Cyfoeth Naturiol Cymru
Natural Resources Wales

LANDMAP, Landscape and a Changing Climate

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1. Crynodeb Gweithredol

1.1. Cefndir

Mae newidiadau yn hinsawdd Cymru yn debygol o gael effeithiau uniongyrchol (e.e. trwy newid gorchudd tir) ac anuniongyrchol (e.e. trwy ddylanwadu ar benderfyniadau ynglŷn â defnydd tir) sylweddol ar gymeriad, safon ac arwahanrwydd tirweddau lleol. Mae digwyddiadau llifogydd a sychder, tywydd eithafol mwy rheolaidd, erydu arfordirol, tanau gwyllt, heintiau sy'n effeithio gorchudd coed, a newidiadau mewn gorchudd tir, cynefinoedd a chwmpas rhywogaethau yn enghreifftiau o sut y gall y dirwedd newid i raddau mwy neu lai, yn y tymor byr neu hir.

Gall cymeriad y dirwedd ddarparu dull cyfathrebu pwysig i godi ymwybyddiaeth a dealltwriaeth o'r risgiau a chyfleoedd a gyflwynir gan y newid yn yr hinsawdd gan fod gan bobl gysylltiadau â thirweddau fel lleoedd i fyw a gweithio ynddynt a'u mwynhau. Mae'n felly amser cyfleus i ddod â gwybodaeth ar effeithiau hinsawdd sy'n newid ynghyd a'u cymhwyso o safbwynt tirwedd.

Y prosiect hwn yw'r cam cyntaf i ddechrau nodi ac adrodd effeithiau uniongyrchol ac anuniongyrchol y newidiadau hinsawdd rhagweledig i Gymru yn 2050 ar gymeriad a nodweddion y dirwedd a sut olwg allai fod ar y dirwedd yr ydym yn ei hadnabod heddiw. Mae'r prosiect hwn yn nodi effeithiau newid hinsawdd ar fathau eang o dirwedd gan ddefnyddio set ddata ofodol Synhwyraidd a Gweledol LANDMAP. Mae'n darparu mapiau sy'n nodi dosbarthiad gofodol y mathau eang o dirwedd a gefnogwyd gan ystadegau allweddol, ac mae'n cynnig cyfres o naratifau ysgrifenedig o newid posib i bob math o dirwedd.

1.2. Amcanion

<u>Mapio ac ystadegau</u>

1. Creu fersiwn ychwanegol o set ddata ofodol Synhwyraidd a Gweledol LANDMAP sy'n cynnwys y systemau dosbarthu tirweddau eang newydd fel y'u diffinnir ym manyleb y prosiect (gweler Atodiad 8.1).
2. Cynhyrchu cyfres o fapiau thematig (ar lefelau cenedlaethol ac awdurdod lleol dethol) yn dangos y mathau newydd eang o dirweddau a'u perthynas ofodol â ffiniau a nodweddion daearyddol dethol, gan gynnwys perygl llifogydd ac ardaloedd o dan y cyfuchlinedd 1 metr.
3. Cynhyrchu set o dablau ystadegol a delweddau data i gefnogi'r mapiau ar raddfa genedlaethol.

<u>Naratifau</u>

Paratoi cyfres o naratifau testun i wneud y canlynol:

4. Crynhoi pob un o'r 14 math newydd o dirweddau eang a ddeilliwyd o gategorïau tirwedd Synhwyraidd a Gweledol presennol LANDMAP ar lefel uwch.
5. Disgrifio'r effeithiau rhagweledig o'r newid yn yr hinsawdd yn 2050 ar bob un o'r 14 math newydd o dirweddau eang, gan fanylu ar y ffynonellau o wybodaeth a ddefnyddiwyd i gynhyrchu'r naratifau.

1.3. Methodoleg

Mapio ac ystadegau

Defnyddiwyd meddalwedd Systemau Gwybodaeth Ddaearyddol i ddeillio set o fathau cyfanredol newydd o dirweddau o'r 45 o gategorïau tirwedd presennol ar lefel uwch i Gymru a oedd yn gynwysedig yn set ddata ofodol Synhwyraidd a Gweledol wreiddiol LANDMAP. Datblygwyd dau ddosbarthiad tirwedd newydd: LMP14 a LMP09, y ddau'n cynnwys 14 a naw dosbarth tirwedd eang yn y drefn honno. Gwnaed y gwaith prosesu a dadansoddi data gan ddefnyddio iaith raglennu ffynhonnell agored R, a chynhyrchwyd mapiau'r cyflwyniad gan ddefnyddio meddalwedd System Gwybodaeth Ddaearyddol ffynhonnell agored QGIS. Defnyddiwyd amrediad o setiau data eraill yn ychwanegol at set ddata ofodol Synhwyraidd a Gweledol LANDMAP, a chaiff y rhain eu crynhoi yn Atodiad 8.3. Am fwy o fanylion ar y fethodoleg, gweler Adran 3.2.

Naratifau

Mae'r naratifau'n cynnwys:

1. Disgrifiadau cryno yn Adran 5 o gymeriad ac ansawdd brofiadol y mathau o dirwedd, gyda gwybodaeth bellach yn Adran 8.4 – wedi'i deillio o wybodaeth ac arsylwadau sydd ar gael – ar y prosesau allweddol sydd wedi arwain at eu cymeriad presennol ac sy'n effeithio arnynt nawr.
2. Disgrifiadau cryno yn Adran 6 o effeithiau canlyniadau allweddol disgwyliedig y newid yn yr hinsawdd (h.y. tymereddau cymedrig cynhesach, hafau poethach a sychach, gaeafau cynhesach a gwlypach, stormydd mwy dwys, ac ati) ar brif elfennau'r 14 math o dirwedd. Darperir hefyd fatrics wedi'i godio â lliw i ddangos gradd bosib effeithiau ar raddfa saith pwynt (gan amrywio o effaith gadarnhaol uchel i effaith negyddol uchel). Gellir dod o hyd i well manylder a ffynonellau gwybodaeth a ddefnyddiwyd i benderfynu ar effeithiau tebygol yn Adran 8.5.

1.4. Crynodeb o'r gwaith

Gellir gweld crynodeb o'r prif ystadegau ar lefel genedlaethol ar gyfer mathau o dirwedd LMP14 yn Nhabl 2.1 (tudalen 17).

Mae'r naratifau tirwedd yn cynnwys disgrifiad o gymeriad y mathau o dirwedd LMP14 gan ddefnyddio llenyddiaeth berthnasol, dadansoddiad o'r ardaloedd LANDMAP eu hunain, a gwybodaeth a beirniadaeth arbenigol i ddisgrifio nodweddion ac agweddau perthnasol y categorïau tirwedd.

Roedd naratif y newid yn yr hinsawdd yn cynnwys datblygu graddfa saith pwynt i asesu'r effaith debygol o ganlyniadau newid hinsawdd ar elfennau penodol yn y dirwedd. Mae elfennau'n ymwneud â thirffurf, gorchudd coed, llystyfiant, ffiniau caeau, dŵr wyneb, aneddiadau ac adeileddau, ac asedau archeolegol. Defnyddiwyd y naratifau tirwedd, llenyddiaeth berthnasol yn nodi effeithiau'r newid yn yr hinsawdd, a beirniadaeth arbenigol i adnabod pa elfennau yn y dirwedd a fyddai'n cael eu heffeithio gan bob canlyniad newid hinsawdd penodol, a gwnaed dyfarniadau ynglŷn â maint ac arwyddocâd yr effeithiau. Cyflwynir y canlyniadau mewn set o fatricsau yn Adran 8.5 yn manylu ar effeithiau pob canlyniad newid hinsawdd perthnasol ar yr elfennau tirwedd, ac maent wedi'u crynhoi mewn matrics wedi'i godio â lliw i amlygu lle bydd disgwyl cael yr effeithiau mwyaf.

1.5. Casgliadau

Mae dadansoddiad ar gyfer llunio'r naratifau tirwedd yn Adran 5 ac 8.4 wedi amlygu'r angen am ddadansoddiad gofodol mwy manwl sy'n ymatebol i wahaniaethau hanesyddol sydd yn aml yn ddwfn ac sydd wedi siapio cynefinoedd a chymeriad tirwedd mewn ardaloedd ucheldir ac iseldir Cymru. Mae dyfnder amser ei thirweddau ffermio nodweddiadol, er enghraifft, yn aml yn dangos gwahaniaethau amlwg o'r dwyrain i'r gorllewin mewn cysylltiad agos ag amrywiaeth rhywogaethau a chyferbyniadau a arsylwyd mewn pensaernïaeth draddodiadol. Mae dealltwriaeth ofodol o ddatblygiad ac arwyddocâd ardaloedd coetir a gwlyptir, ynghyd â phorfeydd garw, sydd wedi lleihau o ran maint i raddau helaeth, hefyd yn wael. Er bod mapiau Arolwg Ordnans o'r 19eg ganrif yn dangos nifer o ardaloedd fel parcdir, mae eu datblygiad hanesyddol a chymeriad naill ai fel cynefinoedd parcdir â chyfoeth o rywogaethau neu olion diraddedig tirweddau ffermio neu chwaraeon hefyd yn aneglur.

Nododd dadansoddiad o effeithiau newid hinsawdd yr ardaloedd lle mae'r effeithiau mwyaf sylweddol yn debygol o ddigwydd o ran y mathau o dirwedd LMP14. Mae'r dadansoddiad yn awgrymu bod rhai manteision lefel isel sy'n codi o dymereddau cymedrig cynhesach (e.e. o ran newidiadau i dwf cnydau a llystyfiant) ond y bydd yr effeithiau cyffredinol yn cael effeithiau negyddol ar dirweddau. Bydd yr effeithiau mwyaf sylweddol yn gysylltiedig â'r gwasgariad posib o blâu, pathogenau a heintiau, yn arbennig ar gyfer gorchudd coed a llystyfiant. Mae hafau poethach a sychach hefyd yn debygol o gael effeithiau sylweddol ar orchudd coed a llystyfiant trwy gynyddu straen, gan arwain at ostyngiadau mewn amlygrwydd ac argaeledd dŵr wyneb, yn enwedig mewn ardaloedd ucheldirol. Mae gaeafau gwlypach a stormydd mwy eithafol yn debygol o greu set wahanol o broblemau, gan gynnwys pridd dyfrlawn, rhagor o ddŵr ffo a pherygl llifogydd uwch, gan effeithio ardaloedd iseldirol ac ymyl yr arfordir yn arbennig.

Roedd y dadansoddiad yn seiliedig ar feirniadu effeithiau canlyniadau newid hinsawdd dros y cyfnod rhwng 2019 a 2050. Mae'r dadansoddiad yn tynnu sylw at yr ansicrwydd sy'n gysylltiedig ag ymgymryd â rhagfynegiadau'r dyfodol, yn enwedig wrth geisio deall y canlyniadau posib o effeithiau synergaidd nifer o newidiadau mewn systemau ecolegol a hydrolegol dros ardaloedd mawr a gwmpesir gan fathau o dirwedd LMP14. Mae effeithiau rhagweledig yn seiliedig ar feirniadaeth ac yn cynnig cwmpas bras. Bydd effeithiau yn unrhyw un lleoliad yn cael eu llywio gan amodau lleol a nodweddion daearegol, pridd a thirffurf sylfaenol.

1.6. Llywio polisi

Mae'r naratifau a ddatblygwyd ar gyfer y prosiect hwn yn cynrychioli ymdrech gychwynnol i ddangos sut y mae tirwedd Cymru yn adlewyrchu rhyngweithiad ffactorau dynol a naturiol dros filoedd o flynyddoedd. Mae hyn yn galw am ddulliau integredig o ddatblygu sylfaen dystiolaeth a llywio ymatebion polisi. Mae newid yn yr hinsawdd yn 'lluoswr risg', y bydd ei ddifrifoldeb wedi’i gysylltu'n agos ag ysgogwyr hirdymor a mwy diweddar ar gyfer newid. Mae angen deall y rhain yn well i lywio polisi a strategaethau addasu, a fydd yn ehangu y tu hwnt i senarios newid hinsawdd penodol i strategaethau lliniaru a newid patrymau amaethyddiaeth, rheoli coetiroedd, cadwraeth cynefinoedd, seilwaith, cynhyrchu ynni, a chynnal cymunedau trefol a gwledig wrth iddynt addasu i fyd sy'n newid.

Mae’r naratifau newid hinsawdd yn crynhoi mewn nifer bach o fatricsau nifer mawr o wybodaeth ynglŷn ag effeithiau newid hinsawdd ar dirweddau. Fel y cyfryw, maent yn darparu trosolwg o ble mae effeithiau yn fwyaf tebygol o fod yn sylweddol a'r mathau o dirwedd sydd fwyaf tebygol o gael eu heffeithio. Fel y cyfryw, mae'r dull matrics yn cynnig ffordd o flaenoriaethu ymatebion ac yn awgrymu lle gall cymorth am newid ymaddasol fod yn angenrheidiol neu fwyaf manteisiol.

2. Executive Summary

2.1. Background

The changing climate of Wales is likely to have significant direct (e.g. changing land cover) and indirect (e.g. by influencing land use decisions) impacts on landscape character, quality and local distinctiveness. Flooding and drought events, more frequent extreme weather, coastal erosion, wildfires, diseases affecting tree cover and changing land cover, habitats and species ranges are examples of how the landscape may change to a greater or lesser degree, in the short or long term.

Landscape character can provide an important communication tool to raise awareness and understanding of the risks and opportunities of climate change because people relate to landscapes as places to live, work and enjoy. It is therefore opportune to bring together information on the impacts from a changing climate and apply them to a landscape perspective.

This project is the first step in starting to identify and communicate the direct and indirect impacts of projected climate changes for Wales in 2050 on landscape character and qualities and what that might look like in the landscape we recognise today. This project identifies the impacts of climate change on broad landscape types using the LANDMAP Visual & Sensory spatial dataset. It provides maps that identify the spatial distribution of the broad landscape types supported by key statistics, and offers a series of written narratives of potential change for each landscape type.

2.2. Objectives

<u>Mapping and Statistics</u>

1. Create an additional version of the LANDMAP Visual & Sensory spatial dataset that includes the new broad landscape classification systems as defined in the project specification (see Appendix 8.1).
2. Produce a series of thematic maps (at national and selected local authority levels) showing the newly derived broad landscape types and their spatial relationship to selected geographical boundaries and features including flood risk and areas below the 1 metre contour.
3. Produce a set of statistical tables and data visualisations to support the national scale maps.

<u>Narratives</u>

Prepare a series of text narratives to:

4. Summarise each of the 14 new broad landscape types derived from existing higher-level LANDMAP Visual & Sensory landscape categories.
5. Describe the projected impacts of climate change in 2050 on each of the 14 new broad landscape types, specifying the sources of information used to produce the narratives.

2.3. Methodology

Mapping and Statistics

Geographical Information Systems software (GIS) was used to derive a set of new, aggregated landscape types from the 45 existing higher-level landscape categories for Wales contained in the original LANDMAP Visual & Sensory spatial dataset. Two new landscape classifications were developed: LMP14 and LMP09, each containing 14 and 9 broad landscape classes respectively. Data processing and analysis was done using the open source programming language R, and the presentation maps were produced using the open source GIS software QGIS. A range of other datasets were used in addition to the LANDMAP Visual & Sensory spatial dataset, and these are summarised in Appendix 8.3. For more detail on the methodology, see Section 3.2.

Narratives

The narratives comprise:

1. Summary descriptions in Section 5 of the character and experiential quality of the landscape types, with further information in Section 8.4 - derived from available information and observation - on the key processes that have driven their present-day character, and that are affecting them now.
2. Summary descriptions in Section 6 of the impacts of anticipated key outcomes of climate change (i.e. warmer mean temperatures, hotter drier summers, warmer wetter winters, more intense storms, etc) on key elements of the 14 landscape types. A colour coded matrix is also provided to illustrate potential scale of impacts on a 7-point scale (ranging from high positive to high negative impact). Greater detail and sources of information utilised to determine likely impacts can be found in Section 8.5.

2.4. Summary of work

A summary of the key national-level statistics for LMP14 landscape types can be seen in Table 2.1 (p. 17).

The landscape narratives involve description of the character of the LMP14 landscape types utilising relevant literatures, analysis of the LANDMAP areas themselves, and expert knowledge and judgement to describe the relevant characteristics and aspects of the landscape categories.

The climate change narrative involved development of a seven-point scale to assess the likely impact of climate change outcomes on specific elements in the landscape. Elements relate to landform, tree cover, vegetation, field boundaries, surface water, settlements & structures, and archaeological assets. The landscape narratives, relevant literature identifying effects of climate change, and expert judgement were utilised to identify which elements in the landscape would be affected by each particular climate change outcomes, and judgements made about the magnitude and significance of the effects. Results are presented in a set of matrices in Section 8.5 detailing impacts of each relevant climate change outcome on the landscape elements and summarised in a colour coded matrix to highlight where the largest impacts are expected.

2.5. Conclusions

Analysis for the drafting of the landscape narratives in Sections 5 and 8.4 has highlighted the need for more detailed spatial analysis that is responsive to often profound historic differences that have shaped habitats and landscape character in upland and lowland areas of Wales. The time-depth of its distinctive farming landscapes, for example, often show marked contrasts from east to west in close association with species diversity and contrasts observed in traditional architecture. Spatial understanding of the development and significance of woodland and wetland areas, and rough pasture which has greatly diminished in extent, is also poorly understood. Whilst 19th century Ordnance Survey maps indicate many areas as parkland, their historic development and character as either species-rich parkland habitats or the degraded remnants of farming or sporting landscapes is also unclear.

Analysis of the climate change impacts identified where the most significant impacts are likely to occur in respect of the LMP14 landscape types. The analysis suggests there are some low-level benefits arising from warmer mean temperatures (e.g. in terms of changes in crops and vegetation growth) but overall impacts will have negative impacts on landscape. Most significant effects will be related to the potential spread of pests, pathogens and diseases, in particular for tree cover and vegetation. Hotter drier summers are also likely to have significant effects on tree cover and vegetation through increasing stress, and lead to reductions in visibility and availability of surface water, especially in upland areas. Wetter winters and more intense storms are likely to create a different set of problems including soil waterlogging, increased run-off and higher potential for flooding, affecting lowland and coastal edge areas in particular.

The analysis was based on judging the effects of climate change outcomes over the period from 2019 to 2050. The analysis highlights the uncertainties associated with undertaking future predictions, in particular in trying to understand the potential outcomes from synergistic effects of multiple changes on ecological and hydrological systems over large areas covered by the LMP14 landscape types. Predicted impacts are based on judgement and are broad brush in scope. Impacts in any one location will be affected by local conditions and underlying geological, soil and landform characteristics.

2.6. Informing Policy

The narratives developed for this project represent an initial attempt to demonstrate how Wales's landscape reflects the interaction of human and natural factors over millennia. This calls for integrated approaches to the development of an evidence base and informing policy responses. Climate change is a 'risk multiplier', the severity of which will be closely linked to long-term and more recent drivers for change. These need to be better understood to inform policy and adaptation strategies, which will extend beyond specific climate change scenarios to mitigation strategies and changing patterns of agriculture, woodland management, habitat conservation, infrastructure, energy generation and sustaining urban and rural communities as they adapt to a changing world.

The climate change narratives condense into a small number of matrices a large amount of information about the effects of climate change on landscape. As such they provide an overview of where impacts are most likely to be significant and the landscape types most likely to be affected. As such the matrix approach offers a means of prioritising response and suggests where support for adaptive change might be required, or most beneficial.

Table 2.1 Summary table of selected national-level statistics for LMP14 landscapes

LMP14 Landscape Type	Area (% Total Wales)	<=1m ASL % total area within each LMP14 Type	Flood Zone 2 (% total area within each LMP14 Type)	Flood Zone 3 (% total area within each LMP14 Type)	Landscape Value (% total area within each LMP14 Type)			
					Low	Moderate	High	Outstanding
Coastal edge	2.45	50.94	60.32	59.22	0	8.45	56.44	35.12
Developed (amenity)	0.24	1.28	25.26	20.96	20.29	68.27	8.5	2.93
Developed (communities)	4.47	0.5	16.8	12.75	0	0	0	0
Developed (industry)	0.43	0.31	5.07	4.02	78.7	5.75	13.72	1.83
Lowland (wooded & wetland)	2.37	3.53	19.5	17.24	2.01	16.81	71.31	9.88
Lowland valleys (hedgerow)	15.03	0.06	5.28	4.38	0.27	52.72	40.55	6.46
Lowland valleys (open)	16.59	0.34	17.82	16.24	1.11	66.14	28.16	4.58
Upland (grassland)	23.17	0.01	2.44	2.11	0.59	62.29	35.3	1.82
Upland (moorland)	14.44	0	0.54	0.48	2.85	10	52.85	34.31
Upland (rock)	0.81	0	0.34	0.28	0	0.66	0.06	99.28
Upland (wooded hills)	3.26	0	1.11	0.96	6.14	34.73	55.09	4.05
Upland (wooded)	15.73	0.01	2.26	1.91	2.97	45.32	45.96	5.75
Water (inland)	0.5	13.83	78.08	75.57	0	29.46	29.27	41.27
Water (sea)	0.51	44.59	64.39	64.26	0	0	19.52	80.48

3. GIS Maps and Statistics: National-Level

3.1. Introduction

This section presents the results of the first part of mapping and statistics element of the project, meeting the following objectives:

1. Create an additional version of the LANDMAP Visual & Sensory spatial dataset that includes the new broad landscape classification systems as defined in the project specification (see Appendix 8.1).
2. Produce a series of thematic maps (at national-level) showing the newly derived broad landscape types and their spatial relationship to selected geographical boundaries and features:
    - **Map 1**: LMP14 landscape types (see Section 3.2.1 below).
    - **Map 2**: LMP14 landscape types with NRW Operational Areas overlaid.
    - **Map 3**: LMP09 landscape types.
    - **Map 4**: LMP14 landscape types highlighting land less than 1m in attitude (indicating vulnerability to rising sea levels).
    - **Map 5**: LMP14 landscape types with Flood Zone 2 data[1] overlaid, identifying landscapes at risk of flooding.
    - **Map 6**: LMP14 landscape types with Flood Zone 3 data[2] overlaid, identifying landscapes at risk of flooding.
    - **Map 7**: LMP14 landscape types showing the predominant boundary types in each landscape type area, derived from the LANDMAP Visual & Sensory spatial dataset.
    - **Map 8**: LMP14 landscape types showing overall landscape value, derived from the LANDMAP Visual & Sensory spatial dataset.
3. Produce a set of statistical tables and data visualisations to support the national scale maps.

3.2. Methodology

3.2.1. Reclassification and New Dataset

As with all of the data analysis in this project, the reclassification of the LANDMAP Visual & Sensory spatial dataset into broad landscape types was done using the R programming language (https://www.r-project.org/) . The

[1] Flood Zone 2 - land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% – 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% – 0.1%) in any year.

[2] Flood Zone 3 - land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

advantage of using R is that the entire data processing and analysis workflow can be clearly documented with computer code, allowing rapid reproducibility and modification of the technical data and GIS aspects of the project. Also, because R is an open source programming language and software environment, access to the code and the software needed to run it will remain free into the future.

Using R to manipulate the original LANDMAP Visual & Sensory spatial dataset, two new broader landscape classification systems were derived from the 45 existing landscape types classified at 'Level 3' (see the LANDMAP Visual and Sensory guidance document available here.) The full reclassification system for these new LMP14 and LMP09 landscape categorisation schemes is described in Appendix 8.1.

The input and output datasets, computer code and other resources (e.g. lookup tables) used to perform the landscape reclassification analysis is available via the project's online GitHub repository[3]. Guidance on using the output dataset, which comprises the original LANDMAP Visual & Sensory spatial dataset plus the additional columns holding attribute information on the new LMP14 and LMP09 landscape classifications can be found in Appendix 8.2.

3.2.2. Statistics

A series of land area statistics, in the form of tables and bar charts, were produced to support the national-level maps described in Section 3.1. This was also done using the R programming language, and access to the full code used to do this is also available via the project's online GitHub repository[3].

3.2.3. Maps

Presentation maps were produced using QGIS software (version 3.4.2). The output of the reclassification analysis performed using R was used to create thematic maps showing LMP14 and LMP09 landscape types as spatial polygons, using the reclassification scheme described in Section 3.2.1. Layer symbology (i.e. the cartographic visual styling and colour scheme) were saved as a series of QGIS style files. These QML style files are also available via the online repository[3].

3.2.4. Metadata

A summary of the spatial data layers used in in this project (for reclassification, statistics and mapping) is available in Appendix 8.3.

3.3. Section Structure

The national-level maps and statistics (objectives 2 and 3) are presented in the remainder of this section. Each sub-section contains a single map followed by its accompanying statistics.

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[3] https://github.com/robertberryuk/LANDMAP_ClimateChange.

3.4. LMP14 Landscape Classification

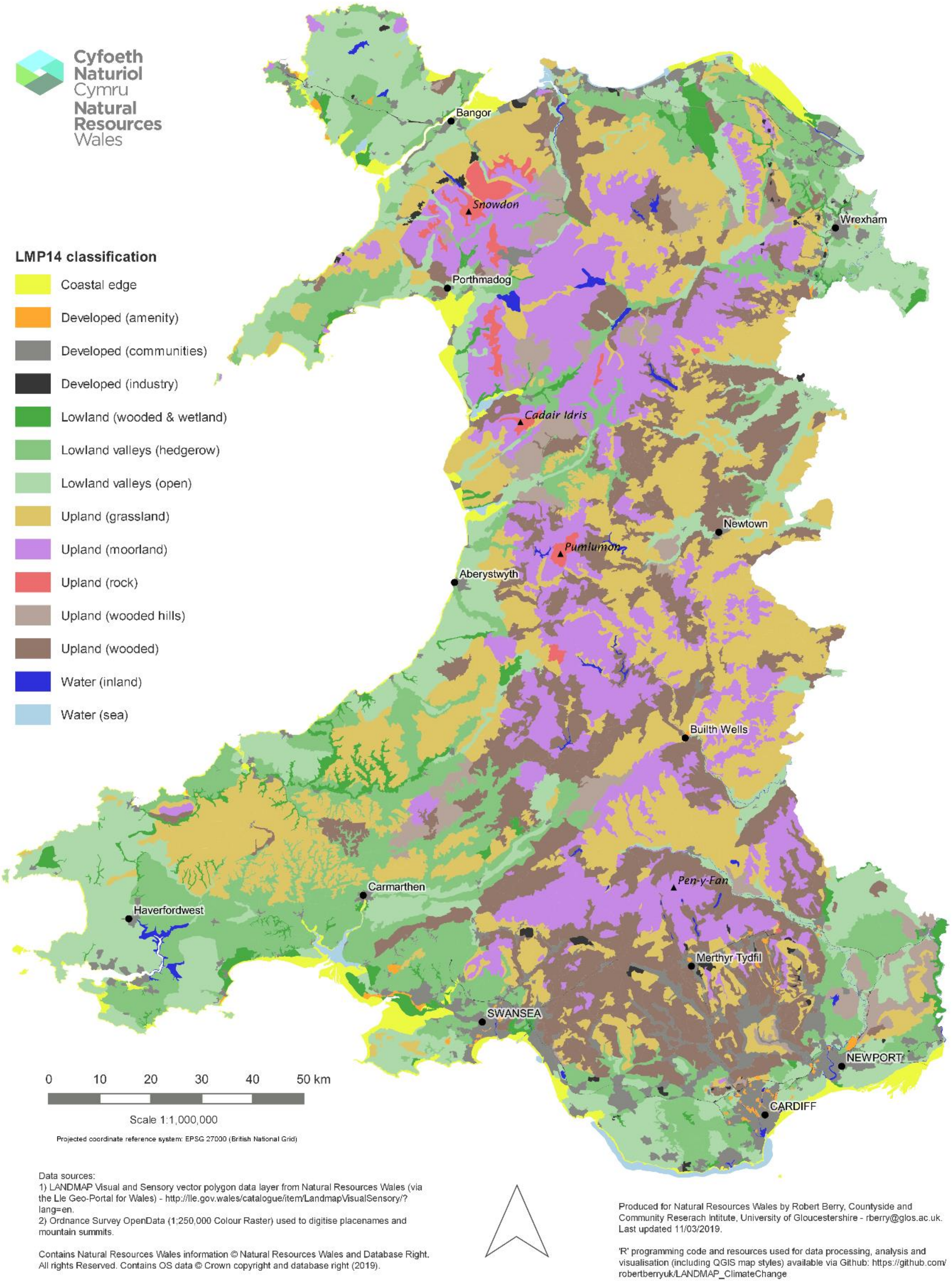

Figure 3.1 LMP14 landscape types (all-Wales)

Table 3.1 Area statistics for LMP14 landscape types (all-Wales)

LMP14 Landscape Type	Area (km^2)	Area (% Total)
Upland (grassland)	4924.91	23.17
Lowland valleys (open)	3525.22	16.59
Upland (wooded)	3343.7	15.73
Lowland valleys (hedgerow)	3195.27	15.03
Upland (moorland)	3068.68	14.44
Developed (communities)	950.57	4.47
Upland (wooded hills)	692.63	3.26
Coastal edge	520.03	2.45
Lowland (wooded & wetland)	503.26	2.37
Upland (rock)	172.43	0.81
Water (sea)	107.78	0.51
Water (inland)	106.29	0.5
Developed (industry)	92.33	0.43
Developed (amenity)	50.21	0.24

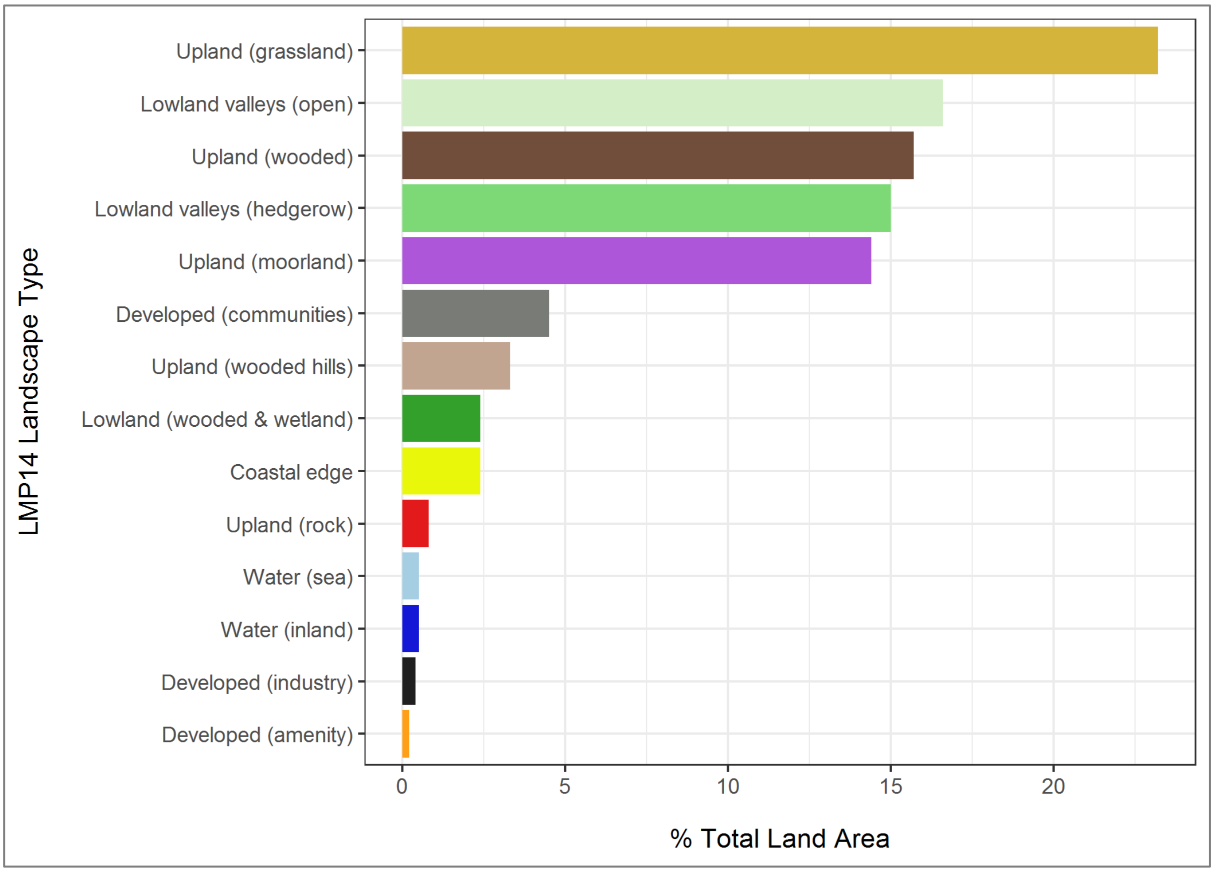

Figure 3.2 Area statistics for LMP14 landscape types (all-Wales)

3.5. LMP14 Landscape Types by NRW Operating Area

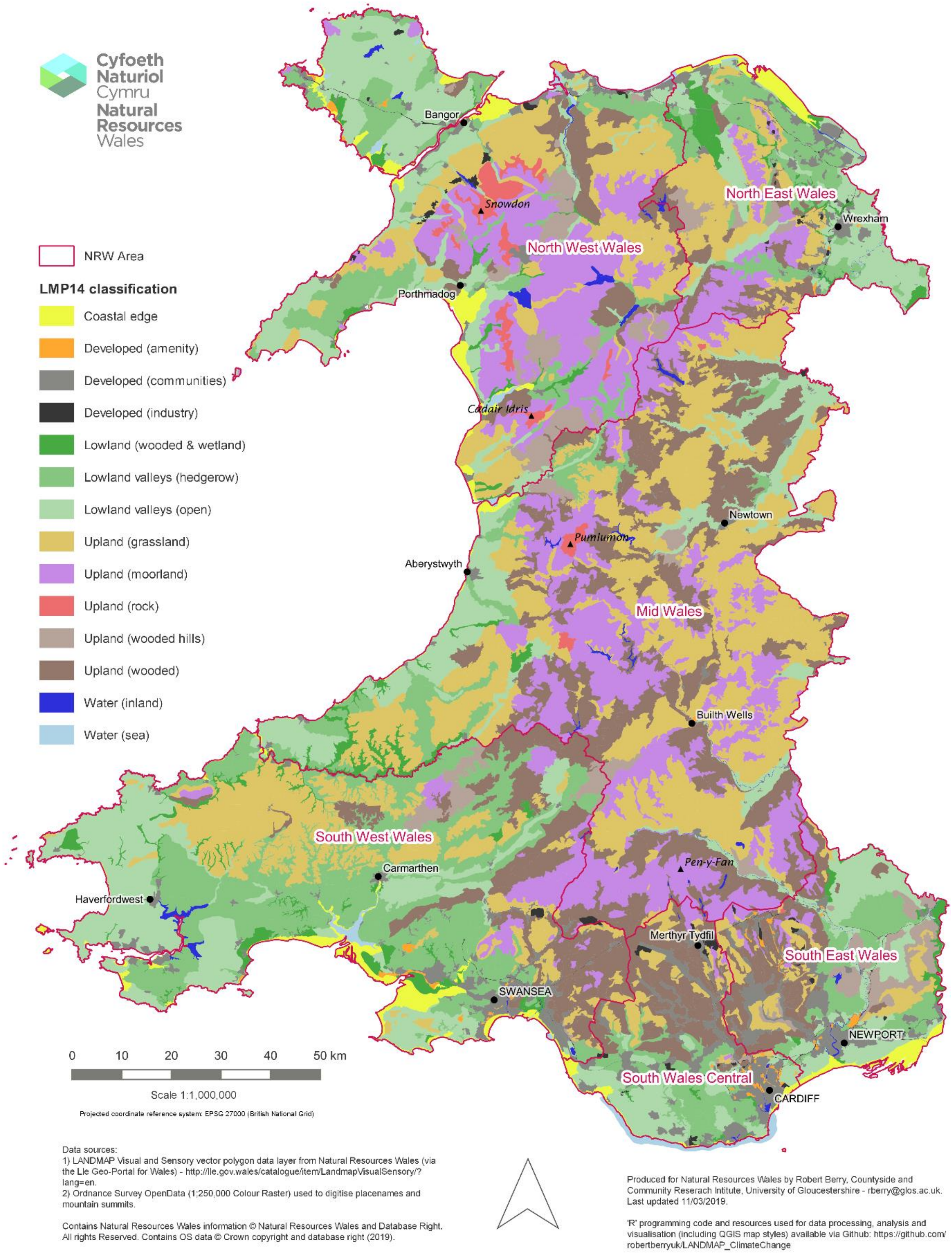

Figure 3.3 LMP14 landscape classification with NRW Operating Areas

Table 3.2 LMP14 landscape types by NRW Area (km^2)

NRW Area	Coastal edge	Developed (amenity)	Developed (communities)	Developed (industry)	Lowland (wooded & wetland)	Lowland valleys (hedgerow)	Lowland valleys (open)	Upland (grassland)	Upland (moorland)	Upland (rock)	Upland (wooded hills)	Upland (wooded)	Water (inland)	Water (sea)
Mid Wales	28.95	0.78	59.97	7.26	122.63	411.43	813.77	2745.94	1945.33	29.27	304.99	1944.14	31.6	5.55
North East Wales	58.31	2.71	127.81	13.97	109.05	359.18	406.73	557.35	588.03	0.1	63.34	219.13	5.9	3.69
North West Wales	168.48	5.93	119.67	24.31	78.41	647.32	912.82	1027.7	1260.27	141.92	295.26	408.74	38.55	37.19
South East Wales	53.78	13.29	220.25	23.77	40.77	247.06	376.35	193.77	196.99	1.14	169.53	383.18	10.18	0
South Wales Central	58.86	12.84	272.18	28.29	7.42	249.71	265.4	173.72	192.86	0	4.28	560.31	6.17	47.56
South West Wales	196.7	14.87	233.74	16.53	243.09	1533.8	1023.01	1009.76	418.25	0	134.56	999.7	25.36	23.52

Table 3.3 LMP14 landscape types by NRW Area (% of the total land area within each NRW Operating Area)

NRW Area	Coastal edge	Developed (amenity)	Developed (communities)	Developed (industry)	Lowland (wooded & wetland)	Lowland valleys (hedgerow)	Lowland valleys (open)	Upland (grassland)	Upland (moorland)	Upland (rock)	Upland (wooded hills)	Upland (wooded)	Water (inland)	Water (sea)
Mid Wales	0.34	0.01	0.71	0.09	1.45	4.87	9.63	32.49	23.02	0.35	3.61	23	0.37	0.07
North East Wales	2.32	0.11	5.08	0.56	4.34	14.28	16.17	22.16	23.38	0	2.52	8.71	0.23	0.15
North West Wales	3.26	0.11	2.32	0.47	1.52	12.53	17.67	19.89	24.39	2.75	5.71	7.91	0.75	0.72
South East Wales	2.79	0.69	11.41	1.23	2.11	12.8	19.5	10.04	10.21	0.06	8.78	19.85	0.53	0
South Wales Central	3.13	0.68	14.48	1.51	0.39	13.29	14.12	9.24	10.26	0	0.23	29.81	0.33	2.53
South West Wales	3.35	0.25	3.98	0.28	4.14	26.12	17.42	17.19	7.12	0	2.29	17.02	0.43	0.4

Table 3.4 Area statistics for LMP14 landscape types (Mid Wales NRW Area)

LMP14 Landscape Type	Area (km^2)	Area (% Total)
Upland (grassland)	2745.94	32.49
Upland (moorland)	1945.33	23.02
Upland (wooded)	1944.14	23
Lowland valleys (open)	813.77	9.63
Lowland valleys (hedgerow)	411.43	4.87
Upland (wooded hills)	304.99	3.61
Lowland (wooded & wetland)	122.63	1.45
Developed (communities)	59.97	0.71
Water (inland)	31.6	0.37
Upland (rock)	29.27	0.35
Coastal edge	28.95	0.34
Developed (industry)	7.26	0.09
Water (sea)	5.55	0.07
Developed (amenity)	0.78	0.01

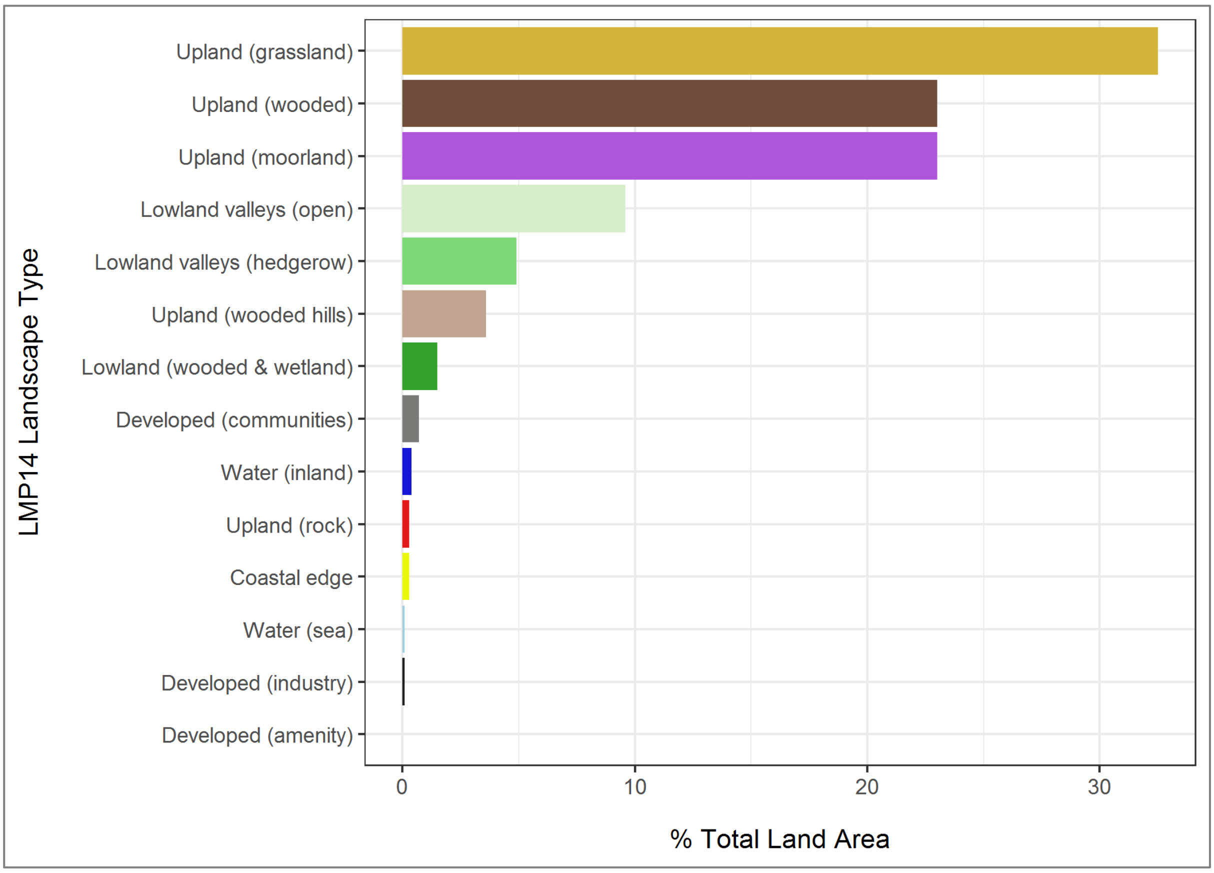

Figure 3.4 Area statistics for LMP14 landscape types (Mid Wales NRW Area)

Table 3.5 Area statistics for LMP14 landscape types (North East Wales NRW Area)

LMP14 Landscape Type	Area (km^2)	Area (% Total)
Upland (moorland)	588.03	23.38
Upland (grassland)	557.35	22.16
Lowland valleys (open)	406.73	16.17
Lowland valleys (hedgerow)	359.18	14.28
Upland (wooded)	219.13	8.71
Developed (communities)	127.81	5.08
Lowland (wooded & wetland)	109.05	4.34
Upland (wooded hills)	63.34	2.52
Coastal edge	58.31	2.32
Developed (industry)	13.97	0.56
Water (inland)	5.9	0.23
Water (sea)	3.69	0.15
Developed (amenity)	2.71	0.11
Upland (rock)	0.1	0

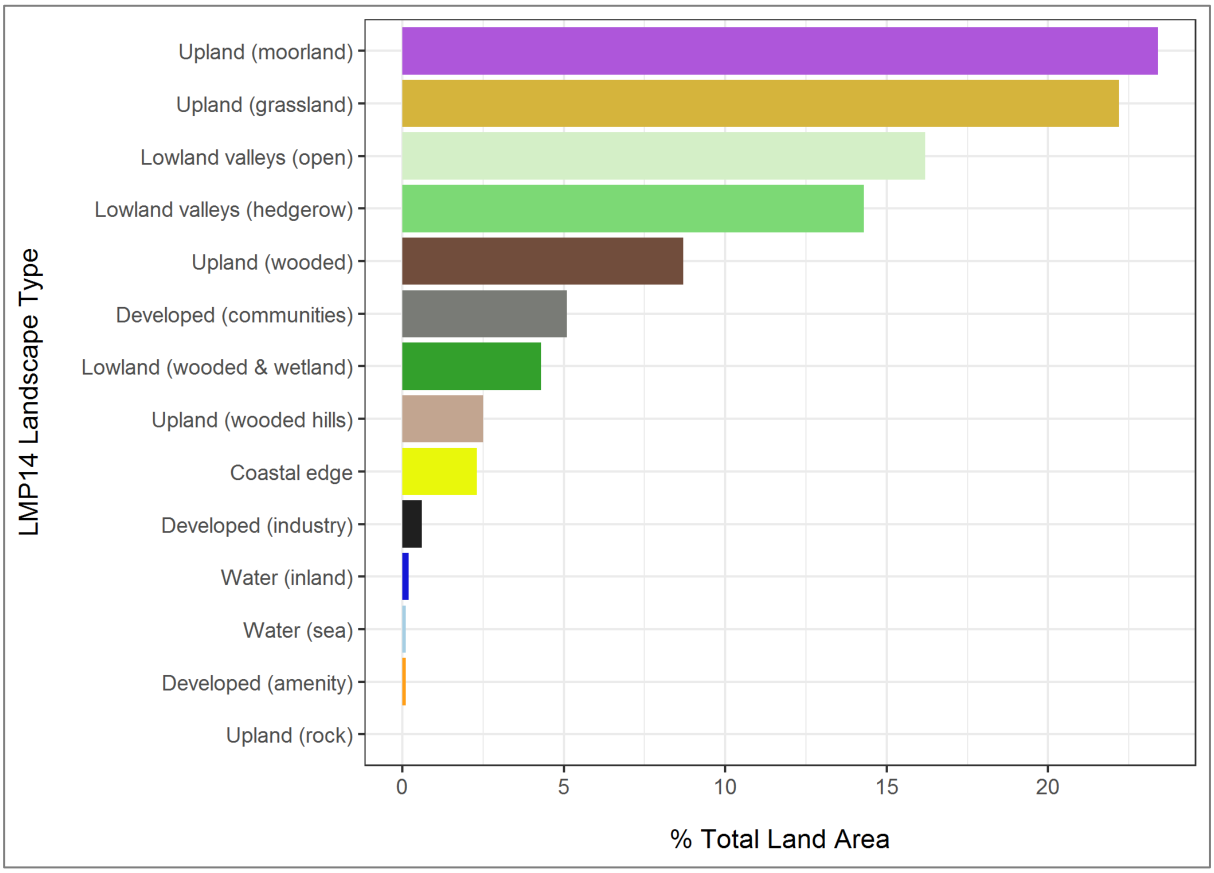

Figure 3.5 Area statistics for LMP14 landscape types (North East Wales NRW Area)

Table 3.6 Area statistics for LMP14 landscape types (North West Wales NRW Area)

LMP14 Landscape Type	Area (km^2)	Area (% Total)
Upland (moorland)	1260.27	24.39
Upland (grassland)	1027.7	19.89
Lowland valleys (open)	912.82	17.67
Lowland valleys (hedgerow)	647.32	12.53
Upland (wooded)	408.74	7.91
Upland (wooded hills)	295.26	5.71
Coastal edge	168.48	3.26
Upland (rock)	141.92	2.75
Developed (communities)	119.67	2.32
Lowland (wooded & wetland)	78.41	1.52
Water (inland)	38.55	0.75
Water (sea)	37.19	0.72
Developed (industry)	24.31	0.47
Developed (amenity)	5.93	0.11

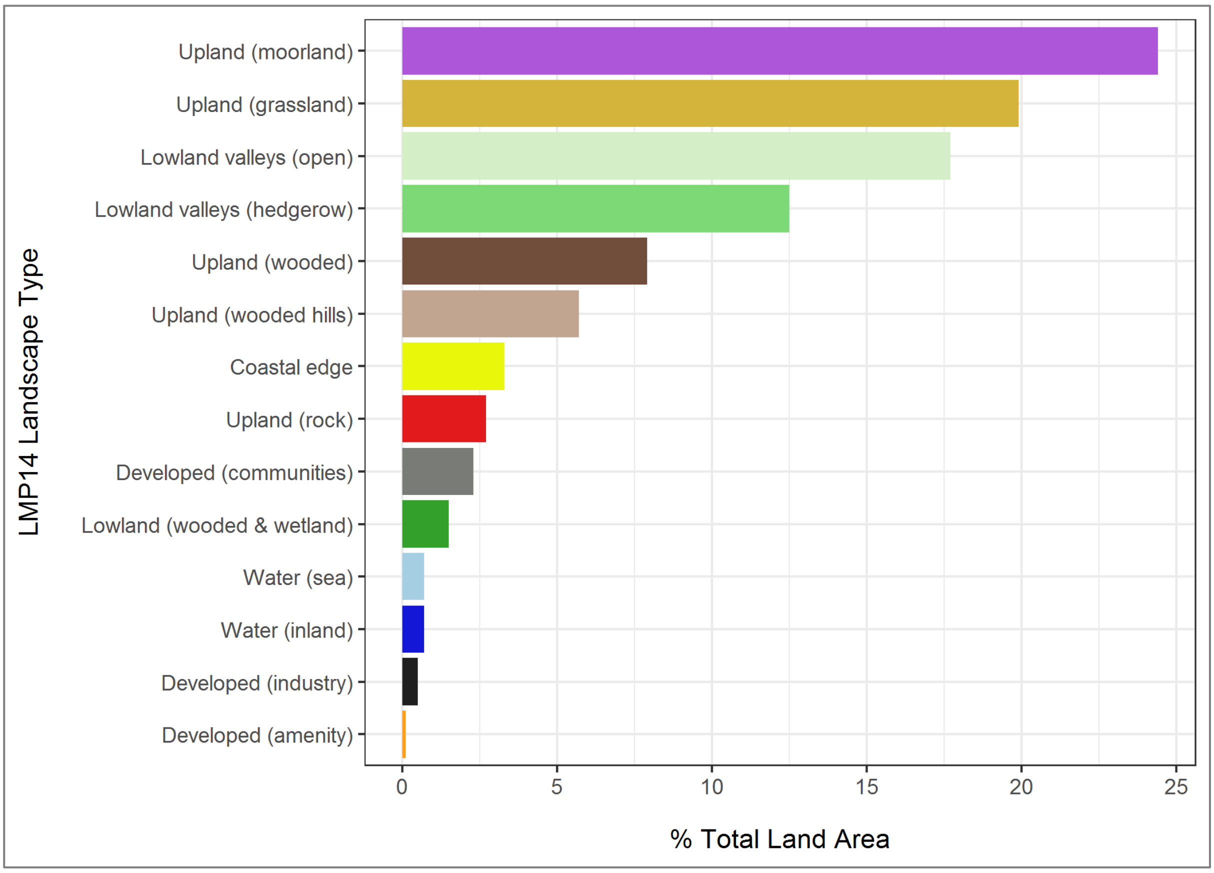

Figure 3.6 Area statistics for LMP14 landscape types (North West Wales NRW Area)

Table 3.7 Area statistics for LMP14 landscape types (South East Wales NRW Area)

LMP14 Landscape Type	Area (km^2)	Area (% Total)
Upland (wooded)	383.18	19.85
Lowland valleys (open)	376.35	19.5
Lowland valleys (hedgerow)	247.06	12.8
Developed (communities)	220.25	11.41
Upland (moorland)	196.99	10.21
Upland (grassland)	193.77	10.04
Upland (wooded hills)	169.53	8.78
Coastal edge	53.78	2.79
Lowland (wooded & wetland)	40.77	2.11
Developed (industry)	23.77	1.23
Developed (amenity)	13.29	0.69
Water (inland)	10.18	0.53
Upland (rock)	1.14	0.06
Water (sea)	0	0

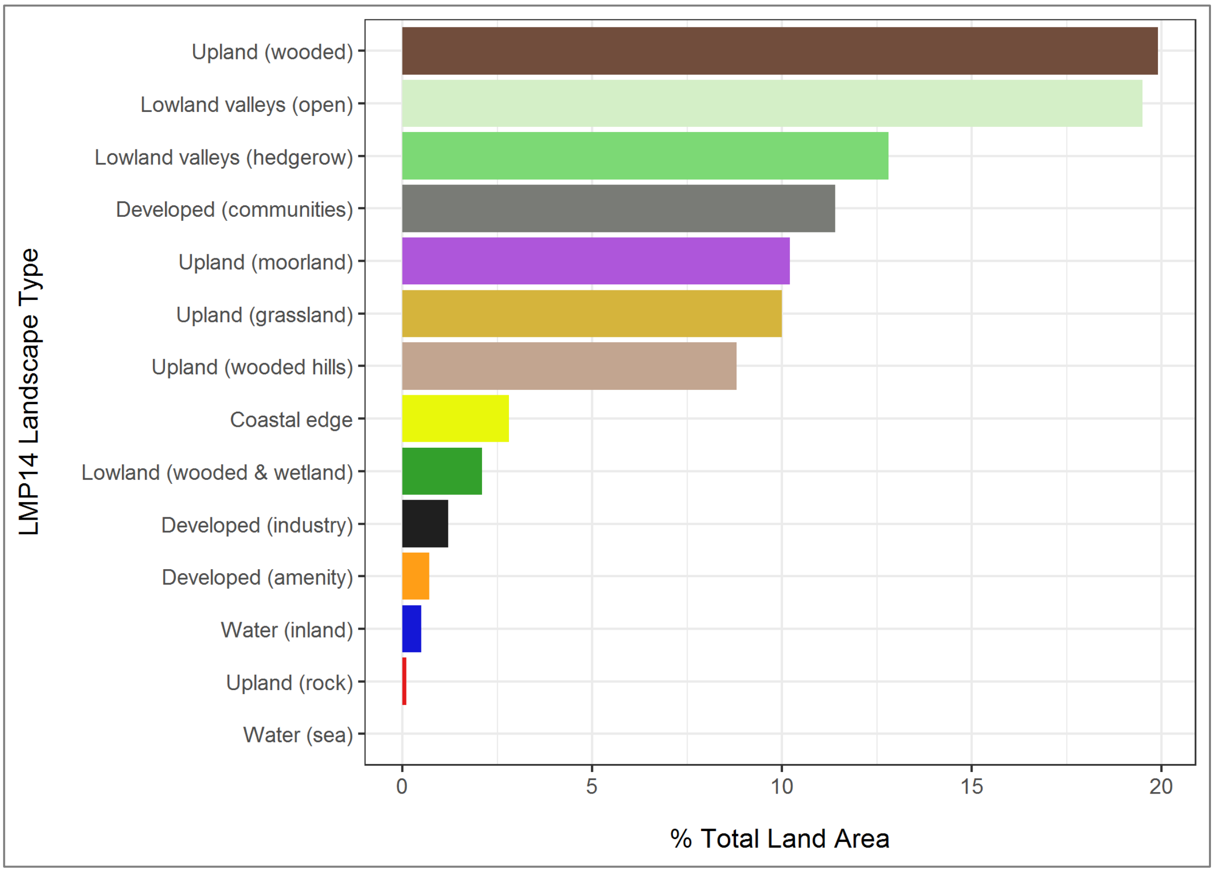

Figure 3.7 Area statistics for LMP14 landscape types (South East Wales NRW Area)

Table 3.8 Area statistics for LMP14 landscape types (South Central Wales NRW Area)

LMP14 Landscape Type	Area (km^2)	Area (% Total)
Upland (wooded)	560.31	29.81
Developed (communities)	272.18	14.48
Lowland valleys (open)	265.4	14.12
Lowland valleys (hedgerow)	249.71	13.29
Upland (moorland)	192.86	10.26
Upland (grassland)	173.72	9.24
Coastal edge	58.86	3.13
Water (sea)	47.56	2.53
Developed (industry)	28.29	1.51
Developed (amenity)	12.84	0.68
Lowland (wooded & wetland)	7.42	0.39
Water (inland)	6.17	0.33
Upland (wooded hills)	4.28	0.23
Upland (rock)	0	0

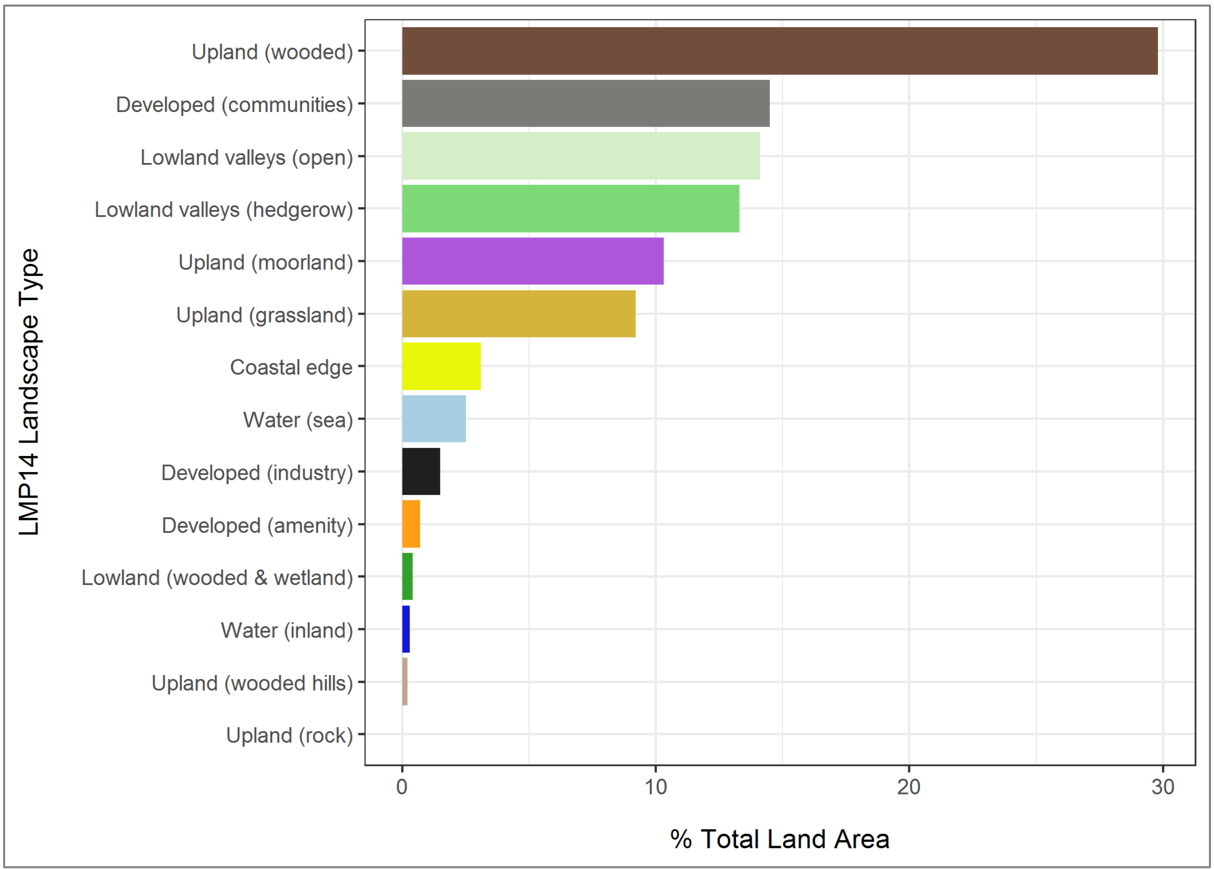

Figure 3.8 Area statistics for LMP14 landscape types (South Central Wales NRW Area)

Table 3.9 Area statistics for LMP14 landscape types (South West Wales NRW Area)

LMP14 Landscape Type	Area (km^2)	Area (% Total)
Lowland valleys (hedgerow)	1533.8	26.12
Lowland valleys (open)	1023.01	17.42
Upland (grassland)	1009.76	17.19
Upland (wooded)	999.7	17.02
Upland (moorland)	418.25	7.12
Lowland (wooded & wetland)	243.09	4.14
Developed (communities)	233.74	3.98
Coastal edge	196.7	3.35
Upland (wooded hills)	134.56	2.29
Water (inland)	25.36	0.43
Water (sea)	23.52	0.4
Developed (industry)	16.53	0.28
Developed (amenity)	14.87	0.25
Upland (rock)	0	0

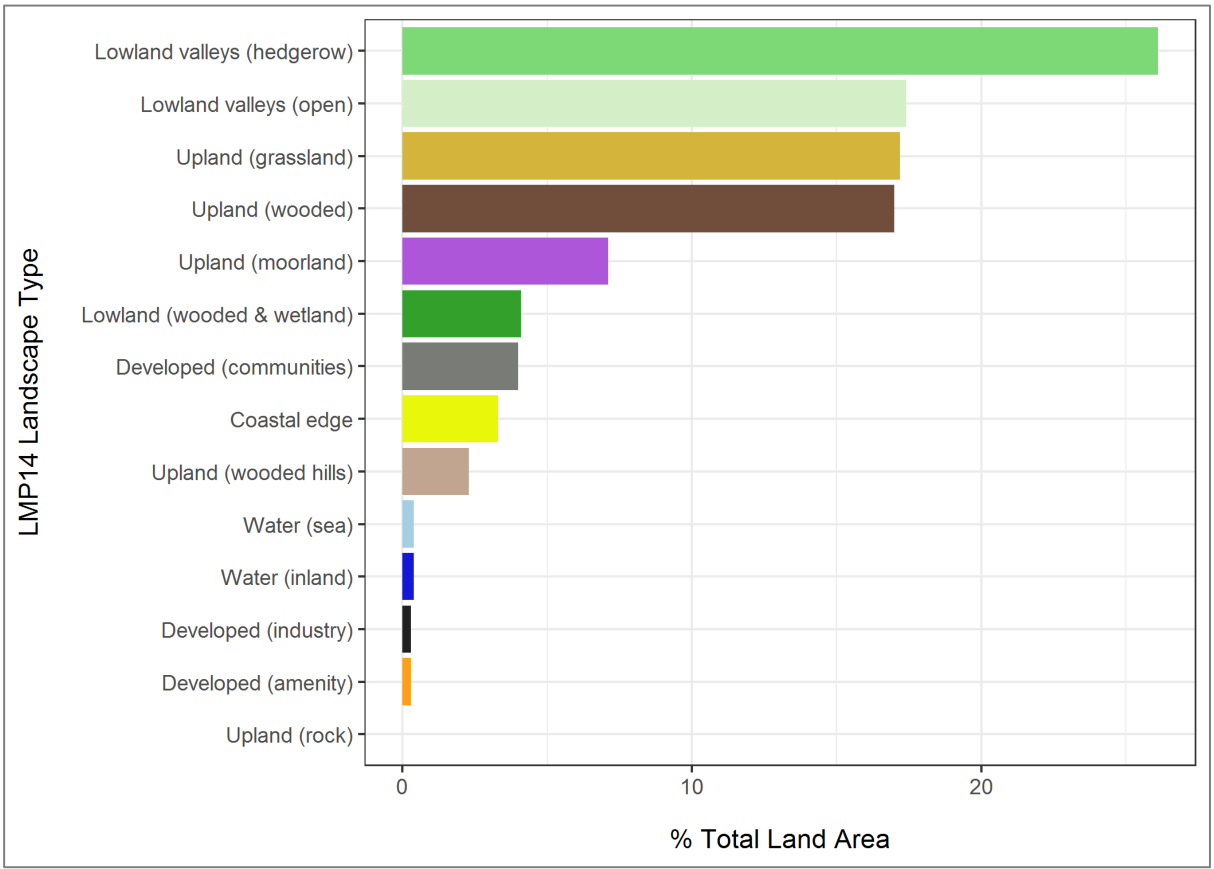

Figure 3.9 Area statistics for LMP14 landscape types (South West Wales NRW Area)

3.6. LMP09 Landscape Classification

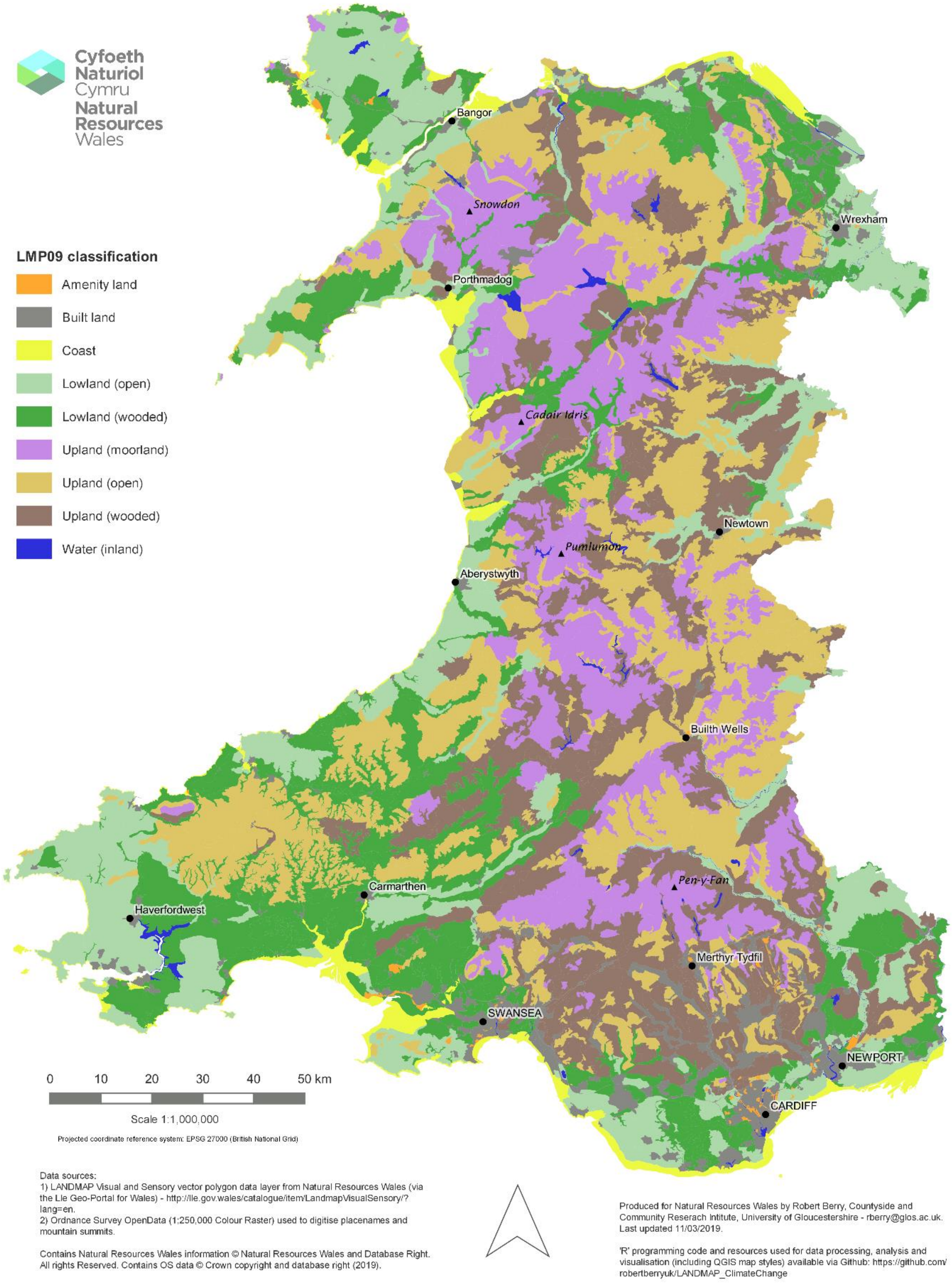

Figure 3.10 LMP09 landscape types (all-Wales)

Table 3.10 Area statistics for LMP09 landscape types (all-Wales)

LMP09 Landscape Type	Area (km^2)	Area (% Total)
Upland (open)	4924.91	23.17
Upland (wooded)	4036.33	18.99
Lowland (wooded)	3698.53	17.4
Lowland (open)	3525.22	16.59
Upland (moorland)	3241.11	15.25
Built land	1042.9	4.91
Coast	627.81	2.95
Water (inland)	106.29	0.5
Amenity land	50.21	0.24

