Land use planning in urban areas – towards an ecosystems approach

Chapters 7 and 8 standalone document of all Figures

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Figures from Chapter 7

Developing new spatial models for urban planning: how do we know where urban ecosystem services are required?

Figure 7.1 Overall structure of the flood control model

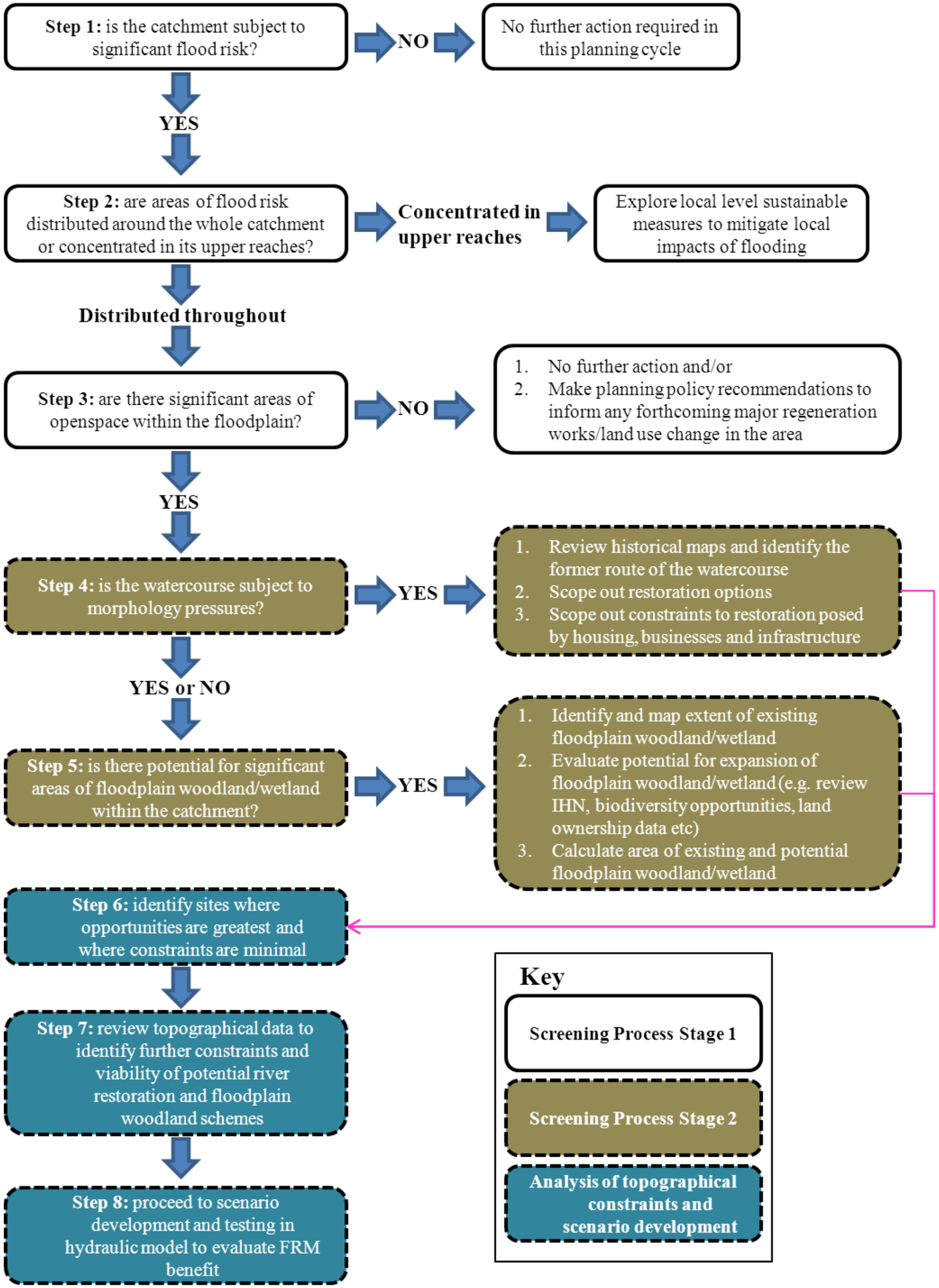
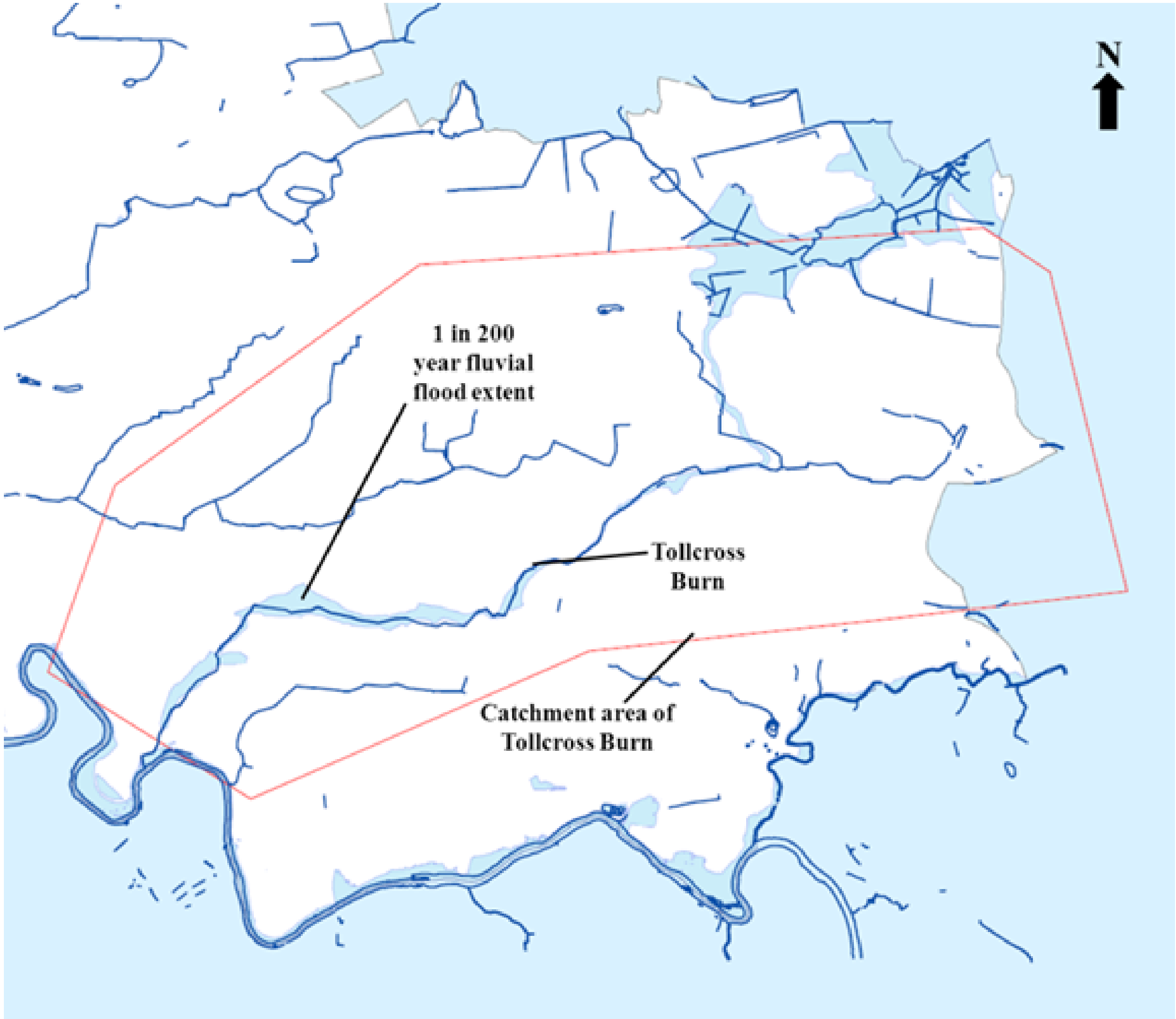


Figure 7.2 Flood control model Step 1, Tasks 1.1 and 1.2 – example model output

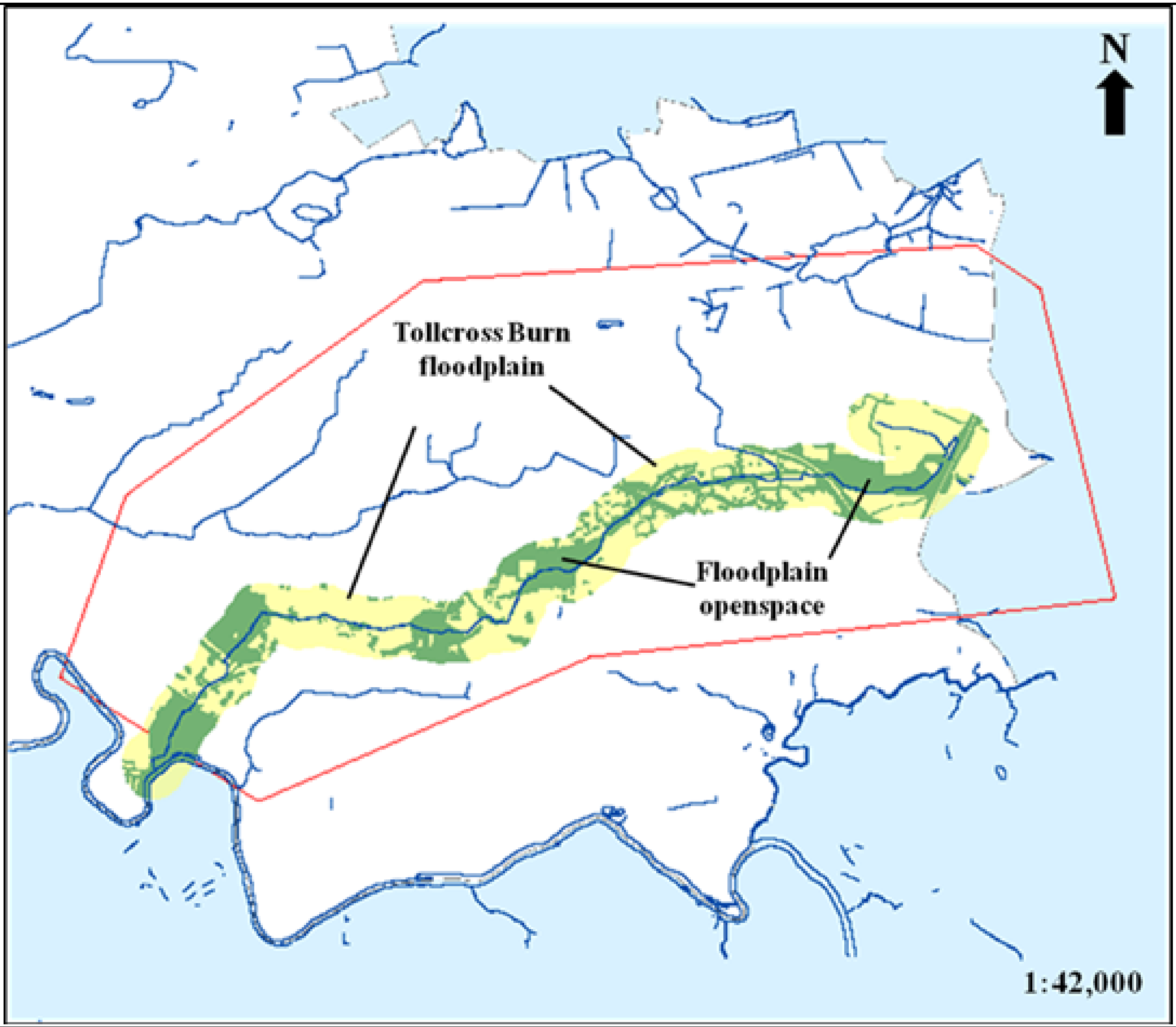


Summary details of example output	
Model	Flood control
Step	1
Step title	Is the catchment subject to significant flood risk?
Tasks	1.1 and 1.2

Note: Figure also available within standalone CD-ROM.

Notes: This example flood control model above shows the hydrology and fluvial flood extent of the Tollcross Burn catchment.

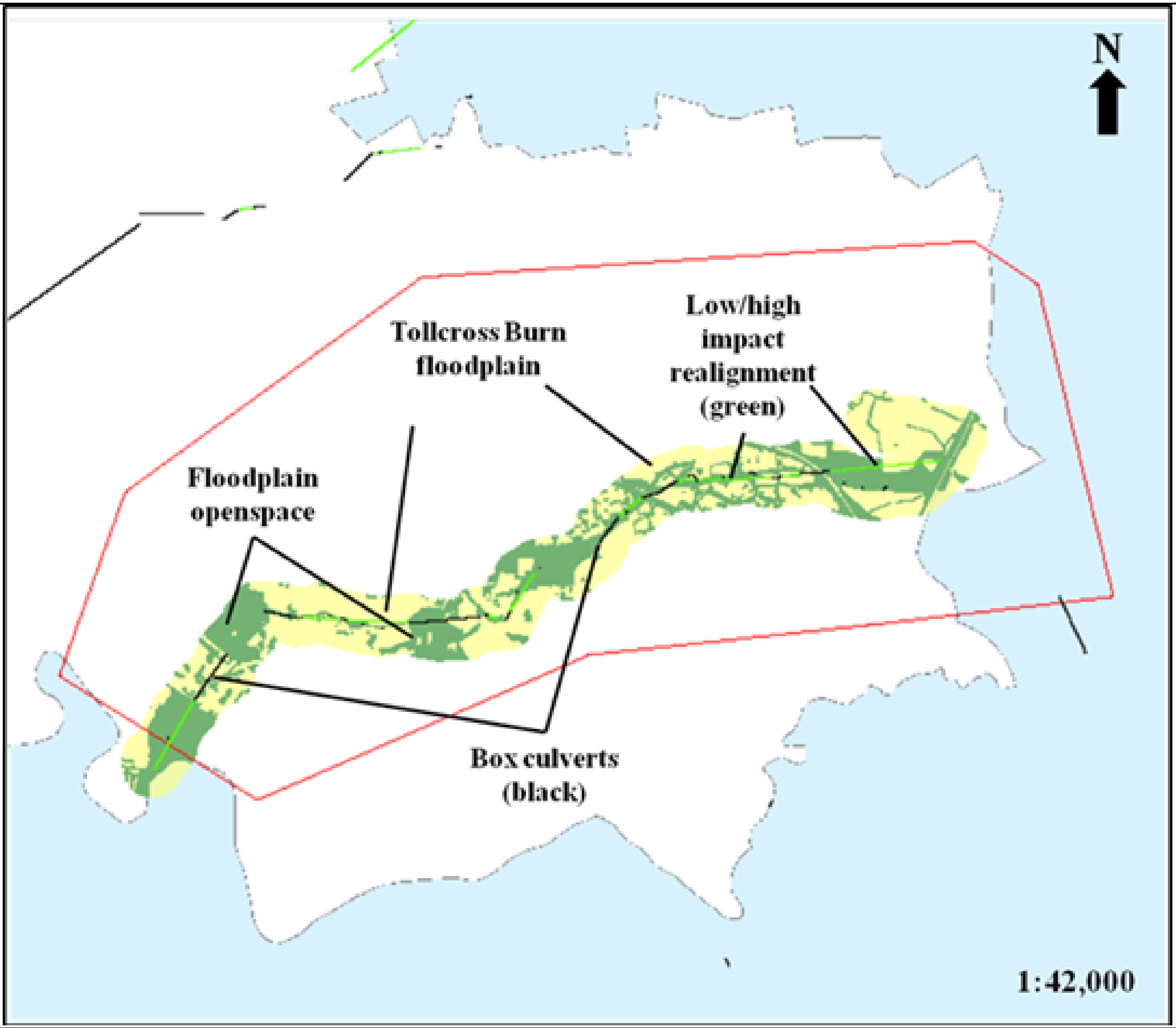
Figure 7.3 Flood control model Step 3 – example model output



Summary details of example output	
Model	Flood control
Step	3
Step title	Are there significant areas of openspace within the floodplain?
Task	N/A
Note: Figure also available within standalone CD-ROM.	

