Site-wide Water Balance Update 2023 - 2024

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Report Prepared by

srk consulting

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SITE-WIDE WATER BALANCE UPDATE FOR THE ENGEBØ RUTILE AND GARNET PROJECT IN VESTLAND, NORWAY

Prepared For

Nordic Mining ASA

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Report Prepared by

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SITE-WIDE WATER BALANCE UPDATE FOR THE ENGEBØ RUTILE AND GARNET PROJECT IN VESTLAND, NORWAY

1 INTRODUCTION

In 2022, Nordic Mining ASA ("Nordic Mining") engaged SRK Consulting (UK) Limited ("SRK") to develop a site-wide water balance for the Engebø Rutile and Garnet project ("the Project") located in Vestland, Norway. The Project involves the development of an open pit together with a waste rock dump (WRD), ore stockpiles, underground crusher, processing plant, stacking and loading facilities and deep-water port. Tailings will be disposed of undersea, in the fjord to the south.

SRK developed a simple predictive site-wide water balance (SWWB) using a dynamic systems model (DSM) in the GoldSim software platform. The GoldSim SWWB model considers the first 15-years of operational conditions only. A report describing the construction and results of this SWWB was produced in February 2023 (see Table 3-1, reference 17).

The SWWB was subsequently updated in 2024 in order to better inform an updated Water Impact Assessment (WIA) and associated Water Management Plan (WMP), described in SRK 2024a and 2024b, respectively. The main updates to the existing water balance include:

- Reduction of the model timestep from monthly to daily to give improved resolution and better confidence in the predictions.
- Incorporation of a WGEN[1] model within GoldSim which generates stochastic daily precipitation based on monthly statistics from the local meteorological station historic precipitation timeseries.
- Incorporation of updated hydrology inputs; daily runoff, snowpack accumulation and snowmelt are combined into a single lumped parameter model integrated within GoldSim, using the CemaNeige[2] model for snowpack and snowmelt, and the GR4J[3] rainfall-runoff model. The rainfall-runoff model replaces the simple runoff coefficient approach previously used for the catchment.
- Upgrade to the Waste Rock Dump (WRD) model. Runoff from the WRD is estimated based on the SCS Curve Number (CN) Method[4]. A delay element is used to estimate the amount of time it takes for surface infiltration to percolate through the WRD and report as toe seepage.

1 Stochastic weather generator originally developed in the 1980s in Fortran at the US Department of Agriculture Agricultural Research Service (Richardson and Wright, 1984).
2 Snow accumulation and ablation model
3 Rural Engineering Model with 4 parameters daily (Perrin et al, 2003)
4 The CN Method was originally developed by the SCS for conditions prevailing in the United States i.e. empirical analysis of runoff from small catchments monitored by the USDS. The National Resources Conservation Service (NCRS), formerly referred to as SCS, CN method is described in detail in NEH-4 (SCS 1985).

- The water balance is determined probabilistically (Monte Carlo) to accommodate the potential uncertainty and variability in model input parameters related to surface water.
- Incorporation of the latest sedimentation pond water storage facility design (see Table 3-1, reference 18).
- The catchment areas with runoff reporting to the sedimentation pond have been updated.
- The water balance has been coupled with a non-reactive solute mass balance (mixing) model using the GoldSim contaminant transport module.

This report presents a summary of the updated GoldSim water balance, including the proposed layout of water management aspects of the Project, modelling approach, results of the water balance in terms of key flows and stores, and provides a summary of key conceptual-stage considerations related to water management at the Engebø site. Key assumptions adopted in the SWWB are also documented, being key to understanding the limitations and requirements for further work.

2 OBJECTIVES

The objectives of the SWWB outlined in this report were as follows:

- Produce a predictive "SWWB" in GoldSim that collates material[5] flows and stores, estimated from existing studies, into an integrated balance[6] of the operational period of the Project.
- Use the SWWB to predict water flows across the site under various water management scenarios.
- Use the SWWB to predict upon potential flow impacts to the surrounding environment.
- Produce a predictive non-reactive solute mixing model using the GoldSim contaminant transport module to predict water quality in the site sedimentation pond and receiving surface water environment.
- Use the results of the SWWB to develop optimal site water management strategies both in terms of operational water management as well as minimising water impacts, informing a site Water Management Plan (WMP).
- Devise and evaluate impact mitigation options, where appropriate.

At this stage, the model considers operational conditions only although it could potentially be adapted to look at post-closure conditions in the future if required.

The SWWB has been coupled with a to predict water quality for the sedimentation pond and receiving environment.

[5] Materiality is subjective but a flow is generally considered to be material where its omission from the water balance could influence water-related decisions by users of that information.
[6] Where inputs = outputs + change in storage.

3 AVAILABLE DATA

An initial site visit was undertaken by an SRK mine water management specialist on 15th December 2022 during which the following tasks were undertaken:

- Site walkover (pit area, WRD area, plant area, Grytaelva)
- Drone flyover
- Meetings with key site personnel to gather and collate data and to discuss conceptual site understanding.
- Develop an initial flow schematic which was reviewed and agreed on site.

SRK reviewed all available information from the site visit and documents provided by Nordic Mining and supplemented with public domain data, where required, to inform the water balance input parameters and assumptions. The key documents used to produce the site water balance are summarised in Table 3-1.

Table 3-1: List of key input data

Reference	Description	Document title/filename	Author	Date
1	Site general layouts	Overview Engebø.jpg, regpl_engebo e_v05d.jpg, Regulation_Plan.dwg	Asplan Viak/Nordic Mining	Various
2	Engebø Open Pit Feasibility Study - Hydrogeological Study technical memorandum	Engebø Pit FS Hydrogeological Study_v5_with apps.pdf	SRK	April 2018
3	Definitive feasibility study report: chapter 11 hydrogeology, chapter 13 waste dump deposit, chapter 15,16,17 Infrastructure	Engbo_UDFS_Chapter 11 Hydrogeology.pdf Engbo_UDFS_Chapter 13 Waste dump deposit.pdf Engbo_UDFS_Chapter 15,16,17 Infrastructure.pdf	Hatch	May 2021
4	Phase 6 waste dump and drainage design	G201.pdf	Asplan Viak	April 2022
5	Final (Phase 7) waste dump and drainage design	G202.pdf	Asplan Viak	April 2022
6	Open pit designs – Early, Intermediate and Final	.dxf and .dm files (various)	Nordic Mining	June 2022
7	Waste rock designs – Phase 1-7	.dwg files (various)	Asplan Viak	June 2022
8	Catchment and runoff model notes	NOTES_Site Wide Water Balance – Engebo.pdf	Asplan Viak	July 2022
9	Waste Management Plan	Nordic Rutile - Engebøprosjektet-Avfallshåndteringsplan_Norsk.pdf	Nordic Mining	July 2022
10	Site visit notes and photos	N/A	SRK	Dec 2022
11	Conceptual water balance for the process plant	Process plant water balance.pdf	Nordic Mining	Dec 2022
12	Conceptual plan layout for process plant	Buildings in process area.pptx	Nordic Mining	Dec 2022

Reference	Description	Document title/filename	Author	Date
13	Waste rock scheduling information	Email - Steinar Kleppe	Nordic Mining	Jan 2023
14	Sedimentation pond and initial spillway design	VER 3 Notes Storm Water Runoff and preliminary calculations of sedimentation pond.pdf	Asplan Viak	Jan 2023
15	Precipitation data	https://www.ncei.noaa.gov/cdo-web/	National Oceanic and Atmospheric Administration's (NOAA)	Jan 2023
16	Temperature data	https://www.met.no/en/free-meteorological-data	Meteorologisk institutt (MET) Norway	Jan 2023
17	Conceptual SWWB report	31223_Water_Balance_RevB.pdf	SRK	Feb 2023
18	Natural catchment areas and runoff coefficients. Latest sedimentation pond design	Rensløsning gråbergdeponi_V2.pdf	Asplan Viak	June 2023
19	Engebø preliminary water impact assessment	32082_Engebo_WIA_v1.pdf	SRK	Sept 2023
20	Spot flow monitoring undertaken by ERG, May 2023 to April 2024		ERG	May 2024

4 MODELLING APPROACH

4.1 Overview

Based on the agreed water balance flow schematic, a predictive SWWB was developed using the GoldSim software platform. GoldSim is a Monte Carlo simulation software that allows users to create customised models based on built-in functions within the software. The software is well suited for water balance projects and GoldSim can be used for probabilistic simulation (Monte Carlo), to evaluate the potential uncertainty and variability in model input parameters related to groundwater and surface water.

The SWWB runs on a daily timestep and reports on a monthly timestep basis, consistent with the level of data available. The site-wide water balance focusses on the first 15 years of operations. Note that an arbitrary start date of 1st January 2025 is adopted for the simulations, consistent with the latest production schedule.

The SWWB is constructed to be flexible, in order to facilitate further updates as water demand and return estimates and water storage facility(s) design are refined.

4.2 Water Balance Components

An overview of the site layout and key geographical areas considered in the water balance is shown in Figure 4-1

A schematic summary of the key components of proposed water management for the Project is presented in Figure 4-2.

Facilities included in the SWWB, organised in the modelling platform using container objects, include:

- **Open pit**: groundwater and surface water pit inflows are managed via an operational pit sump and pumped out to an intermediate sump on the pit rim.
- **Intermediate (ex-pit) pond**: a storage facility (small pond) on the pit rim that receives pumped dewatering flow from the pit from where it is pumped on to the sedimentation pond.
- **WRD**: waste rock extracted from the pit will primarily be managed via the WRD. Seepage and runoff from the WRD will be routed to the sedimentation pond.
- **Sedimentation pond**: a storage facility that receives pumped overflow from the intermediate sump and “contact”[7] surface runoff within the catchment to the north of the project area, which includes runoff from haul roads, laydown/service and equipment parking areas, and the WRD, as well as some natural ground catchment areas. The sedimentation pond allows for settling of suspended solids in site contact water prior to discharge via an open drainage channel to the environment (fjord). A relatively small amount of water for haul road dust suppression will be sourced from the sedimentation pond during the summer months only.
- **Water treatment plant**: fjord water is treated via reverse osmosis (RO) and used as the principal freshwater make-up water supply source for the project[8]. This study also considers an alternative scenario whereby surplus water from the sedimentation pond is used for plant freshwater supply thereby offsetting some of the requirement to produce raw water using RO.
- **Process water tank**: RO water is pumped to the process water tank from where it used in the processing/plant area or in the underground materials handling area.
- **Process plant and underground materials handling**: make-up freshwater demand for the processing plant and underground operations (dust suppression at the underground crusher and conveyor) has been provided by Nordic Mining as the output of a separate, stand-alone water balance which is not included in this study. Water usage in the process includes process-water top-up and water loss through tailings co-disposal.

The above components, together with other key input data and assumptions, are discussed in more detail in the following sections. Potable water supply and firewater are not included in the water balance as they are not considered material at this stage.

[7] Runoff from site that is deemed to have come into contact with disturbed areas of the site and therefore is treated as potentially contaminated with respect particularly to suspended solids.
[8] Note that the process plant also has a large seawater demand for use in tailings co-disposal back to the fjord.

