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YANKEE DOODLE TAILINGS IMPOUNDMENT
CLIMATE CONDITIONS REPORT

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Knight Piésold CONSULTING

EXECUTIVE SUMMARY

Montana Resources, LLP (MR) operates an open pit copper and molybdenum mine in Butte, Montana. MR has owned and operated the mine site since the 1980's and is currently mining the Continental Pit at a nominal concentrator throughput rate of approximately 49,000 tons per day. Tailings produced from the process are stored in the Yankee Doodle Tailings Impoundment (YDTI). This report presents climate information for the YDTI and contributing upstream catchment areas for use in operational planning and design studies. The information presented in this report consists of the following:

- Measured climate records collected at the site climate station from 2014 to 2020
- Measured climate and snowpack records collected at regional stations from 1895 to 2020
- Estimated values for meteorological parameters that are not practical to measure directly, such as sublimation and evapotranspiration
- Analysis of extreme precipitation
- Estimates of probable maximum flood (PMF) parameter values of probable maximum precipitation and extreme snowpack
- Analysis of climatic variability and long-term climate change

Many of the parameter values presented in this report were developed in previous studies using long-term regional data, prior to the availability of short-term site data. For this report, the previously developed parameter values were largely retained for the YDTI unless the site data indicated material differences between the values.

Estimated climate values are primarily presented for the YDTI, but temperature and precipitation values are also provided for the area upslope of the YDTI. The estimated values are largely based on the more than 100 years of climate data available for the Butte Bert Mooney Airport station (BBMA), which were adjusted according to correlations between concurrent data for the BBMA and the MR climate station (YDTI estimates) and for the BBMA and the Moulton Reservoir station (Upslope of YDTI estimates).

The climate values presented in this report are best estimates of current conditions and do not account for future potential climate change effects, except for extreme precipitation values, which are used for the design of water management structures. However, since the estimated parameter values are largely based on long-term historical data, they inherently reflect any changes in the climate that have occurred over the historical data period. These values are considered appropriate for modeling climate conditions up to approximately 20 years into the future. Adjustments for possible future climate change effects should be made explicitly to the parameter values when assessing conditions any further into the future.

The recommended values for key parameters representative of climate conditions in the YDTI area are summarized below.

Mean Annual Temperature:

- YDTI: 41.0 °F
- Upslope of the YDTI: 34.5 °F

Mean Annual Precipitation:

- YDTI: 15.9 inches
- Upslope of the YDTI: 22.2 inches

Mean Annual Pond Evaporation:

- YDTI: (including sublimation): 28.1 inches

100-Year 24-hour Precipitation:

- YDTI: 3.0 inches
- Upslope of the YDTI: 3.6 inches

Probable Maximum Precipitation:

- YDTI: 24-hr Spring PMP: 14.4 inches
- Upslope of the YDTI: 24-hr Spring PMP: 19.9 inches

100 Year Maximum Snowpack (SWE):

- YDTI: 11.3 inches
- Upslope of the YDTI: 14.6 inches

Climate Change Since 1960:

- Mean annual temperature: Increasing trend
- Mean annual precipitation: No trend
- Annual Extreme 24-hr precipitation: No trend

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATIONS

BBMA	Butte Bert Mooney Airport
EGBC	Engineers and Geoscientists British Columbia
EL.	elevation
HMR	Hydrometeorological Report
IPCC	Intergovernmental Panel on Climate Change
KP	Knight Piésold Ltd.
MR	Montana Resources, LLP.
NOAA	National Oceanic and Atmospheric Administration
NRCS	U.S. National Resource Conservation Service
PET	potential evapotranspiration
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SWE	snow water equivalent
WRCC	Western Regional Climate Center
YDTI	Yankee Doodle Tailings Impoundment

1.0 INTRODUCTION

1.1 OVERVIEW AND LOCATION

Montana Resources, LLP (MR) operates an open pit copper and molybdenum mine in the northeastern part of Butte, Montana. The location of the MR Mine is shown on Figure 1.1. The operation includes a mill throughput of roughly 49,000 short tons per day and a small-scale leach operation. The MR Mine produces copper sulfide concentrate, molybdenum disulfide concentrate, and copper precipitate (cement copper) for sale in U.S. and world markets.

Tailings produced from the process are stored in the Yankee Doodle Tailings Impoundment (YDTI). The YDTI was originally constructed in 1963 and has been continuously constructed to a crest elevation (EL.) of 6,400 ft using rockfill from the Berkeley Pit (until 1982) and from the Continental Pit (beginning in 1986). The YDTI comprises a valley-fill style impoundment that is created by a continuous rockfill embankment, which for descriptive purposes is divided into three embankment sections (North-South, East-West, and West).

The MR Mine site is bounded by the city of Butte to the south, Rampart Mountain to the east, and the town of Walkerville to the west. The area to the north (upstream) of the project site consists of the catchments for Yankee Doodle, Dixie, and Silver Bow Creeks. Most of the precipitation (rainfall and snowfall) runoff that occurs in these catchments drains into the YDTI. Precipitation occurring in the Moulton Reservoir watershed (part of the large Yankee Doodle watershed) is collected in the Moulton Reservoirs, which are part of the Butte public water supply system.

1.2 SCOPE OF REPORT

This report presents climate information for the YDTI area for use in operational planning and design studies. The information presented in this report consists of the following:

- Measured climate records collected at the site station from 2014 to 2020.
- Measured climate and snowpack records collected at regional stations from 1895 to 2020.
- Estimated values for meteorological parameters that are not practical to measure directly, such as sublimation and evapotranspiration.
- Analysis of extreme precipitation.
- Estimates of Probable Maximum Flood (PMF) parameter values of probable maximum precipitation and extreme snowpack.
- Analysis of climatic variability and long-term climate change.

Many of the parameter values presented in this report were developed in previous studies using long-term regional data, prior to the availability of short-term site data. For this report, the previously developed parameter values were largely retained for the YDTI unless the site data indicated material differences between the values.

Estimated climate values are primarily presented for the YDTI, but temperature and precipitation values are also provided for the area upslope of the YDTI. The estimated values are largely based on the more than 100 years of climate data available for the Butte Bert Mooney Airport (BBMA), which were adjusted according to correlations between concurrent data for the BBMA and the MR station (YDTI estimates) and for the BBMA and the Moulton Reservoir station (Upslope of YDTI estimates).

The climate values presented in this report are best estimates of current conditions, and do not account for future potential climate change effects, except for extreme precipitation values, which are used for the design of water management structures. However, since the estimated parameter values are largely based on long-term historical data, they inherently reflect any changes in the climate that have occurred over the historical data period. These values are considered appropriate for modeling climate conditions up to approximately 20 years into the future. Adjustments for possible future climate change effects should be made explicitly to the parameter values when assessing conditions any further into the future.

LEGEND:

- CLIMATE STATION
- CITY
- ROAD

NOTES:

1. BASE MAP: 2021 AERIAL IMAGERY PROVIDED BY MONTANA RESOURCES, LLP AND ESIR ONLINE WORLD IMAGERY.
2. COORDINATE GRID IS IN FEET. COORDINATE SYSTEM: MR2007.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:75,000 FOR 8.5x11 (LETTER) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	10AUG'21	ISSUED FOR REPORT	JRG	KK	JGC

MONTANA RESOURCES, LLP

YANKEE DOODLE TAILINGS IMPOUNDMENT

PROJECT AND CLIMATE STATION LOCATIONS

Knight Piésold CONSULTING

P/A NO. VA101-126/24
REF NO. 2

FIGURE 1.1
REV 0

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2.0 CLIMATE DATA SOURCES

2.1 REGIONAL STATIONS

Climate parameter values were developed primarily using the data measured at the BBMA climate station for the period of 1895 through 2020, which are available from the Western Regional Climate Center (WRCC) website and the National Oceanic and Atmospheric Administration (NOAA) Climatic Data Center website. This station is at elevation 5,540 ft and is located approximately 5.5 miles south of and 1,000 feet below the crest of the YDTI. Estimates of precipitation also considered six years (1980-1986) of precipitation data available for the National Oceanic and Atmospheric Administration (NOAA) Moulton Reservoir (Moulton) station (245886), which is located at elevation 6,700 ft within the watershed that drains to the YDTI. The locations of these stations are shown on Figure 1.1. Snowpack estimates are based on annual snowpack data for five regional snow survey sites that are operated by the U.S. National Resource Conservation Service (NRCS) in the general vicinity of the YDTI.

2.2 MONTANA RESOURCES SITE STATION

MR has operated a climate station on the crest of the YDTI embankment since 2014 and data are assessed in this report for the period to the end of 2020. This station is at elevation 6,350 ft and collects data for temperature, precipitation, wind speed and direction, relative humidity, and barometric pressure. The location of the station is shown on Figure 1.1 and a photo of the station is provided on Figure 2.2.

Figure 2.2 MR Climate Station

3.0 CLIMATE PARAMETER VALUES

3.1 PREVIOUS STUDIES

Several documents have previously been prepared by KP and others presenting estimated climate values for the YDTI. The relevant studies are listed below and are included in the noted Appendices.

- Mean Climate Parameters – William M. Schafer Memorandum, May 6, 2016 (Appendix A1)
- Mean Climate Parameters – KP Memorandum VA15-03327, February 1, 2016 (Appendix A2)
- Extreme Precipitation Estimates – KP Memorandum VA15-03332, February 1, 2016 (Appendix A3)
- Estimates of Return Period Snowpack – KP Memorandum VA16-00129, February 2, 2016 (Appendix A4)
- Review of Precipitation Estimates for the MR Mine Site – KP Memorandum VA20-01741, January 22, 2021 (Appendix A5)
- Review of the PMF Estimate for the Yankee Doodle Tailings Impoundment – KP Letter VA15-03210, March 10, 2016 (Appendix B1)
- Review of PMF Estimate in Light of Recommendations in the Extreme Work Group Summary Report – KP Letter VA17-00410, March 7, 2017 (Appendix B2)

These documents, except for the one in Appendix A5, were all prepared without the input of site-specific climate data, which where were not available at the time. Since then, data collected at the MR climate station have been compiled, and these data are used in this report to assess the estimated climate parameters and update them, as appropriate.

3.2 SITE DATA

Monthly and annual summaries of the available climate data collected at the MR station are provided in Tables 3.1 to 3.7 and on Figure 3.1. All summaries are based on a 24-hour (calendar day) data summary file provided by MR.

Table 3.1 Monthly and Annual Mean Temperature (°F)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	-	-	-	35.2	48.4	52.1	66.4	61.8	54.0	45.7	28.0	25.2	-
2015	27.4	30.2	36.1	38.6	46.1	62.0	62.4	64.1	54.5	47.6	27.0	22.9	43.2
2016	24.8	31.3	32.1	42.1	46.1	59.3	62.9	61.5	50.8	42.5	37.2	17.9	42.4
2017	16.9	26.3	34.8	36.9	47.7	56.5	69.7	65.7	52.6	38.9	30.3	23.6	41.7
2018	26.7	18.6	29.7	36.6	49.5	53.5	66.2	62.3	52.6	40.5	29.1	22.6	40.7
2019	23.8	12.5	24.9	37.8	44.3	54.5	63.5	63.1	53.4	32.4	30.2	24.4	38.7
2020	24.9	23.4	29.5	36.2	46.5	53.5	62.1	66.0	56.5	41.4	30.5	26.8	41.4
Mean	24.1	23.7	31.2	37.6	46.9	55.9	64.7	63.5	53.5	41.3	30.3	23.3	41.4
Minimum	16.9	12.5	24.9	35.2	44.3	52.1	62.1	61.5	50.8	32.4	27.0	17.9	38.7
Maximum	27.4	31.3	36.1	42.1	49.5	62.0	69.7	66.0	56.5	47.6	37.2	26.8	43.2

Note(s):

1. Values represent the average temperature recorded during each month and year.

Table 3.2 Monthly and Annual Maximum Temperature (°F)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	-	-	-	49.1	78.8	77.5	88.3	90.5	80.6	71.4	63.0	50.6	-
2015	61.1	54.3	66.6	71.2	72.1	94.7	89.6	91.7	82.7	77.1	51.6	44.2	94.7
2016	55.4	56.9	59.9	72.8	75.4	88.0	87.8	88.3	84.9	74.1	66.2	38.7	88.3
2017	51.7	54.2	59.0	59.1	79.9	88.2	94.4	90.6	91.5	68.0	55.7	51.1	94.4
2018	50.4	46.8	55.1	72.4	78.0	79.9	92.1	96.7	85.2	71.8	52.3	47.4	96.7
2019	48.4	45.2	59.5	68.7	75.3	83.7	91.4	90.8	88.3	66.8	60.6	46.1	91.4
2020	48.3	52.7	55.7	75.8	82.8	86.4	92.6	93.7	91.8	78.9	66.2	54.3	93.7
Mean	52.5	51.7	59.3	67.0	77.5	85.5	90.9	91.8	86.4	72.6	59.4	47.5	93.2
Minimum	48.3	45.2	55.1	49.1	72.1	77.5	87.8	88.3	80.6	66.8	51.6	38.7	88.3
Maximum	61.1	56.9	66.6	75.8	82.8	94.7	94.4	96.7	91.8	78.9	66.2	54.3	96.7

Note(s):

1. Values represent the maximum temperature recorded during each month and year.

Table 3.3 Monthly and Annual Minimum Temperature (°F)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	-	-	-	23.6	24.0	32.5	41.8	39.7	27.5	26.4	-10.8	-17.1	-
2015	-6.3	-7.2	0.0	17.1	28.9	39.4	39.9	37.8	35.0	28.9	0.5	1.2	-7.2
2016	1.3	1.3	6.4	21.7	27.0	35.4	37.5	37.8	31.9	22.3	17.7	-5.1	-5.1
2017	-13.0	-10.0	11.9	18.8	25.9	29.0	44.7	45.1	29.0	20.8	5.6	-7.6	-13.0
2018	5.4	-15.9	5.7	13.5	31.2	32.0	37.5	36.6	30.9	19.4	7.6	2.0	-15.9
2019	-7.4	-16.4	-17.0	12.8	14.9	32.1	40.2	42.9	20.5	-2.2	1.1	2.9	-17.0
2020	-1.6	-0.3	6.0	7.2	28.4	30.5	36.1	43.1	27.3	0.5	1.6	7.9	-1.6
Mean	-3.6	-8.1	2.2	16.4	25.8	33.0	39.7	40.4	28.9	16.6	3.3	-2.3	-10.0
Minimum	-13.0	-16.4	-17.0	7.2	14.9	29.0	36.1	36.6	20.5	-2.2	-10.8	-17.1	-17.0
Maximum	5.4	1.3	11.9	23.6	31.2	39.4	44.7	45.1	35.0	28.9	17.7	7.9	-1.6

Note(s):

1. Values represent the minimum temperature recorded during each month and year.

Table 3.4 Monthly and Annual Precipitation (inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	-	-	-	-	0.6	2.7	0.9	3.6	1.0	0.5	1.2	-	-
2015	0.3	0.1	0.4	0.4	1.5	0.7	1.4	1.0	2.1	0.6	0.7	0.3	9.5
2016	0.2	0.2	1.6	1.0	2.0	1.4	5.1	0.8	1.4	2.0	0.2	0.0	15.8
2017	0.3	0.4	1.0	1.2	2.6	3.8	0.5	0.2	0.8	1.2	0.5	0.1	12.6
2018	0.6	0.5	0.5	1.2	2.9	5.3	0.3	1.9	0.9	0.6	0.5	0.1	15.2
2019	0.3	0.5	0.7	1.5	2.0	1.2	0.8	1.1	2.5	0.5	0.4	0.1	11.4
2020	0.1	0.7	0.2	0.4	2.4	5.7	0.7	0.4	0.6	1.1	0.2	0.0	12.5
Mean	0.3	0.4	0.7	1.0	2.0	3.0	1.4	1.3	1.3	0.9	0.5	0.1	12.8
Minimum	0.1	0.1	0.2	0.4	0.6	0.7	0.3	0.2	0.6	0.5	0.2	0.0	9.5
Maximum	0.6	0.7	1.6	1.5	2.9	5.7	5.1	3.6	2.5	2.0	1.2	0.3	15.8

Note(s):

1. Values represent the total precipitation recorded during each month and year.

Table 3.5 Monthly and Annual Average Wind Speed (mph)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	-	-	-	8.6	7.5	7.7	7.8	7.1	7.7	7.9	8.1	7.1	-
2015	5.5	7.8	8.1	7.9	8.8	7.8	7.7	8.0	7.5	7.2	7.4	7.3	7.6
2016	5.4	8.0	9.2	8.3	8.3	8.7	8.2	8.3	7.7	6.8	6.7	6.3	7.7
2017	4.9	7.6	7.9	8.1	7.5	8.7	7.4	7.0	6.5	8.6	7.0	6.0	7.2
2018	6.5	7.2	7.9	7.7	7.1	8.4	7.6	7.5	7.2	6.8	6.3	7.0	7.3
2019	7.0	4.9	4.8	8.4	7.6	8.0	7.9	7.4	8.1	8.1	6.7	5.5	7.0
2020	7.7	8.6	8.3	8.7	8.6	8.5	7.4	7.8	8.6	8.9	7.4	6.4	8.1
Mean	6.2	7.4	7.7	8.3	7.9	8.2	7.7	7.6	7.6	7.8	7.1	6.5	7.5
Minimum	4.9	4.9	4.8	7.7	7.1	7.7	7.4	7.0	6.5	6.8	6.3	5.5	7.0
Maximum	7.7	8.6	9.2	8.7	8.8	8.7	8.2	8.3	8.6	8.9	8.1	7.3	8.1

Note(s):

1. Values represent the average wind speed recorded during each month and year.

Table 3.6 Monthly and Annual Maximum Wind Gust Speed (mph)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	-	-	-	37.2	40.0	65.4	44.2	54.2	52.7	63.5	69.4	59.0	-
2015	42.7	47.1	56.3	55.3	59.0	67.1	58.4	61.5	48.7	47.7	64.0	59.1	67.1
2016	39.2	53.9	53.1	58.9	63.4	72.6	44.6	48.7	51.5	44.7	38.7	56.0	72.6
2017	42.0	45.5	50.7	57.3	75.8	52.5	63.1	42.4	41.2	78.5	50.0	36.8	78.5
2018	44.8	47.0	49.0	46.9	37.4	60.5	41.2	51.9	51.3	41.1	51.0	50.3	60.5
2019	49.7	31.3	30.0	43.3	54.1	50.1	54.2	52.2	50.3	51.9	59.0	42.2	59.0
2020	47.7	61.7	49.7	49.9	47.1	75.6	72.2	50.9	47.2	57.7	47.4	47.1	75.6
Mean	44.4	47.8	48.1	49.8	53.8	63.4	54.0	51.7	49.0	55.0	54.2	50.1	68.9
Minimum	39.2	31.3	30.0	37.2	37.4	50.1	41.2	42.4	41.2	41.1	38.7	36.8	59.0
Maximum	49.7	61.7	56.3	58.9	75.8	75.6	72.2	61.5	52.7	78.5	69.4	59.1	78.5

Note(s):

1. Values represent the maximum wind speed recorded during each month and year.

Table 3.7 Monthly and Annual Mean Relative Humidity (%)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	-	-	-	71.9	56.5	60.4	45.7	56.0	55.5	59.8	68.1	73.9	-
2015	71.4	64.0	56.5	59.4	63.4	47.9	51.7	42.4	53.5	59.3	69.5	72.2	59.1
2016	72.7	62.5	63.5	60.3	64.3	45.4	45.1	43.3	61.2	68.9	60.5	68.8	59.6
2017	65.4	68.4	63.9	63.4	57.7	52.5	36.4	36.7	55.7	58.9	67.5	67.3	57.7
2018	70.2	70.3	63.2	63.5	68.0	61.9	38.5	44.4	50.8	62.5	70.4	67.3	60.8
2019	66.3	70.8	66.0	65.4	62.4	53.9	44.4	47.3	57.6	61.9	62.5	67.0	60.4
2020	66.1	65.2	61.7	55.4	58.1	58.6	46.3	38.9	42.5	55.5	59.1	63.0	55.9
Mean	68.7	66.9	62.5	62.8	61.5	54.4	44.0	44.2	53.8	61.0	65.4	68.5	58.9
Minimum	65.4	62.5	56.5	55.4	56.5	45.4	36.4	36.7	42.5	55.5	59.1	63.0	55.9
Maximum	72.7	70.8	66.0	71.9	68.0	61.9	51.7	56.0	61.2	68.9	70.4	73.9	60.8

Note(s):

1. Values represent the average relative humidity recorded during each month and year.

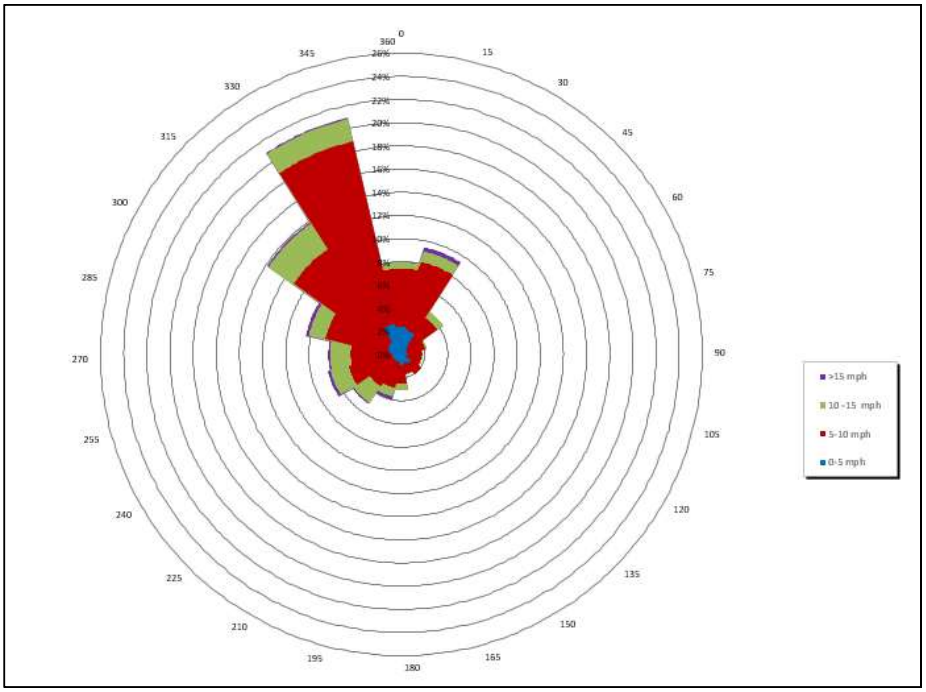

Figure 3.1 MR Climate Station Wind Rose

3.3 TEMPERATURE

The long-term mean annual temperature at the YDTI is estimated to be 40.3°F and temperatures can range enormously, from lows in the order of -63°F to highs in the order of 104°F. The highest temperatures generally occur in July and August and the lowest temperatures typically occur in December and January. The estimated monthly distribution of temperatures at the YDTI is provided in Table 3.8 along with corresponding values for the BBMA and areas upslope of the YDTI.

Table 3.8 Estimated Long-Term Daily Temperatures

Location	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
BBMA	Mean Temperature (°F)	18.9	22.5	29.6	39.1	47.6	55.7	63.6	61.8	52.1	41.7	29.2	20.5	40.3
	Standard Deviation (°F)	6.8	6.1	5.4	3.6	3.2	3.1	2.8	2.7	3.2	3.5	5.2	5.4	2.2
	Extreme Maximum Temperature (°F)	57.8	62.2	71.2	86.6	94.4	102.2	104.4	104.4	97.8	88.8	72.2	67.8	104.4
	Year	2005	1995	1994	1910	1919	1988	1936	2000	2000	2010	1999	1917	1936
	Extreme Minimum Temperature (°F)	-58.8	-63.4	-45.6	-23.4	4.4	18.8	25.6	20.0	-2.2	-31.2	-52.2	-63.4	-63.4
	Year	1937	1933	1948	1982	1975	1916	1971	1992	1926	1991	1959	1983	1933
YDTI	Mean Temperature (°F)	22.3	25.2	30.8	38.3	47.0	55.5	63.6	61.7	51.7	41.0	30.5	23.6	41.0
	Standard Deviation (°F)	5.4	4.9	4.3	3.7	3.3	3.2	2.9	2.8	3.3	3.6	4.1	4.3	1.9
Upslope of YDTI	Mean Temperature (°F)	15.9	19.0	25.2	33.5	40.9	48.0	54.8	53.2	44.8	35.8	24.9	17.3	34.5
	Standard Deviation (°F)	5.9	5.3	4.7	3.2	2.8	2.7	2.5	2.3	2.8	3.1	4.5	4.7	1.9

Temperature values for the YDTI were previously presented in the Mean Climate Parameters memorandum (Appendix A2) based on historical data for the BBMA climate station. These were updated by correlating concurrent monthly average temperature values for the MR station and the BBMA station, and then applying the correlation equations, which are shown in Table 3.9, to the long-term temperature records for the BBMA. Estimates of temperature for areas upslope of the YDTI were similarly based on correlating concurrent monthly average temperature values for the Moulton Reservoir station and the BBMA station, and the corresponding correlation equations are also shown in Table 3.9. These equations can be applied to daily temperature records for the BBMA to produce long-term daily temperature values for the YDTI and upslope of YDTI locations.

