SOUTHERN PACIFIC RESOURCE CORP.




STP MCKAY THERMAL PROJECT - PHASE 2
HYDROLOGY ASSESSMENT

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nhc
northwest hydraulic consultants

STP McKAY THERMAL PROJECT – PHASE 2 HYDROLOGY ASSESSMENT

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EXECUTIVE SUMMARY

The regional and local baseline surface water hydrology for the STP McKay Thermal Project – Phase 2 was described and mapped and historical climate and streamflow data were evaluated. Local water levels, streamflows, channel geometry and snow depths were measured. Flow variability was evaluated from the regional data and from an Hydrologic Simulation Program Fortran (HSPF) model calibrated to regional data and validated with local data.

The hydrology evaluation assessed a baseline development case consisting of existing and approved developments and an application development case including the development of the Phase 2 Project. Compared to pre-development conditions, baseline developments were found to increase annual runoff volumes by up to 9.0% in smaller watersheds. The application development is expected to affect some smaller watersheds but not increase annual runoff relative to the baseline development. Average peak flows may decrease as much as 12% in some areas and there may be small changes in the timing of peak flows, with peaks typically occurring slightly earlier. Changes in magnitude of annual minimum flow rates appear to be large in some of the watersheds because they are relative to very small flows. In most of the watersheds the net effect will be less years with zero flow.

Annual peak water levels and surface areas in the streams and ponds may change slightly due to changes in annual peak flow. These changes will be imperceptible compared to natural variability. Minimum water levels and surface areas may be slightly higher due to increased minimum flows; however, zero flows will still occur in most of these small watersheds.

Channel morphology and sediment concentrations will not change due to the application development case because changes to the flow regime are small, and because road and utility corridor stream crossings will be designed to minimize the disturbance to the channels.

The effects of the project will be mitigated by design and by reclamation. The surface disturbances will be set back from channels and designed to discharge runoff into undisturbed vegetated areas, rather than to drain directly to existing channels. Stream crossings will be designed and constructed to minimize the impact on the streams. Reclamation activities will be initiated when feasible. Upon project completion, the entire project disturbance will be reclaimed and the landscape restored to be similar to the pre-existing conditions.

Runoff volumes from the plant site runoff ponds will be monitored to determine how much runoff is pumped into the natural environment. Sediment monitoring will be carried out during the construction of stream channel crossings to ensure that sediment from construction sites do not adversely impact the downstream channels.

CREDITS AND ACKNOWLEDGEMENTS

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1 Introduction

Southern Pacific Resource Corp. is proposing to expand its existing STP McKay Thermal Project from 12,000 barrels per day (bpd) to 36,000 bpd. The Project is located about 45 km northwest of the community of Fort McMurray (Figure 1). The STP McKay Thermal Project – Phase 2 (the Project) will use the existing access road which was built to provide access for the STP McKay Thermal Project – Phase 1.

This report provides a summary of the baseline hydrologic characteristics in the vicinity of the Project, and addresses the impacts of the existing and approved developments and proposed Phase 2 Project on the surface water hydrology. Included in this evaluation is an assessment of the regional meteorological and hydrologic characteristics, the local hydrography, a brief description of the development plan, and an assessment of the impacts of the development on the streamflows, water levels and channel characteristics of the affected watersheds.

2 Baseline Setting

2.1 LOCATION

The STP McKay Thermal Project – Phase 2 is located in Rge 14-15, Twp 91 west of the 4th Meridian. Figure 1 shows the location of the Project and the relevant climate and hydrometric stations in north-eastern Alberta. The Project is located in the MacKay River watershed along the mainstem of the MacKay River near the mouth of Thickwood (Birchwood) Creek

The Project lies within the Central Mixedwood subregion of the Boreal Forest of northern Alberta. This low-relief plain is relatively poorly drained. Organic soils are dominant in the region. Well drained areas consist of mixed-wood forests of deciduous and coniferous species. The most abundant trees are trembling aspen and balsam poplar with white spruce, black spruce, and balsam fir also occurring. Poorly drained areas consist of wetlands including bogs, fens, swamps and marshes which contain tamarack and black spruce.

The hydrology assessment focused on 21.75 sections identified by Southern Pacific Resources as areas of potential development. The Local Study Area (LSA) for surface water hydrology was defined as these sections. The boundary of the LSA is shown in Figure 2.

The Regional Study Area (RSA) for surface water hydrology is defined as the area in which stream flows and water levels could be affected by development of the Project. The RSA is composed of the LSA and the portions of Tributary M16 and the MacKay River between the LSA and the confluence of the two streams as shown in Figure 3. The RSA is limited to this area because potential impacts are expected to be negligible in the MacKay River downstream of this confluence.

2.2 CLIMATE

Climate influences many hydrologic characteristics. Over the long term, the climate and local surficial geology determine the vegetation in the area. Surficial geology and vegetation affect the runoff coefficients and evapotranspiration rates in the area. On a shorter time scale, the magnitude of the winter snowpack and severity of summer rain events affect the severity of spring and summer runoff events.

Environment Canada (EC) provides climate data for three stations in the vicinity of the Project: Fort McMurray Airport (3062693), the Legend LO station (3073792), and Livock LO (3063930). The Fort McMurray station provides a long term continuous climate record for the area while the other two stations provide shorter term summer air temperatures and precipitation data.

EC operates a long term climate station located at Fort McMurray Airport (3062693) about 45 km southeast of the Project (Figure 1) at an elevation of 369 m, which is somewhat lower than the mean elevation in the LSA of 465 m. This station provides a long term continuous climate record for the area, reporting measurements as far back as 1944. This station reports air temperatures and precipitation, as well as rainfall intensity, wind speed and direction, atmospheric pressure, hours of bright sunshine, and humidity.

The Legend LO station (3073792) is located 75 km northwest of the LSA (Figure 1). This station provides air temperatures and precipitation from 1962 to present for the period from May to August. The elevation of this station of 911 m is much greater than the mean elevation in the LSA of 465 m.

Another station, Livock LO (3063930), is located 75 km southwest of the LSA (Figure 1). This station provides air temperatures and precipitation from 1966 to present for the period from June to August. The elevation of this station is 579 m, which is somewhat higher than the mean elevation in the LSA of 465 m.

2.2.1 AIR TEMPERATURE

Air temperature is a significant climatic variable in the hydrologic cycle because it determines the relative proportion of rain and snow within the total annual precipitation and the start and severity of snowmelt runoff in the spring. The monthly maximum, mean, and minimum temperatures at Fort McMurray A, Legend LO and Livock LO for the climate normal period between 1961 and 1990 are summarized in Table 1 and the mean temperatures are shown in Figure 4. This period was selected for comparison because the more recent climate normals from 1971 to 2000 are not available for Legend LO and Livock LO. The normal air temperatures at Fort McMurray for the 1971 to 2000 period are typically within 1°C of the 1961 to 1999 temperatures.

At Fort McMurray, the mean monthly temperature ranges from 17°C in July to -20°C in January. The extreme monthly temperatures range from 23°C in July to -25°C in January. The mean daily air temperature drops below freezing in November and rises above freezing in April.

Summer air temperatures at Legend LO station are generally 2- 3°C lower than those of Fort McMurray, with temperatures at Livock LO typically falling between the other two sites. The lower temperatures at Legend and Livock LO are likely due to the higher elevations of these sites. Air temperatures in the vicinity of the LSA are expected to fall between those at Fort McMurray and those at Livock LO.

Table 1 Summary of monthly temperature characteristics for the climate normal period from 1961 to 1990

Month	Monthly Average Temperatures								
	Fort McMurray A			Legend LO			Livock LO		
	Max (°C)	Mean (°C)	Min (°C)	Max (°C)	Mean (°C)	Min (°C)	Max (°C)	Mean (°C)	Min (°C)
Jan	-15	-20	-25						
Feb	-9	-15	-21						
Mar	-1	-8	-15						
Apr	9	3	-4						
May	17	10	3	13	8	2			
Jun	22	15	8	18	12	7	19	13	8
Jul	23	17	10	19	14	9	21	16	10
Aug	22	15	9	18	13	8	20	14	8
Sep	15	9	3						
Oct	8	3	-2						
Nov	-5	-9	-14						
Dec	-13	-17	-22						
Annual	**6**	**0**	**-6**						

2.2.2 PRECIPITATION

Precipitation is the most important climate variable that affects the hydrologic cycle. Winter snowfall influences the magnitude and duration of the spring snowmelt flows, while summer rain events produce summer peak flows. Precipitation from previous events also affects the amount of runoff from a rainfall event.

The average monthly precipitation for the climate normal period from 1961-1990 for Fort McMurray, Legend LO and Livock LO are shown in Figure 5 and listed in Table 2. Both Legend LO and Livock LO have about 20% more precipitation than the Fort McMurray station in June and July but have precipitation similar to Ft. McMurray in May and August. The winter precipitation is relatively constant from month to month, averaging about 20 mm per month at Fort McMurray. Generally, all of the precipitation between November and March falls as snow and is stored on the ground until April and May, when the snow melts and snowmelt runoff is produced.

Table 2 Summary of monthly precipitation characteristics for the climate normal period from 1961 to 1990

Month	Monthly Mean Precipitation			Daily Extreme Precipitation		
	Fort McMurray A (mm)	Legend LO (mm)	Livock LO (mm)	Fort McMurray A (mm)	Legend LO (mm)	Livock LO (mm)
Jan	20			16		
Feb	16			13		
Mar	17			30		
Apr	23			27	18	13
May	41	44		39	41	38
Jun	64	75	82	46	46	69
Jul	79	98	92	52	61	62
Aug	72	71	68	95	53	94
Sep	51			61	41	43
Oct	32			29	16	
Nov	26			16	3	
Dec	23			23		
Annual	**465**					

The variations in annual precipitation (Nov-Oct) for Ft. McMurray are shown in Figure 6. The mean annual precipitation for this entire 1945-2010 precipitation record is 435 mm, which is slightly less than the mean annual precipitation for the climate normal period from 1961-1990. The maximum annual precipitation of 683 mm occurred in 1973, while the minimum annual precipitation of 238 mm occurred in 1998.

The variation in winter precipitation (November to April) is also shown in Figure 6. The maximum of 228 mm (water equivalent) occurred 1951 and the minimum of 58 mm occurred in 1949. The average winter precipitation is 116 mm.

Extreme daily precipitation data for all three stations for the climate normal period from 1961-1990 are also summarized in Table 2. The greatest monthly precipitation occurs in July, averaging about 79 mm at Fort McMurray, 98 mm at Legend LO, and 92 mm at Livock LO. Based on elevation, monthly precipitation in the vicinity of the Project is expected to fall between that of Fort McMurray and Livock LO.

The nearest and most representative climate station, for which rainfall intensity-duration statistics are available, is Fort McMurray. The statistics for this station are summarized in Table 3. The 100-year 24-hour rainfall of 93.5 mm is similar to the extreme daily precipitation for the station while the 10-year 24-hr rainfall of 63.4 mm is about two-thirds of this value.

Table 3 Rainfall intensity-duration-frequency statistics for Fort McMurray

Duration	Rainfall (mm)					
	2-year	5-year	10-year	25-year	50-year	100-year
5 minutes	5.1	7.4	8.9	10.8	12.3	13.7
10 minutes	7.0	9.9	11.8	14.1	15.9	17.7
15 minute	8.3	11.7	14.0	16.8	18.9	21.0
30 minutes	10.6	15.3	18.4	22.4	25.3	28.3
1 hour	12.8	17.6	20.9	24.9	28.0	30.9
2 hour	16.6	22.7	26.8	31.9	35.8	39.5
6 hours	25.0	34.8	41.3	49.6	55.7	61.7
12 hours	31.7	44.8	53.5	64.4	72.5	80.6
24 hours	39.3	53.8	63.4	75.6	84.6	93.5

2.2.3 EVAPORATION

Evaporation causes lake levels and soil moisture levels to drop during the open water season. Evaporation can be measured by evaporation pans or estimated by changes in lake levels. Lake evaporation tends to be about 70% of the measured pan or potential evaporation due to the higher humidity over the lake, although this percentage varies substantially with location (Linsley, et al, 1982). Evaporation from small ponds may be higher than lake evaporation and may approach the potential evaporation measured by evaporation pans.

Lake evaporation can be calculated from consideration of air temperatures, solar radiation, atmospheric pressure, and humidity; however, the first two parameters are most significant, especially in shallow lakes. Alberta Environment (1999) calculated potential and lake evaporation for Fort McMurray from 1972 to 1995. The average annual lake evaporation for this period of 578 mm is about 70% of the average annual potential evaporation of 823 mm for the same period.

Evapotranspiration, the combination of evaporation and transpiration from vegetated land, tends to be lower than lake evaporation due to the limitation of soil moisture availability. The median annual evapotranspiration for Fort McMurray is estimated to be about 288 mm (Alberta Environment, 1999), which is about 50% of the lake evaporation.

