SECTION E
STREAM CHANNEL CONDITION

INTRODUCTION

This report provides the results of an assessment of the stream channels of the Mendocino Redwood Company (MRC) ownership in the Greenwood watershed analysis unit (WAU). The assessment was done following a modified methodology from the Watershed Analysis Manual (Version 4.0, Washington Forest Practices Board). The stream channel analysis is based on field observations and stream channel slope class and channel confinement information developed from a digital terrain model in the company's Geographic Information System (GIS).

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., 1986)

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 stream 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 that 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 current channel condition to provide for the evaluation of aquatic habitat conditions.

Stream Segment Delineation

The stream channel network for the Greenwood WAU was partitioned into stream segments based on three classes of channel confinement and several classes of channel gradient. These classifications were based on channel classifications prepared from digital terrain data in Mendocino Redwood Company's Geographic Information System (GIS). The slope classes used for delineation are 0-3%, 3-7%, 7-12%, and 12-20%. Channel confinement was classified by confined, moderately confined, and unconfined. Confined channels have a valley to channel width ratio of <2, moderately confined channels have a valley to channel width ratio of <4, and unconfined channels have a valley to channel width ratio of >4.

Channel segments were delineated based on either a change in slope class or change in channel confinement. The channel segments were numbered with a two letter code, corresponding to the planning watershed the channel segment is located, followed by a unique number (*1 through n* for each planning watershed). For the Greenwood WAU data, channels for 2 planning watersheds are delineated. The delineated stream segments are shown on Map E-1.

Field Measurements and Observations

Selection of field sites for stream channel observations was based on gathering a sample of response (0-3% gradient) and transport (3-20% gradient) channels from each planning watershed of the WAU. No attention was focused on the source reaches (>20% gradient), these reaches are analyzed only for sediment source hazard in the mass wasting module of this watershed analysis.

For each channel segment the bankfull width, bankfull maximum depth, bankfull average depth, floodprone depth, floodprone width, and channel bankfull width to depth ratio are measured at a cross section representative of the channel segment. A pebble count of 50 randomly selected pebbles is counted at the cross section to determine the D50 (median particle size) of the streambed. Streambed sediment characteristics are interpreted from observations of gravel bars, amount of fine sediments observed and particle size of the stream bed material. The segment is classified by morphology types based on Montgomery and Buffington (1993) and Rosgen (1994). The channel morphology is further interpreted by flood plain interaction (continuous, discontinuous, inactive, none) and channel roughness characteristics. Large woody debris (LWD) functioning in the channel is evaluated (presented in Section D, Riparian Function). The number and type of pools (LWD forced, bank forced, boulder forced, free formed) are observed. The field observations are summarized and defined in Table E-1.

Geomorphic Units

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 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.

Interpretations related to sediment supply, transport capacity and LWD response were the basis for development of sensitivity of geomorphic units to coarse sediment, fine sediment and LWD inputs. These interpretations were based primarily on the morphology of the channel along with existing condition of the stream channels.

Long-Term Stream Monitoring Sites

To monitor stream channel morphology conditions and stream sediment characteristics related to fish habitat, 2 long-term stream channel monitoring segments were established in the Greenwood WAU. Along these segments thalweg profiles, cross sections and streambed D50 measurements were surveyed. Stream gravel bulk samples and permeability of spawning gravels were measured on one of the channel monitoring segments in Upper Greenwood Creek (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 fish habitat conditions. Observations along these 2 long-term channel monitoring segments were taken in 2001 and 2003. Surveys of LWD within these long term monitoring segments were included in the 2003 surveys. The long-term stream channel monitoring segment locations are shown on Map E-1.

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 cemented into the ground adjacent to the nail.

The thalweg profile is a survey of 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 distance along the channel is measured and the elevation is recorded. In the absence of visually apparent changes, thalweg measurements are taken every 20-25 feet along the channel. A profile graph of the channel’s thalweg is created from the survey (see Appendix E for Thalweg profiles from the Greenwood WAU). A computer program (Longpro 2.0 for Windows) 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 thalweg 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 thalweg profile, 3 channel cross sections on Lower Greenwood Creek and 4 channel cross sections on Upper Greenwood Creek 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 Greenwood Creek). 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

Stream Channel Observations

Field channel surveys or observations were taken on 16 stream segments in the Greenwood WAU during the summers of 2003. Of those 16 segments 13 had all channel survey variables collected, 3 had only select observations. Table E-1 provides a summary of the data collected. Further detail specific to in-channel fish habitat relationships is found in Section F - Fish Habitat Assessment. LWD inventoried and evaluated for stream channels is presented in Section D - Riparian Function of this watershed analysis.

Key to Table E-1.

Stream Channel Dimensions

Category	Description
ID #	The stream identification number (see Map E-1), two letter planning watershed code followed by unique number for the planning watershed. CG- Lower Greenwood Creek CU- Upper Greenwood Creek
Geo Unit	Number of the geomorphic unit the channel segment is in.
Confinement	confined=channel width to valley width ratio < 2; moderately confined=channel width to valley width ratio 2-4; unconfined=channel width to valley width ratio >4.
Surveyed Length	Length of segment surveyed.
GIS slope class	Slope class as designated by DTM in GIS.
Observed Slope	Mean slope of segment as observed in field.
Max Bankfull Depth	Maximum bankfull depth of representative cross section.
Average Bankfull Depth	Average bankfull depth of representative cross section.
Bankfull width	Bankfull width of representative cross-section.
Width/Depth Ratio	Ratio of bankfull channel width to average bankfull depth.
Floodprone depth	Maximum depth during flooding, estimated by 2 times max. bankfull depth (Rosgen, 1996).
Floodprone width	Width of water at floodprone depth (Rosgen, 1996).
Entrenchment Ratio	Ratio of floodprone width to bankfull channel width.

Sediment/Bedform Characteristics

Category	Description
Mont/Buff	The channel morphology type based on Montgomery and Buffingtion (1993): PR = pool/riffle, FP/R = forced pool/riffle, SP = step pool, PB = plane bed, CAS = cascade
Rosgen	Rosgen channel morphology classification, (Rosgen, 1994).
Floodplain	Description of floodplain/channel interaction either: C=continuous, I=inactive, D=discontinuous or none.
Roughness	B =boulders, C=cobbles, F=bedforms, V=live woody veg., LWD=large woody debris., R=bedrock, Bk=banks and roots.
Gravel Bar Abun.	Qualitative measure of amount of gravel bars in segment. F= few, C=common, A=abundant
Gravel Bar Type(s)	Gravel bar type either: A=alternating point bars, P=point, M=medial, or F=forced.

Gravel Bar Class	Proportion of stream segment in gravel bars: 0-25%, 25-50%, 50-75%, 75-100%.
Fine Sediment Abun.	Observation of amount of fine sediments S=sparse, M=moderate, A=abundant
Fine Sediment Type	type of fine sediment accumulation: P=isolated pockets, M=moderate accumulations, B=high accumulations including in gravel bars.
D50	Median gravel size of the stream bed particle distribution at representative cross section.

Pool Characteristics

Category	Description
Free	number of free formed pools in segment.
LWD Forced	number of LWD forced pools in segment.
Boulder Forced	number of boulder forced pools in segment.
Bank Forced	number of bank forced pools in segment.
Total # Pools	total number of pools in segment.
Pool Spacing	average space between pools by bankfull widths.
Mean Res. Pool Depth	The average of all residual pool depths in segment.

Table E-1(a). Stream Channel Dimensions for Select Stream Channel observations for Greenwood WAU, 2003.

Stream Name	ID #	Geo Unit	Confinement	Survey Length (ft)	GIS Slope Class	Observed Channel Slope	Max. Bankfull Depth (ft)	Average Bankfull Depth (ft)	Bankfull Width (ft)	Width/ Depth Ratio	Floodprone Depth (ft)	Floodprone Width (ft)	Entrenchment Ratio
Greenwood Creek	CU2		Confined	1020	0-3%	≈2%	3.8	2.6	40	15.4	7.6	65	1.6
Valente Gulch	CU6		Confined	630	0-3%	3.1%	2.3	1.75	17.3	9.9	4.6	30	1.7
Valente Gulch	CU9		Confined	-	-	15-23%	-	-	-	-	-	-	-
Tributary to Valente Gulch	CU7		Confined	-	-	15-22%	-	-	-	-	-	-	-
Big Tree	CU12		Confined	330	>15%	15%	2.1	1.1	9.8	8.9	4.2	12	1.2
Greenwood Creek	CU4		Confined	1175	0-3%	≈2%	2.7	2.1	20.7	9.9	5.4	35	1.7
Big Tree	CU10		Confined	350	7-12%	5%	1.6	1.1	8.3	7.5	3.2	14.0	1.7
Greenwood Creek	CG4		Confined	1450	0-3%	≈3%	2.9	2	40.4	20.2	5.8	52	1.3
Barn Gulch	CG30		Confined	350	7-12%	3.2%	2.4	1.9	8.9	4.7	4.8	15	1.7
Greenwood Creek	CG6		Confined	1300	0-3%	1.1%	2.7	1.9	41.9	22.1	5.4	56	1.3
Unnamed	CG16		Confined	500	0-3%	≈3%	2.7	2.4	9.9	4.1	5.4	17	1.7
Unnamed	CG17		Confined	-	3-7%	1-2%	-	-	-	-	-	-	-
Corrals Tributary	CG25		Confined	580	3-7%	2.1%	1.9	1.3	15.9	12.2	3.8	18	1.1
Corrals Tributary	CG26		Confined	500	3-7%	3.7%	2	1.3	13	10.0	4.0	23	1.8
Corrals Tributary	CG27		Confined	400	>7%	9%	1.6	1.1	14	12.7	3.2	18	1.3
Greenwood Creek	CG1		Confined	1075	0-3%	1.6%	4.2	2.85	52.2	18.3	8.4	110	2.1

Table E-1(b). Stream Channel Sediment Bedforms and Pool Characteristics for Select Stream Channel Observations for Greenwood WAU, 2003.

