Memo

Date	21.5.2019
To	Andrea Richardson, Senior Planner
cc	
From	Duncan Gray, Senior Scientist

Subject: Cumulative aquatic habitat loss, a step change in biodiversity and the case for legislative change

Environment Canterbury (ECan) has stated that a 'step change in biodiversity' is required to meet community aspirations. In Canterbury, it is acknowledged that wetlands and lowland streams on the coastal plains have suffered the greatest loss of biodiversity through the historic drainage of wetlands and subsequent agricultural and urban encroachment on remnant waterbodies (Beech, 2008; ECan, 2015). Considerable effort is already being expended to reverse the decline in biodiversity values of the lowland streams through the Canterbury Water Management Strategy. The Science and Consent Planning groups have identified, through either processing or providing technical advice on resource consent applications, potential policy impediments in the Land and Water Regional Plan (LWRP) to a 'step change in biodiversity' values:

1. The absence of adequate protection for the ecological values present in naturally flowing[1] waterways deemed to be 'artificial drains' rather than 'modified natural' watercourses.
2. Inadequate policy and rules to regulate the re-alignment, diversion (out of the current river bed), piping and reclamation of natural and modified water courses.

We believe that restriction of activities that remove or degrade aquatic habitats, through policy and plan provisions, will make a significant contribution towards a 'step change in biodiversity'. This memo details the scientific justification for legislative change.

[1] In this memo, "naturally flowing" includes both continually or intermittently flowing watercourses that with naturally derived baseflow. This includes watercourses that have low levels of natural baseflow and which are then augmented from an external source (e.g. via targeted stream augmentation or when used for conveyance of irrigation water). However, "naturally flowing" watercourses does not include artificial watercourses that only flow due to discharge of water into them from another source (e.g. water supply races).

Drains

In order to undertake statutory obligations for the management of water, the status of any watercourse or body must be clearly defined and identifiable.

Under the RMA (1991) and LWRP a river means:

> '*…a continually or intermittently flowing body of fresh water; and includes a stream and modified watercourse; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal)*'.

Conversely, an artificial watercourse means:

> '*… a watercourse that is created by human action. It includes an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal channel. It does not include artificial swales, kerb and channelling or other watercourses designed to convey stormwater*'.

While '*Farm Drainage Canal Channel*' is not defined, a drain is determined to:

> '*include any artificial watercourse that has been constructed for the purpose of land drainage of surface or subsurface water and can be a farm drainage channel, an open race or subsurface pipe, tile or mole drain, or culvert*'.

There is little dispute that irrigation canals, water supply races and canals for the supply of water for electricity power generation are artificial watercourses. However, artificial watercourses are not without their ecological values and should be managed with regard for any downstream receiving environment. There has also been considerable debate and successive legal interpretation as to whether many drains are artificial or might more appropriately be termed a modified watercourse. The problem appears to arise because although the watercourse is a cut channel created by human action, the water that the channel intersects is part of a natural water body, typically a historic wetland or shallow groundwater. It could be argued that the cutting of a channel or drain has modified an existing natural waterbody by creating a watercourse. Thus, the watercourse is not entirely artificial, more a modification of a naturally occurring body of water.

Planning criteria and definitions aside, there is a compelling scientific reason to differentiate between permanently or intermittently flowing drainage canals and the less controversial artificial watercourses. Across large areas of the Canterbury Plains there were historic wetlands of considerable ecological value. Approximately 10% of the Canterbury Region's wetlands remain (Pompei & Grove 2010). These wetlands would have been coursed by flowing channels of water, but also areas of standing water and sometimes simply "damp ground" (Figure 1A). These wetlands were of enormous value to Ngāi Tahu and were habitat to species of invertebrates, fish and birds, many of which are consequently now extremely rare or threatened. The drainage networks cut explicitly to drain these wetlands now represent the vestiges of the wetland biodiversity values of the Canterbury Plains (Figure 1B). Moreover, irrespective of whether these drains are considered as artificial or modified watercourses, they hold considerable biodiversity values and should be manged accordingly.