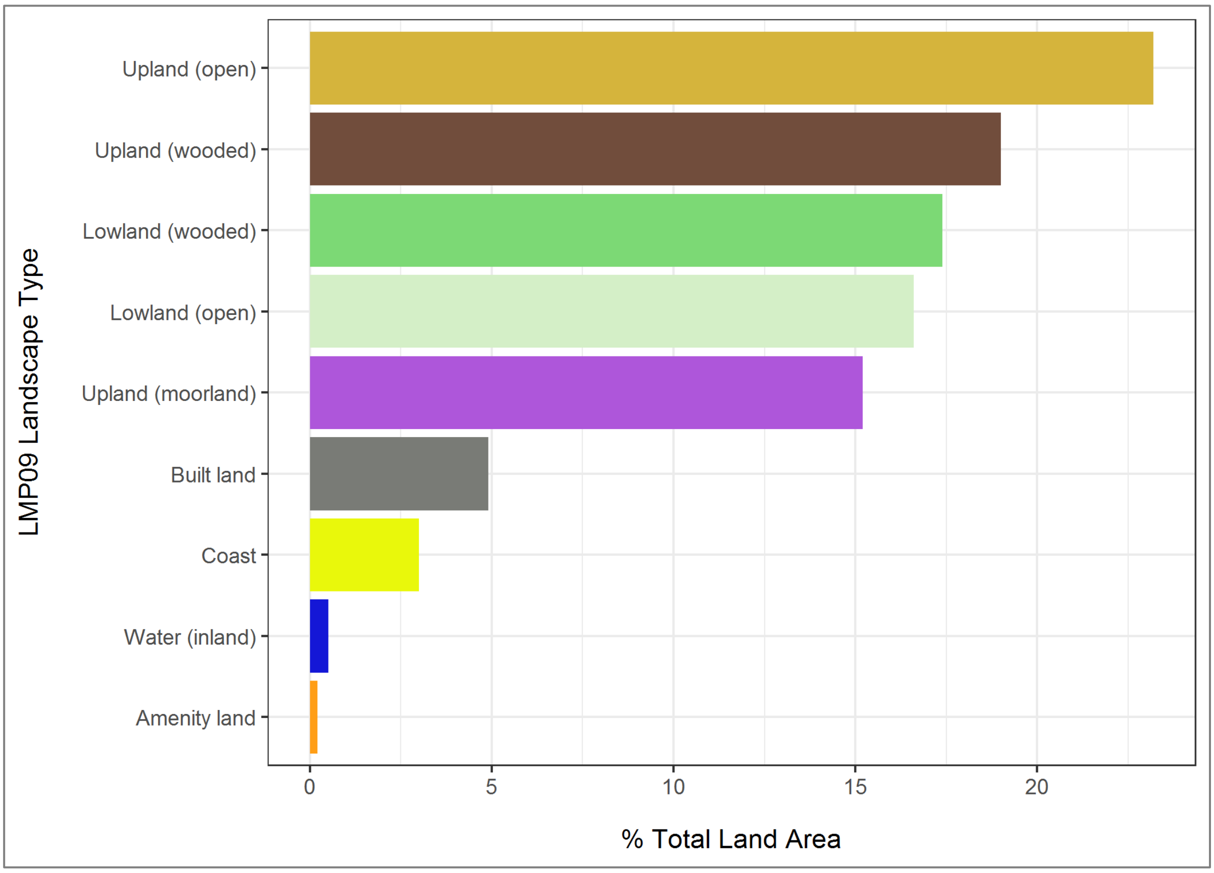

Figure 3.11 Area statistics for LMP09 landscape types (all-Wales)

3.7. +1m Sea Level Rise

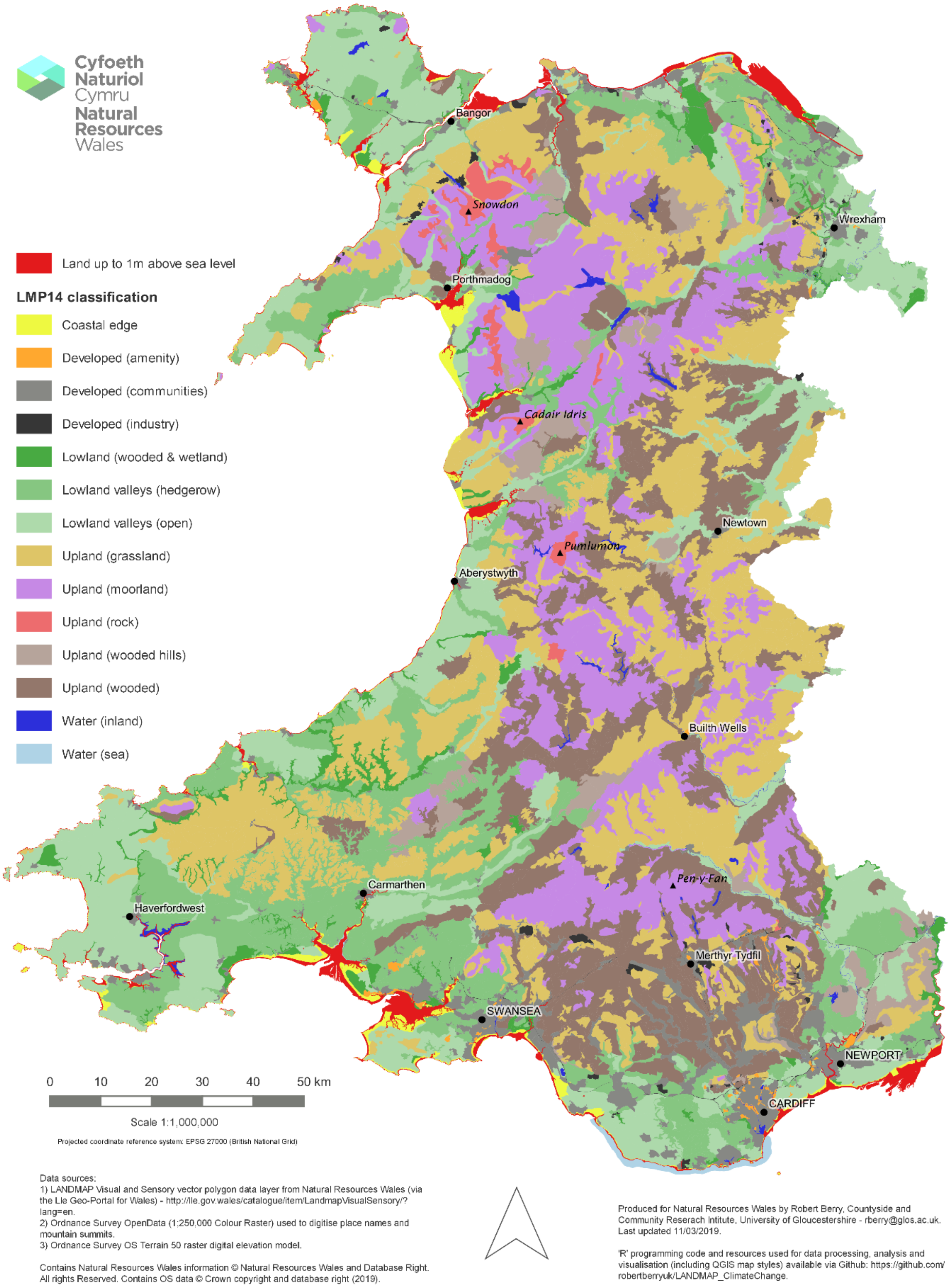

Figure 3.12 LMP14 landscape types with land up to 1m above sea level (all-Wales)

Table 3.11 Area statistics for LMP14 landscapes up to 1m above sea level

LMP14 Landscape Type	Total Area (km^2)	Area <=1m ASL (km^2)	Area <=1m ASL (%)
Coastal edge	520.03	264.92	50.94
Water (sea)	107.78	48.06	44.59
Water (inland)	106.29	14.7	13.83
Lowland (wooded & wetland)	503.26	17.77	3.53
Developed (amenity)	50.21	0.64	1.28
Developed (communities)	950.57	4.75	0.5
Lowland valleys (open)	3525.22	11.91	0.34
Developed (industry)	92.33	0.28	0.31
Lowland valleys (hedgerow)	3195.27	2.05	0.06
Upland (grassland)	4924.91	0.36	0.01
Upland (wooded)	3343.7	0.36	0.01
Upland (moorland)	3068.68	0.03	0
Upland (wooded hills)	692.63	0.02	0
Upland (rock)	172.43	0	0

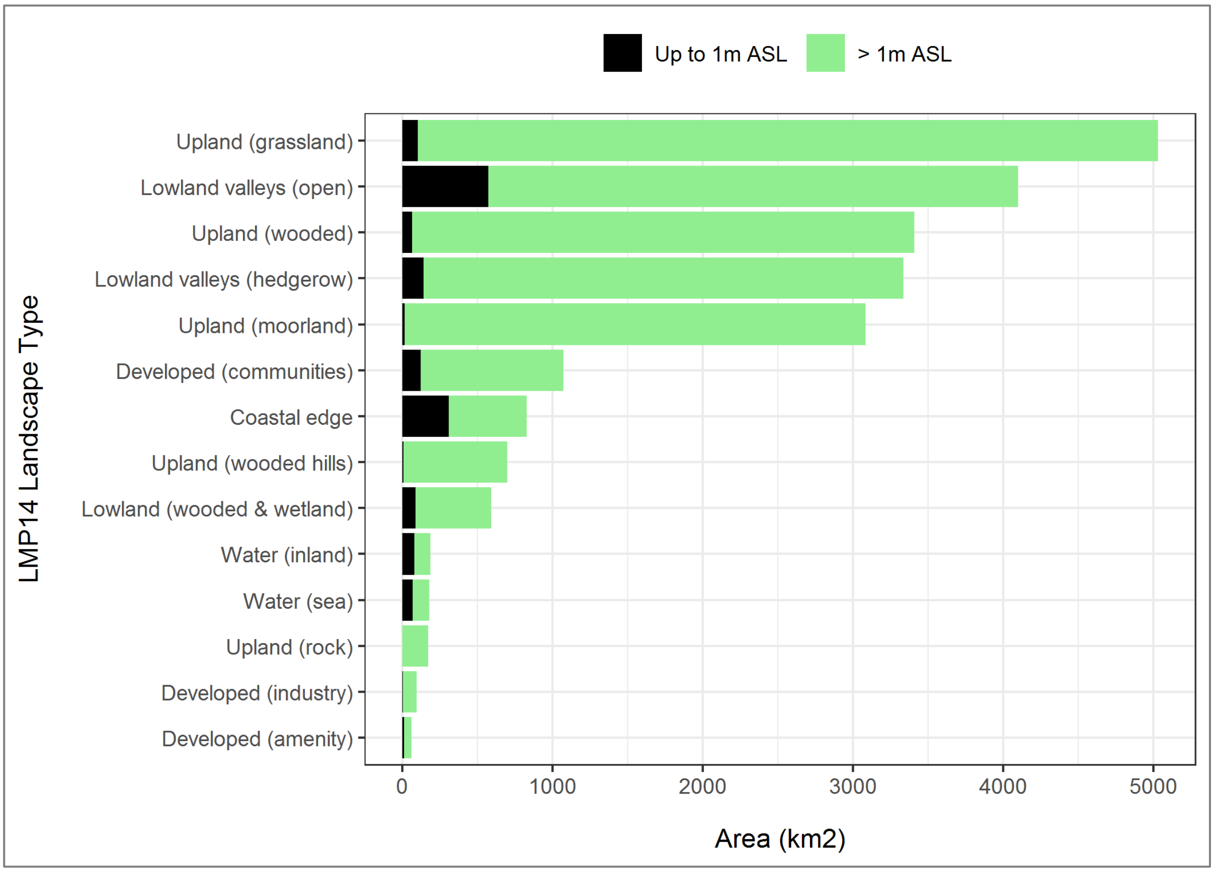

Figure 3.13 Area statistics for LMP14 landscapes up to 1m above sea level

3.8. Flood Zone 2

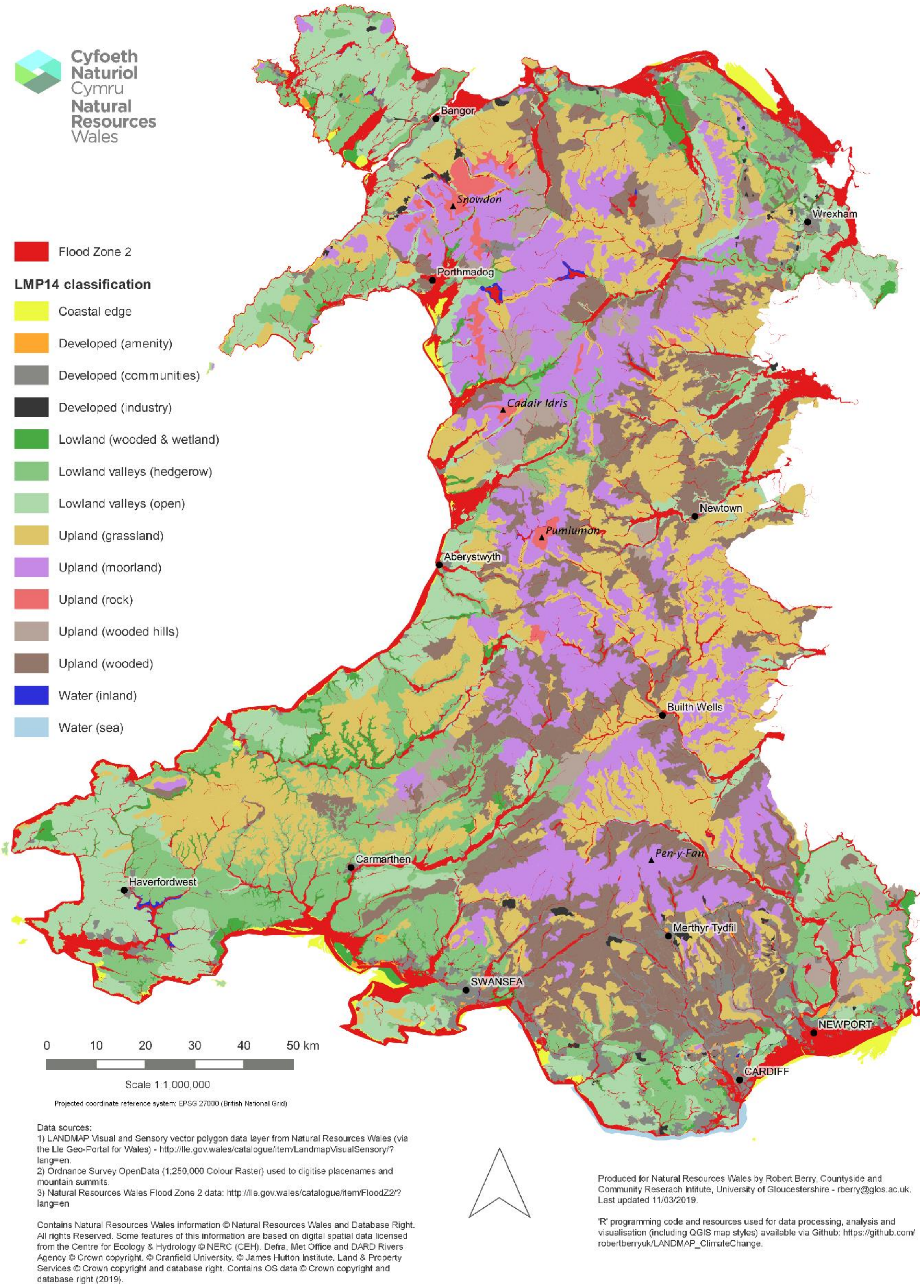

Figure 3.14 LMP14 landscape types with Flood Zone 2 (all-Wales)

Table 3.12 Area statistics for LMP14 landscapes and Flood Zone 2

LMP14 Landscape Type	Total Area (km^2)	Area Non-Flood Zone 2 (km^2)	Area Flood Zone 2 (% total per LMP14 type)
Water (inland)	106.29	82.99	78.08
Water (sea)	107.78	69.4	64.39
Coastal edge	520.03	313.7	60.32
Developed (amenity)	50.21	12.68	25.26
Lowland (wooded & wetland)	503.26	98.12	19.5
Lowland valleys (open)	3525.22	628.19	17.82
Developed (communities)	950.57	159.67	16.8
Lowland valleys (hedgerow)	3195.27	168.69	5.28
Developed (industry)	92.33	4.68	5.07
Upland (grassland)	4924.91	120.03	2.44
Upland (wooded)	3343.7	75.6	2.26
Upland (wooded hills)	692.63	7.69	1.11
Upland (moorland)	3068.68	16.62	0.54
Upland (rock)	172.43	0.58	0.34

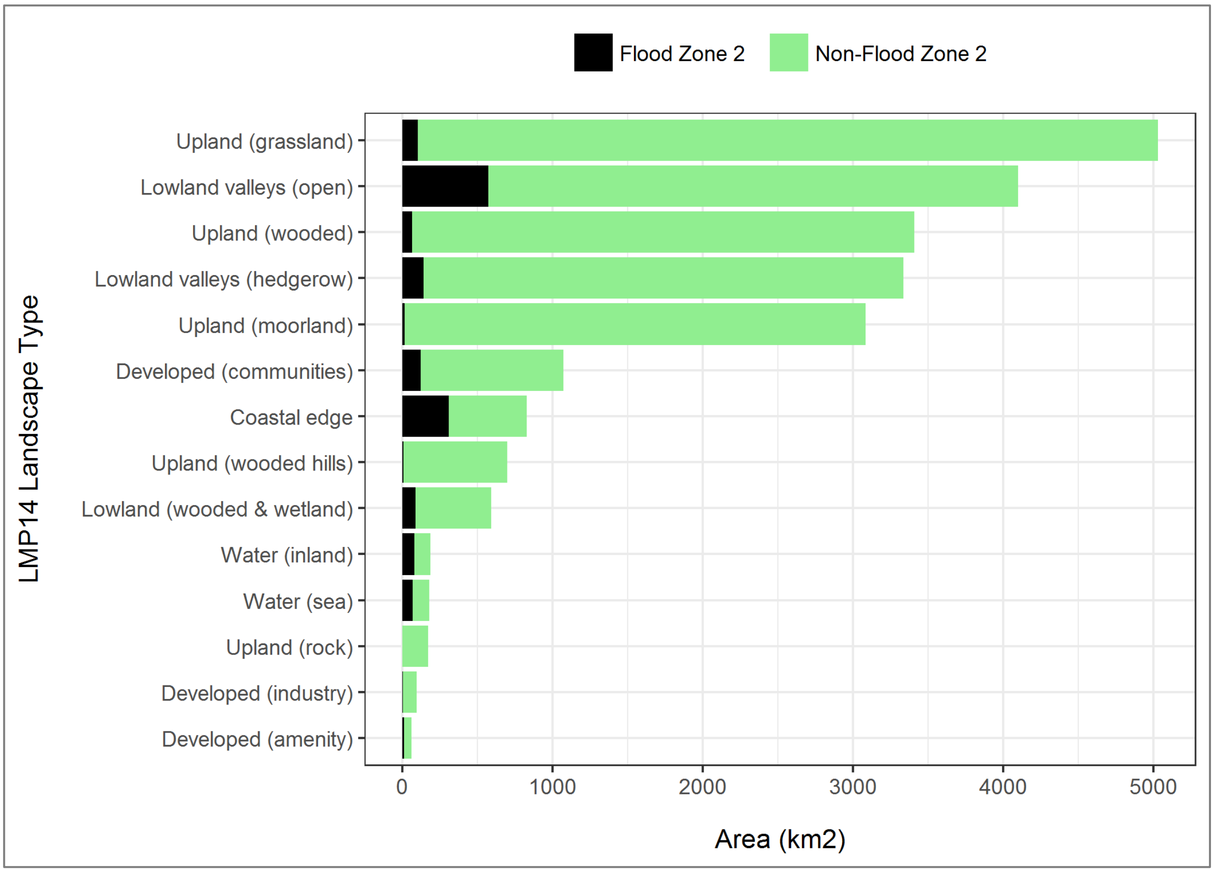

Figure 3.15 Area statistics for LMP14 landscapes and Flood Zone 2

3.9. Flood Zone 3

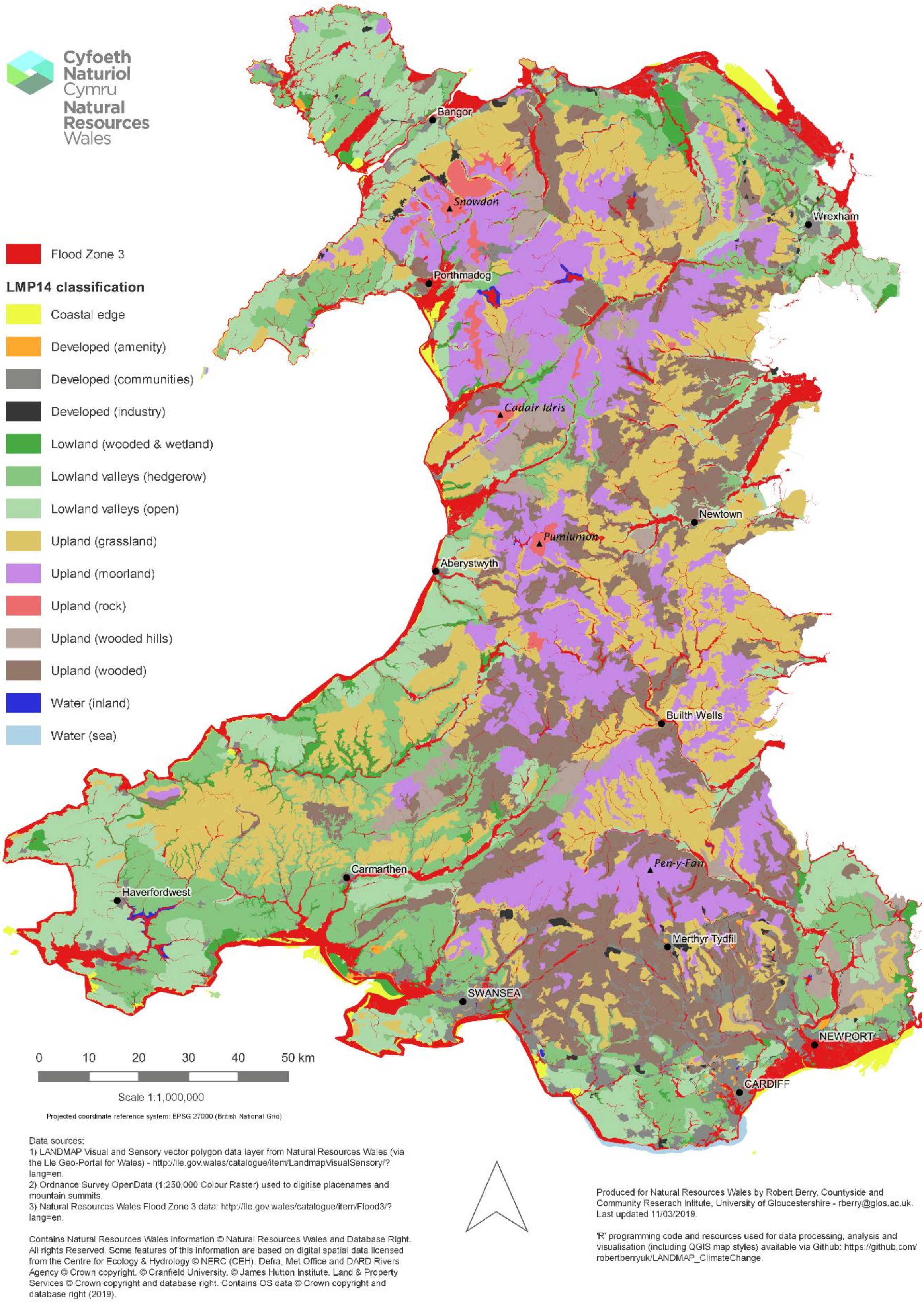

Figure 3.16 LMP14 landscape types with Flood Zone 3 (all-Wales)

Table 3.13 Area statistics for LMP14 landscapes and Flood Zone 3

LMP14 Landscape Type	**Total Area (km^2)**	**Area Non-Flood Zone 3 (km^2)**	**Area Flood Zone 3 (% total per LMP14 type)**
Water (inland)	106.29	80.32	75.57
Water (sea)	107.78	69.26	64.26
Coastal edge	520.03	307.99	59.22
Developed (amenity)	50.21	10.52	20.96
Lowland (wooded & wetland)	503.26	86.77	17.24
Lowland valleys (open)	3525.22	572.63	16.24
Developed (communities)	950.57	121.16	12.75
Lowland valleys (hedgerow)	3195.27	139.86	4.38
Developed (industry)	92.33	3.71	4.02
Upland (grassland)	4924.91	104.06	2.11
Upland (wooded)	3343.7	63.8	1.91
Upland (wooded hills)	692.63	6.68	0.96
Upland (moorland)	3068.68	14.78	0.48
Upland (rock)	172.43	0.48	0.28

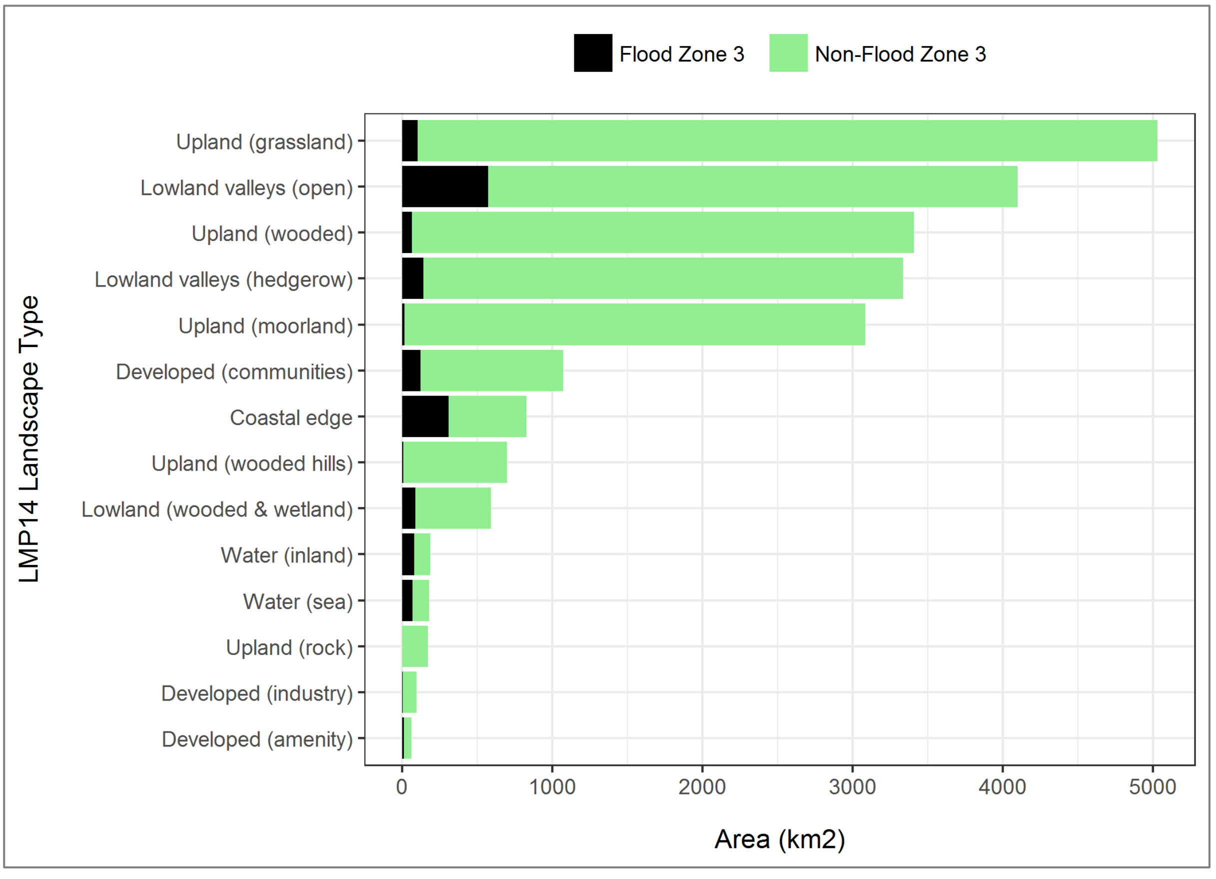

Figure 3.17 Area statistics for LMP14 landscapes and Flood Zone 3

3.10. Boundary Type

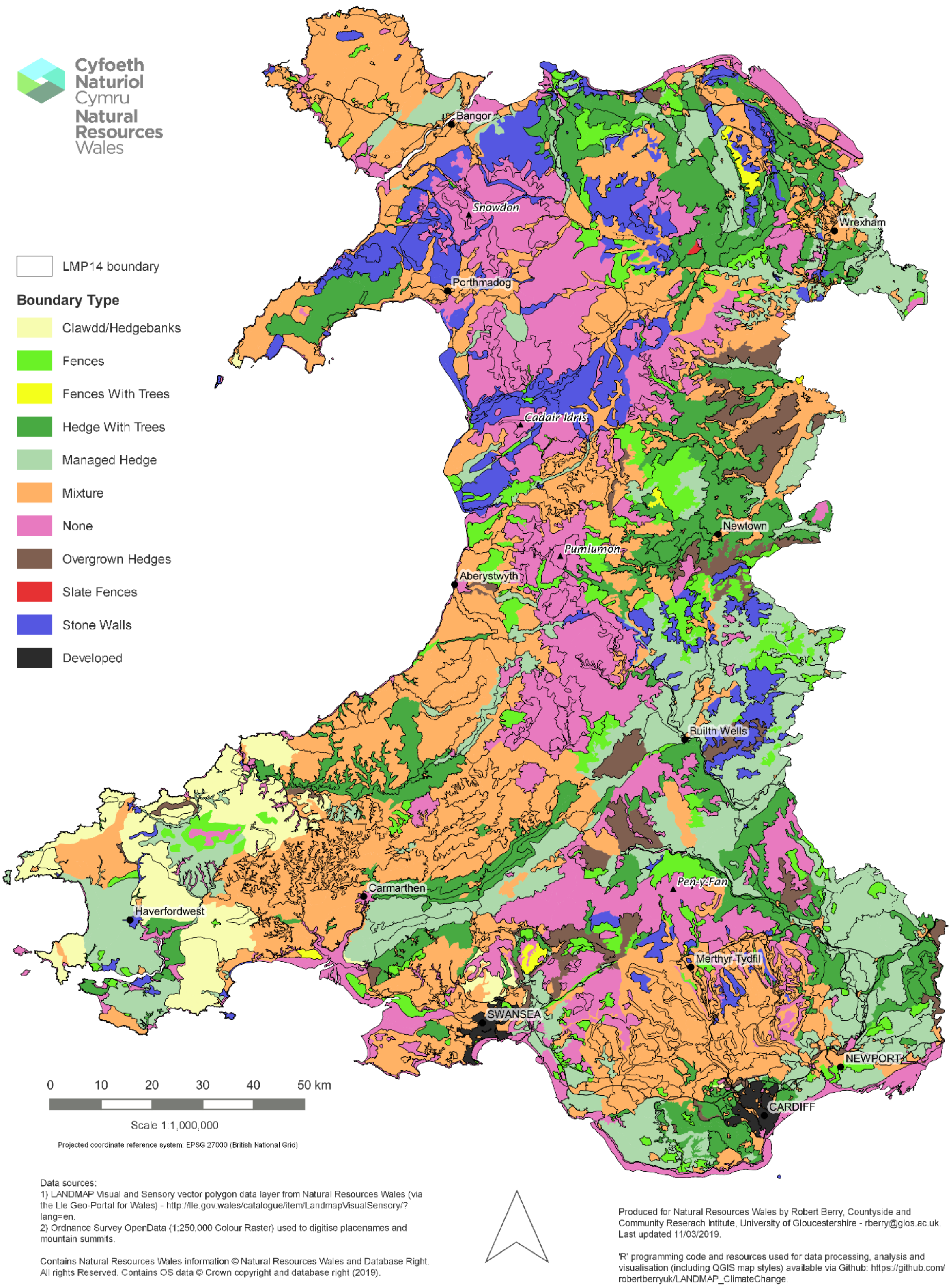

Figure 3.17 Predominant boundary type with LMP14 landscape boundaries (all-Wales)

Table 3.14 Area statistics for LMP14 landscapes by boundary type (km^2)

LMP14 Landscape Type	**Clawdd/Hedgebanks**	**Developed**	**Fences**	**Fences With Trees**	**Hedge With Trees**	**Managed Hedge**	**Mixture**	**None**	**Overgrown Hedges**	**Slate Fences**	**Stone Walls**
Coastal edge	0	0	9.02	0	0	0	4.82	459.12	0	0	47.07
Developed (amenity)	0	0	10.84	0	0	0	31.25	7.45	0	0	0.67
Developed (communities)	0	950.57	0	0	0	0	0	0	0	0	0
Developed (industry)	0	0	46.91	2.51	0.28	0	20.99	20.83	0	0	0.81
Lowland (wooded & wetland)	14.56	0	41.2	0	150.93	74.74	84.16	72.96	37.84	0	26.87
Lowland valleys (hedgerow)	303.13	0	0	0	975.77	488.71	1347.7	0	10.15	0	69.81
Lowland valleys (open)	354.22	0	71.51	7.22	264.74	1239.7	1486.03	47.89	26.23	0	27.68
Upland (grassland)	201.78	0	482.28	18.09	573.85	1015.6	1643.24	160.61	308.32	3.53	517.61
Upland (moorland)	9.84	0	42.02	22.23	9.77	0	150.52	2200.89	0	0	633.41
Upland (rock)	0	0	0	0	0	0	0	172.43	0	0	0
Upland (wooded hills)	0	0	16.53	0	124.27	103.43	147.68	297.06	3.66	0	0
Upland (wooded)	14.2	0	356.13	7.61	718.46	392.94	1045.11	427.36	277.28	0	104.61
Water (inland)	0	0	12.24	0	0	1.33	23.33	69.12	0	0	0.27
Water (sea)	0	0	0	0	0	0	0	95.53	0	0	12.25

Table 3.15 Area statistics for LMP14 landscapes by boundary type (% of total LMP14 type)

LMP14 Landscape Type	**Clawdd/Hedgebanks**	**Developed**	**Fences**	**Fences With Trees**	**Hedge With Trees**	**Managed Hedge**	**Mixture**	**None**	**Overgrown Hedges**	**Slate Fences**	**Stone Walls**
Coastal edge	0	0	1.73	0	0	0	0.93	88.29	0	0	9.05
Developed (amenity)	0	0	21.59	0	0	0	62.24	14.84	0	0	1.33
Developed (communities)	0	100	0	0	0	0	0	0	0	0	0
Developed (industry)	0	0	50.81	2.72	0.3	0	22.73	22.56	0	0	0.88
Lowland (wooded & wetland)	2.89	0	8.19	0	29.99	14.85	16.72	14.5	7.52	0	5.34
Lowland valleys (hedgerow)	9.49	0	0	0	30.54	15.29	42.18	0	0.32	0	2.18
Lowland valleys (open)	10.05	0	2.03	0.2	7.51	35.17	42.15	1.36	0.74	0	0.79
Upland (grassland)	4.1	0	9.79	0.37	11.65	20.62	33.37	3.26	6.26	0.07	10.51
Upland (moorland)	0.32	0	1.37	0.72	0.32	0	4.91	71.72	0	0	20.64
Upland (rock)	0	0	0	0	0	0	0	100	0	0	0
Upland (wooded hills)	0	0	2.39	0	17.94	14.93	21.32	42.89	0.53	0	0
Upland (wooded)	0.42	0	10.65	0.23	21.49	11.75	31.26	12.78	8.29	0	3.13
Water (inland)	0	0	11.52	0	0	1.25	21.95	65.03	0	0	0.25
Water (sea)	0	0	0	0	0	0	0	88.63	0	0	11.37

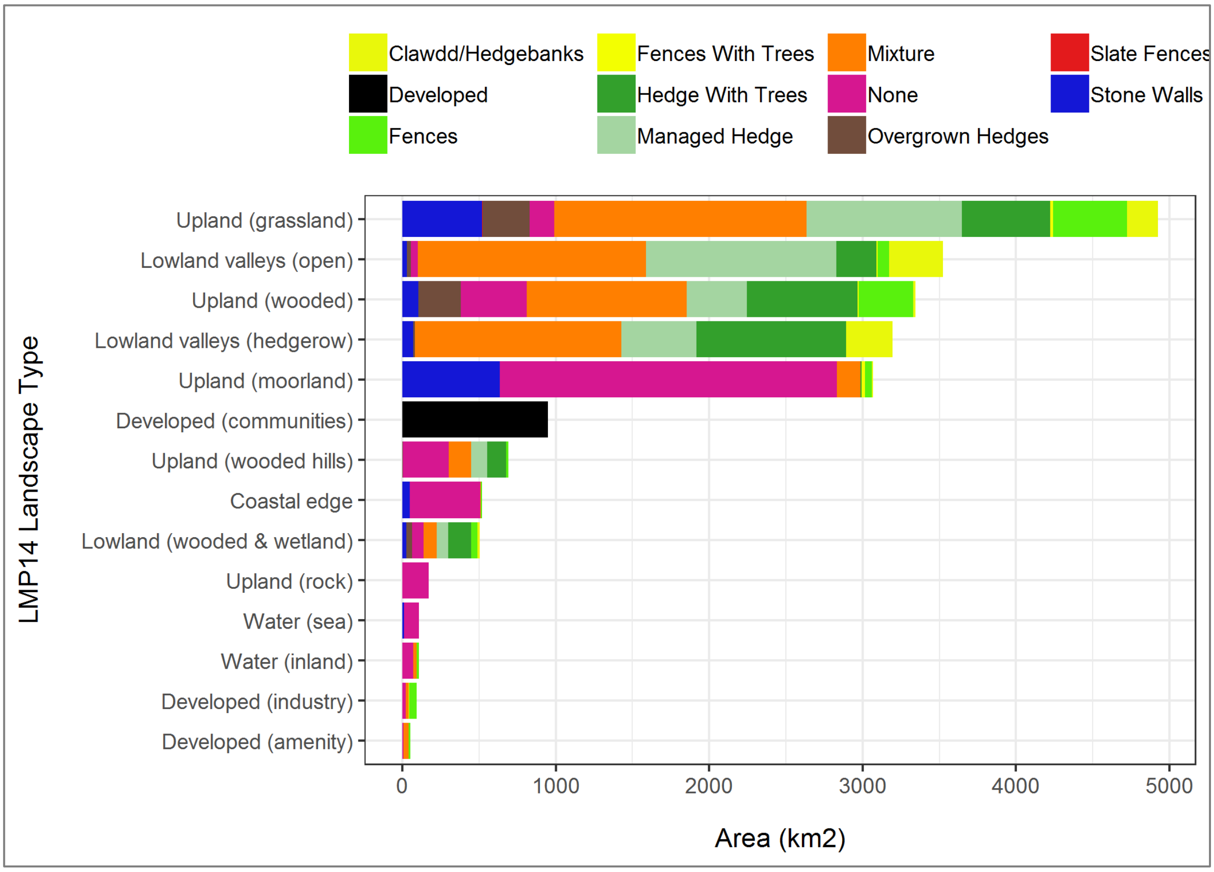

Figure 3.18 Area statistics for LMP14 landscapes by boundary type

3.11. Landscape Value

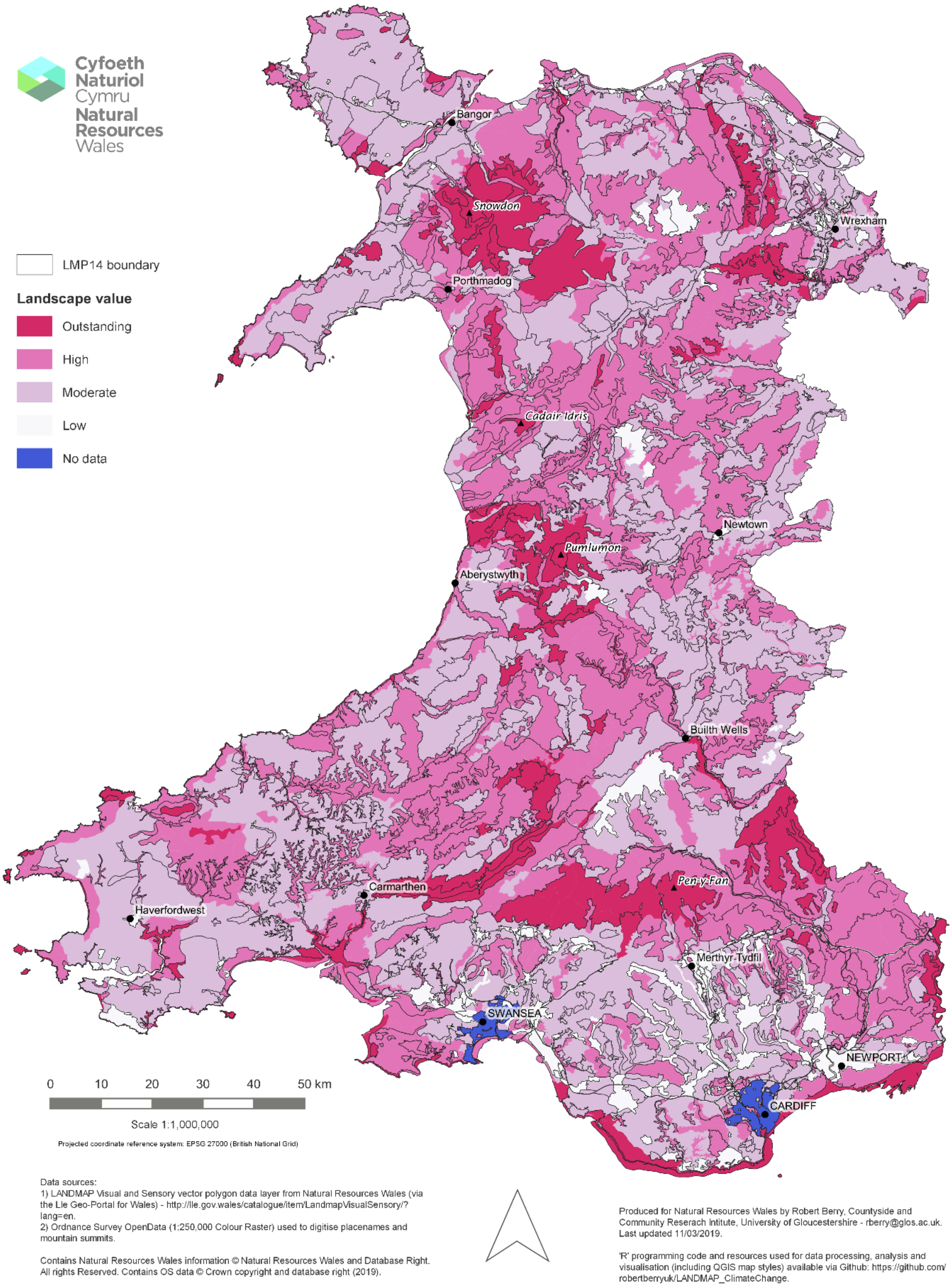

Figure 3.19 Overall landscape value with LMP14 landscape boundaries (all-Wales)

Table 3.16 Area statistics for LMP14 landscapes by landscape value (km^2)

LMP14 Landscape Type	Developed	Low	Moderate	High	Outstanding
Coastal edge	0	0	43.93	293.49	182.61
Developed (amenity)	0	10.19	34.28	4.27	1.47
Developed (communities)	950.57	0	0	0	0
Developed (industry)	0	72.66	5.31	12.67	1.69
Lowland (wooded & wetland)	0	10.1	84.61	358.85	49.7
Lowland valleys (hedgerow)	0	8.55	1684.51	1295.74	206.47
Lowland valleys (open)	0	39.2	2331.69	992.72	161.61
Upland (grassland)	0	29.24	3067.52	1738.39	89.76
Upland (moorland)	0	87.32	306.73	1621.9	1052.73
Upland (rock)	0	0	1.14	0.1	171.19
Upland (wooded hills)	0	42.53	240.53	381.54	28.03
Upland (wooded)	0	99.15	1515.47	1536.67	192.41
Water (inland)	0	0	31.31	31.11	43.87
Water (sea)	0	0	0	21.04	86.74

Table 3.17 Area statistics for LMP14 landscapes by landscape value (% total LMP type)

LMP14 Landscape Type	Developed	Low	Moderate	High	Outstanding
Coastal edge	0	0	8.45	56.44	35.12
Developed (amenity)	0	20.29	68.27	8.5	2.93
Developed (communities)	100	0	0	0	0
Developed (industry)	0	78.7	5.75	13.72	1.83
Lowland (wooded & wetland)	0	2.01	16.81	71.31	9.88
Lowland valleys (hedgerow)	0	0.27	52.72	40.55	6.46
Lowland valleys (open)	0	1.11	66.14	28.16	4.58
Upland (grassland)	0	0.59	62.29	35.3	1.82
Upland (moorland)	0	2.85	10	52.85	34.31
Upland (rock)	0	0	0.66	0.06	99.28
Upland (wooded hills)	0	6.14	34.73	55.09	4.05
Upland (wooded)	0	2.97	45.32	45.96	5.75
Water (inland)	0	0	29.46	29.27	41.27
Water (sea)	0	0	0	19.52	80.48

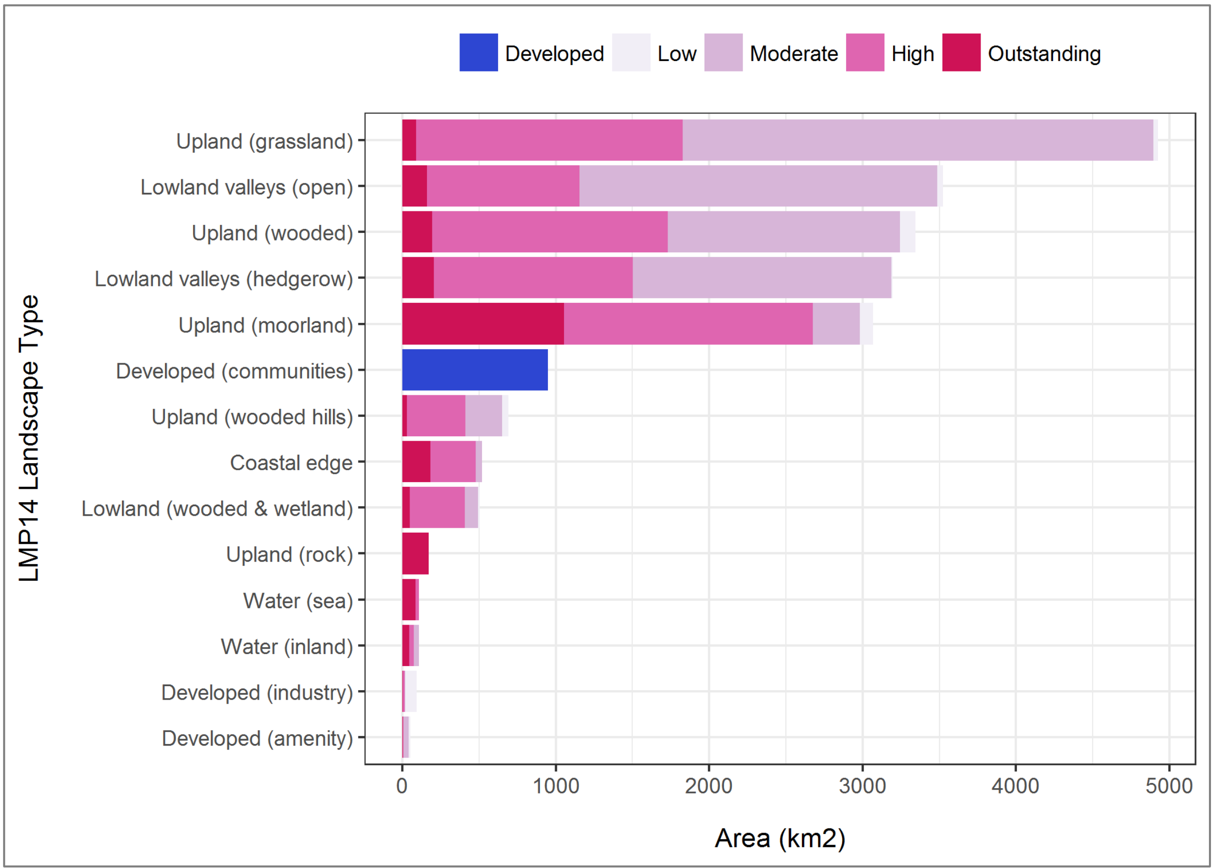

Figure 3.20 Area statistics for LMP14 landscapes by landscape value

4. GIS Maps: Local Authority-Level

4.1. Introduction

This section presents the results of the second part of mapping and statistics task, meeting the following project objective:

- Produce a series of thematic maps showing the newly derived broad landscape types and their spatial relationship to selected geographical boundaries and features, for the following local authorities in Wales:
    - Blaenau Gwent
    - Caerphilly
    - Ceredigion
    - Denbighshire
    - Monmouthshire
    - Newport
    - Torfaen

The local authority-level maps followed the same themes as the national-level maps. Therefore, the following maps were produced for each local authority:

- **Map 1**: LMP14 landscape types.
- **Map 2**: LMP14 landscape types with NRW Operational Areas overlaid.
- **Map 3**: LMP09 landscape types.
- **Map 4**: LMP14 landscape types highlighting land less than 1m in attitude (indicating vulnerability to rising sea levels) Note that there are no sea level rise maps for local authorities where they do not have land below 1m above sea level (Blaenau Gwent, Caerphilly and Torfaen).
- **Map 5**: LMP14 landscape types with Flood Zone 2 data[4] overlaid, identifying landscapes at risk of flooding.
- **Map 6**: LMP14 landscape types with Flood Zone 3 data[5] overlaid, identifying landscapes at risk of flooding.
- **Map 7**: LMP14 landscape types showing the predominant boundary types in each landscape type area, derived from the LANDMAP Visual & Sensory spatial dataset.

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[4] Flood Zone 2 - land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% – 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% – 0.1%) in any year.

[5] Flood Zone 3 - land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

4. **Map 8**: LMP14 landscape types showing overall landscape value, derived from the LANDMAP Visual & Sensory spatial dataset.

4.2. Methodology

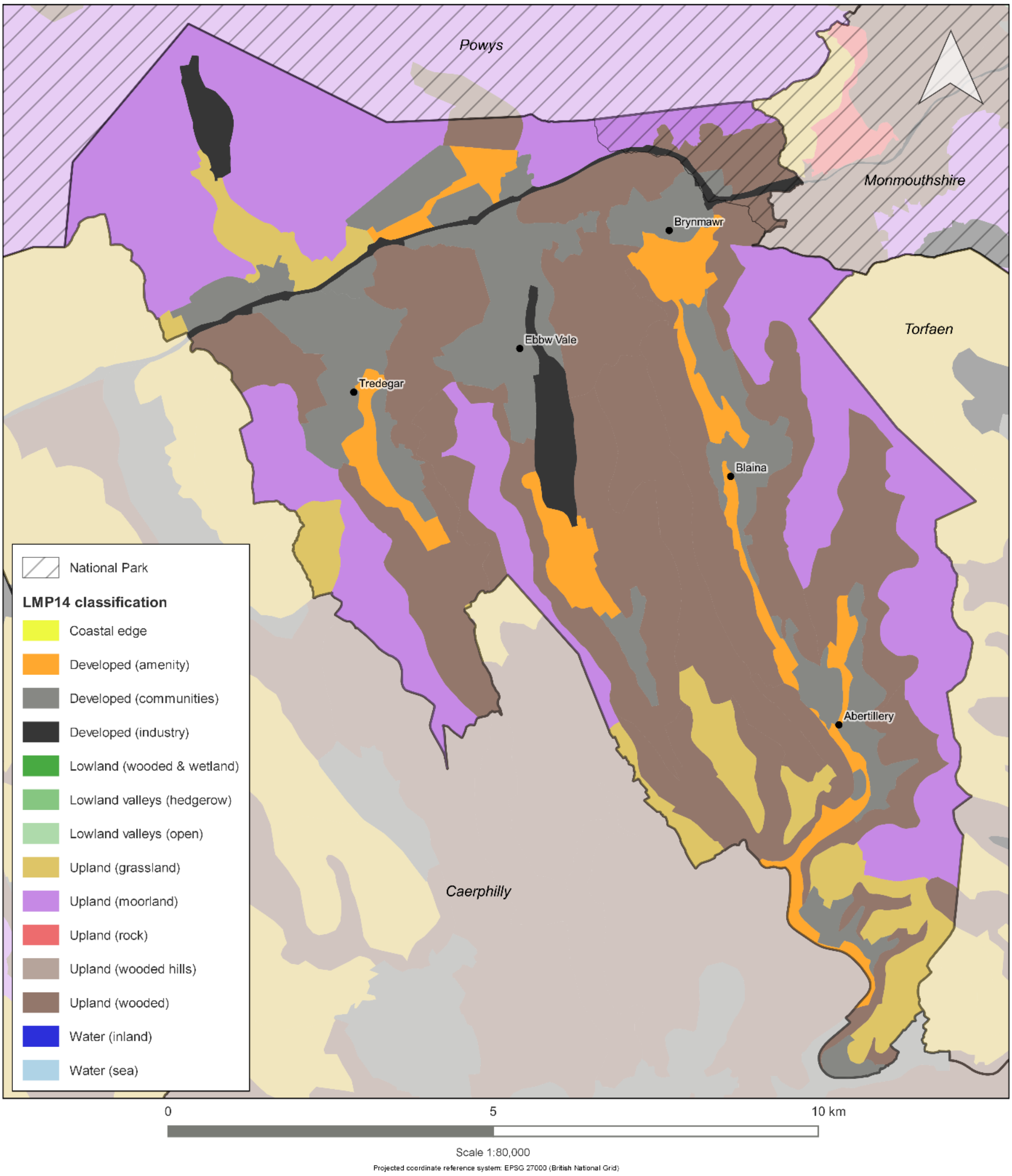
The same software tools (QGIS) and spatial data (with the exception of local authority, National Park and AONB boundaries) used for the national-level mapping were used for producing the local authority-level maps (see Section 3.2.3).

4.3. Section Structure

A total of 53 local authority-level maps are presented in the remainder of this section. Each sub-section shows the series of maps produced for each local authority.

4.4. Blaenau Gwent

LANDMAP Visual & Sensory: LMP14 Classification (Blaenau Gwent)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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Natural Resources Wales

Produced for Natural Resources Wales by Robert Berry, Countyside and Community Reserach Intitute, University of Gloucestershire - rberry@glos.ac.uk. Last updated 11/03/2019.

'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP ClimateChange

Figure 4.1 LMP14 landscape types (Blaenau Gwent)

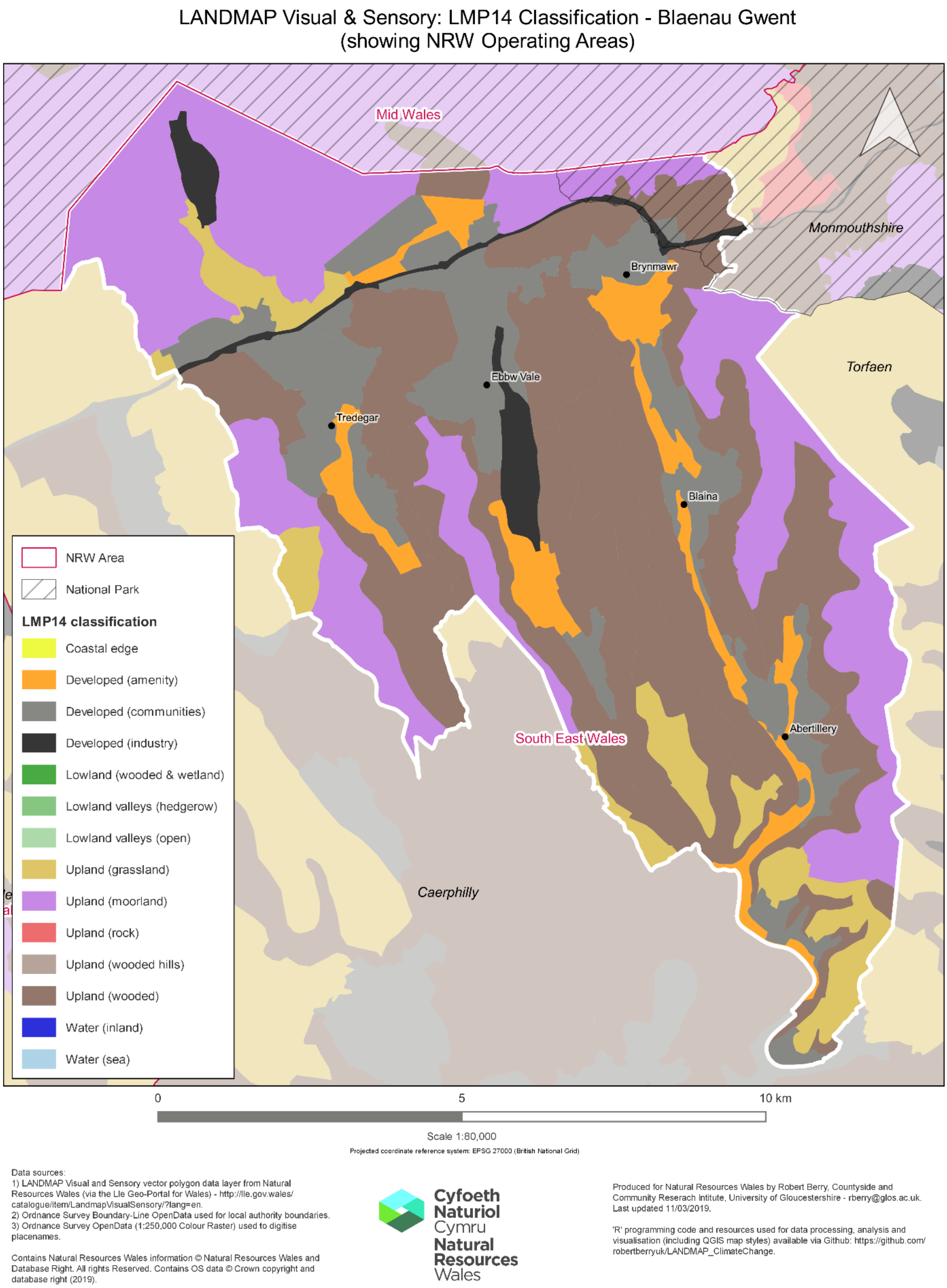
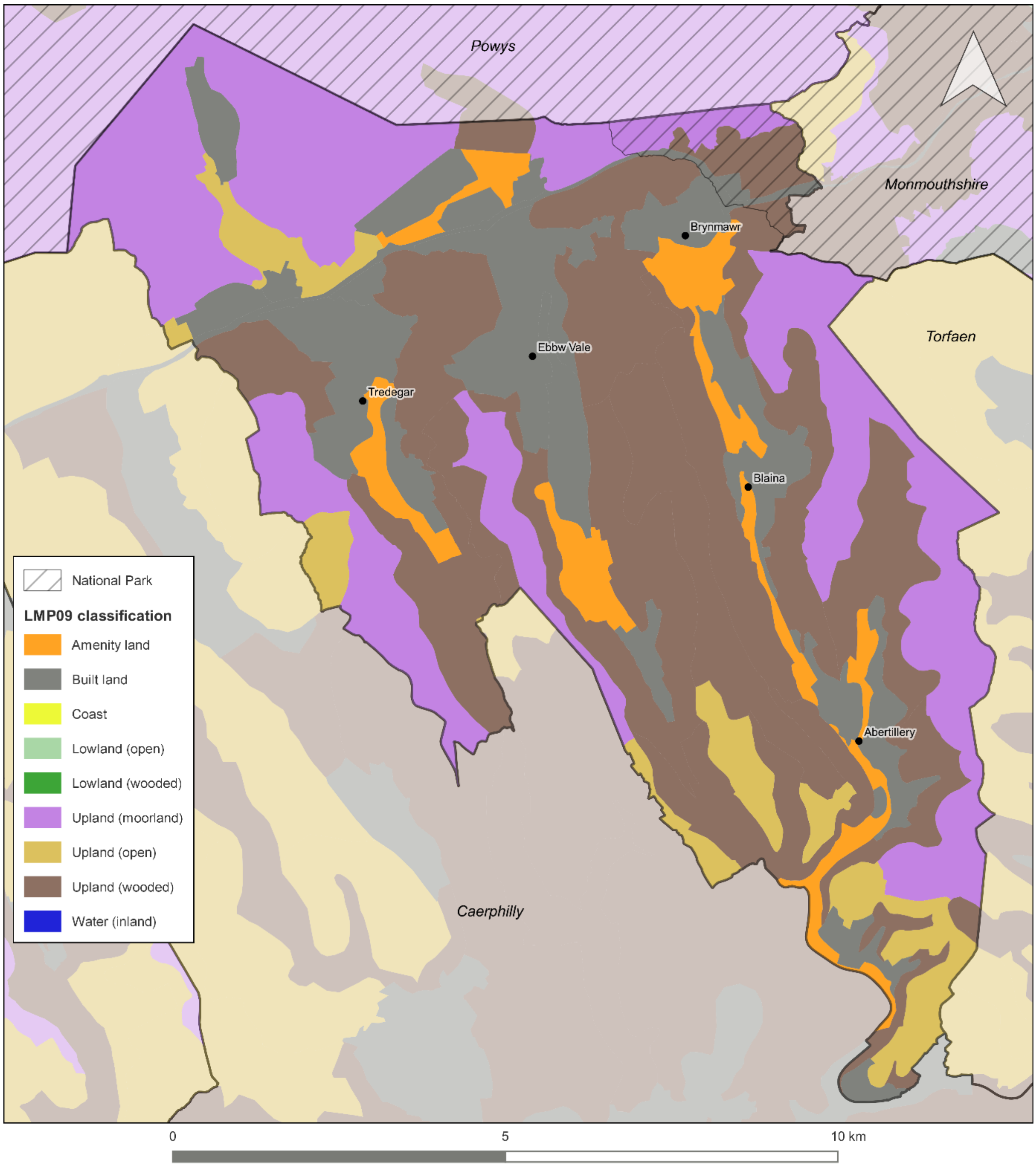


Figure 4.2 LMP14 landscape classification with NRW Operating Areas (Blaenau Gwent)

LANDMAP Visual & Sensory: LMP09 Classification (Blaenau Gwent)



Scale 1:80,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
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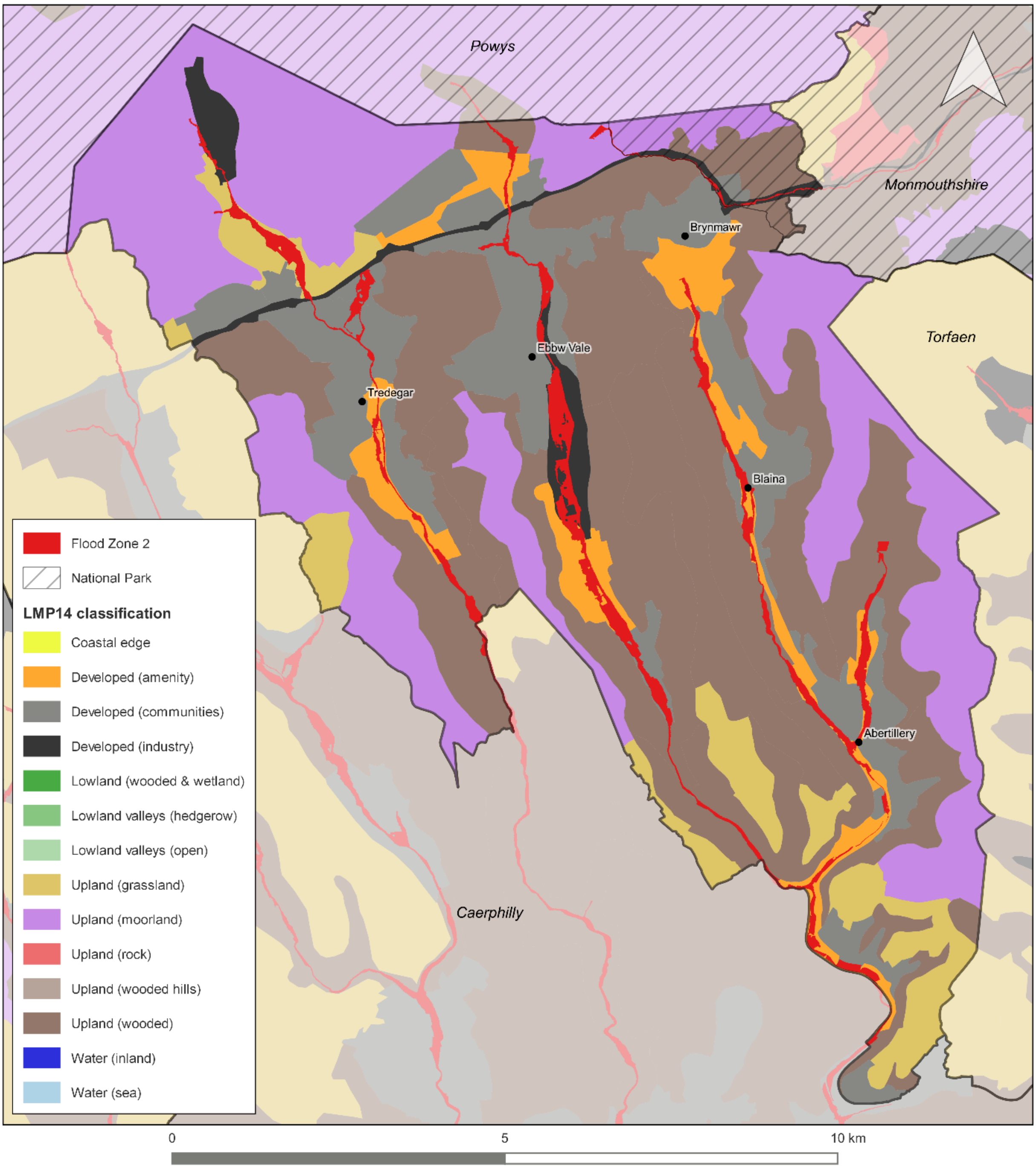
Figure 4.3 LMP09 landscape types (Blaenau Gwent)

LANDMAP Visual & Sensory: LMP14 Classification - Blaenau Gwent
(showing Flood Zone 2 data)



Scale 1:80,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1;250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 2 data: http://lle.gov.wales/catalogue/item/FloodZ2/?lang=en

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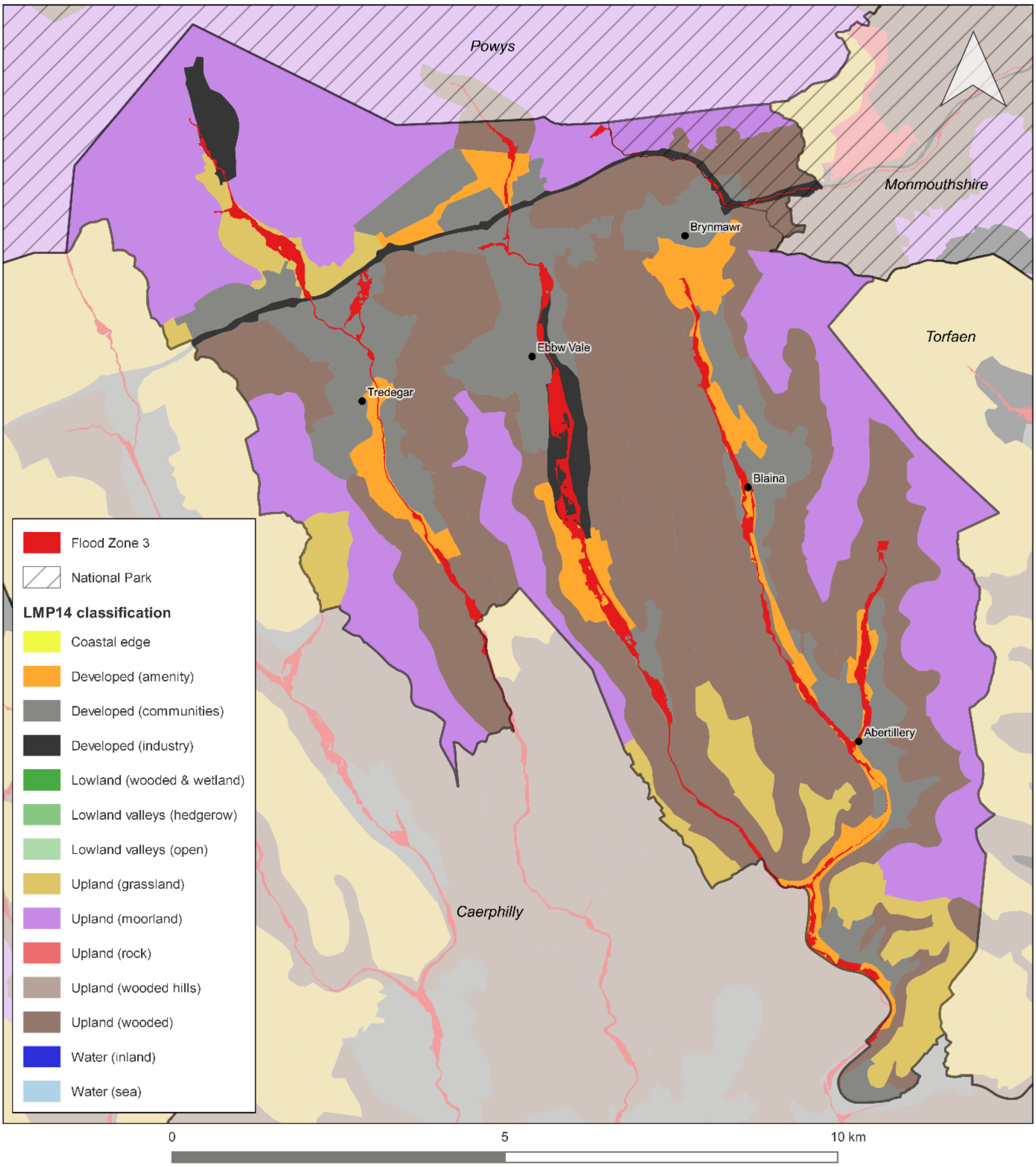
Figure 4.4 LMP14 landscape types with Flood Zone 2 (Blaenau Gwent)

LANDMAP Visual & Sensory: LMP14 Classification - Blaenau Gwent
(showing Flood Zone 3 data)



Scale 1:80,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 3 data: http://lle.gov.wales/catalogue/item/Flood3/?lang=en.

