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Environmental Impact Statement – Chapter 5: Project description

Warragamba Dam Raising

Reference No. 30012078
Prepared for WaterNSW
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SMEC INTERNAL REF. 30012078

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5 Project description

This chapter provides a description of the Project covering its construction and operation. The relevant Secretary's Environmental Assessment Requirements (SEARs) are shown in Table 5-1.

Table 5-1. Secretary's Environmental Assessment Requirements: Project description

Desired performance outcomes	Secretary's Environmental Assessment Requirements[1]	Where addressed
2. Environmental impact statement The project is described in sufficient detail to enable clear understanding that the project has been developed through an iterative process of impact identification and assessment and project refinement to avoid, minimise or offset impacts so that the project, on balance, has the least adverse environmental, social and economic impact, including its cumulative impacts.	b) a description of the project, including all components and activities (including ancillary components and activities) required to construct and operate it	This chapter

1 Note: this chapter specifically addresses SEAR 2 in addition to those general requirements of the SEARs applicable to all chapters and as identified as such in Chapter 1 (Section 1.5, Table 1-1).

5.1 The Project

Warragamba Dam Raising is a project to provide flood mitigation to reduce the significant existing risk to life and property in the Hawkesbury-Nepean Valley downstream of the dam. This would be achieved through raising the level of the central spillway crest by around 12 metres and the auxiliary spillway crest by around 14 metres above the existing full supply level (FSL) for temporary storage of inflows. The spillway crest levels and outlets control the extent and duration of the temporary upstream inundation. There would be no change to the existing maximum volume of water stored for water supply.

The NSW Government announcement in 2016 proposed that the dam wall be raised by 14 metres. Subsequently, the SEARs required the project to be designed, constructed and operated to be resilient to the future impacts of climate change and incorporate specific adaptation actions in the design.

Peer reviewed climate change research found that by 2090 it is likely an additional three metres of spillway height would be required to provide similar flood mitigation outcomes as the current flood mitigation proposal. Raising the dam side walls and roadway by an additional three metres may not be feasible in the future, both in terms of engineering constraints and cost. The current design includes raising the dam side walls and roadway by 17 metres now to enable adaptation to projected climate change. Any consideration of raising spillway heights is unlikely before the mid to late 21st century and would be subject to a separate planning approval process.

The 17 metre raising height of the dam abutments (side walls) and roadway have been considered and accounted for in the EIS and design. The potential maximum height and duration of upstream inundation remains consistent with what was originally proposed in 2016.

The Project would include the following main activities and elements:

- demolition or removal of parts of the existing Warragamba Dam, including the existing drum and radial gates
- thickening and raising of the dam abutments
- thickening and raising of the central spillway
- new gates or slots for discharge of water from the flood mitigation zone (FMZ)
- modifications to the auxiliary spillway
- operation of the dam for flood mitigation
- environmental flow infrastructure.

The Project would take the opportunity, during the construction period for the dam raising, to install the physical infrastructure to allow for management of environmental flows as outlined in the NSW Government's *2017 Metropolitan Water Plan*. However, the actual environmental flow releases do not form part of the Project and are subject to administration under the *Water Management Act 2000*.

5.1.1 Location

Figure 5-1 shows the local and regional context of the Project. The Project site is located approximately 65 kilometres west of the Sydney Central Business District in the Wollondilly Local Government Area (LGA). To the west of the Project site are the Blue Mountains, various national parks and state conservation areas, and the Greater Blue Mountains World Heritage Area (GBMWHA), which make up part of the catchment of Lake Burragorang - the water storage formed by Warragamba Dam. To the east of the Project site are the Warragamba and Silverdale townships and surrounding rural residential areas.

5.1.2 Construction area

Figure 5-2 shows the construction area for the Project including:

- ancillary facilities such as coffer dams, batch plants, material storage areas, and worker facilities
- areas that require clearing of vegetation to allow for construction and access
- areas directly impacted by construction works
- areas that would be used for construction activities but would not be modified by the Project (for example, existing roads, Lake Burragorang).

5.2 Main activities and elements

Figure 5-3 shows the existing dam with its relevant key features. Figure 5-4 shows the modified dam after the Project works have been completed. The Project works include:

- demolition
- thickening and raising of dam abutments
- thickening and raising of central spillway
- modifications to the auxiliary spillway
- other infrastructure and elements
- environmental flow infrastructure.

These are described in further detail as follows.

The Project works reflect the current level of design, and may be modified through further design development.

5.2.1 Demolition

Elements of the existing Warragamba Dam require demolition or removal to enable dam raising construction to proceed. These include:

- the existing road and main spillway bridge across the top of the dam
- the drum and radial gates, and associated mechanical and electrical infrastructure, and portions of the piers within the central spillway
- minor concrete structures to allow the tie-in of the new dam and spillway
- the valve house control room building located at the rear of the valve house
- areas of roads, operational laydown areas, drainage systems and other infrastructure external to, but associated with, the dam
- the existing gantry crane and associated equipment
- the existing hydroelectric power station equipment to allow for new environmental flow infrastructure
- miscellaneous dam crest services and equipment.