Figure 7 shows the mean evaporation and evapotranspiration for each month. The majority of evaporation occurs from May to August, with the highest evaporation rates occurring in July.

2.3 STREAMFLOW

Evaluating the magnitude and variability of stream flows is a major component of a hydrologic assessment. The evaluation of streamflow includes an analysis of runoff coefficients and extreme flows in the region and an assessment of the local hydrography and channel characteristics.

2.3.1 RUNOFF COEFFICIENTS

Water Survey of Canada (WSC) maintains a number of streamflow gauges in the region. The locations of these gauges are shown in Figure 1 and a summary of their characteristics is given in Table 4. The gauges provide a record of discharges for streams with drainage areas ranging from 165 km^2 for the Beaver River above Syncrude (07DA018) to 5570 km^2 for the MacKay River near Fort McKay (07DB001). The period of record begins in 1972. Four of the gauges listed in Table 4 are currently operated seasonally from March to October with discharge data published to the end of 2009 or 2010. Most of the gauges were operated annually for a period of time before being operated seasonally, so there are some historical winter flow data available. Three gauges were only operated for a short periods between 1975 and 1979.

Mean flows for each of the WSC streamflow gauges with nine or more years of record are summarized in Table 4. The mean flow ranged from 0.39 m^3/s for Unnamed Creek near Fort McKay to 13.7 m^3/s for MacKay River near Fort McKay. The trend shown in Figure 8 indicates that mean flow is directly proportional to drainage area.

Annual runoff coefficients define the fraction of annual precipitation which leaves the basin as streamflow each year. As presented in Section 2.2.2, annual precipitation records are only available for Fort McMurray so this data was used for the runoff analysis. Annual precipitation was calculated from November to October each year to associate the accumulated winter snowfall with the runoff in the following spring and summer.

Runoff coefficients were calculated from the streamflow records for the gauges with nine or more years of record listed in Table 4. To provide a meaningful comparison of runoff from the various basins, the seasonal runoff from each basin was calculated from the streamflow for the period from March to October, since winter flow data is only available for portions of the periods of record at most of the gauges. When winter streamflow data was available, it was generally about 6% of the total annual flow so the real annual runoff coefficients may be up to 6% greater than the values provided in Table 4. The average mean seasonal runoff coefficient for the region is 0.18.

Table 4 Summary of WSC gauges in the region

Stream	Location	Gauge Number	Gauge Type	Period of Record	Drainage Area (km^2)	Mean Seasonal[1] Flow (m^3/s)	Mean Seasonal[1] Runoff Coefficient
Beaver River	Syncrude	07DA018	Continuous Seasonal	1975-1987 1988-2010	165	0.49	0.22
Thickwood[2] Creek	Fort MacKay	07DB004	Continuous	1976-1977	176		
Joslyn Creek	Fort MacKay	07DA016	Continuous Seasonal	1975-1981 1982-1993	257	0.62	0.16
Unnamed Creek	Fort MacKay	07DA011	Continuous Seasonal	1975-1981 1982-1993	274	0.39	0.10
Hartley Creek	Fort MacKay	07DA009	Continuous Seasonal	1975-1987 1988-1993	358	1.00	0.20
Dover River	Mouth	07DB002	Continuous	1975-1977	963		
MacKay River	Dunkirk River	07DB005	Seasonal	1983-1991	1010	2.46	0.16
Steepbank River	Fort McMurray	07DA006	Continuous Seasonal	1972-1986 1987-2010	1320	4.65	0.26
Muskeg River	Fort MacKay	07DA008	Continuous Seasonal	1974-1986 1987-2010	1460	3.73	0.19
Dunkirk River	Fort MacKay	07DB003	Continuous	1975-1979	1570		
Ells River	Mouth	07DA017	Continuous	1975-1986	2450	6.32	0.19
MacKay River	Fort MacKay	07DB001	Continuous Seasonal	1972-1987 1988-2009	5570	13.74	0.17

[1] seasonal data are for March to October. Annual flows are typically about 6% higher than season amounts.
[2] shown as Birchwood Creek on maps

2.3.2 EXTREME FLOWS

Extreme flows from the historical records of the nine longer term WSC gauges were evaluated. The mean annual peak flows and peak flows for a range of return periods are summarized in Table 5. The mean annual peak flows generally increase with drainage area (Figure 8).

Table 5 Summary of extreme flows for the WSC gauges in the region

Stream	Location	Drainage Area (km^2)	Mean Annual Peak Flow (m^3/s)	10-Year Peak Flow (m^3/s)	25-Year Peak Flow (m^3/s)	100-Year Peak Flow (m^3/s)	Average Minimum Monthly Flow[(a)] (m^3/s)
Beaver R.	Syncrude	165	9.42	20.7	31.7	53.6	0.046
Joslyn Cr.	Fort McKay	257	13.9	27.8	38.7	58.0	0.011
Unnamed Cr.	Fort McKay	274	5.79	10.6	14.2	20.4	0.057
Hartley Cr.	Fort McKay	358	8.46	18.6	27.3	43.7	0.010
MacKay R.	Dunkirk River	1010	21.0	47.9	72.5	121	0.038
Steepbank R.	Fort McMurray	1320	36.3	69.1	93.3	135	0.38
Muskeg R.	Fort McKay	1460	26.1	49.1	65.8	94.2	0.36
Ells R.	Mouth	2450	71.0	156	237	397	0.81
MacKay R.	Fort McKay	5570	122	258	375	593	0.43

[(a)] winter flow records incomplete

Flow frequency distributions of the annual peak flows from the gauges, normalized by mean annual peak flow, are shown in Figure 9. An adopted regional log-normal distribution based on the flow frequency distribution of the MacKay River at Fort MacKay is also shown in Figure 9. This log-normal distribution also fits the general trend of the regional data.

Average minimum monthly flows are also listed in Table 5 for the WSC gauges in the region. These minimum flows include winter flows when available. Minimum flows typically occur during the winter months but can also occur during summer dry periods. The relationship of these minimum flows with drainage area is shown in Figure 8.

2.3.3 LOCAL HYDROGRAPHY

The STP McKay Thermal Project lies within the watershed of MacKay River. The MacKay River originates to the southwest of the Project, but a large upstream tributary, the Dunkirk River, originates in the Birch Mountains to the northwest (Figure 1). The MacKay River flows from southwest to northeast through the LSA. Most of the LSA is drained by small tributaries and undefined drainages which flow directly into the MacKay River. However, portions of the watersheds of three larger tributaries including Birchwood Creek are also included within the LSA. The extents of these watersheds are shown in Figure 10.

The mapped stream network in the vicinity of the lease was divided into streams with defined channels and drainages without defined channels (Figure 11). Observations in the region indicate that the stream network obtained from 1:50,000 scale National Topographic Service (NTS) maps provides a reasonable indication of where streams with defined channels occur. The streams with defined channels shown in Figure 11 were derived from

NTS maps with some minor modifications to maintain consistency with Digital Elevation Model (DEM) data obtained from the Geobase database and with observations carried out by aerial reconnaissance. Additional hydrography obtained from 1:20,000 scale Alberta Sustainable Resource Development (ASRD) maps are shown on Figure 11 as drainages without defined channels.

The watersheds of 29 tributaries and drainages of the MacKay River were identified, ranging in size from 0.25 km^2 for watershed M10 to 309 km^2 for watershed M20. Note that the 218 km^2 drainage area for Birchwood Creek is somewhat larger than the 176 km^2 value reported by WSC because the basin boundary was modified to be consistent with the available topography. Three watersheds within the Birchwood Creek basin were also delineated.

Table 6 summarises the flood peaks for various return periods for these watersheds. The mean annual and annual minimum monthly flows for the local watersheds were estimated on the basis of the regional relationships shown in Figure 8, except for the MacKay River below the LSA which was prorated on the basis of drainage area from the WSC records at Fort McKay. The log-normal distribution adopted from the analysis of regional flow frequencies shown in Figure 9 was used to estimate the expected flood peaks in the local watersheds.

There are no large permanent lakes in the vicinity of the LSA or RSA; however, small beaver ponds exist on a number of the tributaries.

2.3.4 LOCAL CHANNEL CHARACTERISTICS

Stream measurements were taken at a total of eight sites over a period of three years from 2008 to 2011 to quantify the local flow characteristics. Sites were located on a range of streams including the MacKay River and Birchwood Creek as well as small tributaries such as B01 and M10. The locations of these measurement sites are shown in Figure 12.

Water levels, widths, depths, and velocities were measured at each site. Geodetic elevations were determined within ±0.1 m by post-processing GPS data using the Canadian Spatial Reference System (CSRS) provided by Natural Resources Canada. Velocity measurements were carried out using an electromagnetic flow meter mounted on a wading rod, except for the first set of measurements 2008 which were carried out using the float method. A summary of the flow characteristics observed at the sites is given in Table 7. Discharges estimated from the site measurements ranged from 0.001 m^3/s at Site H5 to 24.1 m^3/s at Site H1. As shown in Figure 8, the measured discharges are similar to the mean annual flows expected for these drainage areas so the observed conditions are typical for these streams and drainages.

Table 6 Summary of drainage areas and estimated flow rates for local watersheds

Watershed	Location	Drainage Area (km^2)	Mean Annual Flow (m^3/s)	Mean Annual Peak Flow (m^3/s)	10-Year Peak Flow (m^3/s)	25-Year Peak Flow (m^3/s)	100-Year Peak Flow (m^3/s)	Average Minimum Monthly Flow (m^3/s)
M01	Mouth	1.29	0.003	0.14	0.30	0.44	0.70	0.000
M02	Mouth	1.91	0.005	0.19	0.41	0.60	0.96	0.000
M03	Mouth	0.85	0.002	0.10	0.22	0.32	0.51	0.000
M04	Mouth	2.95	0.007	0.26	0.58	0.85	1.36	0.000
M05	Mouth	4.53	0.011	0.37	0.82	1.20	1.91	0.000
M06	Mouth	19.46	0.049	1.17	2.61	3.82	6.07	0.001
M07	Mouth	4.67	0.012	0.38	0.84	1.23	1.95	0.000
M08	Mouth	0.92	0.002	0.10	0.23	0.34	0.54	0.000
M09	Mouth	1.15	0.003	0.12	0.28	0.40	0.64	0.000
M10	Mouth	0.25	0.001	0.04	0.08	0.12	0.19	0.000
M11	Mouth	2.69	0.007	0.24	0.54	0.79	1.26	0.000
M12	Mouth	0.29	0.001	0.04	0.09	0.13	0.21	0.000
M13	Mouth	1.08	0.003	0.12	0.26	0.38	0.61	0.000
M14	Mouth	4.30	0.011	0.35	0.79	1.15	1.83	0.000
M15	Mouth	3.38	0.008	0.29	0.65	0.95	1.51	0.000
M16	Mouth	16.17	0.040	1.01	2.26	3.29	5.24	0.001
M17	Mouth	2.32	0.006	0.22	0.48	0.70	1.12	0.000
M18	Mouth	0.79	0.002	0.09	0.21	0.30	0.48	0.000
M19	Mouth	2.12	0.005	0.20	0.45	0.66	1.04	0.000
M20	Mouth	309.35	0.773	10.5	23.5	34.3	54.6	0.033
M21	Mouth	2.67	0.007	0.24	0.54	0.79	1.25	0.000
M22	Mouth	5.49	0.014	0.43	0.96	1.40	2.22	0.000
M23	Mouth	4.11	0.010	0.34	0.76	1.11	1.77	0.000
M24	Mouth	3.69	0.009	0.31	0.70	1.02	1.62	0.000
M25	Mouth	1.43	0.004	0.15	0.33	0.48	0.76	0.000
M26	Mouth	2.32	0.006	0.22	0.48	0.71	1.12	0.000
M27	Mouth	4.02	0.010	0.34	0.75	1.09	1.74	0.000
M28	Mouth	0.54	0.001	0.07	0.15	0.22	0.35	0.000
MacKay R.	Below LSA	3954.23	9.886	79.7	178	260	413	0.305[1]
B01	Mouth	6.11	0.015	0.47	1.04	1.52	2.42	0.000
B02	Mouth	0.59	0.001	0.07	0.16	0.24	0.38	0.000
B03	Mouth	2.11	0.005	0.20	0.45	0.65	1.04	0.000
Birchwood Cr.	Mouth	218.31	0.546	7.99	17.8	26.0	41.4	0.022

[1] prorated from WSC data on MacKay River at Ft. McKay

Table 7 Summary of flow measurements

Site	Stream	Easting (m)	Northing (m)	Date	Wetted Width (m)	Mean Velocity (m/s)	Discharge (m^3/s)	Water Level (m)
H1	MacKay R.	426682	6306200	2008-09-17	30	0.3	11	
				2008-10-07	30.8	0.22	8.45	
				2010-06-08	28.2	0.90	17.9	447.72
				2010-10-06	31	0.75	14.4	447.66
				2011-03-02	22.5	0.07	0.34	447.14
				2011-07-21	31.2	1.07	24.1	447.87
H2	Trib. M14	426739	6306140	2008-09-17	0.7	0.31	0.011	
				2008-10-07	0.84	0.11	0.008	
				2010-06-08	0.79	0.18	0.022	450.68
				2010-10-06	0.95	0.10	0.016	450.71
				2011-03-02	0.83	0.00	0	450.68
				2011-07-21	0.80	0.06	0.005	450.61
H3	Birchwood Cr.	428818	6306339	2010-06-08	6.2	0.38	1.08	458.55
				2010-10-06	5.3	0.42	0.953	458.49
				2011-03-02	5.6	0.03	0.049	458.05
				2011-07-21	5.4	0.42	0.729	458.40
H4	Trib. M20	428460	6308616	2010-06-08	10.1	0.28	1.23	437.65
				2010-10-06	5.0	0.33	0.748	437.60
				2011-03-02	5.0	0.00	0	436.98
				2011-07-21	5.7	0.43	1.15	437.58
H5	Trib. M24	431254	6310492	2010-06-08	0.56	0.10	0.006	461.11
				2010-10-06	0.55	0.07	0.004	461.01
				2011-07-21	0.55	0.05	0.001	460.97
H6	MacKay R.	425638	6305220	2008-09-17	30	0.36	10	
				2008-10-07	31.2	0.29	8.43	
H7	Trib. M06	424944	6304196	2008-09-17	1.4	0.8	0.2	
				2008-10-07	1.12	0.34	0.1	
H8	Trib. M10	425588	6305318	2008-09-17	0.35	0.38	0.006	

Water level recorders were installed at five of the sites and recorded hourly water level fluctuations from June 2010 to July 2011. These water level records were combined with the flow measurements to estimate flows at the sites over this period of record. As shown in Figure 8, the estimated peak flows are below average. The water level and discharge records for these five sites are shown in Figures 13-17 along with cross sections and photographs of the sites. Photographs and cross sections of the remaining three sites are shown in Figures 18-20.

