LET'S GET OUR PRIORITIES STRAIGHT

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ABSTRACT
Water by Design is a capacity building program based in Brisbane, Australia that focuses on waterway health and aims to aid local governments and the development industry in the goal of transitioning to a water sensitive city. Water by Design's survey of the issues affecting waterway health reveal a very broad suite of problems to solve. This includes diffuse and point source pollution, hydrologic change, riparian disturbance, scour and erosion. With the recent implementation of stormwater pollution offsets schemes across Queensland there is a growing financial budget for waterway improvement projects. There are, however, many conflicting priorities. Waterway managers are faced with the problem of guessing what management actions (e.g. ESC (Erosion and Sediment Control), WSUD (Water Sensitive Urban Design), pollutant source control, stream rehabilitation, fish passage, etc.) are best for the environment and how social and economic considerations can be incorporated into the mix. A risk management approach is used to reframe the process to identify critical vulnerabilities. We also explore a number of prioritisation and decision support tools to try and narrow down the options. A 'threat–barrier' diagram is used to simplify the complex interactions between urban development and the natural environment. This paper also introduces an 'opportunity management' approach to maximise the potential benefits of any interventions.
Keywords: waterway, management, risk, opportunity, values, prioritisation, stormwater.

1 INTRODUCTION

The environmental problems of today are often caused by humans not living within their 'ecological' means. For example, issues such as climate change, resource depletion, pollution neutralisation are examples where we have exceeded the carrying capacity of our natural environment.

There *is* an economic solution to fix these problems but the price may be very unpalatable. So taking a pragmatic view it is recognised that in reality funding for environmental projects can be scarce and needs to be managed accordingly. This paper presents the case for reframing our priorities to invest the meagre funds we have into projects that maximise socio-ecological returns. We need to use our business acumen through judicious investing and management of our natural assets to improve and maintain their value.

Fundamental to this approach is a balanced and holistic appraisal of the state of our streams using a triple bottom line valuation and identification of key opportunities and threats.

1.1 Case study – Queensland stormwater management

Queensland has been blessed with outstanding natural assets including the world heritage listed Great Barrier Reef worth $6.4 billion a year to the Australian economy and supporting 39,000 direct jobs [1] and the Ramsar listed Moreton Bay off the coast of Brisbane which is home to abundant wildlife and recreation opportunities for residents.

In order to help protect these assets the Queensland Government regulates stormwater pollution discharge from all new developments. So far, our management interventions to protect and maintain values have been ad hoc across the state and mainly focuses on the 'fully developed' phase stormwater quality. Construction phase erosion control (a key threat) was often ineffective. Attempts have been made to regulate hydrology however these have been

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hit and miss. Stated in the Environmental Protection Act 1994 (Qld) is the need to Protect and Enhance waterway values. While there is much focus on protecting the waterways (and this is important because once biodiversity is gone it cannot easily be replaced) the need for enhancement of waterways is often side-lined. However perhaps the biggest relative gains (biodiversity, waterway health, social capital) can be achieved by enhancement works. Especially when a key habitat reconnection is constructed. Water by Design surveyed stormwater practitioners in 2014 and again in 2017 [2]. Major issues with the stormwater treatment industry include:

- There was little appreciation of the risk pathway; how a hazard comes to diminish waterway value.
- Industry focuses on a narrow band of hazards and values, as a result key risks are left unmitigated.
- Management actions are applied in a blanket 'one size fits all' application of stormwater regulations across the state and do not recognise the inherent variations and distribution of risk and value.
- Management actions were predominately risk focussed, as a result opportunities to enhance values were ignored.
- There were questions regarding the value for money with the current approach.
- Implementation of management actions was inconsistent.

In summary the problem is twofold; a lack of appreciation of the complexity of the system and very little effort to prioritise projects in order to maximise returns. Further detail about the State of the Art in Queensland with respect to stormwater and waterway management are provided throughout the rest of this document.

2 METHODOLOGY FOR UNDERSTANDING THE PROBLEM – THE VALUES MANAGEMENT APPROACH

This paper explores ways to *protect* values through risk management (e.g. water pollution/ waterways disturbance) and *enhance* values through opportunity management (e.g. habitat reinstatement/reconnection). This methodology can be described as a values management approach. It is a holistic/big picture planning approach with the underlying philosophy of maximising *effectiveness* and the *net return* of management actions and interventions. The values management approach requires three main disciplines of management:

- Risk management
- Opportunity management
- Maintenance of values

Who is this for? This values management framework will be useful for anyone who makes an investment in waterway health actions. Whether this be direct actions within the waterway (e.g. bank stabilisations) or indirectly (behaviour change programs). The paper outlines a process for maximising triple bottom line value for a given investment and would be of interest to:

- Local councils
- Land developers
- Land managers
- Transport/civil infrastructure project managers
- Water utilities
- Natural resource managers

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This framework is also important for industries that depend on waterway health for their income e.g. fishing and tourism. Although this paper was originally aimed at waterway managers and stormwater regulators it potentially has a broader application where risk/reward decisions are made. There may be transference of ideas or concepts into the broader risk management or environmental economics space.

How could it be implemented? In Queensland the stormwater regulations are set by the State Planning Policy (July 2017) this would be the natural place to make any policy amendments. Water by Design (WbD) currently has project to review this legislation so there is a window of opportunity to affect systemic change across the state.

It is envisaged that this new approach could complement existing regulations so that local councils have the opportunity to adopt these progressive regulations should they wish or otherwise more conservative councils can adopt a status quo approach of blanket stormwater regulation. There are existing frameworks that could be utilised (such as Living Waterways and stormwater offsets [X]) to help maximise return on investment.

The values management process can be broken down into six steps:

- Step 1 – Identify values
- Step 2 – Identify threats
- Step 3 – Understand the risk pathway
- Step 4 – Identify opportunities
- Step 5 – Identify available management actions – barriers
- Step 6 – Identify available management actions – bridges
- Step 7 – Prioritise management actions

The values management framework uses a threat–barrier/opportunity–bridge diagram to map the risk landscape as illustrated in Fig. 1.

3 STEP 1 – IDENTIFY VALUES

The first step in this approach is to identify values, i.e. what are we trying to protect? The Queensland Government regulates stormwater quality (in particular four parameters: TSS, TP, TN and Gross Pollutants) but it should be pointed out this is a just a surrogate for a much broader range of values. It has been as observed that the natural environment has flourishing ecosystems in a varying range of water quality types – both muddy and clean. So what are we really trying to protect? The **key point** here is that good (or appropriate) water quality underpins ecosystem function and biodiversity and *that* is the key environmental value we are trying to protect. Much work has been done on documenting ecosystem services and ecosystem values. Further information for South East Queensland can be found at the following website: www.ecosystemservicesseq.com.au.

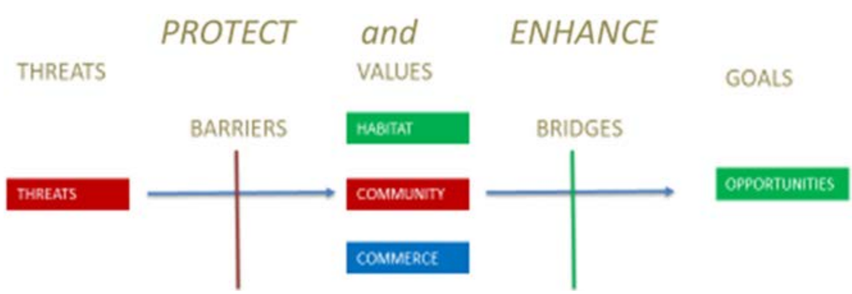

Figure 1: Threat–barrier/opportunity–bridge diagram.