Figure 5-1. Project location

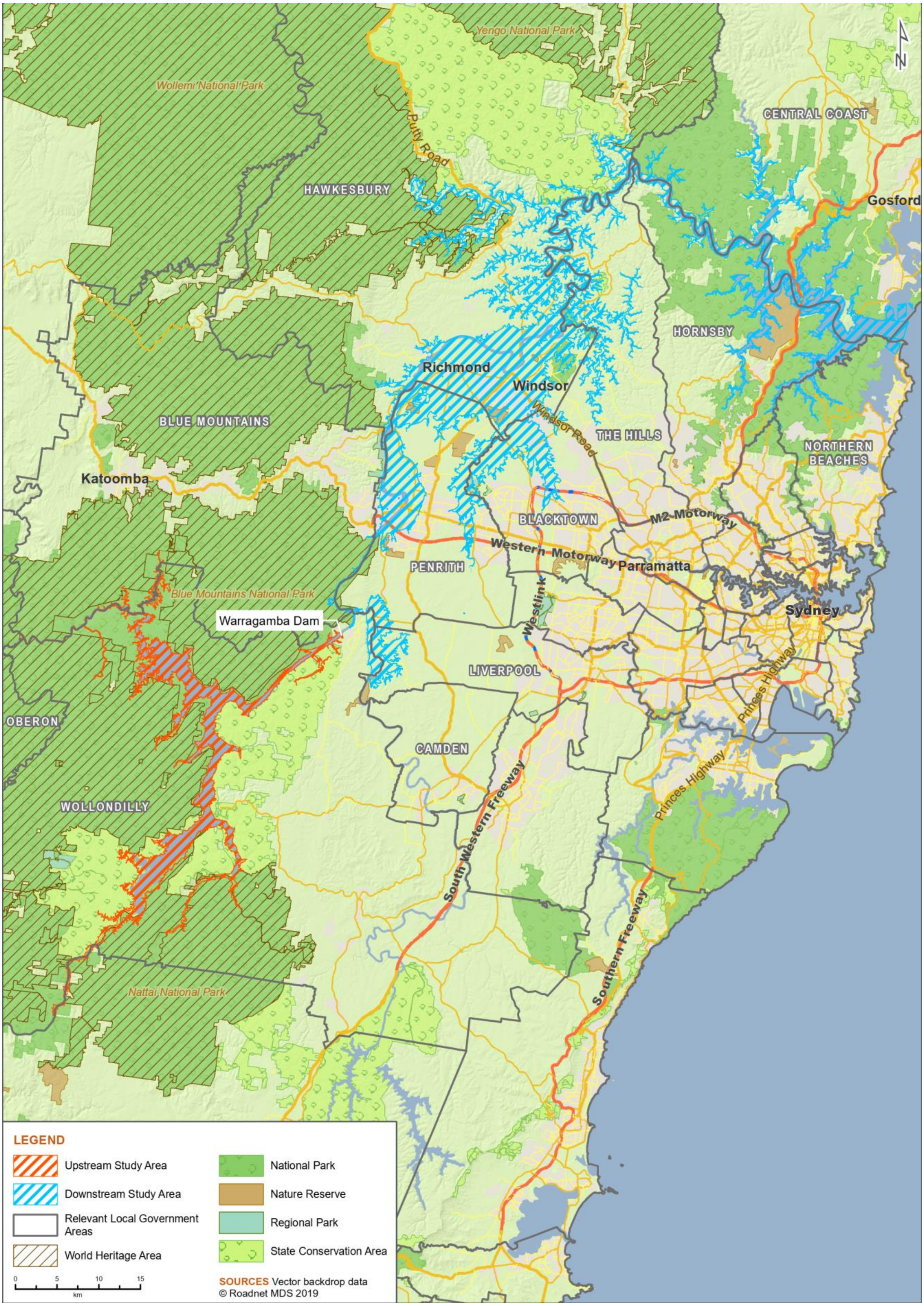


Figure 5-2. Construction area

Figure 5-3. Aerial view of existing dam and features

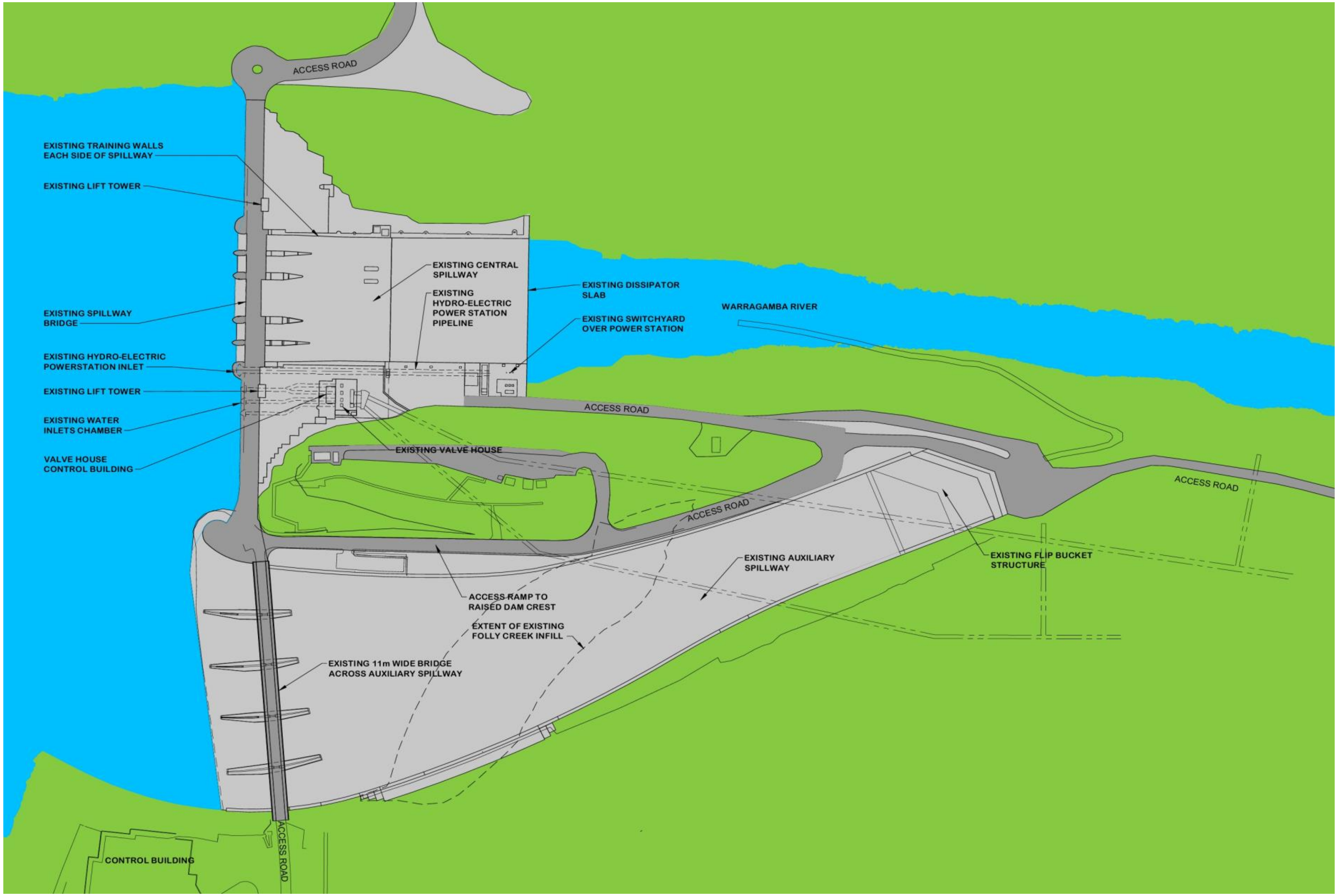
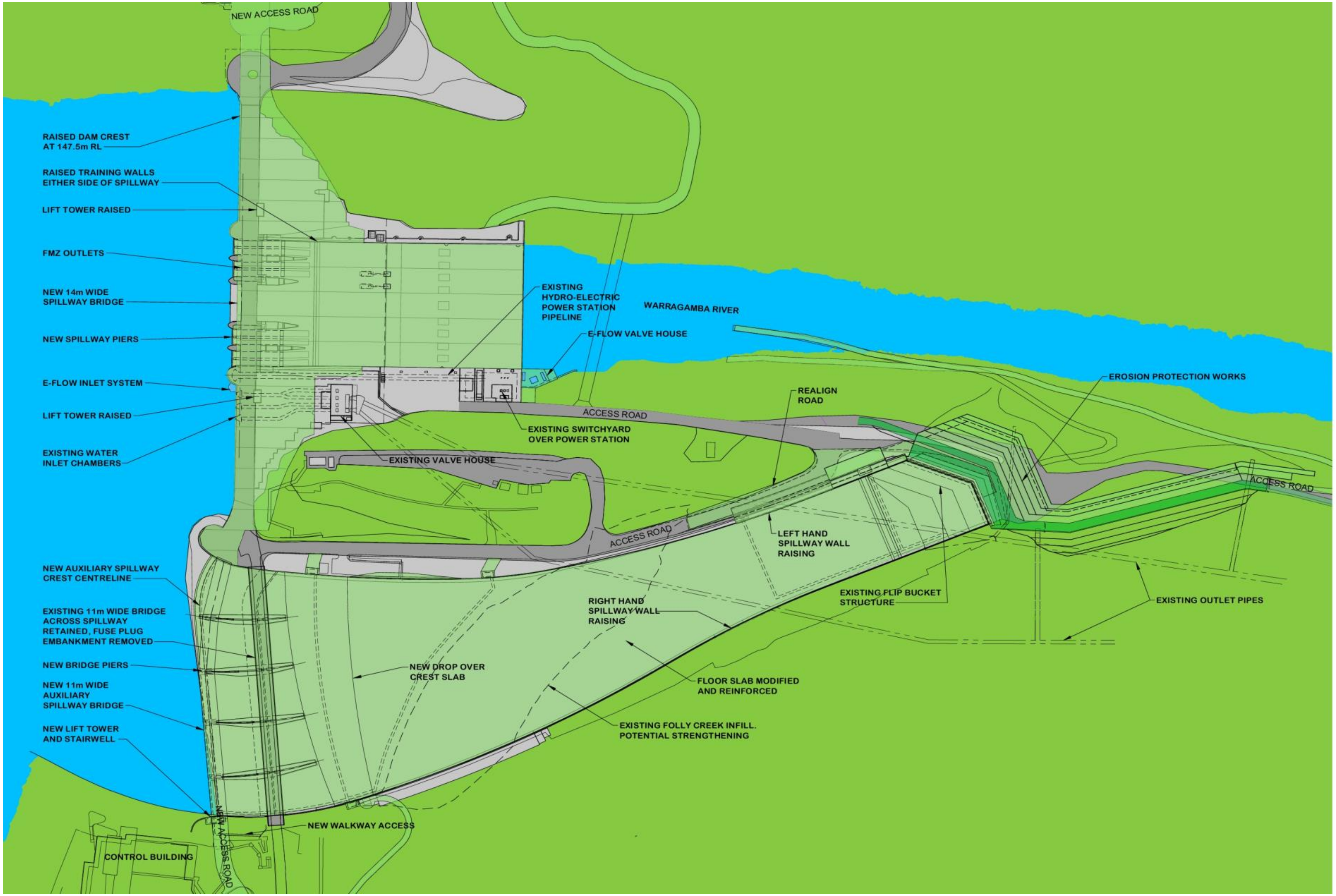


Figure 5-4. Aerial view of modified dam from the proposed Project works



5.2.2 Thickening and raising of the dam abutments

The dam abutments, located either side of the central spillway, would be modified as follows (Figure 5-5):

- dam abutments would be thickened on the downstream side with additional concrete. The face of the abutments would be smooth as with the existing dam
- the abutment height would be increased by approximately 17 metres which includes approximately three metres for resilience to potential future climate change impacts
- the left abutment would extend into the surrounding rock to suit the thickening and raising.

5.2.3 Thickening and raising of the central spillway

The existing central spillway would be modified as follows (Figure 5-6):

- the spillway would be thickened on the downstream face with concrete and it would have a smooth surface
- the spillway crest would be raised by approximately 12 metres to create a flood mitigation zone, including the use of post tensioned anchors within the wall for stability
- gated conduits or slots would be constructed within the central spillway to allow for the controlled discharge of inflows. These openings would be located so the flood mitigation zone could be drawn back down to FSL.

5.2.4 Modifications to the auxiliary spillway

The following modifications would be undertaken on the auxiliary spillway (Figure 5-7):

- removal of the existing fuse plugs (earth/rock embankments designed to wash away in a major flood) and replacement with a concrete spillway crest
- the spillway floor slabs and walls would be modified and reinforced to suit discharging of flood water from the raised dam
- erosion protection would be provided downstream from the auxiliary spillway.

The existing bridge across the auxiliary spillway would be retained for access to the valve house and the base of the dam and spillway.

5.2.5 Other infrastructure and elements

Other infrastructure and elements would include:

- a new bridge would be built above the auxiliary spillway crest to provide access to the raised dam
- the raised abutments and central spillway bridge would allow for vehicle and pedestrian access across the top of the dam, connecting to the approaches and road network on either side of the dam
- new control and instrumentation equipment including mechanical, electrical and communications elements
- new landscaping and urban design features would be provided for areas disturbed by construction and for other areas that require improved integration to the new dam structure
- ancillary works to tie existing services into the raised dam
- the existing two lift towers would be modified to suit the raised dam
- the eel passageway on the left bank would be modified to continue to allow the migration of eels from the river to Lake Burragorang.

