PROBABILISTIC MODELING OF OPERATIONAL DYNAMIC WATER BALANCE SYSTEM FOR A MINING FACILITY

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PROBABILISTIC MODELING OF OPERATIONAL DYNAMIC WATER BALANCE SYSTEM FOR A MINING FACILITY

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ABSTRACT

PROBABILISTIC MODELING OF OPERATIONAL DYNAMIC WATER BALANCE SYSTEM FOR A MINING FACILITY

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Water management in any environment is quite difficult and complex not only because of the effort that is required to comply with the environmental regulations but also due to the dynamic nature of the system not well suited for the deterministic approaches. As a result, probabilistic approaches are developed to make decisions that can actually represent the uncertainties quantitatively as probability distributions. Such methods, considered to be the best practice in mining industry, are very useful to make design planning and management decisions as we predict an ensemble of probable outcomes and to develop strategies minimizing the associated risks.

In this thesis, probabilistic simulation is conducted for the purpose of evaluating the dynamic water balance system for one of the mining facilities, called heap leach, by using a software program called GoldSim, which uses the Monte Carlo simulation to model the dynamic systems quantitatively to represent the uncertainties in the systems.

Primary objectives of this water balance model are to evaluate the ponds capacities and the external makeup water demand during the heap leach operation. The probabilistic model simulations showed that the current ponds have the capacity to accommodate the solution being circulated at the heap leach facility and no overflow would be expected at the storm pond. The model results also show that the external makeup water demand during the operation life of the proposed heap leach facility is estimated to be around 80 m^3/hr (22 L/s) from 2nd to 8th year of the operation, at the 95th percentile.

Key Words: Probabilistic Simulation, Mine Water Balance, Mine Water Management

ÖZ

MADEN TESİSİ İÇİN OPERASYONEL DİNAMİK SU DENGE SİSTEMİNİN OLASILIKSAL MODELLENMESİ

Pelenk, Ümit Giray
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Su yönetimi, sadece çevresel yönetmeliklere uyum sağlamak için harcanması gereken çabadan değil, aynı zamanda deterministik yaklaşımlar için fazla uyumlu olmayan dinamik bir sistem olması sebebiyle bütün çevre koşullarında oldukça zor ve karmaşıktır. Bu sebeple, belirsizlikleri olasılık dağılımları ile nicel olarak temsil edebilen kararlar verebilmek amacıyla olasılıksal yaklaşımları geliştirilmiştir. Madencilikte en iyi uygulama yöntemi olarak kabul edilen bu yaklaşımlar, muhtemel sonuçları öngörerek tasarımsal planlamalar ve yönetim kararları almada ve ilgili riskleri en aza indirgeyen su yönetimi stratejilerini geliştirebilmede oldukça yararlıdır.

Bu tezde, maden ünitelerinden biri olan yığın liç tesisi için dinamik su denge sisteminin değerlendirilebilmesi amacıyla olasılıksal simülasyon gerçekleştirilmiştir. Sistemdeki belirsizlikleri kantitatif olarak temsil ederek dinamik sistemin modellenmesinde Monte Carlo simülasyonunu kullanan GoldSim programı tercih edilmiştir.

Bu su balansı modelinin öncelikli hedefi, operasyon sırasında havuzların kapasitelerini ve harici ham su talebini değerlendirebilmektir. Olasılıksal model simülasyonları, mevcut havuzların yığın liç tesisinde dolaştırılan çözeltiyi muhafaza etme kapasitesine sahip olduğunu ve fırtına havuzunda taşma beklenmediğini göstermektedir. Model sonuçları ayrıca planlanan yığın liç tesisinin işletme ömrü

boyunca harici ham su talebinin işletmenin ikinci ve sekizinci yılları arasında 95. persentilde yaklaşık 80 m^3/saat (22 L/sn.) olacağını göstermiştir.

Anahtar Kelimeler: Olasılıksal Simülasyon, Maden Su Dengesi, Maden Su Yönetimi

TO MY FAMILY

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Lastly and most importantly, I am very grateful to my family, who continuously supported me, and especially my wife, Meryem, and four-year old son, Arel, for being very patient when I was devoting my time I could be with them to this study.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

CHAPTER 1

INTRODUCTION

Making predictions to manage water in any environment is not easy especially if the system input parameters include more than one variable and these variables inherently possess uncertainties. When there are uncertainties, the best way to make quantitative predictions is to express the uncertainties in terms of probability distributions. A probability distribution is a mathematical representation of the relative likelihood of an uncertain variable having certain specific values (GTG, 2018).

Alternative to the probabilistic approaches, deterministic approach can also be used for water balance and water management problems. Although developing water balance deterministically (by using a single value for each variable) is relatively much simpler than using probabilistic approaches, it can be extremely misleading, be difficult to defend, and not be prone to the sensitivity analyses (GTG, 2018).

It should be noted that both probabilistic and deterministic approaches can model the same process. However, probabilistic analysis has an advantage over deterministic analysis to reveal more information because it can explicitly incorporate uncertainty in the form of numbers (Kirchsteiger, 1999).

In one study, Long et al. (2017) studied a better design instruction for waste stabilization ponds by analyzing more than 150 articles, books, and reports from 1956 to 2016 considering several approaches. Uncertainty analysis was one of the approaches that was investigated by making comparisons against deterministic approach. It was concluded that designs that would consider the probabilistic approaches would quantify the uncertainties by including prior uncertainty of inputs and parameters and that they would generate more scientifically reliable outcomes for decision makers (Long et al., 2017) due to being more innovative and economic tools suitable for dealing with large variations in the systems.

Deterministic and probabilistic approaches were also compared based on their performance by Fan et al., (2016) in their hydrological forecasting study for the optimization of the hydropower reservoir. The results suggested that the use of stochastic optimization combined with ensemble forecasts would provide a significantly higher level of flood protection without compromising the energy production.

In one study performed as part of the Flood Operation Simulation Model by Seqwater (2014), flood mitigation performance was assessed by floods from stochastically derived rainfall events. The study revealed that the applied method could differentiate different flood operations considering the dam safety and failures.

In another study performed in north-western Turkey for the Yuvacık Dam Reservoir by Uysal et al. (2014), Ensemble Prediction System, which can provide support with the operators to forecast the maxima and minima of the reservoirs levels, was used. Deterministic and probabilistic streamflow forecasts were used in the reservoir model and comparison of both methods were made. It was concluded that probable scenarios would provide risk ranges better compared with the deterministic one.

Similar study was conducted by Mediero et al. (2010) to determine the best gate operation strategy during a flood events. Probabilistic inflow discharges are estimated by rainfall–runoff forecast module and taking the initial conditions into account at any time step, best reservoir operation strategy is determined.

Considering all these studies and examples, it can be said that probabilistic approaches have more advantages over deterministic analysis for being able to provide more information, represent the uncertainties quantitatively and reveal the risks inherent in the complex systems.

In this thesis, probabilistic water balance is holistically developed for one of the facilities (heap leach facility (HLF)) of a proposed gold mine project located in western Turkey.

Heap leaching is a mining process used to extract metals from ore using a series of chemical reactions that absorb specific minerals. It is considered as a better alternative to conventional processing methods such as flotation, agitation, and vat leaching (Petersen, 2002). Heap leach facility designs are generally subdivided into three major categories: permanent conventional leach pad, valley-fill leach and reusable leach pad (Bleiwas, 2012). At the time of writing this thesis, examples for active heap leach operations in Turkey are Kışladağ/Tüprag, Çöpler/Anagold, Altıntepe/Bahar, and Himmetdede/Koza, and there are several projects including heap leach facility that are under construction, such as; Öksüt/Öksüt and İvrindi/Tümad, all of which are permanent conventional leach pads.

In heap leach facilities, cyanide is most commonly used to recover the gold from the ore and with increasing usage of this chemical in the world mining industry, the Cyanide Code, a voluntary industry program for mining companies to improve the management of cyanide, is developed (ICMC, 2019). The Code is used with the objective of improving the management of the cyanide and assisting in the protection of human health and the reduction of environmental impacts. It represents the best practice for management of cyanide used in the mining industry. Signatories of the Code commit to follow its Principles and Standards in the use of cyanide and one of the Standard of Practice (4.3) is to implement a comprehensive water management program to protect against unintentional releases. Within this best practice, the water balance is recommended to be probabilistic in nature, taking into account the uncertainty and the variability inherent in the prediction of precipitation patterns.

In line with the best practice requirement of the Cyanide Code, the objective of this study is to perform probabilistic simulation model of the dynamic water balance system for the heap leach facility of a proposed gold mine project in western Turkey.

Due to confidentiality obligations, project name is not disclosed but project public information and data is presented upon permission of the project owner.

1.1. Background

A computer program called GoldSim (GTG, 2018) was selected to model the dynamic water balance system probabilistically by using the Monte Carlo simulation. GoldSim is a highly graphical and object-oriented software which is one of the most commonly used tools for probabilistic simulations of mine water balance and mine water management. It supports decision-making and risk analysis by simulating future performance while quantitatively representing the uncertainties and risks inherent in all complex systems to evaluate and compare alternatives to be able to minimize risks, optimize performances, and make better decisions in an uncertain world (GTG, 2019).

The following features makes the GoldSim approach unique (GTG, 2019):

- addressing uncertainties in real-world systems,
- superimposing the occurrence and consequences of discrete events onto continuously varying systems,
- facilitating the construction of complex models,
- being dimensionally-aware,
- being highly extensible, and
- creating compelling presentations of the model.

GoldSim is used for a wide range of diverse applications. Most GoldSim applications fall into one of the following three categories (GTG, 2019);

- environmental systems,
- business systems, and
- engineered systems.

Within the environmental systems; there are examples of using GoldSim for water resources, mine water and waste, radioactive/hazardous waste, energy, ecological, biological and human health risks.

Projects that include water management would most likely involve components that are interrelated and driven by stochastic variables; such as precipitation, temperature, evaporation, water demand, and involve uncertain processes, parameters, and events.

The software is particularly well-suited to applications in the mining industry by allowing the user to create realistic models of mine systems in order to carry out risk analyses, evaluate potential environmental impacts, support strategic planning, and make better resource management decisions (GTG Mining, 2017). GoldSim software has been extensively used in the Mining Industry around the world. The following paragraphs provide a number of examples utilizing GoldSim for probabilistic simulations (GTG Mining, 2017):

For a Diamond Mine in Canada (De Beers, 2013), GoldSim was used to simulate the site-wide water quality conditions and mass loadings to the system during the operation and the closure stages of the project. Groundwater flow and geochemical models were integrated into the GoldSim model to simulate the movement of solutes, derived from mining units.

For a Phosphate Mine in United States (GTG Mining, 2017), GoldSim was used to simulate water management and express the nutrient levels in water and soils. The main objectives of the model were to estimate the probability of the mine to discharge water from the mine and the nutrient levels to exceed regulation limits. Results indicated that the model accurately predicted discharge probabilities and levels by simulating the water management decisions throughout the mine. Additionally, pond water levels were also predicted during varying hydrologic scenarios, result of which were used to improve management decisions.

For a Uranium Mine in Germany (Kahnt, R. & Metschies), GoldSim was used to assess the alternative strategies for the reclamation and closure. The closure concept was to cease pumping water from the mine and allow the regional groundwater in the area to slowly return to the pre-mining levels. It was concluded that the oxidized minerals in the mine workings were expected to generate acidic water with dissolved metals and other contaminants for a long time that could impact local groundwater wells and surface waters once the water level approached steady-state conditions.

For a mine in Tasmania (GTG Mining, 2017), GoldSim was used to address the current and future water management issues through the development of predictive models that allowed an assessment of different water management scenarios, taking into account surface water and groundwater inflows into the pits. A site-wide water balance model was constructed to represent the existing surface water management at the site. The model considered rainfall, evaporation, evapotranspiration, infiltration and the movement of surface water around the site.

For a mine in Peru, GoldSim was used to make predictions about the water quality for different mine components by integrating mine waste characterization results and mine water balances. The program was used to realize the conceptual understanding of each aspect and to provide mine scale water quality projections (Usher et al., 2010)

For a proposed Gold Mine (Öksüt) in Turkey, GoldSim was used to simulate the performance of the heap leach facility and site-wide water management by using similar stochastic analyses and weather generator components for generating daily precipitations (Citrus, 2016).

In conclusion, GoldSim has been used in the mining industry around the world for water balance and water management studies, to support environmental compliance and permitting, and for evaluation of mine development, expansion, remediation and closure plans.

CHAPTER 2

CONCEPTUAL MODEL OF THE OPERATIONAL SYSTEM

First step in building a realistic and useful numerical model is conceptualizing the system through representing the features, processes and events quantitatively at a level of detail appropriate for the objective of the study. As stated previously, the water balance is developed for the heap leach facility of a proposed gold mine project in western Turkey. Water balance in any system have inflows and outflows, and if these two elements are not in balance, there is a change in storage. Water balance of a heap leach facility is not any different. Because it is a dynamic system, which means that the system changes and evolves continuously with time, so does the change in storage.

Primary objectives of developing the water balance model for the proposed heap leach facility are to evaluate the ponds' capacities and the demand for make-up (raw) water from external sources during the operation. Basic flow diagrams with the system components, model input values and assumptions made in the model are presented in the following sections.

2.1. Flow Diagram & System Components

Flow Diagram of the Water Balance System for the Heap Leach Facility that is the subject of this thesis is presented in Figure 2.1.

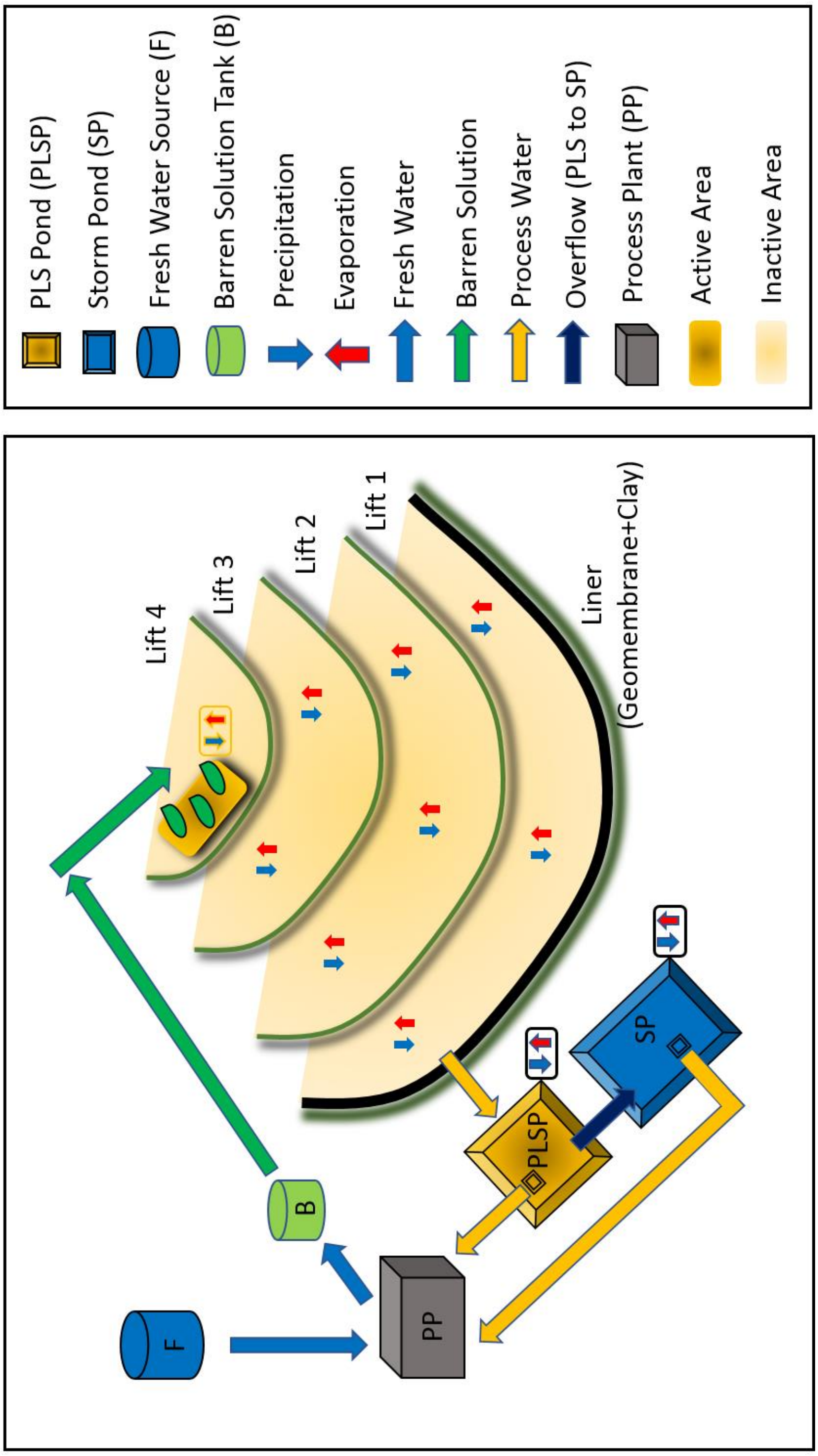

Figure 2.1. *Flow Diagram of the Water Balance System for the Heap Leach Facility*

Inflows to this system are the fresh water required to feed the system, necessity of which will also be discussed and determined in the following section, and the precipitation. Outflow from this system is nothing but the evaporation. It is assumed that no seepage would take place through the foundation of the facility and the ponds. The most important factor in such water balance systems, however, is determining the representative values for inputs, outputs and the system parameters.

System Components would be better understood if the heap leach process shown in Figure 2.1 is simply described. Heap leach process consists of stacking crushed ore on the leach pad in lifts and leaching each lift to extract the metals. Barren solution containing dilute sodium cyanide is applied to the specific area on ore heap surface using drip emitters and/or sprinklers at a design application rate. Application area is called the active area and the remaining areas are called the inactive areas. The barren solution would percolate through the ore to the drainage system above the pad liner. According to the Mining Waste Regulation (MWR, 2015) in Turkey, the liner system must consist of clay, having a minimum thickness of 50 cm compacted at least in two layers and a permeability less than 10^{-9} m/s, and High-Density Polyethylene (HDPE) geomembrane. At the liner pad, the solution would be collected in a network of perforated drain pipes embedded within the drainage layer above the liner. As the cyanide solution percolates through the heap the metals are dissolved into it. This solution is termed the Pregnant Leach Solution (PLS) once it contains precious metals. The PLS drains by gravity from the heap leach into the transfer pipes and ultimately to the PLS pond (PLSP). PLS collected in the PLSP is pumped to the Process Plant (PP) to extract the metals. In the case of major storm events, PLS may overflow from the PLSP to the Storm Pond (SP), which would prevent any unintentional cyanide release out of the system. Solution that is collected in SP would be pumped back to the PP and then on to the heap leach again.

In the heap leach water balance, the objective is to make sure that PLS is circulated between the heap, ponds, and process plant, with no discharge (no overflow from the SP) by considering the system gains (precipitation and raw water supply if/when required) and losses (evaporation).

2.2. Model Input Data

Model input data in the water balance system for the heap leach facility that is the subject of this thesis is described in the following sections:

2.2.1. Climate Data Sets

Climate components have the largest uncertainty in the water balance systems. For the water balance model of heap leach facility; precipitation, temperature and evaporation data are primarily necessary. There is no meteorological station at the project site for climate data records. For this reason, the closest meteorological stations to the project area were determined, and their available daily data were acquired from the Turkish State Meteorological Service (MGM).

A summary of information for the meteorological stations is provided in Table 2-1.

Daily precipitation, temperature and evaporation data periods for the selected meteorological stations are presented in Table 2-2 (MGM, 2019a).

The proposed heap leach site is located in between these stations at an elevation of around 500 meters above sea level.

Table 2-1. *Summary Information for the Selected Meteorological Stations*

Station ID	Station Name	Latitude	Longitude	Elevation	Elevation Difference (m) From Site
17722	Burhaniye	39.4983	26.9755	20	-480
17145	Edremit	39.5895	27.0192	21	-479
18432	İvrindi	39.5914	27.4939	240	-260
17158	Akçaldede R. (Balya)	39.7401	27.6180	631	+131

Table 2-2. *Daily Data Periods for the Selected Meteorological Stations*

Station ID	Station Name	Precipitation	Temperature	Evaporation
17722	Burhaniye	2005-2018	1974-2018	Not Available
17145	Edremit	1959-2018	1959-2018	1962-2018
18432	İvrindi	2013-2018	2013-2018	Not Available
17158	Akçaldede R. (Balya)	2005-2018	2004-2018	Not Available

Burhaniye, İvrindi and Akçaldede Radar meteorological stations are used to generate precipitation and temperature data whereas Edremit station is used to generate evaporation data for the proposed heap leach site. For precipitation and temperature, common data periods are used to determine the relationship between the data records and to compare the similarity of the trends that the stations have.

It should be noted that Edremit station has the longest precipitation data, from 1959 to 2018. However, first three-year period has missing data so the data between the years 1962 and 2018 are used to investigate the long-term precipitation regime near the study area by plotting the total annual precipitation, mean annual precipitation and cumulative deviation from mean annual precipitation for the Edremit station, as presented in Figure 2.2. Cumulative deviations from mean annual precipitations for Burhaniye, İvrindi and Akçaldede stations are also shown on the same graph for comparison.

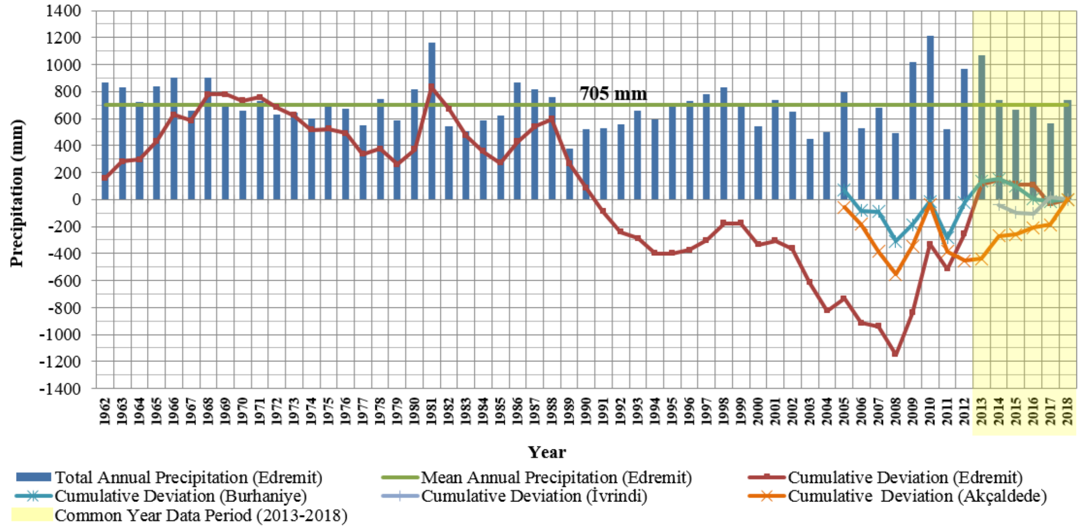

Figure 2.2. *Total Annual Precipitation and Mean Annual Precipitation for the Edremit Station together the Cumulative Deviations from Mean Annual Precipitations of the Edremit, Burhaniye, İvrindi and Akçaldede Stations*

For the 1962-2018 period, with 377 mm of total annual precipitation the year 1989 was the driest year, and with 1213.7 mm of total annual precipitation the year 2010 was the wettest year. The long-term mean annual precipitation for the Edremit station is estimated as 705 mm. Investigation of cumulative deviation from mean annual precipitation for the Edremit Station shows that 1970-1979, 1982-1985, 1989-1994, 2000-2008 years correspond to the dry period and 1962-1969, 1980-1981, 1986-1988, 1995-1999, 2009-2013 years correspond to the wet period.

It is seen that cumulative deviations from mean annual precipitations for Burhaniye, İvrindi and Akçaldede stations have similar trends to the Edremit station for the periods the stations have been in operation. It can also be said that from 2005 to 2018, during the period Burhaniye and Akçaldede stations were in operation, bot dry and wet periods were experienced.

Edremit station (located at elevation 21 m above sea level) is not taken into consideration to generate the project site precipitation data. Instead, Burhaniye station (located at elevation 20 m above sea level) is selected to represent the near sea-level precipitation data. The main reason is that Edremit station has the highest precipitation data among the meteorological stations in Balıkesir Province (Kızılçaoğlu, 1998). It can be seen from Figure 2.3 that annual total precipitation for Edremit station has the highest values during 2005-2013 period. During this period, Burhaniye station, which is closest to Edremit Station and has the same elevation, received significantly less precipitation. This analysis indicates that Edremit station does not represent the regional precipitation pattern. It is possibly related to the topographical characteristics near Edremit, and due to frontal boundaries resulting in high frontal precipitations in Edremit (Kızılçaoğlu, 1998). For this reason, precipitation data for the Edremit station is not used in the precipitation data generation for the project site.

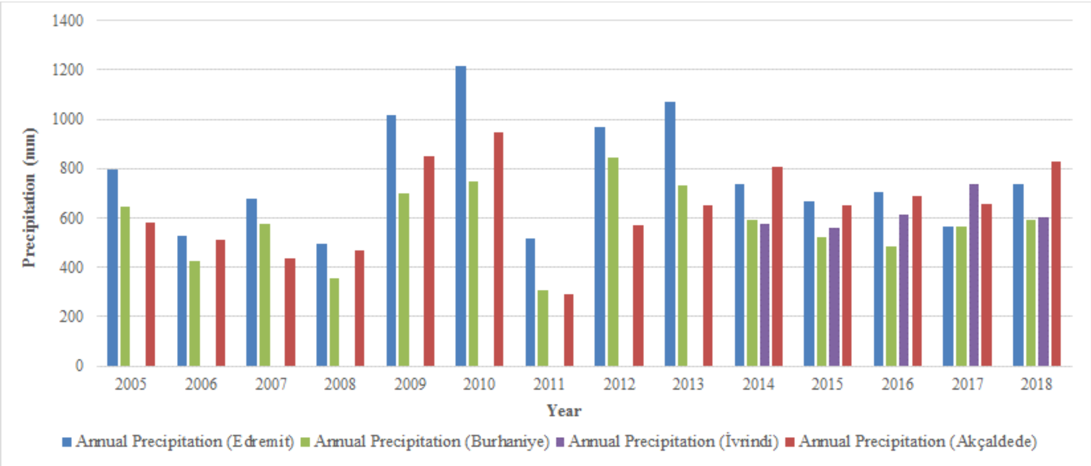

Figure 2.3. *Annual Total Precipitation Amount for the Stations between 2005-2018 Period*

Monthly and annual precipitation amounts for the common period between 2013 and 2018 for Burhaniye, İvrindi and Akçaldede Radar stations are presented in Table 2-3.

Table 2-3. *Monthly and Annual Total Precipitation Amounts for the Stations for Common Data Period (2013-2018)*

Month	**Monthly and Annual Total Precipitation Amounts (mm)**		
	17722 - Burhaniye	**18432 - İvrindi**	**17158 - Akçaldede**
January	125	109	100
February	78	50	71
March	69	74	87
April	42	45	57
May	23	59	56
June	29	51	62
July	8	14	17
August	1	7	15
September	11	16	27
October	53	50	65
November	84	73	75
December	58	57	83
ANNUAL	**582**	**606**	**713**

Because the proposed heap leach site is located within the elevation range of these stations, precipitation and elevation relationship is determined by linear interpolation and used to construct the precipitation data for the proposed heap leach site. The relationship between Elevation and Total Annual Precipitation is presented in Figure 2.4. The results show a high coefficient of determination value (R^2=0.96) and an increase in average annual precipitation with elevation, in the order of 22.3 mm per 100 m of elevation gain. Based on this graph the proposed heap leach site would have an annual precipitation value of 679 mm.

