Preliminary Technical Assessment

River Restoration Work On the Rio Ojo Sarco

East of Dixon, NM

Submitted To:

The Bureau of Land Management

July 15th , 2008

Submitted By:

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Albuquerque, NM and Pagosa Springs, CO

Rio Ojo Sarco Restoration

On BLM land east of Dixon, NM

Preliminary Assessment Report
July 15th, 2008

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Rio Ojo Sarco Restoration
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Introduction

The Bureau of Land Management (BLM) Taos New Mexico Field Office is responsible for approximately 3.0 sq. mi. of land along the eastern edge of Rio Arriba County, east of Dixon, NM. The Rio Ojo Sarco flows through this property, from the SE to the NW. Impacts to riparian vegetation from historic land uses, in combination with periodic influxes of sediment from ephemeral side tributaries, has left this section of the Rio Ojo Sarco in an unstable condition. Many sections of this river on the BLM land do not have any suitable aquatic habitat for fish or other aquatic species.

Perennial flow in the Rio Ojo Sarco has encouraged BLM Biologists to consider restoration work on this section of the river, to improve aquatic habitat conditions. The size of channel is too small and the flows too low to establish a cool water trout fishery. However, there is the potential for suitable habitat to be created for several smaller fish species, including Threatened and Endangered Species like the Rio Grande Silver Minnow and the Rio Grande Sucker.

Site History, Geology and Vegetation

The BLM section of the Rio Ojo Sarco was dramatically changed when regular irrigation water was introduced to the Ojo Sarco valley in the 1780's (Acequia de Ojo Sarco). Irrigation water meant that the Canada Ojo Sarco was no longer an ephemeral drainage and it became known as a "Rio" instead. Return flow from this irrigation project provided regular water to the lower valley area now managed by the BLM. Regular water meant the establishment of riparian vegetation and a resulting increase in channel stability. The upper Ojo Sarco valley included land flat enough for irrigation, while the lower valley was too narrow, too steep and subject to sediment deposits from active tributary drainages. Today, the upper valley remains in private land ownership while the lower valet traverses BLM and State land holdings.

Although the riparian corridor on the BLM land was/is relatively narrow, it still provided better forage than the semi barren uplands of the lower valley. Grazing of domestic livestock in this section of the Rio Ojo Sarco has at times put severe pressure on the riparian vegetation, and has in all likelihood contributed to the unstable conditions observed today. BLM grazing management strategies have changed in the past 10 years, ad the cessation of active grazing for

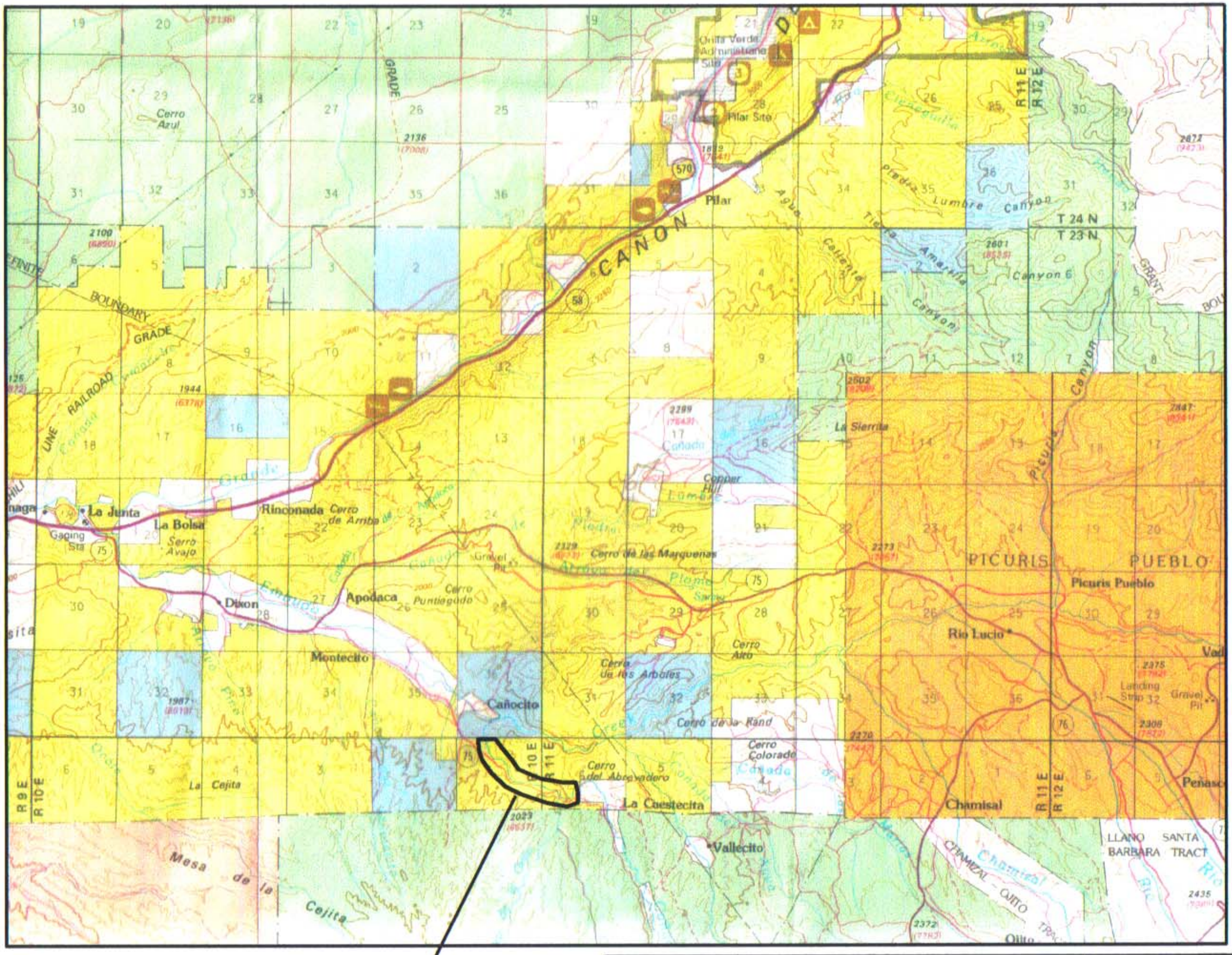
the past 6-7 years has allowed the riparian vegetation to make a dramatic rebound (personal communication, Greg Gustina, BLM).

The lower Ojo Sarco valley is formed by the intersection of two distinct geologic forms. The north side of the valley is steep and rocky, with granite outcrops visible in many locations. Uplift of the Sangre De Cristo mountains brought this granite to the present surface of the land in the past few million years ("Geologic Thinking, …." Greg Aby). The south side of the valley is characterized by soft sedimentary deposits of sand, silt and clay. This soil formation is generally known as the Santa Fe Formation. It was deposited after the granite uplift described previously, and is recognized in the present day for its highly erodible nature.

At the transition from the upper valley to the lower valley, the Rio Ojo Sarco flows through a narrow section of the valley where the granite is completely exposed and a series of rock step-pools transition the river down several hundred feet in elevation. With bedrock control, this section of the Rio is quite stable and the cascading water makes for a very pretty landscape. In the lower valley there are several locations where a granite "plug" crosses the valley floor. Weathering and erosion of these plugs have created a narrow notch in the valley, and have created bedrock grade control in the system at seemingly regular intervals. These granite plugs appear to create dams for groundwater flow in the valley, holding the phreatic water surface closer to the valley bottom in the areas just upstream of the plugs. The evidence of this phenomenon is not direct; however an increased density of riparian vegetation has been consistently observed in the reaches just above the geologic plugs, suggesting greater access to groundwater in these locations. A secondary effect of the granite plugs is that these flow constrictions tend to trap sediment upstream during flood events and simultaneously release a concentrated flow of water to the downstream reach where the focused hydraulic energy and reduced sediment supply have created unstable and eroding reaches.

There are several tributary drainages that flow into the lower valley. Tributaries on the north side are characterized by steep rocky terrain with limited erosion and rapid hydrologic responses. South side tributaries are characterized by larger watershed areas, flatter gradients than the north side tributaries (although still moderately steep), high sediment loads and a higher threshold for the initiation of runoff. The largest of these south side tributaries is the Canada Del Oso, with a watershed area of approximately 8.0 sq. mi. and an active channel width of approximately 30 ft. Sediment delivery from this particular tributary has the potential to temporarily plug the Rio Ojo Sarco and/or deposit enough sediment in the first reach downstream to cover up all the riparian vegetation and obliterate the channel's morphology/vegetation regime.

Riparian vegetation is limited to the margin areas of the low flow channel, or floodplain areas with better access to groundwater. A mix of narrow leaf and valley cottonwood trees dominate the overstory, with sandbar willow and some alder dominating the understory shrubbery. A mix of grass and forb types can be seen in floodplain areas. A few pockets of emergent wetland type vegetation were observed, although their aerial extent was quite limited. Terrace and upland areas quickly revert to droughty vegetation types, with sagebrush and bunch grass species dominant.



