

ACTEWAGL

ENLARGED COTTER DAM

TECHNICAL REVIEW PANEL REPORT NO. 20 BY



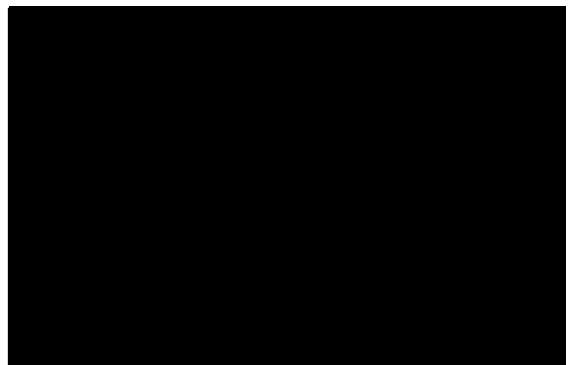
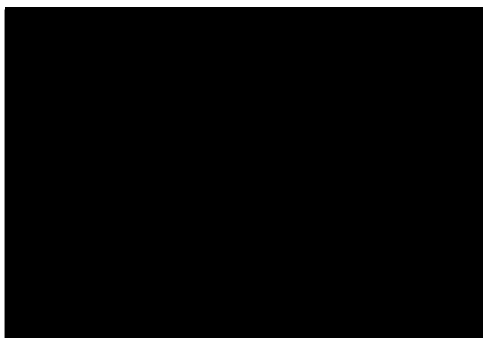
AND



ON MEETING OF

15 AND 16 AUGUST 2012

AT THE DAMSITE OFFICE



CONTENTS

	Page
LIST OF APPENDICES	iii
1. INTRODUCTION AND PREVIOUS MEETINGS.....	1-1
2. THE MEETING.....	2-1
2.1. ATTENDEES AT THE 20TH TRP MEETING	2-1
2.2. INFORMATION MADE AVAILABLE TO THE PANEL.....	2-1
2.3. ACKNOWLEDGEMENTS.....	2-1
3. THE PROJECT.....	3-1
4. SITE INSPECTION.....	4-1
5. ROLLER COMPACTED CONCRETE.....	5-1
5.1. INTRODUCTION.....	5-1
5.2. RCC CONTROL TESTING.....	5-2
5.2.1. Panel's comments	5-2
5.3. DEFECTIVE RCC AND REQUIRED REPAIRS – PANEL'S COMMENTS.....	5-4
5.3.1. Upstream face and downstream steps.....	5-4
5.4. INSPECTION OF CORES AND LIFT JOINT QUALITY – PANEL'S COMMENTS.....	5-4
5.5. ENTRANCE GALLERY CRACKING – PANEL'S COMMENT	5-6
5.5.1. Inspection and meeting presentations.....	5-6
5.5.2. Panel's comments	5-8
5.6. HORIZONTAL CRACKING ALONG THE DOWNSTREAM FACE'S STEPS.....	5-9
5.6.1. BWA presentations.....	5-9
5.6.2. Panel's comments	5-11
6. CONVENTIONALLY VIBRATED CONCRETE (CVC).....	6-1
6.1. INTRODUCTION.....	6-1
6.2. CONCRETE IN THE DOWNSTREAM WORKS – PANEL'S COMMENTS.....	6-1
7. MAIN DAM.....	7-1
7.1. INTRODUCTION.....	7-1
7.2. STRUCTURAL ANALYSES SINCE THE DISCOVERY OF THE CROSS- VALLEY CRACKING	7-1
7.2.1. Introduction	7-1
7.2.2. BWA presentation at 20 th TRP meeting	7-2
7.2.3. Panel's comments	7-3
7.3. DIVERSION WORKS – NEXT STEPS	7-8
7.3.1. BWA presentation	7-8
7.3.2. Panel's comments	7-8
7.4. AERATION STEP – CONSTRUCTION DETAILS.....	7-8
7.4.1. BWA presentation	7-8
7.4.2. Panel's comments	7-9
7.5. PRECAST CONCRETE FOR THE PRIMARY SPILLWAY'S SIDE (CHUTE) WALLS	7-9
7.5.1. BWA presentation	7-9

7.5.2.	Panel's comments	7-10
7.6.	TOPPING OUT OF THE MAIN DAM	7-10
7.6.1.	BWA presentation	7-10
7.6.2.	Panel's comments	7-10
7.7.	FOUNDATION GROUTING	7-11
7.7.1.	BWA presentation	7-11
7.7.2.	Panel's comments	7-11

LIST OF APPENDICES

Note all appendices are included at the end of the main text of the report.

Appendix No.	Title
A	Cross-valley cracking in the gallery entrance – Plan supplied by BWA on 10 August 2012.
B	RCC placement by lane method – BWA’s proposal, TRP’s comments and BWA’s proposed Specification changes.

LIST OF PHOTOPGRAPHS

Note all appendices are included at the end of the main text of the report.

Photograph No.	Title	Page
3.1	The right hand side of the spillway’s stilling basin, showing the partly completed outlet works and the manifold pipework for the Stage 3 of the diversion works.	
3.2	The left hand side of the spillway’s stilling basin, showing the way the outlet of the 3 m diameter conduit of the Stage 2 diversion works is now holding up progress on this side of the stilling basin.	
3.3	The downstream face of the dam as at 15 August 2012. The RCC deck level was at RL 532, which is 20 m below the crest level of the primary spillway.	
5.1	The vertical crack close to the entrance of the gallery on the right side of the spillway’s stilling basin. This crack is in the RCC of the secondary spillway toe channel. It has propagated to the surface of the channel.	
5.2	One of the inner cracks along the entrance gallery. Note its significant “waviness”.	
5.3	Drilled core along the lower of the two horizontal cracks in the downstream face. The joint surface seems to be at the bottom of the cores – the top of the core is the vertical face of the step. The crack has initiated off the joint at the outer face (see Photograph 5.4).	
5.4	The full core into the lower crack. Note the crack initiating off the lift joint.	
5.5	The higher of the two horizontal cracks on the downstream face, which seems to be along an RCC lift joint. It is on the vertical face of the step at RL 485.3.	

1. INTRODUCTION AND PREVIOUS MEETINGS

The 20th Technical Review Panel (TRP or the Panel) meeting on the Enlarged Cotter Dam (ECD) was held over 15-16 August 2012 at the damsite office of the Bulk Water Alliance (BWA). [REDACTED] and [REDACTED] attended the meeting. Like the previous several meetings, this one concentrated almost wholly on the RCC placement operations on the main dam. This meeting was preceded a short time before by the finding of four or five cross-valley near-vertical cracks through the entrance gallery (see Appendix A) and at least two near-horizontal cracks in the vertical faces of a couple of steps on the downstream face of the dam. Otherwise, the main discussion points at the meeting were the outcomes from the recent structural analyses that BWA had undertaken as a result of the cross-valley cracking found in April 2012 and the cores from three reasonably long check cored holes into the RCC. Our meeting began with a comprehensive inspection of the main dam and of the spillway works immediately downstream. We gave a briefing to BWA in the afternoon of 16 August on our assessment of the present situation at site.

Between 25 and 27 July 2012, we were asked to comment on a proposal to adopt a lane method for the placement of the RCC. While, such a method was not permitted under the terms of the present Specification, BWA felt that it might have to resort to this approach as the workers on the top of the RCC were becoming more and more hemmed in by the various items of plant and equipment. BWA's proposal of the method, our acceptance of its adoption and the revised specification clauses are given in Appendix B. In the long run, BWA decided not to proceed with the use of this lane method of RCC placement.

[REDACTED] and [REDACTED] were invited by ActewAGL to form the Review Panel for this dam project in April 2007. [REDACTED] had had two introductory briefings with ActewAGL in February and March 2007. By April 2007, ActewAGL had engaged [REDACTED] to undertake initial geological investigation of the dam site and [REDACTED] was well underway on its assignment. Our first Review Panel meeting was in July 2007 (see Panel Report No.1, dated 27 July 2007). At the time of our first meeting, URS was approaching the end of its field investigation program. The first Panel Report summarized our thoughts about the project at the time, particularly of the site geology and the foundations.

Since July 2007 the Bulk Water Alliance (the Alliance) has been formed to design and build the Enlarged Cotter Dam (ECD). GHD Pty Ltd (GHD), in association with its design partners, was selected as the design consultant in early March 2008. Abigroup and John Holland were announced as being the preferred constructors in April 2008. GHD has been carrying out design stage geotechnical investigations for the project since April 2008.

As well as the ECD package, the Alliance's scope of work includes packages that will cover the Murrumbidgee-Googong Transfer (MGT), the Googong Dam Spillway remedial works (GDS) and the Cotter Precinct. [REDACTED] attended a meeting on the GDS in early June 2008 and has been regularly involved in the Googong works since, especially after construction began in earnest in early 2009.

We [REDACTED] had our second Review Panel meeting on the ECD on 8 August 2008. The meeting included an inspection of the site, review of some of the core from the current investigations and meetings at the project office at Mt Stromlo (see Panel Report No. 2, dated 12

1. Introduction and previous meetings

September 2008). [REDACTED] visited Mt Stromlo on 4 September 2008 to discuss the design criteria document and again on 1 October to inspect a test pit at the low point of the saddle where Saddle Dam 1 is to be sited. He sent a report by email on the 1 October visit to [REDACTED] and [REDACTED] on 6 October 2008 (a copy of this email was repeated in the third Panel Report).

We [REDACTED] had our third Review Panel meeting on the ECD on 19 and 20 November 2008. The meeting included an inspection of parts of the site (including the trial quarry), review of some of the core from the current investigations and meetings at the project office at Mt Stromlo. Panel Report No. 3 was issued on 9 January 2009.

[REDACTED] and [REDACTED] joined the Panel for the fourth Panel meeting over 10 and 11 February 2009. This meeting ranged fully over all aspects of the project from the geology of the foundations to the design of its major features. Of special interest was the development of the RCC for the main dam. At the end of the meeting, it would be fair to say that the abutment excavation and the RCC production had been identified as probably the major issues to be resolved in the project, with still some work needed to confirm the foundations of the main dam from the design point of view. Our report on this 4th Panel meeting was issued early in March 2009.

The fifth Review Panel meeting was effectively held over two separate visits, namely on 23 and 24 April 2009 and 14 and 15 May 2009. [REDACTED] and [REDACTED] attended on 23 and 24 April; [REDACTED] and [REDACTED] attended on 14 and 15 May 2009. As a precursor to the meeting, [REDACTED] and [REDACTED] went to a workshop on the excavation for the main dam's abutments, while [REDACTED] and [REDACTED] both spent time on 22 May with the Alliance team. The meeting included a visit to parts of the site on 14 May 2009 and an inspection of the drill core on the next day. On the last day of the meeting, 15 May 2009, a separate meeting was held at the Mt Stromlo office to address specifically matters on the proposed aggregates for the RCC. [REDACTED] spent some time in a telephone hook-up with the various attendees at that meeting. Our report on the fifth Panel meeting was issued on 10 June 2009.

The sixth Panel meeting was held on 18 and 19 June 2009. By this time, the Alliance was in the throes of reviewing its then latest TOC estimate. Cost savings were being actively sought as it was clear that the TOC estimate was above the expected figure. As well as discussing these important cost saving measures, the Alliance presented some updates on the designs of the main features of the works. Our report for this sixth meeting was issued on 1 July 2009.

The seventh Review Panel meeting was held over 28 and 29 October 2009. Matters covered at this meeting included some of the results from the Stage 2 investigations, the latest results from the RCC trial mix program and the proposed further work on these investigations, updates of the design of some of the features, progress on the spillway's hydraulic model and a possible alternative approach to the overall spillway arrangement. With this meeting coming very soon after approval had been given by ACTEW, the Owner, for the project's TOC, the Alliance briefly outlined its proposed program of design and construction (D & C) packages. Our report on this meeting was issued on 23 November 2009.

