BEFORE THE ENVIRONMENT COURT

IN THE MATTER	of the Resource Management Act 1991 (the Act)
AND	
IN THE MATTER	of appeals pursuant to clause 14 of the First Schedule to the Act
BETWEEN	**MADSEN LAWRIE CONSULTANTS LIMITED & PETER NICHOLLS (ENV-2006-AKL-000973)**
AND	**DAVID OLSEN (ENV-2006-AKL-000994)**
AND	**BN BALLE AND SONS LIMITED & ORS (ENV-2006-AKL-000995)**
AND	**KLOETEN & REIDY (ENV-2006-AKL-000988)**
AND	**AUCKLAND REGIONAL COUNCIL (ENV-2006-AKL-001007)**
AND	**FEDERATED FARMERS OF NEW ZEALAND INCORPORATED (ENV-2006-AKL-000956)**
AND	**HEATHER BALLANTYNE (ENV-2006-AKL-000987)**
AND	**GB MORRIS (ENV-2006-AKL-000954)**
AND	**THE KARAKA GROWTH NODE LAND OWNERS (ENV-2006-AKL-000993)**
AND	**THE SURVEYING COMPANY (ENV-2006-AKL-000970)**
AND	**VERNON FARMS (ENV-2006-AKL-1002**
AND	**P ASTON (ENV-2006-AKL-001000)**

AND	**BLUFF HEIGHTS TRUST (ENV-2006-AKL-000974)**
AND	**STUART SEARLE AND SEARLE HOLDINGS LTD (ENV-2006-AKL-000965)**
AND	**PRIME RESOURCES LTD (ENV-2006-AKL-000986)**
	Appellants
AND	**AUCKLAND COUNCIL, WAIKATO DISTRICT COUNCIL AND HAURAKI DISTRICT COUNCIL (as successors to Franklin District Council)**
	Respondents

STATEMENT OF EVIDENCE OF IAN KENNETH GRANT BOOTHROYD

ON BEHALF OF AUCKLAND COUNCIL

DATE: 21 September 2012

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1. INTRODUCTION

Qualifications and Experience

1.1 My name is Ian Kenneth Grant Boothroyd. I am the Team Leader Ecology and Principal Environmental Scientist at Golder Associates (NZ) Limited, Auckland. I have over 25 years' experience in aquatic ecology and resource management issues. I hold the qualifications of BSc (Hons) Zoology (University of Manchester, UK), MSc Applied Hydrobiology (University of Wales, UK) and DPhil Freshwater Biology (University of Waikato, NZ). I am a chartered member of the Society of Biology, UK (CBIOL, MBS); and a member of the Royal Society of New Zealand (MRSNZ) and the Environmental Institute of Australia and New Zealand (MEIANZ). I am a past-President of the New Zealand Limnological Society (New Zealand Freshwater Sciences Society), and a member and former elected-Councillor of the Royal Society of New Zealand.

1.2 Previously, I have worked for the University of Auckland (Senior Lecturer, School of Geography, Geology and Environmental Science), the National Institute of Water and Atmospheric Research (NIWA) (Project Director), the Hawke's Bay Regional Council (Manager Environmental Monitoring), Waikato Regional Council (Environmental Scientist) and Hauraki Catchment Board (Water Quality Biologist). I established the 'Biodiversity of Freshwater Organisms of New Zealand' national research programme with central government research funding.

1.3 My areas of expertise are in aquatic ecology and entomology, especially the biodiversity of freshwaters, assessments of developments on aquatic and terrestrial resources, assessments of the value and significance of freshwater and terrestrial habitats and biological communities, biological monitoring of freshwaters, and state of the environment monitoring. I have undertaken ecological surveys and site assessments throughout New Zealand for the past 25 years.

1.4 I have experience in working across a range of freshwater resources from large rivers to small streams and wetlands throughout the North and South Islands.

1.5 I have undertaken assessments of freshwater resources and riparian management throughout New Zealand. I have led and conducted scientific research on the benefits of riparian planting to streams and rivers and I have published a number of scientific papers on the subject of the benefits of riparian planting to aquatic ecosystems (Boothroyd and Langer (1999); Rowe et al. 2002; Boothroyd et al. 2004; Quinn et al. 2004). In addition I have co-authored several national protocols for aquatic management and assessments including instream monitoring (Stark et al. 2000) and instream habitat assessments (including riparian assessments) (Harding et al. 2009).

1.6 I am also familiar with frameworks and criteria used for the assessments of the significance of ecological values and their application to biodiversity management and enhancement. I have recently provided Court-mediated independent peer review to matters associated with defining and locating areas of ecological significance in the Canterbury and Bay of Plenty regions.

1.7 I have visited the Environmental Enhancement Overlay Area (EEOA) and other parts of the former Franklin District and I have inspected a number of the drainage catchments and waterways within the area. I have also visited the areas used as example good practice that I have mentioned in my evidence.

1.8 I have participated in an expert caucus with fellow expert ecologists Ms Shona Myers and Dr Vaughan Keesing, and we have provided a Statement of Agreement which is attached to the evidence of Ms Myers.

1.9 I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court Practice Note and that I agree to comply with it. I confirm that I have considered all the material facts that I am aware of that might alter or detract from the opinions I express. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

2. SCOPE OF EVIDENCE

2.1 My evidence addresses the protection, enhancement and restoration of ecological corridors within the EEOA, and how this will achieve significant environmental benefits, as sought by the objectives and policies of Plan Change 14. My evidence has been drafted to sit alongside that of Ms Shona Myers, whose evidence addresses similar and other remaining ecological matters.

2.2 In my evidence I will:

- Discuss the environmental benefits of focusing on the restoration of drainage catchments and riparian areas as ecological corridors within the EEOA, the benefits of riparian ecological corridors to environmental enhancement, and the management of riparian ecological corridors.
- Address how the ecological aspects fit within the overall objectives and context of the Plan Change; and
- Address how the restoration will achieve the objectives of the Plan Change.

My evidence will be structured under the following headings:

- Description of the environment.
- Plan Change 14 objectives and policies.
- Importance of riparian environments.
- Councils' position.
- Definitions
- Conclusion.

3. DESCRIPTION OF ENVIRONMENT

3.1 Here I briefly describe the drainage catchments and riparian environment of the Franklin District and the EEOA, as this explains my position on the Council's proposed rules in Plan Change 14.

Nature of the drainage catchments within the EEOA

3.2 The EEOA is characterised primarily by five major drainage catchments draining north to north east (Tuhitahi Creek, Te Hihi Creek, Whangamaire Stream, Whangapouri Creek and Oira Creek), along with several smaller drainage catchments in the western areas of the EEOA. South of Pukekohe, several waterways drain to the lower Waikato River. All of these drainage catchments are shown as ecological corridors on Map 109Z, which is included as Attachment 1 to my evidence.

3.3 The drainage catchments of the EEOA comprise a mix of permanent, intermittent and ephemeral waterways. For the purpose of my evidence I define[1] each of these categorisations as follows:

- Perennial streams are those watercourses that flow for all of the year and are typically contained within defined or meandering low and flood flow channels respectively.
- Intermittent[2] streams are those watercourses that cease to flow for parts of the year but are typically retained within defined or meandering low and flood flow channels respectively.
- Ephemeral streams are those waterways that may flow during storm events but typically not for extended periods following a storm. These can be divided into ephemeral streams with defined and undefined channels. Ephemeral areas are often in the headwaters of catchments and result from an area of seepage(s) and overland flow path(s) with or without permanently-formed water channel(s) that typically converge on a point(s) downslope in the catchment where a visible incised channel is formed. Seepages and overland flow paths are recognised by often wet and boggy depressions in the landform with distinctive vegetation that differs from the surrounding landuse.

