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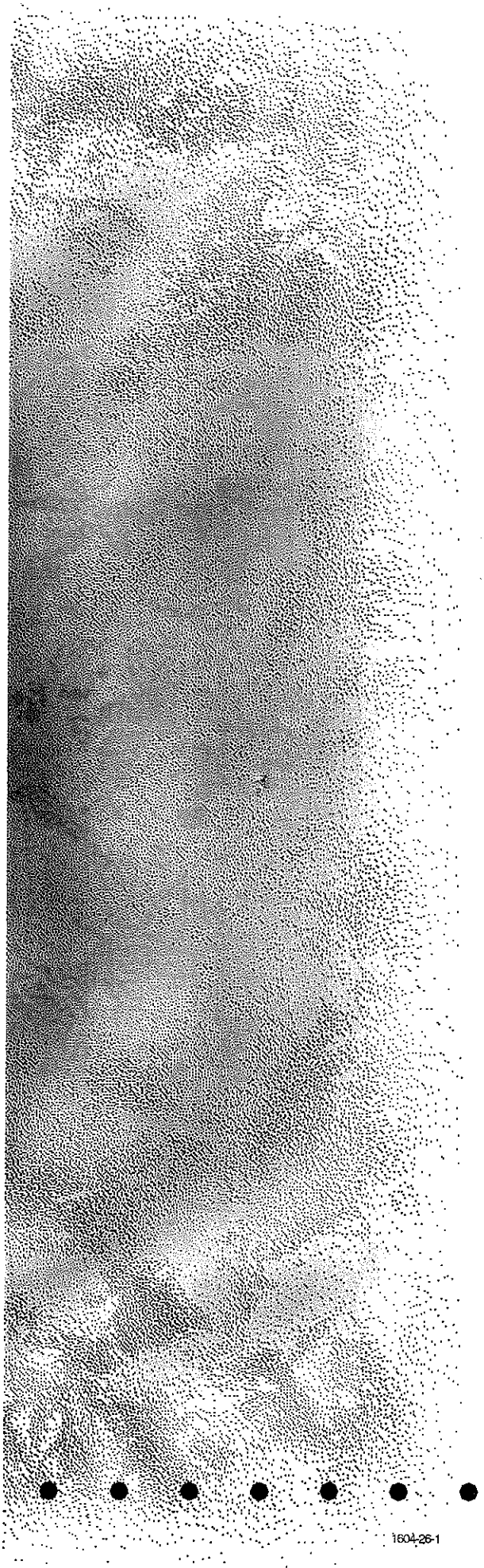
Ministry of Transportation and Highways

KHYEX-TYEE: 1999

Fish Habitat Works

November 15, 1999

Environmental Management Section
Engineering Branch
Ministry of Transportation and Highways
4B-940 Blanshard Street
PO Box 9850, STN PROV GOVT
Victoria, British Columbia V8W 9T5



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	Khyex – Tyee: 1999 Fish Habitat Works
Author:	Eric R. White, RPBio
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Prepared for:	Environmental Management Section Engineering Branch B.C. Ministry of Transportation and Highways Victoria, B.C. Canada
Contact Person:	Environmental Issues Analyst Environmental Services Section Engineering Branch B.C. Ministry of Transportation and Highways 4B - 940 Blanshard Street PO Box 9850 STN PROV GOVT Victoria, B.C. Canada V8W 3E6 Phone: (250) 387-1264
Abstract:	In late 1988, the Ministry undertook fish habitat works at three sites on the Skeena River to compensate for riparian vegetation losses which resulted from the re-construction of Highway 16 east of Prince Rupert. The three sites were protected by rock spurs. At one site, the existing foreshore was elevated and planted with donor vegetation from unimpacted nearby marshes. After completion, natural deposition, induced by the rock spurs, caused further vegetated losses. Since 1994, there has been an increase in vegetated habitat in all three sites. This is attributed to the sites reaching a more stable state in the fluvial environment and a subsequent increase in natural recolonization at the sites. The project is expected to reach a "No Net Loss" state through foreshore vegetation in 2003 and to ultimately return more vegetative habitat than was lost.
Comments:	The productivity of the vegetation on the compensation sites is equal to, or better than, that of the donor marsh area. This is irrespective of whether the vegetation resulted from 1989 transplants, 1990 transplants or natural regeneration.
Keywords:	Khyex Bridge, Tyee Bank, Skeena River, No Net Loss, fish compensation, fish habitat works, Highway 16, British Columbia, Ministry of Transportation and Highways

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Prepared for:

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4B - 940 Blanshard Street
PO Box 9850, STN PROV GOVT
Victoria, B.C.
V8W 9T5

Prepared by:

Eric R. White, RPBio
3093 Heddle Road
RR 1; S 11; C 10
Nelson, British Columbia
Canada
V1L 5P4

Telephone & FAX (250) 825 4392
E-Mail: ewhite@netidea.com

November 15, 1999

Executive Summary

The fish habitat compensation works assessed in this report were undertaken because of impacts to fish habitat from the re-construction of Highway 16 east of Prince Rupert.

This project incurred foreshore vegetation losses of 20 900 m^2 as a result of construction. The lost vegetation was largely sedge meadows dominated by *Carex lyngbyeii*.

There were subsequent further losses of inter-tidal vegetation through 1994 due to sediment deposition within the compensation works and the resultant poor survival of overwintering shoots. This sediment deposition was an anticipated result of the compensation works.

The ratio of vegetated area within the project area now to that of 1987 is 0.59 - i.e. the project is still in a "Net Loss" status with an deficit in vegetated area of 15 399 m^2.

"No Net Loss" analysis of the time after construction indicates that the vegetation in the project area recovered from post-construction losses in 1996. In other words, it took 7 years for the inter-tidal vegetation to recover from impacts due to the compensation works; over and above the direct impacts of highway construction.

Data collected to date suggest that the project will reach "No Net Loss" status *vis-a-vis* inter-tidal vegetation in 2003 - 15 years after the initial vegetation losses were incurred.

There are numerous new plant colonies throughout the East Marsh, Compensation Site and Donor Marsh areas, and to a lesser extent in the Boat Ramp area. The expansion of inter-tidal vegetation colonies, and establishment of new inter-tidal plant colonies, which has been observed to date is expected to continue.

The overall annual rates of expansion of vegetated area within the 5 sub-areas within the project between 1996 and 1999 varies from 0.99 to 1.73. The rates of expansion of individual plant colonies within the Compensation Site and the East Marsh varies between 0.64 and 1.98 during that time.

There may be some loss of existing vegetation in the Donor Marsh area due to the encroachment of accreting mud flat into the marsh there. This is expected to be offset by increases in vegetation on the mudflats themselves.

The establishment of new vegetation on the east part of the West Marsh site appears to be limited by the instability of the substrate surface there.

Vegetative productivity of the vegetation on the Compensation Site is equal to, or better than, that of the Donor Marsh area - irrespective of whether the vegetation resulted from 1989 transplants, 1990 transplants or natural regeneration.

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Fish Habitat Works

Introduction

This report presents an assessment of the state of the fish habitat compensation works built on the foreshore of the Skeena River as part of the Highway 16 re-construction between Khyex bridge and Tyee Bank.

There was an assessment of the compensation works done in 1996, which found that the project had not reached a "No-Net-Loss" status with respect to inter-tidal vegetated area - i.e. there was less vegetation within the project area in 1996 than before the project was completed in 1988. The 1996 assessment projected that "No-Net-Loss" would be achieved by 1999 and the 1999 assessment was commissioned to document whether or not that had, in fact, been achieved.

The status of the works was documented in 1996 in:

White, E.R. 1997. *Khyex - Tyee: Fish Habitat Works.* Unpublished report to the Ministry of Transportation and Highways, Victoria, B.C. 19 pages with Appendices, and

White, E.R. 1997. *Khyex - Tyee: Photographic Record of Fish Habitat Works.* Unpublished report to the Ministry of Transportation and Highways, Victoria, B.C. 84 pages.

Other documents germane to the project are:

The "as-built" foreshore impacts and compensation works are documented in *Khyex-Tyee: Foreshore Habitat Re-construction Works* (White, 1990a). Subsequent assessments are documented by letter (White, 1990b; White, 1991) and in *Khyex-Tyee: 1994: Fish Habitat Compensation and Mitigation Works* (White, 1994).

This report presents information and discussion about the project's impacts to fish habitat to date, an evaluation of whether or not "No Net Loss" has been achieved at this time, and makes projections about the future potential of the compensation works.

It does not re-iterate in detail the background information and site history presented in the aforementioned documents and the reader is referred to them if he/she requires more detailed information.

Project Summary

The foreshore compensation works were built in late 1988 (**Figure 1**). Foreshore vegetation was transplanted onto the constructed works in spring of 1989 and 1990. These efforts were confined to the high ground within the compensation site, and limited in scope, because the site was expected to take several years to stabilize and that any transplanted vegetation would be at risk until the site stabilized.

This proved to be the case. After construction, sediment accretion caused further losses of foreshore vegetation - which were not directly impacted by the highway re-construction - such that all the undisturbed vegetation along the toe-of-fill disappeared by 1991. Less than half of the transplanted vegetation was surviving by 1994. These losses were attributed to burial under accreting sediment.

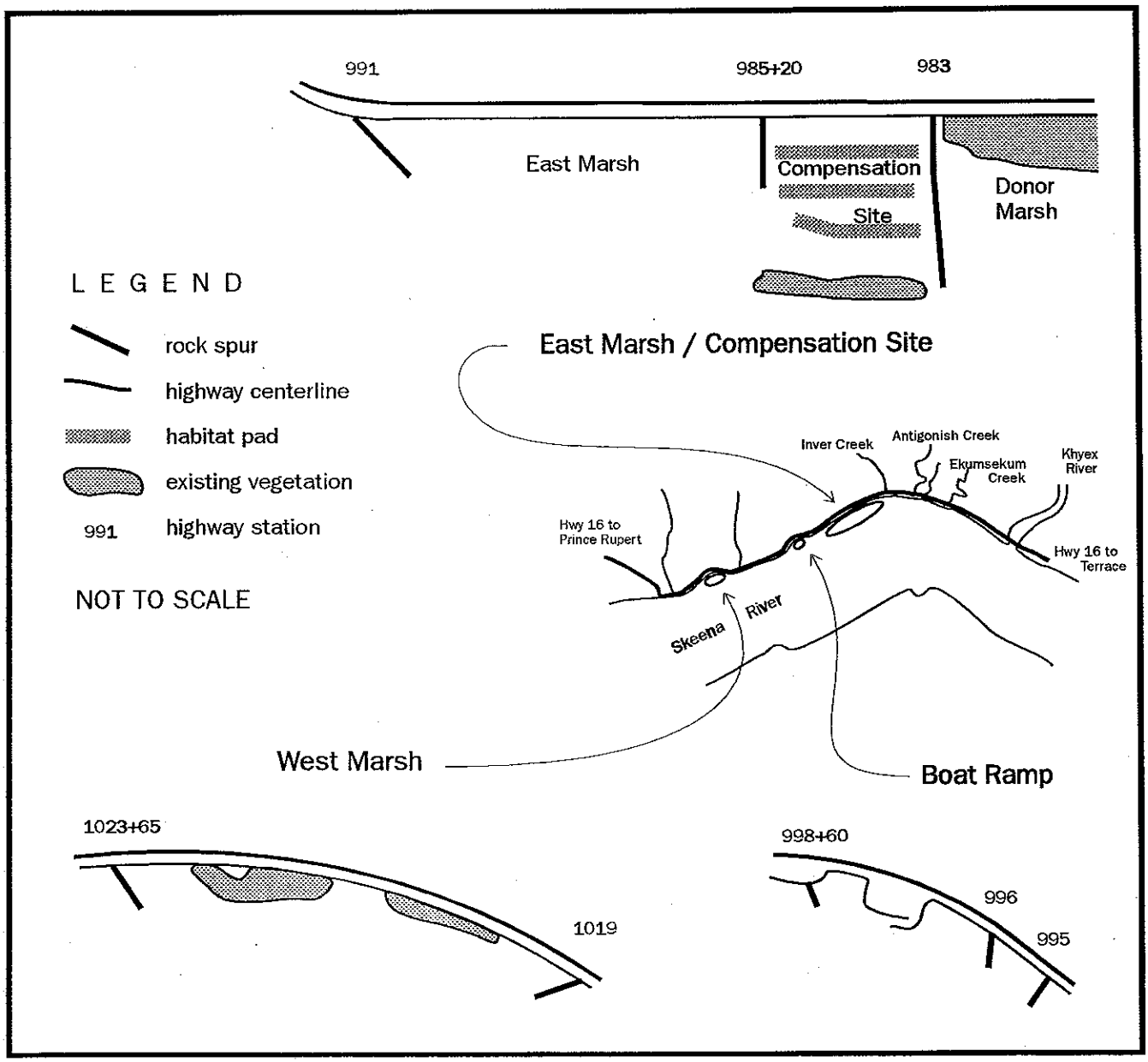


Figure 1: Habitat compensation works on the Skeena river built for this project.

The substrate surface within the Compensation Site and the East Marsh areas rose dramatically during 1989 through 1994 (see the cross sections in **Appendix I**). The rate of increase slowed between 1991 and 1994, and new vegetation colonies were observed on the mud flats during the 1994 assessment (See Photographic Record of Fish Habitat Works (White, 1997). The number of colonies found on the site increased between the 1994 and 1996 assessments. The rate of increase in vegetated area for specific plant colonies in the compensation site varied from 2 times annually to up to 4 or 5 times annually between 1994 and 1996.

Methods

Field work for this assessment was done between July 26 - 31, 1999. A Ministry of Highways and Transportation survey crew and the author measured surface elevations within the inter-tidal areas of the foreshore works, surface elevations of the rock spurs, and inter-tidal vegetated area with a "total station". Data reduction was done by Ministry of Highways and Transportation personnel in Terrace and cross-section elevations were computed from the reduced data.

Digital maps from 1991, 1994, 1996 and 1999 were used to assess changes in area (in m^2) of specific plant colonies. This data was used to calculate rates of change in vegetated area for these colonies. Areas of plant colonies in 1994 and 1996 are derived digitally by the terrain modelling software; in 1991 these areas were derived by planimeter. The estimates of the amount of area onto which inter-tidal vegetation can expand were made using hand measurements from the digital maps.

Biological evaluation was done concurrently with the survey work and consisted of assessing plant growth at different locations within the study site, making field observations and taking photographs at all sites.

Plant growth was assessed both within the Compensation Site and the Donor Marsh. A stratified random sampling scheme was used. Growth data consisted of stem density (stem counts within a 625 cm^2 quadrat) and shoot length (5 randomly chosen shoots from within the quadrat were measured to $\pm$ 1 cm).

Within the Compensation Site, plant growth was assessed for plant colonies which originated from 1989 and 1990 transplant operations, for naturally established plant colonies and for the vegetated island which forms the offshore limit of the Compensation Site. Within the Donor Marsh, plant growth was assessed in the area where the 1989 and 1990 source material was taken and on the banks of a small creek there, an area where the sedge grows vigorously. The samples were taken from the same areas as in previous assessments so that long term trends could be addressed.

Foreshore locations are referred to by name or by station number in this report. Station numbers are the distance in metres of the station from the start of the highway reconstruction work near the Khyex River.

Foreshore Assessment

There were two phases of loss of inter-tidal vegetated area. There was an immediate result of the re-construction of the highway - the marshes were buried under fill. This was followed by a period of sediment accumulation within the shelter of the rock spurs which buried some of the marsh which was not affected by the highway construction directly.

These two facets of the project's impact are discussed separately below, as well as discussions about the future potential of the site and the inter-tidal plant growth on site.

Inter-tidal Vegetated Area - "No Net Loss" Status

The vegetated areas found on the 5 sub-areas within the project area are given in **Table 1**. The immediate impact of the highway construction project was a loss of 20 900 m^2 of foreshore vegetation (**Table 1**).

Table 1: Area covered by foreshore vegetation (in m^2) from 1987 to 1999.

	1987	1989	1991	1994	1996	1999
Donor Marsh	7 458	4 878	5 186	5 094	4 978	5 893
Compensation Site	8 717*	5 357	5 169	4 139	5 322	10 101
East Marsh	10 367	1 440	837	743	853	1 920
Boat Ramp Marsh	570				9	47
West Marsh	10 652	5 189	3 432	3 772	4 416	4 404
Total	37 764	16 864	14 631	13 733	15 577	22 365
Deficit		-20 900	-23 133	-24 031	-22 187	-15 399
"No Net Loss" status		0.44	0.39	0.36	0.41	0.59

* the offshore vegetation was not surveyed prior to construction - this figure includes the area of the offshore vegetation as measured in 1989. It is used as a "before" assessment because it is reasonable that there would not have been any significant changes here between the time when the works were done (September 1988) and the time of the survey (July, 1989).

The project has yet to reach a "No Net Loss" situation with respect to foreshore vegetation - the ratio of vegetated area on site prior to construction to vegetated area in 1999 is 0.59. In other words, there is 60% of the vegetation on site now relative to prior to construction and there is still an outstanding loss of 15 399 m^2 of riparian vegetation.

Post-Construction Vegetation Losses

There were further losses of vegetation after construction (**Table 2**). Clearly, the compensation works incurred further impacts to the inter-tidal vegetation in and of themselves. These post-construction losses were incurred in the marsh adjacent to the highway shoulder which had not been directly impacted by the construction.

Table 2: Changes in area of inter-tidal vegetation (in m^2) from 1987 to 1999.

	Direct Construction Impact	Post-construction Impacts			
		89-91	89-94	89-96	89-99
Donor Marsh	-2 580	+308	+216	+100	+1 015
Compensation Site	-3 360	-188	-1 218	-35	+4 744
East Marsh	-8 927	-603	-697	-587	+480
Boat Ramp Marsh	-570			+9	+47
West Marsh	-5 463	-1 757	-1 417	-773	-785
Total	-20 900	-2 240	-3 116	-1 287	+5 501

Consider the "No Net Loss" status of the sub-areas with respect to the impacts of the compensation works separate from the impacts of construction:

- the Donor marsh has been in a "Net Gain" situation since construction,

- the Compensation Site and the East Marsh changed from "Net Loss" to "Net Gain" in 1996,
- the Boat Ramp and West Marsh sites are still showing a "Net Loss" of inter-tidal vegetation - 11 years after the initial impacts were incurred, and
- the vegetated area at the West Marsh site has not changed significantly since 1996, and that area is almost 800 m^2 less than what was there immediately after construction. In other words, the West Marsh area has not recovered from the impacts of the compensation efforts at this time and it may not in the future, if present trends continue.