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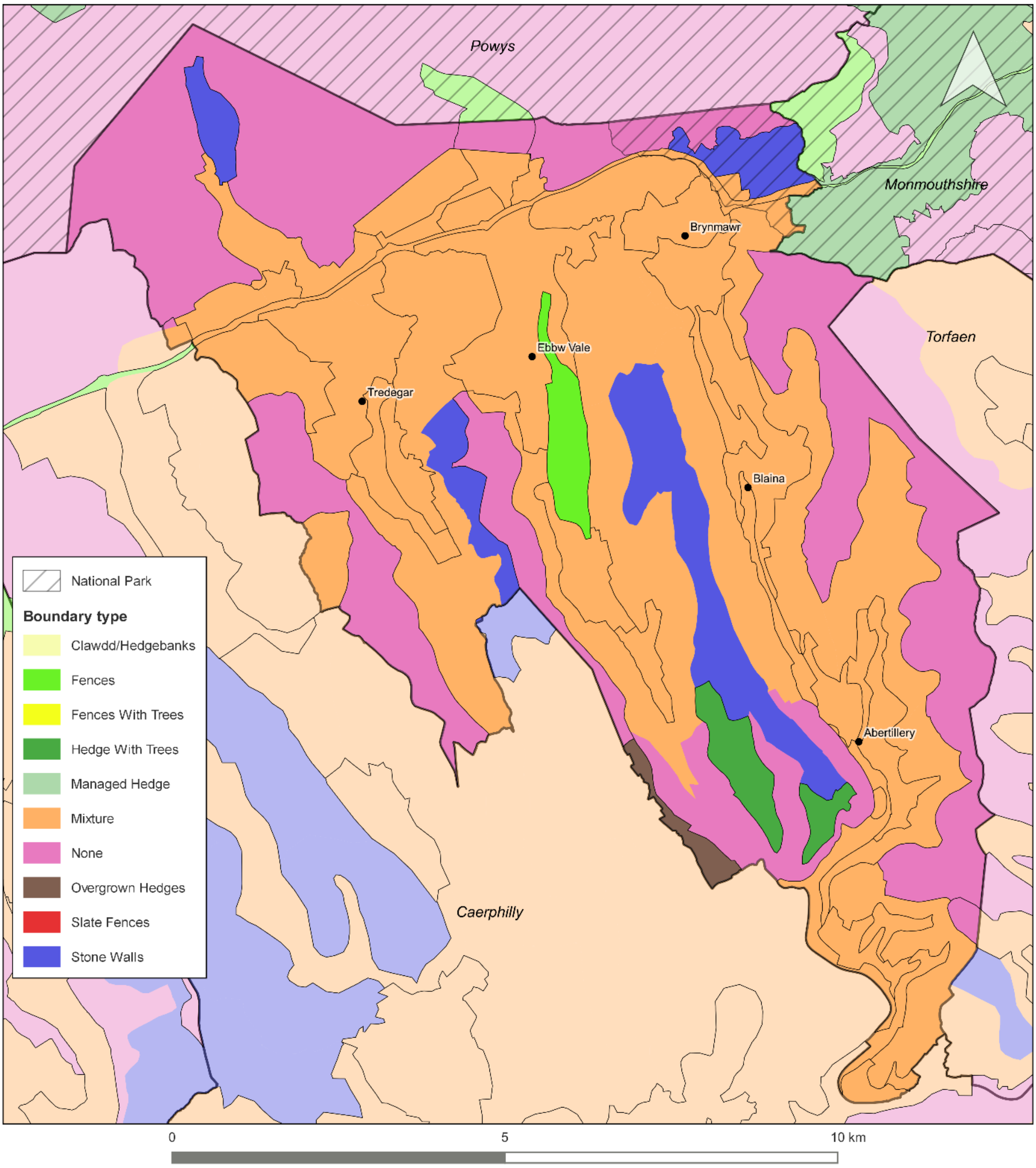
Figure 4.5 LMP14 landscape types with Flood Zone 3 (Blaenau Gwent)

LANDMAP Visual & Sensory: LMP14 Boundary Types - Blaenau Gwent



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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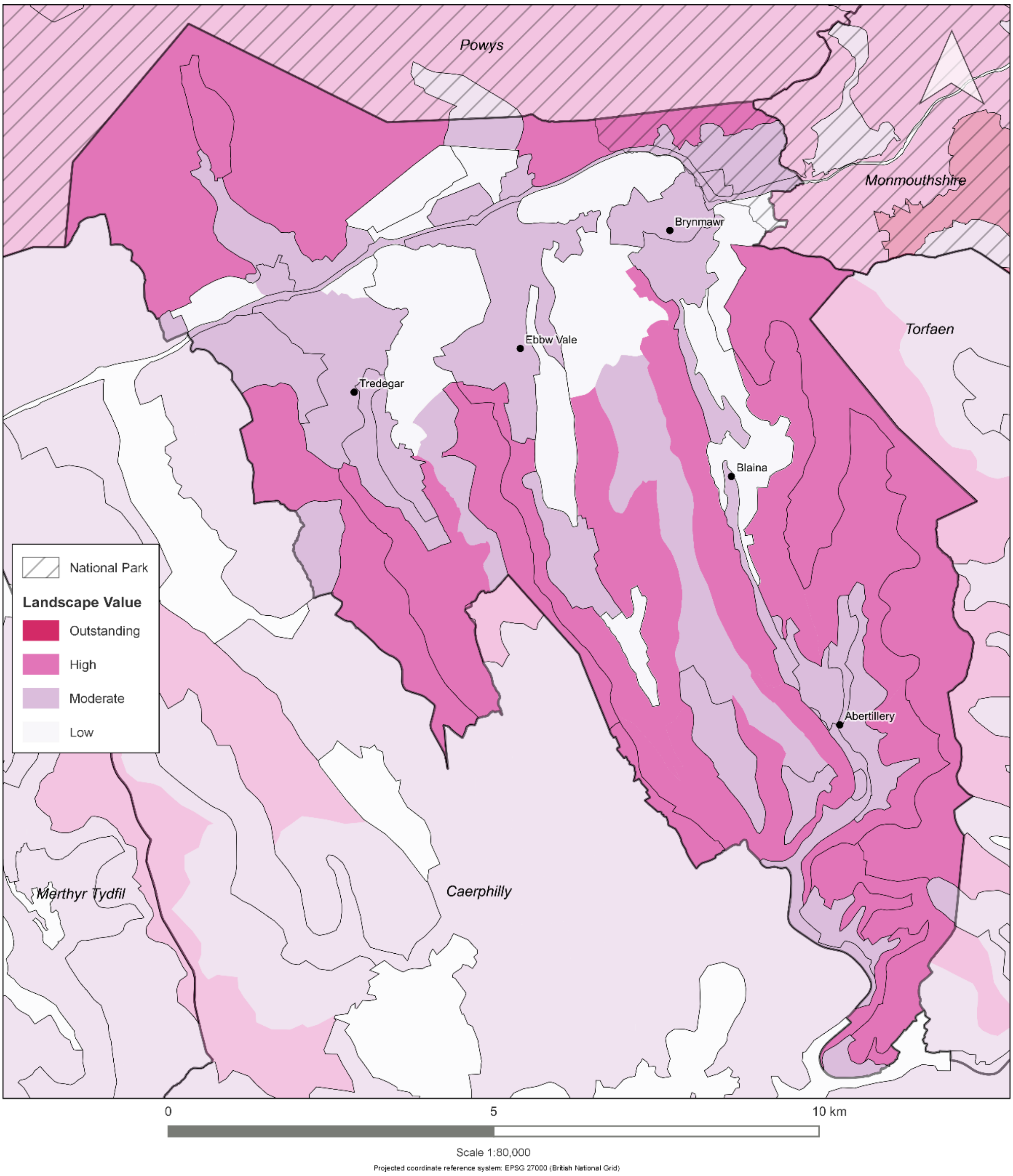
Figure 4.6 Boundary type with LMP14 landscape boundaries (Blaenau Gwent)

LANDMAP Visual & Sensory: LMP14 Landscape Value - Blaenau Gwent



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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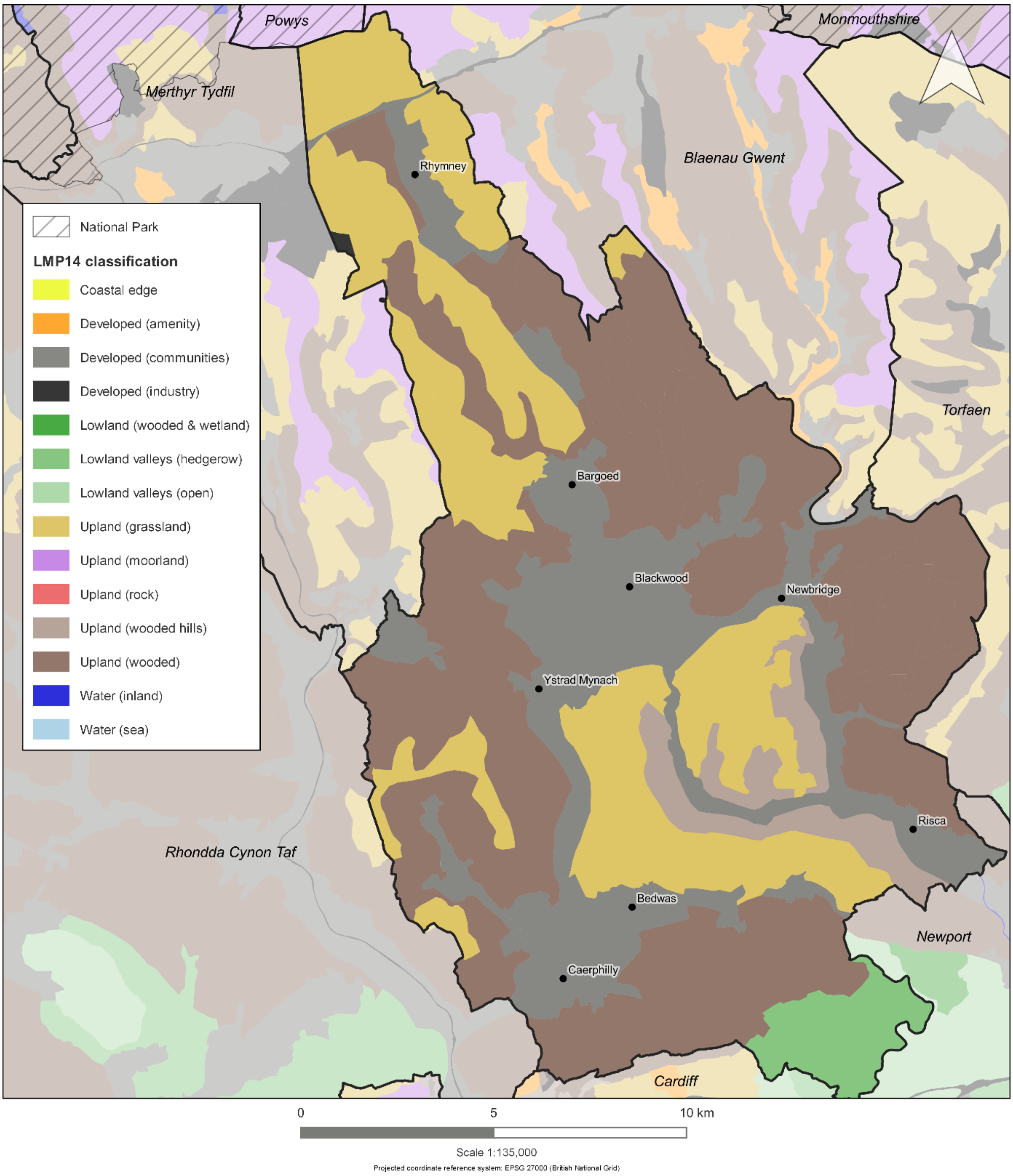
Figure 4.7 Landscape value with LMP14 landscape boundaries (Blaenau Gwent)

4.5. Caerphilly

LANDMAP Visual & Sensory: LMP14 Classification (Caerphilly)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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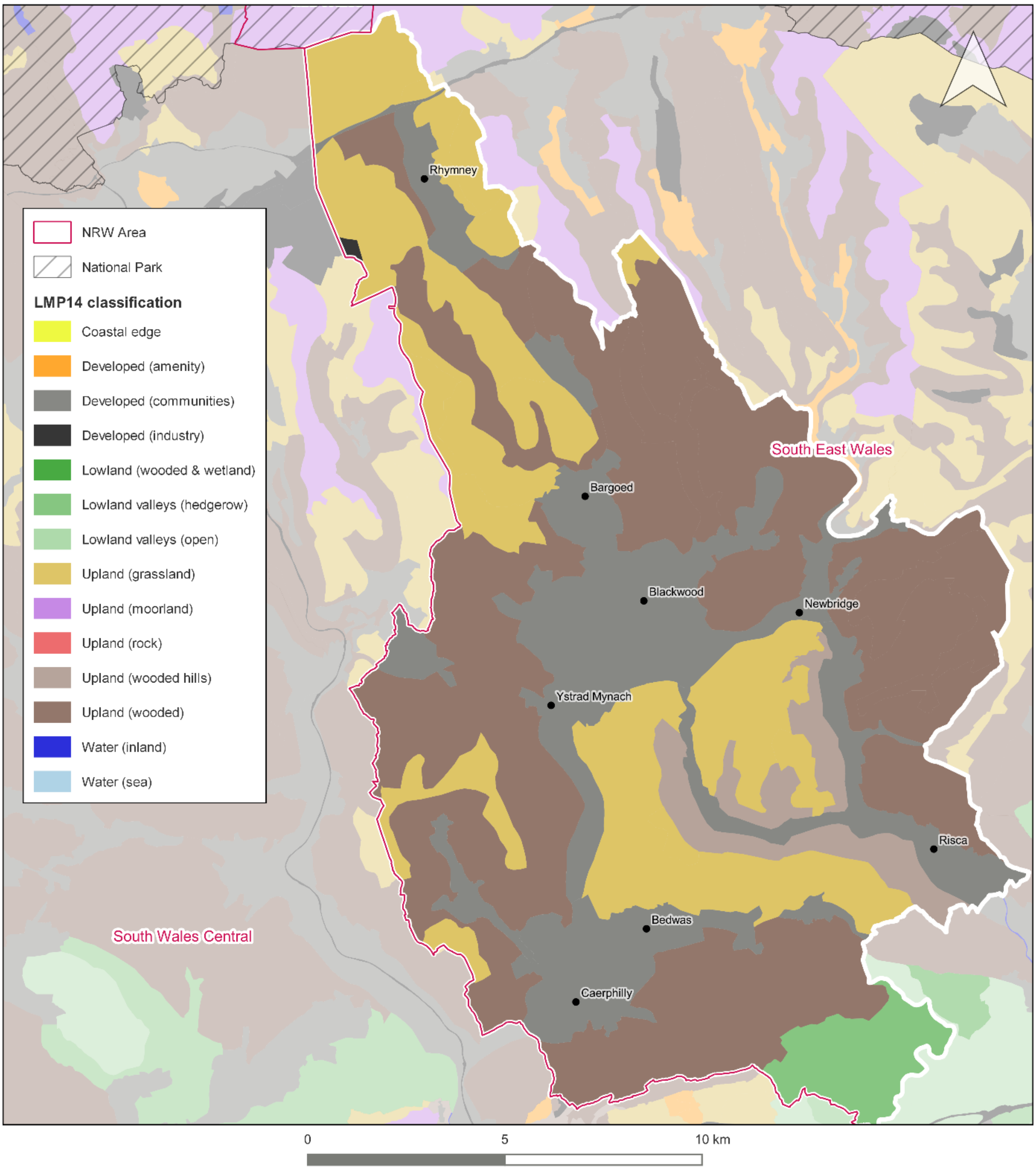
'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.8 LMP14 landscape types (Caerphilly)

LANDMAP Visual & Sensory: LMP14 Classification - Caerphilly
(showing NRW Operating Areas)



Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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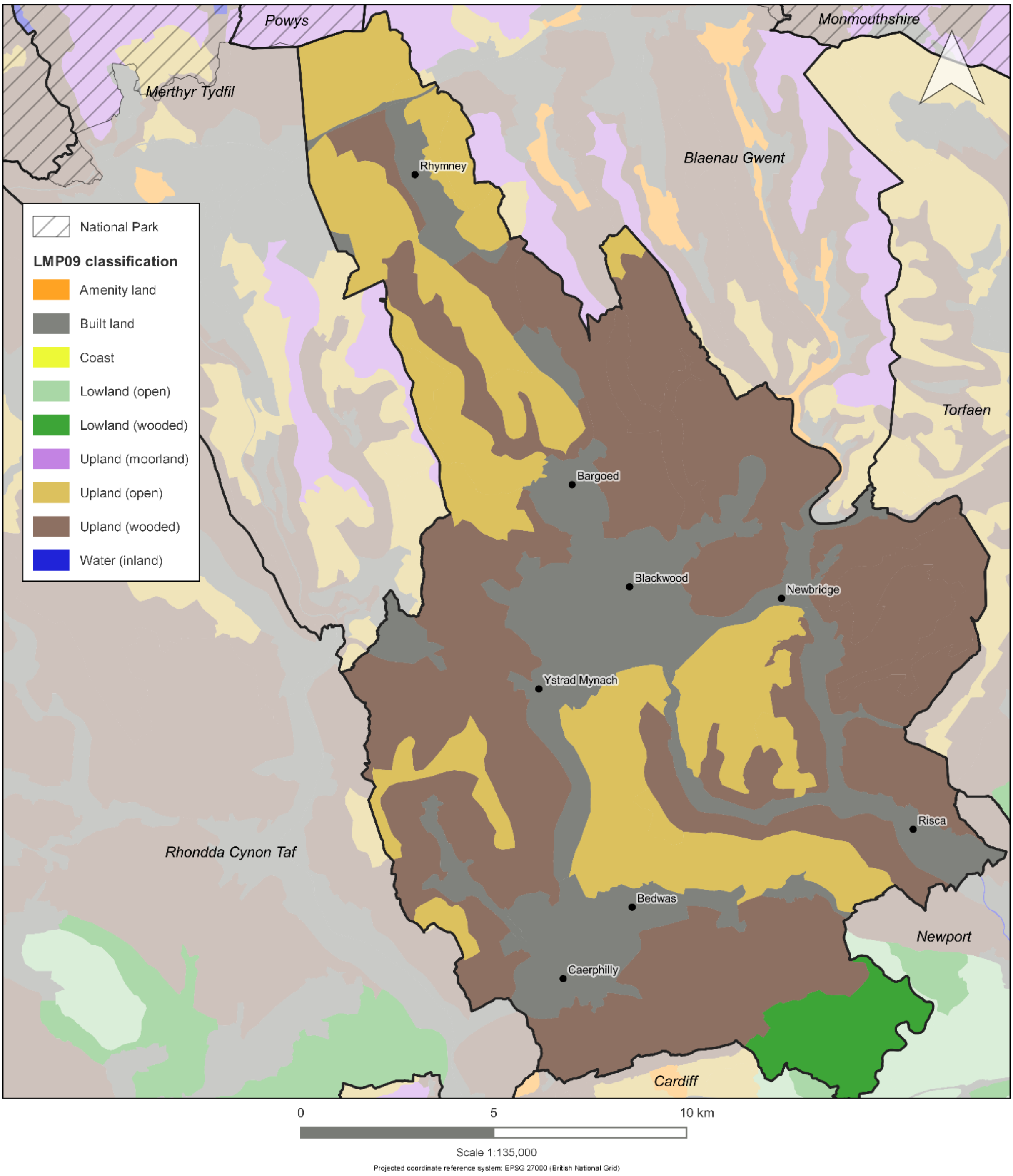
Figure 4.9 LMP14 landscape classification with NRW Operating Areas (Caerphilly)

LANDMAP Visual & Sensory: LMP09 Classification (Caerphilly)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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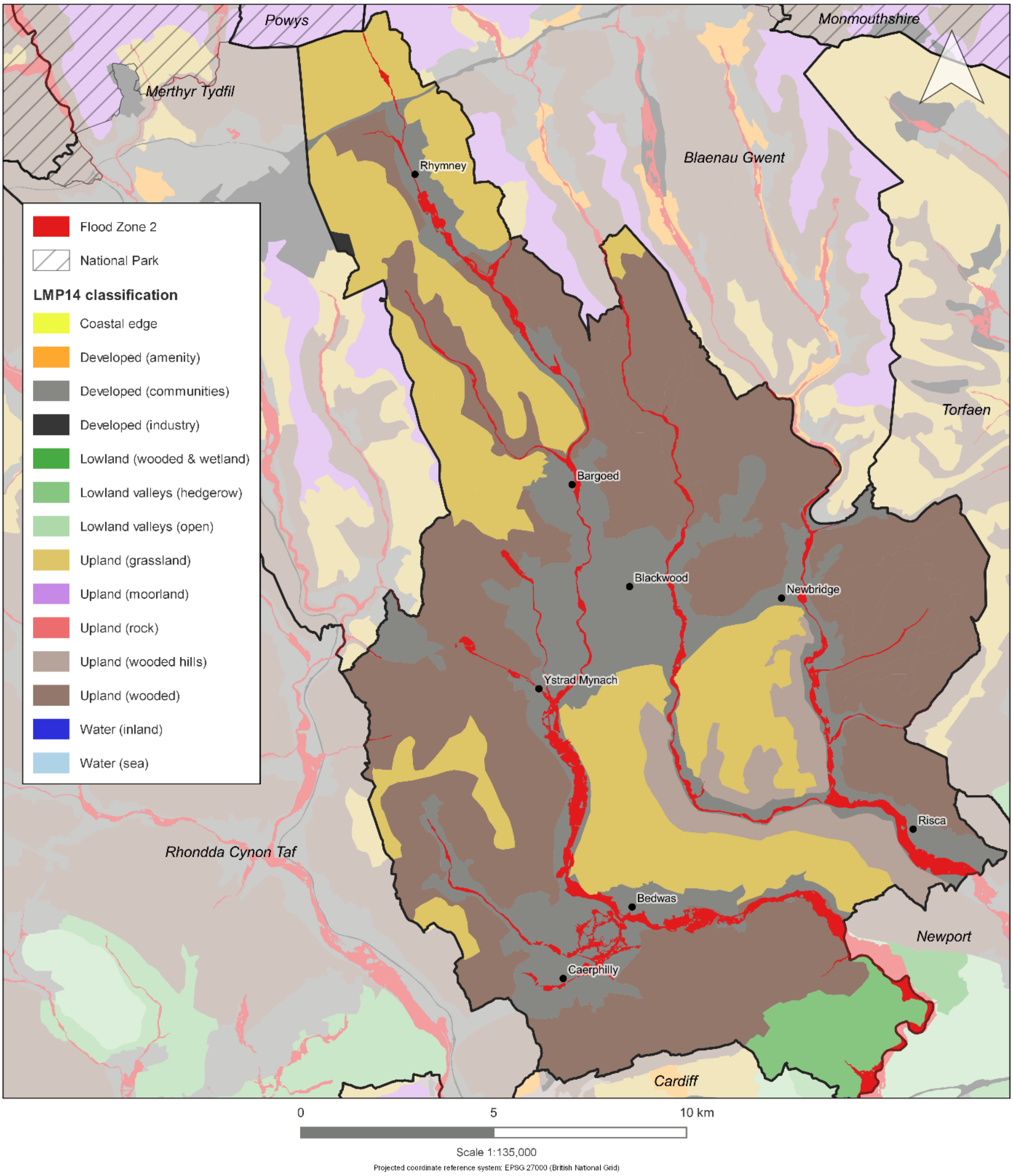
Figure 4.10 LMP09 landscape types (Caerphilly)

LANDMAP Visual & Sensory: LMP14 Classification - Caerphilly
(showing Flood Zone 2 data)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 2 data: http://lle.gov.wales/catalogue/item/FloodZ2/?lang=en.

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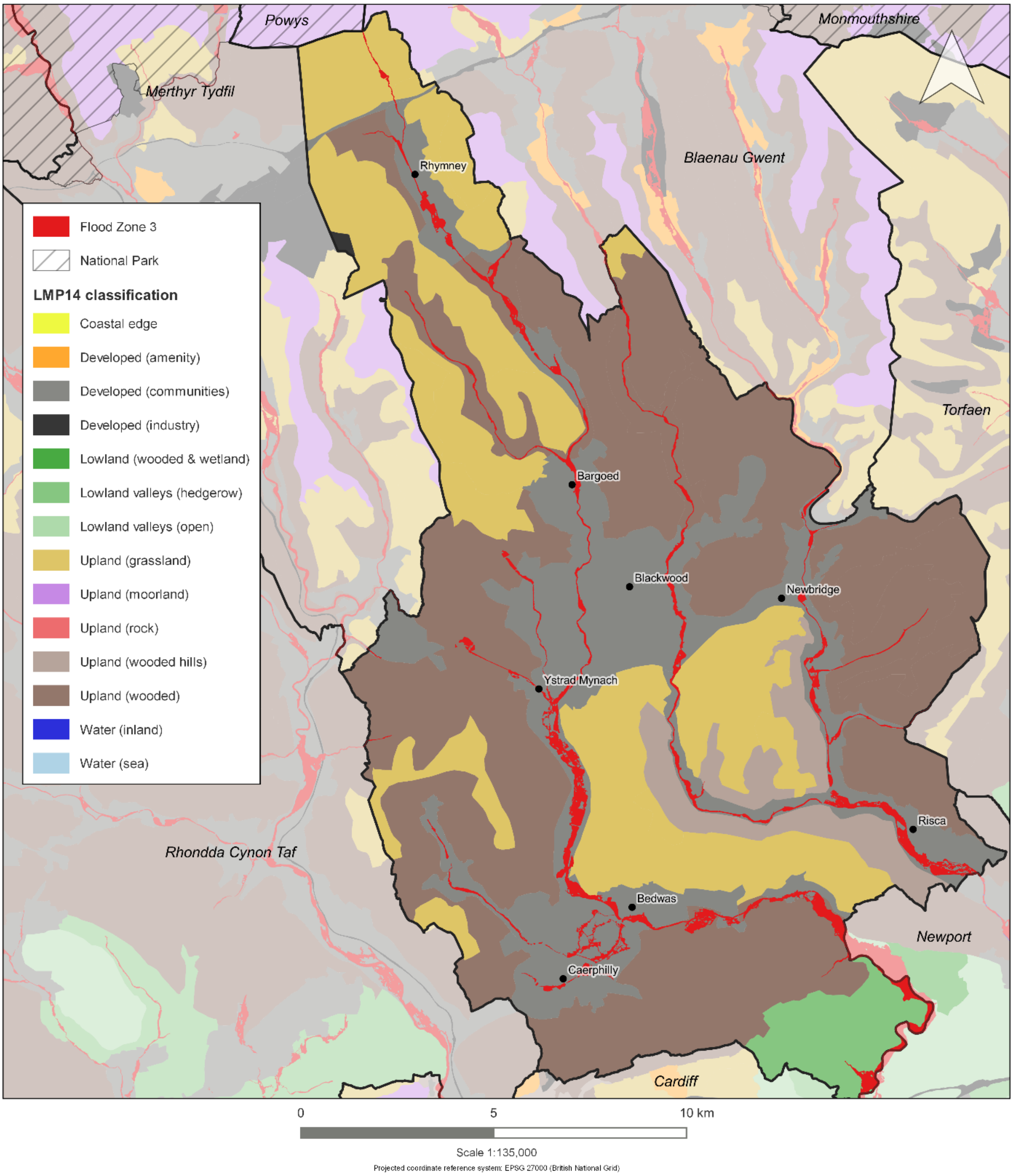
'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.11 LMP14 landscape types with Flood Zone 2 (Caerphilly)

LANDMAP Visual & Sensory: LMP14 Classification - Caerphilly
(showing Flood Zone 3 data)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 3 data: http://lle.gov.wales/catalogue/item/Flood3/?lang=en.

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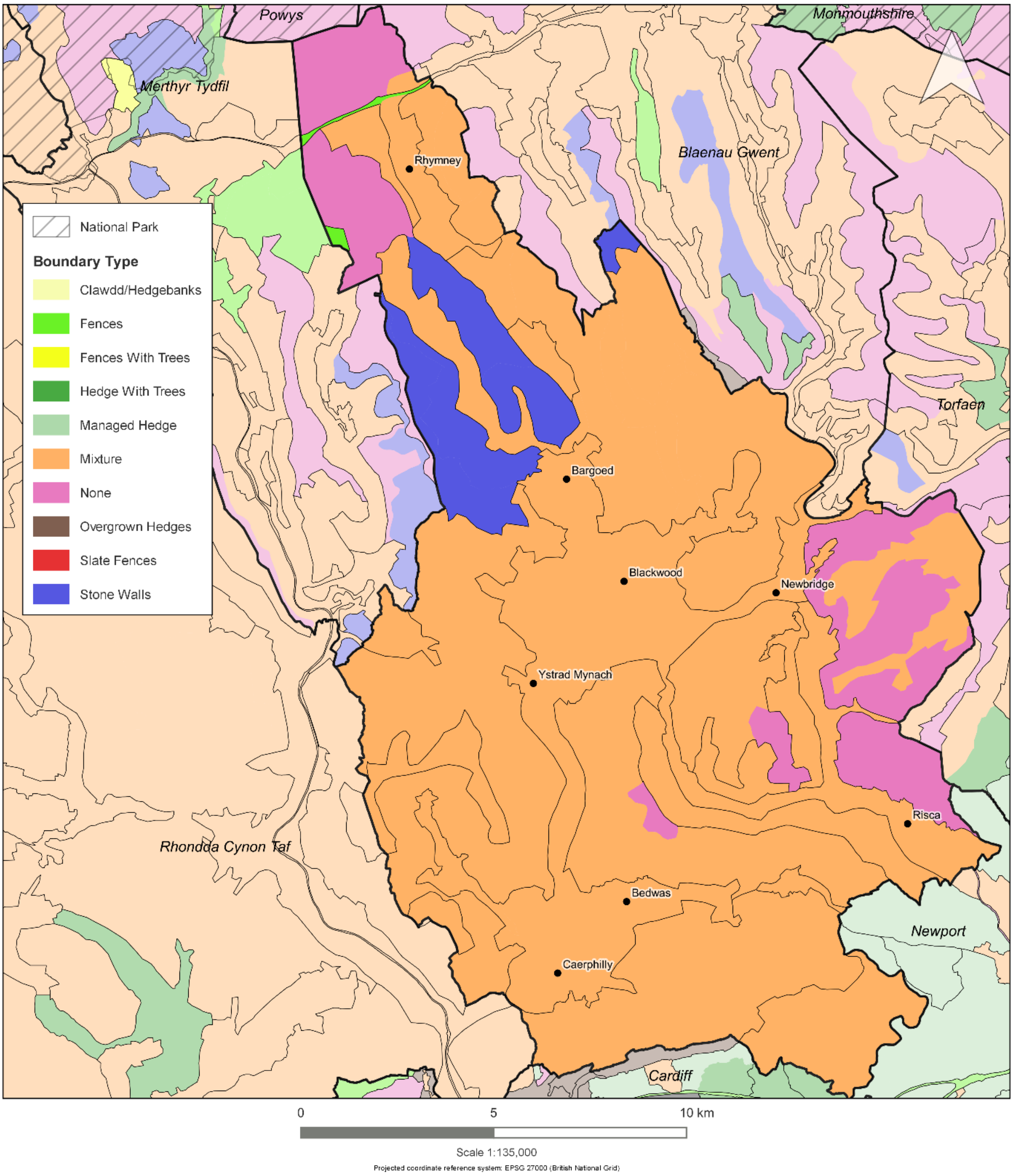
Figure 4.12 LMP14 landscape types with Flood Zone 3 (Caerphilly)

LANDMAP Visual & Sensory: LMP14 Boundary Types - Caerphilly



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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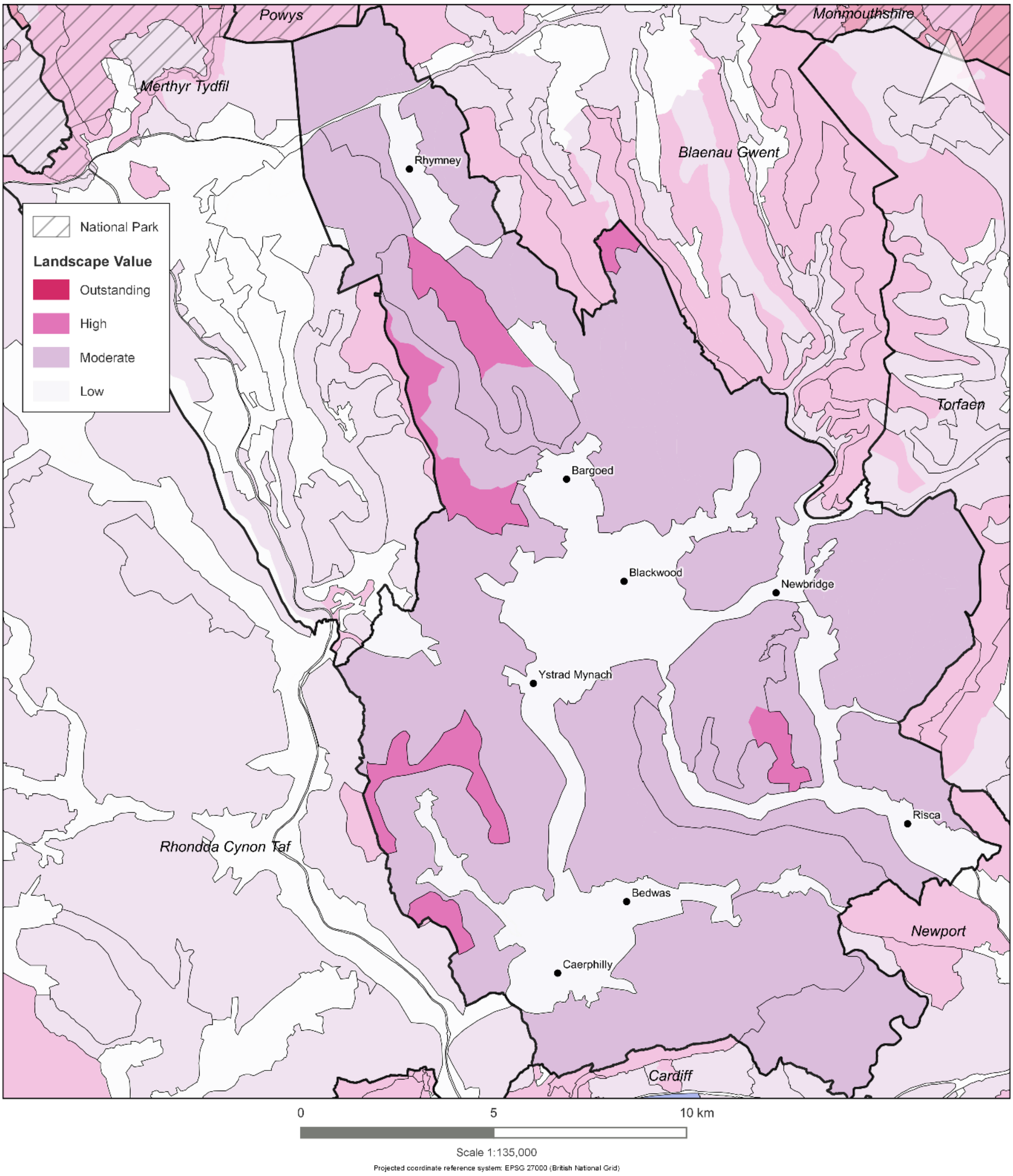
Last updated 11/03/2019.

'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.13 Boundary type with LMP14 landscape boundaries (Caerphilly)

LANDMAP Visual & Sensory: LMP14 Landscape Value - Caerphilly



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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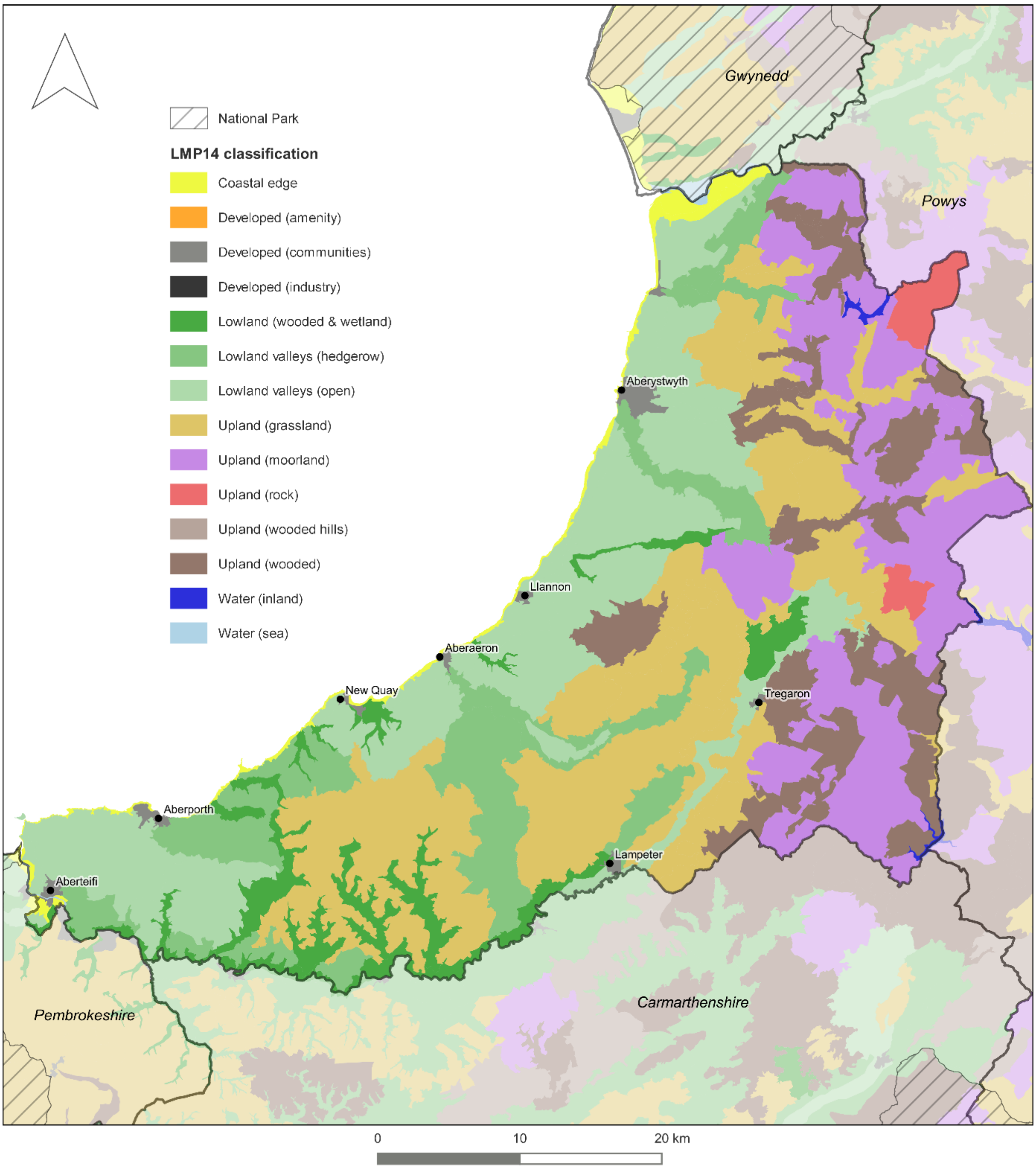
'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.14 Landscape value with LMP14 landscape boundaries (Caerphilly)

4.6. Ceredigion

LANDMAP Visual & Sensory: LMP14 Classification (Ceredigion)



Scale 1:375,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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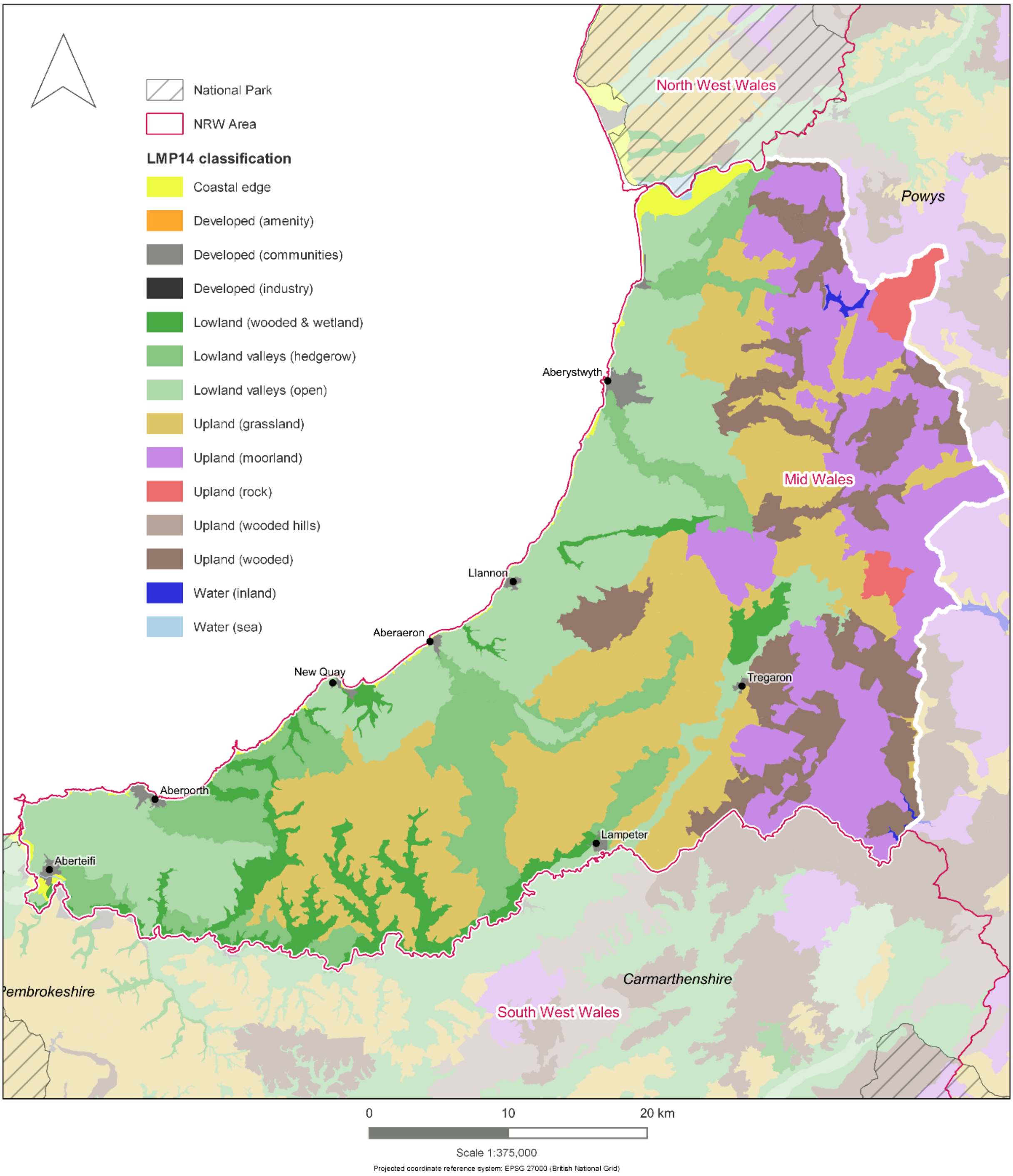
Natural Resources Wales

Produced for Natural Resources Wales by Robert Berry, Countyside and Community Reserach Intitute, University of Gloucestershire - rberry@glos.ac.uk. Last updated 11/04/2019.

'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.15 LMP14 landscape types (Ceredigion)

LANDMAP Visual & Sensory: LMP14 Classification - Ceredigion
(showing NRW Operating Areas)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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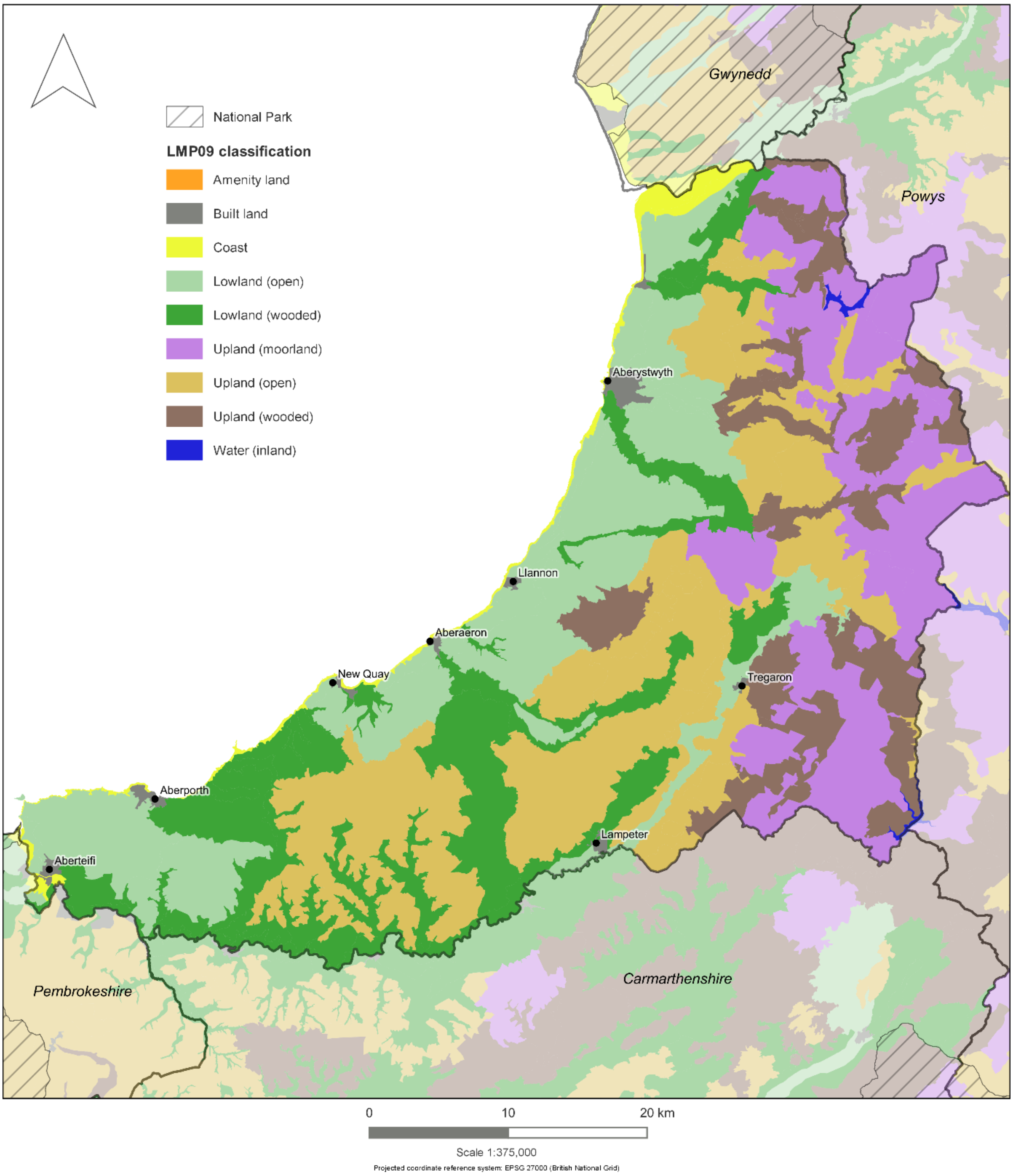
Produced for Natural Resources Wales by Robert Berry, Countyside and Community Reserach Intitute, University of Gloucestershire - rberry@glos.ac.uk. Last updated 11/03/2019.

'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.16 LMP14 landscape classification with NRW Operating Areas (Ceredigion)

LANDMAP Visual & Sensory: LMP09 Classification (Ceredigion)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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Natural Resources Wales

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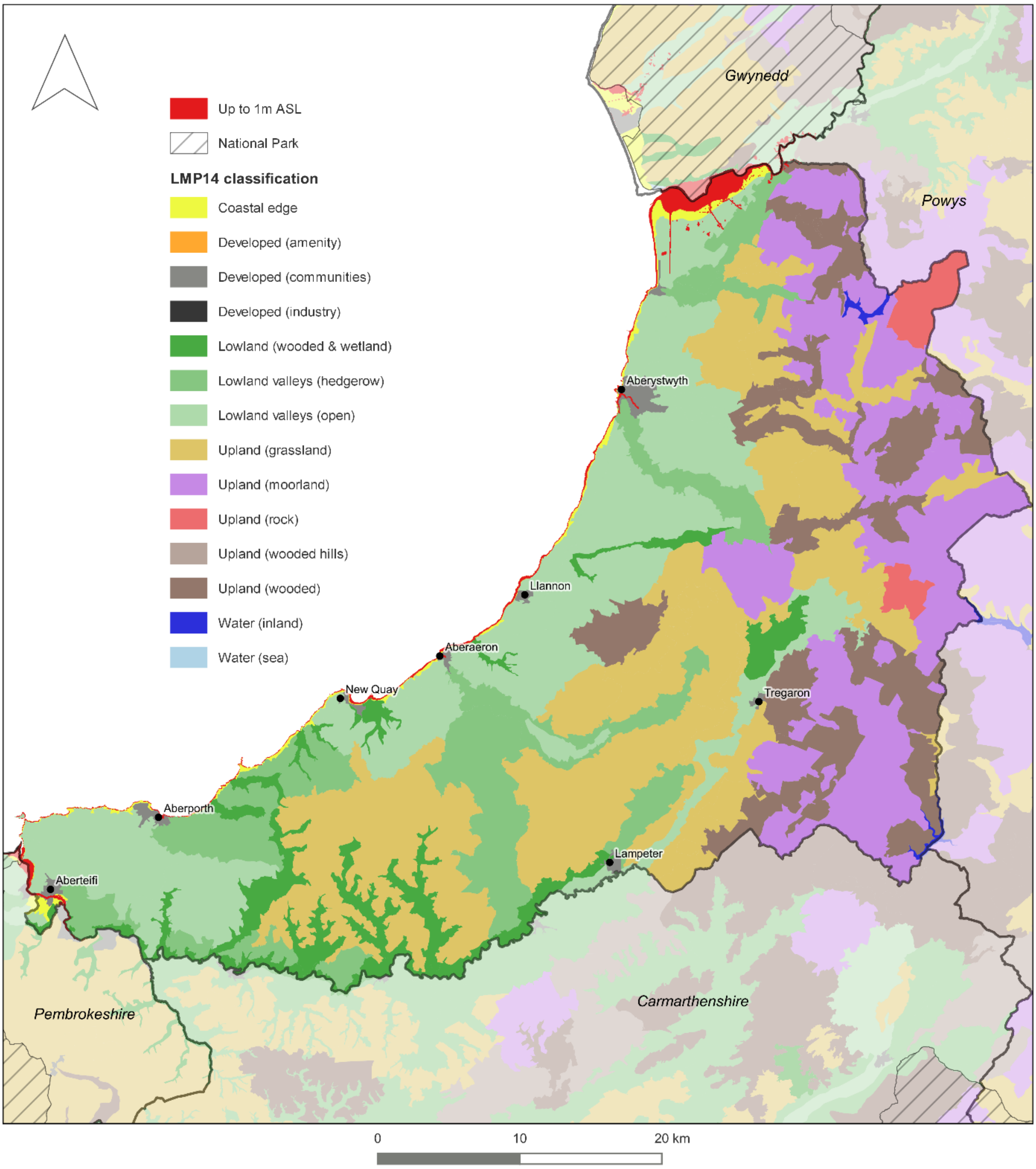
Last updated 11/03/2019.

'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.17 LMP09 landscape types (Ceredigion)

LANDMAP Visual & Sensory: LMP14 Classification - Ceredigion
(highlighting land up to 1m above current sea level)



Scale 1:375,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.
4) Ordnance Survey OS Terrain 50 raster digital elevation model.

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Natural Resources Wales

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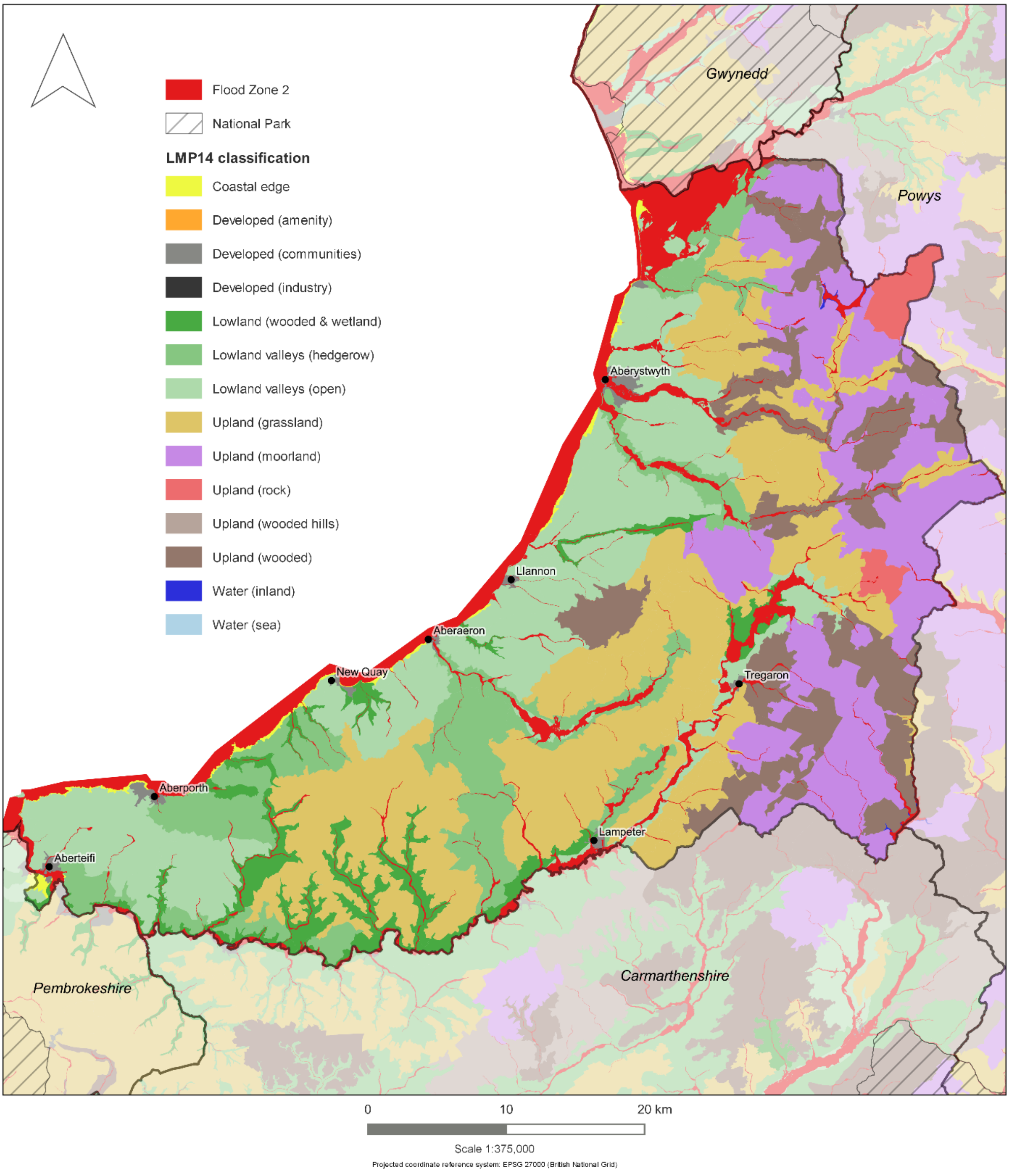
Figure 4.18 LMP14 landscape types with land up to 1m above sea level (Ceredigion)

LANDMAP Visual & Sensory: LMP14 Classification - Ceredigion
(showing Flood Zone 2 data)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 2 data: http://lle.gov.wales/catalogue/item/FloodZ2/?lang=en.

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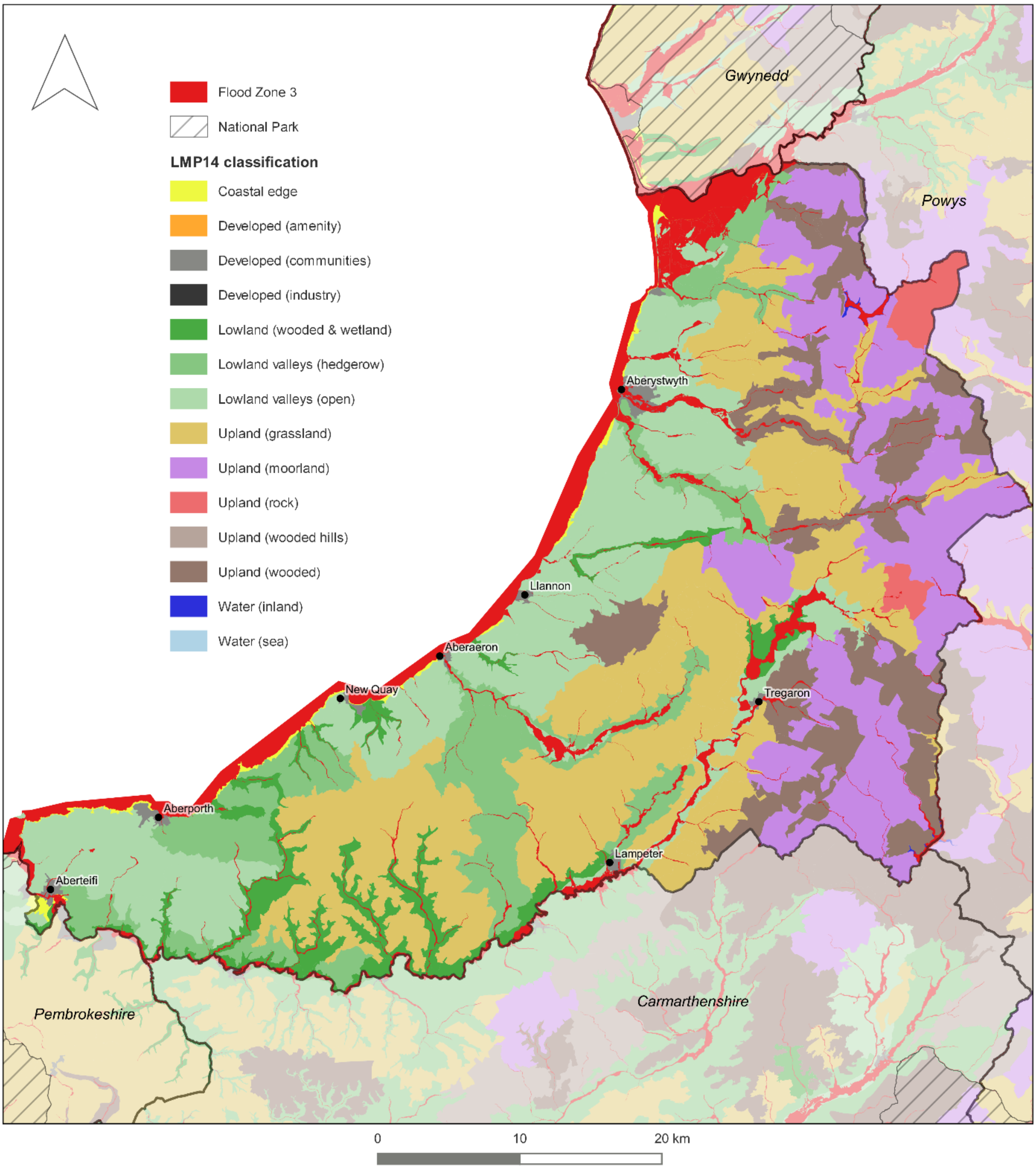
Figure 4.19 LMP14 landscape types with Flood Zone 2 (Ceredigion)

LANDMAP Visual & Sensory: LMP14 Classification - Ceredigion
(showing Flood Zone 3 data)



Scale 1:375,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1;250,000 Colour Raster) used to digitise placenames.
4) Natural Resources Wales Flood Zone 3 data: http://lle.gov.wales/catalogue/item/Flood3/?lang=en.

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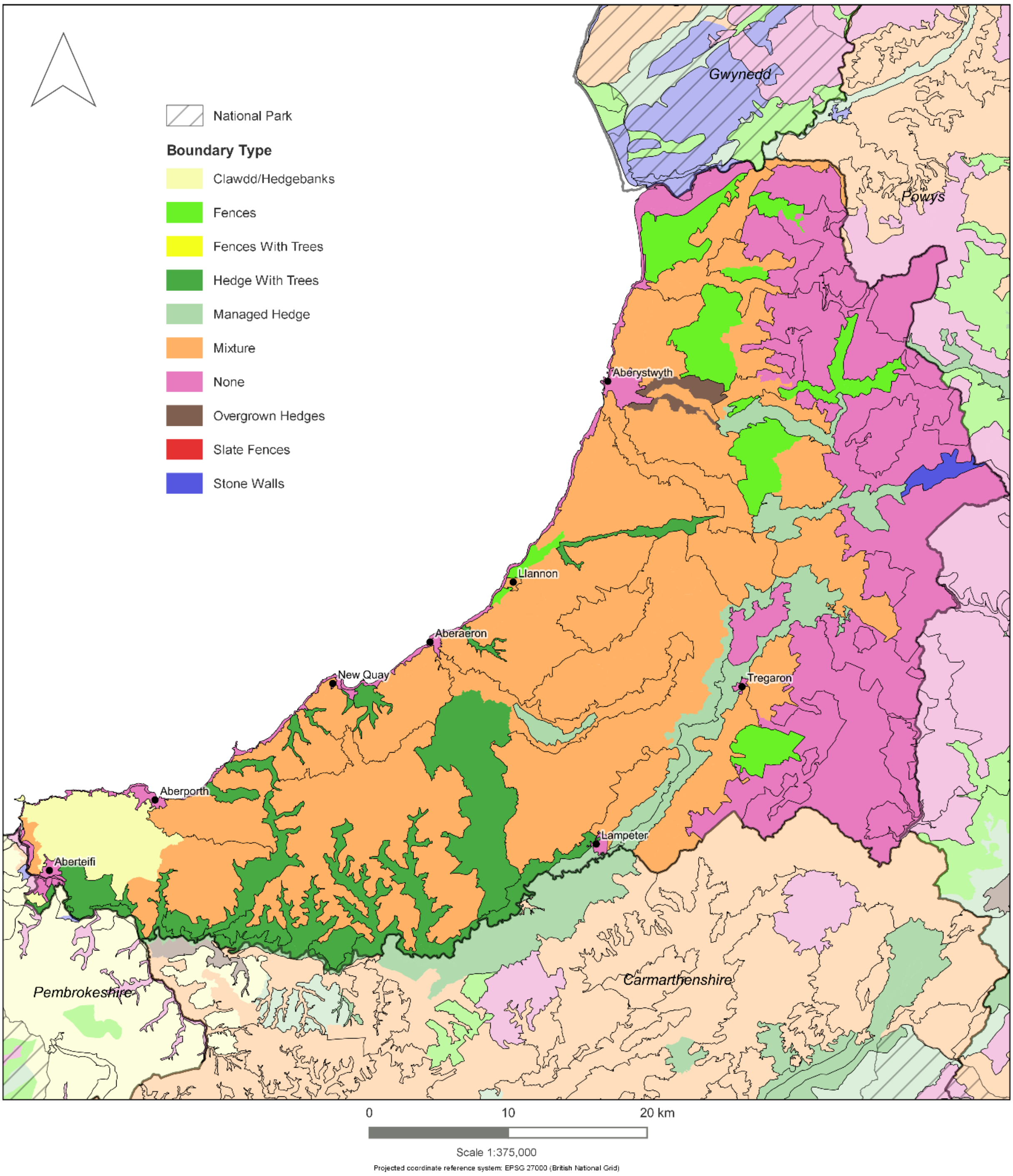
Figure 4.20 LMP14 landscape types with Flood Zone 3 (Ceredigion)

LANDMAP Visual & Sensory: LMP14 Boundary Types - Ceredigion



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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Last updated 11/03/2019.

