Ballater Outline Design

Project Report

Ballater Royal Deeside Ltd & Ballater and Crathie Community Council

cbec eco-engineering UK Ltd

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1. INTRODUCTION

1.1 OVERVIEW

cbec eco-engineering UK Ltd has been commissioned by Ballater & Crathie Community Council (BCCC) to undertake scoping and outline design work to improve flood resilience within Ballater on the River Dee, Aberdeenshire. Following Storm Frank, flood studies have been undertaken for Ballater previously by RPS on behalf of Aberdeenshire Council: the 2019 Ballater Flood Protection Study (BFPS) and the 2023 Ballater Additional Flood Study (BAFS). cbec provided geomorphological input to both of these studies.

Further information relating to both studies is provided in Section 2.4. Broadly, the BFPS was intended to identify an option or options to provide a 0.5% Annual Exceedance Probability (AEP) Standard of Protection, settling on Option 3A, which included: direct defences, pumping stations, relocation of at-risk properties (including the caravan park), property level protection and resilience measures. It has been proposed that the scheme progress to outline and detailed design phase.

BCCC have noted that the community's preference is that design events be referred to based on the modelled peak discharge, rather than using the AEP or 'return period' terminology. Accordingly, hereafter, specific design events are discussed using discharge values in m^3/s throughout this document, based on flow estimates for RPS's hydrological assessment point HAP_08, which is located just downstream of the site of interest for the present study. These discharge values have been rounded to the nearest 50 m^3/s for ease of reference. Table 1.1 illustrates how these flow estimates correspond to AEP/return period based on the hydrological analysis in the BFPS.

Much of the flooding affecting Ballater is associated with more frequent events at flow rates between 500 and 1000 m^3/s and the formal flood protection scheme identified by the BFPS has yet to progress to the design phase. Additionally, the planform of the River Dee in the vicinity of Ballater Golf Course has changed considerably since the 2019 BFPS. Accordingly, the BAFS was subsequently undertaken to identify the impacts of these changes on flood risk and assess the potential for minor works to manage flood risk to Ballater prior to a formal flood scheme being implemented (that is not likely to be implemented for many years). The preferred option identified in the BAFS report has been progressed to some degree through informal works, including construction of a bund and some channel clearing activities. However, BCCC would now like to consider additional options for mitigating flood damage associated with the more frequent, less catastrophic flood events, including the 500 to 1000 m^3/s events. This report details work undertaken by cbec to develop such options to outline design stage.

1.2 PROJECT APPROACH

A range of potential river/ floodplain management options have been developed here, intended to contribute towards the sustainable management of flood risk. It is important to note that the approach adopted represents an alternative to traditional flood risk engineering and the presented options are not intended to replace or supersede a formal flood protection scheme. Rather, these options are intended to supplement previous works undertaken for Ballater and to extend the range of protection offered, with a focus on the smaller events noted above. The options have been developed according to a 'nature-based' or 'process-based' approach, which involves working with rather than resisting natural river processes. This explicit consideration of fluvial geomorphology as part of the design process tends to produce more sustainable solutions that are less likely to require ongoing and costly maintenance. Nevertheless, it is acknowledged that the primary focus of this project is reduction in flood risk, with benefits for river form and process and wider biodiversity improvements of secondary importance.

To effectively manage flooding, a combination of measures within the upper catchment to intercept rainfall and slow/ temporarily store runoff and options to protect against and alter the course of flood waters within the impacted area are required. It is understood that the BCCC are in liaison with CNPA to explore the former; therefore, this report will focus on the latter, building on the previous flood studies undertaken in 2019 and 2023. Options appraised in this report will seek to address primarily the higher frequency, lower magnitude flood events ranging from ~500 m^3/s to 750 m^3/s. Where possible, larger events have also been considered as part of the options development (e.g. the 100 year or ~1000 m^3/s event), although it is important to note that the measures presented here are unlikely to provide any significant protection against an event of this magnitude. It is also important to note that the analysis presented here is based on specific design events modelled by RPS. Accordingly, it has not been possible here to determine specific flow magnitudes at which different flood mechanisms are activated.

1.3 SITE LOCATION

The River Dee rises in the Cairngorms National Park, flowing westerly towards Aberdeen. This study has focused on a ~2.5 km section of the River Dee and adjacent floodplain, around Ballater, a village situated within the middle course of the Dee. Assessments undertaken have been centred on potential to provide flood protection to Ballater, which is situated on the inside of a meander bend of the River Dee. The study site location is illustrated in Figure 1.1.

Table 1.1 Summary of design events considered here (flow estimates at HAP_08 of the BFPS).

AEP (%)	Return Period (years)	Modelled Peak Flow (m^3/s)	Peak Flow Rounded (m^3/s)
20	5	523.8	~500
10	10	607.3	~600
3.33	30	762.8	~750
1	100	985.2	~1,000
0.5	200	1146.9	~1,150

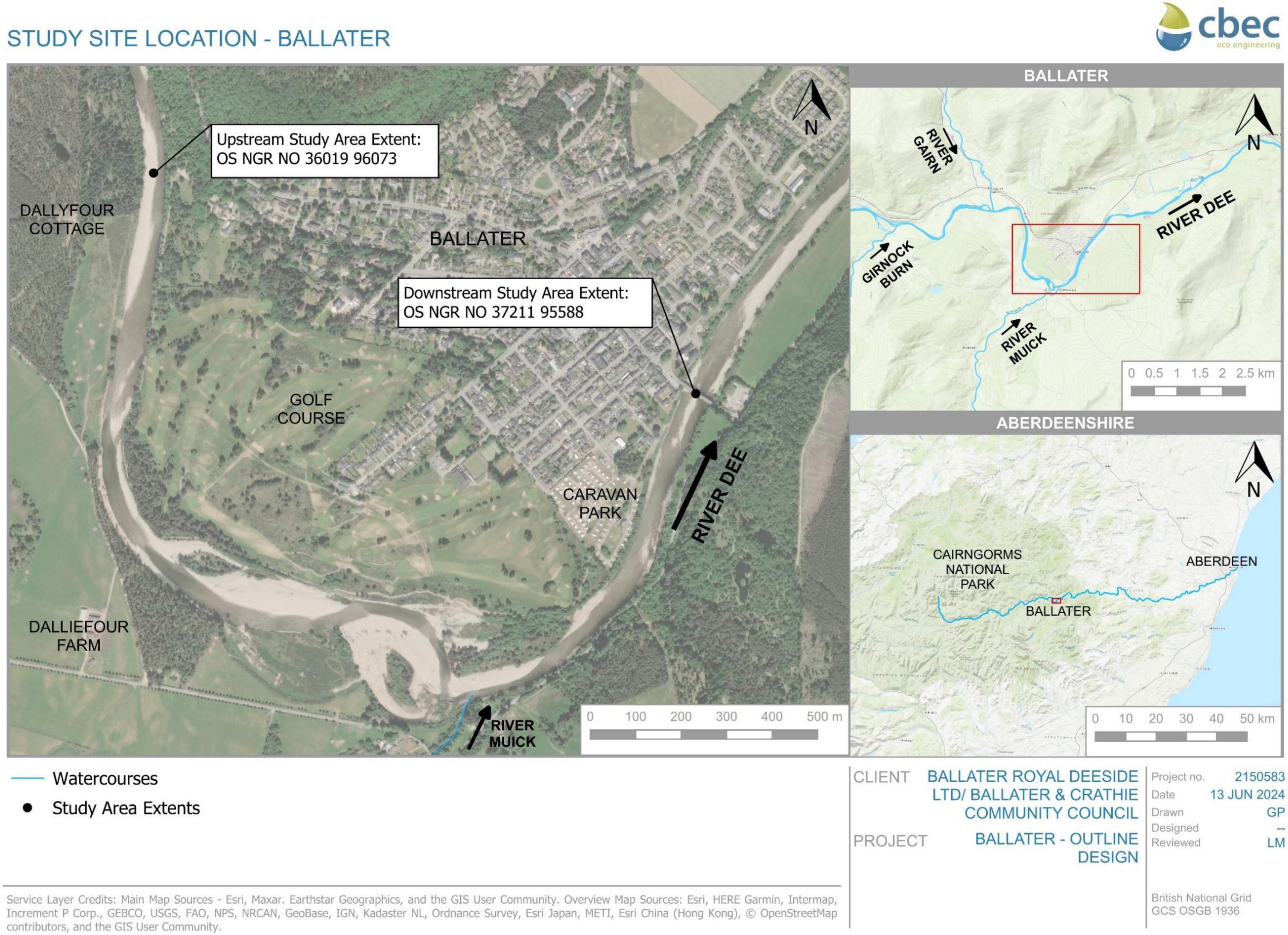

Figure 1.1. Study site location.

2. COLLATION AND REVIEW OF EXISTING DATA

2.1 CATCHMENT CONTEXT

Several desk-based assessments have been undertaken previously to contextualise the geomorphic condition of the River Dee at Ballater within the context of the wider catchment. Geomorphic characteristics at the reach scale are influenced by both catchment-scale and reach-scale processes. Accordingly, it is important that any local river management decisions are made with a full understanding of river processes, both at the management site and across the wider catchment. These desk-based assessments included consideration of numerous factors, including topography, land use, geology, soils and conservation designation. These factors, where relevant to the design process, have been considered here as a foundation for the subsequent fluvial audit (Section 3) and the development of suitable flood management options. The assessment also investigated site-specific considerations (Section 2.2), reviewed and updated historical mapping undertaken for previous studies (Section 2.3) and reviewed previous reports produced, namely the RPS flood study report from 2019 (BFPS) and the RPS Ballater Additional Flood Study (BAFS) report from 2023 (Section 2.4).

2.2 SITE-SPECIFIC CONSIDERATIONS

This project will focus on measures that can be implemented in the vicinity of Ballater to provide increased flood protection and resilience. An understanding of land use within and surrounding the study site is important to inform the space available for and suitability of various measures. Although important from a wider catchment flood management perspective, land use and topography across the wider catchment are not considered in detail here. Ballater itself is a mixture of recreational land (Ballater Golf Course and Caravan Park), residential and business properties, as well as woodland and scrubby grassland along the northern side of the river corridor. On the southern side of the River Dee the land is predominantly managed for agriculture and forestry.

Based on consideration of catchment context, it is evident that the River Dee is a dynamic river system, with a plentiful supply of coarse sediment and evidence of lateral adjustment over time. This dynamic character is evident at the study site, particularly in the vicinity of the River Muick confluence, and will inform the development of designs.

A review of Historic Environment Scotland's designated assets database (2024) was undertaken to identify areas of archaeological significant or heritage value. Focus was given to sites situated within the active floodplain, to ensure that flood management opportunities proposed do not disturb these heritage assets. Construction within or alteration to such structures or areas will be subject to additional legislation and permitting. Ballater is classified as a Conservation Area (ID: CA444), owing to the architectural and/or historical value of the village. This classification encompasses over half of the properties within the village and consists of both B & C Listed Buildings. Ballater Royal Bridge, crossing the River Dee ~220 m downstream of the caravan park, is also a Category B Listed Building (ID: LB21851). Invermuick Bridge over the River Muick, ~150 m upstream of its confluence with the Dee, is a Category C (ID: LB9302). Flood management options developed within this report will take into consideration these designations to ensure that they will not be impacted by the construction or resultant change to flood risk of the proposed measures. Additionally, the central motivation for this study is to improve flood protection to the residents and businesses within Ballater, which will in turn benefit the village's Conservation Area. A summary of these archaeological and heritage assets is provided in Figure 2.1.

NatureScot's SiteLink website was used to check for protected areas within the vicinity of the site to ensure that these protected areas remain unimpacted by the proposed flood management opportunities identified within this report. On the northwest side of Ballater is a Site of Special Scientific Interest (SSSI; PA Code 429), encompassing Craigendarroch Hill and a section of the left bank of the River Dee, upstream of the golf course. The River Dee itself is classified as a Special Area of Conservation (SAC; PA Code 8357), owning to the presence of freshwater pearl mussel, Atlantic salmon and otter. This designation extends to include several tributaries within the catchment, including the rivers Gairn and Muick which join the Dee within the vicinity of Ballater. Any flood management works proposed within this SSSI and/or SAC will be subject to additional permitting. A summary of these ecologically protected areas is provided in Figure 2.1.

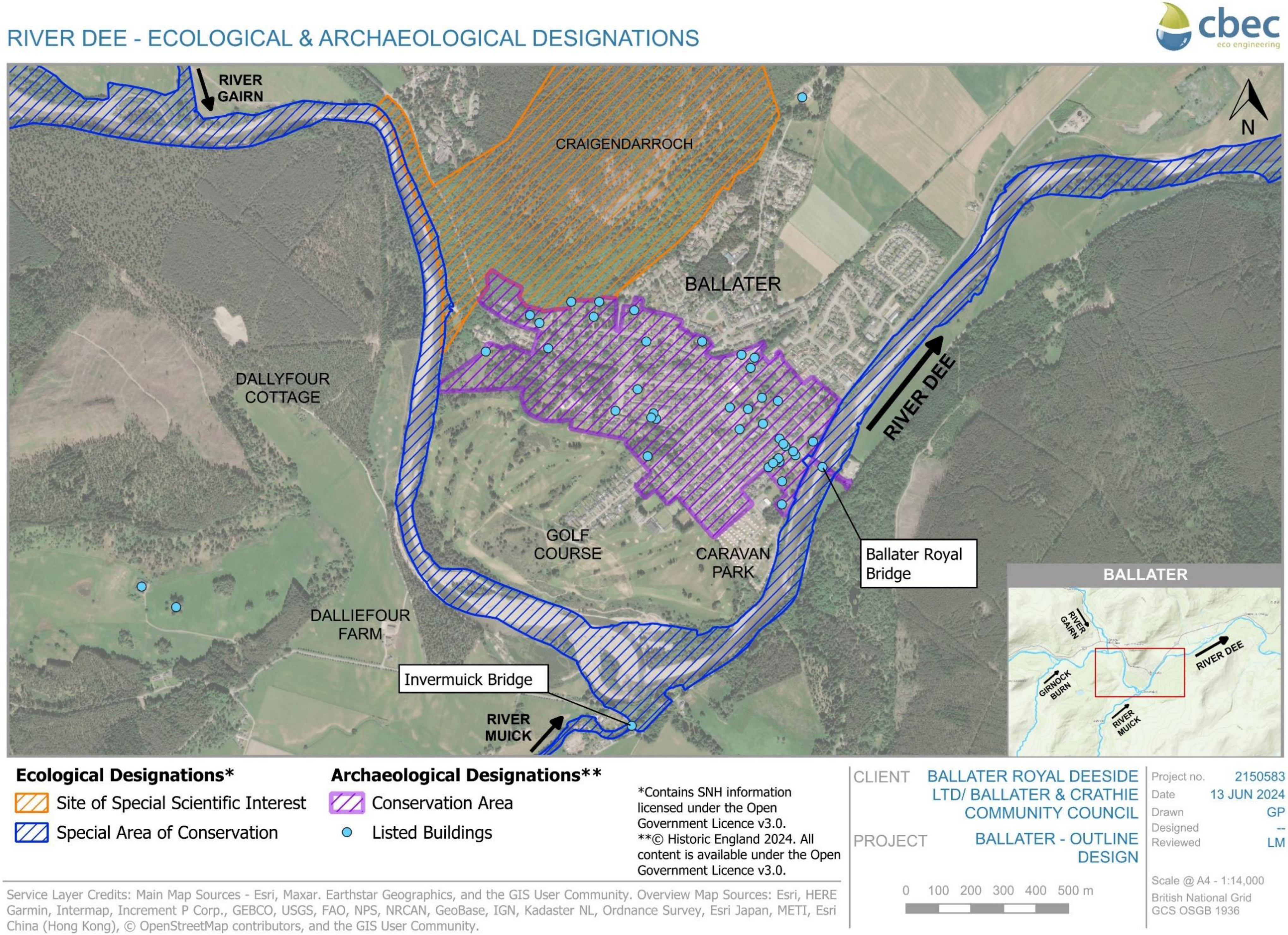

Figure 2.1. Ecological and archaeological designations within the vicinity of Ballater.

2.3 HISTORICAL ASSESSMENT

Analysis of historical datasets (such as old maps, photos and aerial imagery) adds valuable context to the data collected during field surveys. Such analysis allows evaluation of historical changes in channel planform along the river as a basis for assessing (a) the degree of dynamic channel behaviour resulting from natural fluvial processes, as opposed to human activity and (b) the low-impact 'reference state' of the river system. A review of the National Library for Scotland's (NLS) historical map archive[1] (mid/ late 1800s to present day) and available aerial imagery (Google Earth, 2010 to present) was undertaken to provide historical context, including areas of historical channel adjustment. A summary of the results from this historical assessment are presented in Figure 2.2 to Figure 2.3. Within these Figures, aerial imagery of Ballater from June 2023[2] has been overlain by historic planform positions of the River Dee from the NLS Ordnance Survey map archive. This comparison has enabled areas of localised widening and channel migration over the last ~150 years to be identified.

The results of this assessment indicate that the section of the River Dee on the southern side of Ballater, between Dalliefour Farm and the confluence of the River Muick, has displayed the most dynamic behaviour over the last ~150 years. This has been characterised by widening of the channel south-easterly from the island nearest Dalliefour Farm and northwards towards the golf course around the second island, near the River Muick confluence. This channel adjustment is thought to have been driven by an increase in the spatial extent of the existing barforms, reflecting generally greater sediment storage within this section of the river. These changes appear to have occurred between 2010 and 2020, likely in association with Storm Frank[5]. Poor-quality coverage or no aerial imagery of the Ballater area was available from Google Earth's aerial imagery archive; therefore, the exact timing of this change could not be determined from this data source. However, anecdotal evidence indicates that significant morphological change occurred within this region of the River Dee during and after the Storm Frank flood event, which occurred in 2015; it is considered that Storm Frank lowered geomorphic thresholds within the river, thus amplifying subsequent change.

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[1] 1869: National Library of Scotland Map Images, Ordnance Survey, Surveyed 1866, Published 1869, Aberdeenshire: Sheet XCI, Six Inch Scale. [Online]. Last accessed 14.06.24 via https://maps.nls.uk/view/74425442

1901: National Library of Scotland Map Images, Ordnance Survey, Revised 1900, Published 1901, Aberdeenshire: Sheets XCI.7 and XCI.11, One Inch Scale. [Online]. Last accessed 14.06.24 via https://maps.nls.uk/view/82862925 and https://maps.nls.uk/view/82862943

1972: National Library of Scotland Map Images, Ordnance Survey, Surveyed 1969 to 1972, Published 1972, Aberdeenshire: Sheets NO39NE-A and NO39SE-A, 1:10,000 Scale. [Online]. Last accessed 14.06.24 via https://maps.nls.uk/view/188141244 and https://maps.nls.uk/view/188141250

[2] Aerial Imagery from June 2023 was sourced from Esri, Maxar. Earthstar Geographics, and the GIS User Community.

