

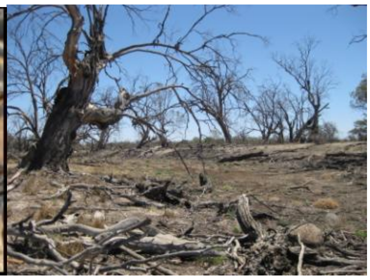

Expert Panel Evaluation of Risk Assessment for Chowilla Regulator

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Background and scope of work

The Chowilla floodplain and anabranch system is a significant ecological asset of the Murray-Darling Basin; it is an Icon Site of the Living Murray and is a RAMSAR listed wetland of international importance. Although the Chowilla floodplain is currently undergoing a severe decline in environmental condition owing to river regulation and prolonged periods of low in-flows, it still retains much of its natural character. Discrete areas of floodplain have benefited from an environmental watering program which has been conducted here since 2004. However, owing to constraints with the delivery of environmental water these programs are only conducted on a small scale and much of the rest of the floodplain continues to decline. Despite dramatic declines in fish populations in the lower Murray River, Chowilla remains an important site for native species. It has abundant small-bodied species, the presence of several threatened species and good populations of Murray cod and callop (yellow belly or golden perch), both popular angling species. These latter two species are associated with fast-water habitats in the inflowing creeks, rather than the slow weir pools of the Murray River. The Murray cod population appears to have regular spawning and recruitment, one of the few sites where this occurs in South Australia. Native fish populations in Chowilla should further benefit from the recent addition of fishways to barriers in the lower Murray river.

A range of management options to halt the decline of the Chowilla floodplain and to meet The Living Murray's First Step Decision have been evaluated. Brookes *et al*. (2006) concluded that the construction and operation of an environmental regulator on Chowilla Creek to artificially inundate a large portion of the Chowilla floodplain was the only option considered that came close to meeting these objectives. However, they cautioned that owing to the scale of the project being considered detailed assessments of the potential risks involved in the operation of the regulator should be undertaken before a final decision was made.

Between 2007 and 2009 a series of detailed investigations and risk assessments have been undertaken for a range of assets that may be affected by regulator operations. These included abiotic factors such as floodplain geomorphology, surface water quality and ground water, surface water and soil salinity interactions. Flora and fauna responses to regulator operation where also considered including predicted responses of avifauna, amphibians, fish, pest plants and terrestrial vegetation (including both trees and understorey vegetation). The risk assessments are summarised in the document Environmental assessments of the Chowilla Creek environmental regulator (SA Murray-Darling Basin NRM Board, 2009)

The panel who contributed to the Brookes *et al*. (2006) report of potential risks and benefits were reconvened to review the individual risk assessments that were undertaken in response to this report. The panel were asked to comment on four points:

1. The adequacy and breadth of ecological assessments completed to date,
2. The balance of risks and benefits and potential tradeoffs associated with regulator operation vs no action,
3. A recommendation on whether or not to proceed to construction based on the potential risks and benefits, and, if the project proceeds
4. Recommendations regarding ongoing operation

Introduction
Critically low water availability throughout the Murray Darling Basin is severely impacting water-dependent natural assets including the Chowilla Floodplain system. The installation of a flow regulator on Chowilla Anabranch will enable a significant proportion of the Chowilla floodplain to be inundated and achieve considerable environmental benefit for the ecological communities deprived of water. However, this option may also carry significant environmental risks, particularly to fish communities. These risks need to be managed appropriately during regulator use.

The aim of an environmental regulator is to provide water to the floodplain as efficiently as possible. The scheme will water parts of the system desperately in need of water. However, it is important to stress that this scheme will not reinstate a natural flood. There are clear distinctions between a floodplain inundation facilitated by a regulator and a natural flood e.g. differences in the shape of the hydrograph, direction of the flow and the biogeochemistry in the water column. Management of the regulator must be sensitive to these differences, carefully set objectives for each regulator use, actively monitor ecological response and adaptively manage as new information becomes available.