ID #	Sediment/Bedforms									Pool Characteristics						
	Mont/Buff	Rosgen	Floodplain	Roughness	Gravel Bar type(s)	Gravel Bar Class	Fines/ Abun	Fines/ Type	d50 (cm)	LWD Pools #	Bldr. Pools #	Bank Pools #	Free Formed Pools #	Total Pools #	Pool Spacing	Mean Residual Depth (ft)
CU2	PR/CAS	Bc3/B3/B2	D	B-R	P-F	0-25%	M	B	71	0	4	4	2	10	2.6	2.5
CU6	PR/FPR/ CAS	G4/A1	D	C-B-F-R	P-F	25-50%	M	M	59	2	2	5	0	9	4.0	1.8
CU9	CAS	A3/A2	D	B-C-R- LWD	F	0-25%	M	M	-	-	-	-	-	-	-	1.7
CU7	CAS/FPR	A4	N	LWD-B-R	F	25-50%	M	M	-	-	-	-	-	-	-	-
CU12	CAS/SP	A3/G3	N	B-C-LWD	F	0-25%	S	M	-	1	7	0	0	8	4.2	-
CU4	PR/SP	Bc3/Bc4	D	B-C-R	P	0-25%	S	M	81	0	8	7	5	20	2.8	3.7
CU10	FPR	A4/G4	N	B-LWD	F	25-50%	M	M	46	3	3	2	0	8	5.3	1.8
CG4	PR	Bc4/F4	D	F-R-B	P-M	25-50%	S	P	48	1	2	4	3	10	3.6	3.2
CG30	CAS/FPR	G4/A1	N	R-F	F-P	25-50%	M	M	38	1	0	3	4	8	4.9	1.5
CG6	PR	Bc4/F4	D	C-B-R	P-M	0-25%	M	B	16	0	1	1	4	6	5.2	-
CG16	FPR	G4	D	W-B-F	F	25-50%	M	M	32	4	4	3	0	11	4.6	1.2
CG17	P/R	E4/G4	C	V-BK- LWD	F	0-25%	A	B	-	-	-	-	-	-	-	-
CG25	PR/FPR	G4/G1/B4	N	C-R-LWD	P-F	0-25%	S	P	51	4	1	8	6	19	1.9	1.8
CG26	FPR	B4	D	C-B-LWD	F	0-25%	S	P	39	2	2	1	3	8	4.8	1.7
CG27	CAS	A3/B3	N	B-R-LWD	F	0-25%	S	P	80	3	10	0	0	13	2.2	-
CG1	PR/SP	Bc3/F3	D	B-C-R	P	25-50%	M	M	144	1	5	0	2	8	2.6	3.3

Stream Geomorphic Units

Stream geomorphic units were developed for the stream network on the MRC property in the Greenwood watersheds. These units are general representations of stream channels with similar sensitivities to coarse sediment, fine sediment and large woody debris inputs. Five stream geomorphic units were developed for interpretation of stream channel response to forest management interactions in the Greenwood WAU. The five stream geomorphic units are described below.

Geomorphic Unit I. Confined Low Gradient Channels.

Segments: CG1, CG2, CG3, CG4, CG5, CG6, CU1, CU2, CU3.

General Description:
The channels within this unit meander through confined canyons. The channels of this unit have their bed and banks frequently controlled by bedrock. Hillslopes control the lateral movement of the channels; some inner gorge topography is found along sections of the channel. Though highly confined the river channels exhibit some occasional floodplain development, though discontinuously. The bankfull channel varies from approximately 25-50 feet in width. The channels in this unit exhibit responsive or depositional channel gradients (0-3 percent), but sediment transport capacity is moderately high due to the confined channel keeping water energy directed within the channel with relatively large drainage areas producing greater water flow.

Associated Channel Types:
This unit primarily exhibits pool/riffle morphology, isolated areas of step pools and cascades were observed. The Rosgen classification (Rosgen, 1996) for these channels exhibit B2, B3, Bc3, Bc4, F3, and F4 morphologies. The F type morphology occurs from high entrenchment within the canyon, not entrenchment within alluvial materials.

Fish Habitat Associations:
The confined channels of this unit have a high sediment transport capacity during high flows, which flushes fine sediment, with the potential to create high quality spawning gravel. This same high-energy transport, in conjunction with bedrock and LWD, dominates pool development. Currently this unit has low amounts of large woody debris, however due to the confined canyons, wood recruitment would have a positive effect on the quality of in-stream habitat by providing the shelter associated with pools and the stream habitat more complex. Over-wintering habitat is facilitated by bedrock that creates deep pools but can be limited in areas without this. LWD when present in this unit provides an important source of over-wintering habitat for juvenile salmonids.

Conditions and Response Potential

Coarse Sediment: Moderate Response Potential
These channels are depositional areas for coarse sediment due to their low gradient. The high confinement of these channels creates relatively high sediment transport capacity. If the supply of coarse sediment surpasses the transport capacity of the stream, pools can be filled, and the influence of large woody debris and bedrock controlled sections are lessened. The width to depth ratios of these channels is high. If significant amounts of coarse sediment are supplied to these channels then the channels are vulnerable to aggradation. Because the channels are typically entrenched within the canyon the tendency toward widening or adjustments in meanders is minimal.

Fine Sediment: Moderate Response Potential
The channels of this unit have high fine sediment transport capacity due to high flow capacity of the channel. However, when there is a high fine sediment supply in transport, accumulations of fine sediment do occur in this unit. Sparse to moderate accumulations of fine sediment was observed in this unit. These accumulations were observed in the gravel bars, along channel margins, and in some pools.

Large Woody Debris (LWD): High Response Potential
Large woody debris is at low levels in this unit. The LWD that is present is providing stream habitat development and cover. The confined high energy flow and large channels of this unit require very large LWD pieces or debris jams to keep the LWD in place. Very large LWD is recruited into channels infrequently due to the long growing times of streamside trees. However, LWD in this unit is important because the channels in this unit gain greater pool depths and cover, for fish habitat diversity, with increased LWD.

<u>Geomorphic Unit II.</u> Low Gradient Confined to Moderately Confined Transport Channels.

Segments: CG9, CG16, CG17, CG25, CG26, CU4, CU5, CU6.

General Description:
The channels within this unit flow through confined canyons. Hillslopes or alluvial terraces control the lateral movement of the channels. Some recent terraces development is present and floodplains are present, though discontinuously. The channels in this unit within moderately confined canyons were observed to be entrenched within alluvial materials. The bankfull channel is typically 10 and 40 feet in width. The channels are at the lower gradient range of transport channels and upper end of depositional channels. The gradients observed ranged from 2-5% (with isolated areas higher). These channels exhibit moderate sediment transport capacity. Localized areas of high gradient cascade morphology can be found within this unit, however these areas area infrequent. The confined channel keeps water energy directed within the channel but the relatively smaller drainage areas does not produce as much water energy from surface flow as Unit I.

Associated Channel Types:
This unit primarily exhibits step pool and forced pool/riffle morphology; areas of pool/riffle and cascade morphology are found. The Rosgen classifications (Rosgen, 1996) for these channels are primarily G4 and B4, with areas of G1, A1, A4, Bc3, and Bc4.

Fish Habitat Associations:
These channels are confined within narrow canyons producing good recruitment potential for LWD. The recruited LWD in turn facilitates pool development and offers shelter. Rearing habitat availability can be good where sufficient LWD creates good pool habitat and shelter, however summer rearing can be absent because some of the streams in this unit can go subsurface during the summer rearing period. Young fish would have to migrate to other areas to survive through the summer months. Over-wintering habitat is provided by large cobble/boulder and bedrock substrates. LWD when present in this unit also provides over-wintering habitat for juvenile salmonids.

Conditions and Response Potential

Coarse Sediment: Moderate Response Potential
These channels are on the transition from transport to depositional areas for coarse sediment. The moderate gradient makes these channels vulnerable to changes in supply of coarse sediment. Fluctuations of coarse sediment can occur that will surpass the transport capacity of the stream. When this occurs pools can be filled, the influence of large woody debris and bedrock controlled sections are lessened and the channels can aggrade. Aggradation of the channel can create greater bank erosion in the entrenched reaches or produce limited lateral movement increasing localized bed scour thus causing the channels to entrench further.

Fine Sediment: Moderate Response Potential
The channels of this unit have sufficient flow energy due to the moderate channel gradients to transport fine sediments. However, when there is a high fine sediment supply in transport, accumulations of fine sediment do occur in this unit. Accumulations of fine sediment were observed in this unit. These accumulations were observed in the gravel bars, along channel margins, and in some pools.

Large Woody Debris(LWD): High Response Potential
The alluvial composition of the bed material in conjunction with moderate gradient channels makes these channels highly responsive to LWD inputs. LWD is a dominant influence for forcing pool development, sediment storage behind LWD accumulations and stabilization of bank and bed-forms within the channels in this unit. For the most part LWD levels are below desired targets; additional LWD will greatly enhance the aquatic environment.

Geomorphic Unit III. Moderate Gradient Confined Transport Channels

Segments: CG27, CG30, CG31, CU10.

General Description:
Typically stream channel segments in this unit are confined within canyon walls though widths are locally sufficient to allow some isolated terrace formation and channel meandering. The channel segments in this unit are transport channels. Due to the moderate gradient (3-10 percent, though higher gradients do occur in this unit) of the channels, they are responsive to aggradation and degradation from changes in the stream sediment supply. The bed of the stream of these channels varies from gravel to boulder sized particles. The terraces in this unit appear to be created from large episodic sediment loads such as mass wasting. The gradient of the stream is high enough that stream segments in this unit easily down-cut through the terrace deposits when flow is concentrated.

Associated Channel Types:
This unit primarily exhibits forced pool/riffle and cascade morphology. The Rosgen classifications (Rosgen, 1994) for these channels vary from G3, G4, A4, and A1.

Fish Habitat Associations:
Spawning areas in this unit are infrequent, due to lack of accumulations of gravel sized particles. The steeper gradient segments of this unit typically form step-pool, cascade, and some pool-riffle habitat. The cascades are LWD or boulder formed which provide both rearing and over-wintering habitat.

Conditions and Response Potential

Coarse Sediment: Moderate Response Potential
The channels in this unit have relatively high sediment transport capacity. In the lower gradient sections of these channels coarse sediment can create pool filling and aggradation, resulting in increased bank erosion and poor stream habitat. The cascade sections of these channels have relatively stable cobble and boulder components that can remain static except in extreme flows. Increased coarse sediment supply can create pool filling, but is only moderately influential on the morphology because pool filling at these moderate gradients creates lower channel roughness which in turn promotes increased sediment transport, provided high inputs of coarse sediment subside.

Fine Sediment: Moderate Response Potential
The channels of this unit have high fine sediment transport capacity due to high flow capacity of the channel. However, when there is a high fine sediment supply in transport, accumulations of fine sediment do occur but typically have short residence times in this unit. Moderate accumulations of fine sediment were observed in this unit. These accumulations were observed in the bed and along channel margins.

Large Woody Debris: Moderate Response Potential
The high confinement or entrenchment of these channels provides little opportunity for the channel to meander or develop a floodplain. Water energy is concentrated within the confines of canyon walls or stream banks making the role of LWD less sensitive. LWD is less likely to enter the channel because it becomes suspended over the channels narrower bankfull width. The role of LWD is typically as sediment storage or forced pool development in these channels. Bed

morphology in channels with slope gradients of 4-10% is typically step pool or cascades (Montgomery and Buffington, 1993). The large bed forming material of step pool morphology is generally stable making the role of LWD in these channels less sensitive than other channel types.

<u>Geomorphic Unit IV.</u> High Gradient Transport Channels.

Segments: CG7, CG8, CG10, CG1, CG12, CG13, CG14, CG15, CG18, CG19, CG20, CG21, CG22, CG23, CG24, CG28, CG29, CG32, CG33, CG34, CG35, CG36, CG37, CG38, CG39, CG40, CG41, CG42, CG43, CG44, CU7, CU8, CU9, CU11, CU12, CU13, CU14, CU15, CU16, CU17, CU18, CU19, CU20, CU21, CU22, CU23, CU24.

General Description:
Channel segments in this unit are high gradient transport reaches from 8-20% with high sediment transport capacity. The channel segments in this unit typically flow through tightly confined, steep canyons. However, many of the channels are located in more open or U-shaped colluvial and alluvial filled canyons. The channels tend to be highly entrenched in these areas making them as confined as channels directly adjacent to hillslopes. These are typically zones of scour during high flows or debris flows. Stream substrate is typically from cobble to large boulders. Typically, there is little to no water flow in this unit in the summer drought season.

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 and only during winter storm events. The Rosgen (Rosgen, 1996) classification for these channels varies between A2, A3, A4 and isolated lower gradient areas observed to have G4 morphology.

