Probabilistic Seismic Hazard Assessment

Iduapriem Gold Mine, Ghana

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# Executive Summary

This executive summary provides the principal design values reported in the companion HTML document which is also available online at the following [URL](https://arm2j21.srk.ar/): https://arm2j21.srk.ar

AngloGold Ashanti Iduapriem Ltd (AAIL) retained SRK Consulting (Ghana) Ltd (SRK)(SRK) as Engineer of Record to complete a probabilistic seismic hazard assessment (PSHA) for the Greenfields Tailings Storage Facility (GTSF), located near Tarkwa, Western Region, Ghana. The project comprises underground mining operations and associated tailings management facilities, with the primary commodity being Gold. This assessment provides the technical basis for seismic design for all facilities at , consistent with international standards GISTM(2020), ANCOLD(2019) and CDA(2021). All seismic hazard metrics, ground-motion parameters, and design criteria presented in this report have been developed in direct response to project needs and industry practice.

This report documents the probabilistic seismic hazard analysis (PSHA), site-specific ground response analysis, slope displacement modeling, and seismic design criteria developed for the tailings storage facilities (TSFs) at Greenfields Tailings Storage Facility (GTSF), as commissioned by AngloGold Ashanti Iduapriem Ltd. The assessment adheres to international standards (GISTM, CDA, ANCOLD) and reflects consequence-based performance objectives across the full lifecycle of the facility.

## Seismic Hazard

Probabilistic seismic hazard analysis (PSHA) was completed using a comprehensive logic tree that integrates all relevant sources, ground‑motion models, and explicit uncertainty treatment (see Methodology). Hazard at the reference‑rock condition ( m/s) is quantified by numerical integration over all earthquake scenarios (magnitude, distance, source parameters) per the total probability theorem. Source recurrence, geometry, and maximum magnitude are fully specified, with alternatives and distributions encoded at the branch level. GMPEs are mapped to tectonic regimes/source groups, with branch weights and parameter alternatives implemented as specified. Aleatory variability follows each GMPE’s sigma with exceedance computed in the lognormal framework. For every realization (unique source–GMPE branch set), hazard curves are constructed and weighted per the logic tree. Disaggregation identifies controlling magnitude, distance, and residual parameters at each hazard level.

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| Table 1: Design Ground Motions in terms of horizontal pseudo-spectral acceleration PSA [cm/s2] for return periods ranging from 475 to 9975 [yr] and structural periods Tn ranging from 0.05 to 5 [s]. Spectral ordinates were obtained assuming rock site conditions with Vs30 = 760 [m/s]. (p=mean)   | **TR[yr]** | **poe[%]** | **0.05** | **0.1** | **0.2** | **0.5** | **1** | **2** | **5** | **ID** | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 475 | 10.0 | 65 | 78 | 59 | 24 | 9 | 3 | 1 | max | | 975 | 5.0 | 108 | 123 | 91 | 38 | 15 | 6 | 1 | max | | 1,975 | 2.5 | 171 | 189 | 135 | 57 | 24 | 9 | 2 | max | | 2,475 | 2.0 | 198 | 215 | 154 | 64 | 27 | 11 | 2 | max | | 4,975 | 1.0 | 305 | 320 | 224 | 93 | 40 | 16 | 3 | max | | 9,975 | 0.5 | 463 | 473 | 322 | 132 | 57 | 24 | 5 | max | |

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## Site Response

Dynamic site response analyses were performed for six shear‑wave velocity classes aligned with NEHRP categories (ASCE 7; NBC 2020). Site effects were incorporated via two complementary PSHA‑consistent methods: (1) an ergodic ground‑motion model (**gem**) based on Vs30‑dependent GMPEs, and (2) a site‑specific amplification model applied to reference‑rock hazard ( m/s) to capture nonlinear effects (**sdLnSaFC1**). For each site class and method, spectral accelerations and PGA were computed with full propagation of aleatory and epistemic uncertainties using Monte Carlo simulation. Site‑specific design spectra and PGA were developed for service levels with annual exceedance probabilities from 1/475 to 1/9,975, consistent with risk evaluation and consequence classification.

