ANALYSIS - RIO GRANDE MAIN STEM

The purpose of this phase of the study is to perform detailed scour and deposition analyses that can be used by the USIBWC to carry out an improvement program to stabilize the river channel from Percha Diversion Dam to American Diversion Dam. The procedures applied in this study were selected to yield the most reliable results to estimate sediment loads and yields. The U.S. Army Corps of Engineers Hydrologic Engineering Center computer program HEC-6, Scour and Deposition in Rivers and Reservoirs was used to model sediment transport in the study reach and to evaluate the efficiency of the proposed improvements. The analysis procedures, assumptions, and results are described in Volume 4; the supporting data and calculations are presented in Appendices A through H in Volume A4.1, and the HEC-6 computer models and output files are included in Volumes A4.1 and A4.2, Appendices I through K. Appendix L, Volume A4.2, presents plan view maps of the HEC-2/HEC-6 cross-section locations and recommended sediment control structures. Appendix M, Volume A4.2, includes the Rio Grande bed profiles from 1958, 1962, 1967, 1972, and 1980. Appendix N, Volume A4.2, presents a summary of problem areas identified during the field survey and recommended improvements.

Four HEC-6 models were developed in order to simulate the river response to three flow scenarios and also to evaluate the effect of recommended sediment control measures. Each of the models includes the entire 105-mile study reach. A brief description of each HEC-6 model follows:

1. An average low-flow year which represents the 10-year lowest flow period, current river geometry and features (November, 1993) HEC-6 model:

   Based on evaluation of the available flow gage data, RTI selected ten years of consecutive lowest flows from the period of record, and an average low-flow year was computed to evaluate the river response to low flows. This analysis is also called the 10-year low-flow period analysis.

2. An average high-flow year which represents the 10-year highest flow period, current river geometry and features (November, 1993) HEC-6 model:

   Based on evaluation of the available flow gage data, RTI selected ten years of consecutive highest flows from the period of record, and an average high-flow year was computed to evaluate the river response to high flows. This analysis is also called the 10-year high-flow period analysis.

3. 100-year return period storm, current river geometry and features (November, 1993) HEC-6 model:

   The 100-year return period storm over the entire study area was modeled by the Albuquerque District using the HEC-1 program (refer to Volume 2). The runoff hydrographs from the HEC-1 model were used as input to the HEC-6 model to evaluate the river response to large flows of short duration. This model includes the 100-year hydrographs and associated sediment loads from most of the contributing basins. Some of the smaller basins were not considered in this analysis because their impact was negligible.

4. 100-year return period storm, current river geometry and features (November, 1993) with recommended sediment control measures HEC-6 model:

   Based on the results from the previous 100-year model, sediment control measures were proposed and incorporated into this model to evaluate the effects of the recommended measures.

SUMMARY AND CONCLUSIONS OF THE AVERAGE LOW- AND HIGH-FLOW YEARS (BASED ON 10-YEAR PERIODS) HEC-6 MODEL RESULTS FOR CURRENT RIVER GEOMETRY AND FEATURES

Appendix I in Volume A4.1 presents the average year low- and high-flow model output files. The output files were reviewed and the relatively significant bed changes are summarized in Table 2-9 in Volume 4. Local water discharge rate changes along the study reach are modeled, but tributary water and sediment inflows are not included in the low- and high-flow models.

The average year low-flow model results indicate a maximum scour depth of 1.7 feet at cross-section 925 and a maximum deposition depth of 0.7 feet at cross-section 895. Therefore, it appears that only minor scour and deposition problems would occur during a low-flow year which may be reasonable if local problems from sediment or water inflows from tributary arroyos are not considered.

The average year high-flow model results indicate a maximum scour depth of 2.6 feet at cross-sections 925 and 841, and a maximum deposition depth of 1.0 foot at cross-section 801. Therefore, it appears that significant, but not catastrophic, scour and deposition problems would occur during a high-flow year which again may be reasonable if local problems from sediment or water inflows from tributary arroyos are not considered.

SUMMARY AND CONCLUSIONS OF 100-YEAR RETURN PERIOD STORM HEC-6 MODEL RESULTS BASED ON CURRENT RIVER GEOMETRY AND FEATURES

Table 2-10 in Volume 4 summarizes the 100-year return period storm HEC-6 model results based on current river geometry and features. Table 2-10 also presents the computed water surface elevations with respect to the approximate levee or high-bank elevations and the resulting freeboard relative to the lower levee or bank elevation. Tributary water and sediment inflows are included in the model for all major arroyos.

