APPENDIX O HYDROLOGIC MODELING STUDY

Goliath Gold Project
Hydrologic Modeling Study

1493900200-REP-C0001-00
September 2014

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1.0 INTRODUCTION

1.1 Background

Treasury Metals Incorporated (TML) has been conducting exploration activities at the Goliath Gold Project (the Project) in the Kenora/Dryden Mining District of northwestern Ontario since 2008. The project site (the Site) is approximately 8 km northwest of the village of Wabigoon, 20 km east of Dryden. Engineering, environmental, geotechnical, logistical, metallurgical and socio-economic studies are being completed as part of preliminary design of the Project.

1.2 Objective and Scope

The objective of this study is to develop and calibrate a Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) model to observe flows within the drainage watershed. The calibrated model will then be used to predict stream flows during single rainfall events, as well as continuous modelling over a period of months or years. The report layout is as follows:

- Section 2 Describes the site hydrology
- Section 3 Presents the HEC-HMS model, calibration methodology and results
- Section 4 Provides the results of the model
- Section 5 Conclusions
- Appendix A Baseline model data
- Appendix B Model validation results
- Appendix C Simple water balance calculation

1.3 Previous Studies

Studies related to this project:

- **Goliath Gold Project – Baseline Study**, Klohn Crippen Berger, September 2012.
- **Wetland Baseline Study (2013)**, DST Consulting Engineers Inc., March 2014.
- **Hydrology 2013 Baseline Study**, DST Consulting Engineers Inc., April 2014.
- **Hydrogeological Pre-Feasibility/EA Support Study**, AMEC Environment & Infrastructure, a division of AMEC Americas Limited. May 2014 Draft
- **Pre-Feasibility Water Management Strategy**, Lycopodium Minerals Canada Ltd. 2014. June 2014 Draft

2.0 SITE HYDROLOGY

2.1 Watershed

A Digital Elevation Model (DEM) terrain model of the Project site from TML was used to determine the limits and drainage in the vicinity of the Site. Individual subbasins were delineated using an eight-direction pour point algorithm (D-8), based on 15 m elevation grid of the DEM. Stream paths generated during the analysis have shown remarkable consistency with watercourse information from Land Information Ontario; this suggests subbasins have been delineation within the watershed to an acceptable degree of accuracy.

The watershed analysis identified 17 subbasins, with the largest being 749 ha, the smallest 27 ha, and an overall area of 3,796 ha (Figure 2-1). The drainage is divided into 3 streams:

- Unnamed stream to Thunder Lake (northernmost)
- Hoffstrom's Bay Tributary to Thunder Lake (westernmost)
- Blackwater Creek to Wabigoon Lake (southernmost)

The Site is situated primarily in the southernmost tributary draining to Blackwater Creek, with some portions being in or within close proximity to the areas draining to Thunder Lake.

2.2 Surficial Geology

Surficial data from the Province of Ontario (the Province) indicate that much of the watershed is comprised of fine grained glaciolacustrine soils with some organic, bog or marsh areas and rare outcrops of rock (Figure 2-2). Most of the soils are classified as sandy loam, with some outcrops of loam and clay loam in the southern subbasins.

Infiltration characteristics in the model were estimated using standard infiltration parameters for each soil type and homogenized for each subbasin through an area weighted method (

Table **2-1**). Unfortunately data was not available from the Province for the southernmost subbasins; soil characteristics for the subbasins missing data were assumed to share the same characteristics as the southernmost subbasin with partial data (S4444).

Table 2-1 Summary of surficial geology within the Goliath Gold Project watersheds.

Soil Type	Area (ha)	Percent of total Area (%)
Gravel	-	-
Sand	-	-
Sandy Loam	2,378	62.6
Loam	25	0.6
Silty Loam	-	-
Clay Loam	272	7.2
Organics*	473	12.5
Rock	42	1.1
Water	11	0.3
Wetland	-	-
Unknown (Data Not Available)	594	15.7
Total	3,795	100.0

* Organics were treated as wetlands, based on satellite imagery and ground observations.

2.3 Land Cover

The Site is located within the Boreal Shield ecozone, primarily known for dense coniferous forests and exposed granite bedrock, as well as rolling hills, glacial lakes, and wetland areas. The KCB baseline study describes the study area as dominated by forest at 62%, water and wetlands at 29%, developed land at 9%, and rock and barren sands accounting for less than 1% of land cover (KCB 2012).

For this study, the forested areas have been simplified to only coniferous and deciduous treed areas as these exhibit different evapotranspiration characteristics. The land cover makeup of the overall watershed was compiled by calculating evapotranspiration parameters for each subbasin (Figure 2-3;

Table 2-2). Areas without land cover data were assumed to have the same composition as the areas of the subbasin that do contain land cover data.

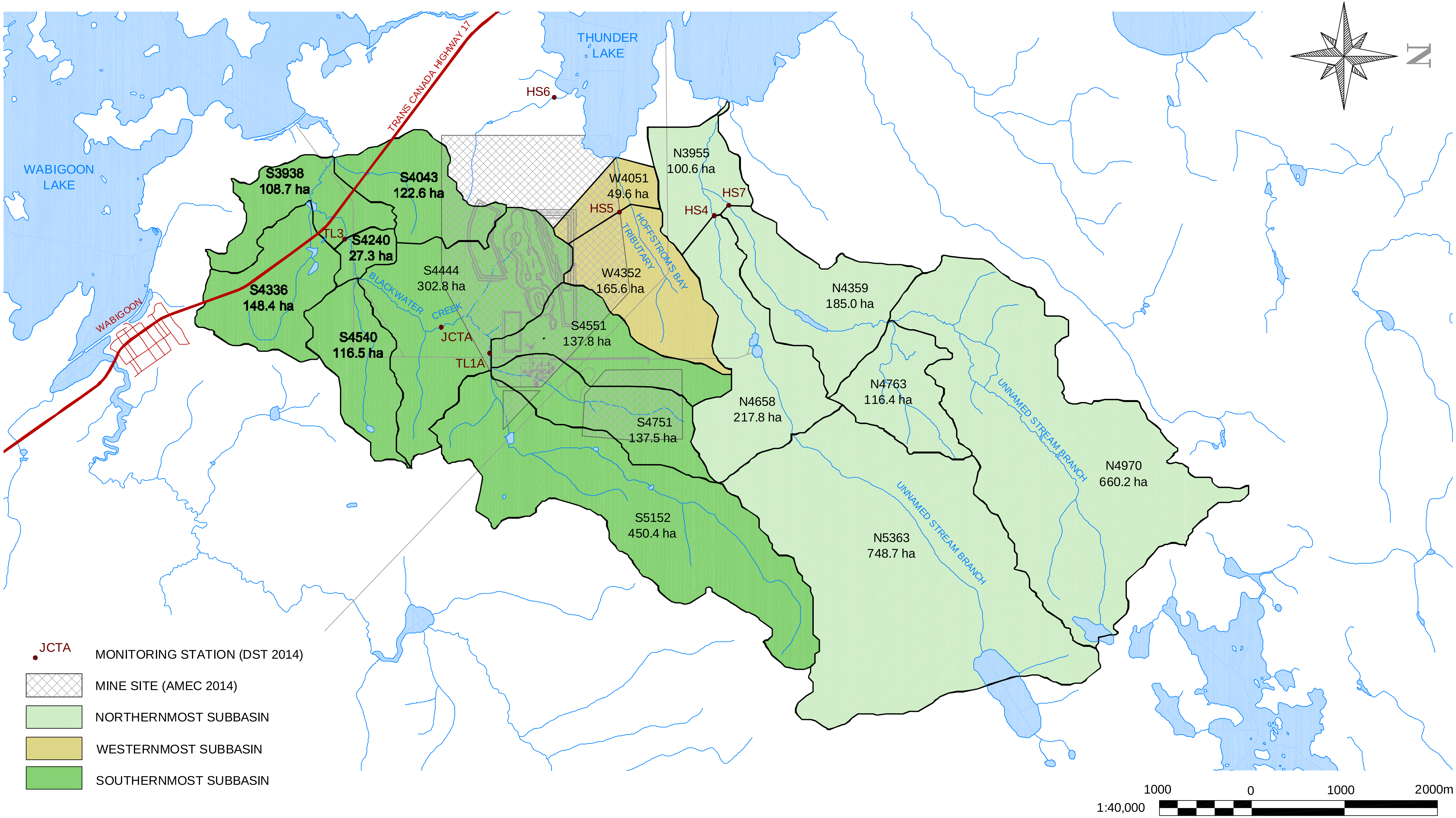
Table 2-2 Summary of land cover types within the Goliath Gold Project watersheds.

Land Cover	Area (ha)	Percent of total Area (%)
Coniferous Forest	1,472	38.8
Deciduous Forest	490	12.9
Wetland Areas	724	19.1
Rock	4.2	0.1
Sand *	9.9	0.3
Not Applicable Areas **	283	7.5
Unknown Areas ***	812	21.3
Total	3,795	100.0

* Note: Data from a different dataset than surficial geology data

** Not Applicable Areas include developed areas, highways, water bodies, etc.

*** Unknown Areas represent areas that did not have land cover data



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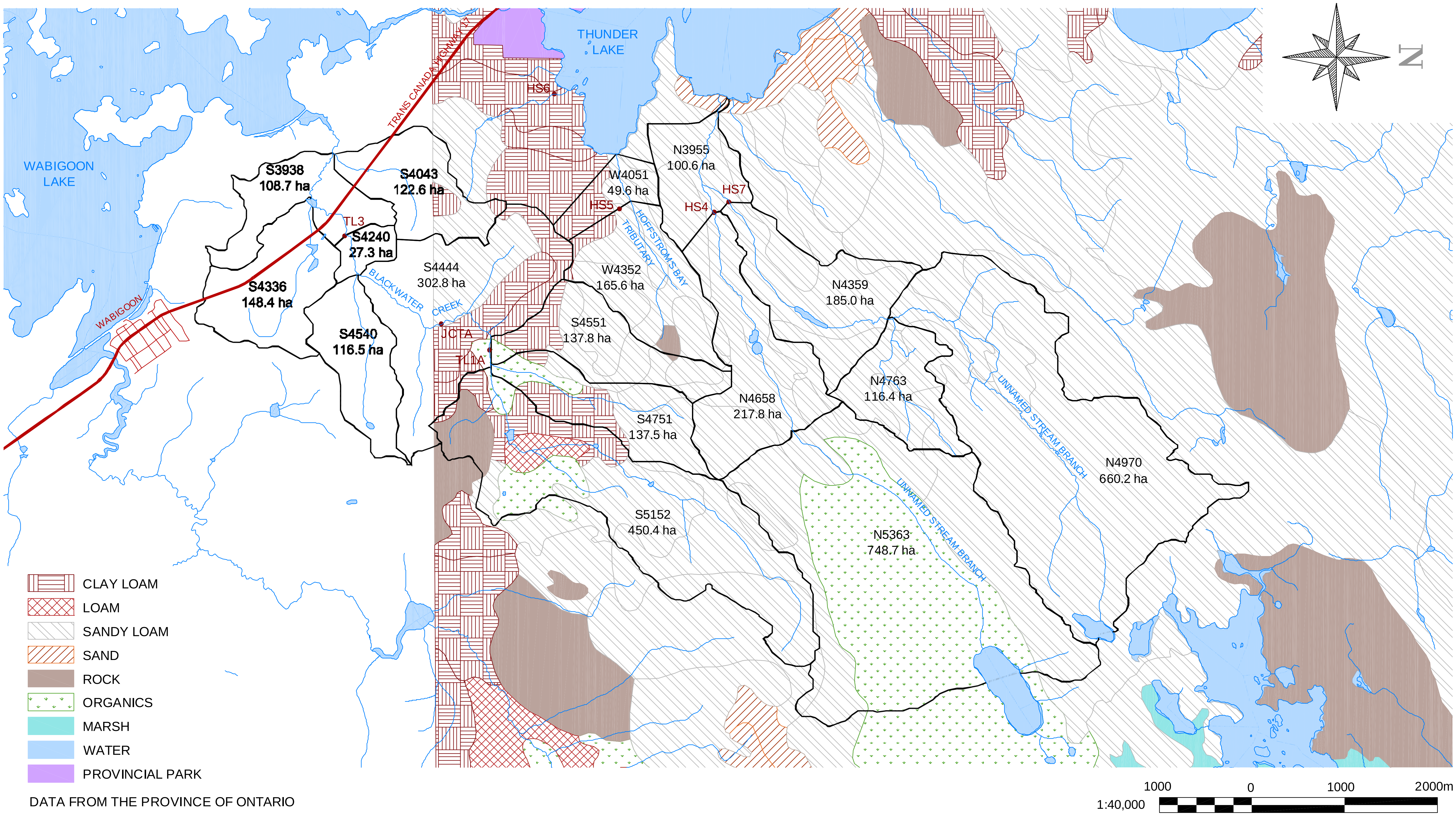

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DRAWING DESCRIPTION
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FIGURE 2-2

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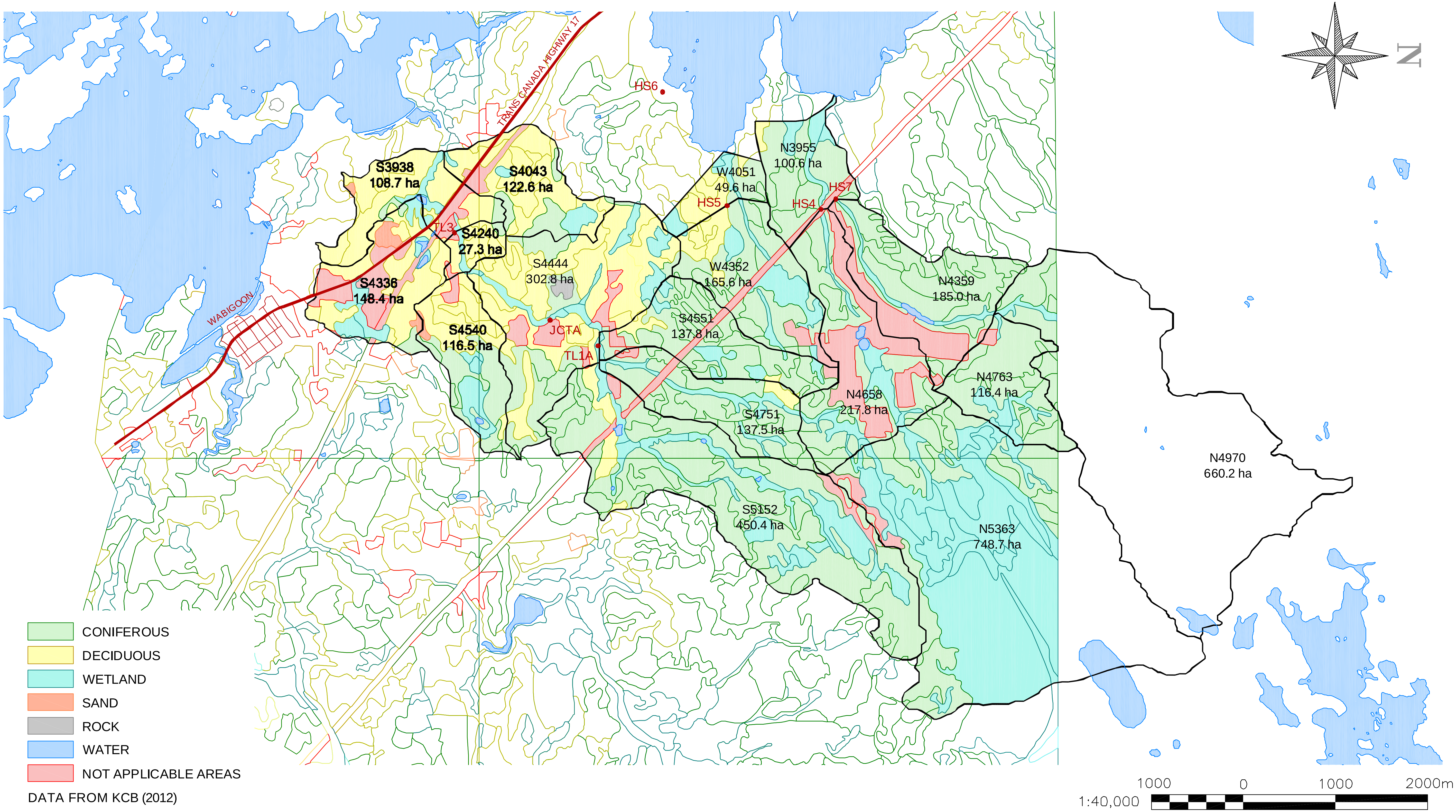

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DRAWING DESCRIPTION
LAND COVER
FIGURE 2-3

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2.4 Climate Data

The Project location is near the centre of the continent and east of the prairies, leading to harsh seasonal temperatures (average monthly temperatures of 18.9 °C in the summer, -16.2 °C in the winter), and a semi-arid climate (average annual rainfall of 540 mm). There is no weather station at the Project site, therefore, 44 years of Environment Canada historical weather data was compiled from three weather stations based at the Dryden Airport located approximately 12.5 km from the site (Table 2-3).

Table 2-3 Location and data range summary for the Environment Canada weather stations at Dryden.

