Hydro Tasmania
The power of natural thinking

The Gordon River Basslink Monitoring Program

2001–2012

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Cover: Jamie McAllister (left) and David Ikedife (right) measure their fish catch

Summary

Dr Malcolm McCausland and Kevin Macfarlane electrofishing in the upper river

Tasmania was connected to Australia's National Electricity Market (NEM) via the Basslink undersea power cable in 2006. Hydro Tasmania conducted a monitoring program from 2001 to 2012 on the Gordon River in Tasmania's Wilderness World Heritage Area to detect any adverse environmental impacts associated with changed operation of the Gordon Power Station as a result of this connection. Predictions indicated that 'hydro-peaking' would be the dominant flow pattern, and could have a number of negative environmental effects.

The multi-disciplinary monitoring program examined hydrology, water quality, fluvial geomorphology, karst geomorphology, riparian vegetation, algae, macroinvertebrates and fish. Pre-Basslink conditions were compared with post-Basslink conditions to determine both the impact of changed power station operations due to Basslink, and the effectiveness of two measures, an environmental flow and a ramp-down rule, designed to mitigate against the predicted effects of altered flow in the Gordon River.

Access only by helicopter

Extensive knowledge gained from the monitoring program has increased our understanding of the processes operating in the Gordon River and how the river responds to a number of different operating scenarios. This understanding has been summarised in five conceptual models.

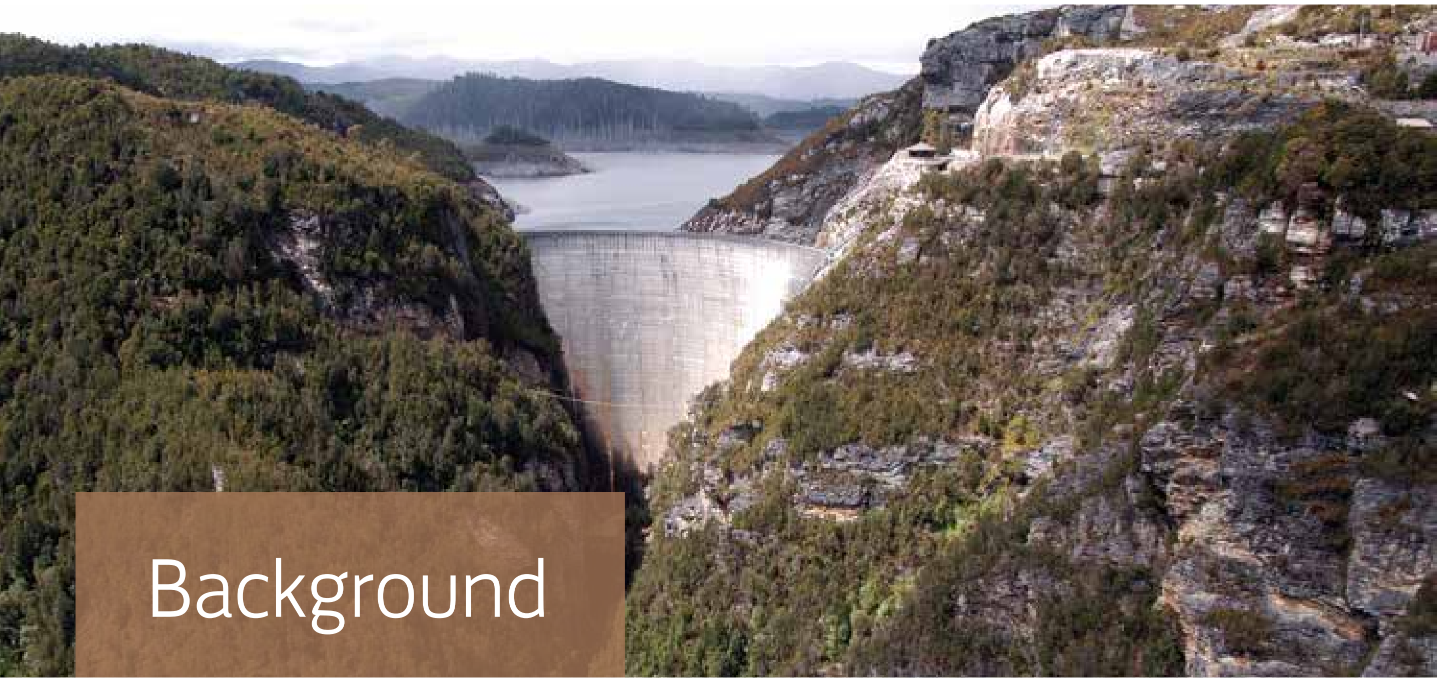
The key findings of the Basslink Monitoring Program were:

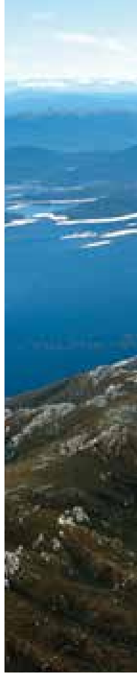
- Power station operation differed from that predicted and it became clearer that a number of factors in addition to the Basslink connection influenced power station discharge. This made it difficult to link environmental changes to Basslink.
- No major adverse impacts were detected in the Gordon River following the commissioning of the Basslink cable.
- The minimum environmental flow was effective during the monitoring period. Macroinvertebrate indicators showed improved conditions related to the implementation of the environmental flow.
- The ramp-down rule as it was first implemented did not fully achieve the aim of reducing seepage erosion and has since been revised to ensure both environmental and operational benefits.

The full results of the monitoring program have been reported in annual reports, a baseline report before Basslink commissioning and in two review reports after three and six years of post-Basslink monitoring. Reports are available on Hydro Tasmania's website:

www.hydro.com.au/environment/basslink-studies

Background





The Gordon Dam

Hydro Tasmania and Basslink

Hydro Tasmania is Australia's largest hydropower generator and water manager, operating 30 hydropower stations and having responsibility for 53 storages. Basslink is an undersea power cable across Bass Strait that links Tasmania to Australia's national electricity grid. Commissioned in April 2006, the cable allowed Hydro Tasmania to join many other generators in the National Electricity Market (NEM), and to operate as an exporter and importer of electricity.

The operating regimes of some of Hydro Tasmania's power stations were expected to change with the different demands of the NEM. Changes to the operating regime and discharge patterns of the Gordon Power Station in Tasmania's south-west, adjacent to the World Heritage Area, were of particular interest.

The Gordon River and the Gordon Power Scheme

The headwaters of the Gordon River are in the King William and Gordon Ranges in central Tasmania. For 180 kilometres its tannin-dark waters flow through broad valleys and short, steep gorges, cut at right angles through parallel ranges, until reaching Macquarie Harbour on Tasmania's west coast. This is the country of Tasmania's Wilderness World Heritage Area; the land is rugged, mountainous, wild and inaccessible, vegetated with rainforest, shining gum and stringy bark wet forest, button grass moors and wet scrub. The river directly provides habitat for freshwater macroinvertebrates, native and introduced fish, freshwater crayfish, platypus and native water rats, and indirectly supports many different native plants and animals.

The whole catchment covers an area around 7220 km^2, with approximately 2000 km^2 draining into the Gordon Power Scheme's two water storages, Lake Pedder and Lake Gordon. Lake Gordon is the largest water storage in Australia, with a total capacity of 11,900 gigalitres (GL). Since 1978, when the power scheme was first commissioned, the Gordon River has had a highly regulated and modified hydrology that has impacted upon the river system.

Gordon Power Station and its intake tower

The Gordon Power Station

The underground Gordon Power Station is the largest in Tasmania and plays a key role in the state's hydropower system, generating up to 430 megawatts (MW). Two turbines were commissioned in 1978 and a third in 1988. Water from Lake Gordon enters the power station through an intake tower and is used to turn the turbines before being discharged through a tailrace tunnel into the Gordon River below the dam. The Gordon Power Station has a maximum release of 270 cubic metres of water per second (a flow rate of 270 cumecs). That flow of water would fill an Olympic-sized swimming pool in less than 10 seconds. The water level in the Gordon River below the power station can fluctuate by as much as four metres depending on power station operations.

Lake Gordon and Lake Pedder (Peter Bellingham Photography)

Predicted effects of Basslink operation on the Gordon River

The Gordon River Basslink Monitoring Program was designed to detect environmental impacts on the Gordon River associated with predicted changes to discharges from the Gordon Power Station after connection to the NEM via the Basslink cable. It does not assess environmental impacts of the pre-existing power station itself. The predictions were that there would be frequent variations in water discharge between low or no flow to very high flow, a pattern called 'hydro-peaking', and that the power station would operate more during winter than previously. The frequency of short-term shut-downs, when no water was discharged, was also anticipated to increase.

These forecast changes to the operation of the power station were predicted to have the following effects on the river environment:

- **Fluvial geomorphology** — changes in the geomorphic processes controlling stability of the Gordon River banks. River banks would be susceptible to seepage erosion which would combine with scour erosion creating cavities under root mats increasing bank collapse and slumps.
- **Riparian vegetation** — increased rates of loss of riparian vegetation communities.
- **Benthic macroinvertebrates** — reduced habitat for macroinvertebrates and changes in composition of macroinvertebrate communities, further reducing diversity and abundance. Macroinvertebrate abundance was expected to decline substantially upstream of the Denison River, and would be dependent on natural flows from small tributaries.
- **Fish** — reduced habitat and food for fish and increased risk of stranding mortality.
- **Water quality** — reduced incidence of low dissolved oxygen levels; reduced incidence of seasonally cooler water release.
- **Karst geomorphology** — potential changes in sediment movement within karst features.

