1. Executive Summary

1.1 Background

A monitoring requirement of the Waikanae Floodplain Management Plan (WFMP) is that the Council survey river cross-sections, at approximately five yearly intervals. The cross section survey extends from the mouth to the Kapiti Coast District Council (KCDC) water treatment plant weir, and its purpose is to monitor bed level changes. These cross-sections were initially surveyed in 1991 and subsequently in 1995, 1999 and 2004. The results of the 1999 survey were reported to this Committee in June 2000 (Report 00.475). The levels from the latest survey (2004) have now been analysed and are reported below. This report summarises the survey results, highlights the issues raised, and outlines the proposed actions.

1.2 Summary of survey results

A comparison of the 1991, 1995, 1999 and 2004 cross section surveys has been undertaken. The results were reported to the Landcare committee in May 2005 in report No 05.172. The Landcare report forms the basis of this executive summary.

Attachment 1 to this report shows the gravel volume and bed level changes between sections from the mouth to the water treatment weir. **Attachment 2** shows the general location of the cross-sections.

The results show a continuation of the general trend of aggradation from the mouth to Jim Cooke Park (JCP) (section 300) and degradation above this point. This is much the same trend as was observed after the 1995 and 1999 survey.

The results show an overall net increase of gravel in the survey reach below Jim Cooke Park of 33,000m^3 between 1999 and 2004 and a decrease in the volume of gravel above Jim Cooke Park of 10,000m^3. Since the initial survey in 1991, the volume of gravel build up downstream of Jim Cooke Park is in the order of 83,000m^3 despite the extraction of 38,000m^3 of gravel in that period.

The volume of gravel degradation above Jim Cooke Park is significantly less than occurred in the period 1995-1999 indicating that the bank protection works and bed level controls installed following the October 1998 floods have reduced the gravel supply from the reach. In the 1995 – 1999 period approximately 40,000m^3 of gravel was degraded from the area whereas only 10,000m degraded from the area in the period 1999-2004.

A total of 15 of the 59 sections were resurveyed immediately following the January 2005 floods. This resurvey showed there was significant gravel movement that can be attributed to the single flood event. In the downstream reach some mean bed levels increased by approximately 300-400mm. No significant changes were noted in the upstream reach above Jim Cooke Park most likely due to the fact that only a few cross sections were resurveyed in this reach. However post flood inspections showed a substantial length of bank erosion between Section 500 and 510 just below the water treatment plant and that the foundations of the SH1 to Maple Lane works have been exposed and will need reconstruction.

1.3 Issues raised by the survey results

The aggradation below JCP is continuing at a significant rate and causing concern to residents in that reach. Our analysis has shown that the loss of flood capacity in major floods is not that significant but that there is a measurable loss in the smaller 10-40 year return period events. The gravel is also migrating further downstream into the Scientific Reserve where the bed of the river

has traditionally been sand based. This gravel will influence the behaviour of the mouth during flood events.
Extraction is considered the only viable way of addressing the gravel accumulation in the lower reaches in the short to medium term. Greater control of vegetation cover in the upper catchment may help in the longer term but more analysis of the erosion areas would have to be undertaken to ascertain what benefit this would have. During the January 2005, storm bush covered catchments eroded as well as pasture land, however the relative areas have not yet been assessed. It needs to be acknowledged that erosion from the upper catchment and deposition in the lower reaches is a natural process. Additionally unless the lower reaches of the river are allowed more room to meander, and deposit gravels over a wide area ongoing extraction will be required.
The degradation above JCP is also continuing and will continue into the future. No extraction is undertaken in this reach. The degradation is a result of the increased erosion capacity of the river now that is confined to a single channel and flood flows no longer spread over the floodplain. Additional bed level control structures and bank protection measures are likely to be required to minimise further lateral erosion in the future.

1.4 The proposed new extraction programme

1.4.1 The current policy

The Waikanae Floodplain Management Plan recommends that material be extracted from the river at approximately the same rate as it is accumulating. This is in an attempt to maintain overall bed levels at the status quo (the 1991 surveyed levels). Outcome ***3.3.4 Gravel Extraction*** of the plan states:
"Review the amount available for annual extraction on the basis if the results of the river cross section surveys and an inspection of the river condition. (The amount of gravel extracted over the longer term, will depend on the findings of five yearly bed level analysis). The aim is to ensure that the total gravel balance below the KCDC water treatment plant is maintained at the status quo."

1.4.2 Our proposed approach over the next five years

The current ongoing annual extraction volume is set at 3000m^3. This is authorised under resource consent Wellington.
In addition to the annual extraction, a separate resource consent (WGN 020106) was obtained to extract a further 35,000m^3, over five years, from the lower Waikanae River to remove the gravel build-up that occurred following the 1998 floods. The 35,000m^3 is planned to be completed by May 2006.
Our analysis of the survey results, as set out in Section 3, shows that the ongoing annual extraction volume should be increased to 9000m3 per year in the lower river to maintain the flood capacity. These calculations are based on removing the ongoing build-up of gravel from Section 40 (the coastal marine boundary and the limit of the river covered by the Operations and Maintenance consent) to cross section 300.
It should be noted that the current effective annual extraction rate (under both resource consents) is about 10,000m3 per year.

1.4.3 Work required to implement the increased extraction rate

Preparatory work required to implement the increased extraction will include:

- Completing the survey analysis technical report, including possible peer review.

- Confirm the reach of the river over which the extraction will actually take place. It is expected that the extraction will generally be within the reach from Section 220 to Section 70. By extracting in this reach we should minimise the requirement to work in the coastal marine area.

- Apply for an amendment to our operations and maintenance resource consent to enable extraction from below water level. The current consent only enables extraction from dry beaches (100mm above normal water level) which will only cover about half the proposed extraction reach. The methodology proposed for extracting below water will be similar to that contained in the one off consent (WGN 020106) we already have to extract the 35,000m^3 following the 1998 flood.

Supply the results of the survey to the Department of Conservation and discuss with them the implications. If appropriate, seek their approval to proceed with extraction in the tidal reach of the Waikanae River. This approval would be sought as part of an overall agreement to undertake river management works in the Scientific Reserve.

1.5 Other proposed actions

In the longer term we should investigate further the source of the gravel that is accumulating in the lower river and the transport processes that gets it there. We also should consider options for mitigating the degradation that is occurring above Jim Cooke Park.
Accordingly we think that the 10 year WFMP plan review programmed for 2006/07 should include:

(a) A study of the impacts of the erosion in the upper catchment following the January 2005 flood to determine what benefits would be gained from greater controls on vegetation cover in the upper catchment.

(b) Reconsider the river training approach above Jim Cooke Park to determine whether more bed controls structures may be required to minimise bed level degradation.

2. Contents

LIST OF TABLES

LIST OF FIGURES

3. Introduction

The Waikanae Floodplain Management Plan (WFPMP, 1997) requires that a full cross-section survey be undertaken on the Waikanae River every 5 years or following a 20-year flood event. This cross-section data is used to monitor gravel movement within the river.