In addition to the annual precipitation, by using the same method, monthly precipitation values were used to construct the monthly precipitation data for the project area. As it is presented in Table 2-4, the estimated precipitation values for the project area ranges from 12 mm at minimum in August to 103 mm at maximum in January. Relationships between elevations and total monthly precipitations are presented in Appendix A-1.

By using the daily precipitation data of the stations selected in the vicinity of the project area for common year data period (2013-2018), relationships were built between the stations and were used to generate not only the monthly and annual precipitation amounts, but also the daily precipitation amounts for the project area. Due to being at relatively similar elevation, daily precipitation data of the Akçaldede Radar station (Station ID: 17158) is factored (daily values were decreased by 5.08%) to estimate the daily precipitation data for the project site for the operation period of the Akçaldede Radar station (2005-2018). Daily precipitation data was used to generate the probabilistic precipitation as described in Section 2.2.2.

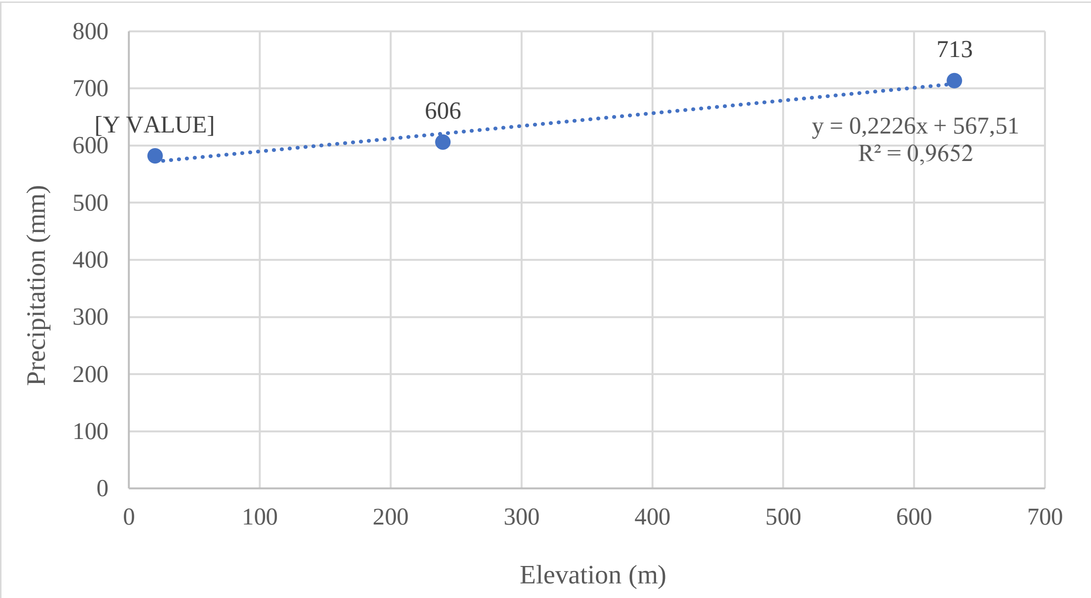

Figure 2.4. *Elevation vs Total Annual Precipitation Relationship*

Table 2-4. *Monthly and Annual Total Precipitation Amounts (mm) for the Proposed Heap Leach Site*

Month	**Precipitation (mm) at Heap Leach Site**
January	103
February	65
March	83
April	53
May	55
June	58
July	16
August	12
September	23
October	60
November	75
December	75
ANNUAL	**679**

In addition to the precipitation, temperature and evaporation data are also required for the water balance model of heap leach facility.

Monthly and annual average temperature for the common period between 2013 and 2018 for Burhaniye, İvrindi and Akçaldede Radar stations are presented in Table 2-5.

Table 2-5. *Monthly and Annual Average Temperature for the Stations for Common Data Period (2013-2018)*

Month	**Monthly and Annual Average Temperature (°C)**		
	17722 - Burhaniye	**18432 - İvrindi**	**17158 - Akçaldede**
January	7.4	4.3	3.3
February	9.6	7.3	5.6
March	11.8	9.2	7.7
April	15.5	12.8	12.1
May	20.3	17.1	15.9
June	24.4	21.1	19.4
July	27.4	24.1	21.7
August	27.9	24.5	21.8
September	23.2	20.4	18.9
October	17.3	15.6	12.9
November	13.2	10.3	9.5
December	8.2	5.0	4.3
ANNUAL	**17.2**	**14.3**	**12.8**

Because the proposed heap leach site is located within the elevation range of these stations, temperature and elevation relationship is determined by linear interpolation and used to construct the temperature data for the proposed heap leach site. Relationship between Elevation and Annual Average Temperature is presented in Figure 2.5. The results show a high coefficient of determination value (R^2=0.90) and a decrease in annual average temperature with elevation, in the order of 0.7°C per 100 m of elevation gain. The results of this assessment show that the proposed heap leach site would have an annual average temperature of 13.4°C.

In addition to the annual average temperature, by using the same method, monthly temperature values were used to construct the monthly temperature data for the project area. As it is presented in Table 2-6, the estimated average temperature values for the project area ranges from 3.7°C at minimum in January to 22.8°C mm at maximum in August. Relationships between elevations and monthly temperature values are presented in Appendix A-2.

By using the daily temperature data of the stations selected in the vicinity of the project area for common year data period (2013-2018), relationships were built between the stations and were used to generate not only the monthly and annual average temperatures, but also the daily temperatures for the project area. Due to being at relatively similar elevation, daily temperature data of the Akçaldede Radar station (Station ID: 17158) is factored (daily values were increased by 4.44%) to estimate the daily temperature data for the project site for the operation period of the Akçaldede Radar station (2005-2018).

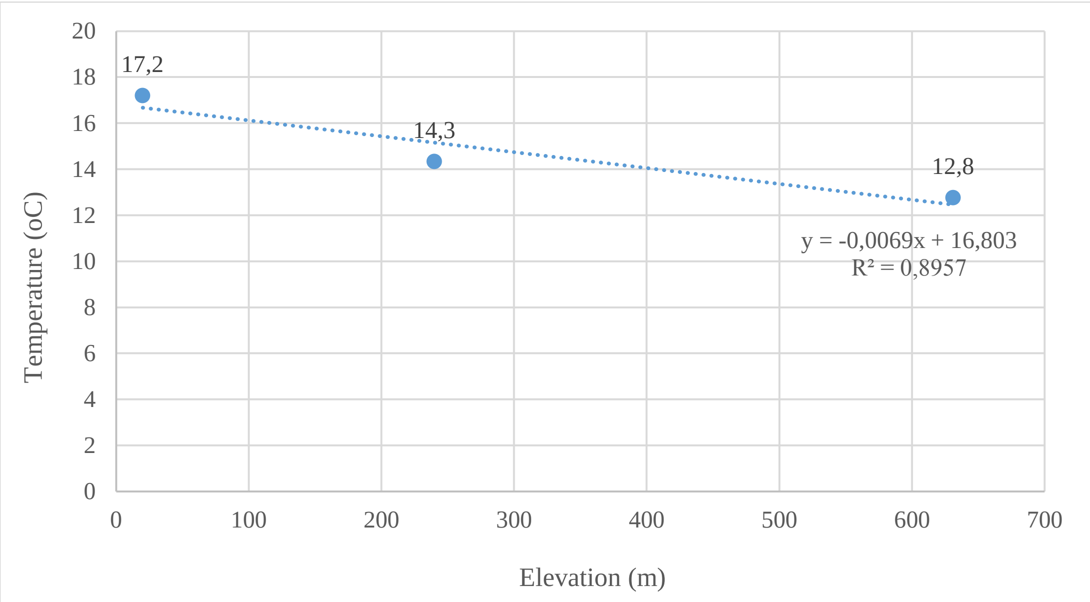

Figure 2.5. *Elevation vs Annual Average Temperature Relationship*

Table 2-6. *Monthly and Annual Average Temperature (°C) for the Proposed Heap Leach Site*

Month	**Temperature (°C) at Heap Leach Site**
January	3.7
February	6.2
March	8.3
April	12.4
May	16.4
June	20.1
July	22.6
August	22.8
September	19.5
October	13.9
November	9.9
December	4.6
ANNUAL	**13.4**

Generated daily temperature values for the project site are inserted into the model directly without the need to generate the daily stochastic time series of temperature synthetically unlike the precipitation data because this parameter is not the main driver as the precipitation in the water balance.

Evaporation data were available only at the Edremit station (Station ID: 17158). Average Monthly and Annual Total Evaporation Amounts for the Edremit Station are presented in Table 2-7 (MGM, 2019b). It is seen that long-term average monthly evaporations from June to August are above 200 mm. Annual total evaporation is estimated as 1471.6 mm.

Table 2-7. *Average Monthly and Annual Total Evaporation Amounts for the Edremit Station (1962-2017)*

Month	**Evaporation (mm) at 17145 - Edremit**
January	34.3
February	39.4
March	61.8
April	107.4
May	165.3
June	214.8
July	269.5
August	250.5
September	169.4
October	100.7
November	45.4
December	30.3
ANNUAL	**1471.6**

Due to scarcity of the evaporation data at the meteorological stations in the vicinity of the project area, similar interpolation methods used to construct the daily precipitation and daily temperature could not be used to construct the daily evaporation data. Instead, a relationship was built between the daily evaporation and daily temperature data for the Edremit station. The relationship between Temperature and Evaporation for the Edremit Station for 1962-2018 period is presented in Figure 2.6. It is seen from this graph that there is wide scatter in the data (same evaporation value can be observed in 15°C temperature range) and the second order polynomial fit provided the best coefficient of determination value, which is 0.64.

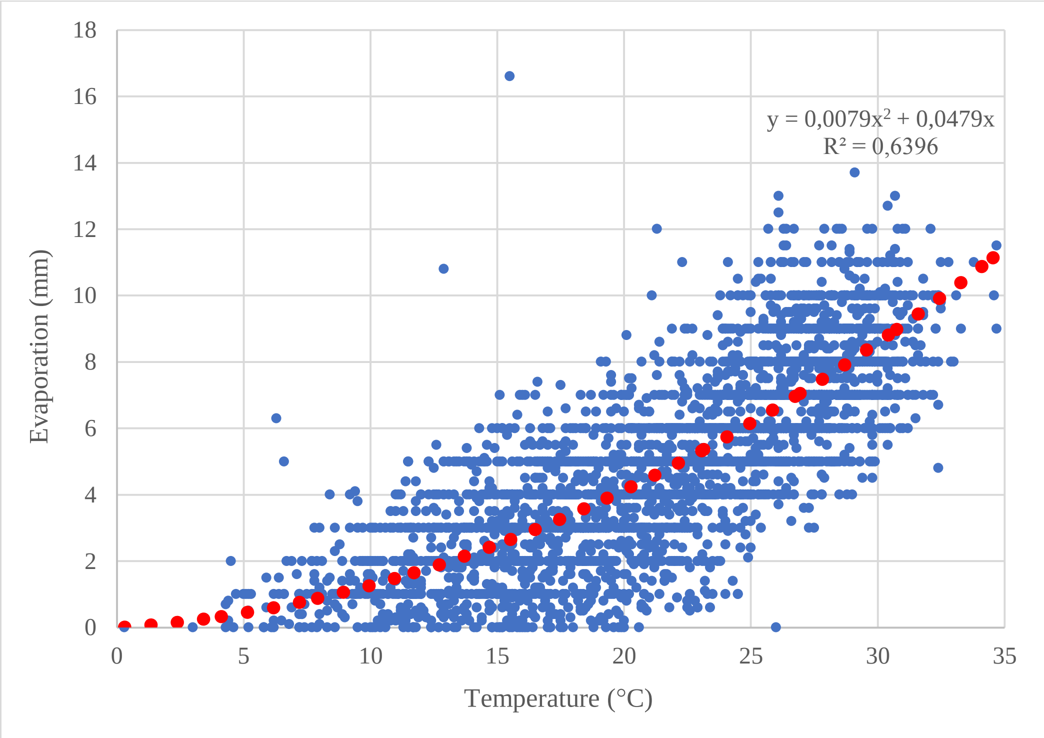

Figure 2.6. *Temperature vs Evaporation for Edremit Station (1962-2018)*

Daily evaporation values for the heap leach site are generated by using the daily temperature values generated for the heap leach site with the relationship built between temperature and evaporation for the Edremit station (Figure 2.6). Monthly and Annual Total Evaporation Amounts for the Proposed Heap Leach Site are presented in Table 2-8. Based on the generated data, it is seen that monthly evaporation data for the proposed heap leach site are as high as 200 mm in July and August and as low as 18 mm in January. Annual total evaporation is estimated as 1117 mm.

Generated daily evaporation values for the project site were input into the model directly without the need to generate the daily stochastic time series of evaporation synthetically.

Table 2-8. *Monthly and Annual Total Evaporation Amounts (mm) for the Proposed Heap Leach Site*

Month	**Evaporation (mm) at Heap Leach Site**
January	18
February	22
March	38
April	69
May	115
June	160
July	195
August	193
September	140
October	87
November	52
December	28
ANNUAL	**1117**

In summary, since there is no meteorological station at the project site, meteorological variables required for the water balance model of heap leach facility; precipitation, temperature and evaporation, are generated on daily, monthly and annual time scales.

Given that the simplest water balance would consider precipitation and evaporation, generated monthly evaporation values together with the generated monthly precipitation values for the proposed heap leach site are collectively presented in Figure 2.7 for comparison. Yellow-colored area indicates the months when water deficit occurs.

Monthly Water Deficit and Surplus for the Proposed Heap Leach Site is presented in Figure 2.8. It is estimated that the project site has annual water deficit of 438 mm. There is a water deficit in the region for seven months, between April through October, and water surplus in the remainder of the year. This information is used while assigning the moisture content to the ore at field capacity; during the months when there is water deficit ore would require more barren solution whereas the months when there is water surplus ore would require less barren solution to reach its field capacity.

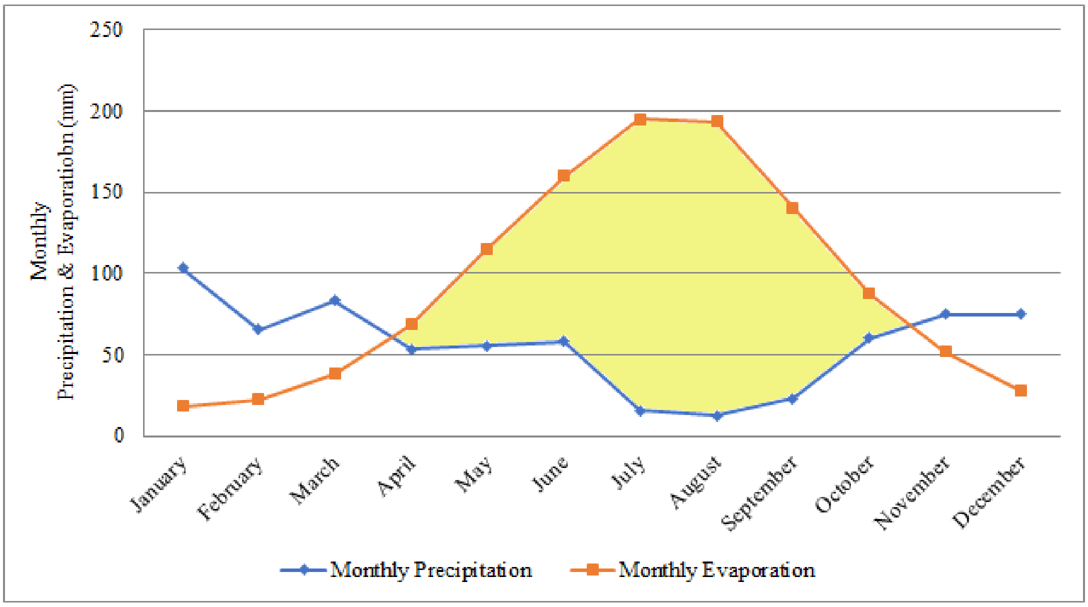

Figure 2.7. *Monthly Precipitation and Evaporation (in mm) for the Proposed Heap Leach Site*

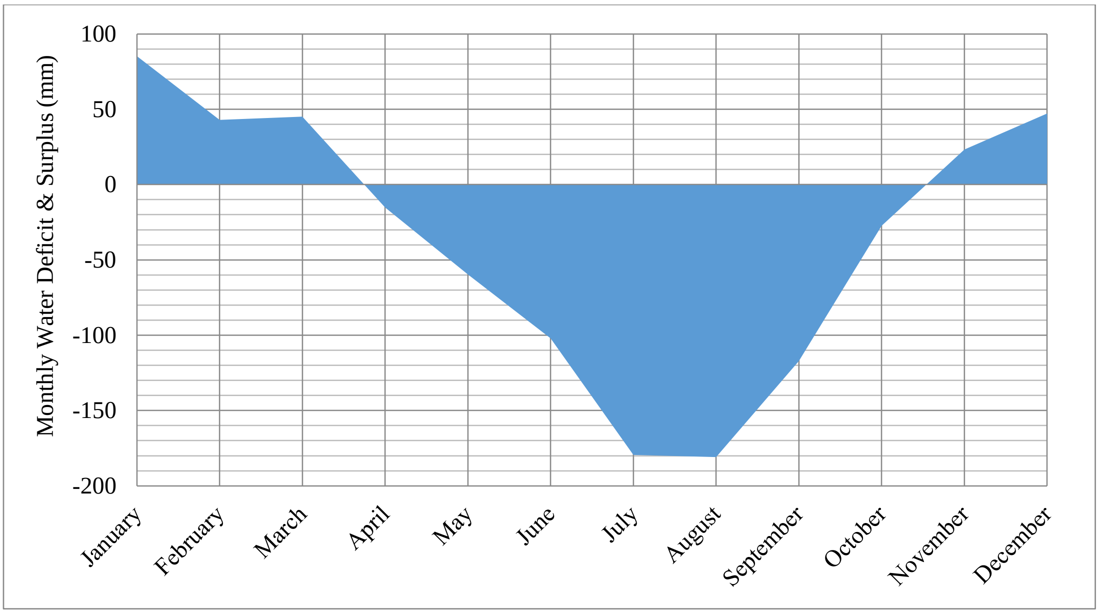

Figure 2.8. *Monthly Water Deficit and Surplus (in mm) for the Proposed Heap Leach Site*

2.2.2. Generating Probabilistic Precipitation Using Weather Generator

Daily precipitation values for the project site are the most important input for the model. By using the constructed data for the project, daily stochastic time series of precipitation is generated synthetically with the same statistical characteristics as the actual data. This is performed by the simulation model called Weather Generator (WGEN), which is also integrated into the GoldSim model.

There are many weather generators developed for generating daily weather variables (Jones et al. 1972, Bond 1979, Nicks and Harp 1980, Bruhn et al. 1980, Larsen and Pense 1981), all of which rely on some statistical principles. Due to its general applicability and ease of use (Richardson and Wright, 1984), WGEN is selected to generate the daily weather variables for this project.

As mentioned in the previous section, the daily precipitation data for the project site were constructed by factoring the daily precipitation data of the Akçaldede Radar station, which has been in operation for 14 years (2005 through 2018). For WGEN, the longer the historical data available, the better statistical characteristics can be developed. However, the module was tested in other studies based on shorter data period and provided successful outcomes.

WGEN was evaluated by Soltani et al. (2009) to generate weather variables based on limited (3 to 10 years) actual historic weather data. The actual and generated weather series were used as input to the model and the results showed that the generated data were similar to the actual data used for parameter estimation for all base periods tested. It was also concluded that to generate data similar to long term historic data, a longer base period (>10 years) would be required for parameter estimation. However, it was shown that the WGEN could be used as a reliable source of weather variables generation if it is required that the generated data represent recent history rather than a long-term period.

The details of the WGEN component will be presented in this section while the rest of the model components will be described in Chapter 3.

WGEN accounts for the persistence of each variable, the dependence among the variables, and the seasonal characteristics of each variable. It is a stochastic weather generator originally developed in the 1980s in Fortran at the US Department of Agriculture, Agricultural Research Service (Richardson and Wright, 1984) based on the procedure described by Richardson (1981).

The precipitation component of WGEN is a Markov chain-gamma distribution model. A first-order Markov chain is used to generate the occurrence of wet or dry days. When a wet day is generated, the two-parameter gamma distribution is used to generate the precipitation amount.

With the first-order Markov chain model, the probability of rain on a given day is conditioned on the wet or dry status of the previous day. Let Pi(W/W) be the probability of a wet day on day i given a wet day on previous day, and let Pi(W/D) be the probability of a wet day on day i given a dry day on previous day. With Pi(W/W) and Pi(W/D), the transition probabilities for the Markov chain would be fully defined (Richardson and Wright 1984). Operation logic of the WGEN Synthetic Precipitation Generator is presented in Figure 2.9 (Hoekstra, 2015).

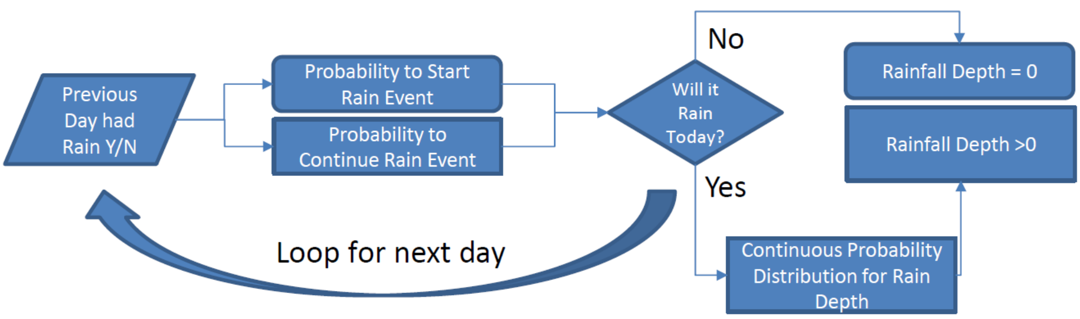

Figure 2.9. *WGEN Synthetic Precipitation Generator Operation Logic (Hoekstra, 2015)*

To be able to estimate the Pi(W/W) and Pi(W/D), the statistical parameters of the daily precipitation data presented in Table 2-9 are used.

Table 2-9. *Statistical Parameters (obtained from observations) to Develop the Markov Parameters*

Month	**Sum of Today is Wet, Tomorrow is Wet**	**Sum of Wet Day**	**Sum of Today is Dry, Tomorrow is Wet**	**Sum of Dry Day**	**Count of Rain or Dry**
January	117	183	66	251	434
February	109	173	67	219	392
March	96	171	71	263	434
April	48	99	52	321	420
May	64	113	47	321	434
June	48	86	37	334	420
July	10	27	16	407	434
August	5	18	15	416	434
September	46	90	48	330	420
October	71	127	54	307	434
November	80	137	57	283	420
December	101	166	65	268	434
TOTAL	**795**	**1390**	**595**	**3720**	**5110**

Pi(W/W), the probability of a wet day on day i given a wet day on previous day, is estimated by dividing "the sum of today is wet, tomorrow is wet" by "sum of wet days".

Pi(W/D), the probability of a wet day on day i given a dry day on previous day, is estimated by dividing "the sum of today is dry, tomorrow is wet" by "sum of dry days".

As stated above, two-parameter gamma distribution is used in the WGEN to describe the distribution of rainfall amounts. Even though several probability density functions have been used to generate the rainfall data, such as exponential, gamma, and mixed exponential distributions used by Woolhiser and Roldan (1982) and compound exponential distribution used by Smith and Schreiber (1974), it was shown by Richardson (1982) that two-parameter gamma distribution is significantly better for describing daily precipitation amounts than the simple one-parameter exponential distribution.

Two-parameter gamma distribution requires specification of α (alpha) and β (beta) parameters. α is known as the shape parameter while β is referred to as the scale parameter. The shape and scale parameters of a gamma distribution can be calculated from the mean and the standard deviation. For this reason, mean and standard deviation of the daily precipitation data are also calculated for each month.

Markov Parameters and Parameters to Develop α and β for Gamma Distribution are presented in Table 2-10.

Table 2-10. *Markov Parameters and Parameters to Develop α and β for Gamma Distribution*

Month	**P(W/W)**	**P(W/D)**	**Mean**	**Standard Deviation**
January	0.6393	0.2629	5.6431	6.1728
February	0.6301	0.3059	5.9167	7.1368
March	0.5614	0.2700	5.3614	6.2684
April	0.4848	0.1620	6.5473	9.1590
May	0.5664	0.1464	4.6677	6.8045
June	0.5581	0.1108	6.6695	8.2262
July	0.3704	0.0393	5.1888	6.1527
August	0.2778	0.0361	6.3172	8.4900
September	0.5111	0.1455	5.9882	8.6412
October	0.5591	0.1759	7.6374	12.5806
November	0.5839	0.2014	6.2603	7.9449
December	0.6084	0.2425	6.2805	7.3340

Because the mean is less than the standard deviation for each month, it can be said that the “Case I of the gamma distribution’s shape” occurs, which means that the gamma distribution is exponentially shaped and asymptotic to both the vertical and horizontal axes.

The values of Pi(W/W), Pi(W/D), mean and standard deviation (and hence α and β) vary continuously during the year. In WGEN, each of the four precipitation parameters are constant for a given month but are varied from month to month.

These parameters are fed into the WGEN container in the model and the model is run for "one year for 100 realizations" with the generated model inputs. WGEN Container with Generated Model Inputs is presented in Figure 2.10. A realization in GoldSim is a single simulation run representing a particular outcome. Given that this is a probabilistic simulation, multiple realizations are carried out in order to simulate a large number of possible outcomes (in this case, there are 100 possible outcomes for a daily precipitation for each day in one year).

The generated daily precipitation data are used to generate the monthly precipitation data, which is then evaluated by comparing against the monthly source (constructed in Section 2.2.1.) data. Even though the results are very similar, it is required to calculate the precipitation correction factor for each month to be able to generate the daily stochastic time series of precipitation with exactly the same statistical characteristics of the source data. Once the precipitation correction factor is calculated for each month by dividing the source data by the generated data, they are inserted into the WGEN container. WGEN container with precipitation correction factor is presented in Figure 2.11. The model is run for "one year for 100 realizations" again but with the precipitation correction factors inserted in the model this time. Similar to the uncorrected data processing, monthly precipitations are calculated by using the corrected daily precipitation data.