Notes: This example flood control model output shows the modelled floodplain for the Tollcross Burn (the pale yellow polygon) and areas of floodplain openspace (green polygons).

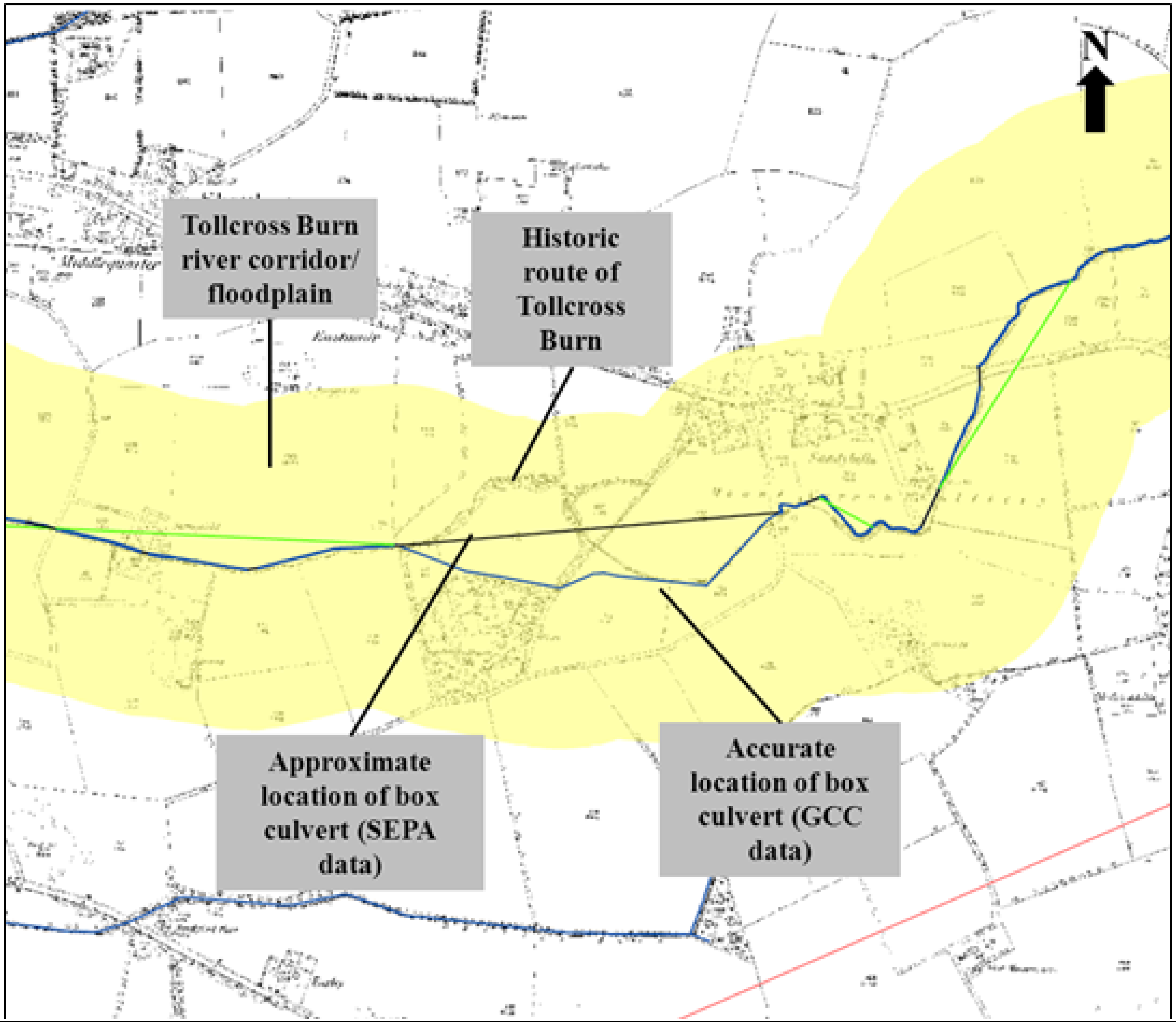
Figure 7.4 Flood control model Step 4, Task 4.1 – example model output



Summary details of example output	
Model	Flood control
Step	4
Step title	Is the watercourse subject to morphology pressures?
Task	4.1
Note: Figure also available within standalone CD-ROM.	

Notes: This example flood control model output shows floodplain openspace and the approximate location of culvert pressures (black lines) and realignment pressures (bright green lines).

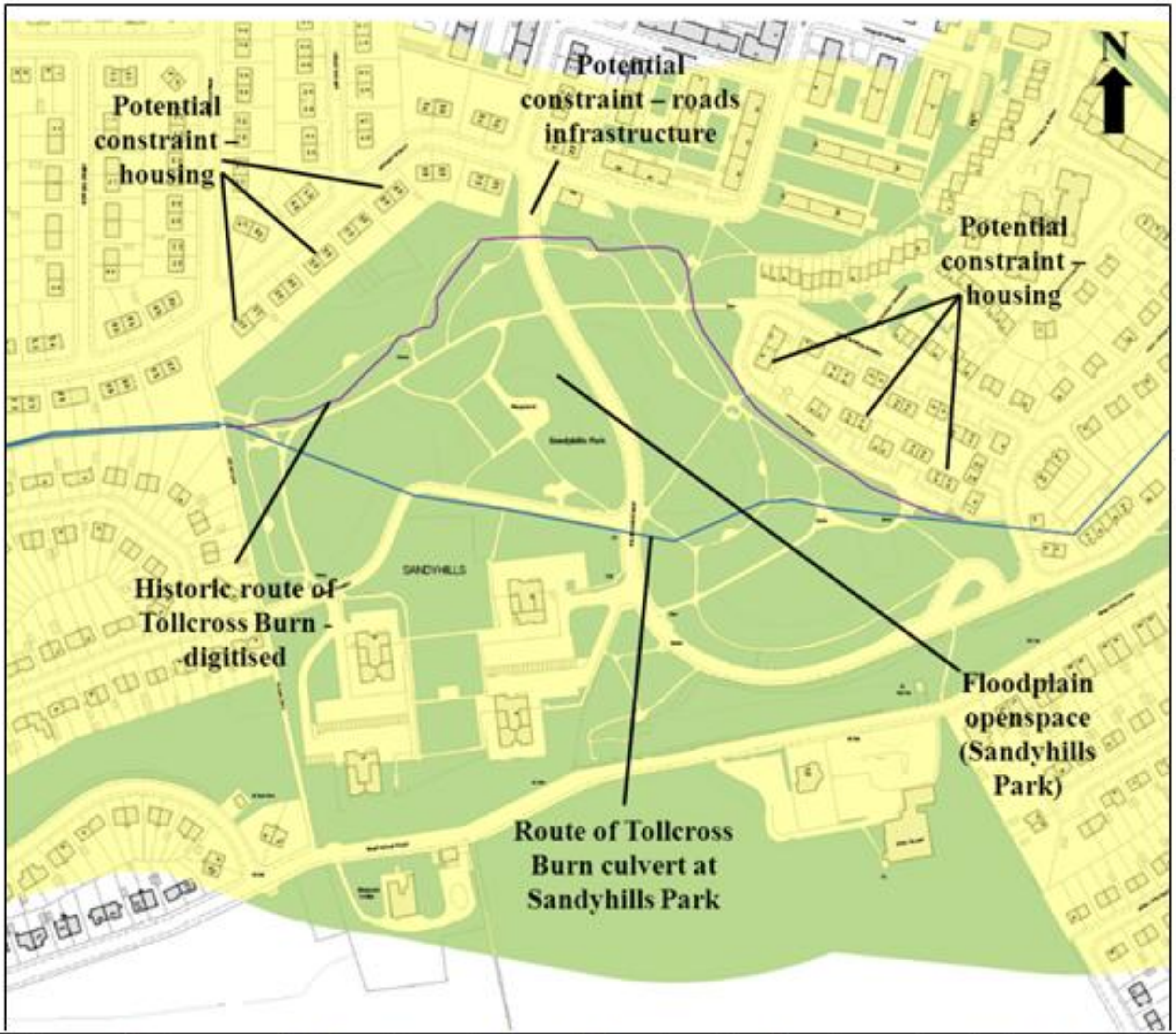
Figure 7.5 Flood control model Step 4, Task 4.2 – example model output



Summary details of example output	
Model	Flood control
Step	4
Step title	Is the watercourse subject to morphology pressures?
Task	4.2
Note: Figure also available within standalone CD-ROM.	

Notes: This example flood control model output shows the location of a specific culverted reach of the watercourse under investigation relative to 1860s base mapping. Note that the 1860s base mapping shows the historic route of the watercourse including detail of a significant meander to the north that has been straightened out by the modern culvert.

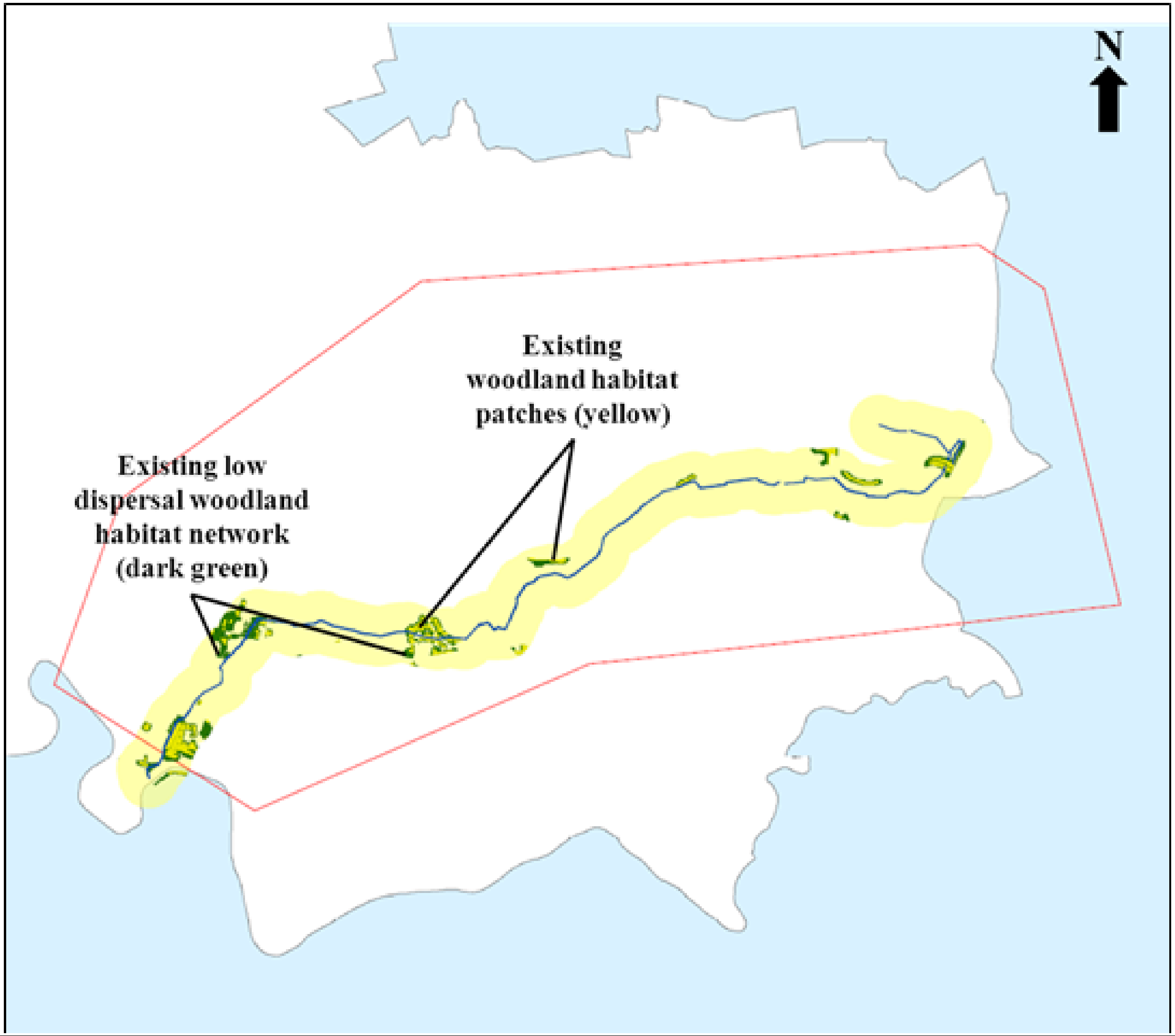
Figure 7.6 Flood control model Step 4, Task 4.3 – example model output



Summary details of example output	
Model	Flood control
Step	4
Step title	Is the watercourse subject to morphology pressures?
Task	4.3
Note: Figure also available within standalone CD-ROM.	

Notes: This example flood control model output indicates potential restoration constraints were the watercourse to be restored to its original route i.e. reinstating the sizeable meander to the north. Under this restoration scenario, key constraints are housing and roads infrastructure.

Figure 7.7 Flood control model Step 5, Task 5.2 habitat patches and habitat networks in the floodplain – example model output



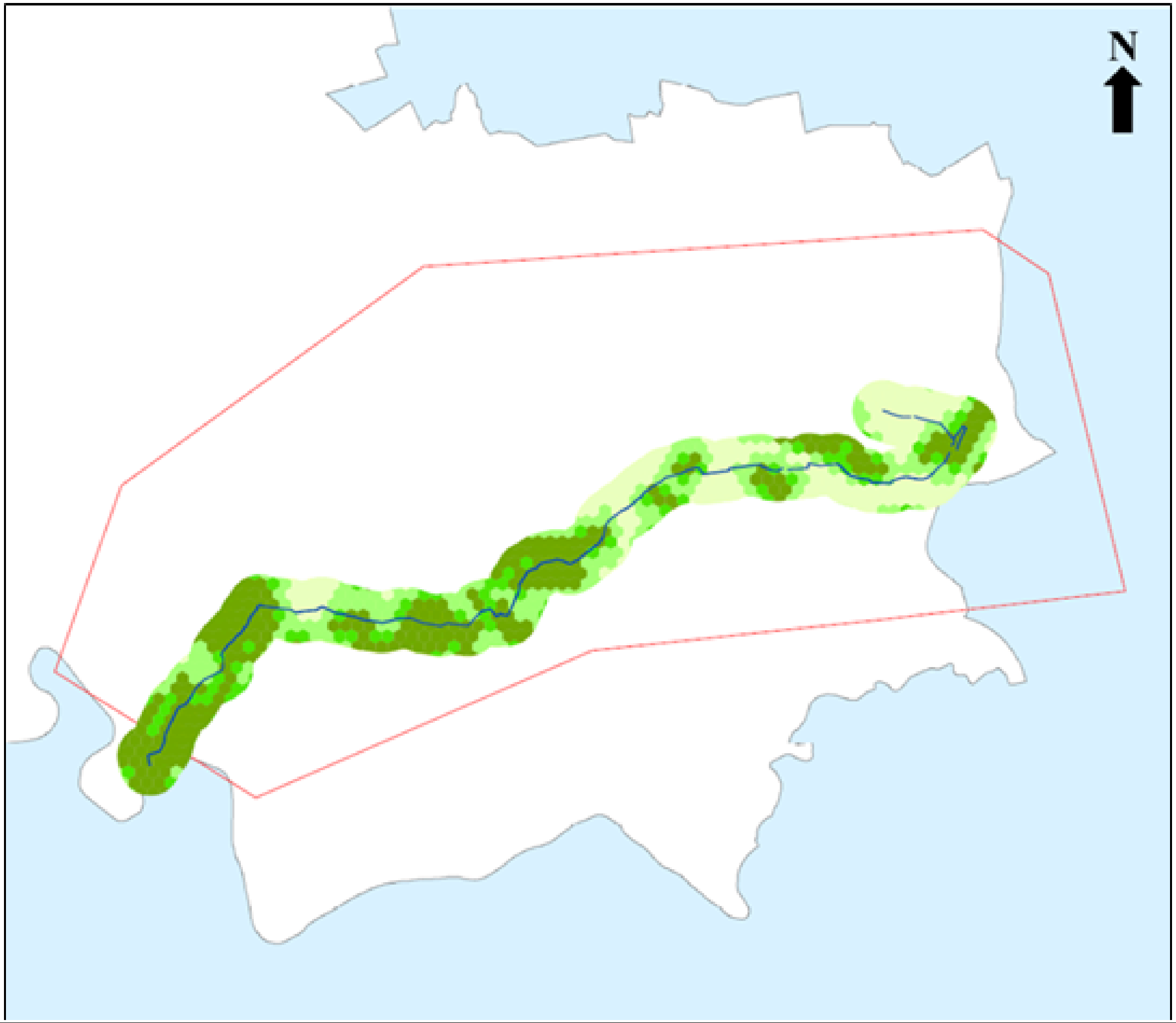
Summary details of example output

Model	Flood control
Step	5
Step title	Is there potential for significant areas of floodplain woodland and wetland?
Task	5.2

Note: Figure also available within standalone CD-ROM.