Full river surveys have been carried out in 1991, 1995, 1999, and 2004. The following report analyses the data from all four surveys to determine volume and bed level changes in the river. The gravel inflow rate for the river is calculated and used to determine the gravel extraction rate for the next five years. Following the January 2005 flood 25% of the cross sections were resurveyed and these results are also discussed. The January 2005 flood is estimated to have been an 80 year return period event. Only 25% of the cross sections were resurveyed following the event because of budget constraints.

4. Background

The Waikanae River – River Characteristics and Sedimentation report (Williams, 1992) and the Waikanae River Gravel Analysis: 1991-1999 report (Kennedy, E., 2000) looked at the data available and made assessments of the gravel movement trends in the Waikanae River. The assessments in this report have now been updated based on the latest data from the 2004 full cross-section survey and the 2005 part survey. The locations referred to in this report are shown in Figure 4.1 and on the aerial photos in Attachment A.

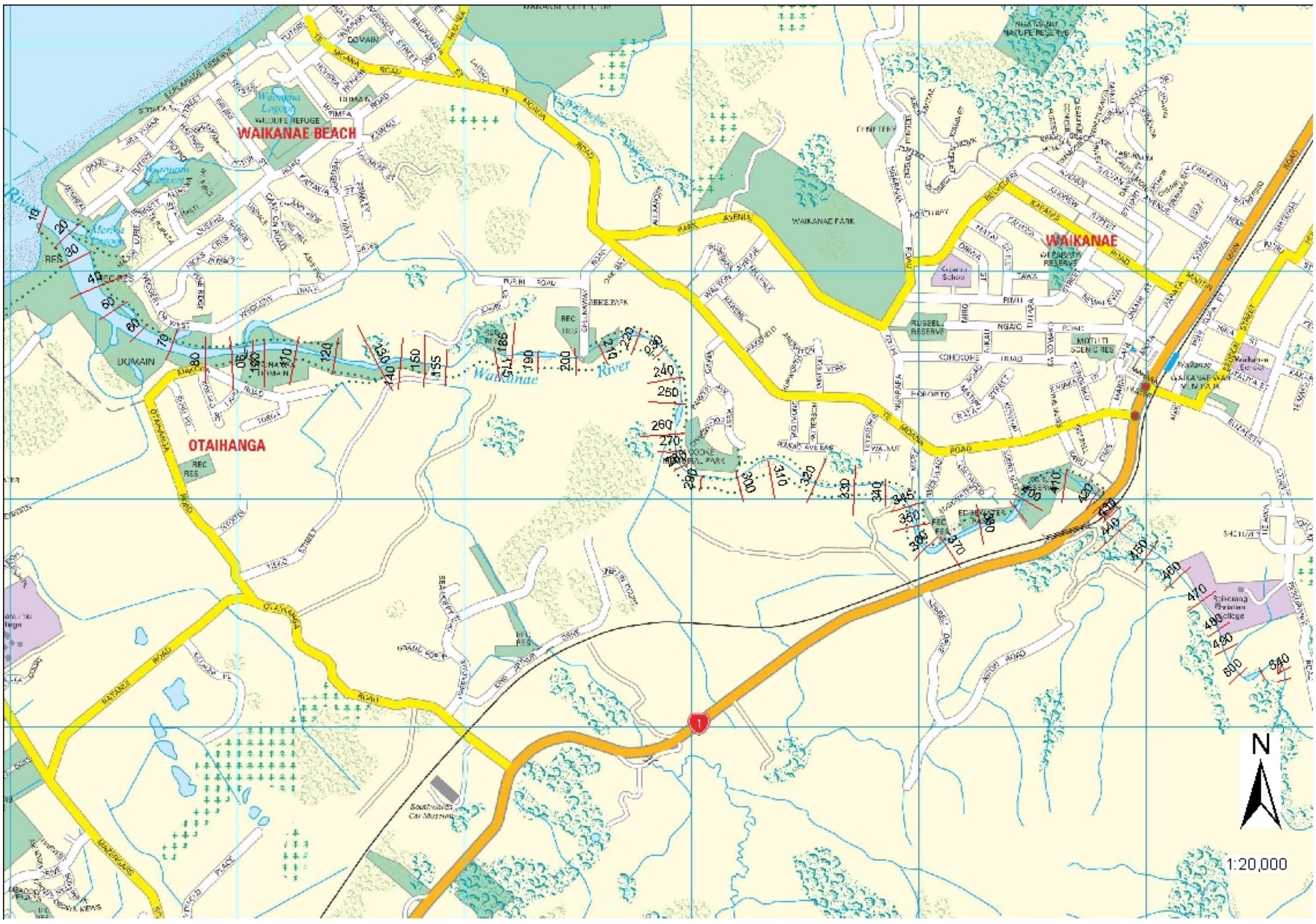

Figure 4.1: The locations of the Waikanae River

4.1 Catchment and River Characteristics

The Waikanae River catchment covers an area of land west of the Tararua Range that contains range land and terraced gravel deposits. The steep catchment still has forest cover and there is little catchment erosion, therefore most of the gravel in the river system comes from stream bank erosion and channel reworking. A significant estuary exists at the river mouth, and longshore drift down the Kapiti Coast tends to cause the mouth to migrate south (Williams, 1992). No gravels are evident in the estuary or along the coast in this area indicating the river configuration and flows are insufficient to transport the gravel through the estuary to the coast.

4.2 Cross-Section Surveys

4.2.1 2004 Survey Report

This survey started in November 2004 comprising re-stablishment of 32 Sighting points, and survey of 59 Cross Sections. The early completion of Field work by Landlink enabled the re-survey of 15 Cross Sections in January 2005 following an early January flood event. Survey started at the Mouth and proceeded towards the Treatment Plant. The Mouth reach was surveyed first as gravel extraction works was scheduled to begin in February 2004. The survey was ahead of schedule & very well organised. This allowed for additional survey work to be completed by Landlink immediately following a Jan 2005 flood. All work was completed under budget & within designated timeframes. Final data was supplied before 25 Jan 2005. All documentation relating to the survey was placed on file N/6/9/9.

4.3 Data Analysis Software

Previous analyses of rivers in the Wellington region have been conducted using software called Ricoda. However, there are a number of issues with this software, and it was decided in June 2004 that the Windows-based Hilltop software would be used instead.

Volumes in Hilltop are calculated using the End Area Method. The formula for the End Area Method is

$$V = \frac{d\left(A_1 + A_2\right)}{2}$$

Where the variables are as shown in Figure 4.3.1. This method can be easily checked manually to ensure Hilltop is giving correct results.

