SECTION E

STREAM CHANNEL CONDITION

INTRODUCTION

This report provides the results of an assessment of the stream channels of the Garcia WAU. The assessment was done in 1997 following the methods described in the Watershed Analysis Manual (Version 4.0, Washington Forest Practices Board). The stream channel analysis is based on field observations, aerial photo interpretation and existing stream channel information from Louisiana-Pacific's Sustained Yield Plan (1997).

The goals of the assessment were to determine the existing channel conditions and identify the sensitivity of the channels to wood and sediment. Stream channels are defined by the transport of water and sediment. A primary structural control of a channel in a forested environment, besides large rock substrate, is from woody debris. Channel morphology and condition therefore reflect the input of sediment, wood and water relative to the ability of the channel to either transport or store these inputs (Sullivan et. al., 1987).

Stream channel conditions represent the strongest link between forest practices and fisheries resources. Changes in channel condition typically reflect changes to fish habitat. Because of this the fish habitat and stream channel assessments were done in the same reaches. The results for the fish habitat parameters are presented in Section F - Fish Habitat Assessment.

METHODS

The methods of the stream channel assessment are designed to identify channel segments which are likely to respond similarly to changes in sediment or wood and group them into distinct geomorphic units. These geomorphic units enable an interpretation of habitat-forming processes dependent on similar geomorphic and channel morphology conditions. The channels are also evaluated for the historical changes and current channel condition to provide baseline information for the monitoring of channel conditions over the long term.

Stream Corridor Delineation

The stream channel network for the Garcia WAU was partitioned into stream segments based on three classes of channel confinement and three classes of channel gradient. These classifications were based on channel classifications prepared from digital terrain data. Channel segments were delineated based on either a change in slope class or change in channel confinement. Channel slope class or confinement information was re-classified based on field observations. The stream segments are shown on Map E-1.

Historic Trend

Historic trends in channel changes are observed from aerial photo interpretation for the main stem of the Garcia River in the WAU. Aerial photo observations were made from 1952, 1966, 1978 and 1996 photos. The width of the Garcia River was observed in the same locations for each of the photographs interpreted. The width was measured by observing the fluvial boundary of recent sediment accumulations, such as bars or terraces.

The tributaries to the Garcia River were not measured due to difficulty in observing the actual channel from aerial photographs. There was little influence from debris flows or torrents observed in the Garcia WAU (see section mass wasting assessment), so the tributaries had few riparian vegetation disturbances to allow a channel width observation from aerial photographs.

Field Measurements and Observations

Selection of field sites for stream channel observations was based on gathering a representative sample of response (0-3% gradient) and transport (3-20% gradient) channels from each hydrologic unit of the WAU. Little attention was focused on the source reaches.

For each channel segment the bankfull width, bankfull depth, valley width, flood plain connectivity and channel slope were taken at several locations along the segment. Stream bed sediment characteristics were measured by pebble counts, observations of gravel bars, channel aggradation or degradation, and particle size of the stream bed material. The segment was further classified by its appropriate morphology type based on Montgomery and Buffington (1993) and Rosgen (1994). Large woody debris (LWD) in channel and potential recruitment trees were tallied. The abundance and type of pools were also observed. The field observations notes are in the appendix of this module. The field observations are summarized and defined in Table E-3.

Geomorphic Units

Channel segments were grouped into geomorphic units by similar attributes from the channel conditions of the 1997 field observations, position in the drainage network, and gradient/confinement classes. The intent of the geomorphic units are to stratify channel segments of the Garcia WAU into units which respond similarly to the input factors of coarse sediment, fine sediment, and LWD. These geomorphic units can then be interpreted to have similar habitat-forming or sediment routing processes.

Long-Term Stream Monitoring Sites

To monitor stream channel morphology conditions and stream sediment characteristics related to stream habitat, 5 long-term stream channel monitoring segments were established in 1998 and re-surveyed in 2000 in the Garcia WAU. Along these segments longitudinal profiles, cross sections and streambed pebble count measurements were surveyed. Stream gravel permeability of spawning gravels was also measured in 1997 and 2000; some bulk gravel samples (“McNeil” samples) were taken in 1997 (methods and results presented in the Fish Habitat section). These long-term segments will be re-surveyed and monitored over time to provide insight into long term trends in channel morphology, sediment transport and stream habitat conditions. In future surveys of the long term channel monitoring segments LWD will be included in the surveys.

The stream monitoring segments are typically 20-30 bankfull channel widths in length. Permanent benchmarks (PBMs) are placed at the upstream and downstream ends of the monitoring segment. The PBMs are monumented with nails in the base of large trees along with a re-bar pin in the ground adjacent to the nail.

The longitudinal profile is a survey of the thalweg, the deepest point of the channel, excluding any detached or "dead end" scours and/or side channels. At every visually apparent change in thalweg location or depth, the station along the channel and the elevation is recorded. In the absence of visually apparent changes, thalweg measurements are taken every 15-20 feet along the channel. A profile graph of the channel's thalweg is created from the longitudinal survey (see Appendix E for longitudinal profiles for the Garcia WAU). A computer program (Longpro) developed by the USGS for Redwood National Park was used to analyze the profiles. This program converted the surveys into standardized data sets with uniform five-foot spacing between points and determined the residual water depth of each point. The residual water depth is the depth of water in pools of the channel segment defined by the riffle crest height at the outlet of the pool. No minimum pool depth is specified. The distribution, mean and standard deviation of the residual water depths for the longitudinal profile segment are calculated. This provides the ability to statistically evaluate changes in the residual water depths from the thalweg profile over time.

Along the longitudinal profile, 3-5 channel cross sections are surveyed (locations are permanently monumented). The cross sections are located along relatively straight reaches in the monitoring segment. Cross sections are surveyed from above the floodprone depth of the channel. A graph of the cross section is created from the survey (see Appendix E for cross sections graphs for the Garcia WAU). At each cross section a pebble count is done, to determine the particle size distribution and median particle size (D50), by measuring 100 randomly selected pebbles along the cross section fall line.

RESULTS

Historic Trend

Historic aerial photo interpretation showed changes in channel width along the main stem Garcia River, channel segments 1-6 (Table E-1)(Form E-2). The changes in width appear to be from changes in the sediment deposited and stored in the main stem Garcia River. In all of the channel segments there is an increase in channel width observed in the 1966 photos, with the channels narrowing in subsequent years. The exception to this is segment 5 which shows an increase in width in 1966, a decrease in 1978, and another increase in width in 1996.

Table E-1. Garcia River Channel Width and Width Changes from 1952-1996

Segment #	***1952 width (ft)***	***1966 width(ft)/change from 1952 (ft)***	***1978 width(ft)/change from 1966 (ft)***	***1996 width(ft)/change from 1978 (ft)***
Segment 1	69	122/53	116/-6	89/-27
Segment 2	120	144/25	125/-19	115/-10
Segment 3	81	110/29	110/0	98/-12
Segment 4	129	132/4	103/-29	98/-5
Segment 5	105	135/30	118/-17	143/25
Segment 6	107	135/28	119/-16	109/-10

The greatest channel width change is observed in the 1966 aerial photographs. Prior to 1966 there were many large storm events, including the famous 1964 storm which caused extensive flooding in Northern California. However, the 1964 flood was not the flood of record in the Garcia watershed (see Hydrology section). A 1995 storm was the largest flood in the watershed. In fact, 1966, 1970, 1974, and 1986 all had larger flood events then 1964. With the exception of the 1966 flood all of those larger events are in time periods where the Garcia River channel was narrowing. This suggests that it requires more than just a large flood to widen the Garcia River. It requires high floods in conjunction with high sediment loads being delivered to the mainstem Garcia River. The period from 1952-1966 was when the first "modern" forest management occurred. The harvesting practices of this time period created more erosion problems than current forest practices (see Surface Erosion and Mass Wasting sections). This large influx of eroded material in conjunction with some large storms probably created the river widening observed in the aerial photographs. Following this period the sediments in the main stem Garcia River are probably being re-vegetated, re-distributed, or transported downstream, creating the narrower channel widths.

Current Stream Channel Conditions

Field channel surveys were done on 23 stream segments in the Garcia WAU during the summer of 1997. Table E-3 provides a summary of the data collected. Further detail specific to in-channel habitat relationships is found in the fish habitat section of this report. Information on LWD in stream channels was collected in the stream channel assessment and is presented in the Riparian Function section.

Key to Table E-3

Channel Dimensions

Category	Description
SYP Confinement -	c = confined, mc = moderately confined as classified in the SYP
Slope length-	length of segment used for slope calculation
Total length	total length of segment surveyed
obs. slope	observed slope
m. BFD	mean bankfull depth of surveyed segment, as estimated in field
m BFW	mean bankfull width of surveyed segment, as estimated in field
W/D ratio	bankfull width to depth ratio
Valley W	valley bottom width, from the edges of the slope break of the channel inner gorge
observed confine	observed confinement, valley bottom to bankfull width ratio

Mont/Buff	the channel type: p/r = pool/riffle, fp/r = forced pool/riffle, stp = step pool, plnbed = plane bed, cas = cascade
Rosgen	Rosgen channel classification, see Rosgen (1994).
Floodplain	description of floodplain/channel interaction: C = continuous, D = Discontinuous, I = inactive, N = no floodplain

Sediment/Bedform Characteristics

Category	Description
in past agg. or degr.	evidence of past aggregation or degradation of channel
current agg. or degr.	currrent aggregation or degradation of channel
Channel roughness	B =boulders, C=cobbles, F=bedforms, V=live woody veg., W=large woody veg., R=bedrock, Bk=banks and roots
bar abundance	gravel bar abundance: F=few, C=common, A=abundant
bar type	gravel bar type: A=alternate, F=forced, P=point, M=medial
bed material	visual interpretation of texture
fines/abun	abundance of fine sediment: S=sparse, M=medium, A=abundant
fines/type	type of fine sediment accumulation: P=isolated pockets, B=bars
d50	the median gravel size of the stream bed
pool spacing	number of pools per bankfull width

Table E-3. Stream Channel Observations for the Garcia Watershed Analysis Unit, 1997 (see Map E-2 for stream segment locations).

Segment Name	Segment ID #	confinement	Slope Length (ft)	Total Length (ft)	obs. slope (%)	m. BFD (ft)	m. BFW (ft)	W/D ratio	Valley W (ft)	observed confine	Mont/Buff	Rosgen	floodplain
Garcia River	1	mc	3094	4417	0.5	7	144	20.6	1000	6.9	p/r	C4	D
Garcia River	2	mc	3028	17150	0.5	5.5	144	26.2	1000	6.9	p/r	C4	D
Garcia River	3	c	2647	2800	1.43	5.4	141	26.1	190	1.3	p/r	F4	N
Garcia River	4	mc	3204	3204	no data	6.3	144	22.9	333	2.3	p/r	F4	D
Garcia River	5	c	2288	2288	no data	6	131	21.8	298	2.3	p/r	F4	I
Garcia River	6	c	2853	2853	no data	6	117	19.5	250	2.1	p/r	F4	I
South Fork Garcia	84	c	1073	2338	2.4	3.5	46.7	13.3	118.3	2.5	fp/r	F4	D
South Fork Garcia	86	c	1032	2208	3.4	4.2	35.4	8.4	52	1.5	fp/r	B4	N
South Fork Garcia	83	mc	1463	1463	2	2.75	63.25	23.0	125	2.0	p/r	C4	D
South Fork Garcia	85	c	993	2079	2.4	3.88	32.5	8.4	57.5	1.8	fp/r	B4	N
South Fork Garcia	101	c	679	1200	3.2	3	24.25	8.1	42.5	1.8	fp/r	B4	N
South Fork Garcia	111	c	1093	1093	3	2.4	26.4	11.0	34	1.3	fp/r	B4	N
South Fork Garcia	102	c	865	1300	4.2	3.5	19	5.4	24.8	1.3	stp	A3	N
Mill Creek	53	c	1206	1559	3	3.9	33	8.5	88	2.7	p/r	B3	D
Rolling Brook	19	c	1058	3118	2.7	4.3	42.2	9.8	108.5	2.6	plnbed	B3	I
Rolling Brook	20	c	805	2526	10.1	4	35.6	8.9	76.2	2.1	stp	A2	I
Unamed trib. (Bueler)	149	c	800	1120	5.3	3.6	27.5	7.6	36.5	1.3	cas	A3	N
Unamed to(Garcia)	121	mc	510	2078	16	3.5	21	6.0	32	1.5	stp	A3	N
Unamed (Bueler)	150	mc	507	675	8.3	3	23.3	7.8	26	1.1	cas	A3	N
Unamed to (Sfk Garcia)	89	c	415	1300	21	2.3	8	3.5	15.4	1.9	cas	A4	N
Unamed to (Garcia)	155	undefined	500	987	20	3.4	17	5.0	22	1.3	cas	A2a	N
Unamed to (Garcia)	127	undefined	305	2884	23	3.9	15	3.8	30	2.0	cas	A4	N
Unamed to SFk	90	mc	735	3897	3.4	2.83	18.3	6.5	53.3	2.9	plnbed	B4	D

Table E-3 (continued). Stream Channel Observations for the Garcia Watershed Analysis Unit, 1997 (see Map E-2 for stream segment locations).

