# Design and Commissioning of the 378 Sand Fill Plant at Thompson Mine

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**Abstract**
Vale Base Metals' Manitoba Operations currently use hydraulic backfill, comprised of classified mill tailings, to fill underground stopes at their T1 and T3 mines. A new sandfill plant was built to service the planned future mining of the T3 mine. Due to the distance of the T1 sand plant from the future T3 mining horizons, studies showed that a new backfill plant was better suited to service the T3 stopes. Based on material availability, mill tailings dewatering capabilities, location of backfilling, and costs, a hydraulic backfill plant was selected as the preferred method of backfill. This plant is designed to use a combination of alluvial sand and classified tailings for backfill.

This paper provides a case study with regards to the recipe selection, plant design/selection, and commissioning of a new hydraulic backfill plant at Vale Base Metals' Manitoba Operations. The laboratory testing, design, and commissioning experience will be presented, along with the key design parameters of the new plant.

Key words: hydraulic fill, backfill, sand fill, test work, commissioning, Thompson Mine

## Introduction
Vale Base Metals' Manitoba Operations includes two active mines, T1 and T3, within the city of Thompson, Manitoba. The underground mines use vertical block mining (VBM) and cut and fill mining to extract nickel, copper and other precious metals. Current mining horizons extend to a depth of ~ 1509 m (4,950 ft) and ~ 1585 m (5,200 ft) at T1 and T3, respectively (Figure 1). The primary backfilling method is hydraulic fill (HF).

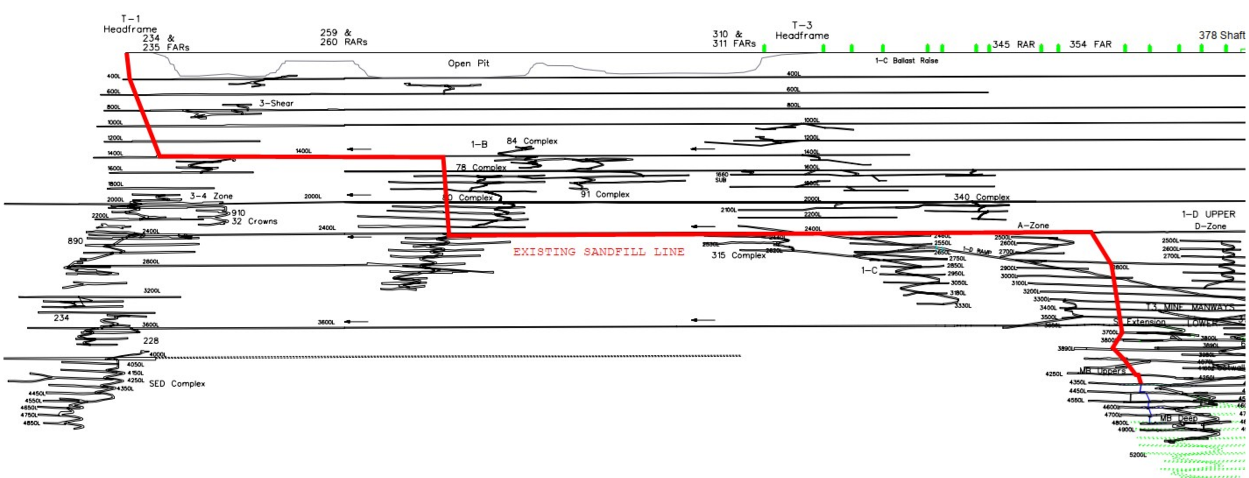


Figure 1. Thompson Mine Longitudinal for T1 & T3 Mines.

The existing backfill system located near the T1 headframe uses classified tailings from the Thompson mill, and a 1:1 blend of fly ash and Type 10 Portland cement as the selected binder type. The binder content of the fill varies according to the strength requirements of the plug and stope body. Stopes that do not border future mining areas are filled with development rock either entirely or above stope plugs. In such cases, development or other waste rock, is dumped directly into open stopes from the top sill horizons.

As the T3 mine expands to greater depths, the ability to deliver HF from the T1 plant will become challenging using the existing gravity fed system. Due to this limitation, a study was initiated to investigate the most efficient way of backfilling the current and future mine workings while informing the design of a new backfill plant.

**Study Overview**

Initially, the project team conducted pastefill studies; however, the capital expenditure for pastefill was deemed excessive, and a less complex, fit-for-purpose backfill plant was desired by Vale. Paterson & Cooke joined the project team after the initial pastefill studies to investigate backfill alternatives and complete test work to support decision-making at the conceptual stage of the project. The team explored various concepts for HF plants, including assessment of the Underground Distribution System (UDS) for delivery of HF. Test work was completed to assess materials (alluvial sand, tailings, blends) and binders that could be used for the HF plant.