The adequacy and breadth of ecological assessments completed to date,

In the three years since the Brookes *et al*. (2006) report a number of ecological risk assessments have been undertaken (see SA Murray-Darling Basin NRM Board, 2009, for a complete summary and Appendix 1). Briefly, it is evident that floodplain vegetation, amphibians and birds will respond positively to floodplain inundation independent of whether the water delivered as a flood flow or through the operation of the proposed environmental regulator.

There are some risks to downstream water quality through the operation of the proposed regulator, particularly the onset of blue-green algal blooms or low oxygen events associated with carbon mobilisation from the floodplain ('blackwater'), but these can be managed by ensuring the floodplain inundation doesn't occur during overly hot periods. One water quality issue that hasn't been addressed is the potential for the mobilisation of sulfidic sediments during inundation. Mismanagement of sulfidic sediments in inland waterways in the past has resulted in environmental harm (e.g. McCarthy et al 2006) and sulfidic sediments are known to occur in some wetlands on the floodplain (e.g. Tarena Billabong).

There are, however, some real concerns about how the operation of the regulator may impact on fish communities. Fish often select habitats according to flows, respond to different flow cues for movements and are at the mercy of flows during drifting life stages (eggs or larvae). The fast-flowing habitats in Chowilla that support Murray cod and callop are perhaps the ecological features most at risk from the installation and operation of a flow regulator and the most difficult to compensate for.

Mallen-Cooper et al. (2008) undertook a *Risk assessment of the proposed Chowilla regulator and managed floodplain inundations on fish*. This assessment used hydrodynamic modelling to simulate floods or inundation dynamics (inundation area, velocity, depth, daily discharge) then assess the potential responses of each fish species to three different flow regimes. The likelihood and the consequence of each potential impact were then rated. Mallen-Cooper *et al*. (2008) suggested that populations of native fish species that prefer still or slow flowing habitats (common species such as bony herring and carp gudgeons) would be likely to increase with managed inundations. Native species that prefer fast flowing habitats such as Murray cod (an angling and a threatened species) and callop (angling species), would be likely to decrease under such managed inundations. A decreased abundance of Murray cod was assessed as being very likely and having a major consequence. Non-native species, which also prefer slow flowing or still waters were likely to increase. This included a very likely increase in abundance of common carp, also having major consequences. The inundation of large areas of vegetated floodplain, with shallow, slow flowing water provides favoured spawning areas for carp. Increased abundances of carp in Chowilla may also contribute to increases in populations in the Murray River, may impact on freshwater catfish and could interact with frog species. It has been recommended that a separate carp management plan be produced to attempt to address these issues – not all of which may be easily solvable. The impact of decreased water quality and fish kills could not be addressed as the water quality risk assessment had not been completed, and this now needs to be considered as a risk to fish on some areas of the inundated floodplain. Depending on the operation of the regulator, there is also the chance of fish being stranded on the floodplain.

The full impacts on fish, however, could not be adequately determined due to limited hydrodynamic modelling and additional modelling and assessment was required. Further investigations are currently being undertaken to more fully assess the impacts on fish. Unfortunately, this additional work has not been completed at the time of this overall assessment, but should be taken into account when available.

The balance of risks and benefits and potential tradeoffs associated with regulator operation vs no action.

There is no 'Silver Bullet' for repairing water-dependant ecosystems deprived of a natural flooding regime. While there needs to be a real commitment to the reinstatement of flooding flows in the Murray-Darling River system, this is unlikely to occur on a regular basis in the immediate future. Pragmatic solutions are required to ensure environmental watering of the Chowilla Floodplain at intervals sufficient to enable system preservation and recovery. While far from ideal, the construction of a regulator which will periodically inundate a significant proportion of the Chowilla floodplain appears to be the only feasible solution to delivering water to a habitat that is critically in need of freshwater.