PROJECT LOCATION

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RIO OJO SARCO RESTORATION	
FIGURE No. 1	
LOCATION MAP	
NTS	7/10/08

Hydrologic Conditions

The Rio Ojo Sarco watershed is a naturally ephemeral system, with a trans-basin diversion ditch (Acequia Ojo Sarco) from the Rio Trampas providing a near perennial flow of 2-5 cfs. Natural flows in this 21 sq. mi. watershed include a small annual flow from snowmelt, estimated to peak in the range of 20-50 cfs. Periodic flood flows from convective type thunderstorms have the potential to create large flow rates. Table 1 shows calculated peak discharge rates for this watershed for a range of frequency events, based on USGS regression equations for the North Central Mountain Region of New Mexico. Stream gage data or other direct measurements of discharge for the Rio Ojo Sarco were not available.

Return Frequency (yrs)	Estimated Peak Discharge (cfs)
2	157
5	358
10	568
25	894
50	1240
100	1630

Table 1 – Estimated Peak Flows in the Rio Ojo Sarco
(based on USGS regional regression equations)

The near-perennial base flow seen the Rio Ojo Sarco is largely irrigation return flows from the upper Ojo Sarco Valley. Some time in the 1830's residents of the village of Trampas constructed a long diversion canal to bring water from the Rio Trampas into the Ojo Sarco watershed, thereby allowing for irrigation of suitable lands in the Ojo Sarco Valley. Current operation of this diversion structure allows for a near continuous flow into the Ojo Sarco Valley. Excess irrigation water and return flow water continue down the valley through the BLM tract of land, joining the Rio Embudo near the settlement of Canoncito. Interruptions in this irrigation water supply may occur when the diversion ditch needs maintenance, when the ditch ices over in winter or becomes temporarily incapacitated for other reasons. It is possible that water rights allocations could decrease or stop the diversion of water into the Rio Ojo Sarco, although the water rights in the Ojo Sarco Valley must be some of the most senior in the Rio Trampas watershed. These senior water rights would seem to guarantee a steady supply of return flow water to the BLM reach of the Rio Ojo Sarco. However, the BLM may wish to consider filing for a water right to this return flow, as any aquatic habitat restoration effort will depend on a reliable supply of water.

River Morphology, Hydraulics and Sediment Movement

Channel form and stability vary considerably in the Rio Ojo Sarco as it crosses the BLM land. There is evidence of periodic sediment pulses form the south side tributaries, depositing

large quantities of sediment into the Rio and temporarily altering the channel form. The granite "plugs" which cross the valley tend to trap sediment upstream, and tend to encourage scour and channel instability downstream. Historically the overall form of this channel was probably similar to other ephemeral drainages in a semi-arid environment: limited vegetation provides a limited influence on channel form and large flow events can re-arrange the active channel's location, width and depth. More recently, the steady supply of base flow water from irrigation in the upper valley has helped establish a strong riparian community in discrete locations. This base flow is not large enough to actively shape the channel or move all bed sediments on a regular basis. The resulting channel form is characterized by a low flow channel with a capacity of approximately 5 cfs, a small floodplain bench adjoining the channel, and then a higher floodplain at an elevation consistent with a "bankfull" morphology. Bankfull flow events in this ephemeral system are likely to occur with rainfall events in the 3-5 year return frequency occurrence.

The location of granite "plugs" and south side tributary sediment inputs combine to create a series of stream reaches with recurring patterns of behavior. The Rio Ojo Sarco on BLM land has been divided into 9 separate reaches, according to channel form, sediment deposits, vegetation type and density. Locations of these reaches are shown on the overall site map, Figure 2. Field topographic survey data was used to establish a centerline of existing channel, with reference Stationing established from upstream to downstream. The characteristics of each reach are described below. Supporting geomorphic data for the alluvial reaches are included in Appendix B.

The hydrologic regime in the Rio Ojo Sarco creates a bi-modal channel evolution scenario. On the one hand, the steady but small flow of irrigation return water creates a healthy riparian community along the sides of what would usually be considered a "spring fed" river system. The flow rates associated with this regime are insufficient to have a dramatic channel forming effect, although the persistent low flow can (and does) move sand size particles through the system slowly over time. On the other hand we have occasional flood flows from several tributary ephemeral watersheds, the largest of which is nearly 8 sq. mi. in size. These flows are infrequent in occurrence, but can (and do) have an impact on channel form in the Rio through erosion or deposition. These flow events are characteristic of arroyo behavior in a semi arid environment. Near the outlets from the south side tributary drainages, sediment deposits and channel instability are observed.

CURRENT CONDITIONS

Reach 0 – This Reach is the transition from the upper valley to the lower valley. The Rio flows over weathered granite in a steep, narrow canyon. Channel morphology is a step-pool system with a bedrock substrate, which would classify as an A1 channel in the Rosgen classification system. The channel is stable and supports pockets of healthy riparian vegetation. The step-pool system creates man small waterfalls which could limit the upstream migration of certain aquatic species.

Reach 1 – This Reach is the transition from the rock cascade to the lower valley. In this Reach the valley has a bedrock substrate but also has the influence of large-but-infrequent sediment pulses from Canada Del Oso. Sand size sediments from this tributary deposit in the main Rio Ojo Sarco channel, blocking the flow at times and disrupting the evolved channel form. A few pockets of wetland plants are observed, however the episodic sediment flows from the Canada Del Oso tend to alter the landscape on a frequent basis.

Reach 2 – This Reach has had only temporary stability in the past, because of episodic sediment loading from Canada Del Oso and from the destabilizing effects of recreational vehicle traffic. There is evidence of recent channel avulsion and relocation, where an abandoned channel can be seen meandering through a good stand of riparian vegetation on the south side of the valley floor. The current channel location has little riparian vegetation at the margins and is incised into an older sediment deposit. Steep eroding banks, no active floodplain for the low flow channel, and sagebrush vegetation on the bankfull bench/terrace are indicative of recent channel relocation. It is believed that sediment loads deposited in the channel have resulted in the low flow channel relocating itself. This section of the Rio classifies as a B4 channel, due to the relative steepness and low sinuosity. With more water in the system a braided channel morphology might be observed (D4 channel) since the cyclical deposition of sediment prevents the channel form from getting fully established.

Reach 3 – This Reach has a stable form of the low flow channel and a well vegetated floodplain. The riparian vegetation is mature and there are no signs of active channel erosion or meander migration. It is believed that sediment pulses from Canada Del Oso dissipate somewhat before they get to this location. The dense riparian vegetation tends to slow down flood flows and cause sediments to deposit amongst the vegetation. Whichever the dominant influence is, only a limited quantity of sediment is transported through this Reach. A granite "plug" exists at the downstream end of this Reach, and it is believed that this geologic control raises the level of groundwater. The dramatic increase in riparian vegetation in this Reach, as opposed to the upstream Reach, strongly suggests better access to groundwater. The stability afforded by the vegetation allows for the channel to sustain a single thread form, resulting in a C4 claasification.

Reach 4 – This Reach is essentially a narrow channel eroded through one of the granite "plugs", with exposed bedrock in the channel bed and sides. The valley width constructs dramatically to a narrow notch through the rock. At the downstream end of this reach the low flow channel has a step-pool form as it transitions off of the granite formation. County Road 69 passes through the same narrow notch in the valley as the Rio does, further constricting the available flow width.

Reach 5 – This Reach is unstable and has ongoing bed and bank erosion. The causes of this instability are thought to be a combination of reduced sediment supply and concentrated hydraulic discharge from the Reach above. The present channel form is braided and subject to constant change in the location of the low flow channel. Little riparian vegetation exists to help with stability. It is believed that the underlying bedrock drops well below the channel bed in this Reach, so the vegetation has poor access to groundwater. The characteristics of this Reach lead to a nominal B4 classification, although the instability of the system and frequent relocation of the active low flow channel suggest a D4 system. Rosgen's classification system specifically nots that the classification system cover a continuous spectrum of channel form, and this location

appears to have both B and D characteristics. Similar to Reach 8, the available shear stress in the 2-yr flow event (1.9 lbs/sq ft) far exceeds the threshold necessary for movement of all of the sediment sizes observed in the channel bed.

Reach 6 – In this Reach the riparian vegetation density increases noticeably, and it is inferred that the downstream geologic plug helps to raise the groundwater level upstream. A narrow low flow channel is observed, with a small but active floodplain parallel to the channel. Flows from the 2-5 year events (roughly "bankfull") are contained on this floodplain form in most locations. There are a couple of places where bedrock is visible in the channel bottom, particularly as one gets further downstream in the Reach. However, this bedrock does not control the channel meander patter, width and depth to the same extent as the riparian vegetation influences these characteristics. Mild incision of the channel within the alluvial floodplain leads to an "E" channel classification within the exact classification guidelines, in part because the low flow channel tends to be quite narrow. However the waterway used by a 2-5 yr return frequency flow is considerably wider, leading to a low sinuosity C channel form.

Reach 7 – This Reach is similar to Reach 4, in that the channel is essentially an eroded notch through the granite "plug" form that crosses the valley.

