Improving participation in environmental decision-making using Bayesian Belief Networks: an exploratory case study

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Abstract

Participation is increasingly recommended to improve democratic processes; however, in practice it is often perceived as *an empty and frustrating process* (Arnstein, 1969, p. 216). In participatory environmental decision making (PEDM) extractive methods of data collection focus on accuracy of data rather than democratic values and prioritise expert knowledge over public views. As a result, participants become disillusioned and negative feelings develop into active opposition (Wolsink, 2007), causing delays, spiralling costs, and conflict (Haggett, 2008). Previous studies claim that features of advanced statistical modelling, such as Bayesian Belief Networks (BBNs), could aid participation. Using an exploratory case study, a proposed tidal energy scheme in the UK's Solway Firth, Solway Energy Gateway (SEG), this study investigates how features of BBNs could be harnessed to improve PEDM. A Participatory Action Research (PAR) inspired framework of phases of action and reflection was used to collect and analyse qualitative data from a diverse sample of stakeholders. BBNs were co-produced and co-analysed with the participants over five cycles of engagement. The capacity for BBNs to improve PEDM was evaluated against criteria derived from theoretical ideals of deliberative democracy, procedural environmental justice, and science and technology studies. BBNs were found to partly contribute to the fulfilment of the criteria. Working through the logical structure of the BBNs helped the participants broaden their thoughts and generate knowledge. However, the complexity of BBNs caused anxiety and consultation fatigue. Knowledge was lost as BBNs were built, reducing the ability to communicate knowledge and facilitate learning between participants. BBNs highlighted opposing views, emphasising existing hostilities. There is capacity for BBNs to aid in the scoping phase of PEDM. Further research is needed to explore this proposition and how BBNs could be used in combination with other modelling tools to implement a more comprehensive solution to the challenges associated with PEDM.

For my Mama, Barbara Carrick (1955-2018)

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List of Abbreviations

BBN	Bayesian Belief Network
CPT	Conditional probability table
DD	Deliberative democracy
DECC	Department for Energy & Climate Change (UK Government department, which become part of the Department for Business, Energy and Industrial Strategy in 2016)
DQI	Discourse quality index
EA	Environment Agency
EIA	Environmental Impact Assessment
KI	Key informant: participant in this study. See Table 3.3 for full list of key informants (KI-A to KI-P) on page 82
kW	Kilo Watt of electricity refers to generation capacity of a renewable energy installation
MMO	Marine Management Organisation: regulatory body for marine activities in England
MW	Mega Watt of electricity refers to generation capacity of a renewable energy installation
PAR	Participatory Action Research
PEJ	Procedural environmental justice
RSPB	Royal Society for the Protection of Birds
RQ	Research question
SEG	Solway Energy Gateway: proposed tidal energy scheme in the Solway Firth and subject of this exploratory case study
SEPA	Scottish Environment Protection Agency
SSSI	Site of Special Scientific Interest
STS	Science and Technology Studies
USEPA	United States Environmental Protection Agency
VETT	Venturi Enhanced Turbine Technology; type of tidal energy technology proposed at Solway Energy Gateway

Chapter 1. Background

The Solway Energy Gateway (SEG) is a tidal energy proposal located in the Solway Firth. SEG was first proposed over 10 years ago but has yet to gain enough backing for formal applications for consent to be complied and submitted. The idea to install a tidal energy scheme in the Solway Firth is not new. The Solway Firth has the second largest tidal energy generation potential in the UK, second to the Severn Estuary (O'Rourke *et al*, 2010). Its potential has been explored since the 1960s (Howard *et al*, 2007) and since then various schemes have been proposed. Currently, SEG is one of several proposed tidal energy schemes in the Solway Firth, none of which have progressed to the formal consenting and licencing stages. The delays experienced by SEG and other tidal energy proposals in the Solway Firth are not unique. UK waters have around 50% of Europe's tidal energy resource that could meet up to 12% of the UK's current electricity demand (UK Government, 2013). However, wave and tidal energy combined generated only around 9GWh, or 0.003% of electricity generated in the UK in 2018 (UK Government, 2019).

There are various technological and economic barriers as well as environmental concerns that contribute to the lack of progress in realising the potential for tidal energy in the UK. High capital costs and long payback periods (Burrows *et al*, 2009) associated with a range of novel technologies, many of which are untested at commercial scale, as well as lack of capital support for the fledgling industry (Leete *et al*, 2013) and high electricity grid connection costs are contributing factors. The slow pace of deployment is also partly attributed to the lengthy and expensive licencing and consenting processes for renewable energy developments in the UK (González & Lacal-Arántegui, 2016; Mackinnon *et al*, 2018; and Ocean Energy Forum, 2016).

The licencing and consenting process for marine renewables can be slow and is unpredictable. Complex environmental and social impacts that draw in a diverse range of stakeholders with opposing views often result in delays, consultation fatigue and conflict. This study focuses on the consenting and licencing processes as an area for improvement to lower the barriers for tidal energy. Specifically, this study focuses on the participatory elements of decision-making.

Participation is central to democratic process and a condition for legitimate democratic decision-making (Gould, 1996). Meaningful and legitimate political engagement can improve decision making with provision of new knowledge and serve to politically validate decisions by demonstrating that public opinion has been considered. Consequently, participation is said to improve the acceptance and durability of environmental decisions and policy-making (Aiken *et al,* 2016; Reed, 2008; Sustainable Development Commission, 2007). The instrumental value of public and stakeholder participation to Government was highlighted by the Sustainable Development Commission in 2007 (p. 128):

"The UK Government (and wider society) is increasingly recognising the important benefits to decision-making that can be gained through good public and stakeholder engagement. Recent experience clearly demonstrates where good engagement can support and inform policy decisions, and where inadequate or no engagement results in a failure or derailment of political processes…"

In recognition of these benefits, more recently, Governments have taken steps to institutionalise public engagement. For the Scottish Government, the Commission on Parliamentary Reform (2017, p. 58) states:

"Failing to engage meaningfully with citizens can lead to dissatisfaction with democracy and a lack of trust in the decision takers. Effective engagement….. can improve transparency and policy making by bringing different perspectives, knowledge and skills to the scrutiny process…"

However, realising these potential benefits is difficult. In practice, participatory processes can be complicated, ineffective, and counter-productive, which adversely affects political engagement and the supply of willing participants, encouraging political apathy. Participation in environmental decision making, like proposed renewable energy schemes, exemplifies these challenges (Armeni, 2016).

The term 'participatory environmental decision-making' (PEDM) is used in this study to signify stakeholder participation in consent processes for projects such as marine energy applications, and this is the term that will be used henceforth here.

This study has three elements. First, the licencing and consenting processes for tidal energy in the case of SEG provides the research context to explore the shortcomings of PEDM. Second, the ideals and principles underpinning PEDM provide a theoretical framework. The need to improve the consenting process for tidal energy schemes (Ocean Energy Forum, 2016) and to address the gap between theory and practice of PEDM provides the need and space for this study. The third element is the intervention of advanced statistical modelling, known as Bayesian Belief Networks (BBNs). BBNs model complex systems and can incorporate qualitative data, typical of expert and other stakeholder evidence. This study tests the hypothesis that BBNs can be used to improve PEDM. In a novel approach and departure from the conventional use of BBNs, this study seeks to understand the experience of participants interacting with BBNs to inform an improved template for participatory decision-making. The capacity of decision-making tools, such as BBNs, to enhance participation in decision making and operationalise the normative ideals of PEDM is tested. It is envisaged that the results could be used to inform selection of belief elicitation methods during decision making using BBNs.

The novelty of this study is two-fold: first, the use of BBNs to facilitate participation in the decision-making associated with proposed tidal energy schemes; and second, implementing theoretical ideals of PEDM in BBN modelling. The novel implementation of BBNs in this context provides contributions to the literature on PEDM and marine policy.

Research Questions

To explore how BBNs could be used to improve PEDM the following research questions will be addressed:

RQ 1: How can improvements in PEDM be measured?

RQ 2: Do the features and development of BBNs adequately capture, represent, deepen the understanding of, and communicate knowledge?

RQ 3. Do the features of BBNs improve PEDM?

RQ 4. How could BBNs be incorporated into PEDM to improve the consenting and licencing process for marine renewables?

This study uses the case of SEG to illustrate the challenges associated with PEDM, which could be found in other tidal energy projects and more broadly. These challenges hamper the development of the marine energy sector (Mackinnon *et al*, 2018); this is important because of the scale of the energy and climate change challenge that we face. The remainder of this chapter explains this in more detail. Firstly, I set out the challenges faced by the consenting and licencing processes for tidal energy schemes. An overview of the processes is provided explaining how stakeholder engagement and public consultation fits in and the challenges and opportunities it generates. Secondly, I explain how the features of BBNs could be used to improve PEDM in practice. I briefly explain how they work and how they are applied in other fields, so that their potential use in the case of SEG and PEDM more broadly, is explained. Thirdly, I explain why SEG has been selected as the case study. Finally, I outline the structure of the remaining chapters of this thesis.

1.1 Research context

In this section I provide an overview of the UK consenting and licencing processes for marine renewable energy projects. To illustrate its complexity, I summarise: the differing roles of regulatory authorities in the devolved nations; current tidal energy schemes in the marine licencing process; and potential environmental and social impacts of tidal energy. The current participatory procedures in the consenting and licencing processes and their shortcomings are then discussed.

The potential for environmental and social impacts from marine renewables requires extensive impact assessments. There also needs to be engagement with stakeholders and the public throughout the consenting and licencing process, which falls under the Marine and Coastal Access Act 2009 and the Planning Act 2008.

A Development Consent Order and a Marine Licence are required to build and operate in the marine environment (UK Government, 2018). The Marine and Coastal Access Act 2009 and the Planning Act 2008 represent a new legal framework for consenting. It is a departure from

the previous system, the complexity of which delayed the development of offshore renewables, adversely affecting the industry and Government renewables targets (Gibson & Howsam, 2010). The introduction of the Marine and Coastal Access Act 2009 and Planning Act 2008 aimed to streamline the licencing and consenting process for marine renewables by providing a one-stop-shop for consents, a fixed timeframe for decision-making, and frontloading the application process (Scarff *et al*, 2015). The one-stop-shop approach combines multiple consents (previously required) into a single overall consent to simplify the process (Gibson & Howsam, 2010). Frontloading requires data to be collected, impact assessments completed, and consultations undertaken during a pre-application phase so that issues are sorted out before applications are submitted. The aim is to identify 'show-stoppers' early and avoid iterative requests for and supply of information / data during the application (Scarff *et al*, 2015).

Despite these improvements, marine renewable energy schemes are still subject to a variety of regulatory and consenting processes, depending on their scale and location. Different authorities regulate the terrestrial, coastal and marine environment, so developments may also require separate planning consent for terrestrial infrastructure, e.g. where the electricity cables reach the shore and electrical substations are built.

Illustrating the diversity of legislation governing marine renewables, Hendry (2016, p. 104) lists the following consents and licences needed for tidal lagoons, which comprise structures that connect to the land:

- Development Consent Order (DCO) under the Planning Act 2008
- Marine Licence (ML) under the Marine and Coastal Access Act 2009
- Various Planning Permissions under the Town and Country Planning Act 1990
- Potentially a Harbour Revision Order under the Harbours Act 1964
- Environmental Permits under the Environmental Permitting (England and Wales) Regulations 2010
- Seabed lease from the Crown Estate Commissioners under the Crown Estates Act 1961

The UK regulatory regime is further complicated by powers devolved from the central UK Government to Scotland, Wales, and Northern Ireland. In England and Wales, and if a

development is considered a 'nationally significant energy infrastructure project' (generally >50MW capacity) the Planning Inspector considers the application for development consent (UK Government, 2018). The Marine Management Organisation (MMO) (in England) or Natural Resources Wales consider applications for Marine Licences. In contrast, the Marine Scotland (2018) has established a *one-stop-shop for the consenting and licensing* so that applications for marine licences, planning permission, and electricity generation (section 36 consent) can be *handled simultaneously*.

Marine licences

A review of applications for marine licences illustrates the status of consenting and licencing for tidal energy in the UK. Under the Marine and Coastal Access Act 2009, a marine licence is required for works undertaken within the marine environment and tidal areas. Marine licences are issued by the Marine Management Organisation (MMO) in England's inshore and offshore waters and Northern Ireland's offshore waters. In Wales, Natural Resources Wales issues Marine licences, in Scotland it is Marine Scotland. The Marine and Fisheries Division issues marine licences in Northern Ireland's inshore waters.

The regulatory framework around marine licences is designed so that issues are addressed at the pre-application stage. The aim is to reduce the time decision-making on live applications take because the regulatory authorities are already satisfied concerns have been overcome. The result is that it is difficult to get to the application stage but those that do are more likely to be consented. According to the Scottish Government (2020) seven applications for marine licences to operate tidal energy schemes in Scottish waters have been decided. Of the seven decided applications, six licences have been consented, see Table 1.1.

Six out of seven of the decided applications were consented, indicating that there is a high likelihood of an application resulting in a positive decision. However, the variable decision times (2 months to 4 years) indicates that uncertainty remains a feature of the process. Additionally, one application, The Brims Tidal Array, Orkney, has been caught in the decision-making process since June 2016 (Scottish Government, 2020), and one application, the GSK Montrose Tidal Array, was refused in April 2013.

Table 1.1 Applications for Marine Licences in Scotland

Name	Technology	Total capacity	Decision	Decision Date	Decision time
Argyll Tidal Demonstrator	Tidal stream: a single turbine	500kW	Consented	2014	<2 years
Pentland Firth Tidal Energy	Tidal stream: <61 turbines	398MW	Consented	2014	2 years
NOVA innovation Tidal-turbine Array	Tidal stream: 6 turbines	600kW	Consented	2018	3 months
Sound of Islay Demonstration Tidal Array	Tidal stream: 10 turbines	10MW	Consented	2015	1 year
West Islay Tidal Energy Park	Tidal stream: <30 turbines	<60MW	Consented	2017	4 years
SME PLAT-I Tidal Energy Platform	Tidal stream: 4 turbines	248kW	Consented	2017	3 months
GSK Montrose Tidal Array	Tidal stream: 15 turbines	700kW	Refused	2013	1 year
Brims Tidal Array, Orkney	Tidal stream: <200 turbines	200MW	Undecided	N/A	>4years

The Brims Tidal Array proposals comprise 'between 100 and 200 fully submerged tidal turbines with a maximum total installed capacity of 200MW' (Brims Tidal Array Limited, 2016). A review of the consultation documents (Scottish Government, 2020), reveals that concerns were raised about the potential impacts of the operational turbines on marine mammals, fish, and diving birds (guillemots). Additional data and risk assessment on the potential impacts was requested in 2016. The formal application was preceded by a scoping phase; the scoping report was submitted in 2013. This application indicates that the framework designed to streamline the process, by frontloading it, is not wholly effective. This is further demonstrated by the refusal of the GSK Montrose Tidal Array due to the environmental sensitivity of the site. The proposals, for 15 tidal turbines, near to a road bridge in Montrose generated 20 public objections associated with potential impact on wildlife, showing the significance of public opposition in the consenting process. In its decision letter Marine Scotland (2013) cites *the difficulty in quantifying the likely significant impacts* in their reasons for refusal. Illustrating the complexity and uncertainty associated with the marine environment, the decision letter refers to gaps in baseline data and assessment. If the new process of frontloading worked effectively, the 'show-stoppers' should have been identified

before these formal applications were made, avoiding the delay (of Brims Tidal Array) and refusal (of GSK Montrose Tidal Array).

There have been fewer tidal energy schemes approved in England and Wales than in Scotland. According to the MMO's public register (2020) and Natural Resources Wales (2020) several tidal energy schemes have been licenced; however, the majority are test or demonstrator sites. As shown in Table 1.2, the decision time is variable; between 1 month and 2 years.

Table 1.2 Applications for Marine Licences in England and Wales

Name	Technology	Total capacity	Decision	Decision date	Decision time
Trident-Aquasail (test site)	Tidal stream: 1 turbine	12kW	Consented	2015	1 year
Mojo Marine Limited (platform testing)	Tidal stream: 1 turbine	N/A	Consented	2014	1 month
Neptune Proteus (demonstrator)	Deep tidal stream	500kW	Consented	2011	1 year
Skerries Tidal Stream Array	Tidal stream: 5 devices	10MW	Consented	2013	2 years
Tidal Lagoon (Swansea Bay)	Tidal Range: Lagoon	320MW	Undecided	N/A	>5 years

Perhaps one of the most well-known tidal schemes in the UK is the proposed Tidal Lagoon in Swansea Bay. The scheme comprises a 9.5km seawall and will have an installed capacity of 320MW (Natural Resources Wales, 2019). Tidal Lagoon (Swansea Bay) received development consent on 9 June 2015 (Hendry, 2016); however, Natural Resources Wales (2019) are yet to issue a decision on the marine licence application for the scheme; the application was submitted in 2014.

Barriers to tidal energy development

The UK government has committed to a reduction of carbon dioxide emissions for England and Wales by 100% below 1990 levels by 2050 (Climate Change Act, 2008). Replacing fossil fuels with renewable energy contributes to this target. Considering that the *UK has some of the best wave and tidal resources in the world,* marine renewable energy *has the potential to make a significant contribution to meeting the UK's future energy needs* (DECC, 2013, p. 55)

and the Government's targets. To exploit the potential contribution from tidal energy, the UK Government envisaged that by 2020 there would be between 200MW and 300MW (installed capacity) of wave and tidal energy schemes deployed (DECC, 2013). However, by the end of the second quarter of 2019 there were only 22MW of installed capacity of tidal and wave energy in the UK, all located in Scotland (UK Government, 2019).

The barriers to tidal energy schemes in the UK are variable and, some, site specific. Economic factors are significant; for example, high capital costs and unproven returns on investment have scuppered both tidal range and tidal stream schemes, such as the Tidal Lagoon (Swansea Bay) and the Skerries Tidal Stream Array. The high capital costs prompted the Government to review the commercial viability of the Tidal Lagoon (Swansea Bay). Although the Hendry Review (2016) found the proposals viable, in the context of falling capital costs of offshore wind, the UK Government has since considered that the project is too expensive (Vaughan & Morris, 2018). At Skerries, although all the consents were in place and a grid connection agreed, the developers pulled out in 2015, citing continued financial uncertainty (Tethys, 2020).

The licencing and consenting process compounds the financial uncertainty associated with project development. The time and costs associated with the consenting process itself add to the capital expenditure and payback period. In addition, the risk of applications being refused, with the associated investment being lost, causes additional financial uncertainty. Issues with the consenting and licencing of marine energy developments are not limited to the UK. In Europe, there are a broad range of procedural arrangements for incorporating environmental impact assessment (EIA) and consultation with stakeholders (Simas *et al*, 2015). There are different accounts of the causes of these procedural problems, including the complexity and uncertainty of environmental and societal impacts associated with the use of a variety of novel technologies, as well as diverse and competing stakeholder interests, which are discussed next.

Potential environmental impacts

The protracted nature of consenting and licencing of tidal energy schemes reflects the complexity of the marine and estuarine environment. Lack of data on the environmental

impact of tidal schemes confounds consenting and licencing processes (Quero García *et al*, 2019). Tidal energy schemes deploy turbines underwater in a tidal area to capture energy from passing tidal water. Collisions of fish and marine mammals with underwater turbines during the operation of tidal energy schemes represent obvious risks and impacts on populations of marine fauna. However, the environmental impacts of tidal energy largely depend on the technology used. Tidal technologies are generally distinguished into tidal range, tidal stream, and hybrid devices (Kempener & Neumann, 2014).

Tidal range devices generate energy by holding tide water back behind a wall structure to build up a 'head' (water height difference) before releasing the water through turbines. Tidal stream devices are horizontal or vertical axis turbines fixed in the tidal range, harvesting energy from the tide as it passes. The key difference is that tidal stream technologies do not hold the water back to create a 'head'. Hybrid technologies are where turbines are deployed as part of other infrastructure, e.g. a bridge. The extent to which the different types of tidal technologies connect to the seabed and affect the tidal regime during construction and operation, varies. Consequently, the environmental impacts are diverse.

The adverse environmental impacts associated with tidal range devices (barrages and lagoons) are well known. The construction of the walls of barrages and their footprint while operational affect the seabed, adversely impacting benthic species (Hooper & Austin, 2013). While operational, the process of holding tide water back results in the loss of intertidal area and associated habitats behind the wall, with significant adverse consequences for birds and marine fauna (Wolf *et al*, 2009). The severity of potential adverse environmental impacts of tidal barrages are illustrated by an existing tidal barrage at La Rance, France. Construction of the barrage at La Rance required the estuary to be closed to tide water for 3 years resulting in the eradication of *marine flora and fauna* (Retiere, 1994). Operation of the barrage raised the low tide level of the water behind the wall reducing the intertidal area by approximately 33% (Kirby & Retiere, 2009). However, tidal range devices also have the potential to deliver environmental benefits, such as flood defence and improved water quality. Studies have reported that the changes in sedimentation in the La Rance estuary, caused by the barrage changing the tidal regime, have increased the value of the remaining intertidal area, increasing the carrying capacity and biodiversity of the area (Kirby & Retiere, 2009). Assessing

the positive and negative environmental impacts over time complicates consenting and licencing decision-making.

Tidal stream technologies have smaller footprints on the seabed and represent different environmental impacts. Changes in sedimentary processes in the vicinity of tidal stream turbines affect marine biodiversity (Robins *et al*, 2014). Additionally, as well as fish and marine mammals, diving birds are also at risk of collision with the turbines during operation. The environmental impacts of tidal stream technology are illustrated by the Skerries Tidal Stream Array project (Tehys, 2020): shoreline erosion or accretion and the effect on nearby designated sites, including Hen Borth SSSI; operational noise disturbing marine mammals; collision between marine mammals and devices; displacement of fishing activities during operation; seascape impact; and collision between sea vessels and devices. This highlights the potential for complex social, as well as environmental impacts. For example, the Marine Licence issued for the Skerries Tidal Stream Array (MMO, 2020) identifies potential impacts to commercial fisheries, archaeology; cultural heritage; shipping and navigation; seascape, landscape and visual impacts; tourism, marine recreation and amenity; and the socio-economic environment.

As shown in Tables 1.1 and 1.2, all the consented tidal energy marine licences in the UK are for tidal stream devices. This reflects fewer potential impacts associated with the smaller physical presence of tidal stream devices compared to tidal range technology, as discussed above. This situation is not unique to the UK. Across the world, tidal stream technology is currently more popular, but as the scale of the installations are smaller, they have less generation capacity than tidal range installations which produce significantly more energy (Fairley *et al*, 2014).

To harness the potential of more renewable energy from tidal range installations there has been much research into the potential impacts (Fairley *et al*, 2014; and Ahmadian *et al*, 2010). However, site specific conditions and the range of technologies available create complex and wide ranging environmental and social impacts for each proposal, compounding the complexity of the consenting and licencing processes (Hooper & Austen, 2013).

Stakeholder engagement and public consultation

The complexity of the marine environment and the gravity of potential adverse impacts makes environmental assessment difficult. Site-specific issues introduce a distinct range of interested parties and members of the public and local communities. This means that a diverse and unique range of stakeholders are consulted as part of the licencing and consenting process for each tidal energy proposal.

Participation is integral to democratic decision-making. Democratically, citizens have the right to be involved in decisions and policy making (Bingham *et al*, 2005). Like other environmental and planning decision-making processes, the consenting and licencing processes for marine renewables exemplify the shift towards PEDM and attempts to operationalise ideas of participatory democracy. The current regulatory regime for consenting and licencing of marine renewable energy developments prescribes stakeholder and public engagement. For marine renewables, current procedures involve statutory and non-statutory consultees. These vary in each devolved administration, but generally equivalent organisations are consulted. According to the Scottish Government, statutory consultees include: the relevant planning authority/ies, NatureScot (formally Scottish Natural Heritage), Scottish Environment Protection Agency (SEPA), Historic Environment Scotland, any relevant local authority (as defined in the Marine Works (Environmental Impact Assessment) Regulations 2017), the Commissioners of Northern Lighthouses and the Maritime and Coastguard Agency (Marine Scotland, 2018). The list of consultees in other devolved nations is similar, and includes the equivalent bodies, such as Natural England / Natural Resources Wales, Environment Agency, and Historic England / Historic Wales.

Non statutory consultees cover a range of activities and organisations, including: fisheries, e.g. Fisheries Management, Inshore Fishery Groups, Inshore Fisheries and Conservation Authorities and Fishermen's Federations and Organisations (e.g. the Scottish Fishermen's Organisation); infrastructure, e.g. BT (Radio Network Protection Team), Civil Aviation Authority, The Crown Estate Scotland, Defence Infrastructure Organisation (Ministry of Defence), port and transport authorities, UK Chamber of Shipping; Safety, e.g. Marine Safety Forum, Health and Safety Executive; conservation, e.g. Royal Society for the Protection of Birds, the Wildlife Trusts, Harbours, Whale and Dolphin Conservation; and recreation, e.g.

Royal Yachting Association, Canoe Association, surfing and sports bodies (e.g. Surfers Against Sewage), and tourism bodies (e.g. Visit Scotland).

Considering the diverse range of issues for marine renewable energy developments, many stakeholders have opposing views. The combination of complex and contentious environmental impacts, such as visual impact, and competing stakeholder interests, such as use of shared sea space creates conflict. This is often compounded by pre-existing hostility and mistrust between stakeholders (Gray *et al*, 2005). The result is low public confidence and delays in the licencing and consenting process (Simas *et al,* 2015).

Such stalemate characterises the process of stakeholder participation generally (Carson, 2009). Opposing views on complex issues, based on uncertainty and missing data, are compounded by procedures limited to confirmatory consultations on pre-made decisions that disempower participants. Inadequate participatory procedures create a cycle of conflict that hampers the progress of decision-making and frustrate stakeholders. The cycle continues with further delays, derailment, and spiralling costs, which disillusions and frustrates practitioners and stakeholders alike (Reed, 2008). Although in general the public support marine renewable energy (Bailey *et al*, 2011; and DECC, 2013), specific proposals generate strong public and stakeholder opposition (Bell *et al*, 2005). For example, see Pontardawe and Swansea Angling Society's objection to the Swansea Tidal Lagoon (2017). Consequently, it is widely accepted that the participatory processes should be improved (Alexander *et al*, 2012; and Trainor, 2006).

There are various explanations for the causes and consequences of inadequate and unsatisfactory PEDM in practice. The shortcomings of PEDM in practice are well documented in the context of renewables such as onshore wind farms (Armeni, 2016; Bell *et al*, 2005; Hindmarsh & Matthews, 2008; Rydin *et al*, 2015), as well as the siting of land-based industrial projects (Hunold & Young, 1998), agriculture practices (Pretty, 1995), contaminated land (Carson, 2009), and conservation (Lauber, 1999). Despite the breadth of literature, the shortcomings of PEDM in practice persist. In 2006, a judicial review found that the UK Government's consultation on Nuclear Power was *procedurally flawed* (Vaughan, 2007). A report for the Nuclear Consultation Working Group (Dorfman, 2008) stated that:

"the 2006 consultation had failed. It was ill-conceived, carried out over too short a timescale, and did not involve the public in any meaningful way. Although the government had promised 'the fullest public consultation', what it offered was a tick-box exercise that provided limited useful information, and did not allow for full and frank disclosure of all the important issues…"

This short quotation neatly encapsulates several flaws in the process; consultees were disempowered by inadequate design, time frame, information provision and transparency. Similar flaws have been made of more recent exercises in PEDM, such as the UK Government's 2013 consultation on Marine Conservation Zones (Pieraccini, 2013). The perception that consultation represents a meaningless tick-box exercise is common (newDemocracy Foundation, 2018; Dorfman, 2008; and Pieraccini, 2015). Scholars link this to the sense that participation processes are hollow (Lee *et al*, 2013), *empty and superficial* (Arnstein, 1969, p. 216). This unsatisfactory situation is especially evident for contested topics such as renewable energy developments, where fixed processes limit the breadth of stakeholder views and do not capture *what matters most* to them (Roberts & Escobar, 2015, p. 194). The result is that people feel excluded and ignored (Haggett, 2008). For example, the aforementioned Government consultation on Marine Conservation Zones was deemed to have *ignored* [contributions] (Pieraccini, 2013).

Conventionally, PEDM focuses on technical assessments (risk assessments of potential impacts by scientific advisors and officials on behalf of the public), side-lining democratic values (Fiorino, 1990). The technical aspects therefore receive primary investment and attention, relegating participation to a necessary add-on. The result is that participation is often framed as a *bureaucratic hurdle* (Pieraccini, 2015, p. 33) to be overcome rather than an opportunity for meaningful engagement (Rydin *et al*, 2015). The persistence of prioritising technical assessment over meaningful participation encourages commissioning bodies to adopt models of PEDM that *validate decisions already made*, which are perceived as easier and cheaper than investing in meaningful *deliberative, consensus-based public dialogue* (Armeni, 2016, p. 416). However, participation where decisions have already been made *fuels greater distrust and disillusionment* (Chwalisz, 2017, p. 78)

The prioritisation of technical assessment over meaningful engagement creates a distinction between what is viewed as 'expert' and 'non-expert', 'public' or 'local' knowledge. The moral and political dimensions of decisions on potentially contentious proposals require more than expertise (Roberts *et al*, 2020). Where there is scientific uncertainty and conflicting evidence, lay knowledge and public scrutiny is required to ascertain values and evaluate evidence to legitimatize those decisions (Roberts *et al*, 2020). Although studies have demonstrated that given resources and support, the public are competent and capable in complex decision-making processes, adding knowledge and moral perspectives (Brown, 2006; Roberts & Escobar, 2015), in practice, some decision-makers still doubt the capacity of the public (compared to experts) to make meaningful contributions on complex topics (Brown, 2006; Gerwin, 2018). Theorists and practitioners therefore focus on the potential adverse impact of non-expert contributions to the quality of decision-making; this is discussed further in chapter 2.

There are well-established arguments for the inclusion of lay knowledge in environmental decision-making (Rowe & Frewer, 2000). In his classic study Wynne (1996) argued for the value of including lay knowledge and against the dominance of *objective expert knowledge*, which erodes trust and alienates the public. The practical consequences of inadequate public engagement are evident in proposals for marine renewables. For example, proposals for an offshore wind farm in the Netherlands were consented, but the project was later halted by public opposition because public views of the landscape impacts were not considered adequately during a *highly technocratic, top-down decision*[-making] process (Wolsink, 2010, p. 195). Recognising the practical challenges of public opposition (including delays and increased costs), Wynne argues that the inclusion of lay knowledge is critical to addressing issues of low public trust and alienation of the public (2007, p. 101). The necessity and benefits of including lay knowledge is recognised beyond environmental decision-making. For example, Entwhistle *et al* (1998) notes that including lay perspectives improves the quality and impact of health research.

However, implementing the benefits of including lay knowledge in decision-making is difficult. In practice, a shift towards participation in decision-making is often translated into a blanket

requirement for public consultation, which does not ensure effective engagement. For example, the application of a marine licence (from Natural Resources Wales) for the proposed tidal lagoon at Swansea Bay (Tidal Lagoon Power, 2019a) has included: 24 public events attended by over 1,400 people; a survey; 63 project update presentations; community surgeries; and education workshops. This sounds impressive; however, merely providing the opportunities for a high number of voices to be included in a public consultation does not automatically provide the conditions for meaningful contributions to be heard and incorporated into the decision-making process (newDemocracy Foundation, 2018).

There has also been increasing concern about who carries the burden of participation, related to who pays the price (in time, resources, and risk) for participating (Bromley *et al*, 2015), resulting in unequal access and distribution of information, increasing existing power disparities. Procedures that compensate and provide for access to information are required, as well as allowing for knowledge to change with time as fresh information becomes available (Benn *et al*, 2009). As a result of the burden of participation, self-selection bias is a common issue. Consultations and public events are often populated by people who are already politically engaged and have the time and resources to participate (Roberts & Escobar, 2015; Lezaun & Soneryd, 2007). Self-selection bias threatens the legitimacy of PEDM because citizens outside those self-selecting cannot recognise *people like me* were involved in the process (newDemocracy Foundation, 2018, p. 50). Reduced legitimacy in decision making processes, as well as consultation fatigue, cultivates disillusionment among stakeholders. For renewable energy developments, this increases the potential for conflict, and leads to protracted and unsatisfactory decision making (Haggett, 2011).

In this section, I have set out the research context, summarising existing and proposed UK tidal energy schemes. I have shown that despite the modified licencing and consenting process, there is evidence of delays. Considering the complexity and diversity of potential environmental and social impacts, I have shown that there is potential for, and evidence of, conflict between stakeholders that perpetuates delays and rising costs. The current licencing and consenting process for marine renewables prescribes consultation of experts and the public but to address the practical challenges identified, participatory processes need to be improved.

1.2 Bayesian Belief Networks (BBNs)

As previously discussed, improving the consenting and licencing process for tidal energy schemes needs to balance credible assessment of the potential environmental and social impacts with meaningful participation. There are various views on how to achieve this. One suggestion is the use of better decision-making tools (Hooper & Austen, 2013). One such decision-making tool is a Bayesian Belief Network (BBN).

This section starts by explaining what Bayesian Belief Networks (BBNs) are and how they are used as a decision-making tool. Conventional methods of eliciting participant knowledge for use in BBNs, a process known as belief elicitation, are summarised. The features of BBNs that could improve PEDM are identified, which links to the explanation of how improved PEDM will be measured, set out in Chapter 2.

Environmental and resource managers and decision makers need models to help them understand the effectiveness of alternative management decisions (Barton *et al*, 2012). However, conventional decision-making tools struggle to deal with the complexity and uncertainty of the natural world, social impacts, and the need to incorporate and reconcile stakeholder views (Elsawah *et al*, 2015). It is this combination of uncertainty, complexity and participatory decision-making that leads to the novel proposal developed in this study. Unlike conventional modelling, advanced systems models such as BBNs model non-linear, complex relationships and combine conditional probabilities, to address different, and conflicting interests. The capacity of BBNs to model complexity and uncertainty represents the opportunity to deliver a better outcome (decision) based on more accurate modelling. As well as the potential to improve the accuracy of decision-making, BBNs have the capacity to incorporate and combine qualitative and quantitative data, including participant knowledge (beliefs) elicited from a sample of stakeholders (Johnson *et al*, 2010b).

BBNs are widely used in the military and medicine (Stewart *et al*, 2014) and are being increasingly used in ecological and environmental management (Uusitalo, 2007; and Aguilera *et al*, 2011). Previous studies have used BBNs to model land use and watersheds (Barton *et*

al, 2012), as well as the distribution, management and conservation of species such as tigers (Bolam, 2018), wallabies (Low Choy *et al*, 2010), and salmon (Uusitalo *et al*, 2007).

Conventional use of BBNs is technocratic and top-down, characteristic of PEDM. Previous studies of belief (participant knowledge) elicitation focus on developing methods to improve the quality of the data collected (Johnson *et al*, 2010b), as opposed to democratic values. The novelty of this study is that it uses BBNs with a focus on participatory process and values. The objective is to assess the potential for the use of BBNs to address the causes and consequences of flawed PEDM, discussed in the previous section.

BBNs are a type of graphical statistical model, known as directed acyclic graphs (DAGs). BBNs comprise a network of nodes, which represent variables, linked by arcs that represent conditional dependencies, between the variables (Liao *et al*, 2017). BBNs model the combined likelihood of events (joint probability distributions), which are represented in the modelling by numbers.

The Bayesian approach to scientific reasoning is based on probabilistic induction and the concept of degree of belief. 'Degrees of belief' describe attitudes towards uncertainty (Howson & Urbach, 2006) that are represented as probabilities. Consequently, in BBNs the numerical parameters (joint probability distributions) represent belief and are regarded as expressions of subjective uncertainty (Sprenger & Hartmann, 2019; Stewart *et al*, 2014). Crucially, the Bayesian approach allows for degrees of belief to change in the light of new evidence. The concept of conditional degrees of belief enables the evaluation of the plausibility of a proposition in the light of another proposition (Sprenger & Hartmann, 2019, p. 16).

In the example shown in Figure 1.1 from Campbell *et al* (2012), the probability of a car starting is dependent on having fuel in the tank and clean spark plugs. The dependence is represented by the arrows (arcs) linking the nodes (the blue boxes).

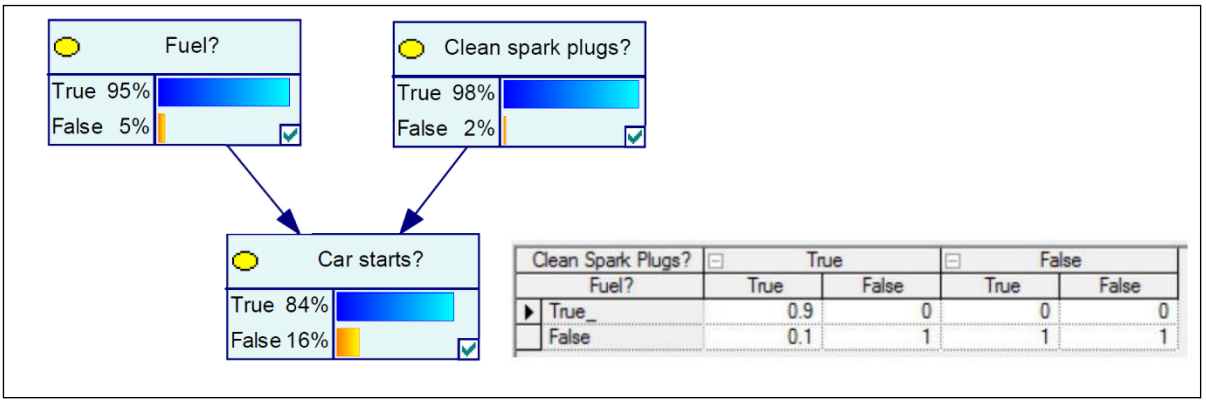

Figure 1.1 Example BBN and underlying conditional probability table (Campbell *et al*, 2012)

In the BBN structure shown in Figure 1.1, the 'car starts?' node would be described as a 'child node' because it depends on the 'fuel' and 'clean spark plugs' nodes, which are describes as parent nodes. Probabilities of events are represented as bars and numbers inside the nodes, categorised in 'states'. For simplicity, in Figure 1.1, the 'states' in each node are labelled 'true' and 'false' to represent the probability of each event occurring or not, respectively. BBNs allow the nodes and states to be labelled by the user and any number of states can be allocated.

BBNs are underpinned by conditional probability tables (CPTs). In Figure 1.1 the conditional probability table shows that there is a 90% chance the car will start if the spark plugs are clean and there is fuel in it. If either the spark plugs are not clean and / or there is no fuel, there is a 0% chance the car will start. It sounds like it would be quite simple to calculate the likelihood the car will start, considering that simple relationship. However, when the probabilities of the 'fuel' or 'clean spark plugs' nodes are not 0% or 100%, calculating the conditional probability of the car starting is difficult. The advantage of BBNs is that they demonstrate this visually and it is possible to work interactively with the model to update the evidence when new knowledge becomes available. For example, if the driver learns that their son took the car for a drive the day before and did not refuel it, they can reduce the probability of fuel being present and the child node (probability of the car starting) will be recalculated. Figure 1.2 shows the effect of reducing the chance of fuel being present ('true') to 60%.

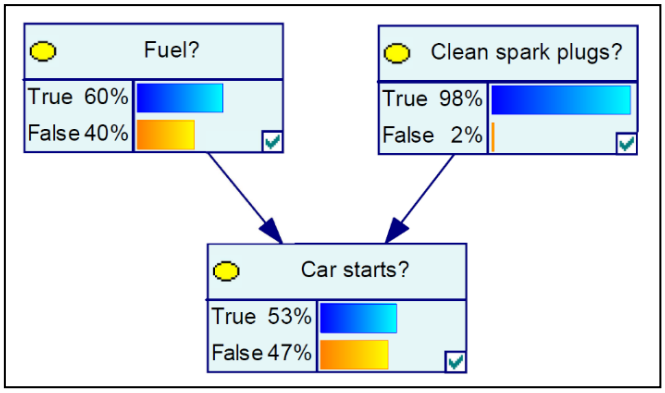

Figure 1.2 Recalculated BBN based on reducing the probability of there being fuel in the car to 60%.

The CPT also allows the modeller to account for relative weights of influence between nodes. In Figure 1.1, the presence of fuel and having clean spark plugs have equal influence; the CPT shows that the likelihood of the car starting is only increased if both the fuel is present and spark plugs are clean, and the likelihood is the same (0) if one or both are absent. However, often the influence of parent nodes is different, which is illustrated later, in the results chapter (Chapter 4).

The structure and numerical parameters of BBNs are constructed from knowledge elicited from participants, usually experts. Other types of Bayesian Networks (BNs) are constructed using a combination of both elicited knowledge and a learning algorithm or using a network structure learning algorithm (Liao *et al,* 2017; and Stewart *et al*, 2014). The capacity of BBNs to incorporate elicited knowledge from participants enables BBNs to facilitate participatory processes such as the licencing and consenting process for marine renewables and PEDM generally.

Methods of Belief Elicitation

BBNs are used to model expert beliefs on interventions. For example, in medicine BBNs can model the effect of medicines on patient outcomes. Understandably, the focus of such applications is technical, and outcome orientated; users are concerned with extracting data from stakeholders that benefits (improves the accuracy of) the model. Consequently, there is a breadth of literature that focuses on developing methods of belief elicitation that improve the validity and reliability of the elicited data (Johnson *et al*, 2010b).

A review of previous studies reveals that belief elicitation for BBN modelling generally comprises a single request for data from a limited range of experts (Carrick, 2016). Typically, belief elicitation is undertaken remotely, e.g. by email or internet-based survey tool. Once the data are provided there is usually no further contact, other than possibly a feedback form asking participants to 'rate' the survey experience. Usually there are no opportunities to review the model and reflect on the contributions (Carrick, 2016).

As described above, elicited beliefs are subjective, therefore bias in elicited data is considered a significant risk to data quality, along with the expertise of participants, and their capacity to understand or learn how to assess probability (Renooij, 2001). While acknowledging its instrumental value, the subjectivity of beliefs and perceptions is considered a *threat* or *handicap* to be overcome (Parmar *et al*, 2001; Johnson *et al*., 2010b). To reduce the potential negative consequences (on statistical significance) of incorporating beliefs, previous studies seek to limit the potential influence of subjectivity, via predetermined protocols and structured elicitation. Consequently, beliefs are generally elicited via closed questions so that the responses can be easily incorporated into the model; examples are shown in Figure 1.3. This damage limitation approach excludes or minimises subjective data, prioritising validity, and accuracy.

BBNs are increasingly used in environmental management and decision-making due to their capacity to: integrate quantitative and qualitative data; manage uncertainty; produce visual representations; and run diagnostic and predictive models (Johnson *et al*, 2016; Barton *et al*, 2012; and Johnson *et al*, 2010a). However, collecting and using expert data is considered a challenge. Uusitalo explains that researchers find that it can be *difficult to get the knowledge out of the experts in a form that can be converted into probability distributions* (2007, p. 315). This indicates that like medical researchers, environmental modellers tend to focus on the accuracy of elicited data, and that the instrumental value of participant knowledge to decision-makers eclipses the intrinsic value of democratic participation and the experience of participants.

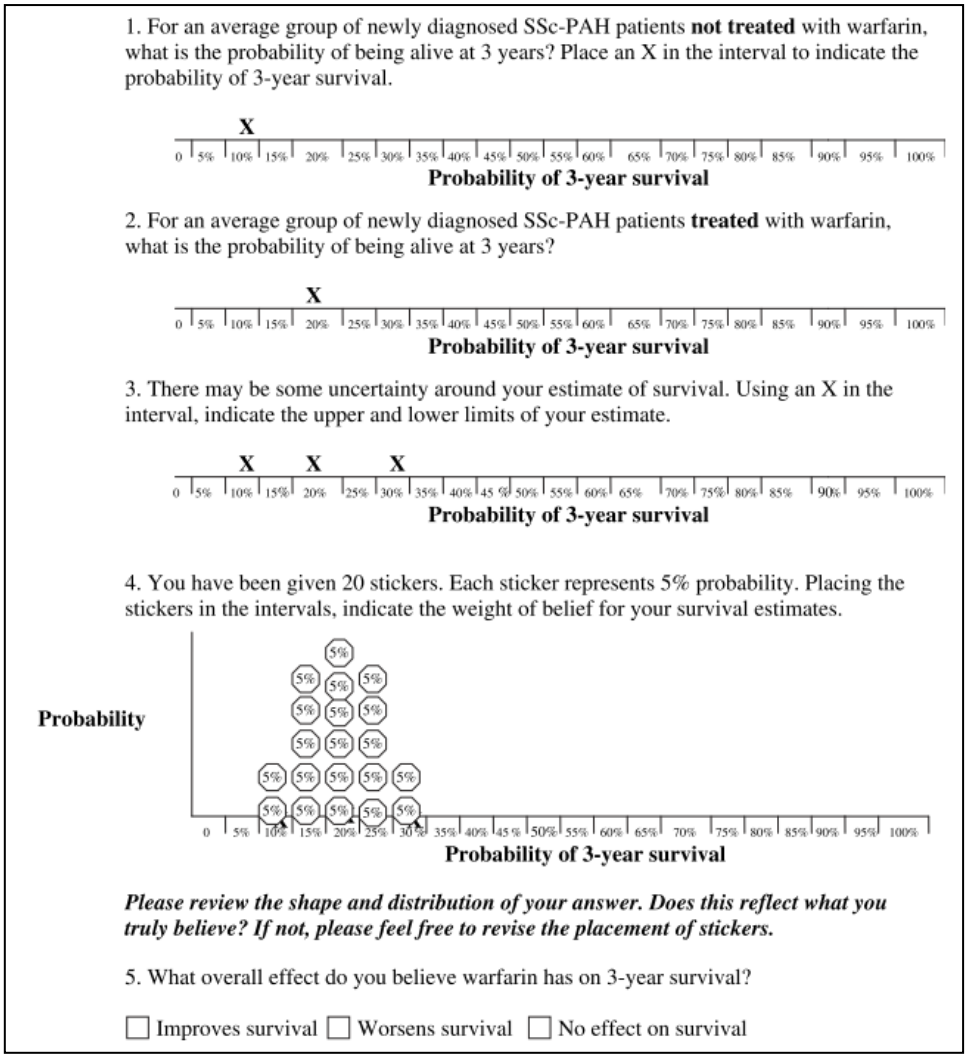

Figure 1.3 Example closed questions for belief elicitation from Johnson *et al* (2010b)

However, there are some examples of studies in environmental decision-making that have built BBNs collaboratively with a range of experts. For example, an interdisciplinary team of experts built a BBN as a marine governance and policy tool (Campbell *et al*, 2012). In this case a BBN was built iteratively in several stages of engagement. Reflecting on its participatory approach, Campbell *et al*, (2012) found that participants from some disciplines struggled more than others to understand the model, particularly the way they were asked to value its components. This was made difficult due to different ways concepts were interpreted and language used between the disciplines. Although the understanding of the model did improve as it was built, participants felt that disciplines were unequally represented in the BBN, specifically those from planning felt that they had 'conceded' to the use of the BBN modelling to appease other participants (Campbell *et al*, 2012, p. 20). Carrick (2016) supports these

findings, reporting that participants of BBN modelling report that BBNs were perceived as a 'black box' or a 'mystery' and that the process of entering the data was difficult to engage with. This indicates that contributors to BBN modelling often struggle to understand the models, which generate feelings of mistrust. Using BBNs in a participatory environment, particularly for the uninitiated, can therefore be frustrating. This supports the need for a refocus on democratic values and participants, identified by this study.

Features of BBNs

The specific features of BBNs that offer the potential to improve PEDM, and which will be tested in this study, are their ability to: produce visual representations; incorporate quantitative and qualitative data; and be updated.

Visual representations display elements of the model (Johnson *et al*, 2016) as networks of nodes that are easily understood (Stewart *et al*, 2014). As graphical models, BBNs are recognised as powerful and effective communication and knowledge representation tools (Campbell *et al*, 2012). Visually presenting variables and their relationships helps stakeholders visualise the impacts of multiple uncertainties in a complex process (Chen & Pollino, 2012; and Marcot & Penman, 2019)**.**

Superficial, empty, and frustrating stakeholder engagement characteristic of top-down decision-making contributes to consultation fatigue and political apathy, which threatens the legitimacy of participatory decision-making (Involve, 2005). Visualisations of BBNs can be used to enable participants to see and understand how their individual views have been included and how they relate to others. The aim is for stakeholders to feel valued by seeing their views included and working in the model.

Visualising data in the network helps participants appreciate the wider context, and interaction with software allows participants to test how changes affect the system, encouraging learning and reflection on their original positions (Barton *et al*, 2012). Interacting with BBN modelling software to explore how the system works and changes, encourages collaborative working, offering the opportunity for improved relationships between stakeholders at SEG ahead of the formal consenting process.

BBNs can incorporate empirical and subjective (belief) data, so that information from a range of sources can be incorporated (Chen & Pollino, 2012), including stakeholder knowledge (belief elicitation) (Johnson *et al*, 2016). Complex empirical quantitative data can be used to generate increasingly accurate models, and accuracy contributes to stakeholder satisfaction. However, considering that decision-making is influenced by differing perceptions of risk, if decision-making fails to account for how people feel, the decisions themselves are not readily accepted or effectively implemented. It is therefore a significant benefit of BBNs that as well as incorporating complex quantitative data, they can also incorporate qualitative data representing stakeholder preferences. Given the broad range of stakeholder interests in the licencing and consenting process for marine renewables, which cannot be reduced to numbers, the capacity of BBNs to incorporate qualitative data contributes to improved stakeholder satisfaction (Campbell *et al*, 2012; Renooij, 2001).

BBNs can be easily updated (Chen & Pollino, 2012) so that prior beliefs can be revised as more information becomes available (Johnson *et al*, 2016). By updating the models to demonstrate different scenarios**,** the distribution, and effects of 'belief' on decision networks (Chen & Pollino, 2012) can be tested, evaluated, and updated with stakeholders. Stakeholders can reflect on their views, or 'update' their 'prior beliefs' by exploring the development of the BBN. The ability to easily update BBNs facilitates and encourages learning and deliberation for prediction, diagnosis, and sensitivity analysis; assessing how sensitive specific nodes are to changes elsewhere in the model. For example, Stewart *et al* (2014) used Bayesian Network to model the relationship between smoking and mortality in people with schizophrenia, using quantitative and qualitative data. Sensitivity analyses were undertaken adjusting the model in different ways to assess the impact on the mortality rate, including adjusting the probability of people smoking and the impact of other factors on the probability of smoking, such as peoples' socio-economic group. The capacity for BBNs to be updated therefore provides stakeholders and decision-makers with opportunities to reflect and appreciate alternative views. This provides opportunities for learning and to reduce conflict between stakeholders, that could be harnessed in PEDM (Low-Choy *et al*, 2009).

1.3 Trying BBNs in Participatory Environmental Decision-Making (PEDM): The Solway Energy Gateway Case Study

To explore how BBNs could be used to improve PEDM, this study tests their use in the case of a proposed tidal energy scheme in the Solway Firth. The use of a single exploratory case study and selection of the proposed Solway Energy Gateway (SEG) as that case study, is explained and justified in this section.

The novel approach to using BBNs in PEDM employed in this study, the existing formal consenting processes, and the ethical and practical (e.g., money, people, and time) limitations of a PhD study set some significant constraints. Single case study research is practical and achievable within these constraints. In this study, a case study provides an opportunity to demonstrate use of BBNs to satisfy theoretical ideals for PEDM.

As previously discussed, the consenting and licencing processes for tidal energy schemes embody many of the challenges for PEDM. As a proposed tidal energy scheme, SEG was selected as a single case study to explore these challenges and address the research questions due to a combination of practical features (locality and stage of development) and complex site-specific features. Practically, the Solway Firth is relatively local for me, facilitating an extended study period. The proposed SEG scheme has yet to be formally submitted into the licencing and consenting process, which reduced the risk of the research adversely affecting a live and commercially sensitive application. Conducting the research before any formal application also increases the potential for the findings, specifically ways to improve PEDM, to influence a future application.

The site-specific features of SEG embody many of the key characteristics of PEDM that BBNs might be able to help address, particularly uncertainty and complexity of environmental and social impacts and potential stakeholder conflicts. The proposed location and design of SEG, as well as a combination of major social and environmental issues, create a uniquely complex case study. The extreme dimensions (described below) provide a difficult test case (George & Bennett, 2005) to explore the challenges of PEDM and test the use of BBNs to address these challenges.

Location

A series of tidal energy installations on the UK's west coast could produce at least 10% of present UK electricity demand (Burrows *et al*, 2009). Due to its large tidal range the potential of tidal energy on the Solway Firth has been explored since the 1960s (Aggidis & Feather, 2012; Becker *et al*, 2017; Burrows *et al*, 2009 and 2008). Consequently, as well as SEG, there are several historical and contemporary proposed tidal energy schemes in the Solway Firth. Others include: a 20mile tidal barrier crossing the Solway Firth from Dumfries and Galloway to the west coast of Cumbria (BBC, 2015); a coastal tidal lagoon on the southern coast of the Solway Firth, north of Workington (Tidal Lagoon Power, 2019b); and two offshore tidal lagoons (Ecotricity, 2018).

The complex range of social and environmental issues in and around the Solway Firth make it an interesting case, suitable for single case study research. On the border between England and Scotland and home to several environmentally designated sites, the Solway Firth presents a series of extremely sensitive and complex environmental and social features. Numerous environmentally sensitive sites in the Solway Firth are protected by local, national, and international regulations. The Solway Firth is located on the border between two different regulatory regimes and cultural contexts. Social and environmental impact assessments, required as part of a consenting process, are therefore extremely complex.

The border between England and Scotland runs down the centre of the Solway Firth. SEG proposes to cross the Solway Firth and the border between England and Scotland, 'landing' on the north shore in Scotland, near the town of Annan, and on the south shore in England, near the village of Bowness-on-Solway. The proposed scheme therefore 'lands' in different marine and terrestrial regulatory regimes. As illustrated in Figure 1.4, the north shore (Scotland) and south shore (England), fall in the jurisdiction of Marine Scotland and the MMO, respectively, that comprise different but largely equivalent institutions, processes, and regulations. The added complication associated with the site straddling two regulatory regimes adds to the complexity of SEG and the justification of its use as an exploratory case study.

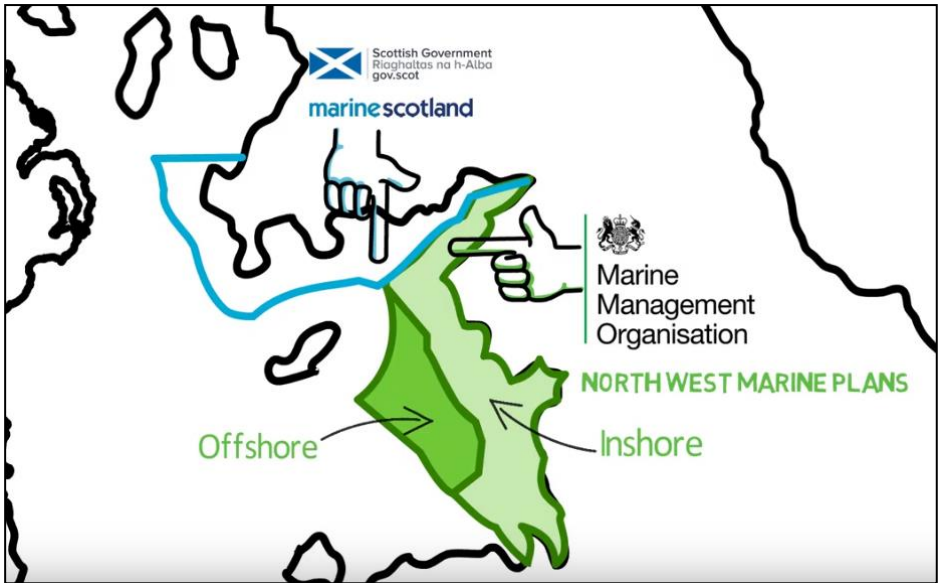

Figure 1.4 Marine planning areas on the Solway Firth, split between Marine Scotland on the north side, and the Marine Management Organisation on the south side (Solway Firth Partnerships, 2019).

The proposed scheme also 'lands' in two culturally, socially and economically distinct communities on either side of the Solway Firth. Although there is only approximately 2.2km (1.4miles) of tidal estuarine waters between the north and south shores of the Solway Firth at SEG's proposed location, the journey by road between Bowness-on-Solway and Annan is approximately 47km (30miles) as there is no bridge crossing. As well as being physically separate, there are also significant local historical and cultural differences between the Scottish and English communities at either end of the proposed scheme. The differences are discussed in more detail later (see section 3.1).

Design

The proposals for SEG include a pedestrian and cycle bridge, linking the Scottish and English coasts on either side of the Solway Firth. The proposed bridge represents the first direct link between the two coasts and communities since a railway bridge (at the same location) was destroyed in the 1920s. The developers envisage that the bridge will reconnect the communities and improve tourism by linking existing cycle trails and tourist attractions such as the end of Hadrian's Wall near Bowness-on-Solway (Solway Energy Gateway, 2011). The inclusion of the proposal for a bridge introduces additional social impacts, adding to the complexity of this case study.

SEG is proposed at the site of a former railway bridge that crossed the Solway Firth. The former railway was part of a wider freight rail network associated with the former steel and coal industries of Scotland and northwest England. The proposed length of SEG is approximately 2km, making it much smaller in scale than other proposals. This reduces capital costs and the development's physical footprint, potentially reducing its impacts. SEG proposes a series of underwater turbines to capture tidal energy as it comes in and reseeds between Bowness-on-Solway in Cumbria and Annan in Dumfries and Galloway. The proposed scheme is a type of tidal range technology with a special type of turbine, known as *Venturi Enhanced Turbine Technology (VETT)*, which, in contrast to conventional barrage technology, *does not need to impound water to create a substantial "head" drop to power the turbines* (Solway Energy Gateway, 2011). Instead the VETT uses *the venturi principles to achieve a pressure amplification* (VerdErg, 2018). Water passes through reduced diameter ducts, to increase the flow rate; *the accelerated water can either drive a turbine directly or produce a pressure difference which is used to drive a remote turbine* (Halcrow Group Ltd *et al*, 2009). In principle, the pressure difference created by the VETT technology accelerates the water through the turbines without the need to hold water back. By using the VETT technology, Solway Energy Gateway (2011) claims the proposed development would reduce the environmental impacts associated with impounding water (associated with other tidal range technologies such as barrages), which affects the quantity and quality of intertidal areas.

SEG was proposed over 10years ago and has yet to reach the formal application process. The developers hoped to begin the assessment process in 2015 with a scoping study and feasibility study, followed by public consultation and environmental assessment, which they hoped to complete by mid-2016 (Solway Energy Gateway, 2011). The vision was to secure the necessary funding, permits and consents so that construction of the scheme could start in 2018.

Since 2008, regular stakeholder meetings and workshops have been held to discuss SEG, including public meetings hosted by local parish councils. Over the same time, laboratory testing of the impacts on the proposed technology on fish were undertaken by the technology provider (de Brujin *et al*, 2013) and feasibility reports have been produced (Halcrow Group Ltd *et al*, 2009). However, despite the preparatory work over the last 10 years, insufficient

financial support for SEG has been raised to reach the formal application stage and no proposals have been formally submitted into the consenting process. This study does not aim to assess the existing proposals for SEG. The intention is to use it as a case study for a novel approach to PEDM. However, the primary data collected, presented, and discussed in this study does highlight some of the potential failures of PEDM processes and the resulting conflict between stakeholders.

In this section, I have introduced SEG as the research case study. The uniquely complex dimensions defined by a combination of potential environmental and social impacts associated with its proposed location in the Solway Firth and its novel design provide a rich source of data and difficult case to test the use of BBNs in PEDM. The methodological approach to the case study is detailed in Chapter 3, including the novel use of BBNs.

1.4 Chapter outlines

Chapters 2 and 3 address RQ 1, explaining how improvements in PEDM will be measured. Drawing on theories of deliberative democracy, procedural environmental justice and Science and Technology Studies (STS), theoretical principles for the 'right kind' of PEDM are identified. These principles are used to measure improvement in PEDM.

The methodological approach of this study is explained and justified in Chapter 3. I explain the selection a single research case study (a proposed tidal energy scheme in the Solway Firth, SEG) to test the use of BBNs in PEDM. The data collection framework is set out, explaining how and why qualitative interview data were collected via interviews in cycles of engagement that are based on stages of action and reflection and inspired by a Participatory Action Research approach.

Chapter 4 presents the results of the primary data collection, explaining how the primary data, as stories and information, were translated and incorporated into the BBNs during each cycle of data collection and modelling. Chapter 5 reflects on the results to address RQ 2, considering how adequately BBNs represent stakeholders' views, deepen their understanding, and communicate their knowledge. In chapter 6, the capacity of the features of BBNs to improve PEDM is assessed to address RQ 3. Improvement in PEDM is measured by

considering if the features of BBNs fulfil the principles for the 'right kind' of PEDM. In the case of SEG, the application of the features of BBNs and their adherence to the principles of PEDM are assessed to determine the extent that BBNs could improve PEDM in practice.

Chapter 7 addresses RQ 4, explaining what the results say about how BBNs could be incorporated into PEDM to improve the MREI consenting process and PEDM generally. Areas for further research are also identified. Finally, chapter 8 summarises the results in response to each of the research questions and the contribution this study makes to the literature.

Chapter 2. Principles and Practical Criteria for Effective Participatory Environmental Decision-Making (PEDM)

Participation is central to democratic process. Meaningful and legitimate political engagement can improve decision making with provision of new knowledge and serve to politically validate decision-making by demonstrating that public opinion has been considered. In this chapter I explore the paradox of participation: ideally and theoretically, the intrinsic democratic right to participate improves decision-making; however, as set out in chapter 1, participation in practice is complicated, often ineffective and can be counter-productive. Unsatisfactory participatory procedures can adversely affect political engagement and the supply of willing participants, while encouraging political apathy.

This chapter critically reviews some of the existing theoretical participatory ideals in the context of their practical implementation in PEDM. The purpose is to address RQ 1: how can improvements in PEDM will be measured? I draw on theories of procedural environmental justice (PEJ), deliberative democracy (DD) and insights from Science and Technology Studies (STS) to provide a new perspective on the effectiveness and achievability of ideal standards of PEDM. Previous discussions of PEDM (informed by STS, PEJ and DD) are synthesised into a set of practical criteria for evaluating PEDM processes. The results provide a framework to measure improvements in participatory environmental decision-making (PEDM), which are used in subsequent chapters of this exploratory case study.

First, some background is provided on existing participatory ideals to illustrate the limits of their achievability and effectiveness and the need for this review. Second, I review existing theoretical ideals central to PEDM. Drawing on an understanding of knowledge as being inherently incomplete and dynamic, informed by STS, and theories of PEJ and DD, I discuss the commitments and values that underpin achievable and effective PEDM. To begin to address the gap between theory and practice, I organise the theoretical ideals into four principles (inclusivity, process orientation, empowerment, and reflection) and associated sub-principles. Third, I translate the principles and sub-principles to practical criteria for their implementation and a new framework for PEDM emerges. The new framework (practical

criteria arranged according to four principles and their sub-principles) is compared to existing criteria for PEDM in the literature to illustrate what it brings to PEDM beyond what has been previously proposed. Fourth, the features of BBNs are mapped on to the new framework.

2.1 Background

In this section I argue that the implementation of theoretical ideals is currently hampered by both unobtainable standards and persistence of power disparities that ignores the need for fair process. This establishes that a new approach is required to address the gap between theoretical ideals and achievable implementation.

The breadth of literature on normative participation illustrates the difficulty of participation in practice. Arnstein's classic study (1969) warns of *empty and superficial* participatory processes that contribute to consultation fatigue, conflict between stakeholders and protracted decision-making. There has been increasing concern for who carries the burden of participation, related to who pays the price (in time, resources, and risk) for participating (Bromley *et al*, 2015). Some have even branded participation as a *tyranny*, associated with the misuse of power and coercion (Cooke & Kothari, 2001).

In response to the gap between the theoretical rights and benefits of participation and the shortcomings of participation in practice, many scholars have sought to define conditions for normative participation. Many studies examine the theory, method, and practice of PEDM. These include attempts to develop criteria that prescribe ideal standards for participation and implementation criteria (such as Pretty, 1995; and Rowe & Frewer, 2000). However, evidence of protracted decision-making, consultation fatigue and conflict between stakeholders set out in Chapter 1 indicates that effective and achievable implementation of theoretical ideals remains elusive.

Underpinning the failure to implement theoretical ideals of participation is a tension between achievable ideals and the need to tackle power disparities. Demand for participation has been typically driven by erosion of trust in elites, as well as the dominance of top-down technical solutions, authorities, and institutions (Palerm, 1999, p. 240). Therefore, ideally participatory

processes should seek full redistribution of power from authorities to citizens. For Arnstein (1969, p.223), the ideal standard for true redistribution of power is defined as citizen control:

"degree of power (or control) which guarantees that participants or residents can govern a program or an institution, be in full charge of policy and managerial aspects, and be able to negotiate the conditions under which "outsiders" may change them"

However, in practice full distribution of power is implausible and often undesirable, where decision-making needs coercion to drive the process towards action (Mansbridge, 1996). In addition, building on Foucault's view that power cannot be eliminated (Mansbridge *et al*, 2010; Watkins, 2010), full citizen control would not eliminate power relations.

In contrast to Arnstein's unachievable aim of eliminating power disparities, other studies propose participatory criteria that maintain power disparities, where contributions are assessed on the quality of their discourse. For example, Webler (1995) and Steenbergen *et al* (2003) propose criteria that measure the quality of the discourse and competence to participate. Webler's 'Evaluation Yardstick' (1995) draws on Habermas's focus on discourse quality, with criteria that measures competence to participate based on conative and lingual standards, access to knowledge, ability to verify claims, and the validity of claims. Steenbergen *et al* (2003) produced a discourse quality index (DQI) to assess the quality of participants' contributions. Also drawing on Habermas' principles on discourse ethics, the DQI assesses contributions on the basis of the *level of justification* given by the contributor, if they provided a statement that appeals to the *common good* and if they showed *respect* (Steenbergen *et al*, 2003). Webler and Steenbergen *et al*'s criteria are designed to enhance the instrumental value of the data extracted from participants. There is little regard here for the intrinsic value of participation from the perspective of the participant. This approach unfairly discriminates against non-experts and vulnerable groups that are least likely to have access to the right standards of competence and access to knowledge, maintaining power disparities.

In this section I have described how participatory ideals that are unachievable and/or perpetuate power disparities contribute to unsatisfactory PEDM in practice, where passive

engagement contributes to suspicion and mistrust between those with access to information and those without (Smith, 2003, p. 55). I argue that a fresh perspective is needed to ensure active engagement, which entails, if not a full shift of power from authorities to citizens, at least transparency to mitigate the effects of unequal power relations. I expand on this in the next section.

2.2 Principles for PEDM

This section takes a fresh look at how theoretical ideals of PEDM can be implemented. To address the gap between theory and practice, a set of theoretical ideals drawn from commitments and values of Science and Technology Studies (STS), Procedural Environmental Justice (PEJ), and Deliberative Democracy (DD), are categorised into four principles. The principles of inclusivity, process-orientation, empowerment, and reflection provide a way to usefully organise the ideals to aid their implementation and were organised loosely based on a PEDM process. The principle of inclusivity groups together ideals associated with who is included and that should therefore be considered before decision-making starts. Process-orientation and empowerment group together ideals associated with what occurs and how participants are treated during the decision-making process. Reflection groups together ideals associated with what happens after contributions are made. Thinking about the principles in terms of pre, during, and post contributions was a useful way to develop the categories, but that does not mean the ideals are limited to a specific time in PEDM. On the contrary, as demonstrated throughout this study PEDM is not a neat linear process and the ideals are and should be applied throughout.