Snow depths were also measured on March 2, 2011 near the winter road between Sites H1 and H3. The average snow depth was 0.63 m and the average water equivalent was 98 mm. This was greater than the accumulated precipitation for the winter period at Fort McMurray of 54 mm.

3 Baseline Development Case

This section describes the hydrologic impacts of the existing and approved developments in the LSA. The footprints of the developments are described and the impacts identified.

3.1 FOOTPRINT OF EXISTING AND APPROVED DEVELOPMENTS

Existing and approved developments within the LSA include the existing STP McKay Thermal Project – Phase 1 and the access road to the project. The locations of these developments are shown on Figure 21. The Project is located in Sections 7, 8, 17 and 18 of Twp 91, Rge 14, W4 and Section 12 of Twp 91, Rge 15, W4. The portion of the access road within the LSA is located in Sections 8-10 and 16, 17 of Twp 91, Rge 14, W4.

There are other minor sources of disturbances within the LSA such as cutlines for seismic exploration and access for oil and gas extraction. These types of activities are wide spread in the region and any hydrologic effects of such minor disturbances will be reflected in the regional historical streamflow data presented in the baseline hydrology study. In the subsections that follow, all references to existing development are meant to include existing as well as approved development.

3.1.1 SURFACE DISTURBANCES

Surface disturbances from the existing Project include a plant site, camps, well pads, borrow pits, soil storage areas, the utility corridor for road, powerline and pipeline right-of-ways and the access road. All of the existing disturbances are located in the MacKay River basin where a number of small watersheds are affected. Table 8 summarizes the extent of the spatial disturbances within the individual watersheds. The total disturbed area in the LSA due to the existing Phase 1 Project is 136.4 ha.

A majority of the surface disturbances, 76.7 ha, are located in watershed M05; however, a significant portion, 23.0 ha, are also located in watershed M09. The disturbances in watershed M09 make up 20% of the area of this watershed, the largest percentage of disturbance of the affected watersheds. About 0.034% of the MacKay River watershed below the LSA is disturbed. It would be impossible to measure the effect of this scale of development on any hydrologic parameter in the MacKay River.

Table 8 Summary of existing and approved disturbance areas

Watershed	Plant Site Area (ha)	Camp Area (ha)	Well Pad Area (ha)	Water Well Area (ha)	Soil Storage Area (ha)	Borrow Pit Area (ha)	Access Corridor (ha)	Total Disturbed Area (ha)	Percentage of Watershed Disturbed (%)
M05	15.7	6.6	13.3		15.1	18.5	7.5	76.7	16.9%
M07				0.2				0.2	0.0%
M08				0.8			3.0	3.9	4.2%
M09		2.5	7.8		7.7		5.0	23.0	20.0%
M10					0.9		0.5	1.4	5.6%
M12				0.1			4.3	4.4	15.2%
M14							13.4	13.4	3.1%
B01							6.8	6.8	1.1%
MacKay R. direct	0.1	0.1					6.4	6.6	
Birchwood							6.8	6.8	0.0%
MacKay R. below LSA	15.8	9.2	21.2	1.2	23.7	18.5	46.7	136.4	

Plant Site

The existing plant site is located in Section 7 of Twp 91, Rge 14 W4M (Figure 21). Most of the 15.8 ha plant site is located in watershed M05 with a small area (0.1 ha) with direct drainage into the MacKay River. The runoff from the plant site may be poorer in quality than the runoff from natural areas so it is collected and stored, and either used for process water or discharged if water quality is within parameters specified in the current Environmental Protection and Enhancement Act approval. An effective runoff coefficient of 0.0 is adopted because even if runoff leaves the plant site it will be discharged slowly well after the surrounding natural runoff so much of it will be lost to evaporation and infiltration.

Camp

A construction camp is located in watershed M05 and the operations camp is located in watershed M09 with a small area that drains directly into the MacKay River (Figure 21). The camp areas are constructed of gravel so the runoff coefficient for the camp areas is expected to be about 0.60. This is substantially higher than the natural annual runoff coefficient of 0.18. The water quality of the runoff from the camps is not expected to be substantially different from the runoff from the undisturbed land so the water will be allowed to runoff freely onto the surrounding undisturbed land.

Well Pads

As shown in Figure 21, well pads are located in watersheds M05 and M09. The surface runoff from the well pads is collected and stored away from the working area. The water quality of the runoff from the well pads is not expected to be substantially different from the runoff from undisturbed areas so it will either evaporate or be discharged after it has been determined to meet water quality guidelines. The well pads are constructed of gravel so the runoff coefficient for the well pads is expected to be about 0.60 which is substantially higher than the natural annual runoff coefficient of 0.18. However, due to the detention of the runoff, little of this water will reach the stream network so a runoff coefficient of 0.0 is adopted for these areas.

Water Source Wells

Three water source wells are currently in place with two used to supply water for the Phase 1 Project (Figure 21). The total disturbed area for the water wells is 1.2 ha (not including the access corridor), of which 0.8 ha is in watershed M08, 0.2 ha is in watershed M07 and 0.1 ha is in watershed M12. The areas for the water source wells have vegetation cleared but no ground disturbance so the runoff coefficient is estimated to be about 0.25.

Soil Storage Areas

Soil storage areas are located to the north and south of the well pads (Figure 21). The total area used for soil storage is 23.7 ha with 15.1 ha located in watershed M05, 7.7 ha in watershed M09 and 0.9 ha in watershed M10. These areas are used to store soil for future reclamation of the disturbed areas. The vegetated slopes of the soil surfaces will be steeper than the undisturbed areas so the runoff coefficient for the soil storage areas is expected to be about 0.40.

Borrow Pits

As shown in Figure 21, borrow pits are located next to the well pads within watershed M05. These borrow pits were used to supply material for construction so the bottom of the pits will be lower in elevation than the surrounding land. The total disturbed area for the borrow pits is 18.5 ha. Any precipitation falling on a borrow pit area will be contained in the borrow pit where it will either evaporate or seep into the ground. No runoff will be generated from these areas.

Access Corridors

The access corridors consist of access roads and utility corridors. The total area of access road and utility corridors is 46.7 ha (Figure 21). The runoff coefficient from the graveled road surfaces is expected to be the same as the well pads, or about 0.60. The runoff from the road surface will flow into the ditches where some of the runoff will be stored. The remaining surface of the access corridor (the pipeline and powerline right-of-ways) will be non-forested vegetation with a runoff coefficient of about of 0.25. Thus, it is estimated that about 40% of the precipitation (an effective runoff coefficient of 0.40) will find its way into the stream system from the access corridors.

3.1.2 Stream Disturbances

The surface disturbances for the existing Project are located where they do not disturb any identified streams with defined channels. These project disturbances are, however, located on mapped drainage pathways (Figure 21). These flow pathways are indistinct but are shown to indicate the general trends in runoff directions.

The access road to the project crosses the MacKay River within the LSA. The MacKay River crossing is a clear span structure. Culverts have also been placed at intervals along the access road to allow runoff to flow from one side of the road to the other on existing drainage pathways.

3.1.3 Water Supply

The main use of water by the existing Phase 1 project is for the production of steam which is injected into the oil bearing formation. This process water is re-circulated and reused as much as possible. However, some of the water is lost in the formation and some of the water will be taken up in disposing of unwanted by-products. This lost water must be replaced from an external supply. Local deep groundwater supplies are used to provide most of the make-up water. The use of local deep groundwater for the Phase 1 Project is not expected to have a measureable effect on flows within the MacKay River or within the local watersheds. Surface water from the plant site storm water runoff ponds may also be used for process water when it is available.

3.2 Hydrologic Impacts from Existing and Approved Developments

The existing and approved developments can affect the hydrology in the LSA. The effects may include changes in the following:

- runoff volumes and streamflows
- water levels and surface areas
- channel morphology and sediment concentrations

These potential effects are evaluated in the following sections.

3.2.1 Runoff Volumes and Streamflows

Surface disturbances from existing and approved developments can cause changes to surface runoff characteristics of the natural environment. Specifically, changes in surface drainage patterns and changes in the runoff coefficients can affect the runoff volumes, peak flow rates, and timing of peak flows in the local streams. Water levels in ponds and wetlands may also be affected.

There are no significant changes in the surface drainage patterns due to the existing and approved SAGD projects. There are no effects on water levels in wetlands since drainage patterns to wetlands were maintained.

The effect of existing and approved development on runoff volumes in each individual watershed depends on the proportions of the watershed that were changed from the pre-developed condition and used for plant site, camps, well pads, borrow pits, soil storage, and access corridors. Camps and access corridors will tend to increase both runoff volumes and flood peaks due to the reduction in vegetation and the addition of less permeable surfaces. Borrow pits will tend to reduce runoff volumes and flood peaks because water will not be released from these areas. The plant site and well pads will tend to reduce the flood peaks and may reduce runoff volumes because the runoff is detained in water quality ponds and may be used as process water or lost to evaporation before being discharged to the natural environment.

Changes in runoff volumes were estimated assuming a worst case condition of the disturbed areas being directly connected to the drainage networks in the watersheds and that the estimated runoff coefficients for each disturbance type are applicable for all runoff events. These changes in runoff volumes are summarized in Table 9. The greatest worst case change in runoff volume occurs in watershed M12, which is estimated to have an increase in runoff volume of about 18% due to the access corridor area in this small watershed. The worst case change in runoff volume in watershed M09 is estimated to be an increase of about 12% due to the access corridor, soil storage and camp areas. Worst case change in runoff volumes in the other local watersheds are in the order of 5% or less. The change in runoff volumes in the MacKay River below the LSA boundary due to the total surface disturbance is expected to be inconsequential, about 0.013% of the runoff volume.

HSPF modelling was used to make a more detailed process-based assessment of the hydrologic effects of the existing and approved developments relative to pre-development conditions. Simulations of the pre-development condition used land runoff parameters determined by calibration to measured regional mean flows and flood flows as presented in Section 2.3.4. The calibrated model was validated by comparison with the local flow data collected during 2010 and 2011, and by comparison with the Water Survey of Canada recorded flows for Beaver River above Syncrude for years 1975 through 2010. The Beaver River watershed is about 165 km^2 which is comparable in size to Birchwood Creek and Tributary M20, the larger tributaries of the MacKay River.

Table 9 Summary of changes in runoff volumes due to existing and approved surface disturbances

Watershed	Total Drainage Area (ha)	Total Disturbed Area (ha)	Worst Case Change in Runoff Volume (%)	Average Change in Runoff Volume (%)	Average Change in 2-Year Peak Flow (%)	Average Change in 2-Year Minimum Flow (%)
M05	453.0	76.7	-1.0%	6.0%	5.1%	-18.0%
M07	467.2	0.2	0.0%			
M08	92.5	3.9	4.4%			
M09	115.2	23.0	11.7%	9.0%	8.0%	48.1%
M10	25.3	1.4	6.7%	5.6%	6.4%	19.5%
M12	28.9	4.4	18.2%			
M14	430.3	13.4	3.8%	3.2%	3.4%	0.6%
B01	611.5	6.8	1.4%	1.1%	1.3%	7.6%
MacKay R. direct	395422.9	6.6	0.002%			
Birchwood Cr.	21831.3	6.8	0.038%			
MacKay R. below LSA	395422.9	136.4	0.013%			

The impacts of the existing and approved development were assessed by adjusting runoff parameters to reflect the effects of development. The effects of clearing trees were simulated using a 25% reduction in potential evapotranspiration in cleared-but-vegetated areas such as utility corridors. A 75% reduction in soil storage capacity was assumed where the land is compacted for gravel roads and well pads. Areas of excavated pits were assumed to be non-draining and were removed from the watershed contributing areas. Plant site runoff was routed through an assumed holding pond with outflow pumped at a constant small discharge rate. Bermed well pads were assumed to release water only via groundwater discharge; surface and shallow subsurface flows from the well pads were assumed to be lost to evaporation.