The 100-year model results indicate that maximum deposition depths are found at cross sections located below major tributaries due to the addition of sediment loads. At these locations, deposition depths of 16.2 feet (Rincon Arroyo), 12.0 feet (Trujillo Canyon), 9.2 feet (Tierra Blanca Canyon), 8.6 feet (Placitas and Faulkner Arroyos), and other lesser depths would be expected. These depths are not design depths and are dependent upon the channel distance between cross sections. They do indicate that excessive deposition (over 5 feet) is likely at these locations.

The 100-year model results indicate maximum scour depths generally in the 3- to 4-foot range with a few 4- and 5-foot depths as shown in Table 2-10 (Volume 4). The scouring reaches are mostly downstream from Mesilla Diversion Dam. The maximum scour locations usually occur near bridges or other features which cause additional local effects on hydraulic parameters such as conveyance, slope, depth, and velocity.

The model results for most sections indicate that scour and deposition values are generally less than 1 foot in reaches between either a bridge or a tributary inflow location. Therefore, based on the model results, the river appears to have the capacity to carry high flows without major scour or deposition problems except at bridges or tributary inflow locations. Consequently, these locations will require detailed analyses and evaluation for specific sediment control projects.

Table 1 in this volume compares the results of the HEC-6 moveable-bed sedimentation analysis discussed above with the results of the HEC-2 fixed-bed hydraulic analysis for the 100-year flood on the Rio Grande. The following classification system was used in an effort to provide a means of prioritizing future levee rehabilitation:

CLASS:	I	HEC-2 CWSEL > top of levee elevation	
	II	HEC-2 CWSEL > top of levee elevation minus 3 feet	
	III	HEC-2 CWSEL < top of levee elevation minus 3 feet	
SUBCLASS:	A	HEC-6 CWSEL > HEC-2 CWSEL	
	B	HEC-6 CWSEL ≈ HEC-2 CWSEL (± ½ foot)	
	C	HEC-6 CWSEL < HEC-2 CWSEL	

For example:

CASE IC would indicate that the levee is in danger of being overtopped, but because of scour or some other moveable-bed phenomenon, the moveable-bed water surface elevation is lower than that of the fixed-bed condition.

CASE IIA would indicate that the water surface encroaches on the levee freeboard, and sedimentation causes an increase in water surface elevation. Potentially, this could be enough to overtop the levee and change the classification.

It should be noted that CLASSES IIIB and IIIC are benign. Also, highlighted data in Table 1 in this volume refer to fixed-bed conditions only.

Caution should be exercised when comparing the results of the HEC-2 and HEC-6 analyses. The models, while sharing many similarities, often employ dissimilar assumptions. HEC-2 assumes steady flow, that is $\partial Q/\partial t=0$. . This assumption is handled by modeling only the peak discharge of an event associated with a specific location. HEC-6 attempts to account for the dynamic processes at work in a moveable bed by modeling a hydrograph as a series of discrete, steady flows of a corresponding duration. As a result of the interaction of the hydrologic, hydraulic, geometric, and sedimentation processes, often the peak water surface elevation does not occur at the same time as the peak discharge. A detailed explanation of the modeling procedures can be found in the HEC-2 and the HEC-6 user's manuals. In addition, the water surface elevations resulting from the moveable bed HEC-6 analysis reported in Table 2-10 in Volume 4 differ from those reported in Table 1 of this volume as a result of different computational methodologies. The water surface elevations reported in Table 1 occur at the time step corresponding to the maximum water surface elevation; however, the water surface elevations reported in Table 2-10 in Volume 4 occur at the time step corresponding to maximum scour.

Under anything less than ideal conditions, any computed water surface profile must be viewed as an estimate only with some inherent degree of uncertainty associated with it. Frequency discharges, hydraulic roughness values, and channel geometry are never exact. They can only represent our best estimates. Traditionally, design engineers dealt with this uncertainty by adding some constant to the profile elevation (freeboard) to account for physical variables which were not always known and phenomena which were not completely understood. The freeboard was often established as a matter of professional judgement, past experience, rule-of-thumb, or agency policy. Recently, there has been a move to more carefully quantify this uncertainty and account for the uncertainty in the design using a risk-based approach. Regardless of the strategy, the designer should set levee elevations with this uncertainty in mind, as well as other variables such as the risk of loss of life associated with levee overtopping or failure, and, of course, economics.