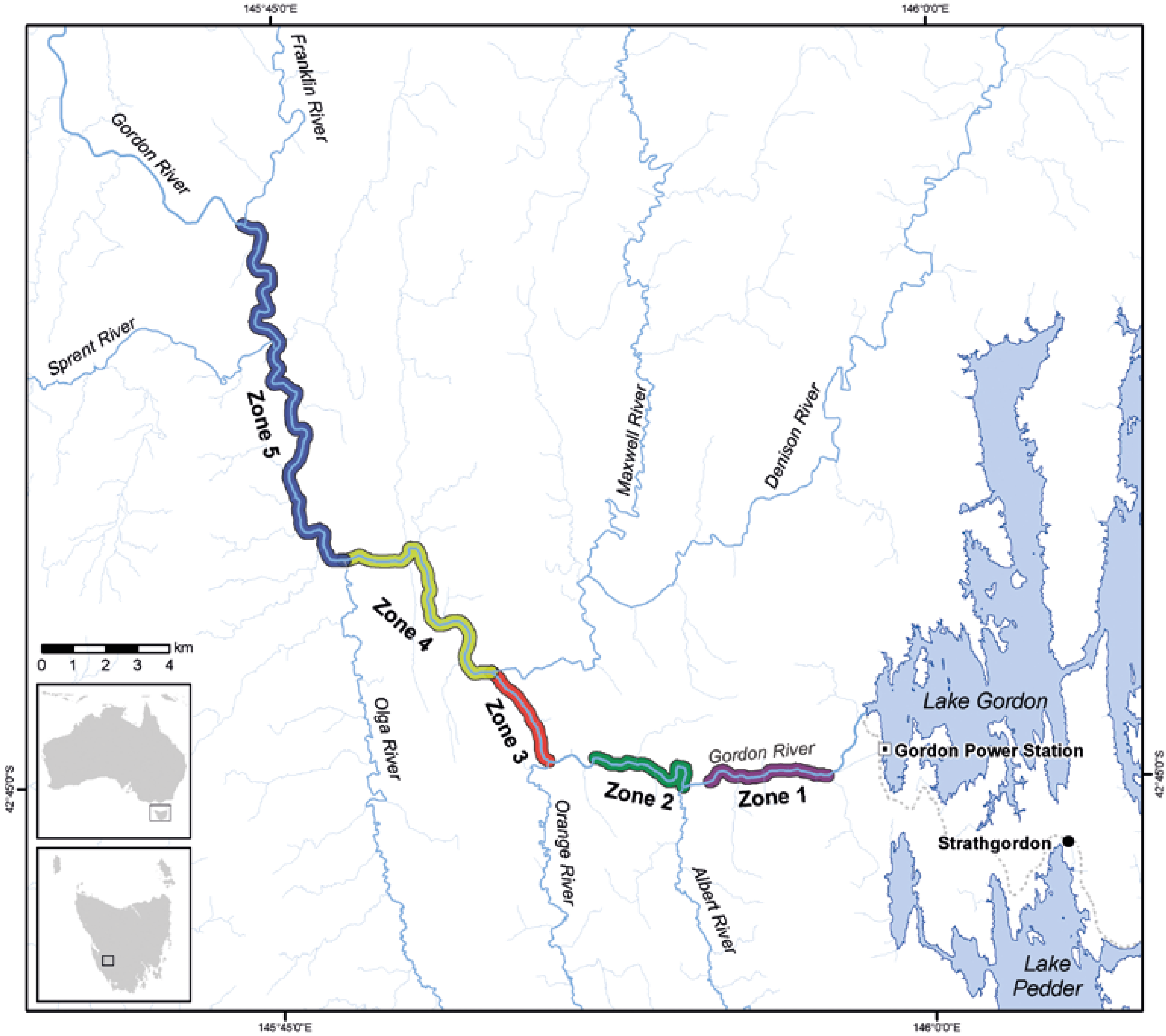
To minimise predicted adverse impacts, two water management mitigation measures were implemented:

1. The **minimum environmental flow** ensures that a continuous flow of water is provided to the Gordon River. Environmental flows of 10 cumecs in summer–autumn and 20 cumecs in winter–spring are provided. The aim of the environmental flow is to improve conditions for macroinvertebrates and provide increased habitat and food for fish.
2. The **ramp-down rule** limits the rate of change of flow when the power station is shut down or reduces discharge after a period of high discharge. This measure operates to protect upper banks from seepage erosion.

Adaptive management

In recognition of the scientific uncertainties associated with environmental management, new knowledge and information from the Gordon Basslink Monitoring Program has been used to regularly review and improve our operational practices and monitoring program. This adaptive approach was a cornerstone of the Basslink Monitoring Program. Results from the monitoring program were reviewed annually by scientific experts on the Gordon River Scientific Reference Committee.

The robust review and advice from the Scientific Reference Committee helped direct adaptive management in the Gordon River.



The monitoring area

The Gordon River Basslink Monitoring Program

The monitoring area covered 35 km of the Gordon River from the Gordon Power Station tailrace to below the confluence with the Franklin River, as well as reference rivers in the region. An extensive monitoring program to establish pre-Basslink baseline conditions ran from 2001 to 2005, providing insight into how the river responded to the existing operation of the Gordon Power Station. Following the commissioning of the Basslink cable in 2006, post-Basslink monitoring began and continued until 2012.

The monitoring program assessed a range of environmental measures, including hydrology, water quality, fluvial geomorphology, riparian vegetation, aquatic macroinvertebrates, aquatic algae and moss, and fish.

Four monitoring trips occurred each year in March and April (autumn), October (spring) and December (summer), each a major undertaking requiring the power station to be shut down to provide safe access to the river. Researchers entered the area by helicopter and accessed individual sites on foot or by inflatable boat. Safety was paramount, as the area is remote and renowned for its dramatic weather changes.

This summary report summarises outcomes of the 11-year monitoring program and improvements in our understanding of the Gordon River system.


Gordon River

Hydrology

The hydrology of the river changes along its course

Flows have been regulated in the middle Gordon River since the construction of the Gordon Power Scheme in 1978. The Gordon Power Station operating regime is influenced by rainfall in all Tasmanian catchments, overall water levels in storages, energy demand in Tasmania, periods of power station shutdown, and electricity pricing signals. The Gordon Power Station is used less during wet periods as the run-of-river power stations located elsewhere in Tasmania are used at such times. The Gordon Power Station may be used as a peaking station when electricity spot prices are high.

The reaches of the river closest to the power station (zones 1 to 3) are subject to greater variation in flow velocity and respond more rapidly to changes in power station discharge due to their close proximity to the point of discharge, short steep gorges and the absence of large tributaries. Therefore the impacts of and responses to the operation of the power station are greatest in these reaches of the river, particularly between the power station and the Denison River.

Tannin-coloured waters of the Gordon River

Flow patterns in the Gordon River after Basslink connection

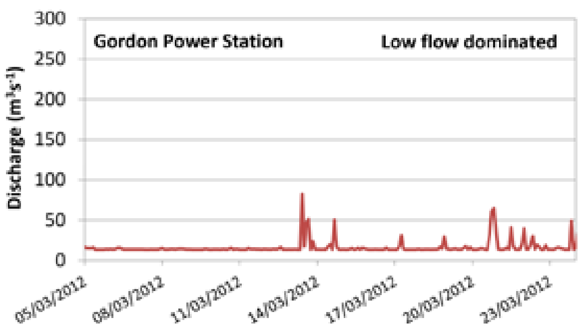
Five distinct flow patterns were identified in the Gordon River during the course of the monitoring program. Each of these flow patterns has the potential to affect the river in a different manner. The processes and responses of the individual components of the river ecosystem are summarised on pages 10–11.

No flow (0 cumecs)

After the Basslink connection, periods of no flow have been very infrequent (1% of the time) because of the introduction of the minimum environmental flow. The power station is only switched off for maintenance or environmental monitoring, when the safety of the monitoring team is paramount.

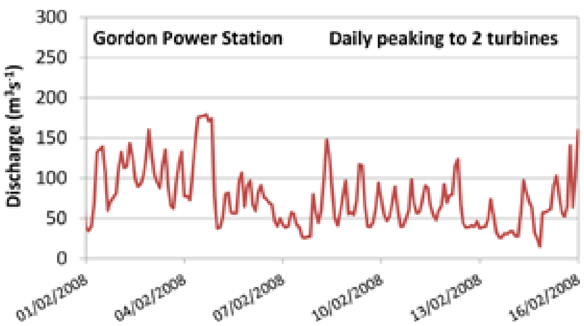
Environmental flow dominant (10–40 cumecs)

This flow pattern is dominated by flows close to the environmental flow with occasional peaks in flow to 1 or 2 turbine operation. It is characterised by little flow variability, low volume, low flow velocity and a fairly constant and permanent wetted river bank area. This flow pattern has only occurred since the commissioning of Basslink, when the environmental flow was first implemented.



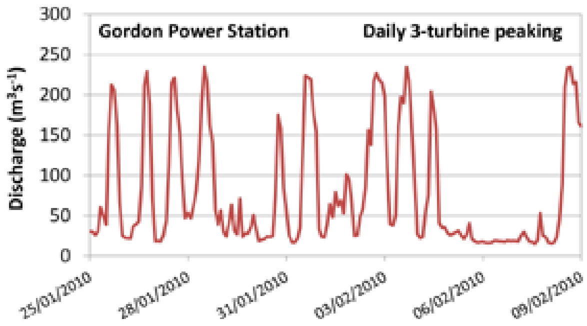
Daily hydro-peaking up to two turbines (10–150 cumecs)

This flow pattern consists of a variable flow with daily fluctuation in discharge in the range between the minimum environmental flow and two turbine operation. Its main characteristics are the rapid variation in flow, moderate flow volumes and flow velocities that range from low to medium. This was the most common flow pattern both before and after the Basslink connection.



