SHORELINE ASSESSMENT OF JEFFERSON COUNTY, TEXAS

A Thesis

by

HOO IL LEE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2003

Major Subject: Ocean Engineering

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Approved as to style and content by:

Billy L. Edge (Chair of Committee)	Robert E. Randall (Member)
Achim Stoessel (Member)	Paul N. Roschke (Head of Department)

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ABSTRACT

Shoreline Assessment of Jefferson County, Texas. (August 2003)

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Chair of Committee: Dr. Billy L. Edge

Shoreline erosion is an issue of economic and environmental concern on the Texas coast. Texas State Highway 87, located in Jefferson County, Texas, has been repeatedly destroyed by storms and rebuilt in the past 50 years. Reconstruction of State Highway 87 cannot be successfully achieved without an exact assessment of shoreline erosion.

This report describes a shoreline assessment to obtain a comprehensive data set that will be used to define the coastal erosion problem and assist in the reconstruction of the roadway. Eight field surveys were conducted that included offshore survey and beach survey (beach profiles). The offshore system utilizes a Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) mounted on a personal watercraft and integrated with a survey quality echo sounder. The beach survey utilizes RTK-DGPS equipment carried by the surveyor in a backpack. The system is an accurate, mobile and efficient method to obtain beach profiles.

The two surveys (beach and offshore surveys) are combined to provide a complete beach profile. Data gathered from beach profile surveys enabled the calculation of sediment erosion or accretion rate and direction.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. Billy Edge for his tireless efforts in the field, guidance, assistance and generosity during my studies at Texas A&M University. I also would like to thank Dr. Robert Randall and Dr. Achim Stoessel for serving on my thesis committee.

I am thankful to Joshua Toepfer, Kwanghyo Jung and Younghyun Park for their help and friendship in the field.

Finally, I want to thank, with the heart of Jesus, my parents, my wife Mijung Chon and my lovely daughter Hannah Lee for their love, patience, and sacrifice.

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CHAPTER I

INTRODUCTION

1.1. Background

Texas State Highway 87 is located on the most northeast corner of the Texas Coast, connecting the southern tip of Bolivar Peninsula to Sabine Pass. A survey area is shown in figure 1. In the 1930's SH87 received its first layer of asphalt concrete (Howard 1999). This section of SH87 lays on a very unstable stretch of beach that has historically eroded at a rate of 2 to 3 meters a year. According to Howard (1999) the road has been destroyed and rebuilt seven times over the last 50 or 100 years. So the original section of paved road now lies around 200 – 250 meters offshore. In 1989, SH87 was closed because Tropical Storm Chantal and Hurricane Jerry touched down and SH87 between Texas Highway 124 and Clam Lake road was washed away at that time.

Texas A&M University is assisting Jefferson County by conducting a shoreline-monitoring program, starting in the summer of 1999 continuing into the fall of 2002. In order to get a practical engineering solution to the SH87 erosion problem, a comprehensive baseline data set was collected and analyzed. The data set obtained from these surveys will be the used to understand the processes at work in the study area.

This thesis follows the style and format of the Journal of Ocean Engineering

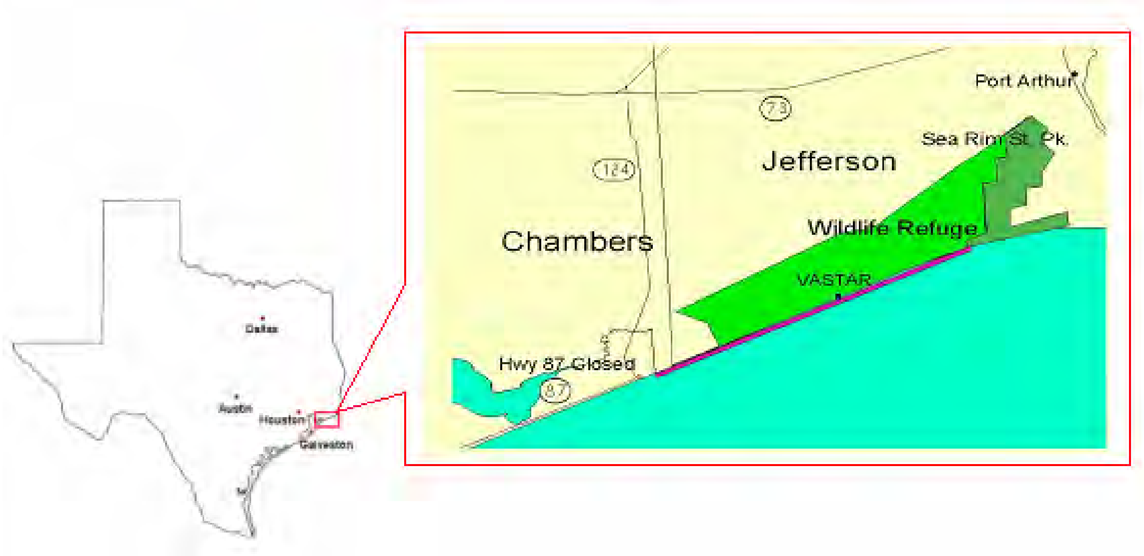

Fig. 1. Survey area - Highway 87 in the Jefferson County (Wamsley, 1999).

1.2. Objectives

The primary objective of this study is to determine the change of the Jefferson County shoreline and the rate at which the beach is either eroding or accreting every year. In order to achieve an understanding of the problem, beach surveying was completed from the summer of 1999 to the fall of 2002. Using the summer of 1999 survey, the original shoreline position, we can compare the original survey with the other seven surveys. The distance that the shoreline changes at a particular elevation in the horizontal shows the amount of erosion or accretion that occurs at an individual profile. These profiles include walking surveys beginning in the freshwater marsh into about one meter of water and jet-ski surveys extending about 600 meters offshore.

CHAPTER II

PREVIOUS WORK IN JEFFERSON COUNTY

Beach erosion between Sabine Pass and Bolivar Roads has been the subject of numerous reports and investigation which originated as early as 1947 when Sheets commented on the beach erosion of 122 meters near High Island and subsequent relocation of State Highway 87 (Morton, 1997).

LeBlanc and Hodgson (1959) also described shoreline recession west of Sabine Pass and the subsequent relocation of State Highway 87 (Morton, 1997). They speculated that during the past several thousand years, the shoreline west of Sabine Pass had eroded several hundred meters.

Shoreline changes a mile on either side of Rollover Pass between 1930 and 1961 (post-Carla) were summarized by Feray who reported net erosion of 106 and 131 meter northeast and southwest, respectively, of the fish pass.

Short-term accretion and erosion at Sabine Pass, High Island, and Bolivar Roads have been recorded by beach surveys conducted by the U.S. Army Corps of Engineers (1968-1974) (Morton, 1997). Beach profile changes at Rollover Pass between 1963 and 1971 were presented by Prather and Sorensen who concluded that the beach in that area was stabilized and changes occurred only seasonal or in response to storms. Additional data presented herein indicate that the beach near Rollover Pass is not stable but erosional.

Beach profiles from Sabine Pass to Bolivar Roads have been surveyed intermittently since 1974 (Morton, White, and Gibeaut, 1996). The most recent shoreline movement between Sabine Pass and Bolivar Roads was documented by comparing shoreline positions in June 1974 and February 1996. The 1974 shoreline was already in the

Bureau's GIS, whereas the 1996 shoreline was derived from a real-time kinematic DGPS survey that was later incorporated into the GIS shoreline coverage.

Distances between the 1974 and 1996 were measured at each transect, then rates of change were calculated for the 21.7 year period and Table 1 was generated. From Table 1 it is evident that from the years between 1974 to1996 this area was eroding more than accreting. From transects 15 through 58, the entire Gulf shoreline retreated. Shoreline recession was highest, more than 3m/yr, in the area between transects 18 and 32, which includes the beach segment where Highway 87 was destroyed by erosion. This beach segment is characterized by a marrow, relatively steep beach and washover terrace composed of sand and shell and underlain by mud. The crest of the washover terrace or edge of the destroyed road is the shoreline feature for this beach segment. Transects 15 – 36 coincide with the survey area of Texas A&M University from the summer of1999 to the fall of 2002.

Table 1
Net shoreline change between Sabine Pass and Bolivar Roads, **1974-1996** (Morton, 1997)

Transect	**Net Change (m)**	**Average Rate (m/yr)**	**Transect**	**Net Change (m)**	**Average Rate (m/yr)**
5	-213.36	-9.83	34	-55.78	-2.57
6	-194.77	-8.98	35	-60.05	-2.77
7	-142.04	-6.55	36	-25.30	-1.17
8	-1.52	-0.07	37	-5.49	-0.25
9	22.25	1.03	38	-1.52	-0.07
10	76.50	3.53	39	-11.89	-0.55
11	79.55	3.67	40	-12.80	-0.59
12	14.63	0.67	41	-8.53	-0.39
13	24.99	1.15	42	-2.44	-0.11
14	28.65	1.32	43	-33.53	-1.55
15	13.41	0.62	44	-30.18	-1.39
16	-35.36	-1.63	45	-37.19	-1.71
17	-61.26	-2.82	46	-42.06	-1.94
18	-80.77	-3.72	47	-27.43	-1.26
19	-78.33	-3.61	48	-33.22	-1.53
20	-75.59	-3.48	49	-32.00	-1.47
21	-80.16	-3.69	50	-15.24	-0.70
22	-93.88	-4.33	51	-39.93	-1.84
23	-114.60	-5.28	52	-23.47	-1.08
24	-103.33	-4.76	53	-42.67	-1.97
25	-89.61	-4.13	54	-50.90	-2.35
26	-95.40	-4.40	55	-32.92	-1.52
27	-102.72	-4.73	56	-17.37	-0.80
28	-87.78	-4.05	57	-35.36	-1.63
29	-77.11	-3.55	58	-4.88	-0.22
30	-75.29	-3.47	59	8.53	0.39
31	-73.15	-3.37	60	14.94	0.69
32	-74.68	-3.44	61	43.28	1.99
33	-64.31	-2.96	62	115.52	5.32

CHAPTER III

COLLECTING DATA

3.1. Method

The beach profile shows that the beach responds to storm tides and waves. Defining the topography enables the shoreline movement to be quantified. Measuring beach profiles is a challenging task for such a long stretch of shoreline. A Global Positioning System was chosen as the most accurate and expeditious method of completing a land and hydrographic survey.

The hydrographic survey was conducted with a boat-mounted echo sounder. This procedure is fast and can be performed in a variety of bottom conditions. A Differential Global Positioning System (DGPS) is combined with an echo sounder to obtain a three-dimensional position. This compensates for the tide, waves and other fluctuations in the still water level. This equipment is mounted on a personal watercraft which decreases the draft requirements of a conventional survey boat and provides excellent maneuverability in the surf zone. The GPS is portable, can be deployed and recovered with a small crew, and is cost effective.

The survey on the beach utilizes Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) equipment carried by the surveyor in a backpack. For our purposes, the beach survey includes measurements from a surf zone wading depth to the wetlands area just landward of the overwash fans. The nearshore bathymetry is monitored by mounting the RTK-DGPS equipment on a personal watercraft and integrating it with an echo sounder. Using navigation software, repeatable beach survey lines are traversed in the nearshore zone. The hydrographic survey includes measurements from the point where the wading survey ends to approximately 600 meters offshore. The two surveys are combined to provide a complete profile from the depth of closure to the start of the wetlands behind the dune field. Figure 2 is a schematic of the profiling system.

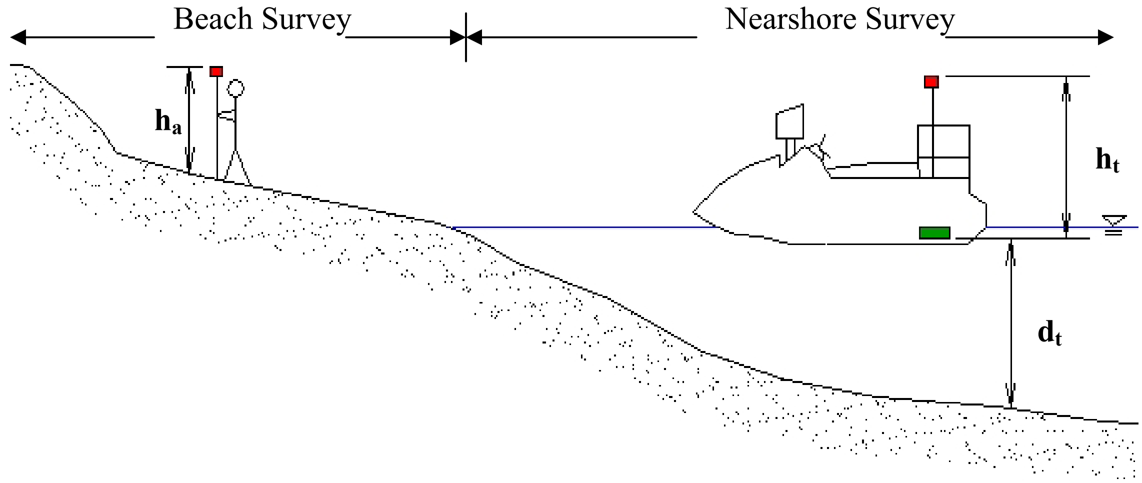

Fig. 2. Survey system (Wamsley, 1999).

When using GPS technology, the location of the base station and the height of the GPS antennas are known, as well as the distance from the base station. Therefore the topography of profiles are calculated based on that information. For the beach surveys, the antenna height, h_a, is subtracted from the antenna location to get the X, Y, and Z coordinates of the beach topography. The nearshore bathymetry is obtained by reducing the measured antenna elevation by the height of the antenna above the echo sounder transducer and measured depth below the transducer, h_t+d_t.

3.2. Benchmarks

Permanent benchmarks were established with a known and non-changing position. Reconnaissance of the study area that was conducted prior to the first set of surveys in Jefferson County before the summer of 1999 reveled that all of the United States Geological Survey (USGS) and the United States Coast and Geodetic Survey markers had all been lost or damaged due to erosion. Because of this damage it was necessary for the replacement of these markers with ones that were stamped at Texas A&M University. These benchmarks were then set up at various points along the survey area to insure uninterrupted and continuous surveying. To ensure that there was adequate radio transmission the benchmarks were placed less than ten kilometers apart from each other. Lastly these benchmarks were placed in stable areas that were far enough removed from the eroding areas to ensure that they will be in place for the time period that surveys are conducted.

Four Benchmarks were selected to provide radio coverage over the entire survey area. The first benchmark named CLAM is located at the corner of Clam Lake Road and SH 87. It is directly across from the old entrance to the shore just west of the entrance off Sea Rim State Park, and west to the entrance to the McFaddin Wild Life Refuge. VASTAR is approximately 12.7 km southwest of CLAM at what was VASTAR Resources shore base. Finally CATT is located in an abandoned cattle corral approximately 15 km southwest of VASTAR.

In order to obtain an accurate base point location, the position of each benchmark is calculated using static baseline processing. This coordinate is confirmed with a static position each time it is occupied. Coordinates that are calculated using this process are accurate to the centimeter level. Table 2 lists the calculated coordinates of the three base stations.

Table 2
Base point coordinates (WGS-84)

Benchmark	Latitude	Longitude	Elevation (m)
CLAM	29°40’04.01576” N	94°04’26.41898” W	-24.856
VASTAR	29°37’23.98413” N	94°11’48.89735” W	-24.964
CATT	29°34’04.69478” N	94°20’16.27692” W	-25.146

The coordinates given in table 2 are in World Geodetic System- 1984 (WGS – 84). The WGS-84 is the mathematical ellipsoid used by GPS since 1987. The raw DGPS data were converted to Texas State Plane coordinates 4204, South Central Zone, NAD 83 horizontal datum, survey meter. The elevations are converted to the NAVD 88 datum by applying the GEOID96 model.

Errors of a few centimeters may have a significant impact on the sand volume because it is applied to such a large horizontal sand area. The accuracy of the beach and nearshore survey systems has been completed in field tests in 2000 (Wamsley, 2000). The beach survey system has a vertical accuracy of $\pm$ 4cm. The hydrographic survey system was tested by repeating transects in the nearshore at Jefferson County, and the repeatability of the profiles demonstrated a standard deviation of 6.2 cm from the mean absolute difference of 8.0 cm (Edge, Tuttle, and Hutchinson 2000).

3.3. Beach and offshore profile surveys

Prior to initiating a monitoring plan, it is necessary to establish a baseline which can be used to calculate distance of a position on the survey line. If the x, y coordinates of starting and ending points are known, it is possible to create the baseline. Coordinates that are calculated using this process are Texas State Plane coordinates 4024, South Central Zone, survey meter. In this study, the x, y coordinates of starting point are 1048645.951 meters and 4199926.538 meters, ending point is 1077390.366 meters and 4213990.941 meters.

The surveys of beach and offshore profiles form the heart of the physical monitoring and can be accomplished by a number of approaches. Profiles are obtained every 400 meters throughout the survey area. Each of the nearshore profiles corresponds to a beach profile. The onshore and hydrographic surveys are combined to provide a complete profile from the start of the wetlands out to the depth of closure.

For the beach survey, lines were established every 400 meters along the entire study area. Each line extends from an approximate safe wading depth to the beginning of the marsh. The 156 lines were defined from coordinates obtained during an initial survey and keyed into the Trimble TSC 1. Each line extends perpendicular to the shoreline and defines the survey transects that will be used for every Jefferson County survey. The lines do not need to be physically marked on the beach since they are stored in the data collector. When the data at Jefferson County is collected it is stored and analyzed. This entails taking data from both the onshore and offshore portions of the survey and analyzing them separately. Once the onshore and offshore data are analyzed separately they are then combined into the final product which shows the overall beach profiles. Once all the lines have been reduced to their final product, the approximate mean sea level (MSL) is determined. Mean sea level is approximated by the surface of the geoid as determined at 0.0m North American Vertical Datum (NAVD) 1988. From here, the MSL of the summer of 1999 survey can be subtracted from the MSL position for the fall of 2002 survey to show the difference from the initial survey over the entire period. This number is the change in position of the MSL and indicates if the profile has eroded or accreted the fall profile is used to determine the net loss of sand over the entire survey area.

3.4. Sand samples

In the spring of 1999 Steven Howard completed the report entitled “Impact of Shoreline Changed Proposed Texas Highway 87 Reconstruction”. In this study Howard defines a research project that is responsible for collecting a comprehensive set of base line data including sediment samples over the damaged section of SH87. He accomplishes this task by achieving the following tasks. The first phase of the project was to acquire data to determine the storm surge and wave set up in the Gulf of Mexico. The next step was to obtain 76 core samples that were then taken to the University of Florida to be run through a rapid sand analyzer. The figure 3 shows the grain size distribution as resulting from the RSA. The samples were taken at every 800m from east to west along the beach on the berm, beach face, and off shore. Line zero is located in 5.6km from the Clam Lake Road.

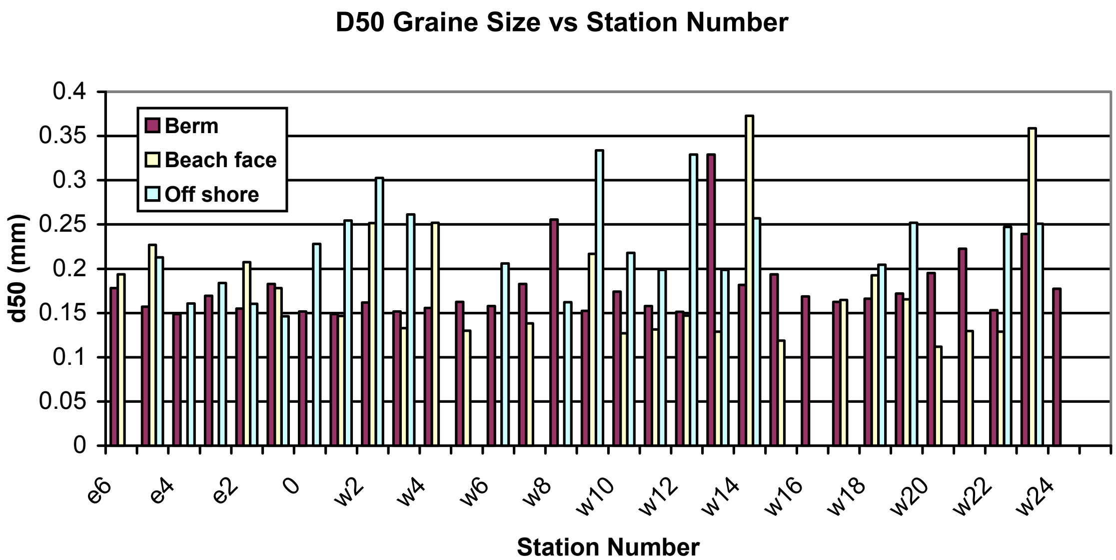

Fig. 3. Sorted RSA results from east to west (Howard, 1999).

Howard was able to determine that the beach was made of fine sands and silts. From this information he determined that quarterly surveys were to be taken along shore position, and cross-shore profiles to the depth of closure, which is around 600 meters off shore.

Sand samples were collected again along the survey region in the fall of 2002. These samples were analyzed using the RSA to obtain the d50. Unfortunately, table 3 Shows just seven comparisons of d50 grain size of two sand samples at the same profile line because the samples were taken at each 3.2 km along the beach on the berm, beach face and in 0.6-1 meter of water in the fall of 2002 so just seven locations of sand samples agree with that of 1999 sand samples in survey area.

Table 3
Comparison of d50 grain size of two different sample periods

2002 Sand samples			1999 Sand samples (Howard)		
Line No	Location	d50 (mm)	Line No	Location	d50 (mm)
	Berm	0.21811		Berm	0.17747
18	Beach Face	0.19041	w24	Beach Face	0
	Offshore	0.16283		Offshore	0
	Berm	0.19368		Berm	0.19504
38	Beach Face	0.19233	w20	Beach Face	0.11179
	Offshore	clay		Offshore	0
	Berm	0.21567		Berm	0.19371
58	Beach Face	0.17559	w15	Beach Face	0.11859
	Offshore	clay		Offshore	0
	Berm	0.21246		Berm	0.17414
78	Beach Face	0.20151	w10	Beach Face	0.12713
	Offshore	clay		Offshore	0.21782
	Berm	0.21715		Berm	0.16241
98	Beach Face	clay	w5	Beach Face	0.12987
	Offshore	clay		Offshore	0
	Berm	0.18576		Berm	0.15172
118	Beach Face	0.14682	0	Beach Face	0
	Offshore	clay		Offshore	0.22819
	Berm	0.15132		Berm	0.157
138	Beach Face	0.16889	e5	Beach Face	0.22697
	Offshore	clay		Offshore	0.21283

CHAPTER IV

ANALYSIS

4.1. Waves

Waves are an everyday occurrence in the physical process that effect beach morphology. Although they are a constant factor that affects the changing beach surface, it is not the waves that occur during the weather that occur every day that can cause the most damage to the beach. Instead the waves that most affect the beaches are caused during severe weather events such as tropical storms or depressions. Breaking waves cause turbulence which disturbs the sediment which causes sediment movement.

There are three types of breaking waves also known as breakers (Figure 4). They are the spilling breakers where each wave gradually peaks until the crest becomes unstable and cascades down known as white water. Plunging breakers occurs when the shore ward face of the wave becomes vertical, curls over, and plunges forward and downward as intact mass of water. Finally Surging breakers peak up as if to plunge, but then the face of the wave surges up the beach face so that the crest collapses and disappears (Komar, 1998).

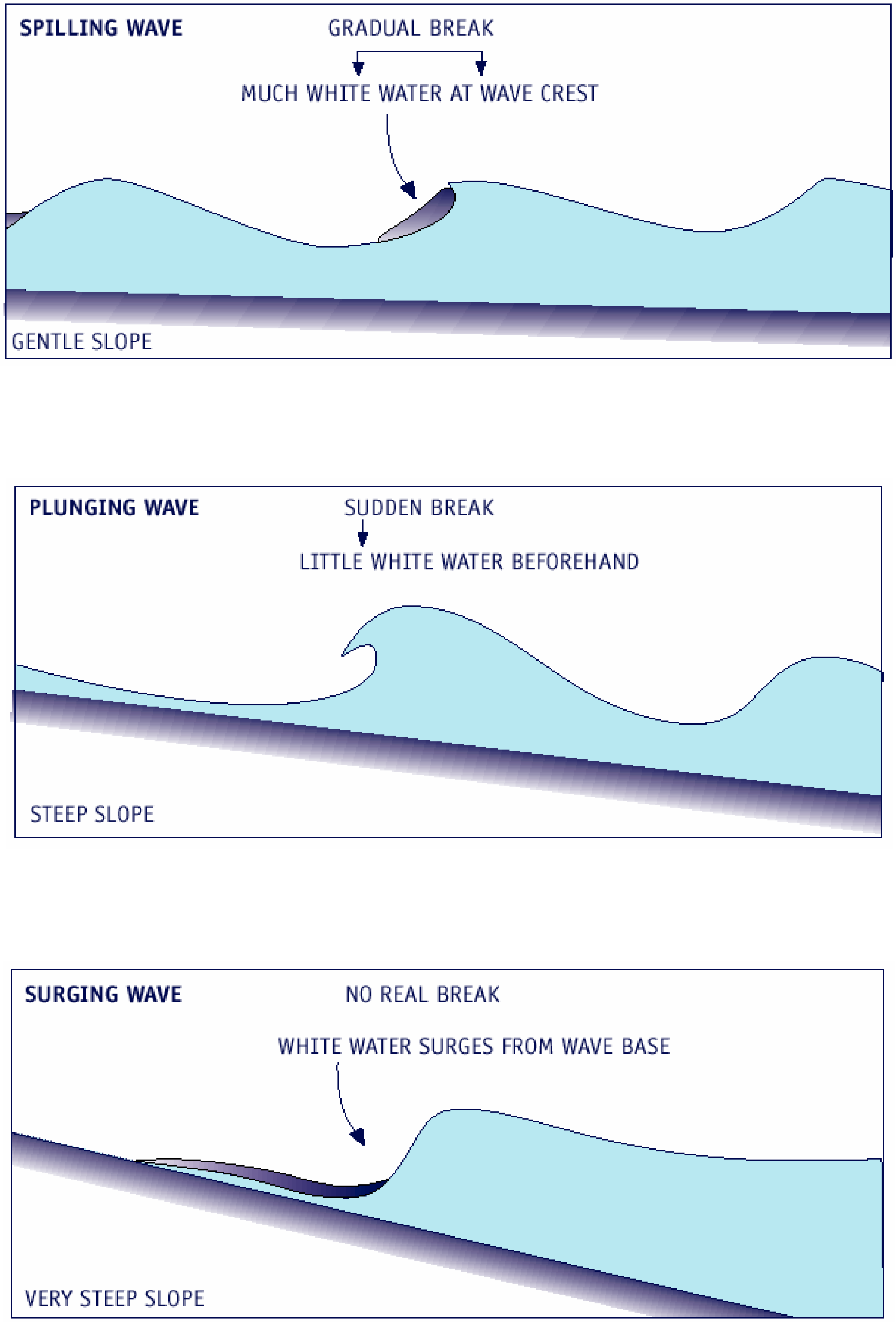

Fig. 4. Three types of breaking waves (www.env.qld.gov.au/environment/science/coasts/bp1111.pdf).

Offshore wave conditions are determined from the historical data recorded at NOAA. This particular data was obtained from the NOAA buoy Station 42035 located outside of Galveston Bay approximately 30 mile south west of the survey area. Table 4 lists the dates, and the wave heights that affected the area during the time of study. In order to determine the effects of waves on the area wave heights above 2 meters were taken the data that is in the time frame of the surveys, i.e. that used for data from January 1999 to December 2002.

Table 4
List of wave heights above 2 meters (All data taken from NOAA database)

Strart Time					**End Time**					**Hmax**
YYYY	MM	DD	hh	WVHT(m)	YYYY	MM	DD	hh	WVHT(m)	**(m)**
1999	12	3	3	2.56	1999	12	5	3	2.36	2.91
2000	1	14	9	2.07	2000	1	14	18	2.29	2.4
2000	10	8	4	2.31	2000	10	8	22	2.02	2.35
2000	11	18	11	2.05	2000	11	19	7	2.19	2.69
2001	3	27	22	2.25	2001	3	28	21	2.10	3
2001	**6**	**5**	**16**	**2.61**	**2001**	**6**	**6**	**11**	**2.07**	**4.25**
2002	2	5	15	2.25	2002	2	6	4	2.21	2.75
2002	3	1	11	2.10	2002	3	2	13	2.07	4.10
2002	4	8	7	2.39	2002	4	9	4	2.03	2.73
2002	9	5	14	2.10	2002	9	7	17	2.04	4.15
2002	9	8	1	2.17	2002	9	8	10	2.08	2.64
2002	9	23	6	2.01	2002	9	23	18	2.07	2.37
2002	9	24	3	2.01	2002	9	26	4	2.10	2.72

Over the last three years there were thirteen events of waves two meters or higher lasting for greater than six hours. The historical storm data show that tropical storm Allison reached the Texas coast south of Galveston on June 6, 2001 and tropical storm Fay passed during September 5 and 8, 2002. The storm dates correlate with the highest wave record during tropical storm Allison. The storm with greatest heights occurred during June 2001 with H_{max} of 4.25 meters.

4.2. Storm surge

Storm surge is simply water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge combines with the normal tides to create the hurricane storm tide, which can increase the predicted water level. Figure 5 shows storm surge. Storm surge allows larger waves to pass over the offshore zone since the depth is greater and then dissipate the increased energy contained in the storm waves onto the beach. The remaining energy is spent in erosion of the beach, berm, and sometimes dunes which are now exposed to wave attack by virtue of the storm surge. The eroded material is carried offshore in large quantities where it is deposited on the nearshore bottom.

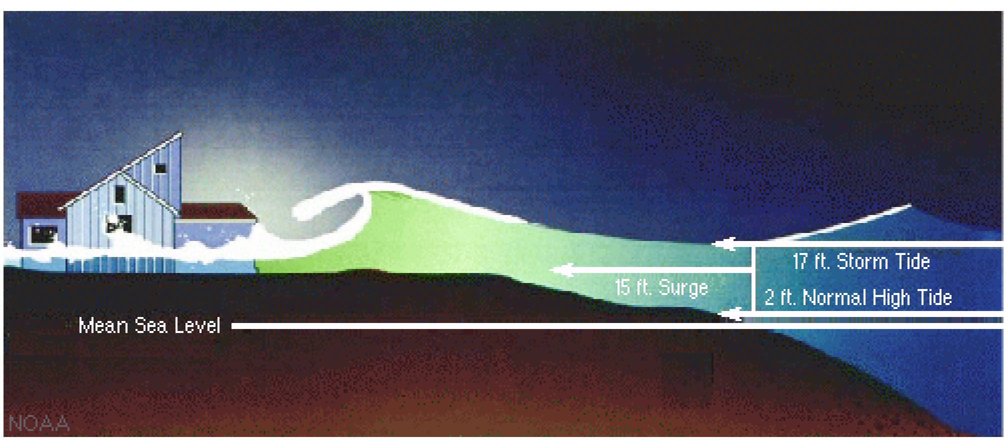

Fig. 5. Illustration of storm surge (NOAA web site).

Estimations of surge have been performed. Due to the low berm elevation, frequent overtopping may occur even under mild water level rise. The berm in this particular area is largely made up of sediment deposited as water overtopped into the wetlands, this has been defined by Dr. Robert Morton as a washover terrace (Morton, 1997). Washover terraces are deposited where beaches are highly erosional and adjacent ground elevations are lower than the highest storm surges.

Historical storm surges were estimated by the Coastal Engineering Research Center (CERC), Waterways Experiment Station in Vicksburg, Mississippi. The work done at CERC used a finite element based model to predict storm surge at stations along the United States coast for 134 historically based hurricanes. All of the historic data was obtained from the HURDAT databases developed by the National Oceanic and Atmospheric Administration (NOAA). The storm surge predictions from WIS station 539 were used to estimate statistical water levels in the SH 87 area. WIS 539 is located approximately 30 miles off the Texas coast at latitude 29.68N, longitude 93.76W. Table 5 lists hurricanes that have impacted the SH87 with storm surge between the years of 1886 and 1994.

Three tropical storms made landfall on the Texas coast during the study period. Tropical storm Frances on September 1998 recorded 1.28 m storm surge at Sabine Pass and 1.83 m storm tide at Bolivar Roads. The second tropical storm is Allison on June 2001 and the third one is Fay on September 2002. Figure 6 shows predicted and actual tidal record when these tropical storms passed through Sabine Pass and suddenly increased water level (Top to bottom, Tropical Storm Frances, Tropical Storm Allison and Tropical Storm Fay). All of the historic tidal data were obtained from the Center for Operational Oceanographic Products and Services (CO-OPS) National Tidal Datum Epoch.

Table 5
Hurricanes impacting SH87 between 1886 and 1994

Date	Name	HURDAT #	Surge (m)
8/12/1886	Not Named	5	0.4
8/27/1900	Not Named	117	2.3
7/13/1909	Not Named	183	1
8/5/1915	Not Named	211	3.6
8/1/1918	Not Named	232	1.4
6/27/1929	Not Named	295	0.4
7/25/1933	Not Named	324	0.5
8/2/1940	Not Named	397	1.5
9/16/1941	Not Named	405	2.3
8/24/1945	Not Named	445	1.1
6/27/1957	Audrey	565	2.6
7/25/1959	Debra	586	1
9/11/1961	Carla	602	2.2
8/3/1970	Celia	690	0.8
9/16/1971	Edith	703	0.9
9/9/1971	Fern	704	0.5
9/4/1973	Delia	722	1.8
9/8/1974	Carmen	731	0.6
9/11//1982	Chris	809	1.7
8/18/1983	Alicia	812	2.4
8/15/1985	Danny	832	0.3
6/26/1986	Bonnie	841	1.3
8/1/1989	Chantal	867	1.6
10/15/1989	Jerry	874	1.3

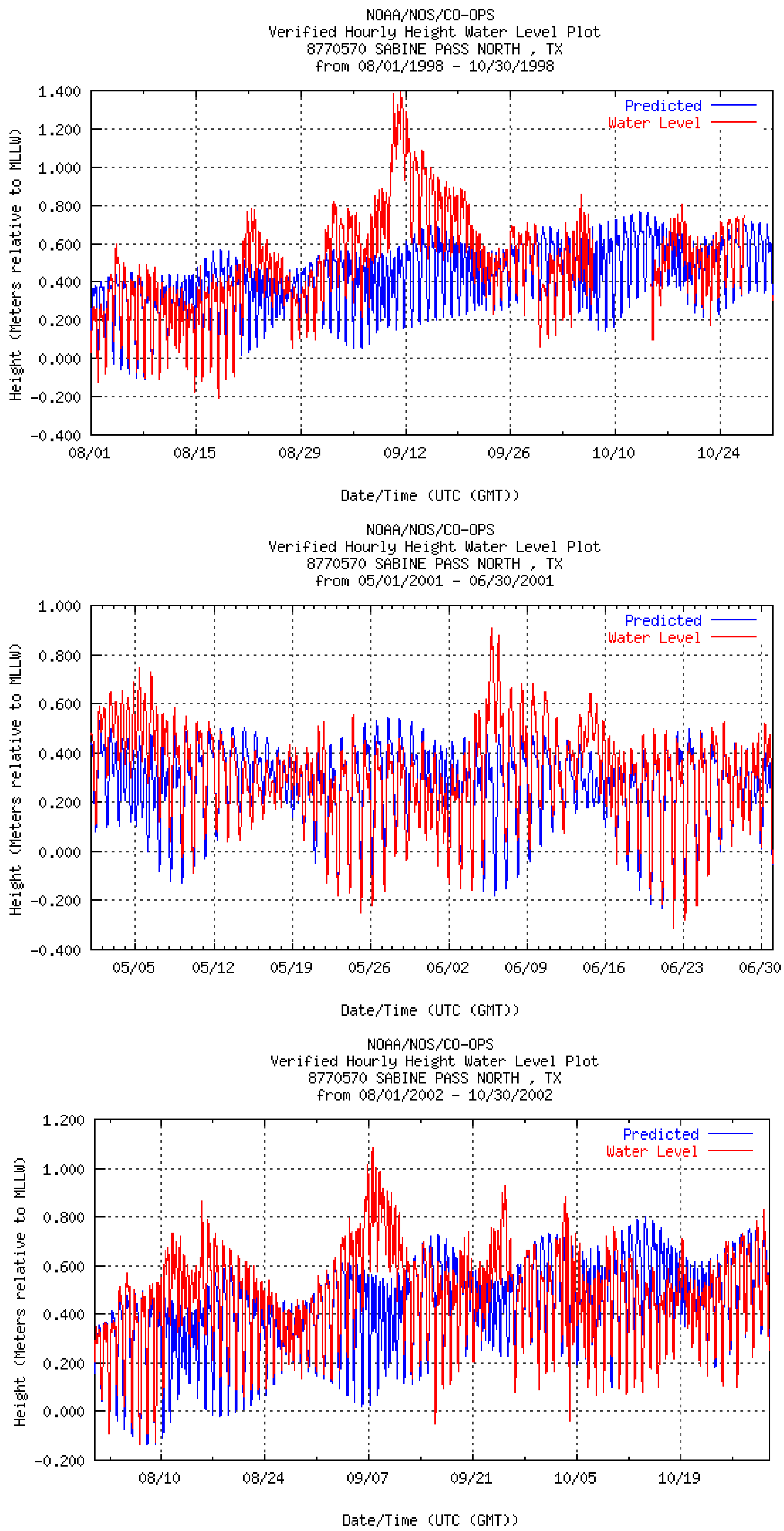

Fig. 6. Historic tide data of Sabine Pass north.

The water level data has been fit to Weibull and Gumble distributions using 95% confidence limits. Calculations were done with the use of the USACE's Automated Coastal Engineering System (ACES) program. The Weibull distribution with k=2.00 was used for design purpose due to its highest correlation coefficient. The correlation coefficient is simply a measure of how well the data set fit the intended distribution. A perfect fit would require a coefficient equal to one. Table 6 presents the 95% confidence limit results for the Weibull Distribution.

Table 6
95% confidence interval (lower bound (m)-upper bound (m))

Return Period (Yr)	FT-I	Weibull Distribution			
		k=0.75	**k=1.00**	**k=1.40**	**k=2.00**
5	0.40 – 1.34	0.55 – 1.37	0.49 – 1.28	0.43 – 1.25	0.40 – 1.19
10	1.19 – 2.07	0.91 – 2.23	1.04 – 2.19	1.13 – 2.19	1.16 – 2.23
25	1.74 – 3.47	1.19 – 3.72	1.49 – 3.63	1.74 – 3.57	1.86 – 3.57
50	2.07 – 4.57	1.40 – 5.00	1.83 – 4.75	2.13 – 4.57	2.26 - 4.48
100	2.35 - 5.70	1.62 – 6.34	2.13 – 5.88	2.47 – 5.52	2.65 – 5.30

The final statistical tool developed is Table 7 which gives the percent chance of occurrence of a specific storm event during a given time period. Table 7 is able to give insight into how much risk a given design elevation assumes.

Table 7
Percent chance of storm event occurrence

Return Period (Yr)	Period of Concern (Yr)					
	2	**5**	**10**	**25**	**50**	**100**
2	75	97	100	100	100	100
5	36	67	89	100	100	100
10	19	41	65	93	99	100
25	8	18	34	64	87	98
50	4	10	18	40	64	87
100	2	5	10	22	39	63

Applying a fifty years storm to the SH 87 problem, it is evident that over the next twenty-five years there is a forty percent chance of water levels reaching between 2.3 and 4.5 meters.

The next essential step in the design process is to determine the average berm height along the survey area and assess its likelihood of breach during a storm. From beach profiles summarized in this study, the berm height is approximately 1.5 meters above mean sea level. Using this estimation, Table 8 clearly shows that the wetlands behind the beach will flood during a ten-year event.

Table 8
Summary of extreme storm event analysis

	Weibull Distribution (meter above MSL)		**Chance of Occurrence Period of Concern**	
Return Period (Yr)	**Predicted**	**95% Limits**	**25yrs**	**50 yrs**
5	0.80	0.40– 1.19	100	100
10	1.70	1.16 – 2.23	93	99
25	2.70	1.86 – 3.57	64	87
50	3.37	2.26 - 4.48	40	64
100	3.98	2.65 – 5.30	22	39

4.3. Sediment erosion estimate

Data gathered from beach profile surveys enabled the calculation of sediment erosion rate and direction. All data in this study were collected and analyzed by Texas A&M University from the Summer of 1999 to the Fall of 2002. Eight beach profile surveys were done in the Jefferson county area. In the first survey, there were 156 lines every 200 meters along the entire survey area but survey lines were established again every 400 meters since the fall of 1999 so just even line profile data are listed in Appendix A and B. Figure 7 shows comparison of on and offshore profile for three surveys. In case of the data of on and offshore profile, there are three surveys. A full presentation of all of the data is listed in Appendix B. A brief presentation of the data is given below.

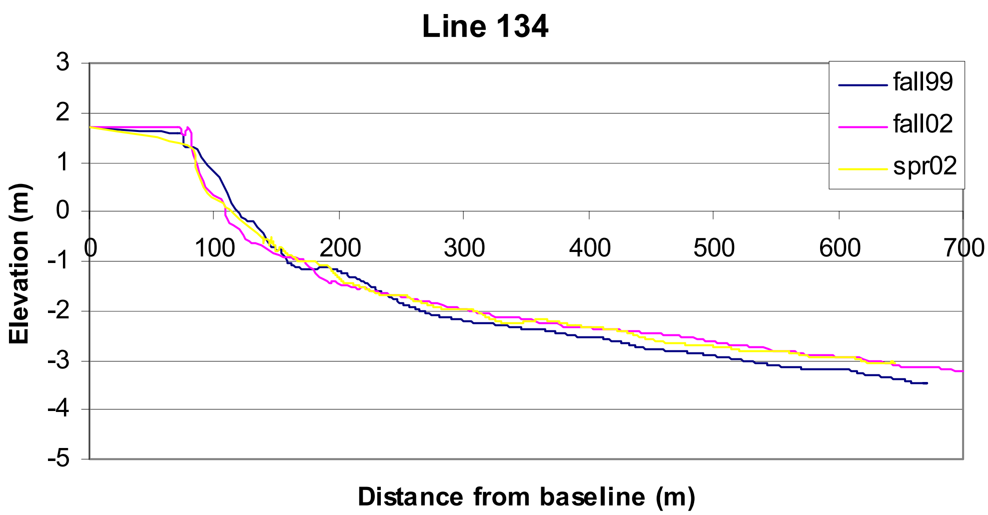

Fig. 7. Comparison of three profiles at line 134.

The survey location is divided into three areas according to the erosion rate. The west section of the survey area is roughly line 1 through 30 where erosion rates are relatively low. The profile line starting at line one contains larger dunes, then they taper out around line eight. On these dunes there is tall grass which inhibits the sand from being washed away from storm surge, or the every day occurrence of wind. At line eight this small dune system completely tapers out to around line 22 where there is less vegetation in that area. Line 22 is located in front of the survey monument CATT. Figure 8 shows near CATT area. At line 22 there are small dunes, but there are also trees, and shrubs on the beach which help the sand from eroding at a quicker rate.

Fig. 8. Near CATT where road is destroyed, picture taken October 5, 2002.

When looking at the overall data at line 22 that is presented in figure 9, it is clear that the formation of a small berm has migrated there over the seasons and rate of erosion averaged about 4m/yr. The small berms could have been created either from storm activity such as storm surge or the natural movement of the sand through the season. Then at line 30 the dunes and vegetation disappears as the rate of erosion increases.

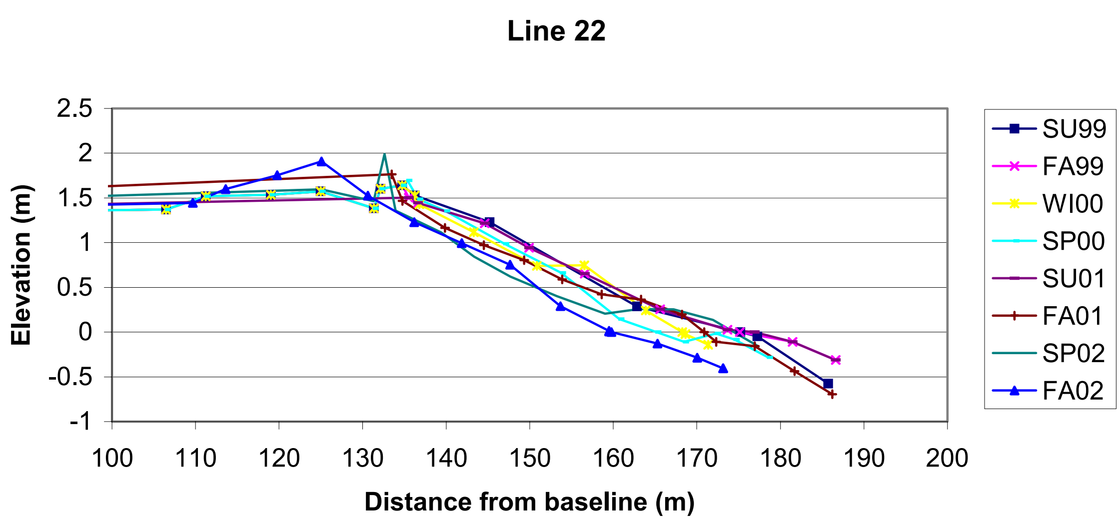

Fig. 9. Line 22 onshore data.

The midsection of survey area from line 30 through 130 includes the beach segment where Highway 87 has been destroyed by erosion. In the middle section where the most continuous erosion occurs there is very little vegetation to be found on the beach. This beach segment is characterized by a narrow, relatively steep beach and washover terrace composed of sand and shell and underlain by mud. The crest of the washover terrace or edge of the destroyed road is the shoreline feature for this beach segment. There are no dunes to prevent the pasture or wetlands from flooding during heavy weather. The only change in topography was created by farmers fixing their fences and scraping a dirt road in January of 2002. From line 90 eastward, there is more mud to be found than sand (physically observed).

Fig. 10. Near VASTAR where the beach no longer exists, picture taken May 24, 2002.

Figure 11 shows line 114 onshore profile with roughly 25 meters of erosion over a four-year period. Line 114 is located near the survey monument VASTAR (Figure 10). It is the most eroded region in the survey area.