The eighth Technical Review Panel (TRP or the Panel) meeting was held over 9 and 10 December 2009 at the Mt Stromlo office of the Bulk Water Alliance (BWA). [REDACTED] and [REDACTED] attended the meeting. This meeting was [REDACTED] first visit to Mt Stromlo and his first as a member of the TRP for the ECD. Matters covered at this

1. Introduction and previous meetings

meeting included further results from the Stage 2 investigations, a consolidation of the present situation on the RCC investigations, including the proposed further work on these investigations, updates of the design of some of the features, progress on the spillway's hydraulic model, and discussions on the control of blasting in the quarry and elsewhere at the damsite. Our report on the meeting, which included input from members of the Alliance's Design Challenge Team, was issued on 16 January 2010. We were very pleased to be able to work co-operatively with the Challenge Team at the eighth meeting and gratefully acknowledge their role at the meeting.

The ninth TRP meeting was held over 28 and 29 January 2010 at the Mt Stromlo office. [REDACTED] and [REDACTED] attended the meeting. [REDACTED] also attended the meeting and sat in on our deliberations. Matters covered at this meeting included presentation of a paper on the potential deep-seated instability of the right abutment of the main dam; discussions on the RCC investigations with specific emphasis on the GERCC; an update on the investigations for and the design of the saddle dam embankments; discussions on the potential for erosion of the rock downstream from the main dam's stilling basin during extreme flood events; and discussion on the comments made by the TRP on the outlet works at the eighth TRP meeting. We were able for the first time to see some real construction progress on site when we were taken on a brief tour of the works. We gave a briefing on our conclusions in the afternoon of 29 January

The tenth TRP meeting was held over 24 and 25 February 2010 at the new damsite office of the Bulk Water Alliance (BWA). [REDACTED] and [REDACTED] attended the meeting. Matters covered at this meeting included presentation of some early results on the thermal analyses of the main dam; discussions on the RCC investigations; a further update on the investigations for and the design of the saddle dam embankments; an update on design refinements that had been made or are being considered for the outlet works; a presentation on the layout of the crushing and screening plant, which is now being erected; and discussions on the modified layout of the quarry, with emphasis on the geological aspects. The TRP members were taken on a tour of the site on the afternoon of 24 February. We gave a briefing on our conclusions in the afternoon of 25 February. We were again pleased to have with us [REDACTED] from the Alliance's internal challenge team. His experience was greatly appreciated.

The eleventh Technical Review Panel (TRP or the Panel) meeting on the Enlarged Cotter Dam (ECD) was held over 22 and 23 April 2010 at the damsite office of the Bulk Water Alliance (BWA). [REDACTED] attended the meeting. Matters covered at this meeting included presentation of some further results on the thermal analyses of the main dam; discussions on source and grade of the flyash for the RCC; some hydraulic and structural design matters for the main dam; discussions on the details for the gallery in the main dam; an update on the instrumentation for the main dam; an update on Stage 2 of the diversion works; a further update on the investigations for and the design of the saddle dam embankments; an update on design refinements that had been made or are being considered for the outlet works; an update on the geological investigations, including information from the works as the quarry and the foundations for the structures are being progressively developed. The TRP members were taken on a tour of the site on the afternoon of 22 April, after a briefing on the construction progress. We gave a briefing on our conclusions in the afternoon of 23 April.

The twelfth TRP meeting on the ECD was held over 22 and 23 June 2010 at BWA's damsite office. [REDACTED] and [REDACTED] attended the meeting. [REDACTED] was unfortunately

1. Introduction and previous meetings

ill at the time, while [REDACTED] at his own request had stood down from the TRP. [REDACTED] will be available for consultation with BWA, should the need arise. Matters covered at this meeting included the quarry; the saddle dam, both on design issues and on the progress on construction; the progress on the excavations for the main dam; the hydraulics of the main dam's spillway plus some discussion on the potential for cracking along the toe of the main dam; an update on the RCC investigations and on the plant for its production; presentation of some further results on the thermal analyses of the main dam; an update on design of the outlet works, which have now been switched from the left bank to the right bank of the main dam. [REDACTED] and [REDACTED] spent some time at site on 21 June, concentrating mainly on the foundation excavations for the main and saddle dams and also the excavations being done above the left abutment to get access into this area. The TRP members were taken on a tour of the site on the morning of 22 June, after a briefing on the construction progress. We gave a briefing on our conclusions in the afternoon of 23 June.

The thirteenth TRP meeting was held over 31 August and 1 September 2010 at the dams site office of the BWA. [REDACTED] attended the meeting. Matters covered at this meeting included the quarry; the saddle dam, mainly on construction matters; the progress on the excavations for the main dam; some details on the spillway's design; presentation of some further results on the thermal analyses of the main dam; design changes to the gallery of the main dam and to Stage 2 of the diversion works, both due to the relocation of the outlet works to the main dam's right abutment; a brief comment on the question of the potential for cracking along the toe of the main dam; an update on the RCC investigations and on the plant for its production; an update on design of the outlet works, part of which have been relocated within the body of the main dam's RCC mass; and a discussion on the recently received tenders for the valve supply contracts. [REDACTED] spent some time at site on 30 August, concentrating mainly on the foundation excavations for the main and saddle dams and the fill placement activities at SD2. The TRP members were taken on a tour of the site on 31 August, after a briefing on the construction progress. During this inspection, the TRP was shown examples of several small RCC trial placements. We gave a briefing on our conclusions in the afternoon of 1 September.

The fourteenth Technical Review Panel (TRP or the Panel) meeting on the Enlarged Cotter Dam (ECD) was held over 30 November and 1 December 2010 at the dams site office of the Bulk Water Alliance (BWA). [REDACTED] and [REDACTED] attended the meeting. The major matters covered at this meeting were the outcomes from the recent RCC trial placement and discussions on the latest results from the thermal analyses of the RCC dam. Other matters discussed included changes to the gallery layout and the construction method for the sloping gallery; the proposed detail at the toe of the dam to cope with possible high pore pressures during spillway operation; changes to the outlet works; changes to Stage 2 of the river diversion; an update on the geology as revealed in the excavations for the main dam's foundations; the quarry operations; and an update on the saddle dam construction. We spent some time at site on 30 November, mainly at the trial RCC placement, but we were able to see the saddle dam sites and view the progress of the excavation for the main dam's foundations from the top of the right abutment. We made a brief visit to the RCC placement on 1 December to see the first 3 m or so of the diamond wire cut through the RCC. We gave a briefing on our conclusions in the afternoon of 1 December.

The fourteenth TRP meeting was preceded by several site visits by [REDACTED] and [REDACTED] during October to see how work was going on the RCC trial placement. Later on 23 November [REDACTED] met with several members of the design team along with [REDACTED] a specialist consultant in dam engineering and also the Chairman of the NSW Dam Safety Committee, and [REDACTED]

1. Introduction and previous meetings

██████████ who recently retired from GHD and who spent some time with the BWA design team, for discussions on the thermal analyses of the main dam.

The fifteenth Technical Review Panel (TRP or the Panel) meeting on the Enlarged Cotter Dam (ECD) was held over 28 February and 1 March 2011 at the damsite office of the Bulk Water Alliance (BWA). ██████████ attended the meeting. The major matters covered at this meeting were an update on the results of the October 2010 RCC trial placement and the proposed new trial placement specifically to investigate 400 mm layers; and the presentations by BWA of its latest results from the thermal analyses and the earthquake load analyses of the main dam. Other matters discussed included an update on the geological aspects of the main dam foundation excavation and of the quarry; a final report on the virtually completed saddle dams; a review of Stages 2 and 3 of the river diversion; an update on the changes to the gallery layout and the construction method for the sloping gallery; progress on and changes to the outlet works layout. We inspected the site on the morning of 28 February. Included in this inspection were the completed saddle dams, the quarry, the main dam foundations and river diversion works from the valley floor. We saw the October RCC trial placement and the site of the 400 mm layer trial placement in the afternoon of our first day and the first layer of RCC in the second trial the next morning. We gave a briefing on our conclusions in the afternoon of 1 March.

Immediately after the meeting, at BWA's request, ██████████ prepared a letter on behalf of the TRP on the thermal and earthquake load analyses and the implications that we have drawn from the discussions at the TRP meeting. This letter was reproduced in full in our report on the 15th TRP meeting as it covered our views on these important analyses.

On 23 – 25 March, ██████████ visited Wyaralong Dam in Southeast Queensland for the final Expert Review Panel Meeting for that dam. Given that the reservoir had completed its first fill within about a month of diversion closure and a flood of 350 m³/s over the spill happened early in January very soon after, he added some comments on some of the “little” things that were picked up by the Wyaralong Dam Alliance site team. It was thought that some of these points may have been of interest to BWA.

The sixteenth Technical Review Panel (TRP or the Panel) meeting on the Enlarged Cotter Dam (ECD) was held over 12 and 13 May 2011 at the damsite office of the Bulk Water Alliance (BWA). ██████████ attended the meeting. The aspects covered at this meeting were:

- A report on the recent 400 mm RCC trial placement.
- Matters related to the impending de-commissioning of the crushing plant.
- Geological matters on the valley floor area, where the final foundation clean-up is now well underway.
- Proposed inclusion of a bulkhead in the connecting gallery between the intake tower and the main gallery in the main dam.

1. Introduction and previous meetings

- Some design changes resulting from the earthquake load analyses of the main dam and the results of the smeared FE model done as part of the thermal analyses of the main dam.
- An update on the design changes to diversion Stages 2 and 3.
- A presentation on the intake tower's structural design.
- An update of the E & M works.

██████████ and ██████████ spent most of the afternoon with ██████████ and ██████████ at the valley floor area of the main dam on 11 May. The TRP, less ██████████, inspected the site on the morning of 12 May. Included in this inspection were the quarry, the crushing plant area, the valley floor area of the main damsite, the 400 mm RCC trial placement and the precast yard. After the meeting on 13 May, we again visited the valley floor area, this time concentrating on the intake tower area. ██████████ spent an hour or two in the valley floor area earlier on 13 May. We gave a briefing on our conclusions in the afternoon of 13 May 2011.

On 21 June 2011, ██████████ attended a special meeting called at short notice by BWA to discuss the locally deepened excavation in the valley floor along the foot of the right abutment. Given that BWA had lost time in this exercise, BWA also asked us to consider and comment on the final foundation treatment procedures then proposed for the stilling basin. We have included our comments on this special inspection as Appendix A to our 17th TRP report.

The seventeenth Technical Review Panel (TRP or the Panel) meeting on the Enlarged Cotter Dam (ECD) was held over 11 and 12 August 2011 at the damsite office of the Bulk Water Alliance (BWA). ██████████ attended the meeting. This meeting concentrated on the works in the valley floor area of the main dam, especially on the RCC of the main dam now underway. On 11 August, after an update on the recent testing from samples from the two RCC trial placements and on the results from the control testing of the foundation concrete and concrete in the stilling basin, the main outlet pipe surround and the intake tower, we were briefed on the placement activities on the RCC. At the end of this briefing, in mid-afternoon we went to the main dam to inspect the RCC and the other nearby works. We spent virtually the rest of this day at the main damsite, until about 9.00 pm, by which time the first of the "night" shifts was well on the way with the next RCC layer. The next day, we inspected the second of the two layers placed over the previous night. Discussions were held after this inspection on the progress of the works at the main dam, concentrating on the RCC placement activities. We gave a briefing to BWA in the mid-afternoon of the last day of the meeting.