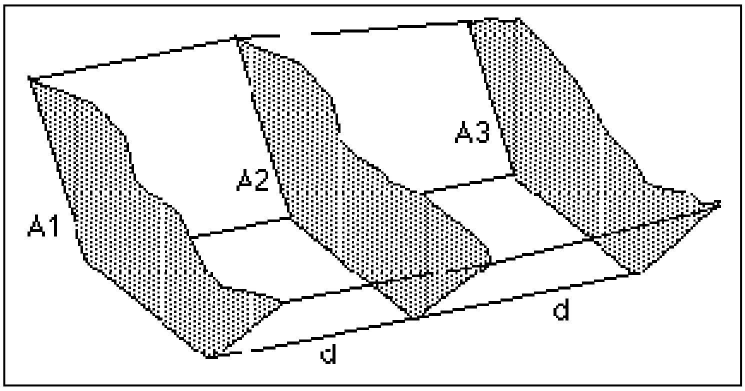

Figure 4.3.1.: End Area Method.

5. Summary of Results

5.1 Channel Characteristics

The changes in grade of the Waikanae River for 2004 are shown in Table 5.1 below, along with the values from previous survey periods for comparison. It can be seen that the trends in grade are very similar between all the surveys, although the slope in the lower reaches between the mouth and section 120 seems to be decreasing.

Table 5.1: Changes in grade of Waikanae River.

Cross-section range	1991	1995	1999	2004
0-120	0.07	0.07	0.06	0.04
120-300	0.33	0.34	0.33	0.33
300-550	0.58	0.61	0.62	0.59

5.2 Analysis of Gravel Change

The net volumes of aggradation or degradation between 1999 and 2004 were calculated for all cross-sections between the mouth (Section 10) and the Water Treatment Plant (Section 550). The values for the 1991-1995 and 1995-1999 survey periods have been taken from the previous gravel analysis reports.

Figure 5.2.1, Figure 5.2.2 and Figure 5.2.3 shows the gravel volume changes over the whole river from 1991 to 2004. The volume for a particular section is calculated between that section and the previous (downstream) section. This in effect averages out the more obvious changes in bed level at individual sections.

By comparison, Figure 5.2.4 and Figure 5.2.5 shows the mean bed level changes from 1991 to 2004 calculated at each individual section, but does not include any information about what has happened between cross-sections.

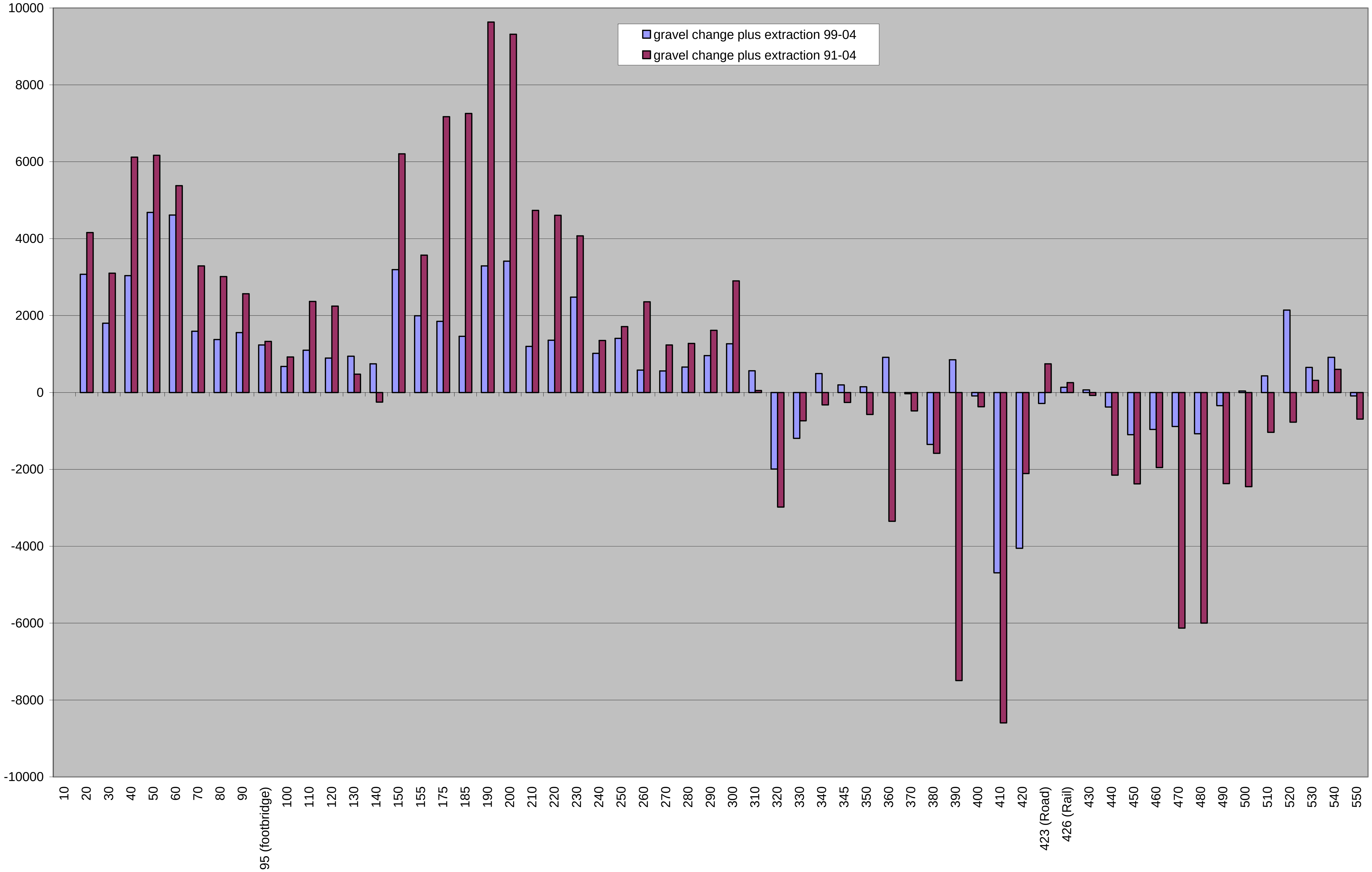

Figure 5.2.1: Gravel volume changes between 1991 and 2004, and 1999 and 2004.