The project area as a whole moved to "Net Gain" with respect to the compensation works in 1996 - in other words, it took 7 years for the project area to recover from the impacts of the compensation works. Therefore, compensation for impacts from the highway re-construction could only begin to accumulate after that.

Future Potential

There is reason to be optimistic for the future. **Table 3** presents an estimate of the area available which is suitable for inter-tidal plant growth, the overall rate of expansion of the vegetated area within each area and the future vegetated areas based on that rate of expansion. This indicates that "No Net Loss" status for the project should be achieved in 2003, if the current trends continue.

Table 3: Future vegetated areas in the project area.

	total available habitat (m^2, est)	1996 - 99 rate of exp	2000 (m^2)	2001 (m^2)	2002 (m^2)	2003 (m^2)
Donor Marsh	28 000	1.06	6 235	6 596	6 977	7 381
Compensation Site	44 000	1.24	12 507	15 484	19 173	23 738
East Marsh	60 000	1.31	2 516	3 298	4 322	5 665
Boat Ramp Site	2 000	1.73	81	140	242	417
West Marsh Site	6 700	0.99	4 400	4 396	4 392	4 388
totals	140 700		25 739	29 915	35 107	41 591
"No Net Loss" status			0.68	0.79	0.93	1.1

The project should ultimately return a substantial net gain of habitat, if present trends continue. Most of the gain in vegetation area will be within the compensation site and the east marsh areas. There should also be an increase in the vegetated area at the Boat Ramp site, but that site is relatively small.

The rates of expansion of individual plant colonies in the period 1996 through 1999 all fall within the range of 1.39 to 1.98 - with one rate of contraction of 0.64 - whereas the 1994 - 1996 rates varied between 1.2 and 6.3, with half of those above 2 (**Table 4, Figure 2**). It seems, therefore, that the rate of expansion has "settled" down and has become much more consistent.

Table 4: Changes in area for plant colonies in the East Marsh and Compensation Site.

	Area (m^2)				Annual Rate of Expansion	
	1991	1994	1996	1999	1994-96	1996-99
Compensation Site:						
1989 Transplants	127	9	139	48.1	1.24	1.51
	101	8	14.2*	69.7	1.37	1.70
			0.9			
1990 Transplants	45	11.5	84.2	308.4	2.79	1.54
			5.2			
	2	13	21.1	333.3	1.44	1.89
	2	8	21.5			
		3	6.8			
			.3			
	45	33	130	363.1	1.39	1.39
	75	37				
			2.6			
			1.8			
natural colonies	2	17.7	65.9	234.6	1.55	1.44
		9.6				
		5.3	12			
	2	13.1	59.7	263.7	1.83	1.47
		4				
	2	7.7	23.6			
West of the Compensation Site:	5	7.1	12.2	3.1	1.31	0.64
		0.7	3.7	11.4	2.30	1.46
		0.7	12.7	78.4	4.26	1.83
		0.4	14.9	150.8	6.28	1.85
		0.2	8.8			
		0.4	9.4	55.4	4.84	1.81
		0.9	4.1	31.9	2.13	1.98

Note: Plant colonies are grouped according to the vegetated area in the latest survey. For example, this colony covered 69.7 m^2 in 1999. In 1996, there were two colonies within the area of the 1999 colony whereas in 1994 there was one colony in that place.

At the time of writing of the 1996 report, it appeared that the site would achieve "No Net Loss" status by 1999. This projection was based on the calculated rate of expansion of plant colonies on the accreted mud flats, both within the compensation site and west of it. There were some very high rates of expansion calculated for plant colonies in the east marsh area which led to the prediction that "No Net Loss" status would be achieved by 1999, which has proved to be wrong.

The rates of expansion were large primarily because the 1994 plant colony was very small. The rate if expansion is based on the ratio of the area in 1996 divided by the area in 1994. If the 1994 area is very small then the ratio will be relatively large even if the 1996 area is relatively modest.

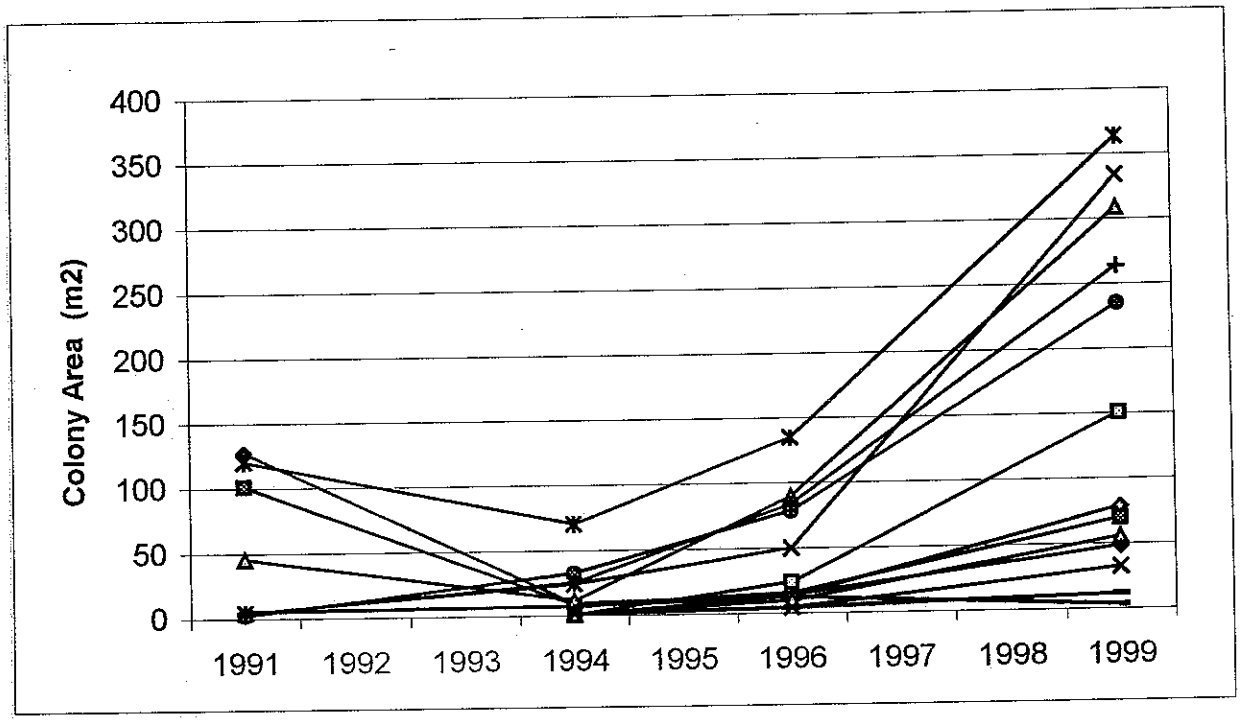


Figure 2: Measured areas of plant colonies in the Compensation Site area: 1991 to 1999.

In 1994 the source of new plants growing on site seemed to be largely as a result of drifting clumps of vegetation coming to rest on site and growing *in situ*. However in 1994 there were many single shoots scattered throughout the area, which suggests the new vegetation colonies are a result of seed based propagation rather than "drifting clump" propagation. The number of plant colonies within the east marsh, compensation site and donor marsh areas have increased dramatically between 1991 and 1999 (**Figure 3**).

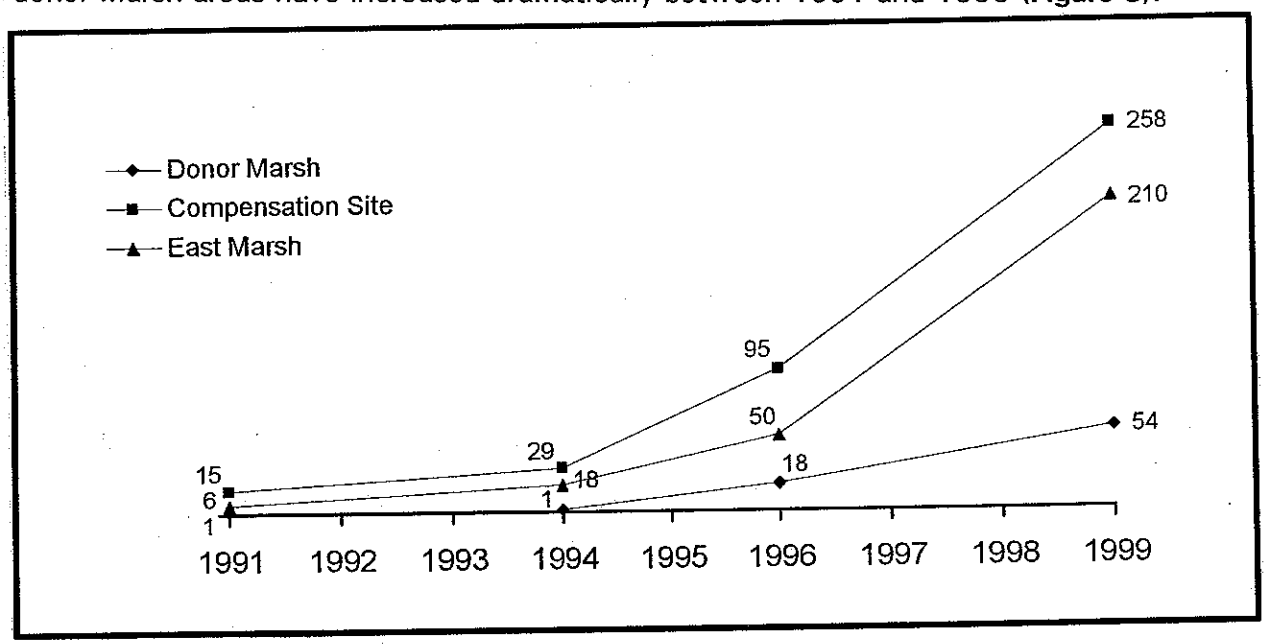


Figure 3: Number of plant colonies: 1991 to 1999.

The increase in vegetated area, and the number of plant colonies, is clearly apparent when comparing the 1996 and 1999 views across the compensation site and across the east marsh. (see photographs in **Appendix II** and in Khyex - Tyee: Photographic Record of Fish Habitat Works (White, 1997)).

A final note: The rock spurs create the fluvial environment which has created the physical environment for the establishing inter-tidal plant colonies. And, their continued existence is critical to the continuation of that environment. There has been little change in the elevation of the rock spurs since 1991 (see centre line elevation graphs in **Appendix III**).

Therefore, it is reasonable to expect that they will remain stable and the fluvial environment will continue relatively unchanged. And, it follows that the observed trends in changes in vegetated area will continue.

Potential for Future Vegetation Losses

There will likely be some vegetation losses in the near shore marsh east of the compensation site.

There is a large accreting mud flat in front of that marsh which is now encroaching into the marsh. There are "holes" in the marsh there which were not there in 1996, which suggests that there will be future vegetation losses in this area. As well, the outer edge of the marsh near the 983 rock spur has retreated about 4.5 metres since 1996. And, the 1999 vegetation map showed that there are sedge clumps offshore of the marsh which coincide with the location of the 1996 marsh edge (**Figure 4**). The elevation change in the donor marsh has been quite small relative to that observed within the compensation site (**Figure 5, Table 5, Appendix I**).

Table 5: Elevation over time at locations where losses of marsh vegetation have been observed.

Station	Location	1989	1990	1991	1994	1996	1999
981+00	64 m offshore	0.54	0.48		0.6	0.75 x	0.87
982+00	44 m offshore	0.53			0.69	0.73 x	0.81
982+60	30 m offshore	1.0	0.74		0.63	0.81	0.95
983+20	toe-of-fill	1.39	1.31	1.22 x	1.77	2.12	2.35
983+40	toe-of-fill	1.01	0.96	0.96 x	1.31	1.54	2.27
984+00	toe-of-fill	0.87	0.87	0.92 x	1.23	1.55	1.78
984+40	toe-of-fill	0.71	0.62	0.6 x	1.03	1.36	1.7
984+80	toe-of-fill	0.32	0.35 x	0.59	0.94	1.36	1.8

Notes: The X between entries in the table indicates that vegetation losses were observed between the two assessments.

The data in **Table 5** indicate that the total elevation change between 1996 and 1999, where the outer edge of the marsh is retreating has been between 8 and 12 cm over three years. If that change occurred smoothly over the three years then that would indicate that accumulations of 3 or 4 cm a year can impact the marsh. However they also indicate that the surface elevation at the outer edge of the marsh has increased by 28 to 33 centimetres at cross sections 981+00 and 982+00 since 1989 with no loss of vegetation. So it seems unlikely that the magnitude of burial, in and of itself, is the cause of the observed impacts.

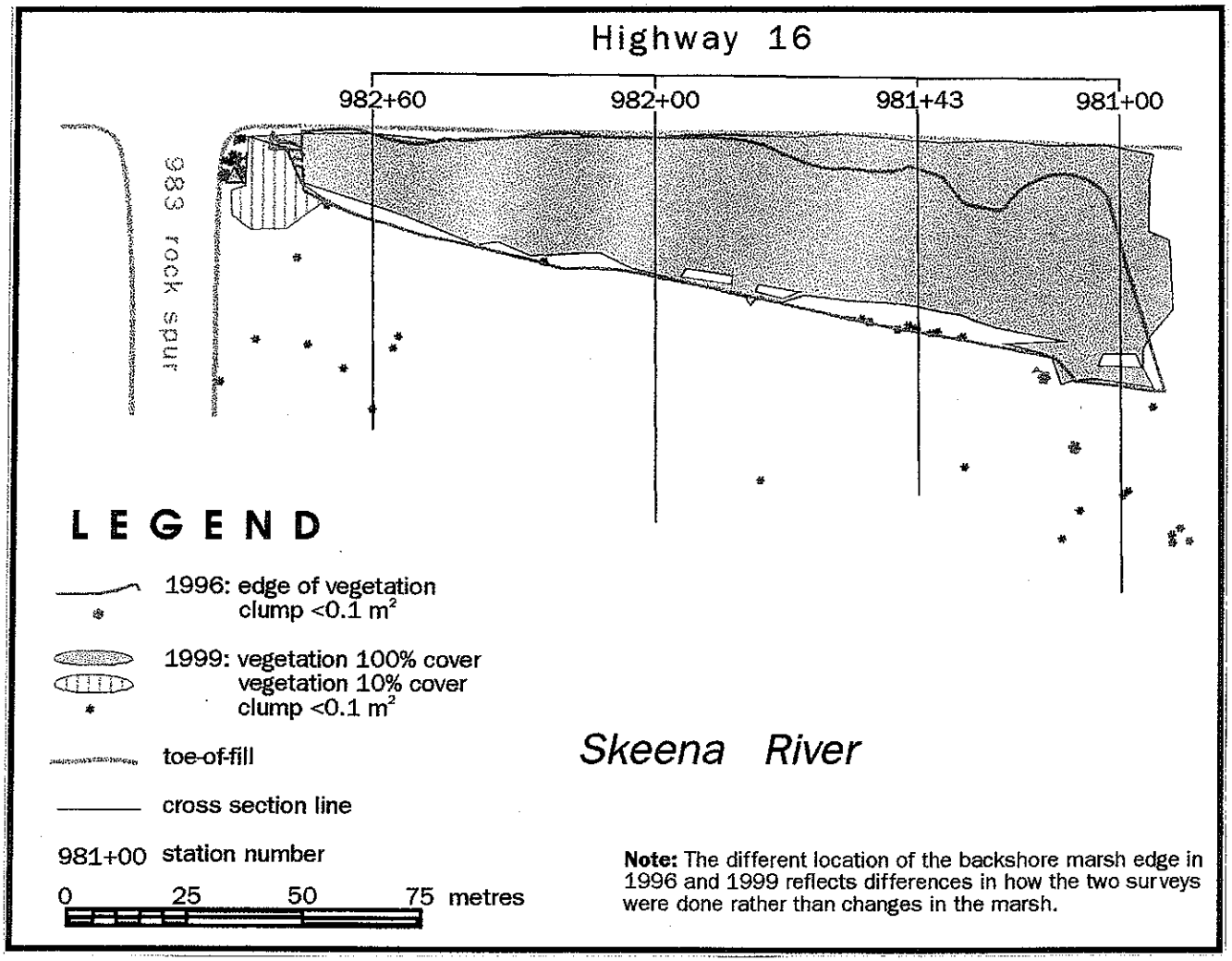


Figure 4: Changes in the marsh east of the compensation site between 1996 and 1999.

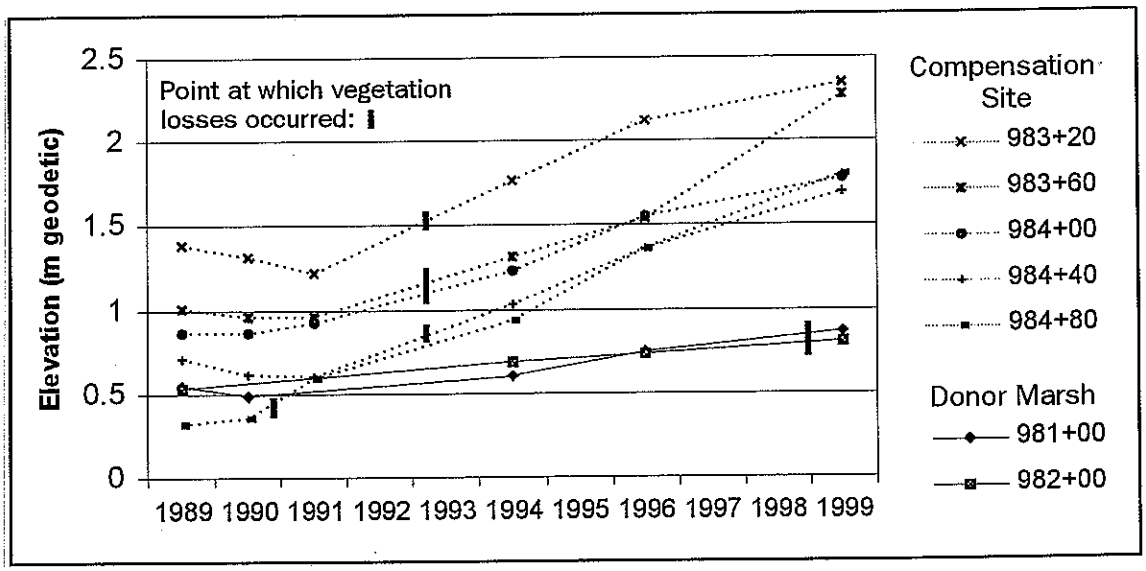


Figure 5: Elevation changes where impacts to vegetation have been observed.