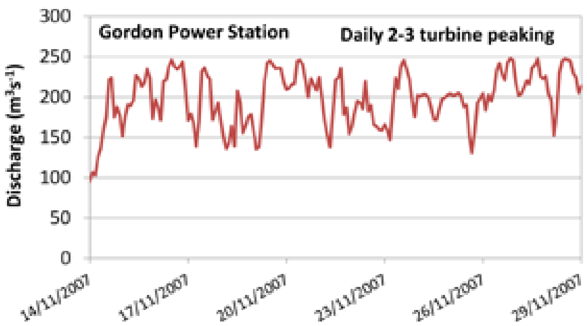
Daily hydro-peaking to three turbines (10–270 cumecs)

This flow pattern consists of a highly variable flow with daily rapid fluctuation in discharge between the minimum environmental flow or no flow and 3 turbine operation. It was expected to be the dominant flow pattern following Basslink connection. The occurrence of this flow pattern increased after Basslink commissioning but has not been the most dominant flow pattern as predicted. The risks of no flow and seepage erosion of this highly variable flow have been mitigated by the minimum environmental flow and ramp-down rule.



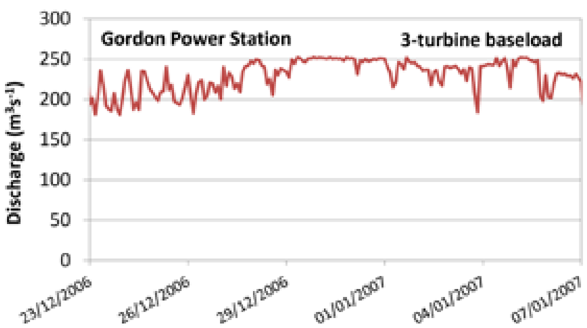
Daily hydro-peaking between 2 and 3 turbines (150–270 cumecs)

This flow pattern consists of fluctuations between 2 and 3 turbine operation with no restriction on the rate at which flows are reduced. Flow variability is across a smaller range than other hydro-peaking patterns, and flow volume and velocity are moderate to high.



Sustained three turbines (220–270 cumecs)

This flow pattern involves the continuous operation of the power station near its maximum discharge. There is very little flow variability in this flow pattern and volume and velocity are both maintained at high levels.



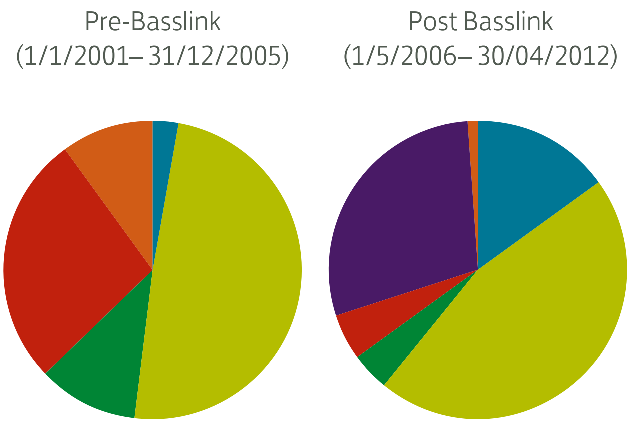
The Gordon River (left); Monitoring trips were undertaken twice a year, with researchers reaching individual sites by inflatable boat (right)

Changes in flow after Basslink connection

A comparison of the prevalence of flow patterns in pre- and post-Basslink periods demonstrates a significant change in operation, however the changes differed from predictions. The major changes in the post-Basslink period have been:

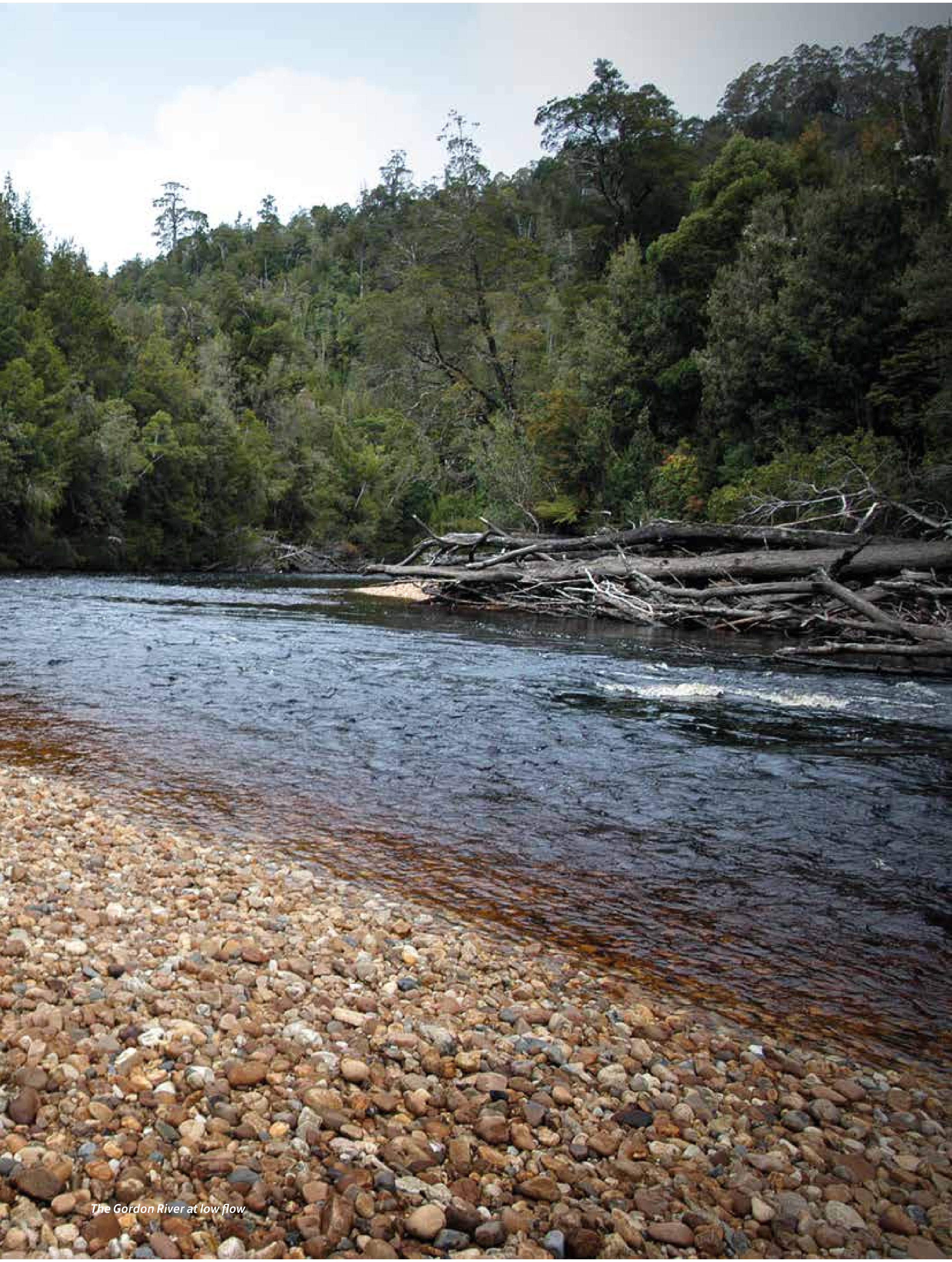
- an increase in daily peaking between 1 and 3 turbine discharge
- a high proportion of operation at the low-flow dominant pattern
- a significant reduction in the occurrence of no discharge (power station off)
- a significant reduction in sustained 3 turbine operation.

Operation of the power station varied among years. In the first two years after connection (2006–2008) high flow patterns were more frequent (daily peaking between 2 and 3 turbines and sustained 3 turbine operation) which resulted in higher annual discharge. During these years, drought and the resultant lack of water for run-of-river power stations meant greater reliance on the major storages, Great Lake and Lake Gordon. In the following four years (2008–2012), there were substantially lower annual discharges because of the predominance of low-flow discharge at the environmental flow levels and periods of peaking in the 1 to 3 turbine range. During these years Hydro Tasmania was re-building water storages after years of drought. After 2008, import from the mainland increased as well as rainfall. Export via the Basslink cable was greater than import for the first time in 2011. This was also the time when the highest level of peaking occurred at the Gordon Power Station.



Pre-Basslink	Pattern	Post Basslink
3%	Daily hydro-peaking to 3 turbines	15%
49%	Daily hydro-peaking to 2 turbines	46%
11%	Daily hydro-peaking between 2 and 3 turbines	4%
27%	Sustained 3 turbines	5%
0%	Environmental flow dominant	29%
10%	Power station off	1%

Qualitative flow pattern analysis for the Gordon River in pre- and post-Basslink periods



The Gordon River at low flow

Environmental monitoring results

Dr Anita Wild and Ray Brereton assess ground cover at a fine scale using quadrats

There were no major adverse impacts on the Gordon River ecosystem following the commissioning of the Basslink cable. Full results of the monitoring program are available in multiple publications at **www.hydro.com.au/environment/basslink-studies**.

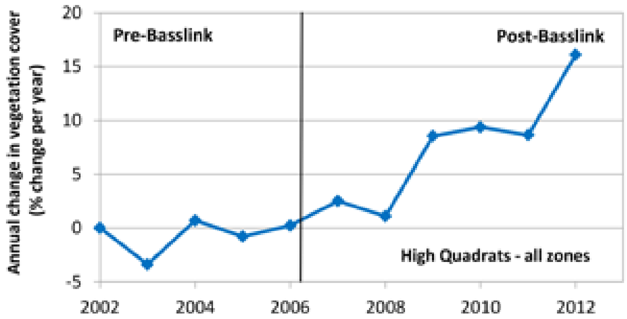
Fluvial geomorphology

Rates of erosion along the banks of the Gordon River after Basslink connection were lower than prior to connection. This is attributable to the large reduction in total flow in the last four years of monitoring (2008–2012), combined with increased deposition associated with local seepage processes influenced by increased hydro-peaking. Changes at erosion pins were governed primarily by the magnitude, duration and draw-down frequency of flows in the river, which translate into scour and seepage erosion on the banks. The flow patterns in the post-Basslink period have resulted in a substantial reduction in erosion in conjunction with an increase in deposition on the bank toes due to seepage, and limited change in the mid (1 to 2 turbine operation) and upper (2 to 3 turbine operation) bank levels.

