Channel Morphology and Sedimentation in the Shag River, North Otago

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Foreword

Understanding the channel morphology and sedimentation characteristics of Otago's rivers enables their effective management. Increasing growth throughout the Otago region has implications for the management of river systems, primarily the extraction of gravel and flood hazard effects.

The Otago Regional Council (ORC) undertakes scheduled cross-section surveys of selected rivers as part of its natural hazards programme. This information is utilised to understand the dynamic fluvial processes of each river and general state of the gravel resource.

This report explores how the morphology and sedimentation of the Shag River has changed over the surveyed periods, while providing a synthesis of the study's results to guide river management into the future.

Executive Summary

Investigations into the channel morphology and sedimentation of the Shag River indicate that the river has experienced, and is still experiencing, significant rates of degradation within the active channel margin, most notably in the upper and mid surveyed reaches. This study has noted that previous levels of sediment accumulation within the active channel may have been attributed to historic mining in the upper catchment of Deepdell Creek. A significant decline in sediment supply is reflected in comparative aerial photography where imagery taken in 1947 (following the recession of gold mining activities) shows significant accumulations of sediment in the active channel margins. Subsequent photography, in 1996 and 2005, indicates that these accumulations have largely been removed from within the active channel.

Channel form and development within the Shag River is indicative of a low natural sediment yield system that exhibits a confined, single thread channel planform which is incising into the river floodplain. Analysis of cross-sections, aerial photographs and anecdotal records indicate that the river is in a presiding degradational state due to a decline in upper catchment sediment supply. This trend is represented in the mean bed level analyses where 16 cross-section locations experienced net degradation compared to six locations which exhibited localised aggradation over the surveyed periods.

Observations of the longitudinal profile indicate that the 2009 channel form exhibits a cyclical sedimentation regime where periods of degradation and aggradation are identified following local increases in the channel gradient. The morphometry of this profile is distinctly different from the 1984 channel form indicating a significant change in the sedimentation characteristics along the surveyed reach of the river.

Observed changes in the Shag River's channel morphometry and sedimentation characteristics infer that the river will continue to degrade under current conditions. This may contribute to further bank erosion, bedrock exposure and channel incision along the length of the river. If the catchment sediment yield remains constant into the foreseeable future, gravel accumulation within active channel margins will be extremely limited.

This report supersedes the Council report Shag River Gravel Management Program (2004) which identified degradational trends based on mean bed level analysis and field inspection. This report includes further mean bed level analysis, utilising the most recent 2009 survey information, as well as more extensive desktop investigation into the nature and dynamics of the Shag River.

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1. Introduction

This document describes morphological change and sedimentation in the Shag River Catchment. Aerial photography, cross-section analyses and anecdotal information is collated and interpreted to provide a comprehensive review of change over surveyed periods. This information can be used to support assessment of flood and erosion hazards and to support decision making with respect to Council's river management objectives.

This report supersedes the 2004 Council report Shag River Gravel Management Program which identified degradational trends based on mean bed level analysis and field inspection. This report includes further bed level analyses, which utilises the most recent 2009 survey information, as well as more extensive desktop investigation into the nature and dynamics of the Shag River.

2. Shag River Catchment

The Shag River is 47km long and drains a catchment area of 544km^2 (Figure 2.1). The upper catchment is bound by the Taieri Ridge to the south and the Kakanui Mountains to the north, where it rises to 1528m above sea level at Kakanui Peak. The catchment follows a south-easterly direction and terminates in coastal lowlands where the township of Palmerston is located.

2.1 Geology

The Shag River Catchment geology is primarily comprised of varying grades of quartzo-feldspathic sandstone interbedded with mudstone. This generally takes the form of greywacke deposits on the true right of the catchment, and argillite on the true left (north of the Waihemo Fault system) (Forsyth, 2001). On both sides of the valley, tributaries of the Shag River are actively eroding these geological units. In the upper catchment, Miocene age volcanic rocks of the Dunedin complex, such as basalt, exist and are being actively eroded by tributaries on the true left of the valley.

In the lower catchment, including the valley floor, alluvial Holocene deposits are common in the form of river floodplains and small fan deposits. Additionally, alluvial fan deposits of Pleistocene age have also been identified in the catchment (Barrell et al, 1998).

Figure 2.1 Shag River Catchment locality map

2.2 Geomorphology

The Kakanui Mountains, on the northern side of the Shag River valley, are being uplifted by the tectonically active Waihemo fault system (Opus, 2004). Slightly dissected to highly dissected alluvial fans are found on the slopes of these mountains from the Shag River estuary to The Grange (Opus, 2009). The fans range in age from oxygen isotope stage 8 (303-245 thousand years ago – ka BP) to oxygen isotope stage 2 (24-14 ka BP). Tributary streams supply gravel from these fans to the Shag River (Barrel et al, 1998).

Deepdell Creek (Figure 2.1) is located on the southern margin of the catchment and is the largest tributary of the Shag River. The creek is steep-sided and tortuous for much of its length and is fed by steep short tributaries which drain the lower slopes of Taieri Ridge (ORC, 1991).

Channel morphology of the Shag River is indicative of an incising river system responding to uplift of the underlying geology. Floodplain incision is observed through much of the coastal lowlands and occurs as the river attempts to attain base level equilibrium with existing sea level. Figure 2.2 shows a reach of the Shag River during drought conditions in 2005. Incision of the floodplain is observed where a distinct terrace edge is evident on the right bank of the river. In some reaches of the river, as observed in the foreground of Figure 2.2, the river has incised down to bedrock.

Figure 2.2 The Shag River during drought conditions in 2005. Extensive areas of bedrock within the active channel margins are noted as well as significant channel incision into the floodplain

2.3 Shag River sediment supply - gold mining impact

Extensive gold mining operations in the Shag River Catchment mainly occurred in Deepdell Creek, the largest tributary of the Shag River, between 1890 and 1946 (Figure 2.3) (Black et al, 2004). Black et al (2004) estimated that discharged mine tailings contributed one hundred times (at least 85,000 tonnes) more sediment to Deepdell Creek than otherwise would naturally occur over this period.

The 1947 aerial photography (Figures 2.4 – 2.7) clearly shows this contribution of excess sediment through an abundance of point and lateral bar formations[1] along the length of the Shag River main stem. By 2005 (Figures 2.4 – 2.7), the prominence of these features had diminished significantly where a more uniform confined channel form was evident. This depletion in active channel sediment storage indicates that bed levels previously observed within the Shag River have been significantly influenced by the contribution of mine tailing discharges. Black et al (2004) note that virtually all of the tailings have been removed from the Shag River system since gold mining ceased in 1946, indicating that the channel now exhibits a more natural form.

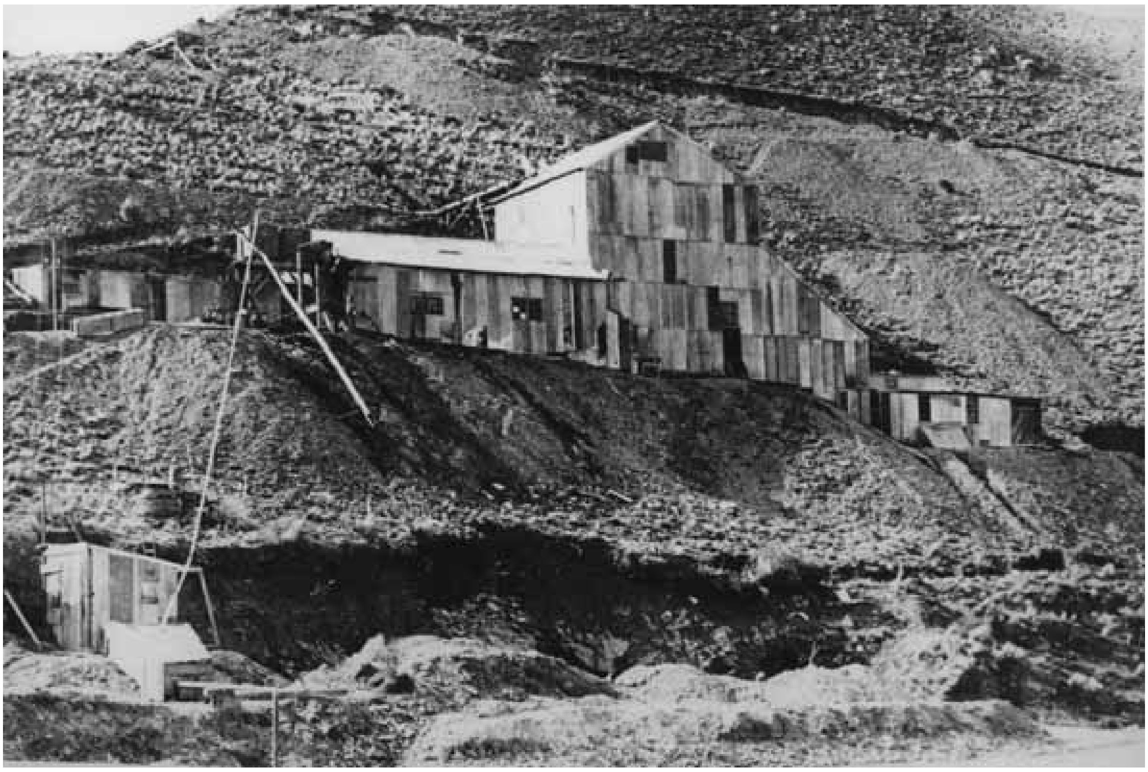

Figure 2.3 A gold mining battery located in the Deepdell Creek Catchment during the 1890s. Image courtesy of Hocken Library Collections

[1] Point and lateral bars are accumulations of sediment within the active channel margins of a river. Point bars are formed on the convex side of channel meanders by the lateral accretion of sediment. Conversely, lateral bars are formed by the accumulation of sediment as the river shifts laterally within the active channel margin. Observations of the spatial distribution of these features can provide insight into the dynamics of the river's sediment supply.

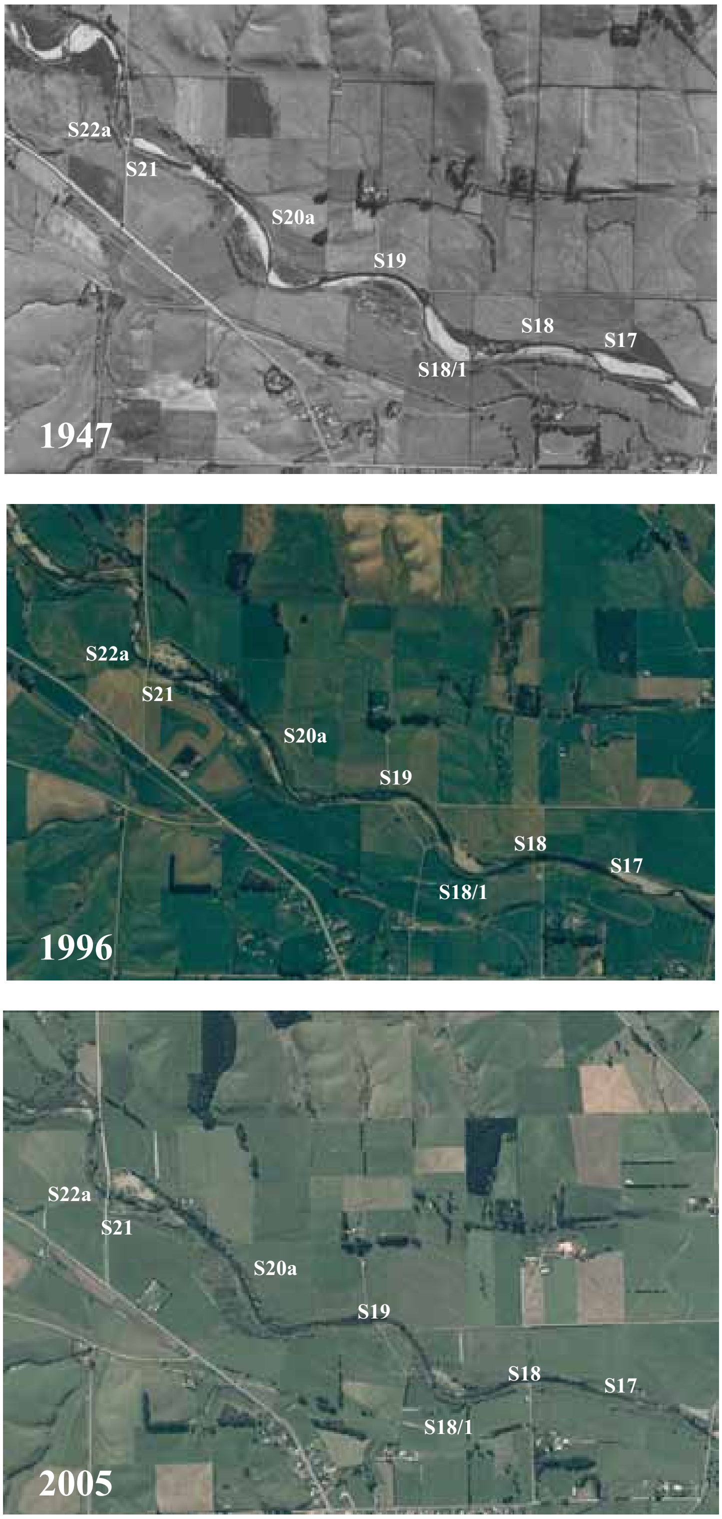

Figure 2.4 Aerial images of the Shag River in the vicinity of cross sections S17 – S22a for 1947, 1996 and 2005. These cross-sections are located just north of Palmerston and are between 9.2 and 11.6km upstream of the river mouth

Figure 2.5 Aerial images of the Shag River in the vicinity of cross sections S22b – S28 for 1947, 1996 and 2005. These cross-sections are located just upstream of Switchback Road and are between 11.9 and 14.7km upstream of the river mouth

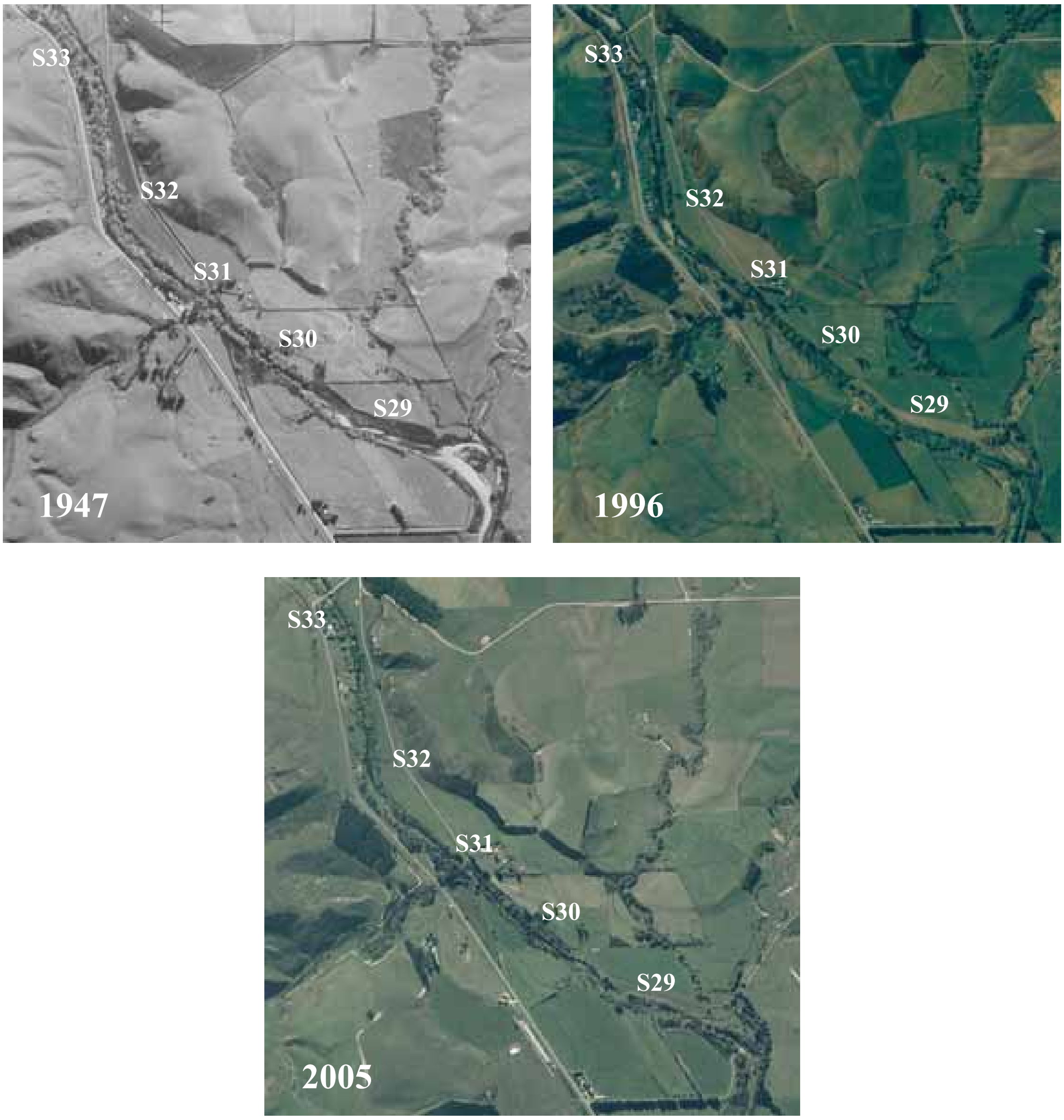

Figure 2.6 Aerial images of the Shag River in the vicinity of cross sections S29 – S33 for 1947, 1996 and 2005. These cross-sections are located downstream of Craig Road and between 15.6 and 17.4km upstream of the river mouth