The eighteenth Technical Review Panel (TRP or the Panel) meeting on the Enlarged Cotter Dam (ECD) was held over 10 and 11 November 2011 at the damsite office of the Bulk Water Alliance (BWA). ██████████ attended the meeting. Due to illness, ██████████ was unavailable, while ██████████ had to decline to come to the meeting as he was about to leave for a holiday. The fourth member of the Panel, ██████████ has all but completed his input to the Panel and for that reason did not attend. Like the seventeenth meeting in August, this one concentrated on the works in the valley floor area of the main dam, especially on the RCC of the main dam now underway. On 10 November, I was briefed on the results from the control testing of the RCC and the concrete

1. Introduction and previous meetings

in the intake tower. Several issues on the RCC were also raised, including some defective concrete on a couple of the downstream face's steps, some localized plastic cracking in the surface of the RCC and some of the ongoing difficulties being faced in the control density testing. BWA summarized some specification and design changes that had been made. On the basis of the results of the latest control testing, BWA presented several points that could be considered for an argument to lower the Portland cement content of the RCC mix. Late in the afternoon of 10 November, BWA gave me a thorough run-down on the progress of the RCC placement. After this final phase of the briefing, we inspected the intake tower works, in particular the installation of the pipework and related valves and the stairs and platforms in the lower part of the tower. On 11 November, I was able to have a very close look at all the RCC works on the main dam. I gave a briefing to BWA in the mid-afternoon of that last day of the meeting.

Between the 17th and 18th TRP meetings, The TRP made two special visits to site. The first of these special meetings took place on 22 September, when [REDACTED] and [REDACTED] were on site to look at the nearly completed excavation of part of the bottom section of gallery. [REDACTED] returned to site the next day for a further inspection; [REDACTED] returned to Brisbane on 22 September. Among the main points inspected and discussed on site was the matter of switching to 400 mm lifts in the RCC. A teleconference between BWA personnel and [REDACTED] and [REDACTED] was held on 29 October to confirm the TRP's endorsement of a BWA proposal to adopt 400 mm layers wherever practicable for the rest of the RCC above the top of the lowest length of the gallery – see Appendix A for a copy of the email message from the TRP to BWA. The second visit was by [REDACTED] on 25 October, when he spent a few hours with the site team inspecting the nearly placed bulkhead concrete at the base of the tower, the gallery, several cores from the upstream face of the dam and the layout of the waterstops along the junction of the secondary spillway RCC placements and the RCC of the main dam. We also inspected and discussed the defective concrete along tops of two of the steps of the downstream face, especially as to what could be possible repair procedures for this poor quality concrete.

On 15 November, I returned to the site and spent several hours in the late afternoon and early evening watching the RCC placement activities on the first 400 mm layer since the gallery excavation shut-down.

The nineteenth Technical Review Panel (TRP or the Panel) meeting on the Enlarged Cotter Dam (ECD) was held on 23 April 2012 at the damsite office of the Bulk Water Alliance (BWA). [REDACTED] and [REDACTED] attended the meeting. Like the previous several meetings, this one concentrated almost wholly on the RCC placement operations on the main dam. Unfortunately, as we now all know, actual placement of the RCC and most of the works in and near the spillway's stilling basin was stopped on 27 February due to ongoing wet weather, a stoppage that was forced into a major stoppage of more than 2 months when early in March a reasonably large flood down the Cotter River overtopped the partly completed main dam. The main dam's RCC had at that stage reached RL 511.3, roughly at half-height of the dam as it will be when completed. RCC placing was due to restart on 5 May. To add to the many difficulties faced by BWA, cracking, including cross-valley cracking was found in the RCC surface on each of the monoliths that is presently against an abutment. Apart from getting an update on the flood overtopping, the resulting damage and the forced delay of nearly 60 days at the date of the meeting (close to 70 days by the time RCC placement restarts), we:

1. Introduction and previous meetings

- inspected the site;
- were given a review of the latest RCC and CVC test data;
- inspected some recent cores from the RCC;
- were briefed on some proposed repairs to the main dam, the most critical of which were the cross-valley cracking that had been found in the tops of the two blocks against the abutments;
- were briefed on what precautions were to be followed on the restart and when the restart was expected to happen;
- were briefed on the specific plans and precautions that would be followed on the RCC placement procedures in the approaching colder weather;
- discussed proposals from BWA to reduce the foundation drilling and grouting operation for the main dam; and
- were briefed on proposed changes to the RCC placement operations, with emphasis on the practices felt necessary for the coming winter period.

We gave a briefing to BWA in the late-afternoon of 23 April on our assessment of the present situation at site. We agreed that we would review the proposed memorandum that BWA was then preparing on the cracking in the RCC, a memo that would be submitted to ACT's Dam Safety Unit. With the permission of ██████████ BWA's Chief Engineer, we included this memo in our TRP report for completeness. It was attached as Appendix A to our 19th TRP report. Drawings were contained within this appendix which show the cracking as it was on the day of our meeting.

Over the 30 November and 1 December 2011, ██████████ visited the damsite to inspect and to discuss the RCC placement operations. This visit replaced his role at the 18th TRP meeting, which he had not been able to attend due to illness. His report on his visit was attached to our 19th TRP report as Appendix B.

After a further a series of cold nights at the damsite in late April and early May, cross-valley cracking roughly in line with the cracking in the abutment blocks extended virtually fully across the dam. As well, more cracking was found near the upstream end of the two abutment blocks, adding to the cracking already picked up near the gallery works. We prepared a special note to BWA after this further cracking was discussed by telephone conference on 4 May. This special note was sent to BWA by email on 5 May. It was attached herewith as Appendix C to our 19th TRP report.

We asked BWA to consider very carefully Section 5.5 of our 19th TRP report, as we wrote of our serious concerns about the design of the dam, given the discovery of the cross-valley cracking, as at the end of the first week of May 2012. We stated that we were more than happy to discuss our concerns on this matter with BWA.

2. THE MEETING

2.1. ATTENDEES AT THE 20TH TRP MEETING

The people involved in the 20th Review Panel meeting in Canberra were:

- [REDACTED] Bulk Water Alliance.
- [REDACTED] Bulk Water Alliance.
- [REDACTED] Bulk Water Alliance.
- [REDACTED] Bulk Water Alliance.
- [REDACTED] Hydraulic Structures, ActewAGL.
- [REDACTED] Bulk Water Alliance.
- [REDACTED] Bulk Water Alliance.
- [REDACTED] Bulk Water Alliance (second day only).
- [REDACTED] Bulk Water Alliance (second day only).
- [REDACTED] Bulk Water Alliance.
- [REDACTED] Bulk Water Alliance (site inspection only).
- [REDACTED] BWA.

[REDACTED] of the ACT's Dam Safety Unit and [REDACTED] and [REDACTED] the Unit's technical representatives for ECD, attended the meeting. [REDACTED] also of the Unit, was present on the first day of the meeting.

2.2. INFORMATION MADE AVAILABLE TO THE PANEL

We were sent a plan and some photographs of the cross-valley cracking in the entrance gallery on 10 August. At the end of the meeting we were given an electronic copy of the power point presentations prepared by BWA staff for the meeting.

2.3. ACKNOWLEDGEMENTS

We would like to thank all we met during the 20th TRP meeting for their very kind welcome. As will be clear from our introduction to this report, BWA has suffered further cross-valley cracking and some horizontal cracking has been found on the downstream face of the dam. Like the discovery of the earlier cross-valley cracking, these incidents will be further tests of character of not only the whole site team, but also the design team away from site. We still firmly believe that the whole team has and is continuing to make excellent progress insofar as has been possible and to produce work of a very high standard on the investigations, on the design and on the construction of the works. For all the difficulties that have arisen in the RCC progress, we have absolutely no doubt whatsoever that a quality product has been and will continue to be constructed. We would both like to acknowledge here the input by [REDACTED] in achieving this excellent RCC product; his experience in RCC construction and his wise counsel have been greatly appreciated by the TRP, me especially.

We still believe that fundamentally our words from several of our earlier reports that the BWA team of designers, geologists, geotechnical engineers, constructors and anyone we have forgotten is

2. The meeting

continuing to work as a unified group. While there may have been the odd ‘hiccup’, perhaps “teething” problems and the inevitable differences of opinion on technical matters as construction has proceeded and, as we now know a serious setback to the works due to the flood incident earlier in 2012, we cannot over-emphasise enough the value of teamwork across the whole group, something that we have seen consistently so far on the job. No doubt, the situation was not helped by that flood incident and the discovery of the cross-valley cracking; all the more important the people maintain that teamwork. The construction phase, especially of the main dam and its associated works, will require continued patience, tolerance, quick-thinking and on the spot decision-making at times and good engineering at all times. Each group within the Alliance must try to recognize the difficulties that each of the other group faces and for each group to use the strengths of the others to support it as it “solves its own problems”. We remain very confident that the Owner will get a dam that everyone will be proud of. We also feel strongly that each member of the Alliance will, at the end of the job, look back with pride at his or her efforts and remember the friendships built up during the work with great pleasure.

3. THE PROJECT

The project, as generally developed by GHD in a study about six years ago, includes:

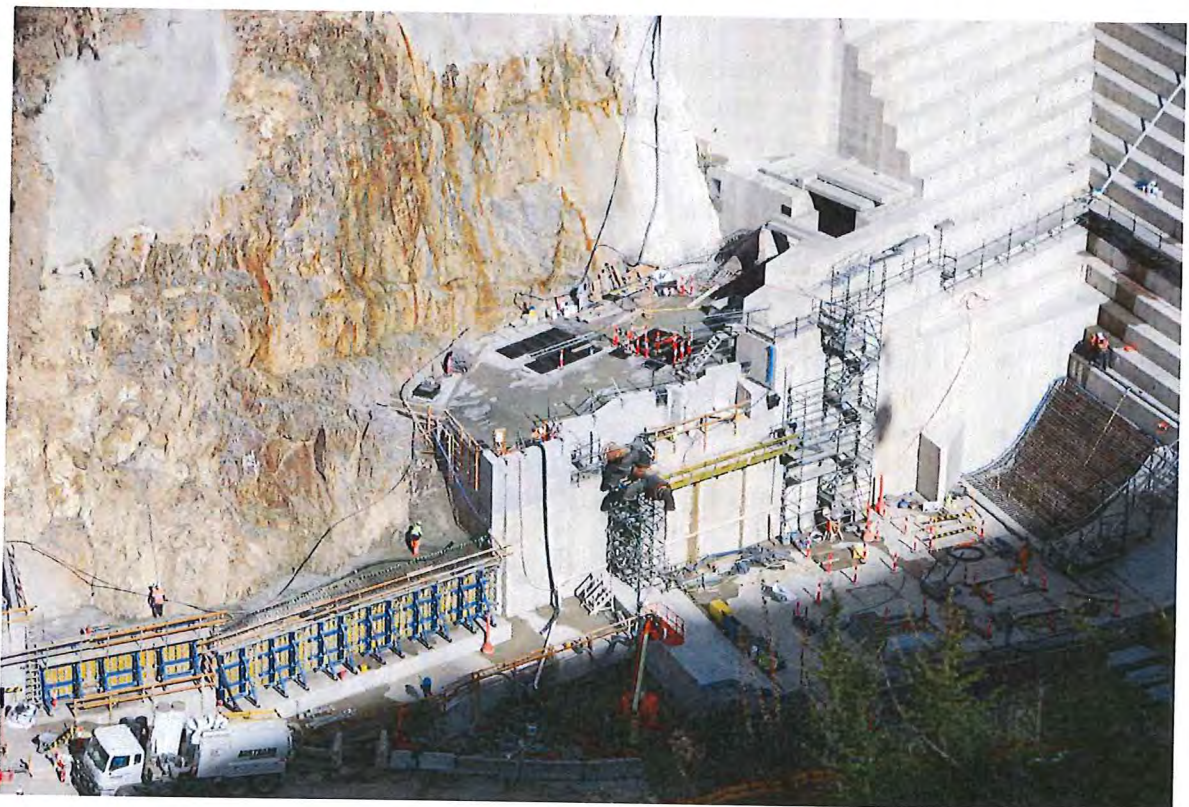
- A main dam about 85 m high, some 100 m downstream from the existing Cotter dam. The main dam is a roller compacted concrete (RCC) gravity dam with a vertical upstream face, a stepped downstream face and a central primary free overfall spillway of about 100 m wide. Down each abutment are channels for the secondary spillway that sits in two halves, one on each side of the primary spillway. These two channels are being constructed in RCC, layer by layer with the main dam RCC.
- Two saddle dam rockfill embankments over saddles in the right abutment ridge.
- A conventional outlet system with an intake tower attached to the upstream face of the dam and an embedded pipe outlet.
- A separate diversion outlet embedded in the dam that will be eventually permanently plugged. Large floods during construction are allowed to overtop the partly completed dam.

