Nominated key threatening process

1. NAME OF KEY THREATENING PROCESS

Please note: there is a listed KTP '*Novel biota and their impact on biodiversity*' (http://www.environment.gov.au/cgi-bin/sprat/public/publicshowkeythreat.pl?id=20) that includes all invasive species. If this nomination is for an invasive species please contact the Department at epbc.nominations@environment.gov.au to discuss the proposed process prior to preparing a nomination.

Alteration to the natural flow regimes of watercourses and their floodplains and wetlands

2. CRITERIA UNDER WHICH THE KEY THREATENING PROCESS IS ELIGIBLE FOR LISTING

Please mark the boxes that apply by clicking them with your mouse. The process could be eligible under one or all three criteria.

☒ Criterion A	Evidence that the threatening process could cause a native species or ecological community to become eligible for listing in any category, other than conservation dependent.
☒ Criterion B	Evidence that the threatening process could cause a listed threatened species or ecological community to become eligible for listing in another category representing a higher degree of endangerment.
☒ Criterion C	Evidence that the threatening process adversely affects two or more listed threatened species (other than conservation dependent species) or two or more listed threatened ecological communities.

3. CONSERVATION THEME

The conservation theme for the 2019 nomination period is:

'Species and Ecological Communities that are severely affected by fire regimes'

Explain how the nomination relates to this theme. Note that nominations which do not relate to the theme will still be considered.

This nomination does not relate to the theme for the 2019 nomination period.

4. DESCRIPTION OF THE KEY THREATENING PROCESS

Describe the threatening process in a way that distinguishes it from any other threatening process, and how the process is a *key* threatening process. Include reference to:

a. the components of the threat (consider both biological and non-biological components),
b. the processes by which those components interact (if known).

Please provide the following information where available:

a. the area of extent of the process, including the ecosystems or landscapes the process affects,
b. the time scale or periodic/seasonal nature of the threatening process,
c. any compounding impacts from, or interactions with, other threatening processes (e.g. climate change giving an invasive species an additional advantage), and
d. the proportion of the range of native species (listed or not) that the threatening process is likely to impact .

Alteration to the natural flow regimes of watercourses and their floodplains and wetlands has been recognised as a "serious and continuing threat to ecological sustainability of rivers and their associated floodplain wetlands" (Bunn & Arthington 2002; Naiman et al 1995; Sparks 1995; Lundqvist 1998; Ward et al 1999). It has been recognised on a global scale that "modification of the natural flow regime dramatically affects both aquatic and riparian species in streams and rivers worldwide" (Poff et al. 1997).

The nomination is intended to provide a national equivalent to two state legislated threatening processes: 'Alteration to the natural flow regimes of rivers, streams, floodplains & wetlands' – a Key Threatening Process listed under the NSW *Threatened Species Conservation Act 1995*; and 'Alteration to the natural flow regimes of rivers and streams' – a Potentially Threatening Process listed under the Victorian *Flora and Fauna Guarantee Act 1988*.

Difficulties in identifying causal relationships

Although there are inherent difficulties in determining which components of a particular altered flow regime are directly responsible for detrimental impacts on species and ecological communities and in separating direct effects of the modified flow regime from the impacts of land use accompanying water resource development, there is nevertheless "no question that the natural flow regime has a profound influence on the biodiversity of streams, rivers, and their floodplain wetlands" (Bunn & Armington 2002; Poff et al. 1997; Hart & Finelli 1999). There are real limitations in predicting and quantifying biotic responses to altering natural flow regimes, limiting the achievement of ecological sustainability of watercourses and their floodplains and wetlands (Bunn & Armington 2002: Bunn 1999, Naiman et al.

1995; Richter et al. 1997). However, given the proven importance of the natural flow regime on relevant species and ecological communities, it can be inferred, and it is sufficiently evidenced, that altering natural flow regimes causes considerable pressure on a number of species and ecological communities and thus necessitates a Key Threatening Process listing.

Defining 'Watercourse(s)'

For the purposes of this nomination, ‘watercourse(s)’ has the same meaning as provided under the EPBC Act / Water Act 2007, being a river, creek or other natural watercourse (whether modified or not) in which water is contained or flows (whether permanently or from time to time); and includes:

(i) a dam or reservoir that collects water flowing in a watercourse; and
(ii) a lake or wetland through which water flows; and
(iii) a channel into which the water of a watercourse has been diverted; and
(iv) part of a watercourse; and
(v) an estuary through which water flows.

For the avoidance of doubt, all terms contained within the above definition have the same definitions as provided for under the EPBC Act / *Water Act 2007*.

Defining 'natural flow regimes'

The natural flow regime is the “characteristic pattern of a river’s flow, quantity, timing and variability” (Poff et al. 1997).

Flow, the movement of water across land, influences the ecology of watercourses (Bunn & Arthington 2002; Vannote et al. 1980; Junk et al. 1989; Poff & Ward 1990; Poff et al. 1997; Sparks 1995). The natural flow regime, geology and landforms determine the “shape and size of river channels, the distribution of riffle and pool habitats, and the stability of the substrate” (Bunn & Arthington 2002; Frissel et al. 1986, Cobb et al. 1992, Newbury & Gaboury 1993). The natural flow regime, in turn, determines the “distribution, abundance and diversity of stream and river organisms” (Bunn & Arthington 2002; Schlosser 1982; Poff & Allan 1995; Ward et al. 1999; Nilsson & Svedmark 2002). Even small variations in flow can influence the distribution and abundance of particular species of plants and animals (e.g., Wetmore et al. 1990), with many stream organisisms including, algae, aquatic plants, invertebrates and fish having a close association with physical habitat (Bunn & Arthington 2002).

Poff et al. (1997) recognises five components of the flow regime which regulate ecological processes in river ecosystems:

1. The magnitude of discharge, being the amount of water moving past a fixed location per unit minute, for example, the amount of water that inundates a floodplain
2. The frequency of occurrence, being how often a flow above a given magnitude recurs over a specified time interval.
3. The duration, being the period of time associated with a specific flow condition, for example a floodplain may be inundated for a specific number of days by a ten year flood
4. The time, or predictability of flows of defined magnitude, being the regularity with which they occur, for example, annual peak flows occurring with low seasonal predictability
5. The rate of change, or flashiness, being how quickly flow changes from one magnitude to another

The natural flow regime of a watercourse derives from precipitation, with climate, geology, topography, soils, and vegetation determining water supply and pathways of precipitation to the channel. In turn, the natural flow regime, particularly the movement of water and sediment defines river ecosystems and habitat (Poff et al. 1997).

The physical habitat of a river includes sediment size and heterogeneity, channel and floodplain morphology, and other geomorphic features. These features form as the available sediment, woody debris, and other transportable materials are moved and deposited by flow. Thus, habitat conditions associated with channels and floodplains vary among rivers in accordance with both flow characteristics and the type and availability of transportable materials (Poff et al. 1997).

Defining 'alteration to natural flow regimes'

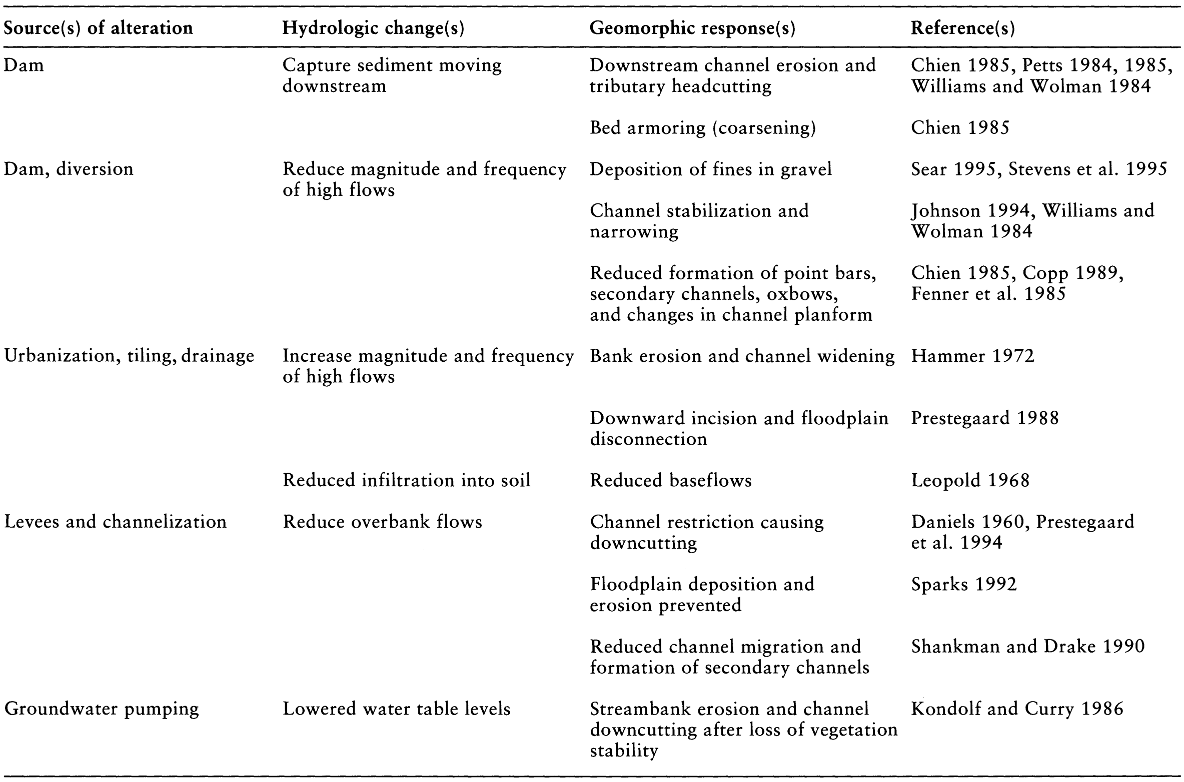
The regulation of river systems for the storage, diversion or transfer of water alters the natural flow regime of watercourses and their floodplains and wetlands. Human modification of natural hydrological processes disrupt the dynamic equilibrium between the movement of water and the movement of sediment that exists in free-flowing rivers (Dunne & Leopold 1978). This disruption alters geomorphic features that constitute habitat for aquatic and riparian species. After such a disruption, it may take centuries for a new dynamic equilibrium to be attained by channel and flood-plain adjustments to the new flow regime (Petts 1985). In some case, a new equilibrium is never attained, and the channel remains in a state of continuous recovery from the most recent flood event (Wolman & Gerson 1978) (Poff et al. 1997).

