

## 6. Assessment of operational issues

This Chapter assesses the operational impacts of the dam safety upgrade options. It includes a description of the process used to determine the magnitude of the PMF and the changes to upstream and downstream inundation resulting from operation of the dam safety upgrade.

The upgrade would not result in any change to the existing full supply level of the dam. It would only affect operation of the dam during floods larger than approximately 1:2,400 AEP. To put this in context, the largest recorded storm in the Namoi River catchment, the 1955 flood, had an estimated chance of occurrence of 1 in 100 years and in Australia, are estimated at 1:1,000 AEP. *Figure 6-1* shows the relationship between the operation of the existing and proposed new infrastructure.

In broad terms, the current dam operating procedure is that all spillway gates at the main dam wall are progressively opened as a flood increases, to maintain the maximum upstream flood inundation at no more than 1 metre above the full supply level (330.6 metres AHD). All spillway gates are lifted clear at approximately 1.2 metres above the full supply level (or 330.8 metres AHD) if it becomes apparent that the 1 metre maximum flood surcharge can no longer be controlled by the spillway gates and the upstream flood inundation will continue to rise. No more operating rules apply until the upstream floodwater inundation recedes back to 1 metre above the full supply level, at which point the spillway gates can be lowered and the upstream inundation controlled again.

There would be no change to these spillway gate operating procedures as a result of the dam safety upgrade.

### 6.1 Determination of the PMF

The operational environmental impact assessment focuses on the impacts likely to result from the PMF, as this sets the upper limit or the 'worst case scenario' for the extent of damage likely to occur. For smaller storms, the effects would be reduced.

The process of estimating the PMF for Keepit Dam involved the following steps:

- identification of the catchment and sub-catchment areas upstream of Keepit Dam
- development of a rainwater runoff-routing model and its calibration against stream flow measurements from each catchment over a range of historical flood events
- derivation of probable maximum precipitation rainfall depths and temporal and spatial patterns

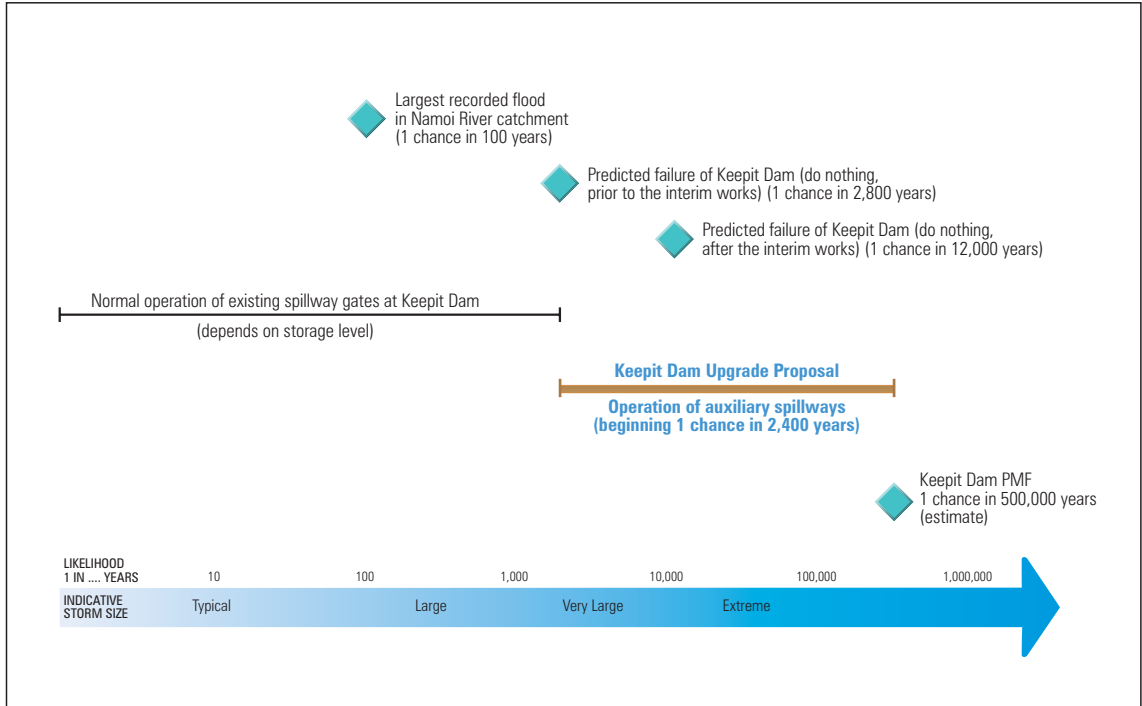


Figure 6-1 Existing and proposed infrastructure operation

- derivation of inflow and outflow hydrographs from Keepit Dam over a range of design storm durations
- identification of the design storm duration that would result in the peak outflow from Keepit Dam.

The peak outflow from the dam sets the required capacity of the dam spillways. The PMF is the total volume of floodwater generated by the design storm, which results in the peak outflow from Keepit Dam.

The following Sections provide an overview of the work conducted for each of these main steps.

#### *Catchment analysis and runoff-routing*

The upstream catchment of Keepit Dam covers an area of approximately 5,700 square kilometres and is drained by the McDonald River, Halls Creek and the Manilla River. Split Rock Dam is located on the Manilla River and controls approximately 25% of the Keepit Dam catchment (DIPNR 2005).

To estimate the PMF, DIPNR (2005) divided the Keepit Dam catchment into five sub-catchments based on the availability of a stream gauging station at or near the downstream end of each sub-catchment. For each sub-catchment, a separate runoff-routing model was developed and calibrated.

The Australian Bureau of Meteorology was commissioned to determine the probable maximum precipitation rainfall depths for the Keepit Dam catchment. The Bureau of Meteorology used a revised version of the Generalised Tropical Storm Method, which took into account that extreme rainfall events in the northern two-thirds of Australia may result from tropical cyclone activity. The current (2003) estimates for probable maximum precipitation of the Keepit Dam catchment range between 350 and 930 millimetres of rain over periods of between 12 and 72 hours (DIPNR 2005).

The spatial rainfall patterns adopted were based on recommendations for various storm durations provided by the Bureau of Meteorology. The temporal patterns adopted were those of the ten largest storms in the Revised Generalised Tropical Storm Method database for each of the standard storm durations.

#### *Inflow hydrographs*

A flood inflow hydrograph is a graph showing the instantaneous flow of runoff over time at a particular location. Flood inflow hydrographs for Keepit Dam were obtained by inputting the design rainfall estimates for each storm duration and the associated temporal and spatial rainfall patterns into the calibrated runoff-routing model. Each sub-catchment was modelled individually, commencing with the uppermost sub-catchment. The runoff generated from each upstream sub-catchment was combined with the computed rainfall excess in the downstream sub-catchment, and with the outflows from the final, lowermost catchment, representing the total design inflow hydrograph for Keepit Dam. This task was completed for each of the ten standard storm durations to arrive at a set of ten inflow hydrographs.

When deriving these hydrographs, it was assumed that Split Rock Dam was at its full supply level and, thus, provided no flood attenuation. This assumption is consistent with the concept of a PMF, because it is assumed that the catchment condition is completely wet from prior storm activity prior to the onset of the PMF.

The ten inflow hydrographs were routed through Keepit Dam using an IQQM GateOps module to simulate the manner in which the spillway gates would be operated during a flood. Ten outflow hydrographs were produced for each standard storm duration. The storage routing assessment assumed that Keepit Dam was initially at its full supply level at the start of each inflow (again providing no attenuation of the flood).

*Selection of the critical storm and adequacy of the existing dam spillway*

The critical PMF is the flood that produces the largest outflow under the range of standard storm durations considered. For the Keepit Dam catchment, a 36 hour storm is predicted to result in a peak discharge of 40,646 cubic metres per second. This is approximately four times the existing maximum discharge capacity of the dam spillway of 11,500 cubic metres per second. A PMF of 36 hours duration would, in theory, result in floodwaters overtopping the main dam wall by approximately 5 metres, although the dam wall would be expected to fail by overturning prior to this happening. The likelihood of dam wall failure in any year was estimated to be approximately 1:2,800 AEP.

The key characteristics of the Keepit Dam PMF are summarised in *Table 6.1*.

**Table 6.1 Characteristics of the PMF for Keepit Dam**

<b>Characteristic</b>	<b>Definition/notes</b>	<b>Value</b>
Catchment size	Total area of upstream catchment	5,700 square kilometres
Design storm duration	Duration of the critical storm that results in peak outflows	36 hours
Overall storm duration	Overall duration of inflows during a PMF event	120 hours
Average rainfall intensity	Average rainfall per hour	582 millimetres per hour
Total rainfall depth	Total depth of rainfall across catchment	20,952 millimetres
Total PMF floodwater volume	The volume of floodwaters generated by a PMF	Approximately 3.6 gigalitres or approximately 8.5 times existing storage capacity

### *Estimated frequency of the PMF*

The frequency of a PMF cannot be reliably estimated because of the statistical manner in which it is calculated; however, it can be approximated by extrapolating data associated with less severe floods, as the frequency is exponentially related to storm size. The frequency of a probable maximum precipitation design flood (PMPDF) is approximately 1:175,000 AEP. For the Keepit Dam catchment, the probable maximum precipitation design flood is approximately 30% less by volume than the PMF. By using this flood as a yardstick, the estimated frequency of the Keepit Dam PMF is expected to be as low as 1:500,000 AEP or lower.

## **6.2 Downstream and upstream inundation**

### **6.2.1 Inundation modelling**

A Mike-11 hydraulic software model was developed to model the downstream effects of the various dam safety upgrade options. The model comprised a one-dimensional model downstream of Keepit Dam to Carroll township and along the Peel River to Somerton, and a two-dimensional model for areas downstream of Carroll. The model was constructed based on 10 metre resolution topographical information, generally between the dam and Carroll, including surveyed cross-sections of the Namoi and Peel Rivers. Between Carroll and Boggabri, detailed photogrammetry was used to analyse landforms. The model was calibrated using a range of historical storms.

The model indicated that flood attenuation increases with distance downstream of the dam. The confluence of the Peel and Namoi Rivers, approximately 13 kilometres downstream of the Keepit Dam main dam wall, is the farthest downstream point at which the relative performance of the options could be assessed. This formed the downstream extent of the options assessment. The model also indicated that, when comparing the dam failure and the dam upgrade scenarios, the resulting depth of floodwaters at the confluence of the Peel and Namoi Rivers differed only by approximately 300 millimetres. In hydraulic terms, this difference is not significant and is well within the range of accuracy of the software model. The conclusion drawn from this result is that Keepit Dam, both with and without the dam safety upgrade, is inherently unable to provide mitigation for extreme flood events, due to the relatively vast size of the PMF compared to the small size of the existing storage. While engineering options could be developed to achieve mitigation of extreme floods, the options analysis process conducted indicated that these are either not technically feasible or prohibitively expensive.

### **6.2.2 Downstream inundation**

#### *Hydraulic effects*

*Figure 6-2* indicates the predicted relative inundation levels of the three upgrade options under a PMF scenario. The dam failure scenario is also shown for reference. When considered in the context of dam failure or a 'do nothing'

scenario, changes in downstream inundation resulting from the dam safety upgrade options are generally beneficial. As shown in the figure, all the options are predicted to result in a reduced area of downstream inundation compared to dam failure scenario. The upgrade options would also result in changes to the frequency of flooding compared to the existing situation. These changes are discussed below under the following categories:

- floods smaller than approximately 1:2,400 AEP
- floods larger than 1:2,400 AEP, but smaller than 1:10,000 AEP
- floods larger than 1:10,000 AEP.

The flood frequencies identified above and throughout the following Sections apply to the Keepit Dam catchment only, unless stated otherwise.

#### *Floods smaller than 1:2,400 AEP*

The modelling indicates that, under all the upgrade options, there would be no change to downstream inundation with a flood smaller than 1:2,400 AEP, relative to the existing situation. Depending on the initial storage level of the dam at the onset of the flood, a portion of the floodwaters could be temporarily stored within the dam, with the excess discharged into the Namoi River from the main dam spillway gates. The existing operating protocols for the spillway gates would continue to apply following implementation of the upgrade.

#### *Floods larger than 1:2,400 AEP, but smaller than 1:10,000 AEP*

The right-hand abutment spillway would commence operation during a flood larger than approximately 1:2,400 AEP. The spillway has been designed so that the release of water would be staged to reduce downstream impacts. This feature is common to all three upgrade options. Under the existing situation, the dam would release water only through the spillway gates up until approximately 1:2,800, following which dam failure would occur. The upgrade would result in more frequent downstream inundation for a limited range of floods between 1:2,400 and 1:2,800 AEP, although the trade-off would be that the dam would be safe (dam failure avoided) and capable of safely passing storms up to the PMF without failure.

A substantial reduction in downstream inundation levels would result from implementation of the upgrade (under all three upgrade options) for floods with a frequency of occurrence of between 1:2,400 and 1:10,000 AEP. Under the existing situation, the dam would fail at approximately 1:2,800 AEP, resulting in massive downstream inundation and damage. By comparison, following the proposal, the discharges would occur in a controlled manner via the main dam wall and the right-hand abutment spillways for this frequency range. All three options showed similar performance for flood events within this frequency range.

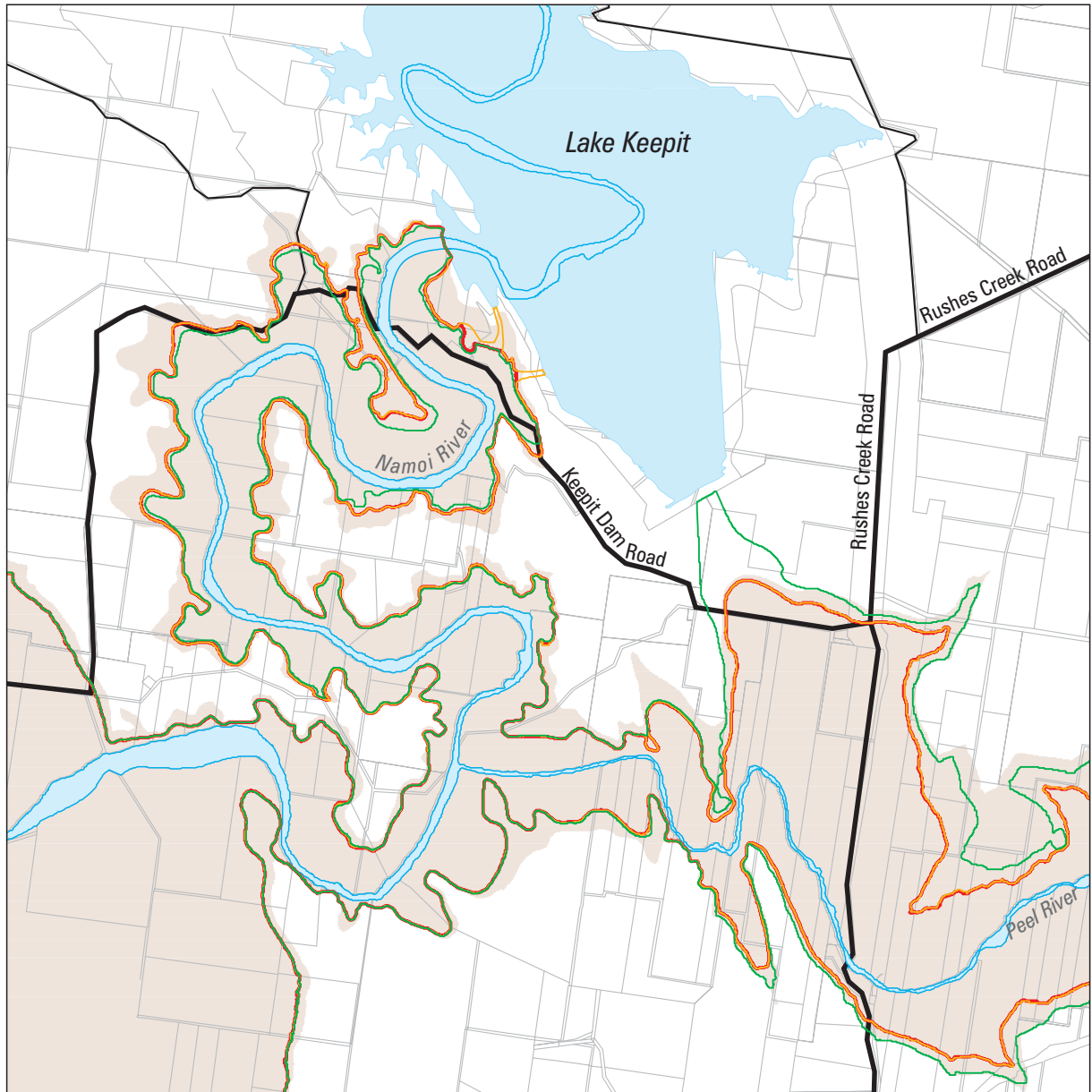


Figure 6-2 **Marginal extent of downstream inundation in the Namoi River during a PMF in the Keepit Dam catchment**

- Dam full supply level
- Option B1
- Option D2
- Option D3
- Existing dam failure

### *Floods larger than 1:10,000 AEP*

For flood events larger than 1:10,000 AEP, the upgrade options were predicted to have different downstream inundation impacts, as follows:

- For Option B1, operation of the subsidiary dam spillway is predicted to occur at approximately 1:10,000 AEP, which would result in additional inundation (when compared to the dam failure scenario) over a distance of approximately 1 kilometre between the subsidiary dam wall and along the Peel River, down to the confluence of the Namoi River.
- For Options D2 and D3, operation of the sailing club spillway is predicted to occur at approximately 1:10,000 AEP, followed by operation of the boat ramp spillway at approximately 1:100,000 AEP.