For ease of explanation, values can be grouped into three categories: environmental, social and economic (i.e. the triple bottom line) (Table 1).

Typically in Queensland the State Government the focus of regulation is on water quality only. **Key point:** there is a much bigger array of values that need to be protected. A values management process is required to maximise a balanced mix the social, environmental and economic value of waterways.

4 STEP 2 – IDENTIFY THREATS

Once values have been established, the second step in this process is to identify threats to the values [3], [4]. There are a diverse range of threats to these waterway values including: pollutants, hydrologic change, disturbance and external threats. These are described in more detail in Table 2.

4.1 External threats (climate threats)

There is a fourth class of threats namely external threats or climate threats. These threats are typically out of the control of waterway managers and include climate change and natural disasters (e.g. droughts and floods, etc.).

Typically in Queensland we regulate stormwater only for Sediment, Nitrogen, Phosphorus and Gross Pollutants. Our management actions generally focus on these target pollutants and the assumption is that if we manage these items then we will have waterway health. This is not the case, waterways continue to degrade on our watch despite these interventions to filter stormwater discharge [XX]. Threats such as hydrologic change, disturbance and external threats however are under-regulated and often result in what we will be calling 'barrier bypass' e.g. the hazard bypasses the mitigation measure and attacks and diminishes the waterway values. **Key point:** there is a much bigger array of threats to ecosystem values that need to be considered.

Table 1: Waterway values.

Environmental values	Social values	Economic values
Waterways have intrinsic value in and of themselves Supports a healthy ecosystem	Cultural Recreational Spiritual	Fishing Drinking water Irrigation water Tourism

Table 2: Waterway threats.

Pollutants/toxicity	Hydrologic change	Disturbance
Sediment Phosphorus Nitrogen Gross pollutants Heavy metals Plastics Hydrocarbons Pesticides Physical parameters	Too much flow caused by urbanization Concentration of flow causing local impacts Redirection of flow – too dry in some areas too wet in others Impervious land leads to reduced infiltration of flow	Weeds Pest species Unintended public access Motor bikes, SUV's Livestock Clearing of riparian areas

5 STEP 3 – THE RISK PATHWAY

In order for a hazard to threaten a value there needs to be a number of steps that line up for this to occur as illustrated in Fig. 2. This is an important point as some practitioners confuse a hazard for a risk. If there is no connection between a hazard and a value then there is *no risk*. The first three steps in the risk pathway concern the nature of the hazard, the next two concern the spatial relationship between the hazard and the value and the last two elements concern the properties of the value. Management actions aim to break the risk pathway at any step.

6 THE TEMPORAL DIMENSION

6.1 Waterway value progression over time

The following figures track the waterway value (for example number of fish) with time. An important component of the values management process is value trajectory analysis. This is illustrated in Figs 3 and 4. There are generally three types of forces that act on waterway value trajectory including:

- *Negative forces* – slow and chronic degradation, acute threats and risks.
- *Neutral forces* – active protection of value from threats, continuous maintenance actions that keep the status quo.
- *Positive forces* – natural resilience, active intervention via key opportunities.

Unfortunately for most of our urban streams in Queensland (with a couple of notable exceptions) there seems to be only one trajectory – downwards. This typical trajectory is illustrated in Fig. 3. An analogy that may assist in visualising this is that of a stock (share) price for a company fluctuating over time.

6.2 Rate of change

Life can adapt, given enough time, to a surprising array of circumstances. **Key point:** more often than not it is not the change itself that is the problem but the rate of change. There are two time scales of threats:

- Acute threats – usually short sharp threats that leads to a step change. This can be considered as death by a single blow, e.g. floods.
- Chronic threats – usually change occurs over a longer period of time that leads to a gradual degradation. This can be considered as death by a thousand cuts, e.g. climate change.

Each type of threat needs to managed but managed differently. **Key point:** although proportional effort should be given according to a risk's degradation potential, one can

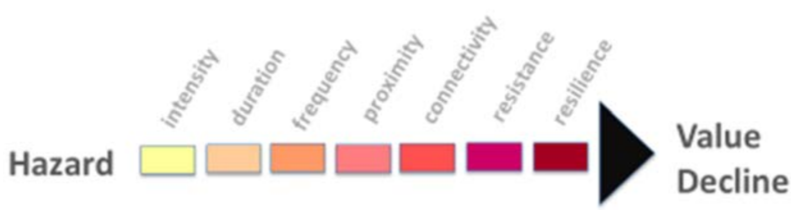

Figure 2: The risk pathway.

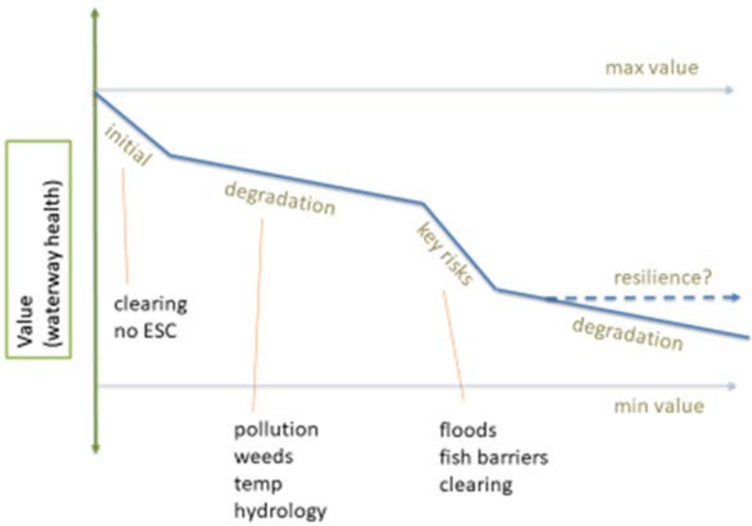

Figure 3: Waterway value – worst case scenario.

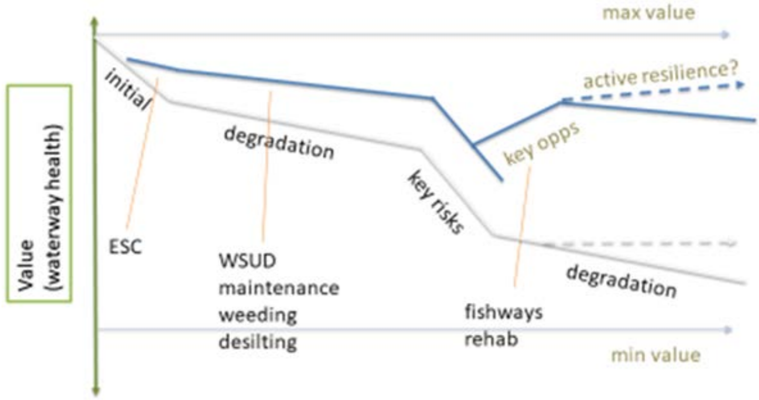

Figure 4: Waterway value – best case scenario (with intervention).

conclude that as a first priority we should be targeting acute threats and acute opportunities followed by chronic threats and opportunities. This point is reinforced by the example below.

6.3 Key fish needs

In essence, the ***key*** indicator of waterway health value for humans is the number of fish on the plate for dinner. Adopting the premise that the quantity of fish and seafood is the key indicator of waterway value, what can be done to maximise these fish stocks? Let's examine fish needs in more detail and apply the Maslow's Hierarchy of Needs model.