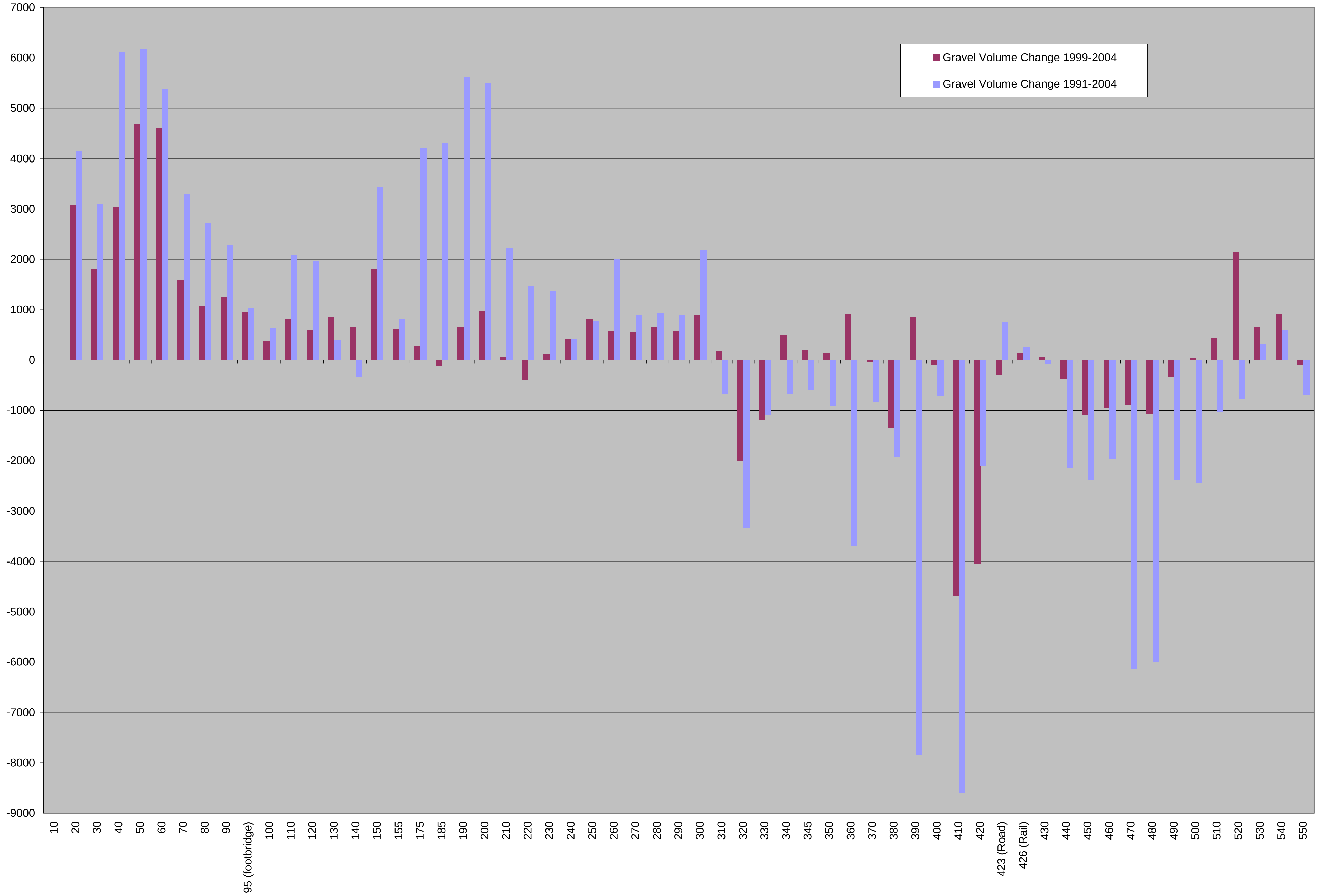

Figure 5.2.2: Gravel volume changes between 1991 and 2004, and 1999 and 2004.

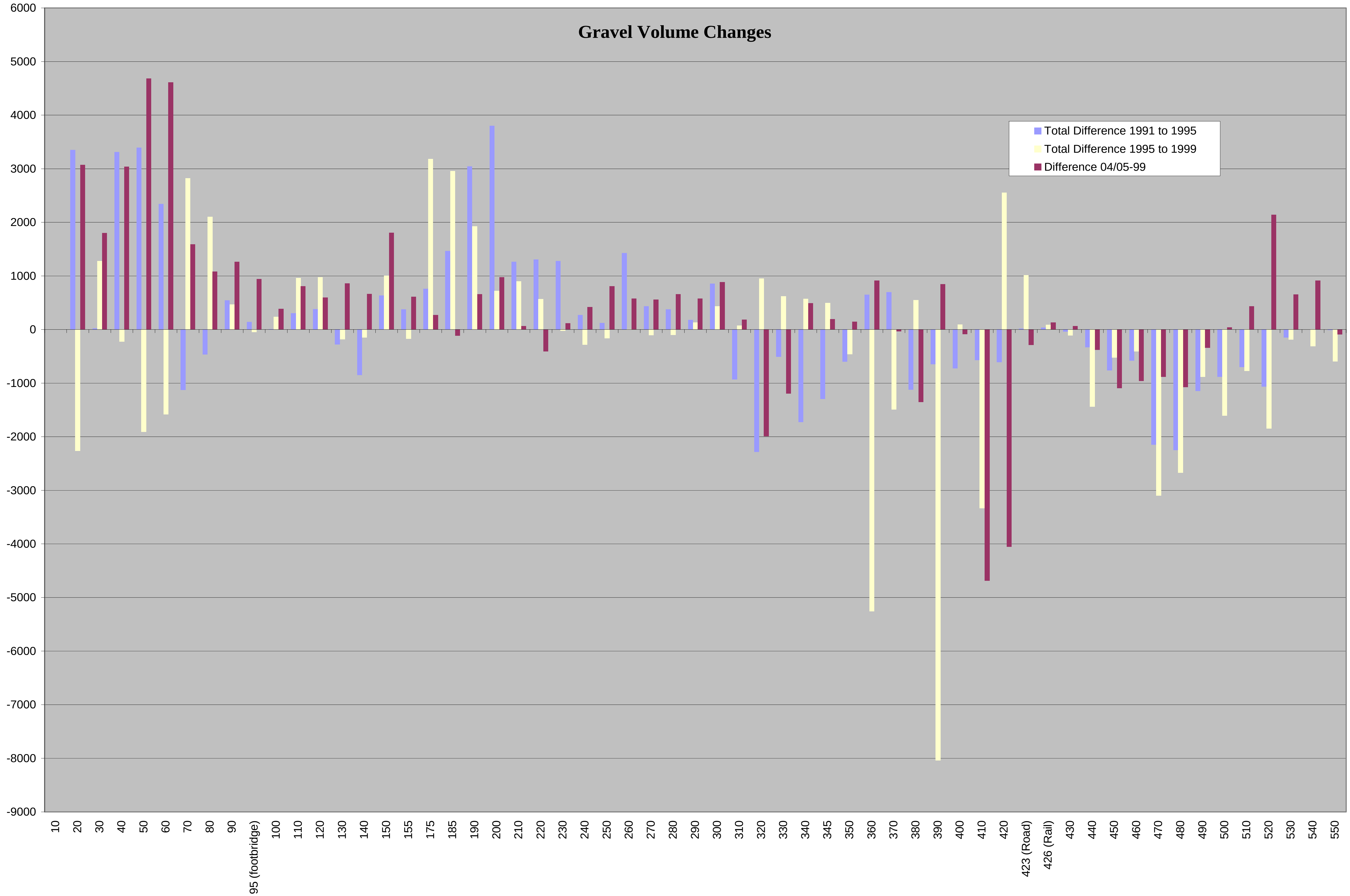

Figure 5.2.3: Gravel volume changes from 1991 to 1995, 1995 to 1999, and 1991 to 2005.

