Commission of Inquiry
PARADISE DAM

PARADISE DAM COMMISSION OF INQUIRY

Commissions of Inquiry Act 1950
Section 5(1)

STATEMENT OF STEPHEN TATRO

Name of Witness:	**Stephen Tatro**
Date of birth:	[redacted]
Current address:	**Tatro Hinds Advanced Concrete Engineering, Inc.** **148 Country Way** **Walla Walla, Washington, USA 99362**
Contact details (phone/email):	**steve@tatrohinds.com**
Statement drafted by:	**Mr Jonathan Horton QC (Counsel Assisting)**
Also present:	**Commissioner Professor John Carter**

I **Stephen Brent Tatro,** Civil Engineer, make oath and state as follows:

Background

1. I am a civil engineer with a Masters Degree in Civil Engineering, concentrating in concrete materials engineering. I am one of two principals (along with James Hinds) of Tatro Hinds, Advanced Concrete Engineering, an organisation based in the Pacific Northwest of the United States. We consult in concrete materials, evaluation, testing, design and construction.

Witness	Taken by

2. I worked for some 30 years for the US Army Corps of Engineers. Roller compacted concrete (**RCC**) was first used for dams in 1982 and, I was on the design team for the first RCC dam. I subsequently participated in the design of many other dams, in various capacities (in the order of 60 or so dams). I was heavily involved in the design and construction for some of them and for some I was more of a 'drive-by' consultant.

3. I retired from the Corps of Engineers in 2011. Before then, I had started Tatro Hinds and for almost 10 years, I have been a consultant, mainly on issues related to RCC.

4. Attached to this statement and marked **'ST1'** is a copy of my resume.

Involvement in the Technical Review Panel (TRP)

5. I became involved in the TRP because I had worked with Queensland Water Infrastructure on the early stages of the Traveston Crossing and then ultimately on the construction of Wyaralong Dam, so I got to know the staff there.

6. Mr David Murray was my primary point of contact for that work, and I believe it was David Murray that recommended to SunWater that I be part of the TRP. I did not become a member of the TRP at that time.

7. A little bit later, the need arose for a detailed review of the determination of shear strength and TatroHinds was engaged by SunWater on that more specific task.

8. I prepared a report on that topic along with Mr Hinds. It is a joint report, but the opinions expressed in it are ones I hold.

9. Attached to this statement and marked **'ST2'** is a copy of that report, which is dated 25 November 2019.

Witness	Taken by

10. I came to Australia between 16 November and 25 November 2019 to attend a meeting of the TRP, to see Paradise Dam, and collect additional information. I attended the third workshop of the TRP on 19 November 2019. I also met with representatives of SunWater and other officials.

RCC and Paradise Dam

11. I have familiarised myself with the properties of the RCC used on Paradise Dam. It was a low cement mix, with which I am familiar. The US Army Corps of Engineers has built dams using a low cement mix and produced standards for such dams.

12. The reports for Paradise Dam show that the mix was as low as 60 kilograms per cubic metre. That is very low, and I have not seen many mixes that have a lower cement content than that.

13. There are features of this type of mix which pose particular challenges in construction. Every mix presents a certain behaviour and performance and the goal is to match up those supplied performance factors with the necessary performance factors for the project. I do not know what the specific performance requirements were for Paradise Dam, but I do know what mix was produced.

14. There are properties of low cement mixes that are difficult to control if the expectations for the mix differs from its characteristics. I read a number of memoranda for Paradise Dam which showed that the people writing those memos had different expectations and were commenting frequently that the mix was not performing in a certain way. Probably the more critical factor mentioned there is the low workability of that mix, and it creates challenges that are less in other kinds of mix. Quality control for low cement, low workability mixes is very important.

Witness	Taken by

15. Workability can be described as follows. Conventional concrete workability is measured in 'slump'; how much a 12-inch-tall cone will compress when left alone. The more it slumps, the more workable it is. But with RCC, the test is a little different. It is a vibration test. The sample is placed in a pot, a weight is placed on it, then it is vibrated and when paste spurts out the top of the test apparatus, the test is stopped. The amount of time (in seconds) is measured (VeBe time) for that test to be completed. Highly workable RCC will have a low number (less seconds), and less workable RCC will have a high number (more seconds).

16. The results for the most workable mix is about 6 to 10 seconds. A more common workability level might be 15 to 20 seconds. However, there are many mixes that have workability results that are beyond that; to the point where it is not even accurate doing the test because, in my opinion, the results would be beyond the limits of the test.