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[1] These definitions of permanent, intermittent and ephemeral streams have been drawn from my own use of the definitions (e.g., Golder 2008); and those of Johnson & Gerbeaux (2004), (McKergow et al. (2005), Wigington et al. (2005), and by Parkyn et al. (2006).

[2] Two types of intermittent stream can be distinguished from an ecological perspective, i.e., those that occur in headwaters and those that occur in mid-reaches of stream networks. Headwater intermittent streams result from the longitudinal expansion and contraction of stream networks in response to seasonally rising and lowering water tables near the tops of catchments. Intermittent streams of the mid-reaches occur where streams that originate in wet upland regions flow across flat plains with water tables that are permanently or seasonally below the river bed (Storey & Quinn 2008).

3.4 Permanent streams are given greater protection from loss and disturbance than intermittent and ephemeral streams under the current operative Proposed Auckland Regional Plan: Air, Land and Water.

3.5 Attachment 2 of my evidence shows a number of photographs of the range of catchment features seen within the EEOA and I have highlighted some of the distinguishing characteristics.

3.6 It is often difficult to discern running water under long rank grass cover, or to establish flowing water in waterways that meander through several channels along a watercourse. In some cases such waterways might not be considered streams by some observers.

3.7 The main drainage catchments (or waterways) listed in my evidence and shown on Map 109Z shape the topography of the EEOA with a network of small and large gully or valley formations. These drainage catchments remain connected via the network of headwater ephemeral waterways, through any intermittent reaches to the permanent waterways that eventually connect to the Manukau Harbour via their estuaries, and to the Waikato River in the south.

3.8 These longitudinal networks connect with other catchment networks laterally via ridges, fragments of vegetation and close proximity of headwater areas. The number of drainage networks and the largely flat gently undulating topography of the EEOA mean that there are multiple connections with the coast, harbour and sea beyond. I discuss further the significance of enhancing connectivity in section 6 of my evidence.

3.9 Within the EEOA it is clear that there is a lack of terrestrial indigenous vegetation or terrestrial habitats for indigenous fauna. In her evidence Ms Myers describes the paucity of biodiversity features within the EEOA.

3.10 Also evident within the EEOA is the paucity of riparian vegetation alongside the watercourses or indeed fencing of waterways to exclude stock.

3.11 I discuss the objectives of Plan Change 14 and the importance and benefits of riparian environments in the following sections of my evidence; and then later in my evidence I discuss how significant enhancement of the riparian environment within the drainage catchments within the EEOA will, through the ecological corridor rule, in my opinion, achieve the objectives and policies as stated in the plan.

4. PLAN CHANGE 14 OBJECTIVES AND POLICIES

4.1 The District Strategic Objectives of the Plan Change (Part 3D of the Operative District Plan as amended by Plan Change 14), as described in the evidence of Mr Phyn, provide for 'limited, directed, integrated and managed countryside living opportunities' and includes:

*'an environmental enhancement overlay area in the rural and coastal zones where there are **significant environmental benefits** and adverse effects on rural character and amenity are avoided, remedied or mitigated' (bold is my own emphasis).*

4.2 These objectives relate to benefits to aquatic ecosystems, wetlands and terrestrial ecosystems. I view the reference to ***significant environmental benefits*** as a key term and a strong signal that the proposed plan change desires to achieve an outcome beyond that conventionally sought.

4.3 In my opinion, while standard approaches to protection provide environmental benefit by themselves, they are unlikely to deliver ***significant environmental benefit***.

4.4 In her evidence, Ms Myers has outlined the denuded state of the ecosystems of the EEOA and the philosophy behind the planned approach of the FDC Plan Change. The denuded state means that there is little ecological substance within the EEOA to 'anchor' an approach to gaining significant environmental benefits.

4.5 I have outlined in Section 3 of my evidence that the most apparent topographical features of the EEOA (apart from the coastline) are the stream systems and gullies (drainage catchments). In my opinion, these topographic landforms form an appropriate feature for commencing environmental enhancement.

4.6 As I explain later in my evidence, I say this because the selected drainage catchments for restoration form a continuous longitudinal conduit from the coast to deep into the interior of the EEOA; and as they occur laterally east-west across much of the extent of the EEOA the selected drainage catchments form substantive ‘stepping stones’ for restoration.

4.7 Accordingly the Councils' proposed plan change rules anticipate that the waterways and gullies (that comprise the drainage catchments) form an important natural ecological corridor for significant enhancement.

4.8 In my opinion, in order to achieve significant environmental benefits, consideration must be given to key environmental attributes such as resilience, sustainability and connectivity[3].

4.9 In my evidence below I will outline how a focus on the riparian environments of the drainage catchments will, in my opinion, achieve the aims of significant environmental benefits through protection and restoration of identified ecological corridors.

4.10 In my opinion, this means approaching the protection and restoration of riparian environments with a view that extends beyond the immediate benefits only to water quality and aquatic ecosystems so the lateral (terrestrial environments alongside streams), vertical (root area to vegetation canopy), and longitudinal (riparian and terrestrial environments up and down streams) attributes of resilience, sustainability and connectivity are benefited significantly.

4.11 In particular, in the context of the proposed plan change, the planted riparian environments can be regarded as ecological corridors that follow the drainage catchments deep into the EEOA and across the EEOA.

4.12 In the following sections of my evidence I outline the importance of the protection, enhancement, and restoration of riparian environments and how this will result in significant environmental benefits. I explain how this will be achieved and how consideration of resilience, sustainability and connectivity will achieve the proposed plan outcomes.

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[3] Resilience = the ability of a system to absorb disturbance and still retain its basic function and structure (Walker & Salt 2006); Sustainability = natural resources remain viable and are not eliminated or diminished; Connectivity = Ability of the landscape to facilitate biological fluxes such as the ability of organisms to move between patches of habitat for food, shelter and breeding (Uezu et al. 2005).

5. IMPORTANCE OF RIPARIAN ENVIRONMENTS

5.1 Riparian areas are transitional semi-terrestrial areas influenced by freshwater extending from the edges of waterbodies to the upland communities. Because of their spatial position, riparian areas integrate interactions between aquatic and terrestrial environments and communities.

5.2 Riparian environments are dynamic environments characterised by strong energy regimes, habitat variety, diverse ecological processes and multidimensional gradients (i.e., horizontal, vertical, longitudinal; Naiman et al. 2005).

5.3 Riparian environments typically possess the wet and sometimes inundated soils that are commonly found on floodplains and near the bottom of hill slopes adjoining streams, as well as the drier upland soils. These transitional areas provide habitats that are important for the survival of a number of native plants and animals.

5.4 The benefits of restored and enhanced riparian environments for enhanced aquatic ecosystems and enhanced biodiversity of terrestrial ecosystems have long been recognised in New Zealand and overseas. It is generally agreed that such areas can serve a number of functions and I have listed these in Table 1 (Attachment 3) of my evidence. These include (but are not limited to):

- Water quality management: for example, reduction in nutrient inputs, decreased sedimentation and temperature reduction.
- Instream habitat enhancement and management: increase in woody debris, decrease in proliferations of periphyton (algae).
- Biodiversity and nature conservation.
- Corridors for the movement of terrestrial and semi-aquatic organisms
- Riparian Microclimate.
- Recreation and amenity.

5.5 With the exception of recreation and amenity benefits, I will provide a brief outline of each of these benefits below.

Water quality management

5.6 Increased nutrients in waterways have the potential to cause eutrophication, increased plant and algal growths, toxic algal blooms, and in extreme cases, proliferations of sewage fungus.

