Forest Research

Opportunities to use woodland measures for Natural Flood Management (NFM) in the Derwent Catchment

Scoping Report

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Forest Research

The Research Agency of the
Forestry Commission

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1. Introduction

Forest Research was commissioned by Forestry England to carry out a desk-based GIS exercise to determine the potential opportunities of implementing Natural Flood Management (NFM) measures in 4 forest areas in the Derwent Catchment. The study focused on the Parkwood Isel, Howgill and Messengemire, Setmurthy and Matterdale forest areas (Figure 1).

The study follows on from similar work carried out by Forest Research for Whinlatter Forest and follows similar methods used in this study.

Implementation of NFM measures in the forest estate will help support community flood risk alleviation, incorporating planting in appropriate areas to help reduce rapid runoff and alleviate flood flows in the catchment, as well as using soft engineering features such as leaky dams in the forest estate to store more water during periods of high flows.

It is proposed that the work be carried out in two phases. Phase 1 will include a GIS-based exercise to quantify the potential scale and location of the NFM opportunities in the 4 areas. Phase 2 will involve ground-truthing the mapping exercise and revising the NFM opportunity map accordingly.

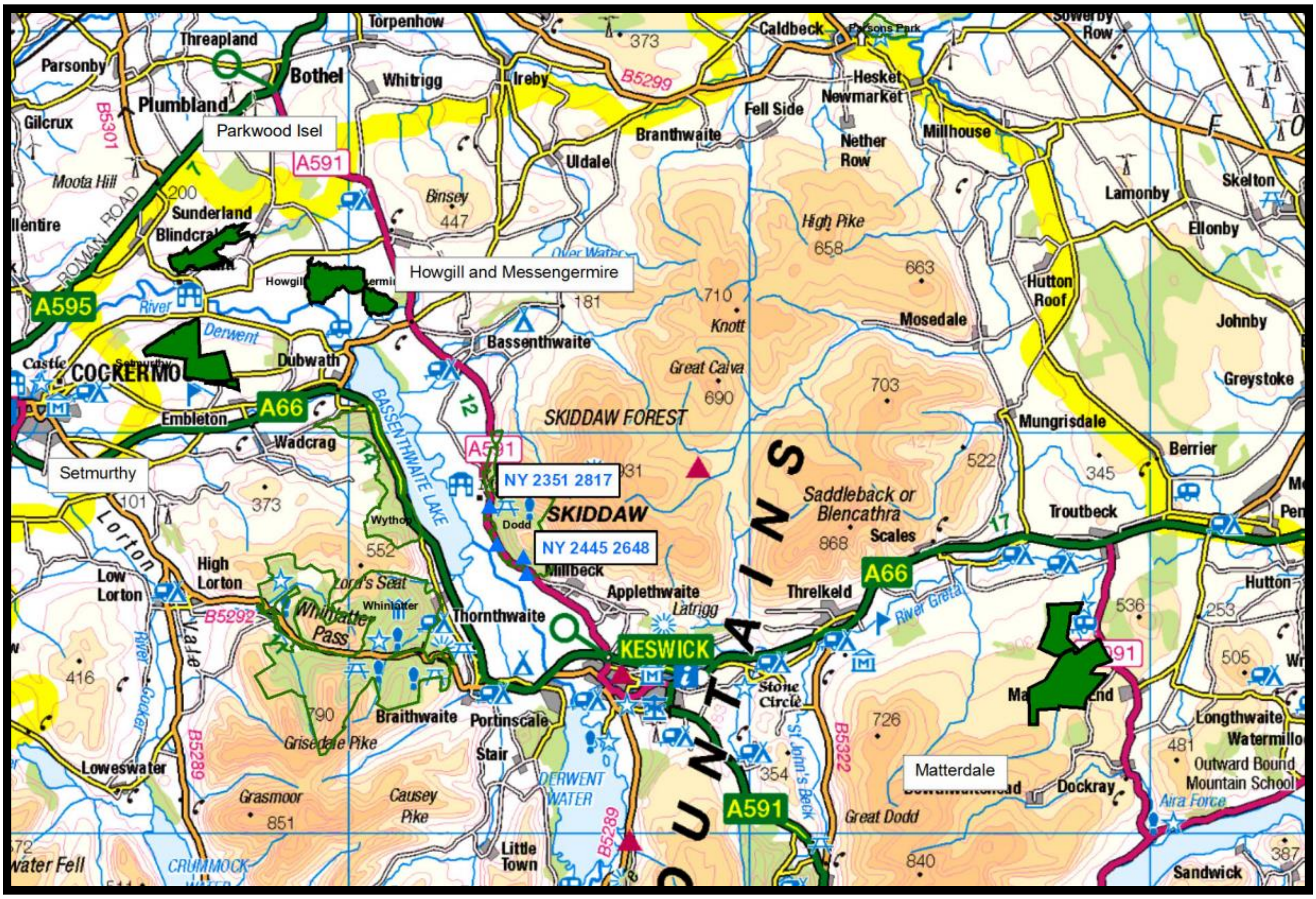

Figure 1 Map showing locations of 4 forest areas

In addition to these proposals, other measures have been considered to support community flood risk alleviation, incorporating planting in appropriate areas to help reduce rapid runoff and alleviate flood flows in the catchment, as well as using soft engineering features such as leaky wood structures in the forest estate to store more water during periods of high flows.

In order to target the most effective locations and assess the potential scale of the natural flood management opportunities in the area, a desk-based GIS exercise was carried out by Forest Research.