Station Name	Station ID	Latitude	Longitude	Distance to Site (km)	Elevation (m)	Date Range
Dryden A	6032119	49° 49’ 61 N	92° 45’ 00” W	12.9	412.7	1970 - 2000
Dryden ‘A’ AUT	6032120	49° 49’ 55 N	92° 45’ 38” W	12.5	412.7	2000 - 2011
Dryden Regional	6032125	49° 49’ 41 N	92° 44’ 38” W	12.2	412.7	2011 - 2013

2.4.1 Air Temperature

Analysis of nearby stations suggests there is no significant temperature variation between the stations within 100 km of the Project site (KCB 2012). This indicates the Dryden Airport stations are representative of the temperatures observed at the Site. Monthly mean, maximum and minimum air temperatures were compiled from the Dryden airport stations (Table 2-4).

Table 2-4 Mean daily air temperatures by month for 1970-2013 at Dryden.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Mean Daily Temp. (°C)	-16.2	-13.4	-6.1	2.8	10.5	15.7	18.9	17.5	11.5	4.5	-4.7	-14.0	**2.3**
Max. Daily Temp. (°C)	6.7	10.2	24.3	28.3	33.8	37.5	35.6	35.4	34.4	26.2	20.6	8.0	
Min. Daily Temp. (°C)	-43.3	-40.8	-34.6	-23.0	-10.9	-1.5	0.0	-0.4	-4.4	-12.4	-33.0	-39.1	

2.4.2 Precipitation

Monthly precipitation data from the Dryden A (1970-2000) station was used for rainfall and snowfall statistics. Data from all three stations was compiled for the entire record period to analyze precipitation data. Five (5) and 10 year highs and lows were determined assuming that monthly precipitation follows a normal distribution.

Table 2-5 Mean monthly rainfall for 1970-2000 at Dryden..

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean (mm)	0.2	1.4	6.2	24.2	68.3	106.4	98.5	84.0	87.1	52.2	10.6	0.8	**540.0**
Maximum (mm)	2.2	21	31.6	105.8	136.2	256.3	175.2	185.2	195.8	143.5	59.3	6.2	
Minimum (mm)	0	0	0	0	12.7	0	36.1	27.9	0	7.6	0	0	

Table 2-6 Mean monthly snowfall 1970-2000 at Dryden.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean (cm)	30.7	22.7	27.5	13.7	3.0	0.0	0.0	0.0	1.2	12.0	33.7	28.4	**172.7**
Maximum (cm)	85.6	42.7	98.6	51.1	21.7	0.6	0	0	13.4	48.2	81.8	54.6	
Minimum (cm)	0	5.4	4.8	0	0	0	0	0	0	0	6.7	0	

Table 2-7 Mean, estimated 5 and 10 year high and 5 and 10 year low total monthly precipitation for 1970-2013 at Dryden.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean (mm)	25.2	19.0	31.0	38.1	76.2	103.8	97.1	80.3	82.0	62.3	39.2	25.6	**679.8**
Maximum (mm)	82.6	44.0	107.6	114.0	159.1	256.3	175.2	185.2	195.8	144.3	94.5	68.1	
Minimum (mm)	0.0	0.0	5.2	1.0	12.7	0.0	36.1	27.9	0.0	9.5	6.1	0.0	
10 Year High (mm)	45.3	32.6	55.7	68.6	122.6	173.2	148.0	126.0	138.1	106.3	66.8	43.8	**837.2**
5 Year High (mm)	38.4	28.0	47.2	58.2	106.7	149.4	130.5	110.3	118.8	91.2	57.3	37.5	**783.1**
5 Year Low (mm)	12.0	10.0	14.8	18.0	45.7	58.3	63.7	50.3	45.2	33.4	21.0	13.6	**576.5**
10 Year Low (mm)	5.1	5.4	6.3	7.6	29.8	34.5	46.3	34.7	25.9	18.3	11.5	7.4	**522.4**

2.4.3 Lake Evaporation and Evapotranspiration

Lake evaporation combines the effects of air temperature, solar radiation, humidity and wind speed and is applied to reservoirs in the model representing open bodies of water such as lakes or wetlands. Pan evaporation data from the Rawson Lake monitoring station (Environment Canada Station 6036904) in the Experimental Lakes area approximately 80 km west of the project site was used to estimate the lake evaporation in the model. Mean annual evaporation at Rawson Lake is 536 mm which is consistent with the 1978 Hydrological Atlas of Canada, which indicated the range of annual evaporation at the Site is between 500mm to 600mm.

Evapotranspiration accounts for the combined effects of soil evaporation and plant transpiration and is applied to the model subbasins. Potential evapotranspiration is a complex relationship affected by air temperature, solar radiation, humidity, wind speed, as well as soil and plant characteristics. The Penman-Monteith method has been used to estimate the potential evapotranspiration based on climatic factors. A single crop coefficient for coniferous forests (K_c = 1.00) and deciduous forests (K_c = 0.80, 50% canopy cover) is applied to the potential evaporation to determine the estimate evapotranspiration based on ground cover type (Table 2-8).

Monthly evapotranspiration values for each model subbasin have been calculated based on an area weighting of each type of land cover (deciduous and coniferous trees, as well as wetland/bog/fen type areas).

Table 2-8 Estimated monthly evaporation and evapotranspiration summary by land cover at the Goliath Gold Project site.

Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Evaporation													
Lake and Wetlands (mm)	0.0	0.0	0.0	0.0	114.7	123.0	127.1	108.5	63.0	0.0	0.0	0.0	**536.3**
Evapotranspiration													
Potential (mm)	0.0	0.0	0.0	0.0	117.8	132.0	136.4	111.0	71.3	37.2	0.0	0.0	**605.7**
Coniferous Areas (mm)	0.0	0.0	0.0	0.0	117.8	132.0	136.4	111.0	71.3	37.2	0.0	0.0	**605.7**
Deciduous Areas (mm)	0.0	0.0	0.0	0.0	94.2	105.6	109.1	88.8	57.0	29.8	0.0	0.0	**484.6**
Wetland Areas (mm)	0.0	0.0	0.0	0.0	71.3	140.6	163.7	126.5	12.4	0.0	0.0	0.0	**514.5**

2.5 Flow Monitoring

DST installed a total of 7 level loggers set to record every 5 to 30 minutes during 2012 and 2013 (DST 2014). Stage-discharge curves using a power law formula were developed by DST to translate the level data recorded to discharge data. A summary of the average daily discharge for each of the monitoring stations is presented in Table 2-9.

Runoff coefficients for each catchment can be estimated by comparing the mean discharge data at each monitoring point to the amount of rainfall received by the upstream subbasins. Runoff coefficients based on a rolling wooded terrain of the watershed are expected to be in the 0.15 to 0.40 range.

Runoff coefficients were estimated from the measured data and resulted in 2012 runoff coefficients considerably lower than 2013 coefficients (

Table **2-10**). The discrepancy is likely due to an incomplete 2012 data set where large runoff events and spring freshet data are missing; the 2013 runoff coefficients are therefore more indicative of actual conditions. The mean runoff coefficients for the measured data were compared to estimates using the Ontario Ministry of Transportation (MTO) Northern Ontario Hydrology Method (NOHM) (Table 2-11).

The NOHM method is based on stream flow data collected from sites across northern Ontario, and is only valid for watersheds located within the Canadian Shield, between 1 to 100 km^2 in area, and with a minimum ratio of 6.0% lake or wetland to watershed ratio (A_d/A). The NOHM formula for coefficient of discharge (Cv, analogous to the Runoff Coefficient) is as follows:

$$C_v = 0.502 \times (1 - A_d/A)^{2.07}$$

Table 2-9 Average daily discharge monitoring results for 2012-2013 at the Goliath Gold Project (after DST 2014).

Monitoring Station	2012 Minimum (LPS)	2012 Maximum (LPS)	2012 Mean (LPS)	2013 Minimum (LPS)	2013 Maximum (LPS)	2013 Mean (LPS)
HS7 (NR4359-2)	19.7	127.7	53.0	15.2	791.6	91.0
HS4 (NR4658)	13.1	77.2	26.8	26.5	569.2	111.6
HS5 (WR4051)	0.4	6.2	1.9	0.0	46.6	1.9
TL1A (SR4551)	0.1	173.3	27.0	9.6	356.3	53.0
JCTA (SR4444)	-	-	-	16.1	930.9	85.1
TL3 (SR4240)	2.7	81.4	17.2	19.9	100.6	66.2
HS6 *	9.2	12.5	10.6	0.1	22.0	3.6

* Monitoring Station HS6 is located outside of the watershed

Table 2-10 Estimated annual runoff coefficients for stations at the Goliath Gold Project.

Monitoring Station	Upstream Area (ha)	2012 Runoff Coefficient	2013 Runoff Coefficient	Mean Runoff Coefficient
HS7 (NR4359-2)	961.8	0.29	0.58	0.43
HS4 (NR4658)	1039.2	0.14	0.65	0.39
HS5 (WR4051)	223.5	0.04	0.05	0.05
TL1A (SR4551)	671.0	0.21	0.48	0.35
JCTA (SR4444)	835.2	-	0.62	0.62
TL3 (SR4240)	1112.3	0.08	0.36	0.22

Table 2-11 2012 – 2013 A comparison of the mean annual runoff coefficients derived from the 2012 and 2013 measured data and coefficients derived using the MTO NOHM.

Monitoring Station	Upstream Area (ha)	Percent Wetland / Water *	Mean Measured Runoff Coefficient (2012 – 2013)	NOHM Runoff Coefficient
HS7 (NR4359-2)	961.8	3.2%	0.43	0.47
HS4 (NR4658)	1,039.2	43.1%	0.39	0.18
HS5 (WR4051)	223.5	20.6%	0.05	0.33
TL1A (SR4551)	671	16.7%	0.35	0.36
JCTA (SR4444)	835.2	14.9%	0.62	0.37
TL3 (SR4240)	1,112.3	14.8%	0.22	0.37

* Percent wetland / water based on land cover data from KCB

3.0 HYDROLOGIC MODEL

HEC-HMS software was developed by the United States Army Corps of Engineers to simulate precipitation runoff processes of stream networks. The software was originally designed for single event simulation but has been expanded to include continuous simulation.

3.1 Model Development

The HEC-HMS model was developed by first delineating the individual subbasins, determining the locations of streams and creating a map file to import into the program, which is used to overlay the individual model components into approximately correct locations (Figure 3-1).

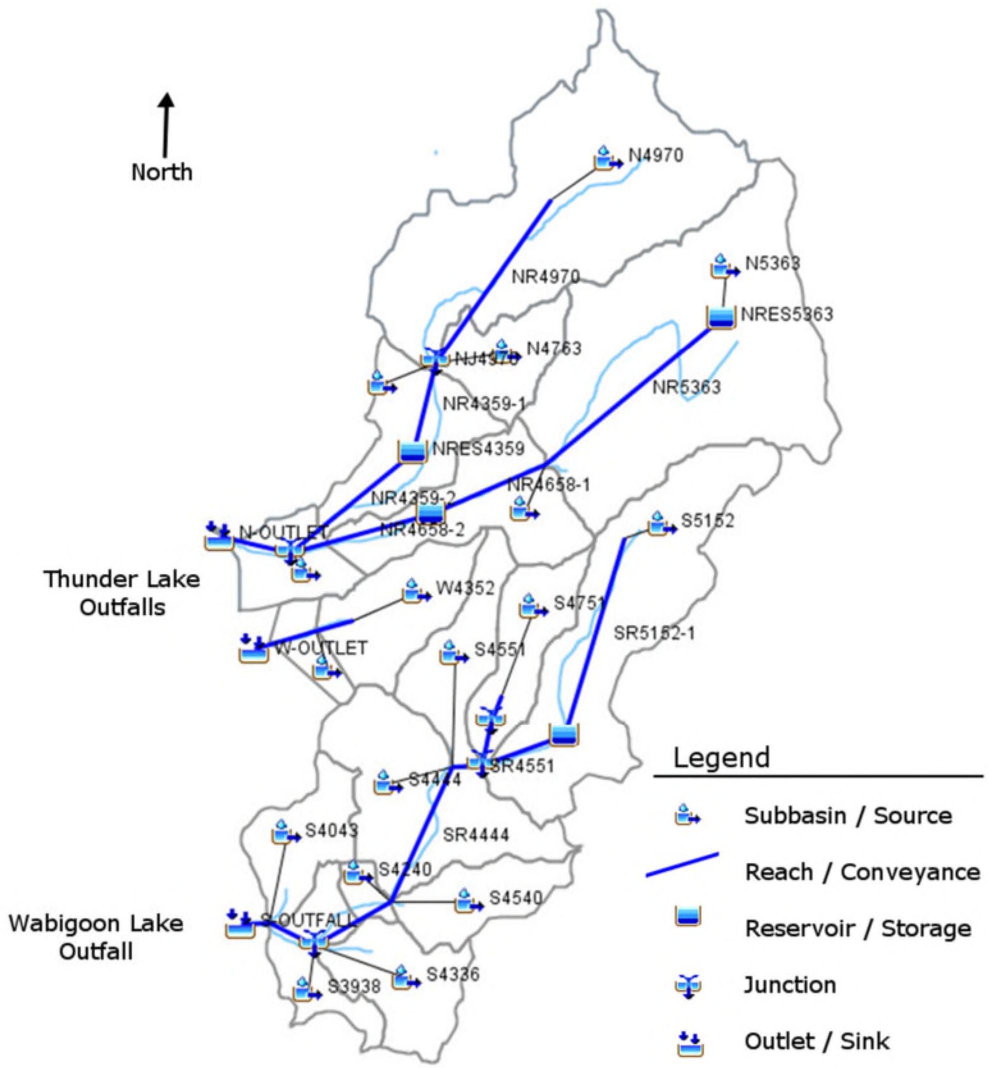


Figure 3-1 Diagram of the subbasins and model components included in the HEC-HMS basin model for the Goliath Gold Project.

Components were named as follows:

- Prefix:
  - N for the northernmost subbasin draining through the unnamed stream to Thunder Lake.
  - W for the westernmost subbasin draining through Hoffstrom's Bay tributary to Thunder Lake.
  - S for the southernmost subbasin draining through Blackwater Creek to Wabigoon Lake.
  - R was added for reach elements.
  - RES was added for reservoir elements.
- 4 Digit identifier based on XXYY coordinates of a superimposed rectangular grid
  - Lower left corner 515,000, 5,500,000. (UTM Zone 15)
  - Upper right corner 545,000, 5,525,000.
- XX based on an X grid coordinate range (0-99).
- YY based on a Y grid coordinate range (0-99).
- Suffixes -1, -2, etc. were added as required during model development.
- Links inherited the name of upstream components.

Subbasins used the Green Ampt infiltration loss method which is based on measured soil properties (moisture content, wetting front suction, hydraulic conductivity and percent impervious) of recognized soil classifications. Flow routing within the subbasin was estimated using the Clark Unit Hydrograph, which creates a synthetic hyetograph of flow from the catchment based on an estimated time of concentration and a storage coefficient.

Data from the 2012 to 2013 hydrology study indicates rather irregular stream cross-sections with steep banks, widths ranging from 0.34 m to 7.4 m, and depths ranging from 0.04 m to 1.52 m (DST 2014). The Muskingum-Cunge routing method was used for the model reaches, and simplified 8 point cross sections have been applied based on the 2012 - 2013 hydrology data. Reach lengths and slopes were estimated from the watershed analysis and DEM data.

Sizeable inline lakes, ponds and wetlands were simulated with reservoirs using elevation-area curves based on the normal water level (NWL) areas, and assumed subsurface side slopes (10:1 for ponds, 20:1 for wetlands). A total of 4 reservoirs were used in the model ranging in size from 1.21 ha to 33.4 ha, with evaporation data from nearby Rawson Lake applied to reservoirs. Reservoir outlets were modeled as single broad crested weir spillways.

Baseflows were simplified using an exponential recession model, which was used to slow basin runoff to the reaches once a certain minimum threshold was reached (20% ratio to peak). This baseflow represents natural subbasin surface runoff and groundwater and occurs after storm events. The recession constant was set near the high end of the typical range to simulate slower runoff via groundwater or interflow.

3.2 Baseline Model Results

An initial baseline model run was conducted using recommended model parameters based on the previously described physical makeup of the watershed and historical climate data. The initial run was conducted to verify the model was running as expected, identify any problem areas, and to compare initial simulated results to the 2012-2013 recorded flow data. An example of the flow results for monitoring station HS7 (reach NR4359-2) is shown in Figure 3-2. Hydrographs for all 6 monitoring stations within the watershed are presented in Appendix A.