The main dam at its proposed height of about 85 m would fully develop the damsite downstream from the existing Cotter dam, with the dam's crest being very close to the top level of the right abutment.

The Alliance is now well into the construction phase of the works. As at mid-August 2012:

- The crushing plant for the RCC aggregate was decommissioned early in June 2011.
- The saddle dam embankments are now complete.
- The Stage 2 diversion works is still service after more than 12 months, with a steady flow of water through the 3 m conduit constructed on the lower left abutment. The control valve for this 3 m conduit was commissioned in August 2011.
- Except for some minor clean-up work on the two steep abutments, work that will be picked up on the way up with the RCC, the abutment excavation has been completed.
- The detailed cleanup of the foundations within the valley floor area at the main damsite was completed in early July 2011 and the "foundation concrete", the mass concrete that was placed over the whole of the valley floor area to a nominal level of RL 471, was finished in late July.
- The two RCC plants and the conveyor delivery system to the main dam are fully operational, as are the three tower cranes at the main damsite.
- Boral's CVC plant has been operating well for a while now, providing concrete for the intake tower and the stilling basin works that have been done so far.

- The main concrete work in the tower has been completed and all work in the bottom of the tower, including the pipework, both embedded and non-embedded, has been done. The main outlet pipe is also fully embedded in concrete to a point about halfway across the stilling basin's end sill. Installation of the pipework, valves and related items is almost complete, with only the top three bellmouth inlets to be done. The concrete bulkhead at the base of the tower has been completed and the bulkhead's access steel door and frame are in place.
- The right hand wall of the stilling basin is almost complete, with the butterfly valves on the environmental release and the water supply line installed in pits at deck level. Progress on the left wall is still being limited by the presence of the Stage 2 diversion conduit. (The need to maintain this diversion conduit in service is now due only to the slow progress on repairs to the upstream face of the dam.) The stilling basin floor, including the end sill, has been constructed to about the halfway line and already one placement of the curved connection to the toe of the dam has been done. The right hand wall beyond the end of the stilling basin is well underway. Photograph 3.1 shows the progress along the right hand half of the stilling basin; Photograph 3.2 shows the state of the left side of the basin.



Photograph 3.1 The right hand side of the spillway's stilling basin, showing the partly completed outlet works and the manifold pipework for the Stage 3 of the diversion works.



Photograph 3.2 The left hand side of the spillway's stilling basin, showing the way the outlet of the 3 m diameter conduit of the Stage 2 diversion works is now holding up progress on this side of the stilling basin.

- Production of the various precast units for the dam, including the roof panels for the whole length of the gallery and the floor panels for the abutment lengths of the gallery, in the site's precast yard was finished in about August 2011. With the decision to precast the primary spillway walls (for top 20 m or so of the dam) in a series of horizontal units equal to the height of one step of the dam's downstream face (1.2 m), BWA decided that such units should be produced off-site. The first two or three units on each side have been embedded in the RCC.
- RCC placement in the main dam began on 1 August 2011. When the overtopping happened in early March 2012, BWA had placed about 194 000 m³ (roughly one-half the estimated total) to reach RL 511.3. (The flood overtopping raised the water level behind the dam to RL 513.24, that is, nearly 2 m above the top of the RCC.) Since the restart on placement, BWA has placed about another 100 000 m³ to reach RL 532. Except for one 400 mm layer to complete a step, all layers of the RCC above the flood-stoppage level of RL 511.3 have been 300 mm thick layers. Photograph 3.3 shows the main dam as it was on the first day of the meeting.



Photograph 3.3 The downstream face of the dam as at 15 August 2012. The RCC deck level was at RL 532, which is 20 m below the crest level of the primary spillway.

4. SITE INSPECTION

Before the meeting, we inspected the main dam works, spending most of our time on the deck of the dam, in and around its downstream side and along the entrance gallery. The work on the deck of the RCC looked to be of a very high standard, with everything being well organised. Clearly the cluttering on the deck of the various items of plant and equipment does impede progress. During the meeting we inspected a number of short drilled cores that had been taken from a couple of the entrance gallery cracks, two of the long check cores and, on the second day, a core from one of the near-horizontal cracks in the dam's downstream face.

5. ROLLER COMPACTED CONCRETE

5.1. INTRODUCTION

Since resuming placement of RCC after the March overtopping event, progress has been relatively slow due to a combination of cold joints together with increasing congestion on the placement surface as the dam width decreases with increasing height. At the time of this visit (15 August 2012), the dam was at RL 532 with some 295,000 m³ placed of the expected projected total of 375,000 m³. With the exception of the first lift placed after resumption, the remaining layers have all comprised 300 mm lift heights.

During the course of the site inspection on 15 August, the Panel was very pleased to note a significant improvement in the apparent quality of the RCC/GERCC placed in both the upstream and downstream faces since our last visit on 23 April 2012, with virtually no visible evidence of defective RCC that would require repair as noted in our last report (TRP 19). At the same time the Panel noted a similar significant improvement in construction processes and attention to detail in the RCC and GERCC being placed at EL 532. The RCC mix was very consistent as well as conducive to grout enrichment while being placed at an ideal moisture content to achieve the specified compaction; there was no visible evidence of segregation on spreading; the bedding mortar placement was as per specification; the rolled surface was live, but smooth, and closed with acceptable rutting apart from the surface immediately below the feed hopper where the truck wheels were leaving deep ruts (this was recognised by the placing crew and the smaller roller was being used to control these ruts); and the observed attention to detail and process of the embedment of the water stop was excellent.

The cross valley cracking caused by thermally induced strains that was discussed in detail in our last TRP report (No 19) has been treated as detailed in that report with the drilled near-horizontal drains from the gallery to beyond the lines of the observed cracks yet to be installed. These drains will include measures to exclude air from entering the drain, such as water filled "S" bends or similar, to ensure the drains do not become blocked by calcite development. Recently, a further five vertical cracks in the cross valley direction have been located intersecting the right bank adit to the gallery. These cracks appear to be caused by thermally induced strains in a similar manner to the previously located cracks and will be discussed later in this report. The presence of some horizontal cracking within the faces of the downstream steps has also only recently been discovered and is currently under investigation. At this stage the cause of this horizontal cracking is not known and until further investigations are completed it is too early to even speculate; this matter will also be discussed later in this report.

Before we start our discussions on the recently discovered cracking and the results of current thermal and earthquake load modelling on the effects of the existing known cross valley cracks on dam stability, we will go through BWA's routine presentations on the RCC strength testing, the repairs that are and will be required and discuss some issues related to the RCC and its placement. There are now available a sufficient number of 180 day test results to allow a reasonable statistical analysis on this basis.

5.2. RCC CONTROL TESTING

5.2.1. Panel's comments

a. Compressive strength testing - RCC

The RCC placed within the dam to date meets and exceeds the specified compressive strength requirements with an average strength of 23.1 MPa at age 180 days with a coefficient of variation of 12.9%.

b. Indirect tensile strength testing - RCC

The Indirect Tensile Strength results of RCC placed within the dam to date also meets the specified requirements with the indirect tensile strength averaging 2.8 MPa at age 180 days, which equates to 12.4 % of the compressive strength with a coefficient of variation of 11.2%. The value of coefficient of variation demonstrates relatively close control and good laboratory practice. Limited direct tensile strength results to date range 6% to 8% of the compressive strength.

It is interesting to note that the relationship of indirect tensile to compressive strength of the laboratory trial mix specimens was higher than that of the dam concrete with an average of 18%. A possible reason for this difference may be due to the rapid mixing time in the site batch plant being insufficient to remove effectively surface coatings of dust and deleterious materials on the stockpiled aggregates, whereas the laboratory trials were mixed for a significantly longer period

c. Insitu density - RCC

The insitu density testing of RCC placed in the dam to date shows that greater than 97.8% of all tests passed the specified criteria.

During the last TRP meeting it was suggested that the initial “failed” test results prior to rerolling and retesting be also recorded in the database so that an analysis of the frequency of failed test and rerolling/retest can be made. This may in turn assist in the analysis of the “construction efficiencies” of placing a 400 mm thick layer versus a 300 mm lift as anecdotal evidence suggested that the incidences of rerolling had increased in frequency within 400 mm thick lifts in comparison to the 300 mm thick layers.

The Panel is pleased to note that this analysis has since been carried out on every 5th layer since lift No.154. The results show that for 525 total density tests there were 7 instances of rerolling or some 1.3% of the total. This was further broken down into 300 mm lifts that showed 3 rerolls in slightly over 300 total tests (about 1%) with the incidence of rerolls in the 400 mm lifts being 4 in slightly over 200 tests (about 2%). It is difficult to draw a meaningful comparison between the effects of the layer heights on compaction, given the small number of retests required but, at the same time, it is pleasing to note the relatively low incidence of retests required.

At another previous TRP meeting it was suggested that it would be helpful to assist in interpretation of insitu density test results to analyse the variation in TAFD based on the mix design moisture content corrected for the placement moisture content compared to the TAFD derived from air-pot tests and compared to the actual Vebe densities obtained over a shift. As laboratory trial mixes comprise closely controlled mix proportions, including grading and moisture content, and the Vebe test is also performed to closely controlled procedures, the relationship of the 2 minute Vebe density to the TAFD for that mix has been found to be very repeatable and reproducible for a particular mix. For the laboratory trial mixes on this project the relationship was found to be 98.5%. The Panel is also pleased to note that this analysis has now been performed showing that the comparison of the Vebe densities to TAFD gave a variation over a range of 1.5% (98% to 99.5%). This indicates that the mix proportions are varying sufficiently to make a comparison of the TAFD value based on the mix design corrected only for moisture content somewhat inaccurate and explains the slightly low percentage of all tests passing (97.8%) and also explains the number of tests giving a seemingly “impossible” result of more than 100% of TAFD.

d. Aggregate gradings - RCC

Gradation test results to date show that the placed RCC has a quite consistent grading demonstrating relatively good batch control with one recent exception. There was a period recently where the RCC was observed to be somewhat “sticky” and it was also difficult to get adequate penetration of grout for the GERCC. The RCC gradings reflected an increase in fines (<75 um) and investigations revealed that the sand was being drawn from an access ramp within the stockpile where the traffic loading had caused breakdown of the weathered and altered sand particles producing an overabundance of cohesive fines. This problem was identified and rectified with personnel now being more aware and vigilant of stockpile winning operations.

e. Compressive strength – GERCC-15

With an average compressive strength of 27.5MPa at age 180 days with a coefficient of variation of 20.8%, the GERCC-15 meets and exceeds the specification. The high coefficient of variation reflects the degree of difficulty in producing consistent GERCC with a non-superplasticised grout at an 0.9 water/cement ratio, if the parent RCC is quite variable and rigorous attention to both detail and procedures is not followed.

f. Compressive strength – GERCC – 25

The average compressive strength of 31.0 MPa at age 180 days with a coefficient of variation of 11.0% meets the specified requirements. The much improved coefficient of variation when compared to the GERCC-15 reflects the increased ease with which the highly superplasticised grout will penetrate and that better vibration and mixing has been achieved. This could also be a function of the Paver.

g. Compressive strength - Bedding mortar

The average compressive strength of 29 MPa at age 28 days meets the Specification, but the coefficient of variation of 16% indicates a lesser degree of control of mix consistency than that of the other concretes.