Consequently, the HEC-2 results should be used as the primary basis for hydraulic design. The HEC-6 results are useful in quantifying a large part of the uncertainty associated with hydraulics, namely, that of a moveable bed. The HEC-6 model provides an indication of the typical fluctuations in the water surface profile due to sedimentation, as well as variations related to specific locations. Additionally, the moveable bed model provides a means of assessing the effectiveness of tributary control measures, both those suggested in the report and any formulated in the future. The HEC-6 model also points to areas in need of more maintenance and allows assessment of measures to reduce dredging or assessment of areas in need of armoring or grade control. Finally, it provides a means of prioritizing construction. However, it should be kept in mind that, as with the HEC-2 water surface profile, there is some inherent uncertainty included within the HEC-6 profile. Because of the relative complexity of the moveable bed model, it could be argued that the HEC-6 results have more uncertainly. The HEC-6 results should be viewed as a means to identify trends as opposed to magnitudes. Hence, the Corps of Engineers suggests using the HEC-2 water surface profile primarily during design.

SUMMARY AND CONCLUSIONS OF 100-YEAR RETURN PERIOD STORM HEC-6 MODEL RESULTS BASED ON CURRENT RIVER GEOMETRY AND FEATURES WITH RECOMMENDED SEDIMENT CONTROL MEASURES

The need for each recommended sediment control measure was based on providing a minimum of three feet of freeboard. Therefore, a sediment control dam is recommended at all tributary arroyos immediately upstream of the cross sections listed in Table 2-10 in Volume 4 that exhibit excessive deposition as a result of a local arroyo inflow and where the freeboard criterion is not met. The procedure used to model a sediment control dam was based on the assumption that the trap efficiency of the dam would be 90 percent. Consequently, the local inflow sediment load rates were reduced to 10 percent of the original values. Local water and sediment inflows are included in the model for all major arroyos, and some local inflow sediment rating curves have been adjusted to simulate the reduction of the total sediment load as a result of a sediment control dam.

The 100-year model results based on the recommended sediment control dams indicate a maximum scour depth of 5.8 feet at cross-section 407 which is located below Mesilla Diversion Dam. Similar to the existing condition model, all closely spaced cross sections as determined by the Albuquerque District for modeling bridges with HEC-2 were removed from the HEC-6 model except the cross section at the upstream face of each bridge. Also, 10 feet was set as the maximum allowable scour depth at all sections excluding structural bed control locations where no erosion was allowed.

The maximum scour locations generally occur near bridges or other features which affect hydraulic parameters such as conveyance, slope, depth, and velocity. All of the scour areas occur in the El Paso subreach which suggests that the proposed sediment control dams in the Mesilla and Leasburg subreaches are appropriate and will not result in undue channel erosion. More detailed analysis is required in subreach R3 (subareas 15 through 20) and subreach R5.1 (Berrenda Creek) to determine the impacts of individual tributaries because it may be desirable not to control sediment inflow from those tributaries.

The maximum deposition depth of 5.2 feet at cross section 563 results from a single basin representing subareas 15 through 20. Therefore, the deposition depth was significantly reduced from the existing condition model by including a sediment control dam on this basin. Once again, detailed analysis of the individual subareas will probably reduce this value. The next highest deposition (4.3 feet) occurs at the Berrenda Creek outfall where a sediment control dam was not recommended because adequate freeboard is available at this location. In general, after sediment control dams are introduced into the HEC-6 model, less than one foot of deposition may be expected.

In addition to the 100-year HEC-6 model results, all arroyos (without dams) and the associated total sediment load results from Volume 3 should be considered for future sediment control dams. It is possible that a minor tributary could create a significant sediment plug. Conversely, it may be desirable to maintain sediment inflow in the lower part of the study reach where erosion tendencies dominate. Detailed HEC-6 modeling of these subreaches, with each tributary modeled separately, may show that the predicted scour depths would be reduced and that it may be desirable to maintain sediment delivery channels to the Rio Grande.

RECOMMENDED IMPROVEMENTS TO THE RIO GRANDE CHANNEL

RECOMMENDATIONS BASED ON FIELD OBSERVATIONS

RTI staff conducted field surveys in 1994 to locate sites that indicate erosion, scour, deposition, vegetation (or lack of vegetation), livestock, or maintenance problems. The following is an inventory of areas that may require improvements. In addition to the station-by-station identification of problem areas, the following trends, which extend for varying lengths along the main stem of the river, have been noted:

1. Rio Grande Main Stem between Sibley Arroyo and Hatch Siphon
   (Station 5205+00 to Station 4754+71)
   "Poor" hydrologic range conditions on right-of-way.