The four principles are focused on fair process and procedure, which is underpinned by an understanding of knowledge as being inherently incomplete and dynamic, informed by Science and Technology Studies (STS). From the perspective of STS, knowledge gaps are accepted and expected, knowledge develops with experience, and knowledge changes over time (Graham, 2016). Accepting this dynamic characterisation of knowledge drives a shift towards an ongoing process of decision making, rather than a single decision outcome; *proactive knowledge production*, where an ongoing program of research addresses the knowledge gaps, followed by *ongoing opportunities…..to consent* enables informed participation as knowledge changes over time (Ottinger, 2013a, p. 251). This approach

challenges participatory procedures that rely on limited information provision and limited opportunities to engage, which reduce the legitimacy of decision making. STS assumes that information changes, so opportunities to contribute cannot be limited and legitimate decision-making is therefore dependent on procedures that focus on process rather than outcome (Ottinger, 2013a). Consequently, to implement PEDM as an ongoing process, this study focuses on fairness in the process of participation (procedural justice) not its outcome (substantive justice).

In the remainder of this section I describe each of the four principles of PEDM in turn: inclusivity, process-orientation, empowerment, and reflection. I show how insights, commitments, and values of STS, PEJ, and DD have been interpreted and integrated into the principles. As shown in Table 2.1, to aid the categorisation and implementation of the theoretical ideals of PEDM, I sub-divided the four principles into sub-principles; I explain this level of organisation below, starting with the principle of inclusivity.

Table 2.1 Commitments and values of DD, PEJ and STS and their relation to the four principles

Contributions and insights		
Science and Technology Studies	**Procedural Environmental Justice**	**Deliberative Democracy**
PRINCIPLE: Inclusivity		
SUB-PRINCIPLE: Multiple and diverse perspectives and voices are heard / represented		
Lay knowledge is legitimate and essential Obligations for proactive pursuit of contributions	Actively seeks diverse voices Includes non-expert / public voices	Seeking and recognising diverse voices Reaching out to alternative views, including traditionally excluded groups
SUB-PRINCIPLE: Fair access to information and opportunity to participate		
Access to information	Access to information Equal right, opportunity, and capacity to participate	The right, opportunity, and capacity to participate

Science and Technology Studies	Procedural Environmental Justice	Deliberative Democracy
SUB-PRINCIPLE: Regard for environmental values		
	Accounts for non-human (ecological) actors Appreciate environment's intrinsic value	Space and flexibility for 'Value Pluralism'
PRINCIPLE: PROCESS-ORIENTATION		
SUB-PRINCIPLE: Deliberation		
The decision is part of an ongoing, iterative process of deliberation and is open to change	Intrinsic value of procedure	Meta-consensus, via mutual understanding Just decision is part of ongoing process of deliberation, reflection, and action
SUB-PRINCIPLE: Transformation and change		
Knowledge is dynamic, allowing space to accept and expect change	Flexible / adaptive via grassroots / bottom-up structure	Transformative process and expectation for change Learning Deliberation transforms self-interest towards ethically defensible and 'common good' positions
PRINCIPLE: EMPOWERMENT		
SUB-PRINCIPLE: Open discussion		
Lay knowledge is sought (not just allowed)		Unconstrained dialogue defended against strategic action
SUB-PRINCIPLE: Trust and respect		
	Fair distribution of power Equal voice and partners at each stage Empowerment through diverse and creative methods of engagement Transparency Recognition and respect	Transparency Coercion /power relations managed, not excluded.

Science and Technology Studies	Procedural Environmental Justice	Deliberative Democracy
PRINCIPLE: REFLECTION		
SUB-PRINCIPLE: Reflective process		
Dynamic knowledge requires ongoing process of engagement and reflection	Equal opportunity for consideration	Reflective process enables change
SUB-PRINCIPLE: Self-awareness		
		Opportunities for participants to recognise the limitations of their own perspectives Engaging and learning from diverse and competing viewpoints

Inclusivity

The principle of inclusivity groups together ideals from STS, PEJ and DD that are associated with who is involved in, has access to, and is heard in PEDM. Inclusivity is subdivided into sub-principles of multiple and diverse perspectives and voices are heard; fair access to information and opportunity to participate; and regard for environmental values. I describe the composition each of these sub-principles below.

Multiple and diverse perspectives and voices are heard / represented

Recognising the need to include and hear multiple and diverse perspectives and voices, beyond immediate stakeholders and experts, is a key requirement for improving PEDM in STS, PEJ and DD literature. STS scholars build on the arguments for the legitimate and essential contribution of non-expert / lay knowledge in democratic decision-making discussed in chapter 1. Fiorino (1990, p. 227-228) highlights the substantive, normative and instrumental value of lay knowledge. Substantively, Fiorino considers that lay knowledge is as sound or more so than those of experts, due to their sensitivity to social and political values and their capacity to account for uncertainty. Fiorino associates the normative value with the ethical presupposition that citizens are the best judge of their own interests. Finally, Fiorino identifies the instrumental value of effective lay participation in risk decisions by making them more

legitimate and leading to better results. Rowe & Frewe (2000) agree, emphasising the public's capacity for participating on technical issues, considering the limitations of experts' perspectives. Therefore, STS prescribes that lay knowledge is legitimate and essential for PEDM, which is incorporated into this sub-principle.

The commitment to including lay knowledge, which is not dependent on a participant's qualifications (Wynne, 2007) contrasts with other attempts to prescribe criteria for PEDM. For example, Steenbergen *et al*'s (2003) DQI limits contributions based on their quality (see section 2.1). Also, Webler's (1995) 'competence' criteria assess contributions based on the quality of their discourse to determine their inclusion. It also contrasts with calls for selective process via systematic stakeholder analysis (Reed, 2008) that introduce the potential for bias selection and would actively exclude some potential contributors.

Accepting STS's understanding of knowledge as dynamic and the value of lay and diverse sources of knowledge, PEDM must conduct a proactive pursuit of contributions (Ottinger, 2013a). Including multiple, diverse, and non-expert voices is also integral to PEJ. For effective implementation of the commitments and values of PEJ, participation would not only allow, but actively seek, diverse voices, by facilitating diverse and creative communication methods and opportunities, incorporating creative methods such as narrative and even storytelling to empower disenfranchised groups in debate (Young, 2000, p. 53).

Deliberative democracy is based on procedural ideals, rather than normative outcomes, where decisions are made with, not to, people, cultivating a sense of ownership, rather than people living with imposed decisions (Smith, 2003). To achieve this, DD provides a systematic framework and institutional context for the *application of scientific and technological knowledge…. within which the barriers between 'expert' and 'lay' knowledge can be challenged* (Smith, 2003, p. 65). This commitment to inclusivity is defined by engagement that reaches out to alternative views, including traditionally excluded groups (Schlosberg *et al*, 2006), which is incorporated into the sub-principle of ensuring that multiple and diverse perspectives and voices are heard.

Fair access to information and opportunity to participate

The sub-principle of access to information and opportunity to participate draws directly from the theories of STS, DD and PEJ. To ensure that all voices are heard or are represented, in DD the fundamental normative conditions for (environmental) deliberative procedures are: the right, opportunity, and capacity to participate (Smith, 2003), which is incorporated directly into the sub-principle of fair access to information and opportunity to participate.

Theoretical ideals for participation are embedded in the development of the grassroots environmental justice movement that is rooted in social activism in the US and connected to issues of race, class, and gender (Jenkins, 2018). As a grassroots movement the *right to participate as equal partners at every level of decision-making* is one of the environmental justice movement's founding principles (First National People of Color Environmental Leadership Summit, 1996). Grassroots movement groups have formalised requirements for access to information, inclusivity, and community engagement to achieve environmental justice. The United States Environmental Protection Agency (USEPA) incorporates *meaningful involvement* into its definition of environmental justice, comprising: opportunity to participate; potential for public contributions to influence decision making; a voice for community concern in decision making; and the involvement of those potentially affected (USEPA, 2020). The underlying principles of procedural justice reinforce the commitment to inclusivity. Specifically, the PEJ literature emphasises access to knowledge and availability of information (Di Chiro, 1997; Jenkins, 2019; Shrader-Fracette, 2002; Schlosberg, 2007). PEJ's commitments to providing the equal right, opportunity, and capacity to participate via access to information is incorporated into this sub-principle.

As set out in the introduction to this section, STS literature assumes that knowledge changes, therefore the commitment to the access to information drawn from STS literature is also incorporated into this sub-principle of fair access to information and opportunity to participate.

Regard for environmental values

The commitment to accounting for environmental values draws on PEJ and DD. The environmental justice movement is characterised by a shift away from anthropocentric

concepts associated with social justice to a wider appreciation of the environment's intrinsic value and a more eco-centric approach (Schlosberg, 2013). The intrinsic value of nature (as defined in DD) describes the *richness and diversity of the non-human world* that has a *value in and for itself*, which is *independent of any particular value placed on it by humans* (Smith, 2003, p 9). As well as prescribing that the intrinsic value of the environment is appreciated, PEJ also prescribes that non-human actors (non-human things that influence the social, including ecology (Bickerstaff & Agyeman 2009)) are accounted for.

PEDM needs to manage competing social and environmental values, while addressing complexity, uncertainty and risk that contribute to conflict between stakeholders and to protracted decision making. Deliberative theory claims to allow for the space for 'value pluralism' that gives voice and sensitivity for diverse environmental and social values and conditions (Smith, 2003), as well as recognising nature's agency (Dryzek, 2007). The sub-principle of regard for environmental values is therefore based on PEJ's commitment to their inclusion and DD's commitment to value pluralism to facilitates their inclusion.

Process-orientation

The principle of process-orientation groups together ideals from STS, PEJ and DD that are associated with the process of decision-making, which is subdivided into sub-principles of deliberation, and transformation and change. Underpinned by the STS understanding of knowledge as dynamic (Ottinger, 2013a), deliberation describes an ongoing, iterative process that is open to change, and transformation and change allows, expects, and encourages change. I describe the composition each of these sub-principles below that draw on PEJ and DD, building on STS's understanding of knowledge as dynamic.

Deliberation

Fundamentally, PEJ is defined by its intrinsic value, as well as instrumental value (Schlosberg, 1999). Walker (2012, p. 47) explains the intrinsic as well as the instrumental value of fair procedure: *procedural injustice does not serve only as an explanation or cause of injustice…..it is also a subject or element of justice… in its own right*. Therefore (procedural) injustice will remain if the processes were unfair, even if they resulted in the desired outcome (the fair distribution of environmental risks and benefits). The focus is on fair processes as opposed to

outcomes (Schmidt, 2014). The intrinsic value of procedure prescribed by PEJ is incorporated into the deliberation sub-principle. Recognising the intrinsic value of participation (as the democratic right to participate) from the perspective of the participant contrasts with previous attempts to define criteria for PEDM that build on Habermas' theory of communicative action. These previous attempts measure the quality of the discourse to enhance the instrumental value of the data extracted from participants (Webler, 1995; Palerm, 1999; and Steenbergen *et al*., 2003).

Along with inclusivity, unconstrained dialogue, and sensitivity to environmental values, just decision-making is a fundamental commitment of DD (Smith, 2003). DD seeks workable agreement and mutual understanding that accepts competing values and different viewpoints (value pluralism) (Smith, 2003). The transformative process allows for the potential for broad agreement in the presence of alternative legitimate voices, so that the outcome itself is open to change (Niemeyer & Dryzek, 2007, p. 500). This contrasts with complete consensus that limits critical dialogue and the voice of minorities and relies on a stable notion of knowledge.

Accepting that complete consensus is unfeasible for effective implementation (Bailey & Grossardt, 2010), it is important that decisions are still taken; deliberation is distinct from dialogue in that decisions are made through a process of exchanging and understanding well-informed and justified individual positions (Raphael & Karpowitz, 2013). In this respect, the outcome becomes part of an ongoing process of deliberation and not an endpoint (Smith, 2003, p. 73), reconciling the understanding of knowledge as dynamic, informed by STS and the commitments of procedural justice. DD's commitments to seeking meta consensus via mutual understanding and just decision-making via an ongoing process of deliberation, reflection and action are incorporated into the sub-principle of deliberation.

Transformation and change

In DD, engagement processes encourage transformation of self-interested positions and individual preferences and values into more ethically defensible positions that are oriented towards the 'common good' (Smith, 2003, p. 63; Niemeyer & Dryzek, 2007). As explained above, an ongoing process of deliberation facilitates learning and change. DD's commitments

to transformative process towards the common good via learning are incorporated into the sub-principle of transformation and change.

Accepting the dynamic nature of knowledge and the contested theoretical ideals of PEDM in the literature, the values and commitments of STS, DD and PEJ are also subject to change. Normative and effective models of PEDM must therefore be flexible, to adapt to case and time specific circumstances, in contrast to current (rigid) attempts to institutionalise models of participation (as described in section 1.1). PEJ provides a flexible and adaptive structure to implement transformative but fair process. As a bottom-up, grassroots movement, environmental justice can be conceptualised as a decentralised structure that is strong enough to confront issues while being flexible and diverse to respond to changes (Schlosberg, 2005, p. 558). The environmental justice movement commits to retaining the flexibility of the grassroots movement that recognises diverse views as it expands and is adopted by institutions (Young, 1990; Gould, 1996). This commitment to flexible and adaptive structure is incorporated into this sub-principle to enable transformation and change to occur.

Empowerment

The principle of empowerment groups together ideals from STS, PEJ and DD that are associated with treatment of participants during decision-making. The principle of empowerment is subdivided into sub-principles of open discussion, and trust and respect. I describe the composition each of these sub-principles below.

Open discussion

The sub-principle of open discussion builds on STS's commitment to include lay knowledge (see above), which is directly integrated into the sub-principle of open discussion. The treatment of participants (including those with lay knowledge) in the deliberative process draws on DD. One of the fundamental normative conditions for (environmental) deliberative procedures is unconstrained dialogue that defends deliberation against strategic action (from powerful actors) (Smith, 2003, p. 56). This commitment is defined by conditions that allow for engagement and reflection with different perspectives and transparency, to enable participants to learn from competing viewpoints, transform their prior beliefs and cultivate mutual understanding (Smith, 2003; Niemeyer & Dryzek, 2007). This contrasts with strategic

engagement that maximises self-interest, for example, by deliberately retaining information to gain advantage over other participants. The commitment to unconstrained dialogue that defends deliberation against strategic action is incorporated into this sub-principle of open discussion.

Trust and respect

There is broad agreement in the PEJ literature that the underlying principles of procedural justice are inclusivity, fair distribution of power, and transparency. The literature emphasises an equal voice, an equal right to participation, an equal opportunity for consideration, and an ability to participate as equal partners in environmental decision making, at each stage of the process (Gould, 1996, p. 181; Honneth, 1992, p. 190-191; Shrader-Frechette, 2002, p. 28-29). However, these commitments can present problems for effective implementation; how to ensure equal power between participants who are unequally affected and resourced. This challenge raises concerns about the way power is exercised, which is compounded by the need to account for non-human (ecological) actors. As set out in section 2.1, some existing participatory ideals maintain power disparities. The environmental justice movement developed out of a widespread critique of top down, centralised procedures that disempowers individuals (Schlosberg, 2005, p. 558), characteristic of contemporary environmental decision-making. In response to the delegitimising effects of power, procedural and institutional reform has been proposed. A 'procedural turn' in the literature demands processes that generate transparency (Pretty, 1995; Mansbridge, 1996; Palerm, 1999). The literature emphasises interdependence between meaningful participation and just procedure. Meaningful participation is considered a precondition of just procedure (Ottinger, 2013a), and the absence of procedural justice adversely affects decision-making and contributes to political deadlock (Tomlinson, 2015, p. 9).

As the movement has evolved, the concept of environmental justice has been expanded in response to demands for respect, recognition, and fairness in participation (Young, 1990, p. 34; Honneth, 1992, p. 190-191; Schlosberg, 2007, p. 26), to comprise three interrelated and interdependent elements: equal distribution of environmental risks; fairness of procedures; and recognition for other participants, issues, and values, irrespective of position and identity (Jenkins, 2018 & 2019). Procedural environmental justice is understood as institutional

processes that determine access to information, participation, decision making and justice (Shrader-Frechette, 2002, p. 28), representing a precondition (Walker, 2012) of addressing distributive injustice as well as issues of oppression and justice as recognition (Young, 1990). This conception also highlights the interdependent relationship between participation and just procedure, showing that participation is embedded in the definition of procedural justice (Sovacool *et al*, 2016). PEJ's commitments to fair distribution of power, equal voice at each stage, recognition of other participants, and transparency have been incorporated into the sub-principle of trust and respect.

While differences in views should not be suppressed in favour of consensus (Escobar, 2019), it is vital to avoid endless deliberation without action. As discussed above under the sub-principle of deliberation, decisions are made through a process of exchanging and understanding well-informed and justified individual positions (Raphael & Karpowitz, 2013) and is therefore distinct from dialogue. To achieve this, Mansbridge (1996) reminds us that coercion can be managed to motivative collective deliberation to action. Therefore, a commitment to fair conditions to manage power, rather than setting unobtainable and undesirable conditions to exclude it, is incorporated in the sub-principle of trust and respect.

Reflection

The principle of reflection groups together ideals from STS, PEJ and DD that are associated with how participants can and should engage with previous contributions. Building on the principle of process-orientation and commitments to an on-going process of decision-making the principle of reflection is subdivided into sub-principles of reflective process and self-awareness. I describe the composition of each of these sub-principles below.

Reflective process

Accepting STS's understanding of knowledge as dynamic, PEDM cannot be limited to passive opportunities for engagement. PEDM must therefore consist of ongoing iterative processes of engagement and reflection (Ottinger, 2013a). This commitment is supported by DD's commitment to change via reflection, where participants re-examine their own and other people's views as part of deliberation (Roberts & Escobar, 2015). To ensure fairness in the deliberative process, I draw on PEJ's commitment to enabling participants to have equal

opportunity to contribute, which continues throughout the ongoing process of engagement and reflection. Reflective process therefore incorporates an ongoing process of reflection to facilitate change (informed by STS and DD), which provides participants equal opportunities to contribute throughout (from PEJ).

Self-awareness

In DD reflective and transformative process is dependent on participants recognising the limitations of their own perspectives while encouraging mutual understanding of different views, via an engagement process that cultivates reflection. Commitments to providing opportunities for participants to recognise the limitations of their own perspectives, and engage and learn from alternative perspectives, are incorporated into the sub-principle of self-awareness.

In this section I have taken a fresh look at theoretical ideals of PEDM drawn from STS, PEJ and DD. To aid their implementation, I have explained how these ideals have been categorised into four principles and sub-principles. In the next section, I discuss how these principles and sub-principles should be translated to facilitate effective implementation.

2.3 Translation of theory into practice: Interpretation of the four principles

As set out in sections 1.1 and 2.1, implementation of theoretical ideals of PEDM in practice is difficult. In this section, the four principles of inclusivity, process orientation, empowerment and reflection, and their sub-principles are translated into practical criteria. A framework for PEDM emerges from the practical criteria that explain how the four principles can be implemented. Examples from previous studies that have attempted to define PEDM are provided to demonstrate the similarities and differences to the proposed practical criteria. This comparison aims to illustrate how the practical criteria have drawn on previous studies and addresses their shortcomings.

Inclusivity

The commitment to inclusivity in PEDM involves ensuring that: multiple and diverse perspectives and voices are heard / represented; there is fair access to information and opportunity to participate; and that there is regard for environmental values. The theoretical

ideals associated with adhering to the commitment to inclusivity are identified in Table 2.2, but in practice, it is difficult to strike a balance between ensuring voices are included and that they are heard. Inadequate inclusion excludes relevant voices, while over-inclusion drowns out individual voices, including those from disadvantaged and minority communities.

Table 2.2 Inclusivity: theoretical ideals and practical criteria

Theoretical Ideals	**Practical Criteria**
PRINCIPLE: Inclusivity	
SUB-PRINCIPLE: Multiple and diverse perspectives and voices are heard / represented	
Lay knowledge is legitimate and essential	Demonstrate proactive engagement, targeting diverse range of voices and minority groups.
Actively seeking and recognising diverse voices	Demonstrate effort to seek alternative voices beyond those immediately affected and experts.
Includes non-expert / public voices	Experts and non-experts are included.
Reaching out to alternative views, including traditionally excluded groups	Diverse engagement and communication tools used (e.g. visual representations). Efforts made to acknowledge and address consultation fatigue to engage stakeholders and enhance participation.
SUB-PRINCIPLE: Fair access to information and opportunity to participate	
Equal right, opportunity, and capacity to participate	Participation is open; individuals or groups can initiate participation without invitation. Consultation is open for sustained and regular periods and is publicised in advance to optimise awareness of the opportunities to participate.
Access to information	Demonstrate what additional information and resources for access is provided (including compensation) to disadvantaged and under-represented groups.
SUB-PRINCIPLE: Regard for environmental values	
Give voice to non-human (ecological) actors	Identify potential environmental impacts (e.g. use existing EIA framework).
Appreciation of the environment's intrinsic value	Demonstrate that environmental values are represented, e.g. use groups representing conservation interests such as the RSPB.
Space and flexibility for value pluralism	Provide opportunities for diverse viewpoints to hear and reflect on alternative perspectives.

Implementing the principle of inclusivity needs to accept the practical implications of unlimited inclusion. For example, drawing on STS literature, Biegelbauer & Hansen's (2011) participatory criteria prescribe that all legitimate interests have a voice. However, trying to

include everyone affected is impractical (Gould, 1996). Implementing this ideal would be hampered by a lack of clarification on what counts as all legitimate voices and may result in procedural deadlock (Tomlinson, 2015), where the process gets bogged down in accounting for all legitimate voices.

The practical criteria in Table 2.2 go some way to striking a balance, shifting away from prescribing that all those affected are included and towards diversity and proactive practices that seek, as opposed to passively allow, participation, as prescribed by STS. The practical criteria focus on the tools of engagement, their design and how they can be used to demonstrate effort to meet the criteria.

Multiple and diverse perspectives and voices are heard

To implement the sub-principle of ensuring that 'multiple and diverse perspectives and voices are heard / represented' the practical criteria in Table 2.2 prescribe that the design of engagement processes enables diverse interactions and should include processes that proactively engage and seek diverse and alternative voices, minority groups and non-experts. The intention is to demonstrate the inclusion of lay knowledge, diverse voices, and non-expert / public voices in the design and implementation of PEDM. While acknowledging that the ideal of including all lay knowledge, non-experts and minorities is unachievable, the practical criteria emphases that voices beyond those immediately affected and experts are sought. These practical criteria are similar to those proposed by Pretty's (1995) study of participation in sustainable agriculture. Pretty (1995) prescribes inclusion of multiple and diverse perspectives, backgrounds, and interpretations; flexible and adaptable methods to enable a context-specific approach; and engagement of expert and lay participants. They also resonate with Reed's criteria for PEDM (2008) which prescribe that local and scientific knowledge are integrated into PEDM.

The practical criteria for ensuring that 'multiple and diverse perspectives and voices are heard / represented' prescribes that demonstrable effort is made to reach out to minority communities that often 'lack effective organisations to represent them', which reflects criteria for PEDM that Hunold & Young (1998) propose for locating new hazardous / waste facilities. To reach out to alternative views, including traditionally excluded groups, the

practical criteria prescribe that diverse engagement and communication tools are used (e.g. visual representations) and that efforts are made to acknowledge and address consultation fatigue. This resonates with Young's plea for the inclusion of alternative forms of communication, such as storytelling, in response to discussion-based deliberation that is *culturally biased* (1996, p. 120). Drawing on developments in deliberative practice (see Involve, 2005) the role of creative methods is recognised to account for and respect diverse backgrounds, cultures, and educational achievements, as well as to address consultation fatigue associated with the typical and ordinary.

Fair access to information and opportunity to participate

The sub-principle of ensuring 'fair access to information and opportunity to participate' prescribes an equal right, opportunity, and capacity to participate; and access to information is provided. This resonates with Webler's 'Evaluation Yardstick' (1995) that measures 'fairness' in the process of decision making based on the participant's ability to attend an event, initiate speech, participate in debate and participate in disputes.

To implement the theoretical ideals associated with the sub-principle of fair access to information and opportunity to participate, the practical criteria emphasise openness to promote equal opportunities for participation while recognising the inherent difference between contributors. To implement the equal right, opportunity, and capacity to participate, the practical criteria prescribes that PEDM is open so that individuals or groups can initiate participation without invitation. A mechanism for self-selection works in conjunction with the proactive engagement described above, to optimise the opportunities to participation.

The practical criteria operationalise the ideal of 'access to information' by prescribing that consultation periods are open for sustained and regular periods and are publicised in advance to optimise opportunities for participation. This draws on Hunold & Young's (1998) proposal that consultation over time, as opposed to sporadic consultations, is required to maximise social knowledge. Recognising that insufficient time and knowledge reduces the capability of citizens to engage in meaningful debate with experts and authorities, in turn reducing public participation and legitimate critique, the practical criteria also require provision of additional information and resources to compensate disadvantaged and under-represented groups. This

draws on Hunold & Young's (1998) proposals for equal resources and access to information to address gross power disparities between experts and citizens. It also draws on Fraser's *objective condition* required for participation that prescribes *distribution of material resources… to ensure participants' independence and voice* via systems that facilitate *means and opportunities* for participation (2001, p. 29). The practical criteria emphasise providing the opportunities for participation, rather than coercion, to recognise the right *not* to participate.

Regard for environmental values

The sub-principle of having 'regard for environmental values' prescribes provision of a voice to non-human (ecological) actors; appreciating the environment's intrinsic value; and the space and flexibility for value pluralism.

The practical criteria for implementing this sub-principle aim to enable decision-makers to demonstrate that environmental values are recognised and accounted for. It is acknowledged that there may be case-specific opportunities for recognition of environmental values which may be more appropriate and should therefore be considered. To operationalise the ideals of giving a voice to non-human actors and appreciation of the environment's intrinsic values, the practical criteria prescribe that PEDM should demonstrate that environmental impacts and values are considered and represented. This draws on Palerm's (1999, p. 234) principles which prescribe that actors without a voice are *given an opportunity to participate, either directly or through actors representing their interests*, for example, those who enunciate environmental values. The specific requirement to consider environmental values addresses weaknesses in Habermas-inspired criteria that are often criticised for underplaying intrinsic environmental values (Smith, 2003, p. 69) and dismissing nature as passive and inert (Dryzek, 2007).

It is acknowledged that existing regulatory frameworks, such as EIA, already include groups representing conservation interests such as the Royal Society for the Protection of Birds (RSPB). To enhance the existing approach and provide the space and flexibility for value pluralism, the practical criteria emphasise that, as well as including diverse viewpoints mechanisms for participants to hear and reflect on alternative perspectives are prescribed.

This resonates with Fraser's (2001) conditions for participation that recognise the diversity of voices and interests that need to be served by diverse systems. Crucially, the focus shifts from equality towards an approach that accepts inherent diversity and inevitable conflict between values, characteristic of value pluralism.

Process Orientation

The existing and accepted approach to decision-making focuses on what the outcome (the decision) is, rather than how it was achieved. For example, Hunold & Young's proposals for PEDM (1998) include a criterion that focuses on the fairness of the outcome, prescribing that the decision should respect the contributions. Recognising the gap between the current approach and ideal standards that focus on achieving a sense of fairness in process, a significant change in mindset and culture is required. The practical criteria, set out in Table 2.3 and described below, translate these ideals into mechanisms that encourage the changes in approach toward process orientation, rather than an expectation of unachievable standards.

Deliberation

The sub-principle of deliberation prescribes that decisions are part of an ongoing process of deliberation that are open to change. Ideally, the intrinsic value of procedure should be recognised so that just decision-making is part of the ongoing process of deliberation, reflection, and action. To aid implementation of these aspects, the practical criteria prescribe that PEDM is designed to facilitate regular decisions and action points that represent milestones, as opposed to an endpoint. Provision should be made for consistent mechanisms for deliberation and reflection beyond the decision and action points. These practical criteria reflect Biegelbauer & Hansen's (2011) commitment to open-ended decision-making processes and obligation for debate and interrogation.

The sub-principle of deliberation also prescribes that ideally, participants should reach mutual understanding. This ideal is interpreted in the context of value pluralism and expectation for change, where the practical criteria encourage query and debate so that broad agreements are found via an iterative process. The idea is that an ongoing iterative design enables

opportunities for reflection and change to defuse the level of expectation and sense of finality associated with a single endpoint.

Table 2.3 Process-Orientation: theoretical ideals and practical criteria

Theoretical Ideals	Practical Criteria
PRINCIPLE: Process orientation	
SUB-PRINCIPLE: Deliberation	
The decision is part of an ongoing process of deliberation and is open to change. Intrinsic value of procedure Just decision is part of ongoing process of deliberation, reflection, and action Deliberation Meta-consensus, via mutual understanding	Consultation and engagement processes facilitate regular decisions and action points that represent milestones, as opposed to an endpoint. Provide consistent mechanisms for engagement beyond decision and action points. Provide opportunities for participants to deliberate and reflect on their own and alternative contributions. Decisions represent broad agreements (rather than complete consensus), which participants are encouraged to query and debate.
SUB-PRINCIPLE: Transformation and change	
Knowledge is dynamic, allowing space to accept and expect change Flexible / adaptive via grassroots / bottom-up structure Transformative process and expectation for change Learning Self-interest is transformed towards ethically defensible and 'common good' positions	A range of engagement activities are provided to provide space for participants to consider alternative perspectives and reflect on prior beliefs. Opportunities and mechanisms for feedback and reflection are provided and promoted. Provide systems to communicate information and knowledge as it changes, before, during and after decision and action points.

Transformation and change

The sub-principle of 'transformation and change' prescribes that PEDM should recognise that knowledge is dynamic, allowing space to accept and expect change. To implement a process that recognises that knowledge is dynamic, the practical criteria suggest that a range of engagement activities are provided to give participants the space to consider alternative perspectives and reflect on prior beliefs.

Ideally, PEDM should be flexible and adaptive via a grassroots / bottom-up structure. To implement this aspect of the sub-principle of transformation and change, the practical criteria suggest that activities are provided that enable participants and decision makers to reflect and provide feedback. Emphasising a flexible and adaptive process addresses potential shortcomings of conventional top-down PEDM.

The sub-principle of transformation and change prescribes that PEDM is a transformative process that expects change. To implement this aspect, the practical criteria prescribe that expectation for change is established from the start via systems that facilitate knowledge and information to be built up and communicated between stakeholders. Adhering to the criteria for transformation and change, which applies to both participants and decision makers, is achieved via co-production of knowledge, as opposed to knowledge extraction that is typical of contemporary consultation practices.

Ideally, PEDM facilitates learning to encourage transformation of self-interest positions towards ethically defensible and 'common good' positions. To implement this aspect, the practical criteria suggest that systems are provided to communicate information and knowledge as it changes, before, during and after decision and action points. The aim is to encourage participants to increase their awareness and appreciation of alternative perspectives so that through learning, they move away from self-interest positions.

The commitment to learning draws on Pretty's (1995) criteria for participatory decision-making that focus on systematic learning, group learning and interaction, engaging expert and lay participants in transformation activities, and sustained action. Pretty recognises the subjectivity and diversity of socially constructed knowledge that is subject to interpretation and transformation. Crucially, Pretty emphasises systems of *learning* to stimulate *action* (1995, p. 1251). This supplements and clarifies the commitment to the intrinsic value of participation, where focusing on process (as opposing to reaching an outcome) could result in endless cycles of (ineffective) reflection and engagement. To implement this theoretical perspective, Pretty (1995) proposes new *systems of learning and action* and twelve *criteria for trustworthiness* (p. 1256). The new 'systems of learning and action' present a range of

diverse and creative participatory methods and tools for engagement. This focus on learning to simulate change is reflected in the practical criteria associated with aspects of the sub-principle of transformation and change (see Table 2.3).

Empowerment

The commitment to empowerment in PEDM depends on open discussion and cultivating trust and respect. Openness, trust, and respect between participants does not simply materialise but it can be encouraged.

Table 2.4 Empowerment: theoretical ideals and practical criteria

Theoretical Ideals	Practical Criteria
PRINCIPLE: Empowerment	
SUB-PRINCIPLE: Open discussion	
Lay knowledge is sought (not just allowed)	Provide mechanisms that enable and promote participation from project conception.
Unconstrained dialogue is defended against strategic action	Provide mechanisms that enable and encourage non-expert and expert participants to frame issues / problems and contribute ideas early in process. Enable unlimited contributions.
SUB-PRINCIPLE: Trust and Respect	
Coercion /power relations managed, not excluded.	State at commencement and reiterate throughout that all contributions are valued and will be included.
Fair distribution of power	Time and resources provided to allow participants to get to know each other, preferably before providing contributions.
Equal voice and partners at each stage.	Communicate the purpose of the project and set out realistic goals to manage the expectations of the participants.
	State and reiterate that the process relies on mutual respect and trust between participants and with the facilitator. Provide a mechanism for issues associated with respect and trust to be heard.
Empowerment through diverse and creative methods of engagement.	Diverse and creative methods of engagement used to encourage participants to contribute.
Transparency	The preferred outcome of the facilitator is set out transparently and does not limit inclusion of contributions.
	Demonstrate the mechanisms for participants to understand the impact and place of their contribution.

As set out in Table 2.4, to implement the principle of empowerment the practical criteria focus on providing the space for a variety of engagement tools to be used with the aim of encouraging openness, trust, and respect.

Open discussion

Ideally, PEDM should ensure that lay knowledge is sought, not just allowed. To implement this aspect of the sub-principle of open discussion, the practical criteria suggests that the inclusion of lay knowledge can be achieved in practice by ensuring that mechanisms are provided that enable and promote participation from project conception.

The sub-principle of open discussion prescribes that ideally PEDM comprises unconstrained dialogue that is defended against strategic action. To implement this aspect, the practical criteria suggests that mechanisms are put in place that enable unlimited contributions from both non-experts and experts, which encourage them to frame issues and to contribute ideas early in the process. These practical criteria draw on Biegelbauer & Hansen's (2011) participation criteria that prescribe that issues are framed by participants, and Steenbergen *et al*'s (2003) DQI that prescribes that participants have the freedom to speak without interruption.

Trust and respect

The sub-principle of trust and respect prescribes that, ideally, power relations are managed not excluded and there is fair distribution of power during PEDM. To implement these aspects, the practical criteria suggest that a statement is made that all contributions are valued and will be included, at commencement of the process and reiterated throughout. Moreover, time and resources should be made available for participants to get to know each other and consider the issues and conflicts before expressing their opinions and then reflecting on them (Röckmann *et al*, 2012).

Ideally, participants should have an equal voice in PEDM and be partners at each stage. To implement this aspect of the sub-principle of trust and respect, the practical criteria suggest that the purpose of the project and realistic goals are communicated to the participants, to manage their expectations. The practical criteria also suggest that a statement is given and

reiterated, which states that PEDM relies on mutual respect and trust between participants and with the facilitator, and that mechanisms are provided that enable issues associated with respect and trust to be heard.

Ideally, PEDM should provide diverse and creative methods of engagement. The practical criteria suggest that diverse and creative methods of engagement are designed and used with the intention of encouraging participants to contribute. This aims to improve on other participatory ideals that neglect the opportunity for diversity and creativity in engagement methods to empower minority, disadvantaged, and disenfranchised groups (e.g. Palerm, 1999).

The sub-principle for trust and respect prescribes that PEDM processes are transparent. To implement transparency, the practical criteria suggest that the preferred outcome of the facilitator is set out to the participants at the outset, and that the inclusion of contributions are not limited. The practical criteria also suggest that PEDM is designed to demonstrate ways for participants to understand the impact and place of their contribution.

Effective implementation of the sub-principle of trust and respect relies on mechanisms and systems to be established and maintained to facilitate reliable and trustworthy communication. The engagement process should therefore be characterised by early and sustained cycles of engagement, with regular action points to demonstrate progress and learning.

The practical criteria for the sub-principle of trust and respect resonate with some of the key features of PEDM identified by Reed (2008), that: there is an underlying philosophy that emphasises empowerment, trust, equity and learning; participants should be engaged early in the process; and objectives are set among stakeholders.

The practical criteria associated with the principle of empowerment, summarised in Table 2.4, aim to address the shortcomings of previous attempts to define PEDM that have struggled to manage power relations and implement ideals of empowerment. For example, Steenbergen *et al*'s (2003) DQI evaluates participants' contributions based on discourse quality,

discriminating against non-experts, and maintaining power disparities between experts and non-experts. Steenbergen *et al*'s (2003) DQI draws on Habermas whose work has been criticised for a fundamental lack of understanding of the power relations that create barriers to *discursive decision-making* that is *needed for political change* (Flyvbjerg, 1998, p. 215). This deficiency in understanding of power relations affects the capacity of scholars that draw on Habermas to fulfil empowerment ideals.

In contrast, Biegelbauer & Hansen's (2011) proposal that issues are framed by participants, adheres theoretically to empowerment criteria but does not define the extent to which power and authority is redistributed. Full power redistribution as proposed by Biegelbauer & Hansen (2011) is unachievable. Similarly, Hunold & Young (1998) propose shared decision-making authority, which also faces challenges of effective implementation in the same way as Arnstein's (1969) ideal standard of citizen control. The practical criteria in Table 2.4 seek to address these shortcomings by managing power fairly, for example, compensating less powerful parties (Mansbridge *et al*, 2010)

Reflection

PEDM in practice should respond to the diverse and evolving nature of values and information in environmental decision making. Reflection is a key requirement for accepting this dynamic nature of knowledge so that decision makers and contributors can consider knowledge as it changes and is built up from alternative views, experience, and new data. The sub-principles of reflective process and self-awareness are set out in Table 2.5 and described below.

Reflective process

The sub-principle of reflective process is based on an understanding of knowledge as dynamic and prescribes that PEDM comprises an ongoing process of engagement and reflection. To implement this aspect, the practical criteria suggest that engagement processes are designed to include decision and action milestones that are discussed before during and after implementation to facilitate reflection and learning.

Ideally, reflective process should facilitate change. To implement this aspect, the practical criteria suggest that systems are provided for participants to reflect on their previous

contributions to facilitate an ongoing process of dialogue, consideration of views, negotiation, and compromise. There should also be equal opportunities for consideration. The practical criteria suggest that systems are provided that enable participants to offer contributions outside formal engagement activities and make suggestions for alternative / additional activities.

Table 2.5 Reflection: theoretical ideals and practical criteria

Theoretical Ideals	Practical Criteria
PRINCIPLE: Reflection	
SUB-PRINCIPLE: Reflective process	
Dynamic knowledge requires ongoing process of engagement and reflection	Design engagement process to include decision and action milestones that are discussed before during and after implementation to facilitate reflection and learning.
Reflective process enables change	Provide systems for participants to reflect on their previous contributions to facilitate ongoing process of dialogue, consideration of views, negotiation, and compromise.
Equal opportunity for consideration	Provide systems to enable participants to offer contributions outside formal engagement activities and make suggestions for alternative / additional activities.
SUB-PRINCIPLE: Self-awareness	
Opportunities for participants to recognise the limitations of their own perspectives	Provide systems that enable contributions to be shared between participants.
Engaging and learning from diverse and competing viewpoints	Establish and agree places and systems to communicate results and findings to enable and encourage feedback.

Self-awareness

To implement the principle of self-awareness, participants should ideally be given opportunities to share and consider their own and alternative views, so that they recognise the limitations of their own perspectives and engage and learn from diverse and competing viewpoints. To implement opportunities for participants to recognise the limitations of their own perspectives, the practical criteria suggest that systems are provided that enable contributions to be shared between participants. Finally, to ensure that participants engage and learn from diverse and competing viewpoints, the practical criteria suggest that places

and systems to communicate results and findings are established and agreed, to enable and encourage feedback.

In this section, I have translated the four principles of PEDM into practical criteria. A new framework (practical criteria arranged according to the four principles of PEDM) is presented to facilitate the implementation of theoretical ideals in practice. This framework will be used to assess how Bayesian Belief Networks (BBNs) could improve PEDM in the case of Solway Energy Gateway (SEG) (set out in the remaining chapters). To set up the exploratory case study, in the next section the features of BBNs are mapped onto the principles and practical criteria of PEDM.

2.4 Aligning BBNs with the principles and practical criteria for PEDM

As discussed in section 1.2, previous studies have claimed that specific features of BBNs (ability to represent data visually, to incorporate qualitative data, and to be updated) aid participation in decision-making (Barton *et al*, 2012; Campbell *et al*, 2012; Chen & Pollino, 2012; Low-Choy *et al*, 2009; Marcot & Penman, 2019; and Stewart et al, 2014). These features are not unique to BBNs; other models may have some or a combination of these features. This study focuses on the particular ways these features work and combine in BBNs and to test the specific claims about the ability of these features to aid participation. In this section, I outline how these features align with the principles, sub-principles, and practical criteria of PEDM so that they can be tested in the exploratory case study of SEG. The alignment is summarised in Table 2.6 and described below.

Visual representations

The capacity of BBNs to incorporate diverse views is enhanced by the ability of BBNs to represent data visually. Visual representations of BBNs offer several opportunities to align with the practical criteria of PEDM.

Considering the practical criteria associated with the principle of inclusivity, visual representations of BBNs offer ways to diversify engagement tools and provide access to information. As illustrated in Table 2.6, used instead of, or in conjunction with conventional text-based tools, visual representations of BBNs could diversify engagement and reduce

consultation fatigue, as prescribed by practical criteria associated with the sub-principle of 'multiple and diverse perspectives and voices are heard / represented'. Additionally, visually displaying data improves access to information, which aligns with the practical criteria associated the sub-principle of 'fair access to information and opportunity to participate'.

Visual representations demonstrate that values have been included and make the relationships between variables explicit (Chen & Pollino, 2012). The capacity to demonstrate that a range of views have been included and valued aligns with practical criteria associated with the principle of process-orientation. Visually displaying data enables knowledge to be shared so that participants can review alternative views, changes in information, and appreciate the values held by different and often opposing stakeholders. This aligns with the practical criteria associated with the sub-principle of 'deliberation' that prescribes that participants are given opportunities to deliberate and reflect on their own and alternative contributions. Visually displaying data also aids transparency that improves legitimacy and facilitates learning (Uusitalo, 2007). This aligns with the sub-principle of 'transformation and change' that prescribes that systems are put in place to communicate information and knowledge as it changes to facilitate learning.

Transparently displaying data in visual representations aligns with practical criteria associated with the principle of empowerment. Visually displaying data in BBNs as it changes helps participants to contribute throughout the process of decision-making. This aligns with the principle of empowerment and sub-principle of 'open-discussion'. Providing diverse methods of engagement to illustrate the impacts of their contribution and place within decision making process aligns with the practical criteria associated with the sub-principle of trust and respect.

Displaying data collected from a range of sources visually demonstrates the range of views included and enables knowledge to be shared so that participants can reflect on alternative views and changes in information. This aligns with the practical criteria associated with the principle of reflection and sub-principle of reflective-process, which prescribes that systems that communicate knowledge are implemented to encourage reflection and feedback on their own and other participants' views.

Updating the model

Incorporating and visually displaying diverse participant data is enhanced by the ability to update BBNs, where different scenarios can be tested, evaluated, and revised with participants' contributions (Chen & Pollino, 2012; Johnson *et al*, 2016). The capacity to update BBNs can therefore facilitate an iterative process of learning, deliberation, and reflection, as prescribed by the practical criteria associated with the principles of process orientation and reflection. The practical criteria associated with the sub-principle of 'deliberation' prescribe that participants are given opportunities to deliberate and reflect. The practical criteria associated with the sub-principle of 'reflective process' prescribes that systems are put in place for participants to reflect on their previous contributions to facilitate an ongoing process of decision and action.

Updating a BBN model with participants also aids their understanding of the impact and place of contributions, as prescribed by the practical criteria associated with the sub-principle of 'trust and respect'. It also provides opportunities for unlimited contributions, as prescribed by the practical criteria associated with the sub-principle of 'open discussion'.

Incorporating qualitative data

The capacity of BBNs to model qualitative and quantitative data enables a range of stakeholder knowledge to be incorporated into decision-making. In turn, this feature enables participation and engagement to be extended beyond the current level of immediate impact and those most affected (decision makers and developers). Table 2.6 illustrates that the capacity of BBNs to incorporate diverse views, including those representing environmental values and lay knowledge, aligns with several of the practical criteria of PEDM, particularly those associated with the principles of inclusivity and empowerment. The inclusion of lay knowledge and diverse views is prescribed by the practical criteria associated with the principle of inclusivity, and sub-principle of 'multiple and diverse perspectives and voices are heard / represented'. Practical criteria associated with the principle of empowerment, and sub-principle of 'open discussion' also prescribe that lay knowledge is sought.

Table 2.6 Summary of the relationships between the theoretical and practical criteria for improving PEDM, and the features of BBNs

Theoretical Ideals	Practical Criteria	Features of BBNs
PRINCIPLE: Inclusivity		
SUB-PRINCIPLE: Multiple and diverse perspectives and voices are heard / represented		
Lay knowledge is legitimate and essential	Demonstrate proactive engagement, targeting diverse range of voices and minority groups.	Combining the capacity to incorporate qualitative data and updating data, enables diverse views to be included throughout the process.
Proactive pursuit of / actively seek and recognise diverse voices	Demonstrate effort to seek alternative voices beyond those immediately affected and experts.	
Includes non-expert / public voices	Experts and non-experts are included.	Capacity to incorporate qualitative data (stakeholder knowledge), negates the need to translate non-expert knowledge into numbers that could exclude non-experts.
Reaching out to alternative views, including traditionally excluded groups	Diverse engagement and communication tools used (e.g. visual representations). Efforts made to acknowledge and address consultation fatigue to engage stakeholders and enhance participation.	Visual representations of the BBN models used to improve communication and engagement, as well as to reduce consultation fatigue compared with text-based presentations.
SUB-PRINCIPLE: Fair access to information and opportunity to participate		
Equal right, opportunity, and capacity to participate	Participation is open; individuals or groups can initiate participation without invitation. Consultation is open for sustained and regular periods and is publicised in advance to optimise awareness of the opportunities to participate.	
Access to information	Demonstrate what additional information and resources for access is provided (including compensation) to disadvantaged and under-represented groups.	Visual representations of BBNs display information in an accessible form, as nodes and arcs.

Theoretical Ideals	Practical Criteria	Features of BBNs
SUB-PRINCIPLE: Regard for environmental values		
Give voice to non-human (ecological) actors	Identify potential environmental impacts (e.g. use existing EIA framework).	
Appreciation of the environment's intrinsic value	Demonstrate that environmental values are represented, e.g. use groups representing conservation interests such as the RSPB.	Visually representing values as nodes and arcs in BBNs demonstrates they are included and represented.
Space and flexibility for value pluralism	Provide opportunities for diverse viewpoints to hear and reflect on alternative perspectives.	Combining the capacity to incorporate qualitative data and update data, enables BBNs to include diverse views to be throughout the process.
PRINCIPLE: Process orientation		
SUB-PRINCIPLE: Deliberation		
The decision is part of an ongoing, iterative process of deliberation and is open to change.	Consultation and engagement processes facilitate regular decisions and action points that represent milestones, as opposed to an endpoint.	Combining the capacity to visually represent and update data to model different scenarios enables BBNs to demonstrate the distribution and effects of beliefs promoting deliberation.
Intrinsic value of procedure	Provide consistent mechanisms for engagement beyond decision and action points.	
Just decision is part of ongoing process of deliberation, reflection, and action	Provide opportunities for participants to deliberate and reflect on their own and alternative contributions.	Utilising the update feature, BBNs can be tested, evaluated, and updated in an iterative process of decision and action points.
Deliberation		The ability of BBNs to incorporating qualitative data, negates the need to translate non-expert knowledge into numbers that could exclude some stakeholders, improving the diversity of views deliberated.
Meta-consensus, via mutual understanding	Decisions represent broad agreements (rather than complete consensus), which participants are encouraged to query and debate.	

Theoretical Ideals	Practical Criteria	Features of BBNs
SUB-PRINCIPLE: Transformation and change		
Knowledge is dynamic, allowing space to accept and expect change	A range of engagement activities are provided to provide space for participants to consider alternative perspectives and reflect on prior beliefs.	The capacity to incorporate qualitative data enables diverse and alternative views to be represented and considered. Visually representing participants' views as nodes and arcs illustrates range of views included, so that participants can consider alternative views. The capacity to update BBNs enables participants to test and re-evaluate their prior beliefs.
Flexible / adaptive via grassroots / bottom-up structure	Opportunities and mechanisms for feedback and reflection are provided and promoted.	
Transformative process and expectation for change	Provide systems to communicate information and knowledge as it changes, before, during and after decision and action points.	BBNs can be updated as knowledge changes and visual representations can communicate those changes.
Learning		Updating BBNs to model and demonstrate different scenarios enables participants to learn from alternative contributions.
Self-interest transformed towards ethically defensible and 'common good' positions		

Theoretical Ideals	Practical Criteria	Features of BBNs
PRINCIPLE: Empowerment		
SUB-PRINCIPLE: Open discussion		
Lay knowledge is sought (not just allowed)	Provide mechanisms that enable and promote participation from project conception.	Capacity to incorporate qualitative data negates the need to translate non-expert knowledge into numbers that could exclude some. Together with the ability to be updated, BBNs facilitate contributions from a range of participants throughout model development.
Unconstrained dialogue is defended against strategic action	Provide mechanisms that enable and encourage non-expert and expert participants to frame issues / problems and contribute ideas early in process.	The combination of visual representations and ability to update BBNs enables participants to contribute and frame the issues throughout the process.
	Enable unlimited contributions.	Ability to update BBNs enables unlimited contributions.
SUB-PRINCIPLE: Trust and Respect		
Coercion / power relations managed, not excluded.	State at commencement and reiterate throughout that all contributions are valued and will be included.	Visual representations of participants' values as nodes and arcs demonstrates that their contributions are included and valued.
Fair distribution of power. Recognition, and respect.	Time and resources provided to allow participants to get to know each other, preferably before providing contributions.	
Equal voice and partners at each stage.	Communicate the purpose of the project and set out realistic goals to manage the expectations of the participants.	
	State and reiterate that the process relies on mutual respect and trust between participants and with the facilitator. Provide a mechanism for issues associated with respect and trust to be heard.	
Empowerment through diverse and creative methods of engagement.	Diverse and creative methods of engagement used to encourage participants to contribute.	Visual representations provide an alternative to conventional text-based consultation methods.

Theoretical Ideals	Practical Criteria	Features of BBNs
SUB-PRINCIPLE: Trust and Respect (continued)		
Transparency	The preferred outcome of the facilitator is set out transparently and does not limit inclusion of contributions.	Visual representations transparently display contributions and the relationships between issues raised as nodes and arcs. The capacity to update the model enables unlimited contributions.
	Demonstrate the mechanisms for participants to understand the impact and place of their contribution.	The combination of updating and visually representing those updates enables BBNs to demonstrate the effects of 'belief' on decisions, aiding understanding of the impact and place of individual contributions.
PRINCIPLE: Reflection		
SUB-PRINCIPLE: Reflective process		
Dynamic knowledge requires ongoing process of engagement and reflection	Design engagement process to include decision and action milestones that are discussed before during and after implementation to facilitate reflection and learning.	The capacity to update BBNs provides the opportunity for ongoing iterative process of decision and action.
Reflective process enables change	Provide systems for participants to reflect on their previous contributions to facilitate ongoing process of dialogue, consideration of views, negotiation, and compromise.	The combination of using visual representations of BBNs to enable participants to review and reflect on their contributions and then updating BBNs following review by participants enables change.
Equal opportunity for consideration	Provide systems to enable participants to offer contributions outside formal engagement activities and make suggestions for alternative / additional activities.	

Theoretical Ideals	Practical Criteria	Features of BBNs
SUB-PRINCIPLE: Self-awareness		
Opportunities for participants to recognise the limitations of their own perspectives	Provide systems that enable contributions to be shared between participants.	Ability to incorporate a diverse range of data, and visually display that data enables views to be shared. Visual representations of the model provide a system to communicate the incorporated data.
Engaging and learning from diverse and competing viewpoints	Establish and agree places and systems to communicate results and findings to enable and encourage feedback.	The capacity to update the model enables and encourages feedback in an iterative process of test, re-evaluate and revise. Capacity to incorporate qualitative data facilitates contributions from a range of participants so that diverse viewpoints can be considered.

In this section I have described the links been the features of BBNs and the theoretical ideals and practical criteria for PEDM. This establishes capacity for BBNs to improve PEDM, setting up the case for testing BBNs in the case of SEG.

2.5 Summary

Ideally and theoretically the intrinsic democratic right to participate improves decision-making; however, participation in practice is complicated, often ineffective and can be counter-productive. Despite the breadth of literature on PEDM, unsatisfactory PEDM persists with practical implications including consultation fatigue and political apathy. A review of existing participatory ideals shows many are unachievable and maintain power disparities, which sustains unsatisfactory PEDM in practice.

To address the gap between theory and practice, in this chapter I have presented a new perspective on participatory ideals. Drawing on an understanding of knowledge as dynamic from STS, and commitments and values of PEJ and DD, I propose a new approach based on translating ideals into practice. Considering PEDM as a process, the commitments and values of DD, PEJ and STS were synthesised into four principles. Inclusivity grouped together ideals associated with who participates and elements that can be considered before decision-making starts. Principles of process-orientation and empowerment group together ideals associated with the management of the process of decision-making and how the participants are treated during decision-making. Finally, the principle of reflection grouped together ideals associated with reviewing previous contributions and providing feedback. The detail of the four principles are honed by sub-principles that add an extra layer of organisation. The four principles and their sub-principles therefore provided a framework for the implementation of theoretical ideals.

The principles may contribute to effective implementation, by providing more achievable and applicable standards. However, to address the implementation gap, I ‘translated’ the commitments and values of DD, PEJ and STS, already organised into principles and sub-principles, into ‘practical’ criteria. Other normative models in theory paint the ideal world scenario, ineffectively implemented by tick box models of unrealistic / inappropriate criteria. In contrast, the practical criteria are orientated towards implementation in practice that

works within the constraints and purpose of the context of PEDM. The intention is that the practical criteria encourage the provision of flexible systems that allow for, and adapt to, contributions and revisions within and outside formal engagement activities. Multiple points of engagement are required to enable participants to review and update their previously held views as knowledge changes. For example, a single questionnaire following a single consultation contribution is inadequate. The practical criteria do not; however, dictate how participants interact and how views are shared. It is recognised that it is sometimes practically impossible or counter-productive for participants to meet face-to-face, and that views could be shared in other ways. The emphasis is on the provision of transparent communication of accrued knowledge and actions to enable participants to reflect on their own and each other's contributions.

The translation of ideals into practical criteria represents an original contribution that links appropriate theoretical ideals to practice via guidelines for implementation. For practitioners, the key understanding is that the way standards are implemented has a more significant effect on the quality of participation than what the standards are (newDemocracy Foundation, 2018; and Niemeyer, 2013). For theorists, the addition of the translation stage means that fulfilling the criteria becomes process orientated, where compliance is defined by design, intention and implementation of the process, as opposed to focusing on obtaining a theoretical ideal standard or end-point.

The practical criteria proposed are designed to be flexible to be broadly applicable to a wide range of participatory decisions. This study focuses on environmental decisions for illustrative purposes, which provide detail such as the principle of regard for environmental values. However, that level of detail could be tailored to other applications. Where fair and just participation is sought, the commitments to inclusivity, process orientation, empowerment and reflection are appropriate, with the underlying detail open to case specific application. The substance of the framework is less important than the structure of the process. Resonating with the commitment to process orientation and the proposal for a translation phase, the essential element of the framework is how theoretical ideals are implemented, not what the criteria are.

As set out in section 1.2, features of BBNs might improve PEDM. I have mapped the features of BBNs (can include qualitative data, be updated, and be visually represented) onto the practical criteria for PEDM, set out in Table 2.6. The efficacy of the new framework using BBNs is tested in the case of Solway Energy Gateway (SEG). The next chapter describes the methodology of how this was done.

Chapter 3. Methodology

It is argued in chapters 1 and 2 that participatory environmental decision-making (PEDM) could and should be improved. As set out in section 1.2, some of the features of BBNs (specifically, their capacity to be updated and incorporate qualitative data, as well as visual representations of the models) could improve PEDM; this chapter describes how this hypothesis was tested.

The Solway Energy Gateway (SEG) was used as an exploratory case study to test the potential of BBNs to improve PEDM. Due to the novelty of using BBNs in the licencing and consenting process for marine renewables, an exploratory case study was necessary to undertake preliminary research. The theoretical ideals and practical criteria for PEDM set out in chapter 2 were used to measure how the features of BBNs affect PEDM in the case of SEG. These elements were brought together using a participatory action research (PAR) inspired framework of cycles of action and reflection that provided the structure for iterative qualitative data collection and analysis. Individually the elements of the methodology are not original; however, one of the distinctive features of this study is how these elements were applied together. This chapter describes how the methodology was developed to bring these elements together.

In section 3.1, I explain the methodological approach, setting out how and why a PAR-inspired framework was used. I describe the features of PAR that correspond to the principles and practical criteria for PEDM to explain the theoretical fit. Building on the introduction to the case study provided in chapter 1, I also explain the selection of SEG as the exploratory case study. In section 3.2, I set out the research design, explaining how the PAR-inspired framework was implemented. I explain how the framework, comprising cycles of action and reflection, facilitated an iterative approach to data collection and analysis, where the research design was continuously reviewed and revised throughout five cycles of engagement. Details are provided of the data collection tools used in each cycle of engagement. I also outline the approach taken to identify and engage with participants, who included a diverse group of key stakeholders (including the development team, statutory consultees, interest groups, and

interested individuals). In section 3.3, I consider the ethical and practical challenges of the methodology.

3.1 Methodological approach

This section describes how and why PAR inspired the research framework. First, I introduce PAR, linking it to the aims of the research. Second, I describe the key features of PAR and highlight those particularly relevant to this study. I explain how the features of PAR correspond to the theoretical ideals and practical criteria of PEDM, identified in chapter 2. I discuss what these connections mean for the research design, highlighting the key features of PAR that are adopted in the research design. In the final part of this section, I explain the selection of the exploratory case study of SEG in the context of the methodological approach.

The participatory approach

The identified need and purpose of this study - to improve participatory practices - informs the methodological approach. This study is undertaken in the participatory paradigm, where knowledge is co-created via *collaborative forms of inquiry* (Breu & Peppard, 2003, p. 184). Collaborative research involves participants and researchers in a collaborative process for knowledge generation (Kindon *et al*, 2007). Participatory Action Research (PAR) is one of the main research approaches in participatory inquiry (Breu & Peppard, 2003; Reason, 1998). The PAR approach prescribes collaborative participation in research that is orientated towards a social or an environmental change (Kindon *et al*, 2007; Pain *et al*, 2012). Fundamentally, in PAR, research is done with (not on) people, to empower them in the production of knowledge and relevant action (Breu & Peppard, 2003).

This study draws on PAR to address the research questions:

RQ 1: How can improvements in PEDM be measured?

RQ 2: Do the features and development of BBNs adequately capture, represent, deepen the understanding of, and communicate knowledge?

RQ 3. Do the features of BBNs improve PEDM?

RQ 4. How could BBNs be incorporated into PEDM to improve the consenting and licencing process for marine renewables?

PAR originated in grassroots movements to engage people that are usually disempowered (Reason & Bradbury, 2001). This links to the commitments and values of procedural environmental justice and deliberative democracy and the principles of inclusivity and empowerment (set out in chapter 2) that are central to this study.

The PAR approach to knowledge generation is also influenced by insights from Science and Technology Studies. The idea of co-production of knowledge is widely attributed to STS literature and Bruno Latour specifically (Graham, 2016). STS prescribes that co-production of knowledge comes from collaboration between researchers and users in a research process (comprising design, administration and dissemination of academic knowledge) (Flinders *et al*, 2016), where users can include community groups and other organisations, and a combination of partners (Pain *et al*, 2015). This approach to knowledge production disrupts and challenges the conventional view of the researcher as extracting data to construct knowledge, e.g. the process of belief elicitation undertaken in conventional BBN construction. The rejection of the extractive approach to knowledge production that underpins STS and PAR, addresses an identified shortcoming of existing PEDM, (see chapter 1), and provides a novel approach to BBN modelling.

Features of PAR

According to Kindon *et al* (2007, p. 14) there are eight key features of PAR:

1. Aims to (positively) change social (and environmental) injustices.
2. Treats participants as competent and reflexive agents in all aspects of the process.
3. Addresses 'real life' problems.
4. Incorporates local beliefs and values.
5. Involves a collaborative process of knowledge generation.
6. Treats diverse experiences as opportunities to enrich research.
7. Constructs new meanings via reflections on action.
8. Measures the value of knowledge based on whether the action solves the identified problem.

These features of PAR share many of the theoretical ideals for PEDM proposed in chapter 2. The key connections are explained below and illustrated in Table 3.1.

Table 3.1 The commonalities between the features of Participatory Action Research (PAR) and the theoretical ideals and practical criteria of PEDM, proposed in chapter 2

PAR features	Commonalities	Theoretical ideals and practical criteria for PEDM*
Incorporates local beliefs and values in a collaborative process of knowledge generation, by treating participants as competent and reflexive agents, and their diverse experiences as opportunities to enrich research	Includes and values diverse local knowledge and treats that knowledge equitably and competently	Lay knowledge as legitimate and essential Provides equal rights, opportunities, and capacity to participate Diverse voices sought and recognised
Seeks to create change to address real-life environmental injustices	Environmental impacts are assessed and identified injustices addressed in a process of change	Identifies potential environmental impacts Mechanisms for regular decision, action, and reflection points Reflective process enables change
New meanings are constructed via reflections on action	Phases of action and reflection	Mechanisms for regular decision, action, and reflection points

* taken from Table 2.6

The PAR approach aligns with aims and the participatory orientation of the study. Improving the incorporation of lay knowledge in PEDM is a key motivation of this research. As discussed in previous chapters, conventionally, while PEDM includes lay knowledge, extractive and superficial processes result in conflict and delays. In the context of improving PEDM, the following features of PAR can be taken together: incorporating local beliefs and values (feature 4) in a collaborative process of knowledge generation (feature 5), by treating participants as competent and reflexive agents (feature 2), so that their diverse experiences are treated as opportunities to enrich research (feature 6).

These features align with the principles and practical criteria for PEDM proposed in chapter 2, particularly the theoretical ideals associated with inclusivity and empowerment. Crucially both PAR and the principles for PEDM focus on how local knowledge is treated as it is incorporated. In PAR participants are treated competently. Similarly, the PEDM principle of

inclusivity commits to treating lay knowledge as legitimate and essential, and to providing equal rights, opportunities, and capacity to participate. These ideals emphasise that the inclusion of local knowledge is valued and supported, so that the participants and their knowledge are treated as competent. In PAR, the inclusion and value of local knowledge is enhanced by diverse experiences, which reflects the theoretical ideals of PEDM; diverse voices should be sought and recognised is an important aspect of the principle of inclusivity.

In PAR, local beliefs and values are incorporated in a collaborative process of knowledge generation. These features can be linked to the theoretical ideals of PEDM, specifically trust and respect, which prescribe that participants are treated as equal partners at each stage of the decision-making (see Table 3.1). To implement this, the associated practical criteria state that the purpose of the project should be communicated, and realistic goals set out to manage the expectations of the participants. Additionally, mechanisms to establish and reflect on trust and respect between participants and with the facilitator should be provided. Committing to and providing the conditions for trust and respect to be established and maintained in accordance with the practical criteria for PEDM enables collaborative knowledge generation, a feature of PAR. The theoretical ideal for PEDM associated with trust and respect also provides the foundation for participants to be treated as competent and reflexive agents, and their diverse experiences as opportunities to enrich research, which are also features of PAR.

PAR aims to change unjust and unsatisfactory social and environment issues (feature 1) and address 'real life' problems (feature 3). In the context of PEDM, taken together, these features show that the PAR approach seeks to create change to address real-life environmental injustices. To address real-life environmental injustices, they need to be identified and understood in 'real-life'. This feature of PAR is reflected in theoretical ideals of PEDM associated with the principle of inclusivity and sub-principle of regard for environmental values (see Table 2.5), which prescribe that environmental values are included in decision-making, and to include them they need to be understood. The associated practical criteria proposed in chapter 2 prescribe that environmental impacts are identified, contributing to gaining an understanding of real-life environmental injustices.

The action part of PAR seeks to resolve injustices that have been identified in 'real-life'. This 'change' part of PAR links to both the proposed PEDM principles of process-orientation and reflection that prescribe that change is allowed, expected, and encouraged. The principle of process orientation prescribes that PEDM is designed to facilitate an ongoing process of deliberation that is open to change. To ensure that deliberation does not go on forever and to facilitate change, the associated practical criteria prescribe that PEDM is designed to include regular decision and action points. The principle of reflection builds on this, prescribing that the reflective process enables change. To facilitate this, the associated practical criteria propose that systems for participants to reflect on their previous contributions are provided. The theoretical ideals and practical criteria of PEDM are therefore orientated towards creating positive change to address environmental injustices, by identifying and understanding the 'real life' issues (environmental impacts). Mechanisms for regular decision, action, and reflection points facilitate this assessment and the change required.

In prescribing mechanisms for regular decision, action and reflection points, the practical criteria for PEDM link to another feature of PAR; new meanings are constructed via reflections on action (feature 7). This feature is key to the way that PAR is implemented in this study. Typically, PAR is implemented in iterative phases of action and reflection (Kindon *et al*, 2007), which has inspired the framework for data collection and analysis used in this study. This framework links the theoretical commonalities between PAR and the ideals and practical criteria of PEDM, to the research design, which is described in detail in section 3.2.

There are, however, some features of PAR that do not easily fit with the PEDM principles, such as PAR's commitment to measuring the value of contribution based on whether the action solves the identified problem. The element of judgement (judging the value of contributions) conflicts with the principle of inclusivity and empowerment that prescribe that all contributions are included and valued, as described in section 2.2. This lack of fit between this study and all the characteristics of PAR is acknowledged. However, I emphasise that this study does not claim to be PAR, rather that PAR inspired the methodological approach and research framework, comprising iterative cycles of reflection and action.

One of the novel elements of this study is the implementation of the PAR-inspired framework to knowledge production via BBNs. As explained in chapter 1, conventionally knowledge incorporated into BBNs (belief elicitation) is characteristically extractive. The PAR-inspired framework facilitates the implementation of the participatory approach, by collaborating to co-produce knowledge, using BBNs, which is detailed in section 3.2.

Exploratory case study

An exploratory case study was selected to undertake preliminary research into the novel use of BBNs in PEDM. As discussed in chapter 1, Solway Energy Gateway (SEG) offers a distinctive range of features. There is a complex combination of sensitive environmental sites and varying layers of local, national, and international environmental designations at and close to the proposed development site. The proposed structure crosses the Solway Firth, connecting England and Scotland, extending into different regulatory regimes and communities. SEG proposes the use of a novel technology (VETT) and it is at the preliminary stage of its development. The combination of these features and the complexity of the site presents the opportunity to explore an extreme range of issues with a diverse range of stakeholders, representing a difficult case study (George & Bennett, 2005) to test the research questions.

The selection of SEG aligns with the participatory approach of the study. As SEG is at the preliminary stage of the development and it has yet to reach the formal consenting process, there is relatively little pre-decided and pre-existing information available. In the context of the aim of improving PEDM this was important. As discussed in chapter 1, one of the failures of PEDM is that participants feel that they are engaging in a process where the decisions have already been made. So, a case study at the early stages of development was chosen to reduce the sense that all the decisions are already made and to increase the sense that stakeholders are engaged early (as prescribed in the theoretical ideals for PEDM proposed in chapter 2).