2. Mapping locations to store water and slow the flow of surface water

2.1 Potential sites for the creation of leaky wood structures (LWS)

Leaky wood structures (LWS) alter the flow hydraulics in the river channel which enhances the river environment in a number of ways:

1. They increase the hydrological interactions between the river channel and the floodplain by holding back and thereby raising upstream water levels, creating increased opportunities for out of bank flows and flood storage.
2. They create spatial diversity in hydromorphology/flow regime providing habitat patches which support a range of organisms at different stages of their life cycle and an important refuge during high flows.
3. They enhance the storage and attenuate the transport of sediments, organic matter and solutes within the catchment. LWS accumulations retain important food resources for aquatic biota.
4. They affect the geomorphology of the river channel; resulting in greater variability in channel form (increased occurrence of riffle and pool sequences) and greater overall channel stability. Consequently the physical habitat diversity of woodland river channels is enhanced.

Past modelling (Thomas and Nisbet, 2012) has shown that LWS can have a marked effect on flood flows by reducing water velocities, increasing upstream water levels and the frequency of out of bank flooding, and delaying the travel time of the flood peak.

To be effective LWS should be constructed at points where they hold water in the stream channel behind the obstruction and ideally can force water out of the channel onto the floodplain. The volume of water held by the dam will depend on the gradient of the stream channel, the height of the banks and the connectivity between the stream channel and adjacent floodplain at high flow.

A digital terrain model (DTM) and digital river network (DRN) model was used to identify the watercourses in the forest areas. The DTM was used as the source elevation data for hydrological modelling. Opportunities for the installation of NFM measures were identified within each forest area.

The slope of the individual line features of the DRN dataset was determined using the DTM. Stream reaches with slopes of <2° were highlighted as the most suitable potential sites for LWS construction (Thomas and Nisbet, 2012), with reaches with slopes of between 2° and 3° also included in the results as slightly less favourable but still having the potential for implementing NFM features. Where possible, data on the width of the channel for each reach was identified in order to assess the suitability of the reach for LWS construction and estimate the number of dams possible along each reach. It is discouraged to construct LWS in channels wider than 5m as the features could become less stable and the risk of collapse is increased. As a result, reaches which are favourable in terms of slope but wider than 5m were discounted.

Access to reaches in order to construct LWS measures can increase build costs significantly and are more difficult to construct therefore reaches within 30m of forest roads were selected as part of the mapping work. It is also recommended that any LWS construction be timed to coincide with felling operations in order to make use of local timber.

2.2 Identification of potential sites for Runoff Attenuation Features

The Working With Natural Processes (WWNP) project (Environment Agency, 2017) provides the evidence base summarising the effectiveness of WWNP measures from a flood risk reduction perspective as well as the wider ecosystem services benefits they deliver. As part of the project, a mapping exercise was carried out to complement the evidence base to identify the areas and type of WWNP measures that would be suitable.

Runoff attenuation features (RAFs) are one such WWNP measure that was mapped. These are areas of high run-off accumulation in the landscape where water can temporarily be held back in additional storage during storm events.

Examples of RAFs (Quinn et al., 2013) include:

1. Overland flow interception. Involves creation of a bund (soil, wood or stone barrier) across a flow path to create storage. These features are designed to drain slowly by being built to be ‘leaky’ or have an outlet drainage pipe installed, or a combination of both of these options.

2. Online ditch barriers. Barriers constructed from natural materials are located in drainage ditches and streams to cause backwater effects.

3. Offline ponds: Water is diverted from the stream network into a pond structure creating temporary storage. The pond is typically drained by an outflow structure in the form of a plastic pipe which is constructed to allow the feature to drain slowly.

A mapping layer was produced as part of the project to identify sites suitable for a 3.3% AEP (or 1 in 30 year flood event) and a 1% AEP (or 1 in 100 year flood event). Using this layer, the potential for RAFs in the Whinlatter area was assessed. Figure 3 shows an overview of the potential sites for RAF construction in the catchments. The map is indicative only and opportunities shown require field assessment to determine their efficacy for flood risk management and assess the potential impact on existing features of high biodiversity value.

On steeper ground, potential for run-off attenuation features were reclassified as gully blocking in the WWNP report. A threshold of >6 degrees (10%) was used, based on the following 2 criteria.

- Different typological classifications suggest slopes >5% are 'steep', have high energy and can cause braiding (Schumm and Khan 1972).

- Above 6 degrees (10%), restoring peatland vegetation becomes unviable (Evans et al. 2005) and so grip blocking becomes less effective as a form of run-off attenuation. Therefore, it has been argued that other methods such as gully blocking to hold back flows are more viable.

Gullies naturally occur on slopes or where artificial drainage features have been eroded. Gully blocking creates pools of water behind the features, which can provide additional temporary flood storage space (if the pools are able to drain down between each event) Additional flow paths can develop during storm events which can increase the travel time of flood water further.

2.3 Woodland Planting

Woodland creation is increasingly viewed as making an effective and sustainable contribution to NFM. Woodland can help alleviate flooding in three main ways: through the potentially high water use of trees increasing available soil water storage and reducing the generation and volume of flood water; by the typically high infiltration rates of woodland soils reducing direct surface runoff and delaying the passage of water to streams; and by the greater hydraulic roughness created by woodland vegetation, acting to increase above ground flood water storage and delay the downstream passage of flood flows (Nisbet et al., 2011a). These mechanisms are to varying degrees location dependent and considered to be greatest where there is most contact between water and woodland, such as along runoff pathways and on floodplains.

2.4 Floodplain Reconnection Potential

The Floodplain Reconnection Potential dataset from the WWNP was used to identify locations where it may be possible to establish reconnection between watercourse and its natural floodplain, especially during high flows. The dataset shows areas where these is currently poor connectivity such that flood waters are constrained to the channel and flood peaks may therefore propagate downstream rapidly.

3. Potential constraints to NFM measures

Construction of NFM measures may be restricted for many reasons in certain areas and consideration should be made before any planned work goes ahead.