Segment ID #	in Past Agg.or degr.	Current Agg.or degr.	channel roughness	bar abundance	bar type	bed material	fines/abun	fines/type	d50 (mm)	pool spacing (# pools/ width)
1	y/a	y/d	F-V	C	A-P	coarse gravel	S	P	22-32, 32-45	3
2	y/a	y/d	F-V	A	A-P	coarse gravel	S	P/B	16-22, 32-45, 22-32	1.8
3	y/a	y/d	F-V-Bk	A	A	gravel/sand	S	P	11-16, 8-11	2.6
4	y/a	y/d	F-V	A	A	cob/grav/sand	M	P	32-45, 22-32	2.4
5	y/a	y/d	F-Bk-V	C	A-M	gravel/cob	S	P	22-32	1.9
6	y/a	y/d	F-Bk-V	C	A	gravel	M	P/B	22-32, 8-11	3.0
84	y/a	y/d	F-Bk	A	M-A	grav/cob/sand	A	P	32-45	2.9
86	y/a	y/a	W-B	C	M-A	cob/grav/sand	M	P	16-22	2.7
83	y/a	y/a	F-V	A	M	sm.grav/sand	A	B	6-8	3.8
85	y/a	y/a	F-W	A	M-A	grav/cob/sand	M	P	11-16	1.9
101	y/a	y/a some d	Bk-W	A	A	grav/cob/sand	S	P	22-32	4.6
111	y/a	y/a some d	F-Bk	A	A-M	grav/sand/cob	M	B	32-45	3.8
102	y/a	y/a some d	W-F-Bk	C	F	Cob/grav/sand	S	P	32-45	7.6
53	y/a	y/d	F-Bk-V	C	A	grav/cob/sand	M	P	32-45, 45-64, 22-32	3
19	y/a	y/d	C-Bk	F	M	cob/grav	S	P	64-90	4.2
20	y/a	y/d	B-Bk-W	F	A	bould/cob/sand	M	P	45-64, 32-45	3.83
149	y/a	y/d	B-W-R	F	F	cob/bolder	S	P	64-90	3.2
121	y/a	y/d	Bk-W	C	F	cob/grav/sand	M	B	32-45	dry
150	n/a	n/d	B-Bk-W	F	F	cob/bould/grav	S	P	90-128	dry
89	y/a	y/d	Bk-W	F	F	cob/grav/sand	S	P	no data	dry
155	n/a	n/d	B-Bk	F	F	bould/cob/sand	S	P	45-64	dry
127	y/a	y/d	Bk-W	F	F	cob/grav/sand	S	P	45-64	dry
90	y/a	y/d	Bk-F	A	M-A	grav/cob/sand	M	P	32-45	8.2

Geomorphic Units

Individual channel segments were categorized into geomorphic units using the interpretation of channel networks described above, the topography of the channel segments, the position in the drainage network, and gradient/confinement classes. Seven geomorphic units were established to represent the range of channel conditions and sensitivities to input factors of coarse sediment, fine sediment, and LWD (see Map E-2).

Geomorphic Unit I. Alluvial Mainstem of Garcia River

Includes Segments: Field verified - 1, 2, 3, 4, 5, 6
Extrapolated – 164, 165

General Description:
The Garcia River, in this unit, flows through alluvial deposits in an incised gorge. The channel gradient is low (0.5-1.5 %), but sediment transport capacity is relatively high due to low channel roughness, and moderate to highly confined channel segments keeping water energy directed within the river banks. The river bottom is composed of coarse gravel to cobble sized particles. The river has some ancient terrace deposits alternating infrequently within the valley bottom. These terraces tend to be above the current river course and are seldom flooded in large flow events.

Associated Channel Types:
This unit is primarily pool/riffle with some plane bed sections. The plane bed sections occur where there is little woody debris and the river channel is tightly confined.

Conditions and Response Potential:

Coarse Sediment: Moderate Response Potential
The alluvial mainstem is a depositional channel for coarse sediment, moderately sensitive to coarse sediment inputs. The unit is composed of alternating point and medial bars. The size and distribution of these bars suggest large coarse sediment storage sites which can increase or decrease with sediment loads delivered to this unit. However the magnitude of the increase of coarse sediment would have to be very large to significantly affect the large storage sites currently present. Historic aerial photographs indicate fluctuations in channel widths with increases in coarse sediment loads. This unit can aggrade, widen, and have lateral channel shifts when coarse sediment loads exceed channel transport capacity. Pool frequency and depth could be decreased and pool/riffle morphology could be shifted toward plane bed morphology with high coarse sediment inputs. From sediment budget analysis a large supply of sediment was delivered to the Garcia River in the 1950's and 1960's. River channel widening occurred from high inputs of coarse sediments with the channel narrowing in subsequent years. The magnitude of the inputs which created the river widening was very large. In recent years, with more moderate coarse sediment inputs, the channel appears to be degrading and is able to transport the coarse sediment loads.

Fine Sediment: Low Response Potential
High accumulations of fine sediment were not observed in this unit. Fine sediment is restricted to the top of gravel bars (particularly if vegetated), on the flood plains associated with over-bank flows, along pool margins and in some pools. However, the fine sediment observations are of only sparse to moderate accumulations, primarily in isolated pockets and not pervasive across the

channel bed. Bulk gravel sample and river gravel permeability information collected in this geomorphic unit (see Fish Habitat Assessment) shows low fine sediment accumulations and reasonable gravel permeability.

The mainstem Garcia River has a high fine sediment transport capacity due to high flow capacity of the channel, higher than other areas of the WAU. Because of this fine sediment has not accumulated in large amounts in this unit.

Large Woody Debris: Moderate Response Potential
Large woody debris is sparse in this unit. Little woody debris is available for stream habitat development or cover. The large channel size and high flows of this unit require very large woody debris pieces or debris jams to keep the woody debris in place. These very large woody debris pieces or debris jams would likely form on the margins or bends of the channel. It is unlikely that this sporadic placement of very large LWD would have a strong influence on the morphology of the channels in this unit. However, having more LWD in this unit is important because the channels in this unit would gain greater fish habitat diversity with increased large woody debris.

Geomorphic Unit II. Low Gradient Depositional Segments of V-Shaped Valleys

Includes Segments: Field verified - 83, 84, 85, 86, 101, 111
Extrapolated -

General Description:
Channel segments in this unit flow through alluvial deposits in gorges which tend to be steeply incised. This unit has the San Andreas Fault running along the valley bottom which has influenced the valley morphology. The channel segments in this unit are depositional and are responsive to aggradation and degradation from changes in the sediment supply. The channel gradient is low to moderate (0.5 - 4 %). The river bottom is composed of sand to cobble sized particles. The streams have some terrace deposits alternating infrequently within the valley bottom. The terraces tend to be very young (within approximately 100 years) due to the narrow valley bottom and interaction of the terraces with large floods.

Associated Channel Types:
This unit has primarily forced pool/riffle morphology with some pool/riffle and plane bed morphology. The pool/riffle and plane bed morphology is found in highly aggraded sections of this unit where large woody debris is covered by sediment and cannot force the channel morphology.

Conditions and Response Potential
Coarse Sediment: High Response Potential
The low gradient and alluvial nature of this unit makes it a depositional channel, sensitive to coarse sediment inputs. The unit is composed of alternate and medial gravel bars. The size and distribution of these bars suggest large coarse sediment storage sites which can increase or decrease with sediment loads delivered to this unit. This unit can aggrade, widen, and have lateral channel shifts when coarse sediment loads exceed channel transport capacity. Large woody debris creates much of the complexity of the channel morphology in this unit. Pool frequency and depth could be decreased and pool/riffle morphology could be shifted toward plane bed morphology with high coarse sediment inputs. Segment 83 has several avulsion channels, high coarse sediment inputs could create frequent channel migration to the various avulsion channels.

Fine Sediment: Moderate Response Potential
Fine sediment accumulations in this unit range from sparse to abundant. Fine sediment is typically found in patches in the interstices of riffle gravels, and the bottoms of pools. Sediment transport capacity is fairly high in these reaches allowing a lot of the fine sediment to be transported out of this unit. However, the pools and roughness elements in this unit do slow water flow allowing some fine sediment to settle in pools and stream gravels. Bulk gravel sample and river gravel permeability information collected in this geomorphic unit (see Fish Habitat Assessment) shows low fine sediment accumulations. The permeability measurements ranged from very permeable to low permeability, suggesting some fine sediment effects of the streambed gravels.

Large Woody Debris: High Response Potential
Large woody debris is sparse to abundant in this unit. Large woody debris provides stream habitat, cover, channel complexity and sediment storage in this unit. The channel size and high flows of this unit does require fairly large woody debris pieces or debris jams to keep the woody debris in place. But, the large woody debris that does stay in place in this unit will provide high quality habitat value.

Geomorphic Unit III. Moderate Gradient Depositional Segments of V-Shaped Valleys

Includes Segments: Field verified - 19, 20, 53, 102
Extrapolated - 103, 112, 113, 133

General Description:
Channel segments in this unit flow through alluvial and mass wasting deposits in gorges which tend to be deeply incised. The channel segments in this unit are near the transition between depositional and transportable and are responsive to aggradation and degradation from changes in the sediment supply. The channel gradient is moderate (2-10 %). This unit is found at the mouth of some primary tributaries of the Garcia River. The channel gradient in this unit starts out low (about 2 percent) and quickly becomes steeper (up to 10 percent) as the channel progresses back into the valley from its outlet. The river bottom is composed of sand to boulder sized particles. The streams have terrace deposits alternating infrequently within the valley bottom. The terraces tend to be very young (within approximately 100 years, based on tree age) and are created from large episodic sediment loads such as frequent mass wasting. The gradient of the stream is high enough that stream segments in this unit easily downcut through the terrace deposits.

Associated Channel Types:
This unit varies it morphology from plane bed to pool/riffle to step pool. The step pool occurs in the steepest segments of this unit. The plane bed is found in areas of low woody debris accumulations and in lower gradient channels of recently down cut terrace deposits.

Conditions and Response Potential

Coarse Sediment: Moderate Response Potential
The moderate gradient and location of this unit at the mouth of some primary tributaries of the Garcia River creates channels moderately sensitive to coarse sediment inputs. The unit is composed of large terraces and few to common alternate and medial gravel bars. The size and distribution of these terraces and bars suggest large coarse sediment storage sites which can increase or decrease with sediment loads delivered to this unit. This unit can aggrade, widen, and have lateral channel shifts when coarse sediment loads exceed channel transport capacity. This occurs in response to large inputs of mass wasting events both locally and upstream. Currently the channels of this unit are downcutting through the terraces of recently stored sediments. The recently stored sediments are quickly mobilized in this unit due to a competent stream power from the moderate gradients.

Fine Sediment: Low Response Potential
Fine sediment accumulations in this unit range from sparse to moderate. Fine sediment is typically found in isolated pockets in the interstices of riffle gravels, and the bottoms of pools. Sediment transport capacity is high in these reaches due to the moderately steep gradient of the unit. Bulk sample and permeability information in this unit (see Fish Habitat Asssessment) show low fine sediment accumulations and highly permeable streambed gravels.

Large Woody Debris: Moderate Response Potential
Large woody debris is sparse to abundant in this unit. Large woody debris provides stream habitat, cover, channel complexity and sediment storage in this unit. The entrenchment of many of the channels in this unit facilitates smaller large woody debris pieces or debris jams for retention. Much of the large woody debris recruited from adjacent hillslopes will not be directly delivered to the channel due to streamside terraces.

Geomorphic Unit IV. Moderate Gradient Transport Segments of V-Shaped Valleys

Includes Segments: Field verified - 121, 149
Extrapolated - 9, 20, 21, 22, 23, 24, 43, 54, 57, 60, 61, 62, 68, 69, 87, 88, 148, 114, 115, 117, 140, 141, 123, 12, 104, 105

General Description:
Channel segments in this unit are part of the primary tributaries of the Garcia River with gradients ranging from 4-20% and relatively high sediment transport capacity. The channel segments in this unit are slightly responsive to aggradation and degradation from changes in the sediment supply, but primarily due to forced storage areas from large woody debris or debris dams. At times the valley bottom can be wide enough to create channel meandering and terrace formation, but these processes are limited to the low gradient segments. The stream bottom is composed of sand to cobble to boulder sized particles.