The outline proposals for SEG do represent some pre-made decisions; however, I considered that it was preferable to use a ‘real-life’ proposal as opposed to a hypothetical scenario. I wanted the participants to be able to relate to something ‘real’ to encourage the production of authentic knowledge. Additionally, enabling the participants to produce knowledge based on real-life proposals, reduced the participatory burden of imagining a hypothetical case.

Being at the early stage of the proposals, choosing SEG as the case study reduced the risk of researcher bias. I deliberately chose a case that I knew relatively little about, in a location I knew little about before the data collection. This allowed me to invert the conventional view of the researcher as an 'expert' who extracts data to assess separately. Instead, I approached the case study with a lack of superior knowledge, promoting the participants' knowledge as the primary source of information. This enabled me to establish the participants' data as the baseline, promoting the value of lay knowledge and reducing the distinction between expert and non-expert. This approach contrasts with conventional approaches to deliberative decision-making in practice, where facilitators shape, constrain and enable contributions based on what is appropriate and their quality (Escobar, 2019). As explained in chapter 2, this conventional approach (of judgement) enforces power disparities.

In this section, I have explained how the PAR approach connects the aims of the study with the theoretical ideals of PEDM. I have also explained why SEG was selected as the exploratory case study. In the next section, I describe how the PAR approach was developed into a framework for iterative data collection and analysis. I explain how this framework was applied in the case of SEG to test the use of BBNs to improve PEDM.

3.2 Research Design

This section sets out how the methodological approach was implemented. First, I describe how the features of PAR were developed into a research framework for data collection and analysis, comprising cycles of action and reflection. Second, I summarise the participant engagement process. Third, I describe the data collection and analysis process, comprising five cycles of engagement. Fourth, I describe the implementation of the iterative research design, which was reviewed and adapted in response to participant feedback and analysis of data collected. I provide a summary of how the design was adapted during the process.

Participatory Action Research (PAR) inspired framework

As discussed in the previous section, one of the key features of PAR is that new meanings are constructed via reflections on action. I drew on Kindon *et al*'s (2007, p. 15) description of phases of action and reflection to design iterative cycles of engagement and modelling that provided a systematic framework for data collection and analysis, see Table 3.2, overleaf.

Table 3.2 Cycles of action and reflection: based on 'key stages in a typical PAR process' (Kindon *et al*, 2007, p. 15)

PAR Stages	Objectives	Analysis	Method / Sampling point
Action	Establish relationships	Stakeholder Analysis	Meetings and networking
Reflection	On research design	Compare the research design to the principles and practical criteria for PEDM	
Action	Establish baseline stakeholder beliefs on SEG via a process of 'broadening out'. Identify issues (what matters) to demonstrate participant's views are heard, recorded, and valued. Explore why each issue matters considering their importance, how sure stakeholder feel about their views, and whether there are any co-dependencies. Cultivate trust and respect with individual stakeholders.	Use transcriptions of interviews and data collected from Participatory Diagramming (PD) to identify themes and patterns	**Cycle 1:** One-to-one unstructured interviews with 5-6 stakeholders. Use PD and / or mapping to facilitate data collection and encourage engagement
Reflection	On the interviews	Compare the qualitative data with the methodological approach,	
Action	Construct a BBN from each interview	Create nodes from the issues raised. Parametrise the BBNs with weightings based on the importance and how sure people felt. Use the identified co-dependencies themes and patterns to create relationships arcs.	BBN Modelling (researcher)
Reflection	Integrate structure of BBNs. Build trust and respect with stakeholders. Identify changes in beliefs and perspectives though interacting with the BBN.	Co-analyse the structure of their own BBN with individual stakeholders discussing any changes in beliefs and perceptions. Review primary data to identify themes and patterns	**Cycle 2:** One-to-one interviews with stakeholders. Use BBN to facilitate interactive PD.
Action	Revise individual BBN from each interview	Use primary data to revise individual BBNs	BBN Modelling (researcher)

PAR Stages	Objectives	Analysis	Method / Sampling point
Reflection	Participation in integration of the individual BBNs. Cultivate trust and respect between stakeholders. Identify changes in beliefs and perspectives though interacting with the BBN.	Co-analyse other stakeholder's BBNs. Discuss changes in beliefs and perceptions. Review primary data to identify themes and patterns in how participants feel about the fairness of the process and what they are learning.	**Cycle 3:** One to one interviews (recorded) with stakeholders OR group event. Use BBN to facilitate interactive PD.
Action	Synthesise the BBNs	Create nodes from the issues raised. Parametrise the BBNs with weightings based on the importance and how sure people felt. Use the identified co-dependencies to create relationships arcs.	BBN Modelling (researcher)
Reflection	Integrate BBN to explore the potential for collective learning and changes in beliefs and perspectives though interacting with the BBN.	Review primary data to identify themes and patterns to identify changes in beliefs and perspectives.	**Cycle 4**: One group event (focus group or workshop). Use BBN to facilitate interactive PD.
Action	Revise structure of BBN based on results of individual and group reflections.	Review primary data to revise synthesised BBNs.	BBN Modelling (researcher)
Reflection	Present final BBN to stakeholder group. Explore how stakeholders felt about it: how the BBN incorporated, valued, and represented their beliefs; how their beliefs changed; and what they learnt through interaction with the BBN.	Obtain feedback during / after the event to record the final positions /beliefs / perceptions held and assess the changes in beliefs from the original positions. Obtain feedback from the participants on whether the process was fair and what they learnt.	**Cycle 5:** Event / exhibition of the findings. Possibly run an exhibition twice, on either side of the Solway to optimise attendance and access.

In contrast to conventional use of BBNs, this study implemented cycles of action and reflection to facilitate the co-production and co-analysis of BBNs with each participant. The cycles of action and reflection are orientated towards iterative decision-making, not reaching consensus, providing a way to work with knowledge change. The idea was that reflection and action led on from each other in cycles, using the features of BBNs to encourage participants to review and transform their prior beliefs, creating change.

Participant engagement featured in both action and reflection phases. Engagement as action occurred in the early phases, where issues and the relationships between them were raised and described by the participants. The first cycle of engagement (an action phase) was designed to establish baseline values and beliefs, from which changes in participant views and beliefs could be assessed. Engagement as reflection occurred in subsequent engagement events, where participants were asked to review and retest their own models to explore their own views. In further phases of reflection, they reviewed each other's models and then the integrated model. In action research, Burns (2007, p. 159) argues that exposing qualitative data from individuals to *increasing circles of peer review* adds to the quality and robustness of the research. The process of iterative review used in this study was designed to facilitate a process of *resonance testing*, where individual models are reviewed by widening networks of participation (Burns, 2007, p. 159).

Participant Engagement

The first key stage of the PAR process (Table 3.2) was to identify and engage with potential participants for this study, undertaken via snowball sampling. To distinguish between stakeholders of SEG who are not participating in this study, and those who are, stakeholders who participated in this study are referred to as key informants (KIs). Each KI who participated in the cycles of engagement was assigned a unique code to preserve their anonymity, as listed in Table 3.3. I describe the ethical considerations of the design of participant engagement in section 3.3.

The snowball sampling started with a representative from Solway Energy Gateway Ltd. (KI-B), who was contacted in March 2017. KI-B provided some background on the scheme, including the proposed design and technology. KI-B stated that discussions about the scheme with

stakeholders had been held since 2008 and provided minutes of several of these meetings. Considering the research project timeframe, I considered that it was beneficial for the KIs to have some knowledge of SEG from previous engagement, therefore the attendees of these meetings were identified as potential participants.

Time and resource constraints limited the number of KIs engaged in each cycle. Being a research project, as opposed to real, high stakes PEDM, also limits the incentive to participate and therefore the number of willing KIs (Roberts & Escobar, 2015). In total 16 different KIs were engaged over five cycles of engagement, and the maximum number of KIs engaged in a single cycle was 12, in cycle 1. The small sample does not claim to provide a representative view of the SEG proposals; the purpose of this study was testing the use of BBNs in PEDM, and not to determine the appropriateness of SEG. The focus was therefore on obtaining diversity in the voices, in accordance with the proposed principle of inclusivity for PEDM.

A review of the attendees of previous SEG meetings showed that most were facilitators or supporters of the proposals, such as financial backers, consultants, technology providers, and research and development specialists. This is perhaps unsurprising as the scheme is not in the formal application process, and other stakeholders may have considered the meetings less relevant. The long list of stakeholders who sent apologies to the previous meetings often matched in number those who attended. Considering this limited diversity in the list of attendees of previous meetings, those who sent apologies and organisations discussed during the meetings were identified as potential KIs.

Table 3.3, overleaf, shows the diversity of the KIs who participated, including stakeholders from Scotland and England. At least 7 of the KIs lived locally to the Solway Firth (in both England and Scotland). Table 3.3 lists some of the KIs' professional roles to illustrate the range of perspectives engaged in the study. However, the KIs spoke beyond their professional remits, providing personal views and local knowledge, as well as contributing knowledge associated with the professional expertise. The classification of expert and non-expert was not defined in Table 3.3; each KI provided what could be defined as expert and non-expert (or local) knowledge. Four attendees of previous meetings participated (KI-B, KI-K, KI-L and KI-P), and a further four KIs were identified by attendees of the previous meetings who did not

participate themselves (KI-D, KI-E, KI-J and KI-M). The remainder were identified by other KIs during the cycles of engagement.

Table 3.3 Key Informants

Codes	General description	Engaged in Cycles	Method of identification
KI-A	Local resident (England)	1, 2, 3, and 5	Snowball sampling – identified by KI-M
KI-B	On SEG development team	1, 2, 3, 4, and 5	Initial contact and attendee of previous SEG meetings
KI-C	Works for a Government body - conservation (England)	3 and 5	Snowball sampling – identified by KI-I, KI-O
KI-D	Works for a Government body - conservation (Scotland)	1, 2 and 3	Snowball sampling – identified by attendee of previous SEG meetings
KI-E	Works for a conservation charity (England)	1, 2, 3, and 5	Snowball sampling – identified by attendee of previous SEG meetings
KI-F	Works for a conservation charity (Scotland)	1, 2, 4 and 5	Snowball sampling – identified by KI-E
KI-G	Works for a Scottish Government - authority	1 and 2	Snowball sampling – identified by KI-B
KI-H	Parish Councillor and local resident (England)	1 and 2	Snowball sampling – identified by KI-B
KI-I	Parish Councillor and local resident (England)	1 and 2	Snowball sampling – identified by KI-B
KI-J	On SEG development team	1, 4 and 5	Snowball sampling – identified by attendee of previous SEG meetings
KI-K	Works for a conservation charity (Scotland)	3 and 5	Attendee of previous SEG meetings
KI-L	Works for a conservation charity (Scotland)	3	Attendee of previous SEG meetings
KI-M	Works for a council funded conservation body (England)	1	Snowball sampling – identified by attendee of previous SEG meetings
KI-N	Works for a Government body - conservation (England)	3	Snowball sampling – identified by KI-A
KI-O	Works for a conservation charity (England)	1	Snowball sampling – identified by KI-E
KI-P	On SEG development team	1	Attendee of previous SEG meetings

Data Collection and analysis

The case study approach defines *an overarching research intent and methodological purpose* that has informed the selection of data collection and analysis methods or *techniques* (Simons, 2009, p. 3). There are a wide range of techniques associated with case study research. Yin (2009) identifies six of the most common sources of evidence used in case studies: documentation; archival records, interviews, direct observation, participant-observation, and physical artefacts. The choice of data collection tools is also intended to facilitate collaborative participation in research, inspired by a PAR approach and the principles of PEDM (Table 3.1). To address these considerations, this study employs a combination of participant observation and participatory diagramming, used in a series of engagement events. As indicated in Table 3.2, one-to-one interviews were planned for the first 3 cycles of engagement, and group events were planned for cycles 4 and 5. The planned interviews and group events established the places for 'formal' data collection to happen, I refer to as 'engagement events'. The following sections detail the proposed use of participatory diagramming and participant observation. I then go onto to describe the proposed engagement events.

Participatory Diagramming

Participatory diagramming (diagrams created by participants, usually on paper) aims to encourage the KIs to contribute collaboratively, generating co-produced knowledge (Kindon *et al*, 2007; and Pain *et al*, 2012). Participatory diagramming was used throughout the cycles of engagement to harness the potential for the visual representations of BBNs. KIs were invited to engage in writing and sketching on physical artifacts (e.g. visual representations of BBNs and maps of the area) and / or use post-it notes to place and move their thoughts around as the discussion developed.

In this study, participatory diagramming was used as an alternative to extractive engagement techniques that are conventionally used in PEDM and in the development of BBNs. This aligns with the practical criteria associated with the principle of inclusivity that prescribe the use of diverse methods to reduce the risk of consultation fatigue and encourage contributions from those who are traditionally excluded by conventional interviewing techniques (see Table 2.6). Visual representations of BBNs were used as a focus for co-producing knowledge. It was

envisaged that researcher and KIs annotate the BBNs collaboratively. This approach was designed to reduce the risk of KIs becoming exhausted, anxious, and frustrated with the complexity of the task, as identified in previous studies (Carrick, 2016). This is important given that this study aims to reduce consultation fatigue and participatory burden (symptoms of poor PEDM).

The KIs were engaged from the start of the development of the BBN models, to cultivate a sense of ownership in their development. In cycle 1, maps of the Solway Firth and cross sections of proposed SEG installation were used to facilitate participatory diagramming, encouraging the KIs to think spatially and identify the issues that mattered to them. These values were used as the baseline for BBNs that were modelled for each KI. In subsequent cycles, visual representations of BBNs were used to facilitate participatory diagramming.

Participatory diagramming and visual representations of the BBN models were designed to encourage KIs to broaden their perspective, in contrast to constraining views with closed questions, common in conventional belief elicitation methods for BBN modelling (see section 1.2 and Figure 1.3). Annotating the visual representations of BBNs was proposed to help demonstrate that contributions were valued and included. This sense of value was reinforced when KIs were revisited to review their previous contributions incorporated into the BBN model, as illustrated in the visual representations. Co-analysis of the visual representations of the model further enhanced the value of KIs' contributions. The process of contributing to co-analysing the visual representations of their own and then later other KIs' views within the BBNs was designed to get KIs thinking and involved in developing the BBNs. This was designed to promote learning and to enable KIs to consider alternative perspectives prior to any group events with the aim of defusing tension at such events.

Participant observation

In contrast to constraining views with closed questions, common in conventional belief elicitation methods for BBN modelling, during the engagement events I used a narrative approach (Riessman, 2008) and conducted exploratory conversations. Narrative research enables participants to tell their story, creating a narrator-listener dynamic (as opposed to interviewer-interviewee) (Allen, 2017). In this study, in accordance with the participatory

approach, KIs led the interviews and reflected on their experiences, making long story-like contributions. To evaluate how KIs, use, develop and work with BBNs, participant observation was used to record qualitative data. I had envisaged that I would use audio recorders. However, during cycle 1 (documented in chapter 4) I sensed that the KIs were uncomfortable being recorded. Elsawah *et al* (2015, p. 505) notes that where interviewees feel uncomfortable being recorded then *effective notetaking* should be used instead. Therefore, I watched and made notes of how KIs interact with the models. This approach gave me the freedom to identify and record (non-audible) subtle emotions such as signs of anxiety.

Engagement events

Participant observation and participatory diagramming was used to collect data at engagement events, scheduled in 5 cycles. The cycles were designed to implement phases of action and reflection (as described in Table 3.2) within the constraints of the research project timeframe. A timetable of engagement, shown in Table 3.4, details the engagement events within the 5 cycles.

Table 3.4 Timetable for data collection

Cycle	Engagement events	Dates	Purpose
1	Interviews	August – September 2017	Ask participants about the issues (what matters), why each issue matters, how sure participants feel about their views, and relationships between issues.
2	Interviews	November - December 2017	Ask participants to review their individual models to ensure correct representation and discuss changes.
3	Interviews or group event*	February - March 2018	Ask participants to review each other's models and consider connections with their own.
4	Group event	May 2018	Participate in the integration of the model.
5	Open day / Exhibition	July 2018	The integrated model will be presented. Feedback on the model and the process will be requested from individuals and the group.

*depending on the views of the participants

The timetable was designed to facilitate iterative data collection and to be flexible; the design was reviewed and updated as the data were collected. The iterative approach to data

collection enabled me to assess the data collection methods during phases of reflection and gave me the opportunity to revise the use of the techniques in subsequent cycles, if required. Table 3.4 lists the cycles sequentially for ease of reference; however, the flexible design enabled them to overlap and / or repeat.

To cultivate a sense of value in individual contributions, BBNs were to be co-produced with individual KIs in initial cycles before being combined in later cycles of engagement. As set out in Table 3.4, the data collection starts with one-to-one interviews to establish confidence and trust between the researcher and each KI and establish baseline beliefs and perceptions. BBNs are then combined and reviewed with KIs, analysing a variety of scenarios. This approach draws on the ideas of Campbell *et al* (2012) and Marcot *et al* (2006) that describe the development of individual BBNs so that KIs develop an understanding of different sectors such as *social-wellbeing, ecology and economy*, before being combined.

The proposed engagement events, planned over 5 cycles, are described below. I then go on to describe the planned BBN modelling of the data collected between each cycle, under the subheading 'data analysis'.

The first engagement events in cycle 1 (identified as an action in Table 3.2) comprised one-to-one interviews with stakeholders (sometimes two KIs were interviewed together). The initial interviews were designed to establish relationships with the KIs and introduce them to the research, as well as collect data that would form the basis o f individual BBNs. At the start of the interviews, I spent time introducing myself and the research to the KIs, to set the foundations for trust and respect to develop (DeJonckheere & Vaughn, 2019). I was transparent about my position on renewable energy and my previous career in the sector early in the interviews. I set out the purpose of the research, introducing the KIs to the SEG proposals and the concept of using BBNs in decision-making. I provided the KIs with a proposed timetable for data collection (Table 3.4), so that they understood that they would be given opportunities to review and revisit their contributions via co-producing models in cycles of engagement. Purposely designing this 'introduction' into the cycles of engagement establishes the basis for the co-production of knowledge, where research is done 'with', not

'on', participants. This 'introduction' aligns with the practical criteria associated with the principle of empowerment and sub-principle of trust and respect.

The co-production of knowledge started in cycle 1. Three large plans, with maps, photographs and diagrams of the Solway Firth were produced, illustrating the area's past, present and the proposed (by SEG) future. The past was represented by historical maps dating from 1924 and 1931, showing the former railway bridge, which were placed next to old photographs of the former railway bridge (retrieved from Solway Energy Gateway, 2011). The present view was represented by a current Ordnance Survey map and contemporary aerial photograph (retrieved from Solway Energy Gateway, 2011). The proposed future was represented by maps and cross sections of the proposed SEG installation (provided by VerdErg, 2018). The purpose was to encourage KIs to think spatially and identify the issues that matter to them. Their values, views, and perceptions were collected via participatory diagramming and participant observation, as previously described.

Cycle 2 comprised one-to-one interviews with KIs previously met in cycle 1. Identified as a reflection phase in Table 3.2, the purpose was for each participant to reflect on the issues and views they raised in cycle 1, as represented as nodes in visual representations of their individual BBN. The engagement events were designed to facilitate co-analysis of the structure of their own BBN with individual stakeholders to discuss how the BBN reflected their views, what can be learnt and understood from the visual representation of their views and to consider any changes in beliefs and perceptions. The visual representations of the BBNs were used to facilitate participatory diagramming, where the KIs were asked to identify any changes, to (or omissions etc. from) the nodes shown and collaboratively contribute to the development of the BBN by sketching and directing amendments. Participant observation was used to collect qualitative data from this process.

In cycle 3, further one-to-one interviews were conducted to review the individual BBNs as well as the visual representations of other KIs' BBNs. The purpose was to review and reflect on their own and alternative views, to encourage learning and co-production of knowledge, contributing to further development of the BBNs. Cycle 3 aims to balance the individual sense of ownership, by maintaining individual models, and appreciation of other perspectives, by

reviewing a BBN produced by another KI. Visual representations of the individual BBNs were tabled and used to facilitate participatory diagramming. KIs were asked to review their own and another participant's BBN - for example, to comment on the inclusion of nodes and arcs. They were invited to add and direct amendments to the visual representations of the BBNs. Qualitative data were also collected by participant observation.

Cycle 4 was designed to comprise a reflective group event. The purpose was to explore the potential for collective learning and changes in beliefs and perspectives though interacting with a combined BBN. Previous studies (Smith, 2003; and Hegland & Wilson 2009) show that group elicitation encourages KIs to work towards the common good as self-interest positions become less defensible. This is identified as ideal of PEDM within the principle of process orientation and sub-principle of transformation and change, see Table 2.6. The aim was that visual representations of the combined BBN would be displayed to facilitate participatory diagramming, with KIs asked to direct and sketch comments and amendments to the combined model to further its development, while learning from alternative perspectives.

Cycle 5 was designed to comprise an exhibition to display the visual representations of the combined BBN. The purpose was to explore how stakeholders felt about: how the BBN incorporated, valued, and represented their beliefs; how their beliefs had changed; and what they learnt through interaction with the BBN. I planned to collect qualitative data at the Cycle 5 engagement event via participant observation and one-to-one interviews. The cycle was designed to obtain feedback from the KIs, recording their final thoughts on the combined BBN, so that changes in their beliefs from their original positions could be assessed.

The cycles of action and reflection facilitated an open and iterative design process. Phases of reflection provided opportunities for me to assess the data collected, which informed the approach to, and use of techniques in subsequent engagement events. Taking this iterative approach meant that the design of the cycles at the start of the process was more certain than the later cycles.

The effects of the iterative design, including how the data collected effected subsequent engagement events, are described in Chapter 4. However, it is worth mentioning here that

the results of the primary data collected in cycle 1, 2 and 3, resulted in significant changes to the planned group events and exhibition in cycles 4 and 5. Feedback from KIs indicated that it would be practically difficult to organise a successful event. A combination of the time and cost of stakeholders attending an event increased the participatory burden. There was also some resistance to committing to working as a group, associated with existing hostilities, as well as anxiety with working with the complex BBN modelling. Key informants had indicated in previous cycles that they wanted to review and annotate the visual representations in their own time. Therefore, I undertook more one-to one interviews in cycle 4, and replaced the group event / exhibition planned for cycle 5 with a postal correspondence, providing hard copies of the visual representations of the BBNs together with written explanations and guidance on providing feedback to provide the KIs with the space and flexibility to respond in their own way. As a result of this change, the consultation period (originally planned for August 2017 to August 2018) was extended (with the last contribution being received, by post, in August 2019).

Another minor change to the research design was that, at the suggestion of the KIs, occasionally I interviewed two KIs together, instead of the planned one-to-one interviews. Further details of these adaptations are provided in chapter 4

So far in this section I have described how PAR inspired a research framework, comprising cycles of action and reflection, and explained how it was implemented for data collection. To close this section, next I explain how the primary qualitative data were analysed within the research framework.

Data analysis

The qualitative data collected in each cycle from participatory diagramming and participant observation were analysed and used in three ways. First, as described above, the qualitative data collected in each cycle were analysed to inform subsequent cycles of engagement in the iterative research design (Reason, 2002). Second, to parametrise the BBNs the qualitative data were analysed and incorporated into the models (see Campbell *et al*, 2012). Third, the results of the analysis were used to explore how KIs interact with BBN modelling to address the research questions.

Table 3.2 describes the stages of data analysis embedded in the cycles of action and reflection and illustrates how the three uses of the data analysis are intertwined during the cycles. For simplicity I describe these three uses in turn, below.

Iterative design

Considering the participatory approach of this study, I used the theoretical ideals and practical criteria for PEDM to guide my reflections on, and adaptations made to the design during the cycles of engagement. As set out in Table 3.2, before the start of the cycles of engagement, the first phase of reflection states that the research design is compared to the principles and practical criteria for PEDM. This provided me with an opportunity to review the overall research design. For example, the practical criteria for inclusivity specifies that potential environmental impacts should be identified. To meet this criterion, the overall approach was to interview KIs representing a range of environmental issues and cycle 1 was designed to include KIs from the RSPB, NatureScot, Wetlands Trust. After cycle 1 I noted that several of the KIs were interested in the other stakeholders participating in the study and the range of perspectives included, and they made some helpful suggestions for additional KIs. The analysis revealed some patterns in the suggestions made and considering the participatory approach and the commitment to identify environmental impacts, I widened the range of KIs for subsequent cycles. I identified additional stakeholders, including those from Natural England and Solway Firth Partnership, which improved the range and diversity of voices representing environmental issues.

After each cycle the qualitative data were analysed to assess how the data collection process aligned with the principles and practical criteria of PEDM, I reflected on the results of the analysis and considered if any amendments should be made. For example, the principle of empowerment prescribes that to establish trust and respect, contributions from participants are unlimited and my (as the researcher) own ‘preferred outcome’ is set out transparently. The overall approach to meeting this criterion was to communicate on first contacting the KIs the purpose of the project and my background in renewable energy. As described in section 3.1, the choice of SEG as the exploratory case study was designed to position me as less knowledgeable than the KIs to reduce my own bias and prejudice on the preferred outcome.

Additionally, the cycles of engagement enabled the KIs to check and review their previous contributions to demonstrate they were recorded and valued. After cycle 1, I reflected that KIs accepted my position and motivation for the research. The KIs understood that the focus was the development of BBNs, and interest in the model varied between being put off (because it seemed too complex, or they had previous bad experiences of modelling) to very interested (because they had an academic interest, and / or liked the idea of an alternative approach to PEDM). In cycle 2, I used visual representations of the BBNs to transparently display their contributions from cycle 1. After the KIs reviewed their BBNs I analysed the qualitative data and reflected that some KIs expressed anxiety about getting their contributions 'right'. Their anxiety, associated with the complexity of the modelling and the sense of obligation to me, is discussed in detail in chapters 5 and 6. However, after cycle 2, I reflected that there needed to be a balance between encouraging KIs to develop a sense of ownership for their BBN and making them feel personally responsible for getting it right. To temper their anxiety, in cycle 3, I reassured the KIs that the success of my research did not depend on them producing the correct BBN and I introduced another KI's BBN to shift the focus on to the modelling rather than their own views and contributions.

I repeated this process of design, review, and adapt with each criterion for each cycle so that the research design could be adapted in accordance with the participatory approach. This created little cycles of action (design and adapt) and reflection (review) within each cycle of engagement: cycles within cycles, characteristic of PAR and co-operative inquiry (Reason, 2002). The cycles of reflection and adaptation enabled me to check both the research design and PEDM criteria before carrying out the study so that any adjustments could be made. The iterative research design provided opportunities for the adaptations to be made in response to feedback and primary data analysis. My reflections on the research design and adaptations made throughout its implementation are documented in chapter 4.

BBN modelling

As detailed, in Table 3.2 qualitative data from each cycle of engagement were incorporated into individual then combined BBNs for review in the subsequent cycles. To reduce the risk of consultation fatigue and the burden of committing time to participate in the research, I undertook the modelling between the engagement events.

In cycle 1, the participants are asked to identify issues that matter to them, why they matter and how they relate to each other. These data are used as a baseline for beliefs from which changes are assessed in the context of SEG. Between cycle 1 and 2, I analysed the data to identify patterns and themes to start to parametrise BBNs. The values and issues raised by each participant were identified and used to define nodes, the basis of the structure of BBNs. The individual BBNs were developed in subsequent cycles, starting with a review of visual representations of these nodes in cycle 2. After cycle 2 the qualitative data were analysed and informed the amendment of nodes, which were added, removed, combined, and / or split up. Connections between the nodes (arcs) were added, developing the structure of the models. Visual representations were produced to repeat the review and development process in cycle 3. After the cycle 3 engagement events, the qualitative data collected were analysed to inform the integration of the BBNs, to form a combined model. Themes and pattens were identified from the individual BBNs and qualitative data. Nodes were created from the issues raised, and arcs from the relationships identified in individual BBNs. The combined BBN was parametrised with weightings based on the importance of the issues and how sure people felt about them. Apparent conflicts in individual BBNs were evaluated using the qualitative data from previous cycles. Subsequent cycles of engagement provided KIs with the opportunity to review and resolve potential conflicts in the combined BBN. After cycle 4, the qualitative data collected from the participatory diagramming and participant observations were analysed and incorporated into the combined BBN, which were reviewed in the final cycle.

Addressing the research questions

The primary qualitative data were analysed to explore how KIs interact with BBN modelling to address the research questions: RQ 2, do the features and development of BBNs adequately capture, represent, deepen the understanding of, and communicate knowledge?; RQ 3, do the features of BBNs improve PEDM?; and RQ 4, how could BBNs be incorporated into PEDM to improve the MREI consenting process? The qualitative data were uploaded in to NVivo and coded thematically to address these research questions. The results of the data analysis are set out in Chapters 5 to 7.

To address RQ 2 the data were coded in NVivo according to how the BBNs translated and represented data from the KIs, and how the resultant visual representations communicated knowledge between KIs. Patterns and themes emerged from the process and were used to define new codes. Through the analysis I identified new themes and patterns, generating emergent codes to explore the causes and consequences of how the knowledge was incorporated in the BBNs. For example, I found that the process of building the BBNs had a range of effects on the KIs, which resulted in emergent codes, specifically: deepening and changing the KIs' own knowledge; facilitating individual reflection by slowing their thoughts; questioning the credibility of the evidence represented in the BBNs; enhancing learning; and increasing interest in and awareness of alternative perspectives. Conversely, through the analysis I also identified patterns of how knowledge was missing from and misrepresented and miscommunicated by the BBNs. I discovered how and why knowledge incorporated into the BBNs differed between KIs and for me as the researcher undertaking the modelling and explored what the consequences of these differences were. In accordance with the iterative research design, I adopted an exploratory approach to the analysis, where the results of the analysis generated a range of emergent codes. The emergent codes were used to investigate the causes and consequences of how BBNs capture, represent and communicate knowledge for a deeper exploration of RQ 2. The results of this analysis are set out in chapter 5.

To address RQ 3, the data were coded in NVivo according to the practical criteria associated with each principle and sub-principle of PEDM in turn. I cross-referenced these codes with the features of BBNs that have the potential to improve PEDM (visual representations, can be updated, and can incorporate qualitative data) (see section 1.2). For example, I coded for: including qualitative data and inclusivity; including qualitative data and process orientation; including qualitative data and empowerment; and including qualitative data and reflection. I worked through each code systematically to assess how the features of BBNs affected adherence to, or deviation from, each of the practical criteria for PEDM in turn. I also identified themes and patterns in the data that described the causes and consequences of the adherence to, or deviation from, each criterion. The results of this analysis are set out in chapter 6.

To address RQ 4, how the BBNs could be incorporated into PEDM, the qualitative data were coded in NVivo to capture the KIs' views on the current consenting and licencing process for marine renewables and where it needed to be improved. The KIs' views on where they could envisage BBNs contributing to PEDM was also coded. For example, some KIs reflected on situations where BBNs could be useful. This analysis is combined with the results from chapters 5 and 6 to address RQ 4; and the findings are set out in chapter 7.

In this section I have explained how and why the research design is based on cycles of action and reflection, characteristic of PAR. I set out how I planned to engage a range of KIs over 5 cycles of engagement, collecting data via participatory diagramming and participant engagement at engagement events. The process of co-producing BBNs with the KIs throughout the cycles of engagement was explained, and how the BBNs were incorporated into the data collection and analysis. The iterative approach enabled the design to be adapted in response to feedback from the KIs and the data analysis, and I explained how this changed the originally planned group events in cycles 4 and 5. In the next section I will reflect on the ethical and practical challenges associated with the research design, and how I addressed these challenges.

3.3 Ethical considerations and practical challenges

This section summarises the ethical and practical challenges associated with the research design, starting with adherence to generic research guidance, and then the specific issues associated with the methodology.

Newcastle University's Ethics Code of Conduct (Newcastle University, 2018) was strictly observed. Ethical approval for the research was obtained on 29 November 2016, and the study was assessed as low risk. The research design, collecting qualitative data from human subjects, raised some generic ethical considerations associated with participant confidentiality and consent. As the participants were all adults and the subject of the study was not deemed sensitive no special permissions or precautions were deemed necessary.

The research data were managed in accordance with current guidance (ESRC, 2020; and Newcastle University, 2018). In accordance with Newcastle University's Ethics Code of

Conduct (Newcastle University, 2018) respect for participants' confidentiality was upheld. Informed consent was obtained from each of the KIs, who were asked to complete a consent form (copy in Appendix I) indicating that they understood the purpose of the research and that the data collected could be used in the thesis. Copies of the completed consent forms are available upon request.

The consent form asked the participants to specify if they wanted their identities to be anonymised or be recognised as sources; all the KIs requested that their identities were anonymised. To preserve the anonymity of the participants, each was assigned a unique code (see Table 3.3). Each code was allocated to the same KI throughout the study to enable me to monitor changes with time. Basic descriptions of their perspectives, in relation to the case study, are provided to demonstrate the diversity of participants (see section 3.2), without providing details that could facilitate identification of individuals.

In accordance with ESRC (2020) guidance, participation in the study was voluntary and participants could withdraw from the research at any time. This information was included in the invitations to participate and reiterated during the first contact with the prospective KIs. I did not coerce anyone into participation and after contacting them once to invite them to participate I did not chase them up if they did not respond. For example, in cycle 2, KI-M did not respond to an invitation to participate and I did not chase up on the invitation. I also accepted it was not realistic to expect all the KIs to contribute to each cycle. The results, presented in chapters 4 and 5, describe how different KIs joined and disengaged from the cycles and the effects that had on the PEDM process.

Participatory research, including PAR, commits to research with, not on, participants and co-production is widely regarding *as a method by which top-down and elitist structures within policy making and academia may be overcome* (Flinders *et al*, 2016, p. 271). According to Banks & Manners (2012), participatory research (including PAR) is guided by ethical principles that generally include: mutual respect; equality and inclusion; democratic participation; active learning; and personal integrity. However, using this approach does not circumvent ethical considerations (Cahill *et al*, 2007). The PAR-inspired approach did raise some specific ethical considerations and it was important to ensure that the ethical principles of

participatory research were implemented. As the PAR-inspired approach aligns with the principles for PEDM (see section 3.1), the principles of PEDM were used as a framework for implementing the ethical research principles throughout this study, as explained below.

The ethical research principle of mutual respect was implemented into the research design by adhering to the practical criteria associated with the PEDM sub-principle of trust and respect. To establish mutual respect between the KIs and me, the research design comprised cycles of engagement, where I took time during the first cycles to establish a good working relationship and explain the motivation, aims and purpose of the study. Revisiting KIs in cycles enabled the KIs to check and review their previous contributions and gave me time to understand the issues that matter to them. These revisits enabled trust and respect between the KIs and me to develop.

The selection of SEG as the research case study was also designed to cultivate trust and respect between the KIs and me. As explained in section 3.1, SEG was deliberately chosen to position me as less knowledgeable than the KIs. This was designed to promote the value of the KIs contributions and reduced my own prejudice and bias, and to enhance trust between the KIs and me.

To cultivate respect between the KIs, the research was designed to adhere to the principle of process-orientation, by encouraging the participants to reach mutual understanding. To achieve this, the cycles of engagement were designed to enable knowledge to be shared using the visual representations of the BBNs, encouraging the KIs to appreciate, query and understand alternative views.

The ethical research principles of equality and inclusion, and democratic participation were implemented into the research design by adhering to the practical criteria associated with the PEDM principle of inclusivity. Snowball sampling was used to reach out to stakeholders beyond those immediately affected and experts, and to ensure diverse voice were included. Participatory diagramming and visual representations of BBNs were used to improve inclusion by providing alternative and accessible tools of engagement. Equal access and opportunities to participate were facilitated by having the consultation period open for a sustained period

(between August 2017 and August 2018). Establishing and publishing the cycles of engagement in a timetable was designed to optimise awareness of the opportunities to participate.

To facilitate the inclusion of, and equality between, expert and non-expert voices, the practical criteria associated with the sub-principle of 'multiple and diverse perspectives and voices are heard and represented', prescribes that experts and non-experts are engaged in co-production and co-analysis of knowledge. This is designed to narrow the distinction between experts and non-experts. However, it is recognised that narrowing the gap between expert and non-expert, does raise other ethical concerns. Blurring the boundaries between researcher and researched presents risks associated with breaching privacy and confidentiality, as well as mixing professional and personal issues (Durham Community Research Team, 2011). These risks are reduced by the non-sensitive and non-personal research topic. In addition, the research design affords limited contact time with KIs; one-to-one interviews as opposed to more immersive design such as ethnography, for example.

The ethical research principles of active learning and personal integrity were implemented into the research design by adhering to the PEDM sub-principle of transformation and change. Ideally, PEDM should facilitate learning and encourage participants to transform their positions of self-interest into ethically defensible and 'common good' positions. To achieve these ideals, the associated practical criterion prescribes that systems are provided to communicate information and knowledge as it changes, before, during and after decision and action points. To implement this criterion in the study, the cycles of engagement were designed to enable communication, co-production, and co-analysis of knowledge around phases of reflection and action.

Although participatory research provides ethical principles, scholars have raised some specific ethical issues with its use. First, there are concerns regarding who has the authority to represent the other stakeholders (Cahill *et al*, 2007). The risk is that 'local knowledge' is perceived in *one homogenous data set* that can be represented by dominant individuals within a community, further marginalising minority voices; the use of self-selection can emphasise this problem (Flinders *et al*, 2016, p. 271). To address this, the research was

designed to ensure that opposing voices were included (as summarised in Table 3.3). Although self-selection was possible, as described in section 3.2, all the KIs were identified via snowball sampling. Participants were able to join and disengage with the process during the cycles of engagement, facilitating diversity. It was also recognised that due to the small sample size, the qualitative data collected from the KIs would not be representative (see section 3.2), reducing the temptation to homogenise the data to represent the population.

Second, the participatory approach raises ethical concerns about how the data are framed and interpreted. In this study, these concerns are emphasised by using a case study and visual representations of BBNs that involve obtaining and then reassembling narratives. As described in section 3.2 and documented in chapter 4, I undertook the modelling of the BBNs between the engagement events to reduce the participatory burden on the KIs. This required me to interpret their views and translate them into the models independently of the KIs, using my subjective judgment. This approach raised the risk of the KIs' views being misinterpreted and misrepresented in the BBNs. This risk was highest after cycle 3, when I combined the individual BBNs into one integrated model, which required me to apply more of my subjective judgement to interpret and translate the KIs' data than in previous cycles. To manage this risk, the cycles of engagement were designed to provide opportunities for the KIs to review and amend the interpretation and representation of their previous contributions within the visual representations of the BBNs. After combining the models after cycle 3, the KIs had two more opportunities to review the combined models in the remaining cycles of engagement. This iterative review process, facilitated by the cycles of engagement, which is integral to the research design (see section 3.2), reduces the risks associated with reassembling narratives.

Thirdly, co-production of knowledge can be *time-consuming…. complex, [and] emotionally demanding* (Flinders *et al*, 2016. p. 266). To ease the burden of participation, I arranged the engagement events at the time and place of convenience of each KI. I also undertook the modelling of the BBNs between cycles.

There were practical challenges to implementing the research approach. However, the iterative design and cycles of engagement enabled me to address these during the process. For example, as discussed in section 3.2, as logistical difficulties associated with organising

well-attended group events were raised, I was able to evaluate the risks of increasing the participatory burden compared with the potential benefits of holding the planned group events. Obtaining and analysing the data from cycles 1 to 3 enabled me to redesign the data collection in cycles 4 and 5 to address these practical challenges.

The iterative design also enabled me to respond to specific anxieties the KIs expressed to maintain adherence to the ethical principles. As stated above, the case study was not deemed sensitive in terms of requiring extra ethical protections such as safeguarding vulnerable people. However, it became clear in cycle 1 that discussing a proposed development, which may be subject to a future, formal consenting, and licencing process, is professionally and commercially sensitive. Several of the KIs expressed a degree of discomfort and anxiety about the ways in which their contributions could be used and how they could affect a future application for consent, which they could be held professionally responsible for. Although KI-F reflected that participation in the research was relatively easy because it "was not a work consultation", in cycle 1 he expressed anxiety about being audio recorded. He continually referred to the "tape" throughout the interview. He often emphasised that what he said might not comprehensively represent the views of their organisation (as a statutory consultee) and referred me to their organisation's official responses to previous tidal applications that "comprehensively" cover their position and the requirement for "appropriate assessment". Moreover, when the "tape" was switched off KI-F visibly relaxed and added some (non-substantive) thoughts and reflections, illustrating the anxiety he felt about being caught out by recorded evidence of his own views if SEG went to application stage. To address these concerns, I replaced the audio recording with participant observation (as described in section 3.2), demonstrating how the iterative design enabled me to manage this challenge.

In this section I have described the ethical and practical challenges associated with the research design. I have explained how the iterative design (described in section 3.2) was instrumental in address these challenges as they arose.

The methodology is summarised in the next section before I present the results of the data collection in chapter 4.

3.4 Summary

In this chapter, I have explained how the hypothesis was tested. I explained the use of a PAR-inspired framework for data collection, comprising cycles of action and reflection to bring together the theoretical and practical elements of the study. The use of the PAR-inspired framework built on the purpose of this study; to improve PEDM by addressing the gap between theory and practice. Theoretically, the PAR approach aligns with the criteria for PEDM. Practically, the PAR-inspired stages of action and reflection provides a systematic framework of collaborative data collection and analysis, which the research design is based on. Cycles of engagement including reflection and action points provide the basis for a timetable of data collection (Table 3.3). Participatory diagramming and participant observation were used to record contributions, which were then incorporated into BBNs. Visual representations of the BBNs, representing co-produced knowledge, were tested, and developed with key informants in subsequent cycles of engagement. Qualitative data from the cycles of engagement were analysed to determine if and how the use of BBNs improves PEDM in the case of SEG and evaluated through participatory diagramming and participant observation.

I explained that independently there is nothing unique about the elements of the research design but bringing these elements together in this study is novel. Bringing together the PAR-inspired framework and BBNs in this study has interrelated benefits. The PAR-inspired framework reconciles theoretical and methodological approaches and provides techniques to initiate the modelling process. BBNs build on the use of PAR, providing ways to introduce sophisticated modelling, to incorporate empirical data and enhance opportunities for learning and transformation of prior beliefs.

Crucially, this study does not just test the use of BBNs in PEDM, rather, it tests the use of BBNs in an approach informed by principles of PEDM. This chapter has explained how this was achieved; using BBNs in the PAR-inspired framework, where the models are developed from co-produced knowledge, which is then tested, evaluated, and updated in cycles of engagement. A diverse group of stakeholders (key informants) in SEG were engaged to record and analyse changes in beliefs and perceptions through interaction with BBN modelling. The

BBNs in the case of SEG, were used to evaluate if and how BBNs could be rolled out to other PEDM projects. An understanding of how and why stakeholder beliefs and perceptions change though interaction with BBN modelling was used to address the research questions.

Practical and ethical challenges were expected during data collection. The research design enabled me to address these iteratively. The phases of action and reflection enabled me to reflect on and act on specific challenges as they arose, so that the approach to subsequent cycles of engagement could be amended accordingly. My reflections and adaptations to the ethical and practical challenges that arose during the research are described in chapter 4.

Chapter 4. How primary data, as stories and information, were translated and incorporated into the BBNs

This chapter describes how BBNs were developed with KIs and the challenges faced during that development. The results of the primary data collection are presented, explaining how the data, as stories and information, were translated and incorporated into the BBNs during each cycle of data collection and modelling. A deeper discussion of what the primary data say about the ability of the BBNs to capture and produce knowledge is provided in Chapter 5, which describes what happened to knowledge during development of the BBNs. The evaluation of knowledge development during the development of BBNs is provided in chapter 6, in the context of the practical criteria for the right kind of PEDM (set out in Table 2.6).

This chapter documents the development of the BBNs over each of the five cycles of engagement, which are described in turn. I explain what, when, and how knowledge was produced in each cycle and how knowledge was incorporated into the BBNs, copies of which are presented in Appendix II. I explain how visual representations of the BBNs were presented to each KI in each cycle. I reflect on the results in Chapter 5, considering how the primary data were included, translated, reduced, and / or lost in the features of BBNs and their development.

In accordance with the iterative approach, the results of each cycle of engagement informed the approach to the next, resulting in variation from the timetable for data collection set out in Table 3.4. Reflecting on KIs' reactions to specific events after each meeting prompted and informed amendments to future engagement, which is explained in this chapter. This included changing the planned group activity in cycle 5 to engaging individuals by post in response to hostility between stakeholders and increasing participatory burden.

Deviations from the original research design are explained. Table 4.1, overleaf, summarises what and when the research was undertaken. Data collection was undertaken between August 2017 and August 2019.

The list of attendees at previous meetings was used to identify established stakeholders and initiate engagement (Armstrong & Banks, 2011). I subsequently used snowball sampling to expand the range of KIs. The process of participant engagement is explained in section 3.2.

Table 4.1 Summary of the data collection activities completed

Cycle	Main activities	Method of engagement	Dates	No. of KIs
1	Introduced myself and research to establish trust. Identified issues. Set up individual BBNs with nodes representing issues identified.	interviews	August – September 2017	12
2	Review individual BBNs and think about issues. Revise nodes and add arcs to individual BBNs.	Interviews and public meeting	November 2017 – January 2018	8
3	Specifying the model and comparing it with someone else's model. Individual BBNs combined into an integrated model.	Interviews	February – April 2018	8 (4 were new)
4	Reviewing the integrated model with KIs. Revised integrated model.	Interviews	June 2018	3
5	KIs reviewed the integrated model and provided final reflections.	Written consultation	August 2018 – August 2019	7

4.1 Cycle 1*:* First meetings to identify issues

The initial interviews were arranged via telephone and email correspondence with established stakeholders, identified from the minutes of previous SEG meetings and snowball sampling, as described in section 3.2. The cycle 1 engagement events took place between 2 August and 21 September 2017 with twelve KIs representing nine organisations. The first meeting was with KI-J and KI-P, part of the SEG development team, on 2 August 2017 at their office. This meeting provided some additional technical information on the proposed scheme before meeting other KIs. KI-J and KI-P provided various schematic plans of the proposed scheme that were incorporated into the PDs used in the remaining cycle 1 engagement events.

KI-M from a Council-funded conservation body located in Silloth, Cumbria was interviewed on the 10 August 2017. KI-M's role is focused on conservation of designated wetland habitats

in the vicinity of Bowness-on-Solway, which a former (now dismantled) railway cut through and had adversely impacted. Considering the connection between the proposed tidal scheme at SEG and the former railway, SEG being located on the route of the former railway, KI-M recommended that a local resident who has knowledge and interest in the former railway should be invited to contribute to this study. Subsequently, KI-A was contacted, and an interview was arranged with them on 29 August 2017 at the Golf Hotel in Silloth; a venue chosen by KI-A.

KI-I and KI-H from a local Parish Council were interviewed on the 10 August 2017 at the home of KI-I near to Bowness-on-Solway, at their convenience. On 11 August KI-D representing a Scottish Government conservation organisation was interviewed at their offices in Dumfries. KI-B, part of the SEG development team, was interviewed on 16 August, at their home in Cumbria. KI-G, representing Marine Scotland was interviewed on 21 August at the Scottish Government offices in Edinburgh, and KI-F representing a conservation charity was interviewed near Castle Douglas on 17 August. Finally, KI-O and KI-E, representing a conservation charity, were interviewed at their office near Bowness-on-Solway on 21 September 2017.

The Cycle 1 interviews were designed to establish relationships with the KIs and to establish baseline data to populate BBN models. To establish relationships and build rapport with the KIs, as the basis for trust and respect (DeJonckheere & Vaughn, 2019), I began the interviews by explaining the research in the context of my career in renewable energy, the motivations for the research, and that I am pro-renewable energy. I established early in the interviews that, although I had work experience in the renewable energy sector and had lived in Cumbria, I was unfamiliar with tidal technology and the Solway Firth. I explained that I had deliberately chosen SEG as a case study to reduce my own prejudice and bias. I also emphasised that the purpose of the research was not to determine the suitability of SEG, but to test the use of BBNs in PEDM. This established me (as much as possible) as a neutral researcher in a potentially high stakes subject, respecting the potential professional and personal risks of participating in the research in the context of a future application.

To establish baseline data to populate BBN models, during the interviews, each participant was asked to identify what issues relating to SEG and the Solway Firth were important to them, why these issues matter, and what the relationships are between these issues. Open discussions were held around maps, photographs, and diagrams to stimulate thoughts about the area (current map), history (historical map) and proposed scheme (plans of the proposed scheme). Recording the data represented the first stage of translating the KIs' views and values into the BBN models.

To capture the knowledge from the cycle 1 interviews, I made notes and annotated the maps, photographs, and diagrams to record what mattered to each participant, a sense of importance that the KIs' attached to the issues raised, and the relationships between the issues raised. Figures 4.1 to 4.3 show examples of annotated plans produced in cycle 1 with KI-B. This information is used to populate the first BBN modelling and acts as a baseline to gauge changes in views and perceptions.

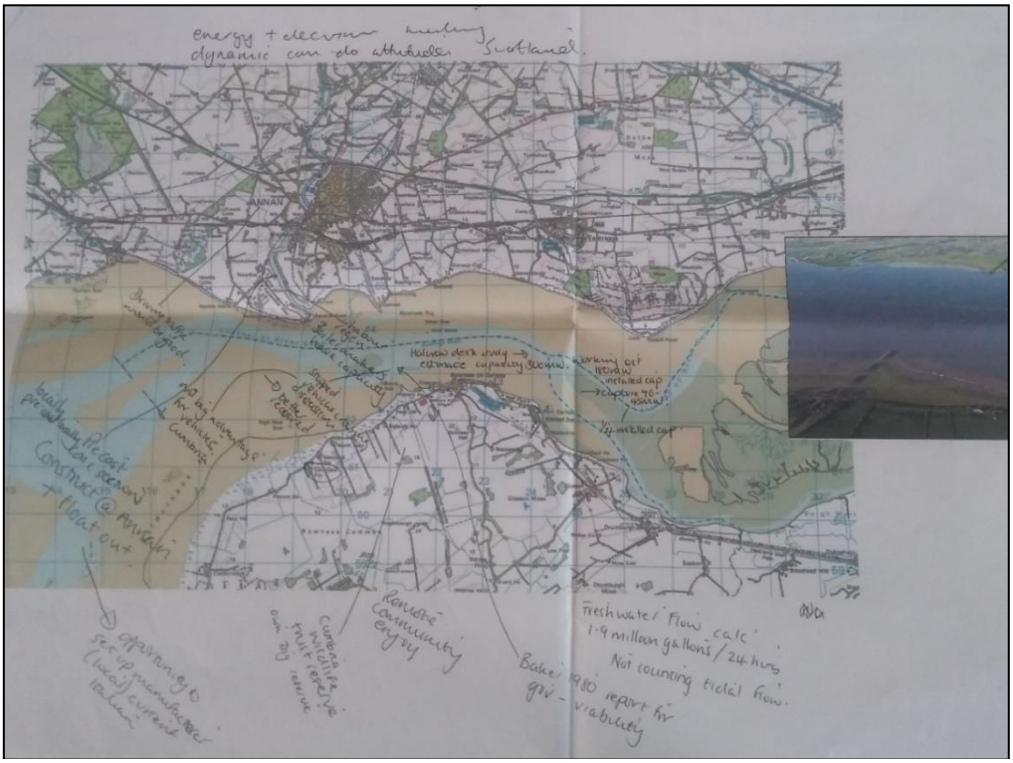

Figure 4.1 Map of Solway Firth and aerial photograph (Solway Energy Gateway Ltd., 2011) annotated in cycle 1 with KI-B

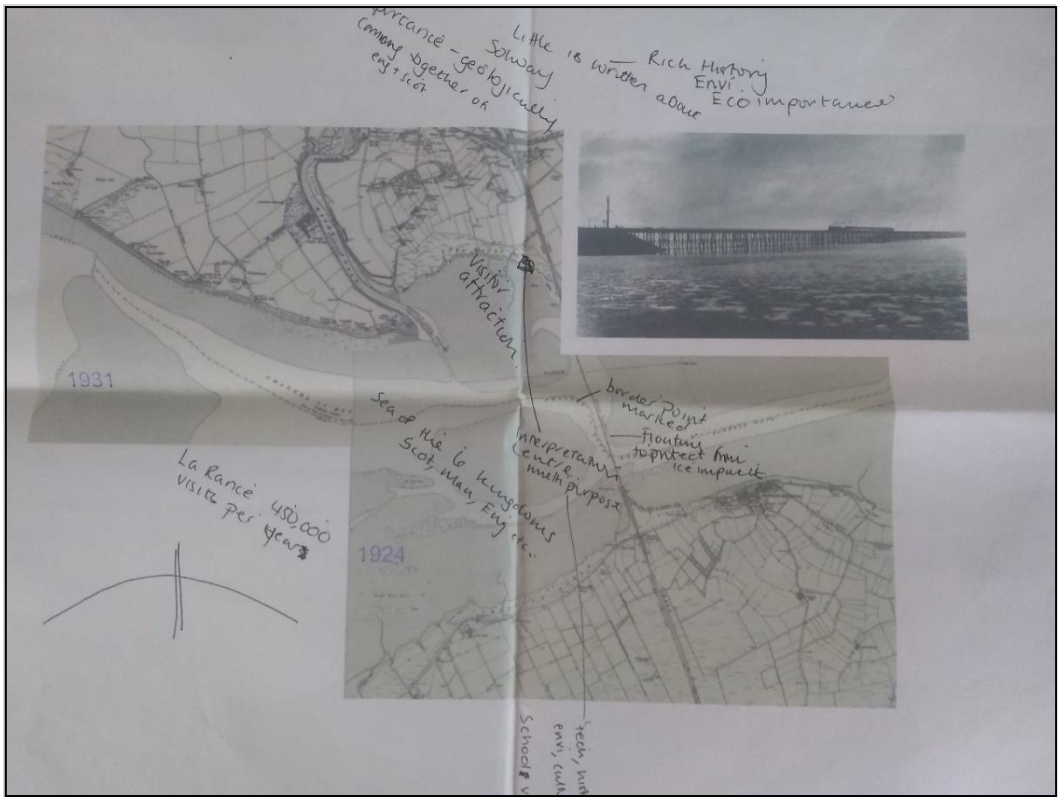

Figure 4.2 Historical maps and photograph (Solway Energy Gateway Ltd., 2011) annotated with KI-B in cycle 1

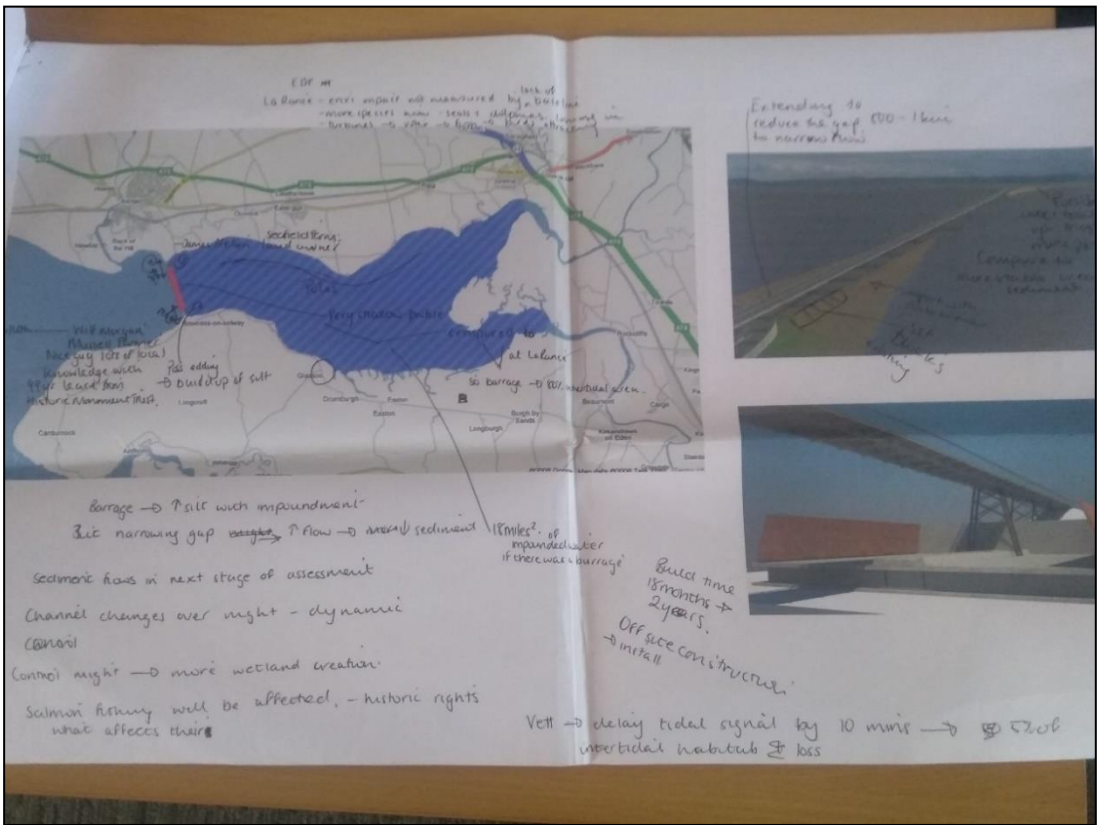

Figure 4.3 Proposed structure (Roberts & Daly, 2014) annotated with KI-B in cycle 1

Detailed reflections on how the KIs engaged and the challenges raised in each cycle are provided in Chapter 5, and only general observations are provided here. Generally, the KIs were engaged throughout the discussions. Some KIs were initially unenthusiastic about meeting me. For example, when I phoned KI-H to ask for a meeting, he stated that he was unsure what he could contribute as SEG was not a live application and suggested I should "walk around Bowness to find out about it". After further email correspondence, explaining the purpose of my research, KI-H confirmed that he and KI-I would meet me but emphasised a lack of time and that a meeting would be limited to one hour. However, despite some initial resistance I spoke to each KI for around 1 hour, and in the case of KI-I and KI-H, for 4 hours. Most had strong opinions about the proposals for tidal energy in the Solway Firth and were keen to discuss the issues they valued. A high volume and diverse range of issues were identified. I anticipated (considering the recognised impacts of tidal range technology, see Chapter 1), focusing especially on SEG's impact on the living environment. However, the emphasis that KIs placed on specific issues differed widely. For example, KIs associated with the SEG development team (e.g. KI-P and KI-B) emphasised generic impacts of tidal schemes such as the impact on fish species during operation. In contrast, local stakeholders (e.g. KI-A, KI-D, KI-H and KI-I) emphasised site-specific impacts such as bird populations and intertidal species. Perhaps more surprisingly, many of the KIs spoke at length about the local history of the area. I had not anticipated the value local KIs particularly placed on the distinctive local identity, which was often revealed in stories. For example, KI-M spoke about the connections between agriculture and a former monastery and Abbey at Abbeytown, Cumbria, where he said the Monks had kept sheep and produced salt in coastal salt pans that was used to preserve meat and as a commodity.

The maps and diagrams provided a good focus for discussions and prompted contributions from KIs, who were able to point out features on the map to relate and situate their points. Although I encouraged KIs to annotate the maps, none did. KI-P did draw a small sketch in the corner of one of the flip-chart sheets, but there was general hesitancy about infringing on materials I had brought. To encourage contributions, I tentatively introduced alternative views as cycle 1 progressed and I accrued knowledge from others to facilitate learning and to communicate new knowledge. As the interviews moved on, I contributed more, indicating accumulation of knowledge. As the cycle progressed, I orally shared increasing knowledge

with the participants, e.g. historical stories about people crossing the Solway for work, family and to steal the church bells! I reflect on the privilege of being the researcher and primary receiver of knowledge in Chapter 5.

Prior to the production of the BBN models most KIs did not express specific thoughts on BBN modelling, except KI-E who, based on previous experience, was concerned that modelling enables decision makers to "trade off nature for jobs". KI-E also raised concerns about the capacity of the BBN modelling, considering that "there is no baseline information about sedimentation in the Solway", which makes it "impossible to model the potential impact" [of a proposed tidal scheme].

During cycle 1 some of the KIs indicated they felt uncomfortable due to the commercial sensitivity of the project, and fear that their views could be used either against, or in place of assessments during a formal assessment process. For example, KI-J and KI-P refused to be recorded, and although KI-F did agree to be recorded they displayed discomfort throughout, continuously looking at the recorder and emphasising that I "shouldn't just rely on [their]… word and the tape". When I switched the recorder off at the end of the interview, KI-F seemed to relax and spoke more freely about issues, including specific designated sites and other stakeholders. Following these incidents, I moved to keeping records of the qualitative data (not by audio recording) by note-taking and participatory diagramming (as discussed in section 3.2).

Modelling after cycle 1: nodes

The knowledge captured during cycle 1 was used to create the first BBN models and acts as a baseline to gauge changes in views and perceptions. An individual BBN was produced for each KI with nodes representing each issue, see Figure 4.4.

Copies of the individual BBNs are provided in Appendix II. There were many issues commonly raised by KIs, which therefore feature in most of the individual models. Potential impacts on bird populations and the tide were raised by most KIs, followed by impact on local history / heritage, fish stocks, intertidal habitats, and the sedimentation regime. In contrast, visual impact, agriculture, and flood risk were among the issues raised by the fewest KIs.

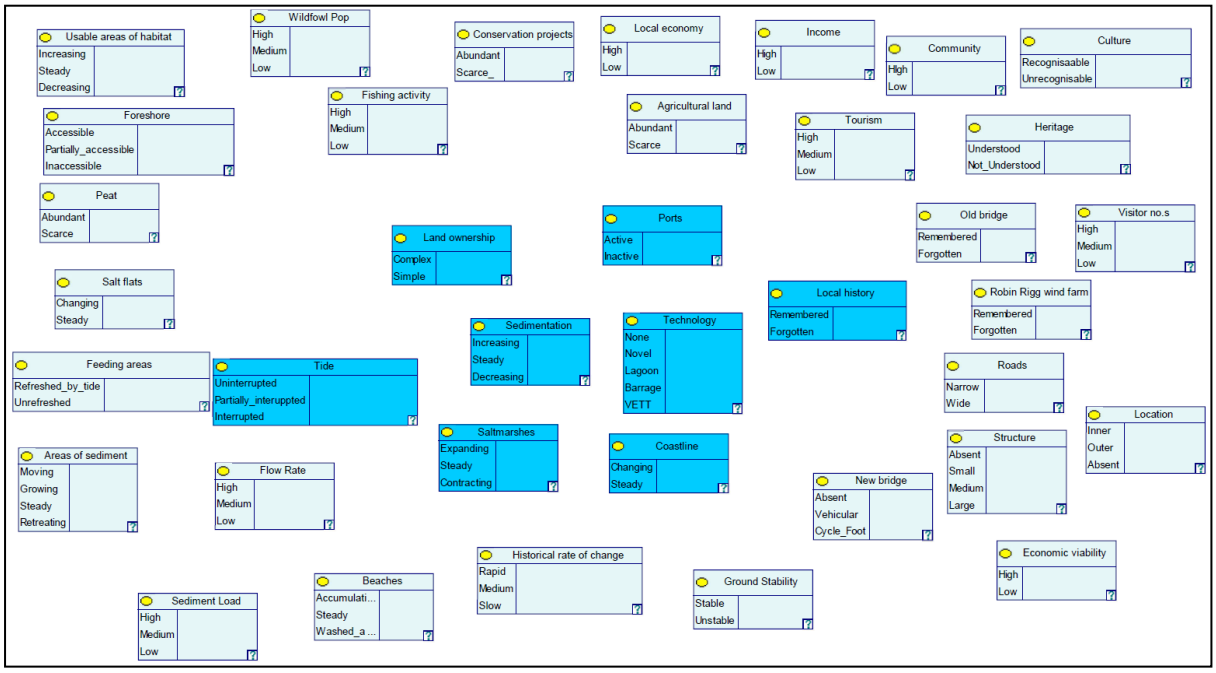

Figure 4.4 BBN model developed in cycle 1 with KI-A; nodes represent the issues raised during one-to-one interview. The issues mentioned most often were represented by the nodes placed in the centre of the diagram and coloured a deeper blue, so they could be easily identified and focused on if time was limited.

As well as identifying all the issues raised by KIs, I also identified the five to ten most frequently raised issues by the individual KIs to get an indication of their relative value to the contributor. Table 4.2 summarises the issues each KI most frequently raised in cycle 1. Frequently raised issues, common among the KIs in cycle 1 include: sedimentation (frequently raised by KI-A, KI-E and KI-O, and KI-F); community (frequently raised by KI-B, KI-D, KI-G, KI-H and KI-I); birds populations and the protection of birds (e.g. RSPB reserves) (frequently raised by KI-D, KI-E and KI-O, KI-F, KI-H and KI-I); and coastal habitats, including saltmarshes, bogs and marshes (frequently raised by KI-A, KI-F, KI-H and KI-I, KI-M).

Table 4.2 Summary of issues raised most frequently by KIs in cycle 1

KI	Issues raised most frequently listed in order starting with the most frequent
KI-A	Sedimentation; technology; coastline; saltmarshes; ports; tides; landownership
KI-B	New bridge; community; construction/ civils; fishing; location; local history; flood risk; stakeholder engagement
KI-D	Recreation; bird populations; designated sites; landscape; community engagement; wading birds; walking routes; access
KI-E and KI-O	Fish stocks; sedimentation; RSPB reserves; feeding areas for birds; technology design; Haaf Netters
KI-F	Change; bird populations; intertidal areas; sedimentation; designated features / sites
KI-G	Community; EIA; procedures; jobs; visual impact; data; stakeholder representation
KI-H and KI-I	Community; bog / marsh habitats; visitor numbers; isolation / quietness; procedures / administration; RSPB reserves; fishing
KI-J and KI-P	Cost; Environment Agency (EA) approval; fish behaviour; ecological impact; parts (technology)
KI-M	Bog habitats; visitor numbers; Haaf netting; old railway; communication; local history

When translating the primary data into BBNs, choices needed to be made about the level of detail incorporated. For example, some KIs discussed individual species of birds and fish, as well as bird populations and fish stocks more generally. Too much detail would result in too many nodes and the visual representations of the models would appear too complex and possibly daunting, which could reduce engagement. I managed this problem in two ways. First, I grouped some issues together under single nodes and made notes to review these nodes in cycle 2 with the individual KIs. For example, I asked KI-D if they wanted lamprey and migratory salmon to be represented as separate nodes, as well as a 'fish stocks' node. Second, I highlighted the nodes representing the five to ten issues each KI had either specified as priorities or mentioned most often during cycle 1, which were translated as 'priority nodes'. These 'priority nodes' were coloured a deeper blue so that they could be easily identified. As stated in Table 4.2, Figure 4.4 illustrates that the issues mentioned most frequently by KI-A in cycle 1 were: sedimentation; technology; coastline; saltmarshes; ports; tides; landownership.

4.2 Cycle 2: Reviewing issues and thinking more about them

The issues KIs had raised in cycle 1 (prior beliefs) had been captured, translated, and incorporated into the individual BBNs. The purpose of the cycle 2 interviews was to interrogate the KIs' prior beliefs (represented as nodes, see Figure 4.4) and to contribute to the development of the BBNs. One-to-one interviews were undertaken with KIs to review visual representation of BBN models and consider why each issue raised in cycle 1 mattered.