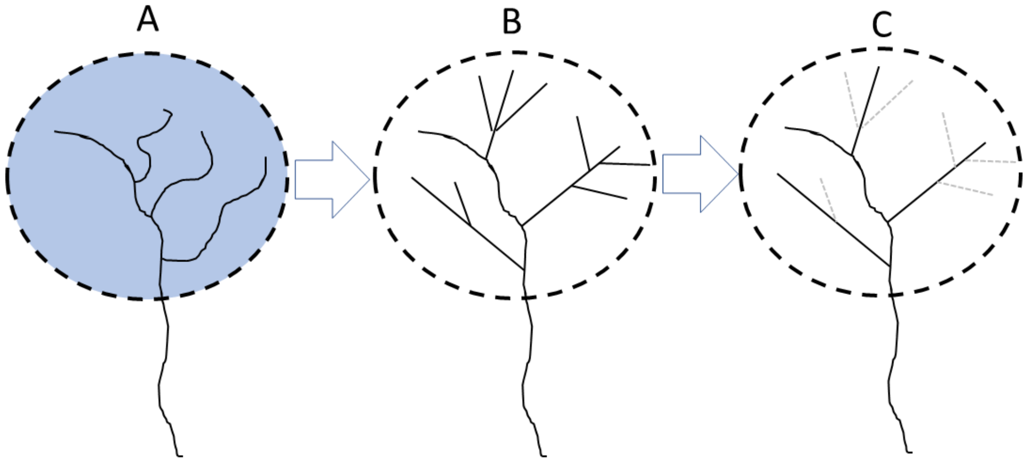

Figure 1*: A) a natural stream system emerging from a wetland (blue circle); B) drainage of the wetland; some new channels are cut while existing stream channels are retained to assist with drainage and others are removed or modified; and C: subsequent piping or tiling of smaller drains.*

Unfortunately, the classification of these drains as artificial watercourses means that they do not fall under the protections afforded to rivers and streams in the LWRP. As such, these artificial watercourses are particularly vulnerable to the re-alignment, diversion (out of the current river bed or channel), piping and reclamation activities described below. As a result, there is an ongoing loss or degradation of aquatic habitat as drainage networks are managed to suit the needs of agriculture and urbanisation (Figure 1C).

There are differences in interpretation of the current definitions of modified versus artificial watercourses. At one extreme, any human-made channel for the purposes of drainage, unless it can clearly be shown there was previously a stream at that location, is artificial. However, a recent legal opinion suggested that any drains cut into an area that was previously wetland should be considered as a modification of that wetland and there is no requirement for evidence of an historic watercourse.

Nonetheless, the status of drains cut to drain historic wetlands, or areas of shallow groundwater where wetlands would have occurred, remains under dispute. Clarification of this situation has the potential to significantly increase the protection of waterways in Canterbury and support a ‘step change in biodiversity’. For example, of the 27,528 km of drains shown on the 1:50000 topo map of Canterbury, 2026 km (7.3%) are within the mapped area of historic wetlands (e.g. Figure 2). None of these watercourses are drawn on the LWRP planning maps and may currently be argued to be artificial watercourses despite often having considerable biodiversity values.

***Figure 2:** An example of current rivers and modified watercourses (blue) and drains (black) within historic wetlands (green, Ausseil et al., 2008). Drains outside of the historic wetlands have been omitted for brevity.*

Re-alignment, diversion, piping or reclamation of watercourses

The re-alignment, diversion, piping or reclamation of stream channels or naturally flowing ‘artificial’ watercourses (drains) is a common practice throughout Canterbury and New Zealand with the potential for significant impact upon ecological values (Figures 3 & 4).

Figure 3: Progressive loss of wetland and stream habitat during the intensification of land use adjacent to the Waiau Uwha River in North Canterbury.

These activities may occur for a variety of reasons in both urban and rural settings. Within urban developments, there is often a desire to pipe headwater streams to allow integration with stormwater networks and increase the availability of land for development (Walsh et al., 2005). In rural settings, an increase in the requirement to fence streams amidst intensive agriculture and the desire to maximise land under pivot irrigation, have resulted in streams being straightened, diverted to the margins of paddocks, or piped. Stream re-alignments and diversions, in both rural and urban settings, may also be proposed for the rehabilitation, or enhancement, of ecological values and stream function of previously modified waterways. Often a proposal may include aspects of both negative and positive impact upon the stream ecosystem. It is important to consider the overall balance of effects and each proposal on its individual merit.

