Dynamic grade control modelling processes at the Waihi Underground Gold Mine

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ABSTRACT

With traditional grade control processes, geological models are created by geologists at the completion of the data collection stage and wireframe construction is closed off at a set date to allow for time to complete the estimation process. Any issues identified at earlier stages or the addition of new data requires the estimation process to be started again. Alternative interpretations are explored only if time allows and often in a limited fashion. An alternative workflow has been developed at the Waihi Underground Gold Mine utilising Leapfrog Edge and Seequent Central. Geological and grade control models are created, dynamically linked, and saved as separate branches. A project geologist is able to work on the grade control model and a mine geologist on the geological model simultaneously. This allows for a non-linear modelling workflow with continual review and feedback. The introduction of new data can occur right up to the model due date, with data collection, validation, alternate interpretation, and review happening incrementally. Models are categorised and stored in Seequent Central according to project status. An approved version of the geological model and grade control estimate are uploaded at the time of release and transparently capture all data used at a point in time, as well as the review process. Dynamically updating models for grade control has reduced turnaround time while increasing accuracy and quality. Estimates of individual domains are vastly improved from being able to rapidly evaluate the effects of model parameter changes in real time and 3D. Development and stope design directly benefit from these streamlined processes, with higher quality, timely production occurring as a result.

INTRODUCTION

Geological modelling and estimation at the Waihi Underground Gold Mine had previously followed industry standard practices with a linear workflow. This began with data collection from diamond drill holes, face chip samples, and geological mapping, followed by geological modelling of lithological, structural and ore contacts and surfaces. Finally, a series of data validation steps and exploratory data analysis were conducted to produce a grade control estimate in the form of a block model. This workflow creates a rigid structure that in most cases requires one step to be completed prior to the next one being started.

The Seequent software suite has been used to develop a new grade control workflow that allows work to be completed at any point along the process, independent of the final outcome. For example, often the final channel data is received, and the geological model wireframe updated only moments before the final model is run. The model typically takes less than half a day to run, during which time the final validation checks and model documentation can be completed.

Leapfrog Geo is used to create geological models, Leapfrog Edge is used for grade control estimation, and Seequent Central is a cloud-based application for the storage and dynamic linking of models created with the Leapfrog applications.

GEOLOGICAL SETTING

The Hauraki Goldfield comprises approximately fifty epithermal deposits (Braithwaite and McKay, 1989) and lies within a NNE-trending Miocene to Pliocene calc-alkaline arc (the Coromandel Volcanic Zone). Gold mineralisation is localised within moderately- to steeply-dipping quartz veining, breccias and vein stock working.

HISTORY OF MINING IN WAIHI

Gold was first discovered near Coromandel township in 1852 but economic gold was not discovered in the Waihi area until 1878. Mining operations were transferred to the Waihi Gold Mining Co. in 1890 and mining activity continued until the close of the mine in 1952. During this time, ~5.5 Moz Au and 38.4 Moz Ag (McAra, 1988) were extracted (~174 t Au and 1193 t Ag). Operations recommenced in 1988 with the opening of the Martha open pit mine. Underground operations at Favona began in early 2005 and several additional orebodies have since been identified and mined. More than 3.2 Moz Au have been extracted by the combined open pit and underground operations since mining recommenced in 1988.

GRADE CONTROL WORKFLOW

Geological modelling in Leapfrog Geo

Importing data

The inputs required for geological model wireframes and grade control model estimations are diamond drill hole data and underground ore control channel data. These exist in separate acQuire databases. The data is exported from the two acQuire databases and combined in an Access database, which Leapfrog then connects to via an ODBC link.

Interval selection

Grade control modelling is done solely in Leapfrog geological software using face channels, drill hole data and polylines. Correctly registering the 3D.obj files is paramount to this process working correctly as the photo scans, which replace traditional paper face sketches, become one of the focal points in which decisions influencing the model are made (Whaanga, Vigor-Brown and Nowland, 2019). The face mapping process has evolved further at Waihi, where ore control geologists now sketch polylines of features such as footwall and hanging wall contacts and minor veins onto photos at the face (Figure 1). Textures and rock types are represented with points digitised onto photos into a texture or lithology layer. This data is imported into Leapfrog Geo to aid the project geologist in modelling the orebody.