HSPF simulations of the effects of existing and approved development were carried out at the outlets to six local watersheds, M05, M09, M10, M14, B01 and B02, which would be most affected by the proposed Project. Runoff volumes, peak flows and minimum flows for the existing and approved development were compared to the values for pre-development to evaluate the effects of the existing development.

The effects of existing and approved development on runoff volumes were greatest for watershed M09 with an overall average increase of 9.0% over pre-development conditions. Runoff volume increases were less apparent in wet years but more noticeable in dry years.

The change in magnitude in 2-year peak flow due to existing and approved development was also greatest in watershed M09, with a predicted increase of 8.0%. There were no perceptible changes in the timing of peak flows.

Changes in magnitude of annual minimum flow rates appear to be large in some of the watersheds because they are relative to very small flows. In most of the watersheds the net effect will be less years with zero flow.

The predicted changes in runoff volumes, peak flows and minimum flows in these small tributaries will be imperceptible in the larger Birchwood Creek or MacKay River due to the much greater flows in these streams.

3.2.2 Water Levels and Surface Areas

Annual peak water levels and surface areas of streams may change slightly due to the effects of existing development on annual peak flows. These changes will be imperceptible compared to natural variability. Minimum water levels and surface areas may be slightly higher due to increased minimum flows; however, zero flows will still occur in most of these small watersheds.

Levels in small waterbodies created by beaver dams are controlled by the height of the beaver dams rather than by inflow volumes therefore small changes in streamflows are not expected to affect the water levels and surface areas of these features.

3.2.3 Channel Morphology and Sediment Concentrations

Sediment concentrations in streams have the potential to increase due to increases in streamflow or from sediment introduced to the stream from disturbances. Sediment concentrations in the streams in the LSA do not appear to have increased due to changes in the surface runoff characteristics. The changes in the flow regime due to surface disturbances from existing development are very small in most cases and would not have a perceptible effect on sediment concentrations.

4 Application Development Case

This section describes the assessment of potential hydrologic impacts of the STP McKay Thermal Project – Phase 2 on the local environment. The project footprint is described, the potential effects identified and their severity assessed.

4.1 PROJECT FOOTPRINT

The development of the proposed Project will produce additional surface disturbances as well as potential stream disturbances. Figure 22 shows the layout of the Project. These developments are located in Twp 91, Rge 14-15, W4.

4.1.1 SURFACE DISTURBANCES

Surface disturbances for the Project include plant site, well pads, borrow pits and utility corridors. Detailed descriptions of these surface disturbance types are provided in Section 3.1.1. The initial phase of the Project will consist of construction of a plant site, operations camp, eight well pads and associated utility corridors. Borrow pits will also be developed to supply material for construction. Future development of well pads and access corridors will be carried out as required to maintain production.

Table 10 summarizes the extent of the spatial disturbances the Project within individual watersheds. The total disturbed area of 502 ha is 0.13% of the total drainage area of the MacKay River below the LSA. The greatest percentage area of disturbance due to the Project occurs in watershed M10, a small watershed of 25 ha where 25% of the area will be disturbed. When the existing and approved disturbances listed in Table 8 are included, the greatest percentage area of disturbance relative to pre-development conditions will still occur in Watershed M10, with 31% of the area disturbed.

4.1.2 STREAM DISTURBANCES

The Project will use the existing access road so no new crossings of the MacKay River are required. However, the utility corridors for future well pads will cross some streams with defined channels. There are five crossings of streams with defined channels proposed for the Project. Field data collected on these channels at nearby locations indicate that Tributaries M03, M06, M15 and M20 are likely not navigable because they are either too small, have debris blockages or have beaver dams. Birchwood Creek will require further evaluation and submission to Transport Canada in order to determine navigability but was previously deemed non navigable upstream at the existing access road crossing.

Table 10 Summary of surface disturbance areas due to the Phase 2 Project

Watershed	Plant Site Area (ha)	Camp Area (ha)	Well Pad Area (ha)	Borrow Pit Area (ha)	Access Corridor (ha)	Total Disturbed Area (ha)	Water-shed Area (ha)	Disturbed Area (%)
M01			14.6		4.2	18.8	129	14.6%
M03			9.5		3.6	13.1	85	15.4%
M04			5.9		0.7	6.6	295	2.2%
M05			4.7	15.5	6.7	26.9	453	5.9%
M06			8.2		5.1	13.3	1,946	0.69%
M07			0.0		4.7	4.7	467	1.0%
M08			9.9		3.4	13.3	92	14.4%
M09			1.6		0.5	2.1	115	1.8%
M10			5.6		0.9	6.4	25	25.4%
M11			0.2		4.6	4.9	269	1.8%
M12			3.8			3.8	29	13.3%
M13			5.6		6.0	11.6	108	10.7%
M14			28.9	45.0	15.5	89.5	430	20.8%
M15			2.8		3.5	6.3	338	1.9%
M17			2.2		1.9	4.1	232	1.8%
M18			4.6		2.0	6.7	79	8.4%
M19			0.5	18.7	3.2	22.3	212	10.5%
M20			13.4		7.6	21.0	30,935	0.07%
M21			4.3		1.0	5.3	267	2.0%
MacKay R. direct			29.6	6.5	5.9	42.0	395,423	0.0%
B01	45.0	2.8	33.1	42.0	16.3	139.2	611	22.8%
B02			13.4		5.1	18.6	59	31.4%
Birchwood direct			15.8	1.1	4.5	21.4	21,831	0.10%
Birchwood at mouth	45.0	2.8	62.3	43.1	25.9	179.1	21,831	0.8%
MacKay R. below LSA	45.0	2.8	218.4	128.7	107.0	502.0	395,423	0.13%

There will also be a number of crossings of mapped drainages without defined channels which are not considered to be navigable. These crossings include two crossings of Tributary M14 which was classified as a drainage without a defined channel after a field inspection was carried out. The drainage pathways at these crossings can be maintained with adequately sized culverts.

Most of the disturbed areas have been located to avoid mapped watercourses; however, there are some well pads located on mapped drainages. These drainages do not have defined channels and surrounding area is quite flat so the drainage can be directed around these well pads and back to their original pathways through drainage ditches.

Construction should be carried out using best management practices to minimize erosion and sedimentation of watercourses. These practices include the installation of silt fences, seeding of disturbed areas and the use of sediment traps in road ditches.

4.1.3 WATER SUPPLY

The Project will use the same local deep groundwater sources as the existing project to supply water. The use of local deep groundwater is not expected to have a measureable effect on flows within the MacKay River relative to the natural flow variability.

Runoff from the plant site will be collected in a storm water pond. The runoff volume stored in the storm water pond contained on the plant site may be used for process water. The mean annual runoff volume from the plant site is estimated to be about 117,000 m^3 (45 ha x 0.6 x 435 mm). This is the amount of runoff water which could potentially be diverted on an annual basis for process water if sufficient storage is available to capture the runoff when it occurs. The volume of the storm water pond will be about 17,000 m^3 which is the volume required to store the 10-year 24-hour runoff as described in Section 4.2.1

There are no currently active licences for surface water withdrawals within the RSA other than an existing licence to withdrawal water from the Phase 1 stormwater retention pond.

4.2 POTENTIAL HYDROLOGIC IMPACTS

The development of the Project may potentially affect a number of valued environmental components (VECs) related to hydrology in the LSA. These VECs include:

- runoff volumes and streamflows
- water levels and surface areas
- channel morphology and sediment concentrations

A summary of the project effects on these VECs is provided in Table 11. These project effects are evaluated in the following sections.

4.2.1 RUNOFF VOLUMES AND STREAMFLOWS

Surface disturbances from the Project developments can cause changes to surface runoff characteristics of the natural environment. The introduction of stormwater runoff ponds, changes in surface drainage patterns, and changes in the runoff rates can affect the runoff volumes, peak flow rates, and timing of peak flows in the local streams.

Table 11 Summary of impact rating on surface water hydrology valued environmental components (VECs)

VEC	Nature of Potential Impact or Effect	Mitigation/ Protection Plan	Type of Impact or Effect	Geographical Extent[1]	Duration[2]	Frequency[3]	Reversibility[4]	Magnitude[5]	Project Contribution[6]	Confidence Rating[7]	Probability of Occurrence[8]	Impact Rating[9]
1. Runoff Volumes and Streamflows												
	Changes to runoff volume, peak flows, and low flows	1) Maintain drainage around disturbed areas 2) Reclaim surface disturbances once no longer required 3) Discharge runoff into natural environment away from streams in accordance with EPEA Approval	Application	Local	Long-term	Periodic	Reversible in long term	Low	Negative	High	High	Low
			Cumulative	Local	Long-term	Periodic	Reversible in long term	Low	Negative	High	High	Low
2. Water Levels and Surface Areas												
	Changes in water levels and surface area due to streamflow changes	1) Maintain drainage around disturbed areas 2) Reclaim surface disturbances once no longer required 3) Discharge runoff into natural environment away from streams in accordance with EPEA Approval	Application	Local	Long-term	Periodic	Reversible in long term	Low	Negative	High	High	Low
			Cumulative	Local	Long-term	Periodic	Reversible in long term	Low	Negative	High	High	Low
3. Channel Morphology and Sediment Concentration												
	Changes in channel shape and sediment concentration due to flow changes and crossing construction	1) Maintain drainage around disturbed areas 2) Reclaim surface disturbances once no longer required 3) Design and construct crossings to minimize impacts	Application	Local	Long-term	Periodic	Reversible in long term	Low	Negative	High	Low	Low
			Cumulative	Local	Long-term	Periodic	Reversible in long term	Low	Negative	High	Low	Low

1. Local, Regional, Provincial, National, Global
2. Short, Long, Extended, Residual
3. Continuous, Isolated, Periodic, Occasional
4. Reversible in short term, Reversible in long term, Irreversible - rare
5. Nil, Low, Moderate, High
6. Neutral, Positive, Negative
7. Low, Moderate, High
8. Low, Medium, High
9. No Impact, Low Impact, Moderate Impact, High Impact

Runoff from the 45 ha plant site area will be collected in a stormwater pond. This pond is required to hold the runoff from a 10-year 24-hour rainfall of 63.4 mm. The storage requirement for this runoff event of 17,100 m^3 was estimated using an adopted runoff coefficient of 0.6 (45 ha x 63.4 mm x 0.6 =17,118 m^3). The 10-year peak runoff rate of 1.7 m^3/s was estimated using the rational method. Runoff from off-site areas will be diverted around the plant site.

There are no significant changes in the surface drainage patterns due to the proposed Project. Runoff will be directed around disturbance areas and directed back to the original drainage pathways so that drainage patterns will be maintained.

The effect of development on runoff volumes in each individual watershed depends on the proportions of the watershed that are used for plant sites, camps, well pads, borrow pits and utility corridors. Borrow pits will tend to reduce runoff volumes and flood peaks because water is not released from these areas. Utility corridors and camps will tend to increase both runoff volumes and flood peaks due to the reduction in vegetation and the addition of less permeable surfaces. The plant site and well pads will tend to reduce the flood peaks because the runoff is detained before being discharged to the natural environment.

Changes in runoff volumes due to the proposed development were estimated assuming a worst case condition of the disturbed areas being directly connected to the drainage networks in the watersheds and that the estimated runoff coefficients for each disturbance type are applicable for all runoff events. The changes in runoff volumes summarized in Table 12 include the effects of the existing disturbances combined with all proposed future development. The development of the entire Project would produce the greatest change in runoff volume in Watershed M10, a decrease of 11% compared to pre-development conditions. Worst case changes in runoff volume of more than 5% may occur in nine watersheds. These watersheds are all small with drainage areas of 6 km^2 or less. The worst case changes in runoff volumes in the larger basins are less than 1%. The change in runoff volume at the mouth of Birchwood Creek will be a decrease of only 0.4% and the change in runoff volume in the MacKay River below the LSA will be a decrease of only 0.05%.

HSPF modelling was used to make a more detailed process-based assessment of the hydrologic effects of the Project relative to pre-development conditions. Details of the HSPF modeling process are provided in Section 3.2.1.

The effects of this development scenario on runoff volumes were greatest for watershed M14 with an average decrease of 8.9% from pre-development conditions. Runoff volume decreases were more apparent in wet years.