Benefits and Risks

This proposal, installation of a regulator on Chowilla Creek, coupled with manipulation of Lock 6, to deliver freshwater to the Chowilla floodplain has been rigorously researched and the ecological risks and benefits assessed. Information is provided on water availability, geomorphology, black-water, cyanobacteria, aquatic, riparian and floodplain vegetation, amphibians, birds, and frogs. Prediction based upon “no action” versus 5 flow scenarios were addressed and discussed extensively at the Chowilla Forum on August 3rd 2009. The forum included 15 oral papers that were supported by detailed reports (See Appendix 1) that demonstrated the benefits of delivering water to selected sites and compared these data with unwatered sites to predict the likely outcome of the “do nothing action” versus the provision of freshwater via the strategic manipulation of weir height and the operation of the regulator. Based upon a rigorous analysis of the extensive data set from a range of disciplines the following will occur if no action is taken:

- A further decline in woodland plant species and a lack of recruitment of new individuals due to a lack of flowering and seed set and favourable conditions for germination
- A riparian zone restricted to a few metres which would severely limited the available habitat for submerged, emergent and amphibious plant species and consequently a loss of biodiversity and ecosystem resilience
- An increasingly depauperate seed and propagule bank of both plants and zooplankton
- A severely restricted food supply for herbivores such as kangaroos, emus and foraging birds that depend upon either vegetation or the associated macro-invertebrates
- A severely restricted habitat for amphibians, waders and other water dependent birds
- A restricted riparian habitat for the recruitment of juvenile fish, frogs and other macro-invertebrates
- No improvement of the connectivity between floodplain and the main river channel limiting the interaction between two icon sites (Chowilla and the River Murray main channel)
- A fish community that would remain essentially the same

The benefits of the installation of a regulator on Chowilla creek would greatly increase watering options compared with the current watering regime in terms of the area inundated (3876 h), and water availability. The regulator would also permit manipulation of the timing, frequency, extent and duration of such inundations. The proposed regulator is essential to ensure that adaptive management has the flexibility to operate across a range of hydrological conditions to maximise the ecological benefit of the water delivered. The ecological benefits of watering the Chowilla floodplain via the installation of a regulator were extensively canvassed at the Chowilla Forum. Furthermore, there is an extensive scientific knowledge base that has critically examined the benefits associated the installation of regulator. In summary,many of the benefits reverse the “do nothing option” and include:

- Stop the decline of woodland species and encourage recruitment of new individuals by providing conditions suitable for flowering, seed set and germination
- Extend the riparian habitat and thereby promote biodiversity of both fauna and flora which will enhance the system’s resilience to future droughts

- Permit replenishment of the seed and propagule store either via upstream dispersal or on-site recruitment which will further increase the system's ability to respond to unfavourable conditions
- Provide an additional primary food source for herbivores and a secondary food source for fish and birds and thereby increase the pathways for the development of alternative food webs and the resilience of the system
- Increase bird habitat
- provide habitats for some small bodied fish
- Promote exchange between two River Murray icon sites, Chowilla and the main river channel
- Replenish freshwater lenses and thus promote healthy woodlands
- Increase carbon productivity and transfer from floodplain to river and vice versa

  It does however, cause risks to large native fish and may increase non-native fish (especially carp) populations.

In addition to these specific ecological benefits, watering of the floodplain does provide a unique opportunity to understand and document the ecological benefits of supplying water to an Australian floodplain that has Australia-wide implications and could be used to test theories relevant to aquatic ecosystems and their applicability to the southern Australian landscape. However, to achieve this, substantial planning of the operation of the regulator must occur and sufficient scientific, logistic and financial support must be provided on an ongoing basis.

The regulator could be expected to offset the adverse effects described under the "no action" scenario, above. It would substantially increase the area of floodplain that can be inundated (3876 ha), compared to what is possible at present. It would also permit manipulation of the timing, frequency, extent and duration of floods, so that the benefits of flooding could be optimised.
Operation of the regulator would bring opportunities for monitoring and research that would benefit the Chowilla Icon Site Condition Management Plan and, in turn, could bring benefits for management of floodplain-river systems elsewhere in the world.