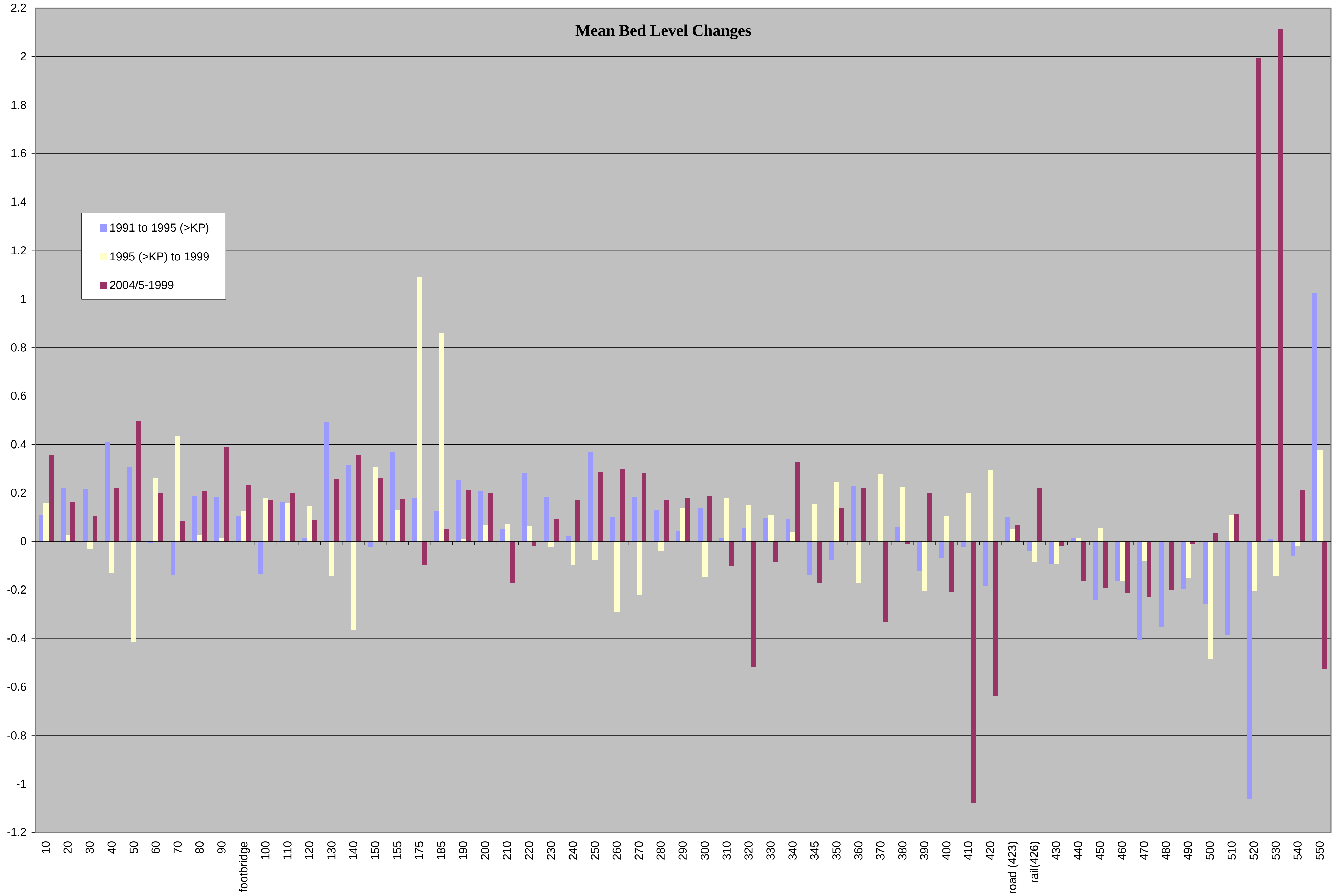

Figure 5.2.4: Mean bed level changes from 1991 to 1995, 1995 to 1999, and 1999 to 2004/05.

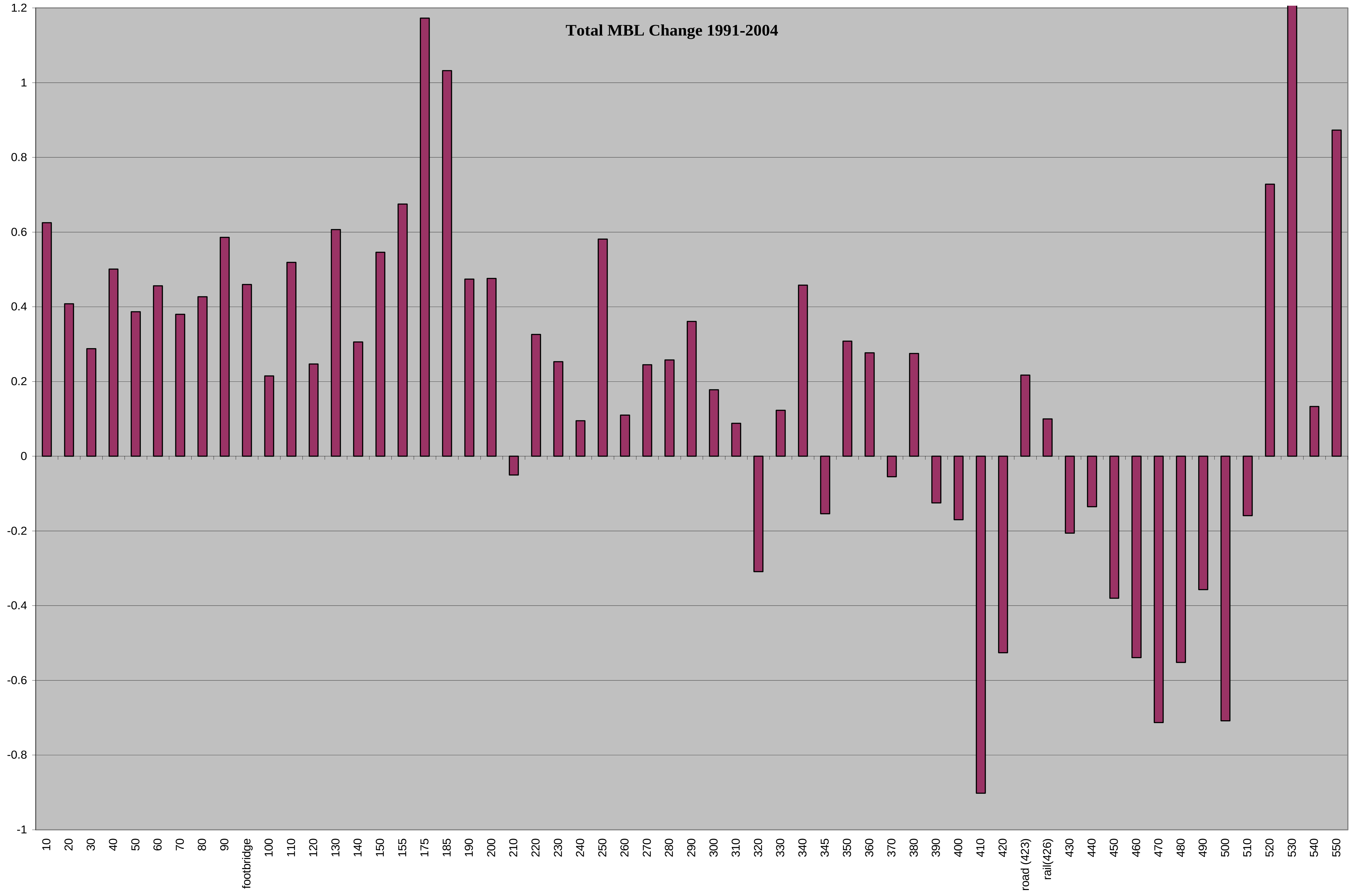

Figure 5.2.5: Total mean bed level changes from 1991 to 2004/05.