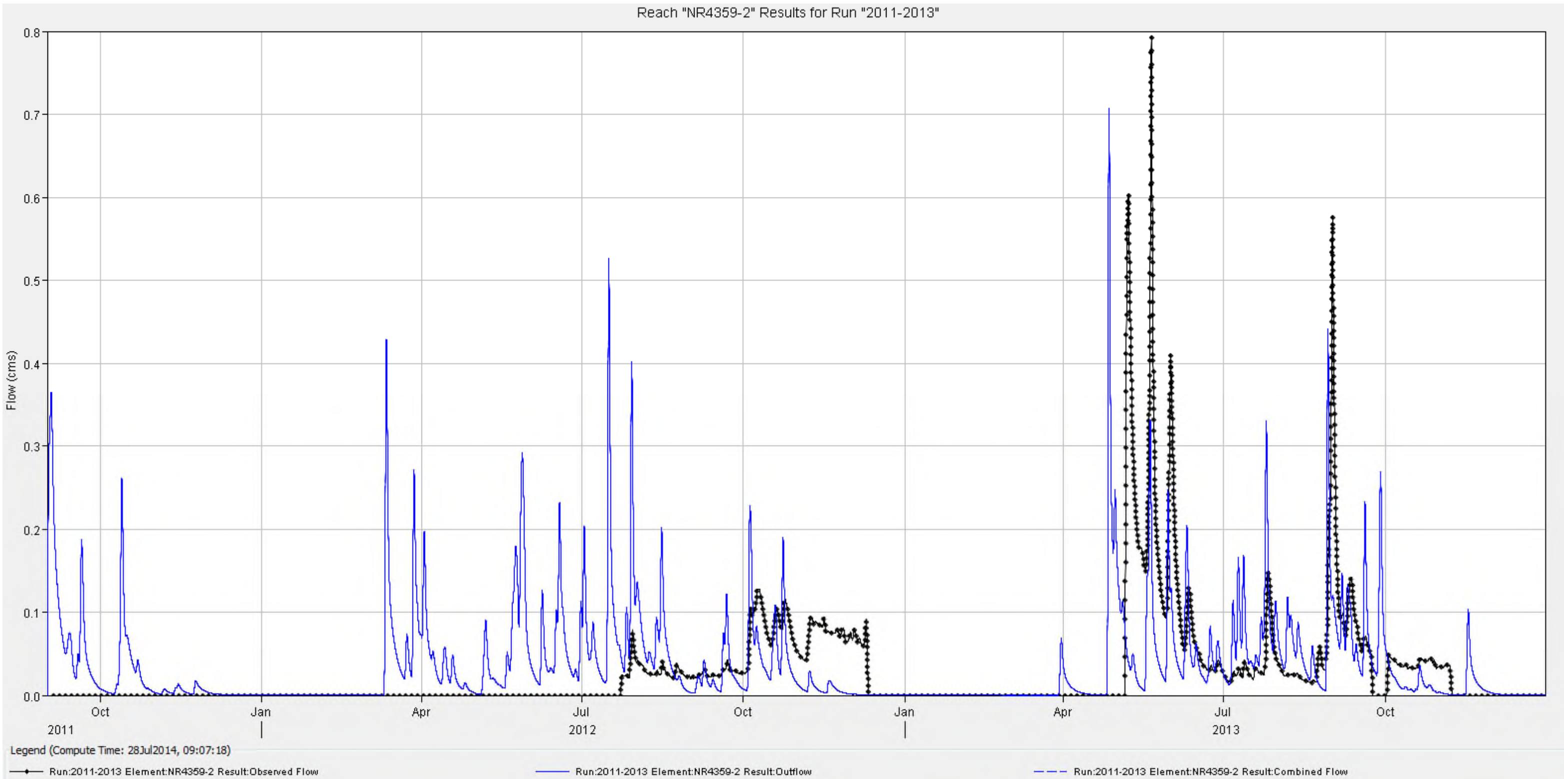


Figure 3-2 Simulated results versus measured data for monitoring station HS7 (NR4359-2). Simulated flow are shown as solid blue lines while measured flows are shown as black dotted lines.

General Observations:

- Flows from simulated rainfall events generally peaked higher than observed data.
- Observed data exhibits sharp peak flows, suggesting runoff is efficiently routed through the watershed with minimal lagging effects from storage elements such as ponds and wetlands.
- Spring freshet simulation does not match chronologically with observed data for most subbasins.
- 2012 observed data is mostly incomplete, 2013 data is more complete and will be favored the remainder of this report.

Monitoring Station HS7 (NR4359-2)

- Model representation: Fair
- Flows from simulated rainfall events generally peaked higher than observed data.
- Some 2013 summertime rainfall events not reflected in observed data.

Monitoring Station HS4 (NR4658-2)

- Model representation: Poor
- Monitoring Station HS4 (NR4658-2) data is inconsistent with rainfall data. There was a large discharge in September 2013 that cannot be represented by Dryden weather data.
- This station was only be used to approximate magnitude of flow from the upstream subbasins.
- Simulated flows were higher than monitored flows; this was likely due to wetland overestimation in subbasin NR5363. Aerial photography shows more vegetation and less wetlands than than the land cover source information (Figure 2-3).

Monitoring Station HS5 (WR4051)

- Model representation: Poor
- Simulated flows were significantly higher than observed flows. This may be due to:
    - Subbasin area overestimation, some flow may drain directly to Thunder Lake.
    - Multiple streams draining subbasin; therefore monitored data does not reflect the entire subbasin.
    - Much higher infiltration rates than expected.
    - Much lower imperviousness than expected.
- Monitoring station HS5 was not considered during calibration or validation.

Monitoring Station TL1A (SR4551)

- Model representation: Fair
- Flows from simulated rainfall events generally peaked higher than observed data, less consistent than other stations.
- Some 2013 summertime rainfall events not reflected in observed data.

Monitoring Station JCTA (SR4444)

- Model representation: Fair
- Flows from simulated rainfall events generally peaked higher than observed data.
- Some 2013 summertime rainfall events not reflected in observed data.

Monitoring Station TL3 (SR4240)

- Model representation: Poor

- Monitoring Station TL3 (SR4240) is downstream of stations JCTA (SR4444), and TL1A (SR4551) but has significantly lower measured flow. This could be an error in the data, or station TL3 may not be positioned on the main stream channel.
- DST (2014) noted beaver action upstream of the monitoring station.
- Monitoring station TL3 was not considered during model calibration or validation.

3.3 Model Calibration

A review of the baseline model results and monitored data concluded that further adjustment of most input parameters was not warranted. For example, if the input parameters were adjusted to reduce the amount of runoff to match the 2013 July storm peak, the simulated 2013 August storm peak would also decrease resulting in greater inconsistency between simulated and observed values (Figure 3-3). The opposite is also true, increasing the runoff to better match the August storm, worsens the July correlation to measured flow.

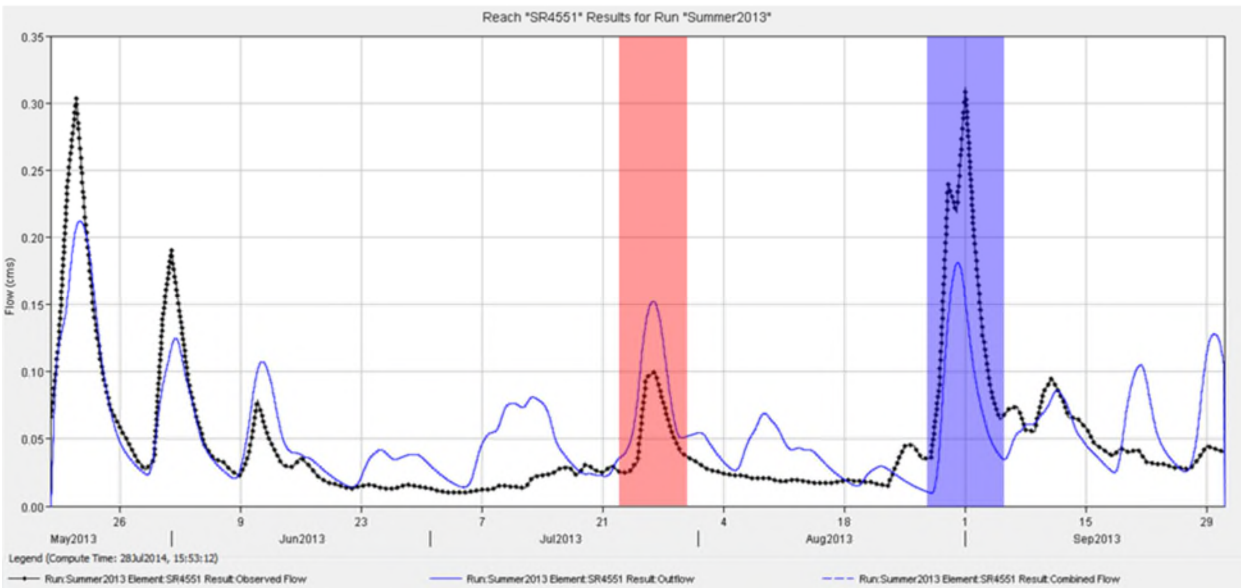


Figure 3-3 2013 Summer model calibration results for monitoring station TL1A (SR4551) at the Goliath Gold Project. Simulated flow is shown as solid blue lines while measured flows are shown as black dotted lines. The red highlight is the response to a July 25, 2013 rainfall event (28.1 mm) while the blue highlighted is a response to an August 29, 2013 rainfall event (43.0 mm).

One of the shortcomings of the HEC-HMS software is that it cannot model different infiltration parameters for different times of the year (soil essentially becomes impervious when frozen). These seasonal parameters make calibration difficult and typically lead to underestimation of spring and early summer runoff, and overestimation of summer and fall runoff.

The only adjustment made to the baseline model was in subbasin NR5363, upstream of monitoring station HS4. Land cover data indicated a large amount of wetland, while aerial imagery showed that much of this area appeared to be well vegetated. The percent impervious was reduced to 17% from 59%, which correlates to 15% of the subbasin being covered by wetland as opposed to the 59% based on the land cover data. Figure 3-4 shows the measured, baseline simulated, and calibrated simulated flows for monitoring station HS4 (NR4658-2).

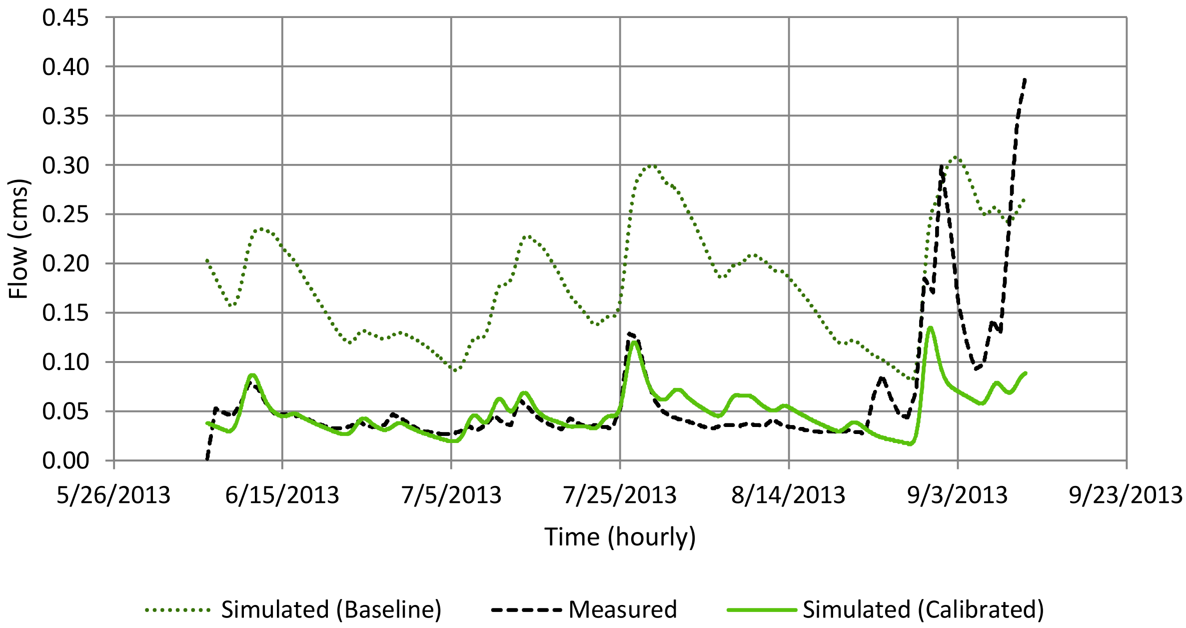


Figure 3-4 Measured, baseline simulation, and calibrated simulation results for monitoring station HS4 (NR4658-2) at the Goliath Gold Project.

3.4 Model Validation

Monitoring stations HS7, HS4, TL1A and JCTA were used for validation. Time windows from the summer of 2013 were used for each station. A comparison between the model and the observed monitoring data for total, average, maximum and minimum flows is presented in Table 3-1 to Table 3-3. Estimated runoff coefficients based on the runoff and total precipitation (upstream subbasin areas and cumulative precipitation during each time window) are shown in Table 3-4. Hydrographs of the model output for the validation windows are presented in Appendix B.

Table 3-1 Model Validation - Total Flow (Runoff) for the Goliath Gold Project.

Monitoring Station	Model (m^3)	Observed (m^3)	Volume Error (%)
HS7 (NR4359-2)	988,189	972,274	1.6%
HS4 (NR4659-2)	417,992	526,968	20.7%
TL1A (SR4551)	668,826	599,072	11.6%
JCTA (SR4444)	1,153,469	1,159,769	0.5%

Table 3-2 Model Validation - Average Flow for the Goliath Gold Project.

Monitoring Station	Model (m^3/s)	Observed (m^3/s)
HS7 (NR4359-2)	0.089	0.087
HS4 (NR4659-2)	0.050	0.063
TL1A (SR4551)	0.057	0.051
JCTA (SR4444)	0.098	0.099

Table 3-3 Model Validation - Maximum and Minimum Flows for the Goliath Gold Project.

Monitoring Station	Maximum Flow Model (m^3/s)	Maximum Flow Observed (m^3/s)	Minimum Flow Model (m^3/s)	Minimum Flow Observed (m^3/s)
HS7 (NR4359-2)	0.714 (May 20, 2013)	0.792 (May 21, 2013)	0.005 (Aug 28, 2013)	0.002 (Sep 23, 2013)
HS4 (NR4659-2)	0.308 (Sep 2, 2013)	0.391 (Sep 10, 2013)	0.082 (Aug 28, 2013)	0.002 (Jun 6, 2013)
TL1A (SR4551)	0.212 (May 21, 2013)	0.312 (Sep 1, 2013)	0.010 (Aug 28, 2013)	0.010 (July 3, 2013)
JCTA (SR4444)	0.473 (May 20, 2013)	0.931 (May 21, 2013)	0.014 (Aug 28, 2013)	0.016 (Aug 28, 2013)

Table 3-4 Model Validation - Runoff Coefficient for the Goliath Gold Project.

Monitoring Station	Model	Observed
HS7 (NR4359-2)	0.273	0.269
HS4 (NR4659-2)	0.175	0.221
TL1A (SR4551)	0.265	0.238
JCTA (SR4444)	0.275	0.276

The hydrographs show significant inconsistencies between the model and observed results for individual rainfall events (Appendices B and C). There are many reasons for observed and simulated data not matching, which include, but are not limited to:

- A complex hydrologic process is grossly simplified to a system of subbasins, reaches and reservoirs based on estimates from the best data available.
- Precipitation data are from a station 12.5 km away; while this appropriately depicts long term trends and overall magnitude of precipitation, it does not accurately predict individual storm intensities which can vary significantly over a small area (i.e. Localized thunderstorm cells).

- The model cannot simulate seasonal variations in parameters; soil infiltration during the spring freshet when the ground is still frozen and therefore imperviousness is much higher than in the summer, resulting in more runoff from the subbasins.
- The model cannot predict changes from natural or manmade causes (beaver dams construction/failure, dewatering, water withdrawals, etc.).
- Potential error in monitored flow data (data are based on level logger data converted with a stage-discharge formula developed from manual discharge measurements and non-surveyed staff gauge readings).

More detailed and site-specific data collection (one or more rain gages within the watershed, increased flow monitoring, soil sampling, etc.) would be required to calibrate and validate the model to individual storms. More detailed data collection is outside the scope of most hydrology models developed for preliminary analysis.

The overall flow characteristics between the model and observed data for subbasins display a much better correlation than correlations at specific flow events (Table 3-1 and Table 3-2). Runoff and average flows at stations HS7 and JCTA are remarkably similar, station TL1A over estimates runoff by 11.6%, while Station HS4 underestimates the runoff by 20.7%. Observed flow at station HS4 had a large flow near the end of the validation window which was not captured in the modeled runoff. If the validation window was over many years, large anomalies like this would be averaged out and the overall error would be much less. In hydrologic modelling volumetric errors less than 10% are considered very good, less than 20% good, and less than 30% error are fair.

The Nash-Sutcliffe Model Efficiency Coefficient and Pearson Product Moment Correlation Coefficients are a measure of how well the model is able to predict the actual hydrological processes (Table 3-5).

Table 3-5 Model Validation - Correlation Coefficients based on 2013 flow hydrographs, for the Goliath Gold Project.

Monitoring Station	Nash-Sutcliffe Coefficient *	Correlation Coefficient **
HS7 (NR4359-2)	0.324 (poor)	0.641 (poor)
HS4 (NR4659-2)	0.269 (poor)	0.617 (poor)
TL1A (SR4551)	0.617 (satisfactory)	0.796 (fair)
JCTA (SR4444)	0.598 (satisfactory)	0.796 (fair)

* Nash-Sutcliffe Coefficient:
1.0, perfect match,
≥ 0.5, considered satisfactory
0.0, observed mean is as good a predictor as the model
< 0.0, observed mean is a better predictor than the model

** Correlation Coefficient:
1.0, perfect match
≥ 0.8, strong correlation
≤ 0.5, weak correlation
0.0, no correlation

The Nash-Sutcliffe Coefficients indicate a poor to satisfactory correlation between the model and observed data, and the Correlation Coefficients indicate a poor to fair correlation. Stations TL1A and JCTA are both located on Blackwater Creek and have fair to satisfactory correlations. The majority of the data discrepancies appear to be from precipitation recorded at the Dryden airport station that were not observed at the Project site. More detailed data collection (one or more rain gages within the watershed, longer duration flow monitoring, etc.) would make a stronger correlation possible but is not deemed necessary. Overall the HEC-HMS model predicts the overall flow characteristics of the watershed to an acceptable accuracy.