Fig. 5 helps to develop the idea of acute and chronic risks further. As you move up the triangle it denotes the survival timescale (i.e. minutes/weeks/years/single generations/ multiple generations) for each parameter. Acute threats are at the bottom and more chronic

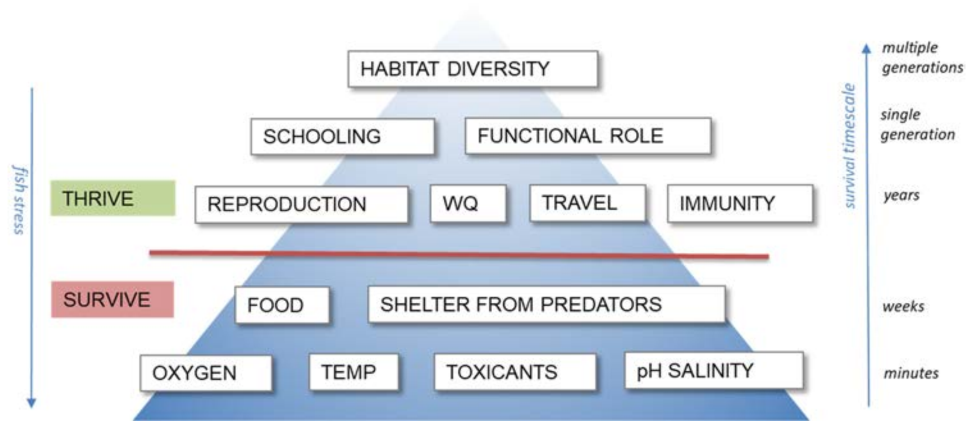

Figure 5: Maslow's Hierarchy of Needs for fish.

threats are towards the top. To give an example of an acute threat, lack of dissolved oxygen can create immediate fish kills. **Key point:** while Water Quality (WQ) parameters such as Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) are important, particularly in creeks and streams, their presence in our waterways is not as critical to fish survival as other parameters. In fact, in the open ocean TSS, TP and TN are often managed by sedimentation and microorganisms and are not such a problem at all.

7 THE SPATIAL DIMENSION

In order for a hazard to compromise a value it needs to be proximal and there needs to be a connection (for example a flow path). It is not always possible to separate a hazard from a value in practice. **Key point:** the distribution of risks and values throughout the catchment is not homogenous (Fig. 6) nor should it be treated as such. The current stormwater management regulations in Qld however apply a 'one size fits all' approach to stormwater treatment that fails to recognise the inherent variation in hazards and values across the catchment. It is also important to note that the insertion point of the hazard within the catchment. Due to increased contact time a hazard released in the upper catchment has the potential to do more damage than a hazard released at the river mouth reinforcing the need to understand the risk pathway.

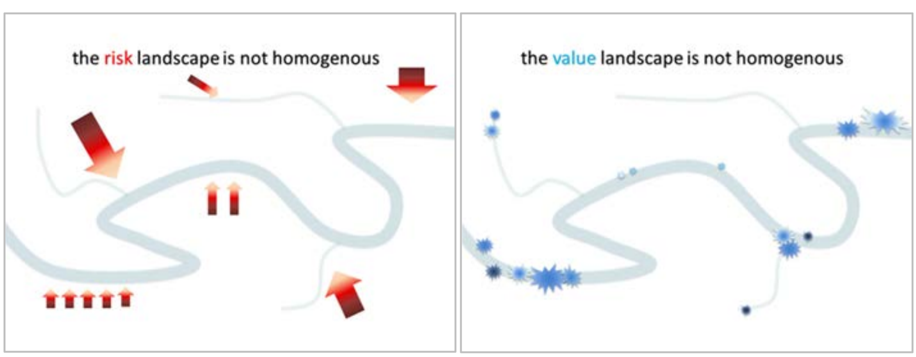

Figure 6: Spatial distribution of hazards and values.

8 THE RESILIENCE DIMENSION – VALUE RESISTANCE AND RECOVERY

External threats (such as natural disasters and climate change) are often beyond the scope of the waterway manager to control. The 2011 Brisbane River Flood released a massive amount of sediment and pollution to the local waterways. This is the elephant in the room that is not talked about in the stormwater management industry. The industry spends a lot of effort on chronic risks and little investment in comparison to this acute risk. **Key point:** These acute risks can contribute to a potentially greater loss in waterway value compared to chronic risks. Applying the risk pathway understanding developed in Fig. 2, one tactic might be to fortify the value, for example a heavily rock armoured river bank will be more resistant to scour caused by flooding than a lesser protected bank. However this is not always cost effective or desirable.

Another tactic to respond to the flooding threat is to invest in 'clean catchment' technologies, these include pollutant source control as well as filtering. However our ability to completely control the pollution threats in a big flood event is limited.

So what else can we do about these unpredictable acute threats? Resilience is essentially the ability of a system to bounce back and or adapt after a significant disturbance. This is one advantage of natural systems over man-made systems; through propagation and reproduction, natural systems can self-restore.

It is noted that there are two types of resilience:

- Natural resilience – given enough time nature will find a way to neutralise the threat and adapt to the prevailing conditions. Factors that contribute to natural resilience include clean inputs (e.g. water, air, soil, etc.), biodiversity, functional ecosystem, connectedness and recovery time.
- Active resilience – human assisted resilience through adaptive management and catalisation.

Much work has been undertaken in understanding how resilience works. The Stockholm Resilience Centre has outlined seven key principles for building (active) resilient socio-ecological systems. They include:

1. Diversity and redundancy
2. Manage connectivity
3. Manage slow variables
4. Foster adaptive thinking
5. Encourage learning
6. Broaden participation
7. Promote polycentric governance

Fig. 7 illustrates how these factors fit into the adaptive pathway. More information can be found on the Stockholm Resilience Centre website [5].

8.1.1 Thresholds – change of state

There needs to be acknowledgement that some threats can be the catalyst for ecosystem collapse and that the consequences aren't always linear and proportional to the threat [6].

Some effort needs to be undertaken in order to understand the economic value of resilience within an ecological system. Once this is known trade-offs between projects can start to be made and would encourage investments in making resilient systems and also removing the impediments to resilience. Once systems are in a resilient state then investment can possibly be tapered off.

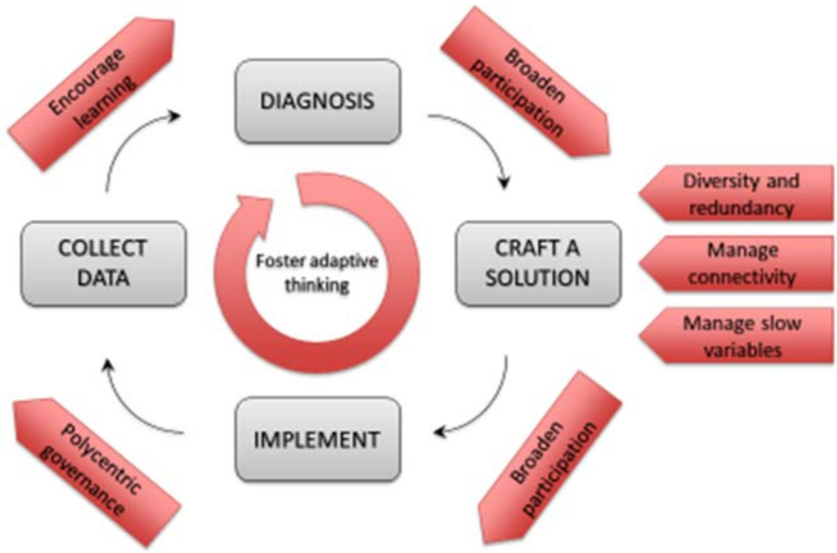

Figure 7: Resilient adaptive systems.