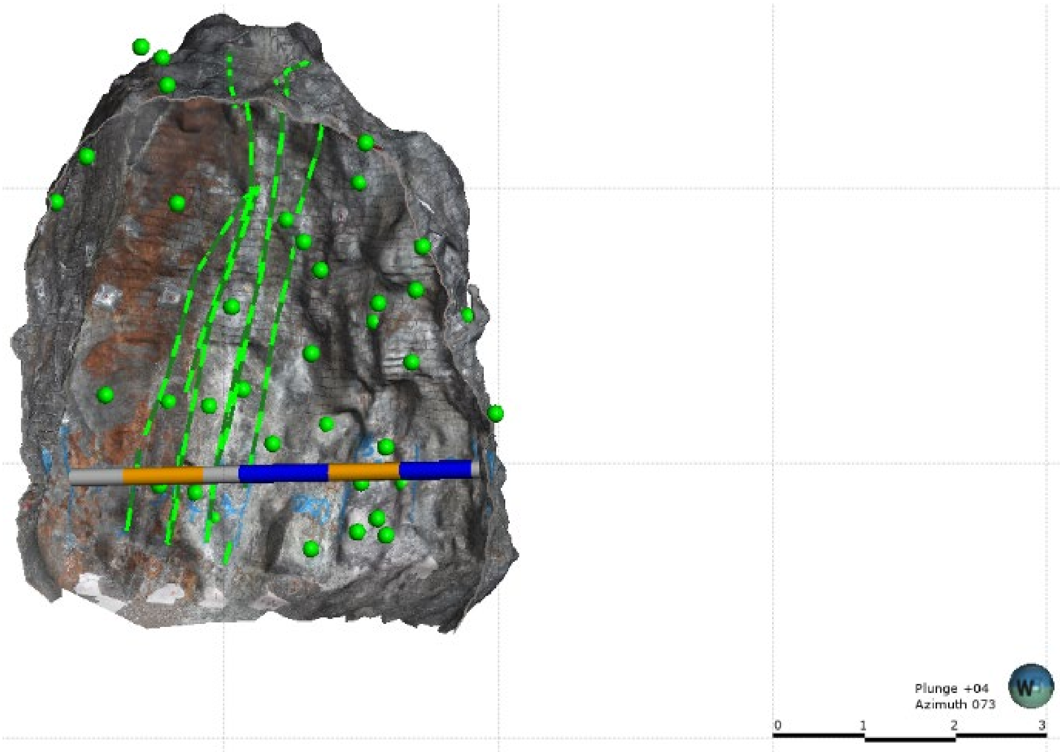


FIG 1 – Polylines digitised underground at the face define the footwall and hanging wall contacts. Points representing rock types and textures are digitised into lithology or texture layers.

The footwall and hanging wall contacts are digitised directly into Leapfrog on the face, back and wall of the scan. Combined with the channel data these give highly accurate polylines defining the geological contacts used to create and update the wireframes (Figure 2).

