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Tailings Storage in a Disused Open Pit and the Conundrum of Explaining the Concept of a Terminal Groundwater Sink

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Abstract

Safe and efficient storage of mine tailings is a complex issue with an unfortunately checkered history. Ensuring that project stakeholders appropriately understand a potential tailings storage strategy can be a challenging task. The response to and findings from a new strategy developed to educate project stakeholders at an existing mining operation in Ghana is presented and discussed. This novel approach adopted a voiced-over animation which described in-pit tailings deposition, coupled with maintenance of a terminal groundwater sink, a potential tailings storage method. Voiced over animation as an educational tool had not been utilised in Ghana previously.

Keywords: Tailings, in-pit storage, terminal groundwater sink, voiced-over animation

Introduction

The Ahafo South mine is located in the Ahafo Region of Ghana, 290km northwest of the Ghanaian capital city of Accra. Ahafo South is the largest gold mine in Ghana and is operated by Newmont Ghana Gold Limited [NGGL], a fully owned subsidiary of Newmont Corporation. Ahafo South is a Newmont Tier-1 asset and to date has produced over 10 Moz of gold, it has Reserves of 4.1 Moz and Resources of 7.4 Moz. Advanced study and exploration work are underway to support underground growth beneath the Subika and the Apensu open pits [www.Newmont.com]. Mining at Ahafo South commenced at the Subika open pit in 2006, with open pit mining subsequently commencing at Apensu in 2007, at Awonsu in 2008 and at Amoma in 2012 Figure 1.

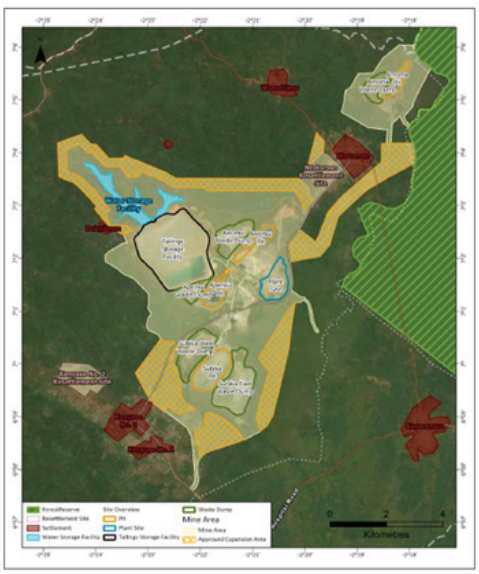

Figure 1 *Ahafo South Site Layout.*

Each of the four open pits at Ahafo South underwent various mining phases, with each phase presenting a lay-back [cut-back], typically with incremental pit floor advancement. Open pit mining was completed at Apensu in 2012, at Amoma in 2017, at Subika in 2025, and Phase 4 mining of the Awonsu open pit is currently forecast to be completed in 2032. In 2017, operations at Ahafo South expanded to include underground mining with commercial production starting at the Subika underground mine. The development of an Apensu exploration decline is currently underway, and initial plans for underground mining at Apensu are being developed, with incremental permitting studies and stakeholder engagement also underway.

The Ahafo South process plant is designed to treat approximately 10 Mt of ore per annum and utilises a conventional Carbon-in-Leach (CIL) circuit for gold recovery. Underground mining at Subika has adopted various mining methods, including longhole open stoping [LHOS] and Sub-level Shrinkage [SLS], similarly underground mine planning at Apensu is expected to utilise a range of mining methods. Ore extracted from Awonsu open pit and the Subika underground mine is stockpiled by grade classification on the Run of Mine ore pad [RoM pad] adjacent to the process plant and is blended prior to processing. Following gold extraction in the CIL circuit, the slurry is treated in a Counter-Current Decantation (CCD) circuit to recover residual cyanide back into the process and reduce Weak Acid Dissociable (WAD) cyanide to below 50 mg/L prior to discharge to a large single cell terrestrial tailings storage facility designated as Cell 1 TSF. By year-end 2025, Cell 1 contained approximately 155M tonnes of tailings, and the facility has an permitted capacity of 220M tonnes. Cell 1 is at Phase 13 of a currently projected 16 Phase construction life. A second, smaller [50Mt] terrestrial facility TSF2 has also been permitted; its footprint is centered immediately to the northeast of Cell 1 with a common embankment.