5.7 Increased sediments in waterways influence the visual clarity of the water, which affects the aesthetic values, fish feeding, light penetration. Fine sediments settling on the bottom of streams and rivers can reduce the habitat for the bottom-dwelling biota and can result in lower species diversity and productivity.

5.8 It has now been demonstrated that riparian areas can significantly reduce the concentrations of sediment and nutrients in surface water and groundwater entering streams. Nitrates and phosphorus (i.e., plant nutrients) inputs to streams can be reduced by as much as 90%.

5.9 Research has shown that most nitrate removal in riparian areas occurs less from plant uptake and more from microbial denitrification. However, without adequate soil-water contact time, riparian areas are limited in their ability to remove nutrients.

5.10 High nitrate removal (>90%) can occur if adequate contact time of 7 days/m is allowed, while low nitrate removal occurs with low residence time (2-4 mins/m) (Burns and Nguyen (2002)). The width of the riparian area will, in part, influence the contact time, or residence time of nutrients and sediments in the streamside management area.

5.11 During high rainfall events, large amounts of nitrate simply move across the surface of riparian areas, without adequate soil contact time, and hence enter waterways. The width and type of riparian planting can influence the residence time of nutrients and sediments during high rainfall events.

5.12 Furthermore, the success of riparian treatment of diffuse sources of nutrients will depend on the soils and geology. If soils are impermeable and poorly drained then more surface runoff will occur, and there is a need to align wider riparian buffer areas and ground vegetation cover with location and size of runoff areas.

5.13 In urban areas, where stormwater runoff from impervious surfaces forms the source of many water quality problems, the benefits of riparian planting and retention are less clear.

5.14 Research has demonstrated that in areas of high impervious cover, riparian management can have little influence over improvements to water quality; especially in the absence of improved infrastructure, stormwater treatment and erosion management (Walsh et al. 2007). This is because the stormwater is delivered to the stream via a network of pipes and there is generally no contact between the stormwater and the riparian soils and vegetation. This can be improved by essential stormwater treatment and the use of rain gardens in association with riparian vegetation.

5.15 Riparian vegetation in urban and peri-urban areas can have an important influence on instream habitat and diversity as I outline below.

Instream habitat enhancement and management

5.16 Riparian areas have significant effects on instream biodiversity, stream productivity, and the composition of the animal and plant communities. The type, diversity, composition, width and scale of riparian areas can influence:

- Stream energy base – inputs of organic matter in the form of leaf fall and twigs and branches.
- Food webs – including the contribution of terrestrial insects for fish feeding.
- Habitats for attachment and food – instream wood and detritus.
- Reduction of stream temperatures and improvements to oxygen levels.
- Refuges where animals can hide-up and avoid predation.
- Provision of important breeding habitat.

5.17 Much of the research and implementation of riparian planting and management has been for the purpose of improving water quality by the management of land-based non-point source runoff; and for the purpose of improving instream habitat through shade and reduction in temperature, and for the stability of stream banks thus reducing sedimentation (cf. improves water and habitat quality).

5.18 My own research (Boothroyd et al. 2004; Quinn et al 2004) has shown that shading from riparian areas improves aquatic ecosystem health through light reduction reducing temperatures and algal production in the stream. This has resulted in more diverse macroinvertebrate communities within waterways.

5.19 Recent research by Greenwood et al. (2011) has shown intensive management, such as in-stream habitat or channel morphology modification, may be needed to address historical factors (e.g., low velocity and sedimentation) which otherwise may continue to limit community recovery. Not surprisingly, Greenwood et al. (2012) also found that smaller waterways were generally more impacted with low velocities and sedimentation than large waterways. Although I have undertaken no sampling or assessments of the waterways of the EEOA, it is likely that the conditions described by Greenwood et al. (2012) also apply to many of the waterways of the EEOA (i.e., low velocity and high sediment laden waterways).

5.20 The hydrology, geology and land-use history of the area, and the size and network position of the river reach can influence the responsiveness of instream communities to riparian enhancement.

5.21 Craig et al. (2008) concluded that reconnecting streams with their adjacent environments would improve nitrogen loadings to the stream; but that the placing of the stream in the catchment network (i.e., stream order) would influence the successful implementation of restoration strategies.

5.22 Wilcock et al. (2009) suggested that even a relatively small increase in riparian management in an area may have considerable benefits for water quality.

Biodiversity and Nature Conservation

5.23 The benefits of the restoration of riparian environments are many-fold for both aquatic and terrestrial biodiversity. The research literature focuses mostly on the benefits of riparian planting to aquatic communities and water quality. However there are important gains for terrestrial ecology with enhancement and protection of riparian vegetation.

5.24 The restoration of natural biodiversity is important both in terms of intrinsic and heritage values, and because of benefits obtained from ecosystem services. As a rule, more habitat-diverse areas have greater species diversity, and more resilience to external perturbations, than less diverse areas. However, small remnants of severely depleted ecosystems are extremely valuable as refugia for flora and fauna, corridors, or nuclei from which to enhance and extend the resource via restoration and reconstruction.

5.25 Healthy ecosystems contribute significant tangible benefits to New Zealand's economy and society. Some examples of ecosystem processes that are enhanced via maintenance of an intact network of indigenous ecosystems within the landscape include:

- Erosion control.
- Maintenance of the productive potential of soils.
- Soil nutrient retention and cycling.
- Maintenance of marine and freshwater quality.
- Regulation of flood flows.
- Crop pollination and agricultural pest control.

Riparian microclimate

5.26 A key element that provides for the benefits of riparian environments is the microclimate that exists within and around the riparian area. The effect of microclimate is apparent when you walk through a riparian environment, and at the stream itself where a mature, closed canopy riparian area will result in a cooler and more humid feel than an open stream.

5.27 The importance of microclimate is typically overlooked in discussion on the benefits of the restoration of riparian environments. The microclimate is important as it strongly influences ecosystem processes and function by providing the necessary climate conditions around and amongst the plants and contributes strongly to resilience of the plant communities. Microclimate is defined as the climate at a small scale and includes but is not limited to (Davies-Colley et al. 2000):

- Sunlight exposure.
- Wind exposure (magnitude and direction).
- Precipitation (rainfall).
- Temperature (of air and soil).
- Moisture content (of air and soil).

5.28 Davies-Colley et al. (2000) found that microclimate gradients varied with variations in the factors listed above. For example, when wind is directed out of forest there was little trend in air movement within the forest[4]. On the other hand when wind is directed in to the forest, then the wind acts as a 'jet' and has potential to cause not only changes to microclimate but also disturbance to plants.

5.29 Davies-Colley et al. (2000) conclude that forest buffers of at least 40 m may be needed to protect forest reserves and streams from climatic exposure. They suggest that buffers of some 40 m either side of small streams is required to protect riparian ecology, especially where the surrounding land use is open pasture (or cropland).

5.30 I note that Davies-Colley et al. (2000) refer to small streams of less than 3.5 m width; for the most part the streams of the EEOA would fall into this category. Likewise, the current landuse alongside waterways of the EEOA would be consistent with the grazed pasture as highlighted in Davies-Colley et al. (2000).

5.31 The findings of Davies-Colley et al. (2000) are consistent with the findings of other research, most notably Young and Mitchell (1994). The latter authors suggested that a 50 m buffer would be required for terrestrial ecology and indigenous species conservation; suggesting that native forest remnants <9 ha in area are dominated by edge microclimate conditions.

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[4] Outward wind is caused by downward turbulence through the forest canopy.

5.32 The findings of Davies-Colley et al. (2000), Young and Mitchell (1994) and similar research have important ramifications for the proposed variations to provisions relating to riparian planting in Plan Change 14.

