Innes Community Council

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River Spey, Garmouth Report, August, 2021

Innes Community Council is a statutory body formed under the Moray Council scheme for Community Councils. The Community Council area is bordered on the eastern side by the River Spey at Garmouth and Fochabers. Two of the current Community Councillors have between them over 100 years living experience in Garmouth and of the River Spey in all its conditions. Innes Community Council is a legitimate organisation to take the lead on this project.

For over 10 years Innes Community has acted in response to concerns raised by residents of Lower Garmouth about the movement of the River Spey westwards and ever closer to Garmouth. The river has moved 600 yards westwards in the past 20 years and half of that distance has been inside the last 5 years. The erosion westwards gathers speed each year, with climate change induced heavier, and more rain not helping the situation. Changes in the main course of the River Spey has seen greatly increased deposition of gravel on the east bank opposite where it is eroding the west bank at Queenshaugh. A high number of trees washed out in floods get stranded on these gravel deposits accentuating the problem, both factors acting to force the river further westwards, especially in high waters.

Innes Community Council has, over the period of time, liaised with all land and property owners affected and threatened by the great increase in the number of flooding incidents. Innes Community Council has liaised and spoken with Moray Council officials and other statutory bodies discussing solutions to reduce the number of flooding events in Lower Garmouth. SNH and SEPA have said that they would support any application for a project that guided the river away from Lower Garmouth on condition that no materials were taken into or out of the area of the engineering works. Any works to guide the river eastwards must be classed as sustainable or ‘green’ engineering i.e. they work in sympathy with natural river process and use natural materials (i.e. Large Wood Structures – LWS) obtained from the vicinity of the works.

The ratio of flooding incidents in Garmouth has risen over the years from an average of 1 or 2 days a year to the current situation where Lower Garmouth and Spey Street were flooded on 11 days between October, 2020 and February, 2021. In January, 2021, Innes Community Council held a virtual meeting of landowners, residents, agencies, politicians and others with an interest in Garmouth. A total of 35 individuals participated. Neither Moray Council officials or SEPA reps attended the meeting. ICC produced a report (attached) showing the net financial loss to land and property owners in Lower Garmouth attributed to increased flooding events over the previous 5 years. The calculated sum was over £1.87 million. Some of those costs are ongoing as the result of loss of land and other household costs. Innes Community Council have kept photographic evidence of this section of river going back more than 10 years. These total more than 5,000 photographs and many have been shared over that time with Crown Estates Scotland and Moray Council officers.

In 2021, Dr Hamish Moir, MSc, PhD, UK Managing Director and Principal Geomorphologist of cbec eco-engineering, Inverness, was commissioned to produce a report detailing what engineering works would be required to guide the river eastwards away from the lands of Essil Farm, and Queenshaugh and, thus, Lower Garmouth. Dr Moir has more than 25 years of experience working in the water resource industry of the UK and the US, particularly in the areas of river engineering, management and restoration. He has extensive training in the fields of fluvial geomorphology, in-stream ecology interactions and river engineering, both in research and consultancy capacities. Dr Moir has extensive experience in project management, both in the delivery of large academic research projects and leading many consultancy assignments in relation to river management.

Dr Moir's report details engineering works that would be classed as a sustainable 'green' engineering. One part was the placing of numbers of trees as engineered Large Wood Structures (LWS) removed from the river following flood events. Wooden piles (made from untreated Larch posts) would be pushed into the west side of the riverbed upstream of the boundary between Essil Farm and the lands of Queenshaugh. Once in place, trees already stored on site would be built around the wooden posts/ piles before being covered in gravel removed from associated adjacent channel management works (see below). This construction would guide the river eastwards away from Queenshaugh towards the original main channel on the east bank opposite Ross House. That channel formed part of the main course of the River Spey up until October 2012. Currently there is a small stream running down the old channel. This would be reprofiled to encourage flow through this more easterly orientation, allowing the river to develop a new main channel along the route of the pre-2012 channel (i.e. the channel management works, referred to above). The combination of the two parts of the projects would take the river away from the west bank. Over time the current channels would become overspill areas for flood waters and would fill up with silt and sediment creating a bank to continue guiding the river eastwards towards its pre-2000 course and, in doing so, dramatically reduce flood events in Lower Garmouth. Sustainable, 'green' engineering methods would be used. See attached report by Dr Moir and diagrams by Innes Community Council of the proposals.

Once this initial project is completed, annual minor maintenance work may be required just to maintain the river in a controllable area which will greatly reduce flooding while allowing the river to adjust naturally. The use of trees washed down from further upstream could be used as part of any further sustainable engineering works.

The proposed engineering works would arrest the current westerly migration of the meander in the vicinity of Ross House. In doing so, the river will be able to push the gravel that annually comes downstream out to sea rather than accumulating upstream of the viaduct and accentuating meandering processes, increasing flood risk to Lower Garmouth. Various reports by experts over the past decades show that the erosion of Kingston Beach is partly caused by the failure of the gravel brought downstream annually by the river to enter the sea and be pushed up as replacement gravel on the beach. Coastal erosion currently is a major problem in Kingston. By opening up the river, such erosion could be prevented, and the beachhead built up naturally by the gravel that should flow down the River Spey.

The proposed engineering works would have other significant benefits to the local ecology and environment. Former native woodlands and plants would flourish, improving the environment allowing the return of various native species of animals and birds. With less unstable dynamic meandering behaviour, aquatic life such as invertebrates would be able to colonise and increase in numbers providing food for both fish and some species of birds. The constant movement of the river and riverbed has caused a large decline in the number of salmonid fish species in the area, partly through less food availability, constant movement of the riverbed disturbing/ destroying habitats (e.g. spawning) Other wildlife has been adversely affected by the erosion and constant flooding. The constant erosion has allowed the growth over large areas of non-native species such as Giant Hogg Weed and Japanese Knotweed all to the detriment of native plant species, thus wildlife.

Innes Community Council is a body capable of taking the lead in the project. The management of the proposed project should be carried out with great experience of river management and hydrology, namely Dr Moir. River management is a specialist skill, not something standard trained general engineers can carry out successfully.

James A Mackie,
Secretary to Innes Community Council.

Attachments: -

Dr Hamish Moir's full report,
Financial breakdown of the project
Simple diagram to show proposed works

PROJECT COSTINGS

PROJECT No: LOWER SPEY 08082021	CLIENT: INNES COMMUNITY COUNCIL	CLIENT REF: GARMOUTH FLOODING	PROJECT: ROSS HOUSE BEND
EQUIPMENT NUMBER: SPEY WORK AUGUST 2021	EQUIPMENT DESCRIPTION: PROJECT WORKSCOPE & COSTINGS	SHEET NUMBER: 1 OF 1	REVISION: A DATE: 10/8/2021

1:PROJECT TEAM:

1a:Project Expert and site supervision
Dr Hamish Moir/ CBEC £5000
1b: Project labour and specialist professionals
3-Contracted Persons on site/ offsite £12000

2: WORK PROGRAM:
Sepa/ Crown approved contractor

2a: Prepare Old Channel	£3200
2b: Prepare Large Wood Structure (LWS) to take fallen trees	£1600
2c: Move existing fallen trees and start to stake	£4800
2d: Obtain other trees as required- contingency	£6000
2e: Stake LWS area	£2000
2f: Backfill LWS area with material extracted from Old Channel	£4000
2g: Tidy up and prepare Viaduct Area	£1600

3: EQUIPMENT:
Specialist Purchase and Hire

3a: Maxi Postmaster	£9100
3b: Non-treated/ extra length Timer stakes	£3750
3c: Water Craft/ River access	£3500
3d: Waders and specialist PPE	£2500
3e: Site hut and welfare unit	£1200

4: MISCELLANEOUS / CONTINGENCY

4a: Prepare West bank and access	£2000
4b: New landscaping and LWS Willow planting	£7800
4c: Tidy work site, banks and access	£2500
4d: Compensate Landowners for loss of crop/inconvenience	£4800

5: POST PROJECT
5a: Post Project monitoring and Adaptive Managemet
Dr Hamish Moir/ CBEC £5000

6: DURATION
The Scope of work is to be done on a "site fit basis" with continuation over a 4 week period in 3rd quarter of 2021.