Table 3.9 Temperature Correlation Equations

Location	Seasonal Period			
	Apr - Oct		Nov - Mar	
YDTI	Y = 1.0316 X - 2.0423	R^2 = 0.9848	Y = 0.7975 X + 7.2641	R^2 = 0.9176
Upslope of YDTI	Y = 0.9378 X - 4.4161	R^2 = 0.9895	Y = 0.8711 X - 0.5731	R^2 = 0.9861

Note(s):

1. These equations can be applied to the daily BBMA temperature record to develop daily temperature datasets for the YDTI and upslope locations.

A comparison of the respective long-term average annual temperature patterns for the three locations is presented on Figure 3.2. This comparison indicates that temperatures at the BBMA and the YDTI are generally very similar and only differ notably during the colder months of November to March, when temperatures at the YDTI are approximately 1.5 ºF to 3.5 ºF higher than at the BBMA. In contrast, temperatures in areas upslope of the YDTI are consistently 5 ºF to 9 ºF cooler than at the YDTI.

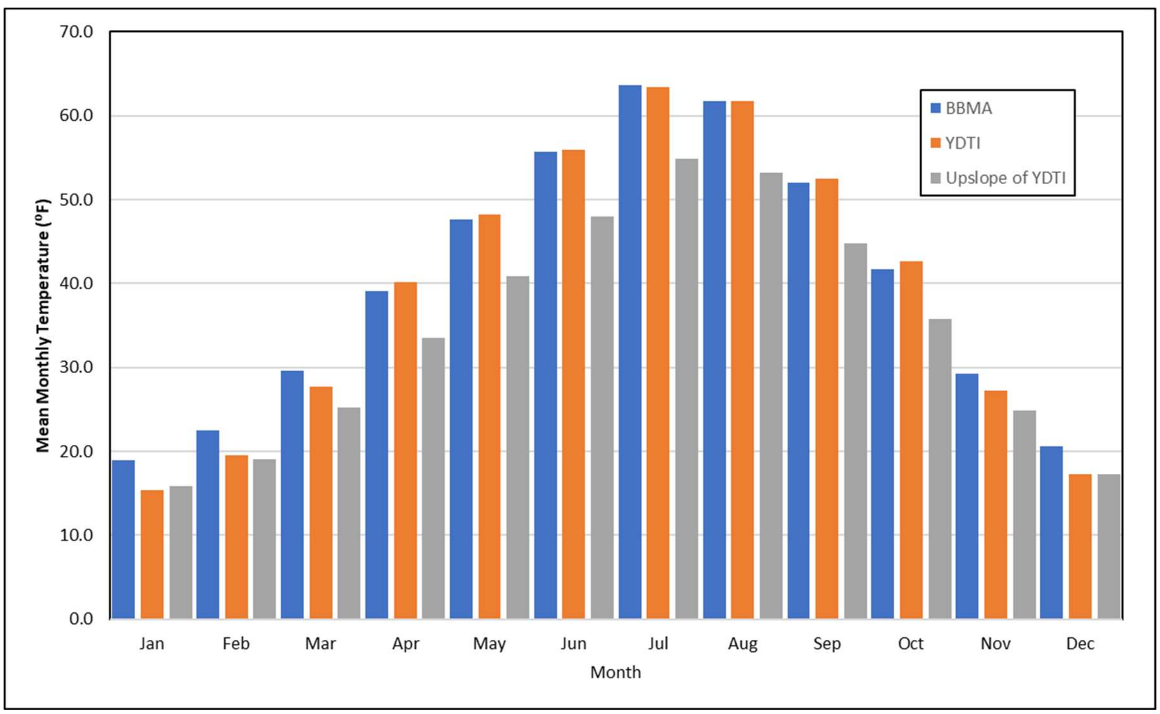

Figure 3.2 Annual Distribution of Mean Monthly Temperatures

3.4 PRECIPITATION

3.4.1 MEAN ANNUAL AND MEAN MONTHLY PRECIPITATION

The long-term mean annual precipitation for the YDTI is estimated to be 15.9 inches, as presented in Appendix A1. A review of this estimate was completed with consideration of data collected at the MR climate station and at the Moulton Reservoir, as detailed in Appendix A5. This review indicated that though the 15.9 inch value is representative of precipitation conditions for MR Mine locations near the YDTI embankment, it is not representative of conditions in the drainage area upslope of the YDTI. Rather, the Moulton Reservoir precipitation values, which indicate a substantially greater mean annual precipitation of 22.2 inches, should be used for conditions in drainage areas upslope of the YDTI. The mean monthly precipitation values that correspond to the annual values of 15.9 inches and 22.2 inches are presented in Table 3.10 and shown on Figure 3.3. The wettest month of the year is typically June and the driest month is typically November, at both the YDTI and upslope of the YDTI.

Monthly factors that can be applied to long-term series of monthly and daily BBMA precipitation data to translate them to corresponding values for the YDTI and for areas upslope of the YDTI are also provided in Table 3.10.

Table 3.10 Mean Monthly and Annual Precipitation

Month	BBMA Precipitation (in.)	Factors for YDTI	Factors for Upslope of YDTI	Estimated YDTI Precipitation (in.)	Estimated Upslope of YDTI Precipitation (in.)
Jan	0.55	2.14	2.36	1.22	1.30
Feb	0.48	2.00	3.71	0.96	1.78
Mar	0.77	1.38	2.68	1.06	2.06
Apr	1.1	1.33	1.59	1.47	1.75
May	1.82	1.17	1.81	2.14	3.30
Jun	2.17	1.03	1.13	2.22	2.46
Jul	1.26	1.21	1.41	1.53	1.78
Aug	1.27	0.87	0.99	1.11	1.25
Sep	1.13	1.35	1.94	1.52	2.19
Oct	0.74	1.44	2.21	1.06	1.63
Nov	0.62	1.01	1.91	0.63	1.18
Dec	0.57	1.74	2.56	0.99	1.46
Annual	12.47	1.28	1.78	15.92	22.15

Note(s):

1. The factors can be applied to the daily BBMA precipitation record to develop daily datasets for the YDTI and upslope locations.
2. Factors for YDTI and estimated YDTI precipitation from Appendix A1 (Schafer, 2016).
3. Upslope of YDTI values from Appendix A5 (KP, 2021).

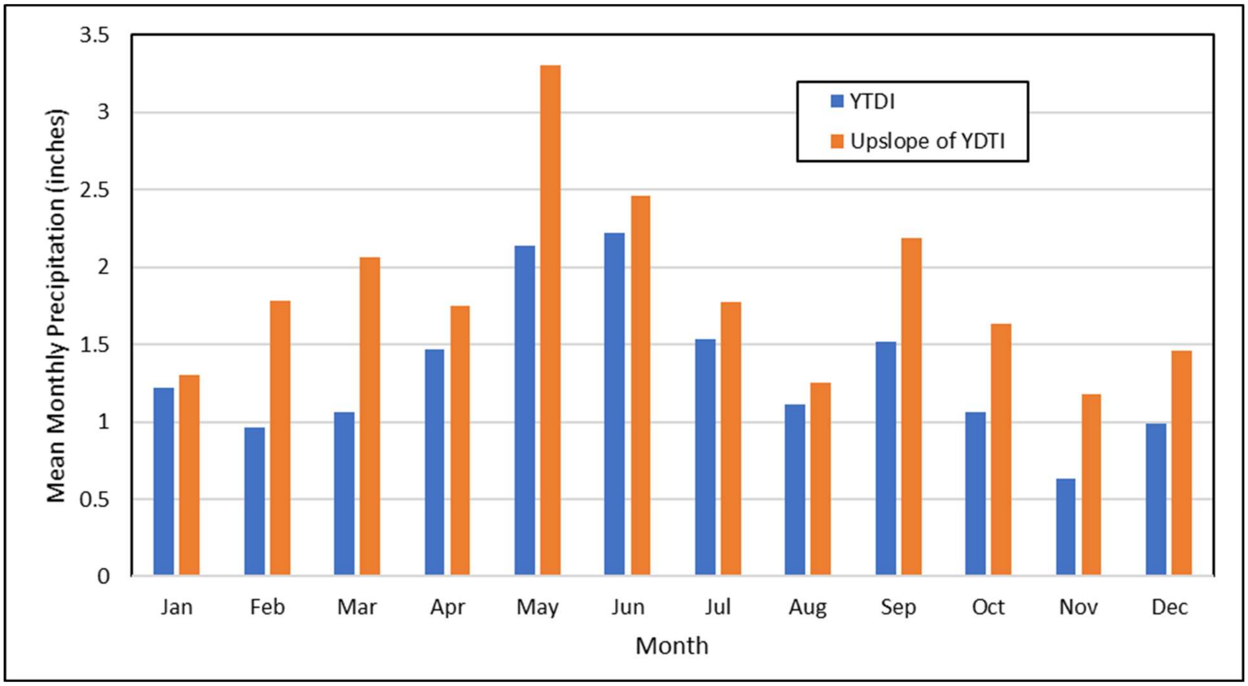

Figure 3.3 MR Annual Precipitation Distributions

It is worth noting that the precipitation values do not scale consistently from one location to the other on a month to month basis. For instance, in January the precipitation values at both locations are very similar, while in February and March the precipitation in the upslope areas is almost double those at the YDTI. It is not known if this variation is a true reflection of actual conditions or if it is an artifact of the datasets available for the two locations. Any assessment of this situation is constrained by the lack of concurrent data; however, this is not particularly important from a mine planning and operation perspective because the ratios undoubtedly vary to some degree from month to month and because the established overall pattern of consistently higher precipitation in the upslope areas, particularly during the colder months of October to April, is reflected in the values. Nonetheless, it is recommended that these values be reassessed if concurrent data for the MR station and Moulton Reservoir locations become available.

3.4.2 RAINFALL AND SNOWFALL FRACTIONS

The portions of precipitation that fall as rain and snow vary from year to year. However, based on the precipitation records for the BBMA station, and assuming a snow water equivalent (SWE) of 10%, it is evident that precipitation falls almost exclusively as rain from June through August and as snow from November through March, and that a mix of rain and snow occurs during the months of April, May, September, and October. Based on the precipitation records for the Moulton Reservoir station, the rain/snow pattern is similar, though temperatures are a little cooler during the transition months at higher elevations, so snowfall also occurs in May and accounts for a greater proportion of precipitation in September and October. Estimated rainfall and snowfall values for both the YDTI (based on BBMA) and upslope of the YDTI (based on Moulton Reservoir) are shown in Table 3.11.

Table 3.11 Rainfall and Snowfall Fractions of Precipitation

Location	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
YDTI	Rainfall Fraction (%)	0	0	0	30	80	100	100	100	90	54	0	0	56
	Snowfall Fraction (%)	100	100	100	70	20	0	0	0	10	46	100	100	44
	Rain (inches)	0.00	0.00	0.00	0.44	1.71	2.22	1.53	1.11	1.37	0.57	0.00	0.00	8.95
	Snow (inches)	1.22	0.96	1.06	1.03	0.43	0.00	0.00	0.00	0.15	0.49	0.63	0.99	6.96
	Precipitation (inches)	1.22	0.96	1.06	1.47	2.14	2.22	1.53	1.11	1.52	1.06	0.63	0.99	15.92
Upslope of YDTI	Rainfall Fraction (%)	0	0	0	0	65	100	100	100	80	20	0	0	44
	Snowfall Fraction (%)	100	100	100	100	35	0	0	0	20	80	100	100	56
	Rain (inches)	0.00	0.00	0.00	0.00	2.15	2.46	1.78	1.25	1.75	0.33	0.00	0.00	9.71
	Snow (inches)	1.30	1.78	2.06	1.75	1.16	0.00	0.00	0.00	0.44	1.30	1.18	1.46	12.43
	Precipitation (inches)	1.30	1.78	2.06	1.75	3.3	2.46	1.78	1.25	2.19	1.63	1.18	1.46	22.15

Note(s):

1. YDTI values of % rain/snow are from Appendix A2 (KP, 2016).
2. Upslope of YDTI values of % rain/snow are based on Moulton Reservoir precipitation data.

It is interesting to note that rain and snow fractions are reversed for the two locations, with a greater proportion of precipitation occurring as rain at the lower YDTI location and a greater proportion of precipitation occurring as snow at the Upslope of YDTI location. This pattern is consistent with the temperature patterns shown in Table 3.8, with cooler temperatures occurring in the upslope areas during the spring and fall shoulder periods.

3.4.3 SNOWMELT PATTERN

A snowpack accumulates every winter and melts during the spring. The Moulton Reservoir snowpack values were selected as representative of basin average conditions for areas that drain into the YDTI basin. The records indicates that the annual snowpack snow water equivalent (SWE) typically peaks towards the end of March but frequently occurs as early as late February, and during very high snowpack years it may occur well into May. Once the spring melt begins, it typically occurs over a period of about two months. The average snowmelt pattern, which is shifted later in the year than that shown in Appendix A2, is estimated to be 10% in March, 70% in April, and 20% in May. At the YDTI, which is essentially at a single lower elevation and typically has warmer temperatures, the average snowmelt pattern is estimated to be 20% in March and 80% in April.

3.5 SUBLIMATION

Sublimation is the process by which moisture is returned to the atmosphere directly from snow and ice without passing through the liquid phase (Liston and Sturm, 2004). Sublimation can play a significant role in the annual water balance in areas where winter precipitation comprises a large proportion of annual precipitation. For example, Liston and Sturm (2004) estimate that sublimation can result in the loss of 10% to 50% of the total winter snowfall in Arctic regions. The YDTI is not situated in an Arctic region; however, snowfall does account for approximately 45% of the total precipitation, and the YDTI may be subjected to high winds that often result in blowing snow, which would aid sublimation. Winds are likely greater in the exposed areas of the YDTI than in the more sheltered upslope areas, and accordingly sublimation is perhaps higher at the YDTI. However, the upslope areas generally have tree cover and more snow, which results in relatively greater snow interception and correspondingly increased sublimation potential. Given the uncertainty in estimating sublimation, it was decided that a value equating to approximately 25% to 30% of the mean annual snowfall at the YDTI would be applicable to both the YDTI and upslope areas. This equates to approximately 2.5 inches of annual sublimation, which has been distributed evenly from November through to March at constant rate 0.5 inches per month. Sublimation during the shoulder months of April and October is accounted for with estimates of evapotranspiration.

3.6 POND EVAPORATION

Monthly potential evapotranspiration (PET) was estimated for the BBMA station using the Penman-Monteith equation and then the PET values were translated to potential pond evaporation at YDTI using monthly factors. Details of this approach are provided in Appendix A1. The estimated mean annual pond evaporation is 28.1 inches, which includes the November to March sublimation estimate of 2.5 inches, as shown in Table 3.11.

Table 3.12 Mean Monthly and Annual Evaporation

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pond Evaporation incl. Sublimation (in.)	0.5	0.5	0.5	2.1	3.0	3.7	5.4	4.9	3.3	3.2	0.5	0.5	**28.1**

Note(s):
1. Evaporation values from Schafer memo (Schafer, 2016).

3.7 WIND SPEED AND DIRECTION

Seven years of wind data are available for the MR climate station, which are summarized in Section 3.1. The monthly average wind speeds and maximum gust speeds were presented in Tables 3.5 and 3.6, respectively, while wind roses indicating wind frequency, speed, and direction were shown on Figure 3.1. Average wind speeds for all months are in the range of 6 mph to 8 mph, and maximum wind gusts typically ranging from about 40 mph to 50 mph in January to 40 mph to 75 mph in July and October, with the highest wind speed of 78.5 mph recorded in October 2018. Wind typically blows from the north-northwest all year round.

3.8 RELATIVE HUMIDITY

Seven years of relative humidity data are available for the MR climate station, which were summarized in Table 3.7. The monthly average relative humidity typically averages about 60%, with average monthly values ranging from 44% in July and August to 69% in December and January. The monthly average values on record range from 36.4% in July 2017 to 73.9% in December 2014.

4.0 EXTREME PRECIPITATION

4.1 RETURN PERIOD 24-HOUR EXTREME PRECIPITATION

Extreme 24-hour precipitation values for the YDTI were initially determined in 2016 based on a frequency analysis of long-term annual extreme precipitation for the BBMA station combined with information contained in the USGS Water Resources Investigations Report 97-4004, as detailed in Appendix A3. These values were derived without accounting for possible variations in precipitation throughout the mine area. However, as discussed in Section 3.4.1 and detailed in Appendix A5, precipitation conditions have been found to vary substantially at MR depending on location. Accordingly, estimates of return period 24-hour extreme precipitation were generated specifically for the YDTI and for areas upslope of the YDTI by prorating the BBMA based estimates according to ratios of non-winter precipitation for the different locations, and the results are summarized in Table 4.1.

Table 4.1 Return Period 24-hr Extreme Precipitation

Location	2 yrs	5 yrs	10 yrs	25 yrs	50 yrs	100 yrs	200 yrs	1000 yrs
BBMA Station (inches)	1.0	1.5	1.7	2	2.3	2.6	2.9	3.7
+ Climate Change (inches)	1.2	1.7	1.9	2.3	2.6	2.9	3.3	4.2
YDTI (inches)	1.2	1.7	2.0	2.3	2.7	3.0	3.4	4.3
+ Climate Change (inches)	1.3	2.0	2.3	2.7	3.1	3.5	3.9	4.9
Upslope of YDTI (inches)	1.4	2.1	2.3	2.8	3.2	3.6	4.0	5.1
+ Climate Change (inches)	1.6	2.4	2.7	3.2	3.7	4.1	4.6	5.9

Note(s):

1. BBMA station values from Appendix A3.
2. YDTI values from Appendix A5.
3. Upslope of YDTI values from Appendix A5.

Values both with and without climate change adjustment are provided. Both sets of values are recommended for design purposes depending on both the design period and the design life of a structure. The values without the adjustment are appropriate for structures that are being built in the near term and that have a design life of less than about 20 years, and values with the adjustment are appropriate for structures planned for construction well in the future or for structures with an extended design life.

The climate change adjusted values include an uplift of 15%, which is a generally recommended factor for accounting for climate change effects on extreme precipitation and peak flow estimates (EGBC, 2018). Long-term extreme precipitation data for BBMA do not indicate trends of increasing storm intensity with time, as discussed in Section 5.0, but an adjustment is still provided because historical records do not necessarily represent possible future conditions and because global climate modelling indicates that climate change is likely to cause increased temperatures and an increased frequency and intensity of rainstorms in Montana (IPCC, 2007; EPA, 2016).

4.2 PROBABLE MAXIMUM PRECIPITATION

The Probable Maximum Precipitation (PMP) is the precipitation that results from the most severe meteorological conditions possible. The PMP for the YDTI was determined according to procedures established by NOAA and published in its Hydrometeorological Report (HMR) No. 57 (Hansen et al., 1994). A 24-hour PMP with a depth of 14.4 inches was selected as the basis of the design for the YDTI and the procedure described in Appendix B1. A corresponding 72-hour PMP was determined to be 19.7 inches, though this was not used for design purposes because it was concluded that use of the 24-hour PMP plus snowmelt from the 100 year snowpack, which is the essential de facto basis for estimating a PMF, provides an appropriately conservative storm freeboard volume for the YDTI.

The Montana Department of Natural Resources and Conservation Dam Safety Program issued an Extreme Storm Working Group Summary Report in December 2016 that presented the results of a comprehensive review of the state of the practice for computing hydrology for dams. This report was issued after the PMP was computed for the YDTI. KP reviewed the Working Group report and concluded that the PMP estimate based on HMR 57 is appropriate and consistent with the Working Group's recommendations, as detailed in Appendix B2.

The PMP estimate of 14.4 inches is applicable to the YDTI. However, as discussed in Section 4.1, extreme precipitation is believed to be substantially greater in areas upslope of the YDTI than at the YDTI. Accordingly, a 24-hour PMP value of 19.9 inches was estimated for areas upslope of the YDTI, as detailed in Appendix A5. A corresponding 72-hour PMP is estimated to be 27.2 inches.

All PMP estimates presented are for operational conditions at the MR Mine, and as such, no climate change adjustment has been applied. If a more conservative approach is desired during the closure phase of the project, it is recommended that a general 15% increase be applied to the PMP to account for possibly more extreme rainfall conditions in the future, unless directed otherwise by relevant and updated guidance that may be available at that time.

4.3 RETURN PERIOD SNOWPACK

There are five regional snow survey sites that are operated by the U.S. National Resource Conservation Service (NRCS) in the general vicinity of the YDTI. The most relevant station is Moulton Reservoir, which has a long period of record and has snowpack values that are reasonably consistent with other regional records. This station is located at the approximate median elevation of the YDTI drainage basin, and its snowpack values were selected as representative of basin average conditions. Estimates of return period snowpack were derived from historical maximum annual snowpack data for Moulton Reservoir, as detailed in Appendix A4. The computed mean (7.1 inches) and standard deviation (2.1 inches) values were fit to an Extreme Value Type 1 distribution using a frequency factor approach, with the factors selected according to the sample size of 40 years.

The estimated snowpack values for areas upslope of the YDTI are provided in Table 4.2 Maximum Snowpack in terms of inches of SWE. To determine corresponding snowpack values for the YDTI location, which are also shown in Table 4.2, the upslope values were reduced according to the ratios of the winter (October to April) precipitation for the two locations, as detailed in Appendix A5.

Table 4.2 Maximum Snowpack

Return Period	Maximum Snowpack SWE (in)	
	YDTI	Upslope of YDTI
2	5.2	6.8
5	6.9	8.9
10	7.9	10.2
15	8.5	11.0
20	8.9	11.6
25	9.3	12.0
50	10.3	13.3
100	11.3	14.6
200	12.3	15.9
500	13.6	17.6
1,000	14.5	18.8
10,000	17.7	23.0

Note(s):

1. Snowpack values are provided in terms of snow water equivalent (SWE).
2. YDTI values were determined from upslope values using the ratios of the winter (October to April) precipitation for the two locations: 100 YR = 14.6 X 11.1 /14.4 = 11.3 inches.

It is worth noting that the snowpack values are based on historical conditions and do not account for potential climate change effects. It is anticipated that warmer temperatures may reduce snowpack depths in the future; however, historical maximum snowpack levels for the upslope of the YDTI indicate no significant trends, as discussed in Section 5.3, so no adjustments are warranted at this time.

4.4 PROBABLE MAXIMUM FLOOD

The Probable Maximum Flood (PMF) is theoretically the largest flood resulting from a combination of the most severe meteorological and hydrologic conditions that could conceivably occur in an area. The PMF is generally used for the design of facilities where the risk of substantial environmental damage or loss of life exists in the event of failure. It is a purely hypothetical event that is intended to be sufficiently large to ensure that it is never exceeded, yet at the same time is not so large that the design requirements are unnecessarily conservative. A design storm evaluation was completed considering historical storm event analyses with several alternative durations and methods for determining the PMF. The design storm event evaluation is provided in Appendix B1.

The selected design flood event for the YDTI is based on the 24-hour PMP combined with complete melt of the 1 in 100 year snowpack, and assuming full failure of the upstream Moulton Reservoirs. The PMF hydrometeorological parameter values for the MR station location, which generally represent conditions for the YDTI, and for the Moulton Reservoir location, which generally represent conditions upslope of the YDTI that drain into the YDTI, are summarized in Table 4.3.