It is important to understanding the future trajectory of a waterway. The natural resilience of a given system may be so strong that it can restore itself to equilibrium regardless of management intervention. Alternatively the reverse may be true, the system may be so fragile that the slightest disturbance may cause irreversible loss of value. **Key point:** this is an area that needs more scientific research and usually depends on the local parameters of a given river.

9 STEP 3 – RISK MANAGEMENT

9.1 Barriers

Management actions are interventions that aim to eliminate, mitigate or offset a threat to any given waterway value. The term 'barriers' is used to denote a management action that blocks a risk from attacking a value. Barriers come in a variety of forms, they can generally be grouped into three categories: avoidance, mitigation and offsets (Table 3). Barriers can intercept a hazard along any point in the risk pathway (Figs 2 and 8).

The closer the threat comes to the value (i.e. waterway) the less control there is (refer to Section 10.4 – the spatial dimension). Priority should be given firstly to avoidance or source control. Since total elimination of threats is typically very hard to achieve there is a role for

Table 3: Common risk barriers.

Avoidance	Mitigation	Offsets
Land management Riparian fencing Source control e.g. green roofs Permeable paving Stormwater harvesting	Dams Detention basins Sediment basins Wetlands Bioretention basins	Rehabilitation Sediment removal from creeks Weed eradication Pest eradication

Figure 8: Threat–barrier diagram.

mitigation measures such as constructed wetlands and bioretention basins. Once an offset is in place it is acknowledged that there is damage to the environment. In certain circumstances this may be perfectly acceptable if greater gains can be made for the same amount of money elsewhere.

9.2 Threat–barrier diagram

A threat–barrier diagram (Fig. 8) is a simple visualisation tool that illustrates the risk landscape and catalogues the potential management actions (i.e. barriers). It can help the waterway manager to quickly identify threat pathways and barrier redundancies [3].

Fig. 9 illustrates how a complex array of risks, values and management actions can be mapped using a threat–barrier diagram. Also highlighted in the figure is the current focus of stormwater regulations in QLD, it operates on a very limited array of hazards (TSS, TP and TN) and results in implementation of a limited array of management actions (bioretention and GPTs) typically.

9.2.1 Barrier bypass

Two threats (natural disasters and climate change) can in effect bypass many of our pollution mitigation measures (e.g. bioretention) and affect waterway values (Fig. 10). The best example of this is with the management of coral reefs; there is a big push to improve water quality in reef catchments. While this is definitely a high priority it is not the complete picture. Should climate change continue on its current trajectory it may result in ocean acidification or bleaching and destruction of the reef. In this way we need a holistic picture of the risks to a given asset, otherwise all our efforts may be in vain. It is worth noting that while we may not be able to address climate change impacts completely, with a concerted effort on many fronts we may buy enough time to facilitate ecosystem adaptation.

As mentioned previously there are three forces that act upon a natural system; negative forces (e.g. degradation), neutral forces (e.g. maintenance) and positive forces (e.g. resilience). Whilst humans are one of the main causes of degradation we also have the ability to arrest it. We also have ability to promote and enhance natural resilience.

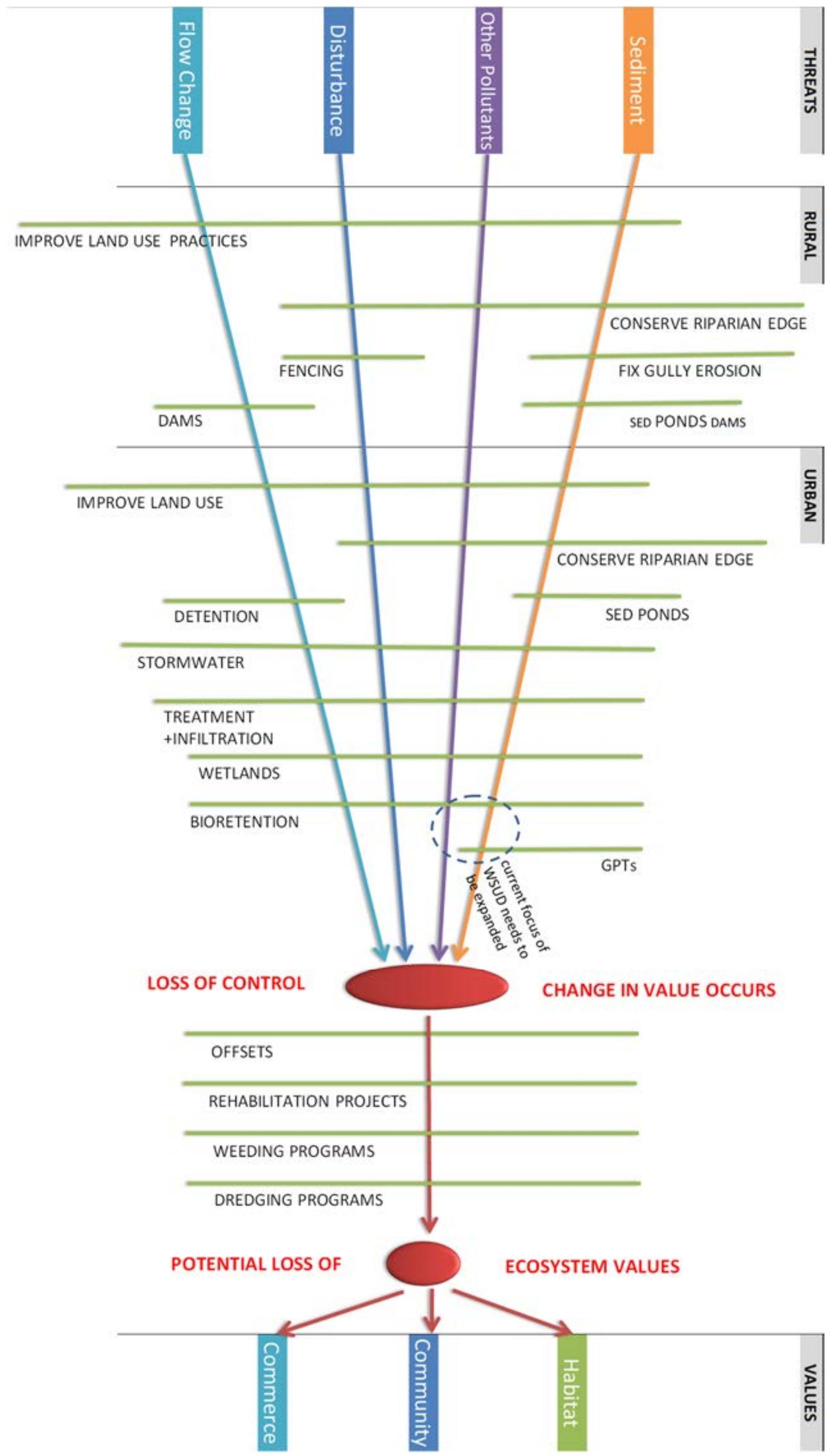

Figure 9: Threat–barrier diagram.

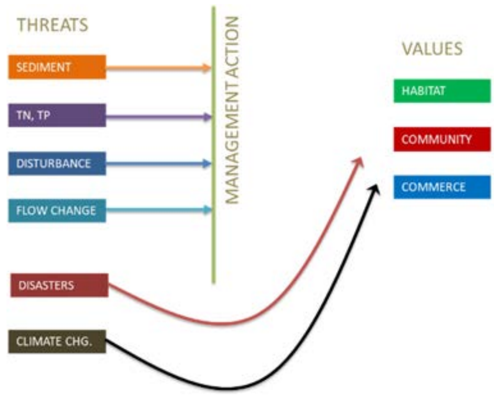

Figure 10: Barrier bypass.