Associated Channel Types:
This unit varies it morphology from step pool to cascades. The cascade morphology occurs in the steepest segments of this unit. The step pools are found in areas of high woody debris accumulations and occasionally from boulders.

Conditions and Response Potential:

Coarse Sediment: Moderate Response Potential
The moderate gradient and location of this unit in primary tributaries of the Garcia River creates channels responsive to coarse sediment inputs. The unit has some small terraces and few to common forced gravel bars. The size and distribution of these terraces and bars suggest coarse sediment storage sites which can increase or decrease slightly with sediment loads delivered to this unit. Large woody debris creates a lot of the complexity of the channel morphology in this unit and provides a key element in sediment storage and routing in this unit. The large woody debris creates storage areas for coarse sediment aggradation and degradation.

Fine Sediment: Low Response Potential
Fine sediment accumulations in this unit range from sparse to moderate. Fine sediment is typically found in isolated pockets. Fine sediment transport capacity is high in these reaches due to the steep channel gradient.

Large Woody Debris: Moderate Response Potential
Large woody debris is sparse to abundant in this unit. Large woody debris provides sediment storage and slows coarse sediment routing in this unit. Much of the step pool morphology of this unit is created from large woody debris.

Geomorphic Unit V. High Gradient Transport Segments of V-Shaped Valleys

Includes Segments: Field verified - 150, 89, 155, 127
Casual Observations - 10, 11, 15, 37, 44, 45, 96, 131, 50
Extrapolated - 13, 14, 16, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 46, 55, 56, 58, 59, 63, 64, 65, 66, 67, 70, 71, 72, 83, 84, 97, 106, 107, 108, 109, 110, 116, 118, 119, 120, 124, 125, 126, 128, 129, 130, 132, 134, 135, 136, 137, 138, 139, 142, 143, 144, 145, 146, 147, 151, 152, 153, 154, 156, 157, 158, 159, 160, 166, 167

General Description:
Channel segments in this unit are high gradient transport reaches from 8-20% but typically greater than 15-20% with high sediment transport capacity. The channel segments in this unit typically flow through tightly confined, steep-sided, V-shaped canyons. These are typically zones of scour during high flows or debris flows. Stream substrate is typically from cobble to large boulders.

Associated Channel Types:
This unit varies it morphology from step pool to cascades with some occasional waterfalls. The cascades and waterfalls occur in the steepest segments of this unit.

Conditions and Response Potential:

Coarse Sediment: Low Response Potential
The unit has very few terraces, bars or storage sites. The roughness of the channels creates varied coarse sediment transport capacity. Large woody debris and large boulders can create some sediment storage.

Fine Sediment: Low Response Potential
Fine sediment accumulations in this unit range from sparse to moderate. Sediment transport capacity is high in these reaches allowing most fine sediment to be transported out of this unit.

Large Woody Debris: Low Response Potential
Large woody debris is sparse to abundant in this unit. Large woody debris provides some sediment storage in this unit however large boulders are the dominant roughness elements in most of these segments. The cascade and step pool morphology would only be minimally affected by an increase or decrease of wood.

Geomorphic Unit VI. Moderate Gradient Segments of Moderate Sloped Valleys

Includes Segments: Field verified - 90
Casual Observation - 49, 73, 98, 99
Extrapolated - 7, 8, 48, 74, 76, 77, 82, , 92, 93, 94, 95, 100

General Description:
These units occur in moderately sloping topography along the west side of the San Andreas Fault in the Garcia WAU. The channels in this unit are within confined canyons with the side walls of the canyon being moderately sloped. Sediment transport in these reaches is moderate due to the lower flows from smaller drainage areas and moderate gradient channels. Channel gradients are typically between 2-20%.

Associated Channel Types:
This unit varies it morphology from plane bed morphology to pool/riffle to forced pool/riffle to step pool to cascade. The step pools occur in the steeper areas of this unit and are typicaly created from woody debris and large rocks.

Conditions and Response Potential:

Coarse Sediment: Moderate Response Potential
The unit has few to abundant medial gravel bars. Some aggradation occurs in the lower gradient reaches of this unit. The low to moderate gradient channels have medium coarse sediment transport capacity. Large woody debris and large boulders can create some sediment storage.

Fine Sediment: Moderate Response Potential
Sediment transport capacity is moderate in these reaches allowing a lot of the fine sediments to be transported out of this unit. The lower stream flows in this unit does not always provide the best transport of fine sediment out of the channels.

Large Woody Debris: High Response Potential
Large woody debris is sparse to abundant in this unit. Large woody debris provides some sediment storage in this unit and is the dominant roughness element. Large woody debris does provide stream habitat and cover for some of the reaches in this unit.

Geomorphic Unit VII. High Gradient Segments of Moderate Sloped Valleys

Includes Segments: Casual Observation - 52
Extrapolated - 17, 18, 47, 50, 51, 75, 78, 79, 80, 81, 91

General Description:
These units occur in the upper portions of the channel network in the moderate to steep sloping topography along the west side of the San Andreas Fault in the Garcia WAU. The channels in this unit are within confined canyons with the side walls of the canyon being moderately sloped. Sediment transport in these reaches is low to moderate due to the lower flows from smaller drainage areas. Channel gradients are typically between 10-30%.

Associated Channel Types:
This unit varies it morphology from step pool to cascade.

Conditions and Response Potential:

Coarse Sediment: Low Response Potential
The unit has very few terraces, bars or storage sites. The moderate to steep gradient channels creates reasonable coarse sediment transport. Large woody debris and large boulders can create some sediment storage.

Fine Sediment: Low Response Potential
Sediment transport capacity is moderate in these reaches allowing a lot of the fine sediments to be transported out of this unit.

Large Woody Debris: Moderate Response Potential
Large woody debris is sparse to abundant in this unit. Large woody debris provides some sediment storage in this unit and is a channel roughness element.

Long Term Stream Channel Monitoring

The graphs of the longitudinal profiles and cross sections surveyed on the long term stream monitoring segments are presented in Appendix E of this report.

Comparison of cross-section graphs between the 1998 and 2000 surveys show little change in the Mainstem Garcia (segment 7) with the exception of some possible aggradation at cross-section #2. Mean residual depths and standard deviation from the thalweg profile surveys for segment 7 increased substantially indicating deeper pools and potentially more variable habitat. Cross-sections in Rolling Brook (segment 19) were mirror images of each other indicating no change in channel geometry. Residual depth values calculated from the thalweg survey in segment 19 showed the same trend, little change. D50 values have decreased in segments 7 and 19.

South Fork Garcia River has received considerable restoration work in the last few years. Multiple erosion control and stream habitat improvement projects have been implemented and the long-term channel monitoring protocol provides a way to monitor the stream channels resulting from these projects. Comparison of cross-section graphs between 1998 and 2000 show considerable change in the lowest reach in the South Fork Garcia (Segment 83). Cross-section

#1 shows that a 12-foot section of bank was removed during high flows. Field observations verified this as trees had recently (within the last year) fallen into the channel from the right bank. Cross-section #2 shows the cutting of a new channel through the sediment. Cross-section #3 shows some shifting of the thalweg location. Residual depth values determined from the thalweg profile survey do show some habitat improvement but the differences are not enough to draw conclusions. D50 values are similar between 1998 and 2000 in segment 83.

Cross-section graphs in Segment 86 (South Fork Garcia at confluence with Fleming Creek) are similar but do show change in the stream channel in cross-section #1. D50 values may be increasing in segment 86. Residual depth values calculated from the thalweg profile surveys are very similar. Restoration work was implemented in the summer of 2000 and channel adjustments from these may show up in subsequent surveys.

Cross-section #1 in segment 101 shows almost two feet of downcutting between the 1998 and 2000 surveys. During the summer of 1998 restoration work occurred just below cross-section #1. A bridge replaced a culvert and rock weirs were installed to aid in pool formation. This work resulted in the changes that are seen in the cross section. The remainder of the cross-sections showed little change in channel geometry. D50 values are similar between 1998 and 2000 in segment 101. Residual depth values calculated from the thalweg profile surveys in segment 101 have decreased considerably between 1998 and 2000 (See Table 1). This potentially indicates decreased habitat quality and diversity. This information suggests the channel is adjusting to the restoration work. Hopefully, this adjustment will correct and put the channel on an improving trajectory.

The cross-section profiles objectively show changes have occurred; there aren't enough years of data to be able to draw conclusions as to the long term trend. However, over time, these surveys will indicate the trend for stream channel morphology adjustments from LWD and sediment in the Garcia River WAU.

Table E-4. Comparison of Residual Depth Data for Long-Term Channel Monitoring Segments in the Garcia River WAU.

Seg ID	**Stream**	**Year**	**Maximum Residual Depth**	**Mean Residual Depth**	**Standard Deviation**
7	Mainstem Garcia River	1998	5.68	0.94	1.12
7	Mainstem Garcia River	2000	6.76	1.51	1.58
19	Rolling Brook	1998	1.44	0.13	0.24
19	Rolling Brook	2000	1.14	0.10	0.19
83	SF Garcia River	1998	2.10	0.21	0.40
83	SF Garcia River	2000	2.51	0.34	0.47
86	SF Garcia River	1998	2.08	0.25	0.45
86	SF Garcia River	2000	2.15	0.42	0.50
101	Little SF Garcia River	1998	5.22	0.91	1.46
101	Little SF Garcia River	2000	1.69	0.17	0.30

LITERATURE CITED

Louisiana-Pacific Corporation. 1997. Sustained Yield Plan for Coastal Mendocino

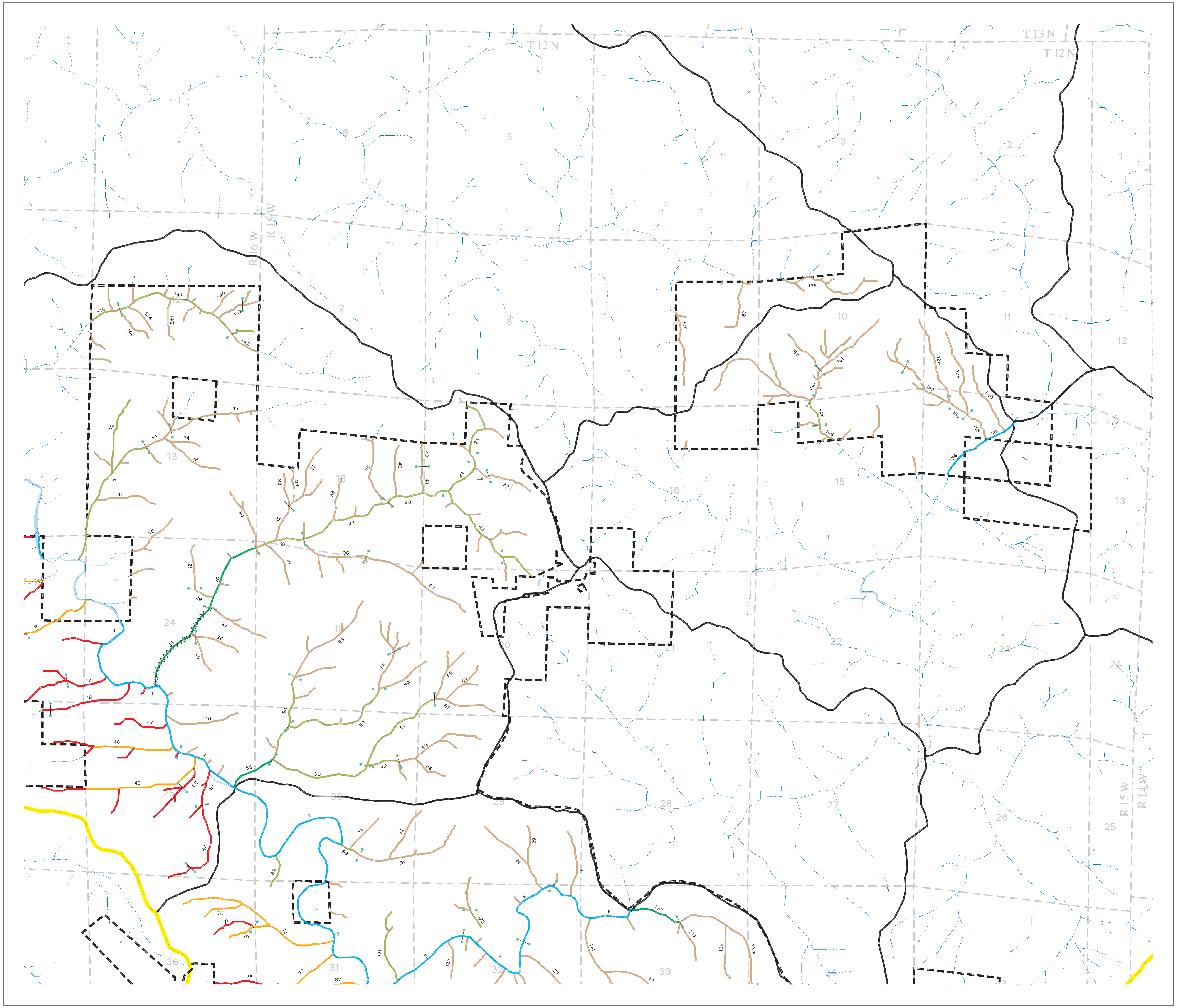
Montgomery, D. and J. Montgomery. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Washington State Timber/Fish/Wildlife report TFW-SH10-93-002. Washington.