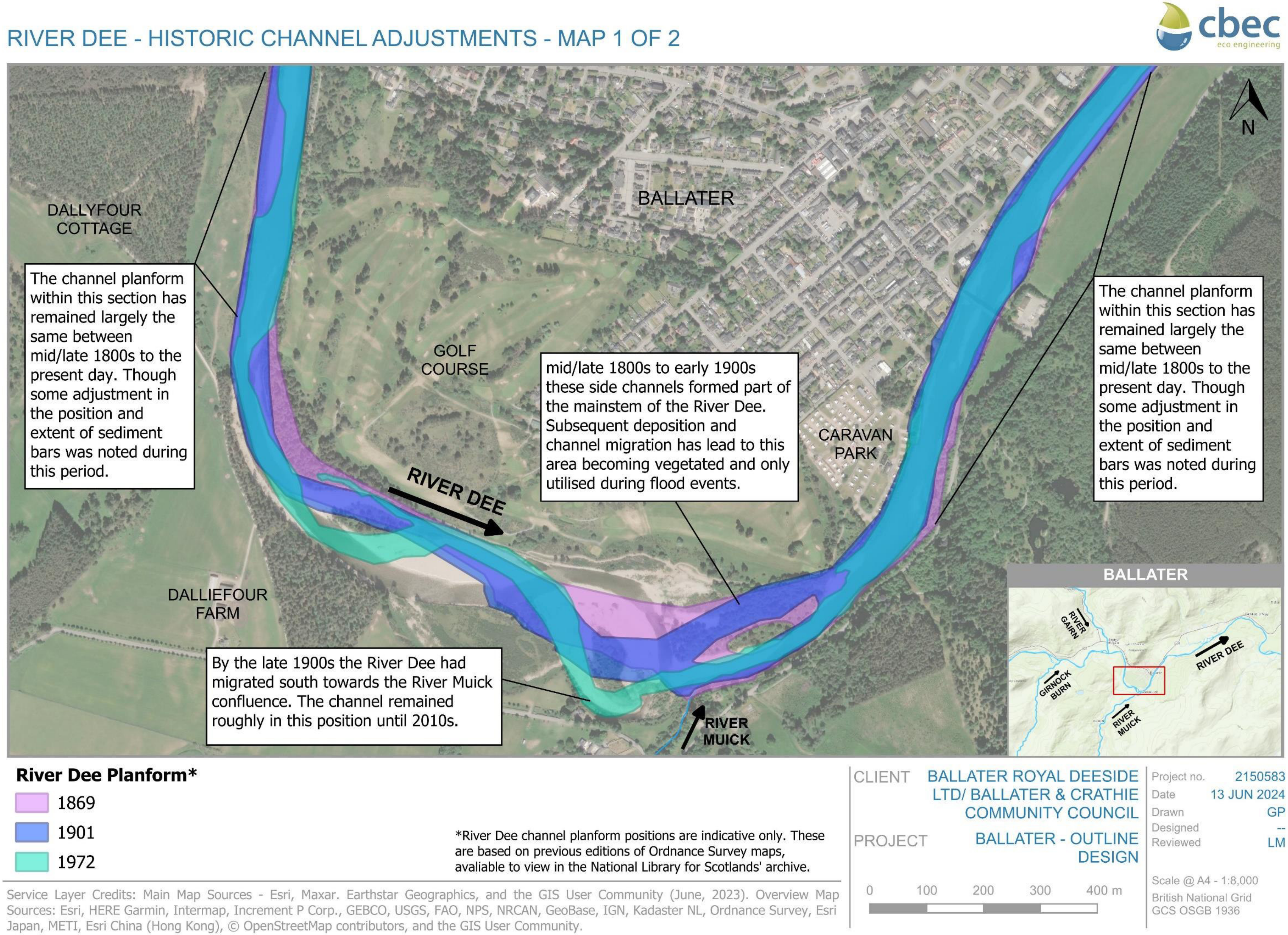

Figure 2.2. Historical channel adjustments of the River Dee. Map 1 of 2: changes between mid/late 1800s to late 1900s.

RIVER DEE - HISTORIC CHANNEL ADJUSTMENTS - MAP 2 OF 2

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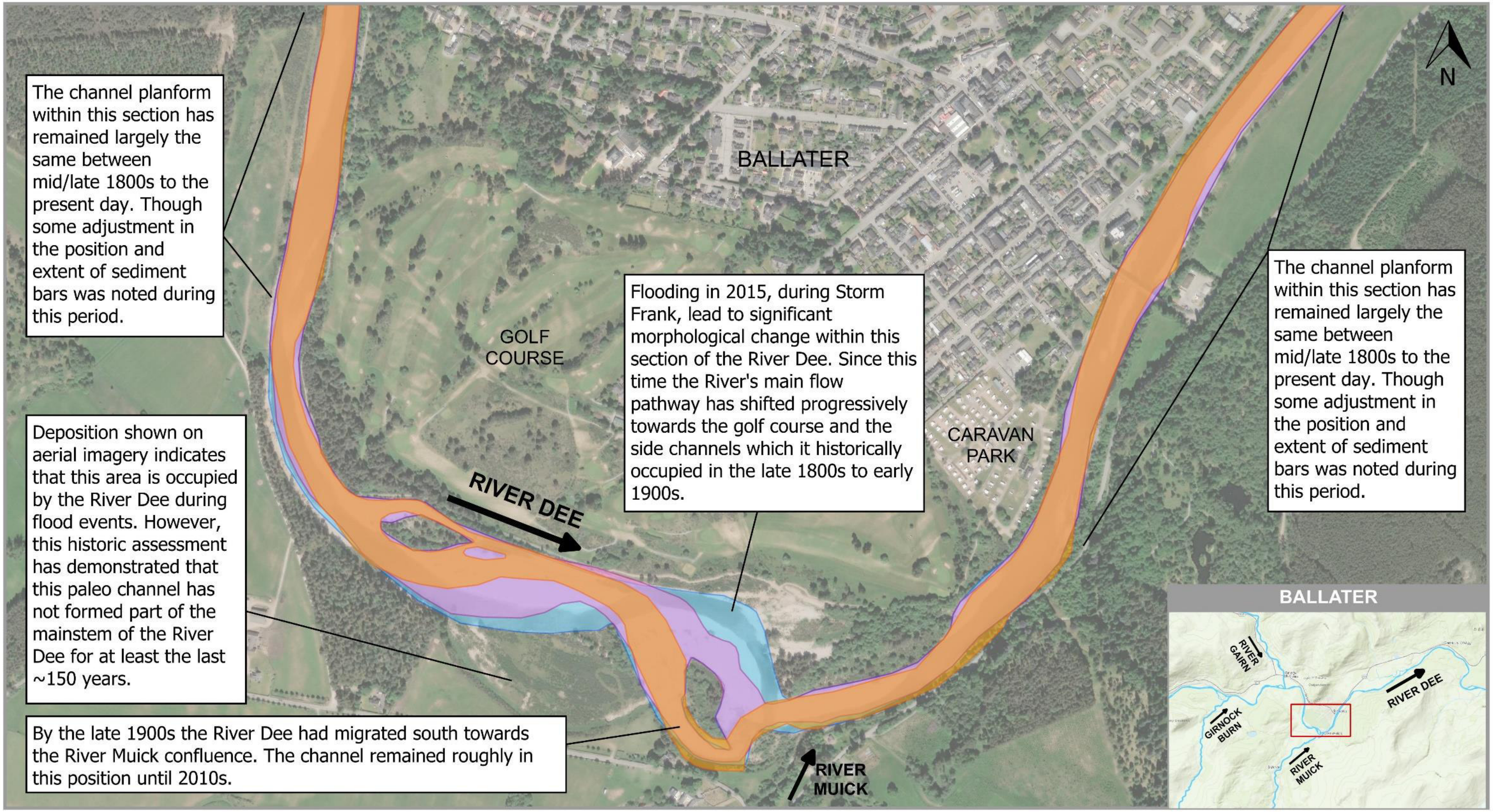


River Dee Planform*

- 2010
- 2020
- 2023

*River Dee channel planform positions are indicative only. These are based on Google Earth's Historical Imagery archive:
2010 - (c) CNES/Airbus;
2020 - (c) Maxar Technologies;
2023 - (c) Esri, Maxar. Earthstar Geographics, and the GIS User Community.

CLIENT	BALLATER ROYAL DEESIDE LTD/ BALLATER & CRATHIE COMMUNITY COUNCIL	Project no.	2150583
		Date	13 JUN 2024
		Drawn	GP
PROJECT	BALLATER - OUTLINE DESIGN	Designed	--
		Reviewed	LM

0 100 200 300 400 m

Scale @ A4 - 1:8,000
British National Grid
GCS OSGB 1936

Figure 2.3. Historical channel adjustments of the River Dee. Map 2 of 2: changes during the early 2000s to present.

2.4 PREVIOUS REPORTS

2.4.1. 2019 BFPS

As noted above, the 2019 RPS study focused on identifying the preferred option(s) to achieve a 0.5% AEP Standard of Protection for Ballater. A comprehensive longlist of potential actions was developed and screened to rule out any actions considered inappropriate or impractical. Following consideration of a wide range of shortlisted options, including both structural and non-structural options, Option 3A was deemed to be the preferred option. This option includes direct defences (including permanent defences, i.e. a flood bund, and glass walls), pumping stations, relocation, property level protection and resilience measures. The direct defences were proposed to follow a route through the golf course and caravan park before running alongside the river left bank of the Dee before terminating downstream of Ballater. This route was deemed to minimise the length of the defences as far as possible and maximise the available floodplain area on the river side of the defences, without incorporating any sharp changes in course adjacent to residential areas.

A number of assumptions and uncertainties were identified in relation to Option 3A, including the potential impacts on flood risk of future geomorphic instability near Ballater and the difficulty of relocating a number of key properties (including the caravan park, the police station and fire station). Further useful information relating to flood extents and mechanisms is provided in the BFPS report. However, as much of this has been superseded by updated modelling undertaken as part of the BAFS (see Section 2.4.2), this is not discussed in more detail here.

2.4.2. 2023 BAFS

It is understood that morphological change to the river corridor following a post-Storm-Frank flood event in 2021 prompted an update of the 2019 flood study. This update, the 2023 BAFS undertaken by RPS on behalf of Aberdeenshire Council, demonstrated that this morphological change had increased the flood extents associated with higher-frequency, lower-magnitude events (up to and including the 3.33% AEP event, corresponding to a flow of ~750 m^3/s), resulting in increased flood risk to Ballater relative to that indicated by the earlier RPS study. The 2023 study also investigated minor works that were suggested to provide protection against these higher-frequency, lower-magnitude events. The minor works considered are summarised in Table 2.1. Of these options, Option 7 was deemed to offer the greatest potential for flood risk benefit and some steps have been taken to implement informal measures in line with this option. The modelling results have been considered as part of the development of options in the present study.

The report also illustrates the main flood mechanisms at Ballater golf course based on the updated hydraulic modelling undertaken as part of the BAFS, with revised flood outlines for all return periods considered. Broadly, the flood mechanisms impacting Ballater can be summarised as follows:

1. Spilling from the left bank parallel to but not entering the golf course drainage channel (activated at the ~400 m^3/s event, or potentially for smaller events that were not modelled);
2. Backwatering of golf course drainage channel at outlet causing spill to northeast (activated at the ~400 m^3/s event, or potentially for smaller events that were not modelled);
3. Backwatering of golf course drainage channel outlet reducing capacity of drainage channel and causing spill further east (activated at the ~400 m^3/s event, or potentially for smaller events that were not modelled);

4. Overwhelming of golf course drainage channel causing spill across golf course and flow towards northeast (golf club house, caravan park; activated between ~400 and ~600 m^3/s);
5. Overtopping of left bank to northwest of golf course (activated between ~600 and ~750 m^3/s).

Flood extents and mechanisms are not illustrated here. However, dominant flow pathways were considered as part of the options development process and are illustrated in the options maps in Section 5.

Table 2.1. Minor works options considered as part of the BAFS report (2023).

Option	Comments
1. Removal of dead trees/ debris along channels cutting through wooded area on river left near golf course outlet	Likely to increase conveyance but unlikely to be sustainable long-term May impact upon caravan park Material could be reused in green bank protection Could result in natural reactivation of previous primary low-flow route and limit excessive recruitment of large wood Modelling shows increased number of properties at risk for most scenarios *Some clearing already undertaken by BCCC*
2. Clearance of channel on Glenmuick side of main channel	Dee mainstem has migrated from Glenmuick side towards Ballater near Muick confluence and former course now occupied by alluvial material Excavation of material from former channel proposed but unlikely to be sustainable if undertaken alone – robust design and modelling required to ensure sustainable design Unlikely to make significant direct contribution to management of flood risk at Ballater – modelling shows increase in number of properties flooded relative to 2022 baseline *Modified version of approach considered as part of this study*
3. Clearance of outlet channel at golf course	Minor watercourse flows through golf course and discharges to Dee just upstream of caravan park Downstream section heavily choked with wood and debris and could be cleared to increase conveyance capacity Option unlikely to be sustainable and would require ongoing maintenance Modelling indicates reduction in flood extents for ~400, ~500, ~600 and ~750 m^3/s events and reduction in number of buildings within flood extents for all four of these events
4. New bund at southern end of golf course	Intended to replace bund that was washed away in 2021 event Short bund (~200 m long) tested that would footprint of previous bund towards the east, terminating at golf course outlet channel Modelling indicated little positive change in flood risk, with increased numbers of flooded properties for some events

	Measure likely to be unsustainable given current channel geometry of mainstem River Dee but potential alternative locations/orientations identified *Small informal bund has already been constructed – improvements to this bund considered as part of this study*
5. Combined 1, 3 & 4	Modelling indicated no change in number of buildings in flood extent for ~400 m^3/s event but increase in number for other events considered
6. Northern bund	Bund ~210 m long and 1 m high, located along left bank of River Dee at northern end of golf course considered Modelling indicated reduction in flood extent and number of buildings flooded for all return periods considered *Potential for bund in this location considered in more detail as part of present study*
7. Southern bund and clearance of outlet channel	Deepening of ~330 m of golf course outlet channel by 0.5 m and construction of 440-m-long bund with height of 1.5 m along left bank of outlet channel Modelling indicated significant reduction in flood extents and number of buildings impacted for all return periods considered Highlighted as preferred option *Initial, informal works have been undertaken on site in line with this option but further work required – modified version of this option considered as part of present study*

3. GEOMORPHIC ASSESSMENT

cbec conducted a geomorphic assessment of the River Dee in May 2022, on behalf of RPS Consulting, to inform the BAFS (Section 2.4.2). As part of the current project, a repeat geomorphic walkover of the same reach was undertaken in May 2024. The purpose of this repeat survey was to assess the condition of the study reach, determining how this section of the River Dee and surrounding floodplain areas have changed since the previous geomorphic field assessment. The walkover included an assessment of Natural Flood Management (NFM) opportunities and other flood relief measures within the northern and southern floodplain. Findings from this survey aided the identification of options and the targeting of the topographic survey to further inform the predicted potential flood risk benefits of these measures.

3.1 METHODOLOGY AND RESULTS

A field-based geomorphic assessment ('fluvial audit') of the physical condition of ~2.5 km of the River Dee was undertaken on 29th and 30th May 2024. The assessment reach extended from Old Line Road Car Park (OS NGR NO 3602 9607) to the Ballater Royal Bridge (NO 3721 9559). The distribution of morphological, sedimentary and ecological factors in combination with human impacts were assessed along the length of the studied sections. This procedure is a location-specific inventory of the physical form of the river (i.e. morphology and sedimentology) that creates a template for key habitats and all likely influencing factors, providing an understanding of both form and function. This enhances our understanding of the causes of river management issues such as flooding and erosion and supports the implementation of sustainable measures to address such issues.

We have collected information including, but not limited to, the following:

- Reach-scale channel morphology (e.g. step pool, plane bed, pool-riffle, wandering). We use a classification system that is a combination of recognised procedures (i.e. Montgomery and Buffington, 1997; Brierley and Fryirs, 2000).
- Morphological/habitat units (i.e. pools, riffles, runs). These are specific 'mesoscale' features that, together, define reach-scale morphology. Such features can be regarded as the fundamental physical 'building blocks' of river channels and are closely related to habitat patterns. Therefore, such data can provide potentially valuable information to support assessments of ecological condition and habitats.
- Indicators of the sediment transport regime (e.g. the size, form, texture, dominant particle size and vegetation cover of bar features and bed forms). This information is essential for interpreting physical process within the river and has implications for ecological condition and habitats.
- Sediment sources (e.g. from upstream on the main river, tributaries, bank/terrace erosion). These sources have been recorded in terms of severity and extent.
- In-channel sediment storage (including alluvial bar features and evidence of bed accumulation). This data also provides an indication of the rate and distribution of sediment supply to downstream areas from within-channel sources. This includes any indicators of sediment transport (e.g. the size, form, texture and vegetation cover of bar features and bed forms).
- Large wood. The incidence, location (e.g. mid-channel, bank-side) and extents of natural large wood within the active channel, including their physical and ecological influence, have been

documented. Non-natural large wood, including bank toe protection, is recorded under the bank protection category.

- Vegetation. Both in-channel vegetation (e.g. macrophytes) and riparian/bank-side cover have been recorded, as well as invasive/non-native species.
- River engineering pressures (e.g. weirs, lades, impeded side channels, bank protection, canalisation, bunds, bridge crossings). These features have been characterised in terms of their extents and the severity of their impacts on river process.
- Floodplain morphology, including drainage channels/ditches, relict natural secondary channels, wetland areas and swales.
- Other indicators of the dynamic physical behaviour of the channel (e.g. abandoned channel courses, historic side channels, age structure of vegetation within the riparian corridor).
- Other land use pressures in the areas draining directly into the watercourses surveyed (e.g. urban drainage, livestock poaching, poor forestry drainage, field cultivation close to channel margins).

The collected data have been recorded using a mobile GIS platform, QField, with integral GPS capability. This allowed accurate determination of the position and extent of important features (e.g. length of bank erosion, areas of sediment stored in active bar features). High-resolution georeferenced photos were also taken throughout the survey reaches to capture significant features/structures and illustrate the general character of specific reaches.

Fluvial forms and processes observed during the 2024 geomorphic assessment are summarised in Table 3.1 and Figure 3.1. This information will be used to inform the options development in Section 5.

Table 3.1. Summary of geomorphic characteristic presented by the study site.

Feature/Dominant Characteristic	Description
Water body type	River
Planform	Actively meandering to wandering
Channel Bed Gradient (based on channel bed elevation surveyed by Aspect Survey in 2022).	Channel bed elevation decreases by 8.8 m over the 2.5 km channel length of the study site. Therefore, the average channel bed slope across the whole study reach is 0.35%. However, localised variations in bed slope were observed throughout the site in relation to varying bed morphology.
Bankfull Channel Width (between top of banks, based on Aspect Survey topographic data collected in 2022 and aerial imagery from 2023).	Ranges from ~50 m at the upstream extent of the survey near to the Old Line Road car park, widening to ~200 m across the area of alluvial deposition, just upstream of the River Muick confluence. The average (mean) width for the study reach of the River Dee is ~80 m.
Bankfull Depth (top of bank to base of the bank, based on Aspect Survey topographic data collected in 2022).	Left bank average (median) height is ~2 m, maximum height is ~3 m. Right bank average height is ~3.5 m, reaching a maximum height of ~8.6 m along the section known as the Red Braes.
Reach Type	Pool-riffle morphology
Bed Substrate	Cobble is dominant substrate size, with boulder/ cobble in the steepest, fastest flowing run sections and gravel/ cobble present within lower gradient riffle, pool and glide sections
Morphological Units and Bedforms	Primarily runs with shorter riffles and glides interspersed. To west and east of Ballater the channel is narrower (~55 m), with alternating lateral (bank attached) bars. To the south of the village the channel exhibits more dynamic behaviour, widening to ~200 m at its widest point. This section is characterised by a series of large alluvial bar forms that influence the dominant flow pathway through this wider reach.
Bank Condition	River left (Ballater/ north side): Bank erosion was noted on this bank in the section ~300 m upstream and downstream of the River Muick confluence. Erosion was particularly prevalent just upstream of the inflows to the side channels at the south-eastern end of the golf course. Bank material in this section consisted of cobble (64-256 mm) and gravel (2-64 mm) with sand (0.06-2mm) and silt (<0.06 mm). Boulder bank toe protection and riprap bank face protection were noted along this bank, throughout the upper third of the study reach, limiting bank erosion. Vegetation limited the visibility and condition assessment of bank toe protection; however, the riprap bank face protection was noted to be in good condition. The left bank had been breached in numerous locations, causing damage to the footpath.