- Some NFM measures, such as LWS, have the potential to increase flood risk; for this reason, the Environment Agency may object to such structures. Consent to the construction of LWS in main river channels would be unlikely.
- Avoid installing instream NFM measures at sites where forest road/track crosses the watercourse
- Avoid woodland creation on sites designated for their open habitat.
- The Forest and Water Guidelines recommend that forest operations should avoid changes to the eco-hydrological conditions on designated sites
- If potential storage areas are within the current standing crop, tree growth may be checked by high water table but in most cases it will not be cost effective to fell trees and create permeable storage bunds until the stand is due to be felled. The restock plans for the site should consider opportunities to block forest drains and hold water on the flat terrace.

4. Results

The results of the GIS exercise are shown for each forest area separately.

Howgill & Messengermire

The Howgill and Messengermire forest areas (total area of 138ha) lie across 4 main tributary catchments (total of 8.8km^2) of the Derwent Water, north of its outlet from Bassenthwaite Lake.

Table 1 shows the extent of opportunities for the creation of LWS in the Howgill & Messengermire forest area, which will enhance the volume of water held and retained within the stream channel. The suitability of the streams for the creation of LWS is based on the average gradient of each reach with streams with an average slope of less the 2° being most suitable. Streams with gradients between 2° and 3° are less suitable due to their effectiveness at holding back water during storm events, but shouldn't be completely discounted.

The expected natural occurrence of a LWS is approximately once every 10 channel widths along suitable reaches. Using this figure and where possible the average channel width for each reach, the total number of potential LWS has been estimated for each reach in the forest area.

LWS can be designed to encourage out of bank flow and reconnect the stream channel to the adjacent flood plain significantly enhancing the volume of water held and retained within the catchment. This can be further enhanced through the construction of timber bunds which increase the depth of water held on the floodplain.

Stream Slope (°)	Length of stream channel (m)	Potential number of LWS
< 2	437	29
2 - 3	467	21

Table 1 Extent of opportunities for the construction of LWS measures in the forest area

Table 2 shows the type, number and total area of opportunities to create RAFs in the forest area. Despite the total potential area of each RAF being on average fairly small, if a number of features are constructed, they could contribute significant additional storage within the forest area.

	RAF 30 year		RAF 100 year	
RAF Type	**Number of Features**	**Total potential storage area (m^2)**	**Number of Features**	**Total potential storage area (m^2)**
Gully Blocking	1	1,399	5	5,941
Run-off Attenuation	10	7,322	13	6,205

Table 2 Extent of opportunities for the construction of Runoff Attenuation Features (RAFs) in the forest area for a 1 in 30 and 100 year storm event.

No additional woodland creation opportunities were identified by the exercise in the forest area, however 1.86km of the river network showed floodplain woodland reconnection potential.

An overview of the location of each NFM feature is shown in Figure 2.

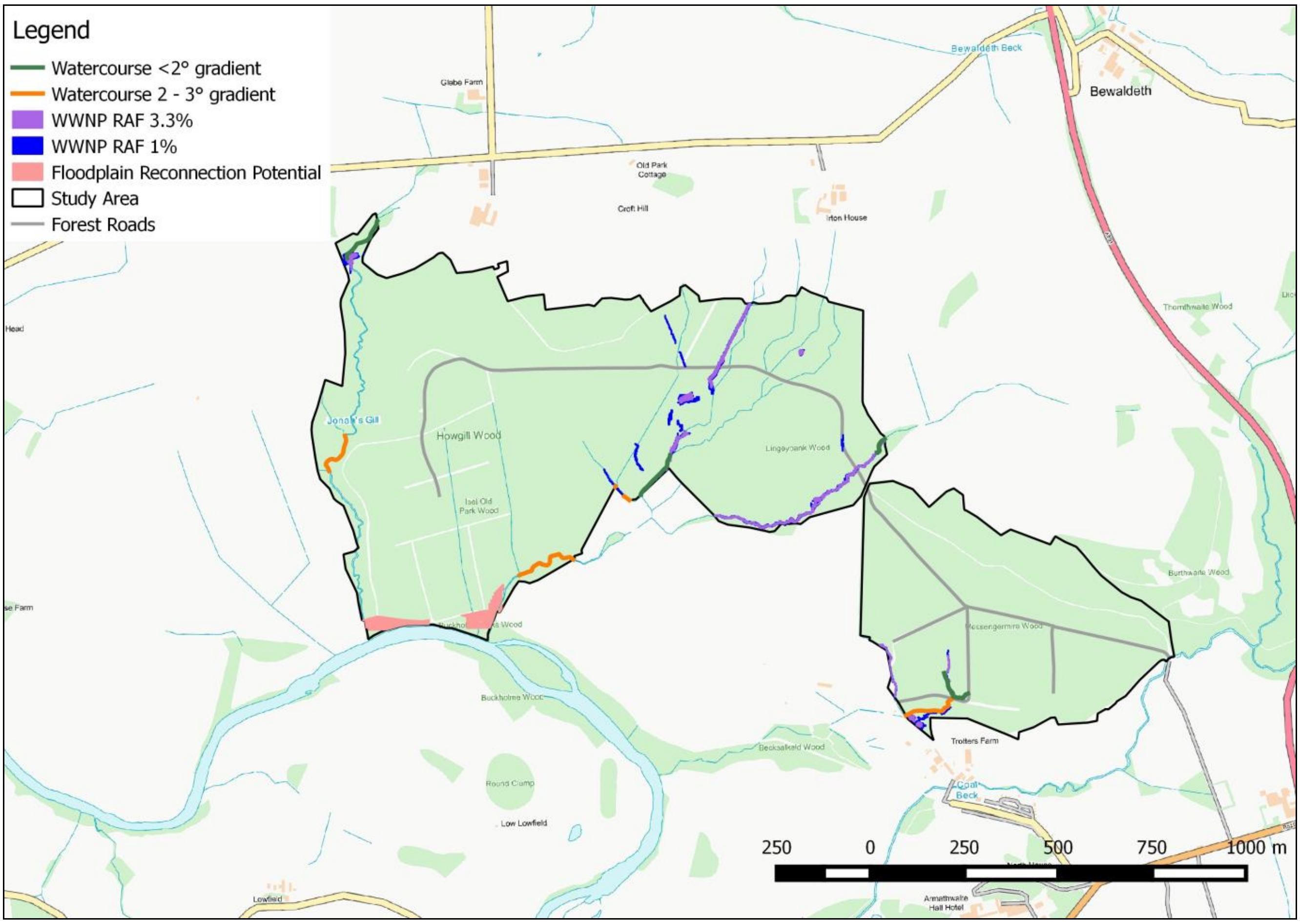

Figure 2 Overview of potential NFM features in the Howgill & Messengermere area

Setmurthy

Setmurthy forest lies to the west of Cockermouth, amounting to an area of 159ha. The north side of the forest area drains directly into the Derwent Water via a number of small tributaries while the southern part of the forest lies within the Bitter Beck catchment which drains into Cockermouth and its confluence with the Derwent Water.

