Combining rapid field assessment with a Bayesian network to prioritise investment in watercourse protection

Brett Bryan[1] and Michael Garrod[2]

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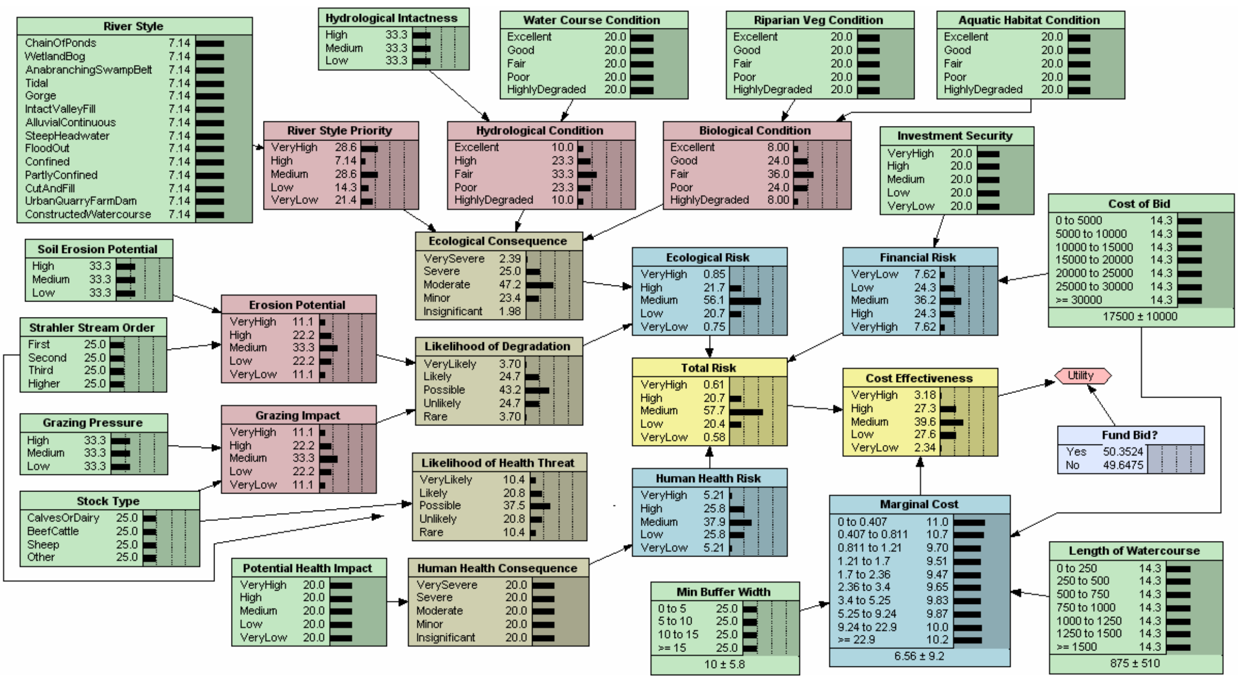

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Executive Summary

This project is a small addendum to the Catchment Care auction project (Bryan et al. 2005) - a collaborative project between the Onkaparinga Catchment Water Management Board and CSIRO Land and Water, funded under Round 1 of the National MBI Pilot Program. This project extends this collaboration between CLW and OCWMB (now the Adelaide and Mt. Lofty Ranges Natural Resource Management Board (AMLR NRM Board)).

The aim of this project is to develop a rapid field assessment protocol and an associated technique for prioritising and selecting landholder bids in an auction to protect high priority water courses from livestock in the AMLR NRM Board region. We adapt and enhance the field assessment protocol and the bid ranking and selection algorithm developed in Catchment Care (Bryan et al. 2005) for prioritising landholder bids for funds predominantly to support fencing activities in high priority water courses.

The rapid field assessment protocol involves the scoring of 14 characters describing various aspects of the type and condition of the geomorphology, hydrology, and biodiversity of the proposed water course, and the nature of the bid including the length of the watercourse protected and the buffer width, the cost and the perceived security of the investment. A risk assessment framework based on the Australian Standard for risk assessment is then used to integrate this diverse set of data to assist in prioritising investment in fencing activities in the AMLR NRM region. A Bayesian decision network is used to implement the risk assessment using the data from the 14 rapid field assessment protocol characters. The Bayesian decision network is able to support the investment decision of the AMLR NRM Board by calculating the confidence with which the decision to fund each bid can be made based upon the cost effectiveness of each bid. Multiple bids can be processed and ranked based on this decision strength. Bids can then be ranked and funded until the available funds are exhausted or until a *reserve price* is breached.

The rapid field assessment protocol combined with the Bayesian decision network works well in simulation but needs to be trialled in the field. It is likely that further refinements will need to be made.

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1. Introduction

This small project was undertaken as an addendum to the Catchment Care auction project funded under the National Market Based Instruments Pilot Program Round 1. Catchment Care was a collaborative project between the Onkaparinga Catchment Water Management Board and CSIRO Land and Water.

In the Catchment Care auction landholders bid for funds to undertake private, on-ground natural resource management works such as fencing off areas from stock, vegetation management and revegetation (Bryan et al. 2005). Landholder bids are ranked based on a risk assessment methodology. Risk is calculated based on a set of characters that are scored in the field or from a Geographic Information System database. Each character is designated either as an environmental value character, or a threat character, depending on the nature of the character. Risk is calculated by multiplying threat character scores by the relevant environmental value character scores and summing over all threats. Landholder bids are ranked by cost effectiveness calculated as environmental benefits per dollar based on several considerations including:

- the environmental risk of the site
- the level of threat reduction achieved by the landholder action
- the magnitude of the landholder action
- the cost to the agency

The most cost effective bids are selected for funding in order in Catchment Care until the funding is exhausted. Bryan et al. (2005) present a full description of this method of investment prioritisation.

Whilst the bid prioritisation process worked reasonably well, there were several problems identified with both the Catchment Care characters and the bid prioritisation method. First, there was some bias remaining in the algorithm even after comprehensive testing using Monte Carlo simulation. This resulted in the preferential selection of bids that involved patrolling for weeds over a large area of native vegetation in relatively good condition. Second, the fit of characters into the risk assessment framework as either environmental value or threat characters was never a natural fit. Third, there was no consideration of uncertainty in field assessment and no capacity to consider uncertainty in the bid prioritisation process. Lastly, the perceived security of investment was not considered. For example, all else being equal, it was not possible to prioritise one bid over another based on the likelihood of underperformance, skill in natural resource management, or potential for moral hazard.

Another auction targeting fencing as a single issue is being developed in the AMLR NRM Board region as a spin off from the Catchment Care auction. The grazing of livestock including beef cattle, dairy cattle, sheep and other animals (alpacas, goats, deer etc.) has a significant environmental impact in the AMLR NRM region. These impacts include increased soil erosion along watercourses, the degradation of riparian biodiversity and aquatic habitat, and the introduction of pathogens (*Escherichia Coli*, *Cryptospiridium* etc.) into waterways and storages. The objective of the fencing auction is the mitigation of these impacts by livestock through exclusion of livestock from high priority sites. In the fencing auction, landholders submit bids for funds to support fencing activities to exclude livestock from specific watercourses on their property. In a strong market for these conservation contracts, demand for fencing funds should exceed the available funds. This provides scope for prioritising bids and selecting the most cost effective bids for funding and rejecting those bids that offer poor value for money. Through this process significantly greater environmental benefits can be achieved for the available funding (Bryan et al. 2005, Connor et al. 2006).

The aim of this small research project is to adapt and enhance the Catchment Care bid prioritisation process and develop a method for assessing, scoring and prioritising landholder bids in an auction to address erosion, biodiversity, and human health objectives in the AMLR

NRM region. To achieve this we first design a rapid field assessment protocol. This involves the scoring of various characters including several aspects of the biophysical nature and condition of the proposed site and properties of the bid including cost, security of investment, length of watercourse, and buffer width. Secondly, we combine these characters using a risk assessment framework in a Bayesian network. The Bayesian network provides probabilistic information supporting the decision of whether to fund each bid or not and this can be used to rank and select the most attractive bids.

2. Site Assessment Protocol

The intent of the Riparian Fencing Auction is to deliver cost effective incentives to landholders who own watercourses that are impacted by stock, in order that they may take steps to ameliorate those impacts by restricting/excluding stock access to the watercourse. The stock impacts include physical/mechanical impacts on the stability of the watercourse (e.g. pugging, trampling, grazing) resulting in watercourse channel instability, and increased sediment and nutrient inputs to the watercourse. An additional objective is to ameliorate the movement of largely faeces borne pathogens into the watercourse. We aim to preferentially protect from stock those watercourses that represent good quality remnant riparian vegetation, good quality aquatic habitat (for fish, frogs, macro-invertebrates etc.), as well as those watercourses where significant sediment, nutrient, and pathogen inputs to watercourses could be reduced through the exclusion of stock.

With the above aims in mind a rapid site assessment protocol was developed. This involved the construction of 14 characters describing the biophysical state of the site and the nature of the bid. These characters include:

1. River Style
2. Hydrological Intactness
3. Watercourse Condition
4. Riparian Veg Condition
5. Aquatic Habitat Condition
6. Soil Erosion Potential
7. Strahler Stream Order
8. Grazing Pressure
9. Stock Type
10. Potential Health Impact
11. Investment Security
12. Cost of Bid
13. Length of Watercourse
14. Buffer Width

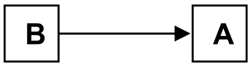
The site assessment sheet describes briefly each character and the criteria by which classes are selected, and is presented in Appendix 1. This rapid assessment framework represents a significant improvement on the riparian and aquatic water quality and biodiversity elements of the Catchment Care (Bryan et al. 2005) protocol. In particular, this protocol enables the consideration of uncertainty in field assessment through the use of confidence levels rather than a discrete scoring approach (e.g. instead of scoring the Water Course Condition character as either Excellent, Good, Fair, Poor, or Highly Degraded, the field officer can score proportions for classes to capture their uncertainty such as Excellent 80%, Good 20%).

3. Decision Support using a Bayesian Network

A risk assessment framework is used in this study to integrate the diverse rapid field assessment data. This is implemented in a Bayesian network which is used to calculate a quantitative metric for prioritising landholder bids for fencing contracts from the AMLR NRM Board. The underlying science and logic behind this methodology has its roots in Ecological

Risk Analysis, a scientifically robust and established technique of prioritising environmental management actions (Suter, 1993; MacEwan et al., 2004; Bryan et al. 2005, Burgman 2005, Standards Australia 2006).