10 STEP 4 – IDENTIFY OPPORTUNITIES

It is important to note that the values management process is different from risk management in that it considers the benefits (rewards) from implementing opportunities equally to value diminishment caused by threats (risks). To give an example, there may be greater merit in letting a portion of creek slowly degrade due to a *risk* (e.g. diminishing water quality) and reinvest money elsewhere in the catchment via an *opportunity* (e.g. reconnect habitats). Risk management has a very strong focus on hazards, whereas opportunity management has a very strong focus on the values themselves.

There is potential for opportunity management to be a counter balance to excessive risk management and encourage the same amount of effort applied to weigh up opportunities that are normally out of scope for a given project. For example a highway project generally has a single focus to mitigate threats to the environment (e.g. through spill containment basins). But very often there are potential environmental opportunities that are missed and could potentially have bigger environmental gains (e.g. stormwater harvesting and reuse schemes) than a given risk mitigation part of the project as was the case for the Gateway Upgrade Project in Brisbane. Both risks and opportunities should be evaluated and treated equally.

Opportunities should not be executed on an ad hoc basis, they need to part of the planned goal or vision for a waterway. Opportunities enhance the waterway value towards that vision.

Opportunities can be grouped under the categories of environmental, social and economic opportunities. They are usually stated as a goal, for example in Singapore they have an ABC (Activate, Beautify, and Cleanse) program for waterways. This is generally a good starting point. Another goal to round out the triple bottom line analysis is to enhance economic productivity.

It is noted that there is currently a legislated driver for risk management through the SPP however there is not the same regulation driving investment in opportunity management. This is an understandable, but serious gap in the industry. There is little appetite to invest in a values enhancement based approach where there is only an environmental return on investment. There needs to be economic research into this aspect so that the environmental returns can be quantified and converted to economic terms and help drive investment in these values enhancement based approaches. This is a major finding of this investigation into the industry.

11 OPPORTUNITY MANAGEMENT

11.1 Bridges

It is important to remember that there is a diverse number of values associated with waterways. There are many potential waterway enhancement opportunities and various opportunities may apply to one value and not another. The term 'bridge' is used to refer to a management action that *connects* a value to an opportunity which then enhances to overall waterway value. In general, opportunities (e.g. habitat reinstatement) need to be connected to an existing value base (e.g. environmental areas) for it to succeed. The 'build it and they will come' philosophy may not work in a literal or metaphorical desert. And this is not an *effective* use of resources. Opportunity implementation should ideally be a positive catalyst for a greater increase of value than just the sum of the parts for example by reconnecting two habitat areas both areas become healthier and more resilient. Examples of bridges are listed in Table 4.

In order to catalogue and capture all available opportunities, a similar approach to the risk management process could be employed, i.e. opportunity registers and analysis spreadsheets could be created for a given project.

11.2 Opportunity–bridge diagram

Mirroring the threat–barrier diagram used in the risk management process above (refer to Section 9.2), we can apply this same logic to map out opportunities and 'bridges' (management actions that connect a management action to a value and future goal) (Fig. 11).

11.3 Further analysis of opportunity management

Further analysis of opportunities needs to be undertaken in order to realise an opportunity.

11.3.1 Likelihood

The temporal dimension (refer Section 5)
Similarly to risk management there is a temporal dimension to opportunity management. Using similar terminology let's call these acute opportunities and chronic opportunities.

- Short term (acute) opportunities e.g. fish barrier removal
- Long term (chronic) opportunities e.g. education of school children about ecology
- Time for take up

11.3.2 Impact

The spatial dimension (refer Section 6)

- Proximity of opportunity to a need

The resilience dimension (refer Section 7)

- Recovery potential of value – **natural resilience**
- Catalisation of positive behaviour change (this relies on adaptive systems that utilise continuous learning and adaptive feedback loops) – **active resilience**

The human dimension (refer Section 9)

- Success of implementation depends on social capacity:

- Willingness
- Ability

As with risk management, it is worth studying the opportunity pathway. All the steps outlined must be undertaken in order to implement an opportunity (e.g. habitat restoration) (Fig. 12).

11.3.3 The human dimension – management effectiveness

The success of a given management action relies on a whole series of factors as described in Fig. 13. In general it is recognised for someone to adopt a positive behaviour two factors must be in place; willingness and ability. Willingness can be fostered through encouragement and enforcement. Ability is fostered through education and capacity building.

12 PRIORITISATION TOOLS – SOLUTIONS

Due to the ongoing collection of funds from stormwater offsets programs in Queensland, there is an increasing budget for waterway management actions. The problem facing waterway managers is where to invest to maximise triple bottom line waterway value. Traditionally a risk mitigation has been the primary focus but these efforts have been focused on a couple of water quality parameters (e.g. TP, TN and TSS). But by taking a holistic view there is the possibility to greatly expand the potential impact on the triple bottom line.

Taking a holistic values management approach involves looking at both risks and opportunities in a balanced manner. Four possible prioritisation tools are briefly described below to help waterway managers to select the best management action and include:

1. Hierarchy of Control
2. Cost Benefit Analysis
3. Strategic Planning
4. Triage

Table 4: Common opportunity bridges.

Environmental	Social	Economic
Fish passage Habitat reinstatement Rehabilitation Reinstate hydrology	Stewardship programs Education and appreciation Amenity Active and passive recreation	Lifecycle analysis Circular economy Increased tourism access

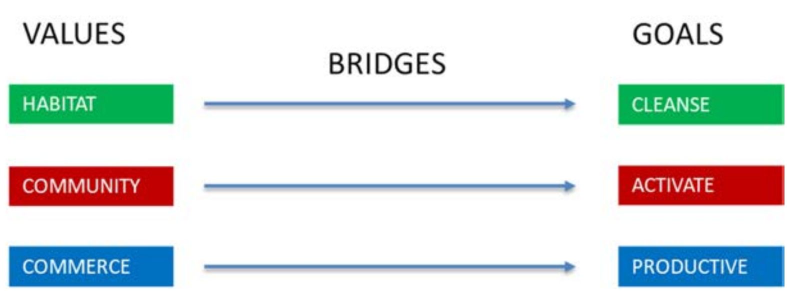

Figure 11: Opportunity–bridge diagram.

Figure 12: The opportunity pathway.

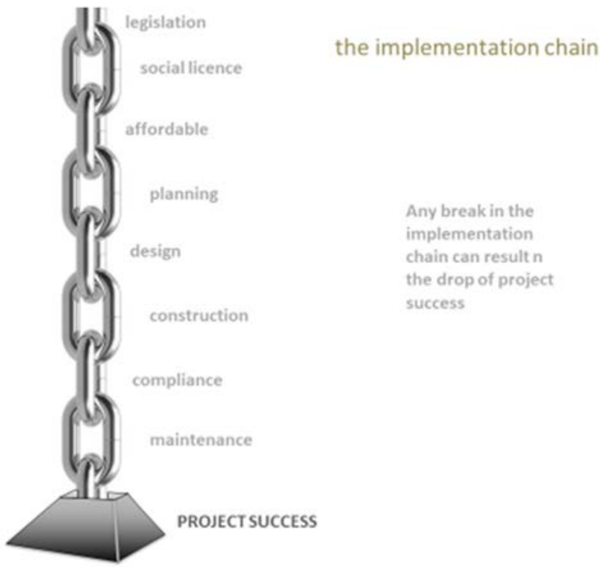

Figure 13: The implementation chain.

12.1 Hierarchy of Control

The Hierarchy of Control is typically used in safety engineering but can equally be applied in this instance to prioritise threat neutralisation measures. A simplified diagram is presented in Fig. 14.