3.5 Pre-Development HEC-HMS Model

The Pre-Construction model is the baseline model discussed in previous sections, and is a representation of the current watershed that will be used as a baseline for comparison.

The monthly water balance was calculated by continuously running the model using the entire climate data set available (1970-2013). The HEC-HMS model requires continuous data, if temperature data were not available on a particular day, a weekly average was computed from adjacent days; if precipitation data were not available for a particular day, the precipitation was assumed to be zero.

3.6 Operational HEC-HMS Model

In order to model the Project site during operations, the model needed to incorporate terrain changes such as increased imperviousness and the loss of evapotranspiration where vegetated areas are to be cleared (Figure 3-5). The model also needed to incorporate changes to the drainage patterns and water use (Figure 3-6; Table 3-6; Lycopodium 2014).

Table 3-6 Site water balance (constant processes) during the operational phase of the Goliath Gold Project near Dryden (after Lycopodium 2014).

Project Process	Flow (m^3/day)
To Process Plant	
Fresh process water (from lakes, wells, streams)	600
Ore Water (5% ore moisture content)	142
Mine Dewatering (groundwater only)	1,145
Mine Processes (Evaporation out of system)	-5
To Tailings Storage Facility	
From Process Plant	1,882
Mine Dewatering (excess)	175
To Polishing Ponds	
From Tailings Storage Facility	2,057
Effluent to Environment	2,057

The pre-development HEC-HMS model was therefore modified as follows to simulate the operational mine site (Figure 3-7):

- A new subbasin (named "minesite"), comprising the waste rock storage area, low-grade ore stockpile, overburden stockpile, and open pit mine, was added to the model.
    - 2,057 m^3/day constant baseflow was been applied
    - A composite percent impervious value (area weighted) was computed for areas draining through the mine components
    - Green and Ampt infiltration parameters for sandy loam were used
- A reservoir (named "SitePonds") downstream of the new subbasin was added and sized based on the following:
    - Tailings Storage Facility: 760,000 m^3
    - Polishing Pond: 64,300 m^3
    - Seepage Pond: 10,300 m^3
    - Collection Ponds: 11,500 m^3 (x 2)
- A second subbasin (named "mineponds") was added to model precipitation falling directly on the ponds in the subbasin. All losses were eliminated (infiltration, evapotranspiration, etc.) and a minimum model time step of 6 hours was used for routing.
- Areas covered by the mine components that drain through the mine site system were removed from existing subbasins.
- Composite percent impervious values were calculated for subbasins with mine components (processing plant, laydown area) draining offsite.

Overall, converting portions of the watershed from a natural state to an active mine site will make the ground more impervious and eliminate evapotranspiration wherever vegetation is removed. The hydrologic effect of the development is that the subbasin will allow more precipitation to runoff and will more efficiently route water off site.

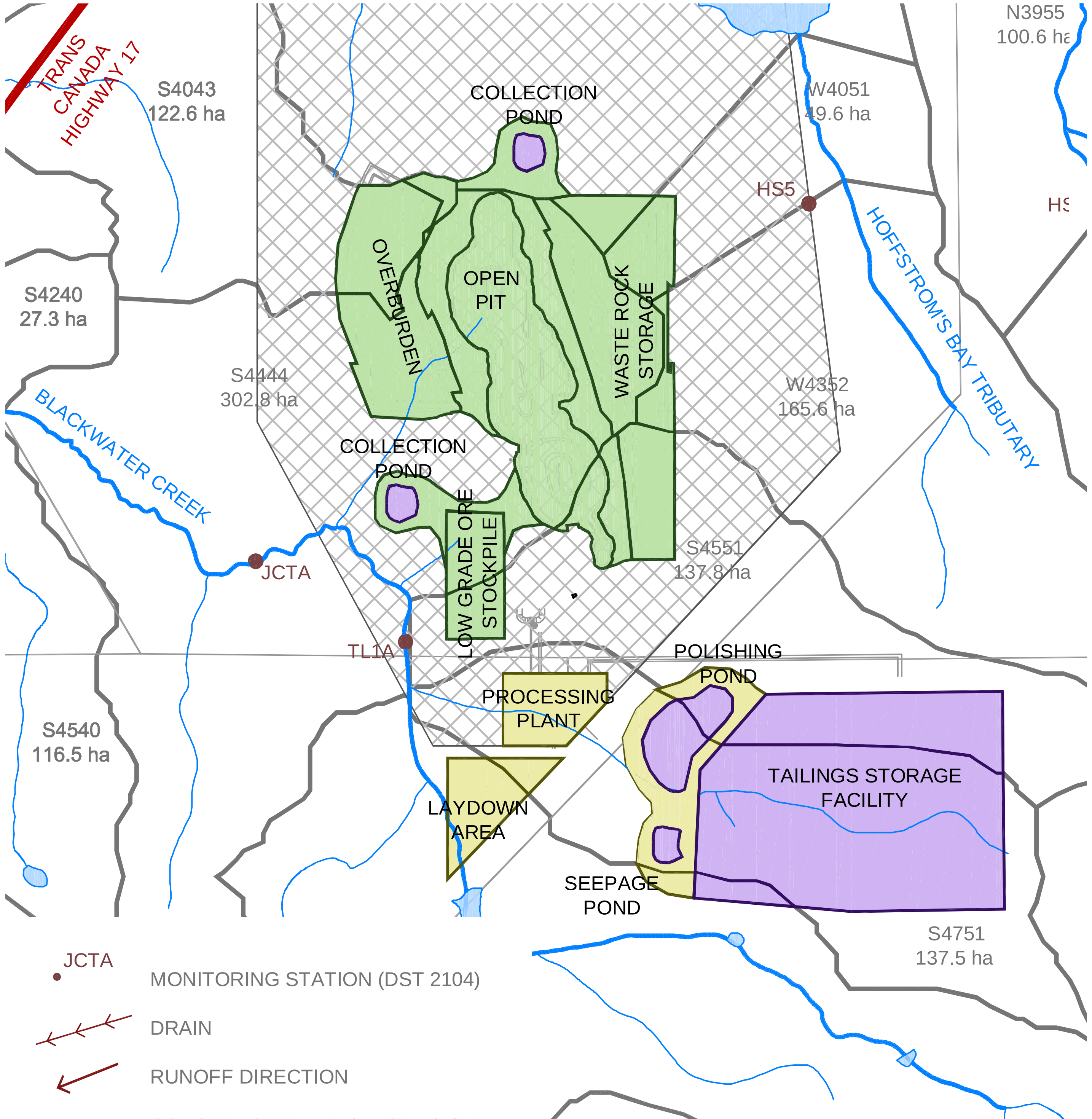
3.7 Post-Closure HEC-HMS Model

The post-closure plan for the mine site is to cap the tailings storage facility (TSF) and ponds with a relatively impervious material such as clay, and direct most water offsite with exception to the open pit area. The open pit will be partially backfilled with waste rock and the remainder allowed to flood and form a pit lake; a discrete amount of area will runoff to the pit lake to maintain minimum water levels (Figure 3-5).

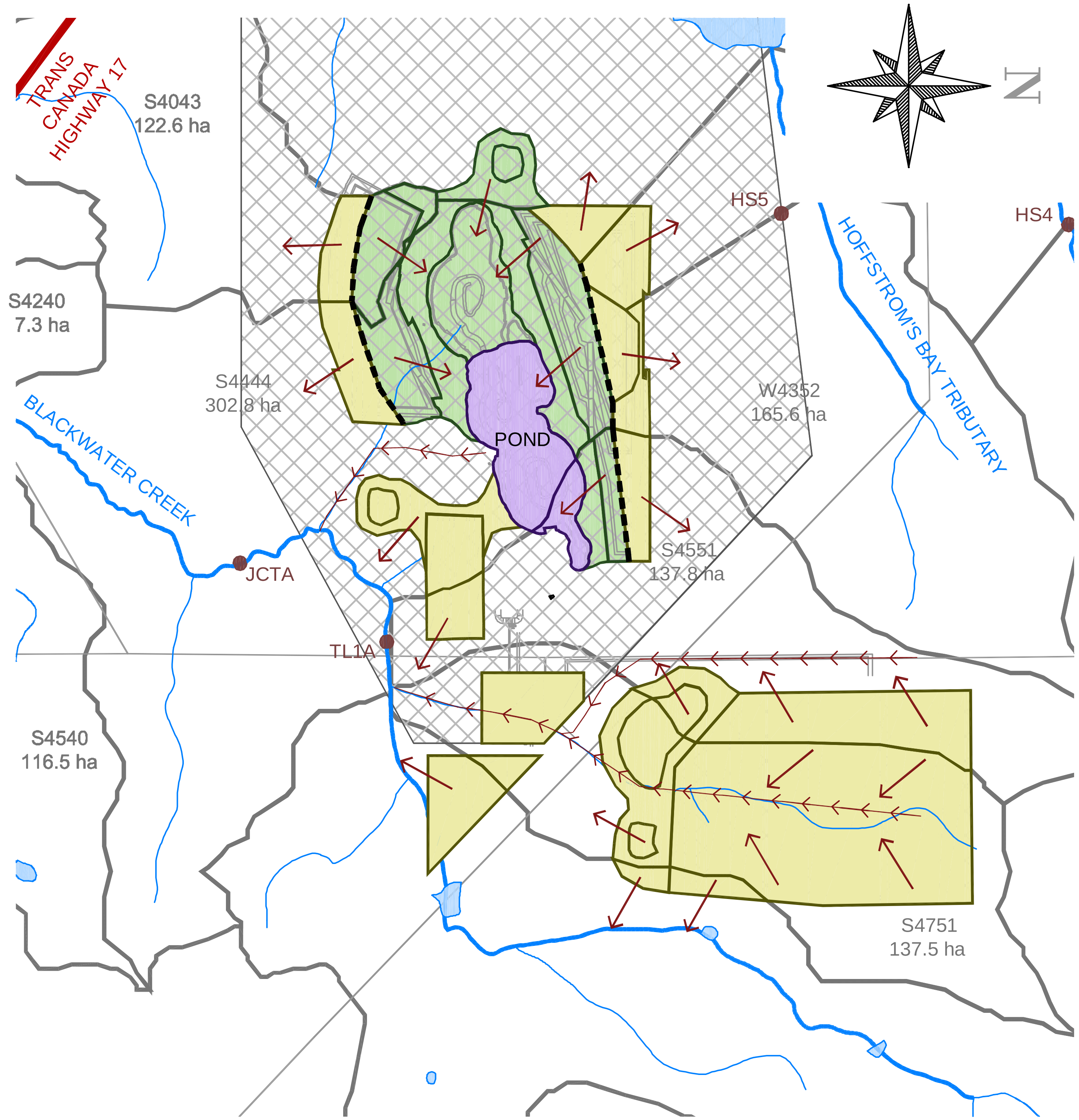
The impervious pond caps and remaining waste rock and overburden piles will also cause a greater volume and quicker runoff than the natural pre-development conditions. The operational HEC-HMS model has been modified as follows to simulate the post-closure minesite:

- The "minesite" subbasin has been reduced in area to reflect the conceptual post-closure drainage plan (green areas in Figure 3-5).
- The "SitePonds" reservoir and "mineponds" subbasin have been reduced to reflect the new pond created in the open pit.
- All areas converted to surface runoff (yellow areas in Figure 3-5) have been rerouted back to their original subbasins and composite percent impervious values computed for each subbasin affected.

X:\T-Z\TREASURY METALS INC - 9390\14939002.00 - GOLIATH GOLD SURFACE HYDROLOGY MODELING\CAD\CIVIL\1493900200-DWG-C0004-A-FIG 3-5 - OP-PC WATERSHED.DWG 14.09.10 4:03 PM CHRISTIANSEN, TREVOR



DURING MINE OPERATION



POST CLOSURE

JCTA MONITORING STATION (DST 2104)

DRAIN

RUNOFF DIRECTION

CONSTRUCTED DRAINAGE DIVIDE

MINE SITE (AMEC 2014)

100% IMPERVIOUS

70% IMPERVIOUS (DRAINS TO PONDS)

70% IMPERVIOUS (DRAINS OFF SITE)

200 0 250 500 750 1000m

1:20,000

NO.	DESCRIPTION
REFERENCE DRAWINGS	

NO.	DATE	DESCRIPTION	PREPARED	REVIEW	DESIGN	AUTHORIZE
REVISIONS/ISSUE			DRAFTING		ENGINEERING	

TETRA TECH
Complex World
Clear Solutions

AUTHORIZED BY:
DATE: -
CLIENT DRAWING NO.

CLIENT: TREASURY METALS Inc

DRAWING DESCRIPTION:
OPERATIONAL/POST-CLOSURE
WATERSHED ANALYSIS
FIGURE 3-5

DESIGNED BY: TRC	DRAWN BY: NL	DRAWING NO.	REV.
REVIEWED BY: KJM	SCALE: 1 :20,000	1493900200-DWG-C0004	A

B (17" x 11")

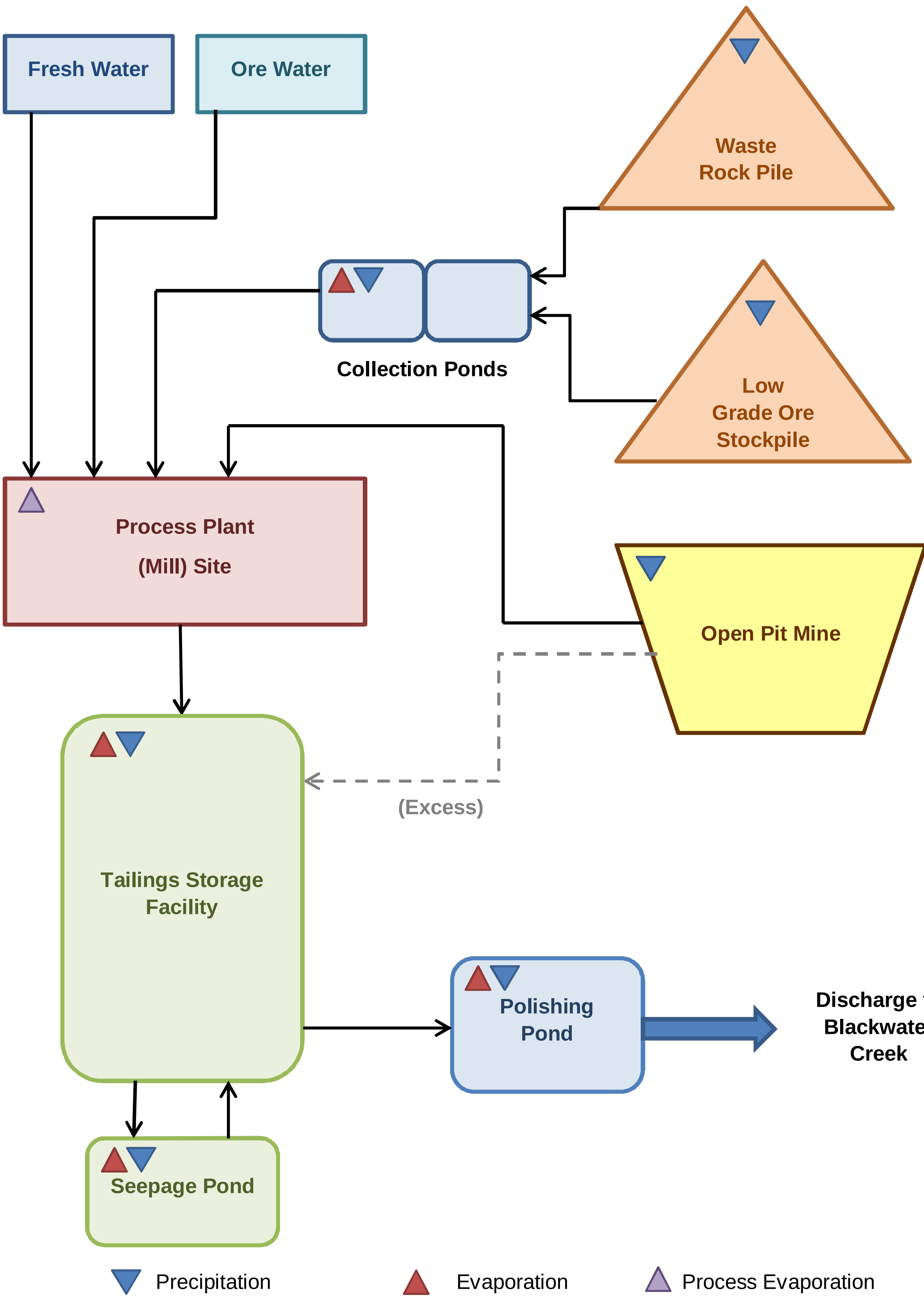
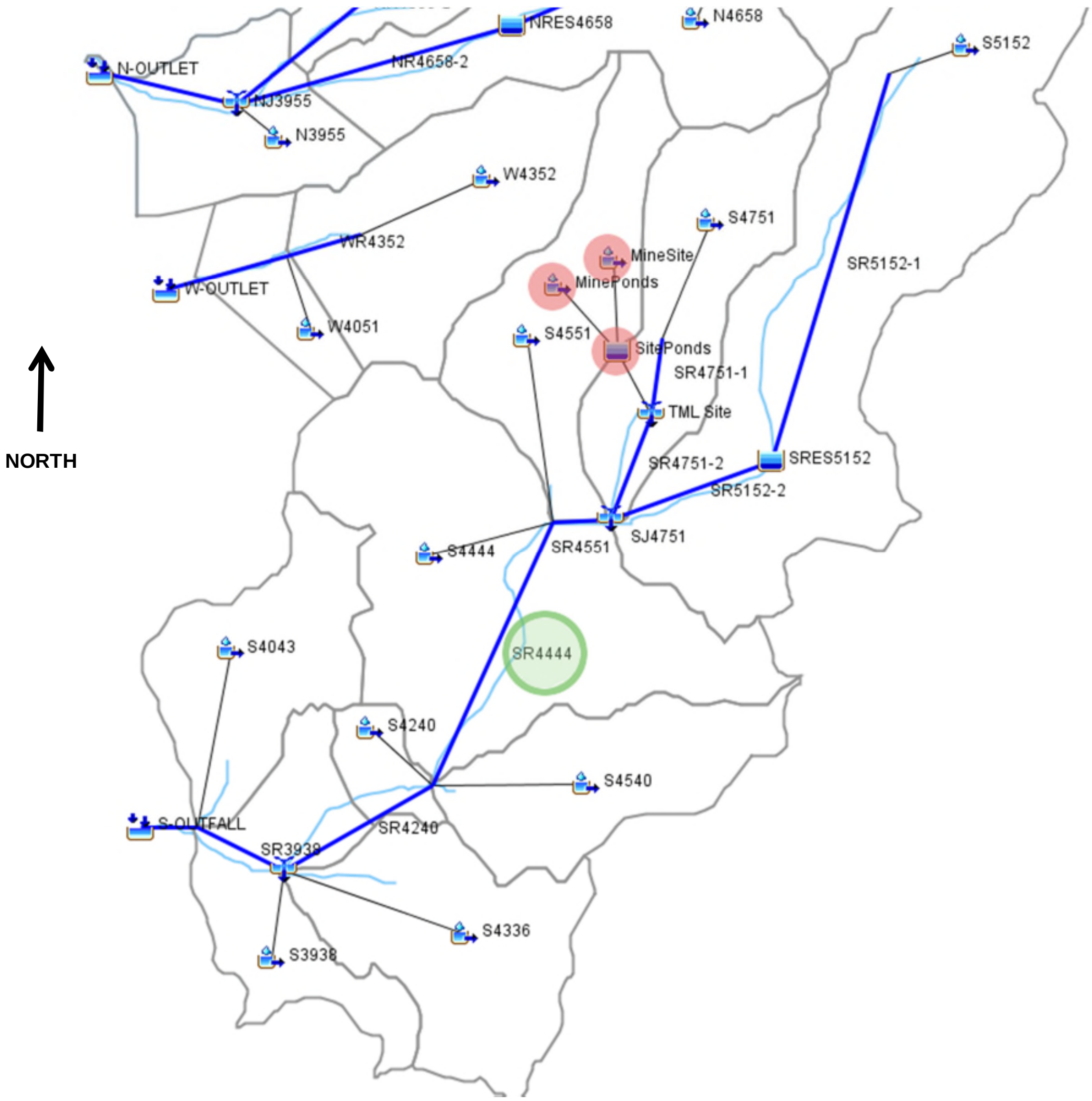


