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Re: Dairi Prima Minerals (DPM) Mine site risks and Tailings disposal safety. Review of Dairi April 2021 EIA Addendum.

I have previously reviewed plans and Environmental Impact Assessments (EIAs) for a proposed tailings storage facility (TSF) at the Dairi (DPM) lead-zinc mine in Sumatra, Indonesia, now starting construction, and made reports[1] on safety issues of the proposed TSF. These previous reports highlighted some of the hazards to which such a facility will be exposed, especially those due to the extreme earthquake potential and high rainfall in the project area acting on the likely unstable foundation conditions at the proposed TSF site

Subsequently I have reviewed Dairi Prima Mineral's (DPM) newly revised Addendum Type A[2] to their Environmental Impact Assessment[3], and present my findings on that addendum. I do this in summary form and have also made a video version[4].

The new EIA2021 Addendum appears to request approval for a 1.2 million tons tailings storage facility, but I understand from various plans 2005-2019 that there is a long-term plan to expand the mine so that the eventual TSF would be to 3.2 million tons. I have used the latter dam size as my working assumption in my sketch figure 1 following. However even if the TSF is ultimately limited to the 1.2 mt size, the hazards to local communities would still exist.

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[1] Meehan R.L. 2020a. DPM Mine Site Risks and tailings disposal safety. https://www.inclusivedevelopment.net/wp-content/uploads/2020/07/DPM-Mine-site-risks-and-Tailings-disposal-safety-April-2020-English.pdf;
Meehan, R.L. 2020b. Dairi Prima Minerals (DPM) Mine site risks and Tailings disposal safety. Review of Dairi 2019 EIA Addendum.
https://drive.google.com/file/d/1OiDnNcnpVIEMqKnSfxX2br0KQRe4b8wX/view

[2] DPM. 2021. Adendum ANDAL, RKL dan RPL Tipe A Kegiatan Pertambangan Seng dan Timbal di Kecamatan Silima Pungga-Pungga Kabupaten Dairi, Provinsi Sumatera Utara. https://drive.google.com/file/d/1O-lfoR5i4-bkWAacJHL1F8OoLSs8rEHU/view

[3] In Indonesian EIA procedures, after an EIA is approved, there can be major addendums (Type A) and minor addendums (Type B)

[4] Meehan, R.L. 2020c .Video about Review of Dairi 2019 EIA Addendum:
https://www.youtube.com/watch?v=Z1hGgyN5gh4

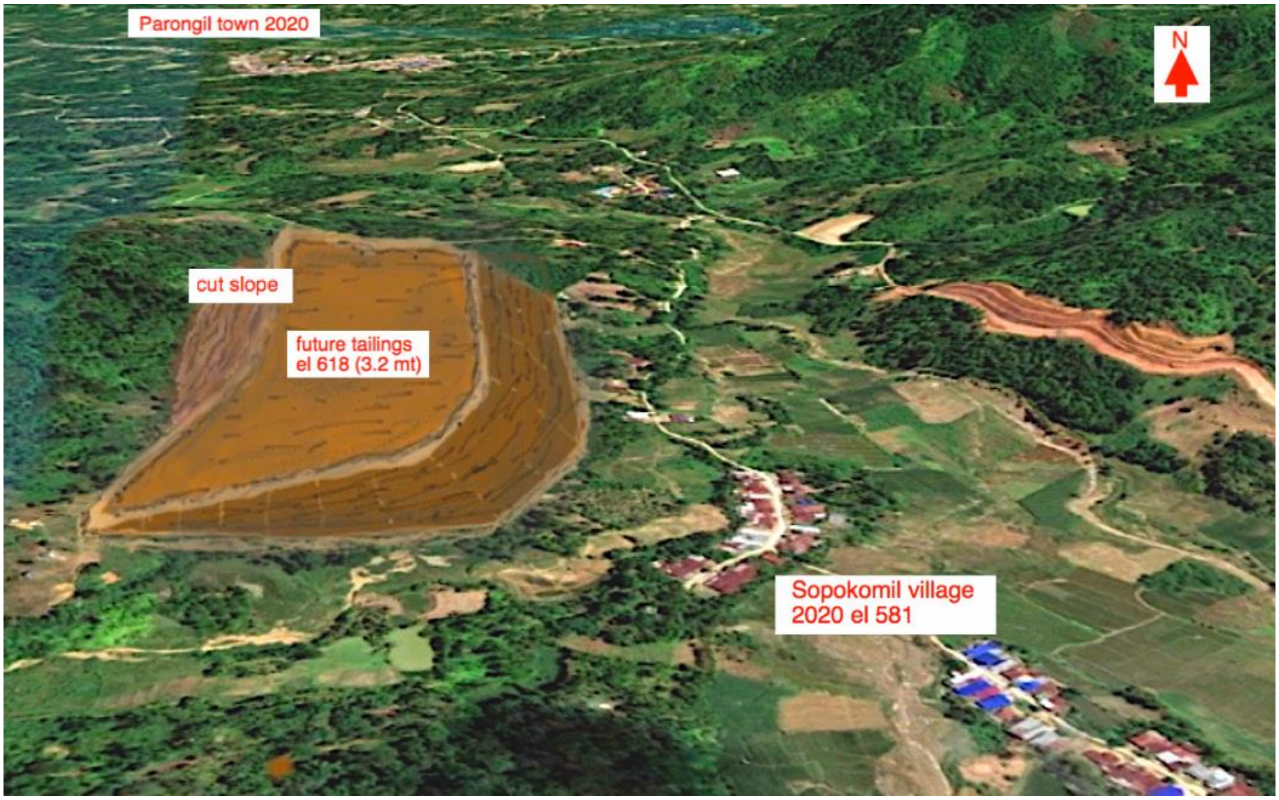

Figure 1. Planned configuration of TSF, 3.2 million tons at elevation 618. TSF configuration (brown color) from EIA Addendum fig 2.22 sketched onto Google Earth image by the author. Breach of the tailings dam above the Sopokomil village is likely in a strong earthquake because the ground between and beneath the village and the TSF and the dam foundation is unstable volcanic ash soils subject to liquefaction and landsliding.