Reach 8 – Reach 8 has characteristics similar to those seen in Reach 5. The upstream reaches tend to trap sediment and the narrow notch of Reach 7 can act as a "fire hose" when large flow events squeeze through the narrow opening. Reach 8 has a similar lack of vegetation and general instability of the channel form. Downstream on the State and parcel a more vigorous riparian vegetation community is observed, coincident with the next geologic "plug" form across the valley bottom. Similar to Reach 6, this Reach classifies as a low sinuosity C channel form during the 2-5 yr return frequency flow events.

Proposed Improvements

The proposed improvements seek to improve riparian health, improve potential aquatic habitat, and to reduce instability in the river system. The design for these improvements assumes a steady supply of water for the low flow channel, with larger flows occurring less frequently in a manner consistent with an ephemeral drainage. Management of sediment in the system is critical, as is the mitigation of flow concentration caused by the geologic "plugs" that occur in the valley.

In most locations the desired channel form for restoration is a single thread channel with a well vegetated active floodplain. The channel form must be bi-modal because of the hydrologic conditions, with a low flow channel sized for irrigation return flow and a semi-active channel hiding beneath the riparian vegetation capable of passing the 2-yr event without spilling out on to the next floodplain level (low terrace). Target channel cross section characteristics are shown in Exhibit A.

REACH-BY-REACH RECOMMENDATIONS

Reach 0 – This reach is stable in its current condition. The step-pool morphology in bedrock provides for good aeration. Pockets of riparian vegetation and small wetland plant communities provide good bio-diversity. No intervention is proposed at this time for this reach.

Reach 1 – This reach is where the episodic pulse of sediment from the Canada del Oso flow into the Rio Ojo Sarco. To deal with this problem a sediment trapping dam is proposed, which should limit the volume of sediment from Canada Del Oso that can influence the main stem of the Rio Ojo Sarco. The proposed dam would be constructed with large boulders, to an approximate height of 6-8 ft above the bedrock channel invert. A notched center would direct low flows, while higher sides to the dam would help trap the bigger volumes associated with less frequent events. Sediment trapped behind the dam would provide a porous media for increased water storage. While the details of the dam must still be worked out, the concept plan is for the embankment to have an impervious upstream liner and a low flow under-drain system that would keep water flowing in the downstream reach even if the upstream diversion was shut down for a few days. The downstream face of the dam would be a series of wide boulder steps, to dissipate energy in an overtopping event and to provide stability for the dam. The intent is to improve water storage in the system, and at the same time limit sediment inflows from disrupting the system.

Reach 2 – This reach will become much more stable with some control over sediment inputs from Canada Del Oso. The proposed restoration in this reach includes putting the low flow water back into an abandoned channel where the riparian vegetation is moderately well developed. Supplemental riparian transplants are proposed to achieve improved channel stability and to allow for selective introduction of desirable riparian species. The overall channel slope and sinuosity will not change significantly from current conditions. To prevent an unintended channel relocation back to the north side of the valley bottom, several low berms are proposed which will push flood flows over to the south side of the valley where the re-established channel is located. These low berms are intended to control channel location periodically, but will allow for channel meander migration to occur within the developed riparian vegetation corridor. A series of small grade control structures are also planned to help prevent downcutting that may occur while the channel bed materials are sorted out. These “low rock weirs” will create small scour pools at their outlets which should improve bed form diversity and holding places for certain aquatic species.

Reach 3 – This reach is quite stable and should be maintained intact in-so-far as possible. A series of small grade control structures is proposed, to ensure that channel downcutting does not occur and compromise the hydrologic conditions that enable this riparian community. Project construction specifications may need to limit the type and size of construction machinery that is allowed to work in this Reach.

Reach 4 – The proposed work in this Reach is limited to a rock or masonry wall to support the County Road. The proposed wall is intended to prevent erosion of the embankment fill in a flood event. Presently, there is little structure in this fill to prevent erosion. It is believed that an erosion event would quickly transport a slug of sediment into the downstream Reach, with a

resulting destabilizing effect. Restoration efforts downstream will be improved when sediment supply and water flow hydraulics can be controlled.

Reach 5 – The proposed improvements for this Reach include full restoration of a stable low flow channel, low flow floodplain and a "bankfull" floodplain. The reconstructed channel will have a sinuosity consistent with the overall channel slope. To encourage the development of a meandering channel pattern, and to slow larger flood flow events, a series of low berms are proposed that would project out from the sides of the valley bottom in an alternating pattern. This would establish minimum requirements for meander development as the channel evolves through time, but allows for channel "self adjustment" between the low berms. Riparian transplants will be installed in a fairly dense planting pattern along the low flow channel margins. The plan shows a series of low rock weirs with adjoining rock sills across the low flow floodplain. These features are intended to prevent flood flows from relocating the low flow channel away from the low rock weirs. The low rock weirs are essentially a notch in the low flow floodplain. An important feature in Reach 5 is the hydraulic transition structure at the upstream end, where the concentrated discharge from Reach 4 will be slowed and then released downstream in controlled manner.

Reach 6 – This Reach exhibits a return to stability and a mature riparian plant community. Proposed improvements are limited to a few low rock weirs for grade control, and supplemental riparian plantings where needed. As with Reach 3, the project specifications may need to limit the size of construction machinery allowed to work in this reach so as to protect the vegetation resources in-so-far as possible.

Reach 7 – This reach is primarily a notch through the rock "plug", so no improvements are proposed at this time.

Reach 8 – Proposed improvements for Reach 8 are similar to those proposed for Reach 5. Restoration of suitable aquatic habitat will require achieving a stable channel form with a healthy riparian plant community. Low berms extending partway across the valley bottom will force the Rio to adopt a mildly sinuous pattern, and intensive riparian transplant density will bring stability to the floodplain and low flow channel margins within a few years. Low rock weirs ensure grade control in the channel bottom, which will keep the local water table as high as possible.

Conclusions

The proposed improvements seek to improve riparian health, improve potential aquatic habitat, and to reduce instability in the river system. The design for these improvements assumes a steady supply of water for the low flow channel. Increased density of riparian vegetation in Reaches 3, 5 and 8 will improve channel stability and improve groundwater storage in the system as a whole. In particular, the sediment trapping dam proposed for Reach 1 may increase subsurface water storage dramatically. The fine grained sizes of sediment in the Rio Ojo Sarco will tend to fill pool features during long periods of low flow, and will be scoured out of pool areas during higher flow events. This means that some bed-form diversity will be achieved, but not to the extent that might be achieved in a cobble bed restoration project. Low berms and low

rock weirs will help achieve vertical and lateral stability in the system, while still allowing for some channel adjustment to occur. The design recognizes that the berms are vulnerable to erosion in a large flow event. However, after the riparian vegetation is established to a reasonable density, the berms can be damaged without compromising the integrity of the whole system. This riparian vegetation is perhaps the most crucial element for long term success, as shade is necessary for a healthy aquatic system and the organic leaf litter provides an important element in the food supply for the aquatic ecosystem.

The design presented in this preliminary report focuses on what we believe will be a self-sustaining channel form (after full establishment of the riparian plant community). This channel form does not include deep pools, because the predominance of fine grain sediment in the system will lead to progressive filling of deep slow water features. Depending on the habitat goals of BLM Biologists, some deeper water features might be considered in an "off channel" location. The best location from a channel stability and hydrologic perspective would be in Reaches 5 and 8, where the low flow channel could be abruptly diverted through a pool area, and where the 2-yr capacity channel would be available to carry flood flows down valley. Underlying bedrock may prevent the excavation of pool forms, and some exploratory test pits may be needed to establish viable locations for deeper water features. But the off-channel pool system would allow for the creation of deeper water less susceptible to filling with sediment during over-bank flood events. Pool chemistry adjustments and supplemental aeration may be needed to achieve the desired habitat conditions. Features such as off-channel pools will only reinforce the need for the BLM to establish some rights to the water flowing through the site, even if those rights are junior to the irrigators in the valley above.