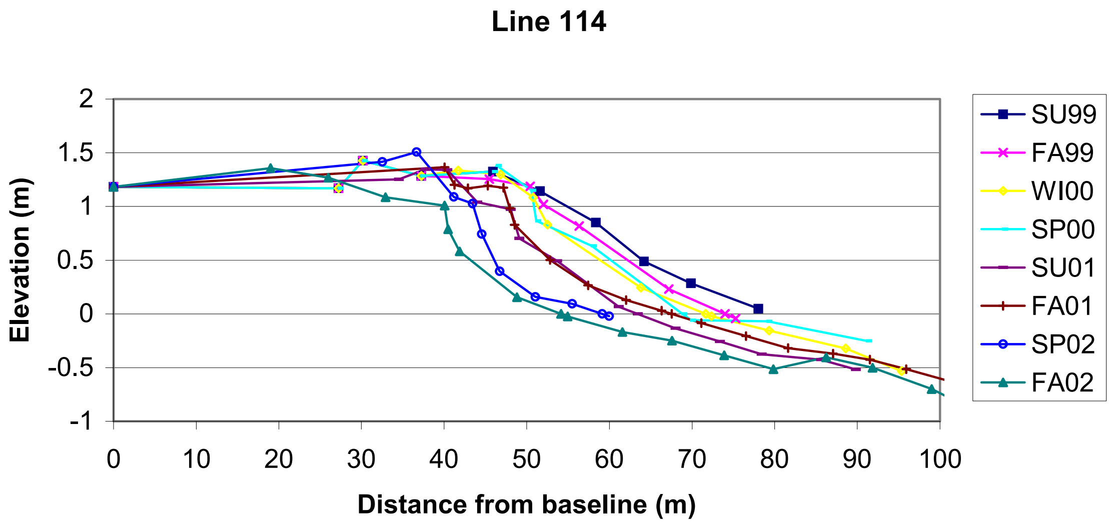

Fig. 11. Line 114 onshore data.

The east section of survey area consists of lines 130 to lines 156, which includes the survey monument CLAM. Figure 12 views near CLAM. The beach of this segment is relatively wide, exhibits low vegetated dunes, and is composed of sand over mud.

Fig. 12. Near CLAM where the beach is wide, picture taken May 24, 2002.

At line 130 the vegetation between the beach and the pasture starts to increase and small dunes start to develop at around 0.5 meters in height. At line 140 the beach looks wider and healthier. This coincides with the dunes in this area, as they also start to increase as well as the vegetation on the dunes. There are also shrubs in this area where inhibit the movement of sand during heavy weather. Figure 13 shows line 144 onshore profile with wide and gentle slope beach.

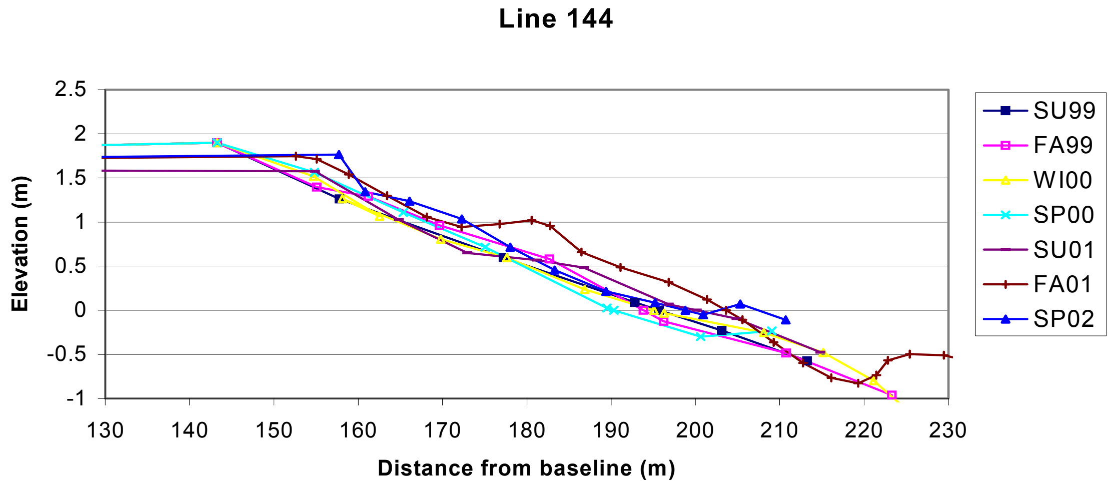

Fig. 13. Line 144 onshore data.

The shoreline is defined as mean sea level (MSL), which corresponds to an orthometric height of zero using the NAVD 88 datum. Using the measured profiles, a zero elevation was interpolated using an Excel spreadsheet at each transect creating a continuous MSL contour.

Figure 14 shows the change of shoreline position. Comparing the shoreline position shows how much erosion occurred over four years. But since the shoreline is not a uniform line we can use the change in position of the zero elevations from the summer of 1999 to the fall 2002 to determine the total amount of erosion that has occurred over the last four years.

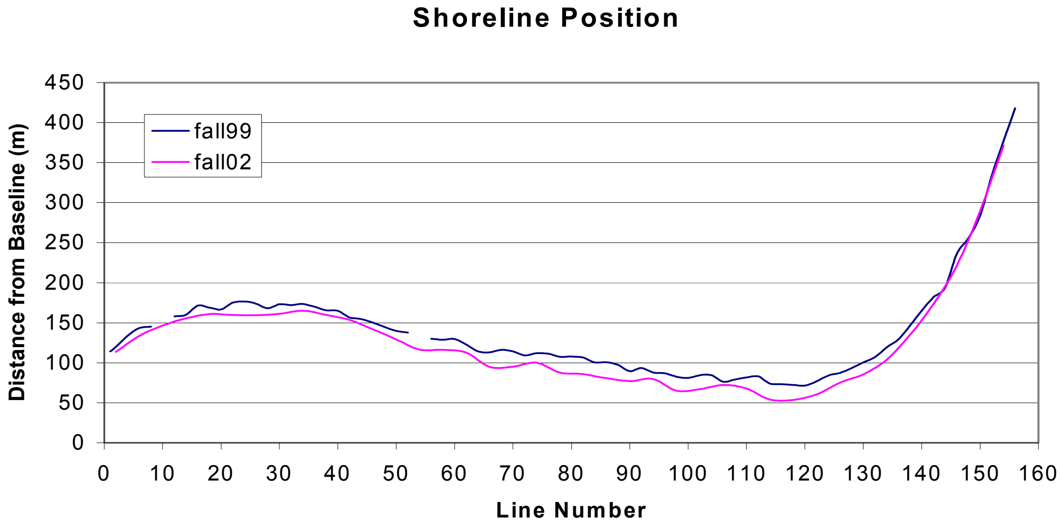

Fig. 14. Change in shoreline comparing the Fall99 and Fall02.

The figure 15 shows the middle region of the survey area has the highest amount of sediment transported away from the site. This supports the hypothesis that maximum beach recession is occurring at the central survey area.

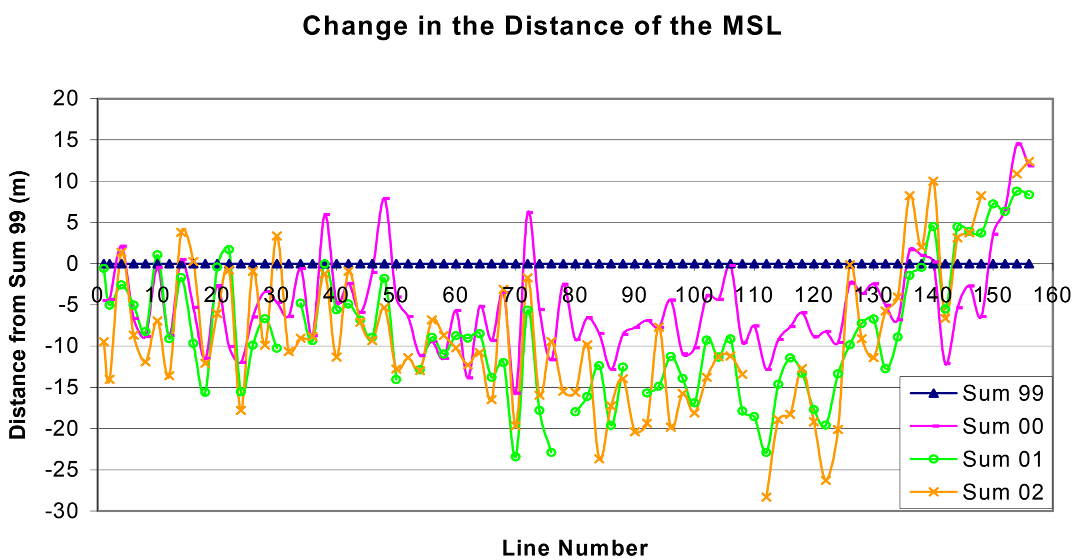

Fig. 15. Graph of the erosion rate based on the distance of the MSL.

The maximum erosion occurred at line 112 with roughly 28 meters of loss over a four-year period. Whereas line 156 shows more than 10 meters of accretion over a four-year period. This accretion could be a result in response to the sand supplied by alongshore transport. The midsection conversely has no dunes, and there is no vegetation on the sand area to prevent the sand from being removed into the overwash area, and permanently lost from the system.

Near profile 114, the sand transport is divergent, called a nodal area. The nodal area refers to a location along the shoreline that experiences excessive erosion because the sediment is being transported both east and west divergently. The current location of a nodal area is near profile 114.

The advance or retreat of the shoreline varies across the study area. Net change rate was calculated from the erosion rate based on the distance of the MSL (Fig 15). Table 9 details shoreline movement from 1999 to 2002 at the western edge of the study area and each of the three benchmarks from west to east. The erosion is relatively low at Chambers County and then gets abruptly worse near the Jefferson County line.

Table 9
Comparison of net shoreline changes 1999-2002

Location	**Morton Transect**	**1996 - 1999 Net change (m)**	**1996 - 1999 Average rate (m/yr)**	**1999 - 2002 Net change (m)**	**1999 - 2002 Average rate (m/yr)**
Chambers county	36	-5.03	-1.68	-10.14	**-3.38**
CATT	34	-14.63	-4.88	-12.08	**-4.03**
VASTAR	23	-14.63	-4.88	-17.72	**-5.91**
CLAM	15	24.69	8.23	12.38	**4.12**

The shoreline historically has receded across the entire study area except at the eastern region. The 1999-2002 yearly average erosion rate at Chambers County increased two times from 1996-1999 surveys but CATT erosion rate agrees closely with the 1974-1996 survey data. On the other hand it has remained constant over the last six years. Erosion rate at VASTAR a little bit increased from the 1996 -1999 survey. At VASTAR, visual evidence collected suggests a significant amount of the erosion since 1999. In June of 2001, tropical storm Allison made landfall at Jefferson County and in the next fall tropical storm Fay and hurricane Lili affected the Texas shoreline. The evidence strongly suggests that the erosion is primarily a result of the storm and not due to normal tide and wave activity. Finally CLAM's accretion rate has slowed by half from the 1996-1999 surveys to just over 4 m/yr, but the beach is still advancing and has not retreated since 1999.

4.4. Equilibrium profiles

A sediment size correlates to a useful simple equation for the equilibrium profile of the form $h(y)=Ax^{2/3}$ in which h is the water depth at a distance x from the shoreline and A is a so-called "profile scale parameter" with dimensions of length to the 1/3 power. The grain size d50 can be got from sand sample data and the parameter A can be estimated directly from table 10. Dean (2002) showed the A parameter to be related approximately linearly to fall velocity w, and recommended these A values.

Table 10
Summary of recommended A value (Units of A parameter are $m^{1/3}$)-Dean (2002)

D(mm)	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.1	0.063	0.0672	0.0714	0.0756	0.0798	0.084	0.0872	0.0904	0.0936	0.0968
0.2	0.1	0.103	0.106	0.109	0.112	0.115	0.117	0.119	0.121	0.123
0.3	0.125	0.127	0.129	0.131	0.133	0.135	0.137	0.139	0.141	0.143
0.4	0.145	0.1466	0.1482	0.1498	0.1514	0.153	0.1546	0.1562	0.1578	0.1594
0.5	0.161	0.1622	0.1634	0.1646	0.1658	0.167	0.1682	0.1694	0.1706	0.1718
0.6	0.173	0.1742	0.1754	0.1766	0.1778	0.179	0.1802	0.1814	0.1826	0.1838
0.7	0.185	0.1859	0.1868	0.1877	0.1886	0.1895	0.1904	0.1913	0.1922	0.1931
0.8	0.194	0.1948	0.1956	0.1964	0.1972	0.198	0.1988	0.1996	0.2004	0.2012
0.9	0.202	0.2028	0.2036	0.2044	0.2052	0.206	0.2068	0.2076	0.2084	0.2092
1	0.21	0.2108	0.2116	0.2124	0.2132	0.214	0.2148	0.2156	0.2164	0.2172

Table 11 Shows comparison of d50 grain size and A values of sand samples at corresponding profile line 5.

Table 11
Comparison of d50 grain size and A values of two different samples collection

2002 Sand samples				1999 Sand samples (Howard)			
Line No	Location	d50 (mm)	A values	Line No	Location	d50 (mm)	A values
	Berm	0.21811	0.105		Berm	0.17747	0.0928
18	Beach Face	0.19041	0.0968	w24	Beach Face	0	
	Offshore	0.16283	0.088		Offshore	0	
	Berm	0.19368	0.098		Berm	0.19504	0.0984
38	Beach Face	0.19233	0.097	w20	Beach Face	0.11179	0.068
	Offshore	clay			Offshore	0	
	Berm	0.21567	0.1045		Berm	0.19371	0.0981
58	Beach Face	0.17559	0.092	w15	Beach Face	0.11859	0.0712
	Offshore	clay			Offshore	0	
	Berm	0.21246	0.104		Berm	0.17414	0.0922
78	Beach Face	0.20151	0.1	w10	Beach Face	0.12713	0.0743
	Offshore	clay			Offshore	0.21782	0.105
	Berm	0.21715	0.105		Berm	0.16241	0.088
98	Beach Face	clay		w5	Beach Face	0.12987	0.0755
	Offshore	clay			Offshore	0	
	Berm	0.18576	0.095		Berm	0.15172	0.085
118	Beach Face	0.14682	0.082	0	Beach Face	0	
	Offshore	clay			Offshore	0.22819	0.1085
	Berm	0.15132	0.0845		Berm	0.157	0.086
138	Beach Face	0.16889	0.089	e5	Beach Face	0.22697	0.108
	Offshore	clay			Offshore	0.21283	0.104

Figure 16 shows native profiles and computed equilibrium profiles. In this study, seven equilibrium profiles were compared with measured profiles listed in table 11. The rest of the equilibrium profiles are listed in Appendix C. The A parameter was taken on the berm from table 11. In figure 16, the slope of equilibrium profile is much steeper than that of native profile and it diverges roughly after 1 meter water depth area. The other approach to determining the A value is based on depths (Dean, 2002). Application of the method of least squares in which the sum of squares of the deviations between the calculated (based on $h(y)=Ax^{2/3}$) and the measured depths are minimized in

$$A_N = \frac{\sum_{1}^{I} h_i y_i^{2/3}}{\sum_{1}^{I} y_i^{4/3}}$$

in which I is the total number of depths available. Applying above equation to the available data for profile 138 results in an A = 0.055 $m^{2/3}$ which is significantly smaller than A value estimated from table 11. That means there exist different grain size or different material on the seabed such as mud, clay or fine sand beyond the 1 meter depth. This characteristic of profile exists in the entire survey area.

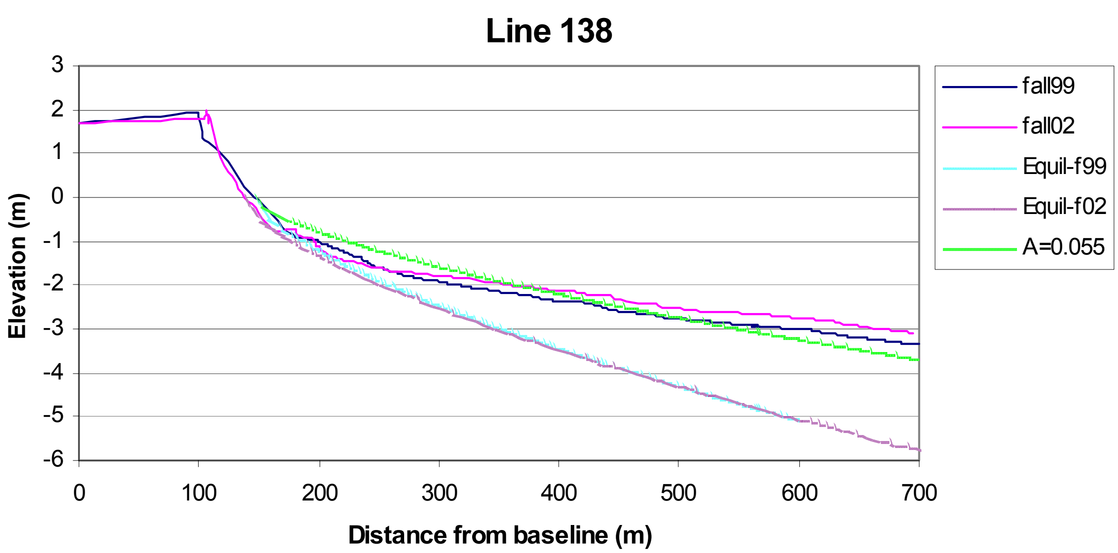

Fig 16. Equilibrium beach profile at line 138.

CHAPTER V

CONCLUSIONS AND RECOMMENDATION

The beach profile data taken during the past four years of the SH 87 area in Jefferson County were processed and analyzed to provide information regarding the coastal processes effecting the upper Texas Coast. Comparison of all surveys shows how much the SH 87 area in Jefferson County is accreting or retreating throughout the survey area.

The highest rates of recession are in the central region from line 30 through 130 including VASTAR. The maximum erosion occurred at line 112 with roughly 28 meters of loss over a four-year period. The nodal point where the sand transport is divergent is assumed to occur at line114. The midsection conversely has no dunes, and there is no vegetation on the sand area to prevent the sand from being removed into the overwash area. During storm event, the sand on the beach face is washed up and over the berm because of storm surge. These storms cause the dune to roll back on itself as the clay is exposed. Without a protective layer of sand to absorb wave energy, the substrate is eroded. Beach survey data and wave data confirm that the greatest shoreline recession coincides with the highest waves.

On the other hand line 156 shows more than 10 meters of accretion over a four-year period. This accretion could be a factor of the beach nourishment, and dune nourishment that has been in affect in that area over the last year.

In view of the results so far achieved, there exists a sand deficit along the entire survey area excluding the most eastern area. The most likely solution to the erosion problem appears to be geotubes and beach nourishment. Geotubes are tubes that have an oval-shaped cross section made of geotextile fabric. When filled with sand they have a cross section of about 3.7m. They are placed parallel to the shoreline with the intent of protecting property from storm surge and erosion. Beach nourishment involves the placement of material offshore with the normal action of waves or will provide protection to the shore from erosion by reducing the effects of waves.

A nourishment project would require the identification of a suitable borrow site. Further research is required on a possible source in the Sabine Banks to determine its viability as a borrow site. Then the sand volume must be quantified both on the beach face and to the depth of closure. Further additional accurate surveys and investigations will provide information and solution that can be used for the design of the new highway.

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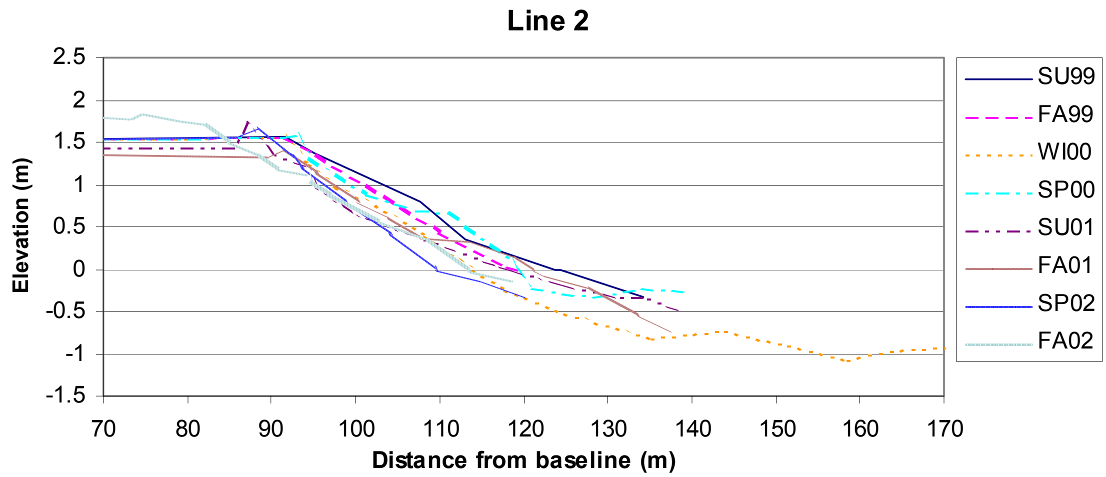
APPENDIX A

BEACH SURVEY PROFILES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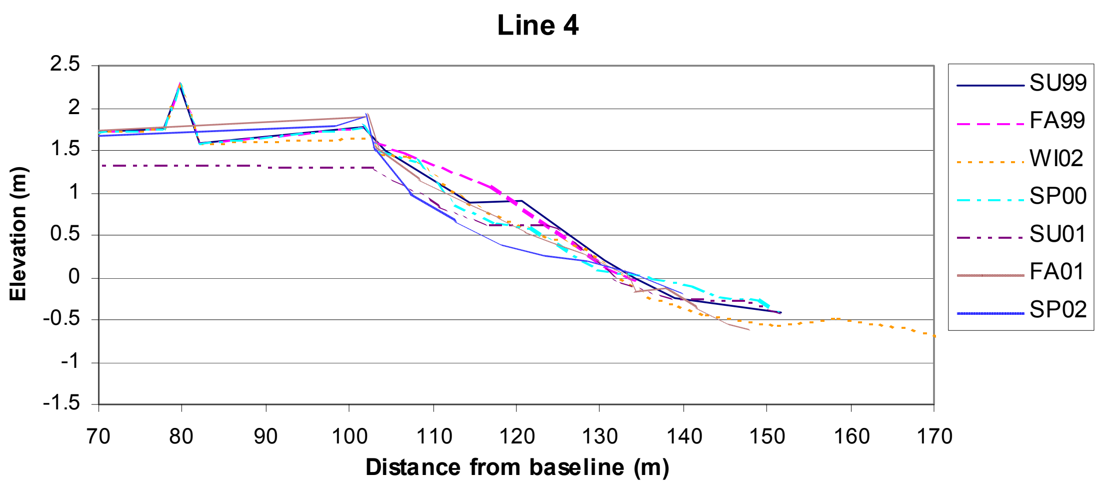
SU01
FA01
SP02
FA02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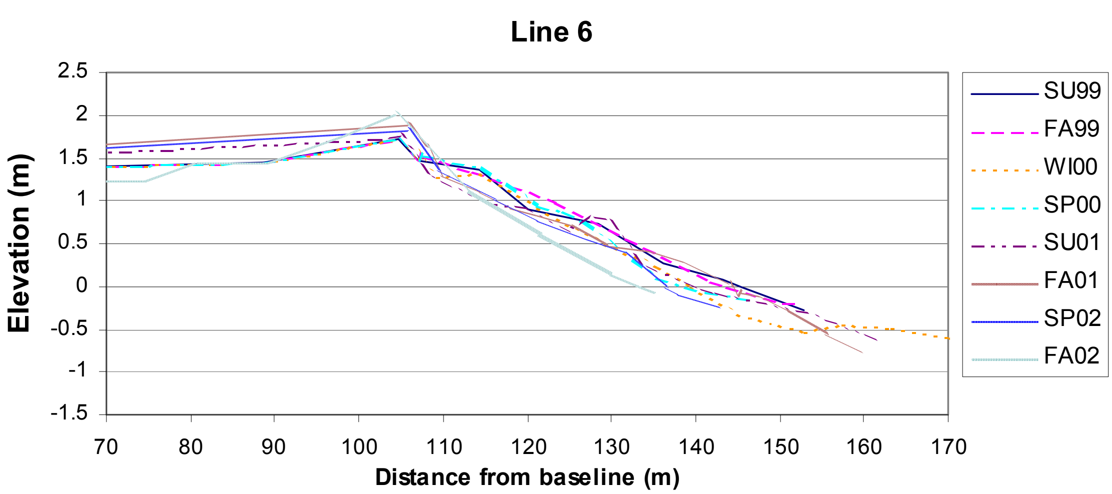
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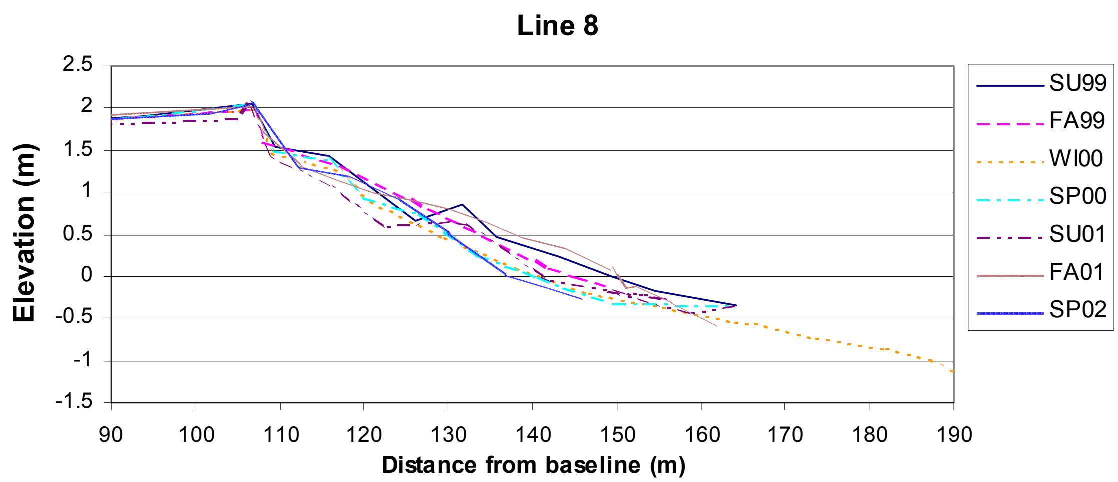
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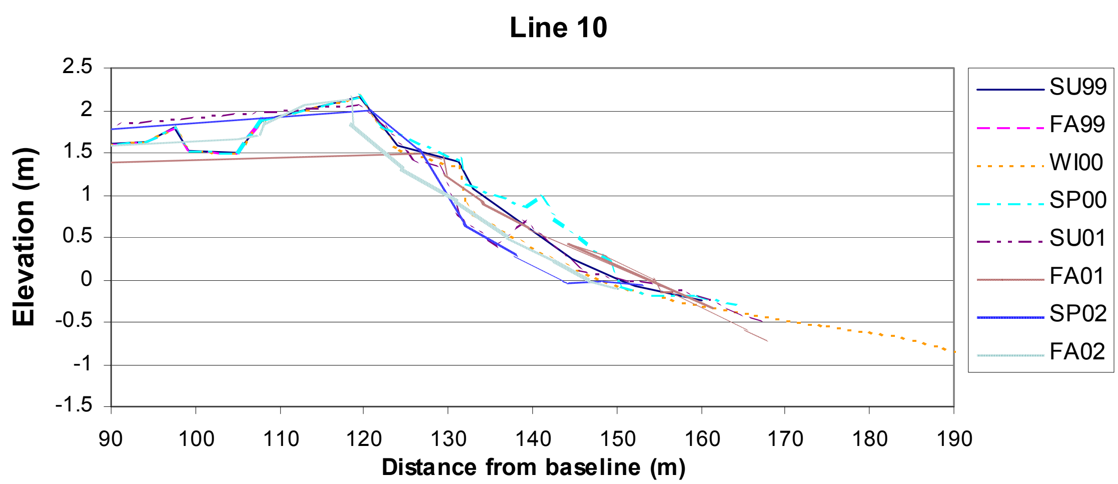
150
160
170
180
190
SU99
FA99
WI00
SP00
SU01
FA01
SP02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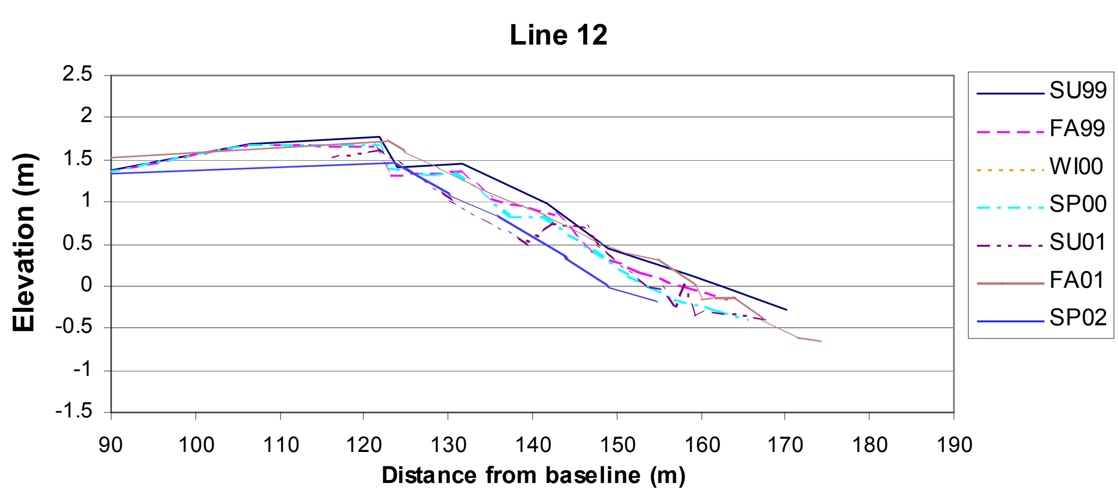
FA02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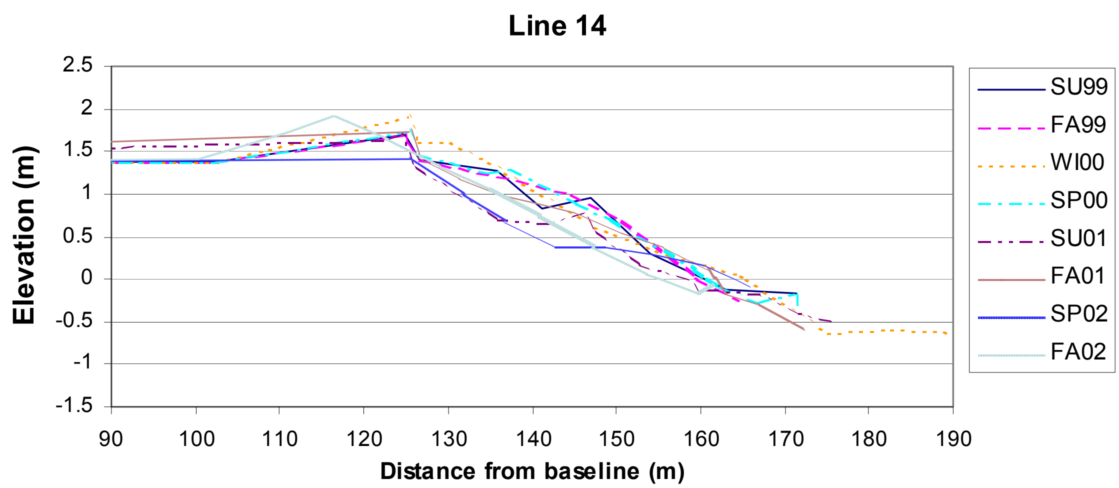
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Distance from baseline (m)
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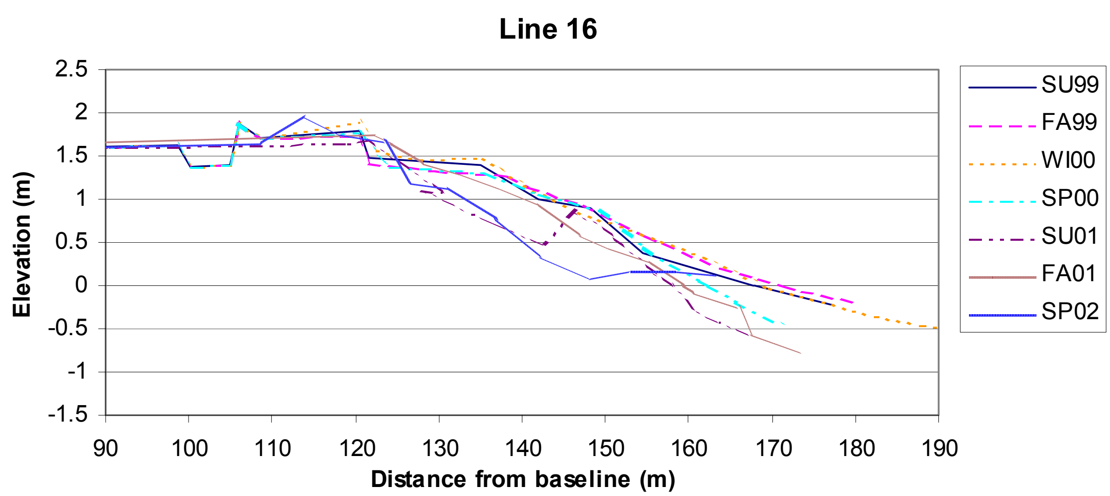
WI00
SP00
SU01
FA01
SP02
FA02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Distance from baseline (m)
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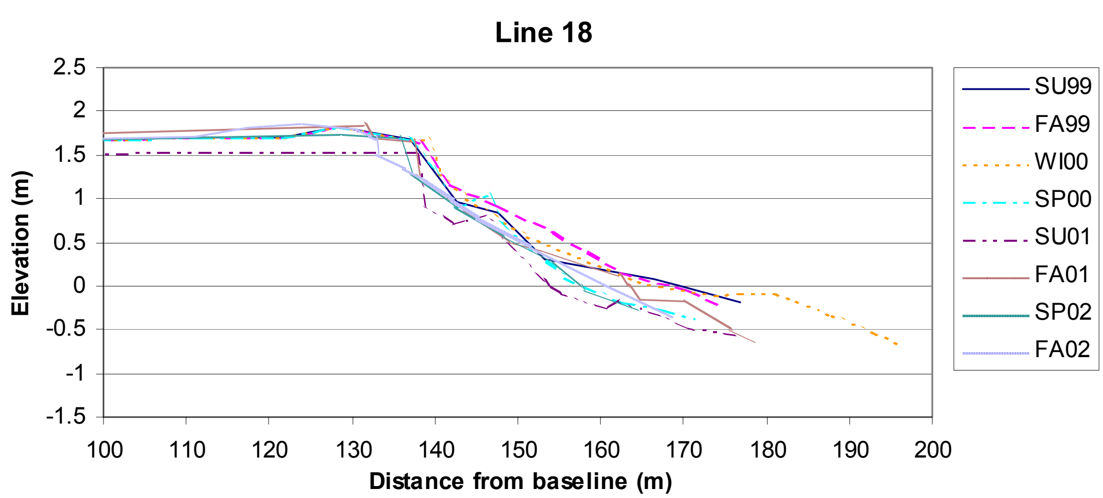
SP00
SU01
FA01
SP02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170
180
190
200
Distance from baseline (m)
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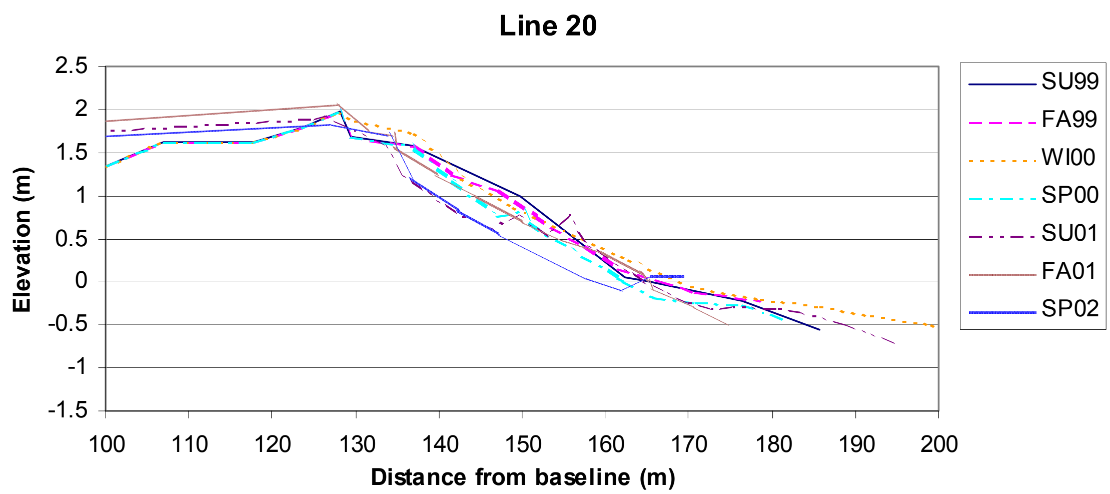
FA99
WI00
SP00
SU01
FA01
SP02
FA02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Distance from baseline (m)
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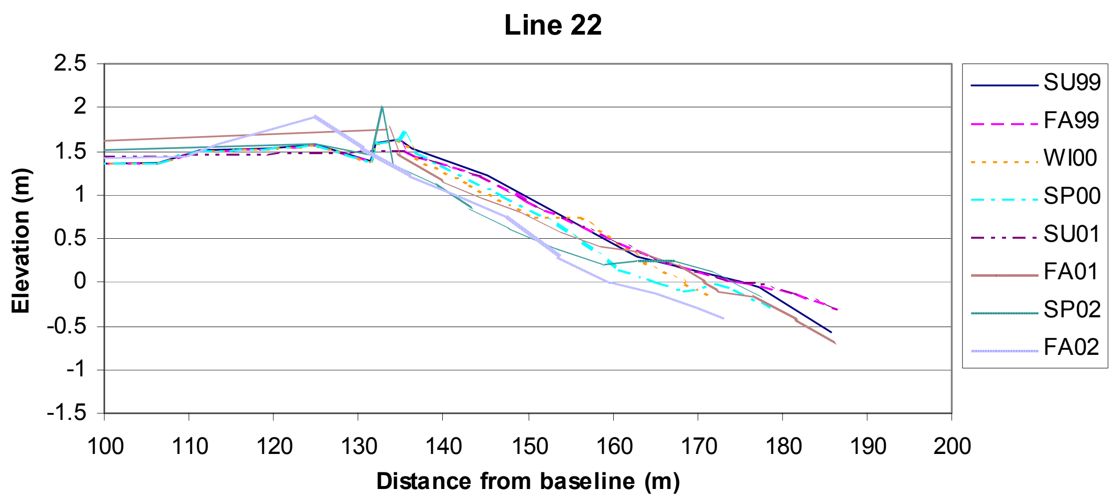
FA99
WI00
SP00
SU01
FA01
SP02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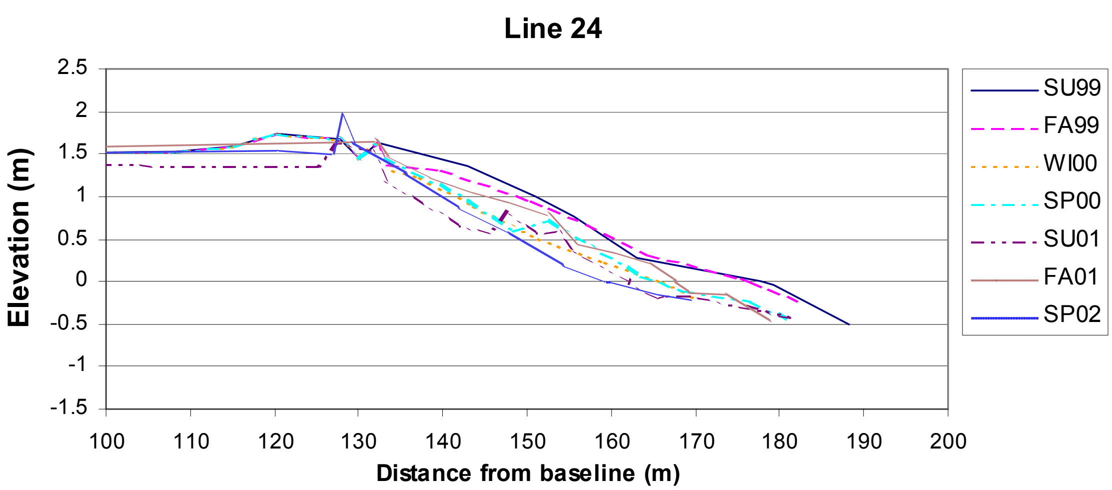
FA01
SP02
FA02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FA01
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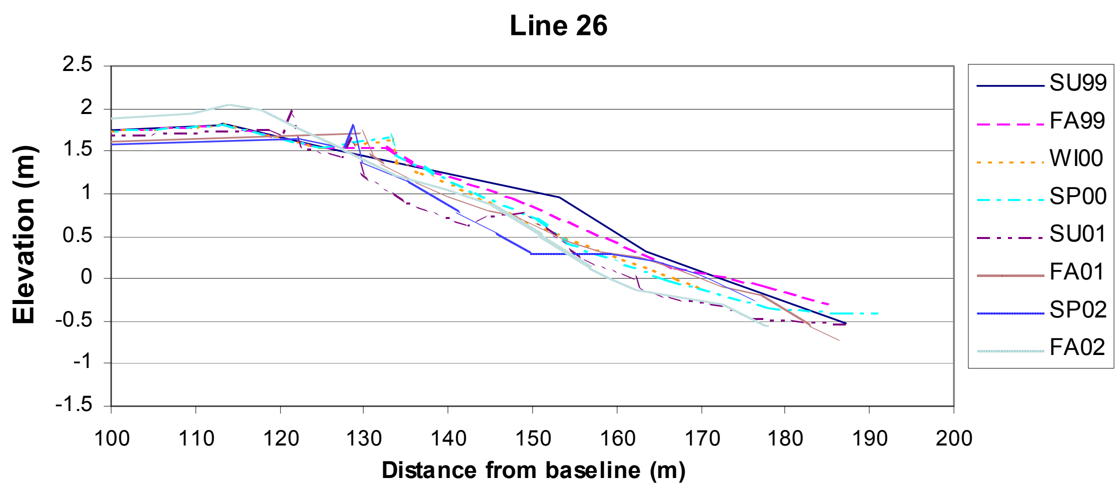
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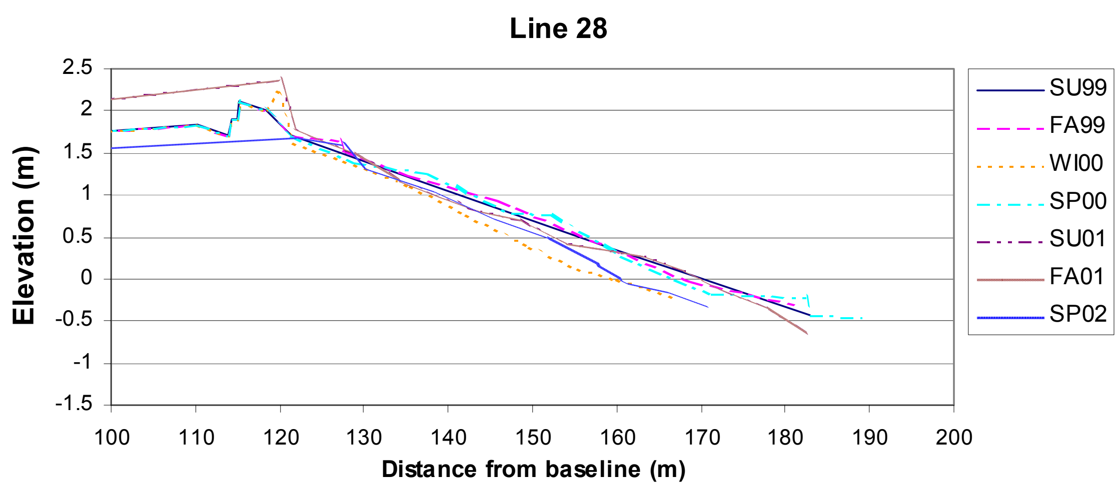
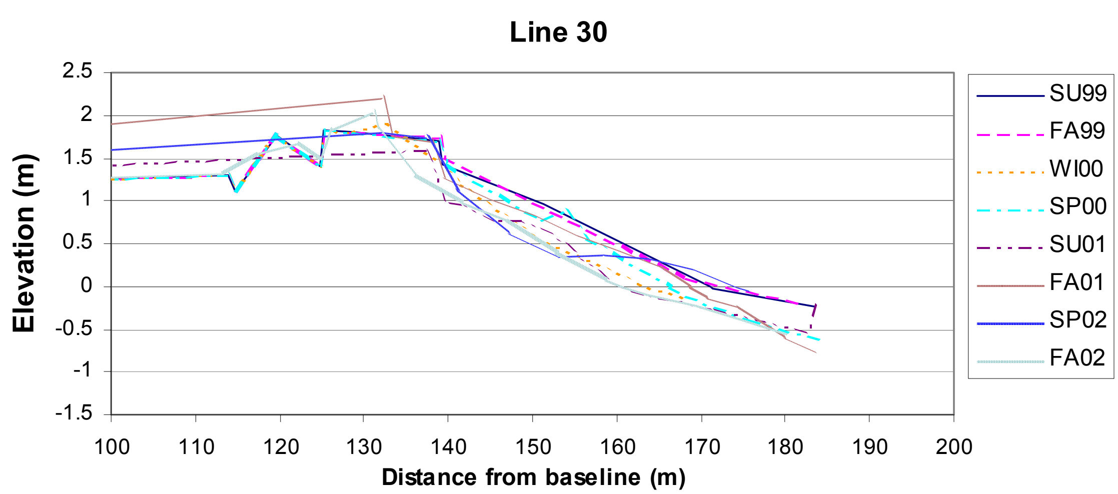
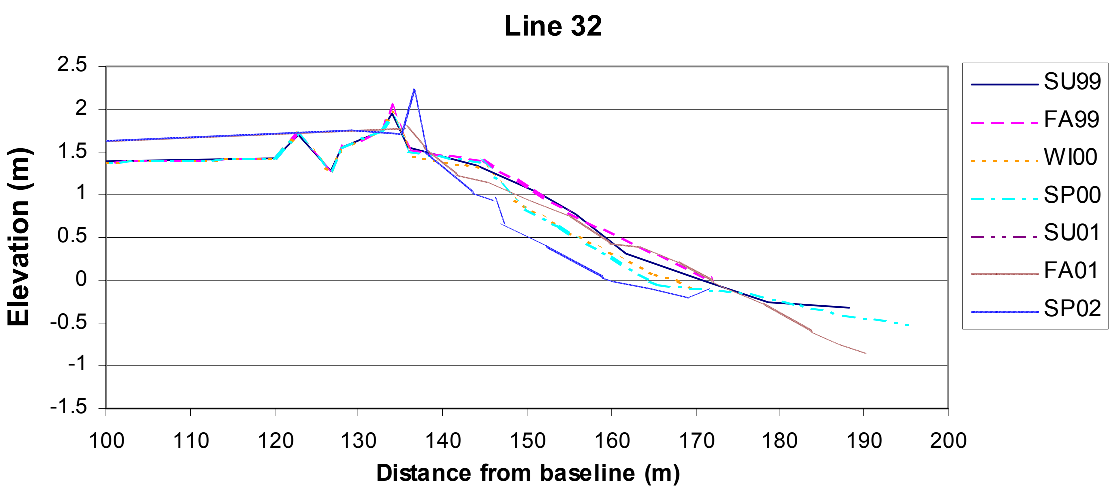
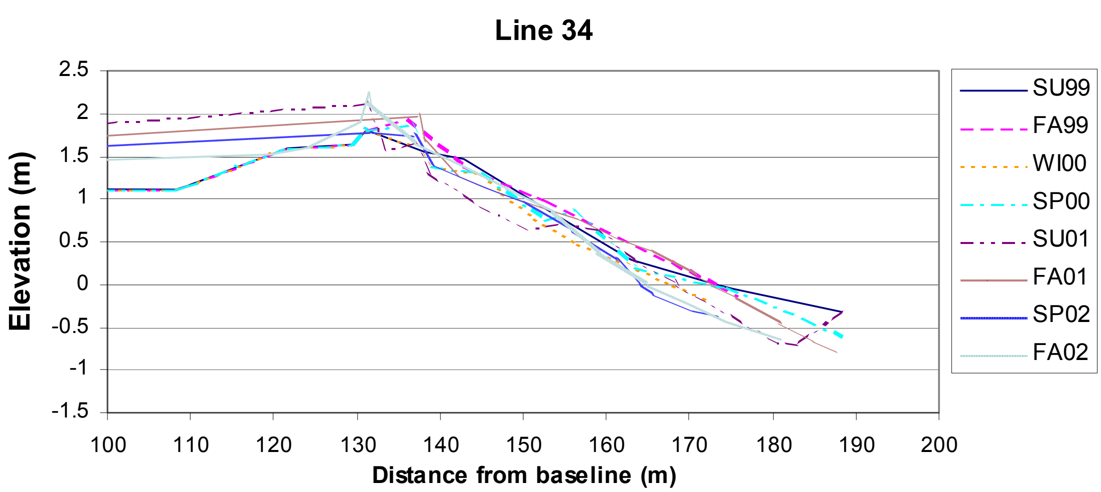
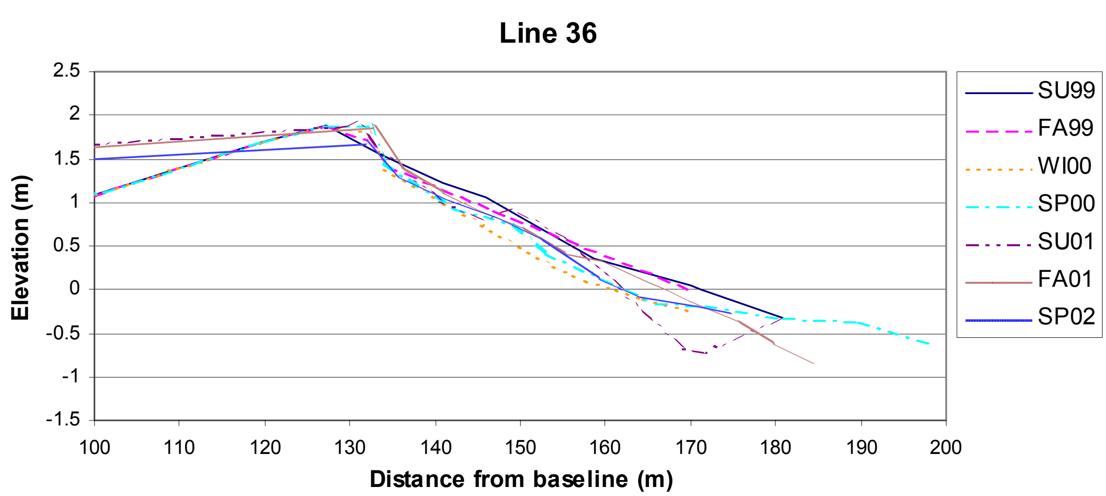
190
200
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