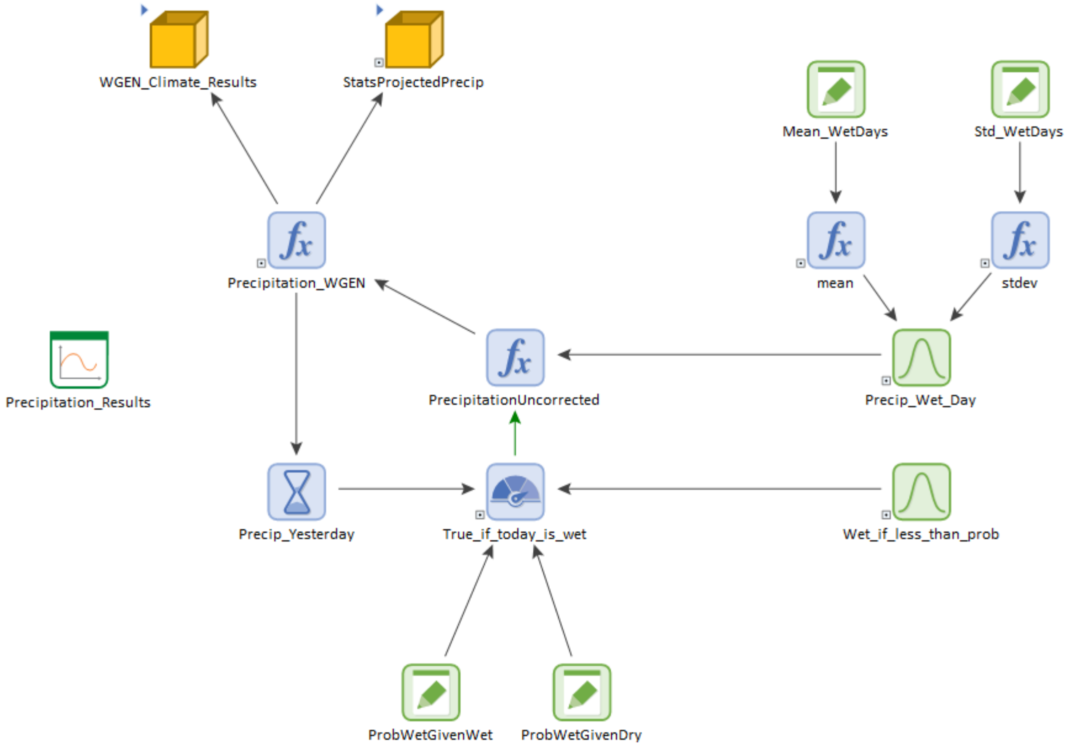

Figure 2.10. *WGEN Container with Generated Model Inputs*

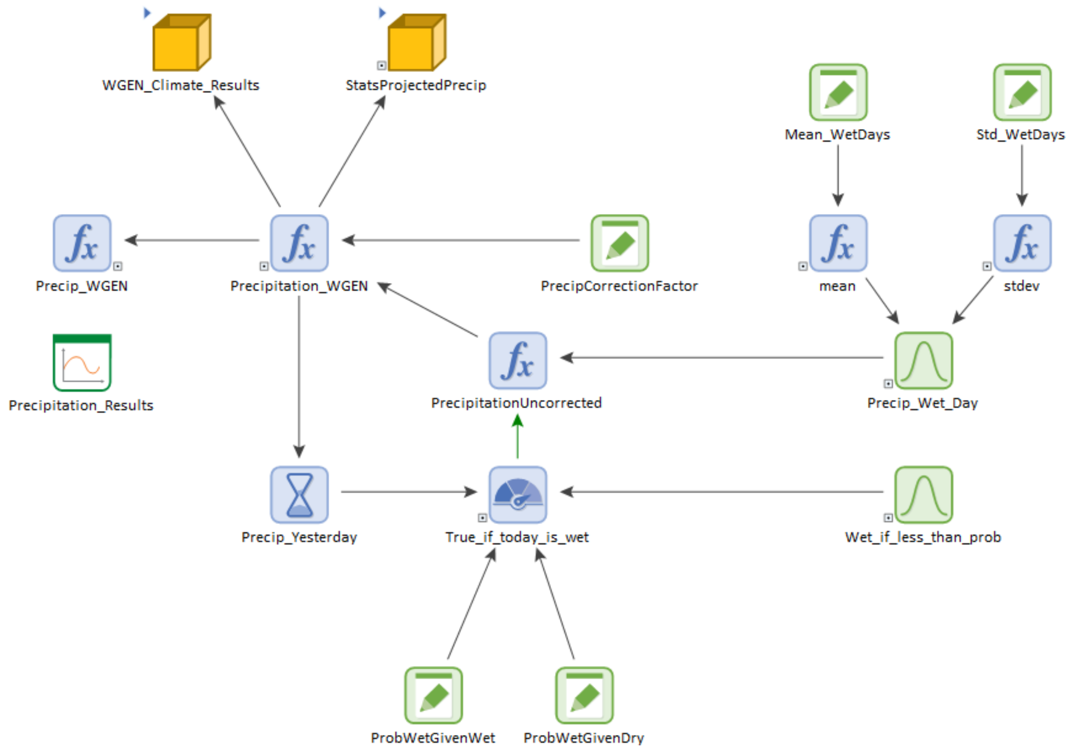

Figure 2.11. *WGEN Container with Precipitation Correction Factors*

With the procedure described above, WGEN module would be ready to generate daily precipitation data for as many years as required with exactly the same statistical characteristics of the source data. The initial generated data is verified by comparing the results to the original data set and correction factors were estimated. The model is re-run to verify these correction factors.

The resulting monthly precipitation statistics (both uncorrected and corrected) from the Monte-Carlo analysis of the stochastic precipitation model are compared to the source data in Figure 2.12.

WGEN generated daily precipitation data for 1-year with 100 simulations are presented in Figure 2.13. Maximum daily precipitation as high as 91.8 mm is observed by using these simulation settings.

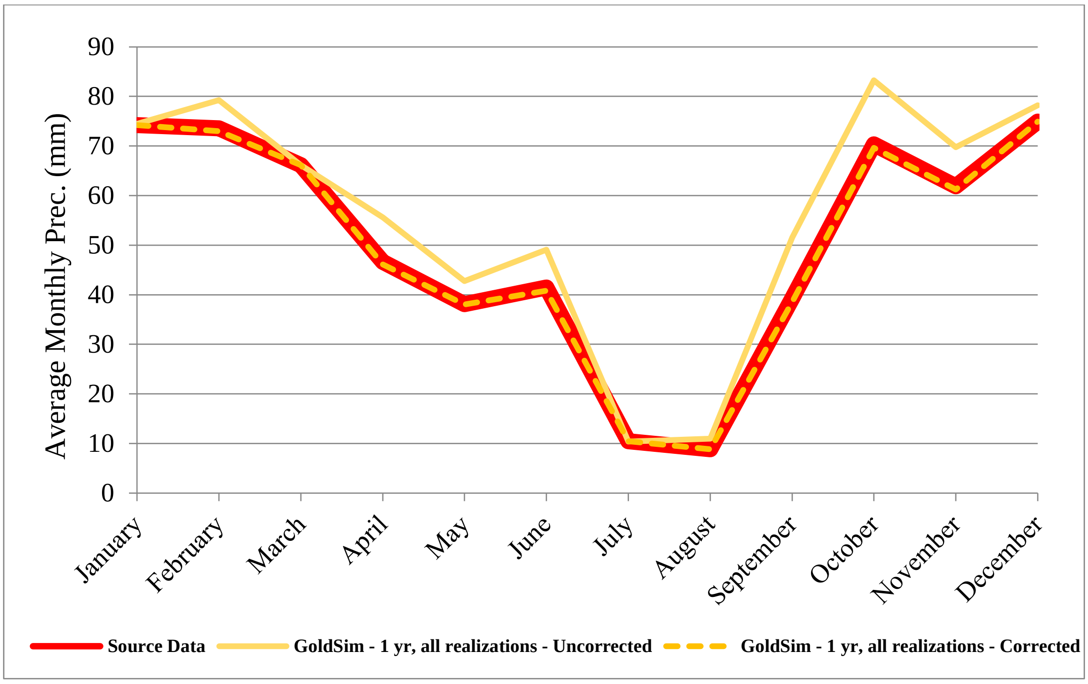

Figure 2.12. *Comparison of Source (Project Site), Uncorrected and Corrected WGEN Generated Data for 1-year simulation*

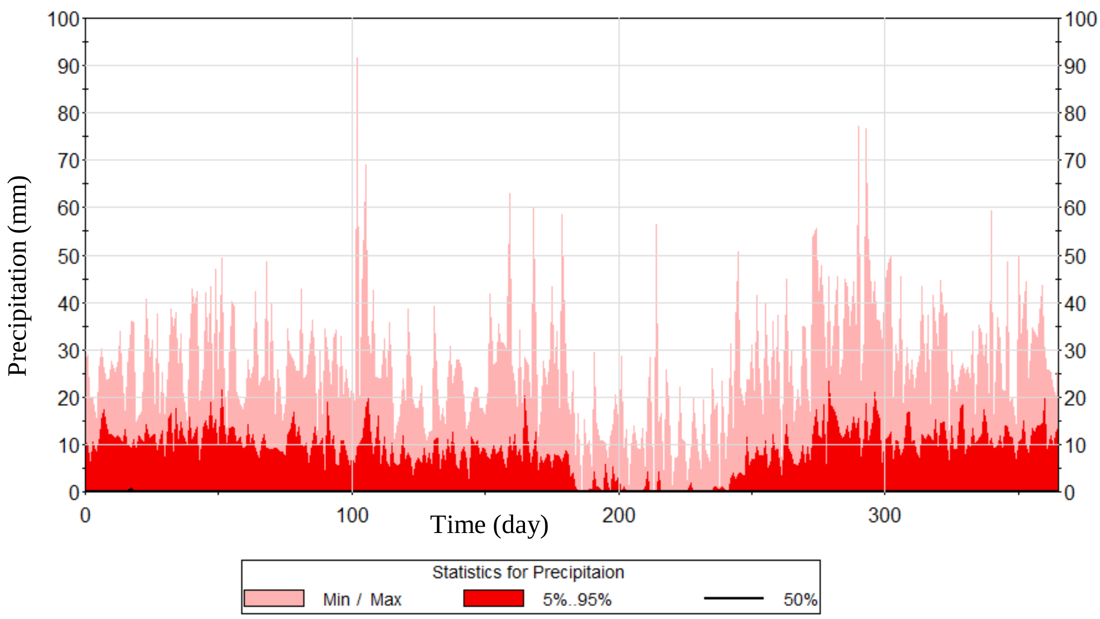

Figure 2.13. *WGEN Generated Daily Precipitation Data for 1-year (365 days) with 100 Simulations (January 1 through December 31)*

Validation of the WGEN module is performed by constructing the WGEN by using the statistical characteristics of the daily precipitation amounts for Edremit station between the period 1962 and 1990 (by using 29 years of daily precipitation data). This period is specifically selected due to consisting of three successive wet/dry periods (1962-1969/1970-1979, 1980-1981/1982-1985, and 1986-1988/1989-1990) and cumulative deviation value from mean annual precipitation becoming zero at the end of the selected period.

WGEN was run for 10 years, from 1991 to 2000, with 100 realizations to generate the daily stochastic time series of precipitation. Minimum, maximum and quartile results are plotted together with the actual annual total precipitations and presented in Figure 2.14. It is seen that actual annual total precipitation data from 1991 to 2000 period are in between 25th and 75th percentile lines most of the period and are not outside the minimum/maximum region . Minimum and maximum lines show the possible values the annual total precipitations can get based on the statistical characteristics of the daily precipitation amounts for the selected period for Edremit station.

It should be noted that if the simulation period is extended beyond 10 years, there may be variations between the actual annual total precipitation data and the WGEN generated data. However, it should also be noted that in this example, WGEN validation is performed for 100 realizations and once the model is run for larger number of realizations, extreme values would be defined with higher confidence due to increased number of samples at the tails of the distribution used.

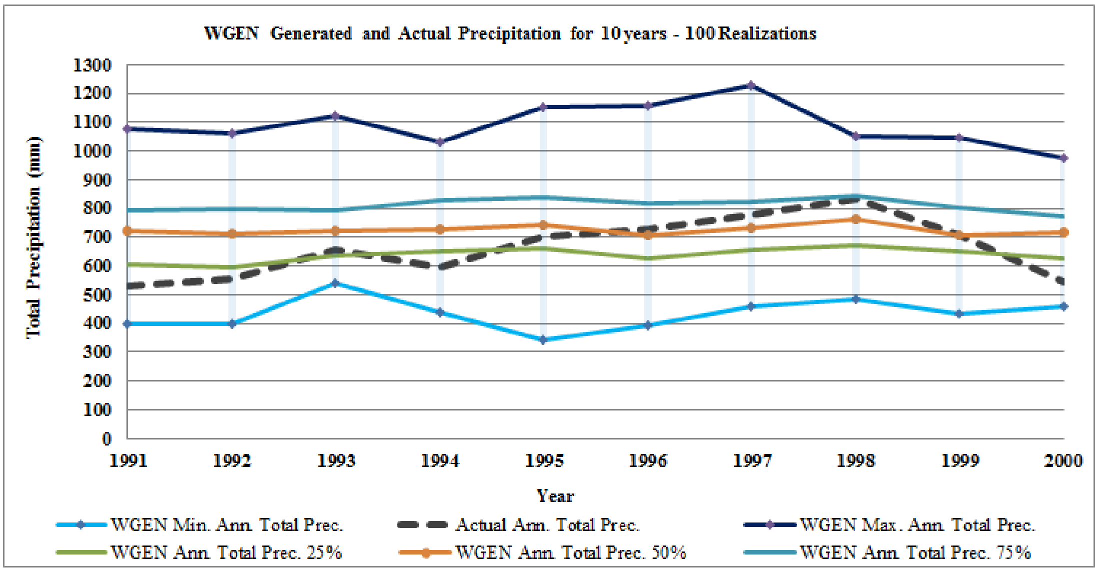

Figure 2.14. *WGEN Generated and Actual Precipitation for 10 years – 100 realizations*

2.2.3. Extreme Events

WGEN-generated daily precipitation data for 1-year with 100 simulations include maximum daily precipitation as high as 91.8 mm. It is presented in Section 3.3 that the heap leach water balance model is run for about 10 years with 1,000 realizations. For this reason, it is expected that higher daily precipitation values would be observed during the heap leach water balance simulations.

It is important to know the extreme precipitation values to make sure that the simulations include these events. It should be noted that none of the stations used in the generation of the project site precipitation data in Section 2.2.1 (Burhaniye, İvrindi and Akçaldede R.) has the precipitation intensity data of standard time series because it requires at least 10 years of reliable and continuous pluviograph rainfall data to produce the Intensity-Duration-Frequency (IDF) curve (MGM, 2019c), which is a mathematical function that relates the rainfall intensity with its duration and frequency of occurrence (Koutsoyiannis, 1998). In addition to this, it was mentioned in Section 2.2.1 that Edremit station was deemed inappropriate for precipitation data evaluations.

For this reason, the precipitation intensity data of standard time series from 5 minutes to 24 hours for Balıkesir station were acquired from MGM. Precipitation Intensity Data of Standard Time Series at Balıkesir Station (MGM, 2019d) is presented in Appendix B. Because the annual total precipitation amount for the Balıkesir station is 583.2 mm (MGM, 2019e) whereas the project site annual total precipitation is estimated to be 679 mm, an adjustment factor of 1.2 (it should be 1.165 but rounded to 1.2 to provide contingency) is applied to the precipitation intensity data of the Balıkesir station to scale the data to the project site.

Frequency Analysis for Different Return Periods and Durations for the Project Site is presented in Table 2-11.

Table 2-11. *Frequency Analysis for Different Return Periods and Durations for the Project Site*

Return Period	Duration (minute)													
	5	10	15	30	60	120	180	240	300	360	480	720	1080	1440
2 Year	6.8	10.4	13.3	17.5	21.1	26.0	29.3	31.7	33.1	34.4	36.0	38.2	41.2	49.4
5 Year	9.8	15.1	19.3	25.6	31.4	37.7	40.8	44.1	46.0	47.4	49.5	52.6	56.4	64.2
10 Year	11.9	18.6	23.9	31.7	39.5	46.4	48.8	52.8	54.7	56.4	58.8	62.2	66.2	72.9
25 Year	14.7	23.8	30.4	40.3	51.0	58.2	59.4	64.1	66.0	68.1	70.8	74.5	78.3	83.0
50 Year	17.0	28.0	35.8	47.4	60.6	67.7	67.7	72.8	74.5	77.1	79.9	83.8	87.2	89.9
100 Year	19.4	32.7	41.8	55.0	71.2	76.2	77.8	81.7	83.2	86.3	89.3	93.2	95.9	96.3
200 Year	22.0	37.8	48.3	63.3	82.9	85.2	88.6	90.9	92.1	95.7	98.9	102.4	102.7	104.6

The data is used to generate the IDF curve for graphical presentation. IDF curve for the project site is presented in Figure 2.15. Intensities of 100 year-24 hour and 200 year-24 hour precipitations are 4.0 mm/hr. and 4.4 mm/hr., resulting in 96.3 mm and 104.6 mm total daily precipitations, respectively.

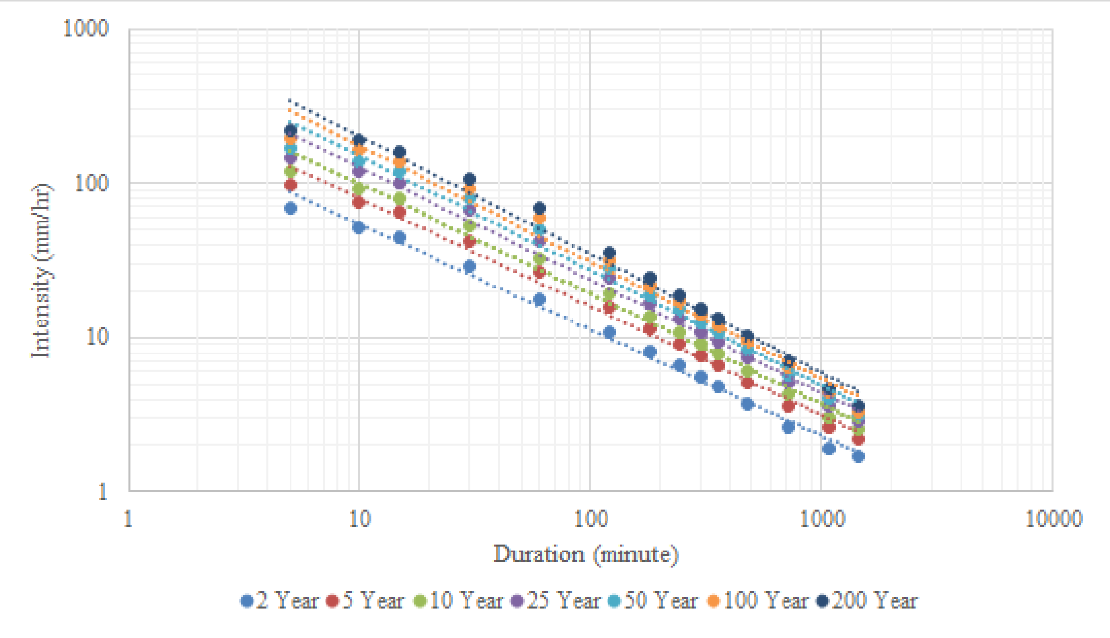

Figure 2.15. *IDF Curve for the Project Site*

2.2.4. Operation and Design-Based Data

In previous sections, climate data sets, which have the highest uncertainty in water balance systems were constructed for the project site and WGEN container in the model, which synthetically generates daily precipitation data with the same statistical characteristics as the actual data was discussed. In addition to these, operation and design-based parameters of the heap leach facility and its components are input into the water balance model. These parameters are presented in Table 2-12.

As mentioned previously, the objective of building an operational dynamic water balance in heap leach facilities is to make sure that leach solution is circulated between the heap, ponds, and process plant, with no discharge (no overflow from the storm pond) by taking the system gains (precipitation and raw water supply if/when required) and losses (evaporation) into account. Because the ultimate objective is to prevent any unintentional releases from the system, pond sizing is of utmost importance. Optimizing the capacities of the ponds is an iterative process and is not performed as part of this study. Instead, designed ponds (PLS pond and storm pond) are evaluated for their design capacities.

As seen in Table 2-12, three different values for the ore moisture content are presented. Moisture content as delivered is the percent of water in the ore when it is delivered to the leach pad. Once the barren solution is applied on the ore, moisture content starts increasing and reaches its field capacity. Any additional solution after this would initiate the leaching (draining) of the solution through the bottom of the pad. The amount of solution required to bring the ore moisture content to its field capacity is termed as primary uptake. As the solution application and the leaching continues to complete leach cycle, moisture content increases and stabilizes as long as the solution application conditions do not change. The amount of solution required to bring the ore moisture content from its field capacity to this condition is termed as secondary uptake.

The leach cycle provides 923 m^3/h flow to the facility. Based on the 10 $L/m^2/h$ solution application rate, target leach (active) area is estimated as 92,300 m^2.

It should be noted that no freeboard (distance between the operation level and maximum water level) is included for the PLS pond given that overflow from PLS pond to storm pond is allowed whereas one-meter freeboard is included for the storm pond. For this reason, operation capacity for the storm pond excludes the freeboard. PLS pond and storm pond capacities are 106,097 m^3 and 207,749 m^3, respectively.

Table 2-12. *Design-Based Facility Data (Golder, 2019)*

Item	**Value**	**Unit**
Ore Annual Production Rate (approximate)	4.0	Mt/yr
Heap Leach Operation Life (approximate)	10	years
Heap Leach Capacity (approximate)	40	Mt
Ore Moisture Content		
as delivered to the leach pad	4	%
at field capacity (November through March - Remaining Months)	8 - 12	%
during leaching at the leach pad	15	%
Ore Density	1.45	t/m^3
Barren Leach Solution Nominal Pumping Rate	923	m^3/hr
Barren Leach Solution Maximum Pumping Rate	1107	m^3/hr
Barren Leach Solution Nominal Application Rate	10	$L/m^2/hr$
Target Leach Area (Active Area for each cell)	92,300	m^2
PLS Pond Capacity (including freeboard)	106,097	m^3
Storm Pond Capacity (including freeboard)	234,267	m^3
Storm Pond Capacity (excluding freeboard)	207,749	m^3

For the purpose of this study, the heap leach is phased as Phase 1, Phase 2, and Phase 3 with the approximate areas of 120,000, 250,000, and 250,000 m^2, respectively. Area for each phase is approximately determined based on the ore production and pad expansion. In the operational heap leach water balance, the phase areas receiving the precipitation are important rather than the geometries of these phase expansions. The simulation results would be affected by the timing of the phase advancement (see Table 3-1).

CHAPTER 3

OPERATIONAL WATER BALANCE MODEL

3.1. Building the Water Balance Model in GoldSim

The operational water balance model for the heap leach facility depends on not only climate data sets, such as precipitation, evaporation and temperature, but also operation and design-based data, such as characteristics of the ore (moisture content, density, etc.), solution application rates, and pond sizes and pond geometries.

In this section, description of the components in the operational water balance model built for the proposed heap leach facility will be made and elements, influences and containers in the model will be presented. Descriptions about how to learn or use the software program are not within the scope of this thesis.

GoldSim uses elements and influences to insert information and to make connections (links) between inputs and outputs. A total of six element groups is present in GoldSim; Input, Stock, Function, Event, Delay, and Result. There is a special type of element group called Container which is used to create organized models in a hierarchical way. Containers are used in complex models which would have hundreds or even thousands of elements to group these elements in a meaningful manner by the modeler. They are simply boxes that elements and influences are placed in. Considering the water balance model in this study, two main containers are present in the model; first one is named as Probabilistic Climate and the second one is named as Water Balances. As it is presented in Figure 3.1, there is an arrow from Probabilistic Climate Container to Water Balances Container. This arrow shows that there is at least one element in the Probabilistic Climate Container that is connected (linked) to the element in the Water Balances Container. These connections (arrows) are called influences. Elements related to precipitation, evaporation and temperature together with the WGEN Container are present in the Probabilistic Climate Container and these elements are naturally affecting the water balance elements.

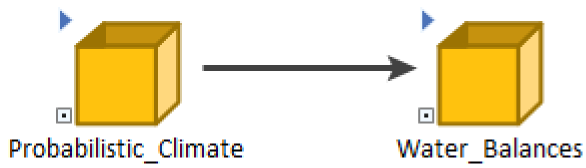

Figure 3.1. *Main Containers in the Water Balance Model*

Default appearance (symbol) of a simple container is an orange box as presented in Figure 3.1. However, their symbols in the model can be changed by images in Enhanced Meta File (EMF) format. Similar changes can also be made for the elements as well. For the heap leach and ponds' containers and fresh (raw) water source element, the default symbols are changed to match the symbols presented in the Flow Diagram of the Water Balance System in Figure 2.1.

As previously stated, elements related to precipitation, evaporation and temperature together with the WGEN Container are present in the Probabilistic Climate Container. Probabilistic Climate Container and its Elements and Influences are presented in Figure 3.2.

Precipitation, evaporation and temperature datasets were discussed in Section 2.2.1 and 2.2.2. Evaporation is triggered when the temperature is above 0°C. Precipitation generated by WGEN is rain when the temperature is above -1°C and snow when it is equal or less than -1°C. There is a snow factor added for both snow amount and rain amount elements. When the condition for precipitation as snow formation is met, snow amount is determined by some percent of total precipitation, which is determined by the snow factor. The complementary precipitation takes place as rain.

For this reason, the model is able to separate rain and snow generations. Snow is melted by snow melt coefficient, which is the degree-day coefficient in mm.

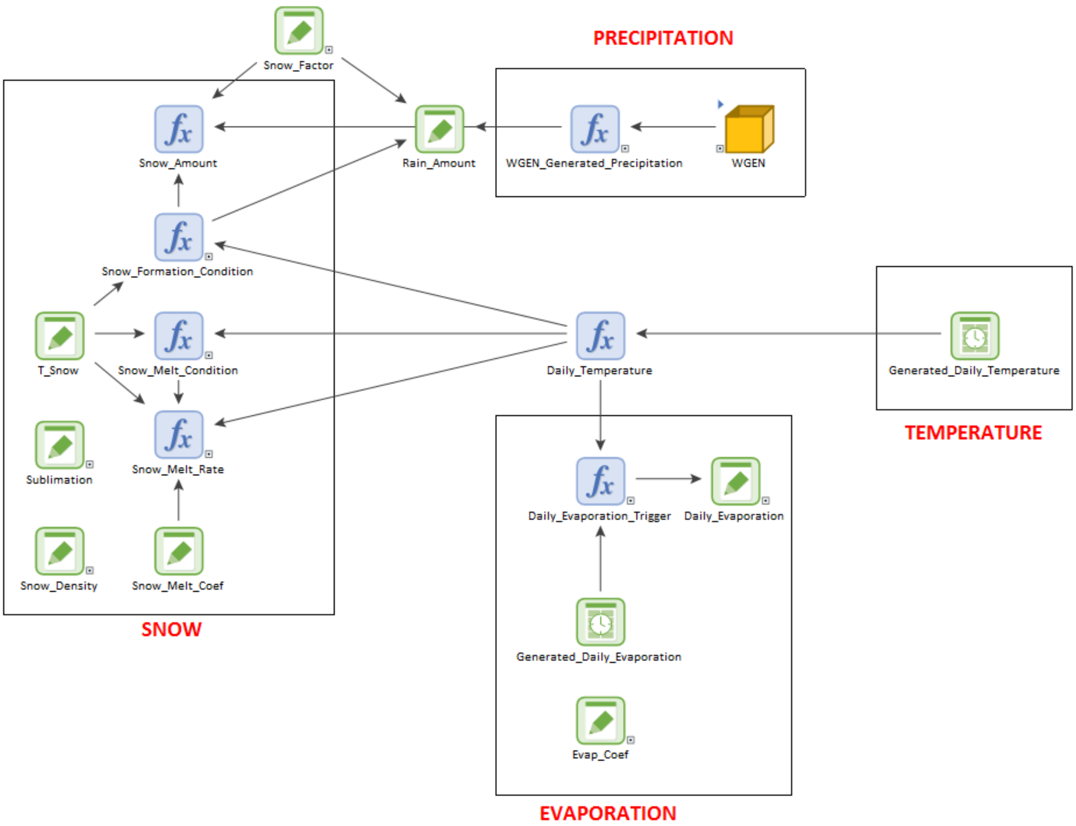

Figure 3.2. *Probabilistic Climate Container and its Elements and Influences*

Lastly, as can be seen in Figure 3.2, there are elements in the Probabilistic Climate Container; such as sublimation, snow density and evaporation coefficient, which do not have arrows linking them to other elements. However, the reason they do not have arrows is that they are not linked to the elements in the same container, but they still have connections to other elements in other containers. They are placed here because this container includes data and coefficients related to climate.