Table 4.3 PMF Hydrometeorological Parameters (inches)

Location	100 yr Snowpack	PMP	Total
YDTI	11.3	14.4	25.7
Upslope of YDTI	14.6	19.9	34.5

The criteria for determining the Inflow Design Flood (IDF) for each structure (embankment, spillway, channel, etc.) should be determined individually by the design engineer in consultation with regulators. Determination of PMF parameter values for specific locations outside of the YDTI and upslope of YDTI values presented above are not included in this report, as they will be dependent on the specific hydrologic characteristics of each basin of interest, and on the particulars of each designed structure. For example, for the design of a channel, the flood peak flow is most important, so the PMF resulting from the largest PMP (non-winter) may govern, while for the design of a pond the flood volume may be more important, so the PMF resulting from spring rainfall plus snowmelt will likely govern.

The potential effects of climate change on the PMF can be addressed by increasing the PMP estimate for the closure phase of the mine by 15%, according to generally accepted engineering procedures (EGBC, 2018). No adjustment to the 100 year snowpack depth is required because there is no trend in historical snowpack data to support a change, though projected warmer temperatures suggest a possible reduction in snowpack depths. This situation should be further assessed at the time of mine closure.

5.0 CLIMATE CHANGE

5.1 GENERAL

The climate values presented in this report are based on historical climate records, which are considered to reasonably represent current climate conditions at the YDTI. However, there is general scientific consensus that the climate is changing and as a result, temperatures and the frequency and intensity of rainstorms will likely increase in Montana, and while mean annual precipitation is expected to remain relatively constant, seasonal precipitation patterns are expected to change with a slight decrease in the winter and slight increases in the spring and fall. Furthermore, the warmer temperatures and decreased winter precipitation will result in decreased snowpack depths (IPCC, 2007; Whitlock et al., 2017).

There is generally high uncertainty around expected patterns and rates of climate change, particularly as they will be quite site specific, so to get some idea of how the climate has been changing in the MR Mine area over the past few decades, trends in the historical temperature and precipitation data at the BBMA Station and in the snowpack data for the Moulton Reservoir Station were reviewed.

5.2 TEMPERATURE AND PRECIPITATION

Historical trends of annual mean temperature and total annual precipitation are shown on Figures 5.1 and 5.2, respectively, for the 125 year period of 1895 to 2019.

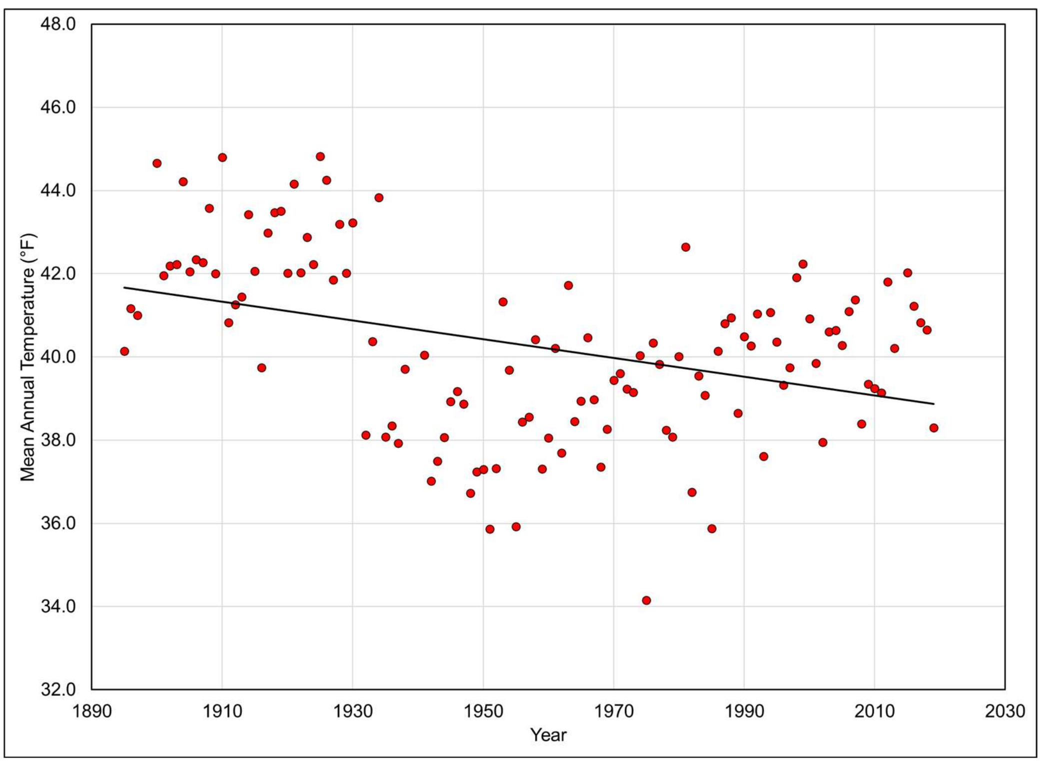

Figure 5.1 Trend of Historical Annual Mean Temperature – BBMA Station

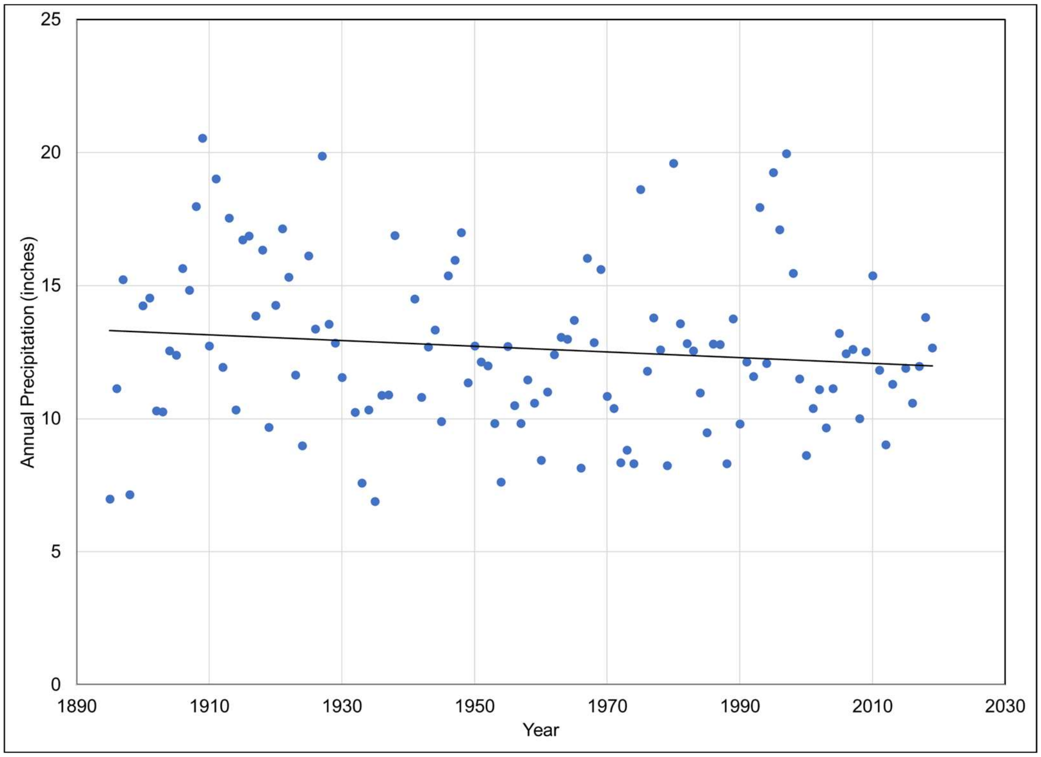

Figure 5.2 Trend of Historical Annual Precipitation – BBMA Station

These plots indicate that both temperature and precipitation generally decreased over time, which is contrary to the patterns presented in the various climate change reports, though the temperature data look very unusual, with a cluster of high values prior to about 1930. It is possible that these earlier temperature values may be erroneous due to the use of different equipment and data collection techniques during the earlier period, or that a climate shift occurred many decades ago and conditions are now trending in a different direction. To address this possibility, data from a more recent period were assessed, and temperature and precipitation trend plots were prepared for the period of 1960 to 2019, as shown on Figures 5.3 and 5.4, respectively.

Figure 5.3 indicates that temperatures have been generally increasing at a rate of approximately 0.3 °F per decade over the past 60 years, and this trend has strong statistical significance (1% level). In contrast, the annual precipitation on Figure 5.4 shows no statistically significant trend, and its year to year variability has also not changed.

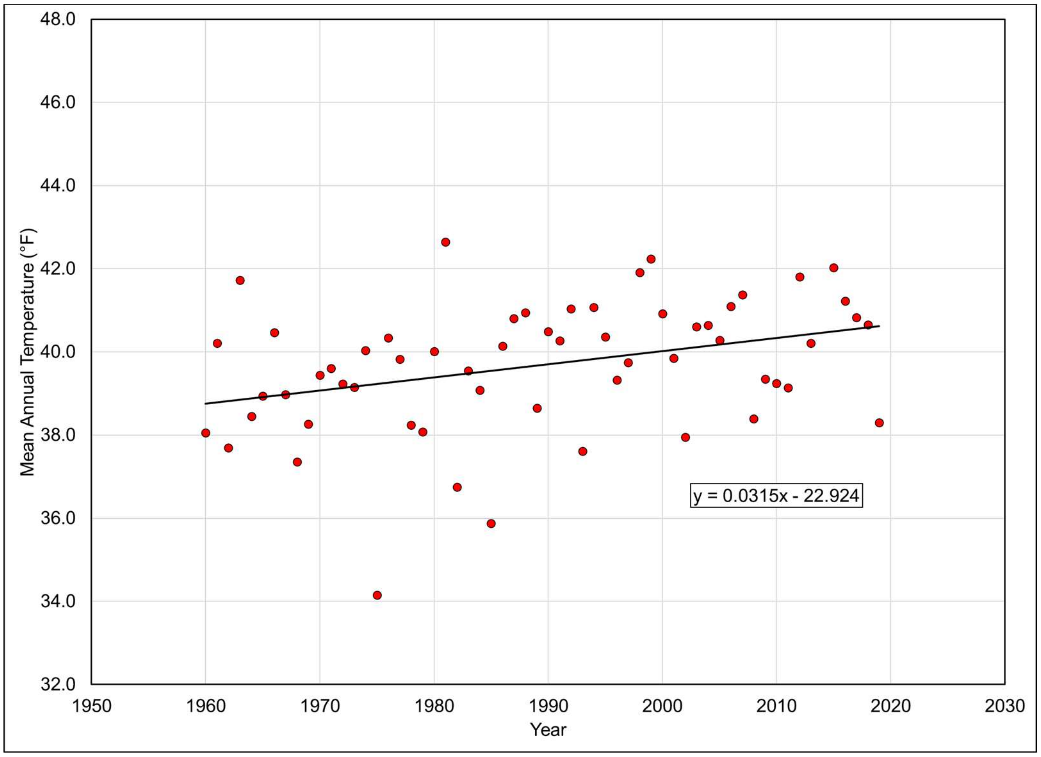

Figure 5.3 Trend of 1960-2019 Annual Mean Temperature – BBMA Station

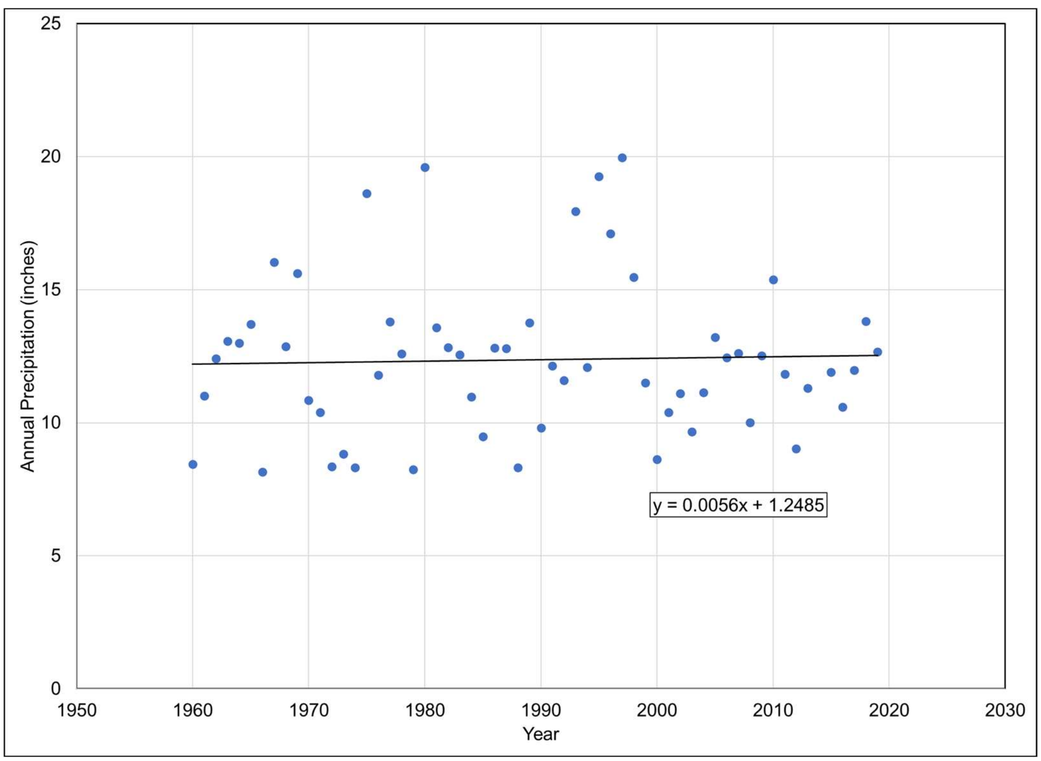

Figure 5.4 Trend of 1960-2019 Annual Precipitation – BBMA Station

5.3 EXTREME PRECIPITATION

A historical trend plot for annual extreme daily precipitation, as shown on Figures 5.5, indicates that extreme precipitation is decreasing in terms of both the mean and the variability of the values.

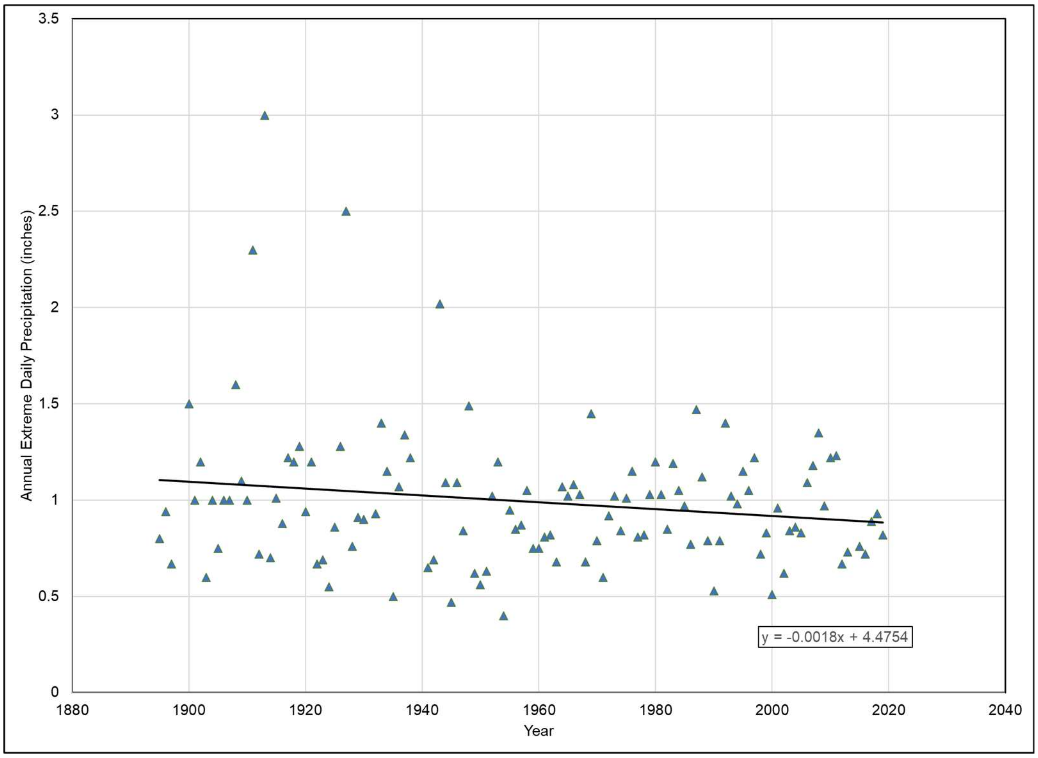

Figure 5.5 Trend of Historical Annual Extreme Daily Precipitation – BBMA Station

However, to address possible concerns about the quality of some of the earlier values, and how these have influenced the trend, a trend plot of data over the last 60 years was also developed, as shown on Figure 5.6. This figure indicates that annual extreme daily precipitation has no trend, and its year to year variability has also not changed with time. It is interesting to note, however, that most of the annual extreme events in the last decade have been lower than the long-term mean value of around 1.0 inch.

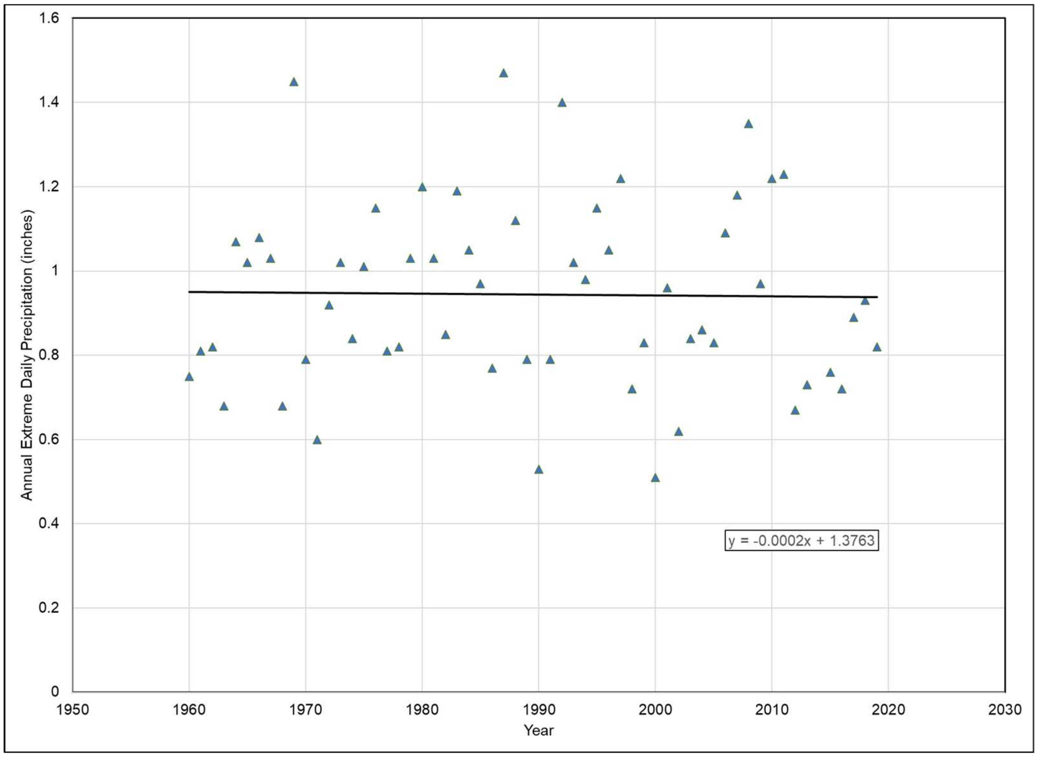

Figure 5.6 Trend of 1960-2019 Annual Extreme Daily Precipitation – BBMA Station

5.4 ANNUAL MAXIMUM SNOWPACK

A historical trend plot of annual maximum snowpack for the Moulton Reservoir snow course station, as shown on Figure 5.7, indicates that maximum annual snowpack has increased slightly over the past 45 years, though this trend is not statistically significant, and the year to year variability of the maximum snowpack has also not changed. This is a bit surprising as temperatures have generally increased, though it appears that they have not increased enough during the shoulder and winter periods to materially affect snowpack conditions, or perhaps the temperature effect has been offset by a slight increase in winter precipitation.

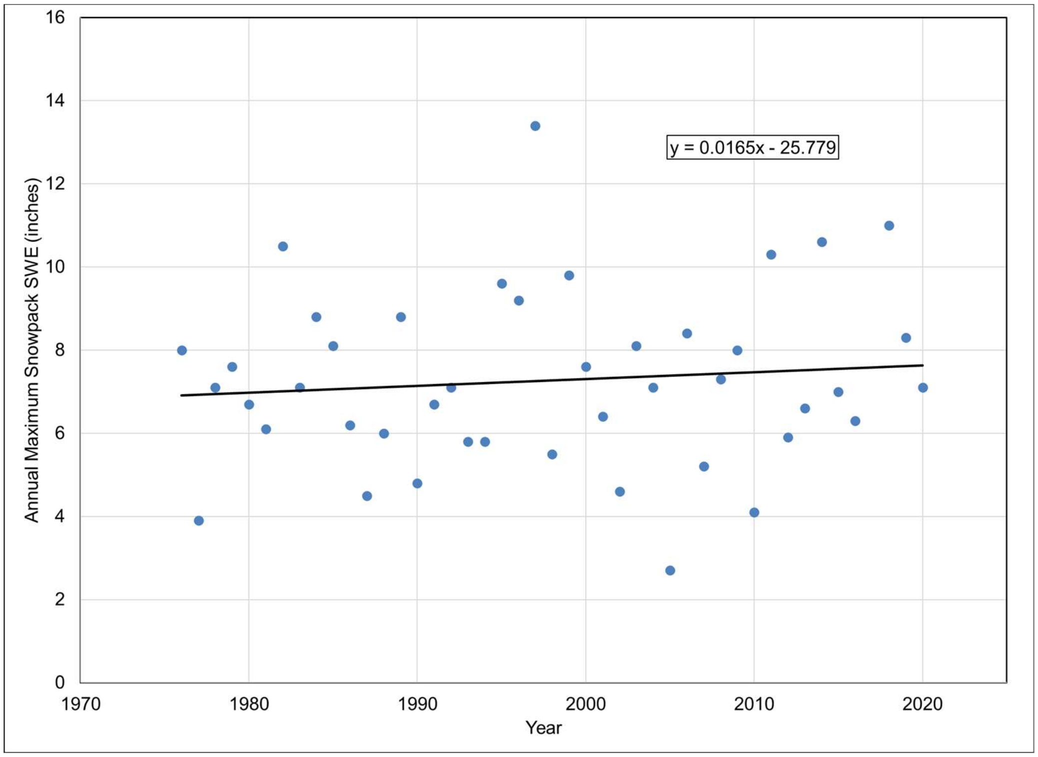

Figure 5.7 Trend of 1960-2019 Annual Maximum Snowpack – Moulton Reservoir

5.5 SUMMARY

In summary, the positive trend in the long-term historical temperature data for the BBMA station supports the climate change modelling based conclusion that temperatures at the MR Mine are likely going to generally increase in the coming years, though the historical rate of increase over the past 60 years is relatively low (~ 0.3 °F per decade) and there are no obvious patterns in the data indicating that this rate is going to increase substantially in the near future. Furthermore, there appears to be no change in annual precipitation totals and no change in extreme precipitation or maximum snowpack. Therefore, possible climate change effects are not likely to have a notable impact on water related operations at the mine, at least not over the next 10 to 20 years, after which climate patterns and their potential effects on mine operations should be reassessed based on new information available at that time. This conclusion is also applicable to extreme rainfall and resulting runoff analyses that are used to design hydraulic structures that must store or convey flood flows, though any structures that are required to operate beyond that 20 year time frame should be based on design flows that specifically incorporate a climate change allowance or justification should be provided at the time as to why one is not required.

6.0 SUMMARY

The recommended values for key parameters representative of climate conditions in the MR Mine area are summarized below. All values are for the YDTI location unless noted otherwise.