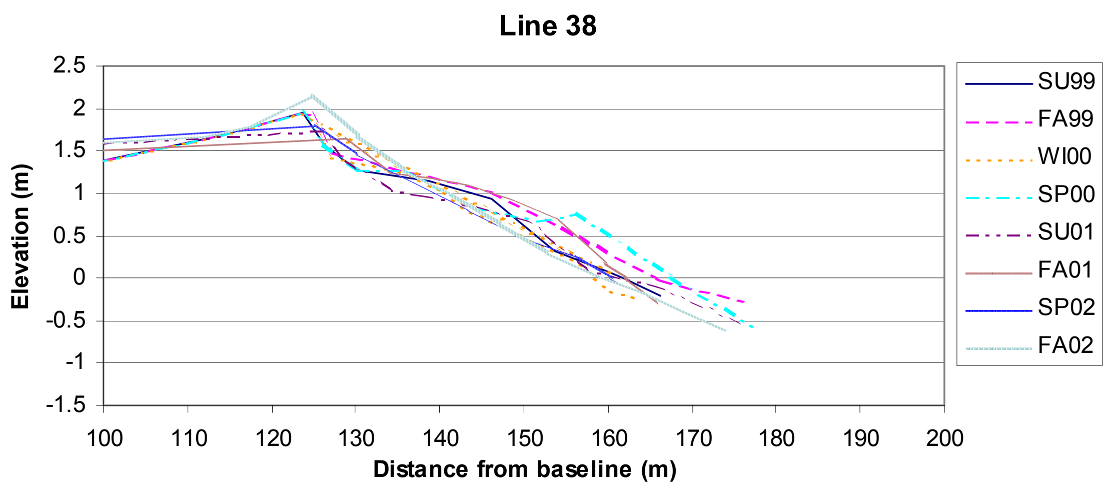

Line 28
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
100
110
120
130
140
150
160
170
180
190
200
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

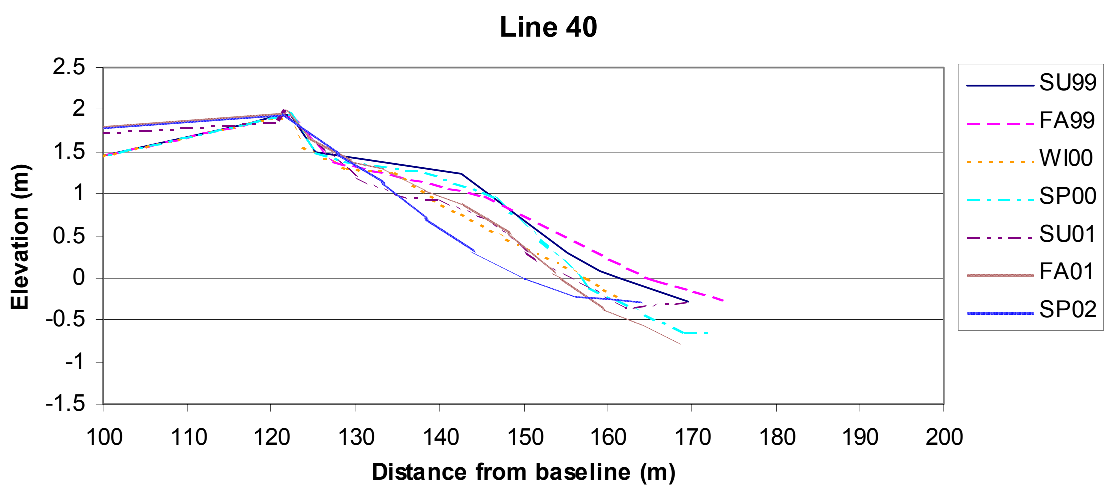

Line 30
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
100
110
120
130
140
150
160
170
180
190
200
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

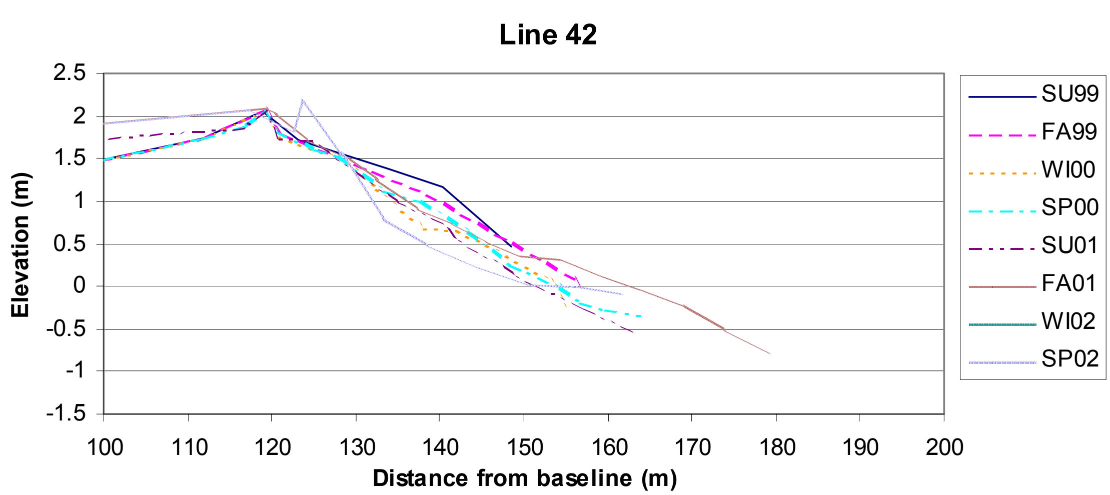

Line 32
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
100
110
120
130
140
150
160
170
180
190
200
SU99
FA99
WI00
SP00
SU01
FA01
SP02

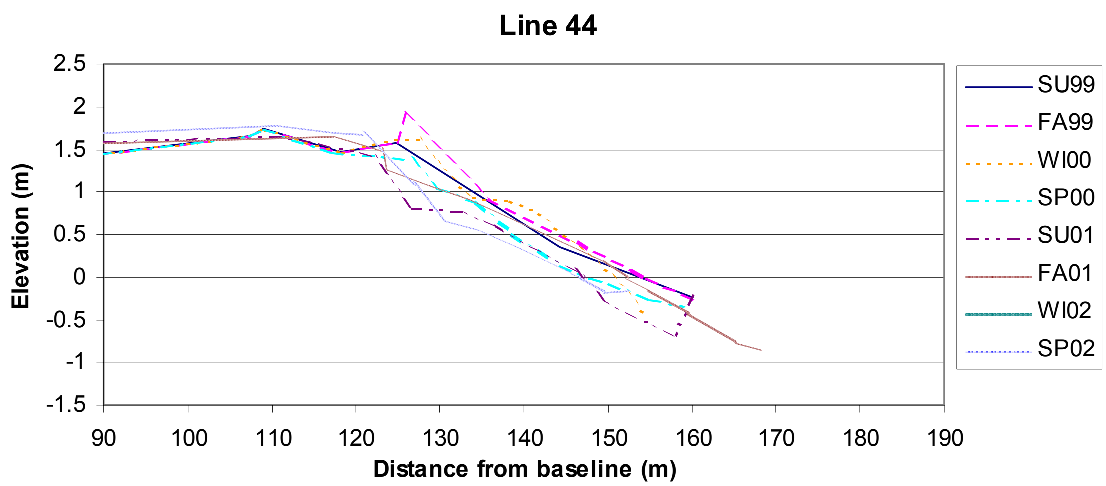

Line 34
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
100
110
120
130
140
150
160
170
180
190
200
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

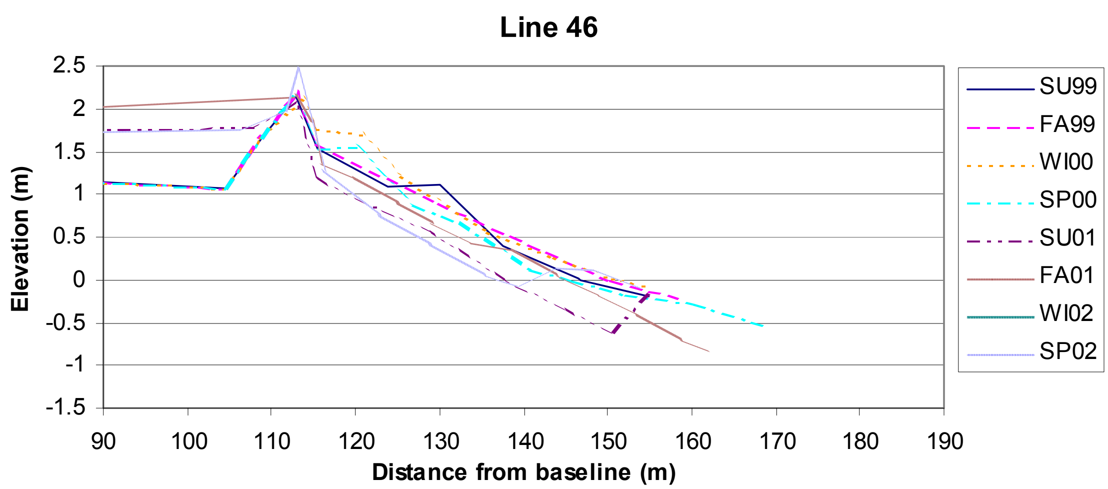

Line 36
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
100
110
120
130
140
150
160
170
180
190
200
SU99
FA99
WI00
SP00
SU01
FA01
SP02

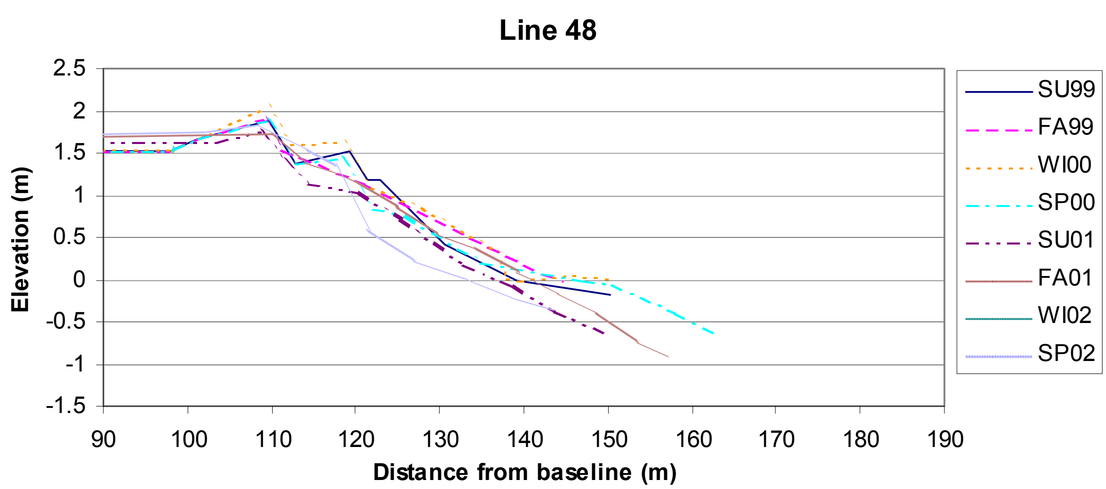

Line 38
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

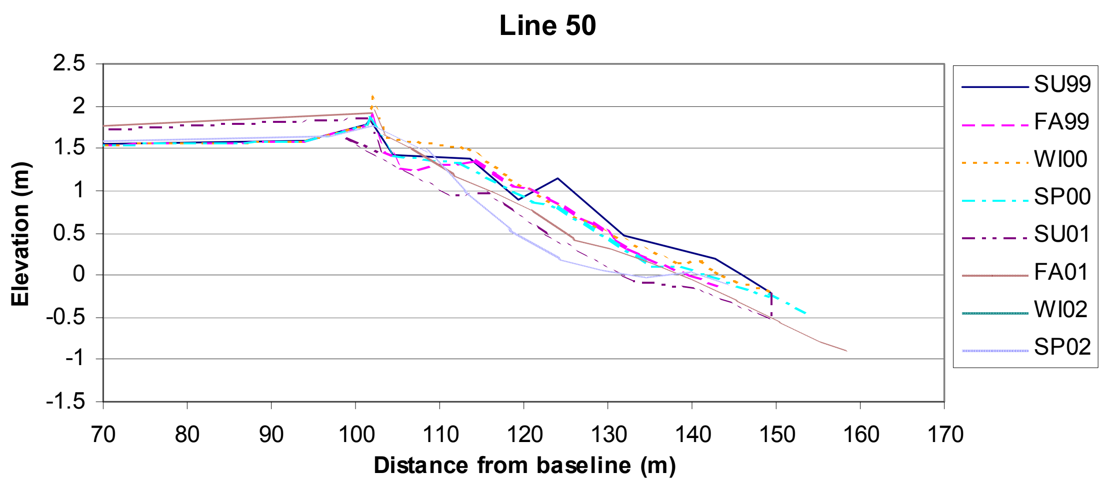

Line 40
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

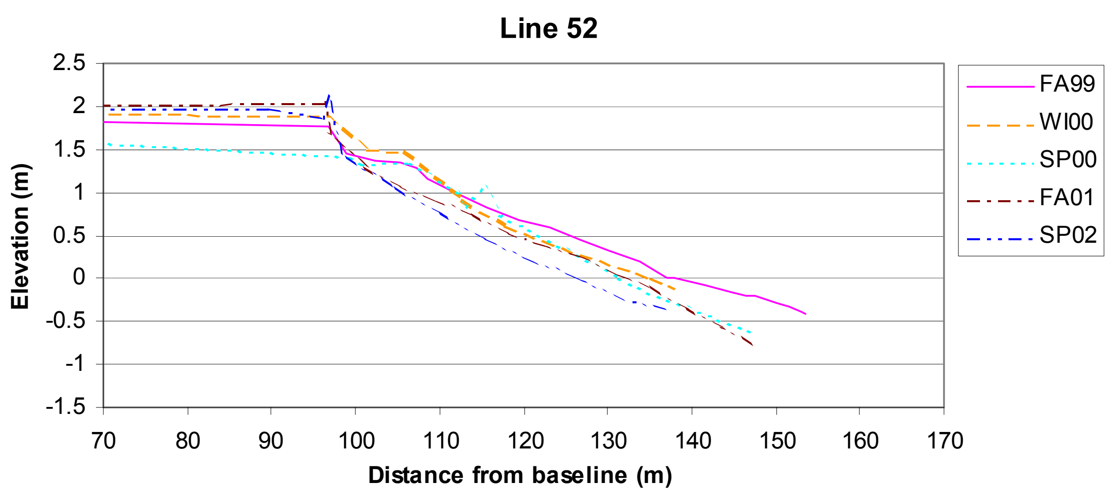

Line 42
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
WI02
SP02

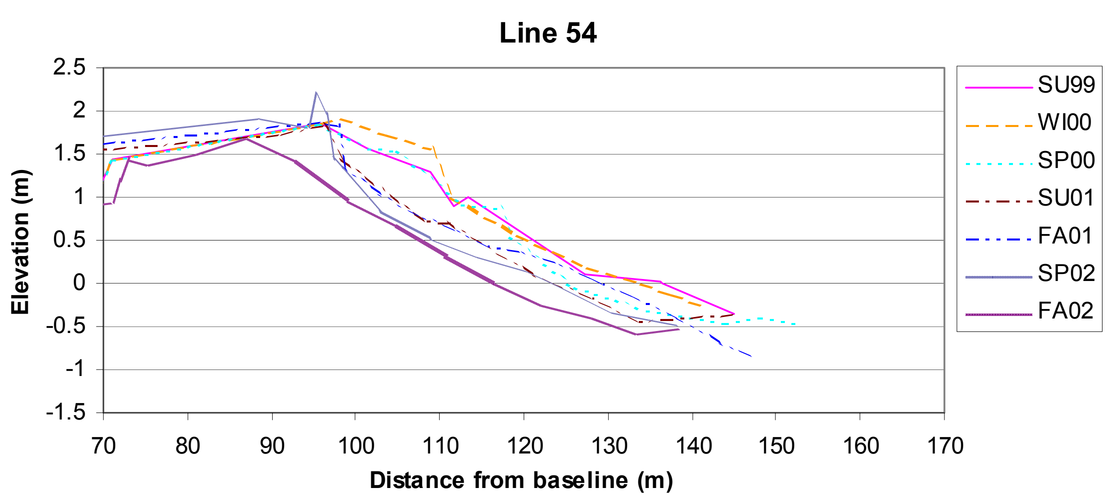

Line 44
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
90
100
110
120
130
140
150
160
170
180
190
SU99
FA99
WI00
SP00
SU01
FA01
WI02
SP02

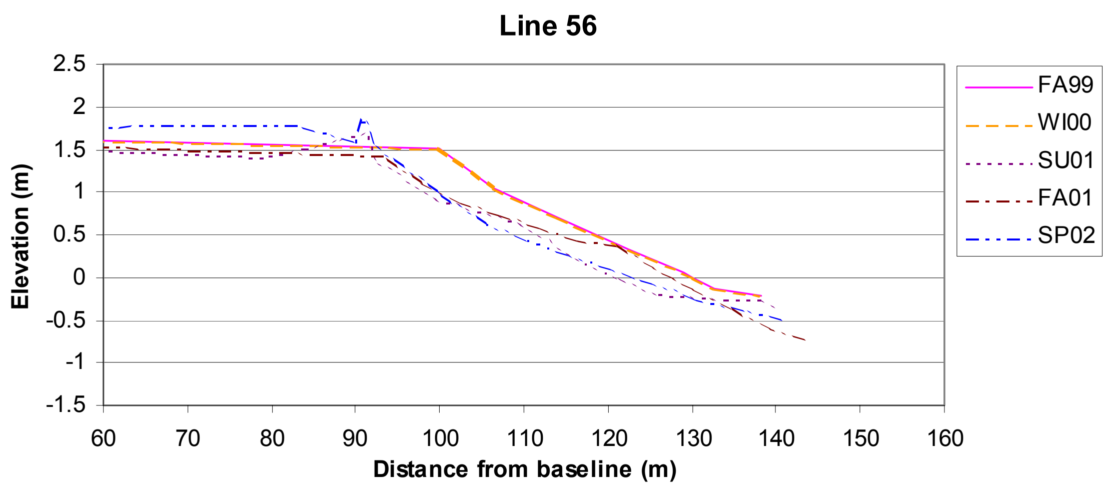

Line 46
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
90
100
110
120
130
140
150
160
170
180
190
SU99
FA99
WI00
SP00
SU01
FA01
WI02
SP02

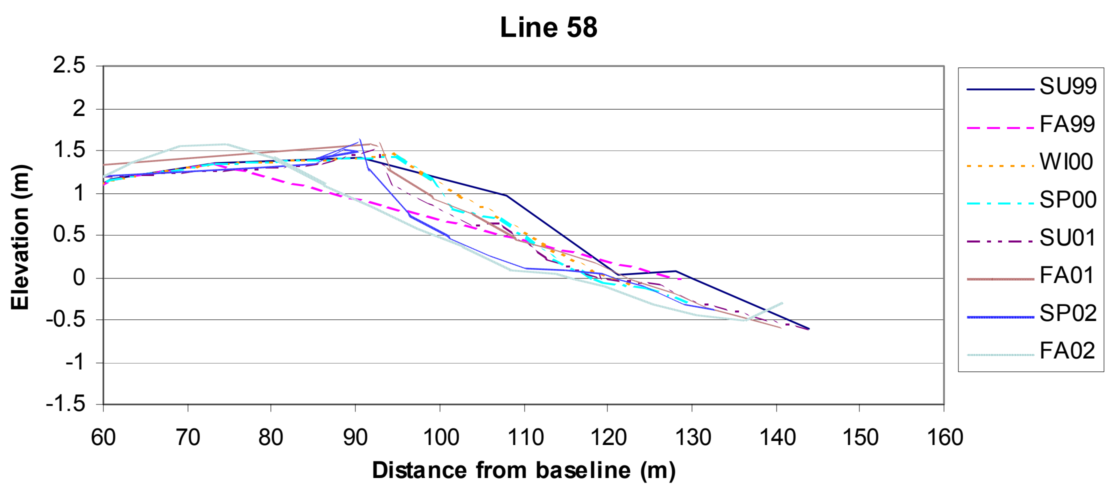

Line 48
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
90
100
110
120
130
140
150
160
170
180
190
SU99
FA99
WI00
SP00
SU01
FA01
WI02
SP02

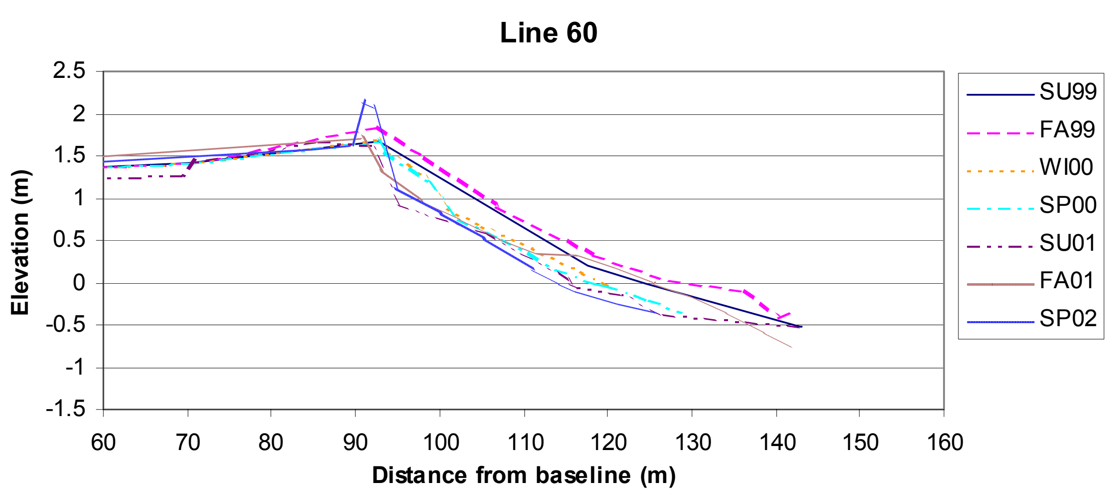

Line 50
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
70
80
90
100
110
120
130
140
150
160
170
SU99
FA99
WI00
SP00
SU01
FA01
WI02
SP02

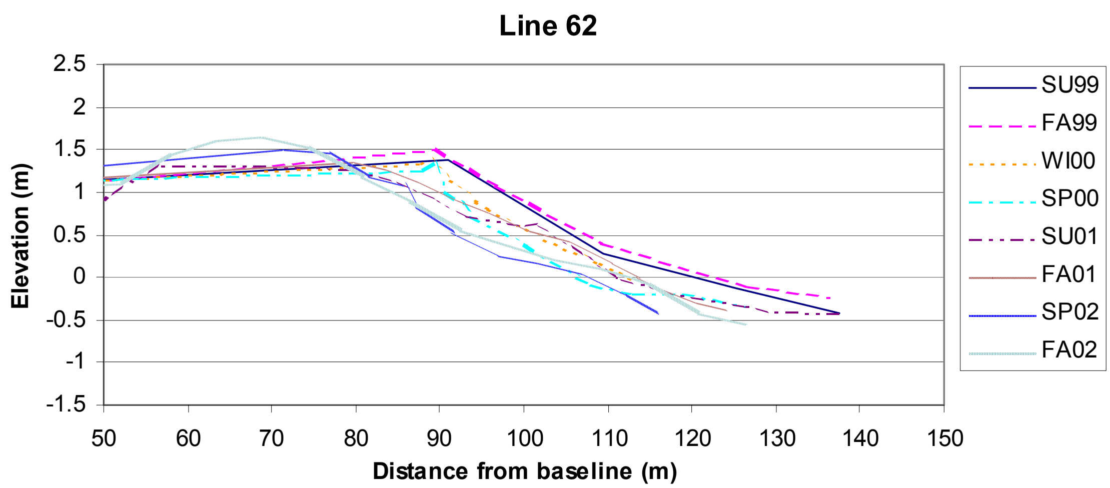

Line 52
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
70
80
90
100
110
120
130
140
150
160
170
FA99
WI00
SP00
FA01
SP02


Line 54
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
70
80
90
100
110
120
130
140
150
160
170
SU99
WI00
SP00
SU01
FA01
SP02
FA02

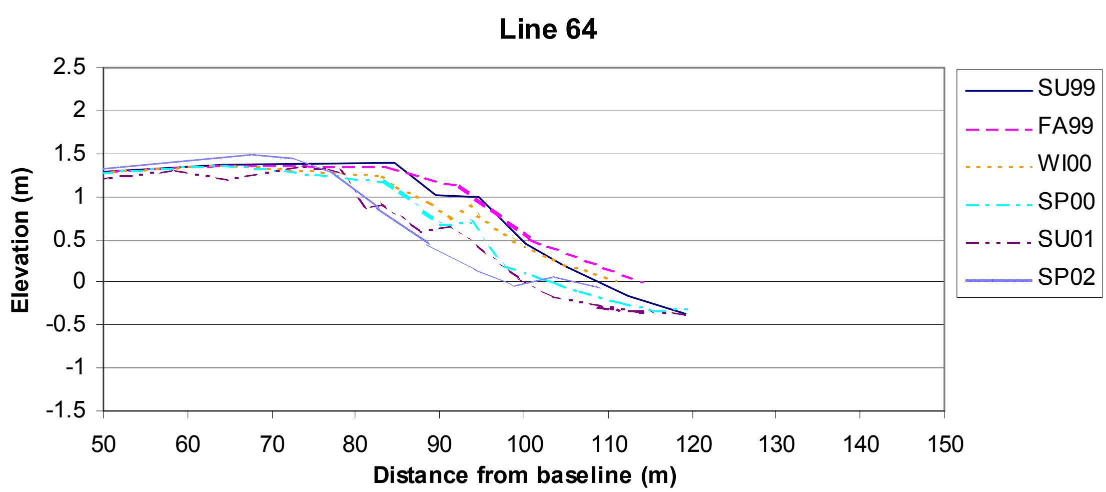

Line 56
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
60
70
80
90
100
110
120
130
140
150
160
Distance from baseline (m)
FA99
WI00
SU01
FA01
SP02


Line 58
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
60
70
80
90
100
110
120
130
140
150
160
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

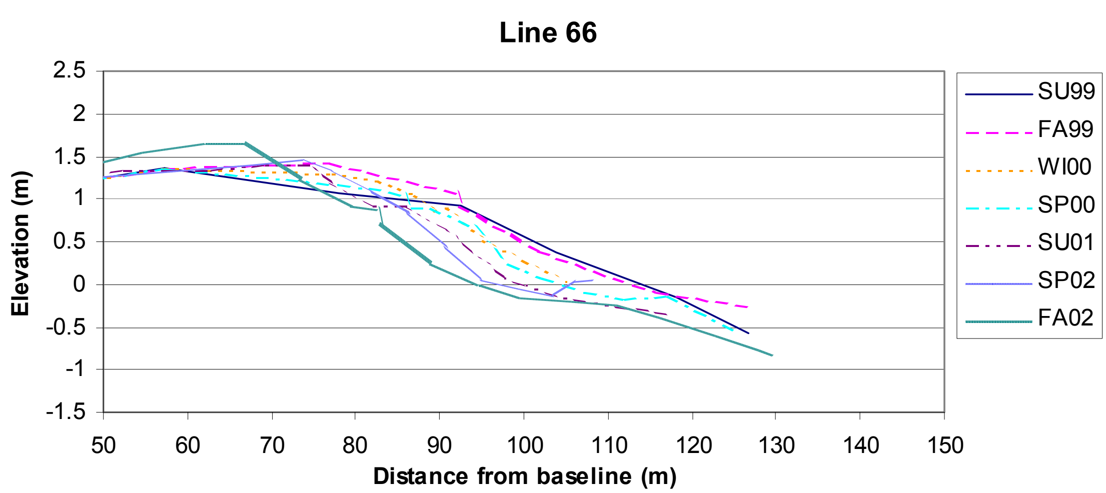

Line 60
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
60
70
80
90
100
110
120
130
140
150
160
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02



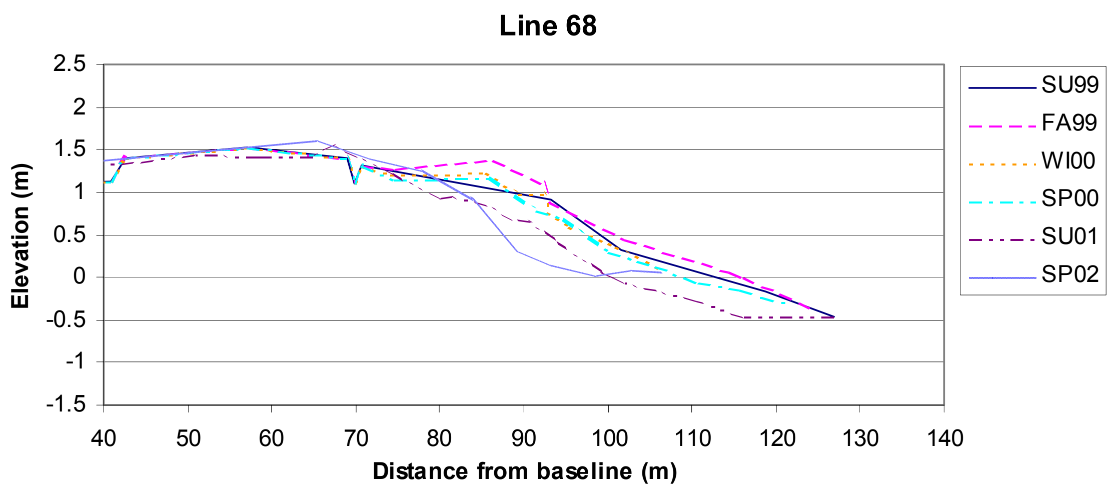
Line 62
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
50
60
70
80
90
100
110
120
130
140
150
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

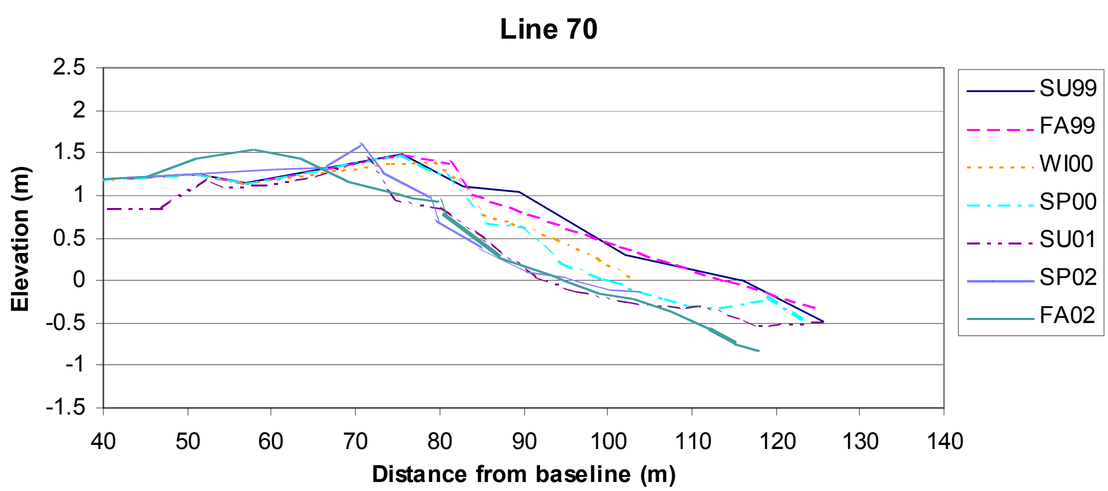


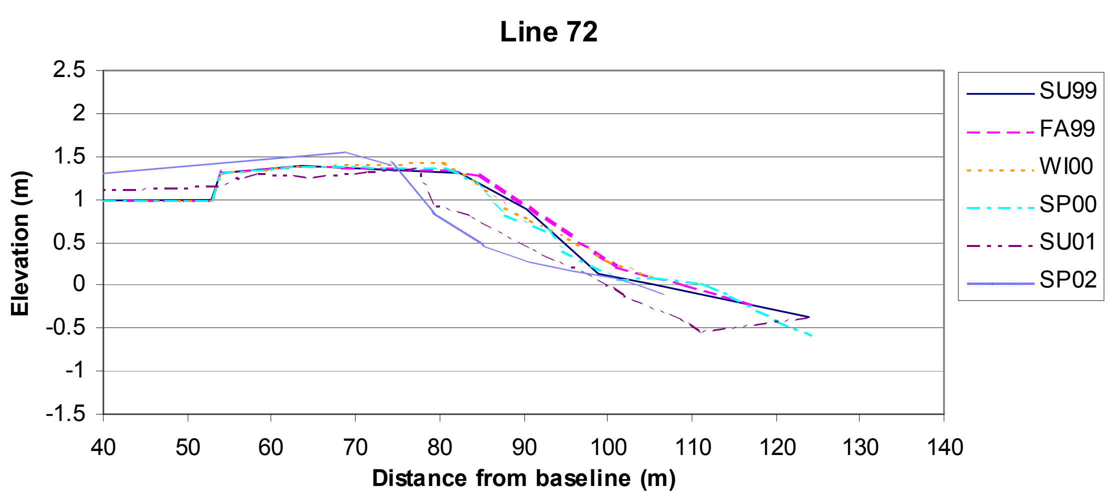
Line 64
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
50
60
70
80
90
100
110
120
130
140
150
SU99
FA99
WI00
SP00
SU01
SP02

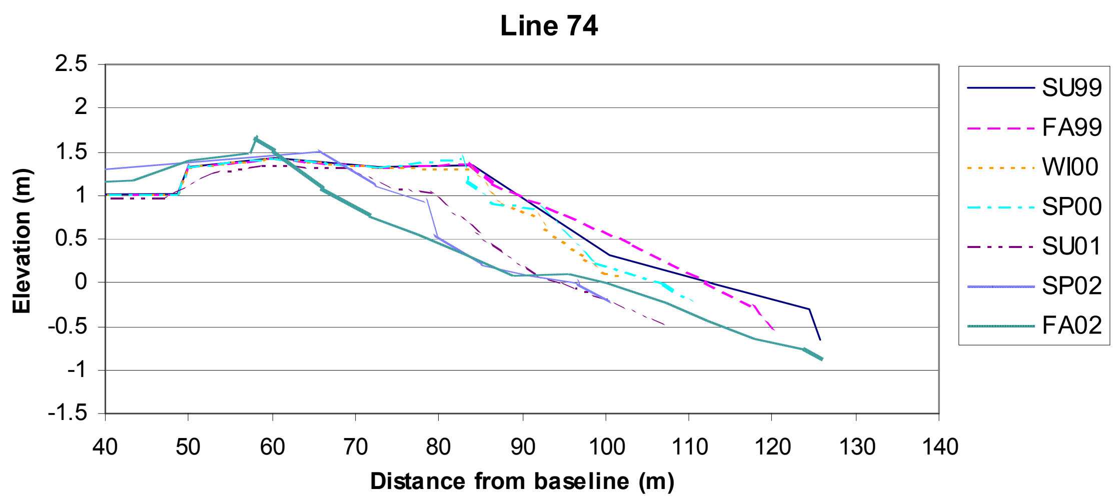


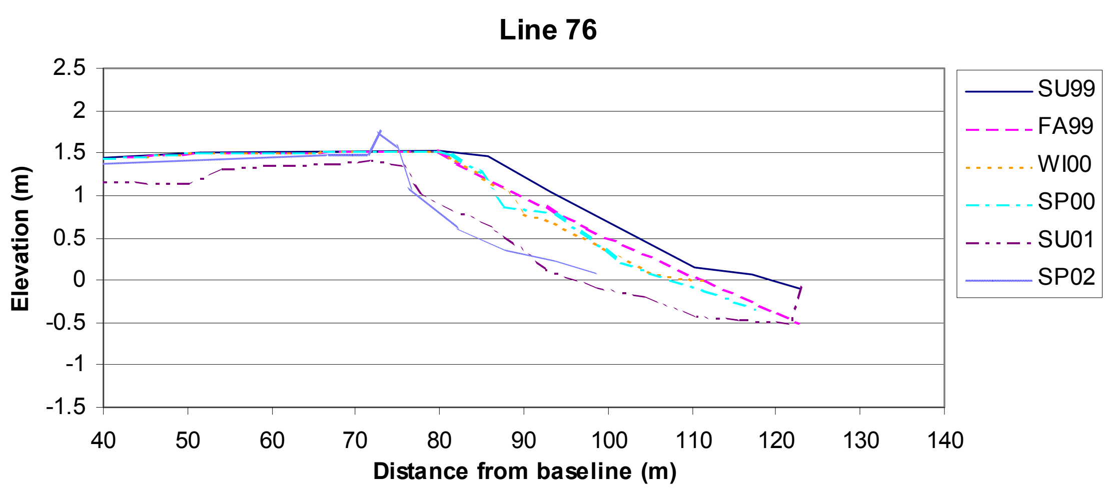
Line 66
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
50
60
70
80
90
100
110
120
130
140
150
SU99
FA99
WI00
SP00
SU01
SP02
FA02

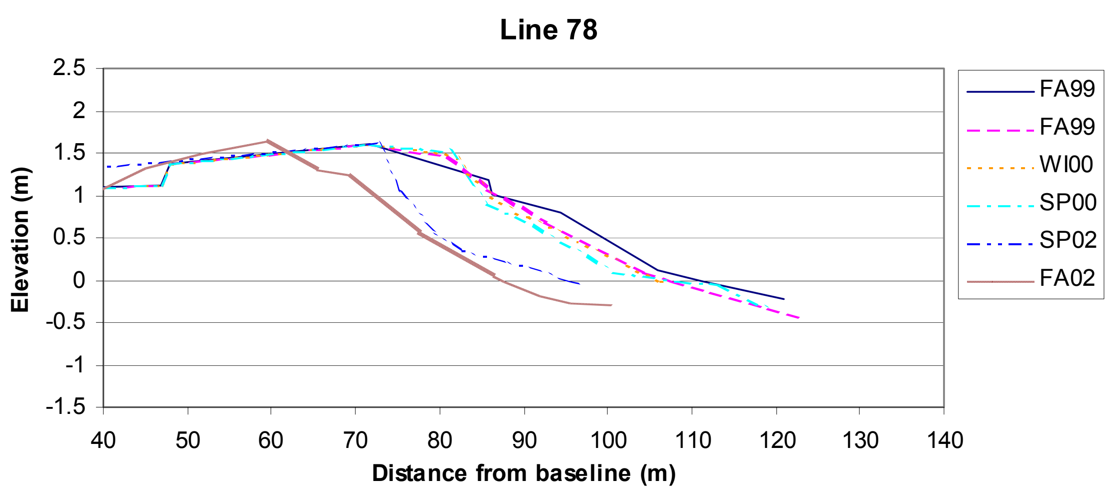

Line 68
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
40
50
60
70
80
90
100
110
120
130
140
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
SP02

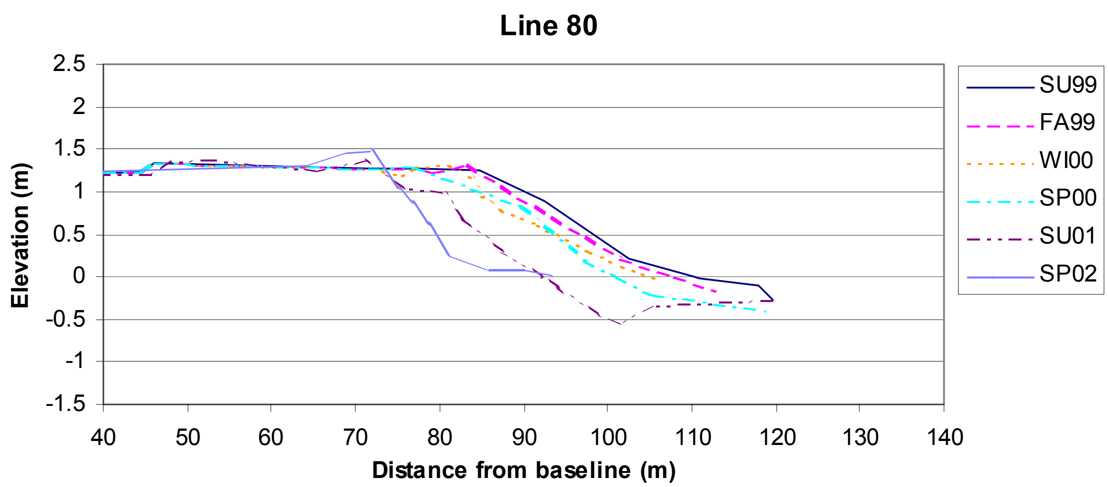

Line 70
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
40
50
60
70
80
90
100
110
120
130
140
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
SP02
FA02

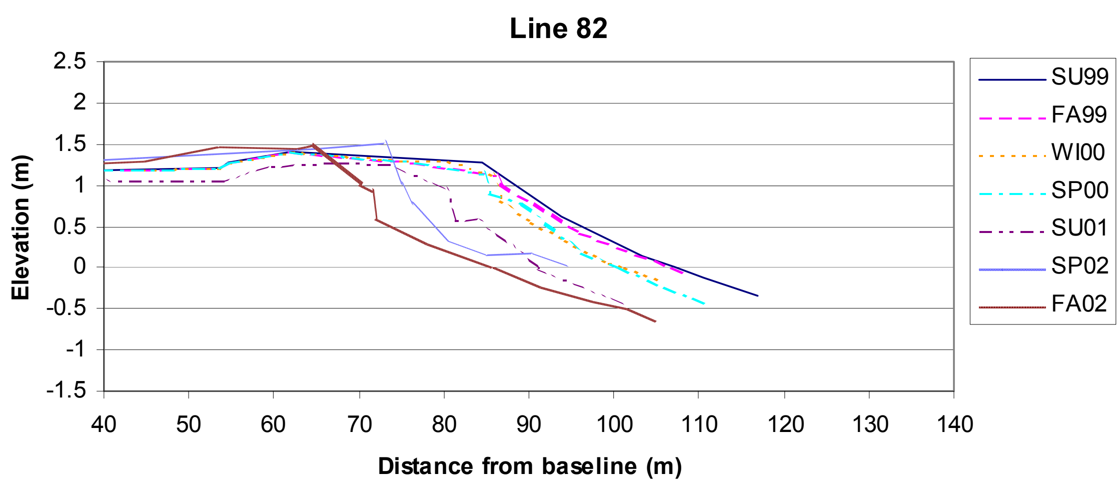

Line 72
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
40
50
60
70
80
90
100
110
120
130
140
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
SP02

