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DROUGHT RISK AND YOU (DRY):

CASE STUDY CATCHMENTS – PHYSICAL CHARACTERISTICS AND FUNCTIONING

WORK PACKAGE 3 DELIVERABLE

CEH PROJECT No. NEC05074

J. R. BLAKE AND R. RAGAB

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC SCIENCE OF THE ENVIRONMENT

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Centre for Ecology & Hydrology
Maclean Building
Crowmarsh Gifford
Wallingford
Oxfordshire
OX10 8BB

www.ceh.ac.uk

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1. INTRODUCTION TO THE CASE STUDY CATCHMENTS

Seven catchments, covering England, Wales and Scotland, have been selected as case studies for the Drought Risk and You (DRY) project. Following an initial screening, around 50 catchments were considered in detail, with the aim to select catchments with: (i.) Contrasting hydrological, geological, agricultural and climatic contexts; (ii.) Contrasting rural, urban and suburban contexts; (iii.) An area of less than 400 km^2, and ideally around 200 km^2, to meet modelling requirements; (iv) Monitored river flow data from the 1960s onwards; and (v.) A variety of water resources management interests. Seven catchments which meet these criteria were selected as case studies: River Fowey at Restormel, River Frome (Bristol) at Frenchay, River Pang at Pangbourne, Bevills Leam at Tebbits Bridge, Afon Ebbw at Rhiwderin, River Don at Hadfields Weir and River Eden at Kemback. Their locations are shown in Figure 1. In the following sections, the physical characteristics and functioning of each of these catchments are summarised.

Table 1. Average annual rainfall (1961-90) in the case study catchments

South - North		**West –East**	
Fowey	1436 mm	Fowey	1436 mm
Ebbw	1456 mm	Frome	792 mm
Don	1009 mm	Pang	695 mm
Eden	799 mm	Bevills Leam	630 mm

Table 1 shows the case study catchments that represent different drought potential, covering UK rainfall/temperature gradients: West-East (SW England–SE England–East Anglia) and South-North (SW England–Wales-N England-E Scotland). This final selection was driven by several primary factors such as the availability of long-term data records that provide a range across: rainfall and temperature; urban (suburban and peri-urban) and rural; different land uses (e.g. grassland, agricultural, horticultural, woodland, upland) to capture impacts on different stakeholder groups and the local communities; water abstraction points and river flow; extent/experience of coping with drought (longer standing and recent); socio-economic, cultural and health impacts, and community responses; variety in water demand patterns, due to e.g. particular industrial , agricultural and environmental needs; catchments with different governance/water use policies in England, Wales and Scotland. For example, built environments included in the proposed catchment selection (Table 1) cover Bristol/Sheffield, two of the UK's eight Core Cities outside of London seen as driving UK economic growth; (www.corecities.com), as well as smaller rural towns/villages. Regions with longer-standing drought-coping strategies (e.g. SE England) will be contrasted with regions with only recent drought experience (e.g. E Scotland). Secondary factors for catchment selection included researchers'/partners' existing networks to optimise synergies with other water related research (Pang - NERC Lowland Catchment Research programme; CEH projects including DiCaSM model development/application; Bevills Leam - Blake's Great Fen Project hydrological catchment model (Blake and Acreman 2009; Blake et al. 2012); Frome - McEwen's AHRC Multi-story water; Don - McGuinness's EPSRC research; Eden - Black's prior stakeholder links).

Incorporating these factors into catchment selection will allow capture of a wide range of drought experiences, stakeholder perceptions, coping strategies and constraints to effective drought management across diverse stakeholder groups, and to identify mitigation strategies and scientific impacts. Modified from DRY Project Proposal (2013).

Figure 1 Case study catchments overview map

2.1 RIVER FOWEY AT RESTORMEL

NRFA gauging station number: 48011

Environment Agency South West Region

Area: 169 km² (see Figure 2)

1961-2013 daily flow data

Moderate relief catchment whose headwaters drain the kaolinised granite of Bodmin Moor. Middle and low reaches drain Devonian slates and grits. Some valley storage in gravels. Low grade agriculture, grazing and forestry.

Substantial modifications to flow from associated public water supply (PWS) abstraction, Colliford (1983) and Siblyback (1969) reservoirs and other PWS exports.

Rural villages with a 50% summer population increase due to tourism, making water demand highly seasonal. River flows dominated by rapid surface runoff. Catchment heavily affected by public water supply abstraction including surface water reservoirs

Drought experience includes: 1976, 1977, 1984, 1990 and 1995

Factors Affecting Runoff

S: Reservoir(s) in catchment affect runoff.

R: Regulation from surface water and/or ground water.

P: Runoff reduced by public water supply abstraction.

Topography (see Figure 3)

Minimum Altitude: 9.2 mAOD

10 Percentile: 95.7 mAOD

50 Percentile: 206.3 mAOD

90 Percentile: 282.2 mAOD

Maximum Altitude: 404.3 mAOD

Land cover (see Figures 4 and 5)

Woodland: 18.3 %

Arable / horticultural: 10.7 %

Grassland: 63.6 %

Mountain / Heath / Bog: 2.1 %

Urban Extent: 0.2 %

Soils (see Figure 6)

Hydrogeology (see Figure 7)

High Permeability Bedrock: 0.0 %

Moderate Permeability Bedrock: 0.0 %

Low Permeability Bedrock: 44.7 %

Generally High Permeability Superficial Deposits: 0.9 %

Generally Low Permeability Superficial Deposits: 11.2 %

Mixed Permeability Superficial Deposits: 1.9 %

Standard-period Average Annual Rainfall (SAAR)

SAAR 1961-1990: 1436 mm

Base Flow Index (BFI) derived from Hydrology of Soil Types (HOST, see Boorman et al., 1995) data

BFIHOST: 0.522

The above information is predominantly sourced from the National River Flow Archive (2014)