In the Namoi River, Option B1 would result in the greatest attenuation of downstream inundation down to the confluence with the Peel River during a PMF, although this would be achieved since a large proportion of floodwaters would be diverted to the Peel River via the subsidiary dam spillway.

In the Peel River, the effect of the discharges from the subsidiary dam spillway for Option B1 would be mitigated by two separate, but co-incident, phenomena. Firstly, following dam failure, the release of the Keepit Dam storage into the Namoi River would result in a backup of flows in the Peel River for several kilometres upstream of the subsidiary dam wall. Secondly, the Peel River would be expected to be in flood simultaneously with floods larger than 1:10,000 AEP in the Namoi River. The relative frequency estimates for a 1:10,000 and 1:500,000 AEP flood in the Namoi River, are 1:300 and 1:1,400 AEP floods in the Peel River, respectively. The additional inundation caused by Option B1 would, therefore, be limited to the overland flow path between the subsidiary dam wall and the edge of the Peel River inundated area, a distance of approximately 1 kilometre.

The depth of release plugs associated with each of the three options would result in different volumes of water being released during a storm larger than 1 in 2,400 AEP. An analysis of the discharge volumes for storm larger than 1:2,400 AEP indicates that discharges associated with Option B1 would initially be approximately 15% greater than Option D3 and to a lesser extent greater than Option D2. Also as a result of the release plug depth, the duration of flows associated with Option B1 would be approximately 3 days longer than Options D2 and D3. When a storm of approximately 1:10,000 AEP is reached, there would be only marginal differences between the volumes of water released from the three dam safety upgrade options and the duration of flows – of the order of 3%.

### *Impacts on infrastructure surrounding the dam*

The operation of the options is predicted to result in the following impacts to public infrastructure around the perimeter of the dam:

- Option B1:
  - ▶ For floods larger than approximately 1:10,000 AEP, the operation of the subsidiary dam spillway for Option B1 would result in inundation of the Lake Keepit State Park sewage treatment plant and golf course, a section of Keepit Dam Road within the State Park, and an area between the subsidiary dam wall and the Peel River currently used for grazing/agriculture.
- Options D2 and D3:
  - ▶ For floods larger than approximately 1:10,000 AEP, the operation of the sailing club spillway for Options D2 and D3 would result in the inundation of a section of Keepit Dam Road in Lake Keepit State Park.
  - ▶ For floods larger than approximately 1:100,000 AEP, the operation of the boat ramp spillway for Options D2 and D3 would also result in the inundation of a section of Keepit Dam Road in Lake Keepit State Park.

The operation of the options was not predicted to result in impacts to any structures (including dwellings) located downstream of the main or subsidiary dam walls on the Namoi or Peel Rivers.

### *Terrestrial biodiversity impacts*

A terrestrial biodiversity assessment has been prepared for the proposal, based on field surveys undertaken between 18 and 22 July 2005 and 29 May and 2 June 2006 (refer *Technical Paper 1* in *Volume 2*). The field surveys were carried out to assess the extent and condition of vegetation communities and potential flora and fauna habitat, especially for threatened species. Sites surveyed included areas potentially affected by temporary upstream inundation and downstream inundation during very large to extreme floods. Given the size of the areas potentially affected by upstream and downstream inundation during very large to extreme floods, a habitat-based approach was adopted in these areas.

The key terrestrial biodiversity impact of the operation of Option B1 would occur downstream of the subsidiary dam wall during operation of the proposed spillway. Options D2 and D3 would not affect this area. As described in *Section 6.3*, operation of the subsidiary dam spillway would have a highly detrimental effect on the area immediately below the spillway, over a length of up to 2.5 kilometres. Land within the flow path of discharges from the subsidiary dam spillway would be eroded and there would be a loss of riparian vegetation for approximately 5 kilometres along the lower Peel River, from below the subsidiary dam spillway to the confluence of the Namoi and Peel Rivers. Sedimentation from this scouring would affect riparian terrestrial habitats along the Peel River; however, as described in *Table 5.2* and *Technical Paper 2 (Volume 2)*, the existing habitats are already highly degraded.

Operation of the proposal under certain flood conditions would result in the inundation of two threatened plant species: *Bothriochloa biloba* (Option B1 only) and *Hakea pulvinifera* (Options B1, D2 and D3). A single individual of *Bothriochloa biloba*, which is listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*, was previously recorded downstream of the subsidiary dam wall. This individual and its habitat would be destroyed during operation of the proposed subsidiary dam spillway for Option B1. An impact assessment for the specimen determined that it is unlikely to be an important population, the affected habitat is unlikely to be critical to the survival of this species, and the proposal is unlikely to significantly impact the species (refer Attachment G of *Technical Paper 1, Volume 2*).

A population of *Hakea pulvinifera* is located near the Namoi River below Keepit Dam, where it grows on a hard, rocky hillside (Department of Environment and Conservation 2006b). *Hakea pulvinifera* is listed as endangered under both the *Threatened Species Conservation Act 1995* and the *Environment Protection and Biodiversity Conservation Act 1999*. All three options would result in reduced impacts on the *Hakea pulvinifera* population, relative to the existing situation. Impacts on the *Hakea pulvinifera* vary depending on the size of the flood and the option selected. For floods with frequencies between 1:2,400 AEP and 1:10,000 AEP, Option B1 has an approximately 15% greater impact on the *Hakea pulvinifera* population than Options D2 and D3. For floods of 1:10,000 AEP or less frequent, Option B1 provides greater protection to the *Hakea pulvinifera* population than Options D2 and D3. The maximum impact on the population would occur during a PMF when, following failure of the dam, an estimated 68% of the population would be destroyed. By comparison, Options B1, D2 and D3 are estimated to result in the loss of 31%, 54% and 56% of the population respectively, during a PMF.

#### *Aquatic ecology impacts*

When compared to the dam failure scenario, all three options would result in reduced inundation of aquatic habitats in the Namoi River downstream of the main dam wall, as a smaller volume of floodwater would be released into the Namoi River during very large to extreme floods. The reduced extent of inundation of the Namoi River downstream of the dam is shown in *Figure 6-1* under a PMF scenario. The benefit of the reduced inundation to aquatic ecology in the Namoi River has not been quantified, due to the difficulty in relating the extent of inundation to damage to aquatic habitats.

Options D2 and D3 would avoid damaging impacts to the lower Peel River by confining discharges into the Namoi River valley. Option B1 would increase the damage to aquatic habitats in the Peel River. Both riverine habitats are highly degraded.

It is difficult to directly attribute the specific potential aquatic ecology impacts to downstream inundation of the lower Peel River as a result of operation of the proposal, because three factors would contribute to the impact, as follows:

- *operation of the subsidiary dam spillway* — For Option B1, the subsidiary dam spillway would release floodwaters to the lower Peel River during floods larger than 1:10,000 AEP.
- *simultaneous flooding in the Peel catchment* — A simultaneous, large flood of approximately 1:300 AEP would occur in the Peel catchment at the time of a 1:10,000 AEP event in the Namoi catchment. For a PMF in the Namoi catchment, a simultaneous, large flood of approximately 1:1,400 AEP, would occur in the Peel catchment. Aquatic habitats in the lower Peel River would be affected by this simultaneous flood, regardless of which option is selected.
- *backwater flows from the Namoi River* — The lower Peel River would be affected by backwater from the Namoi River during very large to extreme floods. However, all the options would reduce the effect of backwater flows on the lower Peel River, as the volume of floodwaters in the Namoi River at the confluence with the Peel River would be smaller than under a dam failure scenario.

The predicted net effect of these three factors on the lower Peel River is shown in *Figure 6-2* for a PMF in the Namoi catchment. The figure shows that the extent of inundation of the lower Peel River would be reduced under all the options, relative to the dam failure scenario, except for Option B1 immediately downstream of the subsidiary dam wall. However, this additional area of inundation for Option B1 would be located well away from aquatic habitat.

There is potential for significant scouring and smothering of aquatic habitats downstream of the main and subsidiary dam walls during very large to extreme floods, regardless of the option selected. These potential impacts are discussed in *Section 6.3.3*.

#### *Cultural heritage impacts*

The impacts of downstream inundation on cultural heritage sites would be similar to the impacts to aquatic ecology described above, in that:

- When compared to the dam failure scenario, all three options would result in reduced inundation of potential Aboriginal archaeological heritage sites along the Namoi River downstream of the main dam wall, as a smaller volume of floodwater would be released into the Namoi River during very large to extreme floods.
- Relative to Options D2 and D3, Option B1 would provide a greater benefit to potential Aboriginal archaeological heritage sites along the Namoi River between the main dam wall and the confluence with the Peel River, as it would divert a portion of the floodwaters into the lower Peel River.

However, this benefit of Option B1 would be at the expense of known and potential Aboriginal archaeological heritage sites and European heritage sites in the lower Peel River valley, between the subsidiary dam wall and the confluence of the Namoi and Peel Rivers.

- It is difficult to directly attribute specific potential cultural heritage impacts to downstream inundation of the lower Peel River as a result of operation of the proposal, because of the likely simultaneous flooding of the Peel catchment and backwater flows from the Namoi River.

*Figure 6-3* shows the impact on known aboriginal and European heritage items in downstream areas. There are ten known Aboriginal heritage sites (KDA6-8, 14-19, 27) and two European heritage sites (KDH6 and 7) located in the Peel River valley below the subsidiary dam wall. A further three known Aboriginal heritage sites (KDA3-5) are located further downstream along the Peel River. There are no known heritage sites immediately downstream of the subsidiary dam wall in the area that would only be affected by the operation of Option B1.

All the options would result in reduced inundation of known and potential (i.e. unrecorded) heritage sites in the lower Peel valley relative to the dam failure scenario. Options D2 and D3 would also avoid inundation of one Aboriginal heritage site (KDH6). There would be differences in the depth and duration of inundation between the options, with Option B1 resulting in a slightly greater depth and duration of inundation than Options D2 and D3.

For Options D2 and D3, operation of the sailing club and boat ramp saddle spillways would not cause direct impacts on any known heritage sites. The potential for scouring to affect unrecorded heritage sites in the area downstream of these spillways is low. This is due to the high level of disturbance that has occurred in this area from the former dam construction camp and the area's steep topography, which reduces the potential for archaeological deposits to occur.

There is potential for significant damage to known and potential heritage sites downstream of the main and subsidiary dam walls during very large to extreme floods as a result of erosion and sedimentation, regardless of the option selected. These potential impacts are discussed in *Section 6.3.3*.

### *Social*

Operation of the proposal would avoid the severe social (and environmental and economic) impacts that would result from catastrophic failure of the dam which have been estimated at \$1.7 billion in total direct damages and significant loss of human life.

For Option B1, operation of the subsidiary dam spillway during very larger to extreme floods of 1:10,000 AEP or less frequent would result in floodwater flow across Lake Keepit State Park, including an access road to the camping area, the golf course and sewage treatment plant and Keepit Dam Road, the main entry road into Keepit Dam. The sewage treatment plant would be entirely destroyed and more than half the golf course destroyed in the event

of a spillway discharge. The affected infrastructure would require repair or replacement following operation of the subsidiary dam spillway. The operation of the subsidiary dam spillway would also affect an area of privately-owned land several hundred metres wide along a distance of approximately 2.5 kilometres between the spillway and the Peel River. The affected land is currently used for grazing/agriculture.

Option B1 would also result in a majority of floodwaters in flood larger than 1:10,000 AEP being discharged into the Peel River which is not the natural course of water from the Keepit Dam catchment. The existing subsidiary dam wall would be converted into an auxiliary spillway and flooding related damage on up to 16 downstream properties could be worsened as a result of high velocity flood flows along the Peel River.

For Options D2 and D3, operation of the sailing club and boat ramp spillways has the potential to damage sections of Lake Keepit State Park between the spillways and Namoi River as well as Keepit Dam Road.

### 6.2.3 Upstream inundation

Keepit Dam is designed to attenuate large flood events by temporarily storing a portion of the floodwaters above the dam full supply level up to the design flood level (RL 333.5 metres AHD). As the inflows to the dam start to reduce, this temporarily stored water is released until the dam reaches its full supply level. Therefore, the current design flood level has been adopted as the base case for assessing the impacts of additional upstream inundation as a result of the dam upgrade options.

The dam upgrade would change the current design flood level around the dam. The increase in design flood level would be relative to the wall raising proposed by each option however depending on the slope of the land, may translate to much greater distances on the ground.

During a large flood event, additional upstream inundation would start to occur at approximately 1:17,300 AEP, 1:6,700 AEP and 1:5,000 AEP for Options B1, D2 and D3 respectively. The differences in frequency between the options at which additional upstream inundation would occur is due to proposed differences in the sill and crest levels of the release plugs in the proposed additional spillways.

The maximum, temporary upstream inundation would occur during a PMF when the level of the storage rises to the design flood level for each option. The marginal areas inundated and the durations of inundation during a PMF are shown in *Table 6.2* and *Figure 6-4*.

Option B1 would result in the least marginal increase in temporary upstream inundation (approximately 1,085 hectares) during a PMF event, because it has the lowest design flood level; whereas, Option D3 would result in the greatest marginal increase in temporary upstream inundation (approximately 1,795 hectares), because it has the highest design flood level.