Risks
The risk assessment protocol has been thorough and more extensive than other major projects currently underway in the South Australia (e.g. The Lower lakes and Coorong, The Upper Southeast Drainage plan). There are risks associated with:

- Changes in geomorphology
- Degraded water quality (including increase in salt load, increase likelihood of blackwater events and higher incidence of blue-green algal blooms).
- Impacts on native and introduced fish species.

Overall the geomorphologic risks are relatively low but there is a high risk of a increasing both the amount and rate of sediment deposition on the floodplain.

Operation of the regulator will mobilise salt from the floodplain – especially during the first few operations. It has been estimated that total EC will increase by up to 100 EC/day during the operation (SA Murray-Darling Basin NRM Board, 2009). However this must be balanced against the increased likelihood of sulfidic sediments building up in floodplain wetlands if the salt is not removed (for a discussion of the potential environmental impacts of sulfidic sediments see for example Hall *et al* 2006). Sulfidic sediments are already present in a number of wetlands on the floodplain (e.g. Tarena Billabong – B. McCarthy unpublished) and it would be prudent to assess the extent of sulfidic sediments on the floodplain before inundation.[1]

Blackwater events are a natural part of the ecology of lowland river systems. During a flood, carbon compounds are leached from leaf litter laying on the floodplain or dry flood runners/creek channels in much the same way that tea is leached from tea leaves. This carbon can be beneficial to downstream ecological communities (e.g. Junk et al. 1989). However, blackwater events can markedly change water quality. Microbes can immediately use about one-third of the carbon leached from the leaf litter. As the microorganisms consume the dissolved carbon they use up oxygen in the water - often at a rate faster than the oxygen can be replenished. Therefore, blackwater plumes often have very low levels of dissolved oxygen. The lack of dissolved oxygen can cause the death of fish and other aquatic animals in the plume. Native fish and other large aquatic organisms require at least 2 mg/L of oxygen in the water to survive, but may begin to suffer at levels below 4-5 mg O_2/L (Gerhke, 1988). However, deoxygenation is temperature dependant. Deoxygenation events usually only occur when the water temperature is high (Howitt et al 2007). Therefore, avoiding operating the regulator during the summer months (especially during the first few operations) is suggested.

Operation of the regulator may also increase the likelihood of blue-green algal blooms downstream of the regulator. Flooding dry floodplain releases nutrients from the soil (Baldwin and Mitchell, 2000). This pulse of nutrients coupled with the relatively still waters behind the regulator could promote a blue-green algal bloom on the flood plain. However, the likelihood of this occurring is substantially reduced if the flooding occurs during cooler periods and at the river flows proposed (>10000ML/day. If blue-green algal blooms do occur, their impacts to drinking water quality can be managed using existing technologies (Chow et al., 1999)

There are significant risks (and some benefits) associated with the fish community. Watering is likely to benefit common species such as bony herring and carp gudgeons but high frequency, low inflows will negatively influence callop There is likely to be no change in the dwarf flathead gudgeon and crimson-spotted rainbowfish. Murray cod and silver perch are likely to respond negatively to high frequency low flows. The risks are impossible to eliminate completely but may be more manageable with the provision of low frequency, high inflows (> 30 000 Ml/d). An increased in the carp populations is the most severe biological risk but this can be minimised by avoiding spawning periods .This timing may, however, also negate any other positives

[1] Many of the wetlands of interest may have been assed in the current MDBA project *Acid Sulfate Soil Risk in the MDB* project.

to common small-bodied native fish. Mallen-Cooper et al. (2008) recommended that a separate carp management plan be produced to attempt to address these issues, though many may be difficult to mitigate. For example, there may be scope to manipulate water levels to limit spawning times . It is not clear if a Williams cage (a carp trap) would be included in the fishway, but this could help to offset the advantage conferred on carp by the pool habitat, although there are multiple entry point to this habitat.

However, the on-balance conclusion is that much of the ecosystem will benefit from the provision of freshwater flows and this must be weighed against the risk of increased carp populations, the loss of important native species and the loss of fast water habitats.