Mean Temperature:

- YDTI
  - Mean annual temperature: 41.0 °F
  - Mean January (coldest month) temperature: 22.3 °F
  - Mean July (hottest month) temperature: 63.6 °F
- Upslope of the YDTI
  - Mean annual temperature: 34.5 °F
  - Mean January (coldest month) temperature: 15.9 °F
  - Mean July (hottest month) temperature: 54.8 °

Extreme Temperature:

- Extreme minimum temperature: approximately -63 °F
- Extreme maximum temperature: approximately 104 °F

Mean Precipitation:

- YDTI
  - Mean annual precipitation: 15.9 inches
  - Mean June (wettest month) precipitation: 2.2 inches
  - Mean November (driest month) precipitation: 0.6 inches
- Upslope of the YDTI
  - Mean annual precipitation: 22.2 inches
  - Mean May (wettest month) precipitation: 3.30 inches
  - Mean November (driest month) precipitation: 1.2 inches

Rainfall/Snowfall Distribution:

- YDTI
  - Approximately 56% rain / 44% snow
- Upslope of the YDTI
  - Approximately 44% rain / 56% snow

Mean Snowmelt Pattern:

- YDTI
  - 20% March, 80% April
- Upslope of the YDTI
  - 10% March, 70% April, 20% May

Sublimation:

- 2.5 inches annual; 0.5 inch/month for November to March

Pond Evaporation:

- Mean Annual Evaporation (including sublimation): 28.1 inches

Wind Speed and Direction:

- Mean annual wind speed: ~7.5 mph
- Maximum recorded wind speed (gust): 78.5 mph
- Prevailing wind direction: from north-northwest

Relative Humidity:

- Mean annual relative humidity: 60%

Extreme 24-hour Precipitation:

- YDTI
    - 10-year: 2.0 inches; with climate change: 2.3 inches
    - 100-year: 3.0 inches; with climate change: 3.5 inches
- Upslope of the YDTI
    - 10-year: 2.3 inches; with climate change: 2.7 inches
    - 100-year: 3.6 inches; with climate change: 4.1 inches

Probable Maximum Precipitation:

- YDTI
    - 24-hr Spring PMP: 14.4 inches
- Upslope of the YDTI
    - 24-hr Spring PMP: 19.9 inches

Return Period Snowpack:

- YDTI
    - 100-year snowpack (SWE): 11.3 inches
- Upslope of the YDTI
    - 100-year snowpack (SWE): 14.6 inches

Climate Change Since 1960:

- Mean annual temperature: Increasing trend
- Mean annual precipitation: No trend
- Annual Extreme 24-hr precipitation: No trend

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8.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

Jaime Cathcart, Ph.D., P.Eng.
Specialist Hydrotechnical Engineer | Associate

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Approval that this document adheres to the Knight Piésold Quality System:

APPENDIX A

Climate Inputs

APPENDIX A1

Reference Climate Data

(Pages A1-1 to A1-7)

Memorandum

May 6, 2016

To: Mr. Mark Thompson, Montana Resources LLP.
Bob Anderson, Hydrometrics
Roanna Stewart, Knight Piesold
Adrianne Yang, Golder

From: William M. Schafer, Schafer Limited LLC

Re: Reference Climatic Data for the Yankee Doodle Tailings Area near Butte, Montana

Purpose and Scope

The purpose of this Memorandum is to describe the basis for selection of reference climate information used to characterize the Montana Resources LLP (MR) mine area near the Yankee Doodle Tailings (YDT). The YDT is located at an elevation of about 6,300 amsl (Figure 1) and is just northeast of Butte, Montana. The purpose of the climatic information is to assess potential hydrologic effects of the mine during operations and after closure. Methods used to assess hydrologic effects include but are not limited to water balance models, models evaluating the performance of soil Evapotranspiration or ET covers constructed on mine facilities to reduce infiltration of meteoric water, and calibration of groundwater and surface water flow models. Sufficient climate data is required to assess both historical and future variations in daily average precipitation, precipitation that occurs as snow, temperature, and potential evaporation and transpiration.

Climate Data Sources

Several sources of climate information were consulted as part of this effort including public data from the Western Regional Climate Center (WRCC 2016), and a water balance study performed by the Montana Bureau of Mines and Geology for MR in 2001 and 2002 (MBMG 2002). WRCC publishes data for most weather stations operated by the Federal government in the western US. Principal data sets acquired from WRCC included daily rainfall, snow, and maximum and minimum temperature from the Bert Mooney Airport (1895 to present) and Moulton Reservoir (1980 to 1986). More intensive data were obtained from a BLM station in Whitehall (2001 to present) for daily precipitation, maximum and minimum temperature plus relative humidity, solar radiation and wind speed. A summary of limited pan evaporation data was available for a few stations (Bozeman, Dillon and Canyon Ferry). The MBMG water balance provided the best available on-site evaporation data.

Two climate models were used to extrapolate climatic data in space and time: PRISM (2016) and CLIMGEN (WSU 2016). The PRISM model was developed at Oregon State University as a tool to spatially average meteorological data accounting for orographic and rain-shadow effects. PRISM was used to account for location adjustments in precipitation data between the airport and Butte and the YDT, a distance of a few miles and about 1,000 feet in elevation gain. CLIMGEN was developed at Washington State University and allows site-calibrated meteorological data to be extrapolated in time, creating a continuous long-term synthetic data set.

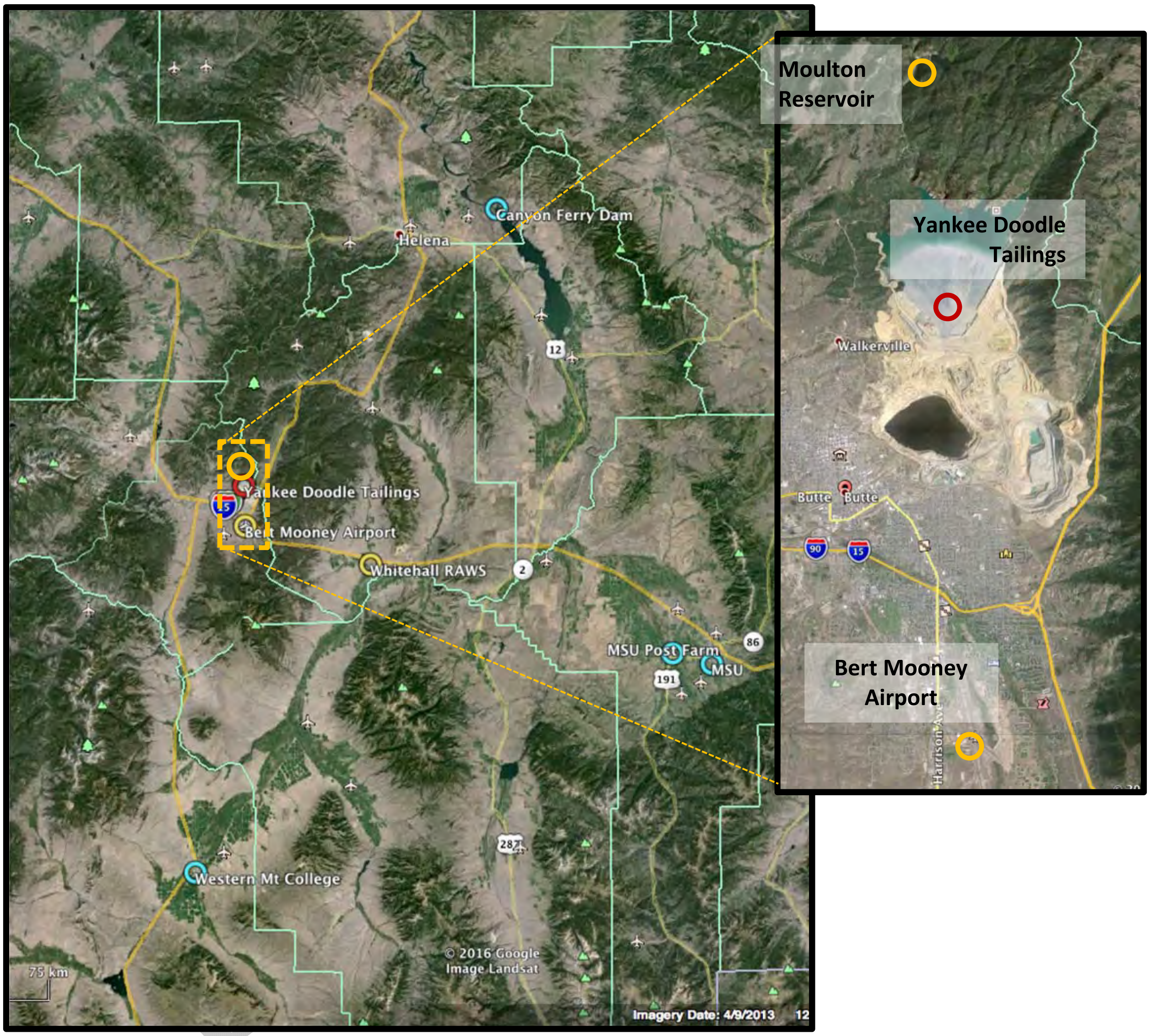

Figure 1. Location of climatic stations referenced in this report.

Approach

Development of a long-term climate data set for the YDT consisted of three steps,

- creation of a combined data set for the Bert Mooney Airport containing each of the necessary meteorological observations. Data were either collected at the airport location (precipitation and temperature) or were based on observations at nearby stations (solar radiation, relative humidity and wind from Whitehall),

- forecasting a long-term (200 year) synthetic data set (in CLIMGEN) representing daily average observations at the Airport, and

- adjusting the precipitation and evaporation estimates using PRISM to the YDT location.

Combined Climate Data for the Bert Mooney Airport

Daily average precipitation and maximum and minimum temperature data for January 1, 1915 to December 3, 2015 from the Bert Mooney Airport (Table 1) were combined with solar radiation, minimum and maximum relative humidity and wind speed from Whitehall for May 2001 to December 3, 2015. This combined data set was then modeled to extrapolate the data in time and spatially to adjust for elevation differences between the airport and the YDT area.

Temporal Extrapolation of a Synthetic Daily Climate Record

The CLIMGEN model uses statistical algorithms to simulate daily and seasonal rainfall and temperature distributions and can then use the site-specific statistical coefficients to extrapolate long-term climate records. All climatic parameters had an adequate period of record to facilitate analysis in CLIMGEN. A 200 year daily data set was created in CLIMGEN representing conditions at the Bert Mooney airport. Monthly precipitation matched closely for the airport data and the synthetic data (Figure 2). The distribution of annual rainfall for 100 years of actual data at the airport were compared to the synthetic data series in Figure 3. The annual rainfall quantities were ranked from smallest to largest and were normalized as a cumulative frequency distribution. The minimum (7 inches) maximum (20 inches) annual precipitation and the median (12.5 inches) were similar for actual and synthetic data. The synthetic data had fewer dry (< 10 inch) and wet (15 inch) rainfall years than the actual record.

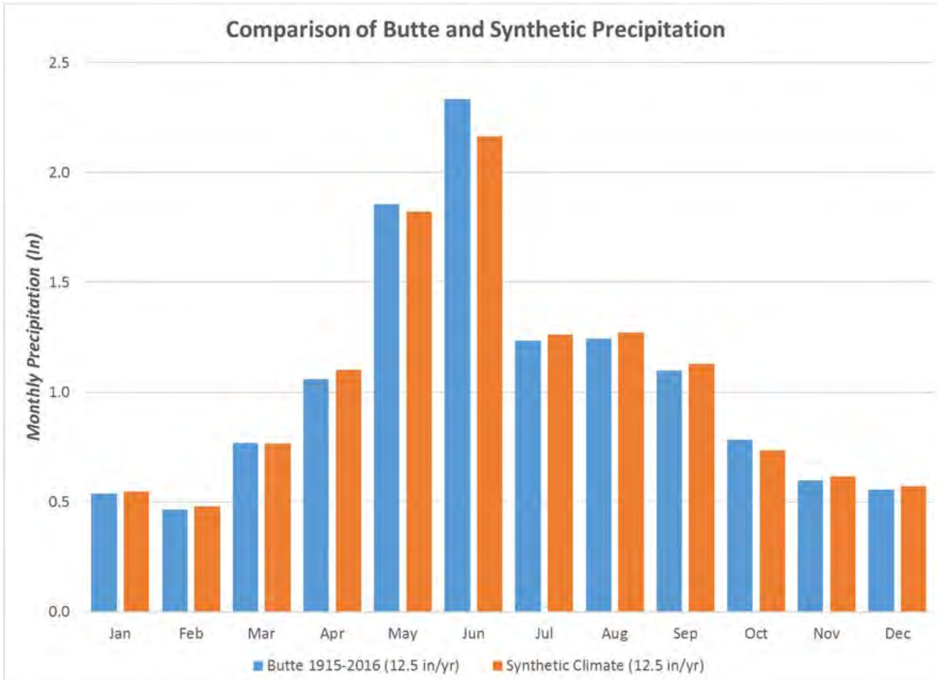

Figure 2. Comparison of monthly precipitation at Bert Mooney Airport to synthetic data.

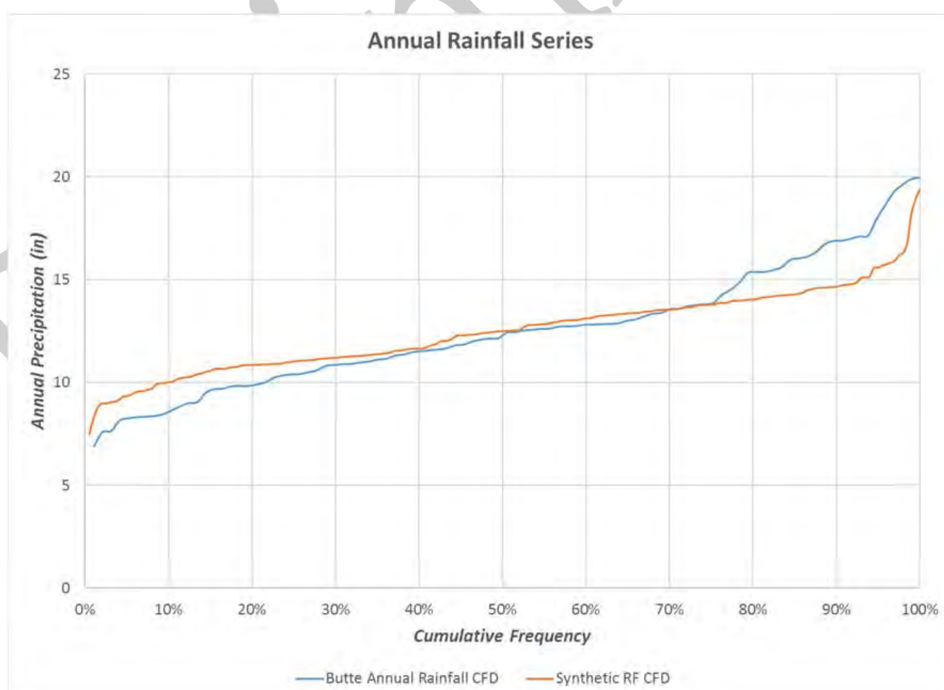

Figure 3. Comparison of annual precipitation at Bert Mooney Airport to synthetic data.

Spatial Adjustment of Climatic Data to YDT Area

The PRISM model was used to correct precipitation data by assessing predicted monthly precipitation at the airport versus the YDT area for a 20-year period of record. Estimated precipitation at YDT was divided by the Butte estimates to develop monthly correction coefficients (Table 1). Average annual precipitation at the YDT was found to be 15.92 inches compared to 12.47 inches at the airport. Differences were greatest in winter when frontal weather systems dominate and were smallest in summer when most rainfall occurs from convective storms. PRISM does not provide a means of adjusting evapotranspiration so ET calibration is discussed in the next section.

Estimating Reference Evapotranspiration

Direct observations of pan evaporation were only available from stations that were more than 60 miles from Butte and were not considered representative. On-site evaporation data collected from MBMG were infrequently recorded for a single year and did not provide adequate temporal detail to create a long-term daily climate record. Therefore, the Penman-Monteith equation (PME, Eqn [1]) was used to predict annual reference evapotranspiration for the Butte airport (FAO 2006).

The PME is widely used to estimate monthly evapotranspiration from a reference surface consisting of well-irrigated grass maintained at a canopy height of 12 cm. Evapotranspiration from irrigated grass will differ from pan evaporation or evaporation from a pond so adjustments are usually required. Since the magnitude of differences vary seasonally, monthly coefficients are often used to equate PME estimates to free water loss from ponds or lakes.

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)} \qquad [1]$$

where Rn is the net radiation, G is the soil heat flux, (e_s - e_a) represents the vapor pressure deficit of the air, ρ_a is the mean air density at constant pressure, c_p is the specific heat of the air, Δ represents the slope of the saturation vapor pressure temperature relationship, γ is the psychrometric constant, and r_s and r_a are the (bulk) surface and aerodynamic resistances.

Estimated annual ET was 44 inches using the PME, which is slightly higher than the regional pan evaporation stations which averaged 36.8 inches from April to October. Pan evaporation data was not recorded for November through March and water loss for these months was estimated to be about 0.5 mm/d or 0.5 inches per month (Allen 1996). Data from Allen for snow cover conditions were mostly used to derive estimated sublimation.

MBMG also installed a Class A Evaporation Pan just north of the YDT, which recorded 36.6 inches of evaporation for March 2001 to October 2002. Class A pans are known to over-predict evaporation from lakes and reservoirs due to temperature and humidity effects. A pan coefficient of 0.7 is often used to adjust pan readings (Dunne and Leopold 1978) (Table 1). An estimated sublimation rate of 0.5 inches per month was used for the November-March time frame. Monthly coefficients were developed to adjust from the PME estimates to estimate estimated free water surface loss. The coefficients are low in winter and spring and increase through the summer and early fall time frame (Table 1). This seasonality is attributed to gradual warming of the pan through the year that tends to increase evaporation rate. The adjusted free water annual evaporation for the YDT area is 28.1 inches

Monthly average solar radiation, minimum and maximum relative humidity and wind speed are provided in Table2. A spreadsheet containing daily estimated values for precipitation, free water evaporation, temperature, solar radiation, relative humidity and wind speed are available upon request.

Table 1. Monthly average precipitation and evaporation for Bert Mooney Airport and YDT.

Month	Butte Airport Precipita-tion (in) 1915-2015	Multiplier derived from PRISM to convert from airport to YDT	Estimated Average Precipit-ation (in) at YDT	Poten-tial ET from PME (in)	Multiplier to adjust Potential ET from PME to Free Water Loss at YDT	Potential Free Water Evaporation adjusted to YDT (in)
Jan	0.55	224%	1.22	1.48	34%	**0.5**
Feb	0.48	200%	0.96	1.73	29%	**0.5**
Mar	0.77	138%	1.06	2.65	19%	**0.5**
Apr	1.10	133%	1.47	3.72	57%	2.12
May	1.82	117%	2.14	5.06	58%	2.95
Jun	2.17	103%	2.22	6.02	61%	3.70
Jul	1.26	121%	1.53	6.86	79%	5.43
Aug	1.27	87%	1.11	5.97	83%	4.93
Sep	1.13	135%	1.52	4.32	77%	3.34
Oct	0.74	144%	1.06	3.00	105%	3.16
Nov	0.62	101%	0.63	1.87	27%	**0.5**
Dec	0.57	174%	0.99	1.41	35%	**0.5**
Annual	**12.47**		**15.92**	**44.08**		**28.13**

Table 2. Monthly average temperature, solar radiation, relative humidity and wind speed for YDT area.

Month	Daily Maximum Temperature (Celsius)	Daily Minimum Temperature (Celsius)	Average Daily Solar Radiation (MJ/m^2)	Average Maximum Relative Humidity (%)	Average Minimum Relative Humidity (%)	Average Wind Speed (m/s)
Jan	-1.0	-14.7	6.7	95.2	30.5	3.6
Feb	1.6	-12.3	10.4	93.5	31.2	3.3
Mar	5.1	-8.4	14.8	91.1	31.1	3.5
Apr	10.4	-3.5	19.3	90.4	33.2	3.2
May	15.8	1.2	22.0	88.5	34.2	2.8
Jun	20.5	5.0	24.7	85.1	32.8	2.6
Jul	26.2	7.6	25.7	80.6	26.0	2.3
Aug	26.0	6.9	21.9	79.3	23.5	2.2
Sep	19.9	2.3	17.4	82.6	26.7	2.3
Oct	12.9	-2.8	11.5	87.4	29.6	2.8
Nov	4.4	-9.1	7.4	90.5	31.0	3.3
Dec	-0.3	-13.7	5.6	94.7	30.8	3.2
Annual Average	**11.8**	**-3.4**	**15.6**	**88.2**	**30.0**	**2.9**

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APPENDIX A2

Mean Climate Parameters

(Pages A2-1 to A2-3)

Knight Piésold CONSULTING

www.knightpiesold.com

MEMORANDUM

To:	Mr. Daniel Fontaine	Date:	February 1, 2016
Copy To:	Mr. Ken Brouwer	File No.:	VA101-00126/12-A.01
From:	Alana Shewan	Cont. No.:	VA15-03327
Re:	Mean Monthly Climate Parameters		

This memorandum has been prepared to present the average climate conditions for the Yankee Doodle Tailings Impoundment (YDTI) that will be used for the Montana Resources (MR) Amendment 10 Design Document application. The climate inputs were developed using the data measured at the Butte Bert Mooney Airport (1895 – 2014), which are available from the Western Regional Climate Center (WRCC) website and the National Oceanic and Atmospheric Administration (NOAA) Climatic Data Center website. The Butte Bert Mooney Airport is located approximately 5.5 miles south of the YDTI at an elevation of approximately 5,500 ft (NOAA). The climate conditions at the airport are assumed to be representative of the climate conditions at the YDTI due to their close proximity and being in the same geographical setting, therefore orographic effects are expected to be minimal.

The mean and extreme monthly temperature values are presented in Table 1.

Table 1 Mean and Extreme Temperatures

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Temperature (°F)	15.2	19.4	27.3	37.7	47.3	56.1	65.0	62.9	52.1	41.0	26.9	17.3	39.0
Standard Deviation (°F)	7.6	6.7	5.9	4.1	3.5	3.5	3.1	3.0	3.8	3.9	5.7	6.1	-
Daily Maximum Temperature (°F)	28.0	32.7	41.9	48.3	57.4	66.0	72.0	69.5	60.0	49.5	40.2	31.6	-
Daily Minimum Temperature (°F)	-11.7	-0.6	14.2	22.1	39.0	48.5	55.3	55.7	40.0	32.1	8.7	-1.1	-
Extreme Maximum Temperature (°F)	57.8	62.2	71.2	86.6	94.4	102.2	104.4	104.4	97.8	88.8	72.2	67.8	104.4
Year	2005	1995	1994	1910	1919	1988	1936	2000	2000	2010	1999	1917	2000
Extreme Minimum Temperature (°F)	-58.8	-63.4	-45.6	-23.4	4.4	18.8	25.6	20.0	-2.2	-31.2	-52.2	-63.4	-63.4
Year	1937	1933	1948	1982	1975	1916	1971	1992	1926	1991	1959	1983	1983

The mean monthly precipitation and evaporation values are presented in Table 2.

Table 2 Mean Monthly Precipitation and Evaporation

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation (in)	0.6	0.5	0.8	1.1	1.9	2.3	1.2	1.2	1.1	0.8	0.6	0.6	**12.7**
Rainfall Fraction (%)	0	0	0	30	80	100	100	100	90	54	0	0	**-**
Rainfall (in)	0	0	0	0.3	1.5	2.3	1.2	1.2	1.0	0.4	0	0	**8.1**
Snowfall (SWE in)	0.6	0.5	0.8	0.8	0.4	0	0	0	0.1	0.4	0.6	0.6	**4.7**
Sublimation (in)	0.13	0.13	0.13	0.13	0	0	0	0	0	0.13	0.13	0.13	**0.9**
Snowmelt (%)	0	10	50	40	0	0	0	0	0	0	0	0	**100**
Pond Evaporation (in)	0	0	0.2	1.1	2.5	3.6	4.8	4.2	2.5	1.2	0.1	0	**20.2**

The long-term mean annual precipitation is estimated to be 12.7 in. The fractions of rainfall and snowfall to precipitation were based on the long-term monthly average snowfall records (1894 – 2000) and assuming a snow water equivalent (SWE) of 10%. It was assumed that precipitation falls exclusively as rain from June through August, as snow from November through March, and that a mix of rain and snow occurs during the months of April, May, September and October.