Fish Habitat Associations:
The high gradient channels of this unit prevent coho salmon from accessing these areas. Potential for steelhead trout utilization is low due to the high gradient; 8% to 20%. Rearing would be unlikely because stream flow typically goes subsurface in the summer months.

Conditions and Response Potential

Coarse Sediment: Low Response Potential
Typically the channel morphology in this unit is cascade, with some step pool morphology at the lower gradients observed in these channels. These channels have bed material that is coarse and relatively immobile. Down cutting or bank erosion are not common in these high gradient, large substrate dominated channels even with increases in sediment supply. Debris flows can cover the substrate creating the cascade morphology but this is generally short-lived due to the high sediment transport capacity of the channels.

Fine Sediment: Low Response Potential
The high gradient of the channels in this unit creates a high fine sediment transport capability. Pools or storage areas for fine sediment in these channels are limited making the impacts from fine sediment minimal. Down cutting or bank erosion can be common in these high gradient, large substrate dominated channels though typically this erosion is transported downstream.

Large Woody Debris: Low Response Potential
The role of LWD in these channels is to provide storage of sediment and also as a source for downstream LWD. LWD is needed in these channels however the need for LWD as a source for downstream LWD is episodic and therefore the least sensitive as other channel types. The storage of sediment by LWD in these channels is necessary, but can be accomplished by a range of size classes of LWD not necessarily very key LWD pieces.

Long Term Stream Monitoring

In 2001 and 2003 two long term channel monitoring segments were surveyed for longitudinal profiles, channel cross sections, and particle size distributions in the Greenwood WAU. In 2003 large woody debris was included in the longitudinal profile observations. The plots of the surveys are included in the appendix of this module (Appendix E). Stream gravel bulk samples and permeability were collected in the Upper Greenwood Creek segment and are presented in Section F - Fish Habitat Assessment of this report.

Table E-2 presents the statistics calculated for each of the longitudinal profiles. The mean residual depth and standard deviation of the residual depths provide the best indication of aquatic habitat conditions over time. An increase in the mean and standard deviation of residual depths indicates deeper pools and increased complexity of the stream channel profile. In the channel monitoring segments from Greenwood Creek a slight trend is toward a decreased mean and standard deviation of residuals depths. However, there is a lot of variability between the two years, future observations need to watch this trend.

Table E-2. Comparison of Residual Depth Observations for Longitudinal Profiles of Long-Term Channel Monitoring Segments of the Greenwood WAU for 2001 and 2003.

Segment ID	Stream	Year	Maximum Residual Depth (ft)	Mean Residual Depth (ft)	Standard Deviation
CG1	Lower Greenwood Creek	2001	2.7	0.47	0. 59
CG1	Lower Greenwood Creek	2003	2.67	0.6	0.68
CU1	Upper Greenwood Creek	2001	7.56	0.91	1.32
CU1	Upper Greenwood Creek	2003	5.84	0.85	1.19

Cross sections and longitudinal profile graphs for the long term channel monitoring segments show some fluctuations in depth and channel shape over time (see graphs in Appendix E). There is a slight increase in the bed elevation, suggesting some aggradation occurring between 2001 and 2003. At each of the cross sections the particle size distribution of the stream bed has been observed through pebble counts (see graphs in Appendix E). Table E-3 presents one statistic of the stream bed particle size distribution, the median particle size (D50), to allow comparison of the observations over time. Generally, the D50 of the stream bed at the cross sections in the Greenwood WAU have shown a slight increase. However, in each stream segment there is one cross section with a decrease in the D50. There is variability in the observations and the increase in D50 is modest. An increase of the D50 can indicate a coarser particle size distribution of the stream bed over time, or in other words less fine particles. An increase in fine particles is usually considered detrimental as it can indicate a high sediment load.

Table E-3. Median Particle Size (D50) for Stream Bed from Pebble Counts at Cross Sections (XS) within Long-Term Channel Monitoring Segments of the Greenwood WAU for 2001 and 2003.

Segment ID	Stream	Year	XS1 D50 (mm)	XS2 D50 (mm)	XS3 D50 (mm)	XS4* D50 (mm)
CG1	Lower Greenwood Creek	2001	48	30	64	-
CG1	Lower Greenwood Creek	2003	45	70	97	-
CU1	Upper Greenwood Creek	2001	11	38	37	45
CU1	Upper Greenwood Creek	2003	23	45	56	28

* Lower Greenwood Creek only had 3 cross sections for monitoring

When combining the general observation of some slight channel aggradation observed in cross sections, a modest decrease in mean residual depth and standard deviations of residual depths, and a modest increase in the stream bed particle size distributions a conflicting trend emerges. Typically if a channel is aggrading (the bed elevation raising) it is due to increased sediment supply which also can be indicated through a finer particle distribution of the streambed, or a decrease in D50. In the case of Greenwood WAU observations we see slight aggradation between 2001 and 2003 yet a coarser bed. Albeit the trend is slight and needs to be watched for a longer time frame. The inclusion of LWD observations in the long term channel monitoring segments (2003 was first time for LWD observations) will assist with future interpretations.

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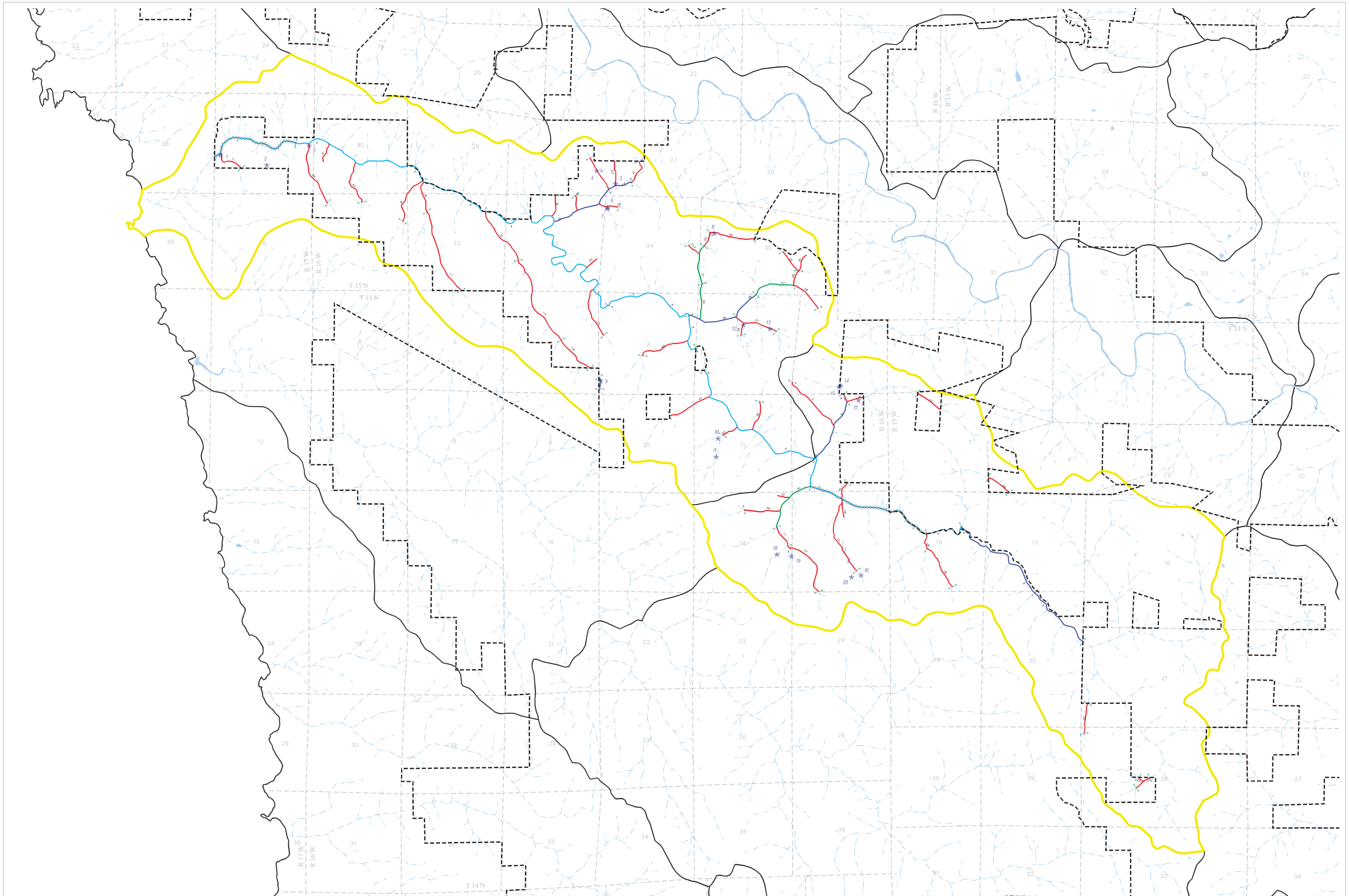
Appendix E

Stream Channel Condition Module



Greenwood Creek Watershed Analysis Unit

Map E-1 Stream Channel Geomorphic Units and Segments

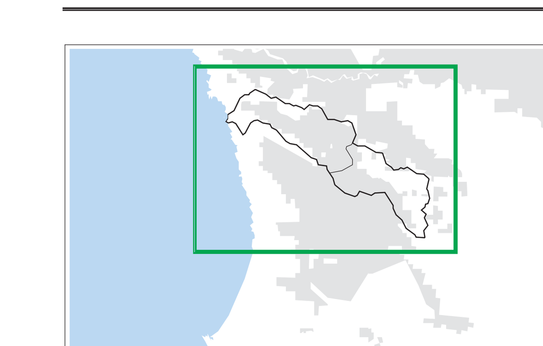
This map presents the stream channel network for the Greenwood WAU partitioned into stream segments based on channel confinement and channel gradient. Channel segments were grouped into geomorphic units by similar attributes of channel condition, position in the drainage network, and gradient/confinement classes. The intent of the geomorphic units are to stratify channel segments of the Greenwood 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 effects.