Second main container in the model is named as Water Balances. Containers, elements and influences in this container are presented in Figure 3.3. This container includes four sub-containers (named as HLF WB, PLS Pond WB, Storm Pond WB and Geometries HLF Ponds) and two elements (named as External Makeup Water Demand and Fresh Water Source), and shows the influences between these containers and elements.

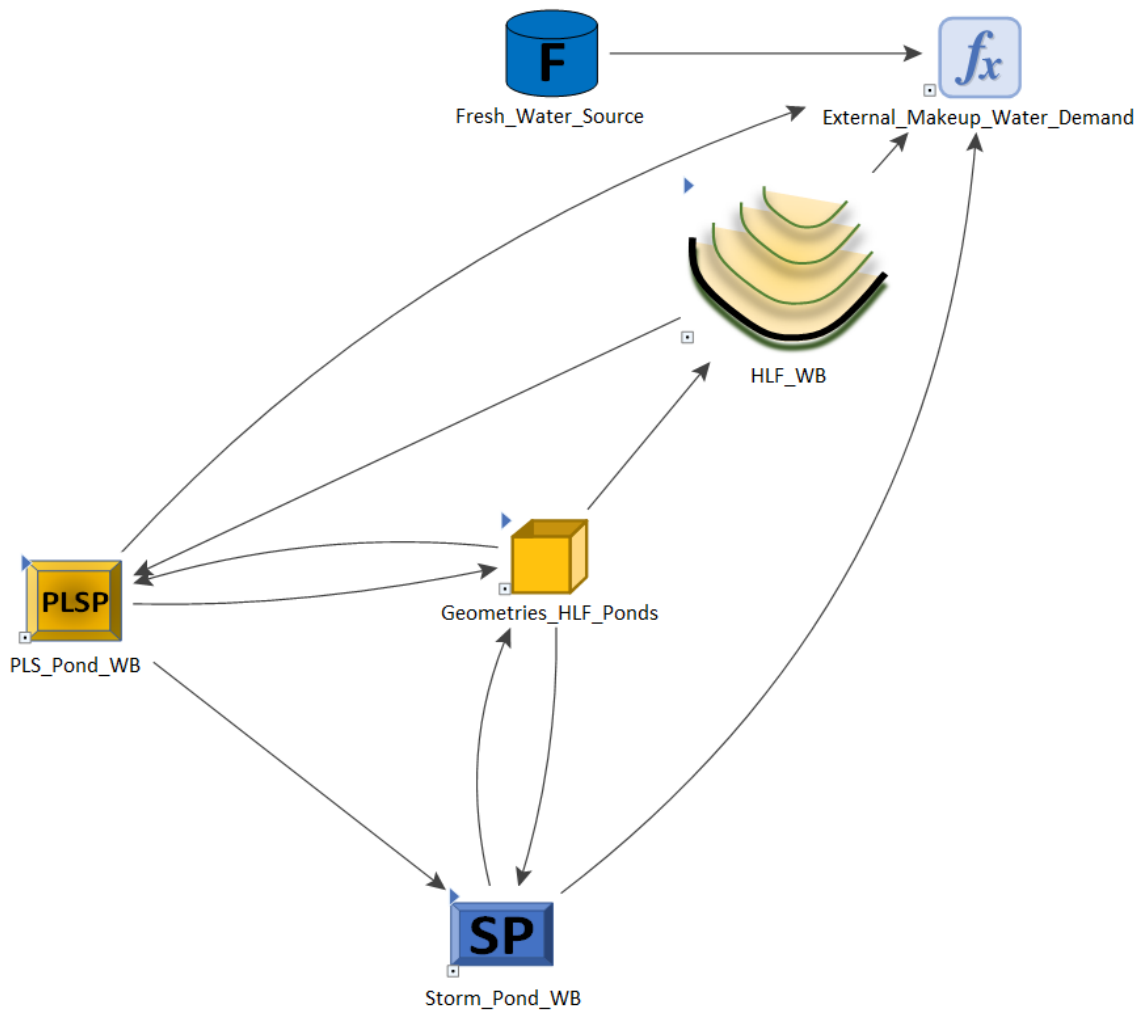

Figure 3.3. *Operational Heap Leach Water Balance Containers, Elements, and Influences*

The container named as Geometries HLF Ponds include the geometrical information of the heap leach pad and the ponds. For the heap leach pad, geometry is defined by the area that would be lined and ready for staking the ore. Based on the ore production, the leach pad is phased as Phase 1, Phase 2, and Phase 3 with the approximate areas of 120,000 m^2, 250,000 m^2, and 250,000 m^2, respectively. As a preparation of the closure stage, it is assumed that the first phase would be covered before the Phase 3 expansion. Phase-Area Advancement of the Facility Based on the Ore Production is presented in Table 3-1.

Table 3-1. *Phase-Area Advancement of the Facility Based on the Ore Production*

HLF Phase #	**Production Month**	**Cumulative Area (m^2)**
Phase 1	Month 0	120,000
Phase 2	Month 21	370,000
Phase 3a	Month 82	450,000
Phase 3b	Month 108	500,000
END	Month 119	500,000

For the geometries of the ponds, as it is presented in Figure 3.4., there are two sub-containers, one for each pond.

Figure 3.4. *Sub-Containers for PLS Pond and Storm Pond inside the Pond Geometries Container*

Elements and Influences inside the PLS Pond Geometry Container are presented in Figure 3.5. Elevations of the floor and the crest of the pond are entered in the data elements. Elevation, area and volume relationships are entered in the lookup table elements. Freeboard is not required for the PLS pond because overflow from PLS pond to storm pond is allowed. As a result, freeboard element is not linked to any of the elements. Maximum capacity of the PLS pond is calculated as 106,097 m^3. To avoid cavitation, minimum pump depth is determined. For this study, it is entered as zero because it is assumed that each pond would have sumps where the pumps would be lowered inside. The sump dimensions would be small that additional storage inside the sump can be ignored.

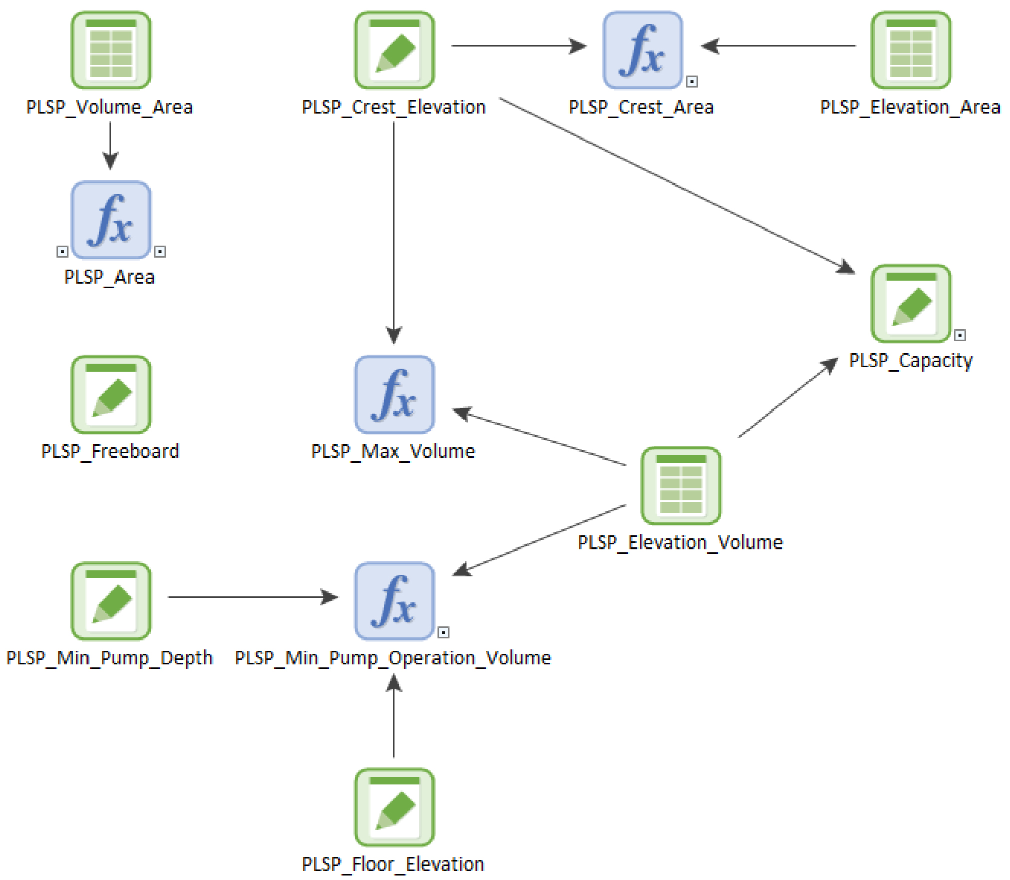

Figure 3.5. *Elements and Influences Inside the PLS Pond Geometry Container*

Elevation, area and volume relationships for the PLS pond is presented in Table 3-2. Floor and crest elevations of the PLS pond are 438 m and 453 m, respectively, resulting in a total pond depth of 15 m.

Table 3-2. *Elevation – Area – Volume Relationships for the PLS Pond*

Elevation (m)	**Area** (m^2)	**Incremental Volume** (m^3)	**Cumulative Volume** (m^3)
438	807	0	0
439	1309	1048	1048
440	1885	1588	2636
441	2535	2202	4838
442	3260	2890	7727
443	4058	3652	11379
444	4931	4488	15867
445	5878	5397	21264
446	6898	6381	27645
447	7994	7439	35085
448	9163	8572	43656
449	10406	9778	53434
450	11724	11059	64493
451	13116	12413	76906
452	14582	13842	90748
453	16127	15348	106097

Stage-Storage Curve for the PLS Pond is presented in Figure 3.6. Because overflow from PLS pond to storm pond is allowed, the freeboard is not required for the PLS. For this reason, total capacity of the pond can be evaluated as the operating capacity.

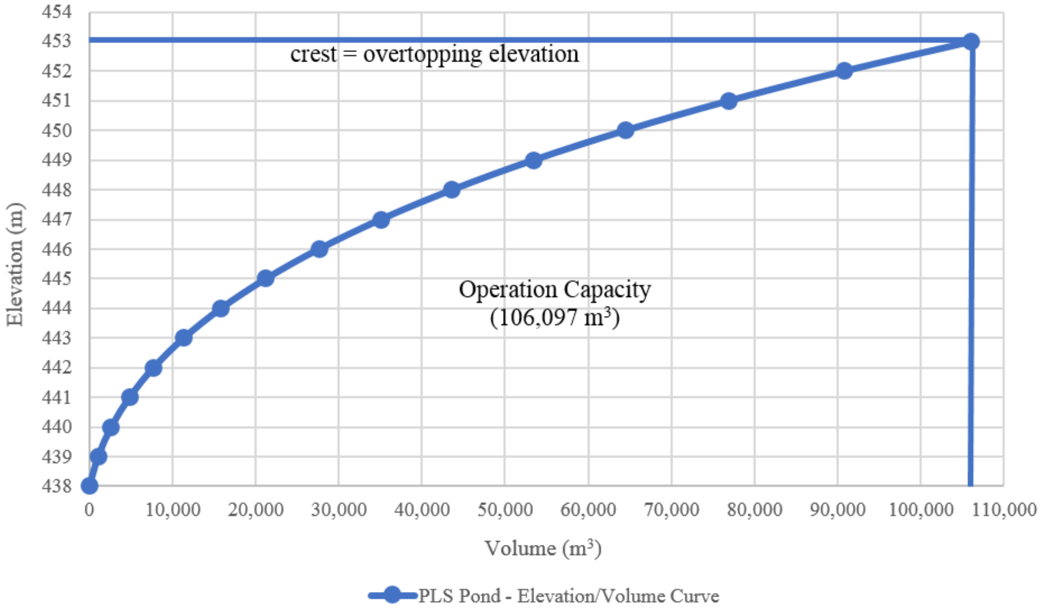

Figure 3.6. *Stage-Storage Curve for the PLS Pond*

Similar to the PLS Pond Geometry Container, Elements and Influences inside the Storm Pond Geometry Container are presented in Figure 3.7. Information on floor and crest elevations, and elevation, area and volume relationships are entered in the related elements. As it is seen, freeboard is added to the equation for this pond and volume calculation is made until the freeboard elevation. Operation capacity of this pond is calculated as 207,749 m^3. Pump depth is entered as zero again with the same reason described for the PLS pond.

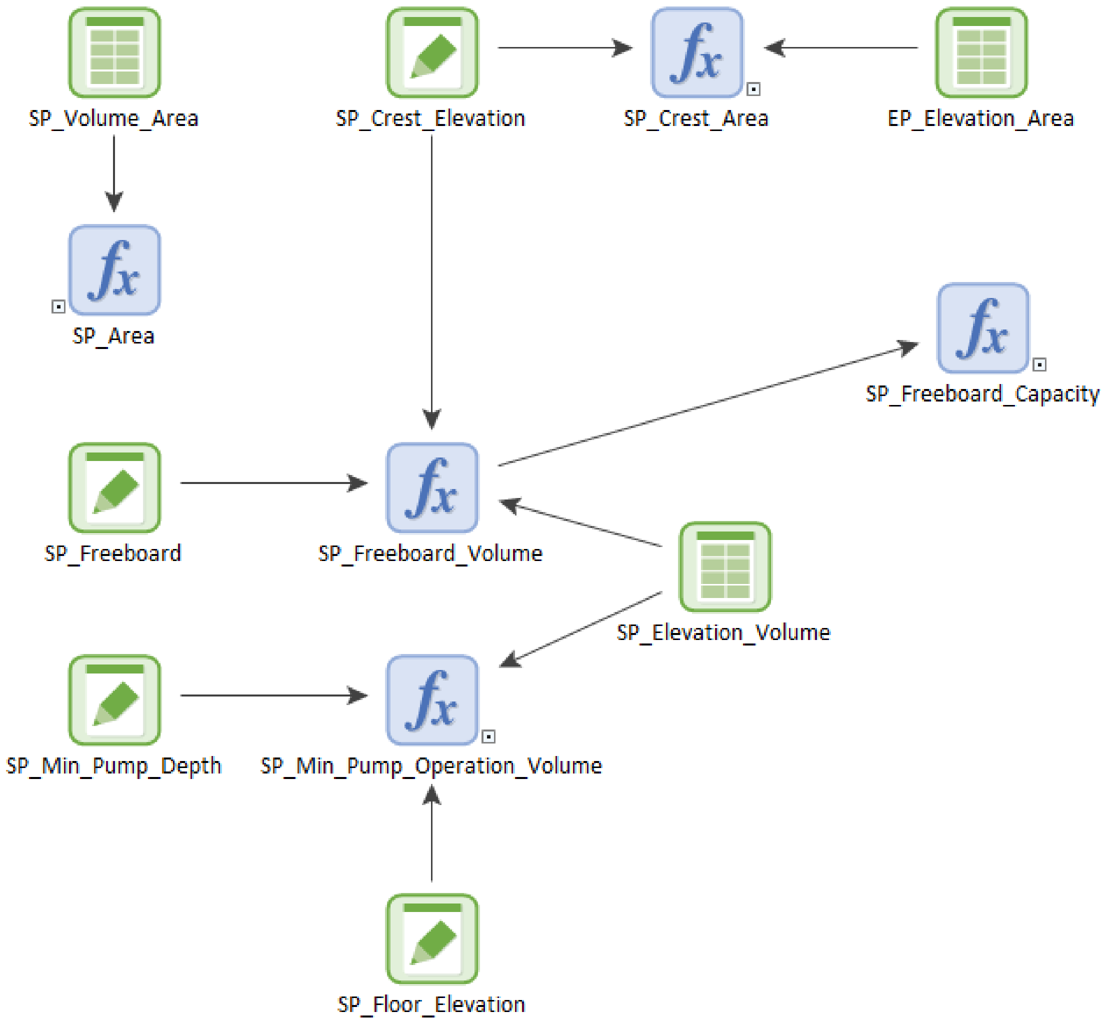

Figure 3.7. *Elements and Influences Inside the Storm Pond Geometry Container*

Elevation, area and volume relationships for the storm pond is presented in Table 3-3. Floor and crest elevations of the storm pond are 433 m and 453 m, respectively, resulting in a total pond depth of 20 m.

Table 3-3. *Elevation – Area – Volume Relationships for the Storm Pond*

Elevation **(m)**	**Area** **(m^2)**	**Incremental Volume** **(m^3)**	**Cumulative Volume** **(m^3)**
433	1256	0	0
434	1722	1483	1483
435	2257	1984	3467
436	2862	2553	6021
437	3535	3192	9213
438	4277	3900	13113
439	5089	4677	17790
440	5970	5524	23314
441	6920	6439	29753
442	7939	7424	37176
443	11411	9623	46799
444	12707	10815	57614
445	14072	13384	70998
446	15507	14784	85782
447	17010	16252	102034
448	18582	17790	119825
449	20224	19398	139222
450	21935	21074	160296
451	23715	22819	183115
452	25564	24634	207749
453	27483	26518	234267

Stage-Storage Curve for the Storm Pond is presented in Figure 3.8. Because no overflow from storm pond is allowed, one-meter freeboard is included for the storm pond for contingency. Operation capacity of this pond is 207,749 m^3 whereas the maximum capacity is 234,267 m^3, resulting in a 26,518 m^3 of freeboard capacity.

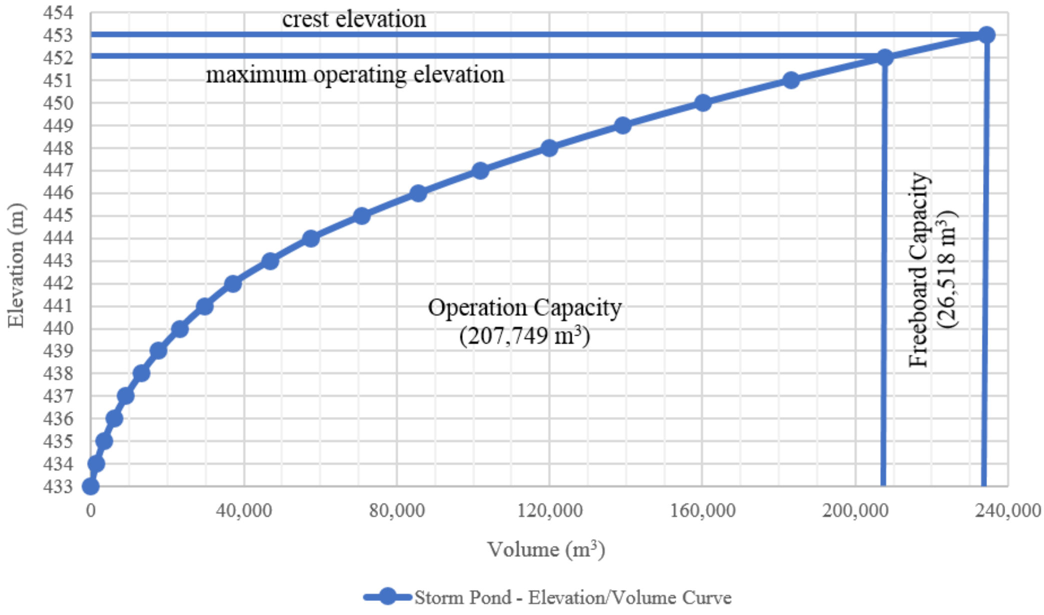

Figure 3.8. *Stage-Storage Curve for the Storm Pond*

After the description of the elements and influences for the PLS pond and storm pond geometries, a brief description of the water balances for both ponds is made in this section. Individual storage reservoirs are modeled for the PLS pond and the storm pond. The fluid volume in each reservoir is computed at each time step based on the volume at the previous time step plus the current time step inflows minus the current time step outflows. Elements and Influences inside the PLS Pond Water Balance Container are presented in Figure 3.9.

A reservoir element is created for the PLS pond to track flows. This element captures the current values, lower and upper bounds based on the stage-storage curve, inflows (additions) and outflows (withdrawals). Flow amounts above the upper bound is recorded as overflow (overflow to the storm pond). Cumulative inflows, outflows and overflows are estimated by the integrator elements. It is known from Section 2.2.1. that the project site has annual water deficit of 438 mm. To be able to provide an option for decreasing the liquid loss through evaporation, an element for the birdball evaporation efficiency is placed but it is defined as 1, which means that pond evaporation takes place without the birdball factor. If the results show that there is water deficiency in the operation, birdball factor would be applied to decrease the losses due to evaporation. Inflows to the PLS pond are the outflows from the heap leach pad into the PLS pond and the direct precipitation into the pond. Outflows from the PLS pond are the pond evaporation from the surface, which changes based on the pond level, and solution pumped back to the heap leach through Process Plant.

There is also an allocator element defined in the PLS pond water balance container. This element allocates an incoming signal to outputs according to the priorities. For example, it is known that outflows from the PLS pond are evaporation and solution pumped back to the heap leach. In this case, first priority is given to the evaporation because it is an inevitable natural process. The decision whether the solution demand can be supplied would be based on the amount of water in the pond. If the volume of solution in the pond is less than the required pumping rate, the pumping would not be initiated until the volume reaches to the required levels.

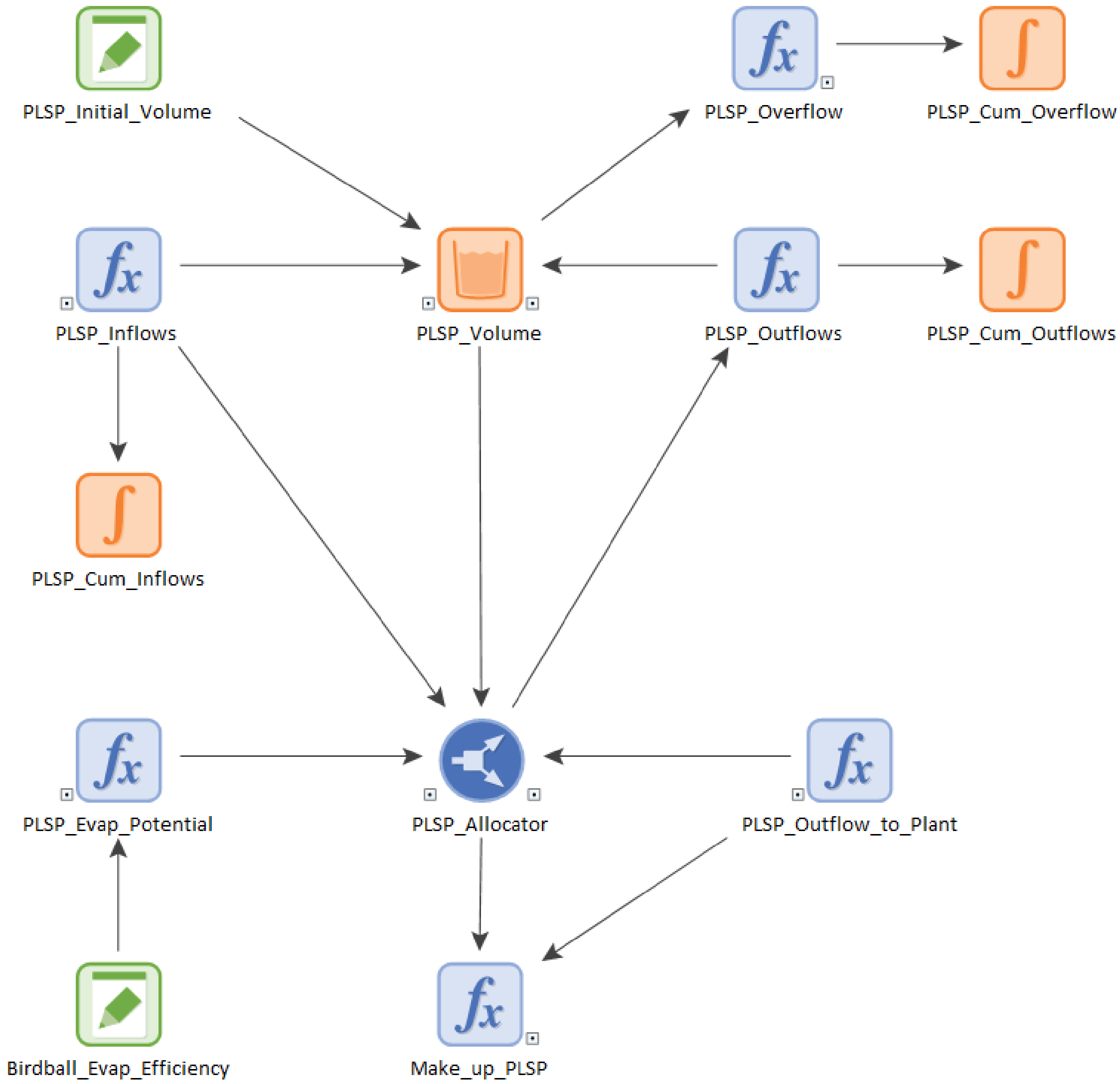

Figure 3.9. *Elements and Influences Inside the PLS Pond Water Balance Container*

Description of the water balance for the storm pond is very similar to the PLS pond. Elements and Influences inside the Storm Pond Water Balance Container are presented in Figure 3.10.

Similar to the PLS pond, a reservoir element is created for the storm pond to track flows capturing initial pond value, lower and upper bounds, inflows and outflows.

An element to record the flow amounts above the upper bound is created (for the overflows). Cumulative inflows, outflows and overflows are estimated by the integrator elements. At the end of the simulations, cumulative overflows are expected to be zero because no overflow should take place from the storm bond. Inflows to the PLS pond are the overflows from the PLS pond and the direct precipitation into the pond. Outflows from the PLS pond are the pond evaporation from the surface and solution pumped back to the heap leach through Process Plant.

