**Riparian DST: Documentation**

The Riparian DST has been developed to predict the likely efficacy of riparian mitigation for design of a stream monitoring plan. The focus is on mitigation of sediment and provision of stream shade, both of which should contribute towards achievement of positive water quality and ecological outcomes.

**1 Types of riparian mitigation**

Three types of riparian mitigation are included in the DST, these are:

* Type 1 = fencing for stock exclusion
* Type 2 = fencing as above combined with a grass filter/buffer strip;
* Type 3 = fencing as above combined with a mixed buffer consisting of a grass filter/buffer plus sedges, shrubs and trees.

**2 Efficacy of riparian mitigations**

The contaminant attenuation and shading efficacy of each type of riparian mitigation is provided in the *Riparian Mitigations Table*. It was assumed that Type 1 mitigation could only mitigate bank erosion, while Types 2 and 3 mitigation could mitigate both bank erosion and overland flow (runoff) as sources of sediment to streams.

For contaminants an efficacy range is given – values from 0-100%. McKergow et al. (2020) defines efficacy (attenuation efficacy, %) as the difference between buffer inflow and outflow load (or concentration), expressed as the proportion of inflow load/concentration. The midpoint of the range has been applied for simplification, but scenarios could be run that apply the range, to account for uncertainty (which may be large). For shading it is assumed that an efficacy of 100% will apply if a target of 70% shade is met, otherwise efficacy is 0%.

The contaminant efficacy of Type 1 was derived from McKergow et al. (2007). The efficacy for Types 2 and 3 were derived from McKergow et al. (2020). Types 2 and 3 efficacy depend on three key factors: the *buffer width to hillslope length ratio*, *land slope*, and *soil clay content*.

The shading efficacy was derived from Davies-Colley et al. (2005) and Rutherford et al. (2018), now simplified in a regional riparian planting guidance document (HBRC, NIWA, DairyNZ 2020). It depends on the *vegetation + bank height to stream wetted width + planting setback ratio*.

**3 Instream ecological targets**

The following targets are assumed to achieve desirable ecological outcomes for instream/aquatic plants and water temperature:

*Shade greater than or equal to 70%*

As an approximate rule of thumb is that this can be achieved with an average vegetation+bank height to stream wetted width+planting setback ratio of 1 or more (Davies-Colley et al. 2005, Rutherford et al. 2018). Note that vegetation will need to be dense with no large gaps between trees to achieve this especially during summer when solar radiation and air temperatures peak.

*Cox-Rutherford index (CRI) less than or equal to 21°C*

CRI is the average of the daily maximum and daily average temperature. This provides adequate protection for common North Island stream macroinvertebrates (e.g., *Deleatidium spp*). However, lower values may be required to protect sensitive species (e.g., stoneflies) in colder South Island streams (Quinn and Hickey 1990). It therefore corresponds to meeting a “B band” status supporting “good” ecological health according to Davies-Colley et al. 2013). It is assumed that where average shading of 70% is achieved over a 1 km or more length of segment in streams with water depth ≤15 cm deep, a 4°C decrease in water temperature at the segment outlet is possible (based on Rutherford et al. 2004, Davies-Colley et al. 2009, Johnson and Wilby 2015).

*Periphyton filaments less than 30% cover or macrophyte channel clogginess less than 50%*

This is likely to be achieved where average shading of the segment is equal to or greater than 70% (Rutherford et al. 1997, Biggs 2000, Matheson et al. 2012, 2017).

**4 Predicted mitigation efficacy**

*Sediment*

To calculate the amount of sediment from bank erosion (SAB, t/y) and runoff (SAR, t/y) mitigated in each segment the following equations were used:

SAB = (SLB x (SEB/100))

SAR = (SLR x (SER/100))

where:

SLB = sediment load (input) to the segment from bank erosion (t/y)

SLR = sediment load (input) to the segment from runoff (t/y)

SEB = sediment efficacy for bank erosion for the mitigation type (%, from *Riparian Mitigations Table*)

SER = sediment efficacy for runoff for the mitigation type (%, from *Riparian Mitigations Table*)

IMPORTANT NOTE: If using sediment yield data from NZ River Maps (Hicks et al. 2011) the sediment load input to the segment is assumed to be the difference between that predicted for the segment, and that predicted for the segment immediately upstream.

To calculate the percentage of the total sediment load input that is mitigated in the segment (SPT, %) is:

SPT = (SAB+ SAR)/SLT) x 100

where:

SLT = total sediment load (input) to the segment (t/y) = SLB + SLR.

The predicted response for each current state sediment attribute at mitigation maturity (AR) was calculated as follows:

AR(TSS) = AC(TSS)/100 x (100 - SPT)

AR(DepSed) = AC(DepSed)/100 x (100 - SPT)

where:

AC = Current state value of attribute

*Shade and water temperature*

The shading efficacy (HP) depends on the vegetation+bank height to stream wetted width+planting setback (HW) ratio. Where the HW ratio is 1 or more, 100% shading efficacy is achieved (i.e. shading target of 70% is met). Where this ratio is less than 1, then shading efficacy is 0%.

