HISTORIC INUNDATION ANALYSIS ALONG THE MIDDLE RIO GRANDE

FOR THE PERIOD 1990 TO 2009

PREPARED FOR THE

MIDDLE RIO GRANDE ENDANGERED SPECIES ACT

COLLABORATIVE PROGRAM -

POPULATION VIABILITY ANALYSIS WORK GROUP

OCTOBER 2010

U.S. ARMY CORPS OF ENGINEERS
SOUTH PACIFIC DIVISION - ALBUQUERQUE DISTRICT
ALBUQUERQUE, NEW MEXICO

ACKNOWLEDGEMENTS

The United States Army Corps of Engineers (USACE) – Albuquerque District office compiled the supporting documents used in this Historic Inundation Analysis for the Middle Rio Grande. The Albuquerque District received the HEC-RAS models used in this study from the United States Department of Interior, Bureau of Reclamation, Albuquerque Area Office. The Albuquerque District office modified and ran the HEC-RAS models used in this report. The contact in the Albuquerque office is Ryan Gronewold, P.E.

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I. Purpose

The purpose of this analysis is to compute estimates of historically inundated areas within the Rio Grande for the years 1990 through 2009. The analysis focuses on the Middle Rio Grande Valley located in New Mexico. The study results will be used in the current Middle Rio Grande Endangered Species Act Collaborative Program's Population Viability Analysis model. Among the different uses of the results will be estimates of Silvery Minnow habitat that are provided in the river at various years and at various locations within the Middle Rio Grande.

The methods and assumptions used to calculate historic inundation are described in this report. This analysis uses a numerical model to estimate the area inundated in both the channel and the overbank for each year. The model was created based on the topography of the reach in 2005, and calibrated using river observations from the same timeframe. In order to estimate geomorphic changes that may have affected the area of inundation prior to 2005, an additional analysis was performed to establish general characteristics regarding channel capacity and surface area for a given river reach. Cross section data sets from 1992 and 2002 were input into the U.S. Army Corps of Engineer's (USACE) Hydrologic Engineering Center's (HEC) River Analysis System (RAS) and used to compute hydraulics along the river. Based on the hydraulic computations the general assumptions of geomorphic changes within the river were established. Finally, those assumptions were used to compute estimates of inundated area for each reach and each year.

II. Previous Studies

In 2005, a hydraulic study of the Middle Rio Grande was completed using the unsteady state two-dimensional model FLO-2D version 2007.06. The model is described in the report titled, *FLO-2D Flood Routing Model Development Middle Rio Grande Cochiti Dam to Elephant Butte Reservoir 250 foot Grid System*, submitted by Riada Engineering, Inc, September 2007. The model used a 250 feet by 250 feet grid with a one-dimensional channel to compute flood depths along the Rio Grande from Cochiti Dam to Elephant Butte. The grid's topography was based on a 2005 topographic data set and was calibrated to discharges during the 2005 spring runoff event.

Based on the FLO-2D model results, initial surface area rating curves for various discharges were generated along the river. The generated curves will serve as the base condition for this analysis. The methods used to shift or modify the base condition, in order to estimate a reach specific inundated area for the different geomorphic conditions in years 1990 to 2009 will be described in Section V.

III. General Study Area

The project reach is located along the Rio Grande and begins at River Mile (RM) 232.3 near Cochiti Dam downstream past San Marcial, NM to RM 60.4. This encompasses ~172 river miles. The study area was subdivided into 13 reaches. Table 1 provides each reach name as well as the associated: river miles, Bureau of Reclamation Aggradation/Degradation Range lines, and HEC-RAS river stations. Figure 1 shows the study area along with the individual reach locations.

Table 1 – Project Reach Definitions

Reach #	Reach Name	River Miles (RM)	BOR Agg/Deg Range Lines	HEC-RAS River Station (RS)
1	Cochiti	232.3 to 210	19 to 235	1759 to 1545
2	Angostura	210 to 203.4	236 to 297	1544 to 1483
3	Bernalillo	203.4 to 199.8	299 to 337	1482 to 1444
4	Rio Rancho	199.8 to 169	338 to 654	1443 to 1131
5	Isleta	169 to 152.3	656 to 828	1130 to 958
6	Peralta return	152.3 to 126.3	829 to 1095	957 to 697
7	Rio Puerco	126.3 to 118.6	1096 to 1181	696 to 611
8	Rio Salado	118.6 to 115.9	1182 to 1206	610 to 586
9	San Acacia	115.9 to 95.2	1207 to 1397	585 to 396
10	Canas/Brown Arroyo	95.2 to 77.2	1398 to 1584	395 to 211
11	RM 78	77.2 to 72.7	1585 to 1652	210 to 147
12	Tiffany	72.7 to 67.8	1653 to 1701	146 to 100
13	San Marcial	67.8 to 60.4	1702 to 1792	99 to 11

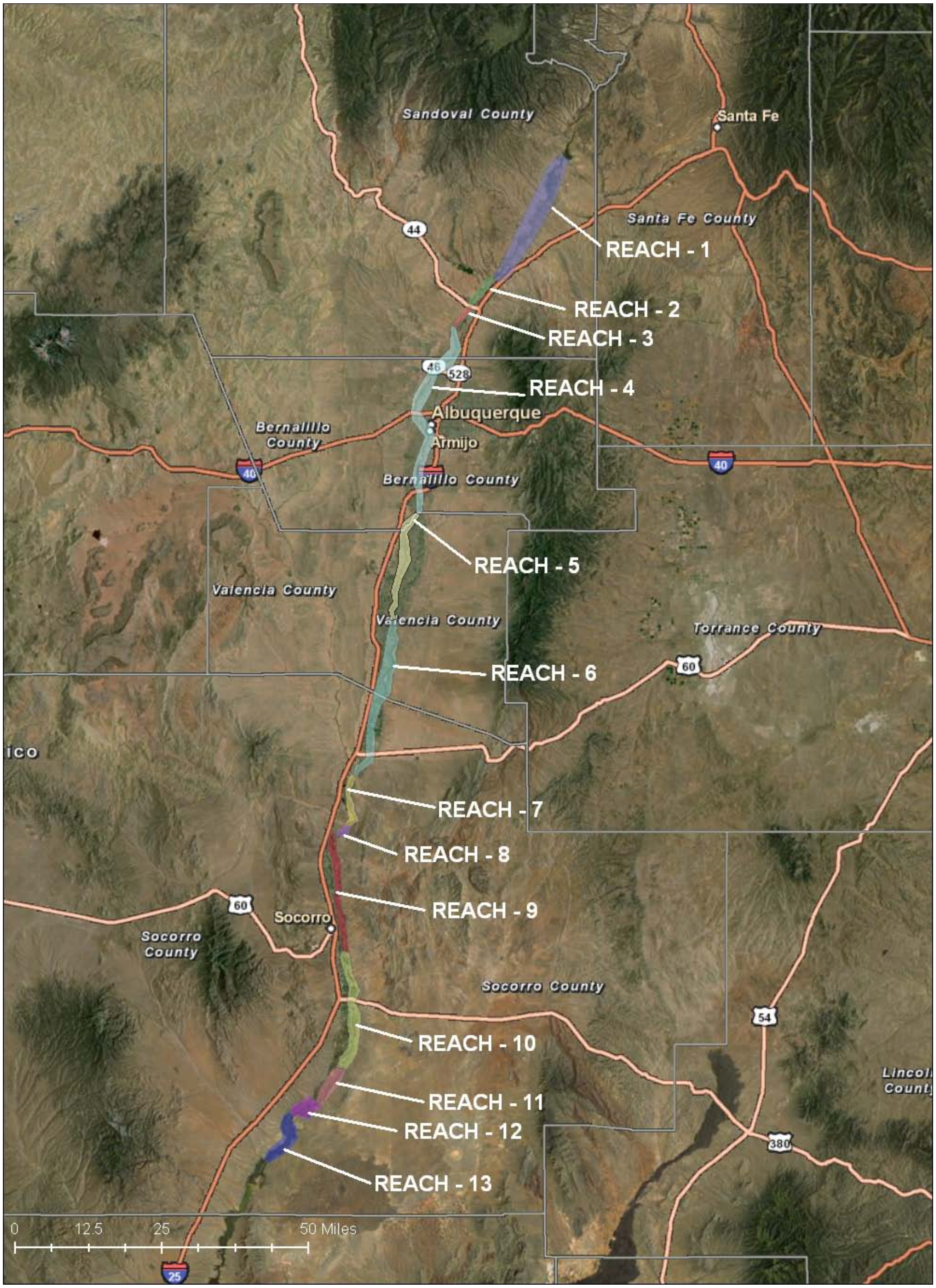

Figure 1 – Reach Location Map

IV. Hydraulic Analysis

The hydraulic analysis uses a numerical model to generate water surface profiles along the project reach. The numerical model used is HEC-RAS version 4.0. HEC-RAS can compute steady state water surface profiles based on the geometry of a natural river channels. The HEC-RAS models were obtained from the Bureau of Reclamation (BOR), Albuquerque Area Office. The models' geometry files contain BOR Aggradation Degradation Range Line data for the years 1992 and 2002. The range lines contain either surveyed or digitized topographic data that are input to the cross-sections. The location of each range line (or cut line) does not change, and they are assumed to be in the same location for both the 1992 and 2002 datasets. This assumption helps in determining general trends of the geomorphic changes within the project reach.

The USACE – Albuquerque District used and ran the HEC-RAS models as received from the BOR, with only minor changes. These modifications are described below.

A. Hydraulic Model Parameters

1. Model Geometry

As previously stated, the HEC-RAS models contain topographic data as surveyed and collected in the years 1992 and 2002 along the Rio Grande. While the horizontal location of each BOR range line is assumed to remain in the same location for 1992 and 2002, the elevation and channel planform data of each dataset (1992 and 2002) will be different. The changes in topography result from geomorphic changes within the active channel, as well as sediment removal or deposition in the river's floodplain. The topographic geometry of each model (1992 and 2002) was not modified from the original dataset obtained from the BOR.

As the USACE was performing preliminary model runs, it was discovered that a discrepancy in modeling techniques existed between the 1992 and 2002 models. The 1992 model included the use of ineffective flow areas downstream of River Station (RS) 300. The ineffective flow areas were placed at various elevations that resulted in an over-estimation of channel capacity in the 1992 model. This over-estimation was corrected by replacing the ineffective flow areas with levee cards. The levee cards closely match the 2002 model, and therefore the 1992 results can be directly compared to the 2002 results. Ineffective flow area or levee card modifications were not made to the 2002 model.

2. Steady State Discharges

The HEC-RAS models computed profiles for 20 steady state discharges. Discharge values of 500 to 10,000 cubic feet per second (cfs) were input to the Steady Flow Editor at 500 cfs increments. This particular set of discharges envelops the range of expected flowrates within the main channel and floodplain, while still providing a fine enough increment in which trends can be seen.

After the appropriate adjustments were made, the models were run with the boundary conditions and flow regime assumptions originally provided with each model. The hydraulic results were then extracted for each of the 20 steady state profiles. The geomorphic characteristics were determined from the HEC-RAS results.

V. Geomorphic Investigations

The results from the hydraulic analysis were used to describe general geomorphic changes between the 1992 and 2002 models. In order to measure these changes two tests were created. The tests were:

1) Plot the computed discharge within the main channel (QChannel) versus the total discharge (QTotal) for the 1992 & 2002 models, and
2) Plot the computed total and channel surface areas (Surface Area) versus the total discharge (QTotal) for the 1992 & 2002 models.

Test #1 is a measure of the proportion of discharge within the channel section to the proportion of total discharge (including discharge in the overbank). These proportions were compared for the 1992 and 2002 data sets. If these proportions differed, it would indicate a change in channel capacity between 1992 and 2002. Figure 2 through 14 provides the results of Test #1 for all reaches. The plots show that Test #1 does not show a discernable difference in the flow characteristics between the 1992 and 2002 data sets for Reaches 1 through 9. Visual inspection of cross sections from these reaches confirmed the results. However, the plots for Reaches 10 through 13 (approximately Socorro to RM 60) show a marked difference between the 1992 and 2002 data sets. Specifically, the 1992 data set indicates a larger proportion of flow in the channel than the 2002 data set for discharges above approximately 2,000 cfs, the implication being that overbank flows were achieved at a lower total discharge in 2002 than they were in 1992. These findings agree with observations made by USACE and BOR employees at those times.