Alteration to natural flow regimes includes reducing or increasing flows, altering seasonality of flows, changing the frequency, duration, magnitude, timing, predictability and variability of flow events, altering surface and subsurface water levels and changing the rate of rise or fall of water levels (Walker et al. 1995; Cadwallader & Lawrence 1990; Gehrke et al. 1995; Kingsford 1995; Maheshwari et al., 1995; Poff et al. 1997; Boulton & Brock 1999; Robertson et al. 1999, 2001).

The alteration of natural flow regimes results from the following actions (in isolation or in combination):
1. Construction of dams;
2. Diversion of flows by structures or extraction;
3. Alteration of flows in floodplains with levees and structures; and
4. Channel changes, including dredging, straightening, and construction of levee banks.

Table 1, as featured in Poff et al. (1997), identifies recognised anthropogenic sources of alterations, the resulting hydrological changes and their consequential geomorphic responses.

Table 1. Physical responses to altered flow regimes.



Source(s) of alteration	Hydrologic change(s)	Geomorphic response(s)	Reference(s)
Dam	Capture sediment moving downstream	Downstream channel erosion and tributary headcutting	Chien 1985, Petts 1984, 1985, Williams and Wolman 1984
		Bed armoring (coarsening)	Chien 1985
Dam, diversion	Reduce magnitude and frequency of high flows	Deposition of fines in gravel	Sear 1995, Stevens et al. 1995
		Channel stabilization and narrowing	Johnson 1994, Williams and Wolman 1984
		Reduced formation of point bars, secondary channels, oxbows, and changes in channel planform	Chien 1985, Copp 1989, Fenner et al. 1985
Urbanization, tiling, drainage	Increase magnitude and frequency of high flows	Bank erosion and channel widening	Hammer 1972
		Downward incision and floodplain disconnection	Prestegaard 1988
	Reduced infiltration into soil	Reduced baseflows	Leopold 1968
Levees and channelization	Reduce overbank flows	Channel restriction causing downcutting	Daniels 1960, Prestegaard et al. 1994
		Floodplain deposition and erosion prevented	Sparks 1992
		Reduced channel migration and formation of secondary channels	Shankman and Drake 1990
Groundwater pumping	Lowered water table levels	Streambank erosion and channel downcutting after loss of vegetation stability	Kondolf and Curry 1986

Interaction between biotic and non-biotic components

Non-biological flow-related factors evoke a number of biotic responses. The non-biological and biological components of altered flow regimes and how they interact is discussed below:

1. **Changed biotic composition through changes to physical aquatic habitat caused by**:
   a) **Increased stability of baseflow and reduction of flow variability**.

This evokes the following biotic responses:

- **Excessive growths of aquatic macrophytes**, which otherwise have patchy distributions due to temporal and spatial variations in flow disturbance frequency and intensity, colonisation success and growth rates (Sand- Jensen & Madsen 1992; Rea & Ganf 1994). For example, reduced summer floods and increased winter flows cause excessive growths of submerged aquatic macrophytes in Norwegian rivers regulated by hydropower stations (Rørslett 1988);
- **Proliferation of nuisance larval blackflies,** as flow regulation may favour the proliferation of specific taxa (e.g., orthoclad chironomids) (Munn & Brusven 1991). For example, the construction of impoundments on the Lower Vaal River, South Africa, regulation of the once sporadic winter flow regime has allowed large populations of blackfly (Simuliidae) larvae to survive the winter and led to periodic plague outbreaks of adults in spring (De Moor 1986);
- **Reduction in fish populations** (Converse et al. 1998), given that associations between fish and their habitat are influenced by flow variability at a range of spatial scales (Poff & Allan 1995). Given the relationships between flow, habitat structure and fish, modifications to flow regimes affect fish diversity in regulated rivers. For example, pulsed reservoir discharges associated with on-demand hydroelectric power generation limit the quality and quantity of habitat available (Rei- ser et al. 1989,

Valentin et al. 1994, 1995).

- **Increased standing crop and reduced diversity of macroinvertebrates** (Armitage 1977; Ward & Short 1978; Lillehammer & Saltveit 1979; Williams & Winget 1979), given that macroinvertebrates are vulnerable to rapid diurnal changes in flow, and regulated river reaches below hydroelectric dams, with erratic flow patterns, are typically characterized by species-poor macroinvertebrate communities (Munn & Brusven 1991)

b) Erratic (diurnal) patterns in flow.

This evokes the following biotic responses:

- **Reduction in species richness of benthic macroinvertebrates** (Munn & Brusven 1991; Mullan et al. 1976; Trotzky & Gregory 1974), given that macroinvertebrates are vulnerable to rapid diurnal changes in flow, and regulated river reaches below hydroelectric dams, with erratic flow patterns, are typically characterized by species-poor macroinvertebrate communities (Munn & Brusven 1991)
- **Reduction in standing crop of benthic macroinvertebrates** (Layzer et al. 1989; Mullan et al. 1976, Trotzky & Gregory 1974; Radford & Hartland-Rowe 1971), with sudden increases in flow causing “catastrophic down- stream drift to the extent that as much as 14% of the standing crop of benthic biota can be eliminated each month in some hydropower operations due simply to drift resulting from increased shear stress (Layzer et al. 1989)”.
- **Stranding of macroinvertebrates** (Kroger 1973) and stranding of fish (Bradford 1997; Bradford et al. 1995) given that stream fish can become stranded on gravel bars or trapped in off-channel habitats during rapid flow decreases. For example, newly emerging salmon larvae, and juvenile salmonids hiding in the stream substrates during winter, are extremely susceptible to being stranded in the substrate during flow reductions (Bradford et al. 1995; Bradford 1997)”. Furthermore, the impact of high flow water releases below hydropower dams can be very selective. Small insect nymphs and invertebrates, which cannot tolerate high velocities, are often underrepresented in down- stream reaches (De Jalon et al. 1994).”

c) Conversion of lotic habitat to lentic habitat.

This evokes the following biotic responses:

- **Decline of populations of riverine crayfish and snails**. For example, “in the Lower Murray River in south eastern Australia weirs have transformed the river into a chain of cascading pools, supplanting most of the riverine environment with pool habitats (Walker et al. 1992). This has affected the distribution of the Murray crayfish (*Euastacus armatus*), now close to extinction, and several species of riverine and wetland snails have declined” (Walker et al. 1992)
- **Elimination of salmonoids and pelagic spawning fishes and dominance of generalist fish species**. For example, the regulation of lowland river Great Ouse, UK by weirds, embankments, navigation locks and dredging converting it into deep reservoir like channels , separated by short, shallow lotic stretches. Impacts on fish include the absence of localized salmonids and pelagic spawning fishes (i.e., bur- bot), historically reported to be abundant; reduction in the range and abundance of rheophilic and limnophilic cyprinids; and the extreme dominance of generalist species (roach and minnows) throughout most of the system (Copp 1990).
- **Loss of fishes adapted to turbid river habitats** (Stanford & Ward 1986a), for example, “The Colorado River is regulated by hundreds of reservoirs varying in area from 1 ha in high-altitude headwaters to 650 km2 in lowland mainstem seg- ments (Stanford & Ward 1986a). Conversion of one quarter of the river to lentic habitat has resulted in the loss of fishes adapted to turbid riverine habitats. In addition, numerous introductions of highly competitive exotic fishes (over 50 species), many thriving in impoundments and regulated river reaches, have con- tributed to the extirpation of native fishes in the Colo- rado River fauna (Stanford & Ward 1986b). Most of the native big-river fish face extinction (Stanford & Ward 1986b). In the headwaters of the upper basin, the range of the Colorado River cutthroat trout (*Salmo clarki pleuriticus*) is limited to a few isolated populations, and nearly all of the endemic desert stream fish are in severe decline” (Bunn & Armington 2002).
- **Loss of fishes due to inundation of spawning grounds** (Hubbs & Pigg 1976)

2. Disturbance of aquatic species life histories through changes to flow regime caused by:

a) Changes in rates of water level fluctuation.