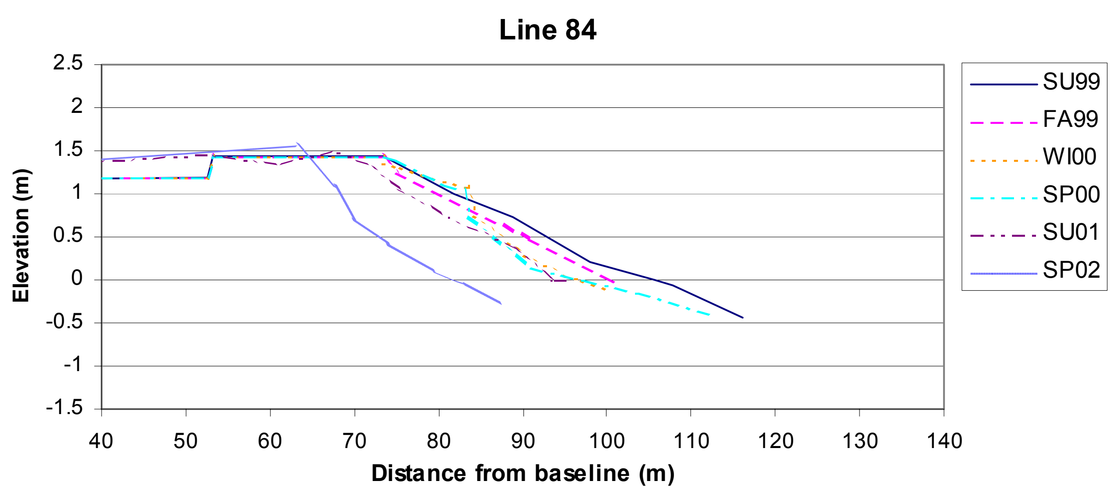

Line 74
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
40
50
60
70
80
90
100
110
120
130
140
SU99
FA99
WI00
SP00
SU01
SP02
FA02

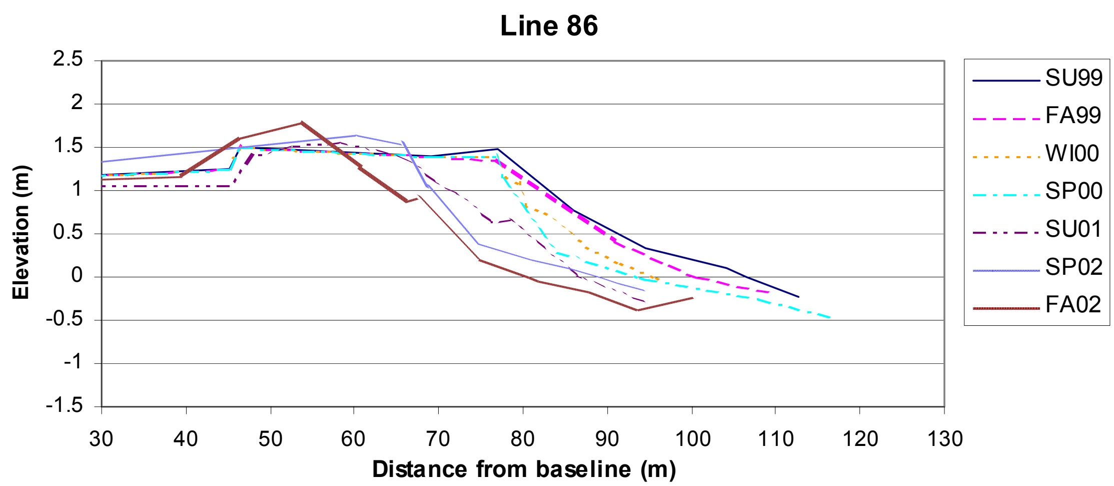

Line 76
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
40
50
60
70
80
90
100
110
120
130
140
SU99
FA99
WI00
SP00
SU01
SP02

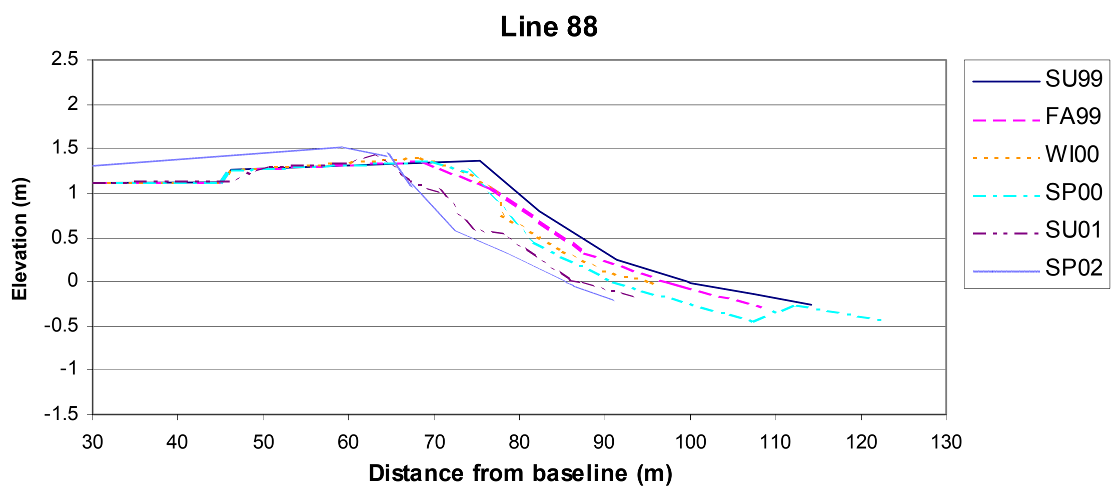

Line 78
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
40
50
60
70
80
90
100
110
120
130
140
FA99
FA99
WI00
SP00
SP02
FA02

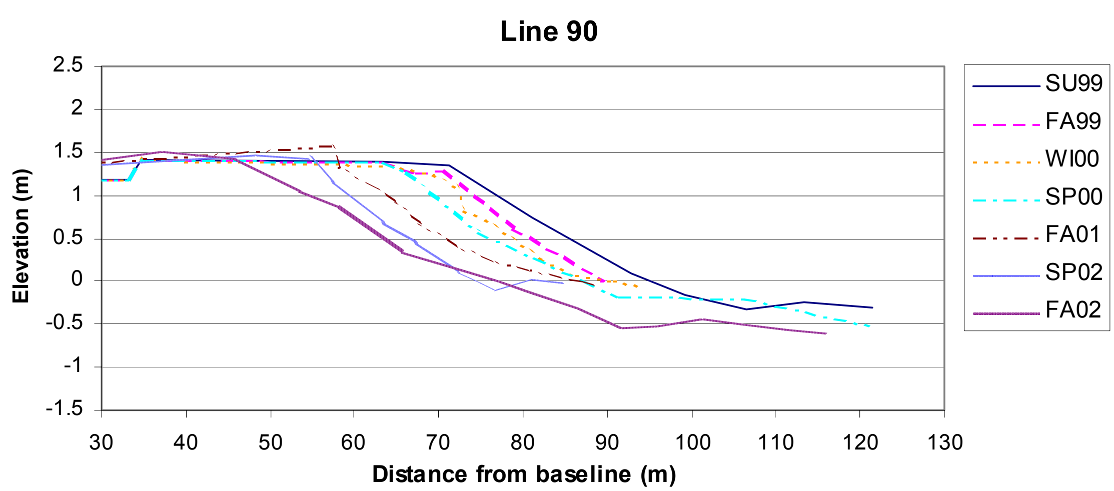

Line 80
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
40
50
60
70
80
90
100
110
120
130
140
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
SP02

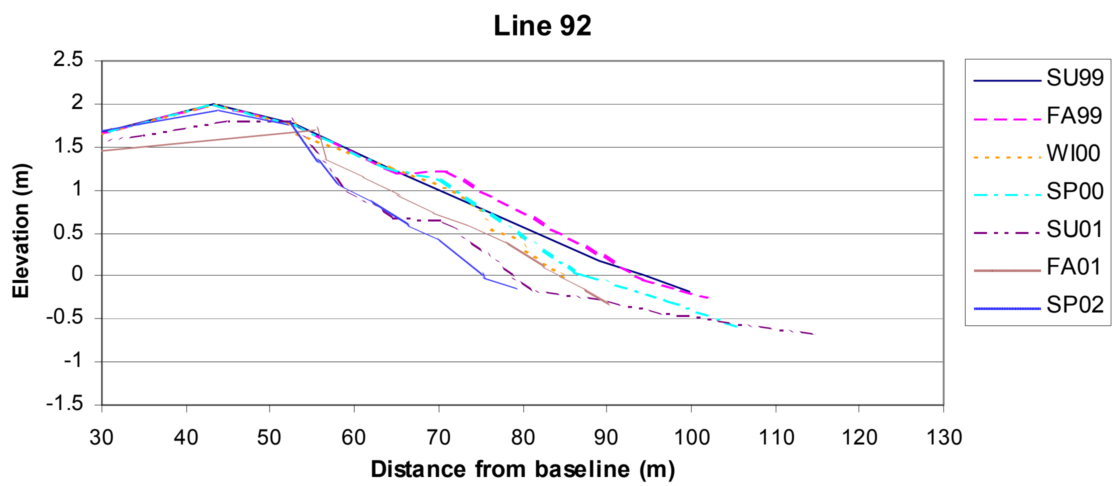

Line 82
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
40
50
60
70
80
90
100
110
120
130
140
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
SP02
FA02

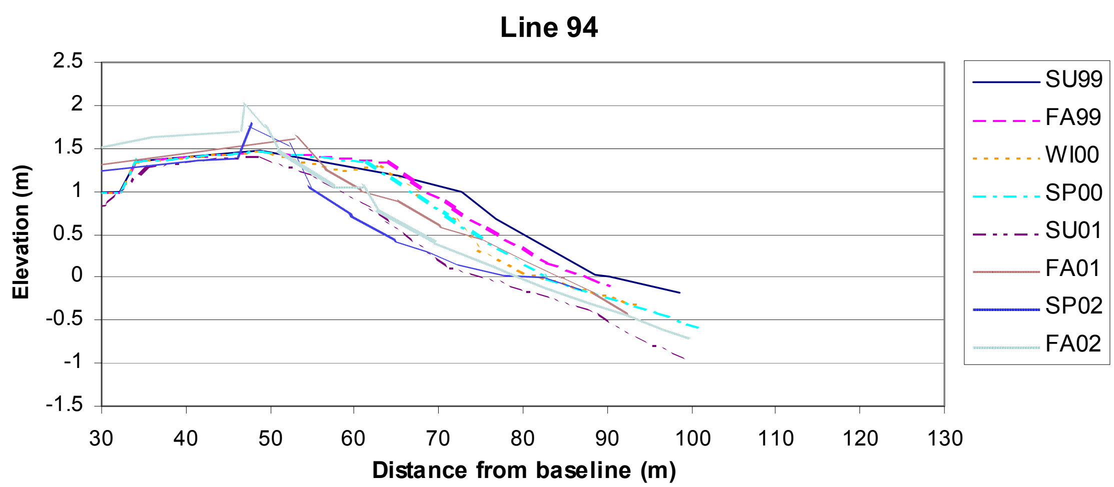

Line 84
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
40
50
60
70
80
90
100
110
120
130
140
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
SP02

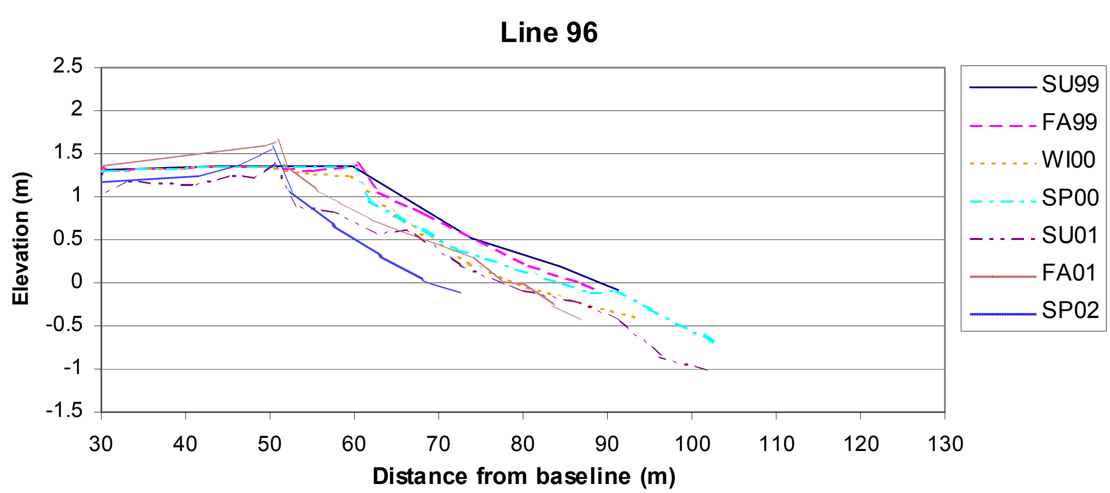

Line 86
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
30
40
50
60
70
80
90
100
110
120
130
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
SP02
FA02

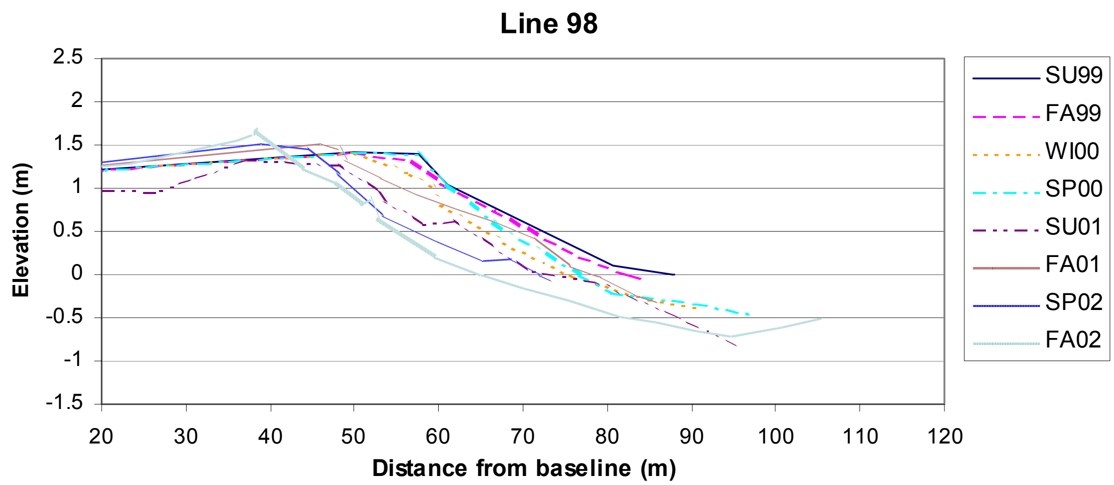

Line 88
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
30
40
50
60
70
80
90
100
110
120
130
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
SP02

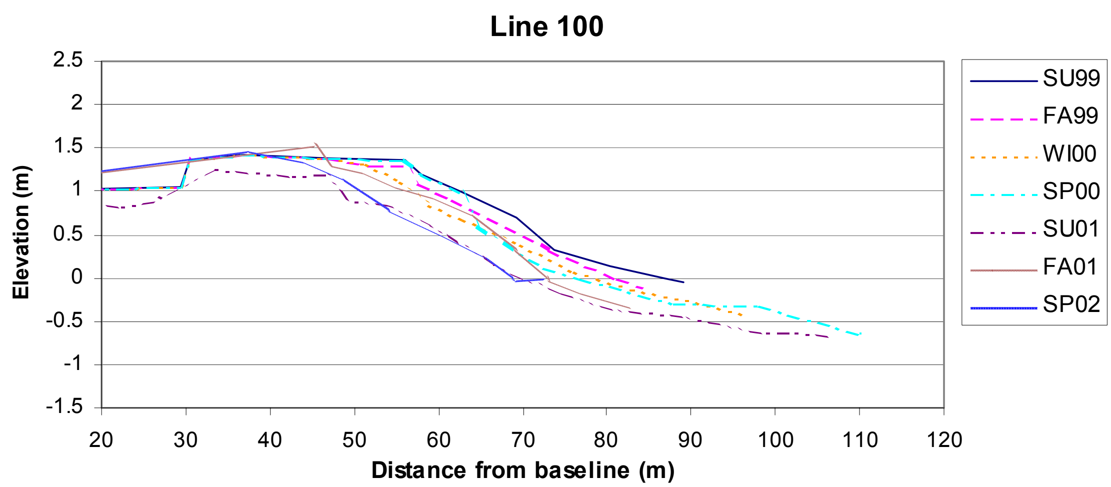

Line 90
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
30
40
50
60
70
80
90
100
110
120
130
Distance from baseline (m)
SU99
FA99
WI00
SP00
FA01
SP02
FA02

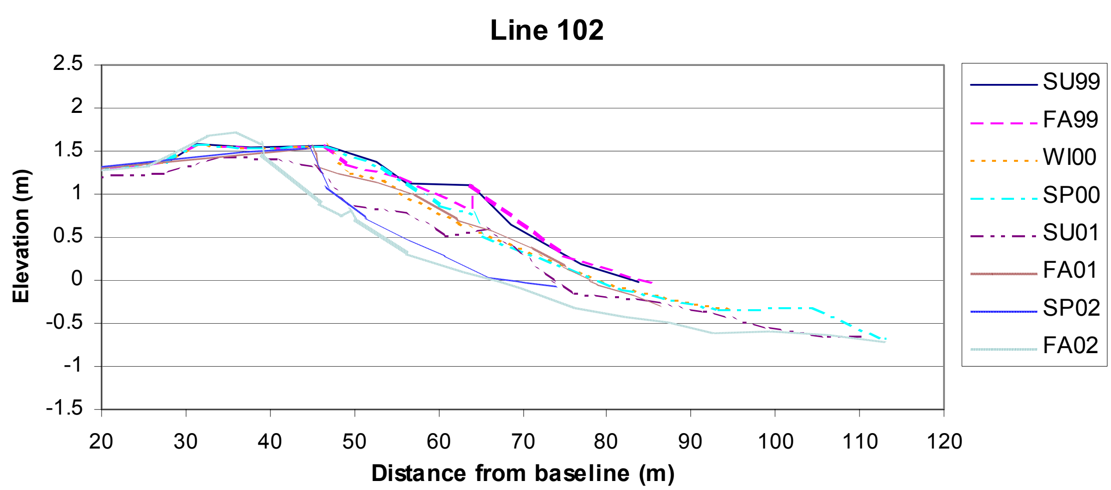

Line 92
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
30
40
50
60
70
80
90
100
110
120
130
SU99
FA99
WI00
SP00
SU01
FA01
SP02

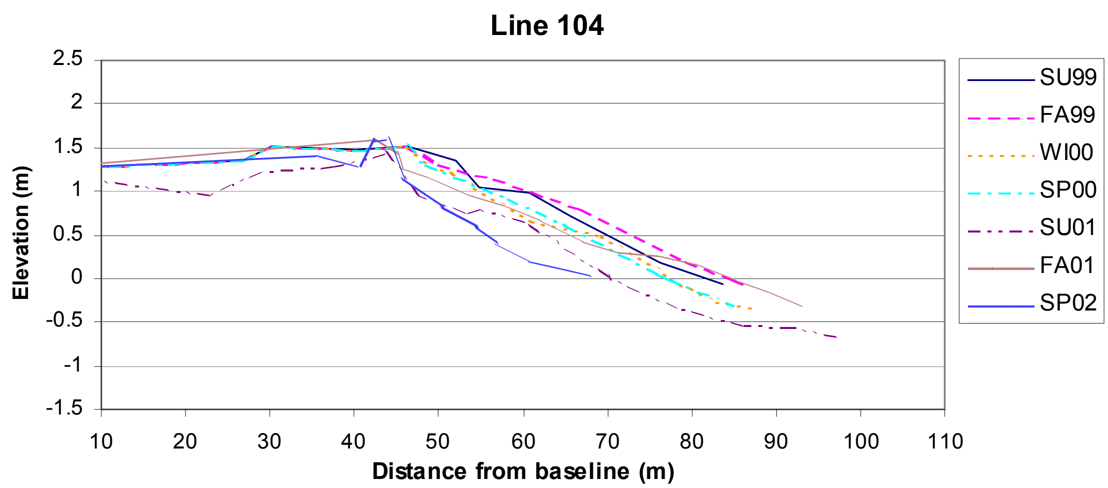

Line 94
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
30
40
50
60
70
80
90
100
110
120
130
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

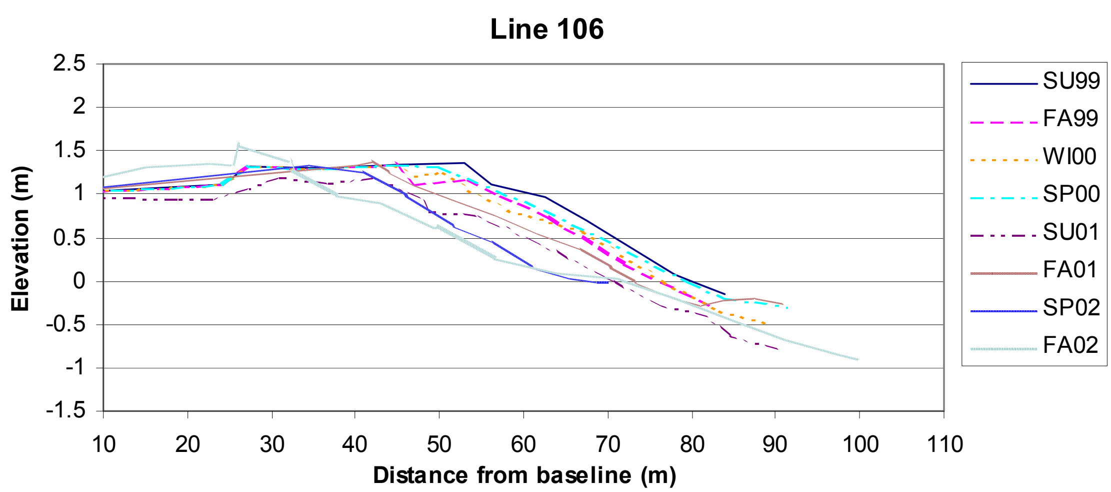

Line 96
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
30
40
50
60
70
80
90
100
110
120
130
SU99
FA99
WI00
SP00
SU01
FA01
SP02

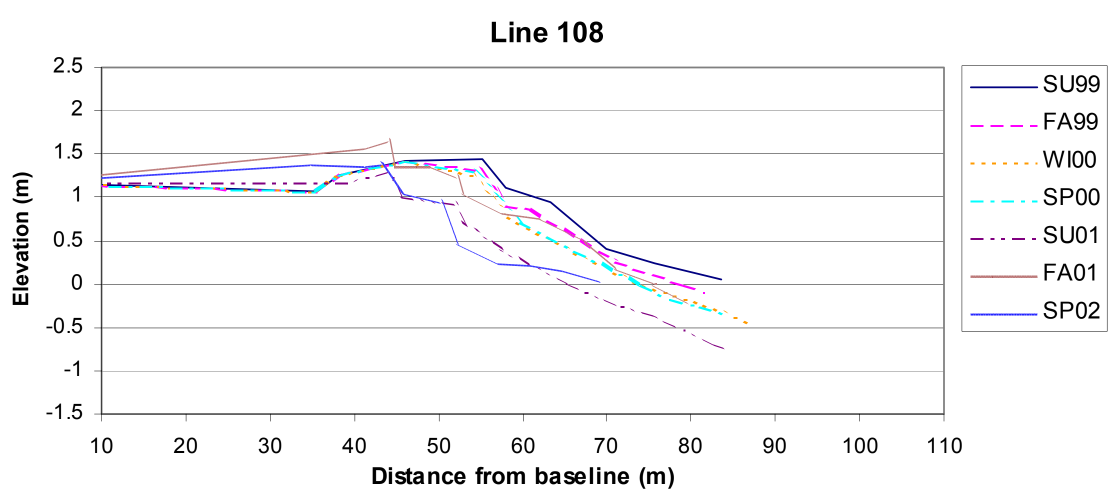

Line 98
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

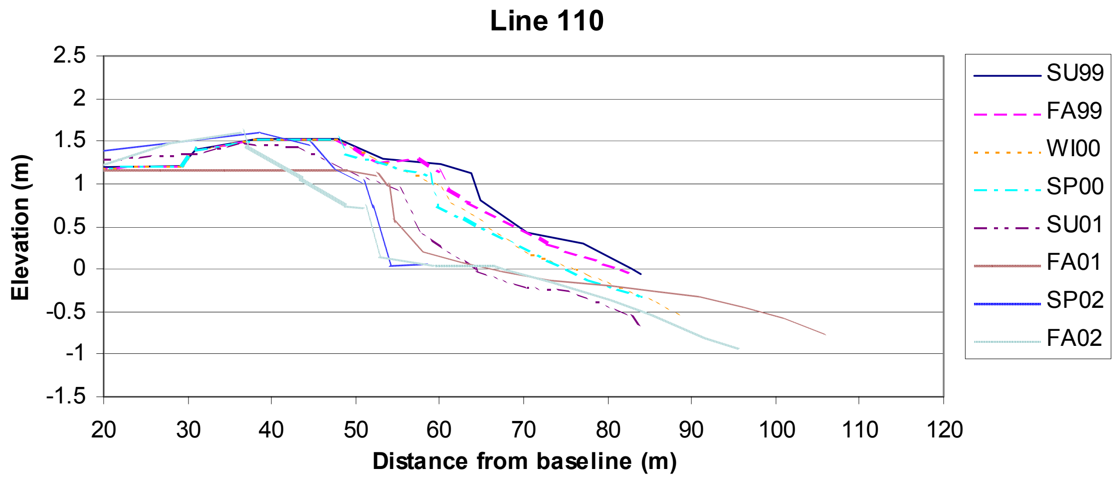

Line 100
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
SU99
FA99
WI00
SP00
SU01
FA01
SP02

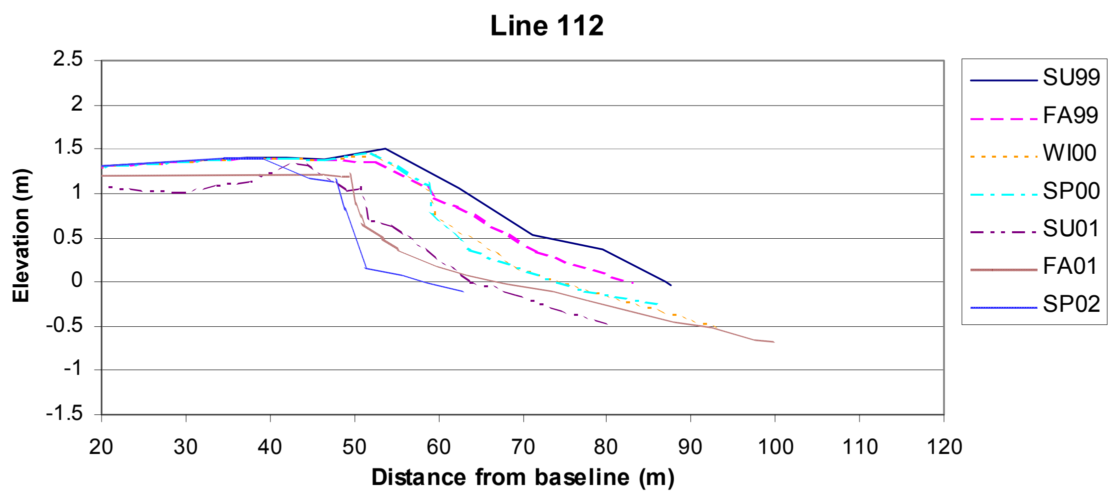

Line 102
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

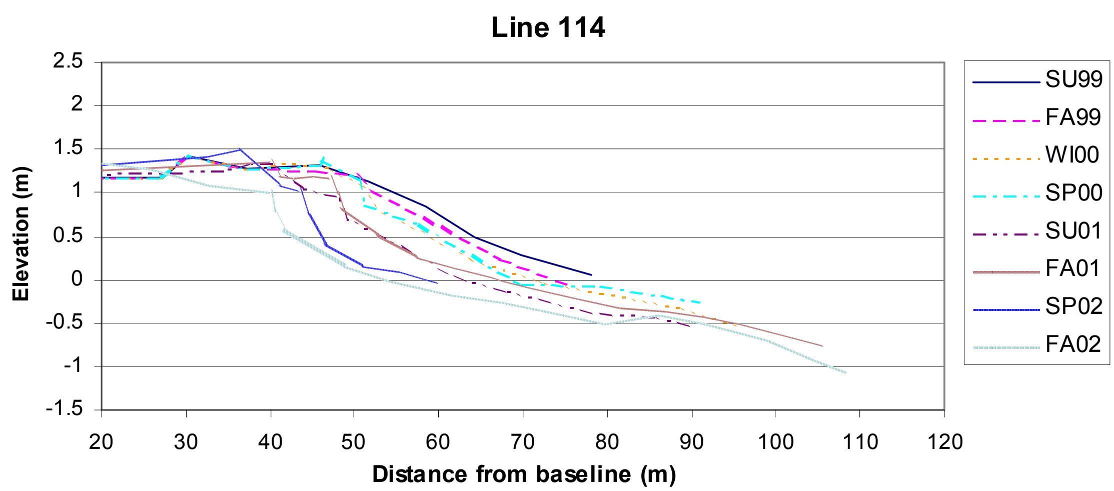

Line 104
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
10 20 30 40 50 60 70 80 90 100 110
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

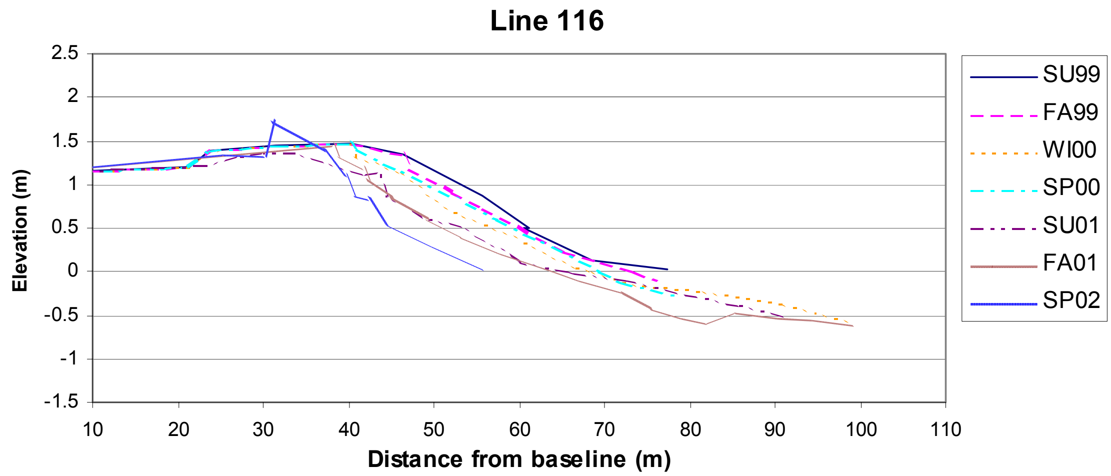

Line 106
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
10 20 30 40 50 60 70 80 90 100 110
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

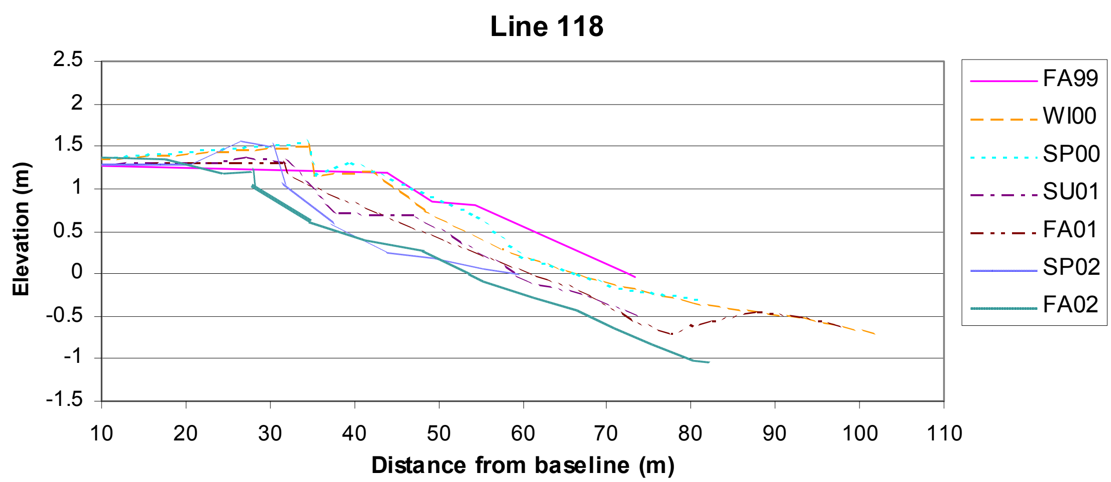

Line 108
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
10 20 30 40 50 60 70 80 90 100 110
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

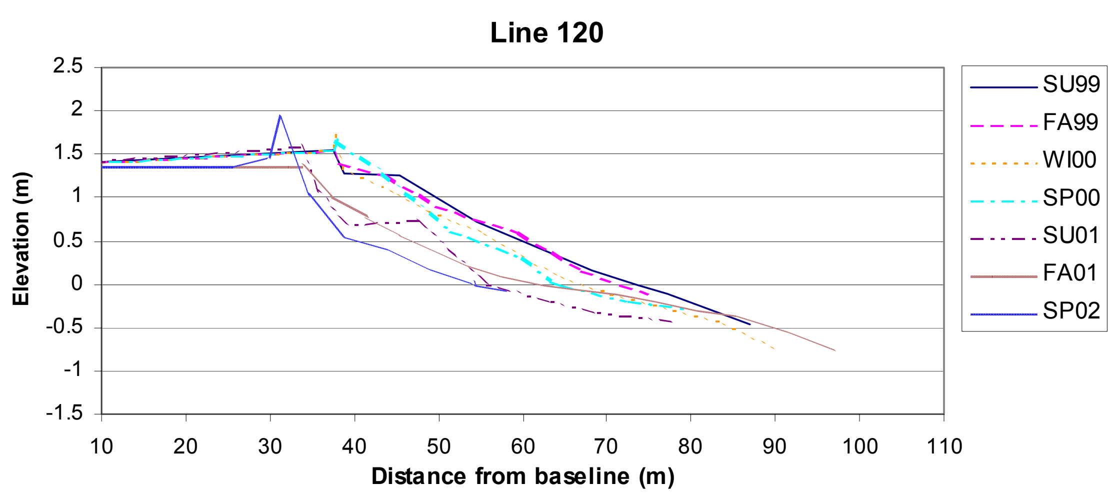

Line 110
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

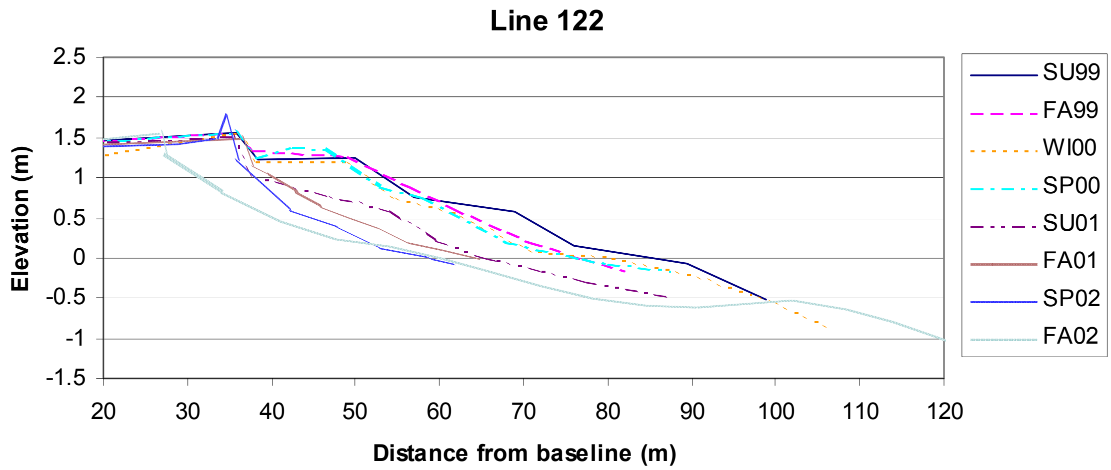

Line 112
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

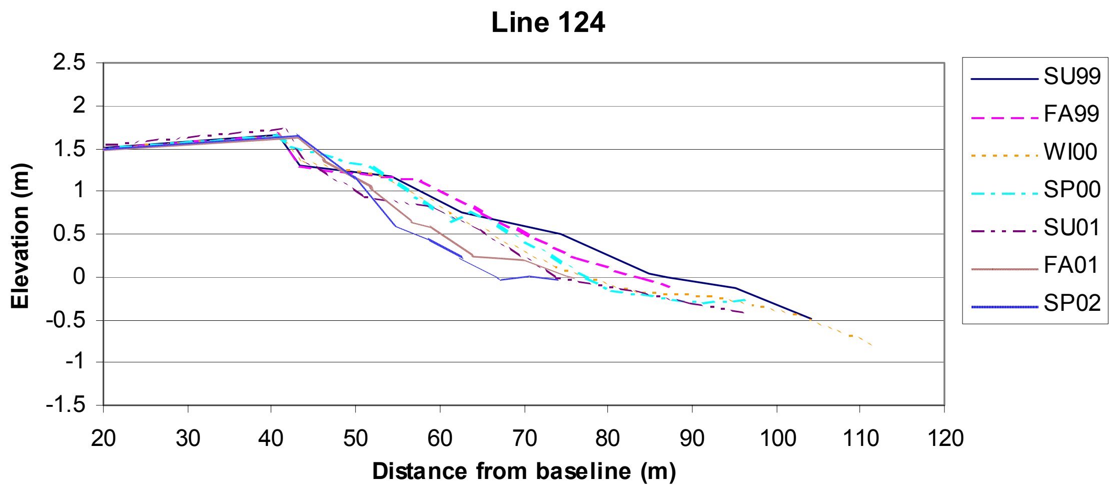

Line 114
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

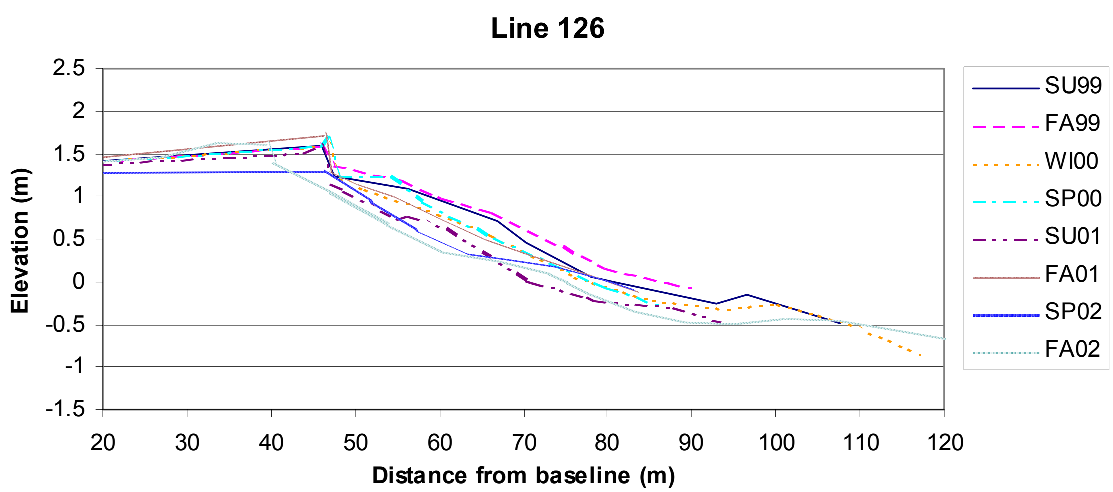

Line 116
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
10
20
30
40
50
60
70
80
90
100
110
SU99
FA99
WI00
SP00
SU01
FA01
SP02

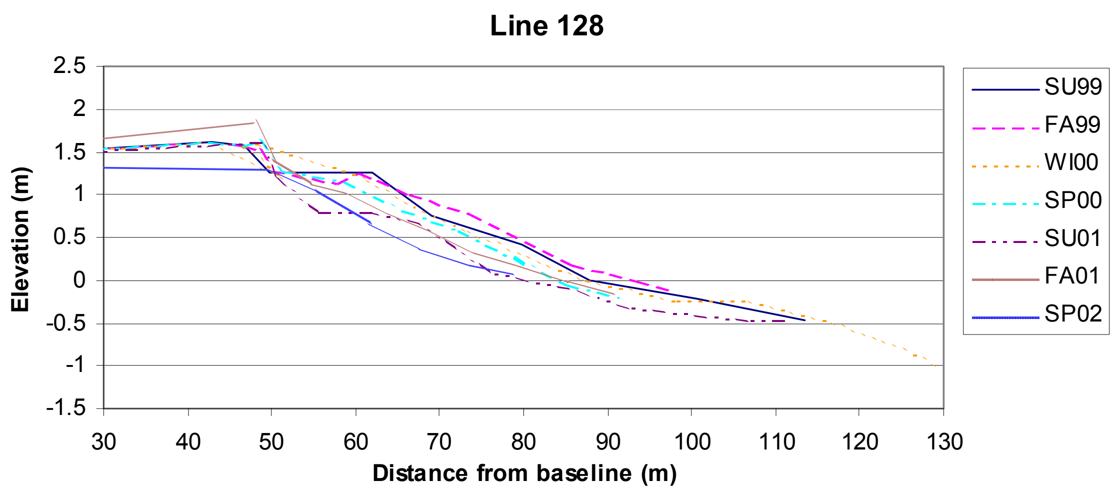

Line 118
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
10
20
30
40
50
60
70
80
90
100
110
FA99
WI00
SP00
SU01
FA01
SP02
FA02

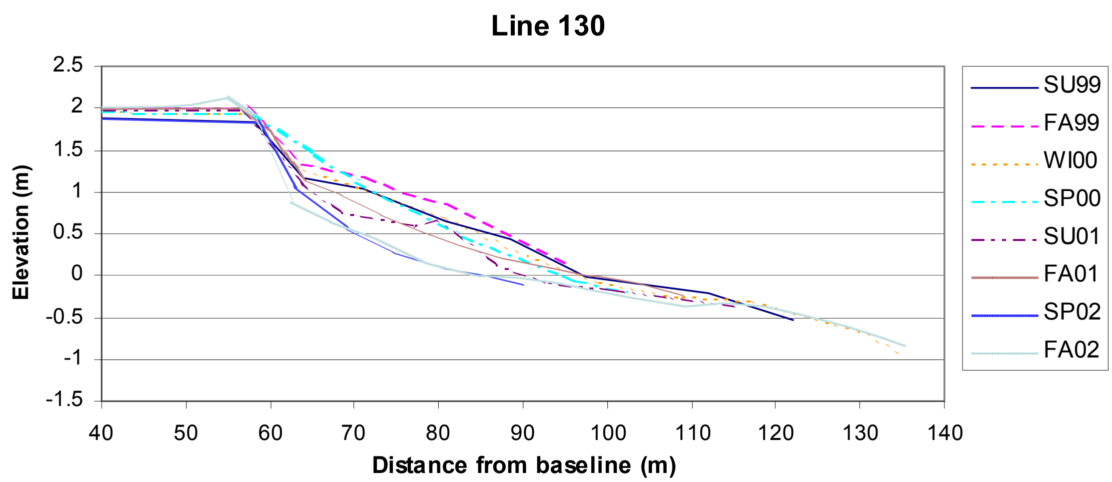

Line 120
Elevation (m)
Distance from baseline (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
10
20
30
40
50
60
70
80
90
100
110
SU99
FA99
WI00
SP00
SU01
FA01
SP02

