Utilisation of GNSS and UAV Technologies in the Generation of the Design Model and Construction of a Greenfield Tailings Storage Facility - Using Tokadeh TSF as a Case Study.

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Keywords: GNSS Technology, Tailings Storage Facility (TSF), Digital Terrain Model (DTM), Real-Time Kinematic (RTK), Geodetic Control Networks, Unmanned Aerial Vehicle (UAV)

SUMMARY

This conference paper explores the application of Global Navigation Satellite System (GNSS) and Unmanned Aerial Vehicle (UAV) technologies in the generation of a design model and the subsequent construction of a greenfield Tailings Storage Facility (TSF) in Tokadeh Liberia. As TSF is a critical infrastructure in mining, its design modeling and construction require the usage of high precision survey techniques from project conception to commissioning.

Global Navigation Satellite System (GNSS) plays a critical role in surveying and mapping activities due to its capability of providing precise positioning, all-weather suitability, accessibility in any part of the world. GNSS significantly improves upon traditional surveying methods by offering high accuracy, ease of operation, and increased efficiency (Jiang & Zhao, 2023)

With the aid of GNSS and UAV technology these objectives can be achieved by providing high accuracy of works.

In addition, with the use of GNSS and UAV technologies including Real-Time Kinematic (RTK) and Post-Processing Kinematic (PPK) systems, we were able to achieve centimeter-level accuracy in geospatial data collection. This data was processed into a high-resolution Digital Terrain Model (DTM), enabling accurate volumetric analyses, slope design, and the boundary of the construction area. Quality assurance protocols were embedded at every stage, ensuring consistency and accuracy through redundant measurements, baseline validations, and integration with traditional surveying techniques.

The project began by deploying both GNSS receivers and UAV systems to capture high-precision geospatial data for the TSF site – the site delineated for the construction of the dams and other facilities.

Utilizing Real-Time Kinematic (RTK) and Post-Processing Kinematic (PPK) solutions, the team was able to achieve centimeter-level accuracy in data collection.

These systems, supported by the high precision survey techniques and a number of redundant measurements provided reliable and accurate positioning even in challenging terrains. GNSS data was processed to create a detailed Digital Terrain Model (DTM), serving as the foundation for the TSF design. The DTM facilitated accurate volumetric analyses, slope design

calculations, and the delineation of drainage paths, ensuring that all design parameters met stringent regulatory and operational requirements.
During the construction phase, GNSS and UAV systems played a significant role in real-time data acquisition of all earthworks to the required design to be built, making sure all specifications are adhered to.
UAV systems were also deployed to give up to date sequences and stages of the project for monitoring and reporting purposes.
Some of the prevalent challenges with the GNSS technology were such as signal obstructions, multipath effects, and satellite geometry limitations. In certain places that are very remote and rugged terrains we found it difficult to establish reliable control networks. These issues were mitigated using a blend of methods such as combining GNSS with traditional surveying equipment like total stations or terrestrial UAV-based photogrammetry to supplement data in areas with poor GNSS signal reception and improve overall accuracy.

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1.0 INTRODUCTION

Tailings Storage Facilities (TSFs) are very key components of every mining operation works, their contributions can not be ignored in making sure mining operations are successful.
TSFs are designed to store byproducts of mineral extractions. The efficient design and construction of TSFs are important for every mining project and all operations.
This paper explores the utilization of GNSS and UAV technologies in the design modeling and construction of a greenfield TSF in Tokadeh, Liberia.
By leveraging these advanced technologies, project managers and engineers can achieve precise monitoring and management of tailings, ensuring compliance with regulatory standards while reducing certain risks associated with the traditional ways of construction approaches.
In recent years, the integration of Global Navigation Satellite System (GNSS) and Unmanned Aerial Vehicle (UAV) technology has transformed the landscape of surveying and engineering, particularly in the domain of greenfield tailings storage facilities (TSFs).
This paper examines the detail applications, methodologies and contributions on the use of these modern techniques, setting the stage for a comprehensive understanding of their significance in engineering projects like TSF and other construction works.

2.0 BACKGROUND OF GNSS AND UAV TECHNOLOGIES IN GREENFIELD TSF CONSTRUCTION

TSFs are engineered structures designed to store mine tailings, which are the by-products of mineral processing.
The design and construction of Greenfield TSF require extensive site investigations to assess the topography, geology and hydrology of the area, hence the uses of GNSS solutions and UAV technologies play a significant role in all of these.
The integration of Global Navigation Satellite System (GNSS) and Unmanned Aerial Vehicle (UAV) technologies has profoundly transformed modern engineering practices by enhancing efficiency and precision in various applications. GNSS provides real-time location data with high accuracy, which is essential for surveying and site assessments, particularly in remote areas where traditional methods may fall short.
Concurrently, UAVs facilitate aerial imagery and data collection, offering a comprehensive perspective on topography and environmental conditions without the need for extensive manpower or physical infrastructure (Lottermoser B). This combination enables engineers to undertake complex design modeling and construction tasks, such as those required for a Greenfield Tailings Storage Facility (TSF), with improved risk management and resource allocation. As these technologies continue to develop, their synergistic application promises to

streamline workflows, reduce project timelines, and ultimately contribute to more sustainable engineering practices in the industry.