This evokes the following biotic responses:

- **Altered aquatic macrophyte growth rates and seedling survival** (Blanch et al. 1999, 2000; Froend & McComb 1994; Rea & Ganf 1994). For example, changes in water regime have a profound effect on the establishment and survival of many aquatic plant species owing to their narrow range of tolerances and inability to regenerate under modified conditions (Bunn & Arthington 2002). “Flow plays a profound role in the lives of fish with critical life events linked to flow regime (e.g., phenology of reproduction, spawning behavior, larval survival, growth patterns and recruitment) (Welcomme 1985; Junk et al. 1989; Copp 1989, 1990; Sparks 1995; Humphries et al. 1999). Many of these life events are synchronized with temperature and day length, such that changes in flow regime that are not in natural harmony with these seasonal cycles may have a negative impact on aquatic biota." (Bunn & Arthington 2002)

b) Changed timing of spates.

This evokes the following biotic responses:

- **Reduced survivorship of larval atyid shrimps following early summer spates** (Hancock & Bunn 1997b)
- **Stable low flows are required for spawning and recruitment of riverine fish, so spawning and recruitment could be reduced** (Milton & Arthington 1983b, 1984, 1985; Humphries & Lake 2000)

c) Reduced seasonality.

This evokes the following biotic responses:

- **Reduced synchrony of breeding in gammarid shrimps** (Bunn 1988b)

d) Changed timing of rising flows.

This evokes the following biotic responses:

- **Loss of cues for fish spawning and migration** (Lowe-McConnell 1985; Nesler at el. 1988; King et al. 1998)

e) Short –term fluctuations in flows.

This evokes the following biotic responses:

- Adverse effect on species of stoneflies with long larval development times (autumn/winter) (Henricson & Muller 1979

f) Modified temperature regimes below dams.

This evokes the following biotic responses:

- **Delayed spawning in fish** (Zhong & Power 1996). In many regulated river systems modified flow regimes are accompanied by major shifts in the thermal regime, especially where dams have hypolimnetic water releases (Crisp et al. 1983; Travnichek et al. 1993) leading to the release of cold oxygen-deficient water downstream. Since aquatic insects and fish use the combined cue of day length and the summation of day-degrees to synchronize emergence as adults, the release of cooler water downstream of impoundments can influence the spawning behavior of fish and life history processes of invertebrates (Penaz & Jurajda 1995) (Table 2). In the long-term, hypolimnetic re- leases can cause selective disappearance of susceptible species from downstream reaches (Bunn & Arthington 2002).
- **Disrupted insect emergence patterns.** Modified thermal patterns and day-length cues have been shown not only to disrupt insect emergence patterns but also to reduce population success (Ward & Stanford 1982) and where dams have hypolimnetic water releases (Crisp et al. 1983; Travnichek et al. 1993) the release of cooler water downstream of impoundments can influence the spawning 6behaviour of fish and life history processes of invertebrates (Penaz & Jurajda 1995). Coldwater releases have been found to delay spawning by up to 30 days in some fish species (Zhong & Power 1996; Lehmkuhl 1972; Gore 1977; Ward & Stanford 1982),
- **Reduced benthic standing crop** (Lehmkuhl 1972)
- **Elimination of temperature-specific species of fish** (Trautman & Gartman 1974)

3. Reduced population viability caused by changes to longitudinal and lateral connectivity of riverine species through:

a) Water abstraction.

This evokes the following biotic responses:

- **Reduction in migrating shrimp larvae** (Pringle & Scatena 1999). "Water abstraction and the construction of dams can have a major impact on the migration of large shrimp (Pringle & Scatena 1999). For example, damming of the lower reaches of one of the main drainages of the Caribbean National Forest in Puerto Rico has had a major impact on shrimp recruitment. More than 50% of migrating larvae were drawn into water intakes for municipal supplies and juvenile shrimps returning upstream faced severe predation below the dam (Pringle & Scatena 1999).

b) Presence of in-stream barriers.

This evokes the following biotic responses:

- **Increased predation on juvenile migrating shrimp** (Pringle & Scatena 1999), and
- **Loss of migratory fish species** (Hubbs & Pigg 1976; Welcomme 1979; Harris 1984a,b; Dauble & Geist 2000; Kareiva et al. 2000; Reyes-Gavilan et al. 1996; Joy & Death 2001), - "Diadromous fishes, which migrate long distances within the main channels and larger tributaries of rivers, are particularly sensitive to barriers to longitudinal passage because obstruction of their migratory pathways may interfere with the completion of their life cycles (Table 3). The disappearance or decline of the major migratory fish species often follows river impoundment and the blocking of passage in the system (Bonetto et al. 1989; Cadwallader 1986; Harris 1984a,b; Joy & Death 2001; Welcomme 1985, 1992). For example, an extensive network of hydroelectric dams, constructed between 1939 and 1975, has blocked access to or inundated most riverine habitat suitable for spawning by fall chinook salmon

(*Oncorhynchus tshawytscha*) in the Columbia River Basin (Dauble & Geist 2000). More that 75% of the original 2500 km of main-stem spawning and rearing habitats has been eliminated" – Bunn & Armington (2002). "In-stream barriers have contributed to the decline of populations of migratory fish species in southern Australia, such as Australian bass, Macquarie perch, and golden perch (Lake & Marchant 1990; Barmuta et al. 1992). Barriers have affected 30%–50% of the potential habitat for migratory fish in 22 coastal drain- ages in southeastern Australia (Harris 1984a). Less than 10% of these barriers had fishways and, of these, only six of the 29 provided suitable conditions for fish migration at the time surveyed (Harris 1984b). River impoundment and the blocking of fish passage are often followed by the disappearance or decline of the major migratory species in river reaches upstream of barriers; this has been observed for Australian bass in east coast river systems (Harris 1984a,b)." "Even small in-stream barriers, such as v-notch gauging weirs, can impede the movement of fish [e.g., western minnows (*Galaxias occidentalis*) in southwestern Australian forest streams (Pusey et al. 1989)]." (Bunn & Armington 2002)

c) Reduced frequency, duration and area of inundation of floodplain wetlands.

This evokes the following biotic responses:

- **Reduced spawning areas and/or recruitment success of lowland river fish (Jubb 1972; Whitley & Campbell 1974; Lake 1975; Welcomme 1979; Geddes & Puckridge 1989; Cadwallader & Lawrence 1990) -** Prior to river regulation, many species of fish in Australian rivers were thought to have used inundated floodplain wetlands of lowland rivers for breeding and juvenile habitat (Geddes & Puckridge 1989). River regulation to prevent flooding has seriously affected such recruitment (Cadwallader & Lawrence 1990), and there is an obvious trend of reduced native species abundance with increasingly regulated catchments (Gehrke et al. 1995).
- **Decline in waterbird species richness and abundance (Kingsford & Thomas 1995) –** For example, on the Macquarie River in eastern Australia, the Macquarie Marshes, a hemispheric wetland reserve for water birds have been reduced to 40%–50% of their original size by flow diversions and weirs (Kingsford & Thomas 1995).
- **Decline in wetland vegetation (Kingsford 2000) -** Low flows have eroded river channels, further reducing flows onto the floodplain, and a water diversion channel and levee banks have alienated parts of the floodplain from the river and retained floodwater on other parts for periods of more than 12 months. The area with river red gums halved between 1934 and 1981, as did the area of reed beds between 1963 and 1972 (Brander 1987). Over several hundreds of hectares of coolibahs (*Eucalyptus coolibah*) flooded behind levee banks have died since the 1970s. Abundance and species richness of water birds in the northern part of the Macquarie Marshes has declined over an 11-year period (Kingsford & Thomas 1995).

4. Facilitation of the invasion and success of exotic and introduced species through:

a) Loss of wet-dry cycles and increased stability of water levels.