In this example there are three classes of risk mitigation including:

- Eliminate threat – e.g. avoid clearing and development of the catchment.
- Engineer a barrier – e.g. install a bioretention basin or pollution mitigation device.
- Behaviour change – e.g. pollution reduction education programs.

It is noted that typically in Queensland the 'engineer a barrier' approach used to mitigate stormwater pollution impacts. It could be argued that more effort needs to be placed on eliminating the threat. The failing of the Hierarchy of Control is that it does not take into account the economic cost of each protection measure. This is where a Cost Benefit Analysis can be used as outlined below.

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12.2 Cost Benefit Analysis

The Cost Benefit Analysis is commonly used for a diverse range of business applications so this paper will not go into great detail except to say that this prioritisation tool is very good at maximising the return on a given economic investment (i.e. biggest bang for buck).

Fig. 15 ranks a variety of sediment management actions according to the cost for each unit of sediment removed from stormwater. From this information the waterway manager can quickly decide which is the cheapest method for removing sediment from stormwater discharge.

Key point: the problem with this approach is that it reduces the analysis down to a couple of variables: cost and sediment. Using this approach is very one dimensional and can result in barrier bypass. As illustrated by the threat–barrier diagram Fig. 9, there is a diverse array of threats there are also a diverse array of values to protect. This approach also totally ignores co-benefits and potential opportunities provided by the values management approach.

In Queensland it should be noted that while protection measures in stormwater regulations (i.e. risk mitigation) are mandated, opportunities are executed only on an opportunistic basis.

In an effort to introduce some '*positive forces*' to increase waterway value some tools are presented below to maximise opportunities.

12.3 Strategic Planning– needs analysis

As mentioned previously in Section 7 there is a spatial dimension to risk and opportunity management and it is acknowledged that these factors are not distributed homogeneously throughout the catchment. Not all parts of the catchment are equal. Both factors rely heavily on proximity and risk/reward pathways. For example hydrologic change induced by a development will have no impact if stormwater discharges to the open ocean however it may have catastrophic consequences if it discharges to a steep, unlined, unvegetated waterway with fragile soils. So for this reason it is crucial to map adjacencies and understand risk pathways.

Key Point: the state government has blanket stormwater regulations across the state. Very little strategic planning is in place to analyse adjacencies and determine what key risks or opportunities are relevant. Offsets programs are useful in diverting funds to where it is needed most.

Figure 14: Hierarchy of Control.

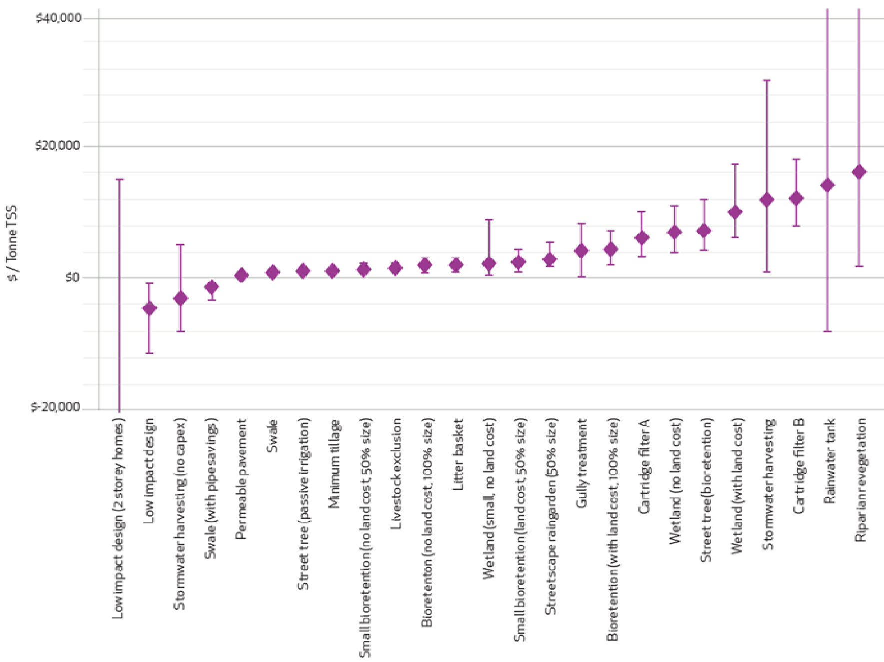

Figure 15: Marginal cost abatement curve. *(Source: Water by Design 2014 [8].)*

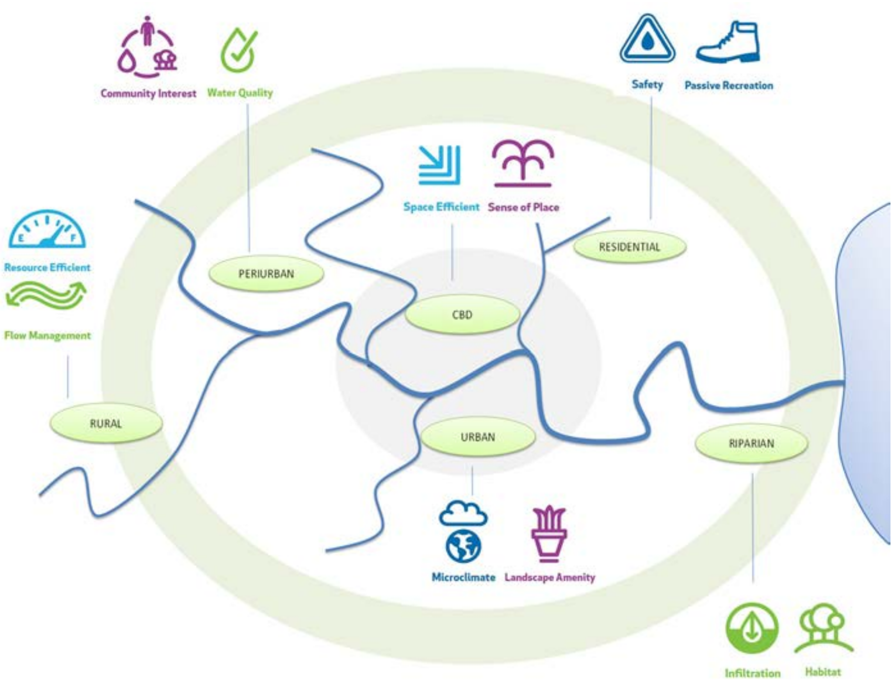

Figure 16: Identification of key needs throughout the catchment.

12.4 Mapping risks and opportunities

The suggested process for mapping spatial variance is to identify *critical adjacencies* via mapping of areas of key values, key hazards and key opportunities. These layers can then be overlain to create a heat map. **Hot spots** would indicate *critical vulnerabilities*. For example if a high value area was next to a high hazard area (e.g. a remnant wetland is adjacent to a future industrial development) then this would indicate a hotspot. **Cold spots** would indicate *critical opportunities*. For example if a waterway of value was adjacent to an area with a particular waterway need (e.g. fish passage installation to connect habitats or stormwater generator and stormwater demand) then this would constitute a cold spot. This information could then be used to map out and identify key bridges and barriers for a given catchment.

12.5 Triage – do we build a bridge or a barrier?

The focus of this prioritisation tool is to direct effort or investment to where it will create the biggest holistic impact in value. This approach borrows from the medical emergency response tactics where there are limited resources. Instead of focusing on patients (i.e. rivers) that will survive regardless of treatment or patients (i.e. rivers) that will die regardless of treatment; effort is focused on actions that will arrest a spiral out of control and other lifesaving operations. In this application of the tool four categories are used including; protect, correct, resurrect and neglect.