TOTALS: £82350

Date:	11th August 2021	Version:	FINAL
To:	Innes Community Council		
From:	Hamish Moir, cbec eco-engineering UK Ltd		
Project:	Lower Spey Sustainable Channel Management		
Subject:	Proposed options and outline designs for channel management at Ross House		

1. INTRODUCTION

cbec eco-engineering UK Ltd was commissioned by Innes Community Council, to undertake the development of sustainable options for the management of the lower River Spey in the reach extending ~500 m upstream from the Spey Viaduct (crossing the main channel of the river at OS NGR NJ 3458 6418). This section of the River Spey has historically been very dynamic but currently is presenting significant risk to local property, services, and infrastructure as it migrates to the west in the vicinity of Ross House.

Recent observations of the lower River Spey at Garmouth indicate that there is:

- Evidence of significant erosion of the channel margin directly impacting Ross House associated with the migration of the channel in this direction and likely exacerbated due to agricultural practices.
- Significant overbank flow onto the west floodplain through preferential flow paths and associated with significant scour through the conduit under the viaduct causeway.
- Significant deposition of large wood and sediment through the reach of interest.
- Significant section of hard bank protection (rock armour/ rip-rap) and embankment extending ~200 m downstream from this at the upstream extent of the surveyed reach that impacts natural river processes.
- The highly dynamic nature of the Lower Spey in the vicinity of the Spey Viaduct means that if left unchecked, continuing erosion of the left bank at Ross House poses a potential risk of destabilising adjacent infrastructure, properties, local amenities, and land use. The existing flood issues at Garmouth are also likely to continue unabated.

The proposed approach is to, through an understanding of local river processes, encourage the dominant flow of the river to migrate back towards a more easterly orientation that approaches the main span of the Spey Viaduct more directly. This is to be achieved through working with natural river process as opposed to traditional intrusive ‘hard engineered’ measures to force the river into a specific course (e.g., rock armour, channel dredging etc). Specifically, after assessments of local river conditions, an approach that implements Large Wood Structures (LWS) within the margins of the active channel in combination with localised sediment reprofiling (i.e., not removal/ dredging) is determined to be most appropriate.

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This type of intervention will judiciously add 'roughness' to the channel, encouraging the natural deposition of sediment (cobbles, gravels etc) that will begin to deflect flow away from the western margins of the river (i.e., where continued migration/ bank retreat presents significant risks to local property, infrastructure, services etc) to occupy an accentuated back channel (a previous course of the main river flow).

This report presents outline designs and an implementation strategy for the deployment of a significant LWS and associated sediment reprofiling at an optimal location on the river and summarises the design process including the outputs of the desk-based site characterisation, geomorphic walk-over and the design approach.

2. CATCHMENT CHARACTERISTICS

The River Spey is an upland river located in the north east of Scotland (Figure 2.1), with a catchment area of 3,008 km^2 at its tidal limit at Spey Bay (NJ 3455 6566). It rises in the western Cairngorm Mountains, then draining into Loch Spey and, from there, it flows north east through Newtonmore, Kingussie, Aviemore, Grantown on Spey, Rothes, and Fochabers in the Vale of Strathspey before discharging into the Moray Firth, a total distance of ~170 km.

The River Spey initially flows through steep and confined glacially sculpted valleys related to underlying resistant bedrock in the upper catchment area. Superficial deposits relate to glacial deposits laid down during the Quaternary period. As the River Spey flows north east, channel gradient (and therefore energy) reduces and valley confinement decreases causing sediment to be deposited, encouraging the development of alluvial barforms. This is enhanced further by a supply of coarse sediment from the numerous tributaries which join the River Spey along its course.

At the downstream extents of the River Spey (i.e., the reach of interest, downstream from Fochabers) in particular, relict meanders are observed within the surrounding floodplain, suggesting active channel migration has occurred over time (Figure 2.2). This dynamic condition is associated with the river actively migrating through and reworking its floodplain, although with associated bank erosion most likely enhanced in recent historic times due to the reduction in riparian tree cover (at the specific site and throughout the catchment), an increase in intensification of agriculture and climate change. Military maps of Scotland produced between 1747 and 1752 by William Roy show that the River Spey was very dynamic which reflects the likely naturally active and morphologically diverse reference state. The channel through this section is eroding into fluvio-glacial, raised marine and alluvial material, providing a plentiful supply of a wide size-range of sediments. Valley confinement and slope decreases downstream of Fochabers, decreasing the channel's ability to transfer sediment and, with a consistent supply of coarse sediment from upstream and adjacent floodplain areas, facilitating the development of extensive alluvial barforms with associated erosion on the opposite banks. Downstream of the Spey viaduct and Garmouth, the valley gradient further reduces at the coastal margin and the River Spey forms multiple channels and a delta at the Spey Bay Nature Reserve.

Land use within the River Spey catchment is primarily agricultural (pastoral and arable) along the lower lying open floodplains, with managed forestry and moorland dominating the steeper valley sides. Soils within the catchment are predominately free draining mineral podzols with smaller areas of brown earths present.

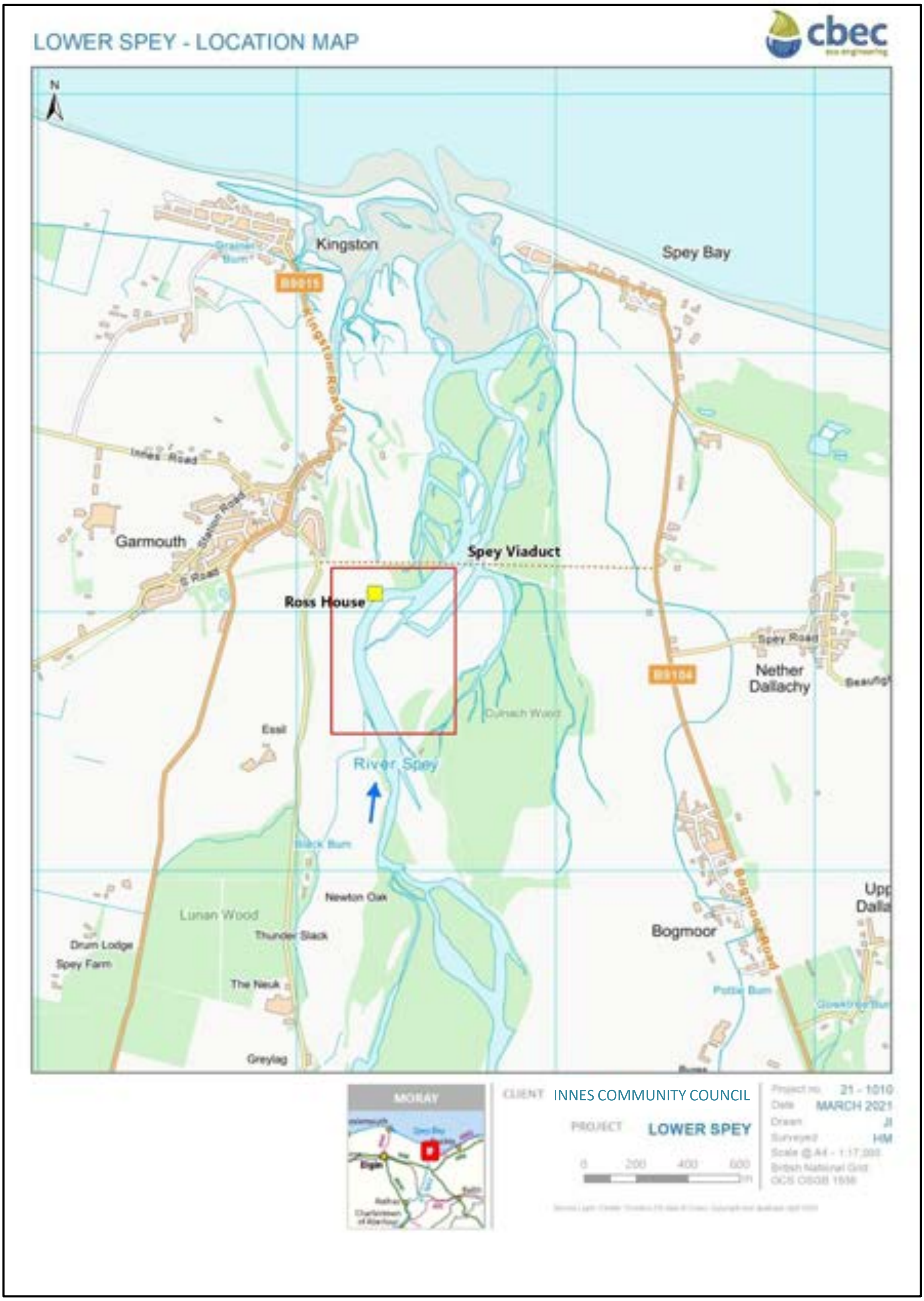


Figure 2.1. Location map for the Lower River Spey study reach in the vicinity of Ross House near Garmouth.