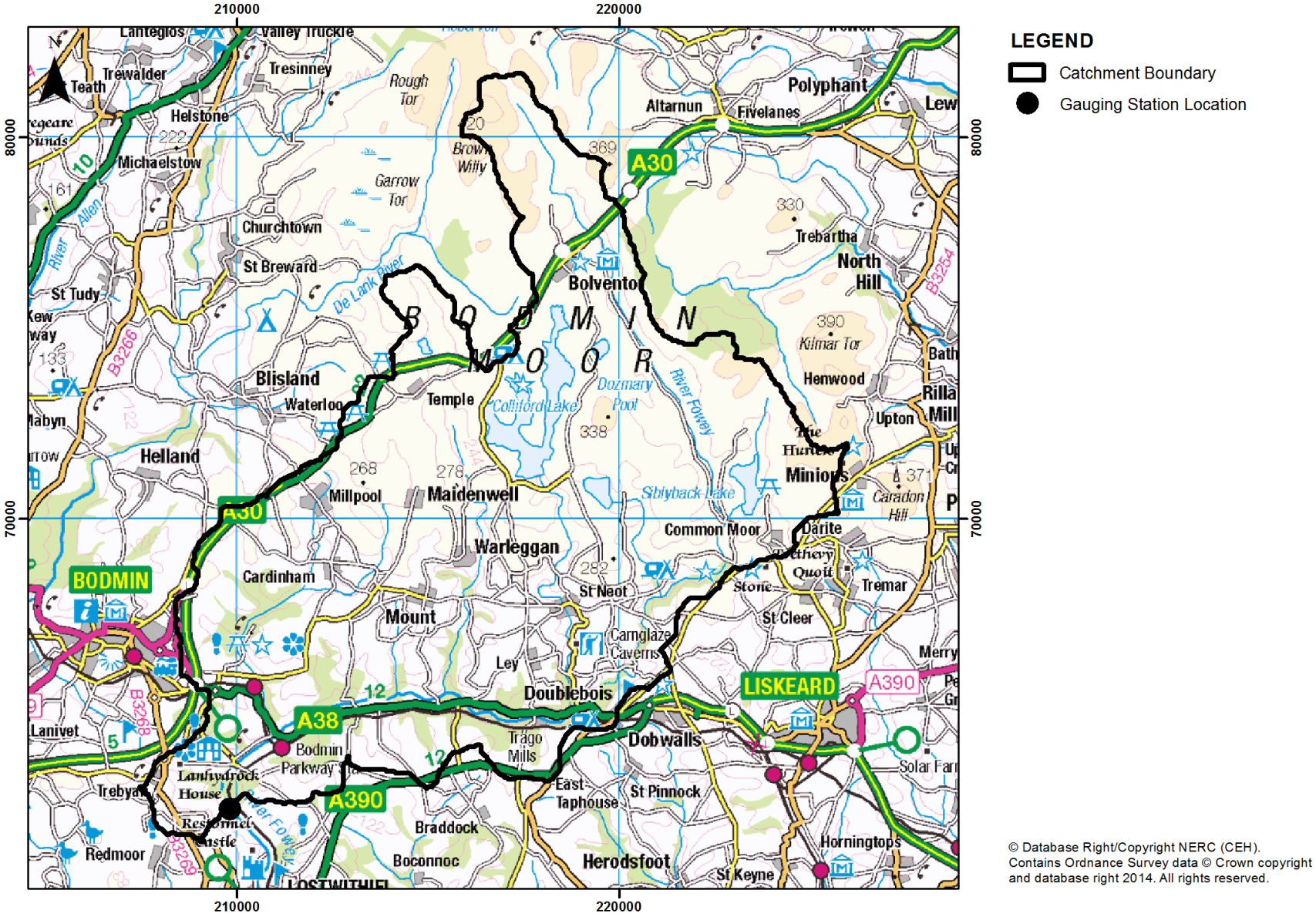


Figure 2 Fowey catchment overview

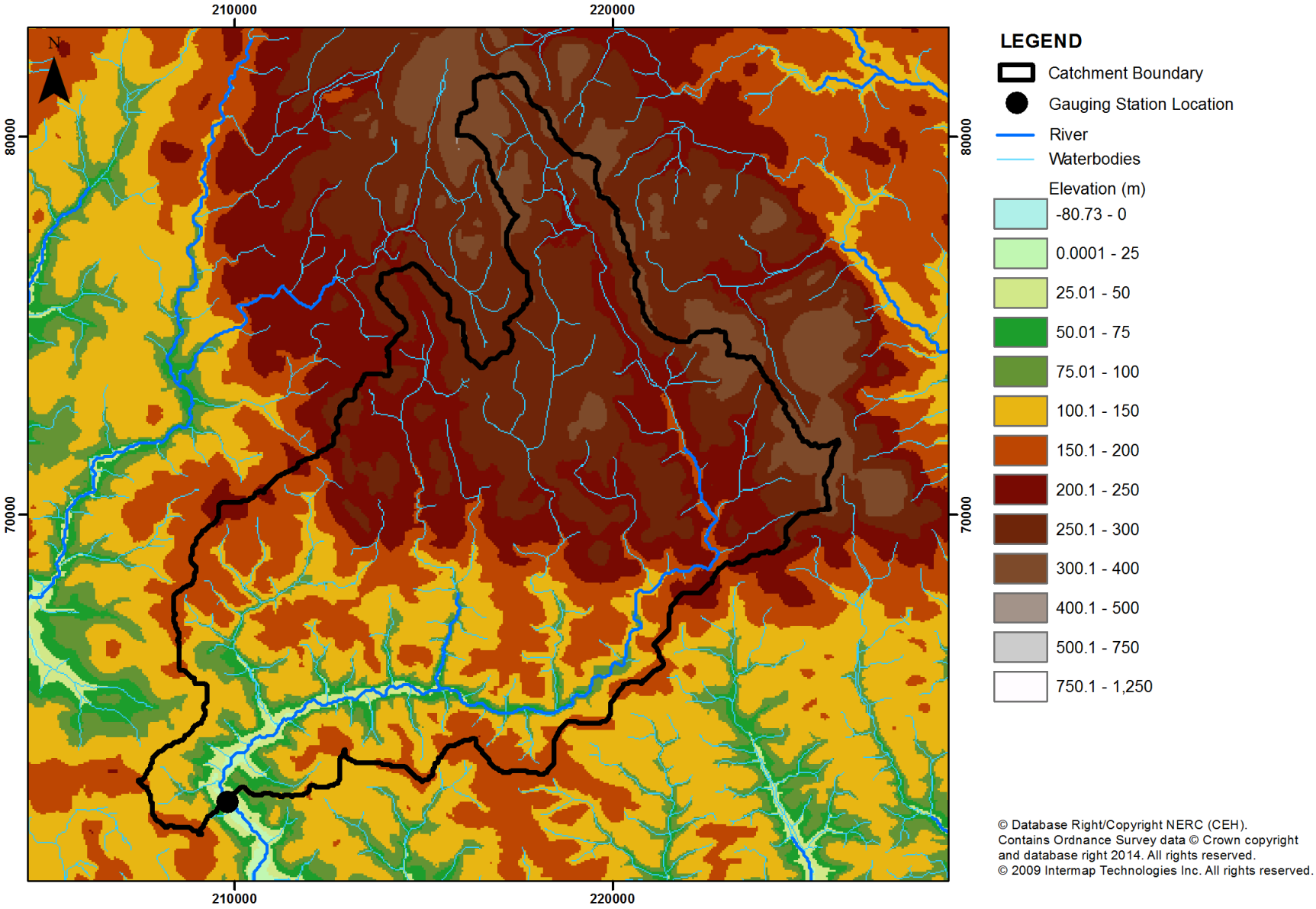


Figure 3 Fowey catchment topography

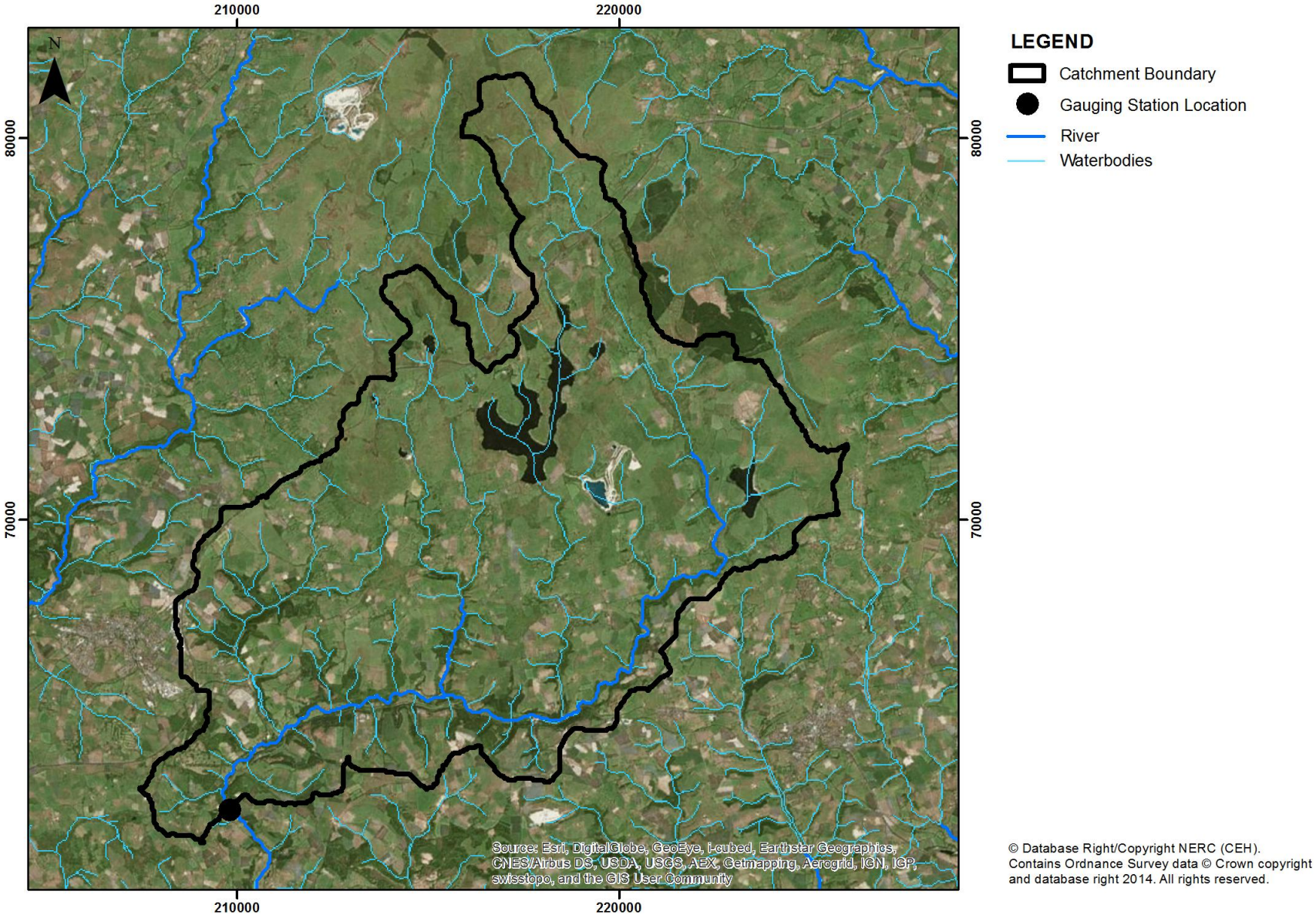


Figure 4 Fowey catchment aerial image

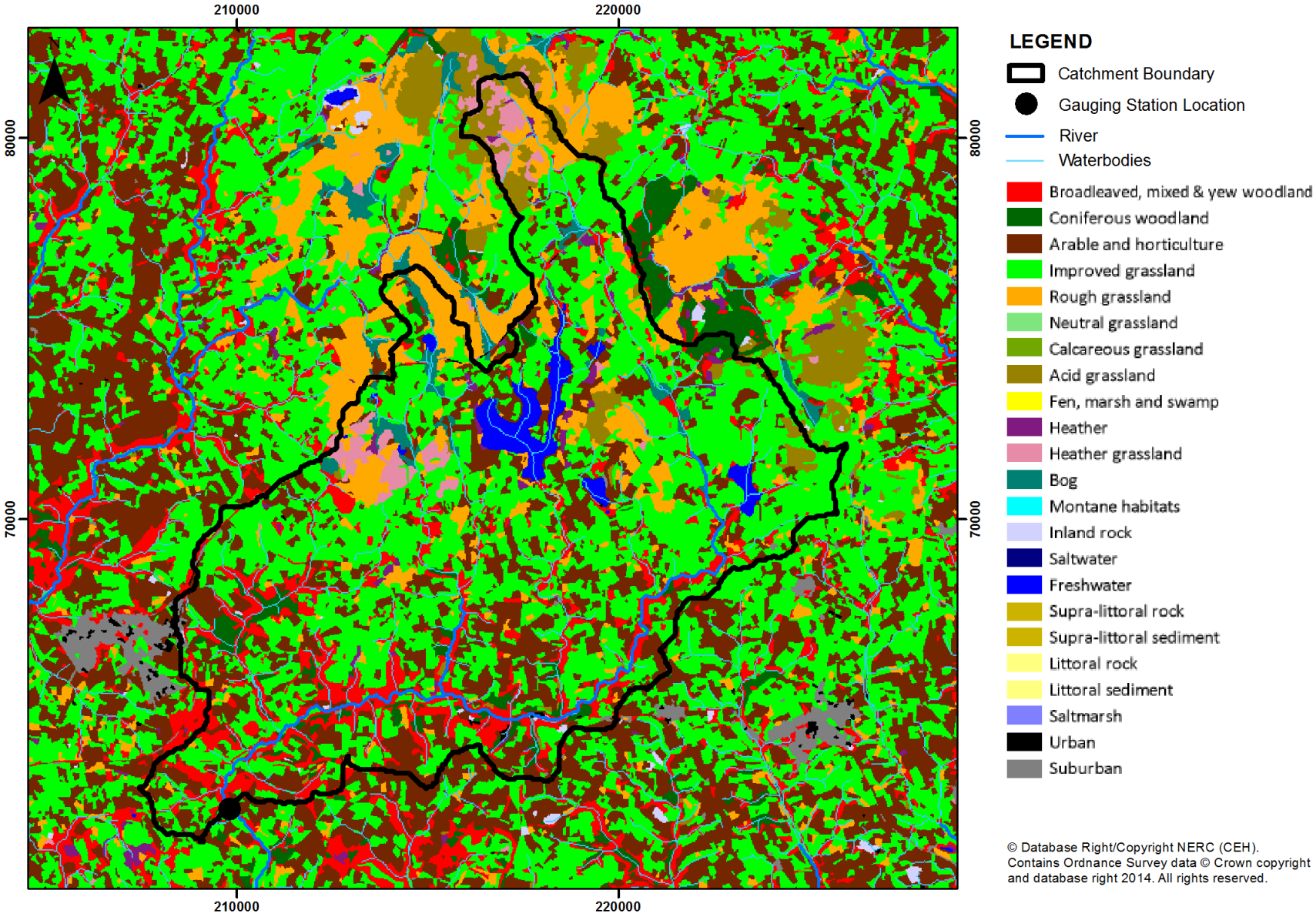


Figure 5 Fowey catchment land cover

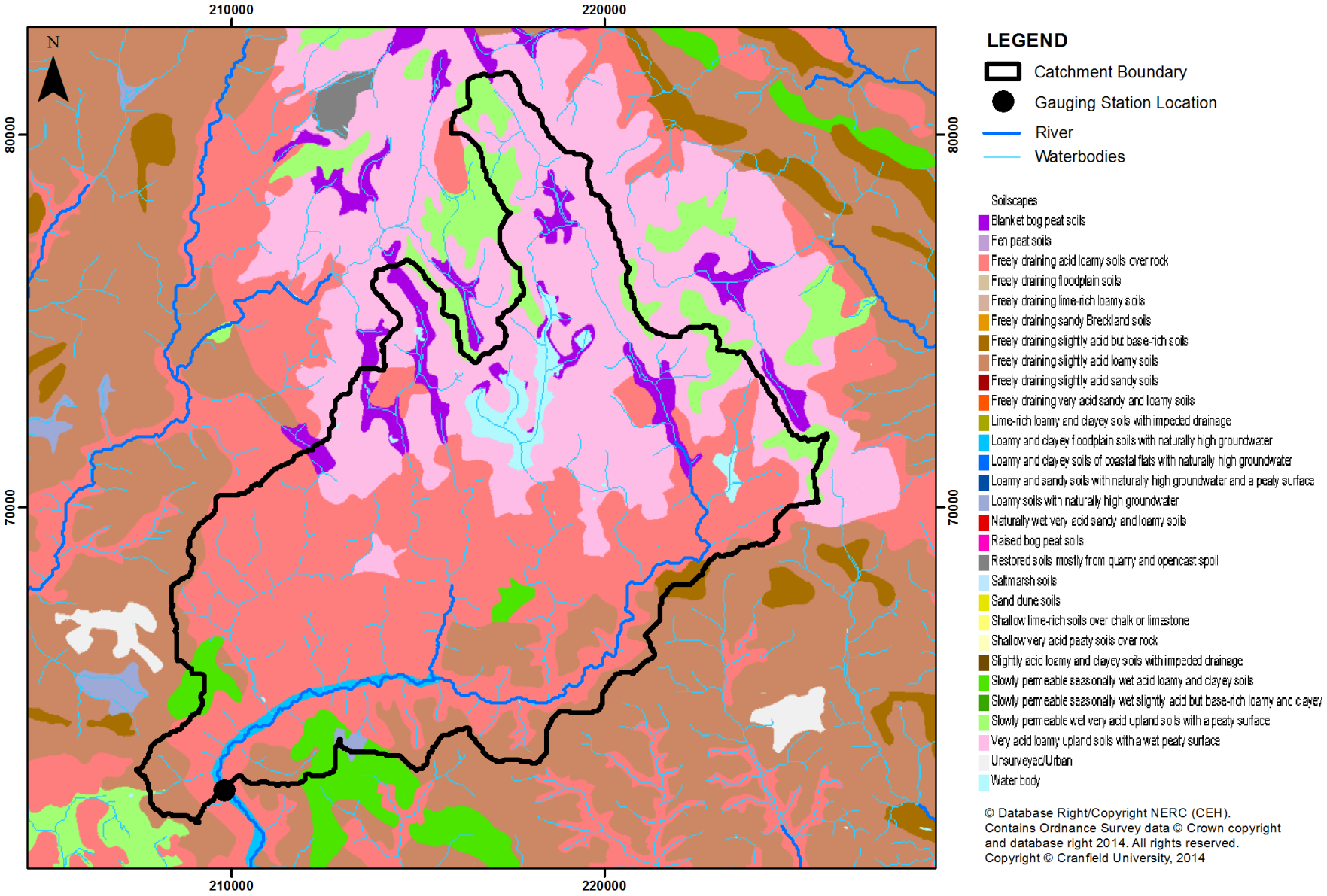


Figure 6 Fowey catchment soils

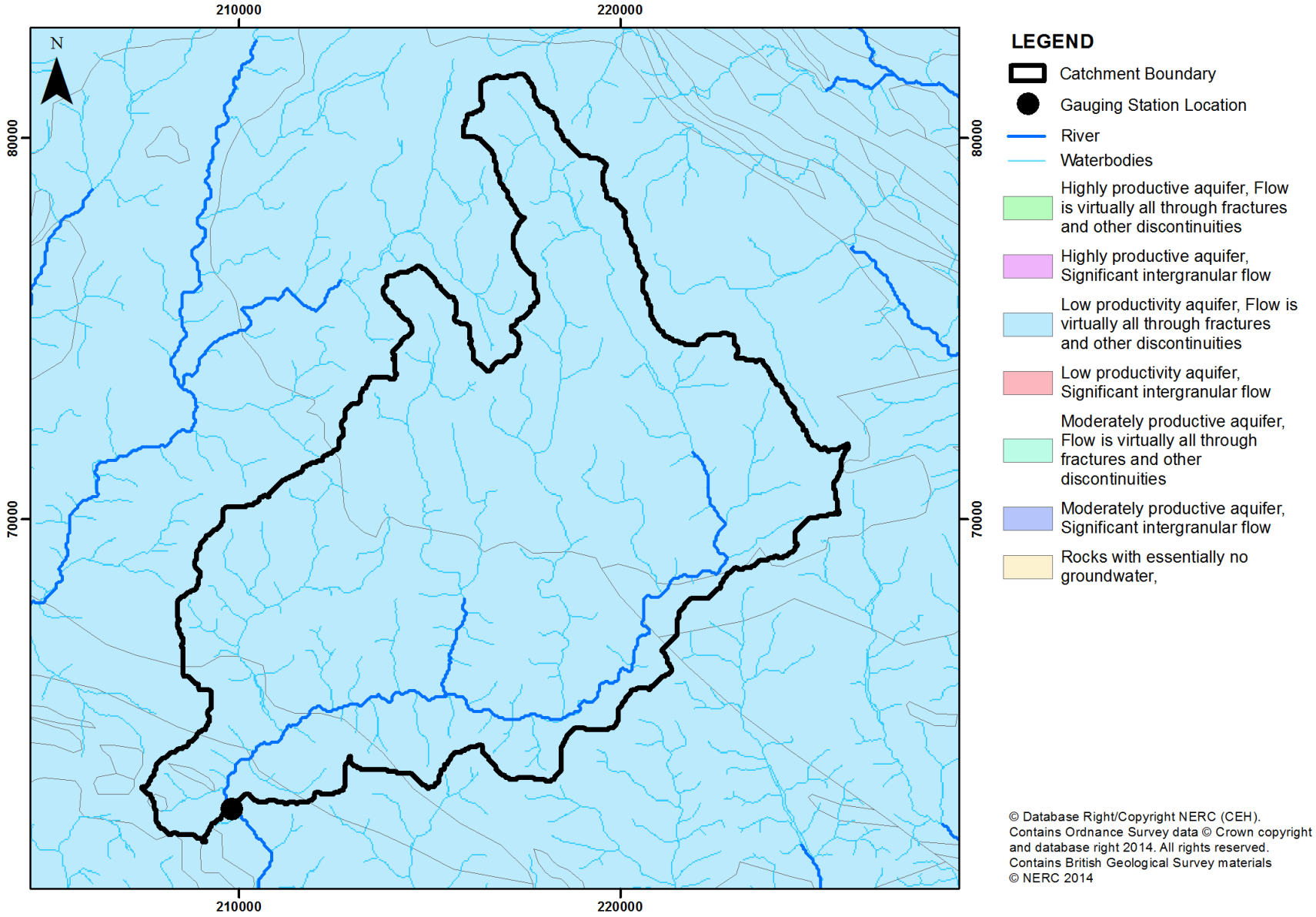


Figure 7 Fowey catchment hydrogeology

2.2 RIVER FROME (BRISTOL) AT FRENCHAY

NRFA gauging station number: 53006

Environment Agency South West Region

Area: 149 km² (see Figure 8)

1961-2012 daily flow data

Catchment of complex geology: eastern and central catchment dominated by sandstones of the Coal Measures and Mercia Mudstone; west less permeable having Mercia Mudstone and Liassic clays. Superficial deposits are meltwater gravels and terraces, mainly in west. Land-use: large proportion of urban development (~23%) in catchment, otherwise rural.

Spans urban and rural; city (Bristol), town (Yate) and villages. Large business parks, retail outlets, university and hospital. River flows dominated by rapid surface runoff. Moderate relief.

Drought experience includes: 1976, 1990, 1995, 2005 and 2011

Factors Affecting Runoff

N: Natural to within 10% at the 95 percentile flow.

Topography (see Figure 9)

Minimum Altitude: 20 mAOD

10 Percentile: 50.1 mAOD

50 Percentile: 65.8 mAOD

90 Percentile: 106.3 mAOD

Maximum Altitude: 194.3 mA

Land cover (see Figures 10 and 11)

Woodland: 5.1 %

Arable / horticultural: 21.7 %

Grassland: 48.1 %

Mountain / Heath / Bog: 0.0 %

Urban Extent: 11.4 %

Soils (see Figure 12)

Hydrogeology (see Figure 13)

High Permeability Bedrock: 1.8 %

Moderate Permeability Bedrock: 12.4 %

Low Permeability Bedrock: 52.5 %

Generally High Permeability Superficial Deposits: 0.7 %

Generally Low Permeability Superficial Deposits: 0.0 %

Mixed Permeability Superficial Deposits: 2.7 %

SAAR 1961-1990: 792 mm

BFIHOST: 0.362

The above information is predominantly sourced from the National River Flow Archive (2014)

