Restoration of the Salton Sea

Volume 1: Evaluation of the Alternatives

Appendix 1M: Sediment Load and Transport

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Sediment Loads and Transport

The Sedimentation and River Hydraulics (Sedimentation) Group of the Technical Service Center conducted an appraisal level study on sediment and hydraulic aspects of alternatives being studied in Phase 1 of the Feasibility Study. The alternatives are outlined in Reclamation's "Salton Sea Restoration Project Feasibility Study – Phase 1, Alternatives and Costs". This section provides details from this appraisal level study.

Sediment deposition was estimated as the total volume entering the Sea based on current and projected future conditions. Sedimentation loads were determined for current and future conditions for the Whitewater, New, and Alamo Rivers. Hydrology of the three rivers was estimated in terms of a flow duration analysis for current and future evolving conditions. Following is an overview of the viability assessment of sediment as related to the Phase 1 Salton Sea alternatives.

Flow Duration Analysis

Cumulative frequency curves, called flow duration curves, show the average percentage of time that specific daily flows are equaled or exceeded at sites where continuous records of daily flow are available. Flow duration analyses were performed for the New, Alamo, and Whitewater Rivers for historic and future conditions. For future conditions, the Future mean, Future 5 percentile and Future 95 percentile scenarios were determined. The historic flow duration for the New River was determined from gauge number 10255550[1] for the New River at Westmoreland. This gauge is located a very short distance from its mouth of the Sea. The flow duration curve is shown on Figure 1. Future evolving flows were generated with the Salton Sea Accounting (SSA) Model developed based on changes in predicted risk based approach to future inflows to the Sea. This risk based approach to inflows is presented in Reclamations report titled: "Salton Sea Restoration Project Feasibility Study – Phase 1, Alternatives Viability".

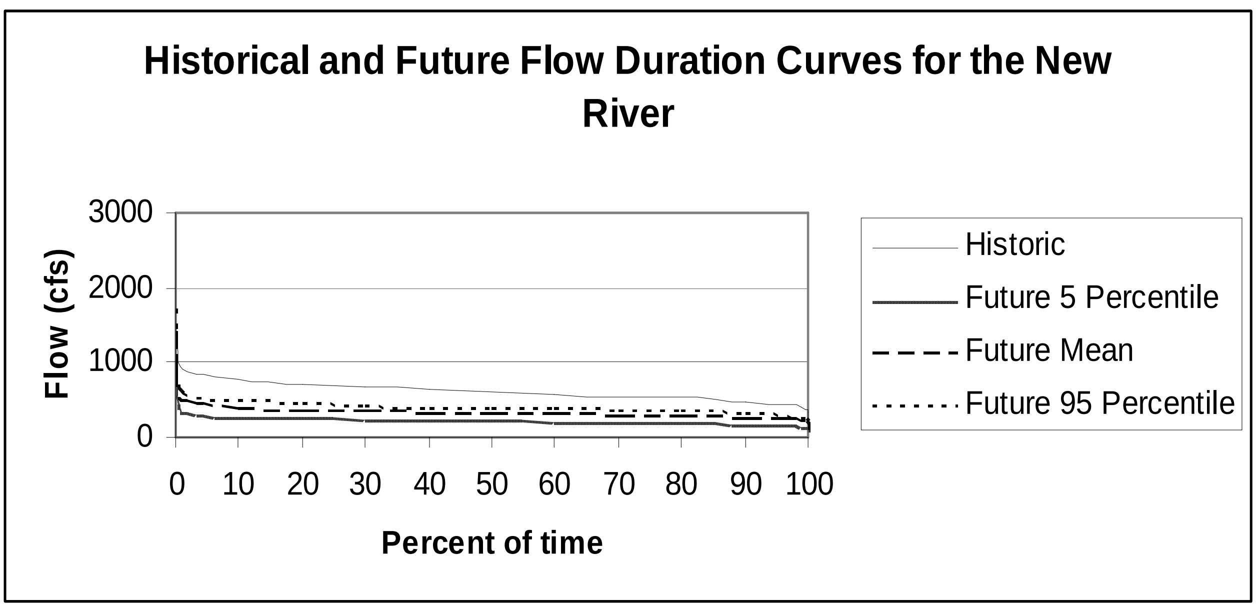

Figure 1. Flow duration curves for the New River.

[1] USGS, 2005. All listed gage data available online: http://nwis.waterdata.usgs.gov/nwis/discharge.

Flow duration curves for the Alamo River were created from USGS gauge number 10254730 located on Alamo River Near Niland, California. The flow duration curve was created from the daily historical data and then future projections were made with SSA Model using the risk based approach to inflows. The data is shown on Figure 2.

Flow duration curves for the Whitewater River were created from daily streamflow for the USGS gauge number 10259540 located on Whitewater River near Mecca, California. The data is plotted on Figure 3.

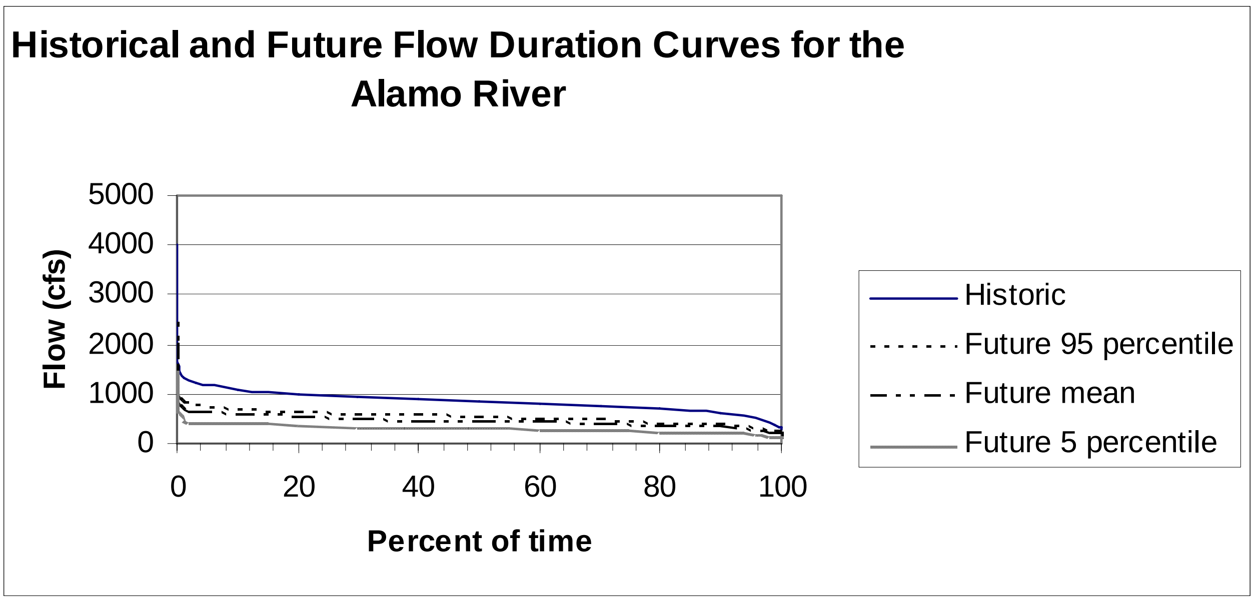

Figure 2. Flow duration curves for the Alamo River.