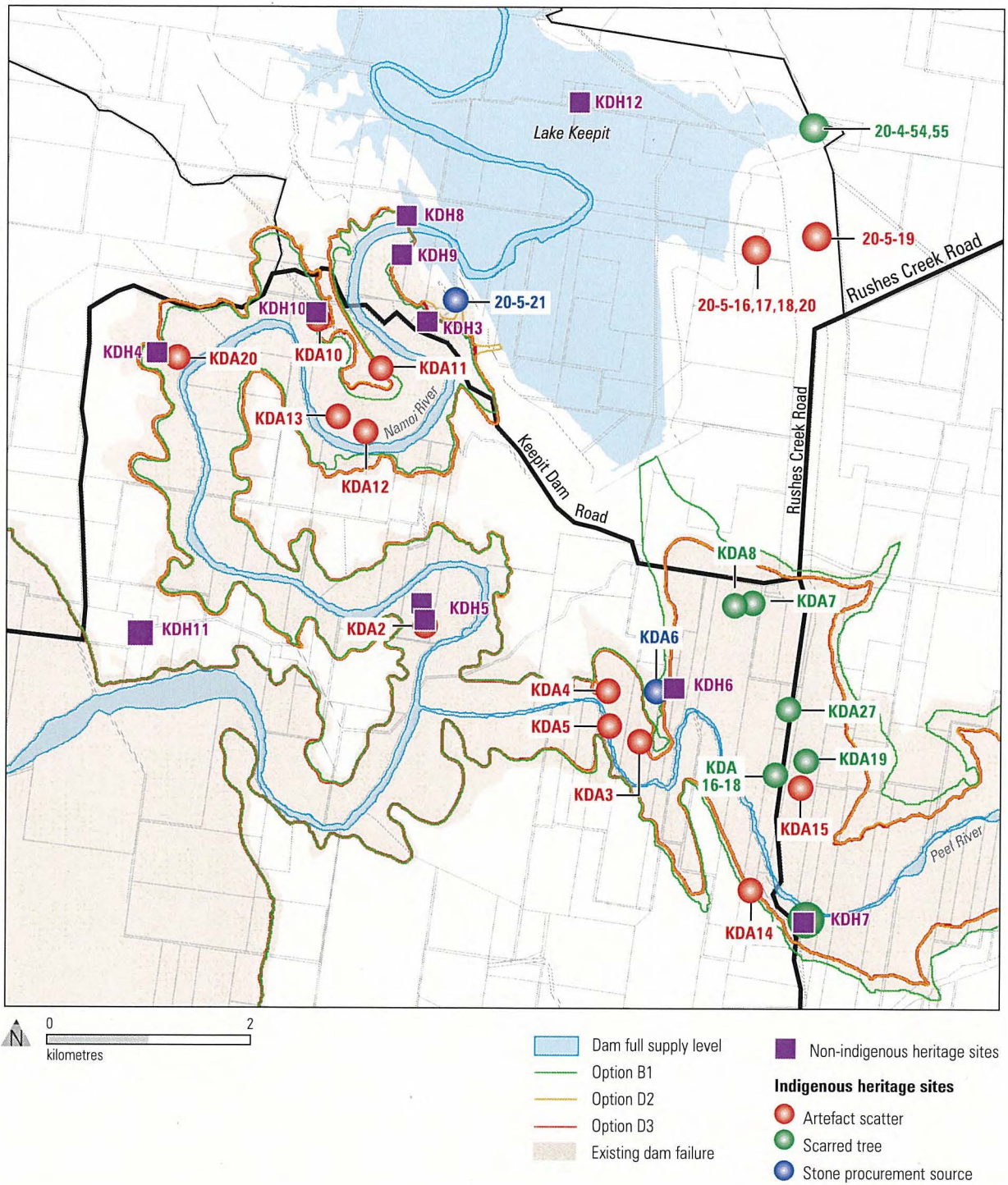


Figure 6-3 Impact on downstream indigenous and non-indigenous heritage sites areas during a PMF

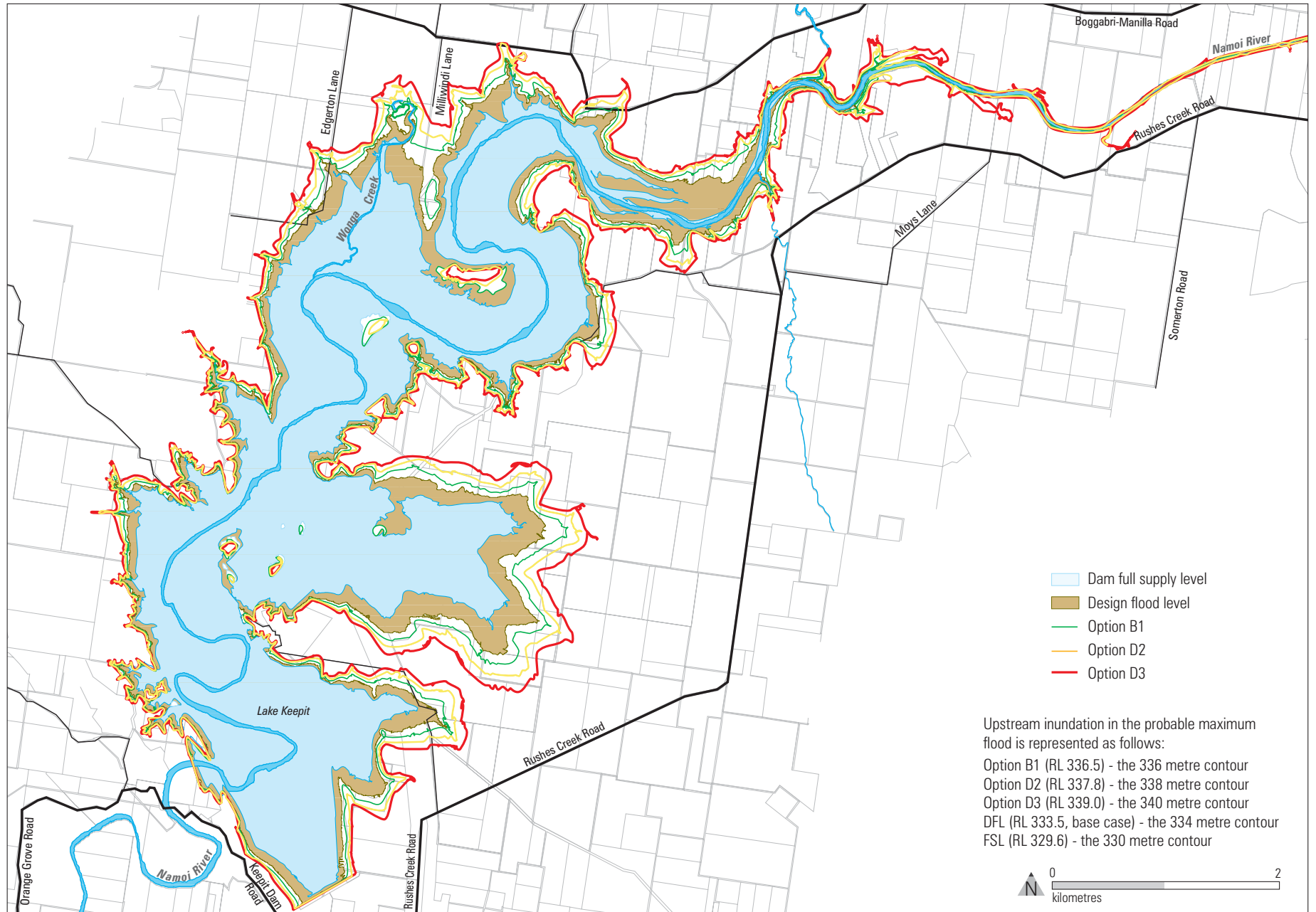


Figure 6-4 Marginal extent of temporary upstream inundation during a PMF event in the Keepit Dam catchment

The upgrade options would also increase the duration of inundation of land between the existing full supply level and the design flood levels. The maximum increase in the duration of inundation would occur at the full supply level during a PMF event. Land at the full supply level would be inundated for durations of 60, 75 and 90 hours in a PMF for Options B1, D2 and D3 respectively. These durations equate to a marginal increase of 10, 25 and 40 hours respectively, relative to the existing situation.

**Table 6.2 Marginal increases in temporary upstream inundation during a PMF<sup>1</sup>**

Option	Approximate maximum area of inundation above the existing design flood level (hectares)	Approximate maximum duration of inundation at the full supply level (hours)
Option B1	1,085	10
Option D2	1,485	25
Option D3	1,795	40

Notes:

<sup>1</sup> The area inundated and the duration of inundation varies, depending on the location above the design flood level. The table indicates the maximums only.

#### *Terrestrial biodiversity impacts*

There has been almost no research on the effects of inundation on Dry Sclerophyll Woodland communities similar to those could be affected by additional temporary upstream inundation during operation of any of three options. However, it is considered unlikely that an inundation period of up to 90 hours (the maximum duration of temporary inundation predicted under any of the dam safety upgrade options at current full supply level) would cause significant tree dieback, based on the condition of trees located near the full supply level that have been previously subject to temporary inundation. Based on this observation, the short duration of the expected additional temporary inundation is unlikely to significantly affect plant communities within this area.

Groundcover animal habitats in areas affected by any additional upstream inundation would be displaced during a very large to extreme flood event. The rise of floodwaters into these areas would be gradual, allowing any ground-dwelling animals sufficient time to move to higher ground. However, animals that use the area could be affected by drowning, temporary habitat removal and/or increased exposure to predators associated with displacement.

#### *Aquatic ecology impacts*

The marginal increase in upstream inundation resulting from all three options would temporarily affect upstream aquatic habitats and species by:

- creating a net increase in available aquatic habitat within the lake

- increasing the extent of shallow, lake margin habitat
- reducing riverine habitat in tributaries of Lake Keepit (principally the upper Namoi River).

The nature of available aquatic habitat would generally be similar to that which would exist when the dam is at full supply level, although some redistribution of this habitat would occur.

#### *Cultural heritage impacts*

Three recorded Aboriginal sites (KDA23, KDA28 and 20-4-54) and part of the former Borah Crossing Aboriginal Reserve are located between the existing full supply and design flood levels and would therefore be affected by periodic inundation during operation of the existing Keepit Dam during floods. These sites would be affected by a longer duration of inundation during operation of all three options in very large to extreme floods.

All three options would result in temporary inundation of historic site KDH1, a house ruin, which is at a level between the existing and proposed design flood levels for each option. Because this site is above the existing design flood level, it has not previously been subject to inundation by the dam. In addition to the potential for inundation during very large to extreme flood events, this site would also potentially be affected by wave action during these events.

Besides impacts on recorded heritage sites, all three options would also have the potential to affect unrecorded Aboriginal archaeological sites. The greatest potential for unrecorded Aboriginal archaeological sites exists along the riparian corridors of the Namoi River and its tributary streams. The sensitivity of these corridors was confirmed by the recording of nine Aboriginal sites in this zone (refer *Figure 5-4*). Apart from these zones, the majority of the area predicted to be temporarily inundated by the marginal increase in upstream inundation has relatively low archaeological sensitivity, due to the gradient of the affected terrain and its distance from a natural water source.

#### *Social*

In the event of a large to extreme flood event, the increased storage in Lake Keepit would temporarily encroach on land areas surrounding the lake. Depending upon the slope of the land, the increase in design flood level may be much greater than the wall raising associated with each option.

Subject to detailed survey, the proposal would potentially result in temporary inundation of areas of Manilla Ski Gardens Caravan Park, the Lake Keepit Sport and Recreation Centre, Lake Keepit State Park, and a number of rural properties. The rise of floodwaters is expected to allow sufficient time for evacuation (if necessary). The effects of inundation on these facilities are not expected to be substantial, although there may be potential for wave action and some settlement to occur.

## 6.2.4 Mitigation measures

For all the dam safety upgrade options, an Emergency Evacuation Plan would be developed jointly by State Water and the State Emergency Service for all properties at risk of temporary upstream inundation. The rise in floodwaters is expected to be slow enough to allow time for warning and, if necessary, to move those affected to higher ground.

State Water would compensate individual land owners for damage incurred to any structures arising from inundation, should a large to extreme flood occur. This measure would be implemented in lieu of any upfront compensation, in view of the remote chance of occurrence of such an event. State Water has discussed this approach with the various land owners and facilities managers that could be affected by the upgrade and has received in-principle agreement.

No mitigation measures for the effects of downstream inundation are considered necessary.

## 6.3 Erosion and sedimentation

This Section identifies the likely magnitude of erosion resulting from spillway releases with the dam safety upgrade options during a 1:10,000 AEP event through to a PMF event, and the likely resultant environmental impacts of downstream sedimentation. A semi-quantitative assessment approach was adopted, since there is a paucity of data for floods of this magnitude, making it difficult to accurately model such an extreme event.

In 2006, State Water convened a panel of experts to gauge the relative level of environmental impacts resulting from implementation of the upgrade options and particularly Option B1. This Section includes a summary of the outcomes of a panel workshop held in February 2006. A detailed account of the workshop deliberations and outcomes is provided in *Appendix E*.

### 6.3.1 Background studies

#### *Floodwater velocities*

Computer software modelling (refer *Section 6.2.1*) was used to determine the predicted floodwater velocities in receiving waters during a PMF event, and the likely changes resulting from implementation of the dam upgrade options.

The base case used to assess the impacts of the upgrade in the Namoi River was the dam failure scenario, which would result in a wall of water approximately 50 metres high cascading down the river at approximately 8.0-8.5 metres per second. This volume of water would result in backwater flows in the Peel River over a distance of approximately 5 kilometres upstream of its confluence with the Namoi River, including the area downstream of the subsidiary dam wall. In the Peel River, the base case comprises the flood that is likely to be concurrent with a PMF in the Keepit Dam catchment in combination with the backwater flows in the Peel River. A

joint probability analysis of concurrent floods in the Namoi and Peel Rivers indicated that a flood of approximately 1:1,400 AEP would occur in the Peel River at the time of a PMF in the Namoi River (refer *Figure 6-2*).

*Table 6.3* shows the expected floodwater velocities under each dam safety upgrade option, relative to the base case.

**Table 6.3 Floodwater velocities at selected locations during a PMF**

Location <sup>1</sup>		Floodwater velocity (metres per second)			
		Dam failure	Option B1	Option D2	Option D3
<b>Namoi River (dam failure base case)</b>					
N1	Immediately downstream of the right-hand abutment spillway	n/a	8.5	8.3	8.1
N2	At the <i>Hakea pulvinifera</i> site on the Namoi River	8.1	3.1	3.6	3.6
BR	Boat ramp spillway	n/a	n/a	8.3	8.0
SC	Sailing club spillway	n/a	n/a	8.3	8.1
N3	Between the <i>Hakea pulvinifera</i> and the confluence of the Namoi and Peel Rivers	5.8	2.9	3.6	3.6
N4	Gorge (downstream of the confluence of the Namoi and Peel Rivers)	10.7	8.9	8.8	8.8
N5	Namoi River at Carroll	2.8	2.2	2.2	2.2
<b>Peel River (1:1,400 AEP flood plus the back-up effects of the dam failure base case)</b>					
P1	Peel River upstream of the subsidiary dam wall	2.0 <sup>2</sup>	2.0	2.0	2.0
S	Immediately downstream of the subsidiary dam wall	n/a	8.5	n/a	n/a
P2	Peel River between the subsidiary dam wall and the Namoi River	2.7 <sup>3</sup>	4.4	2.5	2.6
N4	Gorge (downstream of the confluence of the Namoi and Peel Rivers)	10.7	8.9	8.8	8.8
N5	Namoi River at Carroll	2.8	2.2	2.2	2.2

Source: Sinclair Knight Merz 2005

Notes:

<sup>1</sup> Labels refer to locations shown on *Figure 6-5*.

<sup>2</sup> 1:1,400 AEP flood only. This location is outside the influence of the backwater effects of dam failure in the Namoi River.

<sup>3</sup> Includes the combined effect of a 1:1,400 AEP flood in the Peel River, subsidiary dam discharge and the backwater effects of dam failure.

n/a Not applicable. There are no floodwater discharges at this location based on the option configuration.

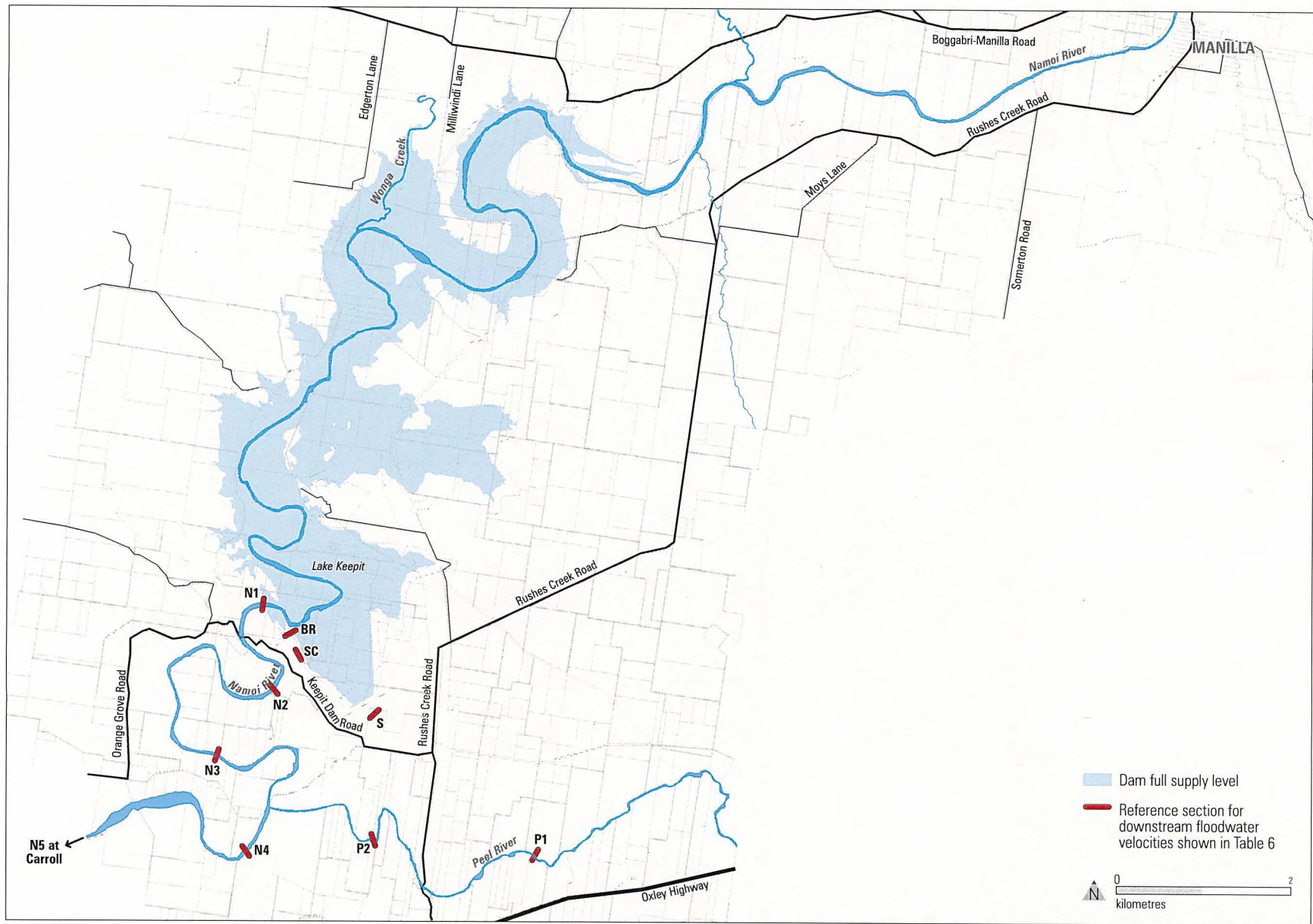


Figure 6-5 Reference sections for downstream floodwater velocities

As indicated in *Table 6.3*, implementation of any of the dam safety upgrade options would result in reduced floodwater velocities at all locations along the Namoi River relative to dam failure. Discharge velocities from all spillways would be in the range of 8.0–8.5 metres per second, with higher velocities associated with the options that involve a temporary loss of storage (i.e. Options B1 and D2). Differences in the effects of the upgrade options are not predicted to be observable beyond the confluence of the Namoi and Peel Rivers; however, all velocities would be reduced relative to the base case.