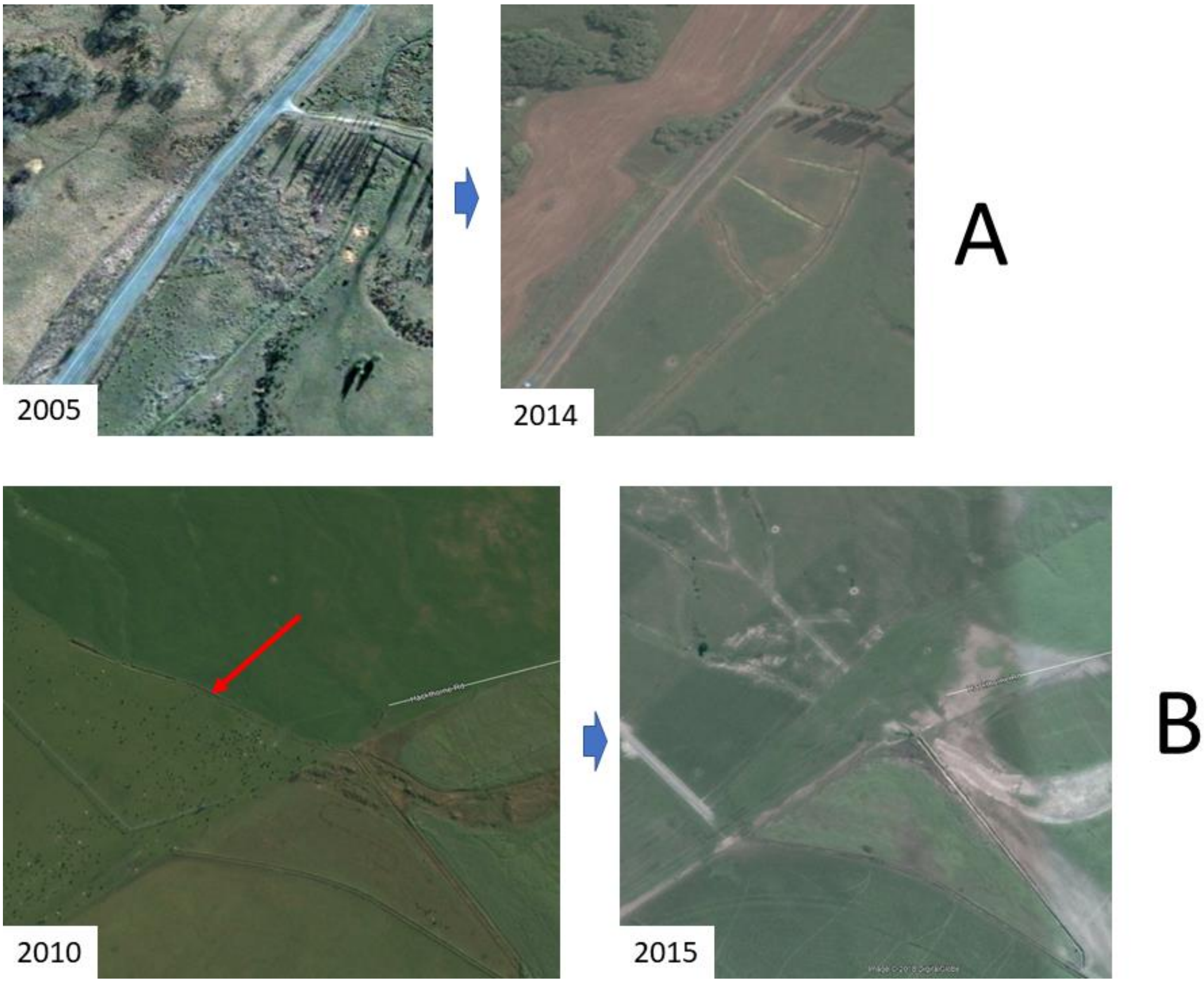

*Figure 4: A) an area of wetland in the Mackenzie basin was drained and reduced in area to 3 cut channels. These channels contained the Nationally Vulnerable bignose galaxias (*Galaxias macronasus*). The channels were infilled with rocks in 2017. B): a length of drain (red arrow) is piped and the area is converted to paddock.*

This section considers the ecological and natural character impacts of the re-alignment, diversion, piping and reclamation of waterways before exploring the planning context for these activities.

Natural Character

The term ‘natural character’ is referred to in the Resource Management Act 1991 (RMA) and throughout ECan plans, strategies and their associated policies. It holistically incorporates:

- Water quality
- Water quantity
- Bed substrate
- Natural processes (movement of sediment, water and biota)
- Natural life-supporting capacity
- Ecosystems and biodiversity
- Landscapes and landforms

- Characteristics of special spiritual, historical or cultural significance to Māori
- Significant places or areas of historic or cultural significance.