Figure 5-5. Cross-section of abutment works

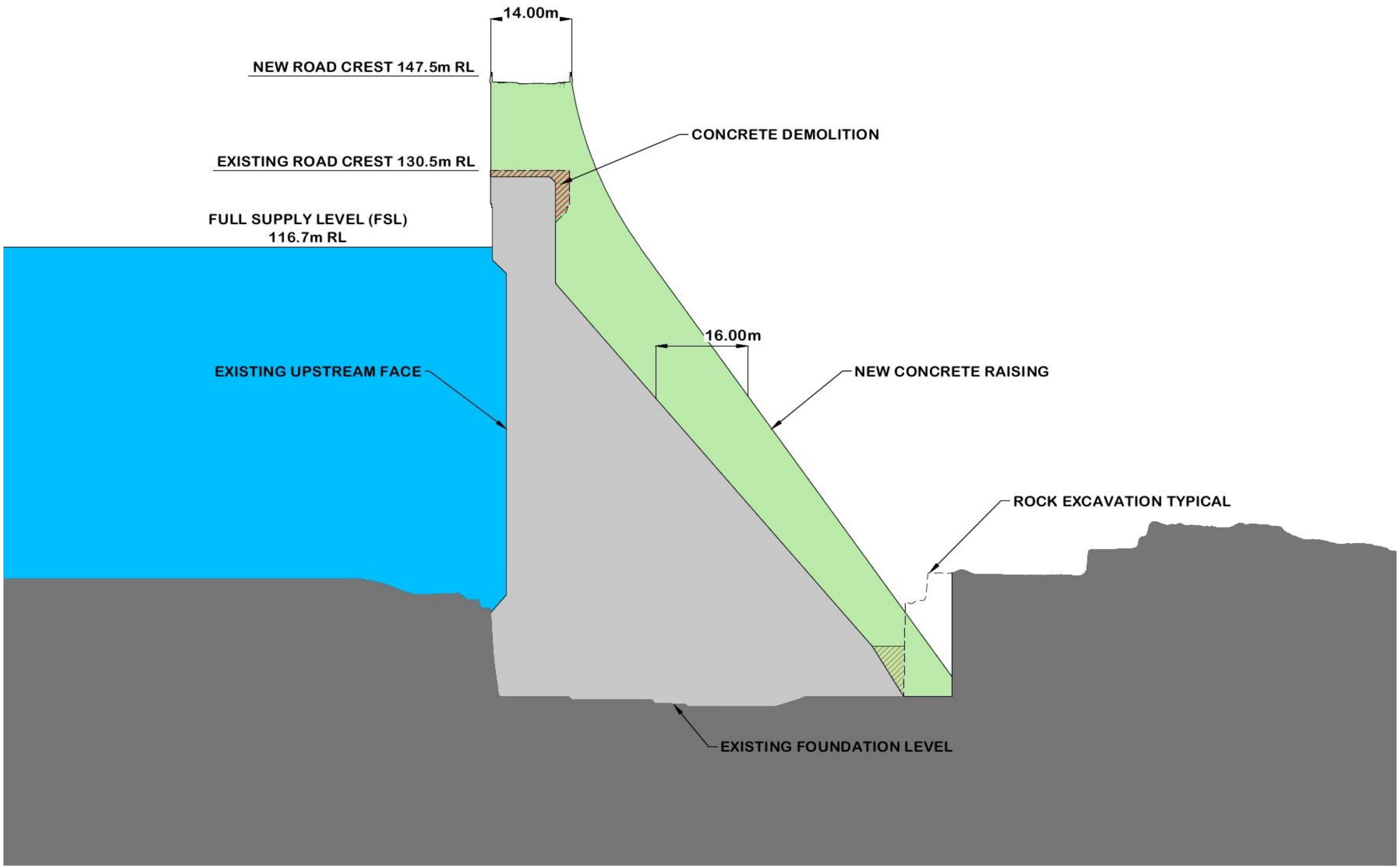


Figure 5-6. Cross section of central spillway works

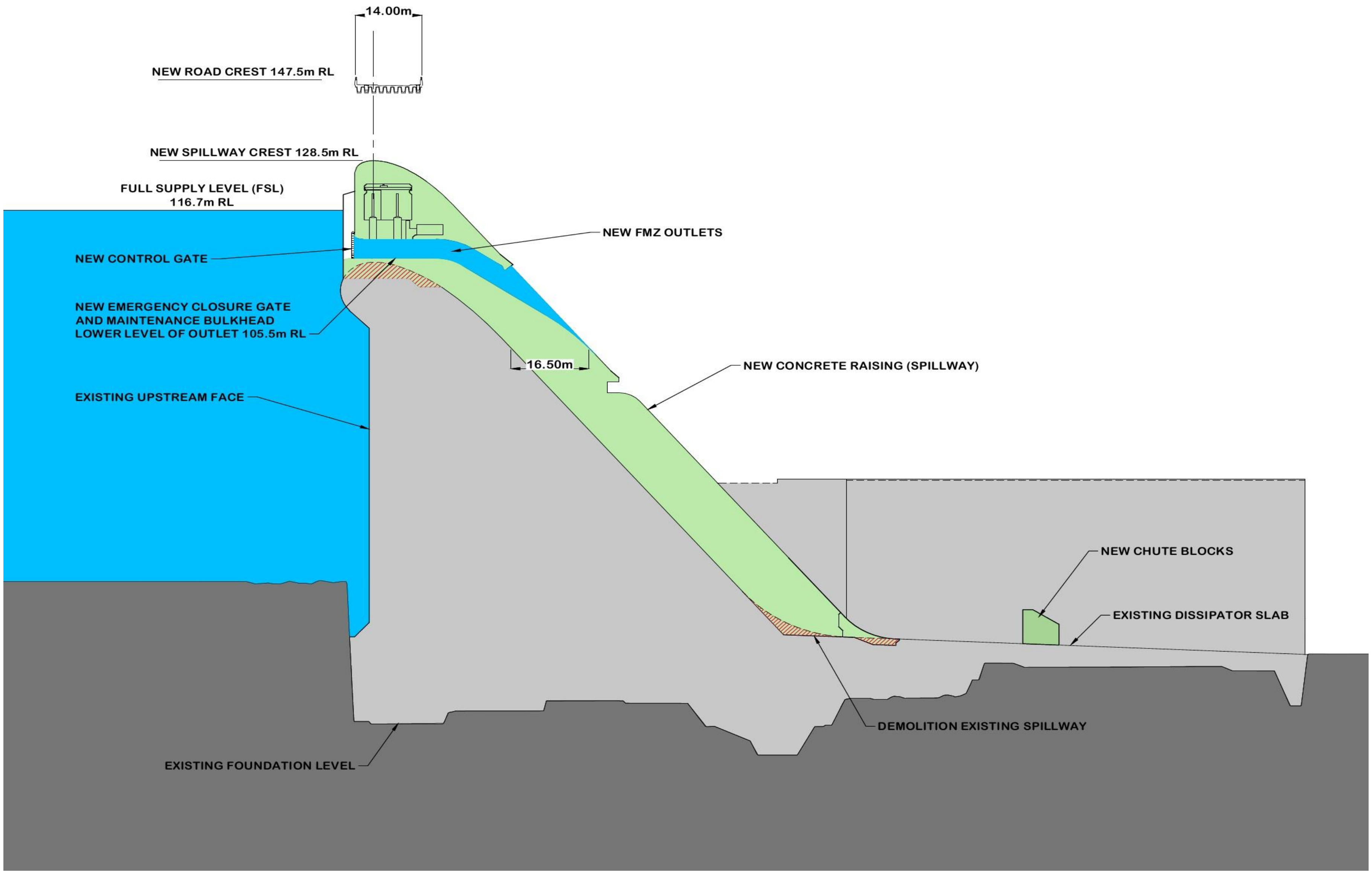
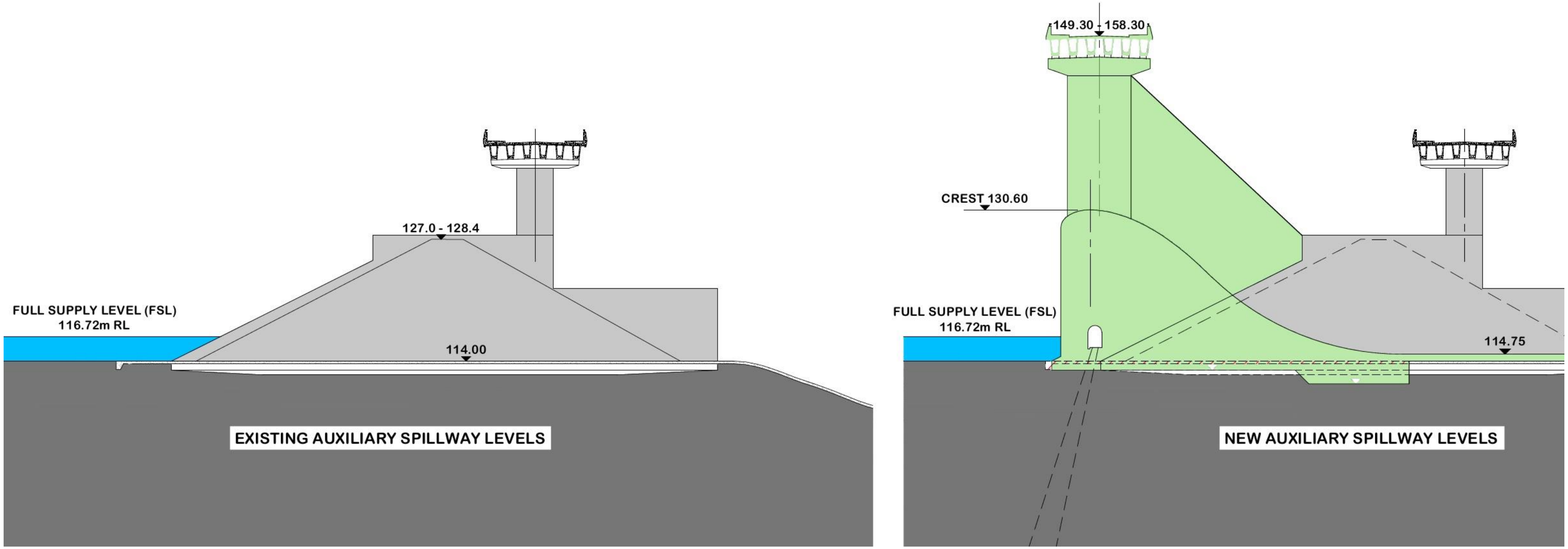


Figure 5-7. Cross sections of existing and modified auxiliary spillway crest



5.2.6 Environmental flows infrastructure

In 2017, the NSW Government released the *2017 Metropolitan Water Plan*[1] which included the introduction of new variable environmental flows from Warragamba Dam to improve the health of the Hawkesbury-Nepean River (Metropolitan Water Directorate 2017).