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| Table 2: Design Ground Motions in terms of peak ground accelerations PGA [%s] for return periods ranging from 475 to 9,975 [yr] assuming site conditions with Vs30 ranging from 200 to 1000 [m/s]. Mean values.   | **TR[yr]** | **poe[%]** | **180** | **270** | **360** | **560** | **760** | **1250** | **ID** | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 475 | 10.0 | 66 | 52 | 45 | 38 | 34 | 36 | max | | 975 | 5.0 | 103 | 81 | 71 | 60 | 54 | 57 | max | | 1,975 | 2.5 | 153 | 122 | 107 | 91 | 81 | 86 | max | | 2,475 | 2.0 | 171 | 138 | 122 | 103 | 92 | 98 | max | | 4,975 | 1.0 | 234 | 198 | 177 | 150 | 135 | 143 | max | | 9,975 | 0.5 | 307 | 275 | 251 | 216 | 194 | 207 | max | |

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## *Seismic Design Criteria*

*Seismic design criteria for tailings storage facilities were established according to the performance-based frameworks defined in GISTM (2020), CDA (2021), and ANCOLD (2019). These standards specify consequence-based design earthquake levels and performance objectives for each facility and lifecycle phase, determined by population at risk, potential loss of life, and the magnitude of environmental and socio-economic impact. For each consequence class and operational phase (construction, operation, closure, and post-closure), ground-motion criteria were identified in accordance with the applicable standard. Resulting design spectra are provided for each consequence class and service level (OBE, SEE, and PCE).*

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| Table 3: Design Ground Motions for operation, closure and post-closure, defined in terms of peak ground accelerations (PGA) [cm/s2] for diffrent consequence levels (**Class**) according to the **GISTM** standard. Spectral ordinates were obtained for AEP ranging from 1/475 to 1/9975s [1/yr] and site conditions with Vs30 ranging from 180 to 1250 [m/s].   | **Standard** | **Class** | **Stage** | **180** | **270** | **360** | **560** | **760** | **1250** | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | GISTM | Low | Closure | 66 | 52 | 45 | 38 | 34 | 36 | | GISTM | Low | Operation | 66 | 52 | 45 | 38 | 34 | 36 | | GISTM | Low | Post-Closure | 307 | 275 | 251 | 216 | 194 | 207 | | GISTM | Significant | Closure | 103 | 81 | 71 | 60 | 54 | 57 | | GISTM | Significant | Operation | 103 | 81 | 71 | 60 | 54 | 57 | | GISTM | Significant | Post-Closure | 307 | 275 | 251 | 216 | 194 | 207 | | GISTM | High | Closure | 171 | 138 | 122 | 103 | 92 | 98 | | GISTM | High | Operation | 171 | 138 | 122 | 103 | 92 | 98 | | GISTM | High | Post-Closure | 307 | 275 | 251 | 216 | 194 | 207 | | GISTM | Very High | Closure | 234 | 198 | 177 | 150 | 135 | 143 | | GISTM | Very High | Operation | 234 | 198 | 177 | 150 | 135 | 143 | | GISTM | Very High | Post-Closure | 307 | 275 | 251 | 216 | 194 | 207 | | GISTM | Extreme | Closure | 307 | 275 | 251 | 216 | 194 | 207 | | GISTM | Extreme | Operation | 307 | 275 | 251 | 216 | 194 | 207 | | GISTM | Extreme | Post-Closure | 307 | 275 | 251 | 216 | 194 | 207 | |

## *Slope Performance*

Slope performance is evaluated probabilistically by integrating site‑specific ground‑motion hazard, slope dynamic characterization, and a suite of Newmark‑type empirical and semi‑empirical displacement models. Shear stiffness, shear‑wave velocities, and fundamental periods are obtained from numerical models spanning representative geometries and material profiles for tailings and waste‑rock facilities. Permanent displacements are computed per scenario using a weighted ensemble of rigid‑ and flexible‑block Newmark models. Aleatory and epistemic uncertainties from ground motion, site amplification, and Newmark models are propagated via Monte Carlo simulation. Performance‑based seismic coefficients are established for different objectives by identifying the minimum yield acceleration that limits the probability of exceeding specified displacement thresholds.

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| Table 4: Performance-based seismic coefficients [cm/s2] for different geometry scenarios (S8 to S75) and service levels (AEP 1/475 to 1/9975). Sesmic coefficients were calibrated for residual displacements 10 [mm] and averaged through different material scenarios (U1 to U8)   | **TR** | **Da** | **p** | **S8** | **S15** | **S22** | **S30** | **S38** | **S45** | **S52** | **S60** | **S68** | **S75** | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 475 | 10 | mean | 17 | 18 | 19 | 20 | 20 | 21 | 21 | 22 | 22 | 22 | | 975 | 10 | mean | 27 | 30 | 29 | 32 | 32 | 33 | 33 | 34 | 35 | 35 | | 1,975 | 10 | mean | 43 | 46 | 46 | 46 | 47 | 49 | 53 | 51 | 52 | 54 | | 2,475 | 10 | mean | 49 | 52 | 54 | 53 | 55 | 57 | 56 | 56 | 60 | 62 | | 4,975 | 10 | mean | 73 | 74 | 76 | 75 | 77 | 79 | 82 | 83 | 82 | 86 | | 9,975 | 10 | mean | 104 | 105 | 104 | 102 | 106 | 106 | 108 | 111 | 122 | 117 | |

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