Formal assessments of natural character are becoming common place during resource consenting with the advent of research on the topic and various guidelines (Bentley et al., 2014; Boffa Miskell, 2009).

Ecological context

A healthy stream is one that retains a broad range of species, interacting within a relatively stable food web, such that the various populations are resilient to disturbance. The stream will be able to assimilate and process the energy and materials that enter it from the catchment, often referred to as ecosystem function, without dramatic changes in the ecological communities and values present.

When undertaking activities within or around a waterway, it is, therefore, important to consider the ecosystem function of the watercourse, as well as the more obvious components of its ecological communities, such as fish and insects. These obvious components are often considered as the 'biodiversity'. However, biodiversity is not limited to threatened and endangered species, but incorporates the full variety of life, from the microscopic bacteria to the vertebrates, that is the foundation of ecosystem function and ecosystem services.

The following section introduces features of stream ecosystem function and systems of relevance when considering the diversion, re-alignment, piping or reclamation of streams.

Ecosystem Function

A stream is inextricably linked to its surrounding landscape such that 'in every respect the valley rules the stream' (Hynes, 1975) and the characteristics of the catchment regulate many aspects of the stream ecosystem. Where natural waterbodies (e.g. wetlands) have been modified by artificial drainage, drains often become 'naturalised' over time and may take on the same role as natural streams in other, less modified, locations. For the following discussion, 'stream' should also be read as including naturally perennial and intermittent flowing, artificial watercourses.

The linkages that affect stream ecosystems include:

- the amount of water gathered from the catchment;
- the chemical and physical properties of that water; and
- the exchanges of energy and materials within and between the stream and the riparian zone.

Stream flow, water chemistry and channel shape are typically consequences of catchment scale, climate, geology and local topography (Allan and Castillo, 2007). The land that borders a watercourse (the riparian zone) often has a predominant influence on water quality, ecosystem function and the suitability of habitat for biota. Riparian vegetation provides shade to the stream and influences bank stability, habitat form, and the quality of water running into the stream from and through the banks. The stream derives energy from the sun, via plants and algae that grow in the water, or in the form of leaf litter entering the stream from the riparian zone (Wallace et al., 1997). This energy is transferred through a stream's food web via macroinvertebrates and fish before being re-cycled or exported downstream or out of the water (Nakano and Murakami, 2001; Vannote et al., 1980).

Streams cycle nutrients and other materials as water moves downstream (Fisher and Likens, 1973). Nitrogen and phosphorus, amongst other nutrients, are vital to the growth of plants and algae. Nutrients are transported from stream headwaters to the sea through a cyclical process where inorganic forms are taken up by organic life, and then re-mineralised in inorganic forms through respiration or excretion (Allan and Castillo, 2007). Organic forms of nutrients range from the algae and aquatic plants at the base of food web all the way up to large predators, such as trout and eels. Inorganic forms of nutrients include nitrates and dissolved reactive phosphorus, often measured to indicate the effects of land use intensification on streams. Nutrients may be lost from the stream system altogether or enter long term storage through processes such as de-nitrification or adsorption to sediments (Mainstone and Parr, 2002; Filoso and Palmer, 2011). These processes are sometimes collectively termed attenuation.

In a stream with high naturalness (e.g. natural streams in unmodified habitats), inorganic nutrients are likely to be found in low concentrations because any available nutrient is rapidly taken up into organic form or otherwise lost from the system. Biological productivity is therefore limited by nutrient supply. As nutrient supply increases, or the ability of the stream to uptake, process or attenuate nutrients is impaired, the food web will begin to change through the process of eutrophication (Biggs, 2000). Algae and aquatic plant growth rates may increase beyond the ability of macroinvertebrates and fish to process the biomass. The end result is disruption of the food web and a variety of undesirable outcomes, including algal smothering of habitat, excessive growth of aquatic plants, and large oscillations of dissolved oxygen between night and day. In addition, excess nutrients (i.e. those that are not taken up by algae and aquatic plants) are exported downstream into larger rivers, estuaries and ultimately into the sea.