In the Peel River, Option B1 would result in an increase in floodwater velocities by approximately 62% relative to the dam failure scenario, whereas Options D2 and D3 would result in slight velocity reductions at the same location. Conversely, in the Namoi River, Option B1 would result in a significant reduction in floodwater velocities between the main dam wall and the confluence.

There would be minimal difference between the velocities in the Namoi River between the main dam wall and the confluence for Options D2 and D3.

#### *Geology and soils*

Previous investigations identified that soils immediately downstream of the subsidiary dam wall variously comprise thinly bedded and highly jointed, meta-sedimentary rocks, comprising the Namoi and Mostyn Vale Formations (Parsons Brinckerhoff 2005). These soils are highly erodible relative to those at the other spillway locations at the right-hand abutment, boat ramp and sailing club, which are located in geological formations of sandstones and limestones, which are stronger. Concerns have been raised by the Community Reference Panel regarding the impacts caused by operation of the subsidiary dam spillway for Option B1 on these highly erodible soils.

Preliminary estimates of erosion were developed based on identified floodwater velocities and desktop geological information. Marginal sediment loads associated with Option B1 under a PMF event were estimated to be approximately 9 million cubic metres (3 million cubic metres under a 1:10,000 AEP event) (Parsons Brinckerhoff 2005). These estimates were based on a range of assumptions regarding hydraulic performance and theoretical erosion rates of the soils and rocks.

The Community Reference Panel indicated that this effect should be investigated further, including the significance of the consequent environmental effects. Because of the unpredictable nature of extreme storms, State Water considered that the only feasible method of studying the issue and the environmental effects further was to convene a panel of experts.

### 6.3.2 Expert panel process

#### *Approach*

There is a paucity of literature regarding the erosion and sedimentation processes that accompany extreme storms such as PMF events. The frequency likely to be attributed to such a storm centred on Lake Keepit would be approximately 1:500,000 AEP or less frequent. The largest storms known to occur in Australia are estimated at 1:1,000 AEP. There is no experience and, therefore, inherent difficulties associated with accurately estimating the magnitude of erosion and resulting impacts that would occur during a storm of this magnitude. A reasonable assumption is, however, that the impacts would be catastrophic. The adopted approach, therefore, was to assemble a panel of experts to provide opinions on the estimated magnitude of erosion and consequent environmental effects.

A budget of erosion from the catchment upstream of Keepit Dam during a flood of 1:10,000 AEP and a PMF event was prepared to enable an estimation of downstream sedimentation impacts associated with the operation of a subsidiary dam spillway (i.e. Option B1) (Sinclair Knight Merz 2006). The ability of the storage to mitigate the sediment flow and the relative proportion of erosion below the spillways relative to the upstream catchment was also estimated. These estimates were considered at the expert panel workshop held in February 2006 prior to the assessment of likely impacts (refer *Appendix E*).

#### *Assessment results*

The upstream catchment erosion budget was estimated based on field inspection, delineation of the catchment into geomorphic land units, and multiplication of the available area of land by the estimated soil depth and delivery ratio (i.e. the ability of that landform to be mobilised during a PMF). The probable maximum sediment discharge for a PMF event was estimated at approximately 3,500,000,000 cubic metres and, for a flood of 1:10,000 AEP, approximately 600,000,000 cubic metres (or 0.14 metres eroded on average across the entire catchment). The relative contribution of erosion resulting from the operation of Option B1 represents approximately 0.5% of the expected total erosion budget for a 1:10,000 AEP event. This was not considered significant, except in a local context. The relative proportion of erosion associated with operation of Option B1 during a PMF event was estimated to be even lower.

Some members of the panel thought that this estimate was excessive and suggested that a 0.01 metre on average erosion across the catchment was more realistic. This would equate to approximately 63,000,000 cubic metres eroded from the total catchment during a 1:10,000 AEP flood event. The relative contribution from Option B1 under this scenario was estimated at approximately 5%.

Further iterations of the calculation were performed and assumed that, regardless of the magnitude of upstream catchment erosion, only 25% would be discharged through the Keepit Dam spillways. Using the results above for the 1:10,000 AEP event, the relative proportion of erosion from operation of the downstream spillway of Option B1 represents only approximately 2% of the total sediment moving through the dam. The relative proportion during a PMF event was predicted to be even lower.

Based on these findings and other iterations performed at the workshop, the panel concluded that the contribution to erosion from Option B1 would only represent a very small proportion of the sediment mobilised. At a regional scale, the effects would be insignificant. Both regional and local impacts are discussed further in *Section 6.3.3*.

### **6.3.3 Overview of consequent environmental impacts**

#### *Regional impacts*

Very large to extreme floods of 1:10,000 AEP or less frequent would give rise to extreme erosion processes that would, in turn, give rise to extreme changes within the Keepit Dam catchment. Enormous quantities of material would be mobilised and transported downstream in these events under all three dam safety options. Sediment derived from a localised scour due to the operation of the subsidiary dam spillway for Option B1 would represent only a tiny proportion of the total sediment processes. While the localised effects resulting from the operation of the subsidiary dam spillway for Option B1 would be marked, they would be insignificant when compared to impacts on the wider catchment.

The expert panel concluded that the storage itself would serve as a 'sink' for the large volumes of sediment mobilised from the upstream catchment during a very large or extreme flood. While large volumes of entrained sediment and other debris would still be expected to be released through the spillways with all the options, some downstream water quality improvement would be expected relative to the effects of dam failure scenario.

Downstream of Keepit Dam, both the Peel and Namoi Rivers have incised deep gorges through the surrounding bedrock down to and beyond the confluence of the rivers, over a combined length of approximately 15-20 kilometres. Within this zone, stream power would be very high and floodwaters would scour all superficial sand, gravel and clay deposits, as well as some of the more weathered bedrock with all the options.

Downstream of the gorges, the Namoi and Peel Rivers discharge onto the Carroll floodplain. Catastrophic widening and straightening of the channel immediately downstream from this gorge would be expected with all the options under a very large to extreme flood, but this effect would diminish with distance downstream. As the stream slope declines in this location and velocities would reduce as a result of flow path widening across the floodplain, deposition would start to occur. Many metres of material would be deposited

across the floodplain, completely altering the pre-flood morphology of the valley. Changes in the downstream channel of the Namoi River would be expected to be marked for many tens of kilometres, while changes to the floodplain would be obvious for hundreds of kilometres.

Very large to extreme floods of 1:10,000 AEP or less frequent would result in severe and irreversible regional environmental damage to terrestrial and aquatic habitats, cultural and European heritage sites, rural development opportunities, visual impacts and agricultural pursuits. Generally, implementation of any of the upgrade options would not worsen these effects, but would more likely result in a slight reduction in adverse regional impacts on account of the detention of a small proportion of floodwaters and the likelihood this storage would act as a sediment sink.

#### *Local impacts*

Below the subsidiary dam spillway, floodwaters released through the subsidiary dam spillway for Option B1 would scour a large hole in the previously unchannelled landscape and incise a new flow path to the Peel River over a distance of approximately 2.5 kilometres. The new channel could be several metres deep and several hundred metres wide. Within the Peel River, discharges from this spillway would exacerbate existing flooding impacts. Immediately downstream of the other spillways at the right-hand abutment, boat ramp and sailing club, floodwaters would result in scouring over short lengths; however, given the more erosion resistant geology at these locations, this would have a relatively smaller impact.

Compared to a base case of dam failure, all three options would result in reduced impacts during large to extreme floods on known and potential heritage sites in the Namoi valley, downstream of the main dam wall to the confluence with the Peel River. It is likely that dam failure would cause significant damage to, or the destruction of, seven known Aboriginal heritage sites (KDA2, 10, 11-13 and 20 and 20-4-0056), five known European heritage sites (KDH 3-5, 9 and 10) downstream of the main dam wall, and the dam wall itself (KDH8). All three dam safety upgrade options would avoid inundation of two of these known European heritage sites (KDH3 and 4), and would avoid failure of the dam wall. Furthermore, all the options would potentially reduce impacts on unrecorded sites and those sites that would continue to be inundated, due to reduced floodwater velocities and scouring (refer *Table 6.3*). Option B1 would lead to the greatest reduction in potential impacts, as it would lower velocity floodwaters in the Namoi River more than Options D2 and D3. However, this benefit of Option B1 would come at the potential expense of heritage sites in the lower Peel valley.

Compared to a base case of dam failure, Option B1 has the potential to increase impacts on three known Aboriginal heritage sites (KDA3-5) and potential Aboriginal heritage sites located along the Peel River between the subsidiary dam wall and the confluence with the Namoi River. These sites would potentially be affected by scouring resulting from higher velocity floodwaters in the Peel River due to the release of floodwaters through the subsidiary dam spillway. A further ten Aboriginal heritage sites (KDA6-8, 14-

19, 27) and two European heritage sites (KDH6 and 7) located below the subsidiary dam spillway could also be similarly affected. However, similar to the difficulties encountered in the assessment of downstream inundation impacts in *Section 6.2.2*, it is difficult to isolate the impacts of erosion and sedimentation caused by the operation of the subsidiary dam spillway from similar impacts caused by simultaneous flooding in the Peel catchment and backwater flows from the Namoi River. Nevertheless, it is considered that the existing potential for scouring impacts on heritage sites in the lower Peel valley would be worsened through operation of the subsidiary dam spillway.

Compared to a base case of dam failure, Options D2 and D3 would result in reduced impacts on known and potential heritage sites in the lower Peel valley downstream of the main dam wall to the confluence with the Namoi River, due to reduced floodwater velocities and scouring (refer *Table 6.3*).

### 6.3.4 Mitigation measures

Two forms of mitigation were considered in regard to erosion and sedimentation impacts. The first mitigation option is to incorporate a design solution into the spillway structure. The second would be event-based, whereby following occurrence of the flood event, some retrospective mitigation would be undertaken. Both options were concluded to be infeasible on account of their likely cost, both in absolute terms and relative to the low frequency of occurrence of the PMF (*pers. comms.* David Watson, State Water, 2006).

Appropriate design solutions to reduce the effects of erosion would seek to reduce the energy of the floodwaters leaving the spillway. Such structures are in place downstream of other dam walls (e.g. Warragamba Dam in Sydney), and could readily be provided where there is steep topographic relief. At the right-hand abutment, sailing club and boat ramps, there are space constraints downstream of the spillways. The geology of the bedrock is also fairly resistant to scour at these three locations. A possible alternative would involve concrete lining the spillway, although preliminary cost estimates indicate this would add approximately 20% to the overall option cost.

Downstream of the subsidiary dam wall, the gentle slope of the land to the Peel River does not readily lend itself to the introduction of a hydraulic structure to reduce floodwater energy without significant earthworks. This would need to be undertaken over the full length of the flow path to the Peel River to avoid the majority of scouring predicted. Providing a concrete lining over this distance was also indicatively costed and, at approximately \$20 million, represents approximately 30% of the capital cost of Option B1. It is, therefore, considered infeasible.

Concrete-lined discharge chutes are not proposed for the sailing club and boat ramp spillways due to the infrequency of their operation (less than 1:10,000 AEP), very high cost (in the order of \$30 to \$40 million) and the impracticality of chutes at these locations.

## 6.4 Water supply security

### 6.4.1 Existing environment

The water released from Keepit Dam is mainly used for irrigated agriculture (approximately 97%), although other uses include town water supplies, stock watering and mining. Keepit Dam is downstream of Split Rock Dam and the capacity of these two storages can supply up to 200% of water demand in the Namoi Valley. Water releases from the dam during normal weather conditions are controlled by the *Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources* (DIPNR 2004b). The Upper Namoi includes the regulated river sections between Split Rock Dam and Keepit Dam. The Lower Namoi includes the regulated river sections downstream of Keepit Dam to the Barwon River. The Plan provides for the environmental needs and ecological processes of the Namoi River and also sets rules for the management of access licences, water allocation accounts, the trading of or dealings in licences and water allocations, the extraction of water, the operation of the dams and the management of water flows.

The *Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources* is a legal document under the *Water Management Act 2000* and is implemented by the Department of Natural Resources.

The Plan establishes environmental water rules for the water source. The water required under these rules is set aside prior to it being made available for access licences. All water extractions, other than basic landholder rights, must be authorised by an access licence. There are five access licence categories: general security, high security, supplementary water, domestic and stock, and local water utility. Each access licence specifies a share component and is expressed as a number of unit shares, except share components for domestic and stock, and local water utility access licences, which are expressed in megalitres.

#### *Available water determinations*

Water is shared between access licences by means of available water determinations. These determinations are made at the start of the water year, and, if required, during the course of the year. A water year is the 12 months running from 1 July to 30 June.

The water made available to general security access licences in the Upper Namoi varies from year to year depending upon the amount of water held in Split Rock and Keepit Dams, and whether more water becomes available during the water year. The water made available to general security access licences in the Lower Namoi is reviewed monthly, but also depends upon the amount of water held in Split Rock and Keepit Dams.

The volume that may be taken over a water year by each supplementary water access licence is set by an available water determination made at the start of each water year (DIPNR 2004b).

### 6.4.2 Assessment of impacts

None of the proposed dam safety upgrade options would result in a change in water availability from Keepit Dam, unless a storm larger than 1 chance in 2,400 each year was to occur.

In this case two of the proposed dam safety upgrade options (Options B1 and D2) are designed so that if a release plug activates, the water released through the auxiliary spillways would include a portion of the full supply level storage (30% and 15% respectively). A potential concern is whether there would be changes in water availability or security (for general security and supplementary water access licences) in the period immediately following a very large to extreme flood event, for example, should a drought occur.

State Water commissioned the Department of Natural Resources to synthesise the past 110 years of rainfall and river flow data in the Namoi River catchment using the Integrated Water Quality and Quantity Model (IQQM) computer software model. The model was used to predict the daily storage level of the dam based over this period (including prior to the dams construction) and incorporating current irrigation demands. *Figure 6-6* indicates the results of the IQQM modelling. The modelling shows that the largest flood on record for the Namoi River occurred in 1955 and had an estimated frequency of approximately 1:100 AEP. There were also four other sizeable floods around this same period. Of these five large floods, Split Rock Dam would have been filled in all but one of the floods where it was 98% full. Therefore it is reasonable that Split Rock Dam would be full if a flood larger than 1:100 AEP were to occur such as a flood which might result in a loss of storage at Keepit Dam.

For Options B1 and D2 where temporary loss of storage would occur, an assessment was undertaken of the likelihood that there would be an extended drought after the restoration of the release plugs following temporary loss of storage. Restoration of the release plugs was assumed to take 12 months. The assessment indicated that two of the five large floods were followed by an extended dry period that was likely to require use of Keepit and Split Rock Dams and, may therefore, affect availability of water supplies. Based on this historical rainfall information, it is estimated that the chance that irrigation water availability would be affected following a large flood that triggers a temporary loss of storage at Keepit Dam for Options B1 and D2 would be approximately 1:3,000 AEP.

### 6.4.3 Mitigation measures

Each of the three dam safety options provides a loss of storage inherent in their design ranging from zero to 30%. Preference for an option incorporating none or a lesser amount of loss of storage would represent the most practical form of mitigation. The project capital cost increases with options involving a lesser loss of storage.