Between Fochabers and Garmouth the river corridor is characterised predominately by a high energy active meandering channel. The banks in many locations are vertical and composed of alluvial material of a sand/ gravel/ cobble mix. The channel bed, where observed, is a mix of large cobbles and gravels and with the extensive point, medial and lateral bars characterised primarily by coarse gravels and sand. Riparian vegetation is poor with the river corridor being mainly grassland with limited tree cover. The surrounding land is primarily given over to pastoral agricultural outside of the channel corridor. To the east of the active channel area within the historical mapped extents of the river, there is a clear succession of vegetation establishment that reflects the physical evolution of the reach (i.e., scroll bars and relict channels associated with varying maturity and types of vegetation, although including some INNS).

In terms of Water Framework Directive (WFD) classification, the River Spey at the study location (River Fiddich to tidal limit waterbody ID: 23065) is currently classified as having an overall WFD status of ‘Good’, as is the Lossiemouth to Portgordon Coastal Waterbody (SEPA, 2018). The River Spey at Ross House forms part of the designated River Spey and Lower River Spey Sites of Special Scientific Interest (SSSI), the River Spey and Lower River Spey-Spey Bay Special Areas of Conservation (SAC), and the Moray and Nairn Coast Special Protection Area (SPA) and Ramsar site.

The closest SEPA gauging station to the study location is on the River Spey at Boat o’ Brig approximately 12 km upstream. This station records annual average rainfall as 1119 mm where elevations reach 1306 mAOD (FEH, 2020). The closest rain gauge to Ross House is located at Dipple at Fochabers (Station number: 115217) which is approximately 5.6 km upstream. This station records average monthly rainfalls ranging between 103mm in August to 48 mm in February over the last 10 years.

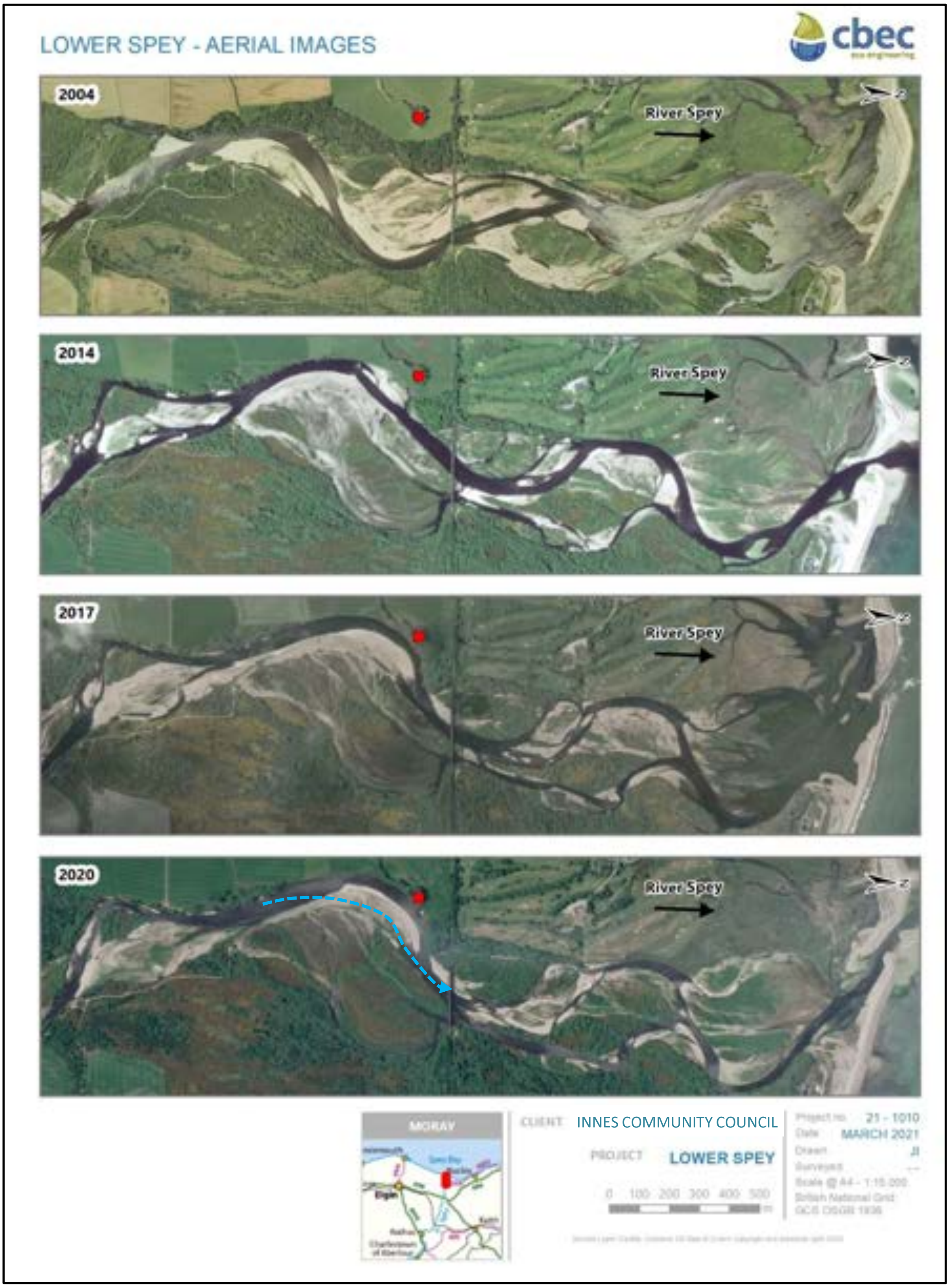


Figure 2.2. Aerial imagery of the lower River Spey at Garmouth and Spey Bay showing significant changes in the location and morphology of the channel between 2004 and 2020. For instructional purposes, the dashed light blue line in the 2020 frame represents the preferred alignment of the main flow of the river that the proposed works intend to deliver.

3. HISTORICAL ASSESSMENT

Aerial Imagery (Figure 2.2) and historical maps (Figure 3.1) illustrate the highly dynamic behaviour of the lower River Spey in the Garmouth area which has implications for the study section at Ross House.

There is a demonstrably high degree of change (both channel migration and associated morphological evolution) over the period of record (i.e., since the earliest accurate topographic maps). From the available aerial imagary, it is estimated that the lower River Spey has migrated diagonally 350 m across its active corridor since 2004 to the northwest as the meander bend has evolved, or translated, across to the Ross House vicinity (Figure 3.2). This lateral mirgation equates to an average of ~17 m of migration per year (although actual migration has been sporadic, primarily in relation to periods of high flow events), indicating a highly dynamic section of the lower River Spey at this location.

In particular, the historical maps[1] note that:

- Ross House is located at the former Mill of Garmouth. Maps produced after 1905 show that the mill lade, Millcroft and Corn Mill to the south of the Mill of Garmouth between Newton and Essil are no longer marked and may have been lost as the Spey has migrated west.
- The Black Burn originates to the south of Newton and flows north through Garmouth to Spey Bay. Between 2004 and 2012 the Black Burn watercourse at this location was also captured by westward migration of the River Spey.
- The Black Burn originally flowed to the west of Ross House and formed part of an artificial drainage network linked with the mill lade system. The former course can be seen on modern aerial imagery as a topographic low/wetter ground.
- Maps published in the 1960s show that there is evidence of a new topographic low to the east of Ross House which has been connected to the Black Burn and the mill lade at the former Millcroft location. It is not clear if this connection was artificially dredged as a navigation/ access channel but remains apparent on recent OS maps and aerial imagery.

Summary of historical observations

The oldest published maps (Roy, 1747-1752) and paleo-evidence from aerial images (i.e. both pre-dating properly geo-referenced maps) indicate a very dynamic environment of an actively wandering/ braided system with very wide active corridor. This is the natural 'reference state' for the river. More recent maps and aerial imagery identify that this condition continues to the present day but now impacts infrastructure. The presence of the viaduct acts as a 'throttle' to sediment transport, resulting in a net accumulation of material in the reach upstream, associated with enhanced geomorphic process (i.e. barform development and associated material channel migration through bank erosion).