Nine of the KIs from cycle 1 were contacted and invited to participate in cycle 2. Some of the previously engaged KIs (e.g. KI-O) had already stated that they were too busy to participate in further cycles. Eight of the nine KIs invited replied and agreed to participate. In accordance with current ethical guidance (see section 3.3) I did not coerce anyone into participation, so I did not chase up the non-responder (KI-M). I also accepted it was not realistic to expect all the KIs to contribute to each cycle and that it would be interesting to consider how KIs were affected by moving in and out of the process.

KI-A and KI-B were interviewed on the 16 November and 17 November 2017, respectively. KI-A was interviewed at the Cumbria Wildlife Trust offices near Carlisle, at their suggestion. KI-B was interviewed at their home. From conservation charities, KI-E was interviewed at their office in Lancaster on 30 November and KI-F interviewed in their office near Castle Douglas on 11 December 2017. From the Scottish Government organisations, KI-G was interviewed at the Scottish Government offices in Edinburgh on 5 December and KI-D was interviewed in their office in Dumfries on 6 December 2017. KI-H and KI-I declined another interview but invited me to speak at a Parish Council meeting in Port Carlisle on 10 January 2018 (Bowness-on-Solway Parish Council, 2018). This represented a deviation from the data collection timetable but given the flexibility in the design and participant led approach, I accepted this invitation and provided a short presentation to the Parish Councillors with questions and answers at the end.

To contribute to the development (co-development) of the BBN models, each KI was presented with visual representations of the BBN models constructed from data collected from cycle 1 (Figures 4.4 and 4.5). Each of the models displayed nodes representing the issues raised during cycle 1.

At the start of cycle 2, the five to ten nodes mentioned most often were placed in the central sector of the diagram and coloured a deeper blue so that they could be easily identified and focused on if time was limited (see Figure 4.4). However, the first 2 KIs interviewed in cycle 2, KI-A and KI-B appeared confused by the colouring. Distinguishing the dark blue nodes as priority issues gave the impression they would be weighted differently by the model, which KI-A became unnecessarily concerned with. Therefore, for the rest of the interviews I coloured the nodes by theme, e.g., living environment, physical environment, economy, social, etc. but arranged the nodes mentioned most often in cycle 1 in the centre of the visual representations, as shown in Figure 4.5.

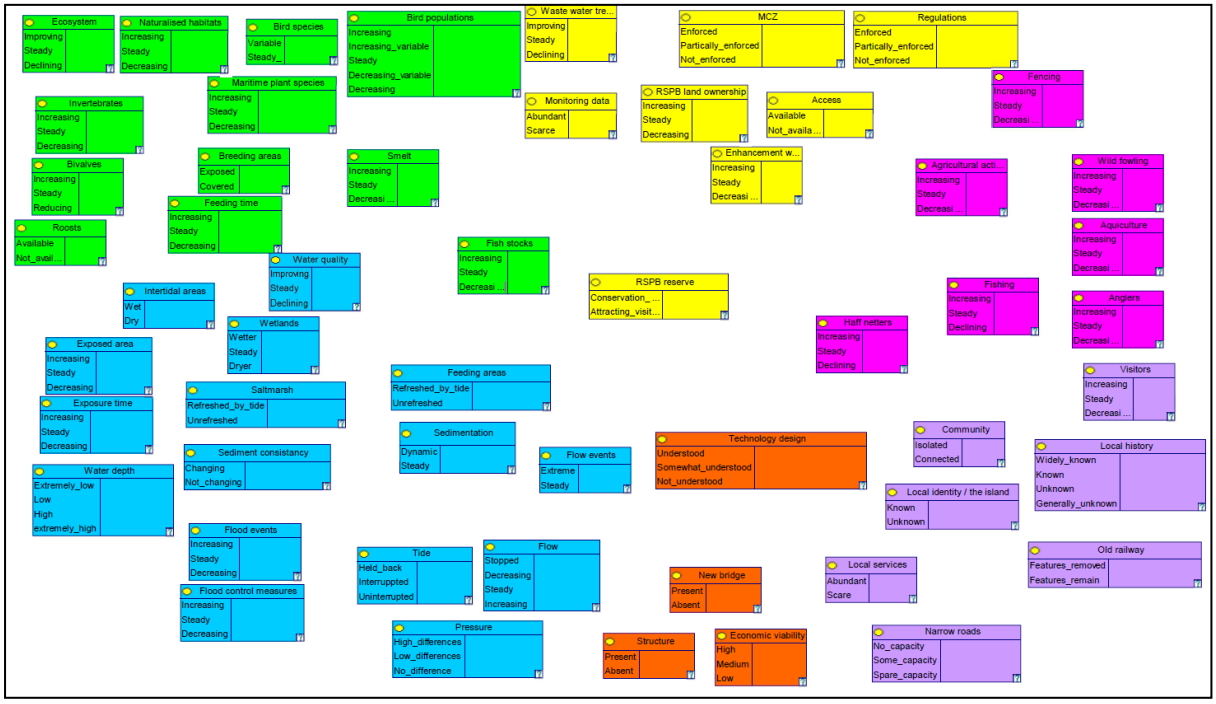

Figure 4.5 BBN model developed in cycle 1 with KI-E; nodes represent the issues raised during one-to-one interview. Priority nodes (those mentioned most often in cycle 1) were positioned in the centre (fish stocks, sedimentation, RSPB reserves, technology design, and Haaf Netters).

Each of the KIs were asked to identify irrelevant nodes that should be deleted; any missing issues, where nodes should be added; if any nodes could be merged; or if nodes should be split up to provide more detail. The KIs were also asked to consider why each issue mattered so that the 'states' of each node could be defined and invited to consider the relationships between nodes so that arcs could be added. For many nodes, it was logical for the states to be defined as quantities. For example, KI-B considered that the quantity of 'fish stocks' is

important, so the states of the 'fish stocks' node were defined as 'increasing, steady, or declining' (see Figure 4.6). However, defining other nodes was more challenging. For example, KI-B defined the states of their community node as 'marginalised, forgotten, sustainable or flourishing', where "flourishing represents a level above sustainable that ……. depends on income and pride".

To capture the knowledge, I annotated the visual representations of the individual KI's model, adding nodes, states, and arcs (see Figure 4.6).

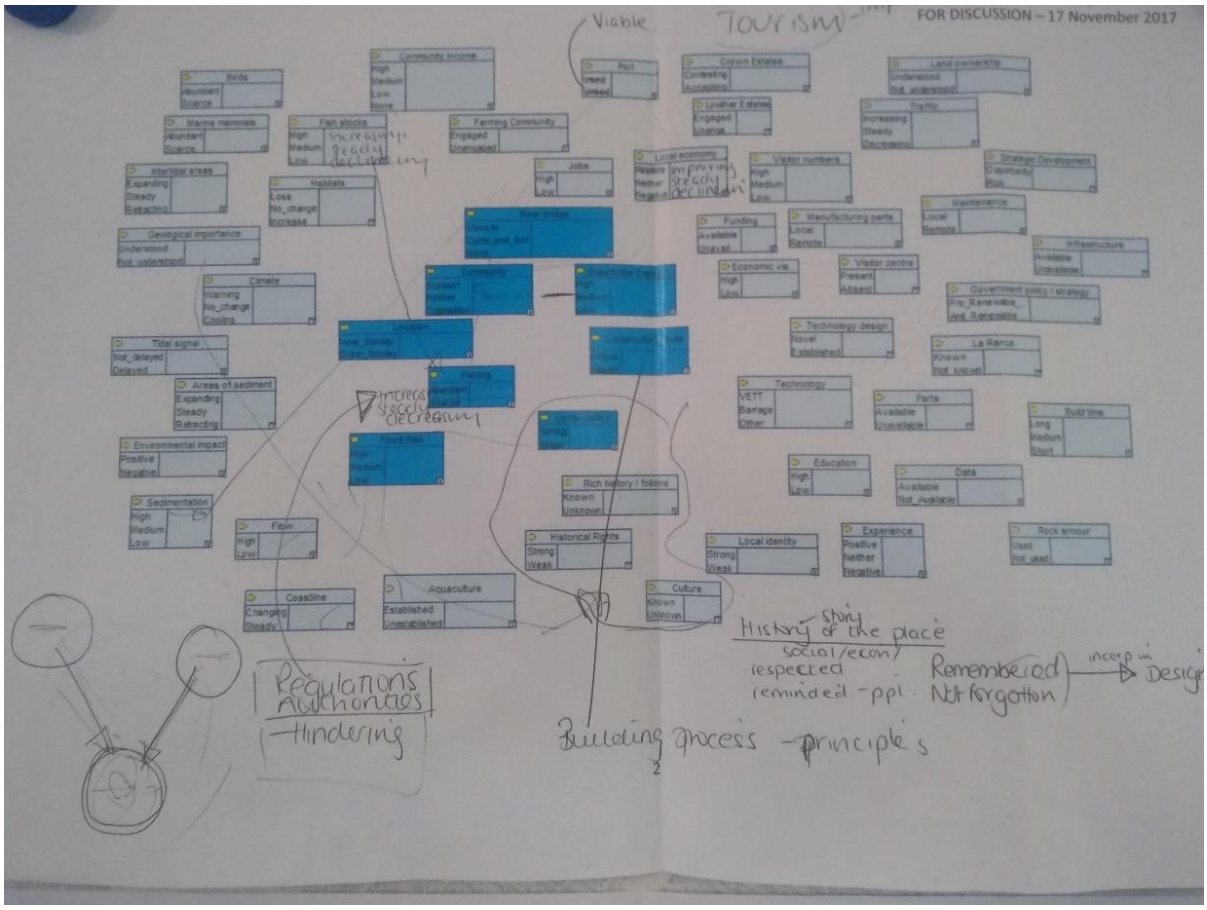

Figure 4.6 Cycle 1 visual representation annotated with KI-B in cycle 2

Identifying the themes by colour worked well. KI-E stated that it provided a "logical 'order" to work round the nodes. I explained that those that were 'mentioned' the most last time were near the centre, working out to the edges as issues were mentioned less often, which KI-E understood straight away and did not get as distracted by the priorities as KI-A and KI-B.

In accordance with the participant-led approach, I set out the purpose of the meeting but allowed the KIs to discuss what they wanted with their model in front of them. However, I sensed some frustration with lack of guidance and progress in the modelling. I was initially concerned that developing the models too quickly would cause confusion, reducing engagement and the sense of ownership. However, I got the sense that engagement and interest were suffering more from lack of progress in the modelling.

Modelling after cycle 2: states and relationships

The results of the interviews were analysed, and 'individual' models revised. The structure of the models was developed by amending the nodes and adding states to them as directed by the KIs. Arcs were placed between the nodes to represent relationships (conditional dependencies) between the issues (variables). For example, KI-D considered that the migratory salmon population in the Solway Firth is declining and believed that was caused by increasing sedimentation and turbidity; these nodes are highlighted in Figure 4.7. KI-D also considered that if structures (associated with a tidal range scheme) were present in the Solway Firth, they would contribute to declining migratory salmon populations. These data are visually represented in Figure 4.7 by the position and direction of arcs that show the 'migratory salmon' node is linked to, and influenced by, both the 'sedimentation and turbidity' and the 'structure' nodes.

As explained in chapter 1, the numbers and bars in the nodes represent the probability of events. The models calculate these probabilities from conditional probability tables (CPTs) that are populated by the primary data. The CPTs sit behind and define each node; their effect is visually represented in two ways. First, the numbers and bars in the nodes that show the result of the combined probabilities are calculated. Second the thickness of the arcs indicates the relative weight of influence between nodes. For example, in Figure 4.7, the arc (arrow) connecting the 'sedimentation and turbidity' node to the 'migratory salmon' node is thicker than the arc connecting the 'structure' (of the proposed SEG) node to the 'migratory salmon' node. The relative thickness of these arcs indicate that improving or declining populations of migratory salmon would be affected more by sedimentation and turbidity in the Solway Firth than by the presence of a structure. The numbers and bars in the node represent KI-D's views that the migratory salmon population is more likely to be declining than improving, and that

sedimentation and turbidity in the Solway Firth is more likely to be increasing than remaining steady. The numbers and bars in the 'structure' node shows that structures are 100% 'not present' because, there are currently no tidal energy structures built in the Solway Firth. The evidence in the nodes can be manipulated to calculate the effect of different scenarios (e.g. changing the structure node to 100% present) based on the CPTs. I will come back to this in cycles 4 and 5.

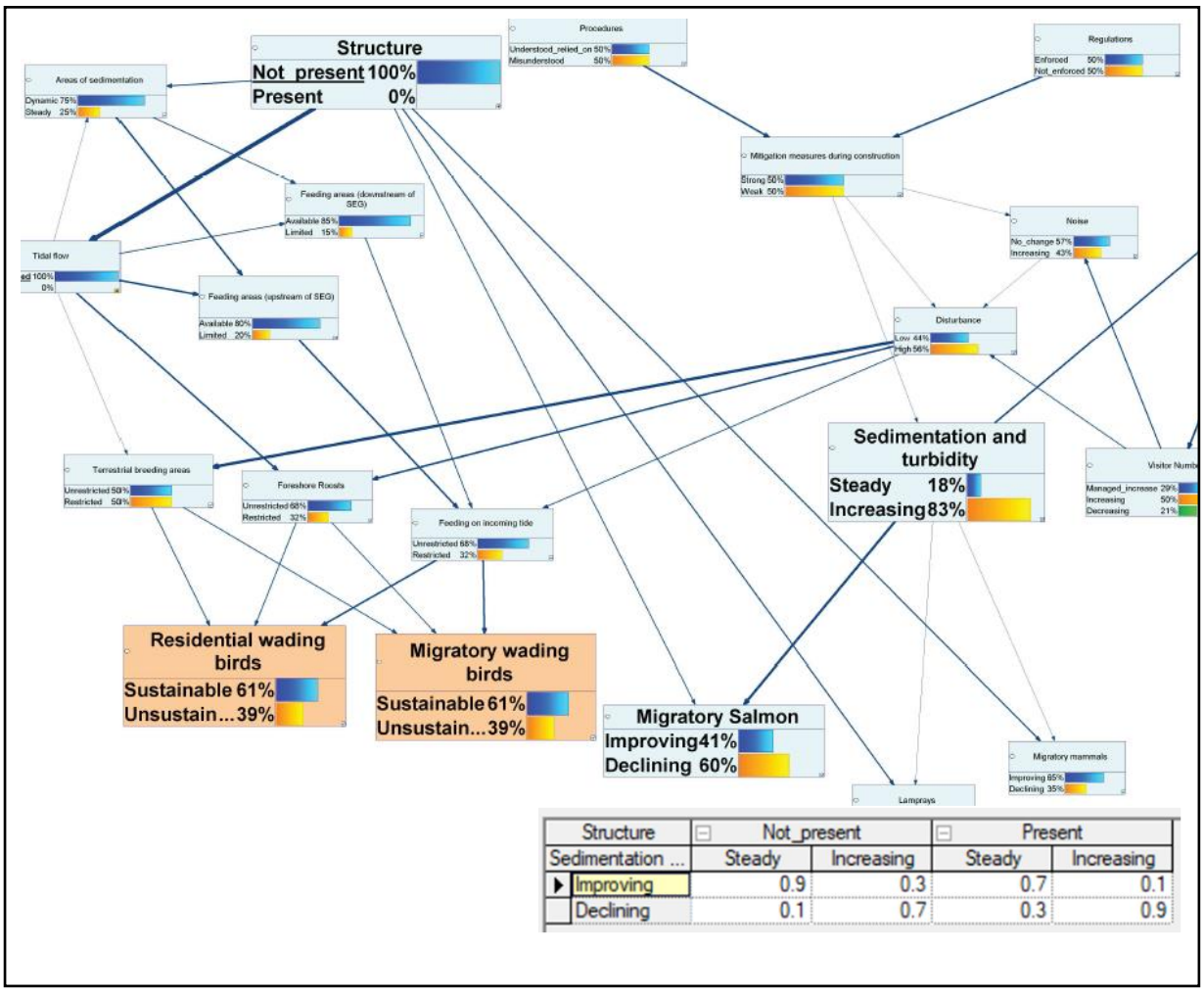

Figure 4.7 BBN model developed in cycle 2 with KI-D; nodes represent the issues raised during one-to-one interview. The following nodes are highlighted to aid discussion: 'migratory salmon', 'structure', 'sedimentation and turbidity', 'residential wading birds', and 'migratory wading birds'. CPT for 'Migratory Salmon' node shown.

The nodes in the visual representations of the models were arranged so the direction of dependence travelled from top to bottom of the page. I considered highlighting the 'end' nodes (at the bottom of the page) to represent decision points. However, considering the shift away from outcome-orientated PEDM, I decided against this. Instead, for some KIs, I

highlighted their 'priority nodes': see Figure 4.7, where KI-D was particularly concerned about 'resident wading birds' and 'migratory wading birds', which were represented by nodes of a different colour (pink) specifying how 'sustainable' their populations are, as represented by the 'states' of the nodes (sustainable and unsustainable). In contrast, for other KIs, I coloured the nodes according to theme (living environment, physical environment, conservation, socio-economic, community, proposed tidal scheme), to reduce the risk of steering KIs towards 'priorities' (see Figure 4.8).

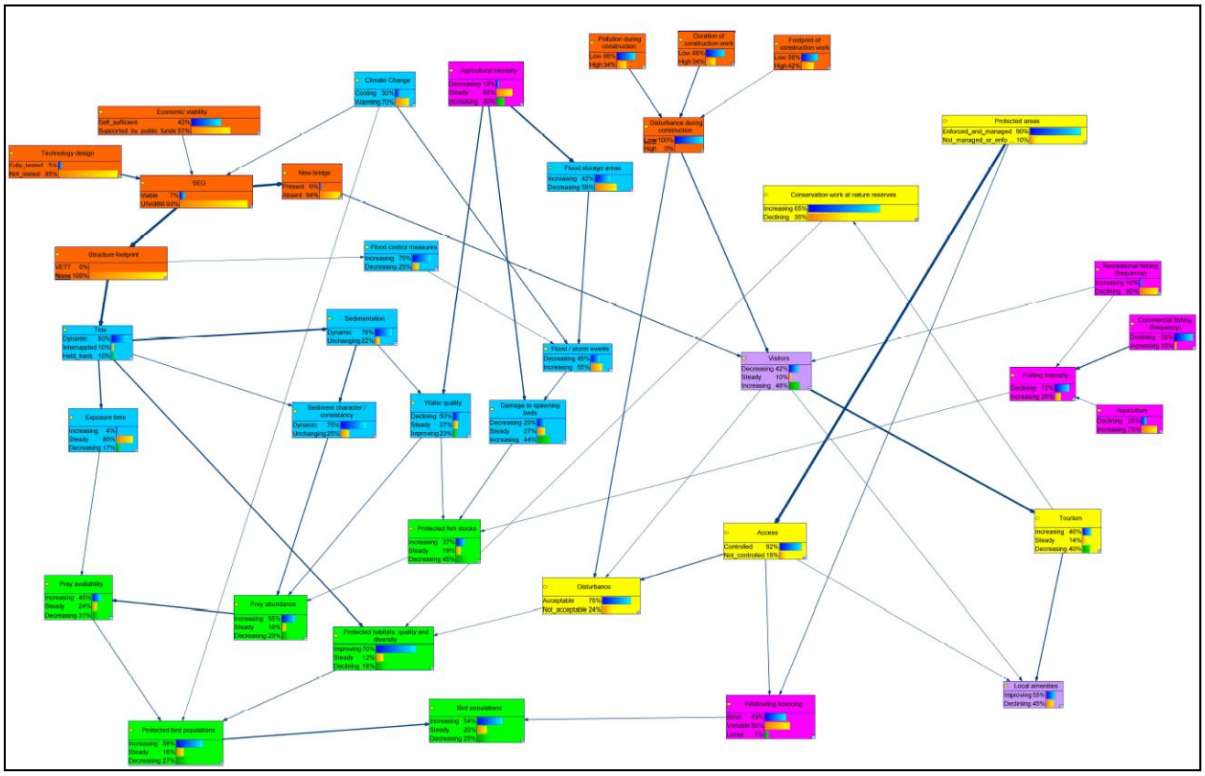

Figure 4.8 BBN model developed in cycle 2 with KI-E; nodes represent the issues raised during one-to-one interview

The BBNs modelled during cycle 2 are presented in Appendix II. Four individual BBNs were developed from the primary data collected in cycle 2: KI-A, KI-B, KI-D and KI-E. Only these four KIs (from cycle 1 and 2) participated in cycle 3. I also introduced new KIs in cycle 3 who reviewed existing BBNs (explained further in the next section).

The four BBNs modelled after cycle 2 show that there are some common themes among the issues raised by the KIs, but also show the different perspectives the KIs have on similar issues. The four BBNs identified community / societal issues as end nodes, but they differed in how they defined the potential impacts. KI-A mentioned the preservation or disruption of

community peace of mind. KI-B emphasised the potential impact on the Scottish community, defining it as flourishing, sustainable or marginalised. KI-D highlighted society and wellbeing as improving, steady or declining. Finally, KI-E concentrated on improving or declining local amenities.

KI-A, KI-D and KI-E identified bird populations as end nodes, but again defined these nodes differently. KI-A distinguished between migratory and permanent bird populations defined as high, medium, or low (population numbers). KI-D also distinguished between residential and migratory birds but defined the populations as sustainable or unsustainable. In contrast, KI-E distinguished between bird populations generally, and protected bird populations, defining them as increasing, steady or decreasing.

The BBNs modelled during cycle 2 were significantly more complex than those produced at cycle 1. The main challenge in producing the models in cycle 2 was managing the complexity of producing the CPTs from the primary data, which was very time consuming. The CPTs are populated from the primary data; each KI's qualitative data provided in the interviews are translated into quantitative data by hand. As discussed in chapter 1, conventionally, beliefs are elicited from experts as quantitative data, directly incorporated into the CPTs. The use of qualitative data to populate CPTs required me to interpret and translate the stakeholder views into quantitative data. The KIs had described the impact of a parent node on each child node and the relative weightings of each parent to each child node. I assigned estimated probabilities within each CPT from these descriptions, using my own judgement. For example, I developed the CPT for the 'migratory salmon' node, illustrated in Figure 4.7, in the following way. KI-D expressed near certainty that migratory salmon populations would improve if both the 'sedimentation and turbidity' node was steady and the 'structure' (i.e. SEG) was not present. Therefore, the CPT (Table 4.3) shows that the probability of migratory salmon populations improving is 0.9 (90%) and as a result, the probability of the migratory salmon populations declining is 0.1 (10%), Conversely, KI-D is almost certain that migratory salmon populations will decline if sedimentation and turbidity increases and a structure (i.e., SEG) is present. The aforementioned probabilities are therefore mirrored on the other side of the CPT; the probability of migratory salmon populations improving, if sedimentation and turbidity increases and a structure (i.e., SEG) is present, is expressed as 0.1 (10%). KI-D

considered, but was less sure, that sedimentation and turbidity would have a greater influence on migratory salmon than the presence of a structure. In the CPT, the probability of improving migratory salmon population is affected by an increase in sedimentation and turbidity (only) to a greater extent (the probability of the salmon population improving is reduced to 30%) than if the structure (only) was present (the probability of the salmon population improving is reduced to 70%). These weightings are represented in the BBN by the thickness of the arcs (see Figure 4.7). The probabilities expressed in the CPTs are therefore dependant on how sure the KIs were in their views, as well as the views themselves.

The interpretation and translation of the KIs' views were undertaken independently of the KIs. The resultant CPTs therefore represented my interpretation of the primary data. As discussed in section 3.3, modelling independent of KIs does risk their views being misinterpreted and misrepresented. This is managed by providing opportunities for the KIs to review the BBNs and to direct amendments in subsequent cycles.

The states and arcs were added to the BBNs, which are directly visually represented and can be relatively easily explained to KIs in cycle 3. In contrast, the CPTs are visually represented indirectly by the numbers and bars in the nodes and the thickness of the arcs. Explaining what the numbers, bars, and the thickness of the arcs represent is complex. The CPTs were populated using the KIs' views but separately from them to reduce the participatory burden of the KIs participating in this laborious task. However, this separation increases the complexity of the explanation. Lack of understanding of the process of populating the CPT, and how they relate to the visual representations represents a potential barrier to engagement in cycle 3.

4.3 Cycle 3: Specifying the model and comparing it to another Key Informant's (KI's) BBN

Four of the KIs engaged in previous cycles participated in cycle 3. KI-A and KI-B were interviewed on 20 and 21 February 2018, respectively. At their requests, both were interviewed in their homes. KI-D was also interviewed in their home at their request on 28 March 2018. KI-E (from an English based conservation charity) was interviewed in their office in Lancaster on 12 April 2018. KI-I and KI-H, as well as the other Parish Councillors, were invited to participate in further cycles of engagement after the Parish Council meeting in

January 2018 but declined. KI-F was unavailable during cycle 3 but agreed to participate in further cycles.

New KIs (KI-C, KI-K, KI-L, and KI-N) were introduced in cycle 3. KI-C represents a Government conservation organisation (based in England) and was identified via snowball sampling by KI-I and KI-O in cycle 1. KI-K and KI-L represent a conservation organisation focused on the Solway Firth. They had participated in earlier meetings about SEG and had been identified as suitable contributors by other KIs (e.g. KI-F) during previous cycles. KI-N represents a Government conservation organisation (based in England) and was identified via snowball sampling by KI-A during cycle 2.

Cycle 3 comprised further one-to-one interviews. Each KI was asked to review and develop their own 'individual' model, that show revised nodes, states and arcs, as discussed in cycles 1 and 2 (see example in Figures 4.7 and 4.8), to check they understood it and that it represented their views. They were also asked to develop the BBN by considering the relative influence of each arc on the child nodes (a node that depends on other nodes) e.g. if there are 3 arcs feeding into a node, do they all have equal influence, and if not can the KIs estimate the relative influence? I presented each KI with two scenarios to show the effect on the likelihood of events with and without SEG. Each KI was also asked to review another KI's model to see if it enabled them to understand an alternative perspective.

The new KIs were asked to review existing individual BBNs, developed by other KIs during cycles 1 and 2 to test if their response to the modelling is different to those that were engaged from the start. The widening out of the KI network to increase the circle of peer review conforms with the concept of resonance testing (Burns, 2007, p. 159), enhancing the robustness and quality of the research, as discussed in section 3.2.

The visual representations of the BBNs provided a focus for the discussions. I annotated the visual representations, to demonstrate the views were recorded to check my interpretation of their views and to help the KIs work through their thoughts. For example, in Figure 4.9, the annotations indicate that the relationships between some of the nodes were revised during the discussion and that additional issues were added.

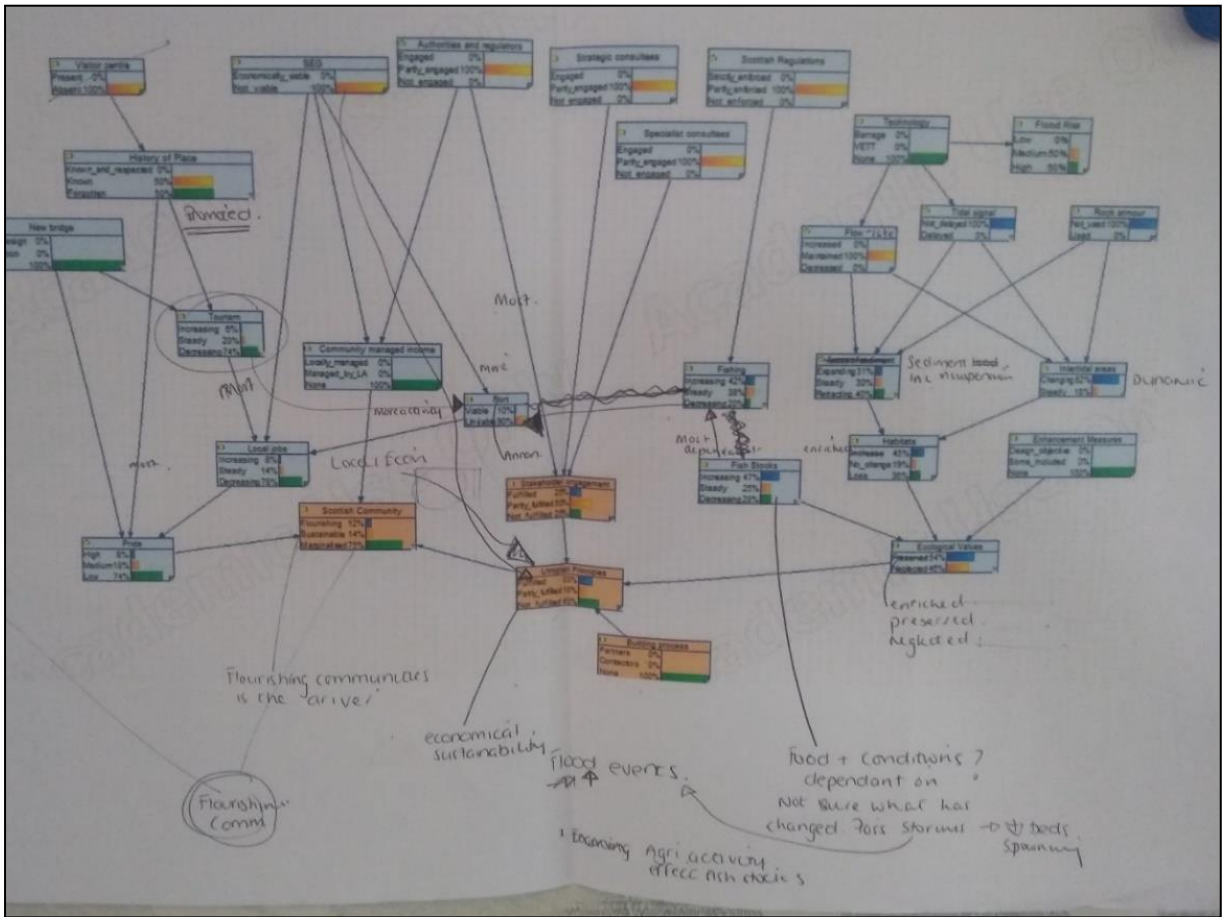

Figure 4.9 Cycle 2 visual representation annotated with KI-B in cycle 3.

The planned timetable was maintained but was implemented flexibly to facilitate convenient engagement (for the participants); eight participants were met during February to April 2018, indicating some slippage (cycle 3 was planned between February and March 2018, see Table 3.4). The flexible implementation of the timetable was a response to the risk of consultation fatigue associated with the burden of participation. Meeting stakeholders at their convenience was considered more beneficial than maintaining the planned timetable and allowed systematic and regular engagement to be maintained.

Flexibility also accommodated time for reflection and modelling between interviews. In contrast to cycle 1 and cycle 2 where engagement and modelling occurred in distinct phases, in cycle 3, KIs were contacted in phases where data collection and modelling were merged. In an iterative process the results of interviews were incorporated into the modelling and subsequent interviews. This resulted in an unequal dissemination of knowledge, where those

KIs who were engaged later in the cycles benefitted from an accumulation of knowledge from those who contributed earlier. I did not resist the unequal dissemination, instead using it to facilitate the development of the modelling and learning between the participants.

The first KIs contacted were KI-A and KI-B. When first presented with the model at the start of the cycle 3 interview, KI-A struggled making sense of it, engaging cautiously. After a few minutes of quiet consideration, KI-A stated they were “not certain” and perhaps the model could be “simplified”, indicating that the complexity of the BBN confused them. Noting this caution and keen to reduce potential anxiety I played a bigger role (than I had during previous cycles) in guiding the interview by pointing out individual nodes to ask opinions about specific issues.

I initially used the KI’s individual BBN to work through their own views before challenging them with alternative perspectives. However, the discussion with KI-B about their own model (Figure 4.9) took 2 hours (planned 1 hour) and there was not time to discuss an alternative model. In subsequent meetings during cycle 3, KIs were introduced to their own model and the alternative concurrently. This enabled the participants to compare, contrast, and move between the two, maintaining the participant-led ethos, where it was up to participants how much time they spent on each, and allowing for observations on the way they considered their own view compared to the alternative.

Modelling after cycle 3: combining the models

I developed an integrated BBN from the results of the cycle 3 interviews, supplemented with data from and models from the previous cycles. A combined BBN model was produced for review in the final cycles, see Figure 4.10.

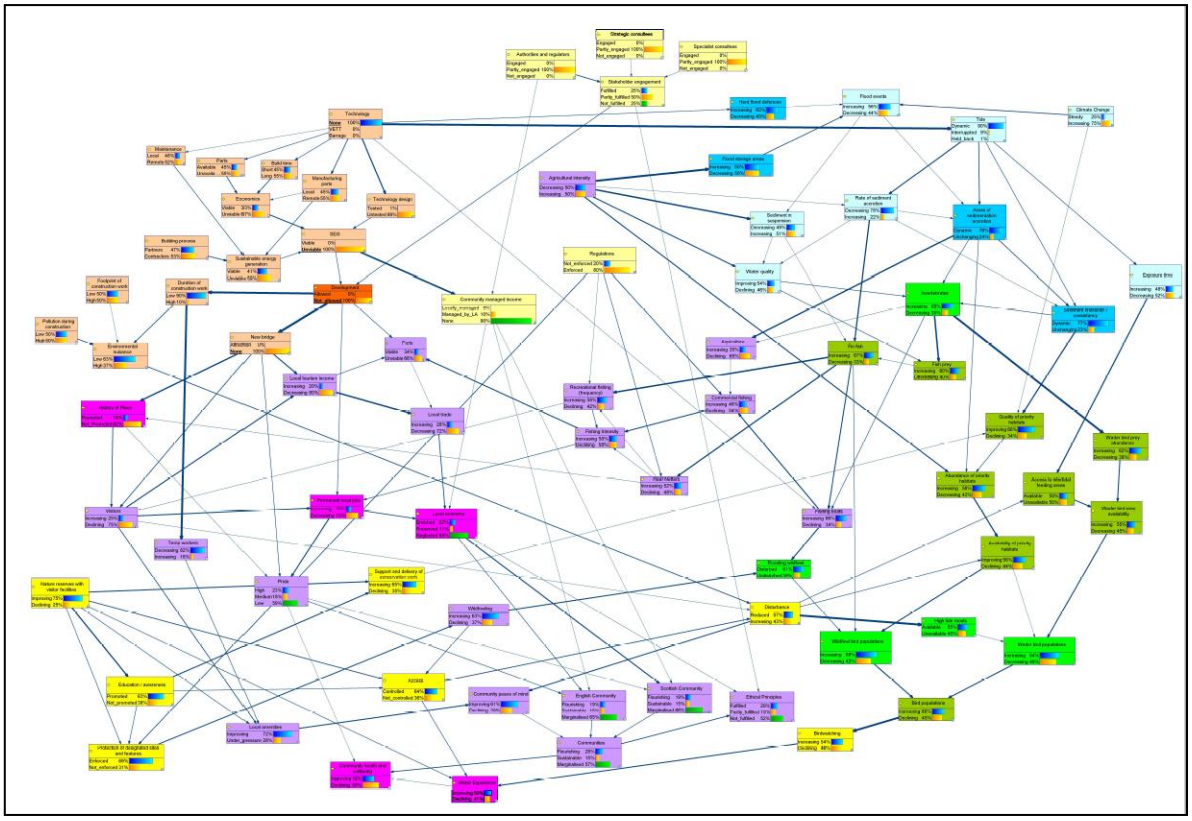

Figure 4.10 Visual representation of the combined BBN model, integrating data from KIs interviewed in cycles 1-3

The combined model aimed to represent the range and diversity of views and values that were contributed during previous cycles. To achieve this, data from cycles 1 to 3 was synthesised manually. Each individual BBN was copied into one GeNIe Modeler file (BayesFusion, 2017) (Figure 4.11).

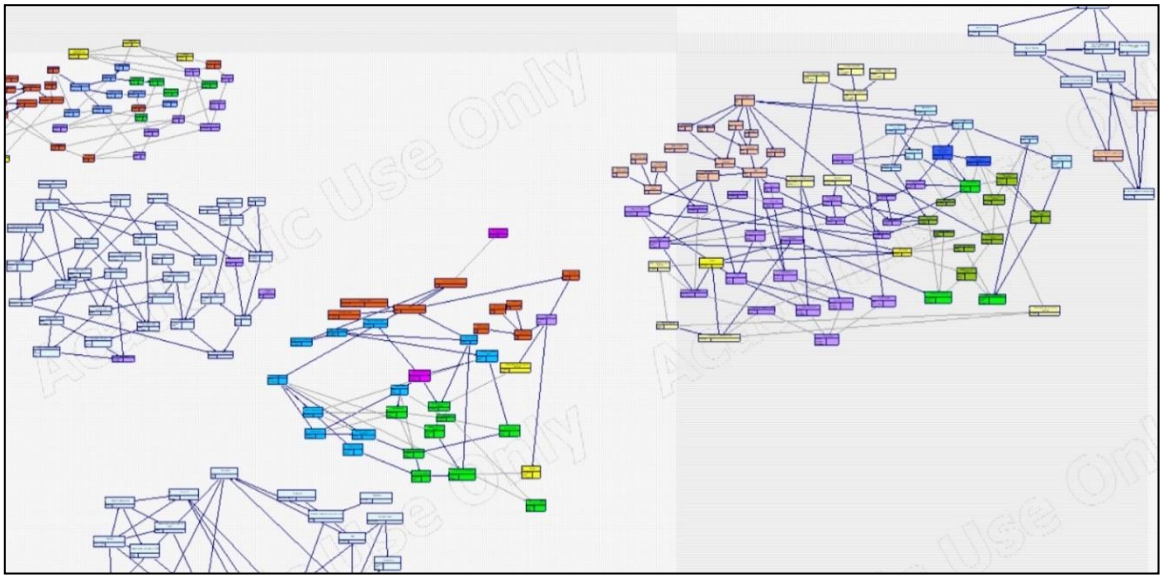

Figure 4.11 Extract from the GeNIe Modeler file space during integration of the models, showing individual BBNs in one file space

Starting with the most common, I used my own judgement to identify nodes to incorporate into the combined model in the centre of the file space. For example, all KIs identified the tide as an issue, so a 'tide' node was generated in the centre of the file space. The states identified by the KIs were used to define each node. The 'tide' node was defined by the states: 'dynamic', 'interrupted', or 'held back' (Figure 4.12).

Inevitably, KIs expressed issues in slightly different ways or different issues in similar ways. Where differences and conflicts arose, I reviewed the interview data to explore how the KIs discussed the issues. For example, most KIs identified sedimentation as an issue, but described different cause and effect relationships, which resulted in conflicting impacts in the model. Some individual models showed that sedimentation would increase with the installation of SEG, as water slowed with the installation of structures, but other individual BBNs showed sedimentation decreasing. Reviewing the interview data, I realised that sedimentation is discussed in a variety of ways, so that although the overall rate of sedimentation would increase if SEG was installed, the structures would reduce the dynamism of the tides reducing the dynamism of the deposition of sediment in the Solway Firth. To clarify the different meanings, four sedimentation nodes were identified: 'rate of sediment accretion'; 'sediment in suspension'; 'areas of sediment accretion'; and 'sediment character and consistency'.

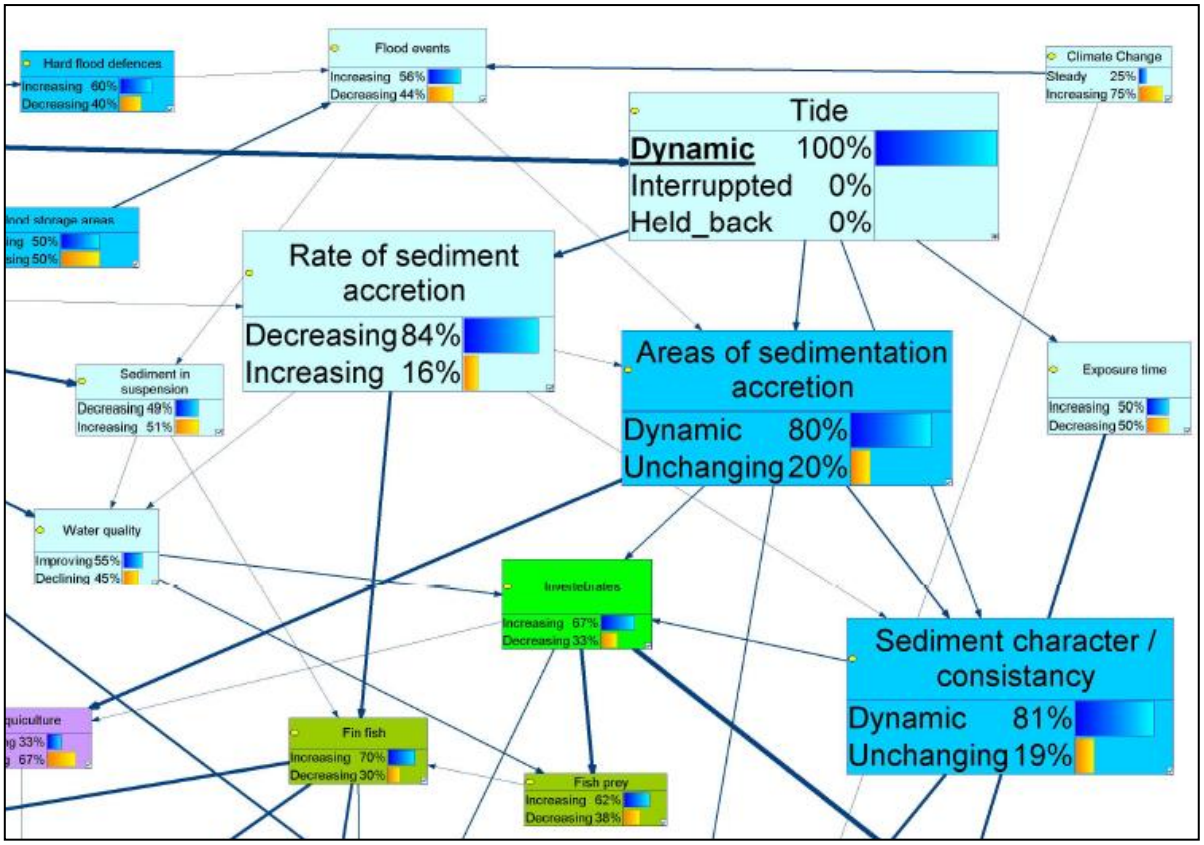

Figure 4.12 Extract from the combined BBN model showing the likelihood of events where SEG is not installed

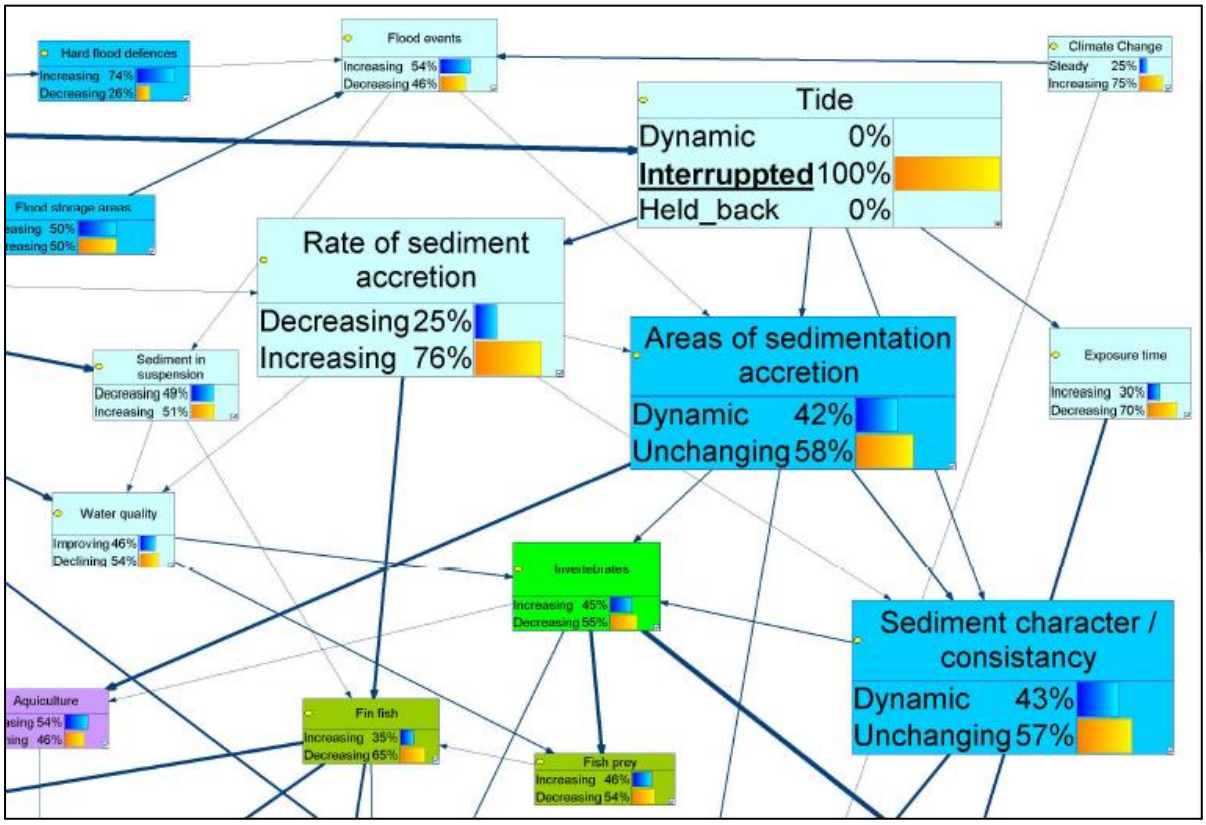

Figure 4.13 Extract from the combined BBN model showing the likelihood of events where SEG is installed

Comparing the 2 scenarios, for SEG uninstalled (current situation), and SEG installed (as VETT technology) (Figures 4.12 and 4.13), indicates that the likelihood of the 'rate of sedimentation' 'increasing' rises from 16% to 76% if SEG is installed. In contrast, the likelihood that the 'areas of sediment accretion' and 'sediment character and consistency' are 'dynamic', decreases if SEG is installed.

Similarly, sometimes KIs identified the same nodes (in their individual BBNs) but defined them with different states. For example, most of the KIs identified the technology proposed in SEG as an issue. For KI-E what mattered was whether the technology was tested or not, therefore the states of the 'technology' node were defined as 'tested' or 'untested'. For KI-B, what mattered was that the technology used was the novel VETT technology, as opposed to a conventional barrage design, and it was important for the BBN to model the different effects of the different technologies. Therefore, the states for the 'technology' node in KI-B's model were 'VETT', 'barrage', and 'none'. To manage this difference during the combination process, an additional node was added to capture the different meanings, so a 'technology' node is defined as 'VETT', 'barrage', or 'none', and a 'technology design' node is defined as 'tested' or 'untested'.

The positions of the arcs were addressed in a similar way. Generally, the KIs agreed on the direction of the relationships between nodes, though some added intermediate issues. I used subjective judgement based on the interview data and the logic of the combined BBN to determine if the intermediate node would be retained. If there was only one arc in and one arc out of a node then it could not affect the conditional probabilities of other nodes and therefore serves no purpose and could be deleted. However, removing nodes without discussion with KIs could reduce their sense of being valued as contributors, so I tried to incorporate the meaning of any node deleted into a surrounding node by broadening another node's description. For example, KI-A's 'bog habitat' was incorporated into the 'priority habitats' nodes (abundance, quality, and availability). Additionally, there were 2 more cycles of engagement for the KIs to comment on the inclusion of issues.

Responding to confusion associated with the complexity of the model expressed by some KIs in cycle 3, I limited the number of arcs entering each node to three. Where additional influences were identified, I added intermediate nodes to simplify relationships. For example, several KIs considered that the construction phase of building SEG would result in disturbance, along with other issues, such as the number of visitors and public access. To limit the number of arcs directed at the 'disturbance' node the construction impacts ('pollution from construction', 'footprint of construction work', and 'duration of construction') were directed into an intermediate 'environmental nuisance' node, see Figure 4.14.

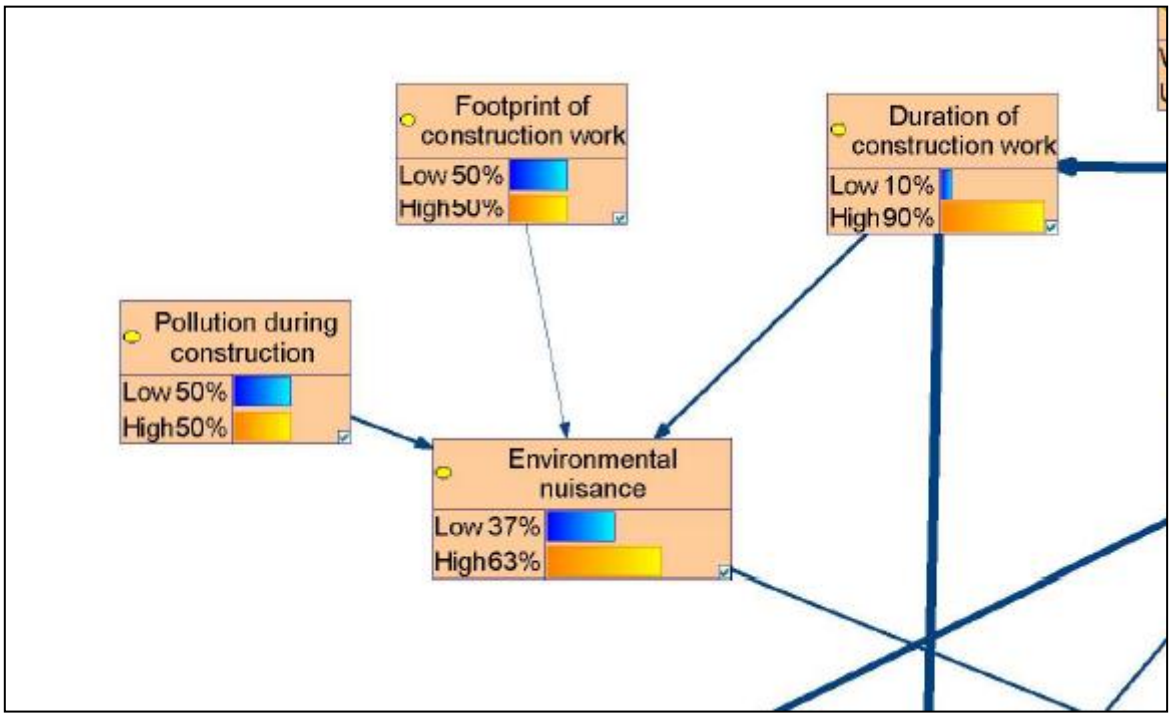

Figure 4.14 Extract from the combined BBN model showing the construction impacts were directed into an intermediate 'environmental nuisance' node

As explained earlier, the influence each parent node has on a child node can be different, as determined by the 'weight' of each arc. Therefore, reducing the number of 'construction' impacts from three nodes to one 'environmental nuisance' node does not reduce their influence on 'disturbance', relative to the other influences ('access' and 'visitors').

The process of combining the individual models was complex. I used qualitative data and modelling from cycles 1 to 3 to clarify differences and conflicts in the individual models, and to review the meanings for each node and arc and the way they developed. This included data

and models from KIs who did not participate in cycle 3. As a result, I needed to undertake more interpretation of the data than in previous cycles, increasing the risks of data being misinterpreted and misrepresented. These risks were managed by the additional opportunities for KIs to review the combined models in the remaining two cycles of engagement.

The integrated BBN differed from the individual models produced after cycle 2 principally in its complexity. The process of reviewing the data from cycles 1-3 to understand the meaning behind the issues raised and their relationships gave me a deeper understanding. However, as the modelling was done independently of the KIs, they did not benefit from this process of deepening understanding and the knowledge that was generated during that process. I reflect on this further in Chapter 5.

Generally, the types of issues raised in cycles 2 and 3 were similar, but in cycle 3 the KIs were thinking about them more deeply. Generally, KIs concentrated on developing the nodes present in cycle 2; redefining them or adding other associated nodes to clarify meaning. This process was aided by the review of a BBN by another KI. For example, after looking at KI-B's BBN from cycle 2, KI-A went back to their own and considered the difference between visitor numbers (a node in their BBN from cycle 2) and tourism (a node in KI-Bs BBN from cycle 2). In cycle 3, KI-A considered that increasing visitor numbers would have a negative effect on community peace of mind due to the strain on local services. However, in cycle 2, KI-B had considered that increasing tourism would have a positive impact on the Scottish community (KI-B did not include a node for 'English community' because he prioritised impacts on Scottish community, which he considered were more supportive) due to increase in local jobs and pride in the area. To account for this apparent discrepancy, in cycle 3, KI-A considered that visitor numbers and tourism should be represented in the combined BBN by separate nodes, to show that visitor numbers could be high, but unless they are spending anything they are not contributing to the local economy, while increasing the strain on local services.

Practically, the main challenge in producing the combined BBN after cycle 3 was the size of the visual representations. Because of the inevitable increase in the nodes associated with combining the data, the space on the paper copies was limited. I wanted to retain the A3-size,

as it was easier to discuss with KIs in their busy offices and homes, where surface space was often very limited. Sometimes I needed to balance the model on my knee due to lack of space, for example for KI-F in cycles 1 and 2.

4.4 Cycle 4: Reviewing the integrated model

Cycle 4 comprised one-to-one interviews with three established KIs to discuss a draft combined model (Figure 4.10) before the final cycle. This amendment to the planned data collection timetable (as described in Table 3.4), reduced the active engagement to three interviews. As explained in section 3.2, this amendment was a response to the lack of enthusiasm for planned group events and the risk of consultation fatigue associated with contacting all established KIs with a combined model that is significantly more complex than previous versions.

Three KIs, KI-B, KI-J, and KI-F, were shown combined models that incorporated the data from the KIs over the first 3 cycles (see Figure 4.10). KI-B (part of the SEG team) was interviewed at home at their request and was included in cycle 4 as they had not shown any sign of consultation fatigue in previous cycles and had readily agreed to meet me again. KI-B had also omitted to review the alternative model in cycle 3, focusing on their own BBN instead, so inclusion in cycle 4 provided them an opportunity to review alternative views before the final cycle. KI-J and KI-F were included in cycle 4 as they had both missed one or two of the previous cycles. KI-J was interviewed via Skype at their convenience; I had already established a relationship with KI-J in cycle 1, so meeting them again in person, to establish a rapport was not considered essential. KI-F was interviewed at their office near Castle Douglas at their request.

The purpose of reviewing the combined model in cycle 4 was twofold. First, to obtain feedback and reflection about the integration of the data, so the combined model could be amended and refined prior to the final cycle of engagement. Second, to assess the extent to which combining the models affected the sense of ownership KIs have compared to reviewing individual models.

I began the interviews by tabling visual representations of the combined model, presented on A3 paper, showing nodes, states, and arcs. The nodes were coloured according to theme (living environment, physical environment, conservation, socio-economic, community, proposed tidal scheme). As the interview with KI-J was online, I emailed pdf copies of the visual representations to them a couple of days before the interview so that they could review it before we spoke.

The three KIs struggled with understanding the complexity of the combined BBN. After looking at it for some time, KI-B asked what other people had thought of the model. Sensing difficulty in understanding the combined model I took time to explain it orally. In confirmation of the need for interpretation, KI-B suggested that the results could be expressed "as a list that show tick-boxes' of priorities……without having to unpick the model", or a "simple list of instructions….that does the interpretation".

KI-F also struggled with the complexity of the BBN, asking me to go through the colour coding, suggesting that a key would be beneficial to help them. KI-F annotated one of the tabled visual representations of the model, noting the meaning of the node colours (see Figure 4.15). Once their understanding of the colour coding was settled, KI-F began to interrogate the numbers in the nodes (expressions of the likelihood of events). KI-F struggled particularly with understanding "how the figures have been arrived at". The complexity of the modelling and their difficulty in grasping the meaning of its features, led KI-F to conclude they were "not a good example", indicating they lacked the technical knowledge to contribute to the research. In chapter 5 and 6, I reflect more on the anxiety expressed by KIs about the complexity of the modelling.

Like earlier cycles I annotated the visual representations of the BBNs with the KIs to demonstrate that their views were being recorded and to encourage participatory diagramming, to enhance engagement (as discussed in chapter 3). Reflecting their struggles to understand the visual representations, in contrast to earlier cycles, KI-F was keen to annotate hard copies, as shown in Figure 4.15. Despite expressing anxiety about the complexity of the BBN, they did ask to keep their annotated copies so that they could review

later. I was keen to encourage further engagement with the BBNs and left them with KI-F, taking photographs to ensure the data was captured.

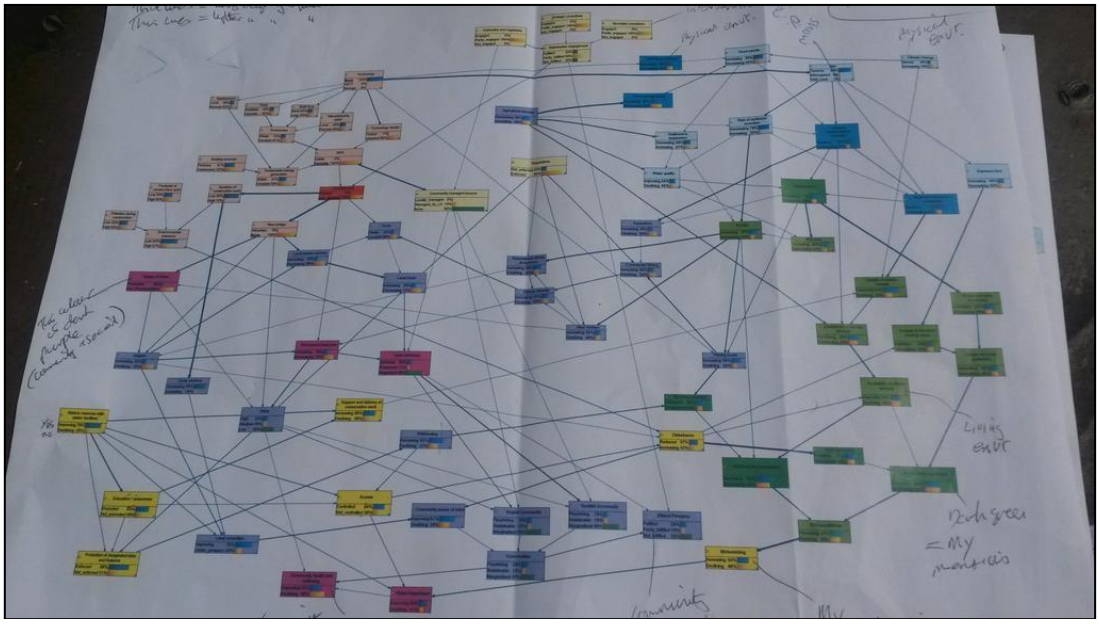

Figure 4.15 Visual representation of the combined BBN model annotated with KI-F in cycle 4

In their online interview, generally, KI-J was positive about the visual representations. Responding to KI-B's suggestion that the BBNs needed interpretation, I started the interview with KI-J with an oral explanation, which they said was "helpful". Reviewing the visual representations, KI-J considered that the BBN "covered everything". Like KI-F, KI-J wondered "how the values were arrived at" and suggested that "there should be a better way to explain the values". However, KI-J liked their inclusion, stating that "people like numbers" and unlike KI-F indicated they had understood after an oral explanation. KI-J observed the benefit for decision making processes of being able to run different scenarios, stating it "makes total sense" and discussing potential applications for other sites they are dealing with. Considering that KI-J had not been involved in cycles 2 and 3, they had not observed the development of the modelling like other KIs. It is therefore interesting that KI-J did seem to grasp the concept of the BBN better than other KIs. I reflect on this more in chapter 5, considering how interaction with BBNs affects the engagement process and the sense of buy-in to the decision-making process.

Modelling after Cycle 4: updating the combined model

The KIs' contributions were used to amend the models before the last cycle of engagement. Possibly reflecting the complexity of the model and consultation fatigue, the KIs made relatively few amendments to the nodes, states, and arcs in the BBN itself. Instead the KIs tended to focus on considering presentational issues to aid interpretation. At their suggestion, a colour key and title were added to the visual representations to aid understanding in the final cycle (see Figure 4.16).

As the KIs in cycle 4 reviewed the same combined model, integrating their comments was comparatively straightforward. Also, as they tended to focus on presentational issues, avoiding detailed interrogation of the visual representation of the BBN, their contributions broadly aligned; they wanted help interpreting the model. The KIs also reflected on the potential uses for BBNs in decision-making processes and had differing views on this. KI-B and KI-J were quite positive about the potential use; however, KI-F was unconvinced. I reflect on the potential for BBN use in PEDM broadly in chapter 7.

The addition of a key and title did aid interpretation; however, the complexity of the model remained high and there was a growing risk of consultation fatigue as the cycles progressed. The lack of significant changes to the model itself after cycle 4 could have frustrated the 3 KIs who participated in cycle 4 (if cycle 5 looked and felt the same). The challenge for cycle 5 was to improve the interpretation of the BBN while making the cycle feel and look different, to reduce the risk of consultation fatigue. The burden of participation was also considered; some KIs (including KI-E, KI-F and KI-N) had clearly stated that the time and cost of travelling to events and dealing with other stakeholders was unappealing. The planned group event, planned for cycle 5 was therefore amended, as explained below.

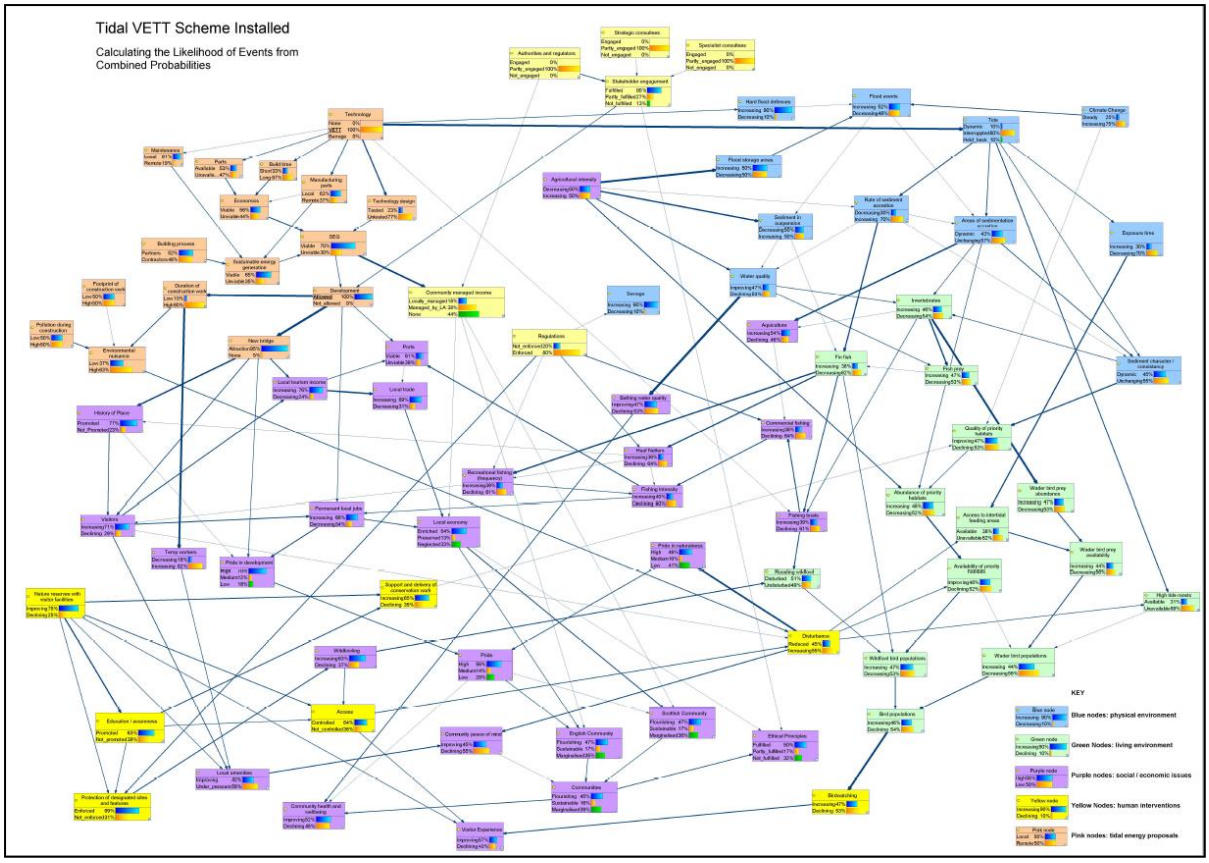

Figure 4.16 Integrated BBN model showing nodes, states and arcs that represent the combined views raised by KIs during previous cycles of engagement. This version of the model shows the likelihood of events if SEG is installed.

4.5 Cycle 5: Final Reflections

In response to the risk of consultation fatigue and anxiety I amended the data collection timetable (see section 3.2) and asked KIs to engage in cycle 5, the final engagement event, via post. This enabled the KIs to review the BBNs in their own time, without the pressure of a one-to-one discussion and reducing the commitment to attending an interview. It also provided more flexibility in how the KIs could contribute (by return of post, email, or telephone) to reduce the burden of participating. Seven out of the ten KIs contacted, responded; KI-A, KI-B, KI-C, KI-E, KI-F, KI-K, and KI-J.

The purpose of the final cycle was to assess the KIs' understanding of the combined model, compared to individual models. The difference between the remote type of engagement and the (mainly one-to-one) interviews, undertaken up to cycle 5 was noted. Cycle 5 entailed posting hard copies of the integrated models to previously engaged KIs, comprising visual representations of two scenarios, showing SEG installed (Figure 4.16) and not installed, and

the subsequent likelihood of events. To aid interpretation and demonstrate how BBNs could aid decision-making I also produced visual representations of sensitivity analysis (Figure 4.17) that illustrate the sensitivity of a selected 'target' node to influencing factors. In cycle 5, I selected 'bird populations' and 'community' as 'target' nodes since most of the KIs recognised the potential impact of the proposed SEG on birds and / or community as significant issues. Figure 4.17 shows sensitivity of the 'bird populations' node to influencing factors. The darker the red colours indicate the higher the sensitivity, indicating that 'bird populations' is highly sensitive to 'tide', agricultural intensity' and the presence of a tidal scheme, represented by the 'technology' node.