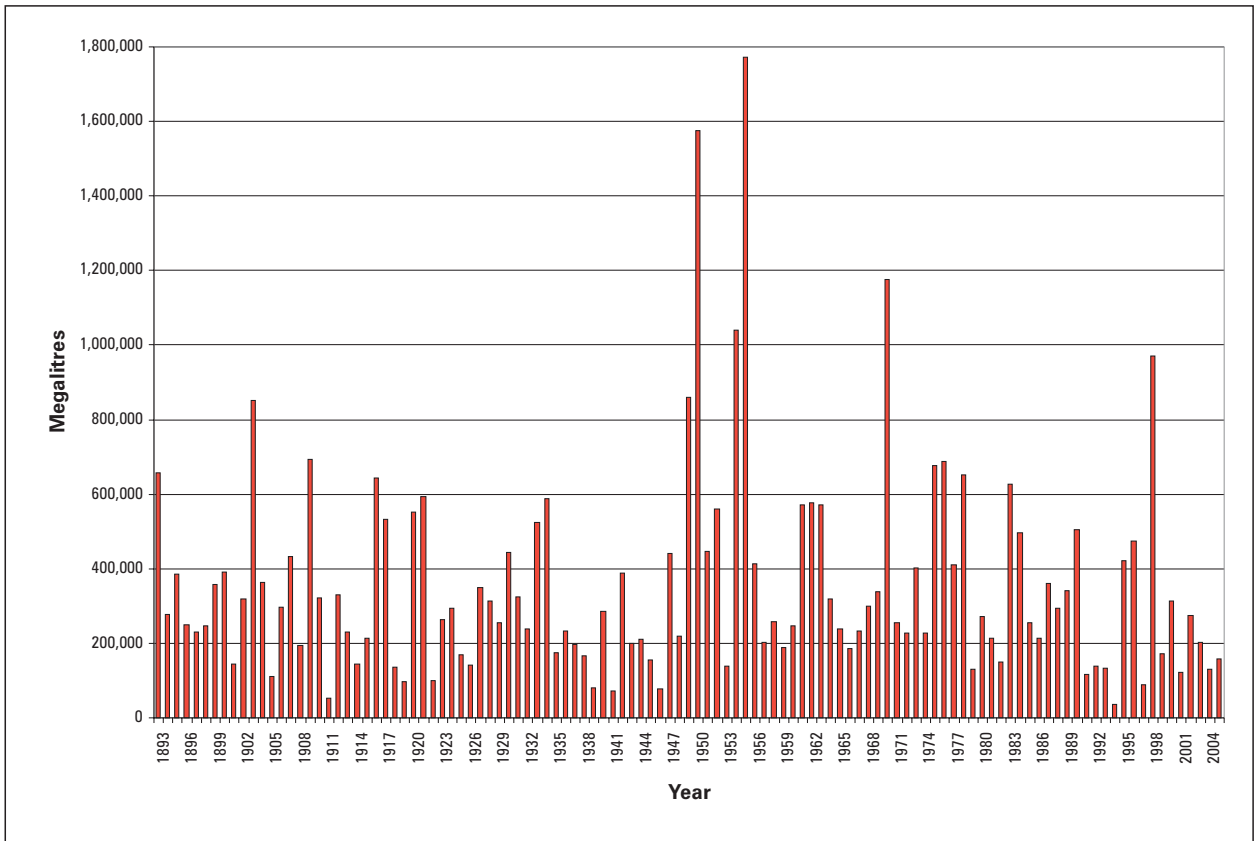


Figure 6-6a **Simulated inflows to Keepit Dam (1893-2004)**  
 Source: State Water, 2007

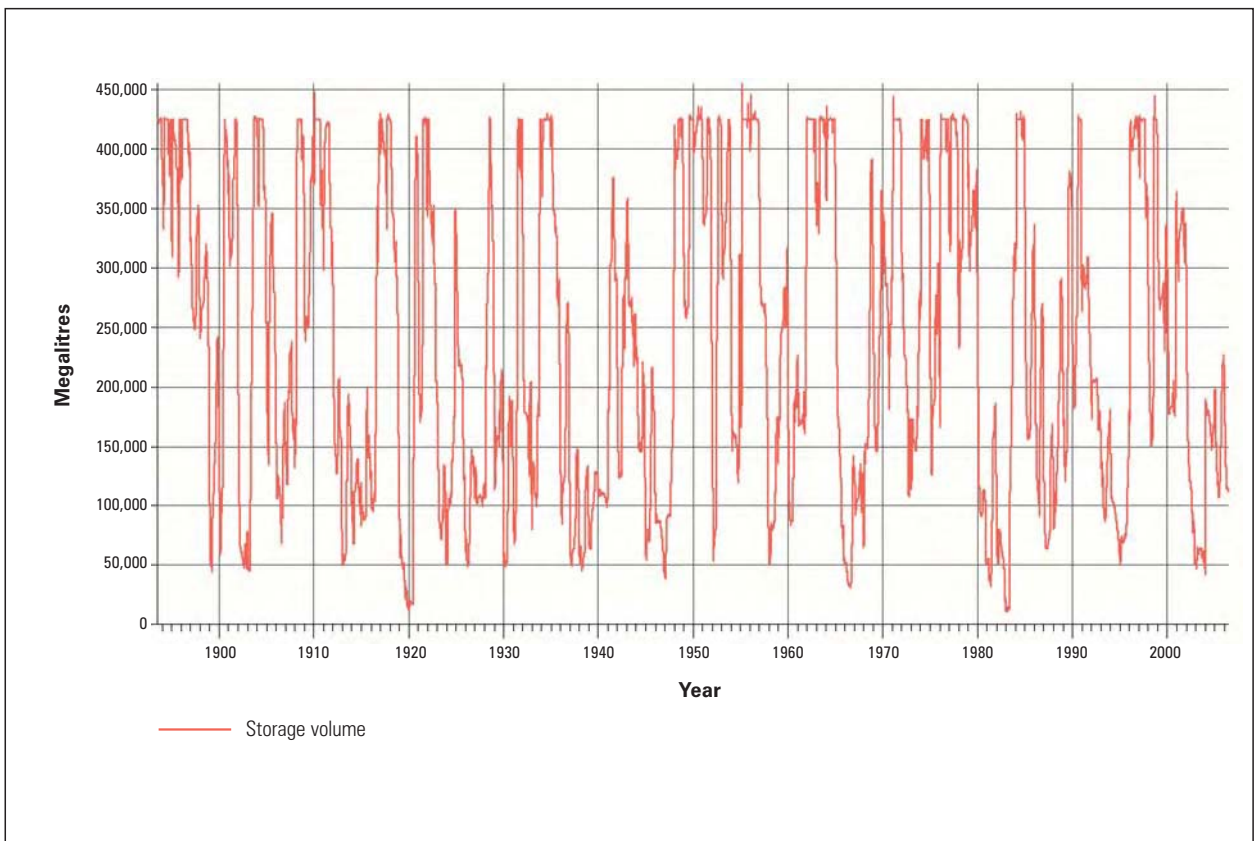


Figure 6-6b **Simulated Keepit Dam storage volume - (1893-2004)**  
 Source: State Water, 2007

## 7. Comparison of dam safety upgrade options

This Chapter provides a ranking of the three dam safety upgrade options for each of the key construction and operational issues considered in *Chapters 5* and *6* respectively. It is intended that this ranking would be used to assist determination of a preferred dam safety upgrade option, following public exhibition of this Environmental Assessment.

### 7.1 Ranking against key issues

*Table 7.1* provides a relative ranking of the options. Ranking was undertaken by:

- assigning a '1' to all three options if they performed equally
- if the performances of the options were all different, assigning a '1' to the best performing option, a '2' to the next best performing option, and a '3' to the worst performing option
- if the performances of two of the options were similar and the third differed, then assigning a '1' to the best performing options and a '2' to the worst performing options.

*Table 7.1* also provides summary of each issue as well as the predicted scale of impact, its likelihood and whether or not the impact is able to be mitigated or reduced through mitigation commitments made by State Water.

**Table 7.1 Dam safety upgrade option comparison**

Category/ criteria	Option ranking			Comment	Relative scale of impact	Chance of impact	Is the impact able to be mitigated (offset or reduced)?	Reference in the Environmental Assessment
	B1	D2	D3					
<b>Construction issues</b>								
Terrestrial ecology	1	2	2	The construction footprint of Option B1 on the threatened White Box Yellow Box Blakely's Red Gum Woodland ecological community is less than Options D2 and D3.	Proposed clearing of White Box Yellow Box Blakely's Red Gum Woodland: <ul style="list-style-type: none"> <li>▪ Option B1: 13.6 hectares</li> <li>▪ Options D2 and D3: 18.0 and 17.6 hectares respectively.</li> </ul>	During construction	Yes by proposed biodiversity offset strategy	See <i>Section 5.1.2</i>
Aquatic ecology	1	1	1	There is potential for water quality/aquatic ecology impacts during construction however any impacts would be the same for all options and are considered to be manageable through implementation of the proposed mitigation measures.	Small	Low	Yes by implementation of the proposed mitigation measures	See <i>Section 5.2.2</i>
Cultural heritage	1	2	2	The construction works for Options D2 and D3 could potentially impact an Aboriginal stone procurement source and encroach upon a historical school/scout hall. The construction footprints of Options D2 and D3 also have a greater potential to disturb unrecorded archaeological heritage sites than the construction footprint of Option B1.	The boundaries of the stone procurement source would need to be determined. The historical school/scout hall site is considered of high local heritage significance. Uncertain until excavation occurs whether unrecorded archaeological heritage sites exist.	During construction  Low potential for unrecorded archaeological sites to exist.	Yes by implementation of the proposed mitigation measures	See <i>Section 5.3.2</i>
Social	1	2	2	The State Park may suffer a loss of patronage during the upgrade construction which could be exacerbated by the direct and indirect impacts of Options D2 and D3 to key facilities such as the kiosk, sailing club, Chalet and boat ramp. It is possible that at least part of any impact may be offset by providing accommodation and supplies required by the construction workforce e.g. meals, recreation needs, short-term accommodation, etc.	Options D2 and D3 would be constructed in close proximity and potentially directly impact the kiosk, The Gums Caravan Park, sailing club, Chalet and boat ramp of the State Park as well as require the relocation of seven more caravans than Option B1. A variety of permanent fixtures attached to the caravans will be unable to be salvaged.	During construction	Yes. Infrastructure would be relocated or upgraded as an early construction activity to reduce potential loss of patronage and overall impacts mitigated in accordance with an agreed master plan developed in conjunction with the Lake Keepit State Park	See <i>Section 5.5</i>

Category/ criteria	Option ranking			Comment	Relative scale of impact	Chance of impact	Is the impact able to be mitigated (offset or reduced)?	Reference in the Environmental Assessment
	B1	D2	D3					
							Trust.	
Visual	1	2	2	Option B1 has fewer spillways and a lower level of wall raising than the other options and would therefore be less visible to users of the State Park.	The visibility of the options is location specific.	During operation	Yes. New infrastructure would be designed to be consistent with the 'look' of the existing infrastructure.	See <i>Section 5.4.2</i>
<b>Operational issues (upstream)</b>								
Terrestrial ecology/ aquatic ecology and heritage	1	2	3	Option D3 with the highest wall raising would result in the greatest temporary upstream inundation. The duration of temporary inundation would be unlikely to affect trees although grasses would probably die. There would be temporary affects on aquatic habitats. One heritage site not already affected by inundation would be affected. The majority of the area to be inundated has a relatively low archaeological potential.	Maximum inundation area and duration caused by a PMF: <ul style="list-style-type: none"> <li>▪ Option B1: 1,085 hectares, 60 hours</li> <li>▪ Option D2: 1,485 hectares, 75 hours</li> <li>▪ Option D3: 1,795 hectares, 90 hours</li> </ul>	Storms larger than: <ul style="list-style-type: none"> <li>▪ Option B1: 1:17,300 AEP</li> <li>▪ Option D2: 1:6,700 AEP</li> <li>▪ Option D3: 1:5,000 AEP</li> </ul>	No	See <i>Section 6.2.3</i>
Social	1	2	2	Upstream inundation caused by Options D2 and D3 would affect facilities including the Lake Keepit Sport & Recreation Centre, the Ski-Gardens/Pelican Point Caravan Park and a number of rural properties.	Maximum inundation area and duration caused by a PMF: <ul style="list-style-type: none"> <li>▪ Option B1: 1,085 hectares, 60 hours</li> <li>▪ Option D2: 1,485 hectares, 75 hours</li> <li>▪ Option D3: 1,795 hectares, 90 hours.</li> </ul>	Storms larger than: <ul style="list-style-type: none"> <li>▪ Option B1: 1:17,300 AEP</li> <li>▪ Option D2: 1:6,700 AEP</li> <li>▪ Option D3: 1:5,000 AEP.</li> </ul>	Yes. State Water, where liable, would compensate land owners in accordance with <i>Section 4.5 Land acquisition and other compensatory arrangements.</i>	See <i>Sections 4.5 and 6.2.3</i>
<b>Operational issues (downstream)</b>								
Hydraulics – small to large floods	n/a	n/a	n/a	The proposal would have no effect on existing flood operations or impacts caused by the existing dam infrastructure for small to large storms.	n/a	Storms smaller than 1:2,400 AEP.	n/a	See <i>Section 6.2.2</i>

Category/ criteria	Option ranking			Comment	Relative scale of impact	Chance of impact	Is the impact able to be mitigated (offset or reduced)?	Reference in the Environmental Assessment
	B1	D2	D3					
Hydraulics – large to very large floods	1	1	1	All options propose a spillway at the right-hand abutment which would operate for storms larger than 1:2,400 AEP.	The deeper spillway of Option B1 would release a larger volume of water earlier (up to 15% greater than Option D3). As a result, the duration of flows following any releases from the right-hand abutment would be up to 3 days longer for Option B1.  No difference between the options is discernable beyond the confluence of the Namoi and Peel Rivers (approximately 13 kilometres downstream of the main dam wall).	Between 1:2,400 and 1:10,000 AEP	No	See <i>Section 6.2.2</i>
Hydraulics – very large to extreme floods	1	1	1	Additional spillways would be activated for all options with the hydraulic differences between the options indistinguishable beyond the confluence of the Namoi and Peel Rivers (approximately 13 kilometres downstream of dam).	Option B1 would discharge approximately 60% of flood flows to the Peel River while Options D2 and D3 would discharge only to the Namoi River consistent with the original design of the dam.	Storms larger than 1:10,000 AEP.	No	See <i>Section 6.2.2</i>
Erosion and sedimentation	2	1	1	A massive amount of erosion of the upstream catchment would be expected to occur during a large to extreme flood. A large proportion of this sediment would be transported through the dam and deposited on floodplain at Carroll's Gap. Discharges from the subsidiary dam spillway from Option B1 would generate additional large scale, localised erosion due to the presence of highly erodible soils in the downstream area including the Peel River valley.	The approximate volume of erosion occurring in the upstream catchment during a 1:10,000 AEP event was estimated at 600 million cubic metres. Option B1 would contribute an increase of 3 million cubic metres resulting from erosion of some 7.5 kilometres of floodway downstream of the subsidiary dam spillway. This represents between 0.5% and 5% of the total estimated volume of erosion and if viewed in the context of the overall sediment load, is minimal. However, the local effect of this erosion would be very substantial.	Storms larger than 1:10,000 AEP.	No, the high cost of erosion protection renders it unfeasible	See <i>Section 6.3.3</i>