Vegetative losses incurred by small accumulations of sediment are a result of when those accumulations occur rather than their size. This relates directly to the life cycle of Lyngbyeii's sedge.

Lyngbyeii's sedge grows prolifically in the early spring, through the use nutrients stored in underground rhizomes, rather than photosynthesis. The onset of this growth is in early April and the above ground shoots will be over 1 metre high by late May.

Spring freshet occurs in late spring on the Skeena River when the sedge shoots would be quite tall (e.g. 0.8 - 1 + m). The plant colonies would be quite robust towards sediment accumulations at that time simply because it would take accumulations of 0.5 metre or more to bury the shoots.

This is not the case in the fall. In August the plant mobilizes the nutrient content of its above ground shoots and moves them below ground for over winter storage in its root system. At the same time, small shoots 5 - 8 cm high appear in the marsh. These are "over wintering" shoots. They remain dormant through the fall and winter until the following spring. And, they are critical.

Sediment accumulations of 10 - 12 cm could bury these shoots if those accumulations occurred in the fall, i.e. from a rain driven September freshet. In that case, there would be no avenue for respiration for the plant colony and it would die from suffocation.

Lack of Plant Establishment

There is substrate at the appropriate elevation for plant growth in the West Marsh area where there is no vegetation growing or becoming established.

Vegetation colonies in the shelter of the 1024+65 rock spur were first observed in 1991 and those colonies have since expanded (**Table 6**). At the same time, the area adjacent to the 1019+00 rock spur is devoid of vegetation even though the substrate there has been in the appropriate elevation range for inter-tidal plant growth since 1991 (**Table 7**).

Table 6: The areas (in m^2) of plant colonies near the rock spurs of the West Marsh site.

	1991	1994	1996	1999
near the 1019+00 rock spur			0.1	
			0.1	
			<0.1	
near the 1023+65 rock spur		0.6	3.4	8.6
		6.3	22.7	41.4
			1.8	8.0
			0.3	0.4
			0.5	0.4
			0.1	<0.1
			0.4	
			0.8	

Notes: The areas given in successive years on the same line are for the same plant colonies. Where there is no area given in a subsequent year then there was no plant colonies at that location the following year.

Table 7: Elevation over time near the rock spurs in the West Marsh site.

	Station	Location	1991	1994	1996	1999
near the east spur	1019+15	toe-of-fill	1.39	1.2	1.4	1.2
	1019+30	toe-of-fill	0.97	0.83	0.91	0.74
near the west spur	1023+43	toe-of-fill	0.14	1.2	1.0	1.0

Notes: The data for stations 1019+15 and 1023+45 in 1994, 1996 and 1999 are derived from site topographic plans (with a contour interval of 0.2 m), therefore 1.2 could be 1.21 and 1.0 could be 1.19. The data for 1991 are point elevations. The data for station 1019+30 is from the cross section data (as plotted in **Appendix III**).

The elevation of the substrate on the east end of the site (near the 1019 rock spur) has moved up and down 20 centimetres or so over the monitoring period, whereas the ground elevation in the west part of the site has been much more stable - it rose initially and has remained at or near the same elevation since 1996 (and possibly since 1994). The ground's instability near the 1019 rock spur is likely preventing plant establishment there.

The substrate under the body of the west marsh is quite rocky (see **Photograph II/14**). It is much rockier than the newly deposited material near the rock spurs (foreground of **Photograph II/15**), or either the recently deposited or pre-existing substrates at the Boat Ramp or the East Marsh / Compensation sites.

The size of material on any given site is indicative of the fluvial or wave energy impacting that site (M. Miles, pers. com., 1999). It follows, therefore, that the west marsh site is subject to greater energies than the other two sites. And, furthermore, it seems logical, therefore, that the difference in stability between the two parts of the West Marsh we are considering here is due to the difference in wave energy impacting on them. And that is due to a difference in exposure.

The area adjacent to the western rock spur is protected from southwesterly winds by the rock spur itself and from outflow winds by the body of the marsh immediately east of it. The area adjacent to the eastern rock spur is open to the southwest, although it is sheltered from the east. It follows, then, that the material on the east part of the site is being re-mobilized periodically and that any plant life there is washed away before it can become established.

Plant Growth

All the vegetation within the compensation site is growing well, irrespective of whether it was there prior to the project, was transplanted or became established naturally after construction. Comparison of growth factor values (**Table 8**) shows that there is very little difference between the vegetation in different parts of the Compensation Site, and that the vegetation within the site is equally or more productive than the Donor Marsh.

There are year to year differences in plant growth (**Figure 6**) which may be related to micro-environmental variation within the site. The rationale for this is that the 1996 growth index for some of the colonies within the site appear to be higher than for other years, however this apparent increase did not occur in the colonies east of the compensation site, nor was it as dramatic for naturally established colonies within the site. It does appear that there is less variation in the undisturbed plant colonies east of the site

compensation site is still undergoing changes both with respect to its physical environment (i.e. sediment is still accreting within the site, although at a much slower rate than previously) and biologically (i.e. the number of plant colonies and the total vegetated area is increasing each year).

Table 8: 1999 indicators of relative growth for inter-tidal vegetation in the study site.

	shoot density (stems/m^2)	shoot length (cm)	growth index*
Within the Compensation Site			
1989 transplants	515	126	65
1990 transplants	521	107	55
naturally established	528	122	65
offshore vegetated island	395	133	53
Within the Donor Marsh			
at the collection site	586	49	29
the channel edge community	442	130	57

Notes: * growth index: (shoot density multiplied by shoot length)/1000. It is a measure of relative productivity.

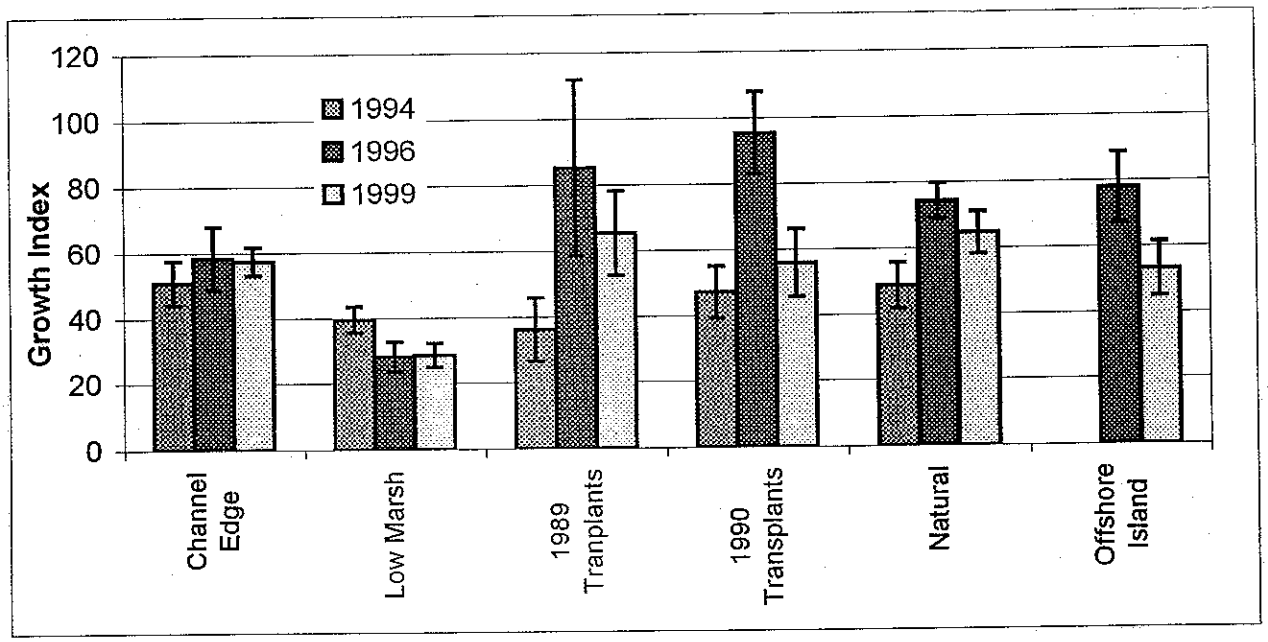


Figure 6: Growth indices for plant colonies from 1994 to 1999.

Conclusions

The overall project is still in a state of "Net Loss" with respect to area of inter-tidal vegetation on the project area foreshore. The loss/replacement ratio is 0.6. There is an outstanding deficit in inter-tidal vegetated area of 15 399 m^2.

There were further impacts incurred to inter-tidal vegetation from the compensation works, and the project area did not recover from those impacts until 1996.

The project should reach overall "No Net Loss" status, *vis-a-vis* inter-tidal vegetation, in 2003. If this is the case, then this will be 15 years after the vegetation losses were incurred.

There is over 12 hectares of inter-tidal area which could support vegetation within the East Marsh, Compensation Site and Donor Marsh areas. If a significant portion of this area becomes vegetated then the project will ultimately return a "Net Gain" of inter-tidal vegetated habitat of more than 3:1.

There has been no change in surface elevations of the rock spurs in the last two assessments. This suggests that the fluvial environment within the compensation site will remain stable and that current trends in vegetation growth should continue.

The long term prognosis for inter-tidal vegetation within the compensation site is excellent. The evidence to support this statement is as follows: Firstly, all the inter-tidal vegetation within the site is growing well. Secondly, the rate of change of the surface elevation is slowing and, therefore, it is quite likely that vegetation losses from sedimentation will be minimal, except upstream of the 983 rock spur. And, finally, inter-tidal vegetation on the site continues to expand, both from expansion of existing colonies and the establishment of new plant colonies.

There may be some vegetation losses incurred in the marsh east of the compensation site in the future. This is due to the encroachment into the marsh of the accreting mud flat in front of the marsh. Any losses are expected to be offset by new vegetation becoming established on the mud flat itself.

The establishment of inter-tidal vegetation on the east part of the West Marsh site appears to be inhibited by the instability of the substrate there.

Plant growth within the compensation is equal to, or better than, that in the pre-existing marsh east of the compensation site.

The author recommends that further site evaluations be done in 2003 and in 2008. These would document the long term results of the compensation efforts within this project.

Sources of Information

References

Kellerhals Engineering Services Ltd. 1984. *Khyex to Tyee Hydrological Mitigation Study.* unpublished report to the Ministry of Transportation and Highways, Victoria, B.C. 59 pages with appendices.

Miles, M. J. 1996. *Khyex-Tyee Project, Review of Topographic Survey Data.* unpublished report to Ministry of Transportation and Highways, Victoria, B.C. 14 pages

White, E.R. 1988. *A Wetlands Mitigation Proposal to Compensate for Highway 16 Re-construction Impacts Near Prince Rupert, B.C.* unpublished report to the Ministry of Transportation and Highways, Victoria, B.C. 35 pages with appendices.

White, E.R. 1990a. *Khyex-Tyee: Foreshore Habitat Re-construction Works.* unpublished report to the Ministry of Transportation and Highways, Victoria, B.C. 16 pages with appendices and maps.

White, E.R. 1990b. Highway 16 Re-construction, Fish Habitat Compensation/Mitigation. unpublished letter to the Ministry of Transportation and Highways, Victoria, B.C. 14 pages with maps.

White, E.R. 1991. Project NO. 04773: Khyex to Aberdeen. unpublished letter to the Ministry of Transportation and Highways, Terrace, B.C. 20 pages with maps.

White, E.R. 1994. *Khyex-Tyee : 1994; Fish Habitat Compensation and Mitigation Works.* unpublished report to the Ministry of Transportation and Highways, Victoria, B.C. 17 pages with appendices and maps.

Personal Communications

Mike Miles. 1999. of M Miles and Associates Ltd., Victoria, B.C.

Appendix I - Cross-section elevations at all sites

To aid the reader these cross-sections have been arranged into three sections:

- The Donor Marsh, the Compensation Site and the East Marsh areas.
  This area extends from chainage 981+00 to 991+00.

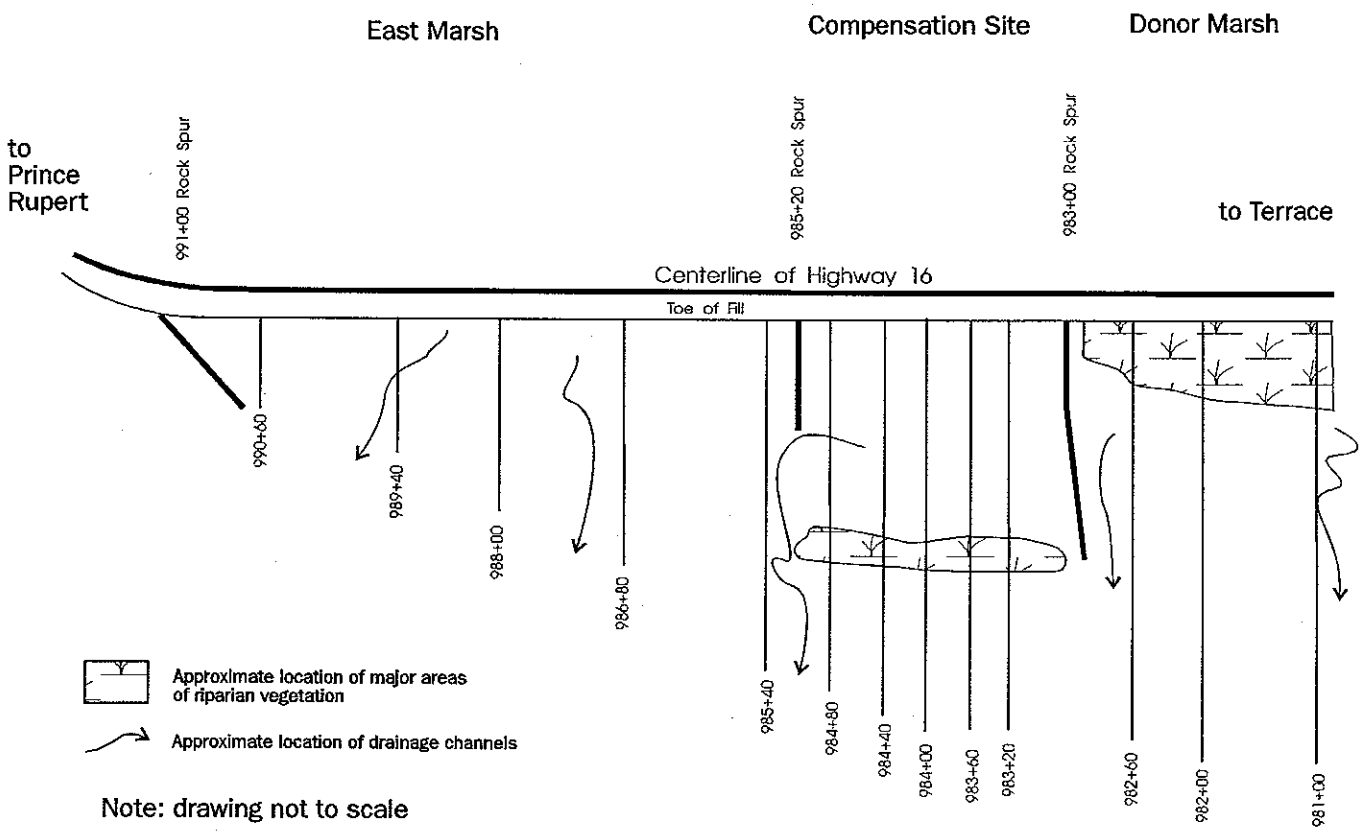
- The Boat Ramp area
  This area extends from the 995+00 rock spur to the 988+ 30 rock spur.

- The West Marsh area
  This area extends from the 1019+00 rock spur to the 1023+00 rock spur.

At the beginning of each section there is a location diagram showing where the cross-sections are within the area and any pertinent information that may help the reader.

The East Marsh, Compensation Site and Donor Marsh Areas

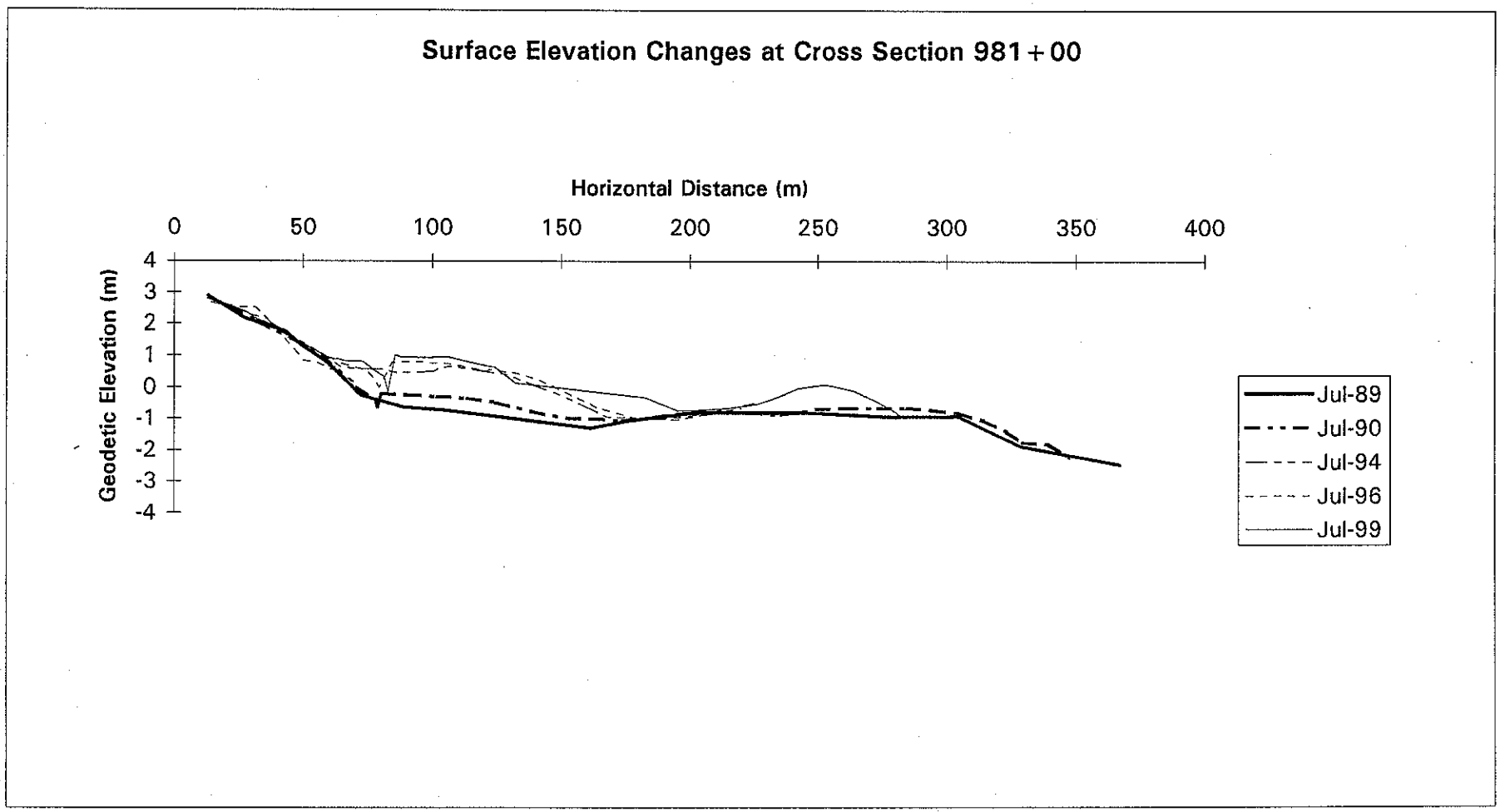
Location of cross sections:

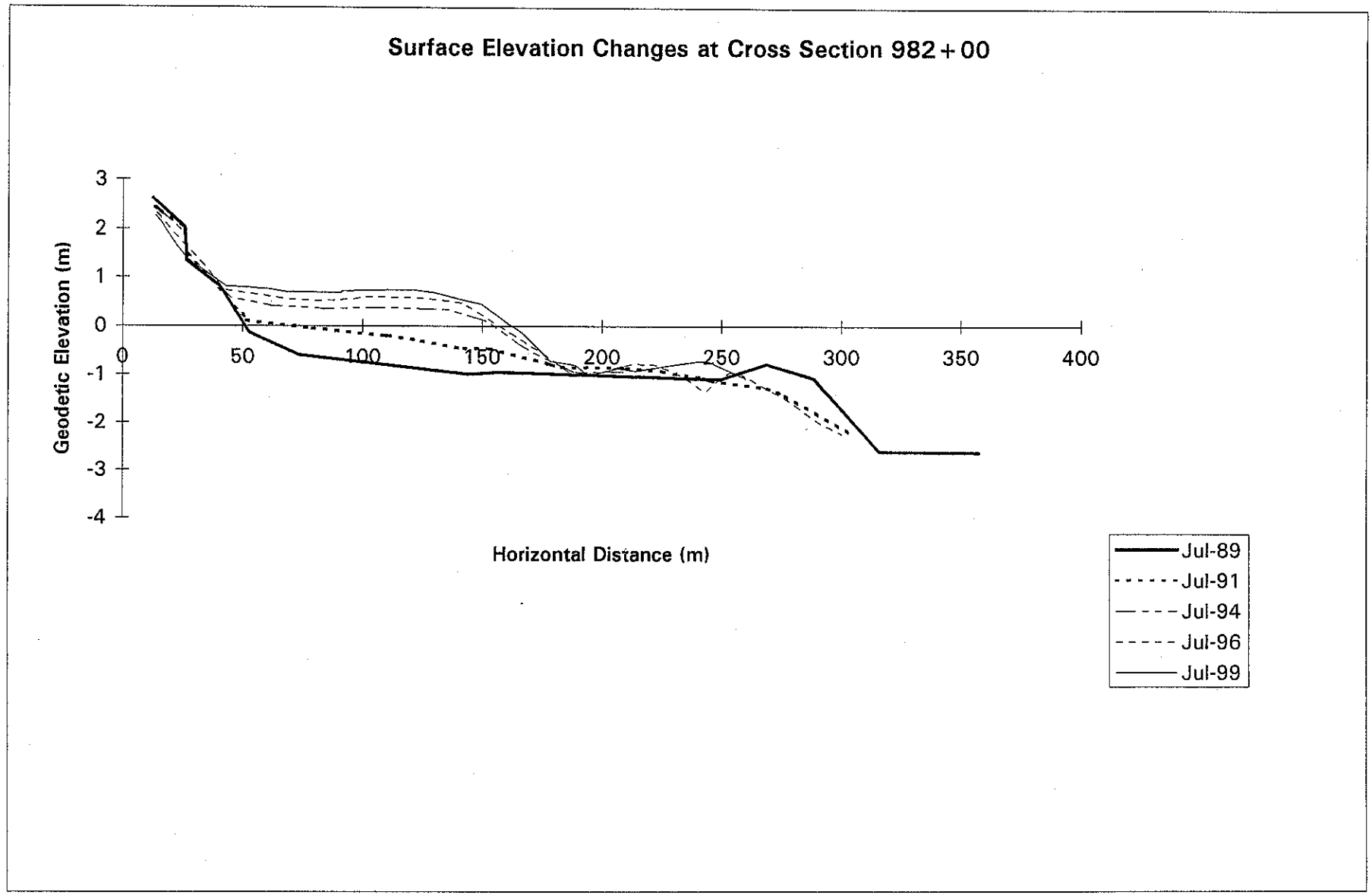


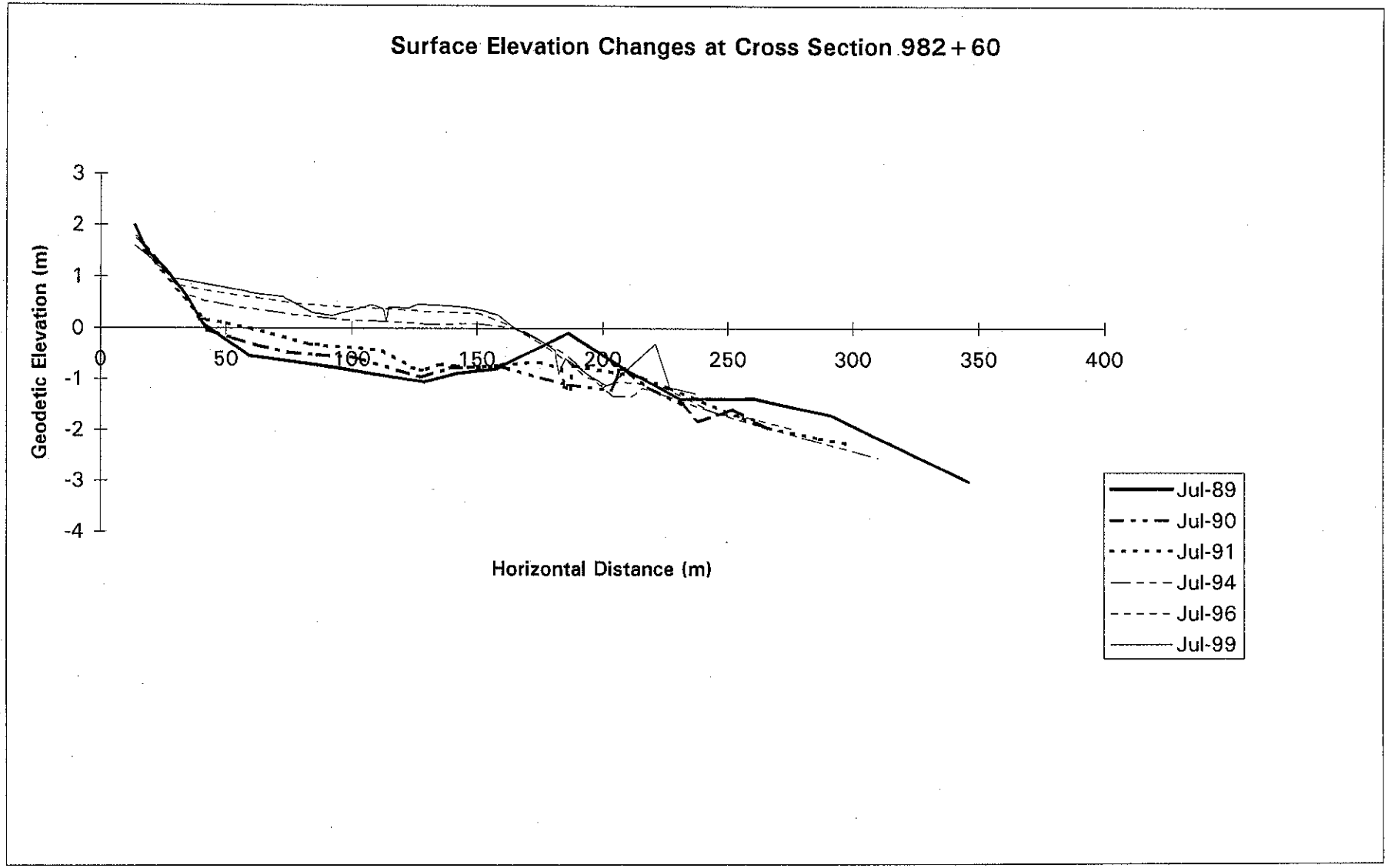
Note: drawing not to scale

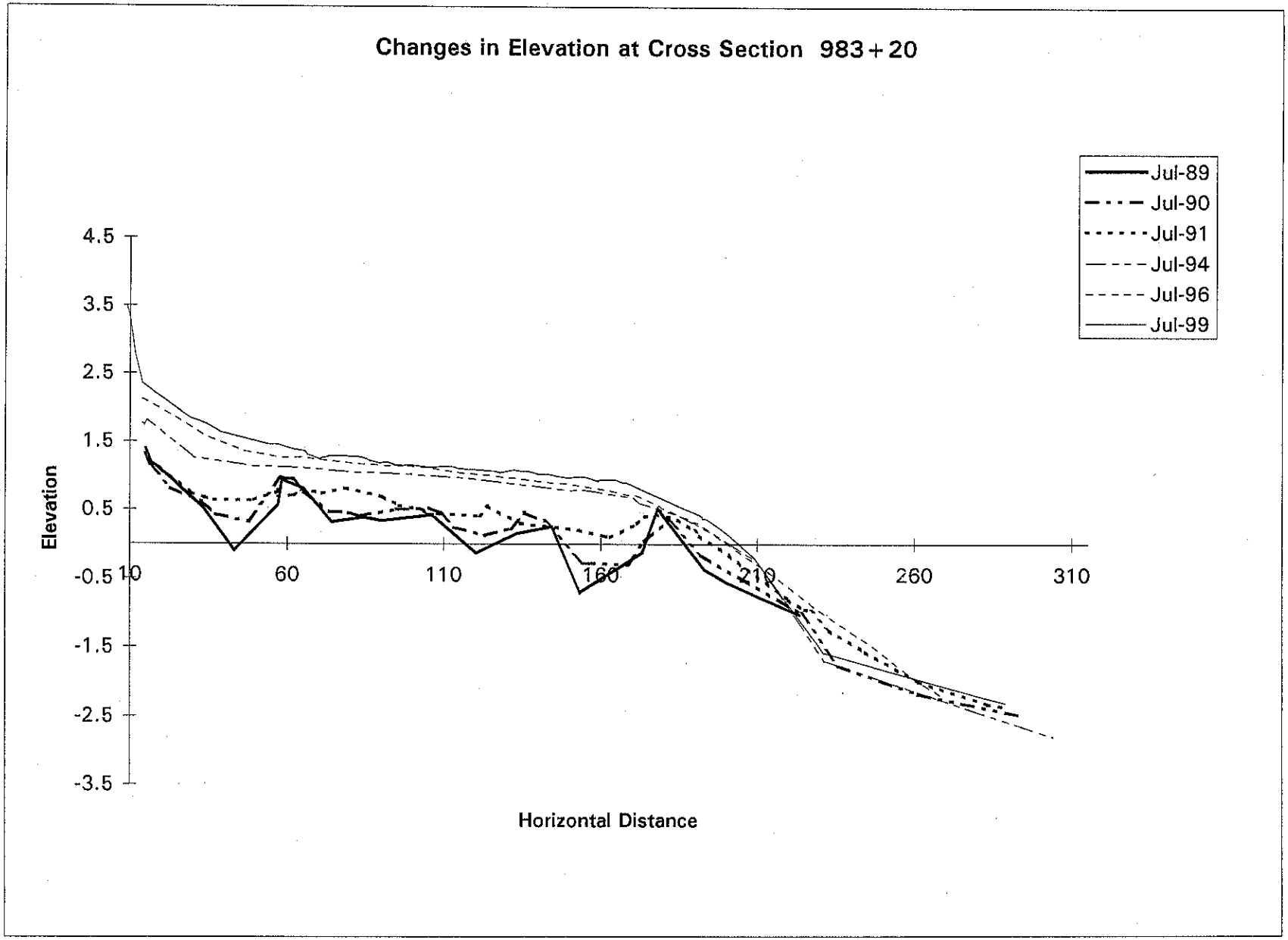
Cross section 984+40 intersected a channel through the offshore vegetation from 1989 through 1991. However, in 1994, the channel had completely disappeared.

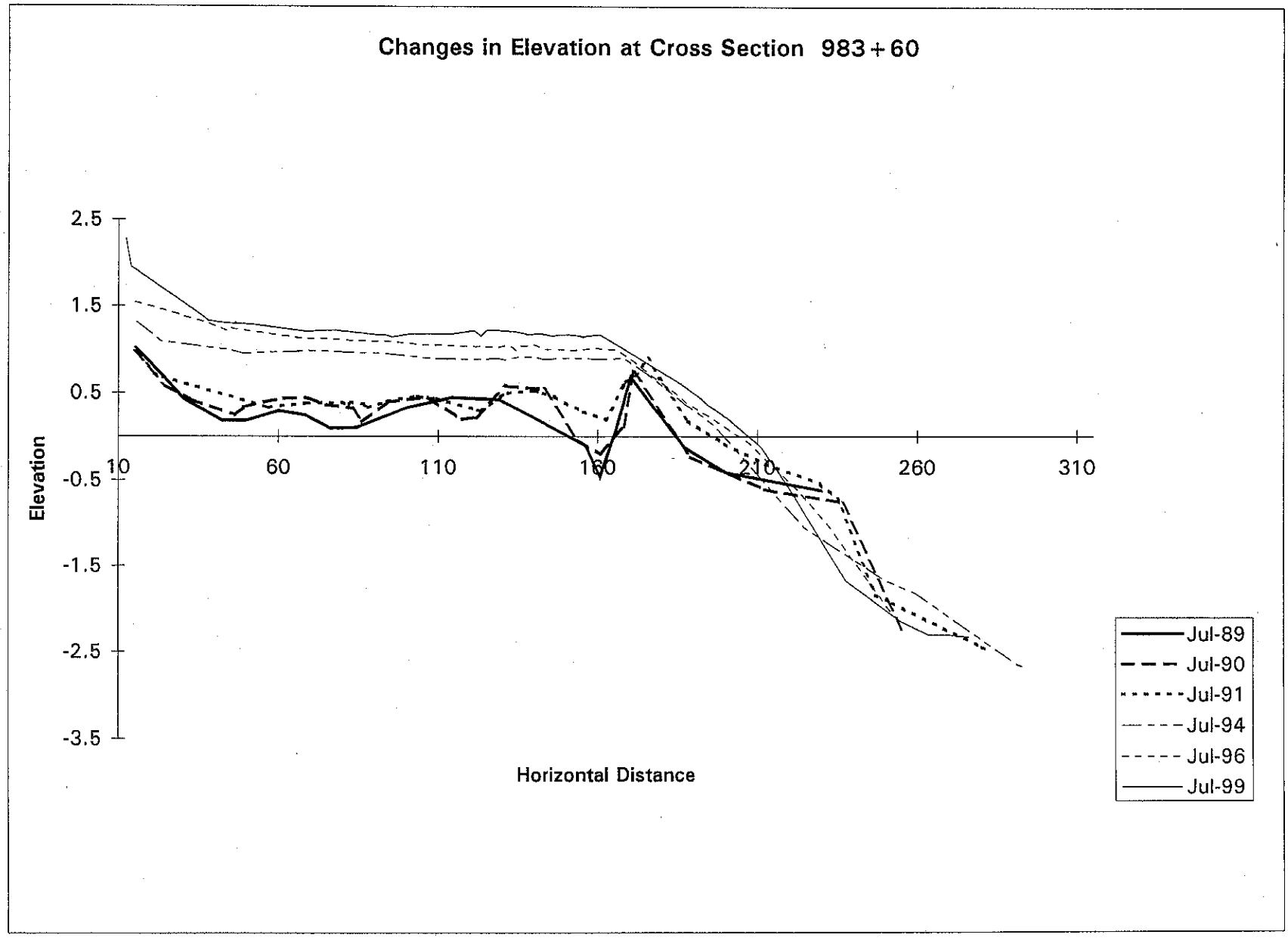
Cross sections between 984+80 and 988+00 intersect the major drainage of the compensation site. This channel has been filling in from the upstream (compensation site) end.