Figure 3-6 Site Water Balance Flow Chart



Red – Elements added to simulate minesite development

Green – Downstream reach element used for model result comparisons

Figure 3-7 Model Modification for Minesite Development

4.0 RESULTS

Each of the three models (pre-development, operational, and post-closure) were run continuously for the entire climate dataset (1970-2013). Model reach SR4444 (monitoring site JCTA) was chosen as the point to compare model results as it is the first component downstream of the minesite that includes all upstream areas affected by the development.

Results for subbasins draining to the west outfall (Hoffstrom's Bay Tributary) are not included as there is a minimal effect from the mine development; the observed and model flows for this area were also inconsistent and diminished the confidence in those results. Likewise, results for the subbasins draining to the north outfall (unnamed creek) have not been included since these areas are not affected by the mine development.

A simple, spreadsheet-based monthly water balance calculation (Appendix C) was also prepared for the operational minesite, as a final check of the validity of the much more complicated HEC-HMS Model. This model utilized average monthly precipitation, and assumed that wintertime precipitation (November through March) was stored on site and release during the month of April. Runoff was estimated based on the minesite catchment areas and simple Runoff Coefficients. Average monthly flow from the simple water balance is shown along with the pre-development, operational, and post-closure results computed with HEC-HMS on Figure 4-1.

4.1 Comparison of Mine Development Stages

The development of the mine site is expected to increase the amount of runoff into Blackwater Creek both during operation and post closure (Table 4-1). The annual water balance produced from the HEC-HMS model includes the calculated operational water balance (Figure 4-1). The calculated water balance tends to predict slightly higher than the model, but is a good indicator of the validity of the model. The exception is in April when the calculated water balance assumes all winter precipitation thaws during that month; the model predicts a more realistic scenario where snow melt occurs throughout the March to May period based on temperature.

The operational stage will increase the average annual flow by 78%; 33% of that increase (0.018 m^3/s) is from modifications to the land, and the remaining 45% is from constant outflow from minesite operations (0.024 m^3/s). Maximum flow is only marginally higher (8%) than the pre-development conditions since much of the peak runoff is routed through the mine pond system. The greatest difference to Blackwater Creek during mine operations will come during periods of low flow, where constant mine effluent will keep the creek running even during periods with little rainfall and during the winter.

The model predicts the post-closure stage of development will increase the average annual flow by 47%. The maximum outflow is increased by 53% since the post-closure area is now more efficient at routing water from the subbasin. Maintaining the collection ponds, or converting the polishing or seepage ponds to retention ponds will reduce the peak flows from the area. Low flow conditions are similar to the pre-development conditions where the creek will dry up after extended dry periods.

Table 4-1 Development stage flow comparison (SR4444) for the Goliath Gold Project.

Development Stage	Average Annual Flow (m^3/s)	Maximum Flow (m^3/s)	Minimum Flow (m^3/s)
Pre-Development	0.055	1.504 (Apr 26, 1989)	0.000 (Multiple events)
Operational	0.097 (78% increase)	1.617 (Apr 26, 1989)	0.006 (July 7, 1979)
Post-Closure	0.081 (47 % increase)	2.297 (Apr 25, 1989)	0.000 (Multiple events)

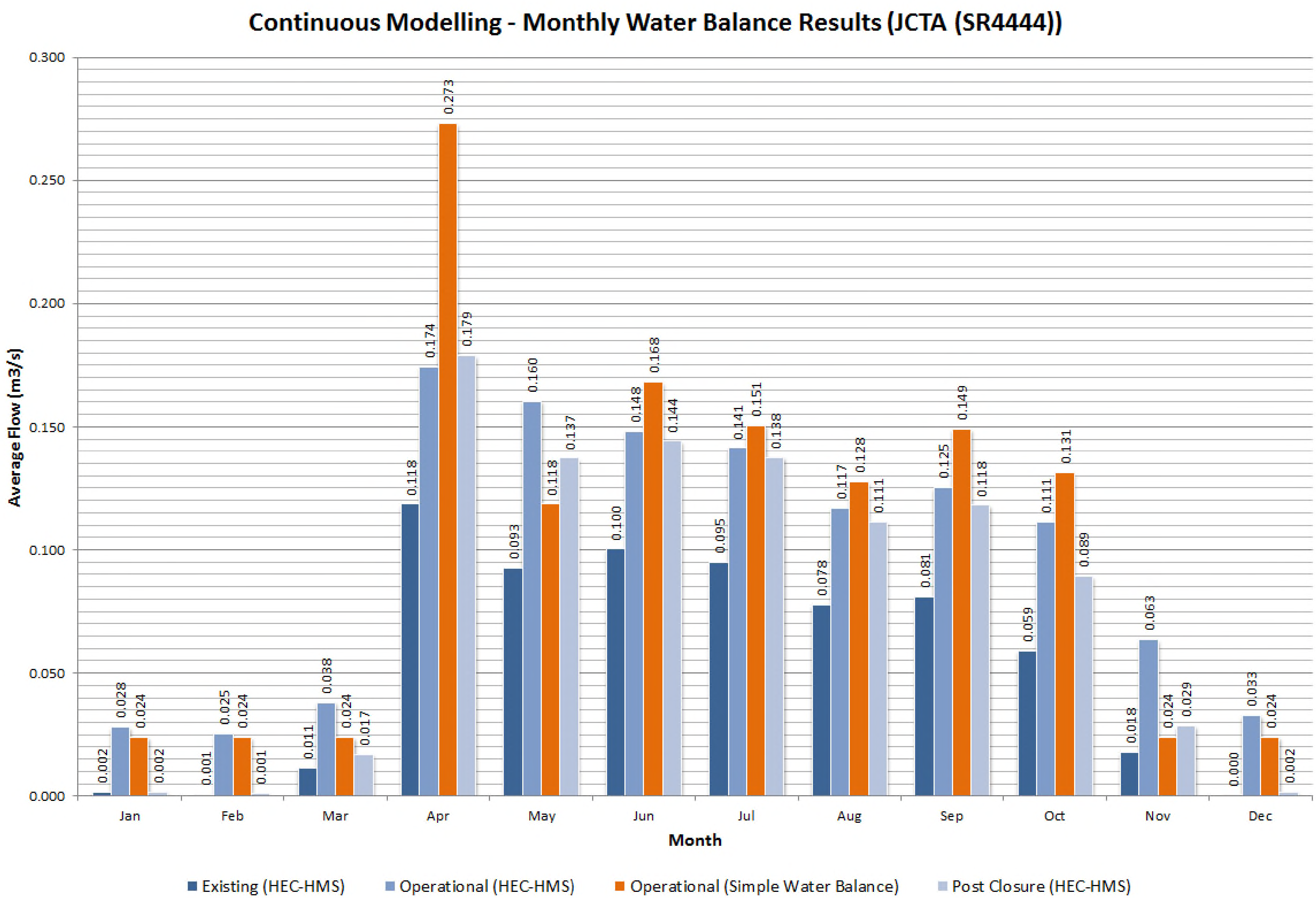


Figure 4-1 Monthly water balance for pre-development, operation, and post-closure phases of the Goliath Gold Project.

4.2 Low Flow Results

The 10 year low annual precipitation from the climate analysis for Dryden is 522.4 mm; four years have been identified as being within ± 5mm of this value:

- 1979 (518.1 mm)
- 1989 (519.8 mm)
- 2005 (522.0 mm)
- 2013 (518.4 mm)

Hydrographs for these four years were extracted from the model output data (Figure 4-2).

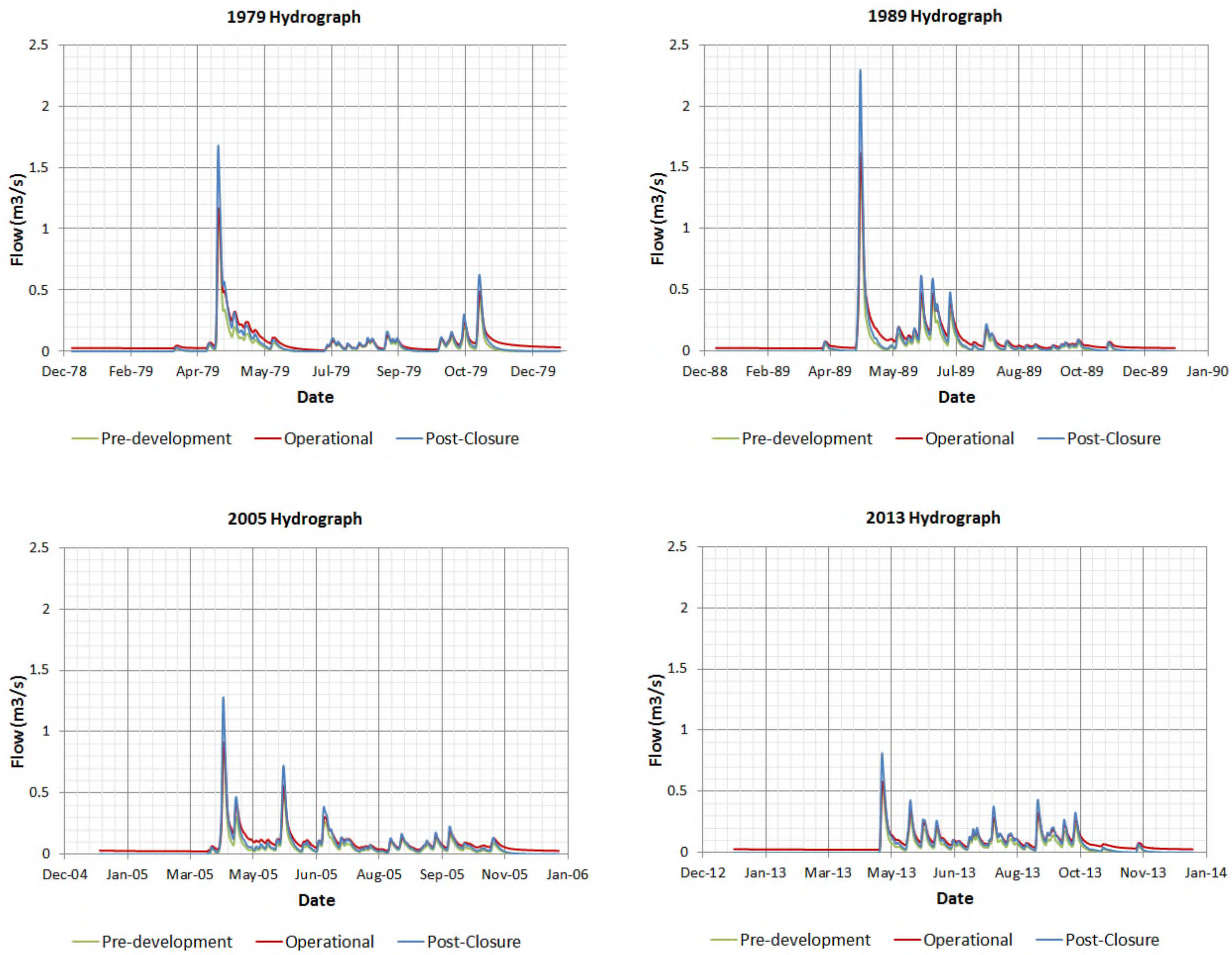


Figure 4-2 Ten year low flow hydrographs extracted from the model for Blackwater Creek at the Goliath Gold Project.

The pre-development and post-closure models predict that Blackwater Creek will dry up after approximately three to four weeks of no rainfall, and will freeze completely in the winter. Based on the channel parameters used in reach SR4444 (channel width of 0.348 m, 1:1 side slopes and a longitudinal slope of 0.4%), the channel velocity from the constant mine site output (0.024 m^3/s) will be approximately 0.38 m/s. This may pose serious problems if effluent is discharged into Blackwater Creek; ice accumulation may eventually block the stream causing large ice jams and overland flooding problems during the spring. If Blackwater Creek is chosen as the discharge point, winter operation should be taken into account during detailed design.

The 1979 spring freshet hydrograph indicates that the development (and closure) of the mine site will primarily affect the peak runoff from individual rainfall events and have little impact on low flow conditions (Figure 4-3). The difference between the pre-development and post-closure peak runoff could be reduced with the use of retention ponds; however, the overall volume of runoff will still remain higher than the pre-developed condition.