Category/ criteria	Option ranking			Comment	Relative scale of impact	Chance of impact	Is the impact able to be mitigated (offset or reduced)?	Reference in the Environmental Assessment
	B1	D2	D3					
Terrestrial and aquatic ecology	1	1	1	<p>For extreme floods, the majority of floodwater for Option B1 would discharge into the lower Peel River. For Options D2 and D3, all floodwaters would be discharged into the Namoi River, as would occur naturally.</p> <p>Option B1 would result in high velocity floodwaters in the lower Peel River which would result in much greater impact than Options D2 and D3. Both river systems are in a degraded condition and it is not clear that one option is superior to the others.</p>	<p>Approximately 7.5 kilometres between the subsidiary dam wall and the river confluence (Option B1) or up to 11 kilometres between the boat ramp/ caravan park spillways and the river confluence.</p> <p>Impacts on the <i>Hakea pulvinifera</i> vary depending on the size of the flood and the option selected. For floods with frequencies between 1:2,400 AEP and 1:10,000 AEP, Option B1 has an approximately 15% greater impact on the <i>Hakea pulvinifera</i> population than Options D2 and D3. For floods of 1:10,000 AEP or less frequent, Option B1 provides greater protection to the <i>Hakea pulvinifera</i> population than Options D2 and D3. The maximum impact on the population would occur during a PMF when, Options B1, D2 and D3 are estimated to result in the loss of 31%, 54% and 56% of the population respectively.</p>	<p>For storms between 1:2,400 AEP and 1:10,000 AEP, impacts to the Namoi River downstream of the main dam wall.</p> <p>For storms larger than 1:10,000 AEP, impacts to both the Namoi River downstream of the main dam wall and lower Peel River.</p>	No	See Section 6.2.2
Cultural heritage	1	1	1	A number of known and potential Aboriginal heritage sites exist along the Namoi and Peel River valleys which would be impacted during extreme flood events (as they would also be during dam failure). It is not clear that one option is superior to the others.	Approximately 7.5 kilometres between the subsidiary dam wall and the river confluence (Option B1) or up to 11 kilometres between the boat ramp/ caravan park spillways and the river confluence (Options D2 and D3).	Storms larger than 1:10,000 AEP	Yes, through collection and relocation of objects if desired by Aboriginal groups	See Sections 6.2.2 and 6.3.3
Water supply security	3	2	1	Options B1 and D2 would result in a temporary loss of storage below full supply level until release plugs are reinstated and inflow of sufficient water to restore the storage to full	<p>Temporary loss of storage of:</p> <ul style="list-style-type: none"> <li>▪ Option B1: 30%</li> <li>▪ Option D2: 15%</li> <li>▪ Option D3: nil.</li> </ul>	<p>Temporary loss of storage would occur at 1:2,400 AEP.</p> <p>Estimated chance</p>	Yes. In the short term, Spilt Rock Dam upstream of Keepit Dam could supplement water supplies if required.	See Section 6.4

Category/ criteria	Option ranking			Comment	Relative scale of impact	Chance of impact	Is the impact able to be mitigated (offset or reduced)?	Reference in the Environmental Assessment
	B1	D2	D3					
				supply level.		of not having a full storage within 12 months of a very large flood i.e. that loss of storage may manifest in inability to deliver required water demand is 1:3,000 AEP.		
Social	2	1	1	Option B1 would affect Lake Keepit State Park sewage treatment plant and golf course, a section of Keepit Dam Road within the State Park, and privately-owned land between the subsidiary dam spillway and the Peel River currently used for grazing/agriculture during floods larger than approximately 1:10,000 AEP. Options D2 and D3 would also affect sections of Keepit Dam Road within the State Park downstream of the sailing club and boat ramp spillways during floods larger than approximately 1:10,000 AEP and 1:100,000 AEP respectively.	The sewage treatment plant would be entirely destroyed and more than half the golf course destroyed in the event of a spillway discharge.	Storms larger than 1:10,000 AEP.	Yes. State Water, where liable, would compensate land owners in accordance with <i>Section 4.5 Land acquisition and other compensatory arrangements.</i>	See <i>Sections 4.5 and 6.2.2</i>
<b>Finance and economics</b>								
Capital cost	1	2	2	Option B1 has the lowest estimated capital cost followed by Options D2 and D3. Costs for Options D2 and D3 are considered to be the same within the order of accuracy of the cost estimates prepared. Costs for environmental improvements are not included as they are the same for all options.	Capital costs (March 2007) of: <ul style="list-style-type: none"> <li>▪ Option B1: \$75 million</li> <li>▪ Option D2: \$87 million</li> <li>▪ Option D3: \$89 million</li> </ul>	n/a	n/a	See <i>Section 4.6.1</i>

Category/ criteria	Option ranking			Comment	Relative scale of impact	Chance of impact	Is the impact able to be mitigated (offset or reduced)?	Reference in the Environmental Assessment
	B1	D2	D3					
Net present value (NPV)	1	2	2	Option B1 has the least negative NPV followed by Options D2 and D3. Costs for Options D2 and D3 are considered to be the same within the order of accuracy of the cost estimates prepared.	Net present values of: <ul style="list-style-type: none"> <li>▪ Option B1: -\$54 million</li> <li>▪ Option D2: -\$63 million</li> <li>▪ Option D3: -\$64 million</li> </ul>	n/a	n/a	See <i>Section 4.6.2</i>
Benefit to cost ratio (BCR)	1	1	1	All the options have similar benefit to cost ratios.	Benefit cost ratios of: <ul style="list-style-type: none"> <li>▪ Option B1: 0.25</li> <li>▪ Option D2: 0.24</li> <li>▪ Option D3: 0.24.</li> </ul>	n/a	n/a	See <i>Section 4.6.2</i>

*Notes:*

n/a – not applicable

AEP – annual exceedence probability

PMF – probable maximum flood

m<sup>3</sup>/sec – cubic meters per second

## 7.2 Overall performance of the options

Option B1 would provide the best performance for all of the construction issues listed in *Table 7.1*. It would result in less need for clearing of native vegetation, including threatened flora species, and have less potential to affect known cultural heritage sites. Option B1 would also result in the least requirement to relocate caravans within the Caravan Park and lower overall disturbance relative to the other options.

Environmental and social impacts related to temporary upstream inundation during large to extreme storms are minimised by Option B1 since the area, duration and likelihood of inundation are least for this option. Option B1 would also have the least visual impacts.

The downstream impacts of the options are similar in regional terms, however, they are different locally. While there is little observable hydraulic difference between the options downstream of the confluence of the Namoi and Peel Rivers (some 13 kilometres downstream of the dam wall), Option B1 would discharge a majority, approximately 60%, of floodwaters down the Peel River while Options D2 and D3 would discharge only to the Namoi River, which is the natural flow path of floodwaters and is consistent with the current spillway discharges from the dam. This new floodway provided by Option B1 into the Peel River raises a potential social equity issue for landowners along a 7.5 kilometre section of river downstream of the subsidiary dam spillway to the confluence with the Peel River.

Option B1 would result in substantial erosion along this section of the Peel River during a storm larger than 1 chance in 10,000 each year on average. High velocity discharges from the subsidiary dam spillway would result in the incision of a new channel between the spillway and the Peel River which could be several metres deep and hundreds of metres wide. While the overland impact would be substantial, the Peel River would also be experiencing concurrent and very substantial flooding of approximately 1 chance in 1,400 each year on average.

Options B1 and D2 would result in a temporary loss of storage of 30% and 15% respectively for floods larger than 1 chance in 2,400 each year on average. The likelihood of this temporary loss of storage manifesting in an inability to deliver the average downstream irrigation demand was estimated at 1 chance in 3,000 each year on average.

Option B1 would result in the loss of the State Park sewage treatment plant and part of the golf course during a storm larger than 1:10,000 each year on average. In these events, Option B1 would also affect an area of privately-owned land several hundred metres wide along a distance of approximately 2.5 kilometres between the spillway and the Peel River. The affected land is currently used for grazing/agriculture.

While Option B1 has the lowest capital cost, the economic performance of all options is similar.

## 8. Environmental improvements

The proposed Keepit Dam Upgrade incorporates two measures to improve downstream environmental conditions — a multi-level offtake and a fishway. Implementation of these measures would be subject to ongoing design and feasibility investigations and availability of funding. The total value of the environmental improvements is estimated at \$24.5 million with \$3.5 million for the multi level offtake and \$21 million for a fishway at Keepit Dam.

### 8.1 Multi-level offtake

#### 8.1.1 Options for a multi-level offtake

State Water, in conjunction with the project's Community Reference Panel (refer *Section 1.6.3*), identified ten options to address the issue of cold water releases from Keepit Dam and related downstream impacts. The options included provision of selective withdrawal mechanisms, aeration of the storage and systems of impellers for mixing. From these, three selective withdrawal options involving a multi-level offtake attached to the existing outlet were identified for further investigation; sliding plates, roller doors and automatic shutters.

A number of investigations were carried out regarding the provision of a multi-level offtake to inform decision-making by State Water and the Community Reference Panel. These investigations included:

- temperature collection within Lake Keepit and data analysis (Manly Hydraulics Laboratory 2003)
- engineering investigations of alternatives (Department of Commerce 2003)
- multi-criteria analysis of three multi-level offtake options
- concept design of three multi-level offtake options (Department of Commerce 2005)
- a review of the validity of the method for assessing the likely performance of the proposed multi-level intake structure (Manly Hydraulics Laboratory 2007).

#### 8.1.2 Assessment of effectiveness

The likely effectiveness of the multi-level offtake under a range of stratification and discharge scenarios at Keepit Dam was investigated (Manly Hydraulics Laboratory 2003, 2007). It was found that a multi-level offtake would provide a means of increasing the release water temperature to a level equivalent with the dam surface temperature at low to medium release volumes. At high release volumes, withdrawal of a mixture of surface and deeper water would lead to a lower temperature than that at the surface.

It was found that whether sufficient warm water is available at the appropriate time to satisfy the downstream fish spawning temperature cues would depend on the irrigation demand and water level. It was also identified that there may be need for an operational regime that could be adjusted each year to meet downstream ecological criteria (Manly Hydraulics Laboratory 2003).

Modelling was also undertaken of the performance of the multi-level offtake during fish spawning periods for releases from the dam of 2,000 megalitres per day (Manly Hydraulics Laboratory 2007). This flow rate is the design criteria for discharge of the multi-level offtake set by the NSW Department of Commerce (2005). The modelling considered the factors affecting average monthly release temperatures including: the extent of stratification, volume and rate of discharge and natural water temperatures. The modelling showed that the desired fish spawning temperatures can be achieved and sustained during spawning periods when the multi-level offtake discharges 2,000 megalitres per day at the average monthly release temperature.

*Figure 8-1* illustrates the results of the modelling. The effectiveness of the multi-level offtake is represented by the green line and shows achievement of the spawning cues for Murray Cod, Silver Perch, Catfish and Golden Perch. The temperature of water releases for the existing dam operation is represented by the purple line and confirms that the existing dam only briefly achieves spawning cues for one species, the Golden Perch. The dashed lines in *Figure 8-1* show the predicted minimum and maximum water release temperatures.

The effectiveness of the multi-level offtake would diminish for releases in excess of 2,000 megalitres per day. During the period 1993 to 2006, approximately 25% of all releases during spring and summer exceeded 2,000 megalitres per day (Manly Hydraulics Laboratory 2007).

### **8.1.3 Costs**

Total life-cycle costs for the three multi-level offtake options were calculated by summing the capital cost and net present value of the operating and maintenance costs for each option. The roller door intake has the lowest estimated lifecycle cost (\$3.5 million), while the sliding plate intake has the highest estimated capital cost (\$4.7 million). The automatic shutters intake option has an intermediate estimated capital cost (\$3.7 million).

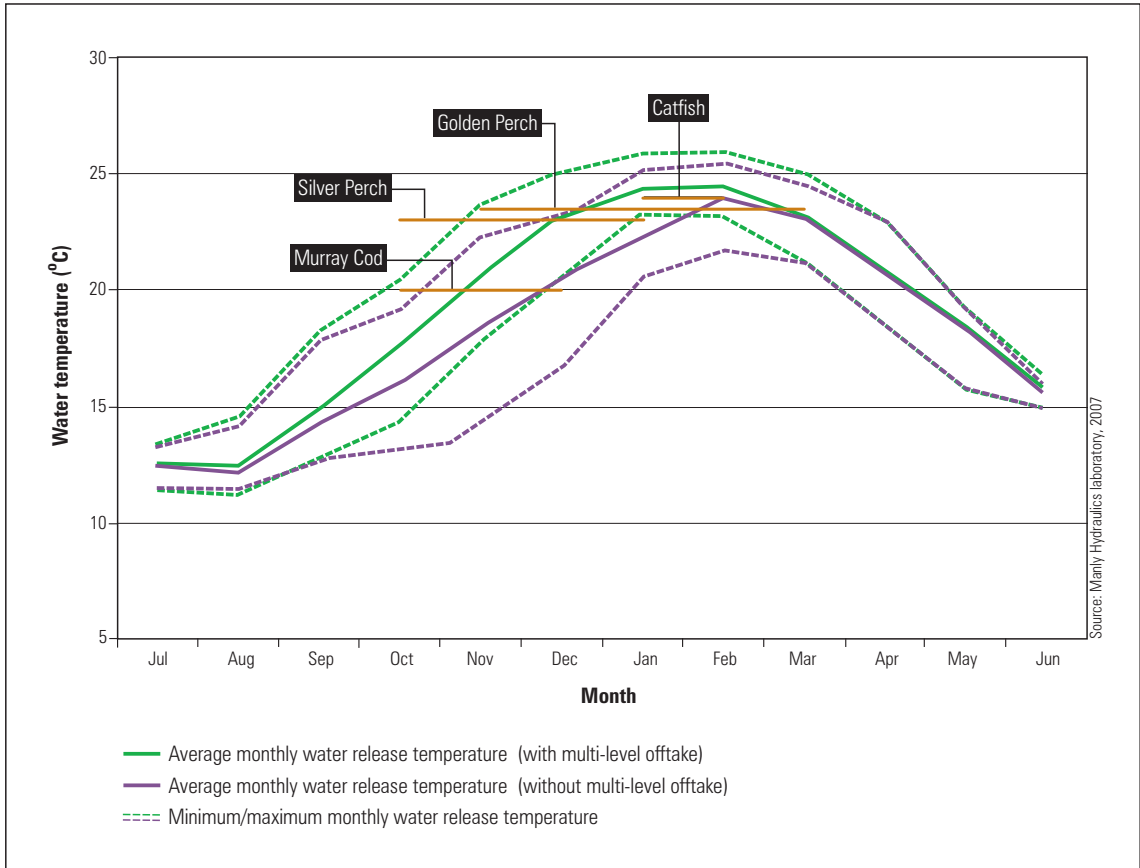


Figure 8-1 Preliminary performance modelling of the multi-level offtake

**Table 8.1 Estimated life cycle costs of the multi-level offtake options**

<b>Multi-level offtake option</b>	<b>Estimated capital cost (\$ million)</b>	<b>Estimated net present value of operating and maintenance costs (\$ million)</b>	<b>Estimated total life cycle costs (\$ million)</b>
Sliding plate intake	4.1	0.5	4.7
Roller door intake	3.0	0.6	3.5
Automatic shutter intake	3.2	0.5	3.7

Source: Department of Commerce 2005

### 8.1.4 Evaluation

The multi-level offtake options were also evaluated in terms of non-financial measures including:

- temperature improvement ability
- operating range and flexibility
- ease of installation and reliability of operations
- maintenance frequency
- occupational health and safety issues.

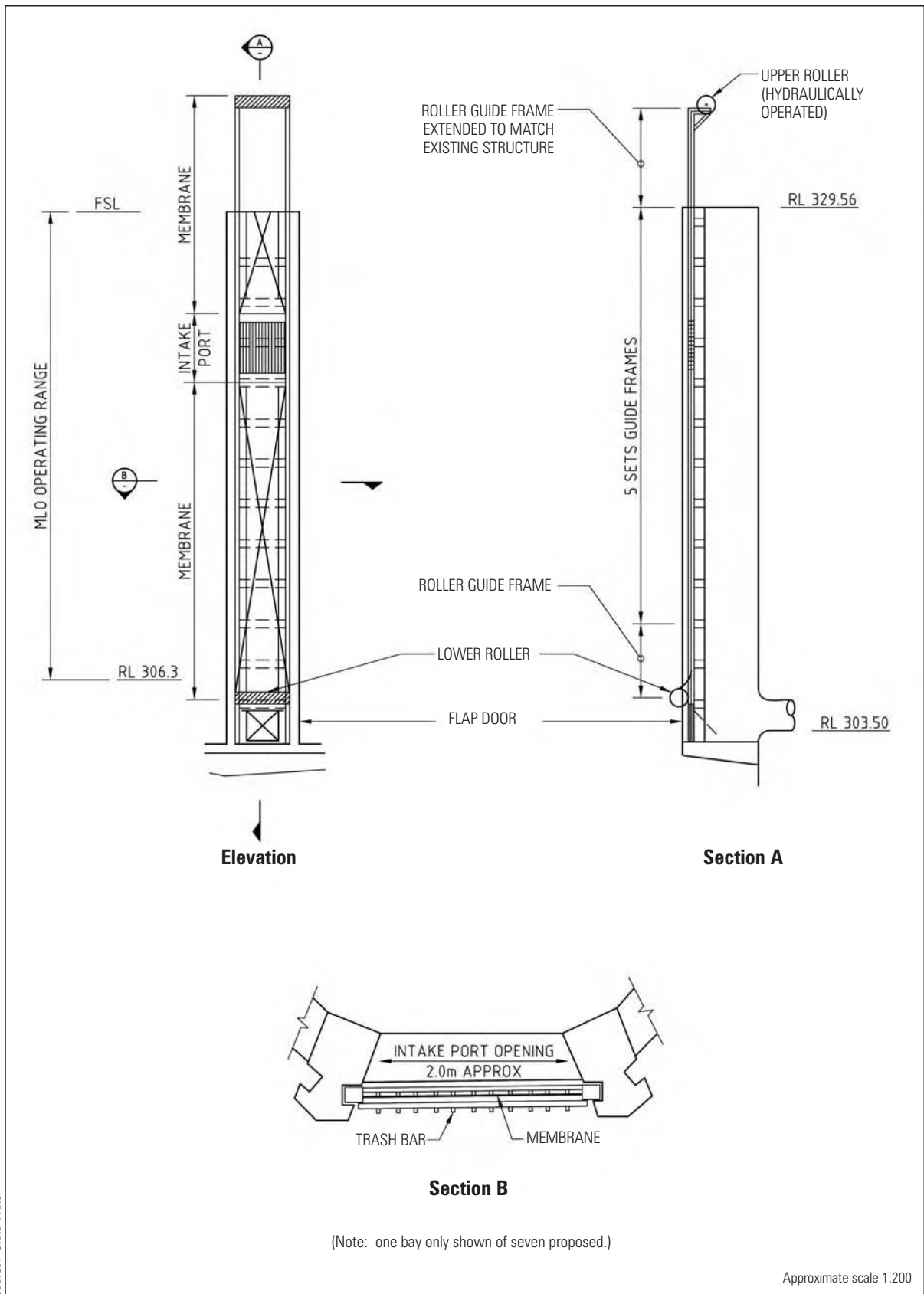
The roller door and automatic shutter intake options scored highest in regard to these criteria, although the overall results favoured the roller door intake option. Based on this outcome, State Water has adopted the roller door intake concept as the preferred option for a multi-level offtake to provide maximum performance and operational flexibility.