We calculated stream shade and periphyton cover attribute responses as follows:

AR (shade)= AC + ((AT - AC) x HP)) where HP is either 0 or 1

AR (periphyton cover)= AC - ((AC - AT) x HP) where HP is either 0 or 1

where AT = Attribute target for ecological response (e.g. 70% for shade, 30% for periphyton filaments cover)

The shading efficacy for water temperature control (HPT) is determined by stream order and the length of the shaded segment according to Rutherford et al. (1997):

In shaded segments of 1st and 2nd order streams:

HPT = L/2000 where 0 < L < 1000 m (increases linearly from 0 to 0.5 over 1000 m)

HPT = 1-500/Lwhere L > 1000 m (increases non-linearly from 0.5 to 1 below 1000 m)

where;

L = length of SHADED segment

In shaded segments of 3rd and 4th order streams:

HPT = L/10000 where 0 < L < 5000 m (increases linearly from 0 to 0.5 over 5000 m)

HPT = 1-2500/L where L > 5000 m (increases non-linearly from 0.5 to 1 below 5000 m)

In shaded segments of 5th order streams:

HPT = L/24000 where 0 < L < 12000 m (increases linearly from 0 to 0.5 over 12000 m)

HPT = 1-6000/L where L > 5000 m (increases non-linearly from 0.5 to 1 below 12000 m)

In unshaded segments of any stream order (i.e., where HW is <1) we assumed that:

HPT = 0

We calculated the water temperature attribute response as follows:

AR (water temperature) = AC – (4 x HPT) where 0 < HPT < 1

For all response attributes to determine progress towards achieving the predicted attribute response at mitigation maturity at interim intervals (ARI) we assumed a linear progression as follows:

ARI = AC – ((AC - ARI)/TR) x TI)

Where TI = time interval elapsed (e.g. 1, 5 or 10 years).

**5 References**

Biggs BJF (2000). New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams: 122.

Davies‐Colley RJ, Rutherford JC. (2005). Some approaches for measuring and modelling riparian shade. *Ecological Engineering* 24: 525–530.

Davies‐Colley RJ, Meleason MA, Hall GMJ, Rutherford JC. (2009). Modelling the time course of shade, temperature, and wood recovery in streams with riparian forest restoration. *New Zealand Journal of Marine and Freshwater Research* 43: 673-688.

Davies-Colley R, Franklin P, Wilcock B, Clearwater S, Hickey C (2013). National Objectives Framework - Temperature, Dissolved Oxygen & pH: Proposed thresholds for discussion. Report No. HAM2013-056 for Ministry for the Environment: 83.

HBRC, NIWA, DairyNZ (2020). Riparian planting in Hawkes Bay. [18449-HBRC-RiparianBro-WEB.pdf](https://www.hbrc.govt.nz/assets/Document-Library/Guides/18449-HBRC-RiparianBro-WEB.pdf)

Hicks DM, Shankar U, McKerchar AI, Basher L, Lynn I, Page M, Jessen M (2011). Suspended Sediment Yields from New Zealand Rivers. *Journal of Hydrology (New Zealand)* 50: 81-142.

Johnson MF, Wilby RL (2015). Seeing the landscape for the trees: Metrics to guide riparian shade management in river catchments. *Water Resources Research 51*: 3754-3769.

Matheson FE, Quinn JM, Hickey CW. (2012). Review of the New Zealand instream plant and nutrient guidelines and development of a new decision-making framework: Phases 1 and 2 final report. Report No. HAM2012-081 prepared for the Ministry of Science and Innovation Envirolink Fund by NIWA, Hamilton: 127.

Matheson F, Haidekker S, Wilding T, Hamer M, Catlin A. (2017). Riparian shading as a tool to manage nuisance instream plants: testing the concept in Hawkes Bay and Waikato streams and rivers. Proceedings of the 5th Biennial Symposium of the International Society for River Science, 19-24 November, Hamilton, NZ.

McKergow LA, Goeller B, Woodward KB, Matheson FE, Tanner CC. (2020). Attenuation of diffuse-source agricultural sediment and nutrients by riparian buffer zones. A review to support guideline development. Report No. 2020037HN prepared for DairyNZ by NIWA, Hamilton: 67.

McKergow LA, Tanner C, Monaghan R, Anderson GC (2007) Stocktake of diffuse pollution attenuation tools for New Zealand pastoral farming systems. Report No. HAM2007-161 prepared for Pastoral 21 Research Consortium: 102.

Quinn JM, Hickey CM (1990) Characterisation and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors, New Zealand Journal of Marine and Freshwater Research, 24:3, 387-409, DOI: 10.1080/00288330.1990.9516432

Rutherford JC, Davies-Colley RJ, Quinn JM, Stroud MJ, Cooper AB (1997) Stream shade: towards a restoration strategy. Department of Conservation, Wellington, NZ: 161.

Rutherford JC, Davies‐Colley RJ, Meleason MA (2018). Modelling stream shade: 1. Verifying numerical simulations with measurements on simple physical models. Ecological Engineering 120: 441-448.

Rutherford JC, Marsh NA, Davies PM, Bunn SE (2004). Effects of patchy shade on stream water temperature: How quickly do small streams heat and cool? Marine and Freshwater Research 55: 737–748.