APPENDIX A

HYDROLOGIC AND SEDIMENT DATA, SITE PHOTOS

National Flood Frequency Program
Version 3.0
Based on Water-Resources Investigations Report 02-4168
Equations from database C:\Program Files\NFF\NFFv3.2_2004-12-14.mdb
Updated by kries 9/22/2004 at 4:03:24 PM fixed decimal place in constant
Equations for New_Mexico developed using English units

Site: Ojo Sarco, New_Mexico
User: Chris Philips
Date: Monday, July 14, 2008 02:22 PM

Rural Estimate: Rural 3
   Basin Drainage Area: 21 mi2
   1 Region
   Region: Northern_Mountain_Region_5
      Drainage_Area = 21 mi2
      Mean_Basin_Elevation = 7810 ft
      24-hr_25-yr_Max_Precipitation_Intensity = 3 in
   Crippen & Bue Region 13

Flood Peak Discharges, in cubic feet per second

Estimate	Recurrence Interval, yrs	Peak, cfs	Standard Error, %	Equivalent Years
Rural 3	2	157	92	
	5	358	82	
	10	568	78	
	25	894	75	
	50	1240	78	
	100	1630	82	
	500	2900	92	
	maximum: 44700 (for C&B region 13)			

BAR SAMPLE - SIZE DISTRIBUTION ANALYSIS

Sieve Sample Worksheet

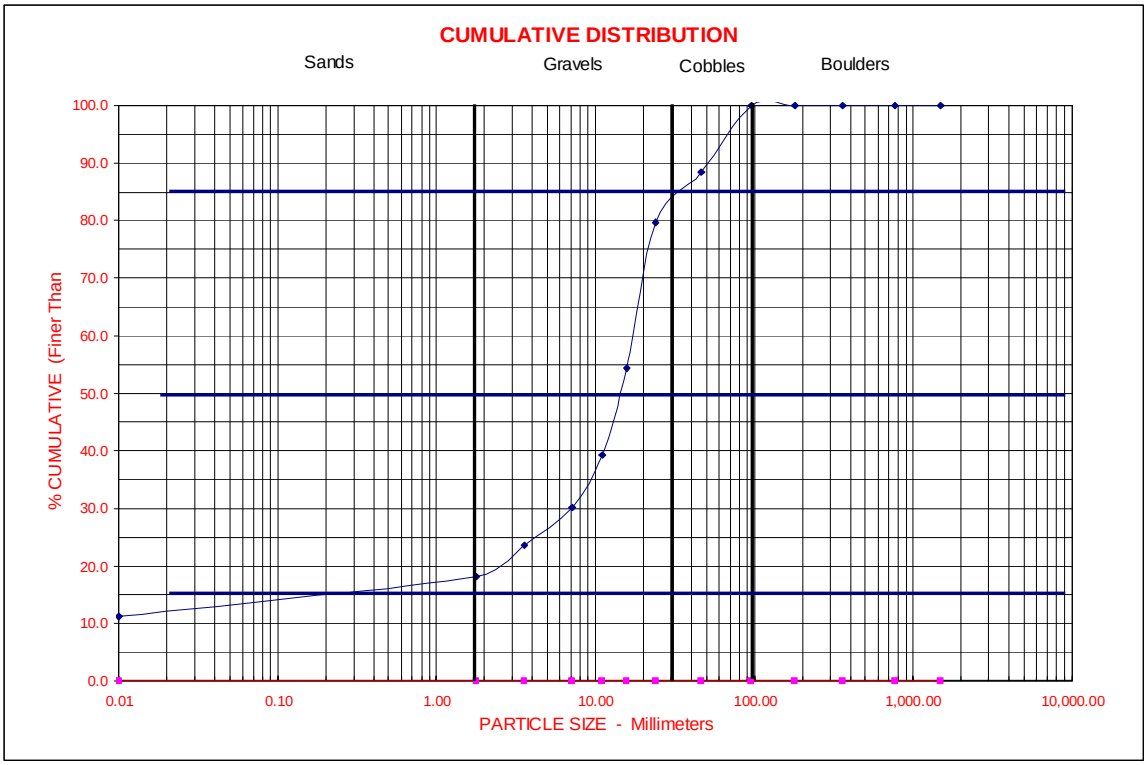
Stream Name: OJO SARCO Date: 6.7.08

Description & Location of Bar: REACH 6 STA 46+00

D15:		mm
D50:	13	mm
D85:		mm
D100:	330	mm

1 200mm

Passing Sieve Series	Median (mm)	Range (mm)	Total wt.(T) (gm)		Pan wt.(P) (gm)		DRY SAMPLE (lbs) T-P (* A if wet)	Dry Wt. Bar Material Data ITEM %	% CUM		Adjustment if sample is wet (A)		WET SAMPLE (lbs) T-P (* A if wet)	Dry Wt. Bar Material Data ITEM %	% CUM
-35	0.01	<1.2	3330	-	**165**	=	3165.00	11.2	11.2	x	0.74	=	2342.10	#REF!	#REF!
35	1.78	1.2 - 2.36	2170.00	-	**165**	=	2005.00	7.1	18.2	x	0.76	=	1523.80	#REF!	#REF!
18	3.55	2.36 - 4.75	1660.00	-	**165**	=	1495.00	5.3	23.5	x	0.78	=	1166.10	#REF!	#REF!
10	7.13	4.75 - 9.52	2022.00	-	**165**	=	1857.00	6.6	30.1	x	0.82	=	1522.74	#REF!	#REF!
5	11.10	9.52 - 12.7	2784.00	-	**165**	=	2619.00	9.2	39.3	x	0.89	=	2330.91	#REF!	#REF!
5/16 in.	15.80	12.7 - 19.0	4422.00	-	**165**	=	4257.00	15.0	54.3	x	0.89	=	3788.73	#REF!	#REF!
5/8 in.	23.80	19.0 - 28.6	7345.00	-	**165**	=	7180.00	25.3	79.7	x	0.89	=	6390.20	#REF!	#REF!
1 1/2 in.	46.30	28.6 - 64	2634.00	-	**165**	=	2469.00	8.7	88.4	x	0.97	=	2394.93	#REF!	#REF!
2 1/2 in	96.00	64 - 128	3446.00	-	**165**	=	3281.00	11.6	100.0	x	no adj	=	#REF!	#REF!	#REF!
Measured	180.00	128 - 256			**NA**	=	0.25	0.0	100.0	x	no adj	=	0.00	#REF!	#REF!
Measured	362.00	256 - 512			**NA**	=	0.25	0.0	100.0	x	no adj	=	0.00	#REF!	#REF!
Measured	768.00	512 - 1024			**NA**	=	2.00	0.0	100.0	x	no adj	=	0.00	#REF!	#REF!
Measured	1500.00	1024 - 2048			**NA**	=	1.00	0.0	100.0	x	no adj	=	0.00	#REF!	#REF!
							28331.5	100.0			TOTALS		#REF!	#REF!	


CUMULATIVE DISTRIBUTION
Sands
Gravels
Cobbles
Boulders
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
% CUMULATIVE (Finer Than
0.01
0.10
1.00
10.00
100.00
1,000.00
10,000.00
PARTICLE SIZE - Millimeters

Rio Ojo Sarco, Reach 0, looking upstream. April, 2008.

Rio Ojo Sarco, Reach 1, looking downstream. April, 2008.

Rio Ojo Sarco, Reach 2, looking downstream. April, 2008.

Rio Ojo Sarco, Reach 3, looking upstream. April, 2008.

Rio Ojo Sarco, Reach 4, looking upstream. April, 2008.

Rio Ojo Sarco, Reach 5, looking upstream. April, 2008.

Rio Ojo Sarco, Reach 8, looking upstream. April, 2008.

Rio Ojo Sarco, State Land below Reach 8, looking downstream. April, 2008.

APPENDIX B

REACH CLASSIFICATION DATA

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Ojo Sarco
Reach Name: Reach2 <-- This is not a Reference Reach
Drainage Area: 0 sq mi
State:
County:
Latitude: 0
Longitude: 0
Survey Date: 07/14/08

Classification Data

Valley Type:		
Valley Slope:	0	ft/ft
Number of Channels:	Single	
Width:	62.16	ft
Mean Depth:	0.53	ft
Flood-Prone Width:	97.86	ft
Channel Materials D50:	13	mm
Water Surface Slope:	0.0281	ft/ft
Sinuosity:	1.03	
Discharge:	157	cfs
Velocity:	70.09	fps
Cross Sectional Area:	32.83	sq ft
Entrenchment Ratio:	1.57	
Width to Depth Ratio:	117.28	
Rosgen Stream Classification:	B 4	

RIVERMORPH CROSS SECTION SUMMARY

River Name: Ojo Sarco
Reach Name: Reach2
Cross Section Name: Sta 1300
Survey Date: 07/13/08

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
-100	0	3.1	
-65.4	0	0.3	
-28.2	0	1.1	
-19.7	0	1.4	
-15.6	0	0.9	
-9.9	0	1.1	
-3.8	0	0.7	
-0.7	0	0.4	
0	0	0.2	
0.8	0	0.4	
3.1	0	0.7	
8.9	0	1.1	
16.4	0	1.6	