Bayesian networks are particularly suited to, and have been used extensively in quantitative support of environmental management decisions, particular those to do with water resource management (Borsuk et al. 2004, Pike 2004, De Santa Olalla et al. 2005, Hart et al. 2005, Sadoddin et al. 2005). A simple Bayesian network is presented below containing just two nodes A and B where B is the parent of A (and conversely, A is the child of B) and there is a causal link between them:



Full exposition of the mathematics behind Bayesian networks is beyond the scope of this report and can be found in Jensen (1996). However, in brief, Bayesian networks are represented as *directed acyclic graphs*. Through directed linkages and the specification of conditional probability tables (i.e. the probability of A occurring given that B occurs $P(A \mid B)$), Bayesian networks are able to propagate probabilities through the network according to Bayes rule where:

$$P(B \mid A) = \frac{P(A \mid B)P(B)}{P(A)}$$

This gets a little more complex when A has more than one parent but the application of Bayes rule still applies (Jensen 1996).

A feature of Bayesian networks however is the ability for both forward and backward propagation of probabilities through the network. This is a very powerful feature of Bayesian networks which allows complex “what-if” analyses to be conducted under various user-specified scenarios and conditions. Bayesian decision networks or *influence diagrams* are a special kind of Bayesian network that enables the calculation of the expected utility and a decision node whose state is automatically calculated to maximise the expected utility.

A Bayesian decision network based on a risk assessment framework was built to calculate a quantitative metric to guide fencing investment decisions in the AMLR NRM region. The risk assessment framework is based on the Australian Standard for risk analysis (Standards Australia 2006) and uses the rapid field assessment characters for prioritising fencing bids (Figure 1). The *Netica* software package was used to build the network (www.norsys.com).

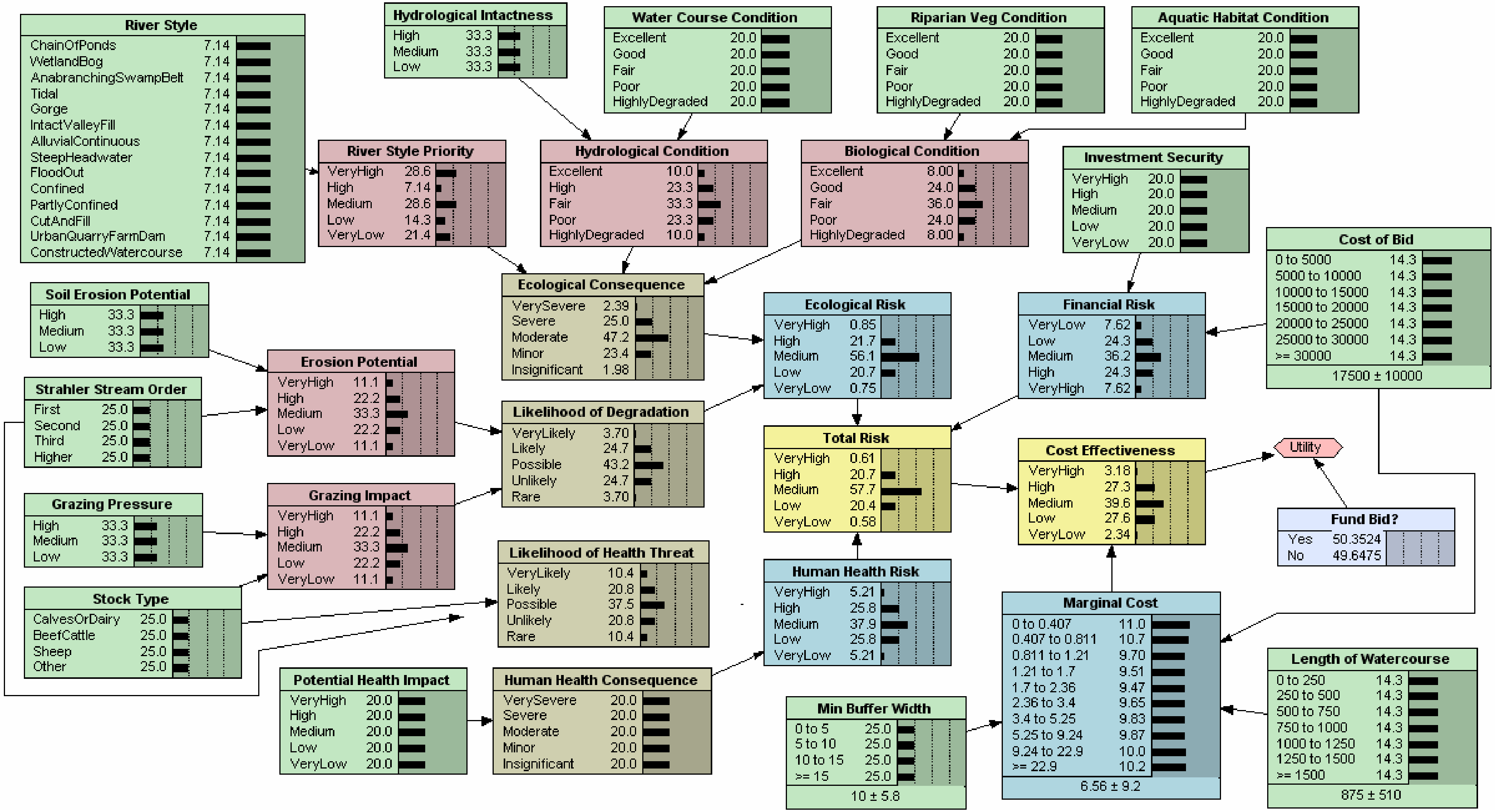
The risk assessment framework involves calculation of risk as a function of the likelihood of an event occurring and the consequence of that event. A high likelihood and high consequence equates to high risk. In the Bayes net for prioritising fencing bids, we assess risk for erosion, risk for pathogens, and financial risk of funding the bid. Bids for fencing sites that are of high risk of erosion and pathogens and that are at a low financial risk have highest total risk.

Marginal cost is an indicator of the length of watercourse protected, the width of the buffer provided, and the cost of the bid. Bids that propose a wide buffer along a long stretch of watercourse at lowest cost have the lowest marginal cost. The cost effectiveness class probabilities feed into a utility function. Bids that are of highest total risk and lowest marginal cost are the most cost effective and the highest *utility* or in other words, the highest priority for funding. The decision to fund a bid or not is represented as a YES/NO decision with percentage confidence levels as calculated by the Bayes net. Bids can be ranked according to the confidence with which a yes decision can be made where there are lots of bids competing for funds. Otherwise, the network can be used to support similar investment decisions at any time, even outside of the competitive auction process.

In Figure 1 the green nodes in the Bayesian network represent required data inputs as assessed in the rapid assessment protocol described above and include uncertainty in assessment as represented by percentage-based confidence levels against class membership. The pink nodes are intermediate nodes aggregating the multiple input nodes as an intermediary step before feeding into the tan coloured consequence and likelihood nodes. These tan nodes link into the blue ecological risk (characterising erosion/biodiversity risk) and human health nodes (characterising risk to pathogens). The green input nodes of investment security and cost of the bid link into the blue financial risk node which links with both ecological and human health risk creating the yellow total risk node. The green input nodes length of watercourse, buffer width and cost of bid link into the blue marginal cost node which links with the total risk node creating the yellow cost effectiveness node. The cost effectiveness node links into the utility node and the purple decision node called Fund Bid? Fund Bid? is the key informational output of the network.

Conditional probability tables were constructed using a linear summation and rescale method. In this method, probabilities of parent nodes are mapped to integer values according to their rank order (e.g. VeryHigh = 5, High = 4, Medium = 3, Low = 2, VeryLow = 1). Where the number of classes is not equal to 5 the integers are then linearly rescaled to values between 1 and 5 (e.g. for the Stock Type node CalvesOrDairy = 5, BeefCattle = 3.67, Sheep = 2.33, Other = 1). All child nodes have five classes (e.g. VeryHigh, High, Medium, Low, VeryLow). Conditional probabilities for all combinations of parent node states are then calculated for the child node by summing the rescaled values and rescaling the sum of these values to a continuous number between 1 and 5. The result is then mapped directly to the five classes by rank order given that (e.g. VeryHigh = 5, High = 4, Medium = 3, Low = 2, VeryLow = 1). For example, a rescaled sum value of 4.67 would return a probability of VeryHigh of 0.67 and a probability of High of 0.33. All conditional probability tables are listed in Appendix 2.

Figure 1 Bayesian network for prioritising landholder fencing bids in the AMRL NRM region.



3.1. Testing and Simulation

Performance of the Bayesian network was tested in two ways. The first test of the Bayesian network involved calculating the sensitivity of the cost effectiveness node to findings in all the other nodes in Netica using the Sensitivity to Findings function. The results of this test are presented in Table 1. Nodes are ranked in Table 1 according to the degree of influence of their findings on the outcomes of the cost effectiveness node calculated as a measure of mutual information. The mutual information between two nodes is a measure of the magnitude with which a finding at one node (*findings node*) is expected to alter the beliefs (measured as entropy reduction) at another node (query node). Mutual information is symmetric between nodes. Variance of beliefs provides an indication of the uncertainty surrounding this estimate. Marginal cost and total risk have the strongest influence on cost effectiveness.