Review of previous reports and findings

My first report (Meehan, April 2020a) discussed the high earthquake and rainfall hazard in the region and considered a possible tailings disposal area in the lower Sopokomil valley. At the time that report was written the only documentary information available on the TSF was that provided in the early history of the project (Middleton 2003), various press releases describing its likely size and duration of operations, and tentative field reports including road construction that suggested a possible TSF that filled the lower Sopokomil valley.

In October 2019 DPM produced a draft of an environmental impact assessment Addendum Type A (EIA 2019), which proposed a specific TSF location which was said to have been based on studies of multiple possible locations carried out by their international consultants. The favored proposed site was located next to the village of Sopokomil in the lower valley. In my December 2020 report reviewing the October 2019 DPM EIA Addendum, I presented evidence that the proposed TSF was probably inconsistent with the DPM international experts studies and recommendations, which had not, and still have not, ever been released by DPM (BAKUMSU, a local NGO have twice requested these reports from the Ministry of Environment and Forestry). I argued that the proposed site was likely underlain by unstable volcanic ash deposits (Toba tuff), rather than stable bedrock as suggested in DPM 2019 EIA Addendum, and that Toba Tuff would represent and unstable site, a high risk of tailings dam collapse or failure, and a high danger to the communities below the facility.

In April 2021 DPM produced another, revised draft EIA addendum which I call EIA2021, which is the subject of this review. This addendum continued to propose the aforementioned TSF site but added a good deal of new information on the site conditions. It did not, however, include either background material BAKUMSU had previously requested on my behalf, or additional new background material including that from a series of exploratory borings at the proposed TSF site. (See Appendix B)

This latest EIA2021 report has not yet been formally translated from the Indonesian language and runs some 800 pages. To date I have been able to complete an interim review based on computer translation of those parts of the report that appear to be new and relate to the TSF.

The report indicates that further background studies have been completed since 2019. Data and reports from those studies was not included in the EIA2021, and has not otherwise been released by DPM. Despite this lack of transparency of base information, the summary of that data by DPM included in the EIA2021 is sufficient for me to update my comments on the safety of the facility as currently proposed in April 2021.

Geotechnical characteristics of Toba tuff

The new borings (K-series) in the area of the proposed TSF confirm that Toba tuff is present at the site to a depth of 50 m or more. The general character of the Toba tuff is worth reviewing in some detail and is discussed in a supplementary Appendix A to this letter. It has profound implications for TSF stability.

Impact of unstable foundation on TSF

The best known tailings failure of our times is the Brumindinho failure in Brazil in 2018. This has been discussed in my previous reports. The photos shown here are during the course of the failure and show the entire containment “wall” of the tailings failing simultaneously. The containment, or a dam wall, in this case was of the dangerous design that was used traditionally in TSF facilities but has a record of high frequency of failure. It consisted of no more than a thin shell of small dikes holding back a large lake of easily liquefied tailings. Failure has occurred with these designs either spontaneously or after even a moderate wet season.

Figure 2 Brumindinho TSF failure 2018

The type of construction used at the Brumindinho TSF, the so-called "upstream method", is no longer accepted in most places today because of its high danger of failure even without an earthquake. The DPM TSF proposes using a sturdier rock fill dam wall to retain the tailings. However, whatever the strength of the dam wall might be (even if it is massive concrete), if it rests on unstable foundations, it will fail by sinking, spreading or sliding, with either overtopping of the sunken dam wall or a local space breach that then enlarges and may substantially empty the TSF with discharge to the lands below. A structure built on a failing foundation will not stand.

Aside from a potential foundation failure an unstable foundation also sets up the possibility of many different kinds of failures of a TSF. Among the most obvious are

(1) failure of the plastic lining which might be undetected and would lead to leakage of toxic chemicals[5] from the tailings into the ground water in this region in the Sopokomil creek watershed

(2) failure of elements of temporary or permanent underground drainage such as occurred at the Chinese molybdenum tailings dam last year and sent toxic materials some 123 km downstream of the facility[6] (figure 3)

Figure 3 An unstable foundation may also lead to a TSF spill that would not necessarily destroy villages, but rather flood downstream streams with toxic waste as here last year at China's Yichun Luming TSF.

(3) Local failure of the tailings dam wall due to foundation failure during earthquake which is the subject of an undocumented stability analysis discussed in the EIA2021, figure 2.44.

While all these failures are possible, even likely given the proposed DPM TSF location, in this report I also highlight one *additional* reasonable failure scenario which has in fact has been suggested in the latest EIA2021 (4) namely large scale landsliding of broad extent in the TSF area.

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[5] Tomy Alvin Rivai1,*, Kotaro Yonezu1, Syafrizal2, Koichiro Watanabe, March 2019, Mineralogy and Geochemistry of Host Rocks and Orebodies at the Anjing Hitam Prospect (Dairi, North Sumatra, Indonesia)and Their Environmental Implications, Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 06, Issue 01, pp.18-28,

[6] China's recent tailings leak the worst in 20 years: https://www.mining.com/chinas-recent-tailings-leak-the-biggest-in-20-years/

The scenario I have in mind is illustrated on the sequence of images on figure 3 and figure 4. Basically, the whole slope on which the TSF is located could move downslope under the weight of the TSF (indeed, Toba tuff has seen similar landslides (see Appendix A) even without loading associated with a TSF). The lower bound of sliding may be within in the Toba tuff layer or at zones of weakness and high pore pressure at the base of the tuff. With such a movement it is difficult to believe that the proposed TSF would not fail, either collapse or by rupture of linings.