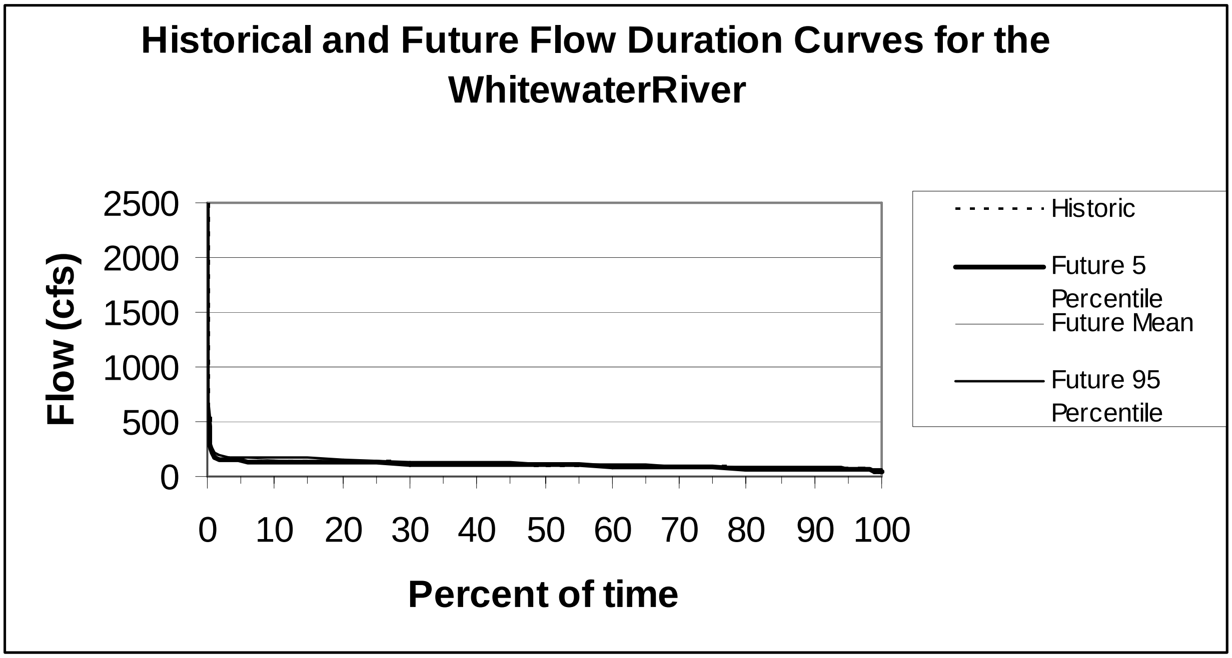

Figure 3. -Flow duration curves for the Whitewater River.

Suspended Sediment Data

Suspended sediment data were analyzed for selected gauges on the New, Alamo, and Whitewater Rivers. Suspended sediment data were analyzed for the New River at International Boundary at Calexico, California (USGS gauge number 10254970). For the New River, a relationship was determined between discharge and suspended sediment concentrations based on a power relationship between sediment and water (Figure2.). The equation of the power relationship as well as the correlation coefficient is shown on the figure. The correlation coefficient was only a little better than 7 percent for the New River, compared to the best possible correlation of 100 percent.

The annual sediment load was determined for the New River based on the suspended sediment analysis and the flow duration curves. The values for the annual sediment load for the New River is shown on Figure 5. The sediment concentration and flow relationship was developed for the New River near Calexico, California whereas the flow duration curve was developed for the New River near Westmoreland, California. The assumption was made that suspended sediment concentrations would be similar for both gauges. However, with the poor correlation between sediment and water, a range of estimate of future sediment loads is shown to account for the uncertainty due to the data limitations. The maximum future annual load for the New River would range between 60,000 cu yd/yr and 120,000 cu yd/yr.

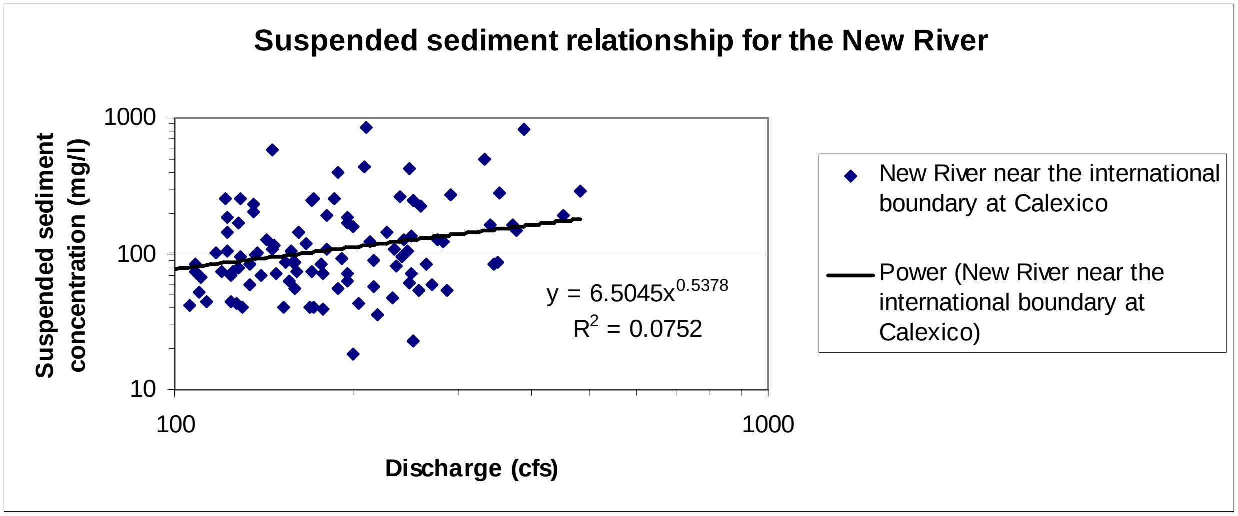

Figure 4. Suspended sediment relationship for the New River.