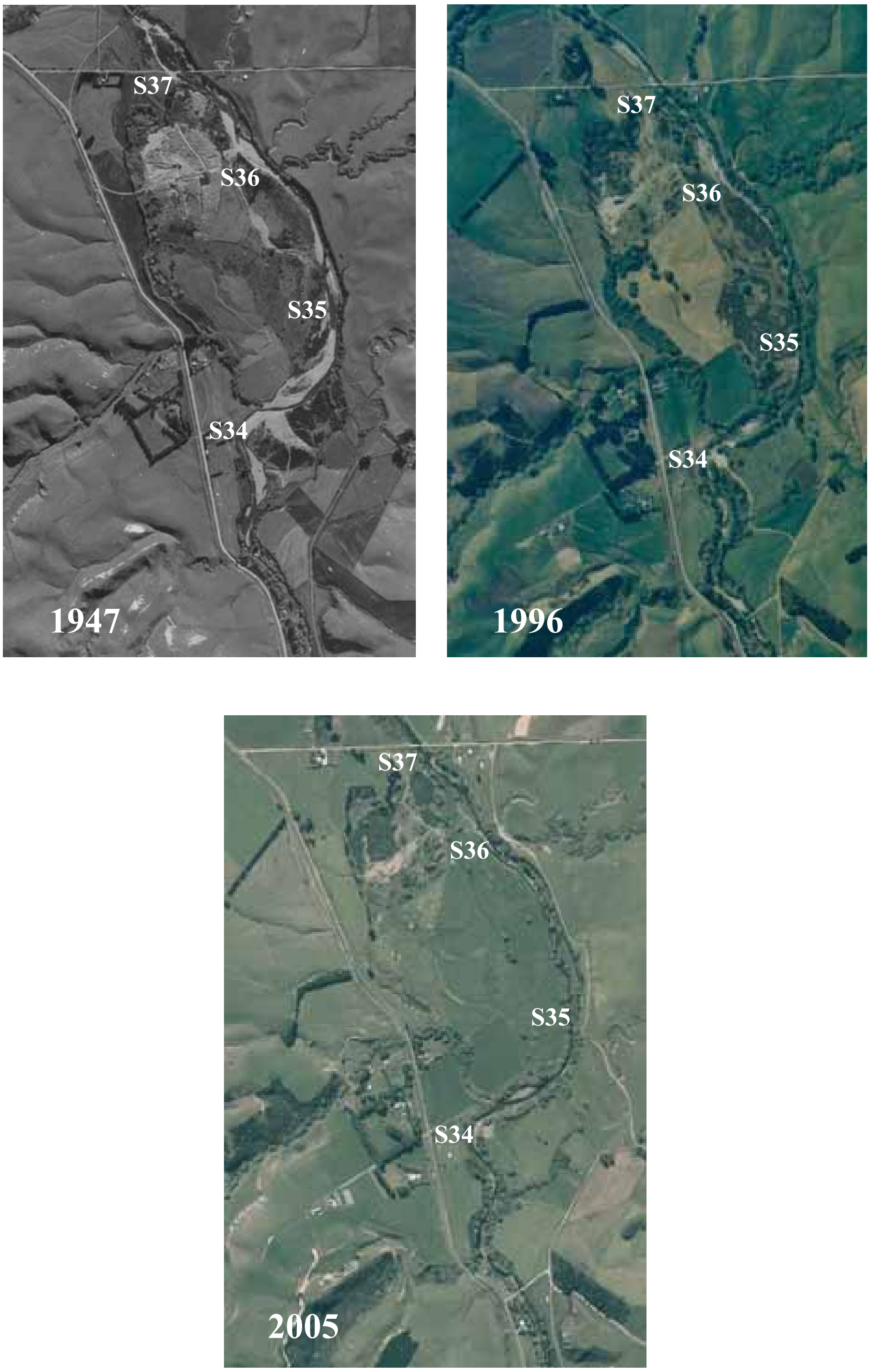

Figure 2.7 Aerial images of the Shag River in the vicinity of cross sections S34 – S37 for 1947, 1996 and 2005. These cross-sections are located downstream of McLew Road and between 18.0 and 19.8km upstream of the river mouth

3. Cross-section and mean bed level analysis

The ORC undertakes scheduled cross-section surveys for selected rivers on a periodic basis. The cross-section programme enables changes in river morphology and sedimentation trends to be monitored.

Twenty-two cross-section locations have been intermittently surveyed on the lower-mid reaches of the Shag River (Figure 3.1). Seven surveys, from October 1977 to April 2009, exist, with comprehensive surveys being undertaken in 1984, 2001, 2004 and 2009. Survey periods generally span 25 years (1984-2009), with the exception of cross- sections S20a, S21 and S22a which span 32 years (1977-2009).

The mean bed level of the active channel in each cross-section was calculated using the X-Sect cross-section database.[2] Table 3.1 shows each year surveyed and the respective mean bed level calculation for each cross-section. Some historical surveys only include part of the active channel. In this instance, mean bed levels have been calculated over these distances but are not directly comparable to the wider active channel results. Additionally, cross-sections surveyed during 1977 tend to have limited point densities. Therefore, the derived mean bed levels for this survey should be regarded as indicative. While results are expressed to two decimal places, these are mean values and may, therefore, have an error margin which exceeds this level of specificity.

Table 3.2 shows the net change in mean bed level over the different survey periods. Surveys that did not cover a representative extent of the active channel margins are included at the bottom of the table.

Annotated plots of each cross-section for all surveyed years are included with Section 8 – Appendices. A commentary is provided for each cross-section noting observed mean bed level, morphological and geomorphic changes.

[2] The database compiles a list of widths and their associated elevations for each cross-section and survey period. X-Sect calculates all output information (minimum, maximum and mean bed levels) from the respective widths and elevations.

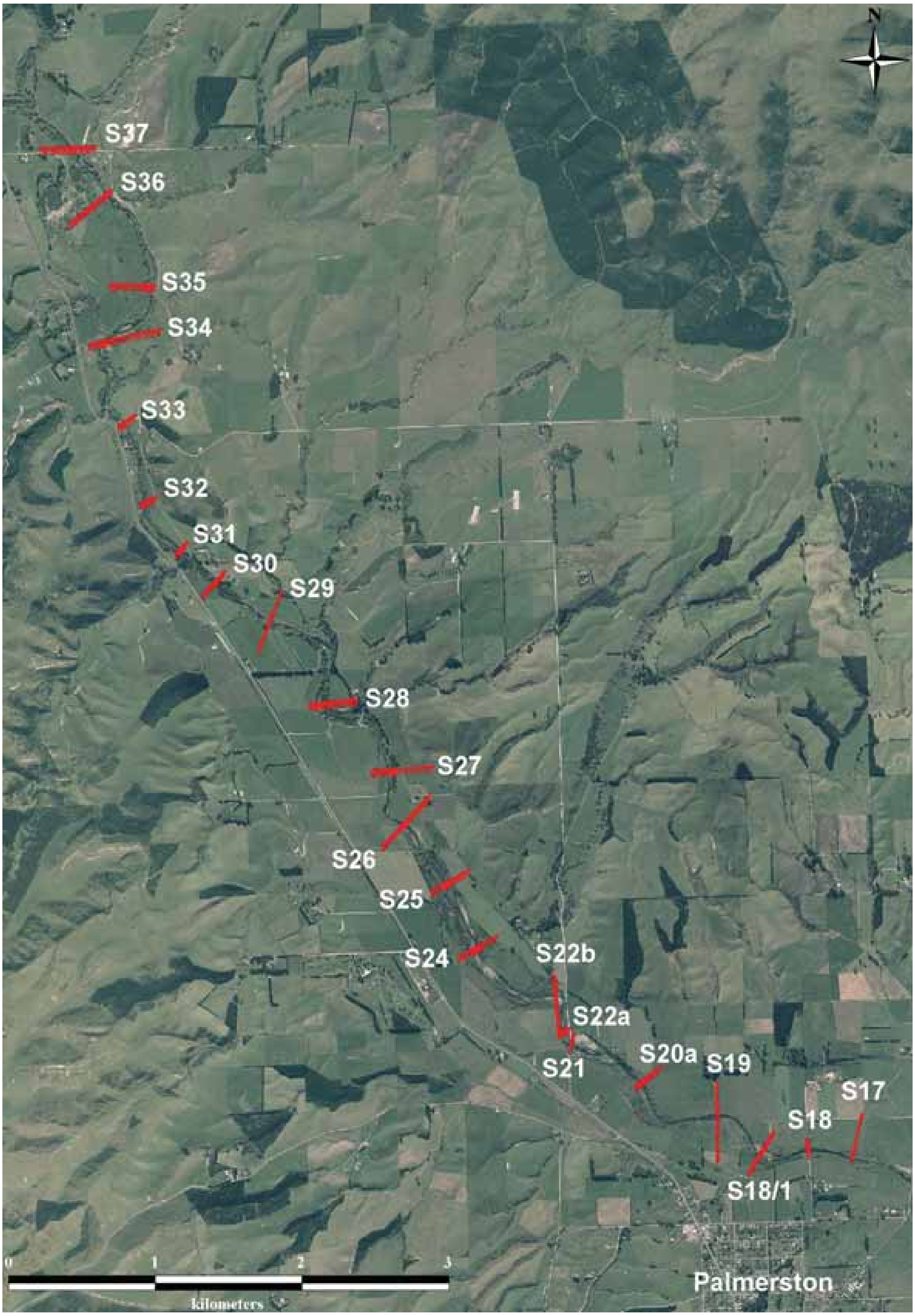

Figure 3.1 Location of surveyed cross-sections for the Shag River superimposed on 2005 aerial photography

Table 3.1 Mean bed level results[3] for surveyed cross-sections of the Shag River. A blank space indicates the cross-section was not surveyed for that year

Cross-Section	Active Channel Width (m)	Oct 1977	Sep 1984	Oct 1987	Jan 1988	Mar/Apr 2001	Apr 2004	Apr 2009
S37	46.78		132.63		132.62		132.19	132.25
S36	55.48		131.49		131.54	130.89	130.96	130.78
S35	35.07		129.77		129.62	128.98	128.97	129.01
S34	41.48		128.47		128.48	127.92	127.88	128.00
S33	21.26		124.26		123.90	124.25	123.97	124.04
S32	37.80		124.02		124.30	124.45	124.55	124.59
S31	27.29		123.58		123.47	123.51	123.46	123.49
S30	26.80		122.55		122.75	122.56	122.52	122.38
S29	54.73		122.39			122.31	122.26	121.96
S28	65.66		120.82		120.84	120.54	120.62	120.49
S27	41.17		118.97		118.86	118.22	118.16	118.10
S26	49.96		117.85		117.64	117.06	117.14	116.97
S25	46.60				116.97	115.99	115.94	116.00
S24	94.00		115.73				115.70	115.71
S22b	117.00		113.47		113.25		113.23	113.48
S22a	36.00	112.29	111.83		111.63	111.58	111.49	111.32
S21	35.46	111.69	110.94		110.48	110.05	110.60	110.48
S20a	59.50	110.43	110.57		110.84	110.78	110.80	110.77
S19	97.00		110.49	110.45			110.29	110.32
S18/1	105.53			109.27		108.93	109.07	109.28
S18	57.24		108.20	108.06		108.01	107.97	107.98
S17	69.70		108.12	108.26		108.22	108.20	108.20
Cross-section surveys undertaken for widths that do not cover the current active channel margin								
S37	31.44		131.87		131.83	131.49	131.34	131.44
S32	44.97				124.57	124.71	124.77	124.85
S30	38.26		122.95		123.07	123.02	122.90	123.09
S28	74.60		120.67				120.53	120.39
S25	55.04		116.95		116.79		115.93	115.96
S24	58.82		115.00			114.82	114.80	114.84
S22b	111.96				113.47	113.48	113.43	113.63
S22a	44.52				111.88	111.87	111.77	111.64
S20a	87.95		110.99		111.22		111.23	111.25
S19	57.38		109.57	109.42		109.14	109.18	109.23
S18/1	52.10		108.55	108.69		108.25	108.49	108.71

[3] Mean bed levels are expressed in the Otago Datum which lies 100m below the Dunedin Vertical Datum 1958.

Table 3.2 Net change in mean bed level for each respective survey period

<table>
<tr><th>Cross-section</th><th>Active Channel Width (m)</th><th>1977-1984</th><th>1984-1987</th><th>1987-1988</th><th>1988-2001</th><th>2001-2004</th><th>2004-2009</th><th>Net Change (m)</th></tr>
<tr><td>S37</td><td>46.78</td><td></td><td colspan="2">-0.01</td><td colspan="2">-0.43</td><td>+0.06</td><td>-0.38</td></tr>
<tr><td>S36</td><td>55.48</td><td></td><td colspan="2">+0.05</td><td>-0.65</td><td>+0.07</td><td>-0.18</td><td>-0.71</td></tr>
<tr><td>S35</td><td>35.07</td><td></td><td colspan="2">-0.15</td><td>-0.64</td><td>-0.01</td><td>+0.04</td><td>-0.76</td></tr>
<tr><td>S34</td><td>41.48</td><td></td><td colspan="2">+0.01</td><td>-0.56</td><td>-0.04</td><td>+0.12</td><td>-0.47</td></tr>
<tr><td>S33</td><td>21.26</td><td></td><td colspan="2">-0.36</td><td>+0.35</td><td>-0.28</td><td>+0.07</td><td>-0.22</td></tr>
<tr><td>S32</td><td>37.80</td><td></td><td colspan="2">+0.28</td><td>+0.15</td><td>+0.10</td><td>+0.04</td><td>+0.57</td></tr>
<tr><td>S31</td><td>27.29</td><td></td><td colspan="2">-0.11</td><td>+0.04</td><td>-0.05</td><td>+0.03</td><td>-0.09</td></tr>
<tr><td>S30</td><td>26.80</td><td></td><td colspan="2">+0.20</td><td>-0.19</td><td>-0.04</td><td>-0.14</td><td>-0.17</td></tr>
<tr><td>S29</td><td>54.73</td><td></td><td colspan="3">-0.08</td><td>-0.05</td><td>-0.30</td><td>-0.43</td></tr>
<tr><td>S28</td><td>65.66</td><td></td><td colspan="2">+0.02</td><td>-0.30</td><td>+0.08</td><td>-0.13</td><td>-0.33</td></tr>
<tr><td>S27</td><td>41.17</td><td></td><td colspan="2">-0.11</td><td>-0.64</td><td>-0.08</td><td>-0.06</td><td>-0.87</td></tr>
<tr><td>S26</td><td>49.96</td><td></td><td colspan="2">-0.21</td><td>-0.58</td><td>+0.08</td><td>-0.17</td><td>-0.88</td></tr>
<tr><td>S25</td><td>55.04</td><td></td><td colspan="2">-0.16</td><td colspan="2">-0.86</td><td>+0.03</td><td>-0.99</td></tr>
<tr><td>S24</td><td>94.00</td><td></td><td colspan="4">-0.03</td><td>+0.01</td><td>+0.02</td></tr>
<tr><td>S22b</td><td>117.00</td><td></td><td colspan="2">-0.22</td><td colspan="2">-0.02</td><td>+0.25</td><td>+0.01</td></tr>
<tr><td>S22a</td><td>36.00</td><td>-0.46</td><td colspan="2">-0.20</td><td>-0.05</td><td>-0.09</td><td>-0.17</td><td>-0.97</td></tr>
<tr><td>S21</td><td>35.46</td><td>-0.75</td><td colspan="2">-0.46</td><td>-0.43</td><td>+0.55</td><td>-0.12</td><td>-1.21</td></tr>
<tr><td>S20a</td><td>59.50</td><td>+0.14</td><td colspan="2">+0.27</td><td>-0.06</td><td>+0.02</td><td>-0.03</td><td>+0.34</td></tr>
<tr><td>S19</td><td>97.00</td><td></td><td>-0.04</td><td colspan="3">-0.16</td><td>+0.03</td><td>-0.17</td></tr>
<tr><td>S18/1</td><td>105.53</td><td></td><td></td><td colspan="2">-0.34</td><td>+0.14</td><td>+0.21</td><td>+0.01</td></tr>
<tr><td>S18</td><td>57.24</td><td></td><td>-0.14</td><td colspan="2">-0.05</td><td>-0.04</td><td>+0.01</td><td>-0.22</td></tr>
<tr><td>S17</td><td>69.70</td><td></td><td>+0.14</td><td colspan="2">-0.04</td><td>-0.02</td><td>0.00</td><td>+0.08</td></tr>
<tr><td colspan="9">Cross-section surveys undertaken for widths that do not cover the current active channel margin</td></tr>
<tr><td>S37</td><td>31.44</td><td></td><td colspan="2">-0.04</td><td>-0.34</td><td>-0.15</td><td>+0.10</td><td>-0.43</td></tr>
<tr><td>S32</td><td>44.97</td><td></td><td colspan="2"></td><td>+0.14</td><td>+0.06</td><td>+0.08</td><td>+0.28</td></tr>
<tr><td>S30</td><td>38.26</td><td></td><td colspan="2">+0.12</td><td>-0.05</td><td>-0.12</td><td>+0.19</td><td>+0.14</td></tr>
<tr><td>S28</td><td>74.60</td><td></td><td colspan="4">-0.14</td><td>-0.14</td><td>-0.28</td></tr>
<tr><td>S25</td><td>55.04</td><td></td><td></td><td></td><td>-0.98</td><td>-0.05</td><td>+0.06</td><td>-0.97</td></tr>
<tr><td>S24</td><td>58.82</td><td></td><td colspan="3">-0.18</td><td>-0.02</td><td>+0.04</td><td>-0.16</td></tr>
<tr><td>S22b</td><td>111.96</td><td></td><td></td><td></td><td>+0.01</td><td>-0.05</td><td>+0.20</td><td>+0.16</td></tr>
<tr><td>S22a</td><td>44.52</td><td></td><td></td><td></td><td>-0.01</td><td>-0.10</td><td>-0.13</td><td>-0.24</td></tr>
<tr><td>S20a</td><td>87.95</td><td></td><td colspan="2">+0.23</td><td colspan="2">+0.01</td><td>+0.02</td><td>+0.26</td></tr>
<tr><td>S19</td><td>57.38</td><td></td><td>-0.15</td><td colspan="2">-0.28</td><td>+0.04</td><td>+0.05</td><td>-0.34</td></tr>
<tr><td>S18/1</td><td>52.10</td><td></td><td>+0.14</td><td colspan="2">-0.44</td><td>+0.24</td><td>+0.22</td><td>+0.16</td></tr>
</table>

4. Longitudinal (thalweg) profile analysis

Figure 4.1 shows a longitudinal profile of the channel thalweg, the lowest point in the cross-section, for 1984, 2004 and 2009. These three years were chosen as all cross-sections exist for each survey and they cover a suitable temporal range.