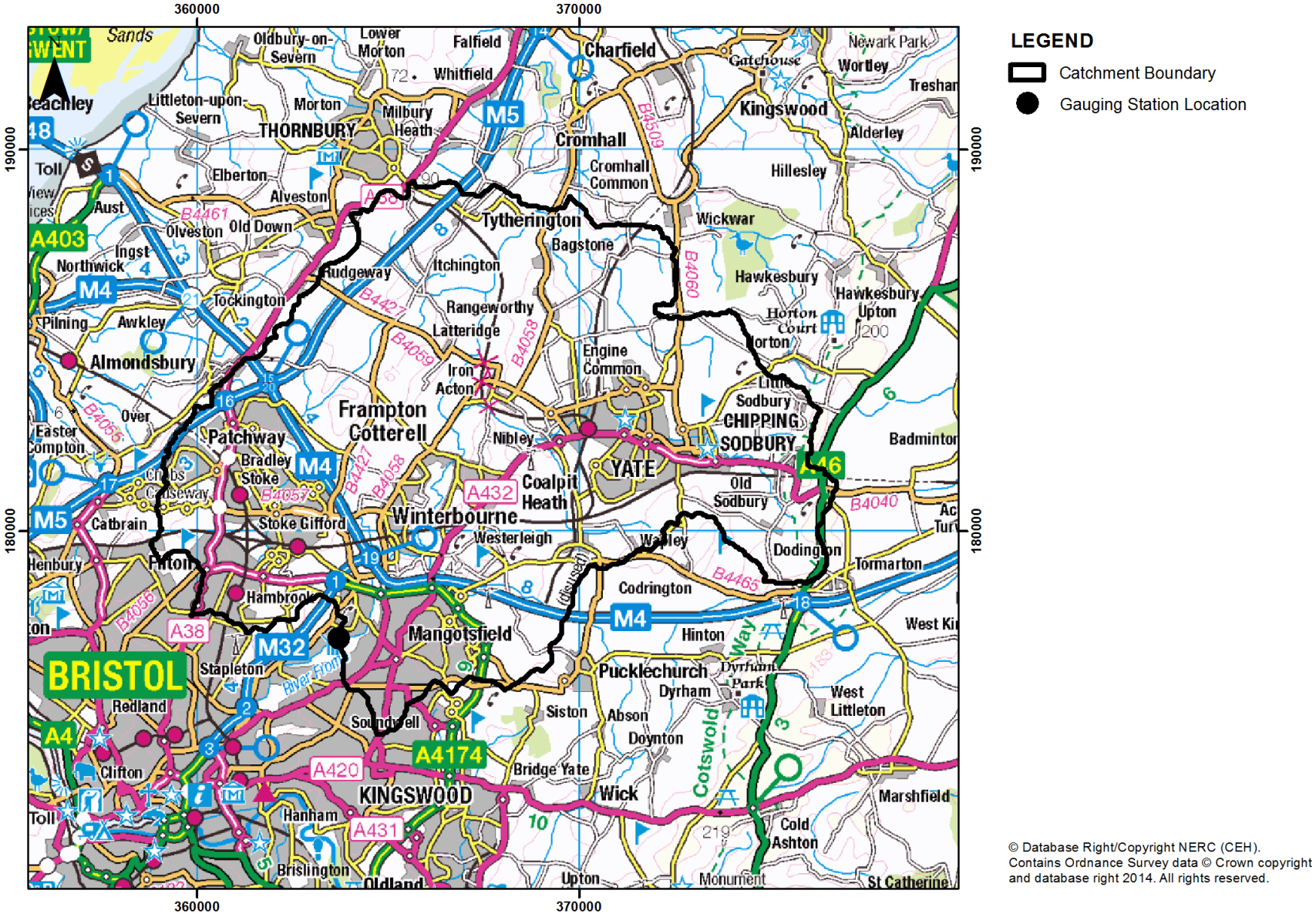


Figure 8 Frome catchment overview

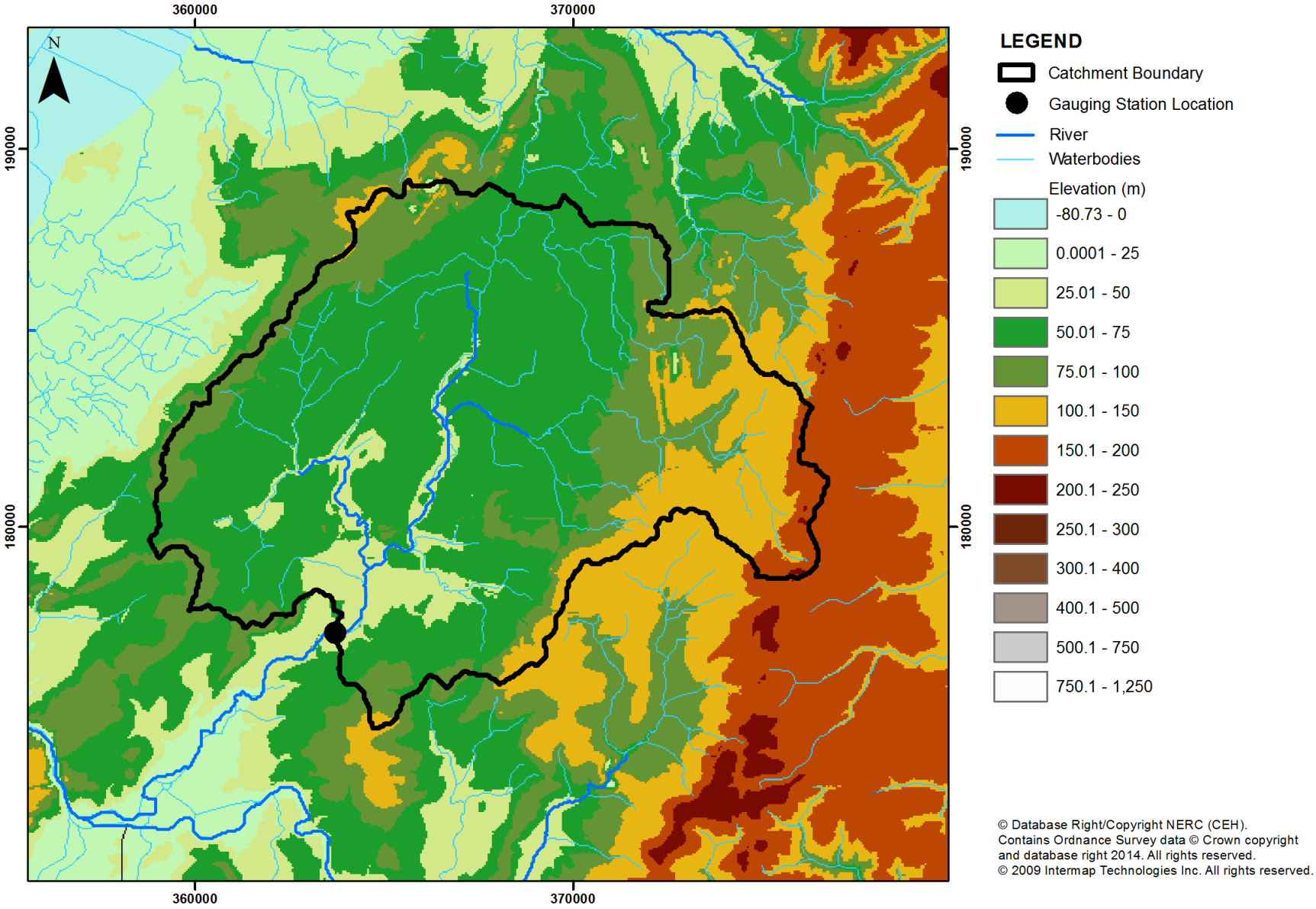


Figure 9 Frome catchment topography

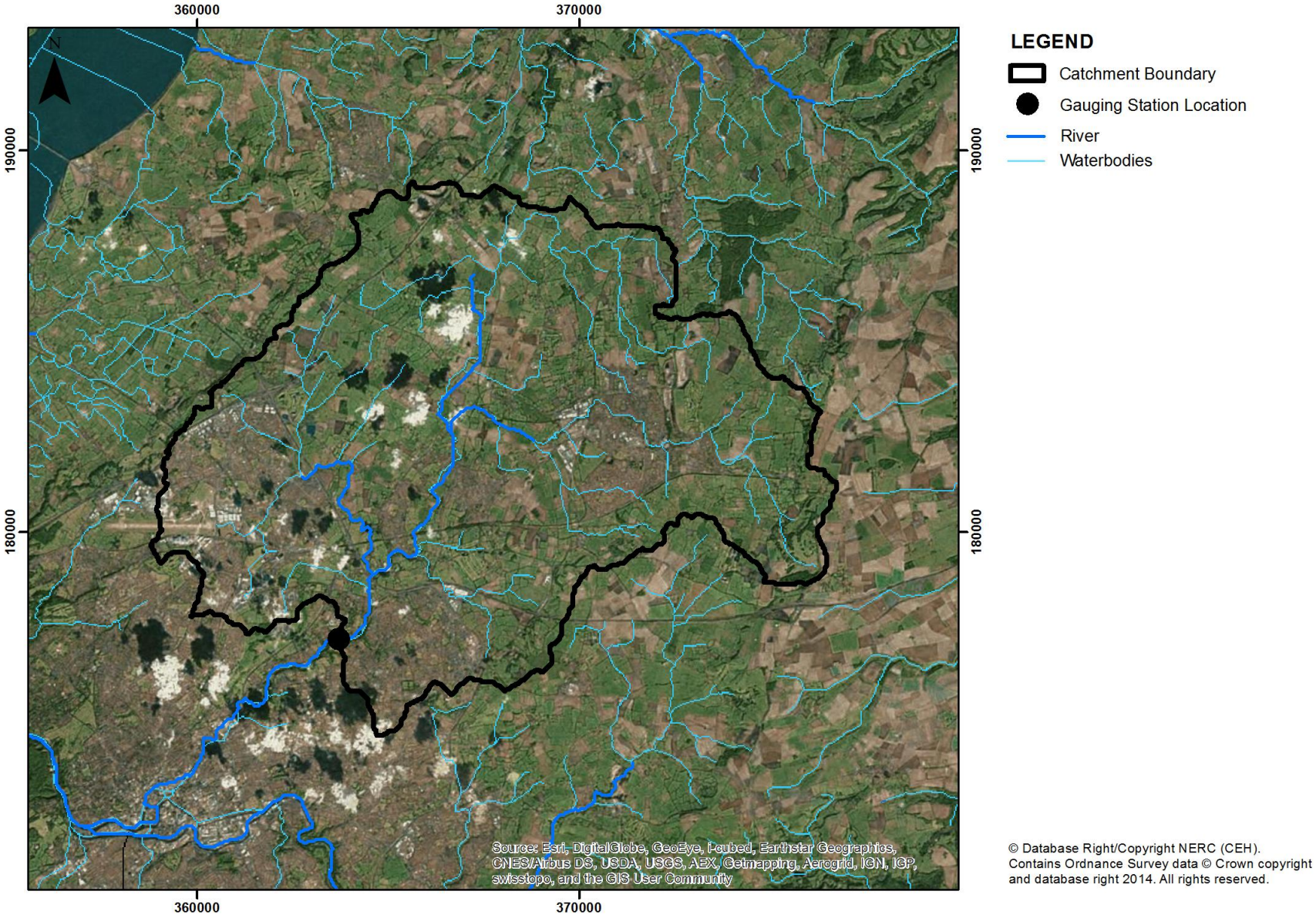


Figure 10 Frome catchment aerial image

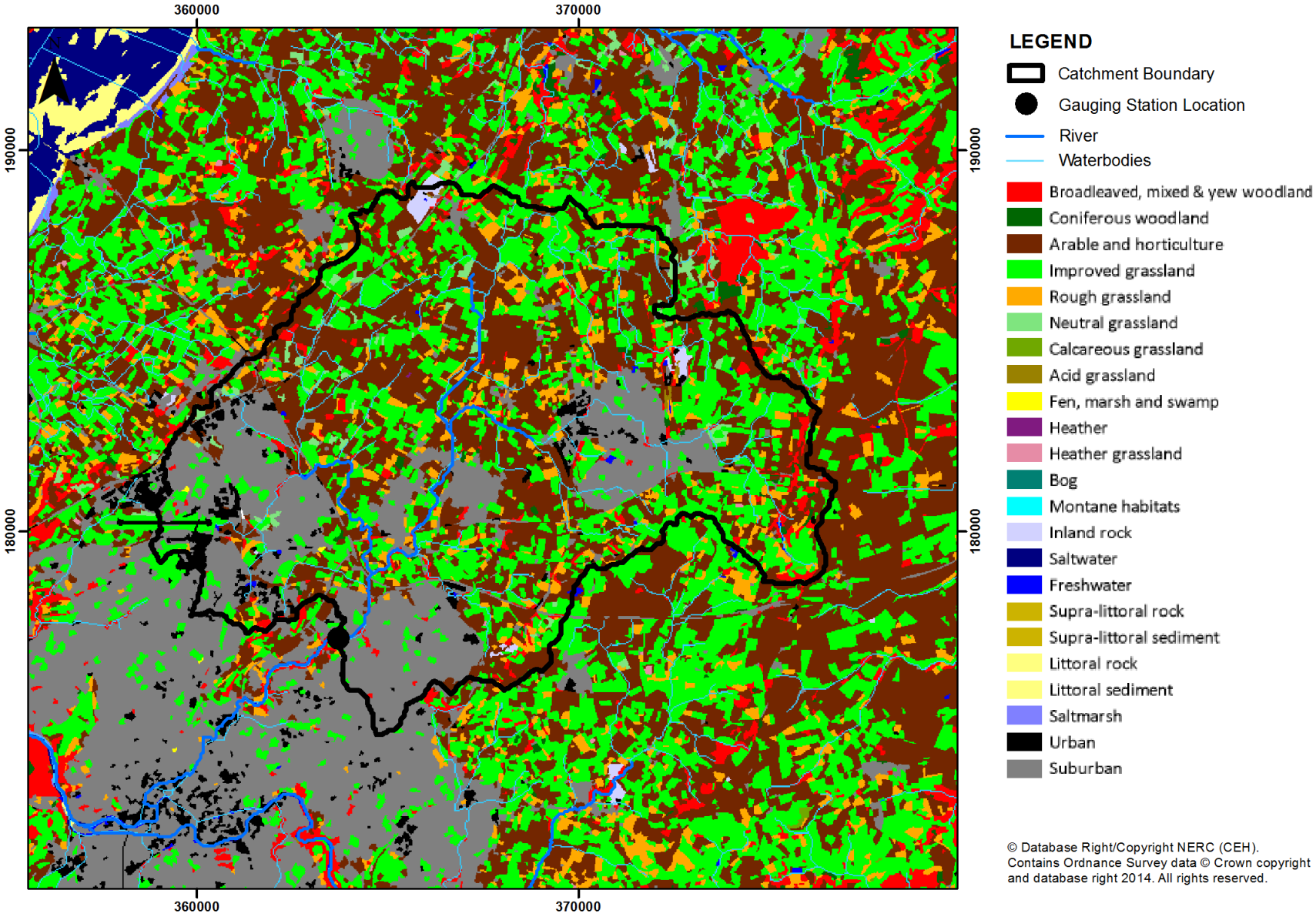


Figure 11 Frome catchment land cover

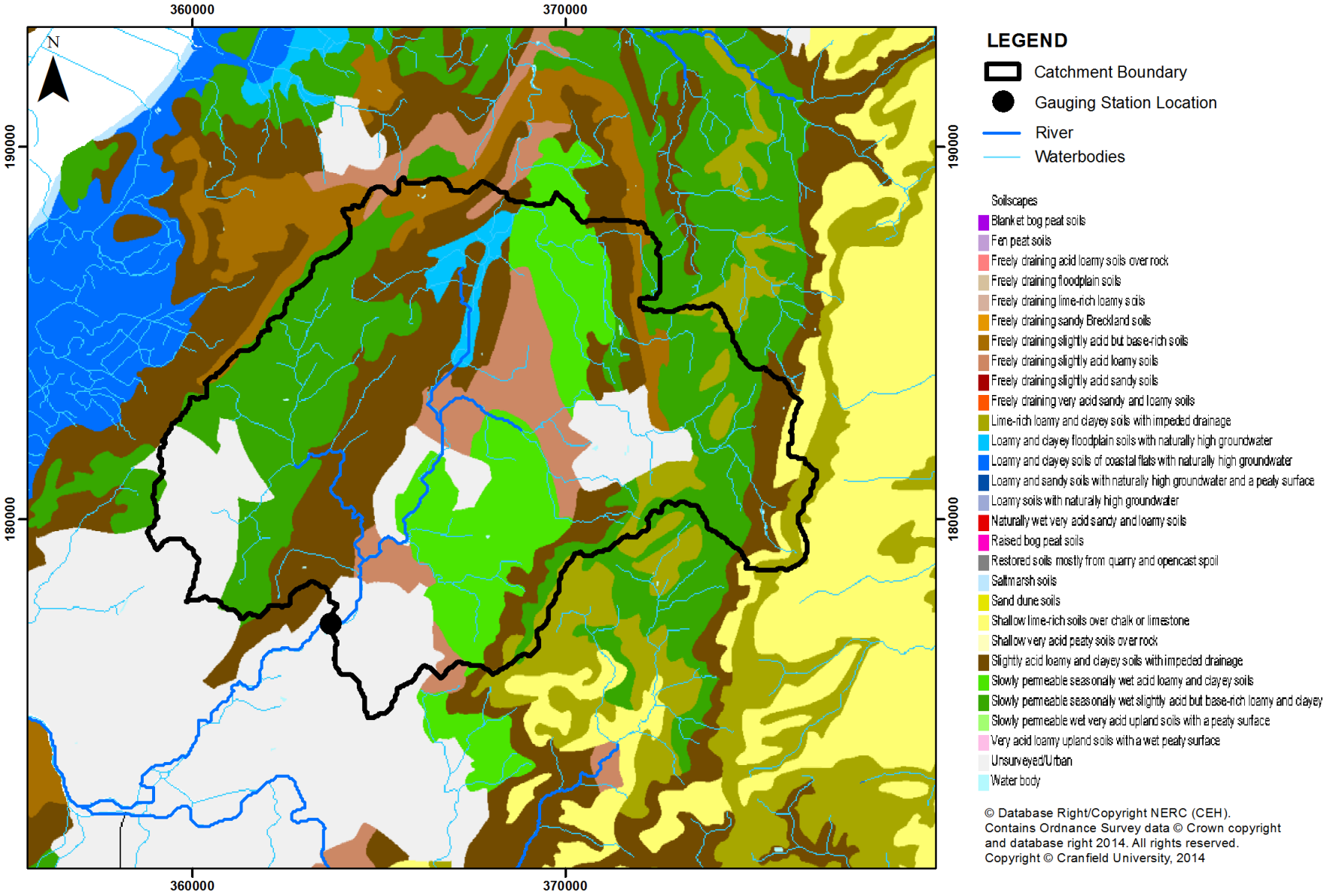


Figure 12 Frome catchment soils

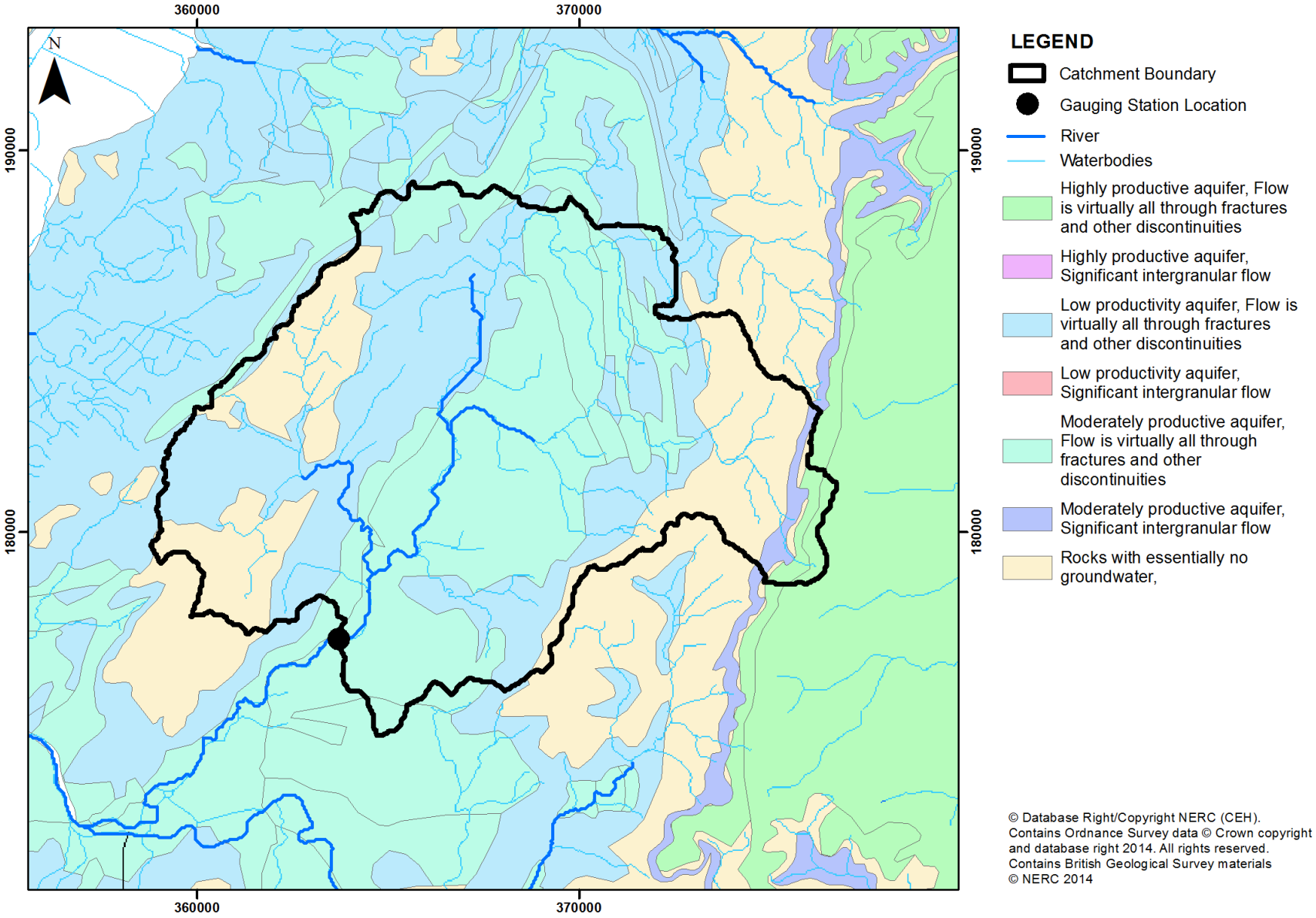


Figure 13 Frome catchment hydrogeology

2.3 RIVER PANG AT PANGBOURNE

NRFA gauging station number: 39027

Environment Agency Thames Region

Area: 171 km² (see Figure 14)

1968-2013 daily flow data

Catchment is principally pervious (Chalk) but about 15% is impermeable (Reading Beds, London Clay and Alluvium); appreciable Drift/Clay-with-Flint cover also. A largely rural catchment with appreciable woodland and scattered settlements.

Runoff substantially diminished by groundwater abstractions (but large reduction in Compton abstraction from early 1990s); occasional impact of West Berkshire Groundwater Scheme (operated by Thames Water and Environment Agency at times of extreme drought to augment river flows with abstracted groundwater) but otherwise relatively few artificial influences on flows.

Representative of typical Southern England chalk downland, river flows dominated by slowly responding groundwater. Rural catchment with a town (Pangbourne) and villages.

Drought experience includes: 1975-77, 1991-92, 1995-97, 2004-06 and 2010-12

Factors Affecting Runoff

R: Regulation from surface water and/or ground water.

G: Runoff influenced by groundwater abstraction and/or recharge.

I: Runoff reduced by industrial and/or agricultural abstraction.

Topography (see Figure 15)

Minimum Altitude: 39.6 mAOD

10 Percentile: 71.8 mAOD

50 Percentile: 118.4 mAOD

90 Percentile: 173.5 mAOD

Maximum Altitude: 238 mAOD

Land cover (see Figures 16 and 17)

Woodland: 17.6 %

Arable / horticultural: 45.4 %

Grassland: 28.2 %

Mountain / Heath / Bog: 0.5 %

Urban Extent: 1.2 %

Soils (see Figure 18)

Hydrogeology (see Figure 19)

High Permeability Bedrock: 75.9 %

Moderate Permeability Bedrock: 0.0 %

Low Permeability Bedrock: 7.0 %

Generally High Permeability Superficial Deposits: 16.4 %

Generally Low Permeability Superficial Deposits: 15.2 %

Mixed Permeability Superficial Deposits: 2.1 %

SAAR 1961-1990: 695 mm

BFIHOST: 0.72

The above information is predominantly sourced from the National River Flow Archive (2014)