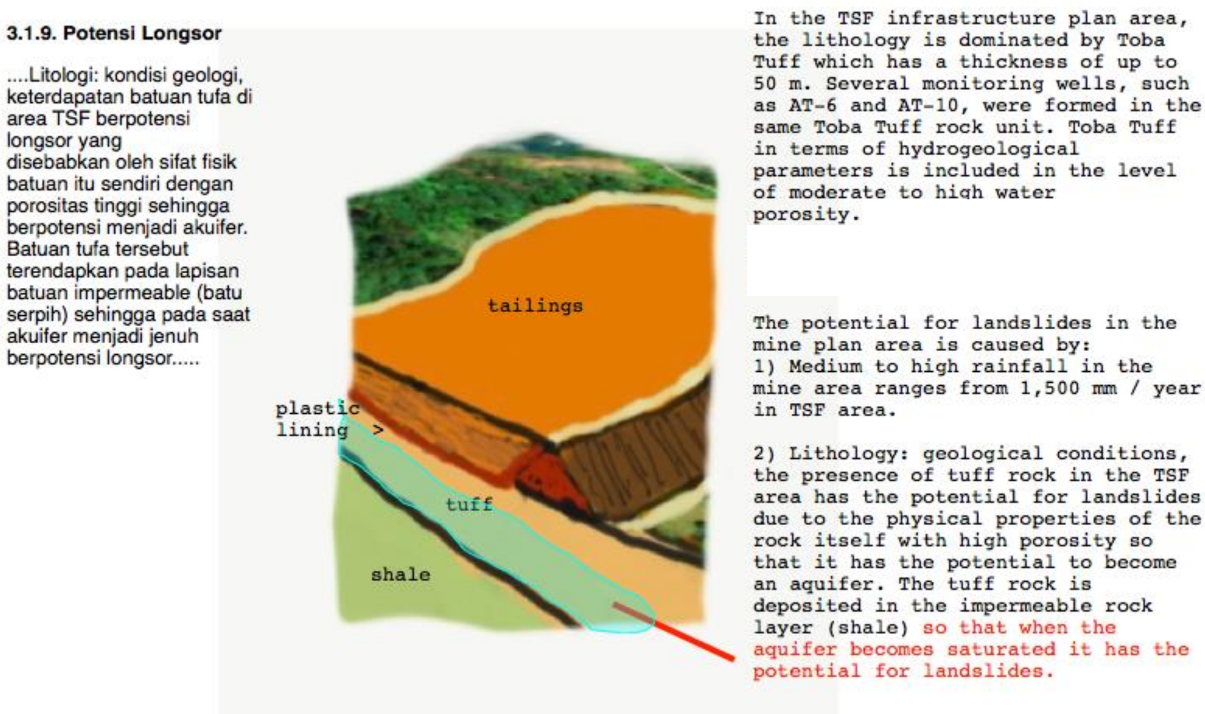

Figure 4 Potential landslide with saturation of the Toba tuff

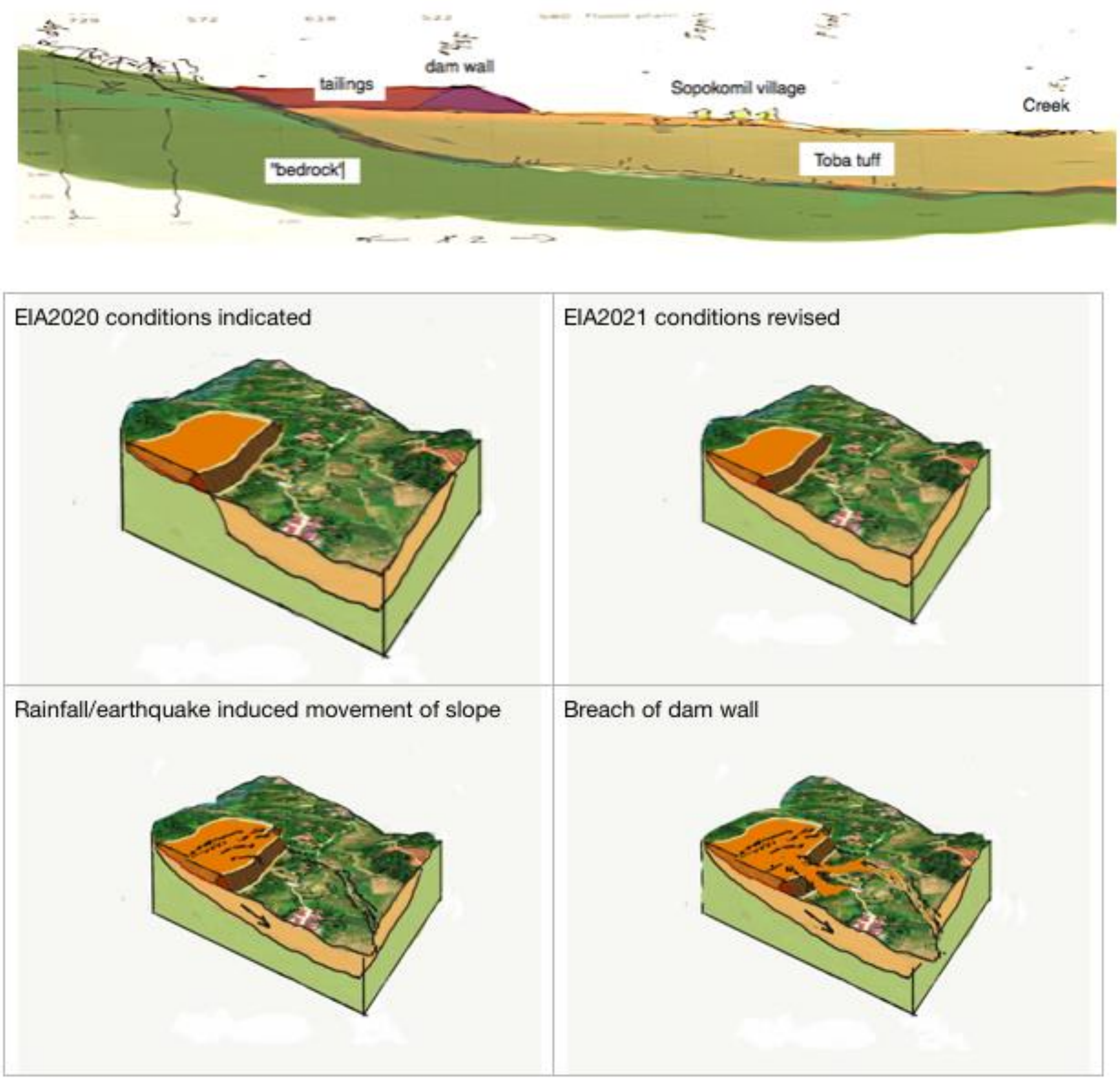

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Figure 5 Cross section as verified EIA2021 with likely ground failure scenario brought on by rain and earthquake