Because of the difference in calculation methods between mean bed levels and volumes, the trends for volume changes can show up one section behind those for mean bed level changes.

These figures give a good indication of the overall trends, but can miss specific areas that may have changed dramatically. It is assumed that the sections are spaced closely enough to minimise any such information loss.

5.2.1 Otaihanga Reach (10-80)

In the 1991 to 1995 survey period, this reach experiences aggradation to section 60, and then small amounts of degradation between section 60 and section 80. The volume of aggradation was approximately 12,430 m^3 and the volume of degradation was 1,595 m^3, giving a total volume change for the reach of 10,835 m^3. The average mean bed level increase through this reach was 0.163 m, while the maximum increase was 0.409 m at section 40.

During the 1995 to 1999 survey period, the reach experienced both aggradation and degradation, with no obvious trend. The total aggradation volume was 6,210 m^3, while the degradation volume was 5,990 m^3, giving a total volume change of approximately 220 m^3. The average mean bed level change through the reach was only 0.042 m, while the maximum bed level increase was 0.437 m at section 70, and the maximum decrease was 0.415 m at section 50. This small total increase in both volume and mean bed level may have been due to the Kauri-Puriri works upstream, which removed a large amount of gravel from the river bed. It may also have been due to the October 1998 flood events flushing the gravel in this reach out to sea.

In the 1999 to 2004 survey period, it can be seen from Figures 5.2.1 and 5.2.5 that both volume and mean bed level values have increased consistently throughout this reach. There was a total gravel volume increase of approximately 19,880 m^3, and the mean bed levels increased by an average of 0.229 m over the reach. The maximum bed level increase was 0.496 m at section 50. This trend of aggradation would seem to be the normal response for this section of the river, possibly due to the flattening of the river grade at approximately section 120.

There was a small amount of lateral erosion (approximately 180 m^3) on the left bank between sections 40 and 60. There was also a small amount on the right bank at section 60, with a volume of 120 m^3.

The flood in January 2005 may have altered this reach significantly. The sections surveyed in 2005 are shown in Attachment B. Section 20 shows considerable degradation between the 2004 and 2005 surveys. Other surveyed sections in this reach (40, 70, and 80) show less degradation, but also increased lateral erosion.

5.2.2 El Rancho Reach (80-150)

During both the 1991-1995 and 1995-1999 survey periods, this reach experiences mostly aggradation, with occasional sections experiencing degradation.

For the 1991-1995 period, the aggradation volume was 2,010 m^3 and the degradation volume was 1,130 m^3, giving a total volume increase of 880 m^3. The average mean bed level change through this reach was an increase of 0.139 m, with a maximum bed level increase of 0.492 m and a maximum decrease of 0.135 m.

In the period between 1995 and 1999, the volume of degradation was only 380m^3, while the volume of aggradation was 3,650 m^3, giving a total volume increase of 3,270 m^3. The average mean bed level change for this survey period was an increase of 0.052 m. The maximum bed level increase was 0.305 m, while the maximum decrease was 0.364 m. In the 1999/2000 gravel analysis report (Kennedy, E., 2000), it was identified that a significant portion of the volume increase in the 1995-1999 period occurred on the berms rather than in the channel.

In the 1999-2004 survey period, it can be seen from Figure 5.2.1 that the volume through this reach has consistently increased, with a total gravel volume change of 7,330 m^3. The mean bed levels have also increased consistently, giving an average increase over the reach of 0.245 m and a maximum increase of 0.389 m at section 90.

There was no lateral erosion in this reach between 1999 and 2004.

Section 100 and section 140 were also surveyed in the 2005 survey. Section 100 shows increased channel asymmetry, with a higher beach on the left side of the active channel, and a lower channel on the right side. The overall volume change is minimal. The bed level at Section 140 has increased slightly.

5.2.3 Kauri-Puriri Reach (150-260)

In the 1991-1995 period, this reach experienced significant aggradation, with a total volume increase of 15,120 m^3 and an average mean bed level increase of 0.177 m. This part of the river had previously had problems with aggradation.

During the 1995-1999 period, the Kauri-Puriri works were constructed. These works, constructed in 1997, included a stopbank, a river realignment that shortened the reach by 45 m, and grade control structures to prevent scour. Approximately 11,000 m^3 (Kennedy, E., 2000) of river gravel was extracted from this reach during construction. Over the survey period, the reach shows some significant aggradation with short lengths of small amounts of degradation. The total volume change over the reach was an increase of 9,620 m^3. The average mean bed level increase was 0.176 m, which is very close to that of the previous survey period. It is difficult to predict how the Kauri-Puriri works may have influenced these trends.

In the 1999-2004 survey period, the reach shows mostly small amounts of aggradation, with degradation between sections 70-80, and 210-220. The aggradation shown through this reach is relatively minor in relation to previous survey periods, with an aggradation volume of 4,510 m^3, and a total volume increase over the reach of 3,985 m^3. The average mean bed level change over the reach is 0.122 m, with a maximum increase at section 260 of 0.299 m, and a maximum decrease of 0.172 m at section 210.

There has been approximately 370 m^3 of lateral erosion at section 240on the left bank, and approximately 610 m^3 at section 185 on the right bank.

Sections 220 and 260 were surveyed in the 2005 survey. Section 220 shows that the river has moved to the far right side of the channel, and has become narrower and deeper. There also seems to have been some build-up of the beach at the far left side of the active channel. At section 260, the bed level has dropped in the main channel, and built up significantly on the right bank berm. The left bank berm has also increased slightly.

5.2.4 Jim Cooke Park Reach (260-350)

Between 1991 and 1995, this reach experienced aggradation to section 300, and degradation from section 300 to section 350. As discussed in Section 5.1 of this report, section 300 is the point at which the river changes grade and flattens out, and therefore is a logical point for the river to change from aggradation in the lower reaches to degradation in the upper reaches. The volume of aggradation through this reach is 1,850 m^3, while the volume of degradation is 7,340 m^3, giving a total volume decrease of 5,490 m^3. The average mean bed level change is an increase of 0.054 m, with a maximum increase of 0.183 at section 270, and a maximum decrease of 0.138 m at section 345.

During the 1995-1999 period, the reach experienced mostly minor aggradation, possibly due to lateral erosion upstream caused by the October 1998 flood events. The degradation volume through this reach is approximately 665 m^3, while the volume of aggradation is 3,285 m^3, giving a total volume increase of 2,620 m^3. The average mean bed level change is an increase of 0.060 m, with a maximum increase of 0.245 m at section 350 and a maximum decrease at section 270 of 0.220 m.