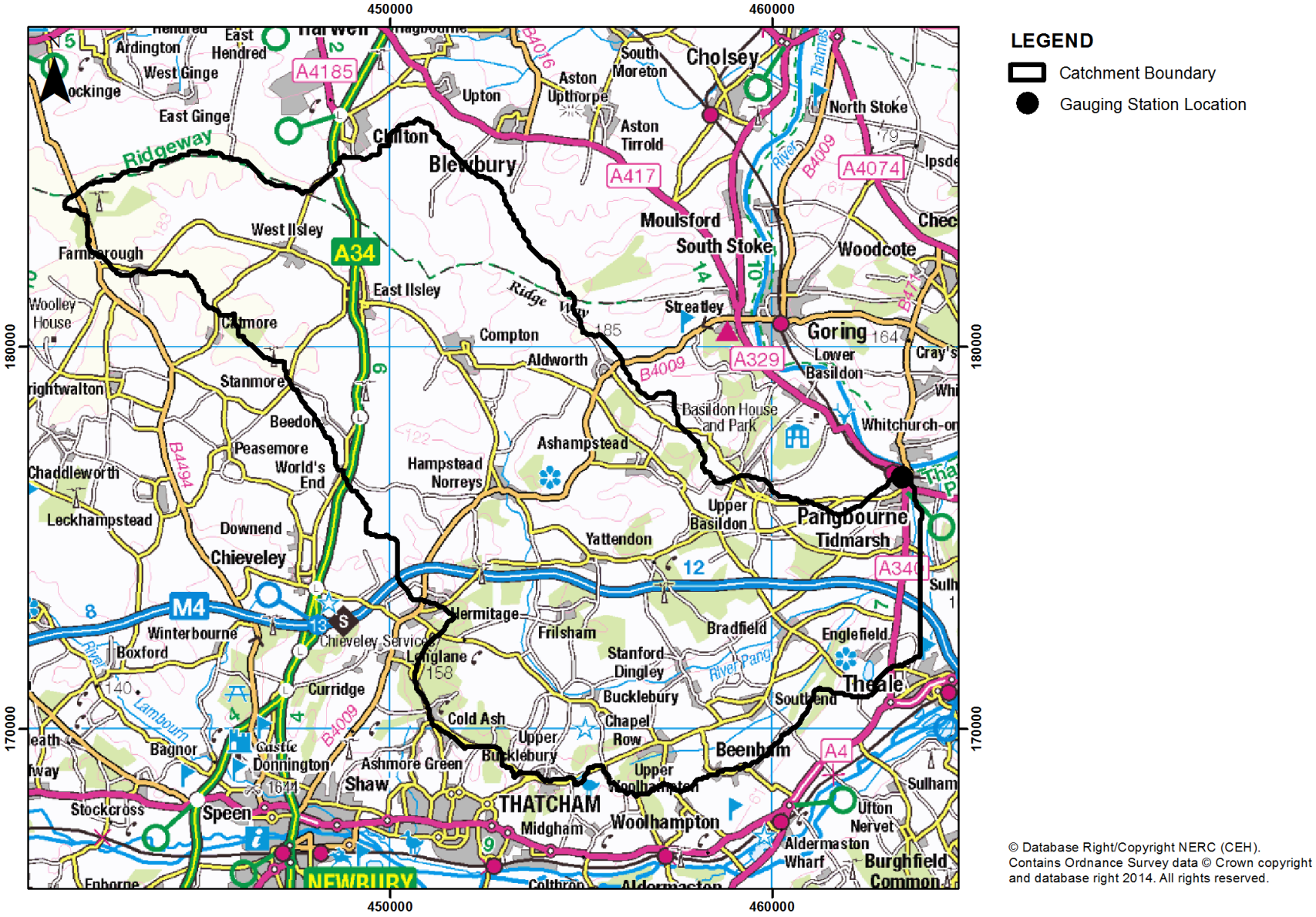


Figure 14 Pang catchment overview

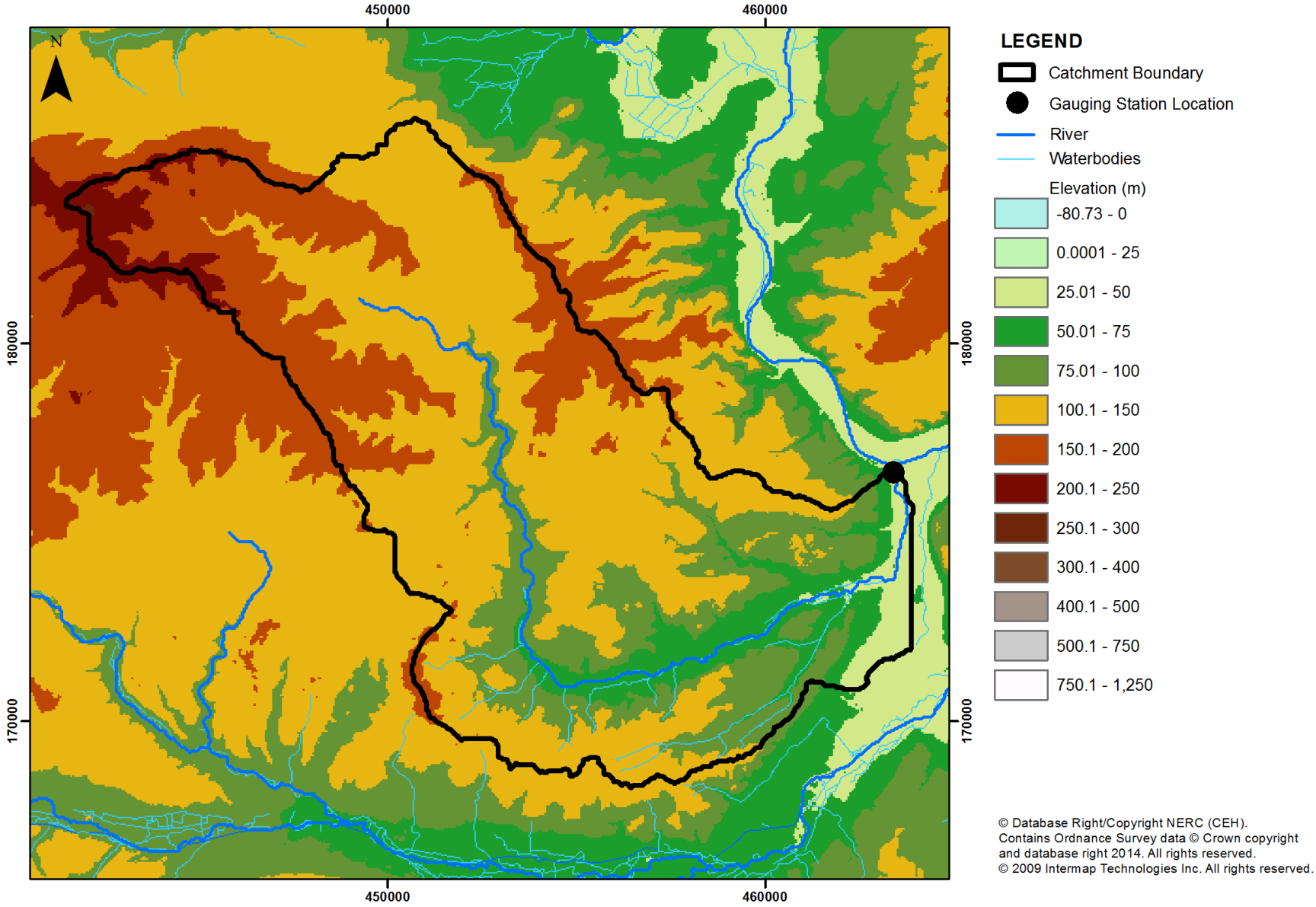


Figure 15 Pang catchment topography

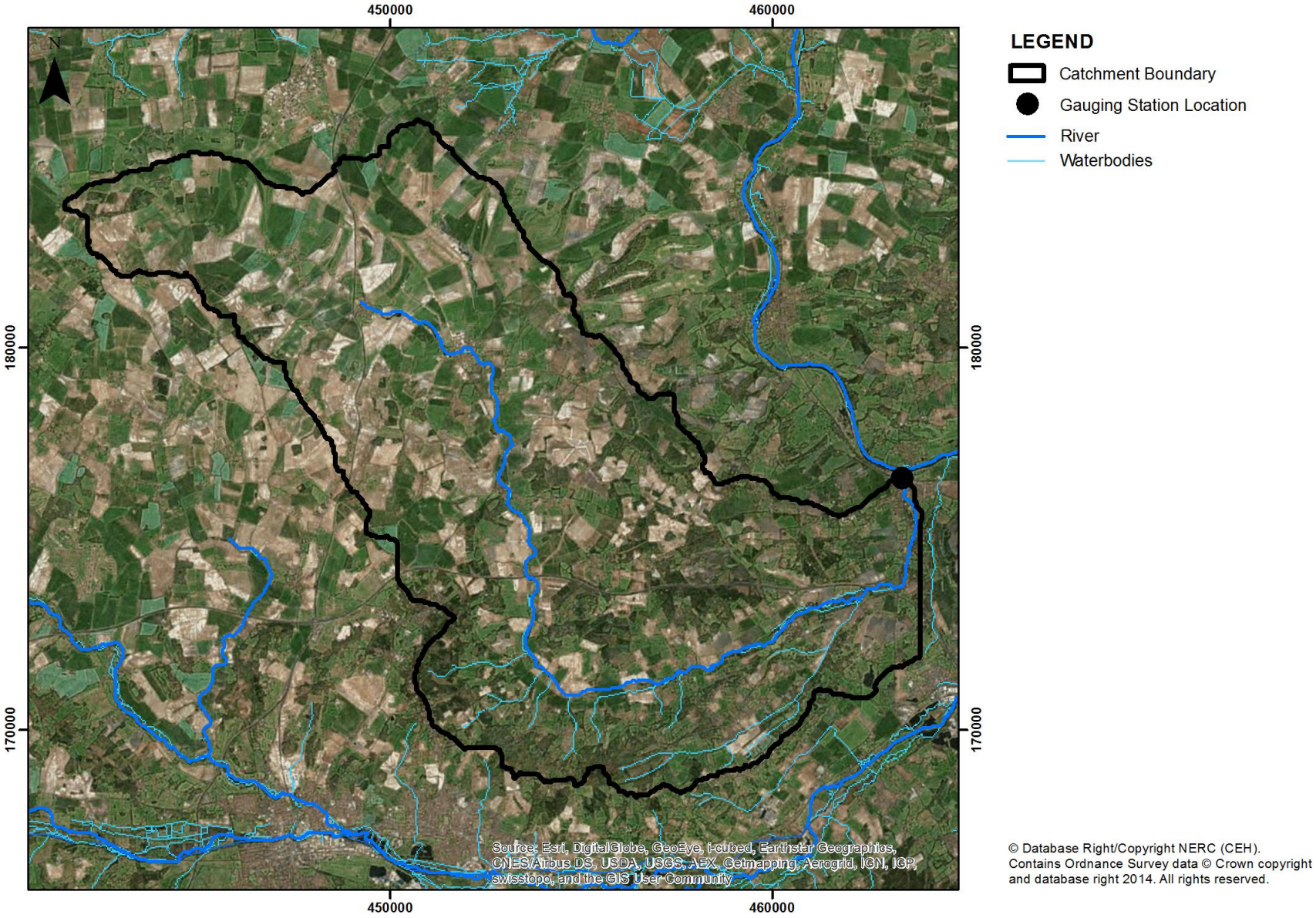


Figure 16 Pang catchment aerial image

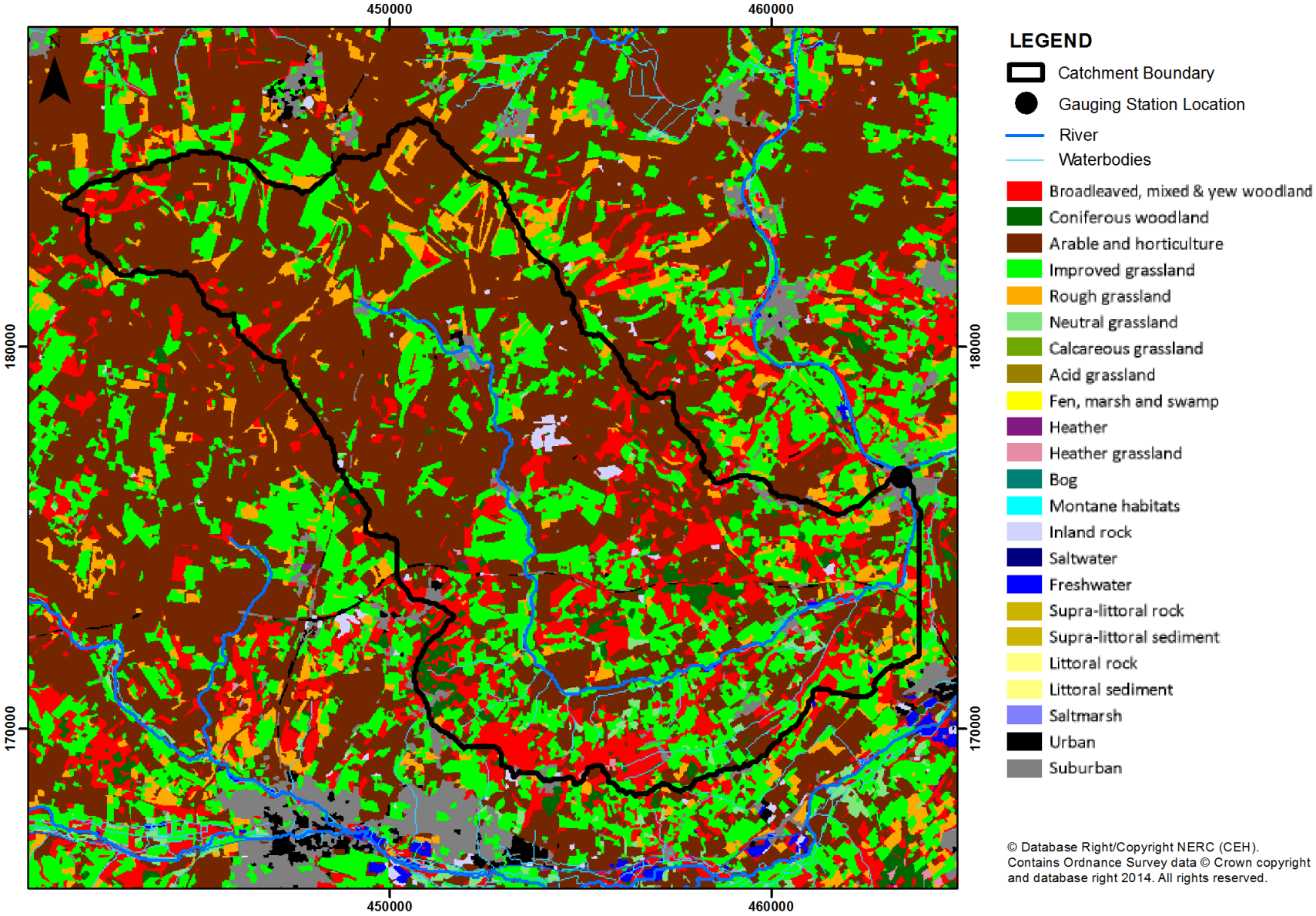


Figure 17 Pang catchment land cover

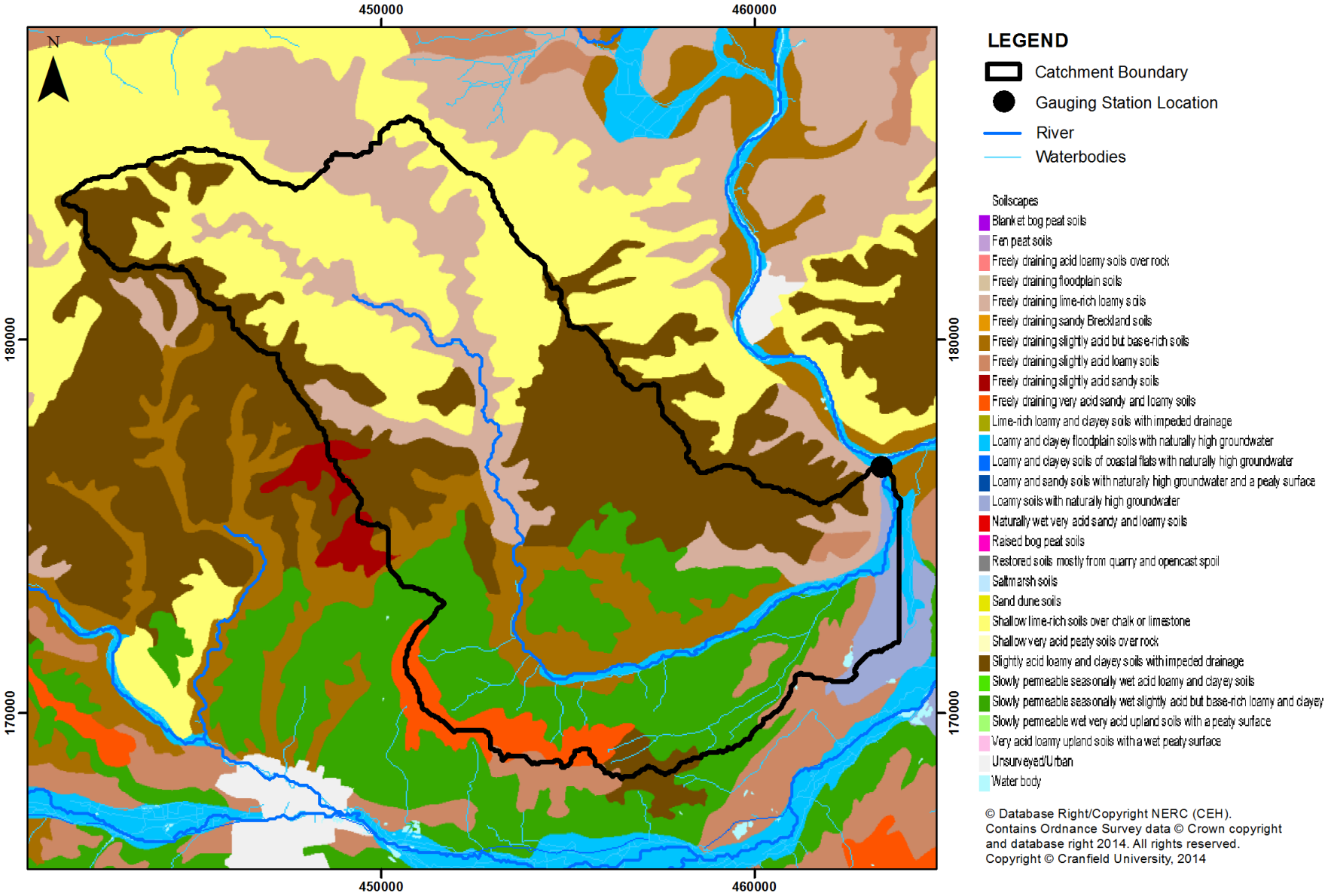


Figure 18 Pang catchment soils

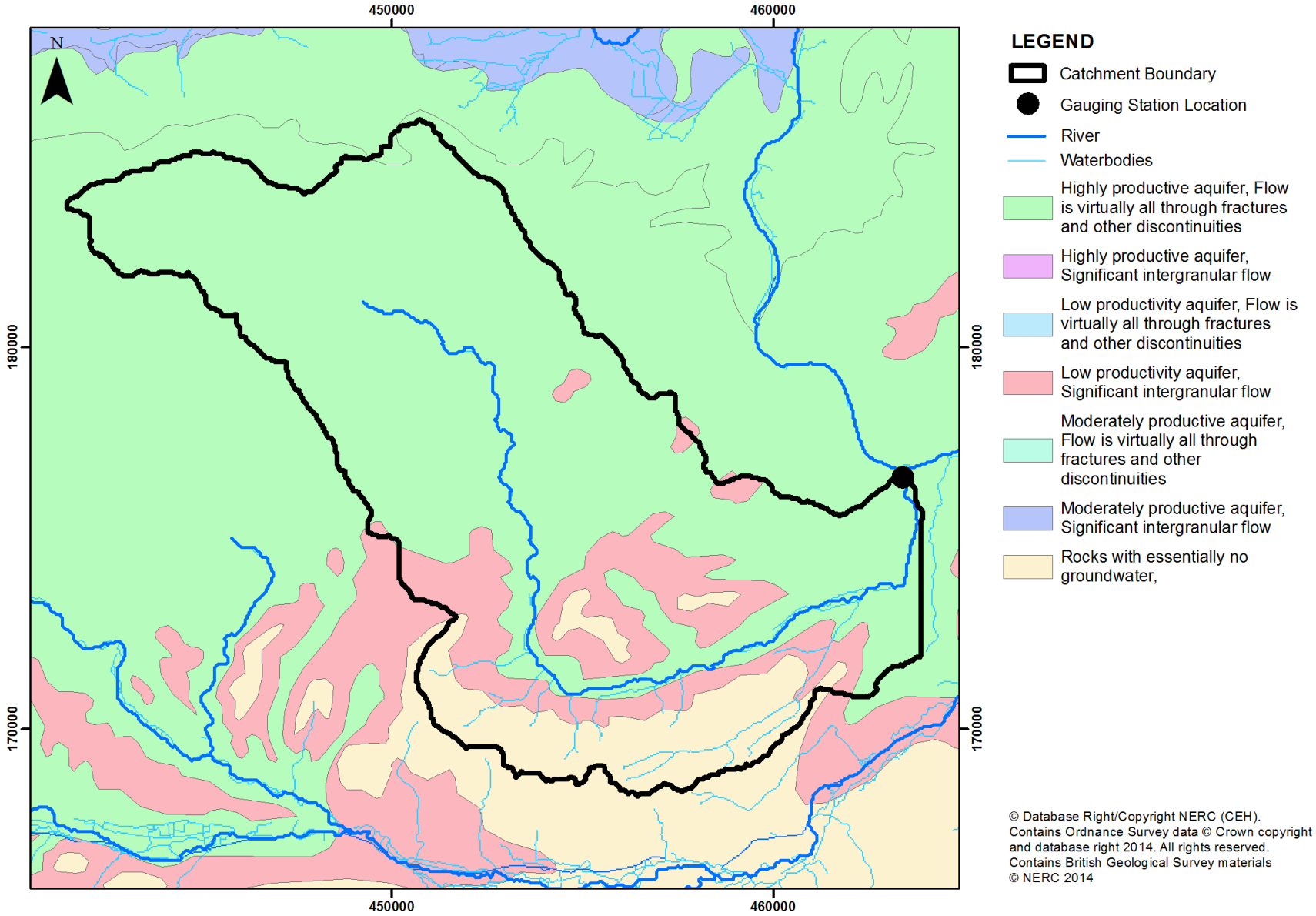


Figure 19 Pang catchment hydrogeology

2.4 BEVILLS LEAM AT TEBBITS BRIDGE

NRFA gauging station number: N/A (Bevills Leam pumping station at Tebbits Bridge)

Environment Agency Anglian Region

Area: 179 km² (see Figure 20)

1963-2001 pumped flow data (later data to be obtained)

Low relief with significant areas of catchment below sea level necessitating a pumped drainage system: water levels in high level drains managed by Middle Level Commissioners, other drains controlled by Internal Drainage Boards (IDBs), farmers, Wildlife Trust and Natural England. Water level management balances winter flood relief, water storage for irrigation and water levels for boating navigation.

'Lowland' area comprising IDBs: large areas of peat soils underlain by impermeable clay; extensive agriculture (40% cereals) including significant spray irrigation (up to 2 million m^3 licensed abstraction per annum; 45% of sugar beet, potatoes and horticulture are irrigated) either direct summer or with winter storage; ongoing wetland ecological restoration (The Great Fen Project, up to 37 km²) linking Holme and Woodwalton Fen National Nature Reserves. Rural villages with imported public water supply.

Drought experience includes: 1965, 1973, 1976, 1990, 1997, 2003 and 2011-12

Factors Affecting Runoff

I: Runoff reduced by industrial and/or agricultural abstraction.

Topography (see Figure 21)

Minimum Altitude: -3 mAOD approx.

Maximum Altitude: 67 mAOD approx.

Land cover (see Figures 22 and 23) – values for IDB 'lowland' area

Woodland: 5.2 %

Arable / horticultural: 85.4 %

Grassland: 5.3 %

Mountain / Heath / Bog: 1.9 %

Urban Extent: 2.2 %

Soils (see Figure 24)

Hydrogeology (see Figure 25)

Low Permeability Bedrock: > 95 %

Mean annual rainfall: 630 mm

The above information is predominantly sourced from Blake and Acreman (2009) and Blake *et al.* (2012).