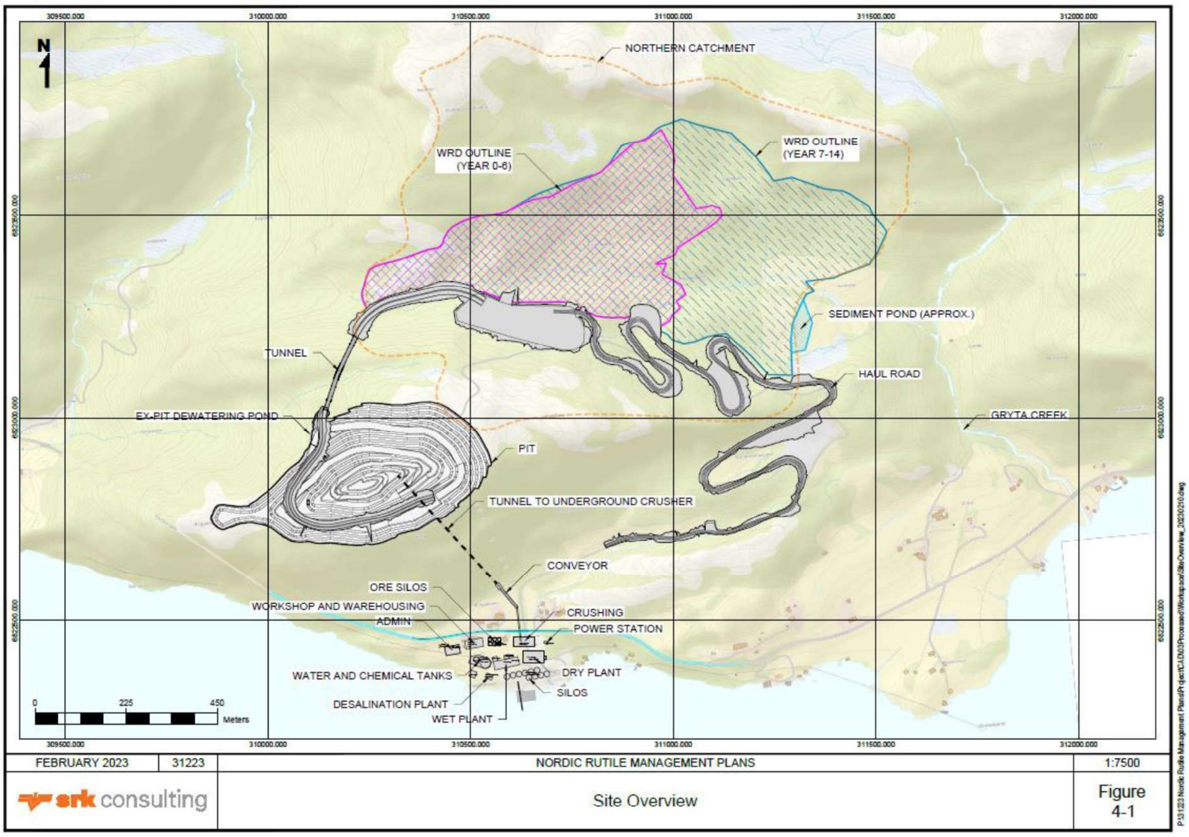


Figure 4-1: General layout of the Engebø Project as considered in the water balance

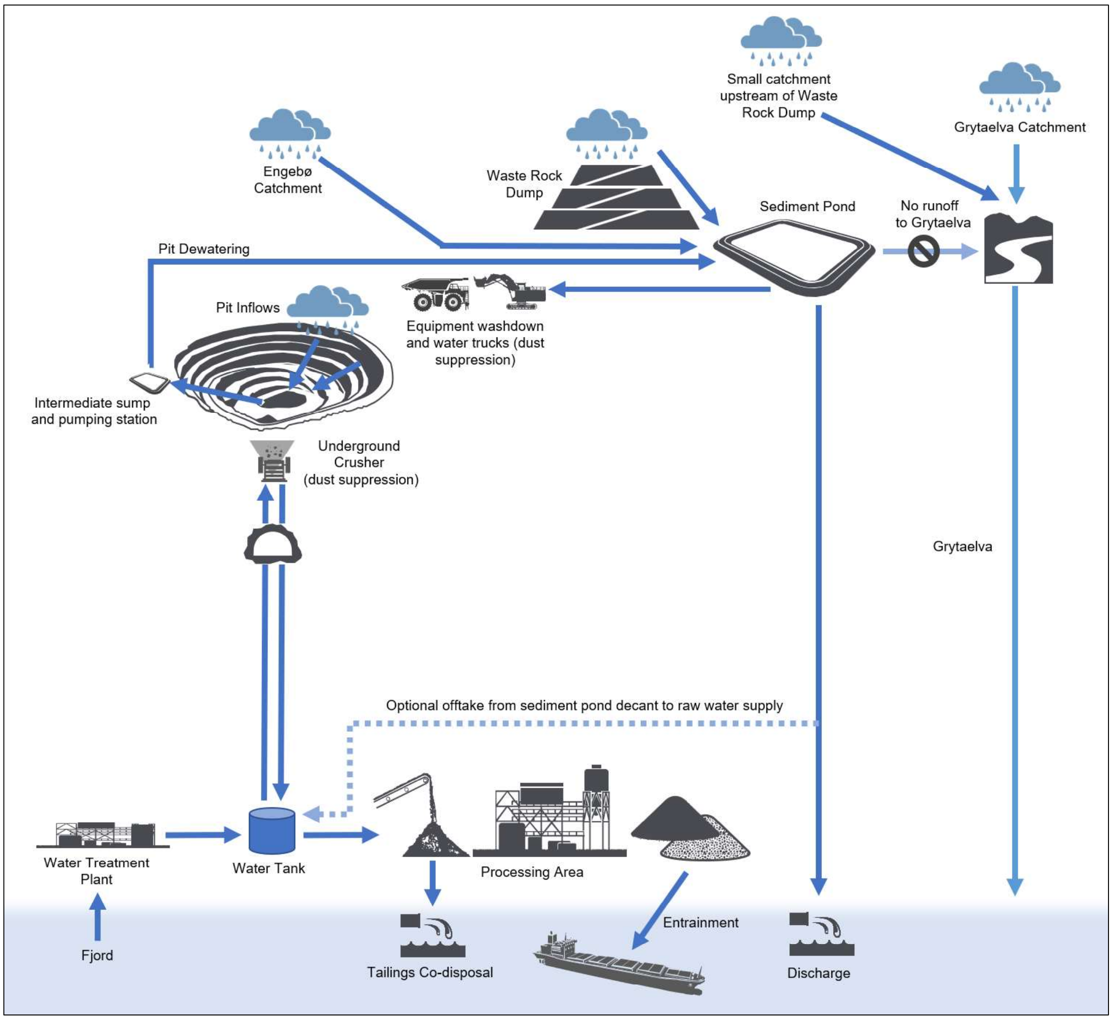


Figure 4-2: Site Water Management Concept

4.3 Climate

4.3.1 General

The climate at Engebø is typical for western coastal Norway and is characterised as temperate with long, warm days in summer and colder, darker and shorter days in winter. Snow is common in winter but due to the proximity to the sea and the relatively low altitude there is no permanent ground freezing or snow accumulation. Annual rainfall exceeds 2,000 mm, with approximately more than 100 mm per month distributed across all four seasons, resulting in significant rainfall throughout the year. The Førde Fjord at Engebø is permanently ice-free.

4.3.2 Available data

No local meteorological station has been installed at the Project site. However, there is an extensive network of active and historical meteorological stations across the country serviced by the Norwegian Centre for Climate Services[9].

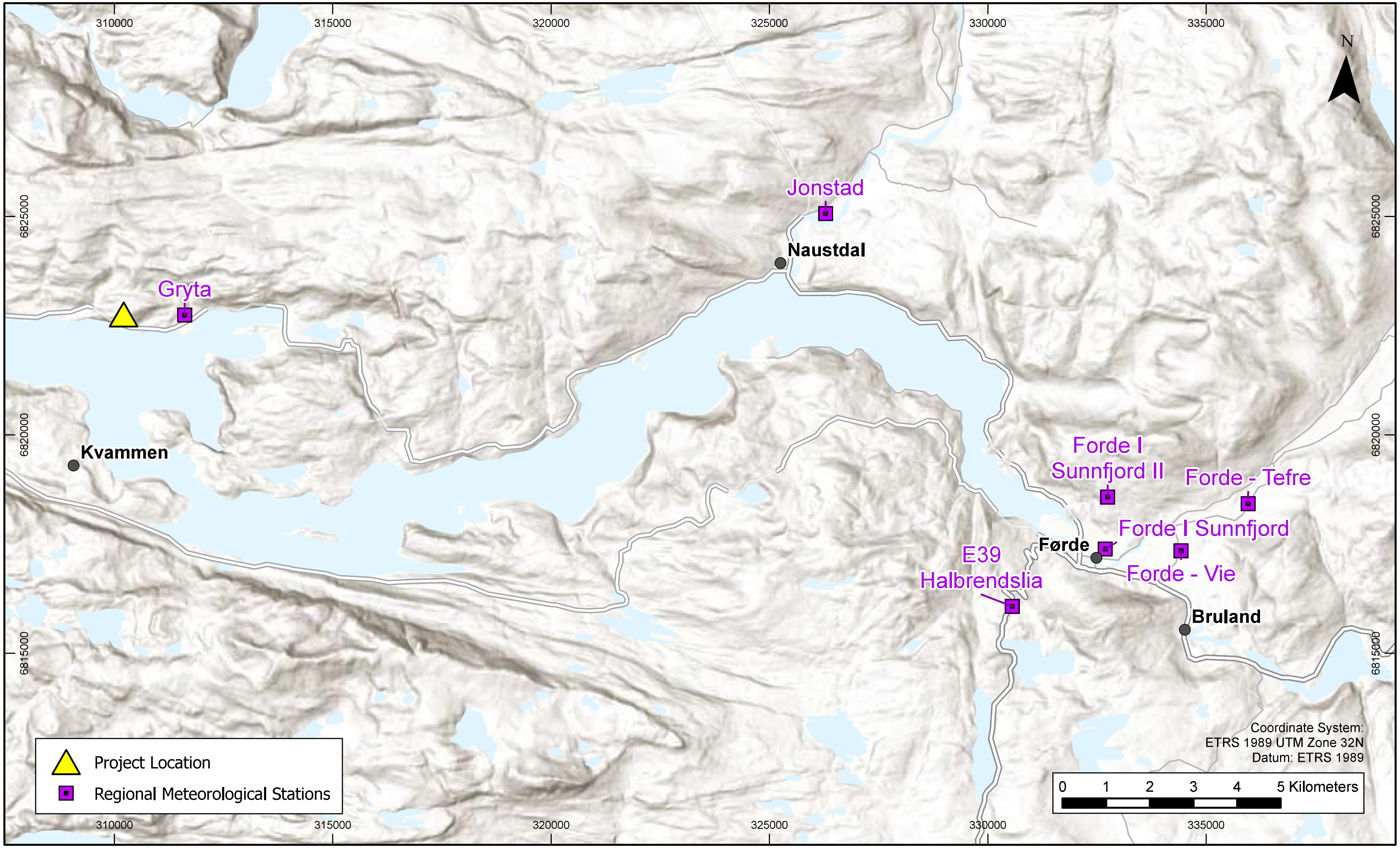
[9] https://seklima.met.no/observations

Historical data is available for the Gryta station located within the Grytaelva ("Gryta") catchment, adjacent to and east of the Project site, close to the Grytaelva mouth where it discharges to the Førde Fjord (Figure 4-3) The Gryta station operated between 1968-1995, although this dataset only contains records for precipitation. Regional data from seven regional monitoring stations has been collated by SRK to support and augment this local record. Stations used in this analysis are shown in Figure 4-3 and summarised in Table 4-1. A preliminary analysis of the regional stations was undertaken to identify periods of time with acceptable data.

Gridded precipitation data from the SeNorge2 website was also used to augment the Gryta station and regional station data (source: SeNorge - Se snøkart og klimakart for hele Norge). SeNorge2 provides high-resolution daily total precipitation across the Norwegian mainland at a 1km resolution for modelling requiring long-term datasets at either a regional or national level. The data extends back 1957 and is particularly suitable for simulating small-scale process in complex terrain (Lussana, C et. al, 2019).

Table 4-1: Summary of the key information from regional meteorological stations used in the climate analysis

Station name	Lat (°)	Long (°)	Elevation (m)	Data period used	Parameters used
Førde I Sunnfjord II	61.46	5.84	41	01.07.1965 - 01.09.1985	Air Temp., Precipitation
Gryta	61.49	5.46	34	01.07.1968 - 31.12.1995	Precipitation
E39 Halbrendslia	61.44	5.82	237	06.07.2017 - now	Air Temp.
Førde I Sunnfjord	61.45	5.86	3	01.01.1919 - 01.06.1965	Air Temp., Precipitation
Førde - Vle	61.45	5.89	11	01.10.1985 - 01.10.1992	Air Temp., Precipitation
Førde - Tefre	61.46	5.92	64	01.12.1992 - 01.01.2018	Air Temp., Precipitation
Jonstad	61.52	5.73	7	07.08.1956 - 31.08.1958	Precipitation



SEPTEMBER 2024	32082	ENGEBØ WATER IMPACT ASSESSMENT	
srk consulting		Meteorological stations - Regional locations	Figure 4-3

P:\32082 Engebo Water Impact Assessment\Project\CAD\03Processed\Workspace\MeteorologicalStations_20230914.aprx

4.3.3 Precipitation

Data from the six regional stations summarised in Table 4-1 was obtained for periods between 1956 to 2019 (note: the period of record varies between stations). The regional stations used for the analysis were Gryta, Jonstad, Førde-Terfe, Førde-Vie, Førde I Sunnfjord, and Førde I Sunnfjord II, the locations of which are shown in Figure 4-3. A summary of the precipitation data obtained is shown in Figure 4-4.