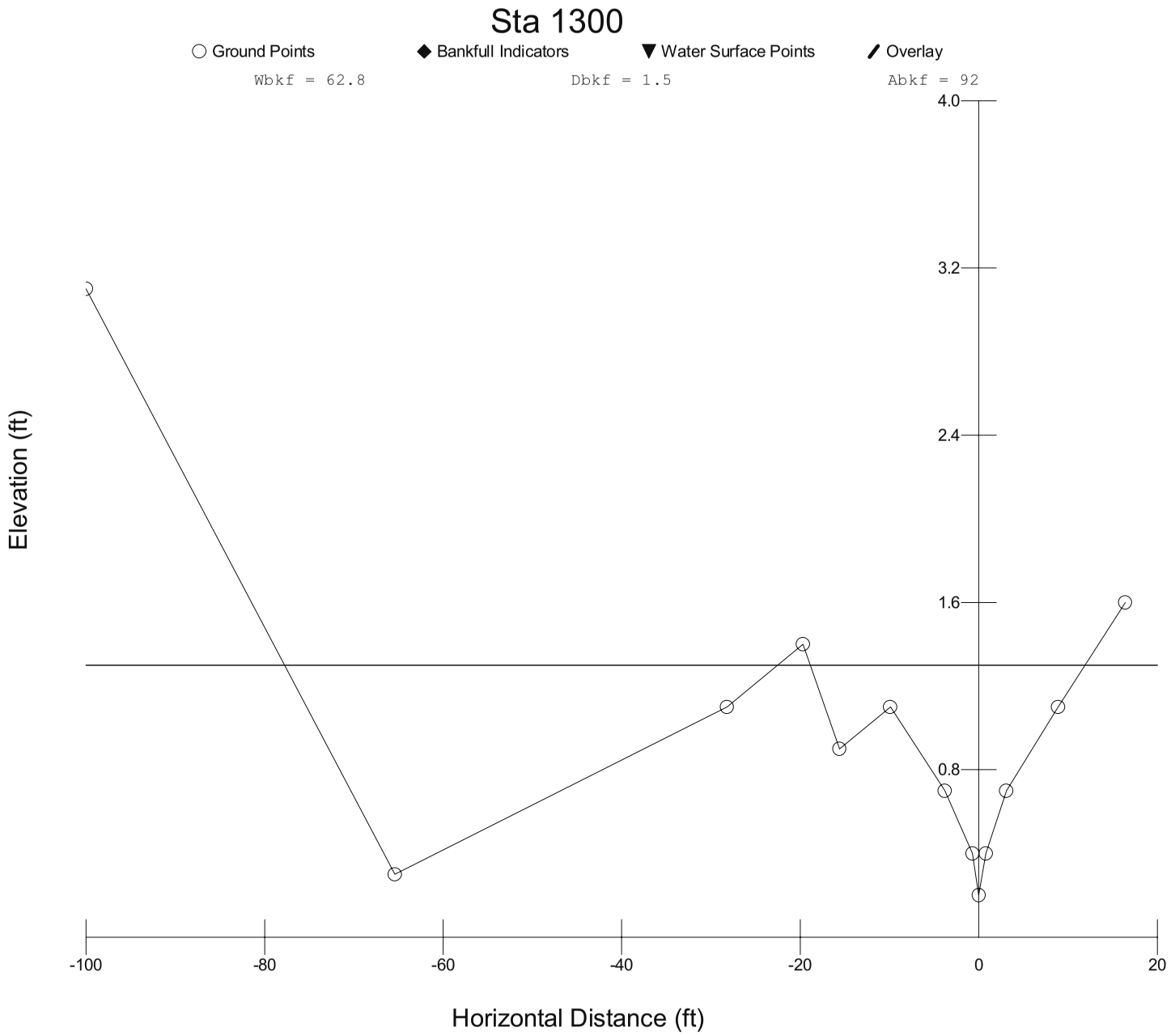
Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	2.4	2.4	2.4
Bankfull Elevation (ft)	1.3	1.3	1.3
Floodprone Width (ft)	62.8	-----	-----
Bankfull Width (ft)	62.8	31.4	31.4
Entrenchment Ratio	1	-----	-----
Mean Depth (ft)	1.46	1.46	1.46
Maximum Depth (ft)	1.1	3.46	3.46
Width/Depth Ratio	43.01	21.51	21.51
Bankfull Area (sq ft)	91.99	91.99	91.99
Wetted Perimeter (ft)	66.69	66.69	66.69
Hydraulic Radius (ft)	1.38	1.38	1.38
Begin BKF Station	25.6	25.6	25.6
End BKF Station	88.4	88.4	88.4

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.0281	0.0281	0.0281
Shear Stress (lb/sq ft)	2.42	2.42	2.42
Movable Particle (mm)	291.2	291.2	291.2


Sta 1300
Ground Points
Bankfull Indicators
Water Surface Points
Overlay
Wbkf = 62.8
Dbkf = 1.5
Abkf = 92
4.0
3.2
2.4
1.6
0.8
Elevation (ft)
-100
-80
-60
-40
-20
0
20
Horizontal Distance (ft)

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Ojo Sarco
Reach Name: Reach 3 <-- This is not a Reference Reach
Drainage Area: 21 sq mi
State:
County:
Latitude: 0
Longitude: 0
Survey Date: 07/13/08

Classification Data

Valley Type:		
Valley Slope:	0	ft/ft
Number of Channels:	Single	
Width:	18.04	ft
Mean Depth:	1.13	ft
Flood-Prone Width:	50.23	ft
Channel Materials D50:	13	mm
Water Surface Slope:	0.0285	ft/ft
Sinuosity:	1.08	
Discharge:	157	cfs
Velocity:	7.68	fps
Cross Sectional Area:	20.43	sq ft
Entrenchment Ratio:	2.78	
Width to Depth Ratio:	15.96	
Rosgen Stream Classification:	C 4b	

RIVERMORPH CROSS SECTION SUMMARY

River Name: Ojo Sarco
Reach Name: Reach 3
Cross Section Name: Sta 1700
Survey Date: 07/13/08

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
-100	0	25.6	
-22	0	3.2	
-21.2	0	3	
-6.3	0	2.2	
-5.9	0	2.2	
-1.8	0	0.4	
-1.6	0	0.3	
0	0	0	
1.9	0	0.2	
1.9	0	0.3	
3.1	0	0.4	
22.9	0	4	
29.3	0	4.6	
62.8	0	6	

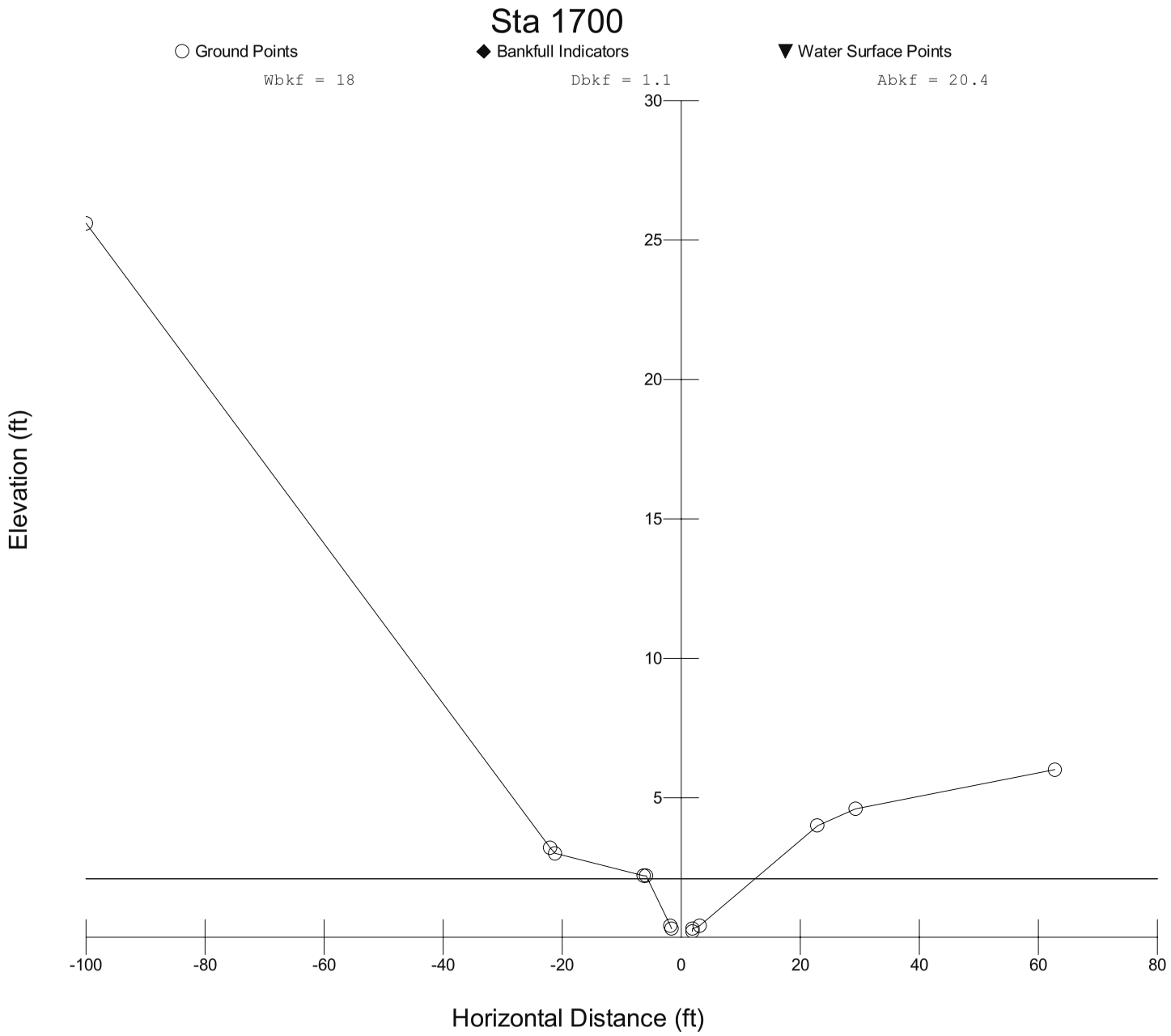
Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	4.18	4.18	4.18
Bankfull Elevation (ft)	2.09	2.09	2.09
Floodprone Width (ft)	50.23	-----	-----
Bankfull Width (ft)	18.04	6.36	11.68
Entrenchment Ratio	2.78	-----	-----
Mean Depth (ft)	1.13	1.28	1.05
Maximum Depth (ft)	2.09	2.09	2.02
Width/Depth Ratio	15.96	4.97	11.12
Bankfull Area (sq ft)	20.43	8.16	12.27
Wetted Perimeter (ft)	18.72	8.78	13.96
Hydraulic Radius (ft)	1.09	0.93	0.88
Begin BKF Station	-5.65	-5.65	0.71
End BKF Station	12.39	0.71	12.39