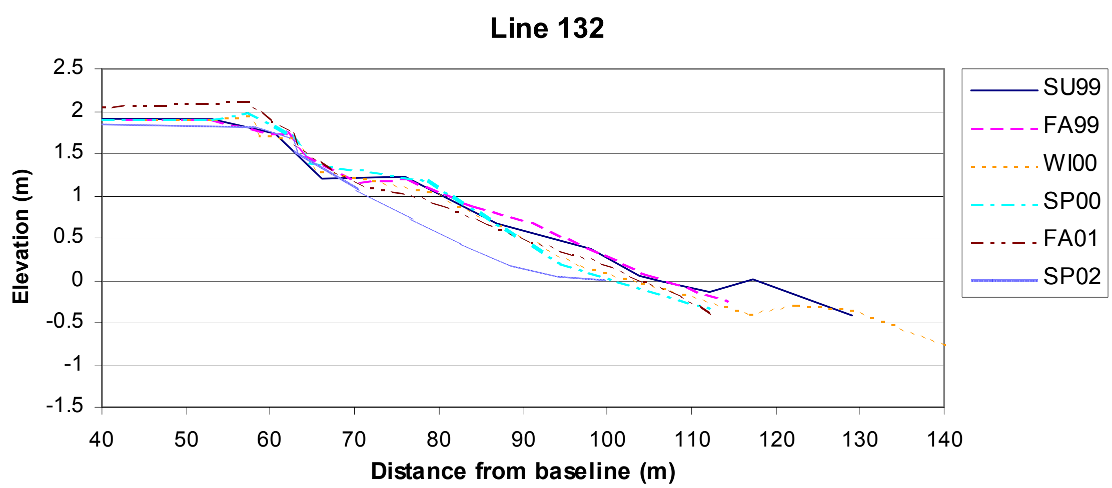

Line 122
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

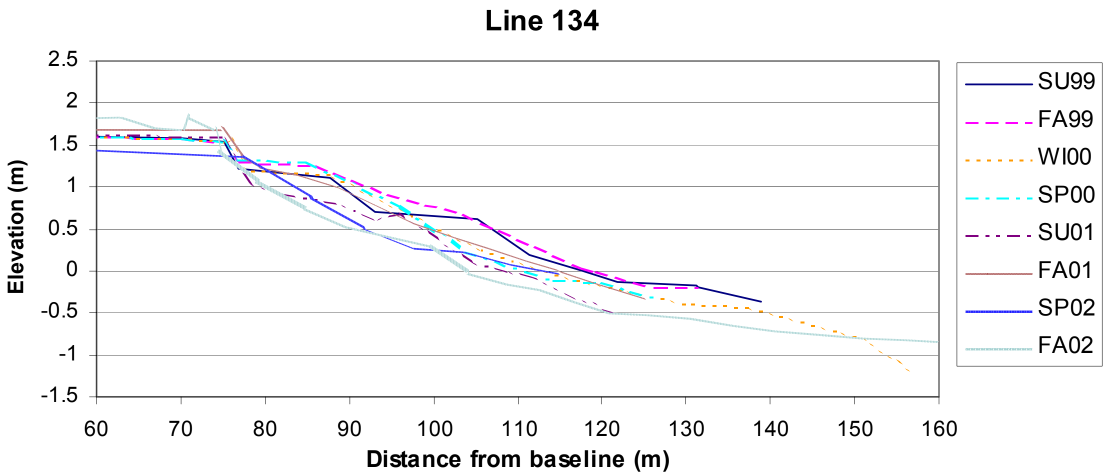

Line 124
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

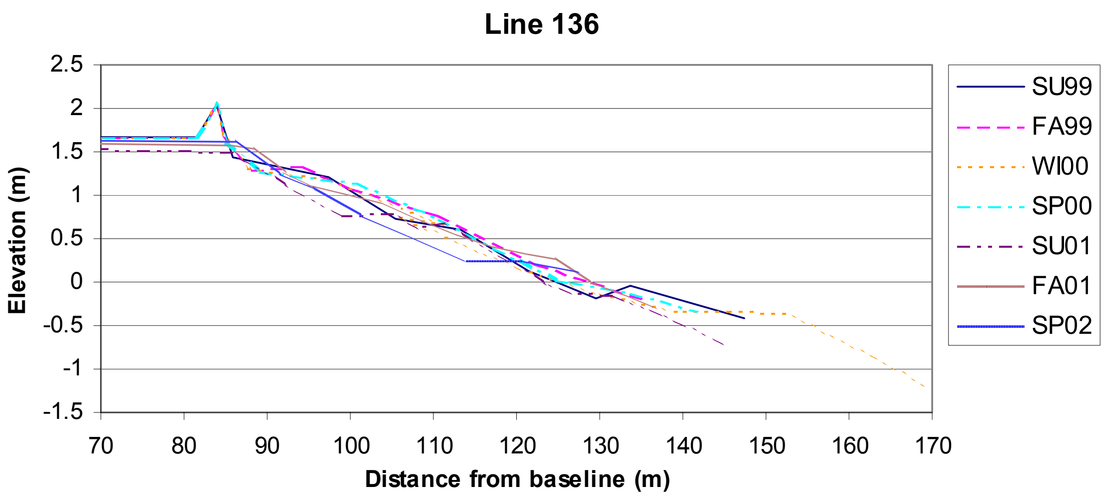

Line 126
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
20
30
40
50
60
70
80
90
100
110
120
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

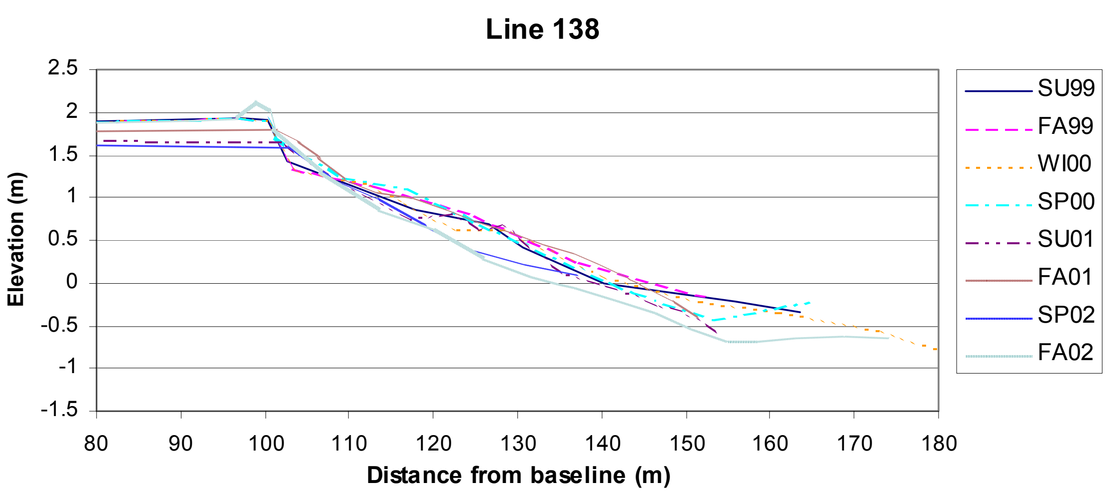

Line 128
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
30
40
50
60
70
80
90
100
110
120
130
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

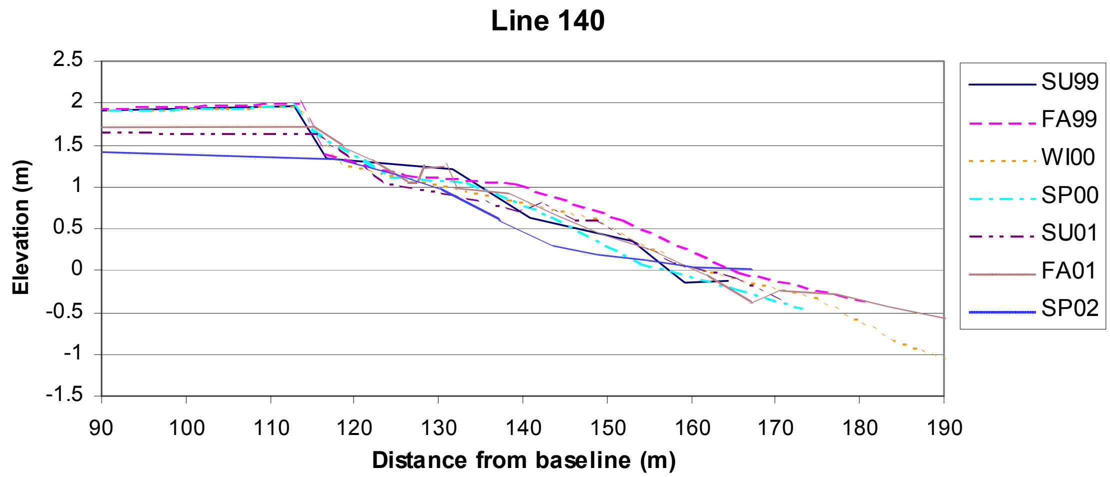

Line 130
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
40
50
60
70
80
90
100
110
120
130
140
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

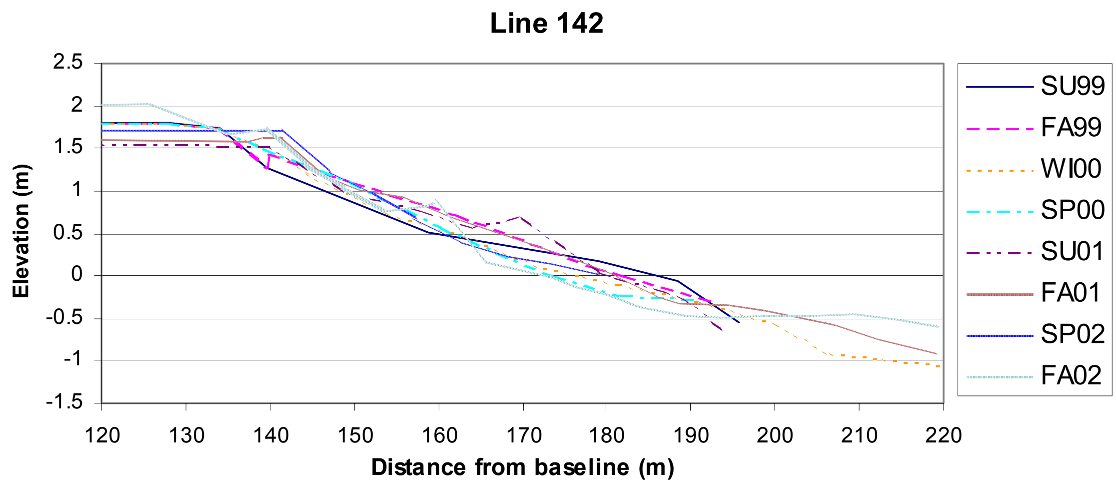

Line 132
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Elevation (m)
40
50
60
70
80
90
100
110
120
130
140
Distance from baseline (m)
SU99
FA99
WI00
SP00
FA01
SP02

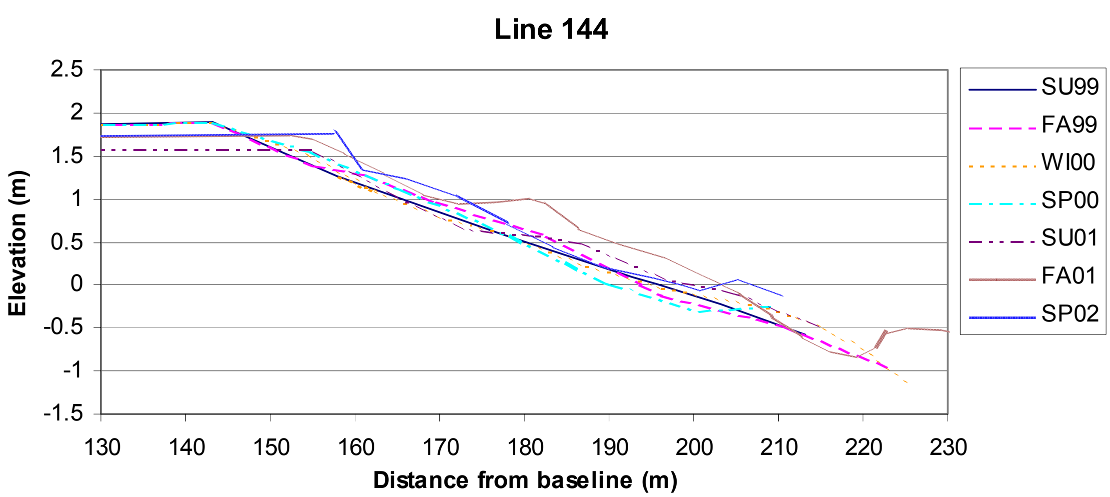

Line 134
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

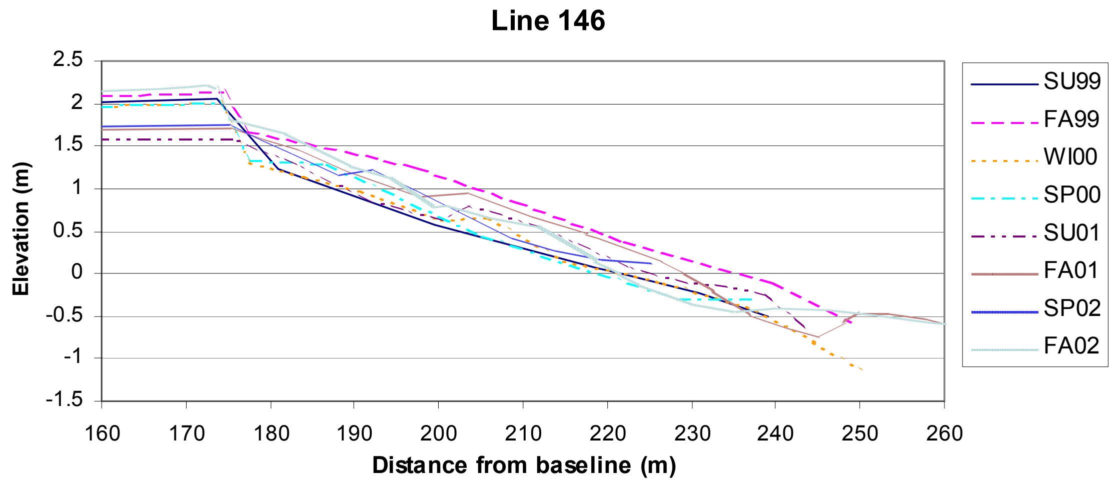

Line 136
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

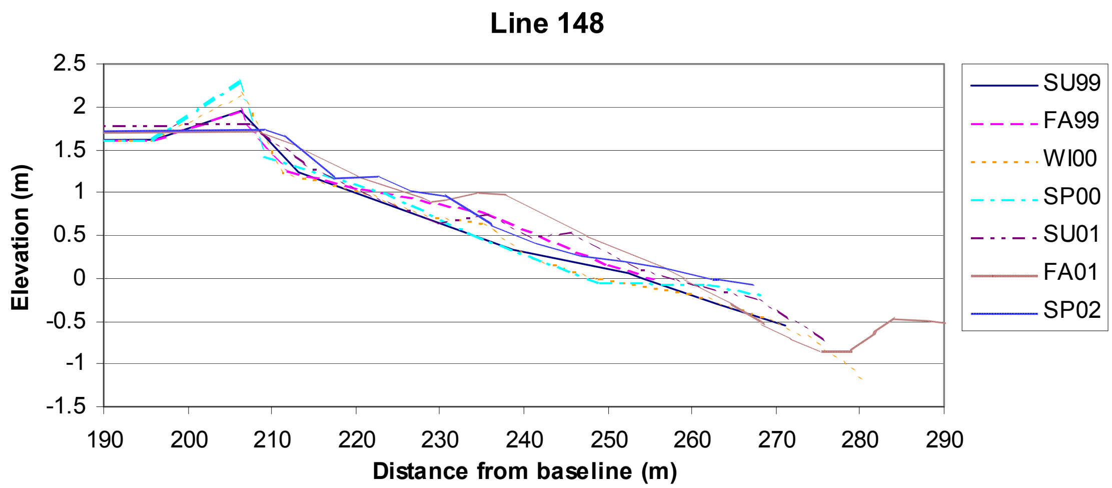

Line 138
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

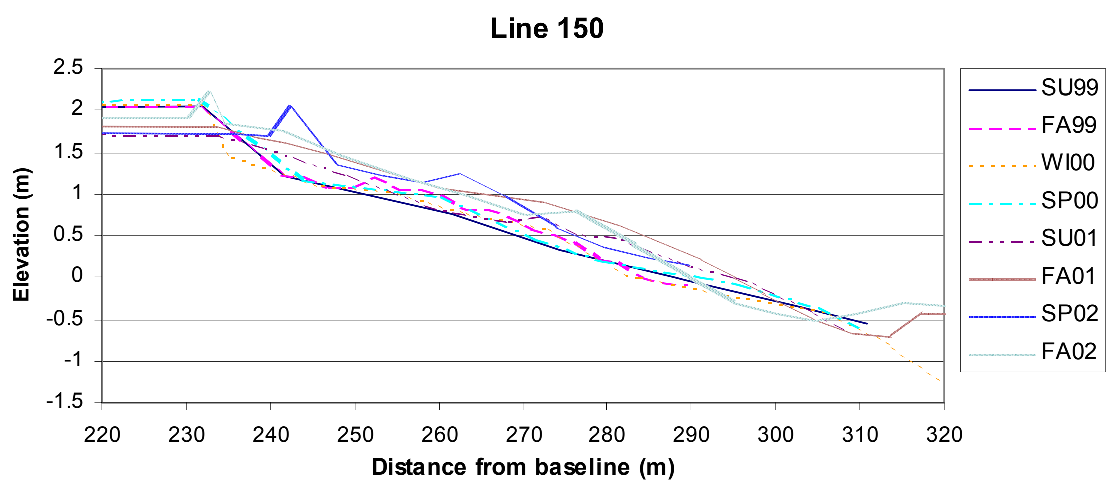

Line 140
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
90
100
110
120
130
140
150
160
170
180
190
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

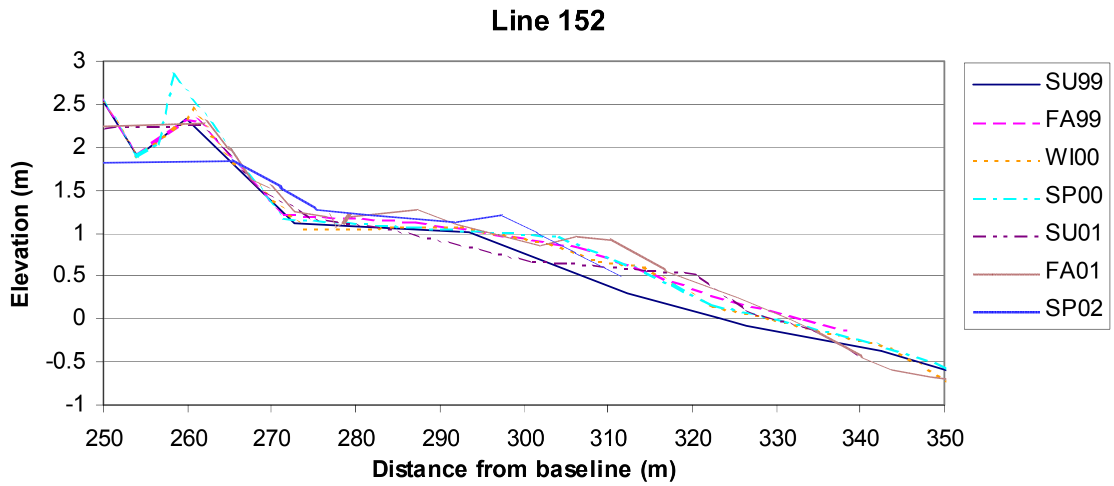

Line 142
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
120
130
140
150
160
170
180
190
200
210
220
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

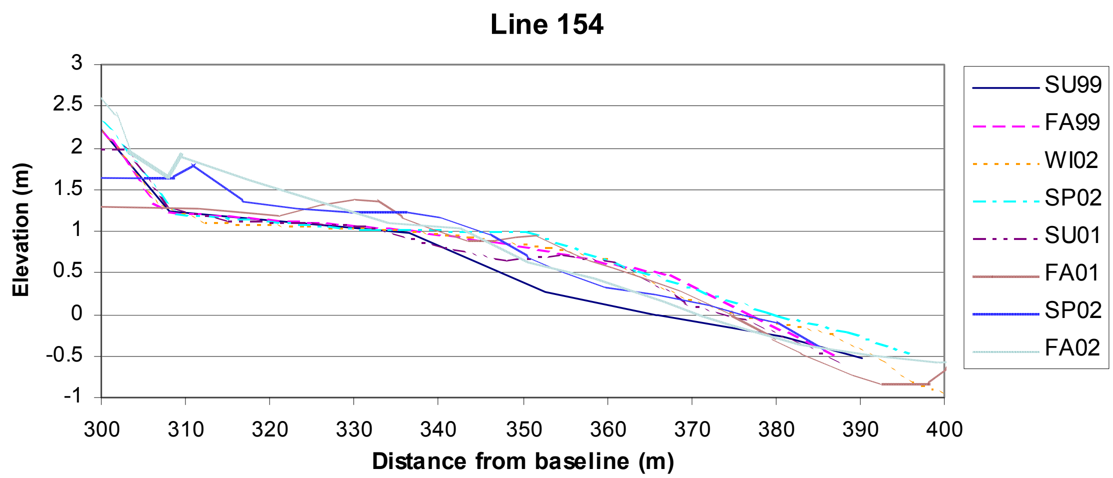

Line 144
Elevation (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
130
140
150
160
170
180
190
200
210
220
230
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

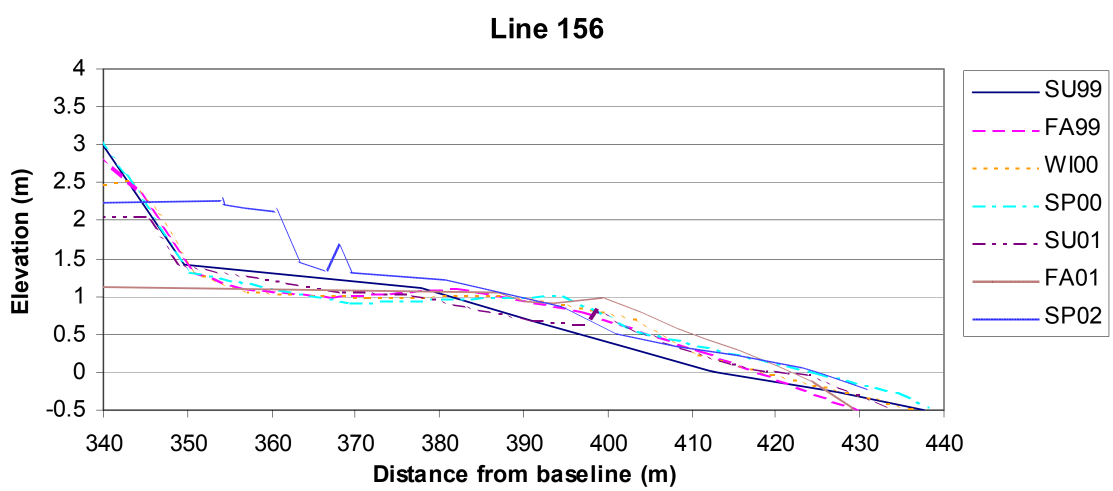

Line 146
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02


Line 148
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02


Line 150
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02
FA02

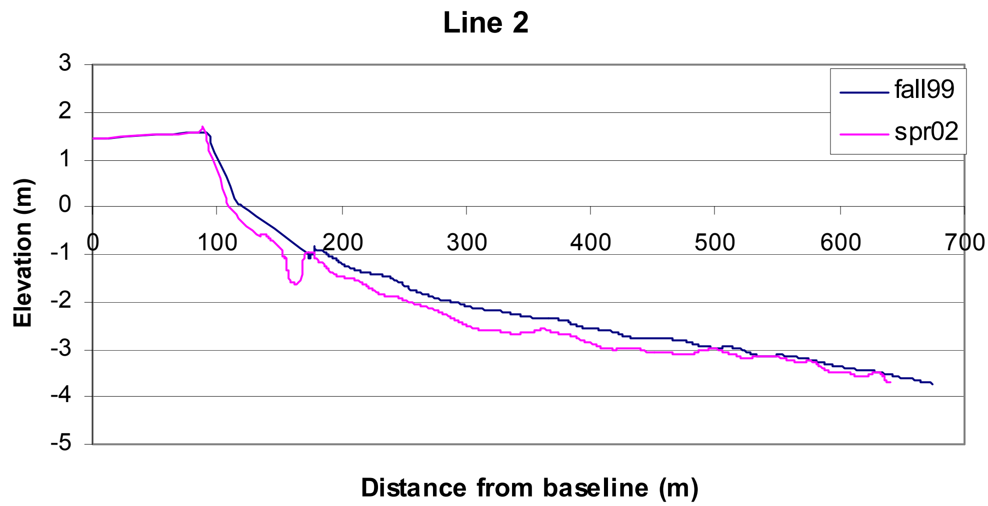

Line 152
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

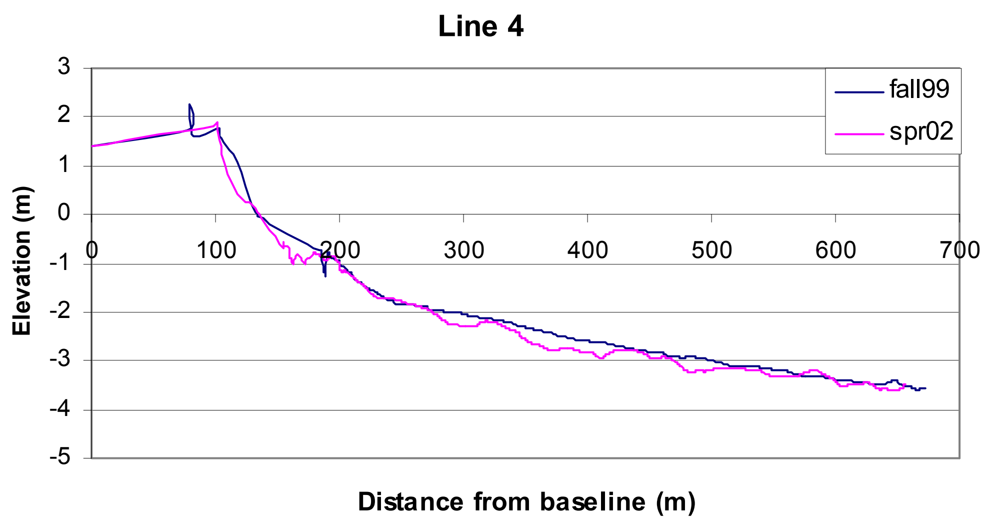

Line 154
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI02
SP02
SU01
FA01
SP02
FA02

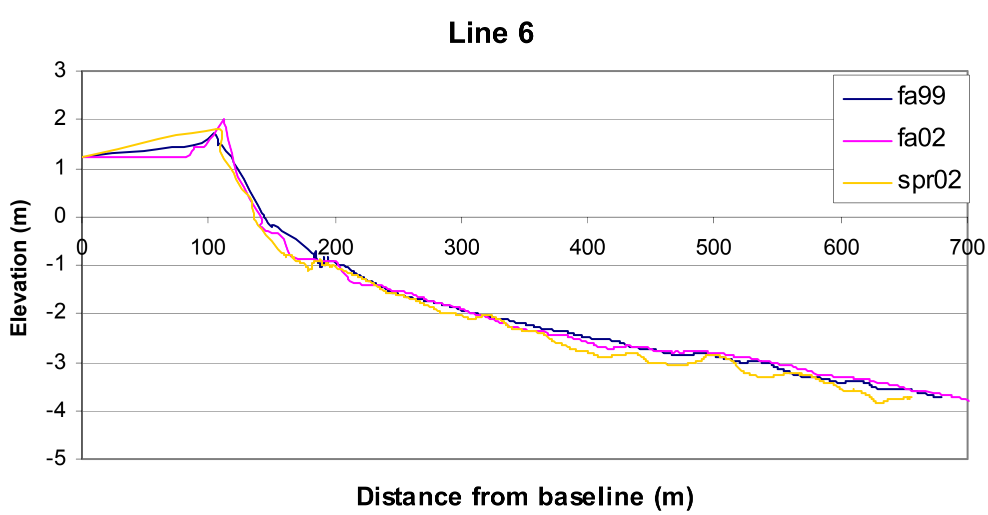

Line 156
Elevation (m)
Distance from baseline (m)
SU99
FA99
WI00
SP00
SU01
FA01
SP02

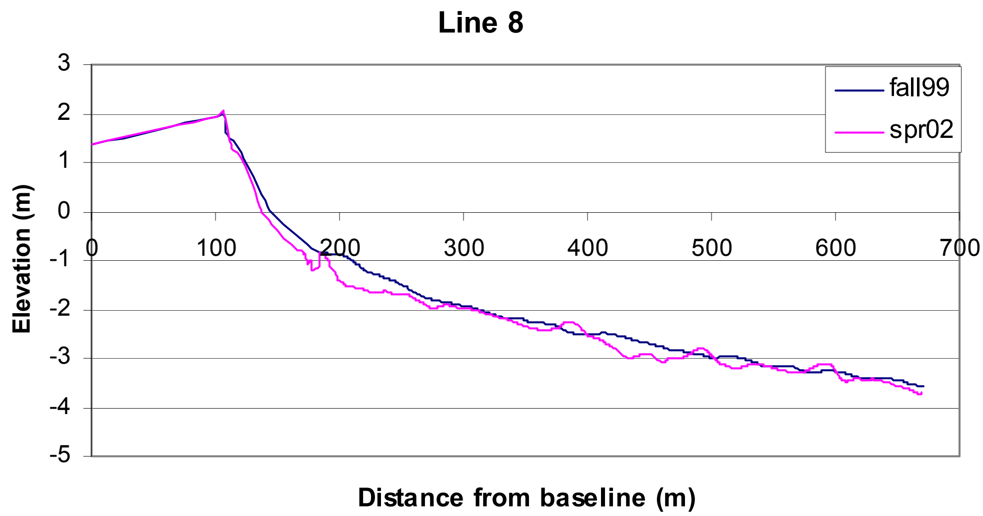
APPENDIX B

ON AND OFFSHORE SURVEY PROFILES

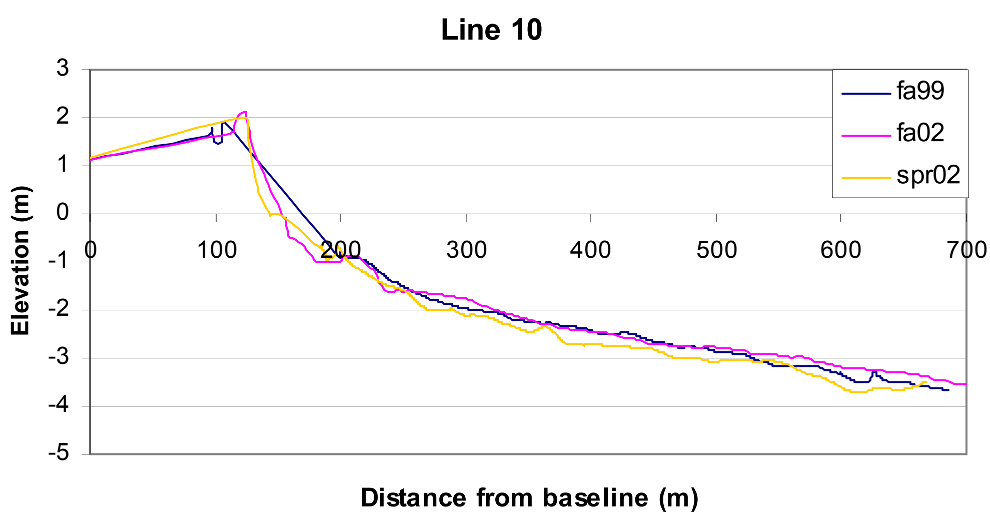

Line 2
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02


Line 4
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

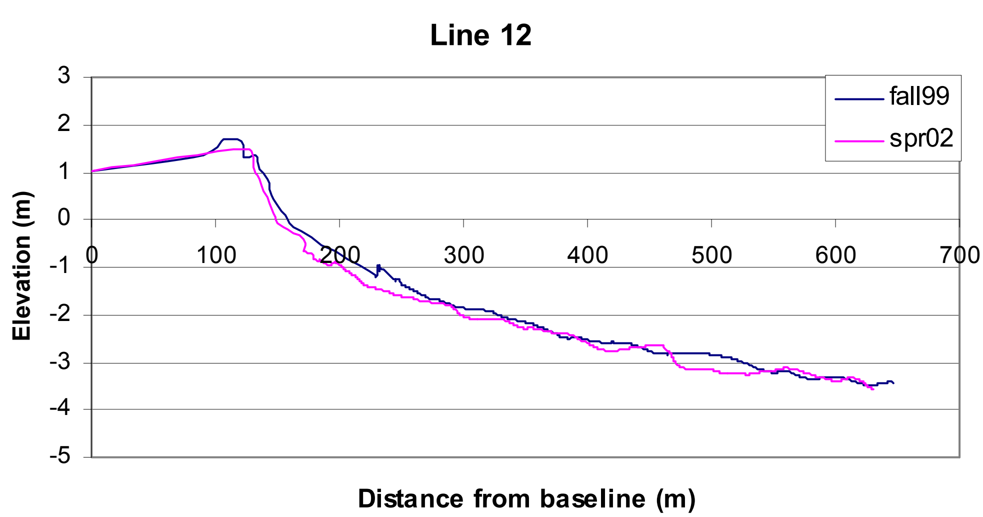

Line 6
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fa99
fa02
spr02



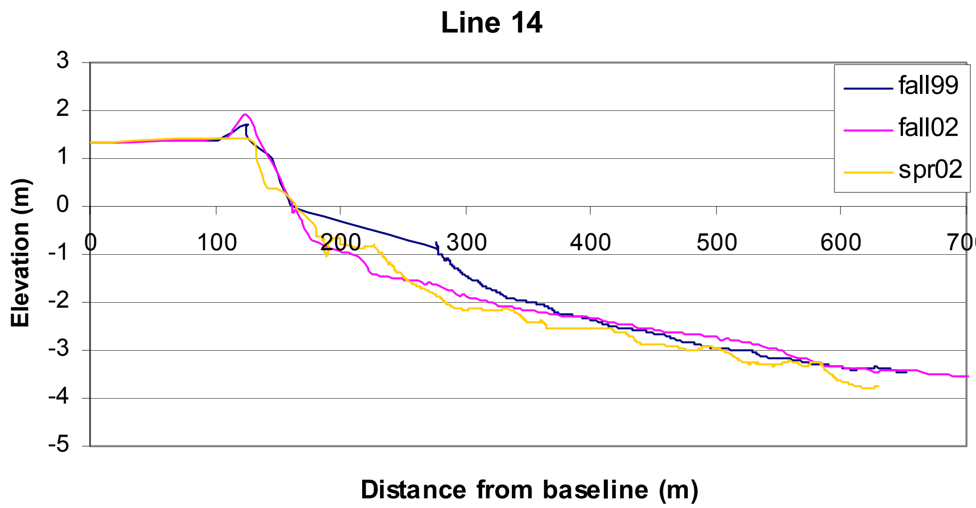
Line 8
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

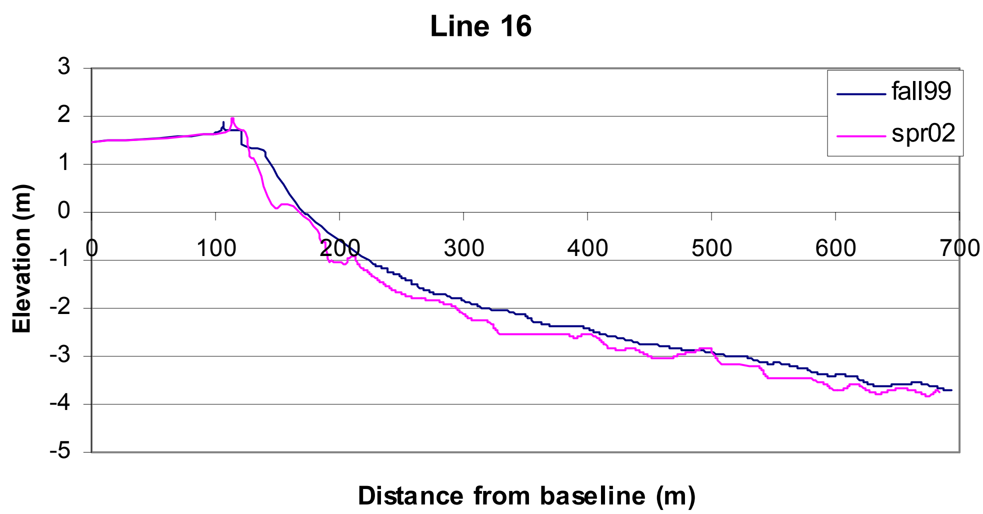


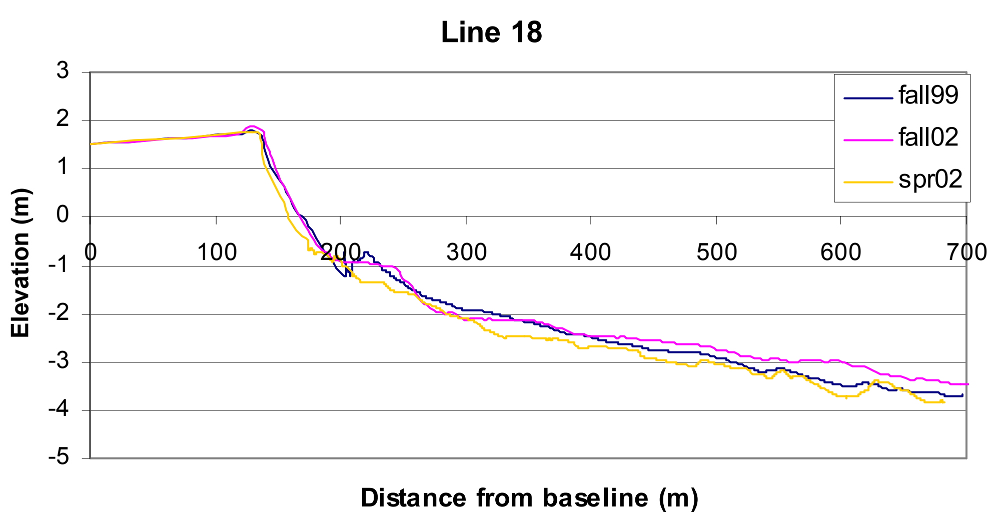
Line 10
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fa99
fa02
spr02



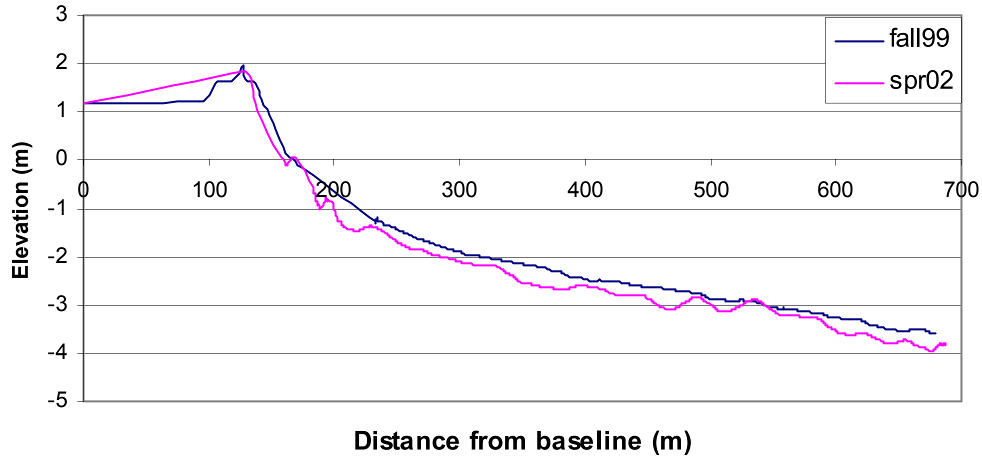
Line 12
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02


Line 14
fall99
fall02
spr02
Elevation (m)
Distance from baseline (m)

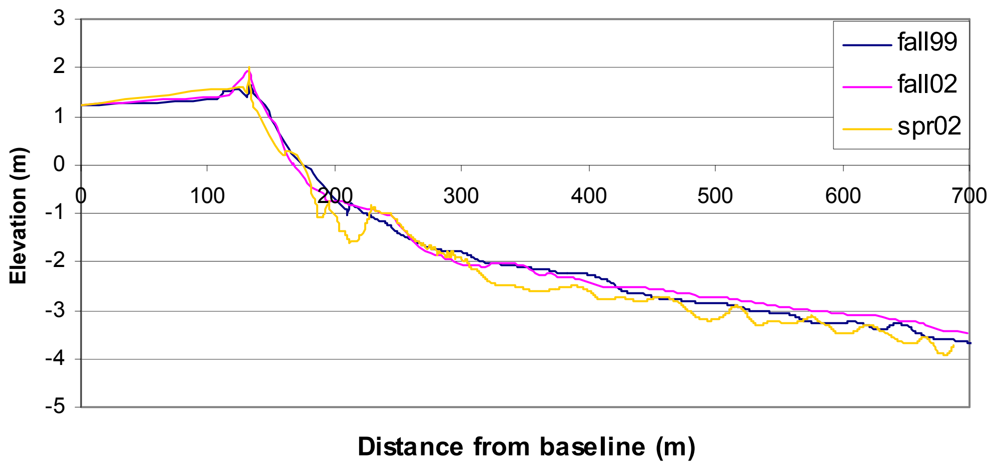

Line 16
fall99
spr02
Elevation (m)
Distance from baseline (m)


Line 18
fall99
fall02
spr02
Elevation (m)
Distance from baseline (m)

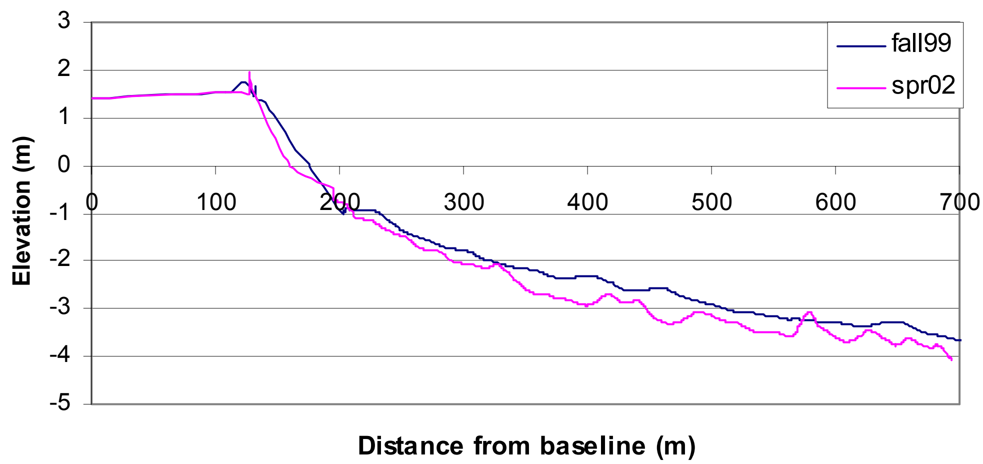
Line 20

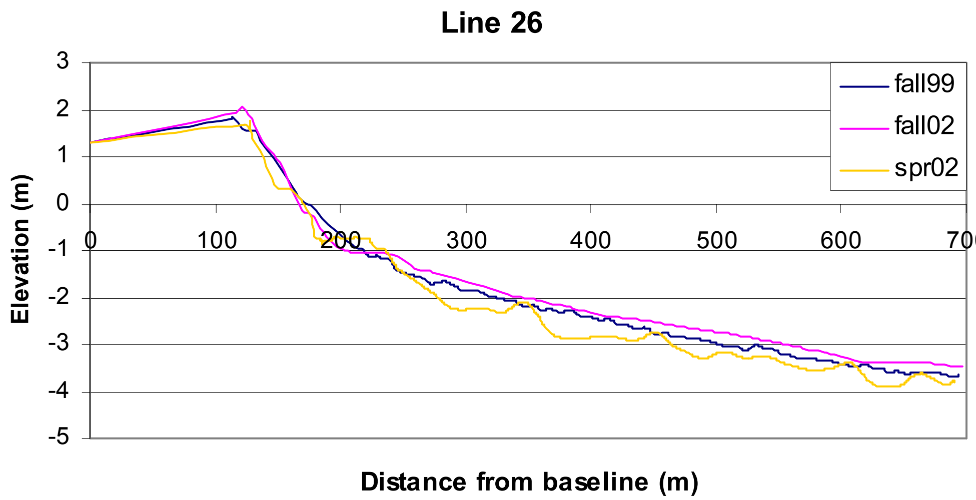


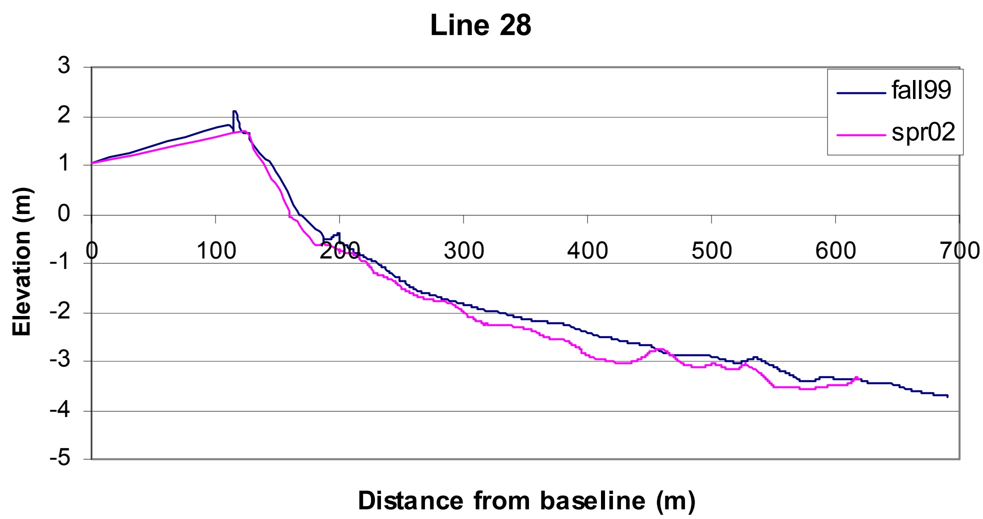
Line 22

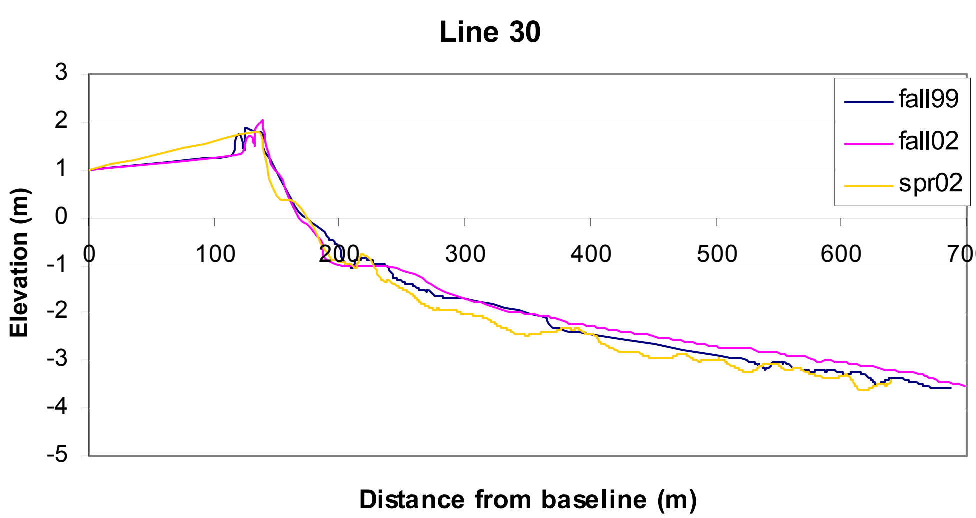


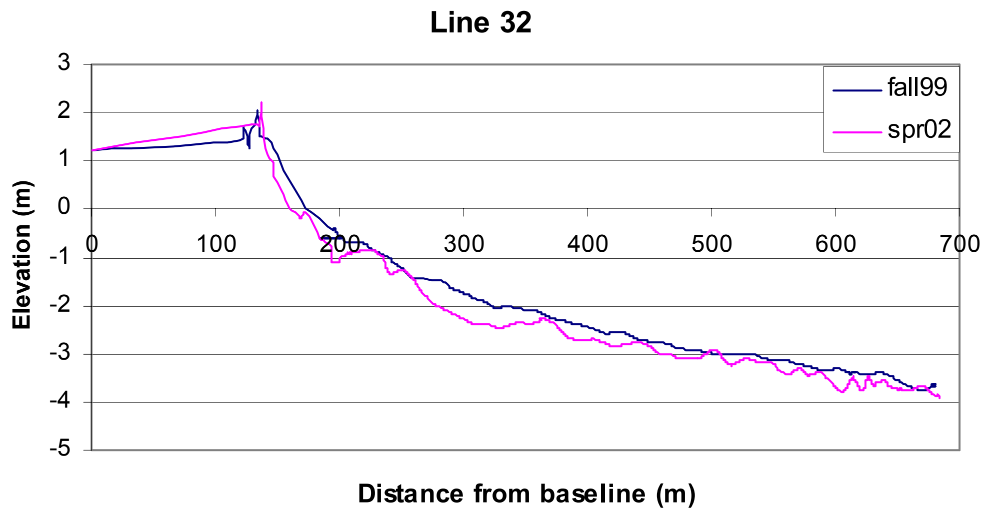
Line 24

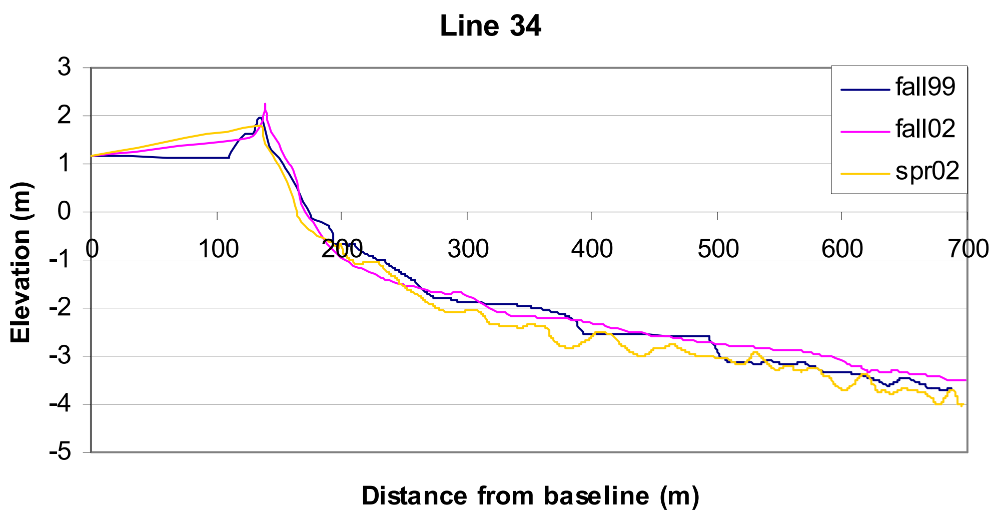


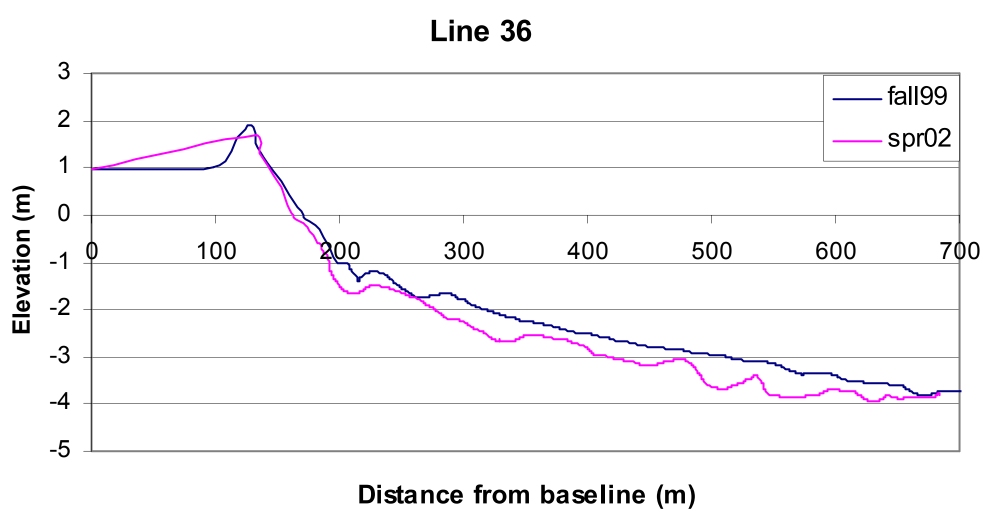

Line 26
3
2
1
0
-1
-2
-3
-4
-5
Elevation (m)
0
100
200
300
400
500
600
700
fall99
fall02
spr02
Distance from baseline (m)