DPM/China Nerin stability analysis

EIA2021 specifies (section 2.5.3) that a stability analysis of the dam wall has been carried out, apparently by a newly introduced engineering firm, China Nerin, using the Australian ANC0LD 2012 specifications.

A proper review of such a stability analysis would require a full appendix to this letter, but in any event cannot be conducted at present because documentation of the analysis reportedly has not been provided by DPM. However, from the few details indicated, namely that the Bishop limit equilibrium analysis has been used with a reported factor of safety of 1.15 (China Nerin, 2021[7]), it is possible to comment on the adequacy of this analysis based on the brief discussion in the EIA2021.

First, it should be noted that the ANCOLD 2012 is outdated, having been replaced by a current standard in 2019. Considering DPM only start to mention ANCOLD in the 2021 revision of the EIA Addendum, this is a significant mistake or misrepresentation. The most recent 2019 ANCOLD takes into account recent major mine tailings disasters and attempts to mitigate against them.

Secondly, even the outdated ANCOLD 2012 analysis would require a more advanced type of analysis that would yield an estimate of the movement, or displacement, of the dam rather than a simple factor of safety. This would be essential in the case of this tailings dam, because:

- the presented factor of safety using the simple method was very low
- the EIA2021 also states that the TSF will contain fragile elements including plastic linings and foundation drainage works. These would be subject to rupture in the case of a significant ground movement, say a meter or more. Destruction of these elements by ground movement would to lead to leakage and pressure backup, possibly being undetected at first. Being beneath the foundation, these would be irreparable, and this situation would unacceptable from a safety standpoint.

Thirdly, both ANCOLD specifications also require that the TSF have a designated design engineer. The latest EIA2021 does not appear to assign specific engineering responsibilities for the design. The only reference to design engineer that I have found in the EIA2021 is to Knight Piesold, in section 2.5.3.2.

> *"The design of the TSF was carried out by a Knight Piesold consultant, whereby the TSF is able to accommodate the maximum monthly rainfall for a duration of 100 years."* [8]

This seems implausible. In the earlier EIA2019, DPM claimed the participation of Knight Piesold, including in site exploration work by another associated international firm, Golder Associates. It was claimed that the work was undertaken in 2010 ("*A total of 119 geotechnical drills with a total depth of 3,473.62 m have been carried out by consultants Golder Associates and Knight Piesold in 2010*"[9]) and the results of Knight Piesold's tests on cores were supposedly taken from those same field explorations were referred to in Table 3.23 of the EIA2019. But that table is dated 2004 and cannot represent any results from the 2010 borings relevant to the TSF siting studies. In fact, the EIAs indicate that Knight Piesold's last involvement in the DPM project was preparation of a report in 2008 (Knight Piesold 2008[10]). What this means is that the designation of Knight Piesold's post-2008 role in both EIAs is either a mistake or falsification. This leaves the project without a design engineer. This is clearly not acceptable for a project in this advanced state of development, and, if designation of Knight Piesold's post-2008 role in both EIAs was a falsification, it would be extremely concerning behavior for a company planning to build a mine and tailings storage facility in a very high risk environment.

EIA2021 mitigation proposals by DPM

With the unstable foundation conditions, now recognised and admitted in the EIA 2021, DPM has briefly mentioned two techniques for stabilizing foundation soils, namely

[7] China Nerin Engineering Co.,Ltd., 2021, Stability Assessment Calculation of The TSF.

[8] Unofficial translation from the original Bahasa Indonesia document that can be found https://bakumsu.or.id/en/advokasi-tambang/ at pp 2;102

[9] Unofficial translation of the original Bahasa Indonesia document that can be found https://bakumsu.or.id/en/advokasi-tambang/ (click "English Version and go to the "resources" section) at pp 3; 41

[10] Knight Piésold Pty Limited, 2008, Tailings Storage Facility Final Design Report, Ref. PE701- 00030/12 Rev., September 2008, unpublished (and never released).

(1) a stone drain column [sic] and
(2) vaguely specified "improvement" of the upper Toba tuff (approx.10 meters).

Given the likely dimensions of probable unstable tuff (dam wall footprint of >100,000 square meters, volume > 3mil cubic meters) either of these techniques would require treatment of massive amounts of unstable soil. Improvement of the Toba tuff foundation would be a project larger than the entire TSF project itself. In short, it would be impractical. Hundreds, if not thousands of rock drains would be necessary to relieve seismic pore pressures. Such a project would be extremely complex - as suggested by attempts to apply these techniques to much smaller projects in China.[11] Indeed, it is hard to believe DPM seriously propose it – and, even if implemented, liquefaction and sliding in unimproved Toba tuff downslope of the dam (between the dam and the Sopokomil village) would allow slide movements that are likely to lead to failure of the dam wall.

Conclusions

I believe that the latest EIA2021 confirms the unstable foundation condition at the TSF discussed in my previous reports. Such a TSF design and location fails to meet reasonable world standards for mining waste disposal.