Notes: This example flood control model output shows the extent and distribution of existing floodplain woodland habitat patches (yellow polygons) and habitat networks (green polygons) within the Tollcross Burn catchment.

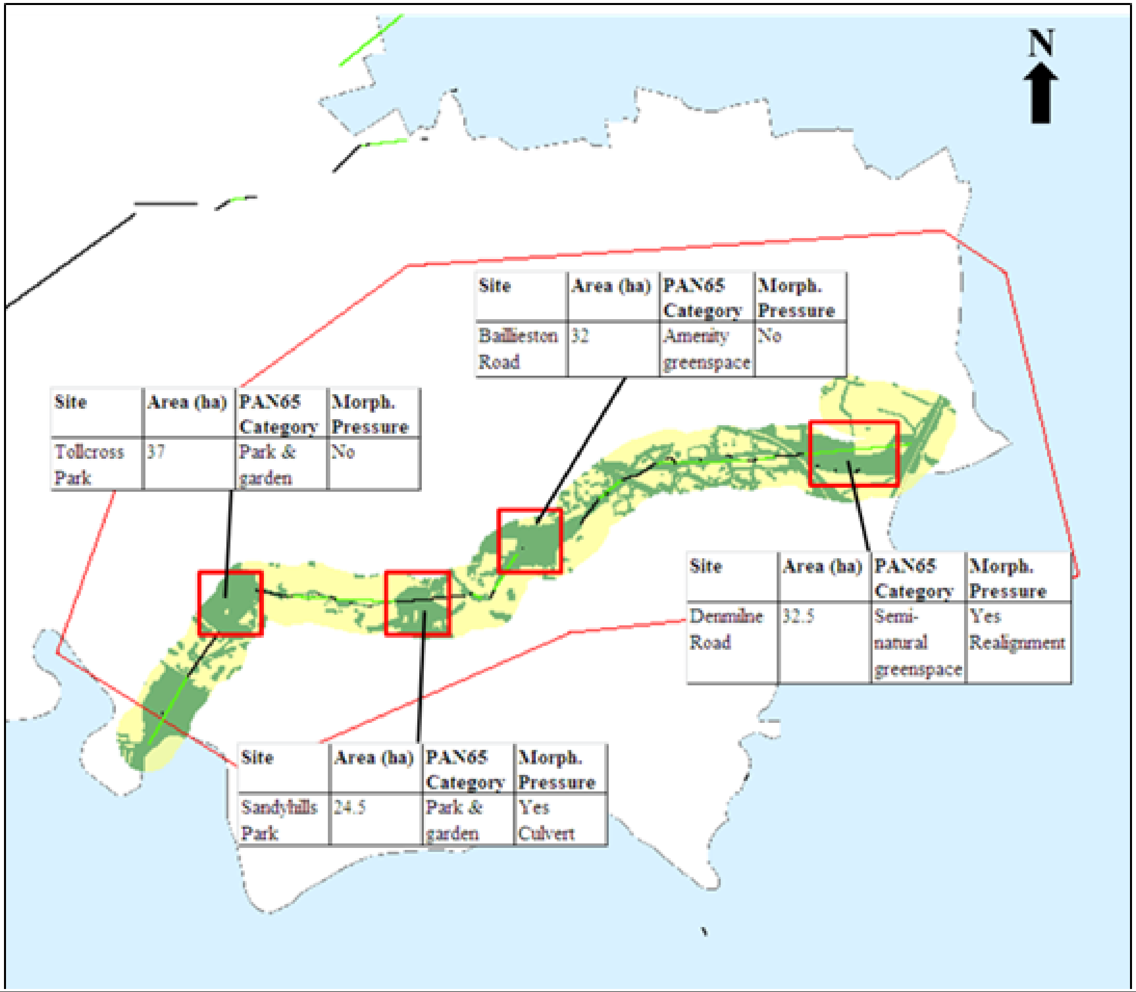
Figure 7.8 Flood control model Step 5, Task 5.2 floodplain woodland opportunity areas – example model output



Summary details of example output	
Model	Flood control
Step	5
Step title	Is there potential for significant areas of floodplain woodland and wetland?
Task	5.2
Note: Figure also available within standalone CD-ROM.	

Notes: Further information on the biodiversity opportunities data is available at section 2.4.2. In summary however, darker green areas indicate land with greater ecological potential to support the establishment of broadleaved woodland habitat. The biodiversity opportunities model developed by Forest Research (Smith et al, 2008) underpinning this data considers a range of parameters including existing land use/land cover and the ecological connectivity afforded by existing habitat patches.

Figure 7.9 Flood control model Step 6, Task 6.1 – example model output

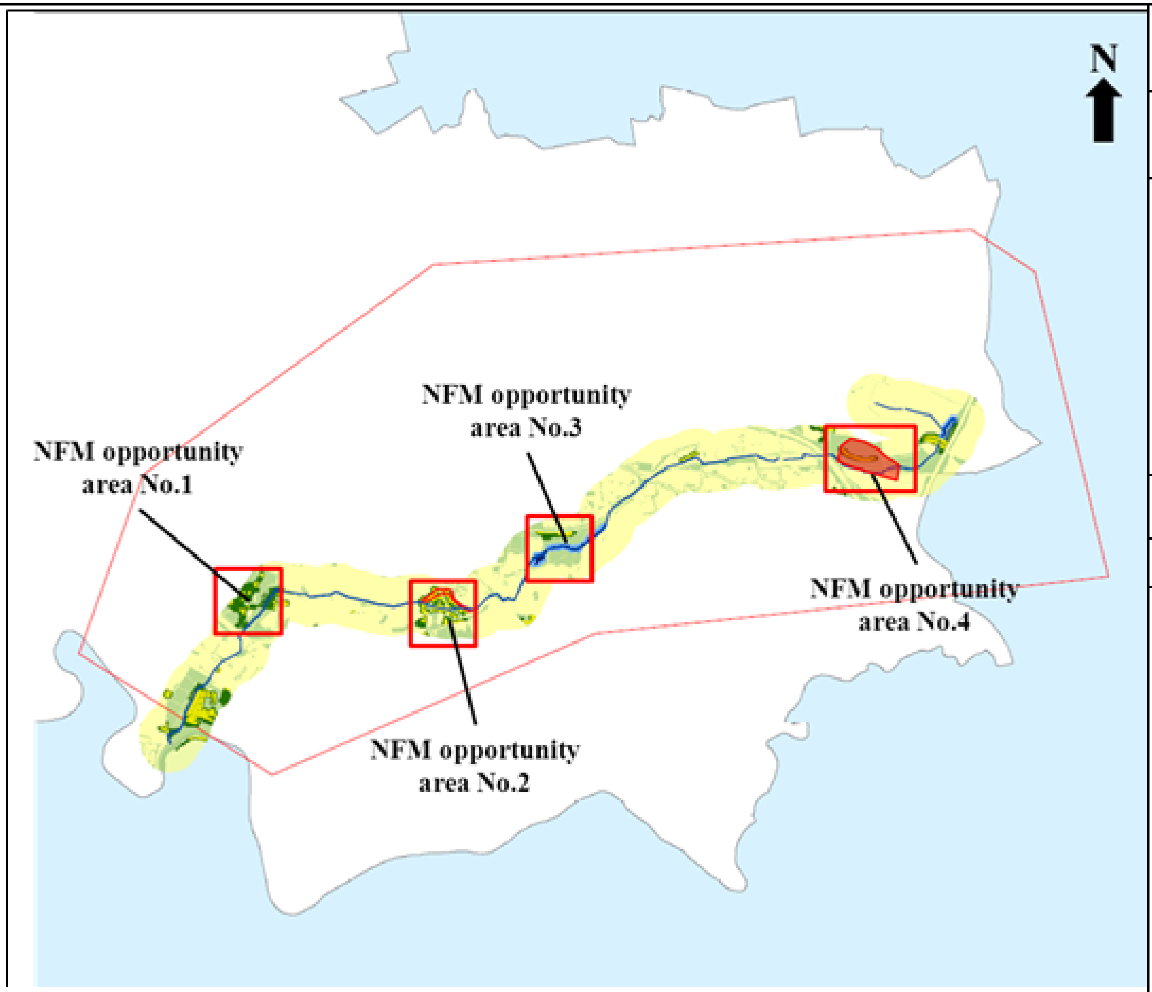


Summary details of example output	
Model	Flood control
Step	6
Step title	Identify sites where opportunity is greatest and constraint minimal
Task	6.1

Note: Figure also available within standalone CD-ROM.

Notes: This example output shows floodplain openspace sites that have been selected for further analysis due to their size (ha), existing land use and existing hydrological connection to the study watercourse. Sites where the watercourse is subject to a morphology pressure are considered 'high cost' as some degree of river restoration activity is likely to be required. Sites without morphology pressures are considered 'low cost' as key NFM measures (e.g. floodplain woodland) can be progressed without the need for any river restoration activity.

Figure 7.10 Flood control model Step 6, Task 6.2 – example model output



Summary details of example output	
Model	Flood control
Step title	Identify sites where opportunity is greatest and constraint minimal
Step	6
Task	6.2

Note: Figure also available within standalone CD-ROM.

This example output illustrates the use of combined flood control model outputs from Steps 3-5 to identify potential NFM opportunities for scoped in floodplain openspace sites from Task 6.1. The very light green polygons are floodplain openspace sites, the red polygons are areas that may be available for floodplain reinstatement following river restoration, the yellow and green polygons are woodland habitat patches/networks and the dark/pale blue polygons are wetland habitat patches/networks.

Figure 7.11 Flood control model Step 6, Task 6.4 – example multi criteria analysis (MCA): low cost site/weighting scenario 1

	LH Matrix: MCA model				RH Matrix: User defined performance and cost scores		
Measure	1. Likely number/total area of potential sites	2. Likely cost of intervention	3. Likely impact on Manning's n/FRM benefit		1. Likely number/total area of potential sites	2. Likely cost of intervention	3. Likely impact on Manning's n/FRM benefit
1. leave site as is and zone in LDP as a flood storage area	0.15	-0.06	0.14	**0.23**	High	Low	Low
2. engineering/bunding of the site	0.09	-0.11	0.42	0.40	Med	Med	Med
3. floodplain woodland expansion	0.09	-0.06	0.42	0.45	Med	Low	Med
4. floodplain wetland expansion	0.03	-0.11	0.42	0.34	Low	Med	Med
5. fully integrated NFM scheme	0.06	-0.11	0.60	**0.54**	Low-Med	Med	Med-High

Performance and cost scores can be altered for specific projects

Weighting

1. number/area of sites	0.15
2. cost	0.15
3. FRM impact	0.70

Weightings can be altered for specific projects
Note1: weightings should ideally be agreed through a stakeholder process
Note2: the sum of the combined weightings should be no more than 1

Performance score

Low	0.20
Low-Med	0.40
Med	0.60
Med-High	0.85
High	1.00

Cost score

Low	-0.40
Med	-0.75
High	-1.00

Figure 7.12 Flood control model Step 6, Task 6.4 – example multi criteria analysis (MCA): low cost site/weighting scenario 2

	LH Matrix: MCA model				RH Matrix: User defined performance and cost scores		
Measure	1. Likely number/total area of potential sites	2. Likely cost of intervention	3. Likely impact on Manning's n/FRM benefi		1. Likely number/total area of potential sites	2. Likely cost of intervention	3. Likely impact on Manning's n/FRM benefi
1. leave site as is and zone in LDP as a flood storage area	0.10	-0.24	0.06	-0.08	High	Low	Low
2. engineering/bunding of the site	0.06	-0.45	0.18	-0.21	Med	Med	Med
3. floodplain woodland expansion	0.06	-0.24	0.18	**0.00**	Med	Low	Med
4. floodplain wetland expansion	0.02	-0.45	0.18	**-0.25**	Low	Med	Med
5. fully integrated natural FRM scheme	0.04	-0.45	0.26	-0.16	Low-Med	Med	Med-High

