Land-Use Trends in Marlborough District:

Consequences for Soil Resources

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Landcare Research
Manaaki Whenua

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Summary

Project and Client

Marlborough District Council contracted Landcare Research via an Enivirolink Small Advice Grant to undertake an analysis of land-use change trends and their impact on soil resources within the district. The council is particularly interested in understanding the extent and pattern of change to versatile soils resulting from urbanisation within the district.

Objectives

- Identify, map and describe soil resources across the Marlborough District
- Analyse land use-trends and evaluate their effects on soil resources, paying particular attention to urbanisation trends.

Methods

- Overlay the following input spatial data layers:
    - Land Resource Inventory (mid-1970s, portions updated 1985 including Marlborough lowlands – 1985 hereafter for simplicity)
    - Land Cover Database Version 1c (1996/97)
    - Land Cover Database Version 2 (2001/02)
    - Agribase (2008)
    - Protected Areas Network-New Zealand Database (2008)
    - Marlborough District 2006 Census boundaries
- Undertake a combinatorial analysis that determines all unique combinations of the input data layers and produces a corresponding spatial grid layer and relational database
- Analyse the results of the combinatorial analysis to determine land-use change trends within the district and their consequences for soil resources.

Results

- 6.0% (62 261 ha) of soils in Marlborough District are LUC Classes 1–3, highly versatile soils suitable for arable agricultural production
- From 1985 (LRI) to 2001/02 (LCBD2) a total of 2055 ha of land was converted to urban uses, defined as Built-up Area, Surface Mine, Transport Infrastructure, Urban or Lifestyle Blocks. Distribution of conversion by LUC Classes was as follows:
    - LUC 1 57
    - LUC 2 203
    - LUC 3 736
    - LUC 4 190
    - LUC 5 7
    - LUC 6 395
    - LUC 7 398
    - LUC 8 69

- Distribution of conversion of land to urban uses was as follows:
    - Built-up Area 540
    - Surface Mine 78

    - Transport Infrastructure 118
    - Urban Parkland/Open Space 167
    - Lifestyle Block 1154
- Some transport infrastructure included facilities related to forestry operations and therefore may only be temporary or periodic in nature, as opposed to conversions to permanent uses such as Built-up Areas, Urban Parks, or Lifestyle Blocks
- Most increases in Built-up Areas occurred adjacent or near to existing urban Centres such as Blenheim, Hastings, Picton, and Seddon although some small areas occurred along the coast of the Marlborough Sounds such as Anikiwa
- Lifestyle Blocks were distributed widely throughout the region with concentrations within the Wairau, Omaka, and Flaxbourne river valleys. Scattered Lifestyle Blocks occurred throughout the Marlborough Sounds
- 321 ha were reported as converting from Town (LRI) to other non-urban land cover (LCDB1/LCDB2). This resulted from differences in delineation of boundaries around key urban centres, especially Blenheim, Picton, and Hastings.

Summary

- Reported conversion rates (% of original extent) for soils by LUC Class were as follows:
    - LUC 1 2.32
    - LUC 2 1.78
    - LUC 3 1.52
    - LUC 4 0.64
    - LUC 5 1.16
    - LUC 6 0.14
    - LUC 7 0.12
    - LUC 8 0.02
- Versatile soils (LUC Classes 1–3) experienced the largest conversion
- Reported land use trends with higher levels of uncertainty, such as the issue of urban boundary delineation around Blenheim, would benefit from a review of independent data sources such as aerial photos from similar time periods
- Given their proximity to existing urban areas and past land-use change trends, versatile soils remain vulnerable to further urbanisation.

1 Introduction

Marlborough District Council engaged the services of Landcare Research via an Envirolink Small Advice Grant to provide information on the status and trends of soil resources in the district to support preparation of their second-generation regional policy statement. The Council wishes to know how land use, particularly the conversion of soils to urban uses, has impacted highly versatile soils over time. Versatile soils are defined as Class 1, 2, or 3 soils as delineated by the New Zealand Land Resource Inventory (New Zealand Soil Bureau 1968). Versatile soils offer the most options for land use, while requiring the least management and highest reliability. Long-term conservation of versatile soils maintains choice going forward. The on-going reduction or loss of versatile soils could limit future production options and/or require additional inputs or management to maintain a given level of output if attempted on soils with less versatility.

2 Background

2.1 Soil resources of Marlborough District

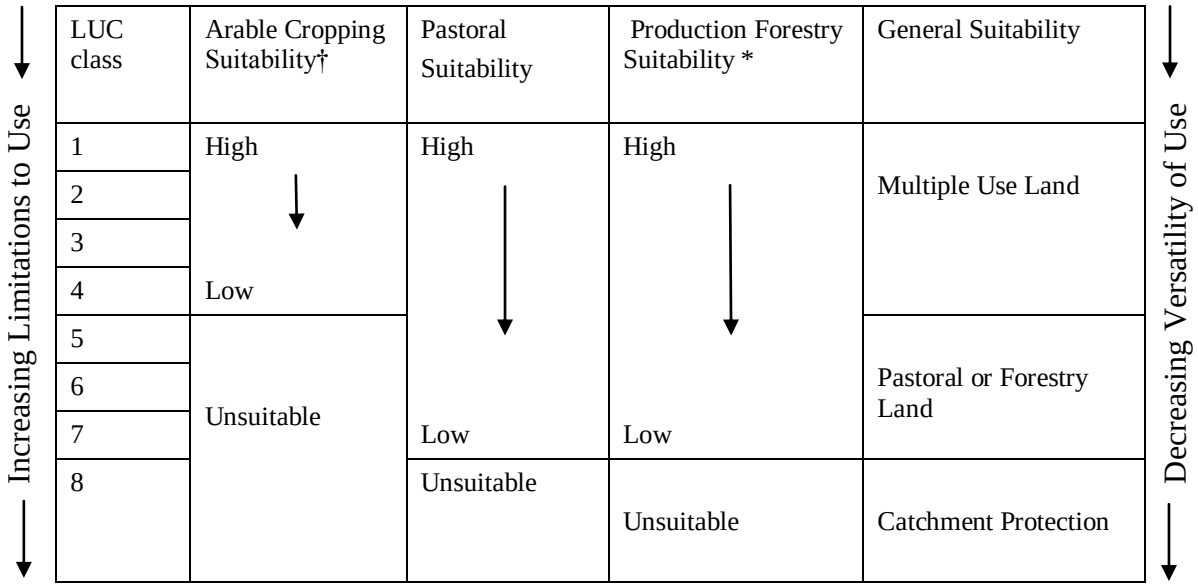
The Marlborough District covers some 10 321 square kilometres and is located at the top of the South Island. It encompasses a varied landscape dominated by mountain ranges, steep and moderately steep hill country, with narrow valley floors, extensive coastal margins and includes the Marlborough Sounds. The region is predominantly underlain by well-indurated, quartzo-feldspathic greywacke and schist. A narrow belt of softer younger rocks, including limestone, occupies the eastern coastal margin. Much of this strongly rolling to moderately steep hill country is overlain by a mantle of loess of varying thickness. Flat to undulating terraces, associated fans and floodplains occupy the narrow fault-controlled valley floors of the Wairau and Awatere Rivers.

The district contains a diverse range of soils reflecting variations in parent material composition and texture, age of soil development, climate, the impact of organisms, relief and landscape position and drainage. These soils exhibit a range of different properties and characteristics and present different opportunities and constraints to land use. The New Zealand Land Resource Inventory (NZLRI) (National Water and Soil Conservation Organisation 1975–79, Lynn 1996) and its derived assessments identified the capacity of land for sustained agronomic production (land use capability or LUC). The NZLRI has been widely applied in New Zealand to identify opportunities and constraints to land use. The land use capability (LUC) classification is an assessment of land's capacity for sustained productive use taking into account physical limitations, including climate, soil conservation needs and management requirements.

The NZLRI has a strong landform and slope bias. On flat to strongly rolling land, a heavy emphasis is given to soil parent material, soil depth, stoniness, and soil drainage, reflecting the agricultural heritage of the system. On moderately steep-to-steep terrain the emphasis is on erosion susceptibility and temperature-related climate constraint to production.

2.2 Land Use Capability classification system

The LUC classification system has recently been reviewed and up graded by Lynn et al. (2009). There are eight LUC classes (Fig. 1). Classes 1–4 are classified as arable land, while LUC Classes 5–8 are non-arable. The limitations or hazards to use increase and the versatility of use decreases, from LUC Class 1 to LUC Class 8.



LUC class	Arable Cropping Suitability†	Pastoral Suitability	Production Forestry Suitability *	General Suitability
1	High	High	High	Multiple Use Land
2				
3				
4	Low			
5	Unsuitable	Low	Low	Pastoral or Forestry Land
6				
7				
8		Unsuitable	Unsuitable	Catchment Protection

† Includes vegetable cropping.

* LUC Classes with a major wetness limitation, and those units in low rainfall areas (<500 mm/yr), or those occurring on shallow soils (<45 cm) are normally not suited to production forestry.

Fig. 1 Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC class 8.

Table 1 provides a general description and suitable land uses for each LUC class. Detailed descriptions, physical limitations, land use suitability, slope limitations, characteristic soil stoniness, depth and workability, texture and drainage, characteristic erosion severity and erosion types, salinity, elevation and annual rainfall ranges are detailed in Lynn et al. (2009).

Table 1 General descriptions and suitable land uses by Land Use Capability Class

LUC class	General description	Suitable land uses
1	Versatile multiple-use land with minimal physical limitations for arable use. Flat to undulating land with deep resilient and easily worked soils and a minimal erosion risk under cultivation.	Highly suitable for cultivated cropping (many different crop types), viticulture, berry production, pastoralism, tree crops, and production forestry.
2	Very good land with slight physical limitations to arable use readily controlled by management and soil conservation practices. Flat to undulating land with moderately deep soils, slightly difficult to work with a slight erosion risk under cultivation.	Suitable for many cultivated crops vineyards and berry fields, pasture, tree crops, and production forestry
3	Land with moderate physical limitations to arable use. These limitations restrict the choice of crops and intensity of cultivation, and /or make special soil conservation practice necessary. Undulating to rolling land with shallow &/or stony soils, often difficult to work with a slight to moderate erosion risk under cultivation.	Suitable for cultivated crops, vineyards and berry fields, pasture, tree crops, and production forestry
4	Land with severe physical limitations to arable use. These limitations substantially reduce the range of crops which can be grown, and/or make intensive soil conservation and management necessary. Ranges from flat to strongly rolling land with very shallow &/or stony soils, often difficult to work with a severe erosion risk under cultivation.	Suitable for some cultivated crops, vineyards and berry fields, pasture, tree crops, and production forestry
5	High-producing land with physical limitations that make it unsuitable for arable cropping, but only negligible to slight limitations or hazards to pastoral, vineyard, tree crop or production forestry use. Includes non-arable land with a slight erosion limitation or hazard under permanent vegetation cover.	Negligible to slight limitations or hazards to pastoral, vineyard, tree crop or production forestry use.
6	Non-arable land that has slight to moderate physical limitations and hazards to use under a perennial vegetative cover. The majority is stable productive hill country but also included are flat to gently undulating stony and shallow terraces and fans, rolling land with a significant erosion risk too great to allow sustainable cropping.	Suitable uses include grazed pasture, tree crops and/or forestry, and in some cases vineyards. Erosion is commonly the dominant limitation, but it is readily controlled by appropriate soil conservation and pasture management.
7	Non-arable land that has severe physical limitations or hazards under perennial vegetation. Consequently, it is high-risk land requiring active management to achieve sustainable production.	Suitable uses include grazing provided intensive soil conservation measures and practices are in place, and in many cases it is more suitable for forestry.
8	Non-arable land with very severe to extreme physical limitations or hazards that make it unsuitable for arable, pastoral or commercial forestry use.	Erosion control, water management and conservation of flora and fauna are the main uses of this land

3 Objectives

- Identify and map soil resources across the Marlborough District.
- Analyse land use-trends and evaluate their effects on soil resources, paying particular attention to urbanisation trends.

4 Methods

Land use trends were analysed by comparing information on land use from spatial data layers from four time periods:

- 1970s –1985 Land Resource Inventory Version 2 (1985 hereafter for simplicity)
- 1996/97 Land Cover Database Version 1c
- 2001/02 Land Cover Database Version 2
- 2008 Agribase (AssureQuality 2008).

The 2006 Marlborough District Census boundary defined the spatial extent of the analysis. Legally protected areas (Rutledge et al. 2008) were also included.

All input spatial data layers were used ‘as is’. No attempt was made to correct errors related to spatial inaccuracy or classification accuracy of the input data layers before processing.

A combinatorial analysis method used in several previous studies (Rutledge et al. 2004; Walker et al. 2005, 2009; Rutledge et al. 2007) was used to combine the input spatial data layers for trend analysis. The method involved the following steps:

- Convert any vector (polygon) spatial data layers to raster (grid spatial data layers) with a 25-m grid cell size (0.0625 ha)
- Overlay and intersect the input spatial data layers
- Generate a look-up table that includes row entries for each combination of input data layer attributes
- Generate a new raster data layer whose cell values correspond to the unique combinations of the input data layers
- Import the resulting look-up table into a relational database (MS Access) for further querying and processing.

5 Results

5.1 Soil resources

The total area reported for the LRI for Marlborough District following the combinatorial analysis was 1 051 689 ha. A total of 8.9% of soils occur in LUC Classes 1 to 4 (Table 2). Over 91% of soils were classed as LUC Classes 6–7, with only a very small area in LUC Class 5 (Fig. 2). A total of 487 403 ha or 46.3% of the district is legally protected, most of which includes LUC Classes 6–8 soils found in the mountainous western portions of the district (Fig. 3).

Table 2 Area of soils by LUC class in Marlborough District

LUC class	Total area (ha)	Area (% of district)	Protected (ha)	Protected (% district)
1	1	0.24	2	0.00
2	11402	1.10	71	0.01
3	48 406	4.68	1220	0.12
4	29 861	2.89	1508	0.15
5	605	0.06	46	<0.01
6	292 362	28.26	54 064	5.14
7	365 692	35.35	197 509	18.78
8	283 668	27.42	230 476	21.91
Estuary	50	<0.01	39	<0.01
Lake	1767	0.17	195	0.02
Quarry	16	<0.01	4	<0.00
River	13 427	1.28	2114	0.20
Town	1982	0.19	154	0.01

Appendix 1 contains a more detailed description of the soils found in the district.

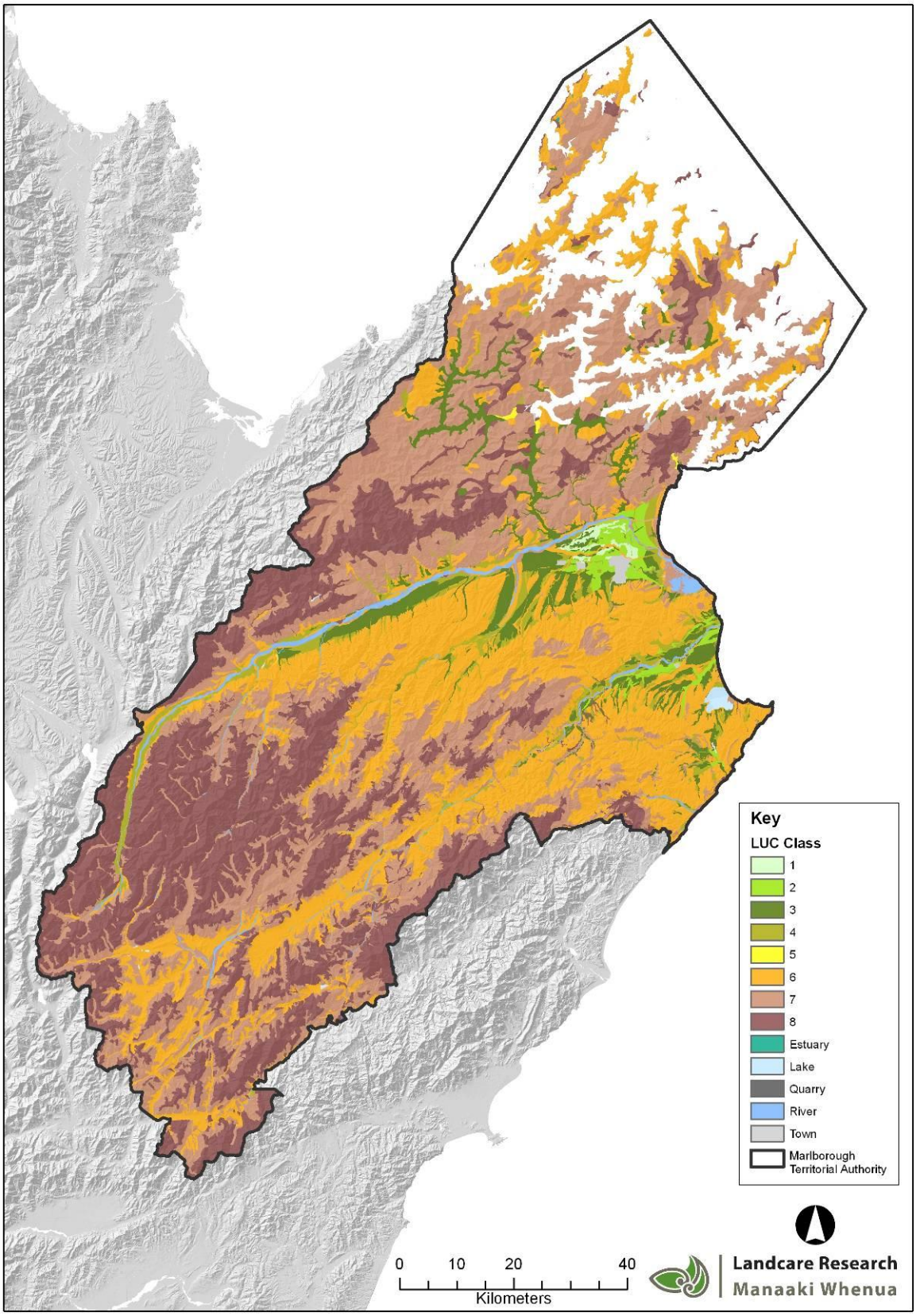


Fig. 2 Distribution of soils by LUC class in Marlborough District.