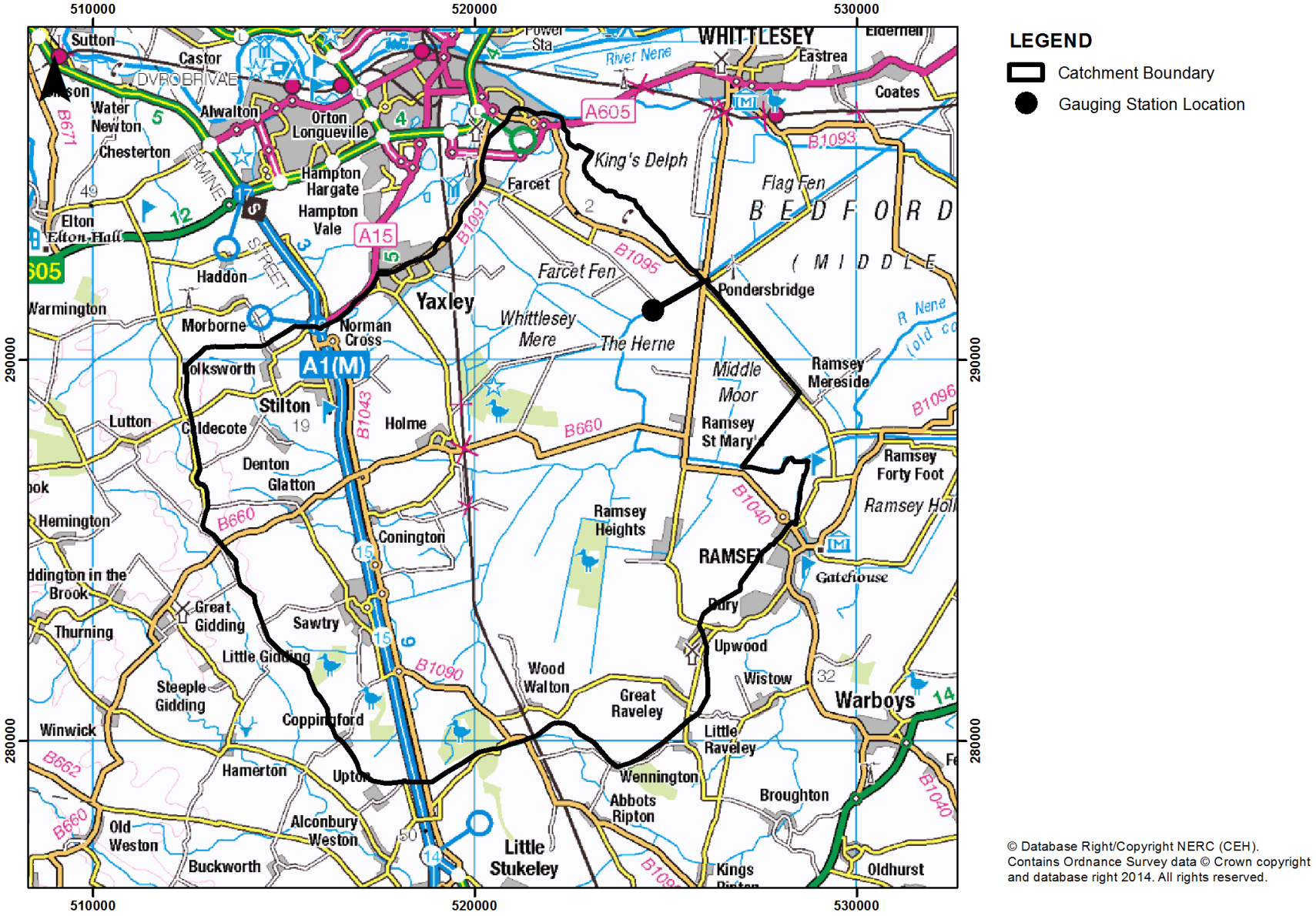


Figure 20 Bevills Leam catchment overview

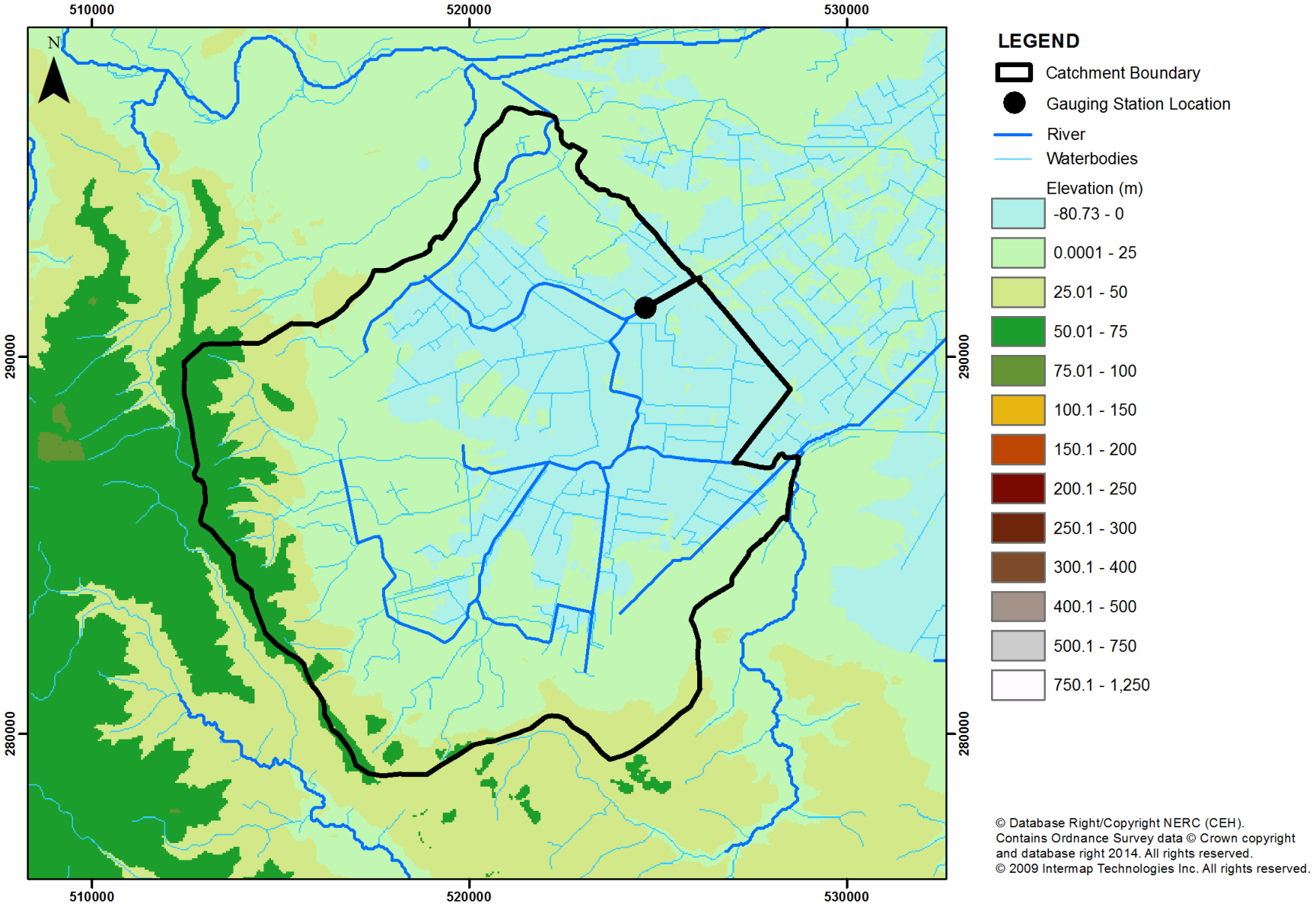


Figure 21 Bevills Leam catchment topography

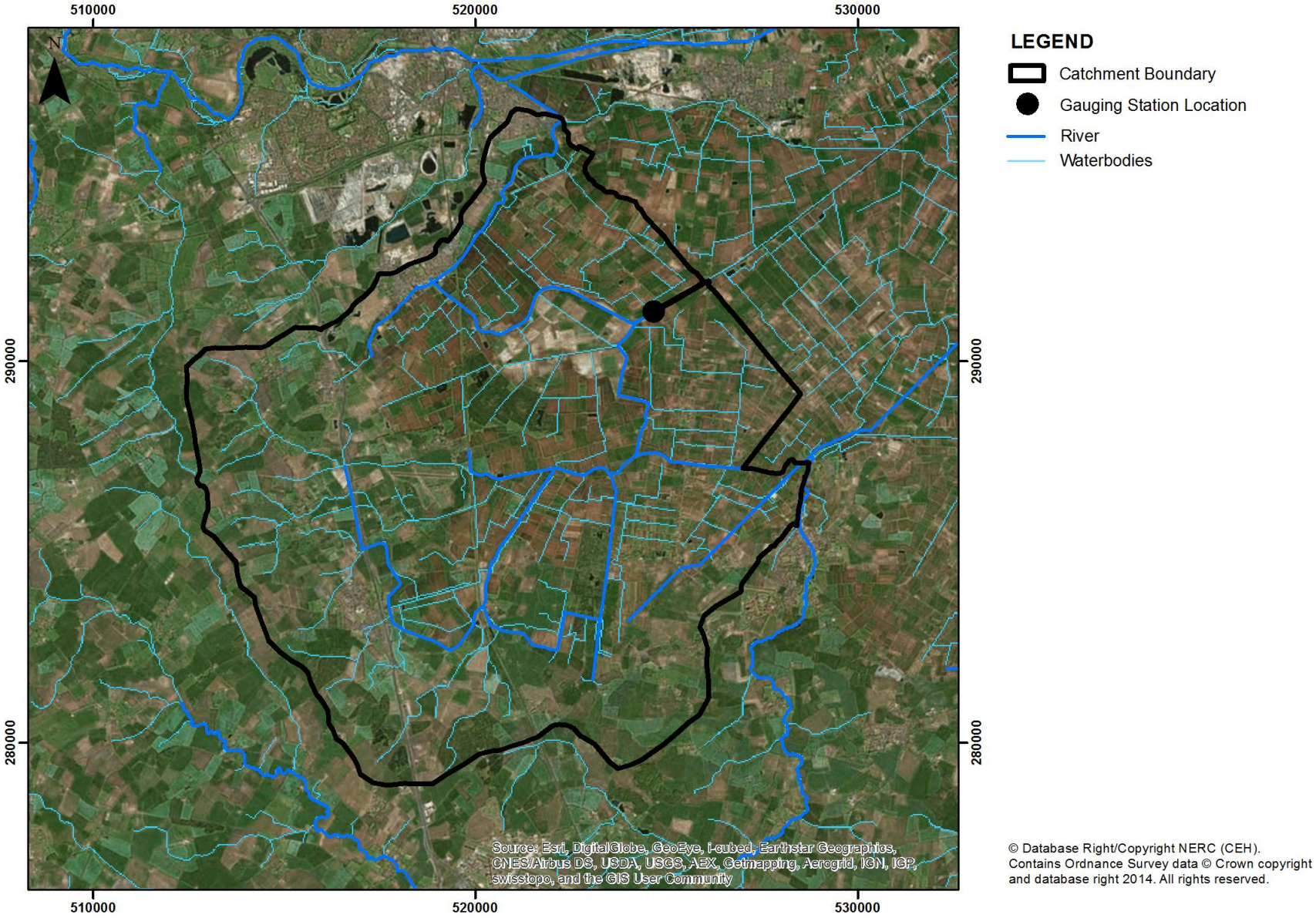


Figure 22 Bevills Leam catchment aerial image

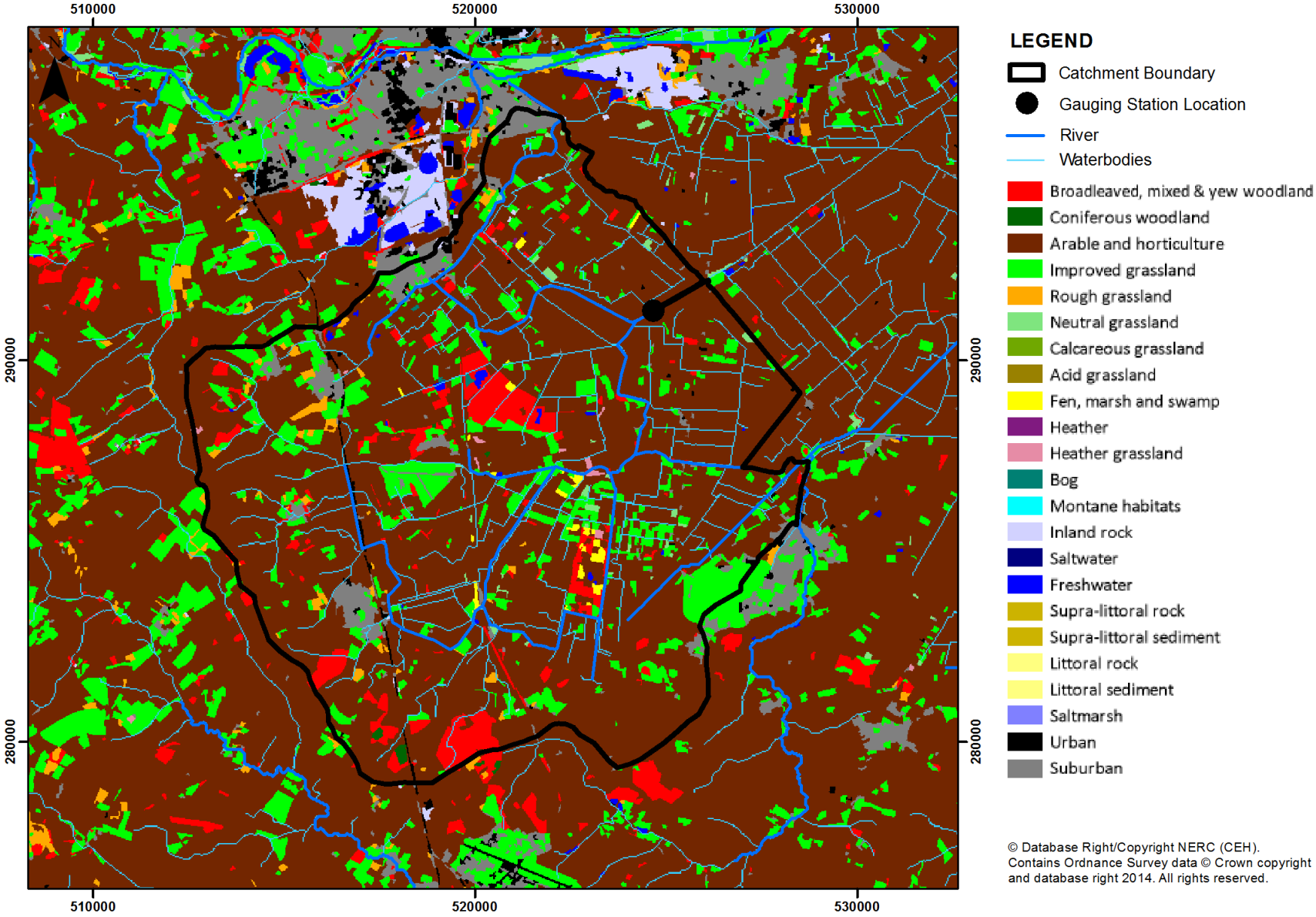


Figure 23 Bevills Leam catchment land cover

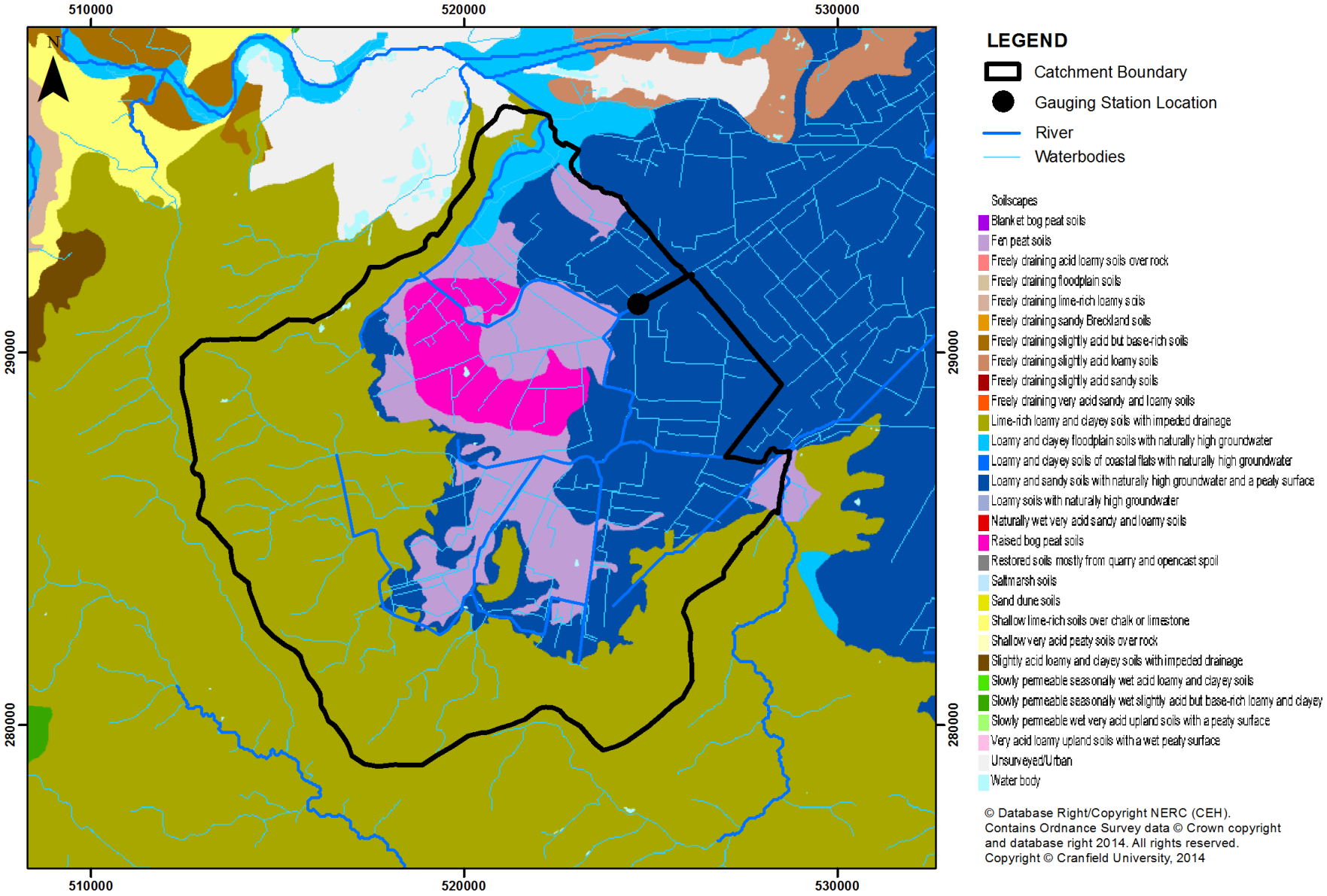


Figure 24 Bevills Leam catchment soils

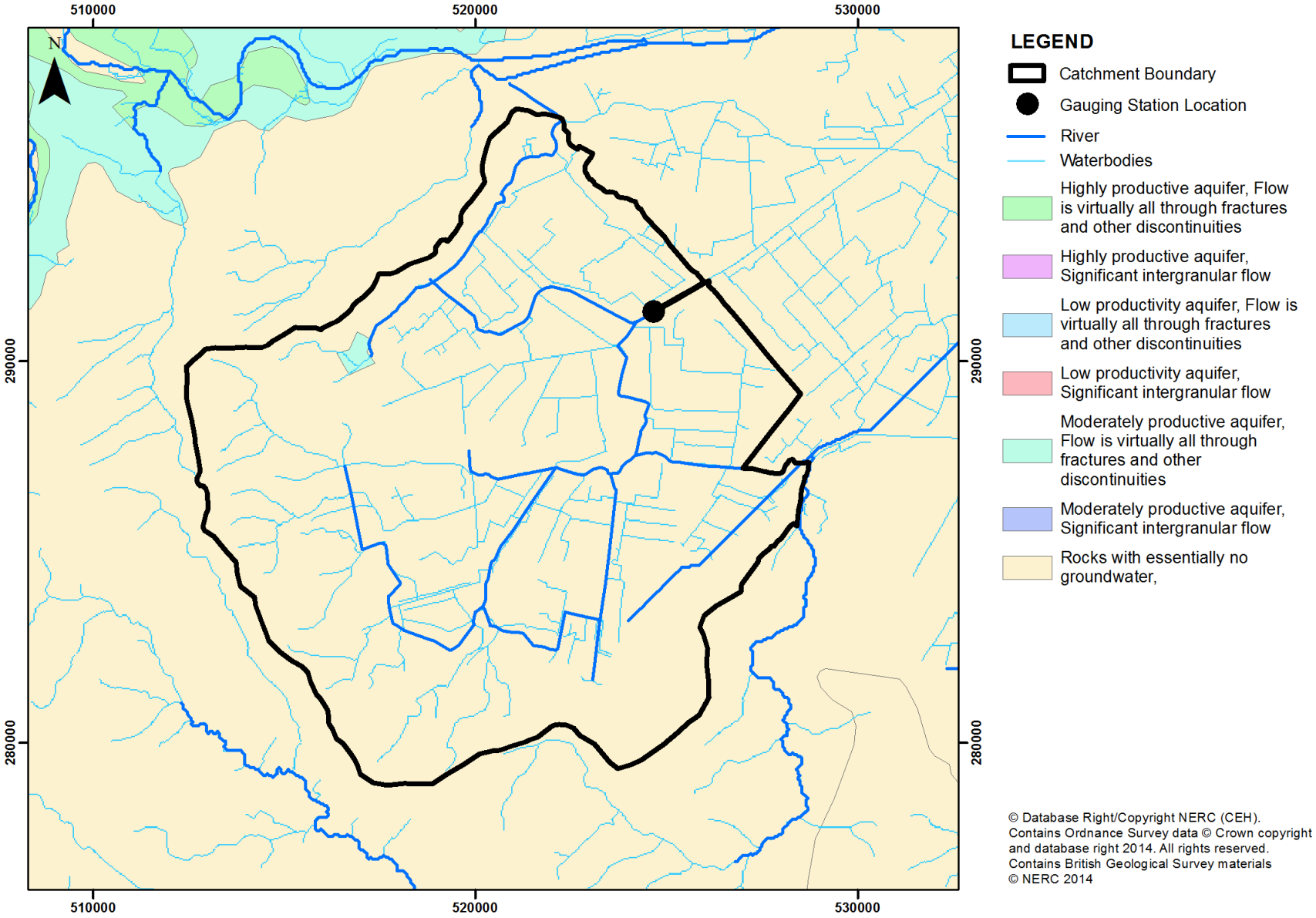


Figure 25 Bevills Leam catchment hydrogeology

2.5 AFON EBBW AT RHIWDERIN

NRFA gauging station number: 56002

Natural Resources Wales

Area: 217 km² (see Figure 26)

1957 – 2013 daily flow data, missing 1976

Geology: moderate permeability, mainly Coal Measures. Mixed land use: 40% grassland, upland heath at highest elevations in North; 15% forest, mainly in lower valley to South. Significant urban development (>10%) in valleys.

Small water supply reservoirs in uplands. Some groundwater abstractions in valley. Drainage water from old coalmines can also influence flows.

Spans urban and rural: Ebbw Vale and Brynmawr conurbation, plus other towns (e.g. Abertillery, Blackwood, Risca).

Drought experience includes: 1964, 1972, 1976, 1978, 1984, 1989-90, 1995-96, 2002, 2003, 2005, 2006 and 2010-11

Factors Affecting Runoff

S: Reservoir(s) in catchment affect runoff.

P: Runoff reduced by public water supply abstraction.

G: Runoff influenced by groundwater abstraction and/or recharge.

Topography (see Figure 27)

Minimum Altitude: 30.6 mAOD

10 Percentile: 154 mAOD

50 Percentile: 323.2 mAOD

90 Percentile: 471.7 mAOD

Maximum Altitude: 614.8 mAOD

Land cover (see Figures 28 and 29)

Woodland: 17.3 %

Arable / horticultural: 3.4 %

Grassland: 41.2 %

Mountain / Heath / Bog: 21.1 %

Urban Extent: 7.4 %

Soils (see Figure 30)

Hydrogeology (see Figure 31)

High Permeability Bedrock: 0.0 %

Moderate Permeability Bedrock: 81.8 %

Low Permeability Bedrock: 2.6 %

Generally High Permeability Superficial Deposits: 0.5 %

Generally Low Permeability Superficial Deposits: 0.5 %

Mixed Permeability Superficial Deposits: 14.7 %

SAAR 1961-1990: 1456 mm

BFIHOST: 0.538

The above information is predominantly sourced from the National River Flow Archive (2014)