The remaining capacity of Cell 1 and the full capacity of TSF2 provide NGGL with tailings storage capacity to approximately year-end 2036. However, ongoing resource definition and exploration drilling programs are expected to confirm additional gold reserves and generate further resources, hence incremental tailings storage at Ahafo South is anticipated to be required.

Over the life of the Ahafo South mine and given the long timeframes involved in evaluating, selecting and permitting tailings storage facilities, NGGL has conducted and continues to conduct studies investigating alternative tailings management and tailings storage methods. Tailings storage methods such as thickened tailings, dry-stack tailings and the use of tailings as underground paste backfill have been investigated and remain under study; however, those potential tailings management methods are not the focus of this discussion.

Further expansion of Cell 1 beyond the currently permitted Phase 16 capacity is influenced by a number of regulatory [Ghana Minerals and Mining Regulations 2012 L.I. 2182], physical and site specific requirements, including downstream construction obligations, proximity to local communities, and the shared function of the Cell 1 northern embankment with the Ahafo South Water Storage Dam. While additional conventional terrestrial tailings storage locations have been identified and remain technically feasible, the expansion or development of incremental or additional surface facilities presents a number of challenges related to;

- construction configuration
- water management
- construction materials sourcing, and
- the timeframe of construction.

Notwithstanding these challenges, terrestrial tailings storage facilities remain a practical and important component of the Ahafo South tailings management strategy.

With the identified challenges to further surface facility construction, NGGL assessed the possibility of in-pit tailings storage at Ahafo South. Of the four open pits, Awonsu presented itself as the most viable opportunity because:

- the Amoma pit is quite small and is located some distance from the centre of operations, and
- both the Subika pit and the Apensu pit present more challenging deposition and management conditions due to existing or possible future underground mining.

While current underground mining at Subika and any possible future underground mining at Apensu do not present a fatal flaw to in-pit tailings storage, underground mining does present greater complexity to a simple open pit void without any associated underground workings.

The primary complexities with underground mining near an open pit largely revolve around the geotechnical aspects of crown pillar integrity and the management of any large seepage or inrush flows from an in-pit storage facility into the underground mining environment.

Given the challenges associated with the expansion of the existing surface facilities or the development of a new surface tailings storage facility, the concept of in-pit tailings storage at Awonsu gained support within the tailings storage assessment study team as part of a broader options assessment. This support was predicated on a number of key aspects, including:

- the use of an existing disturbed area would limit the need for any incremental site disturbance
- the Phase 4 Awonsu pit could potentially provide a considerable storage capacity
- the Awonsu pit is centrally located between the mill and the existing Cell 1
- local and district scale groundwater monitoring coupled with groundwater modelling of the Ahafo South mining district indicates that enforced terminal sink groundwater conditions are easily established and simple to maintain
- the Awonsu pit is already contained within the mining impacted area of the site-wide water balance; hence, water contained within Awonsu would simply transition from being mining impacted water to process impacted water, and there would be no increase in the total volume of water being managed at the site
- the construction effort required to utilise the Awonsu pit would be substantially less than building or expanding a surface facility and hence noise, light and dust issues would be greatly reduced, and
- stability of an in-pit facility is inherently greater than a terrestrial facility.

Given the extensive list of positive attributes, a perception developed within the tailings storage assessment study team that an in-pit tailings storage option would easily garner widespread enthusiasm with the various internal and external project stakeholders.

However, as the study progressed, three key aspects arose that presented various challenges to the in-pit tailings storage project concept:

- There is little prior experience of, and hence limited permitting of in-pit tailings storage facilities in Ghana, with AngloGold Ashanti's Iduapriem mine a rare example
- There is a lack of conceptual understanding of what a terminal groundwater sink is and how it manifests
- There is concern that the use of the open pit for tailings storage, would prevent the possibility of either an additional open pit layback or underground mining in the Awonsu area

Following engagement with various internal stakeholders, it became evident that the greater concern centered around the lack of understanding of the terminal groundwater sink concept.