Performance and cost scores can be altered for specific projects

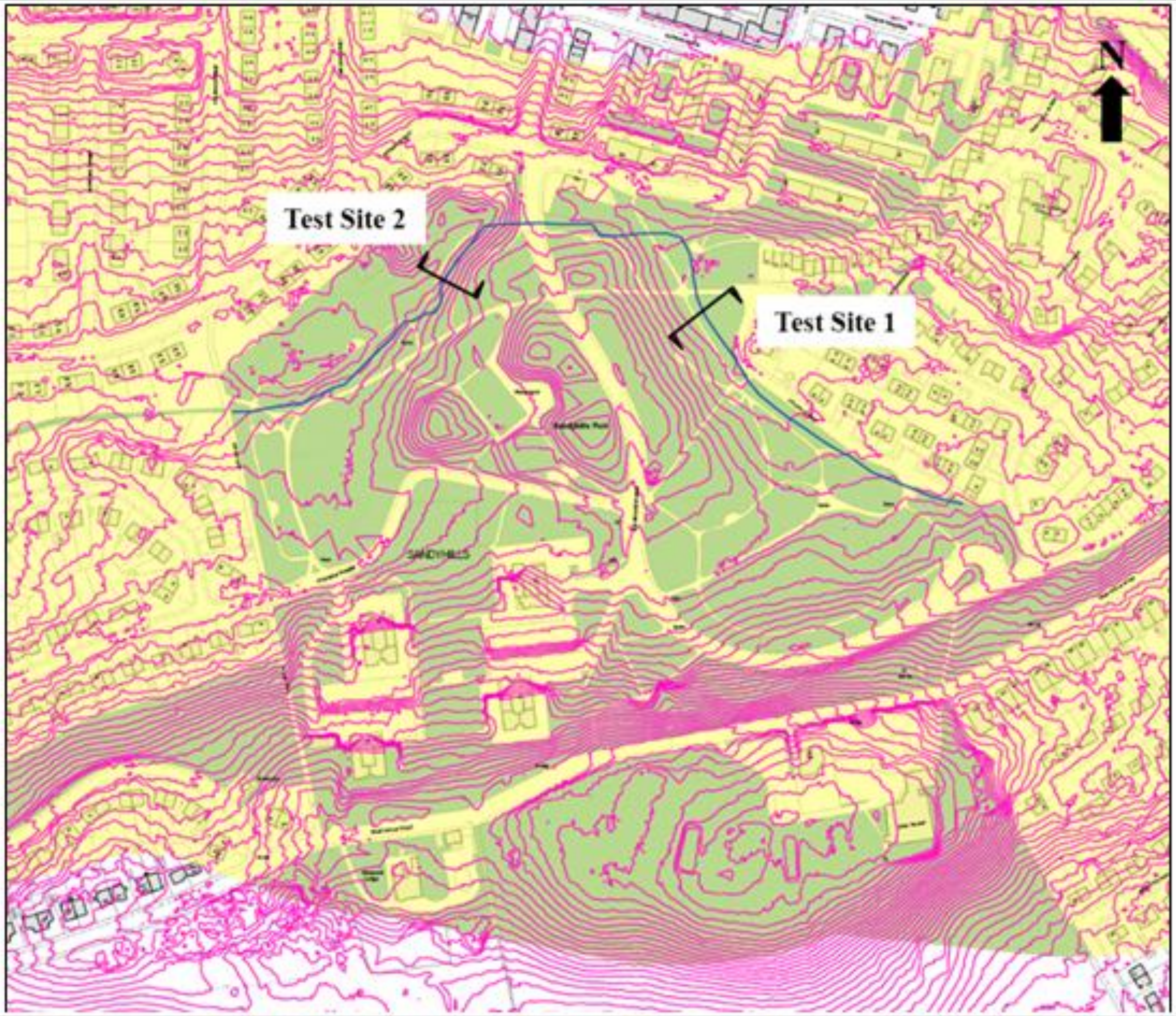
Weighting	
1. number/area of sites	0.10
2. cost	0.60
3. FRM impact	0.30

Weightings can be altered for specific projects
Note1: weightings should ideally be agreed through a stakeholder process
Note2: the sum of the combined weightings should be no more than 1

Performance score	
Low	0.20
Low-Med	0.40
Med	0.60
Med-High	0.85
High	1.00

Cost score	
Low	-0.40
Med	-0.75
High	-1.00

Figure 7.13 Flood control model Step 7, Task 7.1 – example model output



Summary details of example output	
Model	Flood control
Step	7
Step title	Topo. Analysis to identify further constraints and viability of measures
Task	7.1
Note: Figure also available within standalone CD-ROM.	

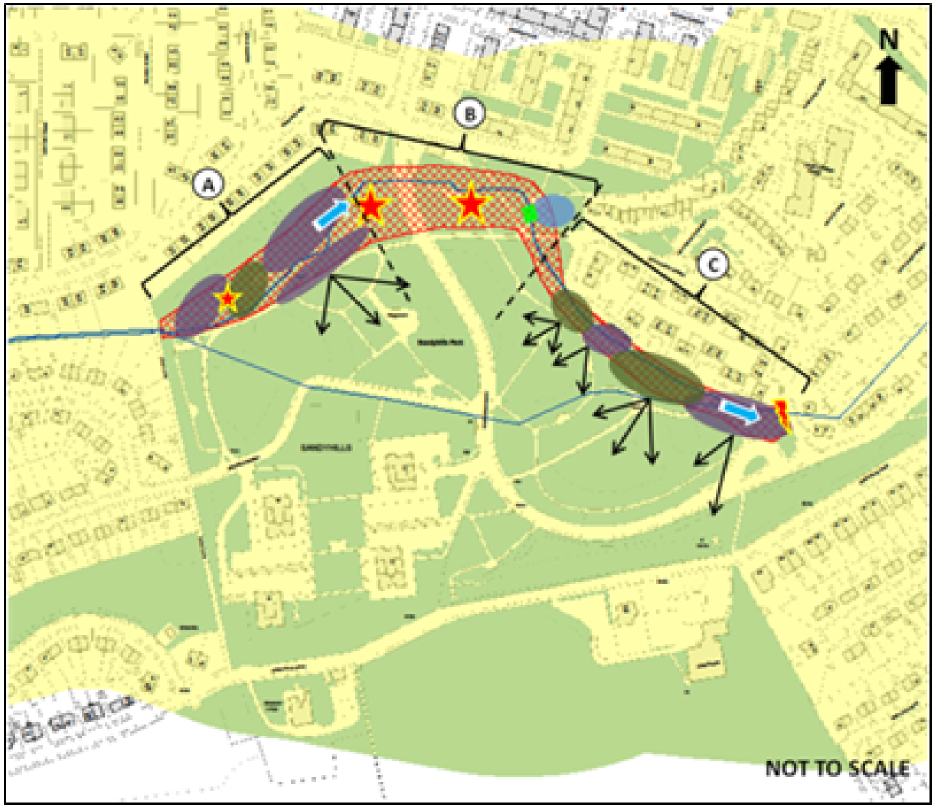
Notes: The figure above shows Sandyhills Park – NFM opportunity area No.2 from Step 6. It is a 'high cost' site. The pink lines are topographical contours at 0.5m intervals. The blue line is the proposed route for restoring the watercourse (as identified at Step 4) which is culverted along this stretch. The black lines indicate the locations of proposed floodplain gradient test sites – i.e. the two steepest sections of the *proposed* floodplain within this NFM opportunity area.

Figure 7.14 Flood control model Step 8, Task 8.3 – example model output

Summary details of example output	
Model	Flood control
Step	8
Step title	Scenario development
Task	8.3
Note: Figure also available within standalone CD-ROM.	

Notes: The figure above details locations at NFM opportunity area No.2 (Sandyhills Park) where earthworks *may* be required to realise a desired floodplain profile. Proposed earthworks denoted with the number '1' are likely to be essential due to floodplain gradients at these locations. Proposed earthworks denoted with the number '2' are desirable but non-essential.

Figure 7.15 Flood control model Step 8, Task 8.6 – typical model output



Summary details of example output	
Model	Flood control
Step	8
Step title	Scenario development
Task	8.6

KEY

- (A) FRM zone – FRM benefit provided by floodplain woodland and two stage channel
- (B) FRM & Amenity zone – FRM benefit provided by two stage channel
- (C) FRM zone – FRM benefit provided primarily by floodplain woodland
- Floodplain scrape
- Spillway
- Anticipated backing up of flood waters caused by floodplain woodland
- Potential increased flood risk due to flood waters backing-up
- Anticipated area of major earthworks to achieve required floodplain profile
- Anticipated area of minor earthworks to achieve required floodplain profile
- Woodland establishment within existing woodland habitat network
- Interplanting and restocking of existing woodland habitat patches
- Integration of new/enhanced woodland with adjacent woodland habitat networks

Notes: The proposals on Figure 5.15 have been informed by the strategies for individual NFM measures detailed above in section 5.1.8. The broad locations for major and minor earthworks and the proposed floodplain scrape have been informed by the outline geomorphology and land engineering strategy plan (see Figure 5.14 and Appendix 4). The proposals for floodplain woodland management and establishment have been informed by the floodplain woodland enhancement strategy plan (see Appendix 4). Figure also available within standalone CD-ROM.

Figure 7.16 Overall structure of the hydrological cycle model

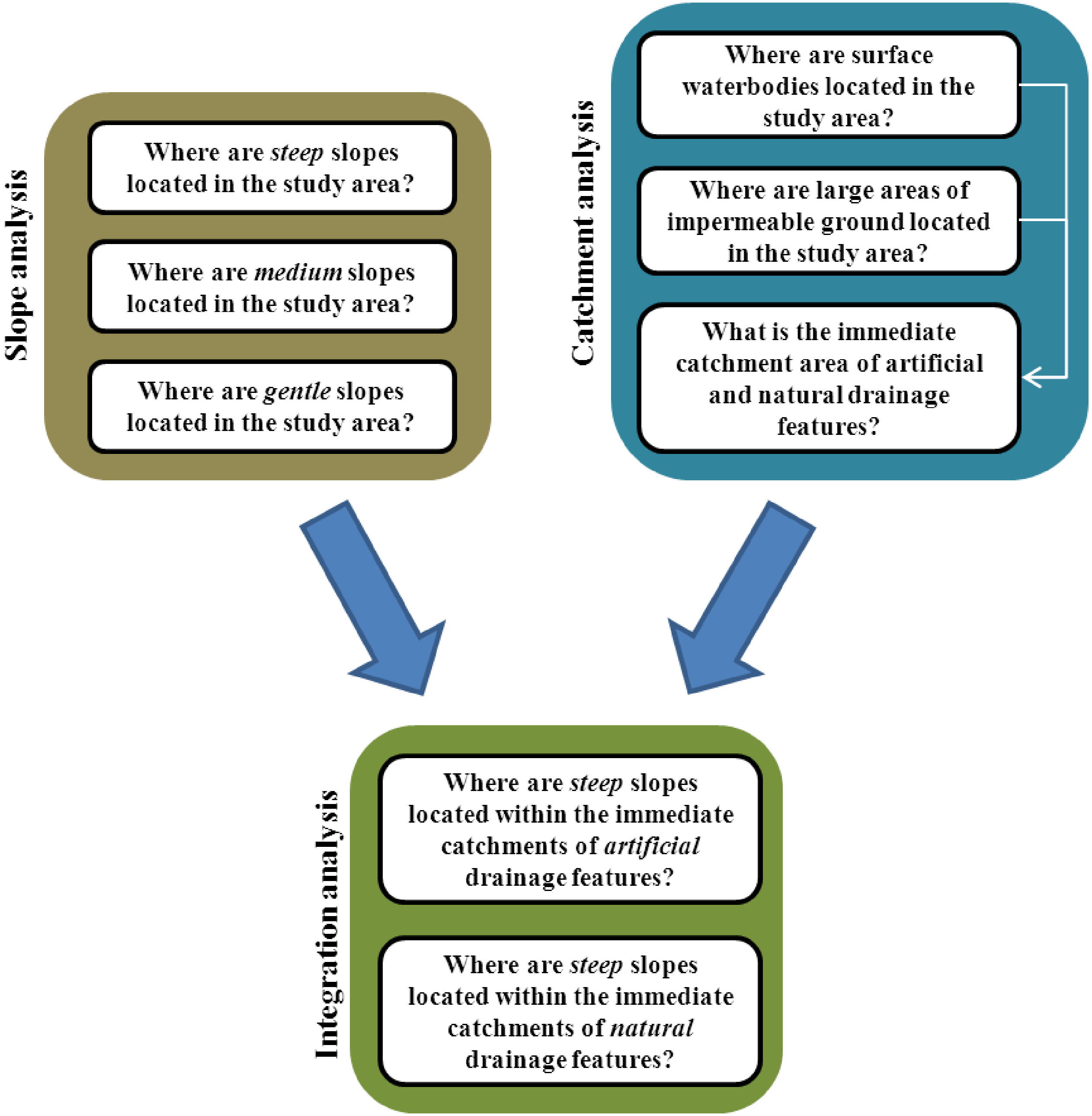


Figure 7.17 Hydrological cycle model – Stage 1 geoprocessing operations (Steps 1 – 8)

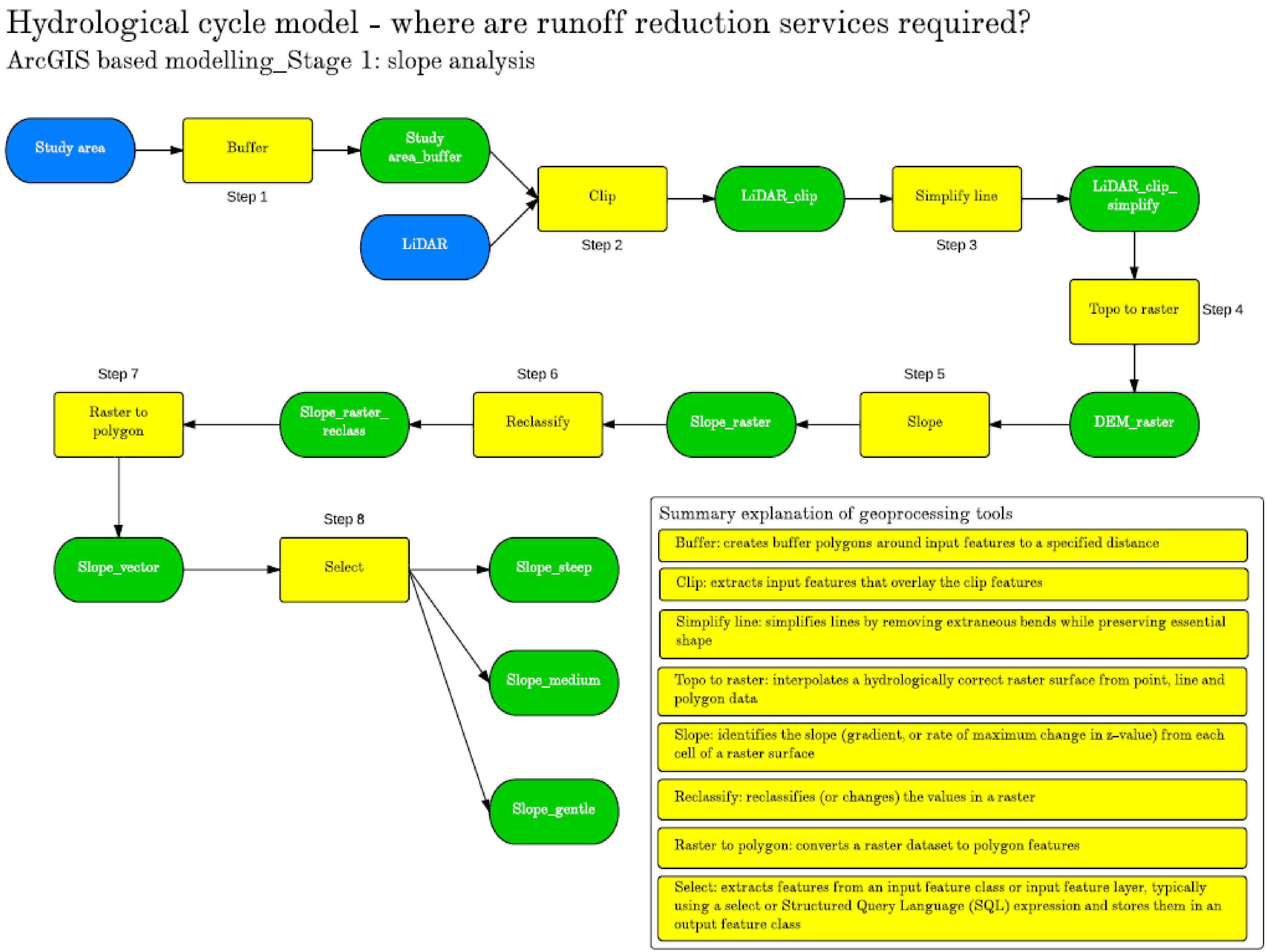


Figure 7.18 Hydrological cycle model Steps 2 and 3 – example outputs

Model	Hydrological cycle model	Model	Hydrological cycle model
Step	2	Step	3
Step title	Clip the topographical contour dataset to the study area	Step title	Simplify the topographical contour dataset
Notes: The example output shows a LiDAR topographical contours dataset at 5m intervals (the pink lines) clipped to the study area. In this example, the study area is defined on the basis of an administrative boundary – the Castlemilk Regeneration Area in southeast Glasgow. For large study areas, it may be necessary to stitch several topographical contour datasets together.		**Notes:** The example output shows the LiDAR topographical contours dataset from Step 2 (see opposite) after a simplify line operation has been undertaken. Simplify line removes extraneous bends whilst maintaining the essential shape. The intention is to reduce the granularity of the dataset to ensure that subsequent steps of the slope analysis are manageable, even with limited computer processing power.	