		River right (south side): Agricultural land uses extend up to the top of bank in multiple locations. In the absence of stabilisation from the root system of a diverse riparian corridor, bank erosion was observed in multiple sections along this bank. Bank material consisted of cobble (64-256 mm) and gravel (2-64 mm) material within a finer matrix of sand (0.06-2mm) and silt (<0.06 mm), which aligns with the river terrace deposits known to be present here. One section ('Red Braes') is approximately ~8-10 m high and the active supply of material from this bank was observed during the walkover.
Vegetation	**In-channel**	Wooded islands are present near Dalliefour Farm and the River Muick confluence. Aside from these, no sign of vegetation colonisation on any of the bars was noted, further demonstrating the dynamic nature of this section. Some pieces of large wood material (e.g. tree trunks and branches) were noted on the bar forms that have formed around these vegetated islands.
	Riparian (river corridor)	River left: The bank side vegetation is predominantly scrubby grassland with tree coverage varying from continuous to scattered throughout the site, with the former more dominant. Beyond this, grassland that has been intensively managed for the golf course and caravan park, is present. River right: Where present, bank side vegetation is grass and ruderal vegetation. The riparian corridor is dominated by scrub, pastural grassland and forestry plantations.
Engineering Pressures		Bund on the river left bank throughout the majority of the site (locally breached). Telegraph poles and associated cabling crossing the channel in two locations. The location upstream of the River Muick confluence is scheduled to be removed. Discontinuous boulder bank toe protection on river left bank. Full bank face protection using rip rap was noted in two locations on the river left. Bridge with three piers at the downstream end of the study site, known as the Royal Ballater Bridge. Centred on OS NGR NO 3722 9559.
Main Areas of Recent Change (from aerial photographs and LiDAR)		The section of channel between Dalliefour Farm and the River Muick confluence exhibits signs of significant geomorphic adjustment. Continued deposition has extended the sediment bar on the northern side of the island, next to the Muick confluence, further northwards. The orientation of this bedform is encouraging the main flow pathway towards the footpath, golf course and the side channels that have recently been cleared. Deposition around the next island upstream, nearer to Dalliefour Farm, has extended to the south and east over time. The development of this bar feature has promoted lateral channel adjustment and meander migration to the southeast, towards a historical channel on the south side of the Dee. These

	areas of change are clear in the comparison of 2010 and 2023 channel planform positions, presented Figure 2.3. The positioning of the two aforementioned barforms encourages the flow towards the golf course, at the location where the Hesco bags have been installed, during flood events. However, dynamic rivers with a high sediment supply such as the River Dee are characterised by their substantial and changeable barforms. Therefore, it is likely that significant geomorphic adjustment will occur in this area during future flood events, which may alter the orientation and position of these barforms.

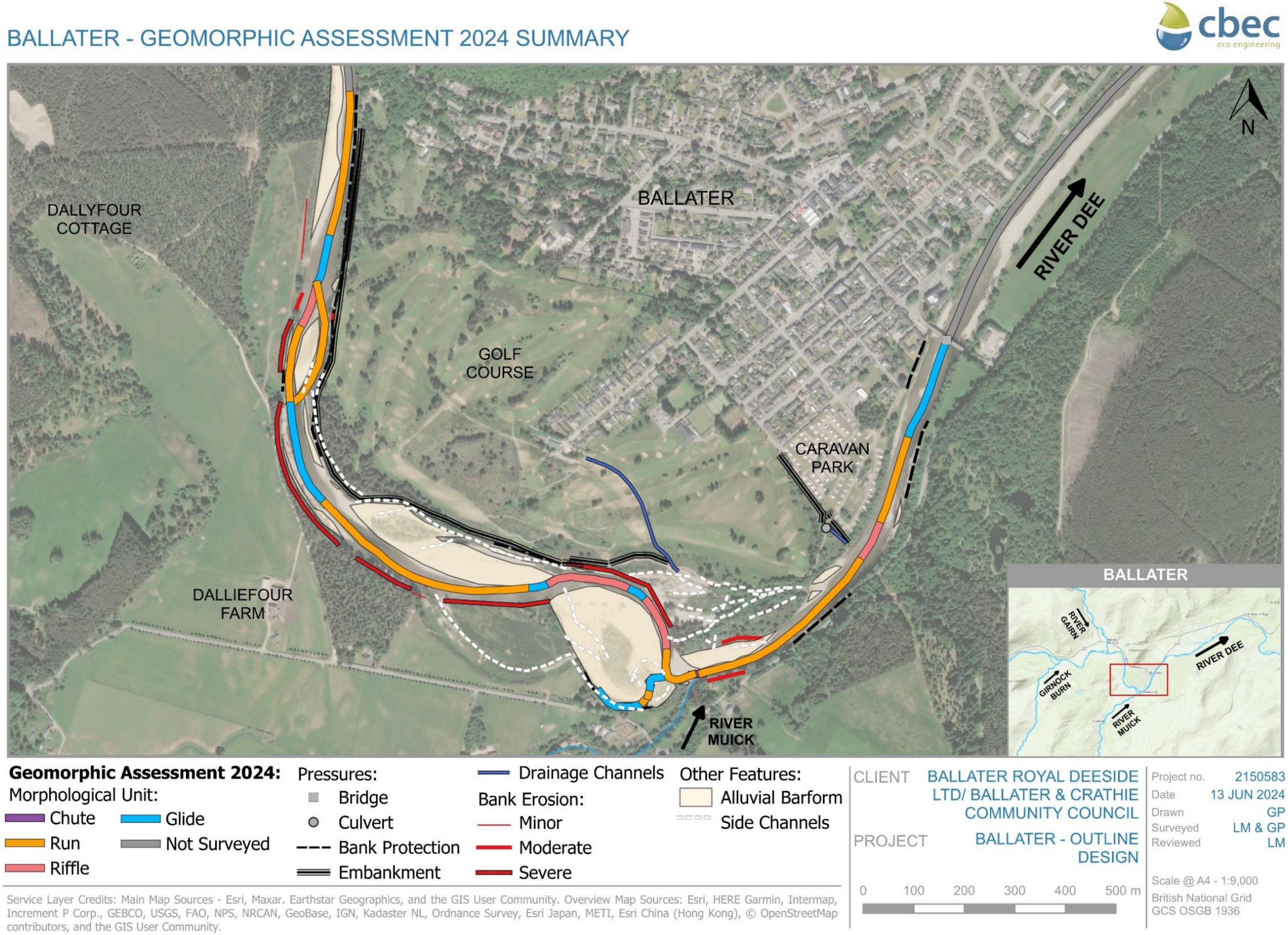


Figure 3.1. Summary of geomorphic assessment undertaken in May 2024.

4. TOPOGRAPHIC DATA

4.1 REVIEW OF EXISTING TOPOGRAPHIC DATA

A search of the Scottish Government's Remote Sensing portal concluded that open-source LiDAR data, surveyed in 2011 to 2012 was available for the Ballater area. Given the significant change to the channel bed and banks during Storm Frank, this LiDAR data will not accurately depict the channel morphology displayed at present[3]. However, it could still be used to advise on the floodplain topography, outwith the river corridor. To supplement this data, as part of this project, a topographic survey has been undertaken to characterise the existing channel and floodplain morphology where flood management works are thought to be feasible. This data collection methodology is further described in Section 4.2, the outputs of which will be utilised to inform the concept design development.

To support the BAFS modelling, RPS commissioned Aspect Surveys to undertake a topographic survey of the River Dee and adjacent floodplain to inform the options modelling. The data collection took the form of a cross-sectional survey of the River Dee from the Old Line Road car park to ~200 m downstream of the Royal Ballater Bridge. Floodplain levels were also recorded, on both banks, from the Red Braes downstream to, and including, the side channels to the south-eastern edge of the golf course. The Aspect Survey data also includes LiDAR covering the southern area of the study site in detail. Whilst this data, collected in March and April 2022, does not cover the full extent of the area assessed for this project, it provides updated coverage of the channel and riparian areas surrounding the most geomorphologically active section of the study.

A combination of the Aspect Surveys data, supplemented with open-source LIDAR for the wider floodplain will be used to inform the design development. However, it is important to note that the data collected to inform the flood study is unlikely to be sufficiently detailed to inform detailed design development in such a complex channel environment. Areas where further change between 2022 and 2024 have occurred and areas not covered within the 2022 survey were captured by an additional topographic survey undertaken by cbec in June 2024. Further details of this assessment are provided in the subsequent section (4.2).

4.2 2024 TOPOGRAPHIC SURVEY

A targeted topographic survey of the study site was undertaken from 11th to 14th June 2024. Data collection was guided by observations made during the geomorphic assessment (Section 3). A detailed, gridded, 2D topographic survey was undertaken in areas identified as presenting potential for flood management measures. Data collection encompassed sections of the River Dee floodplain on both the north and south side of the watercourse, as well as sections of the channel itself. The collected data points were used to produce a Digital Elevation Model (DEM) of the existing conditions at the study site. This dataset was used to inform the options identification (Section 5) and subsequent revisions during the concept design phase.

[3] More recent, post 'Storm Frank' LiDAR from JHI (2016) exists but was not available/provided as part of this project.

5. OPTIONS DEVELOPMENT

5.1 SUMMARY OF SITE CONDITIONS AND CONSTRAINTS

As part of the options identification process, any site-specific features and characteristics that provided an opportunity for a particular flood management approach were identified, as well as constraints that can limit the development of specific interventions. A summary of these findings from the desk- and field-based assessments are provided below.

- The River Dee is classified as a Special Area for Conservation (SAC) owing to the presence of Atlantic salmon, freshwater pearl mussel and otter. Options proposed should therefore consider the potential impacts on existing in-channel and riparian habitats.
- Ballater Royal Bridge, situated at the downstream end of the study site, is classified as a listed building. Therefore, consideration should be given to the implications of any proposed options on the integrity of this structure. Additionally, the options proposed in the subsequent sections will seek to protect against and/ or divert flow away from the properties; therefore, other listed buildings within the village itself will be incorporated within these considerations.
- The golf course and caravan park are two of the larger local businesses, central to tourism and the village economy. Therefore, maintaining the functionality and aesthetics of these sites and the wider village will be a significant consideration in the options development.
- Telegraph poles crossing the watercourse, upstream of the River Muick confluence, are planned for removal. Therefore, this utility line has not been considered as a constraint within the subsequent options appraisal.
- Existing flood defences include the bankside footpath bund, which extends from downstream of the Old-Line Road car park to just upstream of the River Muick confluence on the river left (northern) bank. Following the BAFS report (Section 2.4.2), an additional bund consisting of Hesco bags has been constructed just upstream of the golf course drainage channel confluence with the River Dee. A further informal bund (<0.5 m high) is present along the footpath to the caravan park and could be formalised into a flood defence.
- Community groups have undertaken recent debris clearance in the side channels to the southeast of the golf course. An assessment of historical channel planform adjustment (Figure 2.2 and Figure 2.3) indicated that the River Dee would have previously occupied this area, to the north of the present-day main stem of the channel, between at least the 1860s to early 1900s.[4]
- Ballater is located on the inside of a large meander bend. Typically, a point bar would form adjacent to the inner bank and a pool develop along the outer bank of a meander; this has occurred to some extent, although the process has been impacted by the local storage of sediment in the reach and the near-wandering channel morphology set within the large meander planform of the Dee at this location. The following factors have contributed to the particular complexity of the River Dee's morphology to the south of the golf course:
    - High sediment supply from the upper catchment;
    - Deposition of considerable volumes of large wood, adding to dynamic channel processes within the study reach;

[4] The earliest Ordnance Survey map for the area is dated 1869, according to the National Library for Scotland's historic map archives. See Section 2.3 for further details.

- Widening of the channel and reduction of valley topographic confinement, lowering the energy available for geomorphic work as the flow spreads out across this wider section of the Dee to the south of the golf course, promoting depositional processes;
- Telegraph poles within the active channel interacting with channel hydraulics.

These geomorphic features and constraints have been taken into consideration to inform the options identification outlined within the subsequent two sections (5.2 and 5.3).

5.2 IDENTIFICATION OF OPTIONS

Based on the desk- and field-based assessments detailed above, a range of potential management options have been developed for the site, intended primarily to aid the sustainable management of flood risk. These options have been developed according to a 'nature-based approach' to addressing flood risk, as much as is practicable, working with rather than resisting river processes and thus producing more sustainable long-term solutions.

A high-level assessment of the options considered as potential 'minor works' in the 2023 BAFS report (see Section 2.4) was also undertaken to inform the options appraisal here. Flood maps provided in Appendix F of the BAFS report have been consulted in order to index each of the proposed options semi-quantitatively, considering the expected degree of protection each could offer (i.e. whether a given management option is likely to offer benefit for flood events of various sizes). The identified options are summarised in Table 5.1. Further details on the longlisted options are provided in Section 5.3.

5.3 OPTIONS LONGLIST

As part of the options appraisal process, both qualitative and semi-quantitative assessments of the proposed options have been undertaken. The prioritisation (shown in Table 5.1) is based on cbec's expert judgement as to which measures are most likely to provide the greatest benefit in terms of flood risk, based on the semi-quantitative analysis detailed in this report.

Separate to this prioritisation process, a subjective, qualitative assessment of feasibility based on available information has also been made, regarding the development potential, deliverability and cost of each of the proposed options. Each of the longlisted options has been colour coded on this basis, as summarised in Table 5.2**,** providing an overview of the overall feasibility of the option and including technical and cost considerations. Feasibility in this context refers to how straightforward or complex the subsequent design development and construction (delivery) phases of work are estimated to be for each option. The three assessment criteria, development, deliverability and cost, are not intrinsically linked. These criteria are dependent on the nature and scale of the proposed option as well as site-specific constraints and considerations. For example, an option may be ranked as high for development of the design, due to the complex river geomorphology of the River Dee and hydraulic modelling required, but the delivery of the construction works may require a medium skill level, and the overall cost may be high due to the complexity of the design development and scale of the option.

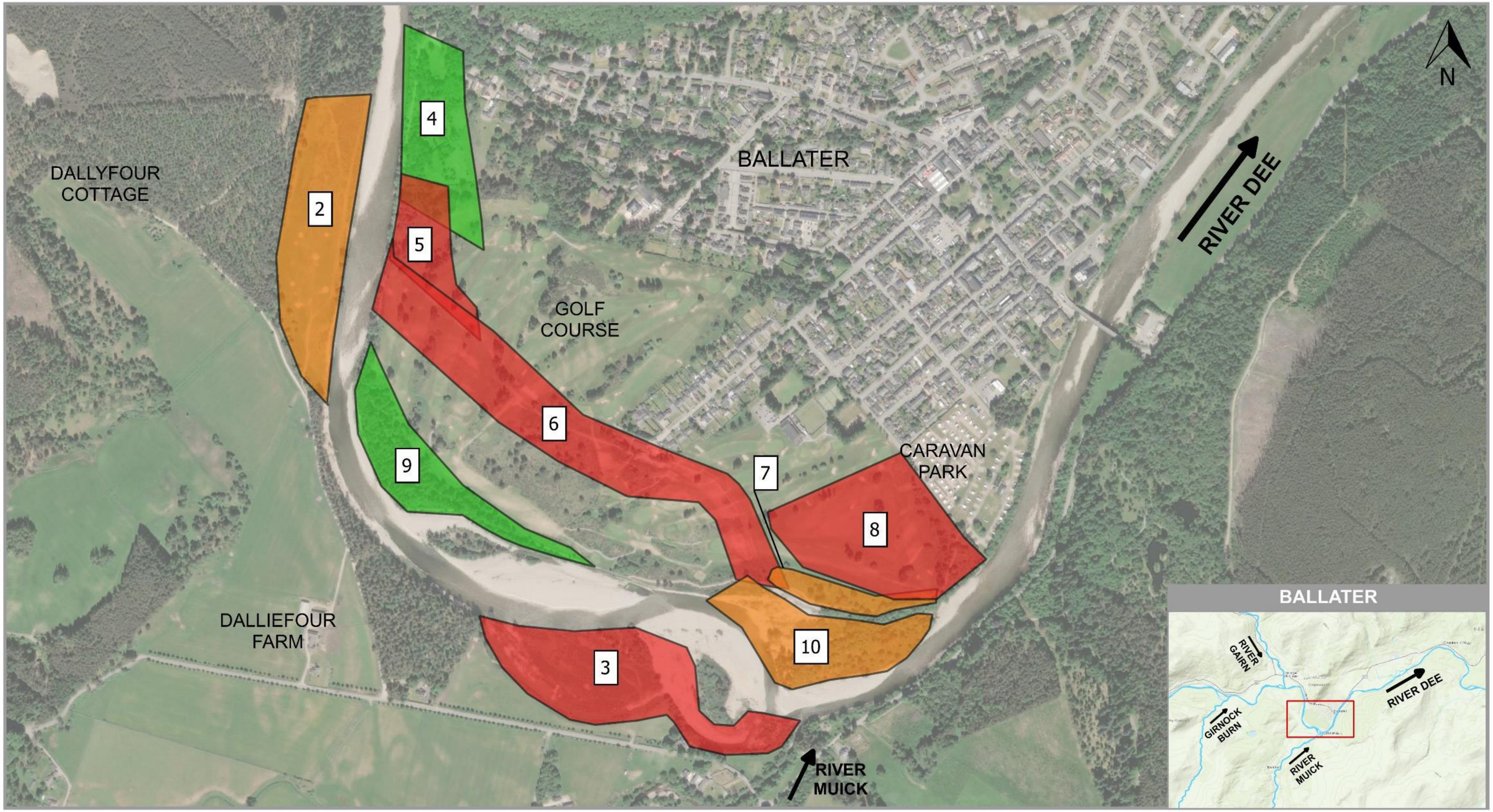
It should be noted that at the scoping/ feasibility stage of a project there are still a significant number of unknowns relating to these options. Therefore, these assessments should be used with caution and the associated risks understood. It is important to note that the feasibility of delivering a given option may increase or decrease when various options are combined within a single implementation area.

Table 5.1. Summary of the options identified.

Number	Option	Priority	Flood scenario benefit (1 in X Years)[5]	Flood scenario benefit (peak discharge in m^3/s)	Comments
1	Do nothing	N/A	None	None	
2	Enhance storage on river right floodplain	Medium	5, 10, 30, 100	>500	additional storage capacity during larger events likely minimal
3	Reactivate former channel courses	High	5, 10, 30, 100	>500	some storage capacity benefits possible but benefits primarily for lower magnitude events and in redirecting flow paths
4	Increase storage in wooded area	Low	100	>1000	flood mechanism only activated at ~1000 m^3/s flood events and above
5	Construct bund to intercept flow exiting River Dee from river left bank	High	10, 30, 100	>600	combine with Option 6 for maximum benefit
6	Increase storage capacity on golf course by constructing swale/ scrape network	High	5, 10, 30, 100	>500	combine with Option 5 for maximum benefit
7	Enhance existing Hesco bag bund	Medium	5, 10, 30, 100	>500	ideally combine with other options to deflect flow pathways away from left bank (e.g. Options 3 & 10)
8	Construct swales linking to culvert/ outflow (see Figure 3.1) and enhance bund along path	High	5, 10, 30, 100	>500	intercept spill that currently travels across golf course towards Ballater
9	Enhance connectivity and storage on left bank floodplain	Low	5, 10, 30, 100	>500	attenuation benefit likely limited, given size of area, but may be other benefits (e.g. drought resilience, habitat improvements)
10	Clear channels in front of Hesco bag bund to divert flow pathways away from golf course	Medium	5, 10, 30, 100	>500	ideally combined with Options 6 and/ or 8 (benefit of increased capacity likely limited for larger events)

[5] This study has focused on the more frequent, lower magnitude flood events, considering how the proposed options will benefit flood events ranging from ~400 to ~1000 m^3/s, based on flow estimates produced as part of the BFPS and flood modelling results presented in Appendix F of the BAFS report. Events up to ~1000 m^3/s (corresponding to the 100 year event) have been considered here, although it is important to note that it is unlikely that the measures proposed here would offer significant protection for events of this magnitude. It is also important to note that the options may have additional benefit for smaller flood events that have not been explicitly modelled.