[1] National Library of Scotland (NLS). Available at https://maps.nls.uk/.

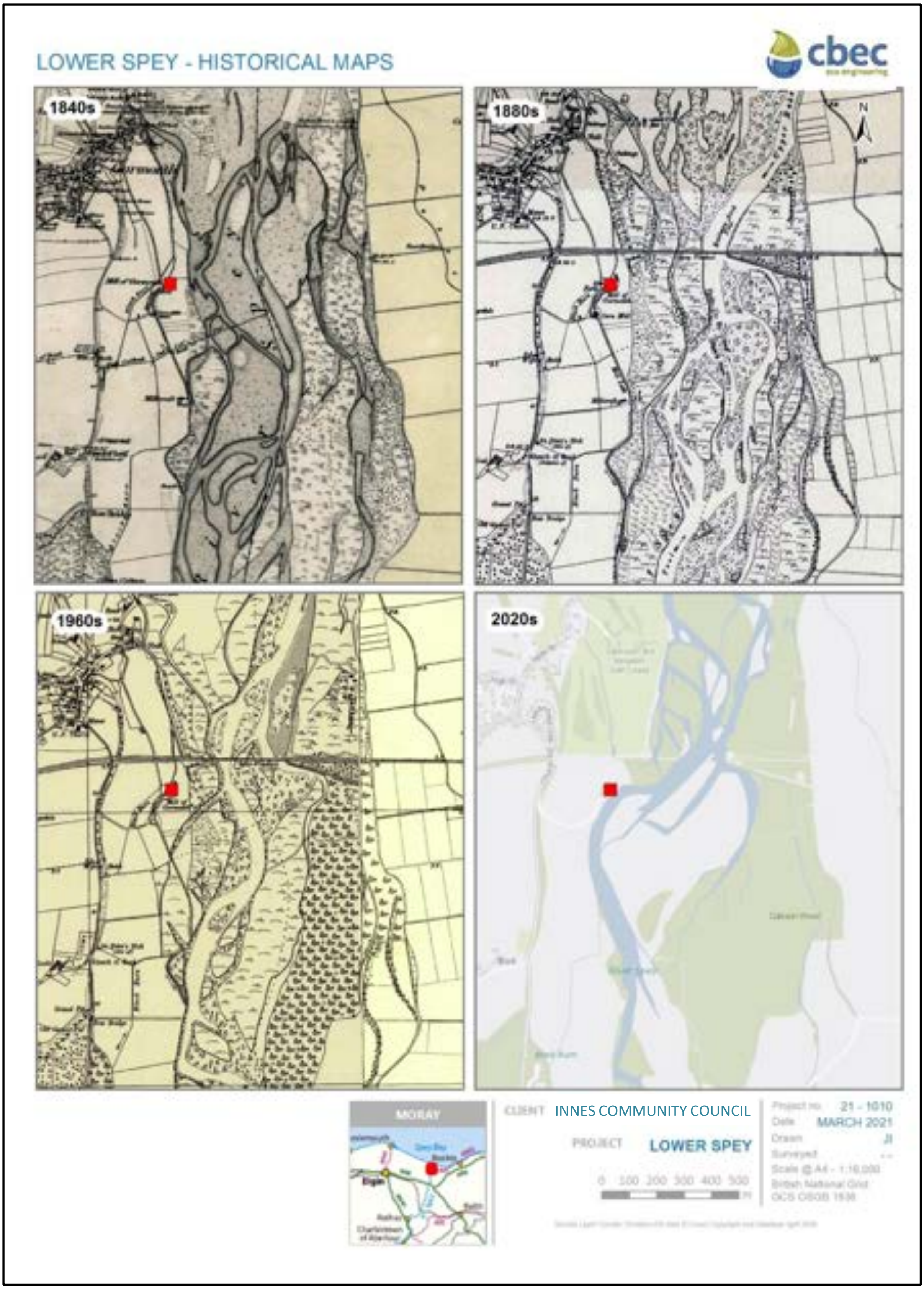


Figure 3.1. Historical channel changes of the lower River Spey near Garmouth from published maps over the last ~160 years. The location of Ross House is indicated by the red square.

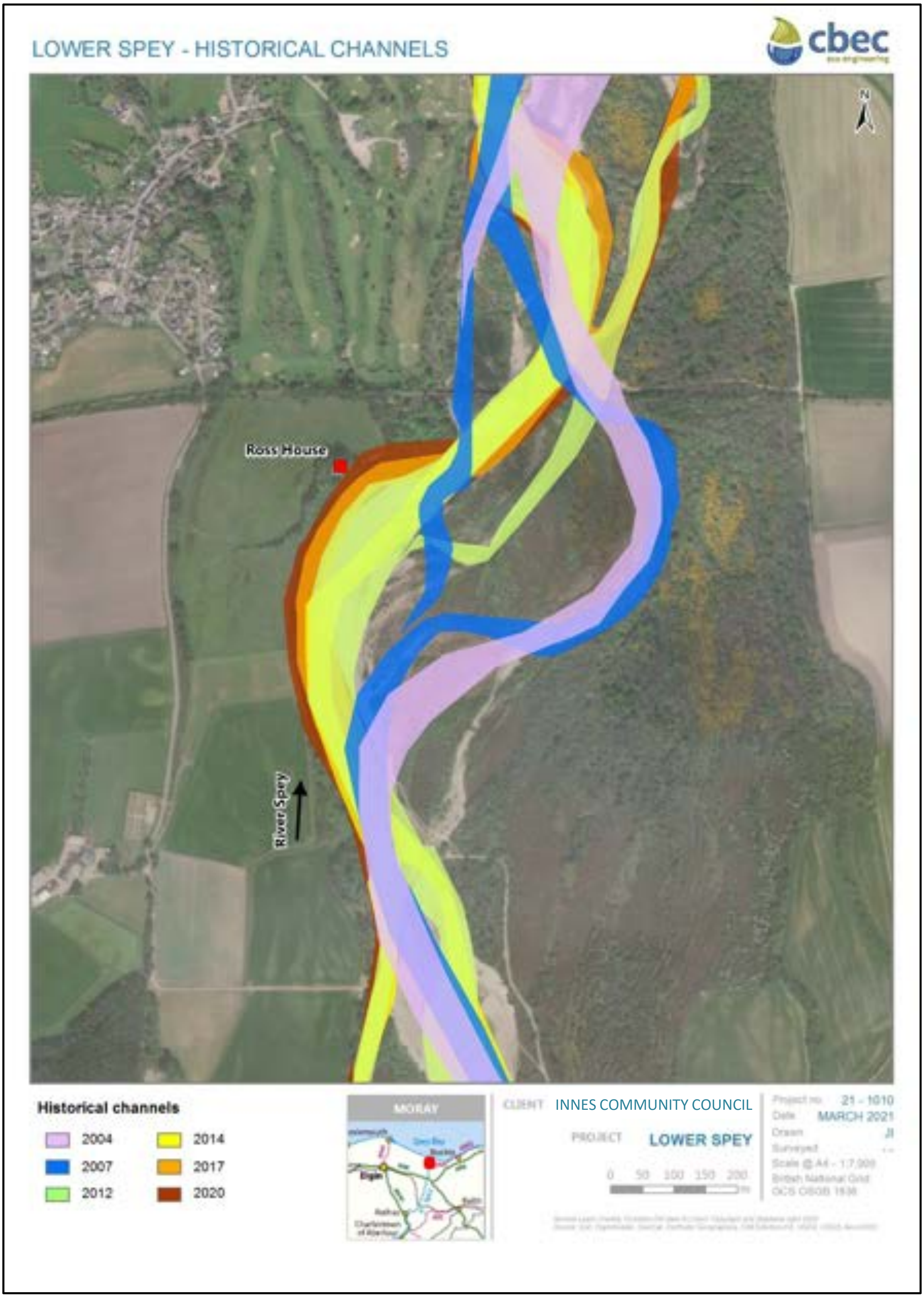


Figure 3.2. Summary of recent historical channel changes of the lower River Spey near Garmouth from aerial imagery since 2004. The location of Ross House is indicated by the red square.