2. Rio Grande Main Stem
   Leasburg Dam - North (both banks)
   (Station 3275+99 - Station 3745+00)
   Nemexas Siphon - South (west bank)
   (Station 3655+00 to Station 3640+00)
   Dense salt cedar (*Tamarix ramosissima*) infestation which may restrict channel flow through reduction of conveyance. Flow quantity may also be reduced by phreatophytic root uptake.

3. Non-Continuous Bank Erosion
   Main Stem from Mesilla Diversion Dam to Canutillo Bridge
   (Station 2075+42 to Station 670+98)
   Approximately one-quarter of this reach (35,000 linear feet) shows some degree of bank erosion or failure in an intermittent pattern.

4. Fifteen to twenty percent of the river banks for the entire study reach are dredge material disposal areas which are highly erodible, reduce channel conveyance, and limit vegetative recovery.

Specific recommendations for resolving these problems may be found in the inventory included in Appendix N (Volume A4.2).

Bank stabilization is required for approximately 18,200 linear feet of river bank. Bank failure appears to be caused by two impacts: those from the water flows in the river channel and those from the management of the adjacent floodway areas. Of these management related impacts, the most significant may be unrestricted cattle access to the river. Vegetative condition improvements have been estimated for 667 acres.

At locations requiring bank protection, RTI recommends riprap or the following alternative bank stabilization measures. Where soil salinity levels are favorable for sandbar willow (*Salix exigua*), RTI recommends: (1) willow planting; (2) willow planting in combination with a "soft" technology bank stabilization such as a polymer soil stabilization grid fabric; or (3) willow planting in combination with riprap. In areas where soil salinity is not favorable for willow, planting with certain salt-tolerant sedge species (*Cyperaceae spp.*) may be possible. Site assessment of each overbank area will determine which measure is to be used.

In areas requiring vegetative improvements, RTI recommends a revegetation program with soil-stabilizing native grasses and construction of stabilized cattle access to the river to prevent bank failure which can be caused by hoof action. Vegetation improvement in the form of grass seeding and brush planting along the banks may satisfy multi-objective, cross-agency management goals. These may include: (1) bank protection, (2) reduction of sediment input to the main stem from bank failure and soil erosion, (3) improved pasture forage for leased floodway areas, and (4) creation of additional fish and wildlife habitat. In addition, a potential flooding problem near Canutillo has been discussed by the Albuquerque District and the USIBWC, and a flood wall has been proposed in Volume 2 of this report.

RECOMMENDATIONS BASED ON HEC-6 SCOUR AND DEPOSITION ANALYSES

The results of the HEC-6 scour and deposition analyses are presented in Tables 2-9 and 2-10 of Volume 4 and are shown graphically on Sheets 1-55 included in Appendix L (Volume A4.2). Tributary arroyos which cause excessive deposition at the confluence with the Rio Grande are identified, and sediment control dams on these tributaries (with at least 90 percent trap efficiency) are proposed. These dams, which are generally located in the upper part of the study reach (the Leasburg and Mesilla subreaches), do not appear to have a significant impact on the lower (El Paso) subreach, which generally tends to be in an erosion mode. RTI did not consider erosion to be a major problem except in localized areas where the levees may be threatened; this type of analysis is beyond the capabilities of the HEC-6 computer program.

The HEC-6 100-year existing river model results were reviewed for scour and deposition bed changes at the Garfield, Hatch, and Rincon siphons; Table 3-1 in Volume 4 presents the results. The Garfield siphon appears to be in a stable reach based on the HEC-6 model results, this also appears to be true upon visual observation. The Rincon and Hatch siphons have both required protection in the past due to bed scour. Protection has been provided by dumping large rip-rap over the siphon. The rip-rap requires monitoring and occasional replacement as a result of transport during high flows. The 100-year HEC-6 model with existing geometry was generated allowing the bed to erode at the Hatch and Rincon siphons to determine the potential scour. The results presented in Table 3-1 of Volume 4 indicate that the Hatch and Rincon siphon locations are expected to scour upstream about 2 feet and 3 feet, respectively, and deposit downstream of the siphons about 2 feet and 3 feet, respectively. The HEC-6 model results do not represent local scour at the siphons which, as noted, has been a very significant problem. A much more detailed design analysis of the scour problems is required to accurately predict the local scour depth in order to design grade control structures.

RTI ran the future condition HEC-6 models by fixing the bed to allow no scour at the siphons by assuming a grade control structure in place. The results presented in Table 3-1 in Volume 4 indicate that scour will occur about 1.0 feet upstream and deposition about 1.0 feet downstream of the Hatch siphon. At the Rincon siphon, scour will occur about 0.5 foot upstream and deposition about 1.0 foot downstream.