Figure 7.19 Hydrological cycle model Steps 4 and 5 – example outputs

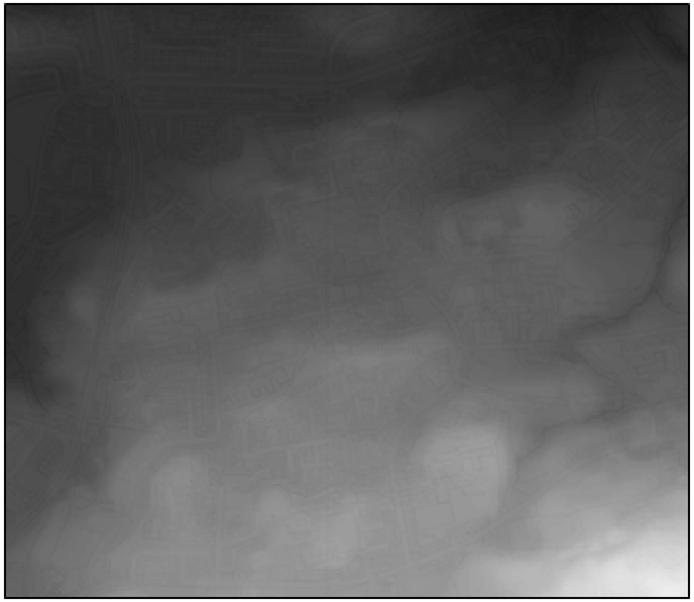
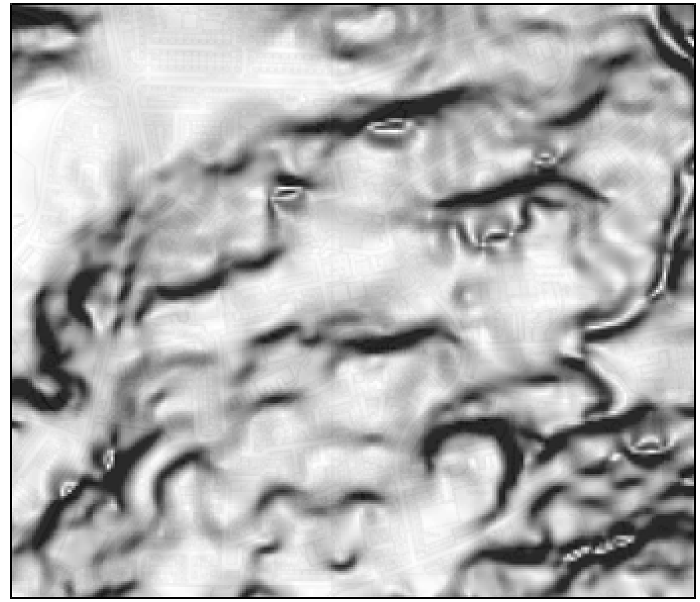
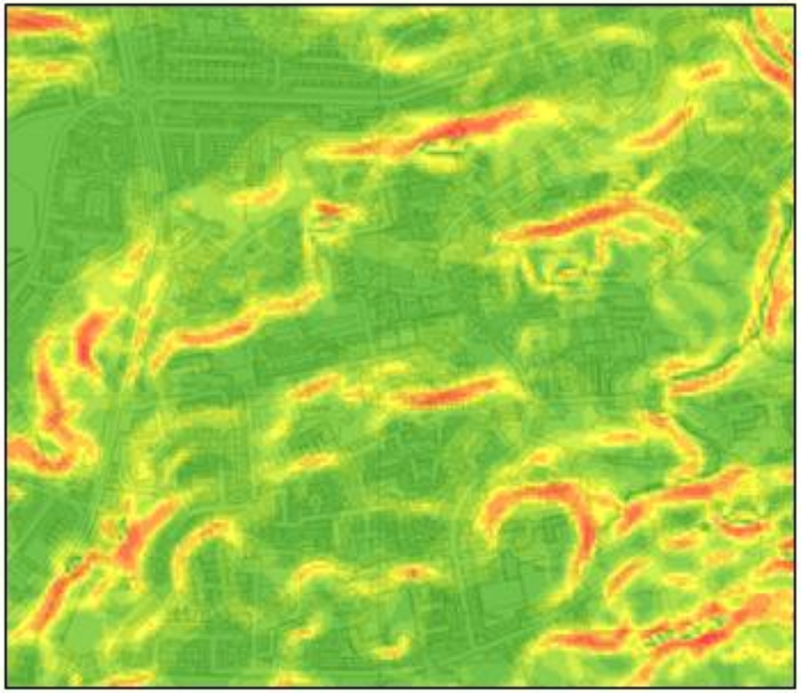
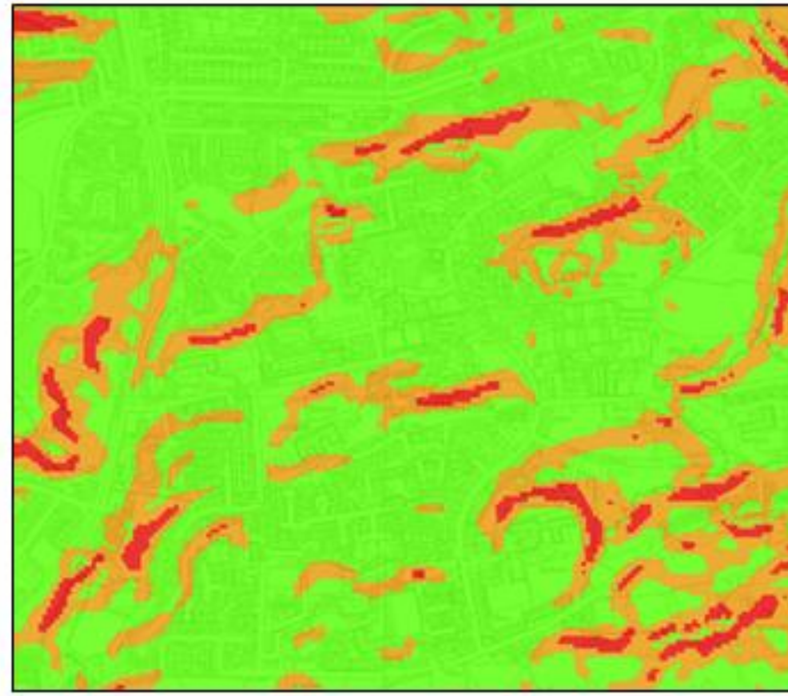
			
Model	Hydrological cycle model	Model	Hydrological cycle model
Step	4	Step	5
Step title	Construct Digital Elevation Model (DEM) raster	Step title	Construct slope raster
Notes: The DEM raster is the starting point for all subsequent slope analysis steps and is constructed using the ArcGIS topo to raster[1] operation based on the simplified LiDAR topographical contours dataset from step 3. Within the DEM raster surface shown above, individual cells represent elevation – lighter cells represent higher elevations and darker cells lower elevations.		**Notes:** The slope raster is constructed from the DEM raster. Slope is calculated in the GIS by analysing the rate of change in elevation between cells in the DEM raster surface (see opposite). Where the rate of change is great, slope is steep and *vice versa*. The figure above shows the slope raster for the Castlemilk case study area – darker cells indicate steeply sloped areas and lighter cells represent flat/gently sloped areas.	

Figure 7.20 Hydrological cycle model Steps 6 and 7 – example outputs

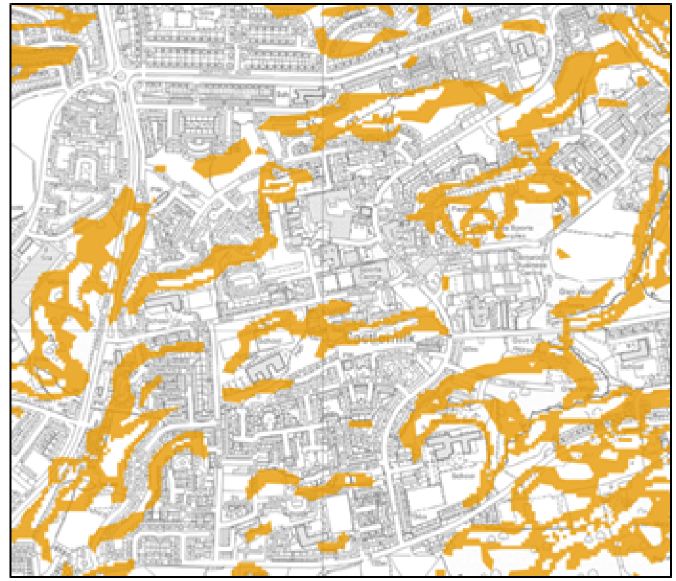




Model	Hydrological cycle model	Model	Hydrological cycle model
Step	6	Step	7
Step title	Reclassify slope raster to discrete slope classes	Step title	Convert the reclassified slope raster to vector format
Notes: The figure above shows the reclassified slope raster for the Castlemilk case study area. Red cells indicate steep slopes, yellow medium slopes and green cells gentle slopes.		**Notes:** Step 7 converts the reclassified slope raster into vector format. Groups of cells sharing the same slope class attribute become polygons in the vector dataset.	

Figure 7.21 Hydrological cycle model Step 8 – example outputs

Model	Hydrological cycle model
Step	8
Step title	Identify and extract **steep**, medium and gentle slope polygons from the vector dataset
Note: The figure above shows polygons from the slope vector dataset indicating areas of steeply sloped land (i.e. slope classes 7, 8 and 9 from the raster dataset). Where these areas of steeply sloped land are located within the immediate catchment of a natural or artificial drainage feature they may represent an opportunity for land use/management intervention to enhance runoff reduction ecosystem services.	



Model	Hydrological cycle model
Step	8
Step title	Identify and extract steep, **medium** and gentle slope polygons from the vector dataset
Note: The figure above shows polygons from the slope vector dataset indicating areas of medium sloped land (i.e. slope classes 4, 5 and 6 from the raster dataset). Where these areas of medium sloped land are located within the immediate catchment of a natural or artificial drainage feature they may represent an opportunity for land use/management intervention to enhance runoff reduction ecosystem services.	

Figure 7.22 Hydrological cycle model – Stage 2 geoprocessing operations (Steps 9 – 15)

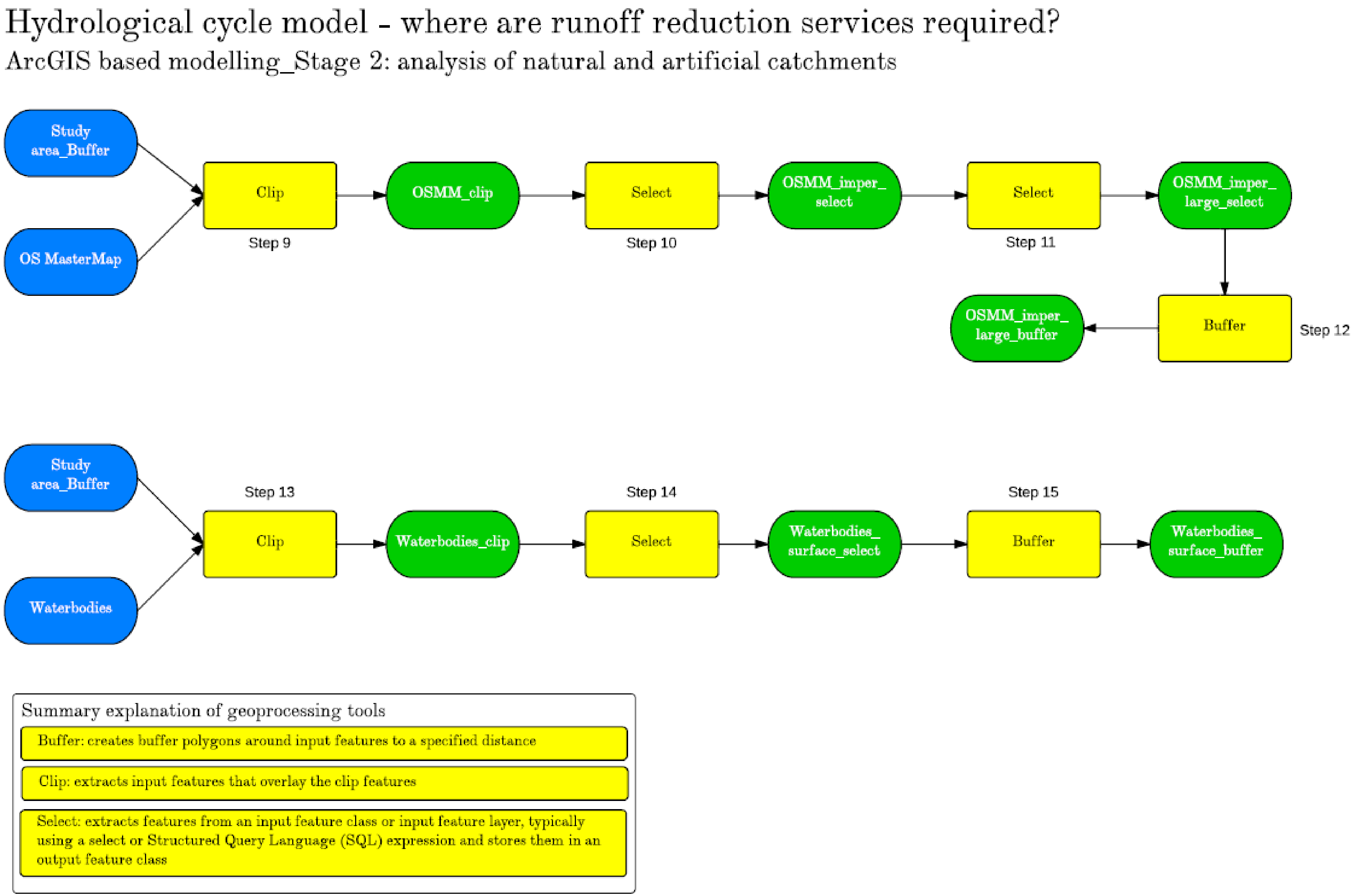
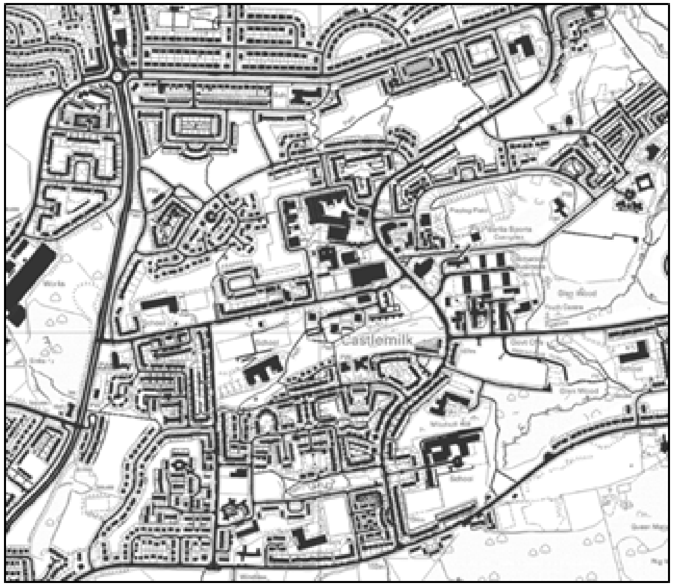
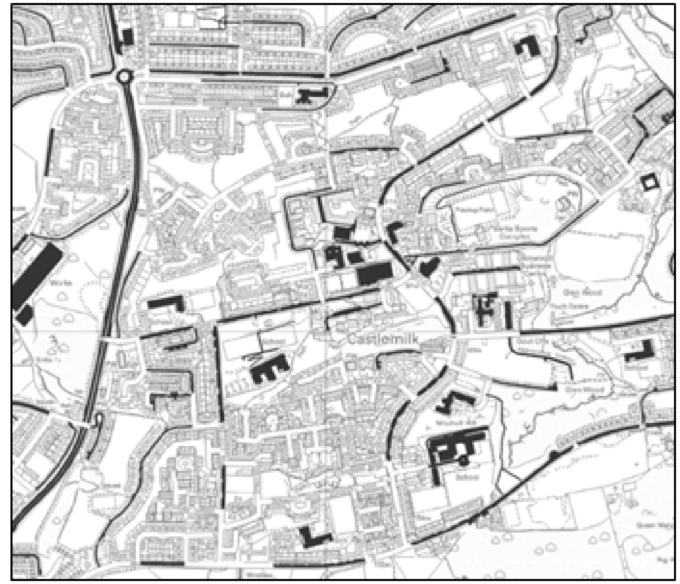


Figure 7.23 Hydrological cycle model Steps 10 and 11 – example outputs



Model	Hydrological cycle model
Step	10
Step title	Identify and extract impermeable ground polygons only from OSMM topography layer

Note: Extracted from the OSMM topography layer, the figure above shows all OSMM polygons that are likely to comprise impermeable ground (black polygons). Polygons are identified and extracted on the basis of specific DESCGROUP attributes.