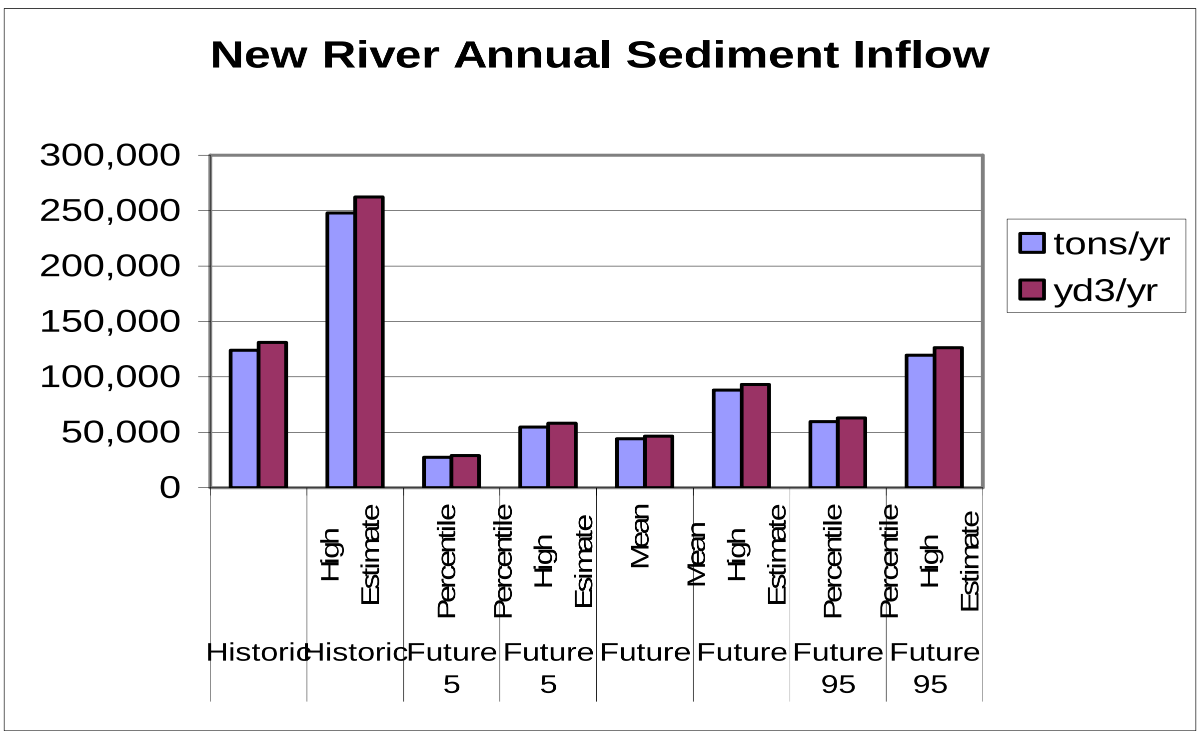

Figure 5. New River Annual Sediment Inflow.

A suspended sediment relationship was developed for the Alamo River using data from the USGS gauge, station number 10254670, located on Alamo River near Calipatria, California (Figure 6). A relationship was determined between discharge and suspended sediment concentrations based on a power relationship between sediment and water. The equation of the power relationship as well as the correlation coefficient is shown on the figure. The correlation coefficient was 50.2 percent for the

Alamo River compared to the best possible correlation of 100 percent. The relationship for this gauge was better than the New River, but was not extremely high in terms of the correlation coefficient. This data was used to determine sediment loads in the Alamo River.

The annual sediment load for historical and future conditions for Alamo River is shown on Figure 7. The assumption was made that the suspended sediment concentrations would be similar for the USGS station number 10254670, located on the Alamo River near Calipatria, California and the USGS gauge number 10254730, Alamo River Near Niland, California. The Near Niland gage is located further downstream from the Calipatria gage and was used to develop the flow duration analysis. The Niland gauge was also used to determine the annual sediment load. Future annual sediment loads for the 95 percent scenario range from 200,000 to 400,000 cu yd/year. A range of loads for the historical and future scenarios in shown on the Figure 7 to account for the uncertainty between estimated sediment loads upstream and downstream in the watershed.

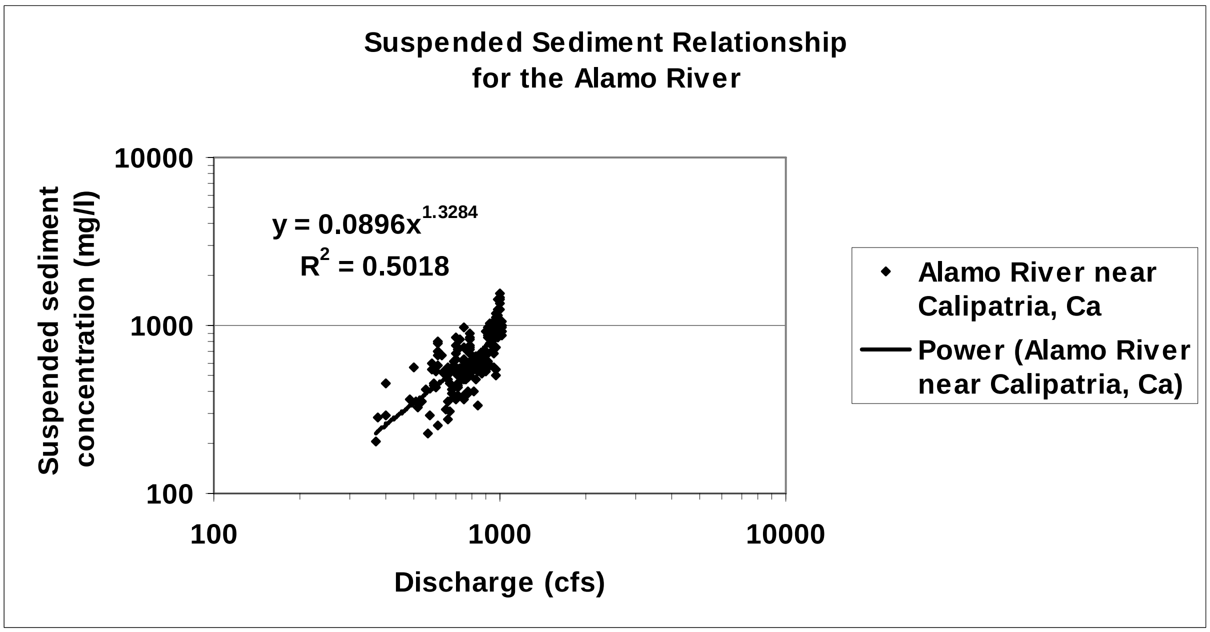

Figure 6. Suspended sediment relationship for the Alamo River.