4.1 Upper section (S37 – S33: 2.4km)

Figure 4.1 shows that the upper reach of the thalweg profile, cross-sections S37 to S34, experienced degradation between 1984 and 2004. The latest survey period, 2004 to 2009, shows that this section of the profile has remained relatively the same as 2004 levels, apart from a small amount of aggradation around S35 over this period. Thalweg levels at S34 have not changed significantly over the period 1984 to 2009.

Between cross-sections S34 and S33, the longitudinal profile indicates another degradational phase with the thalweg lowering between 1984 and 2004 followed by further degradation between 2004 and 2009. Downstream of cross-section S33, the 2004 and 2009 profiles start to increase in level again.

4.2 Mid section (S33 – S25: 4.3km)

Figure 4.1 indicates that the 2009 thalweg level in the vicinity of cross-section S33 is higher than that surveyed in 1984. Between cross-sections S32 and S30 the 2009 profile remains at similar levels to 2004, with some degradation evident at S30. Thalweg levels over this reach are much lower than those surveyed in 1984.

Significant variability in the longitudinal profile is observed between S30 and S28. Within this reach, the 2004 thalweg level was higher than 1984 levels. However, significant degradation has occurred in this reach between 2004 and 2009. This degradation is reflected by deepening of the thalweg by 1.88m at cross-section S29. At cross-section S28, 2009 thalweg levels still lie slightly above 1984 levels but exhibited net degradation between 2004 and 2009.

The reach between cross-sections S28 and S25 experienced significant degradation between 1984 and 2004. Cross-section S27 experienced slight degradation between 2004 and 2009. At cross-section S25, the thalweg level has degraded slightly between 2004 and 2009 but still lies above levels surveyed in 1984.

4.3 Lower section (S25 – S17: 3.9km)

Figure 4.1 indicates that thalweg levels remained relatively constant over all surveyed periods between cross-sections S25 to S22b. The channel at cross-sections S24 and S22b are incised to bedrock which contributes to this constant thalweg level. A significant change in gradient is noted between cross-sections S22b and S21 (Figure 4.2), with bed levels showing progressive degradation over surveyed periods. As the river gradient flattens, a reach exhibiting aggradation (cross-sections S21 and S19) is evident. The reach of cross-sections located farthest downstream have not changed significantly between 2004 and 2009. However, degradation at cross-section S18 is evident during this period.

4.4 Longitudinal profile: summary

The 2009 longitudinal profile exhibits a similar form to that surveyed in 2004 with some locations experiencing minor aggradation or degradation of the thalweg. One exception to this trend is the reach S30 to S28 (Figure 4.1) which experienced significant lowering of the thalweg level over this time. Net degradation of this reach is reflected in lowering of the thalweg at cross-sections S30 and S28, although is best reflected by 1.88m of net degradation at cross-section S29. The longitudinal profile at some locations (S22b and S34) is constrained by bedrock channels and has therefore exhibited little net change between 1984 and 2009. In general, the 2009 longitudinal profile is much lower than the 1984 profile.

Figure 4.2 shows an annotated plot of the longitudinal profile for 1984, 2004 and 2009. An interpretive analysis of the 2009 longitudinal profile indicates that the channel morphometry exhibits a cyclical sedimentation regime where periods of degradation and aggradation are identified following local increases in the channel gradient. Comparatively, the 1984 longitudinal profile exhibits a gentler morphometry with less variability along the length of the channel.

Observed changes in the Shag River's channel morphometry and sedimentation characteristics infer that the river has continued to degrade over the last survey period, 2004 to 2009. Further degradation may contribute to bank erosion, bedrock exposure and channel incision along the length of the river. The current river form is exhibiting a cyclical stepped profile that is controlled in places by the bedrock-lined channels. Additionally, the significant depletion of active channel storage has been identified from comparative analyses of each longitudinal profile. If the catchment sediment yield remains constant into the foreseeable future, gravel accumulation within active channel margins will be extremely limited.

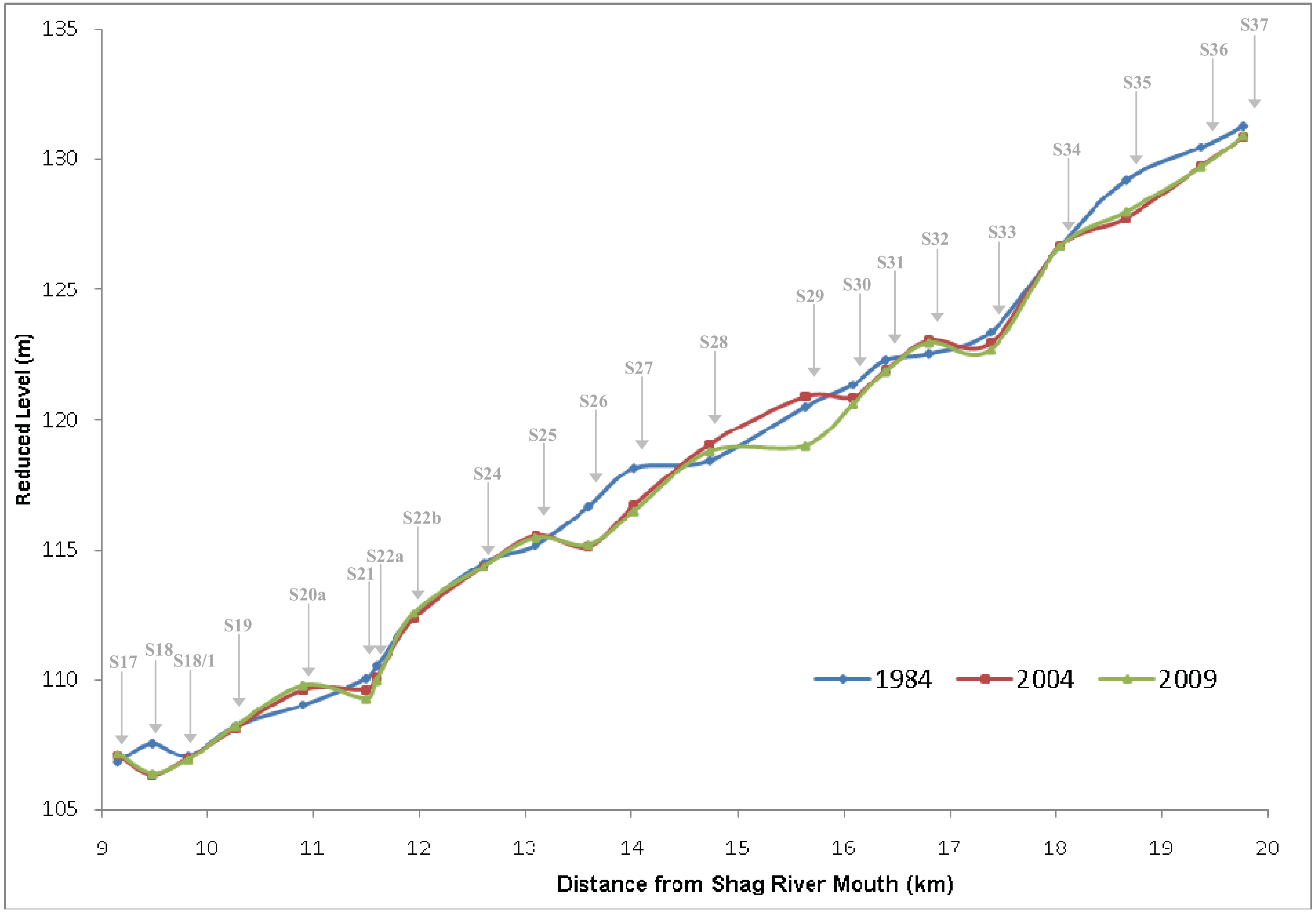

Figure 4.1 Longitudinal profile of the Shag River channel thalweg for 1984, 2004 and 2009

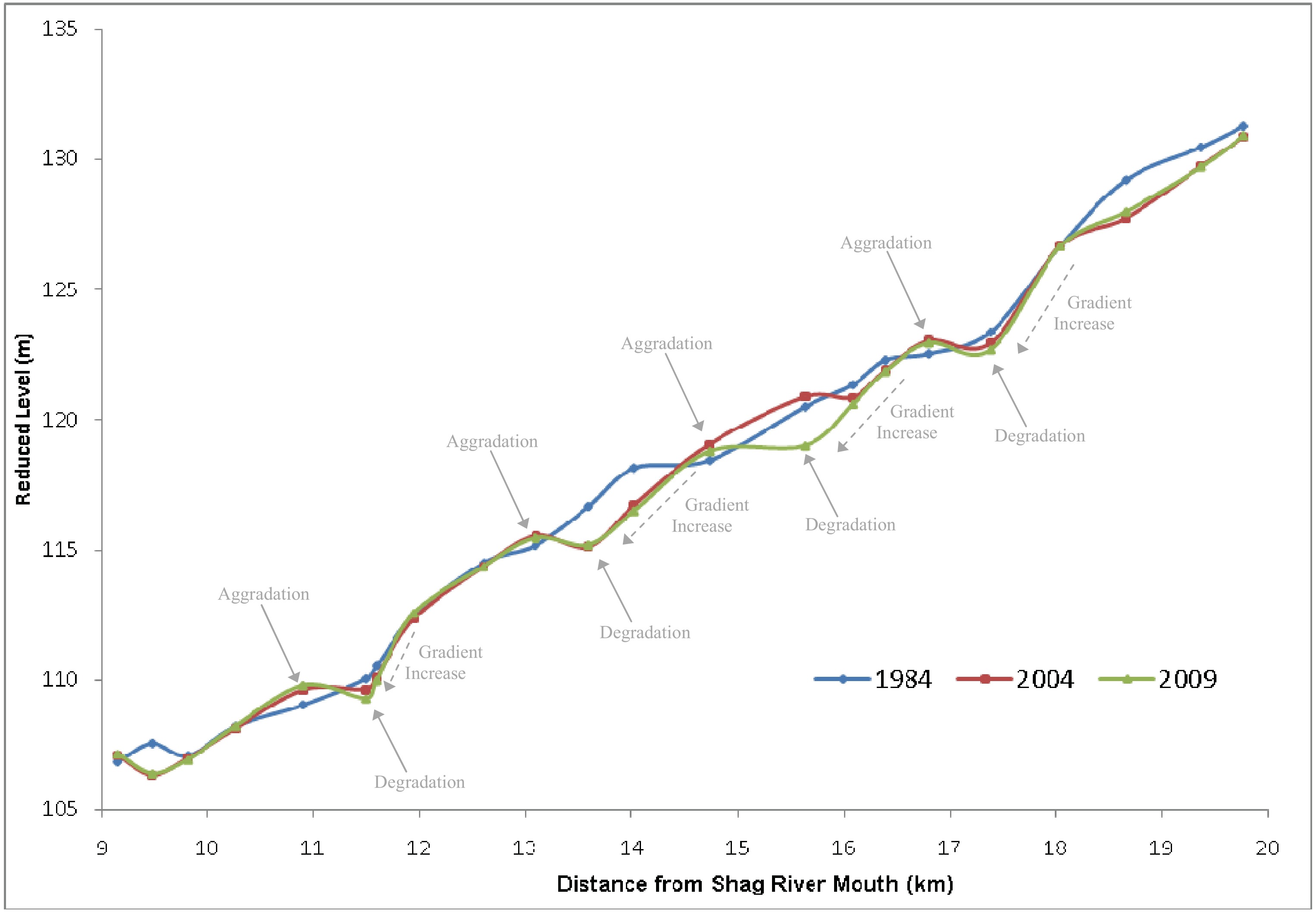

Figure 4.2 Longitudinal profile of the Shag River channel thalweg for 1984, 2004 and 2009 showing morphometric characteristics

5. Discussion

The Shag River is a dynamic system that has experienced significant changes in sediment storage and bed levels since the mid 20th century. Historically, the nature of the river was to laterally migrate between widespread point and lateral bar deposits within the active channel margins. However, contemporary channel form and development is indicative of a low natural sediment yield system that exhibits a confined, single thread channel planform which is incising into the river flood plain. This change in river dynamics is inferred to be a result of variation in the catchment's sediment supply regime which tends to coincide with the recession of upper catchment gold mining activities.

Cross-section analyses and interpretations have also exhibited trends which infer a decline in sediment supply to surveyed reaches. Figure 5.1 shows a graphical representation of the net change in mean bed levels quantified for each cross-section over each respective period of survey. A holistic interpretation of mean bed level results indicates that the general trend of bed level change is one of net degradation with some localised areas of aggradation. Of the 22 surveyed locations, only one cross-section location (S32) experienced net aggradation greater than 0.4m. Comparatively, nine cross-section locations experienced net degradation greater than 0.4m over surveyed periods. Cross-section S21 has experienced the most change in mean bed levels, experiencing 1.21m of degradation over the period 1977-2009 (Figure 5.1).

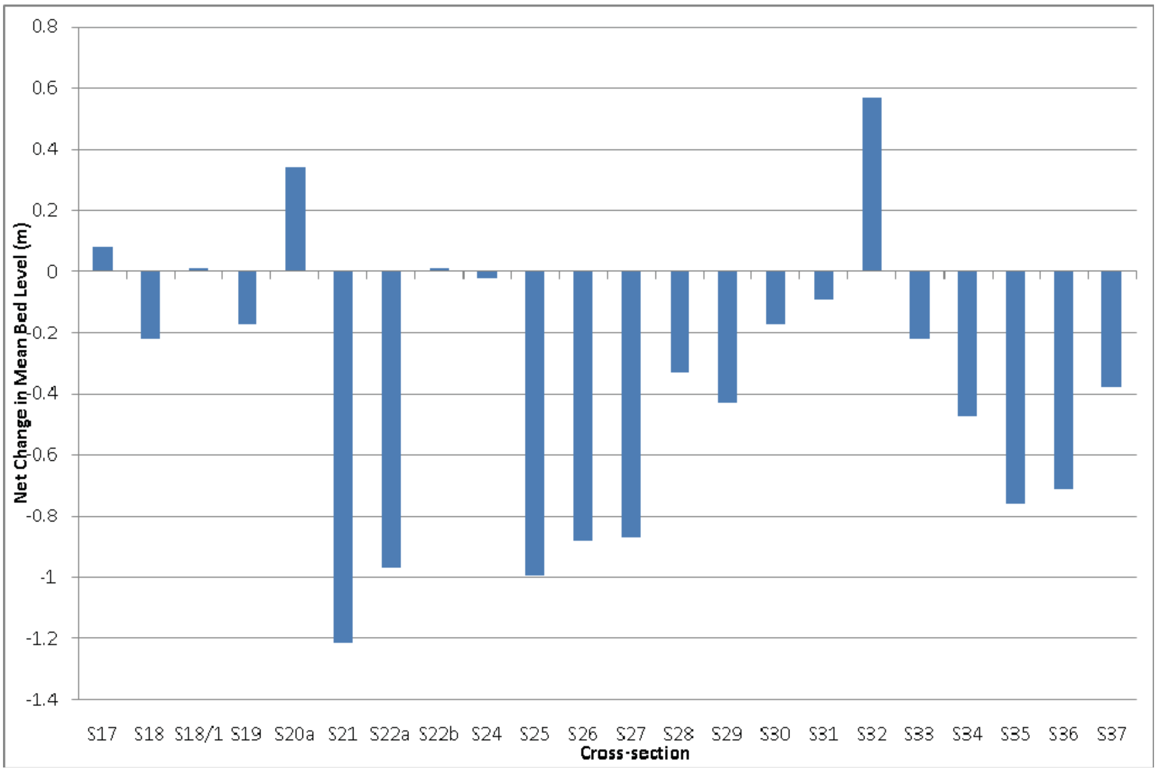

Figure 5.1 Graph showing net change in mean bed level across all survey periods for each cross-section

The analysis of historical aerial photography (Figures 2.4 - 2.7) also indicates that sediment supply rates have significantly declined within the active channel margin since 1947. This is largely represented by a significant reduction in the distribution and extent of point and lateral bars from 1947 to 2005. Additionally, the morphology of the active channel has changed over this time, from a sinuous channel subject to lateral migration to a more uniform confined channel form.