BALLATER - FLOOD MANAGEMENT OPTION AREAS OVERVIEW



Options Area Priority Levels:

- High
- Medium
- Low

Service Layer Credits: Main Map Sources - Esri, Maxar. Earthstar Geographics, and the GIS User Community. Overview Map Sources: Esri, HERE Garmin, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), © OpenStreetMap contributors, and the GIS User Community.

CLIENT: BALLATER ROYAL DEESIDE LTD/ BALLATER & CRATHIE COMMUNITY COUNCIL

PROJECT: BALLATER - OUTLINE DESIGN

0 100 200 300 400 500 m

Project no. 2150583
Date 13 JUN 2024
Drawn GP
Designed LM & HM
Reviewed LM

Scale @ A4 - 1:9,000
British National Grid
GCS OSGB 1936

Figure 5.1. Summary of option area locations and priority levels.

Table 5.2. Qualitative classification of option feasibility, broken down into development, deliverability and costs categories.

Feasibility	Development	Deliverability	Cost
Low	No site-specific design or additional surveys required. Limited consenting requirements.	Manual work requiring minimal unskilled labour and little or no machinery.	£1k-£10k
Medium	Outline design drawings. Some consenting and additional surveys likely.	Requirement for some machinery and skilled labour.	£10k-£50k
High	Detailed design and modelling. Additional surveys and consents required.	Construction requiring heavy machinery, multiple personnel, and specialised staff.	>£50k

In addition to this qualitative ranking, we have presented our semi-quantitative indexing of the potential options in relation to the expected degree of protection. This indexing has been based on the flood extents and depths derived as part of the Ballater Additional Flood Study from 2023 (provided in Appendix F of the BAFS report) and identifies whether each option is likely to impact or interact with flows of a given magnitude (based on the specific design events modelled as part of the BAFS). Although flood mechanisms for the ~400 m^3/s event have also been considered here, and the proposed options are likely to provide benefit for events in this size range, it is understood that it is primarily events with flows exceeding ~500 m^3/s that are of greatest concern for the community; accordingly, the ~400 m^3/s event is not included within the semi-quantitative indexing presented here. It is important to note that it is not possible at this stage to provide a quantitative estimate of precise benefits to flood risk (e.g. changes in flooding extents/ depths or duration for a specific size of flood). However, combining consideration of the BAFS flood maps with high-level topographic analysis based on LiDAR and targeted survey (Section 4) has allowed both this semi-quantitative indexing of the options and a high-level assessment of overall feasibility.

As the primary motivation for this study is the reduction in flood risk to Ballater, this report has focused primarily on flood risk benefits and potential disadvantages/ risks. However, where appropriate, other benefits and disadvantages have also been considered; for example, the Project Group has highlighted concerns over drought resilience in the face of climate change and some of the proposed options have potential to offer multiple benefits such as climate resilience and biodiversity improvement. It is also important to note that individual NFM measures may not have significant flood risk benefits when adopted in isolation; rather, it is the cumulative effects of multiple interventions that are likely to offer the most significant flood risk benefits. For each of the potential options listed in

Table 5.1, indicative outline design maps have been produced, identifying the key features of the option and annotated with relevant details sufficient to inform the option refinement during the concept design phase (i.e. the next phase of this project). A fact sheet for each of the options has also been produced detailing the benefits, disadvantages and risks associated with the individual measures, in addition to the qualitative and semi-quantitative rankings outlined above. It is important to note that the extents and locations of proposed options should be considered indicative only at this stage and that precise benefit to flood risk cannot be quantified within the scope of the present study. Similarly, a more in-depth consideration of the potential alignments, dimensions and design of specific features will require additional assessments (including hydraulic modelling) and design work, although a high-level consideration of these features will form part of the development of outline designs.

Table 5.3 Option 1 factsheet

<table>
<tr><td>Option 1</td><td colspan="12">Do nothing</td></tr>
<tr><td>Benefits expected for events with flows (m^3/s)</td><td colspan="3"><s>500</s></td><td colspan="3"><s>600</s></td><td colspan="3"><s>750</s></td><td colspan="3"><s>1000</s></td></tr>
<tr><td>Qualitative classification of feasibility (see Table 5.2)</td><td colspan="4">Development
Low</td><td colspan="4">Deliverability
Low</td><td colspan="4">Cost
Low</td></tr>
<tr><td>Diagrams</td><td colspan="12">None</td></tr>
<tr><td colspan="13">Description of option
• Cease any regular channel management activities and do not undertake any further maintenance works
• Very occasional ‘emergency’ maintenance measures may still be undertaken</td></tr>
<tr><td colspan="13">Flood risk implications
• No flood risk benefits (with the exception of any arising co-incidentally from natural river adjustment)</td></tr>
<tr><td colspan="13">Wider advantages and disadvantages
• No direct associated costs
• No disruption to existing site</td></tr>
<tr><td colspan="13">Risk appraisal and mitigation measures
Not applicable</td></tr>
<tr><td colspan="13">Further assessments and permissions required
Not applicable</td></tr>
</table>

Table 5.4. Option 2 factsheet

Option 2	Enhance storage on river right (west) floodplain			
Benefits expected for events with flows (m^3/s)	500	600	750	1000
Qualitative classification of feasibility (see Table 5.2)	Development *High*	Deliverability *Medium*	Cost *Medium*	
Diagrams	Figure 5.2 / Appendix A, Section 2			

Description of option

- Enhanced connectivity of River Dee with river right (western) floodplain near Dallyfour Cottage
- Potential to enhance existing channels and create additional storage in form of scrapes and swales
- Option area centred on OS NGR NO 3588 9577

Flood risk implications

- Medium priority opportunity for flood benefits
- BAFS modelling indicates some flow/floodplain inundation from ~400 m^3/s event upwards
- Potential to increase flood storage for ~400 and 500 m^3/s event, e.g. by improving connectivity at upstream end of floodplain and excavating scrapes and swales, (benefit will be limited due to size of area available)
- Benefits for events of ~600 m^3/s and above likely to be minimal, given existing inundation patterns

Wider advantages and disadvantages

Advantages

- Improved biodiversity in localised area
- Storage of water on opposite river bank to Ballater, with potential for temporary reduction in flow downstream and impacting village during flood events
- Flood storage area may also provide ecological benefits through creation of wetland or wet woodland areas
- Potential localised contribution towards drought resilience through storage during and slow release of water following flood events

Disadvantages

- Disruption to current land use during construction and subsequent flood events – landowner may need to be compensated for temporary loss of workable land
- Relatively small area in relation to size of River Dee floodplain locally, so option unlikely to offer appreciable flood attenuation in isolation but would contribute to overall flood protection

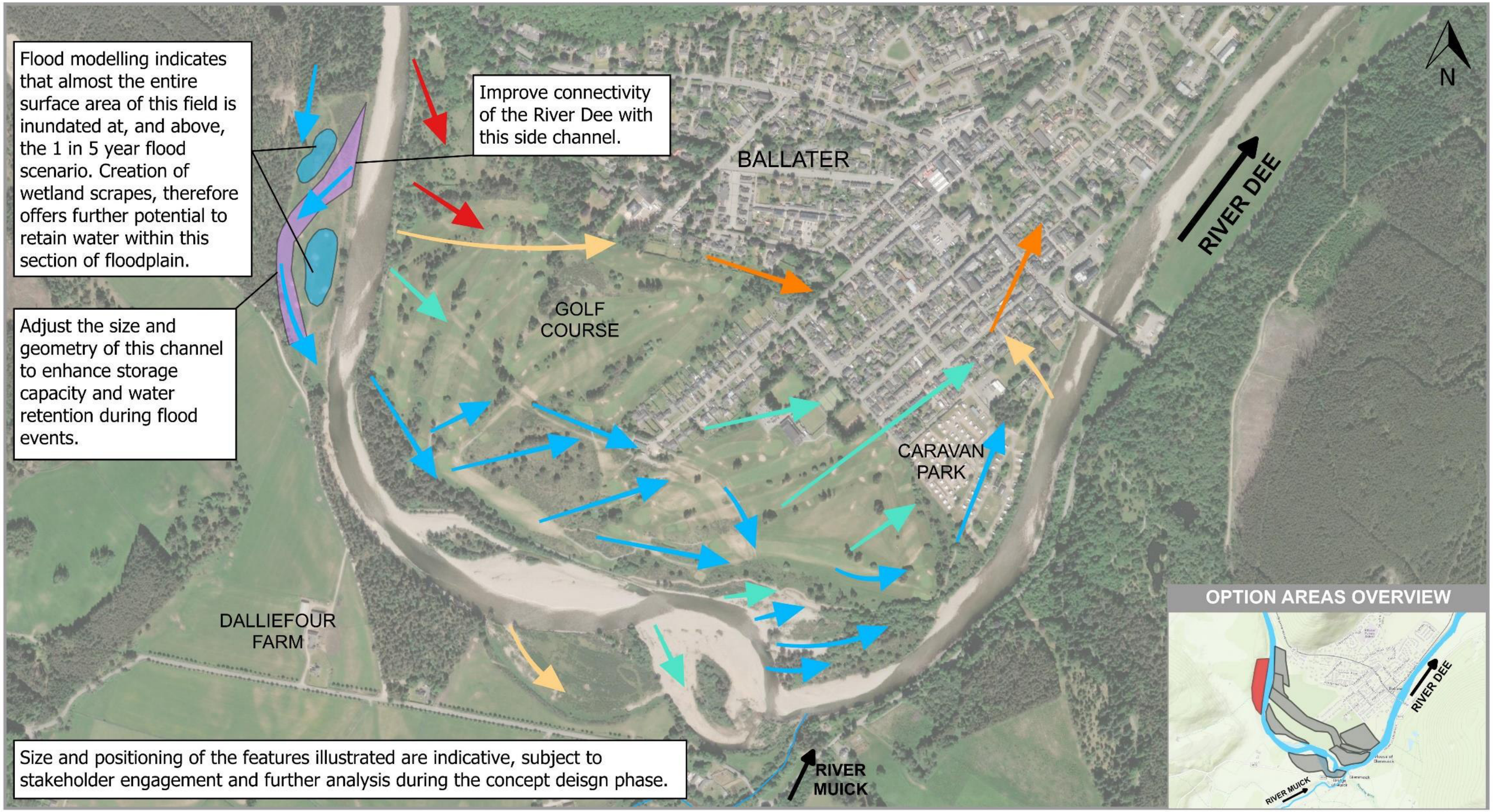
Risk appraisal and mitigation measures

- Downstream tie-in location for flood waters to return to River Dee to be carefully designed to avoid increasing risk of flooding to access road on south side of River Dee and/or having a negative impact on the river left bank and/ or risk of physical instability (i.e. head-cut risk)

Further assessments and permissions required

- Wider topographic data collection, analysis and hydraulic modelling at detailed design phase to determine depth and extent of excavation required to enhance flood storage within field (model recommended to be run for the entire site with combined options, rather than individual models for each option)
- Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater)
- Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC are met and licences can be obtained)
- CAR Engineering Licence (SEPA) – level of licence to be determined at detailed design. Licence fees may apply

BALLATER - OPTION 2 - ENHANCE STORAGE ON RIVER RIGHT FLOODPLAIN



Flow pathways activated at different flow scenarios:*

- ~400 m³/s and above
- ~500 m³/s and above
- ~600 m³/s and above
- ~750 m³/s and above
- ~1,000 m³/s and above

Flood Management - Option 2:

- Enhance side channel
- Wetland scrape creation

*Flow pathways are based on the flood model outputs presented in Appendix F of the Ballater Additional Flood Study.

CLIENT	BALLATER ROYAL DEESIDE LTD/ BALLATER & CRATHIE COMMUNITY COUNCIL
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Drawn	GP
Designed	LM & HM
Reviewed	LM

0 100 200 300 400 500 m

Scale @ A4 - 1:9,000
British National Grid
GCS OSGB 1936

Figure 5.2 Option 2 - Enhance storage on the river right floodplain.

Table 5.5 Option 3 factsheet

Option 3	Reactivate former channel courses			
Benefits expected for events with flows (m^3/s)	500	600	750	1000
Qualitative classification of feasibility (see Table 5.2)	Development *High*	Deliverability *Medium*	Cost *High*	
Diagrams	Figure 5.3 / Appendix A, Section 3 – A & Section 3 - B			

Description of option

- Reactivation of former channel courses to encourage flow away from Ballater
- Includes (A) the relict meander bend on the southern side of the River Dee near Milton of Brackley, centred on OS NGR NO 3630 9495 and (B) a section of the active channel on the approach to the River Muick confluence that was previously the main channel course
- Installation of large wood structures (i.e. tree trunks with root plates attached) to control loci of deposition within channel and promote sustainability of measure
- Localised excavation of sediment within channel required (e.g. at inlet to former course at A and to address partial infilling at B)
- Telegraph poles currently present on barform within B (centred on OS NGR NO 36560 9496) - removal of these (understood to be planned) and associated structures may encourage mobilisation of sediment here

Flood risk implications

- BAFS modelling results indicate (A) still activated at ~600 m^3/s event and above
- Flows exiting River Dee to river left at current apex of meander bend contributing to flooding of river left (east) bank for ~400 m^3/s event and above and known to be causing issues with erosion (including erosion of bund)
- Encouraging shift to historical channel alignment would direct flow away from river left (east) bank and change angle of approach of flows
- Direct impact on flood depth and extent may in reality be small unless channel capacity increased, but likely to reduce erosion risk posed to any other management options adopted. (Channel capacity may naturally increase and become main flow route as channel becomes more frequently inundated).

Wider advantages and disadvantages

Advantages

- Reduced erosion risk to existing bund and any other options implemented as result of present study
- Benefits for natural river form and process through sustainable management of sediment

Disadvantages

- Area is currently a sediment storage area and management measures unlikely to be sustainable without careful design
- Moving channel further south may impact infrastructure and property in this area

Risk appraisal and mitigation measures

- Morphodynamic modelling required to determine likely future evolution of channel, allowing modification of the design to ensure development of a sustainable option
- FRA required to consider risk to river right infrastructure

Further assessments and permissions required

- Wider topographic data collection, analysis and morphodynamic modelling to develop sustainable detailed design (model recommended to be run for the entire site with combined options, rather than individual models for each option)

- Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater)
- Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC are met and licences can be obtained)
- CAR Engineering Licence (SEPA) – level of licence to be determined at detailed design. Licence fees may apply

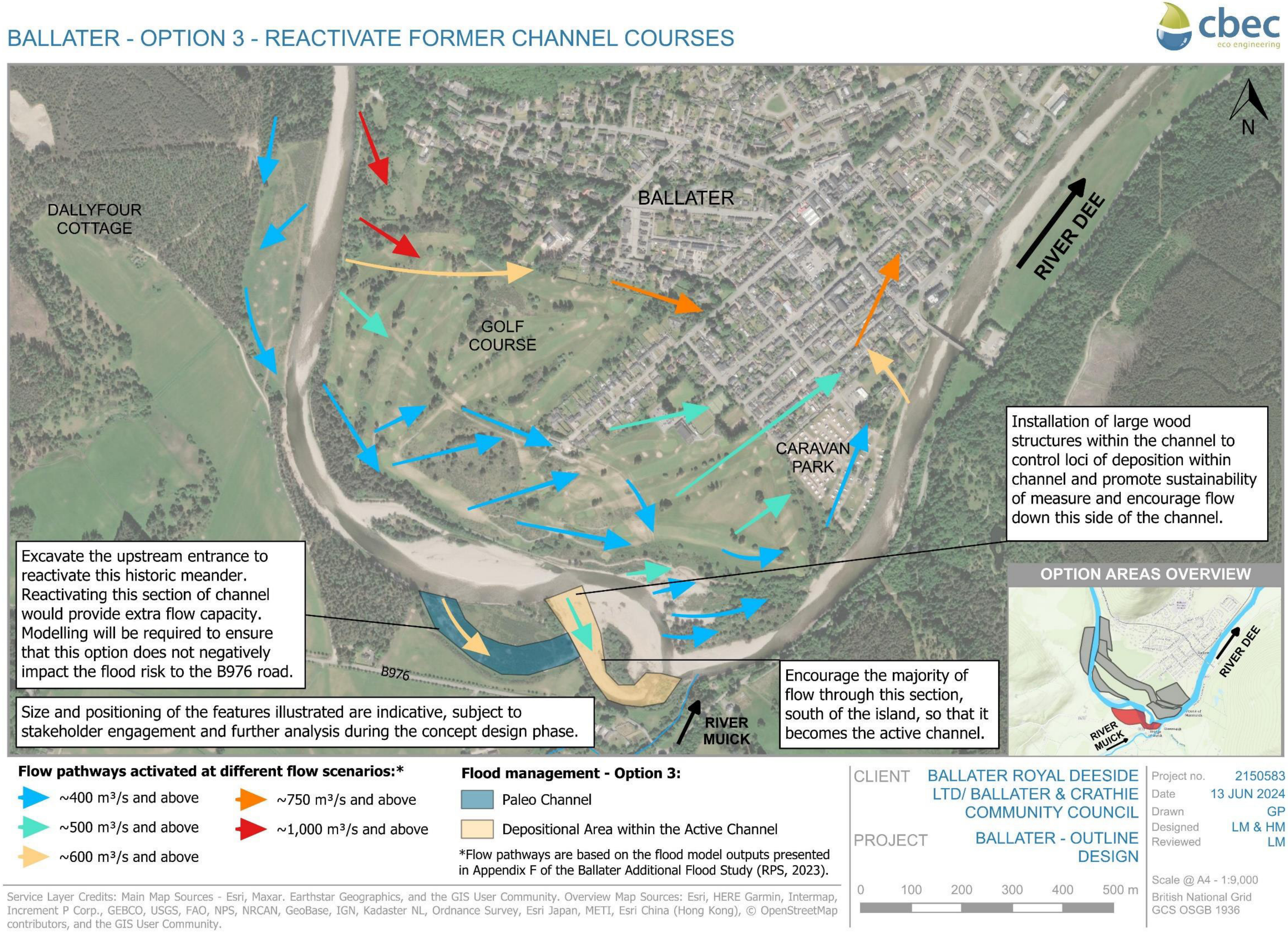


Figure 5.3 Option 3 - Reactivate former channel courses.