**Key Considerations**

Several key items required consideration when generating the design concepts:

1) **Plant Capacity** Ensure alignment with backfill demand, considering low mill utilization (~32%) and alternate materials that decouple the backfill plant and mill.
2) **Backfill Material Availability** Confirm plant will receive sufficient materials on demand to meet the mass balance requirements for backfilling.
3) **Material Storage** Shelter the stockpiled materials (i.e. alluvial sand or filtered tailings) from the harsh environmental conditions in Thompson.
4) **Reliability** Maintain reliable backfilling operations over the proposed life-of-mine (LOM).
5) **Backfill Quality** Produce consistent, high quality backfill with the proposed blend, necessary for the safety of underground (UG) operations and to ensure efficient mining (minimal dilution).
6) **Backfill Recip**e Meet Vale Base Metals' strength requirements within the required cure days.
7) **Constructability/Operability/Maintainability** All three aspects were considered for any mill upgrades or tie-ins to existing infrastructure, minimizing interruption to existing operations.
8) **Social Impact** The social impact of trucking alluvial sand through the City of Thompson required consideration and was to be mitigated as much as practical through use of alternative routes.
9) **Costs** The optimal concept was expected to balance the requirements above while minimizing annual operating costs.

**Concepts Considered**

Six concepts were developed and considered to evaluate materials and associated blends for the HF plant at Thompson, given site layout (Figure 1). Each proposed concept explored unique solutions in consideration of material properties and mass balances, with some concepts discarded early in the development stages due to lack of material availability and/or process complexity. Reflecting on the key considerations noted, the project team generated the following concepts: Figure 2 provides an overview of the mine for relation to the concepts.

- Concept 1: Alluvial sand only
- Concept 2: Classified tailings only
- Concept 3: Classified and whole tailings (50/50 blend)
- Concept 4a: Alluvial sand and whole tailings (50/50 blend – existing plant)
- Concept 4b: Alluvial sand and whole tailings (50/50 blend – 378 shaft)
- Concept 5a: Alluvial sand and classified tailings (50/50 blend – existing plant)

- Concept 5b: Alluvial sand and classified tailings (50/50 blend – 378 shaft)
- Concept 6: Alluvial sand and filtered classified tailings (50/50 blend)


Figure 2. Overview of Thompson Mine current mining locations.

All concepts considered the use of alluvial sand purchased from a third-party source. Given that alluvial sand is not an engineered product as with whole or classified tailings, a drilling campaign was completed to map the particle size distribution (PSD) variation throughout the cross-sectional area of the sand pit at varying depths. These data were used to identify the operational limits that the system would need to handle, and to define an average sample distribution for the project. Figure 3 shows the coarse and fine limits from the drilling campaign plotted with the alluvial sand bulk samples used throughout the project.

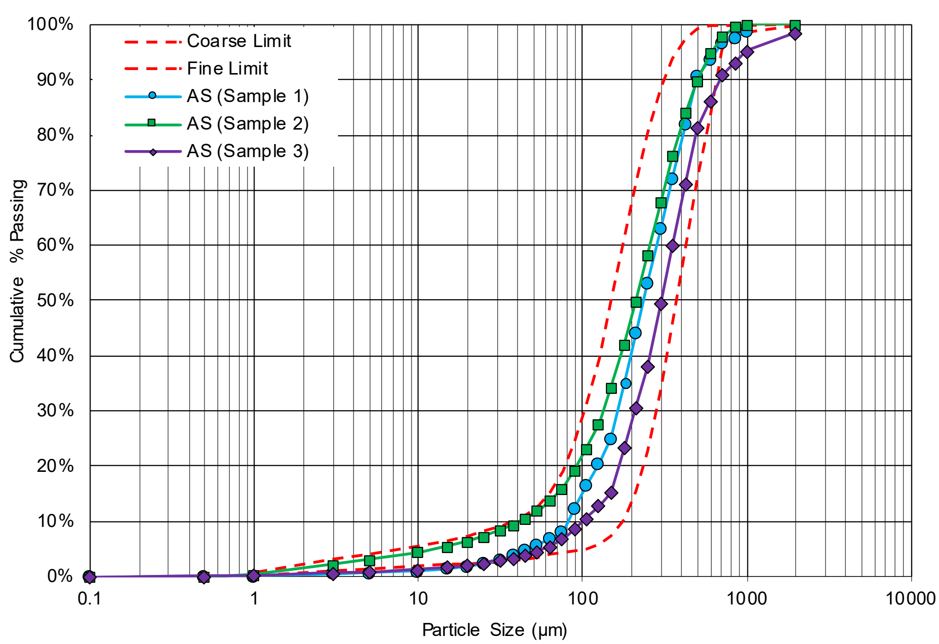


Figure 3. Particle size distribution testing for pit-mapping purposes.

When developing the concepts, PSD benchmarking values were first used to assess whether the material would behave as a settling slurry. Initial consideration of blending ratios between the alluvial sand, whole tailings, and classified tailings meant theoretical PSDs were calculated to ensure that the blended materials were coarse enough to ensure turbulent flow operation (benchmarking of 10% < 10µm, and 20% < 20 µm).