Rosgen, D. 1994. A classification of natural rivers. Catena 22, 169-199.

Washington Forest Practice Board. 1995. Standard methodology for conducting watershed analysis. Version 3.0. WA-DNR Seattle, WA.

Appendix E

Stream Channel Condition Module



Garcia River Watershed Analysis Unit

Map E-1 Stream Channel Geomorphic Units and Segments

This map presents the stream channel network for the Garcia WAU partitioned into stream segments based on channel confinement and channel gradient. Channel segments were grouped into geomorphic units by similar attributes of channel condition, position in the drainage network, and gradient/confinement classes. The intent of the geomorphic units are to stratify channel segments of the Garcia WAU into units which respond similarly to the input factors of coarse and fine sediment, and LWD. These geomorphic units can then be interpreted to have similar habitat-forming processes and responses to forest management affects.

Geomorphic Classes

- Alluvial Mainstem of Garcia River
- Low Gradient Depositional Segments of V-Shaped Valleys
- Moderate Gradient Depositional Segments of V-Shaped Valleys
- Moderate Gradient Transport Segments of V-Shaped Valleys
- High Gradient Transport Segments of V-Shaped Valleys
- Moderate Gradient Segments of Moderate Sloped Valleys
- High Gradient Segments of Moderate Sloped Valleys

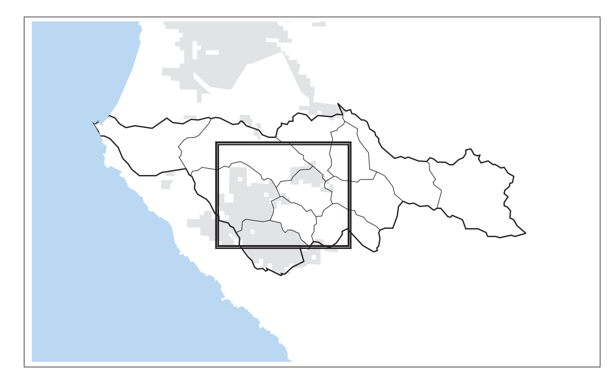
- Long Term Channel Monitoring Sites

- MRC Ownership
- Planning Watershed Boundary
- Garcia River Watershed Boundary

Flow Class

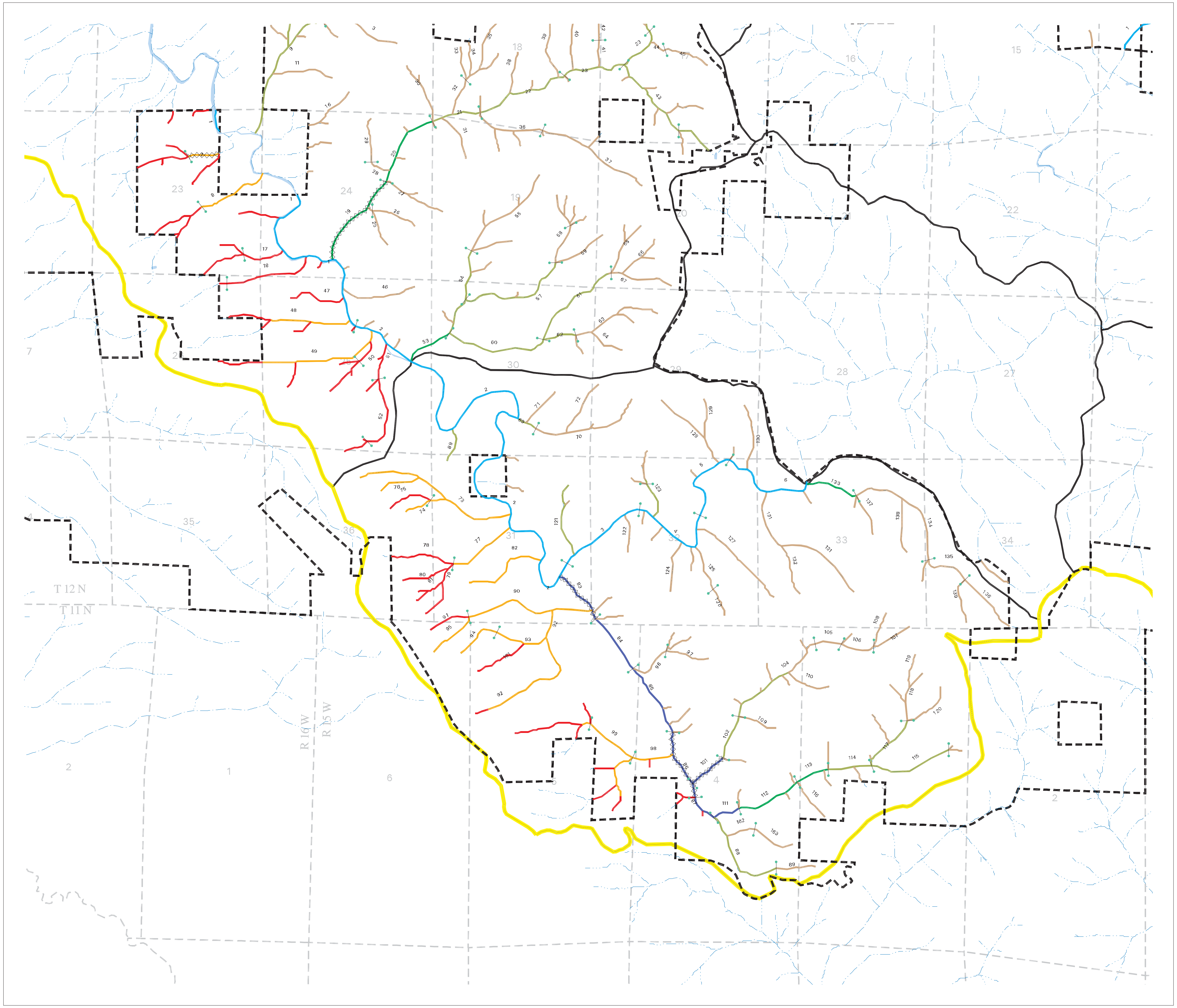
- Class I
- Class II
- Class III

Sheet 1



0 1/2 1 Mile

September 2003



Garcia River Watershed Analysis Unit

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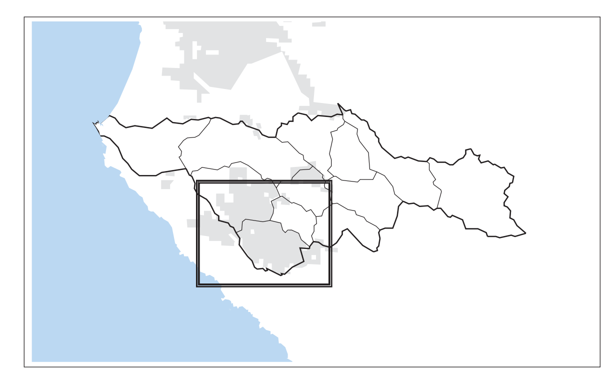
Geomorphic Classes

- Alluvial Mainstem of Garcia River
- Low Gradient Depositional Segments of V-Shaped Valleys
- Moderate Gradient Depositional Segments of V-Shaped Valleys
- Moderate Gradient Transport Segments of V-Shaped Valleys
- High Gradient Transport Segments of V-Shaped Valleys
- Moderate Gradient Segments of Moderate Sloped Valleys
- High Gradient Segments of Moderate Sloped Valleys
- Long Term Channel Monitoring Sites
- MRC Ownership
- Planning Watershed Boundary
- Garcia River Watershed Boundary