Sublimation is the process by which moisture is returned to the atmosphere directly from snow and ice without passing through the liquid phase (Liston and Sturm, 2004). In areas where winter precipitation comprises a large proportion of annual precipitation, sublimation can play a significant role in the annual water balance. For example, Liston and Sturm (2004) estimate that sublimation can result in the loss of 10% - 50% of the total winter snowfall in Arctic regions. The YDTI is not situated in an Artic region; however, snowfall does account for approximately 37% of the total precipitation, and the YDTI may be subjected to high winds that often result in blowing snow, which accordingly aids in sublimation. The sublimation for YDTI was therefore assumed to be 20% of the total winter snowfall and is equal to 0.9 in per year. Sublimation losses have been distributed evenly from October through to April.

The potential evapotranspiration (PET) was calculated using the empirical Thorthwaite equation and the long-term measured temperature record for Butte airport (1895 – 2015). The mean annual PET, which is considered to be approximately equal to pond evaporation, was calculated to be 20.2 inches. Previously, the Draft Remedial Investigation Report for the Butte Mine Flooding Operable Unit (BMFOU) Remedial Investigation presented the annual evaporation for the mine site as 23.75 in (Canonie Environmental Services, 1994). This information was based on only six months of measured evaporation pan data for the Moulton Reservoir from the Montana College of Mineral Science and Technology (Canonie Environmental Services, 1994). The Thorthwaite estimate is based on long-term measured data and was therefore selected to represent the long-term PET for the YDTI. The corresponding monthly calculations are presented in Table 2.

The potential effects of climate change are not considered in the above analysis since historical climate records do not necessarily represent possible future conditions. The purpose of this memorandum was to characterize existing climate conditions; therefore a climate change analysis was not completed.

We trust that this information is suitable for providing mean monthly estimates of climate data for the Amendment 10 Design Document application. Please contact the undersigned if you have any questions or concerns.

PROFESSIONAL
PROVINCE OF
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Prepared: Alana Shewan, MASc., P.Eng. – Senior Engineer

Reviewed: Jaime Cathcart, Ph.D., P.Eng. – Specialist Hydrotechnical Engineer | Associate

Approval that this document adheres to Knight Piésold Quality Systems:

References:

Canonie Environmental Services Corp. 1994. Butte Mine Flooding Operable Unit Remedial Investigation/Feasibility Study – Draft Remedial Investigation Report. Prepared for ARCO.

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/as

APPENDIX A3

Extreme Precipitation Estimates

(Pages A3-1 to A3-3)

Knight Piésold
CONSULTING

www.knightpiesold.com

MEMORANDUM

To:	Mr. Daniel Fontaine	Date:	February 1, 2016
Copy To:	Mr. Ken Brouwer	File No.:	VA101-00126/12-A.01
From:	Alana Shewan	Cont. No.:	VA15-03332
Re:	Montana Resources – Extreme Precipitation Estimates		

This memorandum presents the methodology used for estimating the extreme precipitation events for the Yankee Doodle Tailings Impoundment (YDTI) that will be used for the Montana Resources (MR) Amendment 10 Design Document application. This document presents values for 24 hr events with return periods of 2, 5, 10, 25, 50, 100, 200, and 1,000 years only – the probable maximum precipitation (PMP) estimations are presented in Knight Piésold's (KP) letter titled "Review of the PMF Estimate for the Yankee Doddle Tailings Impoundment" (KP, 2015).

Annual extreme precipitation data for YDTI were determined from daily precipitation data from Butte Bert Moody Airport (1895 – 2014), which are available from the National Oceanic and Atmospheric Administration (NOAA) Climatic Data Center website. The daily values were converted to equivalent 24 hour events using a standard scaling factor of 1.13 (Miller et al., 1973) and then plotted on Figure 1. This was done since daily precipitation accumulations represent a fixed 24 hour observation interval; therefore, these data may underestimate the precipitation that can accumulate in any 24 hour period. The result is a mean annual 24 hour extreme precipitation of 1.13 inches with a standard deviation of 0.43 inches.

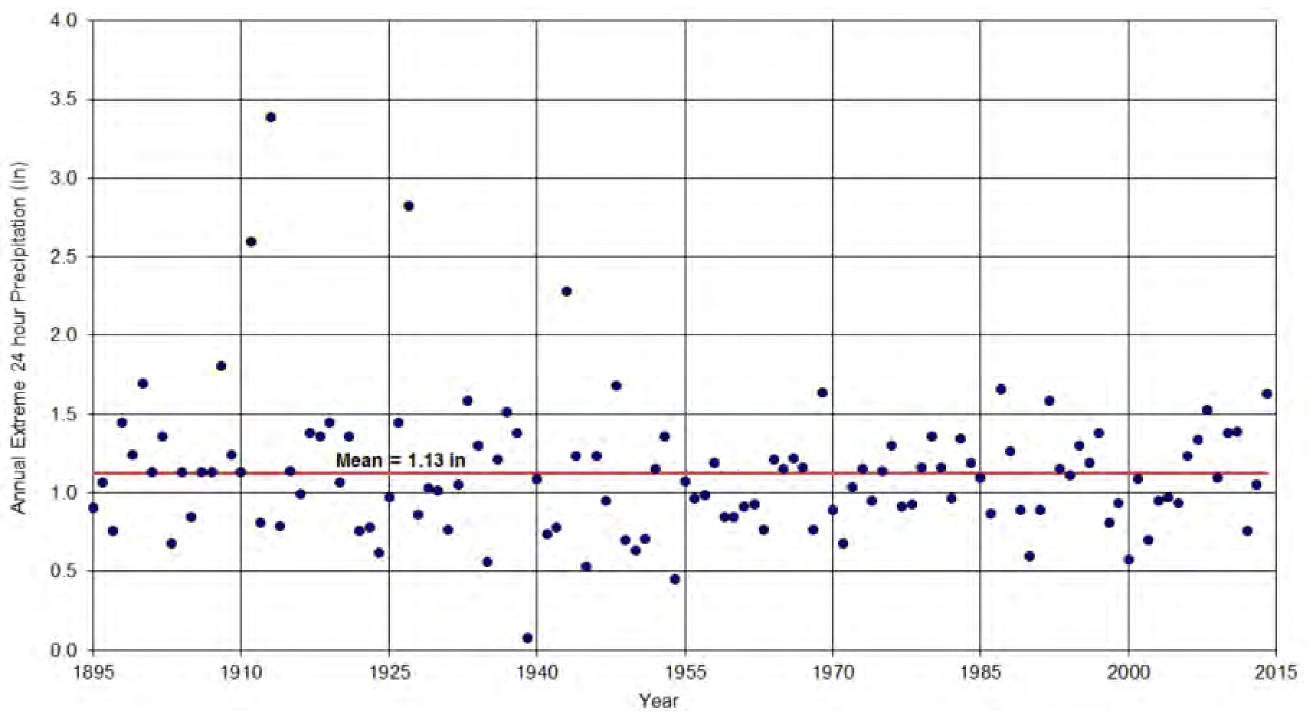

Figure 1 Annual 24 Hour Extreme Precipitation

The various return period 24 hour precipitation events were determined using a Log-Pearson Type III distribution and are summarized in Table 1. The Log-Pearson Type III probability curve and the observed data are shown on Figure 2.

Table 1 Estimated Extreme 24 Hour Precipitation Events

	2 yrs	5 yrs	10 yrs	25 yrs	50 yrs	100 yrs	200 yrs	1000 yrs
Log-Pearson Type III (inches)	1.0	1.4	1.7	2.0	2.3	2.6	2.9	3.7
USGS Report 97-4004 (inches)	1.0	1.5	1.7	-	2.3	2.5	2.8	3.4
YDTI Project[(1)] (inches)	1.0	1.5	1.7	2.0	2.3	2.6	2.9	3.7
+ Climate Change (inches)	**1.2**	**1.7**	**1.9**	**2.3**	**2.6**	**2.9**	**3.3**	**4.2**

NOTES:

1. YDTI Project precipitation selected as the maximum between the Log-Pearson Type III and USGS Report 97-4004 values.

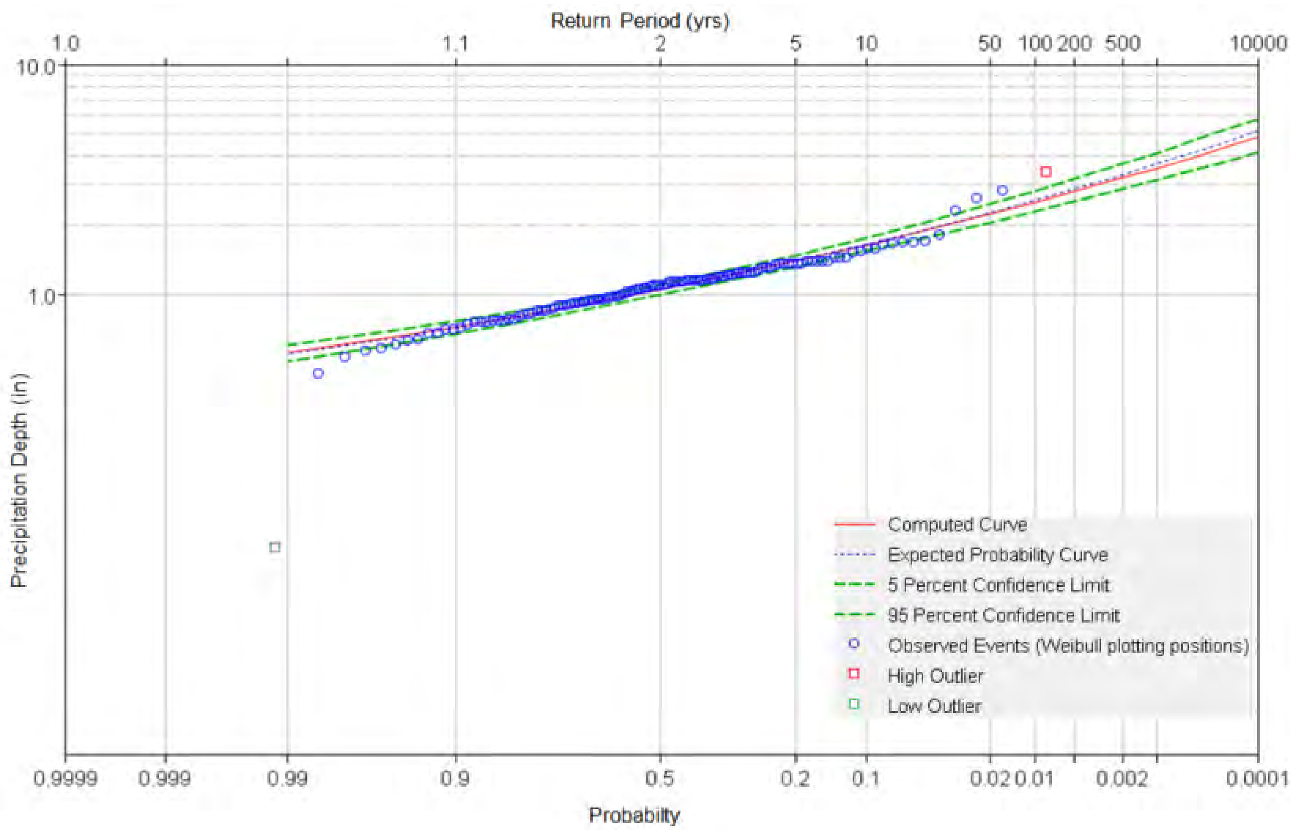

Figure 2 Log-Pearson Type III Frequency Distribution

It can be noted on Figure 2 that the four largest events on record all plot above the 95% confidence limit, which suggests that the curve may underestimated the larger return period events. However, the plot on Figure 1 indicates that all four events occurred in a relatively short 33 year period between 1911 and 1943, inclusive, and that the largest three events, which all register as having return periods of at least 100 years, all occurred in a 17 year period between 1911 and 1927. This clustering of the events, and the fact that they all occurred relatively early in the data record when data collection techniques were more rudimentary than they are today, suggests that one or more of them may be erroneous.

Extreme precipitation depths for 24 hour storm events were also obtained from the "Regional Analysis of Annual Precipitation Maxima in Montana – Water Resources Investigation Report 97-4004" prepared by the U.S.

Geological Survey (USGS, 1997). These values are also summarized in Table 1. The design rainfall depths for the project were selected as the maximum between the USGS and Log-Pearson Type III distribution curve values, and are summarized in Table 1.

The potential effects of climate change are not directly considered in the above analysis since historical climate records do not necessarily represent possible future conditions. The general scientific consensus is that climate change is likely to cause increased temperatures and an increased frequency and intensity of rain storms in Montana (IPCC, 2007), which for the YDTI translates into an increased likelihood of both heavy precipitation events and smaller winter snowpack depths. Climate change is addressed by increasing the design storm depths by 15%, as this is a generally recommended factor for accounting for climate change effects on peak flow estimates (APEGBC, 2012). The various return period 24 hour precipitation events accounting for climate change and are summarized in Table 1.

We trust that this information meets your current requirements. Please contact the undersigned with any questions or comments.

PROFESSIONAL
PROVINCE OF
A. SHEWAN
36661 1 FEB 2016
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Prepared: Alana Shewan, MASc., P.Eng. – Senior Engineer

Reviewed: Jaime Cathcart, Ph.D., P.Eng. – Specialist Hydrotechnical Engineer / Associate

Approval that this document adheres to Knight Piésold Quality Systems: KO

References:

APEGBC, 2012. Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC. Association of Professional Engineers and Geoscientists of British Columbia.

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/as

APPENDIX A4

Estimates of Return Period Snowpack

(Pages A4-1 to A4-3)

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MEMORANDUM

To:	Mr. Daniel Fontaine	Date:	February 2, 2016
		File No.:	VA101-00126/12-A.01
From:	Jaime Cathcart	Cont. No.:	VA16-00129
Re:	Montana Resources – Estimates of Return Period Snowpack		

This memorandum presents the methodology used to estimate return period annual maximum snowpack values for the basin draining into the Yankee Doodle Tailings Impoundment (YDTI). The estimated snowpack values are provided in Table 1 in terms of inches of snow water equivalent (SWE).

Table 1 Return Period Snowpack Estimates for the YDTI Watershed

Return Period	Frequency Factor	Maximum Snowpack SWE (in)
2	-0.164	6.8
5	0.838	8.9
10	1.495	10.2
15	1.866	11.0
20	2.126	11.6
25	2.326	12.0
50	2.943	13.3
100	3.554	14.6
200	4.210	15.9
500	5.001	17.6
1,000	5.576	18.8
10,000	7.580	23.0

NOTES:
1. SNOWPACK VALUES ARE PROVIDED IN TERMS OF SNOW WATER EQUIVALENT (SWE).
2. THE FREQUENCY FACTORS ARE FOR AN EXTREME VALUE TYPE 1 DISTRIBUTION WITH A SAMPLE SIZE OF 40.
3. THE COMPUTED VALUES WERE DERIVED ON THE BASIS OF HISTORICAL MAXIMUM ANNUAL SNOWPACK DATA FOR THE MOULTON RESERVOIR SNOW SURVEY STATION.

Historical maximum annual snowpack data from five snow survey sites operated by the US National Resource Conservation Service (NRCS) in the general vicinity of the YDTI were examined to determine maximum snowpack values for the YDTI watershed. The locations of these stations are shown on Figure 1. The most relevant station is Moulton Reservoir, which is located in the drainage basin of the YDTI at an elevation of 6,850 feet. This is the approximate median elevation of the basin. All of the regional stations shown are located at elevations between 6,600 feet and 7,700 feet.

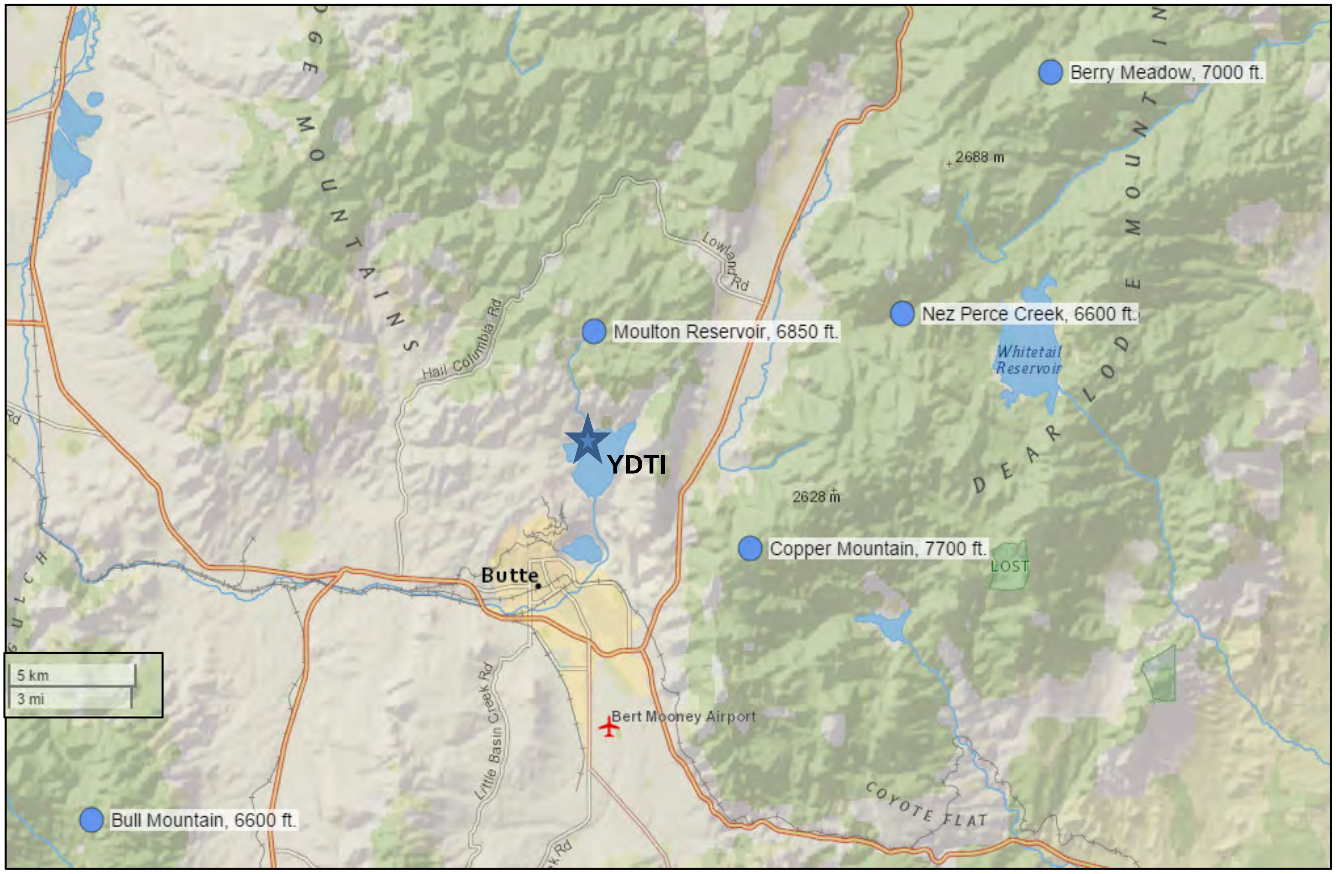


Figure 1 Regional Snow Survey Sites

A summary of the regional snowpack values is shown in Table 2. The data at all the stations are generally consistent, with the mean annual snowpack values ranging from approximately 6 to 11 inches. There appears to be a strong correlation between snowpack and basin elevation, with the highest station having the greatest snowpack and the lowest station having the smallest. The period of record values are very similar to those for the most recent 30 year climate normal period, although there is some indication of a slight trend of decreasing snowpack.

Table 2 Regional Annual Maximum Snowpack

Station				Annual Maximum Snowpack Statistics (SWE)					
				Period of Record			1981-2010 Normal		
Name	Number	Elevation (ft.)	Period of Record	mean (in.)	stdev (in.)	cv	mean (in.)	stdev (in.)	cv
Moulton Reservoir	12C20	6,850	1976 - 2015	7.1	2.1	0.30	7.1	2.2	0.31
Copper Mountain	12C21	7,700	1961 - 2015	11.7	3.0	0.26	11.0	2.8	0.25
Nez Perce Creek	12C22	6,600	1961 - 2015	6.8	2.3	0.34	5.9	1.8	0.31
Berry Meadow	12C23	7,000	1961 - 2012	7.5	2.5	0.33	6.4	1.7	0.27
Bull Mountain	12D08	6,600	1974 - 2015	6.2	2.3	0.37	5.7	2.1	0.37

Given that the Moulton Reservoir station is located in the YDTI drainage near the mid-elevation point, that it has a long period of record, and that the regional snowpack values are reasonably consistent through time and by location, the Moulton Reservoir snowpack values were selected as the most appropriate basis for estimating basin average snowpack conditions in the YDTI basin. The computed mean (7.1 inches) and standard deviation (2.1 inches) values were fit to an Extreme Value Type 1 distribution using a frequency factor approach, with the factors selected according to the sample size of 40 years. This distribution is commonly applied to extreme event datasets for hydrometeorological parameters including flow, rainfall and snowpack. The results indicate a 10 year annual maximum snowpack value of 10.2 inches and corresponding 100 year and 10,000 year values of 14.6 inches and 23.0 inches, respectively.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
J. G. CATHCART

Feb. 2, 2016

Prepared: ______________________________
Jaime Cathcart, Ph.D., P.Eng. – Specialist Hydrotechnical Engineer | Associate

Reviewed: ______________________________
Alana Shewan, MASc., P.Eng. – Senior Engineer

Approval that this document adheres to Knight Piésold Quality Systems: ☒

/jc

APPENDIX A5

Review of Precipitation Estimates for the MR Mine Site

(Pages A5-1 to A5-15)

Knight Piésold CONSULTING

MEMORANDUM

Date:	January 22, 2021	**File No.:**	VA101-00126/23-A.01
		Cont. No.:	VA20-01741
To:	Dan Fontaine		
From:	Jaime Cathcart		
Re:	**Review of Precipitation Estimates for the MR Mine Site**		

1.0 INTRODUCTION

This memorandum presents a review of precipitation estimates that were previously developed for the Yankee Doodle Tailings Impoundment (YDTI) at the Montana Resources, LLP (MR) Mine. The previous precipitation estimates include mean monthly and annual values developed by Schafer (2016) and 24-hour extreme values developed by Knight Piésold (2016). This review is based on consideration of approximately six years (2014 - 2020) of precipitation data collected at the MR climate station located on the crest of the YDTI embankment, six years (1980-1986) of precipitation data available for the National Oceanic and Atmospheric Administration (NOAA) Moulton Reservoir (Moulton) station (245886) located in the watershed that drains into the YDTI, 126 years (1895-2020) of precipitation data available for the NOAA Butte Bert Mooney Airport (BBMA) station (2115439), and ten years (2011-2020) of snowpack data collected by the United States Department of Agriculture (USDA) at the Moulton Reservoir Snow Course (MRSC) (12C20).

2.0 CURRENT MEAN ANNUAL AND MONTHLY PRECIPITATION ESTIMATES

The current Mean Annual Precipitation (MAP) estimate for the YDTI is 15.9 inches (Schafer, 2016), which was estimated by adjusting long-term (1915 - 2015) NOAA precipitation records at the BBMA station on the basis of ratios of PRISM generated mean monthly precipitation estimates for the BBMA station and the MR station. The MR station is located on the embankment crest of the YDTI at elevation 6,350 feet and the BBMA station is located approximately 5.5 miles south and 1,000 feet below it. The historical monthly average BBMA precipitation values, the monthly ratios of MR to BBMA precipitation, and the corresponding estimated mean monthly precipitation values for the YDTI are summarized in Table 2.1.