Once potential blends were confirmed to achieve the benchmark values, the next phase of test work involved refining the hydraulic fill recipe solids concentration (% m) and assessing the permeability properties of the blended materials. Hydraulic filling methods rely heavily on bleed water (drainage) and hydraulic conductivity characteristics of the material to provide efficient stope cycle times and strength development for the fill. The bleed water rate from the stope must be controlled such that it does not hinder the mining cycle, but is not so fast that the cement is washed through the fill completely. The industry rule of thumb for desirable bleed water concentrations is 20–30% cumulative bleed after 24 hrs, and a hydraulic conductivity rate in the magnitude of $10^{-2}$–$10^{-4}$ cm/s. Bleed water and hydraulic conductivity testing were completed using the falling head method. The current permeability rate onsite is ~ $9\times10^{-4}$ cm/s. From the tables below, each of the recipes fell within an acceptable range of the benchmark values and were comparable to the current onsite operation. Each of the blends was considered suitable for use in the backfill recipe.

Tables 1 and 2 provide a summary of the result. The concepts discussed above have been flagged for reader information.

Table 1. Bleed water testing for considered recipes.

| **Sample Name** | **Cumulative Bleed Water Removed (%m of Water)** | | | |
|---|---|---|---|---|
| | **8 Hours** | **24 Hours** | **48 Hours** | **72 Hours** |
| 75%m - Alluvial Sand (C1) | 24.0% | 34.8% | 38.8% | 40.4% |
| 65%m - Alluvial Sand (C1) | 26.1% | 32.5% | 34.3% | 34.6% |
| 70%m - 1:1 Alluvial Sand to Whole Tailings Blend (C4) | 24.0% | 28.7% | 31.4% | 32.6% |
| 60%m - 1:1 Alluvial Sand to Whole Tailings Blend (C4) | 18.4% | 22.2% | 27.1% | 28.6% |
| 70%m – 1:1 Alluvial Sand to Classified Tailings (C5) | 40.3% | 41.3% | 42.3% | 42.6% |
| 65%m – 1:1 Alluvial Sand to Classified Tailings (C5) | 49.5% | 52.1% | 53.2% | 53.4% |
| 60%m – 1:1 Alluvial Sand to Classified Tailings (C5) | 59.5% | 61.0% | 61.6% | 61.9% |
| 55%m – 1:1 Alluvial Sand to Classified Tailings (C5) | 65.2% | 67.5% | 67.9% | 68.1% |

Table 2. Hydraulic conductivity (Falling Head Method) for considered recipes.

| **Material** | **Hydraulic Conductivity (cm/s)** |
|---|---|
| Alluvial Sand (C1) | $2.13 \times 10^{-2}$ |
| 1:1 Alluvial Sand to Whole Tailings Blend (C4) | $4.28 \times 10^{-3}$ |
| 1:1 Alluvial Sand to Classified Tailings (C5) | $9.63 \times 10^{-4}$ |

**Concepts Discarded**

Concepts 2, 3, 4b, and 5a/b were discarded early in the study. Table 3 summarizes the discarded concepts and rationale.

Table 3. Discarded concepts.

| Concept | Reasoning to Discard |
|---|---|
| Concept 2: Classified Tailings Only | Insufficient instantaneous and annual classified tailings available from mill. |
| Concept 3: Classified and Whole Tailings (50/50 Blend) | Marginal ability to produce the required quantities of classified and whole tailings; significant risk that insufficient quantity of tailings would be produced. |
| Concept 4b: Alluvial Sand and Whole Tailings (50/50 Blend – 378 Shaft) | Discarded based on practicality, as this option required a 5 km tailings pipeline from the mill to 378 shaft. Although not fatally flawed, this added significant operational complexity given the northern climate. Concept 4a offered the same blend with less complexity. |
| Concepts 5a and 5b: Alluvial Sand and Classified Tailings (50/50 Blend – Existing Plant/378 Shaft) | These concepts were similar to 4a/4b but used classified tailings in the blend rather than whole tailings. Based on the 14 day unconfined compressive strength (UCS) results, higher strengths (with the same binder content) were achieved with the blend containing whole tailings rather than classified tailings. |

**Concepts Carried Forward**

Concepts 1, 4a, and 6 were carried forward for further development. For each concept, process flow diagrams, refined mass balances, and Capital Expenditure (CAPEX)/Operating Expenditures (OPEX) (± 30%) were developed to a pre-feasibility level.

A suite of UCS testing was completed using cylinder load rates according to ASTM D2166 to quantify the binder consumption required for each of the concepts to achieve the mines' strength targets. The targets were 135 kPa for an early plug cure strength and 275 kPa for a 28 day body pour. Various binder types were investigated to determine the most economical binder of those commercially available to the region.

*Concept 1: alluvial sand*

Concept 1 focused on the use of 100% alluvial sand, simplifying and decoupling the milling and backfilling operations. The HF plant was located at the 378 Shaft, nearer the expanded UG mine workings. Decoupling the mill and backfilling operations allowed for adjustment of the plant utilization and throughput to suit operations' needs. For the purposes of the prefeasibility study, Vale Base Metals elected to set the plant throughput at 200 short t per hour (st/h), which would require the plant to operate at ~ 26% utilization to meet the UG demands.