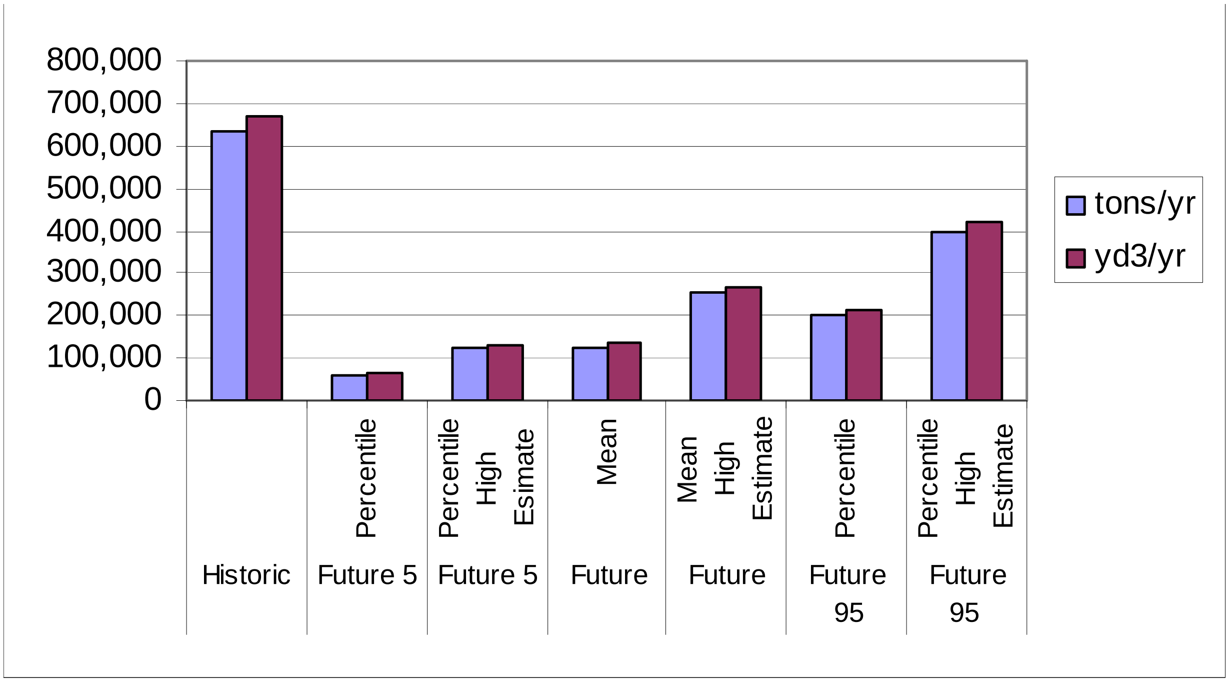

Figure 7. Alamo River annual sediment inflow.

A suspended sediment relationship, Figure 8, was determined for the Whitewater River based on the USGS gauging station number 10256000, located on the White Water River near White Water, California. The relationship was based on the determination of a power curve relationship between the discharge and suspended sediment concentrations. The equation of the fitted curve and the correlation coefficient are shown on the graph. The relationship is considered poor, but only data available.

The suspended sediment relationship developed for the upstream gauge (White Water, California) was used for the suspended sediment relationship and the flow duration analysis was based on gauge closer to the Sea (USGS gauge number 10259540, Whitewater River near Mecca, California). The assumption was made that the suspended sediment concentrations would be similar at each location. The future predicted annual sediment loads are higher for the Whitewater River for all future possible scenarios than the historical annual sediment loads. It is predicted that discharges will increase in the Whitewater basin, due to increased diversions into the river, resulting in increase sediment load (Figure 9).