Review and analysis of credible mitigation measures and the background documents requested is a major task that should be undertaken by an independent reviewer in accordance with current ANCOLD2019 standards. In contrast, the EIA2021 takes the position that final mitigation measures can be left unresolved until some future final design phase. The vague mitigation measures the EIA2021 does propose I believe to be implausible and unproven. Such an approach I regard as failure to meet reasonable international standards, including ANCOLD, especially given that the mine located in an area with extreme earthquake risk and with very high rainfall events.

Approval of the EIA2021 at this time without proper documentation would support the continuation of a project which is likely to be infeasible or would negligently proceed with minimal mitigation treatments. This would render the facility as unsafe as projects that have stimulated revision of the ANCOLD 2012 to ANCOLD2019 -- including notably Mount Polley and Brumindinho.

In summary, I believe that any approval of the DPM mine project as proposed would give a green light to a mine almost certain to result in a human and environmental disaster on the scale of the El Cobre, Aberfan, and Brumnidinho disasters.

Richard L. Meehan.

[11] Wang, G, Wei, X, and Liu, H. 2015. Liquefaction Evaluation of Dam Foundation Soils Considering Overlying Structure. Journal of Rock Mechanics and Geotechnical Engineering, 7(2): 226–232. DOI: 10.1016/j.jrmge.2015.02.005. (https://www.sciencedirect.com/science/article/pii/S1674775515000219)

Appendix A

Notes on the geotechnical characteristics of the Toba tuff.

Geotechnical characteristics of the Toba tuff are not well documented in the technical literature but sufficient information exists to make a reasonable estimate of those conditions at the proposed TSF.

The Toba tuff is an extensive blanket of volcanic ash that covers much of central Sumatra and at least in its youngest phase originated during a great explosive volcanic event centering on Lake Toba 75,000 years ago some 100 km east of the DPM side. The geological character of the Toba tuff is described in Aldiss 1980 and Chester 2011. In the early phase of the DPM project the extent of the Toba tuff mapped by Aldiss was accepted by Middleton 2003 and this general map has subsequently been accepted in the DPM EIA2019 and EIA2021 and verified in the author's study. However, the depth of the Toba tuff at the TSF side and its character Has been a subject of some difference in opinion with DPM insisting an absence of significant depth tuff beneath the TSF until the latest EIA2021 which indicates conditions (50+ m depth at the TSF) close to my estimates. In addition to the existing geological mapping the author has carried out terrain processing studies that highlight the extent of the tuff deposits in this part of Sumatra. Two examples are shown in figures 6 and 7 and can be viewed also online in 3-D Per Meehan 2020 C.

Meehan, RL, Terrain texture maps for area of Dairi mine.
6 km local Dairi mine terrain
https://sketchfab.com/3d-models/sepia6km2-41ff73b164704804b630fb3829851b9e
109 km Northern Sumatra terrain
https://sketchfab.com/3d-models/d109b-f3dda2c61b1d44f0bf25a83f1247db6d