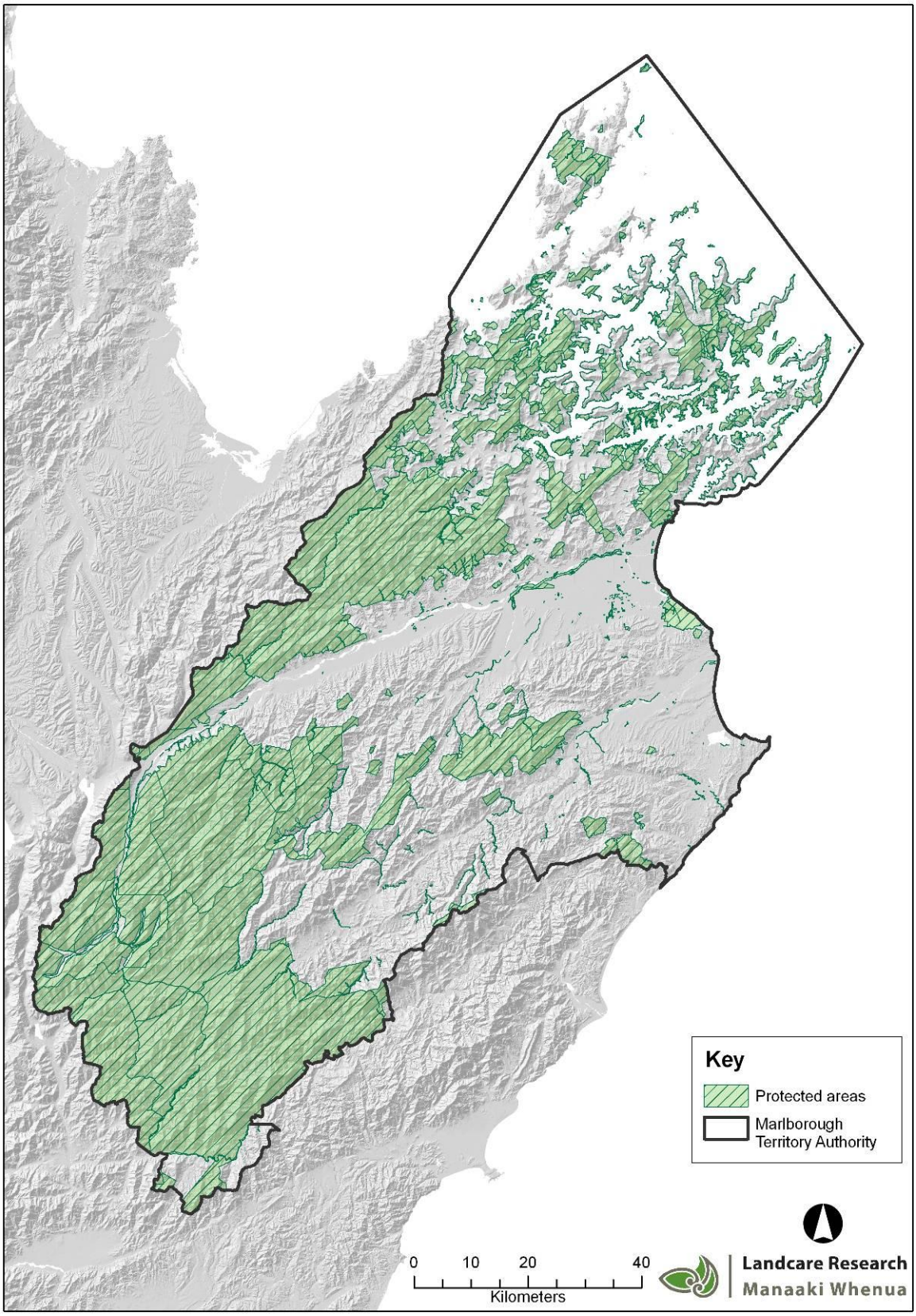


Fig. 3 Distribution of protected areas in Marlborough District.

5.2 Land-cover/land-use trends

Between 1996/97 (LCDB1) and 2001/02 (LCDB2), the combinatorial analysis reported a total of 18 775 ha of land-cover change. Around 3000 ha changed among natural, forestry, and exotic land cover[1] (Table 3).

Among production land uses, pastoral land cover decreased by ~11 400 acres between 1996/97 and 2001/02 with the majority of the transfer being to forestry (7273 ha). Viticulture increased by a total of 5339 ha from decreases in arable, forestry, natural, and pastoral land covers (Table 3).

Table 3 Land-cover change between LCDB1 and LCBD2 for a reduced 8 category land-cover classification. Grey cells indicate no change. All values in hectares

	To LCDB2							
FROM LCBD1	Arable	Exotic	Forestry	Horticulture	Natural	Pastoral	Urban	Viticulture
Arable	2751			31				1332
Exotic		7008	872		1845			
Forestry			63 127					165
Horticulture				538				
Natural			3053		625 818			37
Pastoral		52	7273	212	9	324 718	89	3807
Urban							3952	
Viticulture								4337

Inspection of the full land-cover classification showed that indigenous forest, high producing exotic grassland, low producing exotic grassland, tall tussock grassland, manuka and kanuka, and alpine gravel and rock were the dominant land cover types. Together they accounted for 82% of land within the district (Table 4).

[1] Appendix 2 contains a table showing the relationship between the full LCDB classification and the reduced 8 category classification discussed here and shown in Table 3.

Table 4 Land cover and land-cover change in the Marlborough District as of 1996/97 (LCDB1) and 2001/02 (LCDB2). All values in hectares

Land Cover Class	LCDB1	LCDB2	Change
'Afforestation (imaged, post LCDB 1)'		6013	6013
Afforestation (not imaged)		5153	5153
Alpine Grass/Herbfield	27 424	27 424	-
Alpine Gravel and Rock	62 229	62 229	-
Broadleaved Indigenous Hardwoods	46 321	44 223	-2098
Built-up Area	1887	1951	64
Coastal Sand and Gravel	1029	1029	-
Deciduous Hardwoods	2617	2580	-37
Depleted Tussock Grassland	12 166	12 166	-
Estuarine Open Water	1491	1491	-
Fernland	431	431	-
Flaxland	71	71	-
Forest Harvested		4633	4633
Gorse and Broom	7768	6948	-820
Grey Scrub	998	998	-
Herbaceous Freshwater Vegetation	641	641	-
Herbaceous Saline Vegetation	1140	1140	-
High Producing Exotic Grassland	215 770	205 715	-10 055
Indigenous Forest	215 015	215 015	-
Lake and Pond	570	570	-
Landslide	1440	1440	-
Low Producing Grassland	120 389	119 003	-1387
Major Shelterbelts	112	112	-
Manuka and or Kanuka	106 168	105 222	-946
Matagouri	1160	1160	-
Mixed Exotic Shrubland	1845	1845	-
Orchard and Other Perennial Crops	538	781	243
Other Exotic Forest	3188	3219	31
Pine Forest – Closed Canopy	46 158	41 401	-4757
Pine Forest – Open Canopy	13 945	13 906	-40
River	2333	2333	-
River and Lakeshore Gravel and Rock	11 349	11 349	-
Short-rotation Cropland	4114	2751	-1363
Sub Alpine Shrubland	23 171	23 171	-
Surface Mine	1434	1434	-
Tall Tussock Grassland	111 145	111 145	-
Transport Infrastructure	215	215	-

Urban Parkland/ Open Space	416	442	26
Vineyard	4337	9677	5339

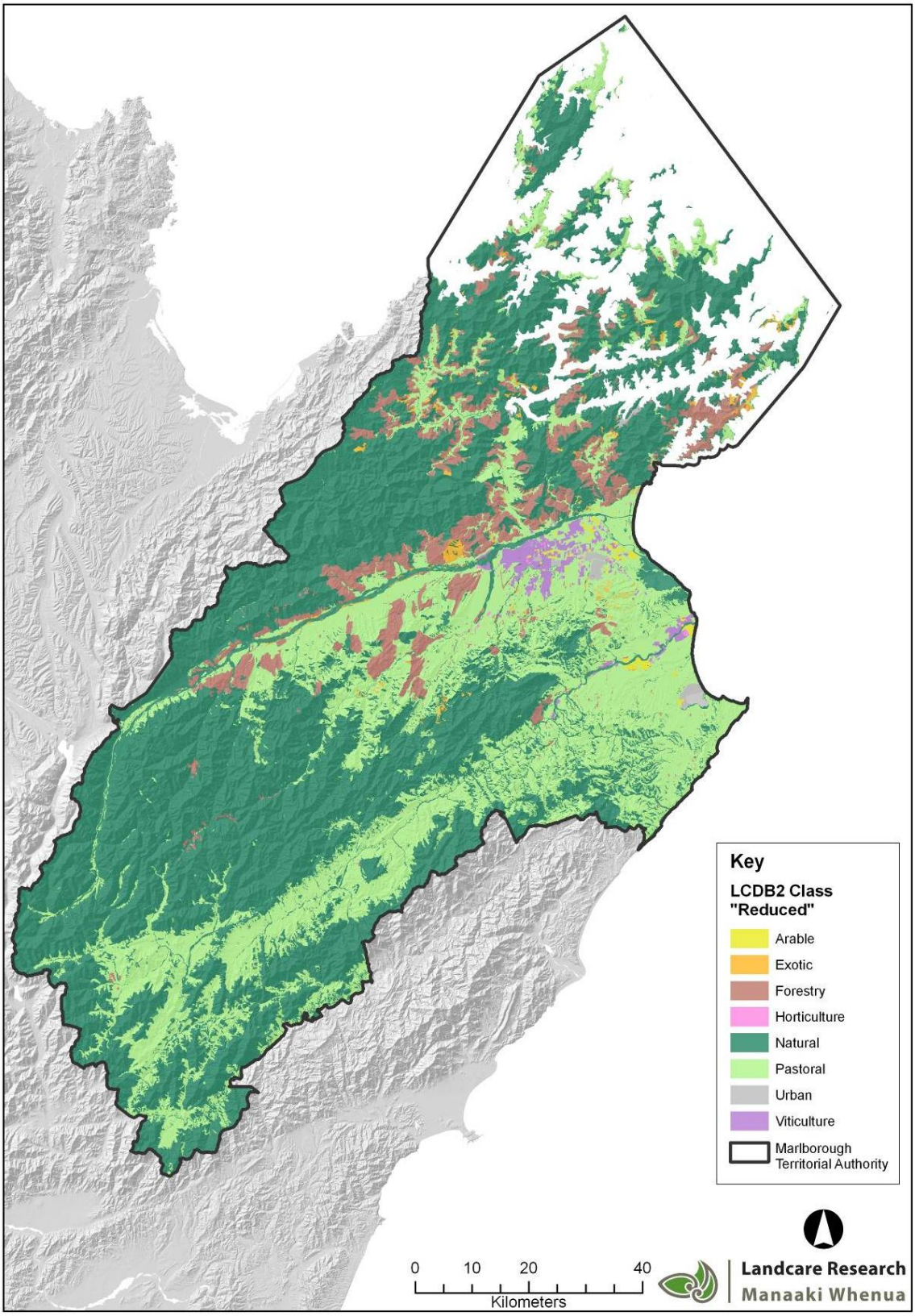


Fig. 4 Distribution of land cover (8 classes) in Marlborough District as of 2001/02 (LCDB2).

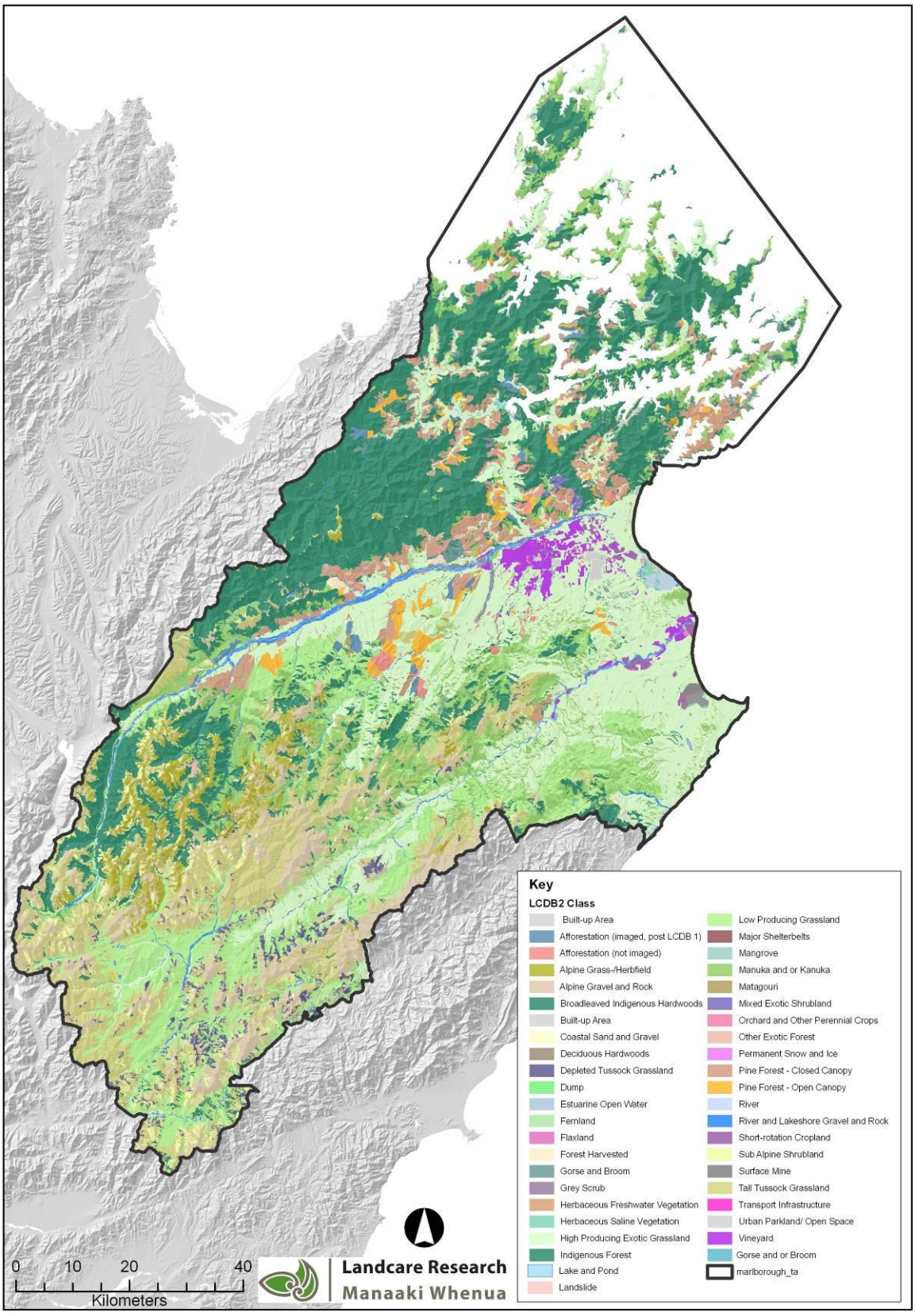


Fig. 5 Distribution of land cover types (full classification) in Marlborough District as of 2001/02 (LCDB2).

5.3 Urbanisation trends

5.3.1 1985 (LRI) to 1996/97 (LCDB1)

The LRI recorded a total of 1982 ha as Town at the time of the re-survey of Marlborough in 1985. By 1996/97 (LCDB1), 874 ha of land with an LUC rating had been converted to Built-up Area, Surface Mine, Transport Infrastructure, or Urban Parkland/Open Space (Table 5). The trend also reported that 381 ha of land designated as Town in the LRI had been classified as another land cover (e.g. high producing grassland, broadleaved indigenous forest) as of 1996/97 (LCB2). Also the total of the four urban classes and the Other Land Cover category totalled less than the 1985 (LRI) land area due to differences in the coastline, i.e. the LCDB2 had overall less area.

Table 5 Urbanisation trends from the 1985 (LRI) to 1996/97 (LCDB1)

		To 1996/97 (LCDB1)				
From 1985 (LRI)	LRI Total Area	Built-up Area	Surface Mine	Transport Infrastructure	Urban Parkland/ Open Space	Other Land Cover
LUC 1	2453	6	3	1		2443
LUC 2	11 402	48	5		3	11 343
LUC 3	48 406	185	3	4	66	48 097
LUC 4	29 861	12	6		29	29 813
LUC 5	605	7				598
LUC 6	292 362	44	40	32	54	290 919
LUC 7	365 692	190	21	75	11	364 005
LUC 8	283 668	18	< 1	6	4	282 935
	Total	510	78	118	167	
Estuary						50
Lake	1767		1 351	90		326
Quarry	16		1	6		9
River	13 427		2	< 1	< 1	13 421
Town	1982	1344			249	381

Increases in Built-up Areas occurred around Blenheim (Figs 6–10), Havelock, Seddon and Picton and in smaller communities such Anikiwa along the coastline between Picton and Havelock (Figs 11–14). Surface Mines occurred west of Bleheim (Fig. 15). The 1351 ha of land indicated as changing from Lake (1985, LRI) to Surface Mine (1996/97, LCDB 2) (Table 5) resulted from the classification of Lake Grassmere as a Surface Mine in LCDB2. Transport Infrastructure occurred west of Blenheim (Fig. 16), near Lake Grassmere (Fig. 17), and in the mountains north of Blenheim (Fig. 18). The last represented infrastructure associated with logging operations.

Urban Parkland/Open Space occurred primarily in and around Blenheim, with smaller areas in/near Picton, Havelock, and Seddon (Figs 19–21). In addition there was a large area identified near Rarangi along the coast. Areas within the boundaries of Blenheim, Picton, and Havelock formerly classified as Town in the 1985 (LRI) were classified as parks and open space as of 1996/97 (LCDB2) (Figs 19–20).

The reclassification of 381 ha of land from Town (LRI) to another (non-urban) land-cover category (LCDB1) resulted from differences in classification detail between the LRI and LCBD and the delineation of town boundaries. The LCDB has a 1 ha minimum mapping unit (Thompson et al. 2003). Areas such as indigenous forest or other natural areas within towns that met that size requirement were therefore (re)classified as such, whereas in the LRI they were included as part of the overall town class (Figs 21–23). LCDB1 also tended to delineate slightly smaller urban areas, which resulted in the reclassification of many strips along town boundaries into other land cover classes (Figs 21–23).