The uptake, processing and attenuation of nutrients in streams is highly dependent on the physical form of the stream and the residence time of water (Arango et al., 2007; Battin et al., 2016; Craig et al., 2008). Firstly, the slower the water moves through a stream system the greater the opportunity for nutrients to be fixed into organic form (e.g. taken up by algae and plants), bound to sediments or released to the atmosphere. Secondly, the more physically and chemically complex a stream is, the greater the likelihood that uptake, processing and attenuation will occur. For example, a straight, narrow channel of swiftly moving water provides less interaction between water and substrates than a slower flowing, meandering channel with pools and riparian wetlands (Filoso and Palmer, 2011). Similarly, streams with limited riparian vegetation have less availability of carbon (e.g. leaf litter and woody debris) to promote de-nitrification compared to a forested stream.

The flora and fauna of streams respond to the complexity of a stream's physical form, or the available habitat. Essentially, there is a positive relationship between the variety of habitats available and the number of species present (Begon et al., 1996). A natural stream does not have a straight channel, it has bends, pools and riffles, shallow and deep water, and may have associated wetlands. There is likely to be a variety of substrate types, from sands to cobbles or wood, as well as patches of aquatic plants and different types of algae. More homogenous streams provide fewer ecological niches (habitat types), fewer available resources and typically support fewer species.

In summary, the sustainable management of stream health and water quality is highly dependent upon the maintenance of physical form and complexity in streams. To protect ecosystem function, biodiversity or ecological values of streams, the potential for changes in physical form and complexity should be a paramount consideration when assessing the potential effects of a proposed activity.

Ecological effects of stream modifications

Re-alignment or diversion

At the most basic level, the re-alignment or diversion (meaning re-location of the channel, rather than moving of the flowing water within an existing channel) of a waterway has the potential to result in a reduction of wetted habitat area and habitat diversity (Figure 5). Stream re-alignment may seek to straighten a waterway, which results in a reduction in the diversity of flow types and habitats present. While historic artificial drains typically have less habitat variability than a natural stream, variations in habitat are likely to have developed overtime. These naturalised artificial watercourses, therefore, often provide a refuge for biodiversity values. Further modification of these naturalised drains has the potential to reduce the diversity of available habitats.

Diversions or re-alignment may result in a greater or lesser length of stream depending upon landscape configuration, but unless the activity is adequately mitigated the resulting waterway may be of uniform width and lack a diversity of habitat types. In Figure 5 the result of re-alignment and diversion is that the stream is shorter and more physically uniform.

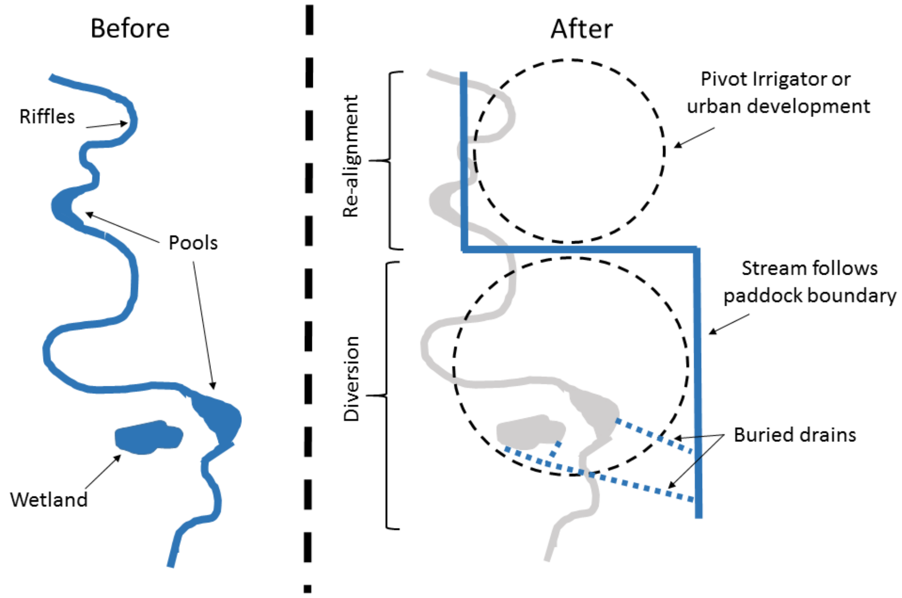

Figure 5. Schematic representation of a stream pre- and post re-alignment and wetland drainage.