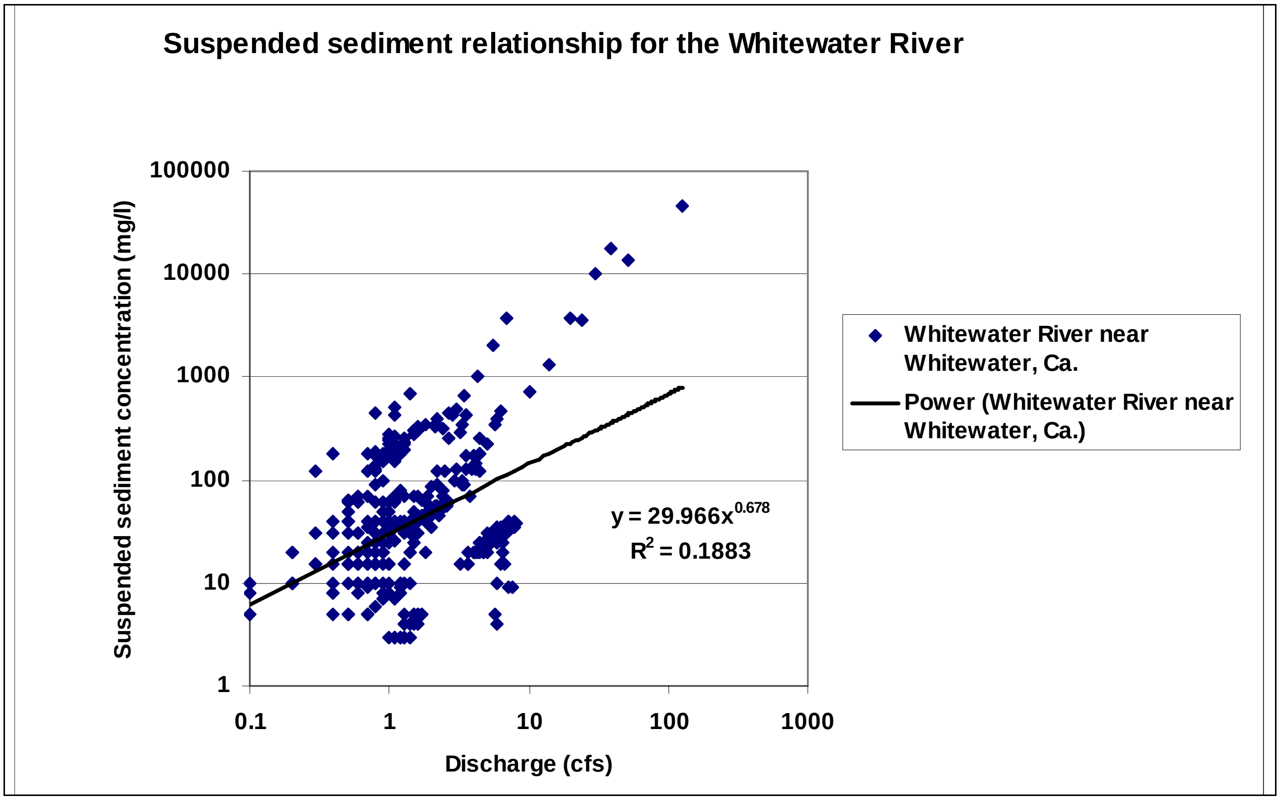

Figure 8. Suspended sediment relationship for the Whitewater River.

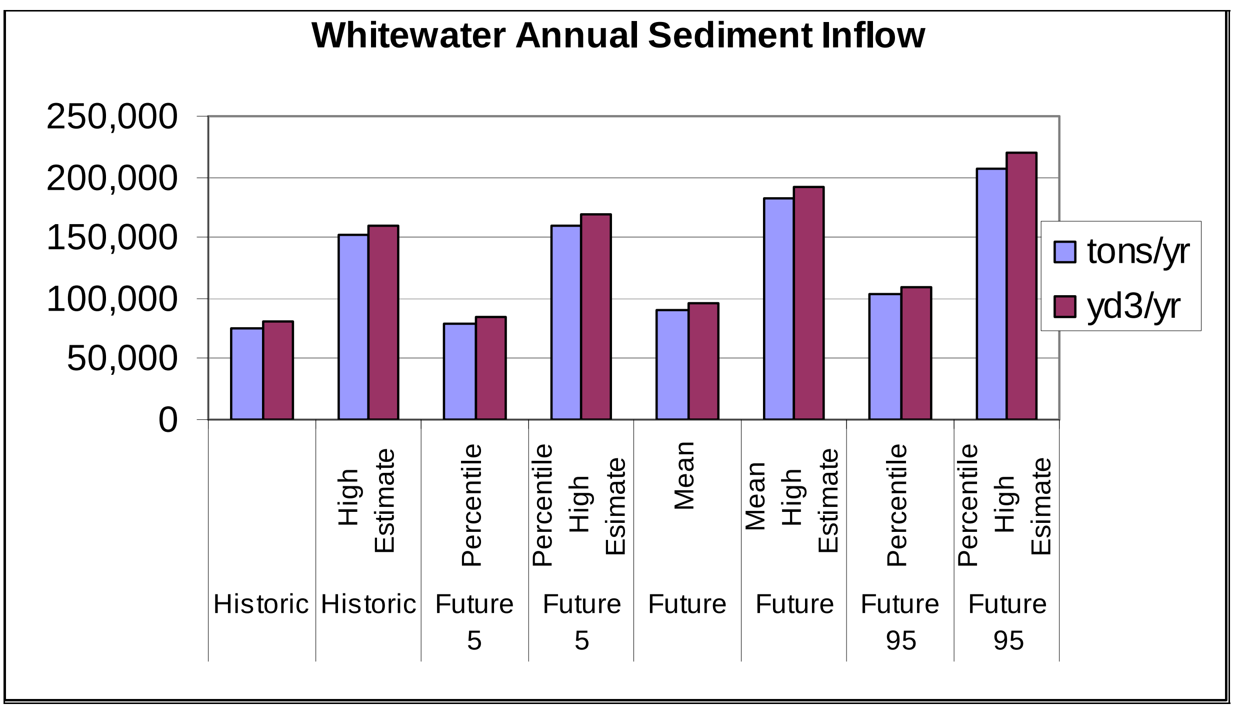

Figure 9. Whitewater River annual sediment inflow.

Total Basin-Wide Sediment Load

The total basin-wide sediment load was estimated for the Salton Sea by two different methods. The first method was an attempt to determine the volume change in the Sea by superimposing three-dimensional grids of the Sea created from 1995 and 2004 survey data. Reclamation collected depth data of the Sea in 1995 (Ferrari, 1997) and a contractor for the USGS collected depth data of the Sea in 2004 (USGS, 2004). The attempt to estimate the volume change by comparing these two surveys was not successful because of several factors. The scope of this study did not allow time for extensive study into resolving these differences, but it is the general conclusion that comparing these surveys is not the best means to determine sediment deposition between 1995 and 2004. Due to the size of the Salton Sea, even an error of 0.1 feet in elevation would result in extreme differences in volumes that can not be justified.

The two surveys were conducted by somewhat different methods and for different purposes. The 1995 survey was a high speed survey with the purpose of mapping the entire Sea for computing a total volume of the Sea. Collection lines where run pretty evenly throughout the Sea using mapping grade GPS with accuracies of +/- 2 meters The 2004 survey did detailed shoreline collection with only a few lines in the main body of the Sea using submeter GPS for positions. Initial examination of the two surveys found too far of a difference in the deeper zones of the contouring. It was determined that the studies used different vertical datums for converting the collected depths to elevations. This significantly reduced the differences, but there are still too many unknowns that need to be resolved. As of this writing the USGS was further studying this issue, but as stated previously a 0.1-foot error has a significant impact.

For this study, the complete basin-wide sediment load was estimated from empirical equations that calculated basin wide sediment yield rates for drainages in the southwest of the United States (Reclamation, 1982). This is a rough estimate of the total yield of the entire Salton Sea basin. The coefficients for the empirical equations are shown on Table 1 along with a range of estimated historical sediment rates determined for the Salton Sea basin.

Table 1. Basin wide annual sediment inflow to Salton Sea

$Q_s = a A^b$	Low Estimate	Estimate	High Estimate	
coefficient (a)	0.368	1.84	9.2	
Exponent (b)	-0.24	-0.24	-0.24	
Drainage area (mi^x)	8,273	8,273	8,273	mi^2
Sediment Yield	0.042	0.211	1.056	acre-ft/mi^2/yr
Sediment Yield	1,839	9,197	45,987	ft^3/mi^2/yr
Sediment Yield	15,218,070	76,090,352	380,451,759	ft^3/yr
Sediment Yield	563,632	2,818,161	14,090,806	yd^3/yr

The future annual basin wide sediment yield estimates are shown on Table 2 for a range of estimates (low, medium and high). These values are based on the future flow duration curves that were created for the three rivers and related to the basin wide sediment inflow estimates. The future 5 , 50, and 95 percentile with factors of 15, 25, and 40 percent of the historic values were utilized to estimate the future basin wide sediment inflows.