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.0285	0.0285	0.0285
Shear Stress (lb/sq ft)	1.94	1.65	1.56
Movable Particle (mm)	247.4	220.1	211.3


Sta 1700
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 18
Dbkf = 1.1
Abkf = 20.4
Elevation (ft)
30
25
20
15
10
5
-100
-80
-60
-40
-20
0
20
40
60
80
Horizontal Distance (ft)

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Ojo Sarco
Reach Name: Reach 5 <-- This is not a Reference Reach
Drainage Area: 21 sq mi
State:
County:
Latitude: 0
Longitude: 0
Survey Date: 07/13/08

Classification Data

Valley Type:		
Valley Slope:	0.0412	ft/ft
Number of Channels:	Single	
Width:	22.02	ft
Mean Depth:	0.76	ft
Flood-Prone Width:	34.98	ft
Channel Materials D50:	13	mm
Water Surface Slope:	0.038	ft/ft
Sinuosity:	1.03	
Discharge:	157	cfs
Velocity:	9.33	fps
Cross Sectional Area:	16.82	sq ft
Entrenchment Ratio:	1.59	
Width to Depth Ratio:	28.97	
Rosgen Stream Classification:	B 4	

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Ojo Sarco
Reach Name: Reach 5 <-- This is not a Reference Reach
Drainage Area: 21 sq mi
State:
County:
Latitude: 0
Longitude: 0
Survey Date: 07/13/08

Classification Data

Valley Type:		
Valley Slope:	0.0412	ft/ft
Number of Channels:	Single	
Width:	22.02	ft
Mean Depth:	0.76	ft
Flood-Prone Width:	34.98	ft
Channel Materials D50:	13	mm
Water Surface Slope:	0.038	ft/ft
Sinuosity:	1.03	
Discharge:	157	cfs
Velocity:	9.33	fps
Cross Sectional Area:	16.82	sq ft
Entrenchment Ratio:	1.59	
Width to Depth Ratio:	28.97	
Rosgen Stream Classification:	B 4	

RIVERMORPH CROSS SECTION SUMMARY

River Name: Ojo Sarco
Reach Name: Reach 5
Cross Section Name: Sta 3600
Survey Date: 07/13/08

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
-100	0	10.7	
-97.9	0	10.7	
-84.7	0	10.8	
-65.2	0	9.6	
-53.5	0	9.1	
-46.5	0	6.8	
-45.5	0	6.4	
-27.3	0	5.8	
-26.2	0	5.8	
-26.1	0	5.6	
-19.5	0	2.6	
-15.4	0	2.8	
-14.6	0	2.7	
-14.2	0	2.6	
-6	0	1.3	
-3.8	0	1.3	
-3.1	0	1.1	
-1.2	0	0.9	
0	0	0.7	
0.2	0	0.9	
2.1	0	1.2	
4.5	0	1.1	
7.8	0	1.1	
10.5	0	1.6	
13.4	0	3.1	
14.7	0	4.1	
14.7	0	4.1	
17.6	0	4	
30.1	0	12.9	

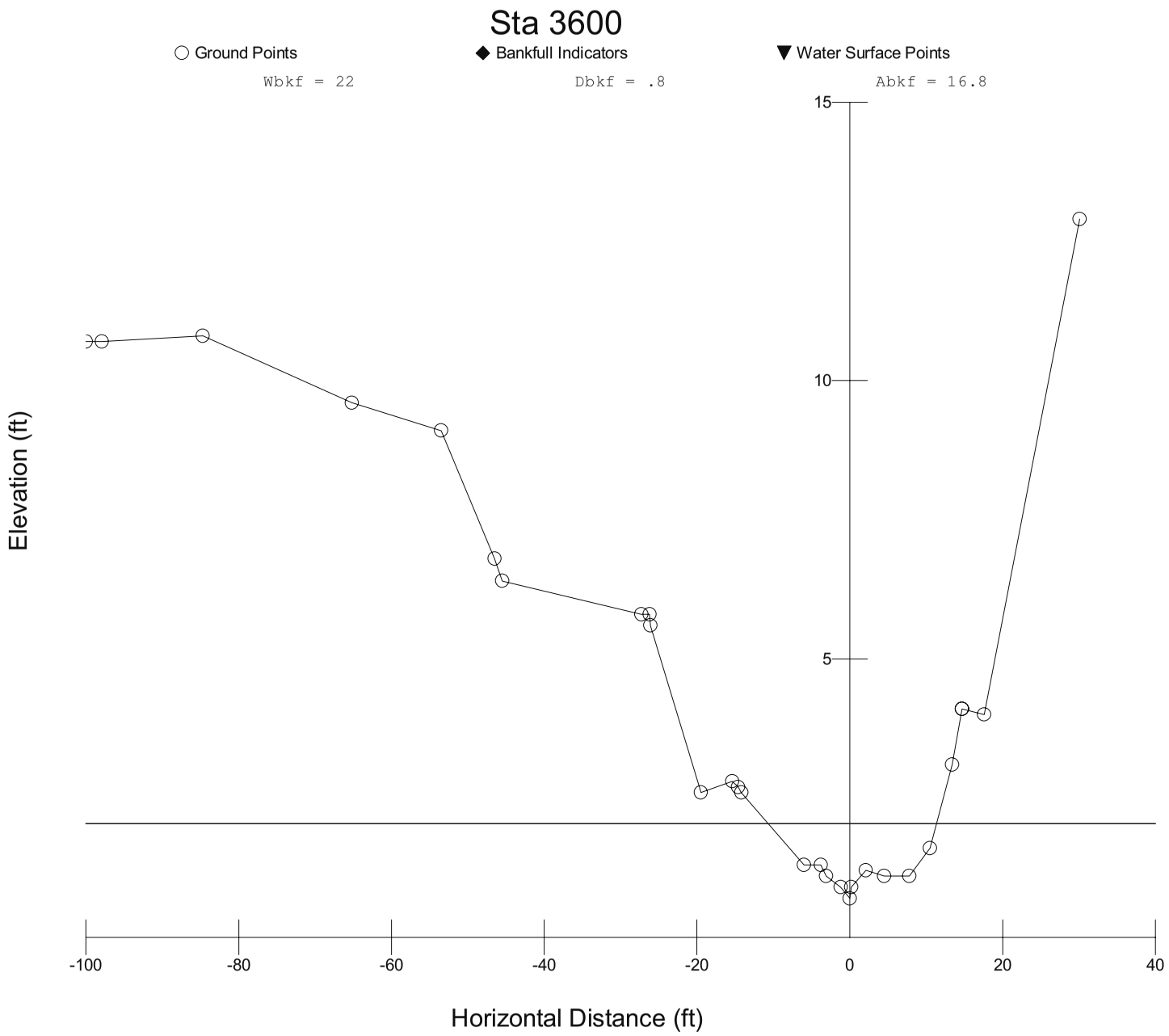
Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	3.38	3.38	3.38
Bankfull Elevation (ft)	2.04	2.04	2.04
Floodprone Width (ft)	34.98	-----	-----
Bankfull Width (ft)	22.02	10.67	11.35
Entrenchment Ratio	1.59	-----	-----
Mean Depth (ft)	0.76	0.69	0.83
Maximum Depth (ft)	1.34	1.34	1.34
Width/Depth Ratio	28.97	15.46	13.67
Bankfull Area (sq ft)	16.82	7.41	9.42
Wetted Perimeter (ft)	22.39	12.12	12.95
Hydraulic Radius (ft)	0.75	0.61	0.73
Begin BKF Station	-10.67	-10.67	0
End BKF Station	11.35	0	11.35

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.04	0.04	0.04
Shear Stress (lb/sq ft)	1.87	1.52	1.82
Movable Particle (mm)	241.1	207.1	236.3


Sta 3600
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 22
Dbkf = .8
Abkf = 16.8
Elevation (ft)
15
10
5
-100
-80
-60
-40
-20
0
20
40
Horizontal Distance (ft)

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Ojo Sarco
Reach Name: Reach 6 <-- This is not a Reference Reach
Drainage Area: 0 sq mi
State:
County:
Latitude: 0
Longitude: 0
Survey Date: 07/13/08

Classification Data

Valley Type:		
Valley Slope:	0	ft/ft
Number of Channels:	Single	
Width:	12.97	ft
Mean Depth:	1.38	ft
Flood-Prone Width:	41.44	ft
Channel Materials D50:	13	mm
Water Surface Slope:	0.0285	ft/ft
Sinuosity:	1.03	
Discharge:	157	cfs
Velocity:	8.76	fps
Cross Sectional Area:	17.93	sq ft
Entrenchment Ratio:	3.2	
Width to Depth Ratio:	9.4	
Rosgen Stream Classification:	E 4b	