Observations of the longitudinal profile (Figures 4.1 and 4.2) indicate that the 2009 channel form exhibits a cyclical sedimentation regime where periods of degradation and aggradation are identified following local increases in the channel gradient. The morphometry of this profile is distinctly different from the 1984 channel form, indicating a significant change in the sedimentation characteristics along the surveyed reach.

Observed changes in the Shag River's channel morphometry and sedimentation characteristics infer that the river will continue to degrade under current conditions. This may contribute to further bank erosion, bedrock exposure and channel incision along the length of the river. If the catchment sediment yield remains constant into the foreseeable future, gravel accumulation within active channel margins will be extremely limited.

6. Conclusion

Investigations into the channel morphology and sedimentation of the Shag River indicate that the river has experienced, and is still experiencing, significant rates of degradation within the active channel margin. This study has noted that previous levels of sediment accumulation within the active channel may have been attributed to historic mining in the upper catchment of Deepdell Creek. A significant decline in sediment supply is reflected in comparative aerial photography where imagery taken in 1947 (following the recession of gold mining activities), shows significant accumulations of sediment in the active channel margins. Subsequent photography, in 1996 and 2005, indicates that these accumulations have largely been removed from within the active channel.

Observed changes in the Shag River's channel morphometry and sedimentation characteristics infer that the river will continue to degrade under current conditions. This may contribute to further bank erosion, bedrock exposure and channel incision along the length of the river. If the catchment sediment yield remains constant into the foreseeable future, gravel accumulation within active channel margins will be extremely limited.

7. References

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8. Appendices

8.1 Cross-section S17

Cross-section S17 is located approximately 9.15km upstream of the Shag River Mouth, marking the furthest downstream cross-section location (Figure 3.1). Figure 8.1 shows a plot of cross-section S17 for the 1984, 1987, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 69.70 metres at this location and is incised 2-3m into the floodplain. Mean bed level analysis shows net aggradation of 0.08m over the active channel width between 1984 and 2009 (Table 3.2). Most aggradation occurred during the period 1984 to 1987, which could be indicative of sedimentation resulting from the large flood events of March and August 1986 (Otago Regional Council, 1991). Further aggradation has occurred within the mid-channel over subsequent survey periods but has not been reflected in the mean bed level analysis due to the erosion of approximately 8 to 10m of the true right bank between 1987 and 2001. No evident change in mean bed level is noted between the 2004 and 2009 surveys at this location.

Aerial photography (Figure 2.4) indicates that the channel form at this location has changed from a sediment rich, unvegetated, low sinuosity channel in 1947 to a uniform straight channel with established vegetated banks in 2005.

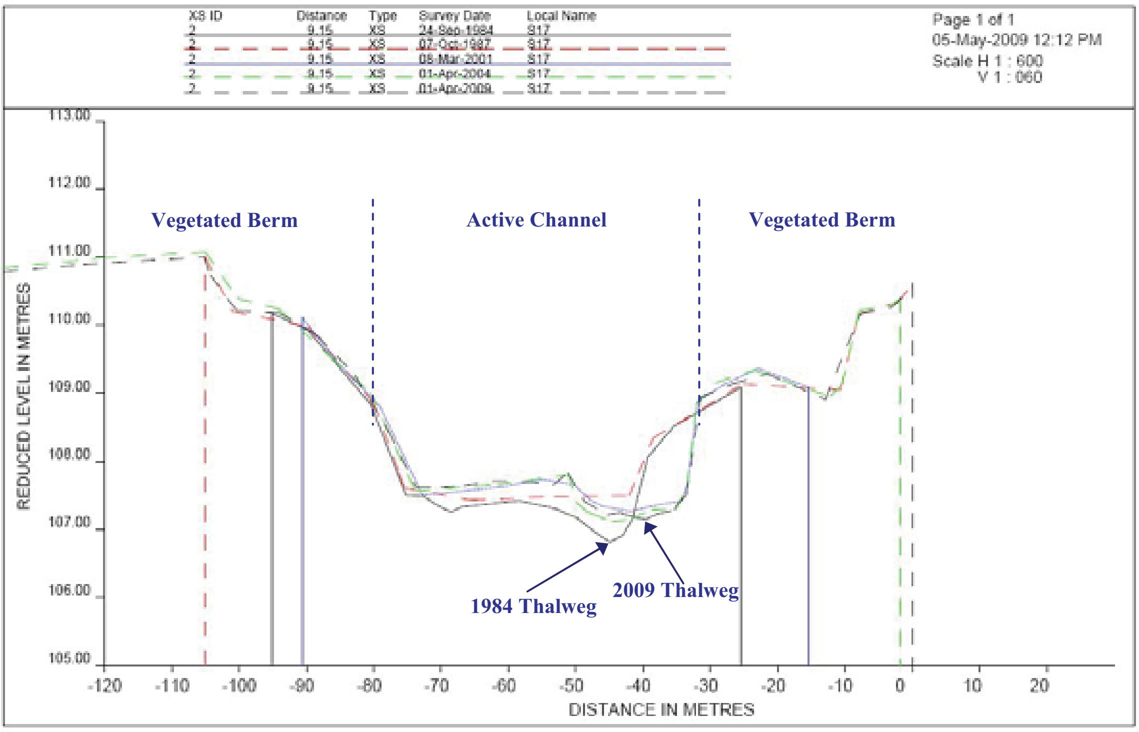

Figure 8.1 Cross-section S17, looking downstream

8.2 Cross-section S18

Cross section S18 is located approximately 9.47km upstream of the Shag River Mouth and is just upstream of the abandoned Mill Road ford (Figure 3.1). Figure 8.2 shows a plot of cross-section S18 for the 1984, 1987, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 57.24m at this location. Mean bed level analysis shows net degradation of 0.22m over the active channel width between 1984 and 2009 (Table 3.2). This degradation is reflected by a true left shift and deepening of the thalweg by 1.16 (Figure 8.2). Additionally, the true right bank has accreted by approximately 20m which is inferred to be due to the construction of a river access, evident in Figure 2.2. No significant change in mean bed level (+0.01m) is evident between the 2004 and 2009 surveys at this location.

Aerial photography (Figure 2.4) indicates that changes in channel form at S18 are similar to cross-section S17. The 1947 photography shows the channel main stem occupying the true left of the active channel with dominant point and mid-channel bar features. Comparatively, by 2005, the active channel appears more confined with well- established vegetated banks. The removal of large willows on the true right bank is noted between 1947 and 1996 at this location.

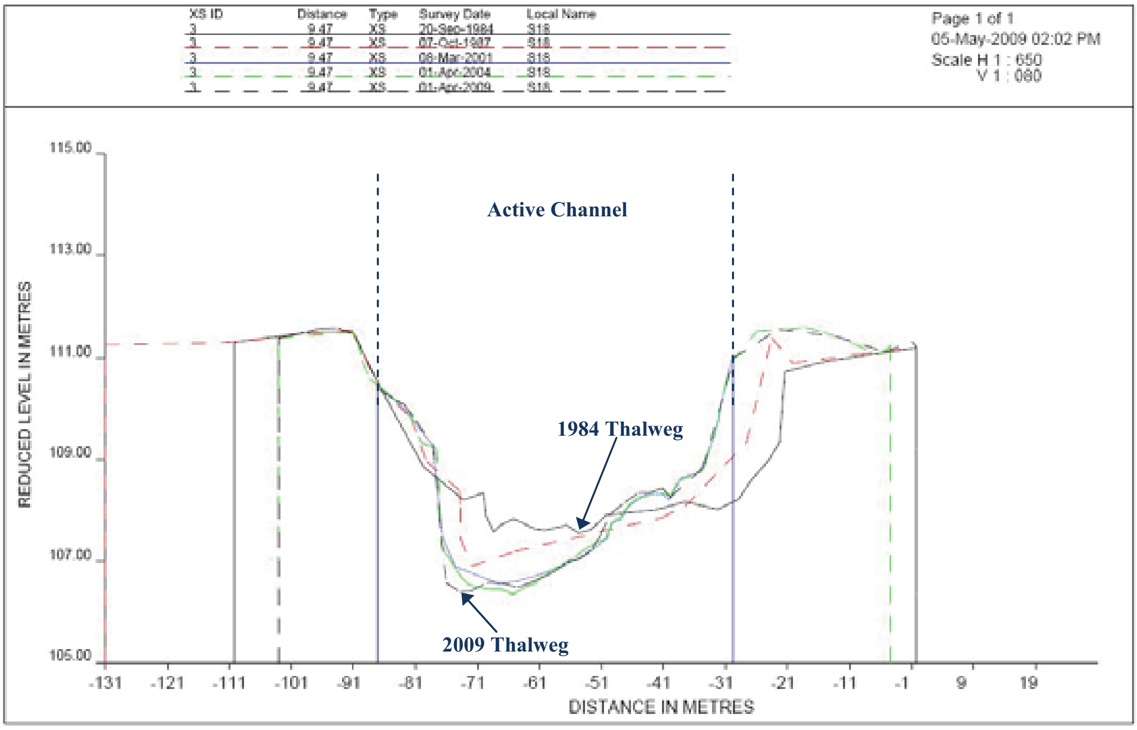

Figure 8.2 Cross-section S18, looking downstream

8.3 Cross-section S18/1

Cross section S18/1 is located approximately 9.81km upstream of the Shag River Mouth and 0.34km upstream of cross-section S18 (Figure 3.1). Figure 8.3 shows a plot of cross-section S18/1 for the 1984, 1987, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 105.53m at this location. Mean bed level analysis shows net aggradation of 0.01m over the active channel width between 1987 and 2009 (Table 3.2). This analysis indicates that bed levels at this location are at similar levels to those surveyed in 1987. However, variation between survey periods is evident where net degradation of 0.34 metres was experienced between 1987 and 2001. Since this time, the active channel has aggraded by 0.35m with 0.21m of this aggradation occurring during the period 2004 to 2009. Both the channel banks and the thalweg[4] location have remained relatively stable over all surveyed periods.

Aerial photography (Figure 2.4) indicates that the channel form has become more stable at this location since 1947. The establishment of the willow trees along much of the true right bank has contributed to this stabilisation. The 1947 photography shows a large active point bar feature dominating this cross-section area whereas this feature largely succumbed to vegetation by 2005.

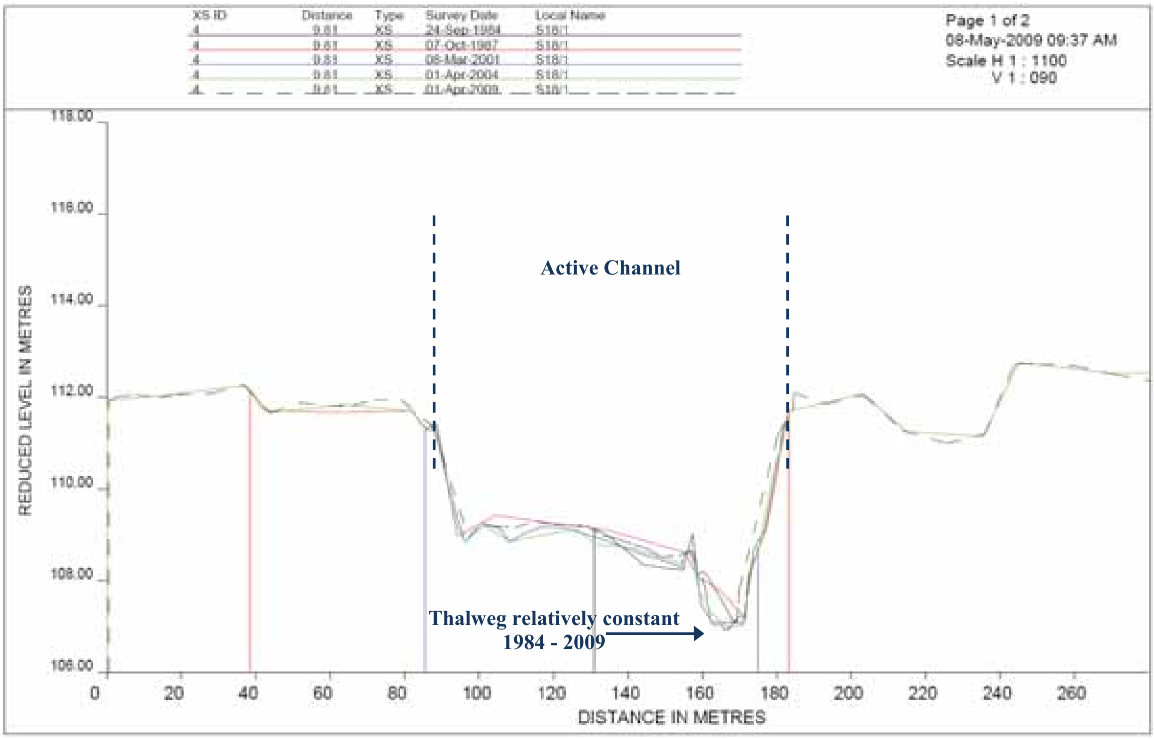

Figure 8.3 Cross-section S18/1, looking downstream

[4] The thalweg is the lowest point of the cross-section i.e. the deepest part of the channel.

8.4 Cross-section S19

Cross section S19 is located approximately 10.26km upstream of the Shag River Mouth and 0.45km upstream of cross-section 18/1 (Figure 3.1). Figure 8.4 shows a plot of cross-section S19 for the 1984, 1987, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 97.00m at this location. Mean bed level analysis shows net degradation of 0.17m over the active channel width between 1984 and 2009 (Table 3.2). Net degradation occurred over survey periods between 1984 and 2004 whereas the most recent survey period, 2004 to 2009, experienced net aggradation of 0.03m. At this location, channel banks have remained relatively stable while the thalweg location has varied across the active channel width.

Aerial photography (Figure 2.4) indicates that the channel form at this location has exhibited change similar to cross-sections S17 and S18. The 1947 photography shows the main channel stem occupying the true left of the active channel margin with fresh bar deposits located on the true right bank. Comparatively, the 2005 photography shows a uniform straight channel with established vegetated banks.

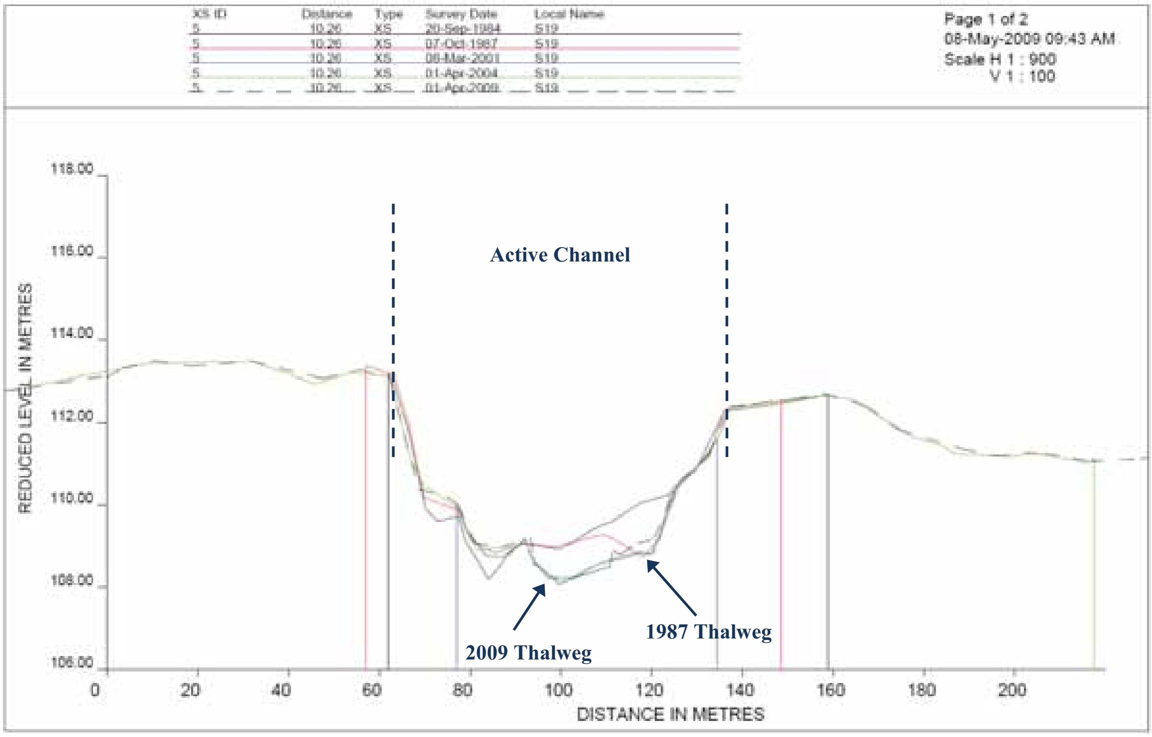

Figure 8.4 Cross-section S19, looking downstream

8.5 Cross-section S20a

Cross section S20a is located approximately 10.90km upstream of the Shag River Mouth and 0.64km upstream of cross-section S19 (Figure 3.1). Figure 8.5 shows a plot of cross-section S20a for the 1977, 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 59.50m at this location. Mean bed level analysis shows net aggradation of 0.34m over the active channel width between 1977 and 2009 (Table 3.2). Most aggradation, 0.41m, occurred during the period 1977 to 1988 which could be indicative of sedimentation resulting from the large flood events of June 1980 and March 1986 (Otago Regional Council, 1991). This aggradation is reflected by the thalweg level increasing by 1.31m over this same period (Figure 8.5). Since 1988, net changes in mean bed level have been relatively small with the most recent survey period, 2004 to 2009, experiencing net degradation of 0.03m.