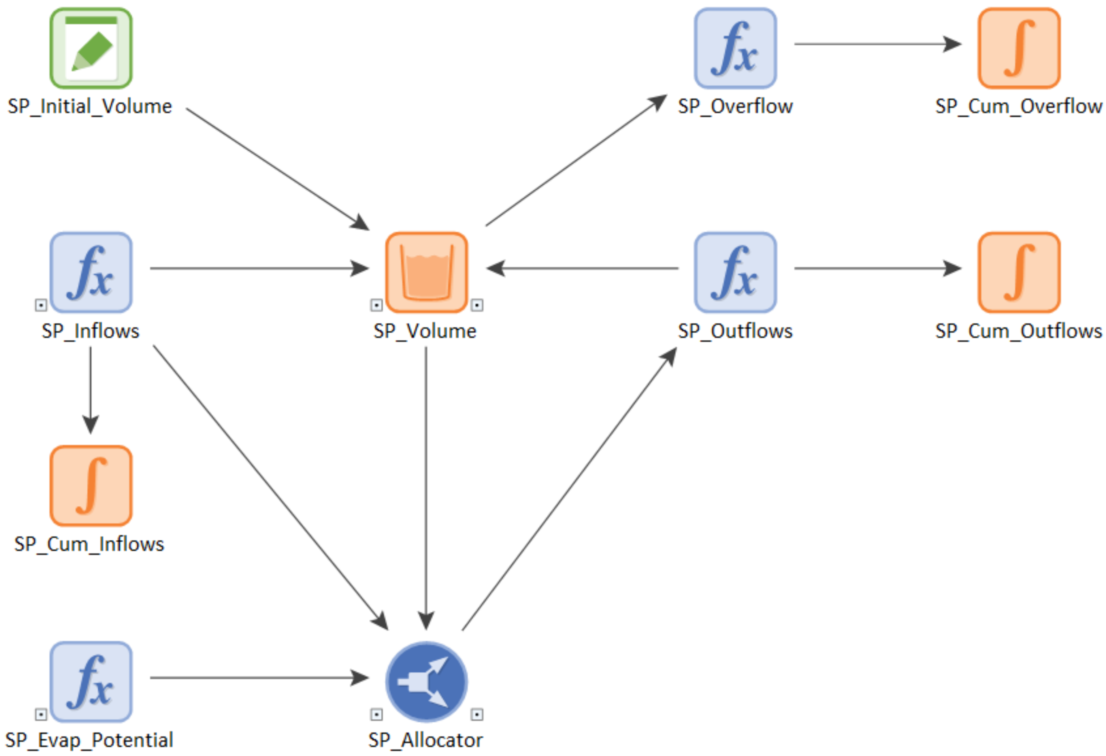

Figure 3.10. *Elements and Influences Inside the Storm Pond Water Balance Container*

Water balance for the heap leach pad includes direct precipitation on the active and inactive areas, barren leach solution nominal pumping rate of 923 m^3/hour on the active area, and evaporation losses. Difference between inflows (precipitation and solution application) and evaporation losses would give the net inflows. As the production continues, ore stacked in the heap leach would require solution to increase its moisture content to reach its field capacity. Any additional solution after this would initiate the leaching of the solution through the bottom of the pad. As described previously, the amount of solution required to bring the ore moisture content to its field capacity is termed as primary uptake. As the solution application and the leaching continues to complete leach cycle, moisture content increases and nearly stabilizes as long as the solution application conditions do not change. The amount of solution required to bring the ore moisture content from its field capacity to this condition is termed as secondary uptake. Primary uptake is subtracted from the net inflows to estimate the solution drained through ore. Secondary uptake is considered to be stored in the ore until the leaching ends in the active area. Once the leaching process ends, the related area becomes inactive and the solution is released through the ore and gained by the water balance system. With some delay and dispersion, it is released from the leach pad to the PLS pond.

With this operating philosophy and containers, elements and influences described, the model is built to track the solution movement at related storage areas (PLS pond and storm water pond).

Parameters, States and Simulation Settings are presented in the following section.

3.2. Model Parameters, States and Simulation Settings

The operational water balance model is developed to show the evolution of the HLF water management requirements over time. The model includes consideration of phased construction, which includes Phase 1, Phase 2 and Phase 3, for ore stacked on the leach pad over an approximate 10-year operation life.

Description of the model components is made in the previous sections. Model components include several parameters and states, and the simulation settings drive the calculations. The values of model parameters and states together with the simulation settings are presented in Table 3-4.

It should be noted that there is no snow data recorded in any of the stations nearby the project site. However, based on the observations made on site and information provided by local people, it is known that snowfall and snow accumulation take place at the proposed heap leach site. To factor in this parameter, snow is modeled in the water balance model to accumulate on the ore heap when the temperature is less than the threshold value of -1°C. Water is released from the snowpack in the water balance model based on a melt coefficient of 1 mm/°C/day with the °C factor as the temperature in degrees above the threshold snow temperature (Dingman, 1994). Sublimation and snow density were assumed to be 20% and 10%, respectively. Melting of snow during months with average temperatures below the threshold snow temperature are not considered in the model. Snow factor of 90% is assumed in the model, which is the ratio of the daily precipitation occurring as snow fall. The other 10% of the precipitation is assumed to be taking place as rain fall.

Table 3-4. *Values of Model Assumed Parameters, States and Simulation Settings*

Group	Item	Value	Unit
Assumed Parameters	Evaporation Coefficient (Pan to Pond)	0.7	-
	Active Area Heap Evaporation Coefficient	0.6	-
	Inactive Area Heap Evaporation Coefficient	0.35	-
	Temperature for Evaporation Determination	>0	°C
	Temperature for Snow / Rain Determination	-1	°C
	Snow Factor	90	%
	Sublimation	20	%
	Snow Density	10	%
	Snow Melt Coefficient	1	mm/°C/day
States	PLS Pond Initial Volume	60,000	m^3
	Storm Pond Initial Volume	200,000	m^3
Simulation Settings	Date Ore Production and Simulations Start	31-May-20	-
	Date Ore Production and Simulations End	26-Apr-30	-
	Simulations Timesteps	Daily	-
	Reporting Timesteps	Monthly	-
	# of Realizations in the Probabilistic Simulation	1,000	-

3.3. Running the Water Balance Model

Using the model input data described in Section 2.2 and assigned model parameters, states and simulation settings described in Section 3.2, the water balance model is developed using GoldSim version 12.1 simulation software. The model is developed using a daily time step, with the simulations starting on 31/5/2020 and ending on 26/4/2030. Monte-Carlo analyses in the stochastic runs were made for about 10 years with 1,000 realizations. The balance of the model is evaluated at each time step and checked for conservation of global inflows, global outflows, and system storage to ensure that unaccounted water is not entering or leaving the system.

3.4. Sensitivity Analysis

Ore moisture content is the parameter which influence the heap leach water balance results significantly. It is explained in Section 2.2.4 that three different values for the ore moisture are required in the operational heap leach water balance model; moisture content as delivered to the leach pad, moisture content at field capacity and moisture content during leaching at the leach pad. These values are determined during the Metallurgical Test Work performed on the ore and presented in the Project Design Criteria (Golder, 2019). For this project, test results provided ore moisture contents as 4%, 8% to 12 %, and 15% for the moisture contents as delivered, at field capacity (seasonally varying based on water deficit), and during leaching, respectively.

As described previously, the amount of solution required to bring the ore moisture content to its field capacity is termed as primary uptake. The amount of solution required to bring the ore moisture content from its field capacity to the design leaching condition is termed as secondary uptake. As a result, for this project, primary uptake values are 4% or 8% and secondary uptake values are 7% or 3%. It should be noted that the model uses one of these values for primary uptake and secondary uptake based on the month of the year. It is explained in Section 2.2.1 that water deficit in the region occurs for seven months, (April through October) and water surplus occurs in the remainder of the year (November through March). During the months when there is water deficit, ore would require more solution whereas the months when there is water surplus ore would require less solution. For this reason, primary uptake from April through October is 8% and from November through March is 4%. Respectively, secondary uptake from April through October is 3% and from November through March is 7%.

Due to sensitivity of the heap leach water balance model to the ore moisture content values, scenario modeling is conducted for the operational heap leach water balance model by increasing and decreasing the primary uptake and secondary uptake values for 1%. In addition to the modeling results performed with the design values, two additional scenarios are modelled to evaluate the changes in the water balance results.

Scenario 1

In this scenario, moisture contents of the ore delivered to the leach pad and during leaching at the leach pad is decreased by 1%. This would result in 1% higher primary uptake and 1% lower secondary uptake. When the modelling results of the design moisture content values compared to this scenario, the expected results would be more solution required by the ore to reach its field capacity and less solution being released through the ore and gained by the water balance system.

Scenario 2

As an opposite scenario, moisture contents of the ore delivered to the leach pad and during leaching at the leach pad is increased by 1%. This would result in 1% lower primary uptake and 1% higher secondary uptake. When the modelling results of the design moisture content values compared to this scenario, the expected results would be less solution required by the ore to reach its field capacity and more solution being released through the ore and gained by the water balance system. Design, Scenario 1 and Scenario 2 Values for the Moisture Content is presented in Table 3-5.

Table 3-5. *Design, Scenario 1 and Scenario 2 Values for the Moisture Content*

Item	**Design Value (%)**	**Scenario 1**	**Scenario 2**
Ore Moisture Content			
as delivered	4	3	5
at field capacity (Nov. through March - Remaining Months)	8 - 12	8 - 12	8 - 12
during leaching	15	14	16
Primary Uptake (November through March)	4	5	3
Primary Uptake (April through October)	8	9	7
Secondary Uptake (November through March)	7	6	8
Secondary Uptake (April through October)	3	2	4

CHAPTER 4

RESULTS

WGEN generated daily precipitation value for about 10 years with 1,000 realizations. It was mentioned in 2.2.2 that WGEN was tested for 1-year with 100 simulations and the maximum daily precipitation was 91.8 mm. It was also mentioned that during the operational heap leach water balance model simulations, the model would be run for about 10 years with 1,000 realizations (as described in Section 3.3), and as a result, it would be expected that higher daily precipitation values are observed. For this reason, WGEN generated probabilistic precipitation results would be important to present to make sure that extreme events are experienced during the simulations.

With the WGEN generated precipitation values, the stochastic operational heap leach water balance model is run to evaluate the capacity of the ponds and external make-up (raw) water required to maintain the heap leach operation. Additionally, sensitivity analysis was also performed based on ore moisture content parameter.

Aforementioned evaluations are presented in the following sub-sections.

4.1. Probabilistic Precipitation Results

WGEN module in the operational heap leach water balance model generated daily precipitation data for 10 years with 1000 realizations. This allowed increased number of sampling at the tails of the distribution by Monte-Carlo analysis. Extreme precipitation amounts estimated for the project site in Section 2.2.3 were considered in the comparison. WGEN Generated Daily Precipitation Data for 10-years with

1000 Simulations is presented in Figure 4.1 together with 24-hour precipitation event lines for 50-year, 100-year, and 200-year return periods.

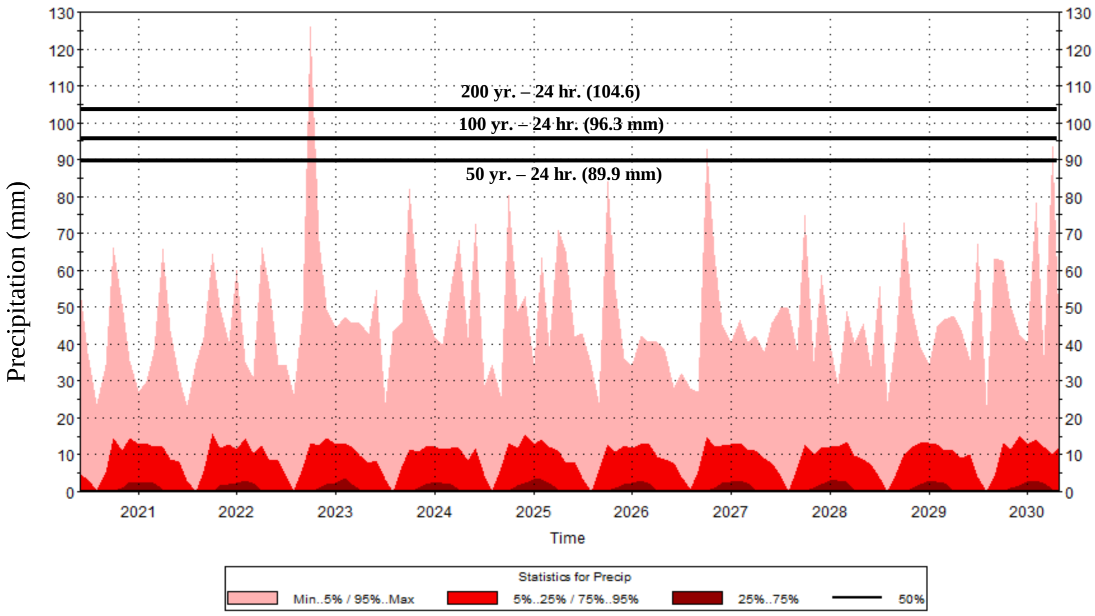

Figure 4.1. *WGEN Generated Daily Precipitation Data for 10-years with 1000 Simulations*

Maximum daily precipitation amounts in each realization is plotted on a histogram plot based on the 24-hour IDF Data range and presented in Figure 4.2. It can be said that the realizations include; two precipitation amounts (126.4 mm and 107.6 mm both occurring in October 2022 in different realizations) exceeding 200-year 24-hour rain event, two precipitation amounts (93.81 mm and 92.95 mm occurring in April 2030 and October 2026, respectively) close to 100-year 24-hour rain event, one precipitation amount (84.23 mm occurring in October 2025) close to 50-year 24-hour rain event, seven precipitation amounts between 10-year 24-hour and 25-year-24 hour events, 17 precipitation amounts between 5-year-24 hour and 10-year 24-hour events, and 44 precipitation amounts between 2-year-24 hour and 5-year 24-hour events.

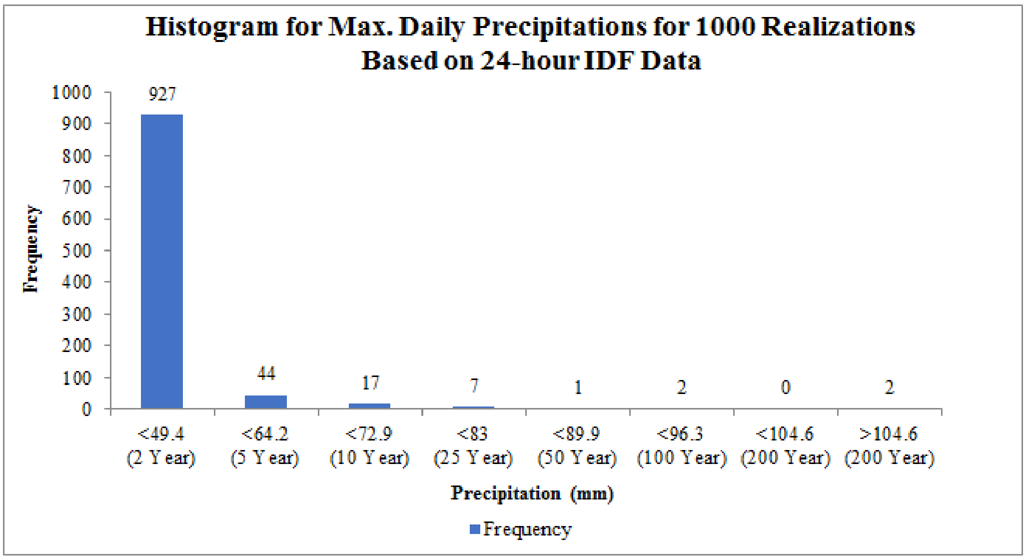

Figure 4.2. Histogram for Maximum Daily Precipitations for 1000 Realizations Based on the 24-Hour IDF Data

4.2. Evaluation of the Ponds' Capacity

The results of the stochastic water balance model for different percentiles for the PLS pond showing the operating volumes and overflows are presented in Figure 4.3. and Figure 4.4, respectively. With the maximum capacity of 106,097 m^3, PLS pond is not expected to overflow in the first two and a half years of the operation. With the expansion of the leach pad and including the Phase 2 area into the water balance system (in 21st Month of the operation), PLS pond capacity becomes inadequate in approximately one year to store the run off in storm events. As it is also seen, at 50th percentile conditions, PLS pond itself would have enough capacity to store the solution. Table showing the PLS Pond operating volumes at different probabilistic levels is presented in Appendix C-1. Overflow amounts from the PLS pond to the storm pond are presented in Figure 4.4. It is seen that the overflows (in cubic meters per hour over monthly periods) equaled or exceeded the 95th percentile occur in between 3 to 6 months during the operation starting in February 2023. Table showing the PLS Pond overflows at different probabilistic levels is presented in Appendix C-2.

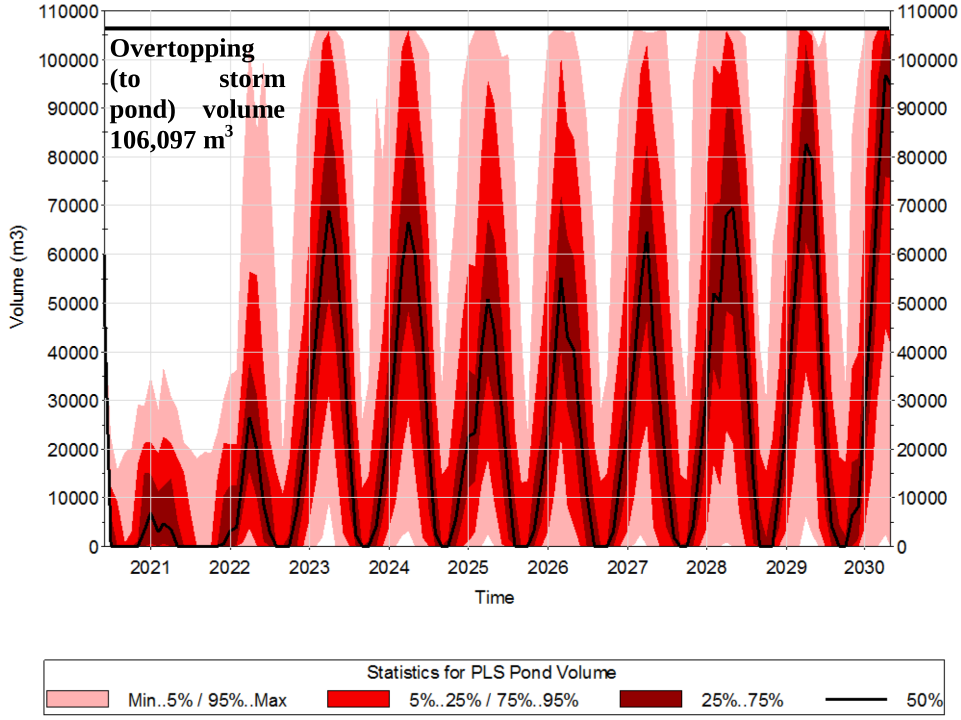

Figure 4.3. *PLS Pond Probabilistic Operating Volumes*

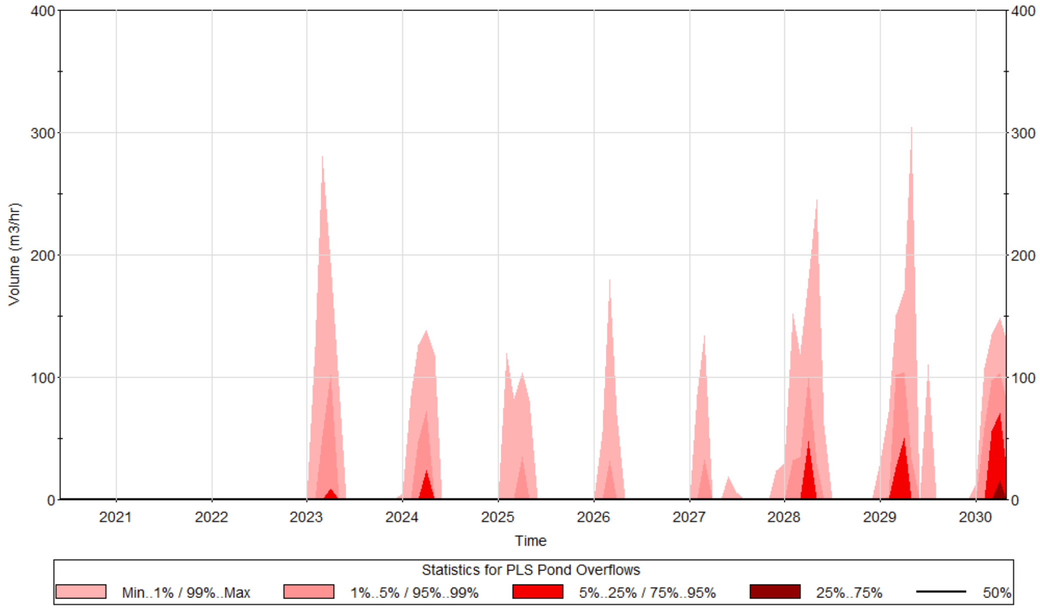

Figure 4.4. *PLS Pond Probabilistic Overflows*

The results of the stochastic water balance model for different percentiles for the storm pond is presented in Figure 4.5. Storm pond has a capacity of 207,749 m^3 when the freeboard volume is excluded. It is seen that even in extremely wet conditions, the volume in the storm pond is not expected to reach 200,000 m^3. In average conditions, the volume in the storm pond is expected to be below 20,000 m^3. Most importantly, no overflow is expected from the PLS pond, which is the ultimate aim of any heap leach operation. Table showing the storm pond operating volumes at different probabilistic levels is presented in Appendix C-3.

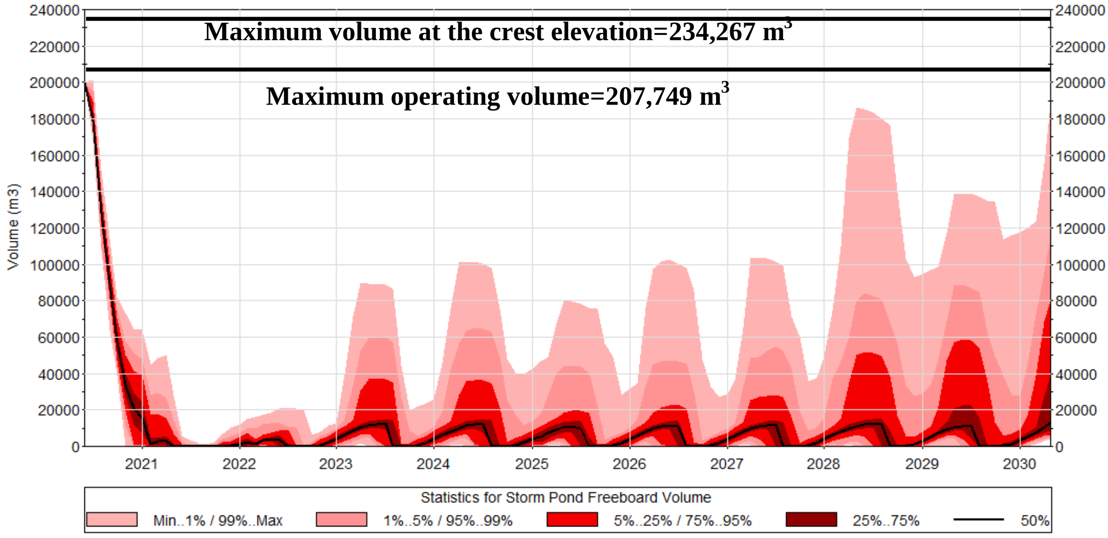

Figure 4.5. *Storm Pond Probabilistic Operating Volumes*

Even though amount of solution balance is made for each pond, Figure 4.6 is prepared to present the annual cumulative excess water volumes from the heap leach operation. Total capacity of the PLS pond and storm pond until the freeboard limit is approximately 314,000 m^3. As it is seen in the graph, maximum excess water volume at maximum expectation is around 200,000 m^3 even with maximum expected volumes between 3rd and 8th years of the operation. It reaches up to 288,098 m^3 in May 2028 and 294,595 m^3 at the end of the operation but never exceeds the total capacity of both ponds. Table showing the excess water volumes from the heap leach facility at different probabilistic levels is presented in Appendix C-4.

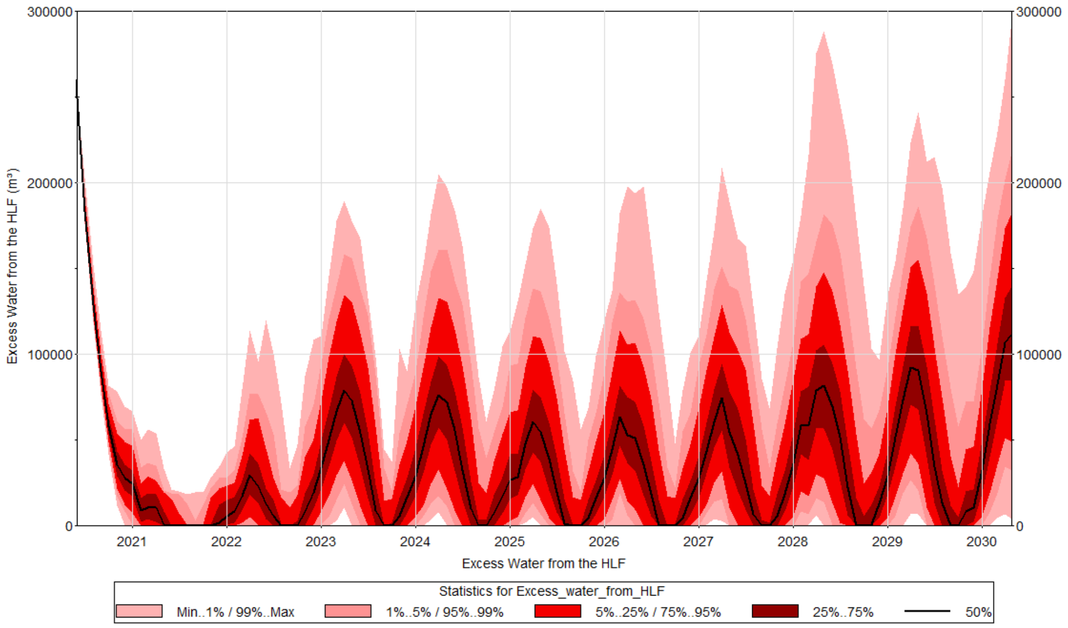

Figure 4.6. *Probabilistic Excess Water Volumes (PLS Pond + Storm Pond) from the HLF*

4.3. External Makeup (Raw) Water Demand Evaluation

Using the stochastic climate option, demand for external makeup (raw) water during the operation life of the proposed heap leach facility is evaluated. External Makeup Water Demand requirement is presented in Figure 4.7.

It is seen that the external makeup water demand at the 95th percentile is around 80 m^3/hr (22 L/s) from 2nd to 8th year of the operation. Table showing the external makeup water demand at different probabilistic levels is presented in Appendix C-5.

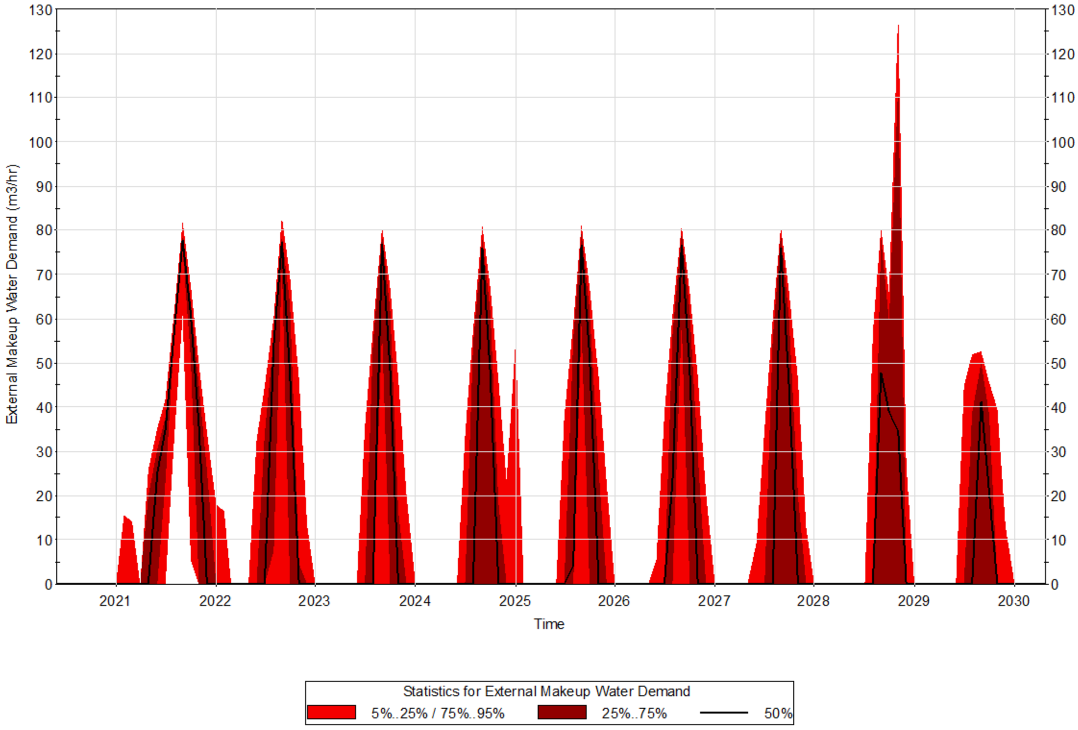

Figure 4.7. *Probabilistic External Makeup (Raw) Water Demand*

Table 4-1 presents the number of months with external makeup (raw) water demand and maximum demand amounts. These are the months when there is not enough water in the ponds to provide the required barren flow rate of 923 m^3/hr (256 L/s). External makeup is not required for the first nine months of the operation provided that the ponds are filled with the initial amounts determined in this study.