RIVERMORPH CROSS SECTION SUMMARY

River Name: Ojo Sarco
Reach Name: Reach 6
Cross Section Name: Sta 4300
Survey Date: 07/13/08

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
-14	0	6.8	
-10.2	0	5.3	
-1.7	0	0.4	
-0.9	0	0.3	
0	0	0.2	
3.7	0	0.3	
3.9	0	0.3	
5.8	0	1	
5.8	0	1	
5.9	0	1.1	
6.1	0	1.2	
10.8	0	3.5	
22.2	0	2.5	
25.7	0	2.8	
27.6	0	2.4	
28	0	2.4	
28.4	0	2.3	
28.4	0	2.3	
29.2	0	2.4	
85.6	0	28.1	
97.3	0	29.2	

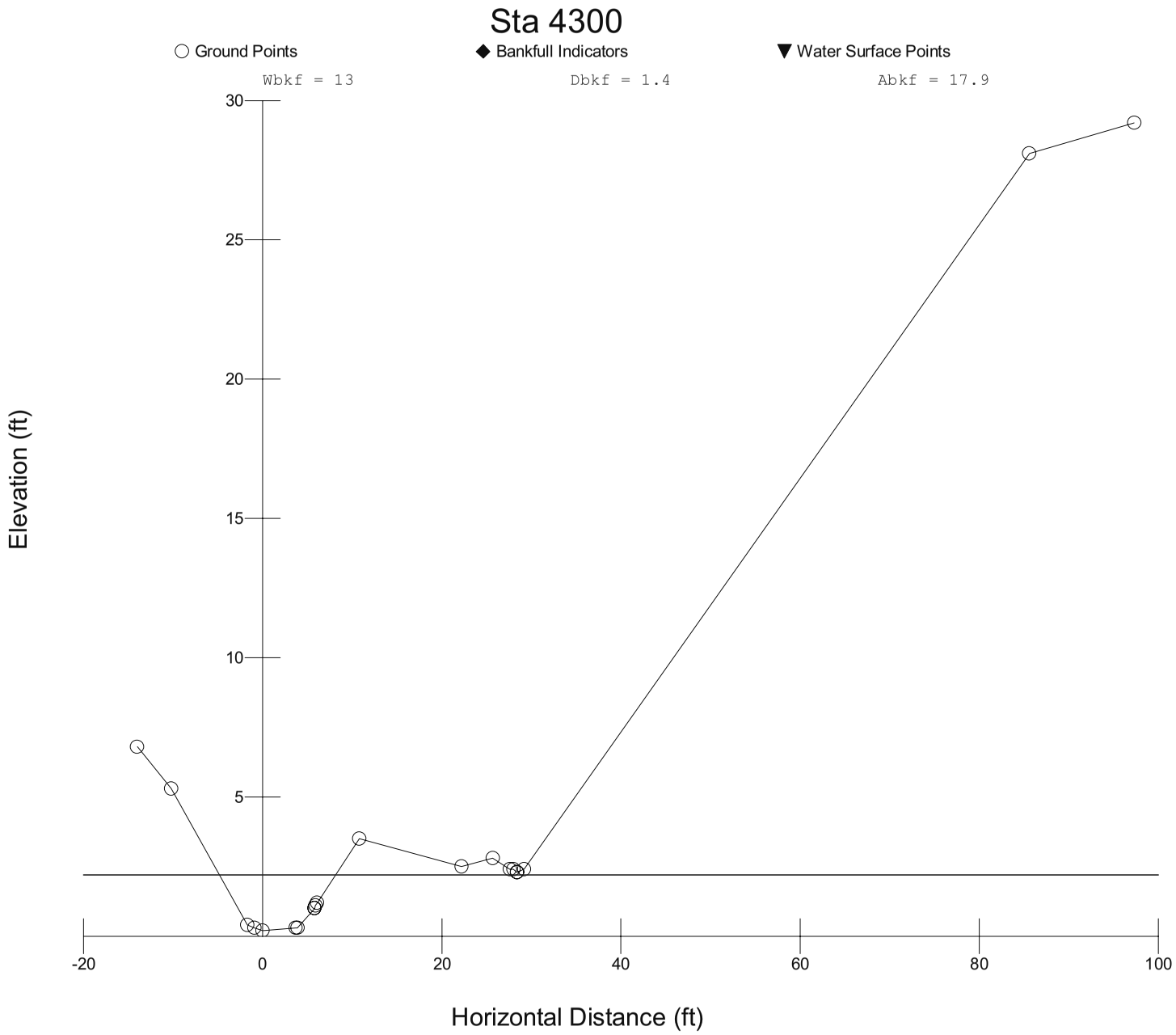
Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	4.2	4.2	-----
Bankfull Elevation (ft)	2.2	2.2	-----
Floodprone Width (ft)	41.44	-----	-----
Bankfull Width (ft)	12.97	83.57	-----
Entrenchment Ratio	3.2	-----	-----
Mean Depth (ft)	1.38	1.38	-----
Maximum Depth (ft)	2	2	-----
Width/Depth Ratio	9.4	60.56	-----
Bankfull Area (sq ft)	17.93	17.93	-----
Wetted Perimeter (ft)	13.88	13.88	-----
Hydraulic Radius (ft)	1.29	1.29	-----
Begin BKF Station	-4.82	-4.82	-----
End BKF Station	8.14	8.14	-----

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.0255	0.0255	0.0255
Shear Stress (lb/sq ft)	2.05	2.05	
Movable Particle (mm)	258.0	258.0	


Sta 4300
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 13
Dbkf = 1.4
Abkf = 17.9
Elevation (ft)
30
25
20
15
10
5
-20
0
20
40
60
80
100
Horizontal Distance (ft)

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Ojo Sarco
Reach Name: Reach 8 <-- This is not a Reference Reach
Drainage Area: 0 sq mi
State:
County:
Latitude: 0
Longitude: 0
Survey Date: 07/14/08

Classification Data

Valley Type:		
Valley Slope:	0	ft/ft
Number of Channels:	Single	
Width:	14.52	ft
Mean Depth:	1.39	ft
Flood-Prone Width:	58.38	ft
Channel Materials D50:	13	mm
Water Surface Slope:	0.0285	ft/ft
Sinuosity:	1.03	
Discharge:	157	cfs
Velocity:	7.78	fps
Cross Sectional Area:	20.17	sq ft
Entrenchment Ratio:	4.02	
Width to Depth Ratio:	10.45	
Rosgen Stream Classification:	E 4b	

RIVERMORPH CROSS SECTION SUMMARY

River Name: Ojo Sarco
Reach Name: Reach 8
Cross Section Name: Sta 6800
Survey Date: 07/13/08

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
-100	0	15.4	
-73	0	7.1	
-70.4	0	6.3	
-59.7	0	4.6	
-16.4	0	4.3	
-9.7	0	4	
-4.4	0	0.9	
-3.4	0	0.9	
-2.1	0	0.6	
-1.6	0	0.5	
0	0	0.3	
1.6	0	0.4	
3.6	0	0.6	
4	0	0.8	
6.5	0	2	
15.5	0	5.4	
18	0	6	
19.5	0	6.6	
24.5	0	5.7	
28.4	0	7.6	
34.5	0	8.1	