Bank erosion in zone 3

Riparian vegetation

In the post-Basslink period there has been a net recovery of vegetation on the banks of the Gordon River. There has been a measurable increase in total vegetation cover at all bank levels. However, it is most pronounced above the level of 2 turbine operation. There has also been an overall increase in species richness over the monitoring period. The increase in vegetation cover and associated increase in species richness have been promoted by the low flows observed over the last four years (2008–2012).



Vegetation cover increased on upper banks, especially when flows were low from 2009 to 2012

Monitoring of benthic algae and moss (left); Karst features provide habitat for unique animals like glowworms (right)

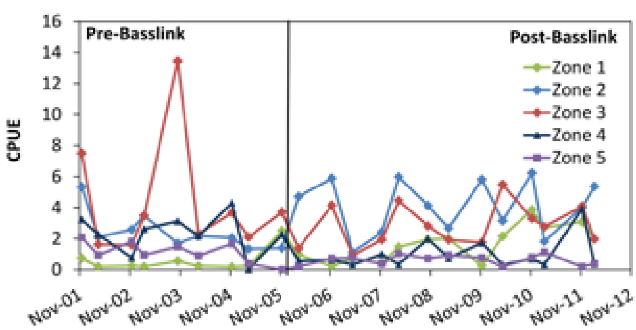
Macroinvertebrate communities

The general condition of macroinvertebrate communities in the Gordon River after Basslink connection was broadly similar to that before connection. There has been a positive impact on the macroinvertebrate community, with increases in abundance and diversity of flow-dependent taxa due to the increase in the occurrence of low flows in the latter years of the post-Basslink period (2008–2012) in conjunction with the minimum environmental flow.

Fish

There has been no significant impact on fish in the Gordon River since the Basslink connection. There have been indications of improved native recruitment and upstream migration in the post-Basslink period.

The low numbers and patchy distribution of fish make it difficult to quantitatively assess the impacts of Basslink on individual species.



Fish catch per unit effort (CPUE) before and after Basslink. The low abundance and patchy distribution of fish makes it difficult to draw conclusions about the effects of the Basslink connection on fish communities

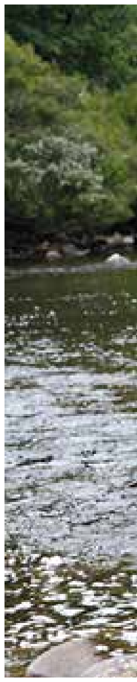
Karst geomorphology

The karst geomorphology showed that the sediments in the caves are more protected and buffered from the effects of the power station operations than the sediments in the river channel. The caves are relatively robust. There were only very small changes in sediment, in the order of a few millimeters per season, which are considered to be of little significance from an ecological, geomorphological or conservation perspective. There was no indication of any changes that occurred to the karst sediment banks in the post-Basslink period.

Water quality

The water quality of Lakes Pedder and Gordon, and the Gordon River, has remained excellent throughout the monitoring period. Variation in water temperature in the Gordon River was observed, related to seasonal temperature changes, degree of mixing in Lake Gordon, and the water level in Lake Gordon. Reduced seasonal variation and generally cooler water temperature were associated with higher water levels.

Dissolved oxygen concentrations fluctuated on a seasonal, daily and hourly basis in response to mixing conditions in Lake Gordon and operational factors. Significant variation in dissolved oxygen was only seen immediately below the tailrace influenced by entrainment of air in the turbines at lower power station output. At locations further downstream the impact of operational factors on dissolved oxygen was insignificant.



Minimum environmental flow

Fast-flowing riffles

The minimum environmental flow was introduced in April 2006 following the commissioning of Basslink. It was established to ensure that important aquatic habitats remained inundated, even when the power station was not required to generate power.

Prior to the introduction of the minimum environmental flow, Gordon Power Station only discharged water when it was required for generation. As a result there were periods when there was little or no flow in the Gordon River above the confluence with its first major tributary, the Denison River. The predictions of more regular periods of no discharge as part of a hydro-peaking flow regime under Basslink operation were considered likely to exacerbate the poor habitat availability for aquatic communities.

The environmental flow delivers a minimum flow of 10 cumecs in summer (December to May) and 20 cumecs in winter (June to November). There was much annual variation in how often the environmental flow release dominated the flow pattern, ranging from 4% of the year in 2006–2007 to 63% of the year in 2011–2012. From 2008 to 2012 the environmental flow dominated for more than 30% of the time in each of these four years.

The introduction of the minimum environmental flow has mitigated predicted adverse impacts along the Gordon River. The environmental flow has maintained aquatic habitats when, in its absence, there would have been substantial periods of no discharge and a large reduction in suitable aquatic habitat. The long-term monitoring program shows positive results for aquatic biology with improved overall health and abundance of some macroinvertebrate and fish communities.

Responses of the river system to the minimum environmental flow

Algal and moss cover

The algal and moss cover in the Gordon River was similar after the Basslink connection to that observed before connection. There were some increases in algal cover coinciding with the lower flows associated with the environmental flow-dominated pattern; on one sampling occasion algal cover exceeded the abundances measured in the pre-Basslink period. Lower flows were favourable for algal growth in the upper reaches of the Gordon River.

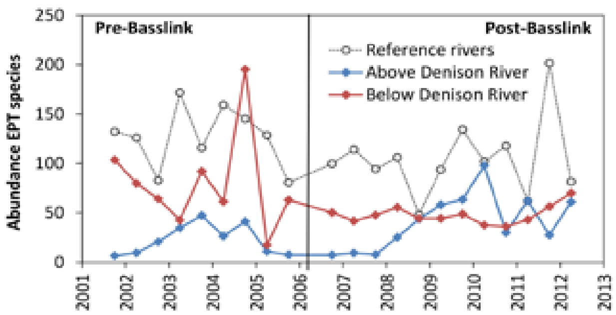
Macroinvertebrates

The minimum environmental flow had a positive impact on the macroinvertebrate community. Increases in abundance and diversity of flow-dependent species indicated a positive response to, and dependence on, the minimum environmental flow during the post-Basslink monitoring period. This was particularly evident for the reach of the Gordon River above the confluence with the Denison River. This part of the river was subject to very low flows during power station shut-downs prior to implementation of the minimal environmental flow.

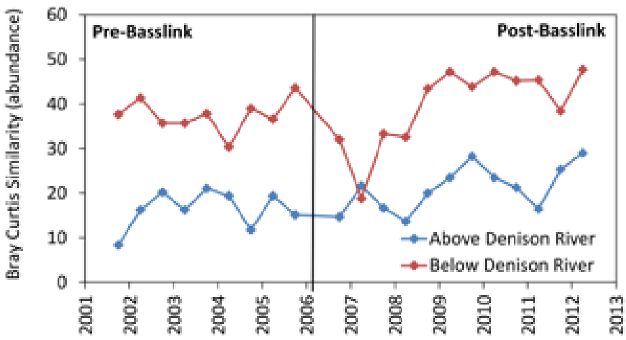
The greatest response to the minimum environmental flow was the increase in abundance of several mayfly, stonefly and caddisfly species. These biologically important species are sensitive to changes in their environment, and increased numbers observed in the upper reaches of the Gordon River indicate improvements in the condition of the macroinvertebrate community.

A number of other biological indicators of the macroinvertebrate community also suggested that the communities above the confluence with the Denison River were converging in diversity, structure and abundance with communities in unregulated rivers in the region.

David Ikedife and Adam Uytendaal electrofishing (left); Spotted galaxias (right)



Abundance of macroinvertebrate indicator species (stoneflies, caddisflies and mayflies) has increased since the Basslink connection, particularly above the confluence of the Denison River

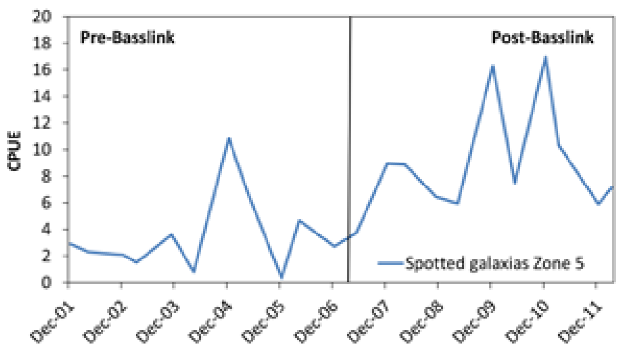


Bray-Curtis similarity is a direct comparison of the Gordon River macroinvertebrate community to that in reference rivers. Higher values during the post-Basslink period indicate a community that has become more similar to the unregulated rivers in the vicinity

Fish

Twelve species of fish have been captured in the Gordon River and its tributaries during the monitoring program. These included eight native species — galaxiids, eels, sandys and lampreys — as well as four introduced fish species — brown trout, rainbow trout, Atlantic salmon and redfin perch. The main measure of fish abundance is catch per unit effort (CPUE), which is a measure of the number of fish caught for the time spent sampling.

Despite the variability in the fish data, there was evidence of increased abundance of spotted galaxias, and increased upstream distribution of sandys and spotted galaxias post-Basslink. Observations of increased galaxiid abundance were predominantly linked to an increased frequency of low-to-medium flows in the downstream reaches of the river, which were a product of the environmental flow releases and low catchment inflows.