Table 5.6. Option 4 factsheet

<table>
<tr><td>Option 4</td><td colspan="12">Increase storage in wooded area</td></tr>
<tr><td>Benefits expected for events with flows (m³/s)</td><td colspan="3">~~500~~</td><td colspan="3">~~600~~</td><td colspan="3">~~750~~</td><td colspan="3">1000</td></tr>
<tr><td>Qualitative classification of feasibility (see Table 5.2)</td><td colspan="4">Development
High</td><td colspan="4">Deliverability
Medium</td><td colspan="4">Cost
High</td></tr>
<tr><td>Diagrams</td><td colspan="12">Figure 5.4 / Appendix A, Section 4</td></tr>
</table>

Description of option

- Anecdotal evidence indicated that flow pathway arises from river left (east) upstream of Ballater for larger flood events, supported by BAFS modelling for ~1000 m^3/s event and SEPA Flood Maps
- Potential to intercept and slow flow and encourage additional storage in wooded area
- Construction of bund to intercept flow pathways and scrapes/swales to enhance flood storage

Flood risk implications

- Main benefits likely to be for ~1000 m^3/s event and above only, although some benefits could be realised for lower magnitude events depending on design
- Could be combined with other options (e.g. Options 5, 6 and 9) to maximise flood benefit
- Unlikely to be feasible option if undertaken in isolation given lack of benefit for smaller flood events
- BAFS flood maps show modelled flood depths of <0.25 m for ~1000 m^3/s and up to ~1 m for 1150 m^3/s event at the location of the proposed bund, suggesting bund with height of ~1 m should be sufficient to intercept flows along this pathway (although iterative modelling/ design would be required to design interventions and determine accurate dimensions of bund and scrapes required)

Wider advantages and disadvantages

Advantages

- Potential to incorporate habitat and access/recreation benefits alongside flood risk objectives
- Unlikely to impact long-term 'playability' of golf course if footprint of bund kept outside boundary

Disadvantages

- Risk of disturbance of existing good habitat may outweigh potential benefits
- Alteration to existing footpath network, which currently runs along the crest of the existing bund, would be required
- Short-term disturbance during construction
- Land ownership may pose constraint to implementation
- Maintenance costs of new bund (e.g. grass cutting to maintain surface stability) and scrapes

Risk appraisal and mitigation measures

- Residual flood risk – to be quantified based on further assessments
- Risk to existing habitat – to be considered based on ecological assessment

Further assessments and permissions required

- Wider topographic data collection, analysis and hydraulic modelling at detailed design phase to determine dimensions of features required to adequately reduce flood risk (model recommended to be run for the entire site with combined options, rather than individual models for each option)
- Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater)

- Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC and Craigendarroch SSSI are met and licences can be obtained)
- CAR Engineering Licence (SEPA) – level of licence to be determined at detailed design. Licence fees may apply

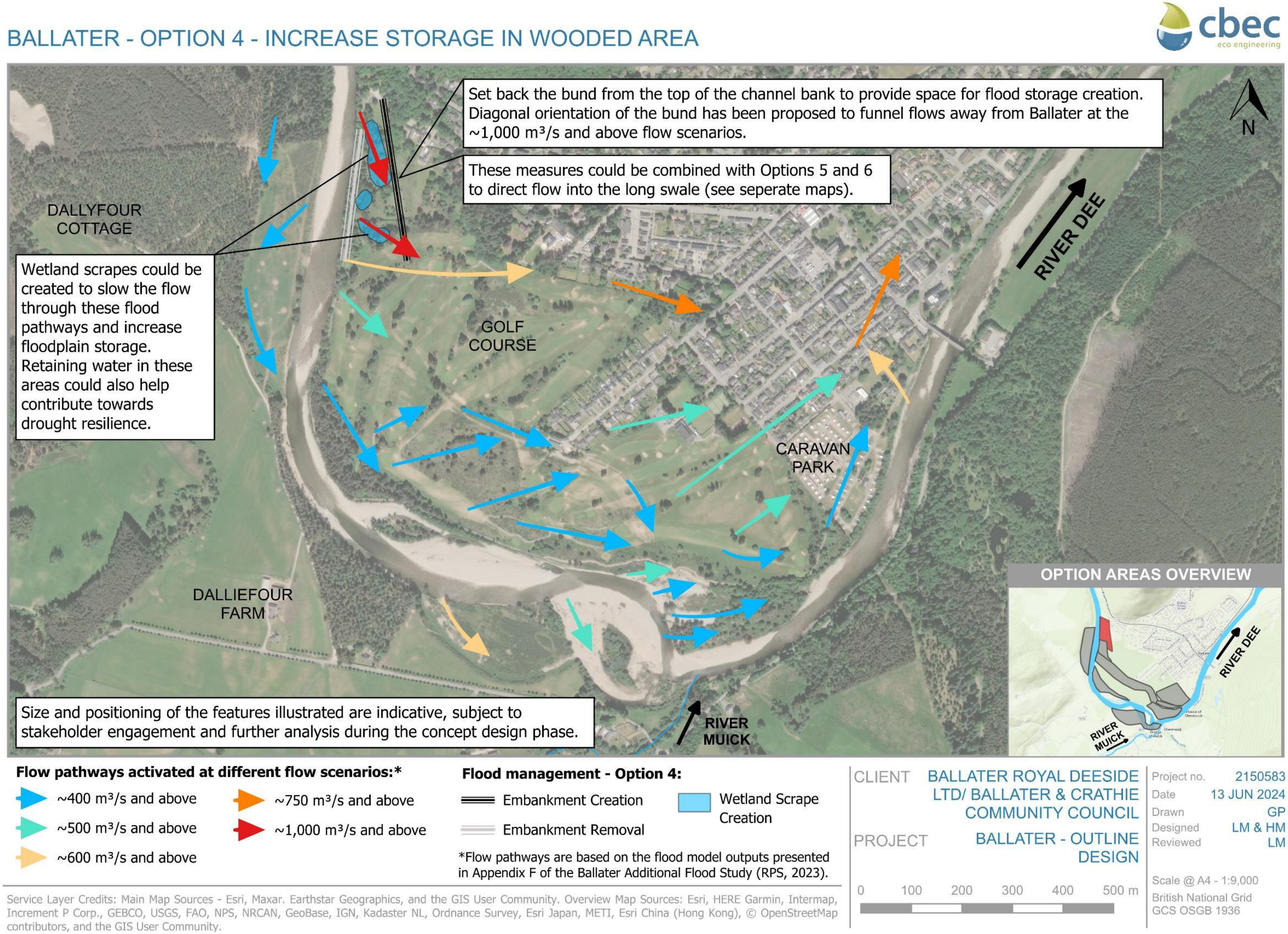


Figure 5.4 Option 4 – Increase storage in wooded area.

Table 5.7. Option 5 factsheet

Option 5	Bund to intercept flow exiting River Dee from river left bank					
Benefits expected for events with flows (m^3/s)	~~500~~	600		750		1000
Qualitative classification of feasibility (see Table 5.2)	Development *High*		Deliverability *Medium*		Cost *High*	
Diagrams	Figure 5.5 / Appendix A, Section 5					

Description of option

- Construction of bund to intercept flow pathway activated for ~600 m^3/s event and above
- Bund would be designed to direct flows southwards to join main flow pathway through golf course
- Ideally combined with Option 6
- Could be carried out in combination with Option 4

Flood risk implications

- Specific flow pathway is activated at ~600 m^3/s event and higher
- Blocking flow pathway would act to reduce flooding of properties on Abergeldie Road and Golf Road in particular but also likely to reduce flood risk for properties elsewhere within Ballater
- Diverting flows southward may increase flood risk elsewhere unless conveyance capacity of channel/flow pathway through golf course can be increased (i.e. as in Option 6)
- BAFS flood maps show modelled depths of up to ~1.5 m along proposed footprint of bund for ~1000 m^3/s event, suggesting bund height of ~1.5 m may be sufficient to divert flows along this flow pathway towards south (assuming sufficient capacity to convey additional flood waters through golf course, and noting that iterative hydraulic modelling/ design would be required to specify interventions and determine accurate dimensions of bund and scrapes required)

Wider advantages and disadvantages

Advantages

- Potential to incorporate habitat and access/recreation benefits alongside flood risk objectives, particularly if combined with Option 4 and/or Option 6

Disadvantages

- Risk of disturbance of existing woodland habitat may outweigh potential benefits
- Alteration to existing footpath network, which currently runs along the crest of the existing bund, would be required
- Short-term disturbance during construction
- Potential for impacts on long-term 'playability' of this north west section of the golf course (may require some modification to the affected golf holes to maintain/enhance the golf experience)
- Maintenance costs of new bund (e.g. grass cutting to maintain surface stability)

Risk appraisal and mitigation measures

- Residual flood risk – to be quantified based on further assessments
- Risk to existing habitat – to be considered based on ecological assessment

Further assessments and permissions required

- Wider topographic data collection, analysis and hydraulic modelling at detailed design phase to determine dimensions of features required to adequately reduce flood risk (model recommended to be run for the entire site with combined options, rather than individual models for each option)

- Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater)
- Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC and nearby Craigendarroch SSSI are met and licences can be obtained)
- CAR Engineering Licence (SEPA) – level of licence to be determined at detailed design. Licence fees may apply

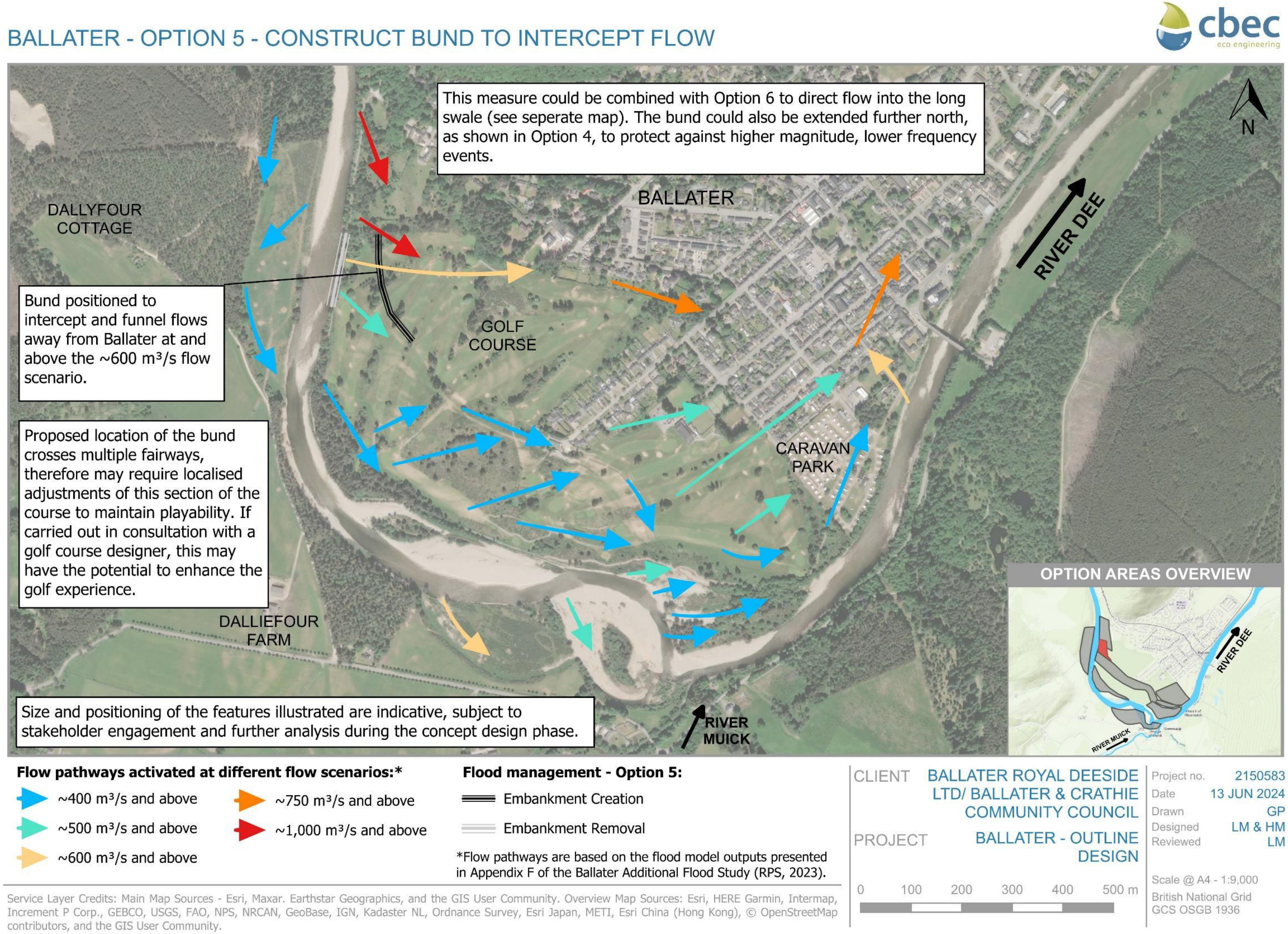


Figure 5.5 Option 5 - Construct bund to intercept flow.

Table 5.8. Option 6 factsheet

Option 6	Increase storage capacity on golf course			
Benefits expected for events with flows (m^3/s)	500	600	750	1000
Qualitative classification of feasibility (see Table 5.2)	Development *High*	Deliverability *High*	Cost *High*	
Diagrams	Figure 5.6 / Appendix A, Section 6 – A & Section 6 - B			

Description of option

- Increase conveyance capacity across golf course area by enhancing existing topographic low points to varying degrees, to construct swale(s) and scrapes
- Alignment of primary swale to follow existing high-flow pathways, modified to avoid properties (e.g. at southern end of Golf Road)
- Objective of swale would be to 'collect' flows entering golf course and release into the River Dee through an enhanced version of existing drainage network
- Depending on achievable capacity, could also reduce spill from golf course towards caravan park

Flood risk implications

- Benefits achievable for all events considered, although capacity sufficient to contain/convey larger events may be difficult to achieve within constraints of site – measures unlikely to eliminate flood risk entirely (particularly for larger magnitude flood events)
- Combining with Option 8 likely to reduce flood risk significantly for all events assessed by intercepting overland flow through golf course towards Ballater and caravan park
- Based on BAFS modelled flood depths, existing topography contains flow for ~400 m^3/s except at downstream end of drainage network, where depths >2.0 m and some overspill towards caravan park occurs
- More extensive overspill towards caravan park evident for events greater than ~400 m^3/s and capacity of existing topography appears to be exceeded in western section for events of ~1000 m^3/s and above
- Topography and flood mechanisms particularly complex here, with associated uncertainty in estimating locations and dimensions of flood mitigation measures without hydraulic modelling

Wider advantages and disadvantages

Advantages

- Potential to incorporate habitat benefits as part of flood management measures (e.g. wetlands, ponds)
- Golf course redesign could enhance the golf experience, if this option was developed in liaison with an experienced golf course designer.

Disadvantages

- Potential for impacts on long-term 'playability' of golf course and potential costs associated with course redesign, if required.
- Short-term disturbance during construction

Risk appraisal and mitigation measures

- Residual flood risk at site – to be quantified based on further assessments as detailed below
- Potential to increase flood risk downstream by increasing pass-forward flows – to be quantified based on further assessments as detailed below
- Risk to golf course playability – to be considered by golf course designers with the potential to enhance the golf experience.
- Disruption to the footpath at the upstream inlet to the swale. A board walk or bridge could be created to maintain access along the bankside path.

Further assessments and permissions required

- Wider topographic data collection, analysis and hydraulic modelling at detailed design phase to determine dimensions of features required to adequately reduce flood risk (model recommended to be run for the entire site with combined options, rather than individual models for each option)
- Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater)
- Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC are met and licences can be obtained)
- CAR Engineering Licence (SEPA) – level of licence to be determined at detailed design. Licence fees may apply

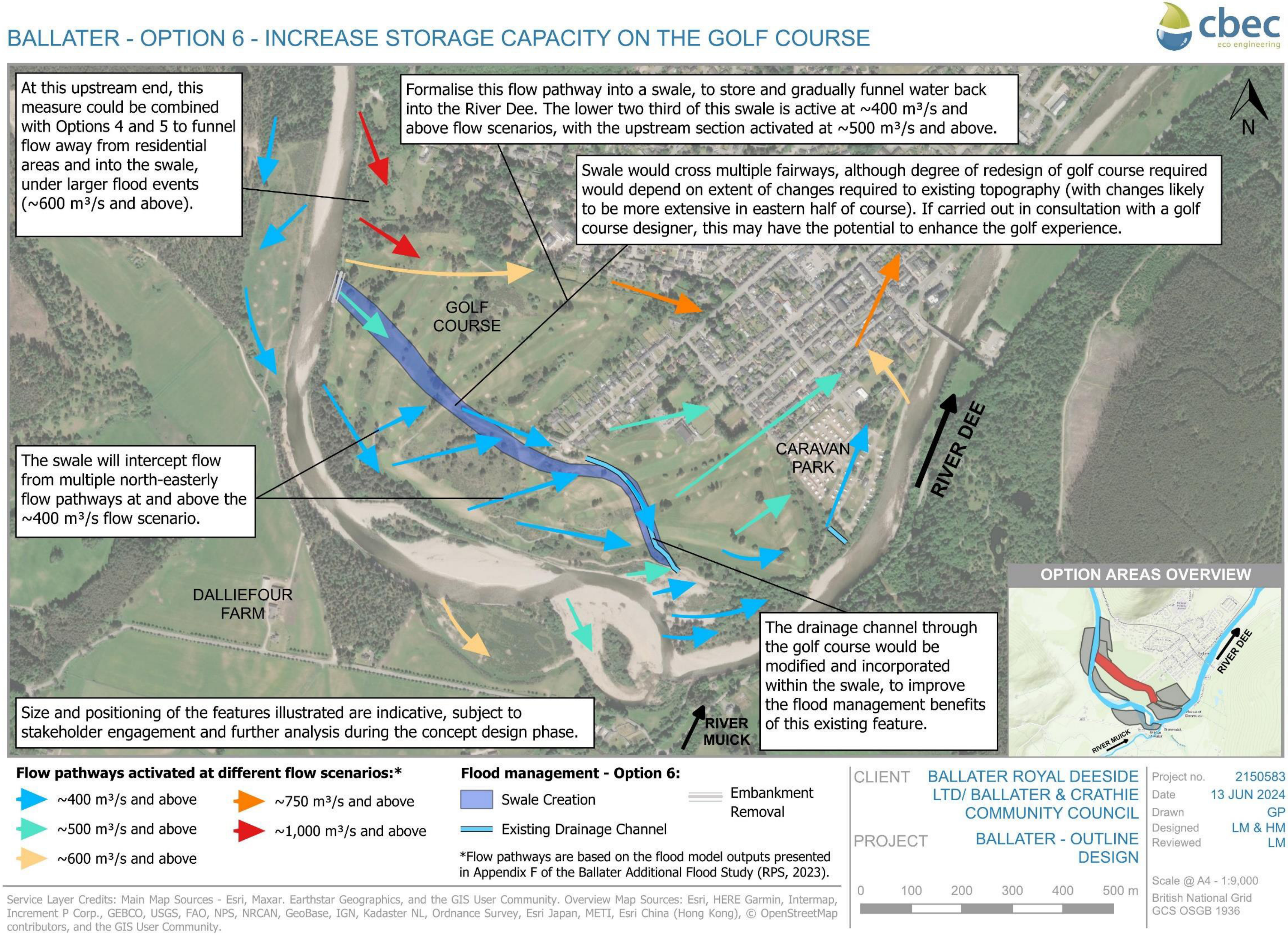


Figure 5.6 Option 6 - Increase storage capacity on the golf course.