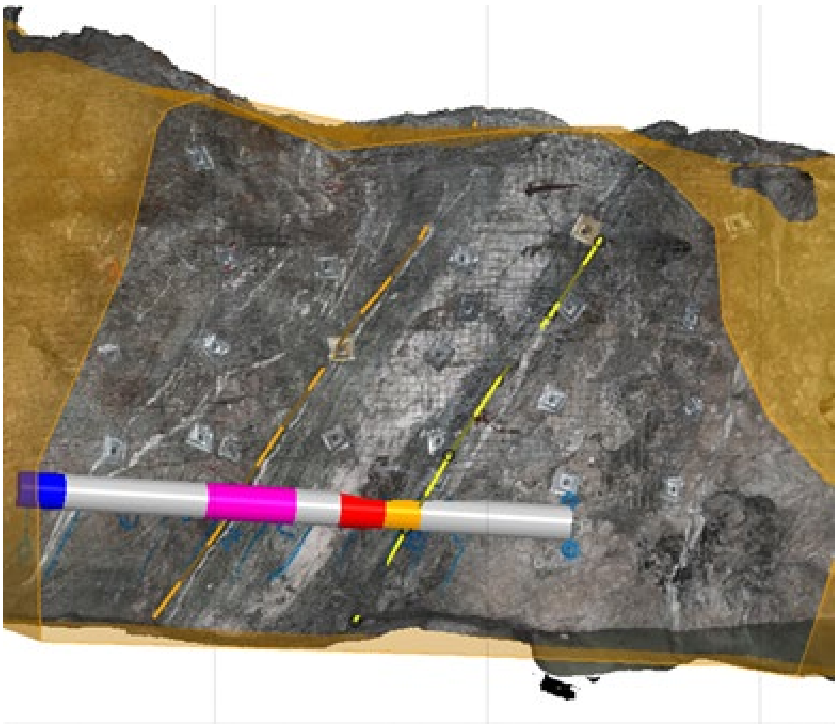


FIG 2 – A 3D scan and level asbuilt file (orange mesh), overlain by the horizontal channel data, and footwall and hanging wall polylines (dashed) of a vein structure (Whaanga, Vigor-Brown and Nowland, 2019).

Using the interval section tool, channel data can be selected using Au values, lithology, or any other field to assign that portion of the channel into the correct domain (Figure 3). Validation of the data can be done quickly in section view by comparing the selected intervals with the channel data, footwall and hanging wall polylines, scan and level asbuilt to ensure the correct spatial location of scans, channel polylines and drill holes (Whaanga, Vigor-Brown and Nowland, 2019).

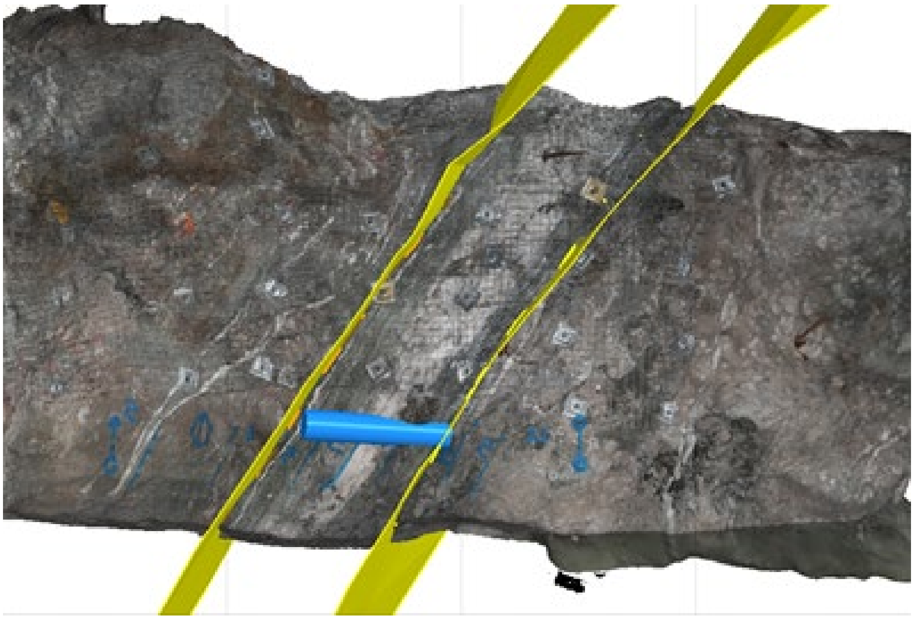


FIG 3 – The same image as Figure 2 after the interval selection tool has assigned the channel interval to the correct domain. The wireframe has been refined using interval selection along channel and footwall and hanging wall polylines (Whaanga, Vigor-Brown and Nowland, 2019).

Resource and production geological models

The Martha Underground project currently has more than 90 domains. Drilled portions of some domains with higher confidence are actively being mined, whilst at the same time other parts of these domains are still being drilled and the model updated by the resource development department. The project requires a resource development geological model as well as an underground production geological model. Although the two models use the same diamond drill hole data set and historic data, there are some differences to their inputs and use:

- The **resource geological model** data exists in a single acQuire database. Wireframes and large-scale resource and reserve estimates generated from the data are currently completed in Vulcan and used for medium to long-term mine planning.
- The **production geological model** uses the same diamond drill hole data as the resource model but has the addition of underground channel data and footwall and hanging wall polylines obtained from 3D scans. The production model requires a high spatial accuracy for short-term mine planning and design of ore drives and stopes.