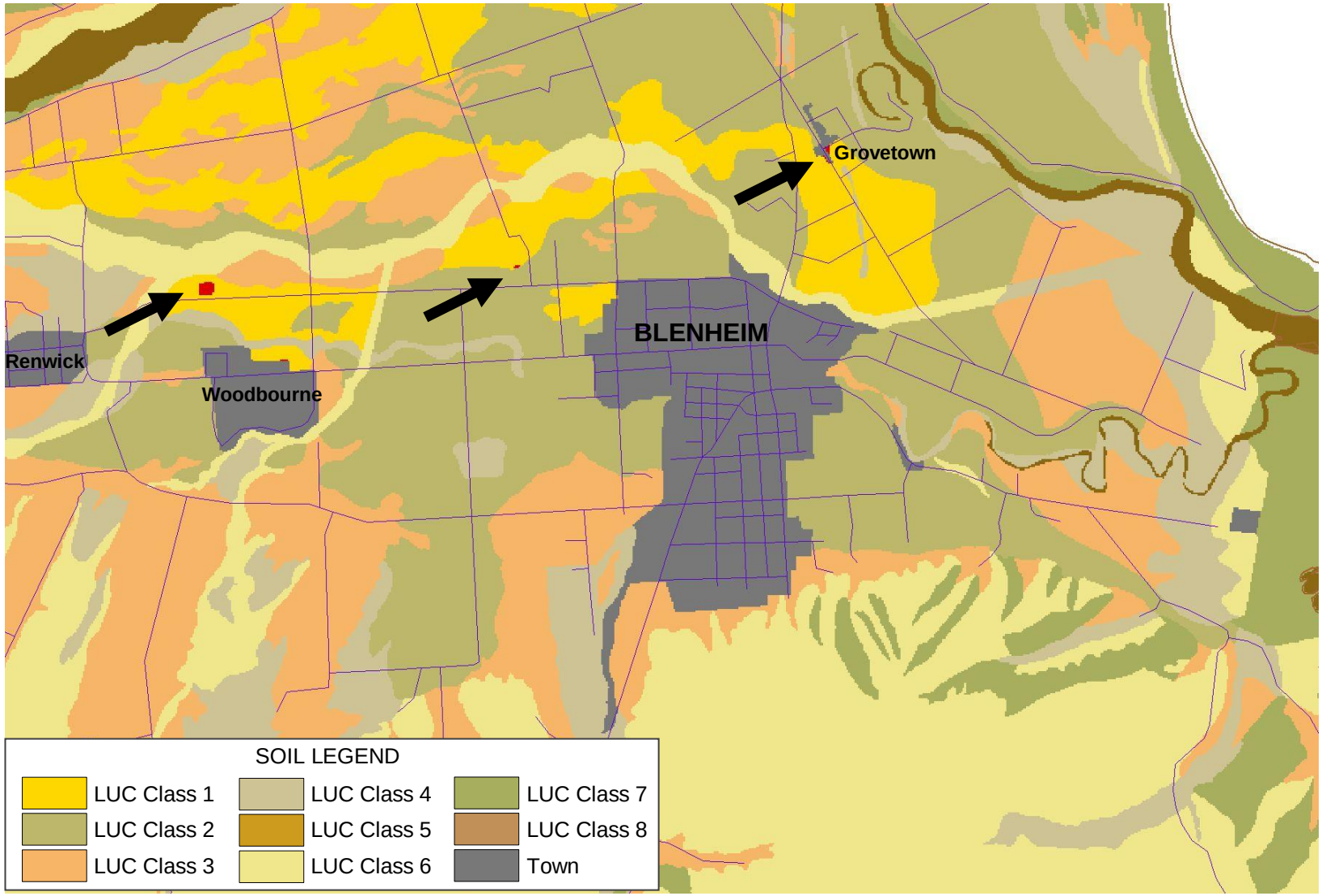


Fig. 6 Increases in Built-up Area (red areas) from 1985 (LRI) to 1996/97 (LCDB1) on LUC Class 1 soils around Blenheim.

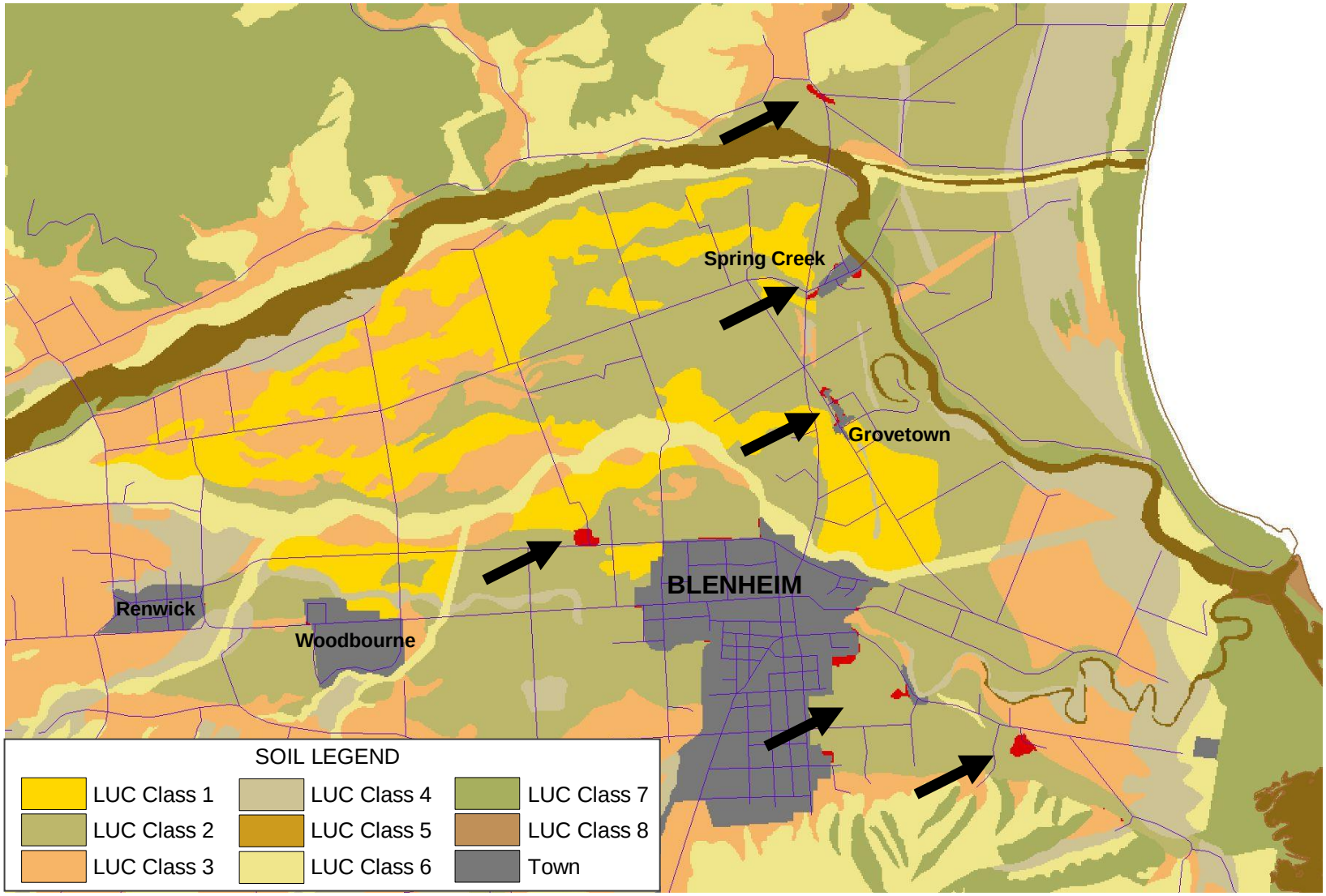


Fig. 7 Increases in Built-up Area (red areas) from 1985 (LRI) to 1996/97 (LCDB1) on LUC Class 2 soils around Blenheim.

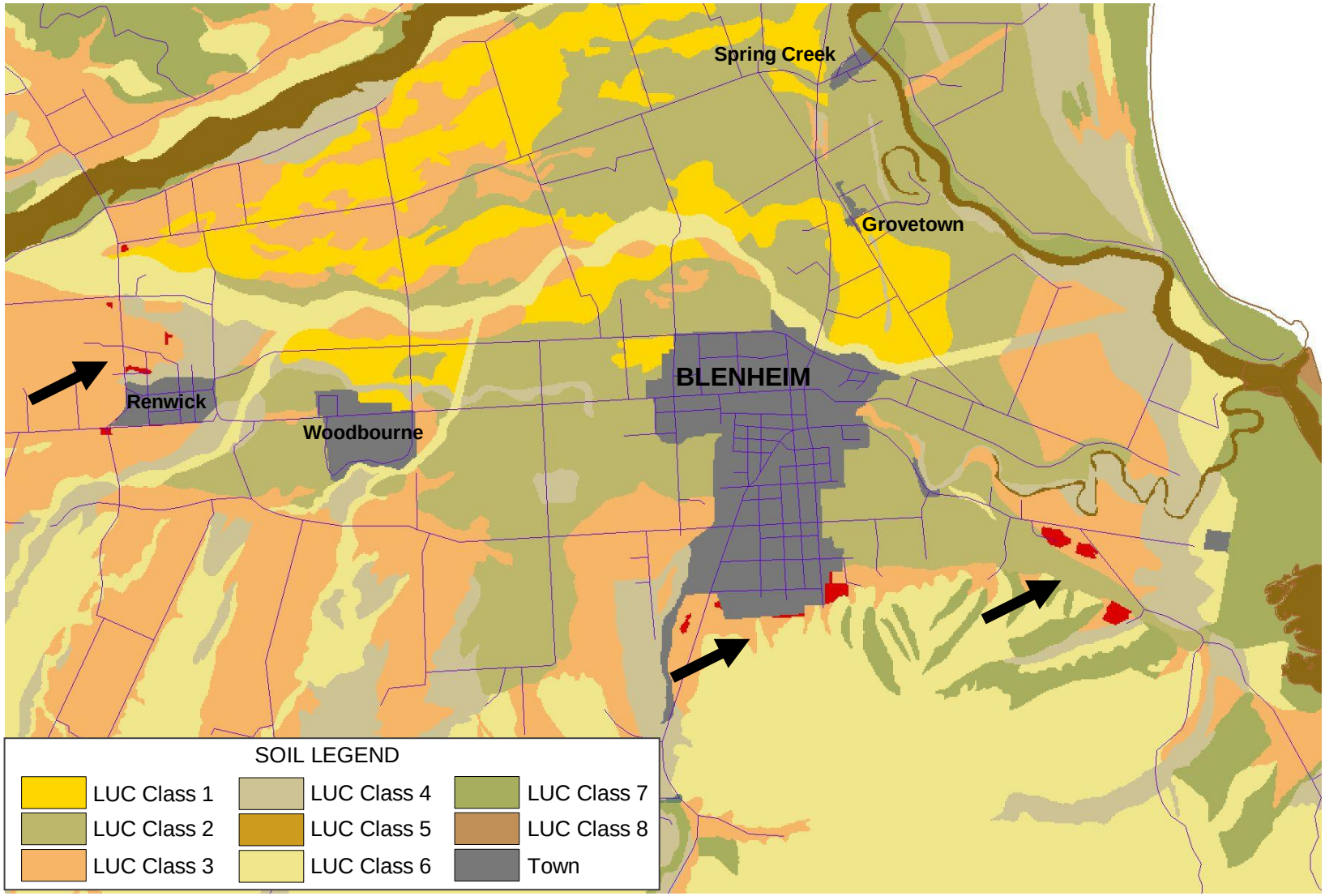


Fig. 8 Increases in Built-up Area (red areas) from 1985 (LRI) to 1996/97 (LCDB1) on LUC Class 3 soils around Blenheim.

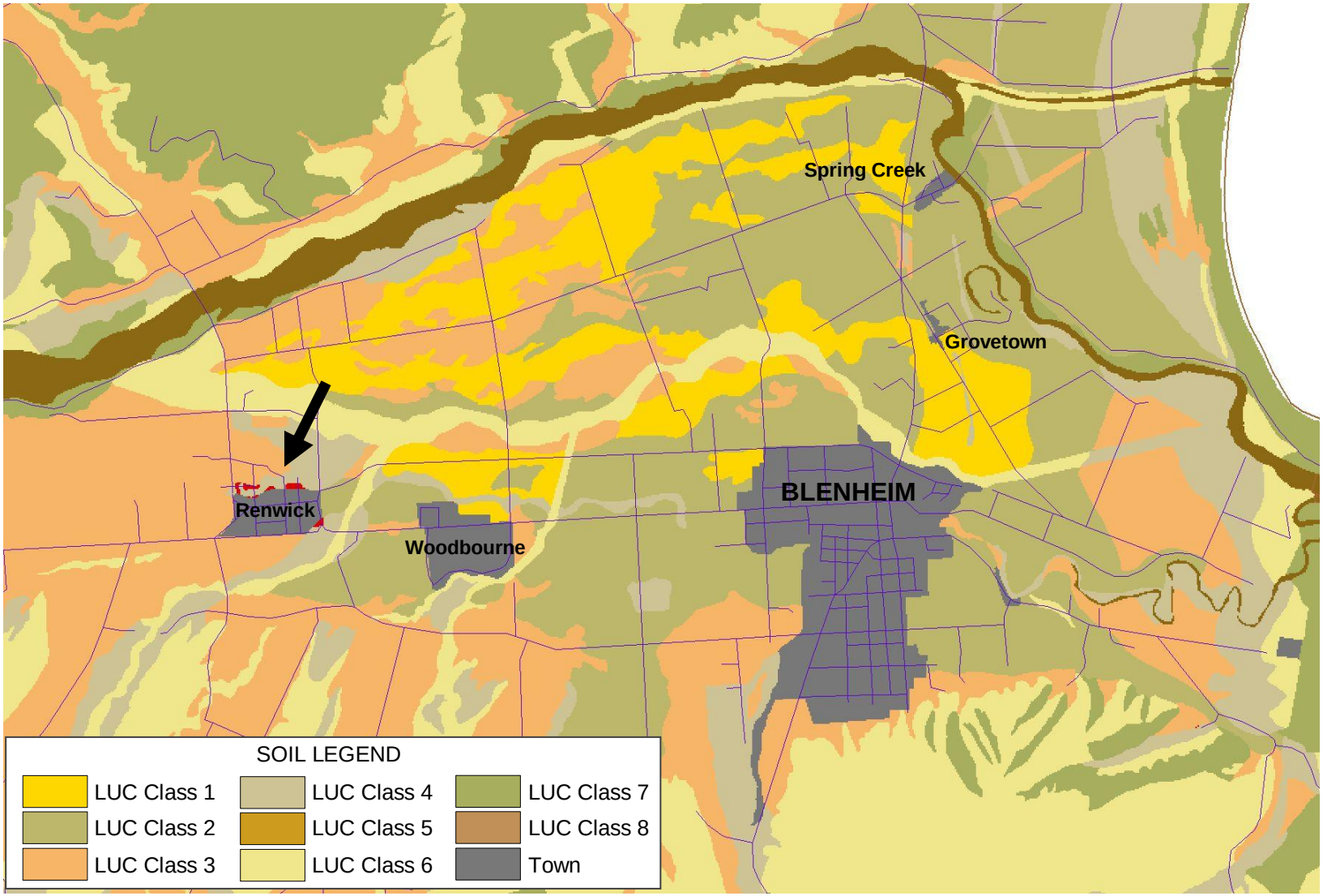


Fig. 9 Increases in Built-up Area (red areas) from 1985 (LRI) to 1996/97 (LCDB1) on LUC Class 4 soils around Blenheim.

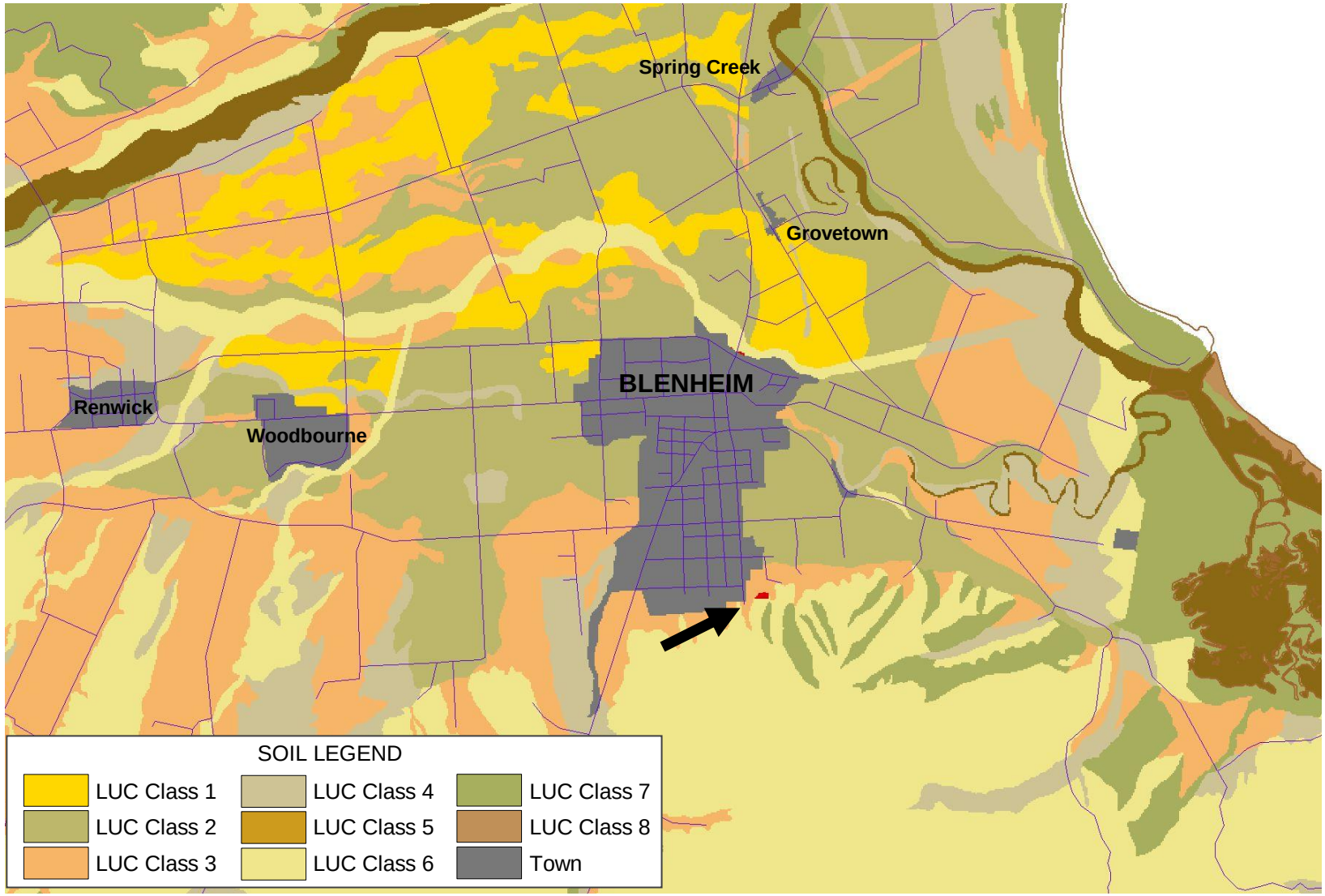


Fig. 10 Increases in Built-up Area (red areas) from 1985 (LRI) to 1996/97 (LCDB1) on LUC Class 6 Soils around Blenheim.