Table 5.9. Option 7 factsheet

<table>
<tr><td>Option 7</td><td colspan="12">Enhance existing bund</td></tr>
<tr><td>Benefits expected for events with flows (m^3/s)</td><td colspan="3">500</td><td colspan="3">600</td><td colspan="3">750</td><td colspan="3">1000</td></tr>
<tr><td>Qualitative classification of feasibility (see Table 5.2)</td><td colspan="4">Development
Medium</td><td colspan="4">Deliverability
Low</td><td colspan="4">Cost
Medium</td></tr>
<tr><td>Diagrams</td><td colspan="12">Figure 5.7 / Appendix A, Section 7</td></tr>
<tr><td colspan="13">Description of option
• Increasing length and/ or height of existing Hesco bag bund to increase level of protection offered
• Naturalisation or ‘greening’ of bund to improve stability and appearance and offer habitat benefits
• Formalise and increase the length of the existing large wood structure bank protection, to increase protection to and sustainability of the existing bund
• Large Wood Structures (LWS) bank protection could be added into the river corridor in the short term to add protection to the Hesco bund whilst other options are designed and taken forward to construction at a later date.</td></tr>
<tr><td colspan="13">Flood risk implications
• Measure likely to have small impact on overall flood risk in isolation, although benefits could be maximised by combining with other options, including Options 3, 6 and 8
• Bund likely to be overtopped even during relatively low-magnitude events – bund height could be increased as part of works and combined with Option 6 for greater capacity benefit
• Benefits primarily in ensuring ongoing stability of bund</td></tr>
<tr><td colspan="13">Wider advantages and disadvantages
Advantages
• Potential to incorporate habitat improvements alongside flood risk benefits
• Potential access/recreation benefits through improved aesthetic appearance of bund
• Development feasibility and cost could be lower if existing footprint and height retained
Disadvantages
• Risk of ongoing erosion of bund if planform of River Dee channel remains in current alignment</td></tr>
<tr><td colspan="13">Risk appraisal and mitigation measures
• Erosion risk – mitigate through careful design (i.e. considering previous buried toe protection recommended by cbec (2024), to prevent undermining) and/or combine with Option 3 to reduce erosion risk
• Residual flood risk – to be quantified based on further assessments</td></tr>
<tr><td colspan="13">Further assessments and permissions required
• Wider topographic data collection, analysis and hydraulic modelling at detailed design phase to determine dimensions of features required to adequately reduce flood risk (model recommended to be run for the entire site with combined options, rather than individual models for each option)
• Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater)
• Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC and Craigendarroch SSSI are met and licences can be obtained)
• CAR Engineering Licence (SEPA) – level of licence to be determined at detailed design. Licence fees may apply</td></tr>
</table>

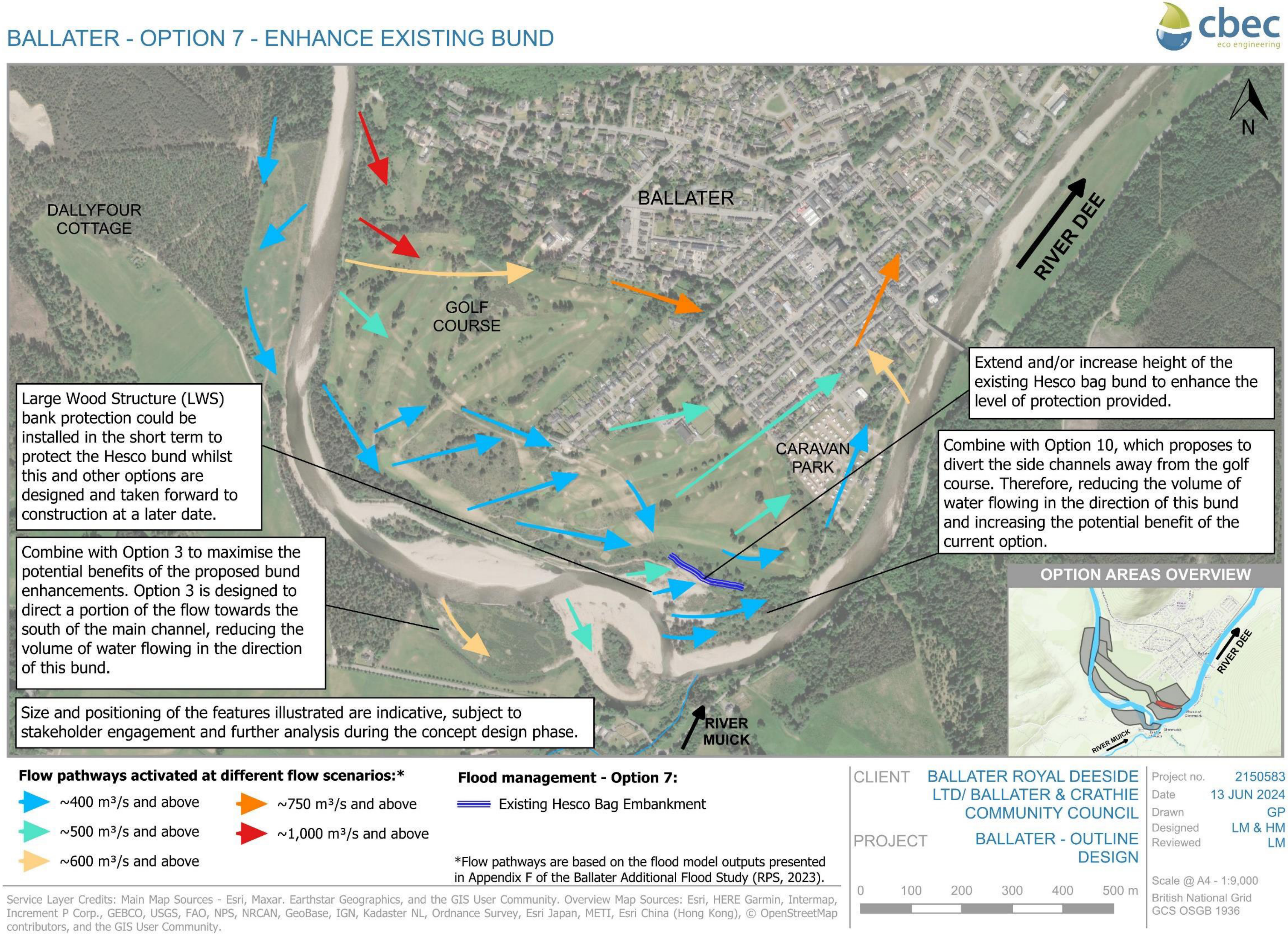


Figure 5.7 Option 7 - Enhance existing bund.

Table 5.10. Option 8 factsheet

Option 8	Construct swales linking to culvert/outflow and enhance bund along path			
Benefits expected for events with flows (m^3/s)	500	600	750	1000
Qualitative classification of feasibility (see Table 5.2)	Development *High*	Deliverability *High*	Cost *High*	
Diagrams	Figure 5.8 / Appendix A, Section 8			

Description of option

- Construction of network of swales to intercept main flow pathways arising from spill generated by insufficient capacity of golf course drainage network (required extent possibly reduced if Option 6 is implemented)
- Swales to tie in to existing culverted channel just upstream of caravan park
- Formalise the existing bund along the footpath to a construction suitable for providing flood protection. Increase the level of protection offered by Increasing length and/or height of this bund.
- Spoil generated from excavation of swales used to increase height of bund along path
- Existing culvert may need to be enlarged to facilitate flow back to into the River Dee – sizing would be guided by hydraulic modelling

Flood risk implications

- Benefit for events <500 m^3/s likely to be relatively low, particularly if Option 6 is progressed
- Potential to intercept majority of flow pathways across eastern part of golf course, reducing flood risk to caravan park, Salisbury Road and adjacent road considerably for ~500 m^3/s event and above
- Combine with Option 6 to maximise flood risk benefits
- Flood depths modelled as part of BAFS show depths of up to ~1.5 m across much of eastern part of golf course and depths exceeding 2.0 m immediately adjacent to the caravan park for the ~1000 m^3/s event. Combination of swales and bund likely to reduce flood risk considerably (in combination with modification of existing outflow and culvert)
- Flow from the mainstem Dee currently backs up in this area – this would require to be assessed in further detail as part of future modelling and design.

Wider advantages and disadvantages

Advantages

- Potential to incorporate habitat benefits as part of flood management measures (e.g. wetlands, ponds)
- Cut material (spoil) could be reused onsite, reducing cost of construction
- Potential to use existing drainage infrastructure, subject to consideration of capacity
- Potential to enhance golf experience within this area of the course if the proposed option was developed in liaison with golf course designers.

Disadvantages

- Potential for impacts on long-term 'playability' of golf course and costs associated with redesign, if required
- Short-term disturbance during construction

Risk appraisal and mitigation measures

- Residual flood risk – to be quantified based on further assessments.
- Risk of blockage and backing up behind the existing culvert – size and position of existing culvert should be assessed during flood/design hydraulic modelling to ensure sufficient conveyance capacity
- Risk to golf course playability – to be considered by golf course designers with the potential to enhance the golf experience.

Further assessments and permissions required

- Wider topographic data collection, analysis and hydraulic modelling at detailed design phase to determine dimensions of features required to adequately reduce flood risk (model recommended to be run for the entire site with combined options, rather than individual models for each option)
- Hydraulic and flood modelling to determine the bund height, length and position. Assessments of model outputs should also consider whether the bund should be extended along the river left bank between the caravan park and the Ballater Royal Bridge to protect this side of the town.
- Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater).
- Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC are met and licences can be obtained)

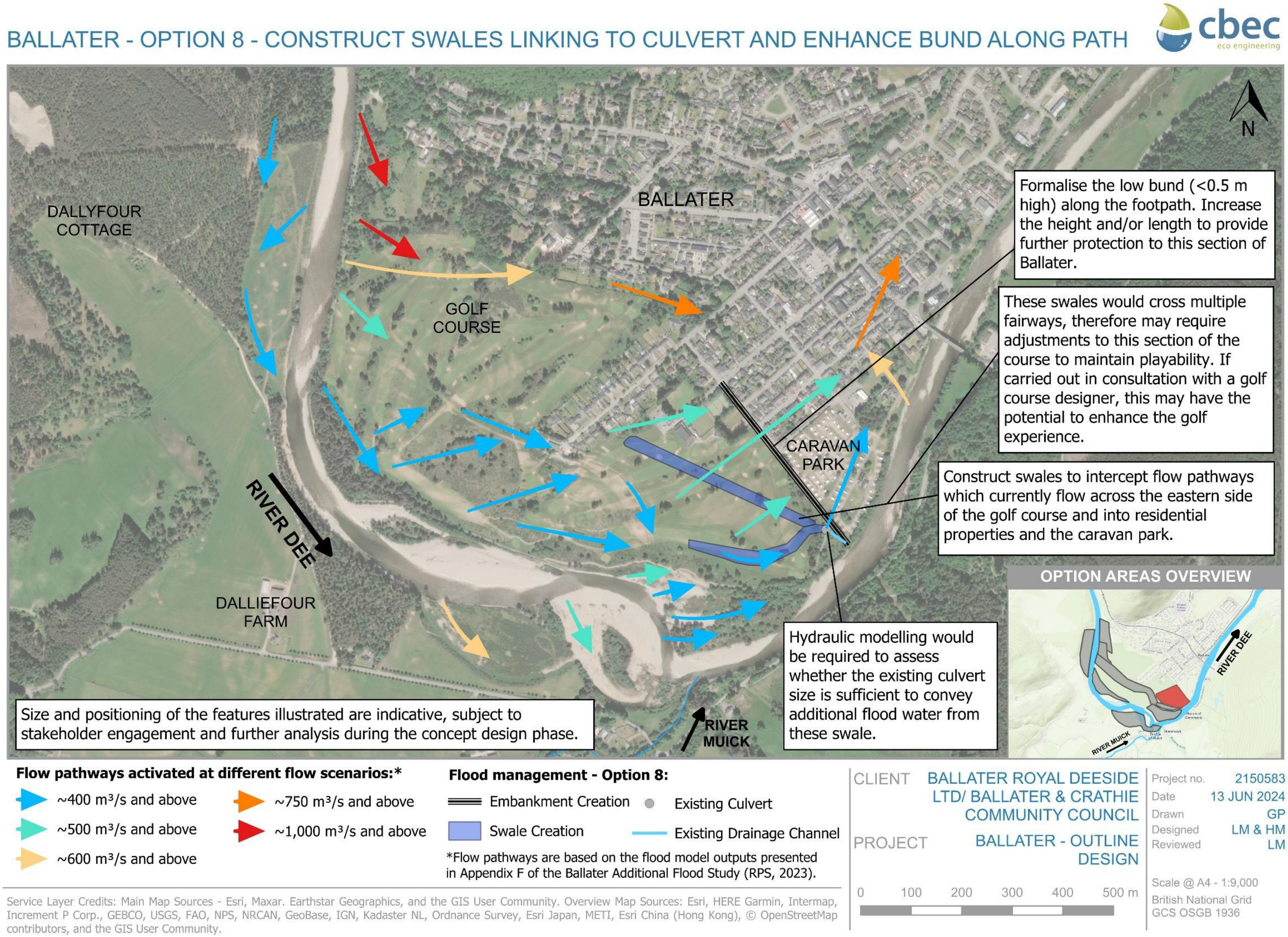


Figure 5.8 Option 8 – Construct swales linking to culvert and enhance bund along the footpath.

Table 5.11. Option 9 factsheet

Option 9	Enhance connectivity and storage on left bank (east) floodplain			
Benefits expected for events with flows (m^3/s)	500	600	750	1000
Qualitative classification of feasibility (see Table 5.2)	Development *High*	Deliverability *Low*	Cost *Medium*	
Diagrams	Figure 5.9 / Appendix A, Section 9			

Description of option

- Formalise existing breach/overflow points along river left (east) bank to encourage enhanced channel/floodplain connectivity over a wider range of flows than at present (i.e. to encourage wetter floodplain habitat outwith flood events)
- Set back bund currently running along bank top
- Enhance existing flow pathways and provide additional storage (e.g. ponds, scrapes) in wooded area

Flood risk implications

- Benefits likely to be modest for all events given existing inundation patterns and relatively small area but could contribute to cumulative benefit if implemented alongside other measures, particularly if existing bund could also be set back

Wider advantages and disadvantages

Advantages

- Potential to incorporate habitat and access/recreation benefits alongside flood risk objectives
- Enhanced channel/ floodplain connectivity over wider range of flows likely to offer drought resilience benefits
- Formalising breach/ overflow points and modifying path network accordingly (e.g. setting back path or creating boardwalk sections) likely to reduce management required to maintain path

Disadvantages

- Risk of disturbance of existing good habitat may outweigh potential benefits

Risk appraisal and mitigation measures

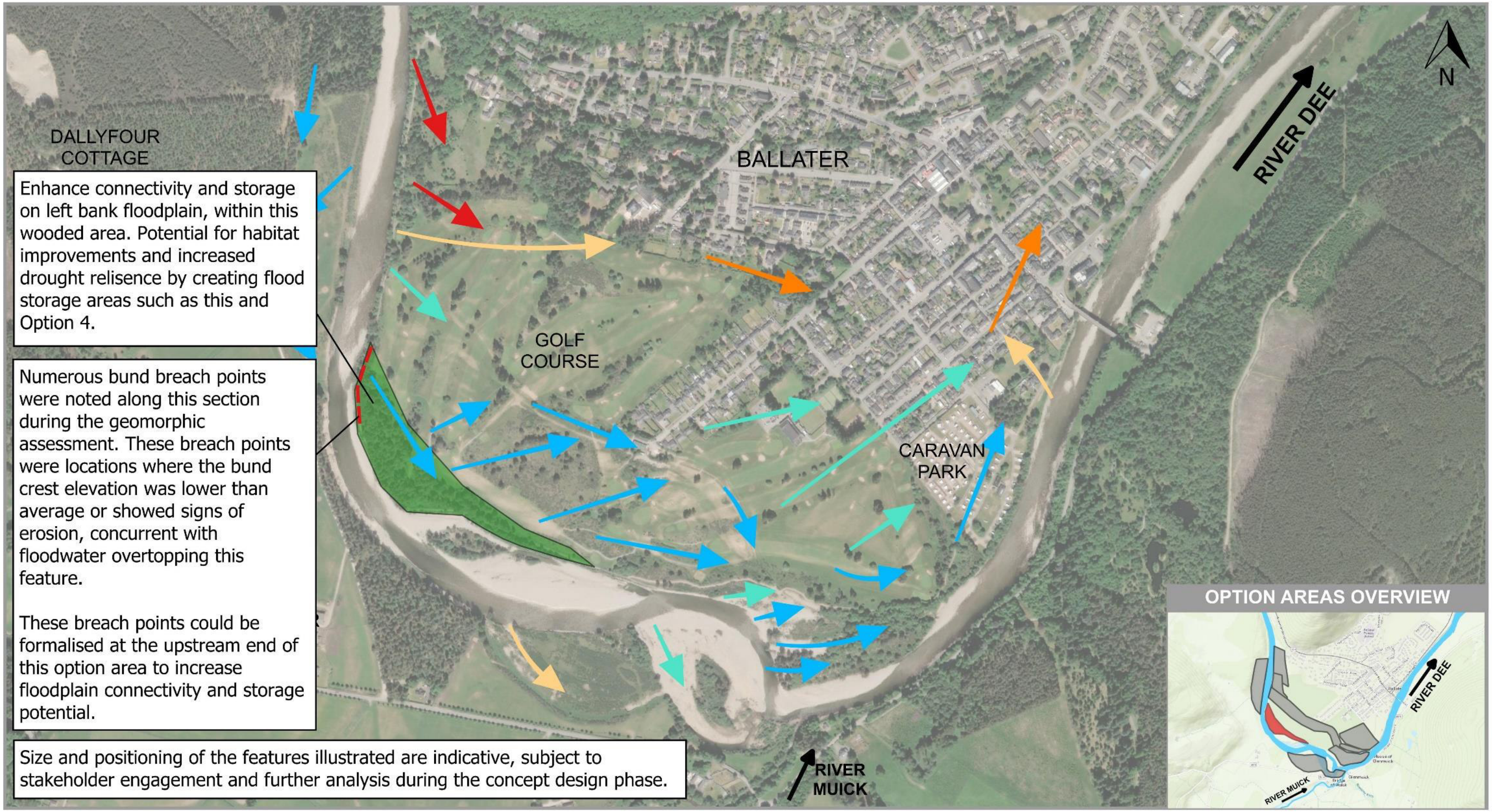
- Existing species may not be suited to wet woodland habitat – to be considered based on ecological assessment
- Potential to increase flood risk to golf course

Further assessments and permissions required

- Wider topographic data collection, analysis and hydraulic modelling at detailed design phase to determine dimensions of features required to adequately reduce flood risk (model recommended to be run for the entire site with combined options, rather than individual models for each option)
- Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater)
- Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC are met and licences can be obtained)
- CAR Engineering Licence (SEPA) – level of licence to be determined at detailed design. Licence fees may apply

BALLATER - OPTION 9 - ENHANCE CONNECTIVITY AND STORAGE ON THE LEFT BANK FLOODPLAIN

cbec eco engineering



Flow pathways activated at different flow scenarios:*

- ~400 m³/s and above
- ~500 m³/s and above
- ~600 m³/s and above
- ~750 m³/s and above
- ~1,000 m³/s and above

Flood management - Option 9:

- Improve Connectivity and Promote Storage
- Formalise Embankment Breaches

*Flow pathways are based on the flood model outputs presented in Appendix F of the Ballater Additional Flood Study (RPS, 2023).

CLIENT	BALLATER ROYAL DEESIDE LTD/ BALLATER & CRATHIE COMMUNITY COUNCIL
PROJECT	BALLATER - OUTLINE DESIGN

Project no.	2150583
Date	13 JUN 2024
Drawn	GP
Designed	LM & HM
Reviewed	LM

0 100 200 300 400 500 m

Scale @ A4 - 1:9,000
British National Grid
GCS OSGB 1936

Service Layer Credits: Main Map Sources - Esri, Maxar. Earthstar Geographics, and the GIS User Community. Overview Map Sources: Esri, HERE Garmin, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), © OpenStreetMap contributors, and the GIS User Community.

Figure 5.9 Option 9 – Enhance connectivity and storage on the left bank floodplain.