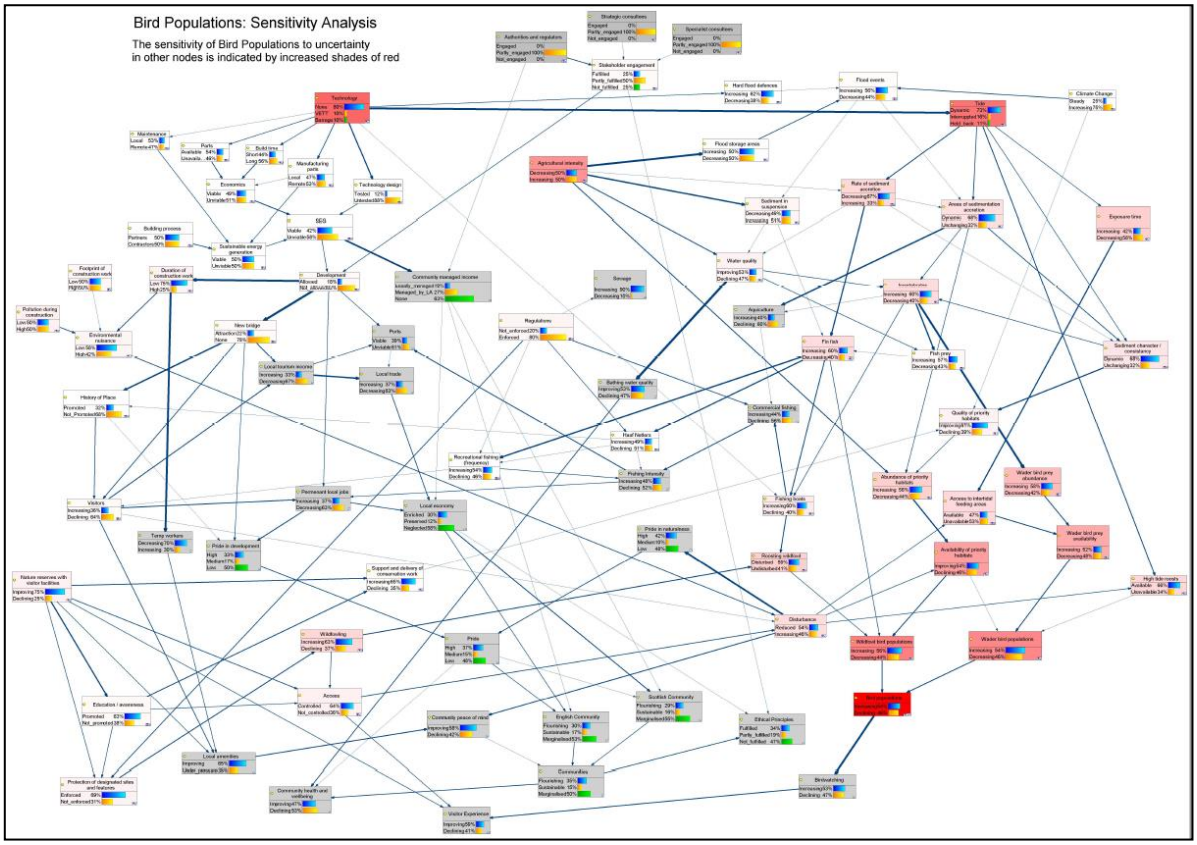

Figure 4.17 Integrated BBN model showing nodes, states and arcs that represent the combined views raised by KIs during previous cycles of engagement. This version of the model runs a sensitivity analysis of the nodes that have the highest impact on bird populations.

A letter asking the KIs to review and comment on the visual representations of the combined BBNs models, was posted to each KI. The letter (copy provided in Appendix III) included explanatory notes and pointers, suggesting the KIs review the nodes, arcs, overall presentation, clarity etc. in their own time. To manage the KIs' expectations, the letter stated

that cycle 5 was the final time I would request their input and thanked them for their contributions.

The KIs responded in a variety of ways. KI-A, KI-C and KI-J sent an email response summarising their thoughts in text, without any annotated visual representations of the BBNs, indicating a personal preference for more formal methods of communication. KI-E emailed their response, but also posted back annotated plans. KI-K fully annotated the visual representations of the BBNs (Figure 4.18) and the explanation notes (Figure 4.19). KI-F annotated the explanation notes in pencil. KI-B did not commit their response to paper, and after chasing them up, we met and discussed the BBNs over hard copies of visual representations of the combined model, which I annotated. The variety of ways the KIs responded highlights a range of personal preferences within this small group of stakeholders and the importance of providing a range of engagement methods.

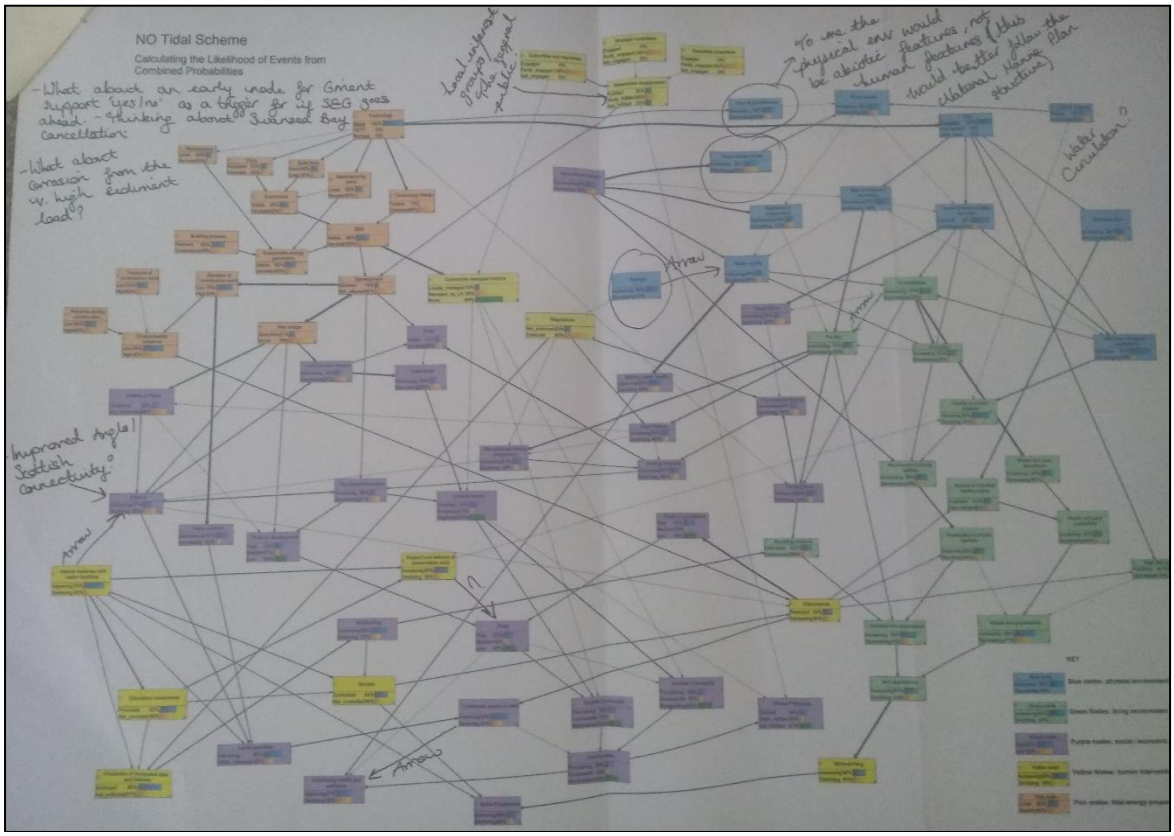

Figure 4.18 Annotated BBN returned by KI-K

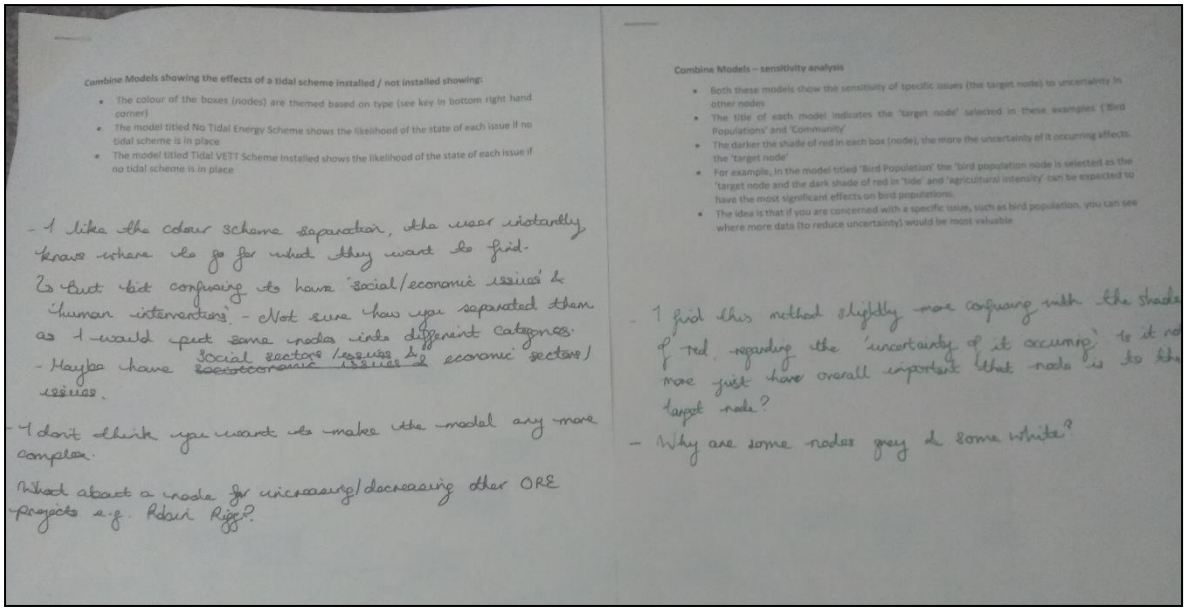

Figure 4.19 Handwritten response from KI-K

A summary of the responses received in cycle 5 is provided in Table 4.3. Many of the KIs struggled with the complexity of the visual representations. KI-K stated the BBNs were “a bit confusing”, focusing on the presentation issues, specifically the colour coding. KI-A and KI-F focused on the numerical values which they found “confusing” (KI-A) and “seems far too complicated” (KI-F). They both indicated concern that their responses would be unsatisfactory. KI-A apologised, stating “I'm sorry if my responses are not as in depth as you might have hoped” and KI-F stated that they felt “really sorry”, linking this to anxiety about their own abilities: “I just can’t overcome my frustration at my inability to understand how this [the BBN] works”. Despite my attempts to aid interpretation KI-F stated that the “guidance instructions are insufficient”. Agreeing with KI-F, KI-B repeated their suggestions from cycle 4 that there needed to be more interpretation, suggesting that “layers of priorities” could be shown “projected in 3D” to “bring out the areas of interest”.

The visual representations seemed to resonate with some KIs more than others. Despite acknowledging that “on first look [the model] is daunting”, KI-J considered that “once you get into it, it makes sense”. Similarly, in their response, KI-E provided reflections on nodes in turn. It is possible that posting out hard copies provided the time and space to review the visual representations methodically, outside the constraints of a one-to-one meeting. However, KI-E also reflected that although they had reviewed 10 nodes, they “haven’t got enough time” to review the model or contribute further.

Table 4.3 Summary of responses received in cycle 5

KI	Date of response	Method of response	Type of response
KI-K	9 Aug 2018	Post. Handwritten annotations on visual representations and instructions sheets.	Provided comments on presentation and classification of the nodes in categories. Suggested additional nodes and arcs.
KI-A	10 Aug 2018	Email, typed response.	Commented on the presentation and the numerical values, focusing on the changes in the likelihood of events calculated from the combined probabilities in the different scenarios.
KI-E	21 Aug 2018	Email typed notes in a table and posted handwritten annotations on the visual representations.	Made notes on specific nodes in a table, commenting on the numerical values and impacts. Suggested additional arcs and nodes. Annotations accompany typed notes, highlighting the position of suggested additional nodes and arcs, and indicating nodes to combine.
KI-C	4 Sept 2018	Emailed typed comments.	Commented on presentation issues.
KI-B	19 Sept 2018	One-to-one meeting, during which I annotated the visual representations	Commented on presentation issues and suggested additional aids to interpretation.
KI-F	Oct 2018	Post. Handwritten annotations on instructions sheets.	Commented on the presentation and instruction sheets.
KI-J	14 Aug 2019	Email typed notes	Commented on the presentation, suggested additional nodes. Sought clarification on the distinctions between some nodes

The responses were received up to 12 months after the letters were posted. Of the 3 KIs who responded after one month, KI-B indicated that they were not keen on submitting a written contribution and I arranged a meeting with them instead. As discussed above, I annotated the visual representations during this meeting, making KI-B the only KI who did not submit a written contribution. KI-F and KI-J were on leave from their place of work (where the letters were posted to), and their contributions were delayed until their return.

After receiving the responses in cycle 5 I thanked the KIs again for contributing and reiterated that brought an end to the planned cycles of engagement from me. I did say that I would welcome any further thoughts if they wanted to get in touch.

4.6 Summary

In this chapter, I have provided a chronological account of the cycles of engagement, describing the production and collection of qualitative data and how they were incorporated into the BBNs between each cycle. Qualitative data were obtained from 32 interactions with the KIs: 25 one-to-one interviews, one of which was by Skype; I presented at and participated in a Parish Council meeting; and I received 6 written contributions. I engaged with 16 KIs over 5 cycles of engagement between August 2017 and August 2018, and I received written responses up to August 2019. Between the cycles of engagement, 14 individual and 2 combined BBNs were produced.

The data collection timetable was reviewed and revised during the cycles of engagement. The proposed group events in cycle 5 were replaced by written consultation in response to feedback from the KIs and to reduce the risk of consultation fatigue and the burden of participation.

The complexity of the BBNs increased with each cycle. Cycle 1 and 2 concentrated on the structure of the models, considering the issues and connections between them. After cycle 2, event likelihoods were represented as numbers in the nodes. Building the BBNs over the cycles of engagement shows that, via the iterative approach, knowledge was produced, reviewed, and refined as issues were raised and revised, and the meanings behind the nodes were gleaned. However, the experience of engaging with models varied across the KIs. Despite being involved in the development, many KIs struggled past cycle 2, particularly with the numbers. As a result, some of the KIs expressed anxiety and doubted their own capabilities and knowledge, as well as the value of their contributions. In chapter 5, I reflect on how the KIs engaged and the challenges raised in each cycle as well as the anxiety expressed by KIs about the complexity of the modelling.

Because it is a laborious task, the modelling was undertaken between the cycles of engagement by me and independent of the KIs to reduce the burden of participation. However, this meant that the KIs missed experiencing how knowledge was deepened during the process of modelling. I recognise that my position as modeller and the primary receiver of knowledge from each KI privileged me in terms of knowledge generation. I reflect on this privilege in Chapter 5.

In reviewing their varying engagement experiences, the KIs reflected on the potential applications of BBNs to PEDM in general. I reflect on the potential for BBN use in PEDM broadly in chapter 7.

Chapter 5. BBNs and knowledge production

This chapter addresses RQ 2: do the features of BBNs adequately capture, represent, deepen the understanding of, and communicate knowledge?

The legitimacy and quality of high stakes environmental decision-making, characterised by complexity and uncertainty, requires participatory approaches to knowledge production (Hage *et al*, 2010). However, as explained in chapters 1 and 2, in practice PEDM is often characterised by extractive data collection processes that focus on accuracy of the data rather than democratic values and prioritise expert knowledge over public views. As a result, participants become disillusioned and negative feelings develop into active opposition, causing delays, costs, and conflict between stakeholders (Haggett, 2008; Wolsink, 2007). The ability of BBNs to incorporate qualitative data, and visually represent and update knowledge has the potential to address these shortcomings. In contrast to expert-focused PEDM practices, the ability of BBNs to incorporate qualitative data increases the diversity of evidence that can be captured and reduces barriers to participation, by negating the need for contributors to reduce their views to numbers. Previous studies have shown that participants dislike assigning numbers for subjective probabilities, as numbers portray an accuracy that participants cannot provide (Renooij, 2001). Visually representing the captured data helps participants visualise the inclusion of their contributions and how they relate to others, so they feel valued (Chen & Pollino, 2012; Marcot & Penman, 2019). The ability of BBNs to be updated as more information becomes available or changes, enables participants to review different scenarios in the visual representations and update their prior beliefs. In contrast to extractive PEDM, the ability of BBNs to update, visualise and revise the modelling facilitates an iterative process of knowledge generation, where participants are encouraged to learn and appreciate alternative views.

This chapter comprises a 'technical assessment' of the extent the above features can be delivered into the case of SEG. This entailed testing BBNs' ability to capture and incorporate qualitative data and a range of perspectives; to represent and incorporate stakeholder views; and to enable participants to reflect on and develop their knowledge in an iterative way.

Having tested these features of BBNs in the case of SEG (see chapters 3 and 4), I explain what the primary data say about the ability of the BBNs to capture qualitative data and produce knowledge in a way that stakeholders can relate to and make sense of. I assess the value of BBNs as an output – a visual representation of knowledge - reflecting on what knowledge was incorporated, translated, reduced, and / or lost in the visual representations. I assess how accurately the modelling represents and interprets the KIs' stories, information, and knowledge. The value of BBNs as a process of knowledge production is explored to assess how the ability of BBNs to be updated and developed contributes to knowledge generation.

The analysis of the primary data showed that the value of BBNs differed as an output, visual representation of knowledge, and as a process of co-producing knowledge, which also differed between users. As outputs and as a process of knowledge production, BBNs delivered variable value for KIs reflecting on their own knowledge, as a method of communication of knowledge between KIs, and the knowledge I accrued. I explain these distinctions in the following sections. In section 5.1, I discuss the value of BBNs to represent knowledge so that individual KIs can reflect on and develop their previous contributions. In section 5.2, I consider the value of BBNs to represent and communicate knowledge between KIs. In section 5.3, the value of BBNs to represent knowledge and as a process of knowledge production for me, as the researcher, is discussed. I compare the process of knowledge production using BBNs to conventional interviewing; specifically, asking the question 'did the BBN add to knowledge generation?' Finally, in section 5.4, I conclude by explaining how the features of BBNs and their development contributed to knowledge generation for the KIs and me.

5.1 The process of knowledge production – reflection on prior beliefs

In this section, I explain what the primary data show about the value of BBNs to the individual KIs, in the process of knowledge production. I evaluate the extent that iteratively building BBNs with KIs encouraged them to reflect on their prior beliefs and generate further knowledge. As documented in chapter 4, visual representations of BBNs, representing previous contributions, were presented to KIs in cycles of engagement, to facilitate a process of reflection and knowledge production. The value of the BBNs to enable this process is therefore dependent on the ability of the BBNs to capture knowledge and present it back to KIs. Below, I discuss how the structure of the BBNs captured knowledge and how the KIs

worked through the structure logically to sort, slow, and broaden their thoughts. I also reflect on how the BBNs facilitated the process of knowledge production, considering the different ways that KIs reflected on, and updated their prior beliefs.

As explained in section 1.2, the structure of BBNs illustrates the issues KIs raised as nodes and the relationships between them as arcs. The direction of the dependencies between each of the nodes are represented by the direction of the arcs. Most of the KIs considered that the structure of the BBNs usefully represented a way of "writing down thoughts", which helped them "check everything is considered" (KI-B). The KIs generally recognised how the structure of the BBNs represented the relationships between the nodes, revealing the inter-connectedness of the issues they raised. KI-A reported that the BBNs showed "how all the many areas interlock" and KI-L recognised that the structure of the BBNs "makes people think about connections and relationships".

The KIs also recognised that the structure of the BBNs illustrated the impact of the relationships; KI-F commented that the BBNs showed that "many factors have knock-on effects on others". The KIs indicated that the logical way BBNs illustrated the relationships between the variables and the impacts of those relationships was useful. KI-C reported that "the interchange between the issues appears logical" and was "making sense". Most KIs appreciated the opportunity to reflect on their previous contributions (prior beliefs), describing it as "interesting" (KI-D, KI-B and KI-F), "intriguing" (KI-E), and "fascinating" (KI-A).

The logical structure of the BBNs enabled the KIs to slow down and sort through their thoughts so they could reflect on, and update, their previous contributions. Several of the KI's appreciated that the structure of the BBNs provided "a way to logically work through" (KI-J) their thoughts, which "helped to get to the nub of the issue" (KI-F). The process of working through the logical structure of the BBNs generated new knowledge, as the KIs revised their own understandings of the issues they raised (represented by nodes) and the relationships between them (represented by arcs).

The KIs reflected on and updated the nodes by simplifying concepts (combining nodes), introducing new distinctions (adding new nodes), and refining and clarifying concepts

(redefining nodes). For example, in cycle 1, KI-E stated that fish stocks, specifically 'smelt', were a "principal feature of the ecosystem" and a "concern" for SEG. After cycle 1, both 'fish stocks' and 'smelt' were incorporated into the BBN as separate nodes. Reviewing the visual representation of the BBN in cycle 2, KI-E considered that these issues could be simplified and directed me to combine the 'smelt' node with the 'fish stocks' node. KI-E then clarified the definition of the 'fish stocks' node, reflecting that that there was a difference between protected species and general fish stocks so redefined the 'fish stocks' node as 'protected fish stocks', so that it could represent other key species such as 'lamprey' see Figure 5.1.

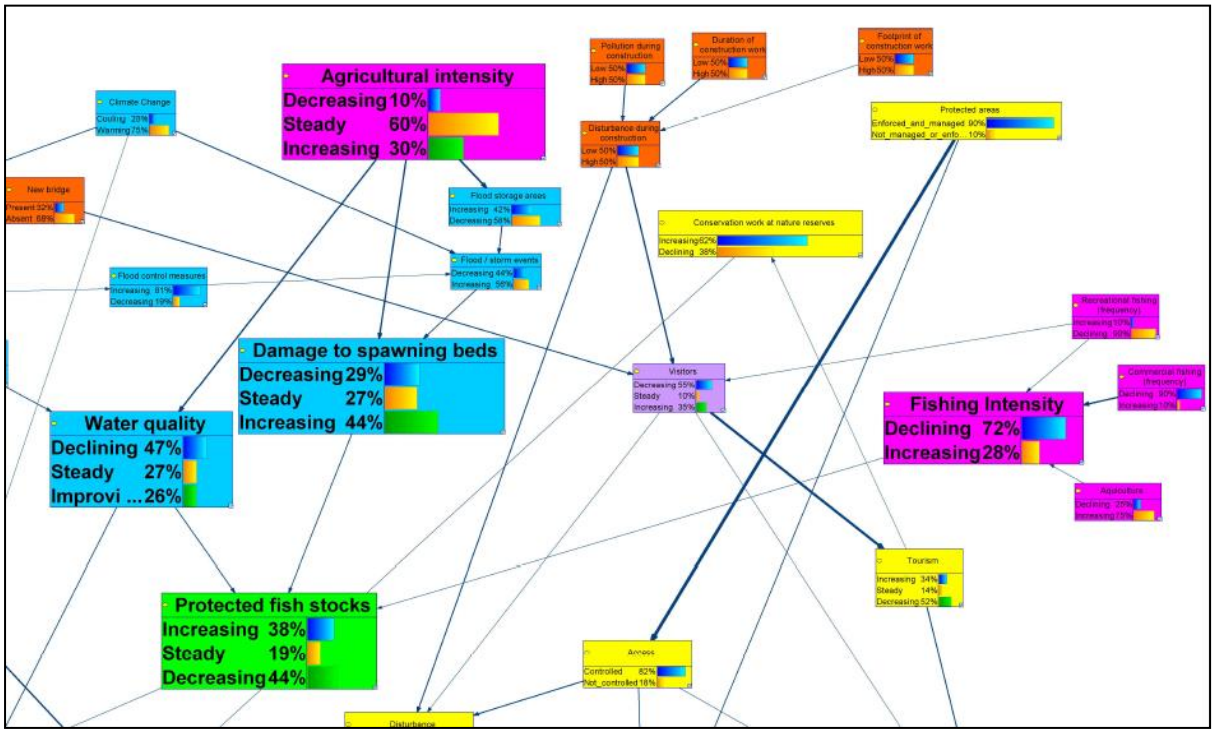

Figure 5.1 Extract from KI-E's cycle 2 BBN highlighting the combined 'protected fish stocks' node that is linked to new nodes of 'damage to spawning beds', 'agricultural intensity', 'water quality', and 'fishing intensity'

Working through the logical structure of the BBNs provided opportunities to reflect on causes and explanations of the relationships between the nodes, represented by arcs. For example, in cycle 1, KI-E had stated that the population of salmon (and other protected fish such as sea trout) in the Solway Firth is currently in decline, which corresponds to Environment Agency data (2018). However, KI-E also stated that conditions that support increasing populations, specifically improving water quality and a reduction in the local fishing industry, were present, represented in the BBN, as 'water quality' and 'fishing intensity' nodes, with arcs representing their influence on the 'protected fish stocks' node (see Figure 5.1). I therefore noted that

other factors (not currently represented in the BBN) must be causing the declining salmon stocks, which prompted me (in cycle 2) to ask KI-E to explain why fish stocks, particularly salmon, were declining. KI-E explained that surface runoff associated with agriculture up-stream of the Solway Firth, produces sedimentation that damages the salmon's spawning beds in the rivers, reducing the opportunities for successful salmon breeding, adversely affecting their population. As a result of this discussion, I added a 'damage to spawning beds' node, showing its dependence on 'agricultural intensity' and influence on 'protected fish populations' with arcs (see Figure 5.1).

By representing issues that the KIs raised as nodes, and the relationships between them as arcs, the BBNs encouraged the KIs to reflect on the relative importance of the issues, as features with intrinsic value, and functions with instrumental value in the system. As noted above, the absence or presence of nodes prompted KIs to emphasise the value of specific issues. On reviewing the BBN in cycle 2, KI-A immediately noted that 'conservation' and 'designated sites / features' were not identified as nodes and emphasised these were priorities relative to other issues that were represented as nodes. Nodes for 'conservation' and 'designated sites / features' were subsequently added. Conversely, the KIs were able to identify issues that they did not value enough to retain, and those nodes were removed.

As well as adding and removing nodes, the KIs refined the nodes to reflect their relative importance. In cycle 1, KI-E discussed 'invertebrates' and 'bivalves' in the intertidal areas, which could be affected by SEG; they were subsequently incorporated into the BBN as nodes. In cycle 2, the presence of these nodes prompted KI-E to reflect on why they were important and considered that their value was in their function (instrumental value) as prey for birds. As a result, KI-E combined the 'invertebrates' and 'bivalves' nodes and redefined them as two 'prey' nodes: 'availability' and 'abundance' that reflect "how birds can get at it [prey]" (KI-E), where 'prey availability' is dependent on exposure time, and 'prey abundance' dependent on water quality.

Reviewing the nodes and arcs together, the KIs recognised that the BBNs enabled them to think about their values; KI-F acknowledged that "it is stimulating to think about why things are important". KI-A also recognised that the BBN encouraged them to think about their own

motivations for including specific issues. They reflected that the BBN represents issues for their "own benefit", meaning that they included issues that mattered to them, and therefore their contributions were biased towards their own values. I reflect further on how the BBNs encouraged the KIs to become more self-aware in chapter 6.

As described in chapter 4, KIs contributed to the development of the BBNs. In each cycle, more details were added: in cycle 1, issues were identified; in cycle 2, the nodes were reviewed and arcs and states were added; in cycle 3, the nodes, states and arcs from each KI's own and another KI's BBN were reviewed, and the weightings of the arcs added and the models combined; in cycle 4, the combined models, incorporating alternative views were reviewed; and in cycle 5, different scenarios were reviewed. This development process facilitated the production of new knowledge as the KIs broadened out their thinking over the cycles of engagement.

In cycle 2, adding the node states encouraged the KIs to consider and work through their justification for why issues (represented as nodes) matter. Adding the arcs between the nodes encouraged the KIs to consider how the issues they raised related to each other. For example, in cycle 1, KI-B noted that the use of local ports, such as the port at Annan, has declined significantly and is now hardly used. In cycle 2, when considering the states for this node, KI-B reflected on the explanation for its lack of use and the relationship between the ports and SEG. KI-B concluded that the lack of use of the port at Annan, and its associated lack of management, has allowed it to become 'silted up', so it is now un-usable. They also calculated that the cost of dredging the silt is currently economically unviable due to lack of economic activity at Annan port to support it. The states of the 'ports' nodes were therefore defined as 'viable' and 'unviable'. However, KI-B speculated that the economic activity associated with the construction and maintenance of SEG would increase the viability of the ports, as they (especially Annan) could be used to harbour delivery and maintenance vessels. An arc from the 'SEG' node to the 'ports' nodes was therefore added.

As the BBNs were developed, they became more complex. Adding the arcs and their weightings enabled the effects of changing probabilities of events such as SEG being installed to be shown by comparing visual representations of two scenarios (SEG installed, and SEG not

installed). Some of the KIs appreciated that the logical structure of the BBNs enabled them to systematically consider the effects of changing probabilities. KI-E stated they "liked working through the logic of changes in probabilities". However, other KIs struggled with the complexity of the BBNs at that stage and their value as representations of knowledge was reduced. This is discussed further in the next section.

The potential for the complexity of the BBNs to adversely affect engagement was recognised in the research design (see section 3.2). The iterative process of developing the BBNs with KIs individually and then combining them was designed to address this risk. Recognising that the integration of the BBNs would significantly increase the complexity of the modelling, integration occurred only after cycle 3. However, some KIs were frustrated by the slow pace. In cycle 2, KIs seemed critical of lack of progress: KI-E considered that the approach was "more time consuming" than existing PEDM. In cycle 3, KIs were keen to see other KIs' views, not just as separate alternatives, but as combined models, to see how the views worked together. The KIs understood that in representing views from others, the combined BBN could "represent different perspectives" (KI-E). They also grasped the benefit of this for decision-making: KI-C noted that representing alternative views would enable them to "identify commonalities".

In this section, I have explained how the representation of knowledge in the BBNs and the iterative process of developing the BBNs enabled the KIs to develop a deeper understanding of their own values and generate new knowledge. The logical structure enabled the KIs to reflect on the issues they had previously raised, to simplify, introduce, refine, and clarify concepts and their relationships to each other. Working through the nodes and arcs encouraged the KIs to reflect on the relative importance of issues raised as features of the model and as functionally in the model. The process of iteratively building the BBN enabled them to broaden out their own thoughts.

In the next section I discuss how the process of building the BBNs affected the representation of knowledge as the complexity of the visual representations increase. I also consider how knowledge is lost in the process of revising and building the BBNs.

5.2 Communicating knowledge

The KIs were introduced to alternative views via another individual BBN in cycle 3, and the combined model in cycles 4 and 5. The KIs generally recognised that viewing alternative perspectives via the BBNs was "a good way to.... raise awareness" (KI-J) and to "appreciate other perspectives" (KI-L and KI-K), recognising that "it is stimulating to think about …. what other people value" (KI-F) and welcoming the opportunity to "think about how to engage" [other stakeholders] (KI-D). However, despite the ability of the visual representations of the BBNs to raise the awareness of the views of other stakeholders, they were less effective in capturing and communicating that knowledge between the KIs. The qualitative data indicates that although the KIs generally understood the structure where issues and their relationships are represented by nodes and arcs, the visual representations did not adequately communicate how KIs' values had been incorporated into the BBNs and how the models were developed between the cycles. This point was highlighted by KI-F in cycle 5 who commented that the BBNs "are insufficient for me to begin to understand…. beyond the fact that many factors have knock-on effects on others". KI-G stated that "you couldn't put the model down in front of people and expect then to understand it".

In this section, I will evaluate the use of the BBNs to communicate knowledge. First, I discuss presentational issues with the BBNs raised by the KIs. Second, I reflect on the knowledge lost in the process of building the BBNs. Finally, I discuss the adverse effects of these issues on the burden of participation and the credibility of the evidence represented in the BBN model.

Presentational issues

The KIs raised several issues about the presentation of the BBNs which affected its capacity for knowledge communication. The KIs identified some specific issues with the visual presentation of the BBNs that could be easily addressed to aid interpretation, for example the thickness of the arcs and the colouring of the nodes. Several of the KIs considered that it is "hard to work out the relative importance portrayed through thickness" of the arcs (KI-C). Similarly, several of the KIs were "not sure what the colours [of the nodes] meant" (KI-F). To address these issues some of the KIs suggested that information could be added to the visual representations to aid interpretation, for example, KI-C suggested that "thicker lines or colour coded lines might help" the interpretation of the arcs.

The iterative process enabled some of the KIs' suggestions about presentation of the data to be incorporated. In cycle 4, KI-F suggested there should be a key for the colouring of the nodes, which was subsequently incorporated. In cycle 5, after a key was added (see Figures 4.12 and 4.13), KI-C stated that "the colour coding works well" and KI-A agreed, stating that "the colours make sense".

The colours of the nodes and the addition of a key were superficial and did not affect the core features of BBNs. They were therefore easy to amend. However, some of the presentational issues that the KIs raised were integral parts of BBNs and therefore difficult to change. As explained in chapter 1, BBNs display the calculated likelihood of events as numbers in each node (as illustrated in Figures 1.1 and 1.2). However, representing the likelihood of events as numbers exposed a tension between qualitative and quantitative data. Previous studies indicate that participants find it difficult to accept that the numbers displayed adequately capture the meaning of qualitative data, and consequently feel undervalued (Campbell *et al*, 2012). The primary data collected in this study supports this reaction. The KIs generally struggled with the meaning of the numbers displayed, which were not well understood. While recognising that "people like numbers" (KI-J), the KIs also found them confusing and "meaningless", causing "a great deal of scepticism" (KI-F), undermining the credibility of the models. KIs perceived the numbers as fixed, unchangeable values as opposed to probabilities that could be updated as the evidence changed. In cycle 4, KI-J recognised the problem, considering that "people instantly think they [numbers] are an observed value" and stated that there needs to be a "better way to explain the numbers".

To address the confusion associated with the presentation of numbers in the BBNs, in subsequent cycles I provided additional oral and written explanation, but this interpretation did not seem to improve KIs' understanding. In cycle 4, KI-F stated that they were "stuck on the figures" because they had "no idea how these [numbers] were calculated". Despite my oral guidance throughout the interview, at the end KI-F stated: "I still don't understand the values". The written guidance provided in cycle 5 did not improve KI-F's understanding, reiterating that he had "no idea how these were calculated…… they seem meaningless to me, I'm afraid". In addition to confusion about what the numbers represented, the KIs were also

concerned about where they came from. KI-N asked how the "numbers were calculated" and KI-F asked how "the figures were arrived at?", which raised concerns about the credibility of the evidence presented in the BBNs, which is discussed later in this section.

The KIs generally struggled with the complexity of the presentation of evidence in the BBNs. This impelled some KIs to suggest that "perhaps the model could be simplified" (KI-A) and made more "easy to model" (KI-E) to aid communication. However, KIs also considered that the BBNs were not detailed enough to adequately represent the system that they intuitively understood. In cycle 1, KI-E stated that "models aren't useful here" because the Solway Firth is "determined by extreme events" that are "impossible to model". Despite the increasing complexity of the BBNs as they were developed over cycles of engagement, in cycle 3, KI-N concluded that a model would always "miss important elements". In cycle 4, referring to the combined model (Figure 4.10), KI-F considered that although the model "showed that the system was complex" it could "never represent the complex connections" of the environment. The visual representations of the BBNs therefore need to be simple to be understood, but complex to be credible. KI-B captured this tension stating that "what works best is simple, [but] it needs to be underpinned by complexity".

The KIs sense that BBNs could not adequately capture the complexity of the natural environment, and its relationships with the community, society and the economy were further constrained by the inability of BBNs to model feedback relationships. BBNs are limited to impacts going one-way (from parent to child node), however, in practice, effects could 'feedback' (from child to its parent node, or further back in the chain). For example, the abundance of prey is likely to increase populations of birds, however, more birds will eat more prey, producing a 'feedback' effect and reducing the abundance of prey. Like previous studies (Amundson *et al*, 2014; Schuchert *et al*, 2012; Uusitalo, 2007), the KIs held that the inability of BBNs to model feedback relationships was a significant limitation. In cycle 4, KI-F stated that the omission of feedback loops was "not helpful". KI-F considered that although BBNs illustrated that the system was complex, the accuracy of the representation knowledge was limited; the BBNs needed to be more complex and be able to model feedback relationships.

In summary, the KIs raised several presentational issues with the visual representations of BBN. The KIs were concerned about what the numbers represented and were confused about where they came from. They doubted the accuracy of the BBNs to represent the complexity of the relationships between the environmental, social, and economic issues raised. The inability to model feedback relationships further reduced the perception of accuracy and consequently the credibility of BBN as representations and communicators of knowledge. The presentational issues identified above were compounded by the loss of knowledge during the process of building BBNs, discussed next.

Losing knowledge

As noted in section 5.1, the primary data indicate that knowledge represented in the BBNs was lost in the process of knowledge production. As the models evolved over the cycles, nodes, arcs, and states were amended, moved, replaced etc., so that the visual representations lose the detail and story of the deliberative process, as described in the examples below.

In cycle 1, KI-A reflected on the connection between the environment and the "unique lifestyle" of the Solway, connected to the local history, including how the monks of Holme Abbey used salt from coastal salt flats as a commodity and to preserve meat and fish. In cycle 2, KI-A developed these thoughts, speaking about the uniqueness of the Solway, and that the "unspoilt" setting contributes to a "way of life" that depends on "emptiness" and "a unique ambience". As the modelling process progresses, issues are refined to be incorporated into the model and the BBNs are amended. In cycle 3, KI-A reflected on the quietness of the area around Bowness-on-Solway, its "unique way of life" and (while reviewing the BBN) the potential connections with SEG. The reflective process helped KI-A to realise that issues mattered because of the potential for disruption associated with the construction of SEG. As a result, they assigned a 'community peace of mind' node to represent the issues previously raised associated with local history, quietness, way of life, emptiness, and ambience. For KI-A, the single 'community peace of mind' node represented their thought process including the meaning of the issues raised along the way. However, the visual representation of knowledge in the resultant BBN has been reduced during the deliberative process, and the full meaning of 'community peace of mind' was not represented by the resultant single node.

KI-B's BBN also lost knowledge over the cycles of engagement. In cycle 1, KI-B identified 'local history', 'rich history / folklore', 'historical rights', 'geological importance' as issues that matter. KI-B spoke in detail about the area's "rich history" of environmental, geological, and ecological importance, which there is "not much written about". KI-B considered that the local history, environment, and culture of the Solway Firth should be publicised better. However, in cycle 2, KI-B considered that 'local history', 'rich history / folklore', 'historical rights', 'geological importance' should be combined into one node: 'history of place'. The revised BBN no longer represented the detail and meaning behind 'history of place' node that KI-B had previously described.

These examples illustrate that the issues, and cause and effect relationships between them can be represented and adjusted by visual representations of BBNs but meaning and detail that is lost in the process cannot be communicated to others. This loss of meaning and capacity for the BBNs to communicate knowledge reduces the opportunities for mutual understanding and learning between KIs, and collaborative co-production of knowledge. This contributes to loss of trust in, and doubts about the credibility of the evidence represented in the BBNs and their capacity to communicate knowledge between KIs, which is discussed later in this section.

Just as the KIs agreed that the "meaning of the values needs to be clearly explained" (KI-J) several KIs suggested that interpretation is required to reinstate meaning that is lost as data are reduced to be incorporated into the model: "for the model to have impact there it needs to be accompanied by interpretation" (KI-B) and that it "needs explanation" (KI-K). During the cycles of engagement, I provided oral and written guidance to supplement the visual representations, illustrating that the BBNs alone were insufficient and would need to be supported by other methods of communication.

KI-B interpreted the visual representations as "the rationale", "foundation to work with" and the "underlying part", and suggested that "the model needs to be accompanied by work on top" like a "visual tool….in dashboard format….that does the interpretation" to "unpick the model" and "demonstrate the effects". This supports the idea that BBNs can be useful as a

part or layer of communication but cannot be used in isolation; BBNs could be part of the process of PEDM, but do not represent the process in its entirety. Although I provided guidance, because the study used a participant-led approach I stopped short of interpreting the results for the KIs, indicating a tension between easing the participant burden by interpreting the BBN and empowering participants to interpret the models themselves. This tension is explored further in chapter 6, where I discuss the fulfilment of the practical criteria associated with the principles of PEDM, including empowerment, proposed in chapter 2 (see Table 2.6).

Burden of participation

The complexity of the BBNs and the loss of knowledge during their development reduced the ability for the BBNs to communicate knowledge between KIs, and the KIs' understanding of the models. Generally, the KIs struggled with the complexity of the visual representations of the BBNs, which increased the emotional and practical burden of participating.

Practically, the complexity of the BBNs increased the time that it took the KIs to review the BBNs. In cycle 5, KI-C stated that "it has taken a while to get my mind around the networks and what is being shown". The practical burden associated with lack of time and resources to participate, is recognised in previous studies. For example, to ensure that *those with fewer resources are not excluded*, compensation is sometimes offered to incentivise and reduce the barriers, for participating (Roberts & Escobar, 2015, p. 201).

The (emotional) burden of understanding the complex visual representations of BBNs increased anxiety. KI-F repeatedly stated that they "didn't understand it" and "can't follow it", and that the BBN would "bamboozle most people". Previous studies have also found that participants express *discomfort* where their participation responsibilities are *too challenging and insufficiently explained* (Bromley *et al*, 2015, p. 904). The complexity of the BBNs and the anxiety and discomfort associated with trying to understand them reduced KIs' confidence and their ability to speak freely and in depth about issues, as the limits of their own knowledge are recognised and exposed. For example, in cycle 3, when discussing the bird nodes, KI-A cut short the discussion by stating that they were "not an expert" [on birds]; in previous cycles

they had discussed birds more freely. Their anxiety in contributing views beyond their established role and area of expertise added to the emotional burden of participation.

As stated in section 5.1, the KIs were eager to have their individual BBNs combined. There is evidence that the emotional participatory burden was linked to the KIs' eagerness to have their individual BBNs combined. It is possible that in integrating the data, the KIs felt that they could share the participatory burden and limit their personal responsibility for a decision based on a BBN that reflects their individual views. However, the extent KIs were willing to share responsibility was limited by the trust they had in the credibility of other stakeholders and conventional roles and responsibilities, as discussed next.

Credibility of evidence

The KIs were eager for the models to be combined; KI-D stated that "the sooner integration happens the better". Despite this enthusiasm to combine the models and share responsibility, the KIs raised concerns about the credibility of the evidence represented in the BBNs. The process of modelling separate BBNs then presenting alternative views expressed in another KI's individual BBN, exposed differences in the evidence, raising concerns about the credibility of other stakeholders. It also raised KIs' doubts about their own credibility when presented with another KI's BBN. Reviewing alternative views in cycle 3 prompted some KIs to doubt the credibility of their own evidence. Reviewing KI-B's model in cycle 3, prompted KI-A to compare it to their own model and consider their own less favourably. Upon first glance, KI-A stated that the other model (KI-B) "looks easier" and "less woolly" [than their own model], indicating that introducing an alternative model encouraged a sense of competition and reduced confidence in their own knowledge.

The iterative process of building the BBNs, where alternative views were presented via individual BBNs in cycle 3, or combined BBNs in cycles 4 and 5 (as explained in chapter 4), highlighted issues that the KIs disagreed about. This prompted the KIs to query the credibility of the evidence represented by the models and its sources, i.e. other KIs, increasing the potential for conflict. For example, looking at KI-A's model in cycle 3, KI-N and KI-E were alarmed by the inclusion of the 'ports' node, because it highlighted the threat of economic issues outweighing ecological issues in PEDM. However, factors independent of BBNs also

contributed to KIs challenging the credibility of evidence, as they referred to existing hostilities and prejudices associated with the use of non-expert knowledge.

KIs were particularly concerned about the credibility of the inclusion of subjective views from non-experts. KI-N stated that the representation of alternative knowledge in the BBNs "highlighted the importance of who is consulted". They kept "coming back to who will be consulted", and repeatedly emphasised that "there is a lot of [published] information and data" and "statutory advice" that should be "fed in[to the BBN]". KI-N joined the cycles of engagement late, in cycle 3, and therefore did not experience the development of an individual BBNs. Other 'later joiners' were also concerned about the credibility of evidence from other KIs presented in the visual representations of BBNs. KI-K wondered "who decides which issues are the most important" and KI-L was concerned that there was "not much about the living environment other than birds", so the model "looks like it is promoting birds". The mistrust of evidence by 'late comers' indicates that the credibility of evidence was reduced where KIs relied solely on the communication of knowledge via the visual representations of the BBNs, without the benefit of the process of knowledge production. Being part of earlier cycles seemed to increase KIs' perception of credibility of the evidence they were able to appreciate and respect the work that had contributed to the development of the BBNs across the cycles.

The focus on the differences in knowledge and concern about the credibility of their own or another KI's evidence seemed to be affected first, by the development of individual BBNs, and then by seeing them as alternatives in cycle 3. The reason for developing individual BBNs first was to ensure that individuals understood their views were valued and included, and to cultivate a sense of ownership in the models (see section 3.2). Although KIs who engaged in several cycles of engagement appreciated the 'work' that had gone into the development of the BBNs, none of the KIs showed a sense of ownership with the individual models. By comparing the knowledge represented by their own and another BBN in cycle 3, the KIs focused on the differences between them. The KIs sought to explain the differences by questioning the credibility of the evidence represented in the alternative BBN or their own knowledge, instead of taking the opportunity to learn from different perspectives.

Considering the concerns that the KIs expressed about the credibility of the evidence from others, the eagerness that the KIs expressed to combine the BBNs is unlikely to be driven by their willingness to learn from others and change their own views. Instead, the degree to which KIs were willing to share the participatory burden seemed to be limited to familiar conventional roles and responsibilities, which were perceived as more credible. Several of the KIs indicated their preference for 'expert' views: KI-N stated that expert contributions "should be given more weight" and stated that they wanted "to pull in different experts". Recognising distinctive 'expert' views enables the role of the contributor and their evidence to be defined and accepted by another stakeholder. The willingness to share the responsibility of the provision of evidence with other stakeholders could reduce the participatory burden but risks limiting participation to identifying and reviewing issues within defined established roles and responsibilities.

In this section, I have discussed the capacity of the BBNs to communicate knowledge between the KIs. Some superficial features, such as the colouring of the nodes, could be easily amended during cycles of engagement. However, the KIs identified several features, such as displaying likelihoods as numbers and lack of feedback loops, which are integral to BBNs and their development, but which reduced their understanding of the knowledge presented. These integral features adversely affected the burden of participation and reduced the credibility of the evidence presented.

The results also highlighted some tensions in the use of BBNs. The BBNs were simultaneously too complex to understand and not complex enough to accurately represent the evidence. Providing guidance and interpretation of the BBNs for the KIs could ease the associated burden of participation but reduced their sense of empowerment.

Developing BBNs iteratively with participants aids their understanding of their own models; however, knowledge is lost from the visual representations in the process, reducing the ability to communicate knowledge to others. Modelling BBNs with individuals before integrating the data into a combined model was designed to encourage participants to buy into the decision-making process. However, the data indicate that it is more likely to increase anxiety associated with a sense of personal responsibility for a (wrong) decision. The KIs were eager

to share the responsibility of the decision-making in combined BBNs, perhaps because they doubted the credibility of their own or other KI's evidence and worthiness to be included. As discussed in the previous section, the BBN enabled the KIs to appreciate the wider context of their views and broaden their thinking, but the doubts around the credibility of evidence from other KIs motivated them to move towards contributions of experts identified by their established roles and responsibilities.

In the next section, I consider the value of the BBNs as outputs and process of knowledge generation for me, as the researcher, representing the decision-maker and / or modeller (in this case study).

5.3 Value to the decision maker

In this section, I describe how the features of BBNs and their development contributed to knowledge generation for me. I reflect on the differences between the way knowledge was produced via the BBNs and conventional interviewing. I focus specifically on how the methodological approach contributed to my knowledge.

As discussed in sections 5.1 and 5.2, the process of developing the BBNs over cycles of engagement produced knowledge as individual KIs reflect on their prior beliefs. However, as the BBNs are amended to reflect their later reflections, knowledge was lost and the amended visual representations of the BBNs do not represent all the knowledge I accrued from the KIs during and between the cycles of engagement as I listened to, and modelled the knowledge from individual KIs.

As the researcher and modeller, I benefited from the process of knowledge production via the development of the BBNs across cycles of engagement in three ways. First, I received the KIs' knowledge unprocessed and unreduced from listening first-hand to their reflections during and between cycles. Second, while processing the primary data I had the opportunity to reflect on the unprocessed knowledge as I incorporated it into the models. Third, through meeting all the KIs, receiving their knowledge and then modelling it, I had sight of the data from all the KIs and an understanding of how it was building up. KI-F acknowledged this

privileged position, commenting that “you know what the model was driving towards”, while to them the BBNs remained “abstract”.

Receiving unprocessed knowledge

In receiving knowledge from KIs first-hand, I benefitted from the stories they told to illustrate issues raised, but which are lost in the BBNs. For example, throughout the cycles of engagement, several of the KIs imparted a sense of the rivalry between the communities on either side of the Solway Firth associated with the location on the border of England and Scotland and communicated through the telling of stories, including those of the border raiders. In cycle 1, KI-I and KI-H raised the story of church bells from the church at Dornock, Scotland that *lies at the door of the sanctuary in Bowness-on-Solway on the English side, taken in reprisal for the theft by the Scots of the Bowness bell and its loss in the Solway* (Scotland’s Churches Trust, 2017). During the interviews we used the map of the area to locate Dornock, providing context to the story of the stolen church bells.

Other KIs also mentioned the story of the church bells, which was incorporated in models as ‘local history’, ‘story telling’, ‘heritage’, and ‘local identity’ nodes. These nodes do not fully represent the detail and meaning of the story. However, receiving the story of the church bells from several KIs enabled me to gain a sense of the significance of historical rivalries and cultural identity associated with the communities on either side of the Solway. I obtained the knowledge through the process and was motivated to learn more about it so I visited the churches in Dornock and Bowness-on-Solway, viewing the church without a bell at Dornock and the stolen bells in the church at Bowness-on-Solway Figures 5.2 and 5.3.

Figure 5.2 The church without a bell, Dornock

Figure 5.3 Stolen bells in Bowness-on-Solway church

Present-day hostilities between stakeholders were linked to these historical rivalries. Several of the KIs suggested that the communities on the opposite side of the Solway Firth receive (unfair) advantages. English KIs (KI-I and KI-J) suggested that the Scottish communities receive more investment to preserve the remains of the former railway bridge on the north shore than the English community does for the remains on the south shore. English KIs (KI-I and KI-E) also claimed that Environment Agency (EA) restrictions on Haaf Netters, an ancient fishing practice that survives in Cumbria (Haaf Netters Fishing, 2018), are more severe than the restrictions that NatureScot place on a comparable historical practice of pole fishing on the Scottish side (Annan Initiative, 2006).

Reflecting while processing

Through receiving and processing the primary data, I had the opportunity to reflect on the knowledge from all the KIs before it was reduced to be incorporated into the models. For example, while processing primary data from KI-A, KI-C and KI-N I developed a deeper understanding of the specific issue of sedimentation. In cycle 3, KI-N disagreed with the knowledge incorporated in the BBN representing KI-A and KI-C's knowledge that showed that the installation of SEG would reduce sedimentation. KI-N was surprised that difference in sedimentation between the 2 scenarios showed that sedimentation would decrease if SEG was in place, exclaiming: "I thought everyone agreed that sedimentation would increase". As

discussed in chapter 4, while incorporating the data into the combined BBN, I could reflect on the knowledge accrued over the cycles of engagement and was able to identify a difference between the rate of sedimentation and dynamism of the areas of sediment accretion. The overall rate of sedimentation would increase as water slowed with the installation of structures associated with SEG. However, as the dynamism of the tides would be slowed by the installation of SEG, the dynamism of the deposition of sediment in the Solway Firth would also be reduced. The areas where sediment is deposited would become more stable and therefore build up as the rate of sediment deposition also increased. As a result, I defined separate nodes for 'rate of sediment accretion' and 'areas of sediment accretion', see Figures 5.4. and 5.5.

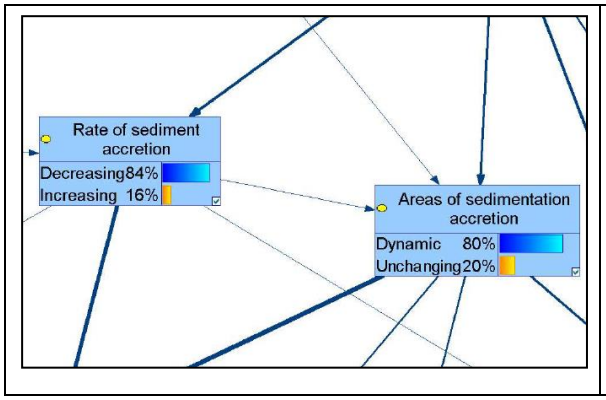

Figure 5.4 Cycle 4 combined model under the 'No SEG' scenario showing 'rate of sediment accretion' and 'areas of sediment accretion' nodes

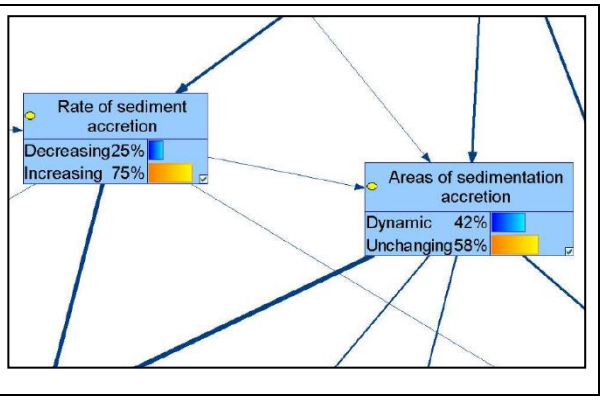

Figure 5.5 Cycle 4 combined model under the 'SEG installed' scenario showing 'rate of sediment accretion' and 'areas of sediment accretion' nodes

Although the visual representations of the BBNs can communicate the separate issues associated with sedimentation, and associated effects of the different scenarios, the process of the knowledge production is not captured. The full meaning and detail 'behind' these nodes are therefore not represented by the BBN and communicated back to the KIs, reducing the opportunity for learning for others.

Build-up of knowledge

I gained a unique perspective of the issues by receiving the combined unprocessed contributions from all KIs during and between the cycles of engagement. I benefitted from an

understanding of the range of perspectives and values the KIs expressed on specific issues, which were not captured fully by the BBN.

The range of perspectives sometimes highlighted conflicting values between stakeholders. For example, the KIs recognised the value of birds was variable, particularly wildfowl which are valued highly by conservationists and bird watchers but represent a cost to local farmers because they feed on pastureland. Some of the KIs, e.g. KI-E and KI-I, highlighted that people liked to shoot the wildfowl. This demonstrates that although BBNs can calculate the probability of an event, e.g. bird populations increasing or decreasing, the value of the outcome is not captured; conservationists and bird-watchers would be happy that bird populations increased but the local farmers would be less pleased.

The KIs expressed a range of conflicting views on flood risk on the Solway. KI-B stated that a primary motivation for developing SEG is its potential to reduce the flood risk upstream by controlling the tidal flow. Reducing flood risk would have potential economic benefits such as reduced clean-up costs. In contrast, the view of KI-E was that the best environmental and conservation outcomes would be achieved by "removing all flood control measures that are damaging the environment" and "reinstating flood plains". From KI-E's perspective, increasing flood risk would "improve the area".

The issue of flooding was further complicated by the views of local residents. In cycle 1, KI-I and KI-H spoke of the flooding as part of the local identity. An area of land to the west of Bowness-on-Solway and Whitrigg, and north of Anthorn is known locally as 'the island' due to narrow roads that are regularly flooded by high tides, cutting the isolated area off (see Figure 5.6).

Figure 5.6 Road sign on road between Bowness-on Solway and Glasson indicating the depth of flood water associated with tidal water

The connection between flood risk and local identify was illustrated during a meeting of Bowness-on-Solway Parish Council I attended in cycle 2. During the meeting, councillors discussed the state of coastal roads since recent high tide and storm events that resulted in debris and flood water blocking / restricting access to some of the local villages. The councillors were concerned the roads were not being cleared quickly enough or fully by Cumbria County Council. Some of the councillors noted that a member of the community (possibly a farmer with a tractor or similar) had stepped into clear debris from the road when the County Council had been slow to respond. The local community's response to the lack of support from the council (based in Carlisle) highlights the physical, social, and political isolation of the area from the rest of the county and their unique connection to the dynamic coast and the tides, linked to their sense of local identity. The BBNs incorporated flood risk as a node. However, the range of responses to changing the states (increasing or decreasing flood risk) of the flood risk node for different stakeholders were not represented in the model and could not therefore be communicated between KIs via the BBNs.

Cumulative benefits

The combination of receiving and reflecting on unprocessed primary data from individual KIs and building up a picture from multiple KIs provided me with a unique perspective on the conflicting views about specific features of SEG. I developed a deeper understanding about

the potential issues associated with specific aspects of SEG during the process of knowledge production facilitated by the BBNs. However, the resultant BBNs do not fully capture the knowledge produced, which reduces the potential for communication between KIs.

The SEG proposals include a pedestrian walkway over the Solway Firth, following the route of the former railway bridge. The bridge would provide a physical link between the communities on either side of the Solway Firth that are separated by approximately 2.2km of estuary, where the current road journey via Carlisle is approximately 30 miles and takes 50 minutes to complete. KI-B suggested that the proposed pedestrian bridge could become a focal point, improving tourism, connecting cycle routes and national trails including the end of Hadrian's Wall at Bowness-on-Solway. KI-D agreed, stating the proposed bridge would provide "new vistas", representing a "new opportunity to enhance recreation". Most agreed that the proposed bridge would increase visitor numbers, which could be adequately represented in the BBNs as 'visitor numbers' node, and 'new bridge' nodes. However, the idea to "re-tie the link with Scotland…improving tourism" (KI-M) had mixed responses from the KIs, considering the economic gains versus stretched local services and infrastructure, and environmental impacts.

KI-D considered that an increase in visitor numbers would be "good for the economy, society and well-being", but KI-I considered that economic benefit from increasing visitor numbers with "a short cut" to Scotland would be limited to "a few B&B owners". KI-I emphasised that the local community would resist anything that could "do away with the quietness", and the minor roads around Bowness-on-Solway were too small and narrow to cope with extra traffic. Other KIs were also sceptical about the benefits of increasing visitor numbers. KI-A explained that due to the lack of facilities around Bowness-on-Solway, irrespective of visitor numbers, tourist spending is low.

KIs also had varied perspectives on the environmental impact of increasing visitor numbers. KI-D pointed out that increasing visitor numbers could adversely affect bird populations via disturbance. However, KI-M considered that increasing visitor numbers would be a positive environmental impact, as it would increase the opportunities to communicate the importance of the habitats and the conservation work that protects them. For example, the wetlands

exhibition at the RSPB visitors centre at Campfield depends on visitors to communicate their message and improve understanding and support for conservation work. Some KIs also pointed out higher visitor numbers justifies more investment in control and management of visitors. KI-E reflected that many areas with low visitor numbers have little management which results in greater impact than in areas with higher visitor numbers and higher control measures in place. KI-D also considered that more visitors sometimes increases peer pressure for visitors to behave better, giving the example that people are more likely to pick up dog mess if there are other people around. The views of the KIs were incorporated into the model and represented by additional 'society and wellbeing' and 'disturbance' nodes and setting the states of the 'visitor numbers' node as 'managed increase, increasing, decreasing', see Figure 5.7.

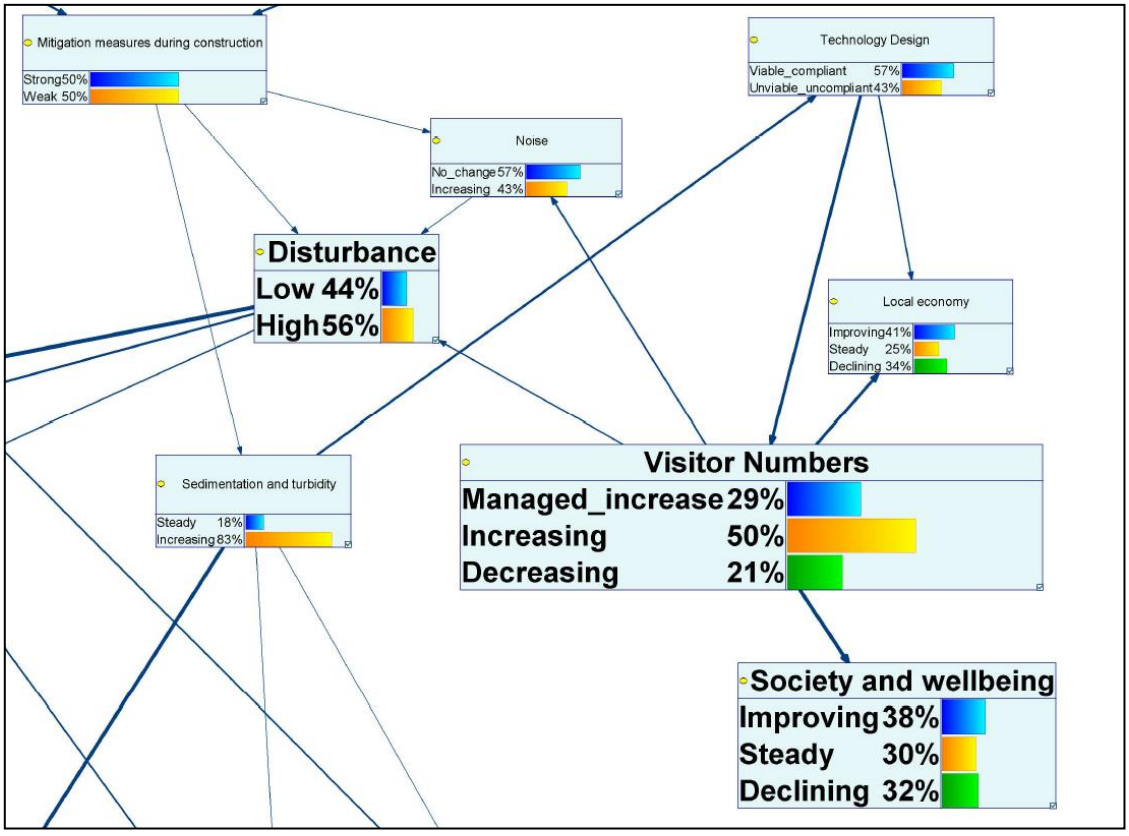

Figure 5.7 Extract of the visual representation of KI-D's cycle 2, highlighting the 'disturbance', 'visitor numbers' and 'society and wellbeing' nodes

The KIs also had a range of views on the technical suitability of renewables in the area, largely informed by the memories of the recently developed Robin Rigg wind farm where two of the wind turbines have been taken down due to instability caused by the shifting sands (Lingard, 2016a). There, the non-expert concerns of local fishers about the stability of the structures

due to the shifting sands were ignored by 'expert' engineers with adverse consequences, reflecting the tension between expert and non-expert advice discussed in Chapter 1 (see also Wynne, 1996; and Ottinger, 2013b). In contrast to the wind farm, the structures associated with SEG could not be taken down quickly and without disturbance. KI-G raised concerns about disturbance associated with decommissioning SEG if the technology "doesn't work". However, KI-E had a different view of the effect the problems at Robin Rigg could have on a proposal tidal scheme in the Solway Firth. KI-E considered the removal of wind turbines due to shifting sands could increase the need for another renewable energy development to take its place, increasing the potential for SEG.

The story of Robin Rigg was lost in the development of the BBNs. For example, in cycle 1, KI-A discussed the decommissioning and removal of wind turbines on the Robin Rigg wind farm because they were undermined by the moving sands that has made them unstable, which was represented by a 'Robin Rigg Wind Farm' with states of 'remembered' and 'forgotten', but the issue was not mentioned in subsequent cycles, and the node was dropped from further iterations. Despite the loss of the representation of the memory of Robin Rigg wind farm from the BBNs, I still accrued that knowledge.

Although the issues, and the cause and effect relationships between them can be represented and adjusted by the visual representations of the BBNs, the significance of specific events, e.g. managed increase of 'visitor numbers' (Figure 5.7), in the memories and experiences of local residents is not fully captured. The model is therefore the start of a conversation or deliberative process that needs to be accompanied with explanation and examples that illustrate and communicate to others.

Knowledge production independent of BBNs

As well as acquiring knowledge during the development of the BBNs, some of the knowledge I acquired was independent of the BBNs. The process of knowledge production was not exclusively facilitated by the BBNs and other tools aided the process. In cycle 1, prior to development of the BBNs, KIs spoke openly about the issues that matter to them about the Solway Firth, around maps of the area. Many of the KIs spoke of the former railway bridge, which the developers propose to use as the site for SEG and its pedestrian bridge to "restore

the link between England and Scotland" (Solway Energy Gateway Ltd., 2011). However, some of the KIs (e.g. KI-I and KI-H) pointed out that the former railway bridge was built to connect industrial areas of Workington and Glasgow, transporting coal for iron works. Despite the bridge not officially serving to connect the local populations either side of the Solway, some KIs noted that local people did walk across the bridge, next to the tracks. KI-A and KI-O noted that historically people from Scotland used the former bridge to walk to pubs in England on Sundays when the licencing laws in Scotland prohibited Sunday drinking.

KI-A and KI-M accredited knowledge of the former railway bridge to the 'Remembering the Solway' (Lingard, 2017) oral histories project and the 'Crossing the Moss' project (Lingard & Smith, 2019), that tells the story of the old railway. 'Remembering the Solway' captured local people's memories of the Solway Firth and the historical inks between Cumbria and Scotland. KI-A recalled the story of a lady whose grandfather used to cross the Solway on the old railway bridge on foot, carrying his bicycle, so that he could then cycle to work at a quarry in Scotland.

Although there was some nostalgia associated with the former bridge, the 'Crossing the Moss' project (Lingard & Smith, 2019), discusses the challenges of building the viaduct and why it was built, as well as its negative impact on the wetlands; "they [the builders] had no idea what it [the railway] was damaging" (KI-M). KI-M, KI-E and KI-O also highlighted the adverse impact the construction of the railway had on the wetlands. The significance of the former railway bridge had been captured, communicated, and recalled in these oral histories' projects in ways that the reduction of knowledge into node, arcs and states could not.

Many of the KIs discussed the destruction of the former railway bridge, which was taken down after it was damaged by "huge ice-floes" in the Solway Firth during a particularly cold winter in January 1881 (Lingard, 2016b). KI-I and KI-H raised concerns that similar ice-floes in the future could damage other structures in the Solway Firth, including the proposed SEG, reducing its feasibility. In cycle 2, KI-I gave me a copy of 4 photographs of ice in the Solway Firth (see Figure 5.8), to validate their view (expressed in cycle 1) that future ice-floes are a potential risk to SEG. For KI-I, these photographs satisfactorily represented and communicated the potential ice risk, illustrating how participants can be satisfied with the use of visual representations as effective communication tools. However, 'ice' was not

represented as a node in the model; it was included in the 'old railway bridge' node (see Figure 5.9) in reference to the story of the bridge, including its destruction by the ice, being 'remembered' or 'forgotten'.

Figure 5.8 Photographs of ice in the Solway Firth in the 1980s, provided by KI-I, clearly showing some ice blocks were much larger than a dog and around the height of a man

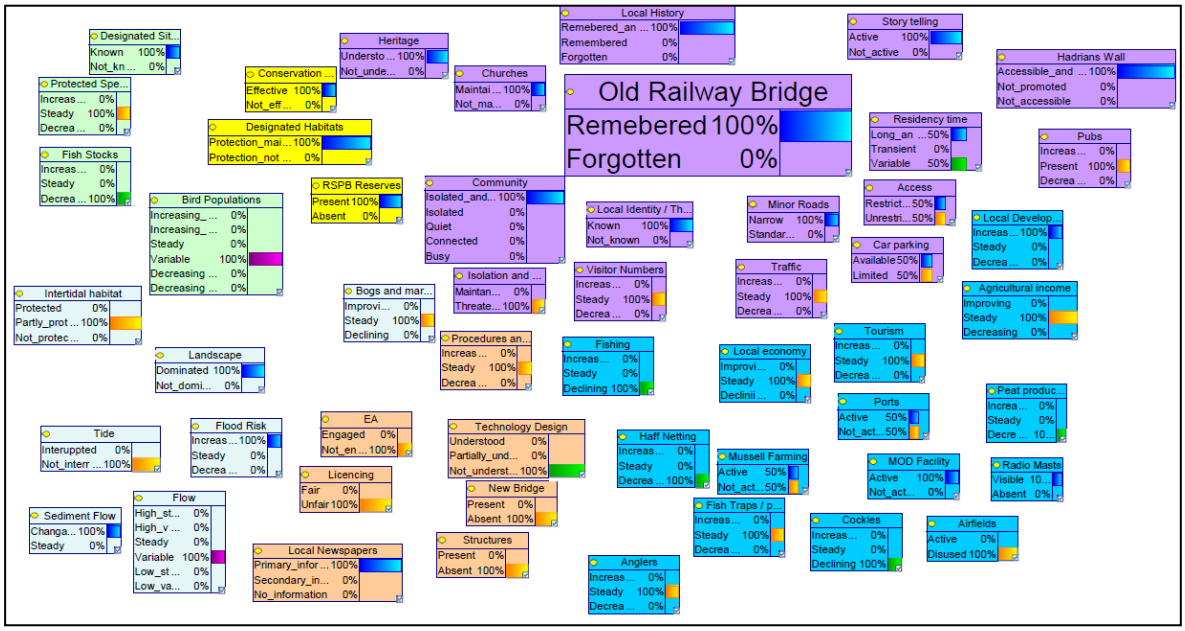

Figure 5.9 Visual representation of KI-I and KI-H's cycle 1 model, highlighting the 'old railway bridge' node

Significantly, KI-I's photographs were their own, so KI-I was familiar with them and had a sense of ownership in them. Their unprompted and voluntary contribution highlights that there is potential for participants to produce their own visual representations and contribute effectively to PEDM. In contrast, the use of BBNs limits contributions to those that fit into a model that participants cannot effectively produce themselves. Unlike photography, BBN modelling is relatively inaccessible and is dependent on a modeller, therefore participants are separate from the modelling. The visual representations of the BBNs are also an unfamiliar form of visual representation, compared to photos, reducing their accessibility and potential use as a tool for engagement. I return to the theme of familiarity in chapter 7.