The models constantly diverge as each one is continuously updated with the addition of new data. However, additional functionality in Leapfrog Geo and Seequent Central means that data can be imported and added, and in some cases linked, so that the models update dynamically from one another.

Interval selections from model to model

Both the resource development and production teams model data that needs to be added to the other model. Interval selections of drill holes are one of the main examples of this. Resource and reserve drill hole interval selections need to be added to the production model, and grade control drill hole interval selections need to be added to the resource model.

Interval selections are exported from one model and imported into the other in a csv format, with hole ID, from, to, and interval selection fields copied into an interval selection merge table. The interval selections can then be displayed for single domains, selected *en masse* and assigned to the correct domain. The wireframe will update automatically using the new data.

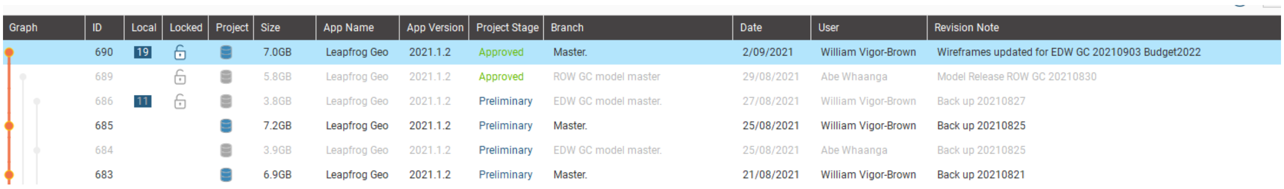
Polylines from model to model

The resource model does not incorporate the underground ore control channel data for wireframing or estimation, and therefore cannot use those selections for spatial location. Instead, the footwall and hanging wall polylines created in the production model are linked to the resource model via Seequent Central. When polylines are updated in the production model and the model is uploaded to Seequent Central, the polylines simply need to be reloaded into the resource model. The resource model wireframes then dynamically update using the new data.

Model linking using Seequent Central

Uploading models

Resource and production models are uploaded and stored in Seequent Central (Figure 4). Using this data storage application, models can be shared between different team members and multidisciplinary teams from anywhere with an internet connection, making the models accessible and collaborative. Models can be uploaded at any stage of progress, from preliminary models where modelling requires peer review, to final versions that are peer reviewed, validated and approved for estimation, mine planning and design. Seequent Central is cloud-hosted so teams have instant access to projects and access permissions can be managed.



Graph	ID	Local	Locked	Project	Size	App Name	App Version	Project Stage	Branch	Date	User	Revision Note
	690	19			7.0GB	Leapfrog Geo	2021.1.2	Approved	Master.	2/09/2021	William Vigor-Brown	Wireframes updated for EDW GC 20210903 Budget2022
	689				5.8GB	Leapfrog Geo	2021.1.2	Approved	ROW GC model master	29/08/2021	Abe Whaanga	Model Release ROW GC 20210830
	686	11			3.8GB	Leapfrog Geo	2021.1.2	Preliminary	EDW GC model master.	27/08/2021	William Vigor-Brown	Back up 20210827
	685				7.2GB	Leapfrog Geo	2021.1.2	Preliminary	Master.	25/08/2021	William Vigor-Brown	Back up 20210825
	684				3.9GB	Leapfrog Geo	2021.1.2	Preliminary	EDW GC model master.	25/08/2021	Abe Whaanga	Back up 20210825
	683				6.9GB	Leapfrog Geo	2021.1.2	Preliminary	Master.	21/08/2021	William Vigor-Brown	Back up 20210821

FIG 4 – The central user interface in Seequent Central showing the project history, including project stage, date of upload, user that uploaded and revision notes.

Version control

Previously to maintain reliability, geologists worked solo on a model, finalising, checking, and having work reviewed once the model was complete. Seequent Central's model branching functions and clear timestamps have eliminated the need to manually track model versions, meaning teams can also work concurrently with confidence that each model is reliable with the version status captured at upload.