4. GEOMORPHIC WALKOVER

cbec conducted a geomorphic walkover (following a 'fluvial audit' type of methodology) to assess the current physical condition of the watercourse. This process allowed accurate interpretation of the location and extent of important features influencing the physical condition of the river (e.g., sediment input from bank/ terrace erosion and tributaries; area of sediment stored in active bar features; anthropogenic/ engineering pressures; riparian vegetation).

4.1.1. Location

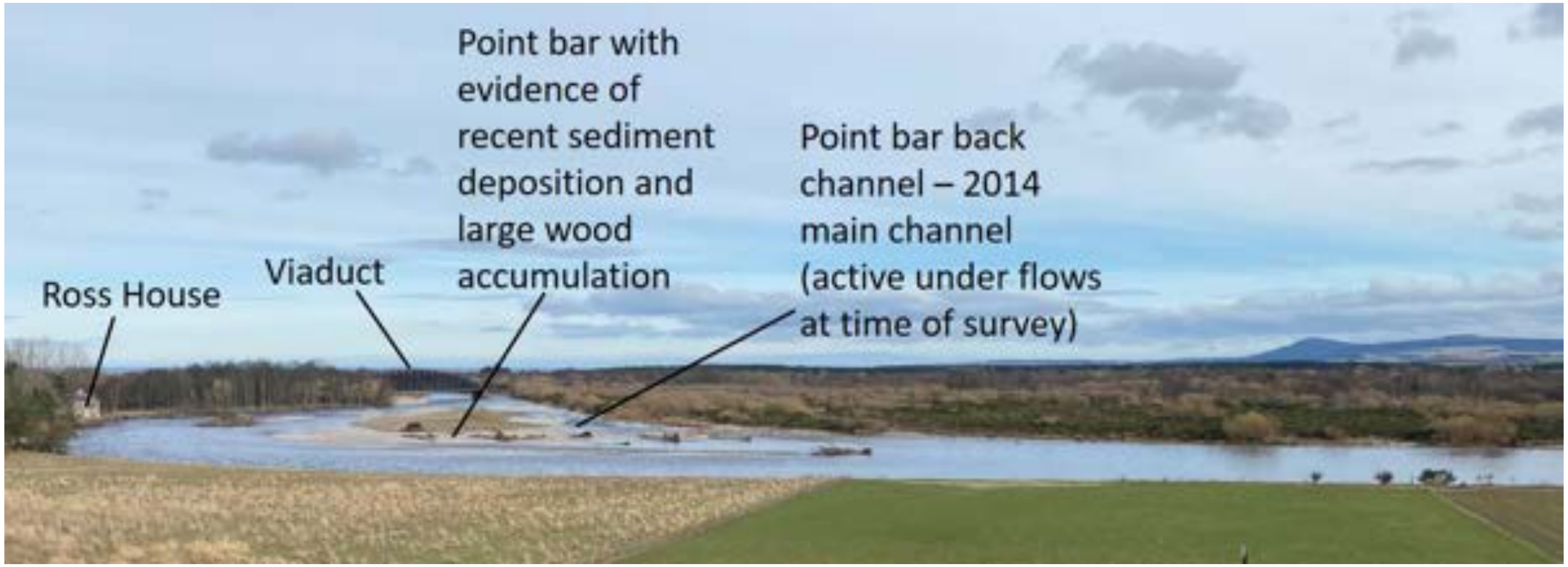
The geomorphic walkover/ fluvial audit survey covered a ~1.5 km extent of the River Spey from just downstream of the Spey viaduct (OS NGR NJ 3446 6437, i.e., downstream extent) upstream to adjacent to Alma Cottage (NJ 3430 6307).

4.1.1. Method

The fluvial audit was undertaken on 9th March 2021 by Dr Hamish Moir and Dr Eric Gillies who have experience in delivering geomorphology and hydraulic modelling assessments and river management solutions. Although not a flood event, river flow was somewhat elevated so certain aspects of in-channel characteristics (e.g., a proportion of the extent of alluvial barforms) were partially obscured. However, this did not significantly hinder the assessment of the geomorphic condition of the site. Locations and characteristics of physical features were recorded using a hand-held GPS and camera. The data were subsequently transformed into GIS format to allow visualisation and further analysis. The types of features and characteristics recorded are listed below.

- **Reach scale channel morphology** (using a classification scheme that draws on aspects of other recognised procedures – SEPA, 2012; Montgomery and Buffington, 1997; Brierley and Fryirs, 2000).
- **Sediment sources/ storage** (e.g., tributaries, bank erosion, within-channel storage in barforms), noting dominant sediment sizes.
- **Indicators of the sediment transport regime** (e.g., the form, texture and vegetation cover of bar features and bed forms).
- **Vegetation** - both in-channel vegetation (e.g., 'large woody material', macrophytes) and riparian/bankside cover, as well as invasive alien species.
- **River engineering pressures** (e.g., bank protection, realignment, embankments, hydraulic structures, bridge crossings, etc.).

Table 4.1. Geomorphic walkover photographs and observations (upstream to downstream, noting that flows were elevated during the survey).

Location	Observations	Photo
Site overview		

NJ 3430 6310 (Alma Cottage, Newton. Upstream extents of survey)	Hard bank protection (rock armour/ rip-rap) at the upstream extent of the surveyed section of the river. This structure (and the associated embankment adjoining downstream) act to inhibit natural river processes (e.g., connection with the west floodplain and channel migration).	
	Artificial embankment extending ~200 m downstream from the end of the rock bank protection in the photo above. This feature inhibits high flows naturally connecting with the river left/ west floodplain, focussing overbank flow into the reach downstream (i.e., in the vicinity of Ross House).	

NJ 3421 6383	View downstream to Ross House with active bank erosion river and location of incipient overbank flow evident on left/ west margins of the channel. The significant sediment and large wood accumulation (i.e., associated with the developing point bar feature) is evident on river right/ east. The point bar back channel is partially visible to the far right of the photograph.	
NJ 3430 6406	The east corner of Ross House, directly on the line of the eroding top of bank edge (note that the bank erosion has extended further since this photograph was taken and a section of the corner wall of the building has collapsed as a result).	

NJ 3437 6411	Looking upstream to Ross House, showing evidence of active bank erosion and large wood accumulation (with associated sediment deposition).	
NJ 3456 6417	Significant sediment accumulation under the viaduct on river left/ west side of channel. Also note the large wood material trapped on around the pier of the viaduct.	

NJ 3458 6418	View upstream from Spey viaduct, close to downstream extent of survey. Note the significant accumulations of large wood and alluvial sediment, indicative of a highly dynamic geomorphic environment. Ross House is located just out of the photograph on the right (i.e., river left/ west). The 2014 back-channel and preferred route is shown as red dashed arrows.	
NJ 3458 6418	View downstream from Spey viaduct, close to downstream extent of survey. As in upstream reach, note the significant accumulations of large wood and alluvial sediment, indicative of a highly dynamic geomorphic environment.	

NJ 3431 6419	Evidence of preferential floodplain flow path around west side of Ross House, towards viaduct causeway.	
NJ 3431 6419	Scour located at the entrance to the conduit under the viaduct causeway related to overbank flow through the floodplain preferential flow paths (see above photograph).	

Summary of walkover observations

- Evidence of significant erosion of the west channel margin, associated with the migration of the channel in this direction (i.e., directly impacting Ross House). Likely exacerbated due to simple riparian vegetation cover (i.e., relating to agricultural practices).
- Significant overbank flow onto the west floodplain through preferential flow paths (i.e., possibly related to natural and anthropogenic historical channels) and associated with significant scour through the conduit under the viaduct causeway.
- Significant deposition of large wood and sediment through the reach of interest, intrinsically linked to (and enhancing) the processes of lateral channel migration and morphological change.
- Significant section of hard bank protection (rock armour/ rip-rap) and embankment extending ~200 m downstream from this at the upstream extent of the surveyed reach that impacts natural river processes - means that overbank flow for moderately-sized flood events is focussed in the area between the downstream end of the embankment (and the viaduct – i.e., potentially accentuating the impact of this process to channel margins and the floodplain). Other than this, little other evidence of direct engineering pressures.
- **The highly dynamic nature of the Lower Spey in the vicinity of the Spey Viaduct means that if left unchecked, continuing erosion of the left bank at Ross House poses a potential risk of destabilising adjacent infrastructure, properties, local amenities, and land use. The existing flood issues at Garmouth are also likely to continue unabated.**

5. DESIGN RATIONALE

The historical assessment and geomorphic walkover observations confirmed the dynamic nature of the lower River Spey which poses a significant risk to the Ross House property on the left bank (and other significant infrastructure downstream).