Particularly in lowland areas, many streams (including artificial drains) are predominantly fed by upwelling groundwater. Springs may occur at the heads of streams, but water can commonly be found upwelling through the stream bed all along its length. This upwelling groundwater may provide a thermal refuge during hot periods, keep the substrate clear of fine sediments and supplies water to the stream. Diversion or re-alignment has the potential to break the connection between ground and surface water, subsequently affecting a number of stream processes and characteristics. Springs can also contain unique macroinvertebrate fauna not seen in the rest of the stream (Scarsbrook et al., 2005; Collier and Smith, 2005; Gray and Harding, 2009). Re-alignment or diversion of a channel may also result in a loss of water to groundwater if the new stream bed is highly permeable. The result of a poorly sealed channel may be drying of the stream over a greater length and for a longer period.

In Figure 5, the ecological value (represented for example by the number of species of macroinvertebrates and fish, stream function, including the ability of the stream to assimilate nutrients, and natural character) is likely to be reduced as a result of re-alignment and diversion. Different fish and macroinvertebrate species prefer different habitats. For example, bluegill bullies and torrentfish prefer faster flowing, broken water associated with riffles, whereas large eels favour pool habitat and mature trout feed at the interface of fast and slow water (McDowall, 2000; Hayes et al., 2016). The homogenous run habitat found in a uniform channel provides none of these habitat types. Macroinvertebrates similarly have varied habitat preferences and homogenous habitats support fewer species.

The ability of a stream to assimilate nitrogen and phosphorus from the water column is strongly influenced by the residence time of water and the surface area and composition of substrates in the stream (Arango et al., 2007; Battin et al., 2016; Craig et al., 2008). In the re-aligned and diverted stream the channel is likely to be designed for the most effective conveyance of water resulting in a short residence time and less interaction between the water, bed and banks.

A reduction in wetted habitat area and habitat diversity, therefore, can have significant impacts on ecosystem function, and subsequently stream health, without appropriate mitigation.

Piping and reclamation

Piping and reclamation tend to be applied to very small waterways and wetlands at the heads of streams, in both urban and rural settings. These waterways are often not even recognised as streams, being ‘shallower than a gumboot and narrower than a stride’ (MAF 2011). However, in terms of water quality, ecosystem function and biodiversity small streams are very important.

It is estimated that typically ~80% of the length of any waterway is a 1st or 2nd order[2] (i.e. small) stream (Benda et al. 2005; de Paula, Luiza, and Piedade 2016). As such, small streams represent a significant proportion of overall aquatic habitat. In addition, small streams are particularly efficient at transforming and retaining nutrients and reduce the potential for eutrophication of downstream environments (Peterson et al., 2001). This is because of the greater proportion of water volume in contact with the surface of the stream bed. Unmodified headwater streams also reduce sediment transport downstream due to their typically bumpy beds and frequent obstructions (Meyer et al., 2003).

Given the extent and diversity of habitats found in small, headwater streams they provide an important contribution to biodiversity (Meyer et al., 2007). Many New Zealand macroinvertebrate species are only found in headwater streams, springs, seeps or wetlands (Scarsbrook et al., 2005; Collier and Smith, 2005; Gray and Harding, 2009). Because of the diversity of habitats found within, and between, headwater streams, at the landscape scale these streams contain more species than larger waterways (Clarke et al. 2008), even if fish and macroinvertebrate communities of individual headwater streams are typically less species-rich than larger waterways.

Piping and reclamation of headwater streams results in a loss of their biodiversity and nutrient processing capacity. Small streams in low relief areas are also often associated with wetlands, which are also lost when the hydrological connections are broken or the land drained.

Construction and ‘healing’ phase

Aside from the long-term implications of reduced stream habitat, water quality and biodiversity, there are acute short-term impacts during the de-commissioning of the current channel and the construction and healing phases of the new channel.

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[2] Stream order is a measure of the relative size of streams. The smallest tributaries are referred to as first-order streams, while the largest river in the world, the Amazon, is a twelfth-order waterway. First- through third-order streams are called headwater streams. When two first order streams join they become a 2nd order stream and so on.

Fish or invertebrate salvage

Dewatering and infilling of a stream channel will result in the mortality of any aquatic individuals that get left behind. Depending on the rates of dewatering, the morphology of the stream and species present some fish and macroinvertebrates may leave the impacted reach. Inevitably however, there will be individuals that, unless actively rescued, will perish.