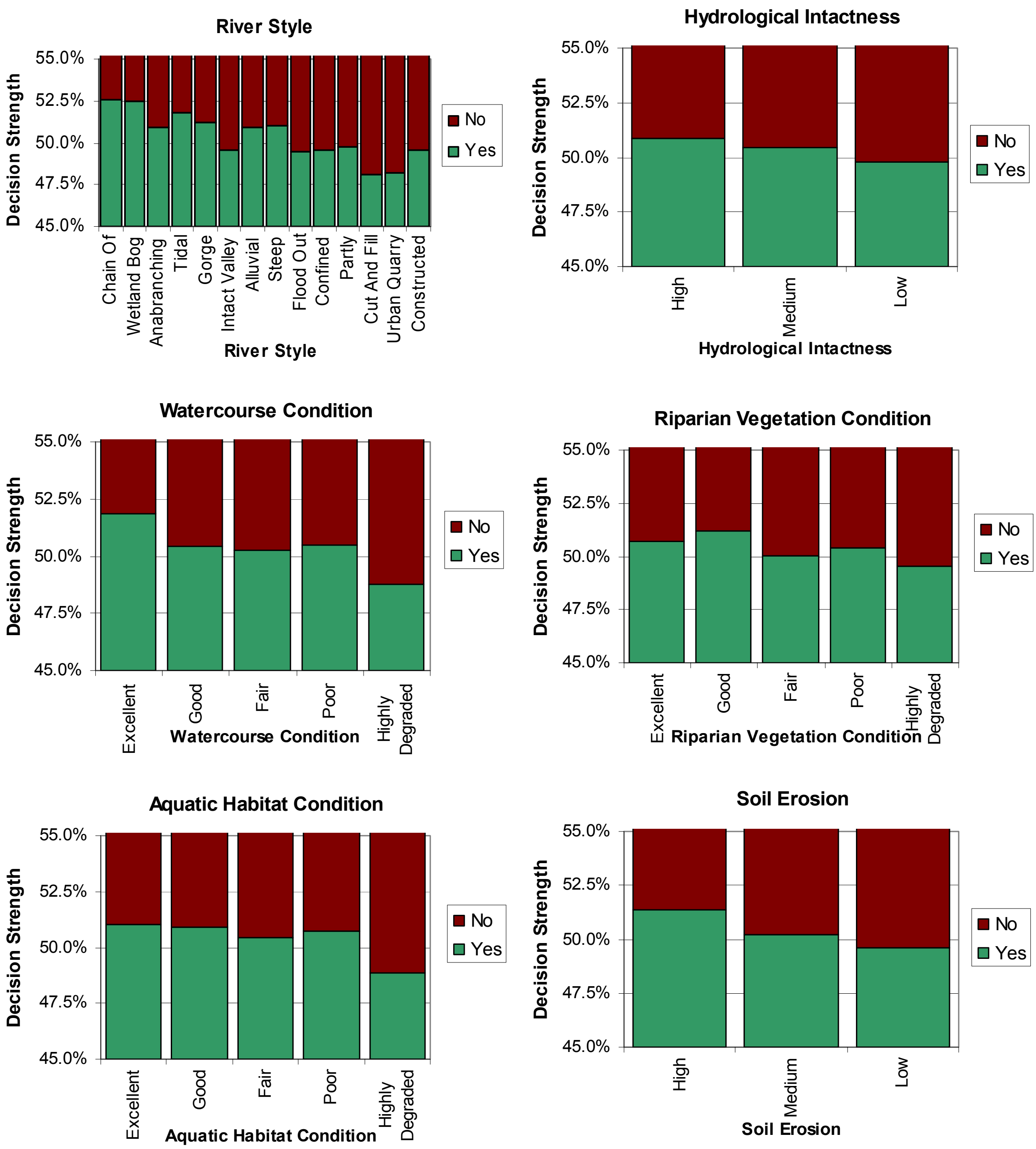
Table 1 Sensitivity of cost effectiveness node to findings in these nodes.

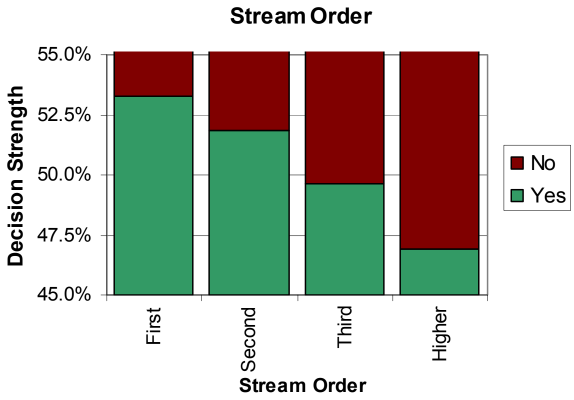
Node	Mutual Information	Variance of Beliefs
CostEff	1.83828	0.4856037
Marginal Cost	0.73981	0.097394
Total Risk	0.2517	0.011444
*Cost of Bid	0.22724	0.022362
Financial Risk	0.16007	0.011699
*Length of Watercourse	0.12808	0.014509
*Min. Buffer Width	0.1228	0.013099
Health Risk	0.04011	0.001326
Ecological Risk	0.0255	0.000873
Likelihood of Health Threat	0.02056	0.000716
Likelihood of Degradation	0.01798	0.000628
*Investment Security	0.01571	0.000554
Human Health Consequence	0.01569	0.000555
*Potential Health Impact	0.01569	0.000555
*Stock Type	0.0097	0.000347
*Stream Order	0.0097	0.000347
Grazing Impact	0.00868	0.00031
Erosion Potential	0.00868	0.00031
Ecological Consequence	0.00507	0.000182
River Style Priority	0.00188	6.81E-05
*River Style	0.00188	6.81E-05
*Soil Erosion Potential	0.00128	4.62E-05
*Grazing Pressure	0.00128	4.62E-05
Hydrological Condition	0.00108	0.000039
Biological Condition	0.00095	3.45E-05
*Hydrological Intactness	0.00057	2.05E-05
*Watercourse Condition	0.00042	1.54E-05
*Aquatic Habitat Condition	0.00042	1.54E-05
*Riparian Vegetation Condition	0.00042	1.54E-05

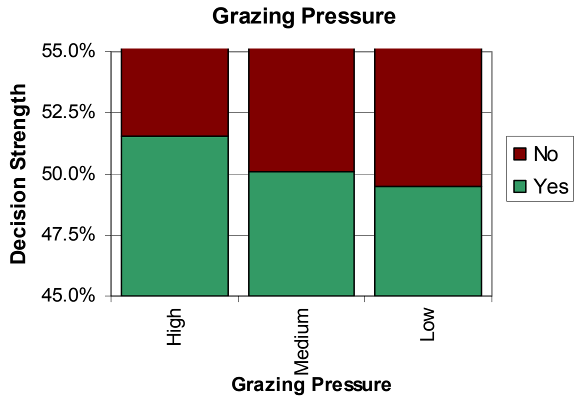
* Input nodes

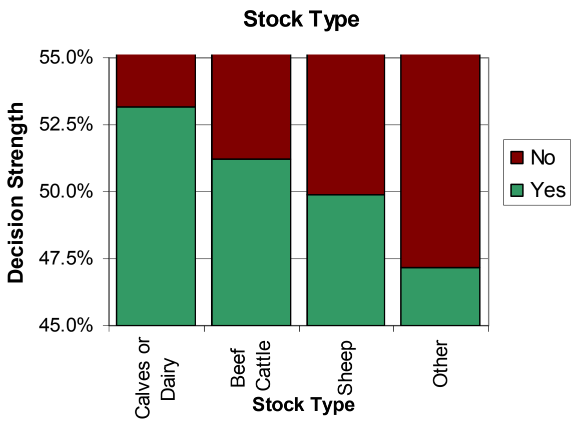
The second test of the Bayesian network involved creating a synthetic database of 10,000 bids using Netica's Simulate Cases function. Each hypothetical bid was attributed a random single state for the each of the green input nodes. For the sake of the simulation, no proportional splits were allowed. For example, for the Grazing Pressure node possible state were either High 100%, Medium 100%, or Low 100%. States of High 70% and Medium 30% were not allowed in the simulation. This data set was then processed in Netica using the Process Cases batch mode and the decision strength of the Fund Bid? node was calculated for each case. The influence of each input node on the decision strength of Fund Bid? was assessed (Figure 2). The individual influence of each input node is relatively minor with most nodes resulting in variation of +/-2.5%. Stream order, stock type, potential health impact and investment security had an effect of between +/-2.5% and +/-5%. Cost, water course length and buffer width had effects in the order of +/-15% on the Fund Bid? decision node (Figure 2).

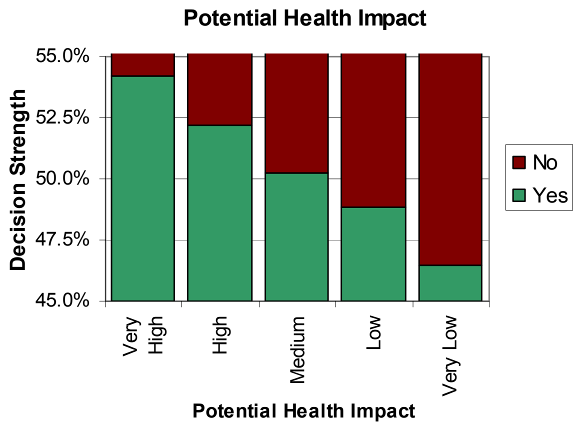
Figure 2 Sensitivity of investment decision to variation in rapid field assessment inputs.

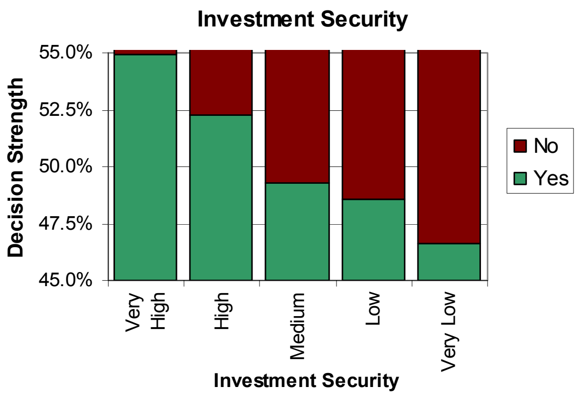


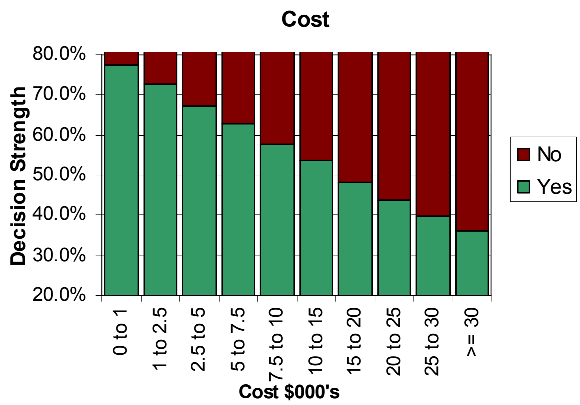

Stream Order
Decision Strength
55.0%
52.5%
50.0%
47.5%
45.0%
First
Second
Third
Higher
No
Yes
Stream Order

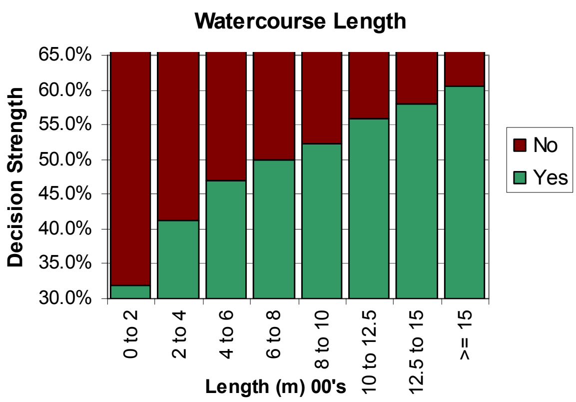

Grazing Pressure
Decision Strength
55.0%
52.5%
50.0%
47.5%
45.0%
High
Medium
Low
No
Yes
Grazing Pressure