Model	Hydrological cycle model
Step	11
Step title	Identify and extract large impermeable ground polygons only from OSMM topography layer

Note: Extracted from impermeable ground OSMM polygons from Step 10, the figure above shows 'large' impermeable ground polygons only (black polygons). In the example above, 'large' polygons are construed as those >1,000m^2. The parameter used to define 'large' in the select operation is a key part of the model where sensitivity analysis can be undertaken to explore different outcomes overall.

Figure 7.24 Hydrological cycle model Steps 12 and 15 – example outputs

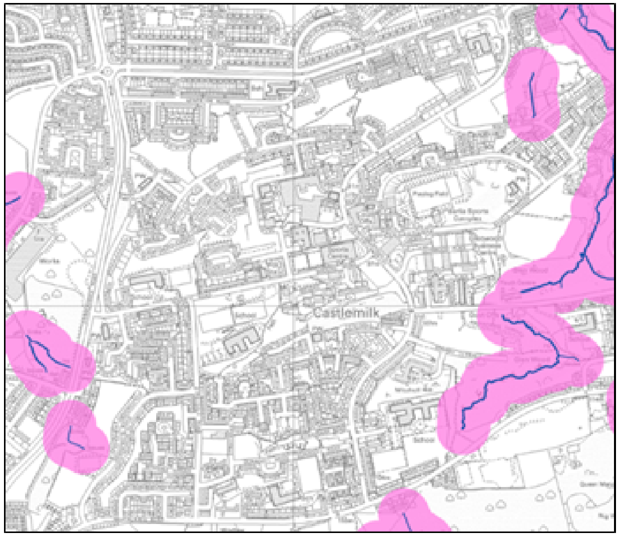
			
Model	Hydrological cycle model	Model	Hydrological cycle model
Step	12	Step	15
Step title	Buffer large areas of impermeable ground to identify the immediate catchment area of artificial drainage features	Step title	Buffer surface waterbodies to identify the immediate catchment area of natural drainage features
Note: The figure above shows large areas of impermeable ground from Step 11 buffered to 30m (green polygons). For the purposes of the hydrological cycle model, these areas are construed as the immediate catchment areas of *artificial* drainage features and may be prime candidates for intervention that enhances runoff reduction ecosystem services. The distance parameter used in the buffer operation is a key part of the model where sensitivity analysis can be undertaken to explore different outcomes.		**Note:** The figure above shows surface waterbodies from Step 14 (see Figure 7.22) buffered to 75m (purple polygons). For the purposes of the hydrological cycle model, these areas are construed as the immediate catchment areas of *natural* drainage features and may be prime candidates for intervention that enhances runoff reduction ecosystem services. The distance parameter used in the buffer operation is a key part of the model where sensitivity analysis can be undertaken to explore different outcomes.	

Figure 7.25 Hydrological cycle model – Stage 3 geoprocessing operations (Steps 16 – 21)

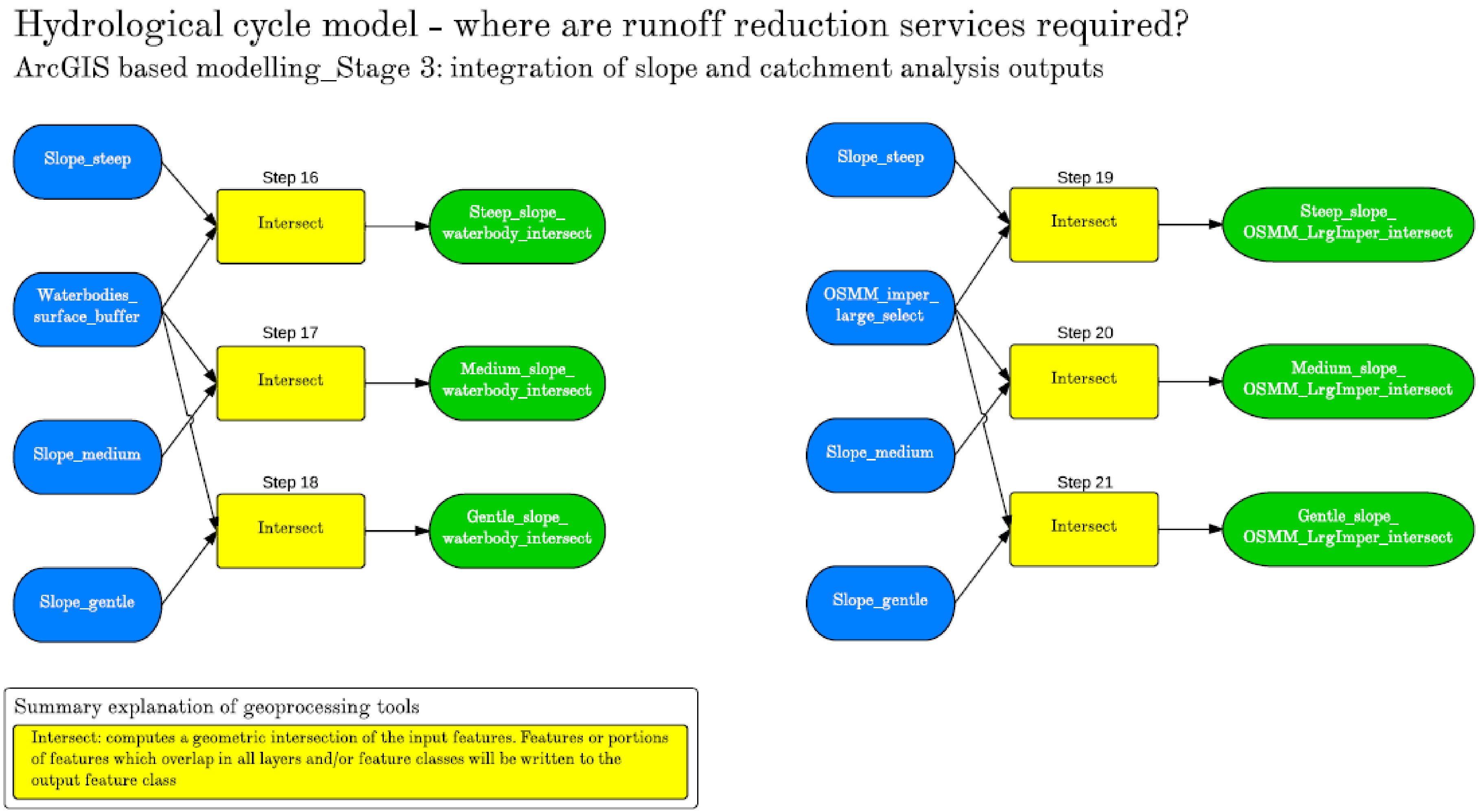


Figure 7.26 Hydrological cycle model Stage 1 (Step 8) and Stage 3 (step 19) – example outputs

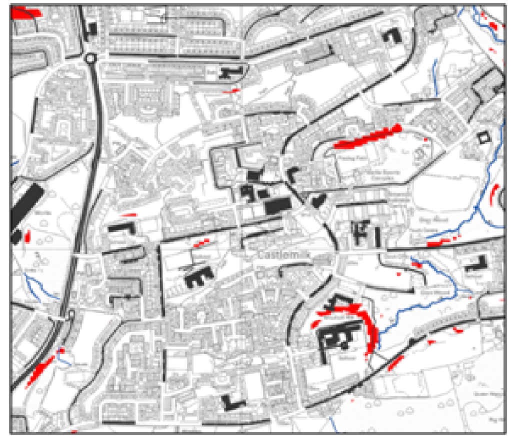
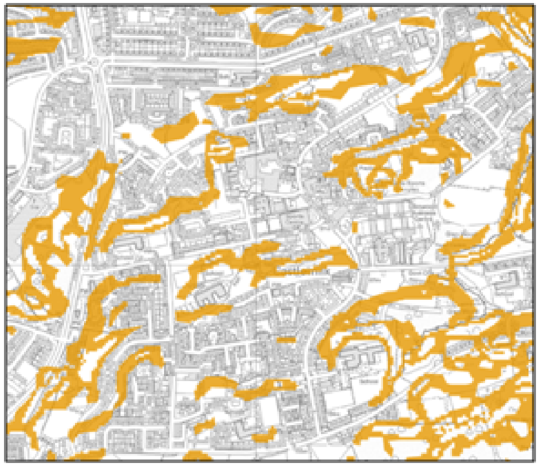
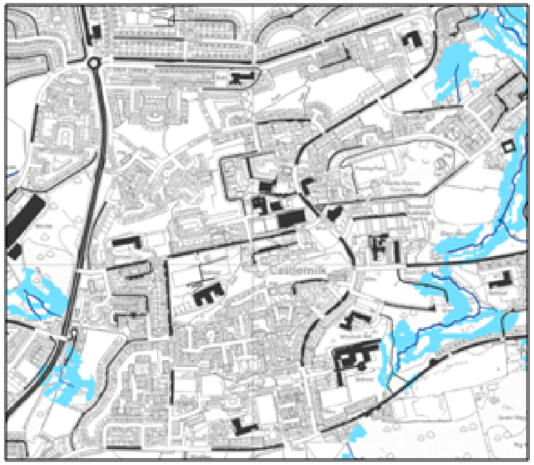
			
Model	Hydrological cycle model	Model	Hydrological cycle model
Step	8	Step	19
Step title	Identify and extract **steep**, medium and gentle slope polygons from the vector dataset	Step title	Identify where areas of **steeply** sloped land falls within the immediate catchment area of **artificial** drainage features
Note: The figure above shows polygons from the slope vector dataset indicating areas of **steeply** sloped land (i.e. slope classes 7, 8 and 9 from the raster dataset).		**Note:** The figure above shows the results of intersecting areas of **steeply** sloped land (Step 8 output polygons – see figure opposite) with the immediate catchment area of **artificial** drainage features (Step 12 output polygons – see Figure 7.2.4). The red polygons on the map above therefore show where areas of steeply sloped land falls within the catchment of artificial drainage features – *note how there are fewer red polygons on the right-hand map than the left-hand map as artificial drainage feature catchments/buffered large areas of impermeable ground (i.e. Step 12 outputs) occupy only a certain portion of the study area* (black polygons are large areas of impermeable ground from Step 11 – see Figure 7.23). These areas of land therefore may be prime candidates for land use/management intervention to enhance runoff reduction ecosystem services.	

Figure 7.27 Hydrological cycle model Stage 1 (Step 8) and Stage 3 (step 17) – example outputs





Model	Hydrological cycle model	Model	Hydrological cycle model
Step	8	Step	17
Step title	Identify and extract steep, **medium** and gentle slope polygons from the vector dataset	Step title	Identify where areas of **medium** sloped land falls within the immediate catchment area of **natural** drainage features
Note: The figure above shows polygons from the slope vector dataset indicating areas of medium sloped land (i.e. slope classes 4, 5 and 6 from the raster dataset).		**Note:** The figure above shows the results of intersecting areas of **medium** sloped land (Step 8 output polygons – see figure opposite) with the immediate catchment area of **natural** drainage features (Step 15 output polygons – see Figure 7.24). The blue polygons on the map above therefore show where areas of medium sloped land falls within the catchment of natural drainage features – *note how there are fewer blue polygons on the right-hand map than there are orange polygons on the left-hand map as natural drainage feature catchments/buffered river corridors (i.e. Step 15 outputs) occupy only a certain portion of the study area.* These areas of land may be prime candidates for intervention to enhance runoff reduction ecosystem services.	