Abundance of spotted galaxias showing increased abundance after Basslink connection

Ramp-down rule

Sand bank on the Gordon River

Adaptive management, review and revision of the ramp-down rule

Connection to the NEM via the Basslink cable was expected to result in increased hydro-peaking of Gordon Power Station. In the absence of any mitigation this would have caused regular, rapid draining of saturated river banks along the Gordon River, resulting in the entrainment and seepage of sediments from the banks, the formation of cavities and potential bank collapse. A ramp-down rule constraining the rate of change of power station discharge was implemented in 2006 to limit the rate of associated changes in river water level. The ramp-down rule was designed to decrease the incidence of seepage erosion, and thus the potential for bank sediment erosion and collapse. It was intended to prevent rapid decreases in water level when banks were saturated, allowing bank sediments to drain gradually as the water level falls.

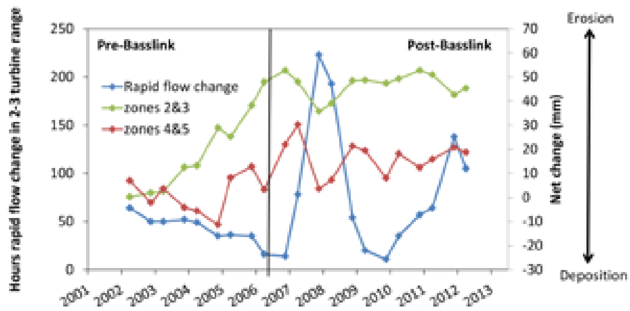
The original ramp-down rule stated that if the Gordon Power Station had been discharging above 180 cumecs for greater than 60 minutes and Hydro Tasmania intended to reduce discharges to below 150 cumecs, the reduction in flow should occur at a rate of less than 30 cumecs per hour. The original ramp-down rule therefore allowed unrestricted discharge changes at flows greater than 150 cumecs, and increased seepage erosion when the power station was peaking in the 2 to 3 turbine range. In addition the ramp-down rule was difficult to implement operationally and was prone to human error. Consistent with adaptive management processes a new ramp-down rule was developed based on modelled and observed levels of bank saturation and rates of draining.

Comprehensive work occurred over a four year period to develop the new ramp-down rule including:

- review of the existing ramp-down rule to identify its flaws
- modelling of the movement of water through the river banks to determine the risk of seepage erosion under different operating regimes
- field testing of different ramping rates at different bank saturation levels to determine when seepage erosion occurs
- developing a robust model that accurately predicts the current bank saturation levels in the Gordon River.

Deriving a ramp-down rule which aligns operational flexibility with environmental goals was a key outcome of the adaptive management process. The new ramp-down rule is based on the saturation of the banks, recognising that seepage erosion is most severe at high bank saturation. The revised ramp-down rule uses a regression model to estimate the saturation of banks in the Gordon River based on recent discharges from Gordon Power Station. When the model indicates that ground water in the river banks would be saturated to a height of 2.75 m, any discharge reductions from above 150 cumecs are made at a rate equivalent to 1 MW/min (approximately 45 cumecs per hour). Therefore, under the revised ramp-down rule, discharge reductions are required whenever banks are saturated and power station discharge is high. This ramp-down rule maintains operational flexibility under conditions of low bank saturation and low seepage risk and only constrains power station discharge reductions when the risk of seepage erosion is high. The ramp-down rule is automatically activated when required, which reduces the risk of human error.

The effectiveness of the revised ramp-down rule has yet to be fully assessed. Monitoring continued in the Gordon River from 2012 to 2014 to determine the effectiveness of this ramp-down rule at reducing the occurrence of seepage erosion. These data are currently being analysed.



In 2007–2008 increased seepage erosion was related to the rapid draining of saturated banks when there was unrestricted hydro-peaking between two and three turbine operation. Seepage erosion appeared as net deposition as the bank slumped

Responses of the river system to the ramp-down rule

Erosion

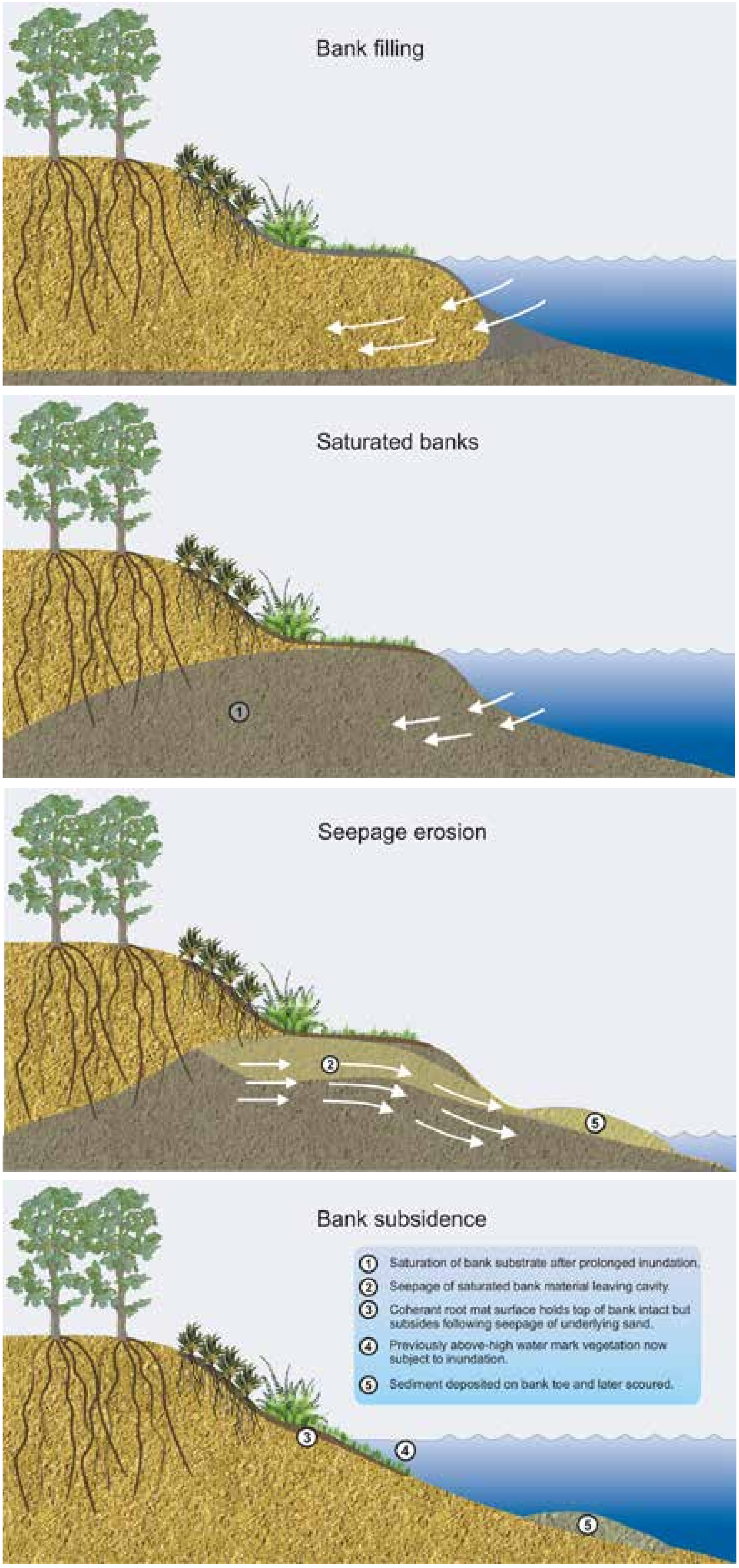
The ramp-down rule was implemented primarily to protect the river banks from seepage erosion and associated loss of riparian vegetation. The original ramp-down rule was effective under most operating regimes. However, in 2007–2008, increased seepage erosion was related to the rapid draining of saturated banks when there was unrestricted hydro-peaking at 2–3 turbine operation. Seepage erosion was detected in all river zones on the upper banks at the 2–3 turbine level. Seepage erosion appeared as net deposition as the bank slumped.

Overall river bank erosion rates were lower post-Basslink compared to pre-Basslink at all river zones, except the lower-most zone 5. This reduction in erosion was largely due to the large reduction in total flows between 2008 and 2012.

Riparian vegetation

Riparian vegetation trends corresponded closely to erosional responses of the river banks. In the post-Basslink period, the vegetation responded to increased seepage erosion in 2007–2008 and resulted in loss of vegetation on upper banks of the river.

The vegetation responded to the low-flow patterns between 2008 and 2012 and the associated reduction in inundation and physical stress by increased recruitment and seedling growth. This resulted in greater species richness and vegetation cover on all bank levels.



Un-ramped hydro-peaking can lead to seepage erosion and loss of riparian vegetation

Riparian vegetation on the banks of the Gordon River

Understanding the Gordon River

The river's ancient geology

Conceptual models represent a working hypothesis about how an ecosystem works. They identify the important components and processes in the system and document assumptions about how these components and processes are related. A conceptual model of the Gordon River was first developed after the four years of pre-Basslink monitoring, and has served as a way of highlighting relationships among ecosystem components as a basis for understanding and interpreting future change. A series of conceptual models have been developed that describe the current understanding of the responses of the river to each of the hydrological flow patterns that have been observed during the Basslink monitoring period.

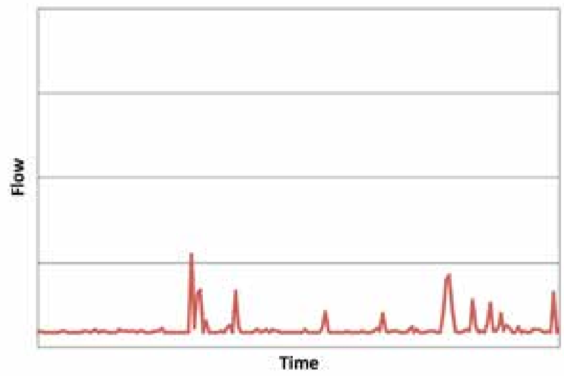
The models represent the Gordon River as stylised cross-sections. They summarise the effects of each flow pattern on ecosystem elements (vegetation, river banks, fish, macroinvertebrates and algae) and processes (erosion, migration, recruitment) at different river heights relating to the general levels of operation (environmental flow, 1, 2, 3 turbines). The effects of the flow patterns are most pronounced upstream of the Denison River. See page 7 for more detail on flow patterns.