A conceptual design of the roller door intake is shown in *Figure 8-2*.

### 8.1.5 Further studies and proposed approach to implementation

If approval is granted for the proposal, State Water would undertake more detailed studies of the effectiveness of the multi-level offtake. This would include a detailed design of the structure and a more accurate cost estimate. A set of operating procedures would also need to be developed based on the expected range of temperature and algal data currently being collected. As part of these procedures, trials of the roller-door design would also be undertaken. Issues associated with the operation of the multi-level offtake would be identified and determined at the subsequent stage of project development as part of the OEMP.

If the results of these studies indicate a high degree of effectiveness, State Water would implement it at the dam. As part of its implementation, State Water would implement an ongoing in-storage and downstream temperature monitoring system to optimise its operation and document its effectiveness.



Source: State Water

Figure 8-2 Concept design of the multi-level offtake

As noted in Section 4.7, the multi-level offtake could be implemented at any point in the future without detriment to its performance.

An additional consideration related to the multi-level offtake is that if it were not implemented, then there would be no benefit from installing any form of fish-passage at the dam since the ability to attract native fish species toward the dam for upstream migration would not be provided. *Section 8.2* provides further information about providing fish-passage at the dam.

## 8.2 Fish passage

### 8.2.1 Preliminary options for fish passage

High-level fishways have been attempted only relatively recently in Australia, with examples on the Pioneer and Burnett Rivers in Queensland and at Yarrowonga on the Murray River. High-level fishways over 30 metres high are also under development at the Tallowa Dam on the Shoalhaven River and at the new Burnett River Dam (Harris 2004). Berghuis *et al.* (2000) reported on the successful use by 22 species of a 15 metre fishlock on the Burnett River. A fishlock is a device that assists the migration of fish over a dam by filling a chamber with water that fish have entered at the base of the dam.

State Water commissioned the Department of Commerce (2003) to investigate the feasibility of three options for fish passage at Keepit Dam. These were a:

- rock ramp fishway
- fish-lift
- vertical slot fish ladder.

Each of these options is described below.

#### *Rock ramp fishway*

This option was for a 2 metre wide and 0.75 metre deep concrete-lined channel following a circuitous route from just downstream of the power station tailrace up to the crest of the dam. The channel would have a bed slope of approximately 1 in 20 and, for every 2 metres change in elevation, there would be a resting pool. The channel would be embedded with rocks to increase hydraulic roughness and simulate a natural river channel.

#### *Fish-lift*

This option was for a fish-lift running behind the training wall adjacent to the power station tailrace area to the downstream toe of the main dam wall. A cage with a minimum depth of water of 1 metre and an approximate capacity of 2.5 cubic metres would operate on the ladder. The cage would be fitted with gates that would open when the cage is at the bottom of the fish ladder and also submerged in the water storage, allowing fish to enter and exit the cage. The gate would be shut when the cage is moving up or down the face of the dam.

### *Vertical slot fish ladder*

This option was for a long, conventional, vertical slot fish ladder along a similar path to that of the rock ramp fishway. However, the ladder would have a slope no greater than 1 in 32, making it an even more circuitous route for fish than the rock ramp fishway.

## **8.2.2 Evaluation**

The three preliminary fish passage options were evaluated by the Department of Commerce (2003), comparing their relative advantages and disadvantages. Based on this comparison, the fish-lift was recommended as the preferred option, on the basis that it had the lowest life-cycle cost option and its advantages were considered to outweigh its disadvantages.

## **8.2.3 Concept development of the fish-lift**

NSW Commerce were engaged by State Water to develop concept of the fish lift. The development of a solution to providing 2-way fish passage at Keepit Dam requires the satisfaction of interacting physical, hydraulic and biological criteria and constraints.

A draft set of preliminary design criteria and requirements for fish passage has been determined (Department of Commerce, 2007) based on proven technology and therefore considered feasible. Further design development work is required to ensure criteria are met to achieve successful fish-lift operation.

### *Upstream of Dam Fish Passage Screens*

A lightweight screen system supported by a floating space truss structure has been developed to exclude fish from the upstream offtakes. Fish migrating in the downstream direction will be attracted by flow entering the dam offtakes meeting the screens and move with the target attraction flow towards the proposed fish lock facility. The screening system relies on the basic searching behaviour of fish.

The proposed screening solution provides an economical means of suspending screens located a long way out from the intakes to ensure velocities are low enough to prevent fish being drawn into the outlets at high flow rates. The screen curtain is designed to be pulled aside prior to spillway operation and removed entirely for cleaning and maintenance. Confirmation of the design loadings and flow behaviour via computational fluid dynamics modelling at the next phase of design will ensure the screening solution meets the design criteria and requirements.

### *Downstream of Dam Fish Passage*

A floating lock structure with constant attraction flow capability is proposed as a luring facility for downstream fish passage. The lock consists of 2 linked chambers; one chamber to attract and capture fish and a second one to provide for the pick up and transfer of fish over the dam wall via a travelling hopper device.

Attraction flow would be delivered through the dam wall via a 300mm diameter flexible pipe. Installing the offtake through the dam wall would involve directional drilling and upstream underwater temporary baulking work. A crane system of 8 to 10 tonne capacity is proposed to transfer the hopper device through the dam crest. The means for transferring the hopper to the downstream outlet works dissipater pool is a track and winch system used for upstream fish passage. A bulkhead gate is required to be fabricated for installation across the opening in the dam crest during extreme flood events.

#### Upstream of Dam Fish Passage

A preliminary concept for trapping and conveying upstream migrating fish up and over the dam has been developed utilising similar features to the recently designed fish lift facility at Tallowa Dam.

Construction of a fish guiding weir below the dam outlet works is required to attract fish to the fish lift entrance and to create a raised pool for releasing fish migrating downstream. The pool would also serve to dissipate high energy flows emanating from the dam outlets. An extension of the spillway dissipater side wall would also be required to form the raised pool and to train spillway flows clear of the new fish passage works. Fish passage is not catered for under conditions of flood release via the spillway gates.

The estimated capital cost for providing a total fish passage solution at Keepit Dam is \$21 million (November 2007 prices).

A concept design of the fish-lift is shown in *Figures 8-3 and 8-4*.

### **8.2.4 Proposed approach to implementation**

Subsequent to the issue of the Director-General's Environmental Assessment requirements for the Keepit Dam Upgrade, the Department of Primary Industries agreed that the investigation of fish passage could extend beyond the public exhibition phase of the Environmental Assessment process.

In conjunction with the Department of Primary Industries (Fisheries), State Water will progress its investigations into the feasibility of fish passage at Keepit Dam following public exhibition of the Environmental Assessment.

Should fish passage be required at Keepit Dam and funding is available, State Water would implement an appropriate means of fish passage in accordance with a timeframe agreed with the Department of Primary Industries (Fisheries) and the Director-General of the Department of Planning. The performance of the fish passage would be recorded and reported to the Director-General and Department of Primary Industries (Fisheries).

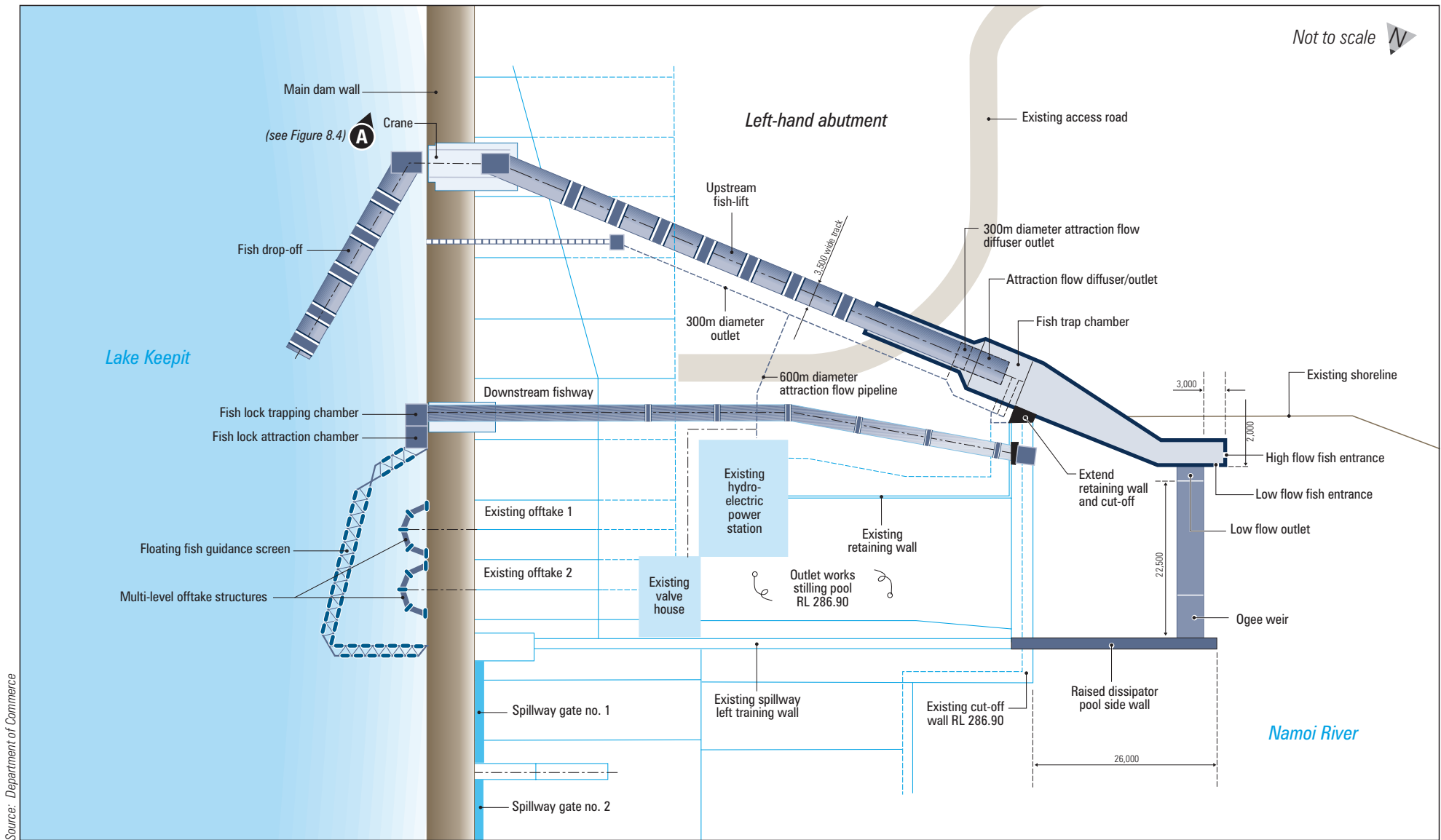
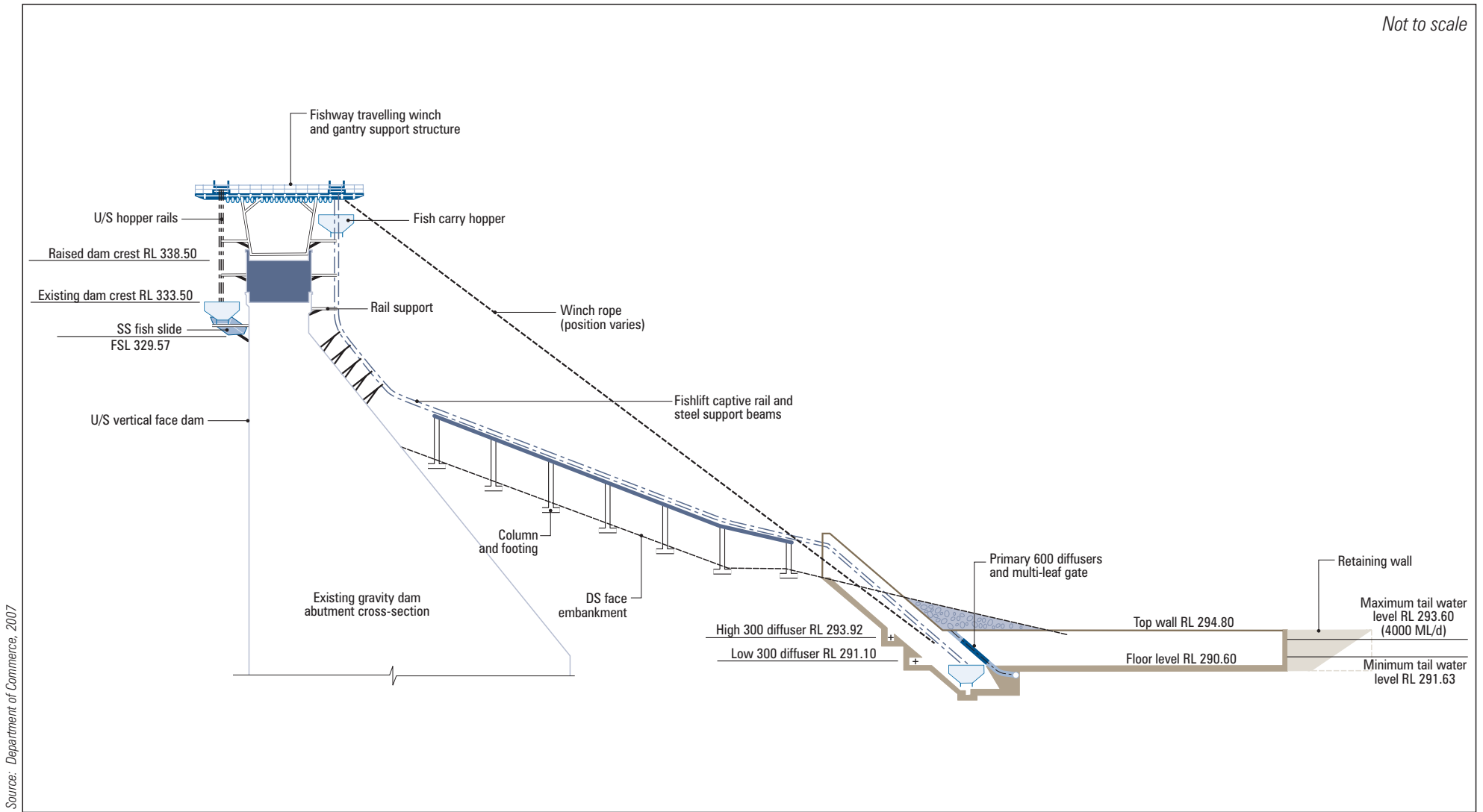


Figure 8-3 Concept design of fish passage at the main dam wall - plan

Not to scale



Source: Department of Commerce, 2007

Figure 8-4 Concept design of fish passage at the main dam wall - longitudinal section

## 9. Draft Statement of Commitments

Table 9.1 provides a summary of the draft Statement of Commitments for the proposed Keepit Dam Upgrade, which, in accordance with the assessment process, would be finalised following exhibition of the Environmental Assessment and receipt of public submissions (refer Section 1.6.4). The Table should be read in conjunction with Appendix D, which provides details of 45 commitments by State Water to the processes and procedures that would apply to enhance the benefits and reduce the impacts of the proposal.