The change in magnitude in 2-year peak flows due to existing and approved development was greatest in watershed B02, with a predicted decrease of 11.9%. The simulations predicted some small changes in the timing of peak flows, typically the peaks occurred slightly earlier.

Table 12 Summary of changes in runoff volumes due to existing and approved and Project surface disturbances

Watershed	Total Drainage Area (ha)	Total Disturbed Area (ha)	Worst Case Change in Runoff Volume (%)	Average Change in Runoff Volume (%)	Average Change in 2-Year Peak Flow (%)	Average Change in 2-Year Minimum Flow (%)
M01	129	18.8	-7.3%			
M03	85	13.1	-6.1%			
M04	295	6.6	-1.7%			
M05	453	103.6	-3.6%	3.3%	2.5%	-11.7%
M06	1,946	13.3	-0.10%			
M07	467	4.9	1.3%			
M08	92	17.2	-1.9%			
M09	115	25.1	10.9%	8.3%	7.0%	49.6%
M10	25	7.9	-11.0%	-8.6%	-10.5%	21.5%
M11	269	4.9	2.0%			
M12	29	8.2	4.9%			
M13	108	11.6	1.6%			
M14	430	102.8	-9.0%	-8.9%	-8.8%	-25.6%
M15	338	6.3	0.45%			
M17	232	4.1	0.03%			
M18	79	6.7	-2.7%			
M19	212	22.3	-7.2%			
M20	30,935	21.0	-0.01%			
M21	267	5.3	-1.1%			
MacKay R. direct	395,423	48.6	-0.01%			
B01	611	146.0	-13.9%	3.0%	3.1%	43.3%
B02	59	18.6	-12.1%	-8.8%	-11.9%	21.8%
Birchwood Cr. direct	21,831	29.9	-0.01%			
Birchwood Cr. at mouth	21,831	194.5	-0.43%			
MacKay R. below LSA	395,423	646.9	-0.05%			

Percentage changes in magnitude of annual minimum flow rates appear to be large in some of the watersheds because they are relative to very low flows. In most of the watersheds the net effect will be less years with zero flow.

The predicted changes in runoff volumes, peak flows and minimum flows in these small tributaries will be imperceptible in the downstream Birchwood Creek and MacKay River due to the much greater flows in these streams.

4.2.2 WATER LEVELS AND SURFACE AREAS

Annual peak water levels and surface areas in the streams may change slightly due to changes in annual peak flow. These changes will be imperceptible compared to natural variability. Minimum water levels and surface areas may be slightly higher due to increased minimum flows; however, zero flows will still occur in most of these small watersheds.

Levels in small waterbodies created by beaver dams are controlled by the height of the beaver dams rather than by inflow volumes therefore small changes in streamflows are not expected to affect the water levels and surface areas of these features.

4.2.3 CHANNEL MORPHOLOGY AND SEDIMENT CONCENTRATIONS

Sediment concentrations in streams have the potential to increase due to increases in streamflow or from sediment introduced to the stream from disturbances. Sediment concentrations in the streams in the LSA are not expected to increase due to changes in the surface runoff characteristics because in most cases the runoff will not increase. Even in watersheds where increases in runoff may occur, changes in the flow regime due to surface disturbances are very small and would not have a perceptible impact the sediment concentrations.

5 Planned Development Case

There are no other planned developments within the hydrology LSA except for a short length of the access road and a few well pads for the Athabasca Oil Sands Corp. (AOSC) MacKay River SAGD Project. No additional stream crossings are anticipated within the hydrology LSA and the effect of the additional surface disturbances on runoff volumes and peak flows is expected to be undetectable.

6 Cumulative Impact Assessment

The cumulative impact of projects in the hydrology RSA was considered; however, there are no other activities in the hydrology RSA which were not already included in the assessment within the LSA. There are other existing and planned SAGD developments within the Mackay River watershed; however, the cumulative impact of these developments on the MacKay River is expected to be similar to the predicted impacts in the RSA for the Application Case, which is very small. These projects are similar in nature so the relative disturbances to other tributaries to the MacKay River are expected to be similar.

The development of the AOSC MacKay River SAGD Project to the south will increase the hydrologic impacts in some of the smaller tributaries of the Mackay River and Birchwood Creek but these impacts are expected to be small and the changes in these small tributaries will be imperceptible in the downstream Birchwood Creek and MacKay River due to the much greater flows in these streams.

7 Mitigation and Monitoring

7.1 MITIGATION

The following practices and procedures will be carried out to reduce the effects of the development on the surface water hydrology:

- Water will not be transferred from one watershed to another along ditches and road right-of-ways.
- Appropriate drainage culverts will be provided at crossings of any identifiable drainage courses to maintain existing drainage patterns.
- Disturbances will be kept away from streams with defined channels. Vegetated buffers will be maintained between channels and any disturbances.
- Sediment control will be utilised for construction activity where runoff may potentially flow directly into streams with defined channels.
- Runoff from well pads will be controlled and will not be directed toward streams with defined channels.
- Run-on from upstream of well pads and plant site will be directed around the disturbances and back into their original pathways.
- Surface disturbances will be reclaimed after they are no longer required.

The drainage pathways around the project components shown in Figure 23 were developed by applying the above practices and procedures.

7.2 MONITORING

Impacts on runoff volumes and streamflows will be impossible to distinguish from natural variability so direct monitoring of streamflows is not necessary. However, the following monitoring should be carried out to ensure that the impacts on the surface water hydrology are low:

- Routine visual inspections should be carried out to ensure that the access road drainage culverts are working as intended to maintain the natural surface drainage patterns.
- Sediment monitoring should be carried out during the construction of stream channel crossings to ensure that sediment from construction sites does not adversely impact the downstream channels.
- Water volumes pumped from the CPF runoff pond into the natural environment should be recorded.
- The volume of any runoff water used for process water should be recorded.

8 Summary of Conclusions

A hydrologic assessment was carried out for the STP McKay Thermal Project – Phase 2 which evaluated physiography, climate, and streamflow characteristics in the vicinity of the Project, assessed the hydrological effects of the project footprint, and recommended mitigation and monitoring strategies.

8.1 BASELINE SETTING

The regional surface water hydrology for baseline pre-development conditions was described and mapped. A regional analysis of historical climate data was carried out to describe the variation in temperature, precipitation and evaporation. A regional analysis of historical streamflows was carried out to describe flow regimes and peak flows in the region. Regional watersheds were mapped and drainage areas quantified.

Local water levels and streamflows were measured at seven stream sites from 2008 to 2011. Snow course measurements were also taken in early spring of 2011. Flow regimes were evaluated from the regional streamflow analysis and from the HSPF hydrologic model calibrated to regional data and verified with local streamflow measurements.

8.2 BASELINE DEVELOPMENT CASE

A baseline development case consisting of existing and approved developments in the LSA was described and the effects of the development on the hydrology were quantified. Effects were evaluated for runoff volumes and streamflows; water levels and surface areas; and channel morphology and sediment concentrations. Runoff volumes were found to increase the greatest in watershed M09 with an increase of 9.0% over pre-development conditions. The increase could be as much 11.7% in dry years. There is no perceptible change on the timing of runoff hydrographs. Peak flows tend to be higher with increases in 2-year peak flows of up to 8.0%. Percentage changes in magnitude of annual minimum flow rates appear to be large in some of the watersheds because they are computed relative to very low flows. In most of the watersheds the net effect will be less years with zero flow.

The effects of existing and approved development on water levels and surface areas are imperceptible compared to natural variability.

Channel morphology and sediment concentrations have not changed due to baseline development because changes to the flow regime are small. The existing stream crossings do not appear to have caused any increases in sediment concentration or erosion.

8.3 APPLICATION DEVELOPMENT CASE

The application development case was described and the effects of the proposed development on the hydrology were quantified. The entire project including existing and approved development was assumed to be developed in combination with the proposed development to assess the maximum effect on the hydrology. Effects relative to baseline pre-development conditions were evaluated for runoff volumes and streamflows; water levels and surface areas; and channel morphology and sediment concentrations.

The effects of this development scenario on runoff volumes were greatest for watershed M14 with an overall average decrease of 8.9% over pre-development conditions. The change in magnitude in 2-year peak flow due to development was greatest in watershed B02, with a predicted decrease of 11.9%. The simulations predicted some small changes in the timing of peak flows, with the peaks occurred slightly earlier. Percentage changes in magnitude of annual minimum flow rates appear to be large in some of the watersheds because they are computed relative to very low flows. The predicted changes in runoff volumes, peak flows and minimum flows in these small tributaries will be imperceptible in the downstream Birchwood Creek and MacKay River due to the much greater flows in these streams.

The effect of the application development case on water levels and surface areas were imperceptible compared to natural variability.

Channel morphology and sediment concentrations will not change due to the application development case because changes to the flow regime are small. The access corridor stream crossings will be designed to minimize the disturbance to the channels so sediment inputs are not anticipated to increase.

8.4 CUMULATIVE IMPACT ASSESSMENT

The cumulative impact of projects in the hydrology RSA was considered; however, there are no other activities in the hydrology RSA which were not already included in the assessment within the LSA.

The oil & gas developments in the RSA are typical of these types of developments which are distributed throughout the region. The hydrologic effects of these developments are believed to be negligible and are already included in the regional flow analysis in the assessment of baseline conditions. No further evaluation of these developments was carried out.

8.5 MITIGATION AND MONITORING

The effects of the project will be mitigated by design and reclamation. The surface disturbances will be designed to discharge runoff into the natural landscape rather than directly into the drainage network as was assumed in the impact assessment. Infiltration, depression storage and evapotranspiration will tend to buffer the effects of increased runoff from compacted soils. Stream crossings will be designed to minimize the impact on stream channels and erosion of channel banks and construction activities will be carried out in such a way as to minimize the impacts on the channels. As well, drainage will be provided around the disturbances so that runoff is not directed from one watershed into another. In general impacts are expected to be less than what is predicted in this report because some areas will likely be reclaimed before other areas are developed so the maximum footprint will always be less than that of the total project. As well, the hydrologic impacts presented in this report will be temporary as the entire project disturbance will be reclaimed to match the pre-existing conditions as closely as possible after the project is complete.

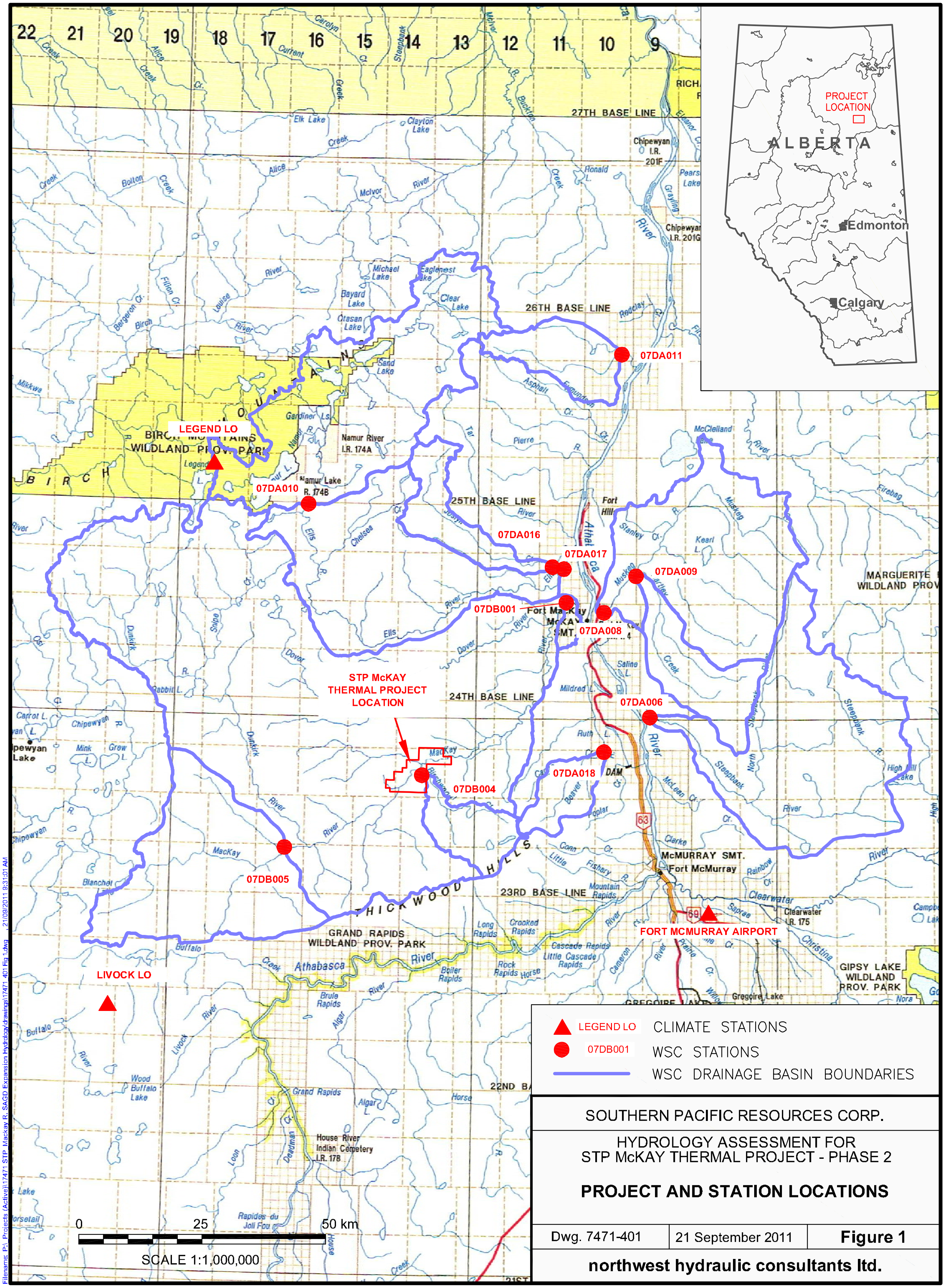
Streamflow monitoring is not required because the effects of the project on streamflows will be small and indistinguishable from natural variability. Runoff volumes from the plant site runoff ponds will be monitored to determine how much runoff is pumped into the natural environment. Sediment monitoring will be carried out during the construction of stream channel crossings to ensure that sediment from construction sites do not adversely impact the downstream channels.