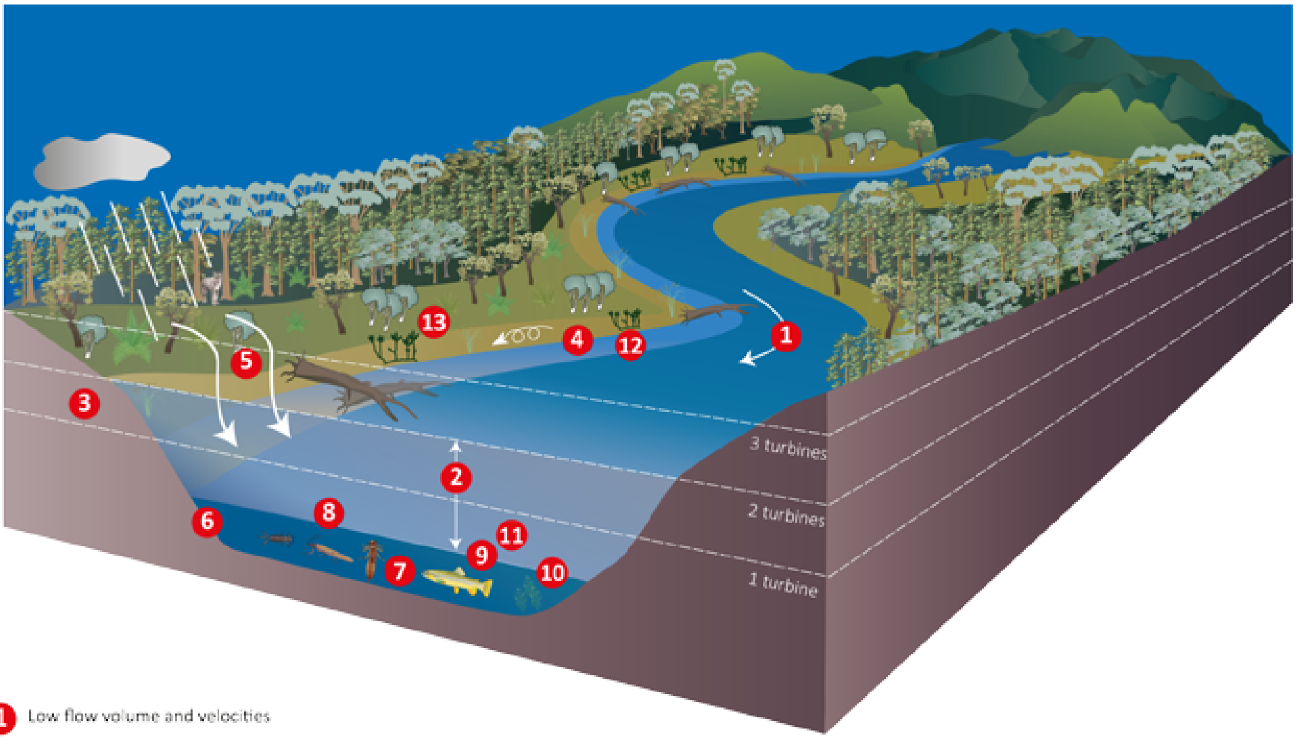
Researchers working on the Gordon River Basslink Monitoring Program arriving at a field site by helicopter

Environmental flow dominant

In the low-flow scenario, river banks are unsaturated. There is little river bank erosion due to the minimal flows. This lack of erosion promotes greater bank stability particularly through the expansion of riparian vegetation under these conditions of little disturbance. The vegetation on the banks is healthy, plants have aerated roots and seedlings are able to establish.

Permanent and stable aquatic habitats provide favourable conditions for many aquatic species of macroinvertebrates and fish. Low flow allows greater light availability to the stream bed and an increase in algal growth.



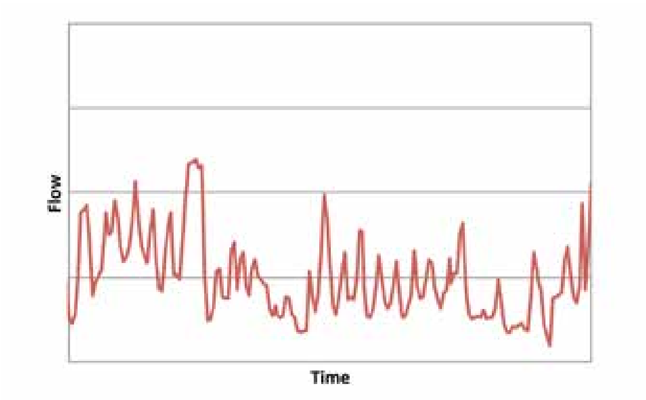


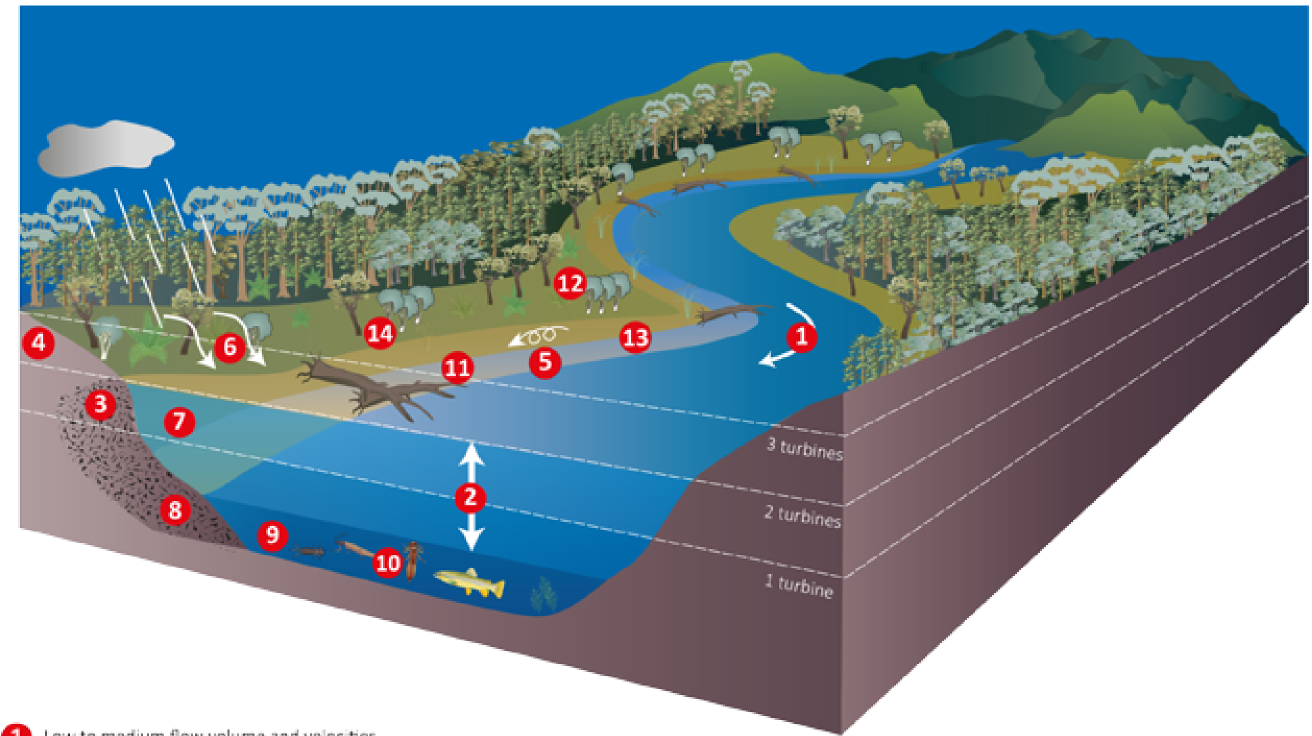
1. Low flow volume and velocities
2. Low flow variability
3. Unsaturated banks
4. Minimal scour
5. Erosion from rainfall (rilling on lower banks)
6. Prolonged saturation of bank toe
7. E flow creating permanent wetted area and habitat for fish and macroinvertebrates
8. Increased total and proportional abundance of EPT (Ephemeroptera, Plecoptera and Trichoptera) species.
9. Increased fish abundances and improved migration opportunities
10. Increased algal growth
11. Increased food supply for fish and macroinvertebrates.
12. Seedling establishment and vegetation growth in 0-3 turbine level due to minimal scour and good aeration of roots leading to healthy vegetation
13. Accumulation of organic matter and sediments

Daily hydro-peaking up to two turbines

This flow scenario has relatively moderate flow volumes and low-to-medium velocities. The upper banks of the river remain unsaturated. Erosion is limited to rainfall-induced erosion. Vegetation is healthy on the upper banks but riparian vegetation on the lower banks (at the 1–2 turbine level) is in poor condition or disappears after prolonged peaking in the 1–2 turbine range.

Some permanent habitat is available for biota, but aquatic habitats are less stable due to the low range hydro-peaking. These habitats continue to provide favourable conditions for many aquatic species of macroinvertebrates and fish, but are less favourable for flow-sensitive species of macroinvertebrates. Light penetration to the stream bed is frequently interrupted, constraining algal growth and reducing food availability for grazing macroinvertebrates.