5.33 The benefits of the restoration of riparian environments for aquatic and terrestrial ecosystems are best achieved where there is a specific management objective. In my opinion, much riparian planting is planned and implemented with little thought to what is to be achieved; and much riparian planting is planned more for aesthetics and beautification than ecosystem function.

5.34 In my evidence above I have outlined the benefits of the restoration of riparian environments and their benefit as ecological corridors for aquatic and terrestrial ecosystems. In her evidence, Ms Myers has also expanded on the role of ecological corridors in biodiversity enhancement. For the most part, these benefits are widely recognised and documented and form a benchmark or a baseline of benefits for the subdivision rules of Plan Change 14.

6. COUNCILS' POSITION: what the Plan Change is aiming to achieve

6.1 In this section of my evidence I will outline how the rules will achieve the objectives and policies of the proposed Plan Change.

6.2 In their respective evidence, Mr Phyn and Mr Tollemache outline the purpose and principles behind the plan change, and detail the respective objectives, policies and rules.

6.3 In his evidence, Mr Phyn makes it clear that the integration of growth management and rural living opportunities is the overarching theme of the Rural Plan Change. Mr Phyn goes on to clarify that a key thrust of the objectives and policies is that significant environmental benefit shall be gained through subdivision.

6.4 Mr Phyn goes on to say that, as the main objectives and policies have been settled by consent order, the main issue to consider is how the methods best achieve the intent and purpose of the policy direction.

6.5 In his evidence, Mr Phyn has outlined the District Plan and Rural Plan change issues, and the objectives and the policies. In Attachment 10 of his evidence, Mr Phyn also outlines the hierarchy of the Rural Plan Change objectives and policies.

6.6 As outlined in Ms Myers' evidence, the Councils' proposed plan change rules aim to:

- Achieve the long-term sustainability of indigenous remnants by protecting and restoring larger natural areas and wider riparian corridors;
- Achieve wide ecological corridors and stepping stones which provide sustainable terrestrial indigenous biodiversity values and not just water quality benefits; and
- Create significant ecological corridors and stepping stones in a fragmented and depleted landscape.

6.7 As I have alluded to in my evidence above, Plan Change 14 contains objectives and policies that relate to environmental lots within the EEOA. The strategic focus within (and outside of) the EEOA is to achieve significant environmental benefits. Objective 17C.2.1.5 provides that ecological benefits are achieved through protection, enhancement and restoration of ecological values. This is reflected in Policy 17C 2.7 "*to ensure significant environmental enhancement and protection occurs*", and Policy 17C 2.2.12 to ensure that all subdivision is designed in a way that "*ecological values are maintained or enhanced*" and that "*areas of significant indigenous vegetation and fauna habitats*" are protected.

6.8 My focus in this section of my evidence is on Part 22B.11.1 'Environmental Lots – within the EEOA' of the proposed plan change. This section of the plan proposes to allow subdivision (of large lots) through the significant enhancement, protection or restoration of natural features, including the restoration and enhancement of riparian environments of freshwater bodies and remnant indigenous vegetation.

6.9 Part 22B.11.1 of the proposed plan change provides for:

- General performance standards for all Environmental Lots in the EEOA (Rule 22B.11.1.1). The general performance standards detailed in this rule are further expanded in rules 22B.11.1.2 and 22B.11.1.3 respectively.

- Specific performance standards for Environmental Lots involving ISNFs (Rule 22.B.11.1.2).
- Specific performance standards for Environmental Lots involving QNFs (Rule 22.B.11.1.3).

6.10 Ecological corridors as riparian management and planting along stream margins are specifically identified in Rule 22B.11.1.3. Here specific reference is made to Map 109Z which shows the anticipated ecological corridors identified along identified drainage catchments (or waterways).

6.11 As I have outlined in section 3 of my evidence, the drainage catchments have been selected for ecological corridors as these waterways penetrate deep into the interior of the EEOA and provide longitudinal conduits for restoration and movements of organisms. The drainage catchments also occur laterally over much of the EEOA, thus creating potential stepping stones across the area.

6.12 In my opinion, specific performance standards in Part 22B.11.1 will achieve the ***significant environmental benefits*** as indicated in the District Strategic Objectives Part 3D of the operative district plan. In the following sections I will explain why I consider that these performance standards are necessary to achieve the objectives of the proposed plan.

Width of riparian planting (environmental enhancement, protection or restoration)

6.13 One of the most frequently asked questions about streamside management areas or riparian areas is ‘How wide should a riparian area be?’ It is well recognised that there is an economic cost to assigning a width to a riparian area and I understand the difficulties in establishing an appropriate area for riparian planting.

6.14 There is no single answer to this question, and in most cases it will depend on the expected purpose or objectives of the riparian area and what the expectations are for the waterway and/or associated terrestrial environment.

6.15 Where there is a goal of reducing impacts of land runoff (i.e., non-point diffuse source run-off) on water quality many guidelines suggest a width of riparian planting of at least 10 m or greater is necessary in order to ensure that adverse effects of landuse and developments on aquatic ecosystems are adequately avoided, remedied or mitigated. The scientific literature suggests that a margin of less width can achieve the goal of improvements to water quality.

6.16 For the Auckland region, the Auckland Regional Council guidelines (ARC (2001)) used Parkyn et al. (2000) for guidance for recommending riparian width as follows:

- 5-6 m wide buffers: these are recommended for small waterways or where there are no other options for wider planting. These buffers are so narrow that edge effects mean natural regeneration of indigenous species is limited and they need on-going maintenance to keep them weed free.
- 10 m wide buffers: these allow for indigenous vegetation succession and should result in a relatively low-maintenance riparian area. Edge effects mean that the outer 1-2 m of the buffer is likely to suffer weed infestations, and these weeds would spread to the interior of the riparian area wherever canopy gaps occurred.
- 15-20 m or wider: buffers of this width are thought to be self-sustaining for indigenous vegetation, and should be required on large waterways.

6.17 ARC (2001) recommended a 10 m minimum buffer width as a general guideline for the purposes of their Strategy and Guideline, with narrower or wider options to be considered appropriate as indicated by site constraints or opportunities.

6.18 ARC (2001) goes on to say that some limitations of indigenous vegetation buffers of even 10-20 m width include:

- Control of shade tolerant weeds along edges may always be necessary.
- Success depends on establishing closed canopy cover early.
- Shading of pre-existing groundcover plants by indigenous tree species may release sediments held in the banks of streams.
- A grass buffer may be better than tree species as a filter for sediment and nutrients.
- Microclimate conditions comparable to those in forest interiors may not be achieved with buffers less than 40 m.

6.19 In my opinion, a planted riparian width of at least 10 m is generally recommended for the purpose of ensuring that adverse effects of landuse and developments on water quality and aquatic ecosystems are adequately avoided, remedied or mitigated; rather than providing for ***significant environmental benefits***.

6.20 However, as noted in section 4 of my evidence and in the evidence of Ms Myers, Mr Phyn and Mr Tollemache, the objectives of the Franklin Plan Change 14 clearly seek ***significant environmental benefits*** as well as seeking that the 'adverse effects on rural character and amenity are avoided, remedied or mitigated'.

6.21 In my view, the evidence is clear that whilst a 10 - 20 m riparian buffer will provide benefit to an aquatic ecosystem, significant benefits to both aquatic and terrestrial ecosystem can only be achieved through providing for resilient, viable and connected ecosystems.

6.22 Indeed, in my opinion, in order to benefit terrestrial ecosystems, while the proposed 30 m riparian margin as a standard for Rule 22B.11.1.3 (cf. Table 22B11.1C) will achieve ***significant environmental benefits***, this margin could be extended to 40 or 50 m width in order to achieve maximum environmental benefits.