Surface Elevation Changes at Cross Section 981+00
Horizontal Distance (m)
0
50
100
150
200
250
300
350
400
Geodetic Elevation (m)
4
3
2
1
0
-1
-2
-3
-4
Jul-89
Jul-90
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 982+00
Geodetic Elevation (m)
3
2
1
0
-1
-2
-3
-4
0
50
100
150
200
250
300
350
400
Horizontal Distance (m)
Jul-89
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 982+60
Geodetic Elevation (m)
3
2
1
0
-1
-2
-3
-4
0
50
100
150
200
250
300
350
400
Horizontal Distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Changes in Elevation at Cross Section 983+20
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99
4.5
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
Elevation
10
60
110
160
210
260
310
Horizontal Distance


Changes in Elevation at Cross Section 983+60
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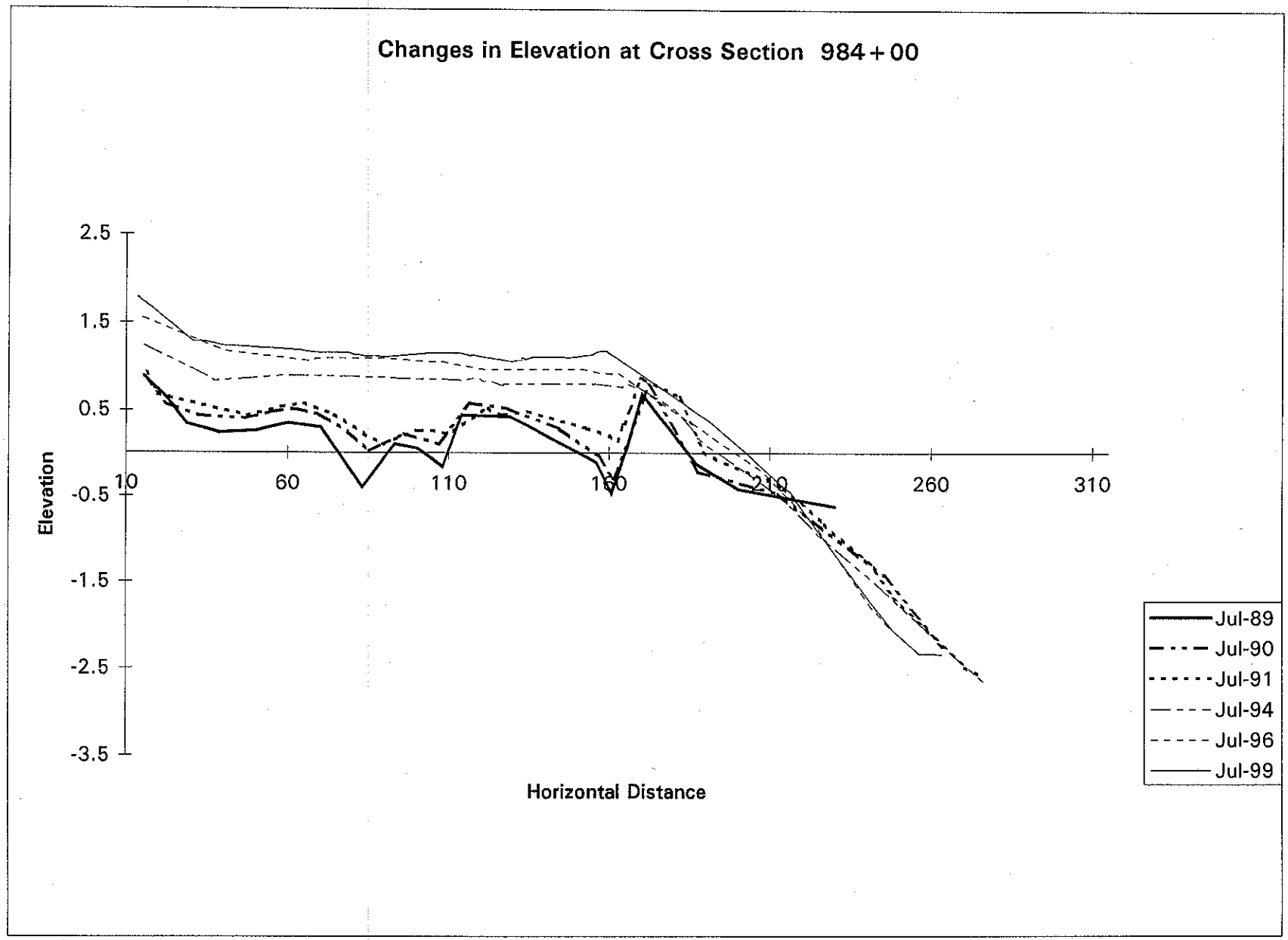
1.5
0.5
-0.5
-1.5
-2.5
-3.5
Elevation
10
60
110
160
210
260
310
Horizontal Distance
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Changes in Elevation at Cross Section 984+00
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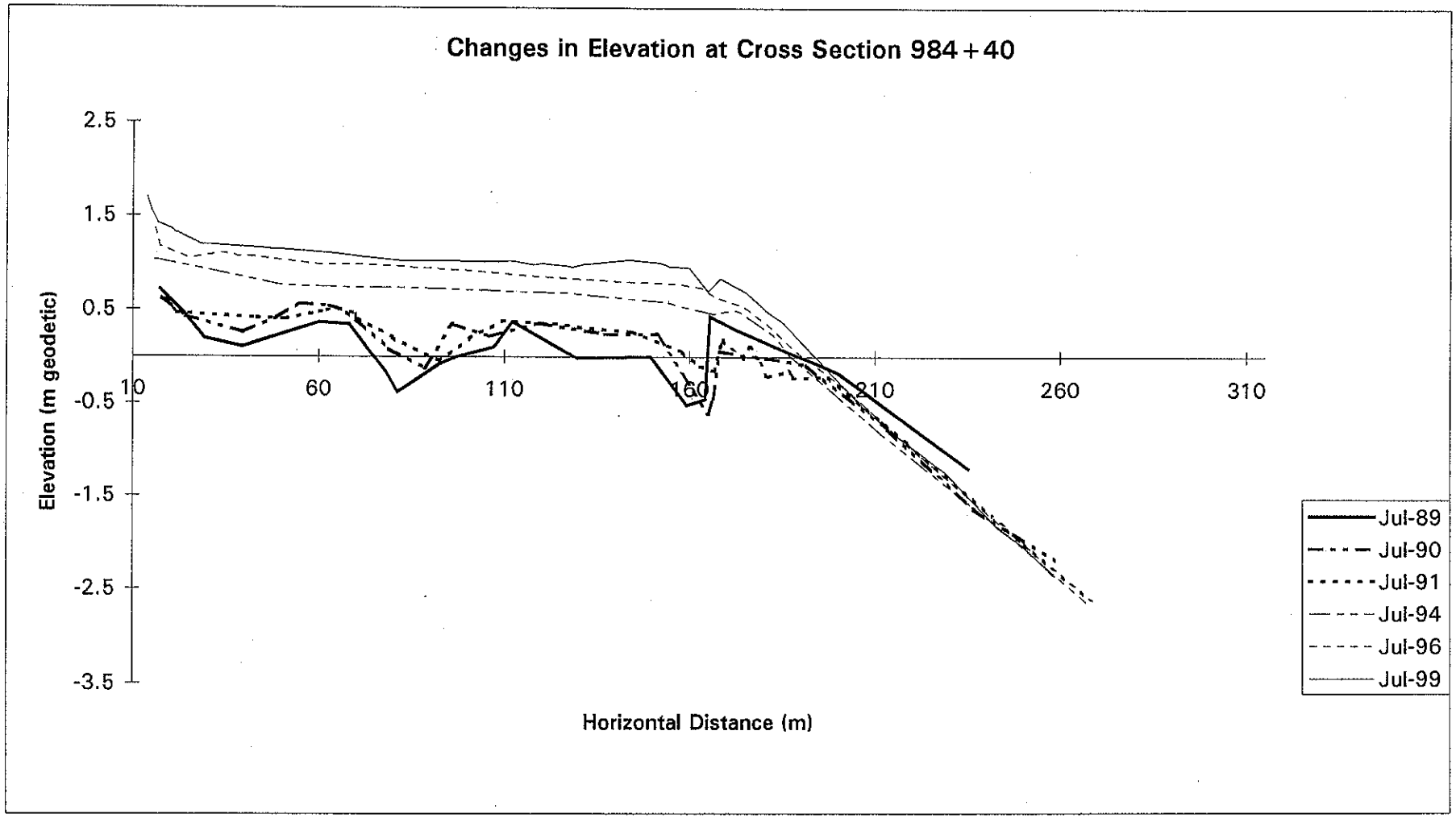
1.5
0.5
-0.5
-1.5
-2.5
-3.5
Elevation
10
60
110
160
210
260
310
Horizontal Distance
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Changes in Elevation at Cross Section 984+40
Elevation (m geodetic)
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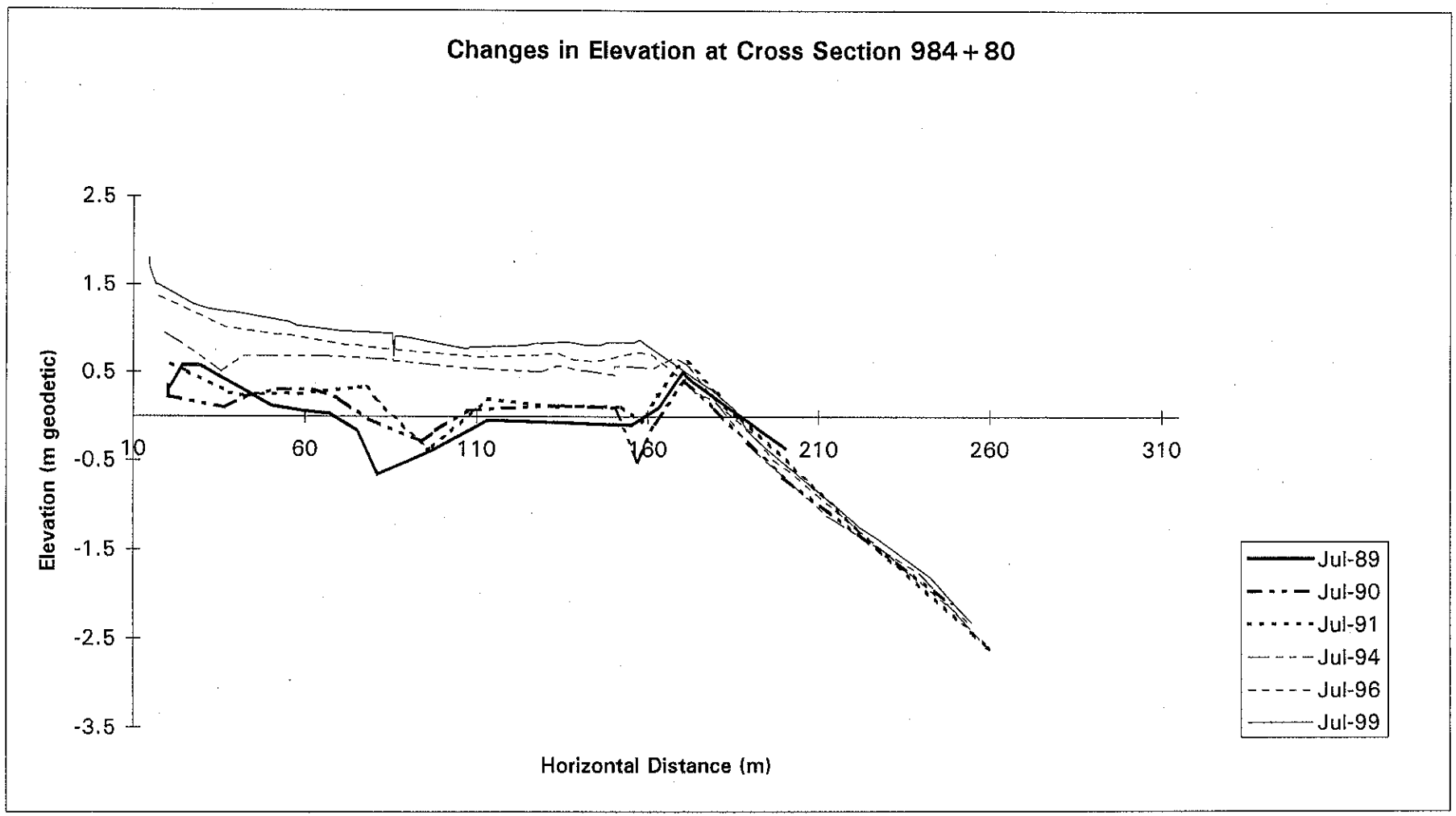
1.5
0.5
-0.5
-1.5
-2.5
-3.5
10
60
110
160
210
260
310
Horizontal Distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Changes in Elevation at Cross Section 984+80
Elevation (m geodetic)
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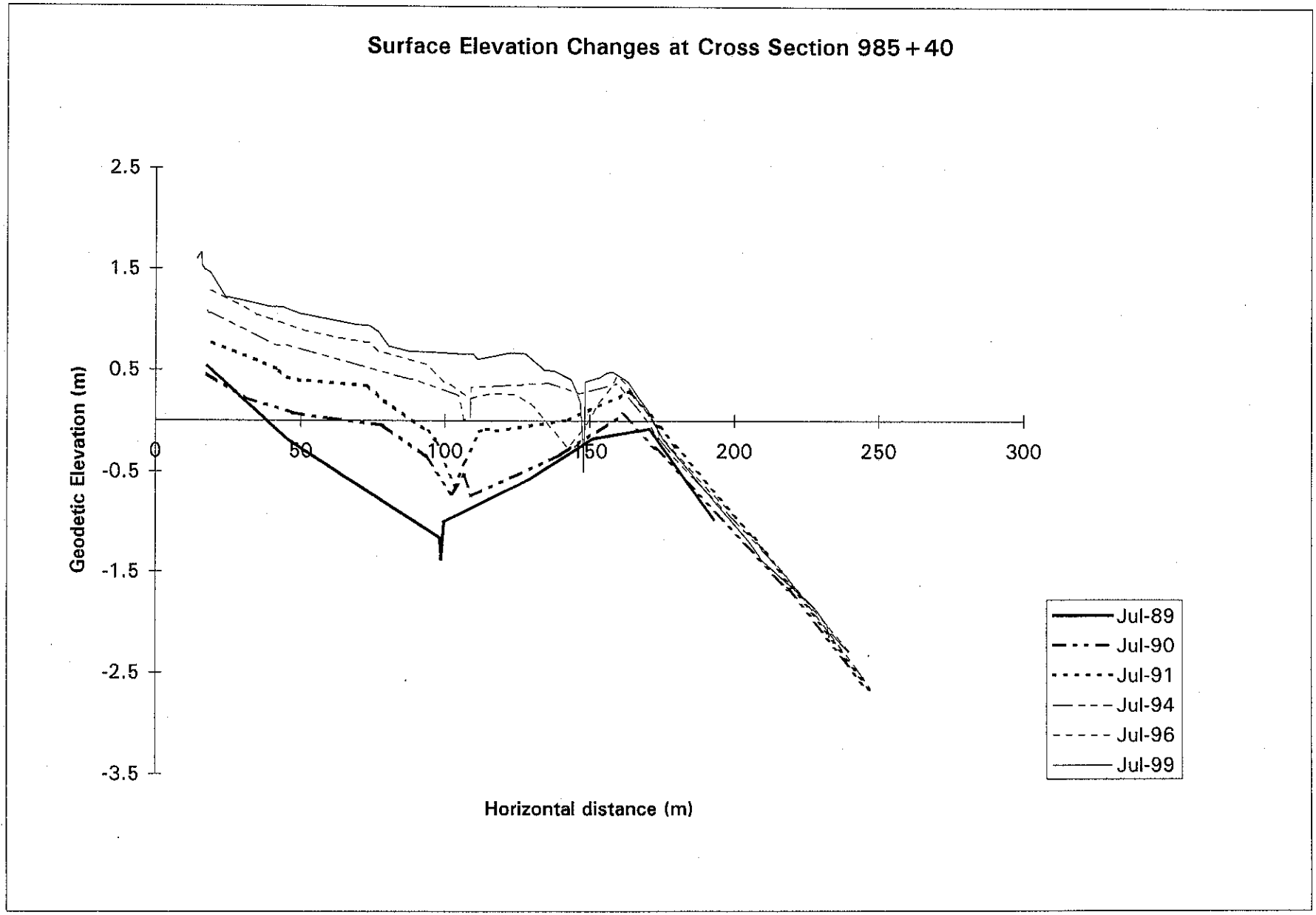
1.5
0.5
-0.5
-1.5
-2.5
-3.5
10
60
110
160
210
260
310
Horizontal Distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 985+40
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0.5
-0.5
-1.5
-2.5
-3.5
Geodetic Elevation (m)
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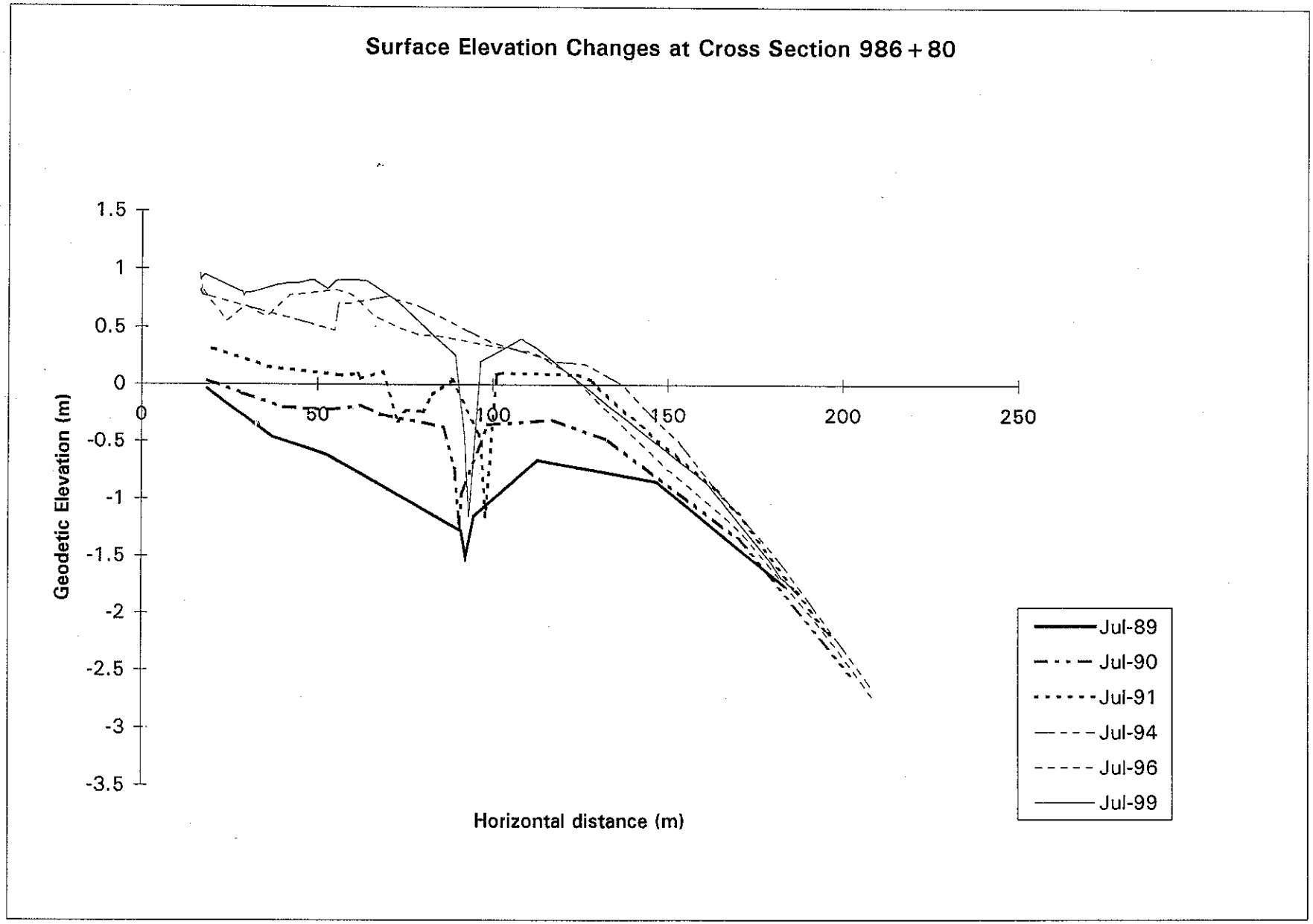
50
100
150
200
250
300
Horizontal distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 986 + 80
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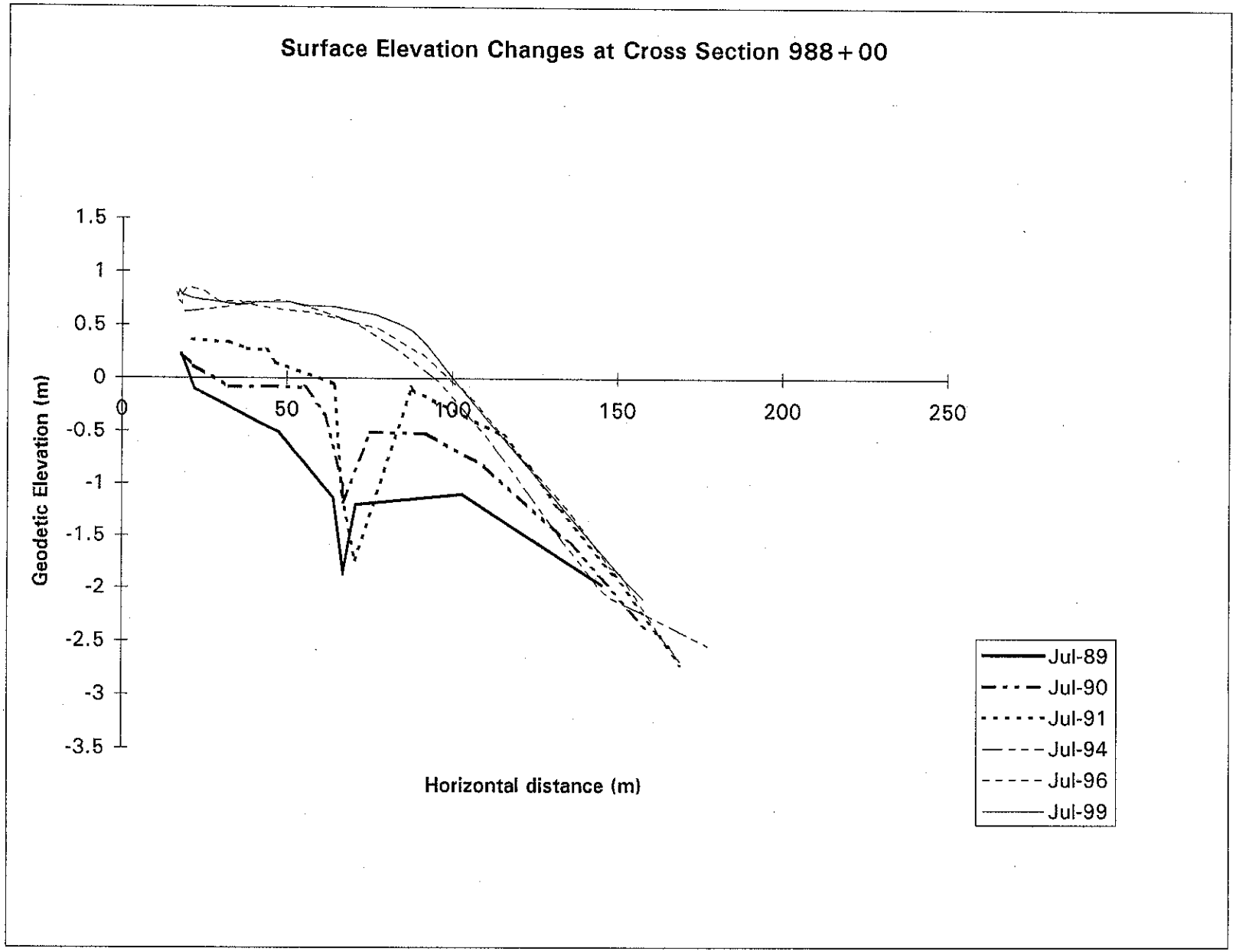
-1
-1.5
-2
-2.5
-3
-3.5
0
50
100
150
200
250
Horizontal distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 988+00
Geodetic Elevation (m)
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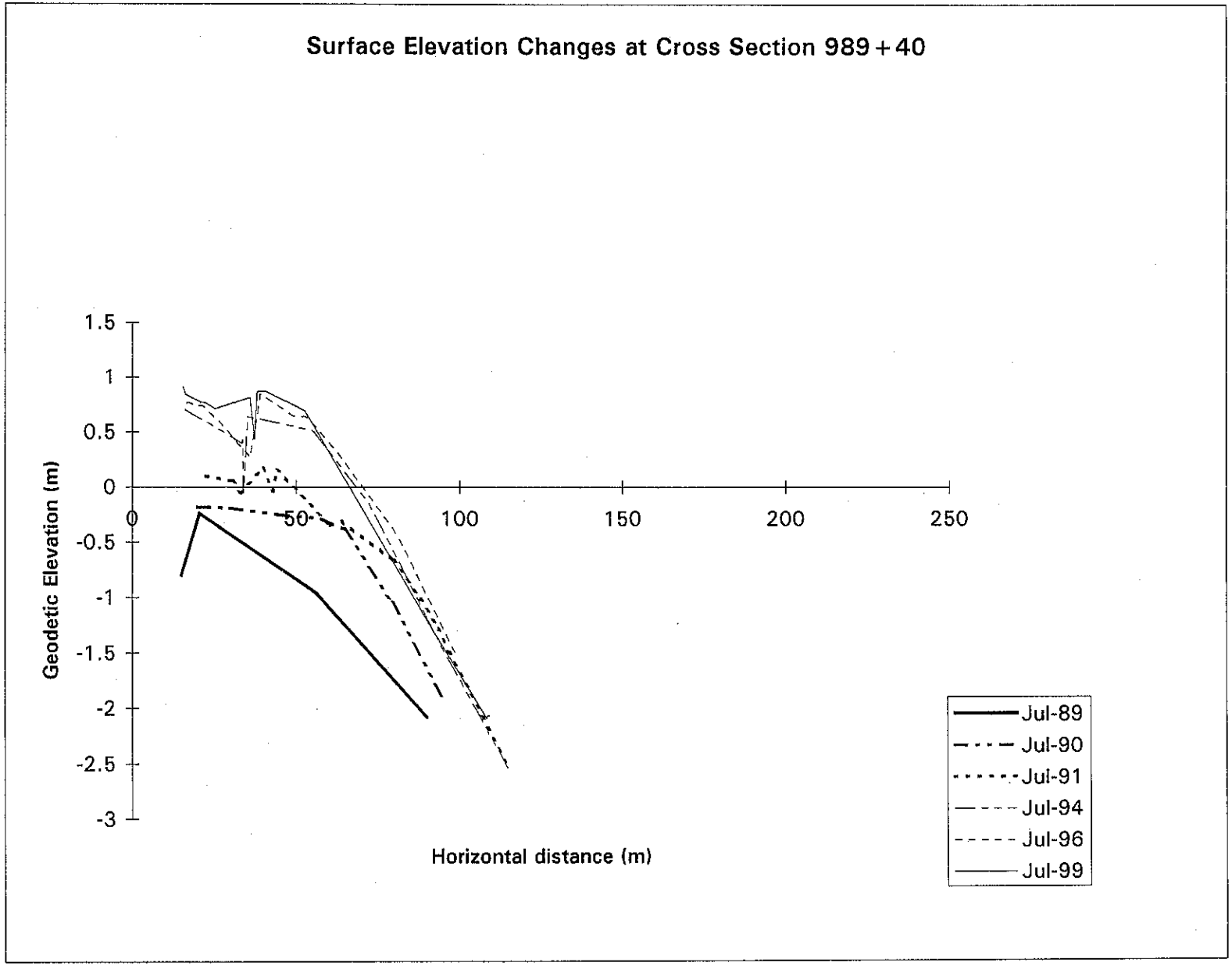
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0
50
100
150
200
250
Horizontal distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 989+40
Geodetic Elevation (m)
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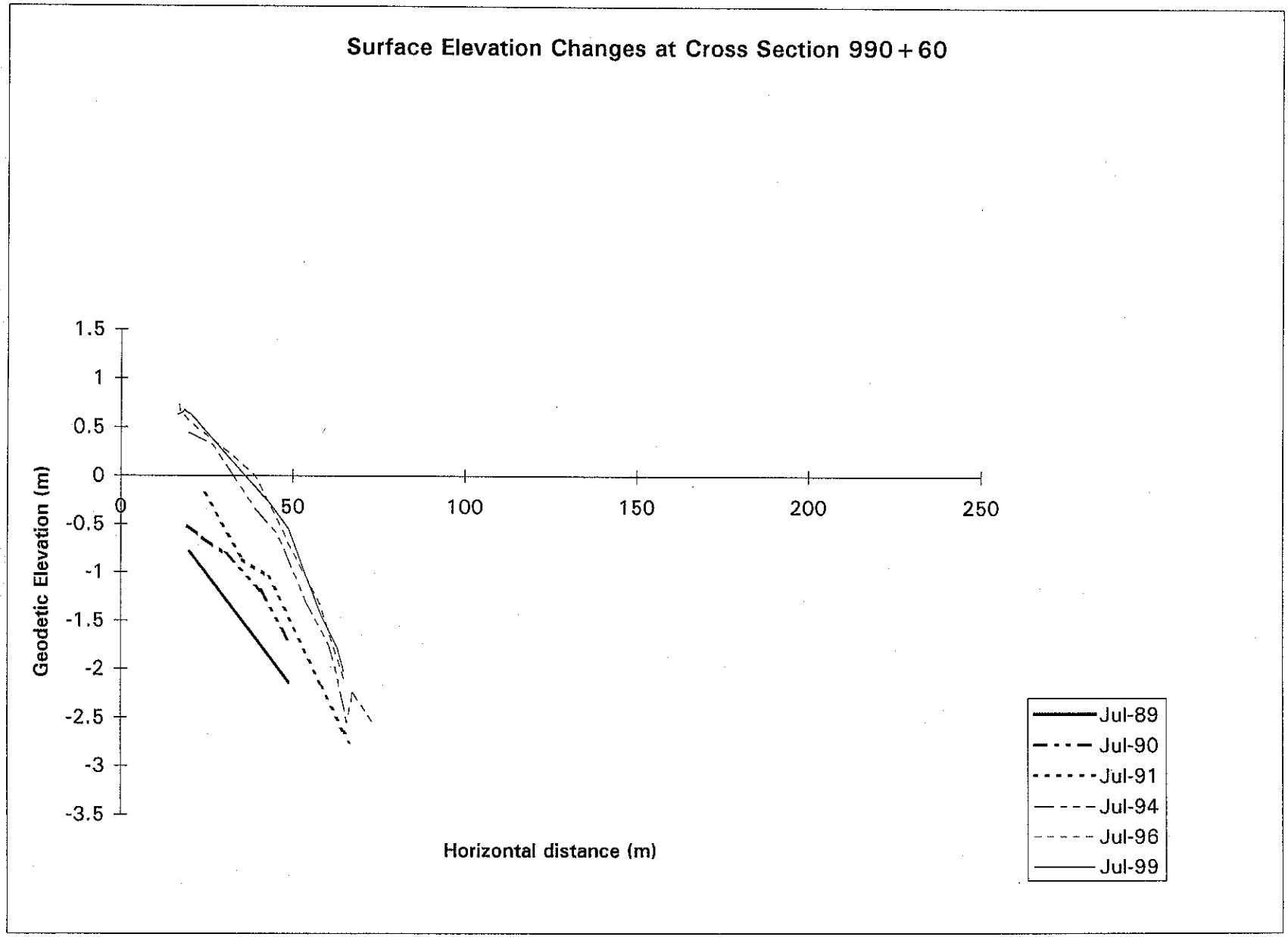
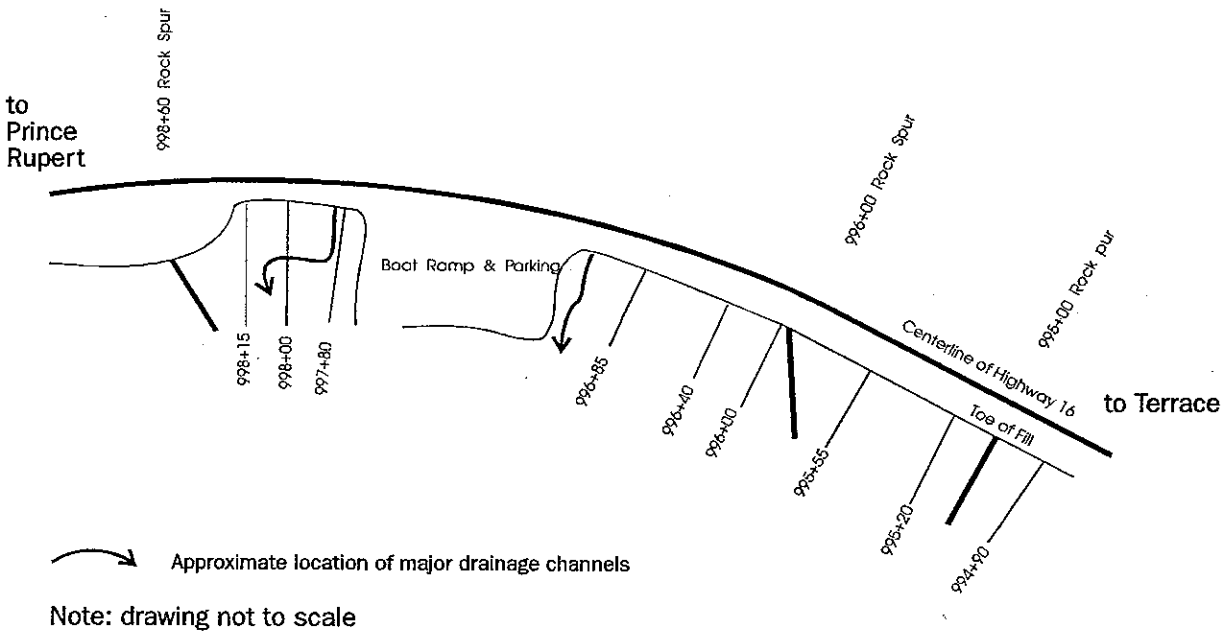
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
50
100
150
200
250
Horizontal distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 990+60
Geodetic Elevation (m)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0
50
100
150
200
250
Horizontal distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99