9 References

Alberta Environment, 1999. Evaporation and evapotranspiration in Alberta, Report 1912 to 1985, Data 1912-1996. Water Sciences Branch, Water Management Division, Alberta Environmental Protection. Edmonton, Alberta.

Linsley, R. K., Kohler, M.A., Paulhus, J.L.H., 1982, Hydrology for Engineers. 3rd edition. McGraw-Hill Inc., New York, New York

Morton. F.I, 1983. Operational estimates of aerial evapotranspiration and their significance to the science and practice of hydrology.



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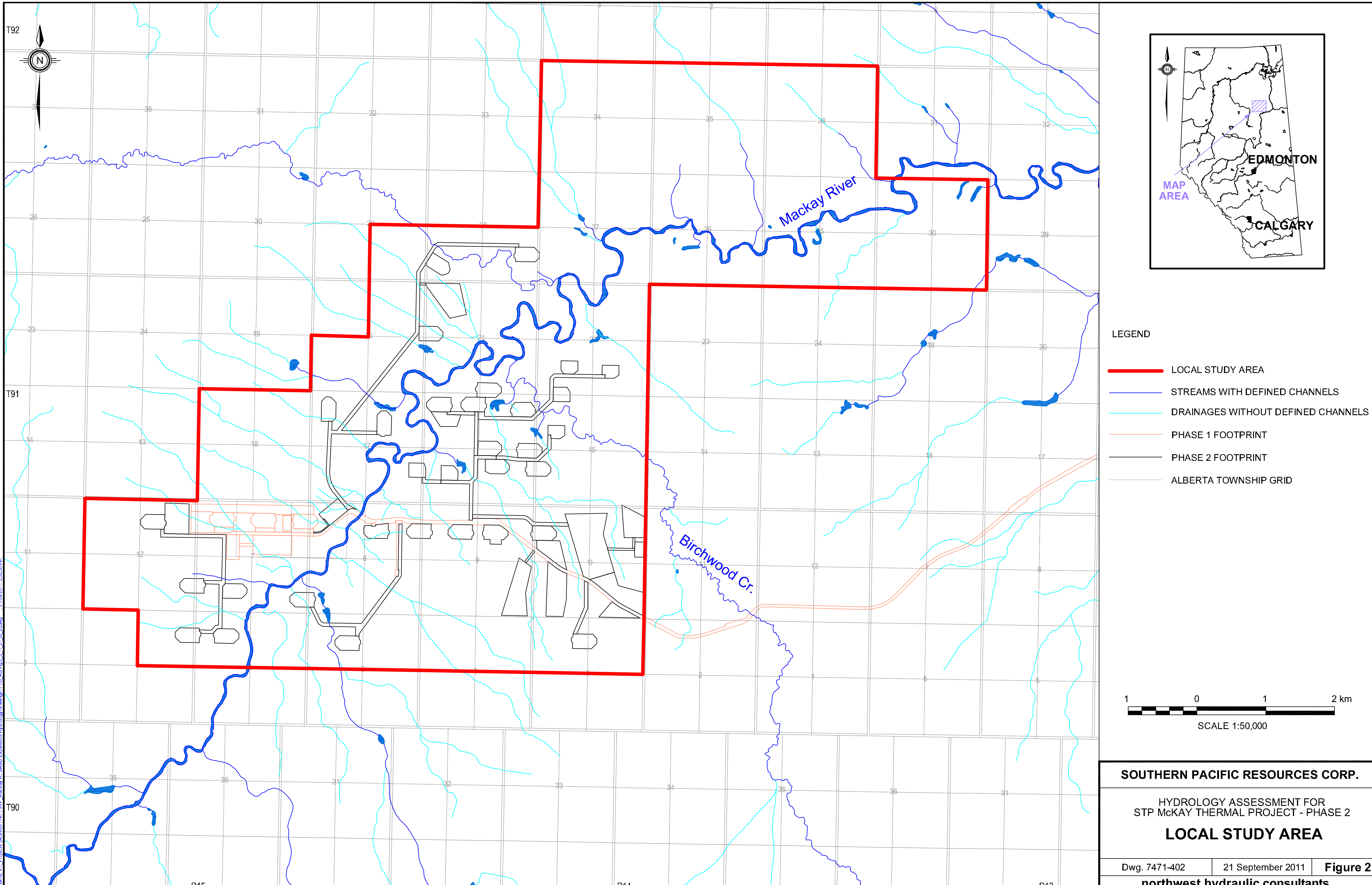
HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

PROJECT AND STATION LOCATIONS

Dwg. 7471-401	21 September 2011	**Figure 1**

northwest hydraulic consultants ltd.


T92
T91
T90
R15
R14
R13
N
Mackay River
Birchwood Cr.
EDMONTON
CALGARY
MAP AREA
LEGEND
LOCAL STUDY AREA
STREAMS WITH DEFINED CHANNELS
DRAINAGES WITHOUT DEFINED CHANNELS
PHASE 1 FOOTPRINT
PHASE 2 FOOTPRINT
ALBERTA TOWNSHIP GRID
1 0 1 2 km
SCALE 1:50,000
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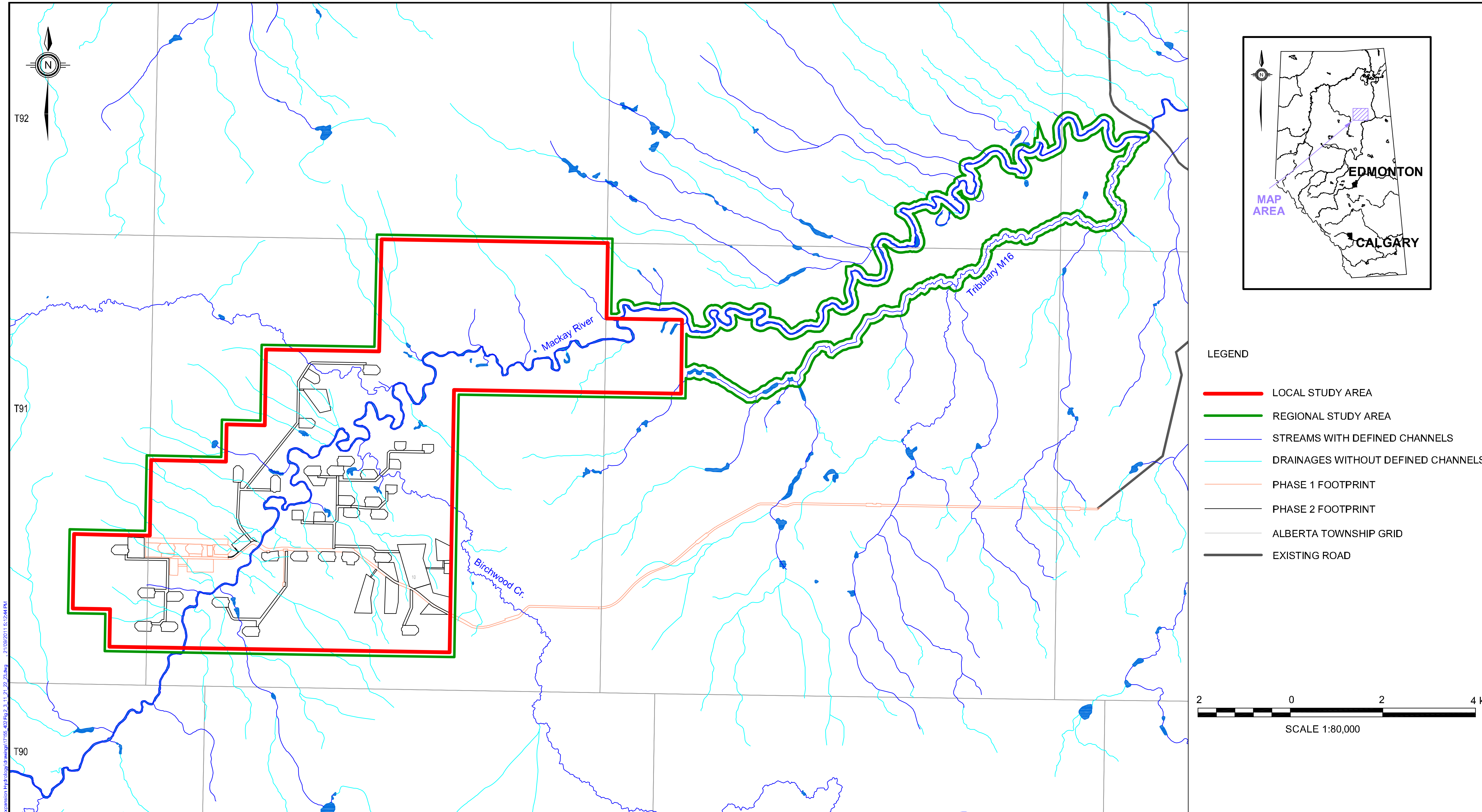
HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2
LOCAL STUDY AREA
Dwg. 7471-402
21 September 2011
Figure 2
northwest hydraulic consultants



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HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

REGIONAL STUDY AREA

Dwg. 7471-403	21 September 2011	**Figure 3**

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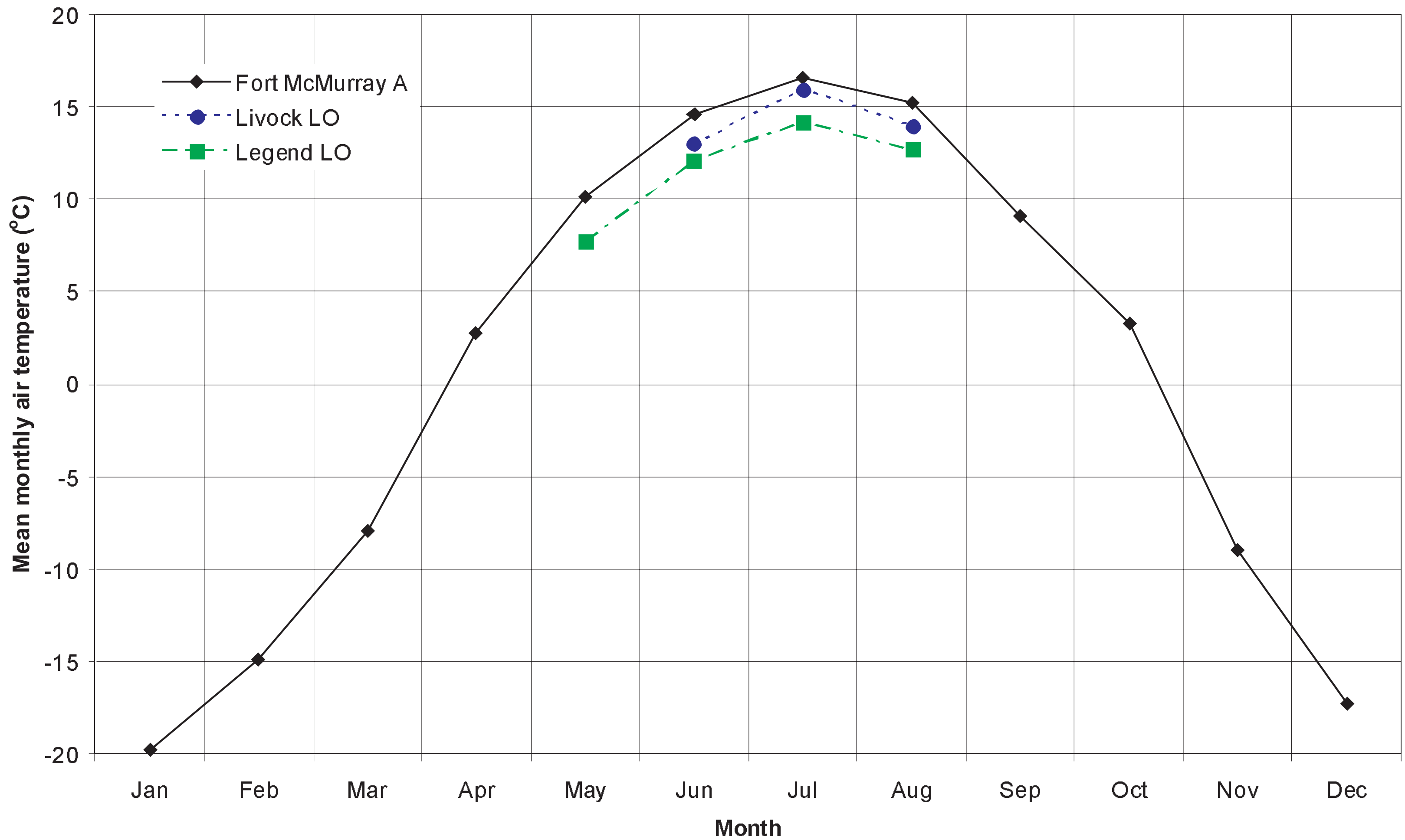