This evokes the following biotic responses:

- **Reduced growth and survival of native aquatic macrophytes and increased invasion of exotics** (Kingsford 2000; Mitchell & Gopal 1991). The loss of wet–dry cycles in floodplain wetlands often has major ecological impacts that favour exotic species. In Australia stable water levels may reduce the growth and survival of native aquatic macrophytes and encourage the invasion of *Typha spp.* and introduced water hyacinth (*Eichhornia crassipes*) (Kingsford 2000).

b) Reduced flow variability and increased seasonal stability. This evokes the following biotic responses:

- **F**avours populations of exotic fish species such as carp and mosquito fish (Edwards 1978; Faragher & Harris 1994; Walker et al. 1995; Gehrke et al. 1999) which may displace native species - Regulation of flows in some Australian rivers is thought to favor exotic fish species such as carp (*Cyprinus carpio*) and mosquitofish (*Gambusia affinis*) (Pusey et al. 1989; Faragher & Harris 1994; Walker et al. 1995; Gehrke et al. 1999). These species appear to benefit from seasonally stable, low flows and may displace native species adapted to more variable flows and heterogeneous habitat conditions. Common carp, tench (*Tinca tinca*), and European perch (*Perca fluviatilis*) have remained relatively insignificant in some Australian rivers for decades, whereas they have been favored by the increased stability of river flows in the Murray-Darling system (Cadwallader 1986). Gehrke et al. (1999) have shown that regulated rivers in the Murray-Darling system have a lower diversity than relatively undisturbed rivers further inland, with the reduction in diversity largely due to greatly increased numbers of carp in regulated reaches. (Bunn & Armington 2002). Carp, tench and perch have remained relatively insignificant in some Australian rivers for decades but have proliferated in the Murray-Darling Basin where there has been increased stability of flow. Although fish species have been introduced into a wide variety of environments, the greatest success has been achieved in waters which have been dammed, diverted, and otherwise modified, creating permanent standing water (reservoirs) and more constant flow regimes than previously existed (Moyle 1986; Arthington et al. 1990) (Table 4). Long-term success (integration) of an invading fish species is much more likely in an aquatic system permanently altered by human activity than in a lightly disturbed system (Moyle & Light 1996a). The most successful invaders will be those adapted to the modified flow regime (Moyle & Light 1996b).

c) Conversion of lotic to lentic habitat.

This evokes the following biotic responses:

- **Proliferation of exotic fish species** (Arthington & Bluhdorn 1994, Davies & Day 1998), e.g. Tilapia in dams. Most successful fish invasions have been in waters that have been dammed, diverted or modified to create permanent standing water. Long-term success (integration) of an invading species is much more likely in an aquatic system permanently altered by human activity than in a lightly disturbed system (Moyle & Light 1996a). Most prominently, this is due to the fact that human disturbed systems (e.g., reservoirs) resemble one another over broad geographic areas and favour species that are also favoured by humans (Gido & Brown 1999). Creating permanent standing waterbodies and/or more constant flow regimes by damming or diverting river flows favours introduced species, many of which are most abundant in lakes and river backwaters in their native range (Moyle 1986). Dominance of aquatic macrophyte communities in slow flowing and impounded river reaches by exotic species, such as the water hyacinth (*Eichhornia crassipes*) is a common occurrence. With its free-floating habit and rapid growth rate, the hyacinth can form dense surface growths covering large areas of open water, interfering with flow and water transport, disrupting recreation, impeding the access of stock to water, and blocking light penetration (Mitchell & Gopal 1991). Conversion of rivers to lentic habitat can lead to the proliferation of exotic species of fish, for example tilapia (*Oreochromis mossambicus*) in large dams in Africa, Sri Lanka, and Australia (Arthington & Blu¨hdorn 1994).

d) Inter-basin transfers of water.

This evokes the following biotic responses:

- **The schistosmaisis; translocation of fish species** (Pitchford & Visser 1975; Skelton 1986; Cambray et al. 1986) Although accidental or deliberate movement of propagules (e.g., stocking) are likely to be the most important mechanisms, alteration of flow regimes and the infrastructure associated with it are also major contributors to the spread of introduced and exotic aquatic species. Historical patterns of species distributions, local endemicity, and metapopulation structure of aquatic organisms are largely determined by catchment boundaries and the presence of natural in-stream barriers (e.g., waterfalls) (Meffe & Vrijenhoek 1988; Bunn & Hughes 1997; Pusey et al. 1998). Inter-basin water transfers can alter natural distribution pat- terns of aquatic biota and enhance the spread of pests and diseases (as well as presenting serious problems in terms of water balance, water quality and the disruption of significant ecological processes). Such schemes are increasing in popularity as the number of sites suitable for dam construction and the scale of individual de- cline (Boon 1992). The South African Orange-Vaal River Project, the Orange-Fish-Sundays River Inter-catchment Transfer Scheme, and the Tugela-Vaal Water Transfer Scheme provide examples of the impacts of interbasin transfers on biological invasions (Cambray et al. 1986) (Table 4). The transfer of endemic flora and fauna between catchments has occurred with a variety of consequences (Skelton 1986). Interbasin transfers of schistosomes in the Orange-Vaal Project into rivers previously free of schistosomiasis have been enhanced by temperature changes below large dams that affect the dynamics of both the snail host and parasite populations (Pitchford & Visser 1975). The catfish *Clarias gariepinnus* has invaded the Great Fish River through the intercatchment transfer tunnel from Lake Verwoerd and has become established in the Sundays River system (Skelton 1986), and there has also been some spread of aquatic macrophytes. Four species of fish have been introduced from the Orange River drainage to the Great Fish River drainage via interbasin water transfers, presumably transferred as eggs or larvae.

5. INDIGENOUS CULTURAL SIGNIFICANCE

Is the key threatening process known to have an impact on species or country culturally significant to Indigenous groups within Australia? If so, to which groups? Provide information on the nature of this significance if publicly available.

Aboriginal societies attribute meaning to water in different ways (Langton 2002). Water plays a central role in many Aboriginal cultures and societies, including various religious, legal, social and economic beliefs and practices (Barber & Rumley 2003). Some examples of how altered flow regimes have impacted on culturally important species and country include: Research in the Fitzroy Valley in the Kimberley region has identified the regulation of rivers, especially impoundment for dams, as a threat to a valued cultural principle: the unimpeded flow of a river body (Touissant et al. 2001); For Indigenous groups in the Ord River region, many culturally important land and sites were flooded by dams, including those of the Miriuwung, Kuluwaring and Gajerrabeng groups.

In the Ord River area, culturally important land and sites were flooded by dams and altered with the introduction of irrigated agriculture, changing vegetation dynamics and introducing exotic species (Barber & Rumley 2003). The traditional owners of these lands believe that water sources such as water holes, creeks, springs and portions of the river were created by different Dreamings. The cultural values vary from location to location, depending on the activity which occurred there during the Dreaming (Jackon et al 2005).

Barber & Jackson (2011) provides detailed information on the Indigenous cultural significance of freshwater in the Northern Territory. It found that archival and field research gathered suggests that Indigenous people in the area studied value water in a manner consistent with reports from elsewhere in the country.

Water itself is understood as an integral part of the world created by the ancestral beings during what is colloquially known as the Dreaming, and those beings are still present in current land and waterscapes. Places with permanent water are usually of key significance, and there are a range of important associations with water evident in the Dreaming stories provided by local inhabitants. Taken together and combined with the fact that this material has been collected over several recent decades, it suggests clear, consistent and ongoing continuities in the role and relevance of water to local people (Barber & Jackson 2011).

There is also evidence of a range of practices, protocols and prohibitions with respect to water, as well as clear statements about the ongoing value of hunting and fishing to contemporary life. The high rainfall levels of the past decade have played a role in more general perceptions of environmental changes occurring in living memory, changes which people interpret in a range of ways but which drive ongoing desires to manage the company appropriately. Such desires for management are one manifestation of a broader sense of ownership over and obligations towards the country that emerge from the Roper data and are consistent with Indigenous attitudes to country found elsewhere (Barber & Jackson 2011).

In turn, this sense of ownership and obligation drives Indigenous responses to contemporary processes such as water planning and management. There are two features of particular note evident in the archival and ethnographic record for the area. One, identified in a publication in the early 1980s, is the significance of riparian vegetation, particularly large trees growing at major water sites, and their association with past and present individual people. This implies an additional layer of meaning and significance for riparian vegetation, in a contemporary water planning context it suggests that some additional management effort with respect to that vegetation may need to be considered (Barber & Jackson 2011).

For a key threatening process to be eligible for listing it must meet at least one of the three listing criteria. You do not need to provide details of the eligibility for all questions 6-11, however the more information you provide the more evidence is available to undertake the assessment. If there are insufficient data and information available to allow completion of the questions for each of the listing criteria, state this in your nomination under the relevant question.

Criterion A: non-EPBC Act listed species/ecological communities

6. SPECIES THAT COULD BECOME ELIGIBLE FOR LISTING AND JUSTIFICATION

Provide details and justification of non-EPBC Act listed species that, due to the impact of the key threatening process, could become eligible for listing in any category, other than conservation dependent. For each species please include:

a. the scientific name, common name (if appropriate), category it could become eligible for listing in;
b. data on the current status in relation to the criteria for listing;
c. specific information on how the threatening process threatens this species; and
d. information on the extent to which the threat could change the status of the species in relation to the criteria for listing.

A number of species reliant on freshwater and functioning hydrological regimes are at risk due to altered hydrology, and it is highly likely that several may become eligible for future EPBC Act listing due to the key threatening process. A considerable number of both faunal and floral species associated with ecological communities detailed in sections 7, 8 and 9 are also at risk due to their reliance on the communities as habitat. Many species are included in these ecological communities are not themselves considered threatened, however their association with declining communities impacted by the key threatening process should be taken into consideration.

Migrating out of freshwater to breed (Diadromous species) is a very common strategy in northern Australian fishes (Pusey et al 2004), and such species are heavily reliant on unaltered watercourses.