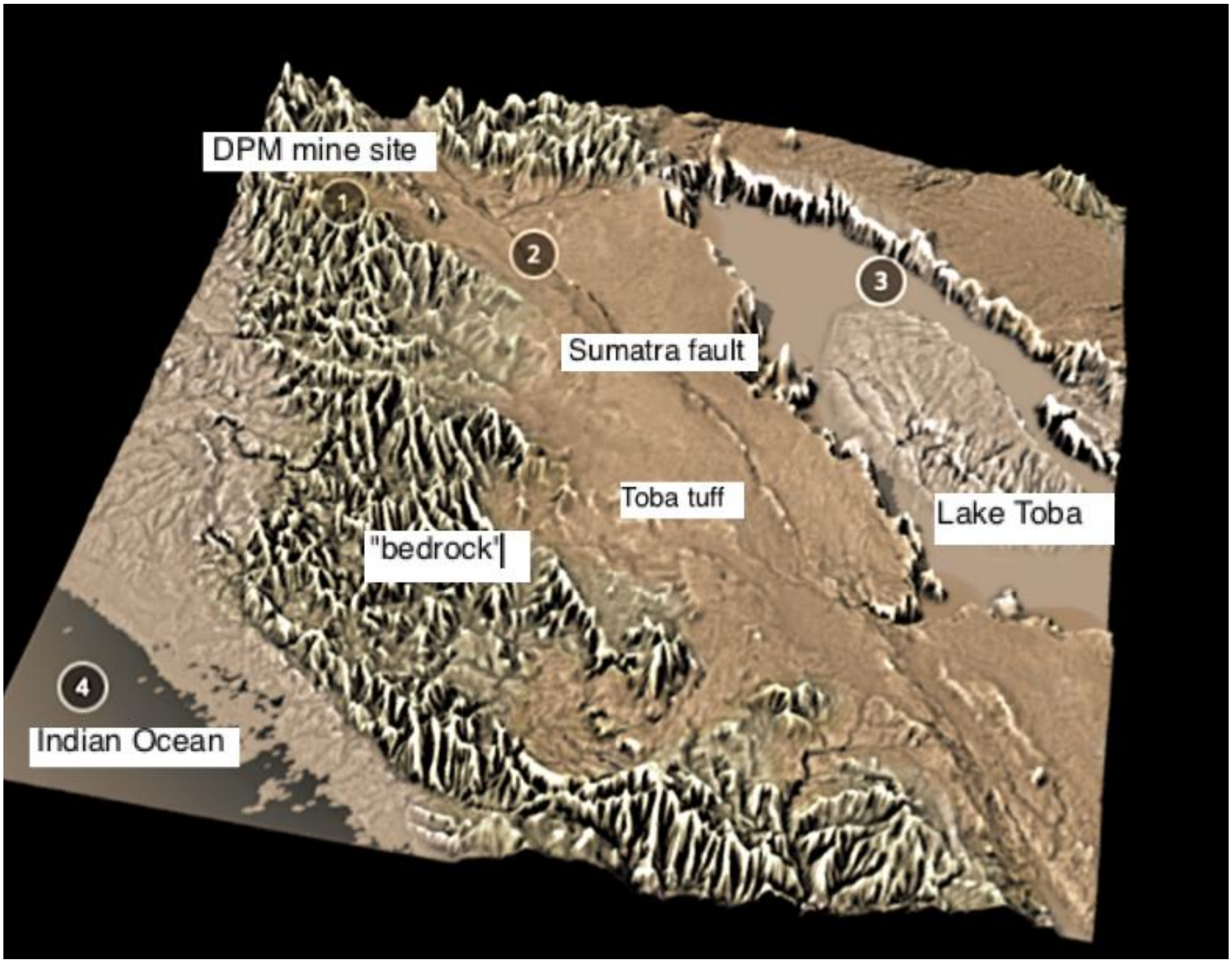

Figure 6 Toba tuff blankets much of central Sumatra

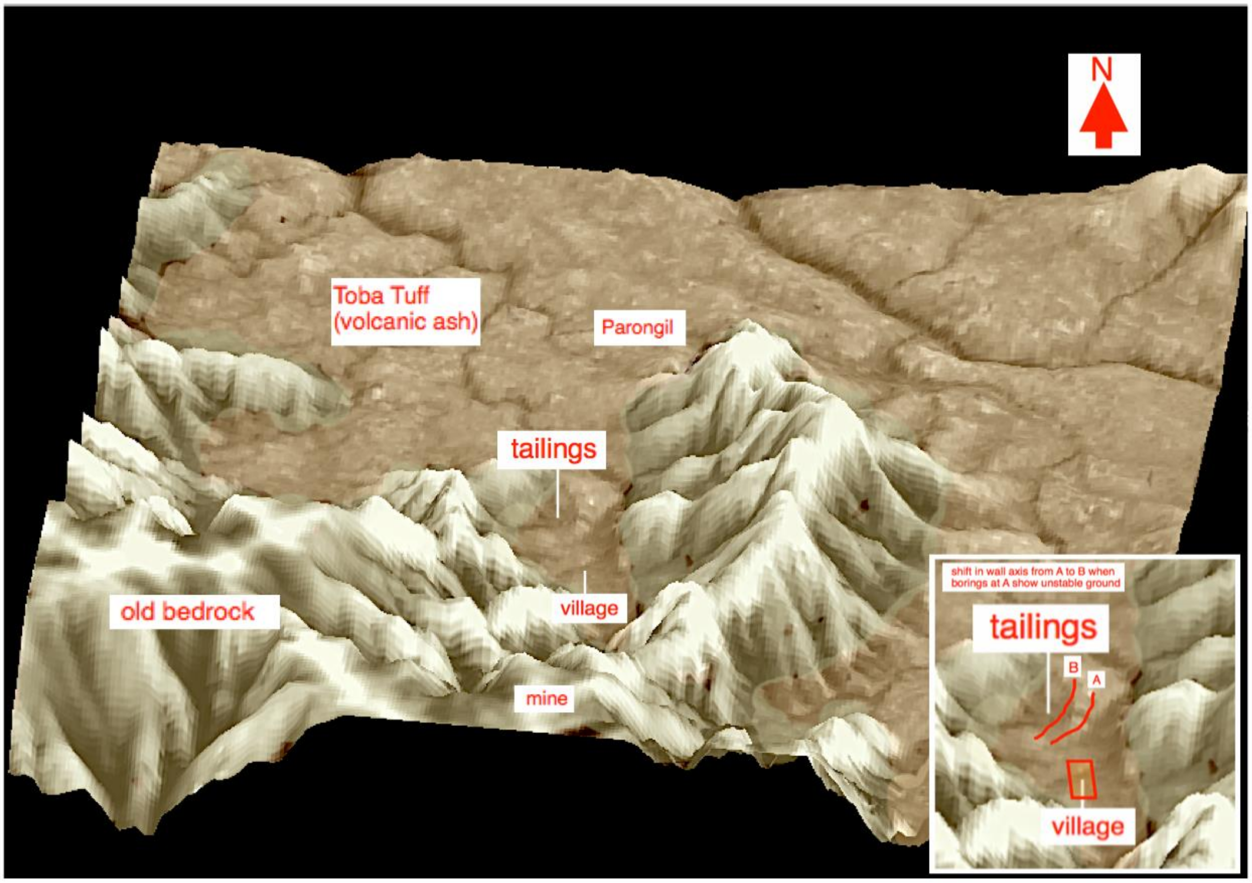

Figure 7 Terrain texture map of DPM TSF site. Lower areas are Toba tuff with protruding bedrock forming the hills around Sopokomil Creek

Toba tuff is a volcanic ash deposit. In some places in the world the term *tuff* brings to mind a more limited class of rocks strictly known as *welded* tuffs which are well-known for their properties as a lightweight building stone or pumice. The term *"welded"* refers to the hardening process that occurs when extremely hot volcanic ash solidifies, usually at some depth in the deposit, after its fall or flow, creating a lightweight, strong, but often fractured rock suitable for quarrying for building purposes. Although the Toba tuff is said to contain zones of welded tuff it is predominantly characterized by unwelded tuff, that is a loose disaggregated body of sandy size volcanic glass shards. (Chesner, 2011, communication to author, 2021). Geotechnical properties of these ash deposits allow for rapid seepage of water and exhibit poor stability especially when wet or saturated.

Figure 8 Mount Sinabung, currently actively spreading volcanic ash 50 km from The DPM site

The deposition of the ash deposits occurs at the time of volcanic eruption and involves turbulent and often violent burial of an existing old landscape including well developed soils, forests, and bodies of water. The high heat of the ash often results in explosive eruption of steam, flash carbonization of vegetation, and at the base of the deposit subsequent formation of clay minerals known for their instability. The result is that the contact zone between ash and older landscape is often a zone susceptible to high seepage and instability. The combination of loose and often saturated character of unwelded tuff at shallower depths (upper 100 m) and the problematical contact zone between tuff and older landscape often gives rise to difficult geotechnical problems including ground subsidence, collapse structures, and landsliding in even shallow slopes aggravated by heavy rain and earthquakes. The coincidence of high rainfall saturating and uplifting the ash strata and large earthquakes of long duration causes many landslides in a region.