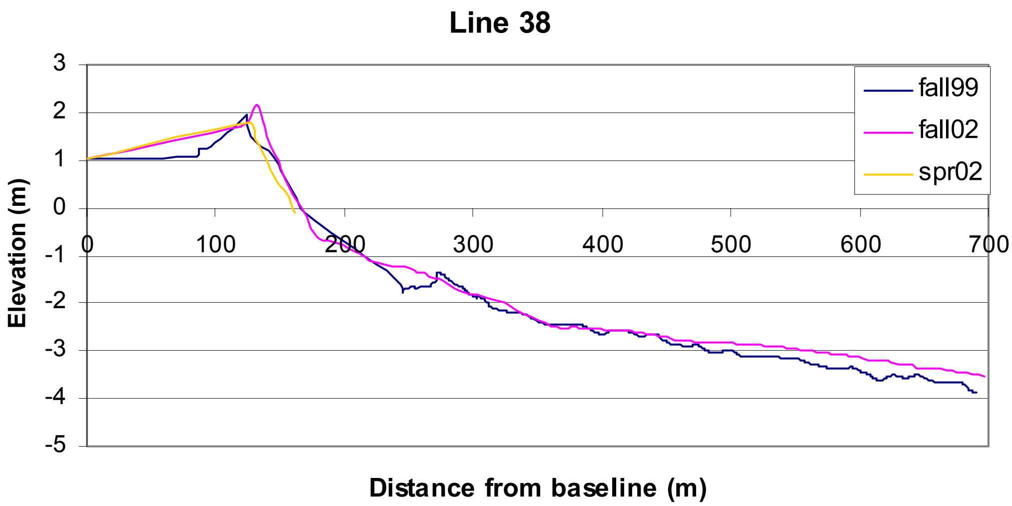

Line 28
3
2
1
0
-1
-2
-3
-4
-5
Elevation (m)
0
100
200
300
400
500
600
700
fall99
spr02
Distance from baseline (m)

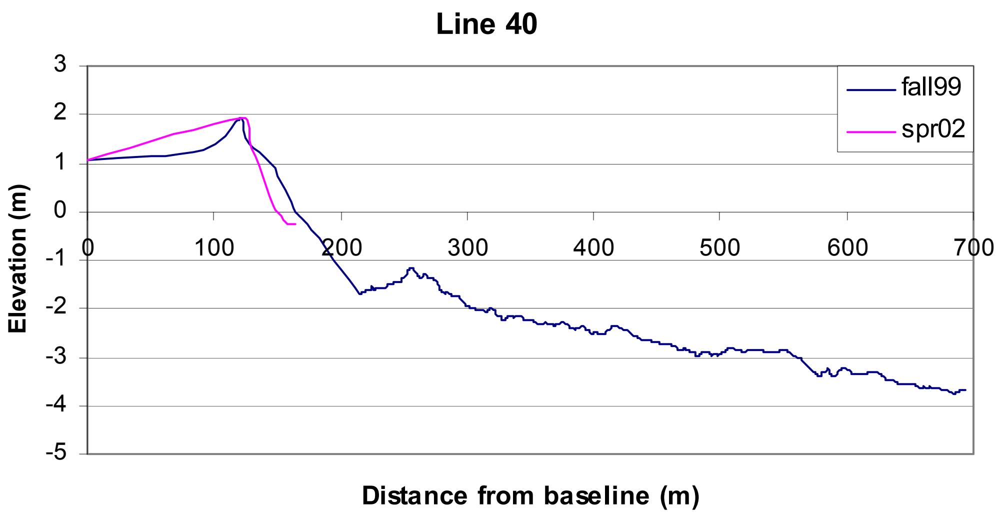

Line 30
3
2
1
0
-1
-2
-3
-4
-5
Elevation (m)
0
100
200
300
400
500
600
700
fall99
fall02
spr02
Distance from baseline (m)

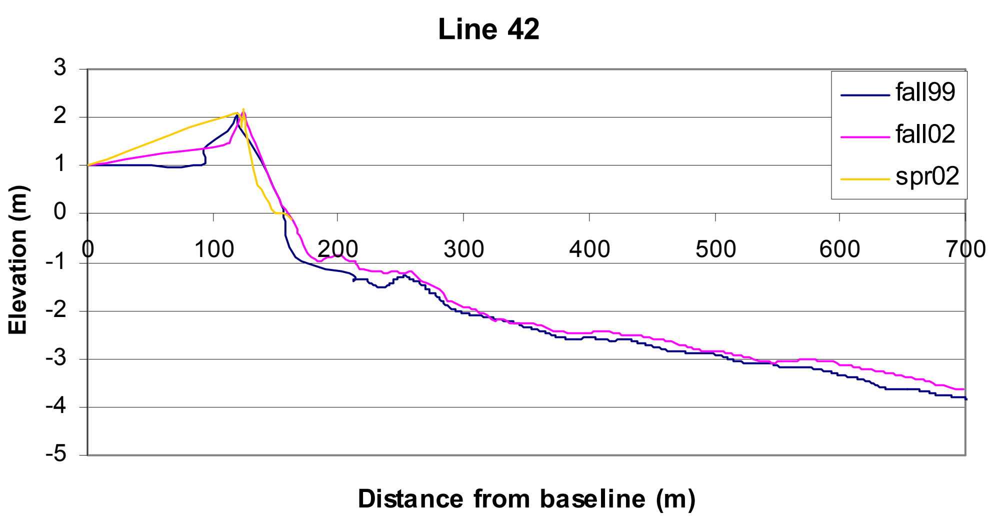

Line 32
fall99
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

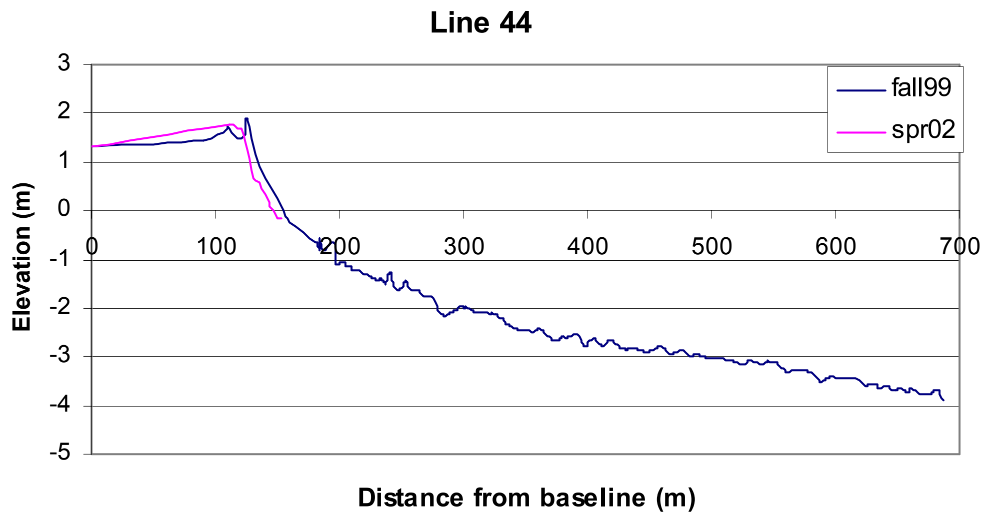

Line 34
fall99
fall02
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

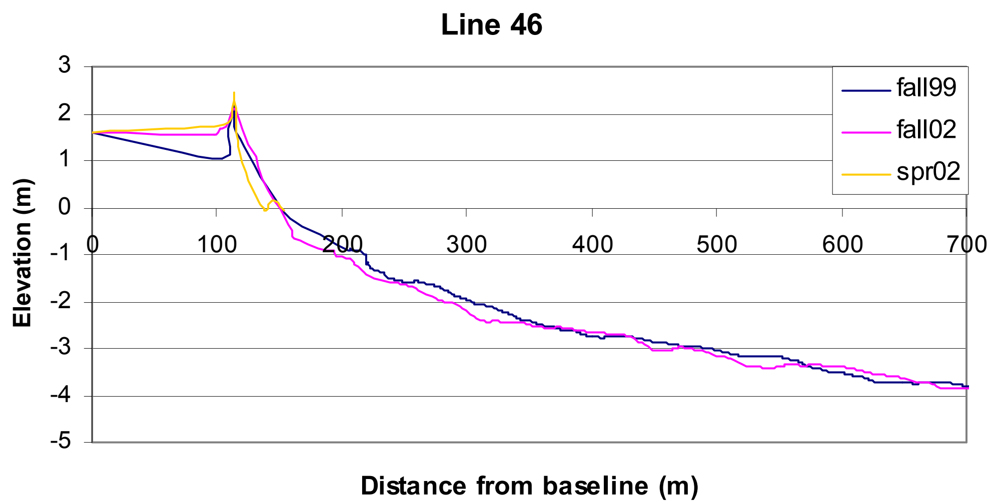

Line 36
fall99
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

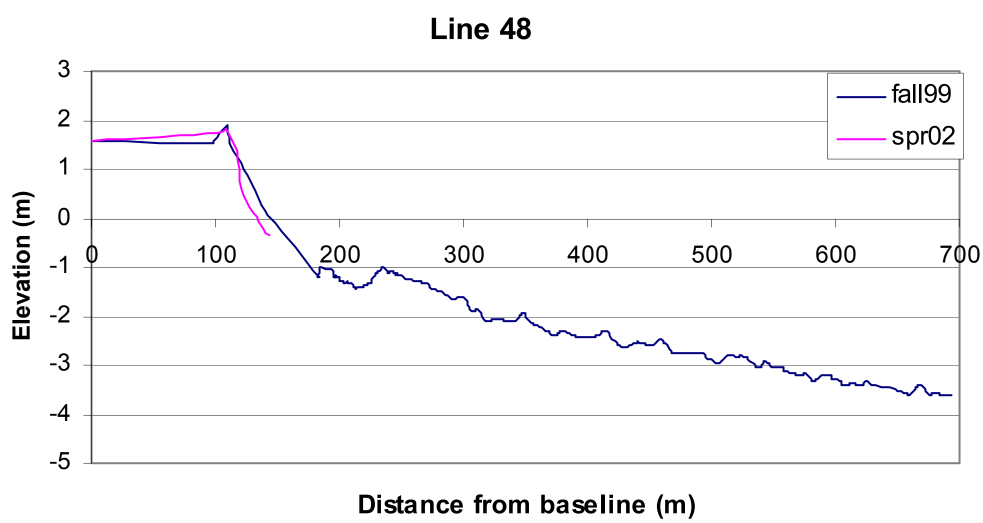

Line 38
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

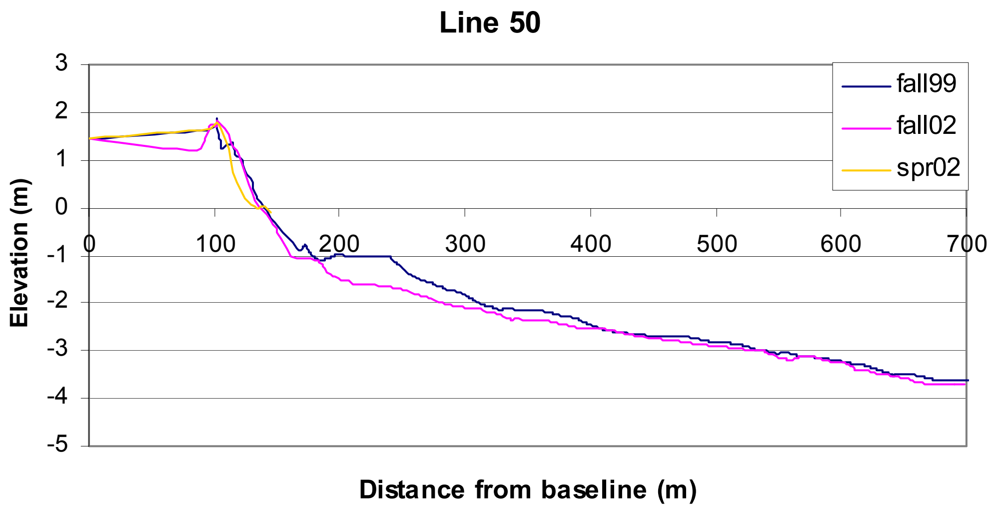

Line 40
Elevation (m)
Distance from baseline (m)
fall99
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

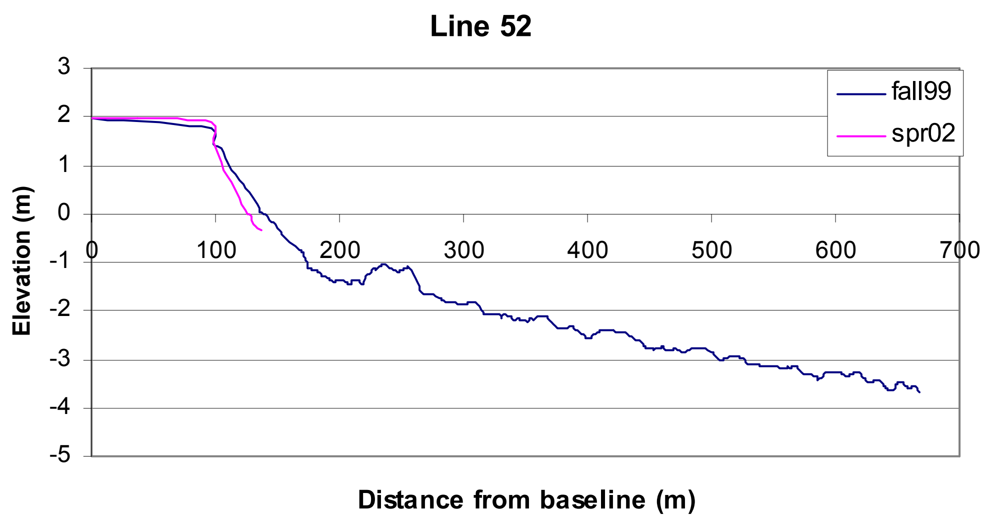

Line 42
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

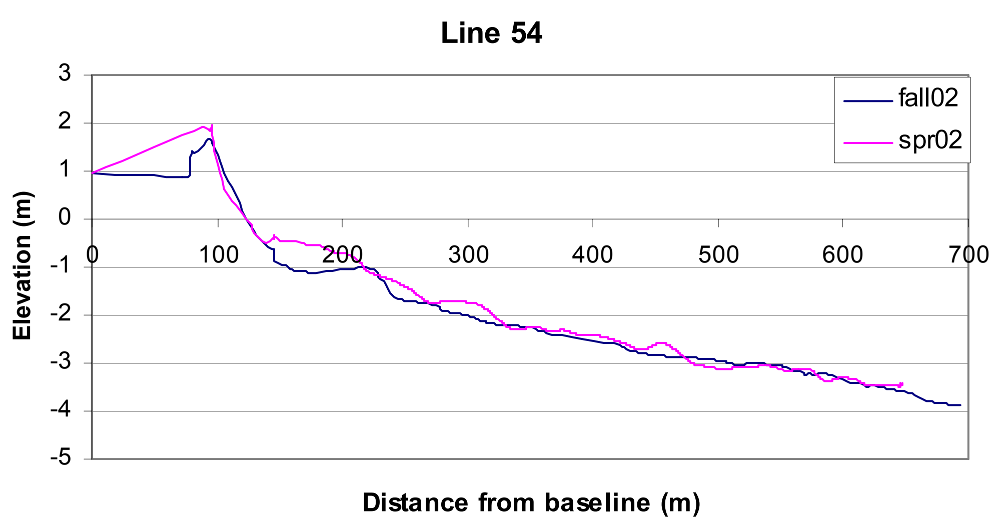

Line 44
fall99
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

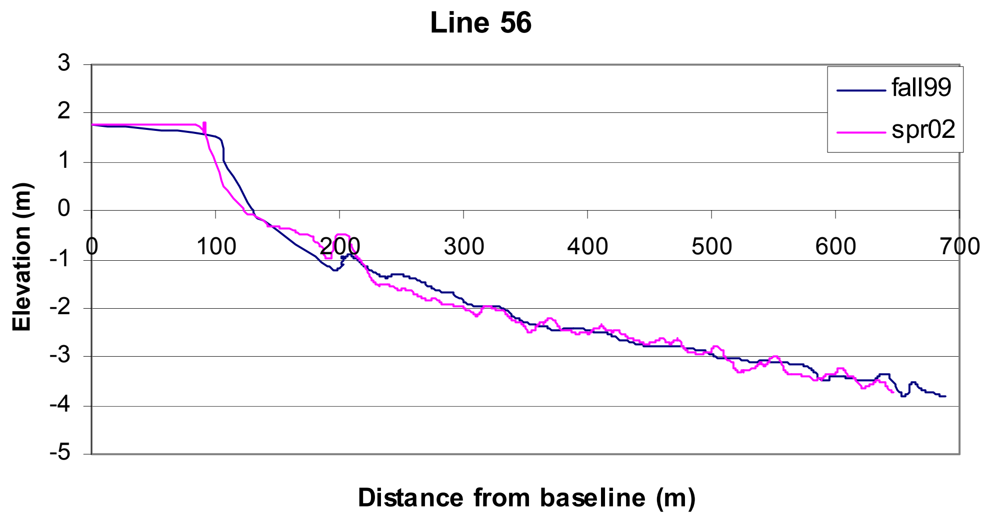

Line 46
fall99
fall02
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)


Line 48
fall99
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

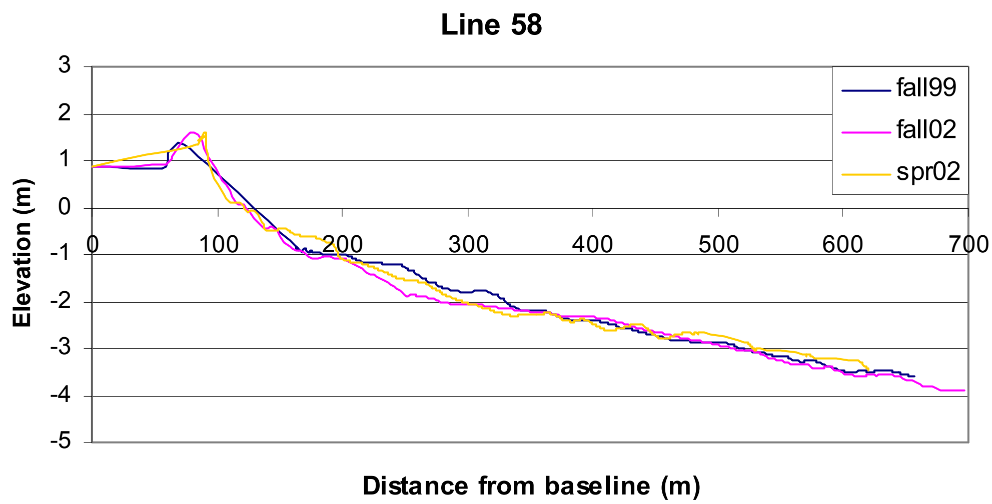

Line 50
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02


Line 52
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

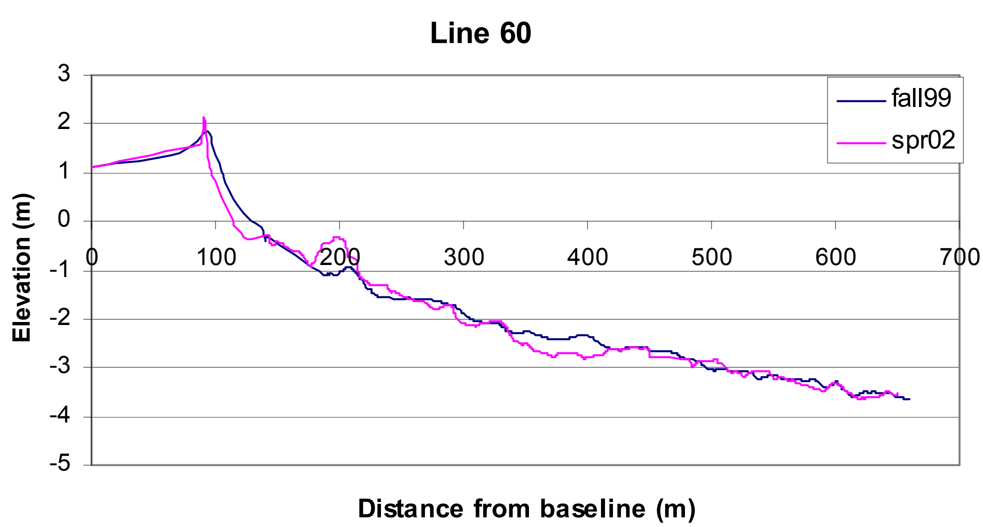

Line 54
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall02
spr02



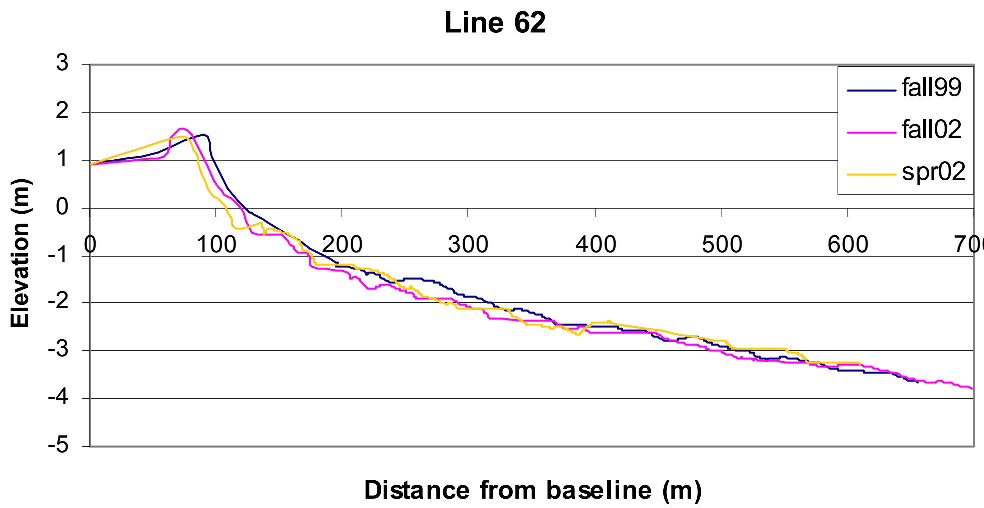
Line 56
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

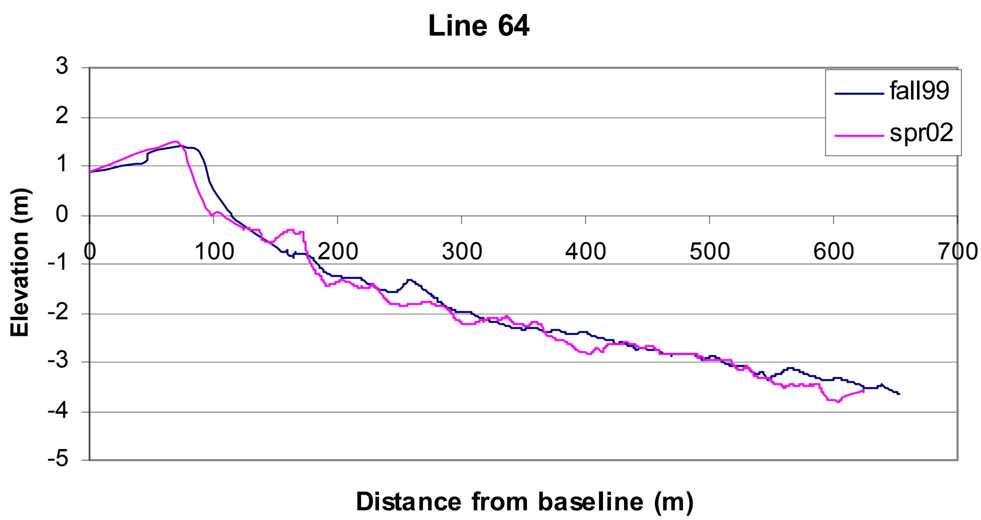


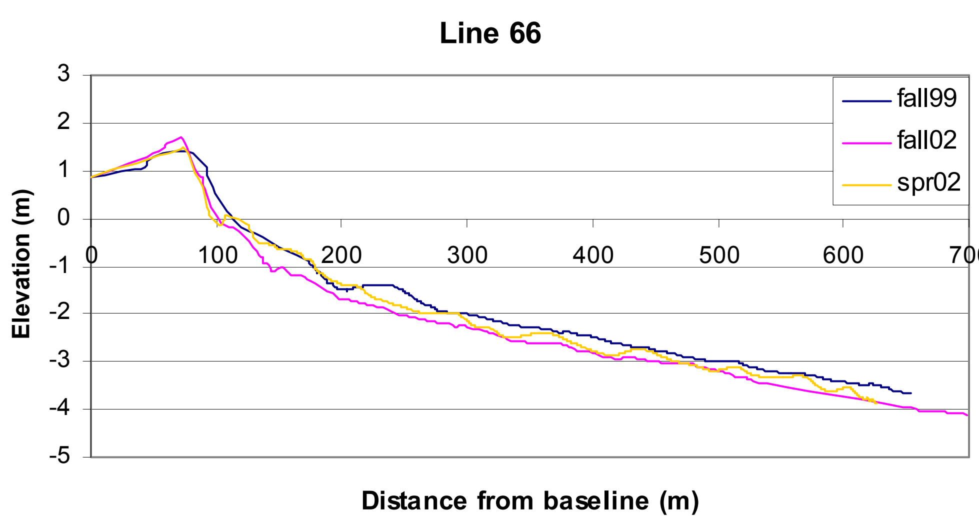
Line 58
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

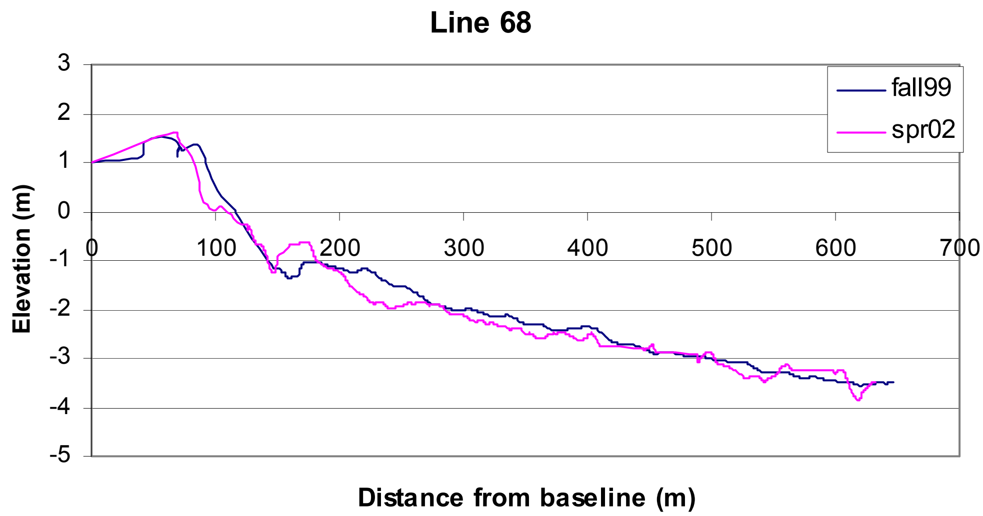


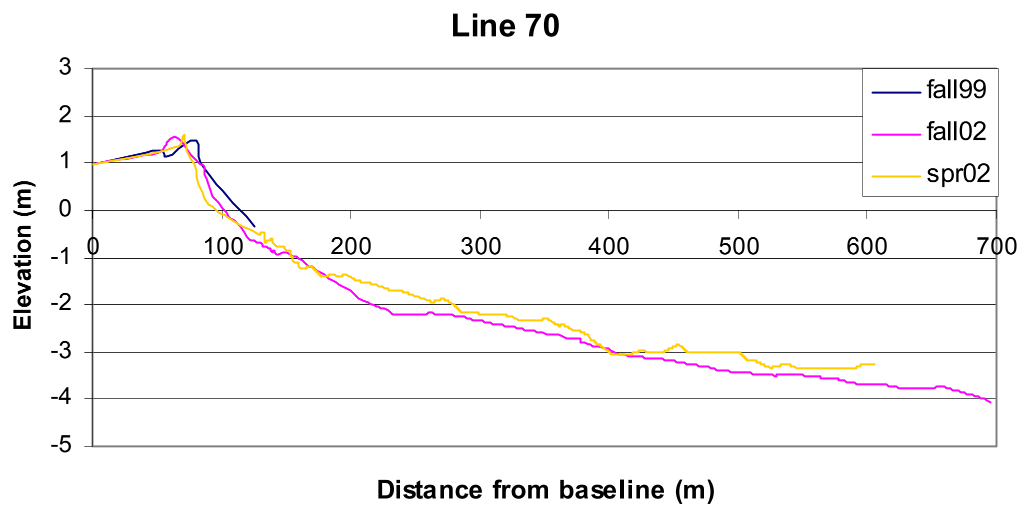
Line 60
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