Table 5.12. Option 10 factsheet

Option 10	Modify and clear channels to divert flow pathways away from golf course			
Benefits expected for events with flows (m^3/s)	500	600	750	1000
Qualitative classification of feasibility (see Table 5.2)	Development *Medium*	Deliverability *Low*	Cost *Low*	
Diagrams	Figure 5.10 / Appendix A, Section 10			

Description of option

- Clear and adjust alignment of side channels to increase conveyance capacity and help divert flows away from golf course
- Side-channel courses can be 'trained' through use of large wood structures (e.g. whole trees with root plates still attached) to focus deposition and channel flow preferentially
- Complementary to Option 3, contributing to wider active channel corridor in line with historical planform (see Section 2.5)

Flood risk implications

- Direct flood risk benefits likely to be minor if implemented in isolation owing to limited potential for increased capacity
- Benefits primarily related to encouraging flow away from river left bank

Wider advantages and disadvantages

Advantages

- Relatively low cost compared to other options

Disadvantages

- Risk of disturbance of existing good habitat may outweigh potential benefits
- Measures may not be sustainable, given tendency of deposition of alluvial material, wood and debris at this location, leading to adjustment of channel form – ongoing maintenance will be required

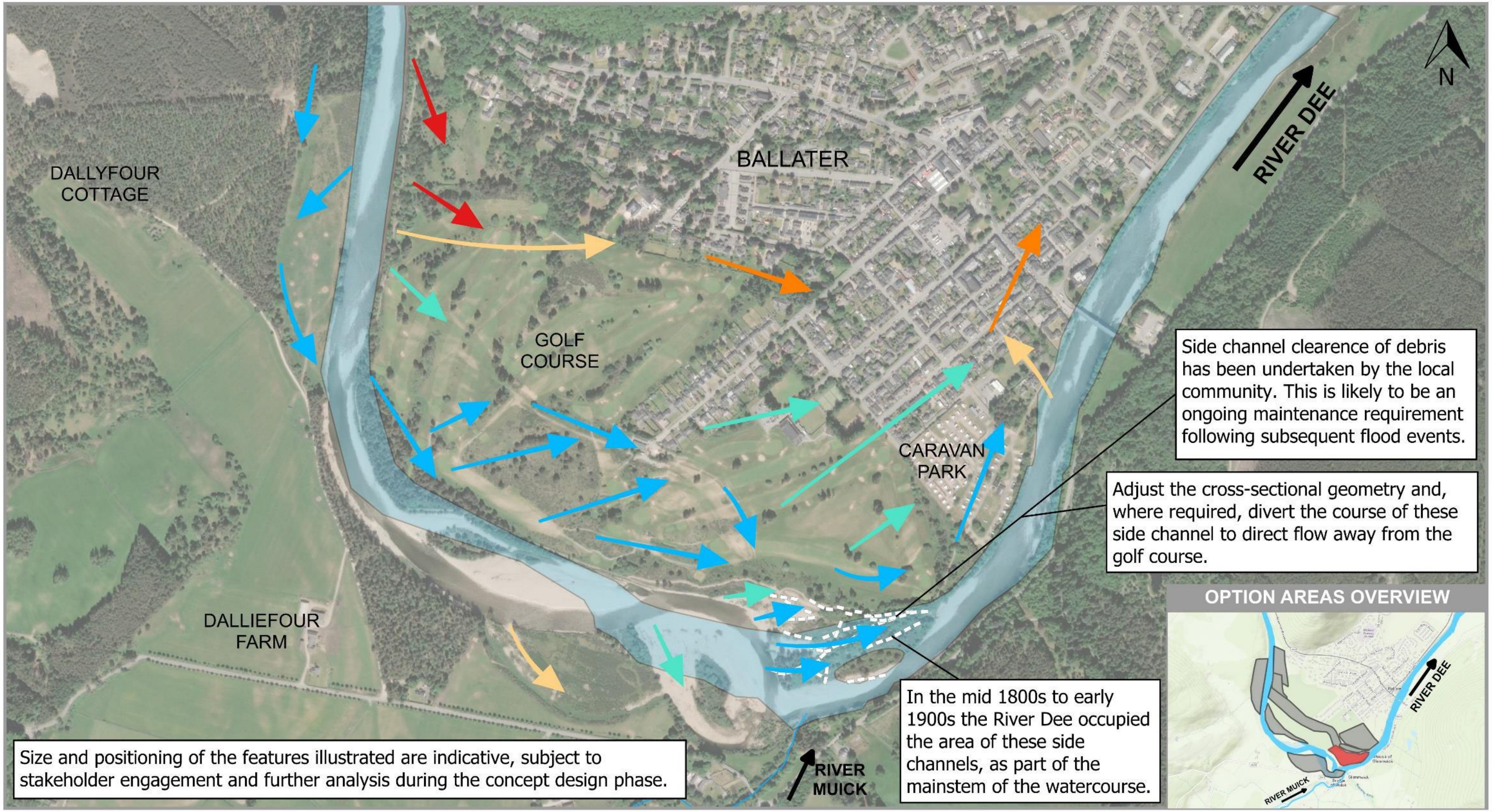
Risk appraisal and mitigation measures

- Residual flood risk – to be quantified based on further assessments
- Risk to existing habitat – to be considered based on ecological assessment

Further assessments and permissions required

- Wider topographic data collection, analysis and hydraulic modelling at detailed design phase to determine dimensions of features required to adequately reduce flood risk (model recommended to be run for the entire site with combined options, rather than individual models for each option)
- Flood risk assessment (quantifying through hydraulic modelling outputs how effective option would be in contributing to flood protection of Ballater)
- Ecological survey (to determine any more detailed species- or -habitat-specific survey required before construction, to ensure all requirements for the Dee SAC are met and licences can be obtained)
- CAR Engineering Licence (SEPA) – level of licence to be determined at detailed design. Licence fees may apply.

BALLATER - OPTION 10 - FORMALISE AND CLEAR SIDE CHANNELS TO DIVERT FLOW FROM GOLF COURSE



Flow pathways activated at different flow scenarios:*

- ~400 m³/s and above
- ~500 m³/s and above
- ~600 m³/s and above
- ~750 m³/s and above
- ~1,000 m³/s and above

Flood management - Option 10:

- Existing Side Channels
- Historic Channel Planform (1869)**

*Flow pathways are based on the flood model outputs presented in Appendix F of the Ballater Additional Flood Study (RPS, 2023). **River Dee channel planform position is indicative only, based on a previous edition of an Ordnance Survey map, published in 1869 and avaliable via the National Library for Scotlands' archive.

CLIENT	BALLATER ROYAL DEESIDE LTD/ BALLATER & CRATHIE COMMUNITY COUNCIL
PROJECT	BALLATER - OUTLINE DESIGN

0 100 200 300 400 500 m

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Scale @ A4 - 1:9,000
British National Grid
GCS OSGB 1936

Service Layer Credits: Main Map Sources - Esri, Maxar. Earthstar Geographics, and the GIS User Community. Overview Map Sources: Esri, HERE Garmin, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), © OpenStreetMap contributors, and the GIS User Community.

Figure 5.10 Option 10 - Formalise and clear side channels to divert flow from the golf course.

5.4 OTHER OPTIONS CONSIDERED

A number of other potential options were discounted during the course of the present study. It is understood that there has been some support in the community for options including dredging and remedial works to protect the eroding bank at Red Braes. These options were considered but excluded early in the options appraisal process for the following reasons.

Dredging of the River Dee was considered as part of the BFPS, with model simulations undertaken to consider how dredging to increase channel depth by ~1.5 m would influence flood risk. This modelling found that dredging would reduce the height and length of direct defences required for the appropriate Standard of Protection, but would not eliminate the need for defences entirely. Additionally, it is important to note that dredging would come with a number of risks and disadvantages. Fundamentally, dredging is not a sustainable or 'nature-based' approach to river management, the central ethos adopted for the development of options in this study. The measure is unlikely to be sustainable in the long-term owing to the nature of the River Dee at this location (which is a locus for the deposition of sediment) and would require considerable ongoing maintenance, which would potentially cause significant geomorphic instability and be costly. Moreover, the River Dee is a SAC, designated for Atlantic salmon, otter and freshwater pearl mussel; in addition to associated regulatory constraints to in-river works, these species rely on habitat that is associated with gravel/ cobble river sediment. Although dredging is not considered feasible at the site, other more sustainable forms of sediment management have been suggested here (e.g. Options 3 and 10).

As part of the BFPS, RPS undertook some additional analysis to consider the impact of accelerated erosion of the Red Braes during the 30th December 2015 'Storm Frank' flood event on inundation mechanisms in Ballater. The report detailing the results of this analysis highlights that the River Dee would have had sufficient competence and transport capacity during this event to transport any eroded material downstream, such that it is very unlikely that sufficient material would have accumulated during the event to impact flood risk to Ballater or alter the dominant flow pathways. We would agree with this interpretation. The Red Braes site is undoubtedly contributing significant volumes of coarse sediment to the River Dee channel, which may be exacerbating deposition in the vicinity of the River Muick confluence to some degree. However, the majority of sediment supply to the study reach is considered to be from upstream of Red Braes, a process that is continuous and driven by successive flood events. Additionally, installation of remedial measures to prevent this erosion would be both extremely costly (due to the length and height of the bank) and at odds with encouraging natural river processes (i.e. because erosion of this type along the outside of meander bends is in keeping with the natural character of the River Dee).

6. SUMMARY AND NEXT STEPS

A series of options have been identified to deliver flood alleviation benefits to Ballater under more frequent, smaller flood events, particularly for events ranging from ~500 m^3/s to ~750 m^3/s (although smaller and larger events have also been considered). Measures proposed include: the construction of swales to collect and direct flood water away from the village; alteration to the position, height and length of existing bunds; development of additional flood storage areas; and improved connectivity with historical and side channels to divert flow away from the left (east) bank of the River Dee. These opportunities vary in spatial scale of application and the degree of flood benefit achievable. Individual options have been targeted to interrupt and redirect flow pathways under different flood scenarios. Therefore, it is recommended that a combination of options are implemented to maximise the flood benefit to Ballater. Hydraulic modelling (and, for some options, morphodynamic modelling[6]) would be required to determine the individual and cumulative benefits to flood risk of the various options and their combinations. When the project moves to the modelling stage, **there will be the option to model individual design elements** or groups of options if required. The number of separate modelled scenarios would be discussed and undertaken as appropriate in agreement with the Project Group.

Stakeholder experiences and opinions will be an essential element to the development of the preferred option or combination of options. These proposed options will be presented, with associated graphics, at a focussed workshop to facilitate discussion with relevant stakeholders. Resident experiences and opinions will be essential to the selection of a preferred option or combination of options and a first public meeting will be held to present and discuss all the work done to date and the options.

Subject to developments with landowners and other stakeholders, this first public meeting will likely be the forum for suggesting potential preferred options to take to the next stage.

To accelerate the delivery of the defences, it is envisaged that further work will have been started by that time to build and test a model which can be used to assess options.

Following selection of the preferred option(s), these measures will be developed to the detailed design stage, utilising the model (and the most recent topographic survey data) to advise on appropriate location, size and positioning of measures and the results will be shared at a second public meeting to confirm community support.

Assuming that the detailed design development of the preferred option(s)/ group of options is carried out in late 2024 to mid-2025, it is assumed that construction of these options would not commence until summer 2026. This timescale estimate allows for a 6-9-month planning permission and permitting period[7], particularly given that the River Dee is designated as a Special Area of Conservation (SAC), as well as 3 to 4 months for the construction tendering and procurement process.

[6] Morphodynamic modelling considers both the movement of water and sediment, where as hydraulic modelling focuses on water only.
[7] Exact timescales will be dependant on the level of planning permission required and would be ascertained at design stage).

7. REFERENCES

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APPENDIX A

SITE CROSS SECTIONS/ INDICATIVE PROPOSALS

Option 2 – Enhance storage on river right floodplain

Legend

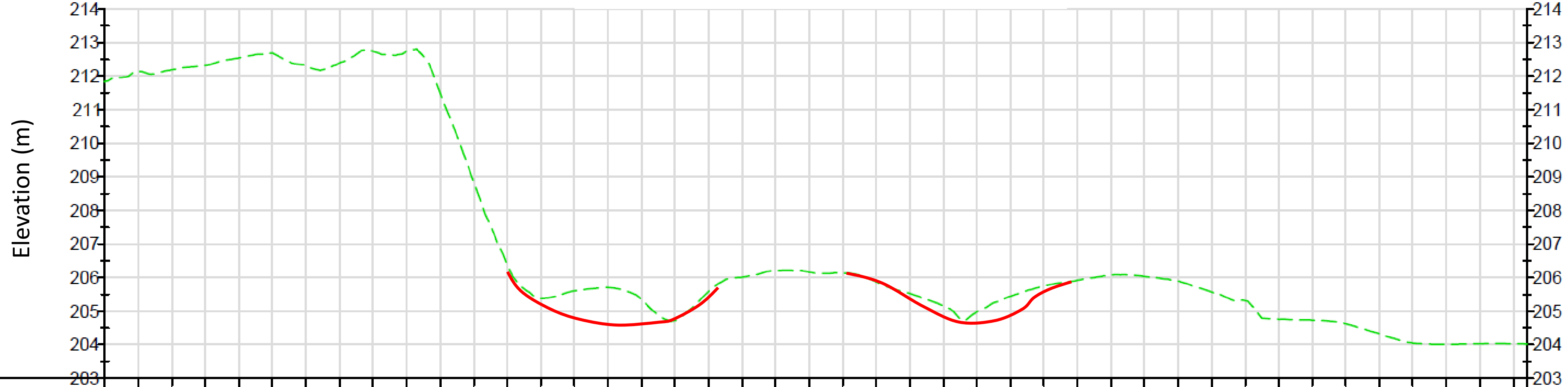
- Existing ground levels (green dashed line)
- Proposed ground levels* (red line)

** (indicative only – would be refined at concept and detailed design stage)*

ALIGNMENT – Section 2 – Longsection

SCALE: H1:1000, V1:200, DATUM: 198.000

x5 vertical exaggeration



Chainage	Existing Levels
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05.000	212.140
10.000	212.190
15.000	212.326
20.000	212.542
25.000	212.690
30.000	212.329
35.000	212.390
40.000	212.741
45.000	212.746
50.000	211.489
55.000	208.848
60.000	206.386
65.000	205.385
70.000	205.608
75.000	205.709
80.000	205.358
85.000	204.723
90.000	205.587
95.000	206.012
100.000	206.213
105.000	206.166
110.000	206.139
115.000	205.875
120.000	205.529
125.000	205.160
130.000	204.976
135.000	205.442
140.000	205.747
145.000	205.919
150.000	206.074
155.000	206.031
160.000	205.896
165.000	205.570
170.000	205.315
175.000	204.761
180.000	204.734
185.000	204.624
190.000	204.323
195.000	204.051
200.000	204.010
205.000	204.030
210.000	204.031
211.996	204.024

Option 3 – Reactivate former channel courses

Legend

Existing ground levels

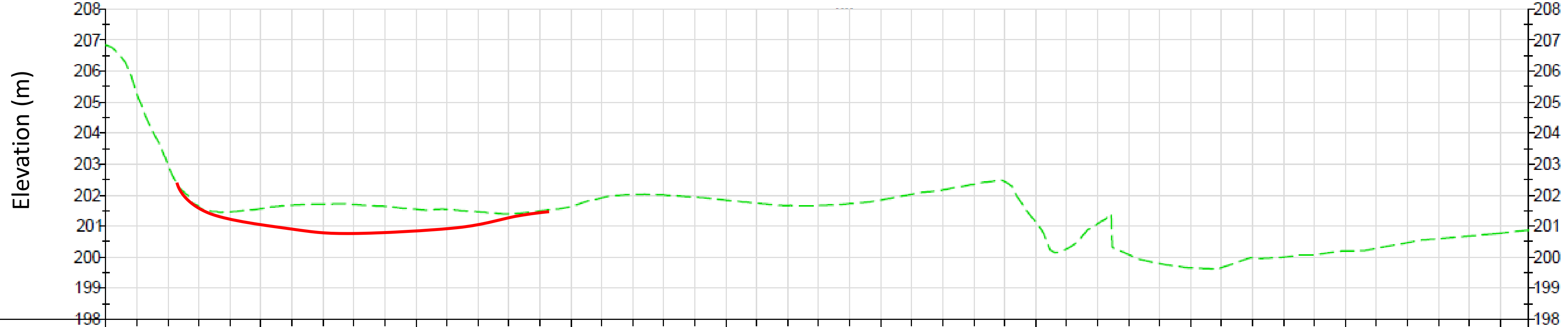
Proposed ground levels*

** (indicative only – would be refined at concept and detailed design stage)*

ALIGNMENT – Section 3 – A – Longsection

SCALE: H1:1000, V1:200, DATUM: 198.000

x5 vertical exaggeration



Chainage	Existing Levels
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15.000	201.625
20.000	201.466
25.000	201.566
30.000	201.677
35.000	201.710
40.000	201.700
45.000	201.642
50.000	201.549
55.000	201.544
60.000	201.464
65.000	201.397
70.000	201.495
75.000	201.633
80.000	201.915
85.000	202.022
90.000	202.007
95.000	201.944
100.000	201.836
105.000	201.745
110.000	201.669
115.000	201.672
120.000	201.723
125.000	201.842
130.000	202.030
135.000	202.169
140.000	202.347
145.000	202.444
150.000	201.145
155.000	200.270
160.000	201.077
165.000	200.086
170.000	199.798
175.000	199.660
180.000	199.667
185.000	199.975
190.000	200.000
195.000	200.071
200.000	200.205
205.000	200.285
210.000	200.469
215.000	200.598
220.000	200.685
225.000	200.777
229.536	200.871

Option 3 – Reactivate former channel courses

Legend

Existing ground levels (green dashed line)

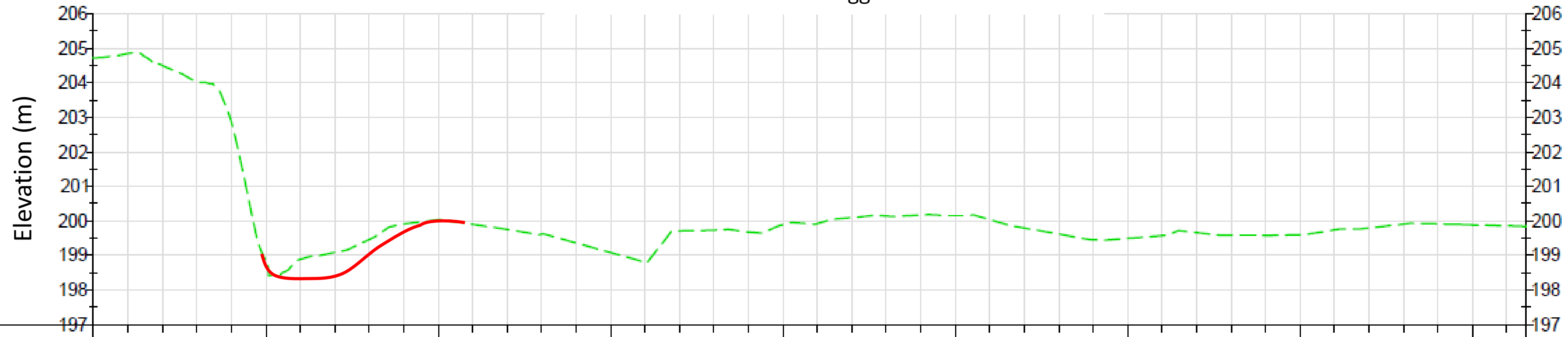
Proposed ground levels* (red solid line)