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HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

MONTHLY AIR TEMPERATURES

Project 17471	23 Sep 2011	**Figure 4**

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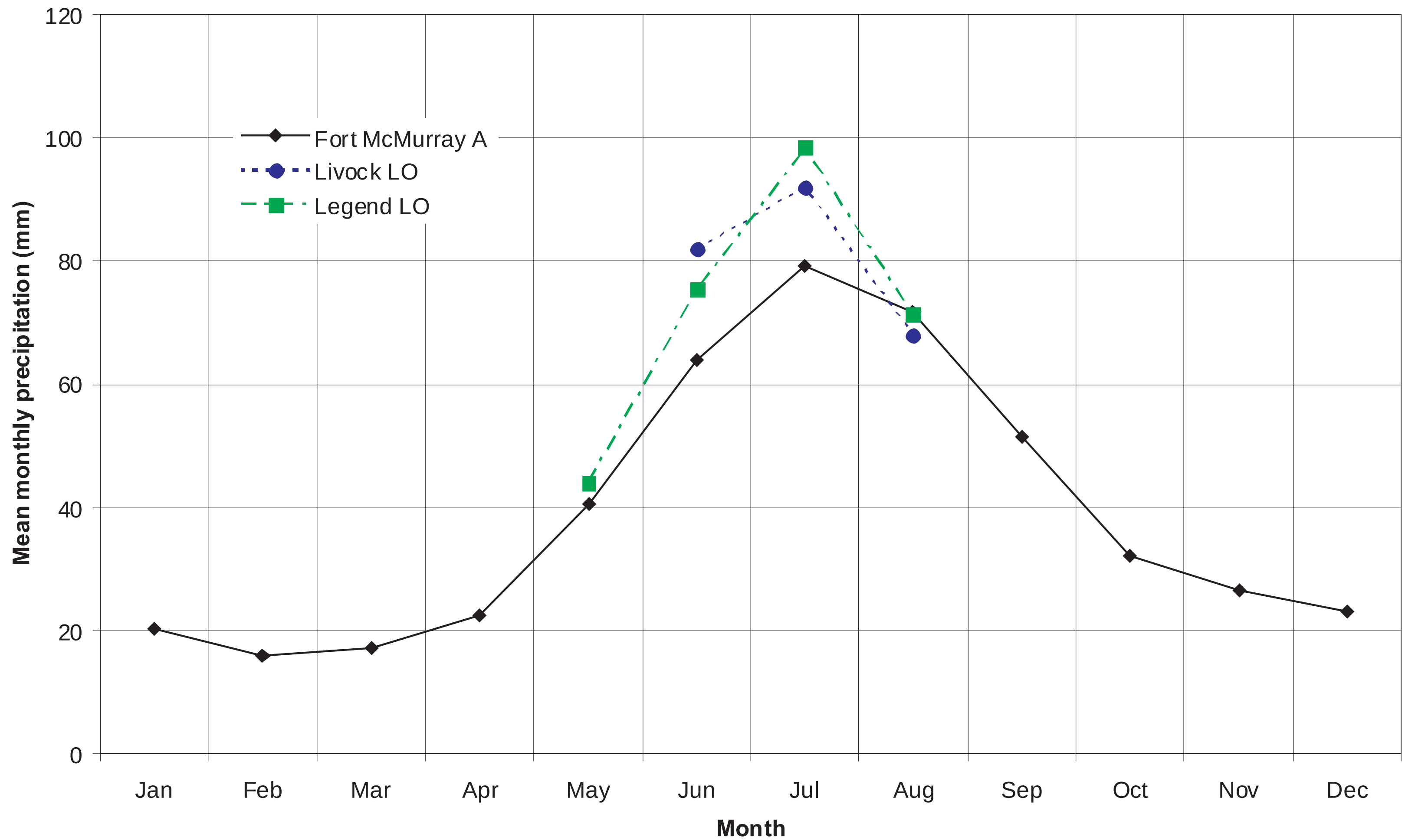

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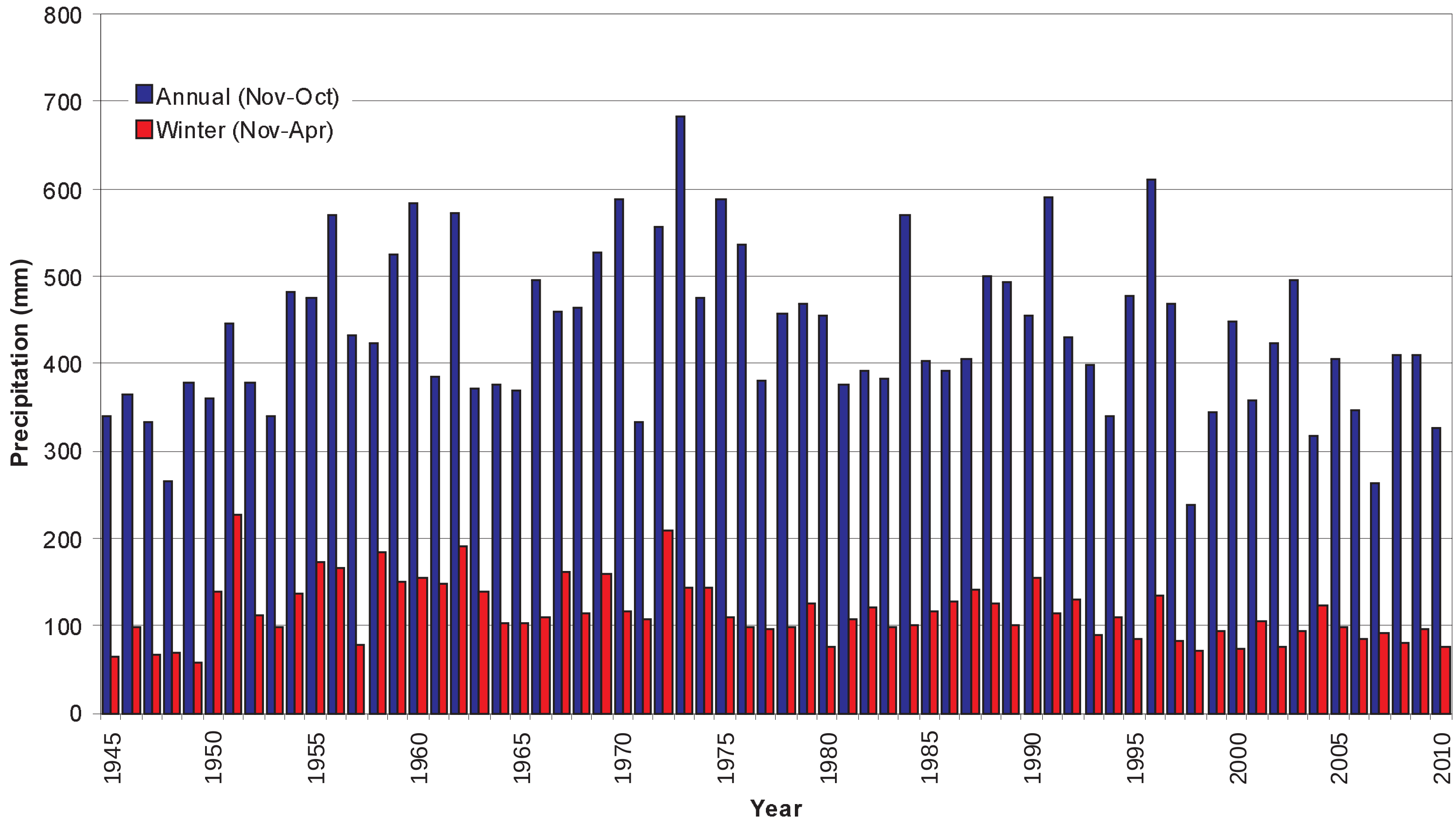
HYDROLOGY ASSESSMENT FOR STP McKAY THERMAL PROJECT - PHASE 2 **MONTHLY PRECIPITATION**		
Project 17471	23 Sep 2011	**Figure 5**
northwest hydraulic consultants		



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HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

ANNUAL PRECIPITATION AND WINTER SNOWFALL

Project 17471	23 Sep 2011	**Figure 6**

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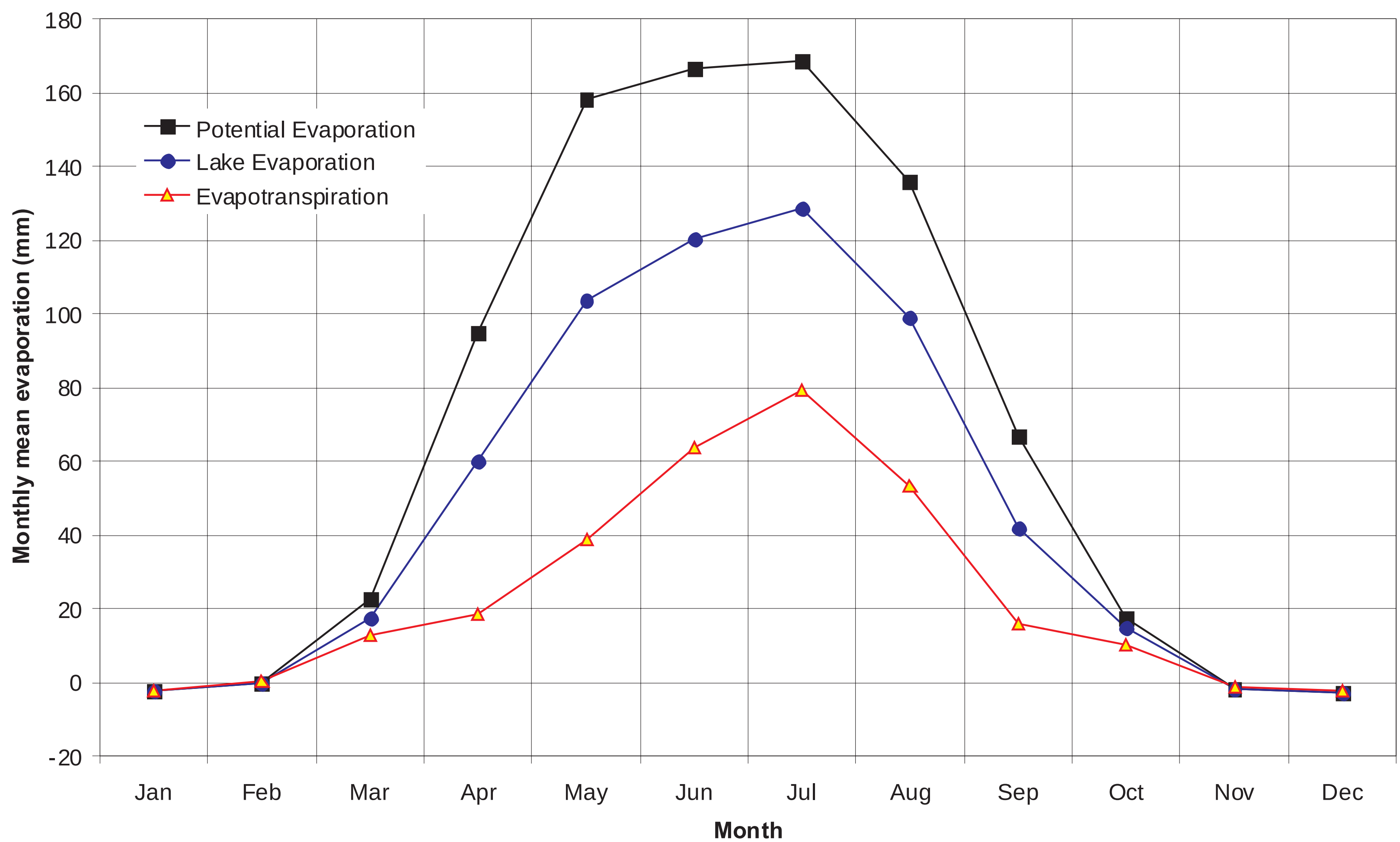