Table 4-1. *Number of Months with External Makeup (Raw) Water Demand and Maximum Demand*

Condition	**Percentile**	**Number of Months with External Makeup Water Demand Required**	**Maximum Demand Amount (L/s)**
Dry	95th	63	36 L/s over the Month
Average	50th	26	22 L/s over the Month
Wet	5th	3	17 L/s over the Month

4.4. Sensitivity Analysis Results Based on Varying Ore Moisture Content Values

Sensitivity analysis is performed with the assumption that ore moisture content values differ from those tested in laboratory conditions during the Metallurgical Test Work because these values are known to be influencing the heap leach water balance most significantly.

In addition to the design conditions, two additional scenarios are modelled for varying ore moisture contents. First scenario assumes 1% higher primary uptake and 1% lower secondary uptake. Second scenario assumes the opposite conditions; 1% lower primary uptake and 1% higher secondary uptake.

It was discussed in Section 3.4 that the expected results for Scenario 1 would be more solution requirement for the primary uptake and less solution requirement for the secondary uptake. Because the secondary uptake is considered to be stored in the ore until the leaching ends in the active area and then it is released through the ore and gained by the water balance system, it can be said that lower volumes are expected in the system compared to the design scenario. Contrary to this, the expected results for Scenario 2 would be less solution requirement for the primary uptake and more solution requirement for the secondary uptake. This would result in higher volumes gained by the water balance system compared to the design scenario.

Results in Section 4.2 and 4.3 are presented with the additional scenarios to the design conditions. PLS Pond Operating Volumes for Different Scenarios at 50th percentile is presented in Figure 4.8. It can be seen that similar to the results presented in Figure 4.3, at 50th percentile conditions, PLS pond itself would have enough capacity to store the solution. In Scenario 1, PLS pond volume would reach up to approximately 82,500 m^3 where in Scenario 2, it would reach up to 106,043 m^3, right below the overtopping volume. At higher percentiles, PLS pond would be overtopping to the storm pond.

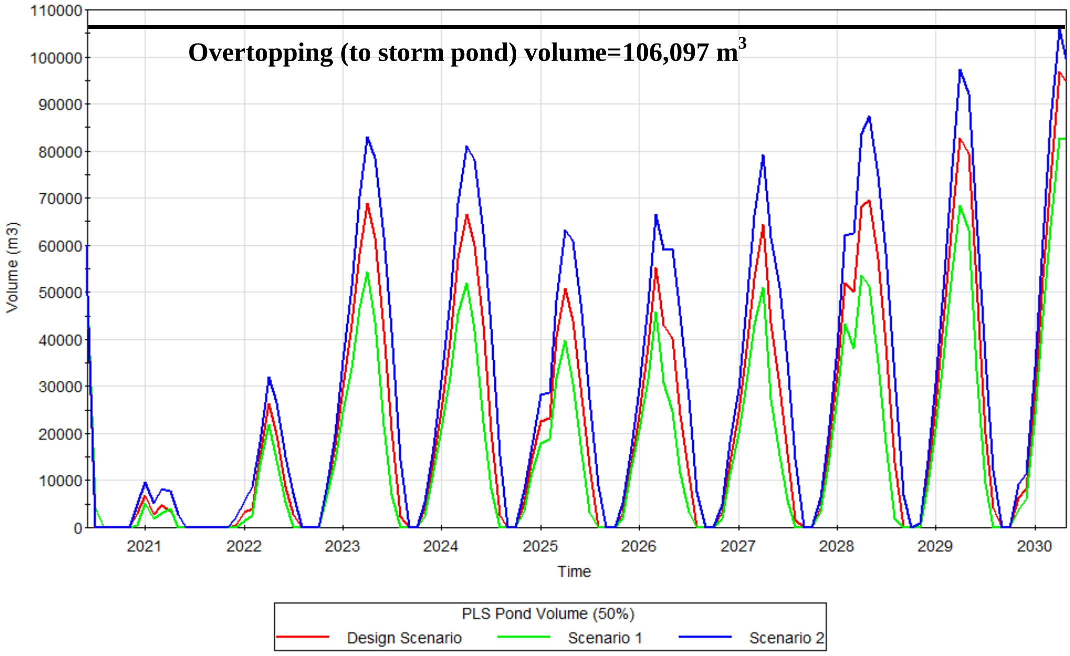

Figure 4.8. *PLS Pond Operating Volumes for Different Scenarios*

Storm Pond Maximum Operating Volume for Different Scenarios is presented in Figure 4.9. It is seen that, exceedance of the maximum operating volume of the pond would take place in the last month of the operation based on Scenario 2 whereas volume in the pond on the same month is estimated to be approximately 140,000 m^3 based on Scenario 1. Between two scenarios, there would be more than 65,000 m^3 volume difference in the storm pond at the end of the operation. Even though the maximum operating volume of the pond is expected to be exceeded, the exceeded volume would be very low and less than the maximum pond volume, which means that no overtopping is expected.

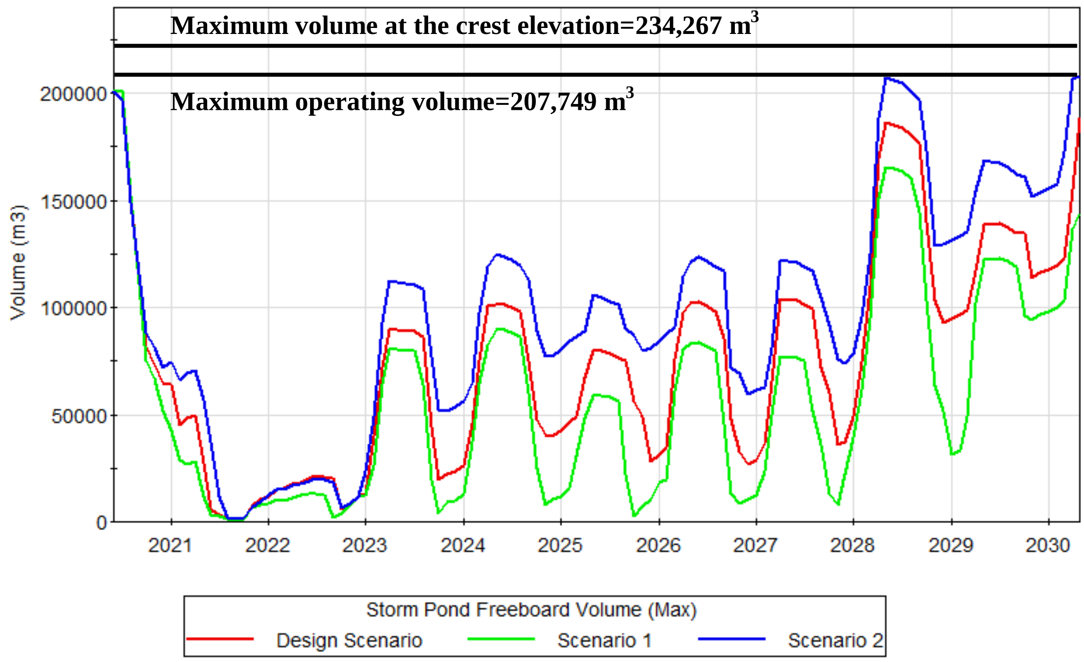

Figure 4.9. *Storm Pond Operating Volumes for Different Scenarios*

Lastly, demand for external makeup water during the operation life of the proposed heap leach facility is evaluated for different scenarios at 50th percentile.

It is seen that design condition and Scenario 1 give similar results most of the time for the first seven years with approximately 80 m^3/hour water requirement whereas Scenario 2 gives results as low as 8 m^3/hour in October 2024, 22 m^3/hour in October 2027, and shows no requirement after November 2027.

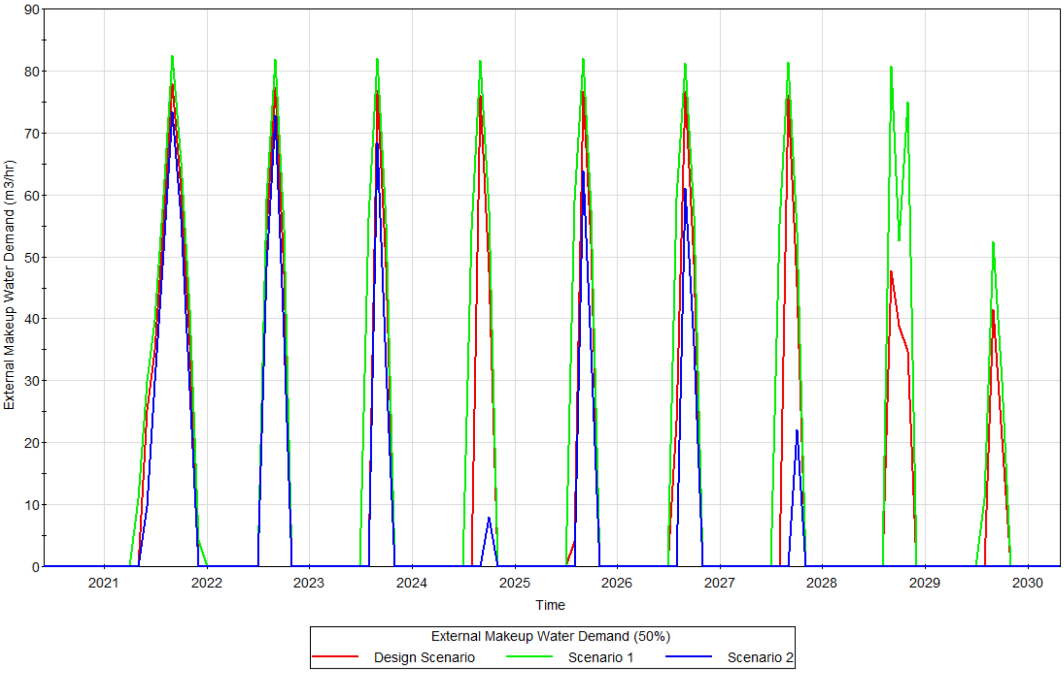

Figure 4.10. *External Makeup Water Demand for Different Scenarios*

CHAPTER 5

SUMMARY & RECOMMENDATIONS

In this thesis, probabilistic simulation was conducted for the purpose of evaluating the dynamic water balance system for one of the mining facilities, called heap leach, by using a software program called GoldSim, which uses the Monte Carlo simulation to model the dynamic systems quantitatively to represent the uncertainties in the systems. Primary objectives of this water balance model were to evaluate the ponds capacities and the external makeup water demand during the heap leach operation.

There was no meteorological station at the project site of the proposed facility for climate data records. For this reason, the closest meteorological stations to the project area were determined, and their available daily data were acquired from the related agency (MGM). Afterwards, climate data sets, which have the largest uncertainty in the water balance systems, were constructed for the project site.

By using the constructed daily precipitation data, daily stochastic time series of precipitation is generated synthetically with the same statistical characteristics as the constructed data by using the simulation model called WGEN.

WGEN module in the operational heap leach water balance model generated daily precipitation data for 10 years with 1000 realizations. This allowed increased number of sampling at the tails of the distribution by Monte-Carlo analysis so that extreme precipitation amounts estimated for the project site could be sampled.

Maximum daily precipitation amounts in each realization were analyzed and it was seen that the realizations include; two precipitation amounts exceeding 200-year 24-hour rain event, two precipitation amounts close to 100-year 24-hour rain event, and one precipitation amount close to 50-year 24-hour rain event.

In addition to constructing the climate data sets and generating the probabilistic precipitation, operation and design-based parameters were input into the water balance model together with the values of model parameters and states.

The water balance model developed using GoldSim version 12.1 was run using a daily time steps for approximately 10 years, which is the operation life of the proposed facility. Monte-Carlo analyses in the stochastic runs were made with 1,000 realizations. The balance of the model is evaluated at each time step and checked for conservation of global inflows, global outflows, and system storage.

The model results show that the proposed ponds would have enough capacity to accommodate the solution being circulated at the heap leach facility. No exceedance of the freeboard limit at the 100th percentile is expected to be experienced at the storm pond.

External makeup (raw) water demand during the operation life of the proposed heap leach facility is estimated to vary from 17 L/s to 36 L/s over a monthly period when the maximum demand is expected in wet and in dry conditions, respectively. External makeup water demand at the 95th percentile is around 80 m^3/hr (22 L/s) from 2nd to 8th year of the operation. External makeup is not required for the first nine months of the operation provided that the ponds are filled with the initial amounts specified in this study.

As a preparation of the closure stage, it was assumed that Phase 1 (an area of approximately 120,000 m^2) would be covered before the Phase 3 expansion at 82nd Month of the operation (in March 2027). It is assumed that the precipitation on this area would be diverted out of the water balance system. It is recommended that the clean run off from this area is stored in a separate pond and used as a water source to minimize the external makeup water demand. It is also recommended that progressive closure is continued for the heap leach by covering the heaps once they reach to the ultimate lift and the solution application is completed. The model did not consider such closure. However, it should be noted that such closure would provide benefit to the water balance.

Sensitivity analysis is performed with the assumption that ore moisture content for the “as-delivered” and “during leaching” values differ by 1% from those tested in laboratory conditions because ore moisture is the parameter which influence the heap leach water balance results significantly. As expected, when the primary uptake is increased and secondary uptake is decreased (Scenario 1), ponds would receive lower volumes compared to the design conditions. When the primary uptake is decreased and secondary uptake is increased (Scenario 2), ponds would receive higher volumes compared to the design conditions, which may cause exceedance of the maximum operating volumes towards end of the operation and usage of the freeboard volume, with no overtopping of the crest elevation. Even this can be prevented by continuously monitoring the pond levels and following the Operation & Maintenance Manual prepared for the heap leach operation.

The water balance model in this study is for operational purpose and is based on the design and the operating conditions of the heap leach facility. Any changes in any of these parameters would have an effect on the outcomes.

It is recommended that pond levels during the operation are closely monitored and water balance model is calibrated based on the recorded pond levels, recorded climate data, recorded makeup water use, recorded leach application flows, and other operational information. With all these, it would be possible to forecast the pond capacities with higher confidence and if necessary, a contingency plan would be implemented to provide additional storage for the later phases of the operation.

It is recommended that the model results and operation monitoring data is continuingly compared, and the model is periodically updated or calibrated when a deviation is observed to better understand some of the input parameters used in the model and to factor in operational and risk profiles based on the operating philosophy.

Any underdrain that may be connected to the water balance system (as an inflow to the system) and potential seepage through the liner (as an outflow from the system) are ignored from the water balance system. If an underdrain system is deemed necessary and connected to the water balance system, the amount should be determined and considered in the model.

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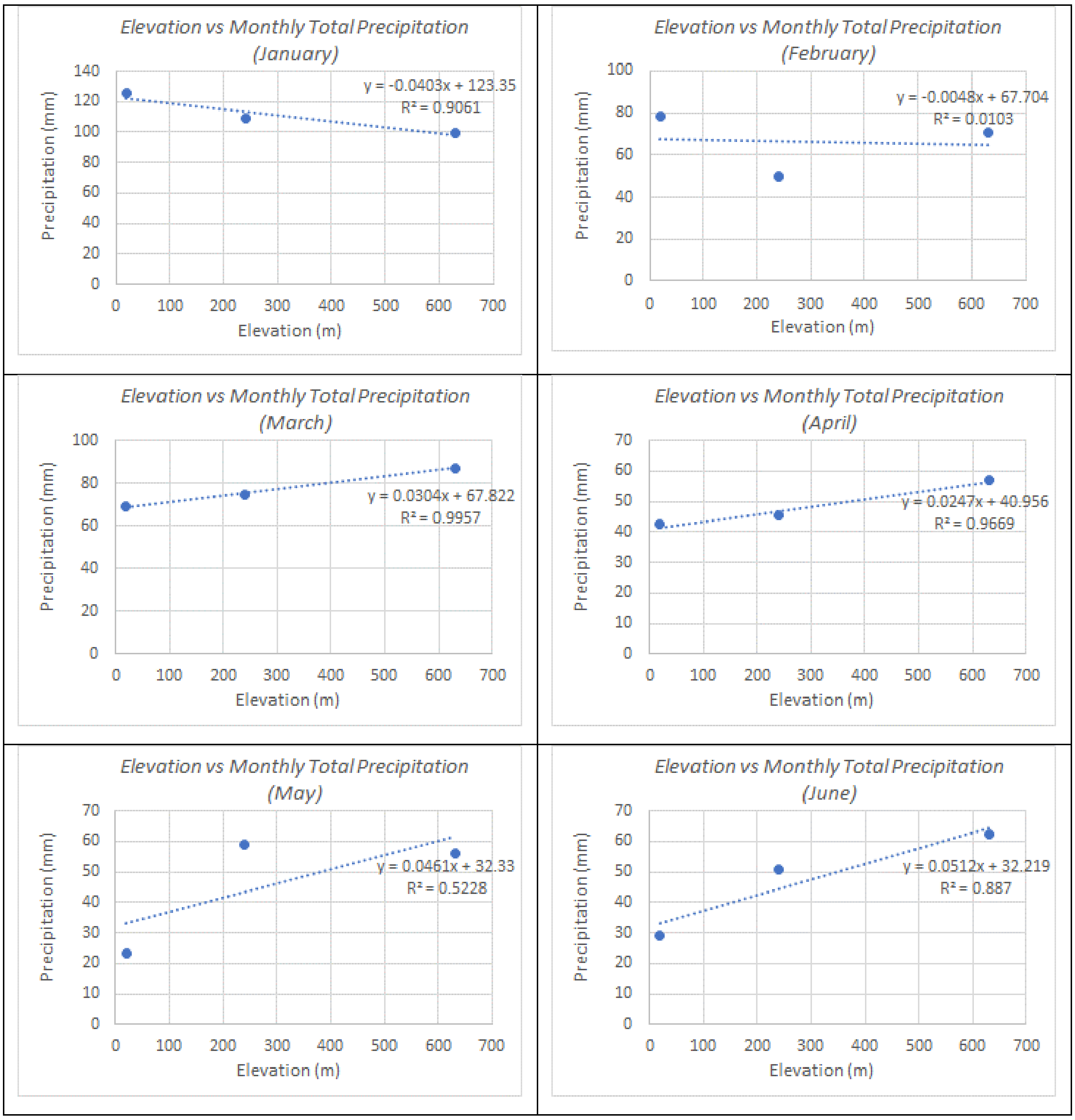
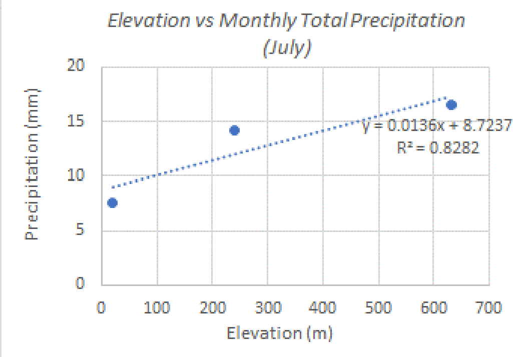
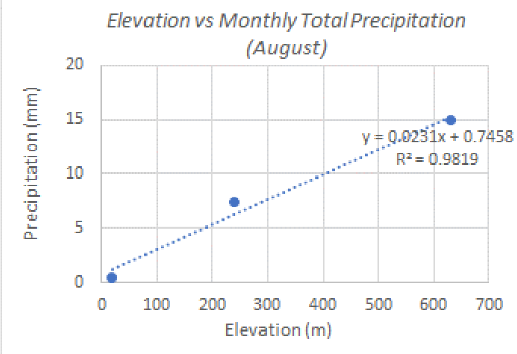
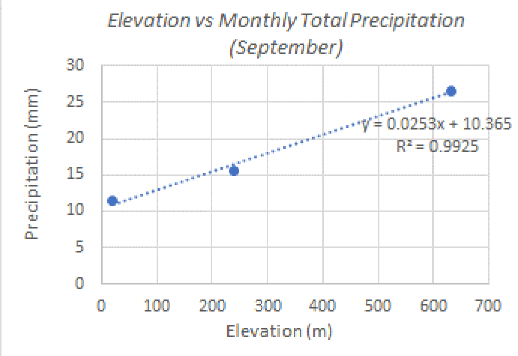
APPENDICES

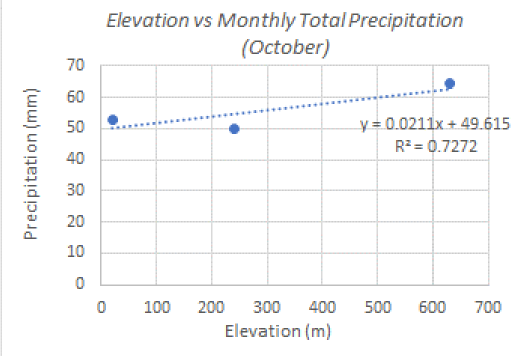
A-1. Relationships between Elevations and Total Monthly Precipitations

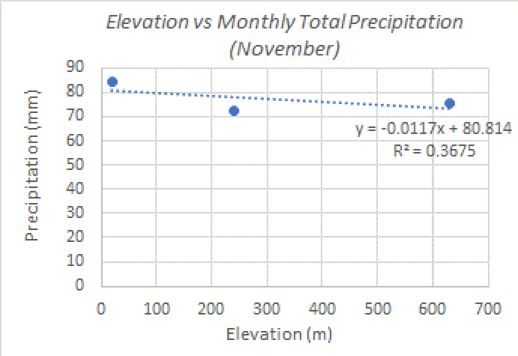


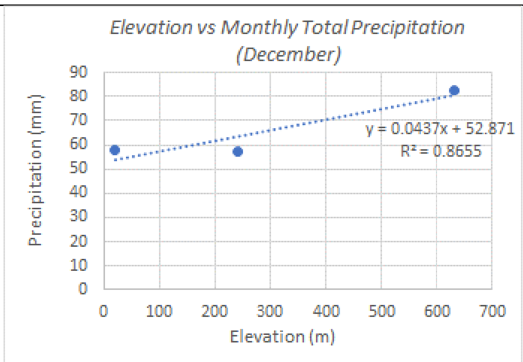

Elevation vs Monthly Total Precipitation (July)
Precipitation (mm)
Elevation (m)
y = 0.0136x + 8.7237
R^2 = 0.8282


Elevation vs Monthly Total Precipitation (August)
Precipitation (mm)
Elevation (m)
y = 0.0231x + 0.7458
R^2 = 0.9819

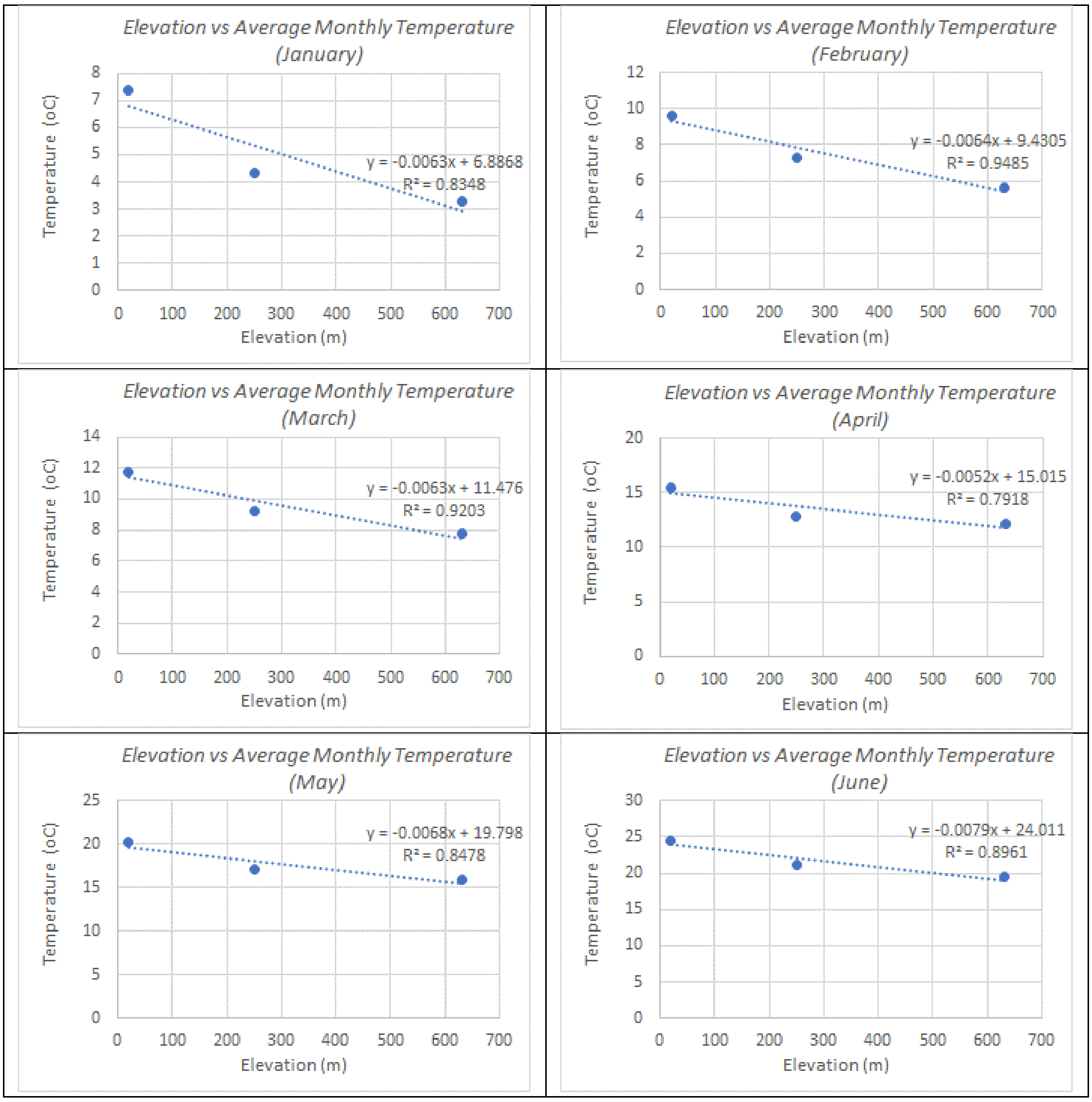

Elevation vs Monthly Total Precipitation (September)
Precipitation (mm)
Elevation (m)
y = 0.0253x + 10.365
R^2 = 0.9925