17. As I understand from the documents I have read, the mix for the Paradise Dam, had a workability in the order of 30 to 30-plus seconds. For mixes done in the 2000s, that tended to be on the less workable number than many others.

18. The terminology between high and low paste mix needs to be properly understood. The distinction is better understood as one of high cementitious content versus low cementitious content and high workability versus low workability.

19. It is not necessarily the case that a low cement content produces lower workability. Just because there may be a low water-cement ratio or a low cement content does not mean there will be low workability. Often, it works out that way because that is how the mix was designed, but they do not always go hand-in-hand. For example, I was involved in building a dam in Puerto Rico that had what many would call very low

Witness	Taken by

cement content. The cement content there was greater than for Paradise Dam, but still it was low, yet we had very high workability levels and very high strength levels.

20. It is possible to have high workability and low cement content. But it is also possible to have high cement content and low workability. It is probably more common to have low cement content and low workability because the goal is to try to get the most out of that mix to save cost: the greatest strength for the least cement content.

21. A combination of things gave us the high workability with low cement content in Puerto Rico. . It was aggregate grading, the type of cement, the use of flyash and certain water contents. But it is important to keep in mind that the fact certain properties were achieved there because of certain proportions in the mix, does not mean that the results apply directly to a different project. Materials are different and the interactions of materials are different.

22. It was a great surprise to me that no fly ash was used in the RCC mix for the Paradise Dam. I am not sure why it was not used. If fly ash had been used in the mix replacing some cement or even in addition to some of that cement, the mix might have been more workable.

23. When I use the terms low cementitious content, it groups together cement and fly ash as the same kind of component, because it is the same cementitious material. When fly ash combines with Portland cement, it creates the same hydration products. So if one takes a hundred kilograms of Portland cement and adds 50 kilograms of fly ash, in general, it will give similar performance to mixtures with 150 kilograms of cement because that is the sum of the parts.

24. A less workable mix means you need more energy to compact it. Typically, the equipment is usually the same, but it just takes more passes of the roller, longer

Witness	Taken by

duration of vibrations, to achieve the necessary compaction. A much bigger machine may be required for certain workability levels. If, for example, if very workable RCC is used, smaller equipment can be can used to achieve density relatively easily.

25. So, with the low workability mix, the procedures in its laying and in the construction practices are more important, particularly as one gets down to, say, 30 seconds with respect to workability. The premise in designing mixes, and maybe more importantly negotiating with contractors about mixes, is that higher workability mixes make the job of the contractor easier. If you can afford the extra cement and fly ash that it takes to get the strength, then, that can often be a favourable direction to move in.

26. There is a tendency for low workability mixtures to segregate more than high workability mixtures during placing. When the material is piling up in trucks or on the ground, the large aggregate tend to separate out and roll off to the side. As the mix becomes more workable, less of that happens. The trick is to find a happy medium.

27. It is the workability that governs the propensity to segregate. The cement content may or may not be an issue because there is also water and that is another factor in workability. If there were no cement, but enough fines in the aggregate and water, it would produce a very workable mix that would not segregate. So segregation is not governed by cement content only and that factor is not acting alone.

Shear testing

28. I reviewed GHD's shear testing and expressed some opinions about it in my report. I said that it seemed to be very inappropriate to use the sample for repeat testings.

29. I went to Queensland thinking that I did not like that shear test and with the view that the testing was not adequate. I then saw how they had done the testing and looked at the testing machine and concluded that although it was not the best test in the world,

Witness	Taken by

there are not a lot of alternatives because it was a small sample. It is not always practical to drill big samples. You have to test what you have and make the best conclusions that you can with what you have. My report does not exactly reflect these matters.

30. My concern then, and my concern now, is whether these results are artificially low because of the way the testing was done. I am not saying the testing was done incorrectly or improperly, but instinctively I do not like that test for this application. There were not a lot of tests done. But testing is expensive, and it is difficult to get mobilised to do it. Although I did not see anything blatantly wrong with wrong with what was done (other than those things that I have pointed out), there remains a real risk in my mind that GHD's testing and evaluation, in effect, is overly pessimistic about the strength of the RCC lift joints.

31. I accept that the type of testing GHD did is one which the US Bureau of Reclamation adopts and endorses with respect to the repeat testing of samples. I have spoken with engineers from the Bureau of Reclamations about that issue in the past and they believe that there is no degradation that results from repeatedly grinding one surface against the next. But I cannot believe that myself.