When working in waterways, the Freshwater Fisheries Regulations 1983 dictate that indigenous, or native, fish shall not be knowingly destroyed (section 70). Permits, consents or approvals to undertake fish salvage, or activities associated with fish salvage, must be obtained under any relevant legislation (including the Resource Management Act 1991, the Freshwater Fisheries Regulations 2003, the Fisheries Act 1996 and / or the Conservation Act 1987). Offences may be committed under these Acts / Regulations for not having an appropriate approval, taking the wrong fish, or using the wrong method to take them, or killing fish. Environment Canterbury has co-authored guidance on fish salvage (Burrell and Gray, 2018).

Although typically not considered, certain macroinvertebrates, such as freshwater crayfish and freshwater mussels, may also require salvage.

Water quality impacts

The release of fine sediment during de-commissioning, channel construction and water diversion is also of concern. Recent research in Canterbury has shown that fine sediment is the most pervading stressor to macroinvertebrate communities in streams (Greenwood et al., 2011). Streambed cover by fine sediments, in excess of 20% of available surface area, results in significant degradation of the community (Burdonet al., 2013; Greenwood et al., 2011). Once fine sediment covers the bed of a spring-fed stream it may remain in perpetuity due to stable flows, and the lack of flushing events.

Adequate sediment and erosion control can prevent the addition of fine sediment to streams with careful planning. Environment Canterbury has provided an online toolbox to guide sediment and erosion control when working around waterways (http://esccanterbury.co.nz/project/waterways-task/).

Healing phase

Aquatic communities are complex and regulated by many factors, and new stream channels or the effects of instream works, take time to heal or 'naturalise'. Depending on the context of the stream, and the proposed adjacent land management, this may take a considerable length of time. In areas of porous land, streams may lose water to the ground or may have lost their connection to upwelling groundwater, with subsequent effects on flows. Fine sediment deposits in the bed must adjust to the prevailing currents, while riparian vegetation must establish and aquatic communities colonise. Colonisation by fish and macroinvertebrates is dependent on the suitability of habitat and a source of colonists (Palmer et al. 1997).

While the provision of a 'suitable' new channel will, in theory, result in a functional species rich community developing this is not necessarily the case. The science of stream restoration or construction is relatively new, and it is therefore preferable to protect existing values rather than gamble on the success of a mitigation proposal.

Mitigation

Due to the documented impacts on habitat availability, habitat diversity, water quality and biodiversity, re-alignments, diversions (re-locations), piping and reclamation of a natural or semi-natural channel (including naturalised artificial watercourses) should be avoided in the first instance. It is not uncommon, however, that waterways have been straighten or diverted historically, and that there is a desire for further change in the location of the waterway in order that individuals and communities can achieve their economic or social aspirations.

In considering potential mitigation or offsets, it is important to consider the balance of values presented by the old and new channels. Does the new channel provide a greater area and diversity of habitat in a more natural form than the existing channel? If the new channel will provide less habitat area and diversity than the old, common in the case of further straightening, the result will be a net loss of ecological values. In addition, the shift to a proposed new channel with equal habitat area and diversity will still result in considerable potential for the mortality of fish and macroinvertebrates during construction. There will also be addition of considerable fine sediment to the stream (good erosion and sediment control practices may alleviate this) and the risk of failure to recreate a comparable ecosystem. In terms of ecological value, total offsetting of the impacts of the construction and healing phase will require the new stream channel to have a greater habitat area and diversity than the old channel to overcome the losses and risk associated with de-commissioning and construction.

Criteria for a positive project

A project with positive benefits for the environment will provide:

- An assessment of the current ecological values of the current waterway or wetland;
- A comprehensive erosion and sediment control plan;
- A fish salvage plan;
- A new waterway or wetland with greater habitat area and habitat diversity than the old habitat. This will include provision of channel features such as variable substrate size, undercuts, meanders, overhanging vegetation etc;
- Commitments to riparian and/or stormwater management conducive to the successful colonisation by fish and invertebrates of the new habitat; and
- Legal protection for any areas set aside for the benefit of the waterway or wetland.

Summary

Lowland streams and waterbodies, often created during historic wetland drainage, contain the remnants of the aquatic biodiversity of lowland Canterbury. However, there is a lack of firm guidance on appropriate management of these waterways within the LWRP, particularly in terms of the re-alignment, diversion, piping or reclamation. The provision and implementation of adequate policy and plan provisions addressing these impediments will make a significant contribution towards a 'step change in biodiversity'. This memo details the scientific justification for policy change.

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