Variable site conditions affecting the viability of in-pit tailings storage

In-pit storage is not always a feasible tailings management option; in some cases, the reasons behind a particular site not being feasible are straight forward, however, in other examples, the reasons are not quite as simple.

In the case of a single pit mining operation, tailings typically can't be stored in the pit that is actively being mined, as there would essentially be no storage capacity available. Hence, for single pit mine sites, a separate terrestrial tailings storage facility is likely to always be required.

With the example of a single pit operation put to the side, the key initial question to be asked or addressed when considering the concept of in-pit tailings storage is whether storage would occur above or below the groundwater surface and more specifically,

if storage would occur below the terminal sink groundwater surface. The terminal sink groundwater surface is defined as a stabilised water level within an open pit or depression that remains permanently below the surrounding regional water table [Edith Cowan University 2013]. In the case of an excavated mine pit, terminal sink conditions are typically artificially established by a dewatering pumping regime; this situation could be termed a "forced" condition. In some circumstances, evaporation from the pit can exceed minewater inflows, and the pit lake level can be more naturally maintained below the regional groundwater level. Awonsu would be an example of a forced terminal sink condition, which would require ongoing pumping. The final closure strategy for the facility would not require on-going pumping; but facility closure is outside the scope of the present discussion.

Depending on the characteristics of a mine pit, the lining of a deep, mined out, fresh bedrock open pit with either compacted clay or a Geosynthetic Clay Liner [GCL] would be at best exceedingly difficult. In these circumstances, tailings seepage management would likely become exceptionally complicated. Identifying an open-pit mine void that presents a viable terminal groundwater sink can prove to be challenging, and the storage capacity below the terminal sink must present a large enough capacity for the pit to be viable.

The hydraulic characteristics of either a natural or a forced terminal groundwater sink [i.e., constant groundwater inflow to the pit] provide for what could be referred to as a hydraulicly lined facility, at which groundwater outflow is simply not possible due to the hydraulic pressure differential.

At Awonsu, as well as more broadly across the Ahafo South operation, the presence of the very favourable geological and hydrogeological conditions makes in-pit tailings storage a viable option from a technical perspective. The Ahafo South district is characterised by the presence of a thin [20–40m] weathered horizon overlying a generally very lightly fractured bedrock. The bedrock at Ahafo South consists of metavolcanics on the hanging wall side and meta-sediments on the footwall side of the district scale Kenyase Thrust. While hydraulic

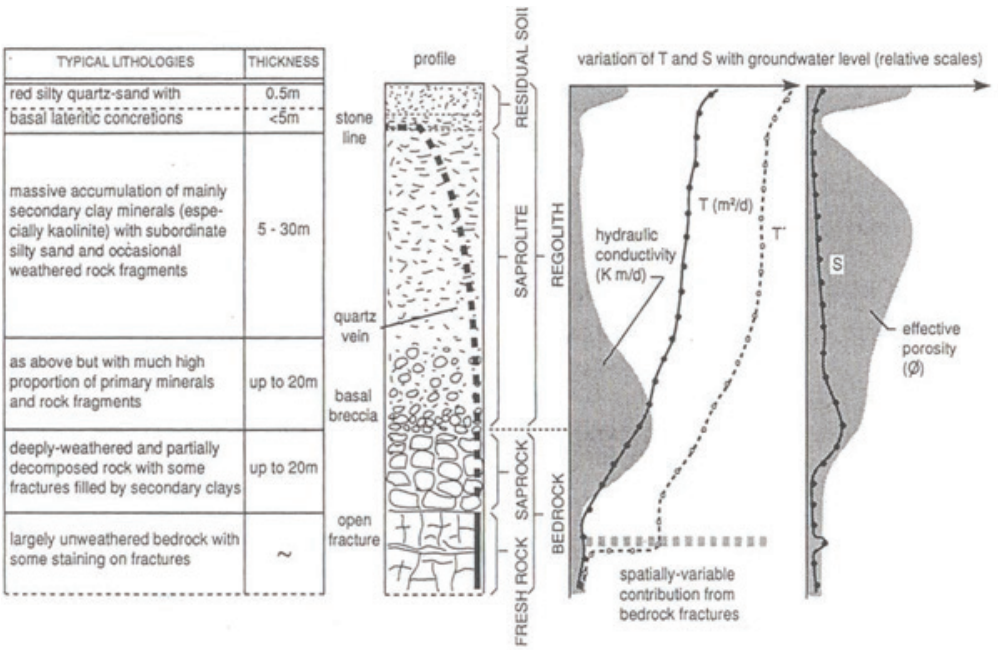

Figure 2 Generalised hydrogeological properties Ahafo South [after Chilton and Foster (1995)].