Table 2. Future basin-wide sediment inflows (cu-yd/yr)

Type of Estimate	Historic	Future 5 Percentile	Future Mean	Future 95 Percentile
Low	563,632	84,545	140,908	225,453
Medium	2,818,161	422,724	704,540	1,127,264
High	14,090,806	2,113,621	3,522,701	5,636,322

Settling Basin Designs

The New and Alamo Rivers empties into the Salton Sea on the south end and the Whitewater River on the north end of the Sea. The mid-sea dam and barrier alternatives would require diversion and conveyance of these rivers to mid-sea. If the north half of the sea is maintained, the New and Alamo Rivers would be conveyed to north of the mid-sea dam or barrier. If the south half of the sea is maintained, the Whitewater river would be conveyed to south of the mid-sea dam or barrier.

For all of these alternatives, a settling basin was designed to be located at the start of the diversion canal for each of the three rivers. The annual sediment deposition was calculated for each river at the diversion canal along with the amount of annual deposition that would occur in each canal. The analysis was based on the average annual discharge for the future 95 percent scenario that would be the future highest average possible flows.

The Sedimentation Group's program "Setsize" was used for the analysis (Reclamation, 1982). The analysis required a particle size distribution of suspended sediment for the river and water temperature data. The available suspended sediment particle size distributions are shown on Figures 10, 11, and 12 for each of the studied rivers. For the New River, the only available data was the percent of sediment below sand size 0.063 mm. A size distribution curve for the New River was generated using the Alamo River data from size 0.002 mm up to 0.063 mm. As shown on figure 12, only a small range of data was available for the Whitewater River.

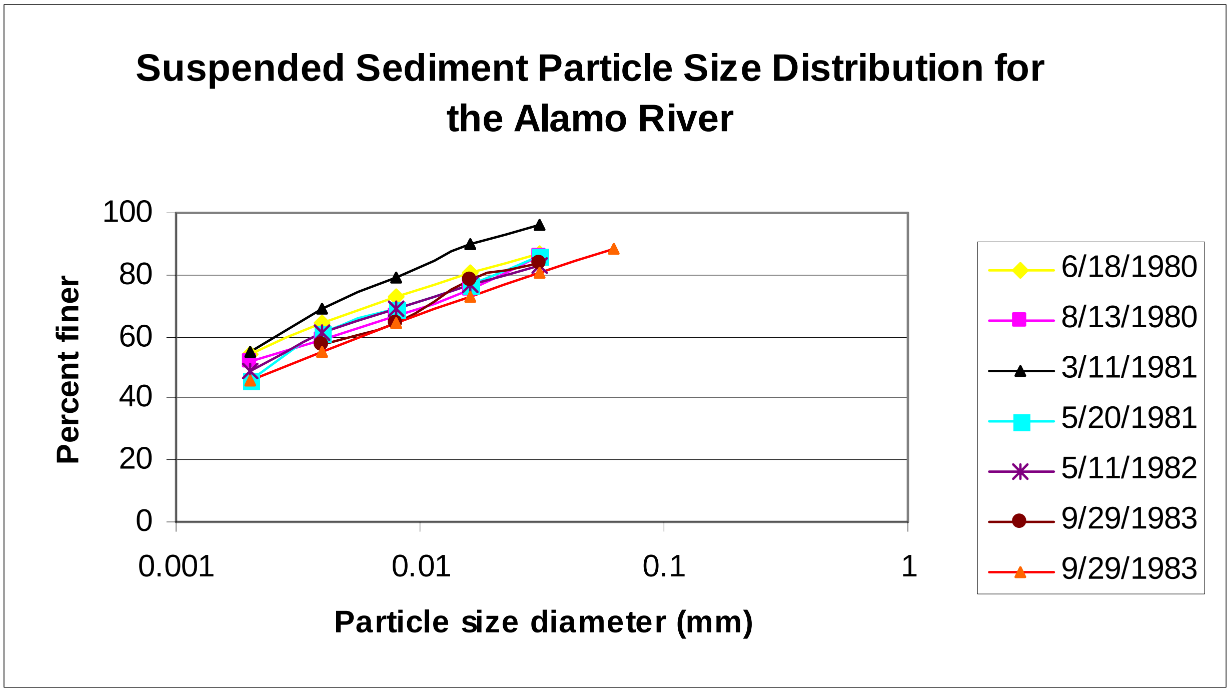

Figure 10. Suspended sediment particle size distribution for the Alamo River.