Fig. 18 further examines the difference in waterway value with and without intervention. An intervention is considered to be either via protection from threats (barrier) or enhancement via opportunity implementation (bridge). The goal of the waterway manager should be to **maximise the *net* benefit** (i.e. the difference between value scores with and without intervention) this takes into account continuing degradation and natural resilience [7].

Key assumptions:

- It is assumed that a given waterway has a maximum value (i.e. ceiling) therefore intervention at this point will not increase waterway value past this point.
- Degradation is initiated by a continuing disturbance, once this is removed natural resilience will start to restore the value.
- It is assumed that once degraded sufficiently no amount of rehabilitation will fully restore a stream to its original condition, i.e. once biodiversity is lost, it is lost.
- It is assumed that a stream condition will degrade over time to a fixed condition due to pressures (i.e. there is a lower floor level) and further degradation will not destroy any more value for this waterway.

Inferences:

- Priority should be given to removing degradation forces from the protect category only – any additional effort to enhance value is wasted and money should be reinvested in correct or resurrect categories only.
- The focus of the correct category should be to remove acute and chronic degradation and allow resilience to restore waterway value and to a lesser extent implement enhancement works.
- The focus of the resurrect category is to reconnect key habitat areas (or social values) (i.e. acute opportunities) and to a lesser extent to remove acute and chronic degradation.

13 THE FOCUS OF THE NEGLECT CATEGORY WOULD BE TO DIVERT FUNDING TO OTHER CATEGORIES [8]. THE LIVING WATERWAYS FRAMEWORK

The ultimate goal of waterway managers is to create living dynamic waterways with socio ecological processes all working in harmony. The Living Waterways Framework was developed by Water by Design in 2014 and is a scorecard that evaluates a proposed stormwater management plan and allows flexibility and trade-offs in water quality controls between multiple categories. It aims to provide balanced solution and can also be used to compare and prioritise projects in order to get the most holistic benefit.

The original version [9] of the scorecard is available via the link: http://hlw.org.au/u/lib/mob/20141010122444_0e4b3b2743623768a/2014_livingwaterwaysscoring-9mb.pdf.

The Living Waterways Framework covers the major risks to waterways with a range of possible ‘barriers’. It also contains a number of elements that if implemented can constitute ‘bridges’ to achieve a certain goal. Water by Design are currently working on Version 2 of this document [10]. This document will be made available online in a user-friendly web

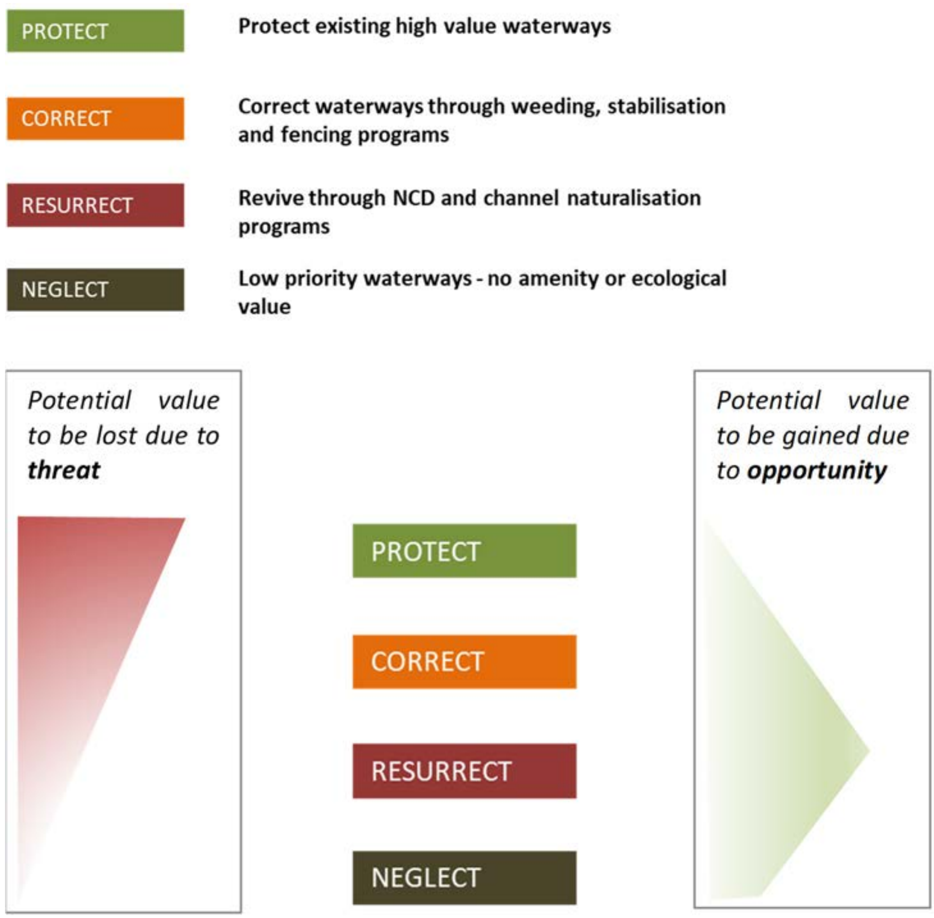

Figure 17: Triage framework.

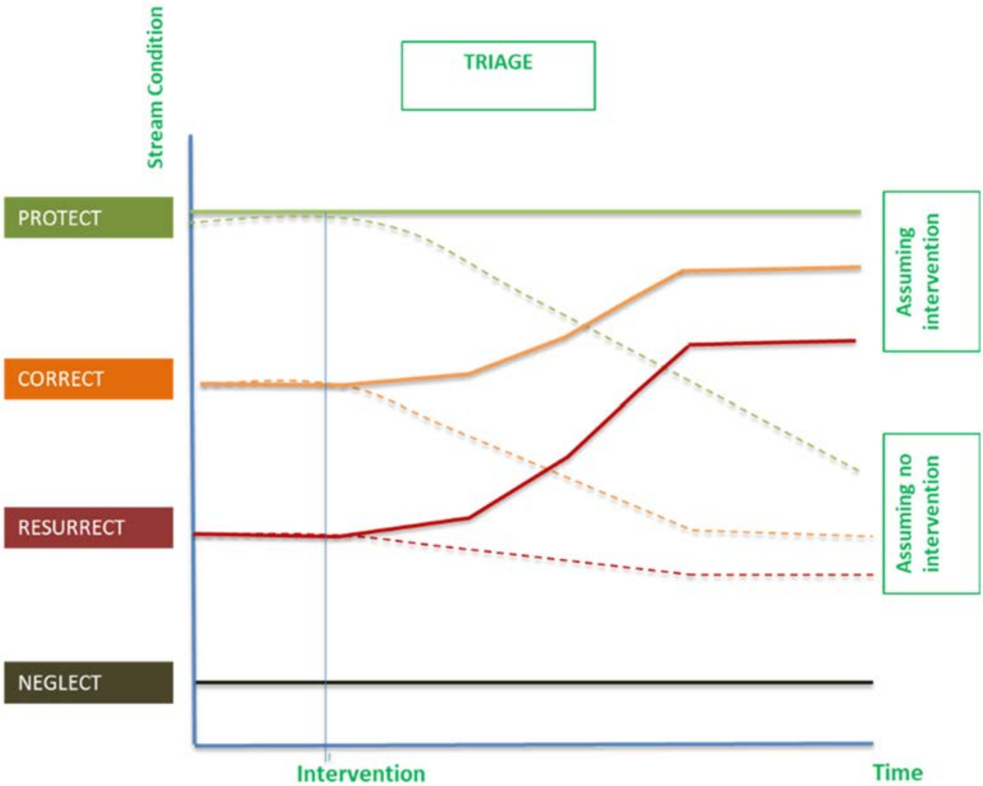

Figure 18: Assessment of intervention value over time.