In this section, I have explained how, as the primary receiver, interpreter and modeller of knowledge contributed by the KIs, I accrued more knowledge than was captured by the models and communicated between the KIs. The production of BBNs primarily therefore privileged me. In practice, this privileged position could be undertaken by a regulator e.g. Marine Scotland or the MMO in the licencing and consenting process for marine renewables. I reflect more on the potential use of BBNs in PEDM in practice in chapter 7.

In the next section I summarise and draw some conclusions from the findings in this chapter.

5.4 Conclusion

The primary data indicate that the process of developing BBNs encouraged individual participants to develop their own knowledge. Reflecting on their prior beliefs represented in the BBNs encouraged KIs to work through their own thoughts and deepen their understanding of issues that matter to them. Asking them to define the states of the nodes encouraged the KIs to consider and justify why things matter. Adding the arcs, representing the relationships between the issues (nodes) in the BBNs encouraged the KIs to consider what the issues raised were connected to, and to recognise other views. The BBNs provided a useful framework to 'discipline' the information that individual KIs contributed and most of them were interested in the process of knowledge production via the BBNs. This suggests that BBNs have the potential to provide a framework that facilitates learning for individual participants in PEDM through broadening out and self-reflection, contributing to stakeholder engagement. I return to this in Chapter 7.

Although the process of generating the BBNs helped to elicit knowledge, the knowledge was not comprehensively captured in the 'outputs' (visual representations of BBNs) because they did not replicate the depth of knowledge the participants have. Meaning and detail was lost in the process of developing the models. The KIs intuitively knew the system, which was not reflected by the BBN in the same way. While the visual representations were not complex enough to replicate the intuitive knowledge (known as implicit or tacit knowledge) that the participants gain from experience (Baars, 2011), they were too complex to communicate or demonstrate knowledge to others. In addition, the 'outputs' captured only snapshots of knowledge in time (as opposed to how knowledge changes over time) and did not comprehensively represent the deliberative process of knowledge production and how knowledge changed and evolved over cycles. This reduces the capacity of the visual representations of BBNs to communicate knowledge and consequently the opportunities for mutual understanding and learning between KIs, and for collaborative co-production of knowledge. The visual representations of BBNs, therefore, need to be supported by other methods of communication.

The results indicate that while BBNs were useful to start a conversation or deliberative process they need to be accompanied with explanation and examples that illustrate and communicate to others and should not be used in isolation. BBNs could be part of the process of PEDM, but do not represent the whole process.

The potential for learning and co-production of knowledge was adversely affected by a lack of confidence in other stakeholders. This lack of confidence was partly informed by previous experience but also by specific features of the BBNs that emphasised differences. For example, reviewing alternative views in individual BBNs in cycles 3 and 4 raised concerns in the minds of some of the KIs about what the numbers represented and where they came from, reducing the credibility of the evidence in the BBN and its capacity to communicate knowledge.

The process of knowledge production also contributed to low confidence between KIs. Producing individual BBNs to demonstrate that individual views were valued (see section 3.2) then combining the models was designed to cultivate a sense of ownership. Instead, the development of individual BBNs seemed to encourage KIs to see differences between their own views and other KIs' views, increasing concerns about the credibility of alternative views. In addition, the results indicate that completing the modelling on behalf of the KIs in isolation reduced the potential for KIs to develop a sense of ownership in the individual BBNs.

The results did indicate that KIs who were engaged in multiple cycles of engagement were less hostile to alternative views represented in the BBNs than those engaged in later cycles. 'Late comers' to the process openly queried the credibility of evidence in existing BBNs, possibly due to their lower appreciation of the work that has gone into producing the models. This indicates that the credibility of evidence was reduced where KIs relied solely on the communication of knowledge via the visual representations of the BBNs, without the benefit of experiencing the process of knowledge production.

Participant-led, one-to-one interviews, where individuals were empowered to consider their own perspectives, were designed to demonstrate that individual views were valued. However, generating and focusing on individual BBNs increased the participatory burden

associated with the weight of responsibility, and conflicted with efforts to cultivate collaboration and co-production of knowledge. The results indicate KIs recognised the participatory burden, and their need for guidance to interpret the BBNs demonstrated a willingness to share (and therefore ease) the burden even at the expense of individual empowerment. However, the KIs' willingness to share the participatory burden was limited to contributions within defined and established roles and responsibilities.

Where the visual representations of the BBNs represent outputs that fail to retain and communicate knowledge from the deliberative process, as the researcher I was able to accrue knowledge because I did not rely on the 'outputs' to receive knowledge. Instead, I benefitted from the process by receiving unprocessed knowledge, having the opportunity to reflect on the knowledge during the modelling process, and building up the knowledge from the range of KIs. Like the findings for the KIs, the process of knowledge production facilitated by the BBNs effectively contributed to the knowledge I accrued. However, the BBNs did not effectively capture, retain, or communicate the range of perspectives, sense of identity and culture associated with the Solway Firth, which was communicated by the KIs through stories.

In this chapter, I have discussed what the results revealed about how the features and development of BBNs captured / represented and communicated knowledge. The results identified tensions in the implementation of BBNs as a framework for PEDM, particularly between valuing individual views and collaboration for co-production of knowledge and opportunities to learn and share. The structure of the BBNs, displayed in the visual representations of the combined models, raised individual KI's awareness about alternative views, introducing discussion points, and opening avenues for potential contributions. However, the defined structure of the combined BBNs reduces an individual's ability to 'frame' the issues, challenging the empowerment criteria for PEDM set out in Table 2.6. I discuss the ways the features of BBNs adhere to, but also challenge, the principles of PEDM in detail, next, in Chapter 6.

Chapter 6. How the features of BBNs comply with the PEDM criteria

Specific features of BBNs could improve participatory environmental decision making (PEDM). Firstly, BBNs can be presented as visual representations that display elements of the model (Johnson *et al*, 2016) as networks of nodes in ways that are easily understood (Stewart *et al*, 2014), and constitute effective communication tools. The ability to produce visual representations of BBNs enables knowledge to be communicated and shared, giving access to information and demonstrating that stakeholder views are included, valued, and used in decision-making. Secondly, the capacity of BBNs to incorporate qualitative data enables diverse stakeholder views and lay knowledge (belief elicitation) (Johnson *et al*, 2016) to be included in the decision-making. Thirdly, the ability to update BBNs with new knowledge as data become available and changes, enables testing, re-evaluation, learning and reflection with stakeholders.

In sections 6.1 – 6.3 of this chapter, I assess the capacity of these features to improve PEDM, using the practical criteria for PEDM outlined in chapter 2. Each of the features of BBNs are compared to the principles of PEDM (inclusivity, process orientations, empowerment, and reflection) in turn, as summarised in Table 6.1. In section 6.4, I bring together the findings and discuss how the features work in combination to align or contradict with the practical criteria for PEDM. Finally, given the results, I present some suggested amendments to the practical criteria to improve their future implementation.

Table 6.1 Summary of how the features of BBNs aligned with the principles of PEDM

Features of BBNs	Alignment with the principles of PEDM
Visual representations	**Inclusivity:** visual representations of BBNs facilitated diverse contributions, but their complexity is a limiting factor. **Process orientation:** visually representing issues raised and their relationships to each other encouraged KIs to broaden and develop their own views. KIs recognised other KIs' views, but their capacity to learn from others was limited by complex visual representations. **Empowerment:** visual representations provided structure to aid KIs to discipline and broaden their thoughts, but engagement was limited by their unfamiliarity. **Reflection:** visual representations raised the KIs' awareness of alternative views, facilitating reflective process and encouraging the KIs to become aware of the limits of their own knowledge, but this is limited by their complexity.
Ability to incorporate qualitative data	**Inclusivity:** incorporating qualitative data enabled the inclusion of local knowledge and diversity; however, this reduced the credibility of the PEDM, where credibility is dependent on familiarity. **Process orientation:** incorporating qualitative data enabled diverse and opposing views to be included; however, this did not help the KIs to reconcile their views or learn from other perspectives. **Empowerment:** incorporating qualitative data facilitated inclusion of local knowledge and open discussion, but some KIs resisted the inclusion of non-expert knowledge. **Reflection:** incorporating qualitative data enabled alternative and diverse views to be included but this reduced the credibility of the evidence and willingness of KIs to reflect on alternative views.
Ability to be updated	**Inclusivity:** updating the BBNs (in combination with to visually representing the updated models) enables KIs to broaden their thinking on issues; however, some KIs were uncomfortable with this. **Process orientation:** updating BBNs enabled the KIs to review and deliberate their own and alternative views, but this increased the burden of participation. **Empowerment:** updating BBNs in an iterative process encouraged the KIs to become increasingly comfortable to share their own views, but this comfort encouraged them to establish, and become entrenched in, self-interested positions and exposed a lack of respect towards others. **Reflection:** updating BBNs iteratively enabled reflection and learning and encouraged the KIs to give feedback on previous contributions.

6.1 Visual representations

In this section, I describe how the ability to visually represent BBNs aligns with the practical criteria for PEDM. Considering the four principles of PEDM in turn, I reflect on what the qualitative data show about how visually representing BBNs fulfilled the practical criteria (associated with each principle) that were outlined in section 2.4 and summarised in Table 2.6.

Inclusivity

As outlined in section 2.4 and Table 2.6, the ability to visually represent BBNs aligns with practical criteria associated with the principle of inclusivity, and sub-principles of 'multiple and diverse perspectives are heard / represented' and 'fair access to information and opportunity to participate'. As an alternative method of communication (to conventional text-based consultation tools) visual representations of BBNs represent the potential to address consultation fatigue and reach out to diverse perspectives.

As described in chapter 5, the BBNs captured diversity in local knowledge, revealing different perspectives on specific issues and their causes and consequences. For example, the KIs had different views on measures to reduce flood risk. While it is generally assumed that everyone would welcome reduced flood risk, the reality, revealed through reflecting on the visual representations of the BBN, was more complicated. Some KIs believed that reducing flood prevention measures (allow more flooding) would help conservation measures. Additionally, as discussed in section 5.3, an area west of Bowness-on-Solway is known as 'the island' due to the frequency of tidal flooding. Reducing flood risk would (adversely) affect the local identity of this area. The visual representations of the BBNs encouraged the KIs to reveal this 'local knowledge', supporting the claim that BBNs can reach out to diverse perspectives.

The results illustrate how visually displaying information also provides access to information. The KIs did appreciate these potential benefits of BBNs. KI-N considered that visual representations of BBNs are "preferable to long texts" and the structured format of online consultations, which "excludes people" (e.g. those without access to the internet). This supports the claim that visual representations of BBNs contribute to practical criteria that

prescribe efforts to address consultation fatigue, as well as access to information and opportunity to participate.

However, as noted in chapter 5, the complexity of BBN models was recognised as a potential barrier to engagement, where lack of understanding reduces their ability to communicate information effectively. As set out in chapter 3, to address this risk, KIs saw the development of the models during cycles of engagement, where the models were built up iteratively. The objective was for KIs to gain an understanding of BBN models so that the visual representations could be used as an effective and engaging communication tool. However, despite participating in the development of the models KIs were generally confused by the increasing complexity of the BBNs as the cycles progressed. As noted in chapter 4, some KIs apologised for not understanding the BBNs and seemed to doubt their technical knowledge. Struggling with the complexity of the BBNs in cycle 4, KI-F asked me for guidance to assist his understanding, stating "you will need to walk me through it". Remaining confused, (as noted in chapter 4) KI-F worried that perhaps they were "not a good example" indicating that they blamed their own lack of technical knowledge, instead of the complexity of the modelling. It seemed that the complexity of the model adversely affected KIs' confidence in their own knowledge. This reduces the potential for BBNs to reach out and include lay knowledge, alternative views, and diverse voices, and therefore reduces fulfilment of the sub-principle of ensuring multiple and diverse perspectives and voices are heard / represented.

The capacity of visual representations of BBNs to demonstrate that diverse values, including environmental values, are accounted for aligns with the principle of inclusivity and sub-principle of 'regard for environmental values'. The inclusion of diverse values was occasionally challenged by KIs. As noted in section 5.2, the contributions from other KIs in the alternative models in cycle 3 or the combined BBNs in cycles 4 and 5, prompted some KIs to query how credible the evidence was and how fairly some issues were being represented. On reviewing the visual representation in cycle 3, KI-L was concerned about adequate and fair representation of values as "some species could be promoted above others". This indicates that while visual representations have the capacity to show participants what, how, and where environmental values are included, participants may not be satisfied that values are represented fairly. This highlights a potential tension between theoretical commitments and

values associated with the principles of inclusivity and empowerment. Commitment to including diverse viewpoints can reduce participants' and stakeholders' perception that values are represented fairly (as prescribed by the principle of empowerment and sub-principle of trust and respect). This tension represents a challenge to implementation that is explored further in chapter 7.

The results show that visual representations of BBNs can be used to diversify tools used to engage participants in PEDM, as prescribed by the practical criteria. However, the complexity of the visual representations of BBNs does limit the potential contribution to improving PEDM. The use of visual representations of BBNs in the case of SEG has also highlighted the challenges associated with implementing conflicting theoretical ideals, which is considered further in this section and chapter 7.

Process Orientation

Visual representations of BBNs could contribute to practical criteria associated with the principle of process orientation by displaying and communicating information, alternative views, and updated information to facilitate an ongoing process of deliberation, learning, and change.

To contribute to the practical criteria associated with the sub-principle of deliberation, visual representations of BBNs can demonstrate the effects of beliefs. The qualitative data indicate that the visual representations did effectively illustrate how a range of issues were incorporated and related to one another. KI-F recognised that the visual representations stimulated "broadened thoughts". This did enable KIs to consider alternative and diverse issues, initiating deliberation. However, while the visual representations did encourage KIs to broaden out their views, the KIs' were sometimes confused and frustrated about what they thought of as going 'off-topic'. KI-F worried that although it was "nice to think about culture", "we didn't really discuss the barrage". KI-F considered that being encouraged to broaden his thoughts felt like he was being encouraged to "get off the issues", which felt like we are just having "a nice chat". This led him to emphasise that there is "a difference between things that are interesting and things that are important". Similarly, in cycle 3, KI-C suddenly apologised for going off topic, stating that there were "too many red herrings……. stop bamboozling me".

This indicated a discomfort with an unfamiliar, informal participant-led approach and visual methods, which potentially reduces the credibility and legitimacy of using of BBNs in this way. I return to the subject of familiarity in chapter 7.

Visual representations of BBNs have the potential to contribute to the sub-principle of transformation and change by displaying a range of views so that participants can learn from alternative perspectives, and by communicating changes. However, the qualitative data indicate that the extent that visual representations of BBNs achieve this is dependent on their effectiveness as tools for communication, which was problematic (see chapter 5). The KIs recognised the benefit of, and potential for, BBNs to display alternative views. When considering the effect of the SEG node, KI-K thought it would be "interesting to see what RSPB said about the lack of decline in bird populations", indicating the visual representations encouraged them to consider and learn from other views. KI-N reflected that it was "good to look at the models", which was an opportunity to "learn about the Solway". Interestingly, both these observations were made in cycle 3 (while reviewing alternative models) by KIs who had not been engaged in earlier cycles. Cycle 3 was also KI-C's first engagement and during the meeting they stated that it would be "interesting to see combined models balancing different views and identifying commonalities". This interest in other models demonstrates the KIs' capacity to appreciate and learn from alternative views, indicating that the capacity for learning and meaningful participation is not dependent on iterative engagement and co-creation of BBNs over cycles of engagement from inception (cycle 1).

KIs who had been engaged throughout the cycles of engagement also demonstrated an awareness of the importance of taking account of other people's perspectives. KI-L and KI-K agreed that visual representations of the BBN model encouraged them to "appreciate other perspectives". This demonstrates that visual representations of BBNs can contribute to the practical criteria associated with the sub-principle of 'transformation and change'.

For visual representations of BBNs to facilitate deliberation, learning, and change (as prescribed by the practical criteria associated with the principle of process orientation) they must be able to communicate knowledge effectively. As noted in chapter 5, the KIs found the complexity of the visual representations confusing, and some KIs expressed anxiety while

engaging with and trying to understand the BBNs. KI-F consistently expressed confusion and anxiety when reviewing the BBNs, stating that they were "struggling" to understand. KI-A admitted that they felt "stressed" before seeing the visual representations in cycle 2 because they "might not understand it", indicating that even the prospect of reviewing them was daunting. Although KI-A stated that they were "less confused" after discussing them in cycle 2, they expressed anxiety in not understanding the visual representations throughout the cycles: in cycle 5, KI-A stated that "perhaps I'm misunderstanding this - my apologies if so". The complexity of the visual representations and lack of understanding by the KIs, led some to conclude that the visual representations would be too difficult for people to understand (see section 5.2).

The anxiety expressed about the complexity of the model seemed to be connected to the pressure of the one-to-one meeting format and time constraints. Some KIs indicated a preference for reviewing the visual representations outside the confines of the one-to-one meeting, whether they engaged with the visual representations during the meeting or not. In cycle 3, KI-E and KI-N engaged well with the models during the meeting, but neither annotated them. KI-N indicated they would annotate them if sent them. KI-E expressed interest in "playing" with the software and asked if I could send a link to the software and the model files. After the cycle 3 meeting, I sent KI-E and KI-N pdf copies of the model to review in their own time and the model files, along with a link to download the software. In cycle 4, KI-F also asked if they could annotate and keep copies of the model after the cycle 4 meeting despite being confused by the complexity of the visual representations and struggling throughout the meeting. They made notes of the node colours and commented that they would review them on holiday.

Suggestions that KIs review the model outside the limitations of a meeting indicate that they acknowledge the potential for visual representations to facilitate deeper, longer reflection of the issues than conventional text-based consultation material in an alternative engagement format, addressing learning criteria. Although none of these KIs sent any further reflections on the modelling after cycle 3 and 4 meetings, I recognised the potential for engagement outside one-to-one meetings. As noted in chapter 3, this led to me re-designing cycle 5 to

comprise a cycle of engagement via post, where participants could review the models in their own time.

As well as enabling the KIs to learn from their own views (as described in section 5.3) I also learnt from the KIs via the visual representations of the BBNs. I intentionally positioned myself as knowing less that the KIs (see section 3.2), so it is unsurprising that I did accrue more knowledge by the end of the process, but reflecting on the visual representations of the BBNs with the KIs did facilitate specific knowledge generation. For example, in cycle 3 with KI-E and KI-N, I asked if the pole fishing with motors on the Scottish side would be included in the Haaf Netting node or be represented separately. Both expressed uncertainty about the 'pole fishing' and the use of motors that I described. KI-N enquired if I had heard the term 'fixed engine' (which I had) and stated that 'fixed engine' is an archaic term to describe (in by-laws) a static (as opposed to drifting) net method of salmon fishing. Assumptions I had made about 'fixed engines' (being associated with motors) were corrected via review of the [fishing] nodes on the visual representations. This demonstrates how a decision-maker (who I represented in this case study) accrued knowledge working with the KIs and BBNs in the cycles of engagement.

The visual representations of BBNs illustrated the issues and their relationships to each other. This encouraged the KIs to broaden and develop their own views and appreciate alternative views. Reviewing the visual representations supported learning for the KIs as well as for me, representing the 'decision-maker' in this case study. The visual representations of BBNs therefore contribute to the practical criteria associated with the principle of process orientation. However, their complexity does limit the potential for effective communication of knowledge between KIs and therefore the capacity for KIs to learn from each other and fulfil these criteria.

Empowerment

Visual representations of BBNs could fulfil the practical criteria associated with the principle of empowerment by showing participants that their contributions are included. As discussed in section 2.4 (and shown in Table 2.6), visually representing data can help participants see their contributions throughout the decision-making process, aligning with the sub-principle

of open discussion. Visually illustrating that contributions are included in BBNs helps participants to feel valued, as prescribed by practical criteria associated with the sub-principle of trust and respect. Showing how contributions relate to each other aids transparency, which is also prescribed by practical criteria associated with the sub-principle of trust and respect.

The qualitative data show that although the commitment to open discussion enabled KIs to broaden their thoughts, the visual representations of BBNs did provide some structure to avoid aimless dialogue. For example, KI-B consistently led the meetings from the start of the engagement meetings, discussing the progress they had made in various (often unrelated) projects, maximising the opportunity for open dialogue and displaying little concern for the needs of the research. But the visual representations of the model provided direction so I could draw the conversation back and push them to think about what specific nodes meant. In cycle 2 and 3, we visited the flourishing communities' node several times and KI-B acknowledged the model "pushed" them to think about "what flourishing communities meant" and how it could be measured.

This sense of being pushed to think about issues raised in different ways highlights the difference between theoretical ideals and their translation into practical criteria for implementation. Using visual representations to guide KIs into considering issues differently could raise tensions with the theoretical ideal of unconstrained dialogue. However, in contrast to this idea that guiding KIs reduces the commitment to unconstrained dialogue, the qualitative data indicate that the visual representations of BBNs helped KIs think about a broader range of issues outside their familiar scope or role. During cycle 3, KI-B reflected that the visual representations of the model "opened up conversations", helping to "broaden out" their thoughts. KI-A agreed; in cycle 5, they stated that "the model has certainly made me broaden my thinking about the proposed scheme - and has confirmed my fears about changes in sediment accretion, characteristics, exposure time". The qualitative data therefore indicate that in contrast to the idea that structure and guidance provided by visual representations could constrain dialogue, they opened areas of discussion that would not have developed from individual participants while avoiding aimless chat. This aligns with the practical criteria associated with the sub-principle of open discussion.

As an alternative to conventional text-based consultations methods, using visual representations of BBNs to engage in participatory diagramming could fulfil the practical criteria associated with the sub-principle of trust and respect that prescribes that diverse and creative methods are used to encourage participants to contribute. However, the qualitative data shows that the extent the visual representations encouraged engagement in creative methods in this case study was limited. As described in chapters 4 and 5, although throughout the cycles of engagement contributions via participatory diagramming were encouraged, most KIs hesitated and resisted writing on the diagrams. In cycle 1, although KI-H was happy to point things out on the maps, they insistently said "I won't draw on your maps". Other KIs actively avoided the maps that I had provided, instead both KI-F and KI-M got up from their chairs to point things out on maps on their office walls. Interestingly, the KIs were not resistant to visual representations and sketching things out in principle. The resistance seemed to be associated with the perceived ownership of the materials; they did not want to infringe on the materials I provided. In cycle 1, KI-P did draw two small diagrams in the corner of the flipchart paper, tentatively asking if they could use some of the paper then restricting their diagram to a corner.

The resistance to participatory diagramming also indicates that the KIs did not develop a sense of ownership in the BBNs, for example KI-L referred to "your habitats" [node] in cycle 3. The KIs repeatedly demonstrated that they were more comfortable relying on familiar props, protocols, and surroundings (e.g. in their own office) than the visual representations of BBNs I presented in each cycle. In cycle 3, KI-K sketched out their thoughts on the layout of the model (left to right) and themes in their own notebook. In cycle 1, KI-J gave a PowerPoint presentation and sent me copies of the proposed scheme after the meeting. In cycle 2, KI-I brought their own photographs of ice in the Solway Firth to illustrate their points made in cycle 1 about climate (ice) and the technical viability of SEG. This shows that although the KIs were comfortable with visual representations, they resisted the unfamiliar ones, preferring to use and/or produce their own artefacts (e.g. KI-I's photos and KI-J's PowerPoint presentation).

The qualitative data therefore indicates that visual representations of BBNs can provide a structure to aid participants to simultaneously discipline and broaden their thoughts,

contributing to the sub-principle of 'open discussion'. Conversely, the resistance of KIs to engage with the visual representations of BBNs and other diagrams and maps I provided, indicates that the extent that using visual representations of BBNs as creative methods can be used to fulfil the practical criteria associated with the sub-principle of trust and respect is limited.

Reflection Criteria

As described in section 2.4 and Table 2.6, visual representations of BBNs can fulfil the practical criteria associated with the principle of reflection by enabling participants to review their own and other participants' views, and how they connect.

The practical criteria associated with the sub-principle of reflective process prescribe a system for participants to reflect on their previous contributions. The visual representations of BBNs were able to capture and display previous contributions, and revisiting KIs in cycles of engagement gave them the opportunities to review these. The qualitative data indicates that these opportunities encouraged the KIs to think about their previous contributions in deeper ways. As discussed in chapters 4 and 5, while reviewing the visual representations of their own BBN models in cycle 2, the KIs took time to reflect on why the issues they had raised in cycle 1, now represented as nodes, mattered so that the states could be added. For example, in cycle 1, KI-A spoke a lot about the dynamic coastline, which is constantly changing with the tide. In cycle 2, considering the states of the 'coastline' node, KI-A found it difficult to explain why the dynamic coastline mattered. However, exploring this led to a deeper and useful discussion about the ecosystem and habitats (i.e. the saltmarsh) that are both supported by the changing coastline and provide a "buffer to the hard edge of the sea". What mattered therefore was whether the coastline was 'buffered' (protected) or not, and the states of the 'coastline' node were defined as 'buffered' and 'exposed'. Reviewing the visual representations of their own models in cycle 3, facilitated further reflection, as the KIs considered that relationships between the nodes and their relative importance defined the position and weightings of the arcs. Reviewing the visual representations of their own BBN in cycle 3, KI-A reflected again on the coastline node, specifically the role of the intertidal areas in 'protecting' the coastline, and identified dependencies (child nodes) of agriculture, habitats and community.

This indicates that the visual representations of BBNs did enable the KIs to reflect on their contributions and engage in an ongoing process of reflection. However, as stated above and in chapter 5, the complexity of the modelling reduced the ability of the KIs to recognise their own previous contributions and understand the contributions made by others. The ability to engage in a reflective process via the visual representations of BBNs was therefore limited.

The practical criteria associated with the sub-principle of self-awareness prescribe that systems are provided to share and communicate the contributions between participants, so they can learn from and engage with diverse views and recognise the limitations of their own knowledge. Despite struggling with the complexity of the modelling, the KIs did acknowledge that the visual representations encouraged them to explore issues outside their field and appreciate alternative perspectives. In cycle 2, KI-F stated that they were "thinking forward to discussions with others", and that they "assume others will have alternative views".

In raising the KIs' awareness of alternative views, reviewing the visual representations also encouraged the KIs to recognise the limits of their own knowledge, which resulted in them recommending other stakeholders to provide knowledge beyond those limits. For example, in cycle 3, KI-D stated that "an ornithologist will need to be consulted" to confirm the numbers and structure of the model around the bird nodes, showing an appreciation of knowledge and values beyond their own knowledge. This indicates that the visual representations encouraged the KIs to identify the limits of their own knowledge and where other stakeholders and alternative views would be valuable, as prescribed by the practical criteria associated with the sub-principle of self-awareness.

The qualitative data show that the visual representations of BBNs did raise the KIs awareness of alternative views, facilitate reflective process and encourage the KIs to become aware of the limits of their own knowledge. However, as previously discussed the complexity of the visual representations did limit the extent that they could fulfil the practical criteria associated with the principle of reflection.

In this section, I have described how the visual representations of BBNs aligned with the practical criteria associated with the four principles of PEDM in turn. Generally, the ability to visually represent BBNs contributed to the practical criteria for improving PEDM associated with each of the four principles. However, fulfilment of the practical criteria was limited due to the complexity of the visual representations. The results also highlight difficulties in implementing theoretical ideals, where efforts to adhere to one principle reduced the potential to adhere to another. Differences between the theoretical ideals and the associated practical criteria also highlighted the difficulties of implementing ideals and the need for their translation into more achievable and effective criteria.

In the next section, I will describe how the ability of BBNs to incorporate qualitative data contributes to the practical criteria associated with the four principles of PEDM.

6.2 Ability to incorporate qualitative data

In this section I will describe how the BBN's capacity to incorporate qualitative data aligned with the practical criteria for PEDM outlined in section 2.4 and Table 2.6. I discuss the alignment with the practical criteria associated with the four principles of PEDM in turn.

Inclusivity criteria

The capacity of BBNs to incorporate qualitative as well as quantitative data increases the diversity of views that can be incorporated into a decision-making process. This aligns with practical criteria associated with the principle of inclusivity and sub-principles of 'multiple and diverse perspectives are heard/ represented' and 'regard for environmental values'. The capacity of BBNs to incorporate qualitative data enables participants to contribute without the need to express their knowledge as quantitative data, which can exclude and disengage non-experts. It therefore enables non-expert and lay knowledge to be included in decision-making, aligning with the practical criteria associated with the sub-principle of 'multiple and diverse perspectives are heard/ represented'. Enabling diverse voices to be heard and included also contributes to the sub-principle of 'regard for environmental values' that prescribe that diverse viewpoints are heard to provide space for value pluralism (see Table 2.6).

The results of this exploratory case study presented in chapters 4 and 5 demonstrate that the ability to incorporate qualitative data did enable diverse and non-expert views to be heard. However, the results also reveal that inclusion of lay knowledge was insufficient to make the process credible. As discussed in section 5.2, some KIs questioned the credibility of the evidence provided by other participants, especially compared to expert voices. For example, some of the KIs raised concerns about the viability of SEG associated with the volume of tidal water at the proposed location and the risk of damage from floating ice. However, these concerns from non-experts, which were incorporated into the BBN, were not taken seriously by the KIs on the development team. In cycle 1, both KI-A and KI-I raised concerns about the technical feasibility of SEG citing low water flow and depth at the proposed location for SEG. KI-A stated that there is "not much water there" and KI-I agreed, saying that the developer "doesn't know what he is talking about". When asked about these concerns, KI-B quoted reports dating from the 1960s and 1980s (summarised in Howard *et al,* 2007) that calculated freshwater flow of 1.9million gallons / 24 hours. KI-B also quoted a report by Halcrow Group Ltd *et al* (2009) that estimated that the flow in the Solway Firth could support a tidal scheme of <300MW capacity, therefore the proposals for SEG with a capacity of 180MW worked on a conservative estimate. KI-B claimed that SEG economic feasibility calculations had considered capturing 40-45MW (quarter of the installed capacity) tidal energy. Based on these expert reports, KI-B was satisfied that the proposals were viable, and he disregarded the concerns of the other stakeholders as 'non-experts'. Similarly, KI-H and KI-I raised concerns about the risk of SEG being damaged by ice, considering the former railway bridge was taken down after it was damaged by ice. When asked about the risk of damage by ice KI-B dismissed the risk as minor, stating that the design "could include a system of floating parts that would protect it from ice".

Other KIs also disregarded values they perceived were from non-experts. When KI-N and KI-E reviewed an alternative model in cycle 3, they identified what they considered inaccuracies, which (to them) demonstrated the limits of lay knowledge. KI-N stated that the model made them think about "who is asked" to contribute and "keeps coming back to who will be consulted". They queried the credibility of the data where subjective views of non-experts / lay knowledge are weighted equally or promoted over expert knowledge (like theirs?) and published data. Rather than including non-expert views, KI-N considered that PEDM should

"pull in different experts" who are given "more weight" so that PEDM is "more evidence led". Their persistent concern about giving weight to non-expert views seemed to be partly associated with experience of public consultation events where "extreme voices" are heard. In conclusion, KI-N considered that although "consultation should be open…… obviously not everyone can have their own" model.

Despite the preference for many of the KIs to resist the inclusion of non-expert voices, facilitated by the ability to incorporate qualitative data, the definition of 'expert' and 'non-expert' was subjective. KI-E referred me to a former colleague whom they described as a "polymath" and trustworthy on a range of topics such as local history, culture, and fishing that are outside the former colleague's professional role. KI-E's view that their former colleague is an expert in, and can be trusted on, issues outside their job title, is a subjective judgement based on their familiarity with this individual. This indicates that the hostility expressed by KIs to including views from those they consider as non-expert is dependent on their familiarity with that stakeholder; they could be happier to accept a stakeholder's views if they know them. This resonates with the evidence that the KIs expressed preference for established and familiar procedures discussed in section 5.2. However, preferences for formal procedures and 'expert' knowledge, exclude those that do not know or understand the process, excluding non-expert and hard to reach stakeholders.

Increasing the diversity of views involved in decision-making increases unfamiliarity. Therefore, the ability to incorporate qualitative data while enabling the inclusion of non-experts and diverse voices, simultaneously reduces the credibility of the PEDM, where credibility is dependent on familiarity. As shown in section 6.1, fulfilment of the practical criteria associated with the principle of inclusivity, challenges other practical criteria for PEDM, particularly those associated with empowerment and the sub-principle of trust and respect.

Process orientation

The capacity of BBNs to incorporate qualitative as well as quantitative data enables diverse sources of knowledge to be represented so that participants can consider alternative views.

This aligns with practical criteria associated with the principle of process-orientation and the sub-principles of 'deliberation' and 'transformation and change' (as set out in Table 2.6).

The sub-principle of 'deliberation' prescribes that participants are provided with opportunities to deliberate and reflect on their own and alternative perspectives. The ability of BBNs to incorporate qualitative data enables alternative views to be included and therefore shared to facilitate deliberation. The results of this study show that the ability to incorporate qualitative data in the BBNs enabled a range of issues to be heard and considered and for the KIs to voice underlying concerns with confidence, contributing to an ongoing process of deliberation. For example, several of the English KIs reflected on the unfair treatment of the Haaf Netters, which are local and unique to the south (English) side of the Solway Firth. Several of the KIs attributed the decline of Haaf Netting to strict licencing imposed by the Environment Agency (EA). KI-I suggested that the EA's licences restrict Haaf Netting to normal 'working' hours (e.g. between 9am and 5pm) to deliberately exclude working age people, i.e. people who could continue the activity in the future. KI-O claimed that the EA use fish stocks monitoring as an excuse to restrict the Haaf Netters, but "fish stocks are not well monitored" in the Solway Firth, and instead suggested that the licence restrictions are enforced to appease anglers further up the River Eden "who pay a lot for their licences" and who "don't want the fish intercepted". To add to the sense of injustice for the English Haaf-Netters, KI-I claimed that pole fishing on the Scottish side of the Solway Firth is not subject to the same restrictions and therefore is unfairly benefitted. KI-E and KI-O agreed, stating that "Scottish fishers were less regulated than English fishers", creating an unfair advantage and commented that illegal cockling is a big problem [on the Scottish side of the Solway].

The inclusion of qualitative data illustrates the contrasts between the neighbouring communities, especially across the border. This shows that the capacity of BBNs to incorporate qualitative data enables rich data, which adds to the context, to be included in the decision-making process. As well as affecting stakeholder relations in PEDM, these common sources of discontent directly affect SEG due to the proposals for a new footbridge across the Solway Firth that would connect the communities. Several of the KIs doubted that the locals wanted to be reconnected [by a new bridge] (KI-E and KI-O). KI-I also complained that a new pedestrian crossing proposed by SEG would result in unequal distribution of costs

and benefits. He stated that associated increased tourism would only benefit “a few B&B owners” and would not reach the wider community who would bear the costs of increased traffic on the narrow local roads. Even historical stories of Scottish drinkers using the former railway bridge to cross into England to avoid Sunday prohibition were not thought of fondly. KI-O suggested that Scottish drinkers “invaded” or “took advantage” of more lax English regulation. They did not think that the crossing bought the communities on the two sides of the Solway Firth closer together. Including qualitative data, therefore, provided the context of historical and contemporary hostilities that was essential to the transparency of decision-making process exemplified in this case study.

Incorporation of qualitative data also enabled KIs to define opposing views of the same issue. KI-A and KI-B expressed different views of the development of SEG. KI-B spoke about wilderness and development being “mutually beneficial” and “achieving balance”, emphasising the potential for enhancement measures within the design and positive human interventions. In contrast, KI-A saw all development as negative, expressing a preference for things to be “left alone”. As discussed in section 5.3, I was able to appreciate and learn from these differences more than the participants themselves. Therefore, the capacity to incorporate qualitative data potentially benefits the decision-maker and / or modeller more than the participants, limiting the fulfilment of the practical criteria associated with the sub-principle of ‘transformation and change’.

The ability to incorporate qualitative data enabled the KIs to voice their underlying concerns with confidence, which could facilitate an ongoing process of deliberation. However, providing the space for diverse and opposing views to be included did not help the KIs to compromise or reconcile their views. This indicates that the ability to include qualitative data only partly fulfils the practical criteria associated with the sub-principle of ‘deliberation’ that prescribes that participants deliberate on alternative perspectives. Additionally, although the KIs could contribute alternative perspectives, their capacity to consider and learn from them was limited. This limits the alignment of the features of BBNs with the practical criteria associated with the sub-principle of ‘transformation and change’ that prescribes that participants consider and learn from alternative perspectives.

Empowerment criteria

The capacity to incorporate qualitative data enables lay knowledge to be incorporated in PEDM. This aligns with the practical criteria associated with the sub-principle of 'open discussion', which prescribe mechanisms to promote and encourage early and unlimited contributions from non-experts.

As discussed above, non-experts are less likely to be able to, or be comfortable with contributing quantitative data in PEDM, therefore the capacity to incorporate qualitative data increases the opportunities for including non-expert views. However, the results of this study show that incorporating lay knowledge can disrupt, rather than promote, participation. Several of the KIs expressed expectations and preferences for expert-led PEDM, based on quantitative data. As discussed in section 5.2, KIs often dismissed the credibility of lay knowledge, compared to published, quantitative data. KI-N stated that PEDM needs to be "led by someone knowledgeable", and KI-C emphasised the need for including "evidence-based [quantitative] data". This indicates a preference for familiar processes and established procedures, as well as a resistance to change. It also highlights pre-existing hostilities and mistrust between stakeholders, as discussed in section 5.2.

Although the capacity to incorporate qualitative data does provide opportunities to promote and encourage the inclusion of non-expert participation, aligning with the practical criteria associated with the sub-principle of 'open discussion', the KIs demonstrated resistance that could hamper the potential for BBNs to improve PEDM. I return to this in chapter 7.

Reflection criteria

The capacity to incorporate qualitative data enables diverse viewpoints to be incorporated in PEDM. This aligns with the practical criteria associated with the sub-principle of 'self-awareness', which prescribes that systems are provided to enable participants to engage and learn from diverse views (as set out in Table 2.6).

As discussed above, the ability to incorporate qualitative data did enable alternative and diverse views to be incorporated into the BBN, as prescribed by the practical criteria associated with the sub-principle of 'self-awareness'. However, because some KIs considered

that including diverse views and lay knowledge reduced the credibility of the evidence (see above and section 5.2), the ability of the KIs to engage or learn from alternative viewpoints was adversely affected. KI-N stated that qualitative data and lay knowledge represented by the BBN should be "part of the scoping stage", indicating that its contribution to PEDM may be limited. This does not mean that BBNs cannot bring advantages to other phases of PEDM, but it does support the findings above. Although the capacity of BBNs to include qualitative data enables diverse views to be included, this feature does not fully address the practical criteria associated with the sub-principle of self-awareness; that prescribes that participants engage with and learn from those views.

In this section, I have described how the capacity to incorporate qualitative data goes some way to fulfilling the four principles of PEDM. This feature enables diverse views, particularly from non-experts to be included in PEDM. However, their inclusion emphasises pre-existing hostilities and mistrust between stakeholders, reducing the potential to satisfy the practical criteria associated with each of the principles and sub-principles.

In the next section I will consider how the ability to update BBNs contributes to the practical criteria associated with the four principles of PEDM.

6.3 Ability to update the models

In this section I describe how the ability to update BBNs aligned with the practical criteria for PEDM in this exploratory case study. Considering the four principles of PEDM in turn, I reflect on what the qualitative data show about how the ability to update BBNs fulfilled the practical criteria (associated with each principle) that were outlined in section 2.4 and summarised in Table 2.6.

Inclusivity

The ability to update BBNs with new and changing knowledge enables diverse views to be incorporated throughout the PEDM process, which aligns with practical criteria associated with the principle of inclusivity. As described in Chapter 4, the BBNs were developed iteratively over cycles of engagement with the KIs. The BBNs were updated in each cycle to include new and changing data, increasing diversity of views included, as prescribed by the

practical criteria associated with the sub-principles of ‘multiple and diverse perspectives are heard / represented’ and ‘regard for environmental values’.

Some of the KIs appreciated the potential for BBNs to be updated. In cycle 3, KI-E indicated they were interested in “playing with the software” between the cycles of engagement and asked if I could send a link to the software and the model files. They also wondered about testing BBNs for HRA (habitats regulations assessment) screening. This indicates that KI-E understood that the BBN could be updated and, by considering spending some time exploring other applications, they recognised the potential benefits to PEDM.

The ability to update the models encouraged the KIs to diversify their contributions beyond their own professional role and responsibilities. As BBNs were updated with new knowledge in each cycle, the visual representations of the updated models encouraged KIs to consider a diversity of issues. For example, in cycle 2, KI-F reflected on local history, culture, and public health, outside their professional role in a wildlife conservation charity. The ability to update BBNs enabled these broader issues to be incorporated into the modelling, which evolved in later cycles.

Although the ability to update the BBNs did increase the diversity of views contributed, which aligns with the practical criteria associated with the principle of inclusivity, it also highlighted KIs’ discomfort in discussing issues outside their own professional role and responsibilities. KI-F stated that their contributions on local history, culture, and public health represented “personal interests” and therefore “are not applicable”. Generally, the KIs were more comfortable expressing the official or organisational line and were uncomfortable expressing views beyond that. This may be associated with a perceived lack of credibility of lay knowledge compared to formal data sources, as discussed in sections 6.1 and 6.2, as well as in section 5.2. It may also be associated with participants limiting their personal responsibility; if they follow procedure and guidelines dictated by their formal role, they cannot be held personally responsible for the wrong outcome. This indicates that the potential of features of BBNs, including the ability to update the models, to facilitate diverse views was limited.

The ability to update the BBNs between the cycles of engagement (alongside the ability to visually represent the updated models) enables KIs to broaden their thinking on issues, beyond their formal remits. This aligns with the practical criteria associated with the sub-principles of 'multiple and diverse perspectives are heard/ represented' and 'regard for environmental values', which prescribe that diverse voices are sought and included in PEDM. Some KIs appreciated the potential benefits to PEDM of being able to update the BBNs and expressed interest in trying the modelling in other applications. For others, being encouraged to contribute diverse views was uncomfortable and they struggled to see the benefit to PEDM.

Process orientation

Utilising the update feature of BBNs enables previous contributions to be tested, evaluated, and developed in an iterative process. The ability to update BBNs was therefore key in implementing the cycles of engagement. Participants could reflect on their previous contributions and contribute to further updates as knowledge changes and evolves. This aligns with practical criteria associated with the principle of process-orientation and the sub-principles of 'deliberation' and 'transformation and change'.

As described in chapters 4 and 5, updating the BBNs with the KIs during the cycles of engagement did provide opportunities for reviewing previous contributions. As well as encouraging KIs to review and develop their own views, the ability to update the BBNs enabled the KIs to review and engage with alternative views. As described in chapter 4, the KIs reviewed other KIs' views in individual BBNs in cycle 3 and in the combined BBNs in cycles 4 and 5. Most KIs acknowledged alternative views when presented with alternative models (see section 5.1). This aligns with the practical criteria associated with the sub-principle of 'deliberation' that prescribes that participants are given opportunities to deliberate on their own and other participants' previous contributions.

The ability to update the BBNs was fundamental to knowledge development; previous contributions are reviewed and evaluated to encourage new contributions, to be incorporated into updated models. This encouraged KIs to iteratively change their views. For example, in cycle 1, KI-E stated that the isolation of the area contributed to their conservation

work, indicating some hostility to the prospect of increasing visitor numbers associated with SEG. As discussed in section 5.3, in cycle 2, although not supportive of increasing visitor numbers, KI-E did acknowledge that high numbers can be managed if proper controls are enforced, recognising that low numbers can have a bigger impact if controls are not enforced properly. They also acknowledged that tourism (positively) affects the RSPB reserve. In cycle 3, KI-E did not express negative views about visitor numbers, or at least did not consider it a significant issue. This indicates capacity for some change and softening of views as the models were updated as the cycles progressed. This demonstrates that updating and reviewing the updated BBNs facilitated a process of review, test and re-evaluate. By updating the modelling, the participants can test and evaluate changes in knowledge, aligning with the practical criteria associated with the sub-principle of 'transformation and change'.

The results of this exploratory case study highlighted the practical challenges of using the update feature of BBNs to facilitate iterative processes of deliberation and transformation of views. Although the KIs were generally engaged with the concept of updating the models, several were frustrated about the pace of the development of the BBNs. In cycle 2, I sensed that KI-G was losing patience and interest. Several other KIs indicated that they were keen to get to the "end point" (KI-F and KI-D), stressing that PEDM processes should "seek outcomes" (KI-D) and "be determined" (KI-L). This illustrates the KIs' familiarity with conventional outcome-orientated procedures, which together with resistance to change is a challenge to introducing new measures, such as BBNs, to improve PEDM; I return to this in chapter 7.

The KIs' frustrations with the iterative process facilitated by cycles of updating and reviewing BBNs highlighted practical constraints associated with time and resources, as well as consultation fatigue. KIs often cited lack of time as a barrier to engagement and were concerned about the commitment required, especially during the early cycles. In cycle 1, KI-H stated that "I hope an hour would be sufficient for a first meeting", but when I got to the meeting the discussion was very open and I spent approximately 4 hours with KI-H and KI-I in total. Similarly, before meeting in cycle 1 with KI-F they stated "just to be clear…. happy to talk to you, but…. certainly can't commit any of my own time to this beyond meeting to discuss". During cycle 1, KI-F stated that they "couldn't commit to working on this" after the meeting and didn't want any "homework". However, there was evidence that as the cycles

progressed and the BBN model was updated, the emphasis on lack of time seemed to reduce. At the end of our meeting in cycle 1, KI-F expressed interest in being involved in future cycles of engagement. By cycle 4, KI-F asked if they could take copies of the BBN model with them on holiday to review and responded to the postal engagement in cycle 5. Similarly, in cycle 2, KI-D limited our meeting to one hour and seemed defensive. However, by cycle 3, KI-D was more relaxed, perhaps because they were in their own home, where they talked openly, seemed more interested and enthusiastic about the project and could have talked for longer than the 2 hours I had available. This indicates that KIs became less anxious about time limits and more willing to spend time engaging with updating the models as the cycles progressed. This could be partly associated with interest in the development of the BBNs, facilitated by the update feature.

The extent of this interest in updating the BBNs was, however, limited. The burden of participating (emotionally due to the increasing complexity of the BBNs and practically due to the time commitment) began to outweigh the interest in the BBNs. As a result of the increasing burden of participating in cycles of engagement to update the BBNs, I revised the research design after cycle 4 and made cycle 5 correspondence-based (see section 3.2).

The results demonstrate that the ability to update BBNs was essential to facilitating the cycles of engagement, which provided the opportunities and mechanisms for KIs to review and deliberate their own and alternative views. This feature facilitated the implementation of practical criteria associated with the sub-principle of deliberation. Updating the models also enabled KIs' knowledge to evolve, aligning with the practical criteria associated with the sub-principle of transformation and change. However, the results also highlight the practical constraints associated with the burden of participation of engaging in cycles of reviewing and updating BBNs. Although the data indicate that the update feature does increase interest to overcome the burden of participation, this is limited. Implementing the update feature to improve PEDM therefore needs to find the balance between increasing interest and consultation fatigue.

Empowerment

The ability to update BBNs enables new stakeholder contributions to be incorporated and tested in the decision-making process. This aligns with the practical criteria associated with the principle of empowerment and the sub-principles of 'open discussion' and trust and respect' (as set out in section 2.4 and Table 2.6).

The ability to update BBNs enables unlimited participant contributions so that participants can engage in unconstrained dialogue, as prescribed by the practical criteria associated with the sub-principle of 'open discussion'. As described above, the results of this study show the update feature enabled and encouraged the KIs to broaden out their views beyond their formal roles and responsibilities. This indicates that contributions facilitated by updating the BBNs were less limited than conventional 'tick-box' consultations (see section 1.1). However, unlimited contributions were not achieved due to other practical factors such as lack of time and consultation fatigue, indicating that this practical criterion (enabling unlimited contributions) is unattainable in practice.

As well as making the unlimited contributions unattainable, lack of time and resources also made this practical criterion undesirable. As discussed in section 5.2 and above, several of the KIs expressed anxiety about their lack of time for PEDM. KI-N was alarmed that enabling unlimited contributions would "lead to stages of confusing consultation", which was "not appealing" (KI-N). This highlights a tension between the practical criterion prescribing unlimited contributions and existing frustrations associated with protracted decision-making, which is one of the justifications for improving PEDM (see chapter 1). Several of the KIs reflect on this aspect of conventional PEDM and I discuss this more in chapter 7.

Updating previous contributions also enables participants to review and test previous contributions, helping them to understand the place and impact of their contributions transparently, as prescribed by the practical criteria associated with the sub-principle of 'trust and respect'. The results of this study indicate that during the cycles of engagements, while updating the BBNs models, several KIs became increasingly relaxed about sharing their personal views. This indicated increasing trust in me. However, as they became relaxed the KIs' views were sometimes hostile to other stakeholders, indicating lack of inhibitions. In cycle

2, KI-E was empowered to voice their own views, which they admitted “could be controversial”, and stated that they “don’t care about [the viability of local pastoral] farmers” because they “only eat plants”. This indicated a lack of respect for other stakeholders.

The ability to update the BBNs in an iterative process and in cycles of engagement with the KIs enabled them to become increasingly comfortable to share their own personal views, contributing to open discussion. Anxiety displayed by some of the KIs in early cycles reduced in later cycles as familiarity, trust, and respect in me developed. However, this comfort in openness also encouraged the KIs to establish, and become entrenched in, self-interested positions that reduced the ability to change and exposed a lack of respect towards other stakeholders. Therefore, using the ability to update BBNs to implement the practical criteria associated with the principle of empowerment was only partly successful. Entrenching KIs into self-interested positions reduces their ability to change, hampering fulfilment of the practical criteria associated with the principle of process-orientation and the sub-principle of transformation and change. Additionally, the results highlight tensions in implementing the practical criteria associated with the sub-principle of trust and respect; although the KIs increased their trust in me, they expressed increasing lack of respect for other stakeholders.

Reflection criteria

The ability to update the model and demonstrate different scenarios with participants enables participants to review, test and amend previous contributions, essential to the fulfilment of the practical criteria associated with the principle of reflection. The practical criteria associated with the sub-principle of ‘reflective process’ prescribes that systems are in place to enable participants to reflect on and learn from their previous contributions. Participants should be engaged in a process of dialogue, consideration of views, negotiation, and compromise. As described in Table 2.6, the ability to update the BBNs after review can facilitate this process. The practical criteria associated with the sub-principle of ‘self-awareness’ prescribes that systems are in place that encourage feedback on previous contributions. As described in Table 2.6, the ability to update BBNs can encourage feedback so that different scenarios can be tested, evaluated, and revised with participants.

The results show that the KIs understood and grasped the ability to update the BBN models. They gave feedback and developed their knowledge while reviewing updated models in each cycle of engagement. For example, while reviewing the BBN in cycle 2, KI-F spent some time thinking about the previously identified issue of designated features (represented as a node). The ability for the model to be updated enabled KI-F to reflect on the issue (node) and consider how it should be connected to other nodes. KI-F thought about "the importance of human connection to the natural word, for wellbeing", so "it is important that the [designated] features are accessible", both physically and intellectually with access to interpretation and information. Reflecting on an "interesting connection between the natural environment and health", KI-F directed me to connect improved access and interest in the natural world to improved human health and wellbeing, stating that this depended on the natural world being protected. The model was then updated to demonstrate these connections. This shows that through reflecting on previous contributions and an understanding that the BBNs could be updated, KI-F was encouraged to discuss his knowledge of specific issues and how they connect. This demonstrated how the ability to review and update the BBNs iteratively facilitated reflection and learning, as prescribed by the practical criteria associated with the sub-principle of 'reflective process'. It also demonstrates that KIs were encouraged to give feedback on previous contributions, on the understanding that the BBNs could be updated accordingly, as prescribed by practical criteria associated with the sub-principle of 'self-awareness'.

In this section, I have described how the ability to update BBNs fulfils the practical criteria associated with the 4 principles of PEDM in turn. The ability to update BBNs was essential to implementing the cycles of engagement, in which previous contributions were reviewed and new knowledge could be incorporated into the BBNs for further review and evaluation in subsequent cycles. This process of updating the BBNs iteratively with the KIs increased the diversity and evolution of knowledge production, as prescribed by the practical criteria associated with the principles of inclusivity and process-orientation. Updating the models enabled the KIs to review, test and give feedback on the evolving knowledge, as prescribed by the practical criteria associated with the principle of reflection. However, the practical criteria associated with the principle of empowerment was less satisfactorily fulfilled. Although the KIs' trust in me increased as they reviewed, tested, and updated the BBNs, they

became increasingly less respectful towards other stakeholders and more entrenched in their own views.

In the next section I draw on the results to address RQ3 and consider if the features of BBNs improve PEDM.

6.4 Conclusion

As set out in chapter 2, in this study, improvements in PEDM are assessed by adherence to a series of practical criteria of PEDM that are organised in four principles to aid implementation: inclusivity, process-orientation, empowerment, and refection. The ability to visually represent and update BBNs as well as their capacity to incorporate qualitative data represent opportunities to fulfil the practical criteria and therefore improve PEDM (see Table 2.6). Drawing on the results set out in sections 6.1, 6.2, and 6.3, in this section I will address RQ 3: do the features of BBNs improve PEDM?

The results revealed a variable picture of compliance with the practical criteria of PEDM. The features worked together to partly satisfy the practical criteria, but the results also revealed contradictions between the practical criteria, highlighting the difficulties in implementing theoretical ideals of PEDM in practice. The areas of compliance and contradictions are summarised in Tables 6.2-6.5 and described below.

The principle of inclusivity broadly groups together ideals associated with who is involved in PEDM. The associated practical criteria are subdivided into ensuring that those included in the process represent a diversity of voices and environmental values, and that participants are given fair access. As summarised in Table 6.2, the features of BBNs did partly fulfil the practical criteria and contribute to improving inclusivity.

Table 6.2 Areas of compliance and contradictions between the practical criteria associated with the principle of inclusivity and the application of BBNs

Practical Criteria	Areas of compliance and contradictions
PRINCIPLE: Inclusivity	
SUB-PRINCIPLE: Multiple and diverse perspectives and voices are heard / represented	
Demonstrate proactive engagement, targeting diverse range of voices and minority groups. Demonstrate effort to seek alternative voices beyond those immediately affected and experts. Experts and non-experts are included.	Combining BBN's capacity to incorporate qualitative data and update that data increased the diversity and range of views throughout the process as KIs were not required to translate their values into numbers. But concerns were raised about the credibility of evidence contributed outside formal remits.
Diverse engagement and communication tools used (e.g. visual representations). Efforts made to acknowledge and address consultation fatigue to engage stakeholders and enhance participation.	KIs preferred visual representations of the BBN models to text-based tools and recognised the potential for visual representations to reduce consultation fatigue but this was limited by their complexity.
SUB-PRINCIPLE: Fair access to information and opportunity to participate	
Participation is open; individuals or groups can initiate participation without invitation. Consultation is open for sustained and regular periods and is publicised in advance to optimise awareness of the opportunities to participate.	
Demonstrate what additional information and resources for access is provided (including compensation) to disadvantaged and under-represented groups.	The potential for visual representations of BBNs to aid access to and communicate information was limited by their increasing complexity, which made the KIs increasingly anxious and burdened.
SUB-PRINCIPLE: Regard for environmental values	
Identify potential environmental impacts (e.g. use existing EIA framework). Demonstrate that environmental values are represented, e.g. use groups representing conservation interests such as the RSPB.	Visual representations demonstrated diverse views were included as nodes. But there were concerns about the fair representation of values due to the BBNs' complexity and lack of clarity about different weightings represented by arc thicknesses.
Provide opportunities for diverse viewpoints to hear and reflect on alternative perspectives.	Combining BBN's capacity to incorporate qualitative data and update that data increased the diversity and range of views throughout the process as KIs were not required to translate their values into numbers. But concerns were raised about the credibility of evidence contributed outside formal remits.

Access to PEDM was improved by being able to incorporate qualitative data, enabling contributions from non-experts. Visually representing contributions in BBNs provides access to those stakeholders who are disengaged or fatigued by conventional text-based consultation tools. Improving access in turn, increases the diversity of voices, including those representing environmental values. Engagement with PEDM was also encouraged by the ability to update the models, where KIs stated they were interested in the development of the modelling.

The fulfilment of practical criteria associated with the principle of inclusivity was limited by the complexity of the visual representations of the BBNs. Although they represent an alternative to text-based tools, the complexity of the BBNs as they were updated generated anxiety and led to disengagement. Updating the BBNs with additional qualitative data increased the complexity of the visual representations until they were no longer accessible or could effectively communicate knowledge between KIs. The lack of effective communication of knowledge generated doubts about the credibility of the evidence provided by others, emphasising pre-existing hostilities.

The principle of process-orientation broadly groups together ideals associated with how the PEDM process should operate. The associated practical criteria are subdivided into those supporting participants to deliberate on and learn from their own and alternative perspectives and those supporting participants to change their views.

The results indicate that the features of BBNs partly fulfilled the practical criteria associated with the principle of process-orientation (see Table 6.3). Visual representations of BBNs enabled the KIs to view their own and other KIs previous contributions. The results show that the visual representations of BBNs enabled KIs to review their own and alternative views. They deliberated previous contributions and developed and broadened their own views, indicating learning and change. The KIs' updated knowledge (as qualitative data) was incorporated into updated BBNs and reviewed in subsequent cycles. The features therefore facilitated the process of review, learn, deliberate, and transform.

Table 6.3 Areas of compliance and contradictions between the practical criteria associated with the principle of process orientation and the application of BBNs

Practical Criteria	Areas of compliance and contradictions
PRINCIPLE: Process-orientation	
SUB-PRINCIPLE: Deliberation	
Consultation and engagement facilitates regular decisions and action points, representing milestones, not endpoints. Provide consistent mechanisms for engagement beyond decision and action points.	Visual representations effectively illustrated how issues were included (represented as nodes) and related to one another (represented as arcs).
Provide opportunities for participants to deliberate and reflect on their own and alternative contributions.	Combining BBNs ability to incorporate, update and visually represent qualitative data facilitated deliberation as KIs worked round the nodes and arcs. However, KIs were uncomfortable with the unfamiliar model, and being encouraged to broaden their views and go 'off topic'.
Decisions represent broad agreements (rather than complete consensus), which participants are encouraged to query and debate.	Combining BBN's capacity to incorporate and visually display qualitative data enabled alternative views to be included and reviewed. However, KIs were not encouraged to compromise or reconcile opposing views, reducing the potential for broad agreement.
SUB-PRINCIPLE: Transformation and change	
A range of engagement activities are provided to provide space for participants to consider alternative perspectives and reflect on prior beliefs.	The capacity of BBNs to incorporate qualitative data enables diverse, alternative, and opposing views to be represented and considered as KIs were not required to translate their values into numbers. KIs were able to identify alternative views (as nodes and arcs) in the visual representations. The ability to update and run different scenarios with the BBNs enabled the KIs to test and evaluate prior beliefs.
Opportunities and mechanisms for feedback and reflection are provided and promoted.	KIs developed their knowledge by reviewing their own and alternative views (represented as nodes and arcs) in visual representations of BBNs.
Provide systems to communicate information and knowledge as it changes, before, during and after decision and action points.	The BBNs could be updated as knowledge changed. However, the modelling process was laborious so was undertaken independently from the KIs, the resultant lack of understanding of the modelling and the complexity of the visual representations reduced the capacity of BBNs to communicate changes of knowledge effectively. The capacity to update BBNs encouraged KIs to learn and their knowledge to evolve. However, as the modelling process was complex and laborious it was undertaken independently from the KIs, who expressed frustration at the pace of change and perceived lack of progress, associated with lack of time and consultation fatigue.

The fulfilment of practical criteria associated with the principle of process-orientation were limited by conditions that were both independent of, and related to, BBNs. Independently of BBNs, KIs stated that they lacked the resources (including time) to engage in iterative PEDM processes, indicating their preference for familiar (if flawed) methods and procedures. Related to BBNs, the complexity of the modelling reduced their ability to effectively communicate knowledge, diminishing the KIs' understanding of alternative views, which in turn reduced the potential for compromise and reconciliation.

The principle of empowerment broadly groups together ideals associated with how participants should be treated in the PEDM process. The associated practical criteria are subdivided into those facilitating open discussion and those cultivating trust and respect. As summarised in Table 6.4, the features of BBNs did partly fulfil these practical criteria and contributed to improving participant empowerment.

Table 6.4 Areas of compliance and contradictions between the practical criteria associated with the principle of empowerment and the application of BBNs

Practical Criteria	Areas of compliance and contradictions
PRINCIPLE: Empowerment	
SUB-PRINCIPLE: Open discussion	
Provide mechanisms that enable and promote participation from project conception.	BBN's combined ability to incorporate and update qualitative data enabled contributions throughout the process.
Provide mechanisms that enable and encourage non-expert and expert participants to frame issues / problems and contribute ideas early in process.	BBN's ability to include qualitative data enabled KIs to contribute values outside their formal remits as were not required to translate values into numbers, but this raised concerns about credibility and disrupted engagement.
Enable unlimited contributions.	Updating the BBNs encouraged the KIs to broaden their thoughts beyond their formal remit, reducing the constraints on dialogue. This highlighted other practical constraints, including lack of time. Visual representations of values as nodes and arcs provided structure that helped KIs think about a broader range of issues while avoiding aimless dialogue.

Practical Criteria	Areas of compliance and contradictions
SUB-PRINCIPLE: Trust and respect	
State at commencement and reiterate throughout that all contributions are valued and will be included.	Visual representations demonstrated that contributions were included as node and arcs.
Time and resources provided to allow participants to get to know each other, preferably before providing contributions.	
Communicate the purpose of the project and set out realistic goals to manage the expectations of the participants.	
State and reiterate that the process relies on mutual respect and trust between participants and with the facilitator. Provide a mechanism for issues associated with respect and trust to be heard.	Updating BBNs in an iterative process encouraged KIs to become increasingly open with me. However, this comfort in openness also encouraged the KIs to establish, and become entrenched in, self-interested positions that exposed a lack of respect towards other stakeholders.
Diverse and creative methods of engagement used to encourage participants to contribute.	BBN modelling is complex and laborious so was undertaken independently from the KIs. As a result, the BBNs were unfamiliar to the KIs, who lacked a sense of ownership of them. The KIs resisted engaging with the visual representations and participatory diagramming, potentially limiting some contributions.
The preferred outcome of the facilitator is set out transparently and does not limit inclusion of contributions.	While updating the BBNs, the KIs were increasingly relaxed about sharing their personal views, indicating increasing trust in me.
Demonstrate the mechanisms for participants to understand the impact and place of their contribution.	Updating the BBNs encouraged KIs to be entrenched in self-interested positions that reduced their inclination to understand the impact of their own views.

Visual representations of BBNs provided a structure for KIs to review their own and alternative views, and together with the ability to update the models, encouraged them to broaden their thoughts. The ability to contribute qualitative data allowed KIs to contribute to discussion of issues outside their formal remit, as they were not constrained by the need to convert their knowledge into quantitative data. The opportunities and ability to broaden the KIs' contributions opened the discussions to new issues, partly fulfilling the practical criteria associated with the principle of empowerment, specifically the sub-principle of open discussion.

Fulfilment of the practical criteria associated with trust and respect was less successful. Although the KIs developed trust in me during the cycles of engagement, facilitated by the ability to update and review the visual representations of the BBN, the KIs generally became less respectful towards each other. The inclusion of non-expert knowledge (from non-experts and experts discussing issues outside their formal remit) was facilitated by the ability to incorporate qualitative data. Reviewing alternative views displayed in the visual representations of the BBNs did raise the awareness of alternative views, but also highlighted existing hostilities between stakeholders, and doubts over the credibility of the included knowledge. The success the features of BBNs had in including non-expert views to diversify the contributions and open the dialogue (as prescribed by the practical criteria associated with the principles of inclusivity and empowerment) emphasised mistrust and encouraged KIs to become entrenched in their own views. This hampers the fulfilment of practical criteria associated with the sub-principle of trust and respect. This illustrates a conflict in implementing these practical criteria and ultimately the difficulty in implementing the theoretical ideals of PEDM.

The principle of reflection groups together the ideals associated with engagement after contributions have been made. The practical criteria are sub-divided into those associated with contributing to an ongoing deliberative process, and those associated with the participants' reflection on, and awareness of their own contributions. As summarised in Table 6.5, the ability to visually represent and update knowledge in BBNs contributed to the KIs engaging in reflective processes. The results show they reviewed, considered, and updated knowledge, especially from their own contributions. The visual representations also encouraged the KIs to recognise the limits of their own knowledge, contributing to a sense of 'self-awareness'.

Table 6.5 Areas of compliance and contradictions between the practical criteria associated with the principle of reflection and the application of BBNs

Practical Criteria	Features of BBNs
PRINCIPLE: Reflection	
SUB-PRINCIPLE: Reflective process	
Design engagement process to include decision and action milestones that are discussed before during and after implementation to facilitate reflection and learning.	BBN's combined ability to be updated and visually display changes facilitated a process of dialogue, consideration of views, negotiation, and compromise.
Provide systems for participants to reflect on their previous contributions to facilitate ongoing process of dialogue, consideration of views, negotiation, and compromise.	The visual representations captured and displayed previous contributions as nodes and arcs, which gave KIs opportunities to review these and think about them is deeper ways. However, BBN modelling is complex and laborious so was undertaken independently from the KIs, reducing their understanding of the process and resultant visual representations, limiting the potential for reflection on previous contributions.
Provide systems to enable participants to offer contributions outside formal engagement activities and make suggestions for alternative / additional activities.	
SUB-PRINCIPLE: Self-awareness	
Provide systems that enable contributions to be shared between participants.	Visual representations of the BBNs encouraged KIs to appreciate alternative perspectives and recognise the limits of their own knowledge. The ability to update BBNs encouraged KIs to give feedback on previous contributions.
Establish and agree places and systems to communicate results and findings to enable and encourage feedback.	Combining BBN's capacity to incorporate and visually display qualitative data enabled alternative views to be included and reviewed. However, KIs raised concerns about the credibility of the evidence, reducing the potential for learning from alternative views.

To fulfil the practical criteria associated with the sub-principle of 'self-awareness', knowledge should be shared so that participants can reflect on alternative views and learn from them. The visual representations of the BBNs did raise the KIs' awareness of alternative views.