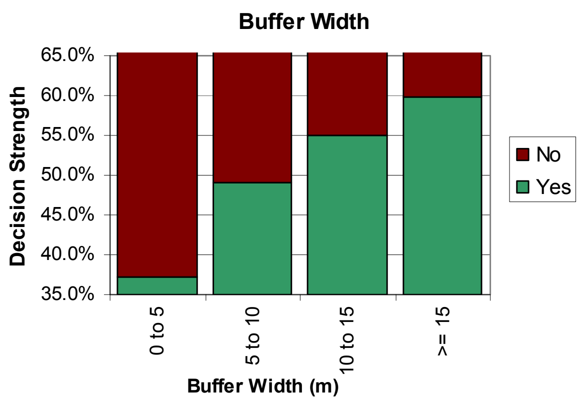

Stock Type
Decision Strength
55.0%
52.5%
50.0%
47.5%
45.0%
Calves or Dairy
Beef Cattle
Sheep
Other
No
Yes
Stock Type


Potential Health Impact
Decision Strength
55.0%
52.5%
50.0%
47.5%
45.0%
Very High
High
Medium
Low
Very Low
No
Yes
Potential Health Impact


Investment Security
Decision Strength
55.0%
52.5%
50.0%
47.5%
45.0%
Very High
High
Medium
Low
Very Low
No
Yes
Investment Security


Cost
Decision Strength
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
0 to 1
1 to 2.5
2.5 to 5
5 to 7.5
7.5 to 10
10 to 15
15 to 20
20 to 25
25 to 30
>= 30
No
Yes
Cost $000's

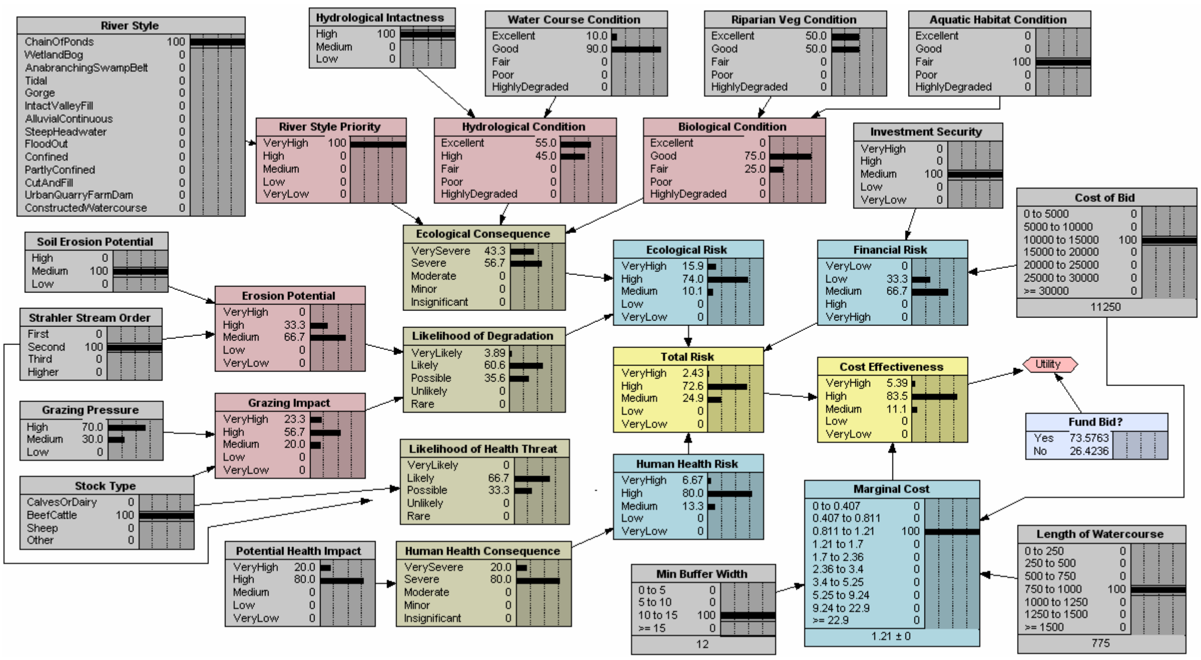

Watercourse Length
Decision Strength
65.0%
60.0%
55.0%
50.0%
45.0%
40.0%
35.0%
30.0%
0 to 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12.5
12.5 to 15
>= 15
No
Yes
Length (m) 00's


Buffer Width
Decision Strength
65.0%
60.0%
55.0%
50.0%
45.0%
40.0%
35.0%
0 to 5
5 to 10
10 to 15
>= 15
No
Yes
Buffer Width (m)

3.2. Using the Bayesian Decision Network

The Bayesian decision network is an interactive tool. Data can be entered into the network in two ways. Firstly, the user can enter data in the Netica interface by right-clicking on each node and selecting the calibration option. Probability or confidence data can then be entered for each state of each input (green) node. This technique is potentially useful for entering individual bids outside of an auction setting where bids come in sporadically. An example of a single case entered into the Bayesian network is presented in. In this example, evidence (or data from rapid field assessment) is entered into each of the input nodes. As evidence is entered the node turns from green to grey. Probabilities are propagated through the network and a decision confidence or strength is calculated. In the example below, the bid should be funded with a Fund Bid? YES decision strength of 73.6%.

Figure 3 Example of processing a single bid in the Bayesian decision network.



It may also be useful to experiment with the network using this technique in conducting *what-if* analyses. In this case, what-if analyses are most useful for understanding the nature of the problem and decisions being made. Some questions that might be of interest in what-if analyses include “If cost effectiveness is very high, what is the likely cost of the bid?” or “If I am not confident that this bidder will successfully complete the proposed actions (i.e. Investment Security = VeryLow), how does the cost effectiveness change?”.

Secondly, Netica also allows the processing of numerous cases in batch mode. This is probably more suitable for use in an auction setting as there will be many bids for which the user will want to calculate the Fund Bid? decision strength and use this to rank bids. However, the data format required by Netica (Version 3.12) is rather quirky. To streamline the data entry process an Excel spreadsheet was developed which enables easy entry of rapid assessment data and export to the Bayes net for processing. To process the cases in Netica, the user selects Process Cases from the Cases Menu. The user then needs to specify a control file (supplied) which specifies the fields to be output. In this case we simply output the case (bid) ID number and the YES/NO decision strength of the Fund Bid? decision node. The user then specifies the input data file to process (which is the file output from Excel) and an output file name. The resultant output file from Netica’s Process Cases can then be loaded back into Excel and used to rank the bids according to the decision strength. The bids where Fund Bid? has a higher value for YES are those that should be funded first.

4. Conclusion

In the Catchment Care project, Bryan et al. (2005) developed a risk assessment framework for the ranking and selection of landholder bids in an auction for conservation contracts. In this study we adapted and enhanced the risk assessment framework to support investment decisions in a fencing auction in the AMLR NRM region. The risk assessment framework is based on the Australian Standard and implemented within a Bayesian decision network. A rapid assessment protocol was also developed to capture quantitative data about each bid. The framework integrates erosion and biodiversity risk, human health risk, financial risk, and marginal cost to calculate the cost effectiveness of each bid and this is used to calculate the strength of the decision to fund each bid or not. Simulation results suggest that the Bayesian decision network should work well although it needs to be tested in the field. Field testing may indicate areas of further refinement.

Appendix 1: Site Assessment Sheet

Riparian Vegetation Condition

Note: Vegetation in a particular category may not necessarily show all of the features in each category but will show a range of parameters within a few categories. Step 1: Choose two most suitable categories. Step 2: Use detail to distinguish percentage confidence that site fits in each of the two categories. Step 3: Enter confidence in percent such that percentage figures sum to 100 & note features that lead to category decision in box below.

Condition	Criteria For Assigning Vegetation Condition Class	Confidence (%)
Excellent	Diverse composition, structurally intact, ongoing natural regeneration, majority of area is without any weeds, soil protected by litter & plants, few signs of un-natural disturbance or plant pathogens, perennial plants healthy.	
Good	Diverse composition but range of plants reduced, good range of regeneration, sparse to little weed throughout, ground protected but occasional disturbance, some signs of minor disturbance, signs of perennial disease or death still within natural limits.	
Fair	Good diversity but some breakdown of structure composition, limited regeneration, a range of weeds but still at controllable levels < 25% of cover, some bare soil. May have frequent signs of disturbance, several instances of perennial diseases or death.	
Poor	Structure severely modified but components recognisable, plant diversity low, little or no regeneration, severe weed infestations & large areas of unprotected soil form up to 50% of area. May include large areas of disturbance, and/or recent grazing or slashing. Commonly includes obvious signs of disease, poor health or death in perennials.	
Highly Degraded	Severely modified, majority of ground cover is weed or pasture species, canopy much reduced, weeds & bare ground > 50%, diversity low, structural components sparse or absent, with little or no regeneration. May include large areas highly susceptible to erosion. Degradation/disturbance levels high & may include current grazing, slashing, mowing and large numbers of perennials that are diseased, unhealthy or dead.	
	SUM	**100**

Comments

Aquatic Habitat Condition

From Earth Tech 2005 *Aquatic Ecosystem Surveys of Subcatchments of the Torrens Rural catchment* based upon a system developed by Peter Schultz of the Patawalonga & Torrens Catchment Water Management Boards. Score each element of the Aquatic Habitat character then sum the totals. Enter into table and convert into a condition class. Include confidence levels as appropriate.

Field	Descriptor	Code	Score
Habitat type and depth (For any habitat >25% of area)	Dominant habitat depth >2	A	0
	Dominant habitat depth >3	B	1
	Dominant habitat depth >4	C	2
Total Habitat Score	Sum of habitat types (A + B + C)	D	**Max 4**
Substrate	>10% Bedrock	E	1
	>10% Bedrock and Cobble	F	1
	>10% Pebbles and Gravel	G	1
	Up to 10% sand	H	1
	10% - 25% sand	I	0
	>10% silt and clay	J	1
	> 5% roots	K	1
Total Substrate Score	Sum of Substrate Scores (E + F + G + H + I + J + K)	L	**Max 5**
Organic Substrate	>10% Detritus	M	1
	10% < Algae < 35%	MA	1
	>65% Detritus	N	2
	>10% Biofilm	O	1
	>65% Biofilm	P	2
Total OS Score	Sum of Reach Scores (M + MA+N + O + P)	Q	**Max 5**
Macrophytes	1-3 *emergent* species present	R	1
	More than 4 *emergent* species present	S	2
	1-2 *submerged* species present = 1, 3+ = 2	T	0 - 2
	1-2 *floating* species present =1, 3+ = 2	U	0 - 2
Total Macrophyte Score	Sum of Macrophyte scores (R + S + T + U)	V	**Max 6**
Macroinvertebrates	Number of species (to lowest taxonomic level)	W	
Total Macroinvertebrate Score	Number of species (W) divided by 8	X	**Max 5**
Special Values	Native Fish present	Y	3
	Frogs, tortoises or tadpoles present	Z	1
	Spring	AA	2
Total Special Value Score	Sum of Special Value Score (Y + Z + AA) (To max 5)	AB	**Max. 5**

Comments		Overall Score	Class	Confidence (%)
		25-30	Excellent	
		19-24	Good	
		13-18	Fair	
		7-12	Poor	
Overall Aquatic Habitat Condition Score (D + L + Q + V + X + AB)		0-6	Highly Degraded	
			SUM	**100**

River Style ©

RiverStyle © should be determined using the appropriate GIS layer prior to site assessment, but checked for accuracy in the field. Confidence levels may be entered to capture any uncertainty but the field officer will often be 100% confident about River Style.