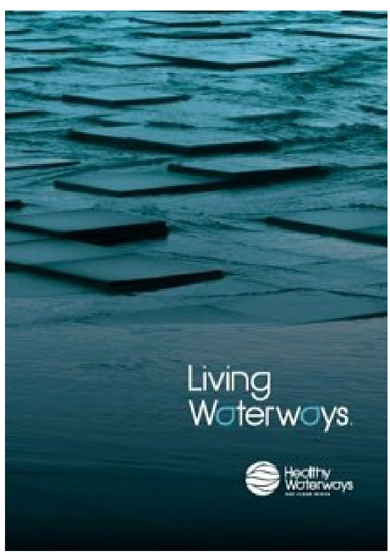

Figure 19: Living Waterways Framework.

calculator. The new version (v2.1) contains a resilience module, a waterway health module and a strategic planning module. A Beta version is available via the link below.

13.1 http://hlw.org.au/u/lib/cms/living-waterways-version-2a-beta-180419.xlsx strategic planning module

The strategic planning module in Living Waterways Version 2.0 combines elements of triage and strategic planning and allows local councils to assess a given project on a range of risk/ opportunity variables. The process is outlined below:

Step 1 - Critical adjacencies

- Inspect – GIS mapping of catchment's opportunities, values and risks

Step 2 – Risk analysis

- Protect – ensure key threats are managed
- Correct – correct small issues that may spiral into bigger problems
- Accept – accept slow degradation and invest elsewhere

Step 3 – Opportunity analysis

- Resurrect – revive stream completely through channel naturalisation or daylighting
- Reconnect – reconnect key habitat areas or recreational uses
- Respect – encourage stewardship program
- Neglect – ignore opportunities and invest elsewhere

14 MAINTENANCE OF VALUES

Unless a given waterway is pristine with no threats or degrading pressures in the catchment then it is likely that some continuous maintenance is needed to sustain current waterway values and counter constant degradation. Maintenance tasks might include:

- Weed/pest removal
- Bank and bed stabilisation
- Sediment removal
- Removal of significant blockages from culverts, etc.
- Repair disturbed areas
- Clean up spills/litter

Typically maintenance programs are often reactive and mainly based on needs of infrastructure (clearing sediment build-up from culverts and footpaths, etc.). This definition of waterway function needs to be broadened and incorporate ecological needs as well.

14.1 Asset registers

Much can be learned from public works asset managers, the same thinking for 'grey assets' can be applied to managing and maintaining 'green assets'. For example an asset register may contain various categories of waterways and for each waterway there would be details of:

- Extent of service
- Type of service
- Level of service

If at all possible, the root cause of a degradation issue needs to be addressed. In this regard, time and effort need to be invested into understanding the risk pathways. In many cases though we cannot hope to completely fix issues at their core so we need to invest in constant treatment of the symptoms. A small amount of continuous effort can reduce the need for vastly greater job later on, for example early removal of weeds can stop them spreading further throughout the catchment and creating a much bigger issue later on.

There is much more to be considered in the field of maintenance of waterway values however this will likely be the subject of future studies by the author.

15 CONCLUSIONS

Through stakeholder research this paper has identified two key problems with the stormwater management regulations; a lack of appreciation of the complexity of the risk/value landscape and an almost apathy towards investing in locations where there are priority hotspots (critical adjacencies) in order to maximise the net return on investment. To address these issues, this paper has presented a Values Management Framework for waterways. To maintain and enhance values, three key areas must be addressed namely risk, opportunity and maintenance. It is also important to recognise the temporal, spatial, resilience and human dimensions to this analysis. A number of tools have been suggested to help waterway managers prioritise catchment works including Hierarchy of Control, Cost Benefit Analysis, Strategic Planning and Triage. It is suggested that the Living Waterways Framework is used as a basis for assessing development plans.

15.1 Recommendations

The following are suggestions for possible modifications to Queensland’s waterway management policies (refer also Fig. 20):

1. Recognise a broader range of values and threats
2. Map values, threats and opportunities
3. Understand risk/reward pathways
4. Identify critical vulnerabilities and hot/cold spots
5. Use a triage approach and focus on increasing the *net positive* benefit (i.e. difference in value with and without intervention)
6. Promote offsets – redistribute funds to where it is needed most
7. Allow trade-offs between risks and opportunities to maximise potential benefits – a flexible framework such as Living Waterways may help
8. As a priority, address acute threats to waterway health (e.g. floods, DO, toxicity)
9. Where possible avoid impact in the first place as it is much harder to return the waterway to original condition

15.2 Further research

There are three main components to a waterway management program. Further research is required in the following areas (refer also Fig. 20):

- Understanding the issues in the catchment
  - Understand risk and opportunity pathways
  - Understand thresholds and catalysers
  - Understanding the resilience of a given waterway

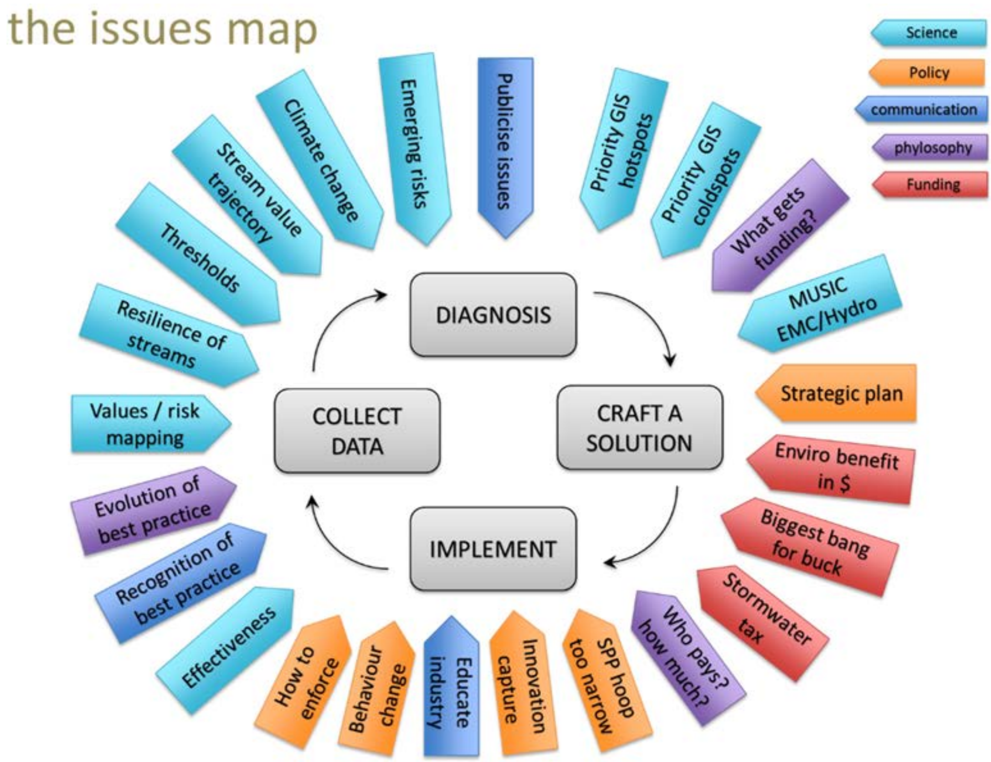

Figure 20: Issues summary.

- Crafting a solution
  - Economic analysis of cost/benefits of particular management actions
- Executing the project
  - Create an effective governance structure
  - Adaptive management – continuous learning and feedback loops – valuation of this quality – gives an insight into the health of the river
  - Understanding influence pathways for the human dimension

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