Flow Class

- Class I
- Class II
- Class III

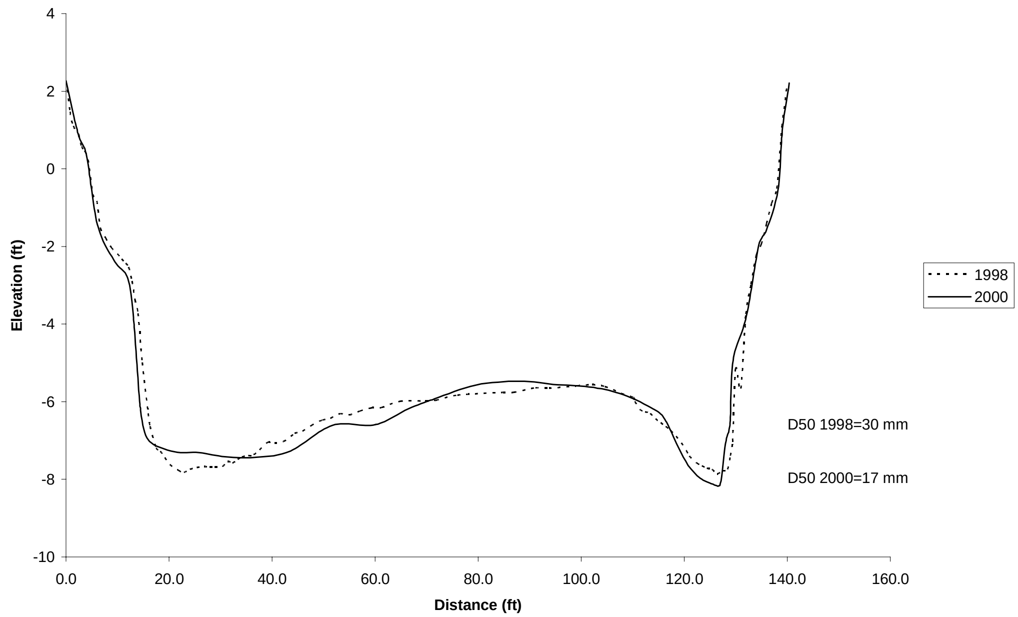
Sheet 2



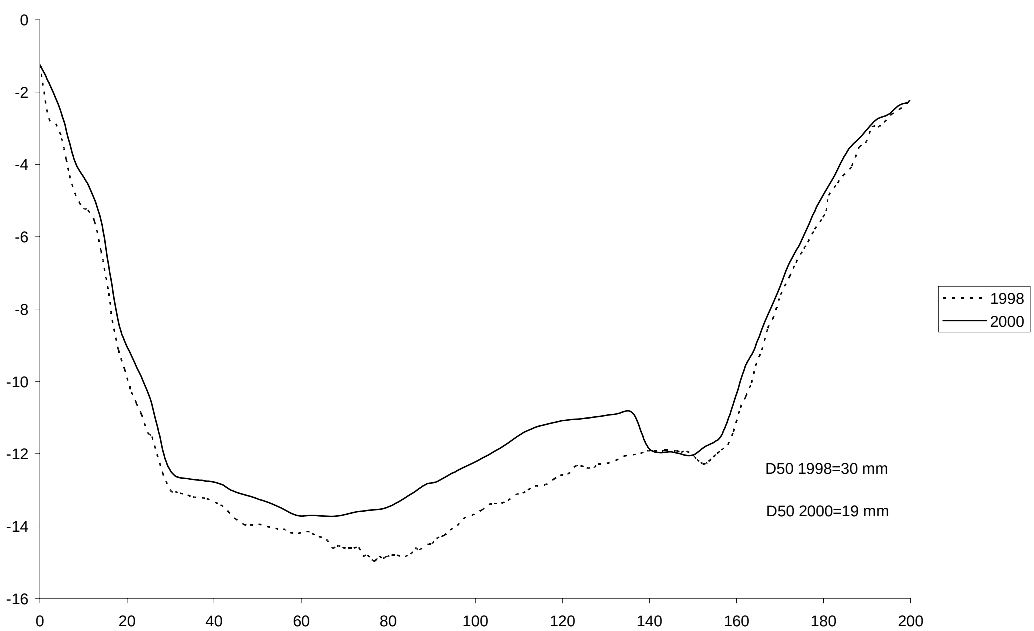
0 1/2 1 Mile

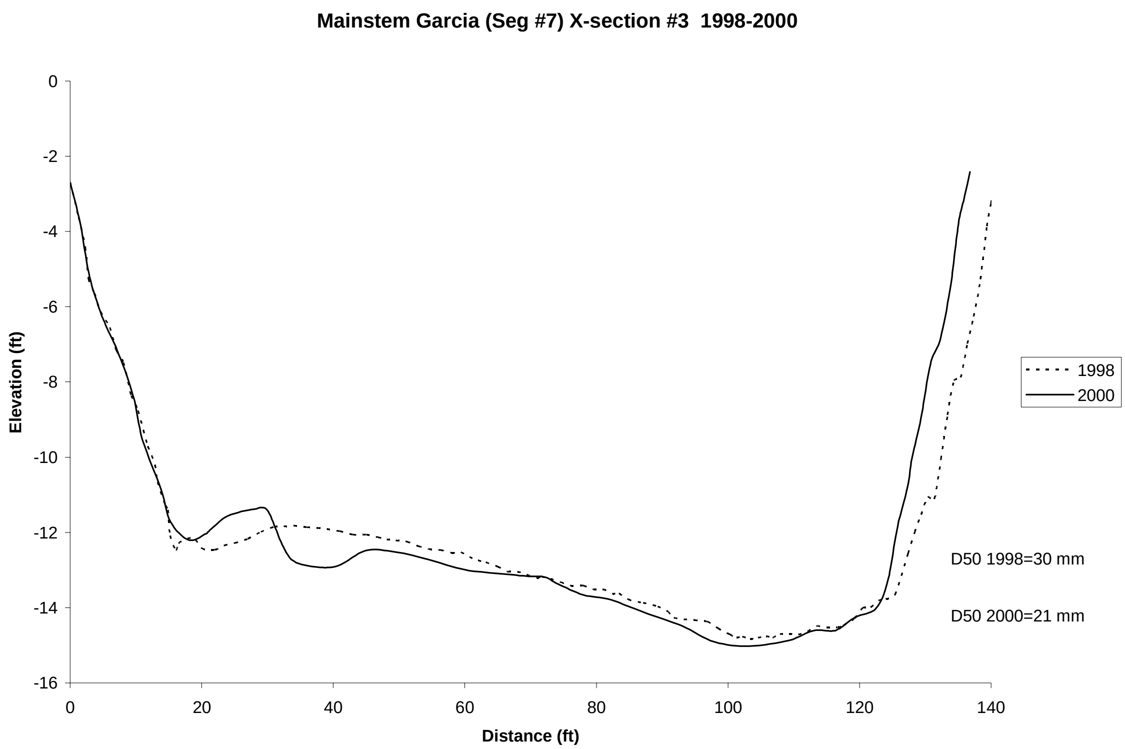
September 2003

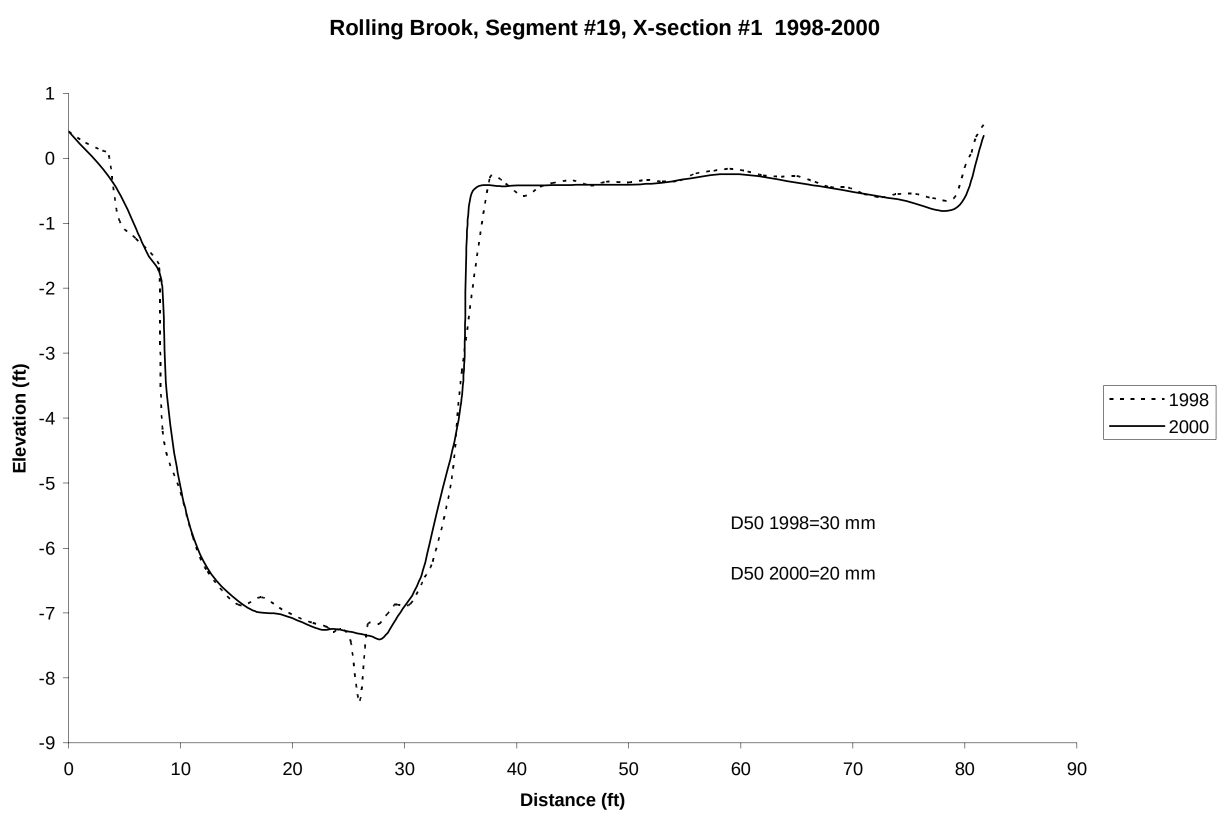
Mainstem Garcia (Seg #7) X-section #1 1998-2000



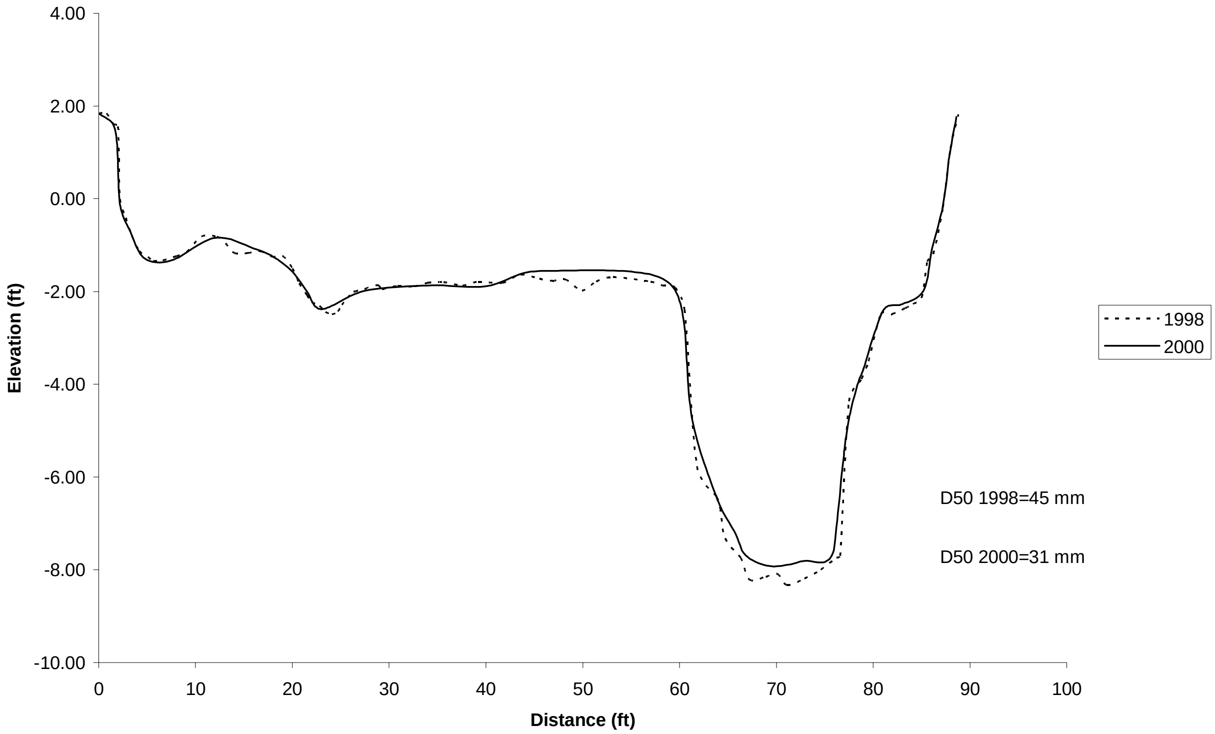
Mainstem Garcia (Seg #7) X-section #2 1998-2000



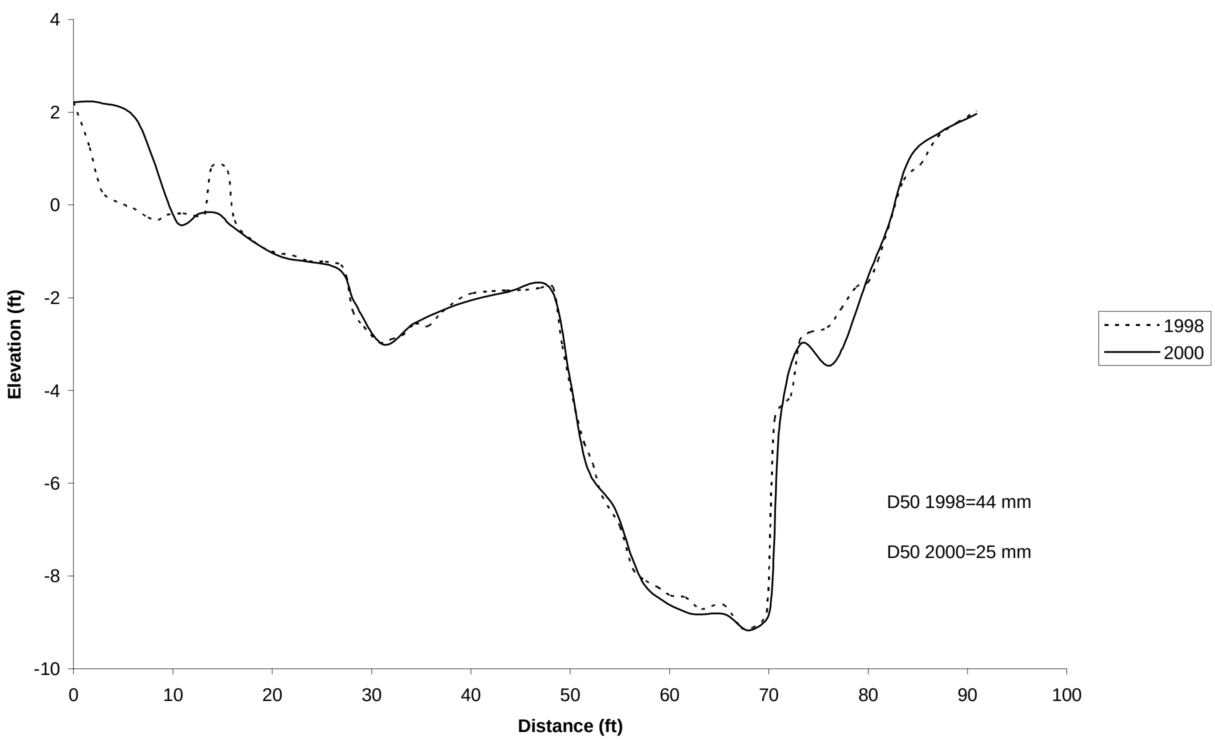

Mainstem Garcia (Seg #7) X-section #3 1998-2000
Elevation (ft)
Distance (ft)
0
-2
-4
-6
-8
-10
-12
-14
-16
0
20
40
60
80
100
120
140
1998
2000
D50 1998=30 mm
D50 2000=21 mm


Rolling Brook, Segment #19, X-section #1 1998-2000
Elevation (ft)
Distance (ft)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
10
20
30
40
50
60
70
80
90
1998
2000
D50 1998=30 mm
D50 2000=20 mm