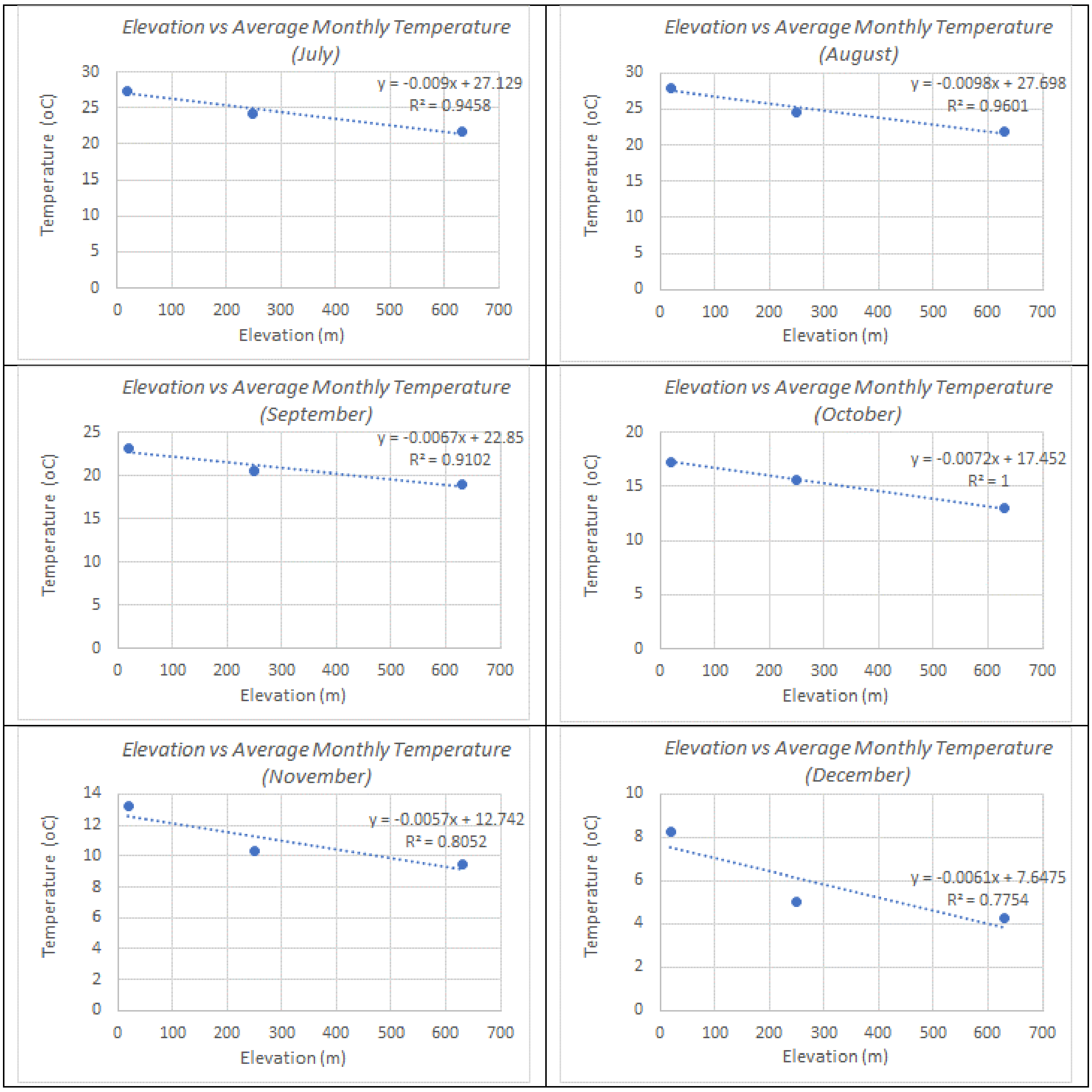

Elevation vs Monthly Total Precipitation (October)
Precipitation (mm)
Elevation (m)
y = 0.0211x + 49.615
R^2 = 0.7272


Elevation vs Monthly Total Precipitation (November)
Precipitation (mm)
Elevation (m)
y = -0.0117x + 80.814
R^2 = 0.3675


Elevation vs Monthly Total Precipitation (December)
Precipitation (mm)
Elevation (m)
y = 0.0437x + 52.871
R^2 = 0.8655

A-2. Relationships between Elevations and Average Monthly Temperatures




Elevation vs Average Monthly Temperature (July)
y = -0.009x + 27.129
R² = 0.9458
Temperature (oC)
Elevation (m)
Elevation vs Average Monthly Temperature (August)
y = -0.0098x + 27.698
R² = 0.9601
Temperature (oC)
Elevation (m)
Elevation vs Average Monthly Temperature (September)
y = -0.0067x + 22.85
R² = 0.9102
Temperature (oC)
Elevation (m)
Elevation vs Average Monthly Temperature (October)
y = -0.0072x + 17.452
R² = 1
Temperature (oC)
Elevation (m)
Elevation vs Average Monthly Temperature (November)
y = -0.0057x + 12.742
R² = 0.8052
Temperature (oC)
Elevation (m)
Elevation vs Average Monthly Temperature (December)
y = -0.0061x + 7.6475
R² = 0.7754
Temperature (oC)
Elevation (m)

B. Precipitation Intensity Data of Standard Time Series at Balıkesir Station

TURKISH STATE METEOROLOGICAL SERVICE BALIKESİR METEOROLOGICAL STATION PRECIPITATION INTENSITY DATA OF STANDARD TIME SERIES (mm)															
	MINUTE				HOUR										
YEAR	5	10	15	30	1	2	3	4	5	6	8	12	18	24	24 +
2015	8.3	14.5	18.2	25.7	44.3	47.8	47.8	47.8	47.9	47.9	47.9	48.0	58.1	59.7	
2014	8.4	14.1	17.5	27.1	31.0	31.6	31.6	32.5	35.0	35.1	39.2	47.3	59.2	63.7	
2013	1.4	2.8	3.1	3.8	5.4	8.3	9.8	11.1	12.4	13.3	14.1	14.7	14.9	58.8	*
2012	6.8	9.1	11.4	13.8	13.8	13.8	17.1	17.2	17.2	17.2	17.3	24.9	26.7	39.8	
2011	8.2	12.2	14.4	24.2	37.1	42.6	43.3	46.3	46.7	46.8	46.8	46.9	47.0	75.8	
2010	6.4	9.9	13.9	20.4	21.4	21.4	26.8	29.5	30.6	31.1	31.1	31.1	31.2	50.6	
2009	3.3	5.3	7.0	10.3	16.7	24.4	27.2	28.9	30.2	32.3	33.3	37.1	42.2	42.9	
2008	2.8	5.7	8.2	10.1	12.8	13.4	14.8	15.7	16.0	17.6	18.7	18.9	19.0	19.0	
2007	2.4	4.7	6.9	9.3	10.6	13.3	16.3	19.6	22.5	25.5	27.1	29.6	33.0	43.5	
2006	6.1	10.8	13.3	21.1	27.9	41.6	42.3	42.5	42.6	42.7	42.8	42.9	43.0	43.1	
2005	4.2	6.8	9.2	11.2	11.4	13.3	14.8	14.8	14.8	14.8	15.1	17.7	17.8	27.5	
2004	2.7	5.1	5.5	5.9	7.1	11.4	14.2	15.6	16.7	17.2	17.2	17.3	21.9	126.8	*
2003	3.2	6.1	8.2	9.9	10.4	11.4	16.1	19.2	22.3	25.2	26.8	30.8	32.9	34.2	
2002	4.7	6.8	9.1	15.1	24.9	31.4	31.4	31.4	31.5	31.5	31.5	31.6	38.5	41.5	
2001	10.1	19.9	28.0	34.2	35.2	36.5	39.3	42.0	42.4	42.5	44.1	48.8	57.2	63.4	
2000	6.8	9.0	10.0	10.5	10.5	13.6	14.5	17.1	19.3	19.3	19.4	19.4	26.3	32.6	
1999	8.4	9.8	14.6	17.0	17.7	17.9	17.9	17.9	17.9	17.9	18.0	18.0	18.0	18.0	
1998	5.6	8.8	12.3	22.1	40.9	54.7	61.0	65.8	68.1	70.8	71.8	71.8	72.0	73.3	
1997	7.4	11.0	13.5	13.7	15.2	24.2	29.4	36.7	38.3	43.3	54.4	61.1	61.2	63.2	
1996	5.3	9.2	11.1	13.3	13.9	20.8	28.9	36.9	42.0	45.6	46.7	46.8	47.0	47.1	
1995	6.7	9.0	12.2	18.1	21.0	21.2	21.3	22.4	24.1	25.6	25.7	25.8	39.2	39.4	
1994	3.7	4.3	4.9	6.4	8.8	13.1	15.5	18.5	19.7	22.2	26.2	29.9	34.1	47.5	
1993	4.2	7.6	9.9	11.3	12.2	17.1	17.1	17.1	17.1	17.1	17.1	17.2	21.5	28.3	
1992	5.6	8.2	9.8	10.0	11.2	12.9	12.9	12.9	13.4	15.9	15.9	15.9	15.9	30.3	
1991	5.7	7.8	9.6	10.7	11.7	11.8	20.5	20.5	20.5	20.5	20.5	20.5	20.5	28.5	
1990	7.3	11.2	14.5	18.2	26.1	40.1	41.1	41.1	41.1	44.4	44.4	48.5	48.5	112.1	*
1989	10.3	12.1	14.3	14.5	14.5	14.5	14.5	14.5	15.1	15.1	15.2	15.2	15.2	36.6	*
1988	3.7	5.7	6.7	8.7	9.2	10.3	10.7	11.0	11.1	11.1	11.1	11.1	11.7	50.6	*
1987	4.1	7.5	8.2	9.8	11.9	14.0	14.1	14.6	17.2	17.2	20.0	20.2	20.2	60.5	*
1986	4.0	4.6	5.1	6.8	8.3	10.7	13.5	15.2	15.7	17.8	18.8	18.8	22.6	42.3	*
1985	11.4	20.2	27.1	32.1	32.3	32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.4	34.3	
1984	5.0	7.8	8.5	9.7	12.7	15.0	19.7	25.1	28.3	28.3	28.3	28.3	28.3	28.3	
1983	10.5	20.9	26.8	34.7	38.0	38.7	38.7	38.8	38.8	38.8	38.8	38.8	38.8	38.8	
1982	7.2	8.8	9.0	9.7	10.2	12.3	13.3	13.3	13.3	15.4	23.8	27.3	31.7	31.7	
1981	4.2	6.0	6.2	7.9	8.7	14.2	16.7	18.3	18.9	19.9	19.9	19.9	19.9	58.8	*
1980	3.5	4.2	5.7	8.1	12.5	22.6	29.8	32.5	34.8	36.3	36.9	38.0	41.2	41.5	
1979	3.8	5.0	9.1	11.4	12.4	15.5	20.5	22.7	23.4	23.7	28.0	32.6	32.6	55.9	
1978	5.5	7.0	12.2	23.8	30.6	35.5	37.6	43.3	48.6	52.1	53.8	53.8	53.8	53.9	
1977	3.7	5.5	7.0	9.2	13.5	22.9	31.4	38.4	38.4	43.2	48.5	58.1	60.0	60.6	
1976	5.8	11.3	15.2	20.8	22.2	23.5	26.1	26.1	26.1	26.1	26.1	26.1	26.1	41.3	
1975	6.2	7.5	8.4	10.1	12.3	20.1	20.4	24.0	27.6	31.1	36.6	37.8	37.8	48.7	
1974	4.0	6.5	7.1	10.3	14.4	15.2	17.6	18.8	19.2	24.5	27.2	31.0	33.8	39.7	
1973	5.9	9.5	10.7	10.7	11.7	16.6	19.2	20.8	21.0	22.2	23.9	24.7	25.0	85.1	*
1972	8.3	9.4	13.8	16.5	16.5	21.4	23.3	23.3	23.3	23.3	23.3	23.3	23.5	23.9	
1971	5.5	6.8	8.2	8.8	13.7	13.8	14.5	14.5	14.5	14.5	14.5	14.5	14.5	37.4	*
1970	7.8	14.8	16.7	19.2	20.6	20.6	20.6	20.7	20.7	20.7	20.7	20.7	20.7	36.2	
1969	4.0	7.3	10.3	16.6	22.2	37.6	38.2	48.0	49.3	49.3	49.3	49.3	49.3	50.8	
1968	7.6	9.5	12.3	14.4	15.1	19.5	19.6	19.6	19.6	19.6	30.6	30.8	30.8	77.9	*
1967	7.7	9.9	10.4	13.5	20.0	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	44.7	
1966	10.9	17.7	18.3	20.0	21.5	21.5	22.1	23.2	23.4	25.8	25.9	27.1	27.1	63.9	*
1965	7.7	8.3	8.6	9.4	9.5	9.9	10.2	12.6	14.2	16.0	16.2	16.3	16.3	41.1	*
1964	6.8	10.3	12.3	15.9	17.2	17.2	17.2	18.4	20.0	20.8	20.8	20.8	20.8	44.0	*
1963	6.0	8.5	10.7	12.2	13.1	13.6	13.8	13.8	13.8	13.8	13.8	13.8	13.8	65.6	*
1962	4.8	6.0	6.7	7.9	10.4	12.0	12.0	14.5	15.9	16.2	17.4	17.6	17.6	97.2	*
1961	4.6	8.2	9.0	11.4	14.0	15.9	23.6	25.9	26.7	26.7	26.7	30.5	30.5	37.2	
1960	5.0	7.3	9.2	14.1	23.3	33.3	34.0	34.8	35.1	35.1	36.1	40.3	41.7	41.8	
1959	9.3	16.8	21.6	29.8	34.3	34.3	35.0	35.2	36.2	36.2	36.2	42.4	43.4	45.1	
1958	5.0	8.5	13.5	14.0	14.7	21.9	23.1	24.9	27.3	28.8	29.4	29.4	33.2	33.2	
1957	18.3	22.4	26.0	26.4	26.9	27.0	27.0	27.0	27.0	27.0	27.0	27.0	28.5	30.0	
N	43	43	43	43	43	43	43	43	43	43	43	43	43	43	59
Y-ORT	6.3	9.8	12.6	16.4	20.1	24.2	26.6	28.7	29.8	31.0	32.3	34.3	36.6	42.6	49.0
Y-EB	18.3	22.4	28.0	34.7	44.3	54.7	61.0	65.8	68.1	70.8	71.8	71.8	72.0	75.8	126.8
Std.S	2.87	4.57	5.83	7.57	9.68	10.83	10.59	11.48	11.82	12.06	12.46	13.04	13.63	13.55	20.86
Car.K	1.88	1.37	1.41	0.96	0.94	0.93	1.03	0.98	0.95	1.01	0.95	0.82	0.64	0.54	1.59
UDF	LP3	LP3	LP3	LP3	LP3	LP3	LP3	LP3	LP3	LP3	LP3	LP3	LP3	LP3	LP3
2 Year	5.7	8.6	11.1	14.6	17.6	21.7	24.4	26.4	27.6	28.6	30.0	31.9	34.4	41.2	44.7
5 Year	8.1	12.6	16.1	21.4	26.2	31.5	34.0	36.8	38.3	39.5	41.3	43.8	47.0	53.5	62.6
10 Year	9.9	15.5	19.9	26.4	32.9	38.6	40.7	44.0	45.6	47.0	49.0	51.8	55.2	60.8	75.3
25 Year	12.3	19.8	25.3	33.6	42.5	48.5	49.5	53.4	55.0	56.8	59.0	62.1	65.3	69.2	92.4
50 Year	14.2	23.3	29.9	39.5	50.5	56.4	56.4	60.6	62.1	64.2	66.6	69.8	72.7	74.9	105.8
100 Year	16.2	27.2	34.8	45.8	59.3	63.5	64.9	68.1	69.3	71.9	74.4	77.6	79.9	80.3	119.8
200 Year	18.3	31.5	40.3	52.7	69.1	71.0	73.9	75.8	76.7	79.8	82.4	85.4	85.6	87.2	134.5
PLF	**0.18**	**0.29**	**0.37**	**0.48**	**0.61**	**0.69**	**0.72**	**0.76**	**0.79**	**0.81**	**0.85**	**0.89**	**0.93**	**1.00**	**1.33**
PLV	**0.16**	**0.25**	**0.32**	**0.41**	**0.49**	**0.58**	**0.64**	**0.68**	**0.71**	**0.74**	**0.76**	**0.81**	**0.86**	**1.00**	**1.00**

C-1. Table Showing the PLS Pond Operating Volumes at Different Probabilistic Levels

		PLS Pond Probabilistic Operating Volumes (m^3)						
Date / Period	**Month #**	**Min**	**5%**	**25%**	**50%**	**75%**	**95%**	**Max**
31-May-20	**0**	60,000	60,000	60,000	60,000	60,000	60,000	60,000
June-20	1	49,418	49,418	49,426	49,427	49,431	49,466	49,709
July-20	2	0	0	0	0	6,362	12,289	22,281
August-20	3	0	0	0	0	0	9,122	15,739
September-20	4	0	0	0	0	0	736	19,441
October-20	5	0	0	0	0	0	2,941	20,328
November-20	6	0	0	0	0	1,102	17,031	29,181
December-20	7	0	0	0	3,039	15,153	21,344	28,864
January-21	8	0	0	575	6,722	14,972	21,655	35,006
February-21	9	0	0	0	2,858	11,332	19,267	28,045
March-21	10	0	0	454	4,797	12,315	22,468	36,685
April-21	11	0	0	0	3,480	13,804	21,144	30,733
May-21	12	0	0	0	0	5,284	18,231	27,978
June-21	13	0	0	0	0	0	15,310	21,281
July-21	14	0	0	0	0	0	7,141	20,074
August-21	15	0	0	0	0	0	0	18,070
September-21	16	0	0	0	0	0	0	19,317
October-21	17	0	0	0	0	0	0	19,199
November-21	18	0	0	0	0	0	14,297	23,441
December-21	19	0	0	0	494	10,562	21,303	30,329
January-22	20	0	0	0	3,222	12,502	21,122	35,134
February-22	**21**	0	0	193	4,015	12,615	21,089	36,159
March-22	22	0	695	7,671	15,195	24,090	37,778	75,633
April-22	23	0	3,662	15,479	26,435	37,930	56,516	104,192
May-22	24	0	0	9,596	19,695	30,975	55,532	85,290
June-22	25	0	0	941	8,687	18,801	37,409	99,661
July-22	26	0	0	0	2,927	12,720	21,711	78,558
August-22	27	0	0	0	0	52	15,425	51,007
September-22	28	0	0	0	0	0	10,642	19,409
October-22	29	0	0	0	0	2,292	17,584	43,839
November-22	30	0	0	0	7,320	17,692	35,514	82,361
December-22	31	0	0	8,245	17,292	26,998	46,091	96,711
January-23	32	0	5,698	18,507	29,718	44,311	65,215	101,366
February-23	33	0	13,466	29,261	43,199	59,508	87,505	106,097
March-23	34	1,709	22,968	42,223	58,081	76,194	103,384	106,097
April-23	35	9,055	30,891	51,015	68,935	88,545	105,809	106,097
May-23	36	0	18,287	42,034	61,618	80,134	96,860	106,097
June-23	37	0	2,724	23,353	41,776	60,332	82,010	106,097
July-23	38	0	0	7,871	20,651	38,595	62,019	93,885

August-23	39	0	0	0	2,282	13,112	28,960	60,104
September-23	40	0	0	0	0	0	12,175	26,172
October-23	41	0	0	0	0	1,069	14,411	33,931
November-23	42	0	0	0	4,149	14,136	31,441	92,901
December-23	43	0	0	5,676	14,462	24,752	43,820	79,384
January-24	44	0	3,946	14,556	25,025	39,788	62,070	106,097
February-24	45	0	8,983	26,040	39,778	56,825	81,302	106,097
March-24	46	1,971	19,283	40,181	57,176	74,057	102,282	106,097
April-24	47	3,205	26,588	48,397	66,616	87,146	106,097	106,097
May-24	48	0	15,607	40,646	59,845	80,353	98,625	106,097
June-24	49	0	1,711	22,166	43,018	62,873	82,176	103,969
July-24	50	0	0	7,090	20,385	40,447	62,695	101,221
August-24	51	0	0	0	2,544	14,320	31,777	69,372
September-24	52	0	0	0	0	53	14,778	32,570
October-24	53	0	0	0	0	1,533	16,409	52,574
November-24	54	0	0	0	5,399	15,983	32,604	70,484
December-24	55	0	0	5,530	14,817	24,579	46,780	94,380
January-25	56	0	1,017	12,129	22,589	36,152	57,948	102,719
February-25	57	0	2,868	13,431	23,369	35,169	57,478	106,097
March-25	58	0	12,478	26,472	40,482	53,017	81,023	106,097
April-25	59	2,454	17,790	35,523	50,872	67,504	95,941	106,097
May-25	60	0	8,952	28,640	44,001	63,105	90,990	106,097
June-25	61	0	195	13,516	27,682	46,734	72,999	100,675
July-25	62	0	0	1,493	13,172	26,353	54,708	100,947
August-25	63	0	0	0	0	9,451	23,784	77,334
September-25	64	0	0	0	0	0	13,208	44,243
October-25	65	0	0	0	0	177	13,516	23,086
November-25	66	0	0	0	3,149	13,797	28,676	62,508
December-25	67	0	0	5,277	13,909	23,680	44,123	89,786
January-26	68	0	3,175	14,468	24,005	37,184	59,292	104,741
February-26	69	0	10,966	24,901	38,505	54,255	80,404	106,097
March-26	70	0	22,254	40,372	55,200	72,464	101,024	106,097
April-26	71	0	8,134	28,361	42,931	63,416	86,595	105,489
May-26	72	0	4,212	22,913	40,308	59,372	84,025	105,763
June-26	73	0	0	10,045	24,070	43,894	71,211	99,507
July-26	74	0	0	0	10,971	24,127	51,509	87,864
August-26	75	0	0	0	0	8,585	21,051	63,634
September-26	76	0	0	0	0	0	13,397	28,231
October-26	77	0	0	0	0	611	14,940	35,317
November-26	78	0	0	0	3,200	13,860	30,243	72,614
December-26	79	0	0	4,778	13,850	23,728	42,230	92,139
January-27	80	0	3,219	13,351	24,431	35,788	61,472	99,964
February-27	81	294	9,732	25,667	37,795	52,616	80,892	106,097

March-27	**82**	2,335	19,671	38,896	52,985	70,498	97,643	106,097
April-27	83	0	25,189	46,813	64,454	82,786	103,105	105,569
May-27	84	0	3,814	24,292	43,390	65,095	87,702	105,597
June-27	85	0	0	12,918	29,859	52,271	77,461	106,097
July-27	86	0	0	3,968	15,727	35,311	62,608	106,091
August-27	87	0	0	0	1,747	13,198	34,693	84,673
September-27	88	0	0	0	0	248	14,643	43,771
October-27	89	0	0	0	0	765	13,644	30,792
November-27	90	0	0	0	4,135	16,882	34,993	95,634
December-27	91	0	0	6,707	16,600	28,732	53,155	106,097
January-28	92	0	3,991	19,772	32,557	48,311	77,097	106,097
February-28	93	0	16,814	36,567	51,880	70,410	99,033	106,097
March-28	94	0	12,352	31,884	50,078	70,701	96,758	106,097
April-28	95	716	23,954	48,374	68,064	90,219	106,097	106,097
May-28	96	0	21,313	47,256	69,642	89,777	103,454	106,097
June-28	97	0	6,796	33,953	57,172	75,474	93,287	106,097
July-28	98	0	0	16,586	38,723	57,778	79,902	104,722
August-28	99	0	0	447	13,908	28,160	50,304	76,967
September-28	100	0	0	0	0	6,762	19,310	41,487
October-28	101	0	0	0	0	1,862	15,547	30,313
November-28	102	0	0	0	0	10,058	22,436	62,117
December-28	103	0	0	3,617	11,215	20,574	36,756	70,024
January-29	104	0	3,515	15,410	25,607	38,814	62,307	106,097
February-29	105	0	13,903	30,347	46,387	62,858	90,088	106,097
March-29	106	0	25,986	47,412	65,443	83,471	106,097	106,097
April-29	107	5,973	35,706	62,558	82,769	103,120	106,097	106,097
May-29	**108**	2,245	29,344	58,024	79,361	93,800	104,718	106,097
June-29	109	0	4,039	29,995	51,951	68,456	84,260	102,354
July-29	110	0	0	7,208	19,985	36,791	60,029	106,097
August-29	111	0	0	0	4,250	15,726	31,938	86,734
September-29	112	0	0	0	0	4,368	18,404	52,261
October-29	113	0	0	0	0	1,988	17,309	32,826
November-29	114	0	0	0	6,432	17,323	36,799	85,400
December-29	115	0	0	1,659	8,247	18,187	39,841	97,555
January-30	116	0	3,883	16,340	28,465	44,585	71,453	106,097
February-30	117	0	15,978	35,394	53,047	70,588	103,440	106,097
March-30	118	0	30,778	55,233	74,035	95,805	106,097	106,097
April-30	**119**	2,288	44,529	75,931	96,884	106,097	106,097	106,097
26-Apr-30	**-**	17	41,366	75,694	94,779	101,802	106,097	106,097

Note: Months showing when overflowing from PLS pond to the storm pond at different probabilistic levels occurs are highlighted.