7. ECOLOGICAL COMMUNITIES THAT COULD BECOME ELIGIBLE FOR LISTING AND JUSTIFICATION

Provide details and justification of non-EPBC Act listed ecological communities that, due to the impact of the key threatening process, could become eligible for listing in any category. For each ecological community please include:

a. the complete title (published or otherwise generally accepted), category it could become eligible for listing in;
b. data on the current status in relation to the criteria for listing;
c. specific information on how the threatening process threatens this ecological community; and
d. information on the extent to which the threat could change the status of the ecological community in relation to the criteria for listing.

Non-EPBC Act listed ecological communities that, due to the impact of the nominated key threatening process, could become eligible for listing (or in some instances already are eligible for listing and have previously been listed in large part due to alterations to the natural flow regimes of watercourses and their floodplains and wetlands) include:

- Long Lowland Rivers of South East Queensland and North East New South Wales (Currently Ineligible)
- River Murray and associated wetlands, floodplains and groundwater systems, from the junction with the Darling River to the sea (Approval Disallowed)
- Wetlands and inner floodplains of the Macquarie Marshes (Approval Disallowed)

Currently Ineligible
Long Lowland Rivers of South East Queensland and North East New South Wales
The Long lowland rivers of south east Queensland and north east New South Wales ecological community occurs in long, lowland subtropical river systems along the eastern coastal plain of continental Australia. Flow is considered the 'master' variable that sustains all natural physical and biological processes in the ecological community. In combination with substrate, it defines the river geomorphology and sediment regime which determines the type, amount and accessibility of habitat for riverine plants and animals. Flow drives food webs, through the transportation of carbon and other nutrients and has a major influence on animal and plant behaviour and life histories (Humphreys et al. 2008). It determines wetting and drying cycles and overbank flows on the floodplain.

The main threats to the aquatic ecological community are (TSSC 2014a):
- Regulation, infrastructure and modification of flow Impoundments (dams, weirs, levees, barrages), other regulating structures and road crossings inundate habitat, alter flow regimes and sediment dynamics, limit the movement of fish and other animals and can disconnect the river from parts of its floodplain.
- Abstraction of water Groundwater and surface water abstraction reduces natural flow, particularly over riffle habitat. It can strand fish, allow weeds to proliferate and degrade water quality, as well as affecting cues for the movement and spawning of fauna.
- Geomorphic alteration of the river channel, riparian zone and the wider catchment area Clearing riparian vegetation destabilises riverbanks and disrupts river food chains (e.g. the loss of riparian zone fauna, such as insects, as well as fruits and leaf litter that fall or are washed into the river). It reduces shading, increases temperature effects and reduces the supply of woody material that is important habitat. Along with sand and gravel extraction it mobilises sediments and nutrient, disrupts flow dynamics and destroys habitat. De-snagging also removes vital river habitat.
- Introduced and translocated plant and animal species Introduced animals and weed species are generally hardy and opportunistic. They prey on local residents, compete for food and habitat, disrupt breeding, introduce disease and parasites, pollute and degrade habitat and even re-engineer ecosystems.
- Fishing and recreation Stocking fish for recreation can change population dynamics and introduce pest species and disease. Fish are caught and killed (legally and illegally) and even catch and release can injure fish and increase mortality, as well as disrupting breeding. Boat movements, particularly at high speed, are a threat to species such as lungfish and turtles.
- Catchment development, urbanisation and diffuse pollution Excessive removal of catchment vegetation increases siltation, erosion, runoff and pollution, decreases dissolved oxygen and kills fish. Diffuse and point source urban pollutants, often in association with some form of channelisation of urban watercourses, leads to eutrophication and species decline.
- The ecological community is potentially threatened by: Climate change Current threats are likely to be compounded by the effects of climate change. In combination with these threats the main effects of climate change on freshwater biodiversity in the ecological community are likely to be changes in species' behaviour, physiology, abundance, distribution and resilience, along with changes in ecosystem productivity and nutrient status. The nature of these threats, their impacts and levels of historical degradation are uneven across the ecological community's range. They are greater in certain rivers (e.g. Brisbane and Logan/Albert Rivers) compared to others (e.g. the Clarence River). Further information on threats is in Appendix E. Much is being done to manage and abate current threats with a number of recovery plans and prioritised actions focused on rivers of the ecological community.

Approval Disallowed
River Murray and associated wetlands, floodplains and groundwater systems, from the junction with the Darling River to

the sea

Appendix E.3 (in TSSC 2014b) provides detailed information on the ecological impacts to changes in flow regimes. Importantly, the proportion of flow within the river channel as opposed to on the floodplain has changed, with the greater proportion of flow now contained within the river channel (TSSC, 2010a). The main impacts on the ecological community relate to reduced flow volume, reduced flow variability, changes to timing of flows, and the loss of moderate sized flows , and flooding that supports overbank flow and connectivity with the floodplain and wetlands (TSSC 2014b).

The MDB is intensively regulated, which influences the environment upstream and resulting flows into the ecological community. The main channel of the ecological community contains 10 weirs and five barrages, as well as extensive levees and offstream regulators. Weirs elevate the water level above them, creating upstream 'weir pools' which confer stability on the system (i.e. reduces variability of water levels and flow) and impact on connectivity with the floodplain (i.e. reduces overbank flows). Many native species of plants and animals rely on variability of conditions as cues for reproduction and dispersal. Riverine-floodplain connectivity is essential to the productivity and ecological function of the ecological community. Barrages can prevent connection with the ocean and impact on diadromous fish, although the presence of fishways can assist to mitigate this barrier (TSSC 2014b).

There is an increasing trend in water extraction from the River Murray which impacts significantly on the ecological community. In 2006, the long-term average diversion from the Murray was estimated to be 34% of the total flow of the river (MDBC, 2006a). In the 1990s, the average flow at the South Australian border was around 6000 GL/y and diversions amounted to nearly twice this annual flow (Close, 1990a); annual flow declined to less than 3800 GL/y in the next decade (MDBA, 2009). There is intensive horticulture along much of the upper ecological community, with water pumped from the river. Along the lower sections of the ecological community there is pasture production for dairying, with gravity flood irrigation used.

Most permanent pools and wetlands in the Eastern Mount Lofty Ranges are largely dependent on groundwater inflows during low rainfall periods. Due to the strong interaction between underground and surface water, increasing exploitation of the underground water resource has serious implications for the ecological community (SAMDBNRM Board, 2010a).

Closure of the River Murray Mouth poses a serious threat to the ecological community. In the 1930s, some 80% of the water entering the River Murray went out to sea, however by the 1990s this was reduced to a median 27%, and for the first eight years of the 21st century this was reduced to 4% (Paton, 2010). Modelling by CSIRO has determined that consumptive water use in the MDB has reduced average annual stream flow at the Murray Mouth by 61% (CSIRO, 2008). Flows to the Murray Mouth are vital for maintaining an open Mouth and a natural and effective connection between the sea and the Coorong and Lower Lakes that is an important part of the natural functioning and variability of the ecological community.

Wetlands and inner floodplains of the Macquarie Marshes

The main threat to the ecological community is changed water flow as a consequence of regulation of the Macquarie River. The effects and impacts of the changed flow regime come about principally because river and wetland biota are adapted to the pre-regulation flow regime. Changes to flow frequency and duration, particularly since the construction of Burrendong Dam (MDBA 2012) include: reduced moderate-to-high flows in the Macquarie River and end-of-system flows; a significant reduction in the frequency of and the area inundated by floods in the Macquarie Marshes. Between 1944 and 1993, the area inundated by large floods reduced by at least 40-50 per cent; an increase in the average period between and a reduction in the average volume of large flows. The average period increased from 2.2 years to 4.7 years; a reduction in the number of small flows likely to cause flooding; permanent low flows in previously intermittent streams (TSSC 2013).

The changed water regime to the Macquarie Marshes has been largely responsible for the decline of structural and functional components of the ecological community, particularly in recent decades. For example, the death of more than 30 per cent of river red gums in the woodlands of the North Marsh has been attributed to lack of flooding (Bacon 2004; Catelotti 2012). Flooding is the primary source of water for eucalypts that inhabit floodplains as it recharges shallow aquifers, maintains soil moisture supplemented by local rainfall. Keystone species such as river red gums depend on flooding for regeneration and to complete their life cycle. River red gums in the Macquarie Marshes need floods every one to two years. Trees that received a flood in 2000 but were not flooded in 2003 were under severe stress or dead.

Most areas of water couch in the ecological community have not received required flows for the past three years and some areas have not received flows at all for more than six years. Bowen and Simpson (2010) found no water couch remaining in the southern portion of the Macquarie Marshes Nature Reserve, a loss of 220 hectares since 1991. Most of the seasonal or intermittent wetlands have disappeared, being replaced by plants more typical of dryland sites, notably colonising chenopod shrubs that are changing sites away from their wetland characteristics. In 1981, Paijmans mapped approximately 500 hectares of cumbungi rushland in the southern portion of the Nature Reserve, most of it outside the southern section of the Macquarie Marshes Nature Reserve. However, in 2006, cumbungi was only found in one location in the South Marsh at Buckiinguy Lagoon (DNR, 2007) and Bowen and Simpson (2010) later found no cumbungi remained in the southern section of the Macquarie Marshes Nature Reserve.