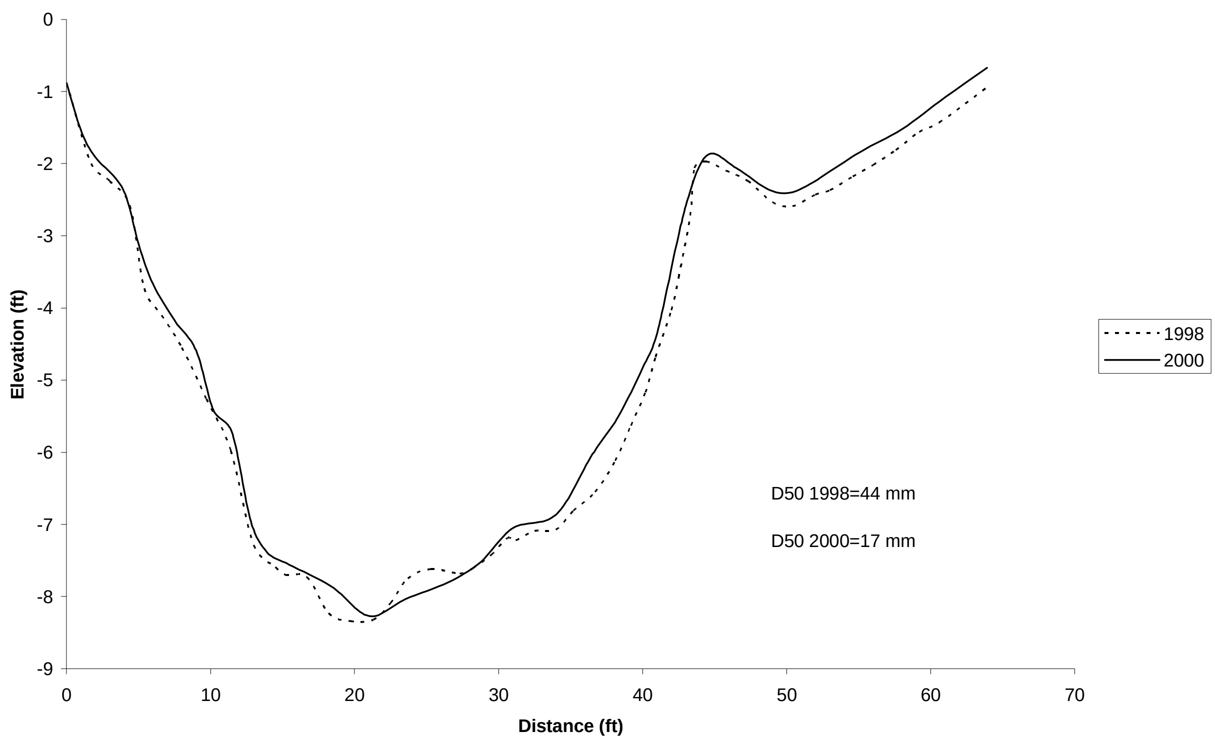
Rolling Brook, Segment #19, X-Section #2 1998-2000



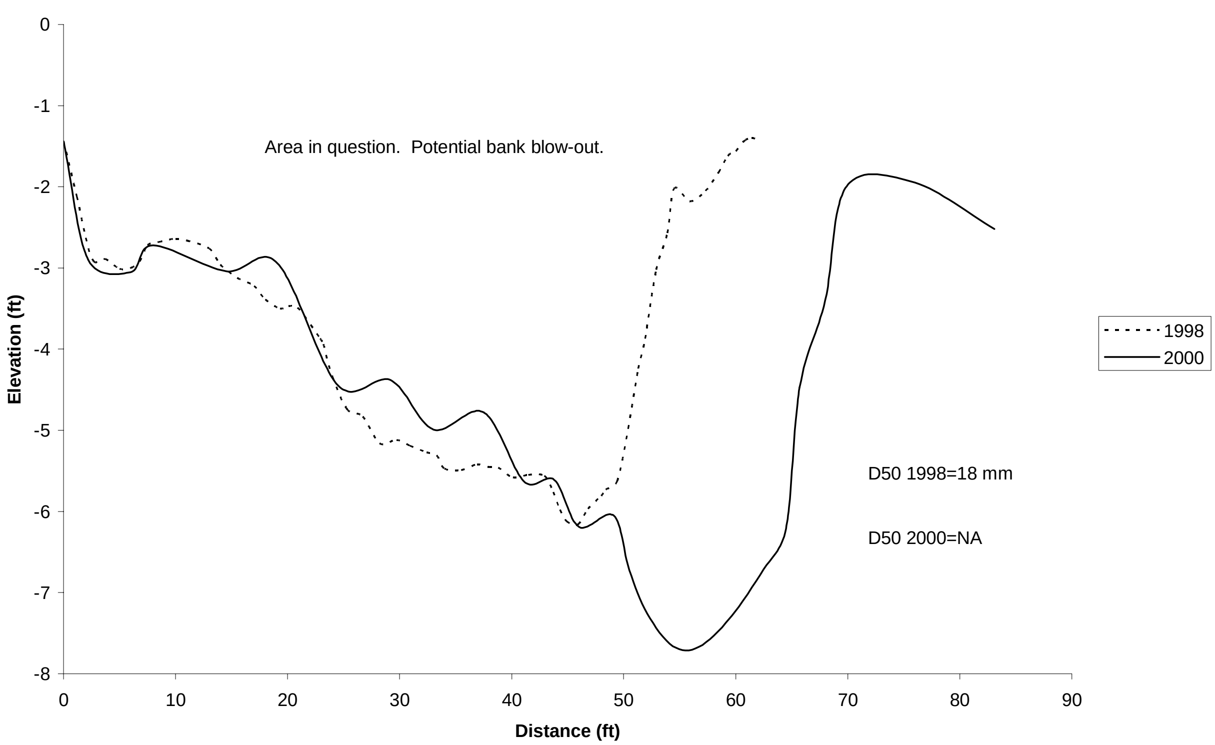
SF Garcia, Segment #19, X-section #3 1998-2000

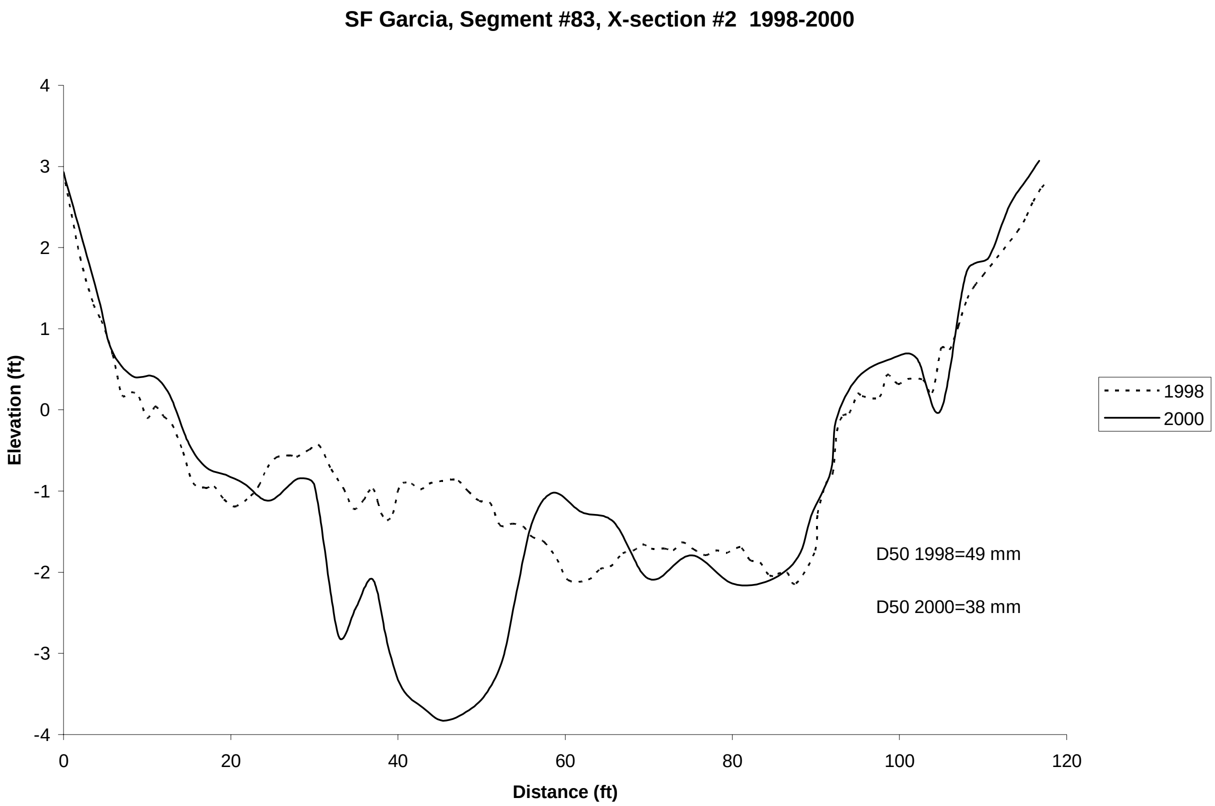


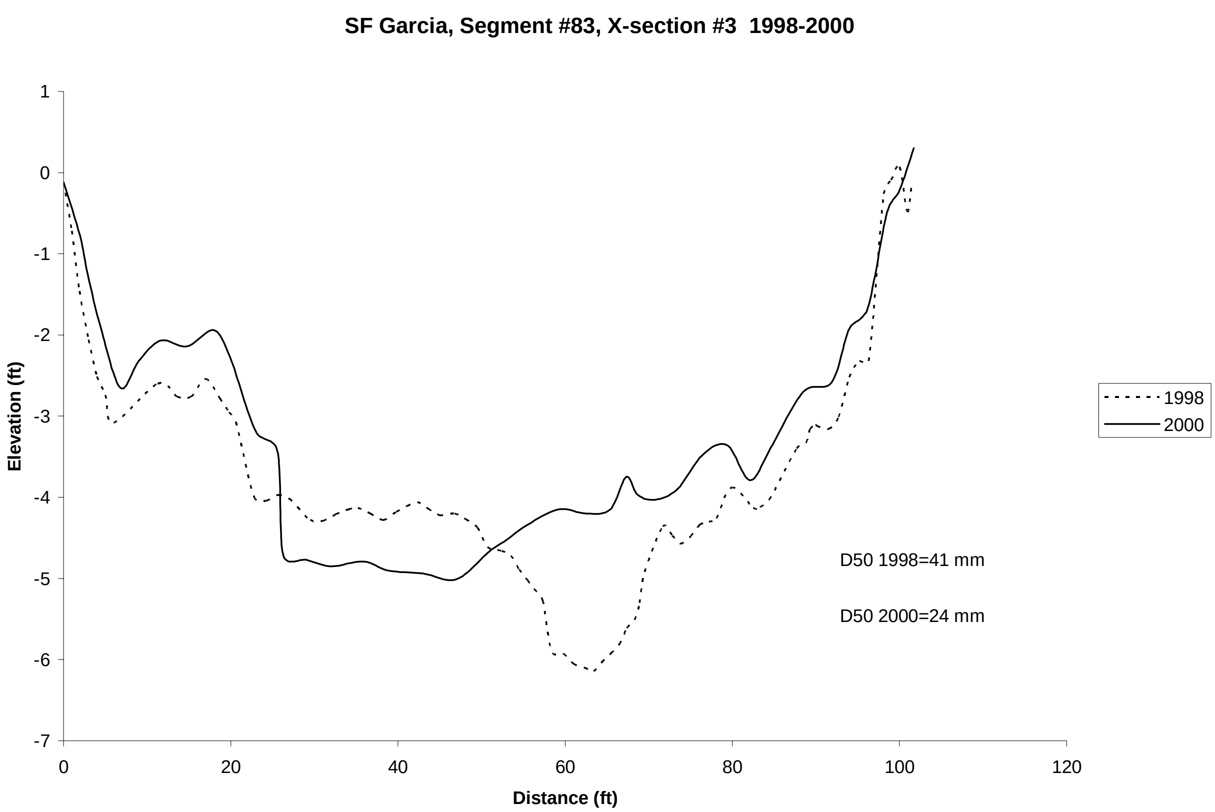
Rolling Brook, Segment #19, X-section #4 1998-2000