6.23 My opinion is informed by the literature on the ecological significance of the prevention of edge effects on indigenous remnant and riparian vegetation and the greater long-term resilience and sustainability of larger forest fragments (Davies-Colley et al. 2000; Young and Mitchell 1994 etc.), as discussed in Section 5 of my evidence.

6.24 Larger riparian areas or indigenous remnants provide for greater habitat and natural indigenous species diversity, which provides resilience. For example, greater biotic complexity helps to reduce and resist weed infestations, reduces wind intrusion and thus provides for less opportunity and frequency for wind throw (the collapse of trees and plants – which create opportunity for weed infestations). It also provides greater diversity and complexity of habitats for terrestrial fauna (i.e., ground and plant dwelling insects, reptiles and birds), more complex food webs and energy flows through trophic levels and greater variety and seasonal chronology of food resources for fauna, and improving viability for future generations of species.

6.25 A landscape of larger riparian areas and/or indigenous remnants also provides more accessible patches of habitat and increases the connectedness of ecosystems across the EEOA as I discuss later in my evidence.

6.26 It is worth noting that research has shown that following riparian planting and as streams return to more forest cover after many years as open grazed pasture, then the width of the stream can begin to increase as the shade reduces the amount of dense groundcover alongside streams. Stream widening is a natural phenomenon as the stream re-adapts to its original state (Davies-Coley 1997). Therefore a wider riparian area can absorb better the change in stream size and meander without losing resilience, sustainability and connectedness that can occur within smaller riparian areas.

6.27 In my opinion the proposed width of ecological corridor planting (as riparian planting) as detailed in Rule 22B.11.1 and Table 22B.11.1C required for subdivision will achieve the objectives and policies of the Plan Change 14.

6.28 The provisions of Table 22B.11.1C were agreed by the expert ecologists ('Expert Ecology Conferencing Joint Statement' dated 19 September 2012) based on the purpose of restoring ecological corridors and not primarily for the sole purpose of improving water quality and instream habitat.

6.29 In my opinion, flexibility is provided for in Table 22B.11.1C as a minimum 15 m width is also provided for; anticipating difficulties with terrain and topography that may be encountered by a landowner.

6.30 In my opinion, the recommended 30 m width of riparian planting for ecological corridors is appropriate to achieve the objectives and policies of the proposed Plan Change 14.

Longitudinal length of riparian planting (environmental enhancement, protection or restoration)

6.31 A much less frequently asked question about ecological corridors or riparian areas is 'How long should a riparian area be?' As discussed above in relation to the width of riparian management areas, it is well recognised that there is an economic cost to assigning a length to a riparian area.

6.32 Again, as for the question of width of riparian planting, there is no single answer to this question, and in most cases it will depend on such matters as the expected purpose or objectives of the riparian area, the topography of the land, the availability of land upstream or downstream and what the expectations are for the waterway and/or associated terrestrial environment.

6.33 The ARC (2011) has developed a methodology (Stream Ecological Valuation or SEV) to calculate an offset for the mitigation for when a stream is lost to a development; the outcome is typically a length of stream planting to be undertaken by the developer. Although the SEV and the offset has been used in stream restoration and enhancement programmes, most typically it has been for monitoring the performance of the restoration rather than establishing the length of planting. The SEV and offset then is typically a means of responding to adverse effects on the environment rather than providing for significant enhancement.

6.34 In my opinion the most compelling evidence of the importance of a longitudinal length of riparian planting along a waterway comes from the research of Scarsbrook and Halliday (1999) who researched effects of isolated patches of indigenous riparian forest on water quality, stream morphology and aquatic macroinvertebrates. They found that it was not until after 300 m along the vegetated stream that some indicators of stream health (e.g., shade, channel width, aquatic invertebrate communities) showed evidence of improvement. This means that at least 250 - 300 m of stream length needs to be planted for riparian vegetation to have an impact on improving aquatic ecosystems.

6.35 Scarsbrook and Halliday (1999) went on to conclude that ‘results from this study suggest that discontinuous restoration of riparian environments could mitigate some changes associated with pastoral land use, but sediment and water quality problems may not be 'solved’. This means that it is appropriate to include rules specifying a particular minimum length of planting.

6.36 My own (unpublished) preliminary investigations of a similar nature in urban environments in Auckland suggest that a length of riparian vegetation may need to be as much as 500 m in order to reach similar conclusions as Scarsbrook and Halliday (1999). Blakely and Harding (2005) found that despite improved in-stream and riparian conditions in limited reaches they have not resulted in significant improvements along a 1200 m reach of urban waterway.

6.37 In my opinion, this research suggests that something in the order of 250 to 350 m is an appropriate length to achieve significant environmental benefit to ecosystems beyond the more conventional approach that seeks to adequately avoid, remedy or mitigate adverse effects.

6.38 Accordingly, it was recommended and agreed by the expert ecologists ('Expert Ecology Conferencing Joint Statement' dated 19 September 2012) that in recognising drainage channels as corridors of ecological benefit a minimum length of planting of 250 to 350 m would better ensure the goal of a functioning ecological corridor.

6.39 I acknowledge that in some circumstances a landowner may not have 250 m of waterway or drainage channel available for planting to meet such a requirement. In such cases a broader lateral area of planting (cf. 2 ha) would still achieve the desired benefit.

6.40 However, I would be concerned if such an outcome (broader planting across a shorter length of waterway) was used extensively across the EEOA as it would fail to achieve the significant environmental benefit desired from the use of the drainage catchments as ecological corridors.

6.41 For this reason, the minimum length of ecological corridor might be better considered as an assessment criterion in Part 22B.9.3, and I note it has now been included in Version 7A as such.

Connectivity of riparian planting (environmental enhancement, protection or restoration)

6.42 Connectivity in ecosystems is a multidimensional phenomenon and occurs laterally (terrestrial environments alongside streams), vertically (root area to vegetation canopy), and longitudinally (riparian and terrestrial environments up and down streams).

6.43 It is not my intention to discuss all of these components of connectivity here but I will focus on the lateral connectivity and the importance of riparian areas as transitional between aquatic and terrestrial ecosystems.

6.44 In her evidence Ms Myers describes the ecological principles of stepping stones and ecological corridors and how they are needed to improve the viability and resilience of the remaining biodiversity in the Franklin area. Ms Myers also goes on to detail the importance of creating larger natural areas to the viability and resilience of the remaining biodiversity in the Franklin area.

6.45 At larger spatial and landscape scales, riparian environments act as strong organisers of ecological systems, especially as the distribution of plants and animals is shaped by the availability of water, food and habitat (Naiman et al. 2005).

6.46 As I have mentioned in my evidence above, and I emphasise here that in my opinion, the natural topography of the EEOA means that the drainage catchments form the natural conduits for connectivity in that landscape and the necessary connections of energy, water, food and habitat.

6.47 This is because the drainage catchments penetrate deep into the interior of the EEOA and thus form natural connections between the coast and headwater areas. Similarly the drainage catchments form an east-west pattern across much of the EEOA.

6.48 Such connections and linkages between remnant and restored ecosystems are important for the dispersal and migration of organisms, and shorter distances between ecosystems benefits the movement of organisms. As I have outlined in my evidence above, remnant and restored ecosystems need to be resilient and viable in order to provide the ecological function to act as a stepping stone or corridor.

6.49 In my view, the reality is that such restoration and enhancement of remnant vegetation and ecological corridors will not occur in an ordered fashion to provide optimum environmental benefit. The restoration of identified ecological corridors will provide some order to the restoration and enhancement and, although restoration of these corridors might at first be patchy, it will avoid the more ad hoc and limited restoration that might otherwise occur across the EEOA. Nevertheless, as I have detailed in my evidence above, and Ms Myers has emphasised in her evidence, the denuded nature of the EEOA, means that even patchy enhancements and restoration of ecological corridors will commence the significant environmental benefits as envisaged by the Plan Change objectives and policies. Over time the connections will become increasingly linked and as they pass through successional phases of ecological development they will provide a stronger degree of linkage, resilience and sustainability.