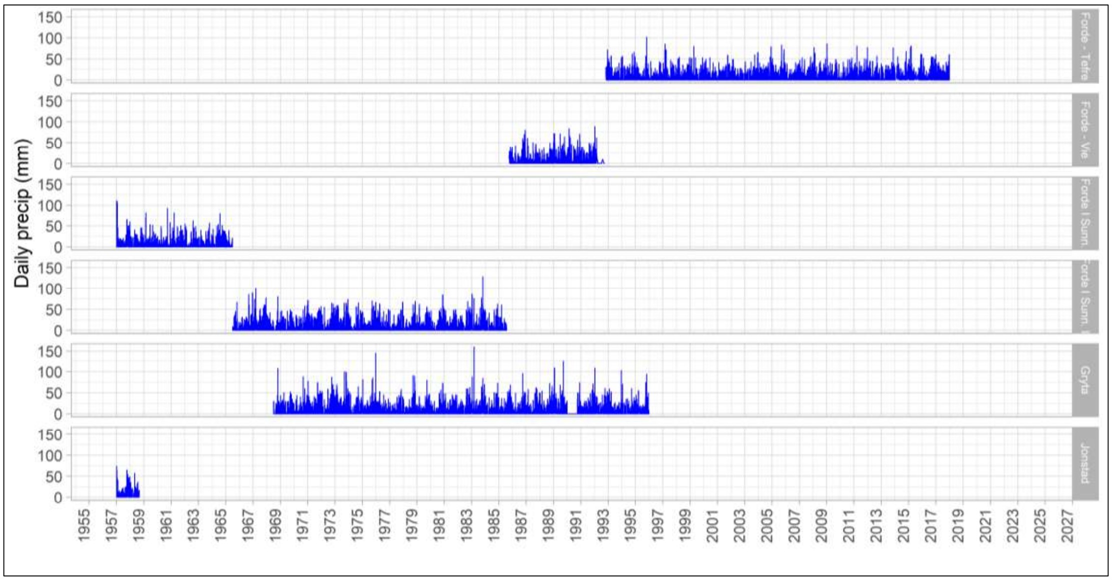


Figure 4-4: Daily precipitation data from the six regional stations

The Gryta station is considered most representative of the Project site due to its proximity and comparable altitude (the station is located adjacent to the Project site, within the lower reaches of the Gryta catchment). Precipitation data was recorded at the Gryta station from 1969 to 1996.

Average annual precipitation at Gryta is just over 2,400 mm. Maximum precipitation occurs in the months of September to December and the driest period is between April through June, with May being the driest month.

Monthly and average annual precipitation for the Gryta station is presented in Table 4-2 and graphically illustrated in Figure 4-5. Available data for regional stations Førde I Sunnfjord II and Førde – Tefre is also presented for comparison purposes. The data show a relatively small variation in monthly and annual precipitation between the three stations, with a mean annual precipitation ranging from 2,260 to 2,400 mm per year.

Table 4-2: Average monthly and annual precipitation in the region (mm)

ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Forde I Sunn. II	223	134	185	104	85.5	107	124	145	287	297	298	293	2,282
Forde - Tefre	249	225	199	122	112	119	133	143	203	233	250	273	2,260
Gryta	248	162	168	112	102	115	137	172	309	294	294	288	2,404

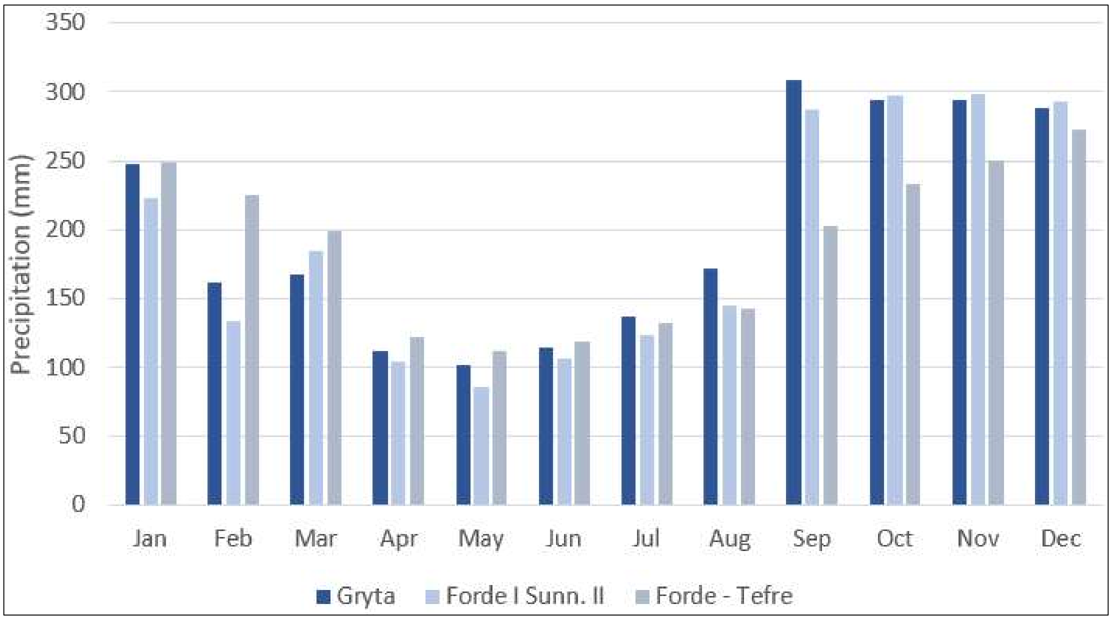


Figure 4-5: Monthly Precipitation

4.3.4 Precipitation corrected for undercatch

Undercatch is the systemic error in measuring precipitation, particularly snow, due to wind blowing across a gauge's opening. Both gauged and gridded precipitation data are impacted by wind induced undercatch in Norway (Lussana, C et. al, 2019), (Kochendorfer, J. et al, 2017). In terms of gridded precipitation, these errors are further exacerbated in mountainous areas of Norway above 2000 masl where gauge networks are less dense than in lower lying areas, leading to further underestimation.

Precipitation from the Gryta station and SeNorge2 gridded precipitation were corrected for undercatch using the methodology described in Macdonald, J., et al., 2007. The catch efficiency (CE) is obtained from windspeed (WS) using the formula below and then applied to the daily precipitation values both datasets, according to the following equation. Wind speed information was obtained using gridded information from MERRA2[10].

$$CE = 1.010 * \exp{(0.09 * ws)}$$

Correction for undercatch can make a material change to precipitation values. As an example, after applying the undercatch correction to Gryta precipitation, an increase in annual precipitation from 2,404 mm to 3,180 mm is observed. Average monthly variation observed at Gryta precipitation, both before and after undercatch correction, is presented in Figure 4-6

[10] The Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) is a NASA atmospheric reanalysis project that provides historical climate data from 1980 to the present. It assimilates a wide range of observational data to produce high-resolution, global climate datasets, which are used for climate research and weather forecasting. It is designed to provide a comprehensive and consistent record of the Earth's atmosphere, land surface, and ocean conditions from 1980 to the present, at a spatial resolution of approximately 0.5 degrees latitude by 0.625 degrees longitude across the globe.

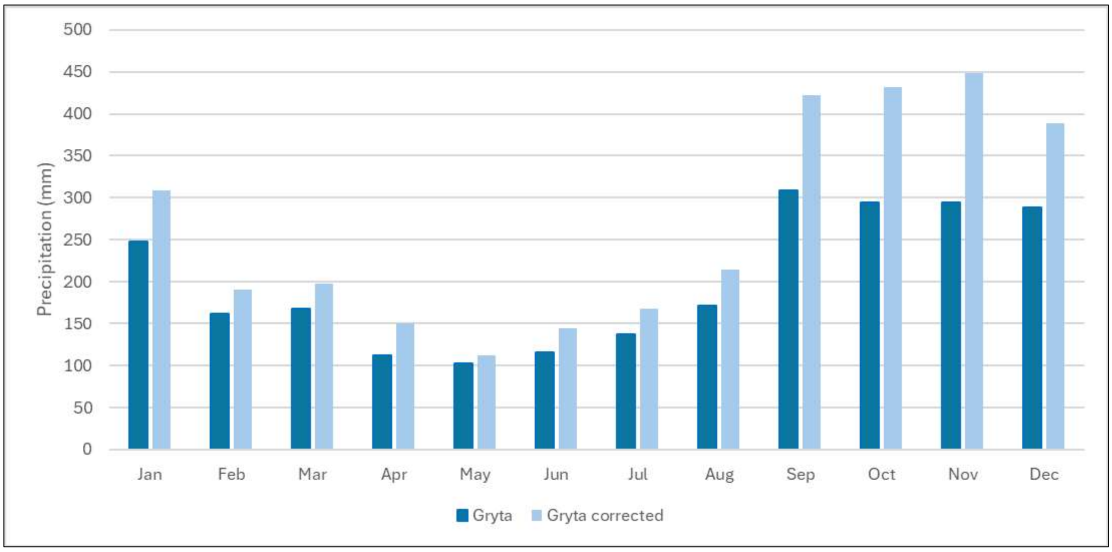


Figure 4-6: Average monthly variation of precipitation before (dark blue) and after undercatch correction (light blue)

4.3.5 Temperature

Temperature data is available at five regional stations; E39 Halbrendslia, Førde-Tefre, Førde I Sunnfjord I, Førde I Sunnfjord II, and Førde-Vie. Figure 4-7 shows that temperature is typically stable over the years for which data is available and that there is no significant spatial variation in the Førde region.

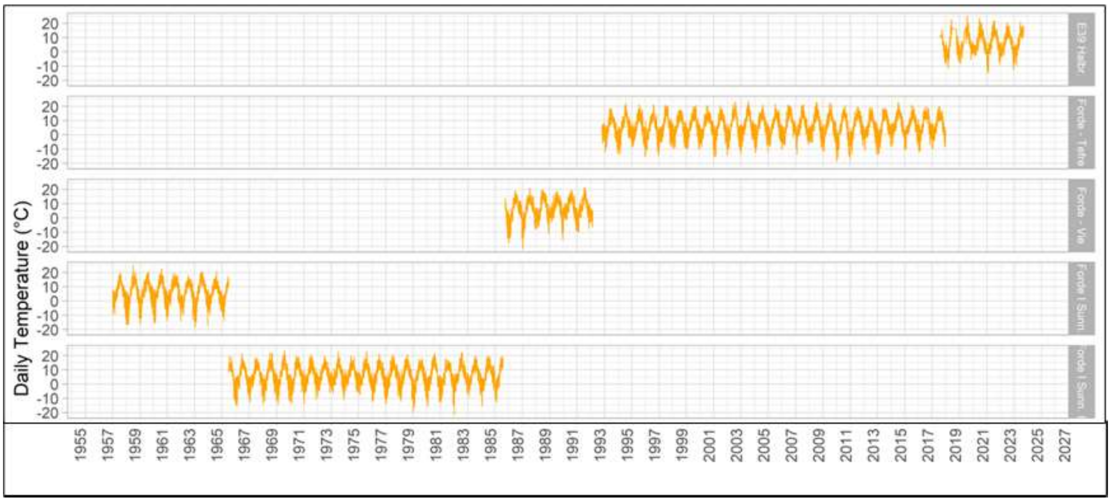


Figure 4-7: Observed daily temperature for the five regional stations

Figure 4-8 shows a box plot of the same data, demonstrating minimal spatial variation in temperature among the four regional stations with similar elevations. Data from E39 Halbrendslia is not included because this station is located at a much higher elevation than the project.

As there is no data available for temperature at the Gryta station, data from the next nearest station at Førde I Sunnfjord II (approximately 30 km from site) has been adopted as a site representative.