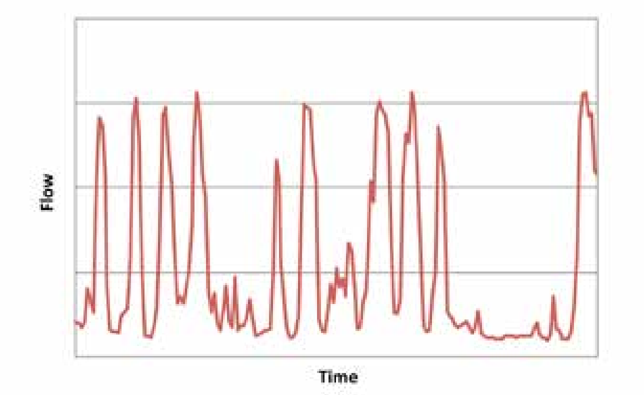


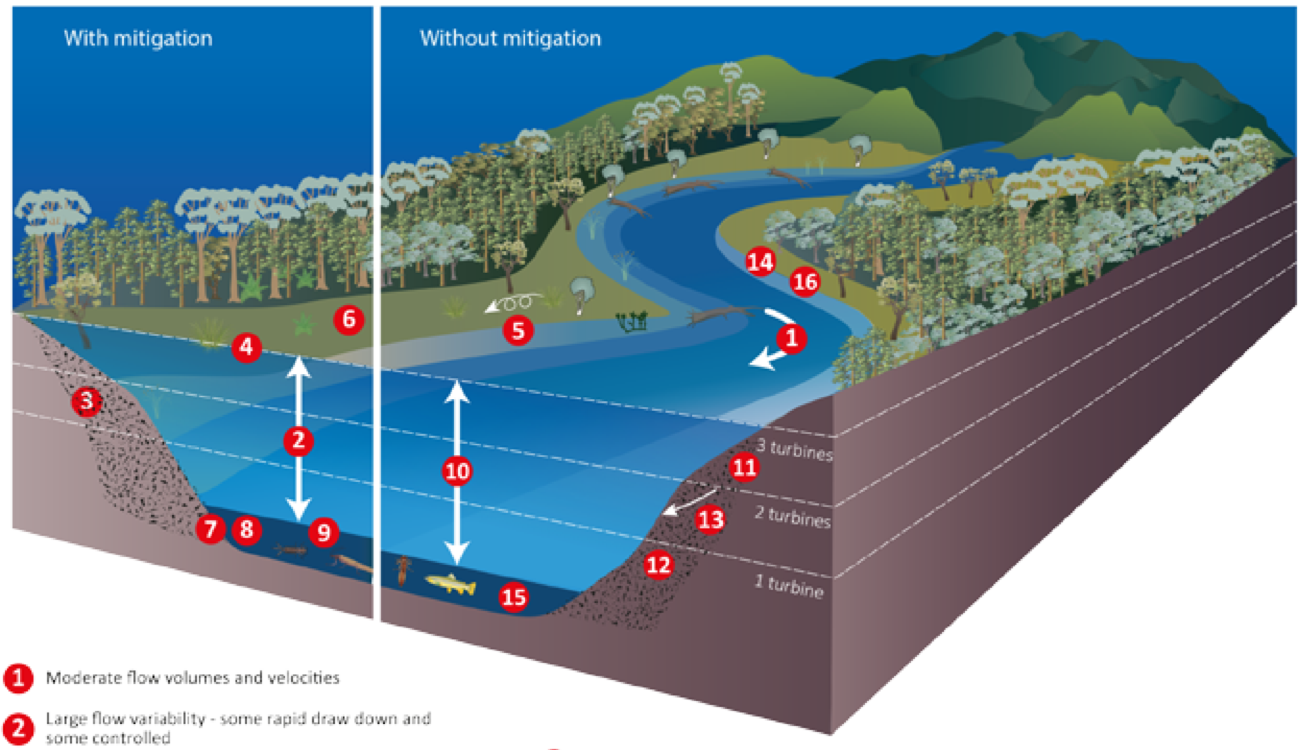
1. Low to medium flow volume and velocities
2. Moderate flow variability
3. Occasional saturated banks in 1-2 turbine level
4. Unsaturated upper banks
5. Limited scour of 1-2 turbine level
6. Erosion from rainfall (rilling)
7. Seepage processes reduce bank angles
8. Prolonged saturation of bank toe
9. E flow creating permanent wetted area and habitat for fish and macroinvertebrates
10. Increased total and proportional abundance of EPT (Ephemeroptera, Plecoptera and Trichoptera) species.
11. Fish reduced habitat for lamprey amocetes in the 1-2 turbine level
12. Seedling establishment and vegetation growth in 2-3 turbine level due to good aeration of roots.
13. Loss or poor health of vegetation in 1-2 turbine level with prolonged peaking
14. Accumulation of organic matter and sediments

Daily hydro-peaking to three turbines

Flow variability is large, flow volumes are moderate and there is short-term high velocity flow. Banks are saturated, and there is a high risk of seepage erosion when bank saturation reaches the height of saturation at 2–3 turbine level. However, the use of the ramp-down rule limits this risk. Riparian vegetation is in poor condition at all bank heights and with prolonged, repeated peaking operation, vegetation is removed.

Some permanent aquatic habitat is available but habitats are unstable due to the high range hydro-peaking. This habitat supports a population of macroinvertebrates and fish, however conditions are less favourable for flow-sensitive species. Algal growth is limited by both light and shear stress during high flow events.



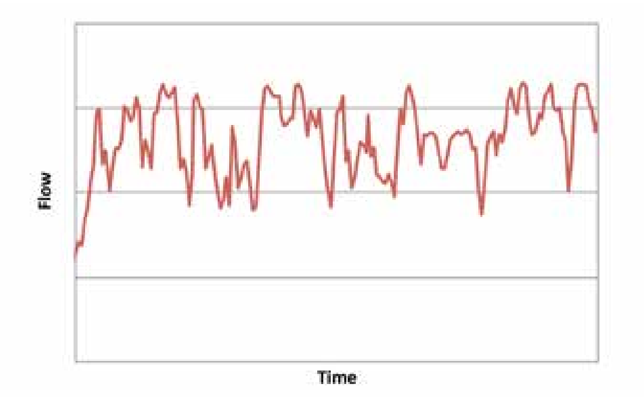


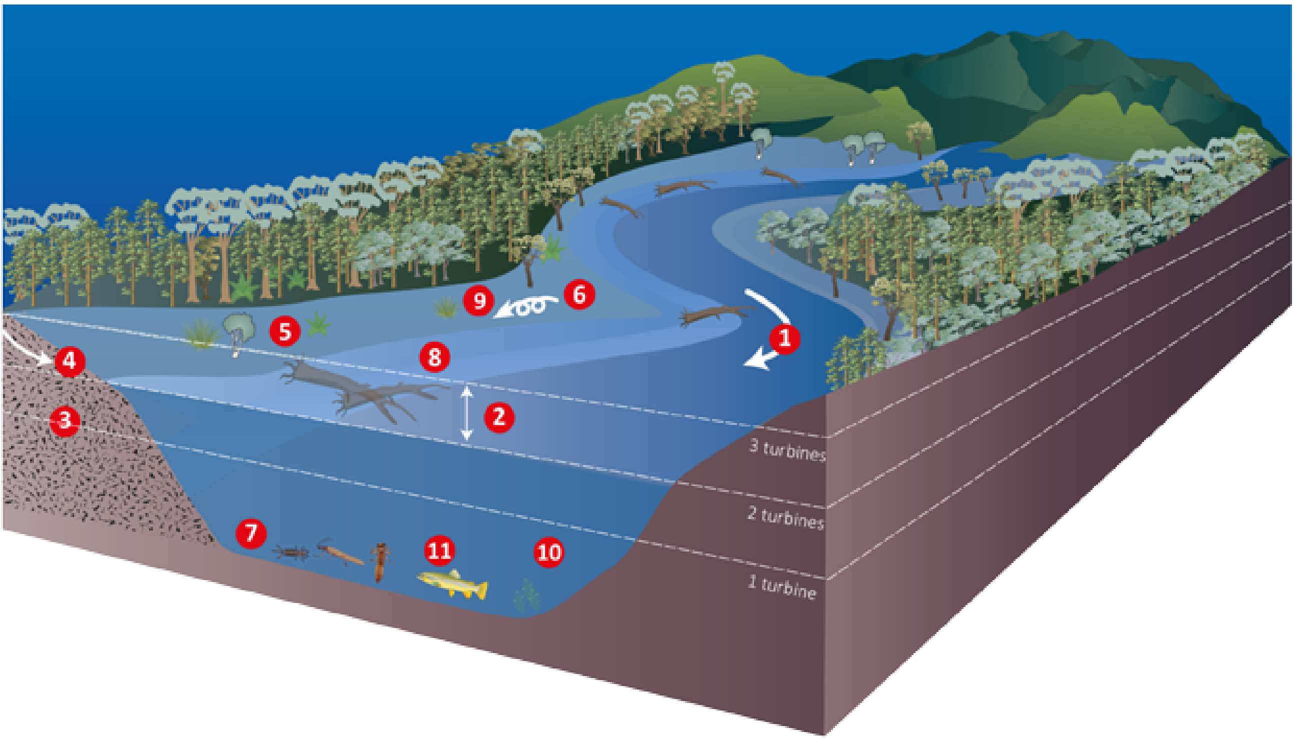
1. Moderate flow volumes and velocities
2. Large flow variability - some rapid draw down and some controlled
3. Occasional saturated banks
4. Reduced risk of seepage
5. Limited scour
6. Poor vegetation condition after prolonged peaking
7. Prolonged saturation of lower bank and toe and flattening of toe
8. Permanent wetted area, habitat for fish and macroinvertebrates
9. Increased total and proportional abundance of EPT species
10. Larger flow variability - numerous rapid draw downs
11. Increased risk of seepage and scour
12. Occasional saturated banks
13. Formation of cavities and slumping
14. Poor vegetation condition after prolonged peaking
15. Smaller permanent wetted area with limited habitat for fish and macroinvertebrates
16. Fish strandings

Daily hydro-peaking between 2 and 3 turbines

Under the original ramp-down rule (or in the absence of a ramp-down rule) seepage processes lead to the loss of sediment in the 2–3 turbine bank level, which undercuts vegetation, leading to the formation of cavities and the collapse of overlying vegetation. Over time, seepage processes (in combination with scour erosion) remove sediment and reduce bank angles to reach a stable, low angle slope and widening the channel. The riparian vegetation is of poor condition at all river bank heights.