Table 3 shows the extent of opportunities for LWS construction identified in the forest area. Opportunities for LWS are fairly limited to short reaches within the forest area.

Stream Slope (°)	Length of stream channel (m)	Potential number of LWS
< 2	221	15
2 - 3	605	40

Table 3 Extent of opportunities for the construction of LWS measures in the forest area

A number of potential areas were identified for RAFs in the forest area amounting to just over 0.47ha in area.

RAF Type	RAF 30 year Number of Features	Total potential storage area (m²)	RAF 100 year Number of Features	Total potential storage area (m²)
Gully Blocking	4	764	4	539
Run-off Attenuation	10	1,843	11	4,225

Table 4 Extent of opportunities for the construction of Runoff Attenuation Features (RAFs) in the forest area for a 1 in 30 and 100 year storm event.

No additional woodland planting opportunities to help reduce flood risk were identified within the study area.

An overview of the location of each NFM feature is shown in Figure 3.

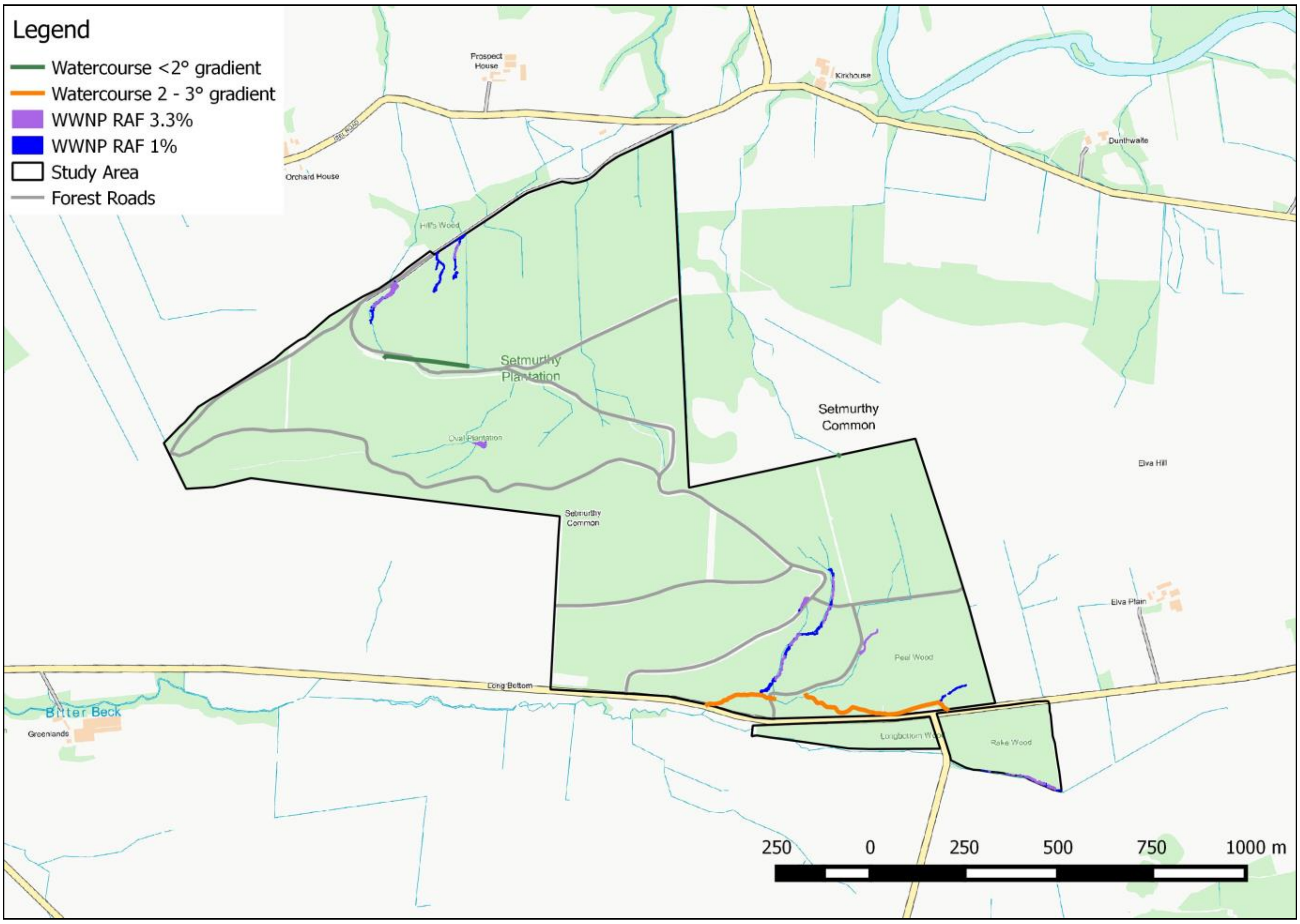

Figure 3 Overview of potential NFM features in the Setmurthy area

Wythop

Wythop forest (278ha in area) is situated on the western shore of Bassenthwaite Lake. Much of the topography is very steep and the tributaries that run through the forest drain directly into the lake. As such, very few opportunities were identified for LWS as well as RAF type NFM features. Most of the LWS potential is identified along Beck Wythop. Some gully blocking opportunities were identified across the study area that would amount to about 5,716m^2 and 5,553m^2 of potential storage area for the 30 and 100 year storm event respectively. A little over 1.6km of watercourse was identified as having potential for riparian woodland creation

NFM measures in Wythop would be limited to localised effects and unlikely to contribute to downstream flood risk reduction due to the large attenuating effect of Bassenthwaite Lake.