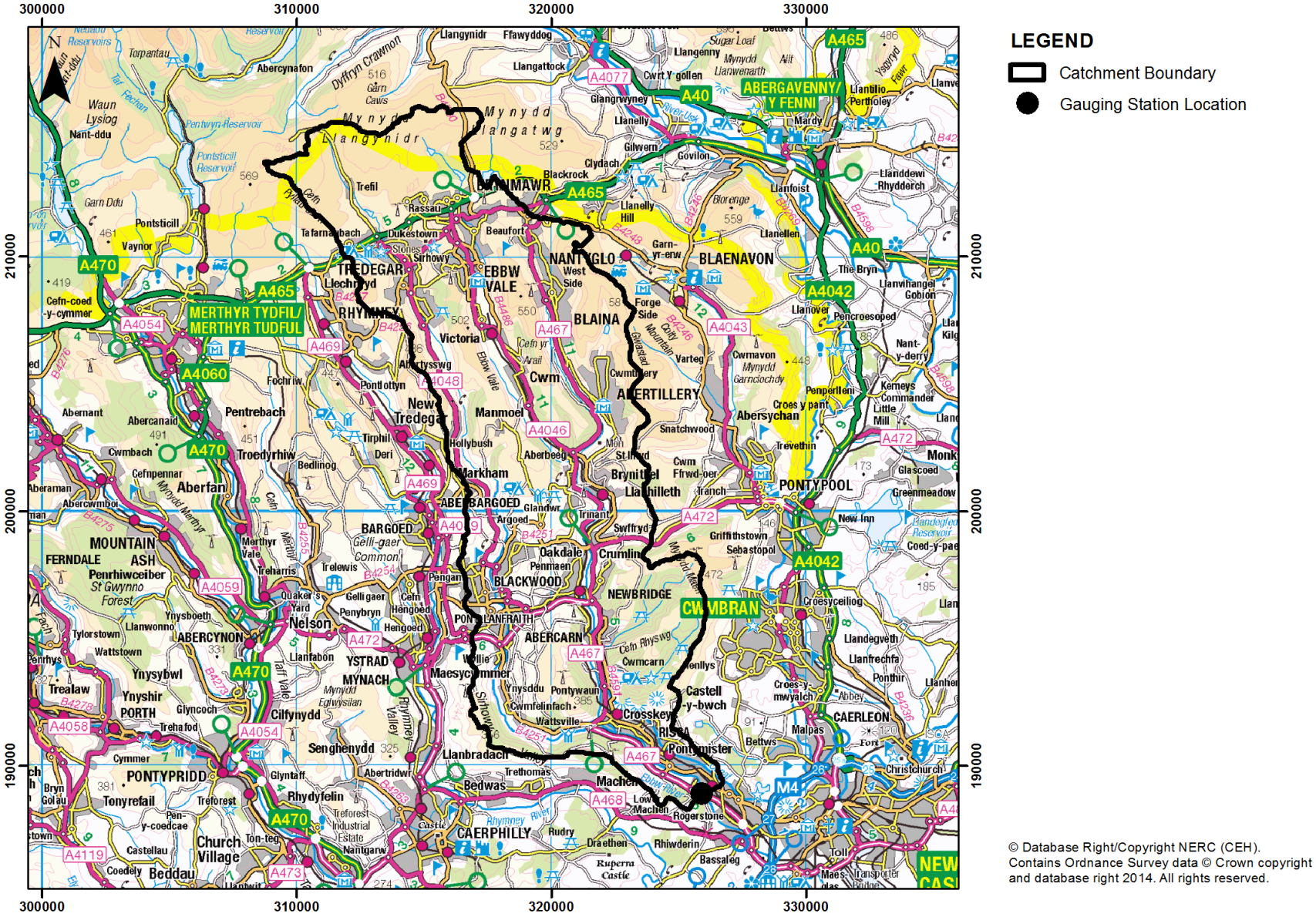


Figure 26 Ebbw catchment overview

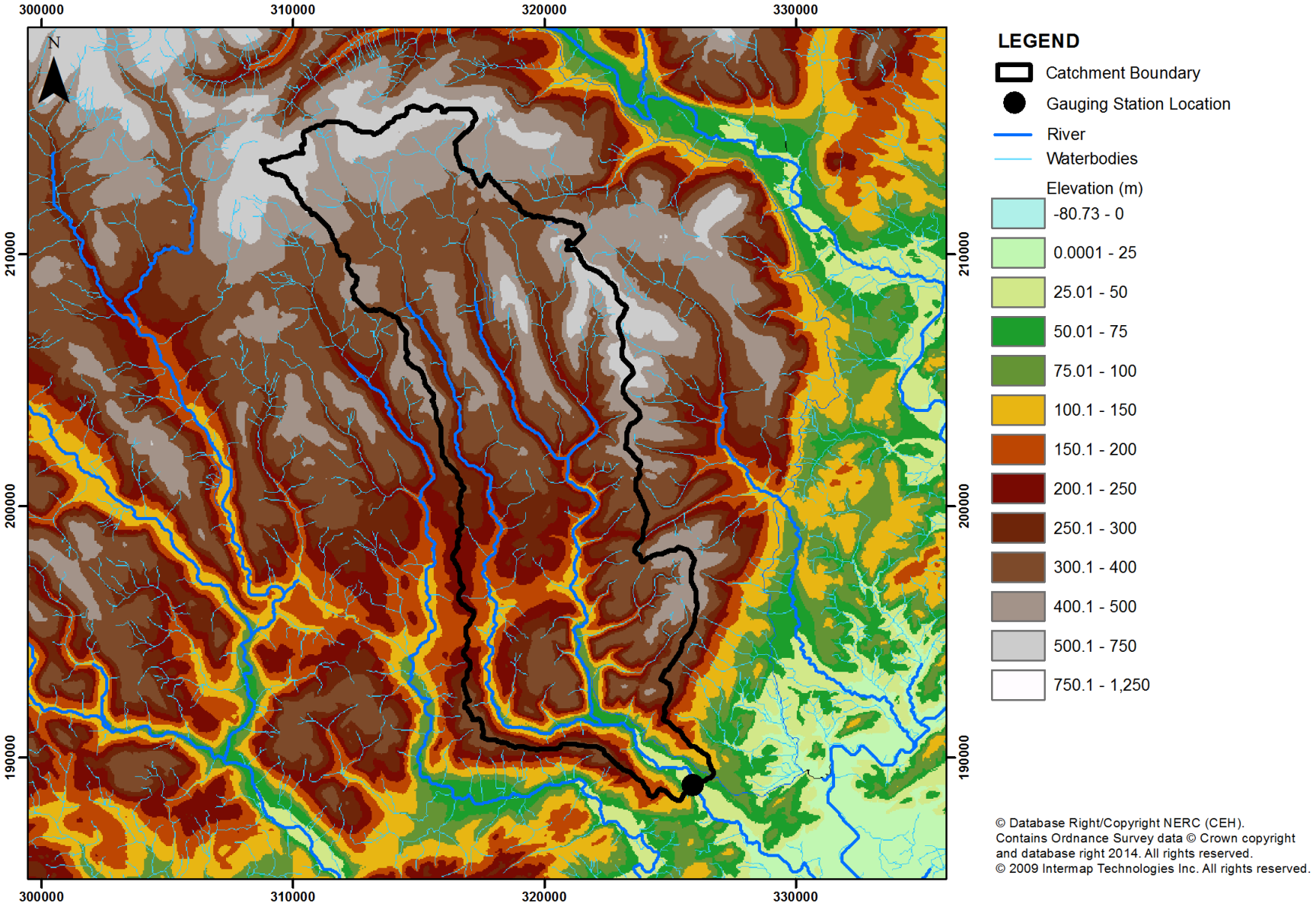


Figure 27 Ebbw catchment topography

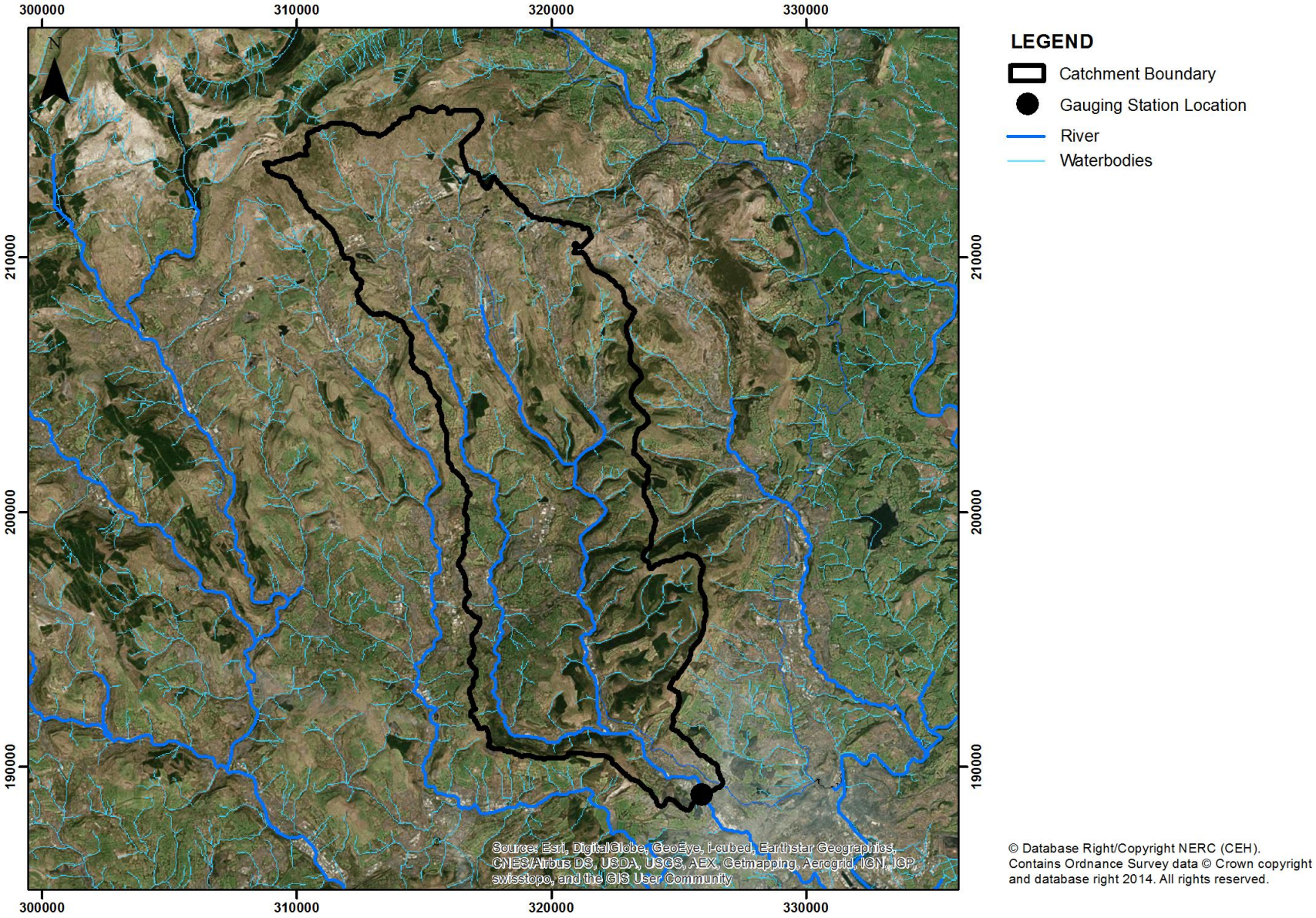


Figure 28 Ebbw catchment aerial image

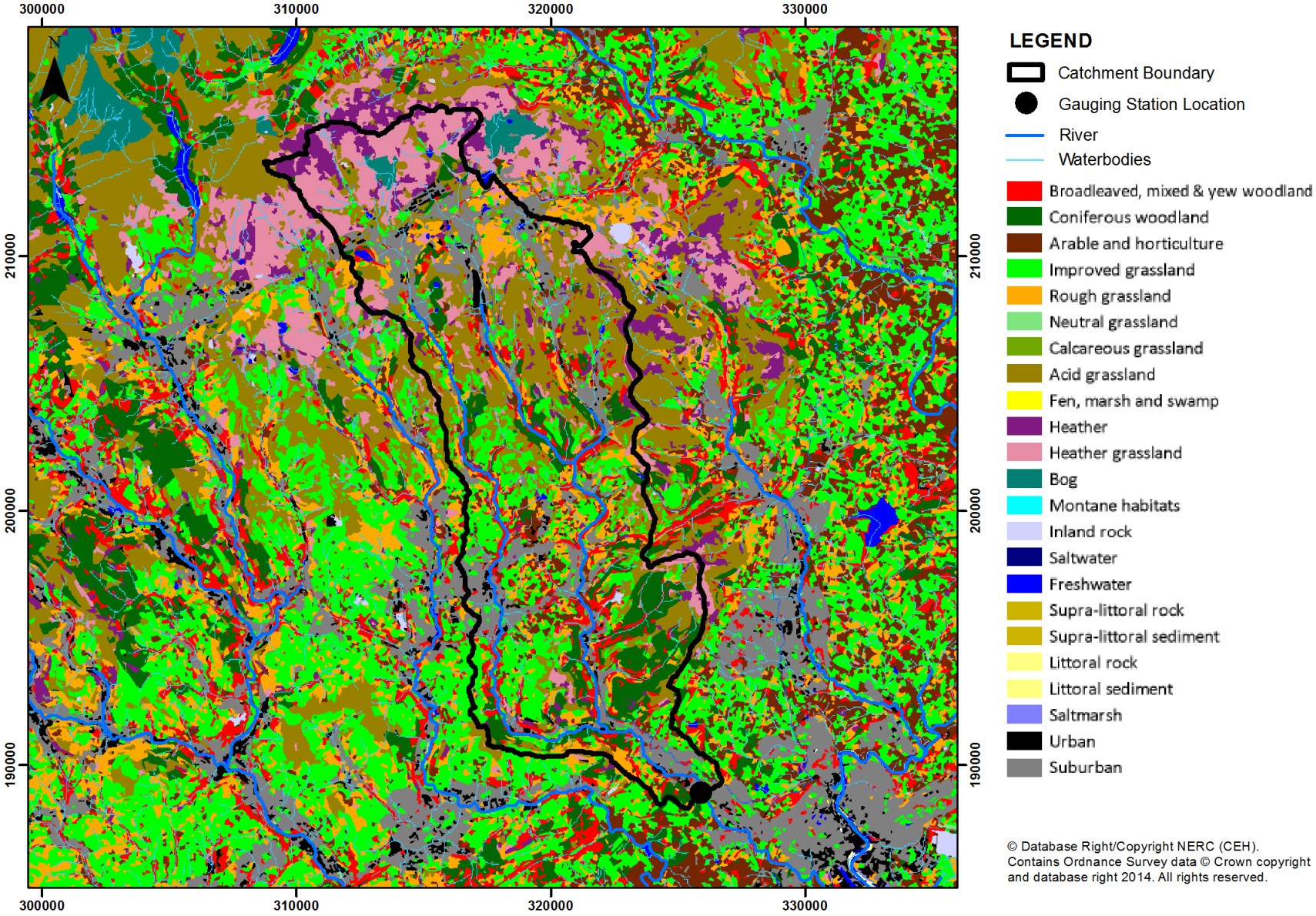


Figure 29 Ebbw catchment land cover

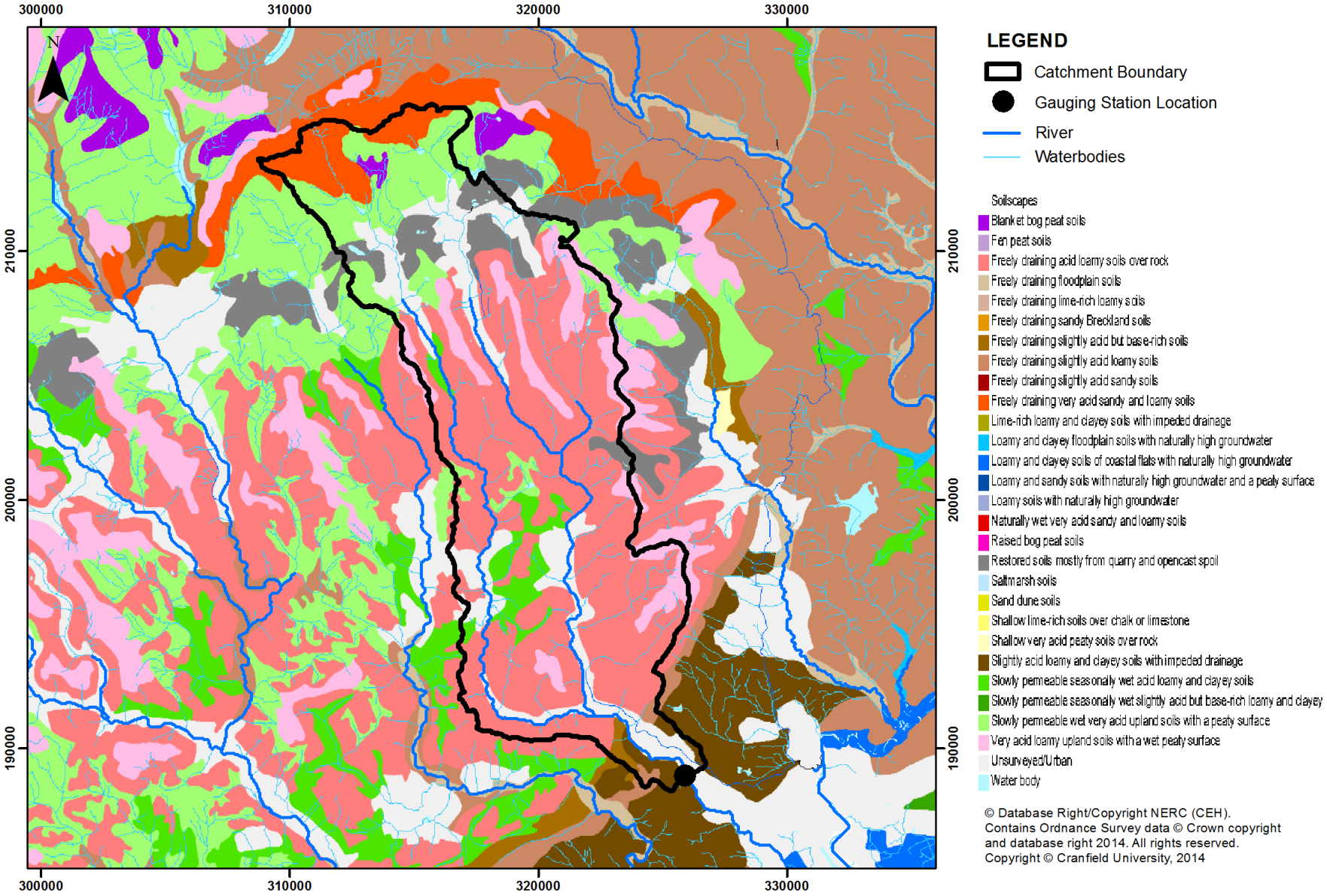


Figure 30 Ebbw catchment soils

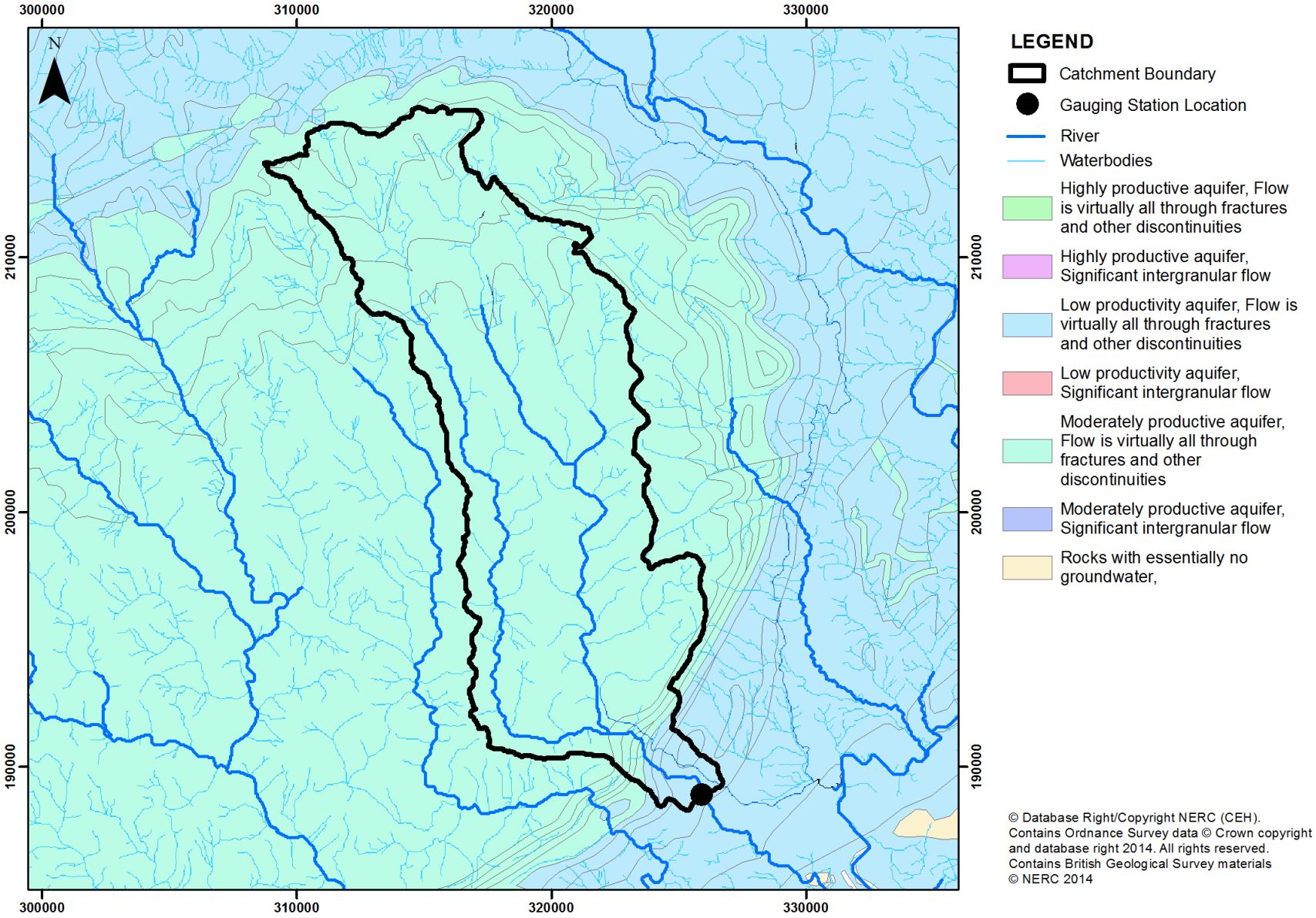


Figure 31 Ebbw catchment hydrogeology

2.6 RIVER DON AT HADFIELDS WEIR

NRFA gauging station number: 27006

Environment Agency North East

Area: 373 km² (see Figure 32)

1965 – 2013 daily flow data

Mixed geology. Moorland headwaters contrast with the heavily urbanised (up to 20% of catchment) lower catchment (now less industrial); mixed rural in mid-catchment.

The upper catchment is considerably reservoired and the impact on the flow regime is substantial - significant net loss of water from the catchment.

Spans urban and rural: city (Sheffield), towns (Stocksbridge; Penistone) and villages; SMEs dominate Sheffield, plus manufacturing base; rural agriculture and tourism

Drought experience includes: 1975-76, 1990, 1995-96 and 2011-12

Factors Affecting Runoff

S: Reservoir(s) in catchment affect runoff.

P: Runoff reduced by public water supply abstraction.

G: Runoff influenced by groundwater abstraction and/or recharge.

E: Runoff increased by effluent returns.

I: Runoff reduced by industrial and/or agricultural abstraction.

Topography (see Figure 33)

Minimum Altitude: 30.2 mAOD

10 Percentile: 112.9 mAOD

50 Percentile: 259.9 mAOD

90 Percentile: 411.7 mAOD

Maximum Altitude: 543.4 mAOD

Land cover (see Figures 34 and 35)

Woodland: 15.8 %

Arable / horticultural: 6.1 %

Grassland: 35.6 %

Mountain / Heath / Bog: 18.9 %

Urban Extent: 13.3 %

Soils (see Figure 36)

Hydrogeology (see Figure 37)

High Permeability Bedrock: 0.0 %

Moderate Permeability Bedrock: 43.4 %

Low Permeability Bedrock: 0.0 %

Generally High Permeability Superficial Deposits: 0.0 %

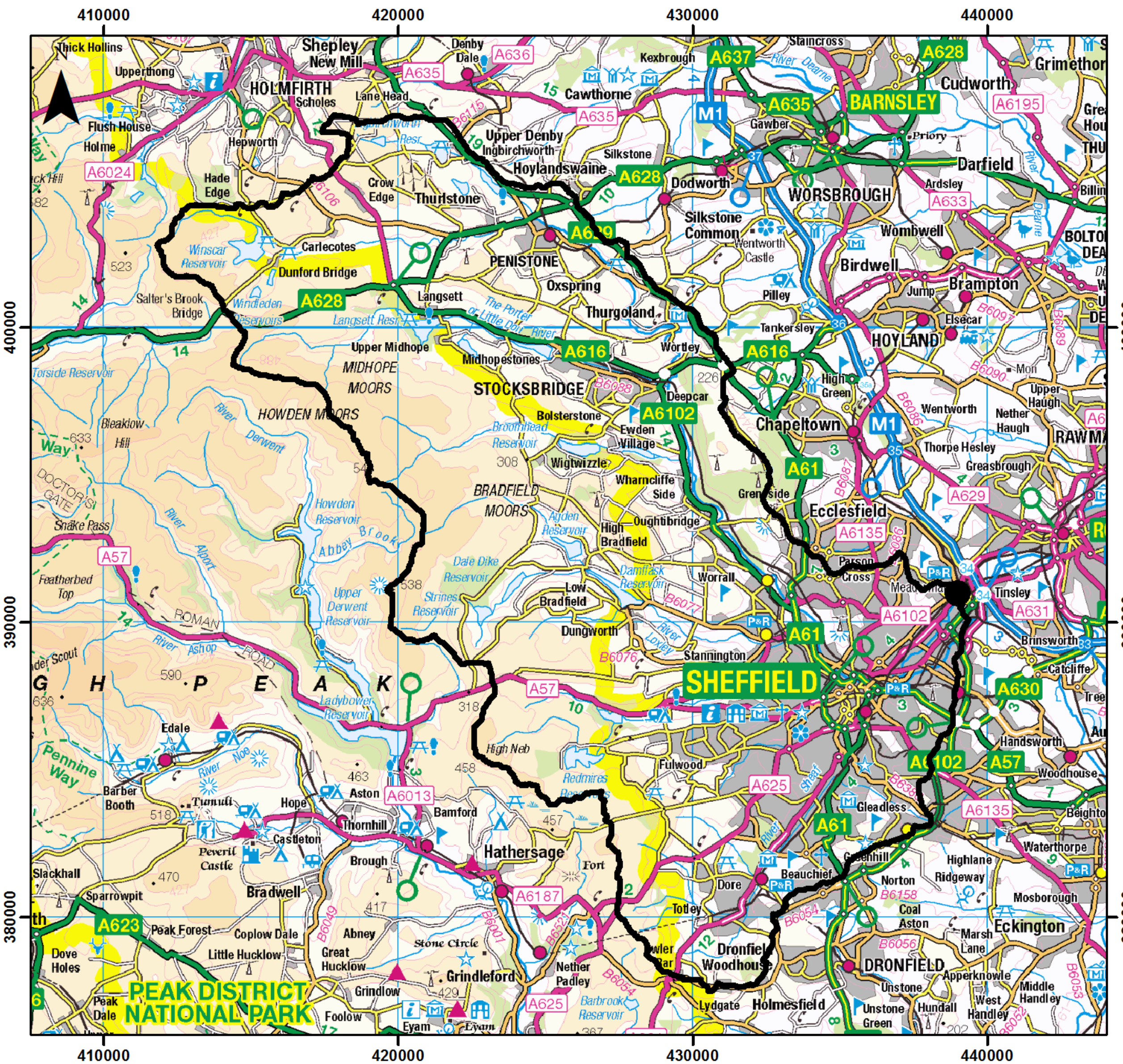
Generally Low Permeability Superficial Deposits: 12.3 %

Mixed Permeability Superficial Deposits: 1.9 %

SAAR 1961-1990: 1009 mm

BFIHOST: 0.416

The above information is predominantly sourced from the National River Flow Archive (2014)