Engineers utilise Deswik CAD software for resource evaluation, short- and long-term mine planning. Models valid for mine design are captured in a 'block model extents' layer. Attributed triangulations cover zones of domains and attributed fields include 'valid model', a step implemented to ensure valid models are used for mine design (Figure 5).

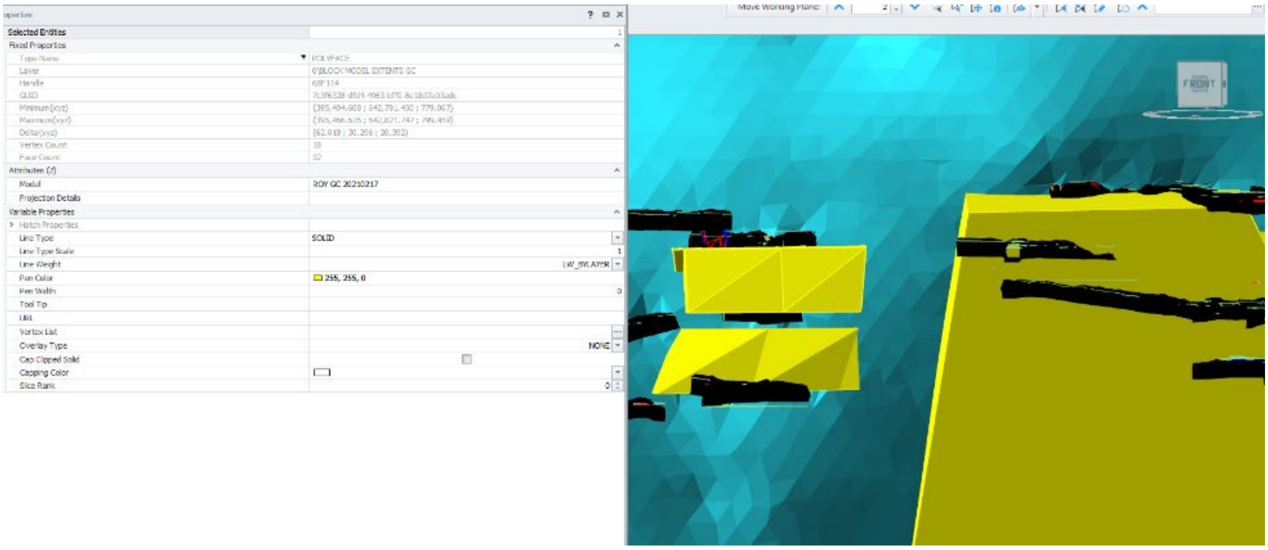


FIG 5 – Deswik block model extents layer with model attributes displayed.

Prior to the introduction of the Seequent software suite, the grade control workflow used multiple software packages for unique parts of the modelling and estimation process. Data relating to a model existed on a file server. Geologists were required keep track of model versions and currency to maintain reliability. Now the data exported and stored on files servers is limited to output wireframes and block models to the engineers, with everything else stored in Seequent Central.

Periodic backups of models mean previous versions are accessible if there is a need to re-visit or check for errors or other issues. The backup can be downloaded to a local computer drive and deleted once the review is complete.

Model relationships

The Martha Underground Mine can be grouped into several principal areas, each with distinct geological characteristics. Grade control models are created for these mine areas and dynamic links are established to the master model. Seequent Central's model branching functions separate each model and show their relationship to master model (Figure 6). Kriging neighbourhood analysis (KNA) is completed for each model and saved as a separate model branch.