The principal driver for the proposed restoration/ management interventions resulting from this project will be the reinstatement, as much as is practicable, of natural channel-floodplain physical and ecological functioning on the study reach (and the associated benefits that this will bring). To achieve this, we propose to apply an over-arching philosophy of 'process-based restoration'. This concept is gaining increasing interest in river management worldwide and Dr Moir has recently co-authored a paper on the practical applications of the philosophy (Beechie *et al*., 2010). The underlying concept of the theory is that by firstly determining the 'reference state' for the river and subsequently tackling the impacts to the processes of water and sediment supply, transport, and storage at the largest possible spatial scale, this will permit the physical recovery of the river in a more natural, stable, and self-sustaining manner, thereby also providing the fundamental basis for ecological recovery. In this way the river itself will subsequently do the work of maintaining a 'natural' and self-regulating environment with the minimal requirement for subsequent intrusive interventions.

To reiterate, since physical form and processes provide the template for many important ecological functions (and the associated biota and their habitats), restoring these generic controls at appropriately meaningful scales will bring about, in the medium to longer terms, a sustainable ecological benefit. Ecological benefit will also be explicitly assessed in terms of local protected species. Therefore, in addition to site-specific restoration interventions, the range of options presented may well include broader-scale suggestions on the management of the entire reach and span 25 years or more into the future.

As with any construction that involves working in the natural environment, complete and spatially continuous supporting data sets (e.g., services, ground conditions etc) are not always available. Therefore, unexpected issues may arise once the construction phase has begun. Under such circumstance, we are required to make decisions at short notice as to how designs need to be modified to solve these issues. This process is known as 'field-fitting', with this term used throughout this document where necessary.

The proposed channel management options are illustrated in Figure 5.1. and aim to reproduce natural processes for the development of stable bar or island features that divert the course of the river and drive long-term morphological evolution. Natural log jams commonly encourage changes in flow process and sediment dynamics that lead to the development of bar features.

Aerial imagery indicates a transverse bar forming a submerged riffle across the channel as it extends from the exposed point bar on the right bank. Figure 5.1 indicates the approximate locations[2] for the proposed implementation works (i.e., installation of LWS, described in more detail below) that aim to align with the sub-surface extents of the riffle; representing an existing net zone of sediment accumulation (i.e., associated with reduced the depth of flow), the aim is to enhance these processes by increasing the roughness of the channel in this area.

Upstream from the riffle, an exposed embryonic lateral bar was evident on the aerial image in Figure 5.1 during low flow conditions. Recent site observations suggest that this lateral bar feature is no longer as apparent although the associated transverse bar/riffle crest have remained largely in situ indicating a zone of net sediment storage. This natural sediment accumulation along the left bank can be accentuated through the addition of a substantial LWS, a feature that will increase roughness and reduce the competency of the flow in the vicinity of the structure, encouraging a zone of enhanced/ preferential sediment deposition. The gradual increase in elevation and volume of this left bank bar associated with the enhanced sediment transport processes will direct flows away from the left bank and towards the existing point bar back channel to the right/ east.

The former 2014 channel (Figures 2.2 and 3.2 and Table 4.1) is preserved as a topographic low within the accumulating right bar feature and acts as a back-channel feature. Reprofiling (i.e., lowering) the channel bed at the entrance to this back-channel feature will further encourage the main flow route of the Spey to follow this former flow path of the river and, therefore, away from the left bank where Ross House and other infrastructure are at considerable risk. Material excavated from the backwater can be redistributed to support the construction and stabilisation of the LWS on the left bank.

There are two potential construction approaches with regards to installation of the proposed management options:

1) Installation follows a phased approach such that the LWS will be installed from upstream to downstream over a series of interventions to better mimic natural bar evolution. In this way the LWS will more effectively tie into the embryonic lateral bar feature, gradually enhance sediment accumulation, and allow diversion of the flow

[2] Note that the physical condition of the channel has changed from that of the background photograph, meaning that the specific location of the works will likely require to be 'field-fitted' to some degree to reflect the current form of the site.

path into the 2014 channel and restoration of adequate dimensions to contain a range of flows. In the absence of detailed morphodynamic modelling this will allow progressive adjustments to designs following high flow events before implementing the next phase of construction. The disadvantage being that this will take quite a lot of time, to the extent that the ongoing risk is not managed in a sufficient timeframe. An issue may also arise with regards to sourcing the required ballast and back-fill for the LWS if the back channel reprofiling is not partially or fully undertaken at the same time.

2) Construction of the full design (i.e., full extent of LWS and associated reprofiling of the back channel) is undertaken is a single phase of works. The advantage of a single phase of works is that it more quickly reduces ongoing risk to property and infrastructure and the number of occasions disruptive in-channel and bankside construction works take place. The disadvantage is that the design cannot be progressively adjusted in response to flow events which increases the risk of damage.

It is recognised that constructing a substantial LWS could potentially constrict the width of the existing River Spey flow path if the former 2014 channel is not sufficiently increased in dimensions. It is therefore advised that, under both options 1 and 2, some degree of associated reprofiling of the back channel is undertaken. However, given the ongoing high risk to Ross House and other downstream infrastructure, construction option 2 is recommended; although allowing for greater confidence that the ultimate implemented works will perform as required, it is likely that the timescales necessary to deliver option 1 will be too great (i.e., given the high degree of risk to Ross House and other downstream infrastructure).

The proposed management options at the locations shown in Figure 5.1 are intended to provide sustainable medium- to long-term solution for the risk posed to the Ross House founded on a process-based approach which work in tandem with interim bank stabilisation measures at the property. It is also anticipated that the management options proposed in this report will tie into long-term plans proposed for this reach of the River Spey which may include restoring the main flow path to the 2004 alignment (Figure 3.2).

