Re: PLP White Paper No. 1: Mitigating Risk in the Design and Construction of Tailings Dams in Alaska – Jeremy P. Haile, P.E. and Ken J. Brouwer, P.E., Knight Piésold Ltd., July 20, 2012

Subj: Peer Review Comments

Fm: David M. Chambers, Ph.D., P. Geop.

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The main claim of White Paper No. 1 is that if a tailings dam is designed by an experienced engineering firm, goes through the proper regulatory review, and is operated by a responsible mining company, there is little or no possibility of dam failure. To accept this line of logic would require a revisionist view of the design and operation of tailings dams. Engineers, regulators, and miners would not only need to have learned about all the possible failure modes for tailings dams, but they must also never again allow the conditions or decisions that led to such failures. Similarly, this revisionist view would seem to ignore the recent history of preventable tailings dam construction and operating errors, such as the dam failures at Omai and Baia Mare, as well as the unpredicted system failures at large industrial operations, like that at the Fukushima Daiichi nuclear power plant.

There is risk associated with the best-designed and operated tailings dam, and the real argument is not about the magnitude of this risk, but about how much risk each individual – some who would be impacted positively, some negatively – is willing to assume.

Specific Comments:

1. White Paper No. 1, Abstract, p. 1

> *"A key conclusion of these analyses is that the performance of tailings dams constructed by the centerline or downstream methods has been markedly better than dams constructed by the historically common upstream method. Additionally, embankments constructed with compacted earthfill and rockfill materials have a proven performance record during seismic loading conditions. There are relatively few incidences of dam instability for downstream and centerline constructed tailings dams and none of these instances include dams exceeding 500 ft in height. Accordingly, downstream and centerline constructed tailings dams are the current preferred methods of construction."*

Although downstream and centerline construction are the preferred methods for tailings dam construction, upstream design for dams and for lifts on top of downstream/centerline dams are still routinely employed (including the final lift on the Fort Knox tailings dam in Alaska, designed by Knight Piésold).[1]

As is pointed out on page 7 of this report, "The upstream construction technique has been used extensively for many tailings embankments worldwide, largely because of the relatively low construction costs associated with this method."

Although the authors strongly emphasize the relative safety of the downstream dam construction design,[2] upstream construction design continues to be utilized worldwide, even in the US, including Alaska. Even

[1] "Tailing Storage at the Fort Knox Mine – An Innovative Expansion to Continue a History of Success," Thomas F. Kerr and Peter D. Duryea, Knight Piésold, Denver, CO, and David T. Quandt, Fairbanks Gold Mining, Proceedings Tailings and Mine Waste 2011, Vancouver, BC, November 6 to 9, 2011

[2] While a majority of tailings dam failures are associated with the upstream construction method, there have been a significant number of failures of downstream-type constructed tailings dams. See: "Tailings Dams - Risk of Dangerous Occurrences, Lessons learnt from practical experiences," Bulletin 121, Published by United Nations Environmental Programme (UNEP) Division of Technology, Industry and Economics (DTIE) and International Commission on Large Dams (ICOLD), Paris 2001, 144 p. [compilation of 221 tailings dam incidents mainly from the above two publications, and examples of effective remedial measures]

though downstream construction may not be planned for a project, its use cannot be ruled out at any project in the future, as the Fort Knox mine example points out.

2. White Paper No. 1, Abstract, p. 1

> *"It is important to note that it is incorrect to imply that any particular proposed or actual dam structure is more or less likely to fail based solely on the extrapolation of general dam failure statistics."*

This statement suggests that statistical analysis or data review is meaningless in assessing what might happen on a future project, simply because the exact conditions of the future project might differ from past projects Although the available statistics for the total number and types of tailings dams, as well as an accurate number of tailings dam failures, are disappointingly incomplete, it would be equally "incorrect" to ignore existing statistics, since these are the only quantitative data available on tailings dam failures. It's obvious that we cannot depend purely on predictions of how individual tailings dams will perform.

Dam failures continue to occur despite engineering predictions, and regulatory approvals, saying that they won't. It is not reasonable to assume that all new tailings dams will be designed, constructed, and operated in a manner that will prevent all future dam failures.[3]

In fact, even Knight Piesold has had some involvement with relatively recent tailings dams that failed (Aurul S.A. plant in Baia Mare,[4] Romania, January 30, 2000; and, Omai Gold Mine,[5] Guyana, August 19, 1995).