For this concept, alluvial sand would be excavated, screened, and delivered to the HF plant at 378 shaft from a location nearby the Thompson airport by a local trucking company on a contract basis. In parallel, the site team conducted a drilling investigation of the sand pit to confirm adequate quantities were available for life of mine.

The envisaged process for this concept (Figure 3) had alluvial sand being delivered and stored in a pre-engineered structure capable of holding approximately 5,500 st of material (24 hours of continuous plant operation). A wheel loader would transfer sand from the storage structure to a live-bottom feeder that discharged to a conveyor. The conveyor would feed the sand to a continuous mixer in the HF plant. A binder system was included to store, transfer, and regulate the amount of binder addition to the mixer. A process water tank was included in the plant, complete with duty standby pumps, to provide the necessary water to the mixer to achieve the desired HF recipe. From the mixer, HF discharged to a hopper that gravity fed the UG reticulation system.

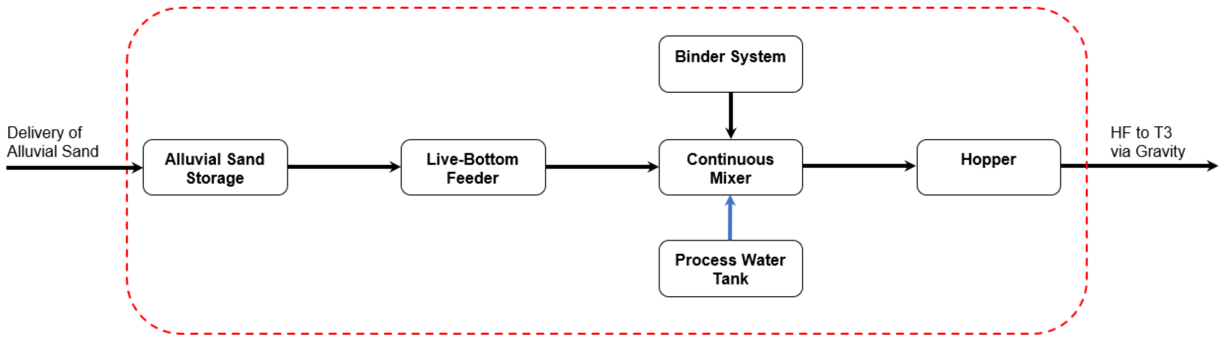


Figure 3. Concept 1: alluvial sand flowsheet.

For this concept, stopes in T1 and stopes in T3 above 4160 level would be filled by the existing hydraulic fill plant in the concentrator at ~300 st/h. Stopes below 4250 level in T3 would be filled by the backfill plant at 378 Shaft at 200 st/h via a new surface to 2800 level borehole.

*Concept 4a: alluvial sand and whole tailings (50/50 blend – existing plant)*
The intent of this blend was two-fold:

1) Reduce the quantity of alluvial sand required in backfill (reducing OPEX costs)
2) The combination of alluvial sand and whole tailings in a 50/50 blend exhibited higher strengths during test work versus other materials/blends when comparing sand to binder ratios. The UCS test results are referenced in Appendix A.
3)

With whole tailings in the blend, this concept (Figure 4) was dependent on mill production. With the mill operating at ~ 32% utilization on an annual basis, the HF plant utilization for this concept was set at 15%. This low utilization accounted for periods of time when the UG mine might not be ready to receive backfill, but the mill would be operating. Further to this, it was expected that the mill would operate continuously for three-to-four-day periods to achieve and maintain steady-state. The backfill plant would not run for this duration and would need to stop, flush the reticulation system, and, in some cases, wait for water to decant from the stopes.

Acknowledging that the mill would operate intermittently, provisions were included in this concept to allow for operation with 100% alluvial sand, offering operational flexibility to ensure the backfill needs of the mine would be satisfied. This method of operation was expected to occur 50% of the time.
The existing T1 hydraulic fill plant was located adjacent to the mill given the need for whole tailings in the blend. As with Concept 1, the alluvial sand would be excavated, screened, and delivered from a location nearby the Thompson airport by a local trucking company on a contract basis. The HF plant included a pre-engineered structure to store alluvial sand with sufficient space to allow transfer of sand to a live-bottom feeder via loader. The live bottom feeder would direct sand to an inclined conveyor that would feed a mixing tank.

For tailings, a thickener was included to achieve a higher mass concentration on the whole tailings prior to mixing with alluvial sand. With the sand and tailings mixed in a 50/50 blend to a target mass concentration of 65% at the mix tank, two pumps in a duty/standby configuration would pump the slurry to the existing mix tank in the HF plant, located internal to the mill. The binder system for the existing HF plant would be re-used with this option, with binder added at the final mix tank per current practice. The cemented hydraulic fill would report by gravity to the existing boreholes.