However, a combination of the complexity of the models, which reduced the effectiveness of the communication of other KIs' views, and concerns about the credibility of the evidence (as discussed above), reduced the potential for the KIs to learn from alternative views. The use of visual representations of BBNs were limited by the KIs' resistance to unfamiliar engagement tools. Although open to visual tools, the KIs did not engage freely with materials I provided, preferring to use and provide their own (e.g. KI-I's production of photographs, KI-J's use of PowerPoint, and KI-M use of his own map).

In summary, the features of BBNs did contribute to the fulfilment of the practical criteria associated with the four principles of PEDM. This indicates there is potential for BBNs to improve PEDM. However, some of the features either neglect or adversely affect the fulfilment of the practical criteria. The visual representations became too complex and were less attractive than other more familiar visual tools. The ability to incorporate qualitative data encouraged non-expert views. This revealed conflict between the practical criteria associated with the principle of inclusivity and the practical criteria associated with the principle of empowerment; inclusion of increasingly diverse views was found to discredit the data. The results demonstrate the difficulty of implementing theoretical ideals of PEDM in practice. To reconcile this tension, the practical criteria could be amended to focus on transparency (of process), as opposed to openness (where participation is open to all) to provide fair opportunities to participate. I discuss this in more detail in the next section where suggested amendments to the practical criteria are provided.

6.5 Recommended amendments to the practical criteria

In this section, I present some suggested amendments to the practical criteria for PEDM, to reconcile the tensions in their implementation, revealed in this case study. The suggested amendments are summarised in Table 6.6 and explained below.

As illustrated in Table 6.6, to address the tensions in the implementations of the practical criteria associated with the principles of inclusivity and empowerment, the suggested amendments are focused in these two areas.

Table 6.6 Amended practical criteria*

PRINCIPLE: Inclusivity
SUB-PRINCIPLE: Multiple and diverse perspectives and voices are heard / represented
Demonstrate proactive engagement, targeting diverse range of voices and minority groups. Proactive recruitment of participants is undertaken, seeking alternative voices beyond those immediately affected and experts. Experts and non-experts are included. Diverse engagement and communication tools used (e.g. simple and understandable visual tools). Efforts made to acknowledge and address consultation fatigue and the burden of participation to engage stakeholders and enhance participation.
SUB-PRINCIPLE: Fair access to information and opportunity to participate
Proactive recruitment of participants is undertaken fairly and transparently e.g. random sample of citizens, so everyone has an equal chance of being selected. The sample may be stratified to demonstrate participants are representative and diverse. Consultation is organised to be convenient and accessible to the participants, e.g. providing evening sessions so that working people can attend. Demonstrate what additional information and resources for access is provided (including compensation) to disadvantaged and under-represented groups, e.g. compensating participants for the cost of childcare.
SUB-PRINCIPLE: Regard for environmental values
Identify potential environmental impacts (e.g. use existing EIA framework). Demonstrate that environmental values are represented, e.g. use groups representing conservation interests such as the RSPB. Provide opportunities for diverse viewpoints to hear and reflect on alternative perspectives.
PRINCIPLE: Process-orientation
SUB-PRINCIPLE: Deliberation
Consultation and engagement processes facilitate regular decisions and action points that represent milestones, as opposed to an endpoint. Provide consistent mechanisms for engagement beyond decision and action points. Provide opportunities for participants to deliberate and reflect on their own and alternative contributions in simple and understandable formats. Decisions represent broad agreements (rather than complete consensus), which participants are encouraged to query and debate.
SUB-PRINCIPLE: Transformation and change
A range of engagement activities are provided to provide space for participants to consider alternative perspectives and reflect on prior beliefs. Opportunities and mechanisms for feedback and reflection are provided and promoted. Provide systems to communicate information and knowledge as it changes, before, during and after decision and action points.

PRINCIPLE: Empowerment
SUB-PRINCIPLE: Open discussion
Provide mechanisms that enable and promote participation from project conception. Provide mechanisms that enable and encourage non-expert and expert participants to frame issues / problems and contribute ideas early in process. Demonstrate that contributions are not deliberately constrained by PEDM processes, such as limiting all contributions to responses to closed questions.
SUB-PRINCIPLE: Trust and respect
State at commencement and reiterate throughout that all contributions are valued and will be included. Time and resources provided to allow participants to get to know each other, preferably before providing contributions. Communicate the purpose of the project and set out realistic goals to manage the expectations of the participants. Provide transparently structured activities that encourage participants to understand the impact and place of their contributions in relation to alternative perspectives, to cultivate mutual respect and trust between participants and with the facilitator, e.g. co-producing models, such as simple BBNs that combine the views of participants early. Provide a mechanism for issues associated with respect and trust to be heard. Diverse and creative methods of engagement used to encourage participants to contribute. The preferred outcome of the facilitator is set out transparently and does not limit inclusion of contributions.
PRINCIPLE: Reflection
SUB-PRINCIPLE: Reflective process
Design engagement processes to include decision and action milestones that are discussed before during and after implementation to facilitate reflection and learning. Provide simple and understandable systems for participants to reflect on their previous contributions to facilitate ongoing process of dialogue, consideration of views, negotiation, and compromise. Provide systems to enable participants to offer contributions outside formal engagement activities and make suggestions for alternative / additional activities.
SUB-PRINCIPLE: Self-awareness
Provide systems that enable contributions to be shared between participants easily; tools must be simple and understandable. Establish and agree places and systems to communicate results and findings to enable and encourage feedback.

*suggested amendments highlighted in red text

Fulfilment of the practical criteria associated with the principle of inclusivity was hampered by the KIs' opinion that the evidence provided by others lacked credibility. As explained in section 6.4, to address this, the practical criteria have been amended, shifting the focus from openness to transparency. Instead of relying on open invitations to provide diverse contributions, I suggest that proactive participant recruitment is undertaken, via fair and

transparent processes. For example, random stratified sampling (a method favoured by mini-publics such as citizens' assemblies) could be used, so that everyone has an equal chance of being selected and the final sample is demographically representative based on criteria such as gender, age, income, and level of education (Chwalisz, 2017; Gerwin, 2018). The idea is that *when people look at the* [participants] *they should be able to come to a conclusion that "this group feels like us."* (Gerwin, 2018, p. 34). There are criticisms of random stratified sampling for excluding minority groups that by their definition do not qualify as 'representative' of the wider population. However, these criticisms could be addressed by (case-dependent) appropriate mechanisms to ensure the inclusion of minority groups (Smith & Wales, 2000). Although participant selection systems cannot claim to be perfect, the key is that the methods are transparent.

To promote fair opportunity to participate, the associated practical criteria have been updated to focus on convenience and accessibility, so that those less likely to participate can. As shown in the results of this case study, time and means to participate are significant limiting factors in engagement, therefore organising engagement events at times and places convenient and familiar to participants is vital. This includes updating fair access to information and resources to include financial compensation for participation to lower the practical burden of participation, e.g. for travel costs, to cover childcare, etc. (Roberts & Escobar, 2015).

Fulfilment of the principle of empowerment and sub-principle of open discussion are constrained by the unrealistic criterion that stipulates that contributions can be *unlimited*. As discussed in section 6.3, in practice, factors such as time and resources and consultation fatigue limit contributions. The KIs were also concerned by the potential for unlimited contributions to worsen already protracted PEDM processes. Therefore, the wording of this practical criterion has been amended to provide more clarity and address its purpose: to translate the ideal of *unconstrained dialogue is defended against strategic action* into an implementable standard for PEDM, see Tables 2.4 and 2.6. The amended practical criterion prescribes that PEDM is designed to demonstrate that contributions are not deliberately constrained by PEDM processes, such as limiting all contributions to responses to closed questions. This links to the preceding criterion that prescribes that participants are enabled

and encouraged to frame issues: issues can be raised participants and cannot be constrained by the process design.

As discussed in section 6.4, the KIs established and became entrenched in positions of self-interest, limiting the fulfilment of the practical criteria associated with the principle of empowerment. To address this (like amendments made to the practical criteria associated with the principle of inclusivity) I suggest that the practical criteria associated with the principle of empowerment are amended to focus on transparency. The practical criterion that formally prescribed that the decision-maker (or facilitator) *states and reiterates that the process relies on mutual respect and trust* is open to participant interpretation and/or being ignored. I suggest that this criterion is strengthened and amended to proactively guide participants towards developing trust and respect, via provision of structured activities. I have linked this to the practical criterion that formally prescribed that mechanisms are provided for participants to understand the impact and place of their contribution. The amended practical criterion prescribes that *transparently structured activities* are provided *that encourage participants to understand the impact and place of their contributions in relation to alternative perspectives, to cultivate mutual respect and trust between participants and with the facilitator*. This amendment illustrates that developing trust and respect is dependent on understanding of alternative perspectives. Reflecting the results of the case study an example of such a transparent and structured activity is provided: co-producing BBNs that combine the views of participants early.

Building on these results, in the next chapter I will reflect on how BBNs might be used to improve PEDM in practice.

Chapter 7. Incorporating BBNs into PEDM

In this chapter, I bring together the findings reported in chapters 5 and 6, drawing conclusions to address RQ4: how could BBNs be incorporated into PEDM to improve the MREI consenting process?

First, I describe the problems with conventional PEDM identified by the KIs and relate them to the common critiques of PEDM made in the literature (discussed in chapters 1 and 2). The purpose is to relate the theoretical concerns with the concerns and experiences of stakeholders in practice so that useful (and plausible) recommendations for improving PEDM can be made. Second, considering the identified challenges of implementing PEDM in practice and the associated space for improvement, I present a set of recommendations for improving PEDM using BBNs. Finally, I suggest areas of further research to test the recommendations.

7.1 Current PEDM

In this section, I set out the problems that the KIs identified with conventional PEDM, which provides some depth and explanation to the common critiques of PEDM made in the literature. This highlights areas where improvements to PEDM are needed so that the recommendations for improving PEDM using BBNs set out in section 7.2 are useful and plausible.

As described in chapter 1, PEDM is sometimes criticised as a meaningless tick-box exercise (newDemocracy Foundation, 2018; Dorfman, 2008; and Pieraccini, 2015), characterised by fixed processes that limit the breadth of stakeholder engagement (Roberts & Escobar, 2015, p. 194). The results of this case study add depth to these complaints, illustrating shortcomings in the procedural design. A frequent complaint from the KIs, was that the format of conventional PEDM is often confusing and complicated, which reduces engagement and consequently the diversity of participants. KI-A considered that written consultations often contain “too many words”, and KI-B described the language used in consultation text as “confusing”, “nonsense”, “disengaging” and “needs to change”. As noted in section 6.1, KI-N emphasised that most consultations are currently online, and therefore “exclusionary” [to

those without internet access]. KI-G also highlighted issues with reliance on online formats, stating that although they are "open to the use of social media to increase engagement", access to the internet could exclude some people, especially in rural areas (such as south west Scotland) where the "broadband connection is not good". The perceived dominance of disengaging text based, and online formats is an area that PEDM could be improved by providing alternatives, such as the visual tools (e.g. BBNs, as discussed in detail in section 7.2).

The KIs also identified problems with most in-person public, group consultation events. For example, reflecting on a consultation event on marine planning (held in Whitehaven in February 2018 by the MMO), KI-A stated that the day had been "wearying". KI-B was at the same event and was also disengaged by the process, stating that he "left early because I was getting angry", because "they [the MMO] were not listening" and "not taking suggestions on board". These observations resonate with other examples of lay knowledge being ignored by decision-makers. Notably, several KIs recalled that during the planning phase of the Robin Rigg offshore wind farm application, decision makers ignored concerns raised by local fishers about the stability of shifting sands on the seabed at the site. Since being built, some of the Robin Rigg wind turbines have been "undermined by the moving sands" (KI-A), so have had to be decommissioned. This supports previous studies that have reported that participants often feel excluded and ignored in PEDM (Haggett, 2008; Pieraccini, 2013), and that ignoring local knowledge is ultimately detrimental (Wynne, 1996).

Commenting on the organisation of the MMO event, KI-A stated that the "facilitator was useless" and KI-B agreed that "they [the organisers] were not adequately prepared". As a consequence, and perhaps a cause of their unsatisfactory format, several KIs observed that attendance at public consultation events is usually poor; KI-G stated that "community meetings are usually not well attended". Accessibility to events also affects attendance. In cycle 2, KI-B discussed a previous consultation event held for SEG in Dumfries, which was more accessible to Scottish stakeholders who were thought to be more supportive (of the proposals) than those from England. Not only did this reduce the diversity of voices heard, it also shows how PEDM can be designed to reduce access in order to fulfil strategic objectives of the organiser hosting the consultation event (here the objective was to raise support by optimising attendance by the (perceived) supportive Scottish community).

The diversity of voices in PEDM is adversely affected by the low numbers of attendees because “it is always the same people that will attend” (KI-E). Moreover, the format of conventional PEDM also narrows the diversity of the contributions made and recorded. During public events, KI-N observed that of those who do attend, often “people don’t speak up”, and only the “loudest voices are listened to”. KI-B agreed, stating that the format of PEDM attracts a narrow group of “self-serving individuals”. This supports the findings of previous studies that report that it is often difficult to attract and hear *ordinary people* beyond those *just here to say something through a microphone* (Lezaun & Soneryd, 2007, p. 285). Methods of recording contributions are often inflexible and narrow, resulting in the “loss of anecdotal evidence” and “missing elements” (KI-N). For example, asking structured and closed questions with limited space for responses, characteristic of conventional belief elicitation methods for BBN modelling (see Figure 1.3). However, the results of this study demonstrate the capacity of BBNs to incorporate qualitative data and visually display that data to improve the diversity of contributions in PEDM, as discussed in detail in section 7.2).

The disengaging format of conventional PEDM (confusing, poorly organised, not being listened to, limited access and opportunities to contribute) indicate that the KIs believe that PEDM often lacks meaningful engagement. These observations are characteristic of the superficial and tick-box processes that blight the reputation of PEDM. As discussed in chapter 1, fixed processes, generally, limit the breadth of stakeholder views and fail to capture what matters most to the public, especially on contested topics such as proposed renewable energy installations (Roberts & Escobar, 2015, p. 194). They also fall short of the theoretical ideals for PEDM identified in chapter 2; for example, online consultations limit access to participation, which is prescribed by the inclusivity criteria.

As well as being frustrated and disengaged by the format of most conventional PEDM practices and linked to a sense of frustration at not being listened to, the KIs also expressed a mistrust of the motivations of the organisers. Of the previously discussed MMO event, KI-A reflected that “I may be being cynical, but I thought the MMO designed the day to push their own agenda”. About PEDM generally, KI-E claimed that “decisions are made by people that bribe those in power”. The KIs indicated that their mistrust of decision-makers and PEDM

processes was informed by previous experiences, where perceptions of unfair decision-making has cultivated bitterness between stakeholders. Negative experiences associated with historical planning and consenting applications often centred around how different values were balanced, specifically how unfair value given to other interests (usually economic), at the expense of their values (usually conservation). In cycle 1, KI-E recalled an application for installation of rock armour along a section of coast that is within a conservation zone. The application was allowed despite the environmental concerns, which led KI-E to bitterly reflect that decision makers "trade off nature for jobs" and that "the developers [had] won". KI-E felt that the blame for this imbalance was with the regulatory authorities, stating that Cumbria County Council gave more weight to economic values and jobs than conservation values and that the current process is "corrupt".

The sense of unfairness, where "the economy usually wins" [over environmental values] (KI-F) is associated with PEDM's outcome-orientated approach. Conventionally, PEDM focuses on an end decision, which inevitably leaves some stakeholders with a sense of disappointment. As KI-D stated, "bad outcomes mean unhappy stakeholders". The KIs highlighted the damage done previously by perceived unfair outcomes. For example, KI-G explained that during the public consultation for Robin Rigg offshore wind farm, the nearby local community in southwest Scotland were encouraged not to object to the proposals by the promise of local economic benefits. However, "local manufacturing jobs that were promised, never happened" (KI-G). As a result, "the community felt let down" and bitterness has festered, so that when new proposals for additional offshore wind farms in the area (Robin Rigg 2 and Wigton Bay) were announced "it created merry hell" (KI-G). Marine Scotland received 750 objections to the new wind farms, associated with visual impact and lack of jobs. The proposals were unsuccessful, and the developers lost the time and money expended in submitting the applications. KI-A agreed that unfair PEDM processes during the Robin Rigg application have "damaged the reputation of renewable energy in the area".

As well as the format of PEDM being disengaging and serving to narrow the range of views, the KIs considered that conventional processes often encourage obstructive engagement and conflict between stakeholders. KI-N reflected that PEDM processes encourage participants to get heard by voicing "extreme views". KIs also considered that most current procedures

encourage entrenched positions via negative engagement procedures, which seek objections to proposals as opposed to encouraging consultees to identify acceptable or even positive elements. In cycle 1, KI-P and KI-J discussed how current PEDM motivates consultees to undermine other stakeholders to promote their own position, where success is characterised by determination to stick to fixed positions as opposed to a transformative process. KI-B characterised other stakeholders as having "entrenched views", while KI-E admitted to their own obstructive strategy, where they gave a standard negative consultation response to an application so that their objection would stall the process.

As a result of its adversarial character, the KIs considered that, frequently, current PEDM does not support satisfactory stakeholder relationships. For example, KI-F did not feel that other stakeholders demonstrate understanding or appreciation of conservation values, blaming a lack of dialogue, where conservation views were not understood or valued, but were devalued during decision making. The KIs also indicated that the lack of mutual understanding enhances power imbalances. KI-P and KI-J stated that they felt disempowered by regulatory authorities, who have the power to determine the pace of decision-making, that can adversely affect costs (in time, resources, and money). KI-P resented the regulatory authorities, expressing frustration about not being able to meet them early in the process, by their indecisiveness, and the ambiguity in the formal and informal communications with the regulators. KI-P also complained about what they perceived, as the regulators' "non-committal and evasive language". This indicates that PEDM could be improved by measures that reduce conflict between different stakeholders, and between stakeholders and regulators. As discussed in section 7.2, the capacity of BBNs to serve this purpose is limited. As outputs, the BBNs did not effectively communicate alternative views between KIs, reducing their capacity to encourage mutual understanding and reduce conflict between stakeholders. However, as the modeller and decision maker, I accrued knowledge effectively and developed an understanding of stakeholder values. BBNs could therefore be used to facilitate communication between the decision-maker and other stakeholders.

Several KIs considered that the inflexibility of PEDM processes is often a weakness for decision-making in practice. KI-D reflected that although the current regulations for PEDM are "in the public interest…. the problem is that the regulations are very firm". Building on a

critique of contemporary PEDM identified in the literature (see Roberts & Escobar, 2015) the KIs linked the inflexibility of the regulations to the outcome-orientated approach. The KIs considered that the focus on a binary decision (approved or refused) leaves little space for solution building or risk management, which is "frustrating because you can't explore managing uncertainty……like careful management and monitoring during construction works" (KI-D). Considering the inherent complexity of PEDM (discussed in chapter 1), in practice, data are often missing, incomplete and change over time, resulting in uncertainty. The regulatory regime around environmental risk assessment and decision-making takes a precautionary approach. In practice, regulators and statutory consultees are limited in their responses to uncertainty in the data by the inflexible regulations; they can only request more information or refuse the application. KI-J noted that regulators often respond to their applications for renewable energy developments with "itty-bitty, itty-bitty" requests, which "drags it out", costing time and money. Consequently, the KIs indicated that inflexible regulation of PEDM increases the potential for stakeholder conflict. KI-F observed that other stakeholders (unfairly) perceived their organisation (conservation charity and statutory consultee) and other environmental organisations as inflexible. Making processes more flexible could therefore improve PEDM. As discussed in detail in section 7.2, the option to use alternative engagement and modelling tools, such as BBNs, should be provided (as a one off, repeatedly, in combination with other models etc).

As well as describing shortcomings in conventional PEDM, the KIs were generally positive about the potential for the consenting process to be improved; KI-G stated that they were "always keen to explore ways to improve engagement". The KIs also suggested ways it could be improved. As discussed in section 6.1, the KIs considered that "more than one format is best" (KI-N) to address concerns about accessibility, particularly considering an over-reliance on online, text-based consultations. PEDM could therefore be improved by a combination of engagement tools, as prescribed by the principle of inclusivity, and sub-principle of 'multiple and diverse perspectives are heard / represented'.

To combat the adversarial context of conventional PEDM, the KIs considered that PEDM could be improved by procedures that "bring people together" (KI-F). The KIs recognised that conflict between stakeholders could be reduced by increasing dialogue before the formal

application is made, to facilitate mutual understanding. KI-P stated that PEDM "could be improved by more one-to-one meetings at an early stage". However, the potential for early engagement is reduced by the lack of time and consultation fatigue. KI-F acknowledged that although procedures could be improved by more dialogue, stakeholders probably do not have the time to engage in meaningful and productive dialogue before a formal application is made, stating that "it would not be practical". KI-N also indicated a lack of time for meaningful consultation outside the formal process, admitting that their "heart sinks when I see a consultation [come in]… we are inundated". This indicates that merely prescribing that stakeholders engage in dialogue more frequently and earlier, would increase consultation fatigue and not address the need for mutual understanding.

Underpinning the desire for early dialogue was a sense of mistrust between stakeholders and decision-makers discussed above. The KIs generally agreed that PEDM would be improved by more transparency. KI-D expressed the need for PEDM processes to "demonstrate people's views are taken account of". KI-J considered that stakeholders need "certainty on the process", where decision-makers "set out what information they need" and clearly state "what does it take" [to reach a decision]. These observations reflect a common theme of promoting trust by improving transparency (rather than more engagement). PEDM could therefore be improved by more transparent and fair processes. As previously discussed, the results of this study indicate that BBNs could be effectively used by KIs as a transparent structure to discipline, order, and develop their views, as discussed in detail in section 7.2.

Several KIs noted that the success of PEDM depends on the personalities of stakeholders and the relationships between them, providing examples of positive stakeholder engagement. In cycle 2, KI-F discussed the success of working with local stakeholders to establish and operate the 'Red Kite Trial' that had delivered multiple benefits, including conservation and tourism etc. KI-F was particularly pleased to have encouraged local farmers into opposing persecution (of Red Kites) and hosting daily Red Kite feeding events for visitors to watch, which have become successful visitor attractions (Visit Scotland, 2020). In another example of positive stakeholder relations, in cycle 1, KI-E reflected on the "good work" that had been done to establish and maintain "good relations" between one of the RSPB reserves along the Solway Firth and its neighbouring farmers. KI-O described how they identified "complementary"

activities, where the farmers pay the RSPB to allow them to graze their livestock on the reserve. This gives the farmer extra grazing land while shortening the grass on the reserve, which is preferred by some of the wildfowl, therefore representing a mutual benefit.

Despite the acknowledgement that PEDM processes could and should be improved, there was also a resistance to change, associated with lack of time, consultation fatigue and familiarity with existing processes, where implementing new tools and processes would increase the burden of participation. KI-E and KI-N emphasised that time was the biggest challenge to consultation, and neither was keen to be involved with a group event as part of this study, both stating that "time [to attend] is difficult".

Several of the KIs also indicated a tendency toward comfort in familiar and formal procedures. In cycle 1, KI-H and KI-I were satisfied with limiting their engagement with proposed development to the formal application processes, valuing less administration and comfort associated with the established procedures. In cycle 2, the Parish Councillors were comfortable (resigned to?) engaging with statutory matters and stated that there was not enough time on the agenda to discuss proposals (pre-application) in any more detail. This indicates that resistance to change and lack of time to engage in informal consultations could be linked to the perception that participation is a necessary add-on to decision-making, and a *bureaucratic hurdle* to be overcome (Pieraccini, 2015, p. 33). The familiarity and acceptance of this situation hampers the opportunities to reframe PEDM as an opportunity for meaningful engagement.

Although for some, the inflexibility of the existing regulatory regime was a source of frustration in PEDM, some KIs were positive about it, perceiving that the numerous local, national, and international environmental designations on and around the Solway Firth protected the area from outside intrusion. Both KI-A and KI-F noted (positively) that access to the Solway Firth was "controlled" due to designated habitats such as honeycomb worm reefs (see Solway Coast AONB, 2020). The role of designated sites in PEDM was described as "showstoppers" (KI-G), because if decisions were made in contravention of regulations, "they [politicians] would have broken the law" (KI-D). KI-I was confident that because of the AONB designation, "we can't have them [wind turbines] here". The comfort that KIs felt in the

existing, inflexible regulatory regime reduces the potential for a more flexible approach to be implemented.

The resistance to changing conventional, familiar PEDM processes is compounded by consultation fatigue, especially where several proposals for the same development had already been considered. For example, during the Parish Council meeting in cycle 2, one of the Councillors suggested that due to the number, variety, and long history of proposed tidal energy schemes in the Solway Firth, the Parish Council were indifferent to consultations on the subject. The Parish Council had previously taken time to understand and engage with previous proposals and expressed frustration with the idea of engaging with the subject further. This consultation fatigue left them unwilling to engage in the subject outside the formal application process. Comfort in familiar processes and consultation fatigue could therefore hamper the implementation of changes required to improve PEDM.

In this section, I have documented the shortcomings of conventional PEDM referred to by the KIs. Many of the issues with conventional PEDM raised by the KIs support the findings of previous studies and illustrate the consequences with their own experiences. The KIs described how the format of both written consultations and public events can be exclusionary and disengaging. This reduces the range of participants, as well as the diversity of the participants' voices included. Further, the KIs indicated that the outcome-orientated approach often cultivates an adversarial environment for PEDM that, in turn, incites mistrust and conflict between stakeholders. To address these shortcomings, the KIs recognised a need for improved opportunities for varied, early, and transparent engagement. However, familiarity, comfort and lack of time and resources reduces the potential for changes in PEDM to be implemented. The potential for BBNs to improve the lack of time and resources, and consultation fatigue in PEDM is limited by their complexity, unfamiliarity, and laborious modelling processes. However, combining them with more familiar engagement techniques could simplify, and therefore reduce the time and burden of participation; see section 7.2 for a more detailed discussion.

The above results support the findings of previous studies that recommend that current PEDM processes could and should be improved and justifies the need for this exploratory case

study. In the next section, I set out some recommendations for how BBNs could improve PEDM, based on the results set out in chapter 5 and 6 as well as the opportunities for improving PEDM described above.

7.2 Incorporating BBNs into PEDM

As described above, the results of this case study support the need to improve conventional PEDM. The results also show that several of the KIs thought that BBNs could contribute to addressing this need and "help in the decision-making process" (KI-J). Several of the KIs recognised that BBNs "could be used as a tool for engagement" to help people assess how proposals affect them because BBNs could "allow people to weigh things up" (KI-G). KI-J agreed, considering that BBNs are a "a good way of demonstrating effects" by comparing the likelihood of events in different scenarios. In cycle 3, KI-E stated that "the modelling is democratic" and "could offer an improvement [on current PEDM processes]". Considering the expressed need to improve conventional PEDM and the potential for BBNs to contribute to meeting this need, in this section I address RQ4: how could BBNs be incorporated into PEDM to improve the MREI consenting process? First, I compare the strengths and weaknesses of using BBNs shown in this case study (discussed in chapters 5 and 6) with the shortcomings of PEDM (described in section 7.1). Second, I present a series of recommendations, for use of BBNs in PEDM.

Table 7.1 Potential uses of BBNs in PEDM

Strengths of using BBN in PEDM	Weaknesses of using BBN in PEDM	Places in PEDM that KIs identified could be improved	Potential uses of BBNs in PEDM
BBNs helped KIs reflect on and broaden their views, opening discussions. BBNs were used as a structure for KIs to discipline, order, and develop their views, encouraging learning Useful way to start the deliberative process	Modelling BBNs independently of participants reduces process transparency and their ability to understand the visual representations as BBNs get more complex in the later stages of development (increasing anxiety and burden of participation)	Transparency and fair process	Identify and explore key issues with participants, e.g. during the scoping phase of PEDM
BBNs improved access to PEDM facilitating contributions from non-experts and diversifying the participant contributions		A range of formats to improve engagement and increase diversity of participants and voices Flexibility	BBNs provide an alternative format and facilitate diversity in contributions. Use BBNs in combination with other techniques
As the researcher (data collector and modeller) I accrued knowledge effectively	BBNs were too complex in the later stages of development and did not effectively communicate alternative views between KIs Time consuming	Reduce conflict More time and resources	Modelling stakeholder knowledge using BBNs to improve communication between the decision-maker and stakeholders

Strengths of using BBN in PEDM	Weaknesses of using BBN in PEDM	Places in PEDM that KIs identified could be improved	Potential uses of BBNs in PEDM
Raised awareness of alternative views	KIs were not encouraged to reach mutual understanding or compromise	Bring stakeholders together and tackle adversarial processes that encourage participants to establish and maintain positions of self-interest	Co-producing combined BBNs with KIs earlier or immediately could encourage participants to share the burden of participation and better understanding of alternative views
	Modelling individual BBNs first and combining them later encouraged KIs to establish and become entrenched in positions of self-interest, increasing the burden of participation		
	BBNs are unfamiliar	Preference for familiar procedures	Use BBNs in combination with other, more familiar engagement techniques

As described in chapters 5 and 6, the results reveal a range of strengths and weaknesses of using BBNs in PEDM. To investigate the potential effect that these strength and weakness could have on PEDM, they are aligned to the spaces for improving PEDM (identified in section 7.1). The links between the strengths and weaknesses of using BBNs in PEDM identified in this case study, the spaces for improving PEDM suggested by the KIs, and the potential uses of BBNs in PEDM, are summarised in Table 7.1 and described below.

As described in chapter 5, BBNs worked well as a structure for the KIs to reflect on their own knowledge, leading them to broaden and evolve their views, and ultimately generate new knowledge. In chapter 6, I discussed how the features of BBNs facilitated this process of learning, exploration, and reflection. The capacity of BBNs to incorporate qualitative data enabled the KIs' knowledge to be captured in the model between each cycle of engagement. The visual representations of the BBNs displayed previously captured knowledge so that it could be reviewed in subsequent cycles. The capacity to update the models was used to facilitate further knowledge production. The results indicate that the visual representations of BBNs and their ability to be updated encouraged the KIs to reflect on and broaden their knowledge throughout the cycles of engagement. Although the visual representations of the BBNs did not comprehensively capture the complexity of the intuitive knowledge held by the KIs, they provided a structure to discipline the thoughts of the individual KIs to explore, reflect on, and learn from their own knowledge. This enabled BBNs to demonstrate how and where contributions are included, which could address the need for improve transparency and fairness in PEDM, as explained in section 7.1.

As indicated in Table 7.1, the value of BBNs in providing a transparent structure that demonstrates how and where issues are included, facilitates reflection, exploration and broadening of participants' views. These qualities lend BBNs to helping participants and decision-makers identify and explore key issues together. For example, BBNs could add value during the scoping phase of PEDM, which occurs prior to a formal application being submitted and aims to *identify the main issues of potential concern at an early a stage as possible so that they can be considered in appropriate detail* within the application (and the associated Environmental Impact Assessment) (Natural Resources Wales, 2017). The use of BBNs during the scoping stages of PEDM, where relationships are formed, and issues are raised was

supported by several of the KIs, who considered that BBNs are “a good way to start” (KI-G) PEDM, because the modelling could help to “identify things to consider” and “see what the priorities would be” (KI-A). KI-J reflected that the model could be used to “plan how to address the issues” and to explore if “everything is covered”. BBNs could therefore be used “as tools in the scoping stages” (KI-N) of PEDM to assess the feasibility of a proposal and inform strategic decision and discussions.

However, this is not to say that the use of BBNs should be limited to the scoping phase of PEDM. There are occasions throughout PEDM where it is useful for decision makers and stakeholders to identify and explore issues together. In accordance with the understanding that knowledge changes described in STS (see chapter 2), issues will be raised, and new data produced during all phases of PEDM. For marine renewables (as well as other developments) this applies throughout the application process and subsequent monitoring of construction, operation, and decommissioning phases. The features of BBNs enable them to be co-produced at scoping phase and updated throughout the process.

As described in chapter 6, the features of BBNs improved access to PEDM and diversity of contributing voices. The visual representations were considered “visually accessible” (KI-N). The ability of BBNs to incorporate qualitative data increased the diversity of voices and perspectives, including lay knowledge, in PEDM. This addresses a significant shortcoming in conventional PEDM identified by the KIs, which they considered to be disengaging, resulting in lack of diversity in the range of participants and views. The KIs raised issues with the format of current PEDM, which excludes some stakeholders and narrows the diversity of participants, as well cultivating conflict, and mistrust between those who do participate. The KIs thought that open, public forms of engagement and fixed formats (often long text-based documents) were disengaging and place the burden of participation onto the participants. As illustrated in Table 7.1, in offering an alternative and accessible format for engagement, BBNs could improve the diversity of participants and voices. This function could also be valuable during the scoping phase of PEDM, to ensure that the diversity of issues is identified and explored.

Using BBNs during PEDM to identify and explore issues, and as an alternative format for engagement, opens the possibility to use them in combination with other engagement tools

(which I discuss further below). The crucial point is that BBNs should be implemented flexibly, aligning with the need for more flexibility in PEDM which was recommended by the KIs (as discussed in section 7.1).

Conflict between stakeholders adversely affects PEDM. This study highlights the, often, adversarial nature of conventional PEDM processes that fuel existing hostilities, as well as lack of time to build trust and establish relationships. The KIs recognised the need to reduce conflict in PEDM as a space for improvement (see section 7.1). As discussed in chapter 5, the BBNs did not effectively represent and communicate knowledge between the KIs. The visual representations of BBNs were simultaneously too complex to interpret but did not capture the complexity of the system that the KIs intuitively understood. Displaying alternative views emphasised differences and existing hostilities between the stakeholders. This reduced the potential for BBNs to address conflict between stakeholders or facilitate learning, as prescribed by the practical criteria associated with the principle of process-orientation (see chapter 6).

Although the BBNs did not effectively communicate knowledge between the KIs, building the BBNs with the KIs generated knowledge for me. Receiving and modelling the data gave me the opportunity to develop and contextualise the evidence in ways that were not available to the KIs themselves. As the researcher, receiver of data, and modeller in this case study I represented the role of decision-maker, regulator, or consenting authority in PEDM (such as the MMO or Marine Scotland in the case of tidal energy schemes). Therefore, BBNs could be used to generate knowledge production for the decision-maker and inform PEDM. It could be argued that this supports the conventional use of BBNs as a tool for data extraction (see section 1.2) where data collected (belief elicitation) is used to inform decision-making independently of the participants. However, my learning from the KIs also cultivated a deep appreciation and understanding of their perspectives. As a tool for decision-makers to learn from the stakeholders, BBNs address the need to reduce conflict between stakeholders, specifically hostilities and mistrust between the decision maker in a regulatory authority and other stakeholders e.g. applicants or consultees.

Although the visual representations of BBNs raised the KIs' awareness of alternative views, the loss of meaning and detail from the visual representations in the process of building the models reduced the ability for the BBNs to cultivate mutual understanding between the KIs. The lack of capacity for the BBNs to communicate knowledge was partly attributable to the inherent features of BBNs, e.g. the lack of feedback loops reduced the ability of the modelling to adequately represent the dynamic system understood by the KIs. It was also partly attributable to the way BBNs were used in this study. Specifically, developing separate BBNs with individual KIs over the first 3 cycles of engagement, prior to combining them seemed to encourage the KIs to establish and become entrenched in positions of self-interest. This approach (keeping KIs separate), hampered the potential for BBNs to address the need for tools that bring stakeholders together. To deal with this issue, as illustrated in Table 7.1, combined BBNs could be co-produced from the start of the engagement process. This suggestion requires further research.

As well as intuitive knowledge about the Solway Firth, the KIs also brought experiences of PEDM in practice and familiarity and comfort in existing PEDM processes (see section 7.1). The KIs' preference for comfort and familiarity hampers the potential for BBNs (a relatively unfamiliar tool) to improve PEDM. The results of the exploratory case study indicate that in practice the use of BBNs in PEDM could create discomfort and anxiety where they diverge from the familiar processes. For example, although several KIs considered that BBNs could help in the scoping stages of PEDM, KI-G insisted that scope of data required is established satisfactorily by the existing formal scoping stage of the EIA, and could not envisage how BBNs could contribute to this process. Anxiety about the unfamiliar (e.g. the BBN modelling) reduced engagement that could add to hostility and conflict between stakeholders. To address this limitation, BBNs could be used in combination with other, more familiar engagement tools (as discussed in section 7.3), to meet the preference for familiarity and address the expressed anxiety about using an unfamiliar engagement tool.

Considering the potential drawbacks of using BBNs in PEDM, described in previous sections, their use would not suit every situation and should therefore be presented as a useful tool rather than a mandatory process. The KIs suggested possible uses during the scoping phases of PEDM, where evidence is brought together and contextualised. However, spaces for

improvements remain. Hostility and conflict between stakeholders were not fully addressed using BBNs. To some extent, the BBNs helped me (representing the decision maker / regulator) to develop a deeper understanding of the KIs' (stakeholder's) views, which could aid relationships between them, but hostile relationships between stakeholders persisted. Conventionally, PEDM in practice focuses on information deficits (how to get more information), but the results of this study demonstrate the importance of managing stakeholder relationships and communication. Fundamentally, the results of this exploratory case study illustrate the importance of establishing and maintaining good relations, which has less to do with obtaining data and more to do with personalities and mutual respect that cannot be created via a modelling tool. KI-F reflected that the "conversation more than the model encourages appreciation of other interests".

Based on the potential contributions to PEDM identified above and in Table 7.1, it is recommended that BBNs could be incorporated into PEDM to improve the consenting and licencing process for marine renewables in the following ways:

- BBNs effectively provide a structure that enables participants to transparently explore and broaden their views, therefore BBNs could be used to identify, explore, and test issues in PEDM, e.g., at the scoping stage.
- BBNs were particularly useful as a mode of knowledge production for me, as the modeller. I developed a deeper understanding of the KIs' views. BBNs could therefore be used by decision-makers, applicants, and those in regulatory authorities to develop a better understanding of the perspectives of a range of stakeholders and how those perspectives relate to one another.
- It is recognised that BBNs will not suit every PEDM situation. The complexity of the visual representations, which increased with their development, increased anxiety and the burden of participation. Therefore, to optimise the potential benefits, their implementation should be optional and flexible.
- BBNs could be used in combination with other formats of engagement or modelling to encourage diverse contributions and facilitate flexible implementation, where the extent they are used is dependent on the needs of each case (proposal).

- Considering that BBNs are likely to be unfamiliar to most stakeholders, and the preference of stakeholders for familiar procedures, it is recommended that the use of BBNs is combined with more familiar engagement techniques.
- BBNs should be combined from the start or early in the process to reduce the potential for stakeholders to become entrenched in position of self-interest

In this section, I have aligned the strengths and weaknesses of using BBNs in PEDM with the spaces for improving PEDM revealed in this case study. Drawing on these findings I have made a series of recommendations for the use of BBNs in PEDM. In the next section, I suggest areas of additional research required to test these recommendations.

7.3 Areas of further research

In this section, I reflect on alternative ways BBNs could be tested in the context of PEDM and make recommendations for further research.

The results of this exploratory case study indicate that BBNs could be beneficially utilised in the scoping phase of the consenting and licencing process for marine renewables. More research is needed to explore this proposition. A case study or case studies of the scoping phase of the consenting and licencing process for marine renewables using BBNs could be undertaken to explore the potential value of BBNs here.

Considering their partial contribution to PEDM, BBNs could be used in combination with other modelling tools to deliver a more comprehensive solution to the shortcomings of conventional PEDM. Previous studies have explored the potential for BBNs to be used in combination with other modelling tools. For example, to deal with the inability for BBNs to incorporate feedback loops, Amundson *et al* (2014) highlight the potential benefit of combining BBNs with systems dynamics (a type of simulation model). In their study Amundson *et al* (2014) ran a systems dynamics simulation with the results from a BBN, the results of which are fed back into the BBN to remodel, in a cyclical process for iterative decision making over time. Examples of combining BBNs with other models are available in the literature. Barbrook-Johnson & Carrick (in preparation) discusses the use of systems models such as BBNs in combination and finds examples of BBNs being combined with: agent

based modelling (Gonzalez-Redin *et al*, 2019; Lee & Braithwaite 2019; Okakpu *et al*, 2019; and Sun & Muella, 2013); cognitive mapping (Giordano *et al*, 2010); fuzzy cognitive mapping (Azar & Mostafaee Dolatabad, 2019; Carvalho & Tome, 2001; Cheah *et al*, 2009; Wee *et al*, 2015; and Wee *et al*, 2018); social network analysis (Okakpu *et al*, 2019; and Varshney *et al*, 2017); and systems dynamics (Amundson *et al,* 2014; Bertone *et al*, 2018; Crookes, 2017; Mohaghegh *et al*, 2009; Punyamurthul & Badurdeen 2018; and Wang *et al*, 2016). The potential for BBNs to be used in combination with other modelling tools to improve PEDM should be explored with further research.

The results indicate that the method of implementing BBNs influenced the extent to which the modelling could improve PEDM. It is considered that the initial one-to-one meetings and individual modelling encouraged the KIs to develop self-interest positions, produced anxiety associated with the weight of responsibility of their own model, and increased the potential for conflict by highlighting differences with alternative views. Earlier integration or building a combined model from the start could have been more successful at bringing the KIs together to co-produce knowledge and consider alternative perspectives. Further research is required to test alternative ways to combine stakeholder views into BBNs, including building combined BBNs earlier and from the start of the process.

In the last chapter I recap how the results of this study address the research questions and relate the findings to the consenting and licencing process for marine renewables. I also state the specific research contributions.

Chapter 8. Conclusion

To explore how BBNs could improve PEDM, this study addressed the following research questions:

RQ 1: How can improvements in PEDM be measured?

RQ 2: Do the features and development of BBNs adequately capture, represent, deepen the understanding of, and communicate knowledge?

RQ 3. Do the features of BBNs improve PEDM?

RQ 4. How could BBNs be incorporated into PEDM to improve the MREI consenting process?

In this final chapter, I summarise the conclusions drawn from this exploratory case study in response to these four questions in turn and explain what the results contribute to the literature.

RQ 1: How can improvements in PEDM be measured?

As discussed in chapter 1, participation in democratic decision-making is essential; however, despite the breadth of literature, in practice it is often implemented unsuccessfully. In high stakes PEDM, such as marine renewable energy developments, the result is delays, rising costs, and conflict between stakeholders (Haggett, 2008; Wolsink, 2007). The findings of this study confirm the gap between theory and practice. In section 7.1, the KIs highlighted several shortcomings of conventional PEDM in practice that could and should be improved, including disengaging and exclusionary formats that reduce diversity and cultivate conflict.

To address the gap between theory and practice, I started this study by reviewing existing theoretical ideals for PEDM from studies in procedural environmental justice, deliberative democracy and Science and Technology Studies. I assessed the ideals based on their applicability to PEDM and the capacity for practical implementation. The list of applicable and achievable ideals was synthesised and categorised into principles of inclusivity, process-orientation, empowerment, and reflection. To optimise the practical implementation of the

ideals, they were then translated into practical criteria, which were used to test the use of BBNs to facilitate PEDM in the case of SEG.

The implementation of the theoretical ideals was tested in the exploratory case study. As described in chapter 6, the results reveal that in practice the theoretical ideals can conflict with each other. Attempts to provide PEDM that is open to everyone, where access and contributions are unlimited, conflicts with other theoretical ideals. Specifically, providing open access paradoxically conflicts with the diversity of participants, and the capacity of those who do participate to learn and transform their views. As discussed in section 6.5, to provide achievable criteria for PEDM, I suggested that the practical criteria could be amended to focus on transparency, as opposed to openness to provide fair opportunities to participate. Instead of relying on open invitations to provide unlimited contributions, structure is provided to guide effective contributions. To address the risk that structures are used to limit contributions, processes for participant recruitment and provision of recruitment should be transparent. Reflecting these amendments, a revised table of the principles and practical criteria for PEDM is provided in Table 6.6.

The critical review of existing theoretical ideals for participation identified a list of achievable and relevant principles for PEDM and provided an alternative perspective on the existing literature on participatory ideals and their application. The principles were developed into practical criteria and in an original contribution to the literature - created a framework for implementing theoretical ideals, based on fair process and an understanding of knowledge as dynamic.

This framework demonstrated a way to identify, sort and translate achievable and relevant standards for practice. The trial application of this framework contained in this study demonstrated ways to reduce gaps between theory and practice, as well as highlighting persistent gaps. The results illustrated that, in practice, successful implementation of participatory ideals depends more on how they are used (defined by the practical criteria) than what the ideals are. The proposed framework, using practical criteria to translate ideals into ‘how to’ steps, therefore, provides an alternative way to implement participatory ideals.

The continued push for more participation and the persistent gap between participatory ideals and practice (as outlined in chapters 1 and 2) mean that the ways to improve PEDM outlined in this study, matter. In summary, the results indicate that PEDM could and should be modified in the following ways. First, I propose that PEDM, in practice, should be refocused on how ideals are implemented, as opposed to what the ideals are. Second, PEDM in practice should focus on transparent processes, as opposed to just having more participation. Third, the results show that, in practice, ideals can be contradictory, therefore they cannot be applied in turn, one at a time (like a 'tick box' list). To account for the contradictions, ideals should be applied together. This leads into the final point; it should be possible to amend criteria during application to account for contradictions, case specifics and as knowledge changes. This requires a flexible approach to implementation. The framework proposed in this study provides one interpretation of the application of theoretical ideals of PEDM. It is not, and does not claim to be, a definitive interpretation, but it can be used, together with these recommendations, to inform the application of the theory in other decision-making contexts.

RQ 2: Do the features and development of BBNs adequately capture, represent, deepen the understanding of, and communicate knowledge?

Previous studies have claimed that BBNs can aid participation by enabling participants to visualise the evidence so they can see their contributions are included and how they relate to other data. As explained in section 1.2, reviewing the visualisations and the ability to update the models allows participants to test the effects of changes, encouraging learning and reflection. For the BBNs to fulfil these claims, BBNs must be able to adequately capture knowledge contributed by participants and represent the knowledge accurately so that it can be communicated. Satisfying the claims of learning and reflection, the BBNs must be able to communicate captured knowledge to: the contributor, so they can reflect on their previous views; other participants so they can learn from alternative views; and the decision-maker, regulatory authority, and commissioning organisation, so they can implement and justify decisions.

The results of this exploratory case study indicate that the BBNs as outputs and the process of their development could help individual participants to explore and learn from their

previously expressed views. The KIs used the outputs to systematically work through their thoughts, deepening their understanding of, and broadening their own knowledge. It is therefore considered that the BBNs provide a useful framework for participants to reflect on, develop, and learn from their own knowledge.

However, the results show how some knowledge was lost in the process of developing the BBNs. As they were gradually amended with individual KIs, the BBNs failed to retain some meaning and detail. Consequently, when reviewing alternative models, some meanings and details were missing, so knowledge was not adequately communicated between the KIs by the BBNs. The potential for the KIs to learn from alternative perspectives was therefore adversely impacted. This exacerbated existing hostilities between stakeholders, where lack of meaning and detail caused KIs to raise concerns about the credibility of the evidence provided by others and highlighted differences between the contributions.

In the case study, as the researcher and modeller, I represented the role of decision-maker or regulatory authority. The knowledge I accrued through the process of developing BBNs with the KIs did not rely on the models' ability to retain and communicate knowledge. I was privileged to receive, process (model), and monitor knowledge produced and developed via the BBNs. Like the individual KIs reflecting on their own views, I benefitted from the use of BBNs as a framework for reflection and learning.

This study represents a departure from the conventional use of extractive data collection methods (belief elicitation) in BBN supported decision-making. In a novel approach, this study explores the use of BBNs through the lens of participatory ideals to investigate claims that BBNs aid participation by capturing and communicating knowledge. The contribution of this part of the study is adding detail to these claims. The results demonstrate the value of using BBNs as a process of knowledge production, however, as an output their value to communicate knowledge is limited. The results indicate that the claims are met differently for: individual participants reflecting and learning from their own views; participants learning from each other; and the person (or people) representing the decision makers or modeller. Interestingly, the case study indicated that BBNs could add most value to the decision-maker / modeller, as the primary receiver and processer of knowledge.

The results of this study can be used to assess the capacity and suitability for BBNs to be used in PEDM and manage the expectations of future users. Where BBNs are used, the results could inform the selection and application of belief elicitation methods. Given the increasing use of BBNs to support environmental decision-making in PEDM (described in section 1.2), it matters that BBNs are used appropriately and effectively. The results of this study could be used to support BBNs in PEDM in practice.

RQ 3. Do the features of BBNs improve PEDM?

The claims that BBNs could aid PEDM are based on three of the model's specific features: ability to incorporate qualitative data; visual representations of the modelling; and the ability to be updated (see section 1.2). To measure the extent BBNs could improve PEDM in practice, the application of each feature (in the case of SEG) was measured against the principles of and practical criteria for PEDM set out in Table 2.6.

The results of the exploratory case study (see chapter 6) indicate that compliance with the principles and practical criteria for PEDM was variable. The ability to incorporate qualitative data and represent it visually enabled the KIs to review their prior beliefs to learn and broaden their thoughts. The ability to update the models facilitated further development of the modelling, enabling further learning and reflection. Fundamentally, these features facilitated inclusion of views, a process of learning, and reflection on their own views. The features therefore contributed in some way to all the principles of PEDM. However, compliance with the practical criteria of PEDM was hampered by the increasing complexity of the visual representations of the BBNs as they were developed over the cycles of engagement. KIs became increasingly anxious when trying to understand and interpret the models. The results show that the KIs' anxiety increased their (emotional) burden of participation. This is likely to reduce engagement in practice, conflicting with the practical criteria associated with the principles of inclusivity and empowerment.

The ability of BBNs to incorporate qualitative data facilitated the inclusion of diverse views and lay knowledge, as prescribed by the principles of inclusivity and empowerment. To ensure that each KI could recognise that their views were incorporated and valued, individual BBNs

were built with each KI before being combined. However, the results indicate that incorporating diverse views and representing them visually, first as individual, and then as combined BBNs emphasised differences between KIs, as well as the complexity of the modelling. This heightened anxiety and existing hostilities between the KIs, in conflict with the principles of PEDM. The practical criteria associated with the principle of process-orientation prescribe that participants are encouraged to reach broad agreement and learn from each other. Similarly, the practical criteria associated with the principle of empowerment prescribes that PEDM cultivates trust and respect between participants. These criteria are adversely affected by the complexity of the visual representations. Although the KIs were able to recognise alternative views in the visual representations of the BBNs, the lack of meaning and detail (as discussed above) meant that the BBNs highlighted differences between views.

The method of modelling individual BBNs with each KI before introducing alternative views also produced anxiety associated with increasing sense of individual responsibility. Despite being hostile to other stakeholders, the KIs generally recognised the limits of their own views by reflecting on the visual representations as the models are updated. To ease their anxiety associated with having personal responsibility for the model, the results indicate that they sought to share the responsibility with others. This indicates that the methods of using BBNs, as well as their features, impact KIs' ability to improve PEDM in practice. As discussed in sections 7.2 and 7.3, I recommend that alternative methods of implementing BBNs are tested, i.e. co-producing combined BBNs with participants earlier or from the start.

This part of the study focuses on the contribution of specific features of BBNs (visual representations, and their ability to incorporate qualitative data and be updated) to improving PEDM. The contribution of this part of the study to the literature is that it provides detail to these claims, describing how and to what extent these features aid participation.

The results challenge the conventional extractive approaches to elicitation of expert opinion for BBN modelling, typically characterised by one survey and no opportunity for reflection. Instead, the results show that the features of BBNs can work together to support the implementation of the theoretical ideals of PEDM in the following ways. First, as tool for

reflection; the KIs effectively reflected on their prior beliefs, considering what matters, why it matters, connections between issues, and the causes and consequences of effects. Second, the process of contributing to and reviewing the developing BBNs encouraged the KIs to broaden and develop their knowledge. Third, the KIs used BBNs to work out, map, and structure impacts, as opposed to quantify impacts. However, the results also show the limitations of the features of BBNs in improving PEDM. For example, using the BBNs did not make the KIs feel confident and resulted in practical and emotional burdens of participation. This study, therefore, demonstrates that the influence and value of BBNs in PEDM depends on the methods used to use them. These qualities and limitations illustrate that BBNs are a useful way to identify and map out stakeholder concerns and potential impacts, which is discussed below.

RQ 4. How could BBNs be incorporated into PEDM to improve the MREI consenting process?

This study used a proposed tidal energy scheme in the Solway Firth, Solway Energy Gateway (SEG), as an exploratory case study to test the use of BBNs in PEDM. The licencing and consenting process for marine renewables (like SEG) exemplifies the challenges of PEDM in practice. As described in chapter 1, despite some of the best marine energy resources in the world, the uptake of marine renewables (wave and tidal energy) in the UK has been poor. There are numerous barriers to the deployment of wave and tidal energy installations, including high capital costs.

To lower the barriers to uptake, previous studies claim that there is space for the consenting and licencing process for marine renewables to be improved (Ocean Energy Forum, 2016). The results of this study support these claims. As described in section 7.1, the KIs described many shortcomings and space for improvements in PEDM, highlighting exclusionary, disengaging, and adversarial formats. Space for more varied, early, and transparent engagement tools in PEDM were identified. In the case study, the KIs considered the potential for BBNs to contribute to improving PEDM, while also recognising that BBNs do not represent a comprehensive solution to the challenges of conventional PEDM. It was therefore considered that BBNs could contribute to part of the PEDM process, specifically during the scoping phase where relationships are formed, and issues are raised.

The results answering the previous research questions (outlined above and detailed in chapters 5 and 6) support the proposition that BBNs could aid part of the PEDM process. BBNs were found to help the KIs to reflect on their own views and contextualise their knowledge, as well as generating knowledge for the decision maker and/or modeller. However, as the models became increasingly complex, the KIs became increasingly anxious. The ability of BBNs to communicate knowledge between participants was limited, reducing the potential for learning between stakeholders. Considering the strengths and weakness of using BBNs in PEDM identified in this case study, the features of BBNs can be partly used to implement the theoretical ideals of PEDM, depending on the methods of their use.

The results show that BBNs can be implemented to contribute to improving PEDM processes such as those associated with the licencing and consenting process for marine renewables. The contribution of this part of the study is that it demonstrates how that influence of BBNs on PEDM would be especially suited to specific features, roles, and methods of their implementation; specifically, in identifying and exploring issues with stakeholders.

In the early cycles of engagement, the structure of the models provided a useful framework for KIs to explore their own views and contextualise their evidence. It is therefore recommended that the contribution of BBNs to improve PEDM could be at the start of the process, e.g. the scoping phase of the consenting and licencing process for marine renewables. However, BBNs could also contribute during the rest of the application process and monitoring work, as they can be easily updated as knowledge changes and new data is made available.

Considering this partial contribution of BBNs to improving PEDM, this case study also highlights the importance of other elements of the PEDM process. The challenges of PEDM processes in practice, like the licencing and consenting process of marine renewables, cannot be overcome with a single theoretical or statistical model. Rather, theories and tools can be used flexibly and in combination. However, ultimately, “it’s all about the people” (KI-J). Having the time and resources to establish and maintain good stakeholder relations is key to addressing the challenges of adversarial PEDM processes.

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APPENDICES

APPENDIX I

COPY OF PARTICIPANT CONSENT FORM

Data Collection – Solway Energy Gateway

The PhD research aims to improve participation in the consenting process for Marine Renewable Energy Installations (MREIs), using Bayesian Belief Networks (BBNs).

Objective

To explore how stakeholder's beliefs and perceptions about a proposed tidal MREI in the Solway Firth are affected by interacting with BBN modelling, and to assess if and how participation is improved. Improvement will be measured by comparison to criteria including inclusivity, empowerment, fair process, and reflection, this means that contributions will be valued, and that participation is not coerced.

Experiment

In a series of individual interviews participants will be asked about their views on the proposed Solway Energy Gateway. The results will be modelled by the researcher. In subsequent engagement events, participants will be asked to review and retest their own models to explore their own views. The participants will also be asked to consider each other's models and how the models could be integrated. Participants will be given the chance to interact with the integrated model and consider if and how their views have changed.

The process will start with one to one interviews to establish confidence and trust between the researcher and each participant. An events outline, below, is provided for structure and to manage expectations, however, the process is participant led; participants will have the opportunity to amend, suggest and request engagement events.

Anticipated dates	Purpose
August – September 2017	Ask stakeholders about the issues (what matters), why each issue matters, how sure stakeholder feel about their views, and relationships between issues.
November - December 2017	Ask stakeholders to review their individual models to ensure correct representation and discuss changes.
February - April 2018	Ask stakeholders to review each other's models and consider connections with their own.
May - July 2018	Participate in the integration of the model.
August 2018	Disseminate the integrated model. Feedback on the model and the process will be requested.

Use of Data

Notes and transcripts from interviews will be provided to participants for review. Participants will have the opportunity to amend and request changes. Data will be used in the research and future publications, unless requested. Participants will be anonymised unless otherwise requested.

Informed Consent Form

I, the undersigned, confirm that (please tick box as appropriate):

1. I have read and understood the above information about the project and have been given the opportunity to ask questions about the project and my participation ☐
2. I voluntarily agree to participate in the project and understand that I can continue or terminate involvement at any time. ☐
3. The procedures regarding confidentiality have been clearly explained (e.g. use of names, pseudonyms, anonymisation of data, etc.) to me. ☐
4. The use of the data in research, publications, sharing and archiving has been explained to me. ☐
5. I understand that other researchers will have access to this data only if they agree to preserve the confidentiality of the data and if they agree to the terms I have specified in this form. ☐
6. I understand that final transcripts and reports will not identify me or anyone mentioned during the data collection events (interviews / group meetings). ☐

Please tick if you DO NOT wish to be anonymised in the research ☐

Participant:

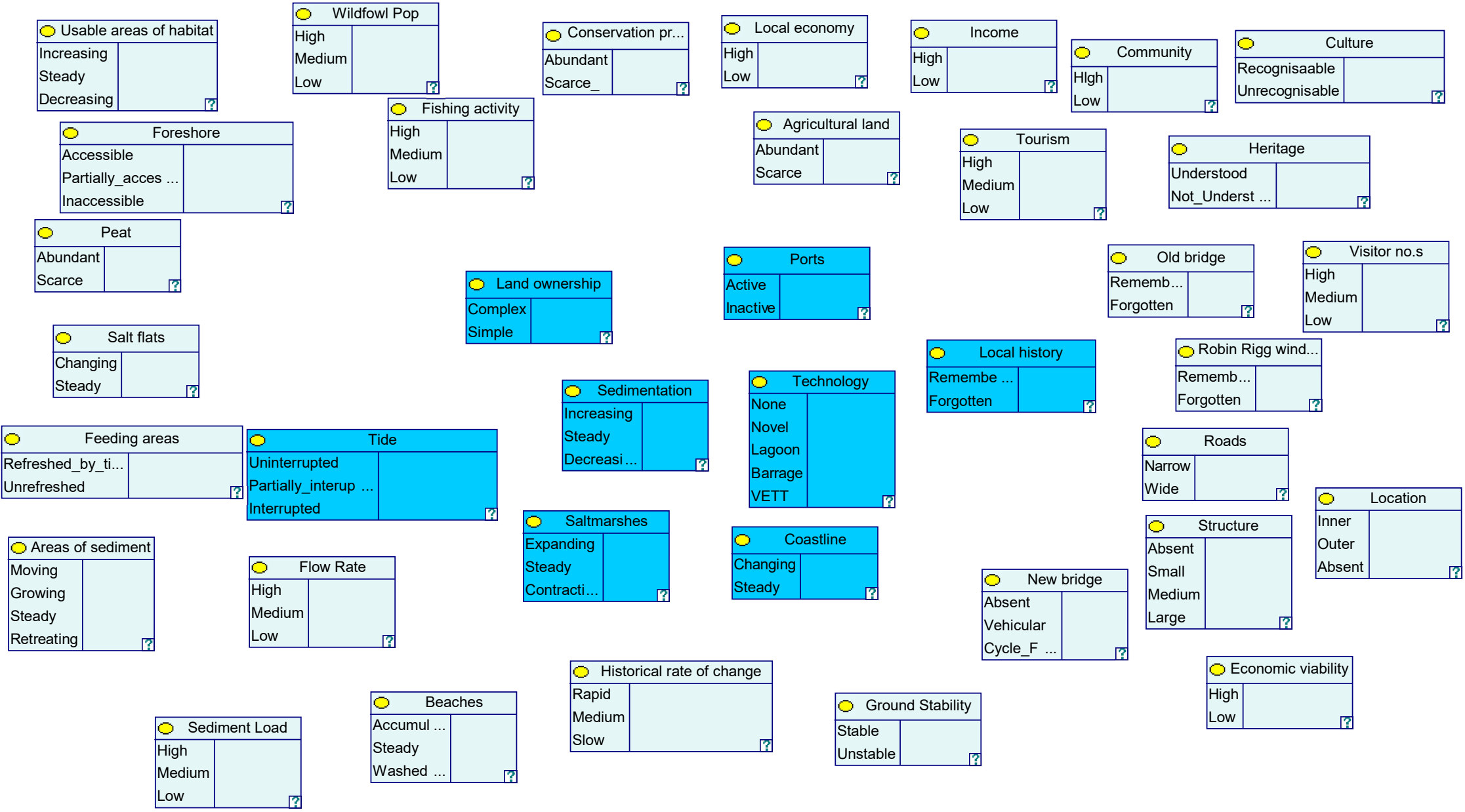
_____	_____	_____
Name of Participant	Signature	Date

Researcher:

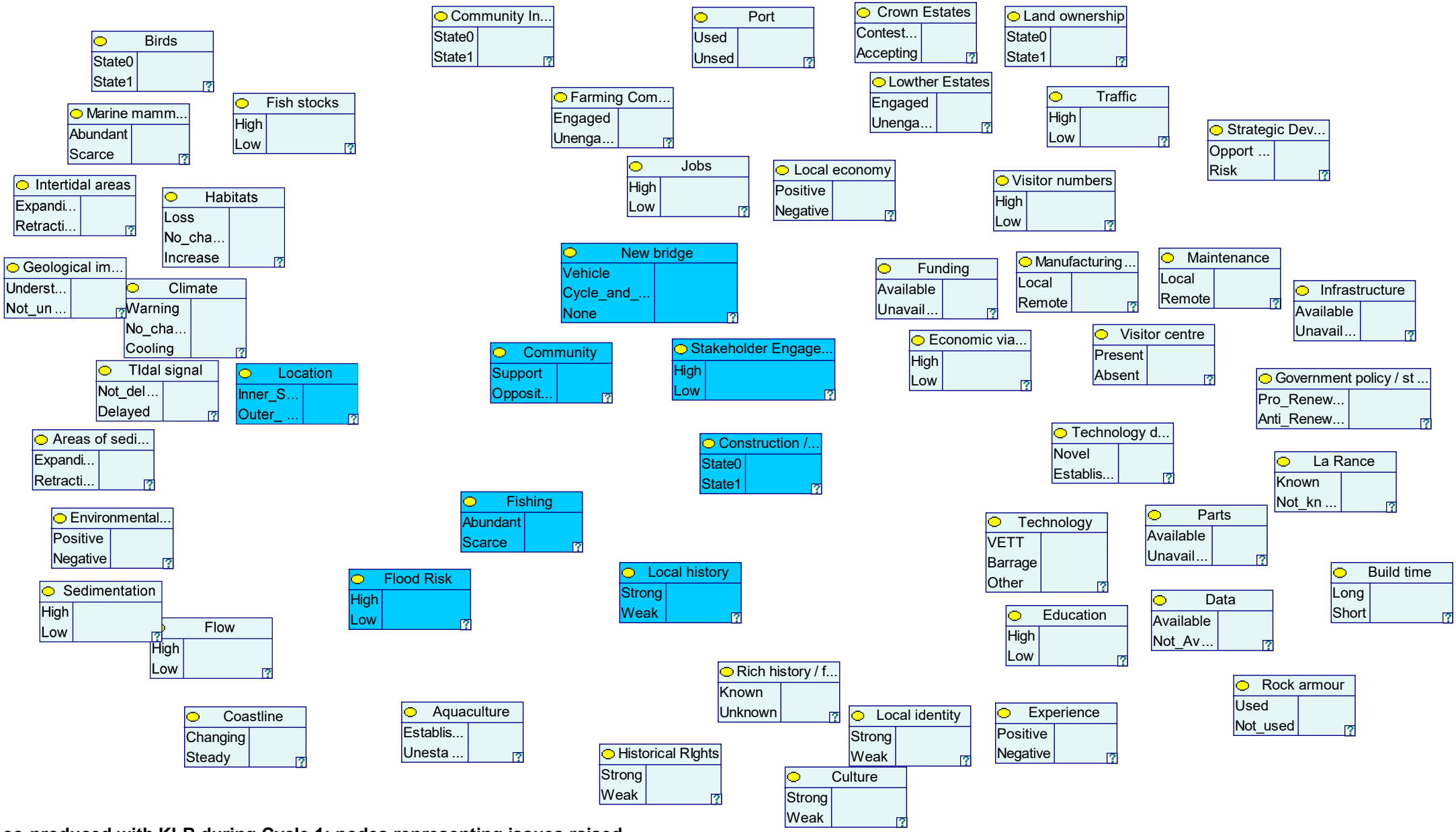
_____	_____	_____
Name of Researcher	Signature	Date