GNSS, which includes systems like GPS, GLONASS, and Galileo, provides real-time positioning data with centimeter-level accuracy. In mining, GNSS is used for surveying, machine guidance, and monitoring. Its ability to deliver precise location data makes it invaluable for TSF projects.

UAVs, commonly known as drones, have become essential tools in mining for mapping, surveying, and monitoring. Equipped with high-resolution cameras and LiDAR sensors, UAVs can capture detailed topographic data and generate 3D models of the terrain. Their flexibility and efficiency make them ideal for large-scale TSF projects.

3.0 **METHODOLOGY**

In this section, we'll dive into the practical steps we took to utilize GNSS and UAV technology in the generation of design models and construction of a greenfield tailings storage facility (TSF) in Liberia. The goal was to ensure accuracy, efficiency, and safety throughout the project. To achieve this, we relied heavily on a Trimble GPS system operating in Real-Time Kinematic (RTK) mode, which provided us with centimeter-level accuracy. Let's break down the process in a way that's easy to follow and relatable.

3.1 **Tokadeh Site selection and Preliminary Survey**

Before any construction could begin, the right and suitable site for the TSF must be selected and surveyed. Purposes of compensation of cash crops and property farm lands were all considered.

Farm survey were undertaken to establish property of farmers and further compensate them, in order to use those areas for the TSF construction.

This also involved evaluating potential locations based on factors like topography, geology, and proximity to the mine. Once a suitable site was identified, we conducted our preliminary survey.

Here's where the Trimble GPS system came into play. We set up the base station at a known control point, which served as the reference for all our measurements. The rover unit, carried by our survey team, was used to collect data across the site. Operating in RTK mode, the rover communicated with the base station in real-time, correcting any errors caused by atmospheric interference or satellite signal delays. This ensured that every measurement we took was accurate to within a few centimeters.

The Trimble GPS system was incredibly user-friendly. The rover unit displayed real-time positioning data on a handheld controller, allowing the survey team to navigate the site efficiently and mark key points such as elevation benchmarks, boundary lines, and potential hazard zones. This step was critical because it laid the foundation for all subsequent work.

3.2 **Data Collection Using UAVs**

With the completion of the preliminary survey, we moved on to capturing high-resolution data of the entire site. For this, we deployed a UAV (drone) equipped with a high-resolution camera and LiDAR sensor. The drone flew over the site in a pre-programmed grid pattern, with all parameters checked, capturing thousands of overlapping images and survey points.

Before launching the drone, we used the Trimble GPS to establish ground control points (GCPs) across the site. These GCPs were marked with highly visible targets and their exact coordinates were recorded using the RTK-enabled rover. These points were evenly distributed across the site area and later served as reference markers during data processing, ensuring that the aerial data was accurately georeferenced.

The drone's flight planning software allowed us to set parameters like altitude, overlap, and speed, ensuring optimal coverage of the site. After the flight, we processed the collected data using photogrammetry software, which stitched the images together to create a digital elevation model (DEM) and an orthomosaic map. These outputs provided a detailed, 3D representation of the terrain, which was essential for designing the TSF and all other planning purposes.

3.3 **Design Model Generation**

With the survey data and aerial imagery in hand, we moved to the design phase. Using engineering software like AutoCAD Civil 3D or ArcGIS, we imported the DEM and orthomosaic to create a 3D model of the TSF. The model included critical elements such as embankment geometry, spillway locations, and drainage systems, link roads and access roads.

The Trimble GPS data played a crucial role here. Because the survey points were so accurate, we could trust the model to reflect the actual site conditions. This level of precision was especially important when calculating volumes for earthworks or determining the optimal placement of structures. For example, we used the model to simulate different scenarios, such as how the TSF would behave under heavy rainfall or how much material would be needed to construct the embankments.

3.4 **Construction Planning and Monitoring**

Once the design was finalized, we moved to the construction phase. This is where the Trimble GPS system truly shined. We used it to guide heavy machinery like bulldozers and excavators, ensuring that they placed materials exactly where they were needed. The RTK mode allowed operators to see their position in real-time on a screen, making it easy to follow the design specifications.

For example, when building the embankments, the GPS-guided machinery ensured that the slopes were constructed at the correct angles and elevations. This not only saved time but also reduced the risk of errors that could compromise the stability of the TSF.

Throughout the construction process, we also used the UAV to monitor progress. Every few weeks, we flew the drone over the site to capture updated imagery. This allowed us to compare the actual construction with the design model and identify any discrepancies. If we noticed issues like slope instability or improper drainage alignment, we could address them immediately, preventing costly delays or any safety concern.

3.5 **Post-Construction Monitoring**

After the TSF was constructed, our work wasn't over. Tailings storage facilities require ongoing monitoring to ensure their long-term stability and safety. Again, the Trimble GPS and UAV proved invaluable.