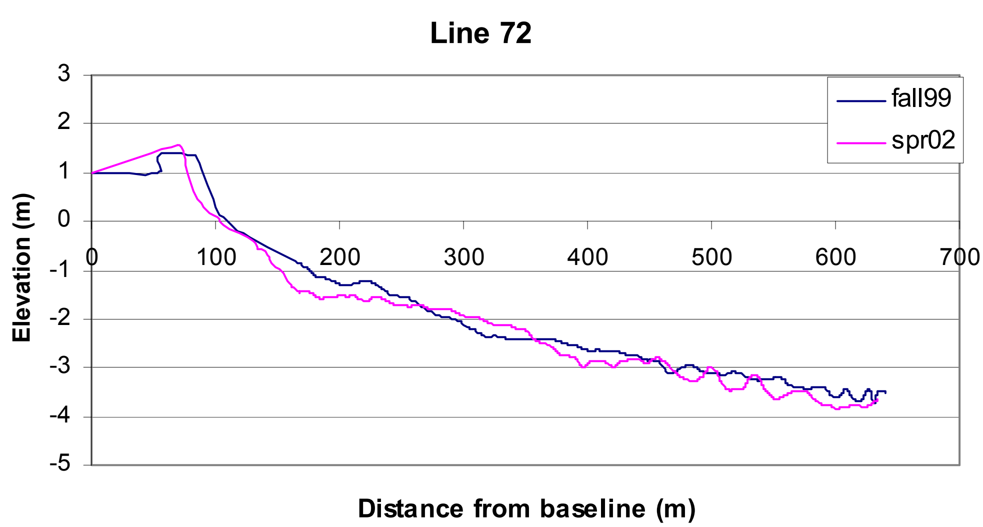

Line 62
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

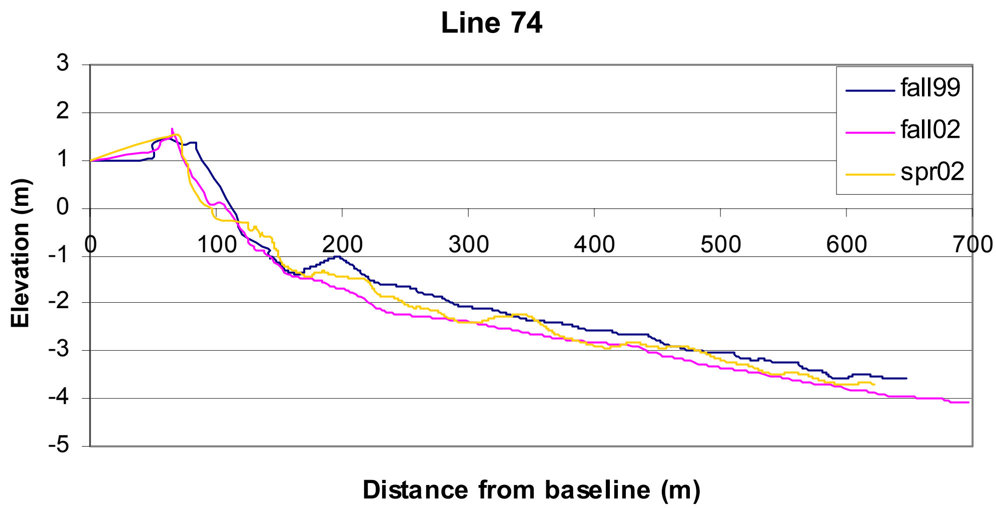

Line 64
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

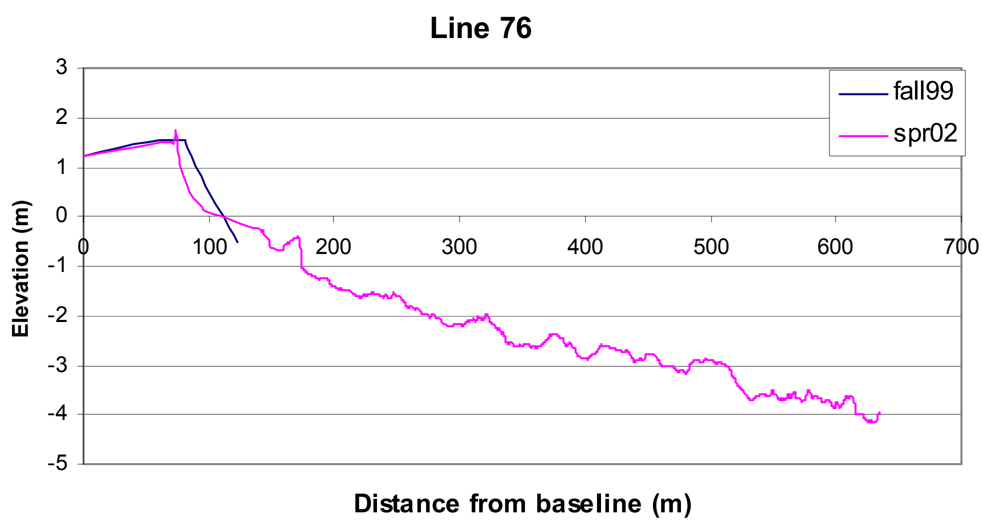

Line 66
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

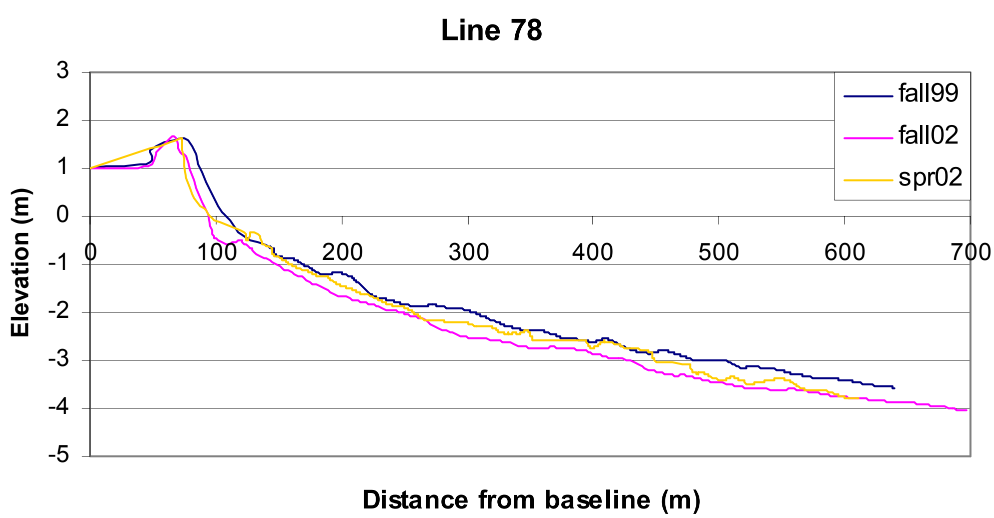

Line 68
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

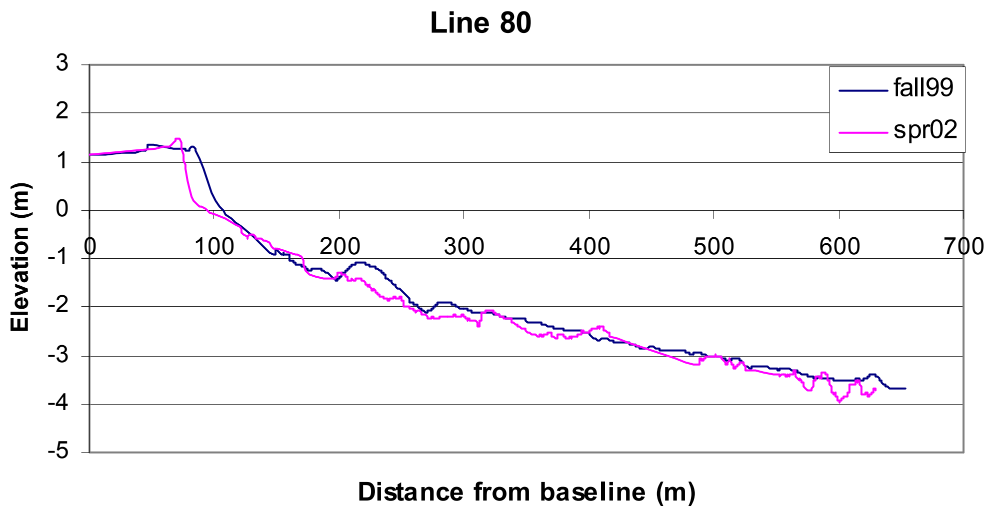

Line 70
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

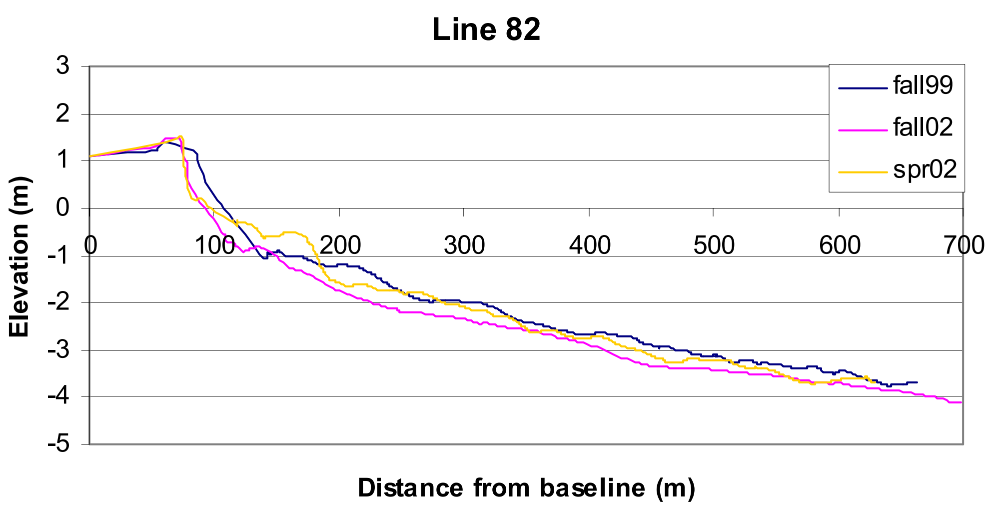

Line 72
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

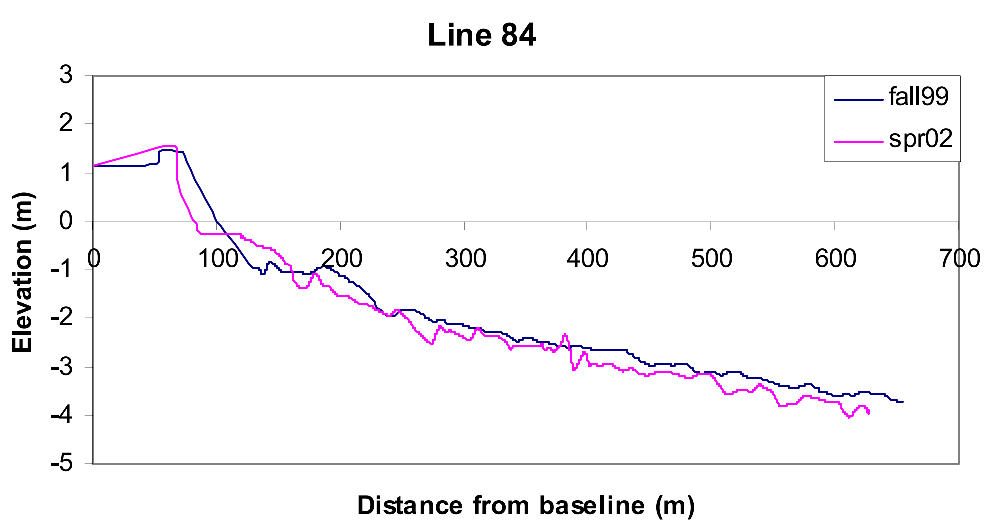

Line 74
fall99
fall02
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

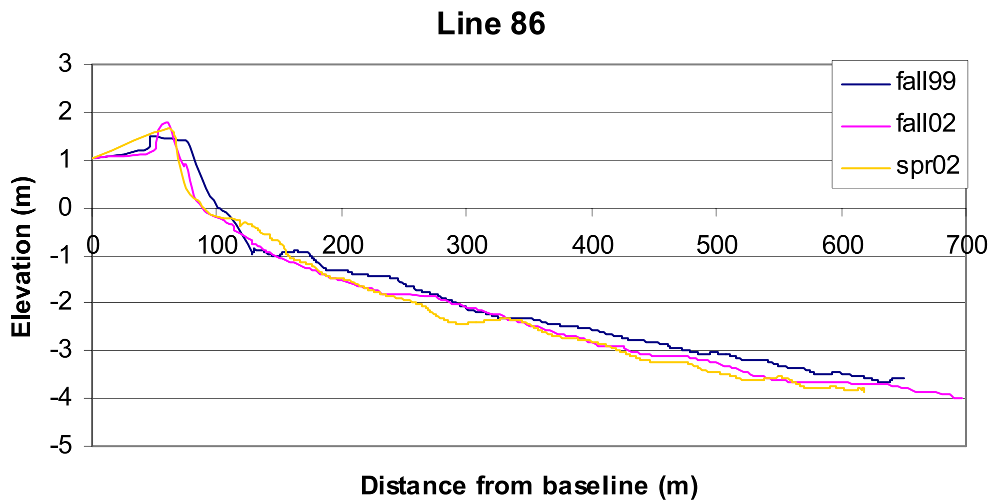

Line 76
fall99
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

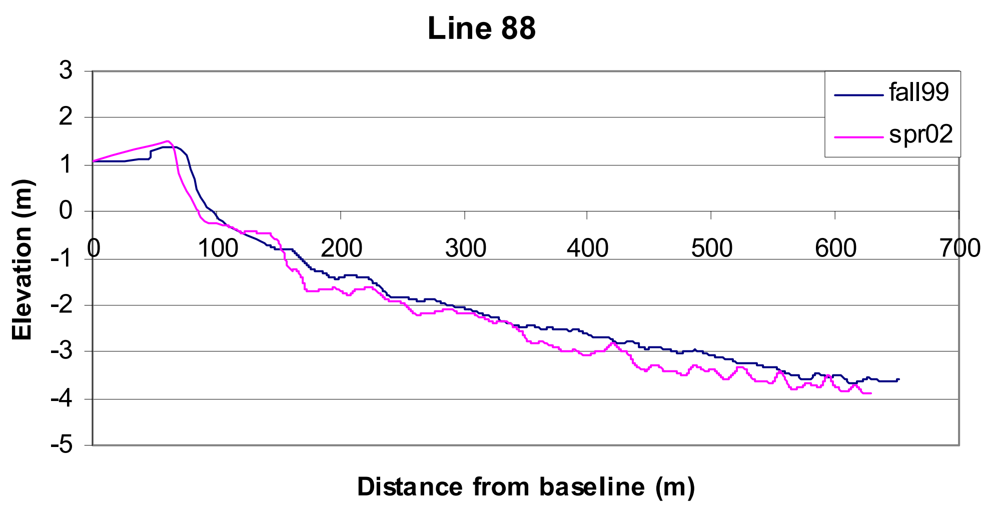

Line 78
fall99
fall02
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

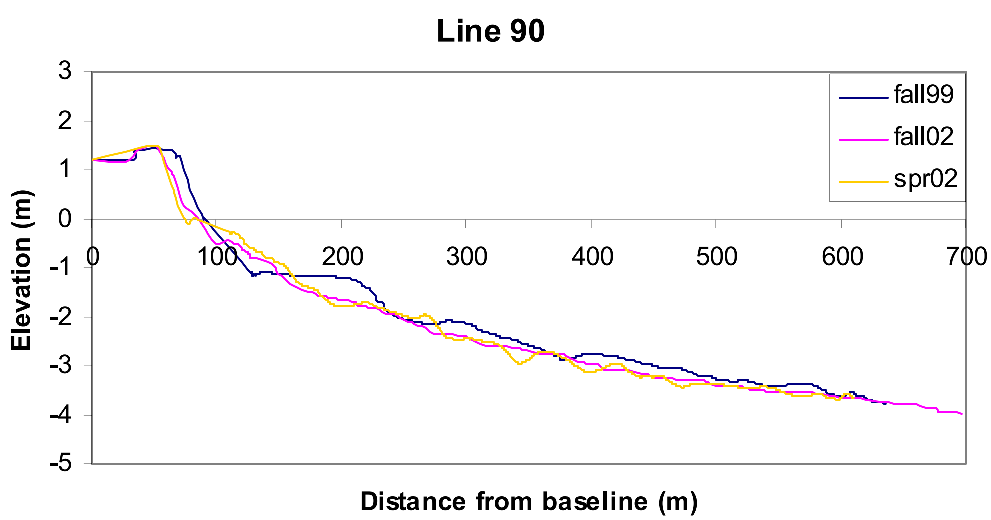

Line 80
fall99
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

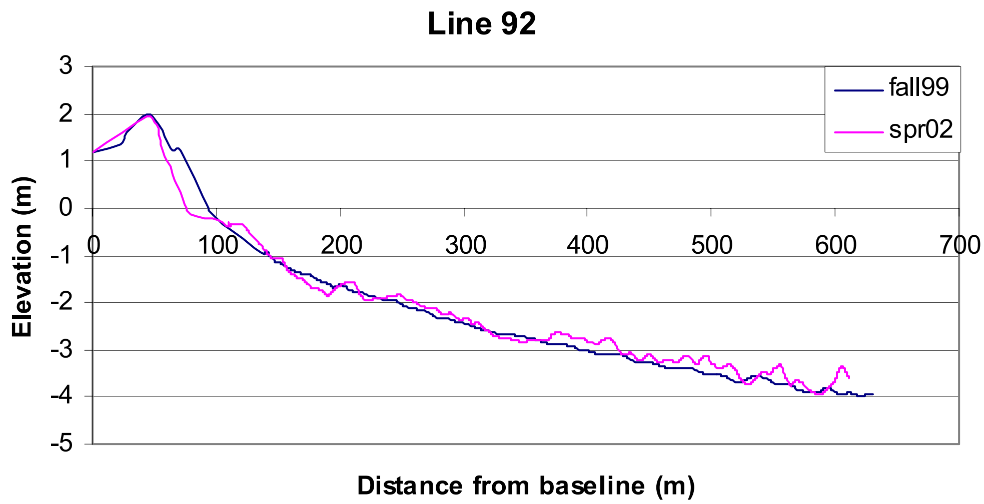

Line 82
fall99
fall02
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

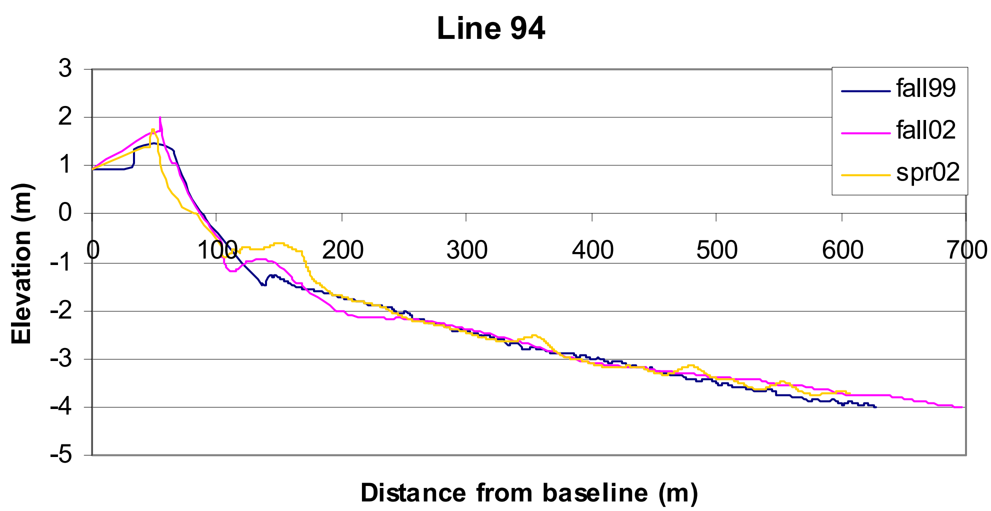

Line 84
fall99
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

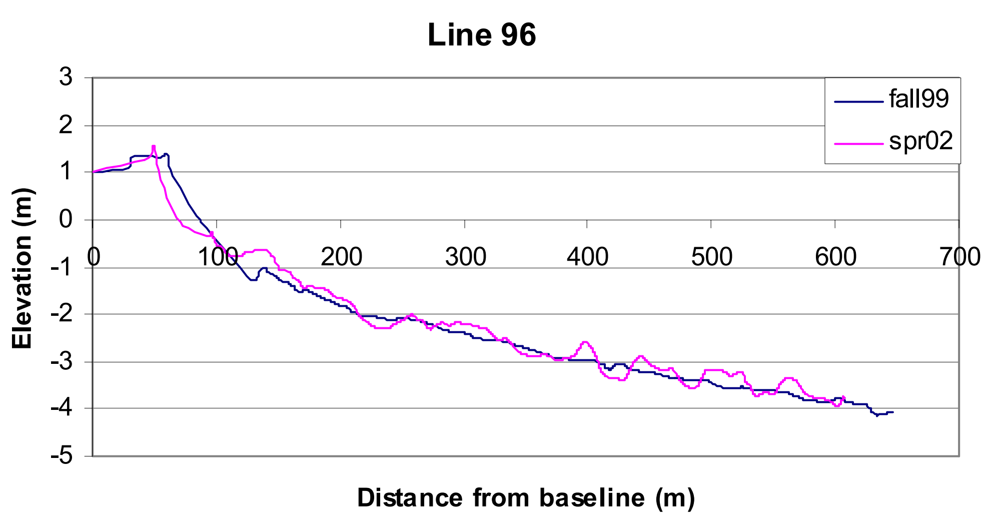

Line 86
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

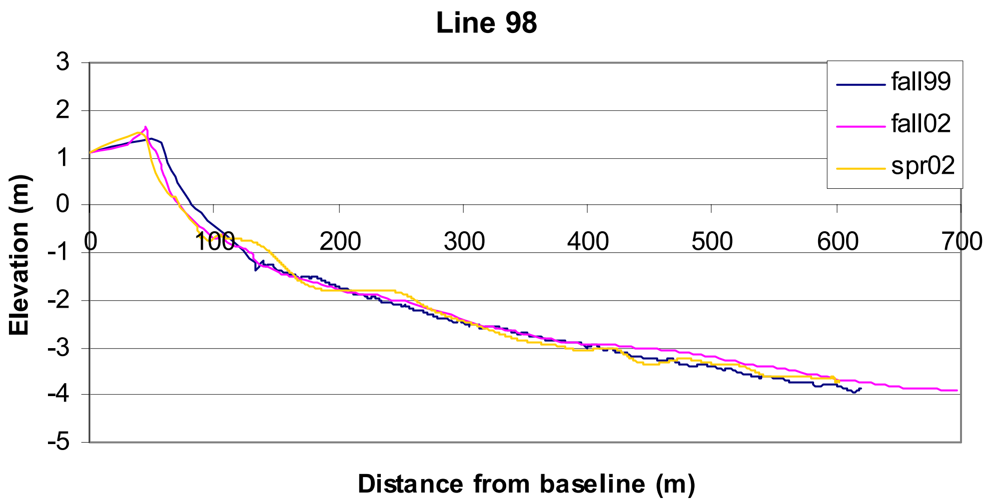

Line 88
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
spr02

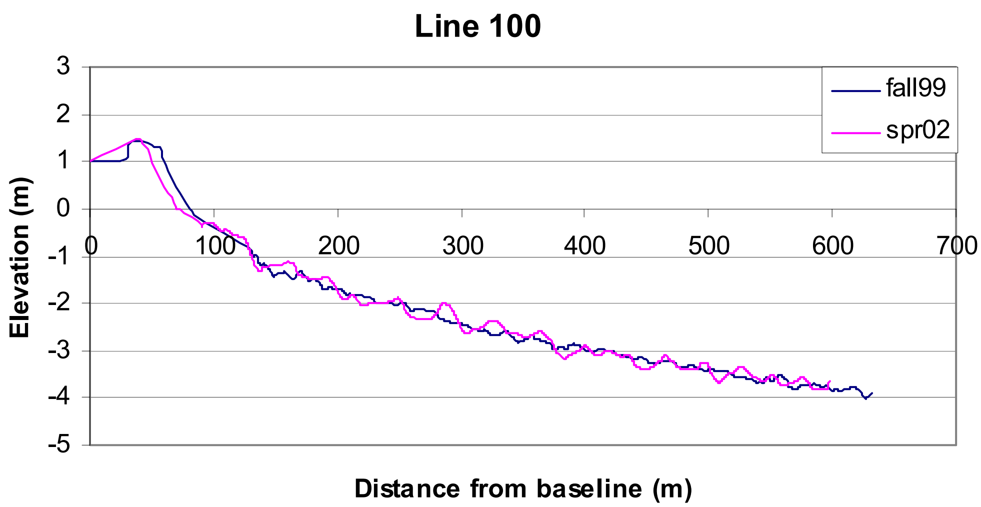

Line 90
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

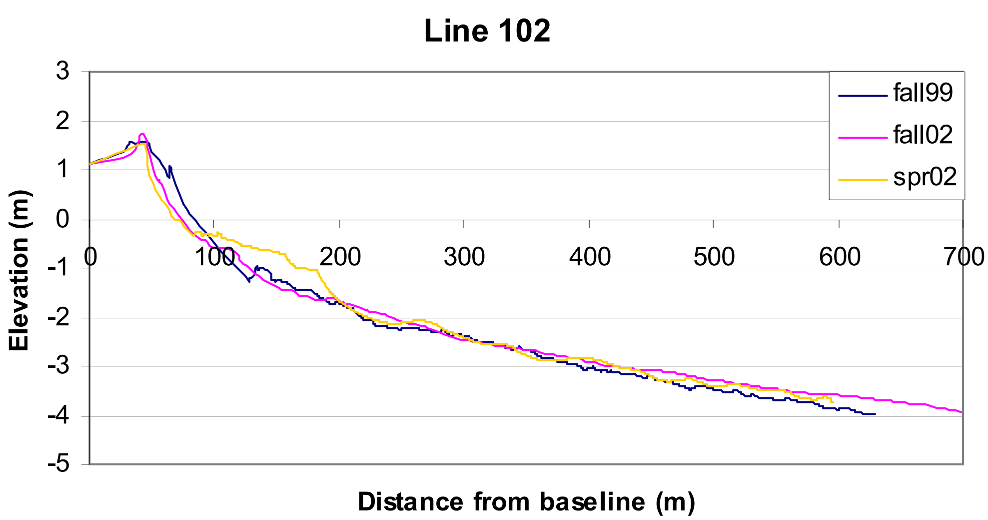

Line 92
fall99
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

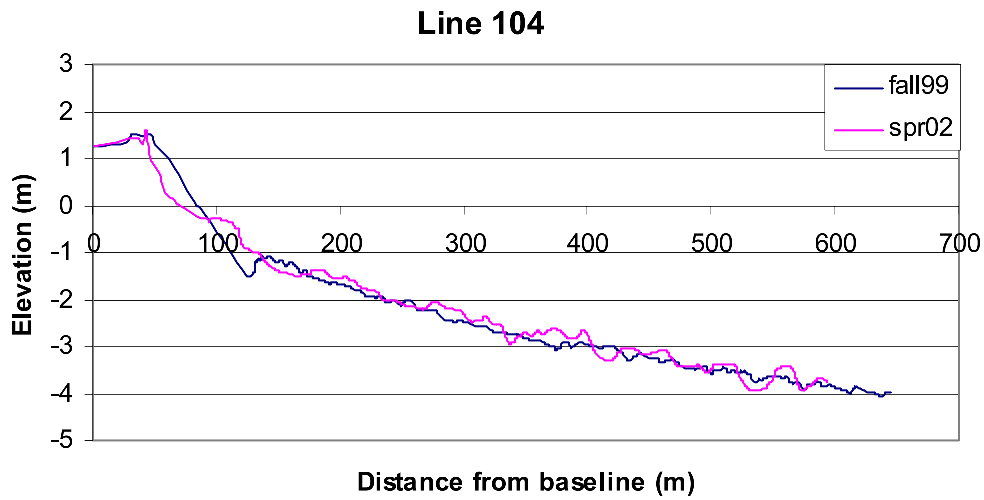

Line 94
fall99
fall02
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

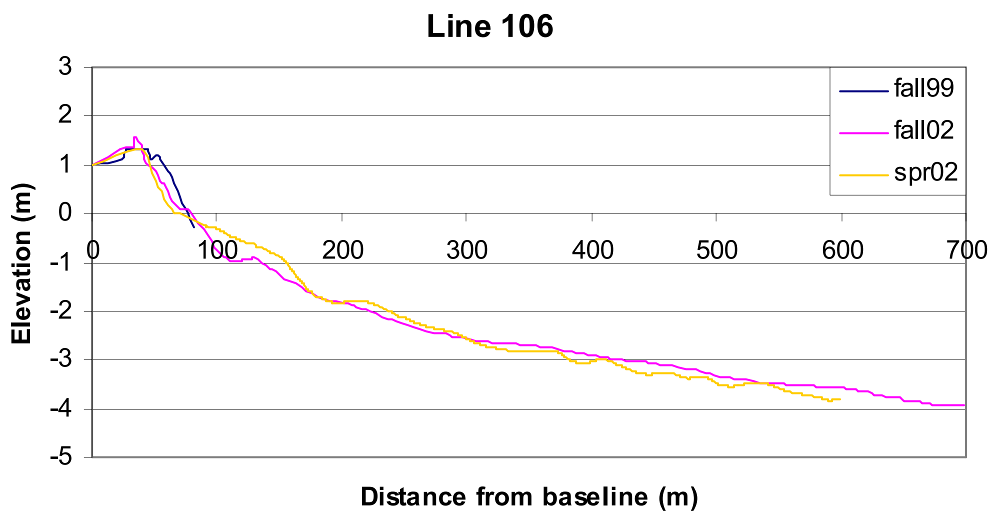

Line 96
fall99
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

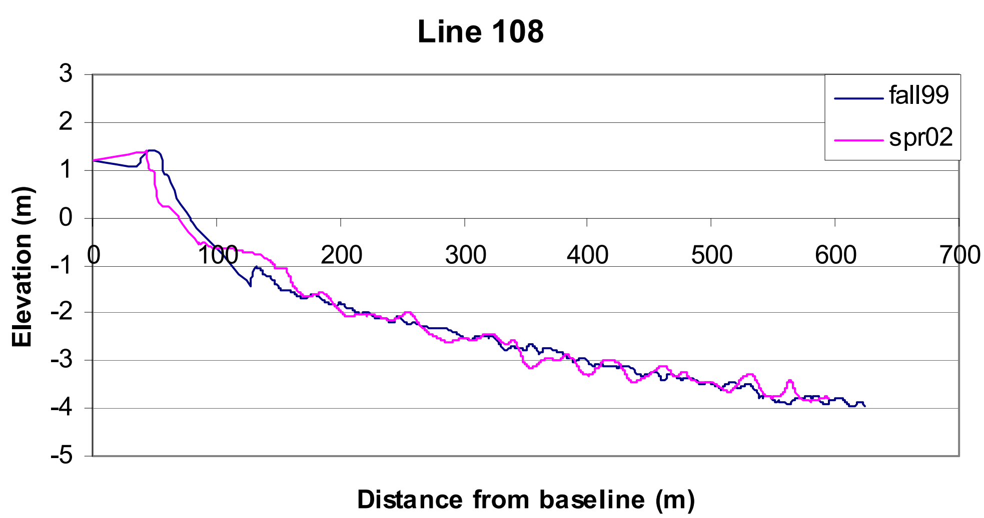

Line 98
fall99
fall02
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

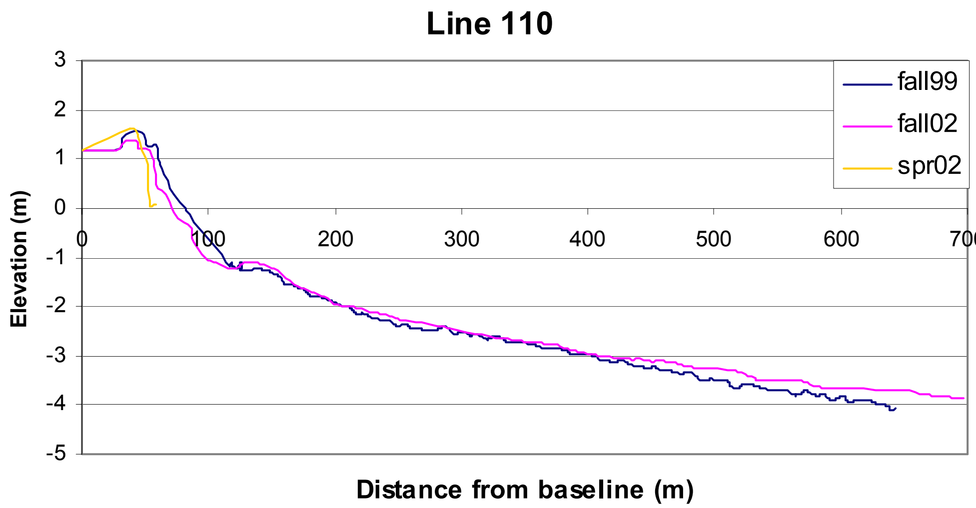

Line 100
fall99
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700


Line 102
fall99
fall02
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

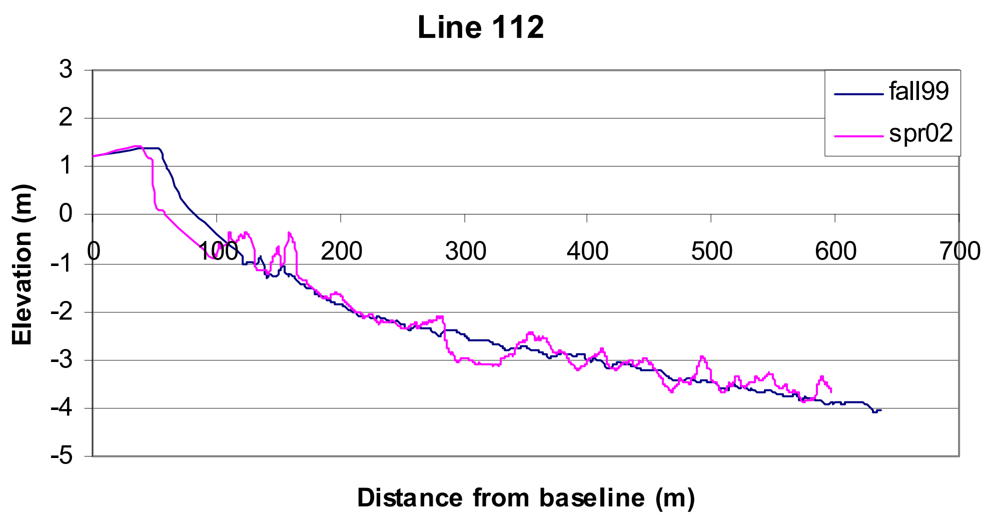

Line 104
Elevation (m)
Distance from baseline (m)
fall99
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700


Line 106
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

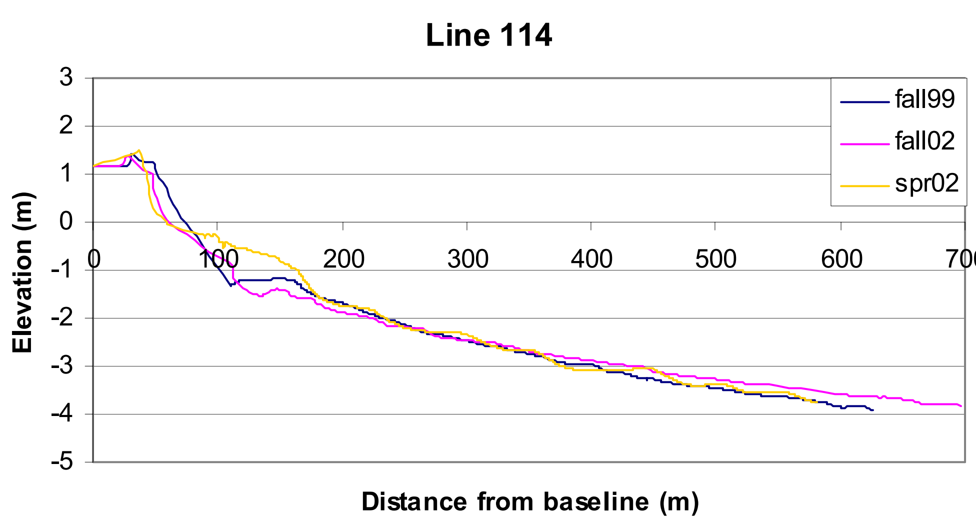

Line 108
Elevation (m)
Distance from baseline (m)
fall99
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700



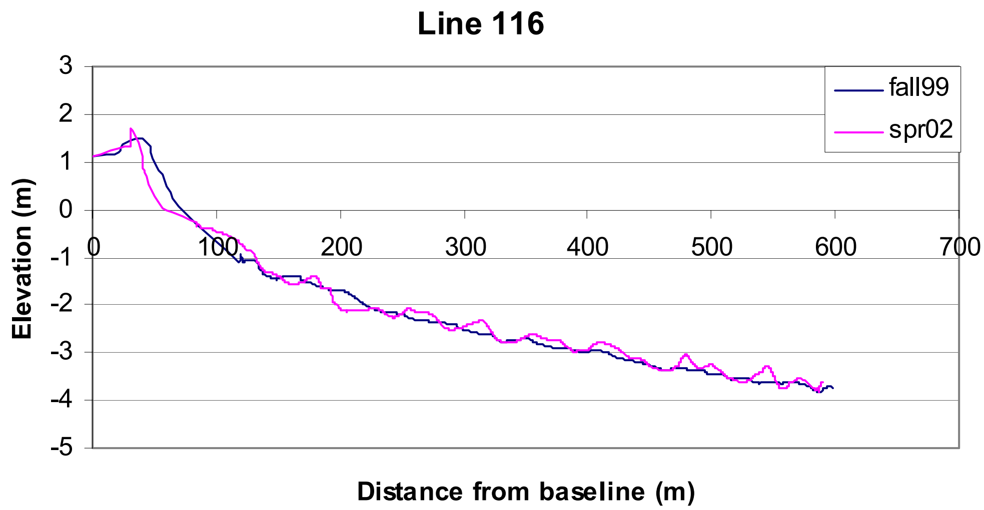
Line 110
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

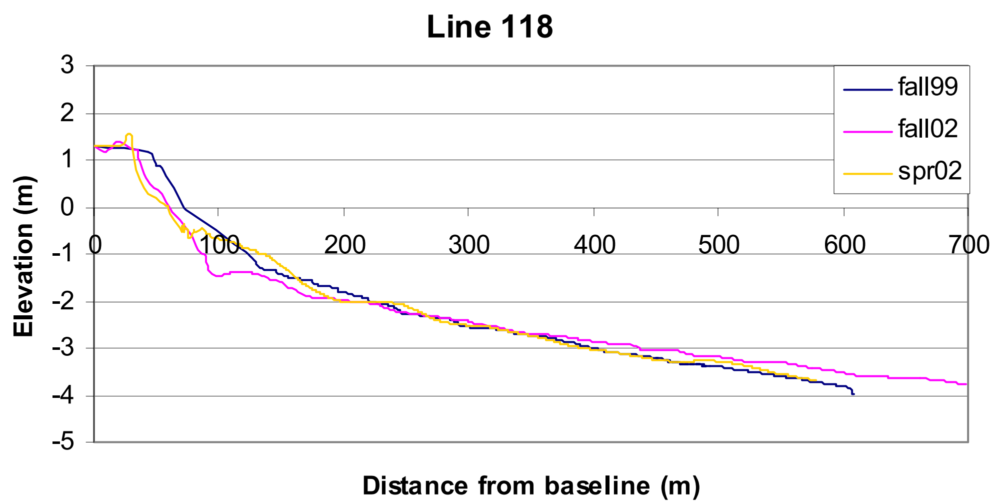


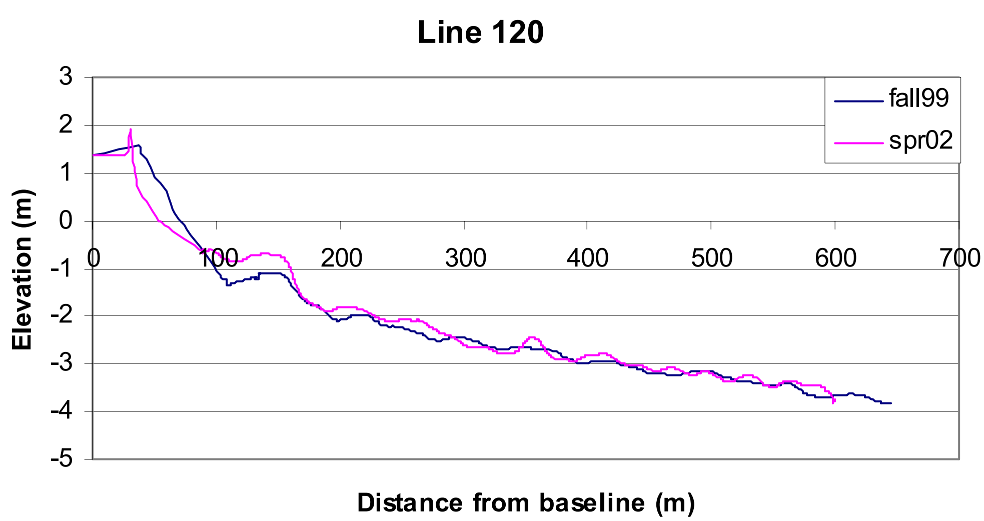
Line 112
Elevation (m)
Distance from baseline (m)
fall99
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

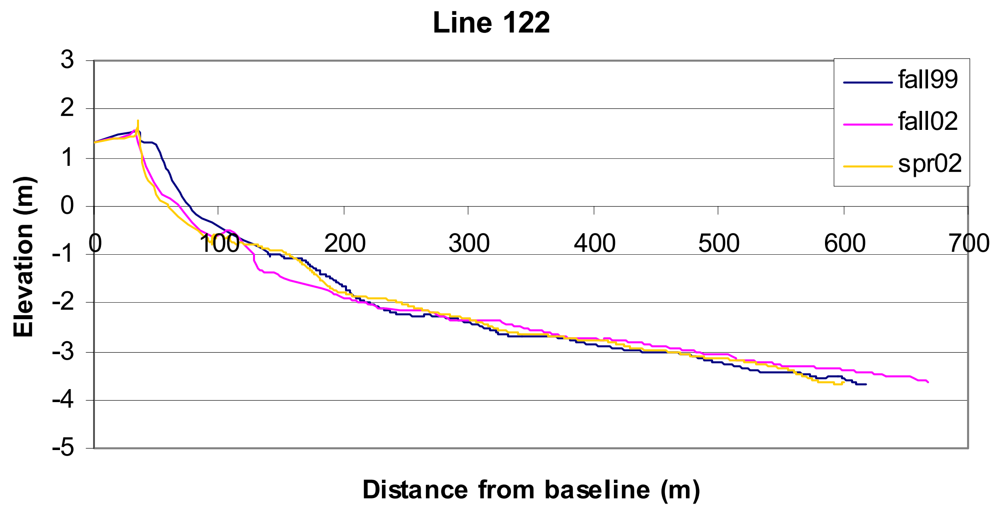


Line 114
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

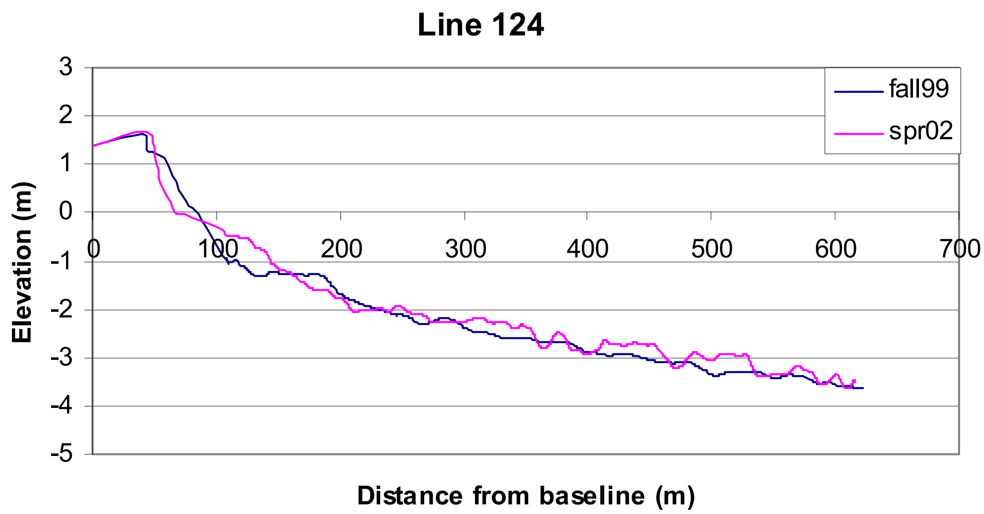

Line 116
Elevation (m)
Distance from baseline (m)
fall99
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700


Line 118
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

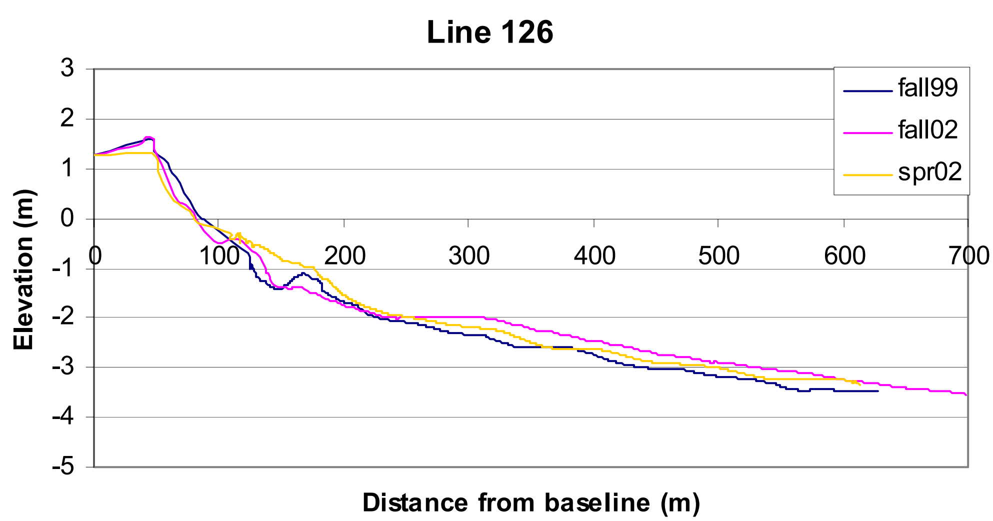

Line 120
Elevation (m)
Distance from baseline (m)
fall99
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700



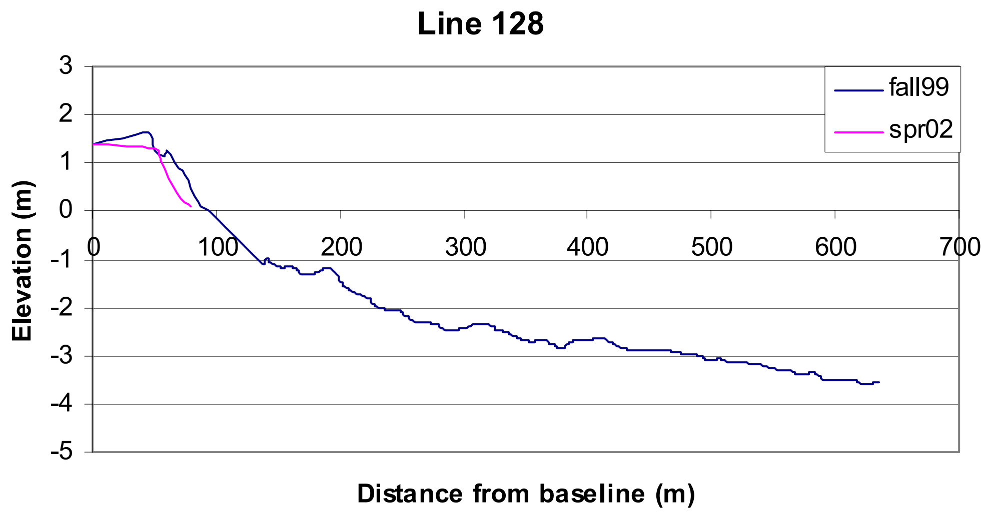
Line 122
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

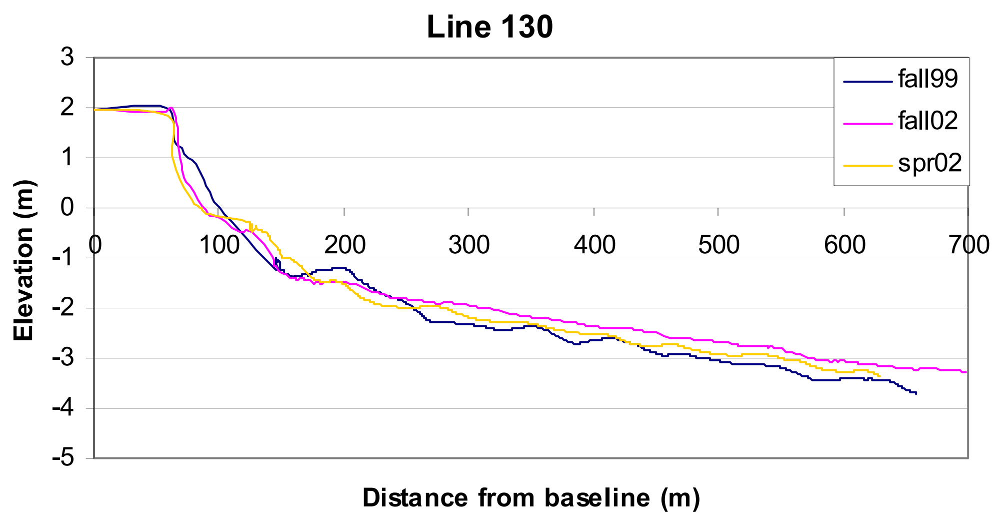


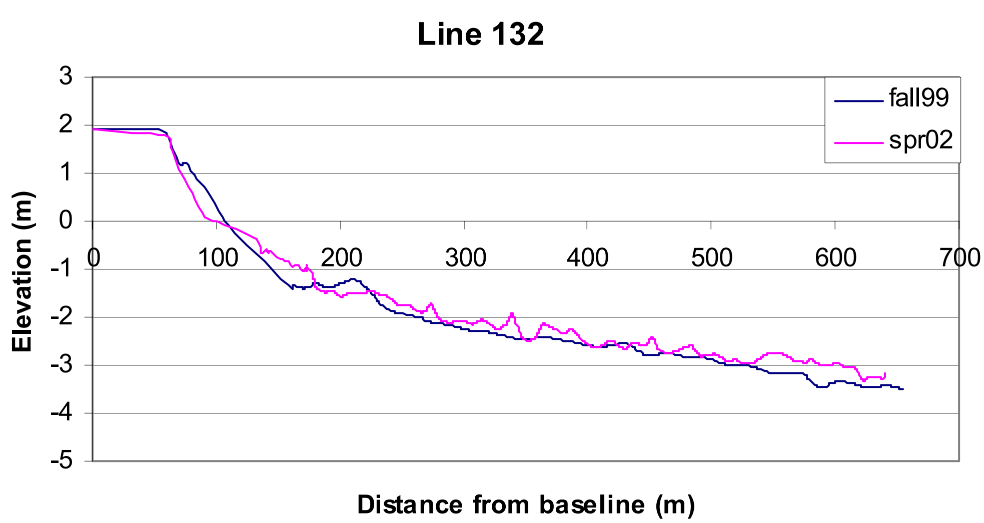
Line 124
Elevation (m)
Distance from baseline (m)
fall99
spr02

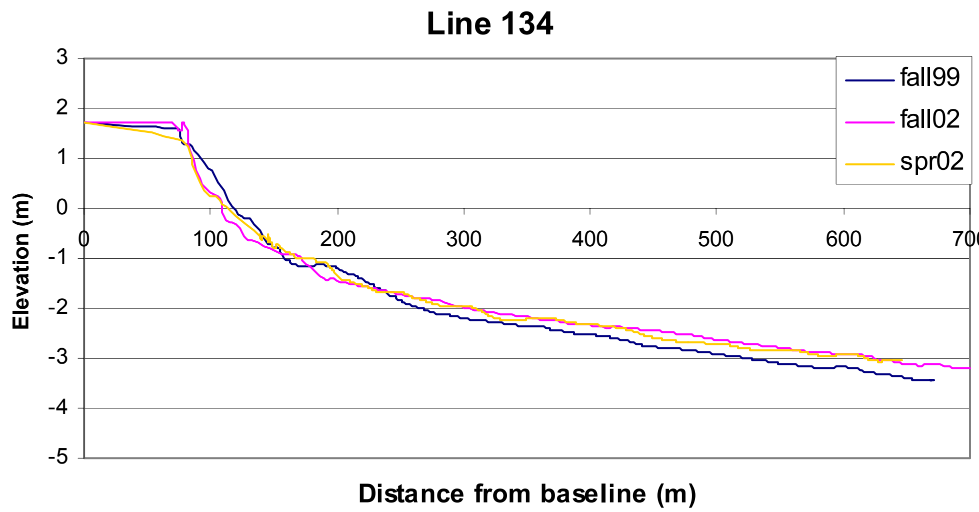


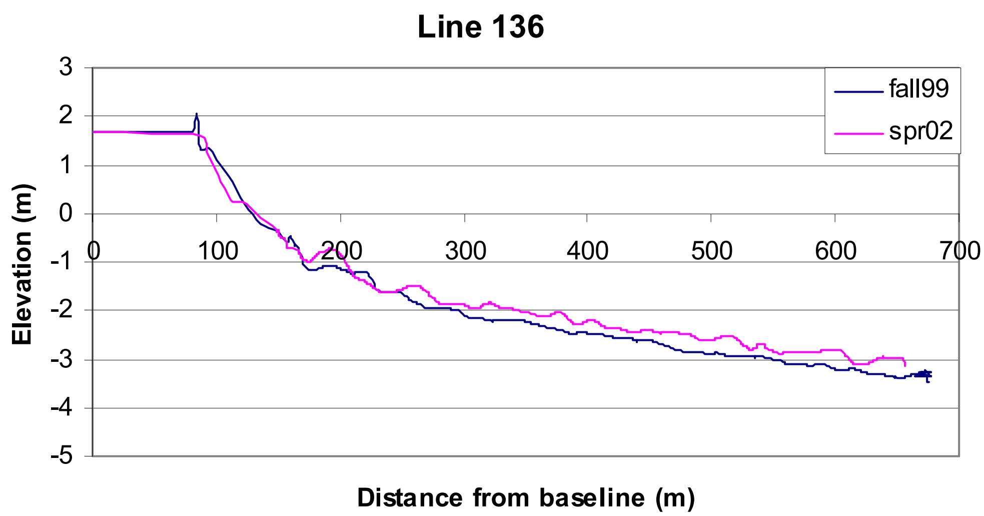
Line 126
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

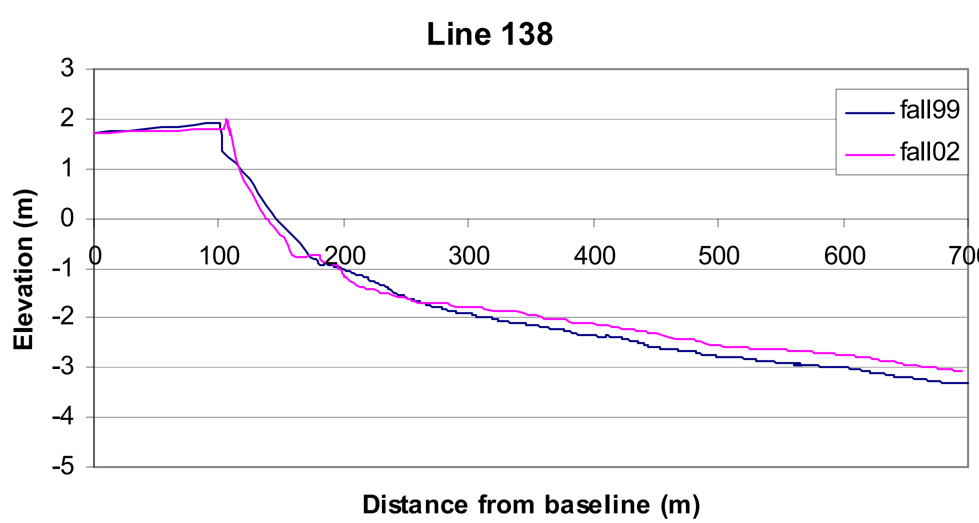

Line 128
fall99
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

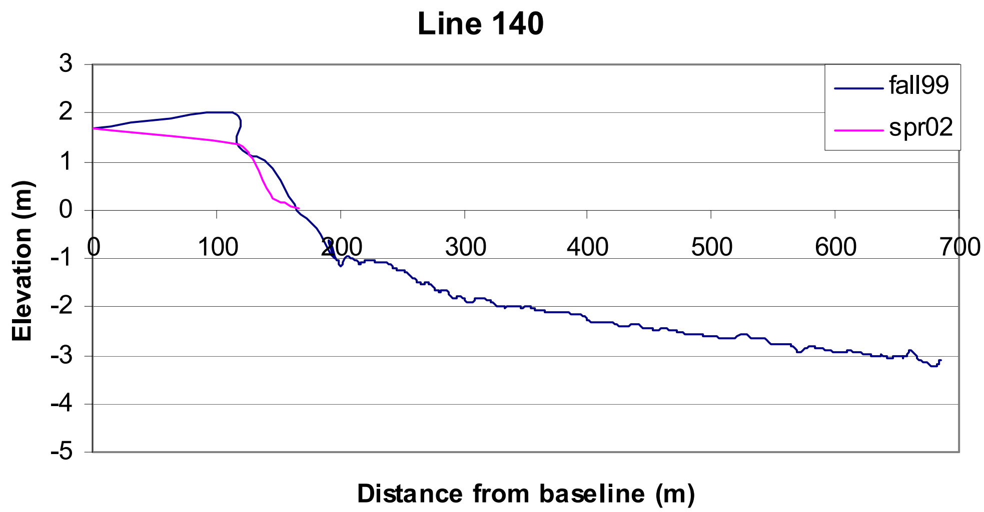

Line 130
fall99
fall02
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

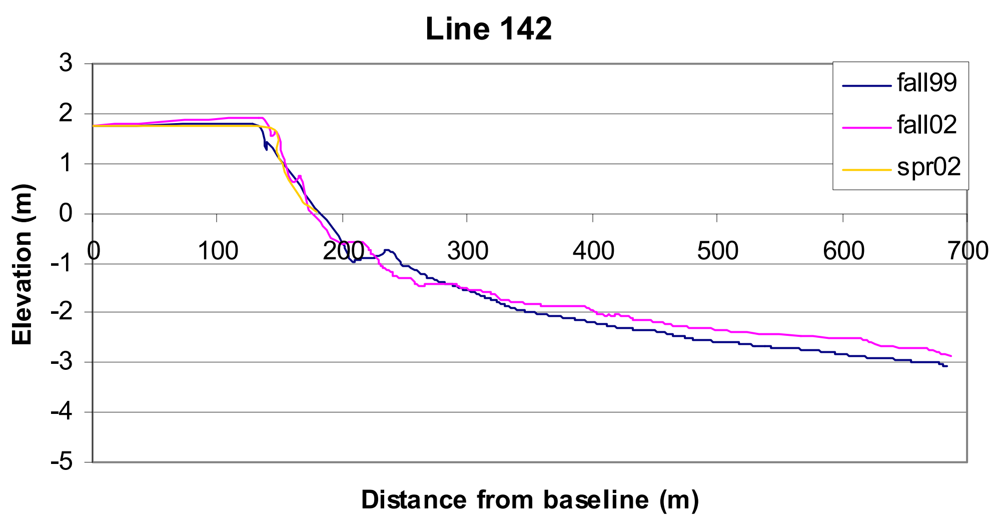

Line 132
fall99
spr02
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
Distance from baseline (m)