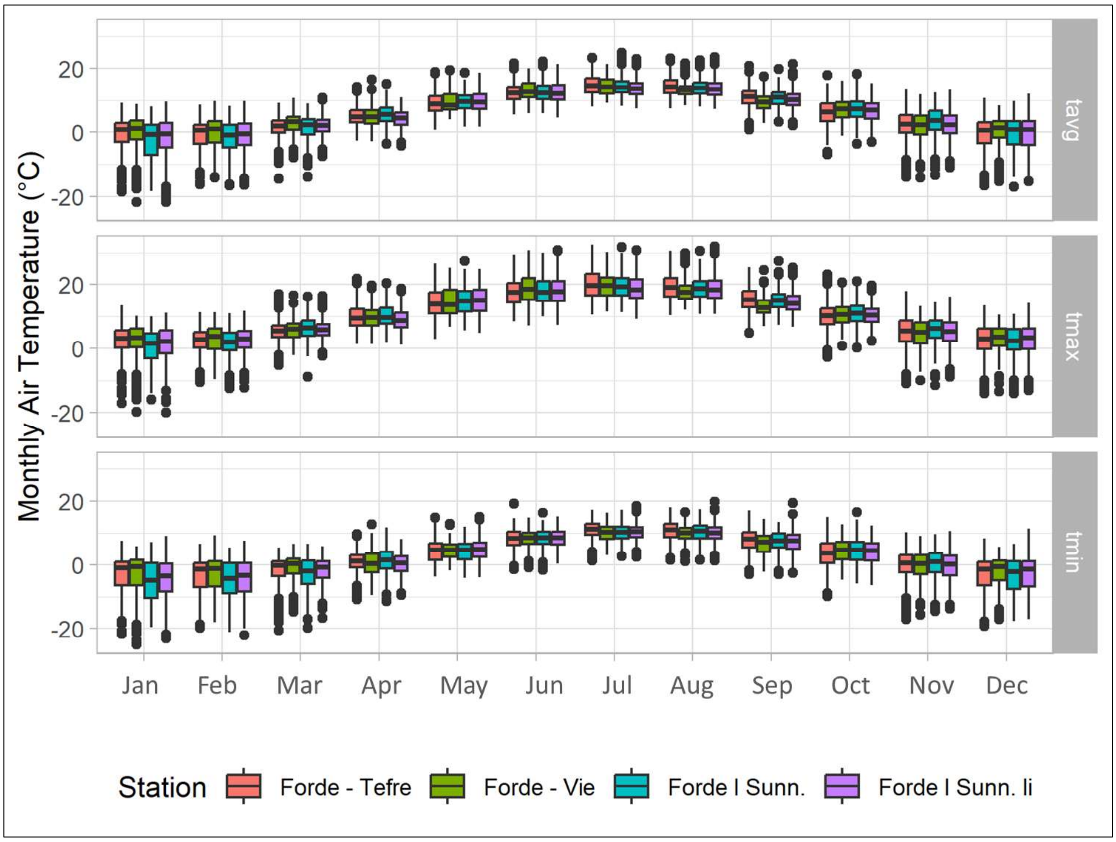


Figure 4-8: Box plot showing spatial variation in temperature across four regional stations

Average monthly temperature at Førde I Sunnfjord II varies from -1.3 °C in January to 14.3 °C in July. Mean annual temperature is 6.3 °C. The monthly distribution of temperature is shown in Table 4-3 below.

Table 4-3: Average monthly temperature (°C) at Førde I Sunnfjord II (1965-1985)

ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Forde I Sunn. II	-1.3	-0.9	2.0	4.5	9.8	13.0	14.3	14.2	10.6	7.0	2.3	-0.2	6.3

Daily maximum and minimum air temperature is simulated in the GoldSim model by enabling time shifting of the Førde I Sunnfjord II historical climate years, shifting the entire time series forward or backward in time as required.

4.3.6 Evaporation

Potential evaporation was estimated using the Hargreaves-Samani method. This method is based on an empirical relationship where reference evapotranspiration was regressed with solar radiation and air temperature data. Average monthly evaporation rates are presented in Table 4-4. Annual average potential evaporation is estimated as 546 mm, with higher rates during the summer months.

Table 4-4: Modelled average potential evaporation (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
3	9	26	50	95	110	107	83	40	18	5	2	546

4.3.7 WGEN stochastic precipitation

The Gryta precipitation (adjusted for undercatch) timeseries was used to develop monthly statistics for use in the WGEN weather generator (Richardson and Wright, 1984) to generate stochastic precipitation daily sequences in GoldSim. WGEN is a stochastic weather generation method which produces a synthetic precipitation data set for the required duration, which is a statistical fit to the analogue record. The generated stochastic precipitation record for the 100 realisations are presented in Figure 4-9 .

The stochastic precipitation generation module allows day to day precipitation patterns to vary, while maintaining consistent seasonal patterns. Occasionally, this module will generate daily precipitation totals that are much higher than observed due to the incorporation of statistical data which allows for potential extreme events not recorded in the period of historical data.

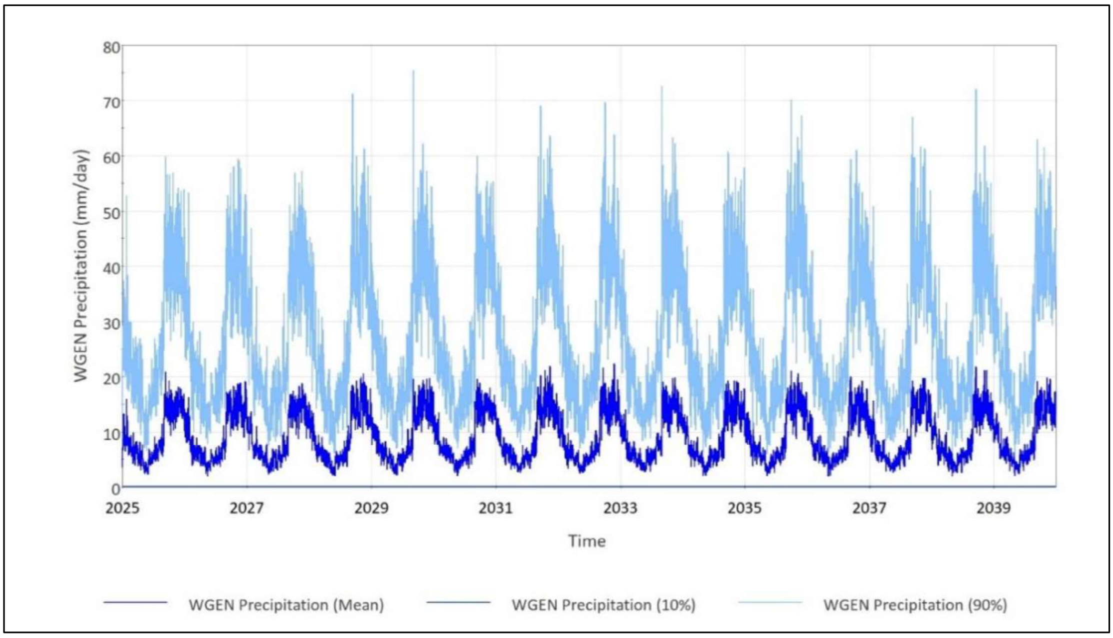


Figure 4-9: Stochastic precipitation

4.3.8 Snowpack and runoff model

Overview

Daily runoff, snowpack accumulation and snowmelt are combined into a single lumped parameter model integrated within GoldSim, using the CemaNeige model for snowpack and snowmelt, and the GR4J (Génie Rural à 4 paramètres Journalier) Runoff model to simulate discharge at the catchment scale.

The CemaNeige model is a snow accumulation and snowmelt model which uses only temperature and precipitation as inputs and two parameters to determine snowmelt; a melt factor based on temperature and second parameter to model the temperature inertia in the snowpack. The CemaNeige model accumulates solid precipitation which is released in the form of melt calculated using the degree-day method (X mm of melt per degree above freezing per day), adjusted by a snowpack temperature inertia term. Rainfall and snow melt is passed to the GR4J rainfall-runoff model. A schematic of the model logic is presented in Figure 4-10.

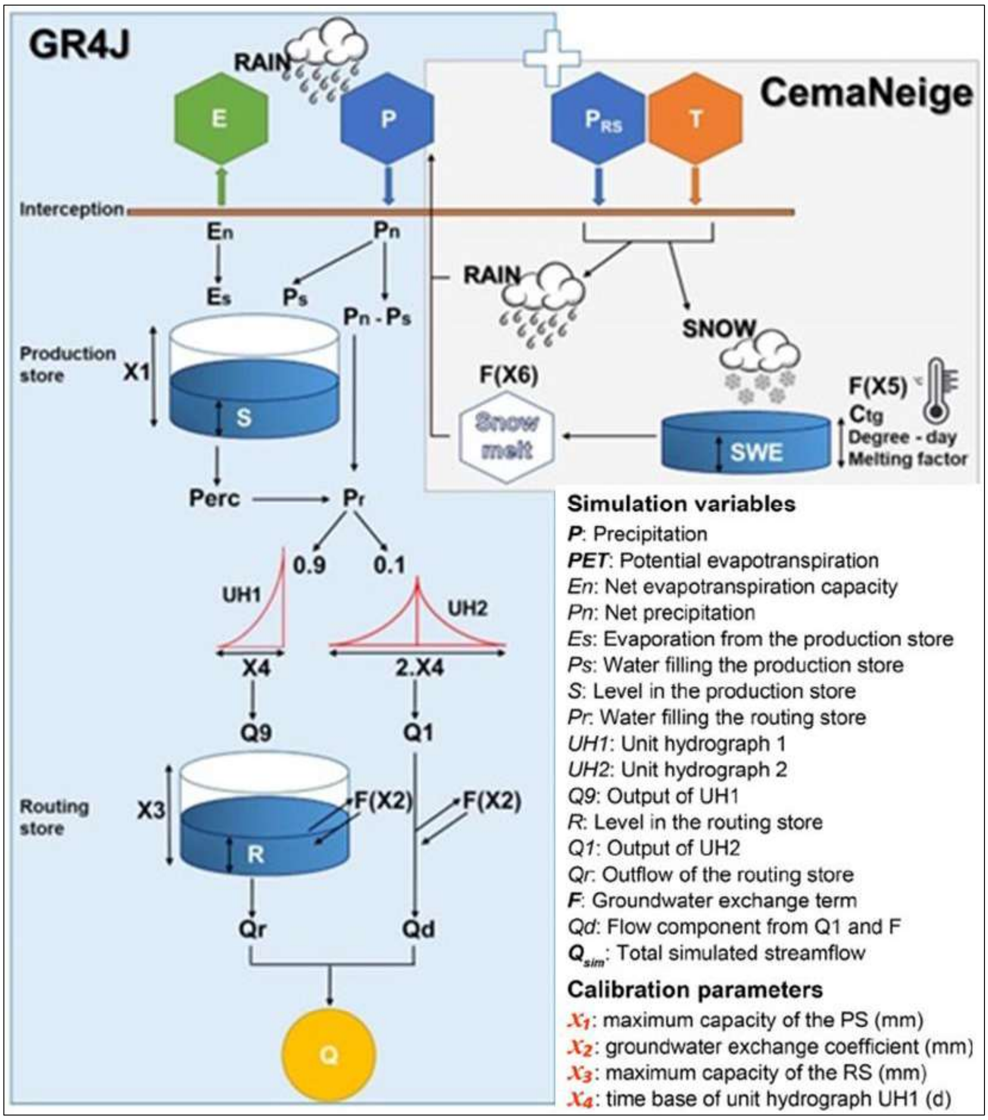


Figure 4-10: Schematic diagram of the GR4J rainfall-runoff model and CemaNeige

GR4J model uses 4 parameters to model interception and evaporation, runoff from a "production store", routing and attenuation through a "routing store" (Perrin, C., et al., 2003). This model was selected to represent site conditions based on the model input requirements and the model's ability to generate specific components of storage and runoff.

This daily precipitation-runoff model requires daily potential evaporation and precipitation to provide a runoff output. The transformation of inputs to runoff as an output is based on calibration of four parameters (X1, X2, X3 and X4). Figure 4-10 depicts the model diagram including the steps for the calculations, simulation variables and calibration parameters. All of these aspects of the model are explained on the right side of the diagram.

Calibration Data

No continuous flow monitoring data is available for the catchment of the Gryta or within immediate proximity of the watercourse. Spot flow measurements have been taken across the site area since May 2023 but continuous monitoring has not yet been installed and will take several years before a useful dataset is produced when it is installed.

The Norwegian Water Resources and Energy Directorate (NVE) maintains a hydrological monitoring system in Norway, consisting of over 400 monitoring stations. The NVE hydrological database provides commercially available hydrological time series for each monitoring station. Data is provided on river flows, snowfall, water level and many other parameters. Some stations are in active working order, while others are defunct and originate from as early as the 1900s.

No NVE stations are available for the Gryta catchment. Instead, suitable donor catchments with established hydrological time series were used to generate an analogue for the Gryta catchment. Donor catchment suitability was evaluated against criteria such as comparable catchment area, catchment characteristics and proximity to the site and is documented fully within the WIA Report (SRK, 2024a).

The five potential catchment donors are shown in Table 4-5. Each was assessed for it's suitability as a donor and initially the Førdeelv was selected based on similarity in catchment characteristic with the Gryta. However, further examination of the rating curves and follow-up discussions with the NVE revealed the rating curve to be poor and therefore this was unsuitable for use as a donor. The daily data for Ullebøelv was found to have a reliable rating curve and was therefore selected as the donor for use in model calibration.

Table 4-5: Extended (50 km) radius monitoring station details and catchment areas

Station Number	Station Name	Monitoring Period	Catchment Area (km^2)
90.1.0	Førdeelv	2007-2023	2.99
86.12.0	Skjerdalselv	1982-2023	23.66
80.4.0	**Ullebøelv**	**1927-2023**	**8.31**
86.56.0	Breelva	2014-2023	8.25
86.7.0	Bortne	1970-1986	15.81

Calibration and Validation Methods

A GR4J model precipitation-runoff was calibrated and validated using the local runoff records from Ullebøelv catchment. Precipitation and temperature at this location were obtained from NVE data. Precipitation was corrected considering undercatch. The hypsometric curve was defined based on the watershed topography. The GR4J model was calibrated using data for 2008 to 2017 resulting in a NSE[11] of 0.56 for daily evaluation, results are presented in Figure 4-11. The model was then validated using flow records from 2018 to 2021. The calibration process produced satisfactory daily runoff results for the Ullebøelv. The six model parameters used to simulate catchment runoff and streamflow are presented in Table 4-6.