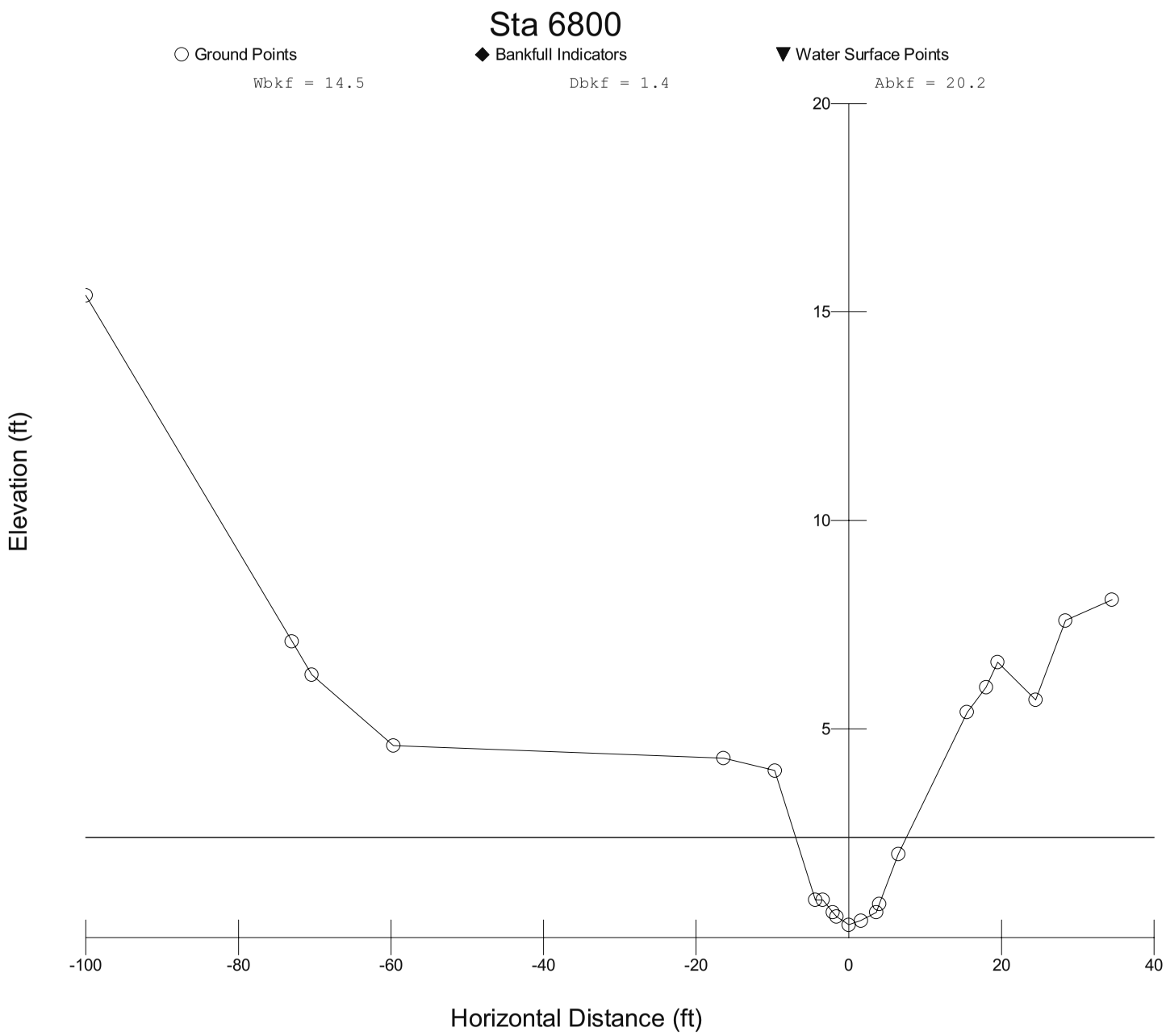
Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	4.5	4.5	4.5
Bankfull Elevation (ft)	2.4	2.4	2.4
Floodprone Width (ft)	58.38	-----	-----
Bankfull Width (ft)	14.52	6.96	7.56
Entrenchment Ratio	4.02	-----	-----
Mean Depth (ft)	1.39	1.39	1.39
Maximum Depth (ft)	2.1	2.1	2.1
Width/Depth Ratio	10.45	5.01	5.44
Bankfull Area (sq ft)	20.17	9.69	10.47
Wetted Perimeter (ft)	15.39	9.53	10.07
Hydraulic Radius (ft)	1.31	1.02	1.04
Begin BKF Station	-6.96	-6.96	0
End BKF Station	7.56	0	7.56

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.0285	0.0285	0.0285
Shear Stress (lb/sq ft)	2.33	1.81	1.85
Movable Particle (mm)	283.2	235.6	239.0


Sta 6800
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 14.5
Dbkf = 1.4
Abkf = 20.2
Elevation (ft)
20
15
10
5
-100
-80
-60
-40
-20
0
20
40
Horizontal Distance (ft)

RIVERMORPH CROSS SECTION SUMMARY

River Name: Ojo Sarco
Reach Name: Reach 8
Cross Section Name: Sta 6400
Survey Date: 07/13/08

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
-71.9	0	8.1	
-70.7	0	7.9	
-69.4	0	7.9	
-58.3	0	3.2	
-56.4	0	2.5	
-46	0	2.2	
-3.3	0	0.4	
-1.5	0	0.2	
-0.8	0	0.2	
0	0	0.1	
2.2	0	0.2	
4.6	0	0.2	
5.5	0	0.7	
5.8	0	0.8	
13.1	0	2.4	
15.2	0	2.7	
17.1	0	2.9	
40.6	0	4.3	
43.5	0	4.4	
52	0	6.2	
60.3	0	9.3	

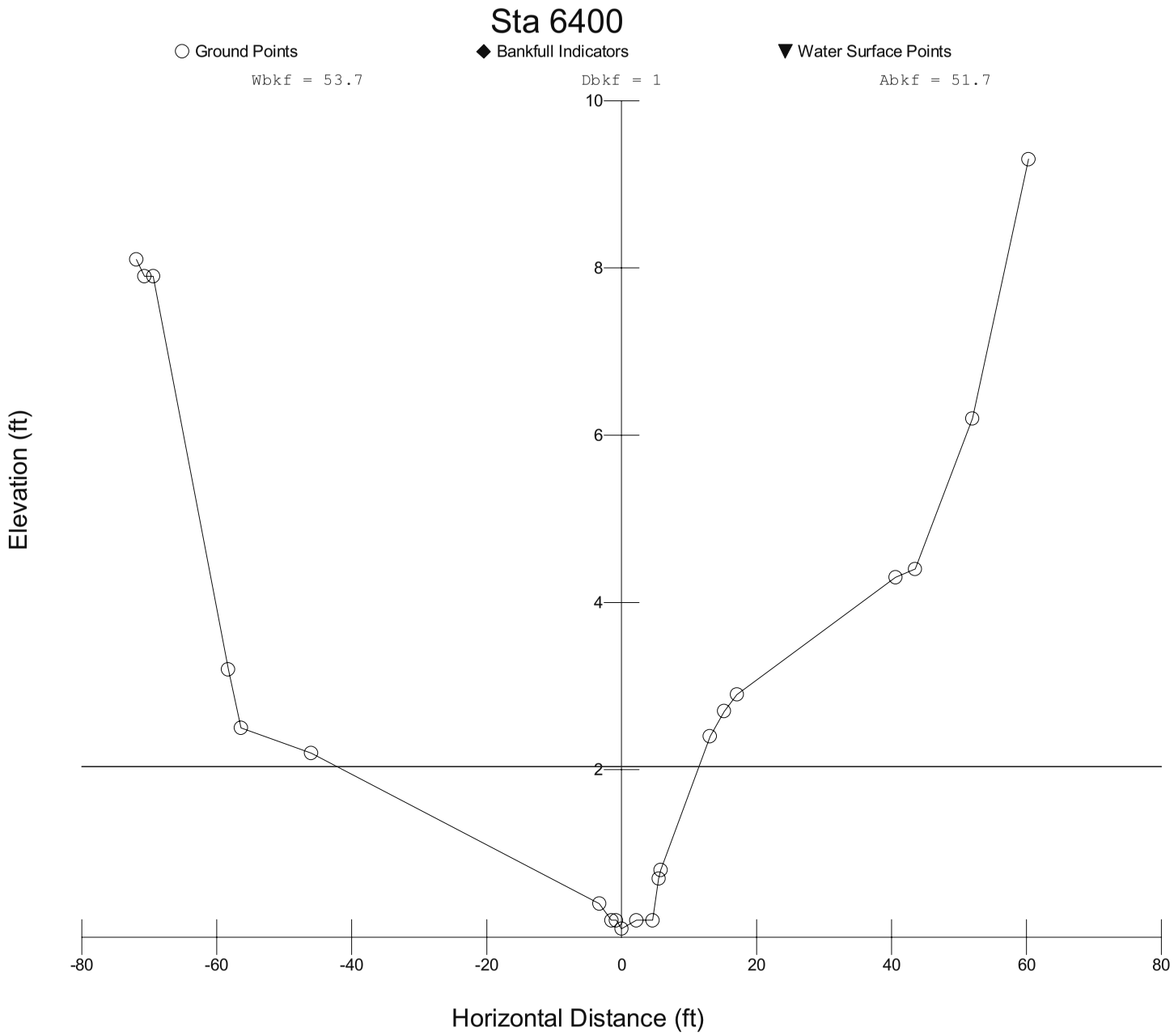
Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	3.98	3.98	3.98
Bankfull Elevation (ft)	2.04	2.04	2.04
Floodprone Width (ft)	95.37	-----	-----
Bankfull Width (ft)	53.66	42.2	11.46
Entrenchment Ratio	1.78	-----	-----
Mean Depth (ft)	0.96	0.9	1.21
Maximum Depth (ft)	1.94	1.94	1.94
Width/Depth Ratio	55.9	46.89	9.47
Bankfull Area (sq ft)	51.73	37.83	13.9
Wetted Perimeter (ft)	54	44.2	13.68
Hydraulic Radius (ft)	0.96	0.86	1.02
Begin BKF Station	-42.2	-42.2	0
End BKF Station	11.46	0	11.46

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0.0289	0.0289	0.0289
Shear Stress (lb/sq ft)	1.73	1.55	1.84
Movable Particle (mm)	227.6	209.9	238.0


Sta 6400
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 53.7
Dbkf = 1
Abkf = 51.7
Elevation (ft)
10
8
6
4
2
-80
-60
-40
-20
0
20
40
60
80
Horizontal Distance (ft)

APPENDIX C

HYDRAULIC MODELING DATA

(NOT INCLUDED IN PDF DOCUMENT)