Over the 1999-2004 period, the reach shows mostly minor aggradation, with degradation between section 310 and section 330. The average mean bed level change is an increase of 0.041 m, with a maximum increase of 0.327 m at section 340 and a maximum decrease at section 320 of 0.518 m. The volumes of aggradation and degradation through the reach are relatively similar, with 3,705 m^3 aggrading and 3,190 m^3 degrading, giving a total volume increase of only 515 m^3.

There has been a small amount of lateral erosion at section 280 on the left bank, with a total volume of 155 m^3. There has been more significant erosion on the left bank between section 340 and section 350, where a total volume of 875 m^3 has been eroded. There has also been lateral erosion on the right bank in several places. The most significant erosion has occurred between section 280 and section 300, with 1,345 m^3 of material eroded. There has also been approximately 575 m^3 of material eroded from the right bank at section 330.

In the 2005 survey, sections 300 and 340 were surveyed. At section 300, the river channel has shifted further towards the centre of the channel, with a beach building at the left bank while the beach on the right side of the channel has reduced in size. At section 340, the large mound on the right side of the channel (offsets 50-60) is a rock groyne. The 2005 survey shows this groyne has changed shape dramatically, which may be damage from the January 2005 flood event. The river has split into two distinct channels here, with the river bed in the left channel building up, while the right channel has deepened past the toe of the groyne.

5.2.5 Below SH1 Bridge (350-420)

This reach is generally characterised by degradation, with a loss of 2,325 m^3 in the 1991-1995 period, and 14,920 m^3 in the 1995-1999 period. There was significant aggradation (2,555 m^3) between sections 410 and 420 in the 1995-1999 period.

The 1999-2004 period shows the same general trend of degradation, with reaches/areas of aggradation between sections 350 and 360, and 380 to 390. Significant degradation has occurred downstream of the bridges between sections 400 and 420. The volume of aggradation through this reach is 1,765 m^3, while the volume of degradation is 10,220 m^3, giving a total volume decrease of 8,455 m^3. The average change in mean bed level is a decrease of 0.263 m, with a maximum increase of 0.221 m at section 360, and a maximum decrease of 1.079m at section 410. This large decrease is partly due to the use of 2004 active channel widths as offsets for calculation, as these do not include the build-up on the right bank due to edge protection works. However, even including this, the bed level has still dropped dramatically through at this section between 1999 and 2004, with a bed level decrease of 0.831 m. Section 420 has also had a large bed level drop through this survey period.

There has been a significant amount of material removed from the left bank between sections 410 and 430, with a total volume of 1,980 m^3 of lateral erosion.

Sections 380 and 410 were surveyed in the 2005 survey. Section 380 shows a general build-up of gravel, both in the channel bed and on the right berm. Section 410 shows very little change between the 2004 and the 2005 surveys.

5.2.6 Above SH1 Bridge (420-550)

This reach is also characterised by degradation, with 10,010 m^3 lost from 1991 to 1995, and 13,360 m^3 between 1995 and 1999. Both survey periods show slight aggradation at the bridge sections, with an aggradation volume of 53 m^3 between 1991 and 1995, and 1,100 m^3 from 1995 to 1999.

In the 1999 to 2004 period, the reach shows degradation to section 490, and then aggradation to section 550. The volume of aggradation through this reach is 4,380 m^3, while the volume of degradation is 5,115 m^3, giving a total volume decrease of 735 m^3. The average mean bed level change is an increase of 0.214 m, with a maximum increase of 2.113 m at section 530, and a maximum decrease of 0.526 m at section 550. Section 520 also shows a large mean bed level increase of 1.992 m.

It is unclear what has caused the significant aggradation at section 520, as this section is directly below the weir and therefore more likely to experience scour than aggradation. The significant aggradation at section 530, shown in the mean bed level changes in Figure 5.2.5, is related to how the section (located at the weir at the Water Treatment Plant) was surveyed in 1999. This is clearly evident in the cross-section, shown in Attachment B. This has had a smaller effect on the volumes for both section 530 and section 540. Section 540 is affected due to the way volumes are calculated using the downstream section.

There has been lateral erosion of the left bank between section 440 and section 500, with a total volume of 1,265 m^3 of material eroded.

Sections 450 and 490 were surveyed in the 2005 survey. Section 450 shows a general increase in bed level within the channel, with significant lateral erosion of the right bank. Section 490 also shows significant lateral erosion of the right bank, with an increase in beach height on the left side of the channel.

5.3 Overall Volume Changes

Table 5.3.1 below shows the volume changes for each reach.

The volume change in the Otaihanga reach has fluctuated considerably, due to either a lack of material after the Kauri-Puriri works, or the October 1998 flood event. The next full survey may show a similar fluctuation, given the size of the 6 January 2005 flood event.

Aggradation in the El Rancho reach has been steadily increasing over each survey period, while in the Kauri-Puriri reach the amount of aggradation has been steadily decreasing. While it seems likely that the trend will continue in the El Rancho reach, it is uncertain if the same will occur in the Kauri-Puriri reach, as the changes are likely to have been influenced by the Kauri-Puriri works.

Table 5.3.1: Volume change in each reach from 1991 to 2004

Reach	Section Range	Change in Volume			
		1991-1995	1995-1999	1999-2004	1991-2004
Otaihanga	10 to 80	10834	218	19881	30933
El Rancho	80 to 150	882	3273	7329	11484
Kauri-Puriri	150 to 260	15118	9620	3986	28724
Jim Cooke Park	260 to 350	-5490	2618	516	-2356
Below SH1 Bridge	350 to 420	-2327	-14920	-8457	-25704
Above SH1 Bridge	420 to 550	-10011	-13359	-1734	-25104
Total	**10 to 550**	**9006**	**-12550**	**21521**	**17977**

The volume changes in the Jim Cooke Park reach have fluctuated over the three survey periods. This reach is likely to alter again in the next full cross-section survey, due to the Jim Cooke Park realignment work that is currently underway.
From section 350 onwards, the general trend of degradation is likely to continue, although the amount of degradation occurring seems to be quite variable.

6. RECENT FLOOD HYDROLOGY

Flood events in the Waikanae River are the major cause of lateral erosion of the river banks, and can also cause significant gravel movement within the river channel. A study of the flood events between surveys can give some idea of how flows may have influenced gravel movement.

Table 6.1 shows the distribution of flood events at the Water Treatment Plant recording station since 1991.

Table 6.1: The distribution of flood events since 1991

Flow (m^3/sec)	Jan 1991 - Jan 1995	Feb 1995 - Jan 1999	Feb 1999 - Dec 2004
100-150	2	3	4
150-200	2	1	5
200-250	0	0	0
250-300	0	1	0
>300	0	1	0

From the Table 6.1 it shows that no extreme floods between February 1999 and December 2004, and January 1991 and January 1995. There was one extreme size event of 304.457 m^3/sec happened on 21 October 1998. This may have destabilised the river system to some extent, leading to some increases in transport rates and affecting gravel movement and lateral erosion.