Aerial photography (Figure 2.4) shows that the channel form in this reach has experienced similar stabilisation and vegetation to cross-section S19. The 1947 photography shows the main channel stem occupying the true left of the active channel margin with fresh bar deposits located on the true right bank. Comparatively, the 2005 photography shows a uniform straight channel with established vegetated banks.

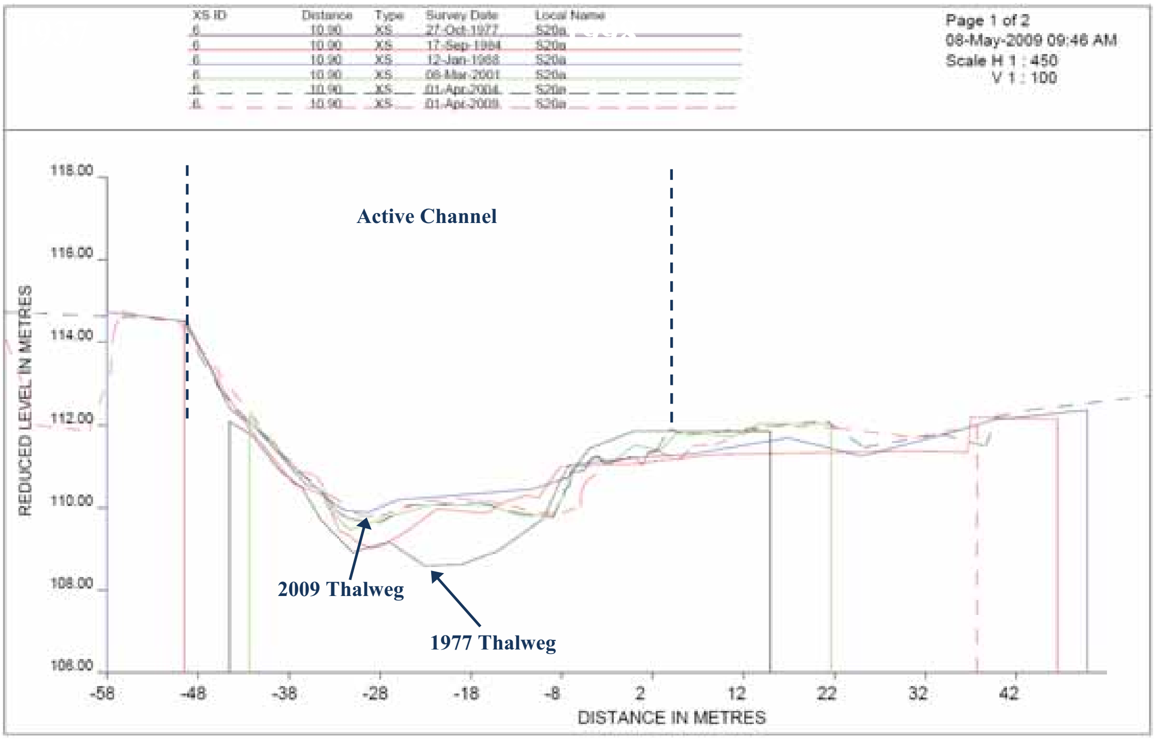

Figure 8.5 Cross-section S20a, looking downstream

8.6 Cross-section S21

Cross section S21 is located approximately 11.49km upstream of the Shag River Mouth and is on the downstream side of the Switchback Road Bridge (Figure 3.1). Figure 8.6 shows a plot of cross-section S21 for the 1977, 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 35.46m at this location. Mean bed level analysis shows net degradation of 1.21m over the active channel margin between 1977 and 2009 (Table 3.2). Most degradation, 1.64m, occurred during the period 1977 to 2001 followed by a period of aggradation, 0.55m, between 2001 and 2004. The most recent survey period, 2004 to 2009, has experienced degradation of 0.12m. This net degradational trend is also observed through lowering of the thalweg by 1.64m between 1977 and 2009 (Figure 8.6).

Aerial photography (Figure 2.4) indicates that the channel has become confined on the true left bank due to the establishment of willow trees between 1947 and 1996. The stabilisation of the left bank and subsequent narrowing of the channel may be a contributing factor to the observed level of degradation at this location. In addition, where the true right bank was occupied by willow trees in 1947, by 2005 this bank had become less vegetated and subsequently dissected by the main stem channel.

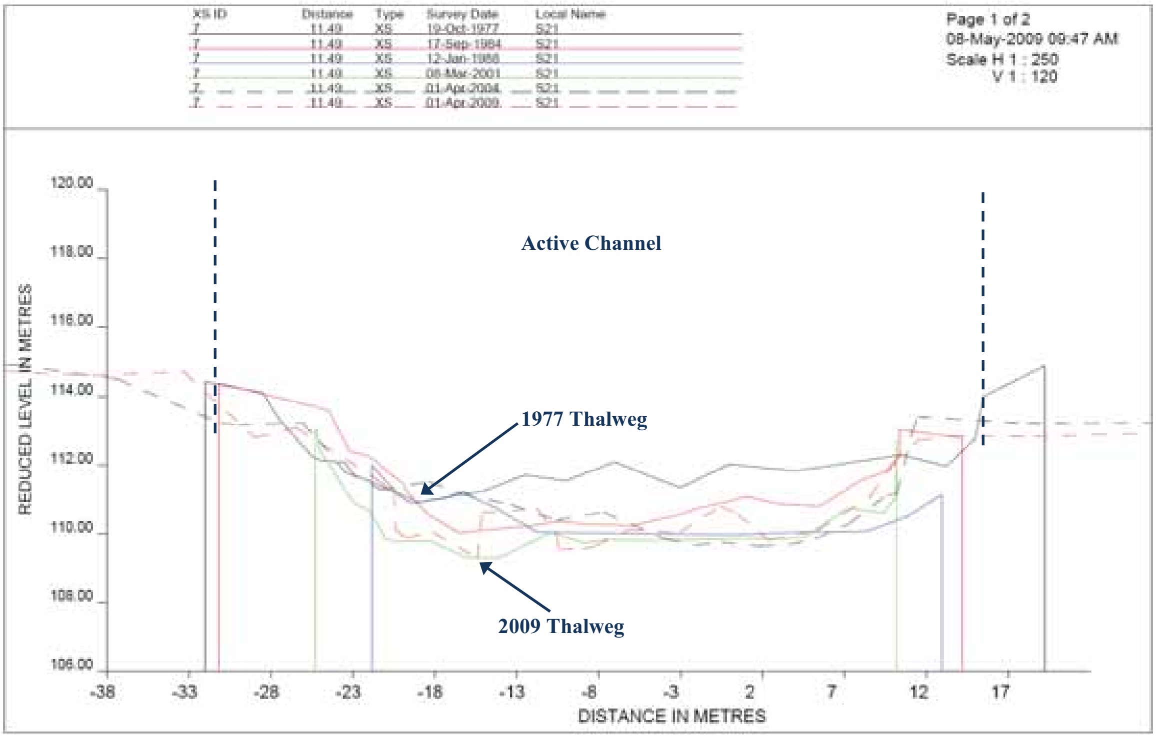

Figure 8.6 Cross-section S21, looking downstream

8.7 Cross-section S22a

Cross section S22a is located approximately 11.59km upstream of the Shag River Mouth and 0.10km upstream of cross-section S21 (Figure 3.1). Figure 8.7 shows a plot of cross-section S22a for the 1977, 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 36.00m at this location. Mean bed level analysis shows net degradation of 0.97m over the active channel width between 1977 and 2009 (Table 3.2). While the largest proportion of this degradation, 0.66m, occurred during the period 1977 to 1988, a consistent trend of degradation is evident for all surveyed periods at this cross-section. The most recent survey period, 2004 to 2009, shows net degradation of 0.17m. The net degradation trend is also reflected by a true right shift and deepening of the thalweg by 1.16m over the period 1977 to 2009 (Figure 8.7).

Aerial photography (Figure 2.4) indicates that the channel form in 1947 is not dissimilar from the 2005 channel form. This is most likely due to the presence of well-established vegetation on both banks that confine the active channel margin. Some bare lateral bar deposits are evident in the 1996 imagery.

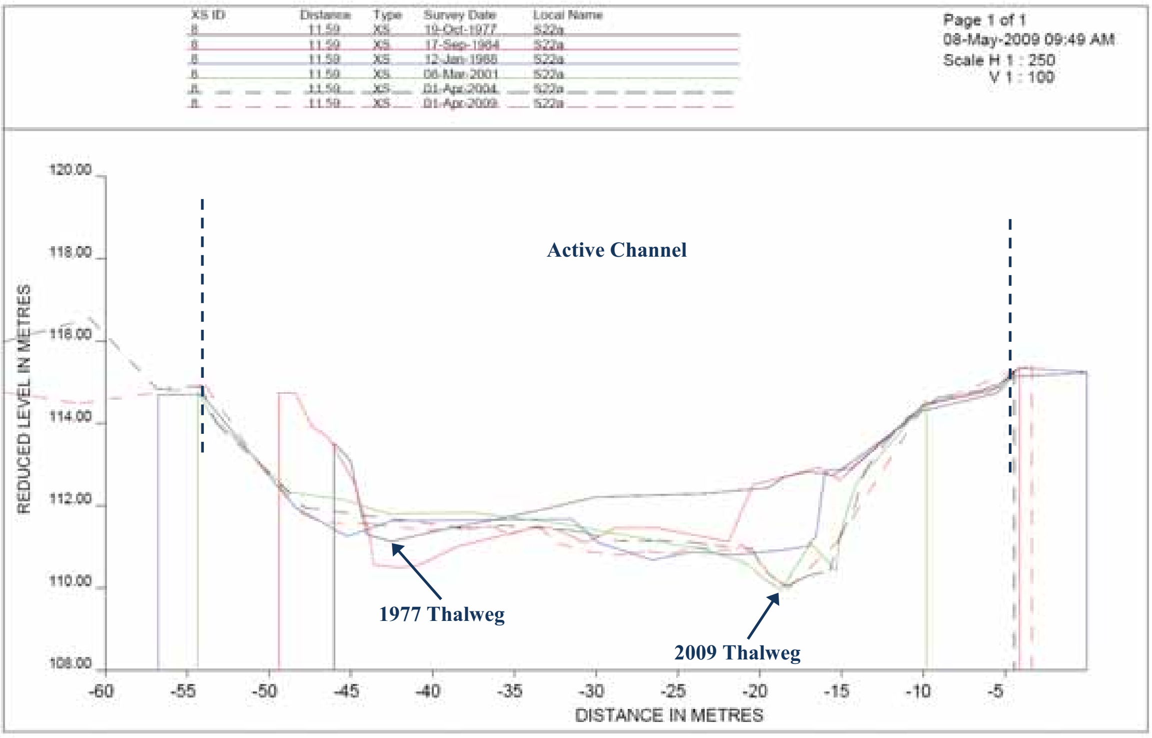

Figure 8.7 Cross-section S22a, looking downstream

8.8 Cross-section S22b

Cross-section S22b is located approximately 11.94km upstream of the Shag River Mouth and 0.35km upstream of cross-section S22a (Figure 3.1). Figure 8.8 shows a plot of cross-section S22b for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 117.00m at this location. Mean bed level analysis shows net aggradation of 0.01m over the active channel width between 1984 and 2009 (Table 3.2). This analysis indicates that bed levels at this location are at similar levels to those surveyed in 1984. However, variation between survey periods is evident where net degradation of 0.22m was experienced between 1984 and 1988. Comparatively, the survey period 2004 to 2009 experienced aggradation of 0.25m. Thalweg levels have remained relatively consistent across surveyed periods with some observed lateral movement (Figure 8.8). Of note is the erosion of approximately 15 to 20m of the true right bank between 1984 and 1988.

Aerial photography (Figure 2.5) shows a sinuous channel in 1947 with a large point deposit formed by the lateral accretion of sediment on the convex (true right) bank. Comparatively, the 1996 and 2005 photographs shows this point bar feature to be largely dissected by the main channel stem with a large proportion of the true left channel now succeeded by vegetation.

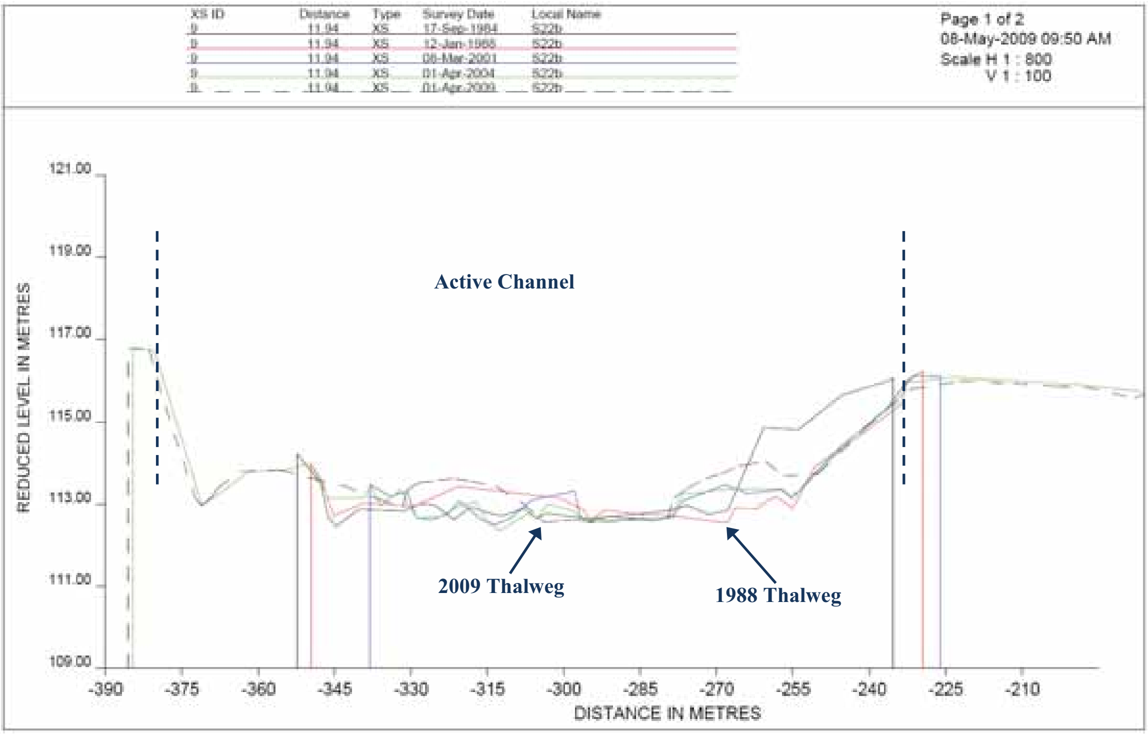

Figure 8.8 Cross-section S22b, looking downstream

8.9 Cross-section S24

Cross-section S24 is located approximately 12.60km upstream of the Shag River Mouth and 0.66km upstream of cross-section S22b (Figure 3.1). Figure 8.9 shows a plot of cross-section S24 for the 1984, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 94.00m at this location. Mean bed level analysis shows net degradation of 0.02m over the active channel width between 1984 and 2009 (Table 3.2). This analysis indicates that 2009 bed levels at this location are at similar levels to those surveyed in 1984. In addition, little variation is evident within surveyed periods with only 0.01m of aggradation evident for the most recent, 2004 to 2009, survey period. Thalweg levels have remained relatively consistent across surveyed periods with some observed lateral movement (Figure 8.9).