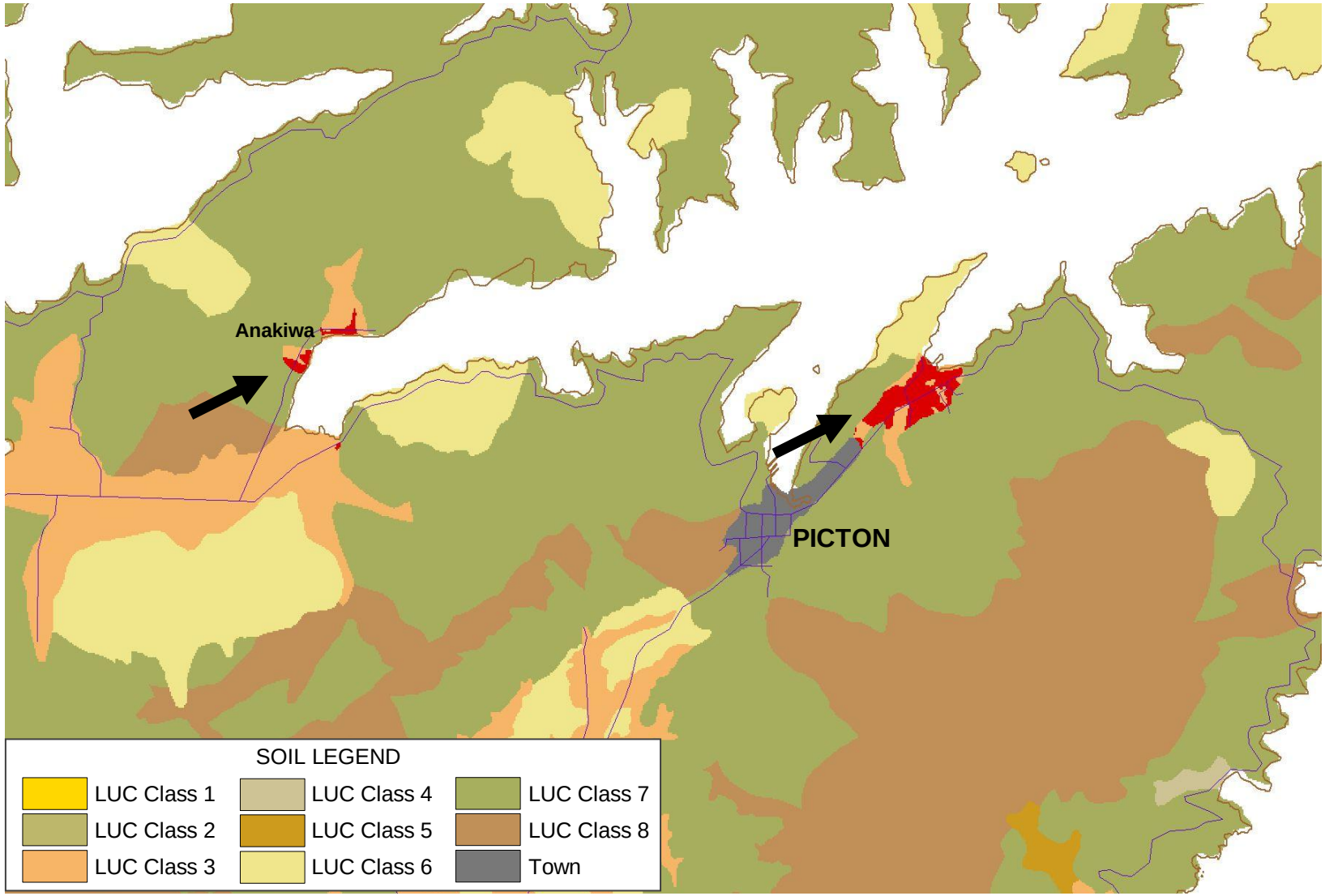


Fig. 11 Increases in Built-up Area (red areas) from 1985 (LRI) to 1996/97 (LCDB1) on LUC Class 3 soils around Anakiwa and Picton.

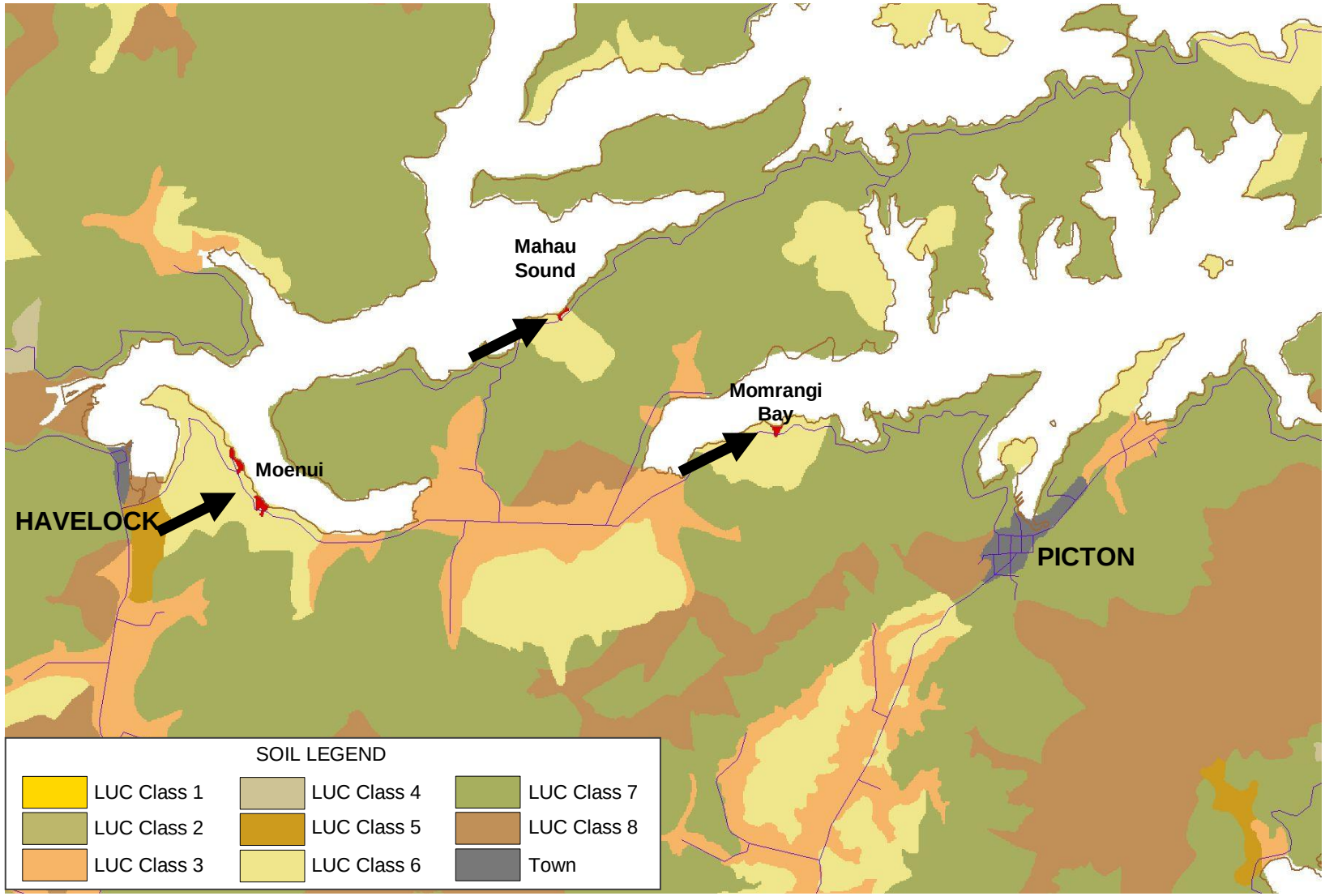


Fig. 12 Increases in Built-Up Area (red areas) from 1985 (LRI) to 1996/97 (LCDB1) on LUC Class 6 soils near Moenui, Momorangi Bay, and Mahau Sound.

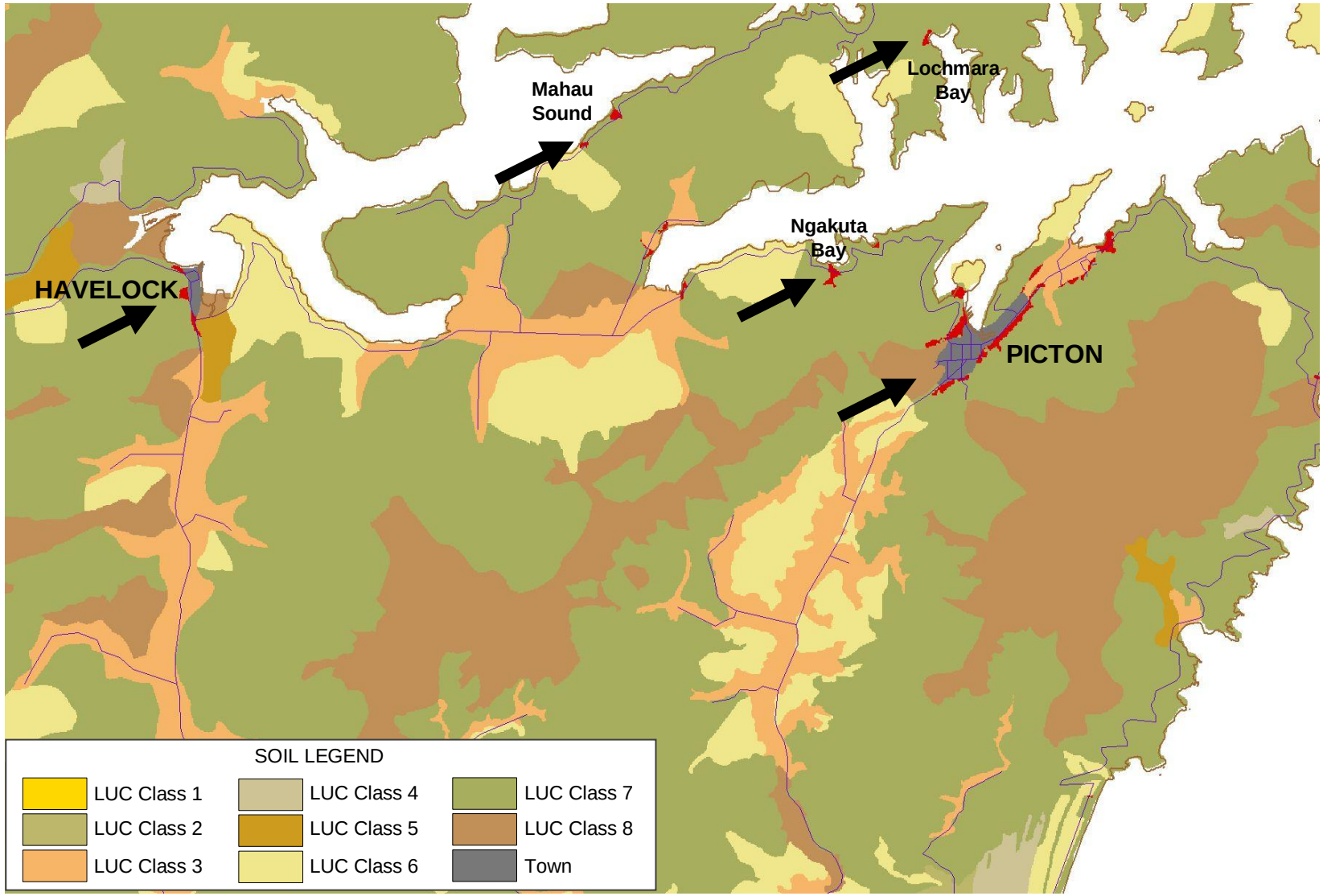


Fig. 13 Increases in Built-Up Area (yellow areas) from 1985 (LRI) to 1996/97 (LCDB1) around Havelock, Picton and environs on LUC Class 7 soils.

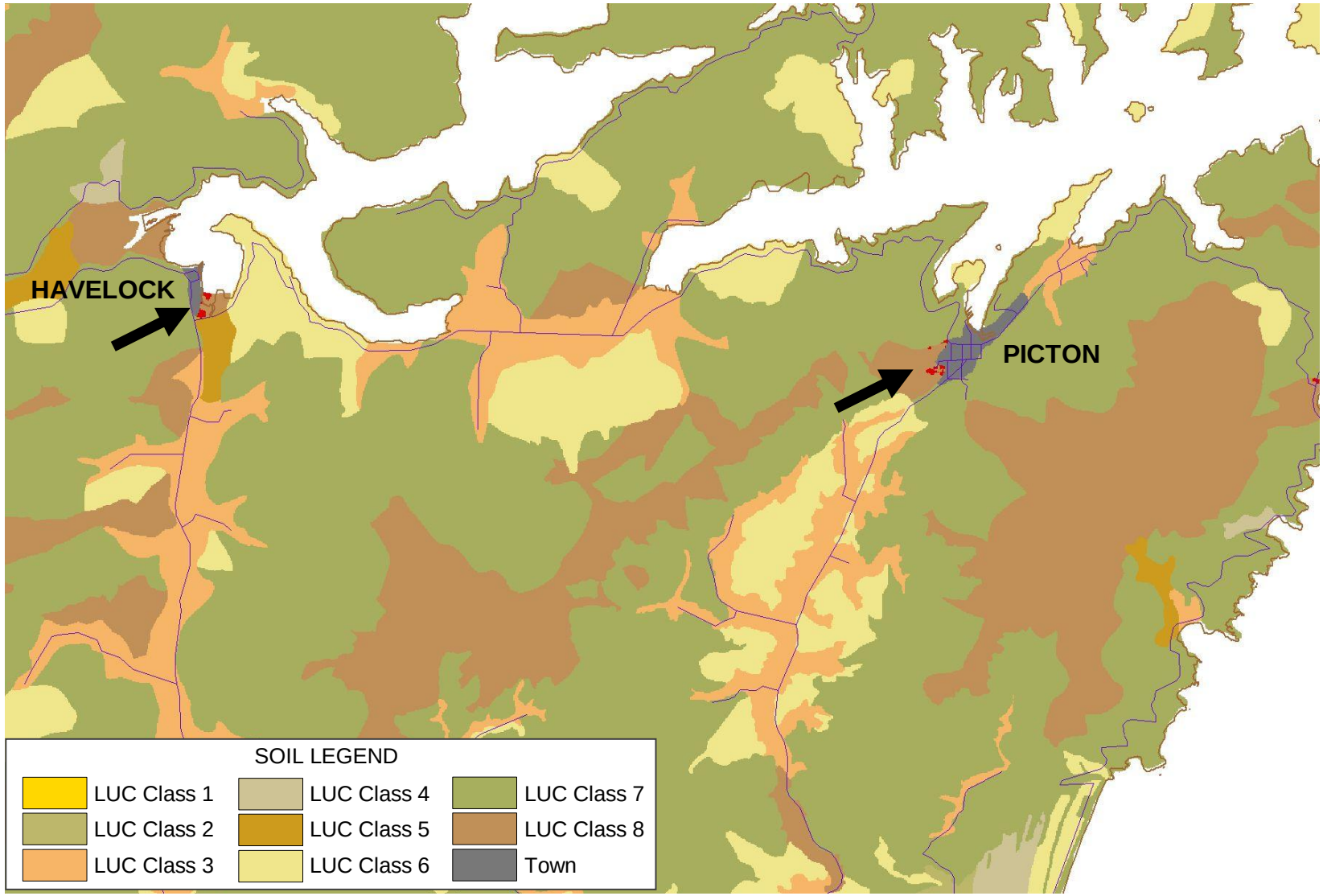


Fig. 14 Increases in Built-Up Area (yellow areas) from 1985 (LRI) to 1996/97 (LCDB1) near Havelock and Picton on LUC Class 8 soils.

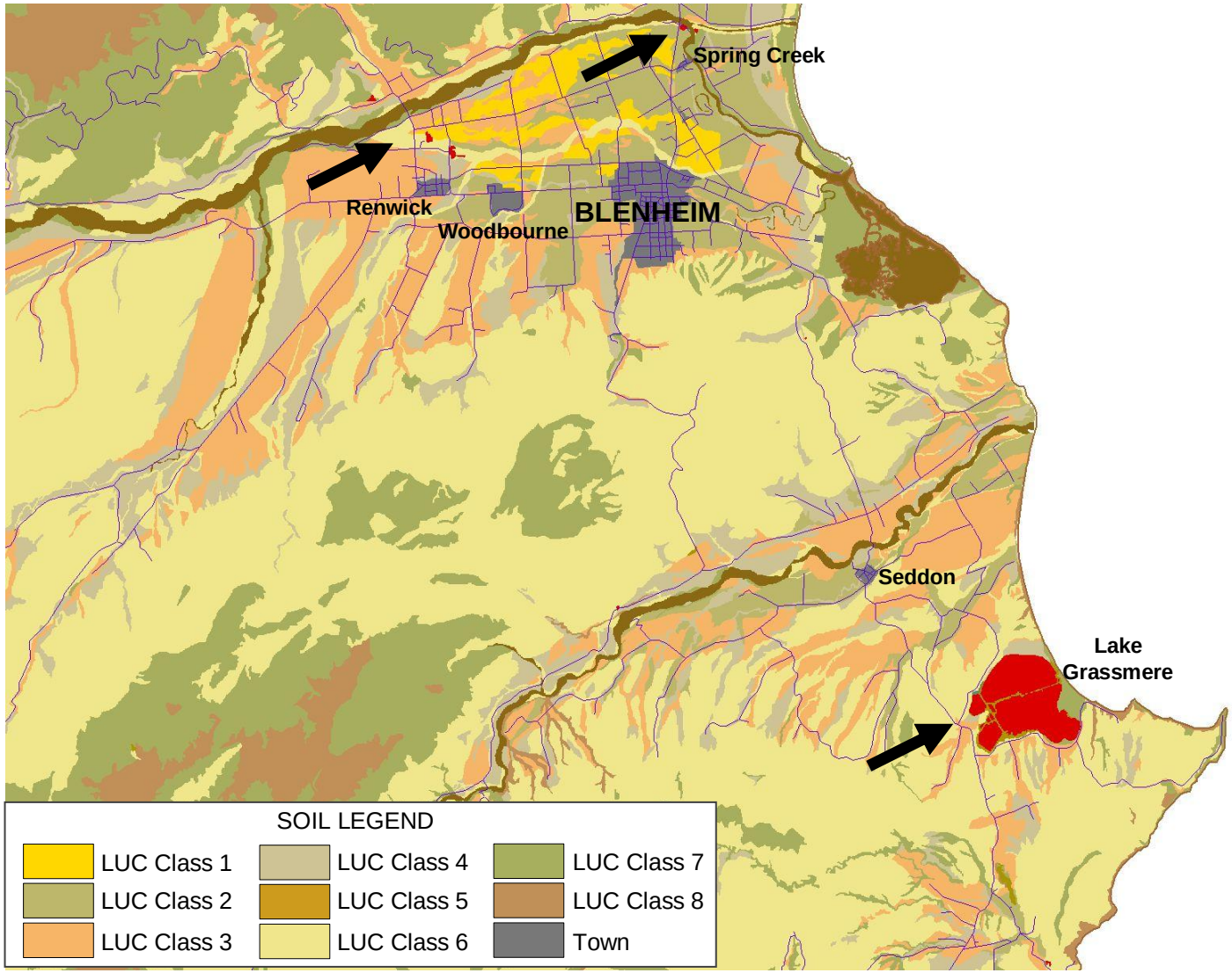


Fig. 15 Location of surface mines as of 1996/97 (LCDB1). Note that Lake Grassmere was classified as a surface mine.