RiverStyle © as determined from GIS	

RiverStyle ©	Confidence (%)	River Style ©	Confidence (%)
Chain of Ponds		Steep Headwater	
Wetland, Bog		Flood Out	
Anabranching Swamp Belt		Confined	
Tidal		Partly Confined	
Gorge		Cut and Fill	
Intact Valley Fill		Urban, Quarry, Farm Dam	
Alluvial Continuous		Constructed Watercourse	

Comments

Watercourse Channel Condition

Condition	Criteria For Assigning Watercourse Channel Condition Class	Confidence (%)
Excellent	Watercourse appears entirely stable. Bed and banks (if present) and immediate surrounds do not display signs of erosion. Native riparian vegetation dominates the bed & banks where present.	
Good	Watercourse appears stable but may be some signs of previous minor disturbance in bed and banks (if present) and immediate surrounds, which is now stable, e.g. minor erosion, loss of cover, previous minor slumping or undercutting of banks, minor tunnel erosion. Vegetative cover present on majority of area and majority is native riparian vegetation.	
Fair	Watercourse generally appears stable but may be some instances of minor erosion and/or loss of cover, in Bed and Banks (if present) and immediate surrounds and/or past erosion damage (minor or major) which is now stable. Vegetative cover present on majority of area and majority is native riparian vegetation. Any pugging very minor.	
Poor	Both bed and banks show signs of recent erosion, over less than 50% of it's length. Some bare soil, evidence of recent slumping &/or undercutting, and bed deepening (erosion head formation). Stabilising, riparian vegetation generally reduced, native riparian vegetation reduced and weedy vegetation likely to dominate, pugging may be prevalent.	
Highly Degraded	Both bed and banks show signs of active accelerated erosion over more than 50% of it's length. Much bare soil, evidence of recent slumping &/or undercutting, and bed deepening (erosion head formation). Stabilising, riparian vegetation largely absent, and weedy vegetation likely to dominate when present, pugging may be common and major.	
	SUM	**100**

Comments

Strahler Stream Order

Stream Order can be determined from GIS data. For mapped watercourses (3rd order and higher), stream order is recorded in the GIS layer. For unmapped watercourses (Below 3rd order) stream order can be determined using aerial photography and contour information.

Stream Order	Confidence (%)
First Order	
Second Order	
Third Order	
Above Third Order	
SUM	**100**

Comments

Hydrological Intactness

Degree of Hydrological intactness has been estimated using modelling techniques, and is available as a GIS data layer. Conclusions made from modelled data should be checked for accuracy in the field.

Degree of hydrological intactness as determined from modelled data on GIS	

Low Flow Disturbance (Dec - May)	High Flow Disturbance (Jun - Nov)	Confidence (%)
Low	Low	
Moderate	Low	
High	Low	
High	High	
	SUM	**100**

Comments

Minimum Buffer Width

The minimum riparian buffer width that the proposed fencing will achieve should be measured at the closest point that the proposed stock exclusion fence gets to the top of bank (excluding necessary stock/vehicle crossings). Buffer width should be measured in metres. Usual minimum distances are between 0 and 15 metres. Buffer width can be entered as confidence levels against the classes below or as a single measure in metres.

Buffer Width	Confidence (%)
More than 15 meters	
Between 10 and 15 meters	
Between 5 and 10 meters	
Less than 5 meters	
SUM	**100**

Comments	
Buffer Width (m)	

Stock Type Score

Type	Criteria For Assigning Stock Type Scores	Confidence (%)
Calves or Dairy Cattle	**Calves or Dairy Cattle** with unlimited access to channel, and where channel is only source of stock water supply.	
Beef Cattle	**Beef Cattle** with unlimited access to channel, and where channel is only source of stock water supply.	
Sheep	**Sheep** with unlimited access to channel, and where channel is only source of stock water supply.	
Other	**Other Hard Hoofed** stock with unlimited access to channel, and where channel is only source of stock water supply.	
	SUM	**100**

Comments

Soil Erosion Potential

Erosion Potential	Criteria For Assigning Erosion Potential Scores	Confidence (%)
High	Soil type or Soil Landscape Unit with soil erosion potential >=6	
Moderate	Soil type or Soil Landscape Unit with soil erosion potential >=3 and <=5	
Low	Soil type or Soil Landscape Unit with soil erosion potential <= 2.	
	SUM	**100**

Comments

Investment Security

Investment Security	Criteria For Assigning Security of Investment Score	Confidence (%)
Very Low	Landholder is willing to enter a Project Management Agreement for the duration of the Project, but future management/use of the site is in serious doubt, e.g. potential development of site is very uncertain, &/or serious reservations about commitment and capacity to make a meaningful, ongoing contribution to the active management of the site.	
Low	Landholder is willing to enter a Project Management Agreement for the duration of the Project, but future management/use of the site is in question, e.g. uncertainty about potential development of site, &/or some question about the commitment and capacity to make a meaningful, ongoing contribution to the active management of the site.	
Moderate	Landholder is willing to enter a Project Management Agreement for the duration of any Project, but some doubt still exists regarding either the commitment or capacity to make a meaningful, ongoing contribution to the active management of the site.	
High	Landholder is willing to enter into a Land Management Agreement (or similar) on the site in question, AND has demonstrated the commitment and capacity to make a meaningful, ongoing contribution to the active management of the site.	
Very High	Landholder has a Land Management Agreement (or similar) on the site in question, or is in the process of doing so, AND has demonstrated the commitment and capacity to make a meaningful, ongoing contribution to the active management of the site.	

NB: It will be a condition of receiving funding support via the program that Landholders are prepared to sign a Project Management Agreement which puts conditions on future activities in the site (eg no planting of exotic species)

Comments

Potential Health Impact

Condition	Criteria For Assigning Potential health Impact Class	Confidence (%)
Very High	Site is located not far upstream of a major water supply storage such as Mt. Bold Reservoir of Happy Valley Reservoir. Pathogen transport vectors are at their most direct. Typical distances upstream are in the order of < 3km along the watercourse.	
High	Site is located not far upstream of an important area used for swimming, fishing and other recreational activities. Pathogen transport vectors are at their most direct. Typical distances upstream are in the order of < 3km along the watercourse.	
Medium	Site is located between 3km and 10km upstream of a major water supply storage such as Mt. Bold Reservoir of Happy Valley Reservoir. Pathogens must travel further to the area of high impact and hence their effectiveness is greatly reduced through biological assimilation, sedimentation, mortality and degradation from UV light.	
Low	Site is located between 3km and 10km upstream of an important area used for swimming, fishing and other recreational activities. Pathogens must travel further to the area of high impact and their effectiveness is greatly reduced through biological assimilation, sedimentation, mortality and degradation from UV light.	
Very Low	Site is either not located upstream of a water storage or recreation area or is located > 10km upstream or these areas. Pathogens must travel a long way to the area of high impact and hence their effectiveness is greatly reduced through biological assimilation, sedimentation, mortality and degradation from UV light.	
	SUM	**100**

Comments

Grazing Pressure

State	Criteria For Assigning Grazing Pressure Class	Confidence (%)
High	**Major** evidence of mechanical disturbance of bed and bank (such as tracking, compaction and hoof shearing/pugging), and suppression of native riparian vegetation along the full length of the reach**.**	
Medium	**Moderate** evidence of mechanical disturbance of bed and bank (such as tracking, compaction and hoof shearing/pugging), and suppression of native riparian vegetation along the full length of the reach**, OR** major impact along a substantial proportion of the length of the reach.	
Low	**Minor** evidence of mechanical disturbance of bed and bank (such as tracking, compaction and hoof shearing/pugging), and suppression of native riparian vegetation along the full length of the reach**, OR** major impact along a small proportion of the length of the reach.	
	SUM	**100**

Comments

Length of Watercourse

The total length of watercourse protected should be measured/estimated in metres along the watercourse itself taking into account the curvature, rather than a linear estimate. Watercourse length can be entered as a single measure in metres or, where uncertainty exists, as confidence levels against the classes below.

Length of Watercourse	Confidence (%)
0 – 250m	
250 – 500m	
500 – 750m	
750 – 1000m	
1000 – 1250m	
1250 – 1500m	
>=1500m	
SUM	**100**

Comments	
Buffer Width (m)	

Cost of Bid

The cost of the bid requires the amount requested of the AMRL NRM Board by the landholder. It should not include in-kind or cash contribution from the landholder. Cost should always be entered as a single dollar value.

Comments	
Total Cost ($)	

Appendix 2: Conditional Probability Tables

Deterministic conditional probability table for River Style Priority

River Style	River Style Priority
Chain of Ponds	VeryHigh
Wetland, Bog	VeryHigh
Anabranching Swamp Belt	VeryHigh
Tidal	VeryHigh
Gorge	High
Intact Valley Fill	Medium
Alluvial Continuous	Medium
Steep Headwater	Medium
Flood Out	Medium
Confined	Low
Partly Confined	Low
Cut and Fill	VeryLow
Urban, Quarry, Farm Dam	VeryLow
Constructed Watercourse	VeryLow

Conditional probability table for Hydrological Condition

Water Course Condition	Hydrological Intactness	Excellent	Good	Fair	Poor	HighlyDegraded
Excellent	High	1	0	0	0	0
Excellent	Medium	0	1	0	0	0
Excellent	Low	0	0	1	0	0
Good	High	0.5	0.5	0	0	0
Good	Medium	0	0.5	0.5	0	0
Good	Low	0	0	0.5	0.5	0
Fair	High	0	1	0	0	0
Fair	Medium	0	0	1	0	0
Fair	Low	0	0	0	1	0
Poor	High	0	0.5	0.5	0	0
Poor	Medium	0	0	0.5	0.5	0
Poor	Low	0	0	0	0.5	0.5
HighlyDegraded	High	0	0	1	0	0
HighlyDegraded	Medium	0	0	0	1	0
HighlyDegraded	Low	0	0	0	0	1