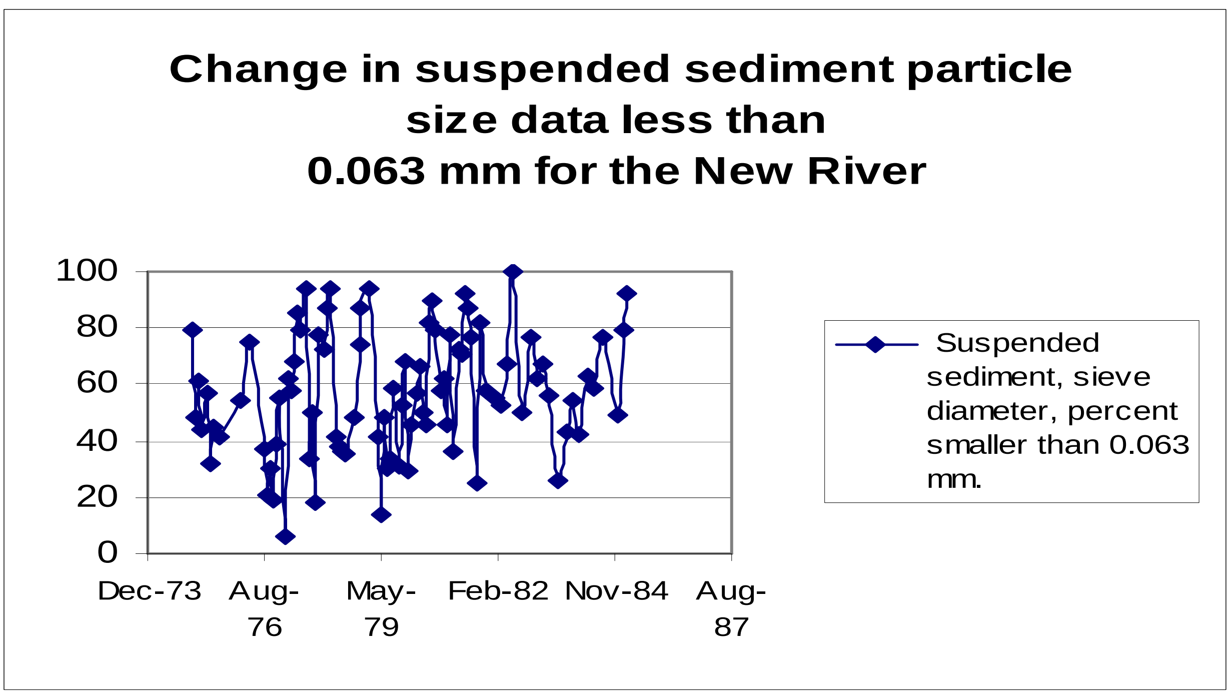

Figure 11. Percent changes in suspended particle size data for the New River (less than sand size).

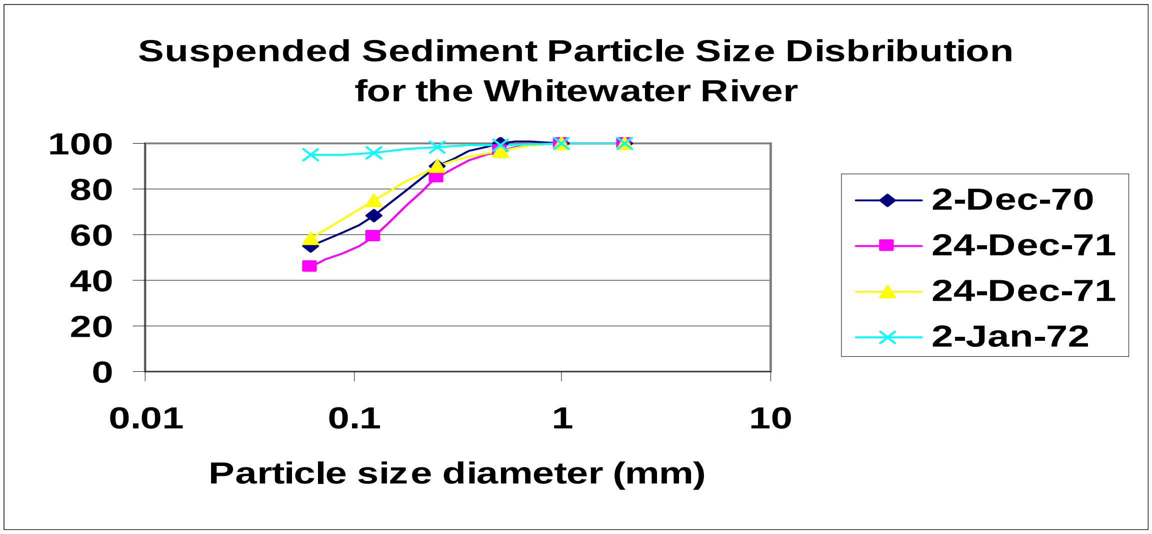

Figure 12. Suspended sediment particle size distribution for the Whitewater River.

Two corridors (options) were considered for conveying the New and Alamo Rivers. A canal would originate at the New River, flow east and collect water from the Alamo River and go around the east side of the sea. Alternatively, a canal would originate at the Alamo River, flow west and collect water from the New River and go around the west side of the sea. One corridor was considered for conveying the Whitewater River, that being west of the sea. Difference distances associated with the Mid-sea dam and barrier options are shown on Tables 3 and 4.

Table 3. Mid Sea dam options

Corridor	Length (miles)
Between New and Alamo Rivers	8
Southeast	20
Southwest	24
Northwest	20

Table 4. Mid Sea Barrier Options

Corridor	Length (miles)
Between New and Alamo Rivers	8
Southeast	14
Southwest	18
Northwest	17

The results of the settling basin analysis are shown on Table 5. The option that was considered for the North Sea Alternatives was the southwest route with water being transferred from the Alamo to the New River and then northwest to the north portion of the Sea. For the south Sea, the water was conveyed from the Whitewater River to the south Sea. Average 95 percentile flows into the seas would be 370 cubic feet per second (cfs) for the New River, 519 cfs for the Alamo River and 107 cfs for the Whitewater River. The estimated total sediment accumulation was 60,000 cu yds for the Alamo River, 72,000 cu yd for the New River, and 83,000 cu yd for the Whitewater River. These estimates are based on the current data available for determining annual sediment loads for each river basin

Table 5. Settling basin data and sediment volume of deposition

Alamo River		New River		Whitewater River	
Settling Basins		**Settling Basins**		**Settling Basins**	
Length	5,000	Length	5,000	Length	5,000
Bottom width	30	Bottom width	30	Bottom width	40
Side slope	1.5	Side slope	1.5	Side slope	1.5
Basin Invert	-250	Basin Invert	-250	Basin Invert	-230
Top Elevation	-232	Top Elevation	-232	Top Elevation	-214
Depth of Sediment	5.62	Depth of Sediment	4.48	Depth of Sediment	6
Accumulated sediment volume (yd^3)	40,000	Accumulated sediment volume (yd^3)	30,439	Accumulated sediment volume (yd^3)	57,000
Channel with sediment accumulation		**Channel reaches with sediment accumulation (Reach 1)**		**Channel reaches with sediment accumulation (Reach 1)**	
Length (ft)	40,000	Length (ft)	20,000	Length (ft)	20,000
Bottom width (ft)	16	Bottom width (ft)	14	Bottom width (ft)	6
Side slope	1.5	Side slope	1.5	Side slope	1.5
Basin Invert	-242	Basin Invert	-231	Basin Invert	-219.8
Top Elevation	-232	Top Elevation	-220	Top Elevation	-213.4
Depth of Sediment	0.78	Depth of Sediment	1.17	Depth of Sediment	0.54
Accumulated sediment volume (yd^3)	19,700	Accumulated sediment volume (yd^3)	14,200	Accumulated sediment volume (yd^3)	2,732
		(Reach 2)		**(Reach 2)**	
		Length (ft)	20,000	Length (ft)	20,000
		Bottom width (ft)	14	Bottom width (ft)	6
		Side slope	1.5	Side slope	1.5
		Basin Invert	-231	Basin Invert	-219.8
		Top Elevation	-220	Top Elevation	-213.4
		Depth of Sediment	0.74	Depth of Sediment	0.28
		Accumulated sediment volume (yd^3)	8,540	Accumulated sediment volume (yd^3)	1,316
		(Reach 3)		**(Reach 3)**	
		Length (ft)	20,000	Length (ft)	20,000
		Bottom width (ft)	14	Bottom width (ft)	6
		Side slope	1.5	Side slope	1.5
		Basin Invert	-231	Basin Invert	-219.8
		Top Elevation	-220	Top Elevation	-213.4
		Depth of Sediment	0.78	Depth of Sediment	0.19
		Accumulated sediment volume (yd^3)	8,759	Accumulated sediment volume (yd^3)	890