Test #2 was then performed on each reach. Test #2 is a plot of the HEC-RAS output of the total water surface area as well as the channel water surface area versus the total discharge for both the 1992 and 2002 data sets. It should be noted that HEC-RAS is a one-dimensional numerical model that computes surface areas by interpolating between cross sections. Surface area results from HEC-RAS are generally relatively inaccurate. However, these results were used as a comparison between consistent data sets, and therefore deemed appropriate for this analysis. After inspection of the plots of Surface Area versus Discharge, there was generally a difference between the data sets for most reaches. However, after visual inspection of the HEC-RAS cross sections it became apparent that for Reaches 1 through 9, those differences could be attributed to inconsistent modeling assumptions between the 2 data sets. Reaches 10 through 13 however showed a very apparent difference in surface area between the 2 data sets. The plots for Surface Area versus Discharge for Reaches 10 through 13 are shown in Figure 15 through 18. The general trend among these reaches shows a greater surface area for given discharge in the 2002 data set when compared to the 1992 data set. This is indicative of greater overbank flows (and lesser channel capacity) at a given discharge for the 2002 data set compared to the 1992 data set, which was indicated in Test #1, as well as observations made during those time periods. Also of note from these plots is the apparent decrease in channel surface area for a given discharge between the 1992 and 2002 data sets for Reach 10 (Canas and Brown arroyos just south of Socorro to RM 78 at the southern end of Bosque del Apache Wildlife Refuge). This decrease in channel surface area is attributable to channel narrowing that was known to have occurred in this reach during this timeframe.