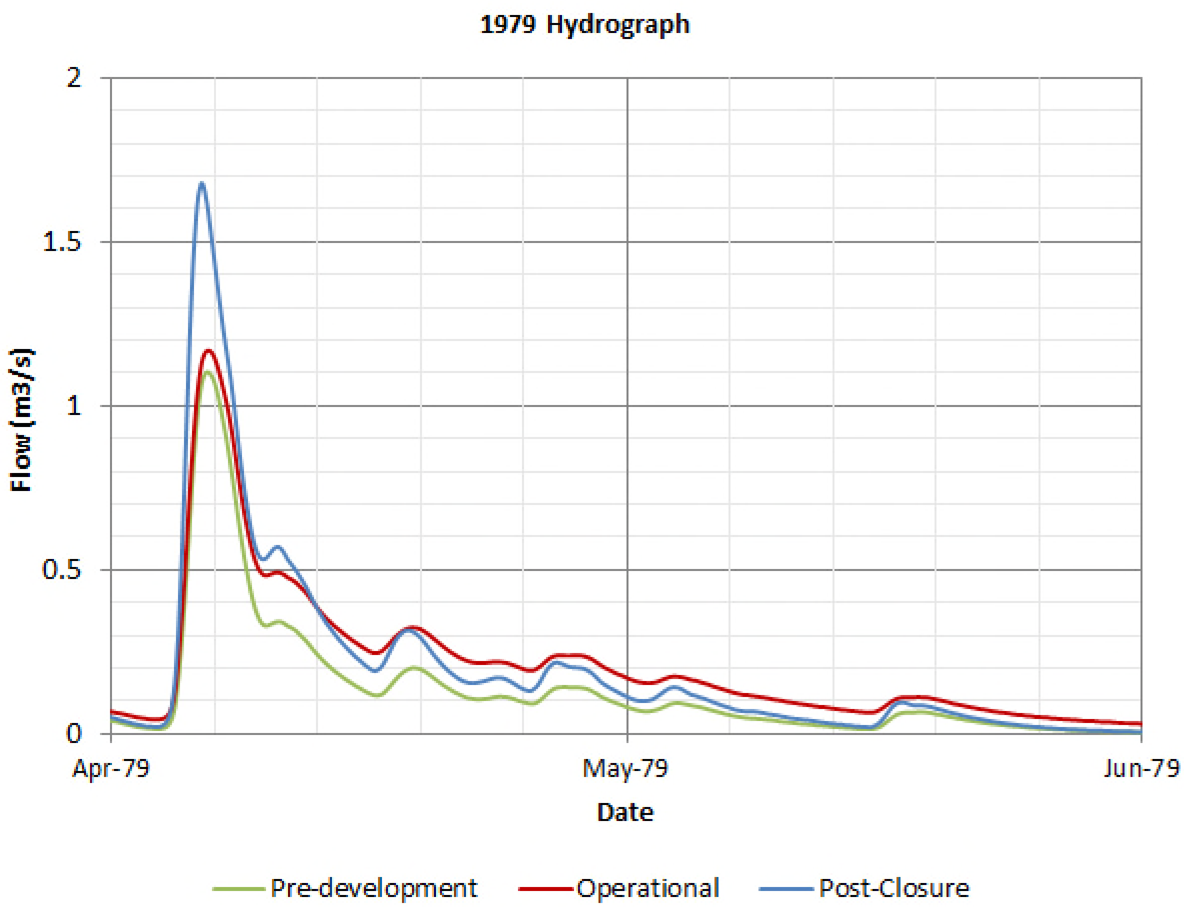


Figure 4-3 1979 spring freshet hydrograph for Blackwater Creek at the Goliath Gold Project.

4.3 High Flow Results

The 10 year high annual precipitation for Dryden is 837.2 mm; four years have been identified as being within ± 12 mm of the 10 year high:

- 1974 (825.8 mm)
- 1991 (835.3 mm)
- 1996 (838.2 mm)
- 2000 (846.1 mm)

Hydrographs for these four years have been extracted from the model output data and presented in Figure 4-4, with a detailed view of the 1996 hydrograph presented in Figure 4-5.

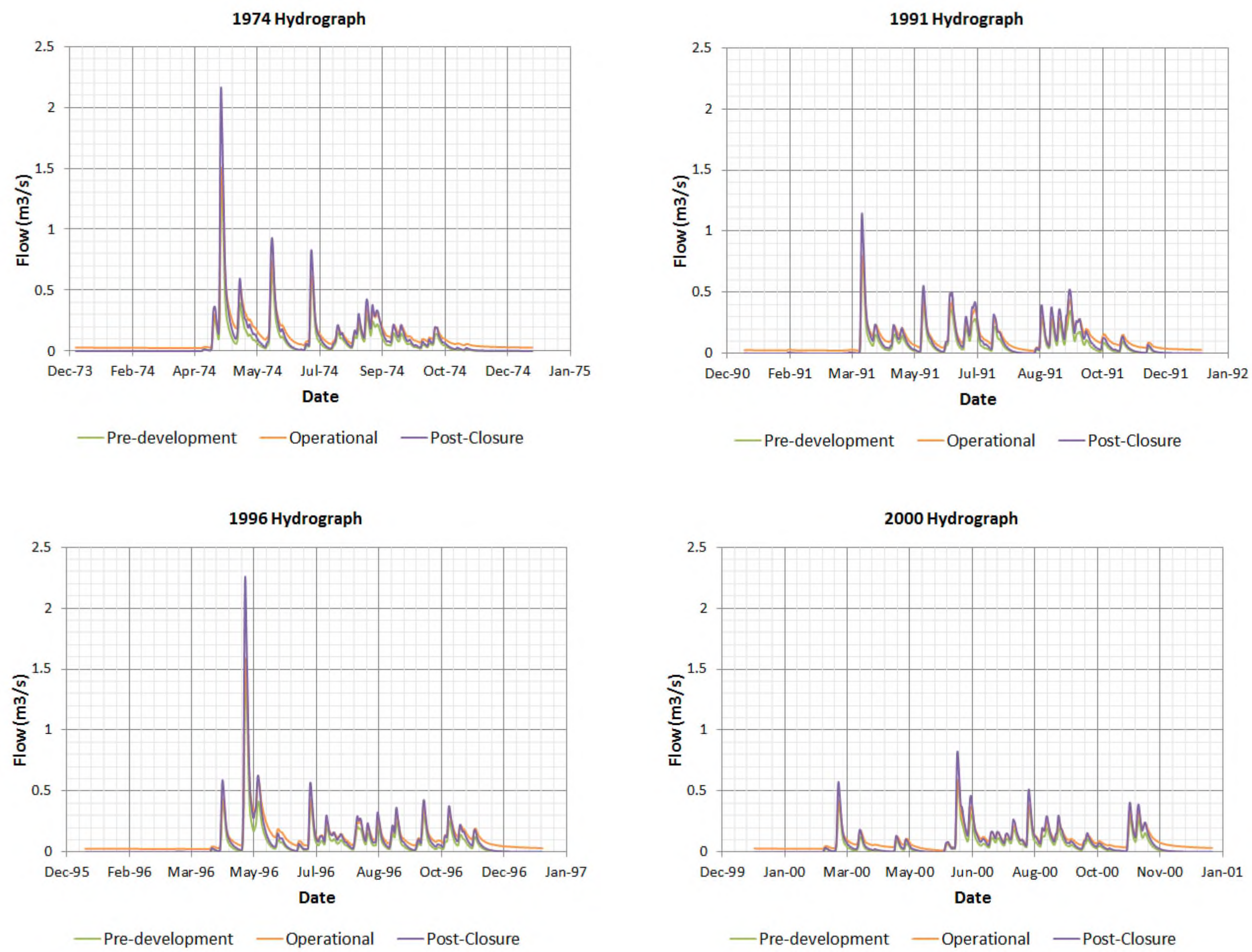


Figure 4-4 Ten year high flow hydrographs for Blackwater Creek at the Goliath Gold Project.

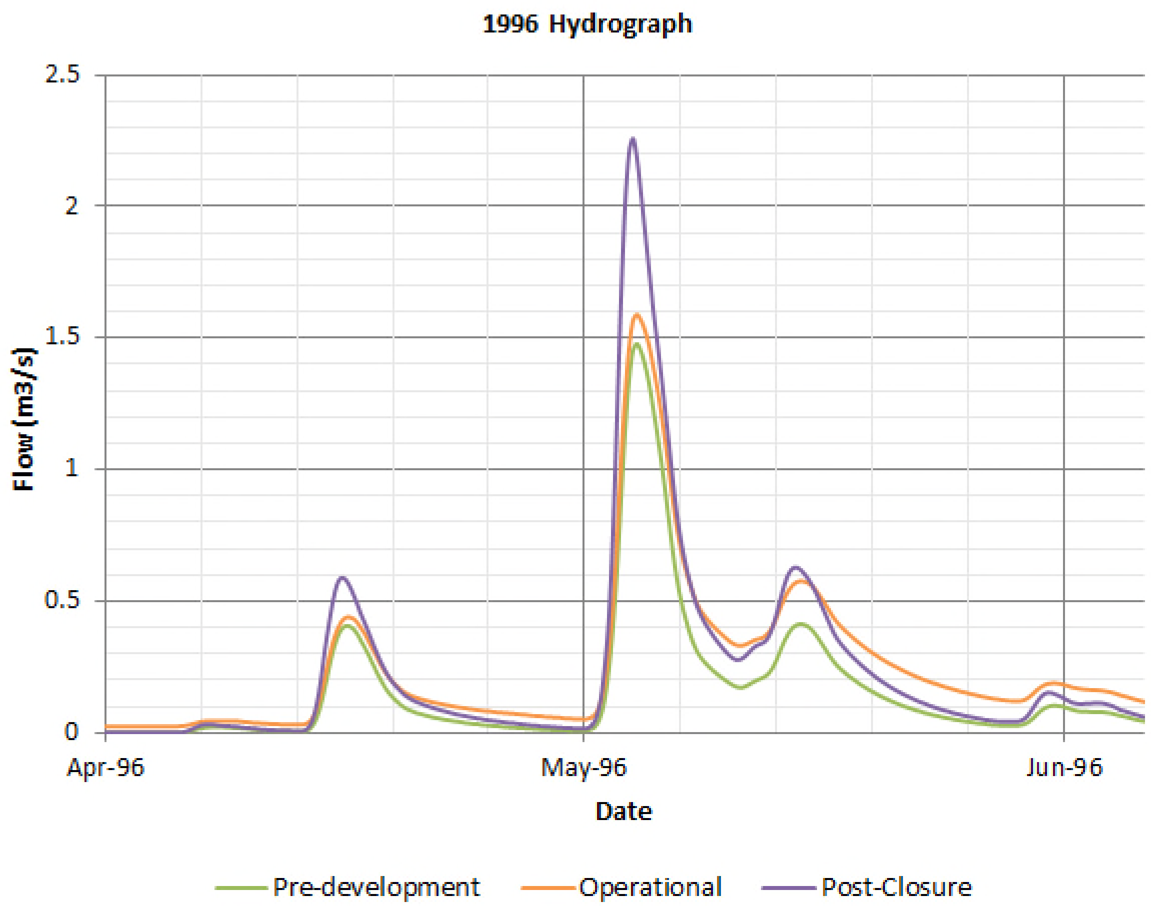


Figure 4-5 1996 spring freshet hydrograph for Blackwater Creek at the Goliath Gold Project.

Channel flow, velocity, and erosion relations were developed based on the parameters used for model reach SR4444 which is representative of Blackwater Creek (Table 4-2). During the 1996 spring freshet, the peak flow increased from 1.48 m^3/s (pre-development) to 2.26 m^3/s (post-closure). The relationship between flow, channel velocity and particle sizes subject to erosion, indicate that the additional flow during post-closure will have little effect on stream velocity and erosion.

Table 4-2 Post-closure channel flow, velocity, and erosion relationship for Blackwater Creek at the Goliath Gold Project.

Flow (m^3/s)	Channel Velocity (m/s)	Particle Size Subject to Erosion (mm) [1]
0.00	0.00	0.000
0.10	0.44	0.009 – 3.0
0.25	0.67	0.004 – 5.5
0.50	0.812	0.003 – 7.0
1.00	0.95	0.003 – 8.0
1.48 (Figure 4-5 Pre-Development Peak)	**1.04**	**0.0025 – 9.0**
2.00	1.15	0.0025 – 10.0
2.26 (Figure 4-5 Post-Closure Peak)	**1.15**	**0.0025 – 10.0**
3.00	1.24	0.002 – 11.0

[1] Based on the Hjulström Curve, 1935

5.0 SUMMARY AND CONCLUSIONS

A hydrologic model of the area surrounding the Goliath Gold Project was developed within the HEC-HMS software platform. This model included:

- 43 years of rainfall input from Dryden Airport (1970-2013)
- Catchments and drainage paths discretized from a digital elevation model (DEM)
- Surface soils from Land Initiatives Ontario
- Land cover/vegetation from the Hydrogeological Pre-Feasibility/EA Support Study by AMEC (2014)
- Simplified storage represented by lakes and marshes identified by orthophotos, LIO maps, and stage-surface area curves from contours and the DEM
- Simplified channel routing assuming simple cross-sections based on the Hydrology 2013 Baseline Study by DST (2014)

The model was used to investigate the project area hydrology. The limited flow monitoring data available from the Hydrology 2013 Baseline Study (DST 2014) was used to calibrate and validate the model. Model calibration was limited by the monitoring and climate data available; additional rain gages within the watershed and a more rigorous monitoring regime and stream surveys would be required for further calibration. Model validation parameters indicate a poor to fair correlation between observed and simulated flows, with fair correlations in Blackwater Creek. Overall the model produces acceptable results and is appropriate for long term hydrology prediction.

The development and subsequent closure of the mine site area will increase the imperviousness of the soils and more efficiently route water to Blackwater Creek. The result of these actions is an increase in total runoff and an increase in peak flows during rainfall events, with little change to periods of low flow.

Table 5-1. Blackwater Creek at Goliath Gold Project.

Development Stage	Average Annual Flow (m^3/s)	Maximum Flow (m^3/s)	Minimum Flow (m^3/s)
Pre-Development	0.055	1.504 (Apr 26, 1989)	0.000 (Multiple)
Operational	0.097 (78% increase)	1.617 (Apr 26, 1989)	0.006 (July 7, 1979)
Post-Closure	0.081 (47 % increase)	2.297 (Apr 25, 1989)	0.000 (Multiple)

Years with similar 10 year low annual precipitation were analyzed and found that the model predicts Blackwater Creek will dry up after three to four weeks which may cause problems during winter operations for the Project. Likewise, four years with similar 10 year high annual precipitation were analyzed and indicated an increase in peak flows being the greatest change. The additional flow and corresponding increase in channel velocity is not expected to have a detrimental effect on Blackwater Creek, although localized erosion and sediment capture methods may be warranted.

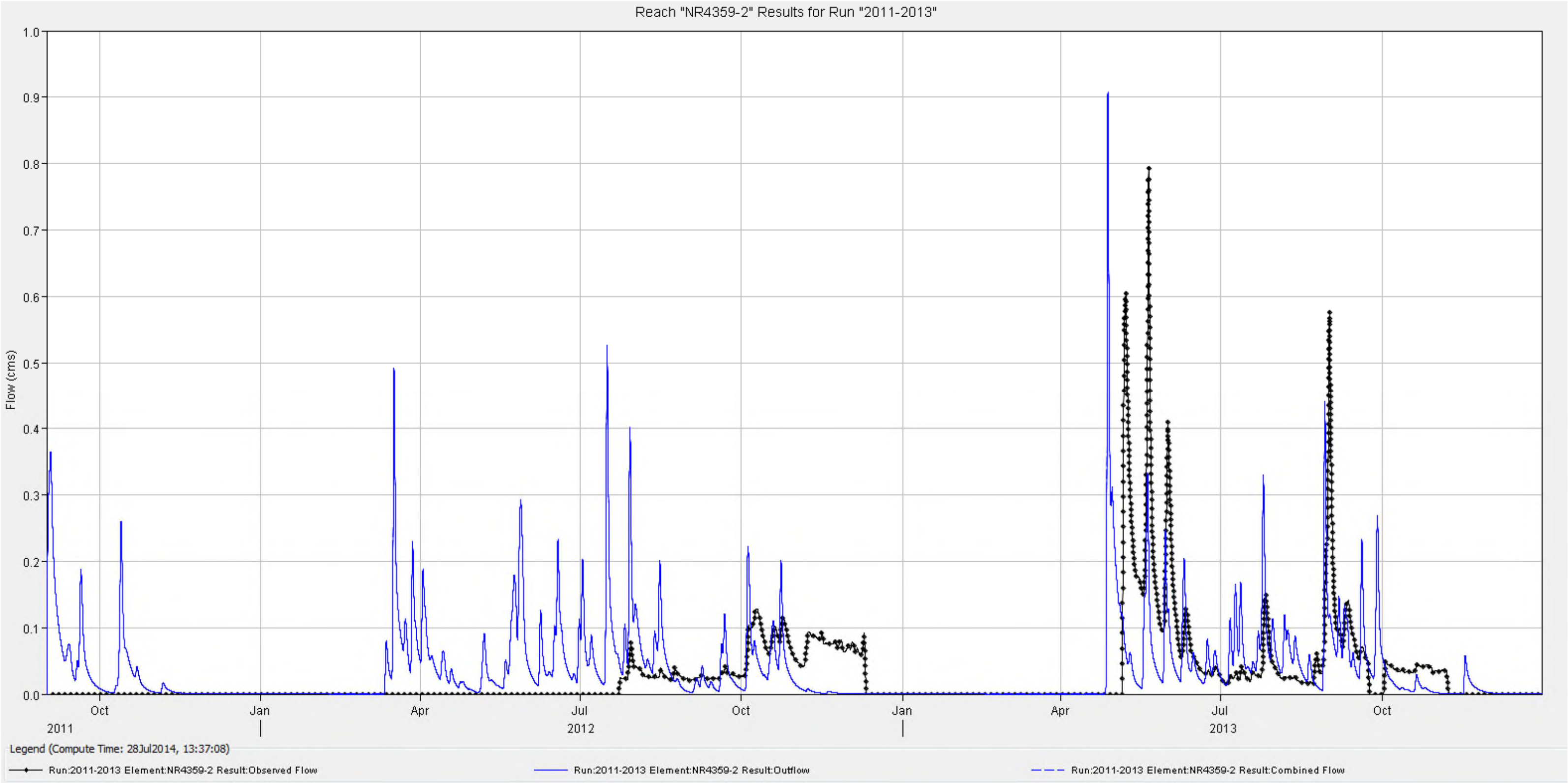
The completed model is available for use during further hydrologic studies including refinement of the calibration using additional rainfall and flow monitoring data, examining groundwater interaction, and examining sediment transport. The model may also be further refined to verify system performance during detailed design. However, the model is suitable for long-term hydrology only and should not be used for developing storage pond outlet works in response to short duration, high intensity rainfall events.