7. GRAVEL BALANCE AND SUPPLY RATES

Bed material continually moves down the channel, and a certain amount will pass through the mouth to the sea. The exact volume cannot be determined, but the total amount of bed material moved down the river must be greater than the net supply to the river channel.

This means an estimate of the gravel inflow from the Hutt Gorge and catchment can be inferred from the volume changes of bed levels and extraction quantities.

7.1 Active Channel Gravel Balances

Table 7.1 shows the gravel balance for the Waikanae River. These results show a total volume of approximately 41,765 m^3 of gravel has been deposited over the five years between 1999 and 2004. This is an average of approximately 8,350 m^3 per year.

Table 7.1: Gravel balance for Waikanae River

Extraction	19,243	m^3
Volume Change	22,522	m^3
Net Change (Total)	**41,765**	m^3
Net Change (Mean Annual)	**8,353**	m^3/year

7.2 Net Gravel Inflow Rate

The inferred inflow rate can be calculated from the gravel balance combined with the lateral erosion figures.

The total volume change for the Waikanae River between 1999 and 2004 is 41,765 m^3, including gravel extraction. The total volume of lateral erosion between 1999 and 2004 is approximately 7,480 m^3. The amount of soil included in the lateral erosion quantities needs to be removed so that only the gravel volumes are being counted. It is assumed that most of the soil in the eroded material has travelled in suspension through the river mouth and out to sea. It has been estimated that approximately 50% of the eroded material is soil (Kennedy, E., 2000). This gives an eroded soil volume of 3,740 m^3 and an eroded gravel volume of approximately 3,740 m^3 over five years.

Removing the gravel volume supplied by lateral erosion from the total gravel build-up in the river gives a total inflow of gravel of 38,025 m^3 over five years. This results in an inferred inflow rate of 7,605 m^3 per year.

The actual inflow rate is likely to be slightly greater because some gravel also travels right through the system and out the river mouth. However, this report is most concerned with the proportion retained by the system.

This is greater than previous calculated inflow rates of 3,000 to 5,000 m^3/year. However, comparison is difficult as these previous values do not appear to have taken lateral erosion into account when calculating inflow rates.

8. GRAVEL MANAGEMENT POLICIES

The Waikanae Floodplain Management Plan recommends that material be extracted from the river at approximately the same rate as it is accumulating. This is in an attempt to maintain overall bed levels at the status quo (the 1991 surveyed levels). Outcome ***3.3.4 Gravel Extraction*** of the plan states:
"Review the amount available for annual extraction on the basis if the results of the river cross section surveys and an inspection of the river condition. (The amount of gravel extracted over the longer term, will depend on the findings of five yearly bed level analysis). The aim is to ensure that the total gravel balance below the KCDC water treatment plant is maintained at the status quo."

The following recommendations have been developed to achieve these policies.

9. RECOMMENDATIONS

9.1 FUTURE SURVEYS

The following recommendations can be made for future surveys,

- All possible information should be provided to the surveyor, electronically if possible. 2 yearly colour Mosaics used on this survey proved their weight in gold providing GW & Landlink staff with excellent current Control, Sighting point, access, cross-section location & alignment location maps in respect to current ground conditions. GW Flood Protection Cadastral maps (W-215 / 1 to 4) were also supplied to the consultant

- Sight-lines should be cleared approx. 3 weeks prior to the cross-section field survey. Sight line alignments that can't be clearly defined in the field or from Mosaic aerials should be left for surveyors to set-out to enable accurate site-line clearing by Depot Staff.

- The sighting and control points should be checked during every survey, in order to retain the integrity of the control survey and the survey data.

- Due to the successful completion & experience gathered from the 2004 survey, Landlink Ltd. should be highly considered for future surveying work in 2009.

9.2 GRAVEL MANAGEMENT

9.2.1 Our proposed approach over the next five years

The current ongoing annual extraction volume is set at 3000m^3. This is authorised under resource consent Wellington.
In addition to the annual extraction, a separate resource consent (WGN 020106) was obtained to extract a further 35,000m^3, over five years, from the lower Waikanae River to remove the gravel build-up that occurred following the 1998 floods. The 35,000m^3 is planned to be completed by May 2006.
Our analysis of the survey results, as set out in Section 3, shows that the ongoing annual extraction volume should be increased to 9000m3 per year in the lower river to maintain the flood capacity. These calculations are based on removing the ongoing build-up of gravel from Section 40 (the coastal marine boundary and the limit of the river covered by the Operations and Maintenance consent) to cross section 300.
It should be noted that the current effective annual extraction rate (under both resource consents) is about 10,000m3 per year.

9.2.2 Work required to implement the increased extraction rate

Preparatory work required to implement the increased extraction will include:

- Completing the survey analysis technical report, including possible peer review.

- Confirm the reach of the river over which the extraction will actually take place. It is expected that the extraction will generally be within the reach from Section 220 to Section 70. By extracting in this reach we should minimise the requirement to work in the coastal marine area.

- Apply for an amendment to our operations and maintenance resource consent to enable extraction from below water level. The current consent only enables extraction from dry beaches (100mm above normal water level) which will only cover about half the proposed extraction reach. The methodology proposed for extracting below water will be similar to that contained in the one off consent (WGN 020106) we already have to extract the 35,000m^3 following the 1998 flood.

- Supply the results of the survey to the Department of Conservation and discuss with them the implications. If appropriate, seek their approval to proceed with extraction in the tidal reach of the Waikanae River. This approval would be sought as part of an overall agreement to undertake river management works in the Scientific Reserve.

9.3 Other proposed actions

In the longer term we should investigate further the source of the gravel that is accumulating in the lower river, and the transport processes that gets it there. We also should consider options for mitigating the degradation that is occurring above Jim Cooke Park.

Accordingly we think that the 10 year WFMP plan review programmed for 2006/07 should include:

(a) A study of the impacts of the erosion in the upper catchment following the January 2005 flood to determine what benefits would be gained from greater controls on vegetation cover in the upper catchment.

(b) Reconsider the river training approach above Jim Cooke Park to determine whether more bed controls structures may be required to minimise bed level degradation.

10. REFERENCES

Kennedy, E., Heiler, D. and Campbell, G. 2000. Waikanae River Gravel Analysis: 1991 to 1999. Wellington Regional Council, PO Box 11-646 Wellington.

WFPMP, 1997. Waikanae River Flood Plain Management Plan: The Community's Plan for the Waikanae River and its Environment. Publication No. WRC/RI-T-97/45. Wellington Regional Council, PO Box 11-646 Wellington.

Williams, G.J. 1992. G & E Williams Consultants. Waikanae River Floodplain Management Plan: River Characteristics and Sedimentation.

11. APPENDIX

Attachment A: Aerial Photos of Waikanae River
Attachment B: Cross sections of Waikanae River

Attachment A: Aerial Photos of Waikanae River

Attachment B: Cross sections of Waikanae River