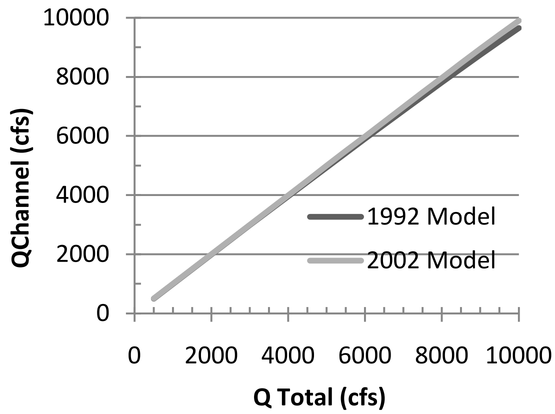

Figure 2 – Channel Conveyance for Reach 1

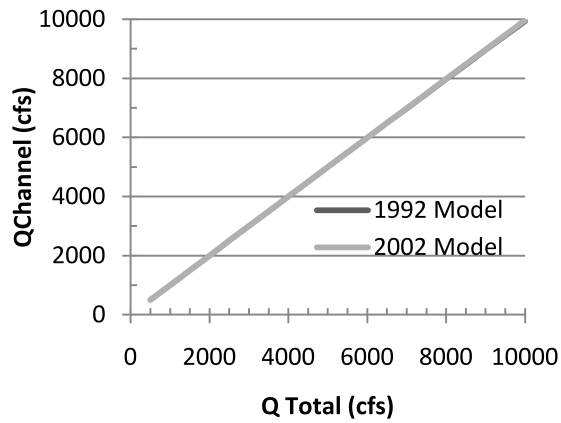

Figure 3 – Channel Conveyance for Reach 2

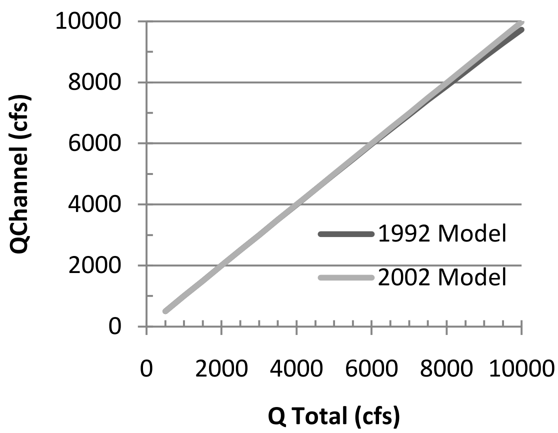

Figure 4 – Channel Conveyance for Reach 3

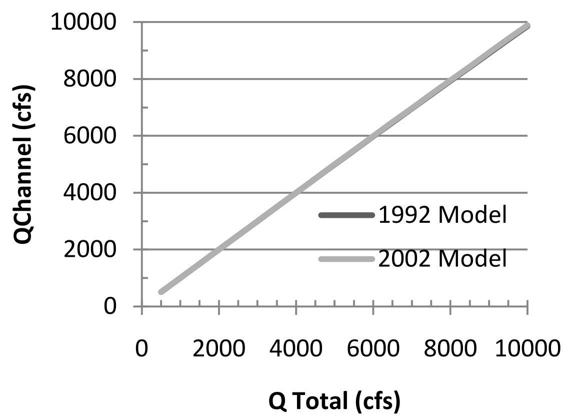

Figure 5 – Channel Conveyance for Reach 4

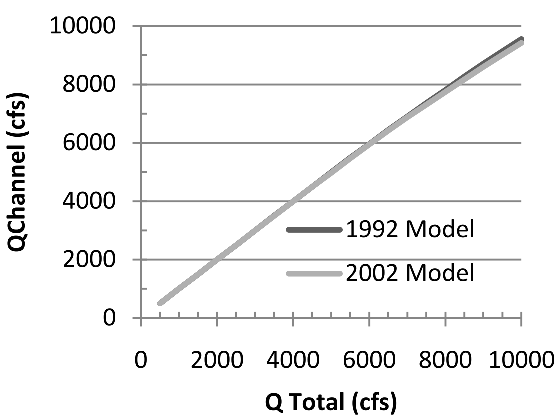

Figure 6 – Channel Conveyance for Reach 5

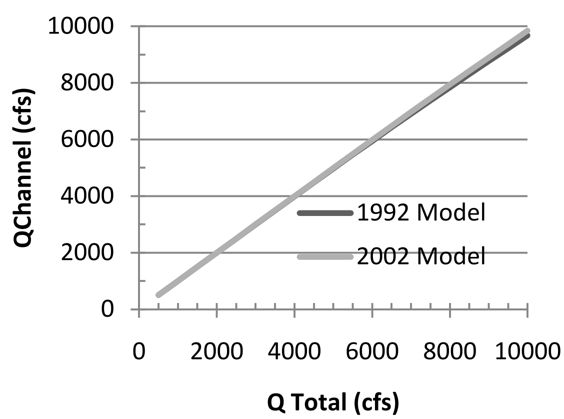

Figure 7 – Channel Conveyance for Reach 6

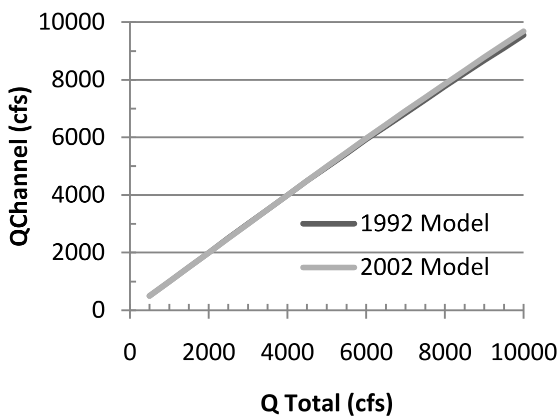

Figure 8 – Channel Conveyance for Reach 7

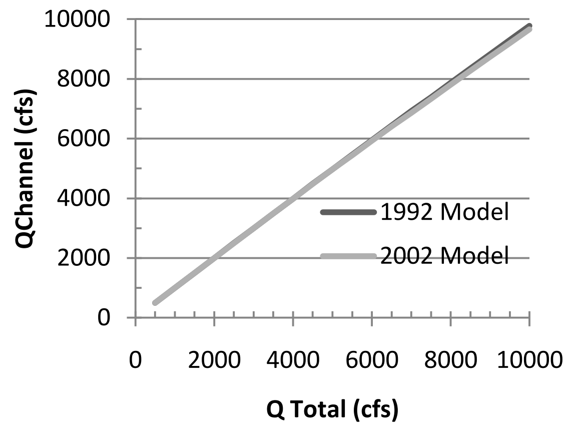

Figure 9 – Channel Conveyance for Reach 8

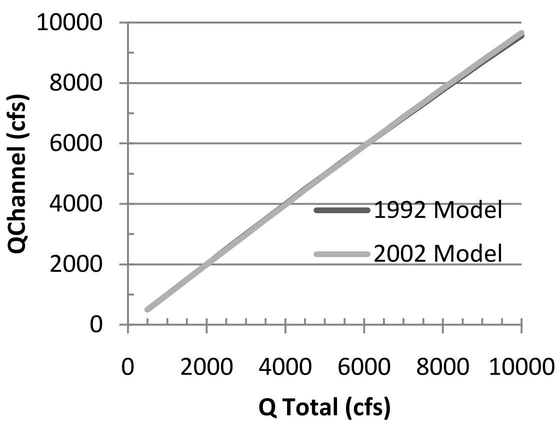

Figure 10 – Channel Conveyance for Reach 9

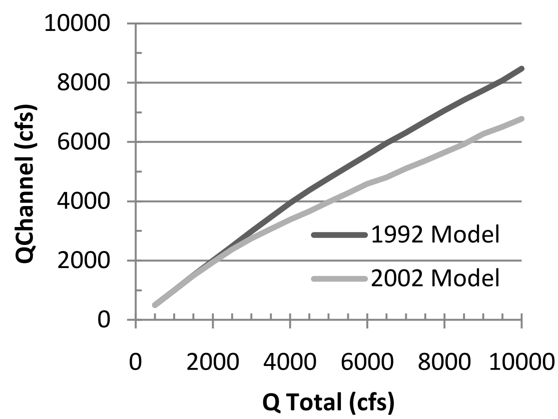

Figure 11 – Channel Conveyance for Reach 10

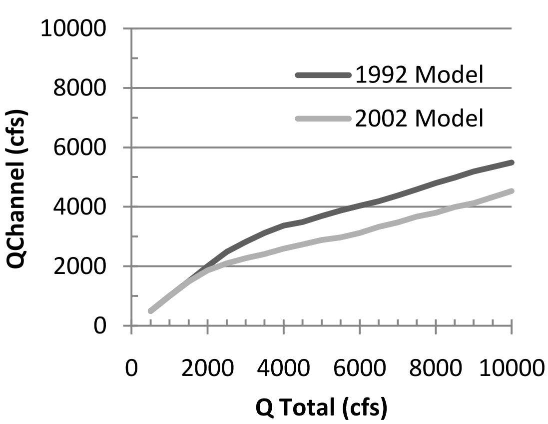

Figure 12 – Channel Conveyance for Reach 11

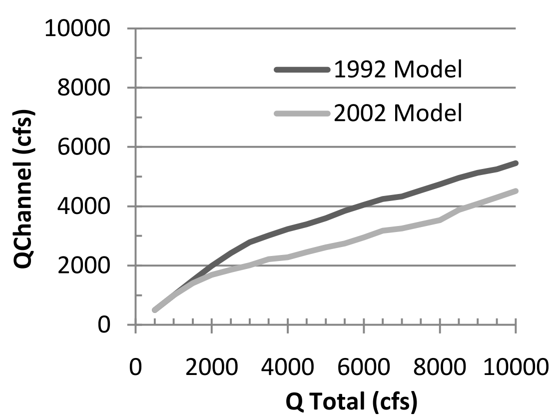

Figure 13 – Channel Conveyance for Reach 12

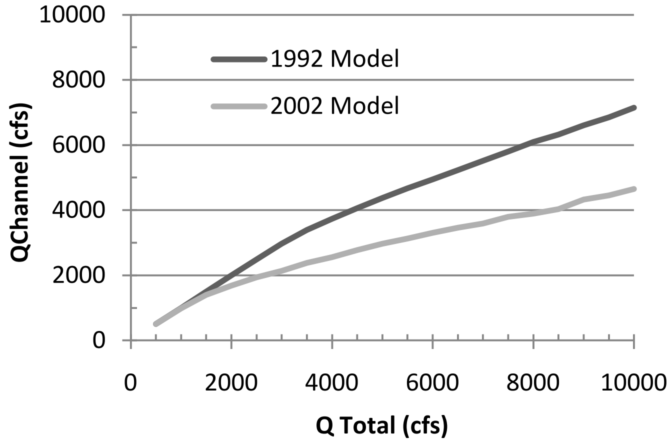

Figure 14 – Channel Conveyance for Reach 13

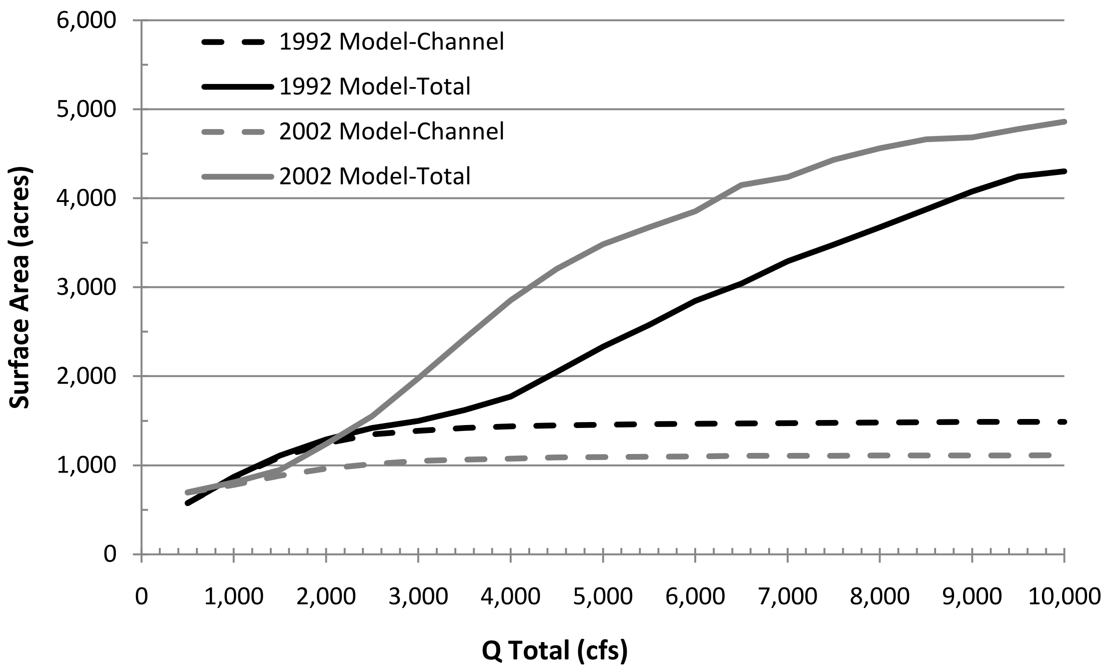

Figure 15 – Surface Area Comparisons for Reach 10

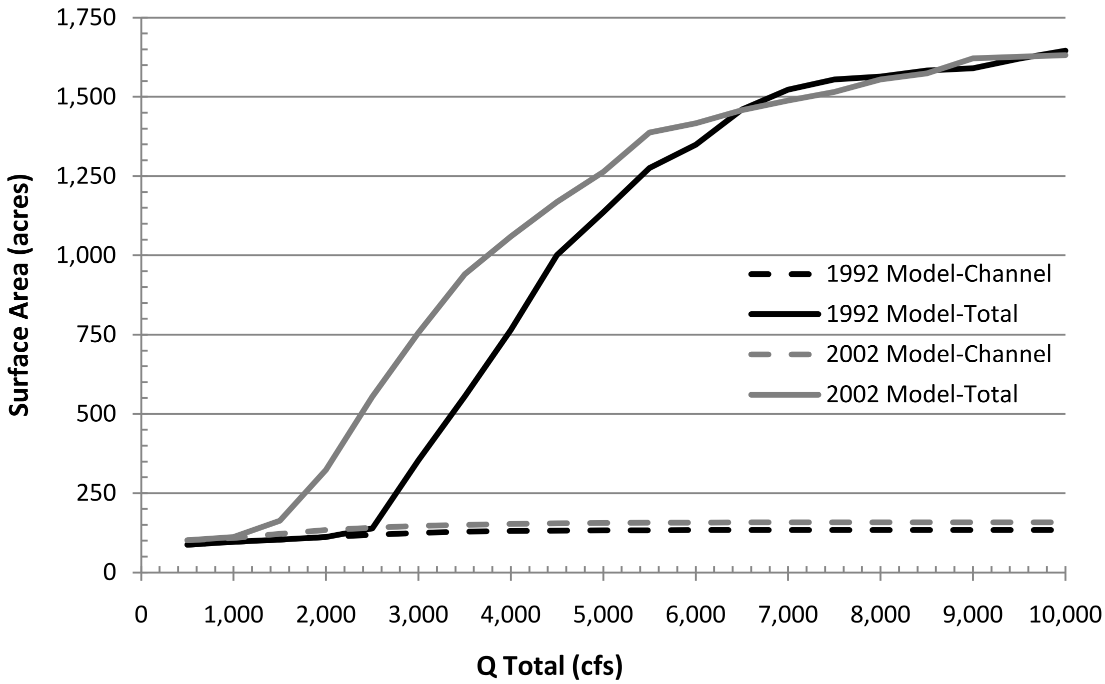

Figure 16 – Surface Area Comparisons for Reach 11

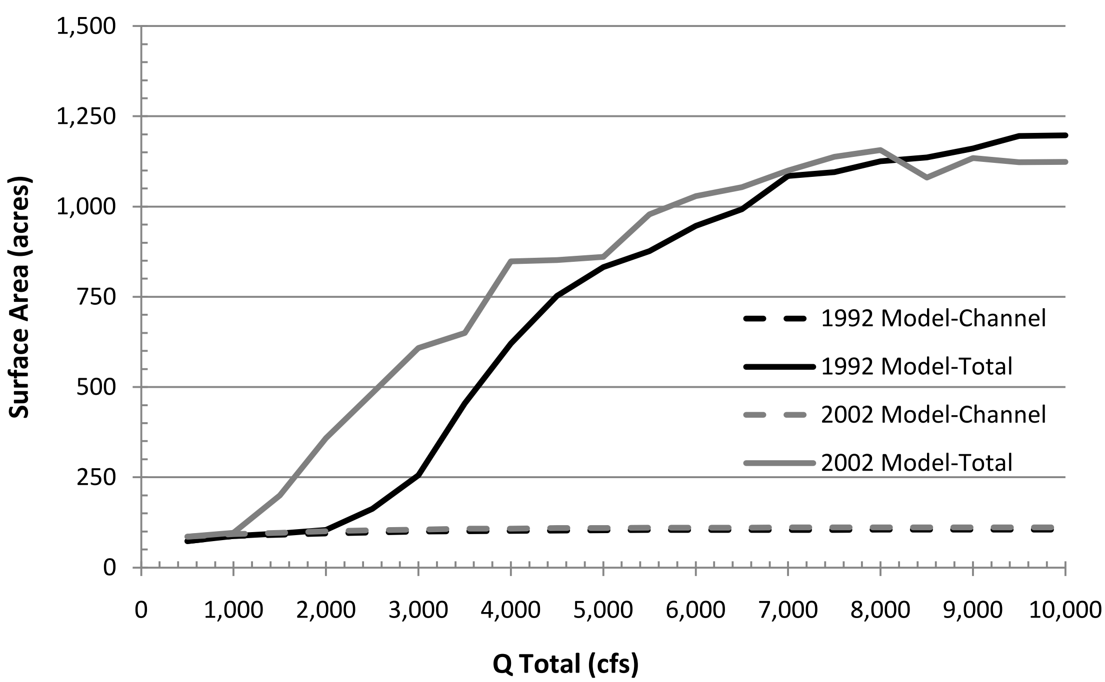

Figure 17 – Surface Area Comparisons for Reach 12

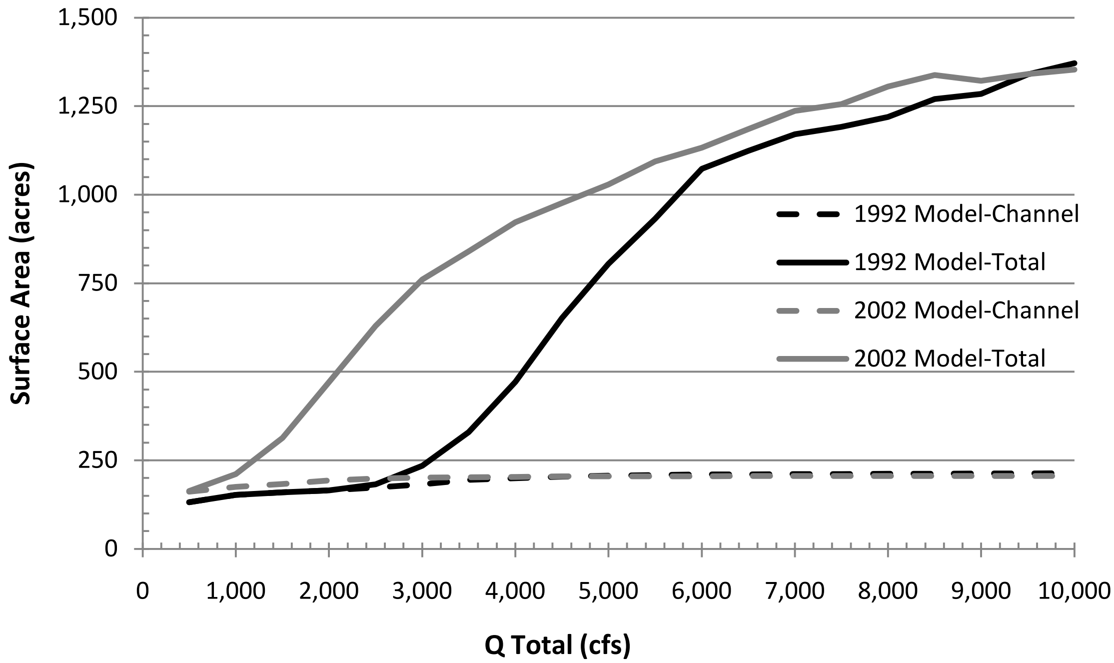

Figure 18 – Surface Area Comparisons for Reach 13

VI. Area of Inundation Computations

The inundated area for each river reach and for each year between 1990 and 2009 was estimated using the FLO-2D generated curve of Inundated Area versus Discharge. The total inundated area was estimated for each reach as well as separately for the channel and overbank areas. In order to account for the geomorphic changes that occurred during the study period, as indicated by the HEC-RAS analysis, a shift was applied to the base condition curve. Due to the fact that only 2 consistent data sets were available to determine the geomorphic changes, a simplifying assumption was needed. A majority of the geomorphic changes in Reaches 10 through 13, measured in the HEC-RAS analysis, occurred during the relatively dry years of 2000 through 2004. Therefore, the 2002 data set was chosen to represent the geomorphic conditions from 2000 through 2009, and including the base conditions Inundated Area versus Discharge curve generated using 2005 topography. The 1992 data set was chosen to represent geomorphic conditions from 1990 through 1999. The shifted curve used for the 1990 through 1999 timeframe was determined by analyzing the plots from Test #2 (Figures 15 through 18) of the geomorphic analysis and the hand computations shown in Appendix A, Figures A.1 through A.4.

These plots show the discharge at which flows begins to enter the overbank for each data set. This may also be viewed as the channel capacity. For each reach, the Floodplain Area of Inundation versus Discharge curve was adjusted according to this change in channel capacity. Also, the Channel Area of Inundation versus Discharge curve was adjusted to account for the channel narrowing in Reach 10. Examples of the adjusted Surface Area versus Discharge curves for the 1990-1999 and 2000-2010 geomorphic conditions are shown in Figures 19 and 20.