The Project would provide the infrastructure to enable environmental flows to be released from the Dam. Procedures would be developed as part of the implementation of the Metropolitan Water Plan.

The proposed environmental flows infrastructure would include (Figure 5-8):

- a multi-level offtake tower on the upstream face of the dam wall to draw water from Lake Burragorang
- the use of an existing pipeline, formerly for the hydro-electric power station, to transfer the water to a valve house
- a new valve house, downstream of the existing hydro-electric power station, to discharge water into the river.

5.2.7 Operation of the dam for flood mitigation

Operational objectives in order of priority are to:

- maintain the structural integrity of the dam
- minimise risk to life
- maintain Sydney's water supply
- minimise downstream impact of flooding to properties
- minimise environmental impact
- minimise social impact.

There would be two different modes of operation for the Project: normal and flood operations. In both modes Warragamba Dam would continue to store and supply up to 80 percent of Sydney's drinking water. The storage capacity, which is the dam's FSL, would not change. The current and proposed future operation of the dam are shown in Figure 5-9 and Figure 5-10 respectively.

5.2.7.1 Normal operations

Normal operations would occur when the dam storage level is at or lower than FSL.

Normal operations mode for the modified dam would be essentially the same as current operations, apart from environmental flow releases. Inflows would be captured up to FSL, after which environmental flows releases would cease and flood operation procedures would be implemented.

5.2.7.2 Flood operations

During large rainfall events when the storage level rises above FSL, flood operations mode would commence. In this mode, inflows to Lake Burragorang would be captured and temporarily stored (increasing water levels in Lake Burragorang and upstream tributaries). The raised dam would provide capacity (i.e. the FMZ) to capture temporarily around 1,000 gigalitres of water during a flood event.

Water would be discharged in a controlled manner via the gated conduits or slots until the dam level returns to FSL. FMZ operating protocols would guide this process and be developed for approval by the relevant regulatory authorities.

> The capacity created by the FMZ will allow for around two Sydney Harbours of water to be held back temporarily during a large rainfall event to reduce flooding downstream.

The raised dam would not be able to fully capture inflows from all floods. For floods that exceed the capacity of the FMZ, water would spill firstly over the central spillway and then, depending on the size of the flood, the auxiliary spillway.

For more information on downstream and upstream impacts and benefits from the Project see Chapter 15 (Flooding and hydrology).