Geomorphic Classes

- Confined Low Gradient Channels
- Low Gradient Confined to Moderately Confined Transport Channels
- Moderate Gradient Confined Transport Segments
- High Gradient Transport Segments
- Long Term Channel Monitoring Sites
- Perennial Watercourse Evaluation Sites
- MRC Ownership
- Planning Watershed Boundary
- Greenwood Creek Watershed Boundary

Flow Class

- Class I
- Class II
- Class III



0 1/2 1 Mile

July 2004

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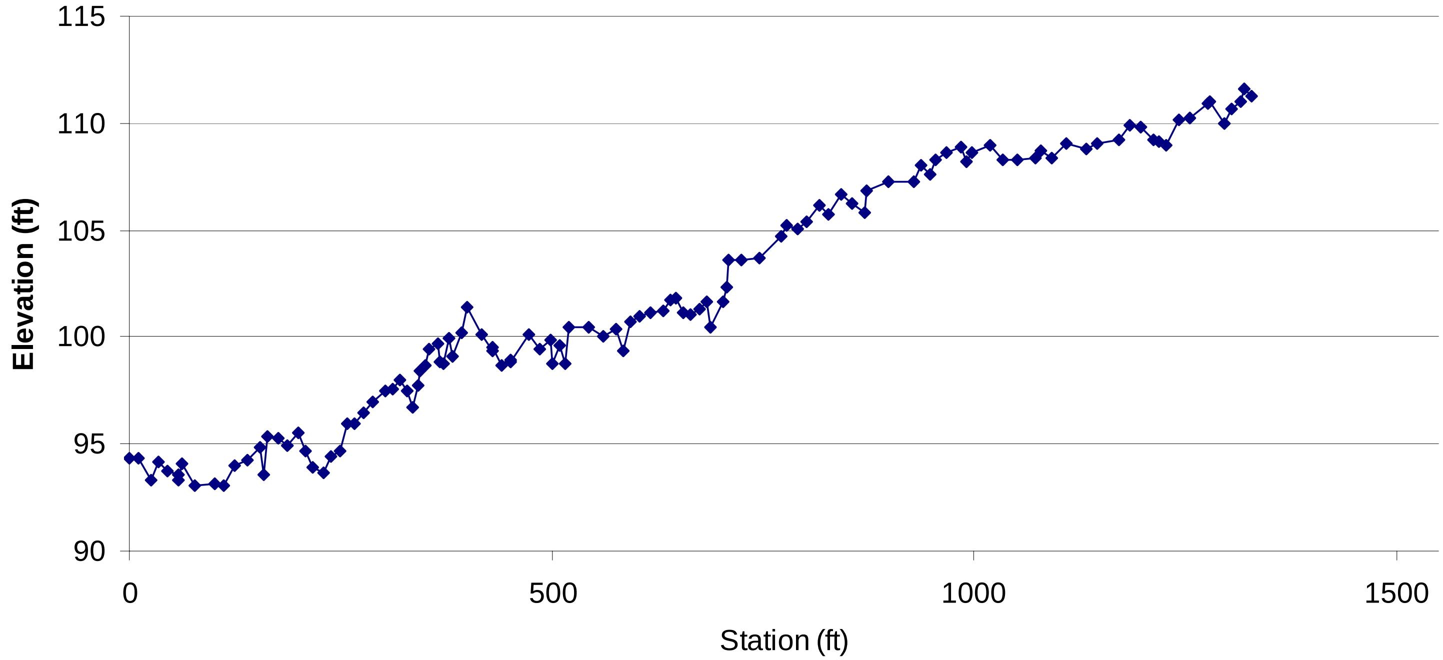
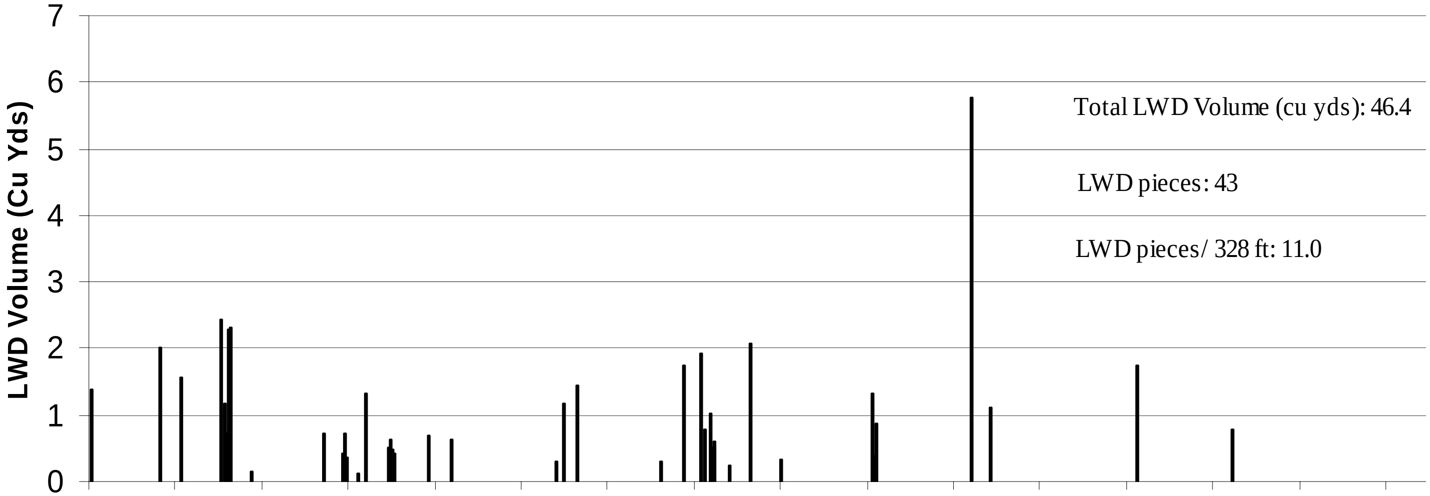
Lower Greenwood Creek Long Term Channel Monitoring Longitudinal Profile and Large Woody Debris, 2003
Stream Segment: CG1





Lower Greenwood Creek Long Term Channel Monitoring Segment (CG1)
September, 2003

Top Elevation: 111.56
Bottom Elevation: 93.03
Reach Length: 1318.00

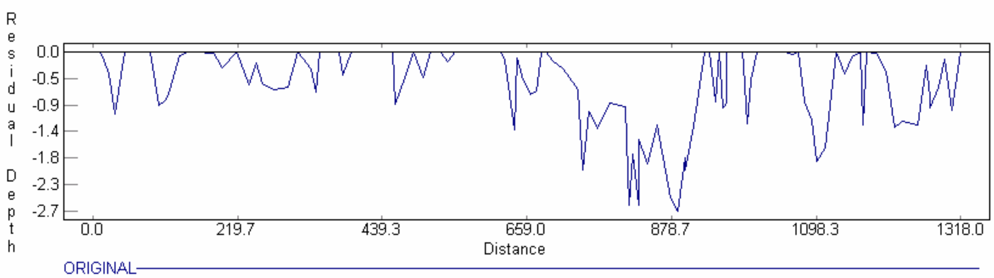
Standardized Statistics:
Number of data points in raw data: 119
Number of data points in Standardized data: 119

Reach Step Distance: 11.08

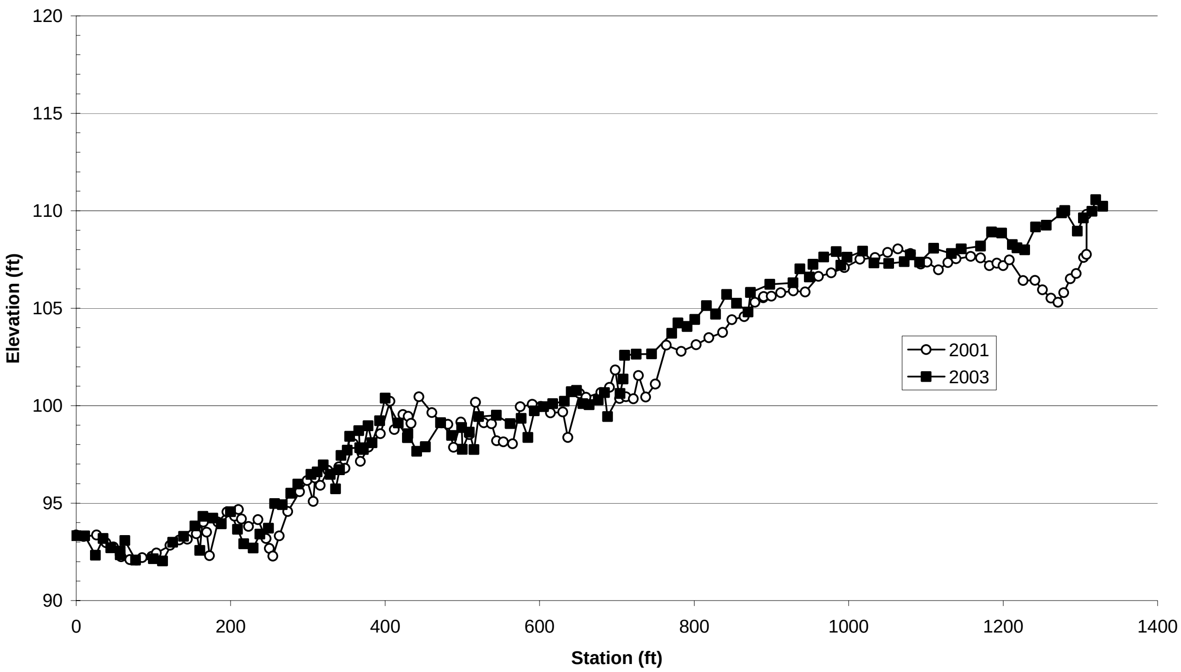
Max Residual Depth: 2.70
Mean Residual Depth: 0.47
Standard Deviation: 0.59

Number of non-zero Residual Depths: 78
Percent of Reach as pool: 65.55
Percent of Reach as riffle: 34.45