Aerial photography (Figure 2.5) indicates that the channel form at this location has remained relatively similar to that in 1947. Some lateral bar formation is still evident at this location although replenishment rates do not appear to be as recurrent with the prevalence of succeeding vegetation evident in the 2005 photography.

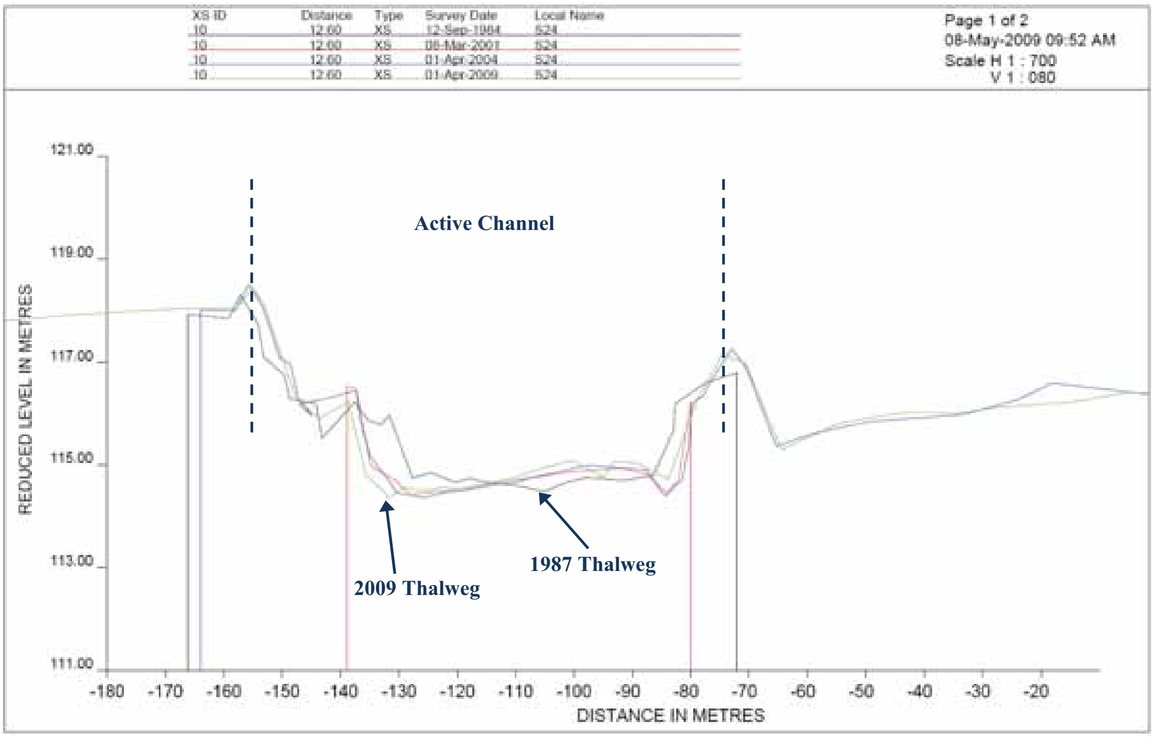

Figure 8.9 Cross-section S24, looking downstream

8.10 Cross-section S25

Cross-section S25 is located approximately 13.09km upstream of the Shag River Mouth and 0.49km upstream of cross-section S24 (Figure 3.1). Figure 8.10 shows a plot of cross-section S25 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 55.04m at this location. Mean bed level analysis shows net degradation of 0.99m over the active channel width between 1984 and 2009 (Table 3.2). Most degradation, 0.86m, occurred during the period 1988 to 2004, which is largely represented in Figure 3.11 as approximately 30m of true right bank erosion in the 1988 to 2001 survey period. In response to this erosion and widening of the channel, the thalweg level rose by 0.83m during the period 1988 to 2009 (Figure 8.10).

The right bank erosion is also evident on aerial photography (Figure 2.5), whereas in 1947 the channel form is uniform and straight with stable banks succeeded by willow trees. The 1996 and 2005 photography shows a section of trees removed in the vicinity of cross-section S25.

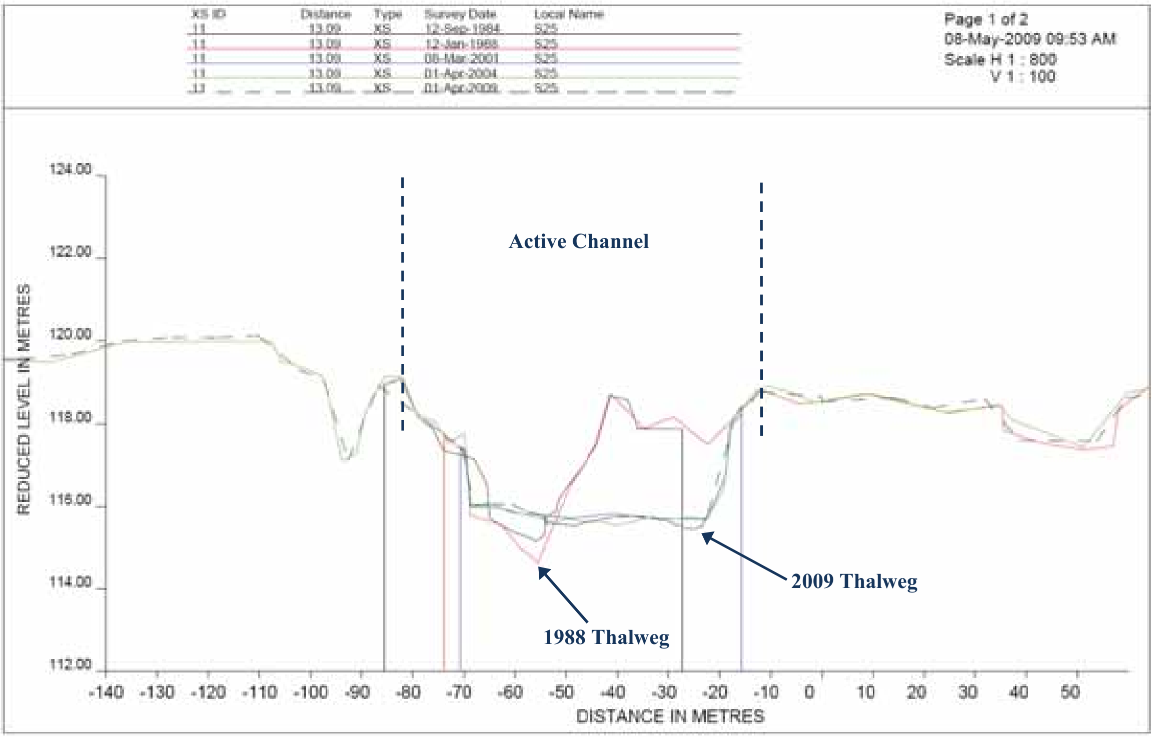

Figure 8.10 Cross-section S25, looking downstream

8.11 Cross-section S26

Cross-section S26 is located approximately 13.59km upstream of the Shag River Mouth and 0.50km upstream of cross-section S25 (Figure 3.1). Figure 8.11 shows a plot of cross-section S26 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 49.96m at this location. Mean bed level analysis shows net degradation of 0.88 over the active channel width between 1984 and 2009 (Table 3.2). Most degradation, 0.79m, occurred during the period 1984 to 2001, which is reflected in deepening of the thalweg by 1.41m. The most recent survey period, 2004 to 2009, experienced degradation of 0.17m. Changes in bank stability at this cross-section are similar to S25 with approximately 10m right bank erosion occurring during the period 1988 to 2001.

Aerial photography (Figure 2.5) indicates that S26 has a similar channel form to S25, whereas in 1947 a uniform, straight channel with stable willow bound banks is evident. This is compared to photography from 1996 and 2005 showing similar morphological changes to S25 with the removal of willows on the right bank and a widening of the channel.

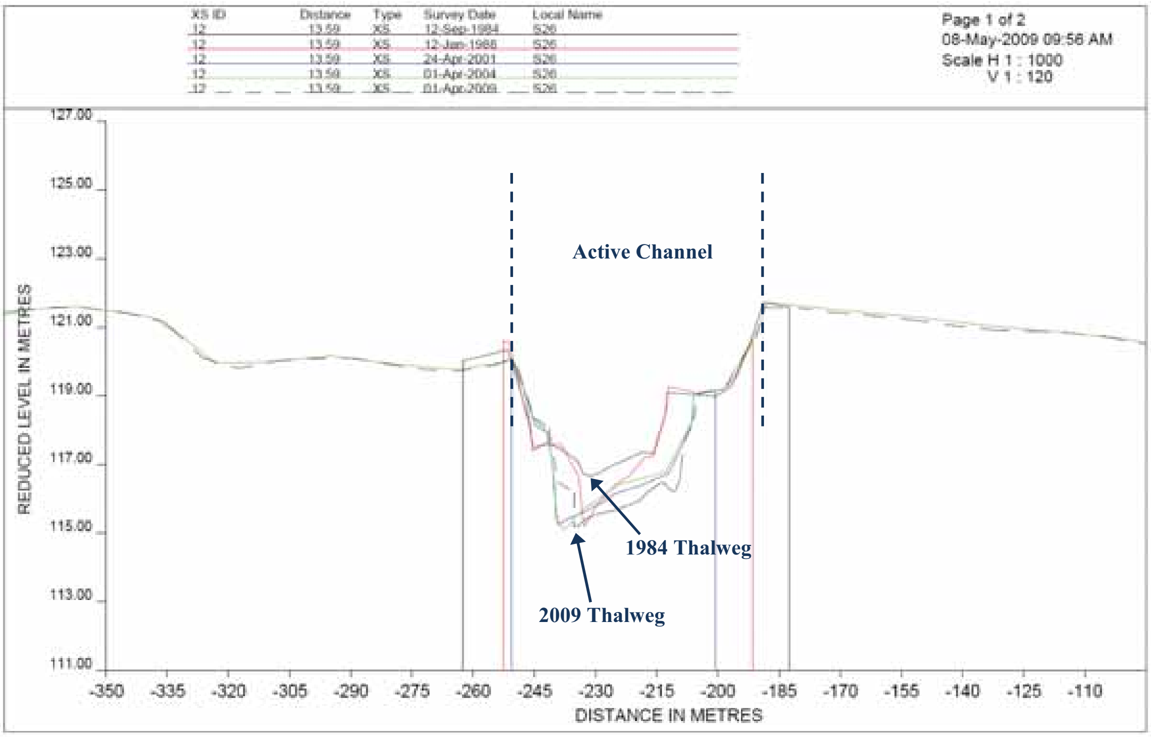

Figure 8.11 Cross-section S26, looking downstream

8.12 Cross-section S27

Cross-section S27 is located approximately 14.02km upstream of the Shag River Mouth and 0.43km upstream of cross-section S26 (Figure 3.1). Figure 8.12 shows a plot of cross-section S27 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 41.17m at this location. Mean bed level analysis shows net degradation of 0.87m over the active channel width between 1984 and 2009 (Table 3.2). While the largest proportion of this degradation, 0.64m, occurred during the period 1988 to 2001, a consistent trend of degradation is evident for all surveyed periods at this cross-section. The most recent survey period, 2004 to 2009, shows net degradation of 0.06m. The overall trend in net degradation is also reflected by a true left shift and deepening of the thalweg by 1.66m between 1984 and 2009 (Figure 8.12).

Aerial photography (Figure 2.5) indicates that the channel form in 1947 is not dissimilar from the 2005 channel form. This is most likely due to the presence of well-established vegetation on both banks that confine the active channel margin.

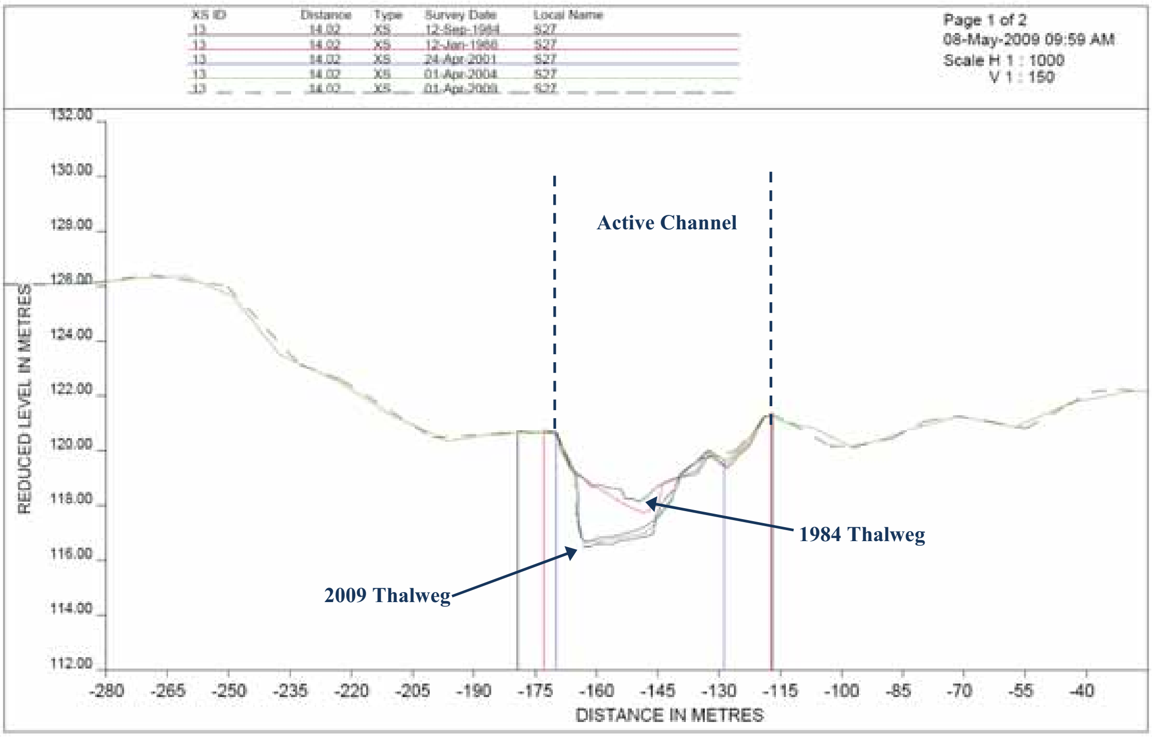

Figure 8.12 Cross-section S27, looking downstream

8.13 Cross-section S28

Cross-section S28 is located approximately 14.73km upstream of the Shag River Mouth and 0.71km upstream of cross-section S27 (Figure 3.1). Figure 8.13 shows a plot of cross-section S28 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 65.66m at this location. Mean bed level analysis shows net degradation of 0.33m over the active channel width between 1984 and 2009 (Table 3.2). Most degradation, 0.30m, occurred during the period 1988 to 2001, while the most recent survey period, 2004 to 2009, experienced 0.13m degradation. Figure 3.14 shows considerable right bank erosion of 9.7m in the period 1988 to 2001 followed by an additional 9.8m in the period 2004 to 2009. These periods of erosion, totalling near 20m, have been consistent with a lateral thalweg shift to the true right.

Aerial photography (Figure 2.5) indicates that the channel form at this location has changed from a sediment rich, active channel with relatively large point and lateral bar deposits in 1947, to a more confined channel with a singular point bar deposit in 2005.

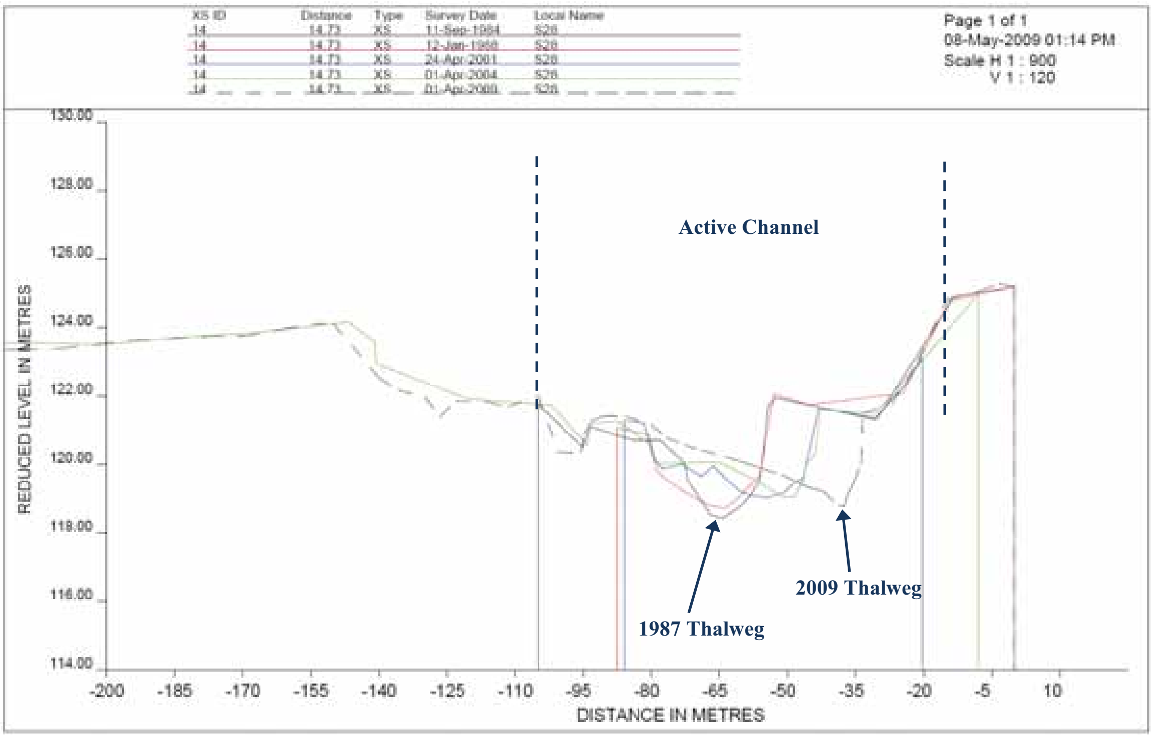

Figure 8.13 Cross-section S28, looking downstream

8.14 Cross-section S29

Cross-section S29 is located approximately 15.63km upstream of the Shag River Mouth and 0.90km upstream of cross-section S28 (Figure 3.1). Figure 8.14 shows a plot of cross-section S29 for the 1984, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 54.73m at this location. Mean bed level analysis shows net degradation of 0.43m over the active channel width between 1984 and 2009 (Table 3.2). The largest proportion of degradation, 0.30m, occurred during the most recent survey period 2004 to 2009, while a consistent trend of degradation is evident for all surveyed periods at this cross-section location. This trend is also reflected by a deepening of the thalweg by 1.88m over the period 2004 to 2009 (Figure 8.14).