[1] www.planning.nsw.gov.au/about-us/Sydney-Metropolitan-Water

Figure 5-8 Cross-section of proposed environmental flows infrastructure

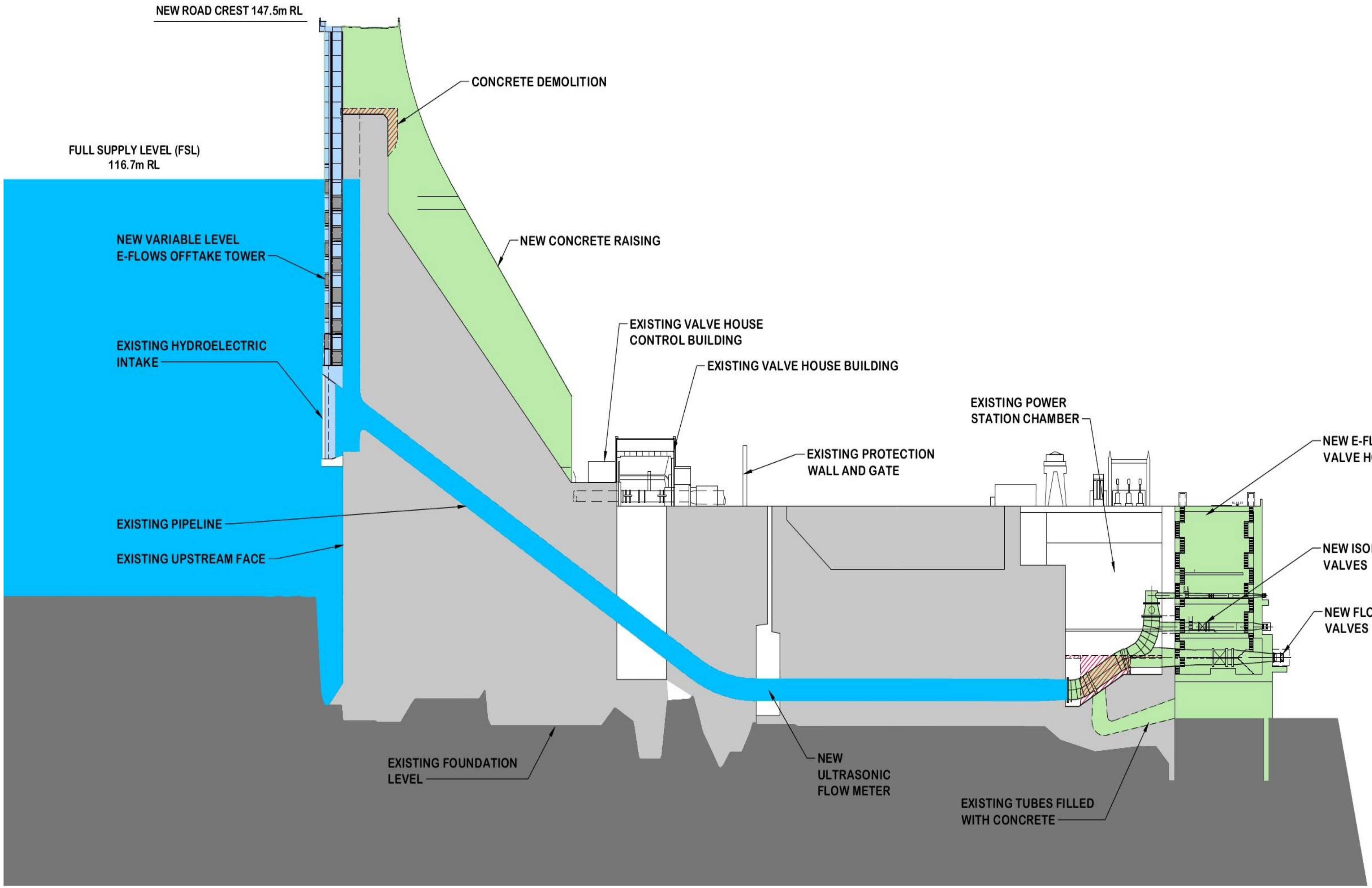


Figure 5-9. Existing operation of the dam

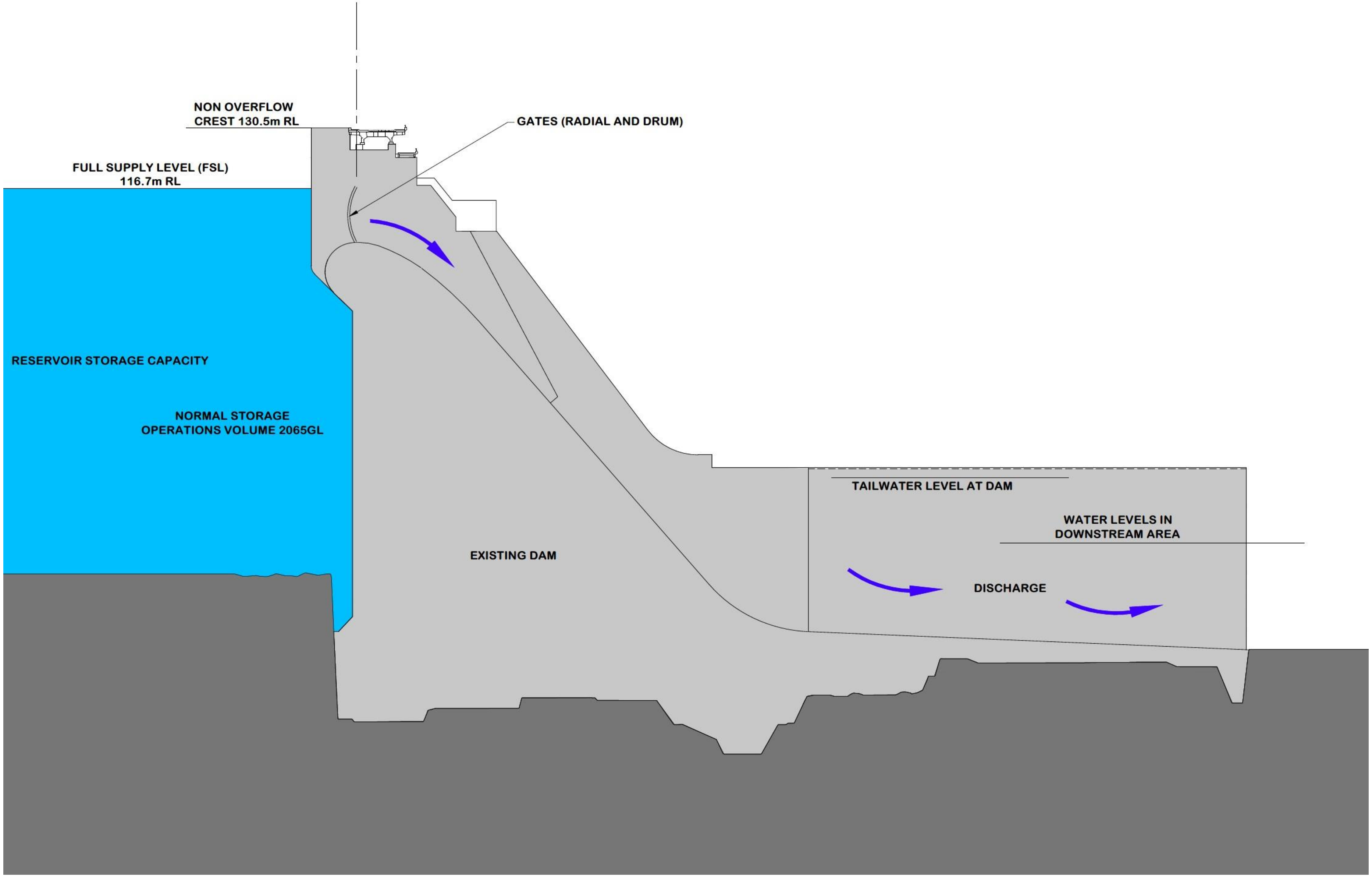
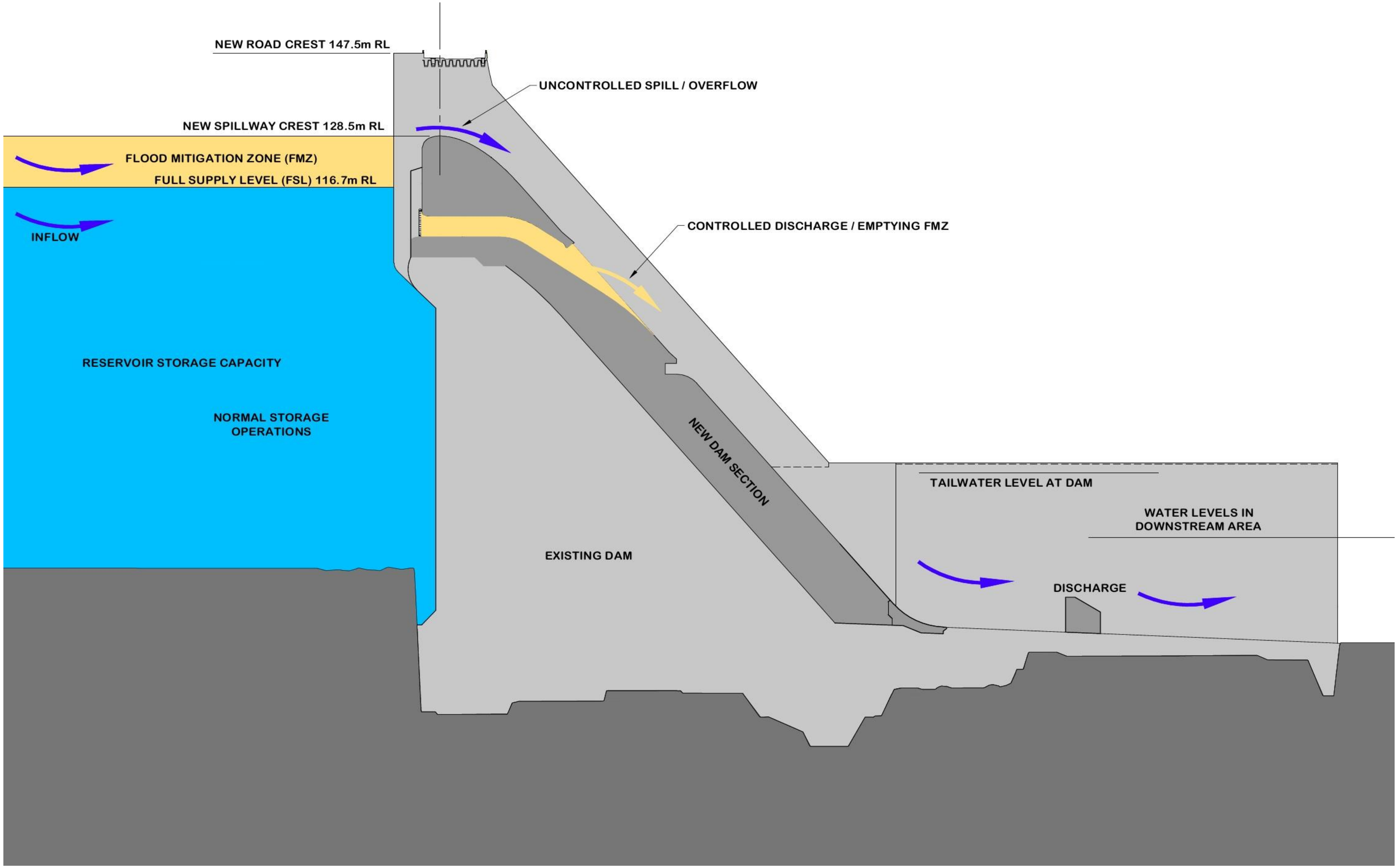


Figure 5-10. Proposed future operations of the dam



5.3 Project design development

5.3.1 General

A substantial body of work has been undertaken since 2013 to analyse alternative infrastructure solutions and then to develop the preferred dam raising design option. Chapter 4 (Project development and alternatives) outlines the alternatives analysis. The option described in this chapter was recommended by the Hawkesbury-Nepean Valley Flood Management Taskforce and endorsed by the NSW Government as the preferred solution, as it provides significant reduction in flood risk and has the highest net benefit of all alternatives considered. Chapter 4 also outlines the earlier stage design development activities that were undertaken prior to the current stage of design.

5.3.2 Detailed concept design

The design is currently at the detailed concept stage. Key activities have focused on investigating the condition of the existing dam and its foundations, analysing the raised dam and defining the proposed design arrangements.

The design has optimised the spillway arrangements to minimise the impacts upstream and downstream of the dam. This has resulted in a reduced extent and duration of upstream inundation and improved downstream flow characteristics, compared with early stage designs. The design was modified to cater for the potential effects of climate change as required by the SEARs. This was achieved by including provision for future raising of the dam spillways by around three metres, should the predicted impact of climate change be realised. Any future changes of the spillway crest height due to climate change are not considered in this EIS and would be subject to a separate environmental impact assessment at the time.

Key activities undertaken in the detailed concept design phase include:

- reviewing all existing dam data
- geological mapping, drilling and testing to assess rock foundation conditions
- existing concrete drilling and testing to understand the strength of the dam concrete
- concrete mix design and laboratory trials to determine the most appropriate concrete mix
- hydrology and seismic assessments and advanced computer structural analysis to determine flood and earthquake loads
- computer based hydraulic analysis and construction of a scale physical hydraulic model to assess the ability of the raised dam spillways to safely discharge water in the flood mitigation zone
- detailing of other civil, mechanical and electrical aspects of the design
- design of environmental flow infrastructure to improve river health.

An early contractor involvement process has been used to provide construction input on the design, further refining the overall solution and identifying improvements. The contractors have considered aspects such as:

- reducing impact of construction works on the community
- improvements to the design to reduce construction duration and cost
- improved management of site access and safety for the public, dam operators and construction workers
- options for access to the visitor and education centre during construction
- confirming the construction methodologies proposed are feasible.

The design process has also considered sustainability. Changes have been included to improve the sustainability outcome in accordance with the Infrastructure Sustainability Council of Australia rating scheme. Chapter 23 (Sustainability) provides further details on sustainability considerations.

5.3.3 Design standards

Large dams in NSW must be designed and managed to comply with the NSW Dam safety guidelines. The guidelines align with the Australian National Committee on Large Dams (ANCOLD) guidelines which, in turn, are aligned with International Commission on Large Dams (ICOLD) guidelines.

There are comprehensive NSW, Australian and international dam design and infrastructure construction standards. A list of the relevant standards relating to the Warragamba Dam Raising design is presented in Chapter 16 (Health and safety).

5.4 Project construction

This section describes the proposed approach to construction. If the Project is approved, further detailed construction planning would take place prior to commencement to inform a construction environmental management plan (CEMP). This plan would be prepared in accordance with all relevant approval conditions, and would also consider methods and the scheduling of activities to minimise impacts on the community and the environment such as noise, access and amenity, and would detail mitigation and management measures.

5.4.1 Construction area

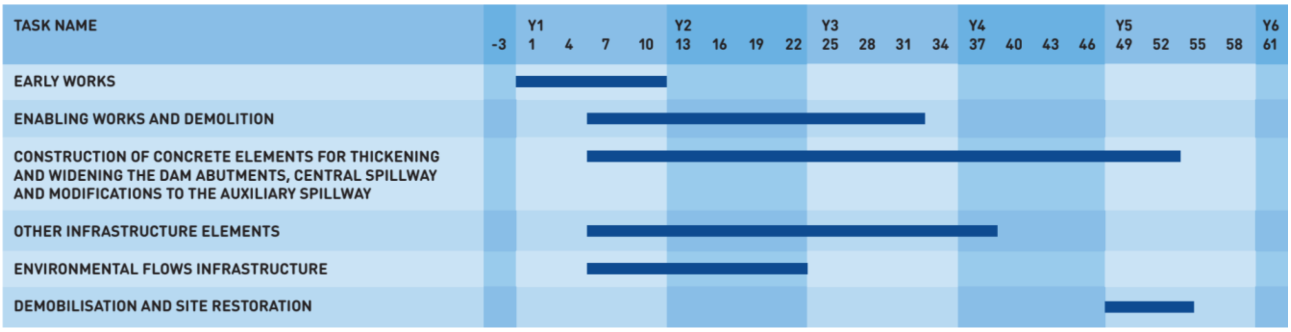
The proposed construction area (refer Figure 5-2) may be refined as part of detailed design and construction planning. The construction area includes:

- areas directly impacted by construction
- areas where access for construction is required
- concrete batch plants and material storage and handling areas
- offices and worker amenities
- visitor and education centre
- other ancillary sites.