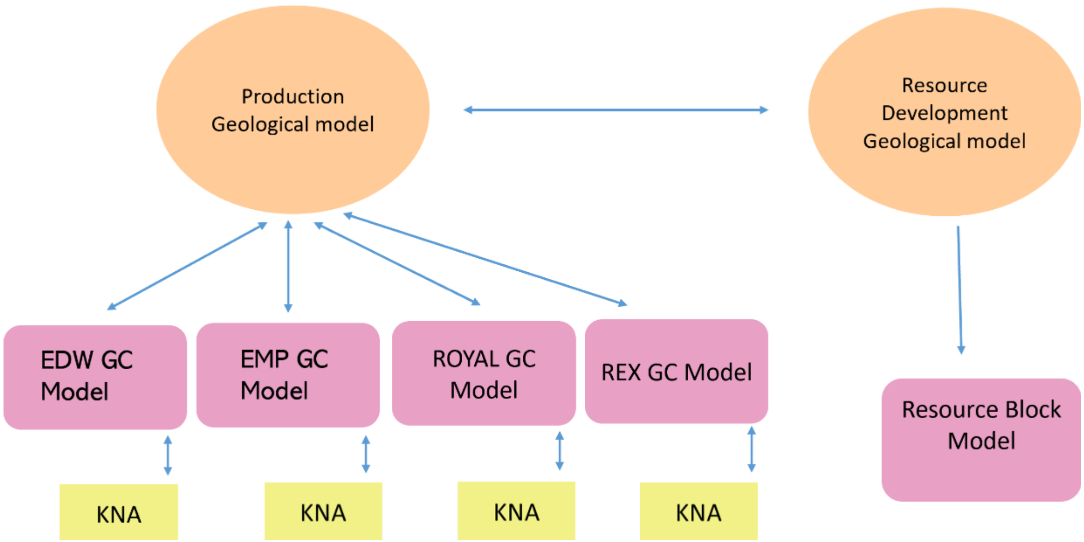


FIG 6 – The dynamically linked relationships between the Leapfrog Geo geological model and Leapfrog Edge grade control and sensitivity models.

Grade estimation in Leapfrog Edge

Dynamic model updating

Leapfrog Edge has a similar workflow structure to Leapfrog Geo. Each step in the estimation process is dynamically linked, from initial composite data built from assays within a wireframe domain, through to block model calculations that create combinations of first and second passes and resource classifications.

Exploratory data analysis is conducted on partially completed wireframe domains stored in the master model branch, utilising all the current available validated assay data. Once the model is set-up, all the steps stay dynamically linked and each step has a final check once the last validated data is uploaded. When a change is made at any step in the process all subsequent steps automatically update, effectively create a new model each time.

The non-linear modelling workflow means that multiple users can be working on different part of the process simultaneously. For example, one geologist can be updating the geological wireframes whilst another geologist is working in the grade control model. Once the geological model is uploaded the grade control model just needs to reload the linked data which results in a dynamic update of the grade control model.

Ability to have multiple iterations of a block model and domained estimators within a project enables dynamic, fast sensitivity analysis and block model optimisation. Parent and sub-blocking sizes can be changed between models and compared. Multiple estimators for a single domain can test parameters around sample numbers and search ranges. Results are compared and scrutinised, the result is a final model of a higher quality than that produced through the previous linear workflow. The ability to test multiple model scenarios at a faster pace means that issues can be addressed immediately, and management can be given advanced warning about grade control risk and losses. Seequent Central's model branching functions are used to separate and timestamp sensitivity projects. Sensitivity models maintain the dynamic links established from the grade control model and are accessible to be reviewed, dynamically updated, and collaborated on.

Ability to run models with relative ease prior to return of final assay data enables a process where engineers are provided with interim models. Using interim models, the engineers at OceanaGold are also able to create different scheduling and planning scenarios. With the final release engineers validate the earlier part of the design and complete the final part (Figure 7). This decreases the time to produce stope designs and increases productivity.