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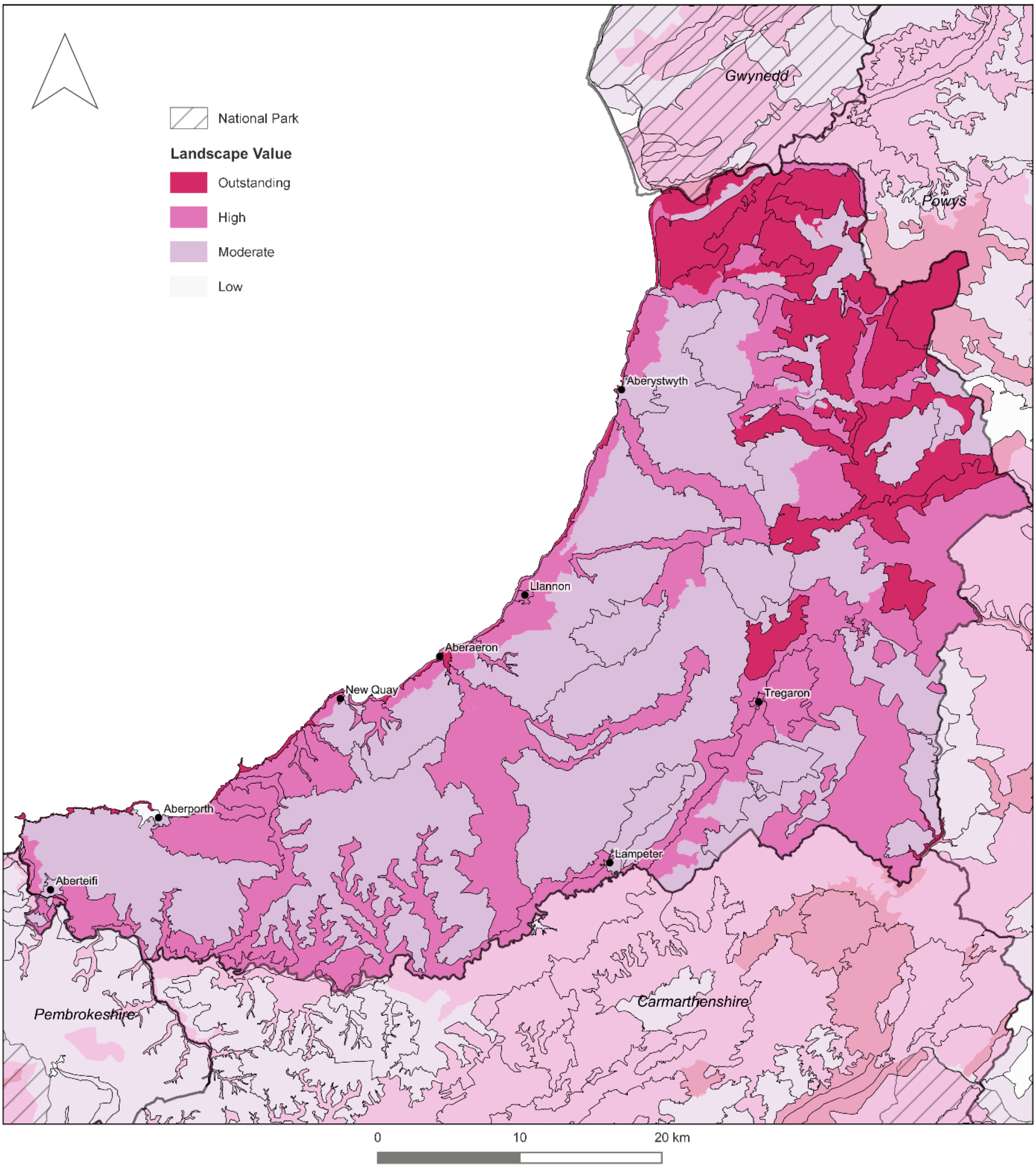
Figure 4.21 Boundary type with LMP14 landscape boundaries (Ceredigion)

LANDMAP Visual & Sensory: LMP14 Landscape Value - Ceredigion



Scale 1:375,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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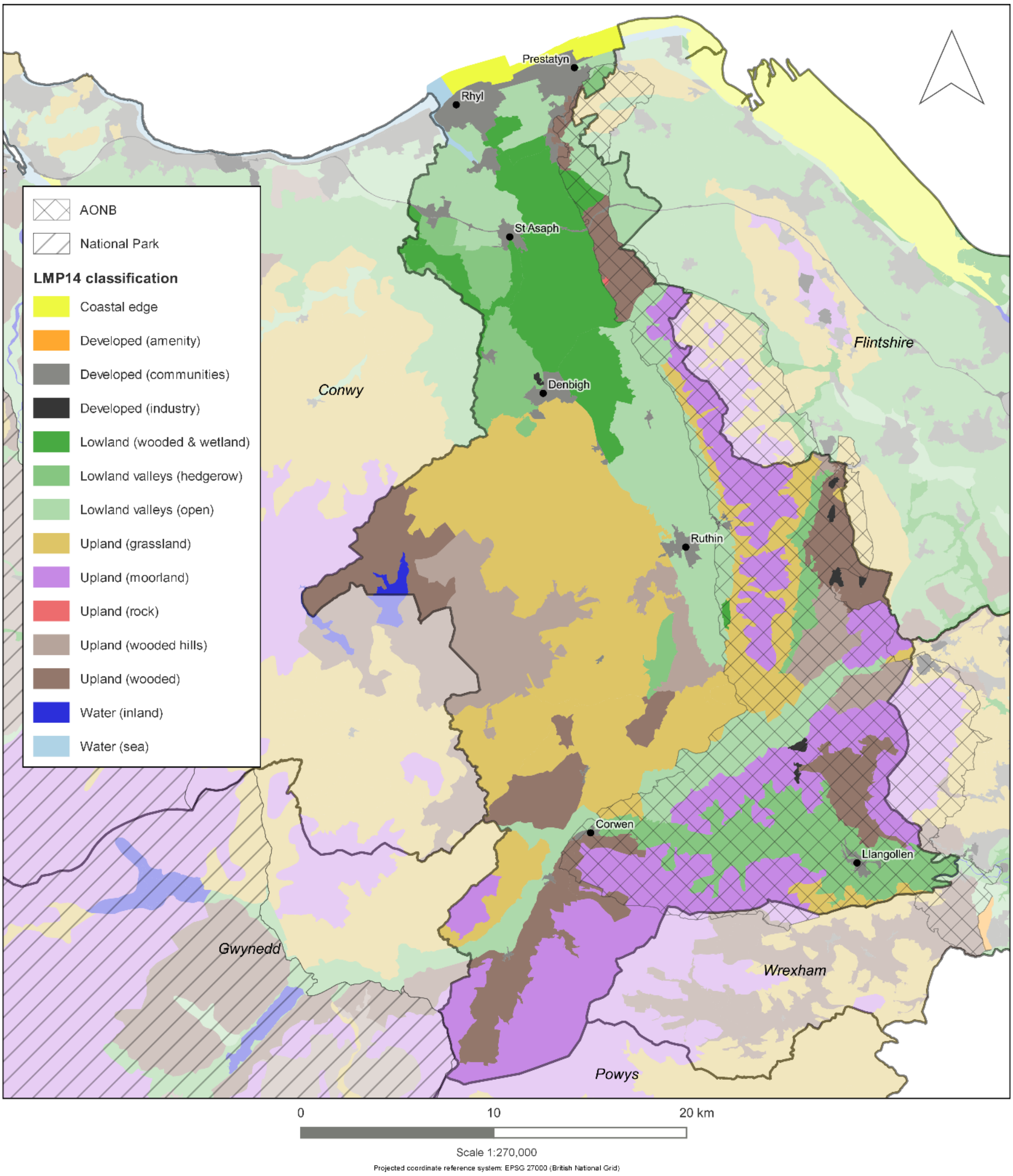
Figure 4.22 Landscape value with LMP14 landscape boundaries (Ceredigion)

4.7. Denbighshire

LANDMAP Visual & Sensory: LMP14 Classification (Denbighshire)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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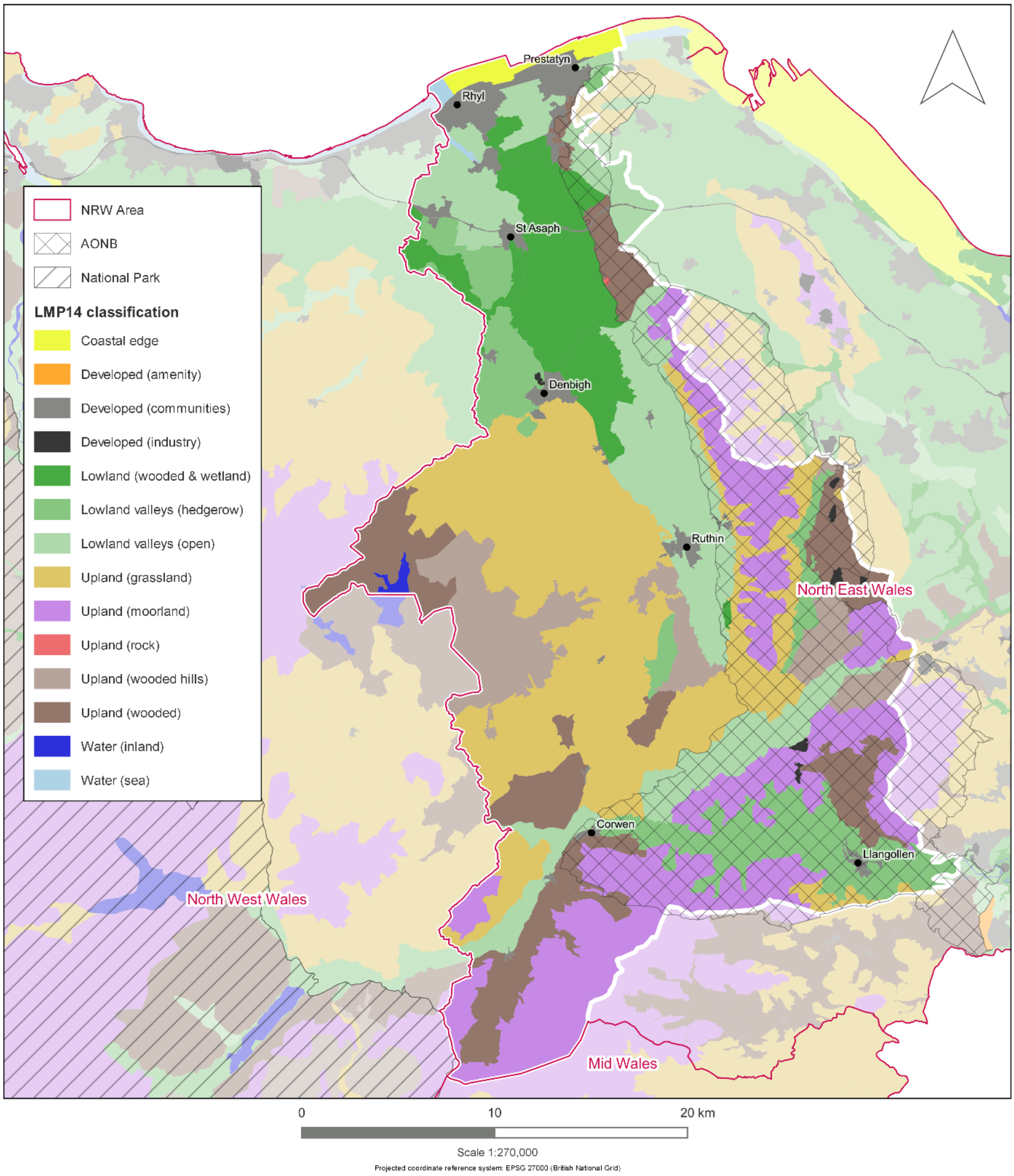
Figure 4.23 LMP14 landscape types (Denbighshire)

LANDMAP Visual & Sensory: LMP14 Classification (Denbighshire)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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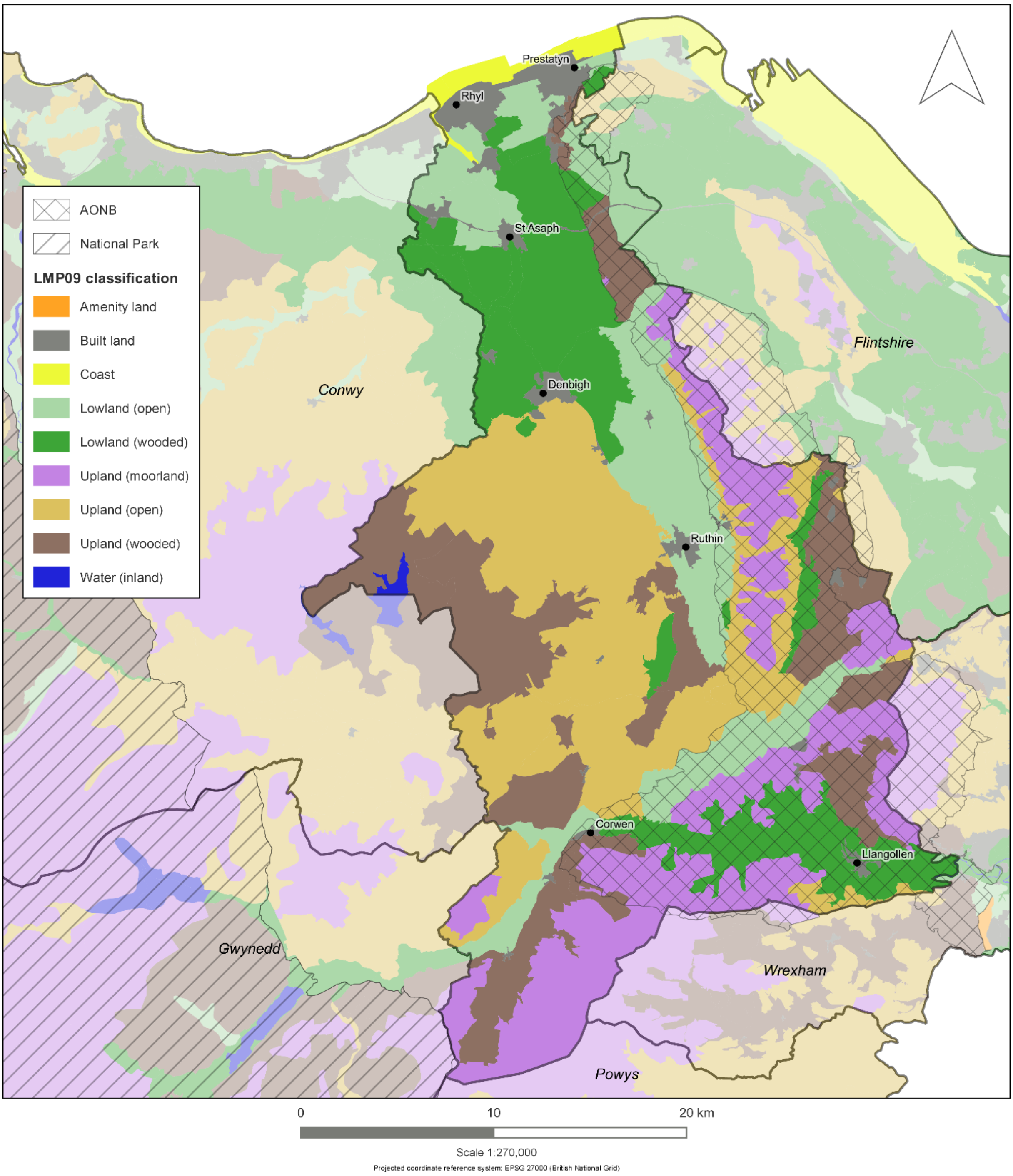
Figure 4.24 LMP14 landscape classification with NRW Operating Areas (Denbighshire)

LANDMAP Visual & Sensory: LMP09 Classification (Denbighshire)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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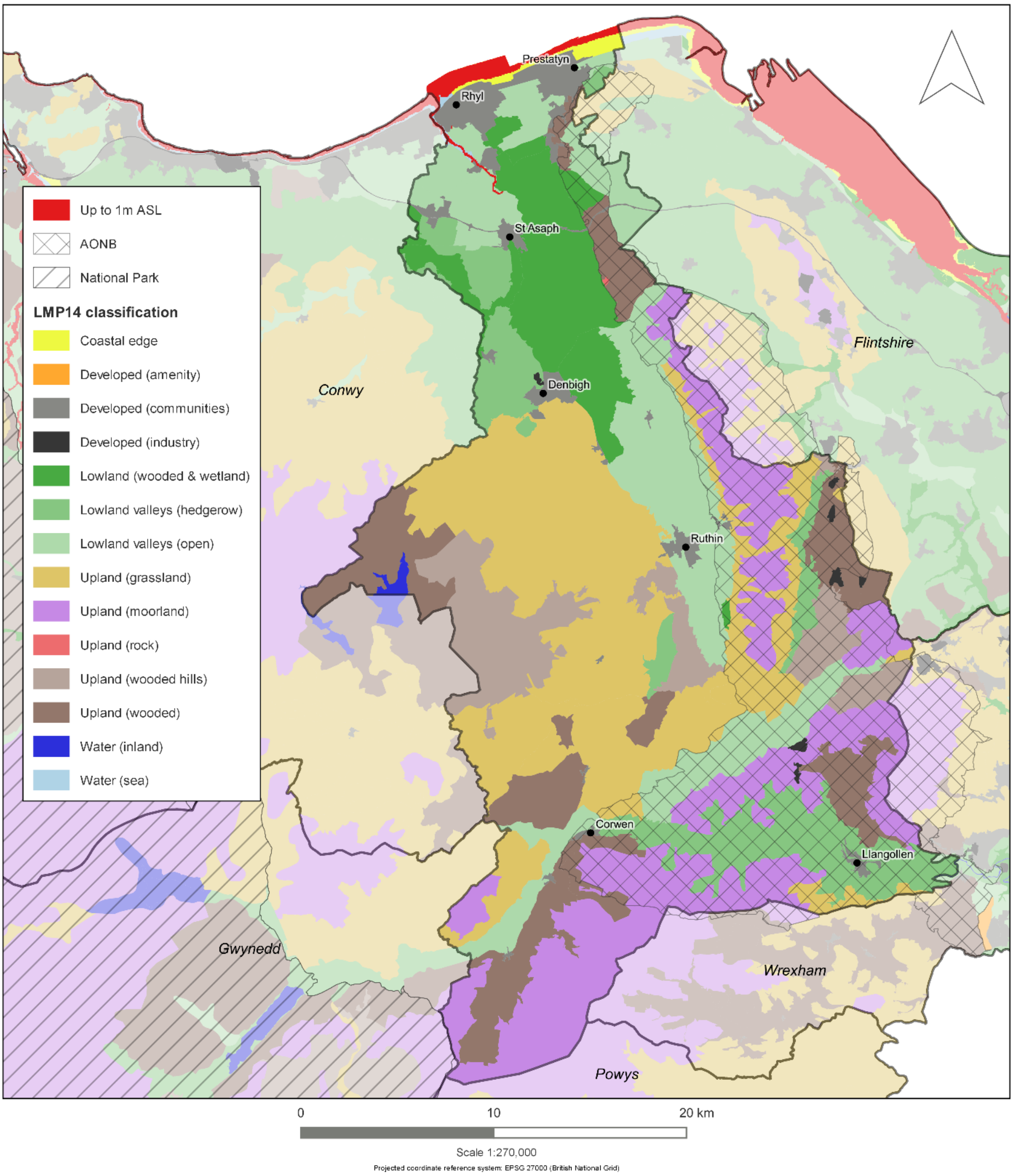
Figure 4.25 LMP09 landscape types (Denbighshire)

LANDMAP Visual & Sensory: LMP14 Classification - Denbighshire
(highlighting land up to 1m above current sea level)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.
4) Ordnance Survey OS Terrain 50 raster digital elevation model.

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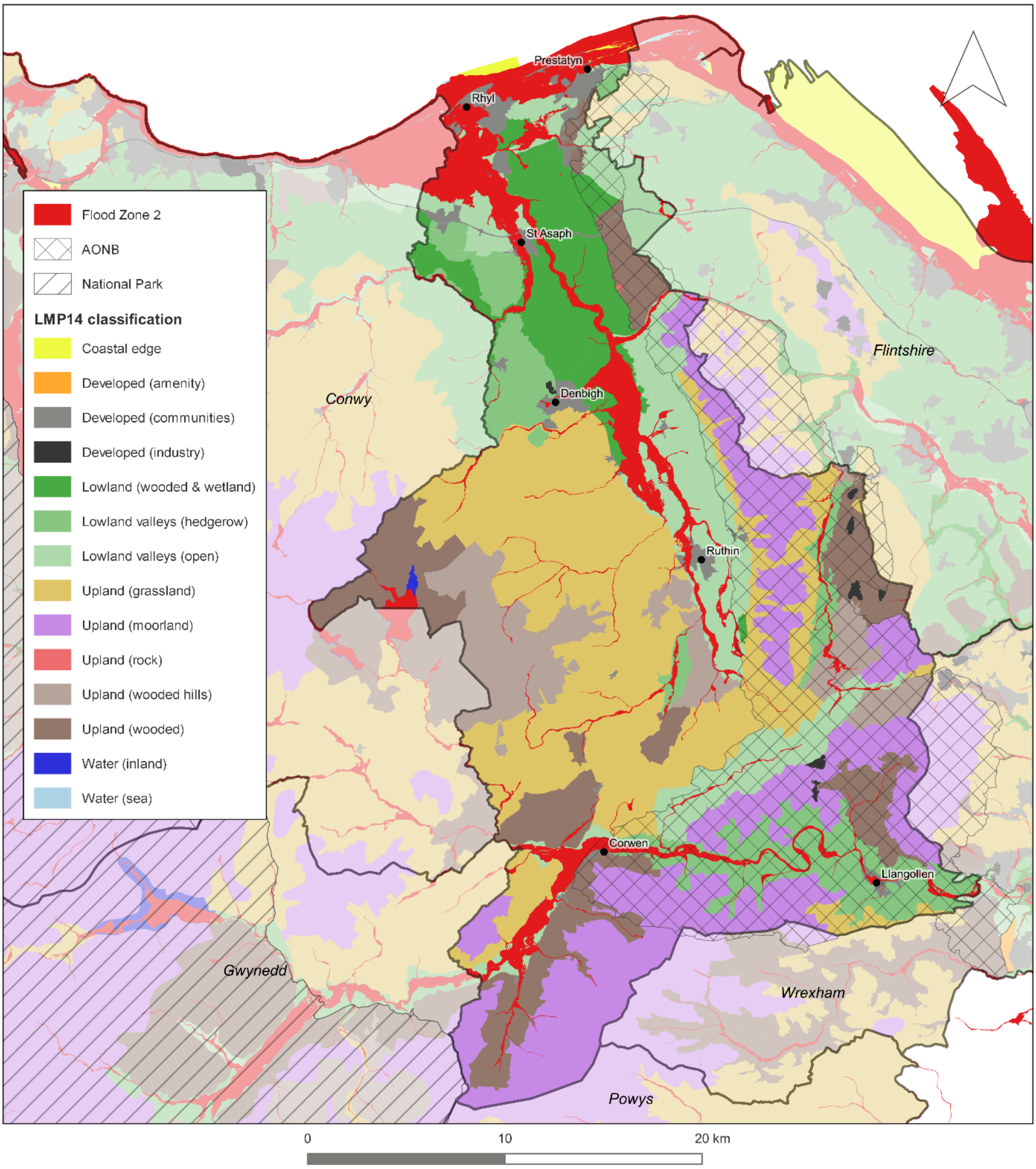
Figure 4.26 LMP14 landscape types with land up to 1m above sea level (Denbighshire)

LANDMAP Visual & Sensory: LMP14 Classification - Denbighshire
(showing Flood Zone 2 data)



Scale 1:270,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 2 data: http://lle.gov.wales/catalogue/item/FloodZ2/?lang=en.

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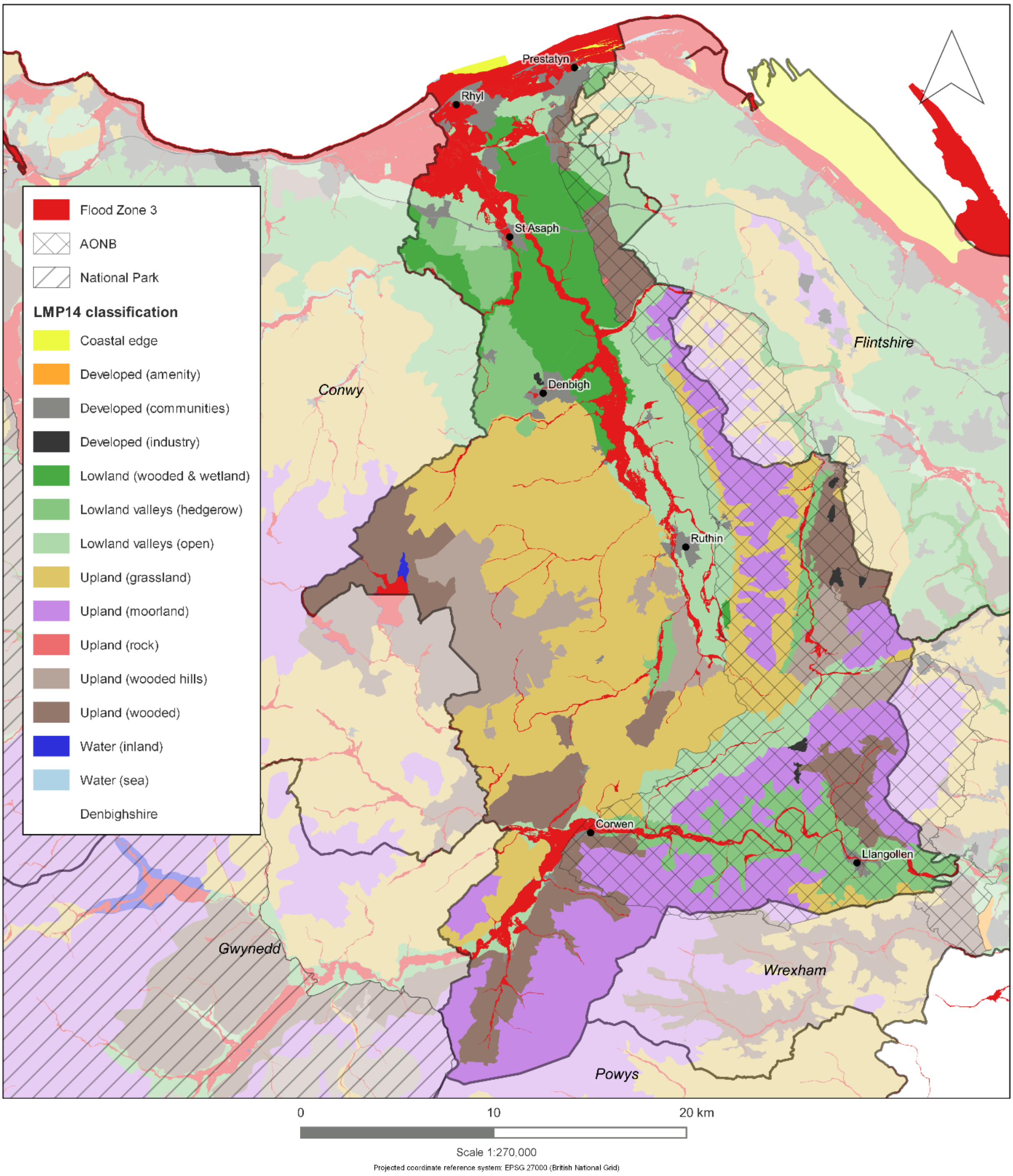
Figure 4.27 LMP14 landscape types with Flood Zone 2 (Denbighshire)

LANDMAP Visual & Sensory: LMP14 Classification - Denbighshire
(showing Flood Zone 3 data)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1;250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 3 data: http://lle.gov.wales/catalogue/item/Flood3/?lang=en.

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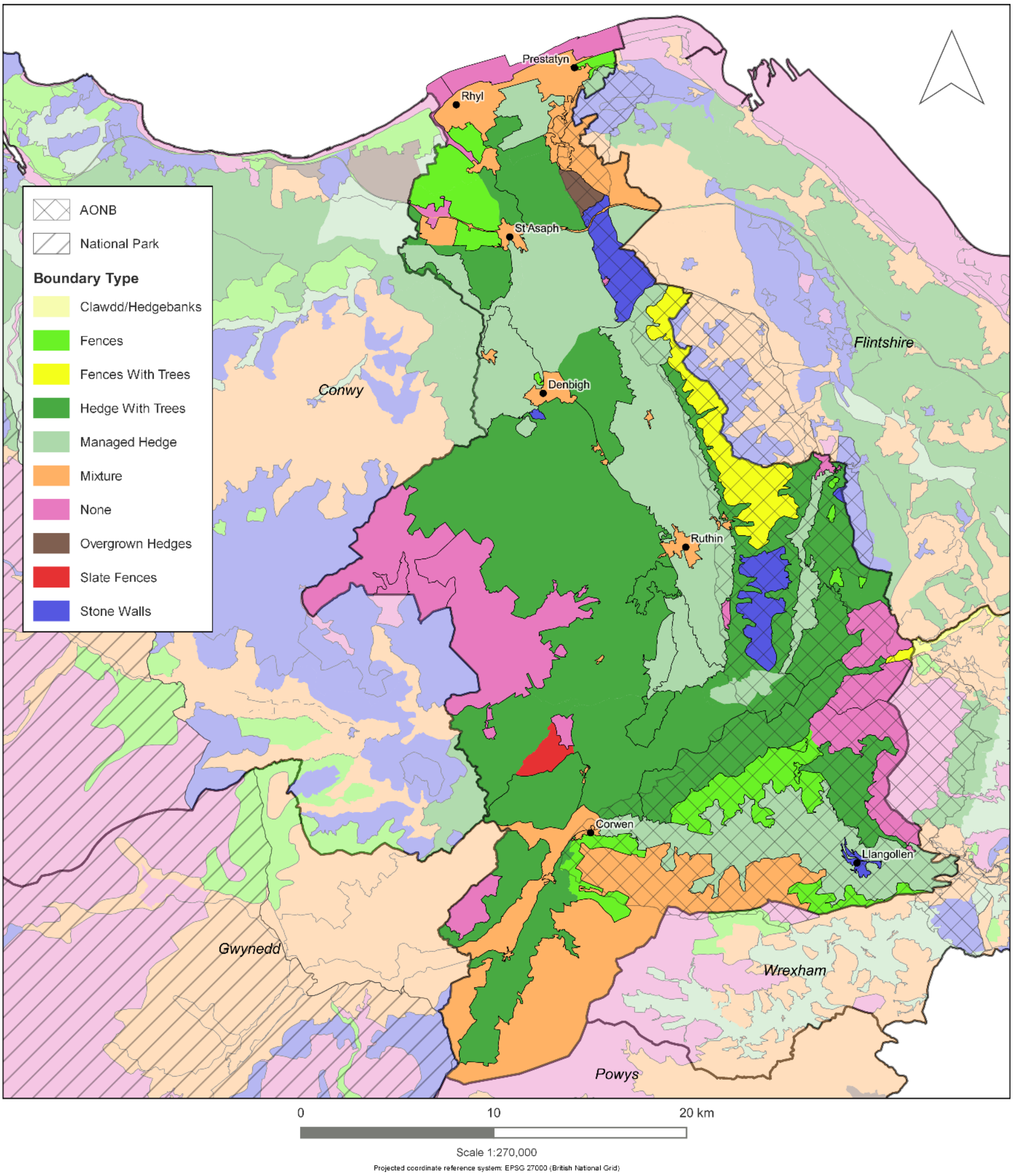
Figure 4.28 LMP14 landscape types with Flood Zone 3 (Denbighshire)

LANDMAP Visual & Sensory: LMP14 Boundary Types - Denbighshire



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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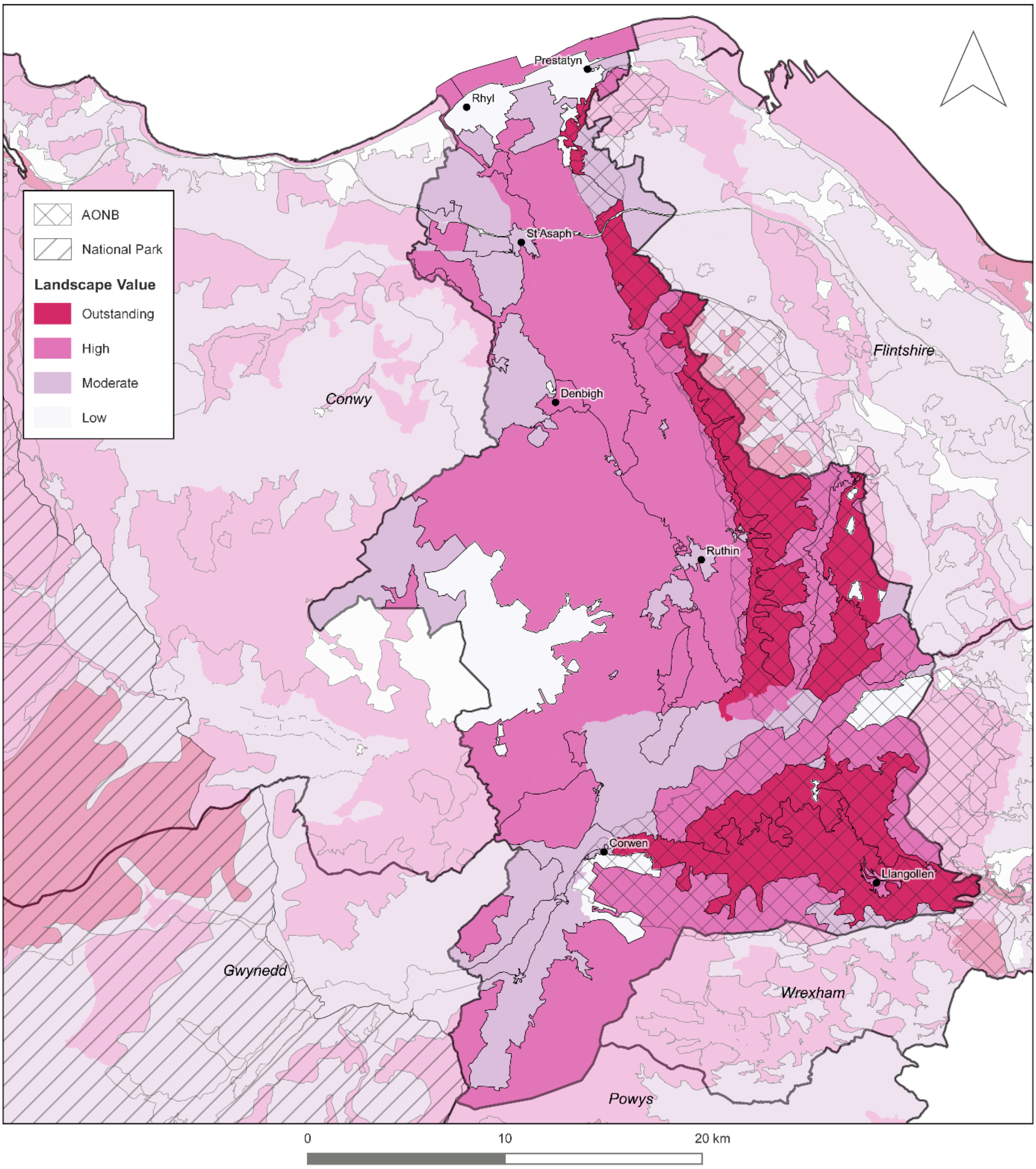
Figure 4.29 Boundary type with LMP14 landscape boundaries (Denbighshire)

LANDMAP Visual & Sensory: LMP14 Landscape Value - Denbighshire



Scale 1:270,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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Figure 4.30 Landscape value with LMP14 landscape boundaries (Denbighshire)

4.8. Monmouthshire

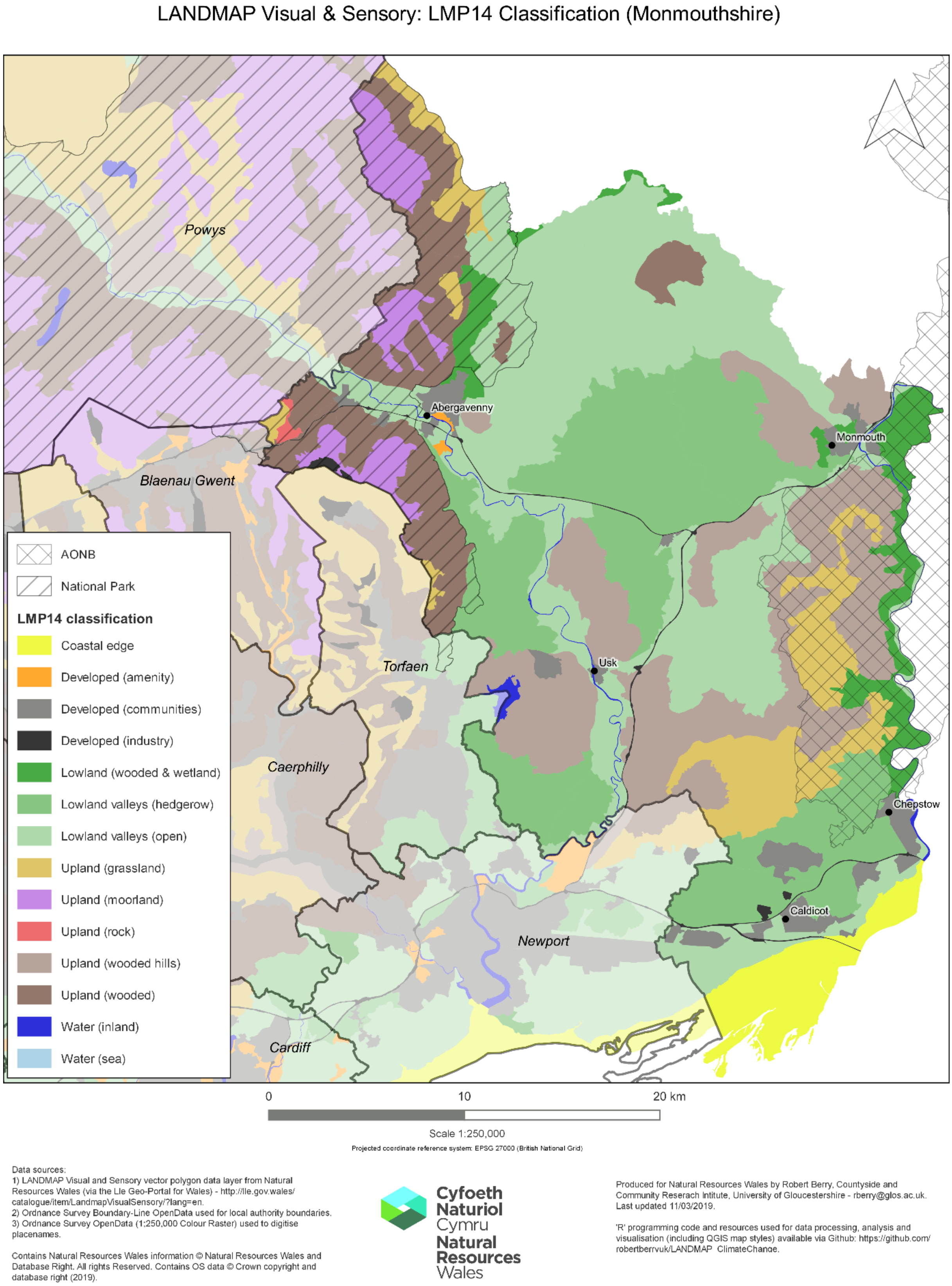
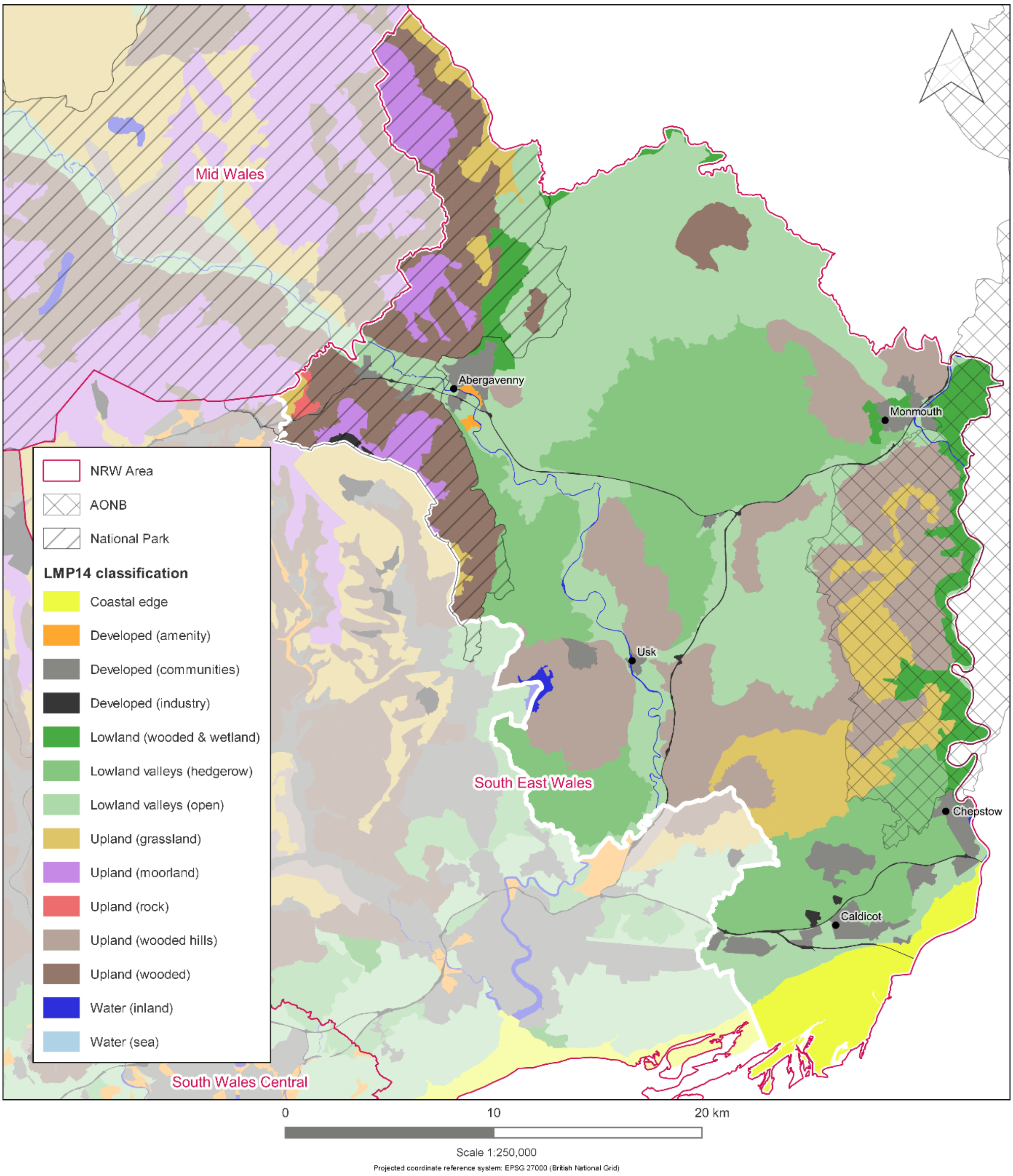


Figure 4.31 LMP14 landscape types (Monmouthshire)

LANDMAP Visual & Sensory: LMP14 Classification - Monmouthshire
(showing NRW Operating Areas)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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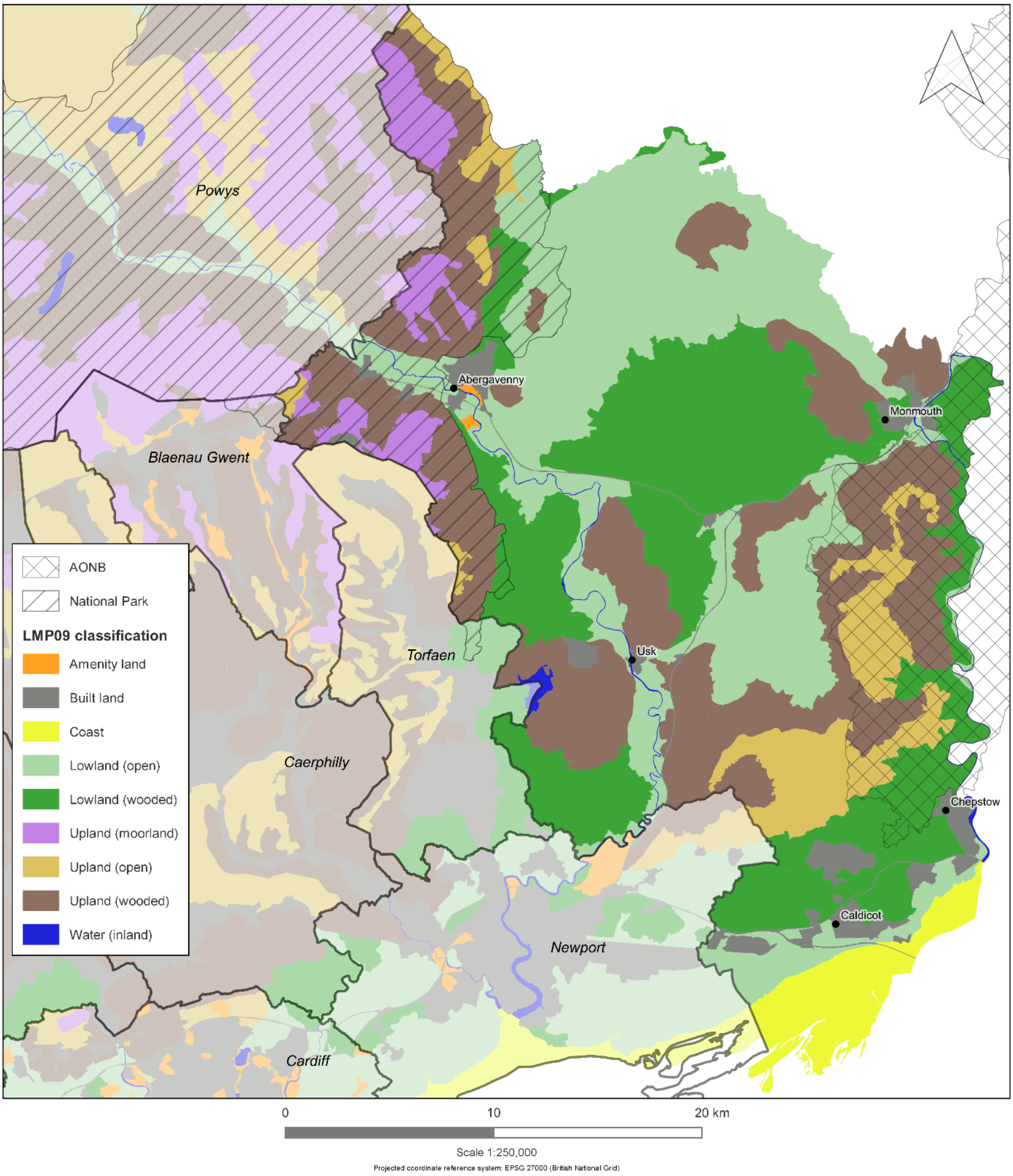
Figure 4.32 LMP14 landscape classification with NRW Operating Areas (Monmouthshire)

LANDMAP Visual & Sensory: LMP09 Classification (Monmouthshire)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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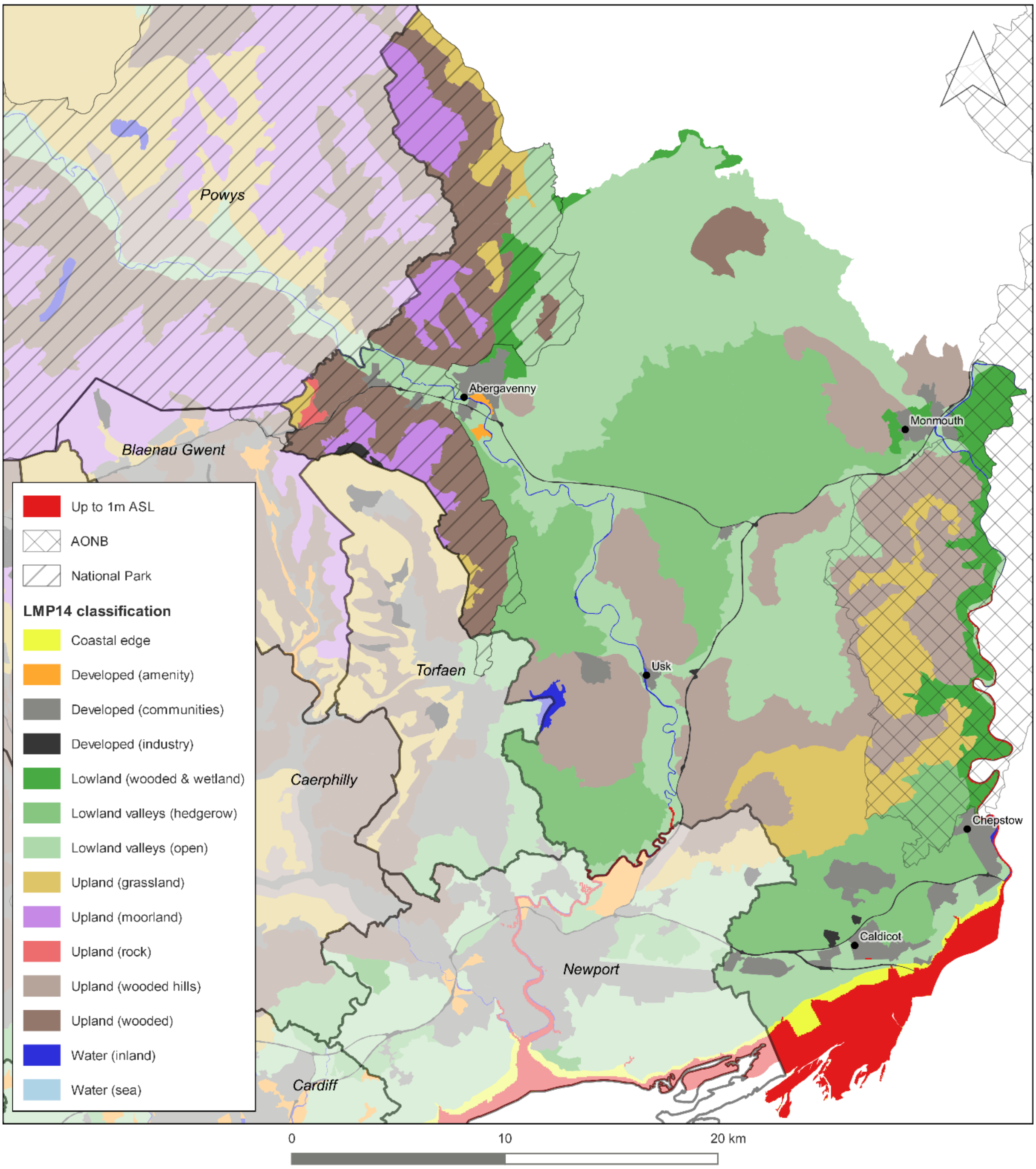
Figure 4.33 LMP09 landscape types (Monmouthshire)

LANDMAP Visual & Sensory: LMP14 Classification - Monmouthshire
(highlighting land up to 1m above current sea level)



Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.
4) Ordnance Survey OS Terrain 50 raster digital elevation model.

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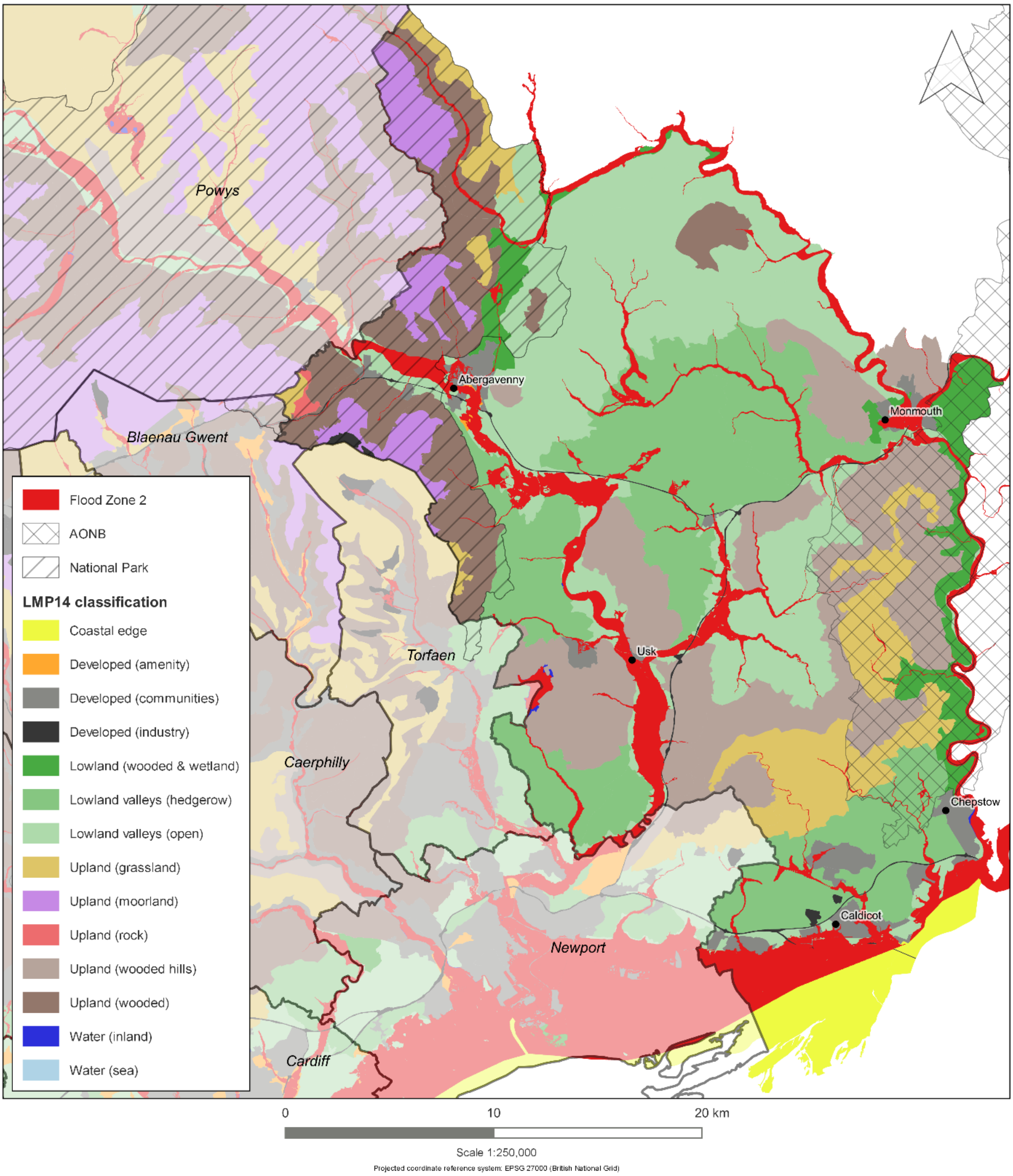
Figure 4.34 LMP14 landscape types with land up to 1m above sea level (Monmouthshire)

LANDMAP Visual & Sensory: LMP14 Classification - Monmouthshire
(showing Flood Zone 2 data)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 2 data: http://lle.gov.wales/catalogue/item/FloodZ2/?lang=en.

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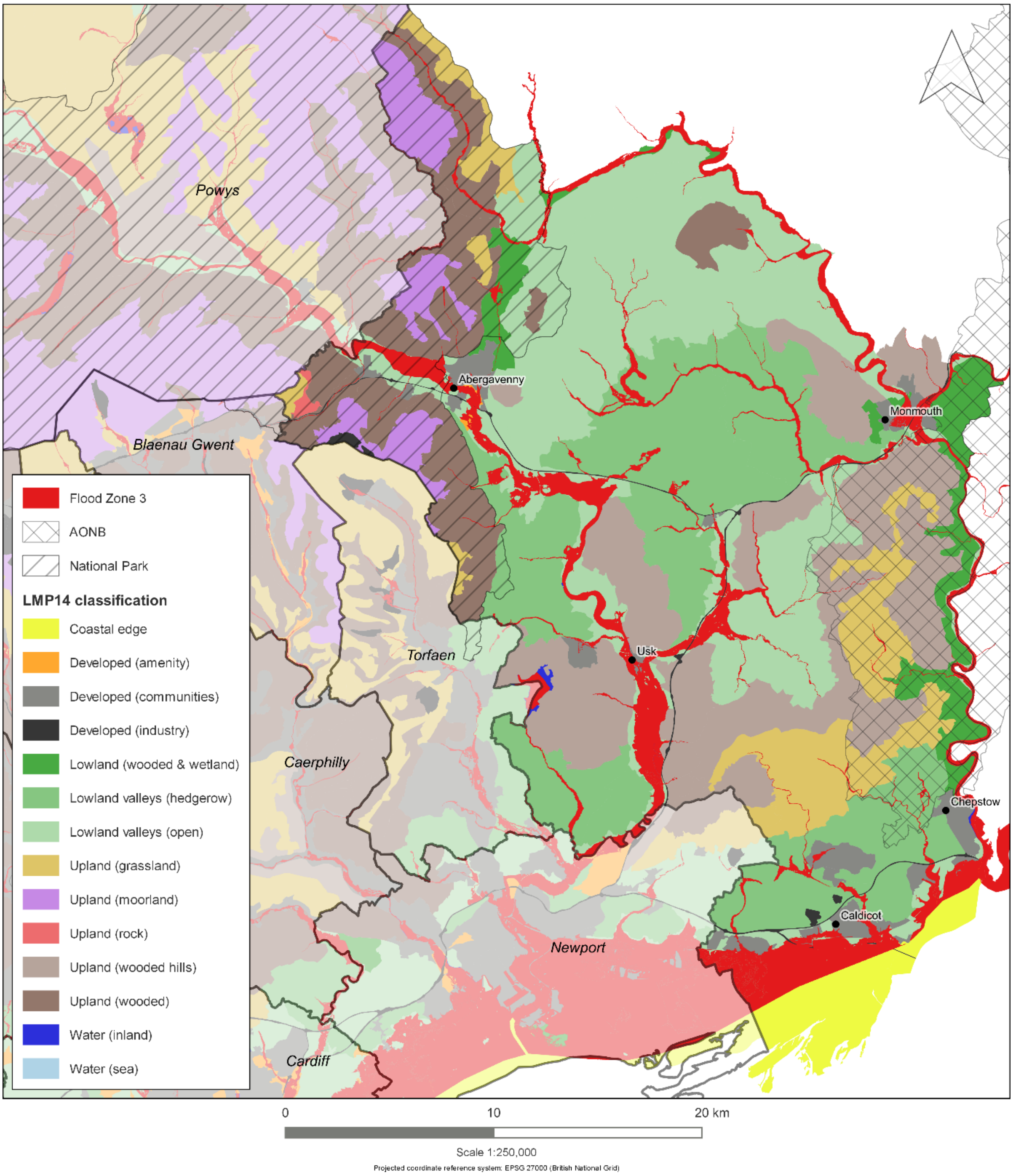
'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.35 LMP14 landscape types with Flood Zone 2 (Monmouthshire)

LANDMAP Visual & Sensory: LMP14 Classification - Monmouthshire
(showing Flood Zone 3 data)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 3 data: http://lle.gov.wales/catalogue/item/Flood3/?lang=en.

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Figure 4.36 LMP14 landscape types with Flood Zone 3 (Monmouthshire)

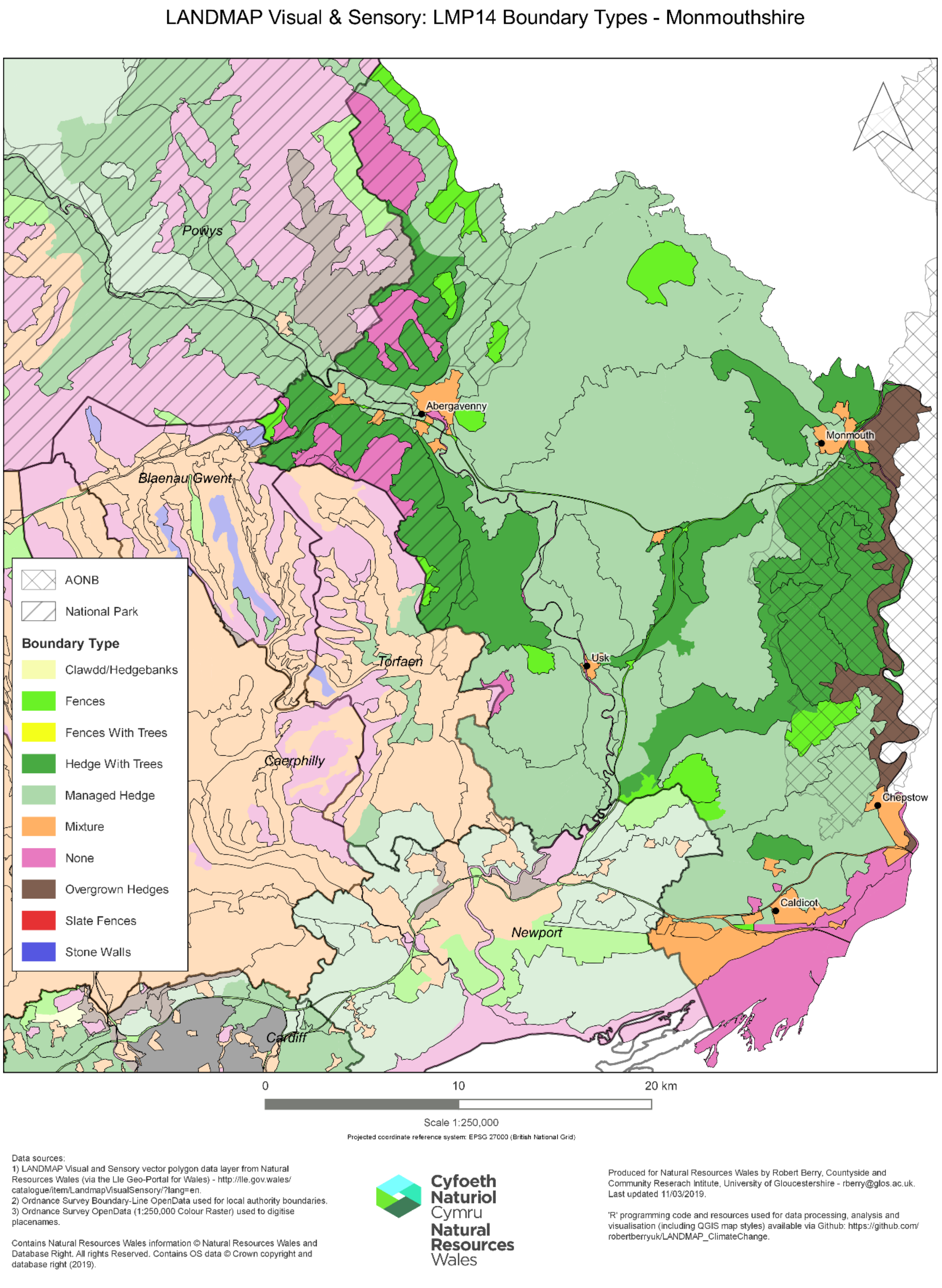
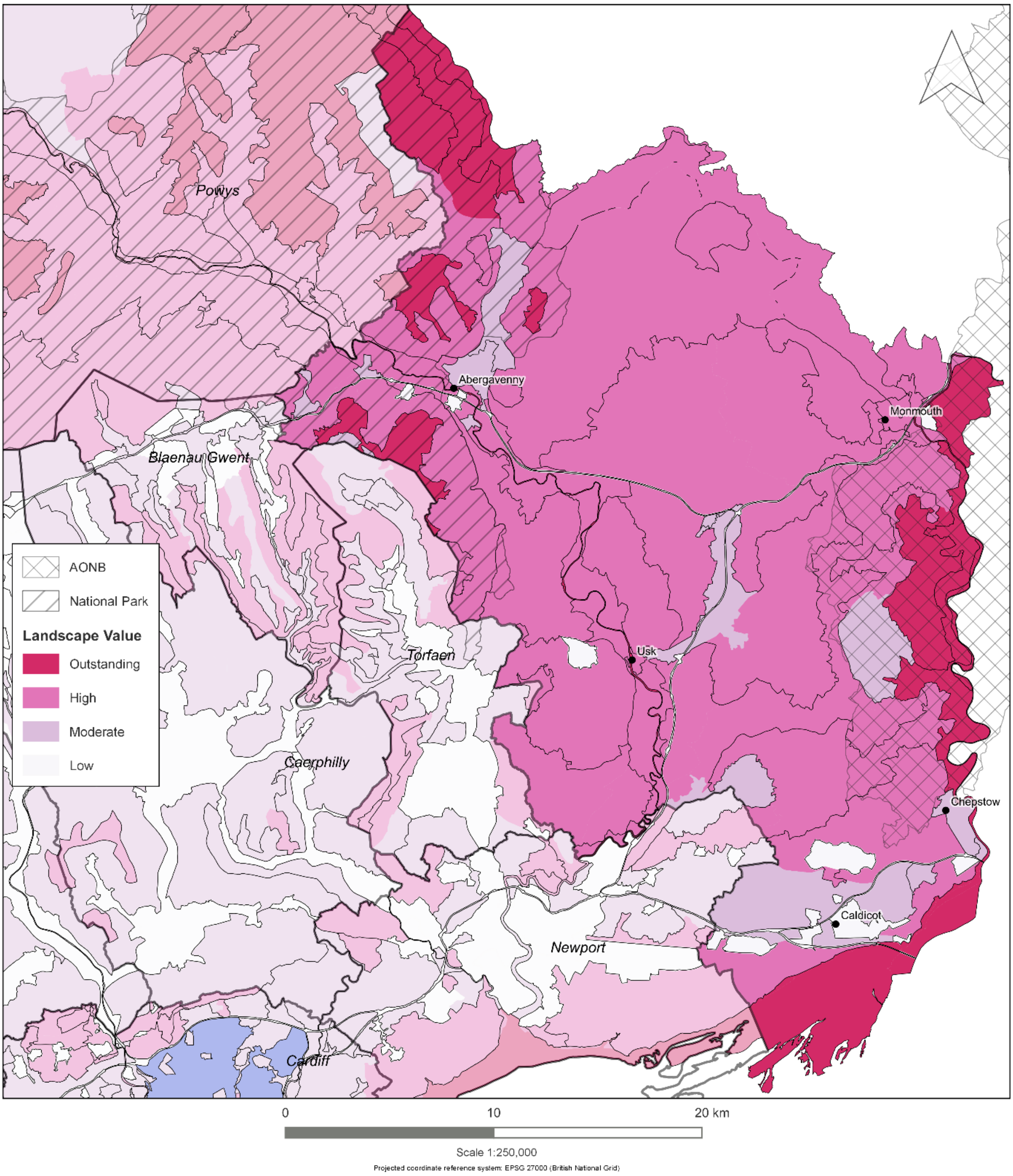


Figure 4.37 Boundary type with LMP14 landscape boundaries (Monmouthshire)

LANDMAP Visual & Sensory: LMP14 Landscape Value - Monmouthshire



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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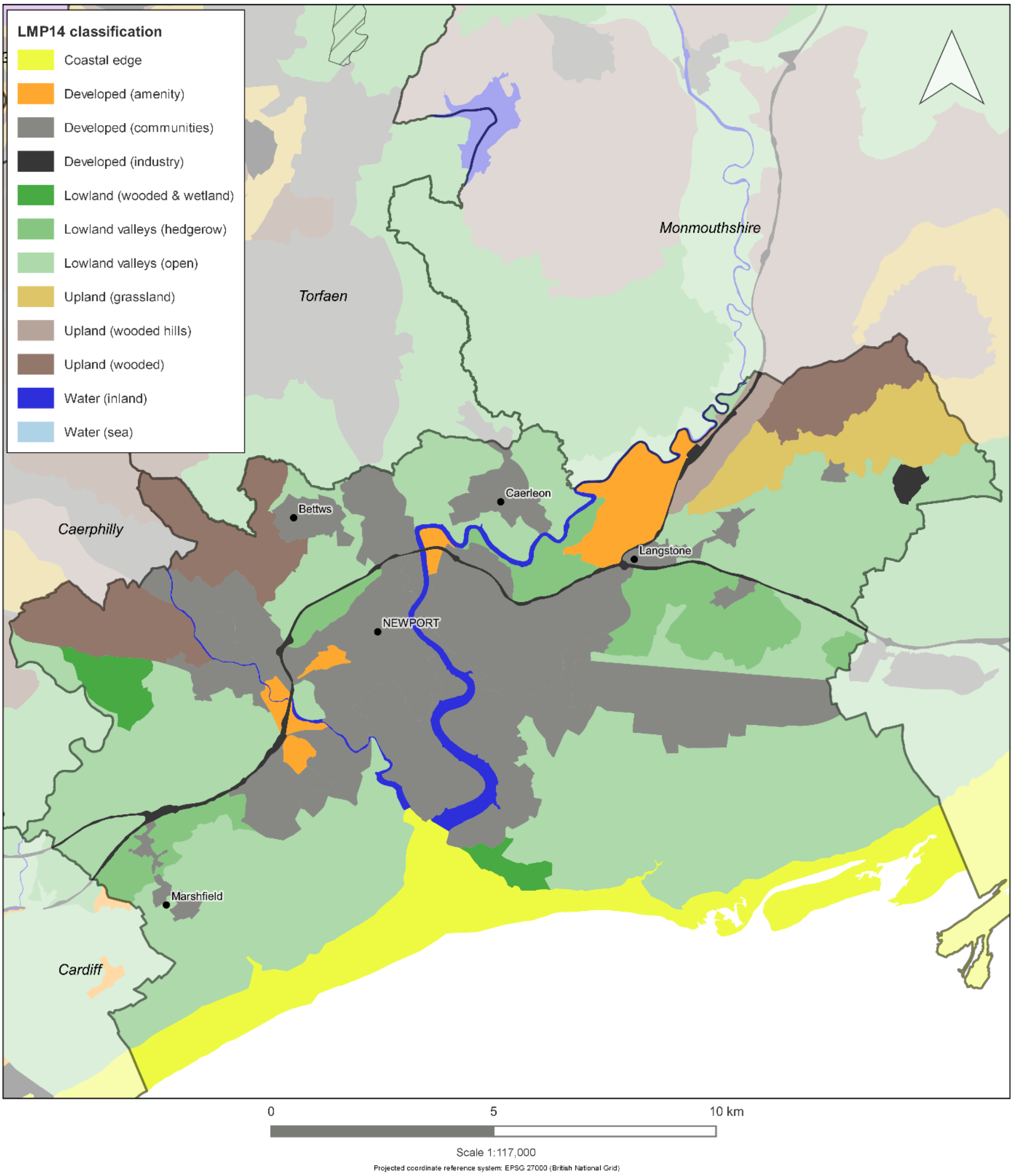
'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.38 Landscape value with LMP14 landscape boundaries (Monmouthshire)

4.9. Newport

LANDMAP Visual & Sensory: LMP14 Classification (Newport)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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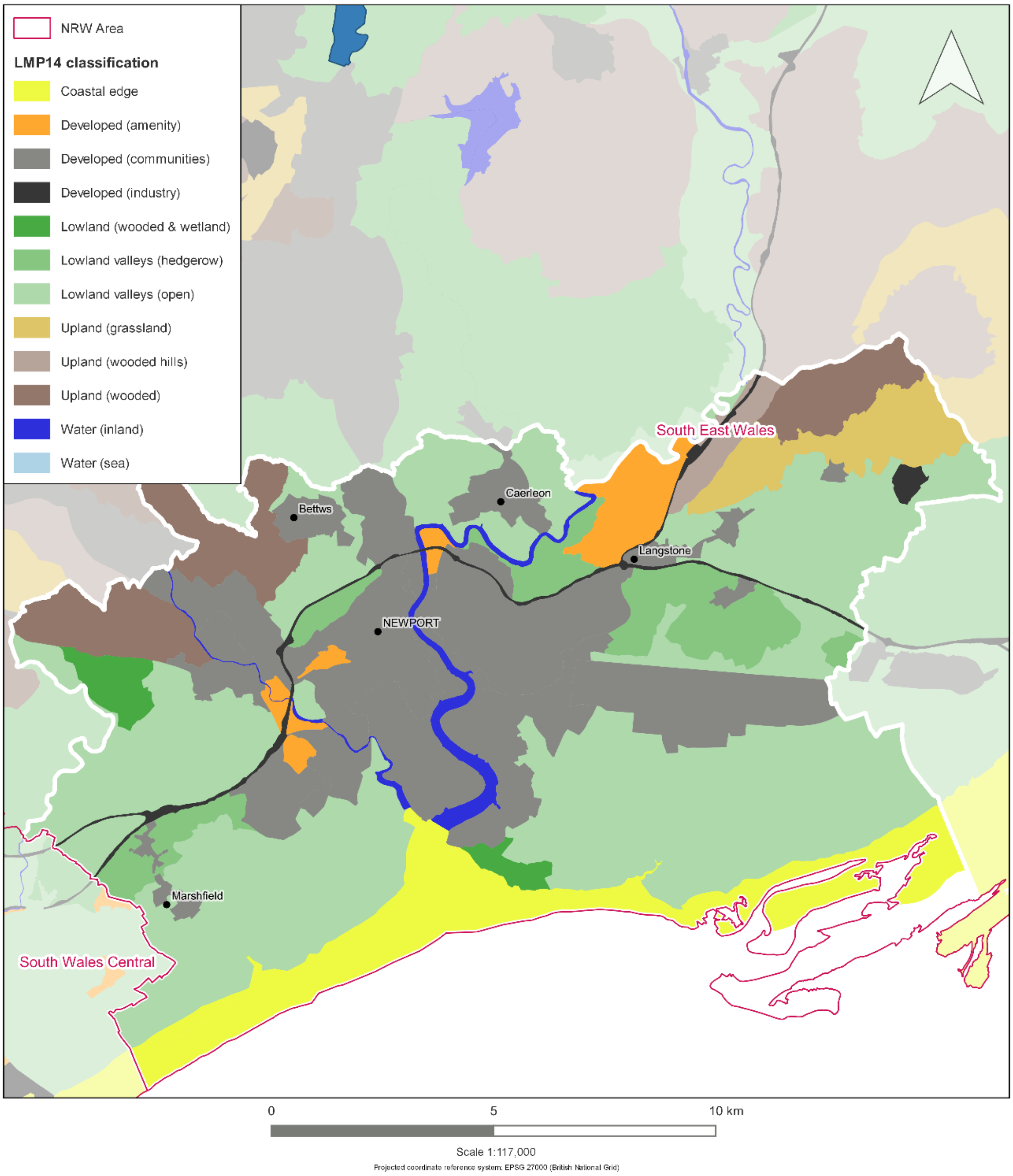
'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.39 LMP14 landscape types (Newport)

LANDMAP Visual & Sensory: LMP14 Classification - Newport
(showing NRW Operational Areas)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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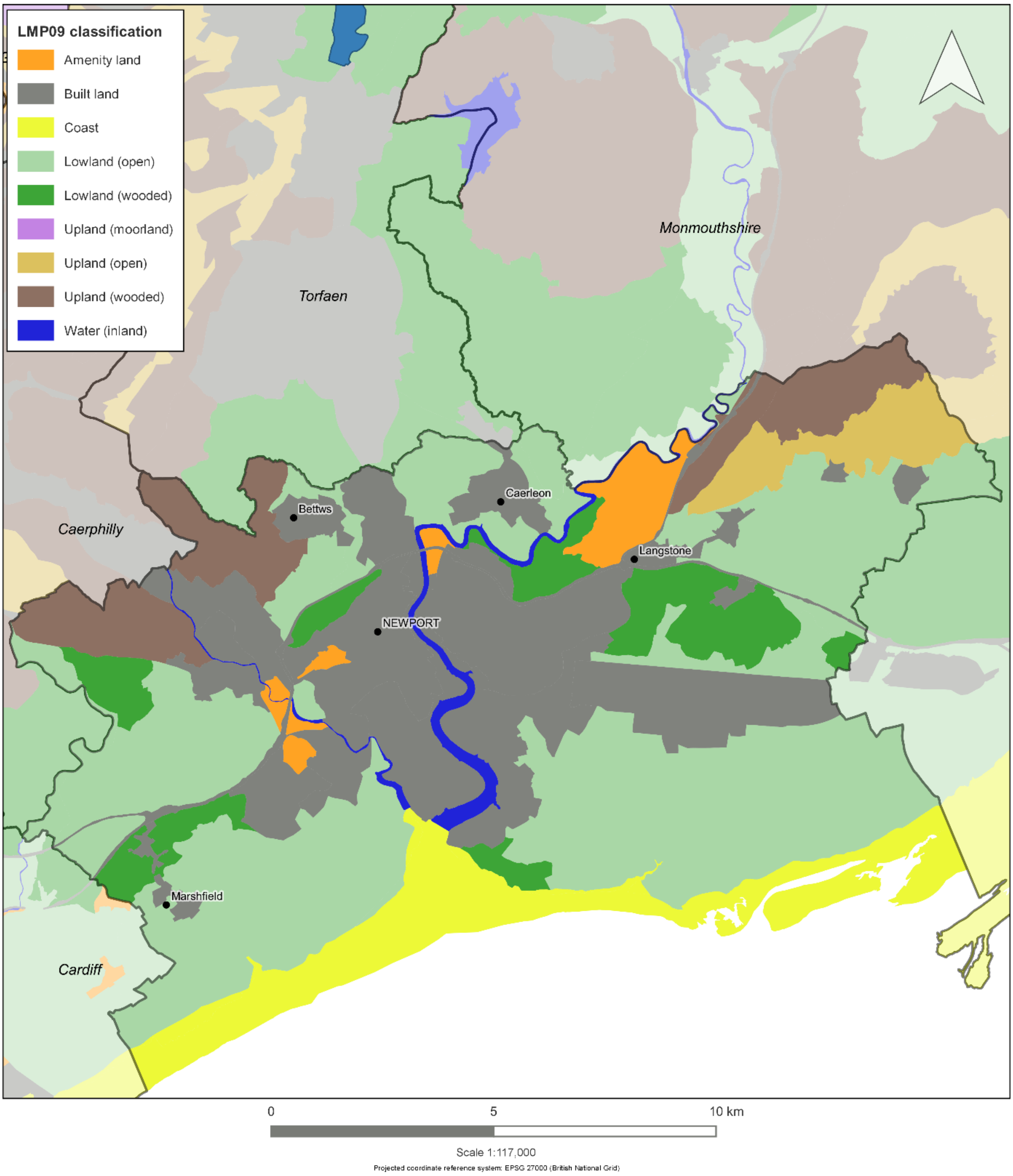
Last updated 11/03/2019.