** (indicative only – would be refined at concept and detailed design stage)*

ALIGNMENT – Section 3 – B – Longsection

SCALE: H1:1000, V1:200, DATUM: 198.000

x5 vertical exaggeration



Chainage	00.000	05.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000	55.000	60.000	65.000
Existing Levels	204.728	204.845	204.498	204.029	202.858	198.873	198.882	199.085	199.457	199.904	200.030	199.901	199.756	199.613

Chainage	70.000	75.000	80.000	85.000	90.000	95.000	100.000	105.000	110.000	115.000	120.000	125.000	130.000	135.000
Existing Levels	199.358	199.079	198.801	199.709	199.730	199.678	199.887	199.922	200.100	200.144	200.170	200.161	200.033	199.791

Chainage	140.000	145.000	150.000	155.000	160.000	165.000	170.000	175.000	180.000	185.000	190.000	195.000	200.000	205.000	207.730
Existing Levels	199.616	199.450	199.493	199.572	199.658	199.586	199.582	199.599	199.739	199.794	199.904	199.909	199.883	199.856	199.842

Option 4 – Increase storage in wooded area (to the north of the site)

Option 5 – Construct bund to intercept flow exiting River Dee from river left bank

Legend

- - - - - Existing ground levels

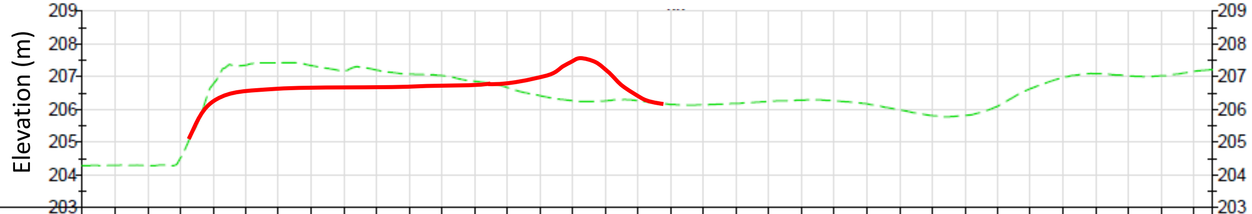
—— Proposed ground levels*

** (indicative only – would be refined at concept and detailed design stage)*

ALIGNMENT – Section 4 – Longsection

SCALE: H1:1000, V1:200, DATUM: 198.000

x5 vertical exaggeration

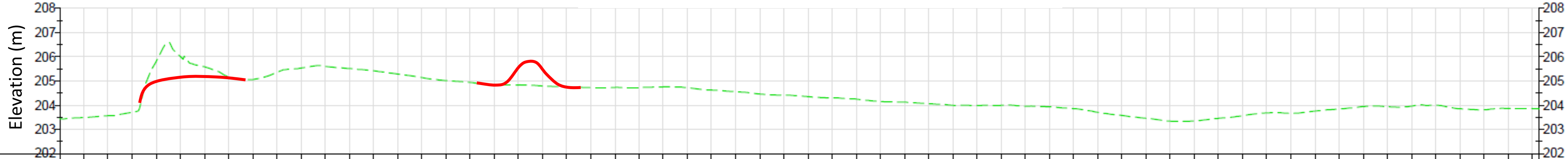


Chainage	Existing Levels
00.000	204.280
05.000	204.294
10.000	204.284
15.000	204.512
20.000	206.772
25.000	207.354
30.000	207.413
35.000	207.339
40.000	207.182
45.000	207.200
50.000	207.079
55.000	207.035
60.000	206.861
65.000	206.668
70.000	206.418
75.000	206.267
80.000	206.264
85.000	206.266
90.000	206.154
95.000	206.151
100.000	206.181
105.000	206.251
110.000	206.285
115.000	206.270
120.000	206.170
125.000	205.991
130.000	205.812
135.000	205.817
140.000	206.098
145.000	206.634
150.000	206.976
155.000	207.092
160.000	207.025
165.000	207.026
170.000	207.160
172.791	207.220

ALIGNMENT – Section 5 – Longsection

SCALE: H1:1000, V1:200, DATUM: 198.000

x5 vertical exaggeration



Chainage	Existing Levels
00.000	203.454
05.000	203.487
10.000	203.566
15.000	203.706
20.000	205.809
25.000	206.008
30.000	205.585
35.000	205.166
40.000	205.062
45.000	205.359
50.000	205.533
55.000	205.608
60.000	205.514
65.000	205.423
70.000	205.286
75.000	205.143
80.000	205.015
85.000	204.942
90.000	204.827
95.000	204.833
100.000	204.794
105.000	204.758
110.000	204.725
115.000	204.733
120.000	204.728
125.000	204.758
130.000	204.720
135.000	204.621
140.000	204.559
145.000	204.462
150.000	204.414
155.000	204.350
160.000	204.300
165.000	204.250
170.000	204.153
175.000	204.124
180.000	204.060
185.000	203.993
190.000	203.986
195.000	203.992
200.000	203.955
205.000	203.936
210.000	203.859
215.000	203.704
220.000	203.576
225.000	203.461
230.000	203.338
235.000	203.353
240.000	203.454
245.000	203.562
250.000	203.680
255.000	203.663
260.000	203.757
265.000	203.836
270.000	203.945
275.000	203.938
280.000	203.959
285.000	203.996
290.000	203.851
295.000	203.808
300.000	203.862
305.000	203.856
305.413	203.849

Option 6 – Increase storage capacity on golf course by constructing swale/ scrape network

Legend

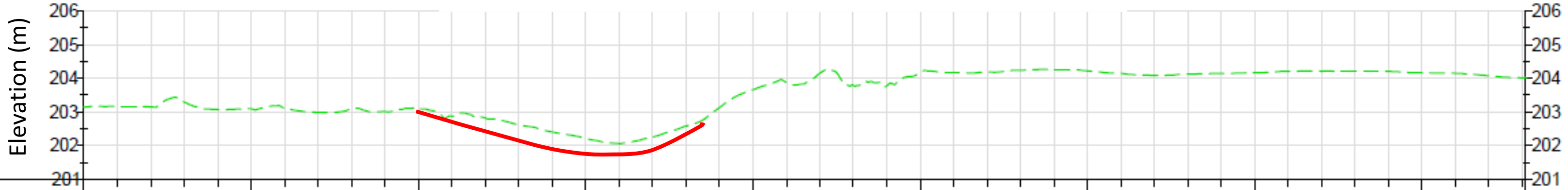
- Existing ground levels (green dashed line)
- Proposed ground levels* (red solid line)

(indicative only – would be refined at concept and detailed design stage)

ALIGNMENT – Section 6 – A – Longsection

SCALE: H1:1000, V1:200, DATUM: 198.000

x5 vertical exaggeration

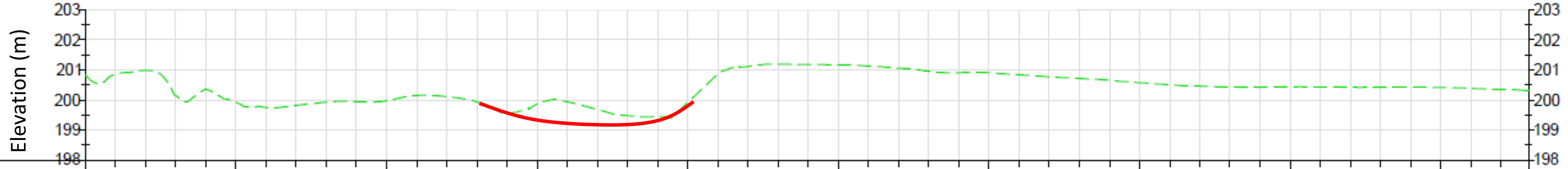


Chainage	Existing Levels
00.000	203.144
05.000	203.163
10.000	203.147
15.000	203.287
20.000	203.069
25.000	203.094
30.000	203.111
35.000	202.990
40.000	203.094
45.000	203.007
50.000	203.119
55.000	202.877
60.000	202.824
65.000	202.617
70.000	202.400
75.000	202.211
80.000	202.062
85.000	202.251
90.000	202.579
95.000	203.130
100.000	203.664
105.000	203.873
110.000	204.147
115.000	203.791
120.000	203.779
125.000	204.169
130.000	204.173
135.000	204.188
140.000	204.238
145.000	204.268
150.000	204.221
155.000	204.149
160.000	204.087
165.000	204.124
170.000	204.142
175.000	204.159
180.000	204.207
185.000	204.214
190.000	204.210
195.000	204.208
200.000	204.160
205.000	204.148
210.000	204.077
215.[illegible]	204.0[illegible]

ALIGNMENT – Section 6 – B – Longsection

SCALE: H1:1000, V1:200, DATUM: 198.000

x5 vertical exaggeration



Chainage	Existing Levels
00.000	200.816
05.000	200.852
10.000	200.983
15.000	200.139
20.000	200.356
25.000	199.925
30.000	199.744
35.000	199.818
40.000	199.922
45.000	199.937
50.000	199.972
55.000	200.146
60.000	200.110
65.000	199.930
70.000	199.546
75.000	199.866
80.000	199.934
85.000	199.677
90.000	199.476
95.000	199.442
100.000	199.913
105.000	200.877
110.000	201.115
115.000	201.192
120.000	201.175
125.000	201.169
130.000	201.126
135.000	201.059
140.000	200.956
145.000	200.906
150.000	200.904
155.000	200.838
160.000	200.765
165.000	200.712
170.000	200.654
175.000	200.570
180.000	200.495
185.000	200.458
190.000	200.433
195.000	200.428
200.000	200.435
205.000	200.437
210.000	200.430
215.000	200.425
220.000	200.418
225.000	200.411
230.000	200.383
235.000	200.348
239.597	200.304

Option 7 – Enhance existing Hesco bag bund

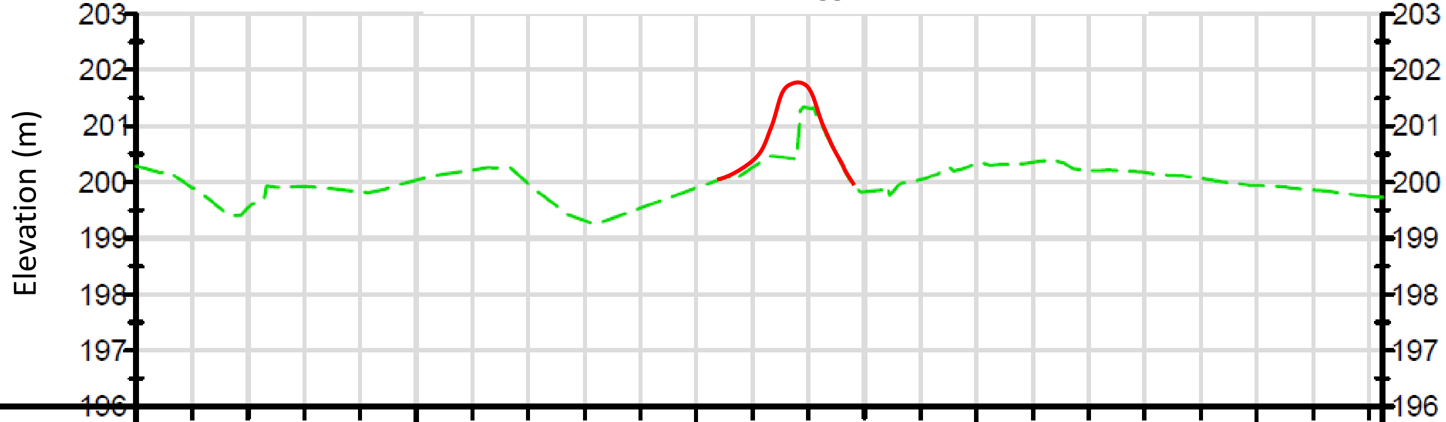
Legend

- - - - - Existing ground levels

—— Proposed ground levels*

** (indicative only – would be refined at concept and detailed design stage)*

ALIGNMENT – Section 7– Longsection
SCALE: H1:1000, V1:200, DATUM: 198.000
x5 vertical exaggeration



Chainage	Existing Levels
00.000	200.280
05.000	199.891
10.000	199.550
15.000	199.921
20.000	199.828
25.000	200.033
30.000	200.211
35.000	199.969
40.000	199.309
45.000	199.535
50.000	199.893
55.000	200.257
60.000	201.323
65.000	199.826
70.000	200.042
75.000	200.328
80.000	200.349
85.000	200.204
90.000	200.172
95.000	200.064
100.000	199.942
105.000	199.858
110.000	199.744
[illegible]	199.729

<u>Option 8 – Construct swales linking to culvert/ outflow and enhance bund along path</u>

Legend

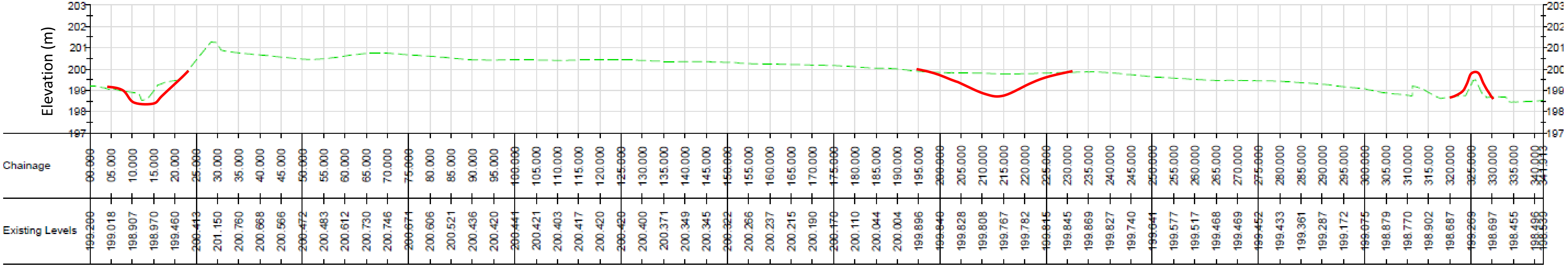
- Existing ground levels (dashed green line)
- Proposed ground levels* (solid red line)

** (indicative only – would be refined at concept and detailed design stage)*

ALIGNMENT – Section 8 – Longsection

SCALE: H1:1000, V1:200, DATUM: 198.000

x5 vertical exaggeration



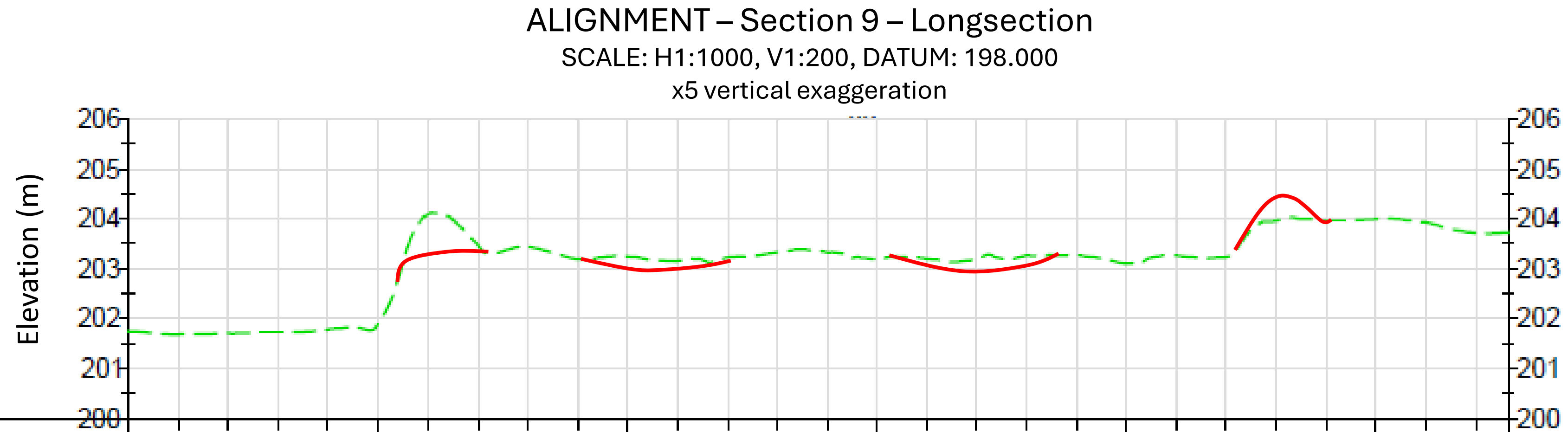
Option 9 – Enhance connectivity and storage on left bank floodplain

Legend

- - - - Existing ground levels

—— Proposed ground levels*

** (indicative only – would be refined at concept and detailed design stage)*



Chainage	00.000	05.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000	55.000	60.000	65.000	70.000	75.000	80.000	85.000	90.000	95.000	100.000	105.000	110.000	115.000	120.000	125.000	130.000	135.000	138.249
Existing Levels	201.747	201.690	201.711	201.723	201.782	201.904	204.085	203.479	203.442	203.198	203.246	203.162	203.228	203.332	203.332	203.200	203.200	203.202	203.267	203.273	203.108	203.263	203.237	203.966	203.990	203.996	203.929	203.714	203.730

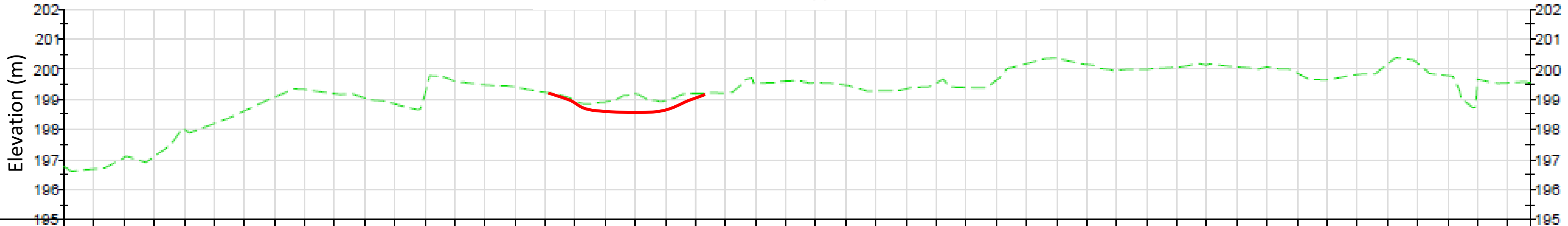
Option 10 – Clear channels in front of Hesco bag bund to divert flow pathways away from golf course

Legend

- - - - Existing ground levels
—— Proposed ground levels*

** (indicative only – would be refined at concept and detailed design stage)*

ALIGNMENT – Section 10 – Longsection
SCALE: H1:1000, V1:200, DATUM: 198.000
x5 vertical exaggeration



Chainage	Existing Levels
00.000	196.767
05.000	196.689
10.000	197.068
15.000	197.106
20.000	198.004
25.000	198.200
30.000	198.619
35.000	199.073
40.000	199.326
45.000	199.188
50.000	199.046
55.000	198.845
60.000	199.188
65.000	199.608
70.000	199.486
75.000	199.412
80.000	199.235
85.000	198.946
90.000	198.910
95.000	199.184
100.000	198.957
105.000	199.195
110.000	199.213
115.000	199.543
120.000	199.612
125.000	199.564
130.000	199.477
135.000	199.279
140.000	199.353
145.000	199.549
150.000	199.398
155.000	199.640
160.000	200.186
165.000	200.368
170.000	200.162
175.000	199.962
180.000	199.996
185.000	200.069
190.000	200.151
195.000	200.081
200.000	200.074
205.000	199.886
210.000	199.659
215.000	199.832
220.000	200.170
225.000	200.201
230.000	199.790
235.000	199.672
240.000	199.555
243.705	199.554

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