3. White Paper No. 1, p. 3

Table 1 – Hazard Potential Classification Summary

Hazard Class	Effect on Human Life	Effect on Property
I (High)	Probable loss of one or more lives	Irrelevant for classification, but may include the same losses indicated in Class II or III
II (Significant)	No loss of life expected, although a significant danger to public health may exist	Probable loss of or significant damage to homes, occupied structures, commercial or high-value property, major highways, primary roads, railroads, or public utilities, or other significant property losses or damage not limited to the owner of the barrier Probable loss of or significant damage to waters identified under 11 AAC 195.010(a) as important for spawning, rearing, or migration of anadromous fish
III (Low)	Insignificant danger to public health	Limited impact to rural or undeveloped land, rural or secondary roads, and structures Loss or damage of property limited to the owner of the barrier

[3] Knight Piesold has submitted preliminary Pebble dam designs to the Alaska Department of Natural Resources. (Pebble Project Tailings Impoundment A, Initial Application Report, Ref. No. VA101-176/16-13, Knight Piesold Ltd, Vancouver, BC, September 5, 2006) It goes against human nature to assume that one's own design could fail – failures are usually someone else's responsibility.

[4] http://www.wise-uranium.org/mdafbm.html, 23Oct12

[5] Stabroek News, "Omai Group to Seek Extension," Wednesday, December 6, 1995

It might be noted that all present and proposed tailings dams in Alaska, including those at Pebble and Donlin, are located in areas classified as "Hazard Class II" where "No loss of life (is) expected, ..."

At these same locations there is "Probable loss of or significant damage to waters …."

All present and proposed Alaska tailings dams, including Pebble, require only a rating of Hazard Class II. This means that although there is the potential for 'loss of or significant damage to waters,' the classification of large tailings dams in Alaska as the safest Hazard Class I category is not required, and is therefore discretionary, and it is possible that a large tailings dam would only be required to be engineered with a corresponding maximum design earthquake of 1,000 to 2,500 years – see Table 2 below.

4. White Paper No. 1, p. 3

Table 2 – Operating and Safety-Level Seismic Hazard Risk

Dam Hazard Classification	Return Period, Years	
	Operating Basis Earthquake	Maximum Design Earthquake
I	150 to >250	2,500 to MCE
II	70 to 200	1,000 to 2,500
III	50 to 150	500 to 1,000

The International Commission on Large Dams (ICOLD) recommends the 10,000 year seismic event as the Maximum Credible Earthquake.[6] Even if a tailings dam were to be deemed Class I by the Alaska Dam Safety Office, this classification still only requires a Maximum Design Earthquake within a range of 2,500 years to the Maximum Credible Earthquake.

There will always be pressure to use less than the Maximum Credible Earthquake for the Maximum Design Earthquake because as the size of the Maximum Design Earthquake gets larger, the cost of the dam rises significantly. Since there is no regulatory requirement that a tailings dam be deemed Class I, or that if deemed Class I that the Maximum Credible Earthquake would be required as the Maximum Design Earthquake, there will always be the potential (usually related to economic pressure) for large tailings dams to be designed and built using less than the most conservative design seismic event – as has indeed happened in many cases in the past.

5. White Paper No. 1, p. 4

> *"All events classified as seismic, hydrologic, failure or breaching, deterioration, mis-operation, or activation of the Emergency Action Plan (EAP), require reporting for a Class I or Class II dam."*

There are 3 large tailings dams presently operating in Alaska (Fort Knox, Red Dog, Nixon Fork) and three large mines without a large tailings dam (Greens Creek and Pogo with dry tailings, and Kensington with lake-disposal).

Despite all of the engineering design, regulatory, and operator controls, there was an overtopping of the Nixon Fork tailings dam on March 9, 2012. The Nixon Fork tailings dam is by far the smallest of the 'large' dams (approximately 75' high).[7] However, the implication clearly being made in section

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[6] "Large Dams the First Structures Designed Systematically Against Earthquakes," Martin Wieland, ICOLD, The 14th World Conference on Earthquake Engineering, Beijing, China, October 12-17, 2008, p. 7

[7] "Nixon Fork Mine Environmental Assessment," Bureau Of Land Management, Anchorage Field Office, October 2005, Figure 2-8

"*2.2.Regulatory and Permitting Process*" is that engineering design, regulatory, and operator controls, in combination, will prevent any dam failure.

As the Nixon Fork incident clearly points out, accidents can happen, and there is risk associated with these structures, despite the best efforts of all involved.

6. *White Paper No. 1, p. 7*

> *"The technology of tailings dam design is based on the same principles as water dams; however, the presence of saturated tailings solids as the stored medium, versus water only, presents unique challenges and design considerations. ... The long term post closure objective for a tailings impoundment usually involves transitioning the solids retention facility into a stable landform, whereas the final closure plan for a water dam would typically involve dam removal."*

There are several important differences between tailings dam design and water dam design that are not mentioned. Tailings dams utilize downstream, centerline, and upstream construction. Earthen water dams use essentially one construction method – downstream – with an occasional centerline lift.