APPENDIX A – BASELINE MODEL RUN

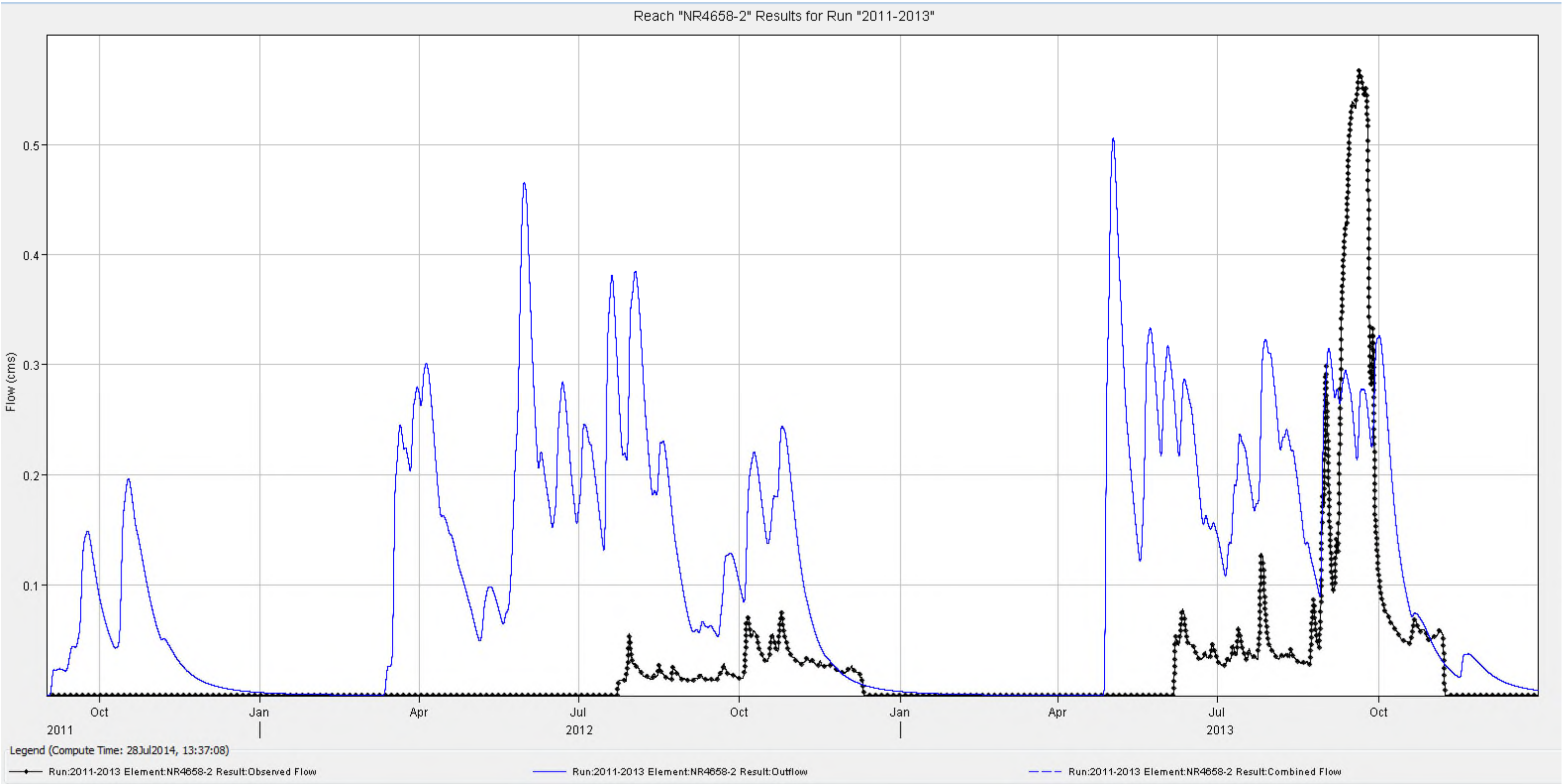
2012-2013 HEC-HMS baseline model results compared to monitoring data at the following monitoring stations:

- Monitoring Station HS7 (NR4359-2)
- Monitoring Station HS4 (NR4658-2)
- Monitoring Station HS5 (WR4051)
- Monitoring Station TL1A (SR4551)
- Monitoring Station JCTA (SR4444)
- Monitoring Station TL3 (SR4240)

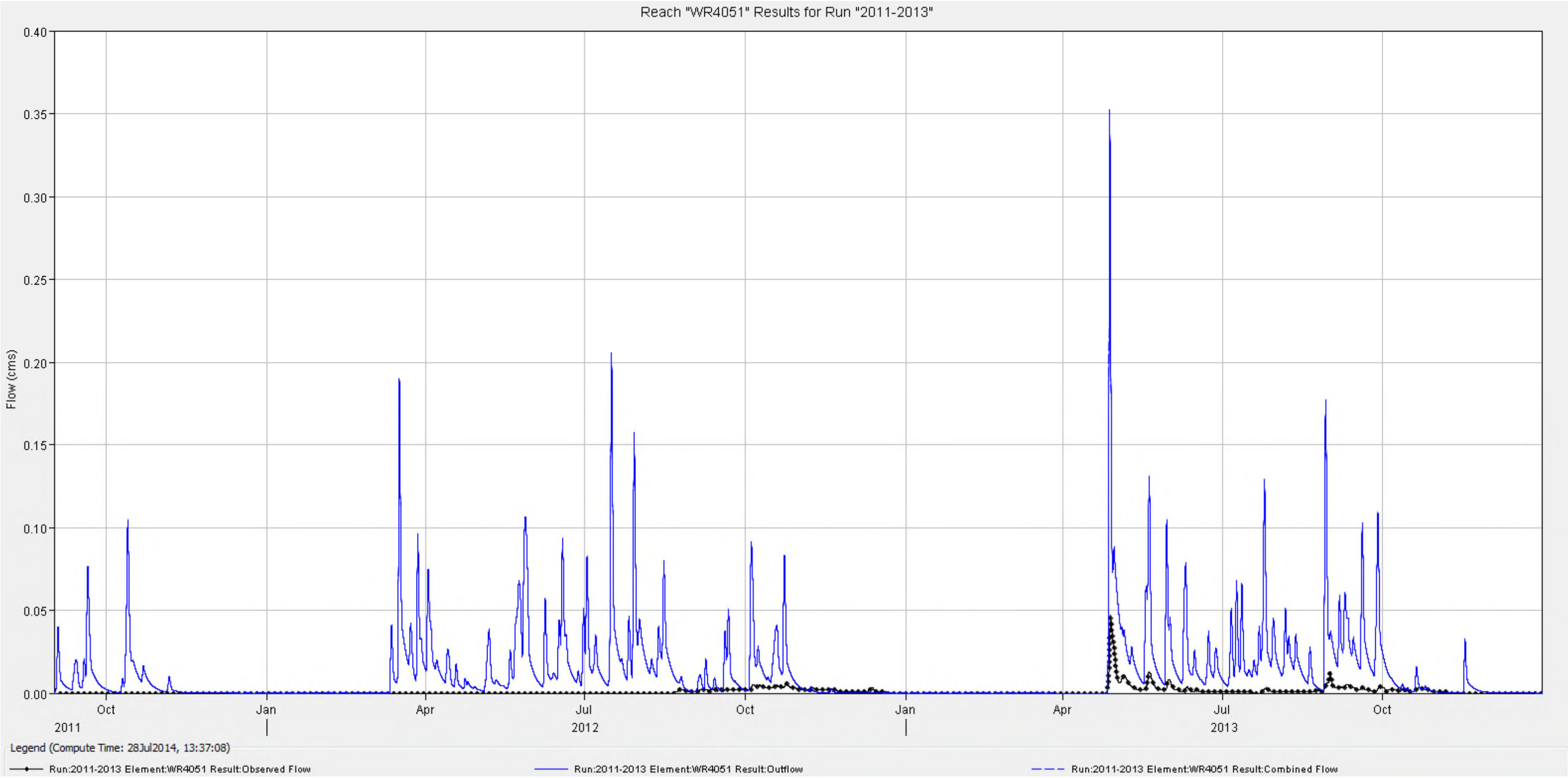
Monitoring Station HS7 (NR4359-2)



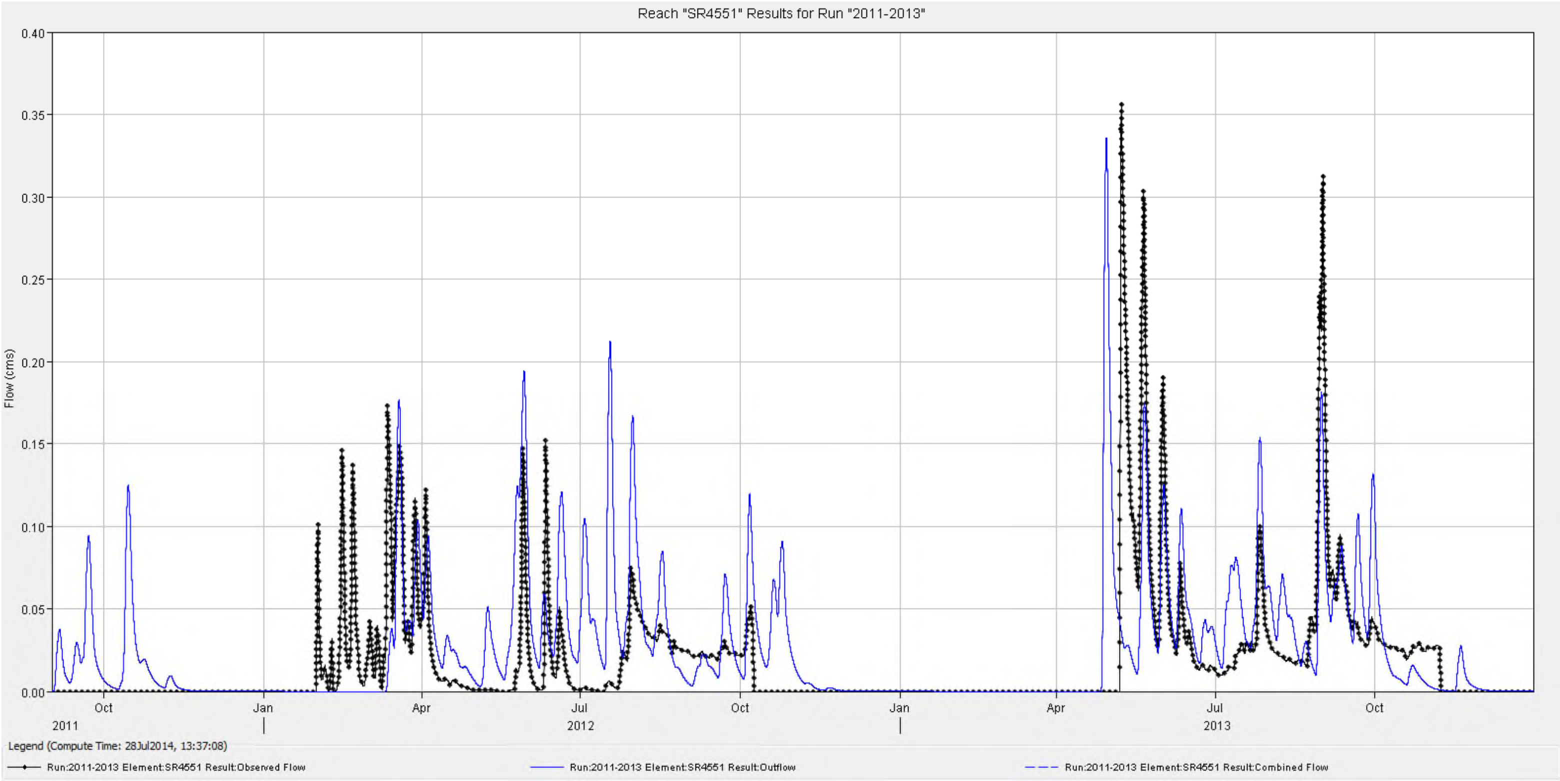
Monitoring Station HS4 (NR4658-2)



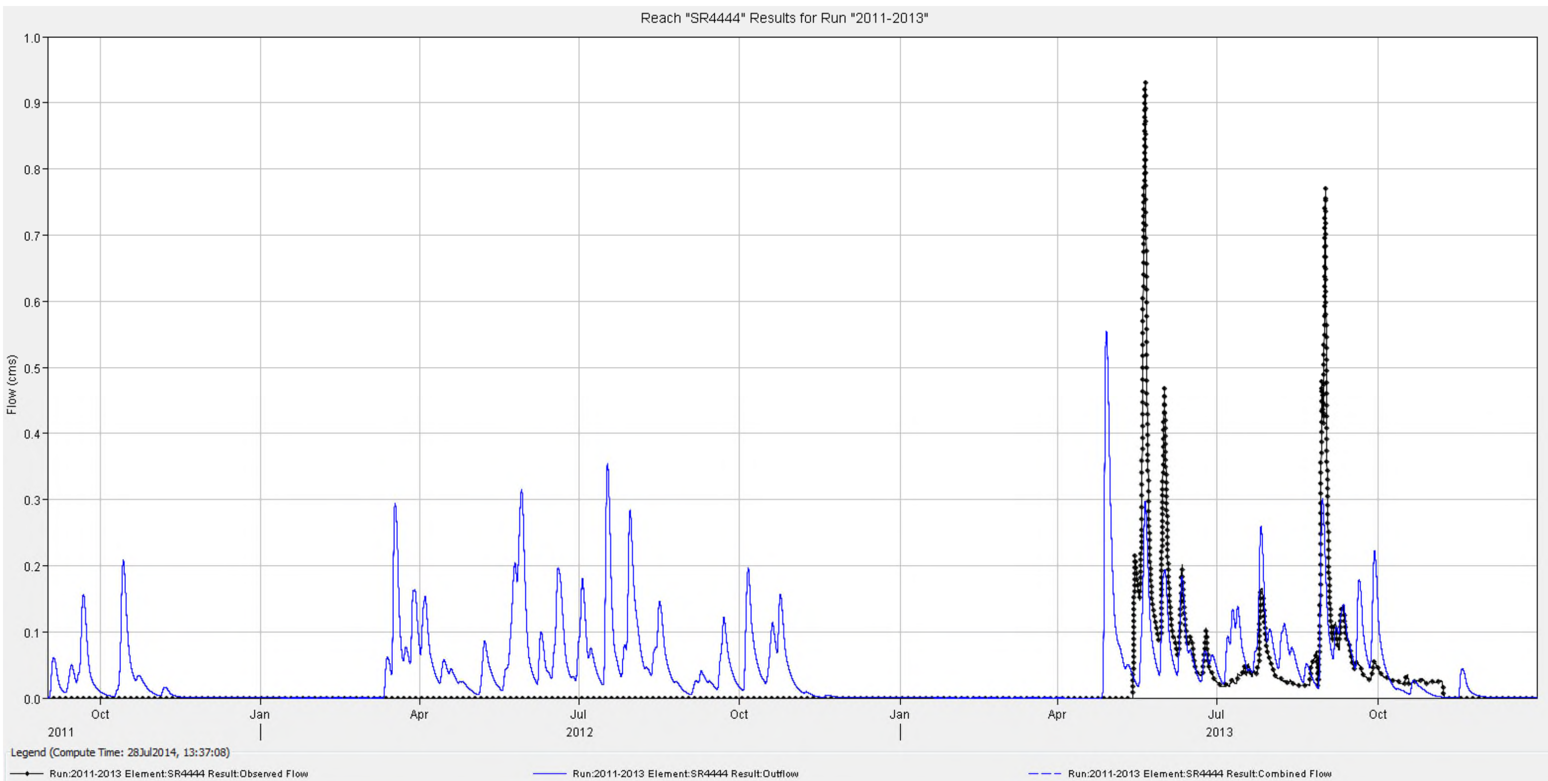
Monitoring Station HS5 (WR4051)