Constant low flows reduce ecosystem productivity by removing the boom and bust cues that trigger and sustain aquatic cycles in the ecological community (Poff et. al., 1997; Ward, 1998). Since 2001, the Marshes have received less than 25% of the environmental water that would be available at 100% general security allocation which means less than 5000 hectares of the Marshes has received a flood every 1-2 years. The mapped area of river red gum forest and woodland in the Marshes was 40 000 hectares in 1991 (Wilson et al., 1993), a large proportion of this is in the North Marsh. In 2008 it is likely that as much as 75% of these woodlands have not received adequate flooding for their survival (Gawne et. al. 2011).

With the reduction in extent and condition of wetland vegetation communities in the ecological community and replacement with invasive native chenopods, there has been a reduction in essential habitat available for wetland birds and other wetland fauna. The impacts of this decline are most obvious in the decrease in the numbers of birds sighted and the number of colonial waterbird breeding events in the Macquarie Marshes (Kingsford and Johnson, 1998; Kingsford and Thomas, 1995; Kingsford and Auld, 2005). For example, in 1986, the time of Ramsar listing, 4590 colonial waterbird nests were counted within the Macquarie Marshes Nature Reserve. Since then, the number of nests, frequency of breeding and location of active breeding colonies has declined throughout the Macquarie Marshes and the Nature Reserve. There have been two colonial nesting waterbird breeding locations recorded in the southern section of the Macquarie Marshes Nature Reserve but breeding has not occurred at these sites since the 1960s (Gawne et. al., 2011).

There was only one waterbird breeding event in the Marshes during 2000-2010. In 2008, a relatively small flood supported a successful nesting of approximately 2000 egrets and cormorants in river red gum forest on the Bora Channel. This was unexpected given such low flows and was the first record of colonial-nesting waterbirds breeding at only one location in the Marshes. In October 2010, following significant rainfall and flooding, straw-necked ibis were recorded breeding in the Macquarie Marshes (Gawne et. al., 2011).

Criterion B: Listing in a higher threat category

8. SPECIES THAT COULD BECOME ELIGIBLE FOR LISTING IN A HIGHER THREAT CATEGORY AND JUSTIFICATION

Provide details and justification of EPBC Act listed threatened species that, due to the impacts of the threatening process, could become eligible for listing in another category representing a higher degree of endangerment. For each species please include:

a. the scientific name, common name (if appropriate), category that the item is currently listed in and the category it could become eligible for listing in;
b. data on the current status in relation to the criteria for listing (at least one criterion for the current listed category has been previously met);
c. specific information on how the threatening process significantly threatens this species; and
d. information on the extent to which the threat could change the status of the species in relation to the criteria for listing. This does not have to be the same criterion under which the species was previously listed.

EPBC Act listed species that could become eligible for listing in a higher threat category due to the impacts of the key threatening process include the northern river shark, freshwater sawfish, speartooth shark, opal cling goby, and Murray hardyhead. Summaries of how altered hydrological regimes impact these species, as contained in their Departmental SPRAT profiles, follows:

Northern river shark (*Glyphis* sp. C) (EPBC Act: Endangered)
The species is thought to utilise rivers and estuaries as nursery areas for breeding, with older animals moving out to marine environments. This species has not been recorded above structural barriers. Structures such as dams that inhibit this migration will pose a significant threat the viability of affected populations by preventing recruitment, leading to local extirpation and the potential uplisting to Critically Endangered or extinct. The installation of any structural barrier would severely reduce the amount of habitat available to this species, reducing the availability of habitat for survival and reproduction, and therefore population viability.

Freshwater sawfish (*Pristis pristis*) (EPBC Act: Vulnerable)
This species is thought to use tidal reaches of rivers as nursery grounds, with juveniles dispersing upstream into floodplain during the wet season. The construction of causeways and weirs may restrict movement of the species,

thereby disrupting dispersal , resulting in disrupted reproduction and reduced population viability, which may lead to local extirpations and potentially species extinction.

Speartooth shark (*Glyphis* sp. A) (EPBC Act: Critically Endangered)
This species has not been recorded above structural barriers. The installation of any structural barrier would severely reduce the amount of habitat available to this species, reducing the availability of habitat for survival and reproduction, and therefore population viability.

Opal cling coby (*Stiphodon semoni*) (EPBC Act: Critically Endangered)
Potential threats include water extraction, which is likely to alter the species' habitat through changes to water quality and flow regime. Construction of physical barriers, such as culverts and dams are also considered possible threats as these structures can prevent movement of the larvae out to sea and the subsequent return of juveniles.

Murray Hardyhead (*Craterocephalus fluviatilis*) (EPBC Act: Endangered)
The Murray hardyhead is endemic to the lowland reaches of the Murray and Murrumbidgee rivers and their tributaries, floodplain billabongs and lakes. Since the 1990s, increasing river regulation and water abstraction, exacerbated by widespread drought in 2001–2009, reduced connectivity between wetland habitats and caused many to dry out. Ten Murray hardyhead populations were lost during the protracted drought, when there would have been physiological stresses and lack of recruitment associated with extreme salinity levels, nutrients and pH, variable oxygen levels and algal blooms in wetland habitats. Its range and abundance declined sharply the 1950s to 1970s, as agriculture, flow regulation and water extractions intensified.

Floral EPBC Act species that could become eligible for listing in a higher threat category due to the impacts of the key threatening process include: Hay River Featherflower (*Verticordia apecta*); Native Wintercress (*Barbarea australis*); Scott River Boron (*Boronia exilis*); and Genoa River Correa (*Correa lawrenceana var. genoensis*

9. ECOLOGICAL COMMUNITIES THAT COULD BECOME ELIGIBLE FOR LISTING IN A HIGHER THREAT CATEGORY AND JUSTIFICATION

Provide details and justification of EPBC Act listed threatened ecological communities that, due to the impacts of the threatening process, could become eligible for listing in another category representing a higher degree of endangerment. For each ecological community please include:

a. the complete title (published or otherwise generally accepted), category that the item is currently listed in and the category it could become eligible for listing in;
b. data on the current status in relation to the criteria for listing (at least one criterion for the current listed category has been previously met);
c. specific information on how the threatening process significantly threatens this ecological community; and
d. information on the extent to which the threat could change the status of the ecological community in relation to the criteria for listing. This does not have to be the same criterion under which the ecological community was previously listed.

Coolibah – Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions - EPBC Act: Endangered (TSSC 2011)

There has been considerable development of river regulation infrastructure and large water storages in past decades to enable widespread irrigation of crops and pastures in northern NSW and southern Queensland (as well as elsewhere in the Murray-Darling Basin and adjacent water catchments). Regulated water infrastructures have had adverse impacts upon the functionality and ecology of the Darling River floodplain and, consequently, the Coolibah – Black Box Woodlands ecological community (NSW Scientific Committee, 2009). Periodic inundation is essential for the persistence of many components of the ecological community. However, as much of this water regulation has only occurred in recent decades, the long-term impacts of regulated water flow on the persistence of the ecological community remains uncertain.

The persistence of plants and animals that depend on flood events is at risk because they are less likely to complete their life-cycles under the changed water regime. Seedbanks have a limited lifespan (Capon and Brock, 2006) and aestivating invertebrates and frogs are limited in their capacity to withstand extended periods without inundation (Boulton and Lloyd, 1992). Over the long term, changes in the inundation regime are likely to create a larger area of open grassland and a small area of open Coolibah woodland as the zone of frequent inundation continues to become smaller and wetter (Sims, 2004). The spatial distribution of these contrasting vegetation types is clearly demarcated by frequency of inundation (NSW Scientific Committee, 2009).

Extended periods of drought that impact on the ecological community exacerbate any impacts due to altered natural water flow regimes. In addition to this, climate change projections suggest that rainfall and runoff in the region are likely to decrease (Newton, 2009). The impacts of drought would act through the physiology of the key plant species involved and their differential responses to low water availability (Roberts and Marston, 2000). It is notable that many trees in the national ecological community died in the severe drought commencing in 2002 (Benson et al., 2006; Benson, 2008).

Regrowth is occurring in the Culgoa/Narran River regions but is rarer in the northern wheatbelt (Benson et al., 2006; Benson, 2008) due to altered flooding and water flow regimes. In addition, the cumulative impact of other activities has also resulted in a long-term threat to key vegetation in the ecological community. In particular, activities associated with the surrounding agricultural landscape tend to inhibit any effective regeneration of the ecological community as ongoing cropping, grazing and application of fertilisers and/or herbicides does not encourage the establishment of native seedlings. Areas in which episodic regeneration does occur are vastly reduced from what would have naturally occurred. Where regeneration has occurred, these patches may be targeted for clearing and thinning.

Criterion C: Adversely affected listed species or ecological communities

10. SPECIES ADVERSELY IMPACTED AND JUSTIFICATION

Provide a summary of species listed as threatened under the EPBC Act, which are considered to be adversely affected by the threatening process. For each species please include:

a. the scientific name, common name (if appropriate) and category of listing under the EPBC Act; and
b. justification for each species that is claimed to be affected adversely by the threatening process.