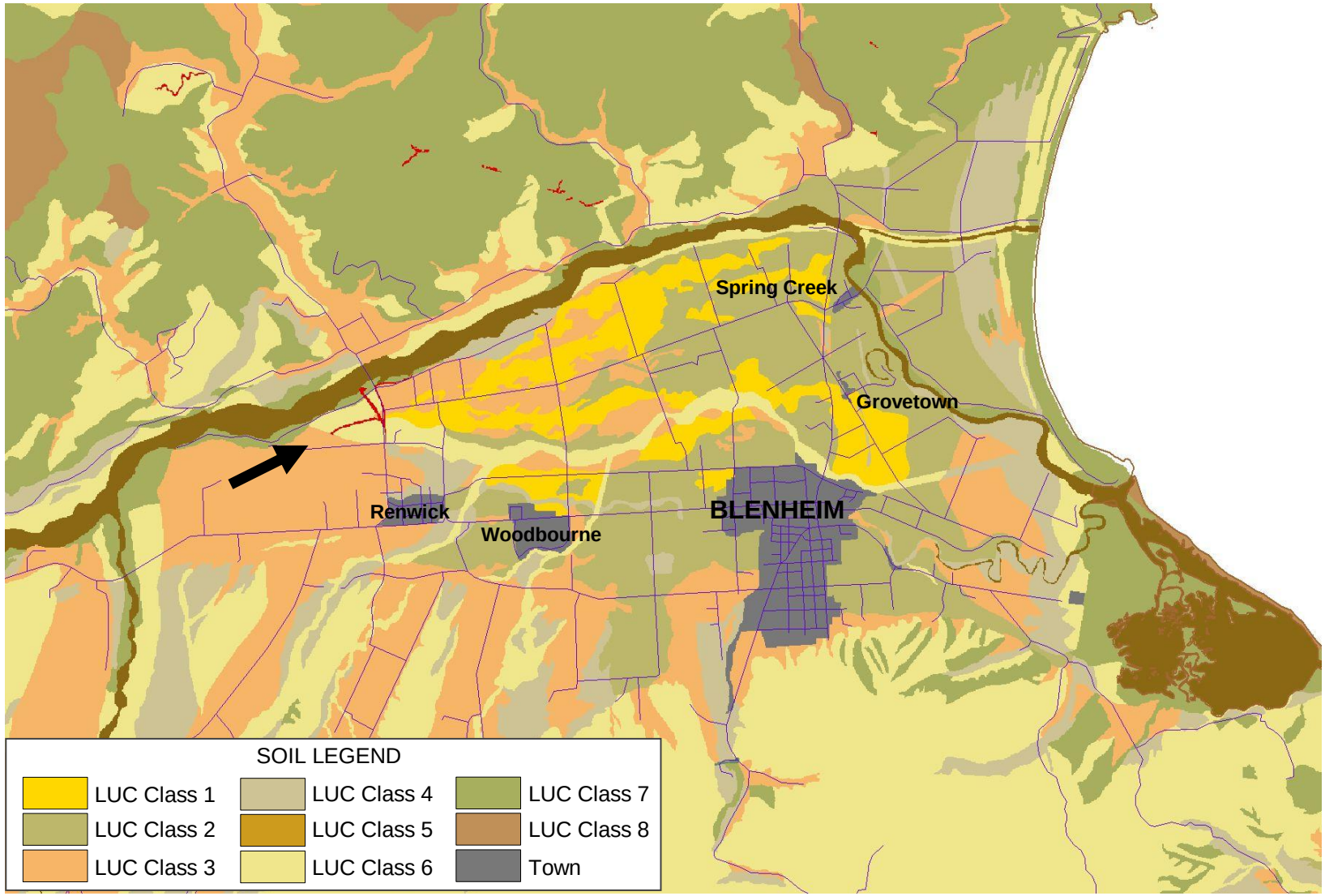


Fig. 16 Location of transport infrastructure (red areas) as of 1996/97 (LCDB1) west of Blenheim.

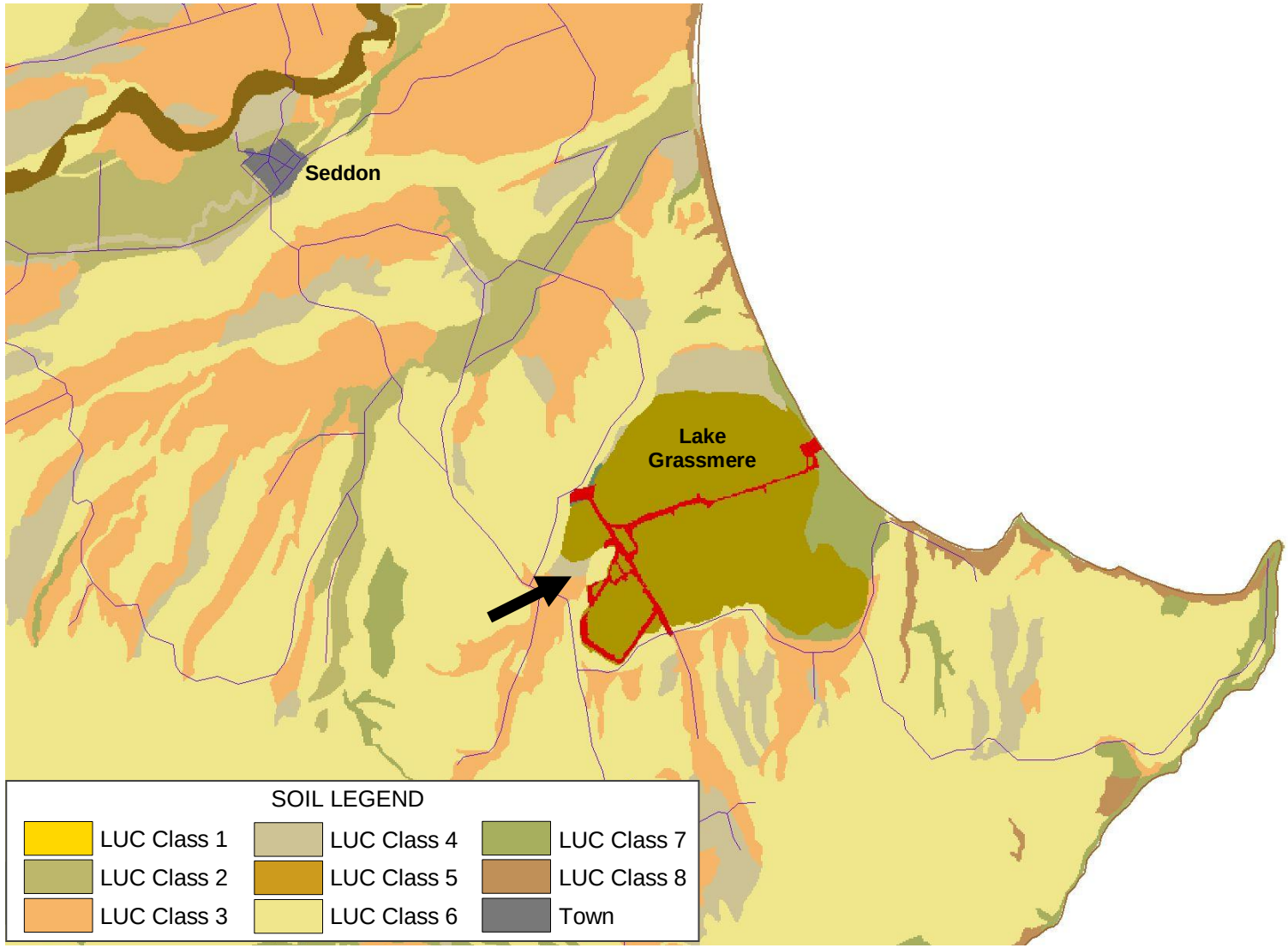


Fig. 17 Location of transport infrastructure (red areas) as of 1996/97 (LCDB1) near Lake Grassmere.

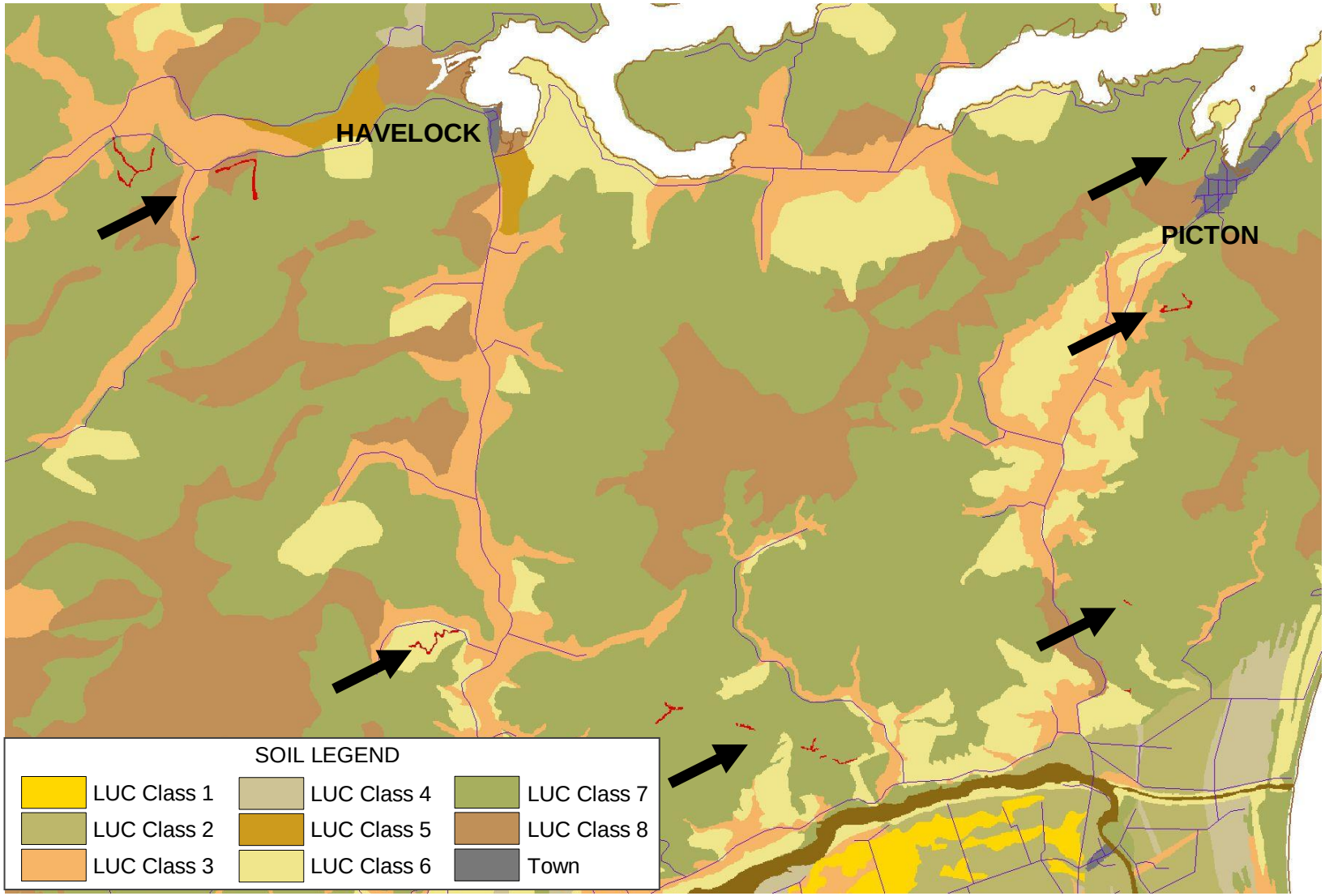


Fig. 18 Location of transport infrastructure (red areas) as of 1996/97 (LCDB1) north of Blenheim. These were most likely associated with logging operations, i.e. logging skids (see Thompson et al. 2003).

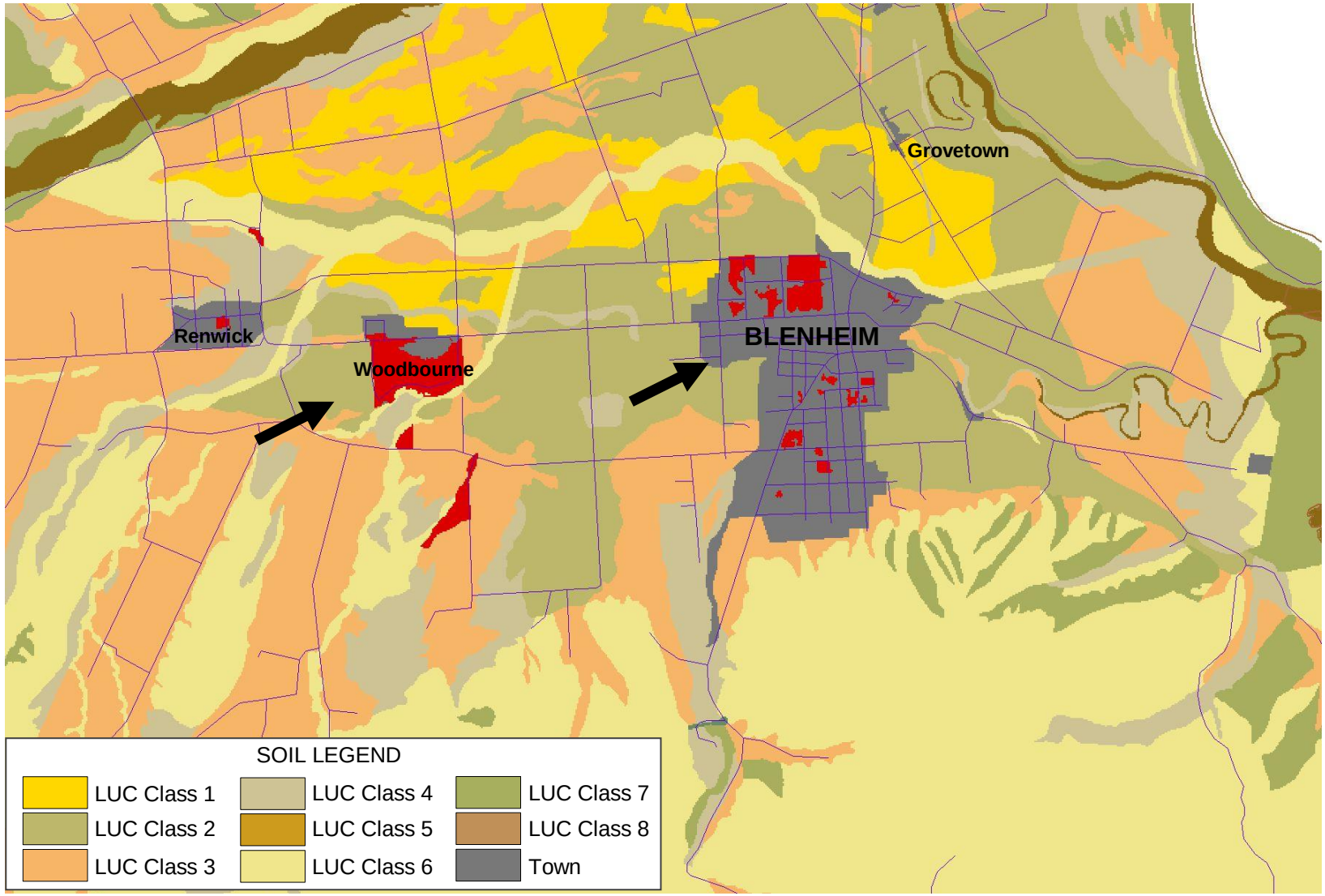


Fig. 19 Location of Urban Parkland/Open Space (red areas) as of 1996/97 (LCDB1) in and around Blenheim. Some areas were new as of 1996/97 and others resulted from a reclassification of Town from 1985 (LRI).

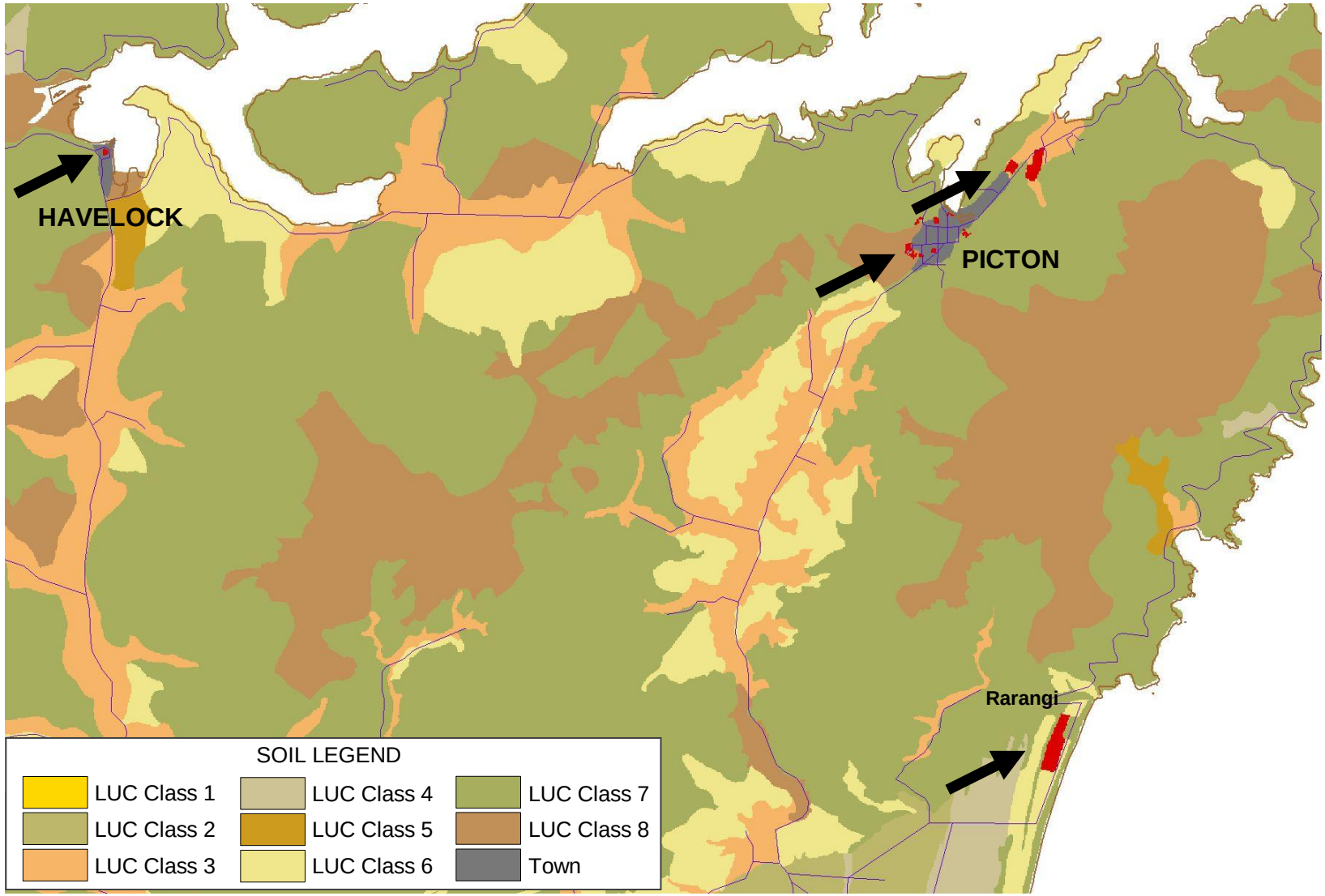


Fig. 20 Location of Urban Parkland/Open Space (red areas) as of 1996/97 (LCDB1) in and around Havelock, Picton, and Rarangi.