'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.40 LMP14 landscape classification with NRW Operating Areas (Newport)

LANDMAP Visual & Sensory: LMP09 Classification (Newport)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

Cyfoeth Naturiol Cymru Natural Resources Wales

Produced for Natural Resources Wales by Robert Berry, Countyside and Community Reserach Intitute, University of Gloucestershire - rberry@glos.ac.uk. Last updated 11/03/2019.

'R' programming code and resources used for data processing, analysis and visualisation (including QGIS map styles) available via Github: https://github.com/robertberryuk/LANDMAP_ClimateChange.

Figure 4.41 LMP09 landscape types (Newport)

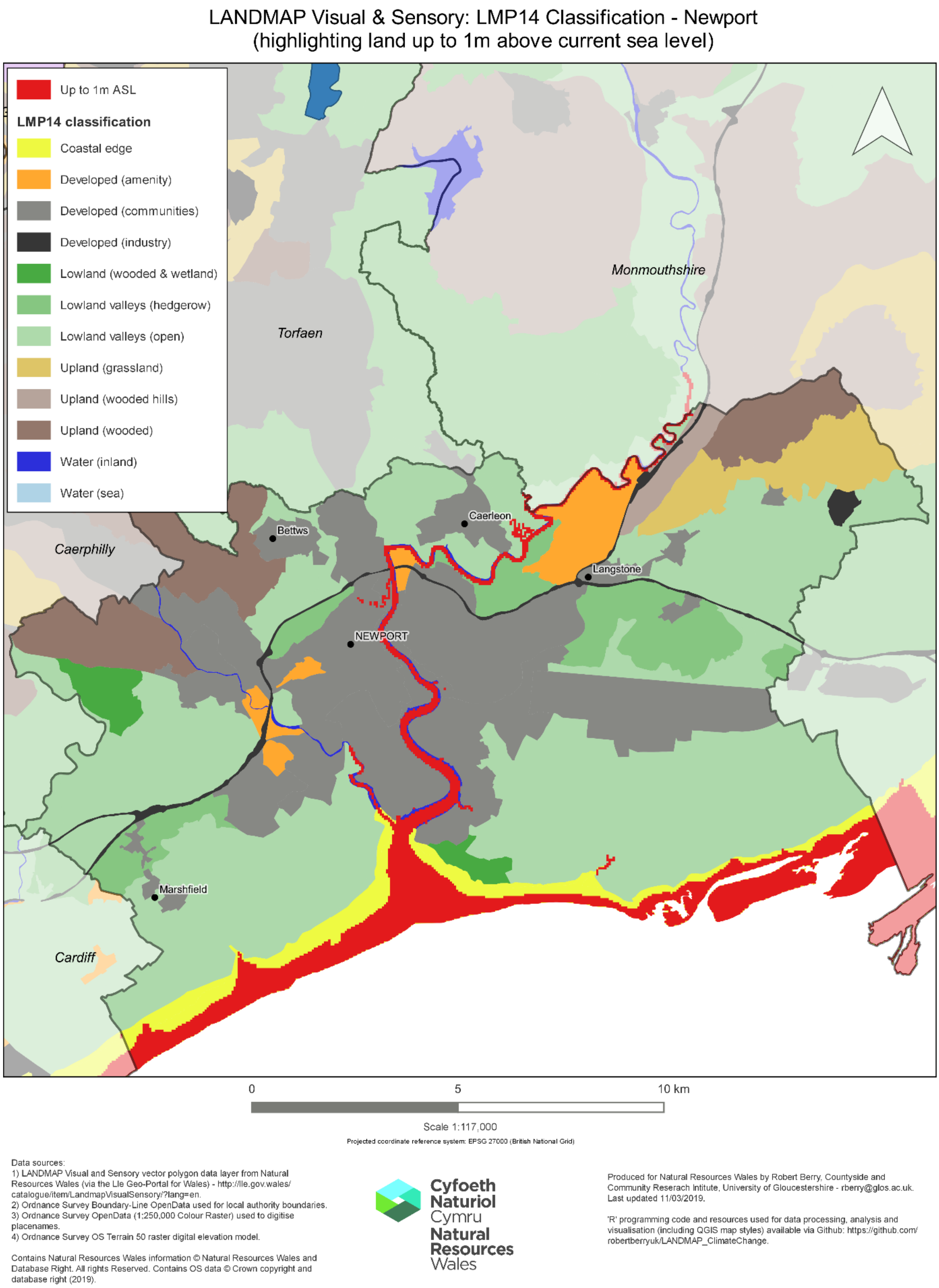
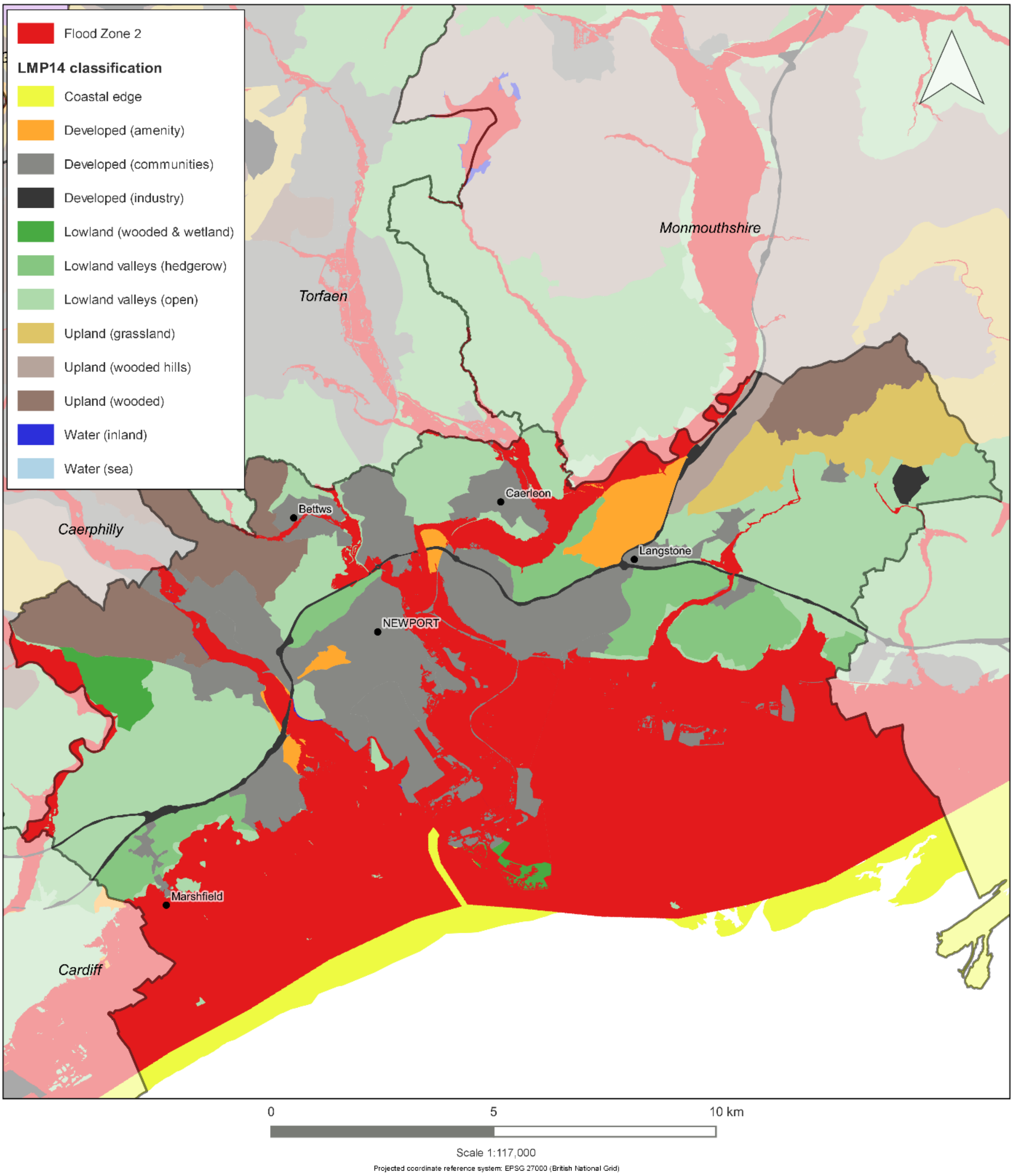


Figure 4.42 LMP14 landscape types with land up to 1m above sea level (Newport)

LANDMAP Visual & Sensory: LMP14 Classification - Newport
(showing Flood Zone 2 data)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames and mountain summits.
3) Natural Resources Wales Flood Zone 2 data: http://lle.gov.wales/catalogue/item/FloodZ2/?lang=en.

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Figure 4.43 LMP14 landscape types with Flood Zone 2 (Newport)

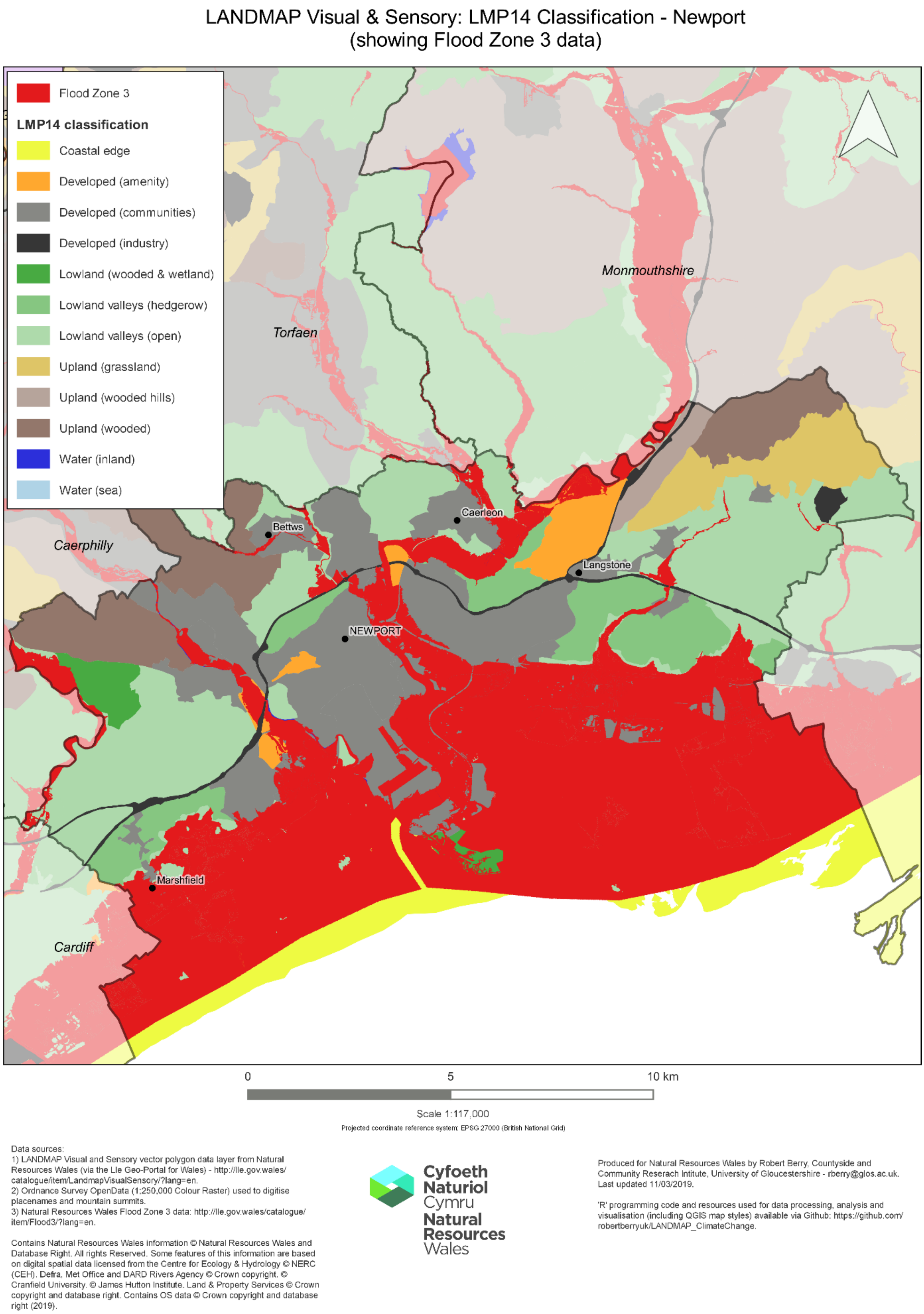
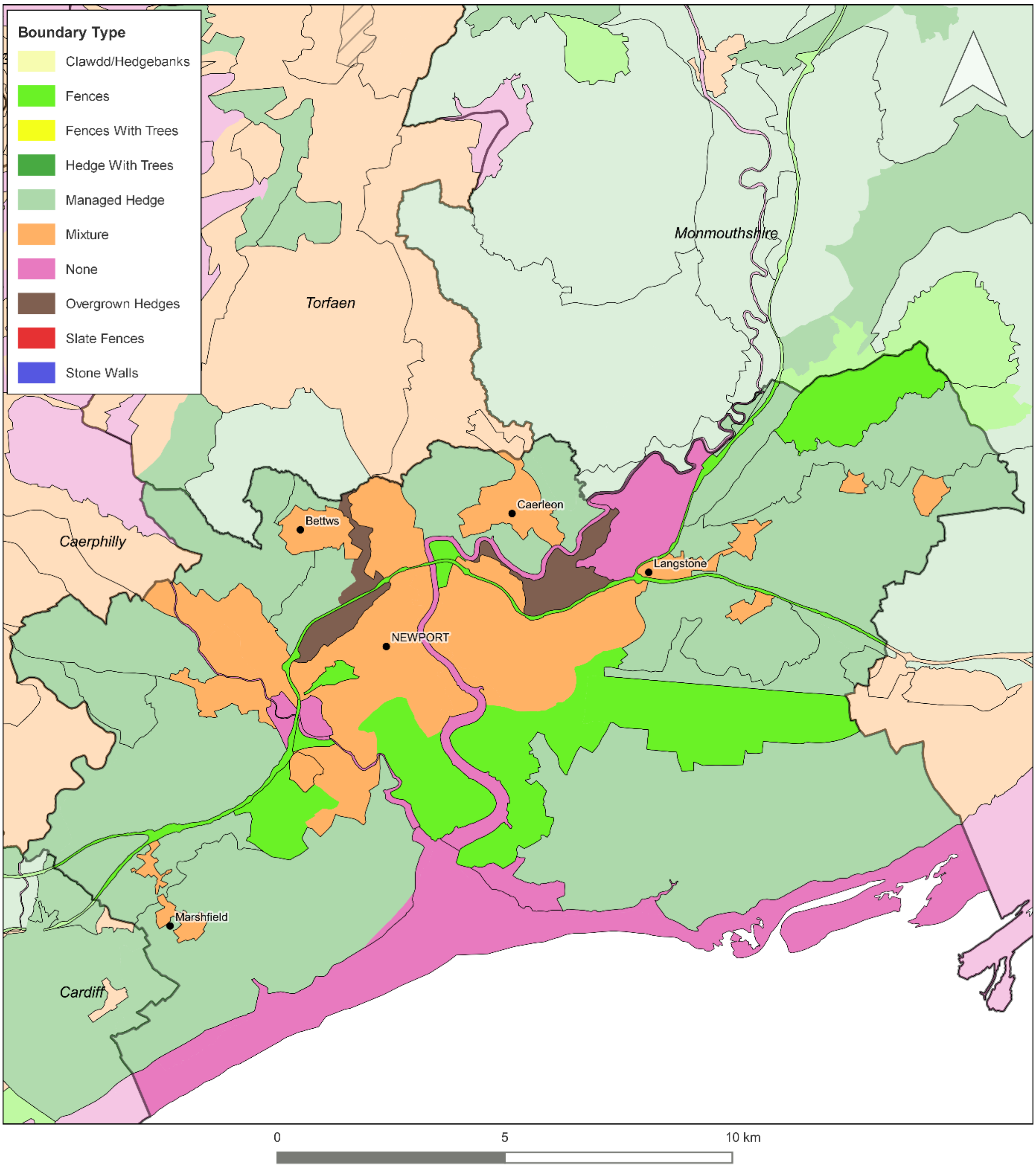


Figure 4.44 LMP14 landscape types with Flood Zone 3 (Newport)

LANDMAP Visual & Sensory: LMP14 Boundary Type - Newport



Scale 1:117,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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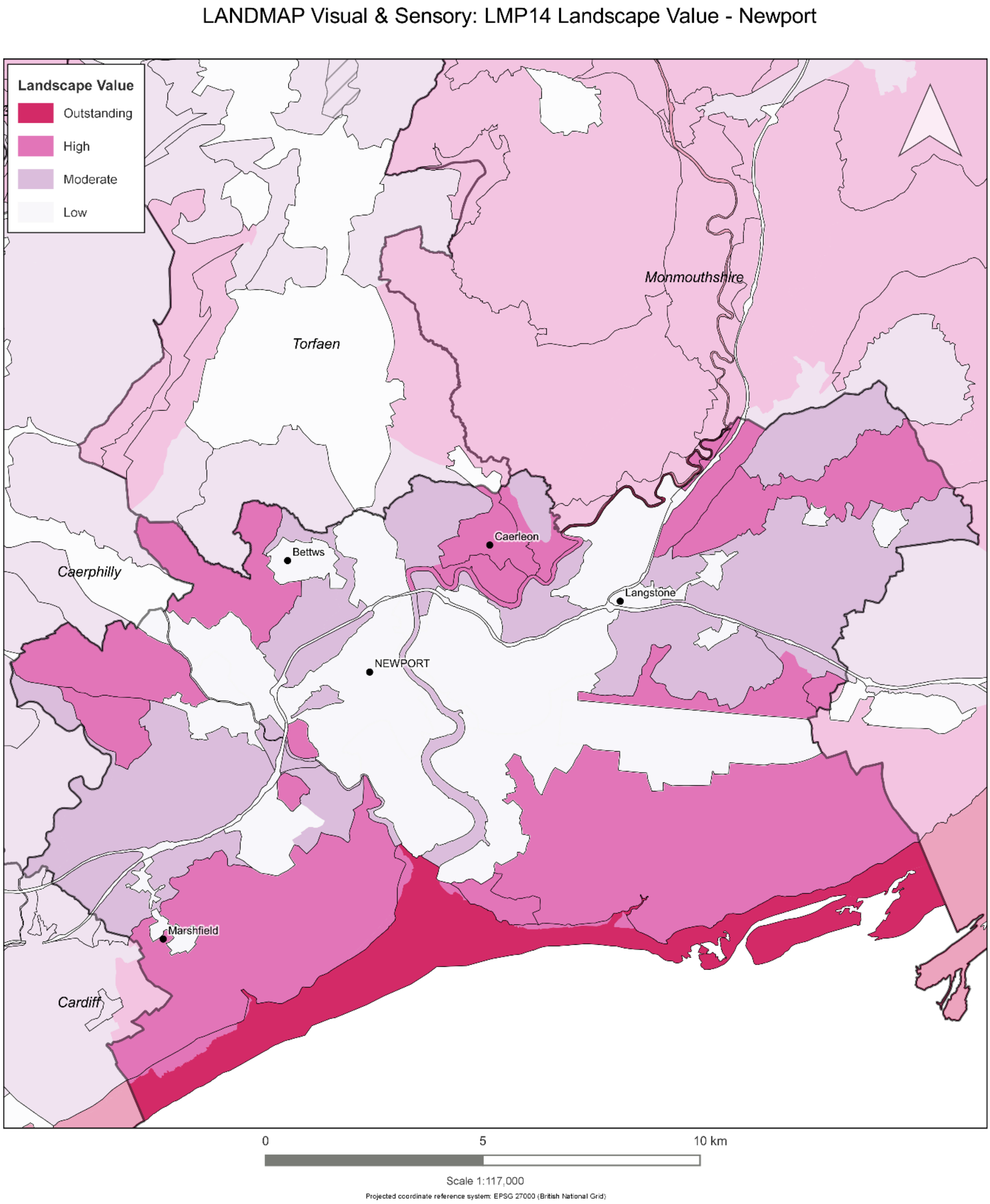
Figure 4.45 Boundary type with LMP14 landscape boundaries (Newport)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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Figure 4.46 Landscape value with LMP14 landscape boundaries (Newport)

4.10. Torfaen

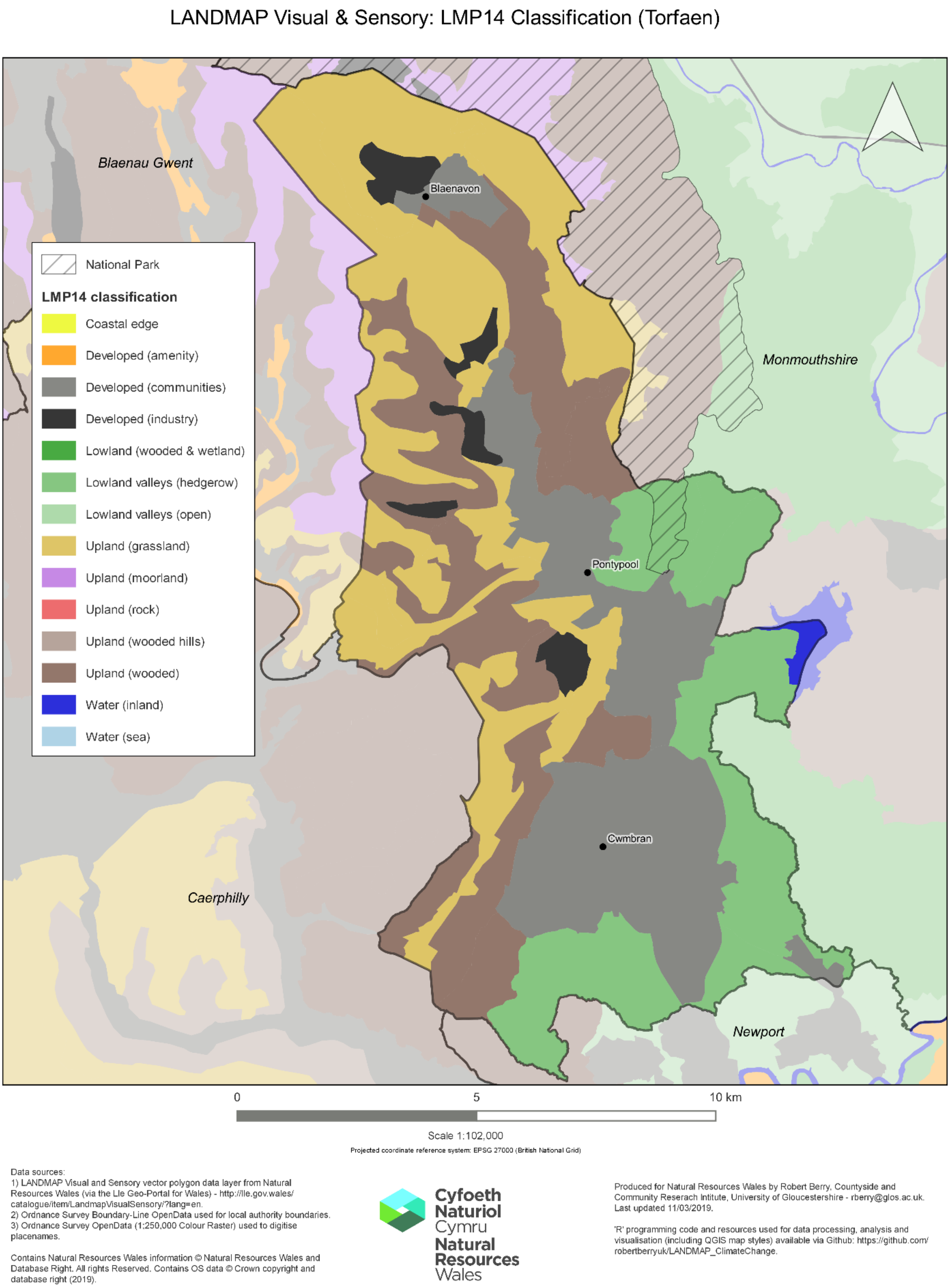
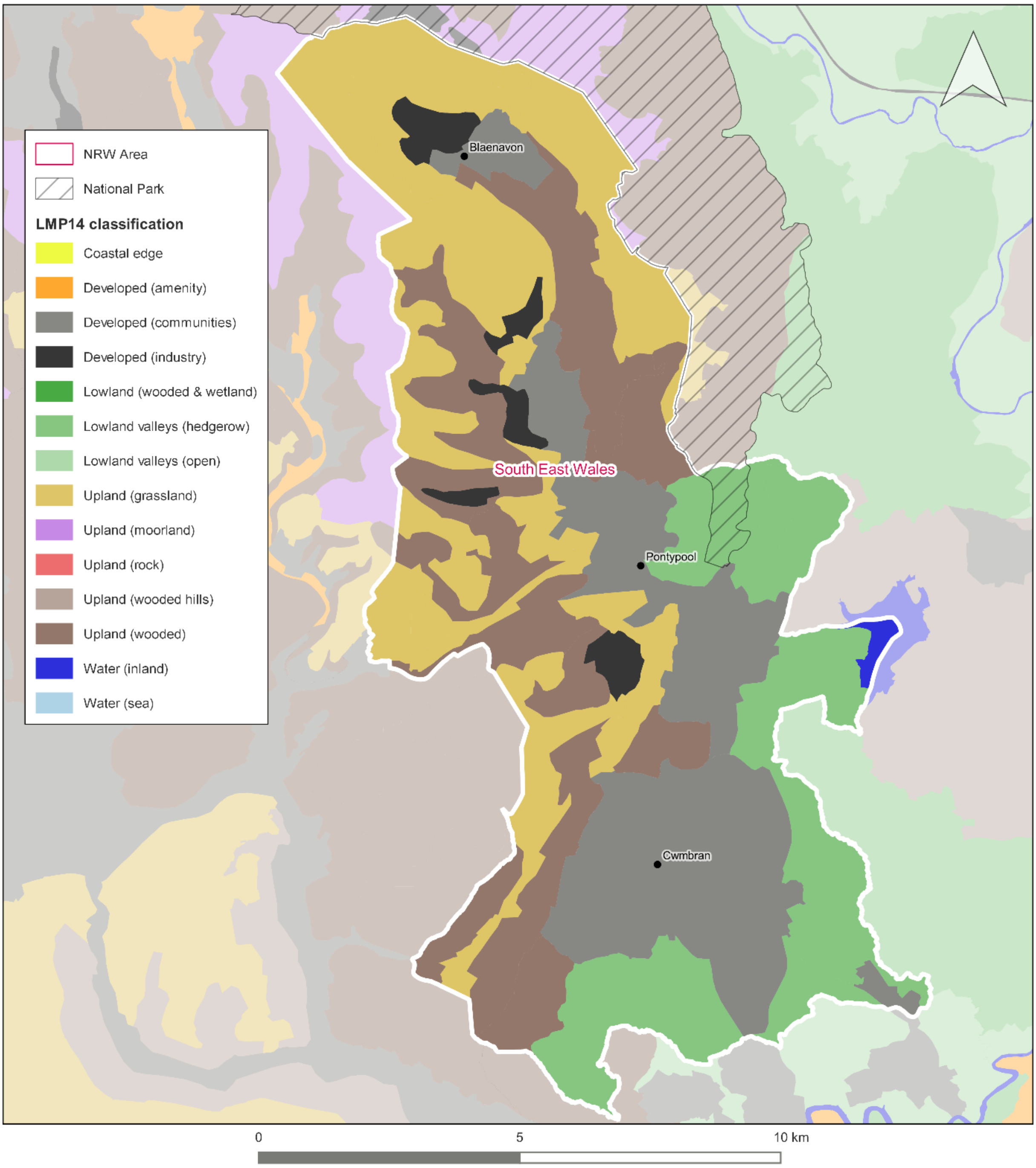


Figure 4.47 LMP14 landscape types (Torfaen)

LANDMAP Visual & Sensory: LMP14 Classification (Torfaen)



Scale 1:102,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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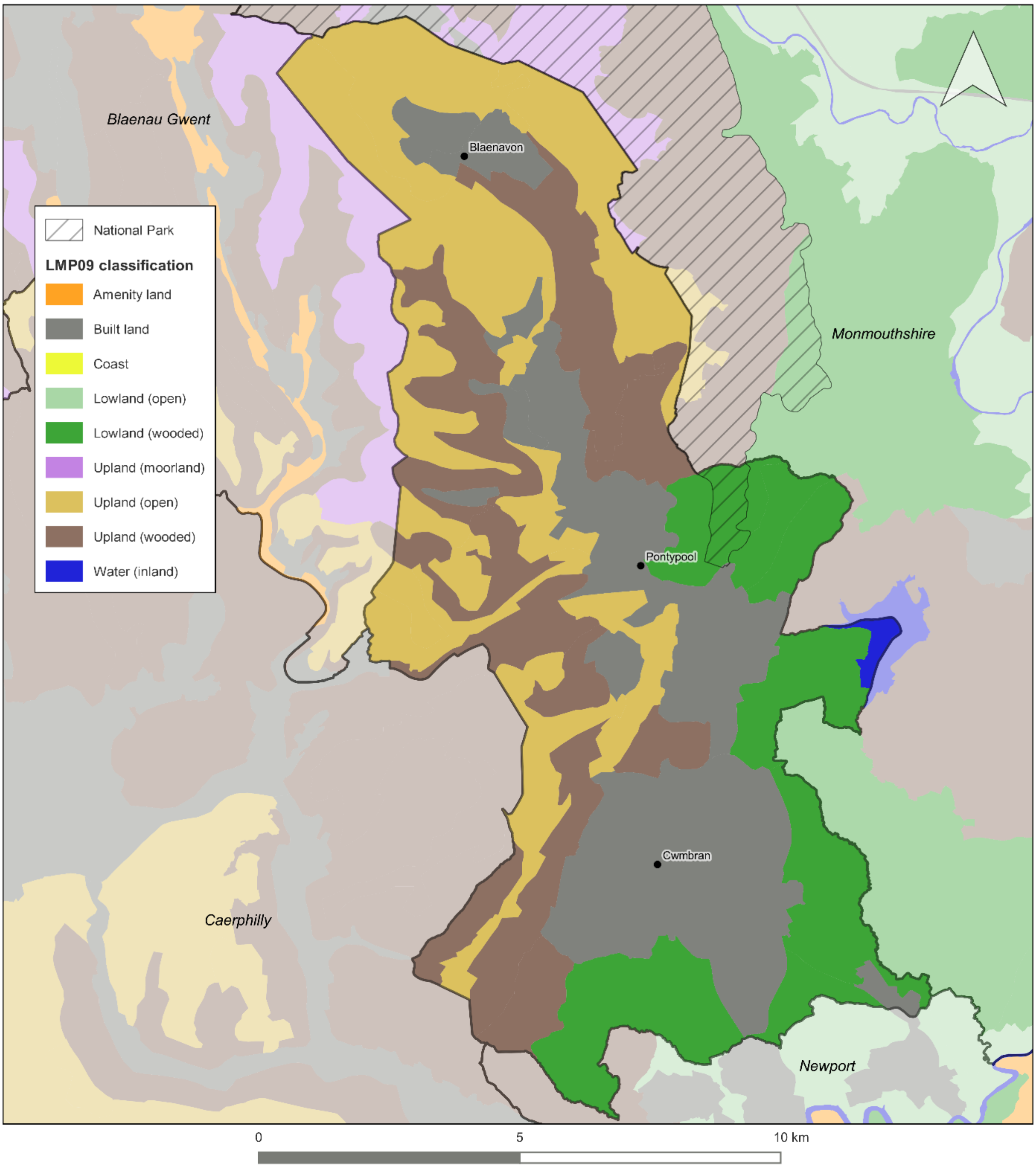
Figure 4.48 LMP14 landscape classification with NRW Operating Areas (Torfaen)

LANDMAP Visual & Sensory: LMP09 Classification (Torfaen)



Scale 1:102,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
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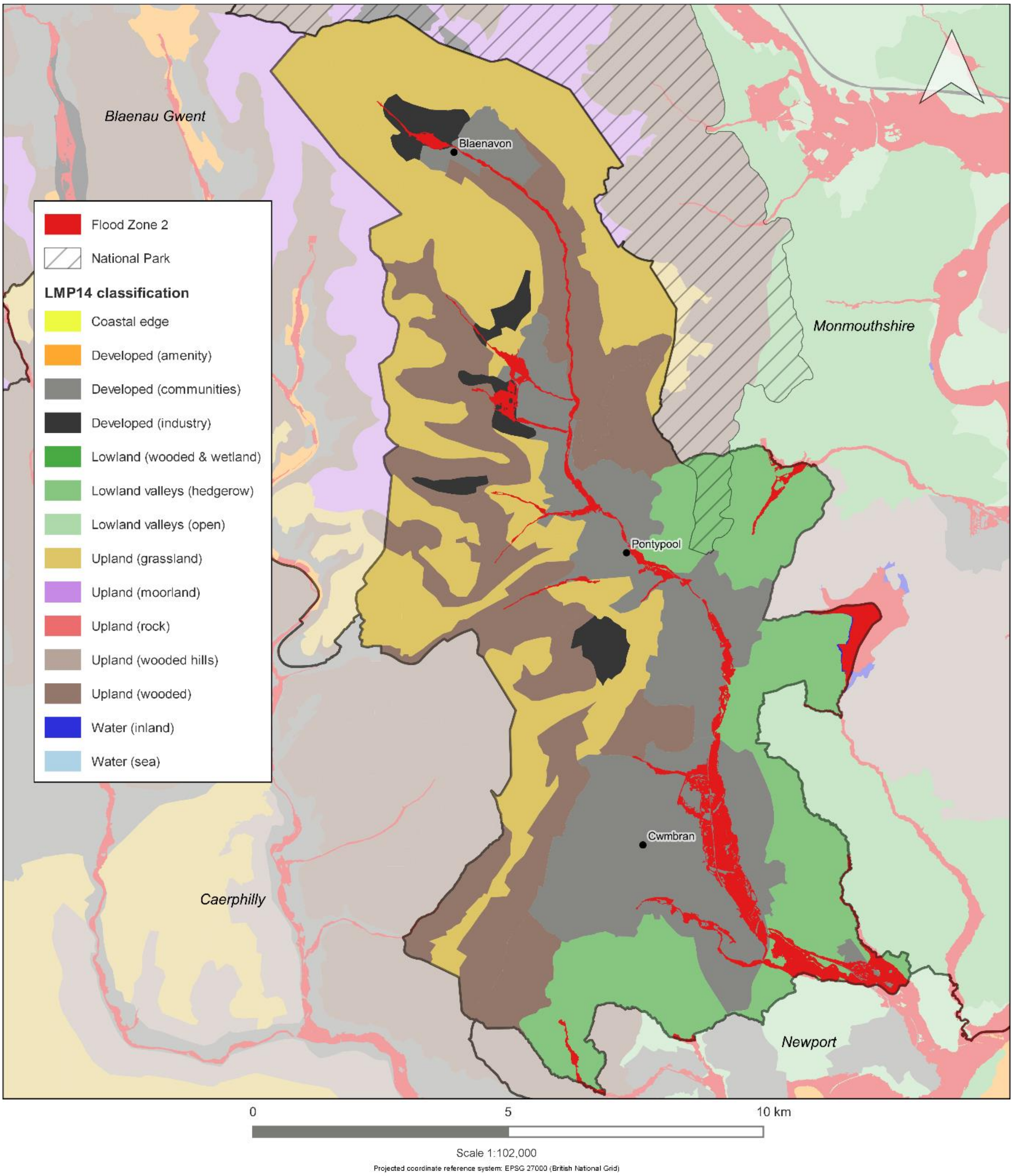
Figure 4.49 LMP09 landscape types (Torfaen)

LANDMAP Visual & Sensory: LMP14 Classification - Torfaen (showing Flood Zone 2 data)



Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1;250,000 Colour Raster) used to digitise place names and mountain summits.
3) Natural Resources Wales Flood Zone 2 data: http://lle.gov.wales/catalogue/item/FloodZ2/?lang=en.

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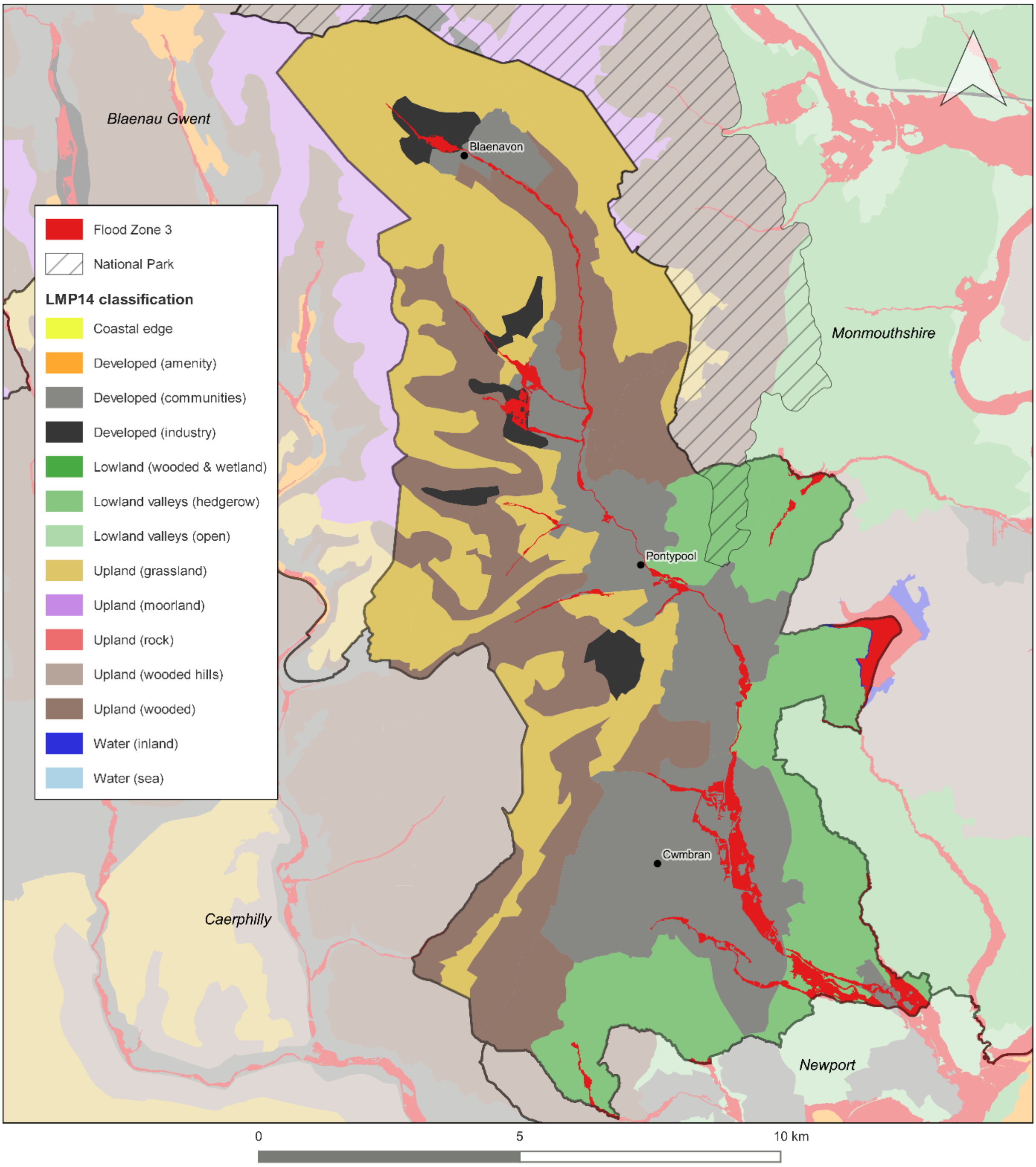
Figure 4.50 LMP14 landscape types with Flood Zone 2 (Torfaen)

LANDMAP Visual & Sensory: LMP14 Classification - Torfaen
(showing Flood Zone 3 data)



Scale 1:102,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise place names and mountain summits.
3) Natural Resources Wales Flood Zone 3 data: http://lle.gov.wales/catalogue/item/Flood3/?lang=en.

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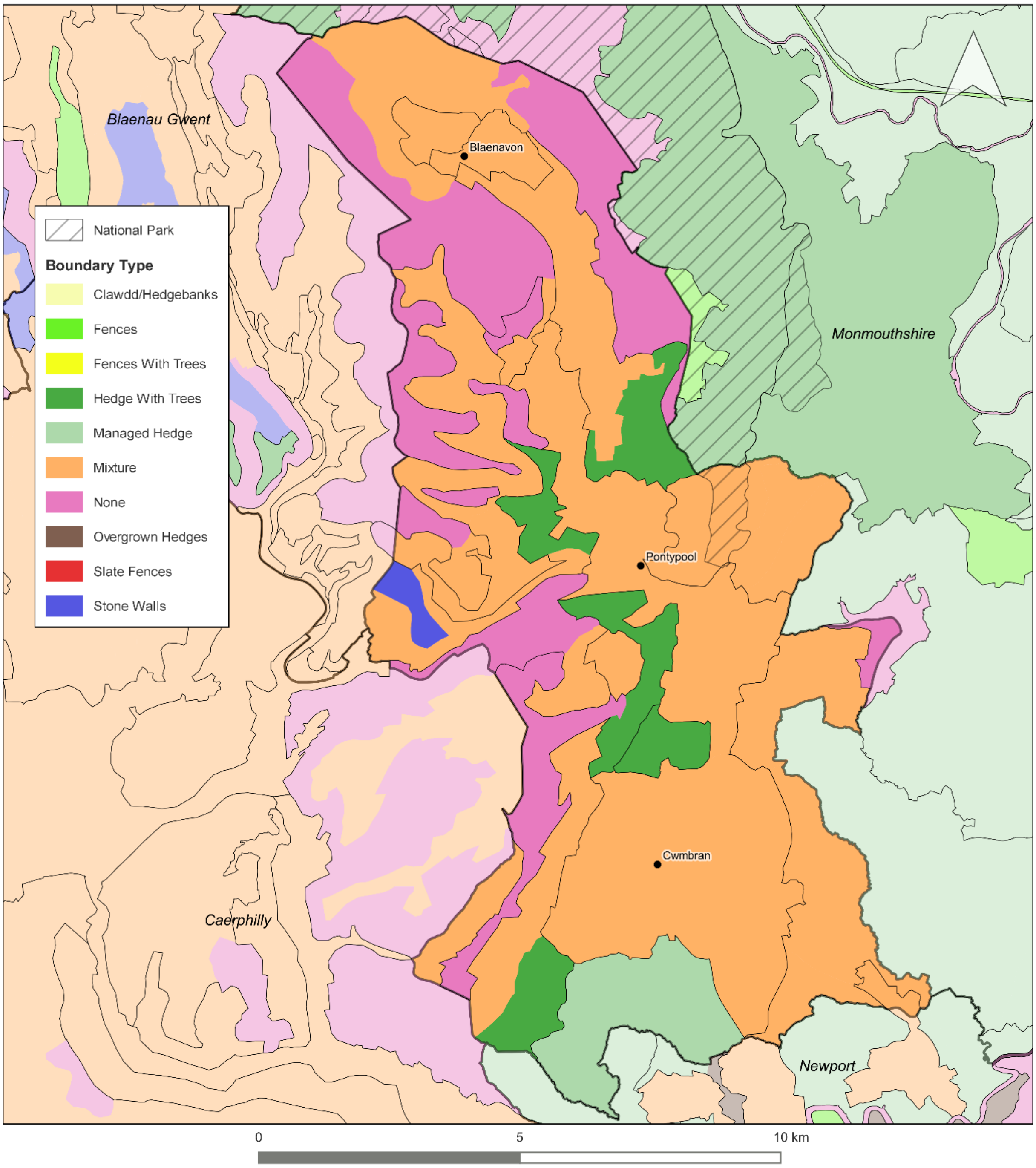
Figure 4.51 LMP14 landscape types with Flood Zone 3 (Torfaen)

LANDMAP Visual & Sensory: LMP14 Boundary Type - Torfaen



Scale 1:102,000

Projected coordinate reference system: EPSG 27000 (British National Grid)

Data sources:
1) LANDMAP Visual and Sensory vector polygon data layer from Natural Resources Wales (via the Lle Geo-Portal for Wales) - http://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en.
2) Ordnance Survey Boundary-Line OpenData used for local authority boundaries.
3) Ordnance Survey OpenData (1:250,000 Colour Raster) used to digitise placenames.

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Figure 4.52 Boundary type with LMP14 landscape boundaries (Torfaen)

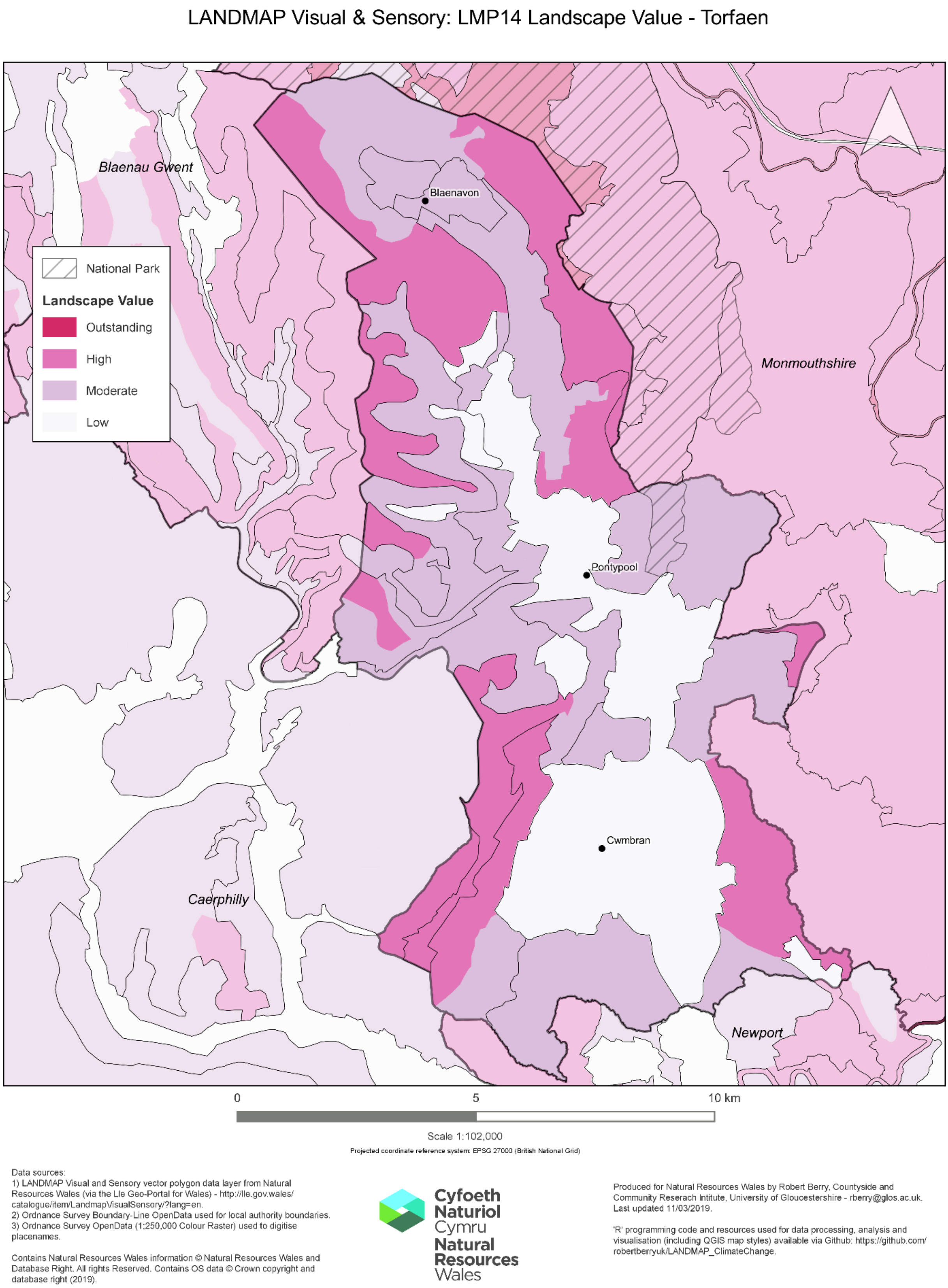

Figure 4.53 Landscape value with LMP14 landscape boundaries (Torfaen)

5. Landscape Narratives

This section summarises the key characteristics of the landscape types and how they are experienced. Section 8.4 contains further information on the key processes that have over centuries affected their character, and the issues that are driving change now and in the foreseeable future. These landscape types are recognisable in LANDMAP, the 48 National Landscape Character Areas for Wales and the Local Landscape Character Areas published by local authorities and National Parks.

5.1. Coastal Edge

Landscape narrative: Coastal edge
• The coastal edge landscape type – 2.45% of the area of Wales covered by LANDMAP - comprises great variety from the inter-tidal zone (beaches, mud and rocks) and small islands, dunes, coastal wild land, cliffs and cliff tops. The rocky headlands and cliffs showcase geological formations. • Characteristic features are the remains of anti-invasion defences, fishing, maritime trade, features from relict industrial mineral mining and quarrying, coastal navigation (lighthouses, daymarks and coastguard houses) and sea defences - including timber groynes and breastwork defences, and more recent beach nourishment and rock beach structures. • Settlement is sparse. Some areas marked by nearby development; 20th century housing and amenity land, mostly golf courses and caravan sites. • Only a very small proportion (11.7%) of this landscape type is enclosed, mostly with stone walls (9.05% of land area) and sometimes with fences (1.73%). Some use of headlands and dunes for rough grazing. Tree cover is also sparse, prevailing winds can create a distinctive windblown tree profile. • Rough grazing has conserved extensive areas of medieval and earlier archaeology, which extends also into the inter-tidal zone, including fossil forests exposed on beach areas affected by the rise in sea levels around 6,000 years ago. • These landscapes have distinct sense of the birdlife and vegetation from coastal heaths, dunes and gorse scrub and their associated colours that are particular to these areas. Often impressive rock faces, screes and shingle. • There is widespread access, including via coastal tracks and paths, to these landscapes and their valued panoramic views, sense of remoteness and wildness. • They are frequently associated with low levels of light pollution and landscapes of outstanding or high importance for their scenic quality and character and highly valued seascapes often part of a designated Heritage Coast, National Park or AONB, generally associated with attractive views.

5.2. Water (inland)

Landscape narrative: Water (Inland)
This landscape type – 0.5% of the area of Wales covered by LANDMAP - comprises substantial areas of freshwater, notably: ◦ Rivers that are typically more than 20 metres in width and inland estuaries (rias) that can extend inland with have tidal characteristics including salt marshes and muddy banks. ◦ Glacial lakes which are strongly associated with mountains, moors and heaths. ◦ Reservoirs dating from the late 19th century, these providing a critical service in view of the lack of natural water storage in Wales and marked as dramatic feats of civil engineering with dams and water towers. • Boundaries (mostly to fields) around these waters, included in this landscape type, are mixed (21.9% of land area) or fenced (11.5%). • The scenic quality of these landscapes, afforded by their combination of reflective water and contrasting rocky and vegetated slopes, is often combined with a strong sense of tranquillity – despite their often intense use for leisure and recreation and location close to busy amenity routes and roads. The sheltered, enclosed, intimate, views that extend down waterbodies or courses are framed by topography and land cover where visually enclosed.

5.3. Water (sea)

Landscape narrative: Water (sea)
This landscape type comprises the coastal waters around Wales. 35% of these being designated as marine protected areas. In LANDMAP only areas above the low water mark are included, there is also the coastal edge landscape type, hence this type only comprises 0.5% of the land area covered by this landscape type in Wales, as they include estuaries that can extend inland which have tidal characteristics including salt marshes and muddy banks. • The coastal waters and estuaries are rich with a sense of history, being used as a major thoroughfare from prehistoric times – the movement of peoples along the Atlantic Seaboard from Spain to Scandinavia, the movement of the early Brittonic saints in the first millennium, and the development of cross-Atlantic and global trade in more recent centuries. Local names and sea charts also provide testament to centuries of use of church towers, landmarks and navigational aids for seafarers, and the sea lanes and coastal areas also retain the wrecks of ships and aircraft. • Seascape character is remarkably varied, from the busy maritime routes along the Dee estuary and Bristol Channel, including its industrial development and one of the world's largest natural harbours at Milford Haven, to the resort areas of the north coast, the Atlantic seaboard seascapes of Pembrokeshire and the comparatively sheltered coastline of Cardigan Bay. • The 29 National Marine Character Areas (MCAs) for Wales and the local scale seascape character assessments provide detailed information on the diversity and character of Welsh marine character areas. These have been published by Natural Resources Wales (https://naturalresources.wales/evidence-and-data/maps/marine-character-areas/?lang=en).

5.4. Developed (communities)

Landscape narrative: Developed (communities)
Developed (communities) – 4.47% of the area of Wales covered by LANDMAP - includes urban communities, villages and other rural settlement exceeding 15 houses in size. Two-thirds of the population (just below 2 million) live in urban areas and a third in rural areas, 11% of the total living in Village, Hamlet and Isolated Dwellings Sparse area types which cover more than half of Wales's land area (Rural Urban Definitions, 2011). **Urban areas**: • 81% of Wales's population of 2.5 million lives in towns and cities. **Urban areas with populations exceeding 10, 000** are concentrated around the industries and coal fields of north-east Wales, along the resorts of the north Wales coast, around the ports of Pembroke and Milford Haven and in both ports and industrial centres of south Wales (eastwards of Swansea) including the valleys and their associated former coal fields extending inland. • **Small market towns** and **ports** are also a strong characteristic of Wales. Of the 81 identified (Wales Rural Observatory 2007), over 75% have populations of 1-5, 000 with five settlements (Aberystwyth. Milford Haven, Bangor, Carmarthen and Abergavenny) accounting for a fifth of the population resident in this category. These typically retain strongly characteristic historic settlement cores, 19th and 20th century growth being comparatively modest, although recent decades have seen some significant expansions of the coastal towns inland. • **Built environment**. Historic urban areas in Wales are dominated by their 19th century building stock, often hiding the cores of earlier buildings in historic cores or in chains of industrial settlements absorbed by later growth. These include market buildings, often built in materials reflecting the underlying geology and standing out in the landscape due to undulating topography. • Open spaces in urban areas and towns provide an important contrast and break from the built environment. **Parkland, gardens, wooded areas** and **open space** retained within the expansion of urban areas includes urban river corridors and woodland, industrial-era transport infrastructure (such as the Lower Swansea Valley and the Taff Trail in Cardiff, which was a tramroad linked to Merthyr Tydfil), formal parks, golf courses and playing fields. Deprived areas are noticeably lower in **tree cover**. • Analysis for Natural Resources Wales of **tree cover** in Wales' towns and cities (https://naturalresources.wales/about-us/what-we-do/green-spaces/urban-trees/?lang=en) has shown that – whilst private residential gardens take up 35% of their land area – densities are extremely low in area of high-density housing, and affected by neighbouring landscape character (being low in Coastal Edge

landscapes and high in Upland (Wooded) area.

- Busy roads and increased light pollution – concentrated in these urban areas and along their linking transport routes - can reduce **tranquillity**.

Rural areas:

Built land in rural areas is strongly characterised by dispersed settlement intermixed with fields enclosed from the medieval period, and unenclosed land which is now a fraction of its former extent:

- About two in eight of the population lives in ‘less sparse’ rural areas and one in eight in sparsely-populated rural areas that characterise most of rural Wales.

- **Medieval villages** with their strip fields are concentrated in the coastal and lowland vale areas with more fertile land and historic Anglo-Norman influence. Many villages, often linear in their form, were established along the new and improved road transport network that developed in the late 18^{th} and 19^{th} centuries.

- Low densities of **scattered or dispersed settlement** dominate Wales, higher densities being found in historic rural industrial areas and in some of the areas where squatter settlements developed along and within commons in the 16^{th}-19^{th} centuries.

- The **traditional domestic and farmstead architecture** of rural settlements makes a fundamental contribution to the distinctive quality of the Welsh landscape and how it is experienced.

- Medieval parish churches are often sited next to an historic manor or *plas*, another common feature being chapels associated with the influence of Calvinistic Methodism.

5.5. Developed (industry and infrastructure)

Landscape narrative: Developed (Industry and infrastructure) (>100ha)
This landscape type - only 0.43% of the area of Wales covered by LANDMAP - comprises working and abandoned industrial sites exceeding 100 hectares in area. Such sites are often associated with large scale power generation, infrastructure and transport networks and industrial plants that can include landmark-scale structures. It includes: • Granite, limestone and aggregates quarries, slate quarries in North West Wales • Lead and ore mines, some now quarried for stone, and opencast coal mines concentrated in North East and South Wales. • The industrial character and noise of South Wales is constrained by topography with development on the valley floors and lower slopes contrasting with the moorland and wooded adjacent landscape types. • Vertical structures, relict tips and spoil heaps are clearly evident in the landscape and often considered to detract from the tranquillity and sense of place of rural historic settlements and landscapes around them (for further details see **Built land – communities**). • Quarrying for building stone now or in the past can leave a distinctive mark on the landscape from disused quarries and locally distinctive stone buildings. • Visible emissions and stack lighting from tall stacks and chimneys may be a recognisable part of local landscapes. • Some industry and infrastructure has distinct cultural heritage value, prime examples include Blaenafon World Heritage Site and the nominated slate quarries of North Wales representing the slate workings, transport, infrastructure and distinctive communities of this area.

5.6. Lowland (wooded and wetland)

Landscape narrative: Lowland (wooded and wetland)
This landscape type comprises 2.37% of the area of Wales covered by LANDMAP. It is defined by having a higher proportion (typically over 50%) of woodland and wetland than other types of lowland landscapes. There are significant (designated and non-designated) vegetation and plant communities in these areas providing diverse texture from a variety of land cover elements including pasture, wetland and woodland. Some woodlands and wetlands are protected because of the diversity of native and rare species. • Settlement is mostly dispersed, and includes 19th century smallholdings and their small-scale fields which developed around and within drained wetland and common pastures. • These settlements farmed unenclosed and enclosed land, surviving areas of wet grassland and other rough grazing habitats now being very rare. 85.5% of this landscape type is enclosed, much of this being of 18th century or earlier date. Dominant boundary types are hedges with trees (30% of land area), mixed boundaries including stone walls (16.7%, stone-walled enclosures taking 5.3% of land area) and managed hedges (14.8%). Hedgebanks (cloddau) take 2.8% of land area and are concentrated in the south-west. • Forestry Commission plantations, contrasting with ancient woodland and 18th-19th century mixed-species plantations, date from after 1919. • Older woodland and wetland is often evident as an intricate network following the tranquil pastoral and wooded valley sides of watercourses. Enclosed land with its historic hedgerows, copses and blocks of woodland provide a framework for visual appreciation of historic settlements, houses and farmsteads. • These characteristics combine to bring a sense of unity, time depth and pattern in the landscapes with recognisable local character, diversity and texture. Scenic quality is generally higher where associated with species diversity and good design and well-integrated in the landscape in size and scale.

5.7. Lowland valleys (hedgerow)

Landscape narrative: Lowland valleys (hedgerow)
This landscape type of valleys and rolling lowlands comprises 15.03% of the area of Wales covered by LANDMAP. It is defined by the strong presence of **hedgerows** and **hedgerow trees**, often associated with a mosaic of farmland and small-scale woodlands occupying between 20 and 50% of its land area. • Patterns of enclosure define this landscape, developing from a varied pattern of dispersed and more rarely village-based settlement. This can range from patterns of irregular 17th century and earlier fields, fields enclosed from medieval strip fields around settlements and 18th-19th century planned enclosures of former common land. This farmed landscape, and the layouts of farmsteads with barns and other buildings, reflect the past importance of mixed agriculture. • Most of this area is enclosed by a mixture of boundaries (42.1%), followed by hedgerows with trees (30.5%) and managed hedges (15.29%) – the latter tending to result from 19th century enclosure. Gorse and thorn hedges are more common nearer the coast. It has after Lowland (open) landscapes the second-highest proportion of hedgebanks (cloddau) of any of the landscape types, at 9.4% of land area and concentrated in the south-west. • The sense of enclosure is enhanced by a strong presence of ancient woodland – often sessile oak with ash, hazel on drier land, willow and alder carr in wetter areas, 18-19th century plantations and some post-1919 softwood plantations. • Parkland is another strong characteristic of this and to a lesser degree the Lowland (open) landscape character type, particularly in east and south Wales. • The field patterns in these landscapes lend a strong patchwork character and sense of place in a settled pastoral and tree-rich landscape, enhanced by the seasonal colours of older, mixed deciduous woodland and mixed-species hedgerows. There has been a significant decline in botanical diversity of both permanent and temporary pasture, now managed intensively for maximum productivity of often ryegrass-dominated swards.

5.8. Lowland valley (open)

Landscape narrative: Lowland valley (open)
This landscape type comprises 16.59% of the area of Wales covered by LANDMAP. It is a pastoral landscape of farms and fields in a rolling or flat lowland landscape, defined by its relative lack of hedgerow trees and a lower proportion of woodland (under 20% of land area) than in other lowland landscape types. • Rural communities developed in village-based (mostly in South West Wales) and a predominantly dispersed settlement pattern of farmsteads and hamlets, working fields enclosed from the medieval period that tended to become larger than in other lowland landscapes. • Patterns of fields and farmstead architecture testify to a varied farming economy. Courtyard farms including threshing barns developed in tandem with the 18th-20th century enlargement of fields with straight thorn boundaries, bringing organised regularity to parts of the landscape and enabling intensive modern agriculture which contributes to its sense of openness. • This landscape type is mostly enclosed by a mixture of boundaries (42.1%, including stone walls), managed hedges (35.17%) and hedgerows with trees (7.5%). Many hedges are thorn hedges resulting from 19th century improvement and enclosure. It has the highest proportion of hedgebanks (cloddau) of any of the landscape types, at 10% of land area and concentrated in the south-west. • Parkland is another characteristic of this landscape character type, and areas of historic commons and rough grazing are very rare and significant as habitats. • These are open landscapes with a strong sense of their relationship to other landscape types - of coastal edges, the sea, up valleys and to historic houses and farmsteads and their associated modern agricultural barns and buildings.

5.9. Upland (grassland)

Landscape narrative: Upland (grassland)

This landscape type comprises 23.17% of the area of Wales covered by LANDMAP. This type includes upland valleys, hillsides, lower plateaux and scarps where grazing land is more than 50% of land use, some parts being internationally and nationally valued for nature conservation.

- These are open, sparsely-settled upland landscapes with isolated farmsteads and hamlets, interspersed with deserted settlements, prehistoric monuments (concentrated in unenclosed land) and in some areas by historic mineral mines marked in the landscape by their spoil heaps.
- A distinctive characteristic of this landscape type is the lower incidence of woodland (typically under 20% of land area) and relative lack of hedgerow trees, although low scrub and bracken are common on valley sides (the ffridd), along with some patches of exposed rock – either loose boulders, slates or scree.
- Some substantial blocks of post-1919 plantations, areas of ancient woodland, intermixed with pre-18th century enclosed fields, and some smaller non-native 18th-19th century plantations. Some parkland, although much less common than in lowland areas.
- Farms developed on both acid-based and loamy soils, historically used for growing crops as well as growing grass but now mostly permanent pastures (for sheep with limited suckler cows) interspersed with wet rush pasture).
- This landscape type is now more strongly enclosed than other upland types (96.7% of land area), enabling the cultivation of crops as well as mostly by a mixture of boundaries (33.7%), managed hedges (20.62%), hedgerows with trees (11.6%), stone walls (10.5%) and fences. In some places these boundaries have been replaced or supplemented by post and wire fences, while fields on lower slopes are bounded by once-dense hawthorn hedges which would traditionally have been laid in order to create sheep-proof barriers. Hedgerows are more common in eastern areas of Wales, as are timber-framed buildings.
- Remaining inland and coastal grazed commons, heath and moor are valuable habitats due to enclosures and post-1940 agricultural improvement.