[11] NSE stands for Nash-Sutcliffe Efficiency, which is a statistical metric used to assess the predictive accuracy of hydrological models. It is commonly used during model calibration and validation to compare the observed data with the model-simulated data.

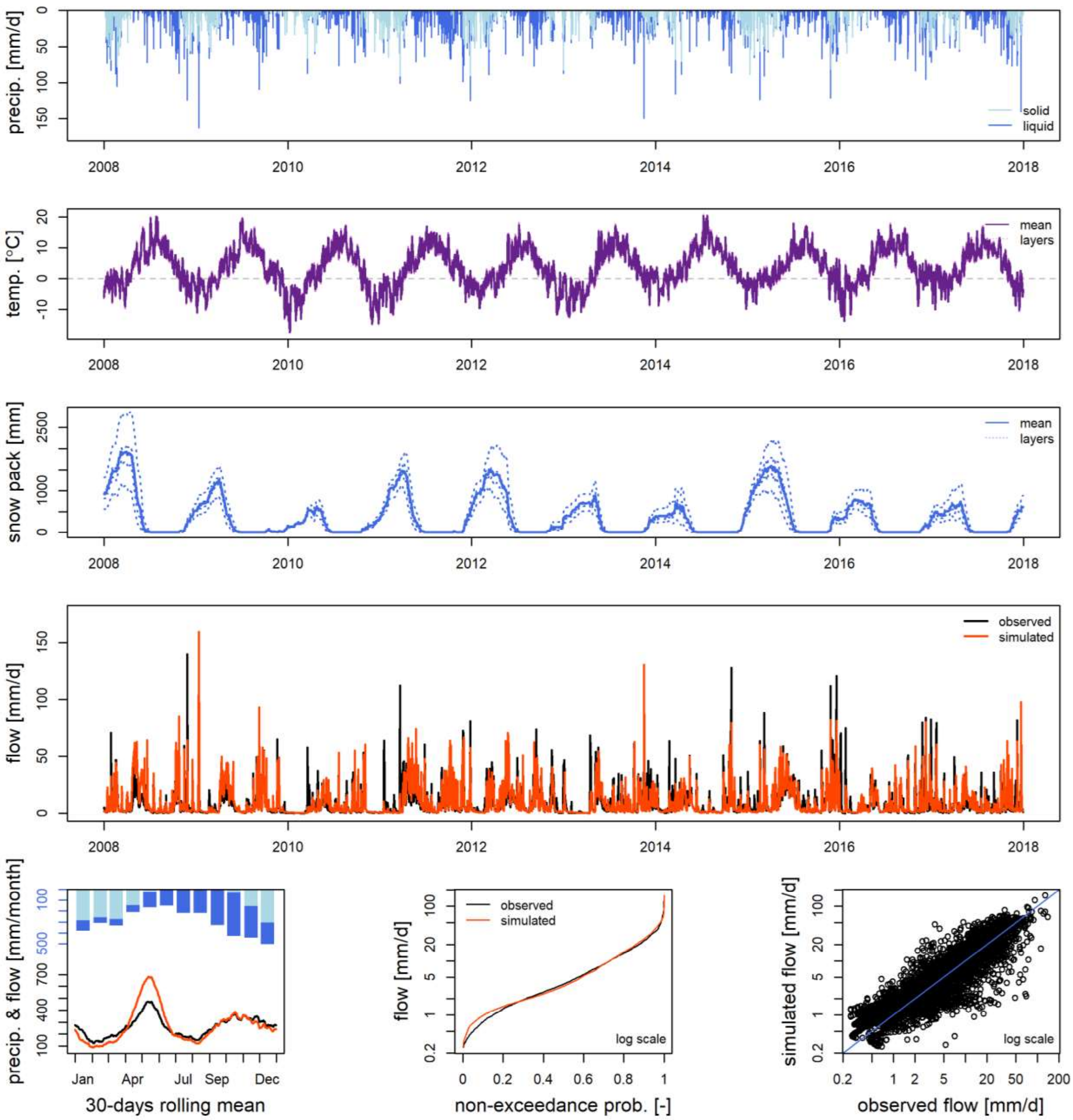


Figure 4-11: GR4J calibration results 2008- 2017 - Ullebøelv catchment

Table 4-6: GR4J Model Parameters

Type of Model	Model	Parameter	Description	Value	Unit
Rainfall-Runoff	GR4J	GR4J X1	Production storage capacity	279.8	mm
		GR4J X2	Intercatchment exchange coefficient	0.21	mm/day
		GR4J X3	Routing store capacity	29.18	mm
		GR4J X4	Time constant of the unit hydrograph	0.94	day
Snowmelt	CemaNeige	CN X1	Weighting coefficient for snow pack thermal state	0.01	-
		CN X2	Degree-day melting coefficient	9.19	mm/°C/d

The GR4J model was then implemented in GoldSim for the Project catchments and validated against spot flow measurements at ST11. This validation is only referential, as it is not possible to directly compare the flow time series produced by GR4J with spot measurements. Results indicate that the model flows from GR4J exhibits a similar pattern and magnitude to the spot measurements.

Figure 4-12 presents the monthly snowmelt results for the GoldSim Monte Carlo simulation. During periods of snowpack accumulation between November and May, “rain + snowmelt” (termed effective precipitation) is lower than precipitation whereas effective precipitaion exceeds precipitation during the spring melt occurring from December through to March.

Figure 4-13 presents modelled monthly GR4J net catchment runoff (mm/day) during the 15-year operational period for the GoldSim Monte Carlo simulation. Results show a strong seasonal influence, with peak modelled catchment runoff occurring during winter months. There is also some fluctuation in runoff across the winter period, with lower runoff for individual winter months due to prolonged periods of below freezing temperatures, resulting in partitioning of precipitation to snowfall and higher rates of snowpack accumulation within the CemaNeige model.

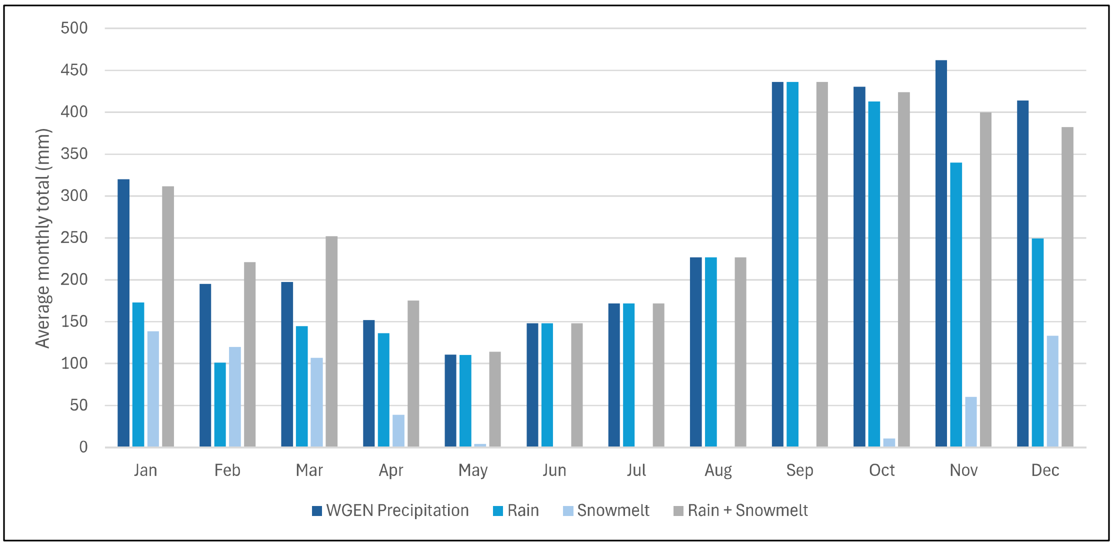


Figure 4-12: CemaNeige model results for the Project catchment showing total precipitation per month (rain and snowfall) versus rain and snowmelt.

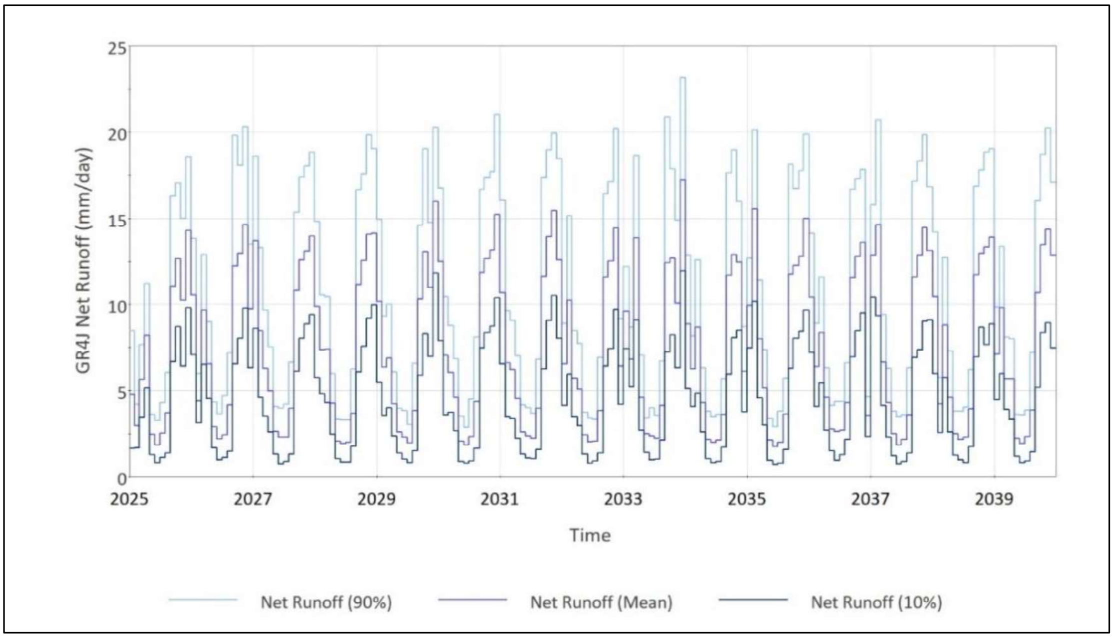


Figure 4-13: GR4J net runoff for the Project catchment (GoldSim Monte Carlo simulation)

4.3.9 Climate change

No site-specific climate change study has been undertaken for the Project site. However, a significant body of scientific research is available for Norway in general, including specific descriptions for the Vestland Region. The following is a general description of the predicted changes in climate that are relevant to this study, as outlined in the currently available public literature.

An increase in precipitation is predicted for all climate change scenarios according to Klimaservicesenter (klimaservicesenter.no, 2021), which predicts climate change precipitation impacts in the Fjordane region in 2045 to be all year median 7% for RCP4.5[12] and 8% for RCP8.5. Predicted precipitation increases are near the predicted median in summer and autumn and slightly lower in winter and spring, but increased precipitation is predicted during all seasons.

Temperature is also predicted to increase by around 2 degrees Celsius on annual basis, with slightly higher predicted temperature increase in winter and spring, which would likely result in higher snowmelt runoff.

Probabilistic Monte Carlo statistical results are presented for mean, 90th percentile and 10th percentile, to allow assessment of uncertainty in model results to climatic (precipitation) inputs. At this level of study, this is deemed sufficient to assess the uncertainty related to any potential climate change impacts during the modelled 15-year operational period. However, a site specific climate change reanalysis could be useful as the project moves forwards in order to be able to better model potential climate change impacts on the SWWB.

[12] Most climate change projections are based on a range of greenhouse gas scenarios called Representative Concentration Pathways (RCPs) developed by the Intergovernmental Panel on Climate Change (IPCC). Each RCP provides a possible emissions trajectory over time (generally up to 2100) from RCP8.5 (higher unmitigated greenhouse gas emissions) to RCP2.6 (lower greenhouse gas emissions due to aggressive mitigation efforts).

4.4 Open Pit

4.4.1 Pit inflows

Pit wall runoff

Precipitation that falls in the pit catchment area runs off to the pit sump in the base of the open pit.

A runoff coefficient was applied to the rainfall and snowmelt output from the CemaNeige model to produce runoff from the pit walls.

The assumed runoff coefficient (ratio between surface runoff generated from a given amount of rainfall over the area) can vary depending on many factors including temperature, evaporation, precipitation rate and duration (on an individual storm basis), wall rock permeability, previous rainfall and slope gradient. However, these complex factors have been simplified and a runoff coefficient of 0.9 or 90% was assigned, owing to the very steep pit slopes and low permeability wall rocks.