We conducted regular surveys using the GPS to measure settlement and deformation of the embankments. The GPS ensured that we could detect even minor changes in elevation, which could indicate potential problems. Meanwhile, the UAV was used to capture aerial imagery and LiDAR data, allowing us to monitor vegetation growth, erosion, and other environmental factors.

This combination of technologies gave us a comprehensive understanding of the TSF's condition and allowed us to take proactive measures to maintain its integrity.

4.0 **CONCLUSION**

The integration of GNSS and UAV technologies made this project a success. Here are some key take away points:

Accuracy: The Trimble GPS with RTK provided centimeter-level precision, which was critical for both surveying and construction.
Efficiency: The UAV allowed us to collect vast amounts of data in a fraction of the time it would have taken with traditional methods and also very minimal labour.
Safety: By using drones for aerial surveys and GPS-guided machinery for construction, we minimized the need for personnel to work in hazardous areas.
Real-Time Feedback: The ability to monitor progress in real-time ensured that we stayed on track and could quickly address any issues.
By combining the precision of Trimble GPS with the versatility of UAV technology, we were able to streamline the entire process—from site selection to post-construction monitoring. This approach not only improved the quality of the TSF but also demonstrated how modern technology can transform traditional mining practices. Whether you're a seasoned engineer or new to the field, these tools can make your projects more efficient, accurate and safe.
The use of GNSS and UAV technologies in greenfield TSF projects have already proven to be a game-changer, offering unparalleled accuracy, efficiency, and safety. By implementing the recommendations outlined above, the mining industry can further optimize the use of these technologies and set new standards for tailings management. As the industry continues to evolve, embracing innovation and collaboration will be key to addressing the challenges of tomorrow and ensuring the sustainable development of mining operations worldwide.

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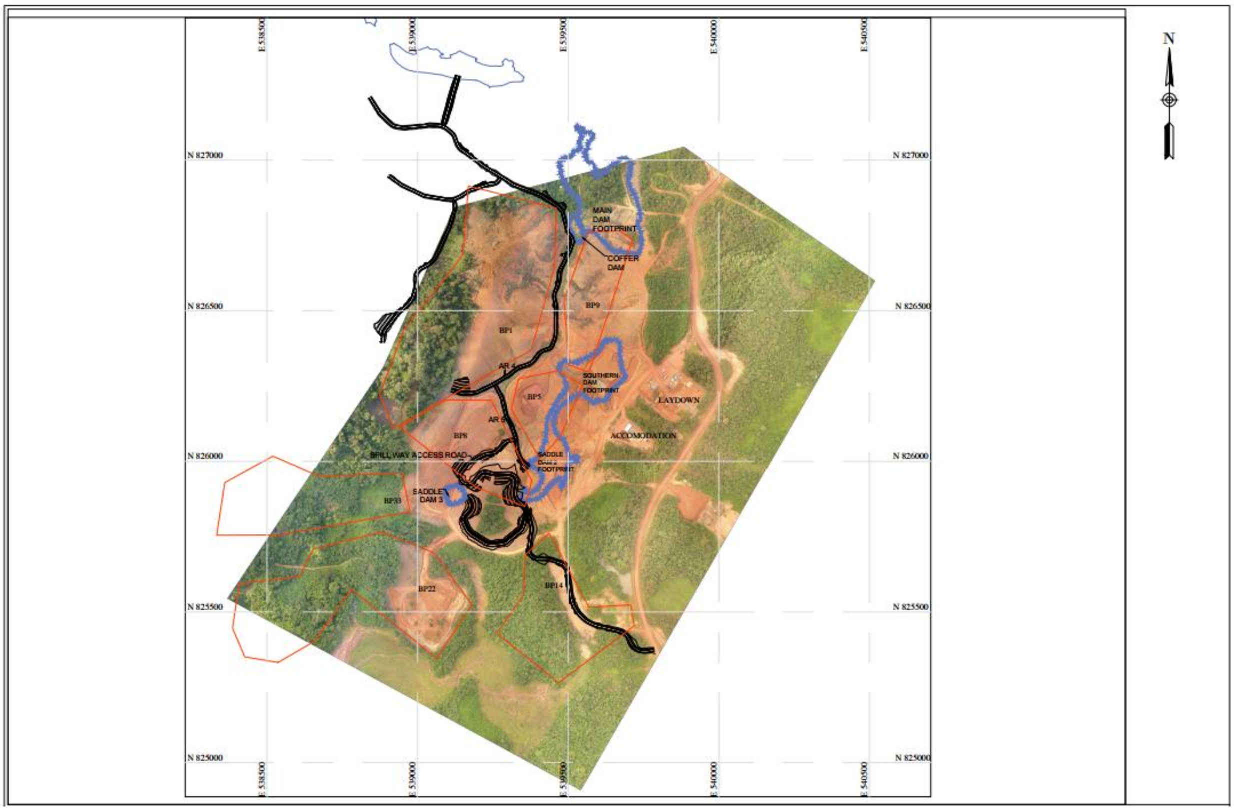
APPENDIX

TIFF showing UAV survey of TSF.



Progress map of the TSF showing dams and borrow pits designs.

Contours from GNSS survey overlay on tiff.

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