Recent research (Letnic et al. 2015) has indicated that dams and other artificial watering points aid the spread of cane toads significantly. As 'The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*)' is already listed as an EPBC Act KTP, the associated species impacts should be partially considered due to the role altered watercourses play in their continued expansion.

Adversely impacted freshwater species listed as threatened under the EPBC Act include:

- Silver perch (*Bidyanus bidyanus*) – Critically Endangered
- Murray cod (*Maccullochella peelii peelii*) - Vulnerable
- Queensland Lungfish, Australian Lungfish (*Neoceratodus forsteri*) - Vulnerable
- Spotted Galaxias (western subspecies) (*Galaxias truttaceus hesperius*) – Critically Endangered

The TSSC listing advice for the Spotted Galaxias details that weirs are known to restrict upstream spawning migration.

11. ECOLOGICAL COMMUNITIES ADVERSELY IMPACTED AND JUSTIFICATION

Provide a summary of ecological communities listed as threatened under the EPBC Act that are considered to be adversely affected by the threatening process. For each ecological community please provide:

a. the complete title (exactly as listed) and category of listing under the EPBC Act; and
b. justification for each ecological community that is claimed to be affected adversely by the threatening process, including the severity of the impact on each species.

The Conservation Advices for several Threatened Ecological Communities listed under the EPBC Act identify alterations to watercourses as threatening the communities' survival. These include:

- Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion (Endangered)
- Clay Pans of the Swan Coastal Plain (Critically Endangered)
- Coastal Upland Swamps in the Sydney Basin Bioregion (Endangered)
- Monsoon vine thickets on the coastal sand dunes of Dampier Peninsula (Endangered)
- New England Peppermint *(Eucalyptus nova-anglica)* Grassy Woodlands (Critically Endangered)
- Scott River Ironstone Association
- Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains (Critically Endangered)
- Shale Sandstone Transition Forest of the Sydney Basin Bioregion (Critically Endangered)
- Subtropical and Temperate Coastal Saltmarsh (Vulnerable)
- Swamps of the Fleurieu Peninsula (Critically Endangered)
- Upland Wetlands of the New England Tablelands and the Monaro Plateau (Endangered)
- Assemblages of species associated with open-coast salt-wedge estuaries of western and central Victoria (Endangered)

The relevant sections of the Conservation Advices for each TEC, as available on their Departmental SPRAT profiles at http://www.environment.gov.au/cgi-bin/sprat/public/publiclookupcommunities.pl (accessed 12/03/2019), are reproduced below:

Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion
Urbanisation of the landscapes that adjoin the ecological community has significant hydrological effects. The 'hardening' of surfaces through road building surrounding the ecological community results in increased runoff. This can change stream flow patterns, causing erosion and often penetrates the ecological community and carries high nutrient and sediment loads, which can encourage weed invasion and impact on habitat for fauna such as frogs (NSW DEC, 2005; NSW DECCW, 2010).

Clay Pans of the Swan Coastal Plain
Changes to the natural hydrology of the wetlands are potentially the most significant threat to the ecological community, as the vegetation suite is dependent on the wetlands filling and drying at appropriate times of the year. Altered hydrology in urbanised areas in particular is likely to be an increasing threat to the clay pans. Drainage to lower watertables, urban land clearing resulting in a decline in evapotranspiration and a subsequent increase in surface runoff, and declining water quality are all likely to increasingly impact on the current hydrologic regimes of the ecological community (Gibson, 2010).

Given the very complicated nature of the hydrology of the ecological community, and the reality that many of the clay pans in the Perth metropolitan region are now isolated remnants within a matrix of urbanisation, the management of and maintenance of the natural hydrological regimes will continue to be a challenge (Gibson, 2010).

Coastal Upland Swamps in the Sydney Basin Bioregion
Any activity that leads to subsidence, warping of the land surface, fracturing of bedrock layers or valley closures thereby changing hydrological processes involving groundwater and/or surface water will change conditions necessary for the persistence of swamps. The conversion of perched water table flows into subsurface flows significantly changes the water balance of upland swamps (Benson & Baird, 2012). Additionally, changes to surface morphology may lead to development of nick points which then result in significant erosion (Young, 1982). Unlike other threats (fire, clearing, disturbance) for which remediation may be possible, changes which alter catchment hydrology pose an irreversible threat to the integrity of swamp ecosystems (Benson & Baird, 2012).

Where the underlying strata of a swamp is fractured and water levels drop, species adapted to moister conditions and periodic or prolonged inundation are likely to be replaced by those species better adapted to drier conditions (DECC, 2007a). For example, frogs are likely to suffer significant adverse impacts as a result of changes to swamp habitats because of their reliance on water for foraging and breeding within these areas. The Coastal Upland Swamps also provides habitat for the NSW listed giant dragonfly, which is now uncommon in coastal regions (NSW Scientific Committee, 2012), largely as a result of loss and degradation of swamp habitats.

Monsoon vine thickets on the coastal sand dunes of Dampier Peninsula
The ecological community may be impacted by development that alters localised hydrology, microclimates and precipitation or where there is alteration to aquifer levels or quality. Stormwater runoff from formed and sealed roads can create concentrated flows. This can lead to erosion and increased local flooding. Flora species within the ecological community that do not readily adapt to changed drainage regimes, such as the overstorey species *Gyrocarpus americanus* (helicopter tree), can decline or die from extended periods of submersion. Runoff from suburban sources is also a vector for weed invasion, increased nutrient loads and rubbish deposition.

After rain, water accumulates in the dune swale habitat of the ecological community and contributes to the recharge of aquifers. The creation of hardstand areas and use of groundwater for development will potentially alter surface flows and lower groundwater levels, reducing water availability for vegetation. Any change to hydrological inputs may affect the trees within the ecological community.

New England Peppermint (Eucalyptus nova-anglica) Grassy Woodlands
Changes to drainage is another significant threat to the New England Peppermint (*Eucalyptus nova-anglica)* Grassy Woodlands ecological community. The ecological community commonly occurs in valley floors where deeply eroded gullies have led to significant changes to local hydrology. In some cases, the hydrological changes may lead to long term instability and requires active management of issues such as seasonal waterlogging of sites. There may be further impacts upon the ecological community that are not necessarily detrimental. For instance, prolonged waterlogging could have some influence on control of scarab larvae, with consequent implications for dieback.

Scott River Ironstone Association
A potential threat to the functional integrity of the ecological community is a change in hydrological regimes. A defining characteristic of the ecological community is seasonal inundation or wet/damp soils from winter rainfall and groundwater. Changes to the regular hydrological regime could therefore have a significant impact. A number of

occurrences are located on the boundary of areas that are highly cleared which can lead to increases in surface flow and groundwater recharge (Lu and English, 2004). Alternatively, abstraction from bores may lower groundwater levels. Changes to groundwater levels may also lead to salt accumulating near the surface (Luu & English 2004). Changes to the period or depth of ponding could affect structure and composition through changes in the timing of growth of annuals which could then favour different plant species including weeds (Luu & English 2004).

Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains
Changes to the hydrology of a wetland may be direct or indirect, with direct influences including filling-in or drainage of wetlands to create dryland or damming to create a more permanent water body. In both cases the seasonal and generally shallow nature of a wetland is altered, with long-term impacts to native flora and fauna that are adapted to temporary inundation. Indirect influences can occur some distance from the wetland proper and include interception of surface water and extraction of groundwater. Interception of runoff to a dam or channel diverts water that would normally contribute to filling a shallow wetland, reducing the depth and duration of the inundation period, reducing subsoil water levels, or permanently drying the wetland.

A high water table is essential for some wetland plants and animals to survive the dry part of the seasonal cycle. If the water table drops too far below the surface, then the roots of some water plants may be unable to access sufficient water. Aquatic invertebrates such as burrowing crayfish and some water beetles (Cameron, 1992) burrow into porous moist soils to survive the dry period, and re-emerge upon re-wetting. A long-term reduction in groundwater levels may impact adversely on the ability of burrowing species to persist as wetlands dry out.

Drainage of wetlands is widespread, and flooding to form permanent water bodies also occurs. A survey of Victorian wetlands in 1992 found that about 41% of freshwater meadows and shallow freshwater marshes had been drained to some extent (DCE, 1992). This is likely to have increased in the intervening twenty years. Many wetlands had been totally drained and the extent of drainage was higher for wetlands that occur on private land. Most of the ecological community occurs on private tenure subject to agriculture (DCE, 2002; DSE 2007c). Particular regions may have higher rates of drainage, for example, in the Goulburn Broken Catchment almost 56 000 hectares (or 72% of the pre-1750 area) of all major wetland types are affected by drainage or altered water regimes to some extent, and almost another 27 000 hectares (or 35% of the 1750ha area) have been totally lost (Howell and McLennan, 2002). The majority of wetlands in this region were small freshwater meadows or shallow freshwater marshes.