Conditional probability table for Biological Condition

Riparian Veg Condition	Aquatic Habitat Condition	Excellent	Good	Fair	Poor	HighlyDegraded
Excellent	Excellent	1	0	0	0	0
Excellent	Good	0.5	0.5	0	0	0
Excellent	Fair	0	1	0	0	0
Excellent	Poor	0	0.5	0.5	0	0
Excellent	HighlyDegraded	0	0	1	0	0
Good	Excellent	0.5	0.5	0	0	0
Good	Good	0	1	0	0	0
Good	Fair	0	0.5	0.5	0	0
Good	Poor	0	0	1	0	0
Good	HighlyDegraded	0	0	0.5	0.5	0
Fair	Excellent	0	1	0	0	0
Fair	Good	0	0.5	0.5	0	0
Fair	Fair	0	0	1	0	0
Fair	Poor	0	0	0.5	0.5	0
Fair	HighlyDegraded	0	0	0	1	0
Poor	Excellent	0	0.5	0.5	0	0
Poor	Good	0	0	1	0	0
Poor	Fair	0	0	0.5	0.5	0
Poor	Poor	0	0	0	1	0
Poor	HighlyDegraded	0	0	0	0.5	0.5
HighlyDegraded	Excellent	0	0	1	0	0
HighlyDegraded	Good	0	0	0.5	0.5	0
HighlyDegraded	Fair	0	0	0	1	0
HighlyDegraded	Poor	0	0	0	0.5	0.5
HighlyDegraded	HighlyDegraded	0	0	0	0	1

Conditional probability table for Erosion Potential

Stream Order	Erosion Potential	VeryHigh	High	Medium	Low	VeryLow
First	High	1	0	0	0	0
First	Medium	0	1	0	0	0
First	Low	0	0	1	0	0
Second	High	0.33	0.67	0	0	0
Second	Medium	0	0.33	0.67	0	0
Second	Low	0	0	0.33	0.67	0
Third	High	0	0.67	0.33	0	0
Third	Medium	0	0	0.67	0.33	0
Third	Low	0	0	0	0.67	0.33
Higher	High	0	0	1	0	0
Higher	Medium	0	0	0	1	0
Higher	Low	0	0	0	0	1

Conditional probability table for Grazing Impact

StockType	Grazing Pressure	VeryHigh	High	Medium	Low	VeryLow
CalvesOrDairy	High	1	0	0	0	0
CalvesOrDairy	Medium	0	1	0	0	0
CalvesOrDairy	Low	0	0	1	0	0
BeefCattle	High	0.33	0.67	0	0	0
BeefCattle	Medium	0	0.33	0.67	0	0
BeefCattle	Low	0	0	0.33	0.67	0
Sheep	High	0	0.67	0.33	0	0
Sheep	Medium	0	0	0.67	0.33	0
Sheep	Low	0	0	0	0.67	0.33
Other	High	0	0	1	0	0
Other	Medium	0	0	0	1	0
Other	Low	0	0	0	0	1

Deterministic conditional probability table for Human Health Consequence

Potential Health Impact	Human Health Consequence
VeryHigh	VerySevere
High	Severe
Medium	Moderate
Low	Minor
VeryLow	Insignificant

Conditional probability table for Likelihood of Health Threat

StockType	Grazing Pressure	VeryLikely	Likely	Possible	Unlikely	Rare
CalvesOrDairy	First	1	0	0	0	0
CalvesOrDairy	Second	0.33	0.67	0	0	0
CalvesOrDairy	Third	0	0.67	0.33	0	0
CalvesOrDairy	Higher	0	0	1	0	0
BeefCattle	First	0.33	0.67	0	0	0
BeefCattle	Second	0	0.67	0.33	0	0
BeefCattle	Third	0	0	1	0	0
BeefCattle	Higher	0	0	0.33	0.67	0
Sheep	First	0	0.67	0.33	0	0
Sheep	Second	0	0	1	0	0
Sheep	Third	0	0	0.33	0.67	0
Sheep	Higher	0	0	0	0.67	0.33
Other	First	0	0	1	0	0
Other	Second	0	0	0.33	0.67	0
Other	Third	0	0	0	0.67	0.33
Other	Higher	0	0	0	0	1

Conditional probability table for Likelihood of Degradation

Grazing Impact	Erosion Potential	VeryLikely	Likely	Possible	Unlikely	Rare
VeryHigh	VeryHigh	1	0	0	0	0
VeryHigh	High	0.5	0.5	0	0	0
VeryHigh	Medium	0	1	0	0	0
VeryHigh	Low	0	0.5	0.5	0	0
VeryHigh	VeryLow	0	0	1	0	0
High	VeryHigh	0.5	0.5	0	0	0
High	High	0	1	0	0	0
High	Medium	0	0.5	0.5	0	0
High	Low	0	0	1	0	0
High	VeryLow	0	0	0.5	0.5	0
Medium	VeryHigh	0	1	0	0	0
Medium	High	0	0.5	0.5	0	0
Medium	Medium	0	0	1	0	0
Medium	Low	0	0	0.5	0.5	0
Medium	VeryLow	0	0	0	1	0
Low	VeryHigh	0	0.5	0.5	0	0
Low	High	0	0	1	0	0
Low	Medium	0	0	0.5	0.5	0
Low	Low	0	0	0	1	0
Low	VeryLow	0	0	0	0.5	0.5
VeryLow	VeryHigh	0	0	1	0	0
VeryLow	High	0	0	0.5	0.5	0
VeryLow	Medium	0	0	0	1	0
VeryLow	Low	0	0	0	0.5	0.5
VeryLow	VeryLow	0	0	0	0	1

Conditional probability table for Ecological Consequence

River Style Priority	Biological Condition	Hydrological Condition	VerySevere	Severe	Moderate	Minor	Insignificant
VeryHigh	Excellent	Excellent	1	0	0	0	0
VeryHigh	Excellent	Good	0.67	0.33	0	0	0
VeryHigh	Excellent	Fair	0.33	0.67	0	0	0
VeryHigh	Excellent	Poor	0	1	0	0	0
VeryHigh	Excellent	HighlyDegraded	0	0.67	0.33	0	0
VeryHigh	Good	Excellent	0.67	0.33	0	0	0
VeryHigh	Good	Good	0.33	0.67	0	0	0
VeryHigh	Good	Fair	0	1	0	0	0
VeryHigh	Good	Poor	0	0.67	0.33	0	0
VeryHigh	Good	HighlyDegraded	0	0.33	0.67	0	0
VeryHigh	Fair	Excellent	0.33	0.67	0	0	0
VeryHigh	Fair	Good	0	1	0	0	0
VeryHigh	Fair	Fair	0	0.67	0.33	0	0
VeryHigh	Fair	Poor	0	0.33	0.67	0	0
VeryHigh	Fair	HighlyDegraded	0	0	1	0	0
VeryHigh	Poor	Excellent	0	1	0	0	0
VeryHigh	Poor	Good	0	0.67	0.33	0	0
VeryHigh	Poor	Fair	0	0.33	0.67	0	0
VeryHigh	Poor	Poor	0	0	1	0	0
VeryHigh	Poor	HighlyDegraded	0	0	0.67	0.33	0
VeryHigh	HighlyDegraded	Excellent	0	0.67	0.33	0	0
VeryHigh	HighlyDegraded	Good	0	0.33	0.67	0	0
VeryHigh	HighlyDegraded	Fair	0	0	1	0	0
VeryHigh	HighlyDegraded	Poor	0	0	0.67	0.33	0
VeryHigh	HighlyDegraded	HighlyDegraded	0	0	0.33	0.67	0
High	Excellent	Excellent	0.67	0.33	0	0	0
High	Excellent	Good	0.33	0.67	0	0	0
High	Excellent	Fair	0	1	0	0	0
High	Excellent	Poor	0	0.67	0.33	0	0
High	Excellent	HighlyDegraded	0	0.33	0.67	0	0
High	Good	Excellent	0.33	0.67	0	0	0
High	Good	Good	0	1	0	0	0
High	Good	Fair	0	0.67	0.33	0	0
High	Good	Poor	0	0.33	0.67	0	0
High	Good	HighlyDegraded	0	0	1	0	0
High	Fair	Excellent	0	1	0	0	0
High	Fair	Good	0	0.67	0.33	0	0
High	Fair	Fair	0	0.33	0.67	0	0
High	Fair	Poor	0	0	1	0	0
High	Fair	HighlyDegraded	0	0	0.67	0.33	0
High	Poor	Excellent	0	0.67	0.33	0	0
High	Poor	Good	0	0.33	0.67	0	0
High	Poor	Fair	0	0	1	0	0
High	Poor	Poor	0	0	0.67	0.33	0
High	Poor	HighlyDegraded	0	0	0.33	0.67	0
High	HighlyDegraded	Excellent	0	0.33	0.67	0	0
High	HighlyDegraded	Good	0	0	1	0	0
High	HighlyDegraded	Fair	0	0	0.67	0.33	0
High	HighlyDegraded	Poor	0	0	0.33	0.67	0
High	HighlyDegraded	HighlyDegraded	0	0	0	1	0
Medium	Excellent	Excellent	0.33	0.67	0	0	0
Medium	Excellent	Good	0	1	0	0	0
Medium	Excellent	Fair	0	0.67	0.33	0	0
Medium	Excellent	Poor	0	0.33	0.67	0	0
Medium	Excellent	HighlyDegraded	0	0	1	0	0
Medium	Good	Excellent	0	1	0	0	0
Medium	Good	Good	0	0.67	0.33	0	0
Medium	Good	Fair	0	0.33	0.67	0	0
Medium	Good	Poor	0	0	1	0	0
Medium	Good	HighlyDegraded	0	0	0.67	0.33	0
Medium	Fair	Excellent	0	0.67	0.33	0	0
Medium	Fair	Good	0	0.33	0.67	0	0
Medium	Fair	Fair	0	0	1	0	0
Medium	Fair	Poor	0	0	0.67	0.33	0
Medium	Fair	HighlyDegraded	0	0	0.33	0.67	0
Medium	Poor	Excellent	0	0.33	0.67	0	0
Medium	Poor	Good	0	0	1	0	0
Medium	Poor	Fair	0	0	0.67	0.33	0
Medium	Poor	Poor	0	0	0.33	0.67	0
Medium	Poor	HighlyDegraded	0	0	0	1	0
Medium	HighlyDegraded	Excellent	0	0	1	0	0