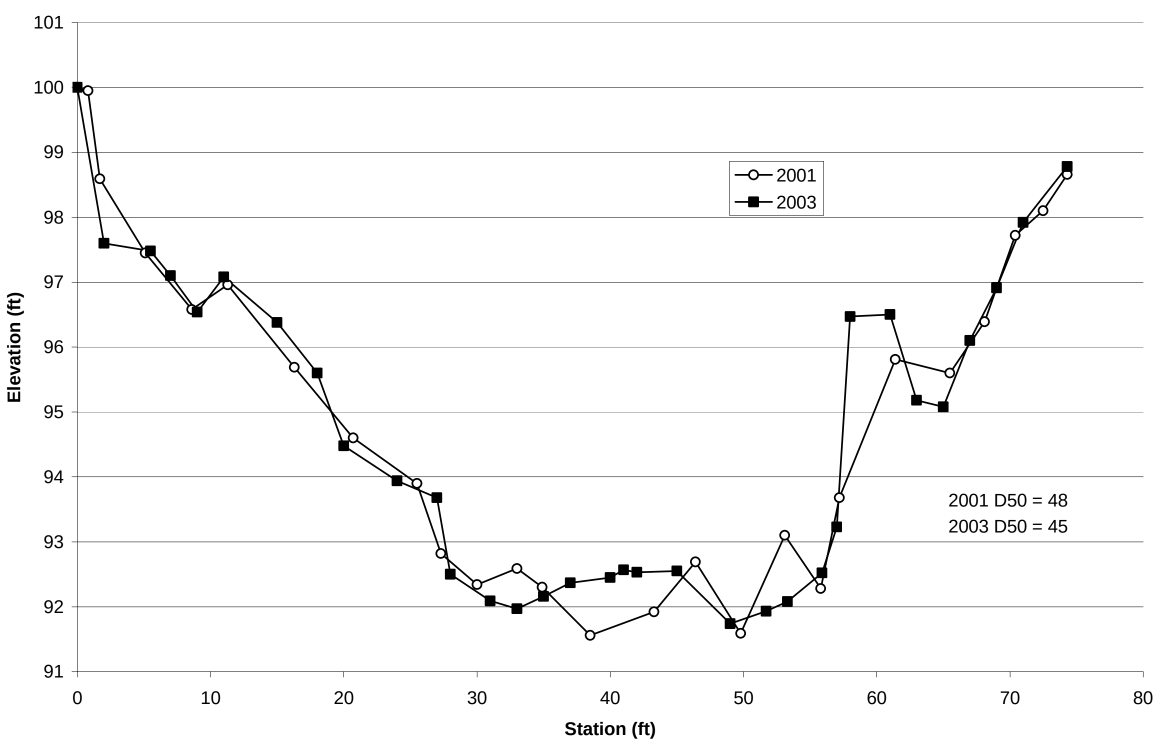
Residual Depth Plot, CG1, 2003



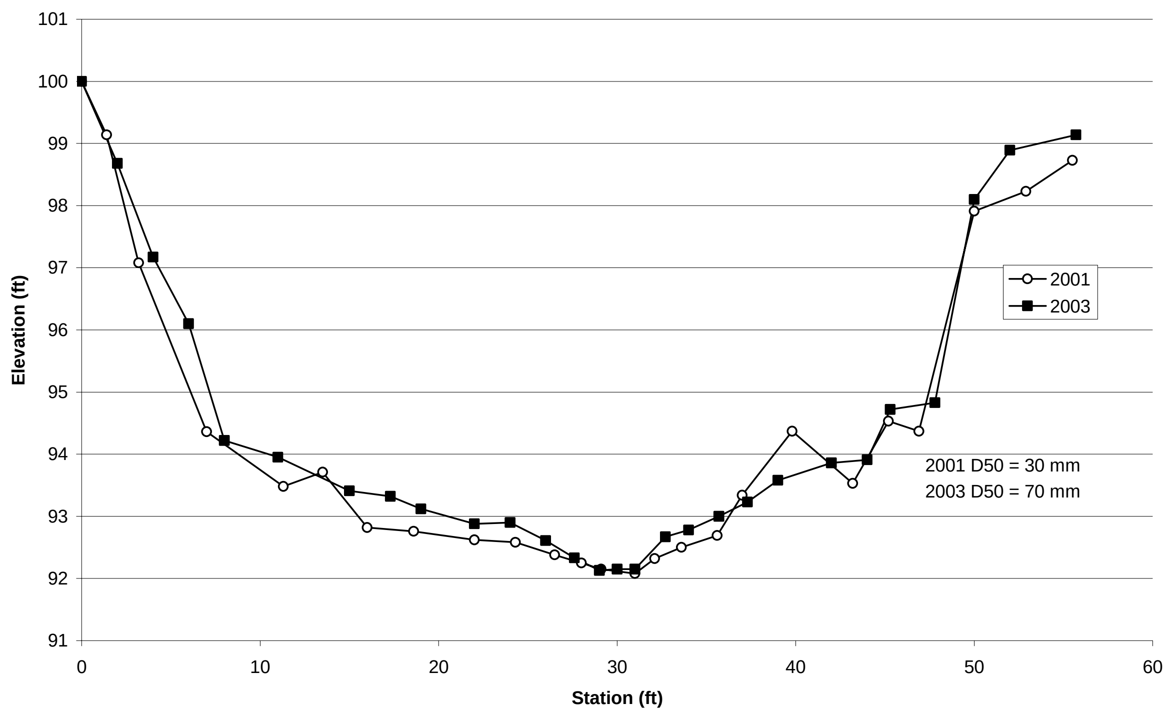
Lower Greenwood Creek Long Term Channel Longitudinal Profiles
Years 2001 and 2003 (Corrected Version)



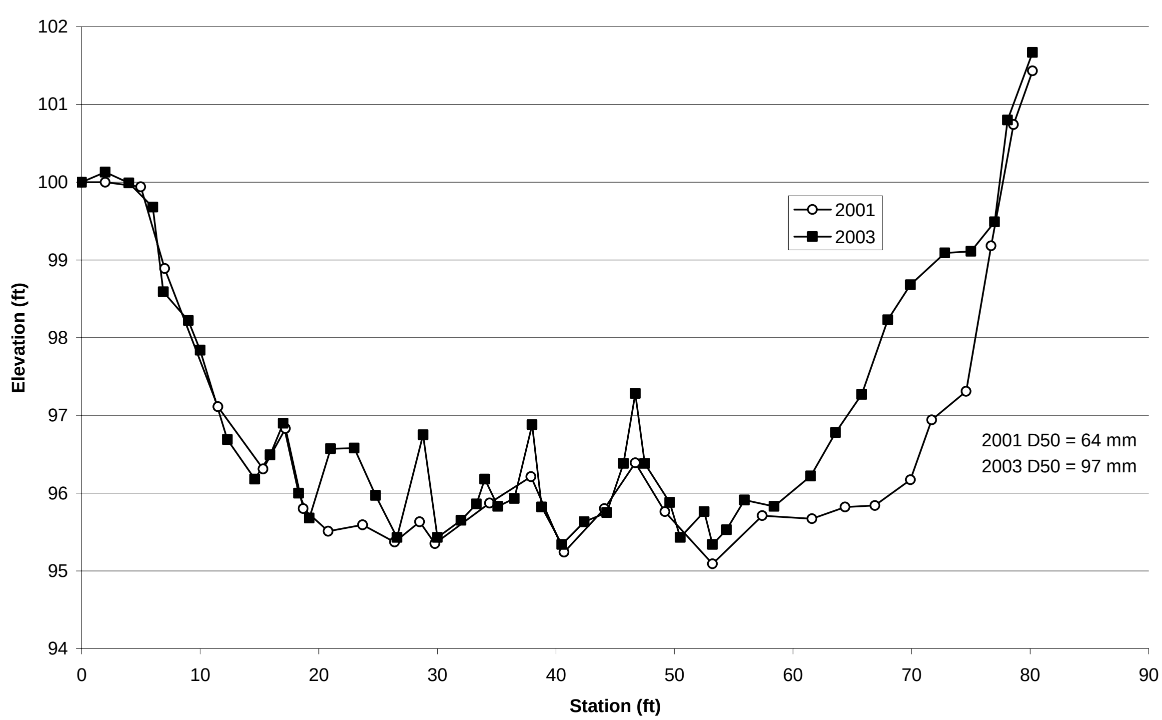
Lower Greenwood Creek Long Term Channel Monitoring
Cross Section 1; Years 2001 and 2003



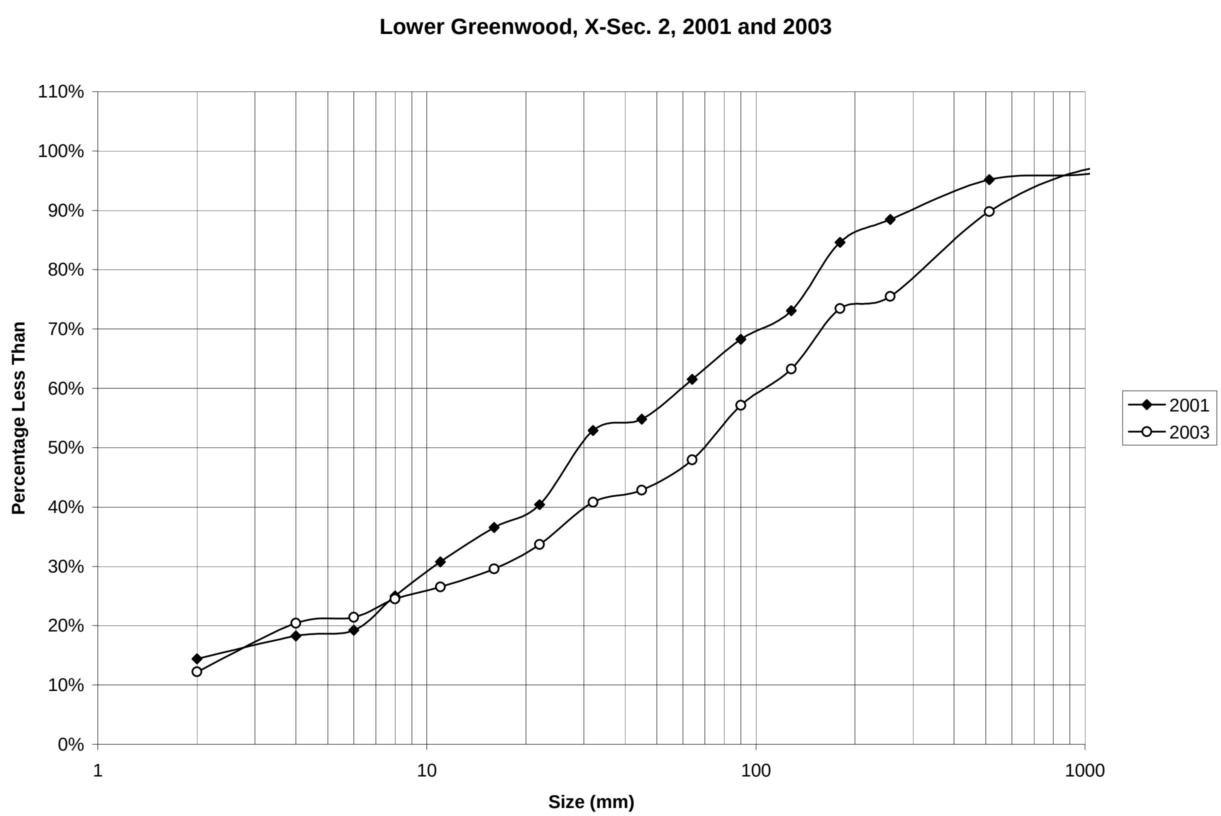
Lower Greenwood Creek Long Term Channel Monitoring
Cross Section 2; Years 2001 and 2003

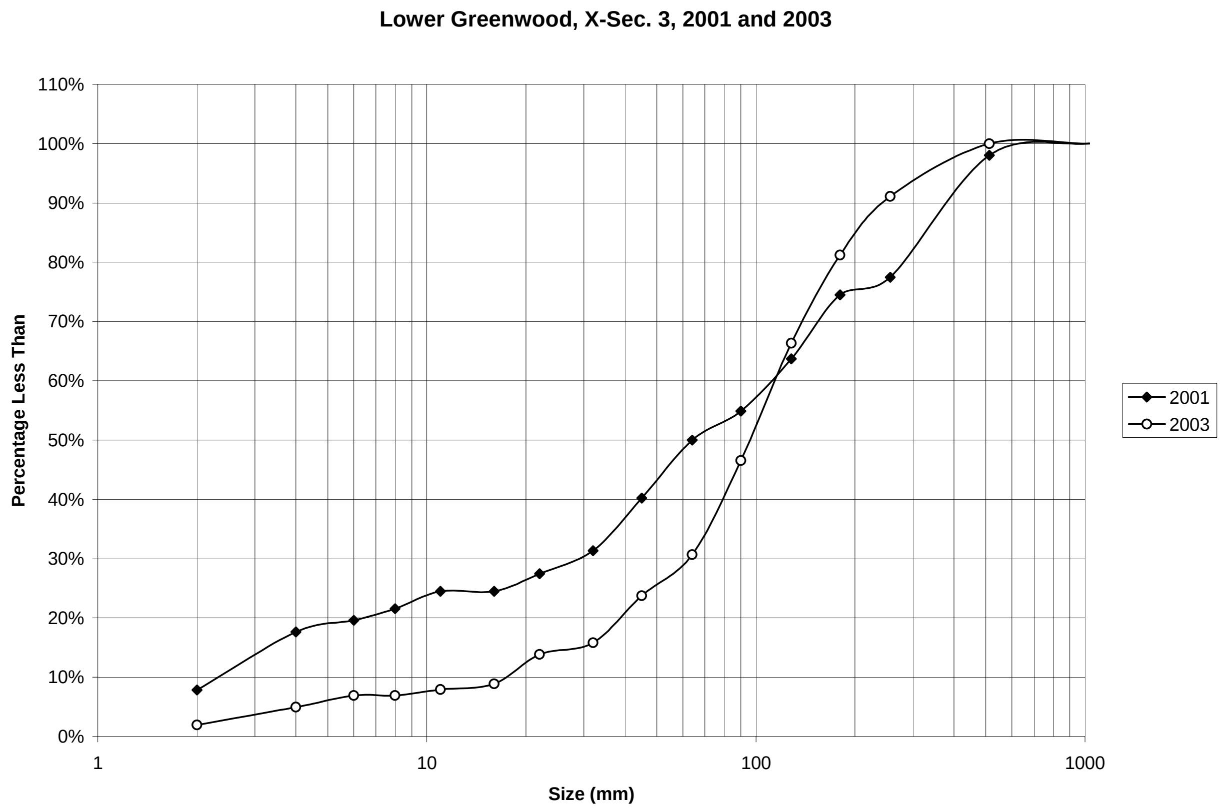


Lower Greenwood Creek Long Term Channel Monitoring
Cross Section 3; Years 2001 and 2003