Seed bank analyses demonstrate that the species composition of a wetland is strongly tied to the nature of the water regime at that wetland site (Brock and Casanova, 1997; Casanova and Brock, 2000). The hydrological changes noted above can have drastic consequences for the floristic composition of a wetland, and are likely to also influence faunal composition. Increases in the frequency, duration and depth of flooding result in a more permanently wet site that favours submerged and amphibious species and reduces species richness, as the submerged zone tends to be less diverse than the edge and terrestrial zones. Conversely, a decrease in frequency, duration and depth of flooding result in a more permanently dry site that is more likely to be colonised by weedy terrestrial species. The effective loss of the edge zone and introduction of weeds are likely to decrease species richness at the site. The response depends on the composition of the wetland seed and spore bank. If submergent or amphibious species are absent or have reduced in the soil seed bank, the capacity of the wetland site to shift to a new wetland state, or to recover from any disturbance, is seriously impaired, without human intervention to assist any regeneration.

Shale Sandstone Transition Forest of the Sydney Basin Bioregion
Urbanisation of the often already cleared shale-based landscapes that usually adjoin the ecological community may have significant hydrological effects, especially on components of the ecological community that are dependent on high groundwater and seepage at or below the shale-sandstone interface.

Within the range of Shale Sandstone Transition Forest, dryland salinity is a threat (DEC, 2005) that results from the widespread and intensive removal of deep-rooted perennial vegetation from the naturally salty Wianamatta Shale that dominates the Cumberland Plain and surrounding shale caps. The removal of this vegetation can result in the upward movement of groundwater bearing salts that can retard and ultimately kill most vegetation. The ecological community is likely to be less at risk from soil salinisation than the generally lower-lying communities on the Cumberland Plain-proper, as Shale Sandstone Transition Forest generally occurs at higher elevations within the area at greatest risk. However, there are occurrences of the ecological community in south-western Sydney that may be at significant risk from soil salinisation due to their atypical occurrence down-slope of hills that previously supported extensive areas of Cumberland Woodlands.

Another form of hydrological change occurring adjacent to urban areas is increased runoff from impermeable surfaces, such as roads. This can change stream flow patterns, causing erosion and often penetrates adjacent bushland and carries high nutrient and sediment loads, which can encourage weed invasion (DECCW, 2010).

Subtropical and Temperate Coastal Saltmarsh
Developments can impact on local microclimates, groundwater access and surface runoff changing hydrological regimes (freshwater and tidal) for vegetation. For example, as a result of agricultural and urban infrastructure, many coastal saltmarshes have had their tidal regime significantly changed (Laegdsgaard et al., 2009; Mount et al., 2010). Alterations to drainage and hydrology have occurred through constructing fixtures such as levees, culverts and floodgates. The impacts from such infrastructure range from habitat destruction to changes to ecological function. For example increased inundation can lead to rot and decomposition of succulent species (Laegdsgaard et al., 2009). Of note, in South Australia, the clearance of native vegetation for construction of flood mitigation levees is covered by an exemption under the Regulations of the *Native Vegetation Act 1991*.

Assemblages of species associated with open-coast salt-wedge estuaries of western and central Victoria
The hydrological processes that characterise the salt-wedge estuaries are threatened by alterations to the inflow of freshwater and outflow of saltwater. Freshwater extractions and water regulatory infrastructure alter flow patterns, reduce estuary flushing and degrade water quality, resulting in altered physical and biological processes and declines in endemic biodiversity. Approximately 44% of the estuaries included in this ecological community are threatened by altered hydrological processes. The effects of altered flow regimes in this ecological community include the decline of keystone species; the loss of critical fish spawning cues and habitat; reduced survival of fish larvae; and epidemic infections by viral pathogens (Newton & Mitchell 1999).

Tidal disconnection often leads to invasion by plants such as *Phragmites australis* which can spread forming monotypic stands that alter the ecology and function of saltmarsh (Laegdsgaard et al., 2009 and references therein). Such downslope migration of *P. australis* and other freshwater reeds, which can also be caused by increased stormwater discharge, threatens *Coastal Saltmarsh* from its terrestrial side (Williams et al., 2011; Sainty et al., 2012c).

Swamps of the Fleurieu Peninsula
Hydrological disturbance (e.g. draining of wetlands, changes in wetting and drying regimes, duration and season)

Upland Wetlands of the New England Tablelands and the Monaro Plateau
Alteration of water regimes through draining or damming of wetlands.

Other Legislation:
Broad leaf tea-tree (Melaleuca viridiflora) woodlands in high rainfall coastal north Queensland
A potential threat to the functional integrity of the ecological community is a change in hydrological regimes. The ecological community occurs on floodplains, and while the majority of water comes from wet season rains, floodplains can also receive water from overbank and sheet flow, streams, run-off from the local watershed, hyporheic flow and other groundwater discharge (DERM, 2011). The ecological community is therefore vulnerable to changes in surface water drainage, natural rainfall distribution patterns, hydrology and water quality (i.e. salinity, pH, sediments/turbidity, nutrients and toxicants). The ecological community is characterised by a diverse ground-layer which includes a proliferation of annual species following inundation in the wet season. Less rainfall, or a change in the rainfall regime, is likely to alter this pattern. Additionally, an increase in inundation may lead to the woodlands shifting towards wetlands dominated by grasses, sedges and herbs (DERM, 2011).

Threat Abatement

12. THREAT ABATEMENT

Describe what actions could be taken to abate the threatening process. Link these to the components of the threatening process as described in question 4.

From Bunn & Arthington (2002):
Numerous species of aquatic plants from permanent backwaters and wetlands on the floodplain of the highly regulated lower Murray River in southeastern Australia have colonized the main channel, where the year-round baseflow in weir pools now provides ideal conditions (Walker et al. 1994). Blanch et al. (2000) suggest that reinstating a greater amplitude of weir pool water levels, more frequent shallow flooding, and longer periods of inundation would be beneficial for many plant species, promoting diversity by restoring a wider range of water regimes.

Water abstraction and the construction of dams can have a major impact on the migration of large shrimp (Pringle and Scatena 1999). For example, damming of the lower reaches of one of the main drainages of the Caribbean National Forest in Puerto Rico has had a major impact on shrimp recruitment. More than 50% of migrating larvae were drawn into water intakes for municipal supplies and juvenile shrimps returning upstream faced severe predation below the dam (Pringle & Scatena 1999). Cessation of water abstraction during evening periods of peak nocturnal larval drift, upkeep of a functional fish ladder, and maintenance of a minimum flow could significantly reduce impacts of the dam and its operations.

13. DEVELOPMENT OF THREAT ABATEMENT PLAN OR AN ALTERNATIVE

Would the development of a threat abatement plan be a feasible, effective and efficient way to abate the process? If so, describe how the threat abatement actions describes in Q12 could be included in a threat abatement plan.
Describe any alternative coordinating documents or measures that may assist in abating the threatening process, either separate from or in conjunction with a threat abatement plan.

Yes, the development of a threat abatement plan could be a feasible, effective and efficient way to abate the process. It could identify regions of particular susceptibility to alteration to natural flow regimes and ensure the collective impacts on the biodiversity values and ecological function of these areas are taken into full consideration in future planning.

Reviewers and Further Information

14. REVIEWER(S)

Has this nomination been reviewed? Have relevant experts been consulted on this nomination? If so, please include their names and current professional positions.

This nomination has been reviewed by [redacted].

15. MAJOR STUDIES

Identify major studies that might assist in the assessment of the nominated threatening process.

Poff, N.L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks and J. C. Stromberg (1997) The Natural Flow Regime. *BioScience*, Vol. 47, No. 11 pp. 769-784.

Bunn, S. E. & Arthington, A. H. (2002) Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. *Environmental Management* Vol. 30, No. 4, pp. 492–507.

The nomination is intended to provide a national equivalent to two state legislated threatening processes:
'Alteration to the natural flow regimes of rivers, streams, floodplains & wetlands' – a Key Threatening Process listed under the NSW *Threatened Species Conservation Act 1995*; and 'Alteration to the natural flow regimes of rivers and streams' – a Potentially Threatening Process listed under the Victorian *Flora and Fauna Guarantee Act 1988*.

16. FURTHER INFORMATION

Identify relevant studies or management documentation that might relate to the species (e.g. research projects, national park management plans, recovery plans, conservation plans, threat abatement plans, etc.).

There is no further relevant information the nominator is aware of.

17. REFERENCE LIST

Please list key references/documentation you have referred to in your nomination.

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18. APPENDIX

Please place here any figures, tables or maps that you have referred to within your nomination. Alternatively, you can provide them as an attachment.

Not applicable.

Nominator's details

Note: Your details are subject to the provision of the *Privacy Act* 1988 and will not be divulged to third parties if advice regarding the nomination is sought from such parties.

19. TITLE

[redacted]

20. FULL NAME

[redacted]

21. ORGANISATION OR COMPANY NAME (IF APPLICABLE)

[redacted]

22. CONTACT DETAILS

Email: [redacted]
Phone: [redacted]
Postal address: [redacted]

23. DECLARATION

I declare that, to the best of my knowledge, the information in this nomination and its attachments is true and correct. I understand that any unreferenced material within this nomination will be cited as ‘personal communication’ (i.e. referenced in my name) and I permit the publication of this information.

Signed: [redacted]

Date: 28/03/19

** If submitting by email, please attach an electronic signature*