Table 2.1 Mean Monthly Precipitation for Butte Airport and the YDTI

Month	Butte Airport Precipitation (in.) (1915-2015)	PRISM Ratio	Estimated YDTI Precipitation (in.)
Jan	0.55	2.24	1.22
Feb	0.48	2.00	0.96
Mar	0.77	1.38	1.06
Apr	1.10	1.33	1.47
May	1.82	1.17	2.14
Jun	2.17	1.03	2.22
Jul	1.26	1.21	1.53
Aug	1.27	.87	1.11
Sep	1.13	1.35	1.52
Oct	0.74	1.44	1.06
Nov	0.62	1.01	0.63
Dec	0.57	1.74	0.99
Annual	12.47	1.28	15.92

NOTES:

1. VALUES FROM SCHAFER (2016).

On an annual basis, precipitation at MR is estimated to be approximately 28% greater than at BBMA, while for the summer period of May to September, when precipitation is largely due to convective storm systems, precipitation at MR is estimated to be approximately 12% greater than at BBMA, and for the winter period of October to April, when precipitation is largely due to frontal systems, precipitation at MR is estimated to be approximately 53% greater than at BBMA.

3.0 UPDATED ASSESSMENT OF PRECIPITATION ESTIMATES

3.1 MR SITE DATA

MR installed a climate station on the YDTI embankment in April 2014 and data have been collected continuously at that site since then, with data currently available up until the end of 2020. A photo of the station is provided on Figure 3.1 and a summary of the monthly precipitation values is provided in Table 3.1.

Figure 3.1 MR Climate Station

Table 3.1 Mean Monthly Precipitation for the MR Climate Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014					0.55	2.66	0.86	3.58	0.95	0.52	1.16	0.04	
2015	0.32	0.13	0.36	0.38	1.45	0.71	1.43	1.03	2.14	0.56	0.73	0.26	9.50
2016	0.15	0.16	1.60	1.02	1.95	1.41	5.10	0.83	1.36	1.99	0.19	0.02	15.78
2017	0.26	0.37	0.99	1.24	2.56	3.81	0.45	0.19	0.83	1.20	0.54	0.11	12.55
2018	0.62	0.48	0.48	1.19	2.92	5.31	0.30	1.87	0.88	0.63	0.48	0.07	15.23
2019	0.25	0.53	0.66	1.45	2.04	1.21	0.75	1.06	2.48	0.49	0.44	0.08	11.44
2020	0.13	0.65	0.24	0.4	2.36	5.71	0.66	0.39	0.58	1.12	0.23	0.03	12.50
Average	0.29	0.39	0.72	0.95	1.98	2.97	1.36	1.28	1.32	0.93	0.54	0.09	12.81

As a means of assessing the quality of these data, and also to quantify differences between the precipitation at the BBMA and MR stations, the concurrent monthly precipitation values for the two stations were directly compared using regression analysis and double mass curve analysis, as shown on Figures 3.2 and 3.3, respectively.

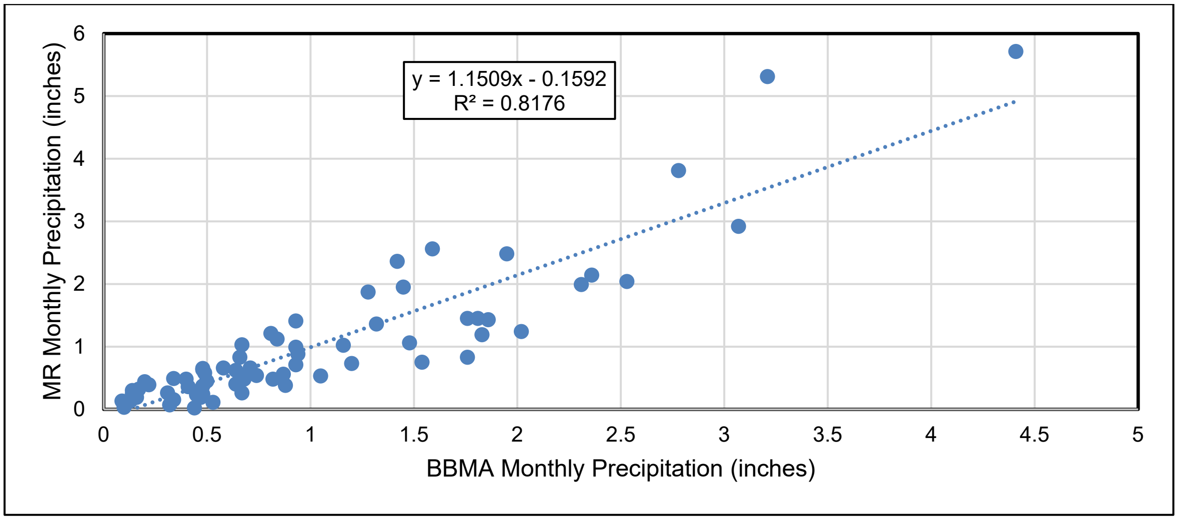


Figure 3.2 Precipitation Regression Analysis: MR Data vs. BBMA Data

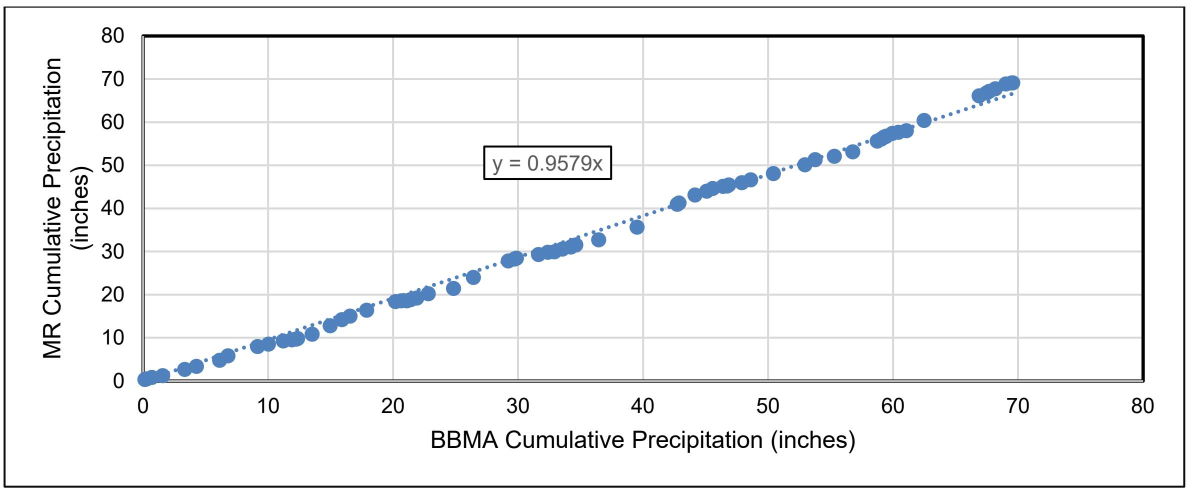
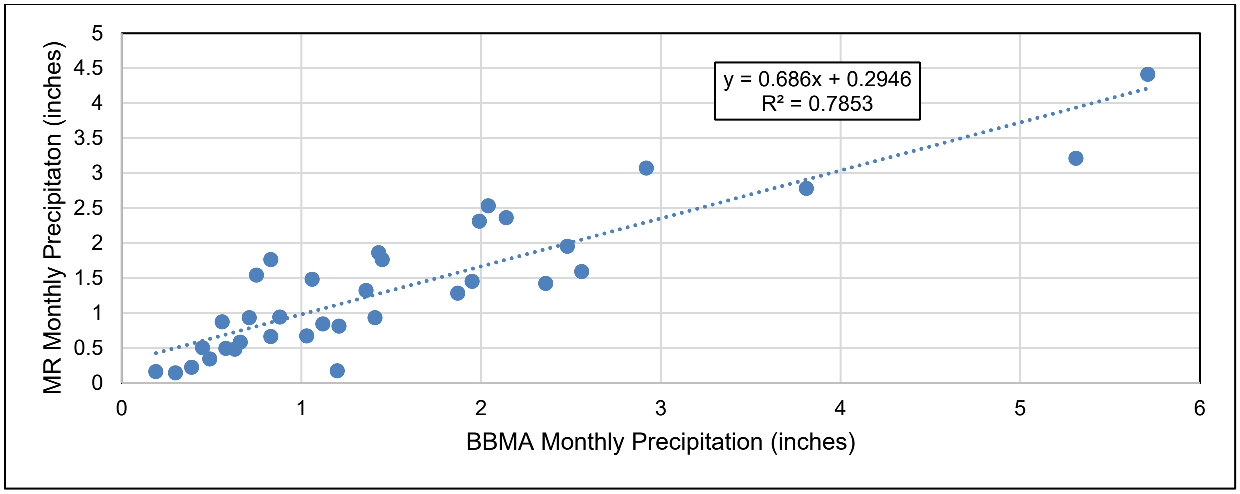


Figure 3.3 Precipitation Double-Mass Curve Analysis: MR Data vs. BMMA Data

These analyses indicate that, on average, the MR station receives approximately the same precipitation as the BBMA station, which is contrary to the expectation that there should be higher precipitation at MR due to its higher elevation.

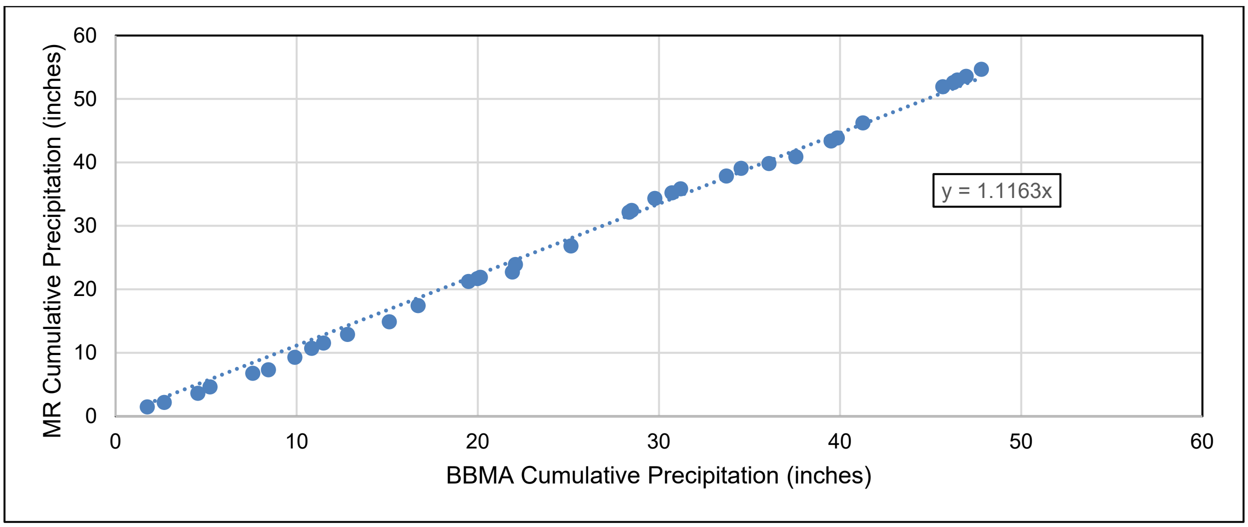
A further and similar assessment that considers summer (May-September) and winter (October-April) data separately results in the summer regression and double mass curve plots shown on Figures 3.4 and 3.5, respectively, and the corresponding winter plots shown on Figures 3.6 and 3.7.



NOTES:

1. SUMMER MONTHS = MAY TO SEPTEMBER.

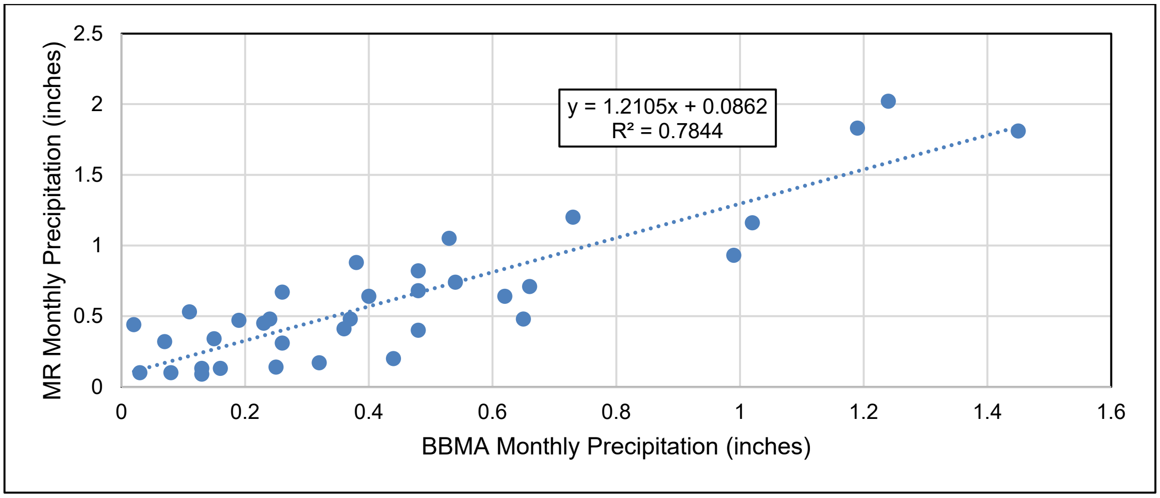
Figure 3.4 Summer Precipitation Regression Analysis: MR Data vs. BBMA Data



NOTES:

1. SUMMER MONTHS = MAY TO SEPTEMBER.

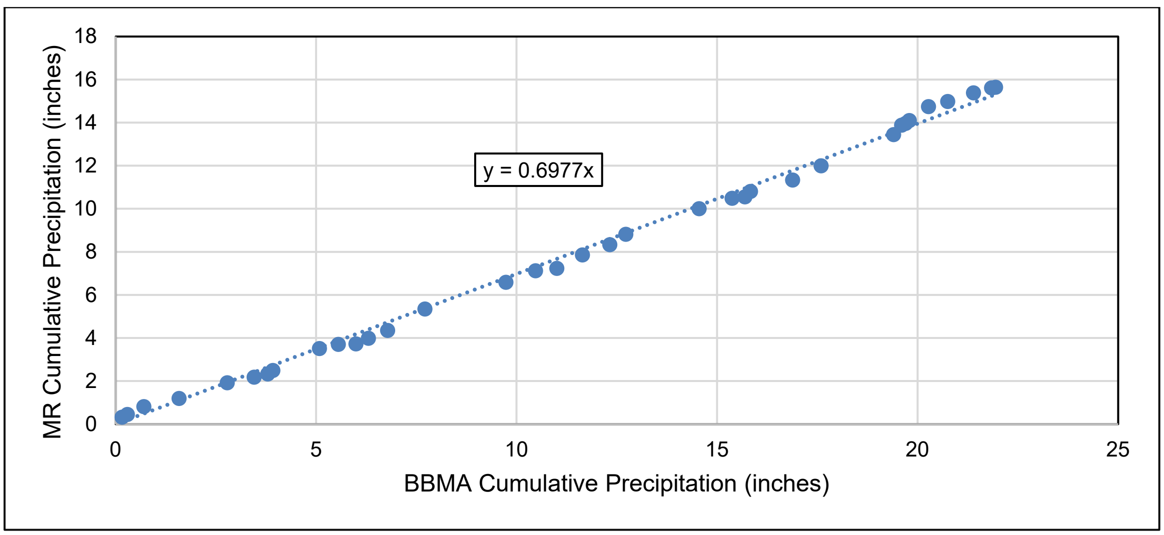
Figure 3.5 Summer Precipitation Double-Mass Curve Analysis: MR Data vs. BBMA Data



NOTES:

1. WINTER MONTHS = OCTOBER TO APRIL.

Figure 3.6 Winter Precipitation Regression Analysis: MR Data vs. BBMA Data



NOTES:

1. WINTER MONTHS = OCTOBER TO APRIL

Figure 3.7 Winter Precipitation Double-Mass Curve Analysis: MR Data vs. BBMA Data

These plots suggest that precipitation during the summer period is about 12% higher at MR than at BBMA, which agrees with and validates the estimated summer precipitation values for MR. In contrast, precipitation during the winter period is about 30% lower at MR than at BBMA, which is very different from the estimated difference of plus 53%, and this discrepancy suggests that the MR winter data are erroneous. Difficulties with accurately collecting winter precipitation data are quite common, particularly with automated precipitation gages such as the one operating at the MR station, which are susceptible to undercatch caused by wind effects and snow bridging of the gage inlet. The MR gage does not have a wind screen, as noted by Heck (2018), who stated in their data and instrument review that "… *Montana Resources should consider moving the gauge closer to the ground and installing a wind screen around it*."

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3.2 MOULTON RESERVOIR PRECIPITATION DATA

To help validate the conclusion that precipitation is likely higher at MR than at BBMA in all seasons, and also to assess whether precipitation at MR is notably different from that in the drainage areas upslope of the YDTI, concurrent precipitation data for BBMA and Moulton were compared using the same types of regression and double mass curve analyses discussed previously. The figures showing these plots for annual, summer, and winter periods are shown on Figures 3.8 to 3.9, 3.10 to 3.11, and 3.12 to 3.13, respectively.

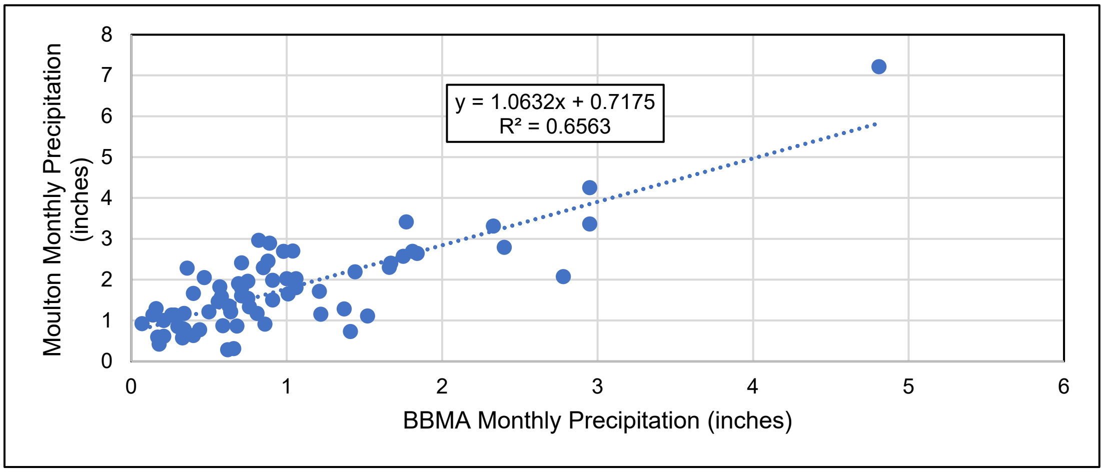


Figure 3.8 Precipitation Regression Analysis: Moulton Data vs. BBMA Data

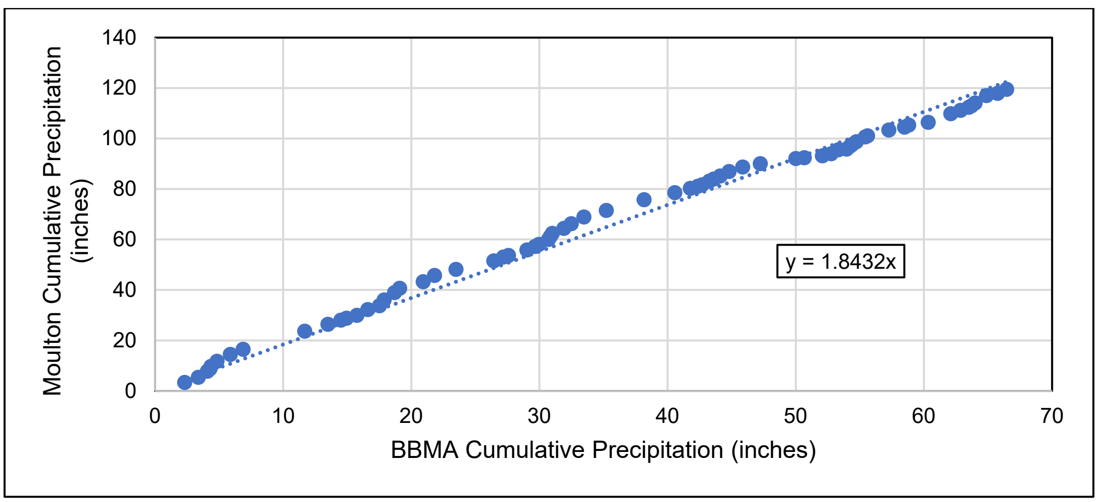


Figure 3.9 Precipitation Double-Mass Curve Analysis: Moulton Data vs. BBMA Data

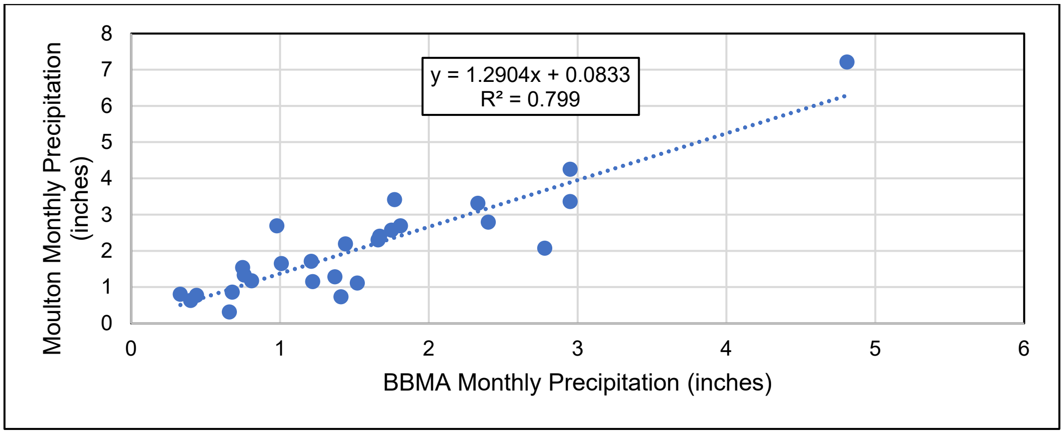


Figure 3.10 Summer Precipitation Regression Analysis: Moulton Data vs. BBMA Data

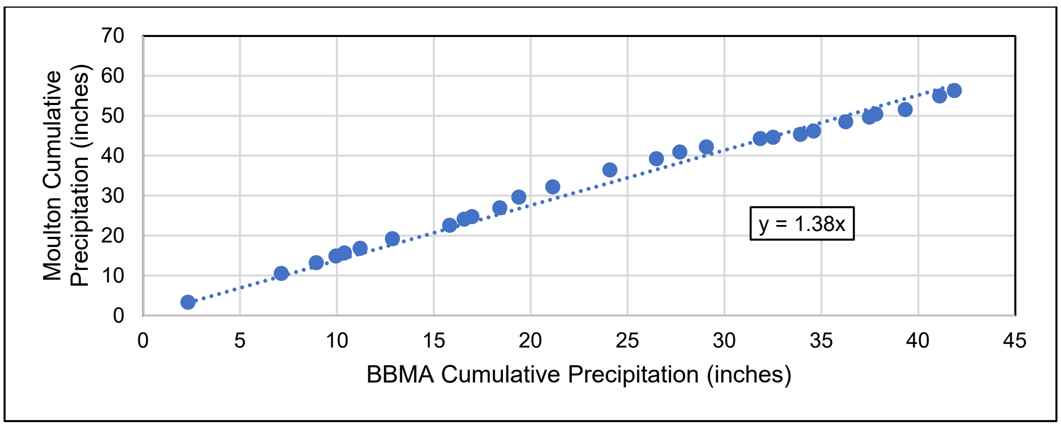


Figure 3.11 Summer Precipitation Double-Mass Curve Analysis: Moulton Data vs. BBMA Data

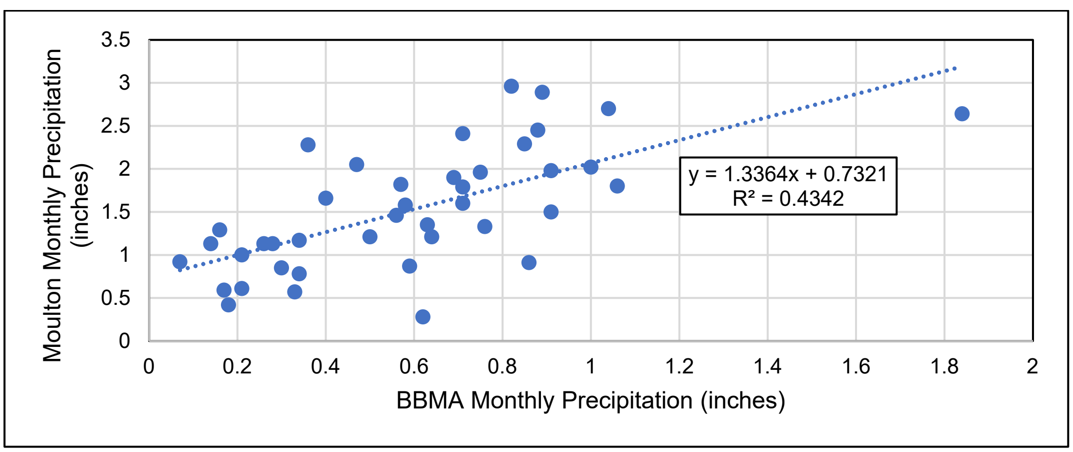


Figure 3.12 Winter Precipitation Regression Analysis: Moulton Data vs. BBMA Data

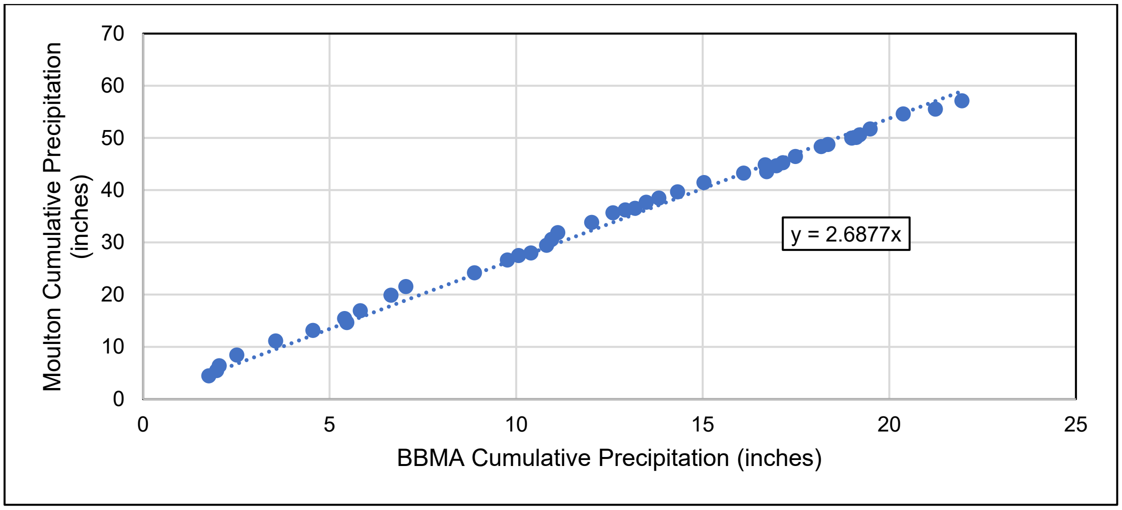


Figure 3.13 Winter Precipitation Double-Mass Curve Analysis: Moulton Data vs. BBMA Data

The annual plot indicates that the Moulton station receives approximately 84% more precipitation than the BBMA station on an annual basis, with the summer period receiving approximately 38% more and the winter period receiving approximately 269% more. It is interesting to note that the correlation between the winter monthly values is quite poor, with an R^2 value of just 0.43. This is lower than what would typically be expected for stations that are not a great distance apart (approximately 9 miles), and it does raise some question about the quality of one or both datasets.