These are expansive and panoramic landscapes with often little to interrupt the view and often dark night-time skies. Traditional farmsteads and houses, mostly of 19th century date, make a fundamental contribution to the character of these landscapes. The ruins of buildings convey a sense of the difficulties that rural communities faced in these areas. In some locations the historic remains of former mining and quarrying activity add texture and colour to the landscape through changes in landform and vegetation cover.

5.10. Upland (rock and scree)

Landscape narrative: Upland (rock and scree)
This landscape type comprises 0.81% of the area of Wales covered by LANDMAP. It occupies the highest parts of mountainous topography with ridges, peaks and often angular skylines including the Cambrian Mountains, Cadair Idris and Snowdonia. It is typified by its exposed location and shallow soils, more than a quarter of its overall area being taken up by rock outcrops, cliffs, slate, shale and scree. • These landscapes reflect Wales's remarkably varied geology, some being designated for their national and international significance. • Relatively sparse evidence of human activity, such as former mineral and stone working, cairns and tracks, intermixed with some distinctive species and nationally important habitats such as feral goats, sub-montane vegetation, mires and blanket bog. • They have a distinctly mountainous character with a sense of being very exposed, tranquil, remote and strikingly different to the settled valleys and more gently undulating upland landscapes around them. • The spectacular and dramatic craggy summits of the higher Welsh mountains offer destinations for walkers and landscapes for climbers, and panoramic views to other landmarks and features.

5.11. Upland (wooded hills)

Landscape narrative: Upland (wooded hills)
This landscape type comprises 3.26% of the area of Wales covered by LANDMAP. These are hillsides, scarp slopes, plateaux and areas with more woodland (more than 20% of land area) than the Upland (grassland) type, but a mix of open land and woods. • Only 57.1% of this landscape type is enclosed, mostly by a mixture of boundaries including stone walls (21.3%), managed hedges (14.92%), hedgerows with trees (17.9%), and fences (2.3%). • Much of this enclosed landscape dates from 19th century enclosure around a dispersed settlement pattern of farmsteads newly-established or rebuilt in the same period, which worked a lower proportion of arable land than other upland types. Some valley sides have 17th century or earlier enclosures. • Like other landscape types it now has high levels of stocking for sheep with no arable cultivation, and surviving patches of unenclosed land with semi-natural vegetation intermixed with enclosed farmland that has massively grown in extent – at the cost of common grazing - since the 18th century. • Woodland is dominated by post-1919 plantations, ancient woodland being concentrated in narrow valleys and with some 18th-19th century plantations. • As a result, and whilst open views can be enjoyed from high ground, these landscapes are more dominated by the all- year colour of conifers, seasonal colours being more common in areas of older woodland but also increasingly the result of the re-introduction of broadleaved species into plantations through forestry policy.

5.12. Upland (wooded)

Landscape narrative: Upland (wooded)
This landscape type comprises 15.73% of the area of Wales covered by LANDMAP. These are hillsides, scarp slopes, plateaux and areas with more than 50% of woodland within and around field enclosures. • Landscapes now characterised by high levels of stocking for sheep with limited arable cultivation, and rare surviving patches of semi-natural grazing land intermixed with enclosed farmland that has massively grown in extent since the 18th century. • Low levels of dispersed settlement dominated by small-scale farmsteads and linear settlements, which developed to serve cattle rearing and sheep-grazing economies. • Most farms and settlements rebuilt in the 19th century in parallel with enclosure of the landscape. 87.2% of this landscape type is enclosed, mostly by a mixture of boundaries including stone walls (31.2%), managed hedges (11.7%), hedgerows with trees (21.4%), and fences (10.6%). • Woodland is dominated by post-1919 plantations, ancient woodland being concentrated in narrow valleys and with some 18th-19th century plantations. • Extensive afforested areas, often angular in design, contrast with adjacent moorland and upland grassland. • Large blocks of coniferous plantation with deciduous woodland fringes on steep hillsides and hilltops introduces texture, colour and woodlands close to key population centres (e.g. South Wales valleys) in landscapes previously visually dominated by industry, often integrating tips and previous industry into the woodland. • These landscapes are often dominated by the all- year colour of conifers, seasonal colours being more common in areas of older woodland but increasingly the result of the re-introduction of broadleaved species through forestry policy.

5.13. Upland (moorland)

Landscape narrative: Upland moorland
This landscape type - 14.4% of the area of Wales covered by LANDMAP - comprises upland moorland, hillside & scarp slopes moorland and hill and lower plateau moorland. • Largely open and unenclosed landscapes resulting from centuries of use as grazing and resources for surrounding communities, sustaining rich layers of archaeology and habitats. Variety in upland moorland is evident, from the very dry, rocky limestone pavements in southern parts of Brecon Beacons, the deep peaty heather-clad hags of Y Berwyn, in contrast to the long tussocky grasslands and bogs of the Cambrian Mountains. • Extensive tracts of upland and high ground with an upland moorland character, frequently associated with extensive views, open horizons and skylines. Notably tranquil with a sense of remoteness and exposure, associated with low levels of night time light pollution. Good seasonal colour and contrast from heather, bracken and semi natural vegetation which lends a sense of wildness to the landscape. • Large-scale Forestry Commission plantations, contrasting with moorland vegetation, date from after 1919, otherwise sparse tree cover with the exception of historic woodland in valleys retaining evidence of timber and fuel exploitation. • Extensive traces of prehistoric archaeology, relict industrial mineral mining, quarrying and 20th century military activity. • Sparse settlements are mostly confined to moorland fringes, including smallholdings and medieval and later farms with stone-built traditional architecture. Only 28.3% of this landscape type is enclosed, mostly by drystone walls (2-.6% of the landscape type). • Upland Moorland retains some of the best evidence for prehistoric settlement and land use in Wales. • Large-scale and regular patterns of enclosures, sometimes associated with the establishment of new farms in the late 18th and 19th centuries. • Extensive evidence for transportation, stock rearing, shelter and summer pastures, in the form of droveways, tracks ‘braiding out’ to open moors and remains of ‘hafods’ or summer farms. • Decline in traditional use of moorland by surrounding communities has resulted in scrub and vegetation growth, which threatens the significant ecological interest of upland moorlands. The traditional use of upland moorland has declined since the 19th century, as its use as amenity land and forestry has increased.

6. Climate Change Narratives

6.1. Background method underpinning the climate change narrative

Climate change predictions for Wales to 2050 are summarised in terms of these four basic scenarios of climate change:

- Warmer mean temperatures, average annual temperatures are projected to increase by 2.3 degrees C
- Hotter, drier summers, daily maximum temperatures are projected to increase by 3.4 degrees C
- Warmer wetter winters/wetter summers, rainfall is projected to increase in winter on average by 14% and decrease in summer by 16%
- More frequent extreme weather

Each of these scenarios have the potential for the following direct outcomes:

- Rise in sea levels
- Longer growing season
- Migration of pests, invasive species and diseases
- Drying out, desiccation and erosion of wetlands and soils
- Stress on some trees and plants
- More flooding events
- Frequent high winds/storms
- Wild fires

Assessment Methodology

The approach aims to ascertain the susceptibility of each landscape type to a changing climate. and how these changes may become evident at the 'landscape type' level. Initial assessment focuses on the potential of an outcome of climate change to impact on elements of the landscape within each of the 14 landscape types. Impact assessment is only carried out where a potential effect is identified. Specific gaps in knowledge and indicative responses to change are also considered.

Landscape Susceptibility: the ability of the current landscape character type to accommodate change without changing landscape character. The susceptibility of each landscape type to climate change would be a key aspect in determining the sensitivity of a landscape type to the effects of climate change. Susceptibility is scored on 7-point scale relating to the extent that key characteristics and qualities of the landscape could be adversely or beneficially affected by expected climate changes and any resulting change in character.

Future Sensitivity: of the landscape to climate change could potentially be obtained by including value judgements (derived from LANDMAP Visual & Sensory evaluations) along with susceptibility to arrive at indicative sensitivity.

Table 6.1 Landscape susceptibility to climate change key

Legend	Level of anticipated change	Description
	High -ve	Key characteristics and qualities are vulnerable and would be adversely affected by expected climate changes resulting in a significant impact on character.
	Moderate -ve	Some key characteristics and/or qualities are vulnerable and may be adversely affected by expected climate changes resulting in a noticeable impact on character.
	Low -ve	Key characteristics and qualities are more resilient and will only be affected in a limited way by expected climate changes. Impacts will only result in minor changes in character.
	No change	No discernible changes are anticipated to character or quality
	Low +ve	Key characteristics and qualities would be beneficially affected in a limited way by expected climate changes. Impacts will only result in minor changes in character.
	Moderate +ve	Some key characteristics and qualities are vulnerable to expected climate changes and may be beneficially affected resulting in a noticeable impact on character.
	High +ve	Key characteristics and qualities would be beneficially affected by expected climate changes resulting in a significant impact on character.

Landscapes with a large number of different elements that are susceptible to climate change, or with individual influential elements that are highly susceptible are those most likely to be sensitive to the projected scenarios for change, although this will be tempered by the scale of climate change, its severity, local context, and regional variations that may occur. The summary matrix provides an overview of the likely impacts and allows for comparison across landscape types.

The information from the assessment is combined in the form of 'landscape impact matrices' for each landscape element examined within each landscape type. The matrix consists of the following sections for each identified outcome:

- Description of change
- Outcome of change
- Impact and landscape response
    - Susceptibility: the susceptibility of landscape elements to climate change
- A qualitative risk assessment of landscape impacts
- Overall appearance:
    - Form, Colour, Texture, Lines are key aspects of landscape, which apply across all elements. The way in which they fit together affects the

overall diversity and appearance of the landscape, and how it reacts to seasonal change.

- Specific gaps in knowledge
- Notes and references

Landscape elements considered

The assessment explores impacts of climate change on material elements that make up the overall landscape character. It is the changes in these elements that will alter landscape character in different ways, for example in terms of pattern, texture colour, and potentially where people choose to live and work. The key landscape elements incorporated in the assessment include:

- **Landform and geology**
    - Soils, exposed ground
    - Change as a result of slippage, movement, weathering/erosion

- **Field boundaries**
    - drystone walls
    - hedgebanks
    - hedgerows/trees
    - post and wire fences

- **Trees and woodland**
    - tree type, planting patterns (e.g. plantations, wood pasture)
    - ancient woodland

- **Vegetation**
    - moorland, heathland, wetland vegetation,
    - crop types, pasture/grassland, effects of land abandonment

- **Surface water**
    - Lakes, ponds, streams, rivers, waterfalls

- **Settlement & structures**
    - Urban, village
    - dispersed (farmsteads, smallholdings, houses)
    - houses
    - farm buildings (in most of rural Wales)
    - industrial buildings (all types)

- **Archaeological assets**

Information on the background context supporting the Climate Change Narratives can be found in Section 8.5 which includes extracts from the literature regarding potential effects of climate change on elements of the landscape such as woodland, fresh water, moorland, coastal areas, etc. Each of the LMP14 landscape types is examined and potential climate change impacts explored. For each landscape type there are a series of matrices: Matrix 1 summarises landscape elements potentially affected by climate change, while a more detailed description of identified impacts is can be found in Matrices 2(i) to 2(iv) for each of the LMP14 landscape types.

6.2. Landscape Character types

6.2.1. Coastal Edge

Landscape character type: Coastal Edge

Outcomes of change

The most significant changes are likely to be caused by sea level rise, compounded by warmer wetter winters (leading to more flooding in winter months) and more frequent and intense storms (again causing flooding, and storm surges with negative impacts on low lying areas).

- Sea level rise is likely to have a significant impact on coastal edge landform, vegetation and habitat, archaeological assets, transport and settlement. The coastline shape is likely to alter with loss of salt-water marshes and inundation of low-lying land, particularly in estuarine areas. Overall there will be a loss of land and erosion is likely to increase, although the level of accretion may also increase in some places.
- Salt water intrusion will impact the coastal vegetation and land use, damaging agricultural land and protected natural habitat with losses of up to 2,300 ha of Natura designated coastal habitat by 2100. Fresh water aquifers in coastal areas may also be affected by salt water intrusion.
- Sea level rise and storm surges will threaten coastal settlements and road/rail transport links, which may require stronger flood defence systems (e.g. higher, more extensive, and/or new embankments) for protection.
- Archaeological sites and ancient landscapes along the coast edge, either in low-lying locations or on exposed cliffs, will be at risk of damage and loss due to coastal erosion and increased storm events.

Summary of landscape change

- The coastal edge is at significant risk of a wide variety of changes. The shape of the coastline may alter along with loss of some specific landscape features such as sand dunes and salt marsh in some areas.
- The coastline may become less diverse as a result of specific plant communities (e.g. salt marsh, dunes) with a reduction in the areal extent of low-lying coastal edge. Some coastal freshwater habitats may be lost, reducing diversity across the landscape.
- Flood protection structures such as embankments may become more visible, and storm damage on settlements, transport structures, and on archaeological assets more frequent and visible.

Summary of potential impacts: Coastal Edge								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.2. Water (inland)

Landscape character type: Water (inland)
Outcomes of change The LANDMAP inland water landscape category only applies to large areas of freshwater (lakes, reservoirs) and inland rivers >20m wide (which are relatively short stretches of river close to the sea). The boundaries are tightly drawn around lake/reservoir edges and river channels. The effects of changes in surface water quality/quantity on the wider landscape context are thus not considered in this discussion. The most significant changes are likely to be caused by hotter drier summers through reduced stream flows, decreased volumes of water in lakes and reservoirs, and impacts on water quality through increased temperatures and low flows. The largest impacts are on water bodies themselves (including rivers) with relatively minor effects occurring on adjacent vegetation. • Hotter, drier summers will reduce water volumes in lakes and reservoirs, and result in longer periods of low stream flows with consequent impacts on aquatic biodiversity. Visible impacts will include exposure of larger areas of lake and reservoir sub-surface areas during the summer months. • Warmer wetter winters are likely to result in higher average stream flows through the winter months and reservoirs at capacity storage levels for longer periods. • More frequent and intense storms are likely to result in localised flooding and in extreme cases impacts on river channels and course alterations. The unpredictability of occurrence and location of storms makes impacts difficult to determine. • Warmer temperatures may alter crop production in arable areas and result in an increase of winter cover crops which may reduce soil erosion and sediment loading. Hotter drier summers may also result in changes to crop types and irrigation requirements. • Low flows from hotter drier summers may impact stream channel and bankside vegetation, in particular trees and woody shrubs, resulting in possible loss of some species. Wetter conditions in winter may lead to increased tree planting on steeper slopes to reduce soil erosion. • Settlements and in-river structures in lowland areas may be more prone to flood damage. • Increased levels of water storage may be required, for both agricultural uses and human consumption, creating pressure for more reservoirs. Localised farm water storage structures may be required for both livestock and arable management.
Summary of landscape change • Water levels in lakes and reservoirs, along with stream flow will have the most noticeable landscape impact. Water levels are likely to fluctuate more widely with low flows in summer and larger areas of river channel, and lake and reservoir sub-surface areas being exposed for longer periods. • Water quality is likely to deteriorate due to low flows, and warmer temperatures with a consequent impact on aquatic biodiversity. Algal blooms may increase in frequency and intensity of rainfall may result in higher sediment loading of watercourses. • Flooding may cause some localised damage to structures, and in extreme case alter river channel configurations.

Summary of potential impacts: Water (Inland)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & structures								
Archaeological assets								

6.2.3. Water (sea)

Climate change narrative: Water (Sea)
Outcomes of change The most significant changes are likely to be caused by warmer mean temperatures which will affect water quality and potential impact on marine ecosystems and well as raise the risk from invasive species. More extreme weather (more intense and frequent storms) will increase likelihood of coastal damage to natural habitat and man-made structures. • The coastal landforms are likely to change under sea level rise and as a result of increased flooding during winter months, and from stronger storms and higher more powerful storm surges. • Intertidal habitats may be significantly affected by storm surges and changes in depth, currents, and movement of sediment. • Warmer sea temperatures are likely to result in invasive species moving into coastal areas threatening protected native species. Warmer temperatures may also give rise to more frequent algal blooms and bacterial impacts on shellfish.
Summary of landscape change • Winter months are likely to reveal broader areal extent of water from inundation of lower lying land from flooding and storm surges. • Coastal outline may alter and tidal flats and mud/sandbanks be altered from changes in erosion and deposition of tidal currents and storm surges. • More damage may be visible form storm surges, impacting natural and manmade structures and habitats. • Algal blooms may occur in warmer summer months. • Extreme weather events and acidification will threaten heritage assets including historic wrecks and prehistoric landscapes, through removal of protective soils and sediments, exposing them to more rapid decomposition.

Summary of potential impacts: Water (Sea)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms.
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.4. Developed (communities)

Landscape character type: Developed (communities)
Outcomes of change The most significant changes are likely to be caused by warmer mean temperatures raising the potential risk from pests and disease; hotter drier summers putting additional stress on vegetation and trees, and increased potential for flood and storm damage during winter months. • Urban landscapes may alter as a result of climate change in both direct and indirect ways. Direct impacts such as warmer mean temperatures may increase pests and disease in vegetation and trees, causing a decline in quality or loss. Indirect impacts may result in changes to species mix of trees and plants utilised in open spaces, parts and streets. • Heat island effects are likely to exacerbate summer temperatures of urban environments putting additional stress on trees and vegetation. In addition rapid run off and limited percolation of water into the soil is likely to lead to drier soils and additional stress on trees/vegetation. • Settlements in areas with high clay content in soils may experience additional subsidence of buildings during summer months. • Structures and settlement near coastal areas will be at higher risk of damage from flooding and wetter winters. • Historic structures likely to be impacted by more severe weather conditions, in particular impacts to building fabric from: wetting/drying, freeze/thaw, storm damage, pests and fungal infestations of buildings, overflowing gutters and water management. • Water bodies (Lakes, streams, ponds, rivers) will have lower flows or dry up during summer months. Water bodies will exhibit increased water temperatures. Waterlogging may occur in winter months due to wetter conditions, and water quality may decline where combined sewers cannot manage additional flows.
Summary of landscape change • Less green vegetation visible during summer months although longer growing season may mean earlier greening of tree canopy in spring and extended autumn foliage. • Less surface water visible, more susceptible to algal blooms and ecosystem impacts from quality decline. • More potential from damage to buildings from more intense storms and floods, particularly in coastal areas.

Summary of potential impacts: Developed (communities)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.5. Developed (industry and infrastructure)

Landscape character type: Developed (industry and infrastructure)
Outcomes of change The most significant changes are likely to be caused by increased fluctuations in the hydrological regime as a result of drier summers and wetter winters. Specialist plant communities may disappear, and some land slippage may occur on unstable slopes due to more intense storms and rainfall. • Limited changes to landform are likely, these will be limited to land slippage and subsidence on unstable slopes and spoil heaps as a result of increased soil moisture fluctuations, wetter winters and/or more intense rainfall during storm events. • Standing surface water is likely to increase during winter months but be less apparent during warmer and drier summer months, i.e. greater fluctuations in the hydrological regime with consequent impacts on local flora and fauna. • Plant diversity is likely to decrease as sensitive species disappear due to increased stress from fluctuating water regimes and/or pests and disease. • There is a potential risk of increased pollution from higher levels of run-off during periods of intense rainfall, but limited in extent (Landscape type only applies to sites >100ha.
Summary of landscape change • Changes to the landscape will be subtle and relatively minor. Small changes may occur to plant communities, particularly loss of specialist plant communities. • Landscapes may appear less green and more barren in summer months due to lack of water, and loss of specialist plant communities on potentially thinner soils. • Landscapes may include larger areas of shallow standing water during wetter winter months. • There may be some slumping and slippage of unstable slopes.

Summary of potential impacts: Developed (industry and infrastructure)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.6. Developed (amenity)

Climate change narrative: Developed (amenity)

There is not a narrative for this landscape type, which amounts to 0.24% of Wales covered by LANDMAP and has no distinguishing characteristics other than the fact that it comprises amenity land exceeding 10 hectares in size and informal open land exceeding 100 hectares in size. The former is mostly urban, and so has been included in the narrative for the Developed (communities) landscape type. The latter are extremely rare and only distinguished from amenity areas in other landscape types on account of their scale. The following text – and the supporting information in 8.5.6 – focuses on amenity land including parkland in a broad sense.

Outcomes of change

The most significant changes are likely to be caused by hotter drier summers and more frequent extreme weather. However, damage from potential increase in pests and disease may also bring about subtle changes in landscape appearance.

- Amenity land is quite varied both in location and ecological character. Climate change impacts are likely to vary depending on the particular micro-conditions, the habitat characteristics, underlying soils and geology, and level of management. More damage would be expected at unmanaged sites compared to one where regular maintenance is likely to pick up on issues such as disease, damage, and vegetation stress early on and alter management practices to mitigate impact.
- Warmer mean temperatures will lengthen the growing season favouring tree and vegetation growth, but these benefits may be outweighed by impacts from invasive species, pests, and disease. Some species may disappear.
- Hotter drier summers will put increased stress on trees and vegetation. Additional water may not be available to provide irrigation. Golf courses in particular may find it increasingly difficult to support high quality grassland. Warmer wetter winters will create problems of waterlogging of soil and increase the intensity of wetting/drying cycles.
- More frequent extreme weather may bring a range of problems depending on site characteristics, including: high winds, storm damage, and localised flooding.
- Sea level rise may also impact some amenity sites in low-lying coastal areas, which will face increased risk of inundation from storm surges.
- Some historic structures may be affected by shrinking of clay soils in hot dry summers.

Summary of landscape change

- Changes will vary depending on site characteristics but are likely to include loss of tree cover, tree damage, and potential loss of plant communities due to drier conditions. Diversity of the landscape in terms of colour and texture is likely to decrease.
- Amenity sites will become green earlier in spring and trees are likely to hang on to leaves longer the autumn.
- Some sites may lose green colouring in summer and turn brown, depending on rainfall patterns and existence of irrigation water.
- Amenity sites in the coastal zone may disappear as a result of sea level rise.

Summary of potential impacts for Developed (Amenity)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.7. Lowland (wooded and wetland)

Landscape character type: Lowland (wooded and wetland)
Outcomes of change The most significant changes are likely to be caused by hotter drier summers and effects of pests and disease on tree cover and hedgerow species from generally warmer mean temperatures. Warmer, wetter winters may lead to increased water logging of soils, higher river levels and more frequent flooding. • The landscape is diverse with river channels, wetlands, woodland (native species, and conifer plantation), small areas of arable land, permanent pasture, valley floor and sides. • Water quality may decline in summer months as low flows and increased water temperature will impact on aquatic ecosystems making them potentially less effective at delivering services such as filtering water and storage. • Surface water may be less apparent in summer months, with lower flows in river channels and temporary ponds disappearing, while water will be more in evidence in winter with more waterlogged soils and potential for more frequent flood events. • Some reduction or loss of tree species (Sitka Spruce, beech, larch, ash) may occur as a result of pests and disease, drought, and or winter waterlogging of the root zone. Only relatively small reductions in woodland area are anticipated, in favoured sites planting may increase due to improved growing conditions making woodland more economically favourable. • Trees are likely to bud earlier in the spring and remain in leaf longer in the autumn. • Higher risk of storm damage, particularly in exposed locations, and windthrow. • Vegetation composition of woodland may alter, though this may only be apparent at certain times of year (e.g. reduction in springtime flowering plants. • Hedgerows may decrease in extent and species composition as a result of pests, disease, and stress from drier conditions. • Where soil desiccation occurs, buried archaeological remains may be exposed and at risk of rapid deterioration. New archaeological assets may be revealed by soil parching.
Summary of landscape change • Little change from the current situation, although extent of woodland might decline in area with the loss of some species, which may alter texture and colour of the landscape slightly. Also potential for increase in woodland area for favoured species benefitting from warmer conditions. • There may be a reduction in hedgerows and loss of some hedgerow trees (e.g. Ash) and an increase in post and wire fencing. • Most changes will be subtle and relate to changes in species composition and water quality. • Greening may occur earlier in spring. • Increased flooding may alter river channels and leave sediment deposits more frequently.

Summary of potential impacts: Lowland (wooded and wetland)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.8. Lowland Valleys (hedgerow)

Landscape character type: Lowland Valleys (Hedgerow)

Outcomes of change

The most significant changes are likely to be caused by hotter drier summers and effects of pests and disease on hedgerow species from generally warmer mean temperatures.

- Vegetation changes in field boundaries (hedgerows) are likely to be more significant than changes in grassland. Drier conditions and pathogens/disease are likely to impact on the species mix in hedgerows and result in more gaps and potentially loss of some hedgerows and hedgerow trees (e.g. Ash). More post and wire fencing may be in evidence as hedgerows decline.
- Some reduction in water quality and in tree species, although less of a dominant characteristic than in Lowland (wooded and wetland).
- Arable farming may increase in area with new types of crops adapted to drier conditions.
- Permanent pasture will be relatively unaffected by climate change, although field margin and hedgerow biodiversity may decline.
- Higher risk of storm damage, particularly in exposed locations, and windthrow.
- Where soil desiccation occurs, buried archaeological remains may be exposed and at risk of rapid deterioration. New archaeological assets may be revealed by soil parching.

Summary of landscape change

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Little change in field form and appearance.
- New types of crops may alter texture and appearance (e.g. vineyards)
- Hedgerows and field boundary tress likely to decline

Summary of potential impacts: Lowland Valleys (Hedgerow)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.9. Lowland Valley (open)

Climate change narrative: Lowland Valley (open)
Outcomes of change The most significant changes are likely to be caused by changes in vegetation brought about by an increase in pests and disease from warmer mean temperatures, and stress caused by shortage of water in hotter drier summers. Lowland valleys are also at risk from increased likelihood of flooding from wetter winters and more frequent and intense, storms. • Tree cover will be the most severely affected element in the landscape. Impacts will occur from higher stress due to drought in summer, in poorly drained areas there may also be impacts from waterlogged soils in winter, and from pests and diseases as a result of higher mean temperatures. • Some tree species may decline from spread of pests and disease (e.g. Oak, Ash, Sitka Spruce). • Hedgerows may be affected through drought induced stress, and pests and disease, resulting in species loss, and an increase in post and wire fencing; field sizes may increase with loss of hedgerows. • Arable farms may increase in area and react to change through adoption of new forms of crops (e.g. vineyards); while hay meadows and permanent pasture are unlikely to alter much in extent or appearance. • A large number of ecological changes that are not immediately obvious to the untrained eye (e.g. to plant communities and assemblages) may occur with little overall impact on landscape appearance. • May be an increase in solar farms on more marginal land (limited to areas close to the national grid), and wind turbines on more exposed sites. • Surface water is likely to decline in summer months with low stream flows and shrinkage and possible temporary disappearance of some shallow ponds and lakes. • Flood damage in winter is likely to increase due to water logged conditions over catchments and higher levels of run-off during intense storms. • Where soil desiccation occurs, buried archaeological remains may be exposed and at risk of rapid deterioration. New archaeological assets may be revealed by soil parching.
Summary of landscape change • Decrease in quality and extent of hedgerows, more gaps, loss of some hedgerow trees. Replacement with post and wire fencing, and/or expansion in field size. • Earlier greening of vegetation/trees in spring due to warmer temperatures. • Agricultural crops may increase in diversity adding texture and colour to the landscape, while natural biodiversity may decrease with limited changes in landscape appearance. • Some tree species may decline while others are introduced to suit the altered climate, potentially adding colour and texture to the landscape. • Surface water will be less visible during summer months.

Summary of potential impacts for Lowland Valley (open)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.10. Upland (grassland)

Landscape character type: Upland (Grassland)
Outcomes of change The most significant changes are likely to be caused by hotter and drier summer creating stress on trees and plants and the increased threats from pests and diseases caused by a warmer mean temperature. • The most noticeable change in the landscape is likely to result from the decline of hedgerows in the upland valleys and replacement with post and wire fencing. Hedgerow vegetation will be affected by pests and disease, as well as by increased stress on vegetation from drier summers. • Hedgerow condition has already declined due to changed agricultural management practices. Some species will be affected more than others (e.g. Ash) creating gaps, reduction in field boundary trees, and loss of effectiveness. • Grassland is relatively resilient to climate change and warmer temperatures may benefit in terms of creating a longer growing season. Greening of the landscape may occur earlier in the year though drier and hotter conditions in summer may result in drying out of vegetation relatively early in the year. Arable farming may increase in area. • Changes are difficult to predict as expected climate change both support grassland and put stress on some species in plant communities. Rainfall patterns in summer will affect local conditions, and in addition the effects of climate on nutrient availability are unknown. • Surface water will be less visible in summer months. • Where soil desiccation occurs, buried archaeological remains may be exposed and at risk of rapid deterioration. New archaeological assets may be revealed by soil parching.
Summary of landscape change • Improved grassland may extend to higher elevations under warmer conditions. • Vegetation changes will be subtle but may extend over large areas. Diversity of colour and texture may decline with species loss or change. • Field boundaries in lower areas will lose some species and may become less distinct as hedgerows decline. • Greening may occur earlier in the year and improved grassland occur at higher elevations. • Increased risk of flooding in upland valleys.

Summary of potential impacts: Upland (Grassland)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.11. Upland (rock and scree)

Landscape character type: Upland (rock and scree)
Outcomes of change The most significant changes are likely to be caused by warmer mean temperatures enabling spread of vegetation to higher elevations and loss of alpine plant communities. Hotter drier summer will limit spread of vegetation and result in decrease in surface water availability. • Landscape changes will be subtle and relate largely to an increase in vegetation (coarse grasses, bracken) growing at higher elevations. • Fewer days with peaks covered in snow in winter. • Surface water less visible in summer, drying up of shallow pools and lakes.
Summary of landscape change • The amount of visible bare rock may decrease as a result of increasing vegetation and more favourable growing conditions. This may be tempered by lack of water in summer months, and more frequent and intense storms, which are likely to have more impact at higher elevations. • High mountains may appear greener in spring and summer, with less grey and bare rock visible. • Alpine plant communities may disappear, reducing overall biodiversity. • Fewer days of snow cover in winter and more surface water visible. • Less surface water visible in summer months.

Summary of potential impacts: Upland (rock and scree)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.12. Upland (wooded hills)

Landscape character type: Upland (Wooded Hills)

Outcomes of change

The most significant changes are likely to be caused by both warmer mean temperatures (which will increase risk of damage from pests and disease), and from hotter drier summers, which will put stress on trees and potentially increase the likelihood of wildfires. Warmer mean temperatures will also increase length of the growing season, and potentially result in more successful tree planting at higher altitudes. There are factors that work both in favour of tree growth and against more widespread planting, with tree planting highly dependent on local conditions.

Vegetation

- Warmer mean temperatures will lengthen the growing season and may also enable trees and shrubby plants to grow at higher elevations, resulting in a raising of the moorland line. Pests and diseases are likely to increase with species such as Larch, Ash and Spruce already affected, raising the importance of linking tree species to micro-site conditions to reduce stress. Hotter drier summers and more frequent storms with high winds may both mitigate against successful tree growth at higher elevations due to increased stress from low and/or infrequent rainfall and wind-throw.
- Conifer planting on upland hills may increase as warmer growing seasons and rising CO_2 concentrations will stimulate productivity and timber production where soil water and nutrient availability allows. Wales also has ambitious tree planting plans to help meet carbon sequestration targets.
- Improved growth may also occur among other tree species, although this is site dependent and higher CO_2 concentrations are not as effective for trees on nutrient – limited soils. Climatic conditions in central and eastern Wales are likely to remain favourable for growing broadleaved species, and oak and ash suitability will remain high although woodland plant communities may alter in response to changes in temperature and moisture.
- Wetter winters may decrease areas favourable for tree growth due to more waterlogged soil conditions on flatter ground, which are not favourable to root growth. In some areas this may result in wider use of trees and other vegetation on well drained slopes to enhance stability and reduce erosion.
- Grass growth benefits from warmer conditions and bracken is likely to spread as a result of warmer, drier summers and less frequent frosts, raising the moorland line.
- Where soil desiccation occurs, buried archaeological remains may be exposed and at risk of rapid deterioration. New archaeological assets may be revealed by soil parching.

Summary of landscape change

- With warmer mean temperatures there is likely to be earlier spring greening of grasslands. A longer growing season may cause expansion of farmland into upland areas and improvement of land at higher altitudes, and may result in outdoor grazing of livestock earlier in spring and later in autumn.
- Changes in appearance will result from reductions in rough grassland, possibly with a higher proportion of improved grassland, and more plantation forestry (most likely conifers), and possibly occurring at higher elevations.

- Broadleaved tree species are likely to be more widespread in central and eastern Wales.

Summary of potential impacts: Upland (Wooded Hills)

Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & structures								
Archaeological assets								

6.2.13. Upland (wooded)

Climate change narrative: Upland (wooded)
Outcomes of change The most significant changes are likely to be caused by drought conditions brought about by hotter drier summers, and the effects of pests and diseases from an overall increase in average temperature. Some species change may occur, with less Sitka Spruce in the south and eastern areas, and on well drained slopes, and more mixed forestry as species are targeted for areas with specific favourable conditions. The most significant changes are likely to be caused by drought conditions brought about by hotter drier summers, and the effects of pests and diseases from an overall increase in average temperature. Some species change may occur, with less Sitka Spruce in the south and eastern areas, and on well drained slopes, and more mixed forestry as species are targeted for areas with specific favourable conditions. • The main changes are related to the impacts of pests and diseases and the longer growing season resulting from warmer temperatures. There may be some change in the mix of species as some are more susceptible to drought, disease and pests, including a reduction in some broadleaved species such as oak and ash in upland areas. Mixed species stands will be a preferred approach to reducing impacts from pests and disease. • The most significant decline is likely to be Sitka spruce which prefers moist and wet conditions. Changes in the wetter western part of Wales might not be so great but drier summer conditions will see a reduction of areas suitable for Sitka Spruce in the south and eastern parts of the country. • Changes may be beneficial resulting in less area of monoculture conifer plantations and a more diverse tree and plant community. Colour and texture will be more varied, and the dark green and straight edges of plantations will be reduced (particularly in the south and east of Wales). • Plant communities may alter as tree species composition changes and there are higher levels of disturbance (e.g. through wild fire). • Rhododendron might increase its elevation range under warmer weather conditions, which will have a visible impact on the landscape. It may also increase disease spread as it is a host for *Phytophthora ramorum,* a tree disease that can affect larch, beech, and several other species. • Surface water is likely to decrease and will be less visible in the hotter drier summers. There will be a reduction in soil moisture and upland bog areas in the summer months. • Where soil desiccation occurs, buried archaeological remains may be exposed and at risk of rapid deterioration. New archaeological assets may be revealed by soil parching.
Summary of landscape change • A decline in Sitka Spruce in some areas, and more diversity in plantations to match species to locations with the most favourable conditions. • Some species (Ash, Oak) may decline in upland areas due to increasing risk of exposure to pests and disease. • Wild fires and windthrow from more intense storms are likely to occur with

greater frequency, potentially opening up the forest canopy to vegetation changes.

Summary of potential impacts: Upland (wooded)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

6.2.14. Upland (moorland)

Landscape character type: Upland (moorland)
Outcomes of change The most significant changes are likely to be caused by hotter, drier summers altering surface water conditions and leading to changes in plant communities. Warmer mean temperatures are also likely to increase the length of the growing season and potentially increase threats from invasive species. • Warmer temperatures will create more favourable conditions for grasses and shrubby vegetation to grow at higher elevations, leading to possible upward movement of the moorland line. • Some invasive species (such as rhododendron) may extend their range to higher elevations in upland western areas under warmer conditions. Warmer, wetter, winters may lead to the spread of fungi. • Increased stress on trees (plantations) in exposed areas due to low or infrequent summer rainfall. • Drying out of peatbogs and reduced summer rainfall will cause changes in upland vegetation such as loss of mosses and peat forming species. Coarse grass species are likely to increase but bare ground may develop where peat is exposed to wind and water erosion, and the surface too friable for vegetation to take hold. • Destabilised surfaces following erosion or wildfire, increased risk of wildfire with parched vegetation and combustible dry material • Drying out of wetlands, peatland boggy ground and reduced surface water, although effects may be localised and dependent on rainfall pattern through the summer months. Erosion of peat post desiccation, leaving features like peat hags in the landscape • Upland streams may dry up in summer as the regulating nature of upland vegetation is reduced/altered. • Where peat dries out carbon-based archaeological remains that have been preserved by the waterlogged conditions (e.g. buried archaeology, paleo-environmental records), are at risk from drying out and more rapid destruction and erosion. Although these are not always visible in the landscape they represent potential loss of a cultural asset.
Summary of landscape change • The moorland edge may rise in elevation potentially changing scenic quality at a local level. • Changes in vegetation will blur the moorland line; colour may alter slightly, become greener with softer texture, or added colour from expanding flowering invasive species (gorse, rhododendron). • Post-wildfire ephemeral visual changes (mosaics or patches of blackened or bare soil, possibly leading to exposed geology where re-vegetation slow or fails and peat is eroded, i.e. some potential for change in landform in exposed places/aspects). • Less surface water will be visible as a feature in the landscape.

Summary of potential impacts: Upland moorland								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover								
Vegetation								
Surface water								
Settlement & Structures								
Archaeological assets								

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8. Appendices

8.1. LMP14 and LMP09 Landscape Classification

LANDMAP, landscape and a changing climate

The adapted LANDMAP Visual & Sensory hierarchical classification* that brings together landform and land cover classes at level 2 and 3 into new summarised categories for reporting the potential impacts of climate change on landscape types and potential adaptations that may be associated with these landscapes. (*https://cdn.naturalresources.wales/media/677816/visual-sensory-landmap-methodology-2016-v2.pdf?mode=pad&rnd=131472708500000000 page 3)

Explanatory notes behind the classification choices

- The hybrid classification uses all three LANDMAP Visual & Sensory classes, however the key determinants behind the classification places particular emphasis on groupings that may reflect landscape habitats and elements such as woodland, hedgerows, moorland and grazing, which may be impacted by potential climate changes such as pests and diseases, wild fires, desiccation/drying out of grasslands and coastal flooding changes more than underlying landform. These factors therefore have increased emphasis in the categories identified.
- Current percentages relating to predominant landcover at level 3 have been highly influential in the categorisation.
- The existing Visual & Sensory 45 classifications at level 3 are refined to 14 new categories that are still underpinned by LANDMAP quality assured and consistent evidence. Table 8.1 illustrates how the categories have been arrived at by grouping classifications. Table 1 includes simplified definitions of the LANDMAP Visual & Sensory classification categories to aid understanding of the basis for the groupings. The full description is available from the methodology link* above, on page 5.
- Table 8.2 summarises the 14 key landscape categories of Table 8.11 and will be the basis for the mapping at the most detailed level
- Colour coding of categories helps with tracing how the categories have been grouped and will relate to the thematic maps to be produced.

Table 8.1 Origin of categories for reporting the potential impacts of climate change on landscape

Grouped level 2 classifications	Containing these Level 3 classifications	Summary definitions
Upland 150-300+m		
Upland, exposed plateau, valleys, hillsides and scarp slopes Wooded 20-50%	Wooded >20% upland & plateaux	woodland >20%
	Mosaic upland & plateaux (<10 ha, 20-50%)	<10ha woodland 20-50%
	Open/wooded(<10 ha, 20-50%) mosaic upland valleys	<10ha woodland 20-50%
	Wooded >20% upland valleys	wooded >20%
	Hillside & scarp slopes mosaic	patchwork woodland 20-50%
	Hill and lower plateau mosaic	woodland 20-50%
Upland plateau, hillsides and scarp slopes Moorland 20-50%+	Upland moorland	moorland >50%
	Hillside & scarp slopes moorland	wooded <20%, <50% open moorland
	Hill and lower plateau moorland	wooded <20% <50% open moorland
Upland Rock & Scree	Barren/rocky upland	>25%rock & scree

Upland valleys, hillsides, lower plateau and scarps Grassland >50%, open, predominantly unwooded	Upland grazing	grazed grassland >50%
	Hill and lower plateau grazing	wooded <20% grazed grassland >50%
	Open upland valleys (<20% wooded)	unwooded <20%
	Hillside & scarp slopes grazing	wooded <20%, grazed grassland >50%
	Open hillside and scarp slopes	predominantly unwooded
	Open hill and lower plateau	predominantly unwooded.
Upland Hills, lower plateau & scarp slopes Wooded >50%	Wooded hillside & scarp slopes	wooded >50%
	Wooded hill and lower plateau	wooded >50%
Lowland		
Valleys and rolling lowland Mosaic 20-50% wooded, hedgerow character	Mosaic lowland valleys	woodland 20-50% hedgerow trees. villages, mosaic.
	Mosaic rolling lowland	small woodland 20-50% density hedgerow trees. other land uses mosaic.
Valleys, rolling and flat lowland Grassland >50%, open, <20% wooded, lacking hedgerow trees	Open lowland valleys	wooded <20% lack hedgerow trees.
	Open rolling lowland	wooded <20% with few trees.
	Flat open lowland farmland	wooded <20% farmland
Valleys, rolling and flat lowland Wooded >50%	Wooded lowland valleys	wooded >50%
	Wooded rolling lowland	Predominantly wooded >50%
	Flat lowland mosaic	woodland 20-50%, mosaic
	Flat wooded lowland	wooded >50%
	Lowland wetland	wetland >50%

Table 8.2 Summary of 14 categories for reporting the potential impacts of climate change on landscape

Upland Hills, lower plateau & scarp slopes Wooded >50%	**Valleys, rolling and flat lowland Wooded >50%**	**Classification key**
Upland, exposed plateau, valleys, hillsides and scarp slopes Wooded 20-50%	Valleys and rolling lowland Mosaic 20-50% wooded, hedgerow character	Inland water
Upland plateau, hillsides and scarp slopes Moorland 20-50%+	Valleys, rolling and flat lowland. Grassland >50%, open, <20% wooded, lacking hedgerow trees	Built land - communities
Upland valleys, hillsides, lower plateau and scarps Grassland >50%, open, predominantly unwooded	Coastal edge, cliffs and islands	Industry and infrastructure
Upland Rock scree	Coastal waters	Amenity and informal space

Table 8.3 Origin of 9 high level categories from 14 categories

<table>
<tr><td rowspan="2">Upland
>20% Wooded</td><td>Upland
Hills, lower plateau & scarp slopes
Wooded >50%</td><td rowspan="2">Lowland mosaic, >20% wooded</td><td>Valleys, rolling and flat lowland Wooded >50%</td><td></td><td>Classification key</td></tr>
<tr><td>Upland, exposed plateau, valleys, hillsides and scarp slopes
Wooded 20-50%</td><td>Valleys and rolling lowland Mosaic 20-50% wooded, hedgerow character</td><td>Inland water</td><td>Inland water</td></tr>
<tr><td rowspan="2">Upland
20-50%
Moorland and scree</td><td>Upland plateau, hillsides and scarp slopes
Moorland 20-50%+</td><td>Lowland open >50% grassland, <20% wooded</td><td>Valleys, rolling and flat lowland. Grassland >50%, open, <20% wooded, lacking hedgerow trees</td><td rowspan="2">Built land</td><td>Built land - communities</td></tr>
<tr><td>Upland Rock scree</td><td rowspan="2">Coast</td><td>Coastal edge, cliffs and islands</td><td>Industry and infrastructure</td></tr>
<tr><td>Upland open >50% grassland</td><td>Upland valleys, hillsides, lower plateau and scarps
Grassland >50%, open, predominantly unwooded</td><td>Coastal waters</td><td>Amenity and informal space</td><td>Amenity and informal space</td></tr>
</table>

Table 8.4 Summary of 9 high level categories for reporting the potential impacts of climate change on landscape

Upland >20% Wooded	**Lowland mosaic, >20% wooded**	**Inland water**
Upland 20-50% Moorland and scree	Lowland open >50% grassland, <20% wooded	Built land
Upland open >50% grassland	Coast	Amenity and informal space

8.2. Guidance Notes on LMP14 and LMP09 Spatial Data Layers

This appendix provides guidance for using the *Landmap_VS_Climate.shp* ESRI Shapefile polygon data layer, which is the main data product produced during this project. *Landmap_VS_Climate.shp* contains all of the fields/columns found in the original LANDMAP Visual and Sensory data layer[6], plus the new fields/columns containing data relating to the new LMP14 and LMP09 landscape classifications.

8.2.1. Column/Field Descriptions

Description of the LMP14 and LMP09 columns added to the LANDMAP Visual and Sensory polygon shapefile data layer (*Landmap_VS_Climate.shp*):

Table 8.5 Description of the new LMP14 and LMP09 attribute data fields

Column/field name	Description
LMP14_CODE	Unique short code for each LMP14 class type
LMP14_D_L	Full textual description each LMP14 class type, as they appear the project specification
LMP14_D_S	Short textual description each LMP14 class type. Useful for mapping outputs (avoids large map legends and cluttered maps).
LMP09_CODE	Unique short code for each LMP09 class type
LMP09_D_L	Full textual description each LMP09 class type, as they appear the project specification
LMP09_D_S	Short textual description each LMP09 class type. Useful for mapping outputs (avoids large map legends and cluttered maps).

8.2.2. Map Symbology

This section provides a summary of the codes, descriptions and map legend colour scheme used for the LMP14 and LMP09 landscape classifications. Custom map legend style files for QGIS software are available for download here:
https://github.com/robertberryuk/LANDMAP_ClimateChange/tree/master/Styles

Note that the static output maps have been produced with the *Layer Properties > Symbology > Layer Rendering > Opacity* set to **90%** (QGIS Version 3.4.2 Madeira) – colours therefore appear slightly brighter in the following tables than they do on the final map outputs.

For more details on the LMP14 and LMP09 classification schemes, please refer to original NRW classification document in Appendix 8.1.

[6] Available for download here - https://lle.gov.wales/catalogue/item/LandmapVisualSensory/?lang=en

Table 8.6 Codes, descriptions and legend colour scheme for LMP14 landscape types

LMP14_CODE	LMP14_D_L	LMP14_D_S	Colour code[7]
LMP14_1	Upland, exposed plateau, valleys, hillsides and scarp slopes (wooded 20-50%)	Upland (wooded)	113,77,60 #714d3c
LMP14_2	Upland plateau, hillsides and scarp slopes (moorland 20-50%+)	Upland (moorland)	174,86,218 #ae56da
LMP14_3	Upland rock & scree	Upland (rock)	227,26,28 #e31a1c
LMP14_4	Upland valleys, hillsides, lower plateau and scarps (grassland >50%, open, predominantly unwooded)	Upland (grassland)	213,180,60 #d5b43c
LMP14_5	Upland hills, lower plateau & scarp slopes (wooded >50%)	Upland (wooded hills)	194,165,144 #C2A590
LMP14_6	Valleys and rolling lowland (mosaic 20-50% wooded, hedgerow character)	Lowland valleys (hedgerow)	124,217,117 #7CD975
LMP14_7	Valleys, rolling and flat lowland (grassland >50%, open, <20% wooded, lacking hedgerow trees)	Lowland valleys (open)	202,239,199 #D4EFC7
LMP14_8	Valleys, rolling and flat lowland (wooded >50%)	Lowland (wooded & wetland)	51,160,44 #33a02c
LMP14_9	Coastal edge, cliffs and islands	Coastal edge	233,248,11 #e9f80b
LMP14_10	Built land - communities	Developed (communities)	121,123,118 #797b76
LMP14_11	Amenity and informal space	Developed (amenity)	255,158,23 #ff9e17
LMP14_12	Industry and infrastructure	Developed (industry)	31,31,31 #1f1f1f
LMP14_13	Coastal waters	Water (sea)	166,206,227 #a6cee3
LMP14_14	Inland water	Water (inland)	20,23,214 #1417d6

[7] First line is the RGB colour code (e.g. 233, 248, 11), second line is the hex colour code (e.g. #714d3c)

Table 8.7 Codes, descriptions and colour scheme for LMP09 landscape types

LMP09_CODE	LMP09_D_L	LMP09_D_S	Colour code
LMP9_1	Upland >20% wooded	Upland (wooded)	113,77,60 #714d3c
LMP9_2	Lowland mosaic >20% wooded	Lowland (wooded)	124,217,117 #7CD975
LMP9_3	Inland water	Water (inland)	20,23,214 #1417d6
LMP9_4	Upland 20-50% moorland and scree	Upland (moorland)	174,86,218 #ae56da
LMP9_5	Lowland open >50% grassland, <20% wooded	Lowland (open)	202,239,199 #D4EFC7
LMP9_6	Built land	Built land	121,123,118 #797b76
LMP9_7	Upland open >50% grassland	Upland (open)	213,180,60 #d5b43c
LMP9_8	Coast	Coast	233,248,11 #e9f80b
LMP9_9	Amenity and informal space	Amenity land	255,158,23 #ff9e17

8.3. Project Metadata Table

Table 8.8 Metadata table for spatial data layers used in the project

Theme	**Data Layer Name**	**Source**	**Spatial Resolution / Geographical Units / Scale**	**Update frequency**	**Reference / collection / publication date**	**Data Type (raster / vector)**	**Data Format**	**Spatial Reference System**	**Access Constraints**
Administrative	Local Authorities	Lle GeoPortal (derived from OS BoundaryLine)	Local Authorities in Wales	Unknown	2016-04-22	Vector	ESRI Shape (.shp)	British National Grid (ESPG:27700)	Open data
	NRW Operational Areas	NRW via Lle GeoPortal	NRW Operational Area boundaries	Unknown	2015-12-31	Vector	ESRI Shape (.shp)	British National Grid (ESPG:27700)	Open data
Base mapping	Ordnance Survey 1;250,000 Colour Raster	Ordnance Survey	1:250,000	Annual	2018-07	Raster	GeoTiff	British National Grid (ESPG:27700)	Open data
Hydrology	Flood Zone 2	NRW, EA via Lle GeoPortal	N/A	Quarterly	2016-04-22	Vector	ESRI Shape (.shp)	British National Grid (ESPG:27700)	Open data
	Flood Zone 3	NRW, EA via Lle GeoPortal	N/A	Quarterly	2016-04-22	Vector	ESRI Shape (.shp)	British National Grid (ESPG:27700)	Open data
Landform / Elevation	OS Terrain 50	Ordnance Survey	50x50m	Annual	2016-07	Raster	ASCII Grid (.asc)	British National Grid (ESPG:27700)	Open data
LANDMAP	LANDMAP Visual and Sensory data layer	NRW via Lle GePortal	LANDMAP Aspect Areas	As needed	2017-09-01	Vector	ESRI Shape (.shp)	British National Grid (ESPG:27700)	Open data

8.4. Background Context Supporting Landscape Narratives

8.4.1. Coastal Edge

Key factors influencing the landscape

- The coastal edge landscape type results from centuries of interaction between the underpinning geology and the sea. The rise of sea levels about 6000 years ago has been of fundamental importance in shaping the coastline. Shell fishing has benefitted from the deep tidal range in many places.
- Rough grazing on moorland, heathland rush pasture has sustained surrounding farms and communities, and distinctive **vegetation** and plant communities resulting from sandy and acidic soils subject to exposure to sea salt, which also extend into **dune landscapes**. Some dune systems result from massive 13th-14th century storm events, and include dune slacks scoured by their exposed positions – with shallow pools in the summer and mossland in the summer. Historic **tree cover** is sparse except in some narrow incised valleys which extend inland.
- As a result of predominantly communal use **field boundaries** dating from the medieval period are also sparse, although there are some areas of reclamation from saltmarsh, freshwater lagoons and rough grazing such as north of Harlech.
- **Settlement** was otherwise sparse until the 18th and 19th centuries except in fishing and small trading communities, the Industrial Revolution giving rise to the development of ports for the export of coal, slate and other mineral products.

  A distinctive characteristic of these landscapes from the late 18th century has been the growth of housing development that exploits the amenity value of these landscapes, including a substantial proportion of retirement homes.
- After the Second World War, land use planning and the National Trust's Operation Neptune campaign have played a critical role in preserving the coastal edge from insensitive development.
- The reclamation of **marshland** extends into the medieval and Romano-British periods; the coastal edge also includes some areas affected and buried by the effects of storm surges, particularly in the early 14th and 17th centuries and known to have affected the Bristol Channel area in particular.
- Coastal edge landscapes are also notable for the survival, conserved by later communal use as **rough grazing**, of field systems and settlements (including hill forts) dating from the first millennium and earlier. The picking of shellfish also sustained many coastal communities.
- Some of these open areas were ideally suited to the development of golf courses from the late 19th century.
- In addition to the timber groynes and other features characteristic of **coastal sea defence**, the coastal edge became a focus of **anti-invasion defence** from the 16th century, concentrated around Pembroke and other dockyards from the early 19th century and the First and (particularly) Second World Wars. Some testing and experimental sites were retained into the Cold War period.

- **Archaeological assets.** Rich environmental and archaeological deposits associated with coastal sand dunes and land cover, successive episodes of reclamation, which have also left a legacy of embankments and other features. There is a rich legacy of submerged prehistoric forests and remains of human activity and settlement in areas of former coastal plain where the sea in Cardigan Bay encroached due to rising sea levels about 6000 years ago.

Issues for change

- Surviving rough grazing subject to same issues for change as Upland Moorland
- Wales has experienced substantial loss of saltmarsh due to taking-in of land for agriculture, a process that accelerated in the 19th and 20th centuries.
- Rise in sea levels, flooding of former drained or freshwater marsh and erosion of notable archaeological and geological beach features (e.g. spit, fossilised forest)
- Growth of scrub that poses a risk to archaeological remains.
- Risks to archaeological sites currently protected by sand dunes and by soils on coastal edge, due to rising sea levels and more frequent and intense storms
- Risk of coastal erosion to archaeological sites.
- Decline in rough ground habitats, exposure to storm events
- High wave potential where face full impact of weather conditions sweeping in from the Atlantic.
- Coastal path slumping or eroding in places.

8.4.2. Water (inland)

Key factors influencing the landscape

- The use of wide rivers and inland rias for navigation as well as wildfowling and fishing, leaving a legacy of weirs, fishtraps, piers and warehousing.
- The use and adaptation of glacial lakes for wildfowling and fishing since the prehistoric period, rich in natural and archaeological significance (for example Llangorse Lake near Brecon with its first millennium AD crannog, a type of defensible artificial island otherwise found in Ireland and Scotland).
- The need to provision growing urban populations in England and Wales, resulting in the purchase of land by municipal authorities (for example the site of Lake Vrynwy by Liverpool City Council in the 1870s) prior to the displacement of communities and the commencement of engineering works, followed by flooding.
- The development of tourism and organised leisure from the late 19th century, with hotels, cafes, boating, fishing and watersports featuring along banksides.

Issues for change

- Climate will have a profound effect on water levels
- Drying out or, in some areas, increased water levels and risks of flooding
- Algal growth due to phosphate/nitrate run-off in lower lying areas surrounded by in-bye farmland.
- Acidification and/or enrichment by sulphur and nitrogen deposition in more remote upland locations

8.4.3. Water (sea)

Key factors influencing the landscape

- The **use of the tidal limits** – for example for harvesting shellfish and seaweed - from the prehistoric period. Post-glacial rises in sea levels resulting in the flooding of landscapes – and their change from forest to saltmarsh and shallow seas - used by Mesolithic to Bronze Age peoples, the celebrated tree stumps at Borth resting upon a basal layer of peat around 6, 500 years old.
- A **strong sense of history**, in view of the relationship of diverse seascapes to major sea lanes along the Atlantic Seaboard from the prehistoric period, with its strong relationship to other parts of north-west Europe and then from the 16th century to trans-Atlantic trade – facilitating the export of products and also the emigration of people to the Americas, Australia and New Zealand in particular.
- The **relationship of the sea to the form of the landscape**, natural and historic landmarks such as church towers and in particular:
    - Place names relating to native peoples and the impact of immigrants, raiders, missionaries and traders – Irish settlers, Brittonic saints and Vikings (mostly Norse) in the first millennium, the Anglo-Norman conquests and English settlements of the 11th-14th centuries
    - Anchorages in bays and other areas protected from prevailing winds
    - Fishing ports, generally small in size and some (for example the replanning of Aberaeron in the early-mid 19th century) expanding into larger trading ports
    - Large ports which developed for the export of coal, iron, bricks, steel and other products, expanding considerably after the development of iron hulls and screw propellers from the 1840s
    - The development of lighthouses and other navigational aids, under increasing state direction from the 16th century and the establishment of HM Coastguard in 1822 (Admiralty charts dating from establishment of Hydrographic Office from 1795)
    - The development of oil and gas terminals in the later 20th century.
    - Wind power and other forms of renewable energy flood and erosion defence in the form of breakwaters, embankments etc
- A rich legacy of **archaeological assets**, most obviously shipwrecks and including the evidence for historic land use in the inter-tidal range and in shallow seas.

Issues for change

- Significant loss of inter-tidal and subtidal ecosystems, such as oyster beds, mudflats and sandflats that have sustained local communities in the past.
- Algae growth in estuaries and coastal waters.
- Ocean acidification and higher water temperatures

8.4.4. Developed (communities)

Key factors influencing the landscape

Patterns of rural settlement are a fundamental part of its distinctive character, the basic elements of which were established by the 14th century:

- Most areas are dominated by **dispersed settlement** of isolated houses, farmsteads and hamlets. **Village-based settlement**, mostly dating from after the Norman and (to a lesser extent) the late 13th century Edwardian Conquest, is concentrated in south Wales and some of the broad eastern vales. Some hamlets and linear settlements developed into villages from the late 19th century.
- Although many settlements shrank or were abandoned as a result of famine and plague in the 14th century, many isolated farmsteads and their associated **enclosed fields** also date from the 15th-17th centuries and result from the growth of larger farms with access to growing markets. Some isolated houses and farmsteads, and often whole communities of smallholders, were established as a result of the enclosure of large areas of communal rough grazing in the 18th and early-mid 19th centuries. The early 20th century saw many rural councils engaged in building distinctive smallholdings.
- **High densities of dispersed settlement** in some rural areas may result from the numbers and small size of farms, and/or industrial activity such as mining and quarrying which increased from the later 16th century and particularly in the 19th century. Many rural settlements were built in linear fashion along new or improved roads in the 19th century, and low-density bungalow development are a characteristics of some areas (e.g. Carmarthenshire and parts of Cerdigion).
- **Traditional rural architecture** is dominated by building in stone and slate, often with limewashed walls, with timber-frame to the east and cob and brick in the south. Whilst the rebuilding of rural Wales in the 19th century has affected all areas, there are some areas that have concentrations of pre-18th century houses and farm buildings that reflect the prosperity of their economies – Snowdonia, the Brecons and large parts of eastern Wales. Linear and dispersed-plan farmsteads are found all areas, especially close to commons and historic dove routes, and larger courtyard farms and larger fields developed in broader valleys where mixed farming was concentrated. **Farm buildings** are dominated by the need to house cattle and their fodder, but threshing barns are found in all areas – a reminder that crops were grown in all landscapes. Most **farmsteads** were built or rebuilt between 1860 and 1900, when half of working farms fell out of use.
- In all areas the **post-1950 restructuring of agriculture** resulted in the decline in boundary maintenance and traditional management of hedgerows, accompanied by the erection of large modern sheds, slurry stores and manure-handling equipment now required to meet water quality / animal welfare / agri-environment scheme requirements and reduce labour costs. Today, much larger buildings support modern dairy installations with feed stores, stock housing, milking and slurry storage and handling facilities. On remaining arable farms, horticulture in polytunnels or intensive indoor livestock buildings (mainly poultry) are also prominent in some areas of the landscape.

- Rural settlement areas are rich in **archaeological assets,** including house platforms and other traces of land use around settlements, although the nature of the resource has resulted in dispersed settlement being less well-understood than the archaeology of village settlement.

Urban development:

- Urban development was small-scale until the 19th century. In the medieval period it was mostly limited to Anglo-Norman religious establishments and **fortress towns** and **ports** in the medieval period, and into the 17th century only 10% of the population lived in (mostly very small) towns with populations exceeding 1000.
- Whilst **market towns** and **ports** have their origins in the medieval period, and industries such as the smelting of imported lead and copper increased from the 17th century, most urban development dates from after the 1760s and especially in the second half of the 19th century when south and north-east Wales became pre-eminent in the production of iron, steel and steam coal.
- The highly-distinctive **south Wales valley settlements** around coalfields are strongly associated with Upland (wooded) and Upland (grassland) landscape types.
- Widespread and scattered **sub-urbanization** and the growth of **resort towns** also emerged as a significant contribution to the housing stock, often clustered in areas with improved turnpike roads and railways. The development of resort towns, linked by rail from the 1840s, became a distinctive phenomenon in the 19th to mid 20th centuries, followed by development in and around coastal communities including the development of second homes.
- In the post-1950 period the petro-chemical industries contributed to the development of Milford Haven area and the Deeside area in north-east Wales, and the **post-war housing programme** to the development of Newtown and Cwmbran.
- From the early 20th century the increased amount of land taken up by housing was enabled by falling land values, transport improvements and longer commuting distances, in particular the motor car and the opening up of routes for buses enabling development between rail corridors. Housing output fell as a result of the termination of public sector housing in the early 1980s, Housing Associations taking the lead in the provision of affordable housing.
- **Archaeological assets** in urban settlement areas are concentrated in historic urban cores of the 18th century and earlier, being more elusive in areas where later expansion has covered earlier farming and rural-industrial landscapes. Historic buildings and archaeological sites in historic industrial sites and in rural-industrial communities (also in Upland landscapes) have particular value in revealing evidence about Wales's transition to an industrial and more urbanised economy and community.

Issues for change

- There will be increasing demand for new settlements and growth points and housing that is affordable and also accessible to an increasingly ageing population.
- There has been a tendency since the 19th century for settlement to become more nucleated and less dispersed, and for smaller sizes of households to occupy more space including gardens.

- More demand for residential development within urban areas as patterns of shopping change.
- Increased pressure for development within existing - particularly larger - house plots.
- Extension to urban areas and villages in particular, including integration of green infrastructure.
- Increasing tendency to conversion and infill as commercial and industrial building stock and zones have fallen out of use.
- Need to address reuse of redundant traditional architecture, particularly farmsteads and field barns, the rates of which will increase in the future.
- Reuse of buildings in upland areas may be linked to new methods and directions in land use.
- Demand on dairy farms for much larger buildings support modern dairy installations with feed stores, stock housing, milking and slurry storage and handling facilities. On remaining arable farms, horticulture in poly-tunnels or intensive indoor livestock buildings (mainly poultry) are also prominent in some areas of the landscape.
- Relationship of all these to development of energy-efficient construction techniques and supply of traditional materials and skills – a key issue in rural areas.
- Significant vulnerability of coastal buildings, also the many settlements clothing the base of steep-sided valleys, to rising sea levels, storm surges and flooding damage.

8.4.5. Developed (Industry and infrastructure)

Key factors influencing the landscape

This landscape type results from the developing scale of 17th-20th century industry, in close association with post-1750s improvements in the transport infrastructure of canals, road, tramroads and rail:

- The extraction of granite and aggregates for construction and road building, including the celebrated Penmaenmawr on the north coast of North West Wales which from the early 19th century provided granite for streets and buildings across the British Isles.
- The quarrying of slate for construction and roofing in the British Isles and overseas, Penrhyn and Dinorwig being the largest slate mines in the world. Slate was exploited from at least the Romano-British period and expanded as a source of roofing and building slate from the 18th century, experiencing massive growth in the second half of the 19th century.
- The mining of copper (in Snowdonia), and of silver, zinc and lead (e.g. Pentre Halkyn and Rhosesmor) in North East Wales, the latter first exploited in the Roman period and experiencing considerable development from the 17th century with the involvement of investors and entrepeneurs from London companies and the Peak District.
- The quarrying from the 17th century of limestone – for fertiliser and construction - and aggregates in North East Wales (e.g. Abergele, Graianrhyd, Minera and Coedpoeth) and South Wales (e.g. Brynamman).
- The combination in North East Wales of quarrying, lead and coal mining with brick-making using local clays (e.g. Brymbo) producing widely-exported distinctive hard red bricks.
- The development from the 17th century of the iron and coal industries in south Wales, connected to Swansea, Cardiff and other ports by tramroads from the late 18th century and experiencing massive growth in the 19th century followed by sudden decline in the 1980s. Open-cast coal mining has continued but is also in decline.
- Since the 1970s increasing levels of Light Natural Gas (LNG) have been imported into coastal terminals (Milford Haven).
- Recent and increasing importance of renewables – large wind and now solar arrays.

These sites can be rich in **archaeological assets** extending to the Roman and even prehistoric periods, the latter often comprising sites in rough ground absorbed into these sites. They have also developed in close association with canals, roads, tramways and railways, and their inclines, engineering and other features, period: these include celebrated sites such as and the railways which served the slate quarries, including the Penydarren Tramroad at Merthyr that connected the ironworks there (established 17784) to Cardiff, Ffestiniog Railway from the port at Porthmadog. Association with workers' housing, churches and Methodist chapels.

These sites can also be rich in habitats and specialist plant communities, from dwarf shrub and acid flushes in slate quarries to calaminarian species in former lead and limestone quarries. These relate to areas of unenclosed land, including historic woodland, the now-distinctive heather moorlands of south Wales which were conserved for shooting by local industrialists, and vegetation communities of calcareous species in areas of quarry spoil.

Issues for change

- Now only localised extraction of slate and coal.
- Aggregates is now main minerals industry.
- Ensuring supplies of minerals including slate and building stone for conservation of historic buildings and for the enhancement of local distinctiveness through development using local materials.
- An increasing reliance on imports of energy minerals, including economically-viable coal, oil and natural gas.
- Potential for higher and more intense rainfall to flush out higher levels of contaminants from former mine workings
- Potential for hydro-fracturing from shale – NE extending to Bowland Field, south Wales

8.4.6. Lowland (wooded and wetland)

Key factors influencing the landscape

This landscape type results from the continued use of ancient woodland, coastal marsh and valley-bottom meadows, or their clearance and intensification to create improved pastures and 20th century largely non-native-species forest plantations.

- **Tree cover** comprises Forestry Commission plantations, contrasting with ancient woodland in narrow incised valleys and 18th-19th century mixed-species plantations, date from after 1919.
- Dispersed pattern of **settlement** (for further details see **Built land – communities**) with farmsteads and smallholdings now working an enclosed landscape, often with mature and veteran trees in hedgerows, hedgebanks (cloddau) and drystone walls:
    - Irregular and piecemeal enclosure, including some areas (most notably in the Vale of Clywd) with thick, species-rich and irregular boundary hedges intermixed with ancient and replanted woodland, all resulting from medieval land clearance.
    - Some areas result from medieval and post-medieval (up to the late 17th century) land reclamation, such as Laugharne and Pendine Marshes with farmsteads and ridge and furrow dating from this period and the Taf Valley marshes which were drained and enclosed with field banks and ditches in the 17th century.
    - Planned late 18th and 19th century enclosure of wetlands, commonly associated with post-and-wire fencing as well as banks and ditches.
- Some areas of poorly-drained and acid soils, historically used for the extraction of peat.
- The highest densities of isolated farmsteads and hamlets are associated with smaller-scale fields, the result of generally pre-17th century enclosure of communal fields intermixed with more ancient enclosure patterns (usually the clearance of woodland in the medieval period).
- Older **woodland** is concentrated in narrow incised valleys either inland or in river valleys leading to the sea. Running water was used to power corn mills and also fulling mills for the woollen and cloth industries that continued in some areas into the 19th century. Ash dieback is affecting woods and hedgerows, loss of larch as a seasonal colour in the landscape
- **Wetland areas** in valley bottoms and in low-lying coastal marsh, traditionally providing hay meadows and also a vital source of grazing, fuel and provisions for nearby communities. These are now a fraction of their former extent and tend to be much less actively managed, although grazing land may be improved and stocked quite heavily. Recent agri-environment and other initiatives have re-wetted and recreated some of these habitats.
- **Farmstead buildings** – including threshing barns, and often arranged around cattle yards - and **field boundaries** also illustrate the development of a mixed farming landscape over centuries, now dominated by extensive grazing for sheep.
- **Heritage, archaeological and natural assets** include farmsteads which mostly result from 19th century rebuilding, wetland which retains distinctive plant communities and palaeo-environmental evidence, and ancient woodland with its evidence for charcoal burning and historic management.

Issues for change

- Surviving rough grazing subject to same issues for change as Upland Moorland.
- Decline in boundary maintenance and traditional management of traditional field boundaries, accompanied by the erection of large modern sheds, stores and manure-handling equipment now required to meet water quality / animal welfare / agri-environment scheme requirements and reduce labour costs.
- Decline in condition and extent of dry stone walls and well-managed (laid) hedgerows. Post-and-wire fences increasingly common.
- Surviving rough grazing subject to same issues for change as Upland Moorland.
    - Decline in boundary maintenance and traditional management of traditional field boundaries, accompanied by the erection of large modern sheds, stores and manure-handling equipment now required to meet water quality / animal welfare / agri-environment scheme requirements and reduce labour costs.
    - Decline in condition and extent of dry stone walls and well-managed (laid) hedgerows.