Minimising risk and optimising benefit for vegetation during initial operations

The risks and benefits of various flooding scenarios as they influence the vegetation are documented in Table 1 and 2. Table 1 indicates the optimal time for germination, growth and flowering for perennial and seasonal (annual) plants. These are further split into life forms, submerged, emergent, amphibious, flood plain and weeds. From this information Table 2 offers a range of flooding options. The assumptions are that the flood would last for 120 days, flow to South Australia 10,000 or 50,000 ML day^{-1}, rates of water level rise would initially be 10 but decrease to 5 cm day^{-1}, rates of fall vary between 0.05 and 0.1 cm day^{-1} and that the deeper areas (3m) on the floodplain would hold water for six months depending upon the timing of the flood.

An initial flood during mid-May to mid-August offers some ecological benefit (primes germination of floodplain plants in anticipation for late autumn early winter spring rain) but carries the risk of falsely triggering germination if there are no follow up rains to encourage growth. The period June to August carries with it minimal risk but some ecological benefit. Because winter temperatures limit biogeochemical process there is less probability of black-water discharges into the main river channel. At this time the main channel is unlikely to thermally stratify and therefore the probability of cyanobacterial blooms is minimised. Furthermore, evaporation and transpiration are minimal and a flood should recharge freshwater lenses that would enhance the health of the woody vegetation in the following spring. A third option is to delay the flood until July through to September. This carries with it significant ecological benefit but does carry with it the risk that as temperatures increase so too does evaporation and biogeochemical process that may lead to a black-water discharge into the main channel at a time when thermal stratification may favour cyanobacteria. Further delays (mid-September to mid-December) in the onset of a flood carry with it an increase in the ecological benefit (plant germination, growth, flowering and seed set) but also an enhanced risk, such weed invasion. Late spring, early summer has the risk associated with carp breeding and should be avoided in the initial trials.

As the project gains an understanding of the responses of the system to floods it would be beneficial to examine how it responds to several pulsed floods of a relatively short duration (4-6 weeks) with an intervening period of 2-3 weeks. In the operation of these pulsed flows particular attention should be paid to the vulnerability of the fish community to high frequency, low flows.

A recommendation on whether or not to proceed to construction based on the potential risks and benefits, and, if the project proceeds

Without action to deliver water to the Chowilla floodplain, key components of the floodplain ecosystem will be lost. This scenario is unacceptable and given the return of flooding flows in the Murray River is unlikely in the short term, and that on-balance the benefits out way the risks, the construction of the Chowilla regulator should proceed.

This recommendation is made with the understanding that the Chowilla flow regulator will be used for the express purpose of providing environmental benefit to the Chowilla floodplain and is not used as a water storage, which would damage the ecosystem.

Each use of the regulator should be preceded by rigorous planning to identify the desired outcomes, the optimum strategy for achieving these outcomes and review of the monitoring program to ensure adequate measurement of indicators.

The Brookes et al (2006) report stated "This proposal has no precedent in Australia, and the outcomes cannot be predicted with certainty. As it is necessary to 'learn by doing', it is imperative that a comprehensive, scientifically rigorous monitoring program is maintained, and that the data and conclusions are subject to critical review." Any operation of the regulator should be conducted within an Adaptive management learning environment, with each operation carefully planned to incorporate, then monitor specific management outcomes. Environmental benefits can then be maximised through the adaptation of future operations. The objectives of each operation may well change to benefit different aspects of the ecosystem.
In particular, the regulator should be used to test particular hypotheses relating to ecological response of floodplain environments to flooding. The results from these experiments should then be incorporated into future management. Benefits from the management of this regulator can only be achieved with high levels of scientific, strategic and logistical support.