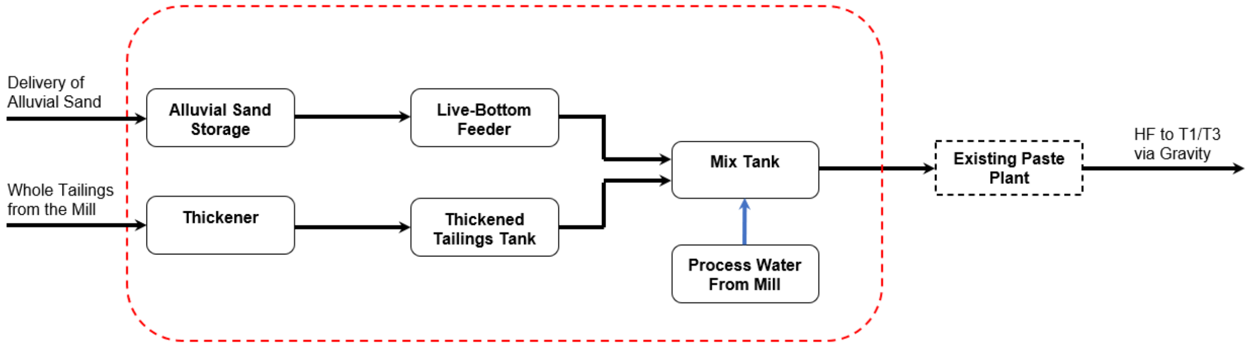


Figure 4. Concept 4a: alluvial sand and whole tailings (50/50 blend) flowsheet.

For this concept, stopes in T1 and all stopes in T3 would be filled by the hydraulic fill plant in the concentrator at ~300 st/h using existing infrastructure as much as practical. The existing piping would be reinforced with anchors, guides, and thrust bracing.

*Concept 6: alluvial sand and filtered classified tailings (50/50 blend)*

The Concept 6 blend was proposed to meet Thompson backfill requirements. Having the tailings portion of the blend filtered decoupled the milling and backfilling operations, similar to Concept 1. With the backfilling operation decoupled from the mill, it allowed the HF plant to be located closer to the mine expansion (378 shaft) and offered flexibility in the plant throughput and utilization. Vale Base Metals elected to set the plant throughput at 200 st/h, which would require the plant to operate at ~ 26% utilization to meet the underground demands.

Alluvial sand would be delivered in a manner similar to the other concepts, while the tailings portion of the blend would take the underflow from the mill hydroclones and transfer it to a new filtration plant adjacent to the mill. Dewatering test work was not completed at this stage of the project; however, it was assumed that the cyclone tailings would be suitably dewatered and two vacuum disc filters (duty/standby) would be sufficient for filtration. Once filtered, the classified tailings would be trucked on-demand to the 378 Shaft location and stored for use in the HF plant.

The HF plant for this option (Figure 5) would be arranged in a similar manner to Concept 1, with the difference being the smaller footprint required for alluvial sand storage and inclusion of tailings. A second pre-engineered building was included for storage of filtered classified tailings. The tailings would be transferred using a wheel loader to a live-bottom feeder, which are then conveyed to a re-pulping tank in the HF plant. The re-pulping tank would include high energy agitation to re-slurry the filtered classified tailings in advance of the mixer. Two re-pulp pumps (duty/standby) would transfer the slurry to the mixer, with in-line density and flow meters to control the mass flow. The remainder of the HF plant would closely replicate that of Concept 1 for the alluvial sand process, mixing, and binder addition.

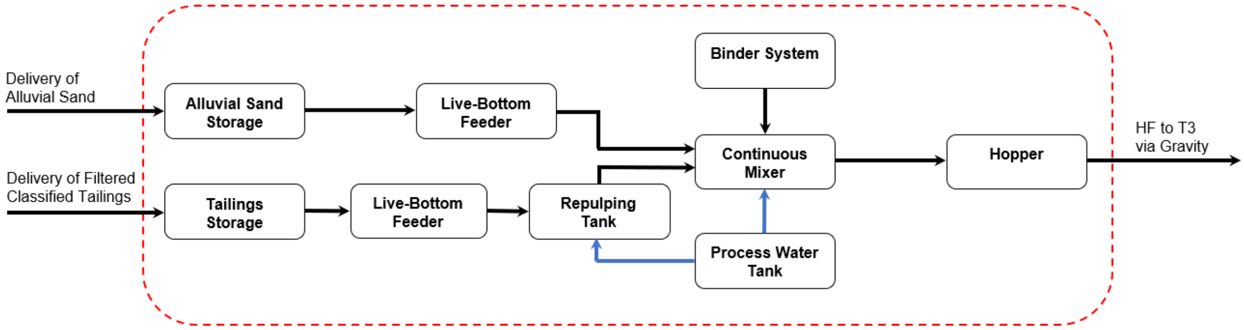


Figure 5. Concept 6 : alluvial sand and filtered classified tailings (50/50 blend) flowsheet; the approach to the UDS in this case is the same as in Concept 1.