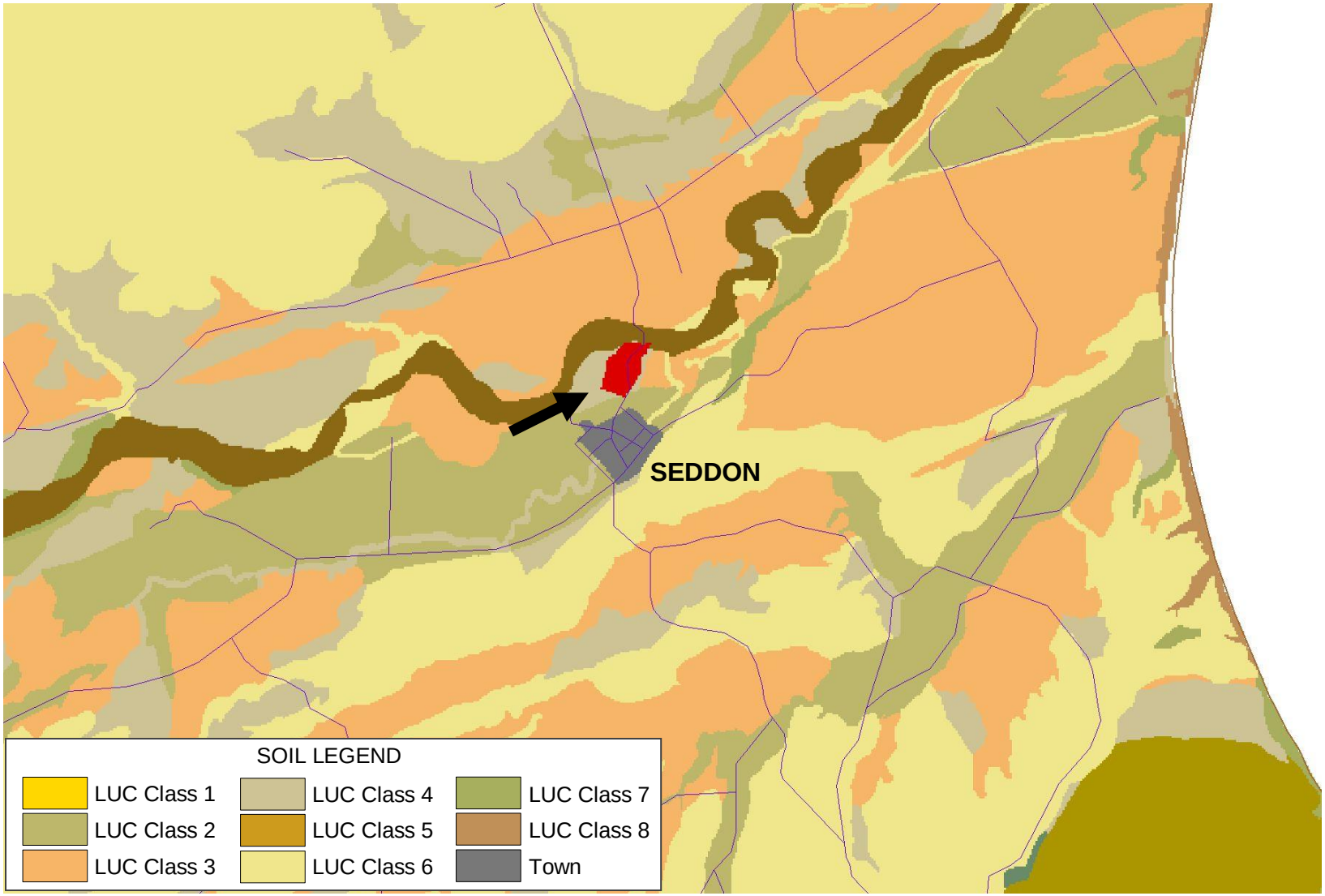


Fig. 21 Figure showing location of Urban Parkland/Open Space (red areas) as of 1996/97 (LCDB1) near Seddon.

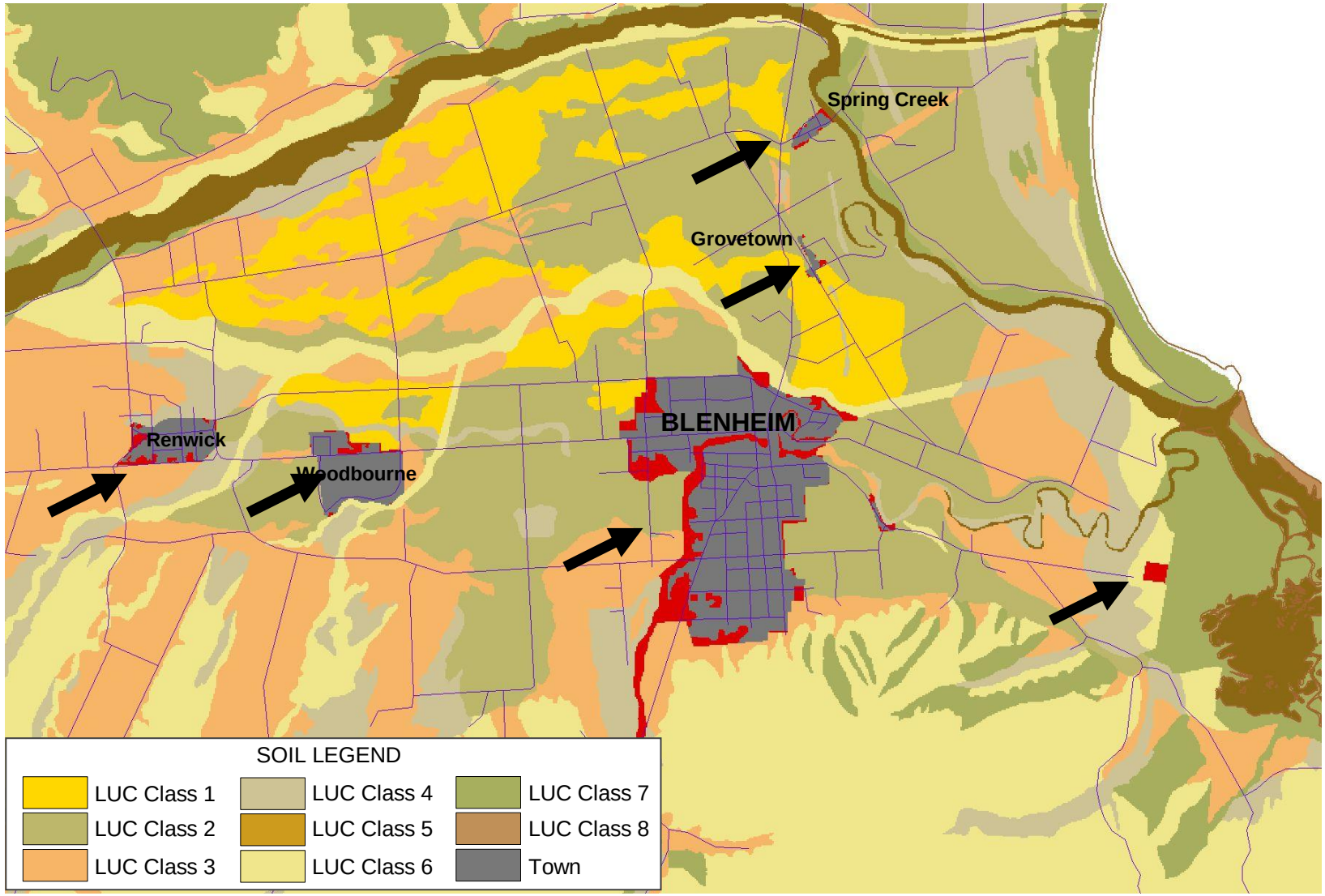


Fig. 22 Location of areas (in red) classified as Town in 1985 (LRI) but as another land cover as of 1996/97 (LCDB1) around Blenheim.

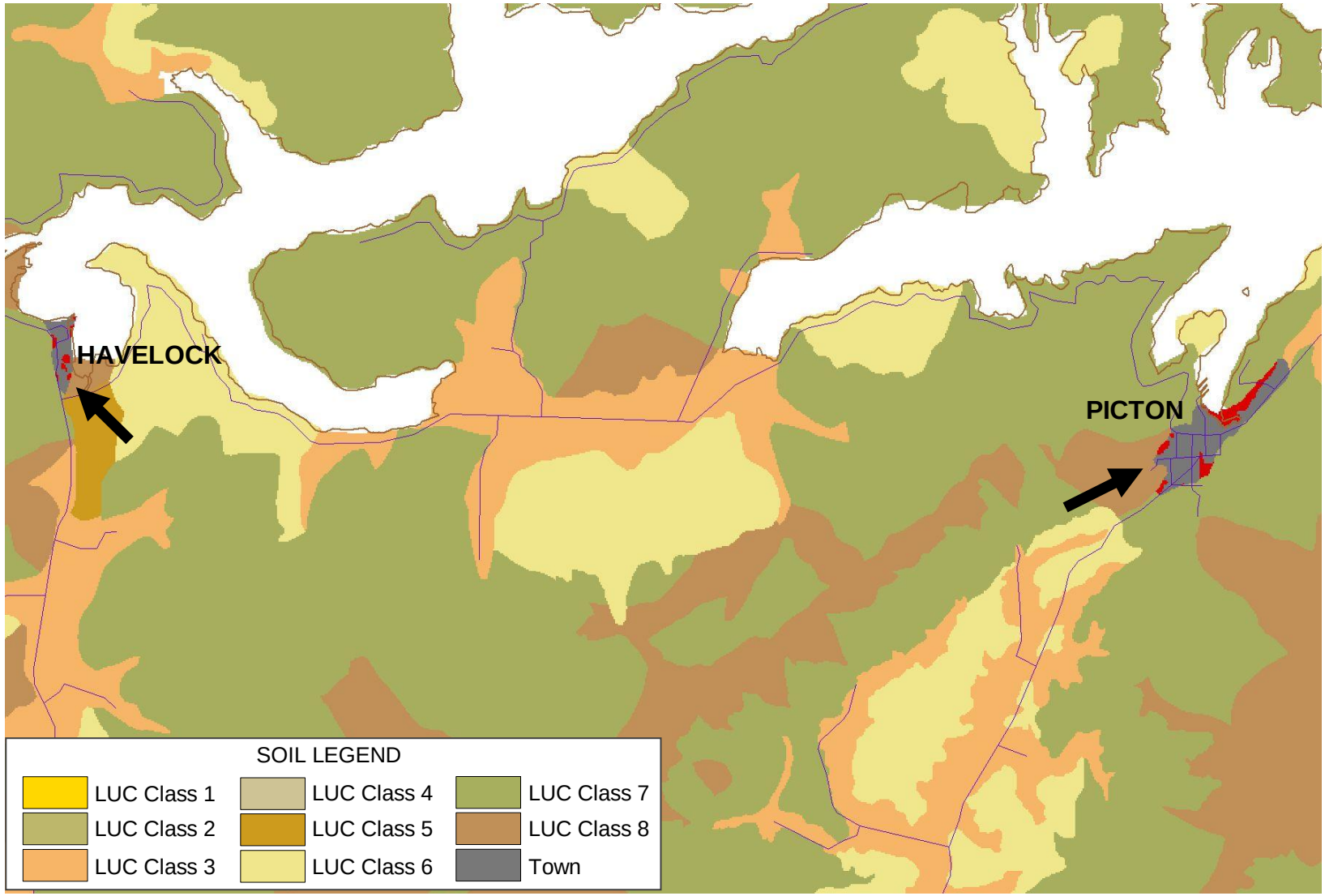


Fig. 23 Location of areas (in red) classified as Town in 1985 (LRI) but as another land cover as of 1996/97 (LCDB1) around Havelock and Picton.

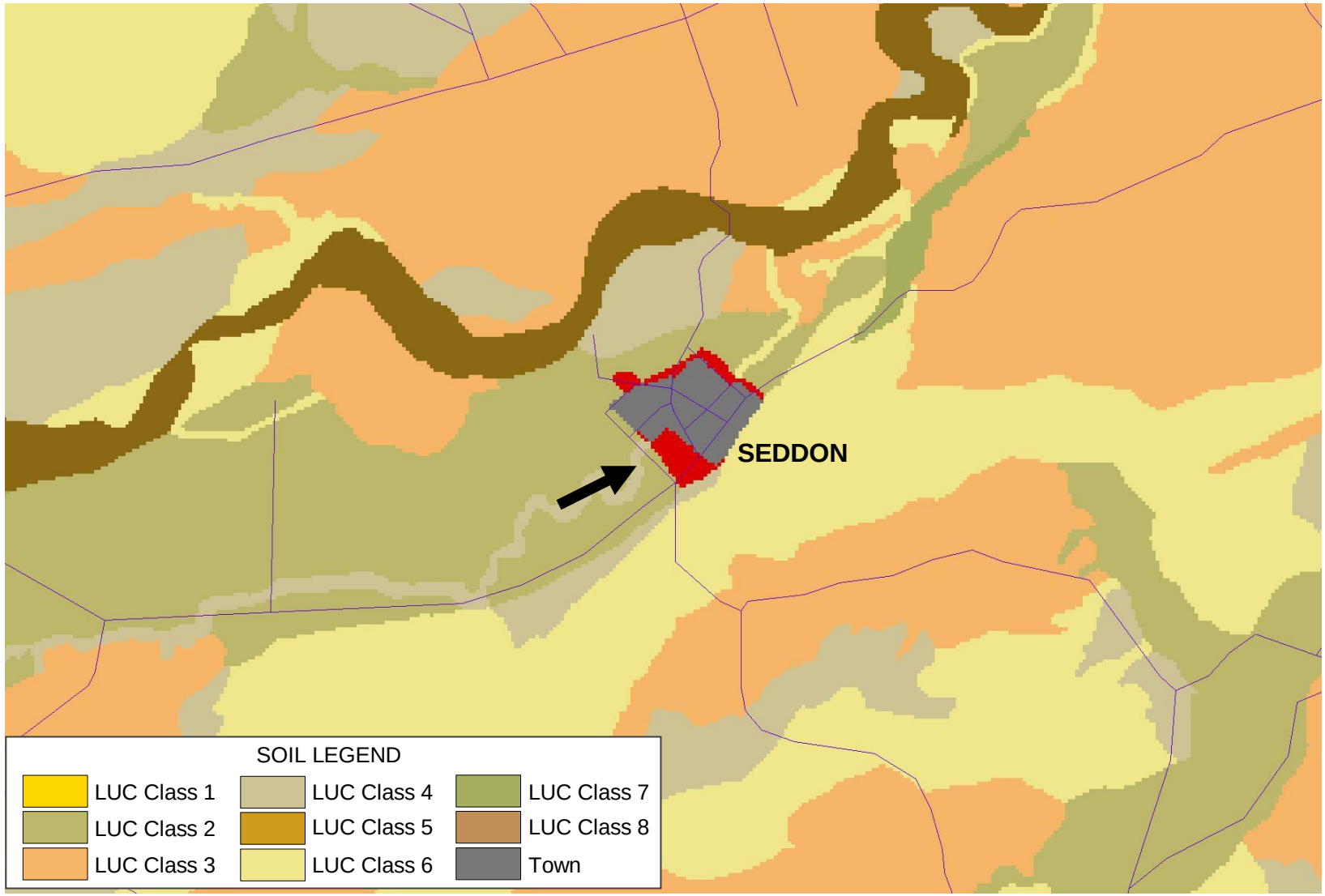


Fig. 24 Figure showing areas (in red) classified as Town in 1985 (LRI) but as another land cover as of 1996/97 (LCDB1) around Seddon.

5.3.2 1996/97 (LCDB1) to 2001/02 (LCDB2)

From 1996/97 (LCDB1) to 2001/02 (LCDB2) an additional 90 ha of land was classified as Built-up Area (64 ha) or Urban Parkland/Open Space (26 ha) (Table 4). Thirty hectares occurred on land not previously classified as Town in the LRI. Of that 10 ha, 1 ha occurred on LUC 1 (Fig. 25), 11 ha on LUC 2 (Fig. 26), and 18 ha on LUC class 3 soils (Fig. 27). Sixty hectares around Blenheim were previously classified as Town in 1985 (LRI), reclassified as another land cover type (High Producing Exotic Grassland) as of 1996/97 (LCDB1), and then reclassified as Built-up Area as of 2001/02 (LCDB2) (Fig. 28).

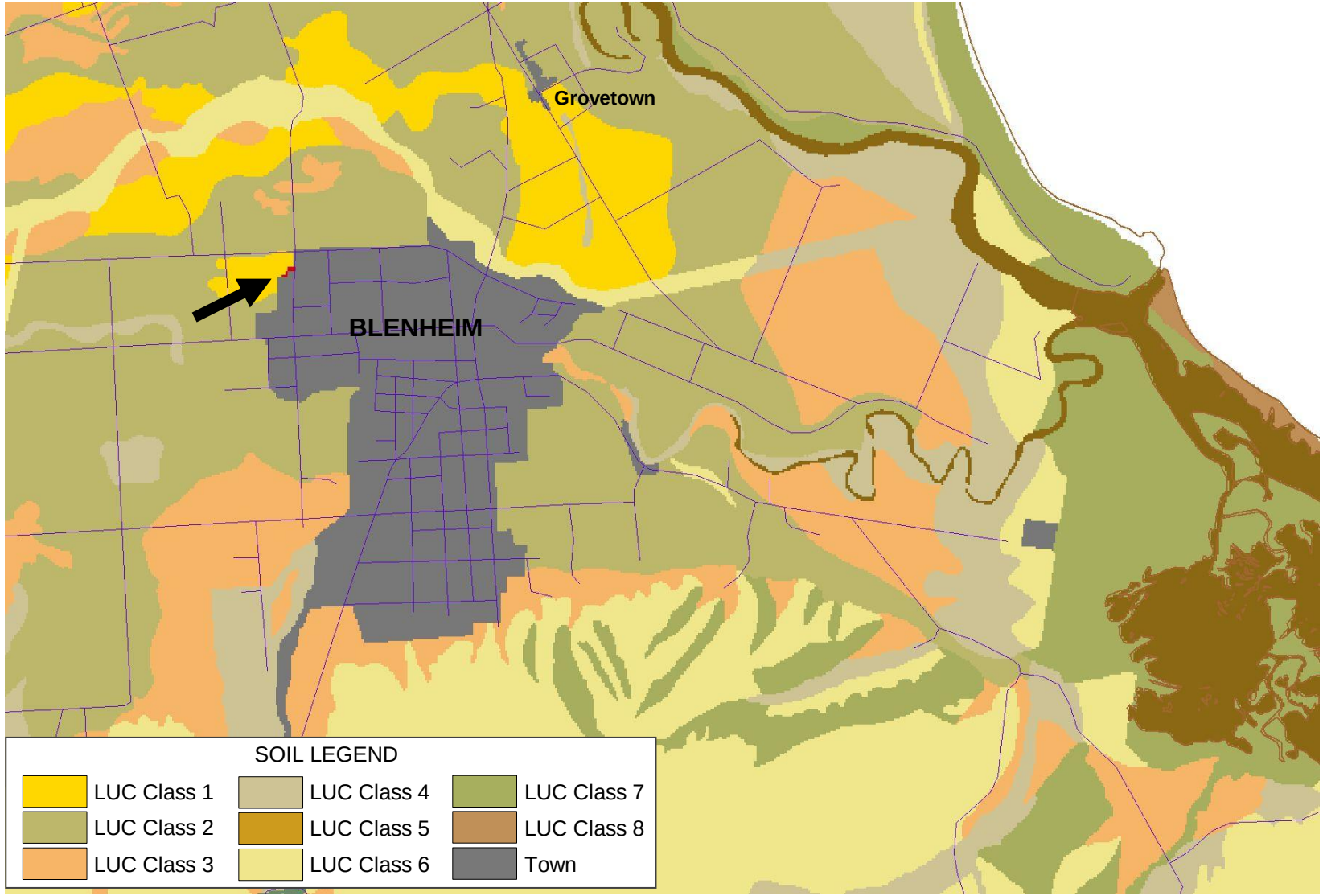


Fig. 25 Location of additional Built-up Area (shown in red) as of 2001/02 (LCDB2) on LUC Class 1 soils near Blenheim.