Throughout the mining operational period, the open pit catchment area is mostly constant at 160,000 m^2 (reference 6, Table 3-1). It is assumed that the pit is bunded, i.e. the upgradient catchment runoff is diverted and therefore is not factored into the water balance.

Groundwater inflow

Analytical estimates of potential pit inflows were developed by SRK (2018) using the Dupuit-Thiem equivalent well methodology. Hydraulic conductivity was estimated based on literature values and previous experience at 10^{-9} m/s (between 10^{-10} m/s and 10^{-8} m/s). Groundwater inflows to the final open pit were estimated to be around 1L/s (reference 2, Table 3-1). No active dewatering is proposed, and all groundwater inflows will also runoff to the pit sump. Given that groundwater inflows are expected to be low, pit inflows to the pit sump are likely to be dominated by pit wall runoff.

4.4.2 Pit outflows

Pit dewatering

Water collected within the pit (groundwater plus surface water) is pumped to the intermediate ex-pit pond at up to 50 L/s (4,320 m^3/day). The volume of water stored within the operational pit sump is explicitly modelled within the water balance and the sump has been assigned a volume of 16,400 m^3 i.e. sized to hold the mean annual daily maximum rainfall event as defined in the Updated Feasibility Study (see Table 3-1, reference 3).

If inflows exceed the pumping capacity of 50 L/s, water is assumed to be stored within the pit until the inflow falls and the pump out rate removes the stored volume.

Ex-pit dewatering pond

It is assumed that the pumping capacity in the ex-pit pond will match that of the pumping capacity in the pit sump to the pond i.e. outflows will match inflows and therefore no storage has been modelled.

Evaporation and seepage losses

No loss of ponded water within the pit sump or intermediate sump was assumed due to evaporation or seepage as these losses are assumed to be insignificant at this stage.

4.5 Waste Rock Dump

The staged WRD footprint (Table 4-7) provided by Asplan Viak (see Table 3-1, reference 7) has been incorporated to the SWWB.

Table 4-7: WRD footprint (as defined in Reference 7 of Table 3-1)

Mine Year	Design file name (*.dwg)	WRD Area (m2)
0	-	-
1	WasteRock_01	33,173
2	WasteRock_02	68,027
3	WasteRock_03	92,694
4	WasteRock_04	106,938
5	WasteRock_05	108,291
6	WasteRock_06	169,791
14	WasteRock_07	373,644

Runoff and seepage from the WRD reports to the sedimentation pond (Section 4.6).

Runoff from the WRD is calculated using the curve number (CN) Method, driven by the rainfall and snowmelt produced by the CemaNeige model (Section 4.3.8). The CN Method produces daily responses to runoff without considering interflow or attenuation beyond one day and is appropriate for small, disturbed areas. The runoff CN is an empirical parameter used in hydrology to predict direct runoff from rainfall excess. The CN value is determined based on a number of parameters, including the type of land cover, hydrological soil group, and antecedent moisture condition (AMC). A CN value of 86 was assumed for the WRD area corresponding to TR55[13] newly graded areas (pervious, no vegetation) cover type and hydrological soil group B. The CN number is adjusted according to three AMC classes, based on 5-day antecedent rainfall i.e. wetter soils generate more runoff, dryer soil less runoff.

Net infiltration to the waste rock is calculated as:

Net Infiltration = Rainfall + Snowmelt – Runoff – Evaporation

A delay element with dispersion is then used to estimate the amount of time it takes for surface infiltration to percolate through the WRD and report as toe seepage. A lag time of 10 days and standard deviation dispersion of 1/3 lag has been assumed.

Typically, waste rock is placed relatively dry and must be wetted up i.e. breakthrough moisture content achieved, in order for infiltration to produce seepage. Uptake potential is simulated using a reservoir element in the GoldSim model and 5% breakthrough moisture content assumed.

[13] NRCS (National Resources Conservation Services) (1986) Urban Hydrology for Small Watersheds. US Department of Agriculture-NRCS. Technical Release 55 (TR-55)

4.6 Sedimentation Pond

4.6.1 Overview

The current proposed sedimentation pond design provided by Asplan Viak (see Table 3-1, reference 18) has been incorporated into the SWWB. The sedimentation pond design allows for approximately 18,600 m³ of total storage volume (Table 4-8). However, the top 9,300 m³ is a dynamic storage volume used to contain storm events and to provide flow to the gravity fed outlet pipe. Furthermore, the bottom 25% of the pond i.e. 4,650 m³, has been set aside to allow accumulation of sedimentation which will be cleaned out periodically.

The SWWB assumes:

- An upper bound for the sedimentation pond at the 50% stage level i.e. 9,300 m3. Excess water above this is discharged via the outlet pipe over the daily time-step i.e. no lag in discharge via the outlet pipe.
- A lower bound for the sedimentation pond at the 25% stage level i.e. 4,650 m^3, to allow for accumulation of sediment.

Table 4-8: Sedimentation pond sizing (as defined in Reference 17 of Table 3-1)

Mine year	Total storage volume (m^3)	Dynamic capacity above outlet (m^3)	Permanent capacity (m^3)	Pond area (m^2)	Total catchment area diverted to sediment pond (m^2)	Catchment area diverted to Engebø (m^2)	Catchment area routed to Engebødalen downstream of sediment pond and to Grytaelv (m^2)
0 to 5	18,600	9,300	9,300	7,750	300,000	170,000	190,000
6 to 14	18,600	9,300	9,300	7,750	500,000	170,000	120,000

4.6.2 Sedimentation pond inflows

The sedimentation pond will receive:

- Pumped overflow (dewatering) from the intermediate sump;
- Contact water runoff from within the catchment to the north of the project area, a sub-catchment of the Grytaelva and the catchment in which the WRD footprint is located. This includes runoff from haul roads, the mine fleet service and equipment parking areas, as well as some uncleared, natural ground; and
- Runoff and seepage from the WRD.

The current proposed WRD design will be constructed in two phases (see Table 3-1, reference 18). Catchment areas provided by Asplan Viak (Table 4-8) with runoff directed to the sedimentation pond, have been applied in the SWWB. The effective catchment area is calculated by subtracting the modelled footprint for the WRD.

Output from the GR4J rainfall-runoff model (Section 4.3.8) is used to simulate catchment runoff to the sedimentation pond.

4.6.3 Sedimentation pond outflows

The sedimentation pond provides water for mining dust suppression on haul roads in the summer months, with an assumed water demand of 757 m^3/day from April to October. This demand was estimated based on a dust suppression rate of 0.5 L/m^2 as defined for haul roads in Kissell (2003)[14] and assuming use of a surfactant which reduces the required wetting frequency to once per week. An approximate haul road area of 10,600 m^2 draining to the sedimentation pond was calculated based on the design site layout (see Table 3-1, reference 1).

Once the available storage capacity within the sedimentation pond has filled up, the overflow or decant for each timestep is discharged to the fjord.

Loss of water by evaporation from the pond surface is calculated for each timestep by multiplying the Hargreaves-Samani evaporation by the surface area of the pond (7,750 m^2).

4.7 Process Plant and Underground

An average daily rate of 1,968 m^3/day (82 m^3/hr) of fresh water make-up water will be required at the processing area and underground crushing/conveying areas for:

- Raw water make up for water loss in tailings disposal, entrainment, evaporation to dryers, etc.;
- Raw water for underground operations (underground crusher and conveyor to the plant area) for use in dust suppression;
- Potable at the plant and admin offices; and
- Fire water pumped to a 400 m^3 combined fire water/raw water transfer tank located at 84 m elevation on the haul road from where water will be available to supply the process plant by gravity at pressure in case of a fire.

The base-case SWWB assumes that the process plant demand (1,968 m^3/day) is met entirely from fjord water run through the RO water treatment plant. Alternative scenarios, where water from the sediment pond is used to offset this demand, have been analysed in the SWWB scenario analysis.

4.8 Summary of Input Parameters

A summary of the input parameters is provided in Table 4-9.

[14] Kissell, F. N. 2003. 'Handbook for Dust Control in Mining', National Institute for Occupational Safety and Health (NIOSH).

Table 4-9: Water balance key input parameters

Parameter	Value	Limitations
Precipitation	Probabilistic generation of daily data-sets using WGEN and Gryta station precipitation record corrected for undercatch.	No local meteorological station at the Project site. Undercatch correction will require validation/ further assessment once a site meteorological station is installed. Climate change expected to stay within the range of current uncertainty for the Project lifetime. However, a site-specific climate change assessment would be valuable for better understanding the impacts of climate change on the SWWB.
Temperature	Førde I Sunnfjord II station record	No local meteorological station at the Project site.
Snowmelt and catchment runoff	Lumped CemaNeige and GR4J model calibrated using the donor catchment flow record to calibrate and validate a combination of 6 input parameters (2 CemaNeige and 4 GR4J) to flow .	Applicability of donor catchment to Project catchment. Model validation limited to spot flow measurements for the Gryta catchment. Capture of automatic continuous stage data at two of the existing flow monitoring locations would allow a continuous flow record to be developed for future calibration and validation of the hydrological model.
Pit catchment area	610,000 m^2	Final footprint used as this is developed from very early in the mine life.
Pit wall runoff coefficient	0.9	Estimated for expected conditions, steep low permeability wall rocks, low evaporation.
Pit groundwater inflow	86.4 m^3/day	Based on limited site-specific hydrogeological investigation and simple analytical estimates. However, does not materially impact the balance as groundwater flows are much less significant than surface water runoff.
Process water demand	1968 m^3/day	Plant and underground water balance implemented at a conceptual level only based on high-level water flows provided by ERG.
Pit sump capacity	16,400 m^3 (sized to hold the mean annual daily maximum rainfall event)	Overtopping of the pit sump unlikely to impact the water balance assuming a suitable freeboard below the main ore pass.
Max dewatering pump rate capacity	4320 m^3/day	See above.
Intermediate sump capacity	16,400 m^3	Does not impact water balance assuming transfer pump system has equal or greater than capacity than in-pit sump pump.
Sedimentation pond capacity	18,600 m^3 total storage capacity comprising: 9,300 m^3 dynamic storage capacity 9,300 m^3 permanent storage capacity	Assumes no seepage and no material loss of volume due to freezing in the winter. Sizing is under review by Asplan Viak for impact storm event capacity but SWWB only accounts for permanent volume which is not expected to change.

Parameter	Value	Limitations
Sedimentation pond total catchment area	300,000 m^2 (from year 0 to 5) 500,000 m^2 (from year 6 to 14)	Allows for diversion of some upstream catchments around the WRD.
WRD catchment area	Staged areas calculated from (reference 7, Table 3-1)	Relies on Asplan Viak designs for WRD phases 1 to 7, reference 7, Table 3-1.
WRD runoff CN	86	Literature value. Runoff from the WRD requires validation/further assessment during operations as this parameter is material in estimating water balance flows as well as sedimentation pond sizing.
WRD breakthrough moisture content	5%	Seepage from the WRD requires validation/further assessment during operations as this parameter is material in estimating water balance flows as well as sedimentation pond sizing. In reality the mechanisms of rainfall infiltration are complex include preferred pathway flow as well as the progressive more broad-scale wetting up of the dump.
Open pit and ex-pit haul road dust suppression demand	757 m^3/day (April to October only)	Literature value only. Does not materially impact the water balance at this stage.

5 WATER BALANCE RESULTS

5.1 Overview

The SWWB was run for a 15-year operational period from 2025 to 2039, using Monte Carlo probabilistic simulation with 100 realisations to capture the sensitivity of the various water balance fluxes to the stochastically generated precipitation sequences. The SWWB outputs are reported on a monthly timestep with flow rates reported in m^3/day. Predicted flows are described below for each of the key components of the site water balance. Monte Carlo results are presented for the mean monthly value based on the 100 simulated sequences, with commentary around 90th percentile (wet case) and 10th percentile (dry case) differences only where relevant. The SWWB was also run for an alternative scenario where sedimentation pond decant is routed to the process plant as fresh make-up water, where available, and the results from this scenario are also described below.

5.2 Open Pit

Predicted mean inflows and outflows to the open pit during the 15-year operational period are shown in Figure 5-1. Predicted mean pit sump volume during the 15-year operational period is shown in Figure 5-2.

Overtopping of the pit sump is predicted for the wet scenario (Monte Carlo 90th percentile) in response to modelled peak monthly winter runoff (indicated on Figure 5-2). Although the pit sump (16,400 m^3 capacity) is sized to the mean annual daily maximum rainfall (reference 3, Table 3-1), the GoldSim model precipitation input includes adjustment for precipitation undercatch (Section 4.3.4) and also accounts for snow accumulation on the pit benches during winter and subsequent snowmelt reporting to the base of the pit. However, overtopping of the pit sump does not have an outlet in the model (indicated Figure 5-1) as it is assumed that sufficient freeboard exists between the sump maximum level and the ore pass to accommodate storm accumulations. This assumption should be reconfirmed.