Based on these results and field observations, grade control structures are recommended to control scour and protect both siphons. The grade control structures may be constructed just downstream of the siphons. The structures may be constructed with reinforced concrete, sheet piling, or possibly gabions. Bank protection may also be required upstream and downstream of the grade control structures due to increased bank heights, probable bank failure, and lateral migration.

404 PERMIT REQUIREMENTS

Structures or work affecting navigable waters of the United States are regulated under Section 10 of the Rivers and Harbor Act of 1899. Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (renamed the Clean Water Act) insures that the biological and chemical quality of the nation's waters is protected from unregulated discharges of dredged or fill material. Section 404 established a permit program to be administered by the U.S. Army Corps of Engineers to regulate the discharge of dredged or fill material. The Act was further amended in 1977 to provide exemptions, general permits, and program turnover to states having approved programs. Other laws which may affect the processing of applications for Corps of Engineers permits include the National Environmental Policy Act, the Fish and Wildlife Coordination Act, the Endangered Species Act, the National Historic Preservation Act, the Federal Power Act, the Wild and Scenic Rivers Act, and the National Fishing Enhancement Act of 1984.

"Waters of the United States" are administratively defined as (1) the traditional "navigable waters of the United States" including adjacent wetlands; (2) all interstate waters including interstate wetlands; (3) all other waters such as intrastate lakes, rivers, streams (including intermittent streams), prairie potholes, mudflats, playa lakes, wet meadows, wetlands, natural ponds, *etc.*; (4) all impoundments of these waters; (5) tributaries of the above listed waters; and (6) wetlands adjacent to the above waters. "Navigable waters" are defined as waters that have been used in the past, are now used, or are susceptible to use as a means to transport interstate or foreign commerce up to the head of navigation. Navigable waters within the Albuquerque District include Navajo Reservoir and the Rio Grande along the international boundary. "Wetlands" are areas inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. The landward regulatory limit for non-tidal waters (in the absence of adjacent wetlands) is the ordinary high water mark. The ordinary high water mark is the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of the soil; destruction of terrestrial vegetation; the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding areas.

An individual Section 404 permit is required for placement of dredged or fill material, including excavation, or construction activities in waters of the United States if the project is not exempted from the Section 404 program and does not fall under one of the nationwide or regional permits. This information is directed to those individuals, companies, corporations, and government agencies planning construction activities in a river, stream, lake, or wetland within the jurisdiction of the Corps of Engineers. Examples of regulated activities are materials excavated or placed in a waterway or wetland for any purpose including: commercial, industrial, or recreational construction; roadfills and causeways where portions of the construction are in waters or wetlands; dams and dikes; and protection devices such as levees, groins, riprap, and other bank stabilization.

In some cases, the formal processing of a permit application is not required because of general permits already issued to the public at large by the Corps of Engineers. These permits are issued on a regional or nationwide basis. Regional permits are issued by the District Engineer for a general category of fill activities when (1) the activities are similar in nature and cause minimal environmental impact (both individually and cumulatively) and (2) the regional permit reduces duplication of regulatory control by state and federal agencies. A nationwide permit is a form of general permit authorizing a category of activities throughout the nation. If the conditions of a nationwide permit can not be met, a regional or individual permit is required; the Corps of Engineers is authorized to determine if an activity complies with the terms and conditions of a nationwide permit. Separate applications may not be required for activities authorized by a general permit; however, reporting may be required. For more specific information on general permits, contact the Regulatory Office of the U.S. Army Corps of Engineers, Albuquerque District.

If an individual permit is required, an application form should be completed. A copy of the application form and instructions for the Department of the Army Section 404 permit is included on the following pages; additional permit applications can be obtained from the Albuquerque District. Information needed includes (1) drawings (size 8-1/2" x 11") sufficient to understand the project; (2) locations, purpose, types and quantities of fill, and intended use; (3) expected start and completion dates; (4) names and addresses of adjacent landowners; and (5) location and dimensions of adjacent structures. Photographs of the site of the proposed activity are not required; however, photographs are helpful and may be submitted as part of any application. The Regulatory Office of the Corps of Engineers should be contacted for additional submittal information. The completed permit can be mailed to:

The District Engineer
U.S. Army Corps of Engineers
Attention: CESWACO-OR
4104 Jefferson Plaza Northeast
Albuquerque, New Mexico 87109-3435

Nationwide permit conditions are periodically revised. Contact the Regulatory Office of the Corps of Engineers for a summary of current nationwide permit conditions.