Recommendations regarding ongoing operation

First Operation: The operation of the Flow Regulator offers tremendous ecological benefits to the floodplain but needs to avoid the realisation of potential risks. The major risks are loss of fast-flowing fish habitat, carp spawning, salt export, and blackwater and cyanobacteria formation. The first operation of the flow regulator should be conservative and timed to minimise the chance of any potential problems being realised. The risk of cyanobacteria and blackwater increases with increasing temperature and so regulator use in warmer months (nominally mid-December to March) should be avoided, at least until the rates of export of carbon and nutrients from the floodplain are understood. Furthermore, carp spawning is seasonal (September -April) and avoidance of this and any other issues regarding native fish spawning periods may be best avoided in the first instance. So it would appear that watering in winter months would minimise the major risks. Benefits to native fish are more likely to occur during spring, but as this will also be favourable to carp, this options needs to be carefully evaluated at a later stage.

The first use of the regulator will enable the validation of models used in the pre-construction risk assessments. Many of the risk assessments, prediction of flow velocities and inundated area rely on the hydrodynamic model which requires validation. In particular, a notable concern is the loss of fast flowing habitat for Murray Cod and monitoring is required to determine where they go or stay in the system[2]. The benefits, risks and trade-off between native fish species and introduced fish species need to be carefully considered and monitored.

Subsequent Operations: Each operation of the regulator should be rigorously planned, be based on scientifically credible predictions of outcomes and have clear ecological objectives. As an example the risks and benefits of various flooding scenarios as they influence the vegetation are documented in Table 1. Table 1 indicates the optimal time for germination, growth and flowering for perennial and seasonal (annual) plants. These are further split into life forms, submerged, emergent, amphibious, flood plain and weeds. From this information Table 2 offers a range of flooding options. The assumptions are that the flood would last for 120 days, flow to South Australia 10,000 or 50,000 ML day^{-1}, rates of water level rise would initially be 10 but decrease to 5 cm day^{-1}, rates of fall vary between 0.05 and 0.1 cm day^{-1} and that the deeper areas (3m) on the floodplain would hold water for six months depending upon the timing of the flood. An initial flood during from mid-May to mid-August offers some ecological benefit (primes germination of floodplain plants in anticipation for late autumn early winter spring rain) but carries the risk of falsely triggering germination if there are no follow up rains to encourage growth. The period June to August carries with it minimal risk but some ecological benefit. Because winter temperatures limit biogeochemical process there is less probability of black-water discharges into the main river channel. At this time the main channel is unlikely to thermally stratify and therefore the probability of cyanobacterial blooms is minimised. Furthermore, evaporation and transpiration are minimal and a flood should recharge freshwater lenses that would enhance the health of the woody vegetation in the following spring. A third option is to delay the flood until July through to September. This carries with it significant ecological benefit but does carry with it the risk that as temperatures increase so too does evaporation and biogeochemical process that may lead to a black-water discharge into the main channel at a time when thermal stratification may favour cyanobacteria. Further delays (mid-September to mid-December) in the onset of a flood carry with it an increase in the ecological benefit (plant germination, growth, flowering and seed set) but also an enhanced risk, such weed invasion. Late spring, early summer has the risk associated with carp breeding and should be avoided in the initial trials.

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[2] Creative use of lock 6 levels and the preference for higher inflows may help maintain fast water habitats. Additional hydrodynamic modelling and the ground truthing of these models during initial operations may assist in future decisions for operations.

Research and Monitoring: The construction of the regulator provides the infrastructure to enable floodplain inundation but a significant investment is required in research and monitoring to determine the ecological responses so that environmental benefits can be maximised. The regulator and its operation should be considered as a large and significant experiment that can add to the adaptive management of Australian's lowland floodplains in times of shrinking water resources. Targeted monitoring within an hypotheses based framework will develop a data and knowledge bank to enable progressive learning on how to maximise ecological benefits from regulator operation. This is the critical part of the regulator operation and requires a tailored multidisciplinary research program and a sophisticated suite of sensors continuously monitoring hydrodynamics, soil moisture, water quality, biogeochemical and organism response. For example one often quoted but poorly understood process occurring on floods is the export of carbon and nutrients from the floodplain back to the river channel and subsequent increase in riverine productivity (Flood-Pulse Concept sensu Junk et al. 1989). The well defined inlets and outlets for flooding water after the instillation of the regulator provides an excellent opportunity to quantify the movement of energy and nutrients to and from the floodplain during floods. Proper flow weighted sampling of both influent and effluent streams at appropriate time intervals will allow the calculation the mass-balance of carbon and key nutrients on the floodplain. If this is coupled with measures of both on-floodplain and in-stream productivity it presents an opportunity to test the Flood-Pulse model of lowland river functioning.