6.50 It is worth noting that although the Plan Change seeks to achieve significant environmental benefit through subdivision, other mechanisms are available for the restoration of ecosystems. For the most part these are voluntary mechanisms that enable part or total funding to be provided to a private landowner for the purpose of a specific environmental enhancement. Such mechanisms include the Auckland Council's Environmental Initiatives Fund.

6.51 Similarly, organised collectives such as local Landcare groups can also seek funding and assistance to enable restoration of indigenous bush remnants and waterways (e.g., Biodiversity Fund).

6.52 In my opinion the restoration of ecological corridors via the planting of the riparian environments of the drainage catchments will create sustainable and resilient stepping stones and corridors and provide the connectivity across the EEOA that will achieve the significant environmental benefits envisaged.

6.53 Connectivity with the coastline is especially important for freshwater ecosystems. In particular, the connection of freshwater systems to saline systems supports the migratory movement of several indigenous fish species that spend parts of their life cycles in fresh and saline water.

6.54 Inanga breed and spawn at the interface between freshwater and saline water[5] at high spring tides. In my opinion it is important that the significant environmental benefits for environmental lots, at least extends as far as potential inanga spawning areas. Significant benefits can be gained from enhancing inanga spawning and juvenile and adult fish habitats further upstream.

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[5] Inanga spawn in vegetation along waterways at spring high tides and where freshwater meets saline water. Inanga spawn amongst riparian vegetation in estuarine areas, usually near the upper limit of the saltwater wedge associated with high tides. Spawning usually occurs during the months of February to May.

6.55 As native fish require access to and along streams and the coastline it is important that fish passage is provided for at all times. This means that the removal of existing barriers (e.g., perched culverts, Attachment 2, Fig. 12) will provide significant benefits, as will the preventing the creation of new barriers to fish movements. I note that this is provided for as an assessment criterion in Part 22B.9.3.

Rule 22B.11.3

6.56 Rule 22B.11.3 provides the Protection, Certification and Planting requirements for restoration and enhancement planting Rule 22B.11.3 applies to any indigenous enhancement planting required under Rule 22B.11. The rule provides the principles and planting guidelines to be followed. The 'Expert Ecology Conferencing Joint Statement' (dated 19 September 2012) recommends that strong guidance is provided through the use of practice notes and measures or indicators of success. The expert statement also recommends that the planting should contain an appropriate density of native species that reflects the ecological sequences and patterns of terrain.

6.57 The 'Expert Ecology Conferencing Joint Statement' (dated 19 September 2012) also notes that TP148 is aimed primarily at the improvement of water quality and in-stream ecological values; and is therefore not the only guidance that should be used for planting riparian environments as ecological corridors.

6.58 I support the recommended standards for planting indigenous vegetation for planting density, for eco-sourcing plants and to reflect the composition of the former natural vegetation likely to have occupied the site.

6.59 I recommend amendments to Rules 22B.9.3.2 as follows:

The extent to which the enhancement and restoration planting of ecological corridors has regard to regional ecological restoration planting guidelines.

Planting guidelines

6.60 In considering guidance to landowners to support the planting of riparian vegetation, I recommend that the District Plan provide guidelines to assist in the preparation and implementation of riparian planting.

6.61 I have been involved in the preparation of specific 'practice notes' for the change to the North Shore City District Plan to provide for a catchment plan for Long Bay. In undertaking that exercise I developed practice notes for riparian planting as well as the provision of fish passage, enhancements to inanga spawning areas, the protection of natural springs and seeps, and the prevention of bank erosion.

6.62 It is my opinion that specific practice notes or guidelines will be useful to the implementation of the proposed Plan Change because:

- Guidelines can be specific to the District rather than all Auckland regions.
- Guidelines can be developed for the lay-person and are not a technical document.
- Guidelines can be supplemented with actual local examples or diagrams.
- Guidelines can be readily available at local community centres.

6.63 I have included examples of draft practice notes for Long Bay catchment as Attachment 4 of my evidence.

Examples of riparian planting

6.64 There are a number of examples of successful riparian planting for environmental enhancement as opposed to the mitigation of the actual and potential adverse effects of developments. Although now somewhat dated, several examples are documented in 'Managing waterways on farms' (MFE 2001).

6.65 Project Twin Streams in the former Waitakere City was established in 2003 with the aim of reducing pollution, flooding, erosion and sedimentation in the predominantly urban waterways. Amongst other things (e.g., improved stormwater treatment), the project set out to restore the riparian environments of the streams. Some 700,000 plants have been planted along 56 km of waterways in one of the largest programmes of its kind in New Zealand. This planting has resulted in the development of ecological corridors along the drainage catchments.

6.66 I have been involved in the aquatic monitoring of the success of the project (Golder 2010). Although it was difficult to discern any changes in water and sediment quality directly related to improvements in the treatment of stormwater, there was evidence that increasing the length of stream planting is having a positive effect on some indicators of stream health. This result highlights the benefits of extensive riparian planting to enhance the longitudinal corridors and connectivity of waterways.

6.67 Within the regional parks network of Auckland, several enhancement programmes have been initiated. Good examples are the stream plantings and fencing at Shakespeare Regional Park (Whangaparaoa Peninsula) and Tawharanui Regional Park. In these cases the plantings have provided for corridors alongside streams and supported stepping stones and corridors for terrestrial indigenous biodiversity.

6.68 The North-West Wildlink Project aims to provide wildlife corridors as a series of stepping stones across Auckland to support indigenous wildlife. A focus on managing animal and plant pests has resulted in improvements in the presence of native birds within the corridor. Minimising forest edges amongst some of the continuous plantings has resulted in greater resilience for the plantings (i.e., less weed infestations).

6.69 The examples I have listed above are largely local or regional government and community-based initiatives. Typically this means greater resources are available to provide for the significant enhancements.

6.70 In other situations, usually implemented as resource consent related responses to mitigate potential adverse effects on waterways, riparian plantings are frequently undertaken, but with much more limited purposes. Although the success of such riparian planting initiatives is generally not monitored, at best the outcomes are variable. In part this is due to the limited width of the riparian plantings but poor planting and maintenance (i.e., weed control) also means that a desired self-sustainability of the riparian area is not met and in my opinion, the anticipated outcomes for aquatic and terrestrial ecosystems are often not achieved.

7. DEFINITIONS

7.1 Version 7A provides for Identified Significant Natural Features (ISNFs), Qualifying Natural Features (QNFs) and Naturally Functioning Freshwater Wetland as follows, and as agreed at the ecological caucusing:

IDENTIFIED SIGNIFICANT NATURAL FEATURE (ISNF) means:

- INDIGENOUS vegetation or WETLAND identified on Map 109Z and located within the ENVIRONMENTAL ENHANCEMENT OVERLAY AREA;
- INDIGENOUS vegetation or WETLAND identified on Map 109X and located outside the ENVIRONMENTAL ENHANCEMENT OVERLAY AREA.

QUALIFYING NATURAL FEATURE (QNF) means:

- REMNANT INDIGENOUS VEGETATION not identified as an IDENTIFIED SIGNIFICANT NATURAL FEATURE; or
- NATURALLY FUNCTIONING FRESHWATER WETLAND not identified as an IDENTIFIED SIGNIFICANT NATURAL FEATURE; or

Within the ENVIRONMENTAL ENHANCEMENT OVERLAY AREA:

- an ecological corridor identified on Map 109Z.