conductivity is marginally greater along strike of the Kenyase Thrust, this aspect is of no material concern. The hydrogeological characteristics of the Ahafo South district have been interpreted to essentially align with the generic hydrogeological properties, as described by Chilton and Foster (1995).

The hydrogeological properties as described by Chilton and Foster constitute a fundamental pillar of the Conceptual Groundwater Model [CGM] of the Ahafo South district. The hydrogeological properties described by Chilton and Foster have been coupled with an overall west to east groundwater flow direction from slightly elevated terrain to the west of the Ahafo South mining district, towards the principal regional surface water drainage [Tano River] to the east. These principal elements combine to form the complete CGM for Ahafo South. The CGM is the basis of a MODFLOW-USG hosted numerical groundwater flow model of the Ahafo South district [Piteau 2025], shown in Figure 3.

The Ahafo South district groundwater model was used to simulate the groundwater flow regime that would be established should Awonsu be utilised for tailings storage, and the facility decant pond was maintained below the terminal groundwater sink elevation of the pit. The numerical modelling demonstrated that the Awonsu pit could be easily maintained as a forced terminal groundwater sink by consistently abstracting water from the Awonsu pit lake [Piteau 2025].

Discussion

For the Hydrogeologists engaged in the Ahafo South tailings storage assessment study team, as well as for many others, there was and is simple recognition and acceptance of both the natural and forced terminal groundwater sink concepts. However, for some internal project stakeholders, fully grasping the theory of a terminal groundwater sink wasn't immediate, and for others, it remains challenging to visualise and hence accept the terminal groundwater sink concept.

Simply put, the fact that groundwater flows from a higher pressure environment to a lower pressure environment, isn't quite as easy to visualise or conceptualise as is the more commonly used expression that "water flows downhill". The inability to visualise

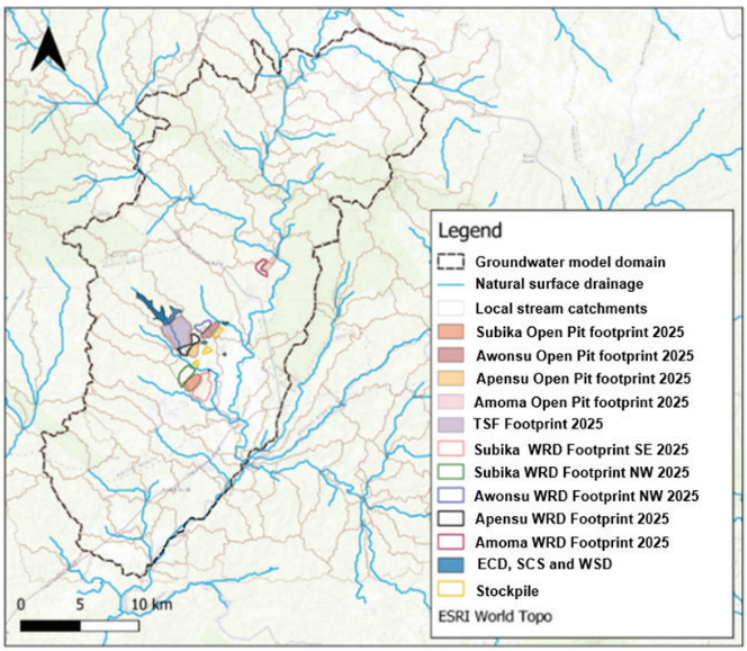

Figure 3 Ahafo South district groundwater model domain [Piteau 2025].

a groundwater surface, or a groundwater head gradient, can leave many stakeholders, including scientists and engineers, not fully understanding the terminal groundwater sink concept.