LEGEND

Catchment Boundary

Gauging Station Location

Figure 32 Don catchment overview

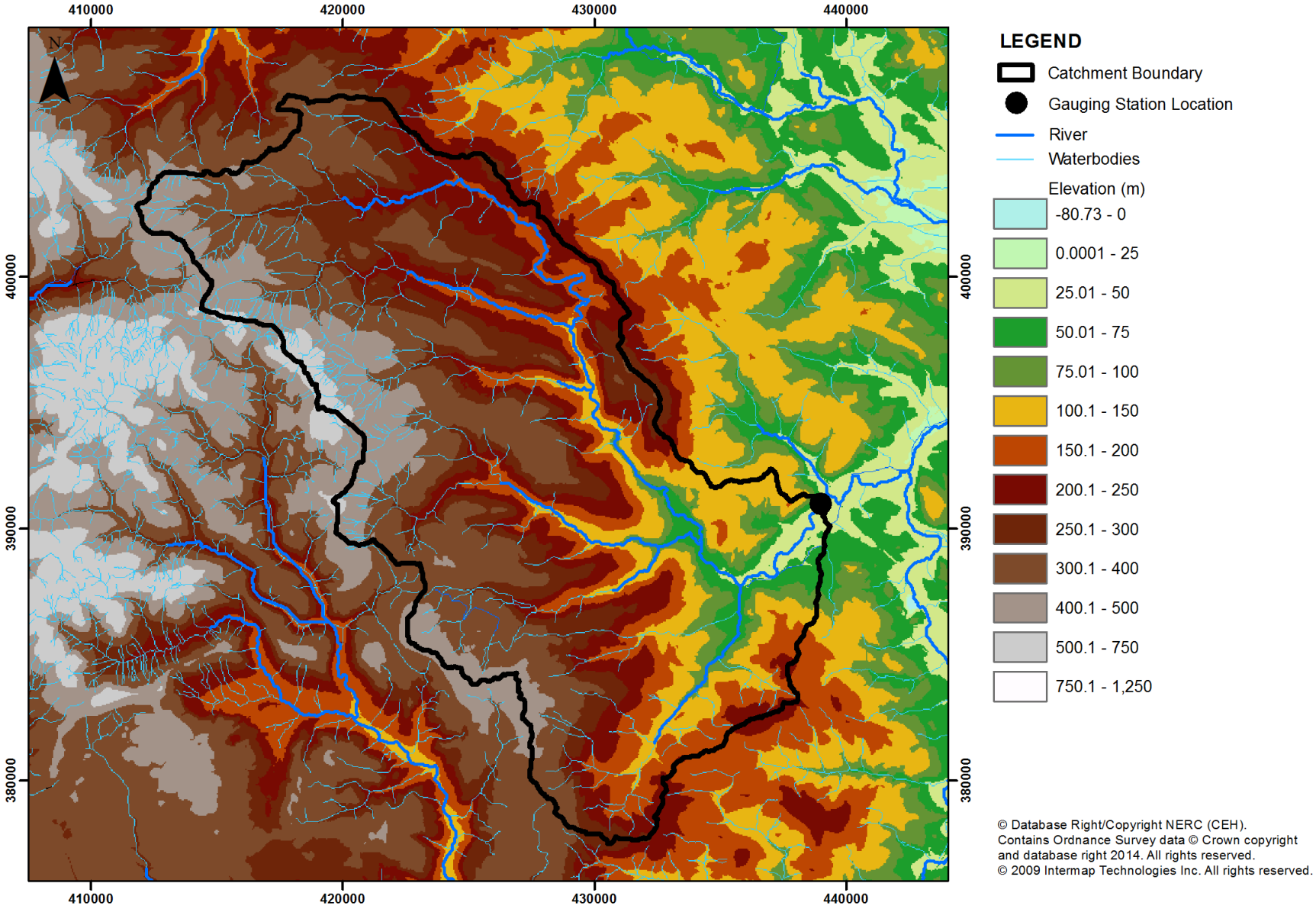


Figure 33 Don catchment topography

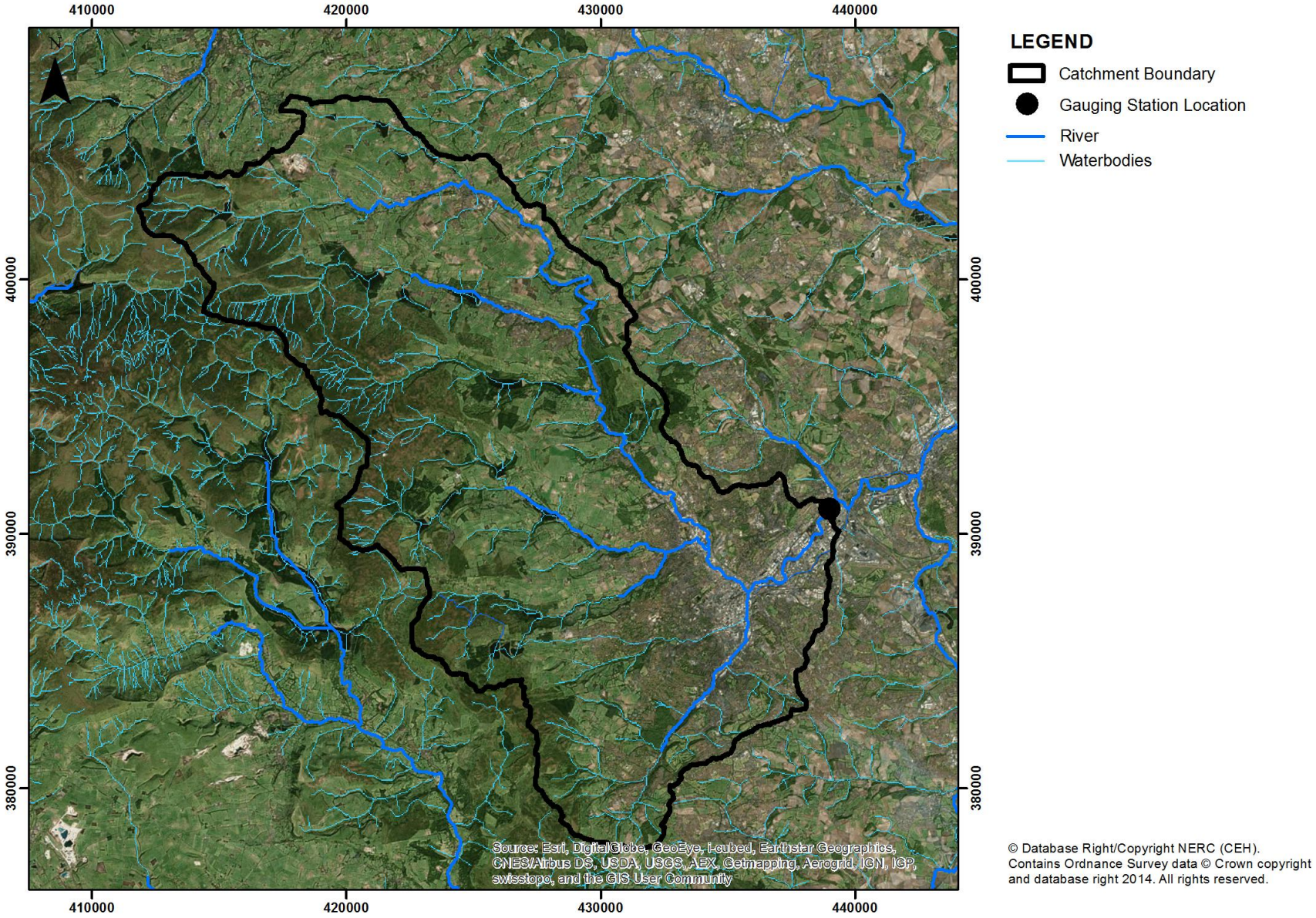


Figure 34 Don catchment aerial image

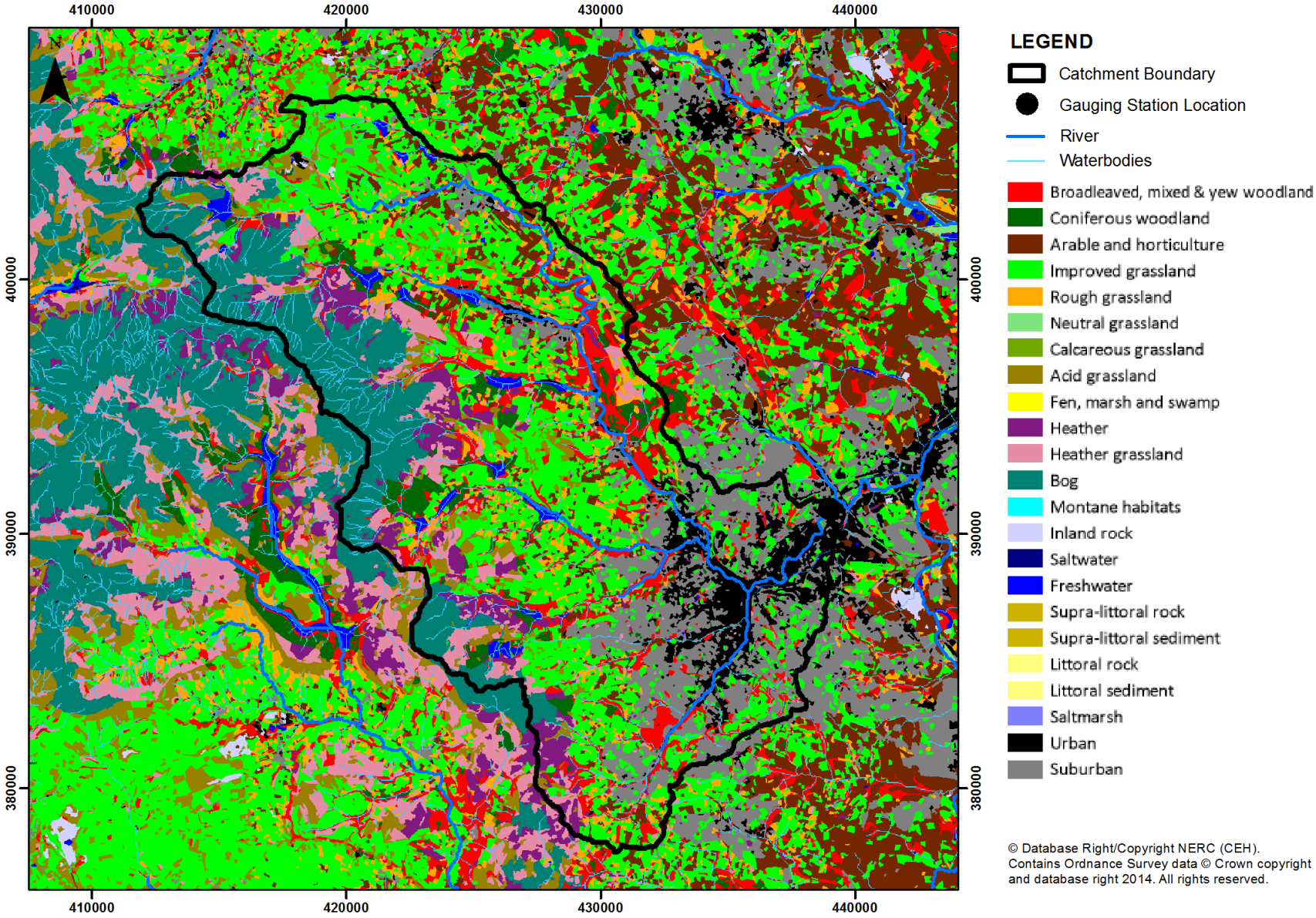


Figure 35 Don catchment land cover

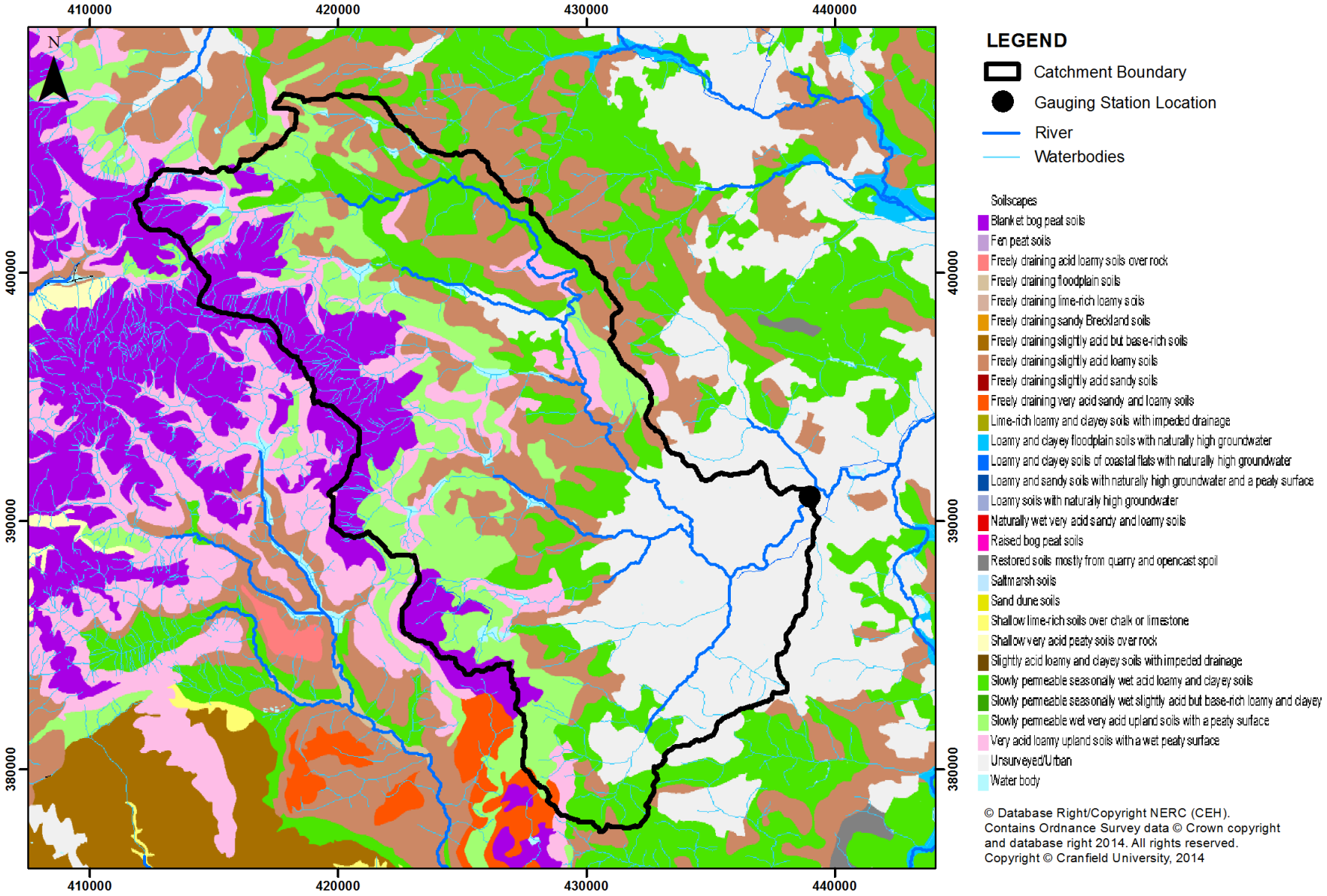


Figure 36 Don catchment soils

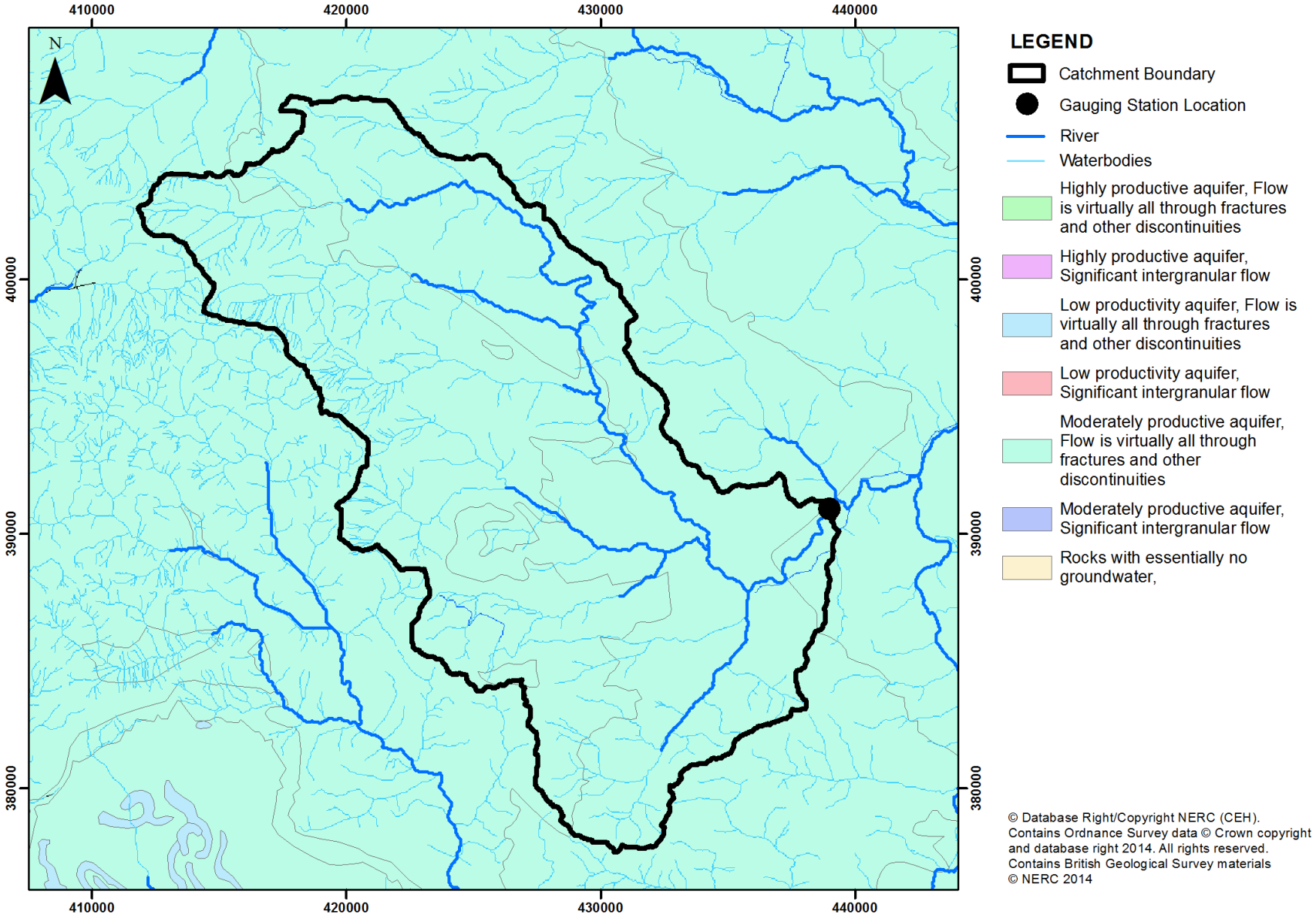


Figure 37 Don catchment hydrogeology

2.7 RIVER EDEN AT KEMBACK

NRFA gauging station number: 14001

Scottish Environment Protection Agency - North East

Area: 307 km² (see Figure 38)

1967 – 2013 daily flow data

A gently sloping and low-lying catchment between the Tay and Forth estuaries. Mixed bedrock geology; Old Red Sandstone along the central valley, igneous to the north, some igneous plus Carboniferous Limestone and sandstone to the south. Land use is mainly arable, grassland, and woodland.

Abstractions for irrigation; groundwater abstractions and effluent returns and small reservoirs in the headwaters.

Rural catchment with a town (Cupar) and villages; significant water users include a whisky distillery and market gardening

Drought experience includes: 1973, 1974, 1976, 1989, 1995 and 2006

Factors Affecting Runoff

S: Reservoir(s) in catchment affect runoff.

G: Runoff influenced by groundwater abstraction and/or recharge.

E: Runoff increased by effluent returns.

I: Runoff reduced by industrial and/or agricultural abstraction.