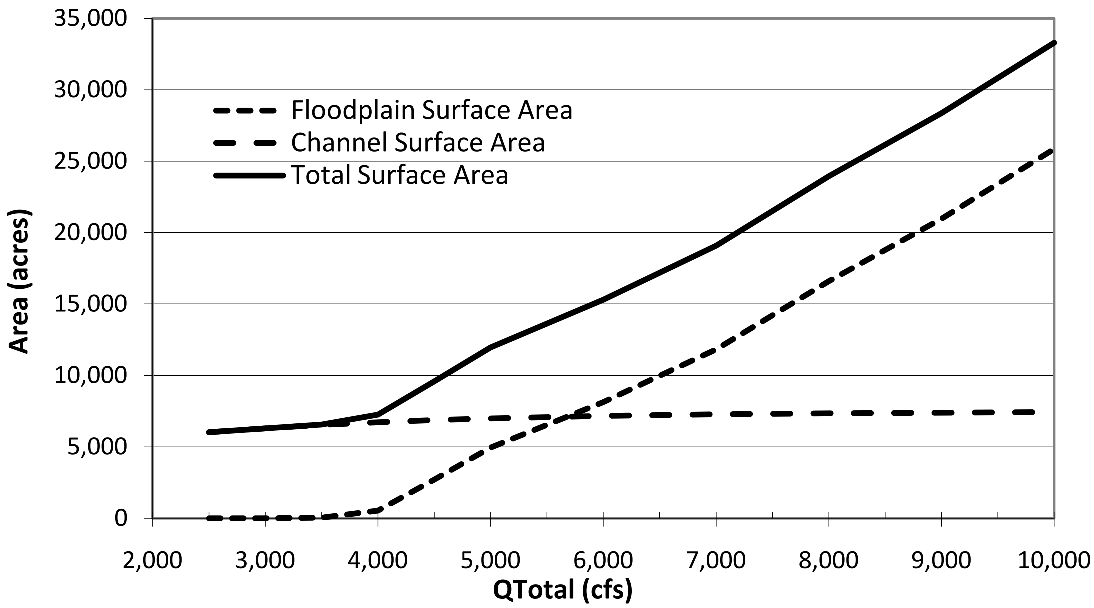

Figure 19 – Surface Area vs. Discharge Curves for 1990 to 1999

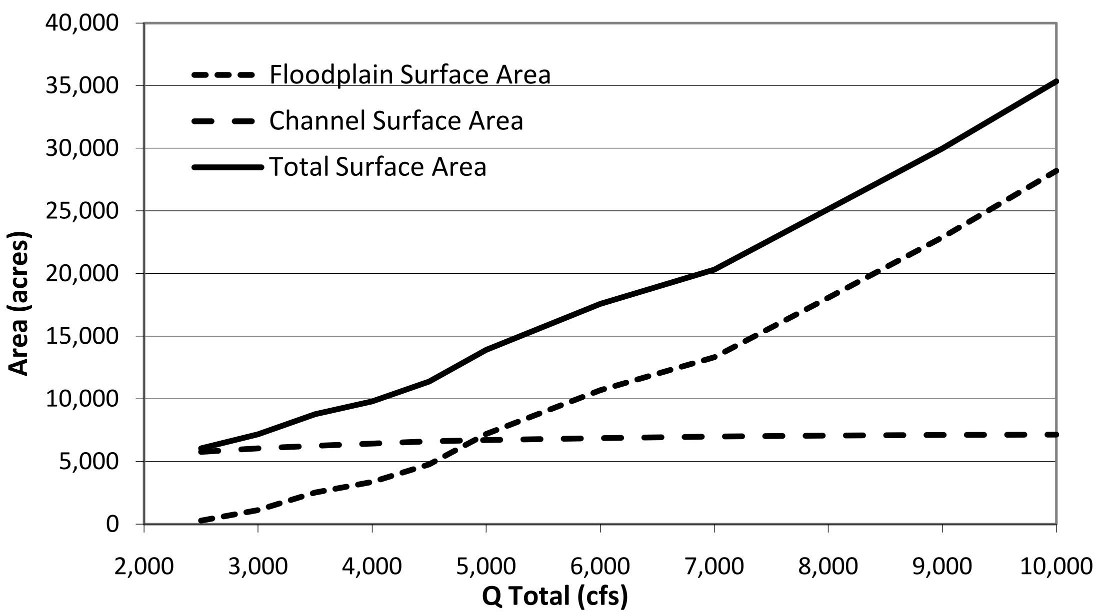

Figure 20 - Surface Area vs. Discharge Curves for 2000 to 2009

A representative discharge for each year was determined from the peak 5 day duration (USGS Rio Grande at Albuquerque gage). The 5 day duration was chosen because this is the length of time that is generally needed for flows to reach the downstream end of the study reach without attenuation due to channel and floodplain storage. The representative discharges are shown in Table 2. These representative discharges were then plotted on the Area of Inundation versus Discharge curves for each year. The Total Area of Inundation for each year and for each reach is shown in Figures 21 through 33. Plots of only Channel Area Inundation, and Floodplain Area Inundation were not created. Rather, tabular data for these specific features is provided in Appendix A as **'Tabular Data for Channel and Floodplain Inundated Areas'**.

Table 2 – Yearly Peak Discharges from the Rio Grande at Albuquerque Gage

Year	1 Day Peak (cfs)	5 Day Peak (cfs)
1990	2,420	2,058
1991	4,290	4,084
1992	5,900	5,468
1993	7,000	6,936
1994	6,250	5,492
1995	6,370	5,812
1996	1,480	1,111
1997	5,980	5,932
1998	3,940	3,520
1999	4,550	4,512
2000	1,500	1,200
2001	4,760	3,350
2002	1,240	910
2003	1,260	905
2004	3,120	2,960
2005	6,510	6,390
2006	1,490	1,187
2007	3,700	3,480
2008	5,150	4,792
2009	4,940	4,750