- Waterlogged environments associated with areas of wetland can preserve significant habitats, archaeological remains and palaeo-environmental data. These are finite, fragile and non-renewable resources which cannot be re-created. As well as being significant for their archaeological and wildlife value, wetlands store and filter water and help control and buffer the effects of flooding.
- Surviving wetlands are often fragmented and fragile, unable to play an effective role in absorbing floodwaters, recharging aquifers and capturing carbon.
- Ash dieback is affecting woods and hedgerows.
- Many small deciduous and some mixed woodlands are not under active management.
- Neglect and/or ryegrass improvement of traditional hay meadows leading to significant loss of biodiversity; loss of arable fields (traditionally used to produce fodder / root crops) from many valleys, reducing habitat diversity for breeding birds and small mammals.
- Decline in active management by coppicing and laying of hedgerows, small woodlands and under-management of wet/acid pastures as stock and crops are concentrated upon the best and most productive areas, leading to significant continued decline in biodiversity, landscape character and accessibility for low-key and informal local recreation.

8.4.7. Lowland valleys (hedgerow)

Key factors influencing the landscape

- These are landscapes resulting from ancient and usually gradual (piecemeal) **enclosure** associated with village-based (mostly in South West Wales) and **predominantly scattered or dispersed settlement** of farmsteads and hamlets dating from the medieval period. Some areas were evidently reclaimed from marsh and woodland from the medieval period. Strip fields and enclosed fields were also intermixed with areas of common land, much of which was enclosed or planted with woodland in the 19th century.
- These farming landscapes generally occupy richer soils, often intensively manured over centuries, and have been heavily adapted – mostly by estates - for improved **mixed farming** from the 18th century, with enlarged fields and straight boundaries. **Farmsteads** display a varied mix of layouts, larger barns demonstrating the continuing importance of mixed farming into the early 20th century. Arable cultivation, dairying and stock fattening (on intensively managed and fertilised ryegrass pastures) developed on the loamy soils and valley meadows of the lower areas.
- **Hedgerow trees and shrubs** offered a rich source of materials for fuel, construction and leaf fodder for cattle and where maintained, this is now primarily for stock control.
- **Woodland** comprises a miix of small ancient woodlands, 18-19th century plantations and some post-1919 softwood plantations.
- In some areas the visible remains of traditionally managed hay meadow are apparent, with shallow channels running across the valley floor where nutrient-enriched alluvial deposits would be washed onto the fields to act as a natural fertiliser. Today, most of the land-use diversity of these areas has declined and been replaced by a mix of improved and semi-improved ryegrass pastures, with rushy and more acid grassland where drainage is less effective. In the most inaccessible fields in recent years, cessation of active grazing has encouraged some scrub encroachment.
- **Heritage, archaeological and natural assets** include shrunken and deserted medieval settlements, surviving traces of medieval cultivation (in lynchets and ridge and furrow), traditional farmsteads, timber-framed domestic and farm buildings in the east dating from the late medieval period and stone vernacular buildings to the west which mostly date from rebuilding from the 1840s.

Issues for change

- Surviving rough grazing subject to same issues for change as Upland Moorland.
    - Decline in boundary maintenance and traditional management of traditional field boundaries, accompanied by the erection of large modern sheds, stores and manure-handling equipment now required to meet water quality / animal welfare / agri-environment scheme requirements and reduce labour costs.
    - Decline in condition and extent of dry stone walls and well-managed (laid) hedgerows.
    - Post-and-wire fences increasingly common.

- As well as being significant for their archaeological and wildlife value, wetlands store and filter water and help control and buffer the effects of flooding.
- Ash dieback is affecting woods and hedgerows.
- Many small deciduous and some mixed woodlands are not under active management.
- Neglect and/or ryegrass improvement of traditional hay meadows leading to significant loss of biodiversity; loss of arable fields (traditionally used to produce fodder / root crops) from many valleys, reducing habitat diversity for breeding birds and small mammals.
- Decline in active management by coppicing and laying of hedgerows, small woodlands and under-management of wet/acid pastures as stock and crops are concentrated upon the best and most productive areas, leading to significant continued decline in biodiversity, landscape character and accessibility for low-key and informal local recreation.

8.4.8. Lowland (open)

Key factors influencing the landscape

- This landscape type, predominantly below 100m AOD, is now characterised by a mix of improved and semi-improved grassland with some arable.
- These are largely **open landscapes** on some of the more fertile soils in Wales, the extent of tree cover in hedgerows being generally lower than in other lowland landscape types. Ancient woodland is mostly confined to narrow valleys. Farmland is also interspersed with some blocks of 18th century and later plantations.
- The larger scale of **fields** results from reorganisation and the amalgamation of farms from the 15th century, most of which occurred in the 19th century and was accompanied by the rebuilding of farmsteads. There are areas of late 18th and 19th century reclamation from marshland, such as Malldreath on Anglesey and Penrhos west of Pwllheli.
- Enclosed land was also intermixed with **common land**, much of which was enclosed or planted with woodland in the 19th century.
- These landscapes were also receptive to the growth and reorganisation of larger mixed farms from the 17th century and sometimes earlier, as reflected in larger fields and new enclosures with straight-sided boundaries.
- These landscapes include more traditional courtyard **farmstead** layouts and larger threshing barns than other areas, indicating the historic importance of arable cropping and of farmyard manure to support its production.
- Decline in boundary maintenance and traditional management by laying (in sheep areas) or coppicing (in dairy areas) of mixed-species or predominantly hawthorn hedgerows – the latter especially characteristic of later enclosures. On remaining arable farms, horticulture in polytunnels or intensive indoor livestock buildings (mainly poultry) are also prominent in some areas of the landscape.
- **Heritage assets** include shrunken and deserted medieval settlements, traces of medieval cultivation (in lynchets and ridge and furrow), traditional farmsteads, timber-framed domestic and farm buildings in the east dating from the late medieval period and stone vernacular buildings to the west which mostly date from rebuilding from the 1840s.

Issues for change

- Surviving rough grazing subject to same issues for change as Upland Moorland.
    - Decline in boundary maintenance and traditional management of traditional field boundaries, accompanied by the erection of large modern sheds, stores and manure-handling equipment now required to meet water quality / animal welfare / agri-environment scheme requirements and reduce labour costs.
    - Decline in condition and extent of dry stone walls and well-managed (laid) hedgerows.
    - Post-and-wire fences increasingly common.

- As well as being significant for their archaeological and wildlife value, wetlands store and filter water and help control and buffer the effects of flooding.
- Ash dieback is affecting woods and hedgerows.
- Many small deciduous and some mixed woodlands are not under active management.
- Neglect and/or ryegrass improvement of traditional hay meadows leading to significant loss of biodiversity; loss of arable fields (traditionally used to produce fodder / root crops) from many valleys, reducing habitat diversity for breeding birds and small mammals.
- Decline in active management of wet/acid pastures as stock and crops are concentrated upon the best and most productive areas, leading to significant continued decline in biodiversity, landscape character and accessibility for low-key and informal local recreation.

8.4.9. Upland (grassland)

Key factors influencing the landscape

The present-day character of upland grassland results from 19th century improvement and the taking in of more farmland for intensive agriculture in the post-1950 period, working upon earlier and agriculturally more-diverse landscapes with enclosed land and large expanses of common land.

- **Farmsteads** dominate the settlement pattern, their varied forms and diversity of building types testifying to the growing of corn as well as the importance of cattle in upland areas. The shorter growing season favoured pastoral farming economies, with cattle (Welsh Blacks) being exported via droveways into England and sheep – kept for their wool and increasingly their meat - becoming more important in the 18th-19th centuries.
- **Higher densities of settlement** are commonly associated with 18th-19th century rural industrial landscapes – ranging from the woollen industry (for example Drefach Felindre, Carmarthenshire) to mining landscapes (for example Dolaucothi, where gold mining expanded around its Roman origins) and the quarrying of slate (Blanau Ffestiniog and the Arfon, south-west of Bangor).
- Generally poorly-drained and acid soils, with a shorter growing season than the lowlands, are best-suited to grazing and small-scale arable/horticulture on better-drained land, grown for fodder and local consumption. Cattle – both dairy and suckler beef - were a mainstay of the rural economy, with calves being reared and exported to England in increasing numbers from the medieval period. Sheep have been the dominant grazing livestock by numbers since the late 18th century, historically reared for their wool but today kept only for meat. In recent decades a limited presence of hardy native cattle breeds has also been a feature of grazing management on the least improved types of pasture and moorland.
- **Fields** are characterised by irregular enclosures around farmsteads and regular enclosures of in-take and former common land, which was very extensive and sometimes wrapped around individual farms and their fields. Often the present pattern of fields has developed out of fields and holdings amalgamated from the 17th century, and especially from the 19th century when the numbers of farms sharply declined as population left these areas and moved towards urban areas both within and beyond Wales.
- **Semi-natural grassland** cover is now a fraction of its pre-19th century extent. Grazed commons, heathlands and wet moorland can support a wide variety of species and are notable for their biodiversity value. Large tracts of rough land – including grazing land held in strips, which may still be reflected in the modern ffridd landscape - were enclosed between the late 18th and mid 19th centuries, often accompanied by drainage to enhance productivity for sheep in particular. Routeways connect these landscapes to farming settlements.
- **Ancient woodland** is concentrated in narrow valley sides and along rivers and streams, and there are plantations of 18th century and later date. 20th century plantations – typically sitka spruce, with some larch - may be associated with the enclosure of common land.

Heritage and archaeological assets. This landscape type, and especially areas of surviving common land, retains a high concentration of prehistoric settlement and ritual sites, long-abandoned field enclosures, and supports a significant diversity of grassland plant communities from highly acid to calcareous, wet and dry, and with palaeo-environmental evidence for past land use. Archaeological evidence also of shrunken and deserted settlement and of field systems and cultivation for crops, and for the development of extractive and other industries. Unenclosed land is especiall6 significant for its landscape, cultural, archaeological and habitat value.

Issues for change

- Surviving rough grazing subject to same issues for change as Upland Moorland.
- Intensive use of pastures for grazing in parallel with neglect of upland grazing areas will continue to reduce landscape character and habitat diversity for breeding birds and small mammals.
- May be considered as areas for new woodland planting in upland catchments
- Decline in boundary maintenance and traditional management of traditional field boundaries, will be accompanied by increasing rates of redundancy of traditional farmsteads and restructuring of upland farms.
- Increased risk within conifer plantations of wind throw and disease due to storm events and changing climate.
- Ash dieback is affecting woods and hedgerows.
- Many small deciduous and some mixed woodlands are not under active management.

8.4.10. Upland (Rock scree)

Key factors influencing the landscape

- Its height and exposure of its geology.
- Its use for quarrying slate and stone, the slate quarries around in North West Wales being the largest in the world in the 19th century, and for the extraction of lead and iron ores.

Issues for change

- Increased risk of rock fall with heavy rain.

8.4.11. Upland (wooded hills)

Key factors influencing the landscape

- This landscape type is distinguished by a higher proportion of **woodland** than the upland grassland landscape type, which:
- can be 17th century or earlier in the valley sides, managed for timber and charcoal production for local industries
- can be 19th century plantations, including those established to make pit props for coal mines, and post-1919 Forestry Commission plantations
- are increasingly resulting from attempts to enhance landscapes in areas affected by the loss of coal mining and other industries
- **Farmsteads** dominate the settlement pattern, the smaller scale of farms and the higher elevations of these areas being reflected in the dominance of small linear and courtyard layouts and buildings almost wholly given over to housing cattle and their fodder. Cattle (Welsh Blacks) were a mainstay of the economy and exported via droveways into England and sheep – kept for their wool and increasingly their meat - becoming more important in the 18th-19th centuries. There are some areas with **higher densities of settlement** associated with 18th-19th century industry and the colonisation of upland commons. There also many ruins of farms resulting from the abandonment of farms in this period.
- Sheep have been the dominant grazing livestock by numbers since the late 18th century, historically reared for their wool but today kept only for meat. In recent decades a limited presence of hardy native cattle breeds has also been a feature of grazing management on the least improved types of pasture and moorland.
- **Fields** are dominated by 19th century enclosures around farmsteads and regular enclosures of in-take and former common land, meadows and marshlands.
- **Semi-natural grassland** cover is now a fraction of its pre-19th century extent. Grazed commons, heathlands and wet moorland can support a wide variety of species and are notable for their biodiversity value. Large tracts of rough land – including grazing land held in strips, which may still be reflected in the modern ffridd landscape - were enclosed between the late 18th and mid 19th centuries, often accompanied by drainage to enhance productivity for sheep in particular. Routeways connect these landscapes to farming settlements.
- **Heritage and archaeological assets.** Extensive evidence of medieval and prehistoric settlement and land use, the decline of farming communities in the 19th century also contributing to the high incidence of abandoned farmsteads and other rural buildings. Some forest is planted on former native woodland and thus it may retain features of historic management including hedgebanks and ancient tracks. Archaeological evidence also of shrunken and deserted settlement and of field systems and cultivation for crops, and for the development of extractive and other industries. Unenclosed land is especially significant for its landscape, cultural, archaeological and habitat value.

Issues for change

- Surviving rough grazing subject to same issues for change as Upland Moorland.
- Intensive use of pastures for grazing in parallel with neglect of upland grazing areas will continue to reduce landscape character and habitat diversity for breeding birds and small mammals.
- May be considered as areas for new woodland planting in upland catchments
- Decline in boundary maintenance and traditional management of traditional field boundaries, will be accompanied by increasing rates of redundancy of traditional farmsteads and restructuring of upland farms.
- More rainfall, accompanied by more sporadic and extreme weather events in upland areas, will threaten erosion of peat soils, more damage to plantations and associated soil damage.
- Increased risk within conifer plantations of wind throw and disease due to storm events and changing climate.
- Ash dieback is affecting woods and hedgerows.
- Many small deciduous and some mixed woodlands are not under active management.

8.4.12. Upland (wooded)

Key factors influencing the landscape

- This landscape type is distinguished by a high proportion of **woodland** than the upland grassland landscape type:
- Ancient woodland is concentrated in narrow valley sides and along rivers and streams, and there are plantations of 18th century and later date. 20th century plantations may be associated with the enclosure of common land.
- A significant proportion of the area is Forestry Commission-planted or managed and much is available for public access with a variety of visitor amenities.
- Upland plantation woodland is commonly sited in large swathes across the landform, often composed largely of non-native coniferous species including sitka spruce, larch and some Douglas fir.
- Many areas were first planted in the immediate post-war periods of the 20th century, often in dense stands. More recent management has restored a greater variety of woodland habitat including glades and some areas of natural regeneration.
- **Farmsteads** dominate the settlement pattern, the smaller scale of farms and the higher elevations of these areas being reflected in the dominance of small linear and courtyard layouts and buildings almost wholly given over to housing cattle and their fodder. Cattle (Welsh Blacks) were a mainstay of the economy and exported via droveways into England and sheep – kept for their wool and increasingly their meat - becoming more important in the 18th-19th centuries. There are some areas with **higher densities of settlement** associated with 18th-19th century industry and the colonisation of upland commons. There also many ruins of farms resulting from the abandonment of farms in this period.
- Sheep have been the dominant grazing livestock by numbers since the late 18th century, historically reared for their wool but today kept only for meat. In recent decades a limited presence of hardy native cattle breeds has also been a feature of grazing management on the least improved types of pasture and moorland.
- **Fields** are dominated by 19th century enclosures around farmsteads and regular enclosures of in-take and former common land, meadows and marshlands.
- **Semi-natural grassland** cover is now a fraction of its pre-19th century extent. Grazed commons, heathlands and wet moorland can support a wide variety of species and are notable for their biodiversity value. Large tracts of rough land – including grazing land held in strips, which may still be reflected in the modern ffridd landscape - were enclosed between the late 18th and mid 19th centuries, often accompanied by drainage to enhance productivity for sheep in particular. Routeways connect these landscapes to farming settlements.
- **Heritage and archaeological assets.** Extensive evidence of medieval and prehistoric settlement and land use, the decline of farming communities in the 19th century also contributing to the high incidence of abandoned farmsteads and other rural buildings. Some forest is planted on former native woodland and thus it may retain features of historic management including hedgebanks and ancient tracks.

Archaeological evidence also of shrunken and deserted settlement and of field systems and cultivation for crops, and for the development of extractive and other industries. Unenclosed land is especially significant for its landscape, cultural, archaeological and habitat value.

Issues for change

- Surviving rough grazing subject to same issues for change as Upland Moorland.
- Intensive use of pastures for grazing in parallel with neglect of upland grazing areas will continue to reduce landscape character and habitat diversity for breeding birds and small mammals.
- May be considered as areas for new woodland planting in upland catchments.
- Decline in boundary maintenance and traditional management of traditional field boundaries, will be accompanied by increasing rates of redundancy of traditional farmsteads and restructuring of upland farms.
- More rainfall, accompanied by more sporadic and extreme weather events in upland areas, will threaten more erosion of peat soils, more damage to plantations and associated soil damage.
- Increased risk within conifer plantations of wind throw and disease due to storm events and changing climate.
- Ash dieback is affecting woods and hedgerows.
- Many small deciduous and some mixed woodlands are not under active management.

8.4.13.Upland (moorland)

Key factors influencing the landscape

- Upland moorland mostly results from a combination of woodland clearance and changing land use following climatic deterioration in the prehistoric period, causing slopewash, the formation of peat and the growth of more impermeable and waterlogged areas. It has for centuries been utilised by surrounding farms and communities for summer grazing, with peat, heather and bracken cut for fuel, bedding, roofing and fodder. Significant and characteristic **vegetation** and plant communities results from this use and the underpinning geology. Historic **tree cover** is sparse except in some narrow incised valleys which can retain ancient woodland which were managed to supply timber and also fuel for communities and industries. Most **woodland** comprises post-1919, post and wire fences softwood plantations driven by national government, increasingly mixed with deciduous species since the 1970s and increasing with current policy objectives for woodland planting.
- Cattle and sheep farms developed in some parts of the upland moorlands in the medieval period, with other areas administered as hunting/shooting forest. The moorlands were increasingly subject to enclosure from the 16th century, the form of **field boundaries** (drystone walls; post and wire fences more recently) resulting from piecemeal enclosure driven by individual farms or large-scale (mostly late 18th and 19th century) and planned enclosure driven by large estates to improve pasture for livestock and secure mineral rights. Some drystone walls may date from the prehistoric period.
- **Settlement** is mostly absent, and **structures** including historic houses and farmsteads dating from the medieval period are concentrated and scattered around the moorland fringes. Chains or clusters of smallholdings and small farms, with small-scale regular and irregular fields, developed on the moorland fringe.

Archaeological assets. Upland moorland retains a high concentration of prehistoric settlement and ritual sites and long-abandoned field enclosures, they support a significant diversity of grassland plant communities. Also evident in the landscape are stock enclosures, mostly for sheep, or the remains of ‘hafods’ (summer farms linked to valley farms) which had mostly been abandoned by the 19th century. barns can be adapted from ‘hafods’ and be of 18th century or earlier date. Upland moorland can retain significant industrial and military archaeological remains, the former sometimes linked to woodland managed for charcoal burning and the latter mainly relating to its use for training in both world wars with ongoing use in parts of Wales. Plantation woodland can retain significant archaeological remains.

Issues for change

- There has been relatively little loss of moorland over the last hundred years, the greatest levels of conversion to improved grazing or arable having been in the post-medieval period. Mountain, moorland and heath habitats now extend over 261,824 ha in Wales, 27% are SSSI, and 60% of the Welsh deep peat occurs in these landscapes. The extent of dwarf shrub, heath and bracken has declined significantly since 2007, with a slight increase in the area of blanket bog since 1990. Since the early 20th Century grazing and fuel collection on blanket bog, whose history usually extended unbroken for several millennia, has normally been abandoned and scrub has invaded, threatening its heritage significance and altering the ability of these areas to provide well-defined and highly valued ecosystem services.

- Uncertain future for traditional structures of ownership and commoning that developed as part of earlier tightly integrated relationships with adjacent farmland and settlements.
- Palaeo-environmental evidence vulnerable to erosion or dessication of wetland parts.
- Most surviving moss or peatland (a fraction of the total present prior to large-scale drainage from the later 17th century) has since the 19C or 20C been largely abandoned as fuel has been obtained from easier sources. The annual cutting, drying and saving of peat has now effectively ceased, removing an important communal activity from these areas. Most is in poor condition due to drains and peat cuttings lowering water tables.

8.5. Background Context Supporting Climate Change Narratives

Climate change impacts

Matrix 1 summarises landscape elements potentially affected by climate change. A more detailed description of identified impacts is can be found in Matrices 2(i) and 2(ii).

8.5.1. Coastal Edge

Matrix 1: Identification of potential impacts for Coastal Edge

Landscape Character type: Coastal Edge								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform	**X**						**X**	**X**
Field boundaries								
Tree cover								
Vegetation	**X**						**X**	
Surface water	**X**							
Settlement & structures	**X**						**X**	**X**
Archaeological assets	**X**						**X**	**X**

Matrix 2(i): Impact of warmer mean temperatures on Coastal Edge

Description of change

- warmer mean temperatures

Outcome of change

- Rise in sea levels

Impact on landscape character elements

(i) Rise in sea levels

Landscape element impacted	Level of anticipated change
Landform	High -ve
Vegetation	High -ve
Settlement pattern & structures	High -ve
Archaeological assets	High -ve

(ii) Longer growing season

Landscape element impacted	Level of anticipated change
Settlement pattern & structures	

Risk assessment
Some low-lying areas could be given over to sea defence, salt marsh and inundation. Some loss of coastal lowland growing areas likely (Meltcalf et al, 2003)
Medium confidence that there will be medium to high risks to species and habitats due to coastal evolution (sea level change, sediment supply and demand, wave size and speed, rainfall and storm event, anthropogenic coastal defences) (DEFRA, 2012b).

Loss of coastal habitats such as saltmarsh and sand dunes (squeezed between rising sea levels and manmade defence structures) (DEFRA, 2012b); some of the main transport links are on the coast because of the steep inland topography. Roads, railways, coast defences and other man-made structures limit the scope for allowing the coast to retreat naturally in many areas. This causes the foreshore to narrow with a consequent loss of intertidal habitats in parts of Wales. This process is often referred to as coastal squeeze (DEFRA, 2012a)
The UK coastline comprises areas that are predominantly stable (e.g. those comprising hard rock formations) and those that are either eroding (where there is a permanent loss of land) or accreting (where coastal sediment builds up) (e.g. soft rock coast, beaches). Sea level rise will lead to an increase in the rate of erosion of some areas and may also lead to an increase in the rate of accretion in others, speeding up the long-term reconfiguration of some coastlines in the UK that is already occurring. This will result in the loss of some habitats and the creation of others; 23% of Welsh coast is eroding (DEFRA, 2012b).

The future magnitude of absolute sea level rise according to UKCP09 is between 12 – 76 cm (1 - 7.5 mm/yr) from 1990 -2095. Sea level rise will also continue beyond 2100 regardless of emissions scenario. The UK National Ecosystem Assessment projected coastal margin habitat losses to reach 8% by 2060 (ASC, 2016). For higher sea level rise scenarios the potential losses may be greater. Estimated UK beach area lost due to coastal erosion and sea level rise by 2080 (based on medium emissions scenario): 1200-6100ha; estimated England & Wales Agricultural land lost: 7720ha (DEFRA, 2012b); NRW have estimated that around 2,300 hectares of Natura 2000 coastal habitat will be lost by the end of the century due to coastal squeeze (ASC, 2016)

Although the north Wales coastline shows little movement, Cardigan Bay is sinking by about 0.4 mm/year. In addition, the south Wales coastline is sinking by approximately 0.5 mm/year around St. Brides Bay to about 0.8 mm/year around Newport. This means that around Newport, for example, relative sea levels are currently increasing by about 4mm/year (DEFRA 2012a).
The combination of higher sea levels and greater loading from wave action would increase damage to natural and built assets (DEFRA, 2012b); loss of coastal habitats would damage long-term viability of coastal defences, which often rely on the natural buffering provided by inter-tidal habitats to absorb wave energy

Damage to property due to flooding and coastal erosion (DEFRA 2012c). In the longer term, rising sea level could have an impact on coastal transport infrastructure, including harbours, ferry terminals, road and rail routes (SNH, 2011).
Risk to coastal communities and infrastructure services from coastal flooding and erosion (CCC, 2016b); The largest cities (Cardiff, Swansea and Newport) and a large proportion of business and industry are on the coast. (DEFRA, 2012a)
Risk to water quality and soil fertility (CCC, 2016b). This could impact agricultural landscape (DEFRA, 2012a).
Ports, rail network and sea walls at risk from increased wave height and storm surges ((ASC, 2016)
It has also been estimated that an average of around 4-6% priority freshwater habitats

in the coastal floodplain could be lost per year due to salt water inundation, most of this being in designated areas. This does not include inundation caused by extreme storm surges (ASC, 2016)
Saline intrusion can affect groundwater as a result of over-abstraction (via pumps, boreholes or wells). The intrusion of salt water into coastal aquifers can impact on fresh water quality. Future risk to aquifers is expected to slowly increase with sea level rise and associated tidal surges.
At risk are buildings, archaeological sites and landscapes along the coast edge, either in low-lying locations or on exposed cliffs, due to coastal erosion and increased storm events (Powell et al 2012)
There could be increased pressure on the coastal environment from increased tourism as a result of warmer and drier summers. This could lead to greater disturbance and damage to coastal areas, and a greater need for conservation and protection (DEFRA, 2012a)

Matrix 2(ii): Impact of warmer wetter winters on Coastal Edge

Description of change

- warmer wetter winters

Outcome of change

- More flooding events

Impact on landscape character elements

(i) More flooding events

Landscape element impacted	Level of anticipated change
Landform	Low -ve
Vegetation	Moderate -ve
Settlement pattern & structures	Moderate -ve
Archaeological assets	Moderate -ve

Risk Assessment

Flood defence structures create barriers between floodplains and rivers, estuaries and coastal waters. This loss of connectivity has adverse impacts on biodiversity: floodplains do not benefit from inundation and sedimentation, and species are unable to utilise floodplains and intertidal areas that are cut off by the defences (DEFRA, 2012a)
Estuarine areas likely to have higher water levels through winter months, and be more susceptible to inundation of low-lying areas.

Inundation of salt water during storm surges can cause significant damage to agricultural crops and grassland. Regular inundation can result in soil salinization with implications for the viability of the land for continued production. (ASC, 2016)
Freshwater and terrestrial habitats in the coastal zone are at risk of saline intrusion. Coastal grazing marsh habitat is particularly vulnerable to the modification of vegetation communities (ASC, 2016).

Matrix 2(ii): Impact of more frequent extreme weather on Coastal Edge

Description of change

- More frequent extreme weather

Outcome of change

- Frequency & intensity of high winds, rainfall, storms.

Impact on landscape character elements

1. **Frequency & intensity of high winds, rainfall, storms.**

Landscape element impacted	Level of anticipated change
Landform	Low -ve
Settlement pattern & structures	Moderate -ve
Archaeological assets	Moderate -ve

Risk Assessment

Ports, rail network and sea walls at risk from increased wave height and storm surges (CCC, 2016b)

At risk are buildings, archaeological sites and landscapes along the coast edge, either in low-lying locations or on exposed cliffs, due to coastal erosion and increased storm events (Powell et al 2012)

Heavy rain likely to overwhelm sewers. Current capacity of sewer system cannot deal deal with increased rainfall, particularly in densely urban areas (ASC, 2016). Combination of climate change, population growth and continued urban infill development all have the potential to increase the amount of surface water entering the sewer system, which could increase sewer flooding by around 50%, and impact water quality through combined sewer overspills (ASC, 2016).

There are risks to transport networks from slope and embankment failure, particularly for older earthworks supporting transport infrastructure. Soil moisture fluctuations can lead to increased risk of shrink-swell related failures. The issue is expected to be most acute in the high plasticity soils of south-east England but may also cause problems in Wales given the long lengths of road and railway located in often steep valleys. Increased incidences of natural and engineering slope failure effecting the road and rail network in the winters of 2012/2013 and 2013/2014 demonstrate their vulnerability to the type of intense rainfall events that are expected. High winds may also cause problems for the electricity distribution network. (ASC. 2016).

Specific gaps in knowledge

Landscape response to outcomes of climate change

- Sea level rise is likely to have a significant impact on coastal edge landform, vegetation and habitat, archaeological assets, transport and settlement. The coastline shape is likely to alter with loss of salt-water marshes and inundation of low-lying land, particularly in estuarine areas. Overall there will be a loss of land and erosion is likely to increase, although the level of accretion may also increase in some places.
- Salt water intrusion will impact the coastal vegetation, damaging agricultural land and protected natural habitat with losses of up to 2,300 ha of Natura designated coastal habitat by 2100. Fresh water aquifers in coastal areas may also be affected by salt water intrusion.
- Sea level rise and storm surges will threaten coastal settlements and road/rail transport links, which may require stronger flood defence systems (e.g. higher, more extensive, and/or new embankments) for protection.
- Archaeological sites and ancient landscapes along the coast edge, either in low-lying locations or on exposed cliffs, will be at risk of damage and loss due to coastal erosion and increased storm events.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- The coastal edge is at significant risk of a wide variety of changes. The shape of the coastline may alter along with loss of some specific landscape features such as sand dunes and salt marsh in some areas.
- The coastline may become less diverse as a result of specific plant communities (e.g. salt marsh, dunes) with a reduction in the areal extent of low-lying coastal edge. Some coastal freshwater habitats may be lost, reducing diversity across the landscape.
- Flood protection structures such as embankments may become more visible, and storm damage on settlements, transport structures, and on archaeological assets more frequent and visible.

8.5.2. Water (inland)

Matrix 1: Identification of potential impacts for Water (Inland)

Landscape Character type: Water (Inland)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform							X	
Field boundaries								
Tree cover								
Vegetation		X			X		X	
Surface water		X		X			X	X
Settlement & structures		X					X	X
Archaeological assets				X				

Matrix 2(i): Impact of warmer mean temperatures on Water (Inland)

Description of change

- Warmer mean temperatures

Outcome of change

- Longer growing season

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Vegetation	Low +ve
Surface water	Low -ve
Settlement & structures	Low +ve

Risk assessment

Vegetation

Farmers may alter the timing of operations such as ploughing and maintaining permanent ground cover vegetation during the fallow period to make use of warmer, wetter winters (SNH 2011).
Cropping regimes may alter and farming practices may adapt to ensure winter ground cover so that sediment is not flushed rapidly into water courses in intense winter rainfall (Metcalf et al 2003) providing a positive benefit. Warmer, wetter winters are likely to maintain higher river flows during winter months and benefit channel bank vegetation growth.

Surface water

Inland water consists primarily of natural lakes in the more mountainous regions, water supply reservoirs, and relatively short and fast flowing rivers. Warmer mean temperatures are likely to increase demand for water, particularly in summer, yet Wales has limited resources and additional consumptive capacity is limited (water is available less than 95% of the time for new consumption in 40% of water bodies). River flows increase rapidly following rainfall but also result in low flows in dry periods due to limited groundwater flows and storage.

Changing thermal regimes of rivers are likely to have diverse ecological implications as water temperature has a strong impact on virtually every facet of the freshwater fauna and flora (Metcalf et al 2003). Elevated water temperatures may lead to more algal blooms and reduced levels of dissolved oxygen with negative impacts on aquatic biodiversity. It is estimated that 40% of Natura 2000 sites may be impacted by changes in hydrology (biodiversity, migratory fish, aquatic ecosystems)(https://cdn.naturalresources.wales/media/684348/chapter-3-state-and-trends-final-for-publication.pdf).

Settlement & structures

With increased temperatures there is potential to develop water sports tourism (Metcalf et al 2003). New tourist industry may affect infrastructure and settlement patterns but also may be limited by availability of water for additional consumption (https://cdn.naturalresources.wales/media/684348/chapter-3-state-and-trends-final-for-publication.pdf). If tourism increases additional storage (reservoirs) may be required.

Treatment plants, pumping stations, sewage pipes/works, and water intakes may not be adequate to manage changes in water availability, some structures may be prone to damage from flooding, requiring changes in structural features (https://webarchive.nationalarchives.gov.uk/20140328091448/http://www.environment-agency.gov.uk/research/library/publications/40731.aspx).
Specific gaps in knowledge Changes in the pattern and quantity of rainfall are unknown. Wetter winters are likely to follow the current pattern with higher levels of rainfall in the western part of the country and relatively lower levels in the eastern areas. Some areas may be more heavily impacted than others.
Landscape response to outcomes of climate change In the wider landscape changed cropping patterns and winter cover crops may result in reduced erosion and sediment loading to surface water bodies in lowland areas and valley floors where arable land is significant. There are unlikely to be any changes in upland areas where livestock farming is predominant. Quantity of waters in lakes and reservoirs is unlikely to alter greatly. Reservoirs may be at or over capacity for longer periods during the winter months. River flows are likely to be higher for longer periods during the winter months. Water quality may deteriorate due to warmer temperatures with impact on aquatic biodiversity. ***Susceptibility and overall appearance (Form, colour, texture, lines, diversity, seasonality)*** There will be limited impacts on appearance of water bodies. Shoreline edges of reservoirs that appear as water volume decreases will be visible for less time during winter months. River flows are likely to be maintained at a higher level. There may be some minor alterations to water management structures (treatment plants, intakes).

Matrix 2(ii): Impact of hotter, drier summers on Water (Inland)

Description of change

- hotter, drier summers

Outcome of change

- Drying out, desiccation, erosion, of wetlands and soils
- Stress on trees and plants

Impact on landscape character elements

(ii) Drying out, desiccation, erosion, of wetlands and soils

Landscape element impacted	Level of anticipated change
Surface water	High -ve

(iii) Stress on some trees and plants

Landscape element impacted	Level of anticipated change
Vegetation	Moderate -ve

Risk assessment

Vegetation

Cropping patterns/types may alter with hotter and drier summers, and growing season may be longer. As a result farmers may be able to grow a wider variety of crops, but may also need to adapt to drier summers by storing water and making wider use of irrigation. On farm water storage may increase, and pressure to build or expand reservoirs (SNH 2011).

Trees and woody vegetation along riverbanks and around lake/reservoir edges may be affected by reduced water availability during prolonged periods of low flows, resulting in loss of some species.

Surface water

Drought and low flows may reduce the distribution of small freshwater streams and lakes (CCRA 2012). River flows will decrease with longer periods of low flow affecting water quality and leaving larger areas of riverbed exposed. Some current permanent ponds may become temporary (LWEC 2015) as a result of drier summers. Riverside wetland areas will dry out possibly resulting in changes in plant communities.

Reservoir volumes are likely to be lower for longer periods, exposing larger areas of shoreline with a visible impact on landscape. Lake water levels, especially in upland areas may decline exposing larger areas of lakebed, and water temperatures increase. There are likely to be higher demands for increased storage capacity, possibly leading to dam construction and flooding of more upland valleys.

Water quality may deteriorate during hot dry summers through increased temperatures, lower levels of dissolved oxygen, and increase the frequency of algal blooms and fish kills in standing waters. Prolonged dry periods can significantly reduce river flows and have an adverse effect on water quality. An increase in the frequency and duration of droughts would change wetlands and the species that depend on them. (Environment Agency, 2016).

Specific gaps in knowledge

The pattern of rainfall during summer months and across Wales is unknown. The pattern of rainfall will become more critical in determination of local impacts on surface water bodies.

Adaptive strategies to manage reduced water and higher demands due to warmer weather are unknown. Demand management may reduce consumption levels limiting the need for new storage capacity, but irrigation demand from agriculture is likely to increase. Both arable and livestock farms may need to invest in water storage to manage reduced water availability in summer months.

Matrix 2(ii): Impact of warmer, wetter winters on Water (Inland)

Description of change

- warmer, wetter winters

Outcome of change

- More flooding events

Impact on landscape character elements

(iv) More flooding events

Landscape element impacted	Level of anticipated change
Landform	Low -ve
Vegetation	Low -ve
Surface water	Moderate -ve
Settlement & structures	Low -ve

Risk assessment ***Landform*** Landforms in lowland areas are likely to be impacted from increased regularity and severity of flooding. There will be limited impact on upland areas although high valleys may be affected by high flows moving larger amounts of rock and scree to lower/flatter areas. In lowland areas, flood damage to river banks and flood plains resulting in scouring and erosion of river valleys and floodplains and deposition downstream (high certainty); some potential in extreme cases for possible changes in river courses (LUC 2011). An increase in prolonged wet periods with more frequent flooding could increase sediment movement, shifting river channels, depositing sediment on floodplains and perhaps even increasing the risk of landslides (Environment Agency 2016). ***Vegetation*** Increased rainfall intensity may lead to expansion of woodland onto slopes and the restoration of natural riverine floodplains to mitigate impacts of flooding (SNH 2011). ***Surface water*** Agricultural land susceptible to flooding could potential provide flood water storage (LCA9). There will be short term visual impacts of floodwaters (LUC 2011), in lowland areas. Lakes and reservoirs may be affected by increased sediment load from soil wash and land slippage. There is Potential for increased leaching of nitrate based agrochemicals into vulnerable inshore waters, which combined with elevated wintertime temperatures, may increase the susceptibility of these areas to planktonic blooms. (Metcalf et al 2003). ***Settlement & structures*** Increased flood risk may cause some structural damage and lead in some cases to engineered flood defences to protect towns, villages and other assets. (SNH 2011). All historic assets which lie within a potential flood zone are at risk, but particularly in relation to fast-flowing water. Historic bridges, weirs, fish traps, quays and jetties are typical examples of high risk assets (HEG 2018).
Specific gaps in knowledge Rainfall patterns and thus frequency and location of flood events difficult to predict. Impacts of flooding likely to occur more in low lying areas where population density is greater.

Matrix 2(ii): Impact of more frequent extreme weather on Water (Inland)

Description of change

- more frequent extreme weather

Outcome of change

- Frequency & intensity of high winds, rainfall, storms.

Impact on landscape character elements

(v) Frequency & intensity of high winds, rainfall, storms.

Landscape element impacted	Level of anticipated change
Surface water	Low -ve
Settlement & structures	Low -ve

Risk assessment

Surface water

Rivers and lakes are likely to be affected by changes in patterns of rainfall and possible increases in the intensity of rainfall events. This could result in changing patterns of erosion and deposition, alterations in river courses and more frequent flood events and landslides (SNH 2011).

Water levels in rivers, lakes, and reservoirs levels may fluctuate more frequently and widely in response to storms. Rivers tend to be short with high flows and highly responsive to changes in rainfall. High water levels in lakes and reservoirs will not be noticed due to natural/controlled management of water levels, though volumes of water in rivers draining water bodies will be greater, possibly leading to increased erosion and sediment load levels. Rivers and water bodies might be affected by increased sedimentation and discolouration from soil erosion.

Settlement & structures

Historic buildings are threatened by increased levels of rainfall causing water penetration into masonry, increasing the risk of dampness, condensation and mould growth and, at worst, structural collapse. Increased extremes of wetting and drying may lead to accelerated decay of stonework and other traditional materials as well as buried artifacts. Changes in hydrology and vegetation patterns can threaten the integrity and visibility of archaeological remains and historic landscapes, including preserved wetland archaeology and designed landscapes and gardens (Historic Scotland 2011)

Specific gaps in knowledge

Pattern, frequency and location of events is unknown.

8.5.3. Water (sea)

Matrix 1: Identification of potential impacts for Water (Sea)

Landscape Character type: Water (Sea)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform	**X**						**X**	
Field boundaries								
Tree cover								
Vegetation		**X**	**X**				**X**	
Surface water	**X**	**X**	**X**					**X**
Settlement & structures								
Archaeological assets								**X**

Matrix 2(i): Impact of Warmer mean temperatures on Water (Sea)

Description of change

- Warmer mean temperatures

Outcome of change

- Rise in sea levels
- Longer growing season
- Migration of pests, invasive species, diseases

Impact on landscape character elements

(i) Rise in sea levels

Landscape element impacted	Level of anticipated change
Landform	High -ve
Surface Water	Low -ve

(ii) Longer growing season

Landscape element impacted	Level of anticipated change
Vegetation	Low +ve
Surface water	Low -ve

(iii) Migration of pests, invasive species, diseases

Landscape element impacted	Level of anticipated change
Vegetation	Moderate -ve
Surface water	Low -ve

Risk assessment

The Welsh coastline is approximately 2,740 km in length, with 56,856 ha of intertidal habitat, including sheltered and exposed rocky shores, wide mudflats, and sandy macrotidal estuaries; 75% of the intertidal habitat of Wales is designated as a Site of Special Scientific Interest (Natural Resources Wales, 2016).
Sea-level rise and increased storm frequency are likely to have a significant impact on intertidal sand, mud and habitats particularly around estuaries and along sections of defended coast (Natural Resources Wales, 2016).

Rises in sea level threaten low-lying land and accelerate coastal erosion…The low-lying estuaries of the Neath, Loughor, Taf and Towy are all subject to flood risk (Farrar and Vase 2000)

Coastal habitats have also experienced the direct effects of climate change through changing temperature profiles, as similar to terrestrial and freshwater systems. This has been most evident with rocky inter- and subtidal species, where warmer 'southern' species are shifting northwards with colder, 'northern' species declining across the UK. The topshell Gibbula umbilicalis has extended its range northwards in Wales in the last decade and Horse Mussel reefs may disappear from Welsh waters in the next 20 years as a result of warming (CCC, 2016a)

Introduction and establishment of invasive non-native species is expected to increase in future due to climate change (Natural Resources Wales, 2016). Non-native invasive species could potentially affect the whole coastline as sea temperatures increase (DEFRA, 2012a)

Although the north Wales coastline shows little movement, Cardigan Bay is sinking by about 0.4 mm/year. In addition, the south Wales coastline is sinking by approximately 0.5 mm/year around St. Brides Bay to about 0.8 mm/year around Newport. This means that around Newport, for example, relative sea levels are currently increasing by about 4mm/year (DEFRA, 2012a).

The pattern of sea level rise across the UK can be broadly characterised by a north-south gradient, with larger sea level rise to the south. Time-mean sea level projections for UK capital cities show the largest sea level rise for London and Cardiff (Cardiff: 0.27-1.13m by 2100, depending on which RCP scenario is modelled). (Met Office 2018)

Increasing coastal tourism as a result of warmer and drier summers could increase pressure on the marine environment. Potential impacts include increases in waste water (and therefore a decline in water quality), increasing demand for seafood and greater disturbance of coastal waters…Coastal water quality could decline as a result of increases in sewer overflows and disease pathogens (DEFRA, 2012a)
It is projected that tidal flooding is likely to increase with adverse consequences for coastal freshwater habitats, for example those on estuaries on the west coast. (CCRA Wales 2012)
Beaches and estuaries may be affected by algal blooms as sea temperatures rise, reducing their appeal to bathers (DEFRA, 2012a). However, this may be offset initially by recent improvements in water quality. The number of designated bathing waters has increased from 50 in 1990 to 102 in 2015. Over this period, quality has improved due to significant investment to reduce discharges from water company assets and to address diffuse pollution in and around bathing waters. In 2015, 82 bathing waters were excellent, 16 good and 4 sufficient (Natural Resources Wales, 2016).

Matrix 2(ii): Impact of Warmer, wetter winters on Water (Sea)

Description of change

- Warmer, wetter winters

Outcome of change

- More flooding events

Impact on landscape character elements

(vi) More flooding events

Landscape element impacted	Level of anticipated change
Landform	Moderate -ve
Vegetation	Low -ve
Surface water	Low -ve

Risk Assessment

Flood defence structures create barriers between floodplains and rivers, estuaries and coastal waters. This loss of connectivity has adverse impacts on biodiversity: floodplains do not benefit from inundation and sedimentation, and species are unable to utilise floodplains and intertidal areas that are cut off by the defences. (DEFRA, 2012a)

It is projected that tidal flooding is likely to increase with adverse consequences for coastal freshwater habitats, for example those on estuaries on the west coast. (CCRA Wales 2012)

Matrix 2(iii): Impact of more frequent extreme weather on Water (Sea)

Description of change

- More frequent extreme weather

Outcome of change

- Frequency & intensity of high winds, rainfall, storms

Impact on landscape character elements

(vii) Frequency & intensity of high winds, rainfall, storms

Landscape element impacted	Level of anticipated change
Landform	High -ve
Vegetation	Moderate -ve
Surface water	Low -ve

Risk Assessment

With a tidal range from 6 m to more than 10 m (see 2.3), increased heights of storm surge may significantly increase the risk of flooding. The current 50-year storm surge can cause over 1.5 m rise in tidal height, the highest surges being in the east (Pugh 1987). Tidal flow in many regions is sufficient to move sediment, causing changes in bedforms and transporting sand along the coast, so the nature of the coastline is continually changing, as is the natural protection afforded by beaches. (Farrar & Vase 2000)

Higher sea levels and increased and bigger wave action (DEFRA, 2012b); sea level rise, larger waves and storm surges (SNH, 2011)
Changes in strength and direction of tidal flows may alter coastal erosion and deposition patterns.
Higher sea levels and increased and bigger wave action (DEFRA, 2012b); sea level rise, larger waves and storm surges (SNH, 2011)
Sea-level rise and increased storm frequency are likely to have a significant impact on intertidal sand, mud and habitats particularly around estuaries and along sections of defended coast (Natural Resources Wales, 2016).

Introduction and establishment of invasive non-native species is expected to increase in future due to climate change (Natural Resources Wales, 2016).

Specific gaps in knowledge

- There is limited understanding of ecosystem health of marine waters.
- There is limited understanding of the potential impact of acidification, storms and displacement of sediment on historic wrecks and prehistoric remains.
- Historically, the marine environment around Wales has suffered significant habitat loss, with key examples being coastal habitat (particularly saltmarsh) and subtidal native oyster beds. A key issue is to understand opportunities available that will enable restoration and/or recovery of these ecosystems (Natural Resources Wales, 2016).
- There are gaps in understanding of the condition of intertidal habitats particularly outside of protected sites and in terms of how condition has changed over time (Natural Resources Wales, 2016).
- Understanding the dynamics of bacterial loading in water and shellfish bacterial flesh quality; understanding of the dynamics between nutrients and accelerated algae growth in dynamic estuaries and coastal waters; understanding of long-term impacts of combinations of chemicals on ecological status (Natural Resources Wales, 2016).

Landscape response to outcomes of climate change

- The coastal landforms are likely to change under sea level rise and as a result of increased flooding during winter months, and from stronger storms and higher more powerful storm surges.
- Intertidal habitats may be significantly affected by storm surges and changes in depth, currents, and movement of sediment.
- Warmer sea temperatures is likely to result in invasive species moving into coastal areas threatening protected native species. Warmer temperatures may also give rise to more frequent algal blooms and bacterial impacts on shellfish.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Winter months are likely to reveal broader areal extent of water from inundation of lower lying land from flooding and storm surges.
- Coastal outline may alter and tidal flats and mud/sandbanks be altered from changes in erosion and deposition of tidal currents and storm surges.
- More damage may be visible from storm surges, impacting natural and manmade structures and habitats.

8.5.4. Developed (communities)

Matrix 1: Identification of potential impacts for Built Land (Communities)

Landscape Character type: Developed (Communities)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries								
Tree cover		**X**	**X**		**X**			**X**
Vegetation		**X**	**X**		**X**		**X**	
Surface water				**X**			**X**	
Settlement & structures			**X**				**X**	**X**
Archaeological assets				**X**			**X**	**X**

Matrix 2(i): Impact of Warmer mean temperatures on Built Land (Communities)

Description of change

- Warmer mean temperatures

Outcome of change

- Longer growing season
- Migration of pests, invasive species; diseases

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Tree cover	Low +ve
Vegetation	Low +ve

(i) Migration of pests, invasive species; disease

Landscape element impacted	Level of anticipated change
Tree cover	Moderate –ve
Vegetation	Low –ve
Settlement & structures	Low -ve

Risk assessment

81% of Wales' population live in towns and cities and these cover less than 10% of the land area of Wales. In 2013, open space provided 22% and private gardens 35% of the total land area within Wales' towns and cities (Natural Resources Wales, 2016). Tree-lined streets may become more evident to increase shade. On the other hand it may be that new forms of shelter are also required to protect pedestrians (and possibly cyclists) from extreme rainfall events.   Questions arise as to whether shelter from both sun and rain can be achieved through similar types of structures, and the extent to which these could be 'natural'. Tree planting on the scale envisioned to provide adequate shade may create public places with an entirely different townscape, especially if non-native species are required (Metcalf, 2003).
Warmer mean temperatures may increase spread of pests and disease. Urban trees affected by other forms of stress (drier conditions, pollution, restricted space) may be more at risk from pests and disease. 160 out of 220 towns (73%) in Wales revealed a decline in canopy cover between 2009 and 2013 with the loss of 7,000 large amenity trees between 2006 and 2013 (Natural Resources Wales, 2016).

Matrix 2(ii): Impact of hotter, drier summers on Built Land (Communities)

Description of change

- Hotter, drier summers

Outcome of change

- Drying out, desiccation, erosion, of wetlands and soils
- Stress on trees and plants

Impact on landscape character elements

(viii) Drying out, desiccation, erosion, of wetlands and soils

Landscape element impacted	Level of anticipated change
Surface water	Low –ve

(ix) Stress on trees and plants

Landscape element impacted	Level of anticipated change
Tree cover	Moderate –ve
Vegetation	Moderate -ve

Risk Assessment

Hotter, drier summers may increase tourism potential and support economic development, but increased visitor numbers can also harm fragile historic environments. [Including lived-in communities] (HEG 2018).
Hotter drier conditions will create more stress on urban parks, open space, and trees. Urban surfaces tend to heat up quickly making our towns up to 3^{o}C degrees warmer than the surrounding countryside (heat island effect) (Natural Resources Wales, 2016).
Surface water (ponds, artificial lakes, rivers/streams will be affected by low flows, possible drying up of shallow streams and ponds, increasing water temperatures (with aquatic ecosystem impacts), and algal blooms (lakes/ponds).

Matrix 2(ii): Impact of Warmer, wetter winters on Built Land (Communities)

Description of change

- Warmer, wetter winters

Outcome of change

- More flooding events

Impact on landscape character elements

(x) More flooding events

Landscape element impacted	Level of anticipated change
Vegetation	Low -ve
Surface water	Moderate –ve
Settlement & structures	Low - ve

Risk Assessment

Potential for enhanced flooding, particularly in winter months when wetter conditions and waterlogged ground will increase run-off. Responses to flooding may take the form of engineered flood defences to protect towns, villages and other important assets (SNH 2011).

Vegetation in settlements may be affected by waterlogged ground in winter months, and damaged by flooding. Surface water quality may decline where sewers cannot cope with additional rainfall (duration and/or intensity). Heavier rainfall may wash more pollutants from hard surfaces into surface and ground waters.

Green infrastructure may be utilised to reduce surface water flow (flood mitigation) and increase shade/lower temperature in urban areas may be an outcome. "Green infrastructure approaches incorporate a variety of bio-filtration SUDS/BMP facilities including green roofs, raingardens, infiltration planters, tree/pit boxes, vegetated swales, pocket wetlands, buffer filter strips, vegetated open space as well as riparian river corridors and urban woodland." (Ellis, 2013)

Strategic planning avoids developing in areas with flooding risk (SNH 2011; Ministry of Housing, Communities and Local Government, 2012). Abandonment of frequently flooded areas is an option (impact on landscape difficult to assess) (Powell et al 2012). Defra estimates that over the next 20 years, 200 homes are likely to be made unsafe to live in due to coastal erosion and an additional 2,000 could become at risk during this period (EAC 2010).

Matrix 2(iii): Impact of more frequent extreme weather on Built Land (Communities)

Description of change

- More frequent extreme weather

Outcome of change

- Frequency & intensity of high winds, rainfall, storms

Impact on landscape character elements

(xi) Frequency & intensity of high winds, rainfall, storms

Landscape element impacted	Level of anticipated change
Tree cover	Low -ve
Settlements & structures	Low -ve

Risk Assessment

New forms of shelter may be required to protect pedestrians (and possibly cyclists) from extreme rainfall events.
Tree planting on the scale envisioned to provide adequate shade may create public places with an entirely different townscape, especially if non-native species are required (Metcalf, 2003)
Many of Wales's historic towns lie partially within low lying coastal areas and are under significant threat by rise in sea level of 0.4m by 2080 and from an increase in storm surges, predicted to be twenty times more frequent by 2100. Potential for damage to and loss of individual buildings and historic character is considerable (Murphy & Ings, 2013).
Potential for urban tree damage from increased intensity of storms and high winds.
Damage to buildings and other structures from more intense storms.

Specific gaps in knowledge

- Limited up-to-date information on the quantity and quality of green infrastructure assets.

Landscape response to outcomes of climate change

- Urban landscapes may alter as a result of climate change in both direct and indirect ways. Direct impacts such as warmer mean temperatures may increase pests and disease in vegetation and trees, causing a decline in quality or loss. Indirect impacts may result in changes to species mix of trees and plants utilised in open spaces, parts and streets.
- Heat island effects are likely to exacerbate summer temperatures of urban environments putting additional stress on trees and vegetation. In addition rapid run off and limited percolation of water into the soil is likely to lead to drier soils and additional stress on trees/vegetation.
- Settlements in areas with high clay content in soils may experience additional subsidence of buildings during summer months.
- Water bodies (Lakes, streams, ponds, rivers) will have lower flows or dry up during summer months. Water bodies will exhibit increased water temperatures. Waterlogging may occur in winter months due to wetter conditions, and water quality may decline where combined sewers cannot manage additional flows.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Less green vegetation visible during summer months although longer growing season may mean earlier greening of tree canopy in spring and extended autumn foliage.
- Less surface water visible, more susceptible to algal blooms and ecosystem impacts from quality decline.
- More potential from damage to buildings from more intense storms and floods.

8.5.5. Developed (industry and infrastructure)

Matrix 1: Identification of potential impacts for Developed (Industry)

Landscape Character type: Developed (industry and infrastructure)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								**X**
Field boundaries								
Tree cover								
Vegetation		**X**	**X**		**X**			
Surface water		**X**			**X**		**X**	**X**
Settlement & structures			**X**				**X**	**X**
Archaeological assets								**X**

Matrix 2(i): Impact of Warmer mean temperatures on Developed (Industry)

Description of change

- Warmer mean temperatures

Outcome of change

- Longer growing season
- Migration of pests, invasive species, diseases

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Vegetation	Low +ve
Surface water	Low -ve

(ii) Migration of pests, invasive species, diseases

Landscape element impacted	Level of anticipated change
Vegetation	Low -ve

Risk assessment

For some industrial processes (e.g. steel production; large scale electricity generation) as temperatures rise, there would be a need for increased cooling for machinery, particularly the heavy industry areas in south Wales. Some industrial areas are close to conservation areas, and the environmental impacts of increased cooling potentially include increased demand for water, and potentially elevated waste water temperatures from the cooling process. This could have adverse impacts on biodiversity (DEFRA, 2012a). Surface water may be affected both by increased abstraction and elevated temperatures of effluent and cooling waters.

Potential spread of developed industry sites with the increase in renewable energy production (wind, solar, hydro, and tidal) (e.g. DEFRA 2009).

Large scale derelict/abandoned industrial sites (e.g. coal and lead mines, quarries, transport links such as railways) can have specialist plant communities, which may benefit from warmer mean temperatures but are likely to be at risk from the spread of pests and disease.

Matrix 2(ii): Impact of hotter, drier summers on Developed (Industry)

Description of change

- Hotter, drier summers

Outcome of change

- Stress on trees and plants

Impact on landscape character elements

(i) Stress on trees and plants

Landscape element impacted	Level of anticipated change
Vegetation	Moderate -ve
Surface water	Low -ve

Risk assessment

Warmer summer periods will increase cooling requirements for some industrial processes (e.g. steel production; large scale electricity generation). Some industrial areas are close to conservation areas, and the environmental impacts of increased cooling potentially include increased demand for water, and potentially elevated waste water temperatures from the cooling process. This could have adverse impacts on biodiversity (DEFRA, 2012a). Surface water may be affected both by increased abstraction and elevated temperatures of effluent and cooling waters.
Hotter, drier conditions could see the spread of large-scale renewable energy production in the form of solar arrays (DEFRA, 2009) which may have impacts on landscape appearance. Location is limited by proximity to, and capacity, of the grid, which may favour older industrial land which is likely to have the relevant linkages. Large scale derelict/abandoned industrial sites (e.g. coal and lead mines, quarries, transport links such as railways) can have specialist plant communities, which are likely to be at risk from increased stress of hotter, drier summers. Industrial land is often disturbed and hydrologically impacted, which can affect both ground and surface water conditions. Compacted land can lead to creation of semi-permanent areas of standing water, which are at risk from drying up under hotter and drier conditions with consequent impacts on dependent local flora and fauna communities.

Matrix 2(iii): Impact of warmer, wetter winters on Developed (Industry)

Description of change

- Warmer, wetter winters

Outcome of change

- More flooding events

Impact on landscape character elements

(xii) More flooding events

Landscape element impacted	Level of anticipated change
Surface water	Low -ve
Settlement & structures	Low -ve

Risk Assessment

There are many brownfield sites from former industries, where flooding can lead to increased pollution from elevated run-off (DEFRA, 2012a).
A large proportion of industry is on the coast (DEFRA 2012a), so coastal flooding risks will impact these and may affect siting/planning for new industry. Water sources are often a requirement for large scale industrial activity, increased risk of localised flooding may require additional flood protection structures such as embankments, storage ponds and drainage channels.
Industrial land is often disturbed and hydrologically impacted, which can affect both ground and surface water conditions. Compacted land may lead to larger areas of standing water during winter periods of increased rainfall. This might apply to both abandoned and active industrial sites.

Matrix 2(iv): Impact of more frequent extreme weather on Developed (Industry)

Description of change

- More frequent extreme weather

Outcome of change

- Frequency & intensity of high winds, rainfall, storms

Impact on landscape character elements

(i) Frequency & intensity of high winds, rainfall, storms

Landscape element impacted	Level of anticipated change
Landform	Low -ve
Surface water	Moderate -ve
Settlement & structures	Low -ve
Archaeological assets	Low -ve

Risk Assessment

There is potential for the spread of developed industry sites with the increase in renewable energy production (wind, solar, hydro, and tidal) (e.g. DEFRA 2009). Wetter winters and more intense rainfall associated with storms might increase potential for hydro development (although this would require additional storage capacity), and wind turbines.

Many abandoned industrial sites include historical assets going back to Roman times, or even earlier. Structures are at risk of damage from increased intensity of storms, for example inclines and rail links may be at risk from embankments that are built to weaker engineering standards. Land slippage and movement may result on disturbed ground and spoil heaps. In extreme cases there may be some minor changes in landform on unstable ground caused by more intense rainfall and storms.

Industrial land is often disturbed and hydrologically impacted, which can affect both ground and surface water conditions. Compacted land may lead to rapid run-off (with potential for pollution and enhanced levels of sediment), and larger areas of standing water as a result of more intense periods of rainfall. This might apply to both abandoned and active industrial sites.

Specific gaps in knowledge

- Limited information on extent and condition of archaeological assets on former and current industrial land.
- Limited knowledge on extent and condition of specialist plant communities on industrial land.
- Limited understanding of contamination risks posed by more intense rainfall.

Landscape response to outcomes of climate change

- Limited changes to landform are likely, these will be limited to land slippage and subsidence on unstable slopes and spoil heaps as a result of increased soil moisture fluctuations, wetter winters and/or more intense rainfall during storm events.
- Standing surface water is likely to increase during winter months but be less apparent during warmer and drier summer months, i.e. greater fluctuations in the hydrological regime with consequent impacts on local flora and fauna.
- Plant diversity is likely to decrease as sensitive species disappear due to increased stress from fluctuating water regimes and/or pests and disease.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Changes to the landscape will be subtle and relatively minor. Small changes may occur to plant communities, particularly loss of specialist plant communities.
- Landscapes may appear less green and more barren in summer months due to lack of water, and loss of specialist plant communities.
- Landscapes may include larger areas of shallow standing water during wetter winter months.
- There may be some slumping and slippage of unstable slopes.

8.5.6. Developed (amenity)

Matrix 1: Identification of potential impacts for Developed (Amenity)

Landscape Character type: Developed (Amenity)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species, diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform	**X**						**X**	
Field boundaries								
Tree cover			**X**		**X**			**X**
Vegetation		**X**	**X**		**X**			**X**
Surface water				**X**				
Settlement & structures				**X**				**X**
Archaeological assets	**X**						**X**	

Matrix 2(i): Impact of Warmer mean temperatures on Developed (Amenity)

Description of change

- Warmer mean temperatures

Outcome of change

- Rise in sea levels
- Longer growing season
- Migration of pests and diseases

Impact on landscape character elements

(i) Rise in sea levels

Landscape element impacted	Level of anticipated change
Landform	Low -ve
Archaeological assets	Moderate -ve

(ii) Longer growing season

Landscape element impacted	Level of anticipated change
Vegetation	Low +ve

(iii) Migration of pests and diseases

Landscape element impacted	Level of anticipated change
Tree cover	Moderate -ve
Vegetation	Low -ve

Risk assessment

Historic sites in coastal locations could be affected by sea level rise, while many sites and historic buildings could be affected by a combination of wetter winters and increased visitor pressure in the summer. (SNH 2011)

South Wales coast is sinking by approximately 0.5 mm/year around St. Brides Bay to about 0.8 mm/year around Newport (DEFRA 2012a); Risk to coastal communities and infrastructure services from coastal flooding and erosion (CCC, 2016b); The largest cities (Cardiff, Swansea and Newport) and a large proportion of business and industry are on the coast (DEFRA, 2012a). Coastal amenity sites such as golf courses near Llanelli – Ashburnham and Machynys Peninsula are therefore under threat from sea level rise.

There are likely to be direct effects on trees and forests reflecting changing patterns of rainfall, increases in storm damage and a potential increase in pests and disease. This could be most evident in agricultural areas, woodlands, designed landscapes and settlements. (SNH 2011). Warmer mean temperatures will enhance conditions favouring spread of pests, disease and invasive species.

Greater negative impact on unmanaged parks and gardens than to managed ones, as trees and other plants lost to pests, diseases and storm damage will not be replaced, and less opportunity to identify pests and diseases early on. Speed of degradation of 'hard' garden features will also increase under more frequent storms. (Powell et al 2012)

In managed parks and gardens celebrated for their exotics, hotter, drier conditions may be an opportunity to introduce new specimens (Powell et al 2012).

Formal parks celebrated for native woodland may be susceptible to change: lowland likely to experience more drought, restricting range of mixed broadleaved woodland with conversion to semi-arid scrub (Ray, Morison and Broadmeadow, 2010); windblow and storms may reduce quantity of standing veteran trees, and increase dominance of rowan, birch and young ash stands (ibid); Rhododendron (and other invasive species) might increase under warmer weather conditions (DEFRA 2012a).

Matrix 2(ii): Impact of hotter, drier summers on Developed (Amenity)

Description of change

- Hotter drier summers

Outcome of change

- Drying out, desiccation and erosion of wetlands
- Stress on some trees and plants

Impact on landscape character elements

(i) Drying out, desiccation and erosion of wetlands

Landscape element impacted	Level of anticipated change
Surface water	Moderate -ve
Settlement & structures	Low -ve

(ii) Stress on some trees and plants

Landscape element impacted	Level of anticipated change
Tree cover	Moderate -ve
Vegetation	Moderate -ve

Risk assessment

Formal parks celebrated for native woodland may be susceptible to change: lowland likely to experience more drought, restricting range of mixed broadleaved woodland with conversion to semi-arid scrub (Ray, Morison and Broadmeadow, 2010); windblow and storms may reduce quantity of standing veteran trees, and increase dominance of rowan, birch and young ash stands (ibid); Rhododendron (and other invasives) might increase under warmer weather conditions (DEFRA 2012a).

Woodlands in designed landscapes and specimen trees could be affected by changing rainfall patterns and higher temperatures. (SNH 2011)

The historical shape and/or planting schemes that were designed for tolerance to colder climate may become unviable in the future (especially parks and gardens established in seventeenth and eighteenth centuries – a time period when Europe was at the height of the so called Little Ice Age) (Metcalf et al 2003)

Within historic gardens the maintenance of specimen plants and fine grass swards may not be viable within new climatic conditions. Milder, wetter winters causing early leaf/bud emergence; this combined with late frosts and drier summers have negative impact on gardens. Gardens are also susceptible to storm damage. (SNH LCA 9, 2002)

Records at Kew Gardens I London have shown that some species (e.g. crocus, bluebells, laburnum and certain cherries) have been blooming earlier - roughly 1 to 2 weeks earlier since 1952, but no
records are kept of autumn leaf fall/turning. Species such as Marbled White and Gatekeeper butterflies and certain types of rare dragonflies appear to be moving their range northwards, and more of these species are being noted at Kew. It is not clear if any species have yet been lost due to changing climate, but in the future drier summers may cause some plants to disappear. Species such as the meadow saxifrage (spring flowering in damp meadow habitat) and the wild camomile may be most at risk. However, even in the hot dry summers such as that of 1995 species reappeared after prolonged drought. A warming climate would widen the range of species present, but lower summer rainfall with more evaporation would reduce the numbers (London Climate Change Partnership, 2002).

Water resources in heritage gardens may also become an issue, either through increased demands on irrigation to maintain historic planting, or through low-flows (or flood flows) diminishing or damaging water supply associated with formal water-gardens and pond systems…Additional threats associated with water features relate to ponds and lakes whose catchments are susceptible to overland flow and sediments erosion. Shifting agricultural practice and climate change may combine to accelerate sediment in run-off leading to infilling of such features. (Metcalf et al 2003).

Matrix 2(iii): Impact of Warmer, wetter winters on Developed (Amenity)
Description of change • Warmer, wetter winters
Outcome of change • More flooding events
Impact on landscape character elements **(i) More flooding events**

Landscape element impacted	Level of anticipated change
Landform	Low -ve
Archaeological assets	Low -ve

Risk Assessment

Assets in floodplain and riverside locations will be at risk from flooding and erosion, and also the need to construct new flood defences for settlement and infrastructure. (SNH 2011)

69% of links golf clubs say their course is facing serious threat from erosion and/or flooding in the next 50 years (Metcalf et al 2003).

Increased waterlogging of soils during winter months.

Matrix 2(iv): Impact of more frequent extreme weather on Developed (Amenity)

Description of change

- More frequent extreme weather

Outcome of change

- Frequency & intensity of high winds, rainfall, storms

Impact on landscape character elements

(ii) Frequency & intensity of high winds, rainfall, storms

Landscape element impacted	Level of anticipated change
Tree cover	Low -ve
Vegetation	Low -ve
Settlement and structures	Low -ve

Risk Assessment

There are likely to be direct effects on trees and forests reflecting changing patterns of rainfall, increases in storm damage and a potential increase in pests and disease. This could be most evident in agricultural areas, woodlands, designed landscapes and settlements. (SNH 2011)

Within historic gardens the maintenance of specimen plants and fine grass swards may not be viable within new climatic conditions. Milder, wetter winters causing early leaf/bud emergence; this combined with late frosts and drier summers have negative impact on gardens. Gardens are also susceptible to storm damage. (SNH LCA 9, 2002)

Greater negative to unmanaged parks and gardens than to managed ones, as trees and other plants lost to pests, diseases and storm damage will not be replaced. Speed of degradation of 'hard' garden features will also increase under more frequent storms. (Powell et al 2012)

Limestone building susceptible to damage by cycles of intense wetting and drying, heavy downpours or increased humidity, and damage to foundations from potential shrinking of clay soils (Powell et al 2012).

Formal parks celebrated for native woodland may be susceptible to change: lowland likely to experience more drought, restricting range of mixed broadleaved woodland with conversion to semi-arid scrub (Ray, Morison and Broadmeadow, 2010); windblow and storms may reduce quantity of standing veteran trees, and increase dominance of rowan, birch and young ash stands (ibid); Rhododendron might increase under warmer weather conditions (DEFRA 2012a).

Specific gaps in knowledge

- There is limited understanding of how vulnerable and resilient coastal margins are to climate change factors, such as increased storminess, changing rainfall and temperature. Limited knowledge of how coastal margin habitats recover after storm events.
- Limited understanding of the impact of coastal defences on adjacent coastal margin habitats and the value of coastal margin habitat in providing /contributing to soft sea defences.
- There is limited understanding of the condition and long-term trends in range and extent of coastal margin habitats, particularly outside of protected sites (Natural Resources Wales, 2016)

Landscape response to outcomes of climate change

- Amenity land is quite varied both in location and ecological character. Climate change impacts are likely to vary depending on the particular micro-conditions, the habitat characteristics, underlying soils and geology, and level of management. More damage would be expected at unmanaged sites compared to one where regular maintenance is likely to pick up on issues such as disease, damage, and vegetation stress early on and alter management practices to mitigate impact.
- Warmer mean temperatures will lengthen the growing season favouring tree and vegetation growth, but these benefits may be outweighed by impacts from invasive species, pests, and disease. Some species may disappear.
- Hotter drier summers will put increased stress on trees and vegetation. Additional water may not be available to provide irrigation. Golf courses in particular may find it increasingly difficult to support high quality grassland. Warmer wetter winters will create problems of waterlogging of soil and increase the intensity of wetting/drying cycles.
- More frequent extreme weather may bring a range of problems depending on site characteristics including: high winds, storm damage, and localised flooding.
- Sea level rise may also impact some amenity sites in low-lying coastal areas, which will face increased risk of inundation from storm surges.
- Some historic structures may be affected by shrinking of clay soils in hot dry summers.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Changes will vary depending on site characteristics but are likely to include loss of tree cover, tree damage, and potential loss of plant communities due to drier conditions. Diversity of the landscape in terms of colour and texture is likely to decrease.