In order to provide greater clarity on the terminal groundwater sink concept and to explain why in-pit tailings storage was even being considered, NGGL turned to a company that produces video-based animations. An animated video was developed, complete with a voice-over to illustrate how an in-pit tailings storage facility would operate and how a terminal groundwater sink manifests. The video was developed so that a greater proportion of project stakeholders could better visualise both what was being imagined with in-pit tailings storage and how it might be implemented in the future.

The animation, see Figure 4 which is of five minutes duration, was originally voiced-over in English. The animation was initially presented to the broader study and operations team to help promote understanding and potentially facilitate communication with a wider stakeholder audience. The presentation was well received, and as such, the NGGL communications team developed a second voice-over in Twi; the most commonly spoken language in the project area.

The voiced-over animation provided a boost in understanding of the concept of a terminal groundwater sink and hence acceptance of the possibility of in-pit tailings storage at Ahafo South. Unfortunately, the animation did not result in universal understanding of the concept and subsequent discussions have identified improvements that need to be made to the animation. Incremental development of the animation and the education program continues.

Additional project elements

To further confound what was, and remains, a complicated issue, a significant increase in the gold price since early 2024 has dramatically changed the economics at Ahafo South and elsewhere. The potential value of incremental open pit mine laybacks and underground mining, which were lesser aspects at lower gold pricing, now present as alternate project strategies in the Awonsu area.

As a consequence of these economic aspects, much larger conventional terrestrial tailings storage facilities can retake the focus, and hence the challenge of clearly explaining the hydraulics of a terminal groundwater sink and in-pit tailings storage can be overshadowed by the possible need for a revised conceptualisation of the tailings storage project.

Conclusions

Studies conducted at the Ahafo South operation suggest that the opportunity to utilise in-pit tailings storage may, even under the best of technical circumstances, not be a simple method to implement. Reluctance to accept the in-pit terminal groundwater sink method can be caused by a difficult technical explanation of the terminal groundwater sink concept and or concerns related to geotechnical or ore recovery aspects.

The development of a voiced-over animation that describes the in-pit tailings storage concept in general, and the terminal groundwater sink concept in particular, has greatly helped to promote better understanding of the in-pit tailings storage strategy. However, refinement of the animation remains a key aspect of what is an iterative and involved process.

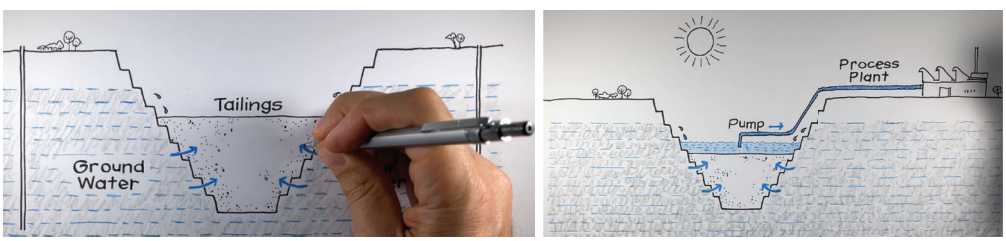

Figure 4 *Ahafo South tailings storage animation [Newmont 2025].*

References

Chilton, P.J. and Foster, S. (1995) Hydrogeological Characterisation and Water-Supply Potential of Basement Aquifers in Tropical Africa. Hydrogeology Journal, 3, 36–49.

McCullough CD, Marchand G, Unseld J, Robinson M, O'Grady B (2012) International Mine Water Association Annual Conference pg. 167–174. Pit lakes as evaporative 'terminal' sinks: an approach to best available practice mine closure.

McCullough CD, Marchand G, Unseld J, (2013)Mine Water and the Environment Vol 32, Num 4: Mine Closure of Pit Lakes as Terminal Sinks: Best Available Practice When Options are Limited?

Piteau Associates (2025). Ahafo South Mine: 2025 3D numerical groundwater model update and mine plan simulation.

Government of Ghana L.I. 2182 (2012). Minerals and Mining (Health, Safety and Technical) Regulations.