5.4.2 Construction program

A preliminary construction program is presented in Figure 5-11 with the Project anticipated to be completed between four to five years from commencement.

Figure 5-11. Preliminary construction program



5.4.3 Construction workforce

The number of workers would vary over the construction program. Up to 300 workers would undertake establishment activities including setting up offices and compounds, assembling the concrete batch plants and beginning early and enabling works. The number of workers on site would increase during construction to around 500 during peak construction periods.

5.4.4 Construction hours

The majority of works would take place during recommended standard construction hours for NSW which are:

- 7am to 6pm – Monday to Friday
- 8am to 1pm – Saturday
- no work on Sundays and public holidays.

This includes the majority of high noise generating activities such as:

- deliveries of materials including concrete, sand and aggregates for concrete production
- demolition work including hydro-blasting (a concrete removal technique that uses high pressure water)
- earthworks, excavations, drilling and blasting (if required).

Some activities would need to take place outside of recommended standard construction hours. These activities may include:

- Operation of chilled water plants for cooling and curing of concrete. Continuous cooling of the concrete is required to ensure that heat does not become excessive, and cause cracking and loss of strength of the concrete during curing.
- Operation of the batching plants for the delivery and pouring of concrete. In warmer periods, concrete pours may not be able to take place in normal working hours. High temperatures may cause thermal issues and cracking during the curing process. Concrete pours may be required at night-time when temperatures are lower.
- Preparatory or emergency works for a flood during the construction period including removing equipment and materials from the construction area, minor earthworks and other activities.
- Work outside the nominated working hours may need to occur in the case of emergencies, delivery of over-sized items or unexpected issues.

The local community would be notified of construction activities including any activities taking place outside of standard construction hours in accordance with the community consultation plan developed by the construction contractor.

5.4.5 Access to Warragamba Dam during construction

The operation of the visitor and education centre may be impacted by construction activities. Options to continue operating the visitor and education centre within the existing site during construction or at alternative locations are being considered. Factors to be considered include safety, impacts to construction, and the visitor and educational experience.

There would be no public access to Haviland Park during construction.

Access to the WaterNSW offices at Warragamba Dam would be maintained for WaterNSW staff and other authorised personnel.

5.4.6 Construction methodology

A high level construction methodology is provided in the following sections. This may be further refined as part of detailed design and construction planning.

5.4.6.1 Early works

Early works are activities that may be able to commence before main construction works and would include:

- further investigations including surveying, geotechnical studies, building and utility condition and location surveys, and other studies as required to assist in the design and construction of the Project
- installation of security fencing and site environmental controls including heritage item protection/relocation, water management, soil management, and noise management measures
- establishment of temporary site offices, and worker facilities
- procuring of concrete batching facilities, cranes, conveyors, and other infrastructure
- clearing of vegetation
- adjustment and provision of utilities for construction facilities
- minor road works and establishment of site access roads including a temporary access bridge downstream of the dam
- establishment of areas for stockpiling of materials such as aggregate and fly ash.

5.4.6.2 Enabling works and demolition

Enabling and demolition works are required to be undertaken before commencement of concrete placement to raise and thicken the dam wall. These would include:

- upgrading the existing boat ramp, pontoon, and access road upstream of the dam to allow for water access to the dam wall

- establishment of batching plants on site so concrete can be poured almost immediately after batching to maintain adequate concrete placement temperatures. Potential on-site locations are Havilland Park or the terraced gardens (Figure 5-2). The facilities would consist of:
  - hardstand area with drainage to environmental control ponds
  - concrete testing and geotechnical laboratory
  - weighbridge and office
  - materials storage bins and sheds (for aggregates, sand, fly ash, and other materials)
  - silos, mixers, conveyors, above ground tanks, control facilities and dust control facilities
  - water and material chilling plant
  - connections to communication, power and water supply services
  - other environmental controls if required (for example, noise walls).
- releasing water from the dam until the water is approximately five metres below FSL; this is required to provide a buffer for floods during construction and allow construction of the new crest in the auxiliary spillway
- emptying (dewatering) the dissipator pool at the base of the dam to enable works to be undertaken
- construction of coffer dams at multiple locations around the dam wall to manage the impact of works on the Warragamba River and protect the site from river backflows. Indicative locations are shown in Figure 5-2 and include at the end of the existing central spillway dissipator, immediately upstream of the auxiliary spillway and downstream of the auxiliary spillway. The number and size of the coffer dams would be confirmed during detailed design
- construction of the raised dam would require demolition of several existing structures and removal of machinery, pipes and operational equipment. These are outlined in Section 5.2.1. The methodology and scheduling would be determined by the construction stages and the need to maintain safe operations of the dam. Estimates of demolition waste are provided in Section 5.4.11.

5.4.6.3 Construction of concrete elements for thickening and widening the dam abutments, central spillway and modifications to the auxiliary spillway

Warragamba Dam is a concrete gravity dam that uses the weight of concrete to resist the horizontal pressure of water. The same design and construction approach would be used for raising the dam wall. Mass concrete would provide the strength to enable the dam height to be increased. Reinforced concrete would be used to construct elements such as bridges, walls, piers, conduits, chambers, etc.

Work would include:

- installing formwork to create concrete blocks. The blocks have been sized to match the existing dam block dimensions and for structural performance. Generally, the formwork would be lifted into place by a crane
- where cooling of the concrete is required after the pour, small pipes may be cast into the concrete to allow chilled water to be pumped through the concrete during curing
- pouring concrete into the formwork and allowing the concrete to set and start to cure. The concrete would be delivered from on-site batch plants by a crane or cableway with a concrete bucket and/or a conveyor
- chilled water may be pumped through the installed pipe systems to assist in curing, if required
- removing formwork and repeating the process for the next concrete block.

Most of the concrete works for the Project would involve mass concrete, however, certain parts would require reinforced concrete. Work would include:

- installing formwork to allow concrete placement as determined by the design. Generally, the formwork would be lifted into place by a crane
- placing reinforcing steel in the formwork in the required locations and patterns. Reinforcement would be either lifted into place by a crane or would be placed by hand
- pouring concrete into the formwork and allowing the concrete to set. The concrete would be delivered from the on-site batch plants by a truck, a crane, a cableway and/or a conveyor
- removing the formwork and repeating the process for the next concrete element.

5.4.6.4 Thickening and raising dam abutments

Works would include:

- excavation and earthworks at the base of the dam wall to provide a key for the concrete buttress used to increase the thickness of the dam wall
- excavation and removal of material for about 30 metres east of the left abutment at the raised dam crest location
- grouting of foundations for the raised dam crest on the left abutment
- controlled blasting to excavate approximately 58,000 m^3 of rock at the toe of the dam and on the left abutment
- hydro blasting the existing concrete wall; between 20 and 50 millimetres of the existing concrete surface of the dam wall would be removed to facilitate the bond between the existing and new concrete
- thickening the abutments on the downstream face using the placement methodology described in Section 5.4.6.3
- raising the abutments about 17 metres higher than the existing dam crest level
- raising of the two lift towers including installation of two new lifts.

The profile of the new abutment would be constructed to mirror the existing profile.

5.4.6.5 Thickening and raising of the central spillway

Works would include:

- excavating the foundations to allow the tie in of the new works
- hydro blasting the existing concrete wall. Between 20 and 50 millimetres of the existing concrete surface of the dam wall would be removed to facilitate the bond between the existing concrete and the new concrete
- installing stress bars in the base of the thickened dam. Holes for the stress bars would be drilled and the stress bars inserted and then grouted
- thickening the central spillway wall on the downstream face using the placement methodology described in Section 5.4.6.3
- raising the central spillway crest about 12 metres higher than the existing FSL
- extending the existing training walls downstream on either side of the spillway, which would tie in with the existing dissipater walls
- constructing two new reinforced concrete bridge piers within the central spillway crest
- constructing eight four-and-a-half metre by four-and-a-half metre conduits through the new central spillway
- installing hydraulically controlled gates in each of the conduits and their control systems
- installing a new maintenance gate including guides for each conduit
- commissioning and testing electrical and mechanical elements for operating the gates.

5.4.6.6 Auxiliary spillway modifications

Works would include:

- removal of the existing earth/rock embankments (fuse plugs) in the crest of the auxiliary spillway
- preparation of the existing bedrock for the foundations of the new auxiliary spillway crest including grouting
- constructing a new uncontrolled concrete spillway crest across the width of the auxiliary spillway. Most of the spillway would consist of mass concrete, however, reinforced concrete sections would be required on top of the crest of the spillway
- constructing of four new reinforced concrete bridge piers within the spillway crest
- installation of additional anchor bars from the spillway floor into the underlying rock. Holes for the anchor bars would be drilled, the anchor bars inserted and then grouted in place
- constructing a 30 to 50-metre-long reinforced concrete drop-over slab across the width of the spillway about 130 metres downstream of the new spillway crest to allow for changed spillway flows
- increasing the height and/or strength of the existing spillway chute walls in various locations. Construction would be either mass or reinforced concrete depending on the degree of heightening or strengthening required, and location of the wall

- raising and/or replacing of shotcrete wall lining with reinforced concrete or new shotcrete in various locations.
- additional scour protection would be required downstream of the auxiliary spillway. Activities would include removing soil, excavation of rock to the required level (including blasting if needed) and installation of rock scour protection, concrete and anchor bars.