An overview of the location of each NFM feature is shown in Figure 4.

Stream Slope (°)	Length of stream channel (m)	Potential number of LWS
< 2	76	5
2 - 3	326	15

Table 5 Extent of opportunities for the construction of LWS measures in the forest area

	RAF 30 year		RAF 100 year	
RAF Type	Number of Features	Total potential storage area (m^2)	Number of Features	Total potential storage area (m^2)
Gully Blocking	11	5,716	15	5,553
Run-off Attenuation	0	0	1	139

Table 6 Extent of opportunities for the construction of Runoff Attenuation Features (RAFs) in the forest area for a 1 in 30 and 100 year storm event.

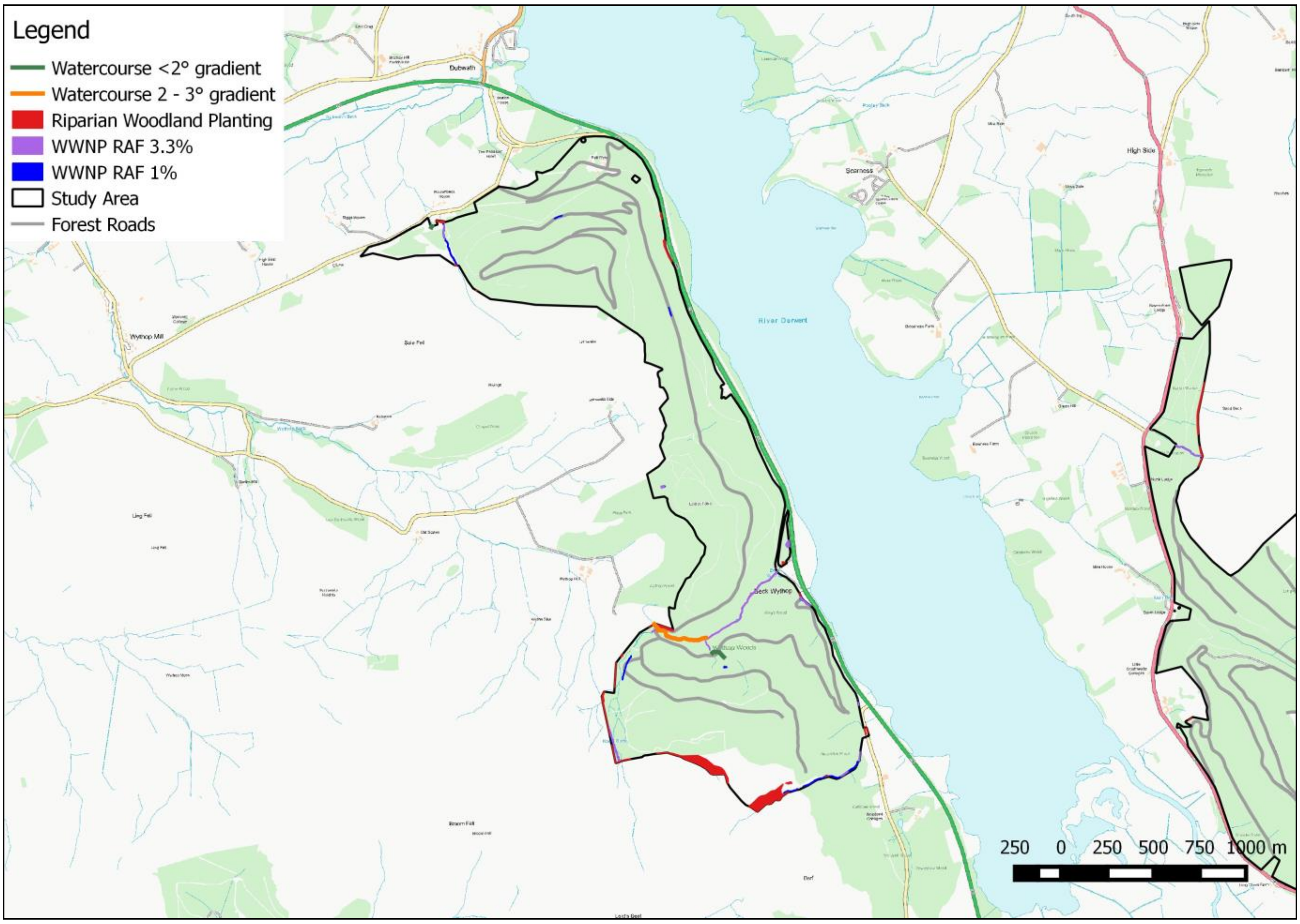

Figure 4 Overview of potential NFM features in the Wythop area

Dodd

The Dodd woodland area lies to the east of Bassenthwaite Lake, covering an area of 302ha. Similarly to the Wythop area on the western shores of Bassenthwaite Lake, the topography is generally very steep, and as such very few opportunities were identified for NFM feature creation. Some 0.5ha of land was identified mainly in the south of the study area as having potential for RAF creation to attenuate runoff during a 100 year rainfall while limited opportunities were identified for riparian woodland planting on the eastern boundary of the area.

Stream Slope (°)	Length of stream channel (m)	Potential number of LWS
< 2	0	0
2 - 3	0	0

Table 7 Extent of opportunities for the construction of LWS measures in the forest area

RAF Type	RAF 30 year Number of Features	Total potential storage area (m^2)	RAF 100 year Number of Features	Total potential storage area (m^2)
Gully Blocking	10	2,566	11	4,928
Run-off Attenuation	0	0	0	0

Table 8 Extent of opportunities for the construction of Runoff Attenuation Features (RAFs) in the forest area for a 1 in 30 and 100 year storm event.