Figure 9 cleaning of streets after light ash fall from Mount Sinabung volcano

The grey, sandy, slushy character of Toba tuff is well known in Indonesia because there continue to be small volcanic eruptions including the region around Dairi. Mount Sinabung which is active in 2021 creates periodic local ash falls usually a few centimeters thick as shown in figure 8 and 9, and various YouTube clips. The very Sinabung volcano has been sporadically active for some time but recent deep deposits of tuff are not seen. Much larger and more dangerous ash falls or floods have attracted attention in historical times are well known at Mount Saint Helens volcano in the US and also in 1815 Mount Tambora in Indonesia. However, none of these match the huge scale of the Toba tuff event which sent ash as far as India and is said to have caused years of global cooling.

The author has been able to identify a few studies of sites proposed for major civil works including dams and a geothermal power plant located on the Toba tuff in central Sumatra. A Japanese study in the 1990s attempted to find dam sites on streams in the vicinity of Medan and noted the presence of Toba tuff throughout the study area. Some of the sites featured or crops of welded tuff which were considered to present feasible foundation condition for dam construction but many of the sites featured unwelded Toba tuff which the investigating engineers considered unreliable as foundations for dams.

A proposed geothermal plant, the Sarulla project also in the Toba tuff involved recent site explorations which are documented as showing unwelded Toba tuff as being in a loose condition (Standard penetration test N values less than 10) with potential earthquake liquefaction potential in the upper 10-30 meters.

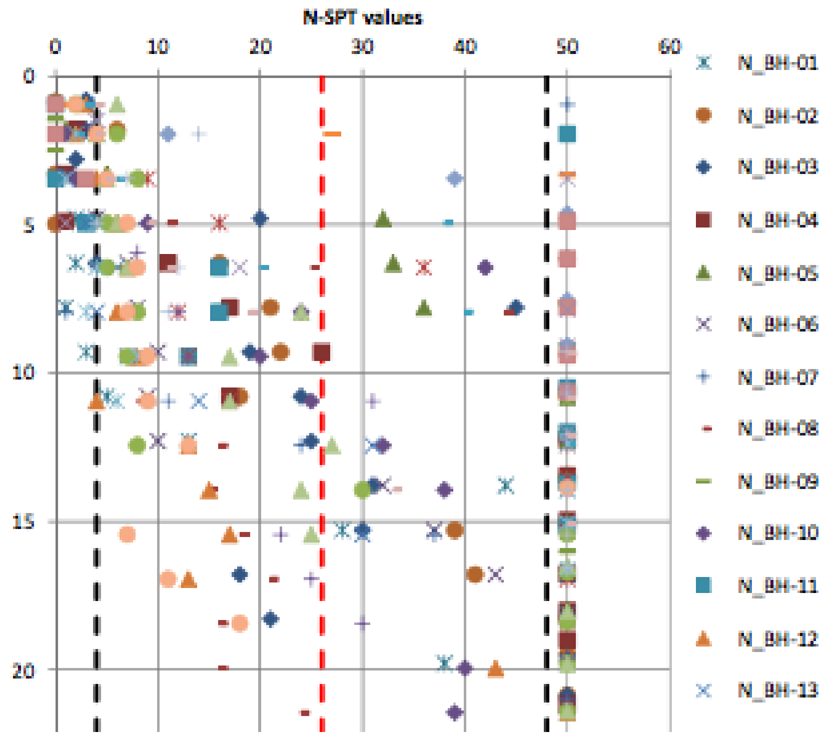

Figure 10 Standard penetration tests in Toba tuff at Sarulla geothermal plant.

Sarulla Operation LTD
Sarulla Geothermal Plant
Seismic Hazard Desk Study
July 2013

The writer has also seen photographs of highway and bridge construction in areas of Toba tuff that show areas exposed by excavation which when soaked by rainfall quickly soften to slushy sand that will not support the weight of a walking person. However, they also show lenticular bodies of welded tough interspersed with the unwelded tuff. All of these descriptions appears to be consistent with the character of the Toba tuff at the DPM TSF site which according to both EIA versions remains uncertain: *"information on the geological structure of the final site has been very difficult to obtain." (Section 3.1.5.3.3)*

Figure 11 ash landsliding in Japan 2020, combination rain and earthquake.

The susceptibility of volcanic ash is well known in many areas of the world where such deposits are present. Japan also features volcanic ash and as recently as June 2020 landsliding occurred in figure 11 with notes by the observing geologist that volcanic soils are particularly dangerous

There are unexpected dangers in the combination of earthquakes and volcanoes. Even when those volcanoes have long been inactive. Beware of volcanic soil.

Landsliding in rain saturated Toba tuff slopes in Sumatra has led to many fatalities. The character of the Toba tuff and its contact with underlying bedrock are described in Gratchev 2020[12]

[12] *Ivan Gratchev, MasyhurIrsyam, Iku Towhata, Bakhtiar Muin, Hasbullah Nawir, GEOTECHNICAL ASPECTS OF THE SUMATRA EARTHQUAKE OF SEPTEMBER 30, 2009, INDONESIA SOILS AND FOUNDATIONS Vol. 51, No. 2, 333–341, Apr. 2011 Japanese Geotechnical Society*
https://www.sciencedirect.com/science/article/abs/pii/S0038080620300445

Figure 12: 2009 fatal landlside at Parmina following heavy rain and earthquake

Geotechnical data on the Toba tuff at the Diari site has not been released by DPM, but the secondary descriptions in the latest EIA are sufficient to make the unstable properties of the stratum clear. For example, section 1111 of IEA2021 a indicates that the tuff beneath the TSF is unstable enough that it will subside under the weight of the tailings dam wall which will require some sort of remedial measures such as a chimney drain or a ground "modification" of an unspecified method.