The Chowilla floodplain ecosystem needs to be managed as a whole with consideration to potential risks and close monitoring of these to ensure they do not eventuate. Attention should be paid to how the regulator is operated and how it compliments other initiatives to provide environmental water to the Chowilla floodplain region. There should be a environmental watering plan for South Australia that describes how much water the different assets require and details the policy and institutional reform necessary to achieve this. Maintenance of diverse of habitats and communities is a necessary outcome from the environmental regulator and management should focus on this and how the regulator can facilitate the achievement of this outcome when used in combination with the other available options.

Plants	J	F	M	A	M	J	J	A	S	O	N	D	Reason
Perennial													
Submerged	Triglochin, Potamogeton ,												
Germination	Germination on wet mud flats, enhanced by spring summer temperatures. Vegetative growth in many species via rhizomes / stolons												Temperature Exposed mudflats
Growth	Growth is continuous, plants don't die back over winter, but spring early summer are the optimal months												Don't die back over winter
Flowering													
Emergent	Eleocharis, Baumea, Schoenoplectus, Cyperus												
Germination	Germination requirements not well known most colonization is via vegetative means. Cyperus in tolerant to top flodding												Temperature Exposed mudflats
Growth													Don't die back over winter
Flowering													
Amphibious	Centipeda, Myriophyllum,												
Germination	Mud flats												Temperature, mud flats
Growth													Don't die back over winter
Flowering													
Floodplain	Lignum, Atriplex												

Germination	Floodplain species respond to rainfall throughout the year												
Growth													
Flowering	Species will flower as soon as placed under water stress, often within 2 months of germination												
Terrestrial													
Germination													
Growth													
Flowering													
Weeds	Phyla canescens,												
Germination	Summer temperatures									Respond to Rainfall but do not tolerate flooding			
Growth	Phyla continuous growing season												
Flowering													

Feature	J	F	M	A	M	J	J	A	S	O	N	D	Reason
Plants													
Cyanobacteria													Warm months promote stratification. Floodplain inundation in Autumn and Spring should only occur if flow is >10000ML/day
Blackwater													
Amphibians													
Birds													
Native Fish													Native fish breeding
Carp													Carp spawning months need to be avoided

Indicates that time period is suitable to minimise risks or dis-benefits from use of flow regulator at this time. Indicates that this time should be avoided potential risk

	J	F	M	A	M	J	J	A	S	O	N	D	REASON
Seasonal													
Submerged	Vallisneria, P. ochreatus, P. crispus, Ruppia , Ottelia. Lepilaena												
Germination													Temperature
Growth													Day-length, temperature
Flowering													Seasonal
Emergent	Phragmites, Typha, Bolboschoenus												
Germination													Temperature
Growth													Day-length, temperature
Flowering													Seasonal
Amphibious													
Germination													Temperature
Growth													Day-length, temperature
Flowering													Seasonal
Floodplain	Epaltes,												
Germination													
Growth													
Flowering													
Terrestrial													
Germination													
Growth													
Flowering													
Weeds	Lagarosiphon Xanthium summer temperatures,												
Germination													
Growth													
Flowering													

Dormant
Germination
Growth
Flowering
Seedset
Salinity

surface water EC <10,000 EC OK; EC > 10,000 Growth and flowering inhibited

Soil salinity EC > 20,000 favour salt tolerant species

Aquatics – submergent – need at least 6 months surface water to flower and complete life cycle from seed. 3 months if growing from established rhizomes.

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Appendix 1. Risk assessments of the proposed Chowilla regulator on aspects of the hydrology, ecology, and geomorphology

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