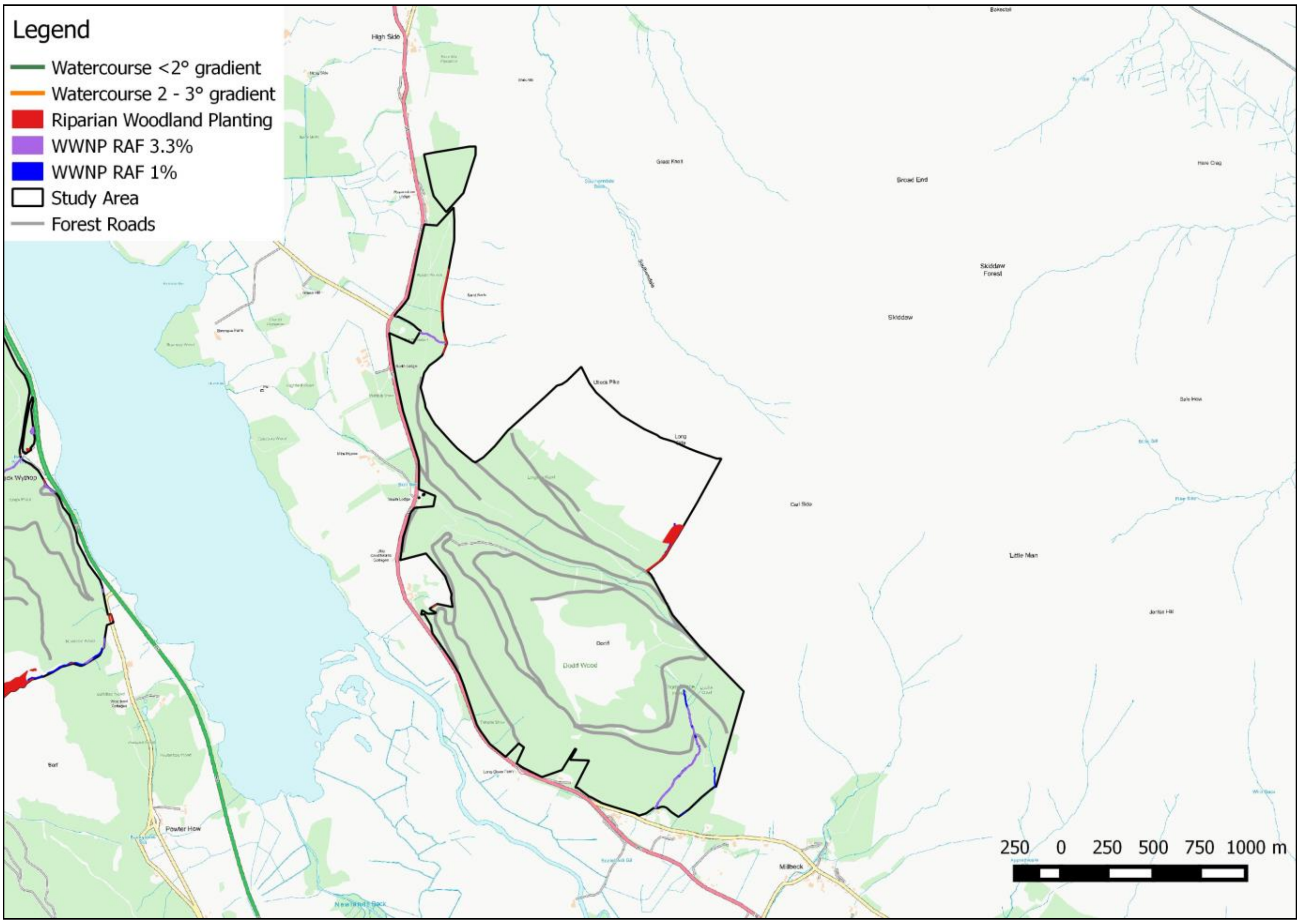

Figure 4 Overview of potential NFM features in the Dodd area

Matterdale

Matterdale forest drains an area of 292 ha in the upper reaches of the Trout Beck catchment (catchment area of 16.2km^2), which drains into the River Greta at Wolt Bridge before its confluence with the Derwent Water downstream of Keswick. A wide range of opportunities were identified in the area, mainly owing to its shallower topography, and watercourses with suitable gradient, and characteristics for implementing NFM features. NFM features implemented within the Matterdale forest area could potentially attenuate runoff from Matterdale Common which lies higher up in the catchment, reducing runoff at source.

Five main reaches were identified as being suitable for the creation of LWS measures in the forest, amounting to over 3.5km of watercourse.

A number of areas were highlighted for the creation of RAFs, potentially storing a significant volume of water during the 1 in 30 and 100 year rainfall events (an area over 1.3ha and 2.6ha respectively).

Small areas (totalling 0.4ha) along Thornsgill Beck (the main tributary running through Matterdale before its confluence with Trout Beck) were identified for potential floodplain woodland planting, with potential for wider catchment woodland planting adjacent to these (total of over 4ha). A further 3.4km of watercourse was identified for potential riparian woodland planting.

At over 18% of the total catchment area of Trout Beck, and over 38% of the catchment area just downstream of Matterdale forest, NFM measures could have a considerable effect on downstream flood risk reduction. The potential to create a broad range of NFM features within the Matterdale Forest area, along with new woodland planting opportunities to help alleviate flooding to downstream areas warrants further investigation into the feasibility of using the forest to enhance flood risk reduction both locally and in the wider catchment.