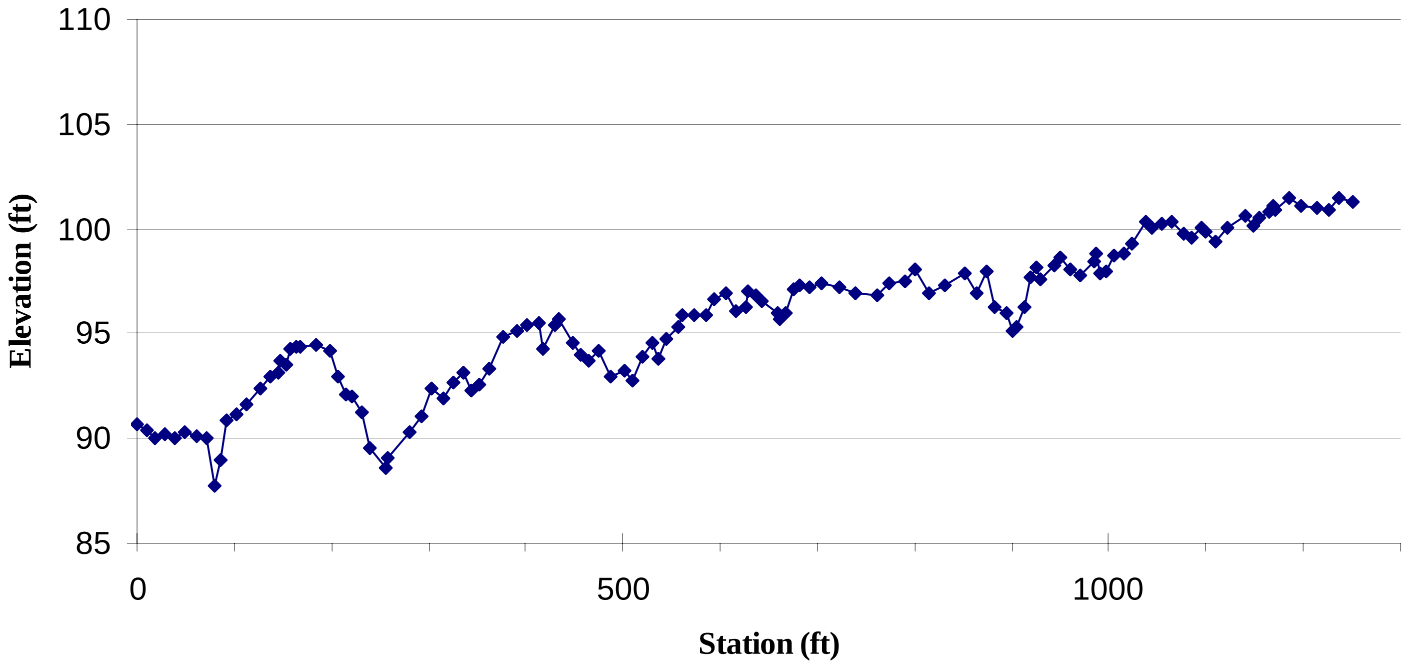

Lower Greenwood, X-Sec. 1, 2001 and 2003
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage Less Than
1
10
100
1000
Size (mm)
2001
2003

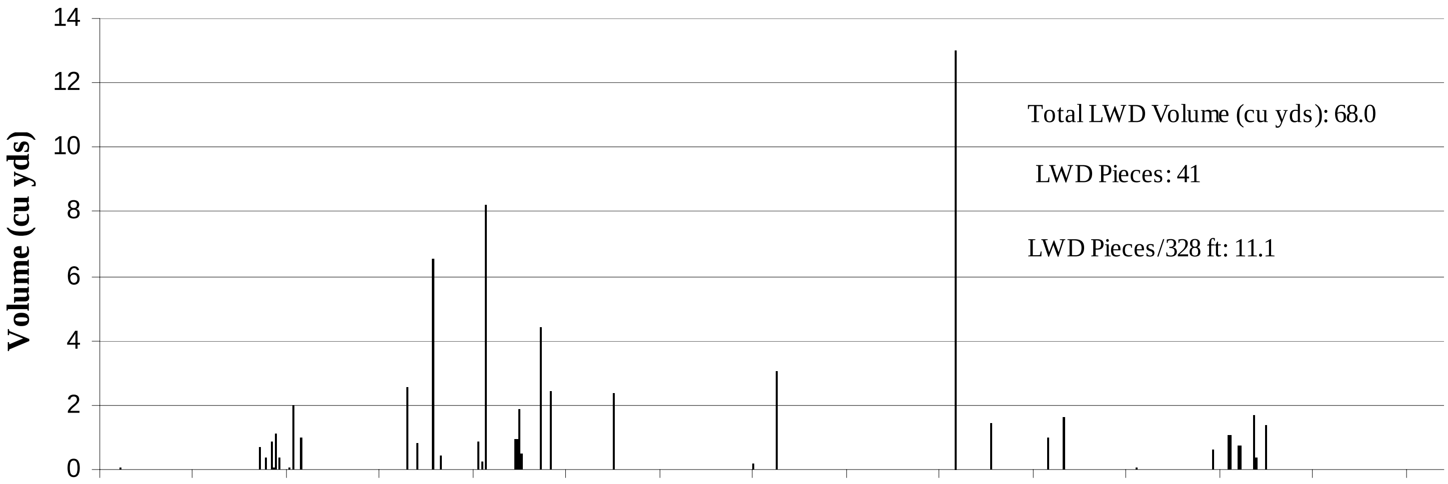

Lower Greenwood, X-Sec. 2, 2001 and 2003
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage Less Than
1
10
100
1000
Size (mm)
2001
2003



Lower Greenwood, X-Sec. 3, 2001 and 2003
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage Less Than
1
10
100
1000
Size (mm)
2001
2003

Upper Greenwood Creek Long Term Channel Monitoring Longitudinal Profile and Large Woody Debris Plots, 2003
Stream Segment: CU1



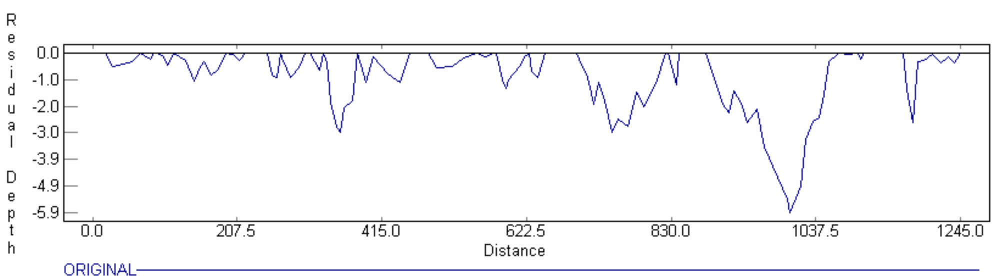


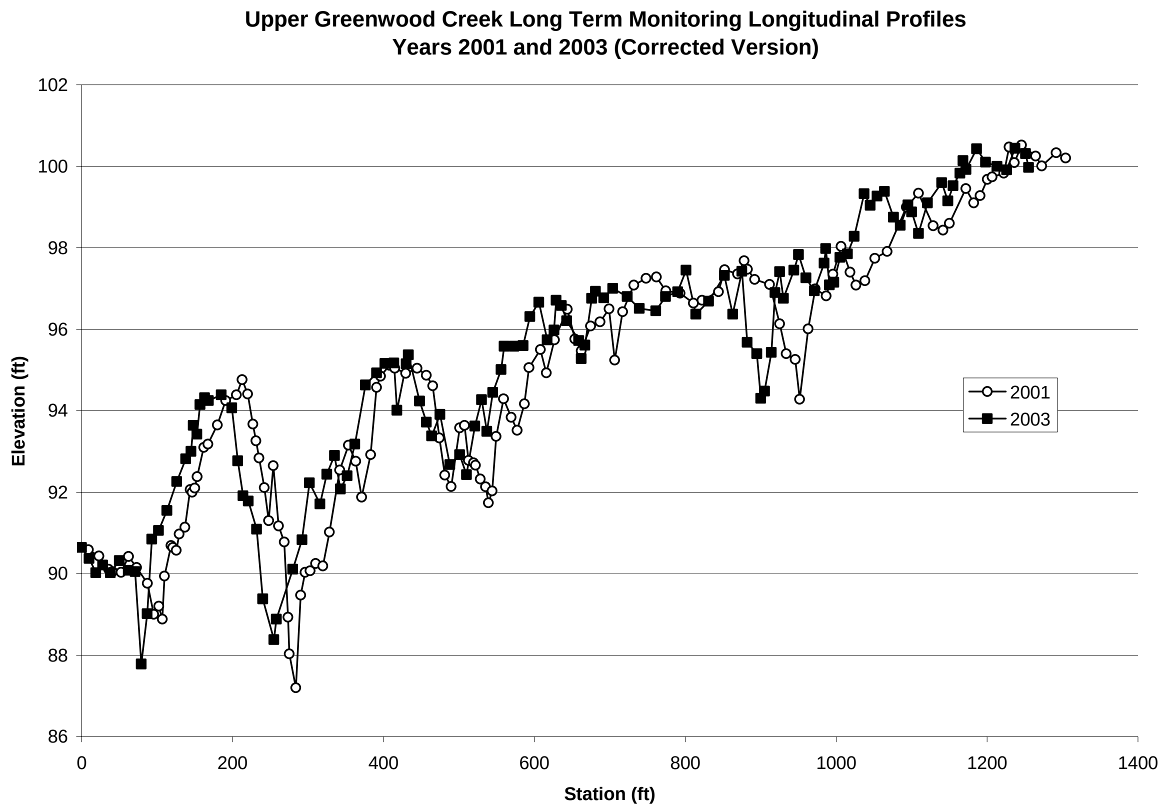
Upper Greenwood Creek (CU1) Long Term Channel Monitoring Longitudinal Profile
September, 2003