**Opportunities, Risks, and Costs**

The opportunities, risks, and capital expenditures (including underground distribution system costs) associated with the three concepts are summarized in Table 4. CAPEX associated with each of the HF plant concepts were developed based on the process flow diagrams (PFD), mass balances, and high-level site plans for comparison. The estimates were prepared to a level of accuracy of ± 30%. Concept 1 had the lowest CAPEX, with Concepta 4a and 6 being relatively higher at ~ 15% and 70%, respectively.

OPEX associated with each of the HF plant concepts were developed to capture the binder, alluvial sand preparation and haulage, tailings haulage, maintenance, power, diesel, and labour requirements for comparison. For Concepts 1 and 6, it is important to note that the T1 and T3 upper stopes would be filled from the existing plant and this was considered when establishing the overall cost for HF on a per dry ton basis. The outcome was Concept 1 having the lowest OPEX; however, all Concepts were close in overall OPEX cost, with Concept 4a being ~3% higher and Concept 6 being ~ 9% higher.

**Study Outcome**

Concept 1 offered the lowest CAPEX solution with a marginally improved annual OPEX relative to Concept 4a. Concept 1 also offered a simplified process that decoupled the mill and backfill plant, allowing for increased operational flexibility over concepts reliant upon the mill tailings production. This concept also provided opportunity to pour to two locations simultaneously. The risks associated with this concept include increased alluvial sand haulage through the City of Thompson and additional tailings reporting to the TMA.

Concept 4a was one solution that offered a higher CAPEX than Concept 1 with similar annual OPEX. This concept included the use of alluvial sand and whole tailings, which increased the complexity of the process relative to Concept 1. With whole tailings as part of the blend, the backfill plant would be reliant on the mill to produce tailings. Concept 6 also offered a viable solution for Thompson's backfilling requirements; however, the infrastructure and equipment required to realize this concept was extensive and costly.

Both Concepts 1 and 4a were deemed to offer viable solutions, with Concept 1 offering a simpler approach at a lower CAPEX and marginally lower OPEX. Vale decided to pursue Concept 1, with the possibility of introducing filtered classified tailings in the future.

Table 4. Opportunities and associated risks for each concept.

| Concept | Opportunities | Risks | Capital Costs (+/- 30%) |
|---|---|---|---|
| Concept 1: alluvial sand only | ▪ Decoupled from mill<br>▪ Simplified process<br>▪ Existing sand plant can be used simultaneously<br>▪ Alluvial sand offers a clean, inert backfill product | ▪ All mill tailings report to the tailings management area (TMA)<br>▪ Alluvial sand haulage required through City of Thompson<br>▪ Mine is potentially exposed to escalation of costs since alluvial sand is outsourced | $41.2M CAD |
| Concept 4a: alluvial sand and whole tailings (50/50 tlend – existing plant) | ▪ Improved strength vs. alluvial sand and other blends<br>▪ Fewer tonnes of tailings reporting to Tailings Management Area (TMA)<br>▪ HF plant can still run on 100% alluvial sand if mill is down | ▪ 50/50 blend requires the mill to be operational; careful planning required<br>▪ Alluvial sand haulage required through City of Thompson (although less than Concept 1)<br>▪ Mine is potentially exposed to escalation of costs since alluvial sand is outsourced<br>▪ Makes use of existing UDS for T1 mine; unable to fill from two separate locations | $47.1M CAD |
| Concept 6: alluvial sand and filtered classified tailings (50/50 blend) | ▪ Decoupled from mill<br>▪ Fewer tonnes of tailings reporting to TMA<br>▪ HF plant can still run on 100% alluvial sand if mill is down<br>▪ Existing sand plant can be used simultaneously | ▪ Significant CAPEX associated with filtration of classified tailings<br>▪ Haulage of two materials rather than one (increased OPEX)<br>▪ Increased process complexity relative to other Concepts<br>▪ Alluvial sand haulage required through City of Thompson (although less than Concept 1) | $69.2M CAD |

**Operation**

With Concept 1 selected, the supply of backfill was contracted to a third party. Based on the set parameters defined by the study and the recipe testing, a mobile/modular backfill plant was selected to deliver the backfill to the required stopes in the T3 mine. The plant was placed and connected to the borehole in June of 2023. The commissioning of the plant began in August of 2023 and was completed by Vale Base Metals personnel with the assistance of the third-party operator/contractor. The backfill design parameters based on the testing are presented in Table 5.

The composition of the backfill will be 100% alluvial sand for the first two years of operations, with a dewatering circuit planned to be added at the mill in 2025. Currently, the recipe is 100% alluvial sand with 10:1 Portland-Limestone (GUL) binder. This binder was selected based on availability. The target density was selected to provide the required strength, while still being able to reach the desired stopes by gravity. The target gradation of the alluvial sand was refined during laboratory testing.