Aerial photography (Figure 2.6) indicates that the channel form in 1947 is not dissimilar from the 2005 channel form. The 1947 photography has a number of fresh lateral bar deposits at this location, whereas more recent photography indicates that sediment supply rates have declined. The 2005 photography shows that vegetation has become well-established along both banks at this location.

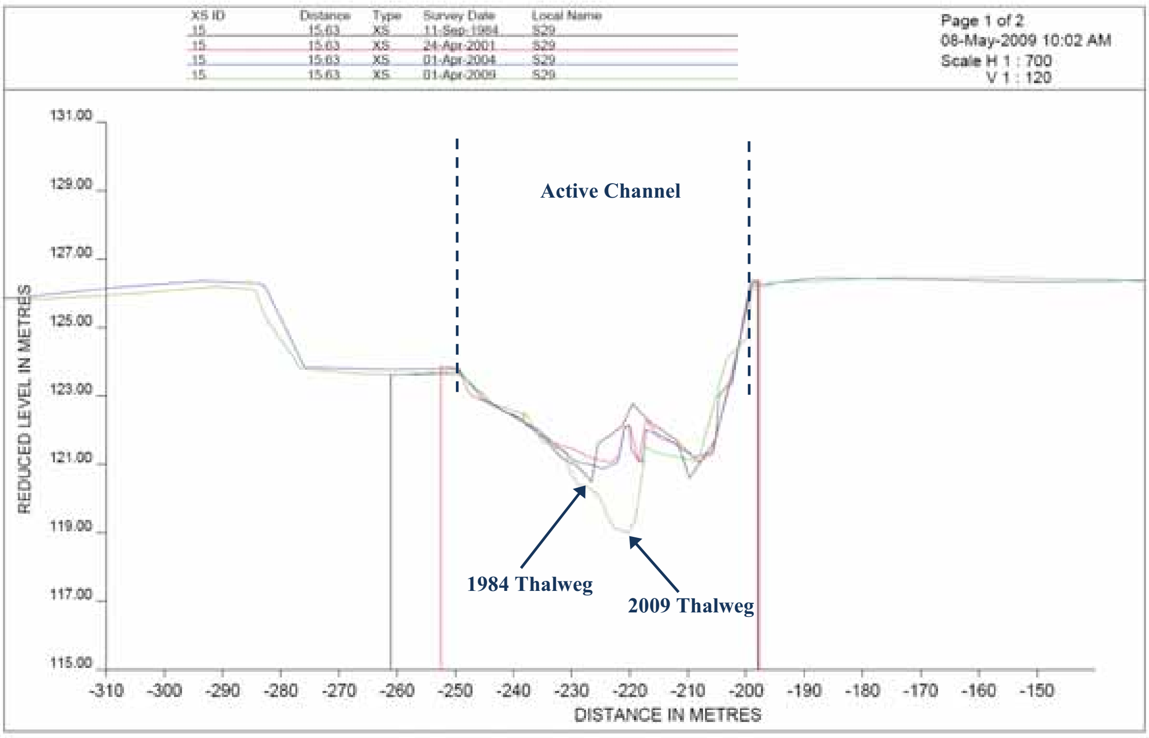

Figure 8.14 Cross-section S29, looking downstream

8.15 Cross-section S30

Cross-section S30 is located approximately 16.08km upstream of the Shag River Mouth and 0.45km upstream of cross-section S29 (Figure 3.1). Figure 8.15 shows a plot of cross-section S25 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 26.80m at this location. Mean bed level analysis shows net degradation of 0.17m over the active channel width between 1984 and 2009 (Table 3.2). The analysis shows that since 1988 the net bed level trend at this cross-section has been degradational. This trend is reflected in the lowering of the thalweg by 0.76m between 1984 and 2009 (Figure 8.15). Of note is significant aggradation of the left bank berm between 2004 and 2009.

Aerial photography (Figure 2.6) indicates that the channel form in 1947 is not dissimilar from the 2005 channel form. This is most likely due to the presence of well-established vegetation on both banks that confine the active channel margin.

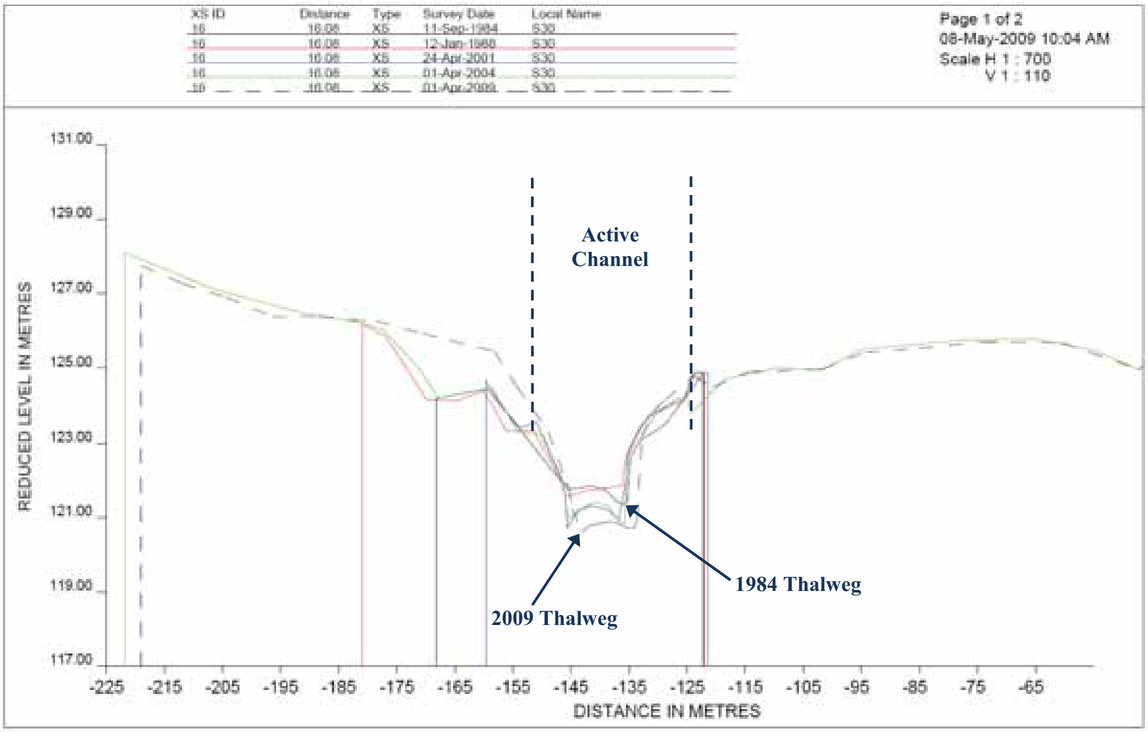

Figure 8.15 Cross-section S30, looking downstream

8.16 Cross-section S31

Cross-section S31 is located approximately 16.39km upstream of the Shag River Mouth and 0.31km upstream of cross-section S30 (Figure 3.1). Figure 8.16 shows a plot of cross-section S31 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 27.29m at this location. Mean bed level analysis shows net degradation of 0.09m over the active channel width between 1984 and 2009 (Table 3.2). At this location, mean bed levels have fluctuated between periods of minor aggradation and degradation between surveys. The most recent survey period, 2004 to 2009, shows minor aggradation of 0.03m.

Aerial photography (Figure 2.6) indicates that the channel form in 1947 is not dissimilar from the 2005 channel form. This is most likely due to the presence of well-established vegetation on both banks that confine the active channel margin.

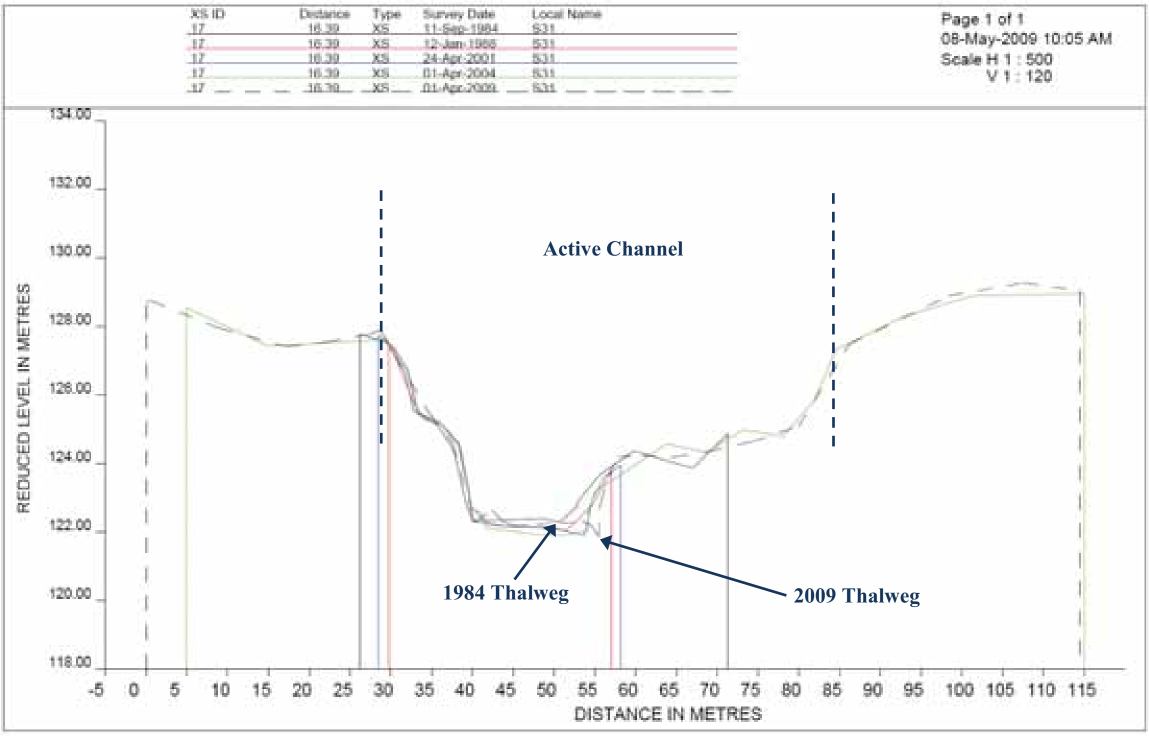

Figure 8.16 Cross-section S31, looking downstream

8.17 Cross-section S32

Cross-section S32 is located approximately 16.80km upstream of the Shag River Mouth and 0.41km upstream of cross-section S31 (Figure 3.1). Figure 8.17 shows a plot of cross-section S32 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 37.80m at this location. Mean bed level analysis shows net aggradation of 0.57m over the active channel width between 1984 and 2009 (Table 3.2). The largest proportion of aggradation, 0.28m, occurred during the period 1984 to 1988, while a consistent trend of aggradation is evident for all surveyed periods at this cross-section location. The most recent survey period, 2004 to 2009, experienced 0.04m aggradation. This trend is also reflected by an increase in the level of the thalweg by 0.41m over the period 1984 to 2009 (Figure 8.17).

Aerial photography (Figure 2.6) indicates that the channel form in 1947 was largely influenced by dense vegetation encroaching on the active channel margins. Comparatively, the 2005 photography shows much less vegetation near the active channel.

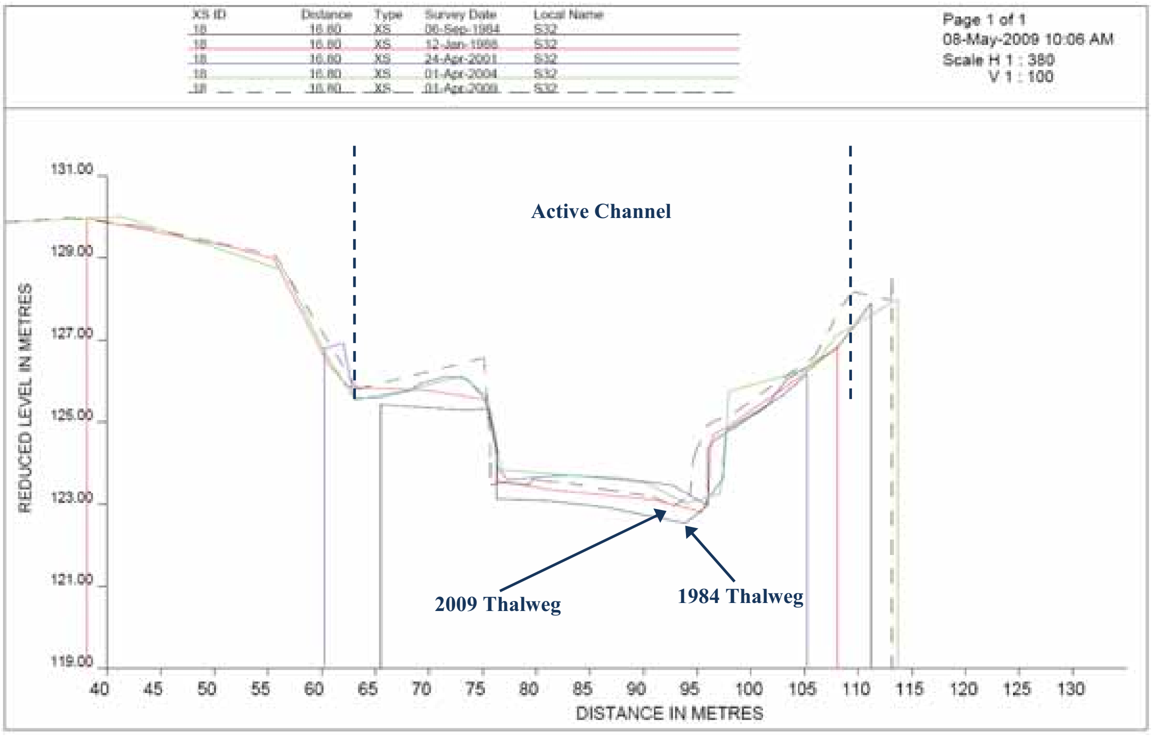

Figure 8.17 Cross-section S32, looking downstream

8.18 Cross-section S33

Cross-section S33 is located approximately 17.38km upstream of the Shag River Mouth and is located just downstream of the Craig Road Bridge (Figure 3.1). Figure 8.18 shows a plot of cross-section S33 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 21.26m at this location. Mean bed level analysis shows net degradation of 0.22m over the active channel width between 1984 and 2009 (Table 3.2). Large amounts of variability in calculated mean bed levels are evident at this location. This is noted by 0.36m degradation for the period 1984 to 1988 followed by 0.35m aggradation from 1988 to 2001. Another period of degradation, 0.28m, was then evident between 2001 and 2004, while the most recent survey, 2004 to 2009, experienced 0.07m of aggradation. The channel is confined at this location by bedrock and as such, the banks have not eroded significantly over the 25-year period of survey.

Aerial photography (Figure 2.6) indicates that the channel form in 1947 is not dissimilar from the 2005 channel form. It is noted that the Craig Road Bridge was not in place in 1947 but is visible in the 1996 photography.