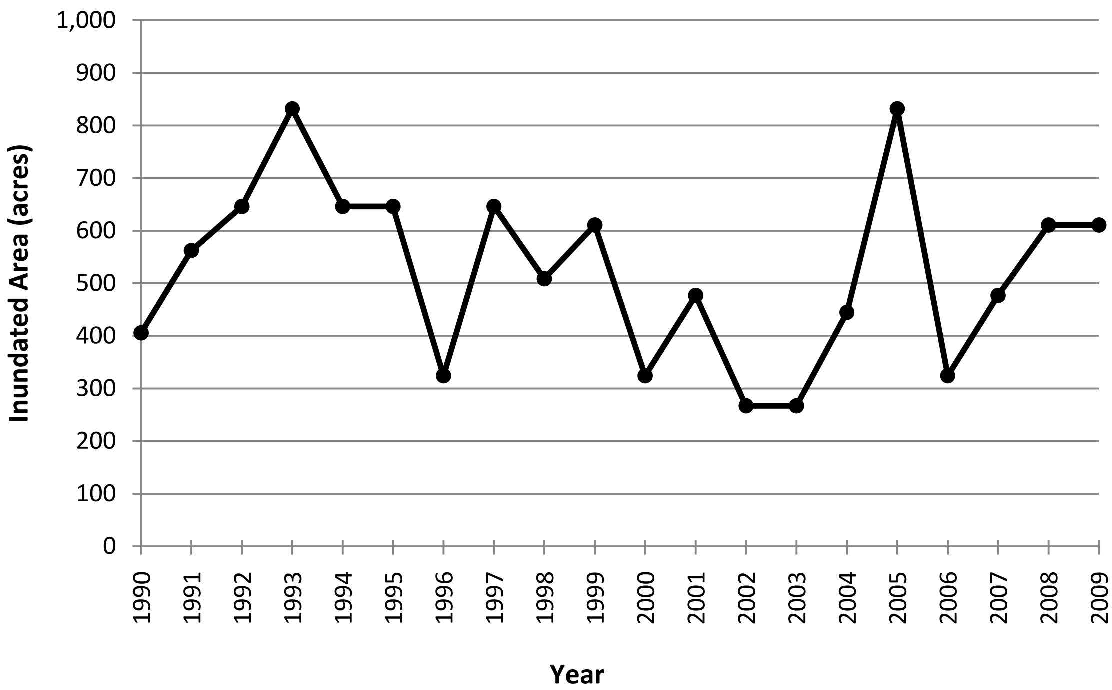

Figure 21 – Total (Channel + Floodplain) Inundated Area for Reach 1

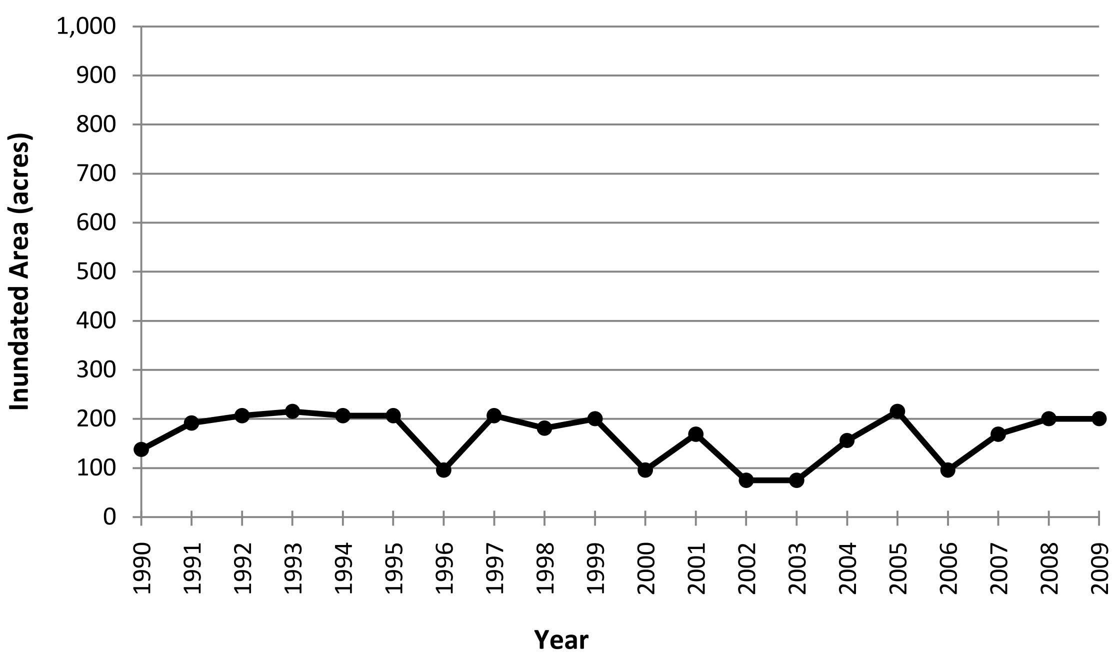

Figure 22 – Total (Channel + Floodplain) Inundated Area for Reach 2

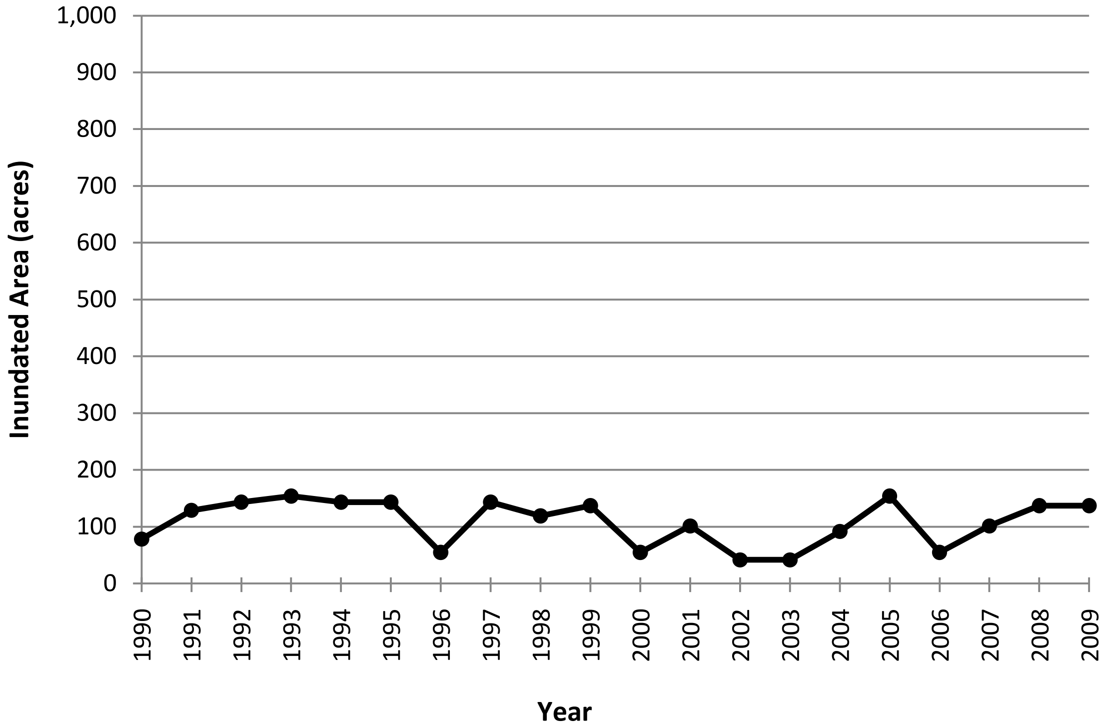

Figure 23 – Total (Channel + Floodplain) Inundated Area for Reach 3

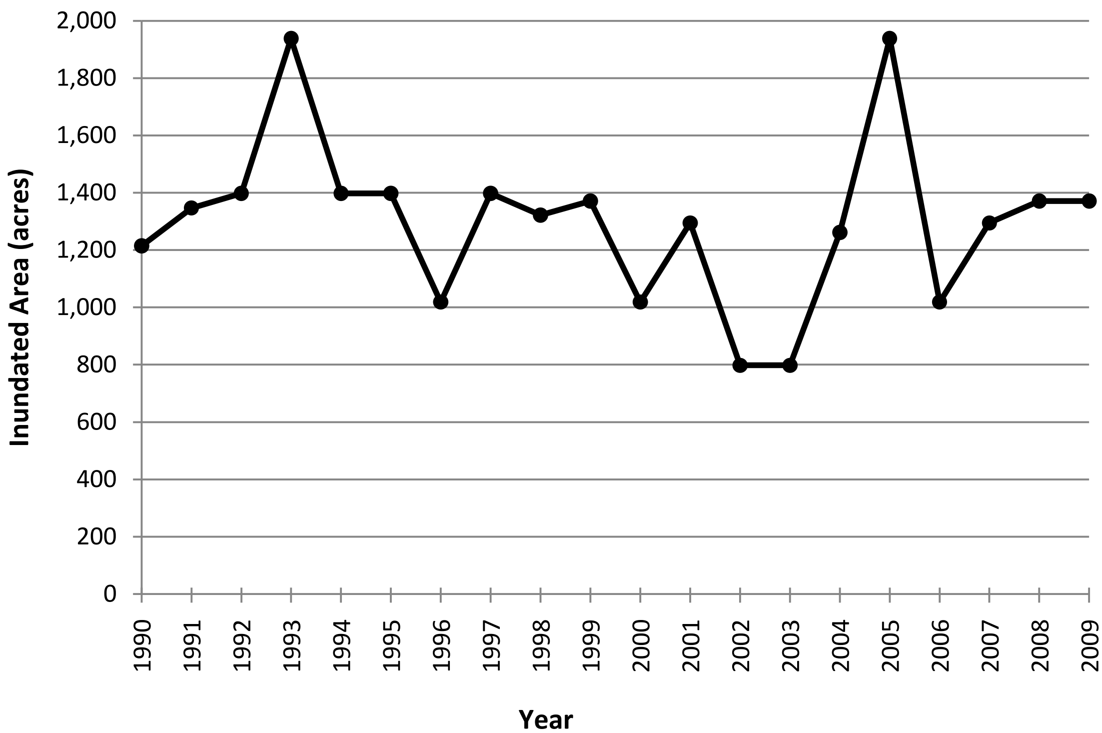

Figure 24 – Total (Channel + Floodplain) Inundated Area for Reach 4

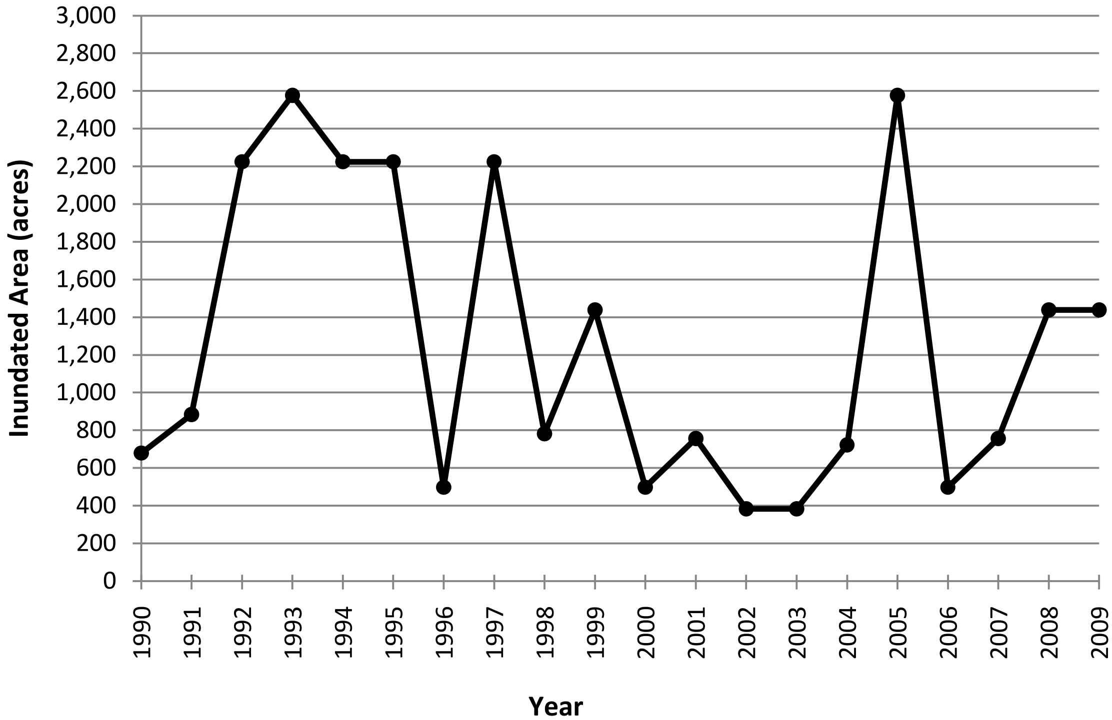

Figure 25 – Total (Channel + Floodplain) Inundated Area for Reach 5

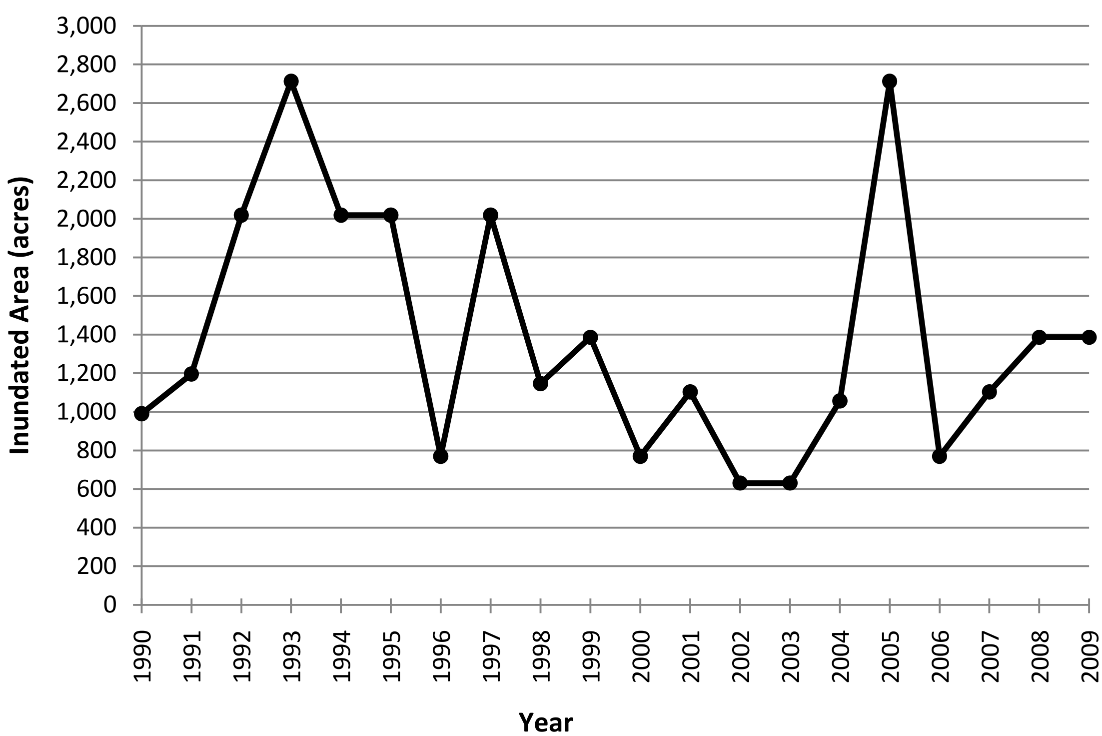

Figure 26 – Total (Channel + Floodplain) Inundated Area for Reach 6

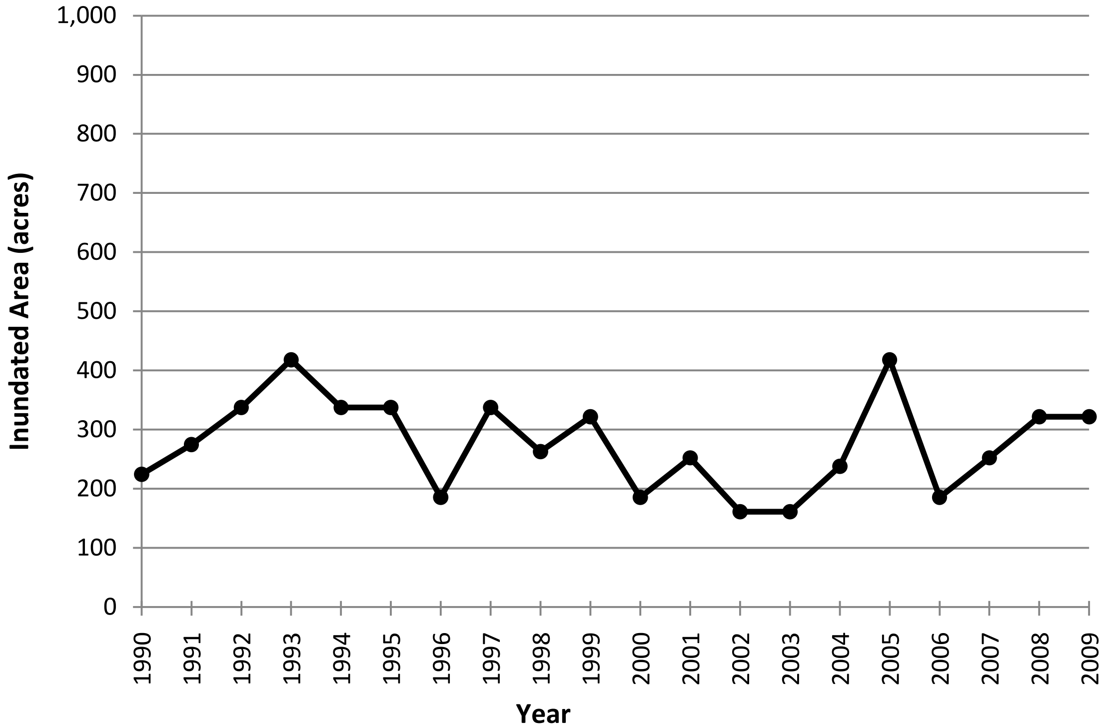

Figure 27 – Total (Channel + Floodplain) Inundated Area for Reach 7

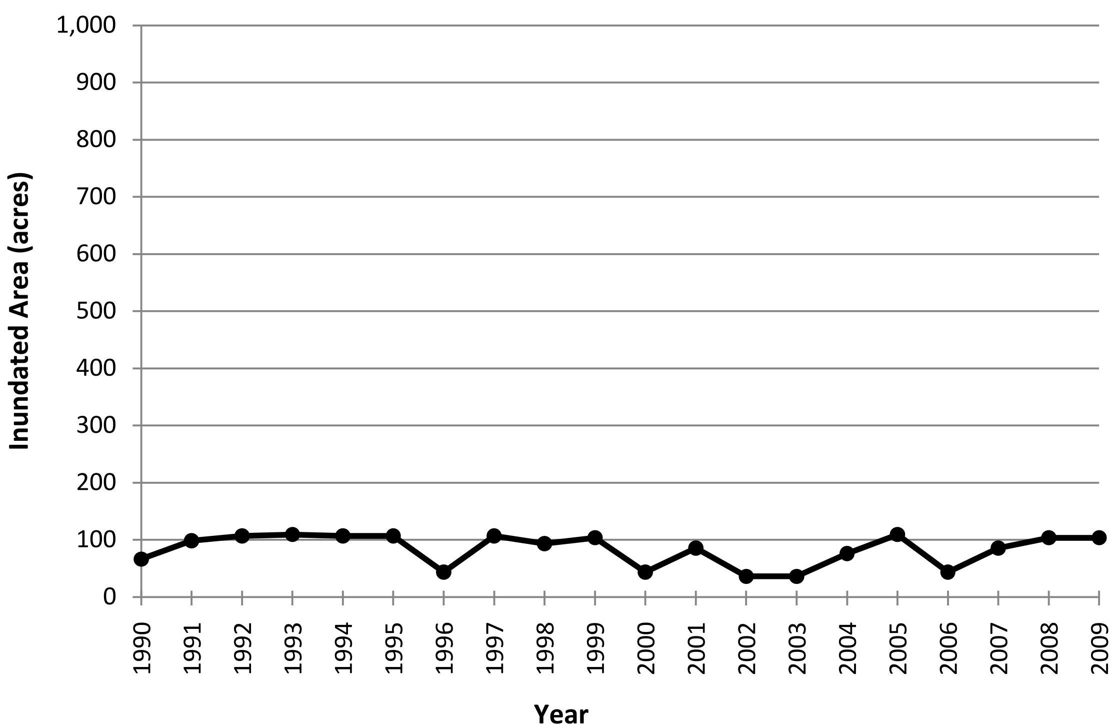

Figure 28 – Total (Channel + Floodplain) Inundated Area for Reach 8

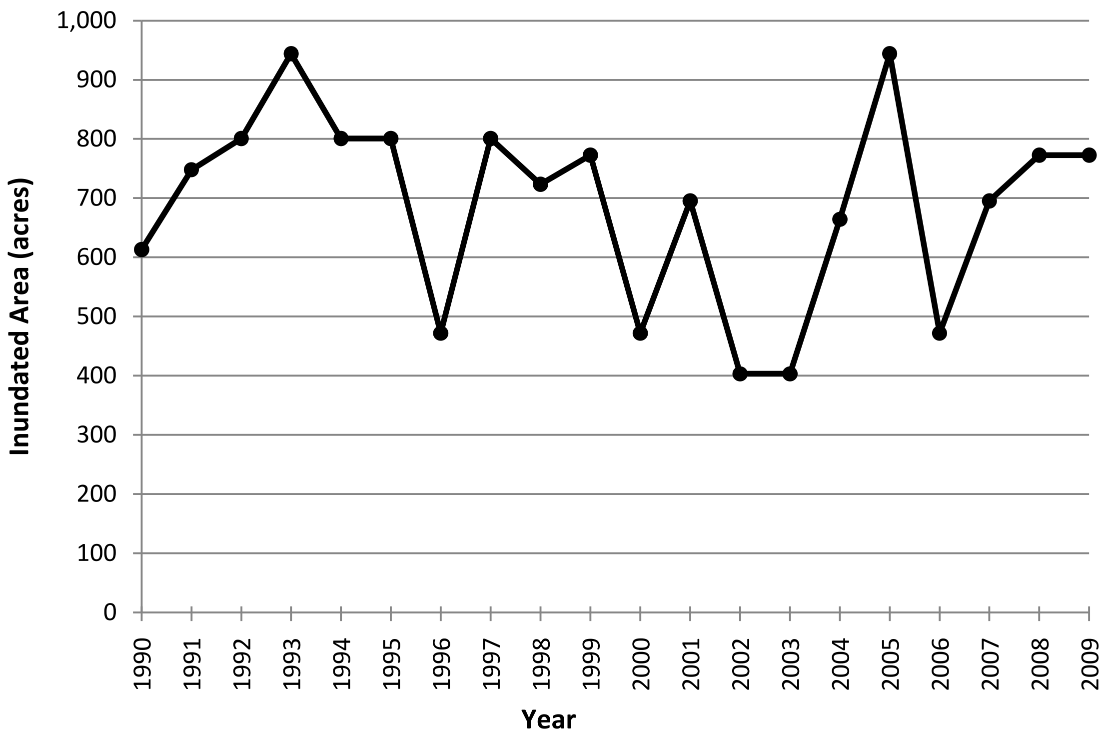

Figure 29 – Total (Channel + Floodplain) Inundated Area for Reach 9

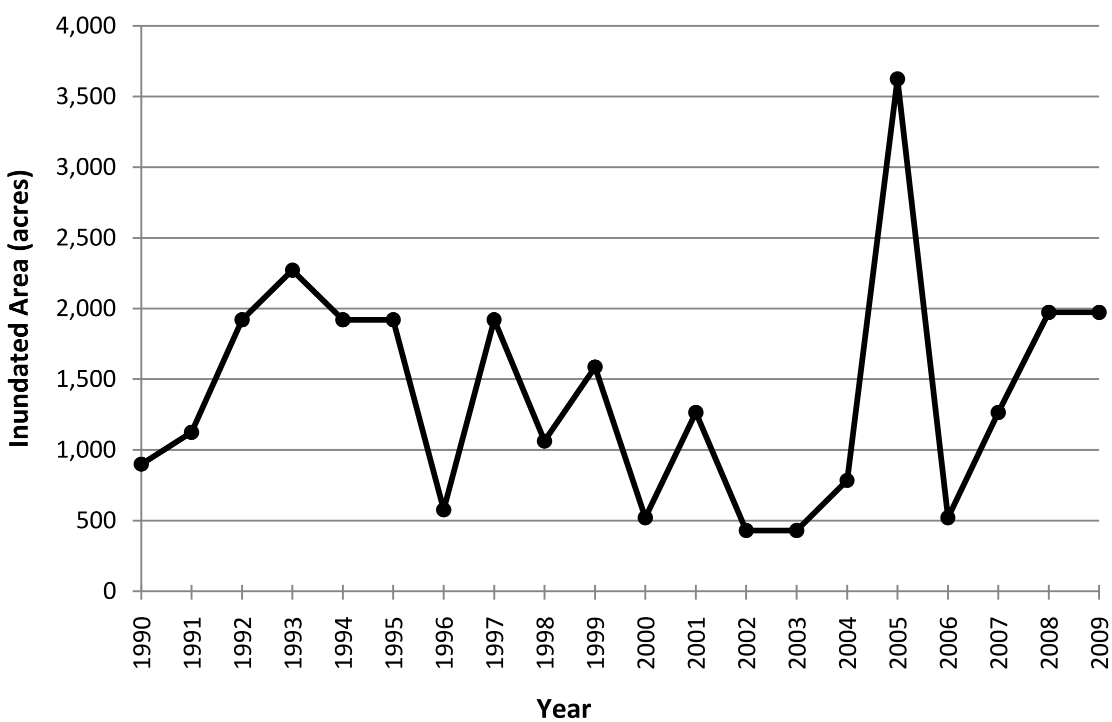

Figure 30 – Total (Channel + Floodplain) Inundated Area for Reach 10

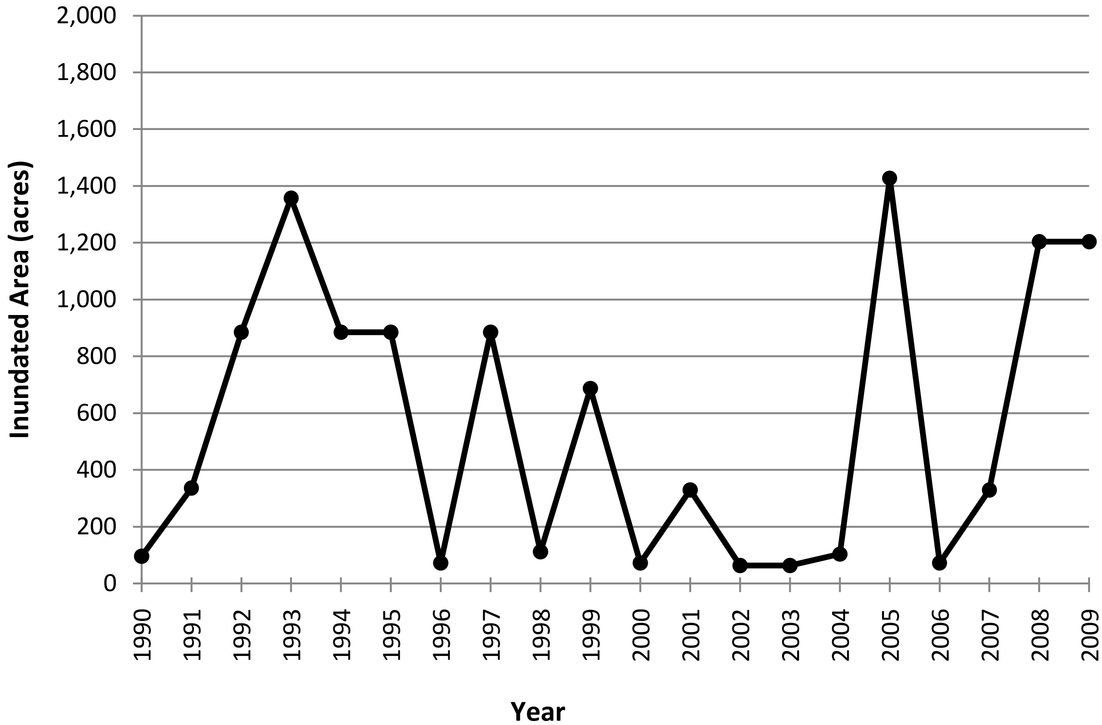