Table 5. Backfill operating parameters.

| Parameters | Values |
|---|---|
| Target Solids Concentration | 70% m |
| D10 (µm) | 32–180 |
| D50 (µm) | 150–475 |
| D80 (µm) | 250–600 |
| Binder Ratio | 10:1 |
| Binder Type | GUL |
| UCS (MPa) | 0.2–1.0 |

The borehole was drilled from the 378 Shaft surface location to 2800 Level, where it connects with the existing T1 UDS (Figure 6). From there, new distribution lines were installed to connect 2800 level to the depths of the T3 mine. The line size was reduced from 6" to 4" (~ 15 to 10 cm) based on the new backfill material. Hydraulic modelling was completed to validate the configuration but is not included in this paper.

**Surface Commissioning**

Dry commissioning was completed as a collaboration between Vale Base Metals and the contracted operating company in August 2023. Dry commissioning involved testing the functionality of each piece of process equipment to ensure operation in accordance with plant parameters. The system was then tested as a whole to confirm process functionality. No alluvial sand or water was used in the dry commissioning process.

The binder system was provided as a contained system with the plant. To calibrate the system, a physical measurement was required to ensure that the human machine interface (HMI) provided accurate data. To accomplish this, the system was run at a set tonnage and buckets were filled for a set amount of time. The mass of binder in the buckets was then weighed to determine how much binder was produced over time and the system was calibrated accordingly.

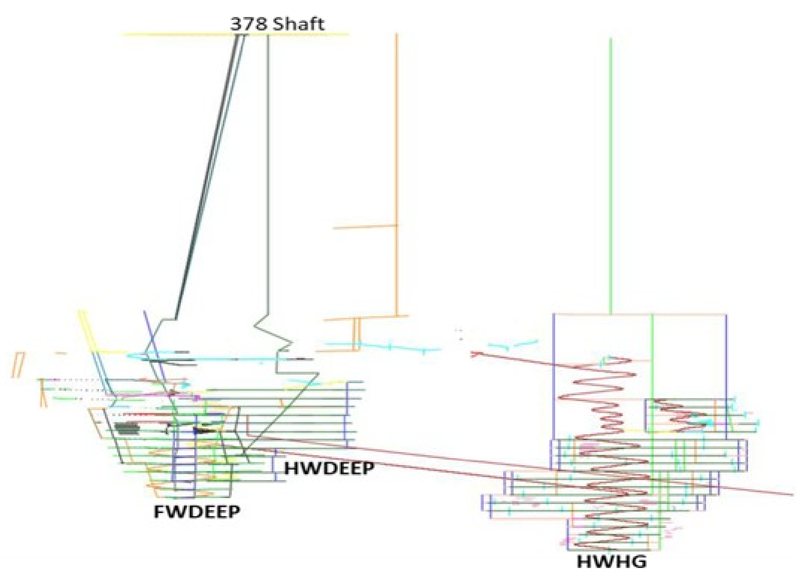


Figure 6. T3 mine layout.

Wet commissioning begins by running water through each individual piece of equipment to ensure it functions as designed. Secondly, the system is run as designed with alluvial sand, water, and binder, with the HF disposed on surface. This ensures the plant runs as desired before commissioning the UG reticulation system and allows for the calibration of instrumentation to ensure the readings being received are accurate and reported to the HMI.

During the wet commissioning process, the binder system was adding binder at the target rate; however, further testing was done to ensure that the 10:1 binder ratio was accurate in the actual backfill material. This was done using a proprietary sieving technique to separate the binder particles from the backfill. The binder was then weighed, and the mass ratio was calculated. Based on the testing, the system was adjusted to meet the target feed and was deemed calibrated at this point. UCS testing was done during commissioning to calibrate the backfill strength to the actual binder addition rates.

**Underground Commissioning**

An UG test stope was selected to receive backfill during commissioning. The initial backfill pours were not within design parameters as there was a need to test the system at different densities. When commissioning a backfill plant and system, it is important to select a non-production stope as the backfill is unlikely to meet specifications and target strengths.

The process to validate the UDS began with sending water down the pipeline to determine if there were any leaks. Minor leaks were found and repaired before the HF was sent UG. The method to test the UDS involved starting with a wetter slurry (~ 40% m) and slowly increasing up to the target density of ~ 70% m. As this was done, the pressure monitoring system and the pressure relief system (rupture discs) were tested and monitored. Pressure monitoring in the pipeline is required to indicate if there are any blockages in the line or if the pipeline is leaking. A low-pressure reading indicates a leak and a high reading indicates a blockage. At high pressure, the rupture disks protect the UDS and will release the pressure in a controlled manner to a pre-determined location UG. A density meter was installed on the borehole to T3 mine for the purpose of monitoring the solids density, which allows the operators to adjust the water addition and maintain target density.

**Testing**

A QA/QC program was established for the backfill operation to ensure the quality of the backfill was acceptable. The following tests were selected to be included in the program:

- PSD testing
- Density testing
- UCS testing.