Constant high velocity flows reduces habitat suitability for many flow-sensitive macroinvertebrate taxa. Macroinvertebrate density and diversity is low. The physical conditions are also unfavourable for flow-sensitive fish species due to reduced upstream migration opportunities and limited habitat availability created by the high velocity flows. Algal growth is limited by light availability.



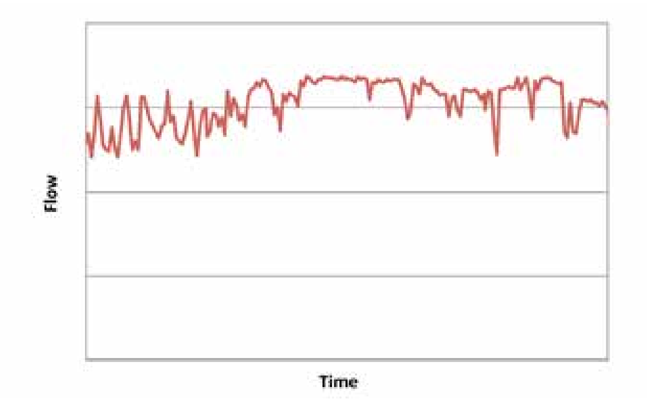


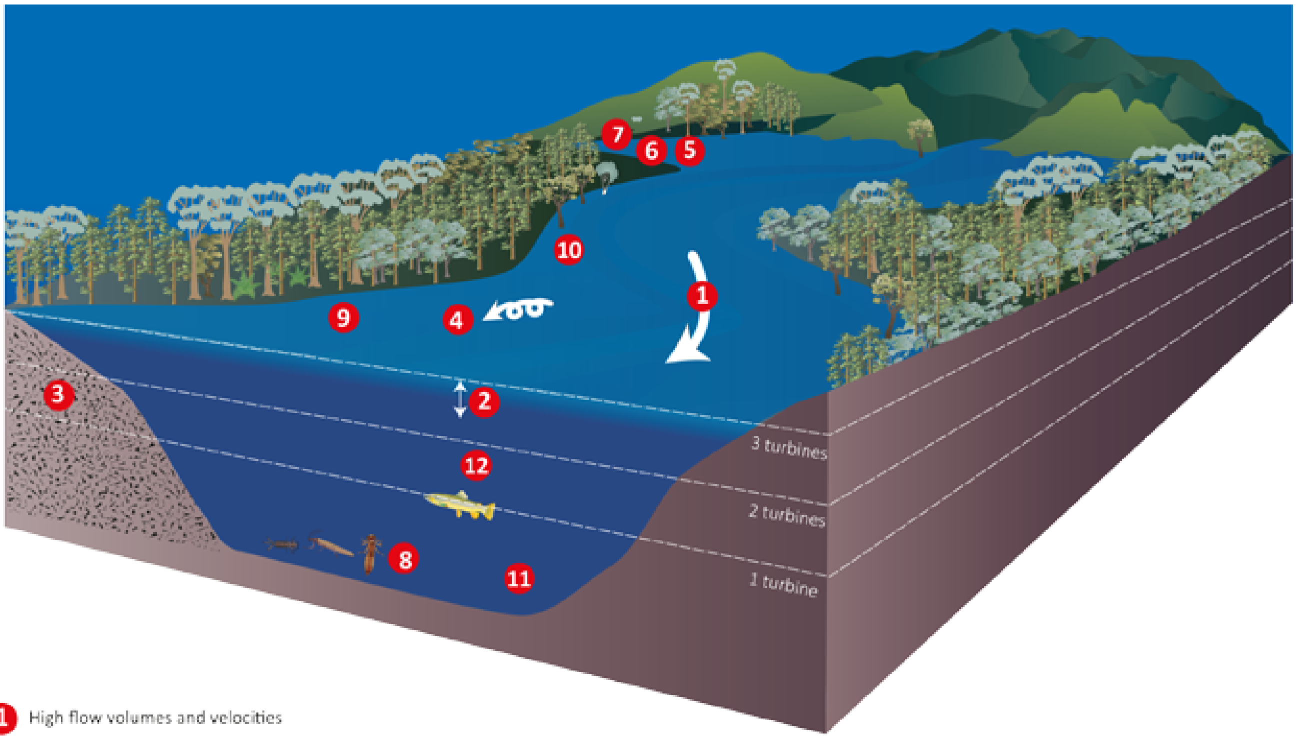
1. Moderate to high volumes and velocities
2. Flow variability in 2-3 turbine level
3. Saturated banks
4. Seepage erosion in 2-3 turbine level
5. Formation of cavities
6. Scour of bank face and root mat
7. Reduced habitat for flow sensitive macroinvertebrate species
8. Vegetation lost from below 2 turbine level
9. Poor survival of vegetation in 2-3 turbine level after prolonged peaking
10. Reduced algal growth
11. Flow sensitive fish disadvantaged

Sustained three turbines

Under this scenario, flow variability is low but flow volumes and velocities are consistently high. Banks are saturated, which increases the risk of seepage erosion at the 2–3 turbine level in subsequent flow reductions. However, after this type of operation the revised ramp-down rule is applied to limit seepage processes. Scour is the dominant erosion process. Seepage erosion may occur in tributaries near the Gordon confluence due to bank saturation caused by backwatering from the Gordon River. Riparian vegetation is inundated for extended periods and exposed to high flow velocities. Both processes lead to loss of vegetation on the banks.

Responses of algae, macroinvertebrates and fish are similar to those for the scenario of peaking between the 2 and 3 turbine levels. Constant high velocity flows reduce habitat suitability for many flow-sensitive macroinvertebrate taxa. Macroinvertebrate density and diversity is low. The physical conditions are also unfavourable for flow-sensitive fish species due to reduced upstream migration opportunities and limited habitat availability. Algal growth is limited due to lack of light.





1. High flow volumes and velocities
2. Low flow variability
3. Inundated and saturated banks
4. High scour rates
5. Tributary inundation due to back water
6. Seepage processes in tributaries
7. Sediment deposition in tributary backwaters
8. Reduced habitat for flow sensitive macroinvertebrate species
9. Loss of vegetation below 3 turbine level
10. Lack of oxygen in root zone
11. Reduced algal growth
12. Flow sensitive fish disadvantaged

Checking erosion pins

Conclusion

The multi-disciplinary team ready to head out for a long day's work on the Gordon River

The Gordon River Basslink Monitoring Program has been a significant 11-year study that has provided many insights into the processes of the physical and biotic components of the Gordon River ecosystem. The comprehensive long-term monitoring and assessment of hydrology, water quality, fluvial geomorphology, karst geomorphology, riparian vegetation, fish, macroinvertebrates and algae make this one of the largest river monitoring programs undertaken in Australia.

The adaptive management approach was implemented throughout the monitoring program. The environmental flow and ramp-down rule mitigation measures continued to be assessed and refined, where required, to improve the environmental outcomes for the river while ensuring that operational and economic priorities were met.

The implementation of the minimum environmental flow regime has had a positive environmental effect. The condition of macroinvertebrate communities in the Gordon River has improved, with greater similarity to reference sites in the greater Gordon-Franklin catchment. In addition, galaxiid abundances and range have increased post-Basslink and appear to be linked to increased low flows associated with the environmental flow.

The original ramp-down rule was improved to ensure that seepage erosion was minimised during peaking operations. The newly implemented changes to the ramp-down rule incorporate measures that respond directly to the saturation levels of the banks, and ramping is implemented when bank saturation is high. This will result in reduced seepage erosion.

Continued monitoring of macroinvertebrate community health and erosion has been maintained for an additional two years to assess the continued effectiveness of the environmental flow and the ramp-down rule.

Determining a clear environmental impact as a result of the Basslink connection to the NEM has been difficult due to the complex interactions between operation of Gordon Power Station and multiple factors other than Basslink.

Researchers collect macroinvertebrates

The discharge from Gordon Power Station depends on a number of independent factors such as market price signals, outages elsewhere in the system, drought, storage levels and Tasmanian electricity supply and demand. In the post-Basslink period, it has become apparent that the combination of these influences has resulted in less predictable discharge with greater short-term variability in comparison to the pre-Basslink period. The combination of flow patterns seen since the commissioning of Basslink has seen some positive impacts to the Gordon River.

The substantial investment in monitoring prior to and after connection of the Basslink cable has led to a huge increase in understanding of the Gordon River system over the last 11 years. This understanding has been summarised into a set of models that can be used to understand the expected environmental responses to power station operation patterns in the future. They can also be used to guide future monitoring and assessment of both the Gordon River and other hydropower systems.

Glossary

Baseline conditions	the existing conditions against which future conditions are assessed
Biota	the total collection of organisms within a geographic region
Cumec	a measure of water flow — cubic metres per second. Also written as m^3/s
Environmental flow	a water release made in a regulated river specifically to benefit the downstream environment of a river
Fluvial	the deposits and landforms created by the action of rivers or streams and the processes associated with them
Galaxiid	native freshwater fish of the genus *Galaxias*
Geomorphology	the study of the earth's shape or configuration
Karst	an area of irregular limestone or dolomite in which erosion has produced fissures, sinkholes, underground streams and caverns
Macroinvertebrates	invertebrate animals that are visible with the naked eye
Ramp-down rule	an environmental operating rule implemented at a power station to reduce flows at a controlled rate
Riparian vegetation	plant communities growing along river margins and influenced by the river
Seepage erosion	erosion that occurs when sediments are removed by groundwater seeping out of the river bank. It is associated with rapid drops in water level when the power station is shut down or greatly reduces its discharge
Scour erosion	erosion produced by the direct physical effect of flowing water
Slumping	the movement of loosely consolidated material a short distance down a slope

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