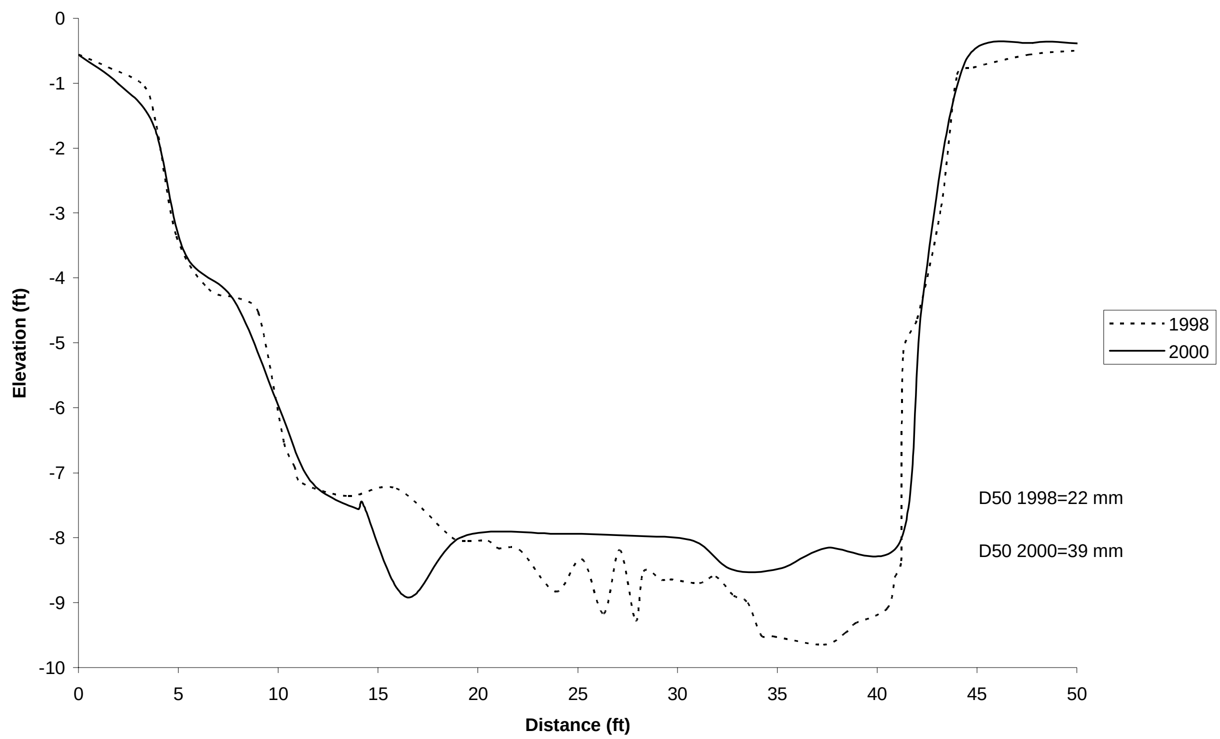
SF Garcia, Segment #83, X-section #1 1998-2000




SF Garcia, Segment #83, X-section #2 1998-2000
Elevation (ft)
Distance (ft)
4
3
2
1
0
-1
-2
-3
-4
0
20
40
60
80
100
120
1998
2000
D50 1998=49 mm
D50 2000=38 mm


SF Garcia, Segment #83, X-section #3 1998-2000
Elevation (ft)
Distance (ft)
1
0
-1
-2
-3
-4
-5
-6
-7
0
20
40
60
80
100
120
1998
2000
D50 1998=41 mm
D50 2000=24 mm

SF Garcia, Segment #86, X-section #1 1998-2000



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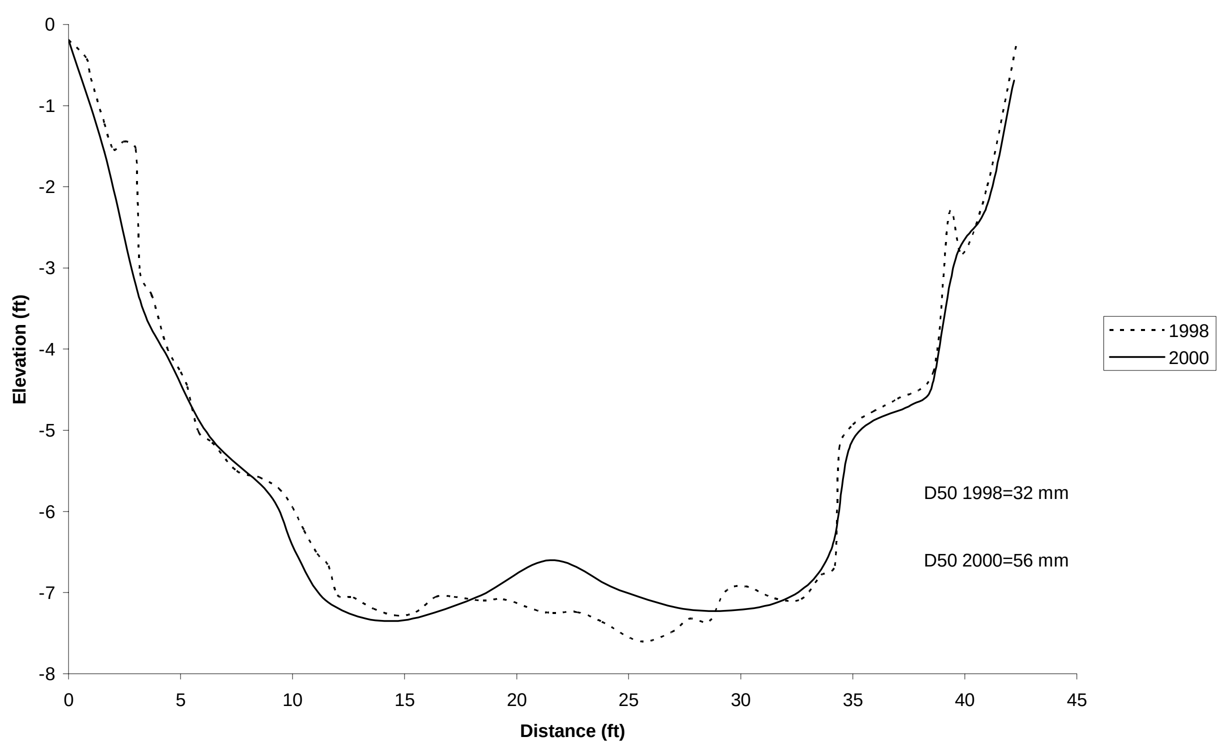
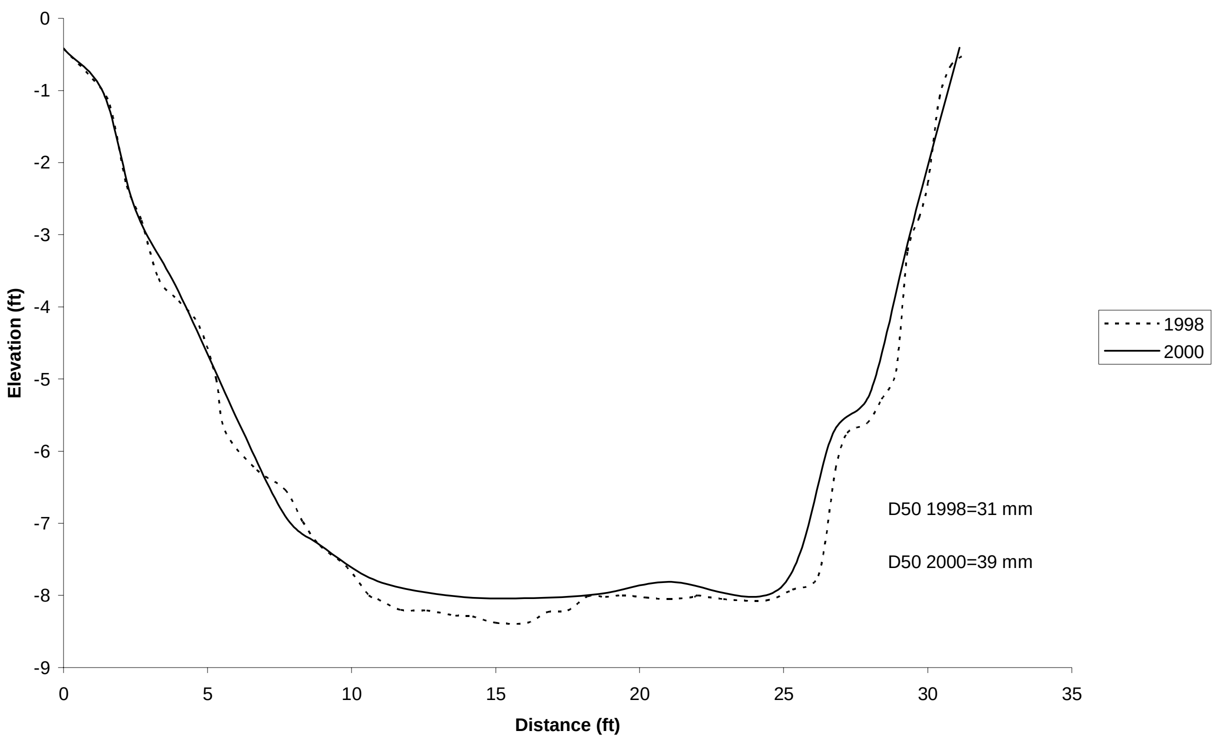
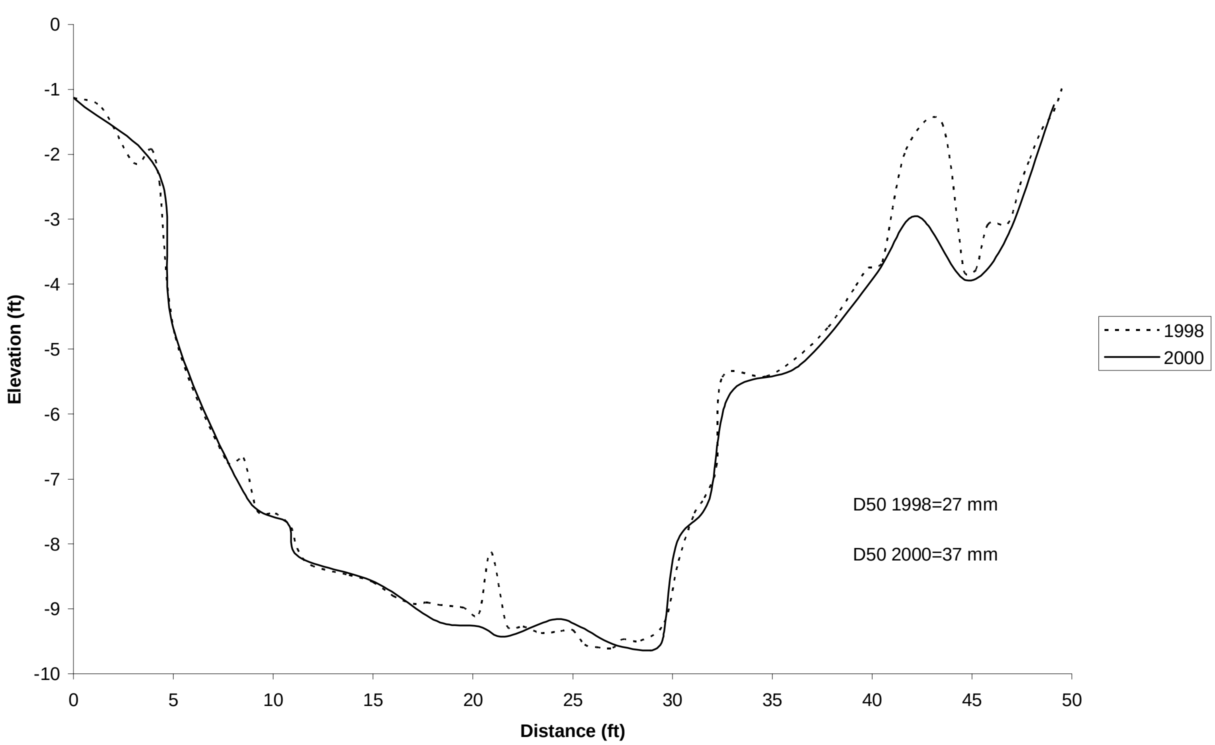
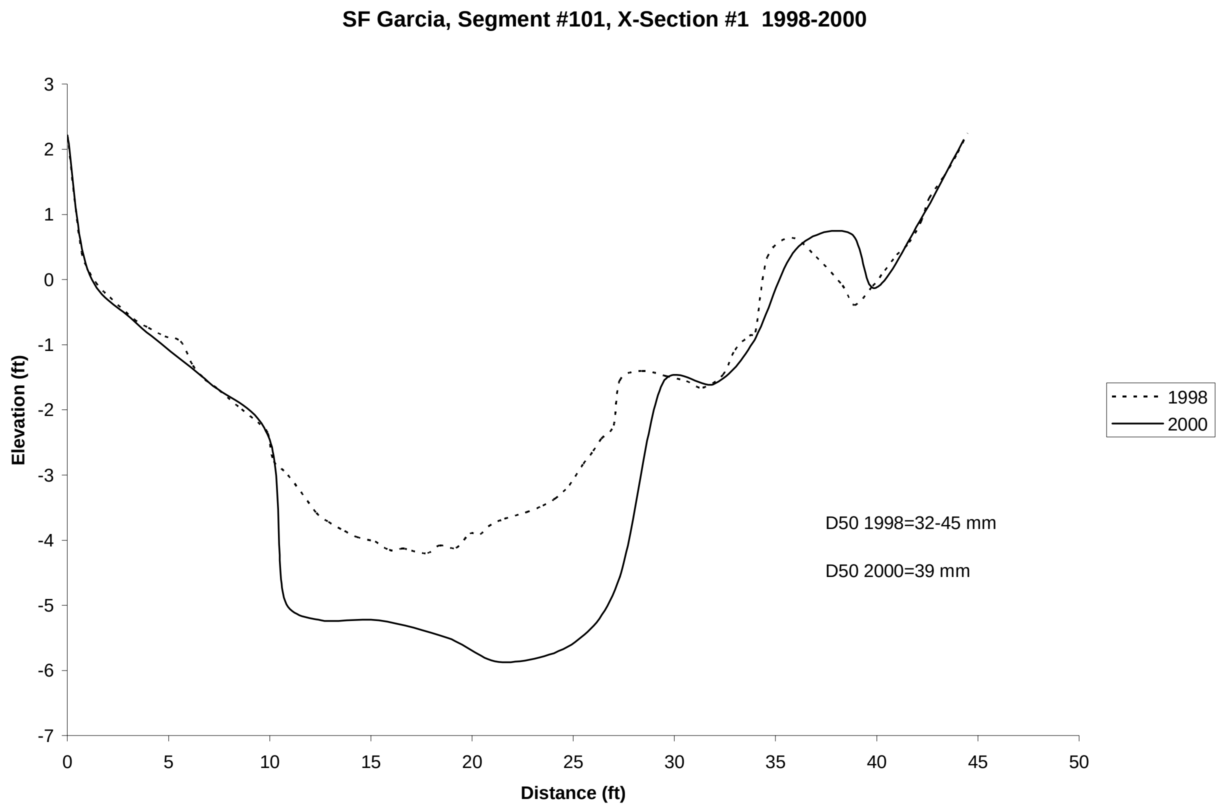