5.4.6.7 Other Infrastructure and elements

A new road and pedestrian access would be built along the top of the abutments, the auxiliary and central spillway. These would connect with the approaches and road network on either side of the dam to provide access and provision of services across the dam crest. Timing of construction of the new access would be linked to raising of the auxiliary, central and abutment crests.

Areas for spoil emplacement may be used for disposal of some excavated materials on-site. Material from the earth/rock embankments removal, the temporary coffer dams and other excess spoil from other excavations may be emplaced into these areas. Activities would include site preparation, emplacing material, site stabilisation and landscaping.

5.4.6.8 Environmental flows infrastructure

Works would include:

- underwater construction of a concrete base for a multi-level water intake tower on the upstream face of the dam
- underwater and above water construction of the new tower using precast concrete units connected to the upstream face of the dam
- underwater excavation of a section of the existing hydro-electric power station intake tower to allow water to pass between the new tower and the existing tower
- installation of hydraulically operated gates into the intake tower
- installation of concrete panels to block off the existing hydro-electric power station intake tower openings
- relining of the existing 4.2 metre diameter hydro-electric power station pipe with epoxy or a new pipe grouted in place
- removal of existing generating equipment within the existing downstream hydro-electric power station including hazardous materials
- construction of a new valve house building, downstream of the existing downstream hydro-electric power station, using reinforced concrete
- installation of new steel pipes within the existing hydro-electric power station and new valve house including new valves.

5.4.6.9 Demobilisation and site rehabilitation

Demobilising and rehabilitation of the construction site would be undertaken progressively, as work in an area is completed, and include activities such as:

- removing temporary construction infrastructure, plant and equipment
- earthworks
- site stabilisation and landscaping
- reinstatement of public areas and facilities.

5.4.7 Construction materials

Concrete production (fly ash, sand, cement, and aggregates) would generate most of the materials required for the Project. The estimated volume and type of concrete for the main components of construction are presented in Table 5-2.

Table 5-2. Volume and type of concrete required

Project element	Estimated cubic metres of concrete
Abutment and central spillway	
Abutment and central spillway thickening and raising (mass concrete)	502,500
Crest kerbs and parapet (reinforced concrete)	300
Spillway (concrete)	5,900
Lift towers (reinforced concrete)	2,500
Spillway training walls (reinforced concrete)	5,800
Outlet conduits (reinforced concrete)	3,000
Bridges	
Bridge piers (reinforced concrete)	11,200
Bridge deck (precast elements)	500
Other bridge elements (concrete)	1,000
Auxiliary spillway	
Spillway overflow (mass concrete)	63,500
Spillway crest (mass concrete)	11,100
Other spillway works (reinforced concrete)	5,600
Spillway (concrete)	6,700
Erosion protection downstream (reinforced concrete)	1,600
Total	**621,200**

Based upon the likely concrete mixes, the weight of different constituents of the concrete is presented in Table 5-3.

There would be two main types of concrete produced:

1. Conventional structural concrete mix – typically used in most construction projects.
2. Mass concrete mix – for the dam thickening and auxiliary spillway crest structure. The mass concrete mix uses less cement but more fly ash and coarse aggregates than a conventional concrete mix.

An assessment of potential sources of aggregates, fly ash and cement was undertaken for the concept design.

Quarries in the Blue Mountains, Southern Highlands, Central Coast and South Coast were identified as capable of supplying coarse aggregates suitable for the Project. Fly ash would be sourced from coal fired power stations in the region or elsewhere if NSW supplies are running low. Cement would be sourced from suppliers in the Sydney region.

Further assessment during construction planning and detailed design would determine the preferred source locations.

Table 5-3. Typical weight of materials for concrete production

Materials	Kilograms/cubic metre of standard concrete	Kilograms/cubic metre of mass concrete	Total weight (Tonnes)
Cement	240	100	75,123
Fly ash	80	135	89,580
Coarse aggregate	1,100	1,250	846,874
Fine aggregate (sand)	800	800	546,656

The estimated amounts of other materials required for construction of the Project are presented in Table 5-4.

Table 5-4. Other construction materials

Materials	Total amount
Steel for reinforcing	8,760 t
Steel for formwork	15,700 m^2
Other steel elements	2,120 t
Engineering fill	24,380 m^3
Timber for formwork	6,313 m^2

5.4.8 Consumption of natural resources

5.4.8.1 Energy use during construction

The main energy sources would be electricity to power the concrete batch plants and chilled water units, and fuel (mainly diesel) to power plant and equipment. Electricity would be sourced from the local power network or from generators. Estimates of energy use during construction is presented in Table 5-5.

Table 5-5. Energy use during construction

Energy source	Estimated energy use
Electricity	701,664 kWH
Fuel	79,401 GJ

5.4.8.2 Construction water use

Construction of the Project would require the use of water. Table 5-6 shows the construction activities with the highest water demand and an estimate of volumes required. Water would generally be sourced directly from the dam where possible. Potable water would be used as required.

Table 5-6. Construction water use

Activity	Estimated total water volume (ML)
Hydro blasting the existing concrete wall	50
Concrete curing	20
Concrete production	93
Other general uses – for example, workers' facilities	20
Total	**183**

5.4.9 Plant and equipment

The types of major plant and equipment for each of the main stages of construction is described in Table 5-7. Light vehicles, powered hand tools and other small items of plant and equipment would also be used during construction.

Table 5-7. Plant and equipment by construction stage

Activity	Plant	
Early works	Excavators Trucks and trailers Dozers Graders Tub grinders Bobcats Hydraulic hammers Generators	Excavators with grabs Articulated dump trucks Mobile cranes Franna cranes Vibrating rollers Watercarts Compressors
Enabling works and demolition	Mobile cranes Franna cranes Crawler cranes Excavators Dump trucks Truck and dog Graders Vibrating rollers Watercarts	Dozers Bobcats Hydraulic hammers Dozers Generators Compressors Dewatering pumps Concrete pumps
Construction of concrete elements for thickening and widening the dam abutments, central spillway and modifications to the auxiliary spillway	Tower cranes Cable cranes Crawler cranes Mobile cranes Truck and dog Dump trucks Trucks Moxy Blasting Drill rigs Hydro blasting equipment Excavator Excavators with rock hammers Excavators with saw cutters	Dozers Concrete batch plant equipment Material handling conveyers Ice plant Chilled water units Concreate agitators Concrete pumps Dewatering pumps Watercarts Boats and small barges Generators Compressors Pneumatic drills
E-flows infrastructure	Tower cranes Cable cranes Crawler cranes Mobile cranes Boats and small barges Trucks Concrete batch plant equipment	Material handling conveyers Ice plant Generator Tower cranes Concrete pumps Compressor
Demobilisation and site rehabilitation	Crawler cranes Mobile cranes Franna cranes Excavators Dozers Trucks	Boats and small barges Bobcats Watercarts Vibrating rollers Generators Compressors

5.4.10 Earthworks volumes

As described in Section 5.4.4, earthworks would be required during construction. The volume of earthworks for relevant activities is presented in Table 5-8.

Table 5-8. Earthworks volumes

Activity	Estimated earthworks volume (m^3)	Waste classification
Removal of the fuse plugs in the auxiliary spillway.	83,000	General solid waste (non-putrescible) Excavated natural material – consisting of basalt rocks and engineered clay core
Excavation for the foundations and tie ins of the modified dam wall including the left abutment works	60,000	General solid waste (non-putrescible) Mostly virgin excavated natural material with some excavated natural material
Coffer dams	21,000	General solid waste (non-putrescible) Virgin excavated natural material, excavated natural material, building and demolition waste, asphalt waste
Access road works	40,000	General solid waste (non-putrescible) Virgin excavated natural material, excavated natural material, building and demolition waste, asphalt waste
Excavation for the auxiliary spillway modifications	25,000	General solid waste (non-putrescible) Virgin excavated natural material, excavated natural material, building and demolition waste, asphalt waste
Erosion protection works downstream of auxiliary spillway	30,000	General solid waste (non-putrescible) Mostly virgin excavated natural material with some excavated natural material Note: If plunge pool is required this volume would increase to about 670,000 cubic metres
Excavations for temporary works such as temporary site access roads and for site facilities such as batch plants	10,000	General solid waste (non-putrescible) Virgin excavated natural material, excavated natural material, building and demolition waste, asphalt waste
Total	**269,000**	

5.4.11 Spoil and waste management

As described in Section 5.4.4, spoil and waste management would be required during construction.

The Project would generate spoil due to the earthworks detailed in Table 5-8. Some material may be able to be reused on the Project for temporary or permanent works, or other off-site projects. Spoil may be temporarily stockpiled before being permanently placed. Once spoil has been placed permanently placed, the area would be covered in topsoil and replanted with suitable native vegetation.

Waste materials would be generated from the demolition of existing dam elements such as the hydro blasting, dam road, radial and drum gates, other electrical and mechanical infrastructure and concrete demolition. These materials would be disposed off-site.

The estimated volume or weight of waste materials generated during construction and potential management options are presented in Table 5-9 and are discussed further in Chapter 26 (Waste).