As a means of assessing the validity of the relatively high winter precipitation data recorded at the Moulton station, the cumulative snowfall values for Moulton were compared with the corresponding maximum snowpack values recorded at the nearby MRSC station, as summarized in Table 3.2.

Table 3.2 Moulton Reservoir: Snowfall vs. Snowpack SWE

Winter	Snowfall (in)	Snowfall SWE (in)	Max Snowpack SWE (in)
1980-1981	95.6	9.6	6.1
1981-1982	156.0	15.6	10.5
1982-1983	99.0	9.9	7.1
1983-1984	91.0	9.1	8.8
1984-1985	81.5	8.2	8.1
1985-1986	70.0	7.0	6.2

NOTES:

1. SNOWFALL IS THE TOTAL SNOWFALL AT MOULTON FROM OCTOBER TO THE END OF THE MONTH WITH THE ANNUAL MAXIMUM SNOWPACK.
2. SWE = SNOW WATER EQUIVALENT, WHICH ASSUMES THAT THE SNOW HAS A SPECIFIC GRAVITY OF 0.1.
3. MAX SNOWPACK IS THE MAXIMUM SNOW WATER EQUIVALENT RECORDED AT MRSC.

The snowfall values are estimated as the total accumulated snowfall that occurred from the beginning of October to the end of the month when the maximum snowpack was recorded. It is understood that the snowfall values listed may underestimate actual snowfall because of possible gage undercatch, as previously discussed. Furthermore, the snowpack values are not fully representative of total accumulated snowfall because of sublimation and possible snow drifting and mid-season melt. It is interesting to note that the total snowfall is greater than the maximum snowpack, as expected, and that snowfall and snowpack are correlated, but that there is very little difference between the values in 1983-1984 and 1984-1985. Nonetheless, the snowfall values in Table 3.2 are generally consistent with the Moulton winter precipitation values, which supports the conclusion that the Moulton winter precipitation data are reasonably valid, and as such, that precipitation in areas upslope of the YDTI is substantially greater than at the MR station.

3.3 SUMMARY

Table 3.3 presents a summary and comparison of precipitation values for MR, BBMA, and Moulton, which helps further highlight the key points discussed in the memorandum, as summarized below.

Table 3.3 Precipitation Summary and Comparison

Data Set	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	May-Sep	Oct-Apr	Dec-Feb
MR estimated (long-term) (inches)	1.22	0.96	1.06	1.47	2.14	2.22	1.53	1.11	1.52	1.06	0.63	0.99	15.9	8.5	7.4	3.2
MR measured (2014-2020) (inches)	0.29	0.39	0.72	0.95	1.98	2.97	1.36	1.28	1.32	0.93	0.54	0.09	12.8	8.9	3.9	0.8
BBMA measured (1915-2015) (inches)	0.55	0.48	0.77	1.10	1.82	2.17	1.26	1.27	1.13	0.74	0.62	0.57	12.5	7.7	4.8	1.6
Moulton measured (1980-1986) (inches)	1.25	1.71	1.99	1.69	3.18	2.37	1.71	1.21	2.11	1.57	1.14	1.41	21.3	10.6	10.8	4.4
MR measured as % of MR estimated	24%	40%	68%	64%	92%	134%	89%	115%	87%	88%	85%	9%	81%	105%	53%	24%
Moulton measured as % of MR estimated	103%	178%	187%	115%	148%	107%	112%	109%	139%	148%	180%	142%	134%	124%	145%	138%

NOTES:

1. MR ESTIMATED VALUES ARE FROM SCHAFER (2016).
2. YELLOW SHADING HIGHLIGHTS THE SIMILARITY OF MR MEASURED AND MR ESTIMATED VALUES DURING NON-SNOW MONTHS.
3. ORANGE SHADING HIGHLIGHTS THE DIFFERENCE BETWEEN MR MEASURED AND MR ESTIMATED VALUES DURING ALL-SNOW MONTHS.
4. BLUE SHADING INDICATES WHEN CONVECTIVE STORMS PREDOMINATE, WHILE GREEN SHADING INDICATES WHEN FRONTAL STORMS ARE MORE PREVALENT.
5. MOULTON MEASURED IS FROM SEPT 1980 TO APRIL 1986.

- The MR station winter precipitation data are erroneous. They greatly under-represent the amount of precipitation that would be expected at the station. The current long-term estimates of average monthly precipitation at MR are very consistent with the measured data at MR for the non-snowfall period of May to September, with the two sets of values very similar each month and almost identical over the five-month period. In contrast, over the period of October to April, when snowfall predominates, the MR measured precipitation is about half of what is predicted (and is also less than what is measured at BBMA), and during the coldest months of December to February, it is about a quarter of what is predicted.

- The precipitation is substantially greater in the watershed above the YDTI at the Moulton station than on the YDTI embankment crest at the MR station. Compared to the estimated precipitation for the MR station, the precipitation at the Moulton station is about 25% greater in the May to September period and about 45% greater in the October to April period, with the precipitation differences varying from month to month. The notable month to month variation in the precipitation, and the fact that the Moulton Reservoir is at an elevation only approximately 400 ft higher than the MR station, suggests that factors in addition to simple orographic lifting are at play in affecting the precipitation patterns in the area.

- Given the two points above, the current precipitation estimates for the MR station seem reasonable and appropriate for that location but are not representative of precipitation conditions in the drainage area upslope of the YDTI for either water supply and water balance assessments or for extreme event runoff assessments. Rather, the Moulton precipitation values should be used to represent precipitation conditions in drainage areas upslope of the YDTI.

4.0 MEAN ANNUAL AND MONTHLY PRECIPITATION ESTIMATES FOR AREAS UPSLOPE OF THE YDTI

The Moulton data record indicates a mean annual precipitation value of 21.3 inches. However, this is for the relatively short-term period of 1980-1986. The long-term BBMA data indicate that precipitation during the 1980-1986 period was approximately 4% lower than over the long-term (1900-2020). Therefore, long-term monthly average values for areas upslope of the YDTI were estimated by increasing the measured Moulton mean monthly values by 4%. This results in the precipitation values shown in Table 4.1.

Table 4.1 Estimated Long-term Moulton Precipitation (inches)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1.30	1.78	2.06	1.75	3.30	2.46	1.78	1.25	2.19	1.63	1.18	1.46	22.15

NOTES:

1. VALUES APPLICABLE TO AREAS UPSLOPE OF THE YDTI.

To estimate a long-term precipitation series for the YDTI, Schafer (2016) provided monthly factors based on PRISM modeling, as shown in Table 2.1, which can be applied to the BBMA historical precipitation record. To assess whether these factors are generally consistent with the pattern of annual distribution indicated by the Moulton Reservoir data, the average monthly precipitation values as a percentage of average annual precipitation were computed for four different datasets, as summarized in Table 4.2, and shown on Figure 4.1.

Table 4.2 Mean Monthly Precipitation as a Percentage of Mean Annual Precipitation

Location	Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Moulton Reservoir	1980-1986	5.9%	8.0%	9.3%	7.9%	14.9%	11.1%	8.0%	5.7%	9.9%	7.4%	5.3%	6.6%	100%
BBMA	1980-1986	2.5%	3.8%	8.3%	6.0%	17.2%	17.3%	9.4%	10.1%	11.3%	6.1%	4.8%	3.2%	100%
BBMA	1900-2020	4.5%	4.1%	6.2%	8.5%	15.2%	17.9%	9.8%	9.0%	9.0%	6.3%	4.9%	4.5%	100%
MR Estimated (Schafer)	long-term	7.7%	6.0%	6.7%	9.2%	13.5%	14.0%	9.6%	7.0%	9.6%	6.7%	4.0%	6.2%	100%

NOTES:

1. 1980-1986 PERIOD IS FROM SEPT 1980 TO APRIL 1986.

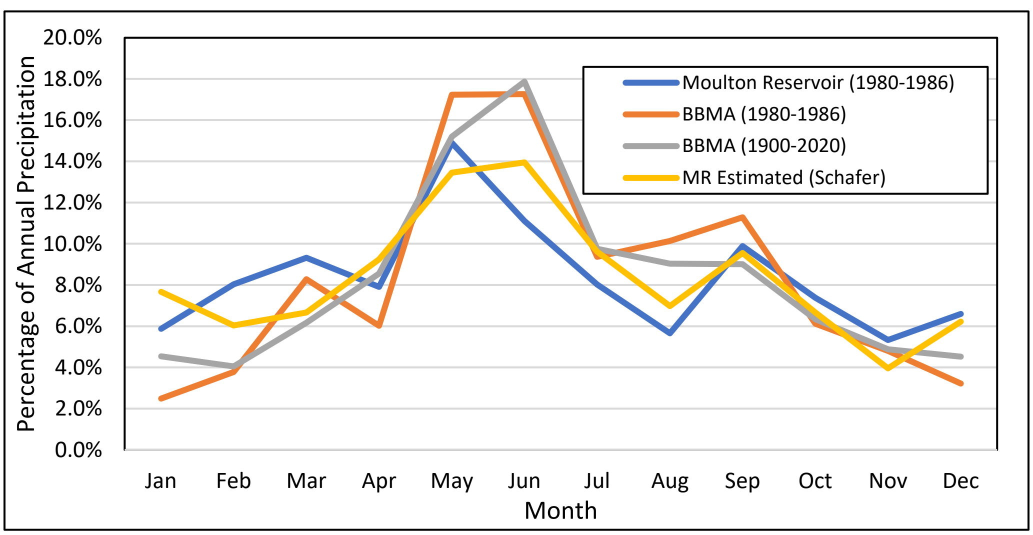


Figure 4.1 Mean Monthly Precipitation as a Percentage of Mean Annual Precipitation

The patterns shown are all generally the same, with the highest precipitation occurring in May and June and the lowest occurring in December and January, and though there is some variation amongst the patterns, there appears to be two groupings, with the two BBMA series closely matched and the Moulton Reservoir and MR Estimated patterns closely matched. The similarity of the Moulton Reservoir and MR Estimated patterns suggests that the Moulton Reservoir data were incorporated in the PRISM modeling used to develop the MR pattern, and this, combined with the pattern's mid position between the Moulton Reservoir and BBMA (1900-2020) patterns supports its use as representative of precipitation conditions in the MR station location. The MR pattern could also be used to represent long-term precipitation conditions at the Moulton Reservoir site, but it is difficult to argue that it is better for this than the pattern of the relatively short-term Moulton Reservoir dataset. Accordingly, the factors developed by Schafer (2016) were kept for estimating long-term precipitation at the MR station location, while factors based on the Moulton Reservoir dataset were selected for use in estimating long-term precipitation at the Moulton Reservoir location. These factors and the corresponding estimated mean monthly and annual precipitation values are summarized in Table 4.3.

Table 4.3 Estimated Precipitation Factors and Long-term Precipitation

Month	Butte Airport Precipitation (in.) (1915-2015)	MR Station Factor	Moulton Reservoir Factor	Estimated YDTI Precipitation (in.)	Estimated Moulton Reservoir Precipitation (in.)
Jan	0.55	2.14	2.36	1.22	1.30
Feb	0.48	2.00	3.71	0.96	1.78
Mar	0.77	1.38	2.68	1.06	2.06
Apr	1.1	1.33	1.59	1.47	1.75
May	1.82	1.17	1.81	2.14	3.30
Jun	2.17	1.03	1.13	2.22	2.46
Jul	1.26	1.21	1.41	1.53	1.78
Aug	1.27	0.87	0.99	1.11	1.25
Sep	1.13	1.35	1.94	1.52	2.19
Oct	0.74	1.44	2.21	1.06	1.63
Nov	0.62	1.01	1.91	0.63	1.18
Dec	0.57	1.74	2.56	0.99	1.46
Annual	12.47	1.28	1.78	15.92	22.15

5.0 EXTREME PRECIPITATION ESTIMATES FOR AREAS UPSLOPE OF THE YDTI

The current extreme rainfall estimates for the MR Mine are general values derived without consideration of possible variations in precipitation throughout the mine area. These values, which are shown in Table 5.1, were developed based on a frequency analysis of long-term annual extreme precipitation for the BBMA station, as well as information contained in the USGS Water Resources Investigations Report 97-4004, as detailed in Knight Piésold (2016).

Table 5.1 Previously Estimated Extreme 24-Hour Precipitation Events

	2 yrs	5 yrs	10 yrs	25 yrs	50 yrs	100 yrs	200 yrs	1,000 yrs
Log-Pearson Type III (inches)	1.0	1.4	1.7	2.0	2.3	2.6	2.9	3.7
USGS Report 97-4004 (inches)	1.0	1.5	1.7	-	2.3	2.5	2.8	3.4
MR Mine (inches)	1.0	1.5	1.7	2.0	2.3	2.6	2.9	3.7
+ Climate Change (inches)	**1.2**	**1.7**	**1.9**	**2.3**	**2.6**	**2.9**	**3.3**	**4.2**

NOTES:

1. THE DESIGN RAINFALL DEPTHS WERE SELECTED AS THE MAXIMUM BETWEEN THE USGS AND LOG-PEARSON TYPE III DISTRIBUTION CURVE VALUES.

As discussed in this memorandum, annual and monthly precipitation conditions vary substantially at MR depending on location, and this variation also applies to extreme rainfall. For example, the values shown in Table 5.1 were derived from the long-term annual daily extreme rainfall values for BBMA, which have a mean of 1.0 inches. In contrast, the Moulton rainfall record, though relatively short-term, indicates a substantially higher mean annual daily extreme rainfall of 1.37 inches. This value agrees very closely with the ratio of the corresponding annual non-winter precipitation values shown in Table 3.3 (10.6/7.7 = 1.38). This is not too surprising, as extreme rainfall is highly correlated to annual and seasonal precipitation (Cathcart, 2001). Similar respective ratios of extreme daily and seasonal rainfall for MR versus BBMA are 1.0 and 1.16 (8.9/7.7), and though these two ratios are not quite as closely matched as the Moulton to BBMA values, they still indicate a strong correlation between the extreme and seasonal rainfall. Based on this finding, estimates of return period 24-hour extreme precipitation were generated for MR and Moulton by prorating the values in Table 5.1 according to the respective ratios of seasonal rainfall (1.16 and 1.38). The resulting 24-hour extreme precipitation estimates for the MR station and the Moulton station are provided in Table 5.2. Values both with and without climate change adjustment are provided. These values are recommended for design purposes. Those without the adjustment are appropriate for use in the near term and for structures that have a design life of less than about 20 years, and those with the adjustment are appropriate for designing structures planned for construction well in the future or for structures with an extended design life.

Table 5.2 Updated Estimates of Extreme 24-Hour Precipitation Events

Location	2 yrs	5 yrs	10 yrs	25 yrs	50 yrs	100 yrs	200 yrs	1000 yrs
MR Climate Station (inches)	1.2	1.7	2.0	2.3	2.7	3.0	3.4	4.3
+ Climate Change	1.3	2.0	2.3	2.7	3.1	3.5	3.9	4.9
Moulton Climate Station (inches)	1.4	2.1	2.3	2.8	3.2	3.6	4.0	5.1
+ Climate Change	1.6	2.4	2.7	3.2	3.7	4.1	4.6	5.9

NOTES:

1. THE MR CLIMATE STATION VALUES ARE APPLICABLE TO AREAS NEAR THE YDTI EMBANKMENT CREST.
2. THE MOULTON CLIMATE STATION VALUES ARE APPLICABLE TO AREAS UPSLOPE OF THE YDTI.

In addition to return period extreme rainfall values, estimates of probable maximum precipitation (PMP) have also been previously developed for the YDTI. These were summarized in KP Memo VA15-03210 (2016), which concluded that an appropriate inflow design flood (IDF) for the YDTI would be the probable maximum flood (PMF) resulting from a 24 hour PMP of 14.4 inches combined with the melt of the 100 year snowpack. This PMP value was determined according to procedures in the US Army Corps

Knight Piésold CONSULTING

Hydrometeorological Report 57 (HMR 57), with the all-season PMP value of 16.5 inches reduced by a factor to produce the spring PMP estimate of 14.4 inches. The PMP isohyetal lines in HMR 57 do not have sufficient resolution to capture the substantial localized difference in precipitation conditions between Butte and the areas upslope of the YDTI, as shown on Figure 5.1.

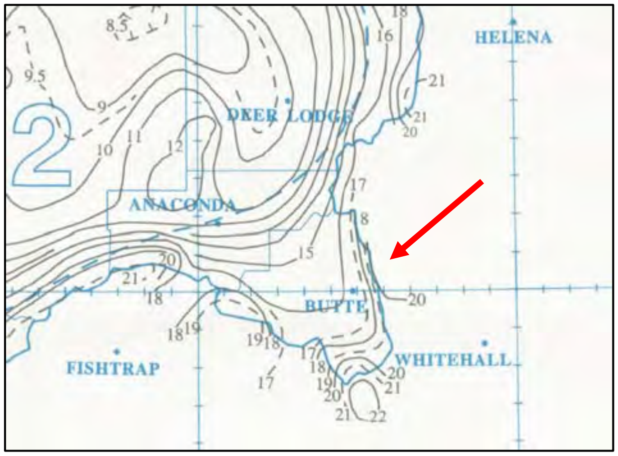


Figure 5.1 All Season 24-hour PMP from HMR 57

However, according to HMR 57, ratios between the PMP and the 100 year precipitation tend to be relatively constant, so ratios of 100 year precipitation can be used to transpose estimates of the PMP between locations. Using this approach, the PMP for the Moulton Climate station, which is representative of areas upslope of the YDTI that drain into the YDTI, was determined to be 14.4 inches x 3.6 inches/2.6 inches = 19.9 inches. This value should be combined with the 100 year snowpack of 14.6 inches to determine the PMF runoff from the area upslope of the YDTI. It should be noted, however, that the snowpack value of 14.6 inches was computed for the Moulton Reservoir location, as previously there was no distinction made between both the PMP and the snowmelt conditions throughout the YDTI drainage area. To derive a snowpack value specific to the MR station location, the Moulton Reservoir values can be reduced according to the ratios of the winter (October to April) precipitation for the two locations, as listed in Table 4.3. That is, 14.6 inches x 11.1 inches/14.4 inches = 11.3 inches.

To summarize, the PMF hydrometeorological parameters for the MR station location, which generally represent conditions for the YDTI, and for the Moulton Reservoir location, which generally represent conditions upslope of the YDTI that drain into the YDTI, are listed in Table 5.3.

Table 5.3 PMF Hydrometeorological Parameters (inches)

Location	100 yr Snowpack	PMP	Total
MR Climate Station	11.3	14.4	25.7
Moulton Reservoir	14.6	19.9	34.5

NOTES:

1. THE MR CLIMATE STATION VALUES ARE APPLICABLE TO AREAS NEAR THE YDTI EMBANKMENT CREST.
2. THE MOULTON RESERVOIR VALUES ARE APPLICABLE TO AREAS UPSLOPE OF THE YDTI.

6.0 REFERENCES

Heck, S., 2018. Summary of Montana Resources LLP Meteorological Calibration Checks Performed August 24, 2018. Bison Engineering, Inc., August 31.

Schafer, 2016. Reference Climatic Data for the Yankee Doodle Tailings Storage Area near Butte, Montana, Memorandum to Mark Thompson et al. from William Schafer, Schafer Limited LLC, May 6.

Knight Piésold Ltd. (KP), 2016. Montana Resources – Extreme Precipitation Estimates, Memorandum VA15-03332, February 1. Vancouver, British Columbia.

US Army Corps of Engineers, 1994. Hydrometeorological Report No. 57 (HMR 57), Probable Maximum Precipitation – Pacific Northwest States.

Yours truly,
Knight Piésold Ltd.

Prepared: Jaime Cathcart, Ph.D., P.E.
Specialist Hydrotechnical Engineer
Associate

Reviewed: Jason Gillespie, P.Eng.
Senior Civil Engineer

Approval that this document adheres to the Knight Piésold Quality System:

/jc

APPENDIX B

Design Storm Event Evaluation

Appendix B1	Review of the PMF Estimate for the Yankee Doodle Tailings Impoundment
Appendix B2	Review of PMF Estimate in Light of Recommendations in the Extreme Storm Working Group Summary Report

APPENDIX B1

Review of the PMF Estimate for the Yankee Doodle Tailings Impoundment

(Pages B1-1 to B1-7)

March 10, 2016

File No.:VA101-00126/12-A.01
Cont. No.:VA15-03210

Mr. Mark Thompson
Environmental Manager
Montana Resources, LLP
600 Shields Avenue
Butte, Montana
USA, 59701

Dear Mark,

Re: Review of the PMF Estimate for the Yankee Doodle Tailings Impoundment

BACKGROUND AND SUMMARY

Montana Resources, LLP (MR) is required by State law (MCA 82-4-376) to prepare a design document to support the proposal to expand the Yankee Doodle Tailings Impoundment (YDTI). The design document must include an evaluation of a design storm event for operations and closure conforming to engineering best practices for the type of facility proposed, including:

- A rationale for the selection of the design storm event
- The magnitude of the design storm event
- The magnitude of the runoff generated by the design storm event to and around the impoundment, and
- Evidence that the dynamic nature of climatology was considered.