Topography (see Figure 39)

Minimum Altitude: 6.2 mAOD

10 Percentile: 41.3 mAOD

50 Percentile: 99.7 mAOD

90 Percentile: 189.1 mAOD

Maximum Altitude: 520.4 mAOD

Land cover (see Figures 40 and 41)

Woodland: 12.0 %

Arable / horticultural: 52.2 %

Grassland: 29.0 %

Mountain / Heath / Bog: 1.8 %

Urban Extent: 1.1 %

Soils (see Figure 42)

Hydrogeology (see Figure 43)

High Permeability Bedrock: 55.3 %

Moderate Permeability Bedrock: 0.0 %

Low Permeability Bedrock: 44.7 %

Generally High Permeability Superficial Deposits: 20.3 %

Generally Low Permeability Superficial Deposits: 0.0 %

Mixed Permeability Superficial Deposits: 55.3 %

SAAR 1961-1990: 799 mm

BFIHOST: 0.609

The above information is predominantly sourced from the National River Flow Archive (2014)

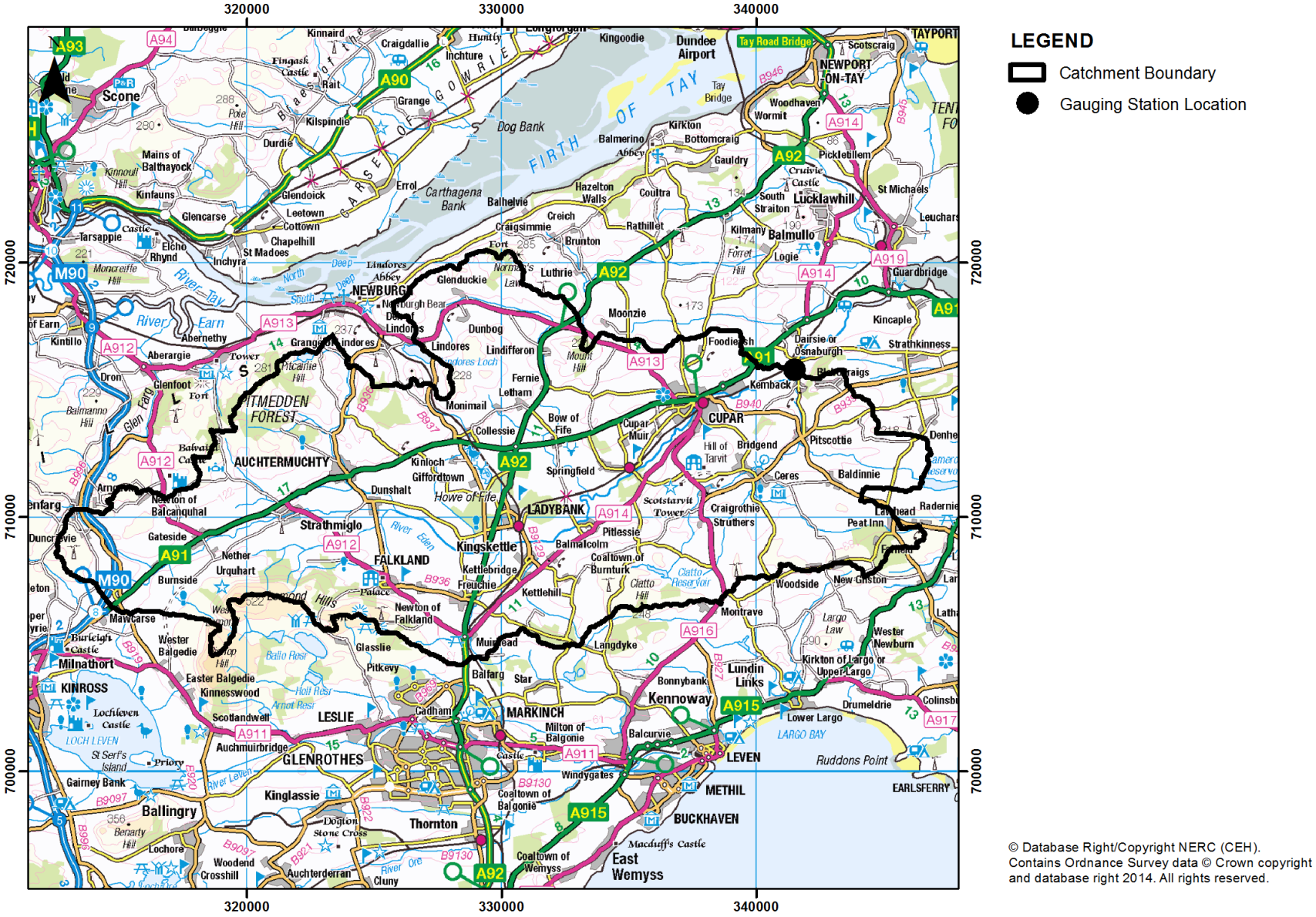


Figure 38 Eden catchment overview

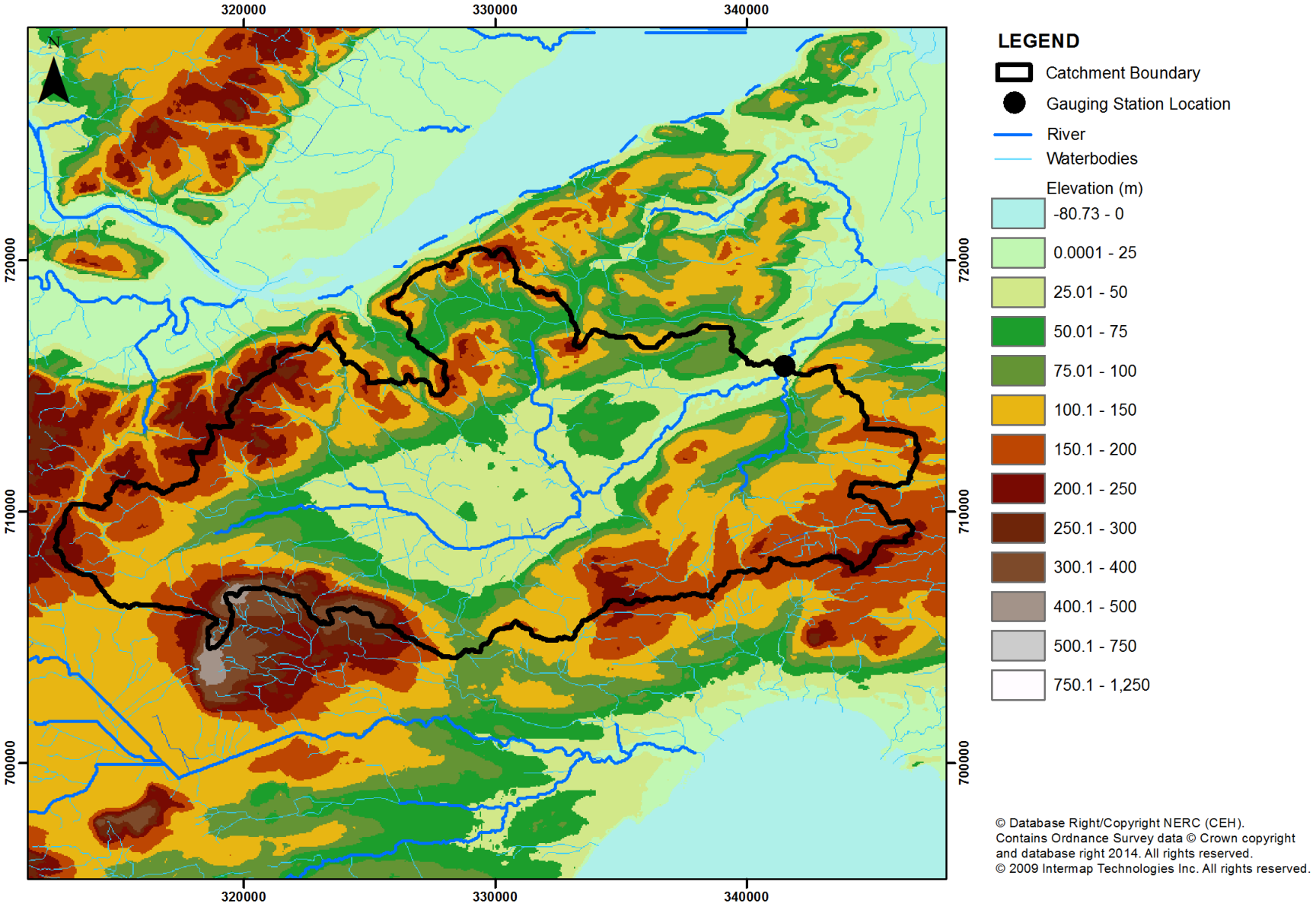


Figure 39 Eden catchment topography

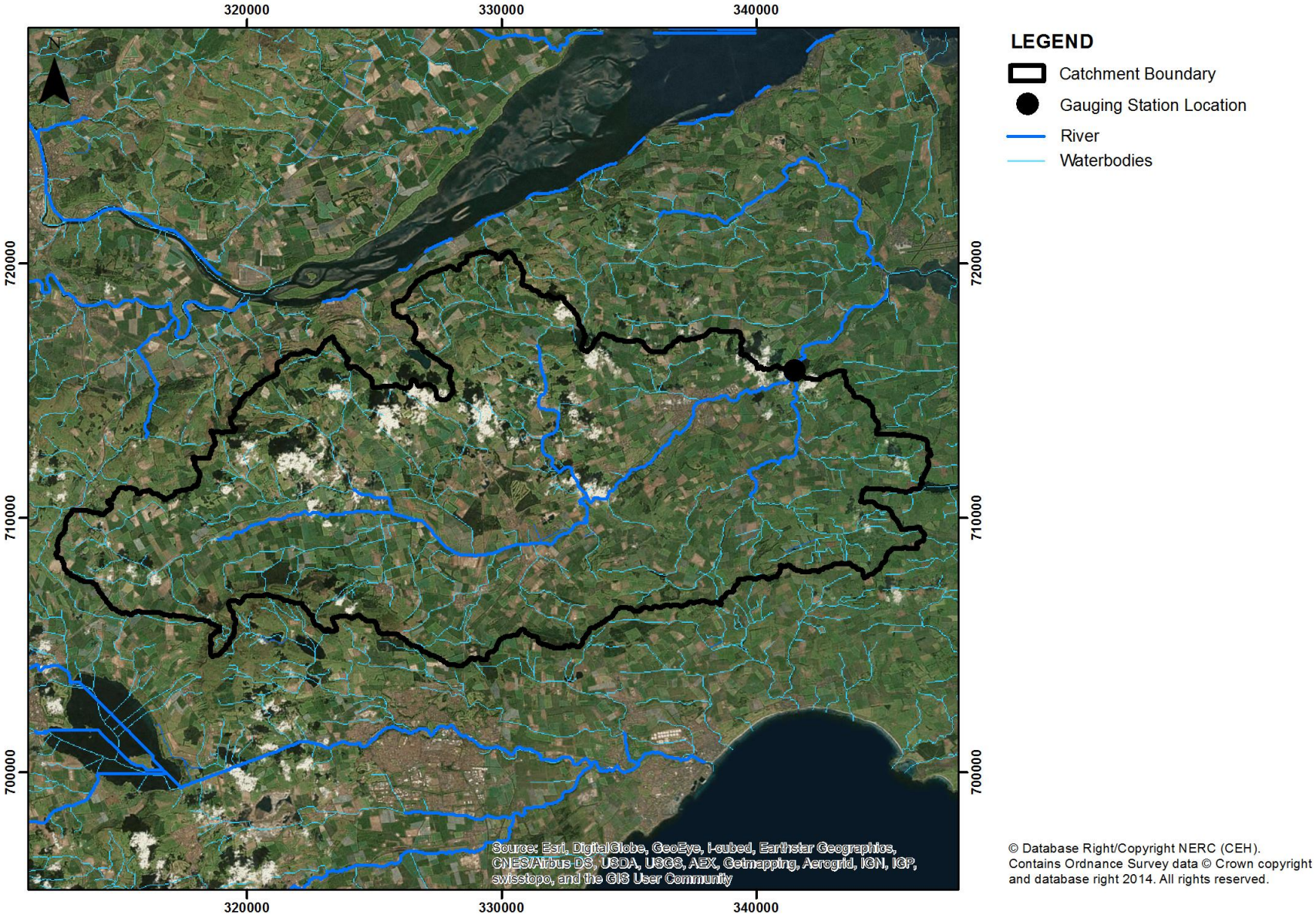


Figure 40 Eden catchment aerial image

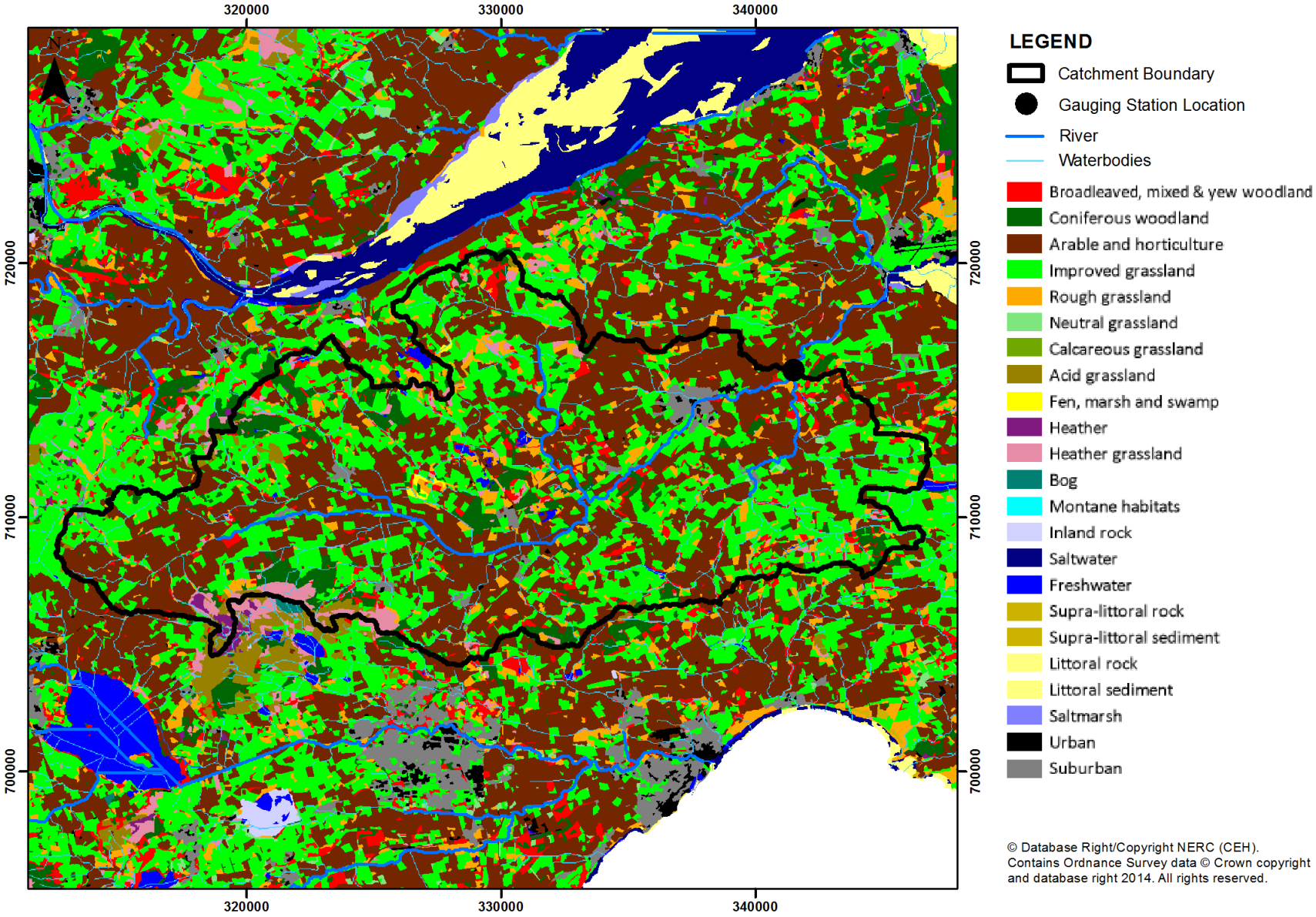


Figure 41 Eden catchment land cover

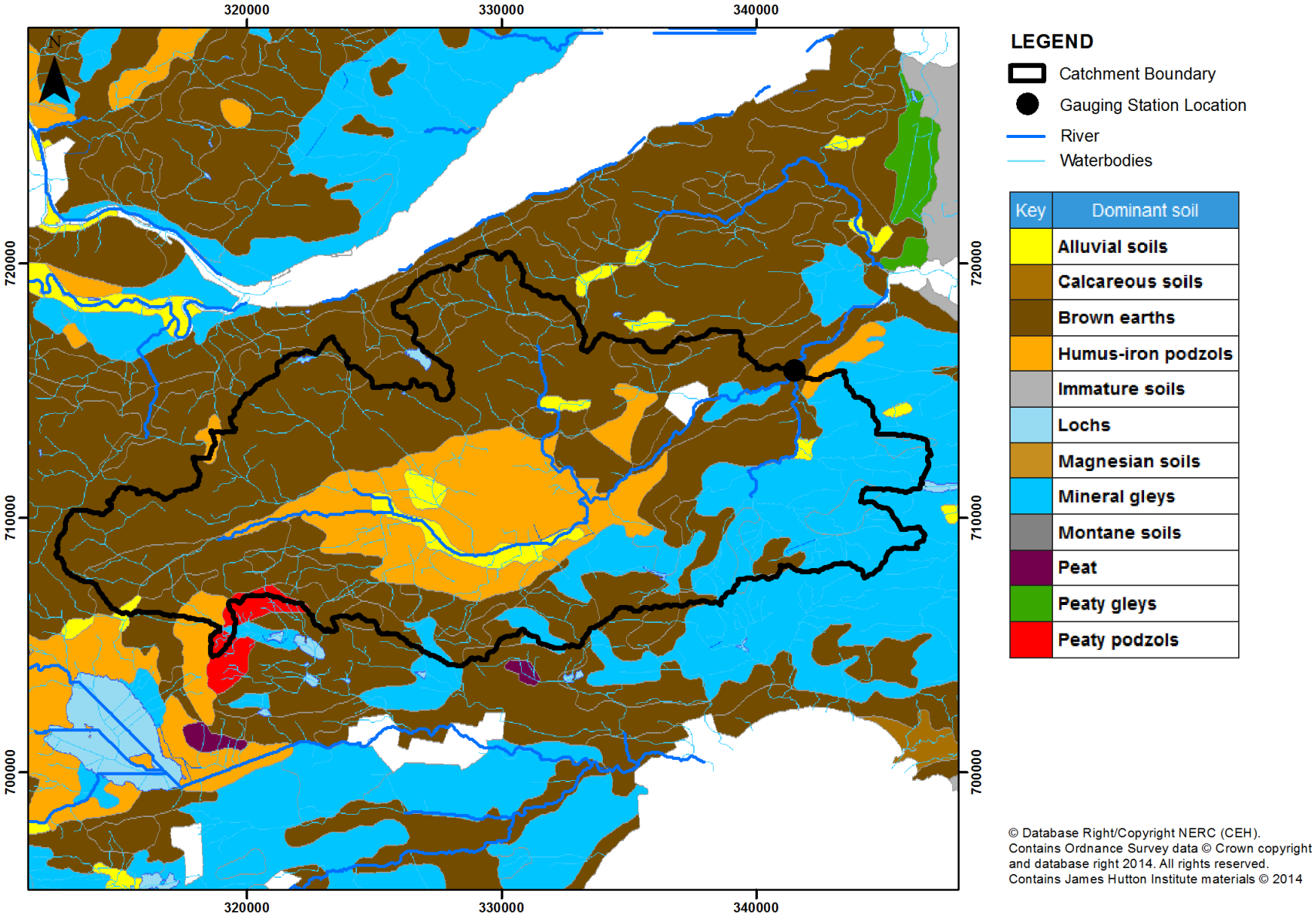


Figure 42 Eden catchment soils

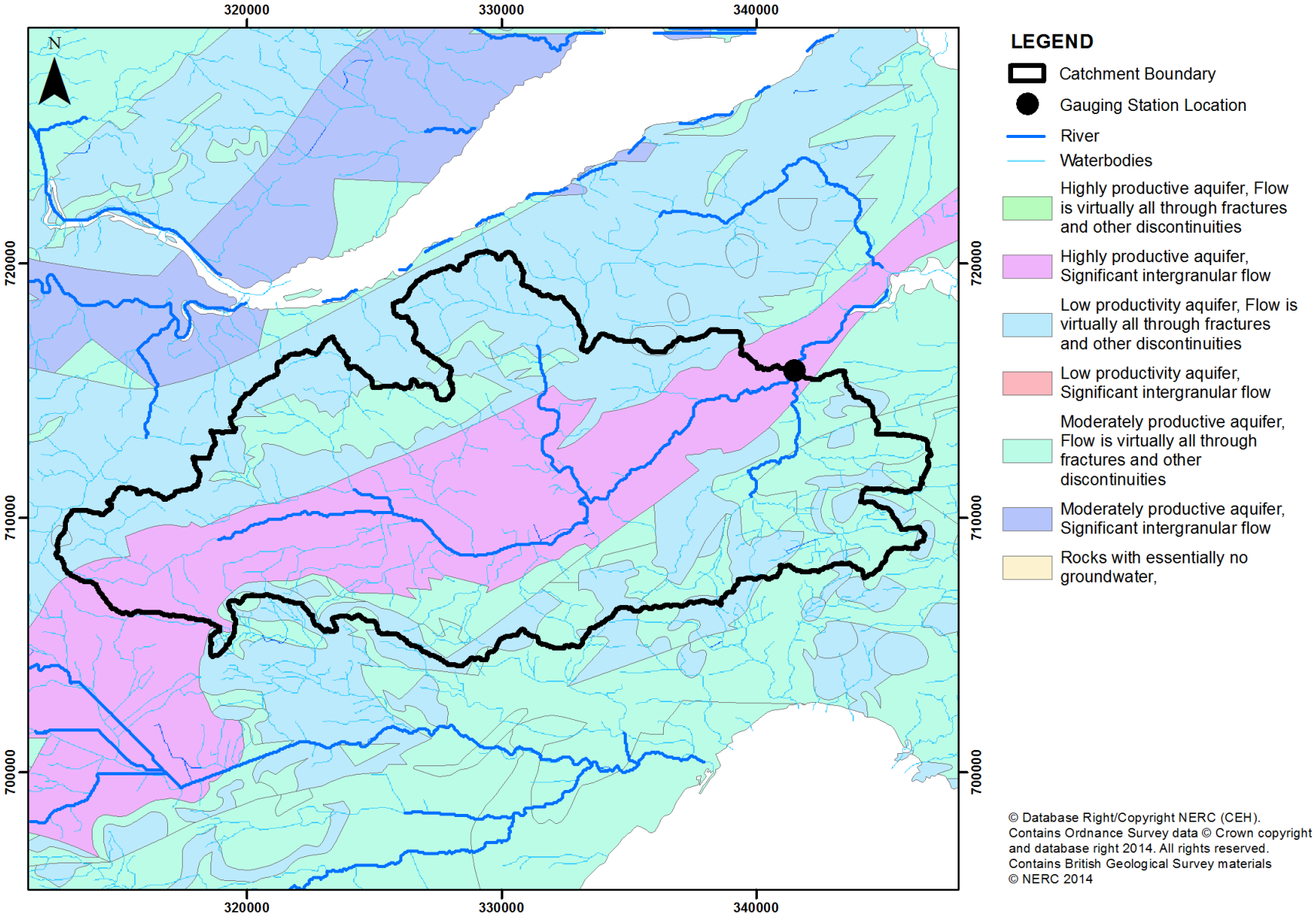


Figure 43 Eden catchment hydrogeology

ACKNOWLEDGEMENTS

Background mapping courtesy of Ordnance Survey ('GB Overview +' and '1:250 000 Scale Colour Raster'). Catchment boundaries and gauging station locations courtesy of Centre for Ecology and Hydrology (for all catchments except Bevills Leam, see Morris and Flavin (1990, 1994), Marsh and Hannaford (2008) and National River Flow Archive (2014); for Bevills Leam see Blake and Acreman (2009)). River and waterbody data courtesy of Centre for Ecology and Hydrology ('Digital Rivers 50km GB' Web Map Service). Elevation data courtesy of Intermap Technologies Inc. (Nextmap 50 m Digital Terrain Model). Aerial images courtesy of ESRI (ArcGIS 'World Imagery' Map Service). Land cover data courtesy of Centre for Ecology and Hydrology (Land Cover Map 2007 (25m raster, GB) Web Map Service, see Morton *et al.* (2007)). Soils data courtesy of Cranfield University (1:250 000 Soilscapes for England and Wales Web Map Service) and James Hutton Institute (1:250 000 Soils of Scotland Web Map Service, 'Qmsoils_UCSS_v1.1_WGS84 – 2013' layer). Hydrogeology data courtesy of British Geological Survey (DiGMapGB 1:625 000 scale digital hydrogeological data).

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