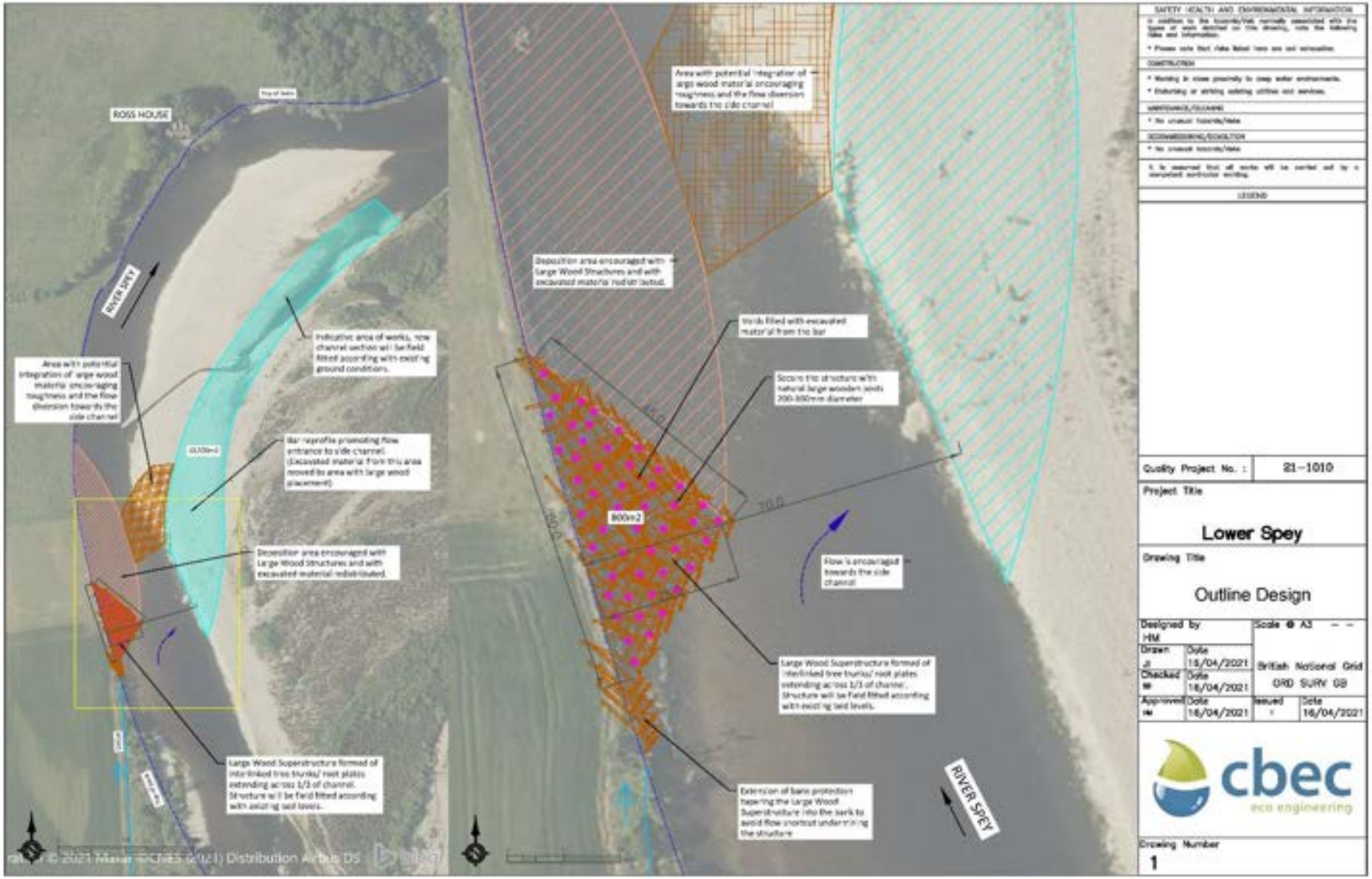


Figure 5.1: Location and general design specifications of proposed channel management works to encourage flow diversion into the former 2014 channel.

6. IMPLEMENTATION AND DESIGN OF LARGE WOOD FEATURES AND CHANNEL REPROFILING

To ensure the effectiveness of the LWS for reducing the risk to the specific area of concern (i.e., in the vicinity of Ross House), the development of the proposed design has also considered the wider study area (and adjacent sections of river) for the site. The interaction between flow, channel geometry (e.g., depth, width, slope) and bed particle size is important for determining how sediment is stored and mobilised in the vicinity of the proposed LWS (and, therefore, how it impacts the evolution of flow patterns over time). Our experience has shown that if the large wood structures are not suitably scaled to the channel dimensions (particularly width), their influence on river processes (i.e., particularly sediment transport) may not be sufficient to provide the desired effect (i.e., in this case, diverting the main flow of the river away from area of risk). For this reason, multiple trees of sufficient size have been recommended to construct the LWS to ensure that the area presented to the flow (i.e., the vertical extent above the channel bed and the width of structure presented to the prevailing flood flow direction) is sufficient to exert an appreciable influence on in-channel processes (i.e., to direct flow into the back-channel feature).

Ideally detailed design specifications would be supported by hydraulic or morphodynamic modelling for best results – both to determine the likely trajectory of evolution of the channel post-construction to result in the required longer-term adjustment of the main flow direction and to ensure that the required stabilisation of the structure has been adequately specified (i.e., relating to hydraulic forces experienced during high flow events). Given the current budget and time constraints, the outline design presented here has been based on expert judgement and, given the complex geomorphic processes exhibited at the site, there is some residual uncertainty associated with this.

6.1 LARGE WOOD STRUCTURES

The trees comprising the LWS should be generally oriented so that the root plates face upstream (i.e., relative to the prevailing flow direction) at an angle of 30°-45°. To further increase structure stability, the root plates should be buried into the channel bed to about half of their diameter and with the retained length of trunk away from the root plate being angled down into the channel bed. Given the dynamic character and high hydraulic forces of the River Spey at the design reach, the proposed LWS requires to be constructed with an interlinked latticework structure, with each large wood[3] element being stabilised by other elements lying over it (i.e., forming an 'engineered log jam', Figure 6.1; with each large wood element overlapping by at least 25% of their total trunk length at their downstream and upstream extents.

Furthermore, wooden posts of 200-300mm diameter shall be buried to a depth of up to 2 m where feasible into the channel bed to stabilise the trunks. These should rest up against the downstream side of the trunks of each large wood element, one at the base (i.e., at the root plate) and another near the opposite end (although other intermediate posts can also be implemented). The placement of the posts will require an element of field fitting to account for the location of branches and the local condition of the channel bed (e.g., difficulty of driving them into the substrate). The design principles are based on extensive experience of the design team gained in high river energy environments, published research and methodological guidelines (e.g., Brooks et al. 2006; Gallisdorfer, M.S. 2014).

Sediment excavated from the associated reprofiling of the eastern back channel (see Section 6.2, below) will be used to infill the voids between the large wood elements comprising the LWS. This

[3] Trunks with root plates attached

material will be sufficient to also fill on top of the wood elements, providing ballast to resist buoyancy and drag forces during high flow events. The resulting engineered log jam structure essentially forms a bank-attached flow deflector as shown indicatively in Figure 6.1. It is anticipated that the constructed structures will have more sediment integrated within them as explained in Section 5 and shown on Figure 5.1.

The combination of the sufficient burial of the large wood elements into the bed/ bank of the channel, their combined interlinked latticework structure, the stabilising wooden posts, and the sediment fill/ ballast, the LWS will remain intact in up to moderately size flood events.

In our experience, an element of field fitting is always required to ensure the structures are implemented correctly, based on site-specific characteristics. For this reason, cbec always recommends that a member of the design team is on site for key stages of the construction phase. This ensures the designs are built as specified, maximising habitat value and the longevity of the structures.

Figure 6.1: Examples of engineered log jam flow deflectors (from Brooks, A. P. 2006)

6.2 CHANNEL REPROFILING

The proposed excavation must be subtle so that it only serves to accentuate the back channel as a preferential flow path rather than constructing a new channel of sufficient cross-sectional area to carry all the flow of the Spey. There must be very gradual lateral and longitudinal grading of the back channel, ensuring that there are no abrupt breaks in slope that subsequent hydraulic processes could exploit causing adverse impacts such as bed incision and head-cut and lateral erosion processes. As such, we recommend field fitting the extent and scale of excavation based on the morphology of the back channel at the time of construction works.

Most of the excavation should be undertaken in the upstream entrance to the back channel – once sufficient flow enters the back channel, hydraulic forces should work to mobilise any excess material within it further downstream.

Riparian planting is normally recommended to reduce erosion rates by promoting increased bank stabilisation through the establishment of root structures and added roughness to the channel margins. Fencing may be required to prevent grazing of native tree species within the planted areas of the riparian corridor whilst acknowledging the limitations of current land use and landownership.

7. IDENTIFICATION OF LICENCES AND PERMISSIONS

Following consultation with the relevant local planning departments and SEPA, the licencing requirements and permissions that may be required to be able to undertake the proposed management works have been outlined in Table 7.1.

Table 7.1 Licencing and Permissions for Lower Spey sustainable channel management

Organisation	Type of Licence/ Permission	Comment
SEPA	Control Activities Licence (CAR)	CAR and/or GBR25 (likely CAR)
SNH	Freshwater Pearl Mussel Survey	To be completed 2 weeks prior to construction works commencing.
SNH	Otter Survey	To be completed 2 weeks prior to construction works commencing.
Moray Council	Planning Permission	Planning permission not required.

8. POST-CONSTRUCTION MONITORING CONSIDERATION

Post-construction monitoring of the physical condition of the study site is important to assess the stability and function of the built design (especially immediately after construction) and to support any 'adaptive management' of the design that may subsequently be required. Prior to developing the monitoring scheme, areas of particular concern or risk should be identified with particular attention on these areas within the proposed plan.

Monitoring is recommended immediately after the construction work has been completed and should ideally involve topographic surveying (although could include less intensive methods such as reconnaissance walk-over surveys and fixed-point or aerial 'drone' photography, see below). This would provide a 'post-implementation' baseline condition of the individual site against which subsequent monitoring could be assessed. The bank stabilisation and in-channel sediment management works will have the greatest potential for change in the period immediately following implementation (particularly in response to high flow events) prior to a state of 'dynamic equilibrium' being achieved. Therefore, resurveys are recommended after significant flood events ('bankfull' or higher) for a period until a condition of stability is reasonably determined to have been achieved.

Potential monitoring methods:

- **Fixed-point photography:** to visually capture the physical evolution occurring at specifically selected GPS-locations, at relatively frequent intervals (e.g., once every three months).
- **Geomorphic walkover resurveys**: post-construction and then subsequent geomorphic walkover surveys to assess the physical conditions of the site. Comparison between surveys allows evolution to be assessed.
- **Drone survey**: overhead survey of the site to visually capture the changes in the physical evolution of the site.