The Boat Ramp Area

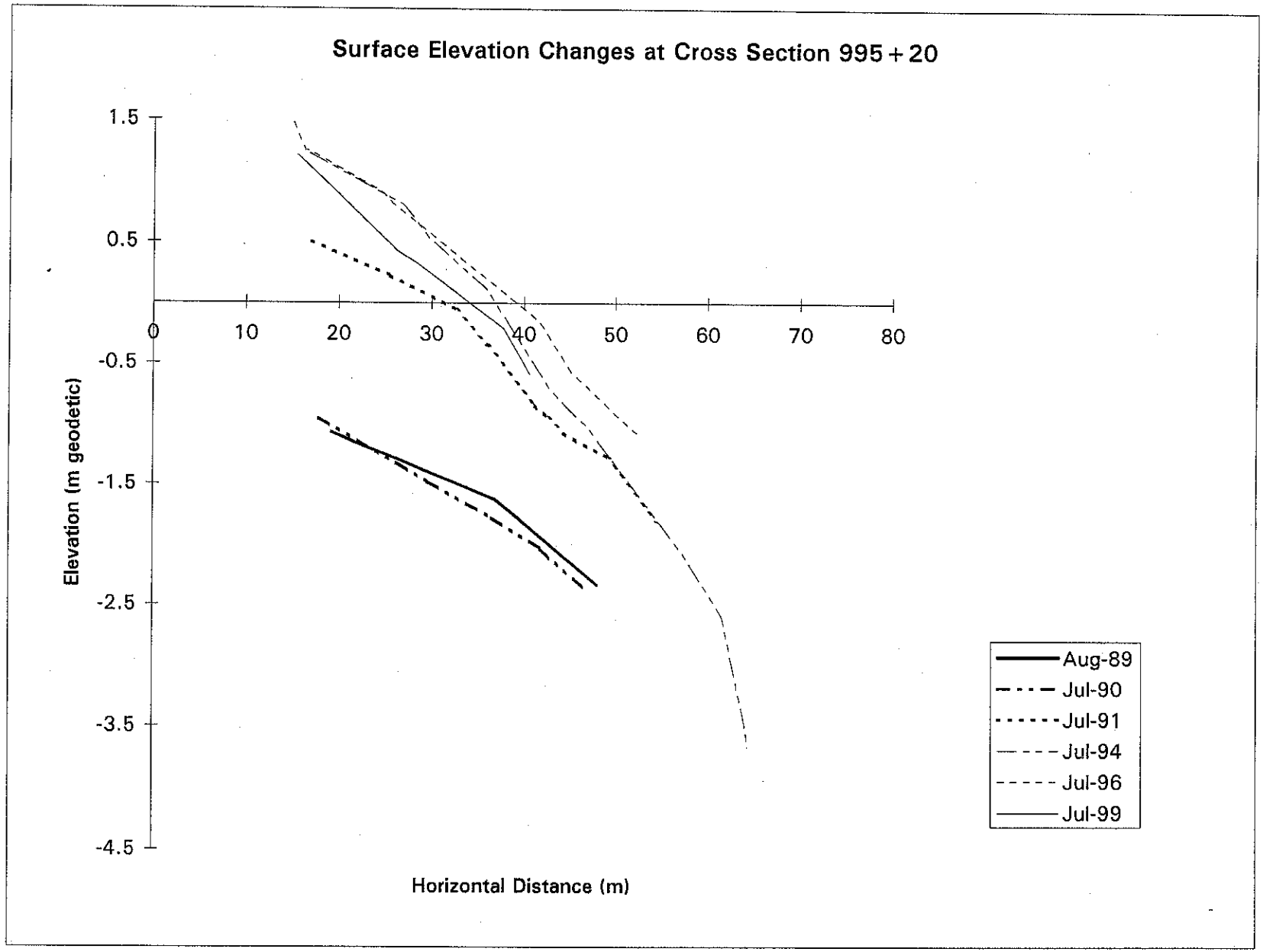
Location of cross sections:

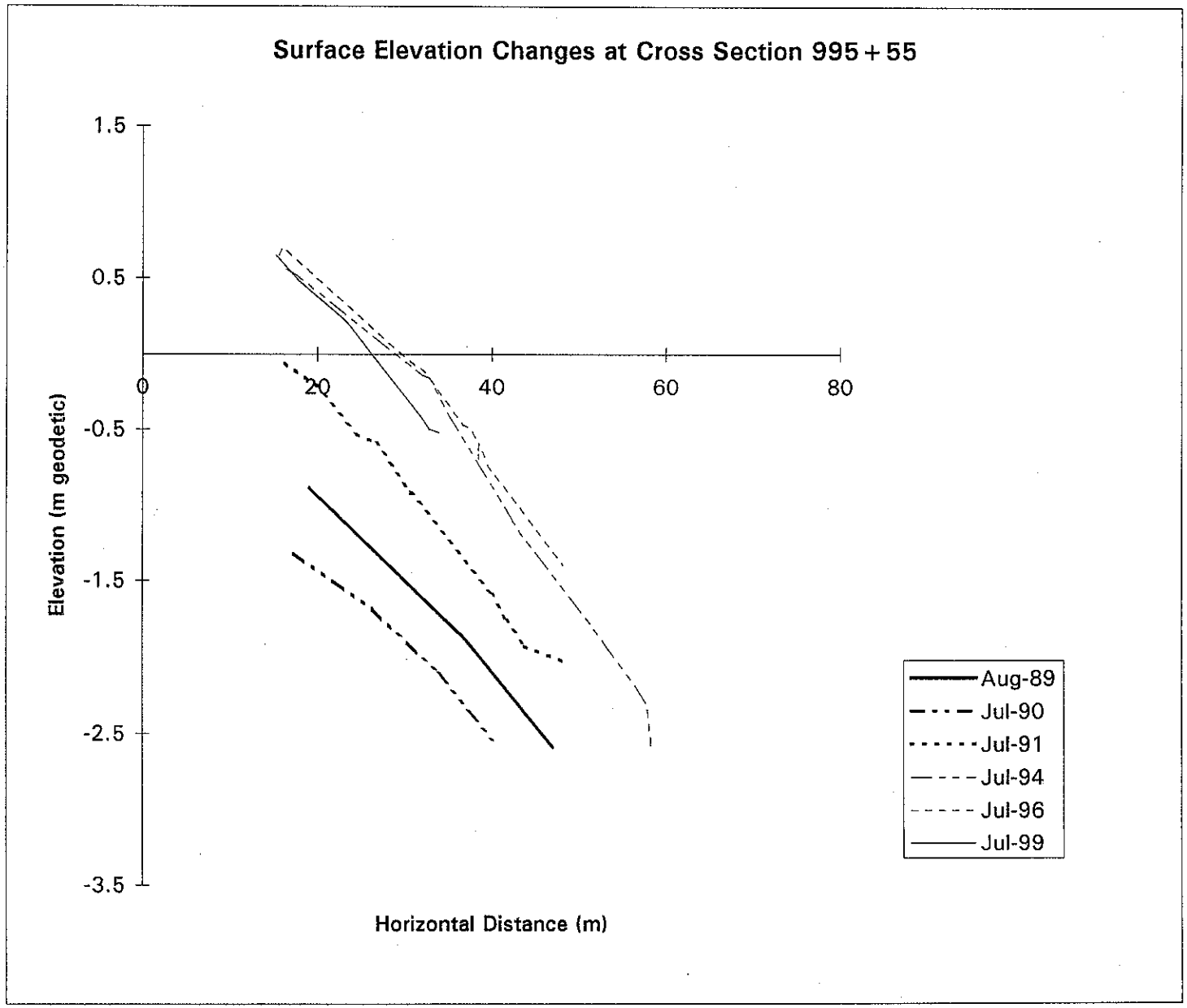


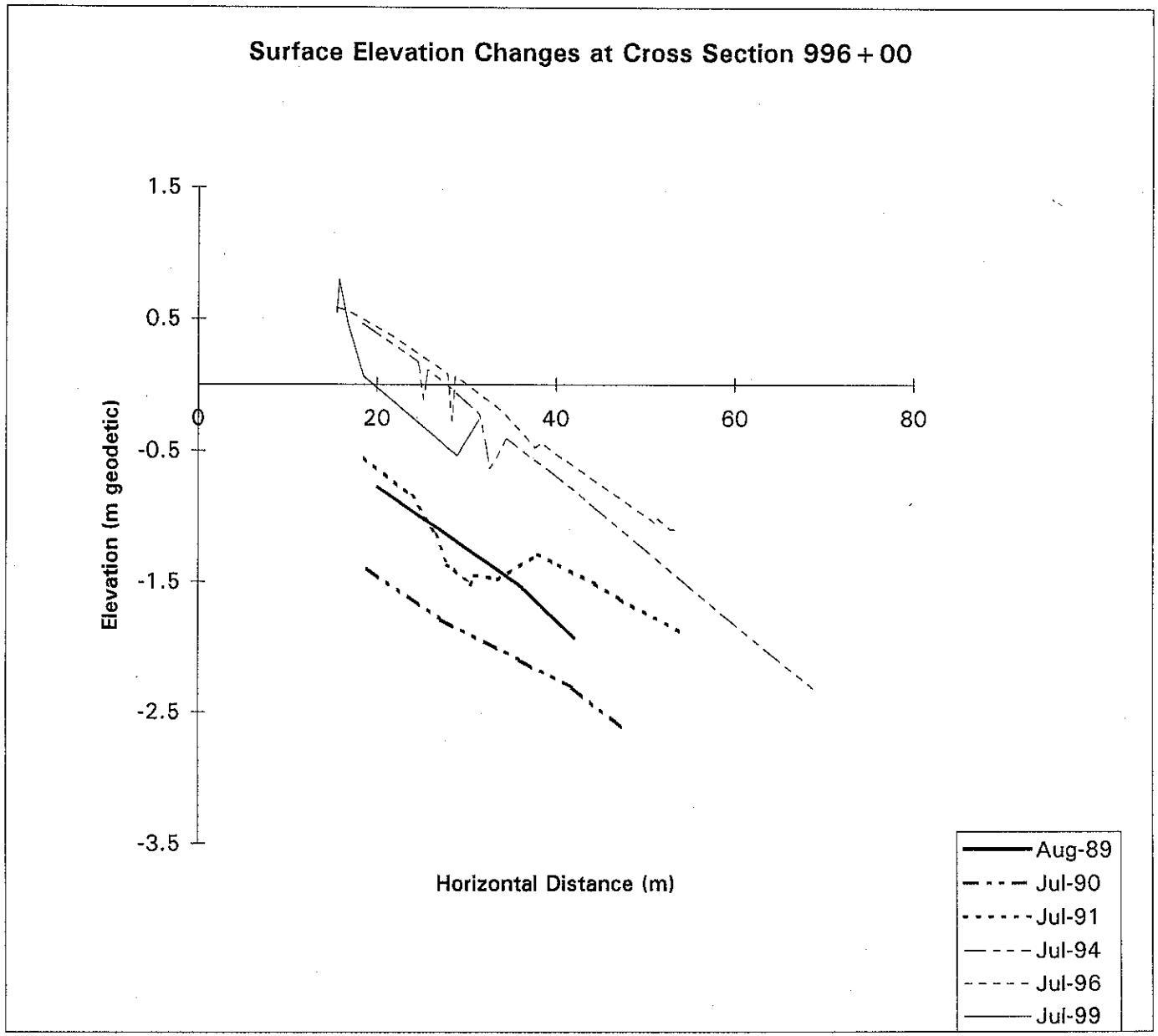
Note: drawing not to scale

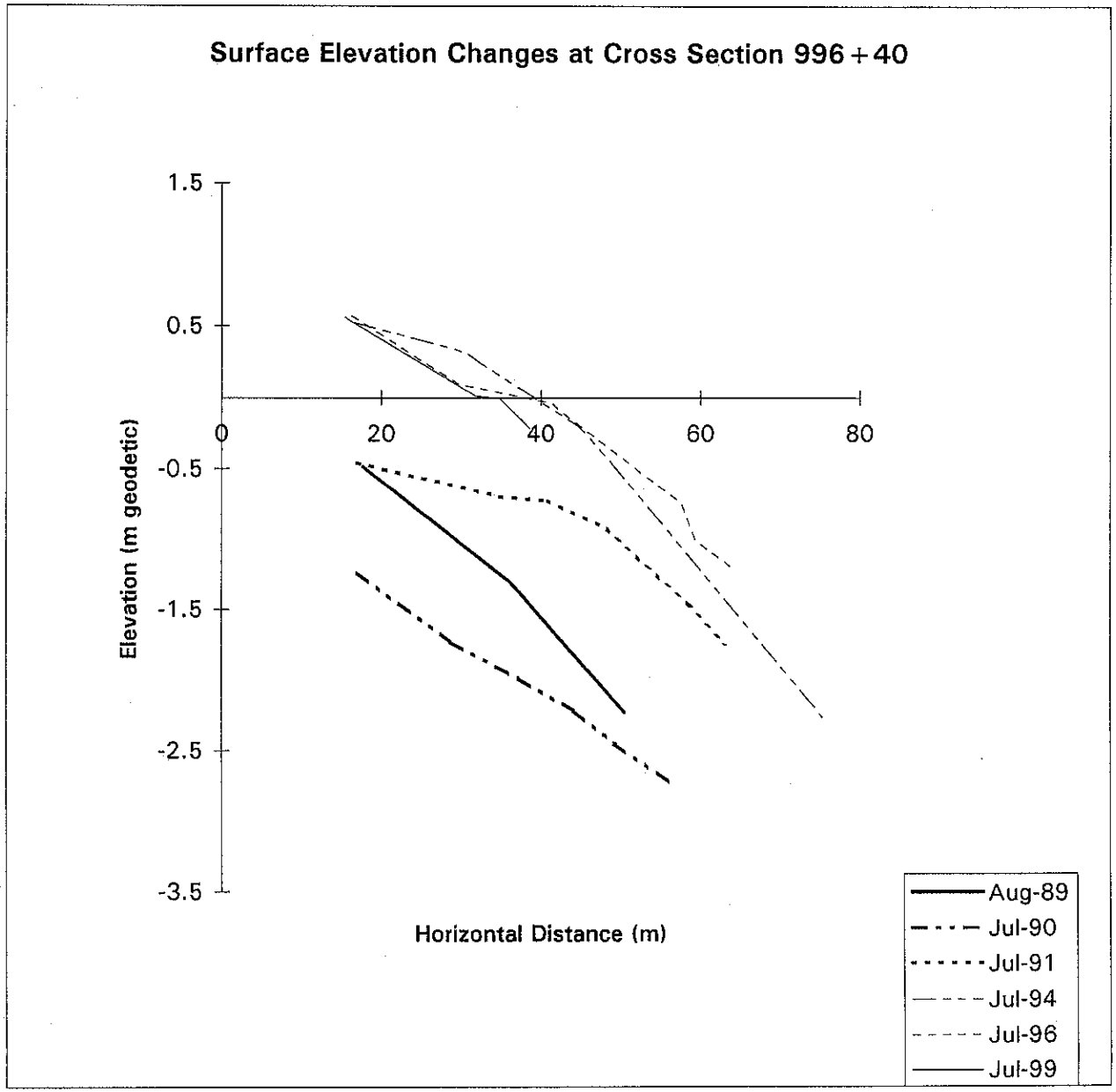
The July 1990 survey in this area appears to be 0.5 m low in all cross sections.

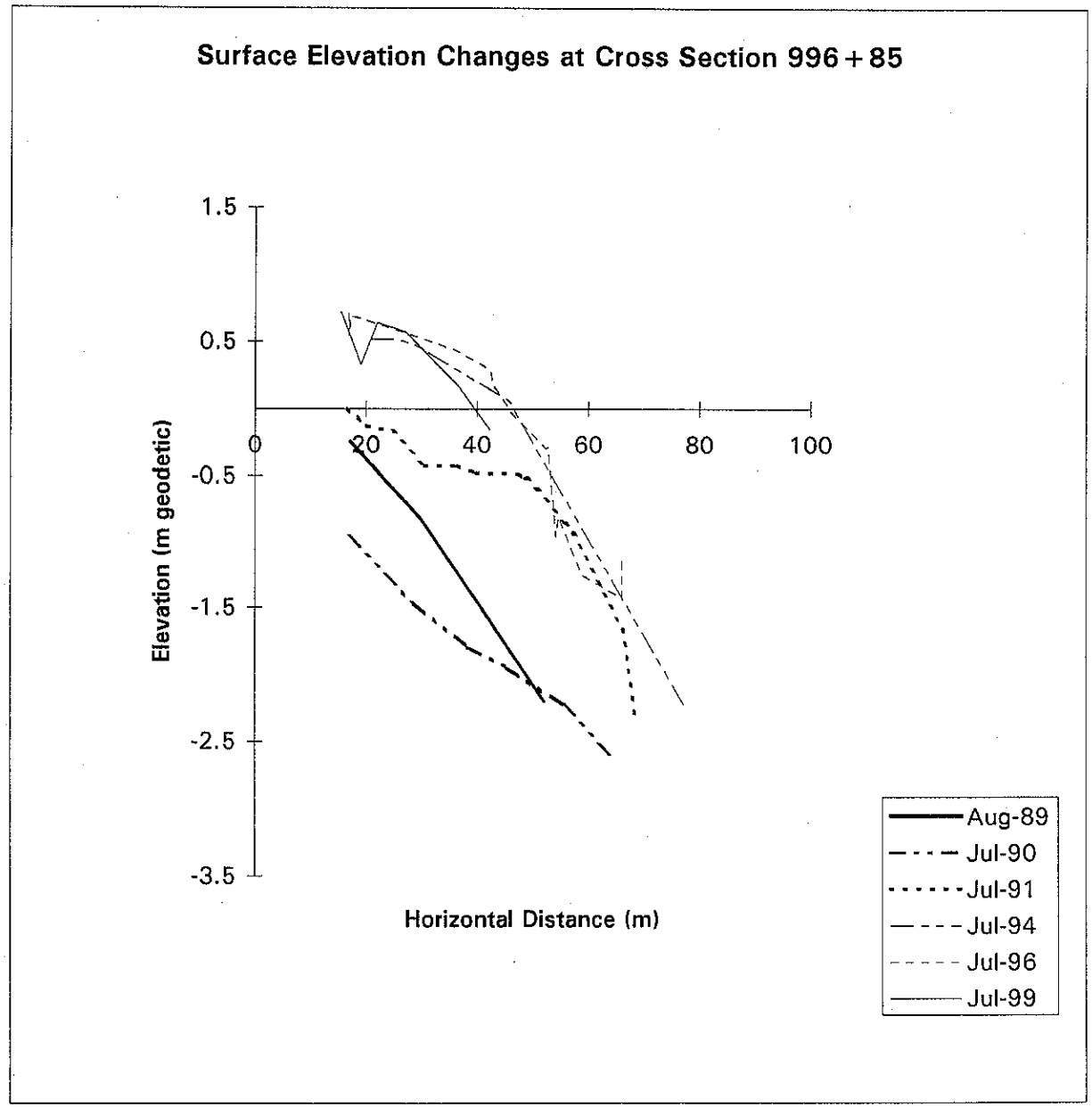
Cross sections 997+80, 998+00 amnd 998+15 intersect, or are closely approached by, a deep drainage channel that carries surface run off from the rock quarry accross the highway.

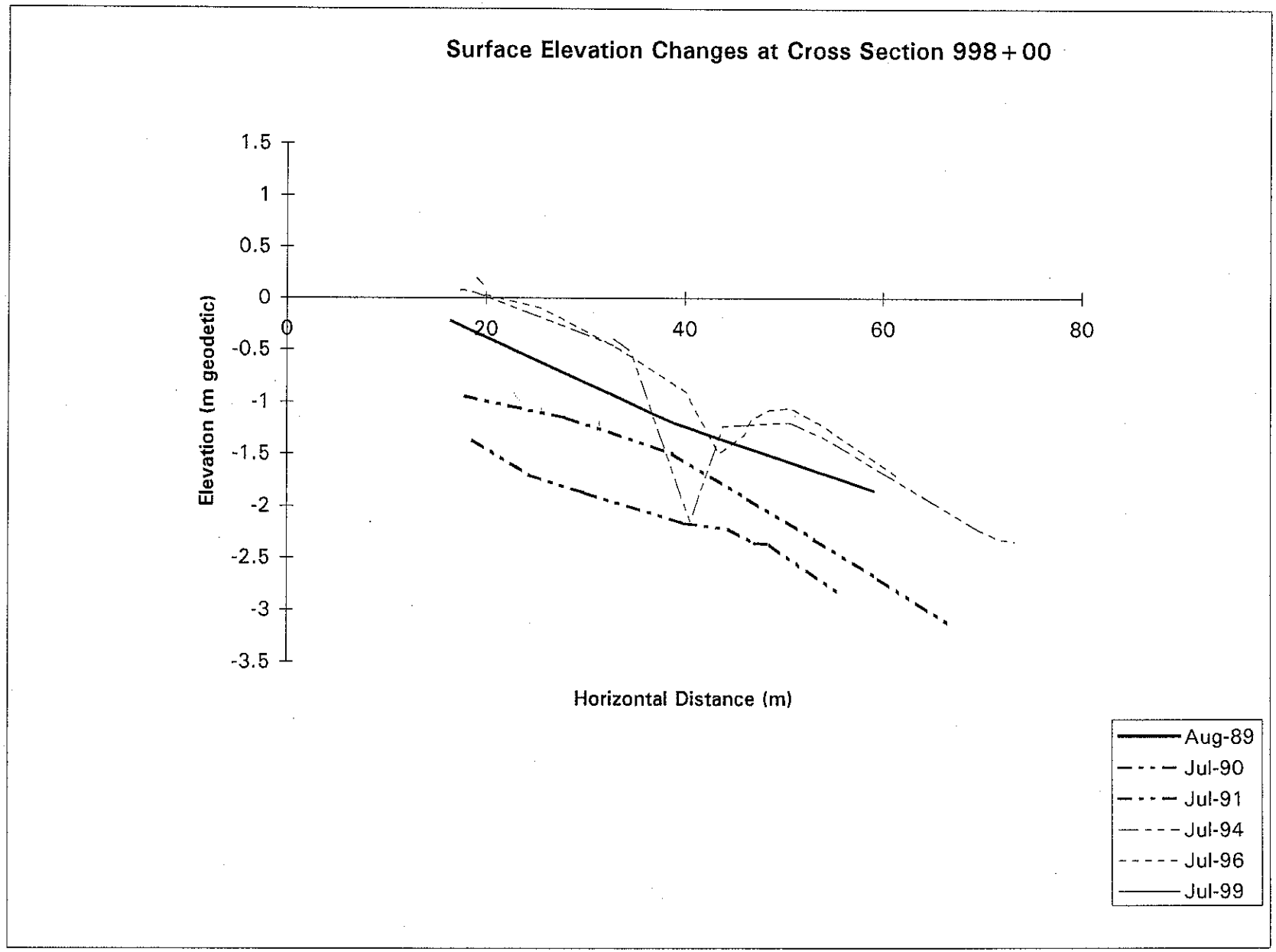

Surface Elevation Changes at Cross Section 995 + 20
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-4.5
0
10
20
30
40
50
60
70
80
Elevation (m geodetic)
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99