5.3. DEFECTIVE RCC AND REQUIRED REPAIRS – PANEL’S COMMENTS

5.3.1. Upstream face and downstream steps

Repair of highly voided (honeycombed) areas of the GERCC on the downstream steps caused by segregation and/or incomplete vibration during construction continues by removing the honeycombed zone and replacing with Renderoc HB25 for shallow (<80mm deep) repairs and with larger repairs utilising a high flyash 20/20 concrete with N16 anchors at 250 mm centres embedded 430 mm into dense GERCC/RCC. Repairs to date appear satisfactory.

Defective areas on the upstream face are being repaired using a similar process with extreme caution not to remove the concrete from too close to the waterstop to prevent damage. The void is being filled with a high flyash 20/20 concrete with N16 anchors at 250 m centres embedded 550 mm into dense GERCC/RCC with N20 bars at 200mm centres horizontally within the concrete at the face. A grout tube leading to behind the waterstop at the repair/GERCC interface is being incorporated to allow grouting of this area if required.

As mentioned previously it was pleasing to note the significant improvement in the quality of both the upstream and downstream faces of the RCC/GERCC placed since resuming after the March flood with virtually no visible evidence of defective concrete that will require repair. We are sure that BWA understands very well that these repairs are very time-consuming, annoying and costly.

5.4. INSPECTION OF CORES AND LIFT JOINT QUALITY – PANEL’S COMMENTS

It is pleasing to note that the Panel’s suggestion in the last TRP Report to carry out further core drilling in an area of RCC placement where there were no impediments to RCC placement, such as there were in the location on the previous core drilling on the right hand secondary spillway channel, has been acted upon. Two cored holes have been put down from EL 512. Both cores are 83mm in diameter, with one hole drilled vertically and intersecting the foundation for a depth of approximately 1 m, and the other hole drilled at approximately 30 degrees to the vertical to test if the inclined hole would give better intact lift joint recovery. The inclined hole had only just been completed and has not yet been appraised for joint recovery and condition, but our brief inspection appears to indicate perhaps an improved intact joint recovery.

Inspection of the vertical hole indicates that of the 119 joints intersected:

- 90 joints remained intact with 29 joints separating.
- 54 were hot joints with 11 separating – 20.4%.
- 47 were warm joints with 16 separating – 34.0%.
- 18 were cold joints with 2 separating – 11.0%.

The lift joints may be sorted based on the lift heights.

For 300 mm lifts there were 68 lift joints:

- 52 joints remained intact with 16 separating.
- Of these 38 were hot joints with 5 separating – 13.2%.
- 23 were warm joints with 9 separating – 39.1%.
- 7 were cold joints with 2 separating – 28.6%.

For 400 mm lifts there were 51 lift joints:-

- 38 joints remained intact with 13 separating.
- Of these 16 were hot joints with 6 separating – 37.5%.
- 24 were warm joints with 7 separating – 29.2%.
- 11 were cold joints with 0 separating – 0%.

The separated lift joints were sorted into three categories defined by the joint surface appearance:

1. Broken aggregate on joint (showing bond).
2. Other signs of bond on joint (bedding mortar or RCC paste on both sides of joint plucking).
3. No clear sign of bond on joint.

The number of separated joints in each category is:

1. - 2 warm.
2. - 3 hot; 5 warm; 2 cold.
3. - 2 hot; 4 warm.

Both category 1 and 2 - 6 hot; 5 warm.

It is difficult to draw any definite conclusions from the observations at this stage as the size of the core is relatively small (60 mm diameter), which is liable to have a significant bearing on the number and manner of joint separations during drilling. The following general comments are made:

- In general, while it would be very difficult to quantify, the majority of broken lift joints displayed some degree of bond.
- As may be seen in the saw-cut surfaces in the two RCC trial placements, the surface roughness of the separated joints together with the macro roughness of the lift surface due to undulations caused by aggregate in the lift above being “indented” in the surface below during compaction of warm joints and penetration of aggregate into the lift below in compaction of hot joints together with surface rutting ensures that the RCC will have high shear resistance on the lift surfaces.

- Of the joints containing bedding mortar, 34% of the warm joints separated compared to 11% of the cold joints. This suggests that the warm joint is not developing the same degree of bond with the bedding mortar as that of the cold joint where the cold surface is green cut before the addition of mortar. There is visual evidence on quite a few of these separated warm joints that suggests the failure of these joints appears to be within a thin film at the contact of the surface of the warm layer and the bedding mortar. This may be the result of inadequate curing where the surface is left to dry out thus leaving a thin surface film of “burnt out” cementitious and/or the surface is ponded, thus leaving a thin film of overly wet cementitious material. This has been noted on previous cored lift joint surfaces.
- Similarly, a lack of inadequate curing of the rolled surface, that is, either too wet or too dry, can explain the lack of bond in failed hot joints where there is no noticeable segregation.
- The lack of adequate bond on surfaces where bedding mortar is applied can also be attributed to the mortar being left too long before being covered with RCC, with associated lack of proper curing allowing the mortar to either dry out and lose workability or become too wet. The mortar must also be worked well into the surface of the RCC layer before the next lift is placed and spread.
- It was pleasing to note that there was no evidence of any segregation either within the lifts or at the base of the lifts with the exception of a very minor small patch of not badly segregated material within one lift.
- It would be beneficial to drill another continuous core hole of a larger diameter, minimum 150 mm, from the top of the completed dam to the foundation to give a much better chance of lift joint recovery. This is a matter for the BWA to consider as it is acknowledged that it would be at some significant cost.

To reiterate what we have emphasised in earlier TRP reports, the places where significant and likely extensive defects can happen in any RCC construction will be at the lift joints. With a total number of joints in the dam of over 200, it is not hard to see that they could become critical features within the finished dam. There are several examples of gravity and arch dams in Australia where poor quality lift joints have proved very costly items for their owners.

5.5. ENTRANCE GALLERY CRACKING – PANEL’S COMMENT

5.5.1. Inspection and meeting presentations

As mentioned earlier in our report and as shown in BWA’s drawing in Appendix A, cross-valley cracking has been found in the entrance gallery. With the right (uphill) side of the gallery being formed by the reinforced concrete surround for the main outlet pipe and with this side also being a monolith joint, the cracks have been picked up only on the other side of the entrance gallery. The drawing in Appendix A shows four cracks, but there are several others. These other cracks are very thin and do not seem to go from top to bottom of the gallery entrance section.

The four cracks shown in Appendix A go from roof level to floor level. At least one of them has propagated across the floor concrete that was placed on the RCC base of the gallery. BWA feels that one of the cracks could link up one of these floor cracks and then with a small one in the reinforced wall. The precast roof slabs masks any propagation of the cracks across the gallery roof.

Two of these wall cracks have been cored, in one case to depth of 2 m. The crack was still clearly visible at the end of the hole.

BWA noted that none of these cracks seems to have propagated to the downstream face of the dam.



Photograph 5.1 The vertical crack close to the entrance of the gallery on the right side of the spillway's stilling basin. This crack is in the RCC of the secondary spillway toe channel. It has propagated to the surface of the channel.

Not shown in the drawing in Appendix A is a very noticeable crack near the entrance of the gallery, under the secondary spillway channel. This crack is shown in Photograph 5.1. This crack seems to extend to the stepped surface of the secondary spillway channel, where it apparently links up with a crack in the surface of the secondary spillway channel.

BWA's contention is that these cracks are thermal/shrinkage induced cracks, initiated probably by the local cooling along the wall of the entrance gallery. Ambient temperatures as low as 2°C have

been recorded within the gallery this winter, whereas it is 8-9°C 300 mm into the concrete and 16°C about 2 m in. This temperature gradient could have been enough to see cracks initiated.

BWA noted that the depth of RCC below the gallery floor here to the foundations was only about 3 m, while at the next monolith joint to the left, that is, towards the maximum section, some 10-12 m away, the depth to rock was about 15 m. BWA considered that the cracks have probably already reached the foundation directly below the entrance gallery, but whether they reach the next monolith joint to the left is a moot point. One would expect that they would stop here.

BWA believes that these cracks should be drained into the gallery by a series of drilled holes from the gallery in case they become pressurized from the foundations. The design team feels that in all other respects this dam monolith should be adequately safe, given that it has the mass of RCC of the secondary spillway channel to act as a buttress.

5.5.2. Panel's comments

We agree in broad terms with BWA's assessment of these cracks and we do support the suggestion that these cracks should be drained.

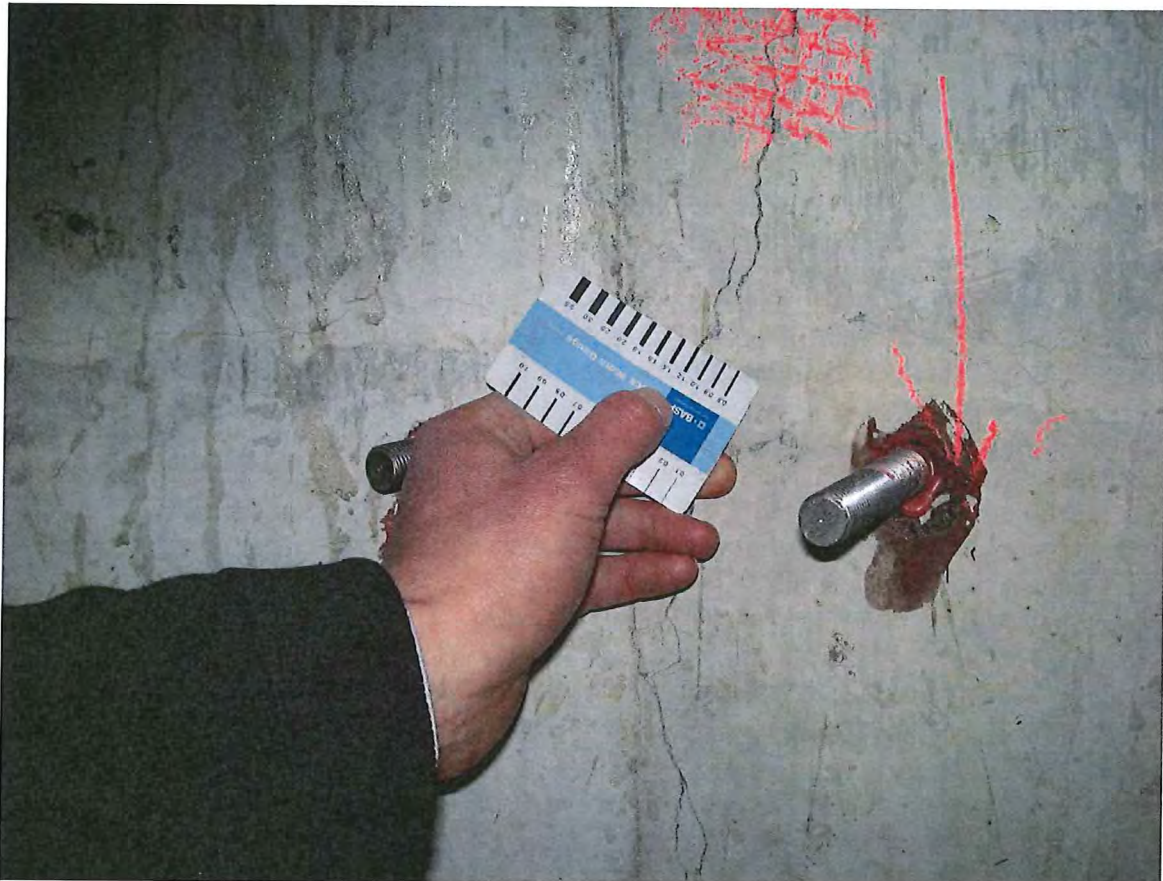
There is no doubt that the gallery should have been kept closed as much as possible, but such would have been difficult, even now well after its completion. The need for access during its construction and for some time thereafter, for access for the repair of damage after the February-March flood overtopping event and for general access would have made the job of sealing the gallery almost impossible, especially given the 24 hour/day work program on the site. Within a couple of weeks, the situation will be even worse, once the grouting sub-contractor begins his job.