**Table 9.1 Summary of the draft Statement of Commitments**

<b>Issues</b>	<b>Outline of commitments/mitigation measures</b>
<i>Administration</i>	
The activity	The activity would be carried out consistent with the procedures, safeguards and mitigation measures identified in this Environmental Assessment.
Compliance	State Water would ensure (as reasonably practical) compliance with all of its commitments. Pre-construction and Pre-operation Compliance Reports would be submitted to the Director-General of the Department of Planning prior to construction, and Construction Compliance Reports would be provided to the Director-General and relevant councils at 6 monthly intervals during construction.
Environmental impact audits	An Environmental Impact Audit Report (Construction) would be submitted to the Director-General a maximum of 3 months after construction is complete.  An Environmental Impact Audit Report (Operation) would be submitted to the Director-General a maximum of 24 months after the activity begins operation.
<i>Environmental management – construction</i>	
Environmental Management System	The successful contractor would be required to demonstrate an externally certified Environmental Management System (EMS) in accordance with ISO 14000.
Construction management	A Construction Environmental Management Plan (CEMP) would be prepared and would incorporate the mitigation measures contained in the draft Statement of Commitments.
Environmental Management Representative	The Director-General's approval would be sought for the appointment of an Environmental Management Representative (EMR) to advise the Director-General and State Water on compliance with the draft Statement of Commitments.
Communication and consultation	The community would be informed of construction works through advertisements in relevant newspapers and an internet site.  A community liaison group would be established and maintained for the duration of construction.  A construction complaints management system would be implemented before construction commences.
Terrestrial ecology	The CEMP would include a Flora and Fauna Sub Plan. The Sub Plan would include standard measures to manage and mitigate impacts to terrestrial flora and fauna.  A biodiversity strategy to offset these impacts would be further developed in conjunction with the NSW Department of Environment and Climate Change following any approval.
Aquatic ecology	The CEMP would include a Flora and Fauna Sub Plan. The Sub

Issues	Outline of commitments/mitigation measures
	<p>Plan would include standard measures to manage and mitigate impacts to aquatic flora and fauna.</p> <p>A biodiversity offset strategy would be prepared in accordance with the conditions of planning approval.</p> <p>The level of risk to fish passage attributable to Keepit Dam and potential ameliorative measures would be evaluated.</p> <p>The cost-effectiveness of the preferred option for multi-level offtake would be evaluated.</p>
Heritage	<p>The CEMP would include an Indigenous Heritage Management Sub Plan and a Historical Heritage Management Sub Plan. The Sub Plans would include both standard and site-specific measures to avoid and minimise impacts to cultural heritage sites.</p>
Noise and vibration	<p>The CEMP would include a Construction Noise and Vibration Management Sub Plan. The Sub Plan would include standard noise and vibration management and mitigation measures.</p> <p>The draft Statement of Commitments (in <i>Appendix D</i>) defines the construction hours and includes a construction noise objective and vibration criteria.</p> <p>Blasting would be managed to minimise annoyance to the local community.</p>
Soil and water quality management	<p>The CEMP would include a Soil and Water Quality Management Sub Plan. The Sub Plan would contain standard erosion and sedimentation mitigation measures and standard water quality management measures.</p>
Air quality	<p>The CEMP would include a Dust Management Sub Plan. The Sub Plan would contain standard dust management measures.</p>
Greenhouse gases and sustainable energy	<p>Measures to minimise greenhouse gas emissions would be implemented.</p>
Social and economic issues	<p>Property inspections would be conducted on all structures (other than structures owned by State Water) in the vicinity of the construction works. These would be used to identify any property damage due to the construction works. State Water would rectify any property or building damage caused by the construction works at no cost to the property owner(s). Alternatively State Water may negotiate just compensation for the property damage with the property owner.</p>
Traffic	<p>A master plan and sub plans would be prepared for affected areas of Lake Keepit State Park in conjunction with the affected recreational entities.</p> <p>Road dilapidation surveys would be prepared for all public roads likely to be used by construction traffic. These would be used to identify any damage caused by construction vehicles.</p> <p>The CEMP would include a Construction Traffic Management Sub Plan. The Sub Plan would contain standard measures to manage and mitigate traffic impacts.</p>
Visual impact and landscaping	<p>The CEMP would include a Visual Impact, Landscaping and Revegetation Sub Plan. The Sub Plan would be prepared in consultation with the community liaison group and Lake Keepit State Park Trust. The Sub Plan would present an integrated landscaping and revegetation design for the activity and would be consistent with the master plan prepared for affected areas of Lake Keepit State Park in conjunction with the Lake Keepit State Park Trust.</p>
Hazards and	<p>The CEMP would include a Hazards and Risk Management Sub</p>

Issues	Outline of commitments/mitigation measures
risk management	Plan. The Sub Plan would contain standard measures to avoid, minimise and manage hazards and risks. This would include the identification and management of any contamination land.
Waste management and recycling	The CEMP would include a Waste Management and Re-use Sub Plan. The Sub Plan would contain standard measures to avoid, minimise and manage waste in accordance with the NSW Government's Waste Reduction and Purchasing Policy.
Utilities and services	Any required alterations to utilities and services would be determined by negotiation between State Water and the relevant service provider(s).
<i>Environmental management - operation</i>	
Operational management	An Operation Environmental Management Plan (OEMP) would be prepared and would incorporate the operational mitigation measures contained in the draft Statement of Commitments. The OEMP will also identify any statutory obligations that State Water is required to fulfil during the activity's operation, including all approvals and licences.
Terrestrial ecology	The Director-General would be provided with annual reports on the implementation and management of the elements of the biodiversity offset strategy for a period of 5 years following completion of construction.
Aquatic ecology	The Director-General would be provided with annual reports on the implementation and management of the elements of the biodiversity offset strategy for a period of 5 years following completion of construction.
	Subject to confirming the cost-effectiveness of the multi-level offtake, an in-storage and downstream monitoring system would be implemented to support the operation of the multi-level offtake. The results of its operation would be included in the OEMP. The operation of the multi-level offtake would be optimised to improve performance based on operational experience and, where necessary, improvements made to the supporting monitoring system.
Social and economic issues	State Water, where liable, would rectify any property or building damage caused by operation of the dam at no cost to the property owner(s). Alternatively State Water may negotiate just compensation for the property damage with the property owner.

## 10. Justification and conclusion

### 10.1 Achievement of the project objectives

The objectives of the proposed Keepit Dam Upgrade were described in *Section 3.5* and are to:

- improve dam safety
- reduce downstream inundation
- improve environmental outcomes
- support sustainable regional economic development.

This Section outlines how the proposal responds to these objectives.

#### 10.1.1 Improve dam safety

The proposal was designed to comply with the safety requirements of the NSW Dams Safety Committee for extreme consequence dams. There is no difference in the level of achievement of these requirements by the three dam safety upgrade options.

#### 10.1.2 Reduce downstream inundation

The proposal would increase the frequency of inundation for a limited range of floods between 1:2,400 and 1:2,800 AEP. However, the proposal would reduce the level of downstream inundation for floods larger than 1:2,800 AEP compared to the base case of dam failure.

The dam is unable to provide a reduction in damage caused by small to medium floods as anticipated in this objective. This outcome is precluded by the small storage capacity of Keepit Dam relative to the large size of the upstream catchment area and limitations on the ability of the infrastructure to simultaneously mitigate small, high frequency floods as well as to withstand very large to extreme, but low frequency floods.

Improvement of the flood early warning system for Keepit Dam was undertaken as part of the interim safety measures completed in March 2003, which will remain following implementation of the proposal. Thus, some improvement in the ability to predict flood events will be achieved however separately from the proposal.

#### 10.1.3 Improve environmental outcomes

During a catastrophic natural event, such as an extreme flood or earthquake, implementing the proposal would avoid approximately \$1.7 billion of direct damage and loss to downstream areas, and potential significant loss of human life. Proceeding with the proposal would also reduce attendant impacts on broader environmental elements, including Indigenous and non-Indigenous heritage sites, parks and reserves, and aquatic and terrestrial ecosystems.

The proposal includes two measures to improve environmental outcomes: a multi-level offtake and fish passage. Installation of the multi-level offtake would provide the ability to discharge waters from levels of the reservoir other than the colder, bottom layers. The increased temperature of the dam water releases would as a result be more consistent with the ambient downstream river temperatures. This would act to improve the spawning cues for native fish species that are precluded by current release arrangements.

A fishway and fish-lift would also be installed at the main dam wall, subject to further investigation of its cost-effectiveness. State Water has committed to proceeding with these investigations post-determination of the proposal and, if it can be proven cost-effective, proceeding with its implementation.

Implementation of either, or both, the multi-level offtake and fish-lift, with optimisation of their operation, is likely to improve the operational impacts of the existing dam.

#### **10.1.4 Support sustainable regional economic development**

A number of aspects or sub-objectives were defined to clarify this objective. These along with the proposal response are outlined below:

- *improving the efficiency and reliability of delivering water* – Investigations to increase the storage capacity of the existing dam were undertaken, however, for a variety of reasons as outlined in *Section 3.6.2*, this does not form part of the proposal.
- *increasing the capacity of the existing hydro-electric power station* – This was investigated (refer *Section 3.6.2*), however for economic reasons, does not form part of the proposal.
- *minimising impacts on social and community infrastructure including issues such as heritage, visual, land use and infrastructure* – The dam safety upgrade options would result in a range of social impacts and on community infrastructure surrounding the dam. Some of these impacts would be associated with construction, while others are less likely to occur and would only result if a very large to extreme storm occurred. These impacts would be reduced by implementing the proposed mitigation measures and are outweighed by the benefits of proceeding with the proposal.
- *achieving the most economic solution (i.e. least cost to achieve the project objectives)* – The capital costs of the dam safety upgrade options range from \$75 million to \$89 million (March 2007 estimates). State Water has indicated it will proceed with the least-cost, environmentally acceptable option.
- *enhancing the recreational quality of Lake Keepit* – A master plan would be prepared in consultation with the Lake Keepit State Park Trust to maintain the recreational quality of Lake Keepit and its surrounds. Depending on the dam safety upgrade option selected, there is a varying need to provide new or reprovisioned facilities as part of this master plan.

## 10.2 Consideration of the principles of ecologically sustainable development

The four principles of ecologically sustainable development (ESD) are outlined in Section 6(2) of the *Protection of the Environment Administration Act 1991* and Schedule 2 of the Environmental Planning and Assessment Regulation 2000. In summary, the principles are:

- *the precautionary principle* — If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- *intergenerational equity* — The present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations.
- *conservation of biological diversity and ecological integrity* — The diversity of genes, species, populations and their communities, as well as the ecosystems and habitats they belong to, should be maintained or improved to ensure their survival.
- *improved valuation, pricing and incentive mechanisms* — Environmental factors should be included in the valuation of assets and services.

The *State Water Corporation Act 2004* and the *State Owned Corporation's Act 1989* require that State Water conducts its activities in accordance with the principles of ESD as outlined in the *Protection of the Environment Administration Act 1991*. Accordingly, the above principles have been considered in planning for the proposal.

*Table 10.1* outlines how the principles have been considered in planning for the proposal.

**Table 10.1 Consideration of the principles of ESD**

Principle	How the principle has been considered
The precautionary principle	<ul style="list-style-type: none"> <li>▪ The Environmental Assessment has considered and analysed the available scientific opinion and data, and considered the extent of scientific certainty, related to various issues.</li> <li>▪ A detailed assessment of numerous alternatives to the proposal was undertaken and the alternatives which would best achieve the desired outcomes were selected.</li> <li>▪ The precautionary principle was considered during the scoping of all technical studies and during consultation with government authorities, the community and other stakeholders.</li> <li>▪ Potential threats of serious or irreversible damage were identified and assessed in the Environmental Assessment.</li> <li>▪ Frequencies of occurrence were predicted for impacts that would cause serious or irreversible damage. This will enable project stakeholders to consider whether the risk of occurrence is sufficiently low to offset the impact predicted. The public exhibition period will provide stakeholders with the opportunity to comment on the risks of the project.</li> <li>▪ A panel of experts was convened to consider the erosion and</li> </ul>

Principle	How the principle has been considered
	<p>sedimentation effects of the dam safety options when a lack of scientific certainty or data was identified.</p> <ul style="list-style-type: none"> <li>▪ Additional flood warning systems have been implemented to provide more timely warnings to emergency services and the local community of possible flood events.</li> <li>▪ Steps to improve the reliability of the existing spillway gate operation have been implemented.</li> <li>▪ Aboriginal groups have been asked to advise whether the collection and re-location of objects downstream of auxiliary spillways, which would be potentially lost during a large to extreme storm, is warranted.</li> </ul>
Intergenerational equity	<ul style="list-style-type: none"> <li>▪ The proposal would avoid dam failure in extreme natural events, thereby preventing \$1.7 billion in direct damages and the potential for significant loss of human life.</li> <li>▪ The level of downstream inundation would be reduced relative to the 'do nothing' situation.</li> <li>▪ A range of dam safety upgrade options is proposed with a corresponding range of capital costs and economic efficiencies.</li> <li>▪ The proposal would not preclude a future increase in the full supply level of the dam.</li> </ul>
Conservation of biological diversity and ecological integrity	<ul style="list-style-type: none"> <li>▪ Potential impacts on species and vegetation communities of local, regional, state and national significance were identified and mitigation measures defined.</li> <li>▪ A biodiversity offset strategy is proposed to offset the flora and fauna impacts of the proposal that cannot be adequately addressed by mitigation measures alone.</li> <li>▪ The proposal includes environmental improvements to the dam operation, subject to confirming cost-effectiveness and availability of funding. These could be implemented separately to the dam safety upgrade at any time without detrimental effect on their performance.</li> <li>▪ The dam safety options variously provide for reduced impacts on identified threatened species of plant and heritage items.</li> </ul>
Improved valuation, pricing and incentive mechanisms	<ul style="list-style-type: none"> <li>▪ State Water has conducted extensive consultation with local land owners, the local community, relevant government agencies and other project stakeholders to gauge community views and values.</li> <li>▪ The project economic evaluation included modelling the performance of the environmental improvements. This work is ongoing at the time of exhibition of this Environmental Assessment.</li> </ul>

### 10.3 Future decision making

The Concept Plan for the proposal described in *Section 4* outlines three options for improving dam safety and two environmental improvements proposed by State Water. The environmental benefits and impacts of each of these elements have been assessed to a similar level of detail in this Environmental Assessment.

State Water will consider all available project information but principally the information contained in this document and the submissions received from the public and other project stakeholders arising from public exhibition, before making a decision on a preferred upgrade option. The preferred upgrade option will be identified in the Preferred Project Report, along with a request for approval by the Minister for Planning and the Commonwealth Minister for the Environment.

A meeting of the State Water Board held in August 2007 resolved that:

“State Water will adopt the least cost environmentally acceptable option and will not be seeking funding to pursue a higher cost option. Based on the Draft Environmental Assessment, Option B1 is currently considered by State Water to be the least cost environmentally acceptable option”.

## 10.4 Conclusion

The proposed Keepit Dam Upgrade would meet the safety requirements of the NSW Dams Safety Committee for extreme consequence dams. The upgraded dam would be able to withstand very large to extreme floods and severe earthquakes. The upgrade would result in the avoidance of approximately \$1.7 billion of direct damages to downstream areas and significant loss of human life.

This Environmental Assessment has investigated the key issues associated with the proposal to upgrade Keepit Dam. The assessment has concluded that the construction impacts would likely be manageable given the commitments made by State Water and that the operational impacts would occur very rarely, if at all within the 200-year lifetime of the dam. If such a large flood, sufficient to trigger the proposed auxiliary spillways were to occur, the resulting social and economic damages would be likely to render environmental issues a lower priority and, in this context, the environmental impacts of all the options are considered acceptable. Option B1 is considered to best meet the project objectives and is superior in relation to construction issues and finance and economics. The proposed multi-level-offtake and fish passage are likely to result in benefits to the environment, however, these are subject to further studies of cost-effectiveness availability of funding.

State Water has discharged its obligations under the NSW and Commonwealth environmental legislation by assembling and evaluating options to resolve the safety of Keepit Dam and undertaking a comprehensive community and stakeholder consultation process. This has resulted in a multi-faceted proposal which is likely to substantially improve a number of impacts associated with the existing dam.

The Environmental Assessment has concluded that the environmental benefits of the proposal substantially outweigh the environmental impacts and therefore submit this proposal to upgrade Keepit Dam for approval by the relevant State and Commonwealth authorities.

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