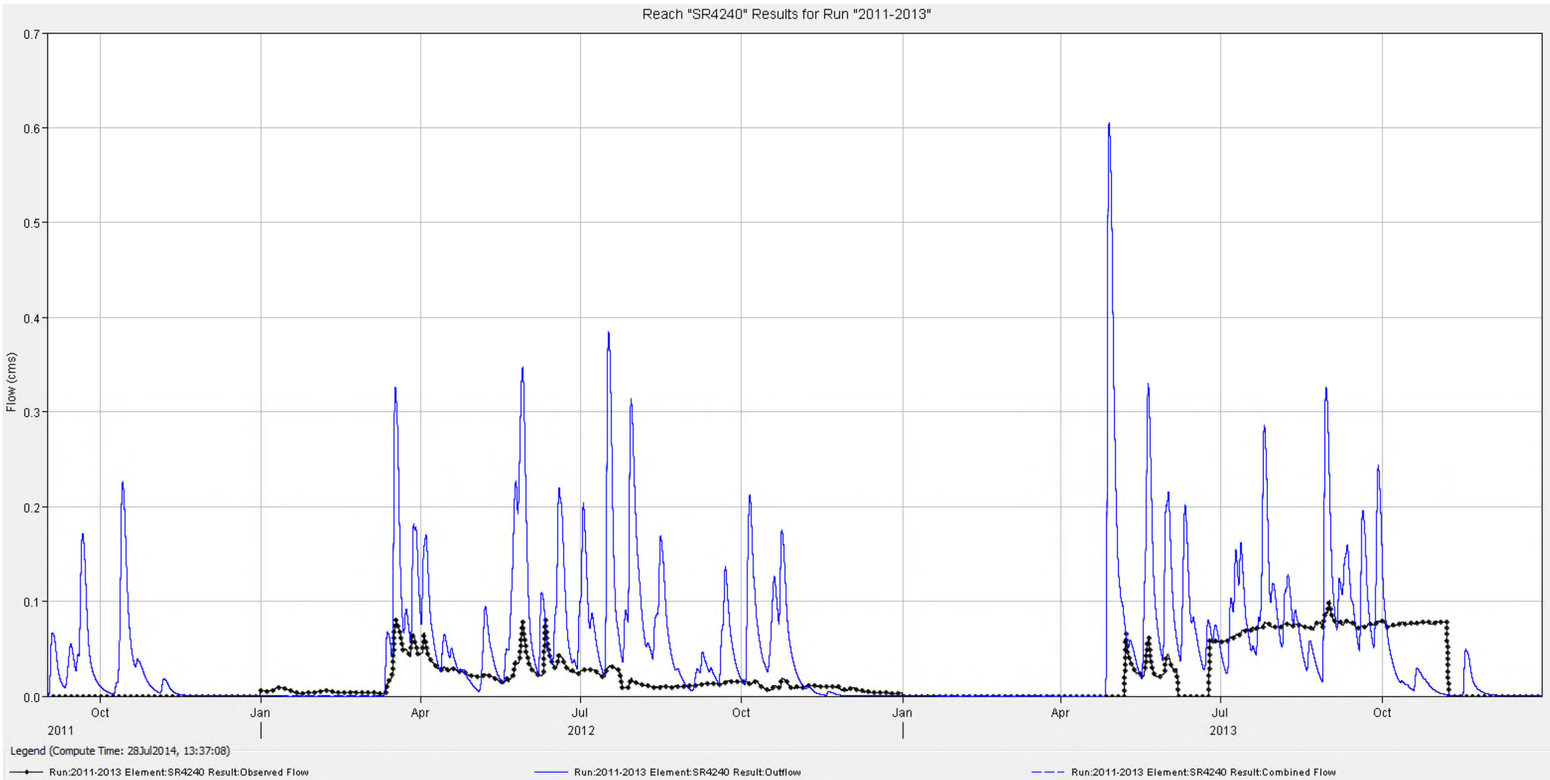
Monitoring Station TL1A (SR4551)



Monitoring Station JCTA (SR4444)



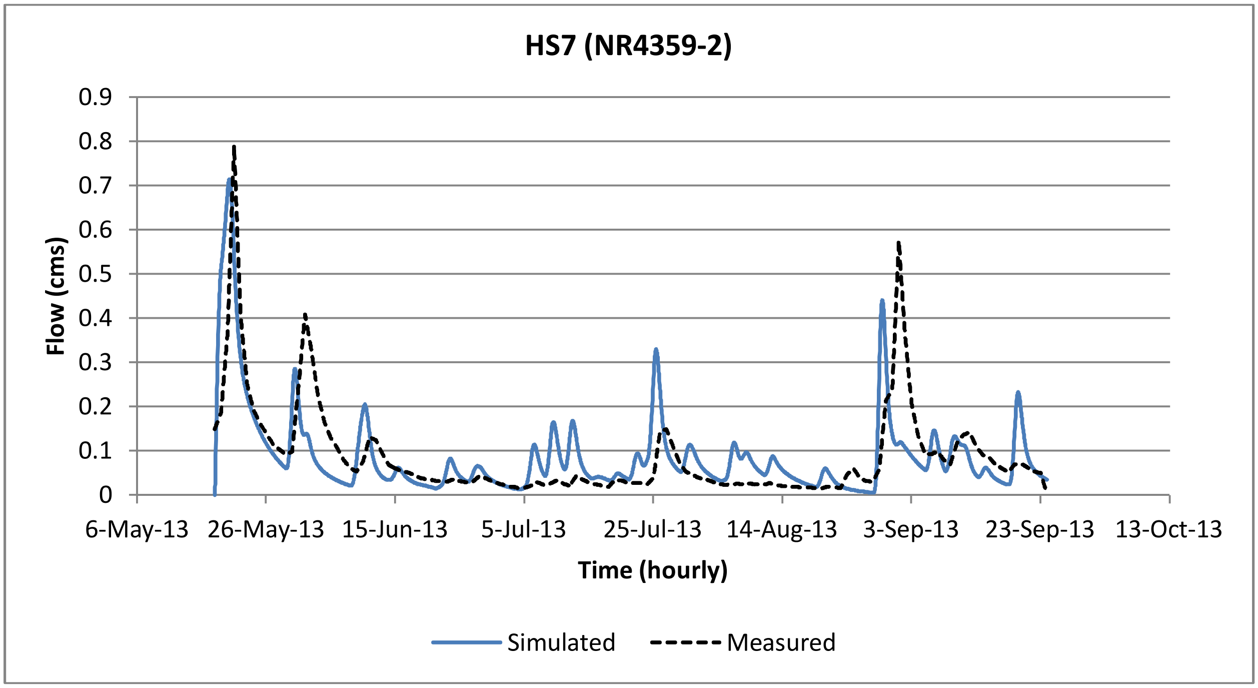
Monitoring Station TL3 (SR4240)

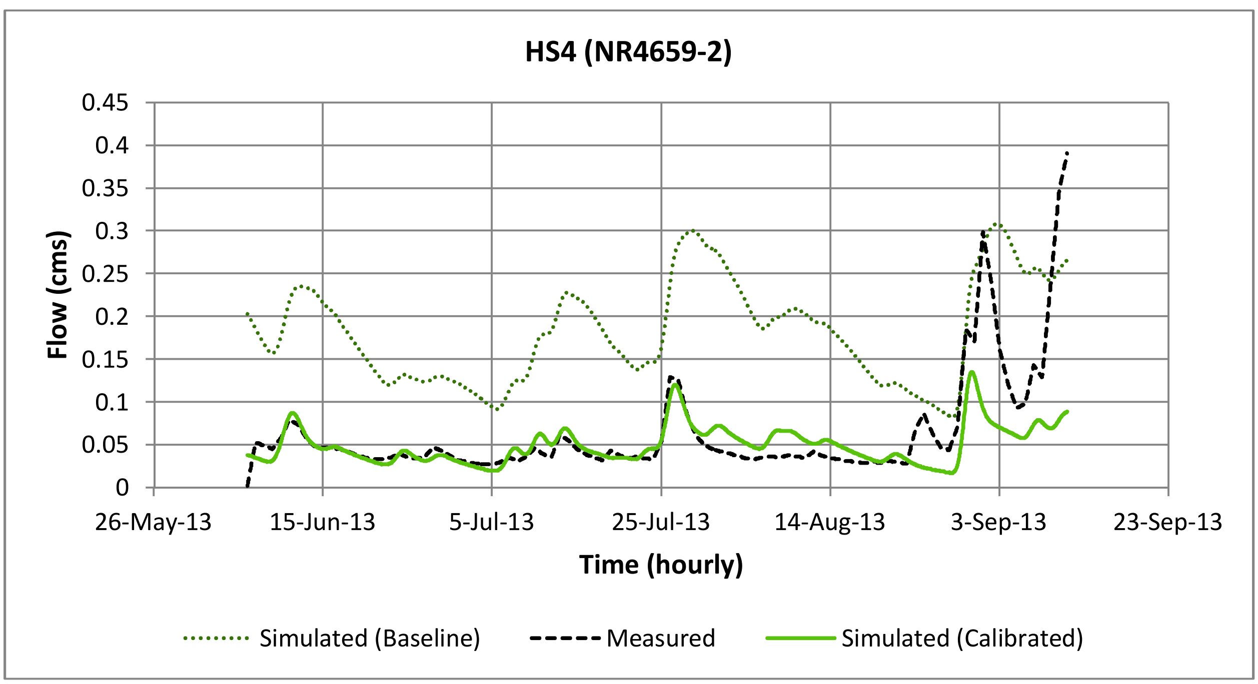


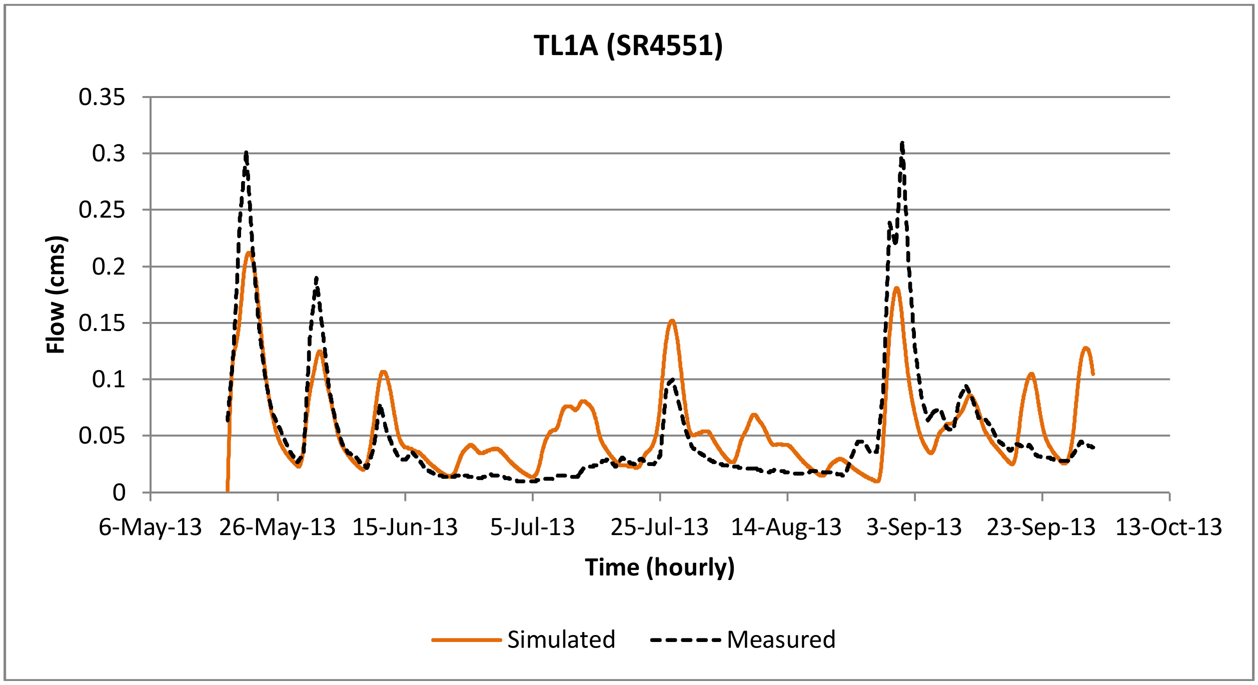
APPENDIX B – MODEL VALIDATION RESULTS

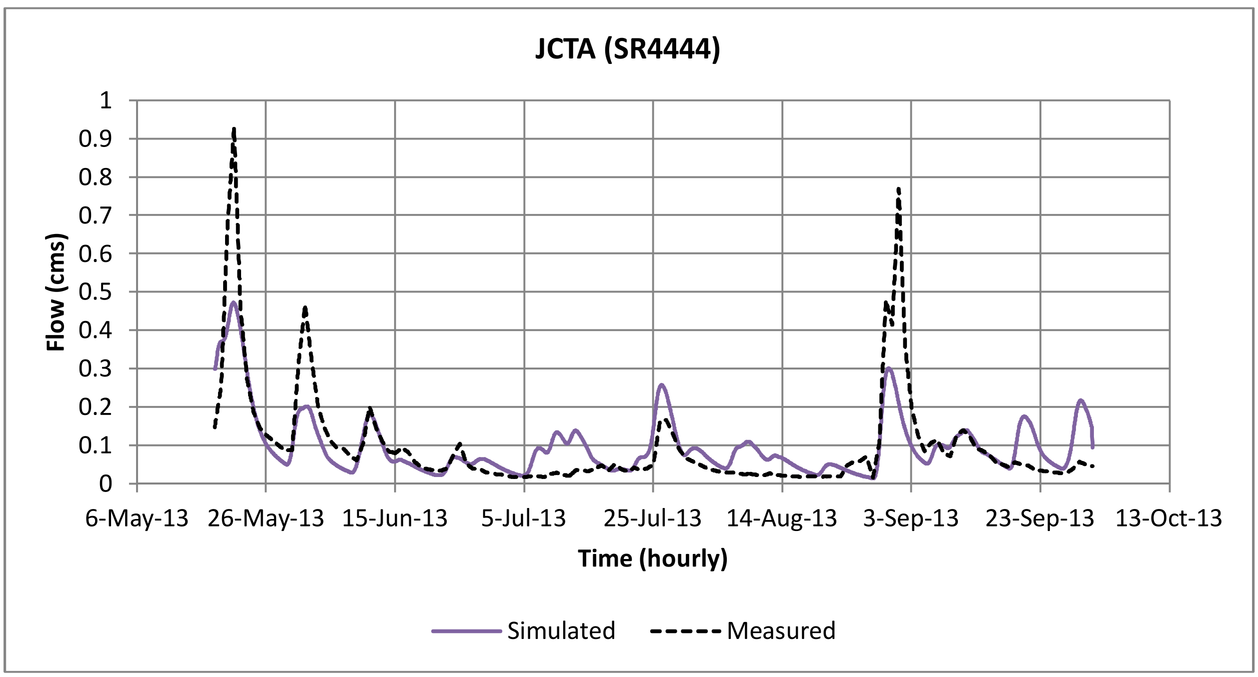
HEC-HMS model results compared to monitored data for 2013 validation periods at the following monitoring stations:

- Monitoring Station HS7 (NR4359-2)
- Monitoring Station HS4 (NR4658-2)
- Monitoring Station TL1A (SR4551)
- Monitoring Station JCTA (SR4444)


HS7 (NR4359-2)
Flow (cms)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
6-May-13
26-May-13
15-Jun-13
5-Jul-13
25-Jul-13
14-Aug-13
3-Sep-13
23-Sep-13
13-Oct-13
Time (hourly)
Simulated
Measured


HS4 (NR4659-2)
Flow (cms)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
26-May-13
15-Jun-13
5-Jul-13
25-Jul-13
14-Aug-13
3-Sep-13
23-Sep-13
Time (hourly)
Simulated (Baseline)
Measured
Simulated (Calibrated)


TL1A (SR4551)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Flow (cms)
6-May-13
26-May-13
15-Jun-13
5-Jul-13
25-Jul-13
14-Aug-13
3-Sep-13
23-Sep-13
13-Oct-13
Time (hourly)
Simulated
Measured


JCTA (SR4444)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Flow (cms)
6-May-13
26-May-13
15-Jun-13
5-Jul-13
25-Jul-13
14-Aug-13
3-Sep-13
23-Sep-13
13-Oct-13
Time (hourly)
Simulated
Measured

APPENDIX C - SIMPLE WATER BALANCE CALCULATION

Annual water balance calculation for the operational minesite stage

Natural Process	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
	Winter Months (Precipitation Accumulated)					Spring Freshet	Summer Months					
Days	30	31	31	28	31	30	31	30	31	31	30	31
Precipitation (mm)	39.16	25.56	25.19	19.00	31.00	38.10	76.20	103.83	97.14	80.34	81.99	62.30
Precipitation (mm)	-	-	-	-	-	139.9	76.2	103.8	97.1	80.3	82.0	62.3
Evaporation (mm) [4]	-	-	-	-	-	-	(114.7)	(123.0)	(127.1)	(108.5)	(63.0)	-

Water Snow Equivalent *10* *cm snow/mm water*

[4] Evaporation Data shown as negative, since it removes water from the water balance

Mine Process	Nov *	Dec	Jan	Feb	Mar	Apr **	May	Jun	Jul	Aug	Sep	Oct
Constant Mine Process effluent	61,710	63,767	63,767	57,596	63,767	61,710	63,767	61,710	63,767	63,767	61,710	63,767
Mine Site (Precipitation)	-	-	-	-	-	131,386	71,563	97,502	91,220	75,446	76,995	58,508
Mine Site Ponds (Precipitation)	-	-	-	-	-	120,086	65,409	89,116	83,375	68,957	70,373	53,476
Mine Site Ponds (Evaporation)	-	-	-	-	-	-	(98,450)	(105,575)	(109,094)	(93,129)	(54,075)	-
Upstream Areas	-	-	-	-	-	394,577.3	214,918.6	292,816.2	273,952.4	226,578.0	231,231.4	175,710.3
Total Volume (m^3)	**61,710**	**63,767**	**63,767**	**57,596**	**63,767**	**707,759**	**317,207**	**435,569**	**403,221**	**341,619**	**386,235**	**351,461**
Daily (m^3/day)	2,057	2,057	2,057	2,057	2,057	23,592	10,232	14,519	13,007	11,020	12,875	11,337
Flow (m^3/s)	0.024	0.024	0.024	0.024	0.024	0.273	0.118	0.168	0.151	0.128	0.149	0.131

* Assume all precipitation is snow
** Assume all snow melts in April (Spring Freshet)