Alamo River	New River		Whitewater River	
	(Reach 4)		**(Reach 4)**	
	Length (ft)	20,000	Length (ft)	20,000
	Bottom width (ft)	14	Bottom width (ft)	6
	Side slope	1.5	Side slope	1.5
	Basin Invert	-231	Basin Invert	-219.8
	Top Elevation	-220	Top Elevation	-213.4
	Depth of Sediment	0.45	Depth of Sediment	0.15
	Accumulated sediment volume (yd^3)	4,838	Accumulated sediment volume (yd^3)	701
	(Reach 5)		**(Reach 5)**	
	Length (ft)	20,000	Length (ft)	27,000
	Bottom width (ft)	14	Bottom width (ft)	6
	Side slope	1.5	Side slope	1.5
	Basin Invert	-231	Basin Invert	-219.8
	Top Elevation	-220	Top Elevation	-213.4
	Depth of Sediment	0.29	Depth of Sediment	0.13
	Accumulated sediment volume (yd^3)	3,155	Accumulated sediment volume (yd^3)	780
	(Reach 6)			
	Length (ft)	20,000		
	Bottom width (ft)	14		
	Side slope	1.5		
	Basin Invert	-231		
	Top Elevation	-220		
	Depth of Sediment	0.2		
	Accumulated sediment volume (yd^3)	2,742		

Load and Transport Summary

Sediment studies were conducted for the Salton Sea (Sea) to determine the effect that sediment transport and deposition would have on future alternatives that are being studied in Phase 1 of the Feasibility Study. The alternatives are outlined in Reclamation’s Salton Sea Restoration Project Feasibility Study – Phase 1, Alternatives and Costs.

The availability of suspended sediment data and estimates of basin–wide sediment data was very limited for this Salton Sea sediment study. Most of the gauges for sediment were further upstream in the basin, whereas the discharge gauges were located further downstream. The correlation between the sediment and water relationships was also poor. This study attempted to address these problems by placing ranges on the sediment loads for individual rivers and for the estimate of basin wide sediment loads.

In order to improve the sediment analysis, suspended sediment and flow data should be collected simultaneously for all of the rivers in the basin on a set basis at a point near where the rivers enter the sea. In addition, bed material samples of each river should be collected to determine the size of material being transport by the rivers. A field investigation of the geomorphology of the deltas of the three rivers would also improve the analysis.

The New River could potentially carry up to 125,000 cu yd/yr of sediment or a minimum of 30,000 cu yd/yr of sediment in the future depending on future water flows and sediment transport (Table 6). The Alamo River in the future could carry a minimum of 65,000 cu yd/yr up to a maximum of 422,000 cu yd/yr of sediment (Table 7). The Whitewater River could carry from a range of 84,000 cu yd/yr to 220,000 cu yd/yr of sediment to a maximum of 422,000 cu yd/yr (Table 8). These volumes of sediment, entering the Sea, affect the alternatives involving water delivery from the rivers. For the barrier and dam alternatives, portions of delivery of water and resulting sediment will be diverted into the canals and a great deal of sediment deposition will occur. This will require annual maintenance to remove the accumulated sediment in the designed settling basins. A summary of the possible sediment that could accumulate in the canals and the settling basins are shown on Table 9. In addition, the basin-wide sediment that could be deposited in the Sea has been estimated (Table 10). This could have an effect on all of the alternatives. The minimum possible sediment that could be deposited in the Sea from the entire basin is 84,000 cu yd/yr up to a maximum of 5.6 million cu yd/yr. The total sediment entering the Sea will affect Alternative 3 and Alternatives 5 through 8 because of the design concepts.

Table 6. Summary of Historic and Projected Future sediment inflows for the New River annually

Quantity	Historic	Historic High Estimate	Future 5 Percentile	Future 5 Percentile High Estimate	Future Mean	Future Mean High Estimate	Future 95 Percentile	Future 95 Percentile High Estimate
tons/yr	123,908	247,816	27,466	54,931	44,080	88,160	59,693	119,385
yd^3/yr	131,120	262,240	29,064	58,128	46,646	93,291	63,167	126,334

Table 7. Summary of Alamo River Sediment Inflow on an annual basis

Quantity	Historic	Historic High Estimate	Future 5 Percentile	Future 5 Percentile High Estimate	Future Mean	Future Mean High Estimate	Future 95 Percentile	Future 95 Percentile High Estimate
tons/yr	632,910	1,265,820	61,595	123,189	126,071	252,141	199,525	399,049
yd^3/yr	669,746	1,339,492	65,180	130,359	133,408	266,816	211,137	422,274

Table 8. Summary of Whitewater River Sediment Inflow on an annual basis

Quantity	Historic	Historic High Estimate	Future 5 Percentile	Future 5 Percentile High Estimate	Future Mean	Future Mean High Estimate	Future 95 Percentile	Future 95 Percentile High Estimate
tons/yr	75,697	151,393	79,744	159,488	90,749	181,499	103,596	207,191
yd^3/yr	80,102	160,204	84,385	168,770	96,031	192,062	109,625	219,250

Table 9 – Sediment deposition in settling basins for each river

Table 10 – Summary of basin-wide sediment inflow (cu yd/yr)

Type of Estimate	Historic	Future 5 Percentile	Future Mean	Future 95 Percentile
Low	563,632	84,546	140,908	225,453
Medium	2,818,161	422,724	704,540	1,127,264
High	14,090,806	2,113,621	3,522,701	5,636,322

References

Ferrari, 1997. Salton Sea 1995 Hydrographic GPS Survey. Bureau of Reclamation, Sedimentation and River Hydraulics Group, Denver, Colorado.

Reclamation, 1982, Reservoir Sedimentation, Technical Guideline, Sedimentation and River Hydraulics Group, Denver, Colorado.

USGS, 2004, Salton Sea Survey, data collected by Quester Tagent and analyzed by Pat Chavez of the USGS, Flagstaff, Arizona.