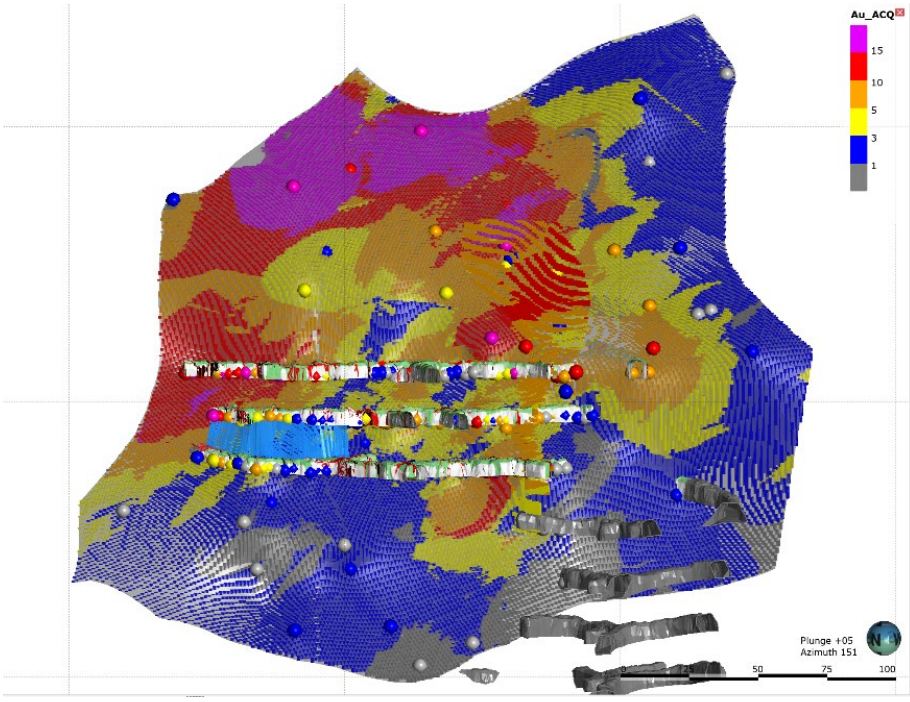


FIG 7 – Long section of estimated domain with full width composites, development drives and stope design shape in Leapfrog Edge.

Unlike the traditional linear workflow where the return of the final data marked the start of the modelling process, the dynamic workflow turnaround time of models is dictated by return of final assay data. When this data is received, the wireframes, domain stats and exploratory data analysis are already complete. The final assay data is added to the drill hole database and reloading dynamically updates the grade estimate. Validated models can be released only hours after the final data is received.

DISCUSSION

Introduction of the Seequent software suite that integrates 3D photogrammetric imagery data has resulted in a multisystem workflow to create a dynamic grade control modelling process. Geological and grade control models are now dynamically linked, and Seequent Central's model branching functions allows for multiple relationships to the master model.

Workflow structures within the software have helped to move away from the traditional linear workflow. The non-linear grade control modelling process has advantages to team efficiency and the broader business. The software has provided a way in which multiple team members can work concurrently on models. Model review is no longer confined to the end of the process but can now occur easily throughout the process, resulting in a higher level of collaboration and an improved result.

Version control is more manageable with cloud-based Seequent Central. The application's model branching function and central upload function timestamps and backs up models, mitigating the risk of lost data.

The dynamic process and the ability to provide interim models has had direct benefits to development and stope design. Rapid evaluation of model parameters has resulted in improved estimates of individual domains. Sensitivity analysis is now dynamic and can be undertaken quickly, resulting in a higher quality estimate.

Final approved versions of block models can now be run as soon as the final data is returned. This faster turnaround time means that an approved final block model can be released hours after the point of final data return.

FURTHER WORK

Currently mapping is imported from Deswik.Mapping™ as a picture file and registered on to survey asbuilts. Improved integration would allow the import of major vein contacts into a Leapfrog project as polylines with vein attributes.

A future step in making the workflow even more dynamic will be to improve functionality around multiple drill hole database connections, enabling the user to select fields from tables across the connected data sets to be combined in merge tables, thus allowing all data to be available for interval selection.

CONCLUSIONS

Geological modelling and estimation at the Waihi Underground Gold Mine has evolved from a linear workflow to a non-linear workflow. This is a result of the of introduction of the Seequent software suite that integrates 3D photogrammetric imagery data. Data acquisition for modelling still mainly adheres to traditional drill hole and underground sample data with addition of 3D scan data. Leapfrog Geo and Edge with the linking capabilities of central provide the tools and functionality to dynamically model and estimate orebodies. This has led to increased efficiency within the geology team and wider operation. The workflow is now an integral part the day-to-day operation at the Waihi Underground Mine.

ACKNOWLEDGEMENTS

The authors would like to thank Dr Angela Storkey for proof reading. The authors acknowledge OceanaGold for granting their approval to publish this work.

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