7.2 The 'Expert Ecology Conferencing Joint Statement' (dated 19 September 2012) recommends that the following definitions better reflect the purpose and meaning of the ISNF and QNF and better represent the ecological conditions of the district than those originally provided to the parties:

NATURALLY FUNCTIONING FRESHWATER WETLAND means a WETLAND representative of the hydrological function and natural ecological diversity and patterns, of WETLANDS in the relevant ecological district. It excludes artificial ponds (such as farm ponds and ornamental ponds), drains and sediment retention areas.

REMNANT INDIGENOUS VEGETATION means an area of existing regenerating or mature INDIGENOUS vegetation that is representative of the natural ecological diversity and pattern of the relevant ecological district.

7.3 In her evidence Ms Myers describes the purpose of the ISNF and QNF and provides a justification for the definition of 'Naturally Functioning Freshwater Wetland' and 'Remnant Indigenous Vegetation'. I concur with the definitions as described in the evidence of Ms Myers.

7.4 I add emphasis to the definition of Naturally Functioning Freshwater Wetland. The hydrological function is paramount to the overall integrity as a freshwater wetland; the surface and groundwater lateral and vertical movements support the chemical, microbiological and biological processes that the ecosystem and the flora and fauna depend upon. A naturally functioning wetland may be modified but still retain natural function, and can be defined if it is dominated by indigenous wetland species.

7.5 In my opinion a hole dug into the ground filled with water (artificial or farm pond) even if planted around the margins with indigenous species does not constitute a 'Naturally Functioning Freshwater Wetland'. Such artificial water bodies are usually contained within boundaries with less natural connectivity to the drainage catchment, are primarily open water, are deeper, and do not retain the essential microbiological activity that is important to wetland function.

7.6 Accordingly, the definition of Naturally Functioning Freshwater Wetland agreed in the 'Expert Ecology Conferencing Joint Statement' (dated 19 September 2012) recommends a qualifier to the definition which states "*It excludes artificial ponds (such as farm ponds and ornamental ponds), drains and sediment retention areas'.*

7.7 In my opinion the proposed definition of a wetland is appropriate and should be included in the amended provisions in Rules 22B.11.1 and 22B.11.2.

8. CONCLUSION

8.1 The remaining indigenous biodiversity in Franklin District is severely depleted and fragmented. In my opinion, the objectives and policies in Plan Change 14 provide mechanisms for environmental lot subdivision that will achieve ***significant environmental benefits***.

8.2 In my opinion, ecological corridors via riparian environments with an average width of 30 m or wider for drainage catchments (stream order 2 or greater, within the EEOA will achieve the objectives and policies of the proposed plan change. The greater riparian area and extent of ecological corridor will provide for ***significant environmental benefit*** that is sought by the objectives and policies of the plan change, as it meets a number of desired ecological thresholds that provide for resilient, functioning ecosystems with a larger viable area, reduced edge effects and increased connectivity with other 'patches'.

Dr Ian Boothroyd

21 September 2012

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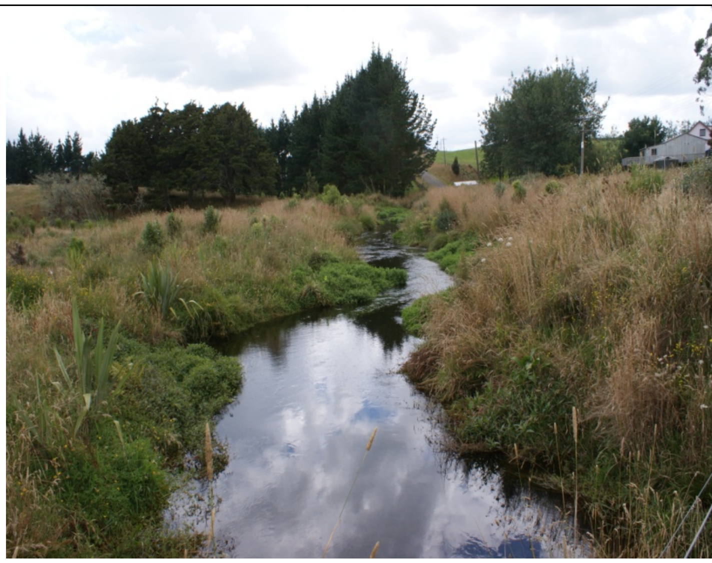
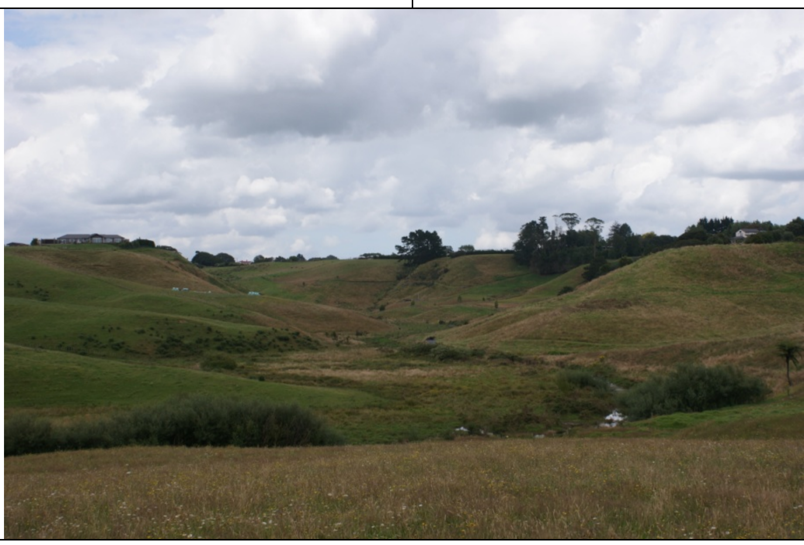
ATTACHMENT 2
CHARACTERISTICS OF STREAMS WITHIN THE EEOA