Stream Slope (°)	Length of stream channel (m)	Potential number of LWS
< 2	2,560	91
2 - 3	987	66

Table 9 Extent of opportunities for the construction of LWS measures in the forest area

RAF Type	RAF 30 year Number of Features	Total potential storage area (m²)	RAF 100 year Number of Features	Total potential storage area (m²)
Gully Blocking	2	364	1	144
Run-off Attenuation	38	12,749	48	26,014

Table 10 Extent of opportunities for the construction of Runoff Attenuation Features (RAFs) in the forest area for a 1 in 30 and 100 year storm event.

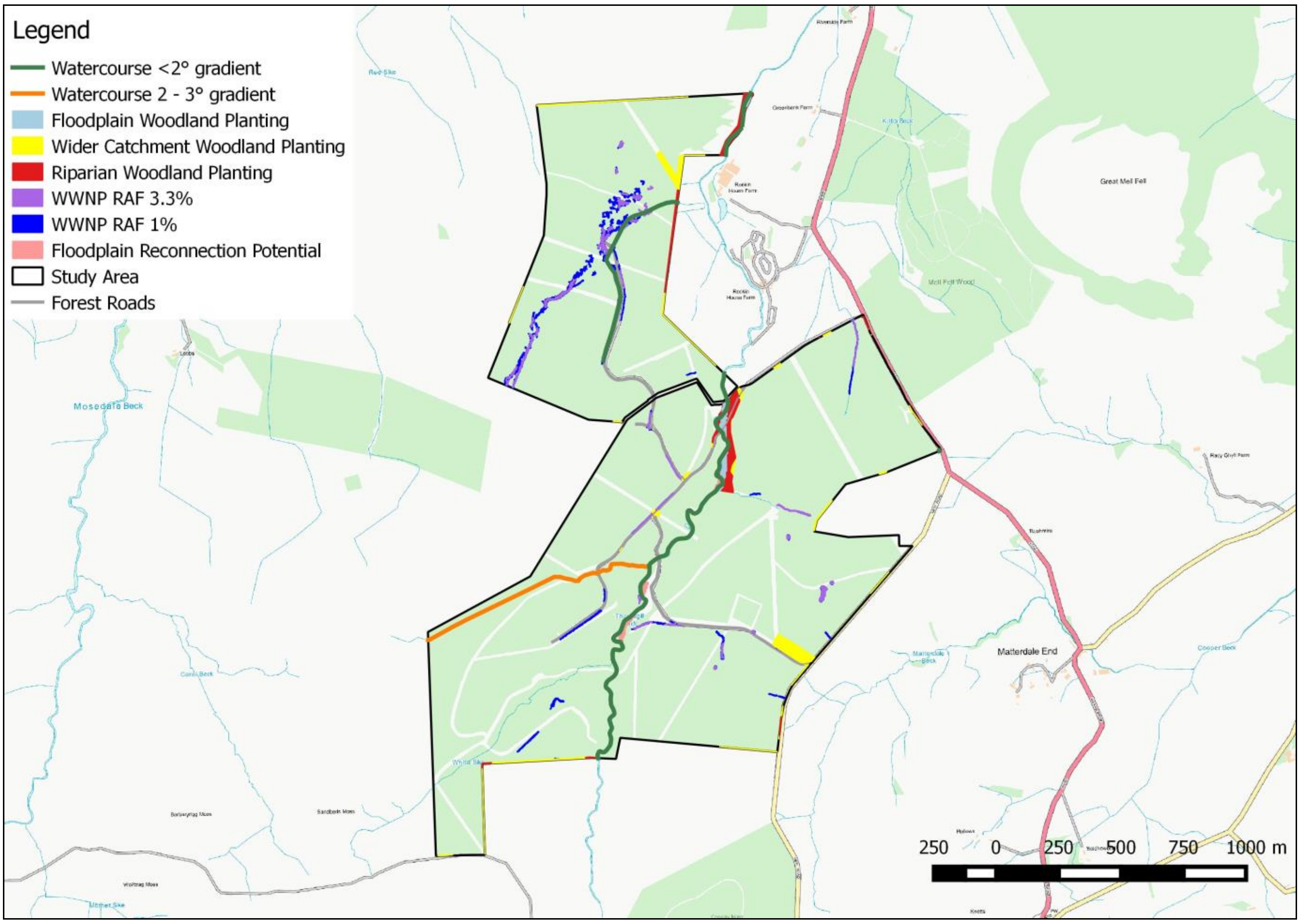

Figure 5 Overview of potential NFM features in the Matterdale area

Isel

Isel forest lies within the Blumer Beck catchment immediately upstream of its confluence with the Derwent at Isel. The woodland covers an area either side of the beck, amounting to over 90ha (almost 6% of the total catchment). Due to it's suitable gradient and relatively small channel dimensions, a significant proportion of the beck and its smaller tributaries (over 1.8km) running through the woodland area were identified as being suitable for LWS features.

Stream Slope (°)	Length of stream channel (m)	Potential number of LWS
< 2	1,558	47
2 - 3	315	21

Table 11 Extent of opportunities for the construction of LWS measures in the forest area

The potential for RAFs within the forest were more limited, however further investigation of the areas identified along a main tributary upstream of Isel is warranted as these may offer significant storage capacity for localised runoff.

RAF Type	RAF 30 year Number of Features	RAF 30 year Total potential storage area (m²)	RAF 100 year Number of Features	RAF 100 year Total potential storage area (m²)
Gully Blocking	2	524	5	888
Run-off Attenuation	1	356	3	412

Table 12 Extent of opportunities for the construction of Runoff Attenuation Features (RAFs) in the forest area for a 1 in 30 and 100 year storm event.

No additional woodland planting opportunities were identified for flood risk reduction in the existing study area, however over 1.6km of watercourse was identified for floodplain reconnection potential.