PSD testing is done to ensure that the alluvial sand meets the specifications established as part of the laboratory testing. Variation in particle size can affect the strength and rheology of the backfill as well as the hydraulic conductivity. If the material does not meet the appropriate specifications, it is rejected. Density testing is done by taking an uncemented wet sand sample and drying it to determine the solids density. Deviations in density from the 70% m target can adversely affect the strength or introduce a risk of plugging the pipeline. UCS testing is done by collecting cemented backfill samples and casting them into cylinders as per Vale Base Metals' procedures for hydraulic fill. The cylinders are cured for 4 and 28 days for plug pours and 7 and 28 days for body pours. Once cured, the cylinders are crushed and the strength is compared to the target strength for each stope. For the first year, each plug and body pour will be tested. Once the results have stabilized and variation from the target is minimal, the test frequency will be reduced.

**Conclusions**

Currently the 378 sand fill plant is producing backfill as per Concept 1 that conforms to the laboratory testing and design parameters. Commissioning was successful and the plant was in full operation within a month of start-up. There has not been any unanticipated flow or drainage issues with the fill noted since the start of the plant operation.

Due to supply issues, the mine was required to use General Use Limestone (GUL) binder instead of the 90/10 slag cement binder (Terraflow) that was used in the study evaluation. All stopes are being poured at 10:1 sand to binder ratio. The target strengths are being achieved; however, the mine is anticipating changing binders for better economics as soon as possible.

Based on the satisfactory operation of the plant and the conformance to the design parameter, the laboratory testing and selected concept appear to have been suitable.

**Appendix A: UCS test results for the various recipes cast.**

| Mix # | Material | Recipe Mass Concentration (%m) | Binder Type | Target Binder to Tailings Ratio | Binder Conc. (%) | UCS (kPa) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 4 Day | 14 Day | 28 Day |
| 1 | Alluvial Sand | 76.2 %m | 100% GUL | 1:10 | 9.1% | 669 | 1,158 | 1,372 |
| 2 | Alluvial Sand | 76.7 %m | 100% GUL | 1:20 | 4.8% | 234 | 290 | 386 |
| 3 | Alluvial Sand | 67.2 %m | 100% GUL | 1:10 | 9.1% | 179 | 283 | 427 |
| 4 | Alluvial Sand | 66.8 %m | 100% GUL | 1:20 | 4.8% | 41 | 55 | 82 |
| 5 | Alluvial Sand | 79.5 %m | 90:10 Terraflow | 1:10 | 9.1% | 655 | 1,730 | 2,231 |
| 6 | Alluvial Sand | 77.7 %m | 90:10 Terraflow | 1:20 | 4.8% | 303 | 965 | 1,282 |
| 7 | Alluvial Sand | 68.4 %m | 90:10 Terraflow | 1:10 | 9.1% | 213 | 669 | 896 |
| 8 | Alluvial Sand | 67.6 %m | 90:10 Terraflow | 1:20 | 4.8% | 76 | 393 | 572 |
| 9 | Alluvial Sand | 77.6 %m | 50:50 Fly Ash to GUL | 1:10 | 9.1% | 352 | 676 | 1,503 |
| 10 | Alluvial Sand | 76.8 %m | 50:50 Fly Ash to GUL | 1:20 | 4.8% | 69 | 165 | 269 |
| 11 | Alluvial Sand | 65.0 %m | 50:50 Fly Ash to GUL | 1:10 | 9.1% | 69 | 159 | 317 |
| 12 | Alluvial Sand | 65.9 %m | 50:50 Fly Ash to GUL | 1:20 | 4.8% | 0 | 48 | 69 |
| 13 | 1:1 Alluvial Sand to Classified Tailings | 71.23 %m | 90:10 Terraflow | 1:10 | 9.1% | 374 | - | - |
| 14 | 1:1 Alluvial Sand to Classified Tailings | 70.5 %m | 90:10 Terraflow | 1:20 | 4.8% | 315 | - | 879 |
| 15 | 1:1 Alluvial Sand to Classified Tailings | 64.0 %m | 90:10 Terraflow | 1:10 | 9.1% | 206 | - | - |
| 16 | 1:1 Alluvial Sand to Classified Tailings | 57.8 %m | 90:10 Terraflow | 1:20 | 4.8% | 0 | - | 579 |
| 17 | 1:1 Alluvial Sand to Classified Tailings | 69.9 %m | 50:50 Fly Ash to GUL | 1:10 | 9.1% | 117 | - | 427 |
| 18 | 1:1 Alluvial Sand to Classified Tailings | 71.9 %m | 50:50 Fly Ash to GUL | 1:20 | 4.8% | 0 | - | 131 |
| 19 | 1:1 Alluvial Sand to Whole Tailings | 70.4 %m | 100% GUL | 1:10 | 9.1% | - | 990 | 1,146 |
| 20 | 1:1 Alluvial Sand to Whole Tailings | 70.6 %m | 100% GUL | 1:20 | 4.8% | - | 286 | 349 |
| 21 | 1:1 Alluvial Sand to Whole Tailings | 61.7 %m | 100% GUL | 1:10 | 9.1% | - | 351 | 461 |
| 22 | 1:1 Alluvial Sand to Whole Tailings | 59.9 %m | 100% GUL | 1:20 | 4.8% | - | 123 | 154 |