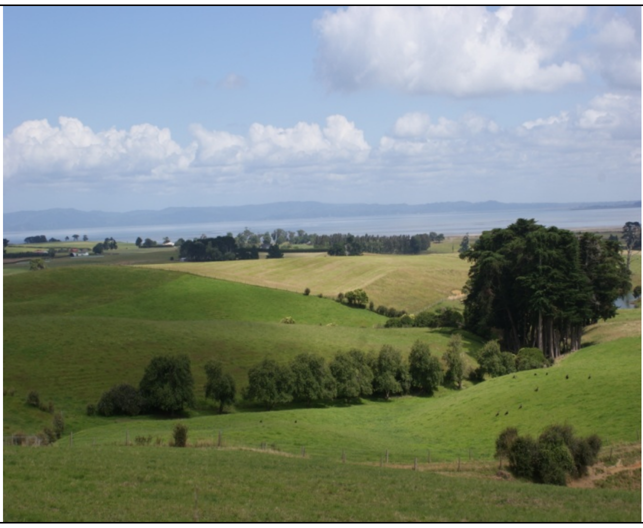
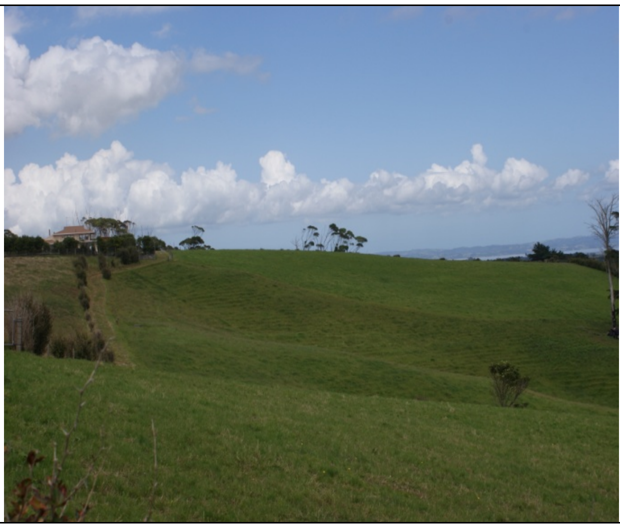
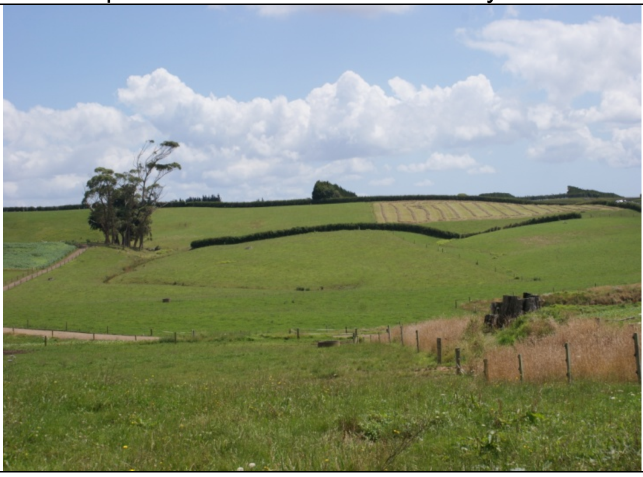
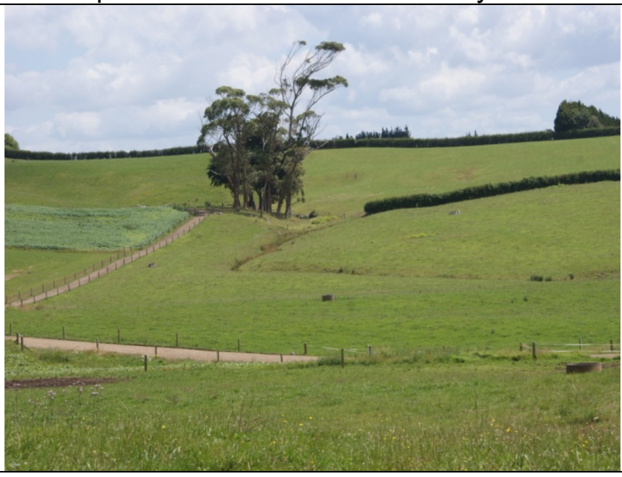
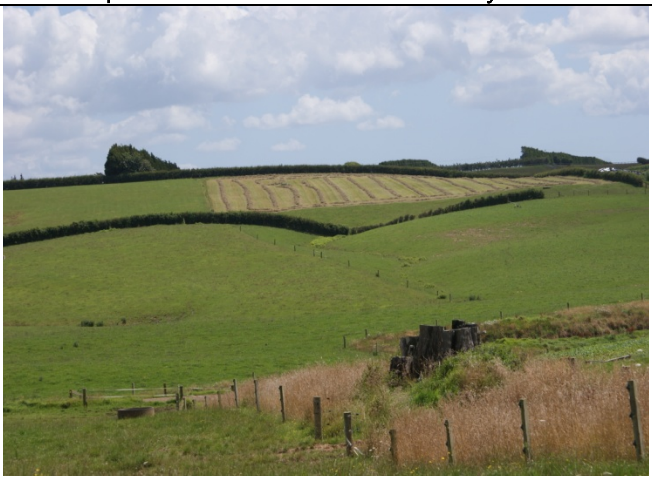
1. Spring fed perennial stream - Whangamaire Stream

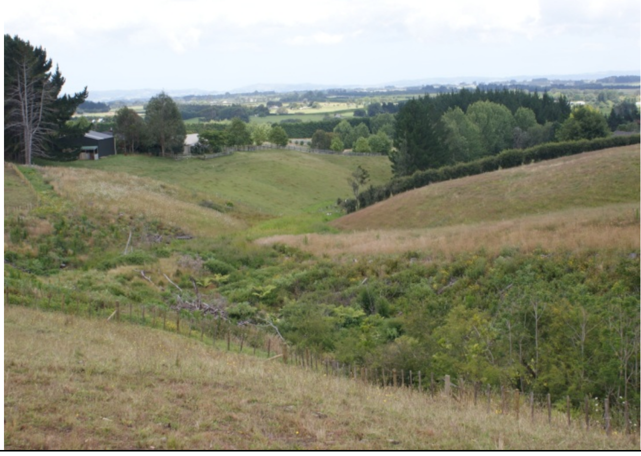


2. Spring fed perennial stream

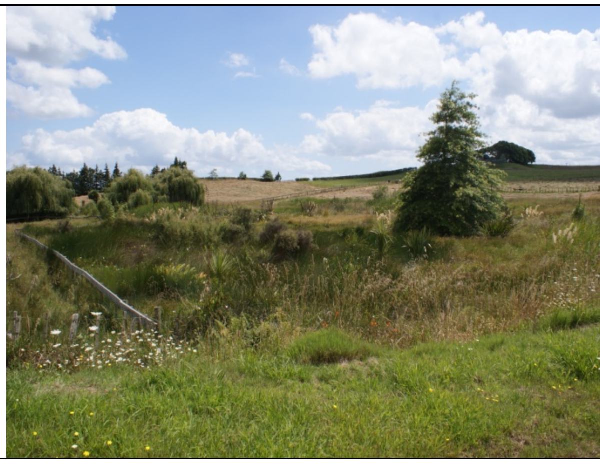


3. Permanent stream in foreground with intermittent/ephemeral gullies

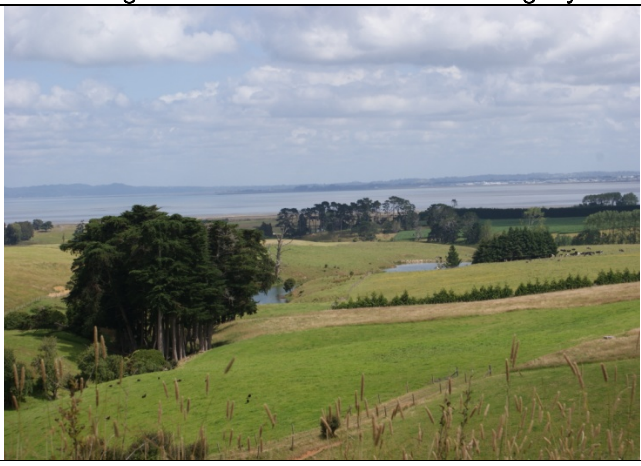
	
4. Ephemeral/intermittent stream system	5. Ephemeral/intermittent stream system
	
6. Ephemeral/intermittent stream system	7. Ephemeral/intermittent stream system
	
8. Ephemeral/intermittent stream system	



9. Vegetated headwater and wetland gully



10. Puhitahi wetland



11. Artificial ponds

12. Perched culvert

ATTACHMENT 3

Summary of riparian area functions that potentially buffer streams from various land use effects (Collier et al. 1995).

Riparian environment function	Potential in-stream effects
Buffers banks from erosion. Buffers channels from localised changes in morphology. Buffers input of nutrients, soil, microbes and pesticides in overland flow. Denitrifies groundwater. Buffers energy inputs. Provides in-stream food supplies and habitat. Buffers floodflows. Maintains microclimate. Provides habitat for terrestrial species. Maintains dispersal corridors.	Reduces fine sediment levels. Maintains water clarity. Reduces contaminant loads. Prevents nuisance plant growths. Encourages growth of bryophytes and thin periphyton films. Maintains lower summer maximum temperatures. Increases in-stream habitat features and terrestrial carbon inputs. Maintains food webs. Reduces floodflow effects. Increases biodiversity.