APPENDIX II

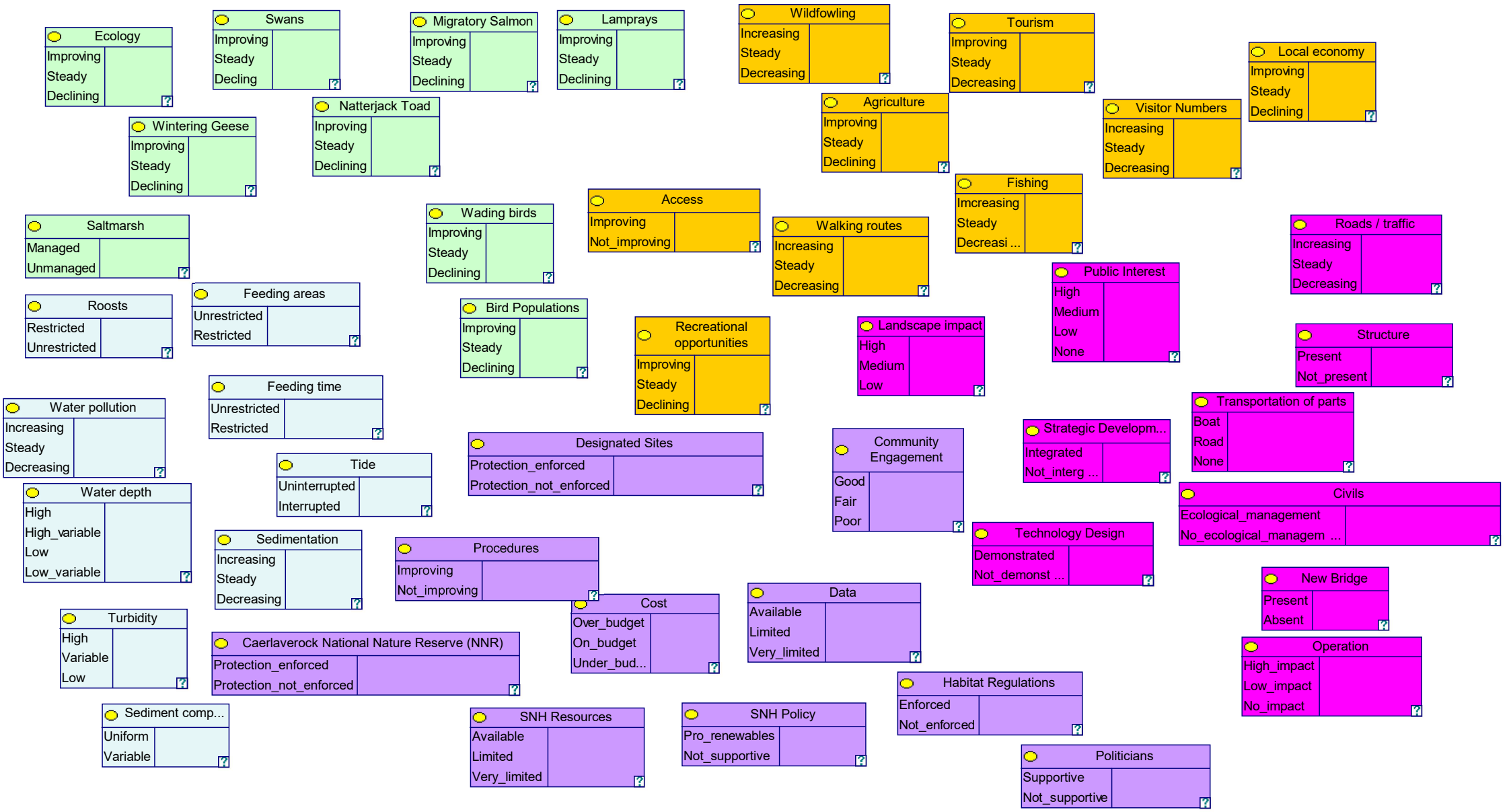
VISUAL REPRESENTATIONS OF BAYESIAN BELIEF NETWORKS BUILT WITH KEY INFORMANTS



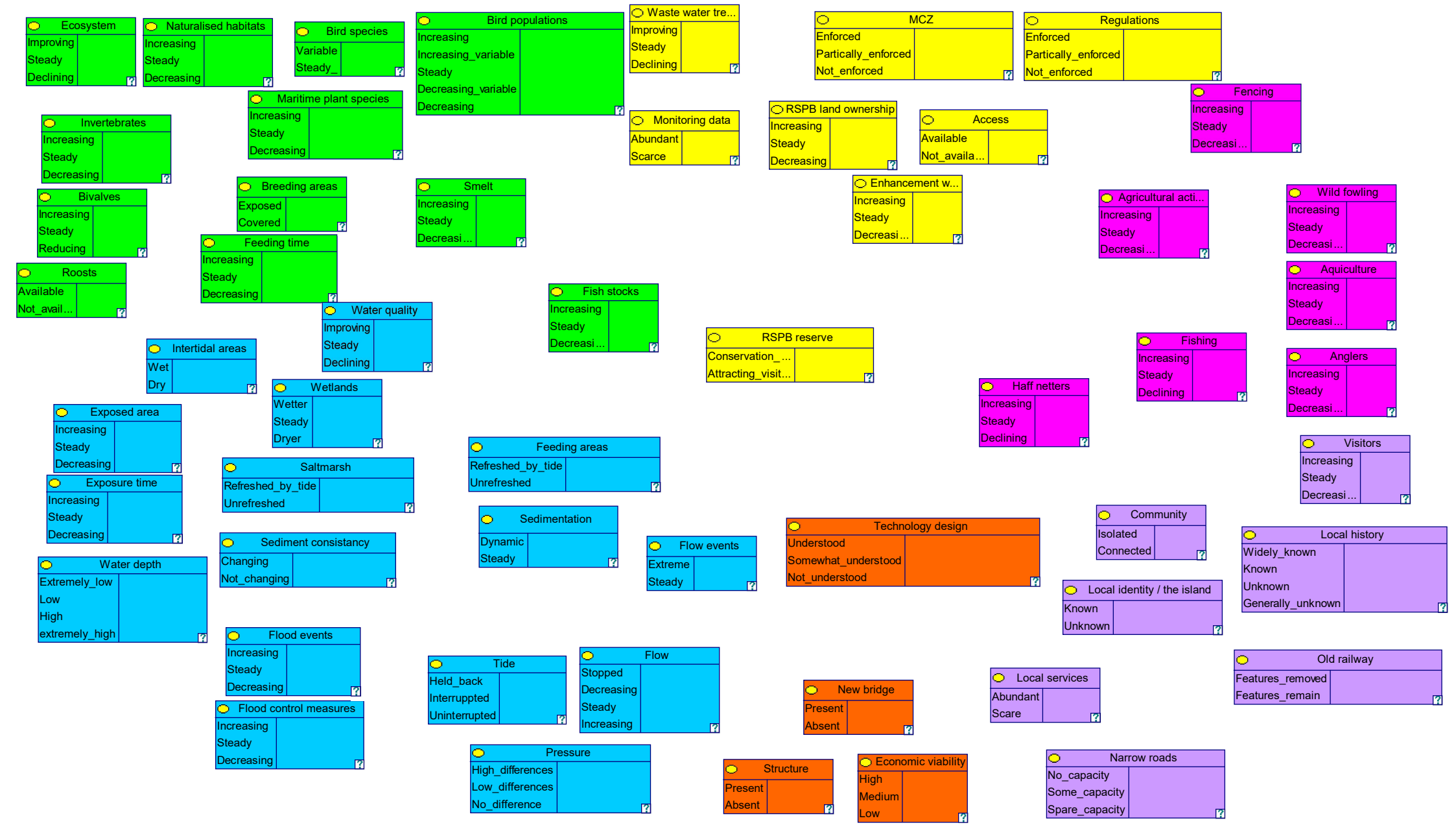
BBN co-produced with KI-A during Cycle 1: nodes representing issues raised



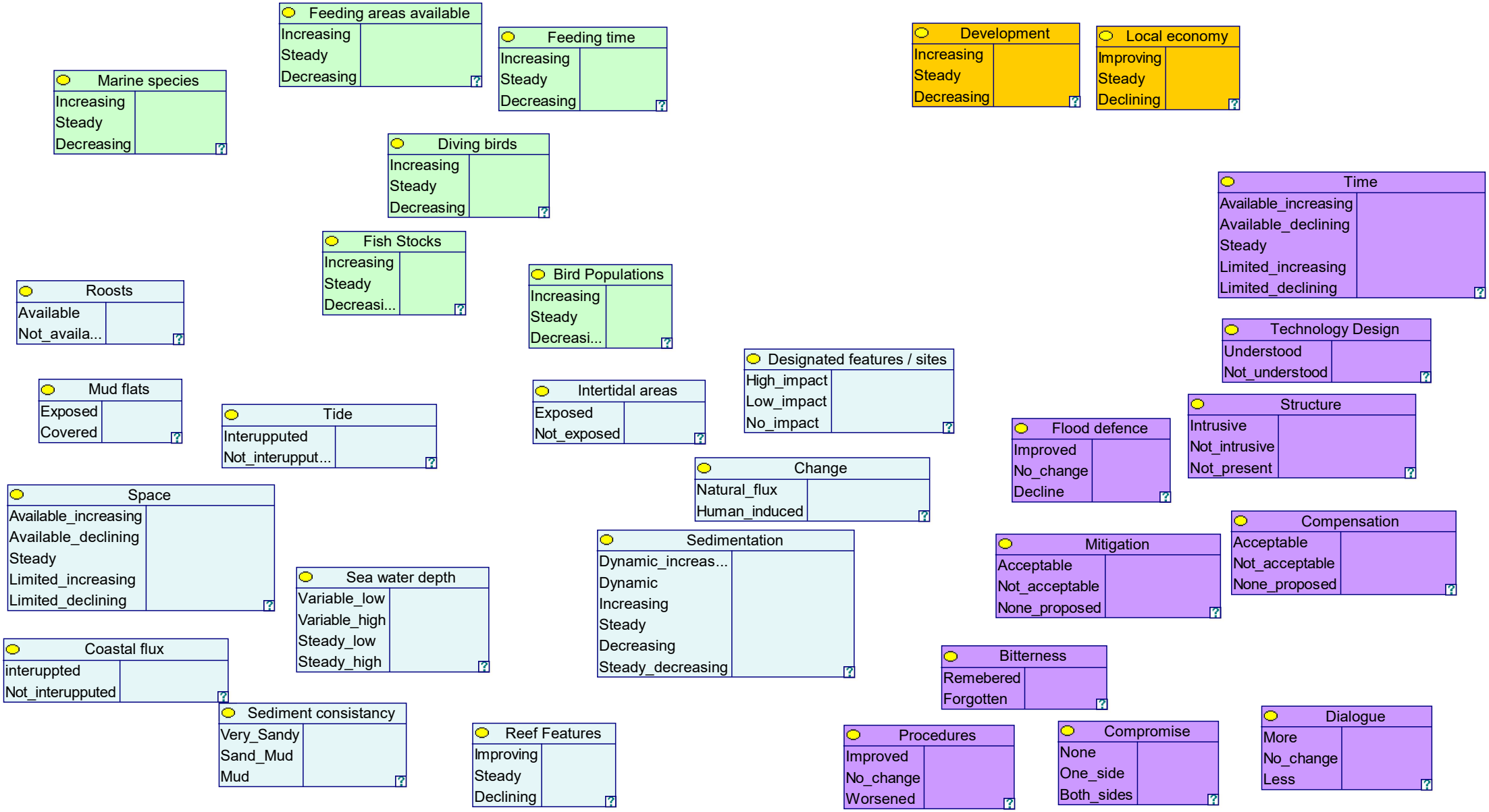
BBN co-produced with KI-B during Cycle 1: nodes representing issues raised



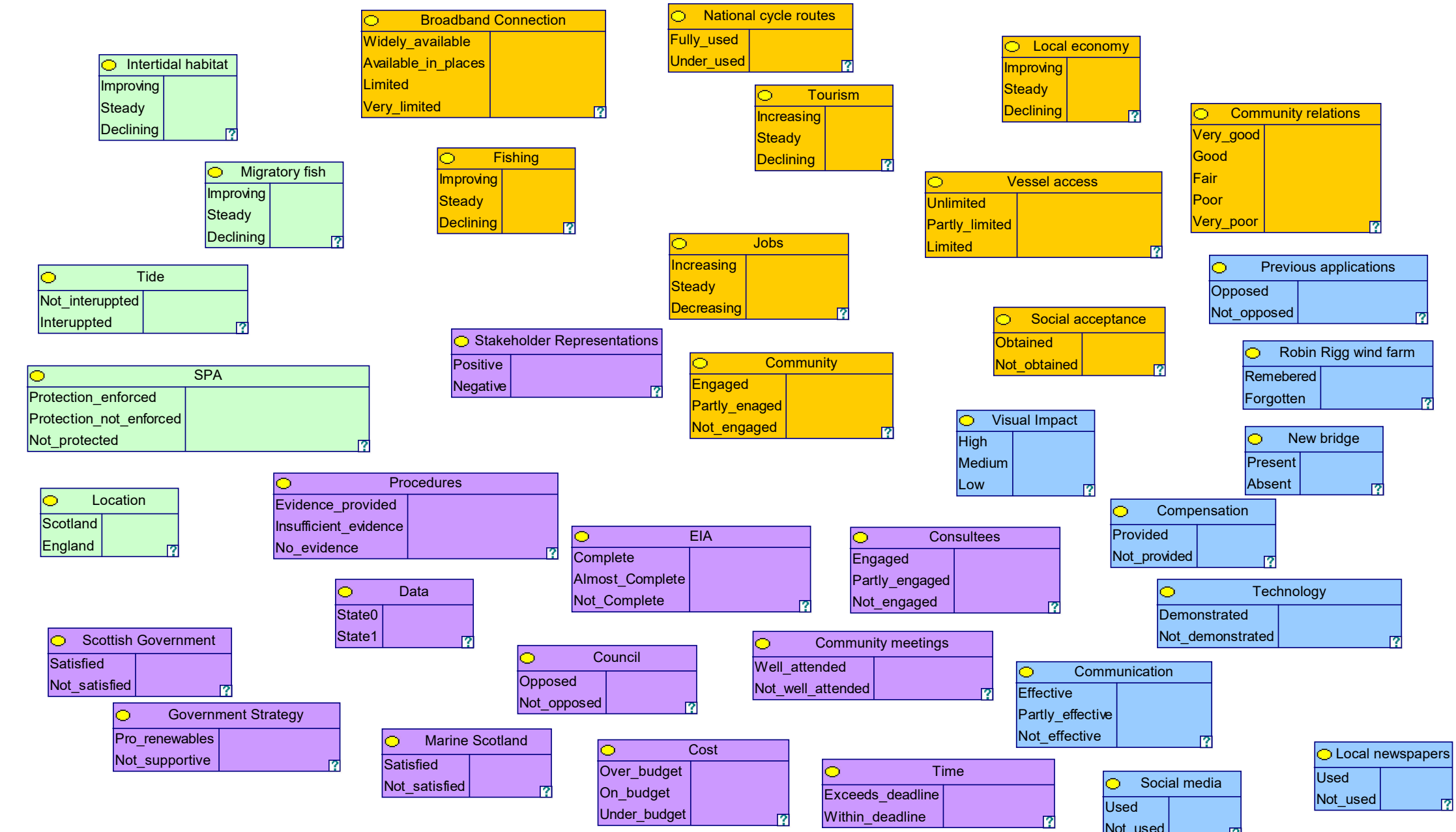
BBN co-produced with KI-D during Cycle 1: nodes representing issues raised



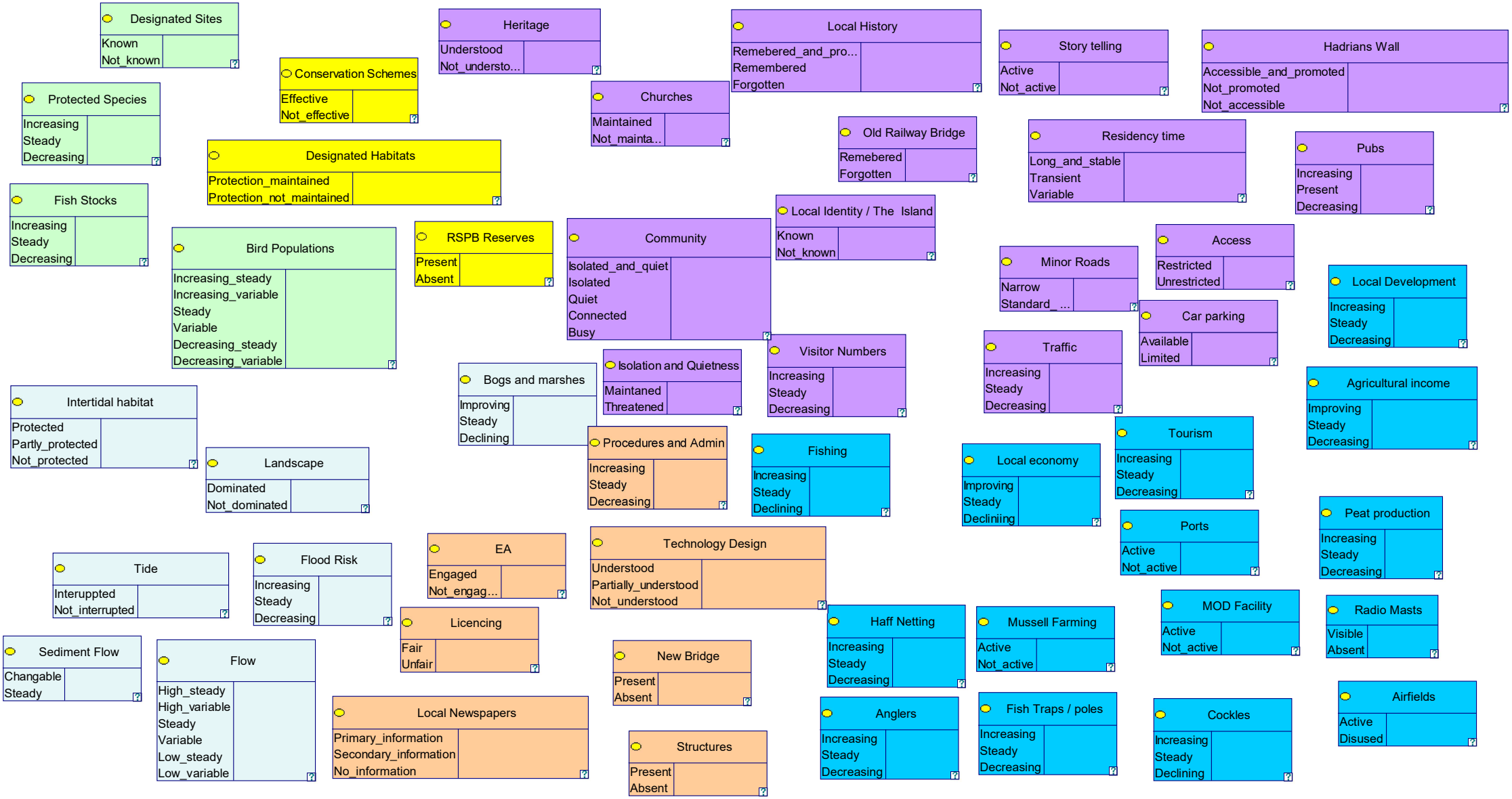
BBN co-produced with KI-E and KI-O during Cycle 1: nodes representing issues raised



BBN co-produced with KI-F during Cycle 1: nodes representing issues raised

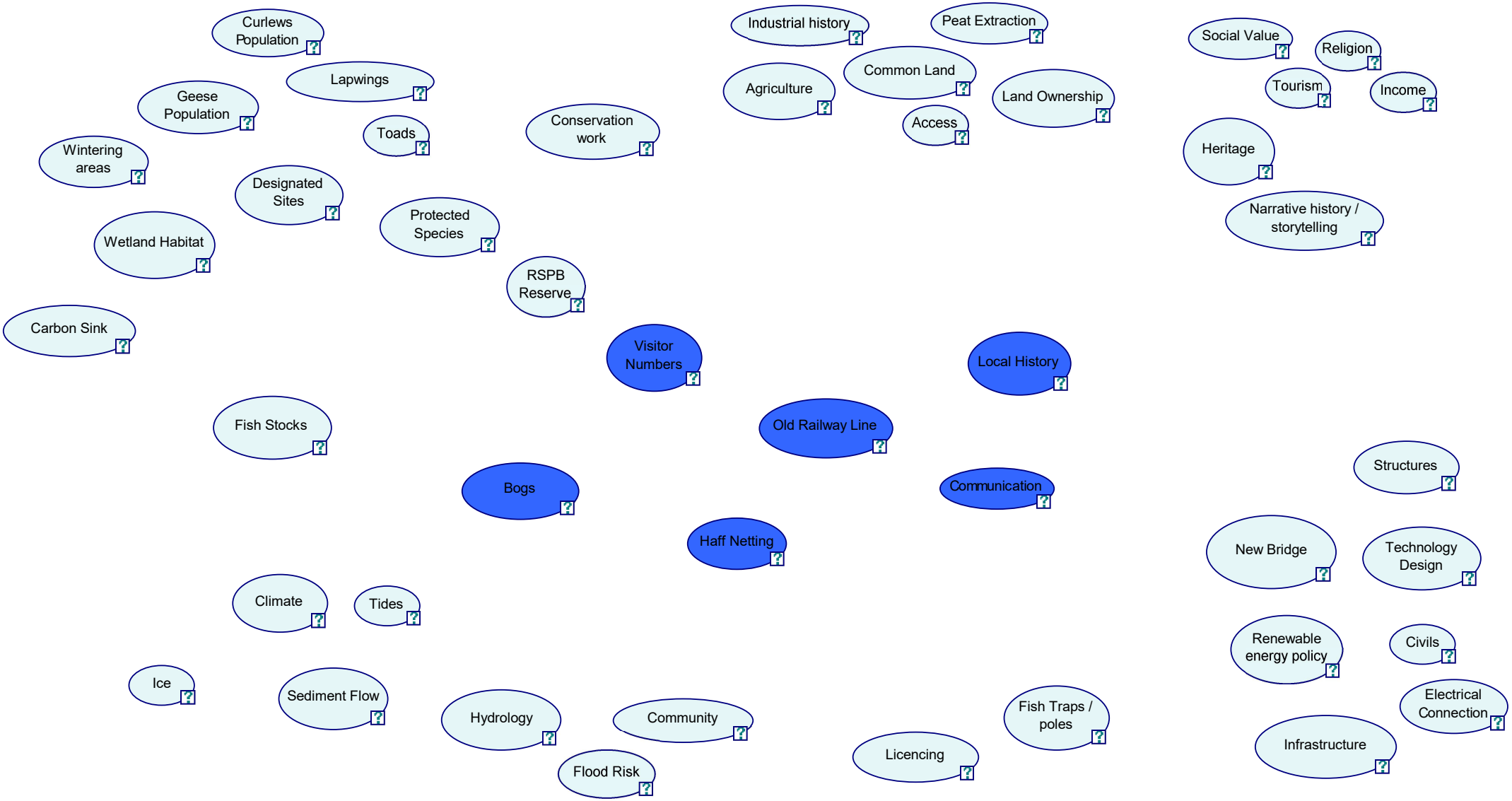


BBN co-produced with KI-G during Cycle 1: nodes representing issues raised

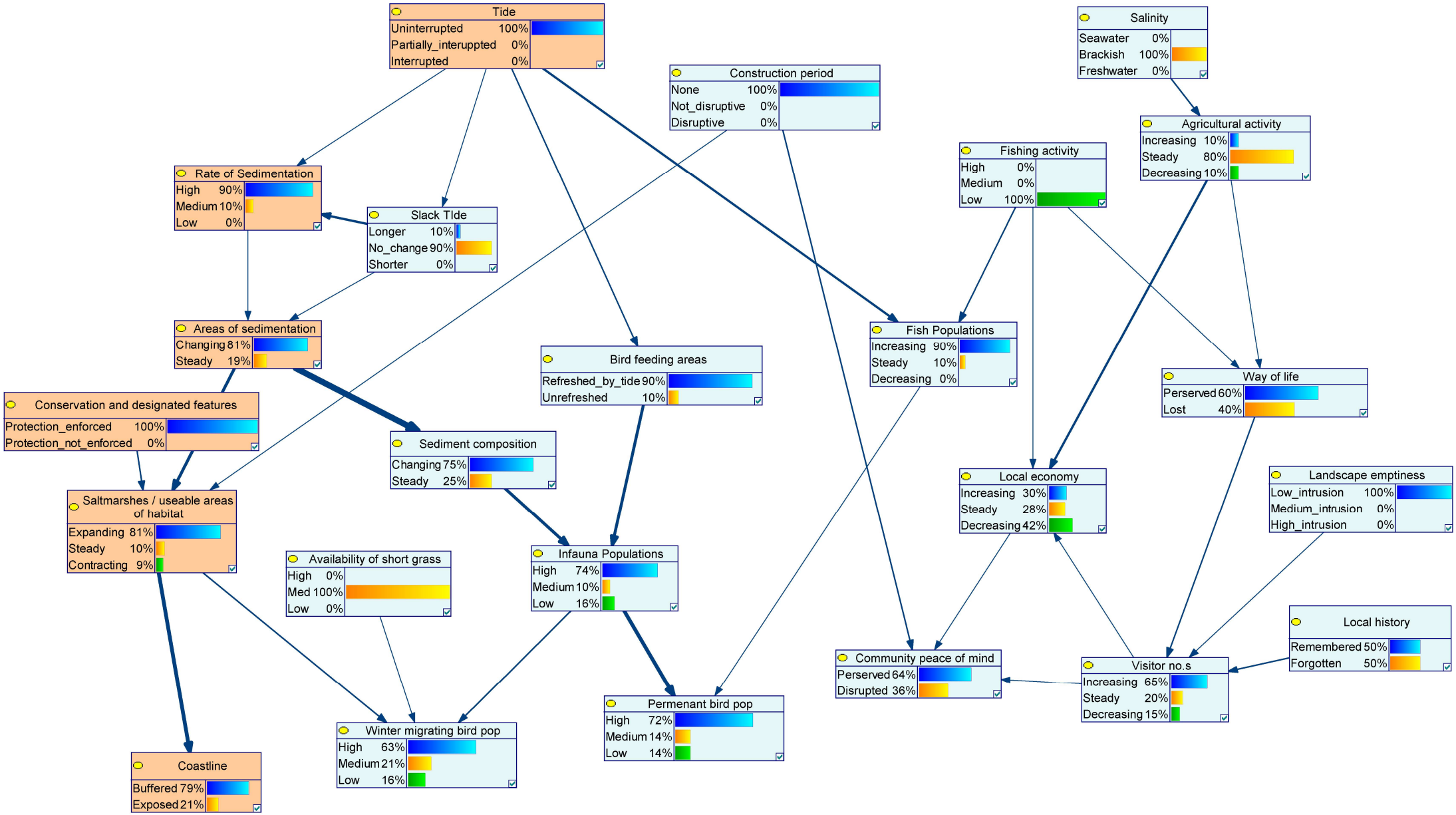


BBN co-produced with KI-H and KI-I during Cycle 1: nodes representing issues raised

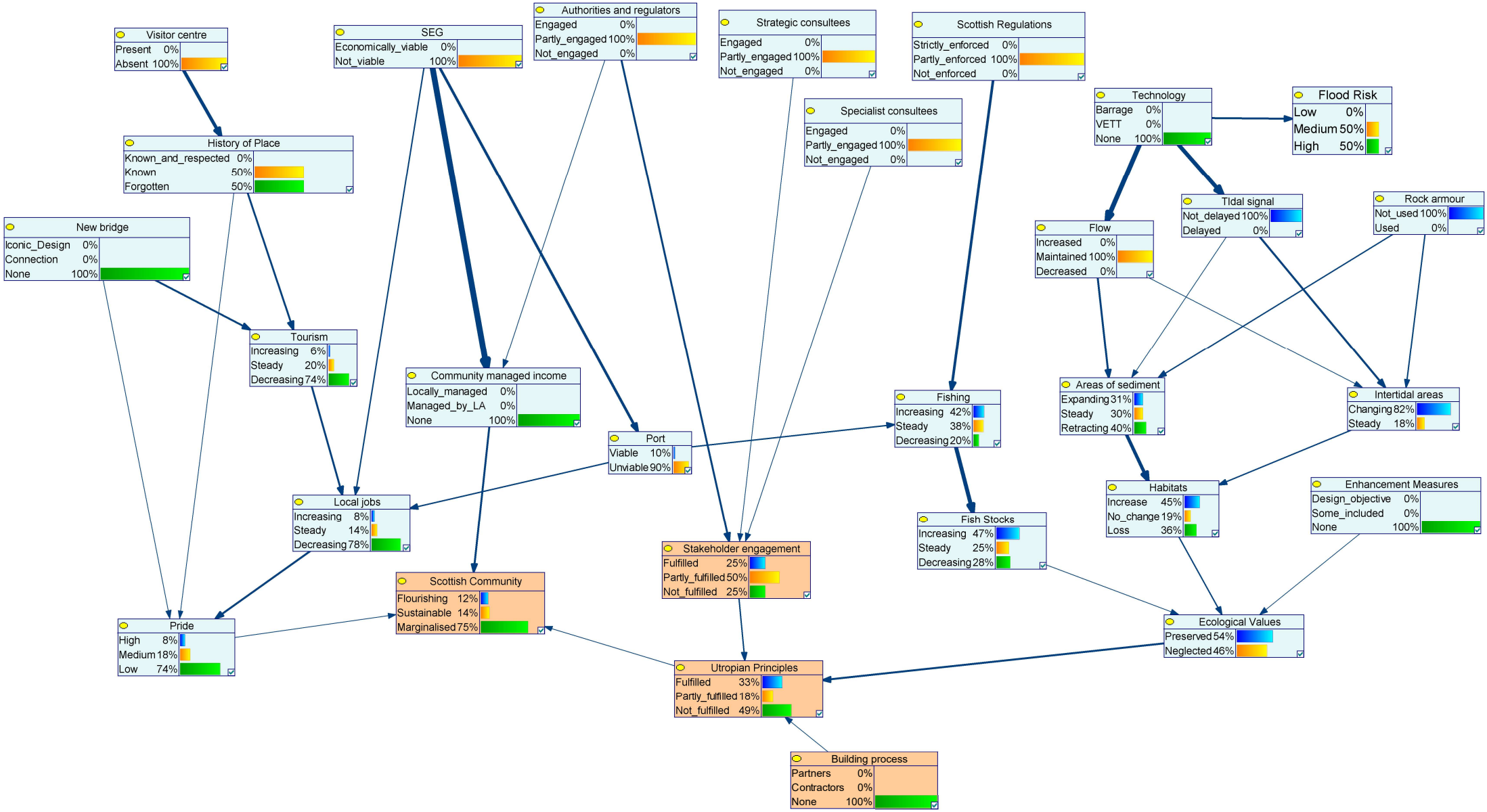
BBN co-produced with KI-J and KI-P during Cycle 1: nodes representing issues raised



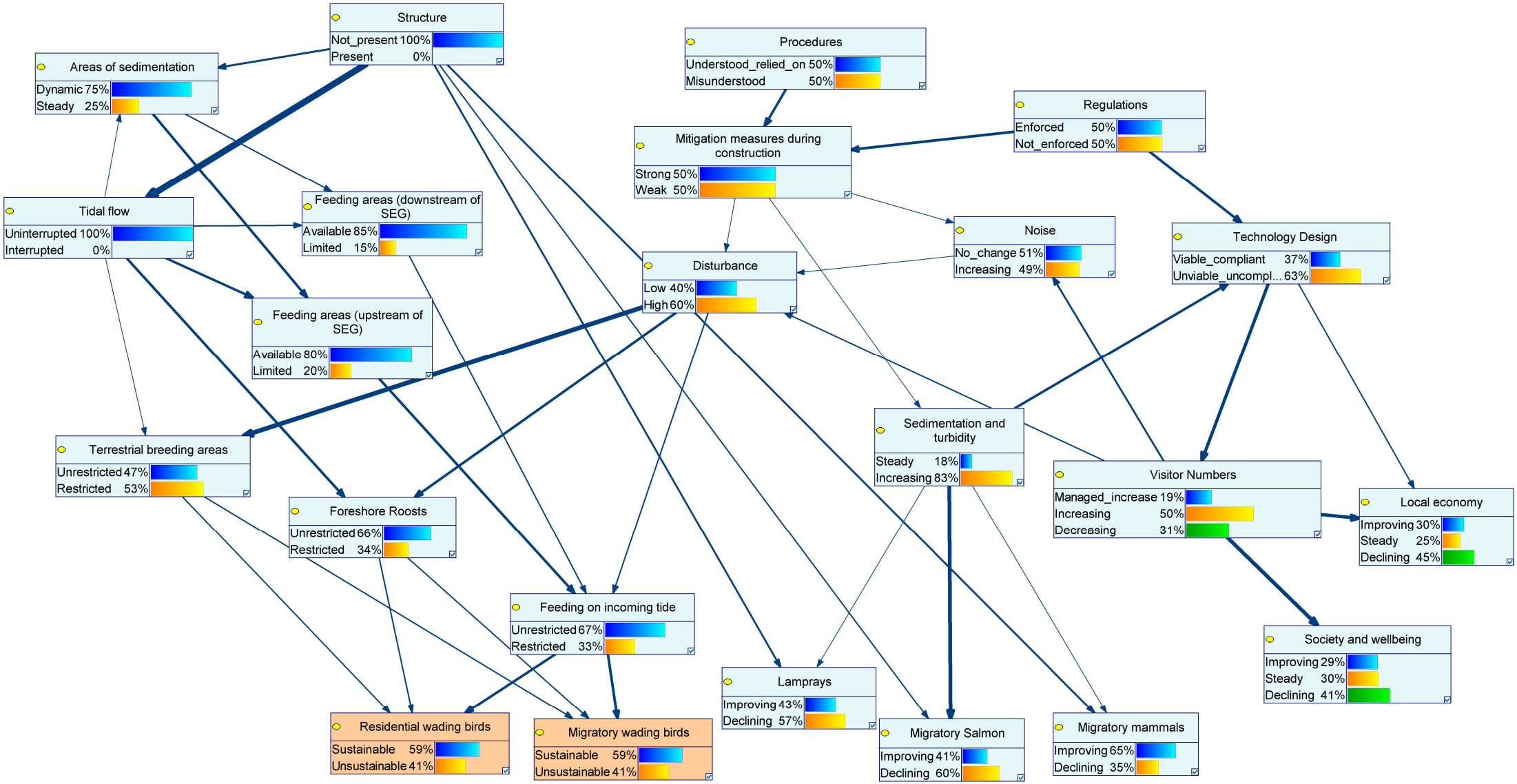
BBN co-produced with KI-M during Cycle 1: nodes representing issues raised



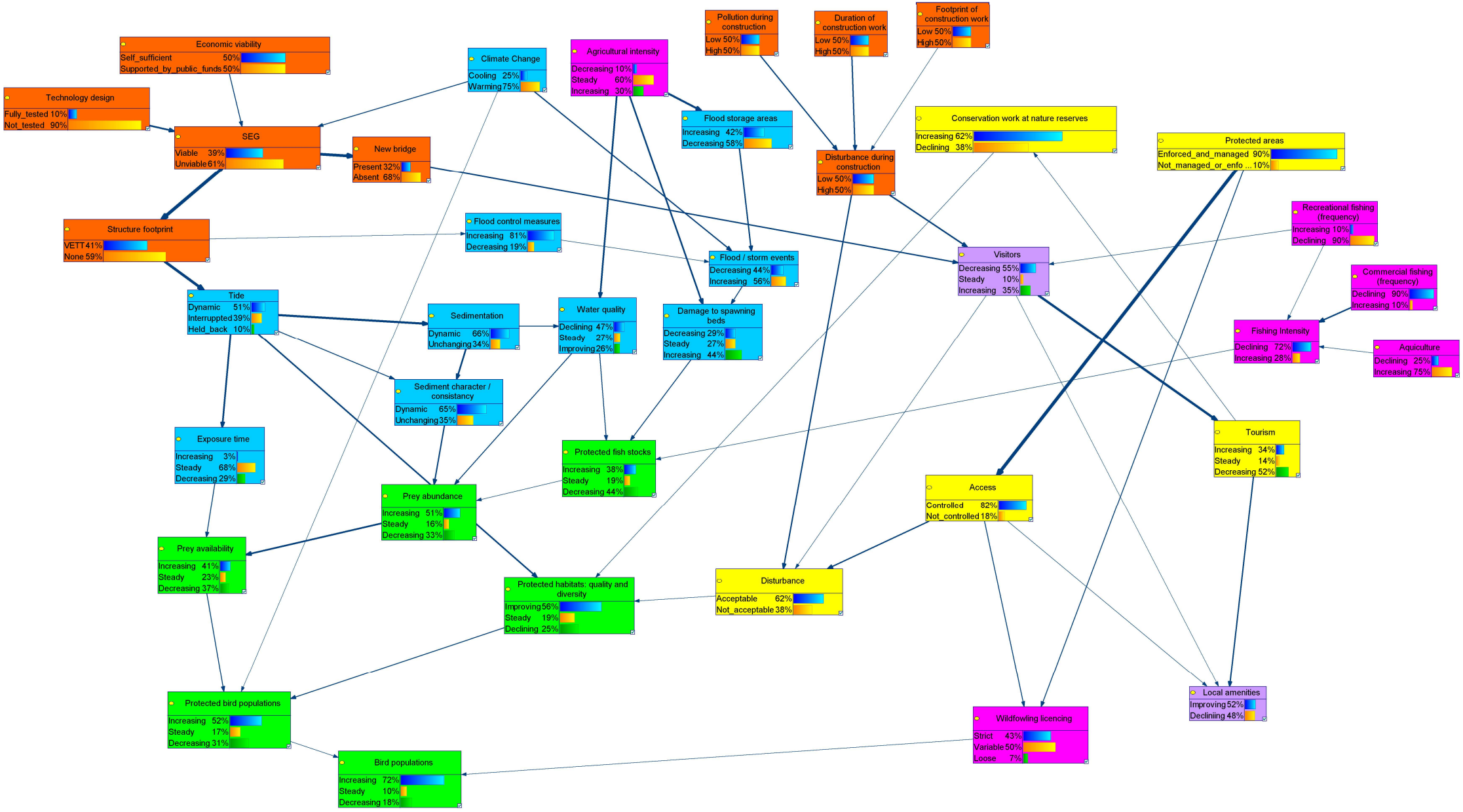
BBN co-produced with KI-A during Cycle 2: nodes, states and arcs representing issues raised and relationships between them



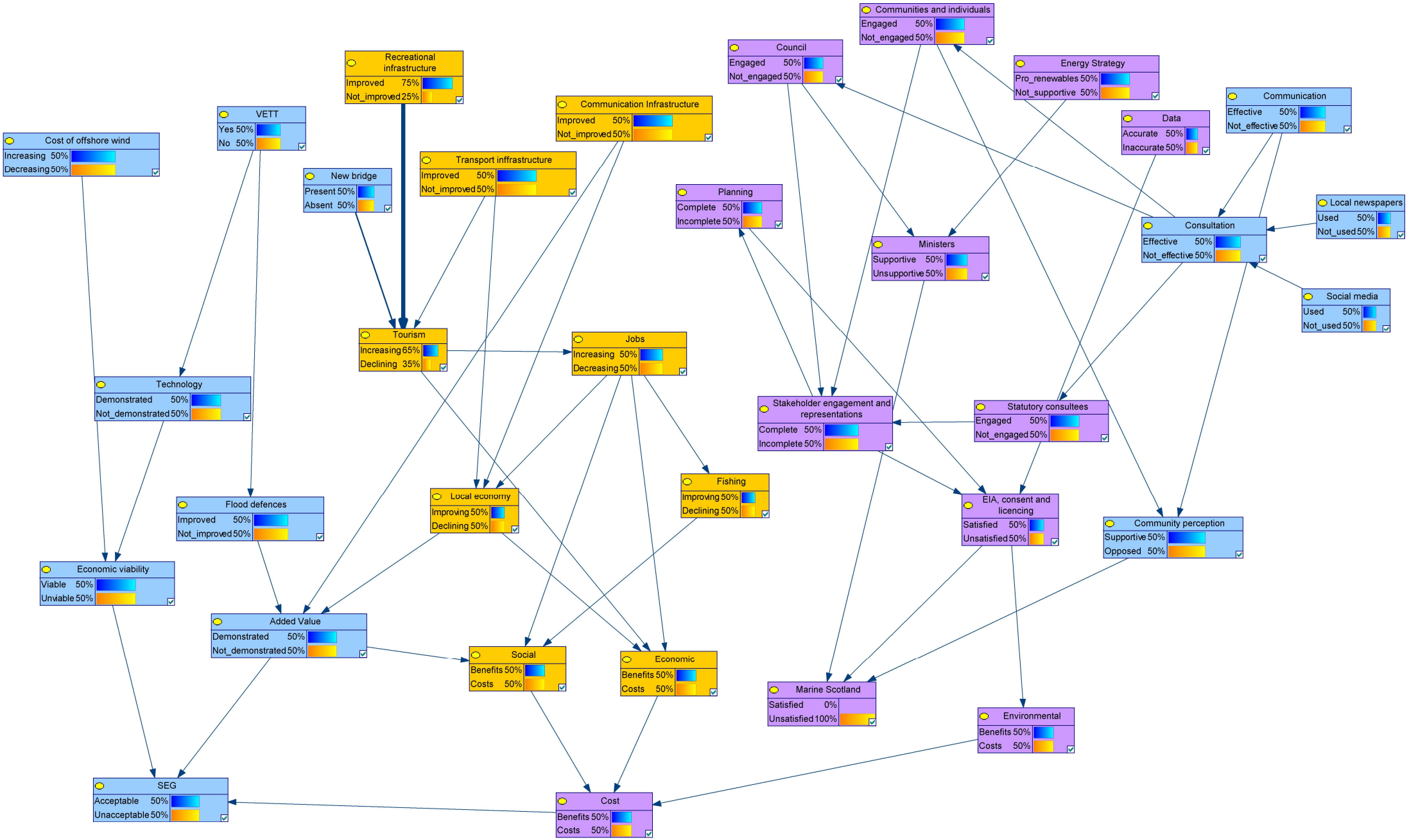
BBN co-produced with KI-B during Cycle 2: nodes, states and arcs representing issues raised and relationships between them



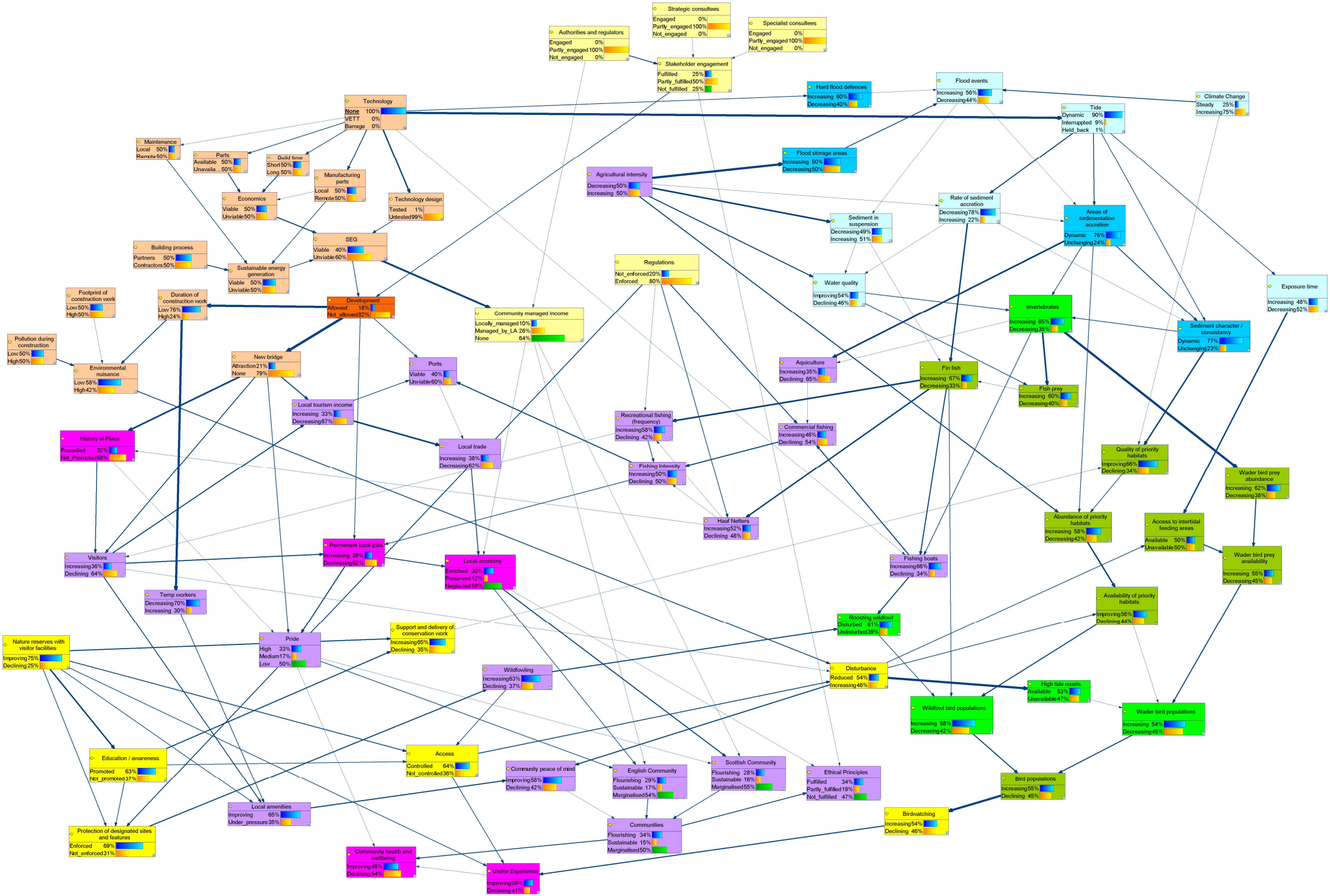
BBN co-produced with KI-D during Cycle 2: nodes, states and arcs representing issues raised and relationships between them



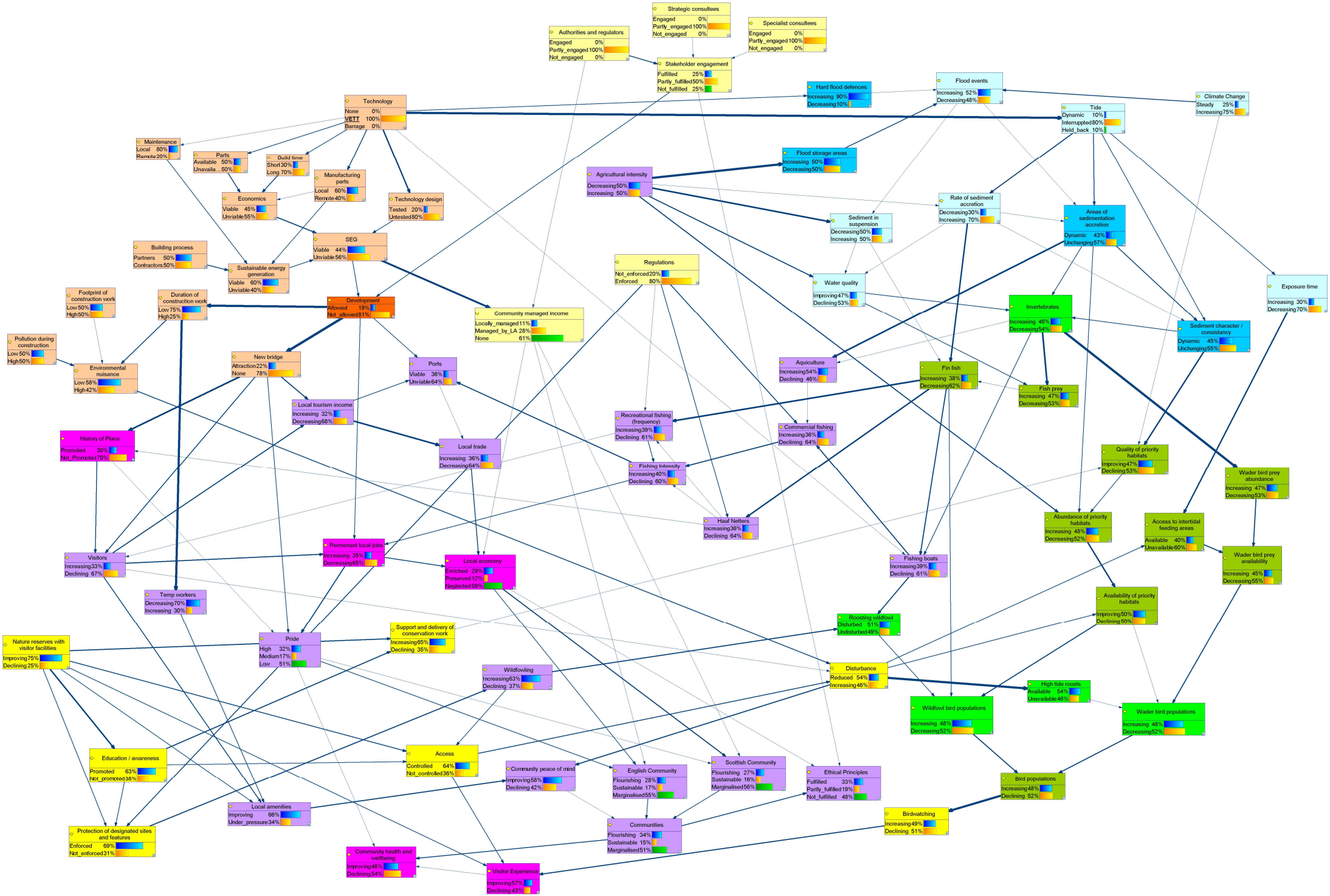
BBN co-produced with KI-E during Cycle 2: nodes, states and arcs representing issues raised and relationships between them



BBN co-produced with KI-G during Cycle 2: nodes, states and arcs representing issues raised and relationships between them



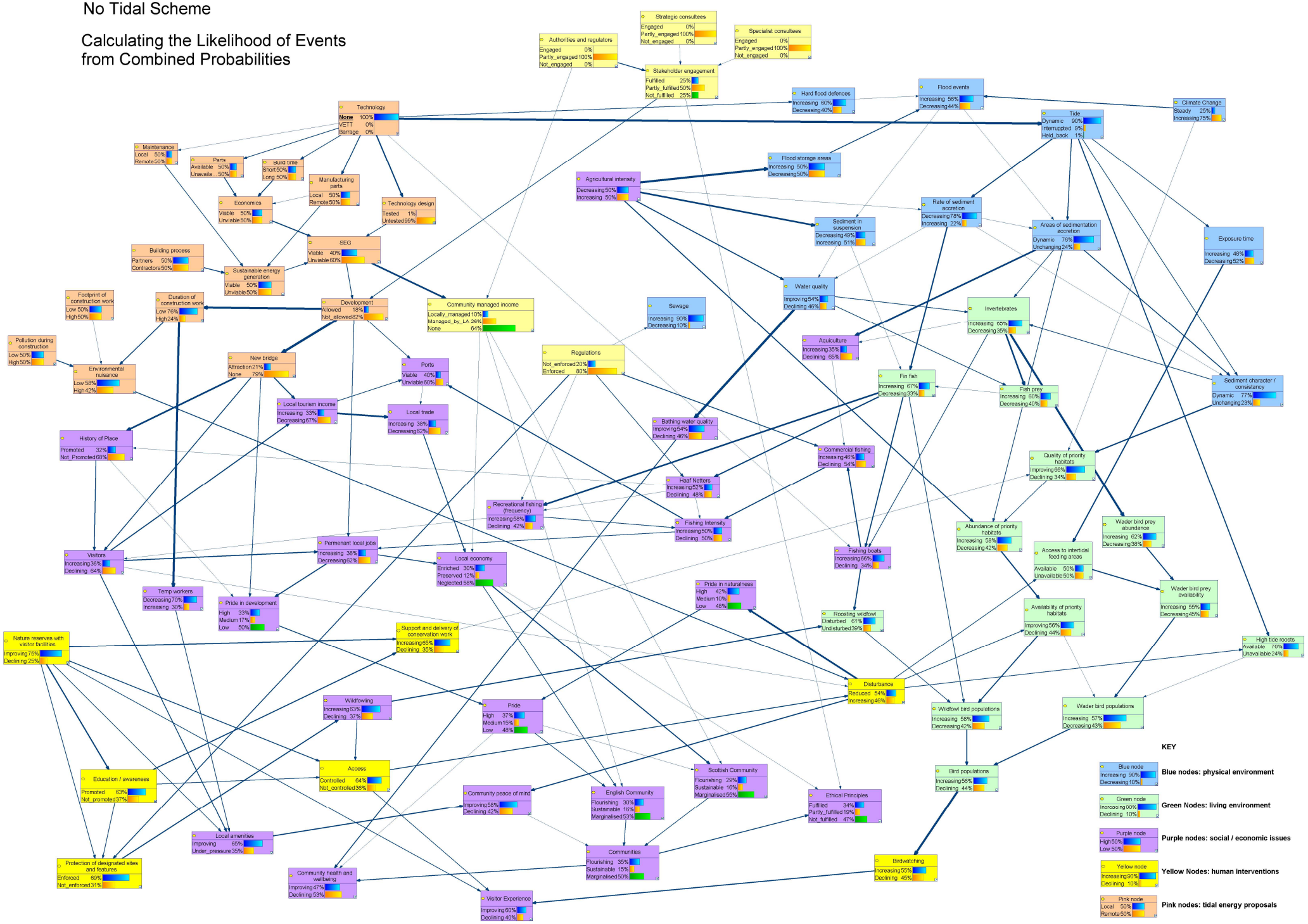
Combined BBN co-produced in Cycle 3: showing the calculated likelihood of events if a tidal scheme is NOT present



Combined BBN co-produced in Cycle 3: showing the calculated likelihood of events if the proposed SEG tidal scheme is present

No Tidal Scheme

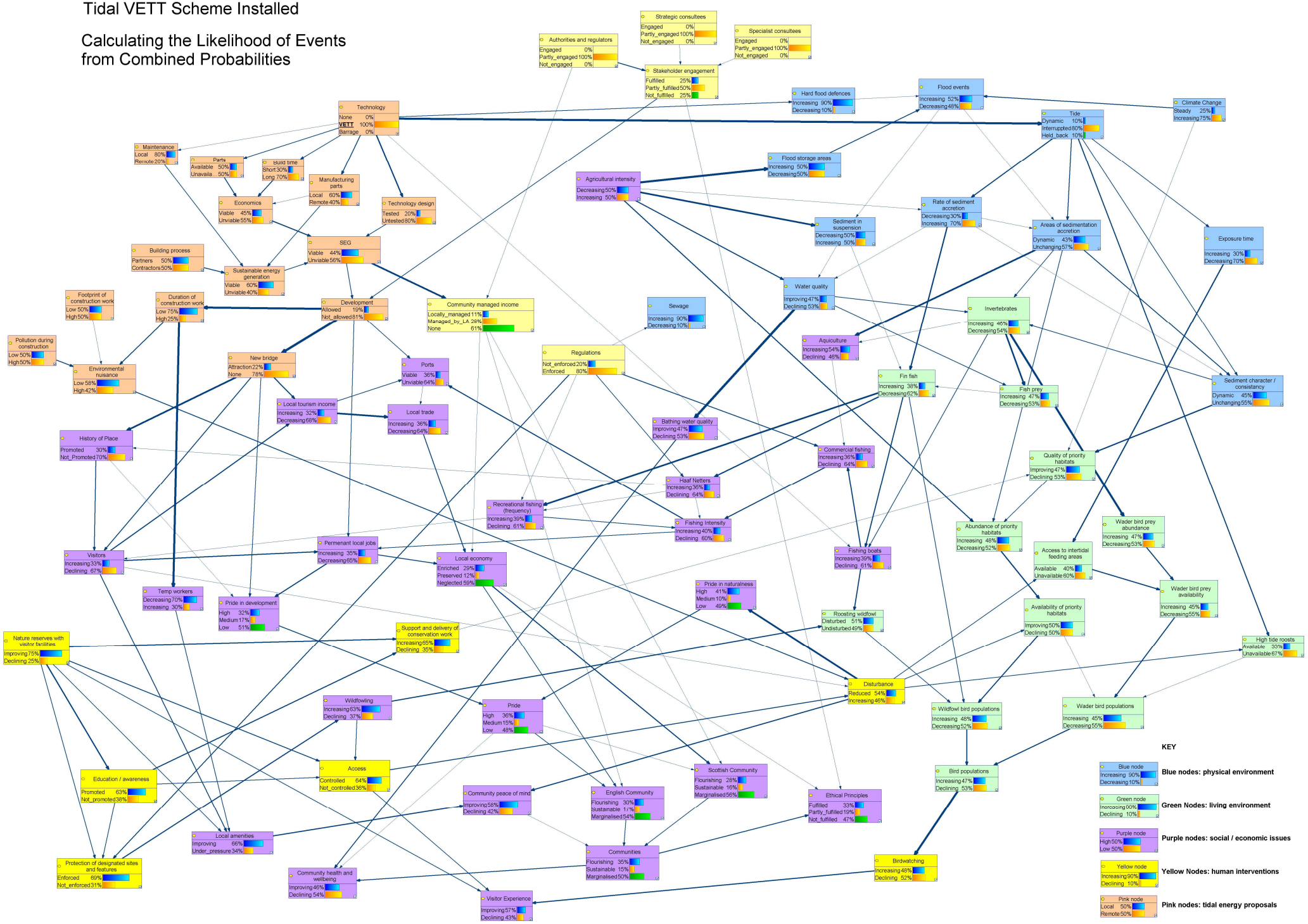
Calculating the Likelihood of Events from Combined Probabilities



Combined BBN co-produced in Cycle 4: showing the calculated likelihood of events if the proposed tidal scheme is NOT present

Tidal VETT Scheme Installed

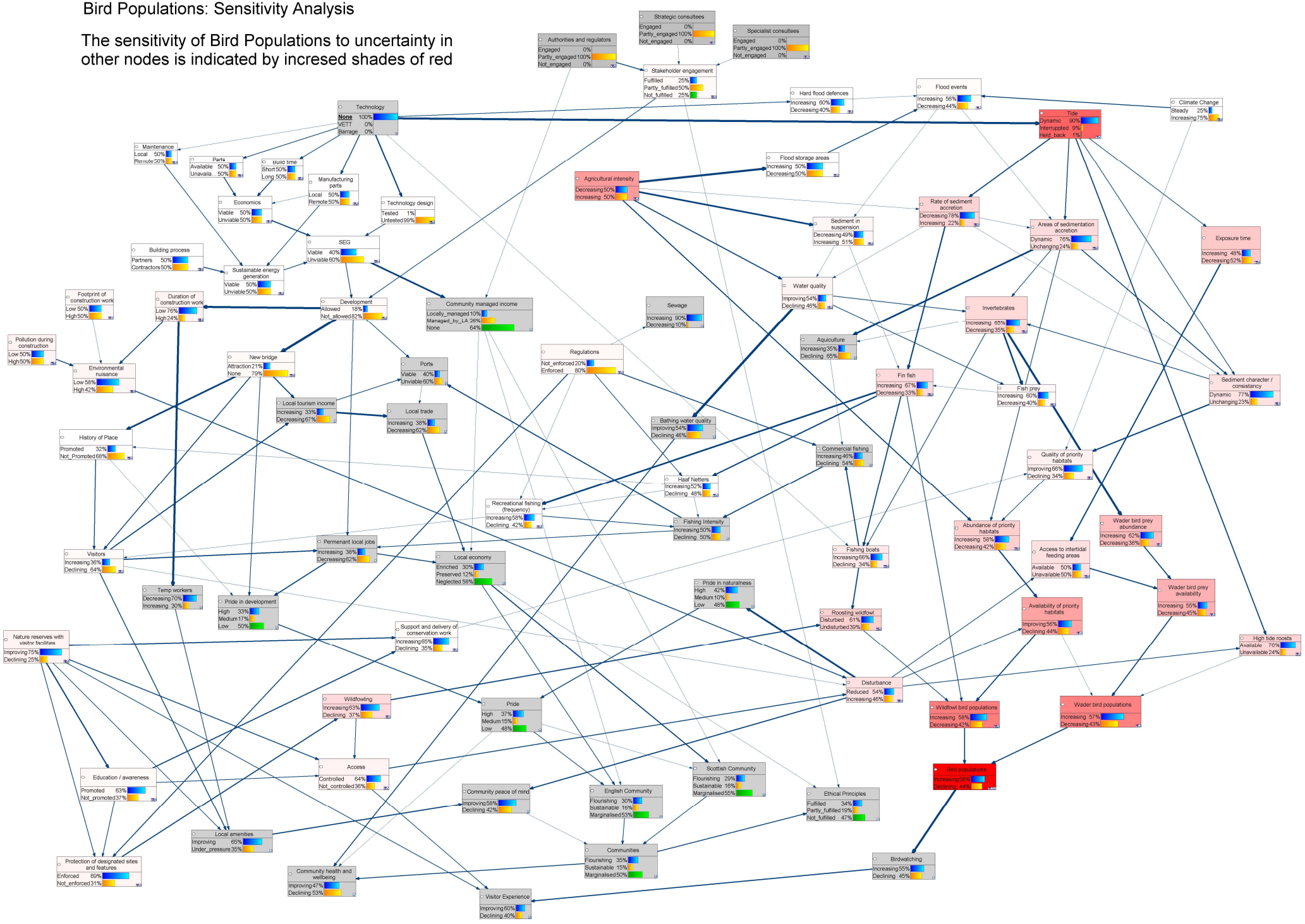
Calculating the Likelihood of Events from Combined Probabilities



Combined BBN co-produced in Cycle 4: showing the calculated likelihood of events if the proposed tidal scheme is present

Bird Populations: Sensitivity Analysis

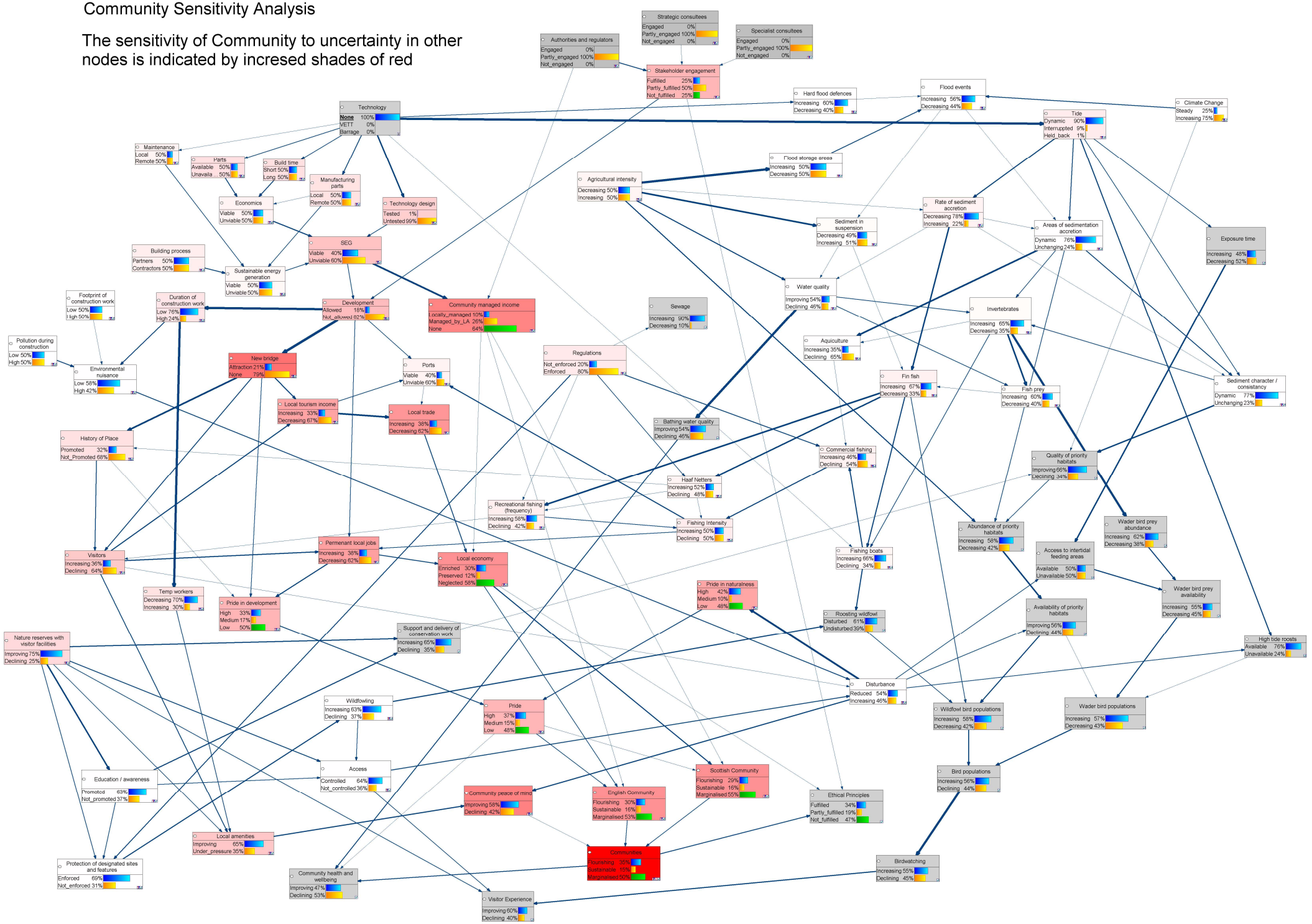
The sensitivity of Bird Populations to uncertainty in other nodes is indicated by incresed shades of red



Combined BBN co-produced in Cycle 4: sensitivity analysis of 'Bird Populations' node

Community Sensitivity Analysis

The sensitivity of Community to uncertainty in other nodes is indicated by incresed shades of red



Combined BBN co-produced in Cycle 4: sensitivity analysis of 'Community' node

APPENDIX III

COPY OF LETTER POSTED TO KEY INFORMANTS IN CYCLE 5

Jayne Carrick

Postal address provided

3 August 2018

Dear XXXXX

I trust this letter finds you well.

You may remember that you kindly took the time to meet me over the last few months to discuss my PhD research project. I am writing to ask for your help and participation in the last part of the research.

You may remember that my project is about testing ways to improve participation in decision-making. I used the proposals for a tidal energy scheme, known as Solway Energy Gateway, as a case study to test the use of a systems model called a Bayesian Belief Network. Hopefully you recall how we discussed the development of the model from identification of the issues that matter, to how the issues are connected and influence each other.

Since I saw you last, I have combined the individual models built from the meetings I had with each person. Enclosed you will find copies of the combined model; there are 4 versions and you will find explanation notes attached to each.

My request

I hope you would be willing to review the enclosed combined models for my research project and let me know what you think. You can do that in several different ways:

1. Scribble / annotate / write your thoughts on the front and the back of the copies of the model and post your thoughts back to me using the enclosed stamped addressed envelope;
2. Take photos of the annotated model and email them back to me – jayne.carrick@newcastle.ac.uk;
3. Send me an email outlining your thoughts – jayne.carrick@newcastle.ac.uk; or

4. Discuss your thoughts on the phone (07815732081) or on Skype (username: carrickjayne@hotmail.com) (you can also request I call you back at a convenient time via email).

The idea is that the models encourage you to think about what you know about the Solway and the proposed tidal scheme. Anything in the model can be changed.

I hope you have time to look over the enclosed information to conclude your contribution to this research.

Yours sincerely

Jayne Carrick

What you need to know about all the models

- Boxes (nodes) identified issues that matter
- The 'states' within each box indicate what matters about these issues, e.g. it matters if the bird population (in bottom right hand corner) is increasing or declining
- The bar graphs inside the boxes indicate the likelihood that each state occurs, given the likelihood of the preceding events, e.g. the likelihood that wader bird prey (in bottom right hand corner) is increasing or decreasing, based on the combined likelihood of the wader bird prey abundance increasing and access to intertidal feeding areas being available
- The arrows indicate connections between issues and the direction of the influence
- The thickness of each arrow indicates the relative weight of influence of the INCOMING arrows e.g. community managed income in the top left area of the model is influenced more by the viability of the Solway Energy Gateway (SEG) than the regulators / authorities (thickness of incoming arrows)

Things you could think about (as pointers)

- Are there any issues missing?
- Do any of the issues not matter?
- Are the arrows in the right place?
- Do the arrows go in the right direction?
- Do the colours make sense?
- How does the structure look?
- Is the model too complex or not complex enough?
- What makes sense?
- What doesn't make sense?
- What other information do you need?
- What do you like?
- What don't you like?
- What would you change?

Please annotate the model and send back or note down your thoughts on a blank piece of paper or in an email. I am also happy to discuss on the phone.

As always, the research is participant led; the questions above serve as pointers and you can contribute as much or as little as you like

Combine Models showing the effects of a tidal scheme installed / not installed showing:

- The colour of the boxes (nodes) are themed based on type (see key in bottom right hand corner)
- The model titled No Tidal Energy Scheme shows the likelihood of the state of each issue if no tidal scheme is in place
- The model titled Tidal VETT Scheme Installed shows the likelihood of the state of each issue if no tidal scheme is in place

Combine Models – sensitivity analysis

- Both these models show the sensitivity of specific issues (the target node) to uncertainty in other nodes
- The title of each model indicates the 'target node' selected in these examples ('Bird Populations' and 'Community'
- The darker the shade of red in each box (node), the more the uncertainty of it occurring affects the 'target node'
- For example, in the model titled 'Bird Population' the 'bird population node is selected as the 'target node and the dark shade of red in 'tide' and 'agricultural intensity' can be expected to have the most significant effects on bird populations.
- The idea is that if you are concerned with a specific issue, such as bird population, you can see where more data (to reduce uncertainty) would be most valuable