Medium	HighlyDegraded	Good	0	0	0.67	0.33	0
Medium	HighlyDegraded	Fair	0	0	0.33	0.67	0
Medium	HighlyDegraded	Poor	0	0	0	1	0
Medium	HighlyDegraded	HighlyDegraded	0	0	0	0.67	0.33
Low	Excellent	Excellent	0	1	0	0	0
Low	Excellent	Good	0	0.67	0.33	0	0
Low	Excellent	Fair	0	0.33	0.67	0	0
Low	Excellent	Poor	0	0	1	0	0
Low	Excellent	HighlyDegraded	0	0	0.67	0.33	0
Low	Good	Excellent	0	0.67	0.33	0	0
Low	Good	Good	0	0.33	0.67	0	0
Low	Good	Fair	0	0	1	0	0
Low	Good	Poor	0	0	0.67	0.33	0
Low	Good	HighlyDegraded	0	0	0.33	0.67	0
Low	Fair	Excellent	0	0.33	0.67	0	0
Low	Fair	Good	0	0	1	0	0
Low	Fair	Fair	0	0	0.67	0.33	0
Low	Fair	Poor	0	0	0.33	0.67	0
Low	Fair	HighlyDegraded	0	0	0	1	0
Low	Poor	Excellent	0	0	1	0	0
Low	Poor	Good	0	0	0.67	0.33	0
Low	Poor	Fair	0	0	0.33	0.67	0
Low	Poor	Poor	0	0	0	1	0
Low	Poor	HighlyDegraded	0	0	0	0.67	0.33
Low	HighlyDegraded	Excellent	0	0	0.67	0.33	0
Low	HighlyDegraded	Good	0	0	0.33	0.67	0
Low	HighlyDegraded	Fair	0	0	0	1	0
Low	HighlyDegraded	Poor	0	0	0	0.67	0.33
Low	HighlyDegraded	HighlyDegraded	0	0	0	0.33	0.67
VeryLow	Excellent	Excellent	0	0.67	0.33	0	0
VeryLow	Excellent	Good	0	0.33	0.67	0	0
VeryLow	Excellent	Fair	0	0	1	0	0
VeryLow	Excellent	Poor	0	0	0.67	0.33	0
VeryLow	Excellent	HighlyDegraded	0	0	0.33	0.67	0
VeryLow	Good	Excellent	0	0.33	0.67	0	0
VeryLow	Good	Good	0	0	1	0	0
VeryLow	Good	Fair	0	0	0.67	0.33	0
VeryLow	Good	Poor	0	0	0.33	0.67	0
VeryLow	Good	HighlyDegraded	0	0	0	1	0
VeryLow	Fair	Excellent	0	0	1	0	0
VeryLow	Fair	Good	0	0	0.67	0.33	0
VeryLow	Fair	Fair	0	0	0.33	0.67	0
VeryLow	Fair	Poor	0	0	0	1	0
VeryLow	Fair	HighlyDegraded	0	0	0	0.67	0.33
VeryLow	Poor	Excellent	0	0	0.67	0.33	0
VeryLow	Poor	Good	0	0	0.33	0.67	0
VeryLow	Poor	Fair	0	0	0	1	0
VeryLow	Poor	Poor	0	0	0	0.67	0.33
VeryLow	Poor	HighlyDegraded	0	0	0	0.33	0.67
VeryLow	HighlyDegraded	Excellent	0	0	0.33	0.67	0
VeryLow	HighlyDegraded	Good	0	0	0	1	0
VeryLow	HighlyDegraded	Fair	0	0	0	0.67	0.33
VeryLow	HighlyDegraded	Poor	0	0	0	0.33	0.67
VeryLow	HighlyDegraded	HighlyDegraded	0	0	0	0	1

Conditional probability table for Human Health Risk

Human Health Consequence	Likelihood of Health Threat	VeryHigh	High	Medium	Low	VeryLow
VerySevere	VeryHigh	1	0	0	0	0
VerySevere	High	0.5	0.5	0	0	0
VerySevere	Medium	0	1	0	0	0
VerySevere	Low	0	0.5	0.5	0	0
VerySevere	VeryLow	0	0	1	0	0
Severe	VeryHigh	0.5	0.5	0	0	0
Severe	High	0	1	0	0	0
Severe	Medium	0	0.5	0.5	0	0
Severe	Low	0	0	1	0	0
Severe	VeryLow	0	0	0.5	0.5	0
Moderate	VeryHigh	0	1	0	0	0
Moderate	High	0	0.5	0.5	0	0
Moderate	Medium	0	0	1	0	0
Moderate	Low	0	0	0.5	0.5	0
Moderate	VeryLow	0	0	0	1	0
Minor	VeryHigh	0	0.5	0.5	0	0
Minor	High	0	0	1	0	0
Minor	Medium	0	0	0.5	0.5	0
Minor	Low	0	0	0	1	0
Minor	VeryLow	0	0	0	0.5	0.5
Insignificant	VeryHigh	0	0	1	0	0
Insignificant	High	0	0	0.5	0.5	0
Insignificant	Medium	0	0	0	1	0
Insignificant	Low	0	0	0	0.5	0.5
Insignificant	VeryLow	0	0	0	0	1

Conditional probability table for Ecological Risk

Ecological Consequence	Likelihood of Degradation	VeryHigh	High	Medium	Low	VeryLow
VerySevere	VeryHigh	1	0	0	0	0
VerySevere	High	0.5	0.5	0	0	0
VerySevere	Medium	0	1	0	0	0
VerySevere	Low	0	0.5	0.5	0	0
VerySevere	VeryLow	0	0	1	0	0
Severe	VeryHigh	0.5	0.5	0	0	0
Severe	High	0	1	0	0	0
Severe	Medium	0	0.5	0.5	0	0
Severe	Low	0	0	1	0	0
Severe	VeryLow	0	0	0.5	0.5	0
Moderate	VeryHigh	0	1	0	0	0
Moderate	High	0	0.5	0.5	0	0
Moderate	Medium	0	0	1	0	0
Moderate	Low	0	0	0.5	0.5	0
Moderate	VeryLow	0	0	0	1	0
Minor	VeryHigh	0	0.5	0.5	0	0
Minor	High	0	0	1	0	0
Minor	Medium	0	0	0.5	0.5	0
Minor	Low	0	0	0	1	0
Minor	VeryLow	0	0	0	0.5	0.5
Insignificant	VeryHigh	0	0	1	0	0
Insignificant	High	0	0	0.5	0.5	0
Insignificant	Medium	0	0	0	1	0
Insignificant	Low	0	0	0	0.5	0.5
Insignificant	VeryLow	0	0	0	0	1

Conditional probability table for Financial Risk

Investment Security	Cost of Bid	VeryLow	Low	Medium	High	VeryHigh
VeryHigh	0 – 5,000	1	0	0	0	0
VeryHigh	5,000 – 10,000	0.67	0.33	0	0	0
VeryHigh	10,000 – 15,000	0.33	0.67	0	0	0
VeryHigh	15,000 – 20,000	0	1	0	0	0
VeryHigh	20,000 – 25,000	0	0.67	0.33	0	0
VeryHigh	25,000 – 30,000	0	0.33	0.67	0	0
VeryHigh	>=30,000	0	0	1	0	0
High	0 – 5,000	0.5	0.5	0	0	0
High	5,000 – 10,000	0.17	0.83	0	0	0
High	10,000 – 15,000	0	0.83	0.17	0	0
High	15,000 – 20,000	0	0.5	0.5	0	0
High	20,000 – 25,000	0	0.17	0.83	0	0
High	25,000 – 30,000	0	0	0.83	0.17	0
High	>=30,000	0	0	0.5	0.5	0
Medium	0 – 5,000	0	1	0	0	0
Medium	5,000 – 10,000	0	0.67	0.33	0	0
Medium	10,000 – 15,000	0	0.33	0.67	0	0
Medium	15,000 – 20,000	0	0	1	0	0
Medium	20,000 – 25,000	0	0	0.67	0.33	0
Medium	25,000 – 30,000	0	0	0.33	0.67	0
Medium	>=30,000	0	0	0	1	0
Low	0 – 5,000	0	0.5	0.5	0	0
Low	5,000 – 10,000	0	0.17	0.83	0	0
Low	10,000 – 15,000	0	0	0.83	0.17	0
Low	15,000 – 20,000	0	0	0.5	0.5	0
Low	20,000 – 25,000	0	0	0.17	0.83	0
Low	25,000 – 30,000	0	0	0	0.83	0.17
Low	>=30,000	0	0	0	0.5	0.5
VeryLow	0 – 5,000	0	0	1	0	0
VeryLow	5,000 – 10,000	0	0	0.67	0.33	0
VeryLow	10,000 – 15,000	0	0	0.33	0.67	0
VeryLow	15,000 – 20,000	0	0	0	1	0
VeryLow	20,000 – 25,000	0	0	0	0.67	0.33
VeryLow	25,000 – 30,000	0	0	0	0.33	0.67
VeryLow	>=30,000	0	0	0	0	1