The objectives of the updated SWWB did not include operational sump sizing. However, further sump sizing analysis and trade-offs could easily be undertaken using the updated SWWB, outputting on a daily time step.

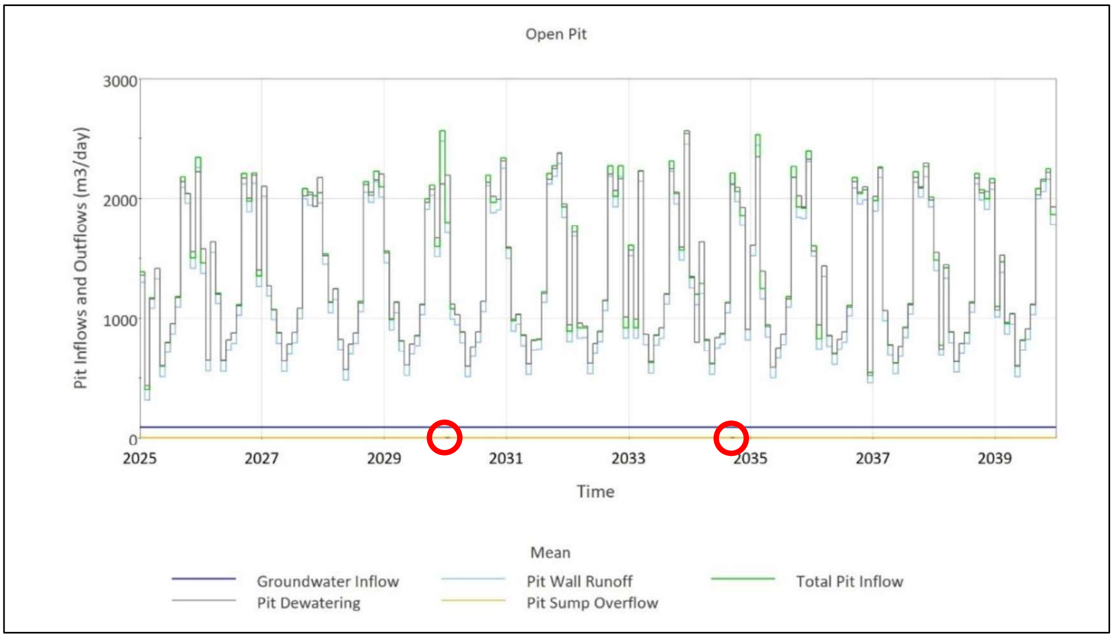


Figure 5-1: Modelled monthly mean inflows and outflows to the open pit over the 15-year operational period

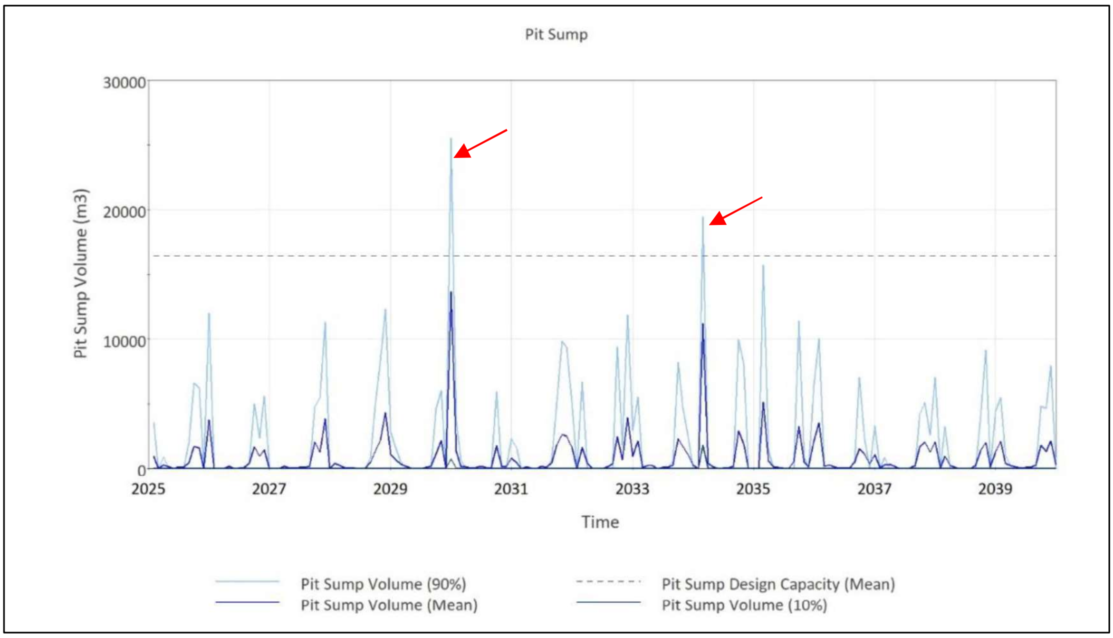


Figure 5-2: Modelled monthly pit sump volume over the 15-year operational period

5.3 WRD

Predicted mean inflows and outflows to the WRD during the 15-year operational period are shown in Figure 5-4.

Net infiltration to the WRD shows a strong seasonal response, with peak modelled infiltration occurring during winter months. Infiltration, runoff and seepage flows increase as the WRD footprint increases over time. Modelled net infiltration to the WRD is around 57% of annual rainfall and snowmelt, which is consistent with literature values for bare, loosely-dumped rock dump material (Williams, 2008)[15].

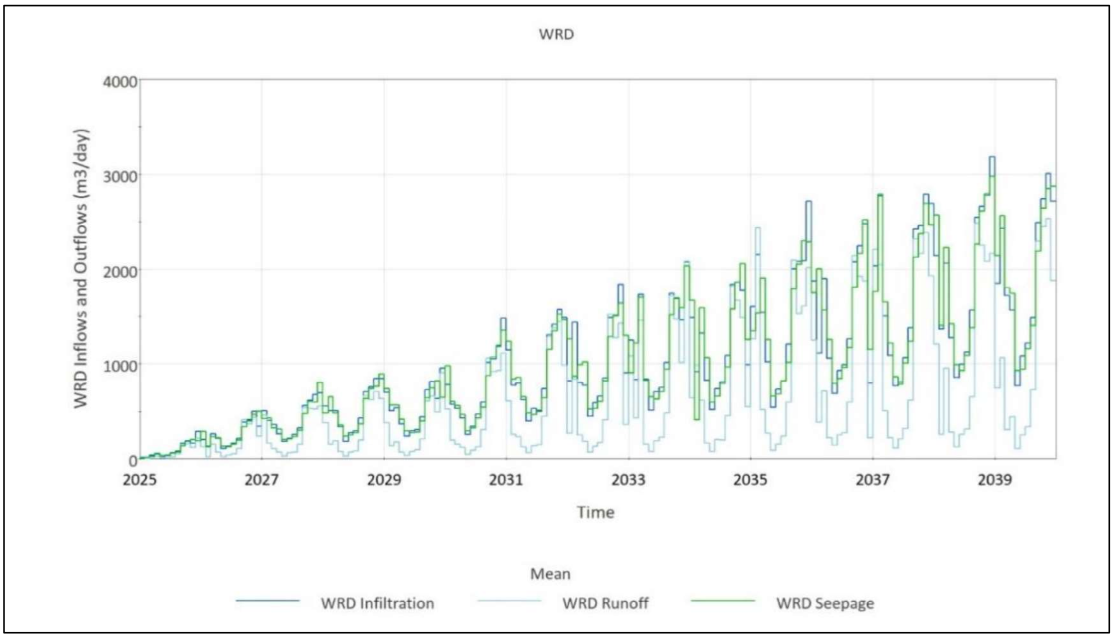


Figure 5-3: Modelled monthly mean inflows and outflows to the WRD over the 15-year operational period

5.4 Sedimentation Pond

Figure 5-4 and Figure 5-5 show the main modelled inflows and outflows to the sedimentation pond under mean conditions.

[15] Williams, DJ & Rohde, TK 2008, 'Rainfall Infiltration Into and Seepage From Rock Dumps — A Review', in AB Fourie (ed.), Rock Dumps 2008: Proceedings of the First International Seminar on the Management of Rock Dumps, Stockpiles and Heap Leach Pads, Australian Centre for Geomechanics, Perth, pp. 79-89, https://doi.org/10.36487/ACG_repo/802_7

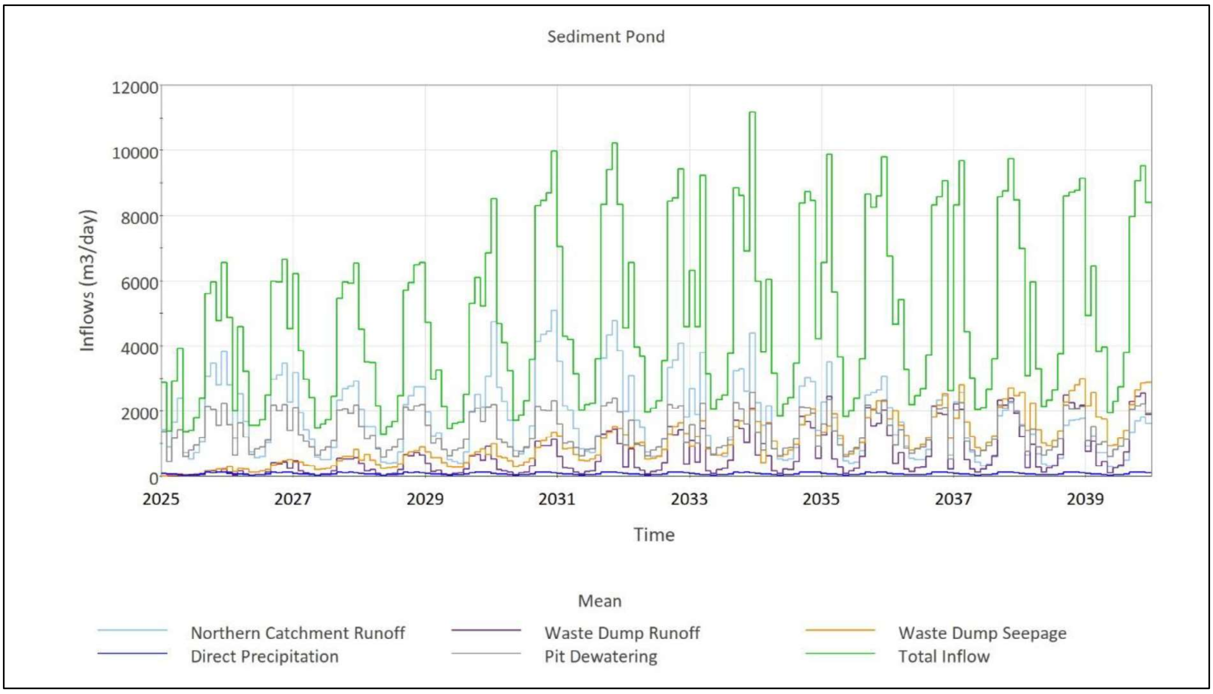


Figure 5-4: Modelled inflows to the sedimentation pond over the 15-year operational period

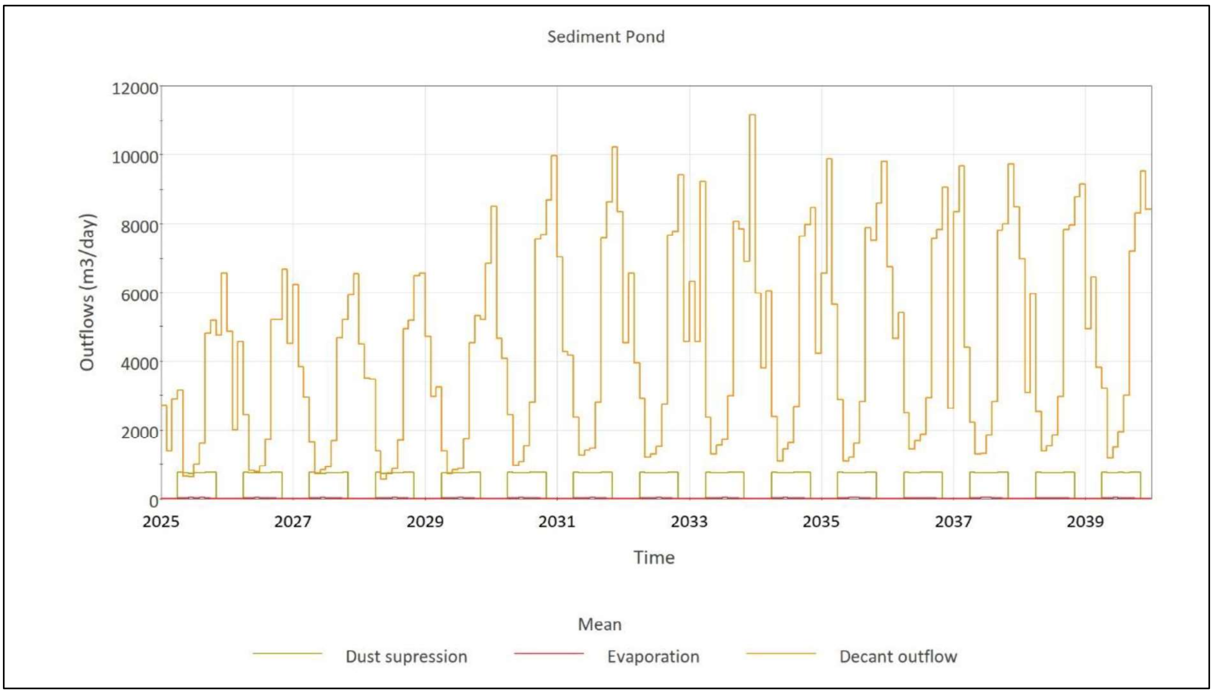


Figure 5-5: Modelled outflows from the sedimentation pond over the 15-year operational period

A key component of the sedimentation pond balance is decant (outflow) to the fjord, which is shown for mean, dry and wet scenarios in Figure 5-6. Results show a strong seasonal influence, with peak modelled decant occurring during winter months.