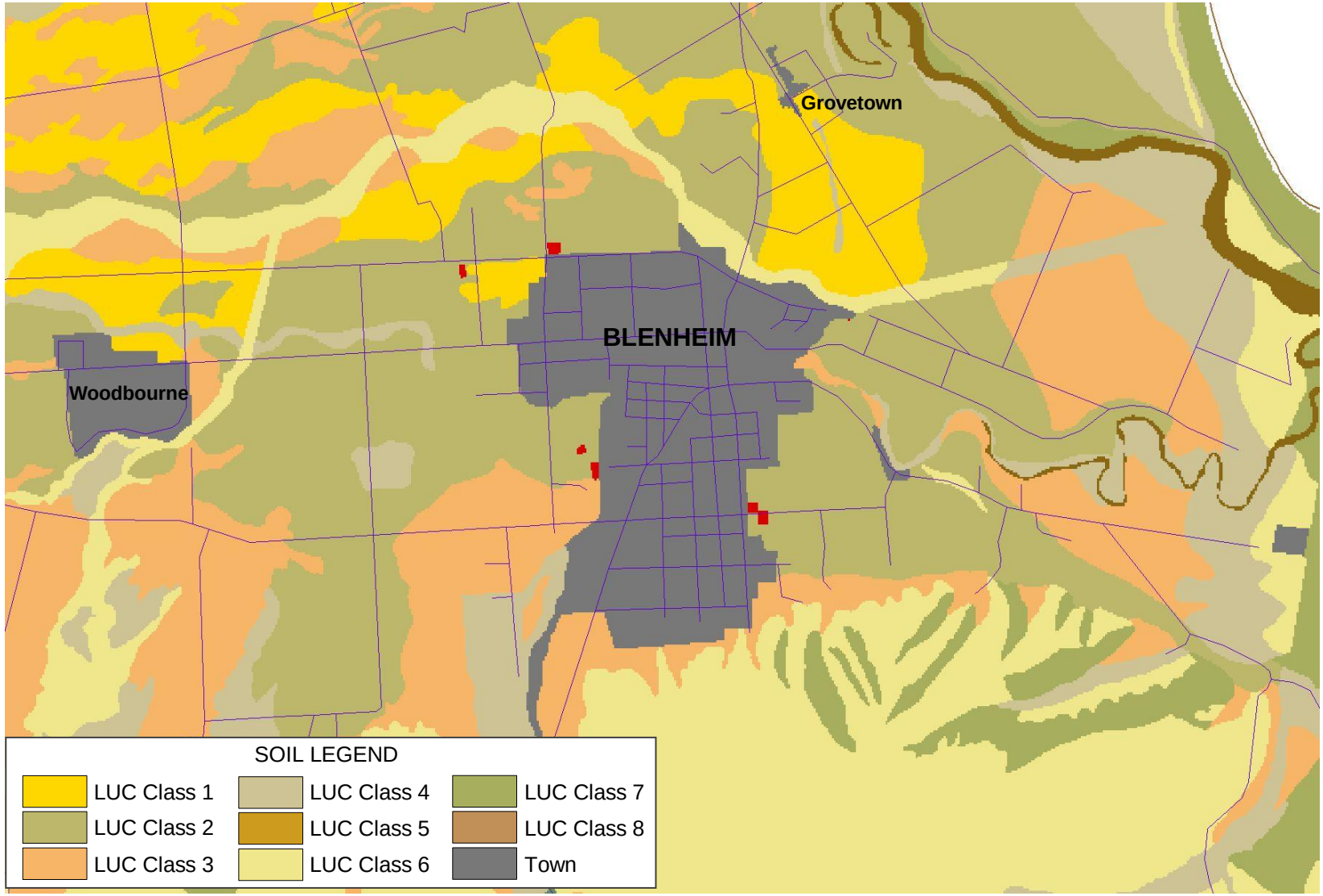


Fig. 26 Location of additional Built-up Area (shown in red) as of 2001/02 (LCDB2) on LUC Class 2 soils near Blenheim.

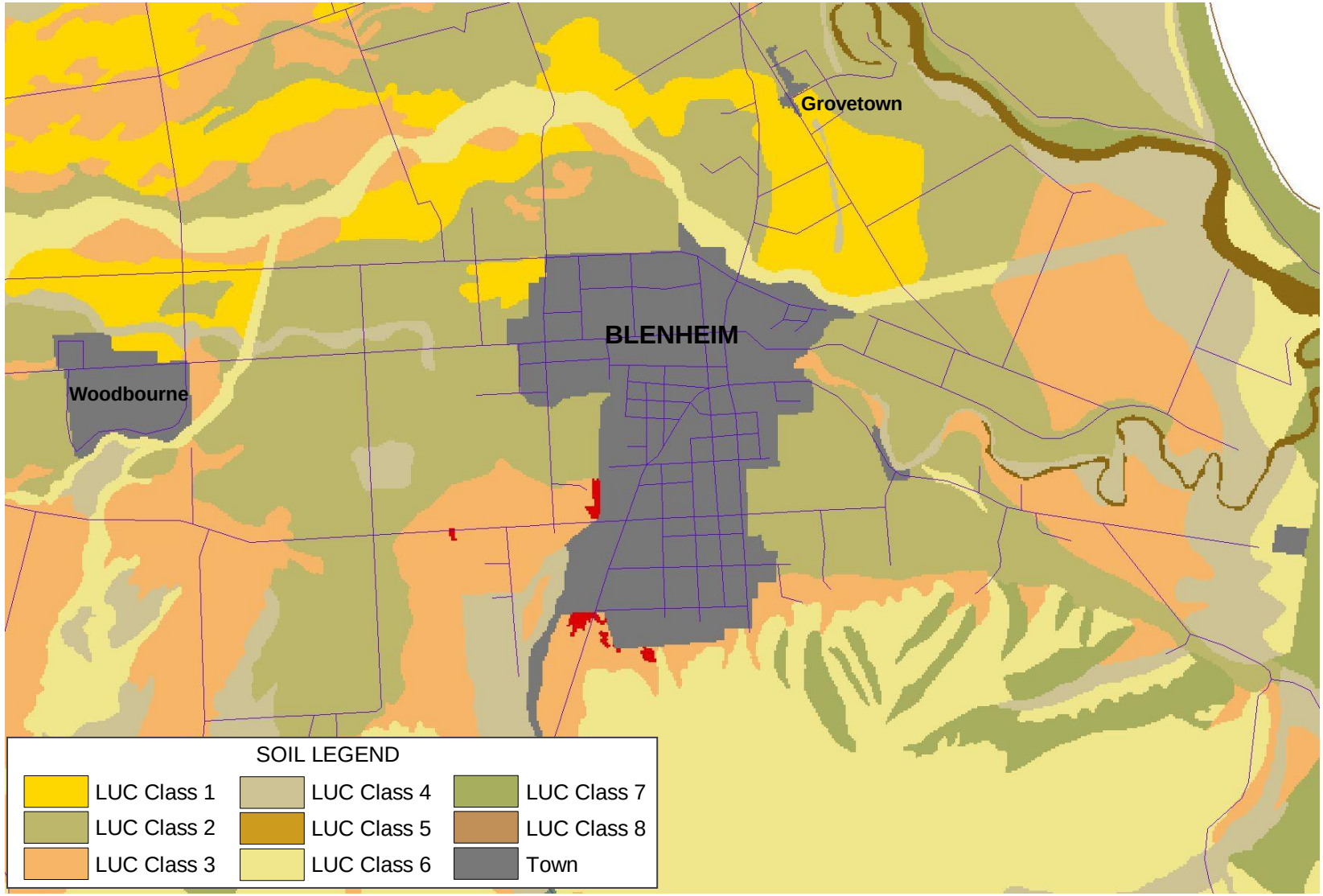


Fig. 27 Location of additional Built-up Area (shown in red) as of 2001/02 (LCDB2) on LUC Class 2 soils near Blenheim.

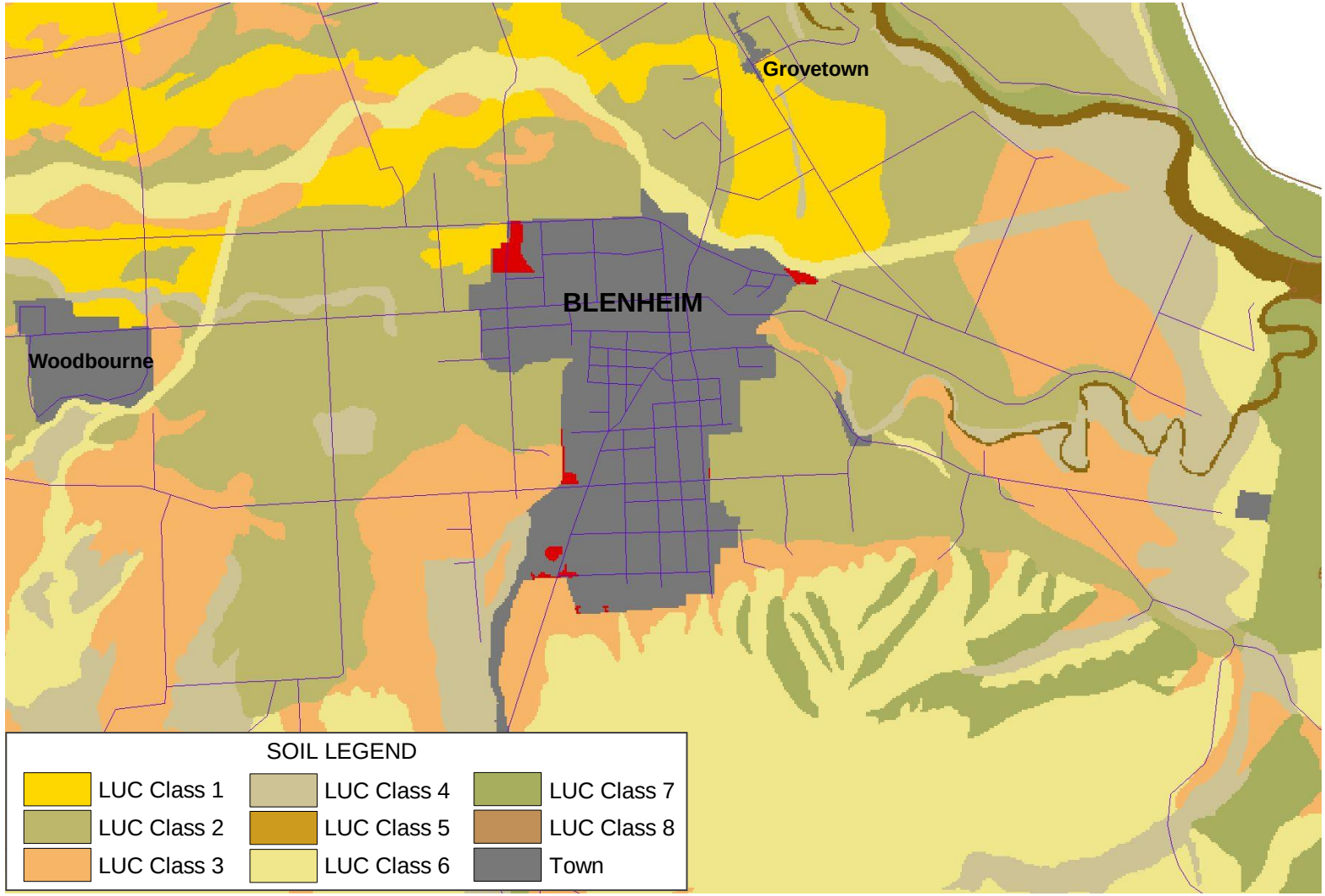


Fig. 28 Location of areas classified as Town in 1985 (LRI), as non-urban (High Producing Exotic Grassland) in 1996/97 (LCDB1) and as Built-Up Area as of 2001/02 (LCDB2).

5.3.3 Rural residential (lifestyle block) trends

Agribase (Assure Quality 2008) classified a total of 3079 ha of land as Lifestyle Blocks as of 2008. Of that amount, a total of 2968 ha occurred on land not already classified as Built-Up Area, Surface Mines, Transport Infrastructure or Urban Parkland/Open Space by 2001/02 (LCBD2), i.e. these lifestyle blocks were in addition to already classified urban areas.

Lifestyle blocks occur throughout the Marlborough Sounds, along the main river valleys (Wairau, Awatere, Opawa) in central Marlborough, and along the south-eastern coast in the Flaxmere River valley (Fig. 29). A large polygon near Avondale in central Marlborough was classified as Lifestyle but upon closer inspection of its attributes was more likely in pastoral production. Removing that block reduced the total hectares classified as Lifestyle Blocks from 2968 to 1154.

Table 6 Area of land by LUC class identified as lifestyle blocks by Agribase (2008)

	Lifestyle blocks (ha)	
LUC Class	With all blocks	Without Avondale Block
LUC 1	46	46
LUC 2	135	135
LUC 3	484	460
LUC 4	198	143
LUC 5		
LUC 6	1473	225
LUC 7	588	102
LUC 8	40	
Estuary	-	
Lake	-	
Quarry	-	
Town	<1	

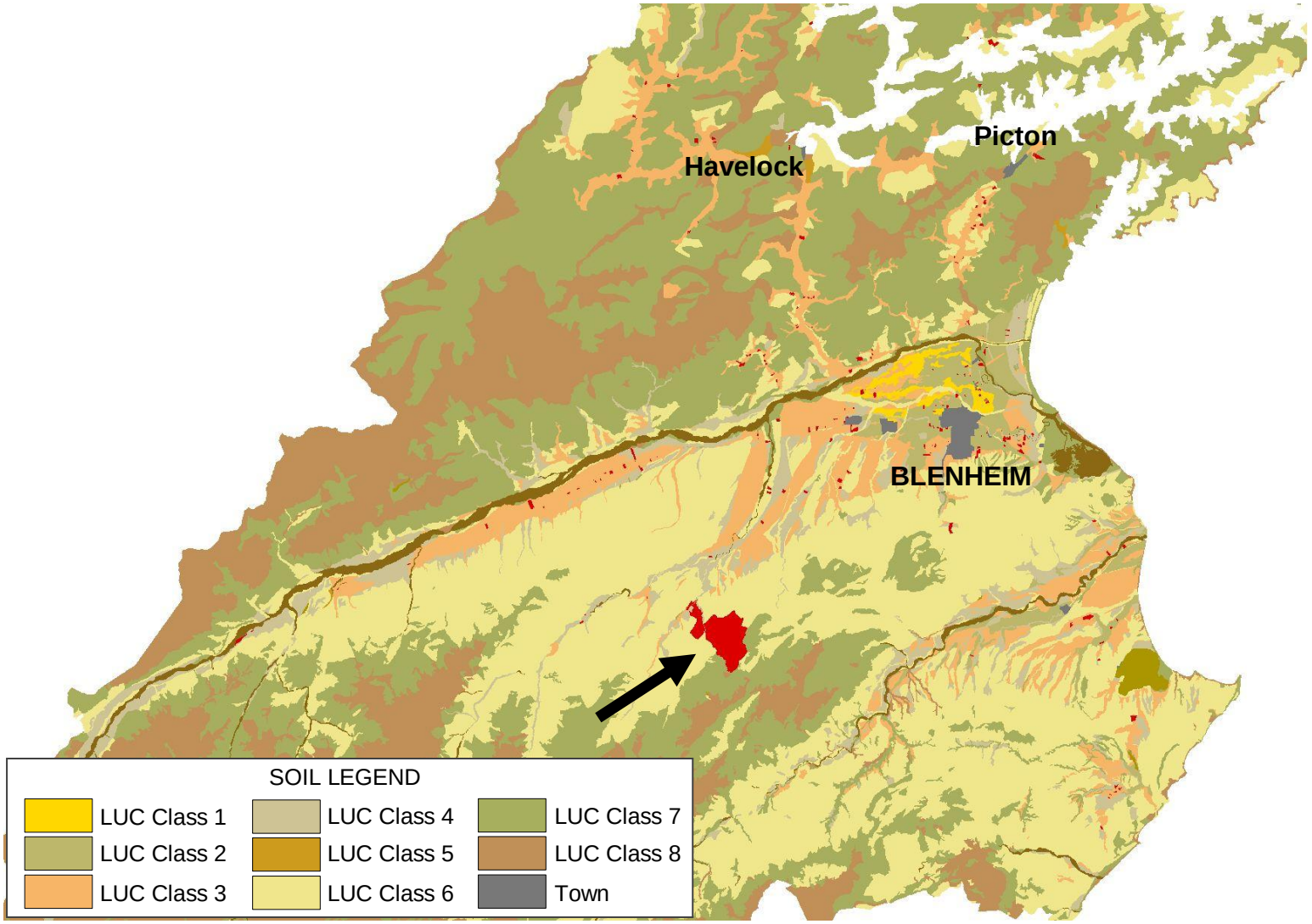


Fig. 29 Location of lifestyle blocks (red areas) as of 2008 (Agribase). The arrow shows the location of the lifestyle block that has most likely been misclassified.

6 Summary

Based on the results of the land-use/cover trend analysis, the most versatile soils (LUC Classes 13) experienced the highest rates of urbanisation (Table 7). Although affecting a relatively small area, LUC Class 1 soils experienced the highest level of conversion – 2.3% – during the period analysed.

Table 7 Urbanisation trends by LUC class in Marlborough District. Urban land uses included Built-up Areas, Surface Mines, Transport Infrastructure, and Urban Parks/Open Space (LCBD) and Lifestyle Blocks (Agribase). Agribase values exclude the area of the suspected misclassified lifestyle block.

	Additional area converted to urban uses					
LUC class	1985 (LRI) (ha)	1996/97 (LCDB1) (ha)	2001/02 (LCDB2) (ha)	2008 Agribase (ha)	Total converted (ha)	Total converted (%)
1	2453	10	1	46	57	2.32
2	11 402	57	11	135	203	1.78
3	48 406	258	18	460	736	1.52
4	29 861	47	-	143	190	0.64
5	605	7	-	-	7	1.16
6	292 362	170	-	225	395	0.14
7	365 692	296	-	102	398	0.12
8	283 668	29	-	40	69	0.02

With any land-use/cover change analysis, care must be taken in interpretation, as errors can result from several sources. Two typical sources of error result from differences in spatial accuracy or misclassification. Regarding spatial accuracy, the LCDB showed slightly smaller urban areas (e.g. around Blenheim) than the LRI. Mapping of urban areas can vary depending on the criteria for delineating boundaries such as how much of the surrounding area to include in addition to buildings, etc. The results suggested that the LCDB mapping used more conservative criteria than the LRI mapping. The analysis would benefit by further verification of reported trends via inspection of independent data sources such as aerial photographs from both time periods.