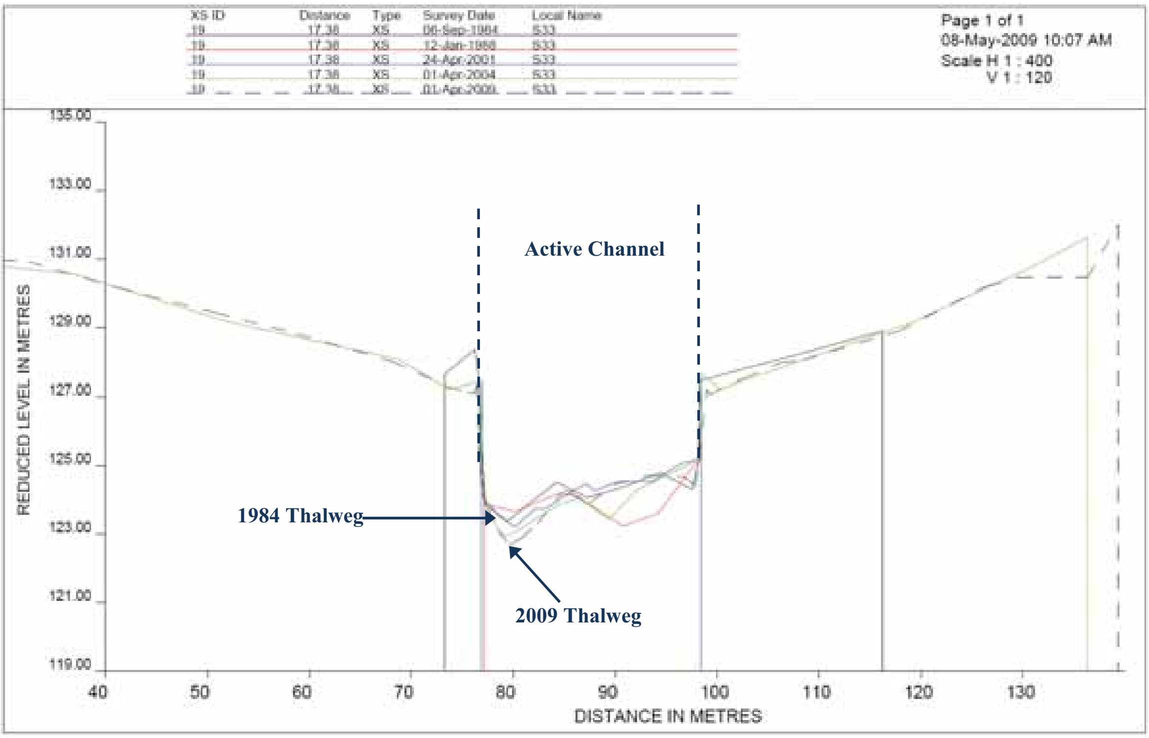

Figure 8.18 Cross-section S33, looking downstream

8.19 Cross-section S34

Cross-section S34 is located approximately 18.04km upstream of the Shag River Mouth and 0.66km upstream of cross-section S33 (Figure 3.1). Figure 8.19 shows a plot of cross-section S34 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 41.48m at this location. Mean bed level analysis shows net degradation of 0.47m over the active channel width between 1984 and 2009 (Table 3.2). Most degradation, 0.56m, occurred during the period 1988 to 2001, while the most recent survey period, 2004 to 2009, experienced 0.12m of aggradation. Bank erosion is evident over a number of the surveyed periods with a large proportion of both left and right banks eroding during the period 1988 to 2001 (Figure 8.19).

Aerial photography (Figure 2.7) indicates the active channel width at this location has been reduced significantly between 1947 and 2009. Some deposition on the main point bar feature at this location is evident in 2005 photography; however, observations note that sediment supply rates have diminished significantly since 1947.

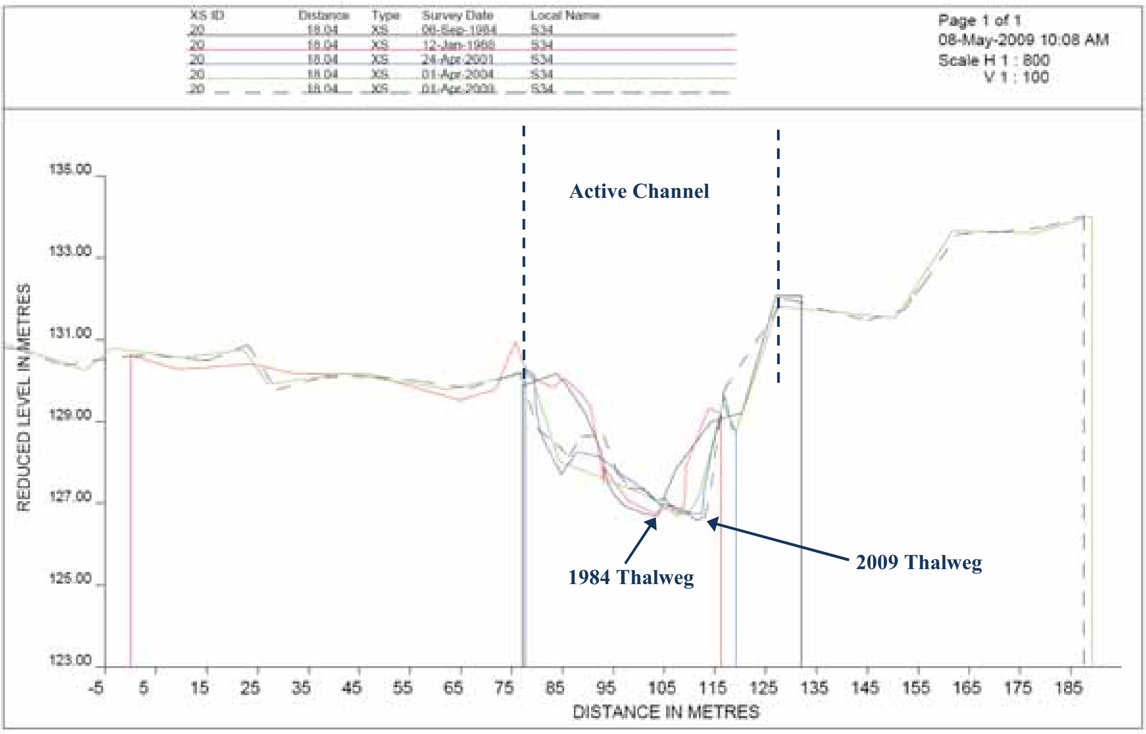

Figure 8.19 Cross-section S34, looking downstream

8.20 Cross-section S35

Cross-section S35 is located approximately 18.66km upstream of the Shag River Mouth and 0.62km upstream of cross-section S34 (Figure 3.1). Figure 8.20 shows a plot of cross-section S35 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 35.07m at this location. Mean bed level analysis shows net degradation of 0.76m over the active channel width between 1984 and 2009 (Table 3.2). The analysis shows that up until 2004 the net trend at this cross-section has been degradational with the largest proportion, -0.64m, occurring during the period 1988 to 2001. This trend is reflected by lowering of the thalweg by 1.24m between 1984 and 2009. The most recent survey period, 2004 to 2009, experienced minor aggradation of 0.04m.

Aerial photography (Figure 2.7) indicates that the channel form at this location has changed significantly from a sediment-rich, semi-vegetated channel in 1947 to a uniform straight channel with established vegetated banks in 2005.

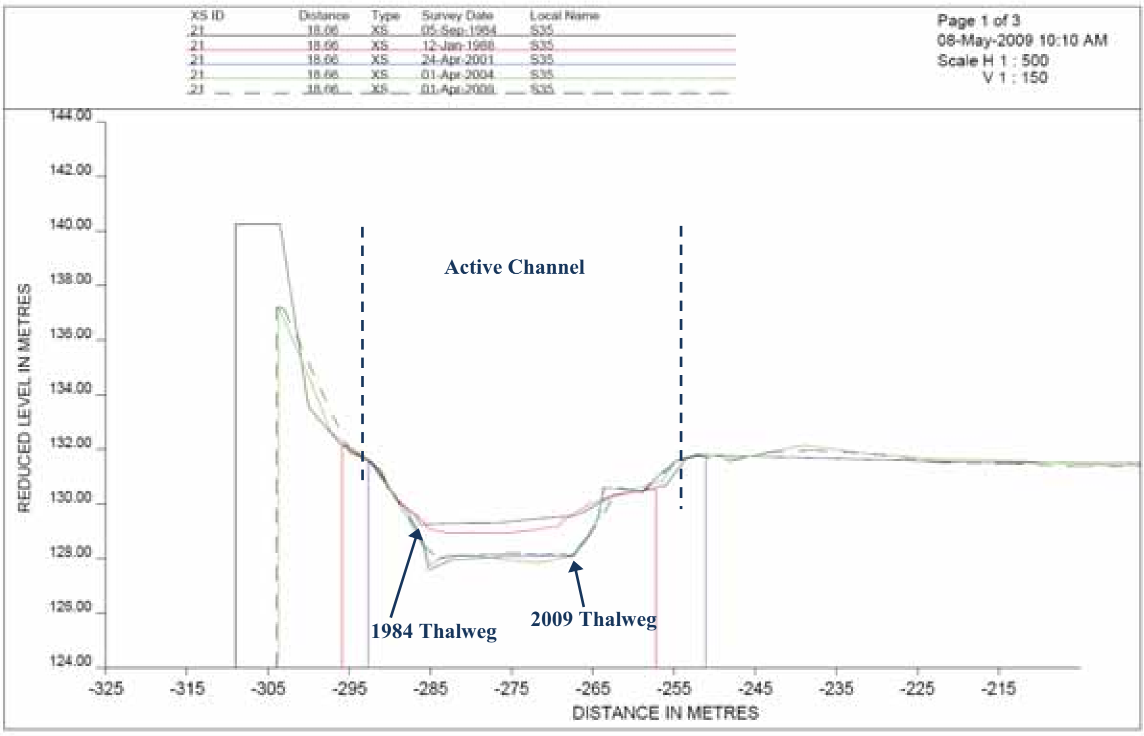

Figure 8.20 Cross-section S35, looking downstream

8.21 Cross-section S36

Cross-section S36 is located approximately 19.37km upstream of the Shag River Mouth and 0.71km upstream of cross-section S36 (Figure 3.1). Figure 8.21 shows a plot of cross-section S36 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 55.48m at this location. Mean bed level analysis shows net degradation of 0.71m over the active channel width between 1984 and 2009 (Table 3.2). The largest proportion of degradation, 0.65m, occurred during the period 1988 to 2001, with another 0.18m of degradation evident in the most recent (2004 to 2009) period. This trend is also reflected by a deepening of the thalweg by 0.77m over the period 1984 to 2009 (Figure 8.21).

Aerial photography (Figure 2.7) indicates that the channel form at this location has changed significantly from a sediment-rich, semi-vegetated channel in 1947 to a more uniform straight channel in 2005. Secondary flood channels (Figure 8.21) are evident in the 1947 photography as bare gravel beaches whereas, in 2005, these appear as less active pastoral land.

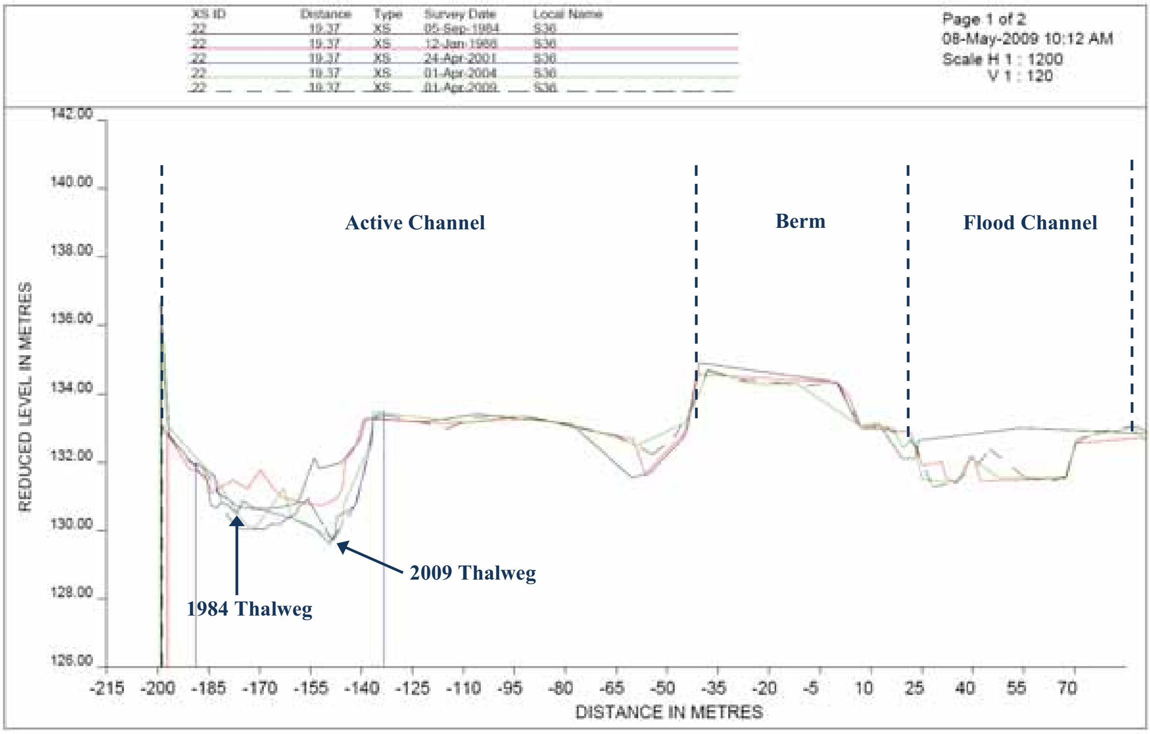

Figure 8.21 Cross-section S36, looking downstream

8.22 Cross-section S37

Cross-section S37 is located approximately 19.77km upstream of the Shag River Mouth and just downstream of the McLew Road Bridge (Figure 3.1). Figure 8.22 shows a plot of cross-section S37 for the 1984, 1988, 2001, 2004 and 2009 surveys.

The active channel covers a surveyed width of 46.78m at this location. Mean bed level analysis shows net degradation of 0.38m over the active channel width between 1984 and 2009 (Table 3.2). The largest proportion of degradation, 0.43m, occurred during the period 1988 to 2004. The most recent survey period, 2004 to 2009, experienced minor aggradation of 0.06m.

Aerial photography (Figure 2.7) indicates that the channel form at this location has changed significantly from a sediment rich, semi-vegetated channel in 1947 to a more uniform straight channel in 2005. Secondary flood channels (Figure 8.22) are evident in the 1947 photography as bare gravel beaches whereas, in 2005, these appear as less active pastoral land.

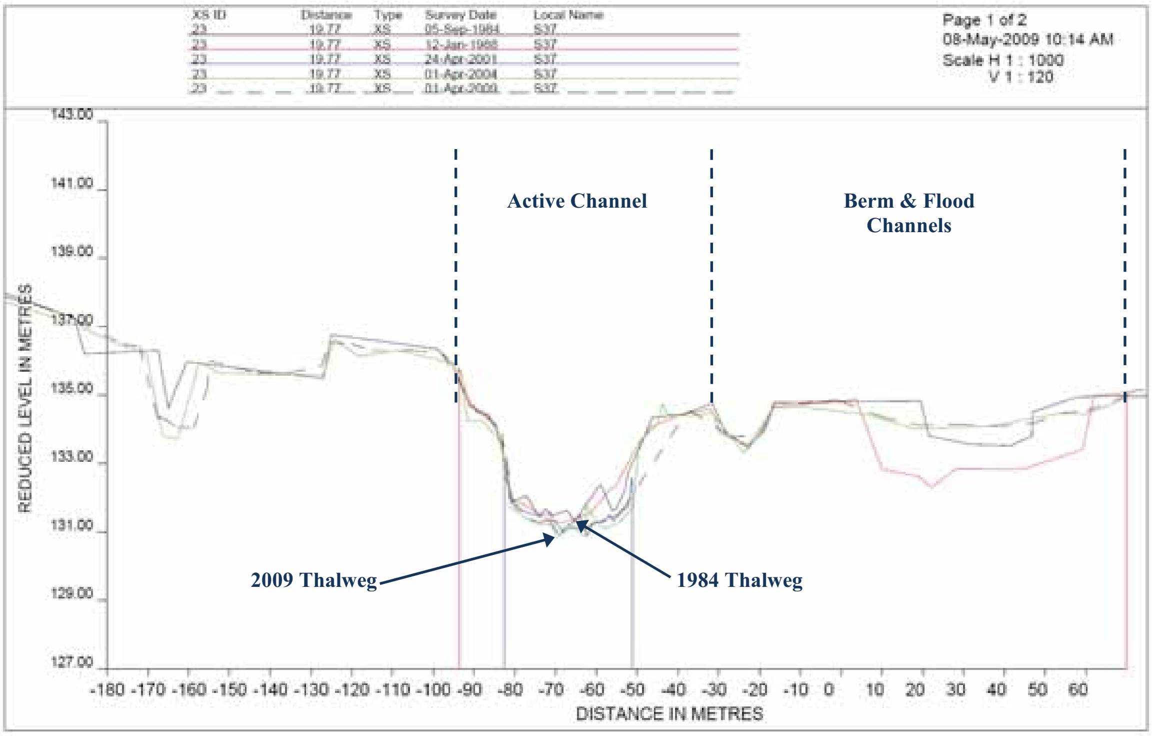

Figure 8.22 Cross-section S37, looking downstream