Decant volumes are highest between September and January. This is consistent with the climate analysis (Section 4.3) with higher precipitation recorded between September to December and modelled snowmelt contributing to runoff between November and March. Modelled decant from the sedimentation pond is lowest between April and July, with May having the lowest decant. Rainfall and therefore runoff reporting to the sedimentation pond is lower over the drier summer months.

During the second phase of WRD construction (year 6 to 14), a larger catchment area (and therefore higher runoff) reports to the sedimentation pond. Modelled decant reflects this with an uplift in monthly decant rate after 2029 (year 6) of ~25%.

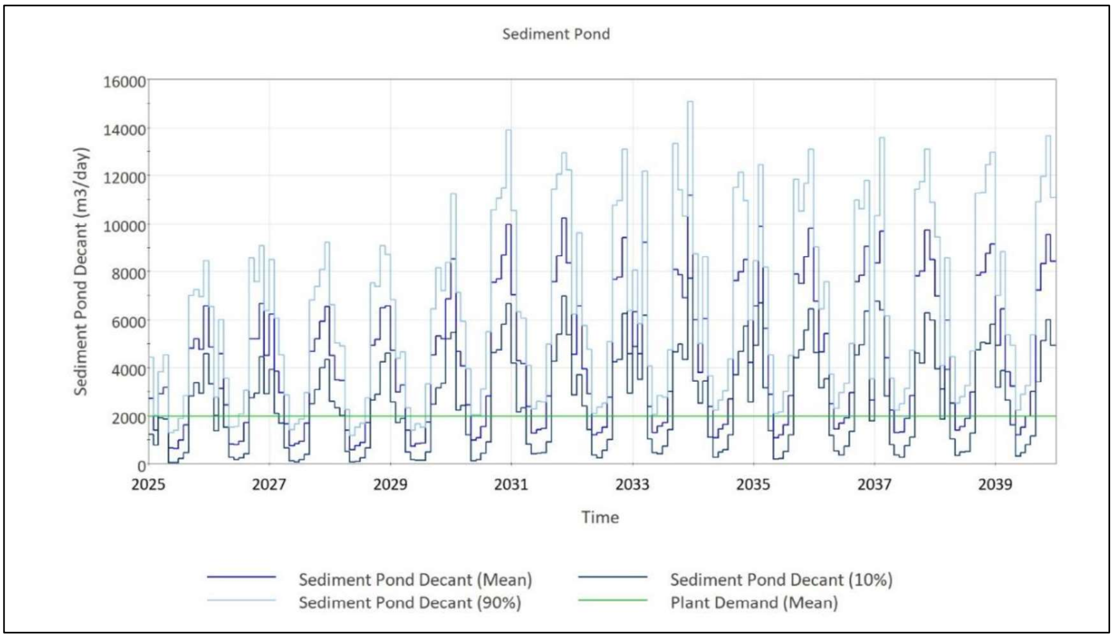


Figure 5-6: Sedimentation pond decant to the fjord over the 15-year operational period for mean, dry and wet precipitation conditions

5.5 Plant and Underground

Flow to the process plant, which includes water used for underground dust suppression, remains constant at the required demand of 1968 m^3/day throughout the 15-year operational period in the base-case scenario. This is because the plant demand in the base case SWWB is fed from the fjord through the reverse osmosis plant with a capacity of 2400 m^3/day (100 m^3/hr). This water is fed via the plant raw water tank which remains constant on a monthly basis, throughout the 15-year operational period.

5.6 Scenarios

5.6.1 Reuse of sediment pond decant for plant water supply

Results for decant (overflow) from the sedimentation pond in the base case SWWB in Figure 5-6 are shown compared to the mean monthly plant make up water demand of 1968 m^3/day. Each year the modelled mean monthly sedimentation pond decant rate exceeds plant demand between September and March. During late spring and summer months (April to August) plant demand is partially met by modelled mean decant.

The GoldSim water balance was used to further investigate a scenario whereby decant from the sedimentation pond is sent to the plant up to the rate required (1968 m^3/day) with any surplus beyond that continuing to be discharged to the fjord. The results of this in terms of RO demand for dry (10th percentile), mean and wet (90th percentile) conditions are shown in Figure 5-7. Base case RO demand of 1968 m^3/day throughout is shown as a red dashed line.

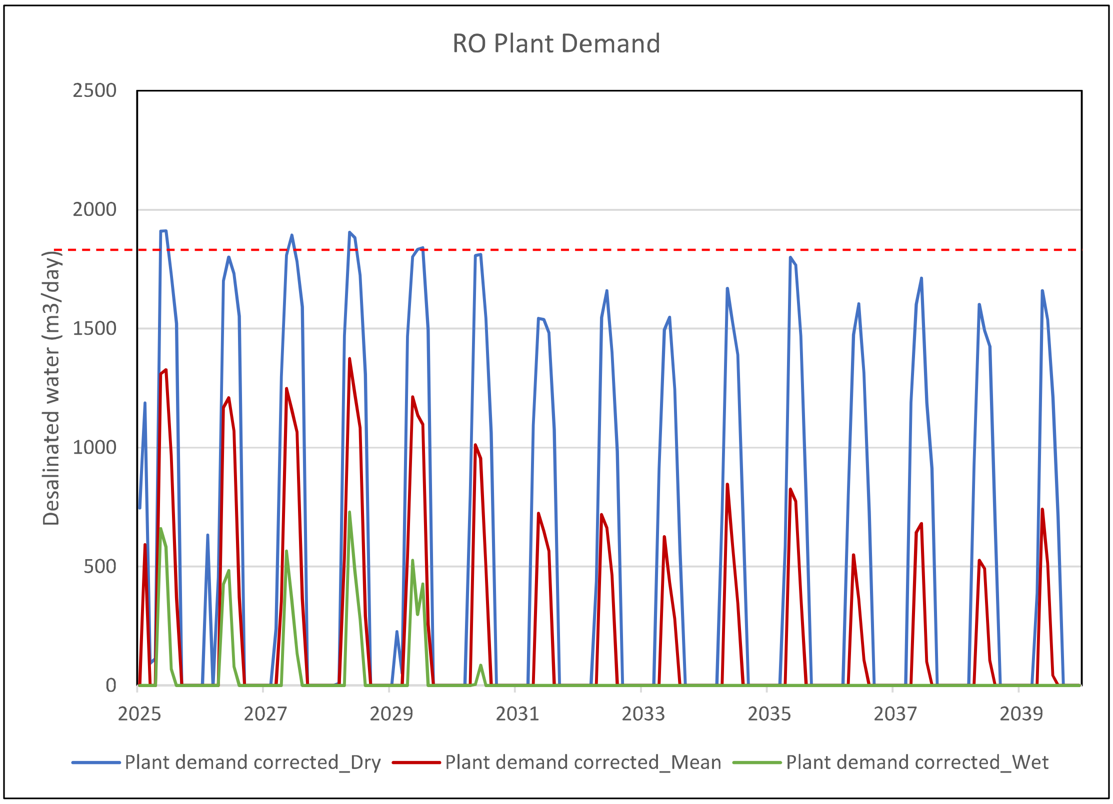


Figure 5-7: Reverse osmosis demand when using sedimentation pond decant water for dry, mean and wet conditions (base case demand shown as a red dashed line)

The results show that if sedimentation pond decant were to be used for plant water supply make-up water, where available, it would reduce the average plant water demand from RO over the 15-year operational period by an average of 85% under mean precipitation conditions. This scenario would commensurately reduce discharge to the fjord.

From a water stewardship and water accounting point of view, surplus discharge to the fjord represents the conversion of Type 1 water (high quality) into Type 3 water (saltwater). Therefore, reuse of this water and offset of RO throughput is highly preferable. This is in addition to the obvious operational cost savings and reduction in energy use/carbon footprint resulting from the significant reduction in RO throughput.

In terms of technical feasibility, running an offtake to the plant raw water tank could be straightforward and would likely comprise a simple valved offtake from the sedimentation pond decant channel to an additional storage pond or tank near the plant. With the plant located at around 20 masl and the sedimentation pond decant invert located at around 110 masl, the offtake to the plant could be gravity fed.

In summary, the justification for reuse of sedimentation pond decant in the plant is highly favourable from both a cost, feasibility and environmental stewardship point of view. ERG are currently looking into the technical feasibility of using sedimentation pond decant in the process.

6 CONCLUSIONS

SRK has developed a SWWB for the Engebø Rutile and Garnet project in the GoldSim software platform. The SWWB model considers the operational phase of the Project only.

Probabilistic Monte Carlo statistical results are presented for the mean, 90th percentile and 10th percentile, to allow an assessment of uncertainty in the model results to precipitation inputs. At this level of study this is also deemed sufficient to assess uncertainty related to any potential climate change impacts during the 15-year operational period.

The key findings are as follows:

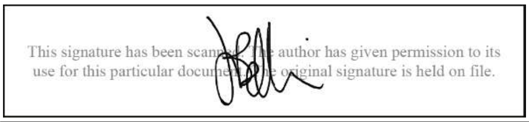
- The current planned pit sump volume is predicted to overtop under the wet scenario (Monte Carlo 90th percentile). The pit sump is sized to the mean annual daily maximum rainfall. However, the GoldSim accounts for precipitation adjusted for undercatch and snow accumulation on the pit benches during winter and subsequent snowmelt, which does not appear to have been accounted for in the current design. It is assumed that overtopping of the pit sump would not reach the ore pass but this should be confirmed.
- The sedimentation pond decant shows a strong seasonal influence, with peak modelled decant occurring during winter months. Decant volumes are highest between September and January, peaking in November and December. Modelled precipitation and runoff reporting to the sedimentation pond is highest for these months. Modelled snowmelt contributes to runoff between November and April. However, the Gryta catchment is a non-glacier catchment and as such no significant 'freshet' spring melt event is evident.
- During the second phase of WRD construction (year 6 to 14), a larger catchment area (and therefore higher runoff) reports to the sedimentation pond. Modelled decant reflects this with an uplift in monthly decant rate after 2029 (year 6) of ~25%.

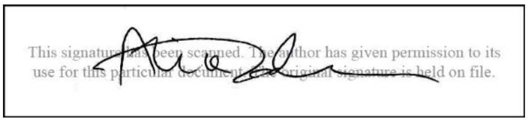
- The site water balance is in excess each year, such that sedimentation pond decant water would be available for raw water make-up, if required, at up to the same rates as are predicted to decant to the fjord. The SWWB was used to further investigate this scenario whereby decant from the sedimentation pond is sent to the plant up to the rate required (1968 m^3/day) with any surplus beyond that continuing to be discharged to the fjord.
- Model results indicate that if sedimentation pond decant were to be used for plant water supply make-up water, where available, it would reduce the average plant water demand from RO over the 15-year operational period by an average of 85% under mean precipitation conditions. This scenario would commensurately reduce discharge to the fjord.

7 RECOMMENDATIONS

- The SWWB could be used to further optimise the operational pit sump design volume, if required.
- The SWWB could be used to further optimise a decant to the plant raw water circuit, if required.
- A review and update of the SWWB model is recommended to incorporate new baseline monitoring data and refined inputs (when available) for the Project.

For and on behalf of SRK Consulting (UK) Limited





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