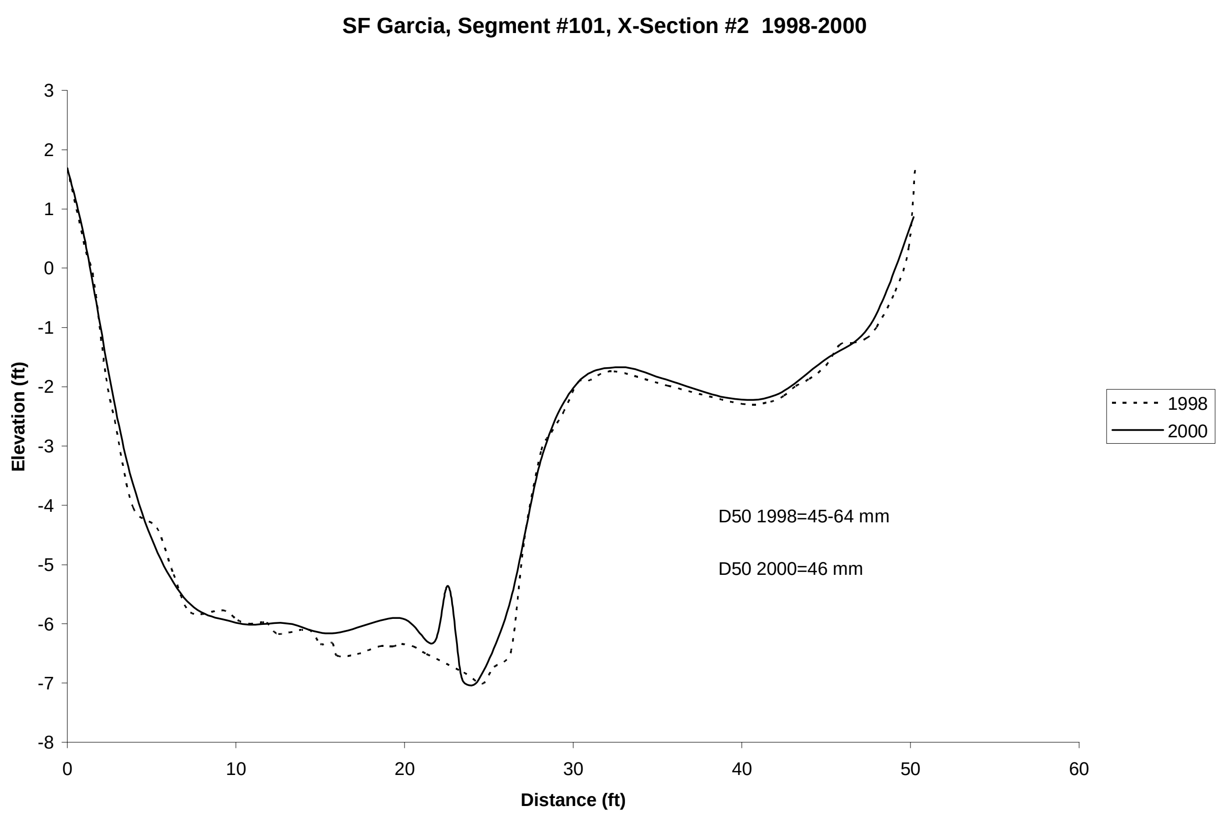
SF Garcia, Segment #86, X-section #3 1998-2000

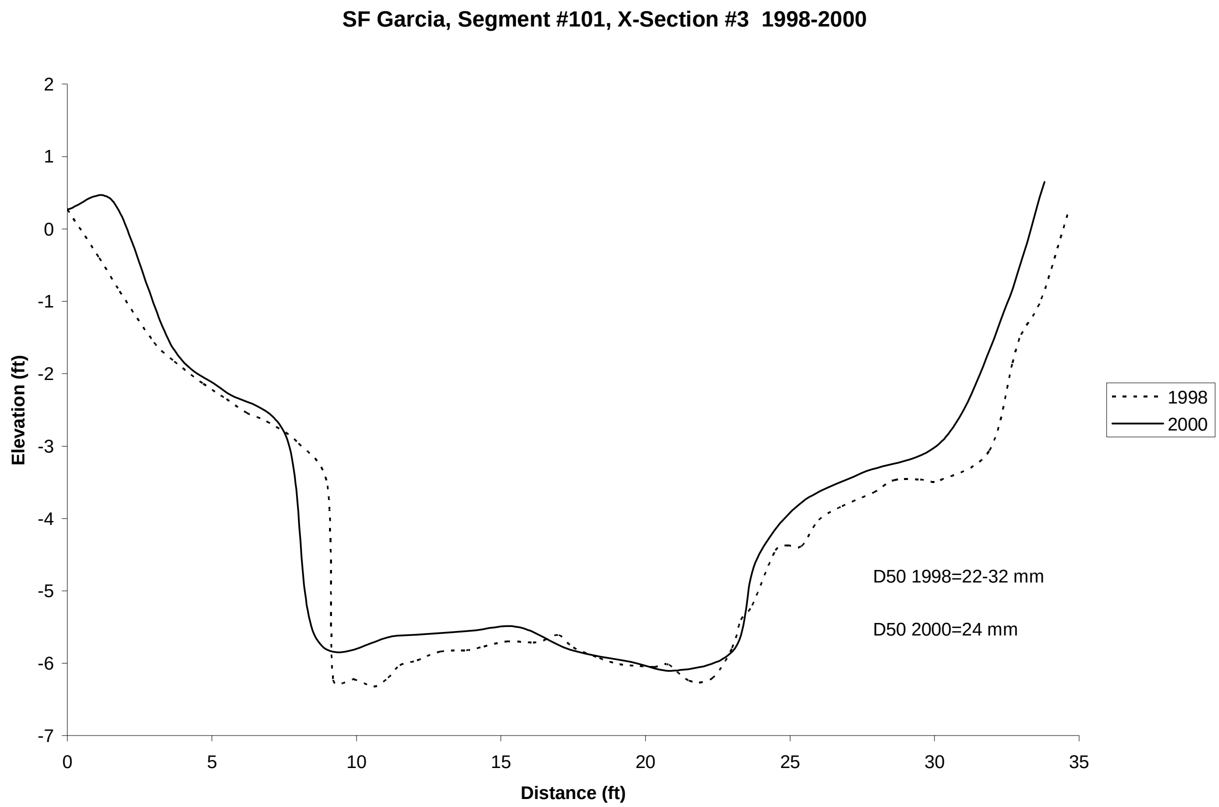


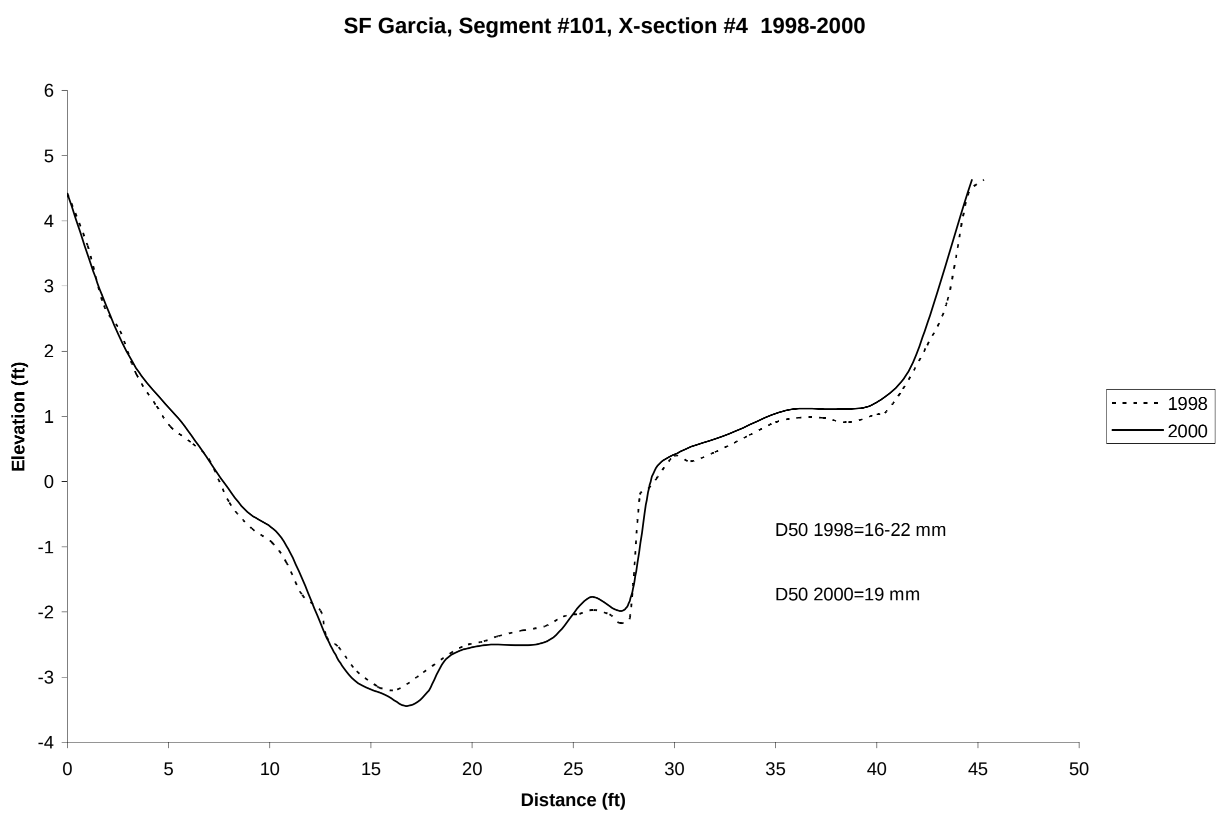
SF Garcia, Segment #86, X-section #4 1998-2000




SF Garcia, Segment #101, X-Section #1 1998-2000
Elevation (ft)
Distance (ft)
1998
2000
D50 1998=32-45 mm
D50 2000=39 mm
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
0
5
10
15
20
25
30
35
40
45
50


SF Garcia, Segment #101, X-Section #2 1998-2000
Elevation (ft)
Distance (ft)
1998
2000
D50 1998=45-64 mm
D50 2000=46 mm
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
10
20
30
40
50
60


SF Garcia, Segment #101, X-Section #3 1998-2000
Elevation (ft)
Distance (ft)
1998
2000
D50 1998=22-32 mm
D50 2000=24 mm


SF Garcia, Segment #101, X-section #4 1998-2000
Elevation (ft)
Distance (ft)
1998
2000
D50 1998=16-22 mm
D50 2000=19 mm