C-2. Table Showing the PLS Pond Overflow Amounts at Different Probabilistic Levels

		PLS Pond Probabilistic Overflows (m^3/hr.)						
Date / Period	**Month #**	**Min**	**5%**	**25%**	**50%**	**75%**	**95%**	**Max**
31-May-20	**0**	0	0	0	0	0	0	0
June-20	1	0	0	0	0	0	0	0
July-20	2	0	0	0	0	0	0	0
August-20	3	0	0	0	0	0	0	0
September-20	4	0	0	0	0	0	0	0
October-20	5	0	0	0	0	0	0	0
November-20	6	0	0	0	0	0	0	0
December-20	7	0	0	0	0	0	0	0
January-21	8	0	0	0	0	0	0	0
February-21	9	0	0	0	0	0	0	0
March-21	10	0	0	0	0	0	0	0
April-21	11	0	0	0	0	0	0	0
May-21	12	0	0	0	0	0	0	0
June-21	13	0	0	0	0	0	0	0
July-21	14	0	0	0	0	0	0	0
August-21	15	0	0	0	0	0	0	0
September-21	16	0	0	0	0	0	0	0
October-21	17	0	0	0	0	0	0	0
November-21	18	0	0	0	0	0	0	0
December-21	19	0	0	0	0	0	0	0
January-22	20	0	0	0	0	0	0	0
February-22	**21**	0	0	0	0	0	0	0
March-22	22	0	0	0	0	0	0	0
April-22	23	0	0	0	0	0	0	0
May-22	24	0	0	0	0	0	0	0
June-22	25	0	0	0	0	0	0	0
July-22	26	0	0	0	0	0	0	0
August-22	27	0	0	0	0	0	0	0
September-22	28	0	0	0	0	0	0	0
October-22	29	0	0	0	0	0	0	0
November-22	30	0	0	0	0	0	0	0
December-22	31	0	0	0	0	0	0	0
January-23	32	0	0	0	0	0	0	0
February-23	33	0	0	0	0	0	0	124
March-23	34	0	0	0	0	0	0	281
April-23	35	0	0	0	0	0	10	194
May-23	36	0	0	0	0	0	0	94
June-23	37	0	0	0	0	0	0	0

July-23	38	0	0	0	0	0	0	0
August-23	39	0	0	0	0	0	0	0
September-23	40	0	0	0	0	0	0	0
October-23	41	0	0	0	0	0	0	0
November-23	42	0	0	0	0	0	0	0
December-23	43	0	0	0	0	0	0	0
January-24	44	0	0	0	0	0	0	5
February-24	45	0	0	0	0	0	0	85
March-24	46	0	0	0	0	0	0	126
April-24	47	0	0	0	0	0	25	139
May-24	48	0	0	0	0	0	0	119
June-24	49	0	0	0	0	0	0	0
July-24	50	0	0	0	0	0	0	0
August-24	51	0	0	0	0	0	0	0
September-24	52	0	0	0	0	0	0	0
October-24	53	0	0	0	0	0	0	0
November-24	54	0	0	0	0	0	0	0
December-24	55	0	0	0	0	0	0	0
January-25	56	0	0	0	0	0	0	0
February-25	57	0	0	0	0	0	0	121
March-25	58	0	0	0	0	0	0	82
April-25	59	0	0	0	0	0	0	104
May-25	60	0	0	0	0	0	0	81
June-25	61	0	0	0	0	0	0	0
July-25	62	0	0	0	0	0	0	0
August-25	63	0	0	0	0	0	0	0
September-25	64	0	0	0	0	0	0	0
October-25	65	0	0	0	0	0	0	0
November-25	66	0	0	0	0	0	0	0
December-25	67	0	0	0	0	0	0	0
January-26	68	0	0	0	0	0	0	0
February-26	69	0	0	0	0	0	0	55
March-26	70	0	0	0	0	0	0	180
April-26	71	0	0	0	0	0	0	69
May-26	72	0	0	0	0	0	0	0
June-26	73	0	0	0	0	0	0	0
July-26	74	0	0	0	0	0	0	0
August-26	75	0	0	0	0	0	0	0
September-26	76	0	0	0	0	0	0	0
October-26	77	0	0	0	0	0	0	0
November-26	78	0	0	0	0	0	0	0
December-26	79	0	0	0	0	0	0	0

January-27	80	0	0	0	0	0	0	0
February-27	81	0	0	0	0	0	0	86
March-27	**82**	0	0	0	0	0	0	134
April-27	83	0	0	0	0	0	0	0
May-27	84	0	0	0	0	0	0	0
June-27	85	0	0	0	0	0	0	19
July-27	86	0	0	0	0	0	0	6
August-27	87	0	0	0	0	0	0	0
September-27	88	0	0	0	0	0	0	0
October-27	89	0	0	0	0	0	0	0
November-27	90	0	0	0	0	0	0	0
December-27	91	0	0	0	0	0	0	24
January-28	92	0	0	0	0	0	0	30
February-28	93	0	0	0	0	0	0	153
March-28	94	0	0	0	0	0	0	119
April-28	95	0	0	0	0	0	48	181
May-28	96	0	0	0	0	0	0	246
June-28	97	0	0	0	0	0	0	61
July-28	98	0	0	0	0	0	0	0
August-28	99	0	0	0	0	0	0	0
September-28	100	0	0	0	0	0	0	0
October-28	101	0	0	0	0	0	0	0
November-28	102	0	0	0	0	0	0	0
December-28	103	0	0	0	0	0	0	0
January-29	104	0	0	0	0	0	0	31
February-29	105	0	0	0	0	0	0	71
March-29	106	0	0	0	0	0	26	151
April-29	107	0	0	0	0	0	51	171
May-29	**108**	0	0	0	0	0	0	305
June-29	109	0	0	0	0	0	0	0
July-29	110	0	0	0	0	0	0	111
August-29	111	0	0	0	0	0	0	0
September-29	112	0	0	0	0	0	0	0
October-29	113	0	0	0	0	0	0	0
November-29	114	0	0	0	0	0	0	0
December-29	115	0	0	0	0	0	0	0
January-30	116	0	0	0	0	0	0	13
February-30	117	0	0	0	0	0	0	108
March-30	118	0	0	0	0	0	56	135
April-30	**119**	0	0	0	0	16	71	149
26-Apr-30	**-**	0	0	0	0	0	28	131

C-3. Table Showing the Storm Pond Operating Volumes at Different Probabilistic Levels

		Storm Pond Probabilistic Operating Volumes (m3)						
Date / Period	**Month #**	**Min**	**5%**	**25%**	**50%**	**75%**	**95%**	**Max**
31-May-20	**0**	**200,000**	**200,000**	**200,000**	**200,000**	**200,000**	**200,000**	**200,000**
June-20	1	199,941	199,941	199,958	199,961	199,971	200,029	200,440
July-20	2	168,072	175,801	176,845	178,979	183,342	189,750	201,146
August-20	3	108,040	121,010	125,445	128,580	132,060	138,184	151,768
September-20	4	63,905	81,374	85,931	89,379	93,525	100,470	114,062
October-20	5	38,974	47,529	53,618	57,575	63,322	70,534	81,841
November-20	6	0	19,727	26,867	33,511	40,154	50,448	73,186
December-20	7	0	863	12,070	20,680	29,315	41,528	64,438
January-21	8	0	921	6,872	15,508	25,015	39,261	64,021
February-21	9	0	0	375	1,131	4,430	17,279	44,818
March-21	10	0	0	1,239	2,690	4,814	17,718	48,262
April-21	11	0	0	568	2,892	5,710	15,585	49,926
May-21	12	0	0	0	22	897	6,763	27,578
June-21	13	0	0	0	0	35	1,009	5,819
July-21	14	0	0	0	0	0	427	3,282
August-21	15	0	0	0	0	0	11	1,569
September-21	16	0	0	0	0	0	0	1,184
October-21	17	0	0	0	0	0	273	2,040
November-21	18	0	0	0	0	290	2,257	7,065
December-21	19	0	0	0	296	1,281	2,966	10,346
January-22	20	0	0	168	1,363	2,685	5,036	11,874
February-22	**21**	0	0	577	2,484	4,553	7,371	14,913
March-22	22	0	184	780	1,403	2,051	4,067	15,968
April-22	23	0	1,007	2,338	3,234	4,146	6,462	17,395
May-22	24	0	0	3,153	4,326	5,342	7,770	18,609
June-22	25	0	0	104	3,572	6,197	8,482	20,545
July-22	26	0	0	0	39	1,478	8,954	21,467
August-22	27	0	0	0	0	0	795	20,709
September-22	28	0	0	0	0	0	106	20,066
October-22	29	0	0	0	0	160	1,148	6,170
November-22	30	0	0	0	695	1,954	4,295	8,109
December-22	31	0	0	926	2,062	3,669	6,045	11,707
January-23	32	0	1,041	2,874	4,228	5,954	8,501	12,926
February-23	33	0	2,730	4,745	6,318	8,168	11,044	39,656
March-23	34	69	4,514	6,767	8,412	10,168	14,271	71,800
April-23	35	1,660	6,138	8,441	10,202	12,267	30,451	89,649
May-23	36	0	7,088	9,551	11,377	13,607	36,777	89,659
June-23	37	0	2,777	10,299	12,128	14,331	37,678	88,693

July-23	38	0	0	9,153	12,618	14,973	36,888	88,634
August-23	39	0	0	0	27	14,171	35,116	86,518
September-23	40	0	0	0	0	0	969	44,260
October-23	41	0	0	0	0	188	1,747	19,900
November-23	42	0	0	0	677	1,880	4,224	21,998
December-23	43	0	0	918	2,008	3,574	5,742	23,603
January-24	44	0	958	2,579	4,024	5,794	8,446	26,064
February-24	45	0	2,486	4,537	6,247	8,079	10,958	45,784
March-24	46	666	4,470	6,463	8,299	10,324	14,095	75,450
April-24	47	952	5,968	8,220	10,057	12,302	28,531	100,807
May-24	48	0	6,715	9,263	11,255	13,564	35,796	101,213
June-24	49	0	1,338	9,961	12,128	14,440	36,237	101,308
July-24	50	0	0	7,466	12,356	15,112	36,503	100,291
August-24	51	0	0	0	50	14,471	34,719	98,091
September-24	52	0	0	0	0	0	21,514	75,347
October-24	53	0	0	0	0	179	2,290	47,937
November-24	54	0	0	0	833	2,200	4,699	40,566
December-24	55	0	0	769	2,078	3,768	6,393	39,750
January-25	56	0	719	2,577	4,107	5,911	8,692	42,736
February-25	57	0	655	2,121	5,423	8,057	10,892	46,536
March-25	58	493	2,288	4,280	7,323	10,133	13,266	49,174
April-25	59	1,294	3,816	6,187	9,114	11,873	15,783	67,376
May-25	60	0	4,798	7,307	10,187	13,018	18,317	79,644
June-25	61	0	0	7,487	10,695	13,843	19,522	79,479
July-25	62	0	0	213	9,597	14,026	19,432	78,314
August-25	63	0	0	0	0	5,054	18,254	76,353
September-25	64	0	0	0	0	0	1,612	75,367
October-25	65	0	0	0	0	64	1,329	56,339
November-25	66	0	0	0	364	1,636	3,914	48,774
December-25	67	0	0	854	1,759	3,199	5,798	28,179
January-26	68	0	716	2,526	3,808	5,323	8,175	31,658
February-26	69	0	2,566	4,533	5,916	7,521	10,552	34,610
March-26	70	0	4,515	6,486	8,067	9,739	13,309	75,992
April-26	71	0	5,809	8,240	9,853	11,671	18,214	97,393
May-26	72	0	1,429	9,184	10,951	12,836	21,233	101,773
June-26	73	0	0	9,406	11,720	13,754	22,216	102,411
July-26	74	0	0	45	11,225	14,273	23,071	100,581
August-26	75	0	0	0	0	1,630	20,598	98,311
September-26	76	0	0	0	0	0	2,532	85,595
October-26	77	0	0	0	0	84	1,164	47,997
November-26	78	0	0	0	311	1,629	3,776	32,606
December-26	79	0	0	645	1,703	3,187	5,620	27,034

January-27	80	0	490	2,262	3,766	5,272	7,765	28,604
February-27	81	0	2,345	4,244	5,912	7,563	10,459	36,530
March-27	**82**	1,036	4,087	6,233	7,902	9,752	13,035	65,354
April-27	83	468	5,811	8,007	9,834	11,770	25,626	103,871
May-27	84	0	3,991	8,978	10,908	12,817	26,959	103,379
June-27	85	0	0	9,342	11,591	13,737	27,918	103,067
July-27	86	0	0	515	11,908	14,371	28,201	101,507
August-27	87	0	0	0	0	13,425	27,063	99,503
September-27	88	0	0	0	0	0	16,376	71,622
October-27	89	0	0	0	0	190	1,884	59,911
November-27	90	0	0	0	518	1,685	4,327	35,931
December-27	91	0	0	850	1,884	3,319	5,786	37,331
January-28	92	0	990	2,638	4,047	5,491	8,182	49,227
February-28	93	0	2,714	4,675	6,158	7,702	10,754	74,529
March-28	94	0	4,152	6,661	8,225	9,988	14,880	109,841
April-28	95	1,283	5,439	8,325	10,095	12,011	34,917	169,605
May-28	96	0	6,281	9,392	11,178	13,515	50,321	186,224
June-28	97	0	5,165	10,069	11,988	14,495	52,077	185,120
July-28	98	0	0	10,464	12,476	15,206	51,449	183,733
August-28	99	0	0	0	11,919	14,866	49,747	180,285
September-28	100	0	0	0	0	8,729	38,754	176,826
October-28	101	0	0	0	0	429	16,541	139,903
November-28	102	0	0	0	8	1,392	5,741	103,105
December-28	103	0	0	407	1,044	2,007	5,447	92,986
January-29	104	0	745	1,954	3,121	4,323	7,905	94,769
February-29	105	76	2,392	4,031	5,292	6,577	10,765	97,017
March-29	106	0	4,098	5,869	7,275	8,836	21,702	98,588
April-29	107	811	5,481	7,628	9,120	13,053	47,029	117,206
May-29	**108**	0	6,346	8,639	10,362	20,882	56,934	138,604
June-29	109	0	4,274	9,346	11,183	22,285	58,786	138,342
July-29	110	0	0	4,418	11,727	22,260	58,233	139,017
August-29	111	0	0	0	647	16,156	54,298	137,589
September-29	112	0	0	0	0	151	35,238	134,887
October-29	113	0	0	0	0	273	13,183	134,558
November-29	114	0	0	0	746	1,940	5,698	113,716
December-29	115	0	0	225	947	3,015	6,679	116,165
January-30	116	0	847	2,012	3,190	5,163	9,451	117,597
February-30	117	0	2,442	3,914	5,397	7,384	16,729	119,859
March-30	118	1,228	4,180	6,003	7,435	10,416	38,423	123,239
April-30	**119**	3,021	5,567	7,764	10,125	27,657	68,368	154,918
26-Apr-30	-	3,957	6,329	8,607	13,180	39,359	80,065	188,498

C-4. Table Showing the Excess Water Volumes at Different Probabilistic Levels

		Probabilistic Excess Water Volumes from the HLF (m3)						
Date / Period	**Month #**	**Min**	**5%**	**25%**	**50%**	**75%**	**95%**	**Max**
31-May-20	**0**	260,000	260,000	260,000	260,000	260,000	260,000	260,000
June-20	1	249,360	249,360	249,383	249,389	249,402	249,495	250,149
July-20	2	175,957	178,178	180,723	183,234	186,436	192,039	202,640
August-20	3	118,664	122,423	125,652	129,027	132,646	138,625	152,467
September-20	4	76,251	81,965	86,259	89,767	93,864	100,622	114,062
October-20	5	41,743	48,735	53,892	57,911	63,723	71,108	81,841
November-20	6	11,393	21,772	29,010	35,512	43,190	54,029	78,563
December-20	7	0	12,305	20,414	27,578	35,761	48,957	69,260
January-21	8	0	7,190	17,349	24,292	32,285	46,495	66,661
February-21	9	0	0	1,949	8,788	15,951	24,443	49,849
March-21	10	0	0	3,726	10,660	18,732	28,764	56,108
April-21	11	0	0	2,412	10,404	18,113	26,346	53,818
May-21	12	0	0	0	616	8,321	19,168	33,310
June-21	13	0	0	0	0	171	15,432	21,281
July-21	14	0	0	0	0	0	7,461	20,074
August-21	15	0	0	0	0	0	149	18,070
September-21	16	0	0	0	0	0	5	19,317
October-21	17	0	0	0	0	0	425	19,556
November-21	18	0	0	0	0	670	15,896	27,672
December-21	19	0	0	0	1,615	12,231	21,862	34,469
January-22	20	0	0	342	5,813	14,978	23,204	42,965
February-22	**21**	0	0	1,730	8,272	16,573	24,758	46,300
March-22	22	0	1,441	8,951	17,150	26,084	40,326	79,272
April-22	23	0	5,236	18,371	29,575	42,195	61,813	113,979
May-22	24	0	469	13,221	22,969	35,870	62,520	95,384
June-22	25	0	0	3,707	12,638	21,890	45,093	120,206
July-22	26	0	0	0	5,403	14,790	27,740	100,024
August-22	27	0	0	0	0	854	16,451	71,715
September-22	28	0	0	0	0	0	10,642	33,287
October-22	29	0	0	0	0	2,719	17,785	47,387
November-22	30	0	0	185	8,279	18,995	39,788	87,339
December-22	31	0	308	9,997	19,320	29,933	50,434	108,418
January-23	32	0	8,117	21,710	33,645	49,705	72,990	110,545
February-23	33	0	17,046	34,191	49,866	67,226	98,130	145,753
March-23	34	2,512	29,388	49,432	66,497	86,680	119,153	177,897
April-23	35	10,715	37,617	60,108	79,014	100,272	134,359	189,530
May-23	36	0	26,421	51,826	72,672	93,478	130,476	177,912
June-23	37	0	11,109	33,749	54,002	77,051	112,170	167,378

July-23	38	0	0	16,054	32,562	55,256	92,226	133,031
August-23	39	0	0	0	8,812	23,655	57,879	98,308
September-23	40	0	0	0	0	0	14,568	44,260
October-23	41	0	0	0	0	1,810	15,632	37,064
November-23	42	0	0	12	5,400	16,001	35,707	103,060
December-23	43	0	17	7,435	16,911	27,598	49,676	89,906
January-24	44	0	5,645	17,818	28,939	45,645	70,149	128,477
February-24	45	0	11,743	30,788	45,920	64,848	91,877	151,881
March-24	46	3,115	24,264	46,984	65,165	83,615	115,768	181,496
April-24	47	7,809	32,840	57,424	76,293	99,141	132,590	205,091
May-24	48	0	21,262	50,111	71,515	93,428	130,510	197,486
June-24	49	0	8,752	32,160	55,326	78,304	114,247	183,835
July-24	50	0	0	14,785	32,230	57,367	93,557	163,557
August-24	51	0	0	0	9,875	25,511	62,421	123,377
September-24	52	0	0	0	0	3,977	24,765	86,415
October-24	53	0	0	0	0	3,181	18,665	60,721
November-24	54	0	0	53	7,122	17,695	37,358	78,517
December-24	55	0	0	7,335	17,247	28,206	53,484	104,201
January-25	56	0	2,505	15,599	26,905	42,384	65,978	113,139
February-25	57	0	5,110	17,822	28,259	41,795	67,326	130,632
March-25	58	1,393	16,504	32,678	47,676	61,547	92,399	151,949
April-25	59	4,781	24,620	42,950	60,384	79,503	110,640	173,473
May-25	60	0	15,259	37,206	54,398	75,190	109,286	184,978
June-25	61	0	4,677	20,299	39,100	60,087	94,963	173,661
July-25	62	0	0	7,811	19,627	39,837	74,647	141,111
August-25	63	0	0	0	1,355	15,447	44,300	101,629
September-25	64	0	0	0	0	37	16,716	84,262
October-25	65	0	0	0	0	637	14,748	56,339
November-25	66	0	0	0	4,171	15,235	31,933	68,353
December-25	67	0	8	6,877	16,222	26,288	49,020	99,035
January-26	68	0	4,037	17,467	27,739	41,915	66,896	119,990
February-26	69	0	14,844	29,520	44,310	61,041	89,169	136,578
March-26	70	0	27,486	46,940	63,333	81,859	113,619	182,089
April-26	71	0	14,466	36,577	52,607	75,158	105,491	198,039
May-26	72	0	9,469	32,345	51,362	72,205	106,777	193,796
June-26	73	0	4	17,857	35,674	58,090	92,964	197,557
July-26	74	0	0	5,445	18,278	37,861	73,651	162,662
August-26	75	0	0	0	229	14,760	43,628	124,267
September-26	76	0	0	0	0	2	16,983	85,595
October-26	77	0	0	0	0	1,122	16,102	47,997
November-26	78	0	0	0	4,173	15,771	33,295	79,101
December-26	79	0	0	6,037	16,149	26,356	47,100	100,683

January-27	80	0	4,801	16,269	28,054	40,286	68,945	111,220
February-27	81	321	12,340	30,580	43,372	59,849	90,645	142,627
March-27	**82**	4,163	24,911	45,630	60,807	79,620	109,880	171,451
April-27	83	2,956	31,582	55,612	74,209	94,286	128,783	208,757
May-27	84	0	10,433	34,034	54,407	78,225	112,896	189,110
June-27	85	0	156	20,064	40,897	67,546	102,070	167,336
July-27	86	0	0	9,686	24,227	50,600	91,309	163,173
August-27	87	0	0	0	6,402	21,026	60,268	128,280
September-27	88	0	0	0	0	3,481	23,586	85,627
October-27	89	0	0	0	0	1,592	16,964	68,588
November-27	90	0	0	15	5,390	18,408	39,293	103,603
December-27	91	0	75	8,149	18,517	31,754	58,797	134,817
January-28	92	0	5,797	22,908	36,386	53,763	84,911	155,324
February-28	93	0	20,012	41,605	58,283	78,111	108,676	180,626
March-28	94	634	17,277	38,061	58,417	80,985	111,837	215,938
April-28	95	5,929	30,054	56,478	78,665	102,088	139,272	275,702
May-28	96	103	27,764	56,671	81,390	105,748	147,736	288,098
June-28	97	0	13,576	44,254	69,589	94,642	136,939	269,652
July-28	98	0	1,850	26,309	51,562	78,482	117,348	246,287
August-28	99	0	0	6,292	22,347	48,199	90,719	222,302
September-28	100	0	0	0	180	16,102	53,565	178,244
October-28	101	0	0	0	0	5,754	24,207	139,903
November-28	102	0	0	0	507	12,141	30,937	103,105
December-28	103	0	0	4,603	13,047	22,727	41,394	96,870
January-29	104	0	4,534	18,079	28,921	43,495	68,934	134,643
February-29	105	76	16,709	34,551	51,897	69,684	99,956	153,673
March-29	106	0	30,496	53,476	73,395	92,590	125,434	184,940
April-29	107	6,784	41,953	70,639	92,389	116,280	150,619	223,303
May-29	**108**	6,674	36,004	67,801	90,384	116,675	155,192	241,359
June-29	109	0	10,694	40,050	65,031	92,816	135,352	212,064
July-29	110	0	0	13,231	34,269	62,239	103,863	215,201
August-29	111	0	0	0	13,454	32,049	75,001	197,110
September-29	112	0	0	0	0	11,736	40,417	158,889
October-29	113	0	0	0	0	4,781	22,010	135,141
November-29	114	0	0	141	8,104	19,751	44,216	139,071
December-29	115	0	0	2,378	10,569	20,965	46,217	148,512
January-30	116	0	5,570	19,148	32,478	50,122	80,245	181,073
February-30	117	0	19,086	39,958	59,660	78,309	115,793	206,139
March-30	118	4,180	35,700	61,407	81,962	105,909	143,628	229,336
April-30	**119**	6,901	51,145	84,263	106,538	132,821	173,537	260,212
26-Apr-30	**-**	4,162	48,908	84,510	111,724	139,372	182,140	294,595

C-5. Table Showing the External Makeup Water Demand at Different Probabilistic Levels

		External Makeup (Raw) Water Demand (m3/hr.)					
Date / Period	**Month #**	**5%**	**25%**	**50%**	**75%**	**95%**	**95% (L/s)**
31-May-20	**0**	0	0	0	0	0	0
June-20	1	0	0	0	0	0	0
July-20	2	0	0	0	0	0	0
August-20	3	0	0	0	0	0	0
September-20	4	0	0	0	0	0	0
October-20	5	0	0	0	0	0	0
November-20	6	0	0	0	0	0	0
December-20	7	0	0	0	0	0	0
January-21	8	0	0	0	0	0	0
February-21	9	0	0	0	0	16	4
March-21	10	0	0	0	0	14	4
April-21	11	0	0	0	0	0	0
May-21	12	0	0	0	20	26	7
June-21	13	0	0	25	30	35	10
July-21	14	0	23	35	38	42	12
August-21	15	31	53	55	57	60	17
September-21	16	61	75	78	79	82	23
October-21	17	6	51	61	64	68	19
November-21	18	0	0	36	45	50	14
December-21	19	0	0	0	26	34	10
January-22	20	0	0	0	0	18	5
February-22	**21**	0	0	0	0	17	5
March-22	22	0	0	0	0	0	0
April-22	23	0	0	0	0	0	0
May-22	24	0	0	0	0	0	0
June-22	25	0	0	0	0	33	9
July-22	26	0	0	0	34	45	12
August-22	27	0	8	54	56	61	17
September-22	28	0	73	77	79	83	23
October-22	29	0	0	47	63	70	19
November-22	30	0	0	0	5	46	13
December-22	31	0	0	0	0	13	4
January-23	32	0	0	0	0	0	0
February-23	33	0	0	0	0	0	0
March-23	34	0	0	0	0	0	0
April-23	35	0	0	0	0	0	0
May-23	36	0	0	0	0	0	0
June-23	37	0	0	0	0	0	0

July-23	38	0	0	0	0	35	10
August-23	39	0	0	0	54	58	16
September-23	40	0	58	77	79	81	22
October-23	41	0	0	48	62	67	19
November-23	42	0	0	0	17	47	13
December-23	43	0	0	0	0	21	6
January-24	44	0	0	0	0	0	0
February-24	45	0	0	0	0	0	0
March-24	46	0	0	0	0	0	0
April-24	47	0	0	0	0	0	0
May-24	48	0	0	0	0	0	0
June-24	49	0	0	0	0	0	0
July-24	50	0	0	0	0	34	9
August-24	51	0	0	0	54	58	16
September-24	52	0	0	76	78	81	22
October-24	53	0	0	48	62	67	19
November-24	54	0	0	0	19	46	13
December-24	55	0	0	0	0	23	6
January-25	56	0	0	0	0	55	15
February-25	57	0	0	0	0	0	0
March-25	58	0	0	0	0	0	0
April-25	59	0	0	0	0	0	0
May-25	60	0	0	0	0	0	0
June-25	61	0	0	0	0	0	0
July-25	62	0	0	0	0	38	11
August-25	63	0	0	4	55	59	16
September-25	64	0	59	77	79	81	23
October-25	65	0	0	52	62	67	19
November-25	66	0	0	0	26	47	13
December-25	67	0	0	0	0	23	6
January-26	68	0	0	0	0	0	0
February-26	69	0	0	0	0	0	0
March-26	70	0	0	0	0	0	0
April-26	71	0	0	0	0	0	0
May-26	72	0	0	0	0	0	0
June-26	73	0	0	0	0	5	2
July-26	74	0	0	0	0	38	11
August-26	75	0	0	23	56	61	17
September-26	76	0	59	77	79	81	22
October-26	77	0	0	49	62	66	18
November-26	78	0	0	0	29	47	13
December-26	79	0	0	0	0	21	6

January-27	80	0	0	0	0	0	0
February-27	81	0	0	0	0	0	0
March-27	**82**	0	0	0	0	0	0
April-27	83	0	0	0	0	0	0
May-27	84	0	0	0	0	0	0
June-27	85	0	0	0	0	9	3
July-27	86	0	0	0	0	35	10
August-27	87	0	0	0	55	60	17
September-27	88	0	0	76	79	81	22
October-27	89	0	0	45	60	66	18
November-27	90	0	0	0	20	46	13
December-27	91	0	0	0	0	13	4
January-28	92	0	0	0	0	0	0
February-28	93	0	0	0	0	0	0
March-28	94	0	0	0	0	0	0
April-28	95	0	0	0	0	0	0
May-28	96	0	0	0	0	0	0
June-28	97	0	0	0	0	0	0
July-28	98	0	0	0	0	0	0
August-28	99	0	0	0	0	57	16
September-28	100	0	0	48	78	80	22
October-28	101	0	0	39	59	66	18
November-28	102	0	0	35	113	129	36
December-28	103	0	0	0	0	27	8
January-29	104	0	0	0	0	0	0
February-29	105	0	0	0	0	0	0
March-29	106	0	0	0	0	0	0
April-29	107	0	0	0	0	0	0
May-29	**108**	0	0	0	0	0	0
June-29	109	0	0	0	0	0	0
July-29	110	0	0	0	0	45	12
August-29	111	0	0	0	39	52	14
September-29	112	0	0	42	50	53	15
October-29	113	0	0	21	38	46	13
November-29	114	0	0	0	0	40	11
December-29	115	0	0	0	0	13	4
January-30	116	0	0	0	0	0	0
February-30	117	0	0	0	0	0	0
March-30	118	0	0	0	0	0	0
April-30	**119**	0	0	0	0	0	0
26-Apr-30	**-**	0	0	0	0	0	0