Another important difference between tailings dams and water supply reservoir dams is the design life of the dam - water supply dams have a finite life, while tailings dams must impound the tailings in perpetuity.

These are significant differences given the fact that a majority of tailings dam failures are associated with upstream construction (which is legal, and in use, in Alaska), and that we have relatively little experience with the long term performance of tailings dams (50-100 years of operating experience with tailings dams, compared with a tailings dam design life of perpetuity). It is not appropriate, in terms of the long term life of a tailings pond, to assume that it will be "converted" to a solid landform. It might happen, especially over several millennia, but to assume that it would take place without engineered compaction that would provide some assurance of long term stability would be inappropriate.

7. *White Paper No. 1, p. 10*

> *"The current data set is insufficient to show that there is a trend towards increasing tailings dam failures over time or that high height dams have a greater or lower risk of failure."*

Likewise, it should also be noted that current data is insufficient to show there is a trend toward "decreasing" tailings dam failures.

Yet, given the 'insufficient' nature of the available data, it is mentioned on page 1 that "*... none of these instances (of dam instability/failure) include dams exceeding 500 ft in height*." This observation, while correct, does not honor the author's criticism of 'insufficient' data for tailings dam failures in general. Data on the total number of tailings dams is not available, although we could probably find out the number of dams over 500 feet because they are so large – but the authors do not know, or do not present, that number

8. White Paper No. 1, p. 10

> *"In fact, Chilean regulations prohibit the use of the upstream construction method for tailings dams."*

Much of the argument in this paper relies on the assumption that downstream or centerline dam construction will be employed. Unlike Chile, Alaska regulations DO NOT prohibit the use of the upstream construction method for tailings dams. Under Alaska regulations specific dam construction type can neither be required nor prohibited, only a review of the overall safety of a proposed dam is authorized.[8]

9. White Paper No. 1, p. 11

> *"It is noted that there are only three failures reported for tailings dams constructed using the centerline method and seven failures for tailings dams constructed using the downstream method. The statistical significance of this observation is difficult to ascertain due to the relatively few failures that have occurred for either embankment construction technique."*

While there is no disagreement with the general conclusion that downstream and centerline construction is much safer than upstream construction, there should be some mention that the lack of adequate data on the total number of upstream, downstream, and centerline tailings dams is also significant to this discussion.

It is extremely unfortunate that we do not have an accurate number for either the total number, distribution, and types of tailings dams, or the number and type of failures for tailings dams. Collecting accurate data on tailings dams would seem to be a neglected issue, but the need for and difficulty of international coordination and cooperation in collecting reliable data is recognized.

10. White Paper No. 1, p. 13

> *"... it is incorrect to imply that any particular proposed or actual dam structure is more or less likely to fail based solely on extrapolation of general dam failure statistics."*

Unfortunately "general dam statistics" represent the best information we have on the nature and frequency of tailings dam failures. If we were to ignore empirical data by claiming that "competent professionals" will design, regulate, and operate all of these dams, we would only perpetuate the fundamental problems with tailings dam failures, as well as sustain unnecessary risk to the public safety and public financial liability.

11. White Paper No. 1, p. 16

> *"The final design of a large embankment includes detailed dynamic modeling under the Operating Basis Earthquake and the Maximum Design Earthquake."*

Unfortunately, the stability analysis for some large and most small tailings dam analysis still employs the less-expensive pseudo-static analysis for analyzing dam seismic stability.[9] Alaska Dam Safety Regulations are not clear about when dynamic modeling must be used,[10] but it is certainly possible for the less expensive pseudostatic modelling to be employed for Alaska Class II dams.

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[8] See: Guidelines for Cooperation with the Alaska Dam Safety Program, Prepared by Dam Safety and Construction Unit, Water Resources Section, Division of Mining, Land and Water, Alaska Department of Natural Resources, June 30, 2005

[9] For example, see Draft EIS for the Montanore Project, Montana, 2009

[10] See "Guidelines for Cooperation with the Alaska Dam Safety Program," prepared by Dam Safety and Construction Unit, Water Resources Section, Division of Mining, Land and Water, Alaska Department of Natural Resources, June 30, 2005, Section 6.3.3 Seismic Study Phases.

12. White Paper No. 1, p. 20

> *"The upstream construction method must be avoided for the dams. … The Fort Knox tailings dam is an example of a large dam that has been constructed and continues to be operated in Alaska. This tailings dam will be raised to its ultimate height of 360 ft in 2013, …"*

The final lift on the Fort Knox dam, designed by Knight Piesold, will be an upstream lift.[1] It is difficult to give credibility to the author's recommendation of 'avoiding' upstream dam construction when the Fort Knox dam, designed by the author's company, will employ this construction method.

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