Figure 7.28 Overall structure of the habitat network model

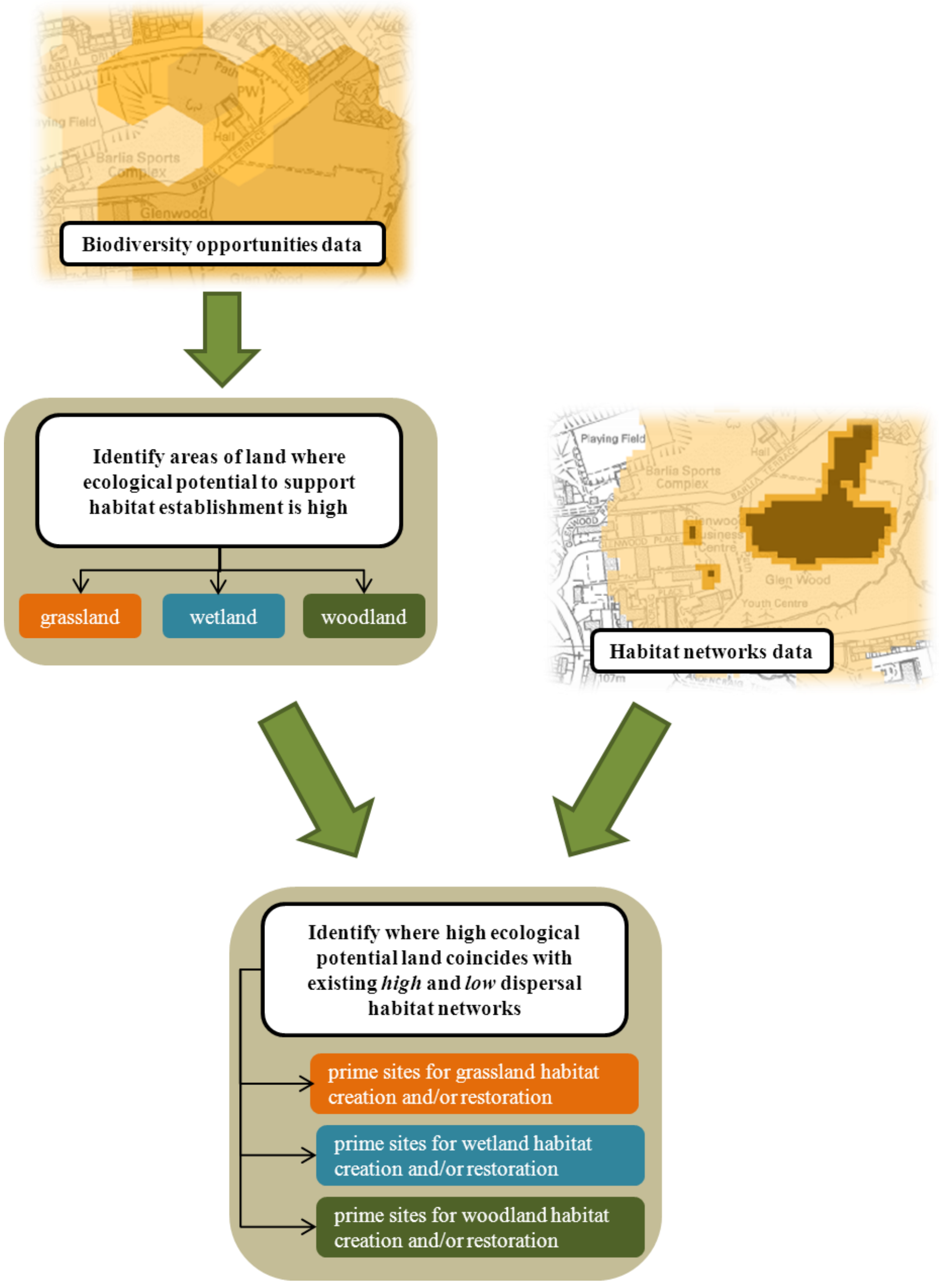


Figure 7.29 Habitat network model – Stage 1 geoprocessing operations

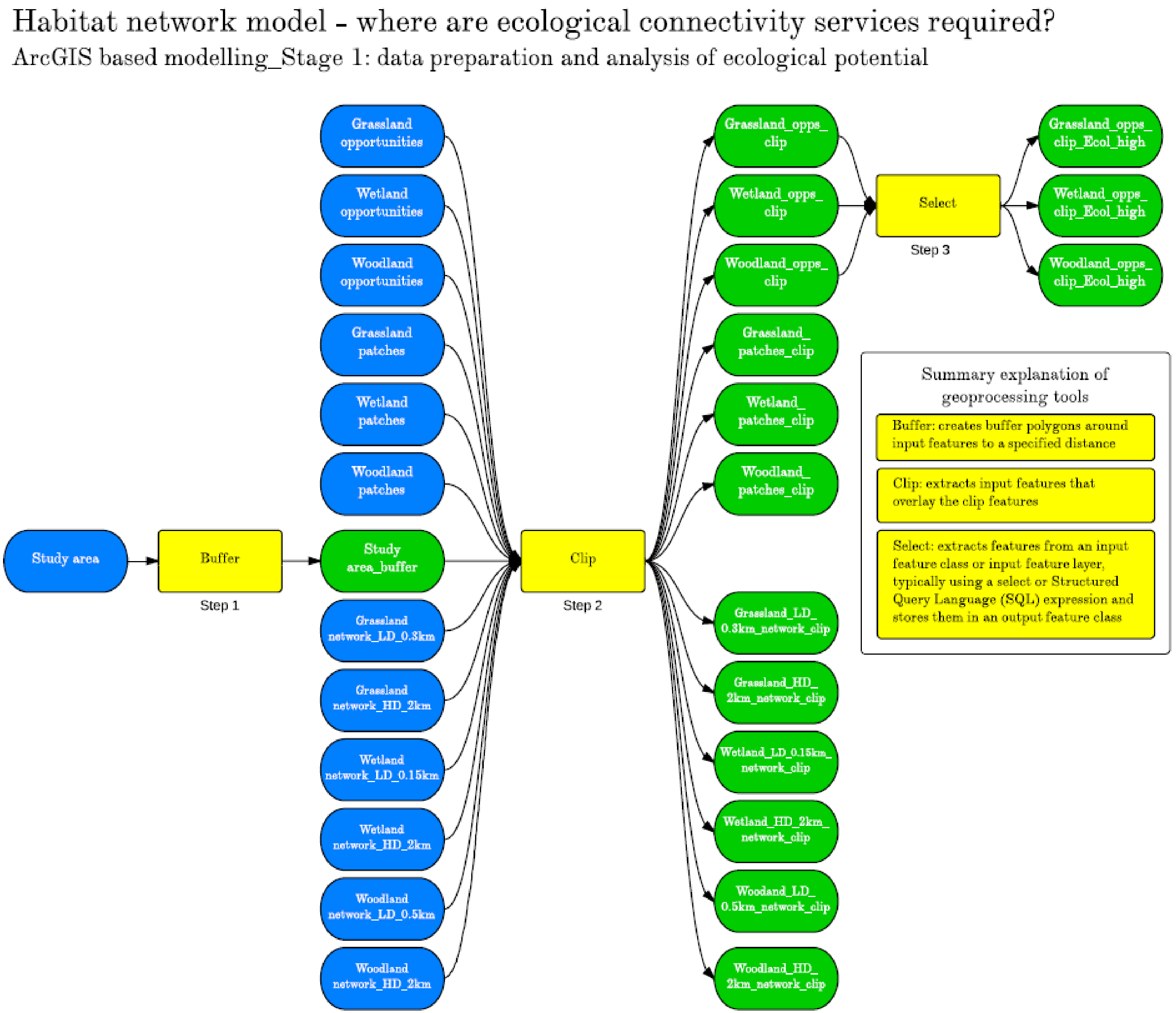
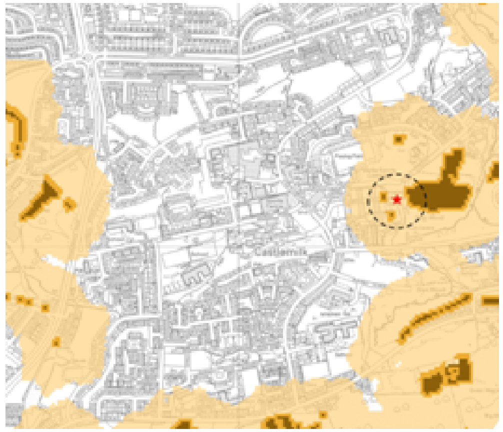
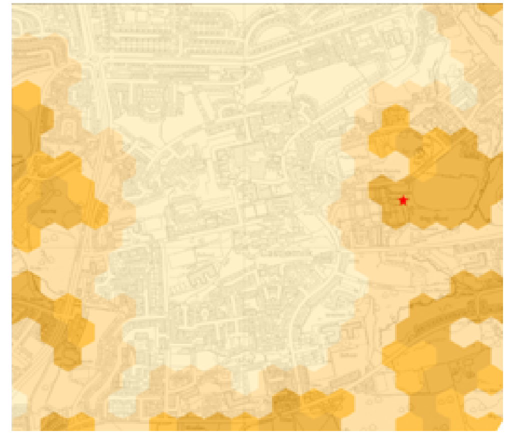


Figure 7.30 Habitat network model Stage 1 (Step 2) – example outputs





Model	Habitat network model	Model	Habitat network model
Step	2	Step	2
Step title	Clip habitat patches and habitat network data to the buffered study area polygon	Step title	Clip opportunities (ecological potential to support habitat establishment) data to the buffered study area polygon

Note: The Figure above shows unimproved/ neutral grassland patches (brown polygons), low/0.3km dispersal habitat network (dark orange polygons) and high/2km dispersal habitat network (pale orange polygons) data clipped to the study area. Note how the spatial delineation of the habitat networks is not uniform, reflecting variation in the permeability/resistance of the surrounding matrix as a result of variation in land use (see section 5.2.2 for further information).

Note: The Figure above shows the grassland opportunities data clipped to the study area. Darker orange polygons indicate land with a higher ecological potential to support habitat establishment. One key parameter considered in Forest Research's biodiversity opportunities data (see section 2.4.2) is the potential for habitat creation/recreation to contribute to increased ecological connectivity. The influence of this parameter is readily apparent in the example shown above as areas of higher ecological potential for grassland establishment (dark orange polygons) are clustered around areas of existing habitat (see left-hand Figure). In effect, these are prime areas where habitat management and creation could help to consolidate existing networks and improve functional connectivity.

The location indicated by the red star on both Figures is a case in point – habitat creation at this location could enhance the functional connectivity of the low dispersal network (dark orange polygons on the left-hand Figure) thereby increasing the area of contiguous network and providing functional connections between the three discrete habitat patches (brown polygons) shown within the black dashed circle. This concept is explained further at section 7.4.2.

Figure 7.31 Habitat network model Stage 1 (step 3) – example output

Summary details of example output	
Model	Habitat network model
Step	3
Step title	Identify land where ecological potential to support habitat establishment is high
Note: The Figure to the left shows land in the study area where ecological potential to support grassland habitat establishment is high (brown polygons). This has been extracted from the overall grassland opportunities dataset shown at Figure 7.30 (right-hand map) using an SQL based select operation in the GIS.	

Figure 7.32 Habitat network model – Stage 2 geoprocessing operations

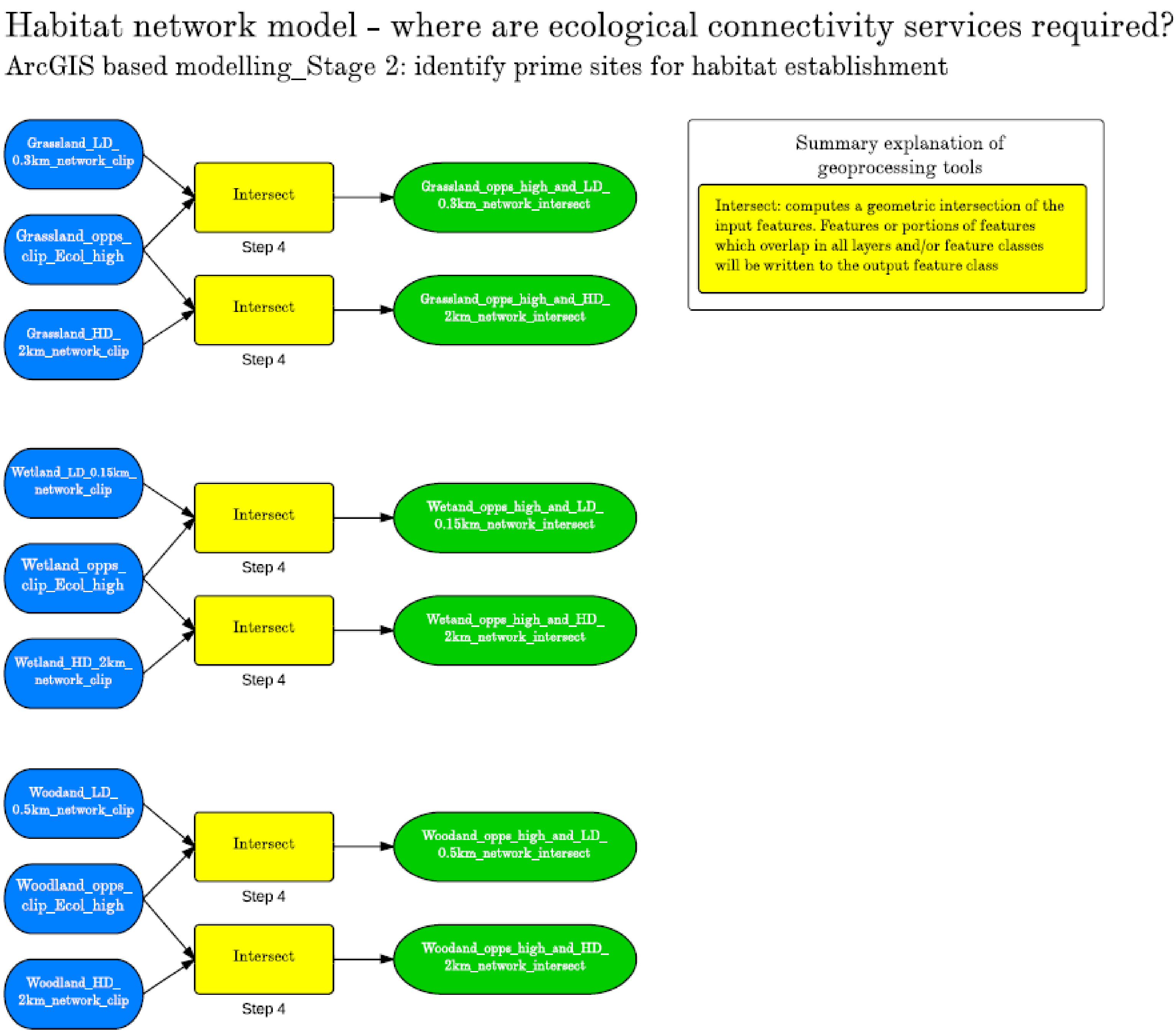
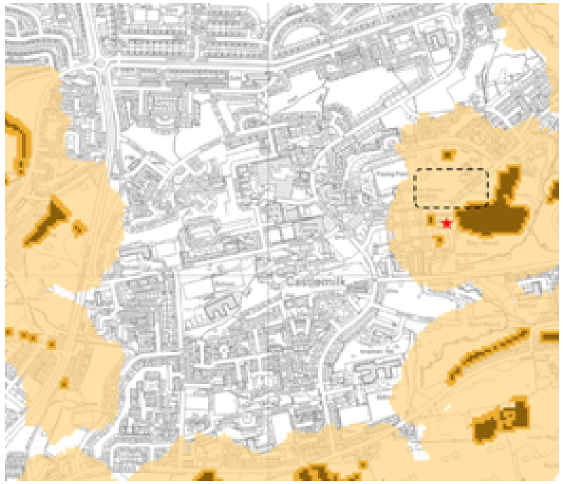


Figure 7.33 Habitat network model Stage 1 (Step 2) and Stage 2 (step 4) – example outputs

<table>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Model</td><td>Habitat network model</td><td>Model</td><td>Habitat network model</td></tr>
<tr><td>Step</td><td>2</td><td>Step</td><td>4</td></tr>
<tr><td>Step title</td><td>Clip habitat patches and habitat network data to the buffered study area polygon</td><td>Step title</td><td>Intersect high ecological potential polygons with existing habitat network polygons</td></tr>
<tr><td colspan="2">Note: The step 2 output from Figure 7.30 has been included here for comparison. The Figure above shows unimproved/neutral grassland patches (brown polygons), low/0.3km dispersal habitat network (dark orange polygons) and high/2km dispersal habitat network (pale orange polygons) data clipped to the study area.</td><td colspan="2">Note: The Figure above shows the output (pale pink polygons) of intersecting land with high ecological potential to support grassland habitat establishment and existing high dispersal grassland habitat networks. The brown polygons show existing grassland habitat patches.</td></tr>
<tr><td colspan="4">The intersect operation shows how the area of high ecological potential land is smaller than the area of land encompassed by existing high dispersal habitat networks (see left-hand Figure) – i.e. although the nature of the matrix within the high dispersal network may be such that it can facilitate species movements, some of the land within this area has lower ecological potential for habitat establishment. This is illustrated by the area of land within the black dashed rectangle – on the left-hand Figure this land falls within the high dispersal network however on the right-hand Figure this area of land is not featured. In effect, the nature of the existing landcover at this site is such that the land has more limited potential to support grassland habitat establishment. Interestingly, the area indicated by the red star shown on the left-hand Figure (see Figure 7.30 also) remains as a key opportunity area on the right-hand Figure whereby habitat related land use/management action could be delivered to improve functional connectivity (including within low dispersal networks).</td></tr>
</table>

Figures from Chapter 8

Integrating spatial models: how do we know where multiple urban ecosystem services are required?