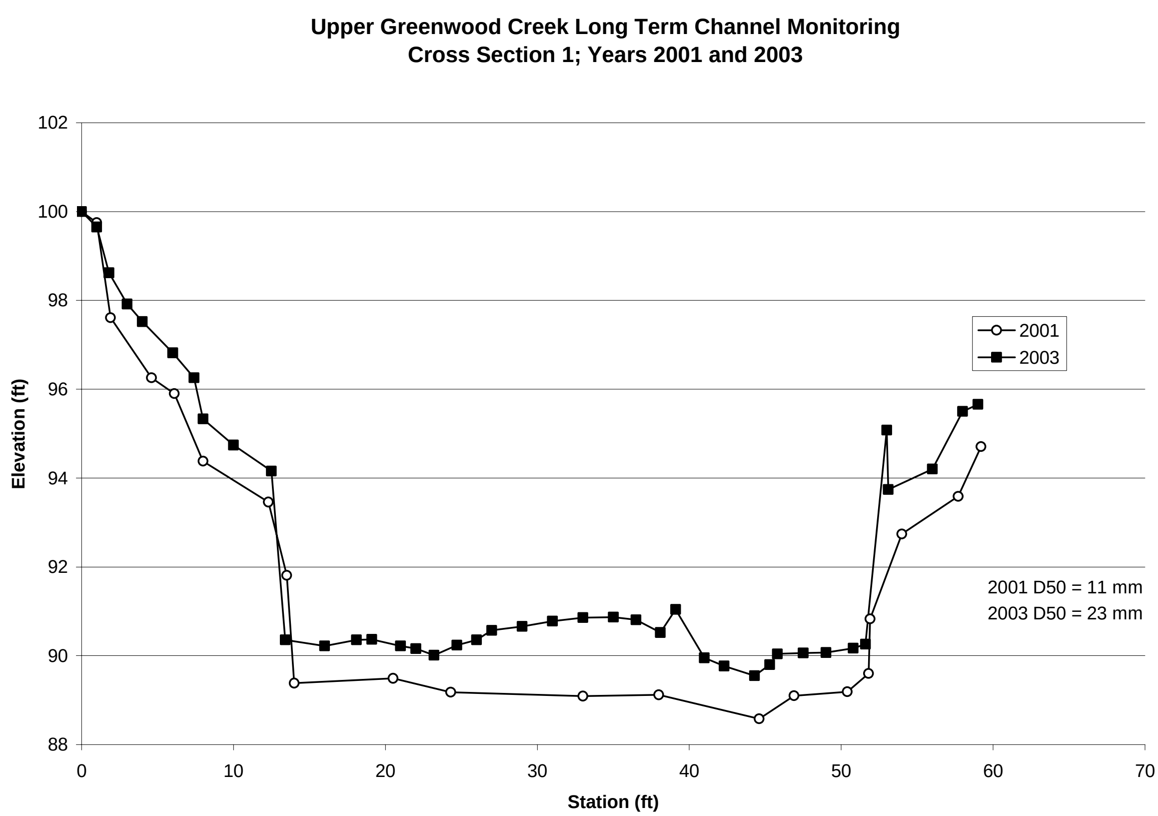
```
   Top Elevation:   101.44
Bottom Elevation:    87.78
    Reach Length:  1245.00
```

-

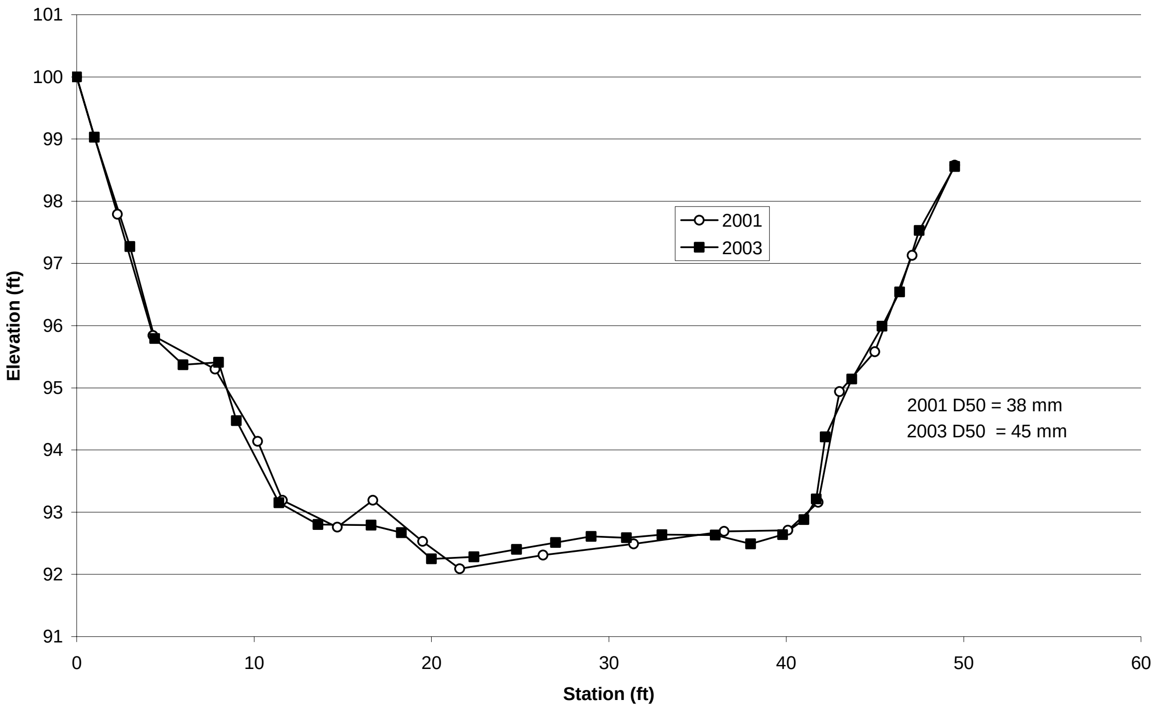
```
Standardized Statistics:
         Number of data points in raw data: 127
Number of data points in Standardized data: 127

Reach Step Distance: 9.80

 Max Residual Depth:     5.84
Mean Residual Depth:     0.85
 Standard Deviation:     1.19

Number of non-zero Residual Depths: 97
  Percent of Reach as pool:  76.38
Percent of Reach as riffle:  23.62
```



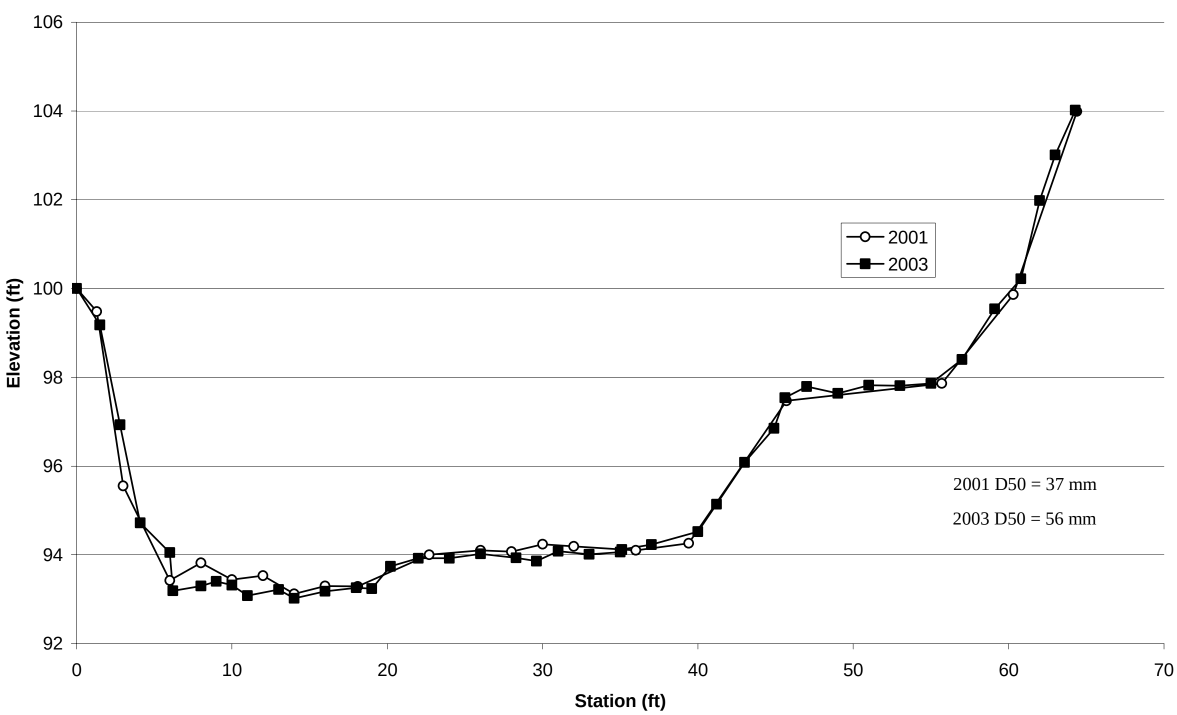

Upper Greenwood Creek Long Term Monitoring Longitudinal Profiles
Years 2001 and 2003 (Corrected Version)
Elevation (ft)
Station (ft)
2001
2003
102
100
98
96
94
92
90
88
86
0
200
400
600
800
1000
1200
1400

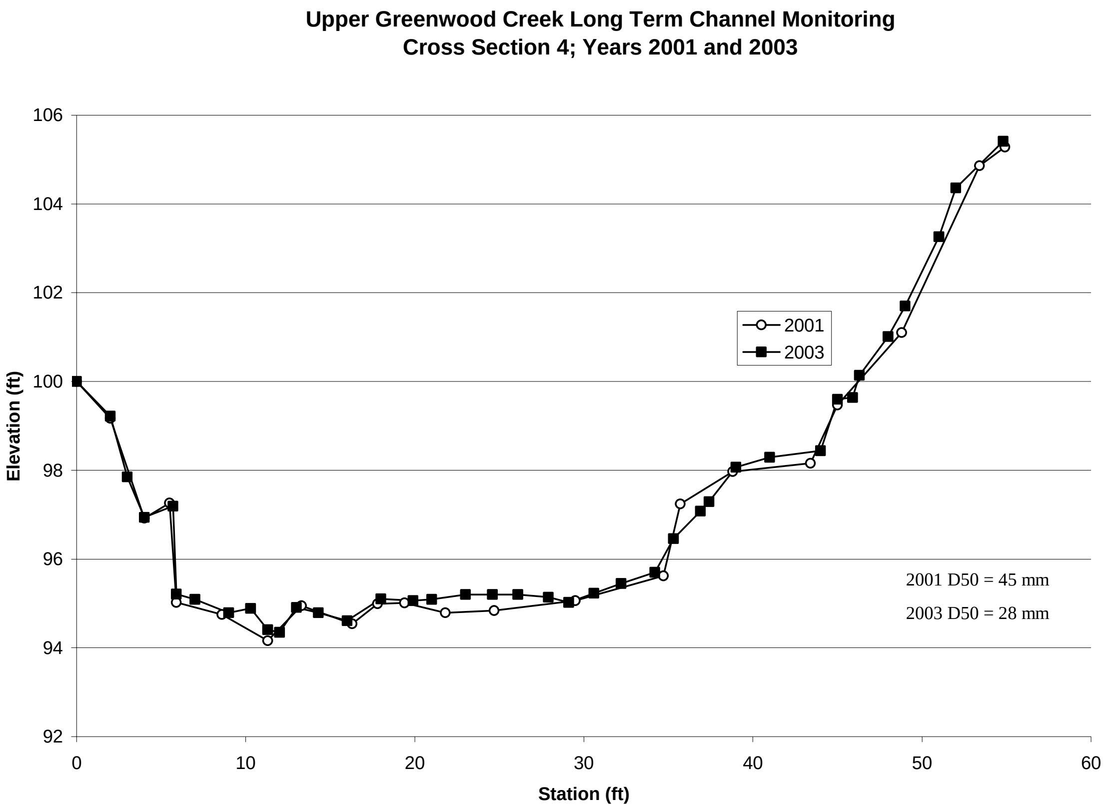

Upper Greenwood Creek Long Term Channel Monitoring
Cross Section 1; Years 2001 and 2003
Elevation (ft)
Station (ft)
2001
2003
2001 D50 = 11 mm
2003 D50 = 23 mm
102
100
98
96
94
92
90
88
0
10
20
30
40
50
60
70