32. So, even if the test results show the same residual friction angles in the subsequent testing, compared to the first round testing, I still hold concerns. That is because the friction angle is the result of many tests. You shear some samples at one normal load and then you shear those samples at a higher normal load, and then you shear them at yet another higher normal load. When those loads are plotted, the shear strength that results is a slope of that line from multiple tests.

Witness	Taken by

33. When you shear at the lowest normal load and then you go to a higher normal load, if you were to get fresh samples (and not test samples that you just tested the time before) those fresh samples might test a little bit higher. And then you go to the highest normal load and you go with fresh samples, they would test a little bit higher yet, and, as a result, you would get a line that is steeper or the friction angle would be greater. So the way the Bureau of Reclamation does it, in my opinion, achieves repeatability, but only because they are doing it the same way each time.

34. GHD sampled lift joints and when they finished, they concluded that, optimistically, maybe 40% of them were unbonded, and pessimistically, maybe 60% or 70% were unbonded.

35. The ANCOLD guide, which is good in my opinion, says, 'If you've got a lot of joints unbonded, we are not even going to consider any of them to be bonded. We want you to analyse the structure as if all of them were unbonded'. I think that is a wise thing to do. That sets the tone, so to speak, of the approach that is taken, and it steers us down, let us call it, 'track B', in effect, that we have too many unbonded joints. GHD did the right thing taking that track, although initially it was not crystal clear in the report that they were doing that. Eventually they concluded that only residual strength had become material, because there were not enough bonded joints to pursue, let's call it 'track A'. And so, I think GHD had the right approach.

36. I think it is clear, whether you take track A or track B, that there are too many unbonded joints, regardless of what the strength levels were or the friction angles. GHD could not take track A because there were not enough bonded joints, so you have to take track B, which is residual strength. At this point the stability analysis of the dam becomes dependent only on the friction angle, the Ø angle.

Witness	Taken by

37. I think the way the testing was done meant that the Ø angle may be a little lower than you would expect in reality. I do not know that, because, we do not have enough data. What we have seen for numbers is very low. GHD compounded this when they did some statistical analysis looking at those values and said, 'We have this variability, so to account for it we are going to assume a little bit lower value'. That is a reasonable thing to do when you are statistically trying to establish a safe value. But in the case of a friction angle, you can push it too low, to a value below what is even possible. I do not know if that is happening here. For example, sand has a friction angle of 45 degrees. But here we have concrete (albeit broken-up concrete) that is showing test values that are 36, 39 degrees.

38. GHD then factor it a little bit lower, statistically, but at that point I seems to me to be out of the range of reality, however you need data to convince yourself of a better position.

39. I do not think that the steps GHD took were fundamentally wrong. They did all the right things and they reacted appropriately to the value that they got. I am concerned, however, that the values may not be quite right and forced a different reaction than would otherwise have been returned.

40. If GHD had obtained the results it did from fresh samples sheared only once, then my primary concern with the testing and the results would have been eliminated. That would leave only the effects of the small scale nature of the testing.

41. I have never seen shear faces that showed the degree of damage after the test that the test samples did in this case (of which I was shown photographs in reports). I did not resolve in my mind exactly why that damage had happened. It might be because of this low cement content, owing to the low strength in the mix and the relatively high

Witness	Taken by

strength rock, such that you are in effect trying to grind up dissimilar materials. But I have not seen this before and my feeling is that someone ought to be worried about that, not just for the stability issue but also in respect of the testing regime.

42. I think that further testing should be done and that the assessments that have been done are insufficient without some further testing.

***OATHS ACT* 1867 (DECLARATION)**

I, Stephen Brent Tatro, do solemnly and sincerely declare that:

(1) This written statement by me dated 13 February 2020 is true to the best of my knowledge and belief; and

(2) I make this statement knowing that if it were admitted as evidence, I may be liable to prosecution for stating in it anything I know to be false.

And I make this solemn declaration conscientiously believing the same to be true and by virtue of the provisions of the *Oaths Act 1867*.

..... **Signature**

Taken and declared before me at Walla Walla County **this** 20th **day of** February **2020.**

Taken By .....

~~**Justice of the Peace / Commissioner for Declarations / Lawyer**~~

Public Notary

CHRIS CHRISTIANSON
COMMISSION NO. 205359
NOTARY PUBLIC
EXPIRES FEB. 20, 2023
STATE OF WASHINGTON