Figure 8.1 Overall structure of the new guiding principles and technical guidance for ecosystems approach based urban land use planning

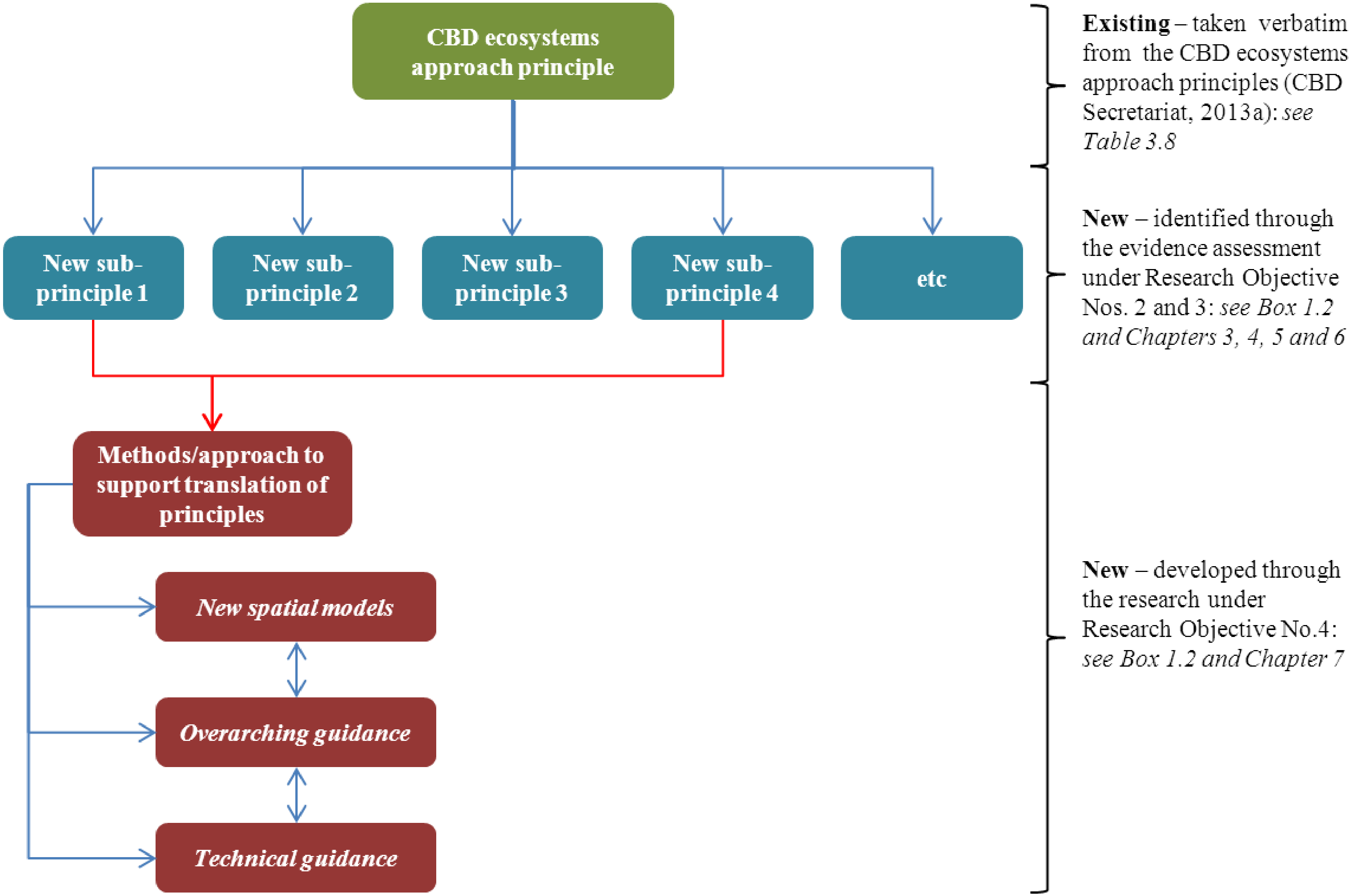


Figure 8.2 Integrating individual spatial model outputs to identify priority areas for multifunctional land use – schematic representation of GIS overlay process

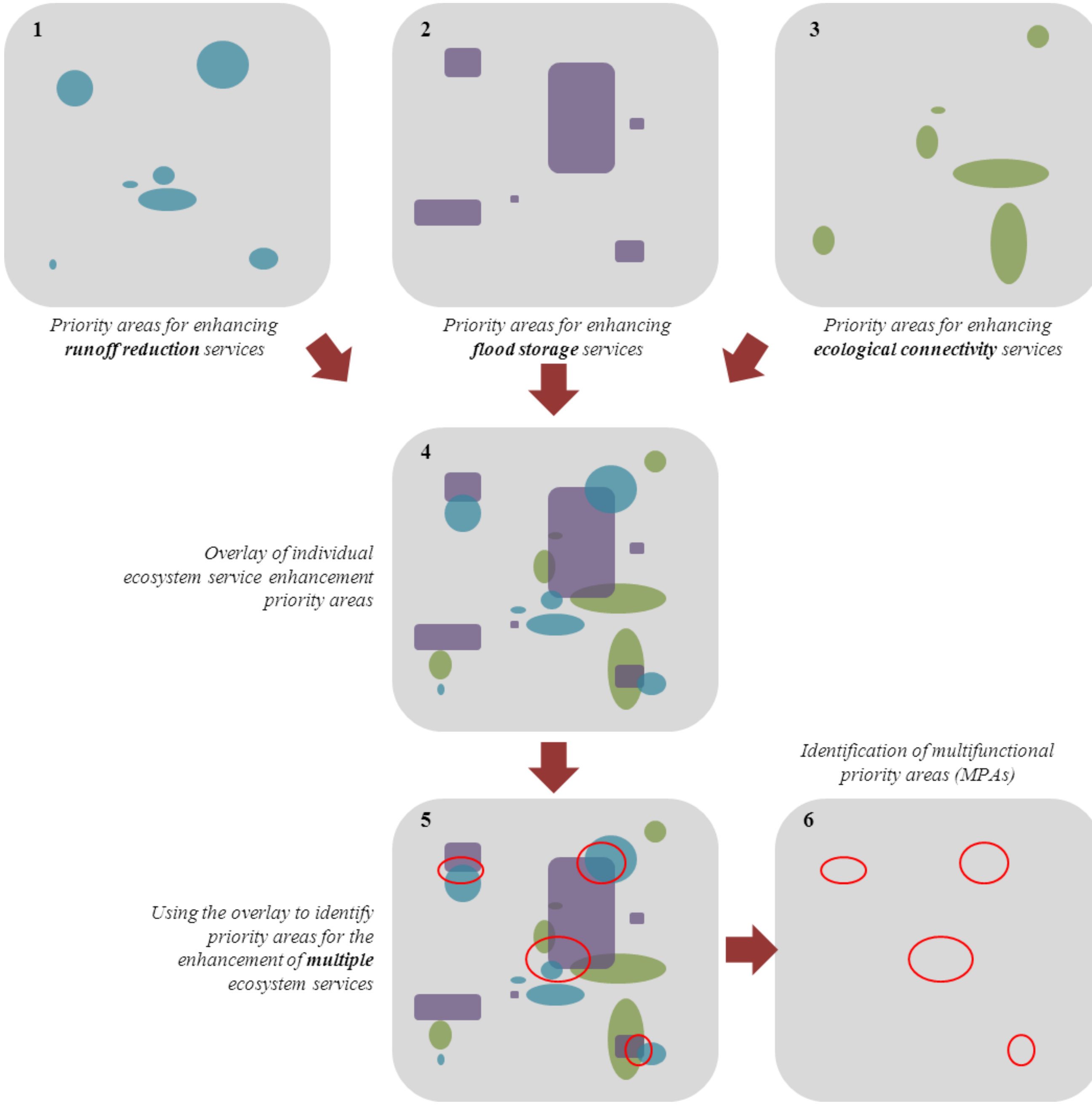


Figure 8.3 Example overlay of hydrological cycle model and habitat network model outputs showing two potential multifunctional priority areas (MPAs)

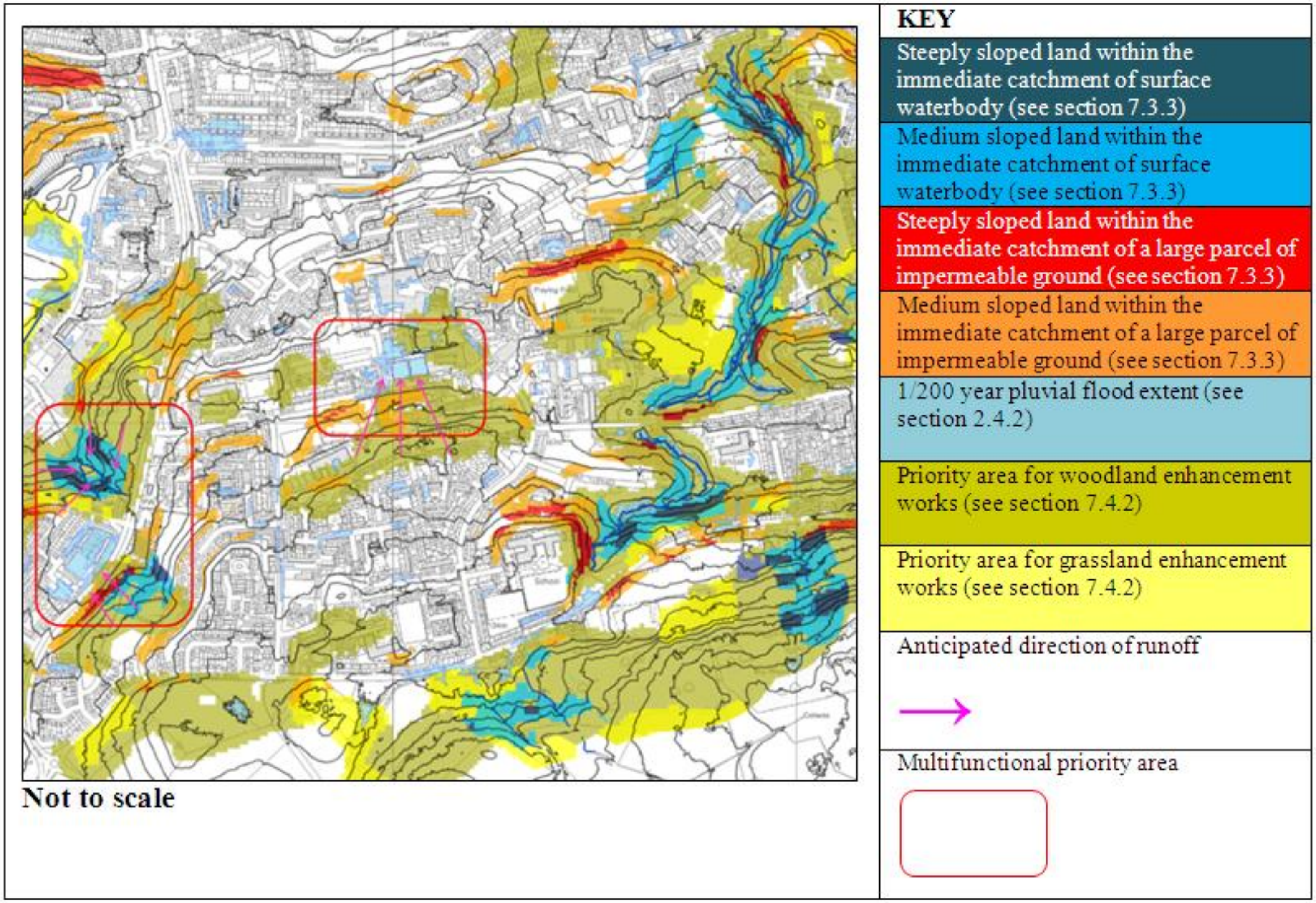


Figure 8.4 Developing broad-brush land use/management intervention proposals for scoped-in multifunctional priority areas (MPAs)

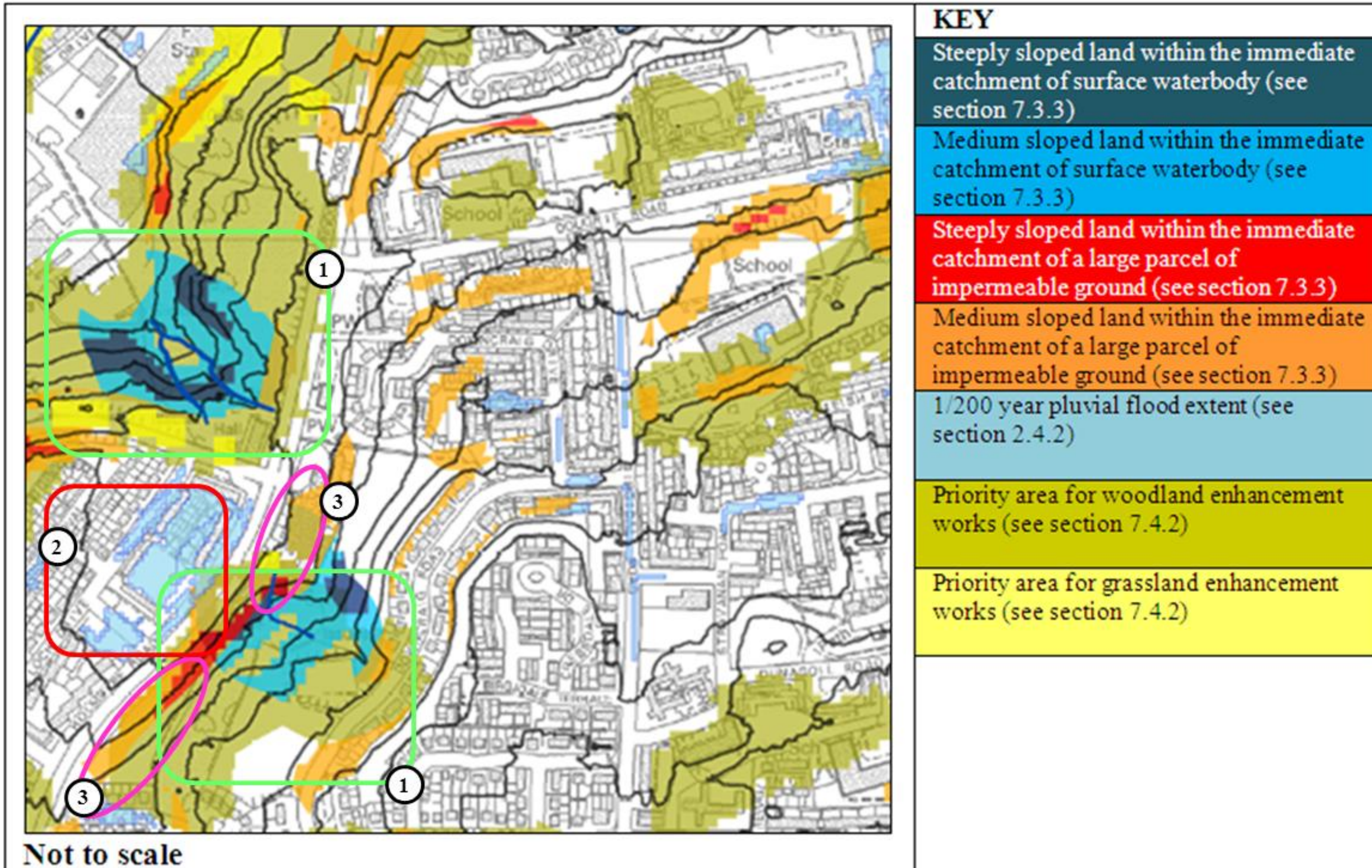


Figure 8.5 Proposed process for integrating the new tools, models and guidance with the statutory Local Development Plan (LDP) process