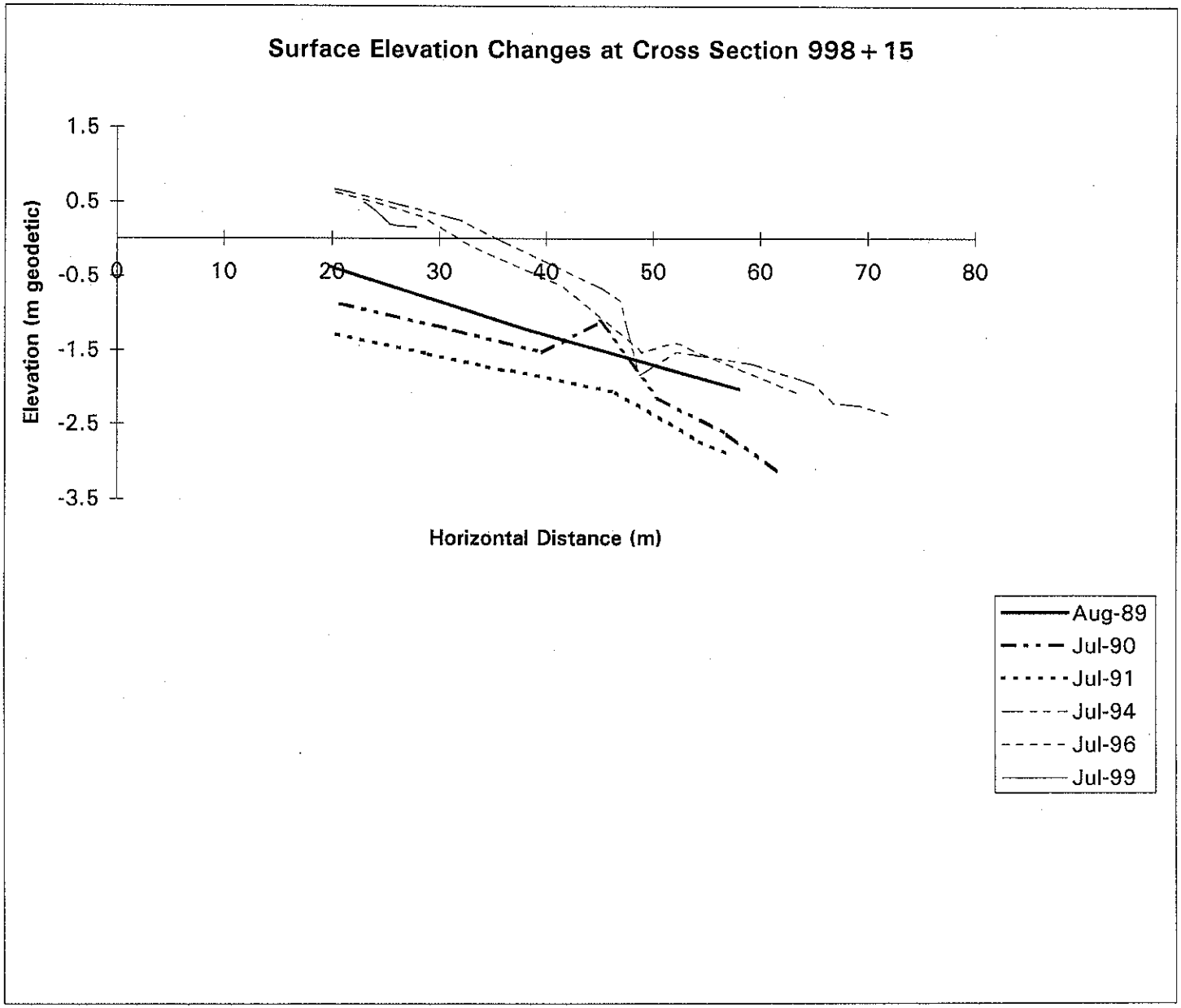

Surface Elevation Changes at Cross Section 995+55
1.5
0.5
-0.5
-1.5
-2.5
-3.5
0
20
40
60
80
Elevation (m geodetic)
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 996 + 00
1.5
0.5
-0.5
-1.5
-2.5
-3.5
0
20
40
60
80
Elevation (m geodetic)
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 996+40
1.5
0.5
-0.5
-1.5
-2.5
-3.5
0
20
40
60
80
Elevation (m geodetic)
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99

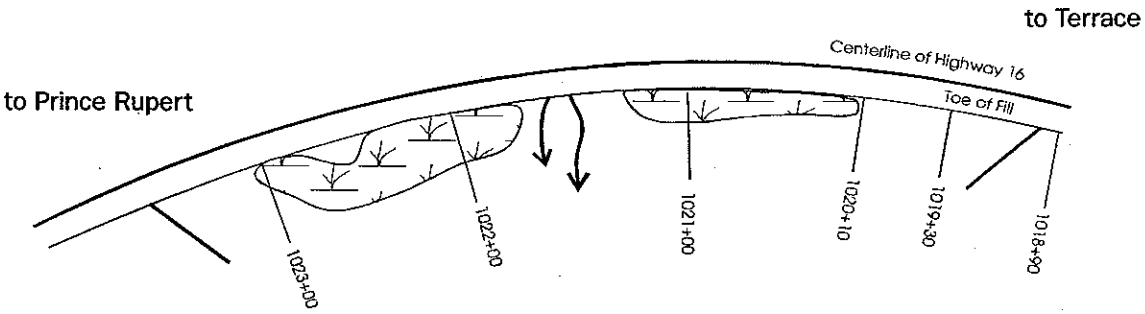

Surface Elevation Changes at Cross Section 996+85
1.5
0.5
-0.5
-1.5
-2.5
-3.5
Elevation (m geodetic)
0
20
40
60
80
100
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 998+00
Elevation (m geodetic)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0
20
40
60
80
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 998+15
Elevation (m geodetic)
1.5
0.5
-0.5
-1.5
-2.5
-3.5
0
10
20
30
40
50
60
70
80
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99

The West Marsh Area

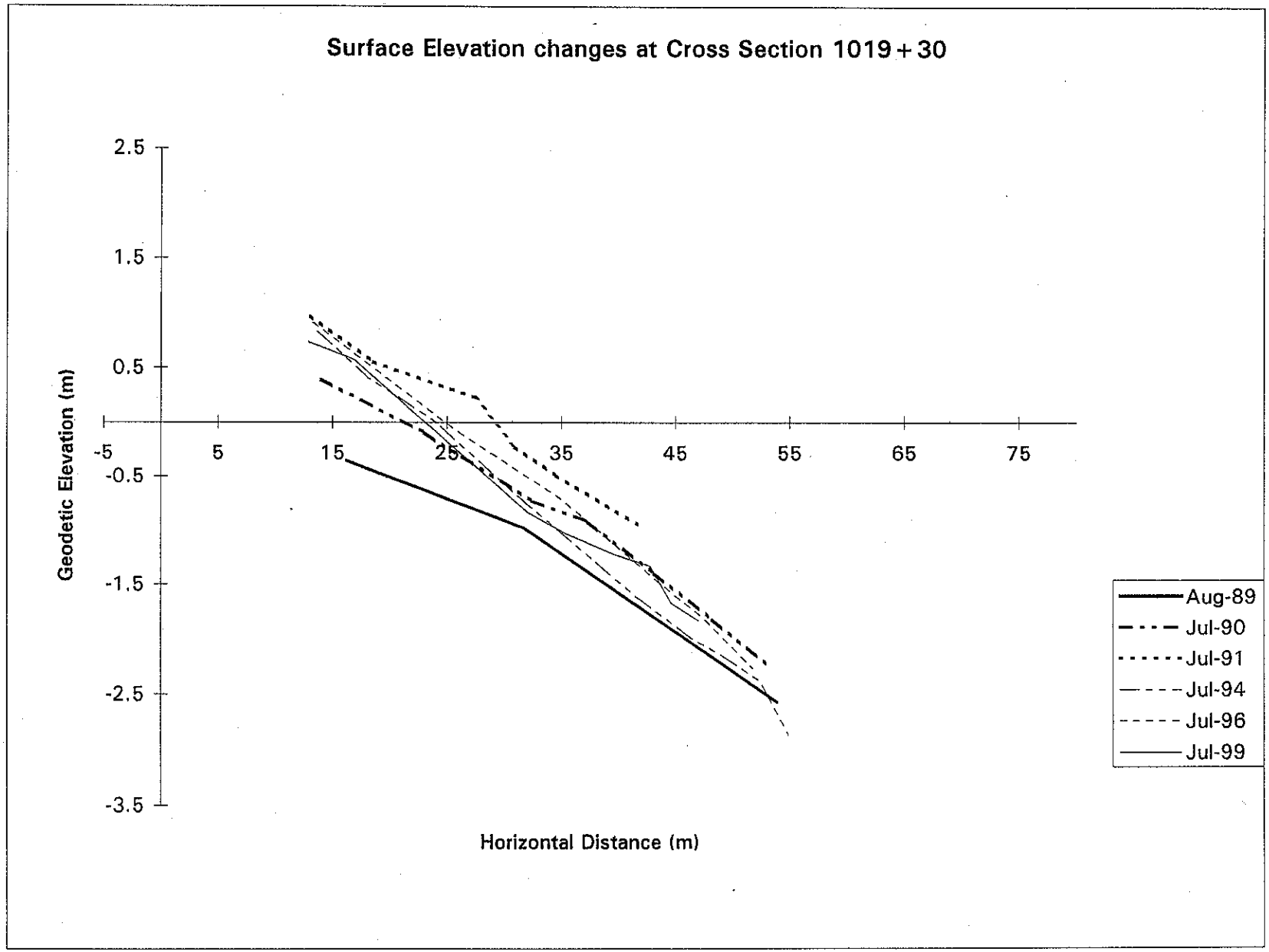
Location of cross sections:

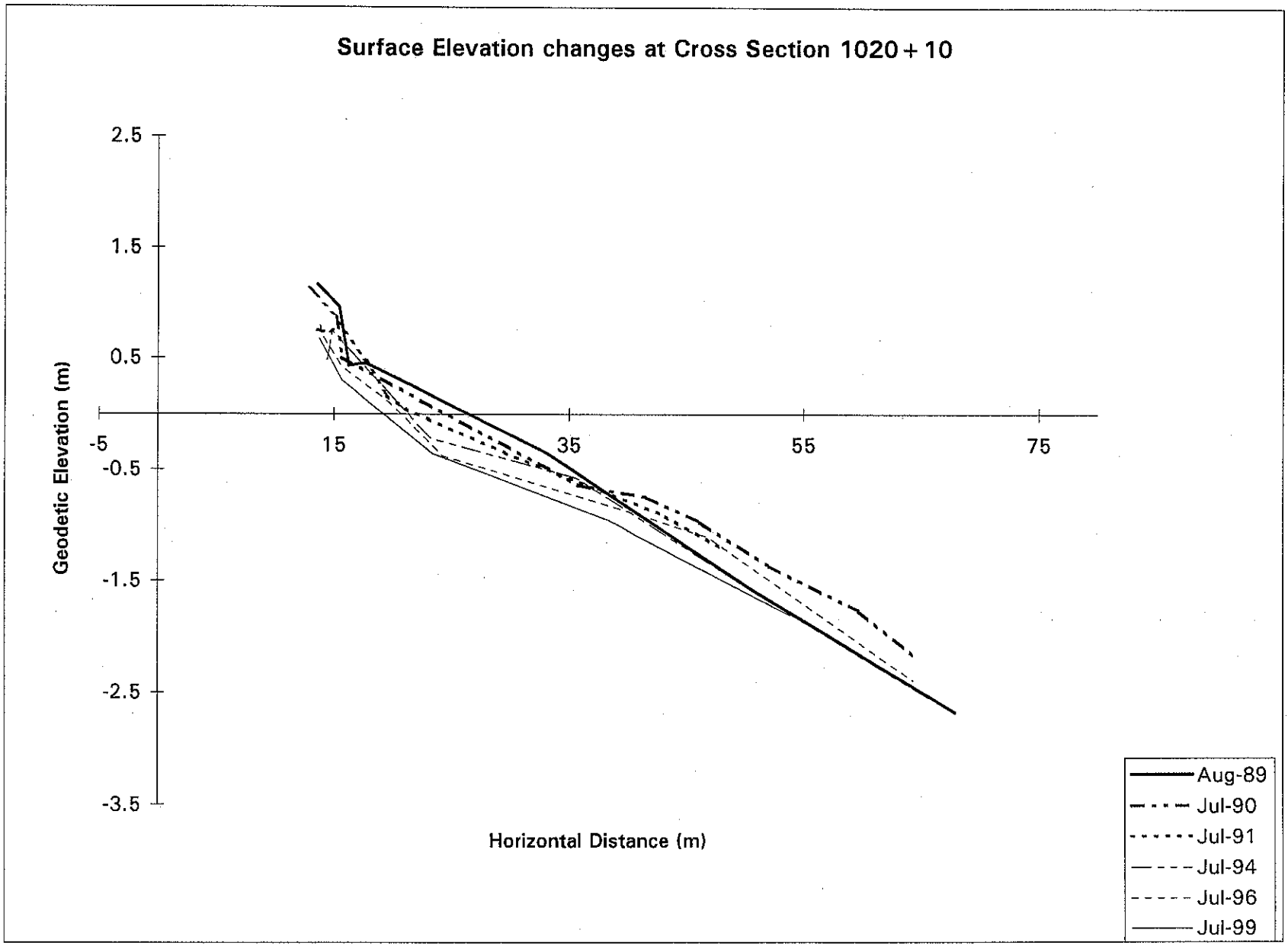


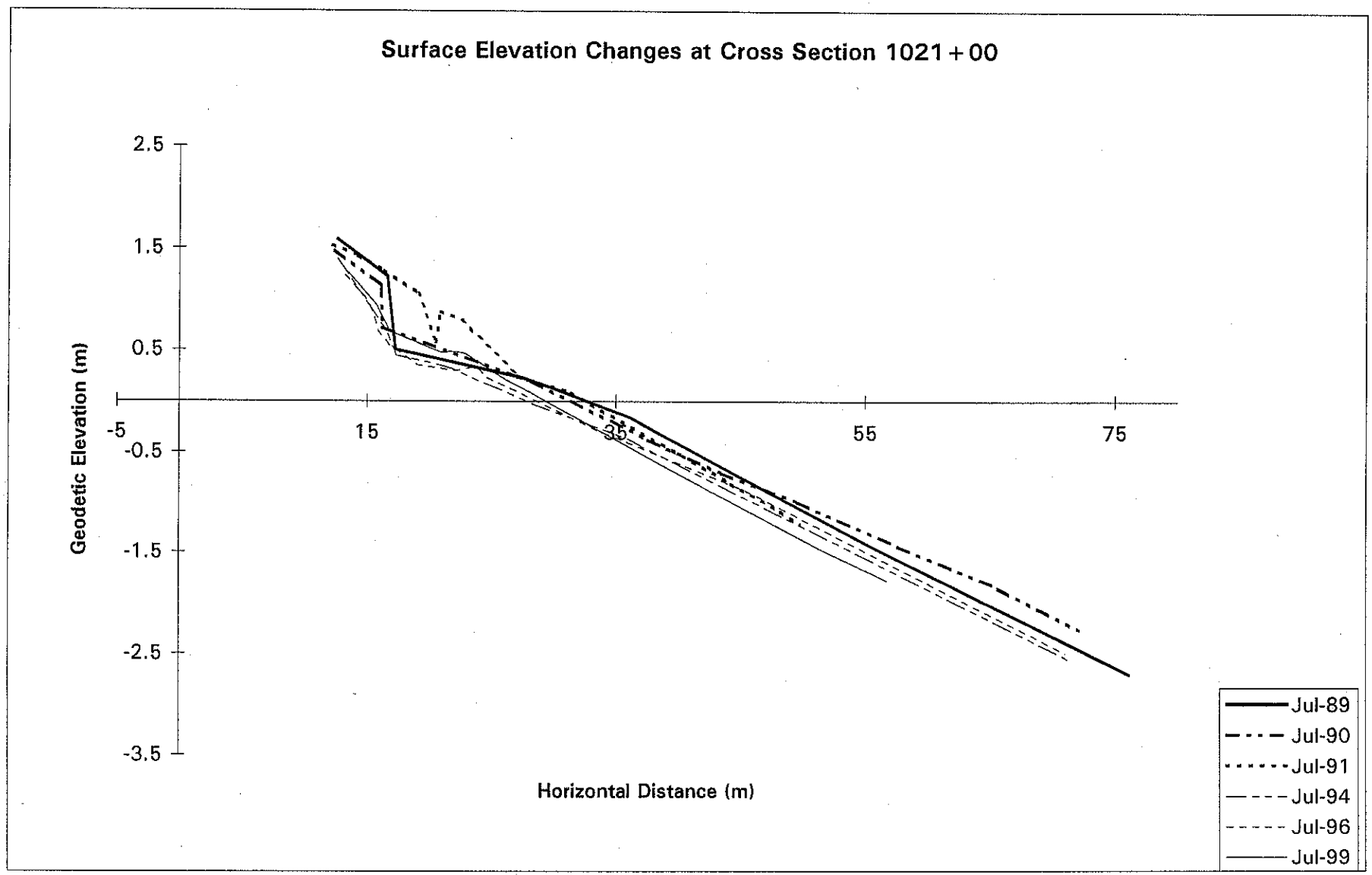
Approximate location of areas of riparian vegetation

Approximate location of drainage hannels

Note: drawing not to scale


Surface Elevation changes at Cross Section 1019+30
Geodetic Elevation (m)
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-5
5
15
25
35
45
55
65
75
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation changes at Cross Section 1020 + 10
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-5
15
35
55
75
Geodetic Elevation (m)
Horizontal Distance (m)
Aug-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99


Surface Elevation Changes at Cross Section 1021 + 00
Geodetic Elevation (m)
2.5
1.5
0.5
-0.5
-1.5
-2.5
-3.5
-5
15
35
55
75
Horizontal Distance (m)
Jul-89
Jul-90
Jul-91
Jul-94
Jul-96
Jul-99