Figure 31 – Total (Channel + Floodplain) Inundated Area for Reach 11

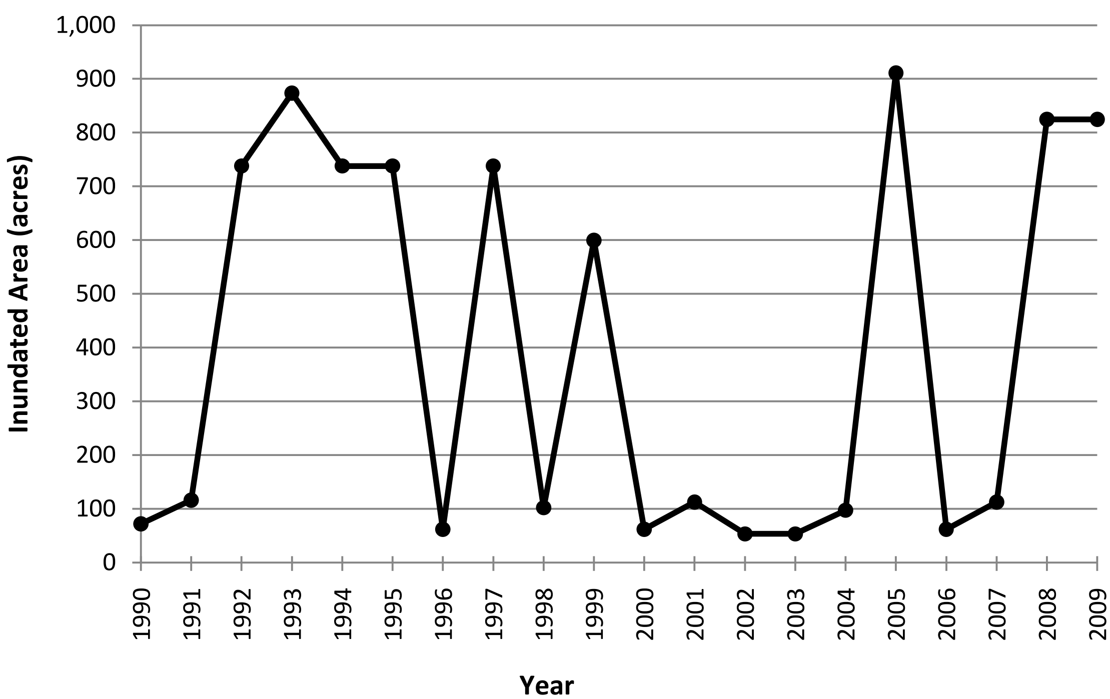

Figure 32 – Total (Channel + Floodplain) Inundated Area for Reach 12

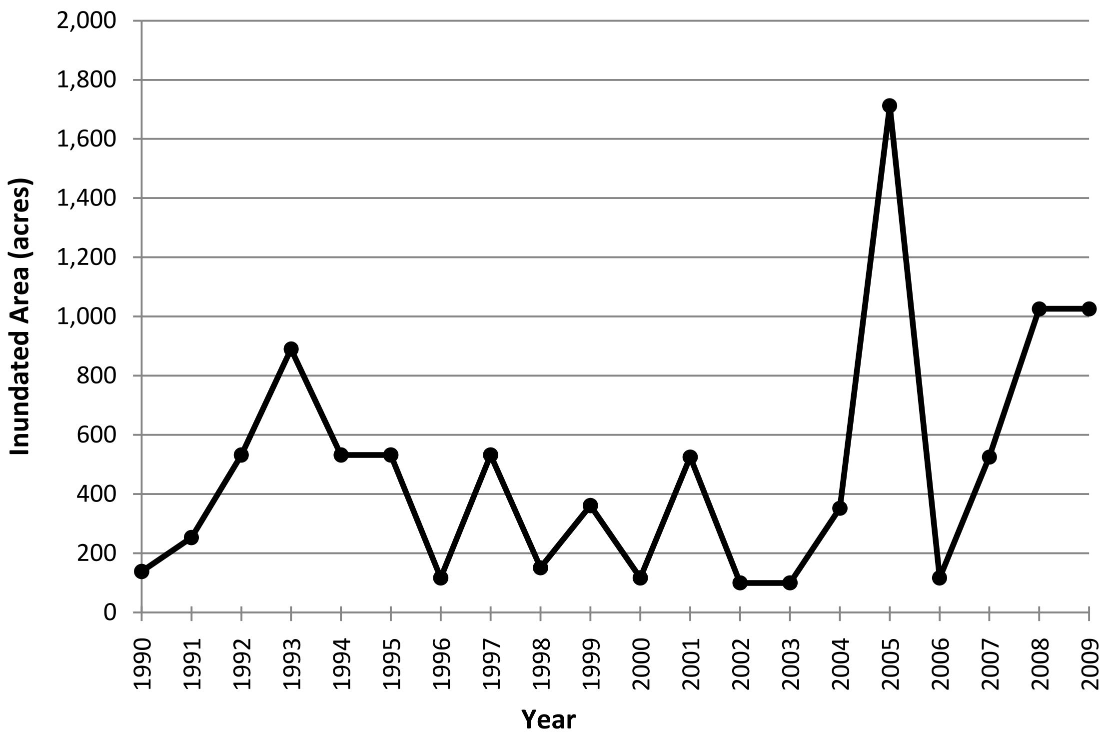

Figure 33 – Total (Channel + Floodplain) Inundated Area for Reach 13

VII. Summary and Limitations

Area of inundation for each year from 1990 through 2009 was estimated for each of the 13 reaches from Cochiti Dam to River Mile 60 upstream of the headwaters of Elephant Butte Reservoir. Estimates were made for the channel, the floodplain (or overbank), and for the combined total of these.

The HEC-RAS analysis of the 1992 and 2002 datasets did not reveal significant geomorphic differences for the upper Reaches 1-9. The analysis indicated a significant reduction in channel capacity for the lower Reaches 10-13. Limitations to these estimates and this analysis include a limited set of consistent temporal data sets. While the HEC-RAS analysis using the 1992 and 2002 data sets capture much of the geomorphic changes that occurred between these timeframes, the intervening and subsequent geomorphic changes are not captured, including