9. REFERENCES

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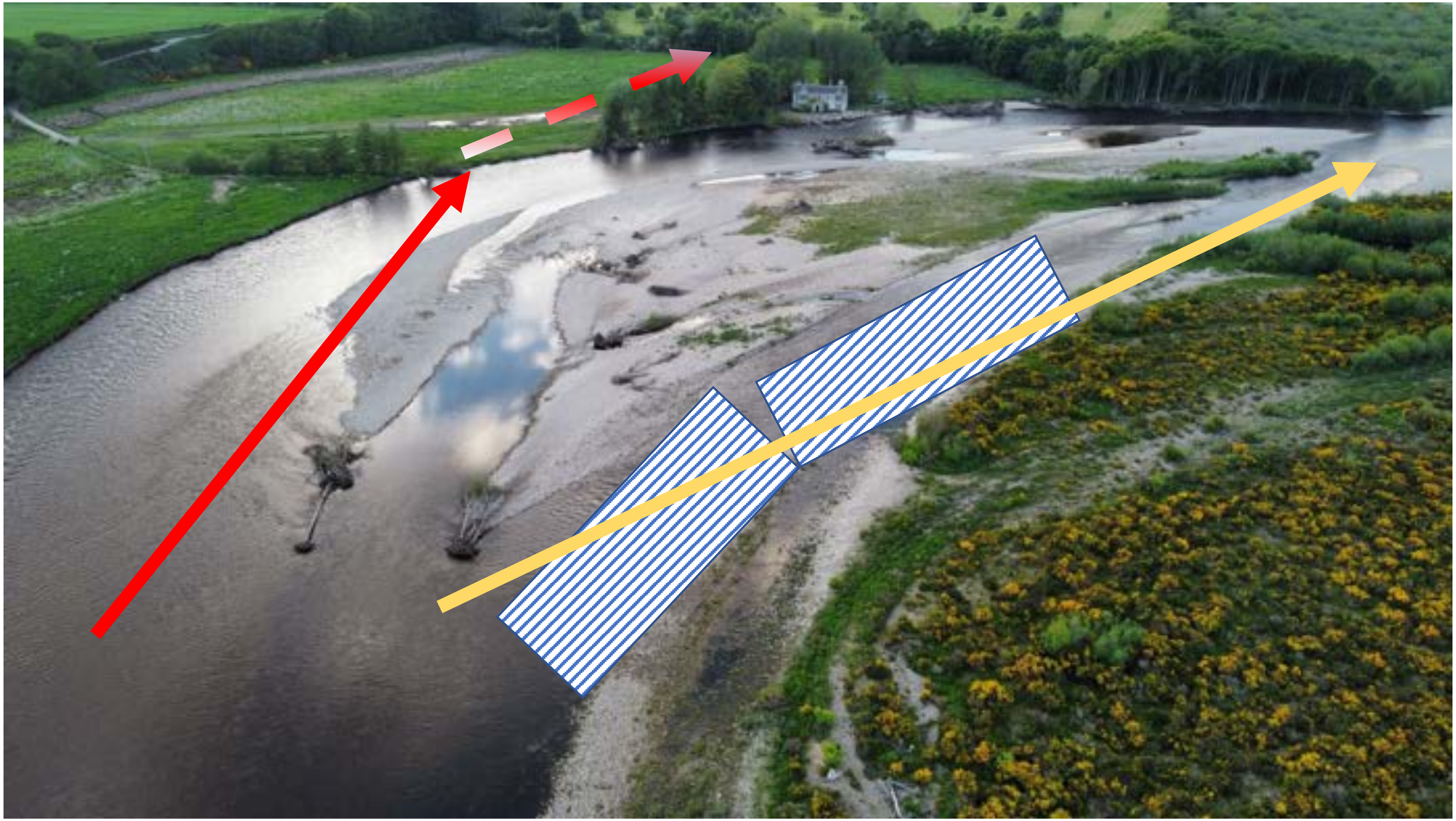
Proposed engineering works for River Spey at Queenshaugh, August, 2021



Red line current main flow of river directly into lands of Queenshaugh.   Broken line direction river heading
Red box represents proposed tree construction to guide river eastwards.   Yellow line direction that river will be guided.
Blue hash box.   Channel to be deepened and widened to encourage river eastwards away from Queenshaugh land.

Prepared by Innes Community Council.   Email secretaryinnesscc@gmail.com Tel 01343870310

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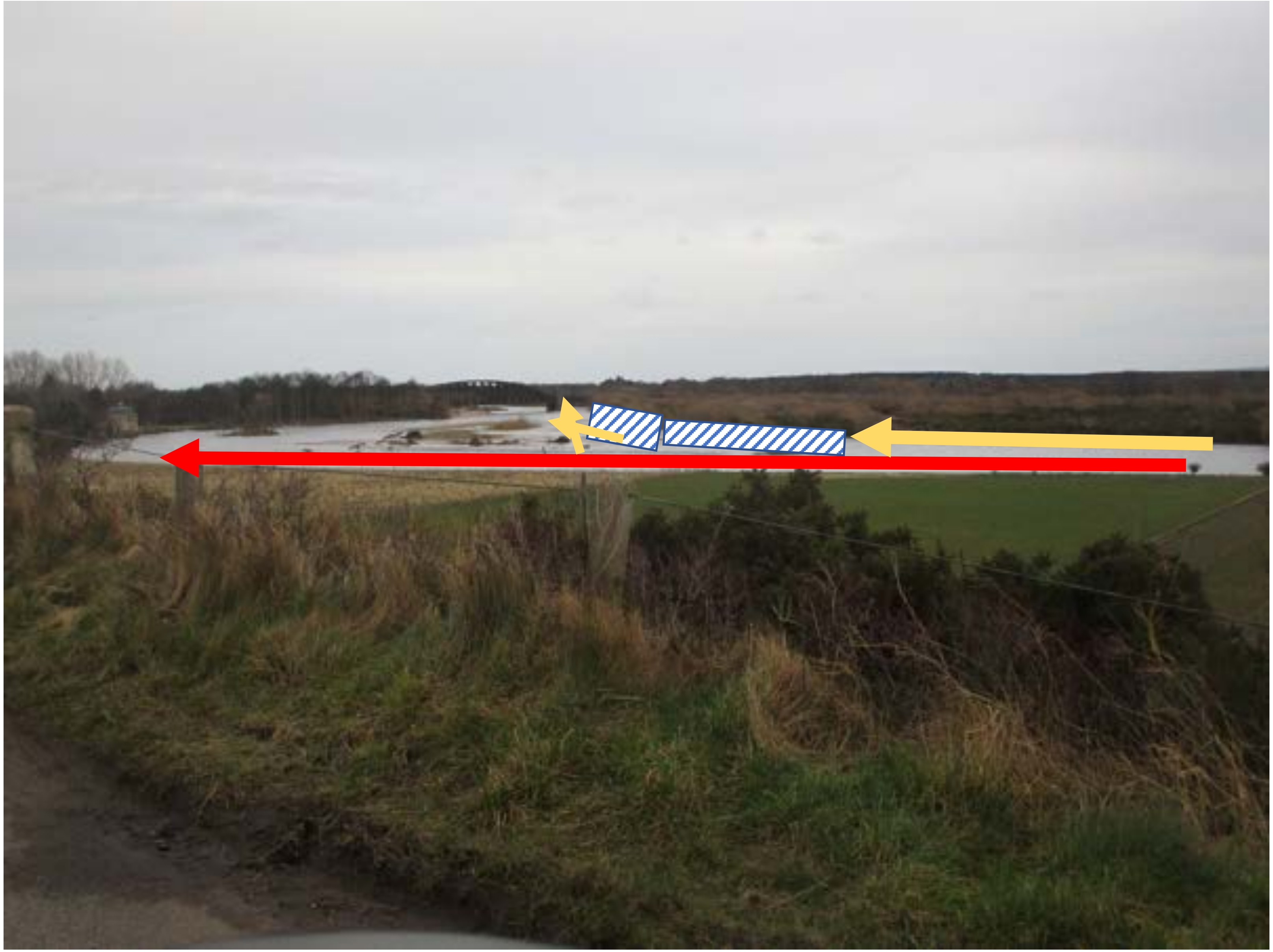

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