Upper Greenwood Creek Long Term Channel Monitoring
Cross Section 2; Years 2001 and 2003

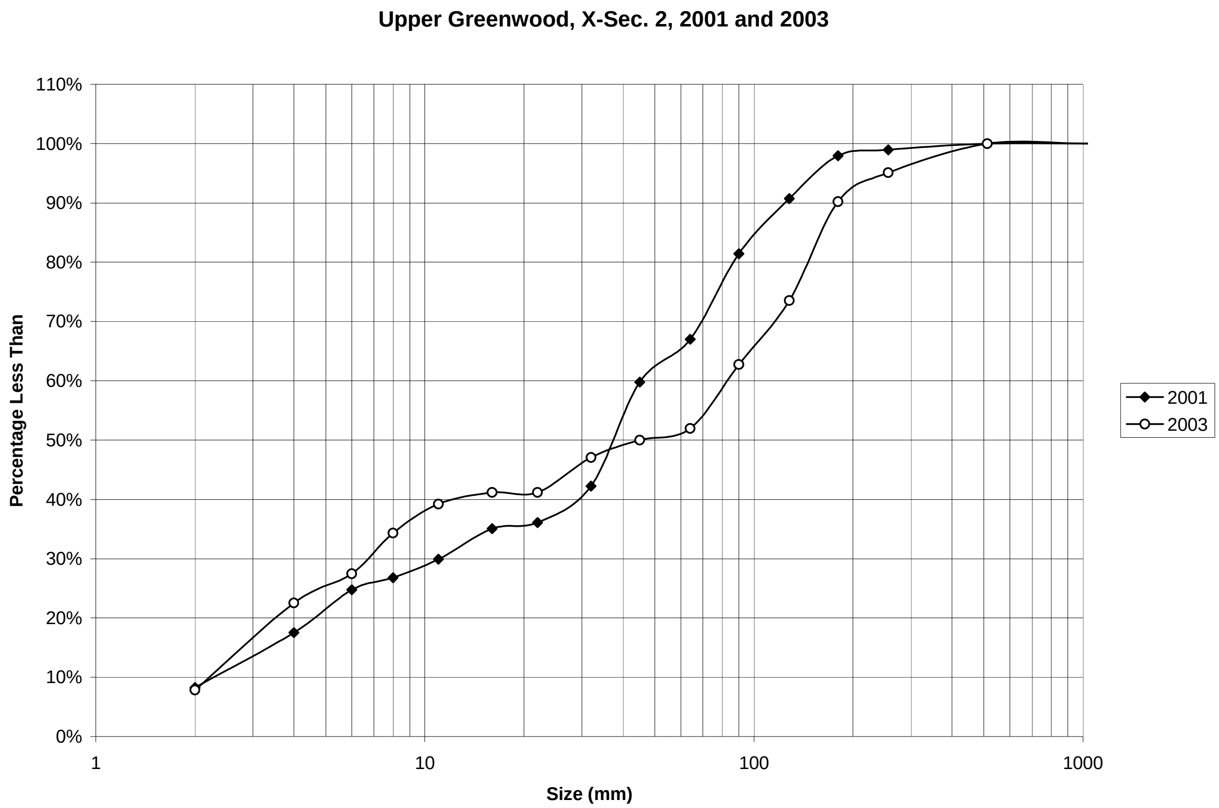


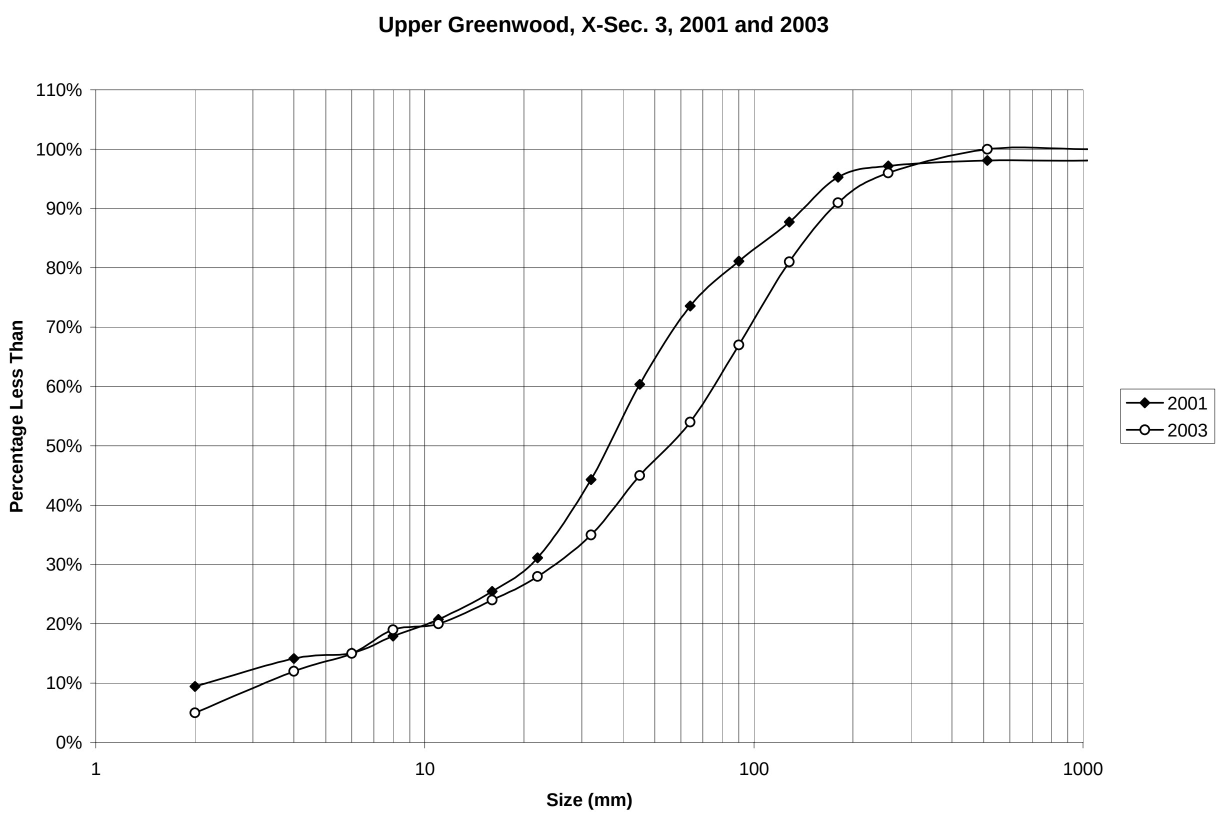
Upper Greenwood Creek Long Term Channel Monitoring
Cross Section 3; Years 2001 and 2003




Upper Greenwood Creek Long Term Channel Monitoring
Cross Section 4; Years 2001 and 2003
Elevation (ft)
Station (ft)
2001
2003
2001 D50 = 45 mm
2003 D50 = 28 mm
106
104
102
100
98
96
94
92
0
10
20
30
40
50
60


Upper Greenwood, X-Sec. 1, 2001 and 2003
Percentage Less Than
Size (mm)
2001
2003
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
10
100
1000


Upper Greenwood, X-Sec. 2, 2001 and 2003
Percentage Less Than
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
10
100
1000
Size (mm)
2001
2003


Upper Greenwood, X-Sec. 3, 2001 and 2003
Percentage Less Than
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100%
90%
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50%
40%
30%
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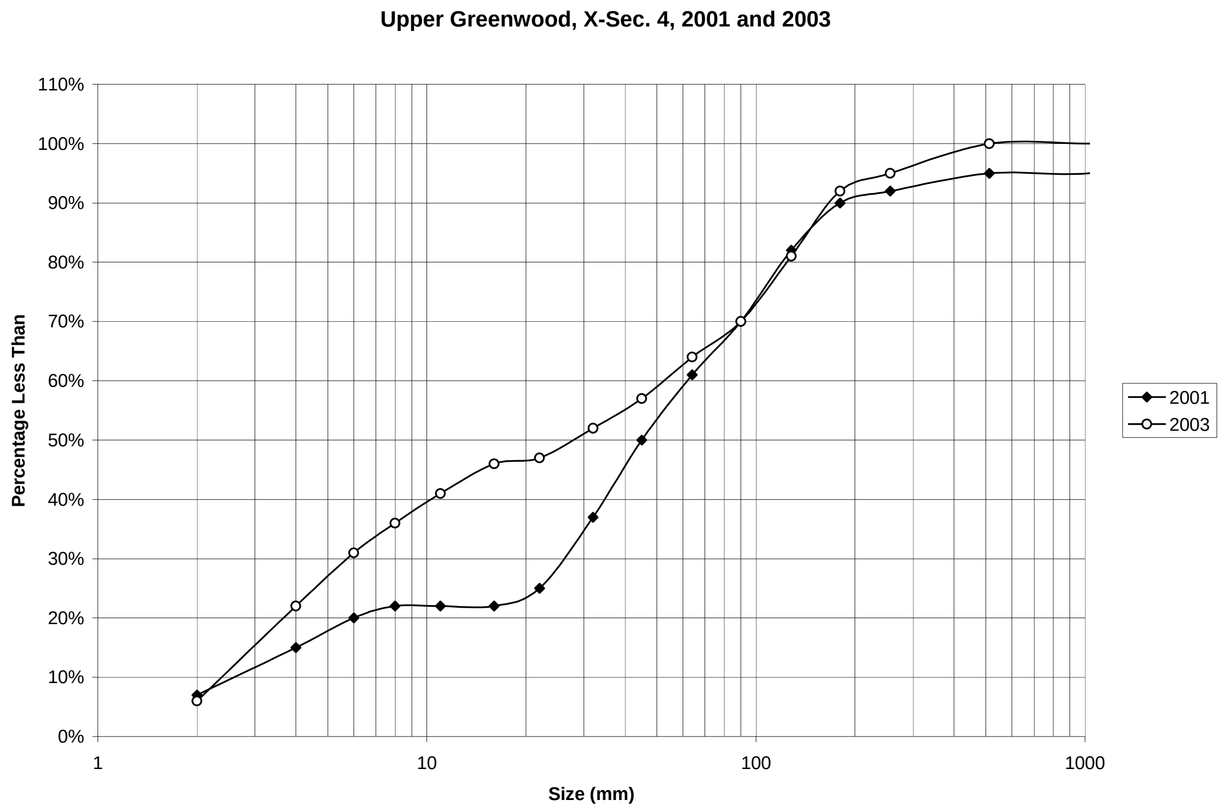
10
100
1000
Size (mm)
2001
2003


Upper Greenwood, X-Sec. 4, 2001 and 2003
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20%
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0%
Percentage Less Than
1
10
100
1000
Size (mm)
2001
2003