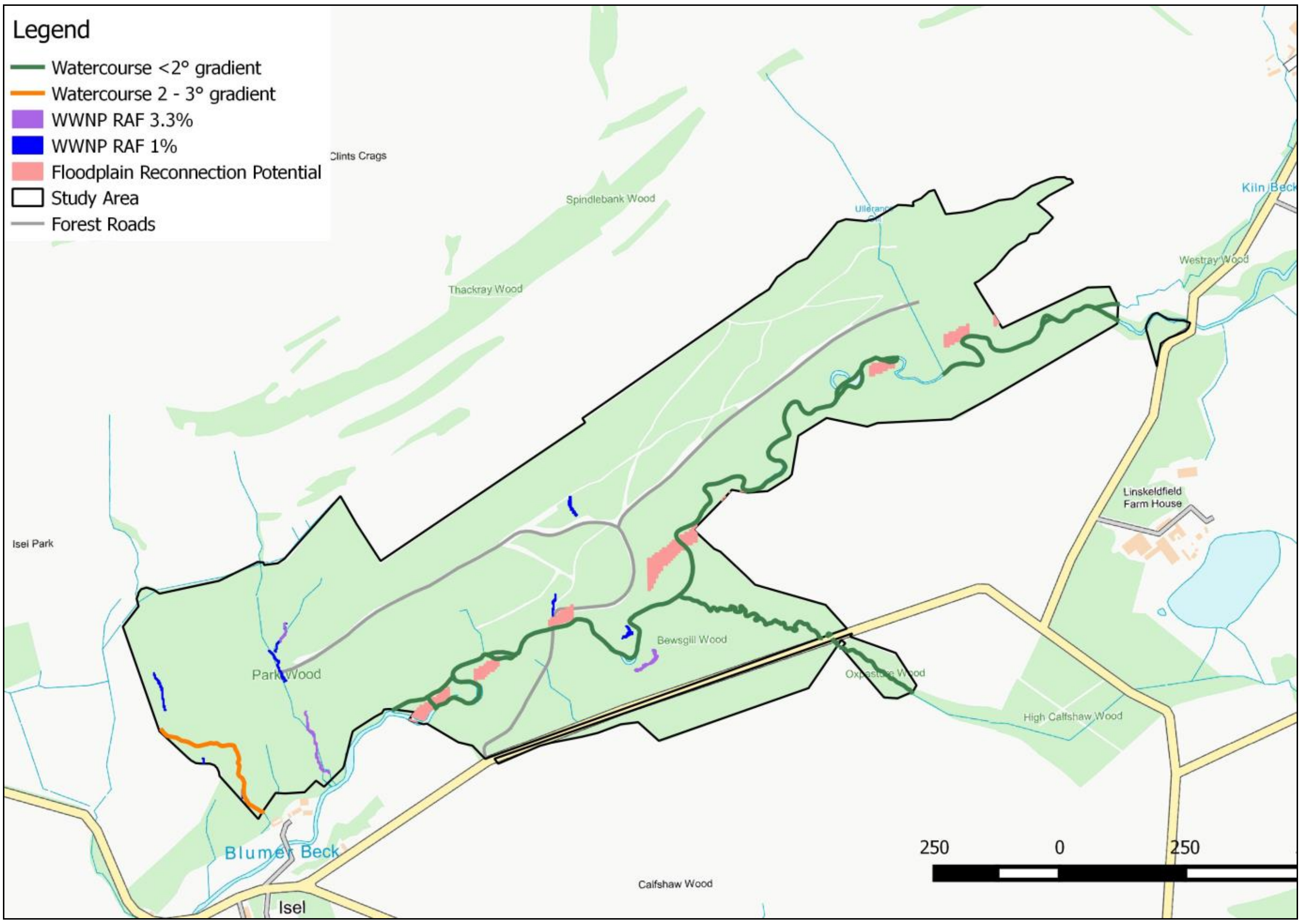

Figure 6 Overview of potential NFM features in the Isel area

5. Conclusions

A desk-based GIS exercise was carried out by Forest Research for Forestry England in order to identify and target the most effective locations and assess the potential scale of Natural Flood Management opportunities in six forest areas (some 1,259ha of forest) within the Derwent Water catchment.

The main NFM opportunities investigated, that could help reduce downstream flood risk, were:

- New floodplain woodland planting
- New wider catchment woodland planting
- New riparian woodland planting
- Floodplain reconnection potential
- Runoff Attenutation Features
- Construction of Leaky Woody Structures

Opportunities were found in all six areas. Matterdale proved to have the most potential over a wide range of NFM measures, including new woodland planting areas to help reduce runoff, with a significant number of LWS building potential and runoff attenuation within the forest area. Isel and Howgill & Messengermire also have the potential for a significant number of LWS features as well as opportunities for floodplain reconnection.

	Howgill & Messengermire	Setmurthy	Wythop	Dodd	Matterdale	Isel
Floodplain Woodland Potential (ha)	0	0	0	0	0.44	0
Wider Catchment Woodland Potential (ha)	0	0	0	0	4.14	0
Riparian Woodland Potential (km)	0	0	1.61	0.75	3.44	0
Floodplain Reconnection Potential (km)	1.86	0	0	0	0.07	1.64
Runoff Attenuation 1% AEP (ha)	1.21	0.48	0.57	0.49	2.62	0.13
Runoff Attenuation 3.3% AEP (ha)	0.73	0.26	0.57	0.26	1.31	0.09
LWS Potential (km)						
Most suitable (<2* gradient)	0.44	0.22	0.08	0	2.56	1.56
Suitable (2 - 3* gradient)	0.47	0.60	0.33	0	0.99	0.31
Potential No. of LWS						
Most suitable (<2* gradient)	29	15	5	0	91	47
Suitable (2 - 3* gradient)	21	40	15	0	66	21

Table 13 Summary of all NFM opportunities in each study area.

It is recommended that the results and maps of this exercise be used to ground-truth the sites identified as potential areas for implementing NFM in order to assess the scale and suitability of the sites for any planned work in future, especially within the Matterdale, Isel and Howgill & Messengermire areas.

6. References

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