Conditional probability table for Total Risk

Ecological Risk	Human Health Risk	Financial Risk	VeryHigh	High	Medium	Low	VeryLow
VeryHigh	VeryHigh	VeryLow	1	0	0	0	0
VeryHigh	VeryHigh	Low	0.67	0.33	0	0	0
VeryHigh	VeryHigh	Medium	0.33	0.67	0	0	0
VeryHigh	VeryHigh	High	0	1	0	0	0
VeryHigh	VeryHigh	VeryHigh	0	0.67	0.33	0	0
VeryHigh	High	VeryLow	0.67	0.33	0	0	0
VeryHigh	High	Low	0.33	0.67	0	0	0
VeryHigh	High	Medium	0	1	0	0	0
VeryHigh	High	High	0	0.67	0.33	0	0
VeryHigh	High	VeryHigh	0	0.33	0.67	0	0
VeryHigh	Medium	VeryLow	0.33	0.67	0	0	0
VeryHigh	Medium	Low	0	1	0	0	0
VeryHigh	Medium	Medium	0	0.67	0.33	0	0
VeryHigh	Medium	High	0	0.33	0.67	0	0
VeryHigh	Medium	VeryHigh	0	0	1	0	0
VeryHigh	Low	VeryLow	0	1	0	0	0
VeryHigh	Low	Low	0	0.67	0.33	0	0
VeryHigh	Low	Medium	0	0.33	0.67	0	0
VeryHigh	Low	High	0	0	1	0	0
VeryHigh	Low	VeryHigh	0	0	0.67	0.33	0
VeryHigh	VeryLow	VeryLow	0	0.67	0.33	0	0
VeryHigh	VeryLow	Low	0	0.33	0.67	0	0
VeryHigh	VeryLow	Medium	0	0	1	0	0
VeryHigh	VeryLow	High	0	0	0.67	0.33	0
VeryHigh	VeryLow	VeryHigh	0	0	0.33	0.67	0
High	VeryHigh	VeryLow	0.67	0.33	0	0	0
High	VeryHigh	Low	0.33	0.67	0	0	0
High	VeryHigh	Medium	0	1	0	0	0
High	VeryHigh	High	0	0.67	0.33	0	0
High	VeryHigh	VeryHigh	0	0.33	0.67	0	0
High	High	VeryLow	0.33	0.67	0	0	0
High	High	Low	0	1	0	0	0
High	High	Medium	0	0.67	0.33	0	0
High	High	High	0	0.33	0.67	0	0
High	High	VeryHigh	0	0	1	0	0
High	Medium	VeryLow	0	1	0	0	0
High	Medium	Low	0	0.67	0.33	0	0
High	Medium	Medium	0	0.33	0.67	0	0
High	Medium	High	0	0	1	0	0
High	Medium	VeryHigh	0	0	0.67	0.33	0
High	Low	VeryLow	0	0.67	0.33	0	0
High	Low	Low	0	0.33	0.67	0	0
High	Low	Medium	0	0	1	0	0
High	Low	High	0	0	0.67	0.33	0
High	Low	VeryHigh	0	0	0.33	0.67	0
High	VeryLow	VeryLow	0	0.33	0.67	0	0
High	VeryLow	Low	0	0	1	0	0
High	VeryLow	Medium	0	0	0.67	0.33	0
High	VeryLow	High	0	0	0.33	0.67	0
High	VeryLow	VeryHigh	0	0	0	1	0
Medium	VeryHigh	VeryLow	0.33	0.67	0	0	0
Medium	VeryHigh	Low	0	1	0	0	0
Medium	VeryHigh	Medium	0	0.67	0.33	0	0
Medium	VeryHigh	High	0	0.33	0.67	0	0
Medium	VeryHigh	VeryHigh	0	0	1	0	0
Medium	High	VeryLow	0	1	0	0	0
Medium	High	Low	0	0.67	0.33	0	0
Medium	High	Medium	0	0.33	0.67	0	0
Medium	High	High	0	0	1	0	0
Medium	High	VeryHigh	0	0	0.67	0.33	0
Medium	Medium	VeryLow	0	0.67	0.33	0	0
Medium	Medium	Low	0	0.33	0.67	0	0
Medium	Medium	Medium	0	0	1	0	0
Medium	Medium	High	0	0	0.67	0.33	0
Medium	Medium	VeryHigh	0	0	0.33	0.67	0
Medium	Low	VeryLow	0	0.33	0.67	0	0
Medium	Low	Low	0	0	1	0	0
Medium	Low	Medium	0	0	0.67	0.33	0
Medium	Low	High	0	0	0.33	0.67	0
Medium	Low	VeryHigh	0	0	0	1	0
Medium	VeryLow	VeryLow	0	0	1	0	0

Medium	VeryLow	Low	0	0	0.67	0.33	0
Medium	VeryLow	Medium	0	0	0.33	0.67	0
Medium	VeryLow	High	0	0	0	1	0
Medium	VeryLow	VeryHigh	0	0	0	0.67	0.33
Low	VeryHigh	VeryLow	0	1	0	0	0
Low	VeryHigh	Low	0	0.67	0.33	0	0
Low	VeryHigh	Medium	0	0.33	0.67	0	0
Low	VeryHigh	High	0	0	1	0	0
Low	VeryHigh	VeryHigh	0	0	0.67	0.33	0
Low	High	VeryLow	0	0.67	0.33	0	0
Low	High	Low	0	0.33	0.67	0	0
Low	High	Medium	0	0	1	0	0
Low	High	High	0	0	0.67	0.33	0
Low	High	VeryHigh	0	0	0.33	0.67	0
Low	Medium	VeryLow	0	0.33	0.67	0	0
Low	Medium	Low	0	0	1	0	0
Low	Medium	Medium	0	0	0.67	0.33	0
Low	Medium	High	0	0	0.33	0.67	0
Low	Medium	VeryHigh	0	0	0	1	0
Low	Low	VeryLow	0	0	1	0	0
Low	Low	Low	0	0	0.67	0.33	0
Low	Low	Medium	0	0	0.33	0.67	0
Low	Low	High	0	0	0	1	0
Low	Low	VeryHigh	0	0	0	0.67	0.33
Low	VeryLow	VeryLow	0	0	0.67	0.33	0
Low	VeryLow	Low	0	0	0.33	0.67	0
Low	VeryLow	Medium	0	0	0	1	0
Low	VeryLow	High	0	0	0	0.67	0.33
Low	VeryLow	VeryHigh	0	0	0	0.33	0.67
VeryLow	VeryHigh	VeryLow	0	0.67	0.33	0	0
VeryLow	VeryHigh	Low	0	0.33	0.67	0	0
VeryLow	VeryHigh	Medium	0	0	1	0	0
VeryLow	VeryHigh	High	0	0	0.67	0.33	0
VeryLow	VeryHigh	VeryHigh	0	0	0.33	0.67	0
VeryLow	High	VeryLow	0	0.33	0.67	0	0
VeryLow	High	Low	0	0	1	0	0
VeryLow	High	Medium	0	0	0.67	0.33	0
VeryLow	High	High	0	0	0.33	0.67	0
VeryLow	High	VeryHigh	0	0	0	1	0
VeryLow	Medium	VeryLow	0	0	1	0	0
VeryLow	Medium	Low	0	0	0.67	0.33	0
VeryLow	Medium	Medium	0	0	0.33	0.67	0
VeryLow	Medium	High	0	0	0	1	0
VeryLow	Medium	VeryHigh	0	0	0	0.67	0.33
VeryLow	Low	VeryLow	0	0	0.67	0.33	0
VeryLow	Low	Low	0	0	0.33	0.67	0
VeryLow	Low	Medium	0	0	0	1	0
VeryLow	Low	High	0	0	0	0.67	0.33
VeryLow	Low	VeryHigh	0	0	0	0.33	0.67
VeryLow	VeryLow	VeryLow	0	0	0.33	0.67	0
VeryLow	VeryLow	Low	0	0	0	1	0
VeryLow	VeryLow	Medium	0	0	0	0.67	0.33
VeryLow	VeryLow	High	0	0	0	0.33	0.67
VeryLow	VeryLow	VeryHigh	0	0	0	0	1

Conditional probability for Marginal Cost

Marginal Cost = Cost of Bid / (Watercourse Length x Buffer Width)

Marginal Cost is a continuous function node and is classified into deciles

Conditional probability table for Cost Effectiveness

Total Risk	Marginal Cost	VeryHigh	High	Medium	Low	VeryLow
VeryHigh	0 – 0.407	1.00	0.00	0.00	0.00	0.00
VeryHigh	0.407 – 0.811	0.78	0.22	0.00	0.00	0.00
VeryHigh	0.811 – 1.21	0.56	0.44	0.00	0.00	0.00
VeryHigh	1.21 – 1.7	0.33	0.67	0.00	0.00	0.00
VeryHigh	1.7 – 2.36	0.11	0.89	0.00	0.00	0.00
VeryHigh	2.36 – 3.4	0.00	0.89	0.11	0.00	0.00
VeryHigh	3.4 – 5.25	0.00	0.67	0.33	0.00	0.00
VeryHigh	5.25 – 9.24	0.00	0.44	0.56	0.00	0.00
VeryHigh	9.24 – 22.9	0.00	0.22	0.78	0.00	0.00
VeryHigh	>=22.9	0.00	0.00	1.00	0.00	0.00
High	0 – 0.407	0.50	0.50	0.00	0.00	0.00
High	0.407 – 0.811	0.28	0.72	0.00	0.00	0.00
High	0.811 – 1.21	0.06	0.94	0.00	0.00	0.00
High	1.21 – 1.7	0.00	0.83	0.17	0.00	0.00
High	1.7 – 2.36	0.00	0.61	0.39	0.00	0.00
High	2.36 – 3.4	0.00	0.39	0.61	0.00	0.00
High	3.4 – 5.25	0.00	0.17	0.83	0.00	0.00
High	5.25 – 9.24	0.00	0.00	0.94	0.06	0.00
High	9.24 – 22.9	0.00	0.00	0.72	0.28	0.00
High	>=22.9	0.00	0.00	0.50	0.50	0.00
Medium	0 – 0.407	0.00	1.00	0.00	0.00	0.00
Medium	0.407 – 0.811	0.00	0.78	0.22	0.00	0.00
Medium	0.811 – 1.21	0.00	0.56	0.44	0.00	0.00
Medium	1.21 – 1.7	0.00	0.33	0.67	0.00	0.00
Medium	1.7 – 2.36	0.00	0.11	0.89	0.00	0.00
Medium	2.36 – 3.4	0.00	0.00	0.89	0.11	0.00
Medium	3.4 – 5.25	0.00	0.00	0.67	0.33	0.00
Medium	5.25 – 9.24	0.00	0.00	0.44	0.56	0.00
Medium	9.24 – 22.9	0.00	0.00	0.22	0.78	0.00
Medium	>=22.9	0.00	0.00	0.00	1.00	0.00
Low	0 – 0.407	0.00	0.50	0.50	0.00	0.00
Low	0.407 – 0.811	0.00	0.28	0.72	0.00	0.00
Low	0.811 – 1.21	0.00	0.06	0.94	0.00	0.00
Low	1.21 – 1.7	0.00	0.00	0.83	0.17	0.00
Low	1.7 – 2.36	0.00	0.00	0.61	0.39	0.00
Low	2.36 – 3.4	0.00	0.00	0.39	0.61	0.00
Low	3.4 – 5.25	0.00	0.00	0.17	0.83	0.00
Low	5.25 – 9.24	0.00	0.00	0.00	0.94	0.06
Low	9.24 – 22.9	0.00	0.00	0.00	0.72	0.28
Low	>=22.9	0.00	0.00	0.00	0.50	0.50
VeryLow	0 – 0.407	0.00	0.00	1.00	0.00	0.00
VeryLow	0.407 – 0.811	0.00	0.00	0.78	0.22	0.00
VeryLow	0.811 – 1.21	0.00	0.00	0.56	0.44	0.00
VeryLow	1.21 – 1.7	0.00	0.00	0.33	0.67	0.00
VeryLow	1.7 – 2.36	0.00	0.00	0.11	0.89	0.00
VeryLow	2.36 – 3.4	0.00	0.00	0.00	0.89	0.11
VeryLow	3.4 – 5.25	0.00	0.00	0.00	0.67	0.33
VeryLow	5.25 – 9.24	0.00	0.00	0.00	0.44	0.56
VeryLow	9.24 – 22.9	0.00	0.00	0.00	0.22	0.78
VeryLow	>=22.9	0.00	0.00	0.00	0.00	1.00

Utility table for the Utility node

Cost Effectiveness	Fund Bid?	Utility
VeryHigh	Yes	100
VeryHigh	No	0
High	Yes	75
High	No	25
Medium	Yes	50
Medium	No	50
Low	Yes	25
Low	No	75
VeryLow	Yes	0
VeryLow	No	100

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