channel incision that has occurred in recent years in the lower reaches. Also not captured, due to the relatively course analysis being performed, were in channel geomorphic changes that have occurred such as channel narrowing due to vegetation encroachment on islands and bars (with the exception being those changes captured in Reach 10). An example of this is the significant channel narrowing in recent years within the Middle Rio Grande, most notably in Reaches 5 and 6 (Isleta to the Rio Puerco).

Appendix A – Miscellaneous Supporting Figures and Tabular Data for Channel and Floodplain Inundated Areas

Miscellaneous Supporting Figures

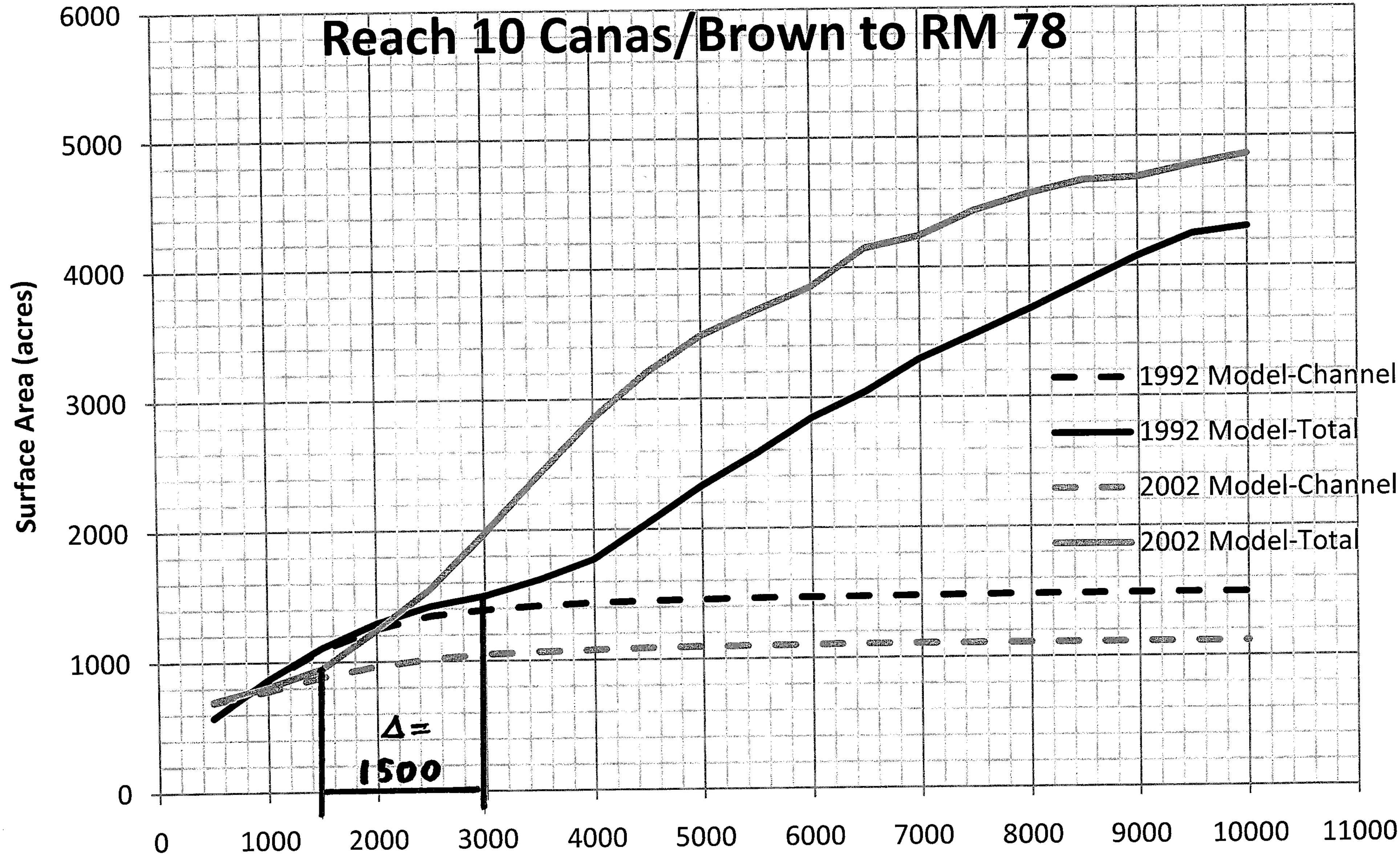
Reach 10 Canas/Brown to RM 78
Surface Area (acres)
6000
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Q Total (cfs)
1992 Model-Channel
1992 Model-Total
2002 Model-Channel
2002 Model-Total
Δ=
1500

FIGURE A.1

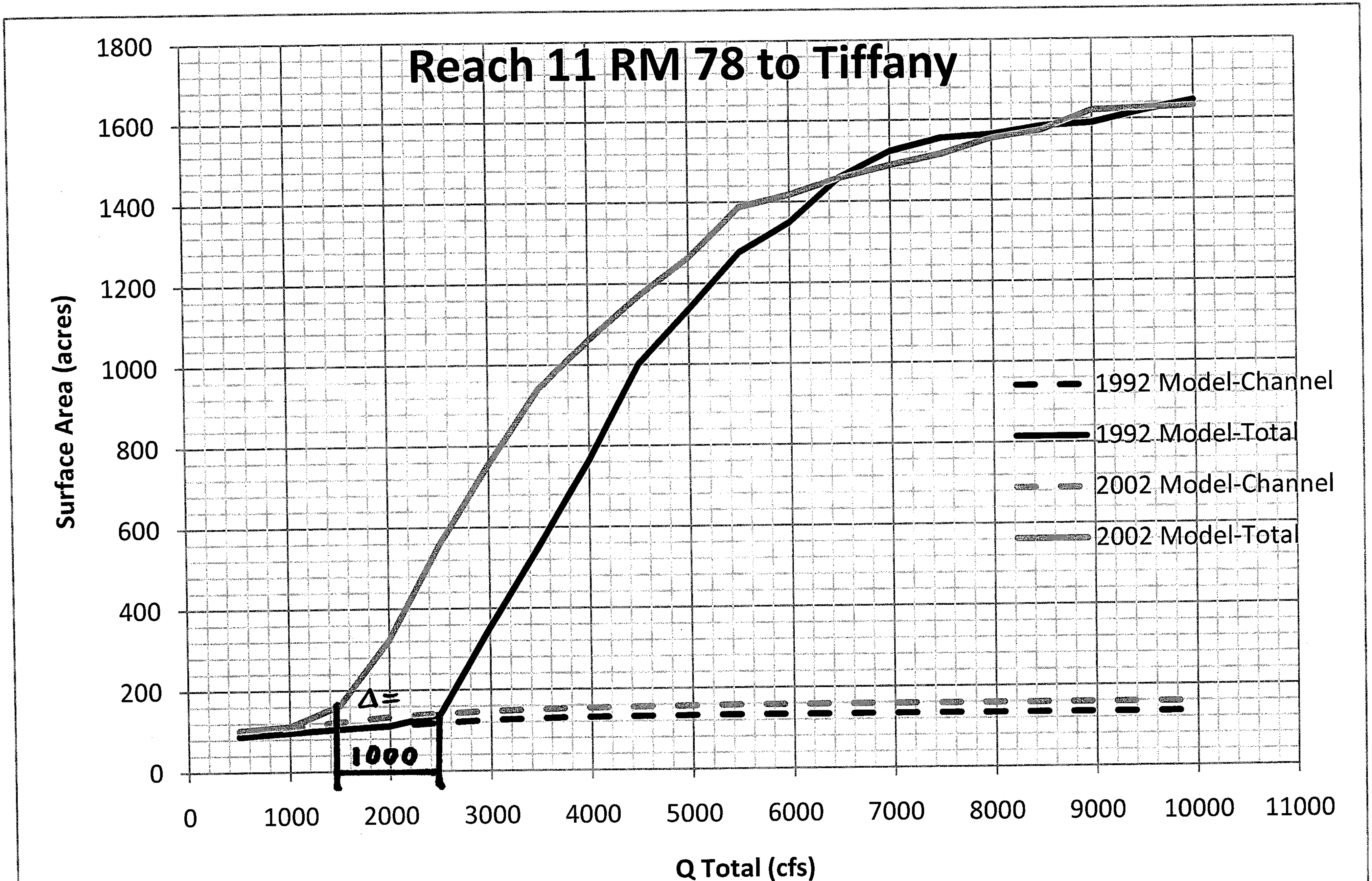
Reach 11 RM 78 to Tiffany
Surface Area (acres)
1800
1600
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Q Total (cfs)
1992 Model-Channel
1992 Model-Total
2002 Model-Channel
2002 Model-Total
Δ=
1000