We should also not overlook the likelihood that the cracking might have been initiated by the cool water from the flood overtopping, as much as the later cooler ambient temperatures within the gallery.

One of the inner set of cracks is shown in Photograph 5.2. In this photograph and in Photograph 5.1, one can see clearly that the cracks are not planar but do meander from the floor of the gallery to the roof. Certainly, the entrance crack deviates even more off the vertical plane near the roof of the gallery (not shown in Photograph 5.1). We would expect therefore that there is considerable shear strength along any of these cracks, in which case, the body of particular monolith should behave virtually as a monolithic concrete mass.

Within the body of the dam, under gravity and water loading these cracks, if they were to propagate upwards, should follow a trend line that follows the line of the compressive principal stress. That line should angle upstream and should not reach the dam's downstream face. The proviso here is that the thermal/shrinkage-induced stresses near the face of the dam do not become so dominant that they cause, for example, some local cracking at RCC layer surface, which we have already seen (see next section of this report), that might propagate into the dam to link up with one of the cross-valley cracks from the gallery. We note that these near-vertical cracks, as maybe seen on the drawing in Appendix A, all lie downstream from the main cross-valley cracks that were picked up in late April 2012 when the RCC was at RL 511.3. Crack 4 in particular is not that far from the downstream face of the dam. **We would strongly suggest that BWA consider this possibility and keep a close eye on the steps above the Crack 4 location.**

Unlike the other cracks, the entrance crack does reach the surface, in this case the surface of the secondary spillway channel. **We would suggest that this crack be sealed at the surface to prevent water getting into it during a spill event. BWA probably could wait a while until the concrete “settles” down before it seals the crack. In the meantime, the surface should be covered to keep dirt out of it.**



Photograph 5.2 One of the inner cracks along the entrance gallery. Note its significant “waviness”.

5.6. HORIZONTAL CRACKING ALONG THE DOWNSTREAM FACE’S STEPS

5.6.1. BWA presentations

BWA reported that at least two horizontal cracks had been found on the dam’s downstream face. One was low down on the face, within the area to be covered by the curved floor slab at the upstream end of the spillway’s stilling basin. It is to the left of the just-placed curved floor slab. The other is almost directly above it along the RL 485.3 step.

The lower of these two cracks is about halfway up the step. It was cored to a depth of 0.4 m. The core is shown in Photographs 5.3 and 5.4. As may be seen, the break is through good quality RCC, perhaps just getting onto a lift joint. The break includes failures through two pieces of aggregate.



Photograph 5.3 Drilled core along the lower of the two horizontal cracks in the downstream face. The joint surface seems to be at the bottom of the cores – the top of the core is the vertical face of the step. The crack has initiated off the joint at the outer face (see Photograph 5.4).



Photograph 5.4 The full core into the lower crack. Note the crack initiating off the lift joint.

The second crack, the one along the step at RL 486.5, seems to be along the top lift joints (see Photograph 5.5). It will be core-drilled soon.



Photograph 5.5 The higher of the two horizontal cracks on the downstream face, which seems to be along an RCC lift joint. It is on the vertical face of the step at RL 485.3.

BWA's suspicion is that these cracks are due to local cooling on top of the step, possibly initiated when the flood overtopping happened in February-March of this year.

5.6.2. Panel's comments

We do agree with BWA's basic suspicion for the cause of these cracks. We feel that they are not likely to propagate very far into the RCC mass, given that there will be a quickly increasing vertical stress as we move away from the face, especially from the localized disjointed stress pattern associated with the inner corner of each step.

Why the lower one failed as it did is hard to understand as there does not seem to be any significant tensile strength weakness here. Given that it will shortly be completely buried by the third of the reinforced curved floor slabs at the upstream end of the stilling basin, we would suggest that no further action is required.

The crack along the RL486.5 step should be investigated by drilling, as now proposed by BWA. . Its "straightness, as shown in Photograph 5.5 does suggest that it is wholly along a lift joint, unlike the lower of the two horizontal cracks that have been picked up by BWA. It may be that it is along

a locally poor lift joint. We would suggest that [REDACTED] be sounded out as to what would be the local hydraulic pressures on this part of the step from the turbulent flow down the stepped spillway, both before skimming flow is reached and beyond that stage. Decisions on whether or not anything other than some crack sealing need be done, indeed if anything need be done, can be made after [REDACTED] review.

6. CONVENTIONALLY VIBRATED CONCRETE (CVC)

6.1. INTRODUCTION

BWA continues to place CVC within and just downstream from the spillway's stilling basin. Our report here will only comment on the finished products as we were not briefed on the control test results.

6.2. CONCRETE IN THE DOWNSTREAM WORKS – PANEL'S COMMENTS

Apart from the odd small crack near a pit corner, the finished concrete looks very good. We were particularly pleased with the results on the curved floor slabs at the upstream end of the stilling basin, where there were very few of those pesky air bubbles that always seem to plague these types of formed surfaces. Even the first right hand wall where we saw a vertical crack soon after placement some time ago is essentially crack-free; that crack must be very small if it is still there.

We noticed that the one stilling basin floor joint finished, the most upstream of the transverse construction joints, seems to have neatly finished surfaces, with the downstream edge being coplanar with the upstream surface. The detail would be improved if the downstream surface were tapered downwards by, say, 20 mm over the 100-150 mm right before the joint so that we would avoid having any high velocity water hitting the vertical face of the joint. We realize that we have reinforcement through the joint plus a waterstop across the joint, but it is always a good idea to reduce the risk of that high velocity water hitting the face of such a joint.

7. MAIN DAM

7.1. INTRODUCTION

The key matters discussed were the results of the structural analyses done as a direct result of finding cross-valley cracking some two months after the dam was overtopped in February-March 2012 and RCC placement had to be suspended. We also discussed several other specific issues on the dam, including:

- The next phase of the diversion works, once the Stage 2 conduit can be closed.
- The construction details of the CVC works for the aeration step.
- Details of the precast chute walls for the primary spillway.
- Proposed details for the topping out of the dam.
- The start-up of the foundation grouting for the main dam.

7.2. STRUCTURAL ANALYSES SINCE THE DISCOVERY OF THE CROSS-VALLEY CRACKING

7.2.1. Introduction

To recall the earlier events, in late February 2012, RCC placement had to be stopped due to ongoing wet weather with the RCC deck at RL511.3. A week later, the dam was overtopped and the wet weather stoppage became a prolonged major stoppage of, as it turned out, more than two months. Almost immediately after the Easter break of 2012, on the 10th of April, three cracks were found in the two monoliths directly against the abutments. Of these cracks, two were cross-valley cracks, one in each of the abutment monoliths. The one in the right abutment monolith began at one corner of the abutment gallery opening and went across to the abutment. The left abutment crack was about 10 m from the downstream face of the dam at the then deck level of RL 511.3. The third crack was a transverse crack that was close to the left abutment contact surface. The cross-valley crack in this monolith ended at this transverse crack.

BWA considered that a sudden drop in the overnight temperatures during Easter probably caused these cracks to initiate. As we saw on the RCC deck on 23 April at our 19th TRP meeting the left abutment monolith transverse crack did run into and along the abutment contact surface downstream from its junction with the cross-valley crack.

BWA presented some sketches of proposed treatment at the top of the cross-valley cracks, which we endorsed in principle.

On 23 April 2012, within three or four days of our TRP meeting, BWA reported to us that after another night of low ambient temperatures, a series of cross-valley roughly coplanar with the existing one in the left abutment monolith extended to, but not across, the intake tower monolith. Our 19th TRP report reflected our concern at this development. While we strongly supported that the proposed remedial measures for the cross-valley cracks should be applied along the tops of all of these cross-valley cracks, we agreed during a special teleconference between us and BWA staff that a curtain of holes drilled from the gallery should be included in the treatment. These holes would provide for the drainage of any excess pore pressures should the cracks indeed propagate to

the foundations. We also advocated the undertaking of some check structural analyses of a model that included a full-depth cross-valley crack. We stressed the need for both static and earthquake load analyses to be done. Finally, we reiterated an earlier point that the work be restarted on the RCC placement as soon as practicable.

7.2.2. BWA presentation at 20th TRP meeting

BWA included three presentations at the meeting. They were:

- dynamic analyses under an MDE load
- post-earthquake analyses
- the thermal analyses.

In each case, the section analysed was the maximum section, applicable to the three centrally located monoliths in the dam. The near-vertical crack mapped when the RCC deck was at RL 511.3 was located about 15 m from the upstream face and was assumed to have propagated vertically to the dam/foundation interface. The crack did not extend upwards from RL 511.3.

The earthquake loading condition was modelled on a specific site recording made during the 1994 Northridge earthquake in California. This reading was spectrally matched to the ES&S design spectrum. The vertical acceleration time history was included in the analyses along with one of the horizontal records.¹ The earthquake analysis was a non-linear analysis, made so by the introduction of contact elements (compressive and frictional shear strength capable) along the dam/foundation interface and along the hypothetical vertical crack from RL 511.3. A third crack, this one a horizontal crack at RL 511.3, extending from the dam's upstream face to the downstream face was introduced in a second run of the earthquake analyses.

In the earthquake analyses, the vertical crack, the horizontal crack at RL 511.3 and the nominal base of the dam were all assumed to have frictional strengths of 55.

Damping was included as an " α/β " relationship rather than as a simple critical damping factor. According to BWA, the amount of damping was automatically adjusted as the internal strains and displacements increased.

The post-earthquake model included all three of these cracks. In these analyses, the frictional strengths were 0°, 40° and 37°, on respectively the vertical crack, the base and the RL 511.3 crack. The vertical crack strength was progressively increased to 37° and 55°.

The thermal analyses were done specifically to check on if the crack would tend to propagate vertically upwards from RL511.3. In this model the base of the dam was fixed, that is, tensile strains could be taken across the assumed interfaces, while the vertical crack was assumed to have propagated downwards, but to have retained some shear strength capacity. The input temperatures were adjusted to include actual data from the partly-completed dam and different start times from the ones assumed in the earlier studies.

¹ Note that if the vertical acceleration time history from the Northridge event were spectrally matched to the ES&S design spectrum, then one would have to question the actual vertical motion time history used in the analyses. The spectral matching does include both scaling of the acceleration ordinates and a phase shift, which may not be appropriate for the design vertical spectrum. The ES&S design spectrum is specifically for horizontal motion.