- Amenity sites will become green earlier in spring and trees are likely to hang on to leaves longer the autumn.

- Some sites may lose green colouring in summer and turn brown, depending on rainfall patterns and existence of irrigation water.

- Amenity sites in the coastal zone may disappear as a result of sea level rise.

8.5.7. Lowland (wooded and wetland)

Matrix 1: Identification of potential impacts for Lowland Wooded and Wetland

Landscape Character type: Lowland Wooded and Wetland								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms.
Landform							X	
Field boundaries			X	X	X			
Tree cover		X	X	X	X		X	
Vegetation		X	X	X	X		X	
Surface water				X				
Settlement & structures								
Archaeological assets				X			X	

Matrix 2(i): Impact of warmer mean temperatures on Lowland Wooded and Wetland

Description of change

- warmer mean temperatures

Outcome of change

- Longer growing season
- Migration of pests and diseases

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Tree cover	Low +ve
Vegetation	Low +ve

(ii) Migration of pests and diseases

Landscape element impacted	Level of anticipated change
Field boundaries	Low -ve
Tree cover	Moderate -ve
Vegetation	Low -ve

Risk assessment

Wetland

The SoNaRR report (Natural Resources Wales, 2016) notes the following:

- 24,000 km of rivers and streams in Wales
- 15% of the land area of Wales drains into 558 lakes (defined as ≥1 ha), including over 150 large scale reservoirs which cover 8,143 ha.
- Raised bog and fen are the main lowland peatland types in Wales; 81% and 59% respectively of the SSSI resource of these habitats are in unfavourable condition.
- Most floodplain areas are heavily modified, with semi-natural habitats accounting for only 16% of the total area.
- Climate change is predicted to affect the amount and distribution of rainfall with subsequent impacts on flows and water levels, drought and flood events and an increase in water temperatures.
- Climate changes may lead to a decline in water quality, impact some species negatively, increase the risk from invasive species and lead to changes in the way ecosystems function; for example, there may be an increased likelihood of algal blooms.

The CCRA 2017 Report states that:

- an increase incidence of warmer, drier summers is likely to increase the risk of low flows and reduced water levels. Combined with higher water temperatures, this increases the risk of ecosystem disruption from reduced oxygen supply, thermal stress to species, reduced dilution of harmful pollutants and increased incidence of algal blooms in water bodies.
- Drought will exacerbate the problems, and increased likelihood of more frequent periods of heavy rainfall could cause further water quality problems due to increased runoff/discharge of pollutants, effluents and sediments into water bodies, including elevated levels of dissolved organic carbon.
- Ecosystems, particularly wetlands and woodlands, regulate and filter the flow of water through vegetation and soils (interception, evapotranspiration, infiltration, drainage, conductivity). Climate related changes to ecosystems will therefore modify their role in buffering against extreme high flows (flood risk) and low flows, in addition to their role in water circulation and purification.

Woodland

Warmer mean temperatures can aid tree growth but pests and diseases present a significant threat.

Chalara (ash die-back) is a major threat to hedgerows. Welsh hedgerows contain a considerable quantity of ash, both in the shrub layer and as standard trees. As ash declines over the coming years, gaps will form in hedgerows and a significant proportion of the mature trees in our landscape will be lost. This is likely to have a major impact on other species dependent on both hedgerows and free-standing trees.

Larch and Sitka Spruce plantations may be affected by spread of disease and pathogens.

Pests and diseases represent a major threat to woodland. These threats may be increased by interactions with the direct effects of climate change on tree function.

Different phenological responses (e.g. between canopy and ground flora and between different elements of food webs) could alter woodland composition; so could increases in herbivore numbers as a result of warmer winters. As an indirect climatic effect, changes in woodland structure could have an important impact on communities of epiphytes that grow on the trees including many mosses. (Morecroft and Speakman, 2015)
Projected climate change may provide new cropping opportunities, but more agricultural land is likely to suffer from water deficits in summer and waterlogging in winter (Natural Resources Wales, 2016).

Matrix 2(ii): Impact of hotter drier summers on Lowland Wooded and Wetland

Description of change

- hotter drier summers

Outcome of change

- Drying out, desiccation, erosion, of wetlands and soils
- Stress on some trees and plants

Impact on landscape character elements

(iii) Drying out, desiccation, erosion, of wetlands and soils

Landscape element impacted	Level of anticipated change
Tree cover	Moderate -ve
Vegetation	Low -ve
Field boundaries	Low -ve

(iv) Stress on some trees and plants

Landscape element impacted	Level of anticipated change
Tree cover	Moderate -ve
Vegetation	Low -ve
Field boundaries	Low -ve

Risk Assessment

Wetland

Climate change is predicted to affect the amount and distribution of rainfall with subsequent impacts on flows and water levels, drought and flood events and an increase in water temperatures. These changes may lead to a decline in water quality, impact some species negatively, increase the risk from invasive species and lead to changes in the way ecosystems function; for example, there may be an increased likelihood of algal blooms. The CCRA17 Evidence Report has identified the risks to freshwater species from higher water temperatures and also the risk from land management practices that exacerbate flood risk. (SoNaRR)

Maintenance of adequate water supply throughout the year is key for wetland productivity. Reduced summer rainfall will adversely affect many lowland wetland habitats (e.g. in north east Wales) and blanket bogs. Drier eastern and southern areas of the UK would tend to be more vulnerable than those to the west and north. Where bogs or wetlands have been degraded as a result of drainage, overgrazing, burning and eutrophication (i.e. over-enrichment with nutrients) they are more vulnerable to drying and erosion. (Morecroft and Speakman, 2015)

Warmer temperatures will increase the symptoms of eutrophication (excess nutrients leading to algal growth) in both plankton and lake-shore plant communities. Indirect climate changes that lead to greater nitrogen deposition and that influence the severity of eutrophication will be more important than direct temperature effects on freshwater systems unless the temperature changes are large; in that case there will be major changes in fish communities, reflecting their heat tolerance. Increased flooding and increased drought may have positive effects in maintaining pond biodiversity, but permanent ponds may become temporary. (Morecroft and Speakman, 2015)

Bioclimatic models suggest that 50% of the peatland area in Great Britain would be vulnerable to change, assuming an average 4.4°C rise in temperature, with drier vegetation types and tree species moving into the space of blanket bog habitats (DEFRA 2012b) Loss of organic content in these soils and their transformation into mineral soils will alter the types of vegetation they can support and with it the character of the historic landscape (Powell et al., 2012).

Inland semi-natural lowland ecosystems are generally likely to be less vulnerable to climate change than coastal ecosystems. However, wetlands such as the internationally important raised bogs at Cors Erdrreiniog on Anglesey and Cors Tregaron in mid-Wales are exceptions. Their ecological characteristics and contribution to biodiversity depend primarily on retaining year-round water saturation. This may be compromised by hotter, drier summers, and especially by droughts, which are predicted to become more frequent. Predicted wetter winters are unlikely to offset the damaging effects of drought. It should also be noted that very little is known about the effects of increasing temperature on nutrient dynamics in soils and waters. If these effects are large there could be substantial ecological changes due to nutrient enrichment of a wide range of habitats. (Farrar and Vaze, 2000)

Changes in temperatures and river flows are likely to have large ecological impacts on freshwater and wetland communities. Some impacts will be obvious, such as the arrival of new species. An increase in the frequency and duration of droughts would change wetlands and the species that depend on them (Environment Agency 2016).

Woodland

The CCRA 2017 analysis concluded that lowland beech and yew woodland habitats are at risk of a considerable contraction in area due to the effect of increasing soil moisture deficit and drying. Whilst Wales has a relatively low number of beech trees, these findings suggest that other priority habitats would be affected by more arid soils.

(DEFRA 2012a)
Many woodlands in lowlands of south and eastern Wales are likely to experience more frequent summer drought, based on projections for moisture deficit (MD) for the period 2050-2080 (between 180mm and 220mm MD) (Ray, 2008); lowland beech woodland and wet woodland would be adversely affected by more frequent or more extreme summer drought in the drier parts of the UK (Morecroft and Speakman, 2015); restricted range of mixed broadleaved woodland with conversion to semi-arid scrub (Ray, Morison and Broadmeadow, 2010); beech and yew woodlands restricted to deeper soils and north facing slopes (ibid)
Tree death following drought has been recorded at long-term monitoring sites; beech, birch and sycamore are more sensitive to drought than other species. This can lead to major changes in the composition and structure of woodland. There is also evidence of reduced growth rates in a range of tree species during dry summers.
Lowland beech woodland and wet woodland would be adversely affected by more frequent or more extreme summer drought in the drier parts of the UK.
Hedgerow species and field boundary trees are likely to be stressed by hotter, drier summers. Lowland valleys may be less impact than uplands as water availability may be higher for longer periods in summer, although run-off in many river basins tends to be rapid with limited storage capacity.

Matrix 2(ii): Impact of Warmer, wetter, winters on Lowland Wooded and Wetland

Description of change

- Warmer, wetter, winters

Outcome of change

- More flooding events

Impact on landscape character elements

(i) More flooding events

Landscape element impacted	Level of anticipated change
Vegetation	Low -ve
Surface water	Low -ve
Structures	Low -ve

Risk Assessment

The CCRA 2017 report notes the following impact on river flows (against a 1961-90 baseline):

- Increases in average winter flows (up to 40%) by the 2050s
- Reduced summer flows up to 80% by the 2050s, especially in the north and west of the
UK.
- Reduced spring flows – reduced flows up to $0% but less confidence in the results

- No clear pattern in autumn flows and Low confidence in results.
- Increases in the magnitude of flood events with a 10 – 25% increase in number of flood events with regard to 1 in20- yr flood event in England and Wales by the 2050s.

The report also emphasises caution in using the projections: “The interaction of these average trends in flow patterns with the high levels of short-term variability occurring in many UK rivers mean that predicting ecological impacts is subject to high uncertainty…future flow projections are based upon direct climate change only and do not include indirect effects through land-use change or increased demands for water abstraction.”

Wetlands

Since the 1960s there is some suggestion that winter flows (September to March) show increasing high flows and autumn flows have increased across the whole UK (especially central and south-west England and Wales, and eastern Scotland) with no clear pattern emerging in summer months. Land use clearly influences river discharge patterns. A major issue is sensitivity of freshwater species to extreme high and low flows, which can damage food webs. Low flows create higher risk, as the quantity of water together with its temperature determines the level of dissolved oxygen available for microorganisms who derive food from organic compounds at the base of the food web. Extreme high flows and associated sediment loads can damage fish spawning beds. (UK Climate Change Risk Assessment, 2017)

Natural floodplains are likely to be restored and areas of new woodlands established to intercept rainfall and slow the speed of run-off; River catchments are likely to see measures to slow the speed of run-off. This could include woodland expansion and the restoration of natural floodplains and upland peatbogs in areas upstream of settlements and other areas vulnerable to flooding (Scottish Natural Heritage 2011).

Possible expansion of wetland systems as adaption technique. If well-established techniques (such as wetland creation, winter storage of water, increased permeability of surfaces, storage areas, forestry and riparian trees), were utilised in a more wide ranging way for all catchments (including urban catchments) we would adapt to climate change through lower run-off in extreme rainfall periods and more effective storage of water for dry periods. (Env Audit Committee, 2010)

Degraded and compacted soils can exacerbate flood risk by increasing the speed of rainwater
run-off and silting up rivers. Some land management practices can cause soil compaction, due to the use of machinery or presence of livestock on waterlogged soils, resulting in damage to soil structure, and the potential for increased erosion due to reduced water infiltration and increased runoff from overland flow.

Agricultural land covers 88% of Wales’s land area, which means that the way in which it is managed can have a profound effect on the wider impacts of flooding. Flood walls and embankments routinely protect what would be the natural floodplain from inundation, forcing water downstream into built-up areas where much more significant damage can be caused.

Warmer, wetter winters and drier summers in the future could affect increase rates of soil weathering and increase soil erosion. This could in turn increase peak flows and hence fluvial and groundwater flood risk. This risk will be exacerbated where soils are degraded and compacted due to land management practices. https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Wales-National-Summary.pdf

Woodland
Wetter winters increases potential for waterlogging of soils with an impact on tree rooting. Woodland on wetter sites is likely to decline as lowland valleys are likely to stay wetter longer as a result of increased flows and higher water tables.

Specific gaps in knowledge

- Measuring woodland condition is expensive, and data on extent and condition – including of our coniferous forests – is limited. The National Forest Inventory (NFI) will provide a sample based indication of condition at a Wales scale when it publishes its official report on woodland condition in 2017.
- There is currently very limited information about the distribution of pest and disease outbreaks throughout Wales and Britain. There is information about the known spread of quarantine pests and diseases but the vast majority of pests and diseases are not mapped. (SoNaRR)
- Ecological impacts resulting from sediment and hydromorphological changes.
- Impacts of new and emerging chemicals and substances, such as neonicotinoid pesticides, nanoparticles and pharmaceuticals, on water quality and ecology.
- Assessment of the condition of the wetland resource. Understanding the impacts of climate change on water quality and the vulnerability of ecosystems, water dependent habitats and species. (SoNaRR)
- Impacts of poor water quality on taxa other than fish, invertebrates and lake plankton are poorly known due to a lack of large-scale studies. Climate-related impacts on ecological processes and the consequences for water-related ecosystem services remain poorly understood.

Landscape response to outcomes of climate change

- The landscape is diverse with river channels, wetlands, woodland (native species, and conifer plantation), small areas of arable land, permanent pasture, valley floor and sides.
- Some reduction or loss of tree species (Sitka Spruce, beech, larch, ash) may occur as a result of pests and disease, drought, and or winter waterlogging of the root zone. Only relatively small reductions in woodland area are anticipated.
- Vegetation composition of woodland may alter, though this may only be apparent at certain times of year (e.g. reduction in springtime flowering plants.
- Trees are likely to bud earlier in the spring and remain in leaf longer in the autumn. Surface water may be less apparent in summer months, with lower flows in river channels and temporary ponds disappearing, while water will be more in evidence in winter with more waterlogged soils and potential for more frequent flood events.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Little change from the current situation, Woodland might decline in area with the loss of some species, which may alter texture and colour of the landscape slightly.
- Most changes will be subtle and relate to changes in species composition and water quality.
- Greening may occur earlier in spring.
- Increased flooding may alter river channels and leave sediment deposits more frequently.

8.5.8. Lowland (hedgerow)

Matrix 1: Identification of potential impacts for Lowland Valleys (Hedgerow)

Landscape Character type: Lowland Valleys (Hedgerow)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms.
Landform								
Field boundaries		**X**	**X**				**X**	
Tree cover								
Vegetation		**X**			**X**			
Surface water								
Settlement & structures							**X**	
Archaeological assets		**X**		**X**				

Matrix 2(i): Impact of warmer mean temperatures on Lowland Valleys (Hedgerow)

Description of change

- warmer mean temperatures

Outcome of change

- Longer growing season
- Migration of pests and diseases

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Field boundaries	Low +ve
Vegetation	Moderate +ve

(ii) Migration of pests and diseases

Landscape element impacted	Level of anticipated change
Field boundaries	Low -ve

Risk assessment

Enclosed farmland covers around 1 million ha or c.54% of agricultural land and plays a major role in food production with resulting impacts on soil, water, biodiversity and GHG emissions. The area of arable and horticultural crops (87,000 ha) has increased by 35% over the last ten years but still only represents some 8.7% of enclosed farmland (Natural Resources Wales, 2016).
The influence of individual climate variables is evident in the results of experimental and modelling studies. Outputs based mainly on modelled outcomes used in Defra Project CC0359 (described by Topp and Doyle, 2004) were used to examine the impacts of higher temperatures and elevated carbon dioxide levels in four sites across the UK. The grass and red clover yield on the study site in lowland west Wales increase linearly with an increase in mean annual temperature. (DEFRA 2012b) The table below summarises some of the model outcomes suggesting a potential increase in yields for grassland as a result of climate change.

Epoch	Intensive management	Grassland herbage	Comments
Baseline yield (tonnes/ha)	15.0	10.5	
2020s	+6% to +14%	+12% to +20%	
2050s	+10% to +32%	+15% to +35%	32% maximum ceiling yield for intensive management (20t/ha)
2080s	+14% to +32%	+20% to +35%	35% maximum ceiling yield for herbage (14t/ha)

(DEFRA 2012a)
Cropping patterns may change as warmer mean temperatures and rainfall patterns favour new types of crop. This may impact on a largely lowland pastoral farming landscape of hedgerows and small fields to one with a higher arable element, fewer standard trees and hedgerows, and larger fields (Powell et al., 2012). Whether a more open filed system is good or bad is open to debate, but the outcome may be a change in landscape across lowland valleys.
Field boundaries, in particular hedgerows, are under threat. The total length of hedgerows in Wales has been estimated at 106,000 km but 78% of this is in unfavourable condition. Some 5,800 km has been restored or is planned for restoration under agri-environment schemes (Natural Resources Wales, 2016).
Chalara (ash die-back) is a major threat to hedgerows. Welsh hedgerows contain a considerable quantity of ash, both in the shrub layer and as standard trees. As ash declines over the coming years, gaps will form in hedgerows and a significant proportion of the mature trees in our landscape will be lost. This is likely to have a major impact on other species dependent on both hedgerows and free-standing trees. The CCRA17 Evidence Report has identified risks and opportunities from changes in agricultural productivity and land suitability. There are also risks associated with water scarcity and flooding; from pests, pathogens and invasive species; and from change in frequency and/or magnitude of extreme weather and wildfire events. Projected climate change may provide new cropping opportunities, but more agricultural land is likely to suffer from water deficits in summer and waterlogging in winter (Natural Resources Wales, 2016).
Projected changes in the climate are likely to impact on Enclosed Farmland as follows:

- More areas experiencing water deficits during the summer months
- Wetter winters will increase the prevalence of waterlogged soils

- Increased risks from pests, pathogens and invasive species
- New opportunities to grow alternative forage crops and diversify existing grassland swards. (Natural Resources Wales, 2016).

Matrix 2(ii): Impact of hotter drier summers on Lowland Valleys (Hedgerow)

Description of change

- hotter drier summers

Outcome of change

- Stress on some trees and plants

Impact on landscape character elements

(v) Stress on some trees and plants

Landscape element impacted	Level of anticipated change
Vegetation	Low -ve
Field boundaries	Low -ve

Risk Assessment

Climatic sensitivity analysis suggests that grassland production in England and Wales is resilient to small perturbations in mean temperature (up to + 2 °C) and precipitation (±10%). The effect of increasing temperature by 1 °C is almost completely offset by

precipitation increases of 10% resulting in little change to the distribution of grassland suitability. However, greater temperature changes (+ 4 °C) have a major influence on the ability of land to support intensively managed grassland because of increased drought stress. Results indicate that a change in the climate comparable with current best estimates for the future would benefit grassland on good quality land at higher altitudes (Farrar and Vaze, 2000). If conditions are too hot and dry there can be negative implications for grass productivity (CCC, 2016a).
The area of arable farming may increase, making use of different types of crop more suited to drier conditions.
Hedgerow species and field boundary trees are likely to be stressed by hotter, drier summers. Lowland valleys may be less impact than uplands as water availability may be higher for longer periods in summer, although run-off in many river basins tends to be rapid with limited storage capacity.
The SoNaRR Report (Natural Resources Wales, 2016) suggests risks to soils from increased seasonal aridity and wetness noting that, 'climate change related risks are threatening the many services that soils provide, notably those that relate to soil biota, soil organic matter, and soil erosion and compaction'.

Matrix 2(ii): Impact of Warmer, wetter, winters on Lowland Valleys (Hedgerow)

Description of change

- Warmer, wetter, winters

Outcome of change

- More flooding events

Impact on landscape character elements

(vi) More flooding events

Landscape element impacted	Level of anticipated change
Vegetation	Low -ve
Surface water	Low -ve
Structures	Low -ve

Risk Assessment

Adapting to climate change in rolling lowlands could include Planting shelter belts and improving hedgerows to protect animals and crops from extreme weather (Clwydian Range and Dee Valley)

The introduction of more frequent storms associated with intense periods of high rainfall is likely to cause more intense localised erosion. Lowland river valleys may experience localised flooding during periods of intense rainfall with impacts on instream structures (e.g. weirs, water intakes).

Specific gaps in knowledge

- Limited information on the current condition of Enclosed Farmland habitats in Wales and also on the distribution of Chalara infected ash trees.
- The extent to which factors associated with climate change, notably increasing temperature, affect the current distribution of species, as compared with the effects of other environmental factors (e.g. habitat loss, acidification, eutrophication) is poorly understood. Habitat fragmentation and isolation are likely to be important, but little is known about their effects on most species. Cultivated arable land or urbanised land will form barriers to the migration of species, but we have little knowledge of which species will be affected most seriously. (Farrar and Vaze, 2000)

Landscape response to outcomes of climate change

- Vegetation changes in field boundaries (hedgerows) are likely to be more significant than changes in grassland. Drier conditions and pathogens/disease are likely to impact on the species mix in hedgerow and result in more gaps and potentially loss of some hedgerows and hedgerow trees (e.g. Ash). More post and wire fencing may be in evidence as hedgerows decline.
- Arable farming may increase in area with new types of crops adapted to drier conditions.
- Permanent pasture will be relatively unaffected by climate change, although field margin and hedgerow biodiversity may decline.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Little change in field form and appearance.
- New types of crops may alter texture and appearance (e.g. vineyards)
- Hedgerows and field boundary tress likely to decline

8.5.9. Lowland (open)

Matrix 1: Identification of potential impacts for Lowland Valley (open)

Landscape Character type: Lowland (open)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea level	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								
Field boundaries		**X**	**X**					
Tree cover		**X**	**X**		**X**	**X**		
Vegetation		**X**	**X**		**X**	**X**		
Surface water								
Settlement & structures								
Archaeological assets		**X**		**X**				

Matrix 2(i): Impact of warmer mean temperature on Lowland Valley (open)

Description of change

- Warmer mean temperature

Outcome of change

- Longer growing season
- Migration of pests, invasive species; diseases

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Field boundaries	Low +ve
Tree cover	Low +ve
Vegetation	Low +ve

(ii) Migration of pests, invasive species; diseases

Landscape element impacted	Level of anticipated change
Field boundaries	Moderate –ve
Tree cover	Moderate –ve
Vegetation	Low -ve

Risk assessment

Unimproved grassland (including lowland meadow, lowland dry acid grassland and lowland calcareous grassland [HAPs published 1998, area in Wales >1000 ha). Difficult to predict effects because much depends upon climate change impacts on nutrient turnover. Available evidence needs to be reviewed. Drying and warming may favour more xeric communities, which could be regarded as beneficial since they are presently more restricted in extent than their more mesic counterparts. (Farrar and Vaze, 2000)

Tree growth and forest productivity will be affected by climate change. In the near and medium term (2030s) it is likely that the cooler upland and wetter areas will have improved growth of many tree species, and the drier, warmer lowland areas will have only small reductions due to increasing drought. In the longer term (2050s and 2080s), trees in present cooler and wetter upland areas are likely to still show increased growth compared with current conditions. However, growth is likely to be reduced in many other locations due to increasingly severe soil water reductions, particularly on lighter soils and in the south and east of Britain. The long lead time for forestry implies that there is high urgency for action to reduce risks. (Brown et al., 2016)

The suitability of existing tree species for the future climate will change, and in many cases decline, especially in the longer term. This is particularly the case for the main species currently used in softwood production in the UK, Sitka spruce, which is a species best suited to cool and moist conditions. Species suitability will also be affected by changing pest and disease risks. Pest and pathogen damage is likely to increase because of more suitable conditions for their spread, including more environmental stresses that will make trees more susceptible, and because of new introductions. Threats are exacerbated by the limited diversity of tree species planted during the expansion of UK forests in the past 60 to 80 years. (Brown et al., 2016)

The CCRA Evidence Report (Brown et al., 2016) indicates the following:

- Particular insect pests as likely to increase with warmer conditions,
- The green spruce aphid could increase with warmer conditions as their populations presently appear limited by cold winter temperatures
- The pine processionary moth has been spreading northwards across Europe
- as temperatures increase
- oak processionary moth (OPM) may do the same if present control measures are not successful. The spread of OPM is also likely to be influenced by the synchrony of oak leaf appearance and egg hatch.
- A recent outbreak of the wood-boring Asian longhorn beetle; a warmer climate will reduce life-cycle duration to 2 years, which implies a faster rate of spread
- Insect pests and pathogens are often associated with each other; for example, beetles and pathogens are both involved in oak declines. Predisposing factors for oak declines will also be affected by drought or late frosts, or insect attacks such as defoliations. Pests and pathogens are also more able to adapt to changing climatic conditions.

Matrix 2(ii): Impact of hotter drier summers on Lowland Valley (open)

Description of change

- Hotter drier summers

Outcome of change

- Stress on trees and plants
- Wild fires

Impact on landscape character elements

(vii) Stress on trees and plants

Landscape element impacted	Level of anticipated change
Tree cover	Moderate –ve
Vegetation	Low –ve

(viii) Wildfires

Landscape element impacted	Level of anticipated change
Tree cover	Moderate –ve
Vegetation	Low –ve

Risk Assessment

Lowland heath is a priority habitat that is threatened by fire and of particular significance for British reptile species including rare lizards and snakes.
The CCRA analysis includes an assessment of the increase in wildfire risk from 1980 to the 2080s using a Fire Danger Index. The projected increases for National Parks are as follows: Pembrokeshire Coast 30 – 40%; Brecon Beacons 30 – 40%; Snowdonia 40 – 50% (DEFRA, 2012a); burning has only minor effect on floristic composition, with the main effect being relative conspicuousness of species. Post-fire 'succession' is largely a matter of regrowth of surviving perennial individuals and re-establishment of shorter lived species from propagules. Fugitive or pioneer species may be conspicuous for a year or two after the fire, but soon decline into insignificance (Maltby, Legg and Proctor, 1990)
Purple moor-grass and rush pastures (HAP published 1995, area in Wales >5000 ha), which are particularly characteristic of parts of lowland Wales, will be adversely affected by a decrease in summer rainfall. Drying could rapidly lead to expansion of Purple moor-grass swamping out small associated species. There could also be loss of characteristic species requiring high summer water tables (Farrar and Vaze, 2000)
The CCRA Evidence Report (Brown et al., 2016) indicates the following:

- Remote sensing on regional and global scales shows extension in forest canopy cover duration in deciduous vegetation in the temperate and boreal regions, both from earlier spring leafing and later autumn senescence; confirmed by other direct phenological observations that show earlier leafing and flowering in the UK.
- Warmer temperatures will bring faster growth rates.
- Synchrony between trees and wider ecosystem including ground flora and herbivores is important for pollination and plant phenology but this may not be so significant in UK as many broadleaved species of importance to UK forestry (e.g. oak, beech, ash) are wind-pollinated, while others such as cherry are insect-pollinated.
- Increased growth in warmer or longer growing seasons is dependent on sufficient moisture supplies.
  Drought can reduce growth and timber quality, through cracking of stems, and cause tree mortality. Across Europe, major droughts have caused tree mortality in recent years and there is increased evidence for drought-induced growth decreases, particularly in beech trees.
- Invasive species such as rhododendron and Gaultheria can affect ground and understorey flora, competing for water and nutrient resources and inhibiting natural tree regeneration.

The fluctuating water table creates problems for the rooting of trees. Increased winter rainfall will lead to more frequent winter waterlogging of soils in some areas and can result in fine root death extending into surface soil horizons (as well as decreased stability). Fine root death limits the ability of trees to take up water and exacerbates the problems of summer droughts. Infection by various soil-borne pathogens,
including species of Phytophthora, is also promoted by fluctuating water tables, which
would be expected to become more prevalent. Predicting changes as a result of insect pest and disease outbreaks is difficult because of the fine balance between pest/pathogen, host tree and natural enemies. But in general stressed trees are
more susceptible to insect pests and diseases, and the majority of insect pests that currently affect UK forestry are likely to benefit from climate change as a result of increased activity and reduced winter mortality. The impact of pathogens may worsen, while some insect pests may become more prevalent (e.g. defoliating moths and bark beetles).

Specific gaps in knowledge

- Limited information on the spread of pests and diseases, and the synergistic effects of larger seasonal fluctuation in water availability (summer drought, winter waterlogging).
- Lack of information on potential changes in terms of agricultural management: crop selection, cover crops, soil management practices, etc. Little is known about the impacts of climate change on species characteristics of permanent semi-natural pastures.
- Limited information on the current condition of Enclosed Farmland habitats in Wales.
- Data on the extent and condition of woodland(including coniferous forests) is limited and there is currently very limited information about the distribution of pest and disease outbreaks throughout Wales and Britain. (Brown et al., 2016)
- Limited information on the distribution of Chalara infected ash trees within Wales.

Landscape response to outcomes of climate change
• Tree cover will be the most severely affected element in the landscape. Impacts will occur from higher stress due to drought in summer, in poorly drained areas there may also be impacts from waterlogged soils in winter, and from pests and diseases as a result of higher mean temperatures. • Some tree species may decline from spread of pests and disease (e.g. Oak, Ash, Sitka Spruce). • Hedgerows may be affected through drought induced stress, and pests and disease, resulting in species loss, and an increase in post and wire fencing; field sizes may increase with loss of hedgerows. • Arable farms may react to change through adoption of new forms of crops (e.g. vineyards); while hay meadows and permanent pasture are unlikely to alter much in extent or appearance. • A large number of ecological changes that are not immediately obvious to the untrained eye (e.g. to plant communities and assemblages) may occur with little overall impact on landscape appearance. • Surface water is likely to decline in summer months with low stream flows and shrinkage and possible temporary disappearance of some shallow ponds and lakes. ***Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)*** • Decrease in quality and extent of hedgerows, more gaps, loss of some hedgerow trees. Replacement with post and wire fencing, and/or expansion in field size. • Earlier greening of vegetation/trees in spring due to warmer temperatures. • Agricultural crops may increase in diversity adding texture and colour to the landscape, while natural biodiversity may decrease with limited changes in landscape appearance. • Some tree species may decline while others are introduced to suit the altered climate, potentially adding colour and texture to the landscape. • Surface water will be less visible during summer months.

8.5.10. Upland (grassland)

Matrix 1: Identification of potential impacts for Upland (Grassland)

Landscape Character type: Upland (Grassland)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform								

Field boundaries		X			X			
Tree cover								
Vegetation		X	X	X	X	X		
Surface water				X				
Settlement & structures								
Archaeological assets		X		X				

Matrix 2(i): Impact of warmer mean temperatures on Upland (Grassland)

Description of change

- Warmer mean temperatures

Outcome of change

- Longer growing season
- Migration of pests, invasive species; diseases

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Field boundaries	Low -ve
Vegetation	Low -ve
Archaeological assets	Low -ve

(ii) Migration of pests, invasive species; diseases

Landscape element impacted	Level of anticipated change
Field boundaries	Moderate -ve
Vegetation	No change

Risk Assessment

The SoNaRR report (Natural Resources Wales, 2016) states that '…grassland makes up nearly two thirds of the land cover of Wales…the majority (more than 1,000,000 ha) is agriculturally improved and only about 192,000 ha is semi-natural grassland (9% of the land cover of Wales). There is also an estimated 78,000 ha of grassland Priority Habitat more than 90% of which is in the lowlands.' The report also notes poor condition of grassland with 'All 8 forms of European protected grassland occurring in Wales have an unfavourable conservation status in the UK and 92% of grassland SAC features in Wales are considered to be in unfavourable condition. A review of grassland features on SSSIs in Wales in 2003 estimated that only 43% were in favourable condition.'

Increases in temperature and solar radiation at key times of the year can have benefits for yields of some crop varieties. Grass growth also benefits from warmer conditions (CCC, 2016a). there may be a spread of bracken as a result of warmer drier summers and less frequent frosts (Powell et al., 2012; Farrar &vase 2000). A longer growing season may result in a change in farming practices, with more/different crops that flourish in warmer regions being grown (e.g. establishment of vineyards), possibly affecting the landscape character (Powell et al., 2012). Potential spread of grassland at higher altitudes and retreat of heather moorland (LUC 2011). Earlier spring greening of grasslands and change in species composition may be seen, especially at climatic tolerance edges (Morecroft & Speakman 2015). Spread of pests, pathogens and disease may impact smaller, more vulnerable habitats within the landscape (e.g. hedgerows and ancient woodland), rather than the open grassland itself.

A longer growing season may cause expansion of farmland into uplands. Ploughing and drainage schemes would be destructive of archaeological remains (Powell et al., 2012; Farrar &vase 2000). Introduction of new crops and farming practices will not alter the character of historic landscapes but will threaten individual historic assets lying within them (Murphy & Ings, 2013).

Field boundaries vary across the Upland grassland landscape. In lower areas on improved land hedgerows are more significant while higher up stone faced hedge banks and drystone walls are more widespread. In both cases post and wire fencing has increased due to costs of maintaining field boundaries. Hedgerows may suffer from increased exposure to pests and disease. Chalara (ash die-back) is a major threat to hedgerows which contain a considerable quantity of ash, both in the shrub layer and as standard trees. As ash declines gaps will form in hedgerows and a significant proportion of the mature trees in the landscape will be lost. This is likely to have a major impact on other species dependent on both hedgerows and free-standing trees (Natural Resources Wales, 2016).

Brown et al, (2016) suggest there is a strong consensus in the scientific community that climate change has caused changes in the UK's biodiversity and ecosystems in recent years (Morecroft and Speakman, 2015). There is now very clear evidence that many species are moving to higher latitudes and altitudes, both within the UK and internationally, responding to changes in climate by colonising new areas as the climate becomes suitable [High confidence]. A recent study of 1,573 animal species with northern limits in the UK showed that most had moved northwards over the past four decades (Mason et al., 2015). The average (mean) northwards movement was 23 km per decade in the first half of the period and 18 km per decade in the second half.

The SoNaRR report (Natural Resources Wales, 2016) states that: 'Soils are diverse with over 400 different soil types identified in Wales. Soils contribute to biodiversity, landscapes and land use and contain 410 million tonnes of carbon.' The report goes on to note the high level of deterioration across all habitats (except for woodlands) and in some places soil erosion which has not been quantified. The report notes that 'around 10-15% of grassland fields in England and Wales are thought to be affected by severe soil compaction and 50-60% are in moderate condition. No data exists on compaction in grassland and arable land across Wales. Comparison of LANDMAP (LMP-14) boundaries with a soils map (National Soil Map of Wales, UK Soil Observatory (UKSO), 2016) indicates that Upland Grassland incorporates a range of soil types.

Projected climate change may provide new cropping opportunities, but more agricultural land is likely to suffer from water deficits in summer and waterlogging in winter (Natural Resources Wales, 2016).

Matrix 2(ii): Impact of hotter drier summers on Upland (Grassland)

Description of change

- Hotter drier summers

Outcome of change

- Drying out, desiccation, erosion, of wetlands and soils
- Stress on trees and plants
- Wild fires

Impact on landscape character elements

(ix) Drying out, desiccation, erosion, of wetlands and soils

Landscape element impacted	Level of anticipated change
Vegetation	Low -ve
Surface water	Low -ve

(x) Stress on trees and plants

Landscape element impacted	Level of anticipated change
Field boundaries	Moderate -ve
Vegetation	Low -ve

(xi) Wild fire

Landscape element impacted	Level of anticipated change
Vegetation	Low -ve

(xii) Drying out, desiccation, erosion, of wetlands and soils

Landscape element impacted	Level of anticipated change
Archaeological assets	Low -ve

Risk assessment

Terrestrial habitats of principle importance extend over a total area of 387,300 ha in Wales. The most extensive (each >30,000 ha) include upland heathland, blanket bog, upland oak woodland, purple moor-grass and rush pasture, lowland dry acid grassland and coastal and floodplain grazing marsh. Upland grassland, however, incorporates some key habitats of conservation importance, which are limited in extent and highly vulnerable (Natural Resources Wales, 2016).

Upland grasslands cover a wide range of habitat types including upland valleys, lower plateaux and scarps with grazing land making up more than 50% of the land use. Some habitats are sensitive to reductions in precipitation and to drought. There is evidence that in southern England drier summers have affected species composition of semi-natural lowland grasslands (Morecroft et al., 2002). There is also experimental evidence from 13 years of climate change manipulations of limestone grassland at Buxton, northern England, of the habitat's overall resilience to climate change, with constancy in the relative abundance and dominance of many growth forms. Small shifts in abundance of some species and only few losses in response to drought and winter heating compared to inter-annual variations due to climate (Grime et al., 2008). Some changes in species abundance and community composition (Fridley et al., 2011), as well as genetic responses by individual species (Ravenscroft et al., 2015), have been identified.

Climatic sensitivity analysis suggests that grassland production in England and Wales is resilient to small perturbations in mean temperature (up to + 2 °C) and precipitation (±10%). The effect of increasing temperature by 1 °C is almost completely offset by precipitation increases of 10% resulting in little change to the distribution of grassland suitability. However, greater temperature changes (+ 4 °C) have a major influence on the ability of land to support intensively managed grassland because of increased drought stress. Results indicate that a change in the climate comparable with current best estimates for the future would benefit grassland on good quality land at higher altitudes (Farrar and Vaze, 2000). If conditions are too hot and dry there can be negative implications for grass productivity (CCC, 2016a).

The SoNaRR Report (Natural Resources Wales, 2016) suggests risks to soils from increased seasonal aridity and wetness noting that, 'climate change related risks are threatening the many services that soils provide, notably those that relate to soil biota, soil organic matter, and soil erosion and compaction'.

Where small areas of peat occur within the landscape desiccation can occur: the loss of the organic content of peaty soils could transform the types of vegetation that can be supported and change the historic character (Murphy & Ings, 2013).

Windfarm developments will introducing large modern structures into many upland and some lowland and coastal landscapes (Scottish natural heritage 2011).

Wildfire represents a sporadic but serious risk to Wales's natural environment. It can affect grassland (CCC, 2016a). The UK uplands are highly sensitive and significant cultural landscapes that have been created by woodland clearance for agriculture and are at threat from fire (Orr et al., 2008).

The introduction of more frequent storms associated with intense periods of high rainfall is likely to cause more intense localised erosion. As some of the best examples of upstanding archaeological sites are located in the uplands, these will suffer erosion as a result of more frequent storms. (Powell et al., 2012)

Specific gaps in knowledge

- There is a general lack of information on the current state and trends of soils in Wales and their vulnerability and resilience to land use, land management and changing weather patterns and climate (Natural Resources Wales, 2016).
- The effects of climate change on highly productive grass species are reasonably well understood, but much less is known about the impacts on species characteristic of permanent semi-natural pastures. Changes in these habitats could have substantial knock-on effects on the livestock industry because of the strong inter-relationships between enclosed farmland and mountain, moor and heath. There are limited recent data on condition of grassland features on SSSIs in Wales and limited information on current extent and condition of grasslands outside protected sites (Natural Resources Wales, 2016).
- Limited information on the current condition of Enclosed Farmland habitats in Wales.
- Limited information on the distribution of Chalara (ash die-back) infected ash trees Wales (Natural Resources Wales, 2016).

Landscape response to outcomes of climate change

- In reference to unimproved grassland, Farrar and Vaze (2000) note that it is 'difficult to predict effects because much depends upon climate change impacts on nutrient turnover'. They suggest that drier and warmer conditions '…may favour more xeric communities, which could be regarded as beneficial since they are presently more restricted in extent'. They also note that field boundary (hedgerow) impacts of climate change ae likely to be less severe than agricultural management impacts.
- Vegetation changes in field boundaries (hedgerows) are likely to be more significant than changes in grassland. Drier conditions and pathogens/disease are likely to impact on the species mix in hedgerow and result in more gaps and potentially loss of some trees (e.g. Ash). More post and wire fencing may be in evidence as hedgerows decline.
- Surface water will be less visible in the landscape during summer months.
- Improved grassland may extend to higher elevations under warmer conditions.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Changes will be subtle but cover large areas. Diversity of colour and texture may decline with species loss.
- Field boundaries in lower areas may become less distinct as hedgerows decline.
- Greening may occur earlier in the year and improved grassland occur at higher elevations.

8.5.11. Upland (rock and scree)

Matrix 1: Identification of potential impacts for Upland Rock

Landscape Character type: Upland Rock								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform		**X**		**X**				**X**
Field boundaries								
Tree cover								
Vegetation		**X**			**X**			
Surface water				**X**				
Settlement & structures								
Archaeological assets								

Matrix 2(i): Impact of Warmer mean temperatures on Upland Rock

Description of change

- Warmer mean temperatures

Outcome of change

- Longer growing season

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Landform	Low -ve
Vegetation	Moderate -ve

Risk assessment

Remnant arctic-alpine communities, although of very limited occurrence in Wales, are of special concern to conservationists who consider that they are particularly vulnerable to climate change (CCW 1999). It is argued that having survived since the last ice age in the few sites where they are able to compete with other vegetation, notably on cool, wet, north-facing cliffs and boulder screes, they have “nowhere to go” if climate change occurs, since the mountains are not high enough to offer refuges at higher elevations. This concern is based on supposition, there being no experimental evidence from studies in Wales or elsewhere to support it.

Evidence from genetic studies on the Snowdon lily (Jones & Gliddon 1009) suggests that the few small Welsh populations of this species, although isolated by considerable distances from the nearest populations in the Alps, are surprisingly varied genetically. This suggests that the Snowdon lily in Wales may be able to respond to climate change more successfully than was previously supposed. (Farrar & Vase, 2000)

Mountain-top plant communities are composed of species adapted to low temperatures and are likely to decline in response to rising temperatures, as a result of increasing colonisation and competition from upland species typical of lower altitudes (Morecroft & Speakman 2015). More vegetation might be observed at higher elevations than previously.

The Met Office Hadley Centre regional climate model projects reductions in winter mean snowfall of typically –65% to –80% over mountain areas (Jenkins et al 2009)

The local landscape of the highest mountain tops may change as patterns of the freeze-thaw cycle change, altering rock weathering and soil features formed by this action. Freeze that actions is likely to decrease the rate of erosion and weathering. (LUC 2011)

Matrix 2(ii): Impact of hotter drier summers on Upland Rock

Description of change

- hotter drier summers

Outcome of change

-
-

Impact on landscape character elements

(xiii)

Landscape element impacted	**Level of anticipated change**
Landform	Low -ve
Vegetation	Moderate -ve
Surface water	Low -ve

Risk Assessment

In mountainous areas the drying out of bogs and other habitats in the summer could lead to a loss of biodiversity and carbon storage. An increase in soil erosion in drier summers could also occur, potentially exacerbated by an increase in tourism, and more frequent intense weather conditions. These changes would affect the mountain landscape. Biodiversity would also be affected by changes in climatic conditions and habitats, including migration of species to higher altitudes. (DEFRA 2012a)
Shallow lakes and streams may dry up in summer months, surface water will be less visible.
Less rainfall and moisture in summer months could have negative impacts on plant communities living at the margins of their natural environment. Few opportunities to migrate to cooler/wetter areas.

Matrix 2(ii): Impact of more frequent extreme weather on Upland Rock
Description of change • More frequent extreme weather
Outcome of change • Frequency & intensity of high winds, rainfall, storms.

Impact on landscape character elements

(i) Frequency & intensity of high winds, rainfall, storms.

Landscape element impacted	Level of anticipated change
Landform	Low -ve

Risk Assessment

More intense storms and rainfall may increase the potential for destabilising steep slopes and washing loose material downslope. Slope instability occurs when particular slope characteristics (such as geology, gradient, sources of water, drainage, or the actions of people) could combine to make the slope unstable. Scotland: Initial results from the risk assessment (Inherent Risk) show that out of 352 'sites' analysed, approximately 95% are exposed to Slope Instability in a way that is deemed unacceptable (Historic Environment Scotland Climate Change Team, 2018).

Specific gaps in knowledge

Landscape response to outcomes of climate change

- Landscape changes will be subtle and relate largely to an increase in vegetation (coarse grasses, bracken) growing at higher elevations.
- Few days with peaks covered in snow in winter.
- Surface water less visible in summer, drying up of shallow pools and lakes.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- The amount of visible bare rock may decrease as a result of increasing vegetation and more favourable growing conditions. This may be tempered by lack of water in summer months, and more frequent and intense storms, which are likely to have more impact at higher elevations.
- High mountains may appear greener in spring and summer, with less grey and bare rock visible.
- Alpine plant communities may disappear, reducing overall biodiversity.
- Fewer days of snow cover in winter and more surface water visible.
- Less surface water visible in summer months.

8.5.12.Upland (wooded hills)

Matrix 1: Identification of potential impacts for Upland (Wooded Hills)

Landscape Character type: Water (Inland)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform						**x**		
Field boundaries								
Tree cover		**x**	**x**		**x**		**x**	**x**
Vegetation		**x**	**x**					
Surface water								
Settlement & structures								
Archaeological assets			**x**	**x**				

Matrix 2(i): Impact of Warmer mean temperatures on Upland (Wooded Hills)

Description of change

- Warmer mean temperatures

Outcome of change

- Longer growing season
- Migration of pests and diseases into Britain

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Woodland	Low +ve
Vegetation	Low +ve

Risk assessment

Woodland

Conifer planting on upland hills may increase as with warmer overall temperatures trees will flourish at higher altitudes. Warmer growing seasons and rising CO_2 concentrations will stimulate productivity and timber production where soil water and nutrient availability allows. For example, increases of 2–4 m^3 ha^{-1} yr^{-1} are expected in upland conifer forests of the north and west of England and in Wales (and Sitka spruce growth rates may increase by up to 2.8 m3 per hectare per year for each 1°C warming if other factors are not limiting https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Wales-National-Summary.pdf). Wales also has ambitious tree planting targets to help meet carbon sequestration targets.
Improved growth may also occur among other species, although species will need to be matched carefully to site conditions (Ray, Morison and Broadmeadow, 2010) as higher CO_2 concentrations are not as effective for trees on nutrient – limited soils. Climatic conditions in central and eastern Wales are likely to remain favourable for growing broadleaved species, and oak and ash suitability will remain high providing some security for native woodland habitats in Wales. Species assemblages of woodland communities may alter in response to changes in temperature and moisture (https://www.forestry.gov.uk/pdf/fcrn301.pdf/$FILE/fcrn301.pdf).
There may also be pressures to use trees and other vegetation to improve the stability of slopes and reduce erosion and landslip (Clwydian range and Dee valley).
All emissions scenarios suggest that winters will be wetter in Wales, resulting in more waterlogged soil conditions. The increased winter rainfall will have a physiological impact on the rooting depth for many tree species, due to the presence of anaerobic conditions in which roots will not survive (https://www.forestry.gov.uk/pdf/fcrn301.pdf/$FILE/fcrn301.pdf).

Vegetation

Grass growth benefits from warmer conditions (CCC, 2016a) and bracken is likely to spread as a result of warmer, drier summers and less frequent frosts (Farrar & Vase 2000). The potential spread of grassland and retreat of heather moorland (LUC 2011). With warmer mean temperatures there is likely to be earlier spring greening of grasslands; and potentially changes in species composition especially at climatic tolerance edges (Morecroft & Speakman 2015).

A longer growing season may cause expansion of farmland into upland areas and improvement of land at higher altitudes. If conditions are too hot and dry, however, there can be negative implications for grass productivity.
Warmer temperatures will benefit grassland productivity, particularly in marginal upland areas. As a result of an extended growing season there may be opportunities for longer outdoor grazing, although if rainfall increases there is an enhanced risk of damage by poaching from livestock (https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Wales-National-Summary.pdf).
Changes in appearance will be based reductions in rough grassland, possibly with higher proportion of improved grassland, and more plantation forestry (most likely conifers).

(ii) Migration of pests and diseases into Britain

Landscape element impacted	Level of anticipated change
Woodland	Low -ve
Vegetation	Low –ve

Risk assessment
Woodland
There are increased risks of a spread of pests and diseases as a result of warmer conditions. Woodland condition and extent is expected to be affected by climate change. Monitoring indicates that tree health is already declining (for example by 2015, approximately 36% of larch in Wales had been found to be infected with Phytophthora ramorum, and Chalara Ash Dieback had been identified at 100 different sites across Wales. (https://cdn.naturalresources.wales/media/684348/chapter-3-state-and-trends-final-for-publication.pdf).
Pest and disease ecology will change with the climate; for example, more frequent green spruce aphid attacks may reduce Sitka spruce growth in west, east and south Wales (https://www.forestry.gov.uk/pdf/fcrn301.pdf/$FILE/fcrn301.pdf).
The epidemiology of tree diseases will change. For example: Wetter and milder winters followed by droughty summers may predispose oak and other broadleaved species to root pathogens such as Phytophthora cinnamomi. Since the 1990s red-band needle blight (caused by the fungus Dothistroma septosporum) has become widespread in Britain, mainly on Corsican pine, less so on other pines. This could be due to increased rainfall in spring and summer coupled with the trend towards warmer spring temperatures. Other species of concern include oak processionary moth (Thaumetopoea processionea) and gypsy moth (Lymantria dispar), and the European spruce bark beetle (Ips typographus) (https://www.forestry.gov.uk/pdf/fcrn301.pdf/$FILE/fcrn301.pdf).
Water scarcity from drier summers, flooding from changes in frequency and/or magnitude of extreme weather, and wildfire events also create enhanced risks for woodland.

Vegetation
Risks of colonisation by new species from Europe are relatively low, but higher from species arriving from other parts of the world as a result of increased travel. As temperatures increases more species are likely to be able to survive. Warmer wetter winters is likely to produce favourable conditions for fungi and species such as rhododendron may increase their elevation range in upland areas in the western parts of Wales (https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Wales-National-Summary.pdf).

Matrix 2(ii): Impact of Hotter, drier summers on Upland (Wooded Hills)

Description of change

- Hotter, drier summers

Outcome of change

- Stress on some trees and plants
- Wildfires

Impact on landscape character elements

(i) Stress on some trees and plants

Landscape element impacted	Level of anticipated change
Woodland	Moderate -ve
Vegetation	Moderate -ve

(ii) Wildfires

Landscape element impacted	Level of anticipated change
Woodland	High -ve
Vegetation	High -ve

Assessment

(i) Stress on some trees and plants

Hotter drier summers will put stress on trees and other vegetation due to drying out of soils and lack of water. Much will depend on the pattern and timing of rainfall over the summer months. Effects are likely to be greater in the eastern parts of Wales, which are have less rainfall than western parts. Drier conditions might limit the level of tree planting that takes place in upland areas, avoiding areas with reduced capacity for water storage such as shallow soils and steep slopes.

Some tree species are particularly unsuited to sites with seasonally fluctuating water tables from very wet to dry conditions, especially beech and Douglas-fir. On imperfectly and poorly draining soil types, drought stress will become more critical when winter waterlogging is followed by summer drought, making trees more susceptible to pests and disease outbreaks (https://www.forestry.gov.uk/pdf/fcrn301.pdf/$FILE/fcrn301.pdf).

(ii) Wildfires

Risk of wildfire will increase for both woodland and upland vegetation with hotter and drier summers. Grassland, peatland, heat and woodland are all at risk. Fires currently occur in dry years. For example there were 174 forest wildfires affecting an area of 107 hectares in Wales in 2012-13. Climate models have indicated that wildfire risk might increase by 30 – 40% in the Brecon Beacons, Pembrokeshire coast, and Snowdonia by 2080 (https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Wales-National-Summary.pdf).

Adaptive management may result in clearing strips of land and undertaking controlled burning in appropriate areas to reduce the risk of wildfires (Clwydian Range and Dee Valley). However, an estimated 40% of Welsh woodlands have minimal or no management, which reduces their resilience, and increases the possibility of fires and other damage (https://cdn.naturalresources.wales/media/684348/chapter-3-state-and-trends-final-for-publication.pdf).

Matrix 2(iii): More frequent extreme weather on Upland (Wooded Hills)

Description of change

- More frequent extreme weather

Outcome of change

- Frequency & intensity of high winds, rainfall, storms.

Impact on landscape character elements

(iii) Frequency & intensity of high winds, rainfall, storms

Landscape element impacted	Level of anticipated change
Woodland	Moderate -ve

Risk assessment

The risk of wind damage to woodlands in upland areas is high, particularly for conifer plantations.

Gaps

Wildfire: full extent of the risk and the identification of vulnerable areas remains unknown

Woodland condition: Data on woodland condition is limited and there is very limited information about the distribution of pest and disease outbreaks throughout Wales and Britain. There is information about the known spread of quarantine pests and diseases but the vast majority of pests and diseases are not mapped. Limitations are likely to continue due to high monitoring costs.

Landscape response to outcomes of climate change
•   *Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)* • •

8.5.13. Upland (wooded)

Matrix 1: Identification of potential impacts for Upland (wooded)

Landscape Character type: Upland (wooded)								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms.
Landform								
Field boundaries								
Tree cover		X	X		X	X	X	X
Vegetation		X	X		X	X		
Surface water				X				
Settlement & structures								
Archaeological assets			X	X				

Matrix 2(i): Impact of Warmer mean temperatures on Upland (wooded)

Description of change

- Warmer mean temperatures

Outcome of change

- Longer growing season
- Migration of pests, invasive species; diseases

Impact on landscape character elements

(i) Longer growing season

Landscape element impacted	Level of anticipated change
Tree cover	Moderate + ve
Vegetation	Low +ve

(ii) Migration of pests, invasive species; diseases

Landscape element impacted	Level of anticipated change
Tree cover	Moderate - ve
Vegetation	Low -ve

Risk assessment

Warmer growing seasons and rising CO_2 concentrations will stimulate productivity and timber production for upland conifers where soil water and nutrient availability allows. Increases of 2–4 $m^3\ ha^{-1}\ yr^{-1}$ in upland conifer forests may result. Improved growth may also occur, initially, in more southerly regions, although species will need to be matched carefully to site conditions (Ray, Morison and Broadmeadow, 2010). Improved forest productivity has been noted over the past four decades, attributed to warmer conditions, increased CO2 concentration, and improved silvicultural practices (Ray, 2008). There is potential for other species to increase in productivity and area, such as upland oak woodland (Sinnadurai, 2005). A longer growing season may also result in earlier bud-burst in some species and later dormancy with prolonged late season growth of timber (Ray, 2008).

Negative impacts of warmer conditions include an increase in mammal numbers (deer and grey squirrel) and a higher level of damage to trees through browsing and bark stripping. Ray (2008) suggests the epidemiology of tree diseases will change as follows:

- Wetter and milder winters followed by droughty summers may pre-dispose oak and other broadleaved species to root pathogens such as Phytophthora cinnamomi.
- Since the 1990s red-band needle blight (caused by the fungus Dothistroma septosporum) has become widespread in Britain, mainly on Corsican pine, less so on other pines. This could be due to increased rainfall in spring and summer coupled with the trend towards warmer spring temperatures.
- Introduced pests and pathogens of concern include oak processionary moth (Thaumetopoea processionea) and gypsy moth (Lymantria dispar), and the European spruce bark beetle (Ips typographus).

Warmer temperatures will bring increased risk from new tree diseases and insect pests (DEFRA 2012c); tree stress caused by summer drought could increase the spread of some fungal diseases, particularly root pathogens (Lonsdale and Gibs, 2002)
Rhododendron might increase elevation range under warmer weather conditions. This will have a visible impact on the landscape itself. It may also increase disease spread as it is a host for *Phytophthora ramorum* (DEFRA 2012a), a tree disease that can affect larch (Larix), beech (Fagus sylvatica), sweet chestnut (Castanea sative), horse chestnut (Aesulus hippocastanum) as well as other conifer species and some non-native oaks (Forestry Commission, 2018).
Brown et al (2016) note that a repeat survey of 103 British woodlands (1970 – 2001) detected a long-term decline in the species richness of ground flora (excluding bryophytes and lichens). This may be caused by poor management and reduced woodland quality although changes in the timing of seasonal events (such as earlier tree-leafing) may also have had adverse implications for ground flora and other woodland species. The data also shows that there have been gains in species richness in some woodlands in southern England as a result of the 1987 storm, illustrating how extreme events can be beneficial for biodiversity in the longer term. The study found little overall change in dominant tree species. However, there is evidence from other studies of shallower-rooted trees (such as beech) being replaced by deeper-rooted species that are less sensitive to drought (Morecroft and Speakman, 2015).

Matrix 2(ii): Impact of hotter drier summers on Upland (wooded)

Description of change

- Hotter drier summers

Outcome of change

- Stress on trees and plants
- Wild fires

Impact on landscape character elements

(xiv) Stress on trees and plants

Landscape element impacted	Level of anticipated change
Tree cover	High + ve
Vegetation	Low +ve
Surface water	Moderate -ve

(xv) Wild fires

Landscape element impacted	Level of anticipated change
Tree cover	Moderate -ve
Vegetation	Low -ve

Risk assessment

Upland oakwood: range restricted to wetter regions and replaced by communities more typical of lowland broadleaved and mixed woodland (Ray, Morison and Broadmeadow,

2010).
A more restricted suitable range of upland oakwoods is predicted under the 2050s High emissions scenario, indicating a more fundamental change to the nature of the vegetation community (Broadmeadow and Ray, 2005). There is also a medium risk to the bryophyte community in upland oakwood (Farrar and Vase 2000). Not sure if this would impact on landscape, but could deduct from overall 'greenness' of woodland.
Hotter drier summers will influence species selection as some conifers, such as Sitka Spruce, are drought sensitive making planting on shallow or well drained soils (such as valley slopes) problematic. The suitability of sites for planting certain species may alter, particularly in southern and eastern parts of Wales which may result in less Sitka Spruce and more mixed species forestry with greater diversity (either between or within stands). Woodland fires are also expected to increase, especially with higher levels of recreation taking place in forested areas (Ray, 2008).
The UK Climate Change Risk Assessment Report (Brown et al, 2016) indicates that the suitability of existing tree species for the future climate will decline beyond 2050, in particular Sitka Spruce.
Ray (2008) notes that upland oakwoods account for around half of the semi-natural woodland cover of Wales but climate change is likely to bring about some changes:

- Warmer and drier summers are likely to have an impact on epiphytes.
- Increased natural disturbance is likely to occur from winter gales which may break branches and blow over trees.
- Milder winters, springs and autumns will allow a wider range of broadleaved species to colonise (e.g. beech colonisation in Atlantic oakwoods).
- There is likely to be an increase in the frequency of disturbance from fire, particularly in oak woodland adjacent to heather moor and in woodlands popular with visitors.

Upland ashwoods comprises about 25% of the semi-natural woodland area of Wales. In the west of Wales, more frequent natural disturbance events may occur, creating canopy openings with colonisation by a greater range of plants. Shade-tolerance of Ash means that tree-species composition may change more slowly in ashwoods than in other woodland types (Ray, 2008).
Surface water will decline as limited upland storage will result in local streams and small ponds, wetlands drying up. Surface water will be less visible.

Matrix 2(iii): Impact of warmer wetter winters on Upland (wooded)

Description of change

- warmer wetter winters

Outcome of change

- Flooding events; in-stream impacts

Impact on landscape character elements

1. **Flooding events; in-stream impacts**

Landscape element impacted	Level of anticipated change
Tree cover	Low -ve

Risk assessment

Wetter winters are likely to lead to increased waterlogging of soils, especially in upland areas. This will have a physiological impact on the rooting depth for many tree species, due to the presence of anaerobic conditions in which roots will not survive. Some tree species are particularly unsuited to sites with seasonally fluctuating water tables from very wet to dry conditions, especially beech and Douglas-fir. On poorly draining soil types, drought stress will become more critical when winter waterlogging is followed by summer drought, making trees more susceptible to pests and disease outbreaks. (Ray, 2008)

Matrix 2(iv): Impact of more frequent extreme weather on Upland (wooded)

Description of change

- more frequent extreme weather

Outcome of change

- Frequency & intensity of high winds, rainfall, storms.

Impact on landscape character elements

2. Frequency & intensity of high winds, rainfall, storms.

Landscape element impacted	Level of anticipated change
Tree cover	Moderate -ve

Risk assessment

Upland confer plantations are more at risk from wind damage.

Upland oakwood and mixed ashwoods: Rowan and birch increase in dominance in areas affected by windblow; Even aged, young stands of ash (Fraxinus excelsior) in areas affected by windblow. (Ray, Morison and Broadmeadow, 2010). More exposed sites likely to lose trees to windthrow.

Upland oakwood: broken branches and windfall (Ray 2008).

More intense rainfall will increase soil erosion, particularly on steep slopes. This may lead to efforts to increase tree growth on steeper slopes rather than other forms of vegetation.

Specific gaps in knowledge

- Relatively little is known about potential movement or impact of pests and diseases.
  - Overall impacts of climate change hard to estimate since some changes (warmer temperatures) will favour tree growth, whole other changes (drier summers and greater fluctuation between wet and dry soils) will have negative impacts.

Landscape response to outcomes of climate change

- Fewer Sitka Spruce plantations over the next 30 – 50 yrs, particularly in the south and east. Woodland likely to be more diverse and the species mix likely to alter to cope with warmer and drier conditions.
- A number of species (e.g. Larch, Ash) are already affected by pests and disease in parts of the country. Climate change is likely to accelerate movement of pests and disease resulting in dieback of some species and replacement with different types of tree. More disturbance is likely to open up forest canopies, allowing for a more diverse ground flora.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Dark green and formal lines of Sitka Spruce plantations likely to decrease in scale and extent.
- Tree and vegetation likely to become more diverse creating wider range of texture and colour.
- Growing season will be longer and dormant season shorter.

8.5.14. Upland (moorland)

Matrix 1: Identification of potential impacts for Upland Moorland

Landscape Character type: Upland moorland								
Expected climate change	Warmer mean temperatures			Hotter, drier summers			Warmer, wetter winters, wetter summers	More frequent extreme weather
Outcome of change	Rise in sea levels	Longer growing season	Migration of pests, invasive species; diseases	Drying out, desiccation, erosion, of wetlands and soils	Stress on trees and plants	Wild fires	Flooding events; in-stream impacts	Frequency & intensity of high winds, rainfall, storms
Landform				**X**				
Field boundaries								
Tree cover		**X**			**X**			
Vegetation		**X**	**X**	**X**	**X**	**X**		
Surface water				**X**				
Settlement & structures								
Archaeological assets			**X**	**X**				

Matrix 2(i): Impact of warmer mean temperatures on upland moorland

Description of change

- Warmer mean temperatures

Outcome of change

- Longer growing season
- Migration of pests, invasive species, and diseases

Impact on landscape character elements

(i) Longer Growing season

Landscape element impacted	Level of anticipated change
A. Tree cover	Low -ve
B. Vegetation	Moderate -ve

(ii) Migration of pests and diseases

Landscape element impacted	Level of anticipated change
A. Tree cover	Low -ve
B. Vegetation	Moderate -ve

Risk assessment

A. Warmer temperatures will create more favourable conditions for trees to grow at higher elevations. Potential for native species to grow at higher elevations.

B. Warmer temperatures will create more favourable conditions for grasses and shrubby vegetation to grow at higher elevations. Bacterial activity and soil formation will be enhanced. Soils will warm earlier in spring. Invasive species, such as Rhododendron for example, might extend their range to higher elevations in upland western areas under warmer conditions (which may also support spread of diseases associated with specific species (e.g. Rhododendron is host to Phytopthora ramorum).

Warmer, wetter, winters may lead to the spread of fungi. There is likely to be improvements in habitat for a range of birds and small mammals.

Specific gaps in knowledge

Interaction between specific aspects and impacts of climate change unknown. Speed of change and capacity of plant communities for resilience to change is unknown.

Landscape response to outcomes of climate change

A. Any changes to tree cover are likely to be minimal and confined to sheltered areas. Any increased cover will be slow to appear and affected by grazing intensity, which is likely to minimise any increase in tree cover, although some may occur in gullies and on under-utilised land.

B. Change is most likely to occur at the moorland edge. Warmer temperatures may lead to agricultural management activity to increase the range of improved land at moorland edges. The moorland margin may rise in elevation.

Susceptibility and overall appearance (Form, colour, texture, lines, diversity, seasonality)

Sensitivity score suggests moderate negative change to moorland vegetation is likely across relatively large areas of this landscaper type. Changes will be limited mainly to the moorland edge, and perhaps some sheltered gullies (increase in trees and shrubby growth). Changes in vegetation will blur the moorland line; moorland colour may alter slightly, become greener with a softer texture, gorse rhod increase colour .

Notes and references

ASC (2016) UK Climate Change Risk Assessment 2017 Evidence Report: Summary for Wales. Adaptation Sub-Committee of the Committee on Climate Change, London.

Matrix 2(ii): Impact of hotter, drier summers on upland moorland

Description of change

- Hotter, drier summers

Outcome of change

- Drying out, desiccation and erosion of wetlands
- Stress on some trees and plants

Impact on landscape character elements

(xvi) Drying out, desiccation and erosion of wetlands

Landscape element impacted	**Level of anticipated change**
Vegetation	High negative
Surface water	High negative
Archaeological assets	Moderate negative
Landform	Low negative

(xvii) Stress on some trees and plants

Landscape element impacted	**Level of anticipated change**
Vegetation	High negative
Surface water	High negative
Archaeological assets	Moderate negative

Risk assessment

A. Increased risk of summer fires anticipated. Recent dry summer (2018) resulted in two serious moorland fires in Wales. Risk assessment based on modelling (Peak District) suggests risks may not increase significantly for 20 – 30 years under the high emissions scenario (not until after 2070 for the low emissions scenario). Fire can result in carbon loss, and damage to peat as well as vegetation. Potential for more severe damage from wind and rain erosion. More difficulties in re-establishing vegetation on desiccated or deeply damaged soils. Vegetation recovery likely to be slow and incomplete. Early stages of re-colonization likely to be dominated by bryophytes, changing appearance and plant community. Potential loss of mosses and other peat creating species. Evidence from 1976 (N. York Moors) suggests up to one third of area affected by fire may remain un-vegetated after a decade.

   "Simulations with warmer temperatures indicate that climate change may increase bracken invasion of the moorland and prevent re-vegetation of bare peat...a reduction in managed burning…causes the dwarf shrub community to become dominated by the older, degenerate growth phase". (Chapman et al., 2009)

   Trees (high level plantations) likely to suffer from stress, perhaps resulting in dieback, and increasing susceptibility to pests and disease.

B. Hotter drier summers will reduce water tables and potential lead to drying out of peat deposits and blanket bog, which may increase wind and rain soil erosion. Capacity for upland bogs to regulate water flow diminished, may result in drying up of streams in summer in uplands and high valleys. Surface water conditions will be heavily influenced by the local summer pattern of rainfall which is likely to vary across the country.

C. Drying out of soils may hasten breakdown of archaeological deposits in upland areas.

Specific gaps in knowledge

Complex interactions between vegetation, soils, temperature and moisture, along with effects from management (burning, draining, grazing, habitat management) make it difficult to predict change.

More information on vegetation change than on predicted changes in surface water. Much will depend on the pattern of rainfall during summer months.

Much of the current information on effects of climate change on water is either at the global level or highly localised (Watts, et al, 2015). Evidence for landscape-wide change is lacking.

Landscape response to outcomes of climate change

- Drier conditions will increase the likelihood of wildfire. Where it occurs, the impacts are likely to be widespread with loss of vegetation, potentially long periods of bare soil, and changes in plant communities as coloniser species dominate.
- Drier conditions will result in a decrease in mosses and sedges and increase in coarse grasses and bracken.
- Surface water streams on hillslopes may disappear in summer due to drying up of boggy areas and wetlands on moorland plateaus, potential loss or shrinkage of shallow ponds/lakes. Drying out of peat may lead to higher levels of wind and rain erosion of friable surface soils.
- Drying out of peat may expose archaeological remains, lead to drying out and more rapid destruction.

Susceptibility and overall appearance (Form, Colour, texture, Lines, diversity, seasonality)

- Vegetation change may result in changes in colour and texture of landscape. Fires will potentially result in mosaics of bare soil and blackened patches, new growth will be more vivid green in the short term. Texture will alter due to changes in plant communities, appear more varied and 'coarser'.
- Potential for loss of vegetation and soil/peat erosion as a result of wildfire and surface desiccation, leading to formation of 'hags' and surface geology as soils are eroded.
- Reduced visibility of surface water, particularly at higher elevations, as streamflow will no longer be adequately sustained by upland peat bogs and wetlands. There could be some variability from west to east with drier conditions occurring away from the coast and further east. Moorlands likely to remain wet and support streamflow in winter months. Drier conditions and wildfire may lead to more diverse plant communities across the landscape.
- Archaeological remains may be briefly exposed and visible.

Data Archive Appendix

Data outputs associated with this project are archived in the Document Management System and the GIS server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] A full set of maps produced in PDF and PNG format.

[C] A series of GIS layers on which the maps in the report are based with a series of word documents detailing the data processing and structure of the GIS layers.

[D] An online Github code repository containing all of the R programming code and data resources (including QGIS map legend styles) used to for the landscape reclassification, mapping, spatial analysis and statistical analysis - https://github.com/robertberryuk/LANDMAP_ClimateChange.

[E] An interactive web-map showing the LMP14 and LMP09 data layers was developed for supporting the narratives tasks. This map is available here: https://arcg.is/0rv8DP

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