FIGURE A.2

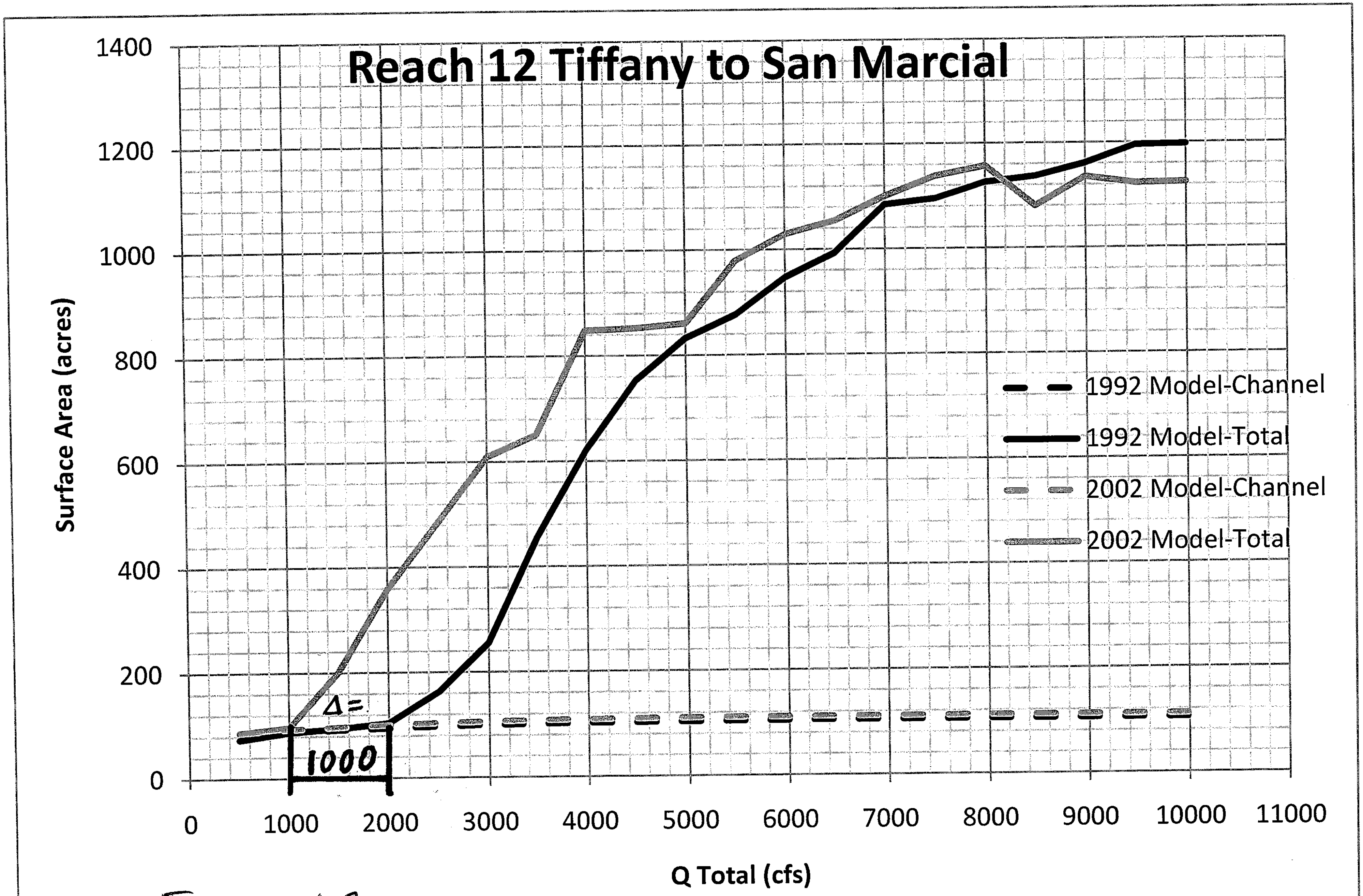
Reach 12 Tiffany to San Marcial
Surface Area (acres)
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Q Total (cfs)
1992 Model-Channel
1992 Model-Total
2002 Model-Channel
2002 Model-Total
Δ=
1000

FIGURE A.3

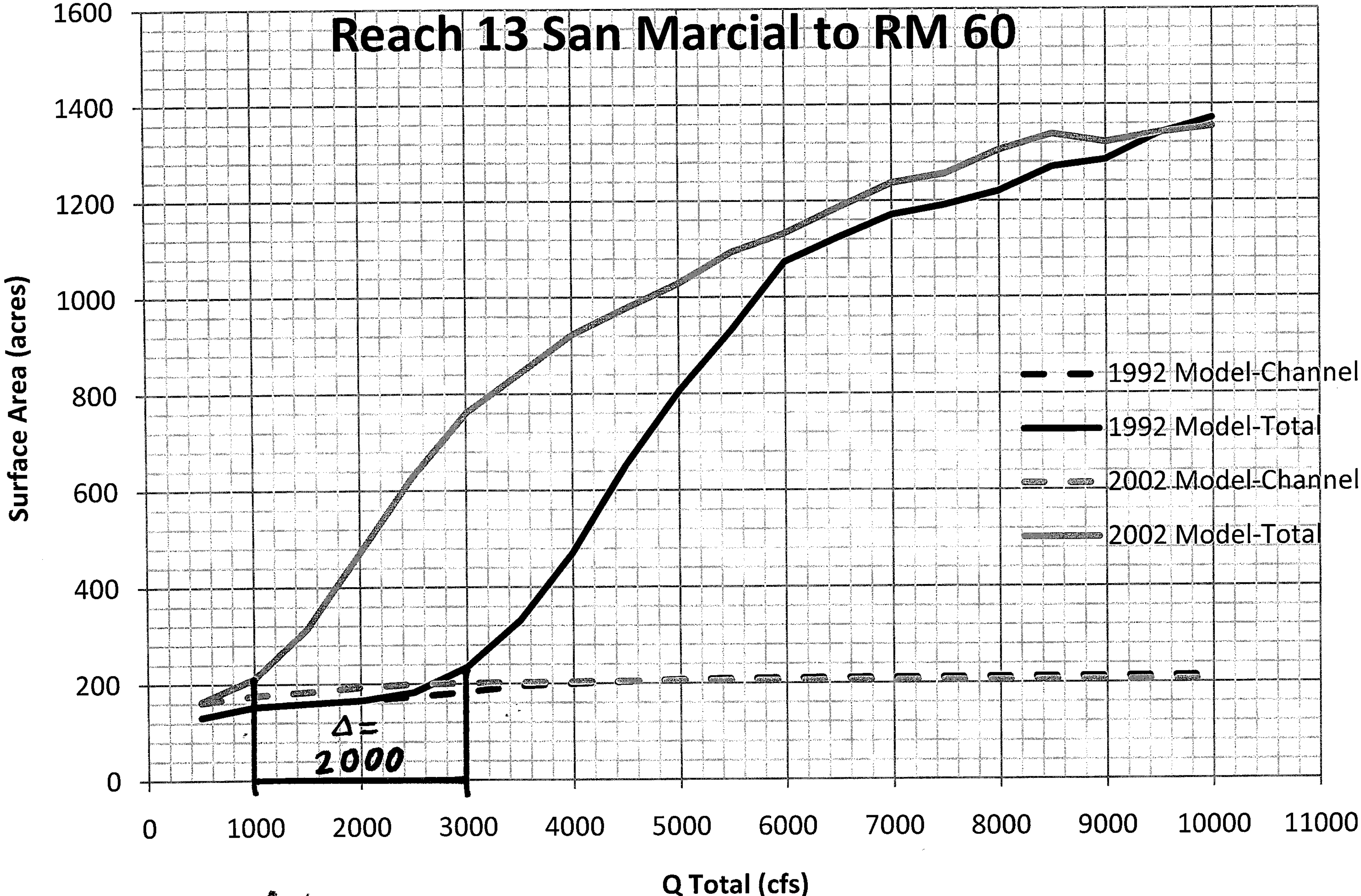
Reach 13 San Marcial to RM 60
Surface Area (acres)
1600
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Q Total (cfs)
1992 Model-Channel
1992 Model-Total
2002 Model-Channel
2002 Model-Total
Δ=
2000

FIGURE A.4

Tabular Data for Channel and Floodplain Inundated Areas

Total Inundated Area (Channel plus Overbank) - Units Shown are in Acres

Year	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11	Reach 12	Reach 13
1990	406	138	78	1,214	679	990	224	66	613	899	96	72	139
1991	562	192	129	1,347	883	1,196	275	98	748	1,124	336	116	253
1992	646	207	143	1,397	2,225	2,019	337	107	801	1,920	885	738	532
1993	832	216	154	1,938	2,577	2,712	418	109	944	2,272	1,357	874	890
1994	646	207	143	1,397	2,225	2,019	337	107	801	1,920	885	738	532
1995	646	207	143	1,397	2,225	2,019	337	107	801	1,920	885	738	532
1996	324	96	55	1,019	498	770	186	43	472	576	73	62	117
1997	646	207	143	1,397	2,225	2,019	337	107	801	1,920	885	738	532
1998	508	182	119	1,322	782	1,146	263	93	723	1,062	112	102	151
1999	611	201	137	1,371	1,439	1,386	322	104	773	1,587	687	599	362
2000	324	96	55	1,019	498	770	186	43	472	520	73	62	117
2001	477	169	101	1,295	756	1,103	252	85	695	1,265	330	113	525
2002	267	75	42	798	383	631	161	36	403	430	63	53	100
2003	267	75	42	798	383	631	161	36	403	430	63	53	100
2004	445	156	92	1,262	723	1,057	238	76	664	784	104	97	352
2005	832	216	154	1,938	2,577	2,712	418	109	944	3,623	1,428	911	1,712
2006	324	96	55	1,019	498	770	186	43	472	520	73	62	117
2007	477	169	101	1,295	756	1,103	252	85	695	1,265	330	113	525
2008	611	201	137	1,371	1,439	1,386	322	104	773	1,972	1,204	825	1,026
2009	611	201	137	1,371	1,439	1,386	322	104	773	1,972	1,204	825	1,026

Channel Only Inundated Areas - Units Shown are in Acres

Year	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11	Reach 12	Reach 13
1990	406	138	78	1,214	679	990	224	66	613	899	96	72	139
1991	528	192	129	1,347	806	1,160	274	98	748	1,084	115	81	153
1992	574	207	143	1,396	834	1,194	290	107	784	1,109	119	84	156
1993	599	216	154	1,440	848	1,210	296	109	801	1,124	121	85	157
1994	574	207	143	1,396	834	1,194	290	107	784	1,109	119	84	156
1995	574	207	143	1,396	834	1,194	290	107	784	1,109	119	84	156
1996	324	96	55	1,019	498	770	186	43	472	576	73	62	117
1997	574	207	143	1,396	834	1,194	290	107	784	1,109	119	84	156
1998	503	182	119	1,322	782	1,136	263	93	723	1,062	112	81	151
1999	555	201	137	1,371	822	1,181	283	104	767	1,099	118	83	155
2000	324	96	55	1,019	498	770	186	43	472	520	73	62	117
2001	474	169	101	1,295	756	1,103	252	85	695	777	109	78	150
2002	267	75	42	798	383	631	161	36	403	430	63	53	100
2003	267	75	42	798	383	631	161	36	403	430	63	53	100
2004	442	156	92	1,262	723	1,057	238	76	664	744	104	76	146
2005	599	216	154	1,440	848	1,210	296	109	801	842	121	85	157
2006	324	96	55	1,019	498	770	186	43	472	520	73	62	117
2007	474	169	101	1,295	756	1,103	252	85	695	777	109	78	150
2008	555	201	137	1,371	822	1,181	283	104	767	824	118	83	155
2009	555	201	137	1,371	822	1,181	283	104	767	824	118	83	155

Overbank Only Inundated Area - Units Shown are in Acres

Year	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11	Reach 12	Reach 13
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	34	0	0	0	77	36	1	0	0	40	221	34	100
1992	72	0	0	1	1,390	825	47	0	17	811	766	654	376
1993	232	0	0	498	1,729	1,502	122	0	143	1,148	1,237	789	733
1994	72	0	0	1	1,390	825	47	0	17	811	766	654	376
1995	72	0	0	1	1,390	825	47	0	17	811	766	654	376
1996	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	72	0	0	1	1,390	825	47	0	17	811	766	654	376
1998	6	0	0	0	0	10	0	0	0	0	0	22	0
1999	56	0	0	0	617	205	39	0	6	488	570	517	207
2000	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	3	0	0	0	0	0	0	0	0	488	221	34	376
2002	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	3	0	0	0	0	0	0	0	0	40	0	22	207
2005	232	0	0	498	1,729	1,502	122	0	143	2,781	1,307	826	1,555
2006	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	3	0	0	0	0	0	0	0	0	488	221	34	376
2008	56	0	0	0	617	205	39	0	6	1,148	1,086	742	871
2009	56	0	0	0	617	205	39	0	6	1,148	1,086	742	871