In all analyses, pore pressures were modelled as body-forces so the quoted stresses were all effective stresses. In the thermal analyses, the crack was assumed to have no influence on the distribution of the pore pressures (within the dam, they varied linearly from the dam's upstream face to its downstream face), but in the earthquake and post-earthquake analyses within the dam below RL 511.3 the crack was assumed to be a perfect drain.

BWA summarised the behaviour of the dam in the earthquake analyses in a series of finite element model pictures, concentrating mainly on the maximum principal stress envelopes (tensile stresses are positive) and the vertical stress envelopes, both as contour stress plots. Graphical plots of total horizontal displacement in the RL 511.3 crack and the base surface, as well as plots of vertical and horizontal displacements on the vertical crack were also given.

The post-earthquake analyses were similarly summarised, but for the dam deflected with its most downstream displacement shape. As well, the displacements on the maximum cross-section were shown as exaggerated, that is, distorted plots of the dam.

BWA concluded from its analyses that:

- A. The dam would suffer a lot of distress, including permanent horizontal displacements of 30mm and 70 mm at the RL 511.3 crack and the base respectively, during the actual earthquake event.
- B. During the earthquake the vertical crack would generally close up, except close to the top of the crack at RL 511.3.
- C. The dam would remain stable under the post-earthquake loading.

The results of the thermal analyses done to simulate the inclusion of a full depth crack below RL 511.3 were presented in a similar way to the results of the earlier thermal studies. Thus, there were various stress plots, including maximum principal stress contours and horizontal stress plots. These plots were prepared for the first summer conditions after, firstly, the expected end of construction, secondly, the first reservoir filling and, finally, a nominal period of 20 years from the end of construction.

BWA was convinced that these analyses showed that, with the precautions taken at RL511.3 with the treatment of the cracks, the crack would not propagate upwards from RL 511.3. The horizontal stresses, that is, the inlayer RCC stresses above RL 511.3, were generally less than 600 kPa tensile at the end of construction and were compressive for the other two conditions.

7.2.3. Panel's comments

a. General

At the outset, we must say that we agree in principle with BWA that:

- With the treatment taken at RL 511.3, the cracks will not propagate upwards.
- The dam would survive the MDE, possibly with some damage.

- The dam would be safe after the MDE.
- b. Shear strength of the vertical crack and of the horizontal surfaces at RL511.3 and the nominal base of the dam

Probably the key factor insofar as the nominal vertical crack is concerned, if it were to propagate downwards from RL511.3, is that it would almost certainly form in a random way and not as a perfectly vertical plane, especially as it would not be controlled by any defined weakness such as an RCC layer boundary. As we can see from the cracking in the gallery entrance, the crack would be expected to meander to give a distinctly wavy pattern. In that way it would have to have a high shear strength with not just a frictional component. We have no doubt that any displacement along this crack would have to develop the shear strength of intact RCC, which we believe would mean that the two parts of the RCC mass would behave as a monolithic mass.

Along the same line of argument, we do believe strongly that the available peak shear strength along an RCC layer boundary is better than has been assumed by BWA. Certainly when one looks at some of the small diameter core breaks in the drill core recovered from the long drill holes recently done on the dam (see earlier discussions in Chapter 5 of our report), the conclusion would have to be surface with a limited shear strength capacity. That conclusion, we consider, can be countered by looking very closely at the diamond saw-cut faces through the two trial banks.

For “warm” and “hot” joints, over lengths of say, at least 6 m in these saw-cut surfaces one can follow the surfaces of the various layer boundaries. Firstly, there are many distortions of that surface under the many larger aggregate particles that end up sitting on the layer surface when the RCC mix is initially spread, the distortion being caused as the aggregate particles are pushed onto the previous layer surface during compaction of the new layer of RCC. The aggregate particles do not seem to penetrate the cement paste of the previous layer, but they do “distort” it locally. Secondly, there is a generally “waviness”, an undulation of the boundary surface due simply to the fact that rolling does not produce a perfectly horizontal surface. The net result is a surface that would have to develop the shear strength of intact RCC, including the many large aggregate particles one finds only the layer boundary before we could get any movement along this surface.

The other lift joint surfaces, the cold surfaces, provided they have been properly prepared, as we feel is the case, should over substantial lengths have more than adequate shear strength in just the same way that we would consider for a conventional construction joint in mass concrete. The cold joints in the trial embankments would fall into the category.

With these thoughts in mind, let us look at each of the above analyses, starting with the thermal analyses.

c. The thermal analyses

We see no reason to dispute BWA's analyses for the maximum section. BWA's analyses assume adequate shear strength along the crack (no actual value is given in the report, but we know that the basic assumption of a fully connected base would automatically limit a differential shear movement along the hypothetical vertical crack), which we believe is a realistic way to model the crack. This conclusion depends absolutely on the effectiveness of the treatment over and along the tops of the crack at the RL 511.3 surface. We believe strongly that they will be effective in stopping the crack propagating upwards.

The maximum section analyses should be reasonably applicable also to the two blocks at each end of the deck at RL 511.3, even though the depth below the RL 511.3 surface is much less. But to be sure, perhaps BWA will need to do specific analyses on these abutment sections (the two blocks at each side) to clarify this point, although we feel that we should have low enough horizontal stresses above the RL511.3 to limit any cracking in these blocks.

d. Maximum section – earthquake analyses

Probably the key factor here is that the hypothetical crack seems to remain in contact except near its top at RL 511.3. Here with the specific treatment of a bond-breaker at the top of the crack, we should be able to tolerate a slight opening of the crack. If we now add in significantly higher shear strength at something approaching the peak strength of concrete, then we can only conclude that even under an MDE the RCC mass will behave as a monolithic mass below RL511.3.

Likewise, we do not believe that the shear strength at either the RL 511.3 crack or on the nominal base is as low as assumed. While we cannot say that we would not have any permanent horizontal displacement as either of these surfaces, we feel confident that any such movements would be less than estimated by BWA's analyses. The problem with the present model is that we cannot model a condition of no slippage up to the point when the peak shear strength is just exceeded, but that can cope with a likely sudden loss in strength once movement starts.

We also feel that our comment made in our TRP Report No. 15 that we probably are over-estimating the permanent displacements at RL511.3 and the base by ignoring the likely loss in shear wave transfer from the earthquake ground motion once actual movement along any surface starts. Our analyses assume that the ground motion is transmitted through the dam at all times through the earthquake, regardless of whether or not there is any movement on a specific surface.

In short, we consider that the hypothetical vertical crack will not change the basic behaviour of the dam during the earthquake. Any permanent displacements on the RL511.3 surface and the base would therefore be independent of the existence of the crack.

As a final comment, if one looks at the earlier thermal analyses of the maximum section, within the RCC below RL511.3 the concrete is generally in compression under the applied static loads. One may thus draw the conclusion that the crack at the maximum section may not propagate downwards. Perhaps the analysts could look more closely at the stress trajectories in this area to see if the crack might curve around and head towards the upstream face, where we know we could have a vertical tensile stress zone.

Clearly the maximum section is not the same as the two abutment blocks at either end of the RL511.3 deck. Perhaps BWA might like to check these blocks out, as it is very likely that any crack would head straight to the foundations. We would think that only a post-earthquake check need be done (see next paragraph).

e. The post-earthquake analyses

As in our previous discussions, the key factor is the shear strength capacity along our hypothetical crack. Our view is that it will be high enough to make our post-earthquake analyses no more critical than they were in our earlier analyses. The several factors and points that we made in TRP Report No. 15 would therefore still apply. Our conclusion then was that the dam would be safe after an earthquake; we still feel such a view is appropriate.

It may be that the pore pressure distribution of a “perfect” drain along the hypothetical vertical crack, which was assumed by BWA, has some justification. It could also be that the “vertical” crack does not become a drain and that the pore pressures should extend across the whole of the RCC mass below RL511.3. So perhaps we should assume pore pressures within all the RCC below RL511.3 to see if this assumption would change our conclusions. In that way we would cover the case that the crack does not propagate as assumed in the analyses.

Even so, we would argue that, even if we were to get permanent displacements as estimated by BWA, the internal and foundation drains would still function as intended. We believe that it is being far too conservative to ignore them in the post-earthquake analyses.

As we mentioned in the previous paragraph, a check of the two abutment blocks at either end of the RL511.3 deck should be checked under post-earthquake conditions.

f. Final comments

The sort of behavior that BWA has postulated in its post-earthquake analyses has been seen before, at Wellington Dam on the Collier River in Western Australia.

At Wellington Dam, the original gravity dam that had been built in the 1930s to a height of 15 m was doubled in height in the late 1950s-early 1960s. For this upgrade, the designers left a gap of about 0.4-0.5 m between the new concrete and the old, with discrete pillars of new concrete supporting the new concrete. After new concrete had been brought up to the original crest level, the gaps between the new and old concrete

were backfilled with prepack concrete, a process where clean single-sized aggregate is placed in the blockouts and is then grouted up.

The designers included a gallery at the top level of the old dam and one along the toe of the old dam.

The dam's axis was roughly north-south and the dam faced west in the downstream direction. Thus, each day and throughout each season the dam's downstream face "copped" the full heat of the sun over most of each day.

The Water Corporation over recent years, especially with the dam having to be upgraded (the upgrade works were completed a year or so ago), did extensive site investigations of the existing dam. As part of these investigations, a hole drilled into the old/new concrete interface found clear evidence of surface grinding. My guess is that at this surface, which would be the off-form surface on the downstream side of the blockouts, we would have had grout against a formed surface. Hence with any reversal of movement we would get down to the residual strength of cement paste, which is close to 35-37°.

The Corporation engineers also noted that along the toe gallery there seemed to be an opening along the toe of the old dam, something that was more noticeable during hot summer days. This apparent gap opening at the toe of the old dam clearly suggested that the mass of the new concrete was expanding under the intense heat from the sun and literally dragging the old concrete with it causing the old concrete to rotate the heel of the dam.

Once a thermal analysis had been done, it was easier to see that daily and seasonal temperature changes in the new concrete on the downstream side of the old concrete caused this part of the dam to slide up on the old concrete, albeit only by a couple of millimeters or so. There was enough shear transfer at the old/new interface to force the old concrete to rotate about its heel.

Without going into details, the investigation team also knew that there was cracking along the downstream wall of the gallery and corresponding cracking along the downstream face of the dam at the same level. A horizontal drill hole from the gallery to the downstream face found conclusively that this crack existed all the way from the gallery to the downstream face of the dam. Later, the Water Corporation team showed that there was an upstream crack at about gallery floor level.

Once the extent of the upper gallery crack had been proven, the whole mechanism came together. The middle and lower part of the new concrete downstream from the old concrete expands each day. It causes the old concrete to rotate about its heel and the new concrete above the old crest level to rotate about a point probably close to the upstream face of the dam at the old crest level. The dam probably operated this way for nearly 50 years and in effect still does. This behavior is similar to, but in the opposite direction to the exaggerated displacements shown the BWA's presentation of its post-earthquake analyses. We believe that a key difference between Wellington Dam's behaviour in the long run is that our hypothetical crack is not planar, as the old/new

concrete interface is, but rather it would be a very rough surface indeed. There would be virtually no differential movement between the RCC on each side of the crack.

7.3. DIVERSION WORKS – NEXT STEPS

7.3.1. BWA presentation

As soon as the critical work on the upstream face has been completed and accepted, BWA will close the control gate at the upstream end of the 3 m diameter conduit of Stage 2 of the diversion works. It proposes to place an initial concrete plug on the upstream side of the gate, using for access a hole already cut in the corrugated steel pipe at the upstream end of the concrete surround some metres from the gate. The permanent plug inside the body of the dam will then follow.