The legislation indicates that for the expansion of an existing tailings storage facility of this size, the design must store or otherwise manage the Probable Maximum Flood (PMF) event with sufficient freeboard for wave action in addition to the maximum operating water level of the facility, or that the expansion does not reduce the tailings storage facility's ability to store or otherwise manage the original facility design storm or flood events.

A design storm event evaluation was completed that considered historical storm event analyses and several alternative durations and methods for determining the PMF. The selected design storm event was the 24 hour Probable Maximum Precipitation (PMP) combined with complete melt of the 1 in 100 year snowpack, and assuming full failure of the upstream reservoirs. The evaluation determined the PMF runoff volume to be 19,000 acre-ft, and concluded that this value was suitably conservative for determining the storm storage allowance for the YDTI.

The potential for climate change was addressed by increasing the PMF event for the closure phase by 15%, according to generally accepted engineering procedures (APEGBC, 2012). No adjustment was made to the PMF estimate for operations because of the relatively short period of operations. The PMF runoff volume for closure was increased to 20,000 acre-ft.

DESIGN STORM EVENT EVALUATION

The existing YDTI is not equipped with an emergency spillway during operations but rather relies on storage to manage the Inflow Design Flood (IDF). The IDF is defined by FEMA (2013) as "The flood hydrograph entering the reservoir that is used to design and/or modify a specific dam and its appurtenant works; particularly for sizing the spillway and outlet works, and for evaluating maximum storage, height of dam, and freeboard requirements." State law (MCA, 2015) prescribes that for the expansion of the YTDI, the IDF should be the PMF. There is no strict regulatory standard specifying how the PMF should be determined, other than that it should involve the PMP, with consideration of coincident snowmelt, if applicable.

The most recent design flood evaluation for the YDTI was completed in 2013 as part of the Failure Modes Analysis Information Summary Report (KP, 2013). The report summarized three different estimates of the PMF volume that had been developed for the YDTI over the years, as presented in Table 1, and suggested that increasing the design flood storage requirement from 16,500 acre-ft to 22,000 acre-ft may be appropriate.

Table 1 Previous PMF Volume Estimates

Study Date	PMF Basis	Basin Area	Runoff Volume	Additional Volume	Total PMF Volume	Comment
1981 (IECO)	**24 hour PMP + 30 day melt of 2 x mean annual snowpack** 24 hour PMP = 9.5 in 30 day melt of 2 x mean annual snowpack = 16.2 in net snowmelt = 16.2 in - 5.7 in (infiltration and evapotranspiration) = 10.5 in	total = 8,832 acres pond = 768 acres	9.5 in x 8832 acres + 10.5 in x (8832-768) acres = 14,048 acre-ft	Failed reservoirs 540 acre-ft	14,820 acre-ft	There appears to be a slight error in the calculated volume, but it is immaterial.
2010 (MR)	**24 hour PMP + 30 day melt of 2 x mean annual snowpack** 24 hour PMP = 16.5 in net snowmelt = 10.5 in	not available	15,960 acre-ft	Failed reservoirs 540 acre-ft	16,500 acre-ft	A substantial increase in the PMP resulted in only a minor increase in the PMF volume. Using the 1981 areas would result in a volume of 19,740 acre-ft.
2012 (KP)	**24 hour PMP + complete melt of 10 yr snowpack** 24 hour PMP = 14.4 inches 10 yr snowpack = 18 inches	total = 7,907 acres pond = 1,536 acres	21,460 acre-ft	Failed reservoirs 540 acre-ft	22,000 acre-ft	No distinction was made between snowmelt on the basin and on the pond. Assumed 100% runoff.

NOTES:

1. IECO = International Engineering Company Inc.; MR = Montana Resources; KP = Knight Piésold Ltd.
2. All snowpack values are provided as snow water equivalent (SWE).

The three estimates in Table 1 all followed the commonly accepted deterministic procedure of calculating the PMF based on the 24 hour PMP plus snowmelt. However, the estimated PMF volumes are substantially different due to differences in estimated basin areas and how the PMP and snowmelt values were determined. For instance, the PMP for the 1981 analysis was determined according to procedures established by NOAA and published in its Hydrometeorological Report No. 43 (HMR 43) (USWB, 1966), while for the 2010 and 2012 analyses it was determined according to procedures in Hydrometeorological Report No. 57 (HMR 57) (Hansen et al., 1994), which supersedes HMR 43. The 2010 and 2012 PMP values are different because of differences in how the PMP isohyetal map in HMR 57 was interpreted. For the snowmelt values, the 1981 and 2010 analyses used a different criterion than the 2012 analysis; they used twice the mean annual snowmelt less monthly infiltration and evapotranspiration, while the 2012 analysis used the melt of the 10 year snowpack.

There is a lack of agreement in professional practice about the appropriate duration of the PMP and the appropriate magnitude of the snowmelt that must be considered in determining the PMF. The duration of the PMP event is of concern since longer durations generally produce greater inflow volumes, and without a spillway and its associated discharge capability, this equates to greater pond volumes. A 48 hour PMP has a greater depth than a 24 hour PMP, and a 72 hour PMP has a greater depth than a 48 hour PMP, but there is no clear directive as to what storm duration is most appropriate. Similarly, the magnitude of the snowpack is of concern because a larger snowpack generally produce larger melt volumes.

The intent of adopting the PMF as the IDF is to provide a design storm volume that is so great that it will never be exceeded, but not so great as to require excessive storage capacity. Historical rainfall and streamflow datasets were evaluated in this assessment in an effort to address the question of design storm adequacy and reasonableness. Probabilistic estimates were compared with the deterministic PMF flood volume estimates of

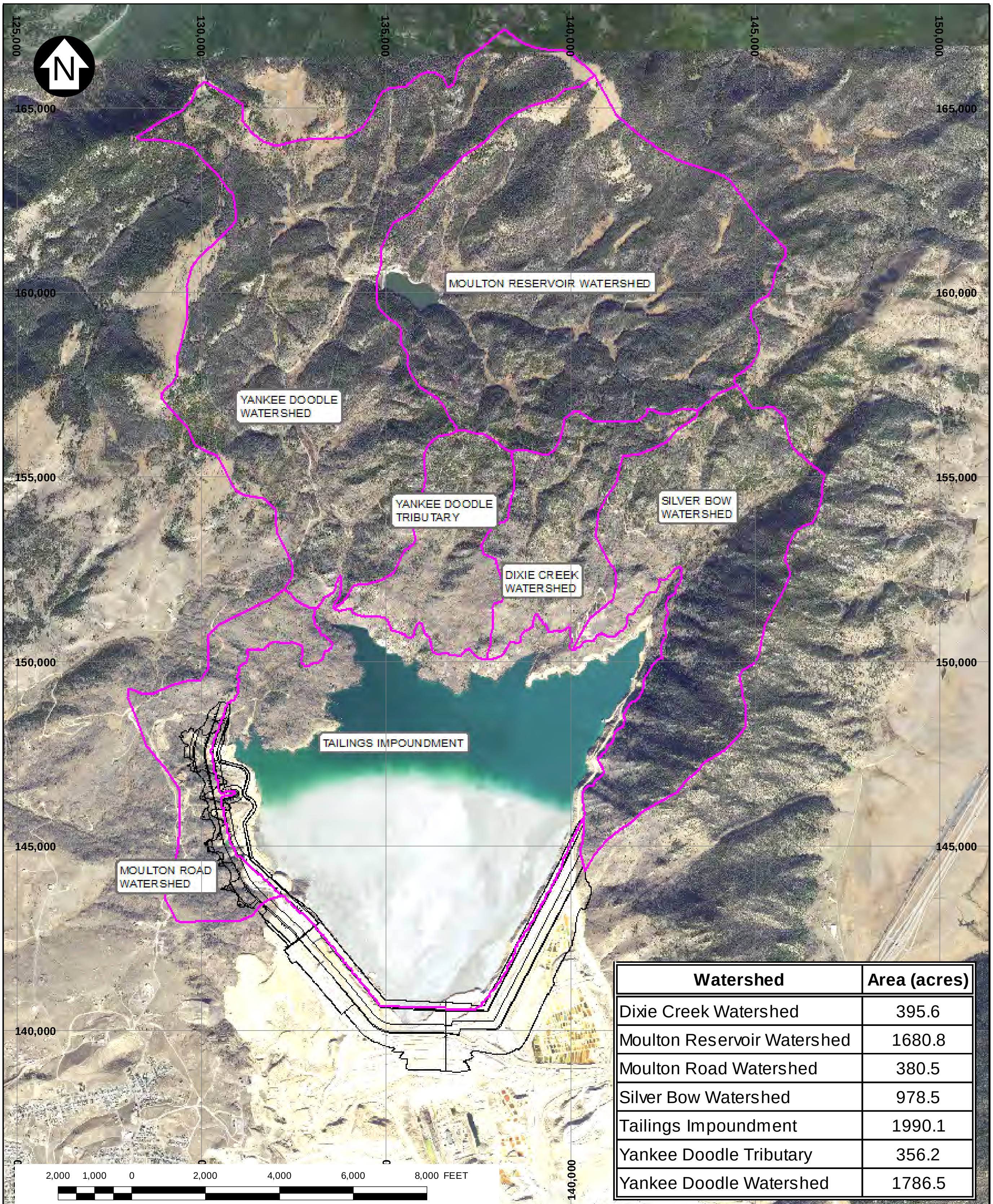
24 and 72 hour durations to see if there was any consistency in the values. This methodology was adopted to provide some historical context to the theoretical and deterministic PMP/PMF values. The computed values are summarized in Table 2, with all design storm volumes assuming 100% runoff from all areas. The catchment areas used in the analysis are delineated on Figure 1.

A brief description of each case is as follows:

- Case 1 is the 2012 PMF analysis by KP. It resulted in a design storm volume of 22,000 acre-ft. The snowpack estimate has since been updated (see Case 2) and the 2012 analysis is now considered obsolete.
- Case 2 includes an updated assessment of the 10 year snowpack snow water equivalent. A detailed review of the regional SNOTEL snowpack records (NRCS, 2015) and their relevance to the project site, particularly with regards to elevation, resulted in a substantially lower 10 year snow pack estimate and a corresponding reduction in the PMF volume.
- Case 3 uses the 100 year snowpack, rather than the 10 year snowpack, since the 100 year value is more commonly used. The 100 year value was estimated on the basis of the updated snowpack assessment, and it resulted in a 17% increase in the PMF volume relative to Case 2.
- Cases 4 and 5 use the 72 hour PMP rather than the 24 hour PMP, and are directly comparable to Cases 2 and 3. As discussed previously, the 72 hour PMP is sometimes used for determining storm freeboard for high hazard dams, but there is no strong rationale for its use in preference to the 24 hour PMP, other than it is more conservative from a dam safety perspective. Use of the 72 hour PMP results in an approximate 15% to 20% increase in the design storm volume over use of the 24 hour PMP.
- Case 6 represents an alternative method for computing the IDF, which emphasizes the snowmelt component as opposed to the rainfall component. The Canadian Dam Association's (CDA) Dam Safety Technical Bulletin: Hydrotechnical Considerations for Dam Safety (2007), suggest that the Spring PMF should be computed as the maximum of two cases:
    - *PMF computed with the spring PMP and snow accumulation with frequency of 1/100 year.*
    - *PMF computed with the Probable Maximum Snow Accumulation and a rainstorm with a frequency of 1/100 year.*

Note that there are no common methodologies for estimating the probable maximum snow accumulation, so the 10,000 year snowpack was computed as a surrogate. The design storm volume from this event is notably lower than those determined using the PMP.

- Case 7 represents a long duration low probability rainfall event. Despite the long duration, the storm volume amounts to only 30% to 40% of the PMF based estimates.
- Case 8 represents a long duration low probability runoff event. This runoff was calculated from the most applicable regional historical streamflow records available, and the range represents values from different streams. The values, which are all from the spring freshet period, are relatively low compared to the rainfall and snowpack values, and thereby suggest that abstraction and evaporation losses are extensive during extended high flow periods and that snowpack coverage is likely quite variable (primarily with elevation) throughout the regional watersheds.
- Case 9 represents the amount of runoff that could be expected in a year, with only a 1 in 1,000 year probability of occurrence. The upper end of the estimated range of this very unlikely event is 50% to 65% of the PMF based estimates.
- Case 10 represents the amount of precipitation that could be expected in a year, on average, and it assumes that 100% of it is converted into runoff and collects in the YDTI, which is not possible because of initial abstraction and evapotranspiration losses. This volume amounts to 40% to 50% of the PMF based estimates.
- Case 11 represents the amount of runoff that could be expected in a year, on average. Even the upper end of the regional range amounts to only 20% to 30% of the PMF based estimates.



Watershed	Area (acres)
Dixie Creek Watershed	395.6
Moulton Reservoir Watershed	1680.8
Moulton Road Watershed	380.5
Silver Bow Watershed	978.5
Tailings Impoundment	1990.1
Yankee Doodle Tributary	356.2
Yankee Doodle Watershed	1786.5

LEGEND:

CATCHMENT

FUTURE EMBANKMENT EXTENTS

NOTES:

1. BASE MAP: 2015 ORTHOIMAGERY PROVIDED BY MONTANA RESOURCES; MICROSOFT BING MAPS.

2. COORDINATE GRID IS IN FEET.
COORDINATE SYSTEM: ANACONDA MINE GRID.

3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:45,000 FOR 8.5x11 (LETTER) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	07MAR'16	ISSUED WITH LETTER	JGC	CAC	DDF

MONTANA RESOURCES, LLP

YANKEE DOODLE TAILINGS IMPOUNDMENT

REVIEW OF PMF ESTIMATE
CATCHMENT AREAS

Knight Piésold CONSULTING

P/A NO. VA101-126/12

REF NO. VA15-03210

FIGURE 1

REV 0

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Table 2 Comparison of Design Storm Volumes

Type	Case	Design Storm Basis	Basin Area	Runoff Volume	Additional Volume	Design Storm Volume
PMF Volumes	1	**24 hr PMP + complete melt of 10 yr snowpack (2012 analysis)** 24 hr PMP = 14.4 inches 10 yr snowpack = 18 inches	total = 7,907 acres	21,460 acre-ft	Failed reservoirs 540 acre-ft	22,000 acre-ft
	2	**24 hr PMP + complete melt of 10 yr snowpack (updated analysis)** 24 hr PMP = 14.4 inches 10 yr snowpack = 10.2 inches	total = 7,600 acres	15,580 acre-ft	Failed reservoirs 540 acre-ft	~16,000 acre-ft
	3	**24 hr PMP + complete melt of 100 yr snowpack** 24 hr PMP = 14.4 inches 100 yr snowpack = 14.6 inches		18,360 acre-ft	Failed reservoirs 540 acre-ft	~19,000 acre-ft
	4	**72 hr PMP + complete melt of 10 yr snowpack** 72 hr PMP = 19.7 inches 10 yr snowpack = 10.2 inches		18,940 acre-ft	Failed reservoirs 540 acre-ft	~19,500 acre-ft
	5	**72 hr PMP + complete melt of 100 yr snowpack** 72 hr PMP = 19.7 inches 100 yr snowpack = 14.6 inches		21,720 acre-ft	Failed reservoirs 540 acre-ft	~22,000 acre-ft
	6	**24 hr 100 yr rainfall + complete melt of 10,000 yr snowpack** 24 hour 100 year rainfall = 2.5 inches 10,000 yr snowpack = 23.0 inches		16,150 acre-ft	Failed reservoirs 540 acre-ft	~17,000 acre-ft
Historical Probability Volumes	7	**1,000 yr 30 day rainfall** P = 9.2 inches		5,830 acre-ft	Failed reservoirs 540 acre-ft	~6,500 acre-ft
	8	**1,000 yr 30 day unit runoff** R = 1.2 to 7.5 inches (range of regional values)		760 acre-ft to 4,750 acre-ft	Failed reservoirs 540 acre-ft	~1,500 acre-ft to ~5,500 acre-ft
	9	**1,000 yr annual unit runoff** R = 5.3 to 16.0 inches (range of regional values)		3,360 acre-ft to 10,130 acre-ft	Failed reservoirs 540 acre-ft	~4,000 acre-ft to ~11,000 acre-ft
	10	**Mean annual precipitation** P = 12.8 inches		8,110 acre-ft	Failed reservoirs 540 acre-ft	~8,500 acre-ft
	11	**Mean annual unit runoff** R = 2.5 to 6.9 inches (range of regional values)		1,580 acre-ft to 4,370 acre-ft	Failed reservoirs 540 acre-ft	~2,000 acre-ft to ~5,000 acre-ft

DESIGN STORM EVENT SELECTION

These comparisons indicate that the PMF based volume estimates are extremely large relative to historical probability based rainfall and runoff event volumes, even for events of very long duration. For instance, the PMF volume for Case 3 is approximately equal to three times the volume of the 1 in 1,000 year 30 day rainfall and more than double the volume of the mean annual precipitation. It is therefore reasonable to conclude that the Case 3 volume, which was computed according to the essential de facto basis for estimating a PMF, provides a sufficiently conservative storm freeboard volume for the YDTI, provided the YDTI continues to be operated without an emergency spillway.

The selected design storm event was based on the 24 hour PMP combined with complete melt of the 1 in 100 year snowpack, and the assumption that the upstream reservoirs fail. The runoff volume for the PMF is 19,000 acre-ft. It is worth noting that although this volume is substantially less (3,000 acre-ft) than the previous design storm volume of 22,000 acre-ft, the reduction is not due to a lessening of the design criteria, but rather due to an update in the analysis of the snowpack estimate and a more accurate determination of the drainage area. In fact, the design criterion associated with this volume is more stringent than that used previously, since it involves the 100 year snowpack rather than the 10 year snowpack.

ADDRESSING CLIMATE VARIABILITY IN CLOSURE

Climate variability is considered in the determination of the design storm volume by using historical regional climate and snowpack records as the basis of the determination. However, the potential effects of climate change are not directly considered since historical records do not necessarily represent possible future conditions.

The general scientific consensus is that climate change is likely to cause temperatures and the frequency and intensity of rain storms to increase in Montana (IPCC, 2007), which for the YDTI translates into an increased likelihood of both heavy precipitation events and smaller winter snowpack depths. These two effects are directly relevant to the determination of the design storm volume, since they correspond to a possible increase in the PMP and a possible decrease in the snowpack runoff. It is not possible to quantify these effects with any confidence; however, since they are offsetting and because the design storm volume has considerable uncertainty, it seems reasonable to conclude that no climate change adjustment need be applied to the design storm volume.

Alternately, if a more conservative approach is desired during the closure phase of the project, it is recommended that the PMP component of the design storm volume be increased by 15%, as this is a generally recommended factor for accounting for climate change effects on peak flow estimates (APEGBC, 2012). This change would result in an increase of the Case 3 volume by increasing the 24 hr PMP from 14.4 inches to 16.6 inches, with a respective increase in storm storage volume of 1,000 acre-ft and a corresponding total storm storage volume of 20,000 acre-ft.

We trust that this information is suitable for your purposes. Please contact the undersigned if you have any questions or concerns.

Yours truly,
Knight Piésold Ltd.

PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — J. G. CATHCART

Prepared: Mar 10, 2016
Jaime Cathcart, Ph.D., P.Eng.
Specialist Hydrotechnical Engineer | Associate

Reviewed:
Daniel Fontaine, P.Eng.
Senior Engineer

Approval that this document adheres to Knight Piésold Quality Systems:

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APPENDIX B2

Review of PMF Estimate in Light of Recommendations in the Extreme Storm Working Group Summary Report

(Pages B2-1 to B2-3)

March 7, 2017

File No.:VA101-00126/16-A.01
Cont. No.:VA17-00410

FS 64925
EMS 550121
OHS 550122

Mr. Mark Thompson
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Dear Mark,

Re: Review of PMF Estimate in Light of Recommendations in the Extreme Storm Work Group Summary Report

Introduction

The Montana Department of Natural Resources and Conservation (DNRC) Dam Safety Program issued an Extreme Storm Working Group Summary Report (ESWGSR) in December 2016 that presented the results of "a comprehensive review of the state of the practice for computing hydrology for dams." This report was issued after the Inflow Design Flood (IDF) was computed for the Yankee Doodle Tailings Impoundment (YDTI) for Montana Resources, LLP (MR). It was considered prudent at this time to evaluate the adequacy of the Probable Maximum Flood (PMF) estimate in light of the recommendations in the ESWGSR. The following summarizes the results of that evaluation.

PMF for the YDTI

The design storm evaluation for future development of the YDTI was presented in letter VA15-03210 (KP, 2016), which is included as Appendix B1 of the Design Basis Report (KP, 2017a). The IDF for the YDTI is the PMF, and was computed as the runoff volume from the 24 hour Probable Maximum Precipitation (PMP) combined with complete melt of the 1 in 100 year snowpack, and assuming full failure of the upstream reservoirs. The PMP used to calculate the IDF was determined following the standard of practice established in Hydrometeorological Report (HMR) No. 57, which is one of a series of HMR reports that were developed by the US Army Corps of Engineers (USACE). HMR 57 constitutes the current standard basis for determining PMP values in the Pacific Northwest of the United States.

The PMP was computed according to the procedure specified in HMR 57 (USACE, 1994). The 24 hr PMP of 14.4 inches was computed by adjusting the all season 24 hr PMP value of approximately 17 inches for Butte, Montana (from Map 3 – SE, an isohyetal map of PMP) by an April/May seasonal factor of 85%. The seasonal factor was interpreted for Butte from Figure 15.5 of HMR 57. Selection of the April/May seasonal period produces the maximum possible PMF runoff depth from the seasonal PMP and snowmelt combined.

Extreme Storm Working Group Summary Report

The summary report states that "The Group concluded that HMRs continue to provide the best information available and are a reasonable means for computing PMP depths in Montana for evaluating the capacity of existing dams to pass the IDF."However, it also states that "For design of new, or rehabilitation of existing, high hazard dams with significant downstream risk, a site specific PMP should be considered."

KP has considered whether a site specific PMP is necessary since the embankment for the YDTI is considered high hazard with a significant downstream risk. We have concluded that the current PMP estimate based on HMR 57 is appropriate for the design basis, and likely larger than what would be determined by a site specific

PMP analysis. Accordingly, derivation of a site specific PMP is not warranted. This conclusion is based on the following:

- The PMF flood volume, which is the result of the HMR 57 derived PMP combined with the 100 year snowpack, is extremely large. The discussion in KP letter VA15-03210 presents this flood volume in the context of extremely improbable climatic and runoff events, such as the 24 hr 100 year rainfall plus complete melt of the 10,000 year snowpack or the 1,000 year 30 day rainfall, and demonstrates the enormity of the PMF flood volume.
- The discussion of site specific PMP values in the ESWGSR suggests that a site specific PMP is likely to be smaller than an HMR based PMP value. This is evident in the following text: "As a consequence of failure increases (e.g., the design precipitation depth approaches the PMP), the engineer may determine that a site specific PMP is warranted...Factors such as the consequence of failure, the potential for a PMP based IDF to limit the number of alternatives that may be available at a specific site, and the potential for a PMP based IDF to result in a configuration that exceeds available funding shall be considered when evaluating the need for a site specific PMP study." These statements imply that a site specific PMP should be particularly considered when an HMR derived PMP results in an IDF that is challenging to accommodate.
- A review of various site specific PMP documents (Tomlinson, 2012; USNRC, 2015; AWA, 2014) indicates that site specific PMPs are generally smaller than HMR based PMPs.
- The YDTI is able to accommodate the derived PMF without any undue challenges, so the costs and potential difficulties associated with deriving a potentially lower PMP value are not merited at this time.

We trust that this discussion demonstrates that the PMF estimate for the YDTI is consistent with the recommendations presented in the Montana DNRC's Extreme Storm Working Group Summary Report.

Yours truly,
Knight Piésold Ltd.

PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — J. G. CATHCART

March 7, 2017

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Approval that this document adheres to Knight Piésold Quality Systems:

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