Table 5-9. Waste materials generated and potential management options

Material	Volume/weight generated during construction	Potential management options
Concrete from hydroblasting	4,300 t	Suitable material would be reused with remainder emplaced on site or taken off-site for reuse or disposal
Other concrete waste	60,000 t	Taken off-site for reuse or disposal
Steel such as drum and radial gates, crest bridge and gantry crane	2,500 t	Taken off-site for reuse or disposal
Timber formwork	11,000 m^2	Taken off-site for recycling
Vegetation from clearing	4,000 t	Reused on-site or taken off-site for disposal
General construction waste	10,000 t	Mulched and reused on site for landscaping

5.4.12 Traffic management and access

5.4.12.1 Construction vehicle movements

Most truck movements would be generated by the delivery of materials for concrete production. There would also be delivery of other materials such as steel, plant and equipment, precast elements and new components for the dam raising. Approximately 500 workers would travel to site during the peak construction period. The number and types of vehicles accessing the Project site during the three main construction stages is presented in Table 5-10.

Table 5-10. Construction vehicle movements

Construction stage	Approximate number of vehicles per day travelling to Project site
Site establishment	Light vehicles – 100 Heavy vehicles – 50
Main works	Light vehicles – 250 Heavy vehicles– 104
Demobilisation	Light vehicles – 50 Heavy vehicles – 25

Generally, vehicles accessing the site from either north, south or east would travel along The Northern Road, Park Road, Silverdale Road, Farnsworth Avenue and Production Avenue. Vehicles from the south would access the site via Silverdale Road, Warradale Road, Farnsworth Avenue and Production Avenue. The northern and southern access routes to the Project construction site are shown in Figure 5-13 and Figure 5-13 respectively.

The impact of construction traffic on the road network and sensitive noise receivers is assessed in Chapter 24 (Traffic and transport) and Chapter 19 (Noise and vibration) respectively.

There would also be on-site traffic movements. A construction traffic management plan would be prepared and implemented to minimise potential impacts of both on-site and offsite traffic movements.

5.4.13 Public utility adjustments

Only minor adjustments of public utilities would be required as the dam area is well serviced by existing utility connections. At this stage, no utilities outside the construction area would require increased capacity or relocation. However, some utilities servicing the dam and associated facilities may require relocation to allow for construction and future operations. These relocations would not affect any services provided to the township of Warragamba or other stakeholders.

Figure 5-12. Southern access route to site

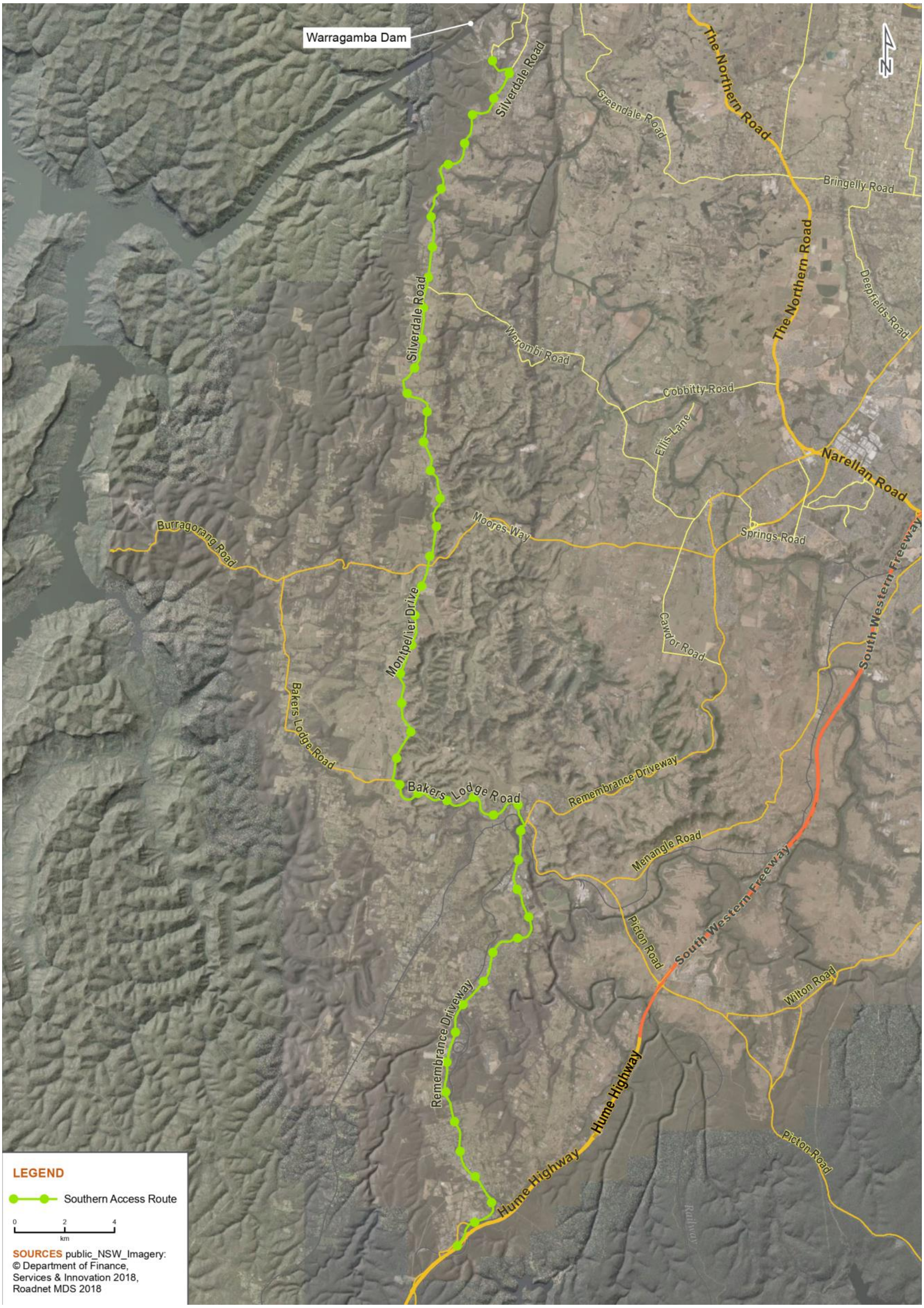
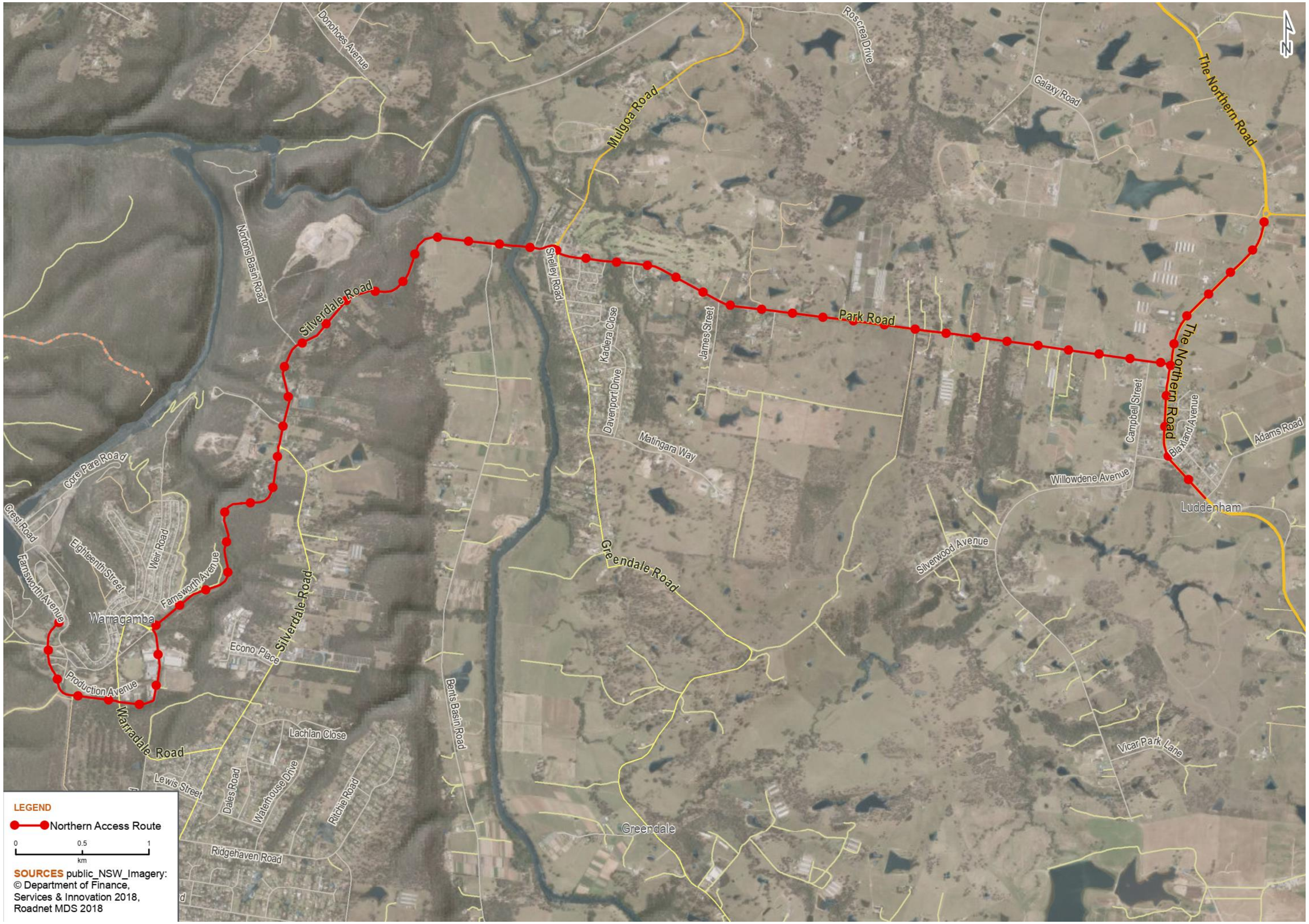


Figure 5-13. Northern access route to site



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