Once the Stage 2 diversion conduit is closed, BWA propose to use the 900 mm diameter environmental release pipe as the Stage 3 diversion system to control the reservoir level upstream whenever required. To this end, BWA has installed a temporary steel pipe extension to the environmental release line through the right-hand wall of the spillway's stilling basin with four HDPE bends connected to it. These bends will in turn be joined to temporary HDPE lines so that water can be released from the reservoir upstream through the lower two inlets of the tower. There will be a gate valve on each of the four temporary lines plus the inlet valves in the tower to control these diversion flows. With the bottom inlet on the tower being at RL 498, the lowest reservoir level that will be achieved in Stage 3 diversion will be about RL 500, which is some 22 m above the Stage 2 diversion's invert level.

When the Stage 2 conduit is closed, the dam will officially become a "working" dam. BWA and ACTEW are now working together to develop a suitable arrangement for ACTEW people to be able to operate the dam.

7.3.2. Panel's comments

The proposed actions in the switch from Stage 2 to Stage 3 of the diversion works seems reasonable to us. We understand that there might be minimal time to get the initial upstream plug in place, if the closure of the Stage 2 diversion is left much longer than mid-September. There is a requirement to bring the existing reservoir up to full supply level soon so that we will lose the present 4 m buffer we now have so that BWA will have to rely on the flash boards that still are in place on the crest of the old Cotter Dam while it completes the closure.

We are pleased that the Owner and BWA have been co-operating closely to smooth the way for the dam to become a "working" dam.

7.4. AERATION STEP – CONSTRUCTION DETAILS

7.4.1. BWA presentation

The aeration pipe, the two end intakes (the "canons") and the primary spillway's outlets will be placed within the special blackout that has been left for these works below about RL 530. BWA has left lines of embedded anchor along the back wall found in the RCC for the blackout.

BWA's thinking for these works, at least its first "thinking", is to position the precast concrete pipe, complete with temporary supports and anchors to cope with flotation from the wet concrete surround, fix the reinforcement, form up the outface of the concrete surround and place the concrete in one lift.

7.4.2. Panel's comments

Generally all seems reasonable, except the thinking to place the concrete in one lift. We would strongly suggest BWA revisit this part of the proposal. The final outline of the concrete, with the present pipe in the bottom part of the pour, does say to us: do the placement in two parts. There is not a great deal of room to compact the concrete properly under the pipe and if the whole operation is rushed we are sure that extensive honey-combing and voids will be the result.

While the whole of the insitu concrete unit is well-anchored up the vertical formed face of RCC, we would suggest that it be well-anchored by vertical grouted bars into the RCC mass below. More anchors than are probably now intended for the pipe's flotation may be needed.

7.5. PRECAST CONCRETE FOR THE PRIMARY SPILLWAY'S SIDE (CHUTE) WALLS

7.5.1. BWA presentation

The side walls of the primary spillway of the aeration step) will extend from about RL 530 (the top of the aeration step) to the crest level of the secondary spillway. To fit in better with the layer construction of the RCC, BWA has decided to use horizontally-positioned precast units well anchored into the RCC to form these walls rather than stick with the originally proposed insitu concrete solution. These precast wall units would be used up to the top of the RCC placement at RL 545. Above that level BWA will switch to the originally proposed cast-insitu wall construction, although these wall components would still be primarily anchored by horizontal grouted bars into the CVC mass concrete.

Each unit, which will be aligned to form part of a converging side wall, is about 500 mm wide and be the height of one step. It will be embedded one step width into the RCC, with the GERCC locally taken around the embedded perimeter by a nominal 400 mm. The embedded portion will be 900 mm high instead of 1200 mm, the full step height. A layer of reinforcement will be placed on top of the second last RCC layers over the embedded portion of the unit and covered with GERCC-25 when the top of the step is placed. Each unit will have four anchors into the RCC from the inner end and three cross-valley anchors within the RCC step.

Each unit has a male shear key at the bottom and a female shear key at the top. Once a unit has been embedded in place, its shear key connection with the next unit down will be grouted through two formed holes.

The units have been precast off site. Already two or three units have been placed above the future top of the aeration step on each side wall

7.5.2. Panel's comments

We fully support the concept for these side walls and by the look of the installed units; the solution is a good one.

Our only comment would be that we would have preferred the lower unit of a pair to have its outer exposed side faces slightly sloped inwards right at the top, say, over a length of 100 mm. In that way, one would be sure that any flows against the walls would not hit the top of each lower unit. So far, this local shaping at the top of each unit is not a concern as the unit's faces of that have been placed are very well aligned BWA should make sure that such is the case on as further units are placed. If there are any misalignments, BWA may need to do a little local grinding to make sure the lower unit of each pair is not protruding beyond the surface of the upper unit.

7.6. TOPPING OUT OF THE MAIN DAM

7.6.1. BWA presentation

BWA intends to deliver RCC with the conveyors on the right abutment until the RCC on the dam reaches RL 543, about 7 m below the final primary spillway crest and 10.5 m below the secondary spillway crest level. At this point, BWA will switch to truck delivery down the right about abutment.

Zone4a (BWA's designation numbers) of the dam, the RCC above RL 543 on the left side of the primary spillway, will be completed as the first phase of the works above RL 543. RCC will be delivered to a telebelt up to RL 546.55 when the telebelt will be moved to the primary spillway area. The rest of the left side's RCC will be completed by delivering RCC to the telebelt, which will load the ejector truck(s) on left side of the dam. When Zone4a is finished the plant and equipment on top of the RCC will be taken off by way of the left abutment.

RCC will then be placed along the rest of the dam to the underside level of top parts of the primary spillway's CVC crest. The final RCC placement, the portion to the right of the primary spillway will follow, but only after a number of other items of work have been done along the rest of the dam, including starting on the CVC for the primary spillway crest and its associated items of work.

7.6.2. Panel's comments

Our only comment is that we are very pleased to see some serious thinking being done on this final operation.

We understand from the meeting that BWA plans to use the rolling screed from its Googong job, now being used for the upstream end floor of the stilling basin, for the top surface of the CVC in the primary spillway's crest structure. The results, as we saw first at Googong and now at the stilling basin floor, would clearly make this method of screeding a worthwhile exercise. The unformed surface in the upper part of the curved floor slab in the stilling basin approached 0.7 horizontal to 1 vertical, not a bad effort for such a surface and all without any hint of bulging.

7.7. FOUNDATION GROUTING

7.7.1. BWA presentation

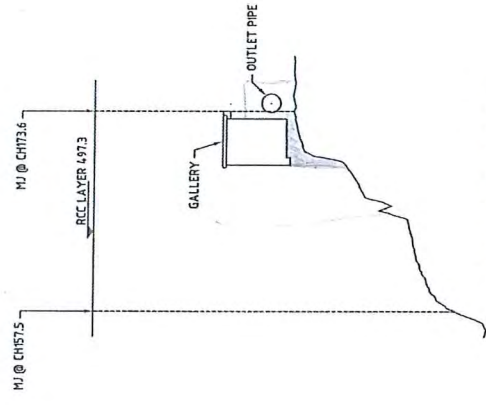
The chosen sub-contractor is due to mobilise to site in the third week of August. The first task will be the trial mixes. He will then move into the bottom gallery and begin on trial panels of vertical and angled holes along selected lengths of the actual grout curtain. The aim is to have the major first phase of the grouting completed up to RL 498 before the Stage 2 diversion is closed to avoid grouting against higher groundwater pressures than exist now.

7.7.2. Panel's comments

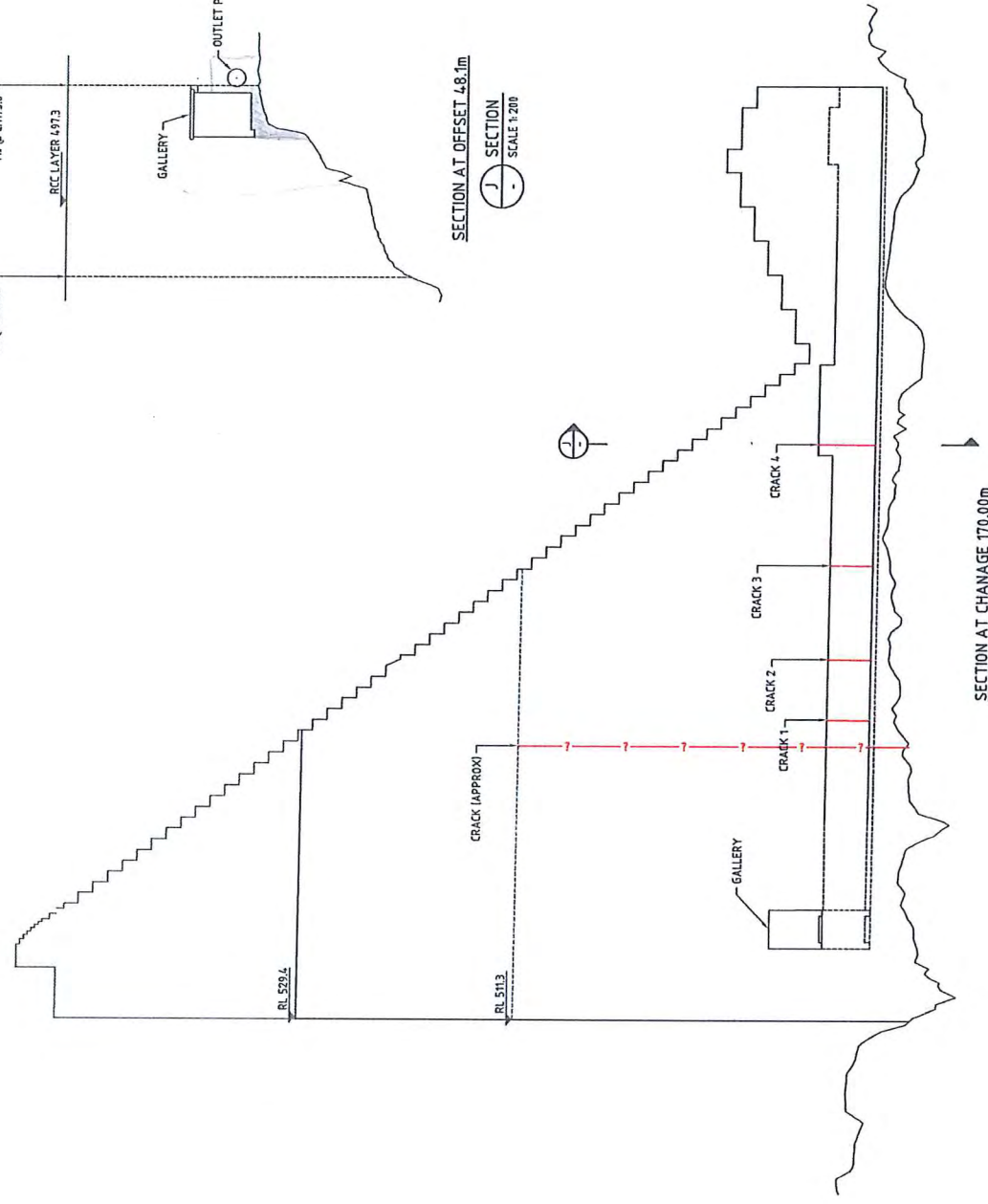
We have no specific comments on the grouting at this time, other than we are pleased that “things are moving”.

APPENDIX A

**CROSS-VALLEY CRACKING IN GALLERY ENTRANCE – PLAN SUPPLIED BY BWA
ON 10 AUGUST 2012**



SECTION AT OFFSET 48.1m
J SECTION
SCALE 1:200



SECTION AT CHANGE 170.00m
H SECTION
SCALE 1:200