Regarding classification errors, the LCDB appeared reliable given the extent and location of the reported changes. Expansion of Built-up Areas occurred adjacent to or near existing urban centres or along the coast. Although widely dispersed, Transport Infrastructure made sense compared with the surrounding context, e.g. linear features along ridges suggesting logging operations or the rail operations near Lake Grassmere. Surface Mines were few, although it was interesting to note that Lake Grassmere qualified as a mine. Most uncertainties of classification stemmed from the urban boundaries for similar reasons as discussed above, which again would require recourse to other data sources to verify. Finally, Agribase

appeared to have one large polygon incorrectly classified as a Lifestyle Block, which resulted in a significant overestimate of the total areas converted.

Given their proximity to existing urban areas and past land-use change trends, versatile soils remain vulnerable to further urbanisation.

7 Acknowledgements

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Appendix 1 Detailed description of soils in Marlborough District

A Arable Land

Arable land is capable of being cultivated (ploughed) for cropping regularly at a frequency greater than that which would be required for pasture renewal. The main limiting factors to cultivation for cropping are slope (<20°), soil depth, topsoil texture and stoniness, and elevation (a surrogate of growing season length).

Approximately 9% of the Marlborough District is classified as arable (LUC Classes 1–4). This land is largely concentrated along the Wairau and Awatere valley floors. Significant areas of arable land are also present in the Waima Valley, the Pelorus and Kaituna valleys and in the Linkwater area. Small areas are also present in the heads of bays and in the small valleys of the Sounds. Along the margin of the hills, the rolling slopes of the loess-mantled downlands are also arable (Fig. 2).

LUC Class 1

Class 1 land is versatile multiple-use land with virtually no limitations to arable use. There are two subclasses in the District. Class 1c land comprises flat to undulating low terraces and floodplains with well-drained deep (>90 cm) silt loam or sandy loam textured, Recent[1] soils of the Wairau[2] soil series (1867 ha) in the lower Wairau valley. Class 1w land consists of imperfectly drained deep silt loam textured Mottled Fluvial Recent soils of the Kaiapoi and Grovetown soil series on the Wairau floodplain.

LUC Class 2

Class 2 land is very good land with slight limitations to arable use, which can be readily overcome by management and conservation practices. Most class 2 lands are flat or undulating. The most common limitations are wetness, coarse topsoil textures or shallowness. There are 4 subclasses.

LUC class 2w land includes imperfectly to poorly drained silt loam or sandy loam textured, Gley soils of the Taitapu, Paynter, Temuka, Grovetown and Spring Creek series, where the depth to low chroma colours, gleying or mottling is greater than 45 cm. This land is predominantly flat to undulating floodplains and low terraces.

LUC class 2s land comprises well-drained moderately deep (45–90 cm) silt loam textured Recent soils of the Wairau mottled, Woodbourne, Gibsons and Waimakariri series on flat to undulating low terraces and; moderately deep silt loam textured Pallic soils with slowly permeable subsoils of the Ugbrooke series on flat to undulating terraces.

LUC class 2e land comprises predominately well-drained moderately deep silt loam textured Pallic soils, e.g. Seddon series, on flat to undulating terraces developed in loess susceptible to wind erosion and weakly structured moderately deep fine sandy loam textured Recent floodplain soils of the Gibsons soil series.

[1] New Zealand Soil Classification (Hewitt 1998)
[2] Soil series are from New Zealand Soil Bureau (1968), Campbell (1986), Laffan & Vincent (1990), or Campbell et al. (2007)

LUC class 2c land comprises well-drained moderately deep silt loam textured Pallic soils, of the Templeton and Woodbourne series, on flat to undulating low terraces and floodplains, where a marked summer moisture deficit and high wind run limits crop choice.

LUC Class 3

LUC Class 3 lands are arable land with moderate limitations to arable use, which restrict the choice of crops able to be grown and/or make special conservation practices necessary. In Marlborough it commonly occurs on shallow and stony alluvial soils, on undulating to rolling land that has a moderate erosion risk when cultivated, and along the margins of slopes where runoff from adjacent hills gives rise to wetness limitations.

LUC class 3s covers a range of soil conditions and geographic locations. It includes:

- well-drained moderately shallow (30–45 cm) and/or stony silt loam textured Brown and Pallic soils, e.g. Renwick and Dashwood series on flat to undulating terraces
- well-drained moderately shallow and/or stony silt loam to sandy loam textured Recent floodplain soils, e.g. Waimakariri, Waimakariri shallow, Awatere and Rapaura series
- moderately well to imperfectly drained, moderately shallow and/or stony silt loam textured Brown and Pallic soils, e.g. Hororata, Kaituna, and Jordon series on flat to undulating terraces
- well-drained moderately shallow and/or stony silt loam to sandy loam textured Recent soils with limited water storage capacity, e.g. Eyre-Paparua series on flat to undulating low terraces
- undulating to rolling loess mantled terraces and downlands with silt loam textured Pallic soils with impeded subsoil drainage, e.g. Sedgemere and Jordon series
- gently sloping coastal lagoon margins with weak to moderately saline sandy loam to clay loam textured saline gley Recent soils, e.g. Motukarara series.

LUC Class 3c land is located in the Marlborough Sounds. It includes moderately well to imperfectly drained, moderately shallow to moderately deep (30–90 cm) silt loam textured Brown soils, e.g. Kaituna and Rai series, on undulating terraces and downs. In these locations the high summer rainfall limits the types of crops that can be grown without artificial drying.

LUC Class 3e land occurs predominately on:

- undulating to rolling loess mantled terraces and downlands with moderately well to imperfectly drained silt loam textured Pallic soils susceptible to sheet and rill erosion when cultivated, e.g. Seaview, Sedgemere and Wither series, and
- moderately well drained, moderately shallow and/or stony silt loam textured Brown soils susceptible to wind erosion, e.g. Hororata series on flat to undulating terraces.

LUC class 3w land occupies flat to undulating floodplains and low terraces with imperfectly to poorly drained moderately deep silt loam to clay loam textured soils where the depth to low chroma colours, gleying or mottling is greater than 45 cm and/or a moderately high water table at or within 45 cm of the surface for up to half the year in both low and moderate rainfall areas. Pallic and Gley soils include the Broadbridge and Temuka soil series.

LUC Class 4

LUC Class 4 lands have severe limitations to arable use. These limitations substantially reduce the range of crops, which can be grown and/or make intensive conservation treatments and careful management necessary. Class 4 land is suited only to occasional cropping but is well suited to pastoral and forestry use. The most common limitations to use are erosion hazard, shallow, stony and/or low fertility soils, excessive wetness and the effects of climate such as those associated with altitude. Class 4 commonly occurs on undulating to strongly rolling land.

LUC Class 4s includes significant areas in the high country. It includes:

- well-drained shallow (15–30 cm) and stony silt loam to sandy loam-textured Recent soils on lowland flat to undulating floodplains, fans, and low terraces, e.g. Waimakariri shallow and Awatere series
- well-drained shallow and stony silt loam textured Brown and Pallic soils, e.g. Renwick, Hororata, Kaituna and Warwick series on lowland flat to undulating terraces
- well-drained, shallow to moderately shallow (15–45 cm) stony low fertility silt loam-textured Brown soils, Katrine and Craigieburn series on flat to rolling terraces and moraine in high country areas
- well-drained, weakly structured soils with low water-holding capacities on flat to undulating coastal sand flats and beach ridges, Tahunanui and Taumutu soils
- well-drained, shallow to moderately shallow (15–45 cm) and stony silt loam to sandy loam-textured Recent soils on flat to undulating floodplains and fans, in the high country, e.g. Tasman soils
- gently sloping coastal lagoon margins with moderate to strongly saline sandy loam to clay loam-textured soils saline gley recent soils, e.g. Motukarara series.

LUC Class 4e land predominately occupies

- rolling to strongly rolling loess mantled downlands with moderately well to imperfectly drained silt loam textured Pallic soils susceptible to tunnel gully erosion and sheet and rill erosion when cultivated, e.g. Wither, Wither hill and Jordon soils
- rolling to strongly rolling downlands with moderately well to imperfectly drained silt loam textured Brown and Pallic soils susceptible to sheet and rill erosion when cultivated, e.g. Kahutara hill soils
- gently undulating to rolling well-drained shallow to moderately deep (30–90 cm) low fertility stony silt loam textured Brown soils, e.g. Craigieburn and Acheron soils in high country areas susceptible to frost lift initiated wind erosion.

LUC Class 4w land occupies

- flat to undulating floodplains and low terraces with imperfectly to poorly drained moderately deep silt loam to clay loam textured soils where the depth to low chroma colours, gleying or mottling is less than 45 cm and/or a moderately high water table at or within less than 45 cm of the surface for up to half the year in both low and moderate rainfall areas, with Gley Temuka soils
- montane valley floor wetlands with Recent Gley Dobson soils where the depth to low chroma colours, gleying or mottling is less than 45 cm and a moderately high water table at or within less than 45 cm of the surface.

B Non-Arable land

Non-arable land is not capable of being cultivated (ploughed) regularly for cropping but may be cultivated infrequently for the renewal of pasture. The main limiting factors to productive use are slope, erosion hazard, soil depth, topsoil texture and stoniness, and elevation as a reflection of growing season length.

LUC Class 5

LUC Class 5 includes high producing land that has limitations that make it unsuitable for cropping but which has only slight limitations to pastoral or general forestry use. The most common limitations that preclude arable use are slope, the presence of boulders and rock outcrops, or excessive wetness. Erosion is not a dominant limitation in this class as the land is relatively stable under a permanent vegetative cover.

In the Marlborough the majority of LUC Class 5 land is flat to gently sloping imperfectly to poorly drained strongly saline sandy loam to clay loam textured soil, Motukarara soils, unsuitable for cropping on prograding river delta/tidal flats or lagoon margins.

LUC Class 6

Class 6 is non-arable land that has moderate limitations and hazards to pastoral or forestry use under a perennial vegetative cover. Erosion is commonly the dominant limitation, which can be minimised by appropriate soil conservation measures. Soil limitations, depth, texture and stoniness also commonly restrict use but wetness and climate factors are less dominant limiting factors. Class 6 encompasses the good relatively stable hill country but also includes stony and shallow soils on terraces, floodplains and fans.

LUC Class 6e occupies includes significant areas of hill country in the lowland. It includes:

- strongly rolling to steep hill country developed on hard rock with moderately well-drained silt loam textured Brown soils in moderate rainfall areas, e.g. Hurunui soils
- strongly rolling to steep hill country developed on hard rock with moderately well-drained silt loam textured Pallic and Recent soils in low to moderate rainfall areas, e.g. Haldon soils
- moderately steep-to-steep hill country developed on hard sedimentary and schist rocks with moderately well-drained silty clay loam textured Ultic soils in moderate rainfall areas, e.g. Ketu soils
- strongly rolling to steep hill country developed on hard sedimentary and schist rocks with moderately well-drained silt loam textured Brown soils in moderate to high rainfall areas, e.g. Kenepuru soils
- strongly rolling to steep lower hill slopes developed on hard rock with low fertility Brown soils in moderate rainfall inland areas, e.g. Tekoa soils
- strongly rolling to steep loessial hill country developed on soft rocks with moderately well-drained silt loam textured Pallic soils in low rainfall areas with a marked summer moisture deficit, e.g. Flaxbourne soils
- moderately steep-to-steep hill country developed on hard rock with moderately well-drained silt loam textured Pallic soils in low rainfall areas, e.g. Muller soils.

LUC Class 6s includes significant areas in the high country environment. It includes:

- well-drained, very shallow (<15 cm) and stony silt loam to sandy loam textured Recent soils on lowland flat to undulating floodplains, fans, and low terraces, e.g. Waimakariri shallow soils
- well-drained, very shallow and stony silt loam to sandy loam textured Recent soils on flat to undulating floodplains, fans, and low terraces in low to moderate rainfall areas of the high country, e.g. Tasman soils
- well-drained, shallow and stony silt loam textured Brown soils, e.g. Acheron and Molesworth series on undulating to rolling terraces and fans in moderate rainfall inland areas.

LUC Class 6c includes significant areas in the high country. It includes:

- undulating to rolling stable terraces and fans below 1100 m a.s.l. in low rainfall montane areas with a favourable sheltered aspect and silt loam to stony sandy loam-textured medium fertility Brown soils, e.g. Molesworth soils
- strongly rolling to moderately steep, stable hill country on hard rock with shallow, medium to high natural fertility soils in low to medium rainfall lowland areas with a marked summer moisture deficit, e.g. Haldon soils

- undulating to rolling stable terraces and fans below 1100 m a.s.l. in moderate rainfall inland montane areas with silt loam-textured low-fertility Brown soils, e.g. Cass soils.

LUC Class 6w includes gently sloping coastal lagoon margins subject to high brackish or saline water tables in low to moderate rainfall areas with sandy loam to clay loam textured saline recent Gley soils e.g. Motukarara series.

LUC Class 7

Class 7 lands are unsuitable for arable use and have severe limitations or hazards under perennial vegetation. It can only support extensive grazing or production forestry with a significant erosion control element. The risk of erosion is frequently the dominant limitation making careful conservation management for grazing necessary. LUC Class 7 lands can also have severe soil wetness or climatic limitations. In Marlborough LUC Class 7 lands include much of the steep inland 'high country', steepland terrain in the Marlborough Sounds, and shallow stony and/or low fertility soils on fans, floodplains and terraces.

LUC Class 7e includes significant areas of steep hill country in the lowlands and steep lower mountain slopes in the inland high country. The variety of class 7 land includes:

- moderately steep to steep coastal hill country developed on hard schistose and sedimentary rocks in moderate to high rainfall areas with low fertility silty clay loam Ultic or Brown soils, e.g. Opouri and Kenepuru soils
- steep mountain slopes developed on hard sedimentary rocks below the treeline in moderate to high rainfall high country areas with Brown soils susceptible to erosion, e.g. Tekoa soils
- moderately steep-to-steep mountain slopes developed on hard sedimentary rocks below 1340 m in low rainfall areas with Pallic and Brown soils susceptible to erosion, e.g. Muller soils
- moderately steep to steep hill country developed on hard schistose and sedimentary rocks in moderate to high rainfall areas with low fertility silt to clay loam Brown soils, e.g. Omamalutu soils
- moderately steep to steep hill country developed on hard schistose and sedimentary rocks in high rainfall areas with low fertility Brown soils, e.g. Pelorus and Patriarch soils
- steep to very steep hill country on hard schistose and sedimentary rocks in exposed coastal areas with moderate rainfall and Brown soils, e.g. Arapawa soils
- steep to very steep hill country on hard sedimentary rocks in moderate rainfall areas with Brown soils with moderate surface erosion, e.g. Hurunui soils
- moderately steep to steep mountain slopes developed on hard sedimentary rocks with Brown soils susceptible to sheet, gully and or scree erosion above the timberline in moderate to high rainfall areas, e.g. Kaikoura soils.
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LUC Class 7s predominantly occurs in the high country. It includes:

- well-drained very shallow (<15 cm) and stony silt loam to sandy loam textured Recent soils on lowland flat to undulating floodplains, fans, and low terraces, e.g. Waimakariri shallow soils
- well-drained very shallow and stony silt loam to sandy loam textured Recent soils on flat to undulating floodplains, fans, and low terraces in low to high rainfall areas of the high country, e.g. Tasman soils
- well-drained shallow and stony silt loam textured Brown soils, e.g. Acheron soils on undulating to rolling terraces and fans in moderate rainfall inland areas
- flat to undulating stony and bouldery former beach and storm ridges in low to moderate rainfall coastal areas, e.g. Taumutu soils.

LUC Class 7c also occurs in the high country and includes:

- undulating to rolling stable terraces, fans and moraine above 1000 m a.s.l. in cool moderate to high rainfall inland areas with silt loam textured low fertility Brown soils, e.g. Cass soils
- undulating to strongly rolling exposed broad upland spurs and shoulder slopes above 950 m a.s.l. in moderate rainfall inland areas with Brown soils, e.g. Benmore soils
- undulating to rolling stable terraces, fans and moraine above 1000 m a.s.l. in cool low rainfall inland areas with Brown soils, e.g. Molesworth soils.

LUC Class 7w includes:

- tidal salt marsh in low to moderate rainfall areas with sandy loam to clay loam-textured saline recent Gley soils, e.g. Motukarara soils
- drainage impeded floodplains and wetlands with sandy loam to clay loam-textured soils and significant standing water in moderate rainfall lowland areas with Waimari Organic soils
- montane valley floor wetlands with Recent Gley sandy loam-textured soils and significant standing water in moderate to high rainfall inland areas, e,g. Dobson soils.

LUC Class 8 land

This land has very severe to extreme limitations or hazards, which make it unsuitable for arable, pastoral, or production forestry use. Soil conservation and water management are the main on-site and off-site concerns of this land. It is suitable for catchment protection purposes, which include water management and recreational uses. The most common limitation to use is extreme actual or potential erosion combined with severe climatic limitations. Class 8 land is often high mountainous country, although it also includes very steep slopes and highly erodible areas at lower elevations such as fore dunes.

LUC Class 8 land occupies steep to very steep high country mountain slopes and very steep hill country in the Marlborough. The most extensive areas are developed on hard sedimentary and schistose rocks in all rainfall zones with Brown, Podzol and Raw soils dominant.

Only minor amounts of land have been classified as LUC Class 8 with ‘c’, ‘w’ and ‘s’ subclasses.

Appendix 2 Land Cover Database reduced classification

Original LCDB class	Reduce LCDB class
'Afforestation (imaged, post LCDB 1)'	Forestry
Afforestation (not imaged)	Forestry
Alpine Grass-/Herbfield	Natural
Alpine Gravel and Rock	Natural
Broadleaved Indigenous Hardwoods	Natural
Built-up Area	Urban
Coastal Sand and Gravel	Natural
Deciduous Hardwoods	Natural
Depleted Tussock Grassland	Natural
Dump	Urban
Estuarine Open Water	Natural
Fernland	Natural
Flaxland	Natural
Forest Harvested	Forestry
Gorse and Broom	Exotic
Grey Scrub	Natural
Herbaceous Freshwater Vegetation	Natural
Herbaceous Saline Vegetation	Natural
High Producing Exotic Grassland	Pastoral
Indigenous Forest	Natural
Lake and Pond	Natural
Landslide	Natural
Low Producing Grassland	Pastoral
Major Shelterbelts	Exotic
Mangrove	Natural
Manuka and or Kanuka	Natural
Matagouri	Natural
Mixed Exotic Shrubland	Natural
Orchard and Other Perennial Crops	Horticulture
Other Exotic Forest	Forestry
Permanent Snow and Ice	Natural
Pine Forest – Closed Canopy	Forestry
Pine Forest – Open Canopy	Forestry

Original LCDB class	Reduce LCDB class
River	Natural
River and Lakeshore Gravel and Rock	Natural
Short-rotation Cropland	Arable
Sub Alpine Shrubland	Natural
Surface Mine	Urban
Tall Tussock Grassland	Natural
Transport Infrastructure	Urban
Urban Parkland/Open Space	Urban
Vineyard	Viticulture