Heavy rains in December 2018 also caused slope instability in the area of DPMs proposed TSF. These are clearly visible on Google Earth and known to the local people for the heavy flow of rock debris that filled local streams. It is described in the latest EIA2021 which also includes a map of the valley adjoining the village of Sopokomil which is indicated as being susceptible to such slides. Many of the most visible slides on upper slopes seen on say Google Earth are debris flows originating in older rock, not Toba tuff, but it also seems likely that sliding in Toba tuff was involved and this is stated as a fact in the EIA2021:

The potential for landslides in the mine plan area is caused by:
1) Medium to high rainfall in the mine area ranges from 1,500 mm / year in TSF area.
2) Lithology: geological conditions, the presence of tuff rock in the TSF area has the potential for landslidesdue to the physical properties of the rock itself with high porosity so that it has the potential to become an aquifer. The tuff rock is deposited in the impermeable rock layer (shale) so that when the aquifer becomes saturated it has the potential for landslides.

Landslide potential map in the area can be seen in Figure 3.23.

3.1.9.

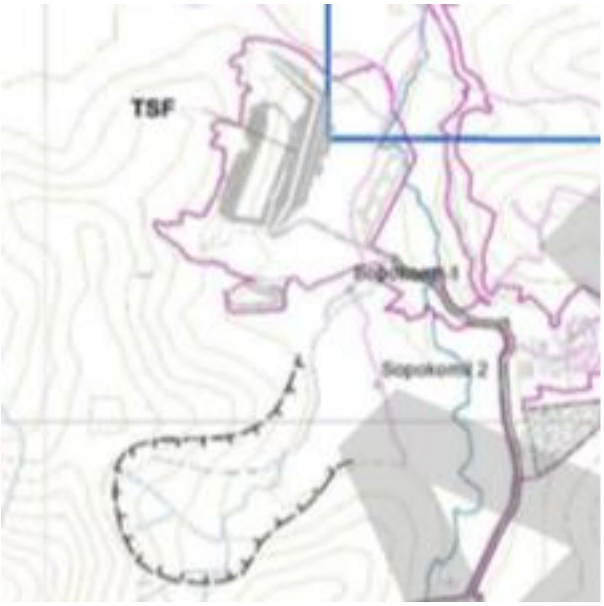

Figure 13 EIA2021 shows landslide potential adjoining TSF

The landsldies are attributed to the presence of the Toba tuff and although the EIA does not show landsliding at the TSF site itself there is reason to believe that the area is also unstable even without the presence of a TSF. The added weight of the TSF whether of short term or long term size, would aggravate the existing instability.

The Toba tuff landform at the site of the TSF is poorly understood according to both of the EIA reports and the author agrees with this. It is possible that the site is underlain by a collapsed Toba tuff arising from secondary vaporization of a water at the time of the ashfall. The area could also be an area of previous landsliding, and there is also in the suggestion that it could be a secondary caldera which could be underline not by bedrock but by rhyolitic extrusive rock. All of these possibilities indicate conditions that would be even more difficult than a simple 50 m deposit of tuff which is my working assumption so they will not be elaborated further here.

Appendix B

Essential documents missing from the EIAs

Previously requested but not yet provided:

From document DPM_Adendum ANDAL RKL-RPL Tipe A-compressed-pages-1-492 (in Indonesian) which we abbreviate here as "EIA2019".

Please provide copies of:

Geotechnical Investigation for The Tailing Storage Facility (2011);
Kajian Hidrologi (2011);

Include all appendices and addenda to reports
EIA p 2-13

....
Please provide copies of:

Geotechnical Investigation for the Tailing Storage Facility (Golder Associates, 2011)

Include all appendices and addenda to reports such as boring logs and field test results
EIA p 2-52

....
Please provide copies of:

Studi yang telah dilakukan terkait dengan rencana TSF di Bondar Begu antara lain:
a. Geotechnical investigation for TSF;
b. TSF final design report;

EIA p 2-57

....
Please provide copies of:

Pada lokasi TSF telah dilakukan pemboran geoteknik pada 28 titik bor dengan total kedalaman 872,57 m

if records of 28 drill points are not included above.

EIA p 55

....
Please provide copies of:

Dokumen studi kelayakan (2015) menjelaskan Konstruksi TSF dilakukan dengan menggali tanah hingga bedrock dan material digunakan untuk meninggikan tanggul.
EIA p 4-19

From the 2021 revised Addendum and currently requested

Hidrologi study
Nerin report stability
Boring logs and tests 2020 K-series borings at TSF

References

(see also references in April 2020 Meehan report)

China Nerin Engineering Co.,Ltd. 2021, Stability Assessment Calculation of the TSF.

DPM. 2021. Adendum ANDAL, RKL dan RPL Tipe A Kegiatan Pertambangan Seng dan Timbal di Kecamatan Silima Pungga-Pungga Kabupaten Dairi, Provinsi Sumatera Utara. https://drive.google.com/file/d/1O-lfoR5i4-bkWAacJHL1F8OoLSs8rEHU/view

DPM. 2019. Adendum ANDAL.

Emerman, S.H. 2020. Hydrologic Aspects of the Proposed Dairi Prima Mineral Mine, North Sumatra, Indonesia. *Inclusive Development International*. https://drive.google.com/file/d/1Q7qn_mgKQ6ZGEJJW5ebXeCkn0BTXQBHZ/view

Gratchev I, Irsyam M, Towhata I, Muin B, Nawir H. 2011. Geotechnical Aspects of the Sumatra Earthquake of September 30, 2009, *Indonesia. Soils and Foundations*, 51(2): 333–341. DOI: 10.3208/sandf.51.333.

Jamasmie, C. 2020. China's Recent tailings Leak the Worst in 20 years. *Mining [dot] Com*. https://www.mining.com/chinas-recent-tailings-leak-the-biggest-in-20-years/

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