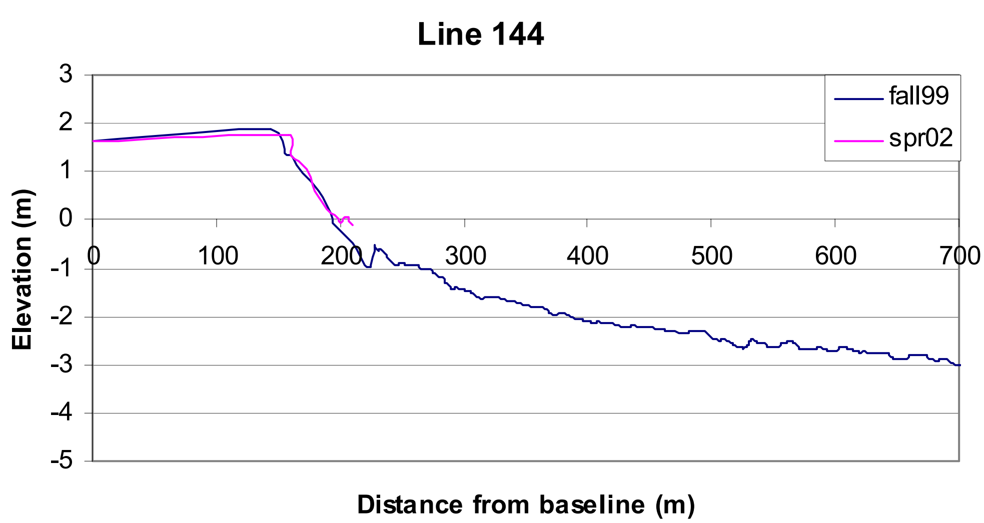

Line 134
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

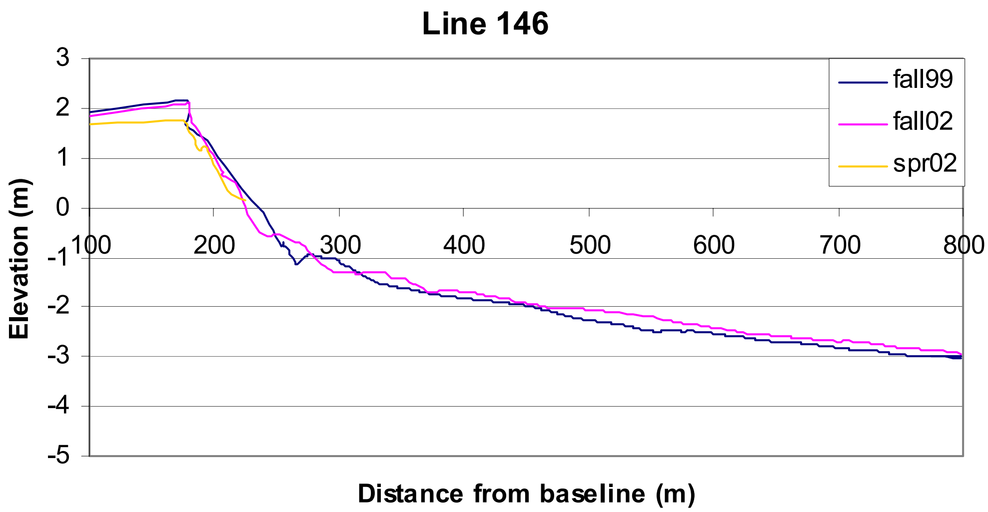

Line 136
Elevation (m)
Distance from baseline (m)
fall99
spr02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

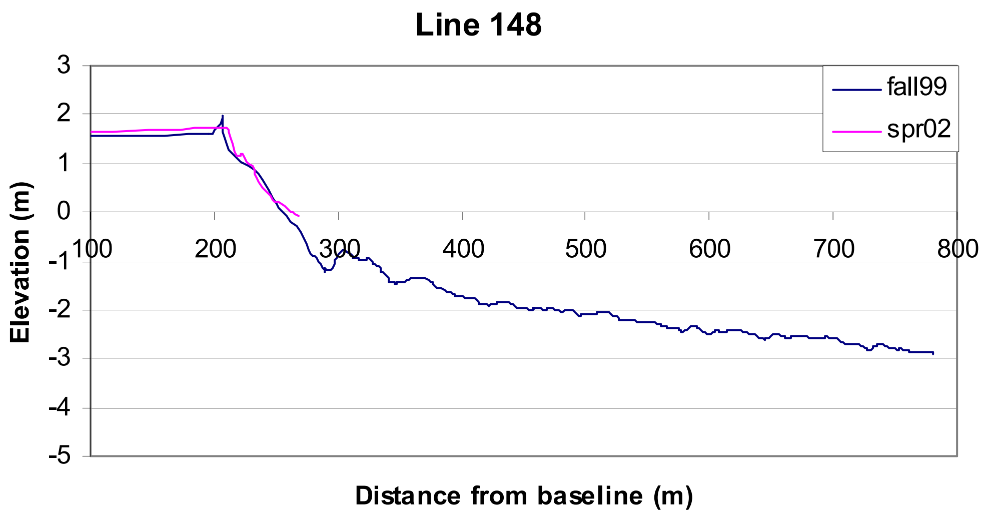

Line 138
Elevation (m)
Distance from baseline (m)
fall99
fall02
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

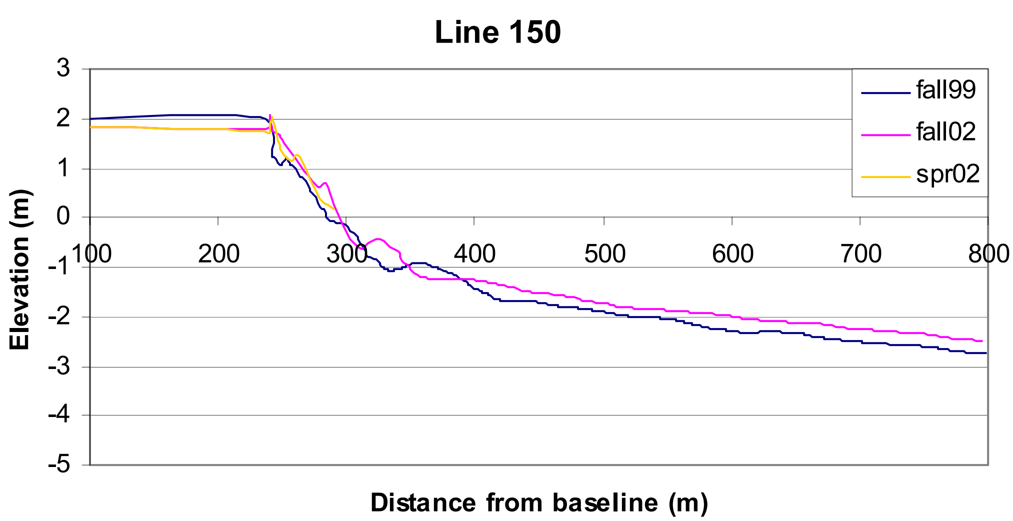

Line 140
fall99
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

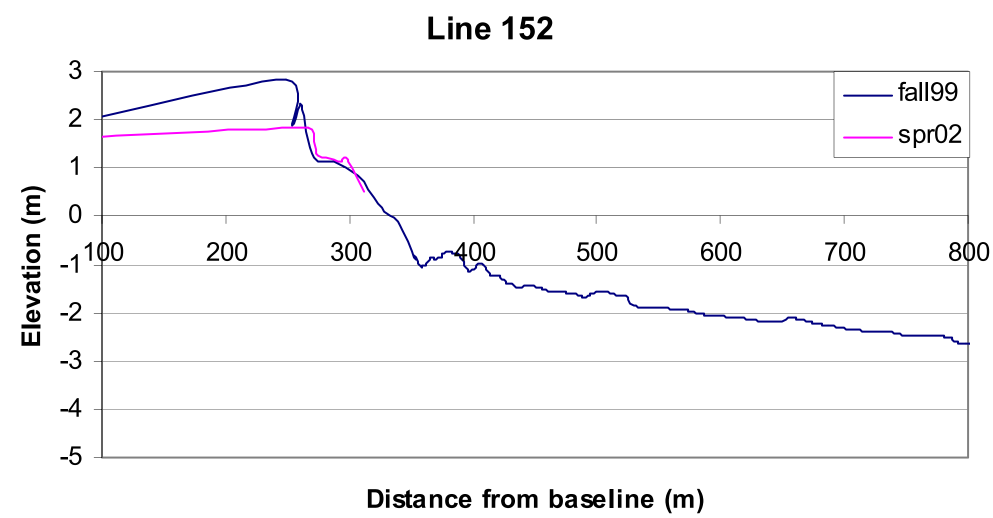

Line 142
fall99
fall02
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

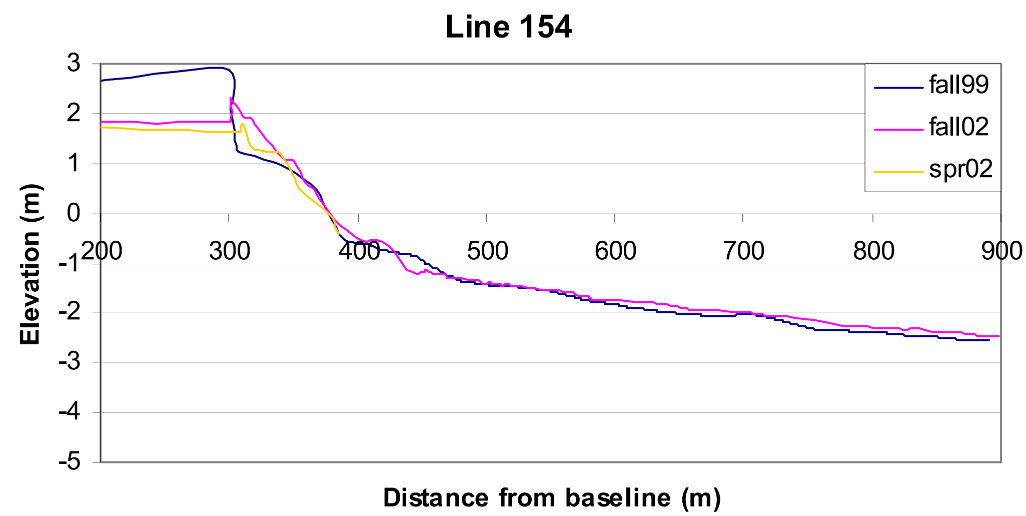

Line 144
fall99
spr02
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700

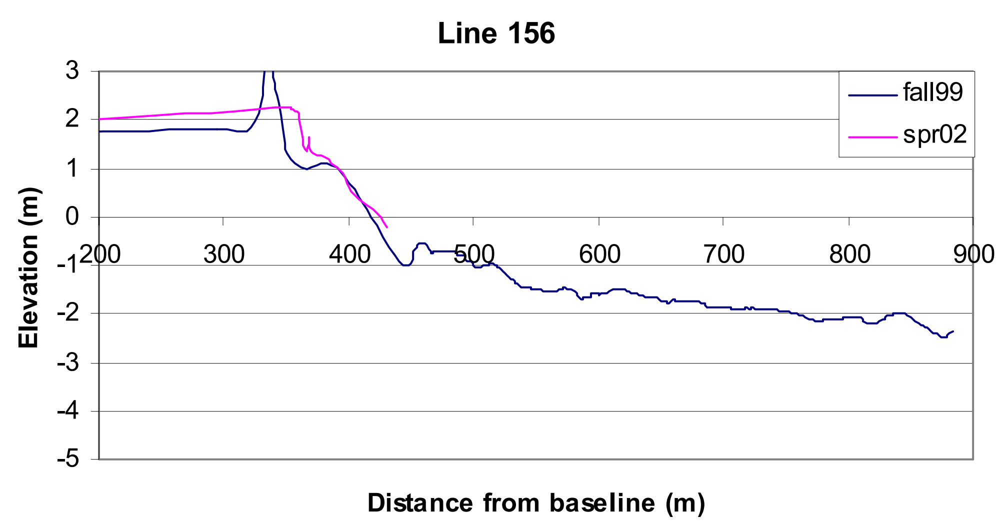

Line 146
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
100
200
300
400
500
600
700
800


Line 148
Elevation (m)
Distance from baseline (m)
fall99
spr02
3
2
1
0
-1
-2
-3
-4
-5
100
200
300
400
500
600
700
800


Line 150
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02
3
2
1
0
-1
-2
-3
-4
-5
100
200
300
400
500
600
700
800

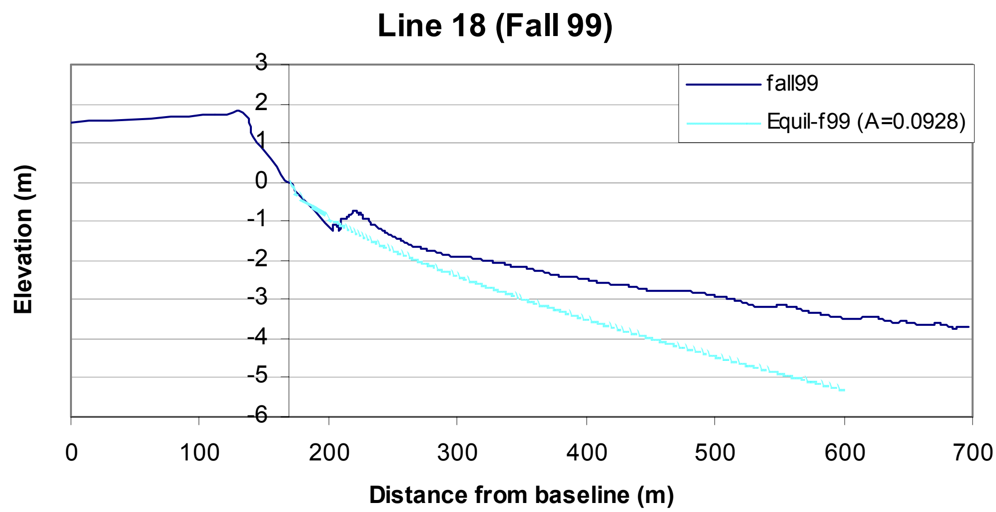

Line 152
3
2
1
0
-1
-2
-3
-4
-5
100
200
300
400
500
600
700
800
Elevation (m)
Distance from baseline (m)
fall99
spr02


Line 154
3
2
1
0
-1
-2
-3
-4
-5
200
300
400
500
600
700
800
900
Elevation (m)
Distance from baseline (m)
fall99
fall02
spr02

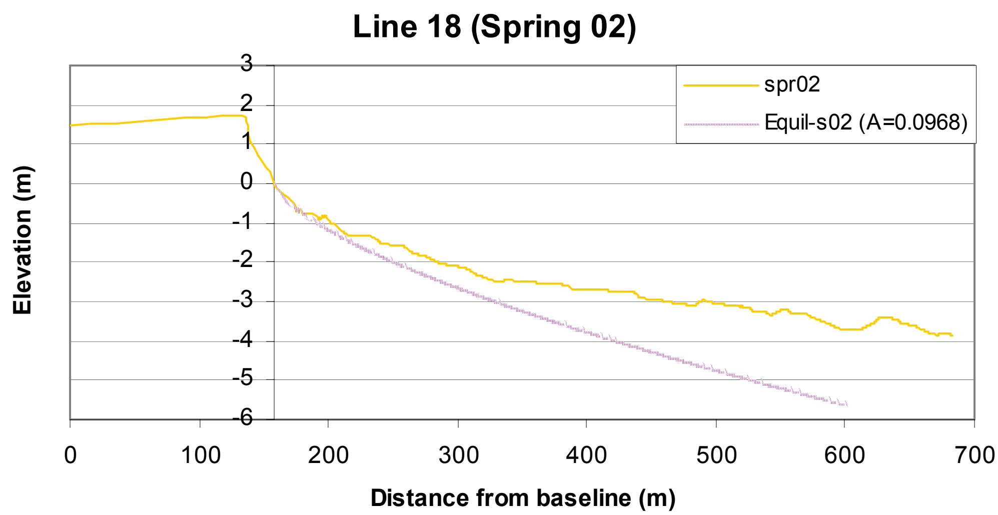

Line 156
3
2
1
0
-1
-2
-3
-4
-5
200
300
400
500
600
700
800
900
Elevation (m)
Distance from baseline (m)
fall99
spr02

APPENDIX C

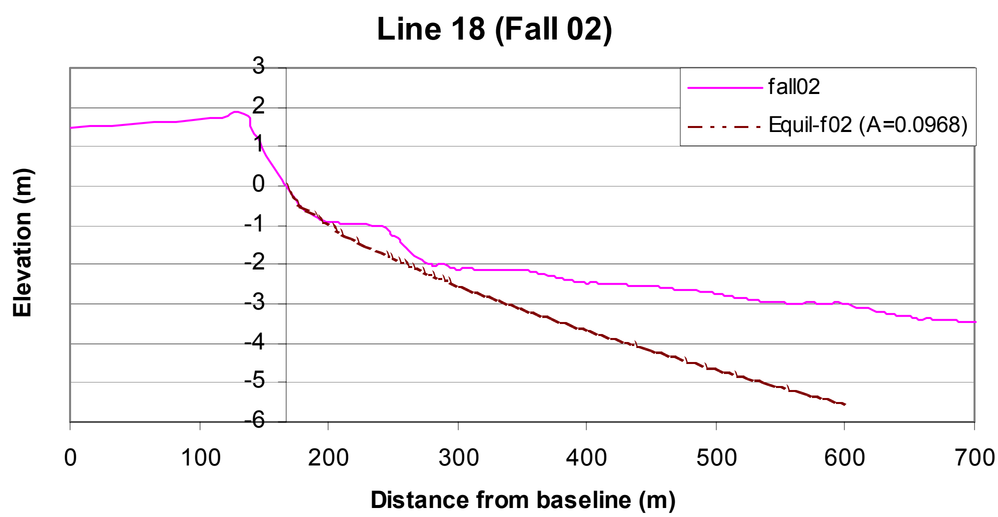
EQUILIBRIUM PROFILES



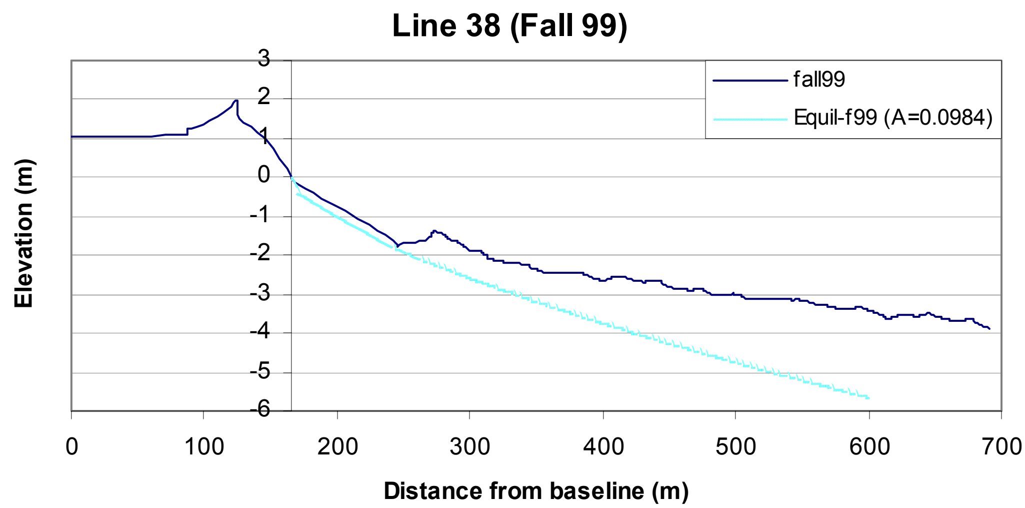
Line 18 (Fall 99)
fall99
Equil-f99 (A=0.0928)
Elevation (m)
Distance from baseline (m)

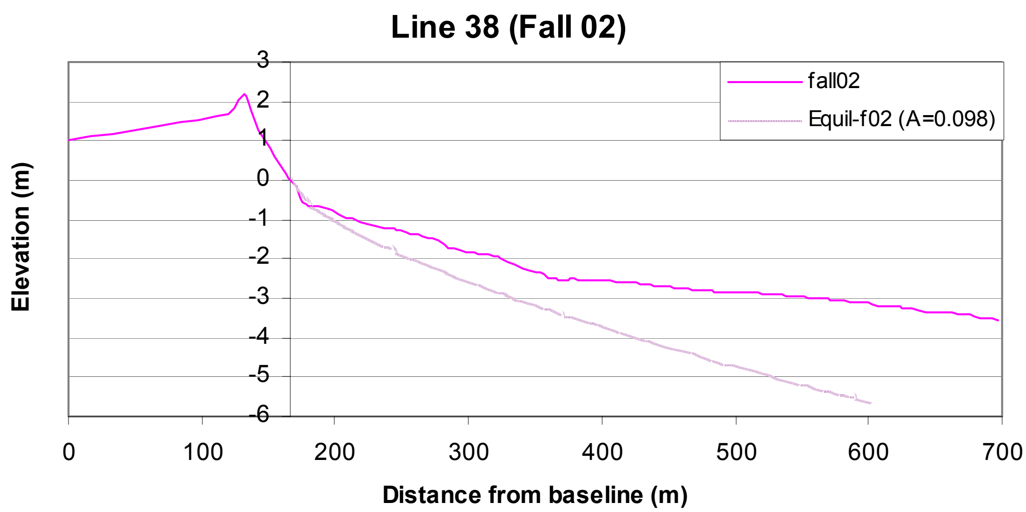


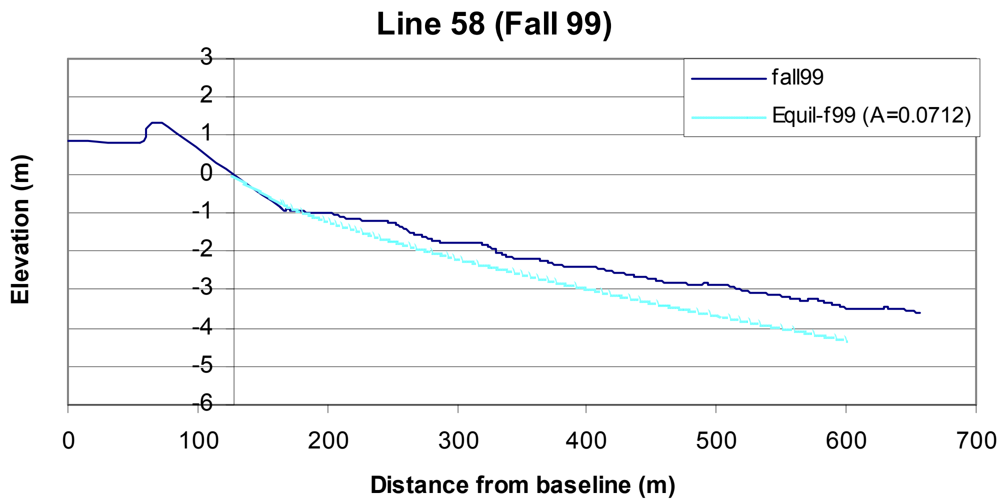
Line 18 (Spring 02)
spr02
Equil-s02 (A=0.0968)
Elevation (m)
Distance from baseline (m)

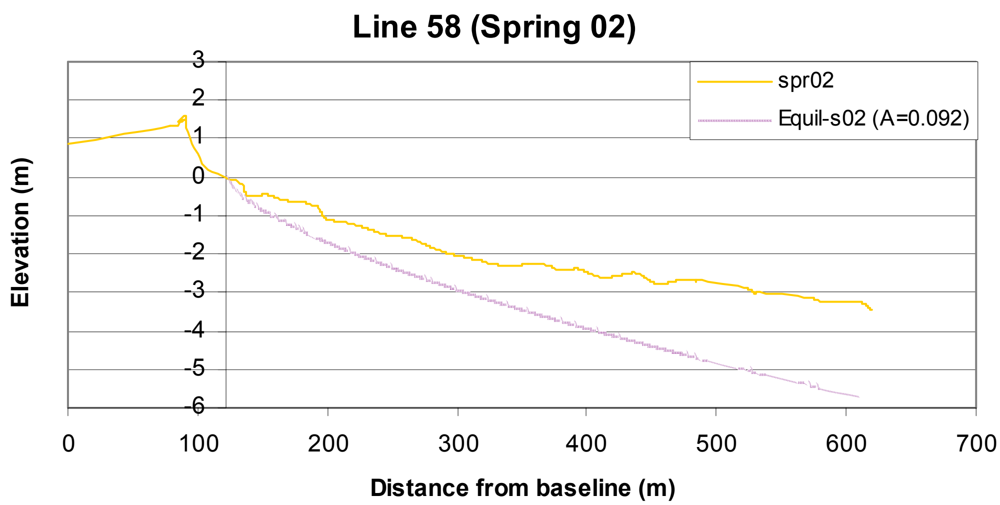


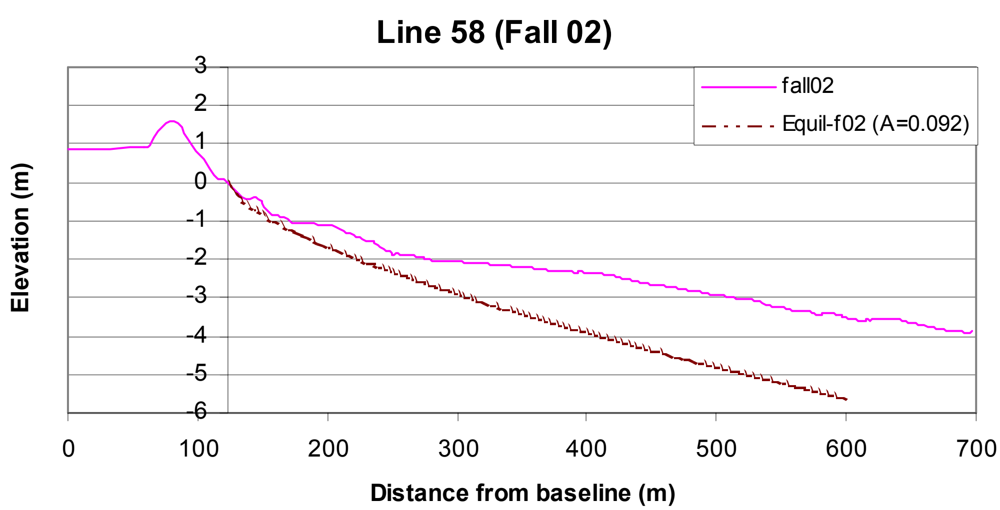
Line 18 (Fall 02)
fall02
Equil-f02 (A=0.0968)
Elevation (m)
Distance from baseline (m)

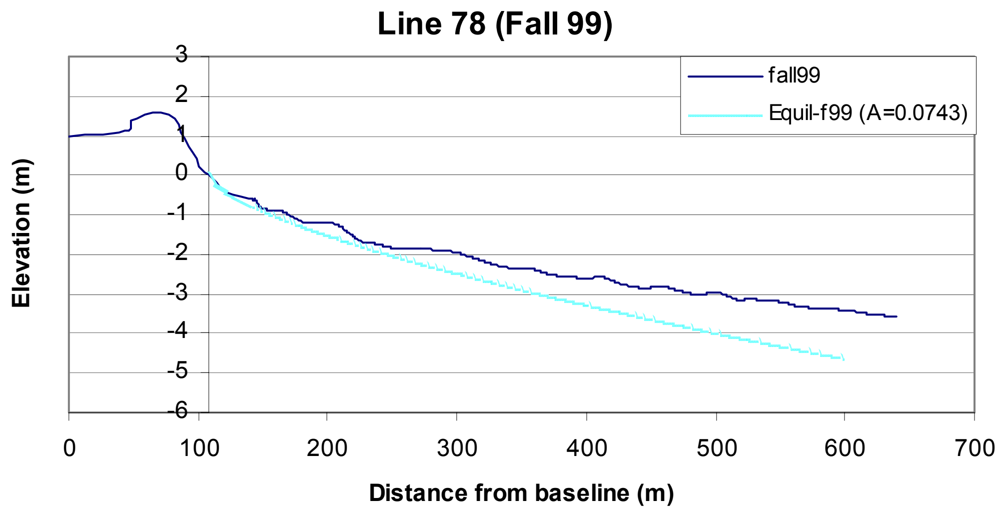

Line 38 (Fall 99)
fall99
Equil-f99 (A=0.0984)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

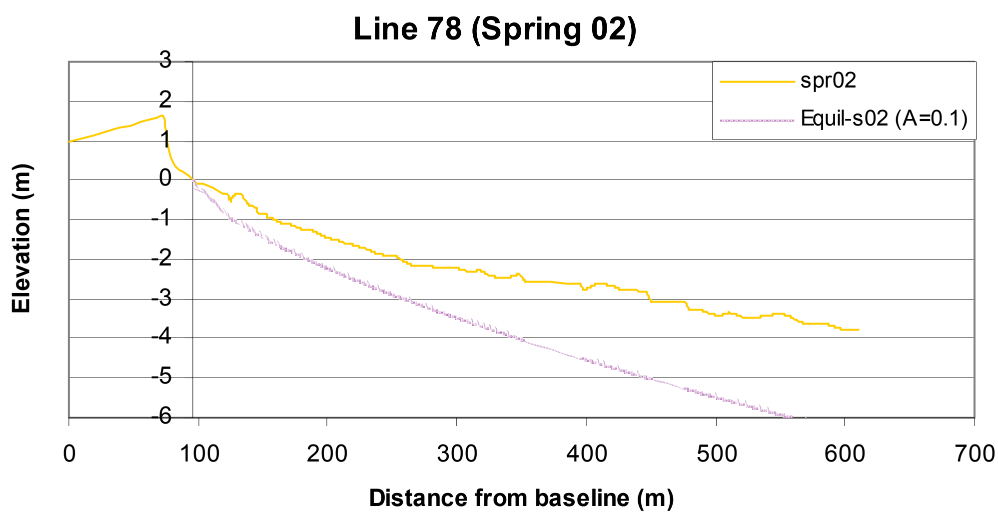

Line 38 (Fall 02)
fall02
Equil-f02 (A=0.098)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

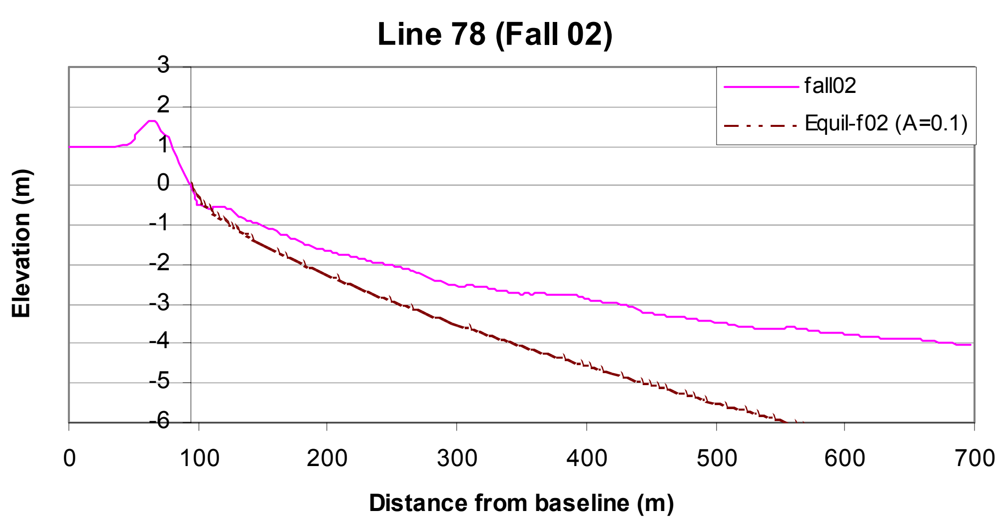

Line 58 (Fall 99)
fall99
Equil-f99 (A=0.0712)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

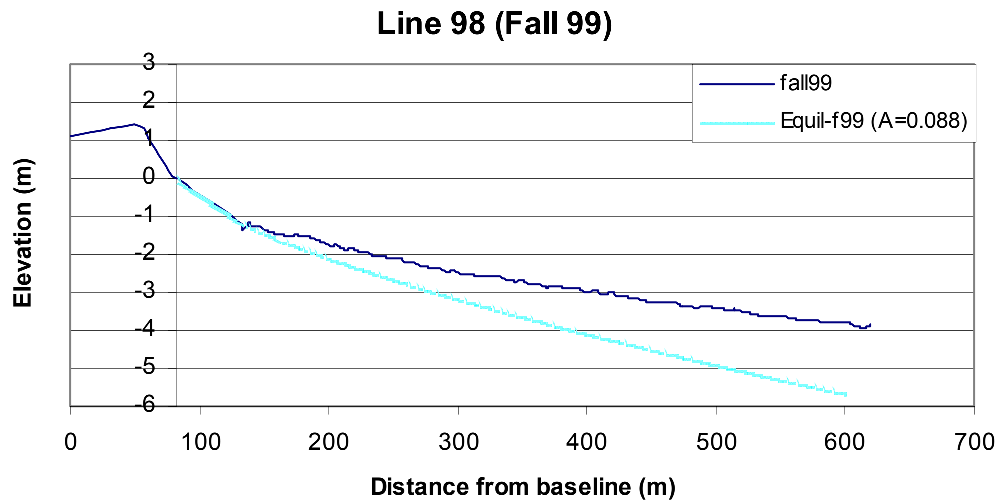

Line 58 (Spring 02)
spr02
Equil-s02 (A=0.092)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

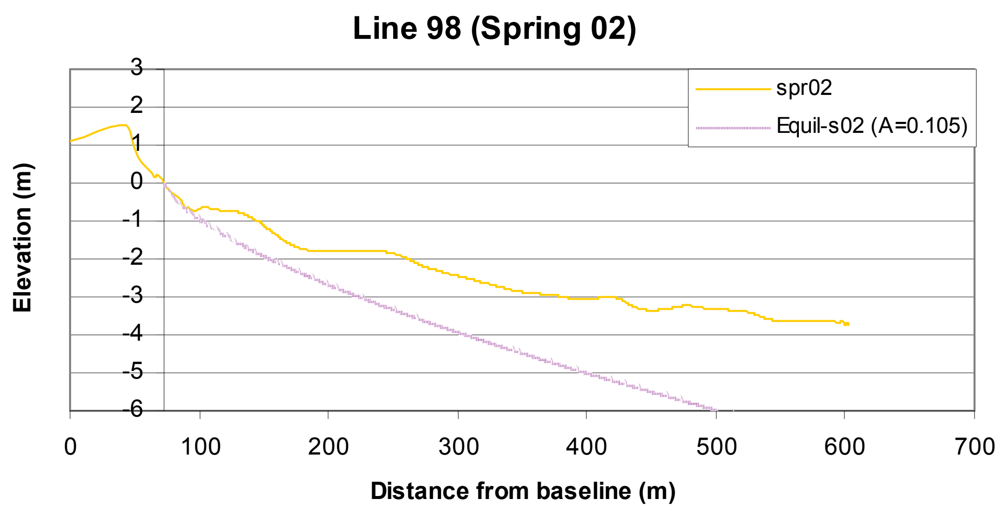

Line 58 (Fall 02)
fall02
Equil-f02 (A=0.092)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

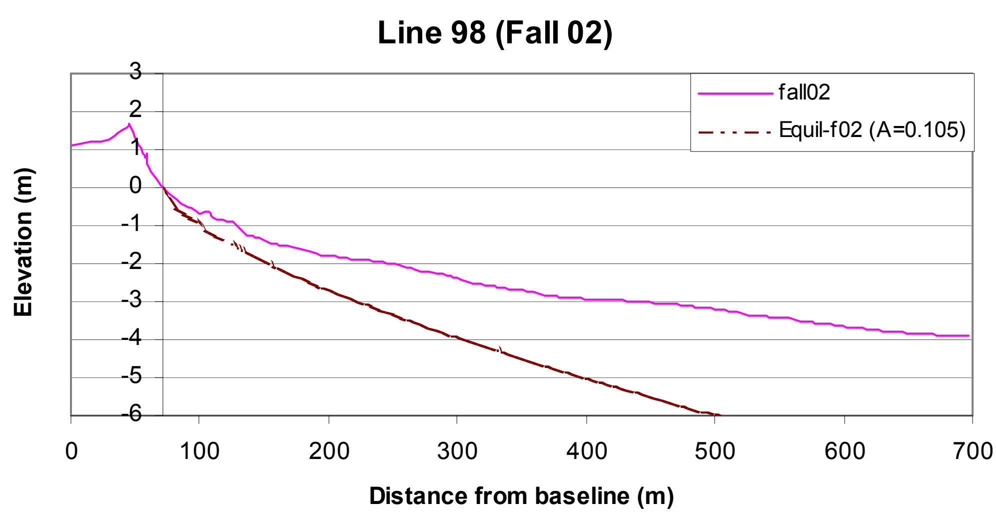

Line 78 (Fall 99)
fall99
Equil-f99 (A=0.0743)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

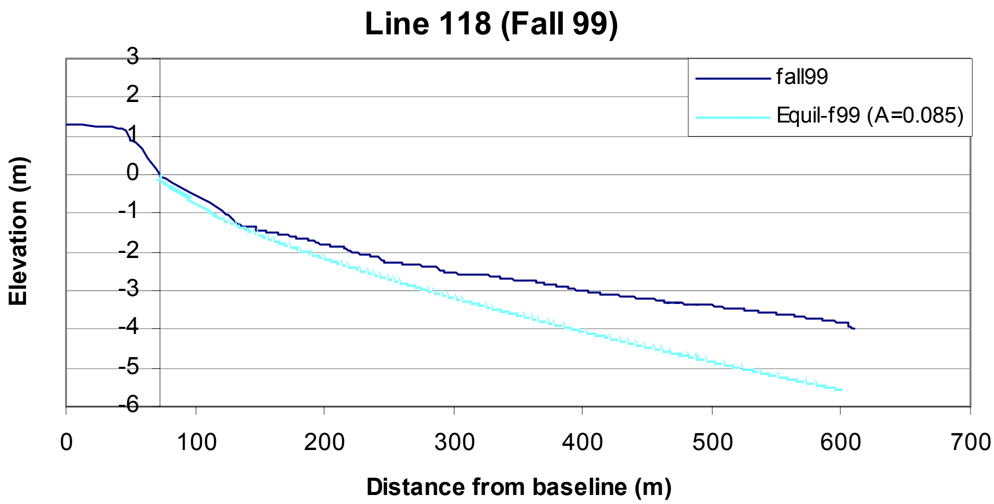

Line 78 (Spring 02)
spr02
Equil-s02 (A=0.1)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700


Line 78 (Fall 02)
fall02
Equil-f02 (A=0.1)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

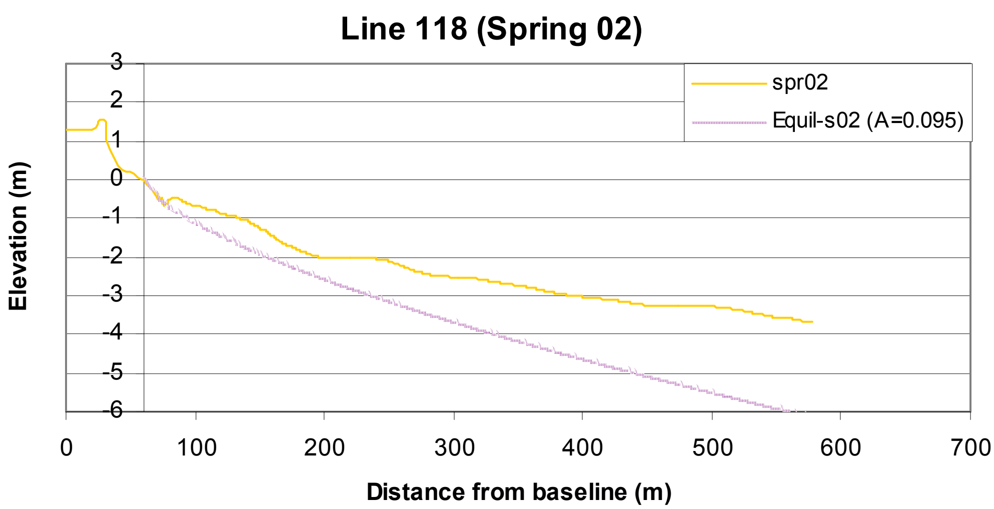

Line 98 (Fall 99)
fall99
Equil-f99 (A=0.088)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700


Line 98 (Spring 02)
spr02
Equil-s02 (A=0.105)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

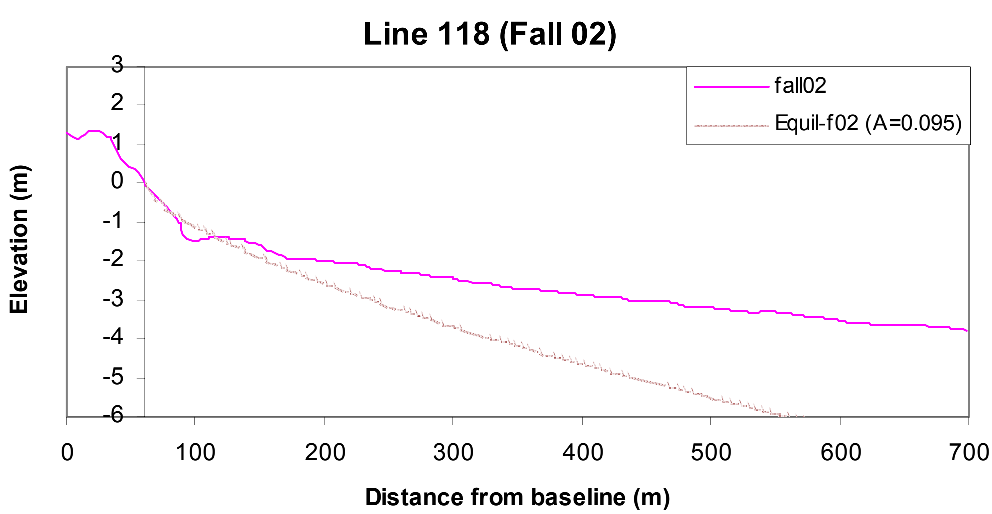

Line 98 (Fall 02)
fall02
Equil-f02 (A=0.105)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700



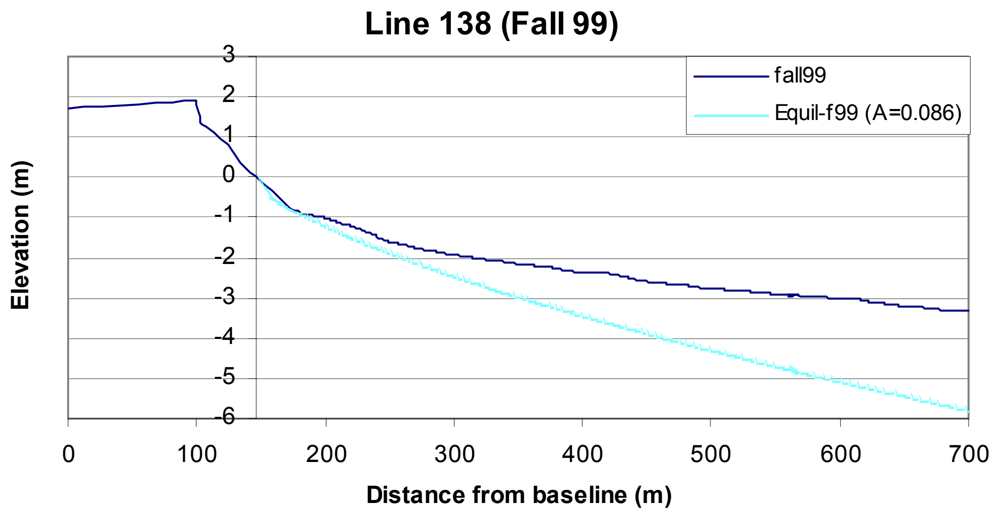
Line 118 (Fall 99)
fall99
Equil-f99 (A=0.085)
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700
Distance from baseline (m)

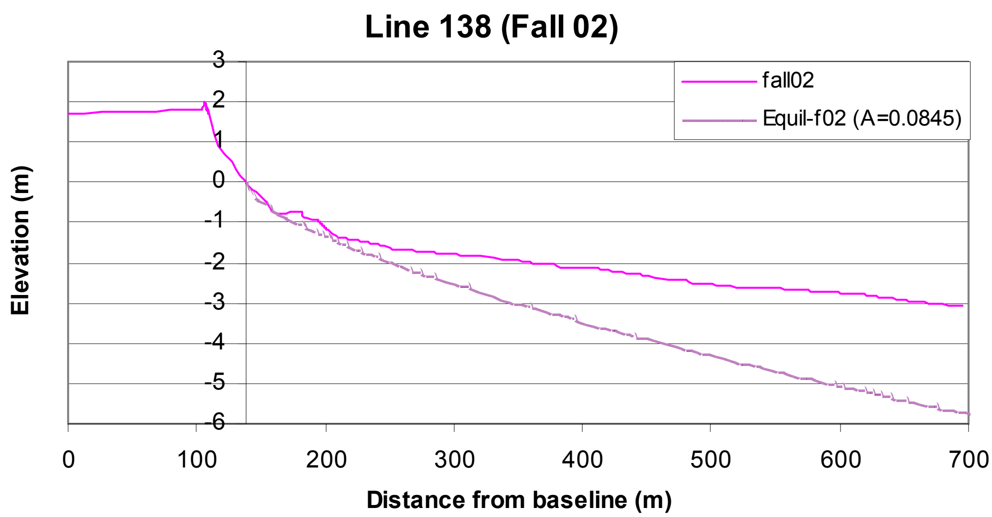


Line 118 (Spring 02)
spr02
Equil-s02 (A=0.095)
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700
Distance from baseline (m)



Line 118 (Fall 02)
fall02
Equil-f02 (A=0.095)
Elevation (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700
Distance from baseline (m)


Line 138 (Fall 99)
fall99
Equil-f99 (A=0.086)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700


Line 138 (Fall 02)
fall02
Equil-f02 (A=0.0845)
Elevation (m)
Distance from baseline (m)
3
2
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700

VITA

Hoo Il Lee was born September 10, 1973, in Seochon, South Korea. He received his Bachelor of Technology degree in naval architecture from Hongik University in 1999. After graduating Hongik University, he came to Texas A&M University in the fall of 2001. His professional interests include coastal engineering and beach nourishment. He can be reached at email address konanlee21@hanmail.net. His permanent address is given below.

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