SOUTHERN PACIFIC RESOURCE CORP.		
HYDROLOGY ASSESSMENT FOR STP McKAY THERMAL PROJECT - PHASE 2 **MONTHLY EVAPORATION AND EVAPOTRANSPIRATION**		
Project 17471	23 Sep 2011	**Figure 7**
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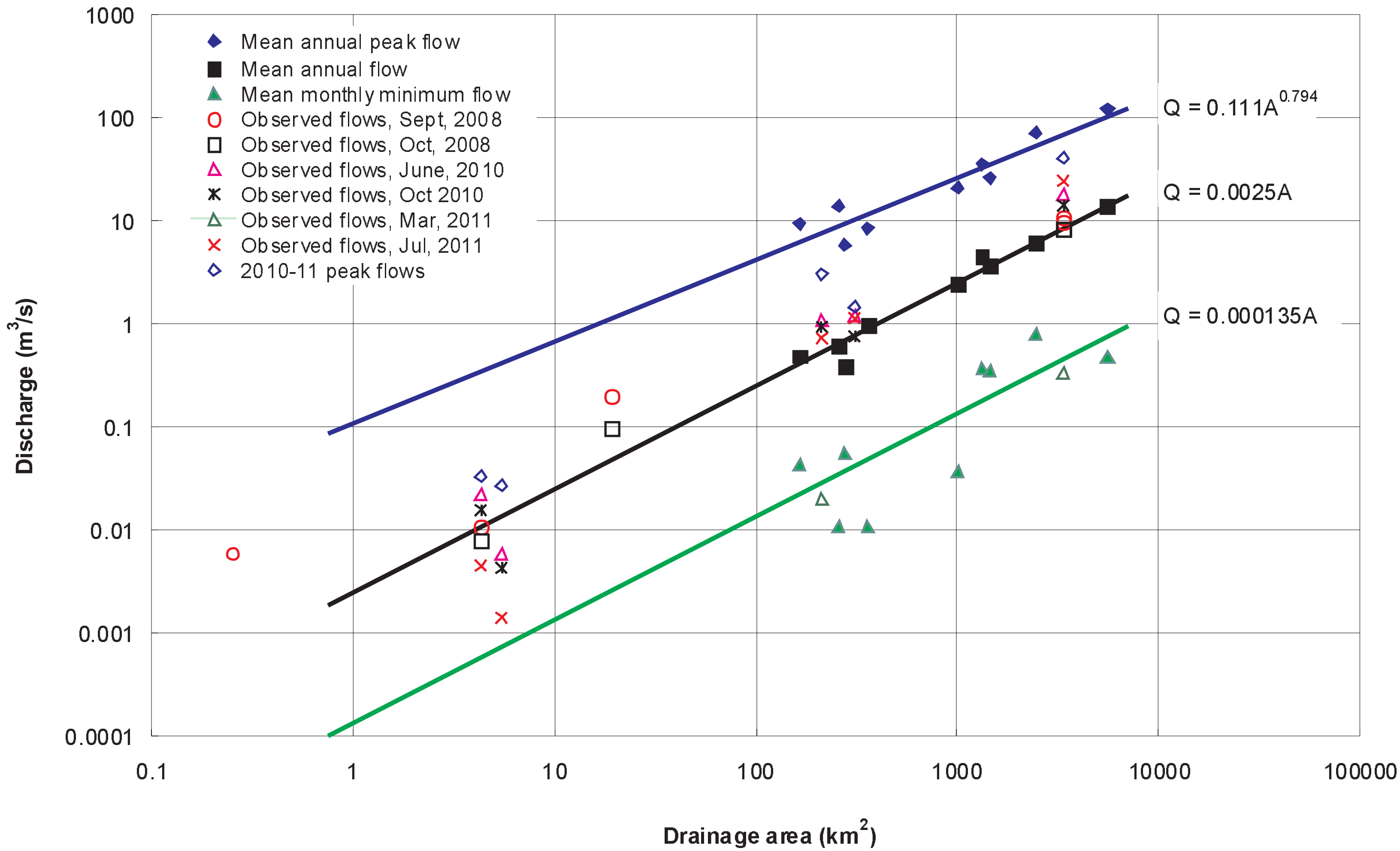

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STP McKAY THERMAL PROJECT - PHASE 2

VARIATION OF DISCHARGE WITH DRAINAGE AREA

Project 17471	22 Sep 2011	**Figure 8**

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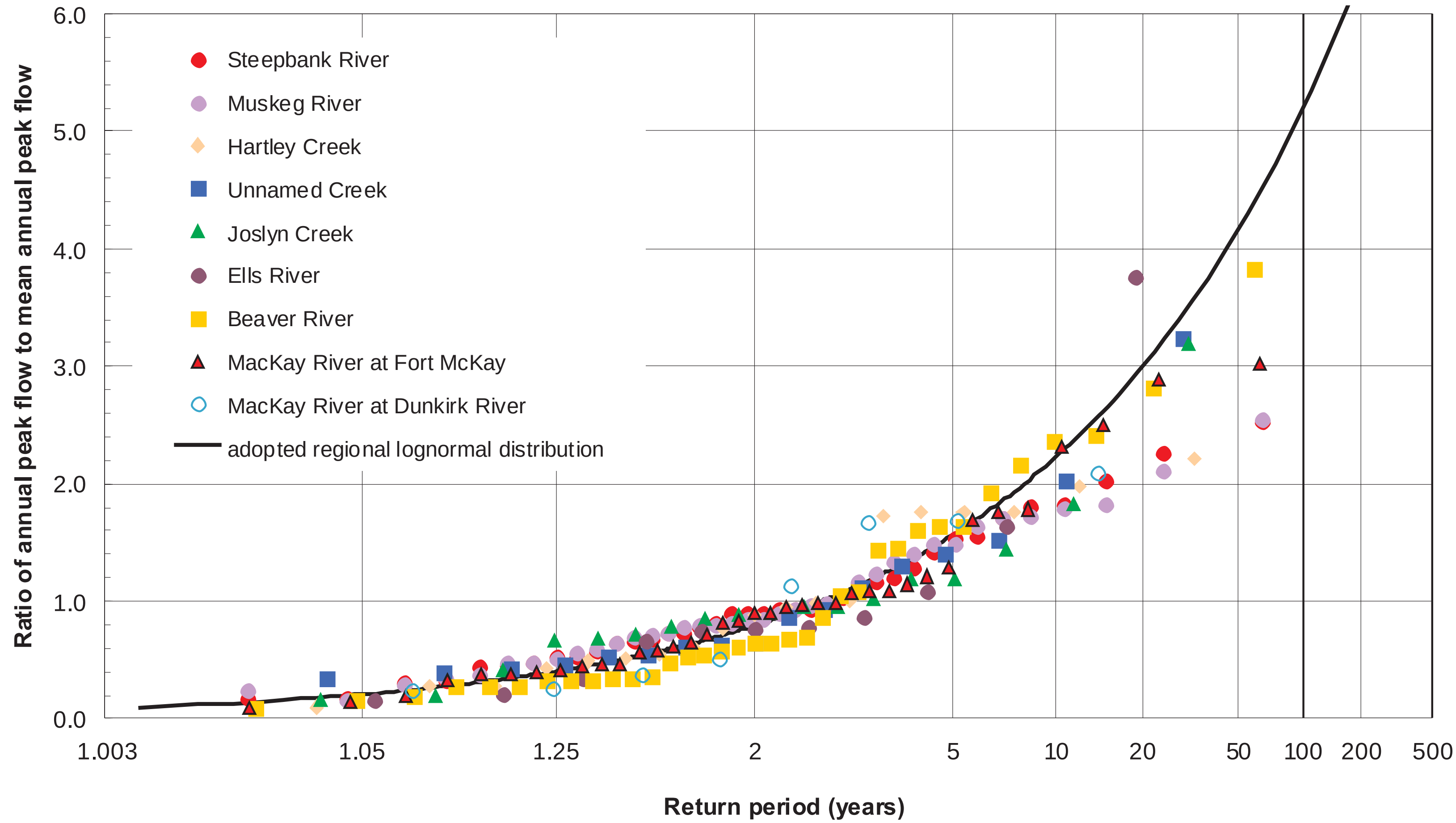

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REGIONAL FLOW FREQUENCY DISTRIBUTIONS

Project 17471	22 Sep 2011	**Figure 9**

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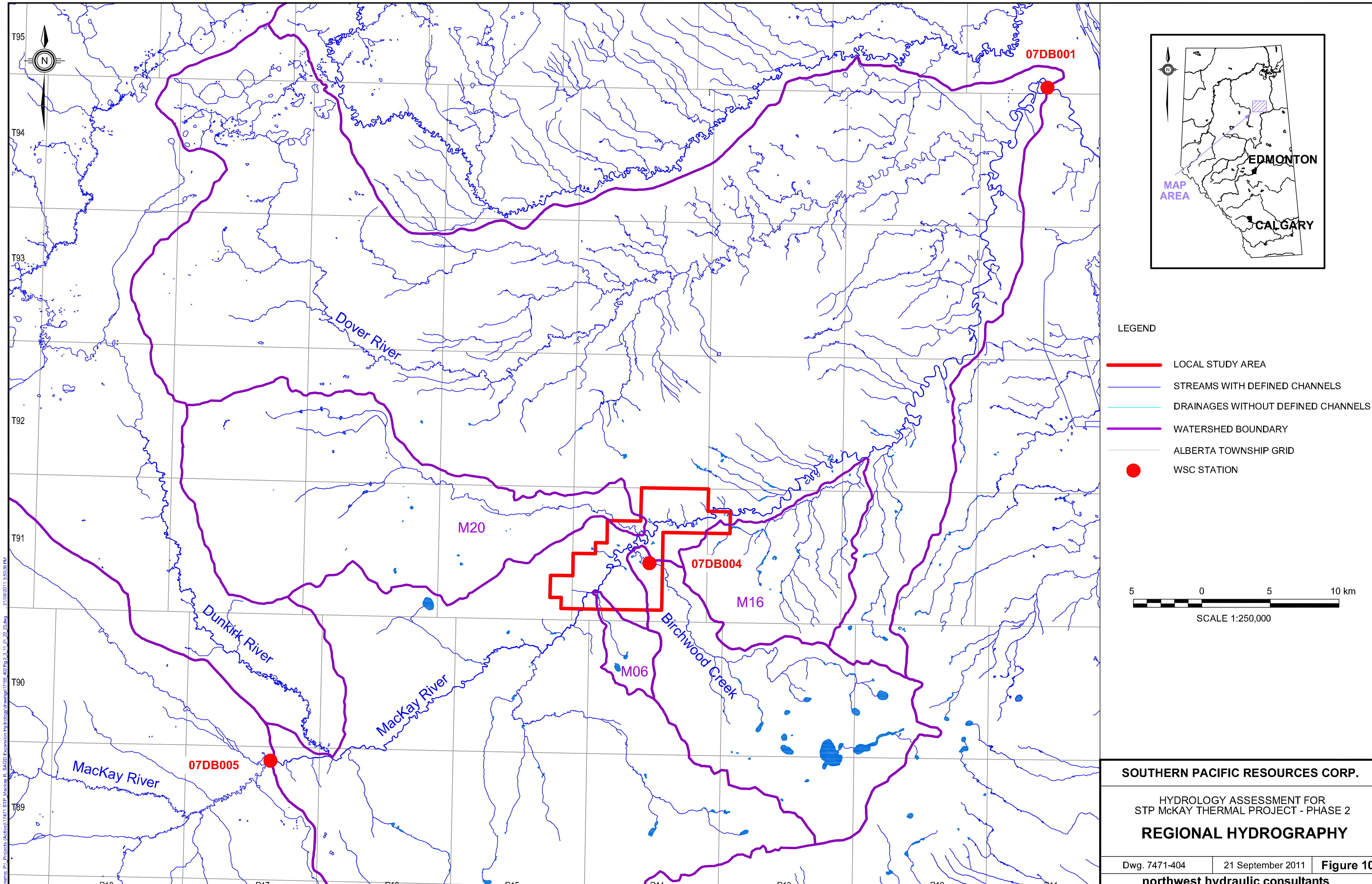
T95
T94
T93
T92
T91
T90
T89
R18
R17
R16
R15
R14
R13
R12
R11
N
07DB001
07DB004
07DB005
Dover River
Dunkirk River
MacKay River
MacKay River
Birchwood Creek
M20
M16
M06
EDMONTON
CALGARY
MAP AREA
LEGEND
LOCAL STUDY AREA
STREAMS WITH DEFINED CHANNELS
DRAINAGES WITHOUT DEFINED CHANNELS
WATERSHED BOUNDARY
ALBERTA TOWNSHIP GRID
WSC STATION
5
0
5
10 km
SCALE 1:250,000
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HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2
REGIONAL HYDROGRAPHY
Dwg. 7471-404
21 September 2011
Figure 10
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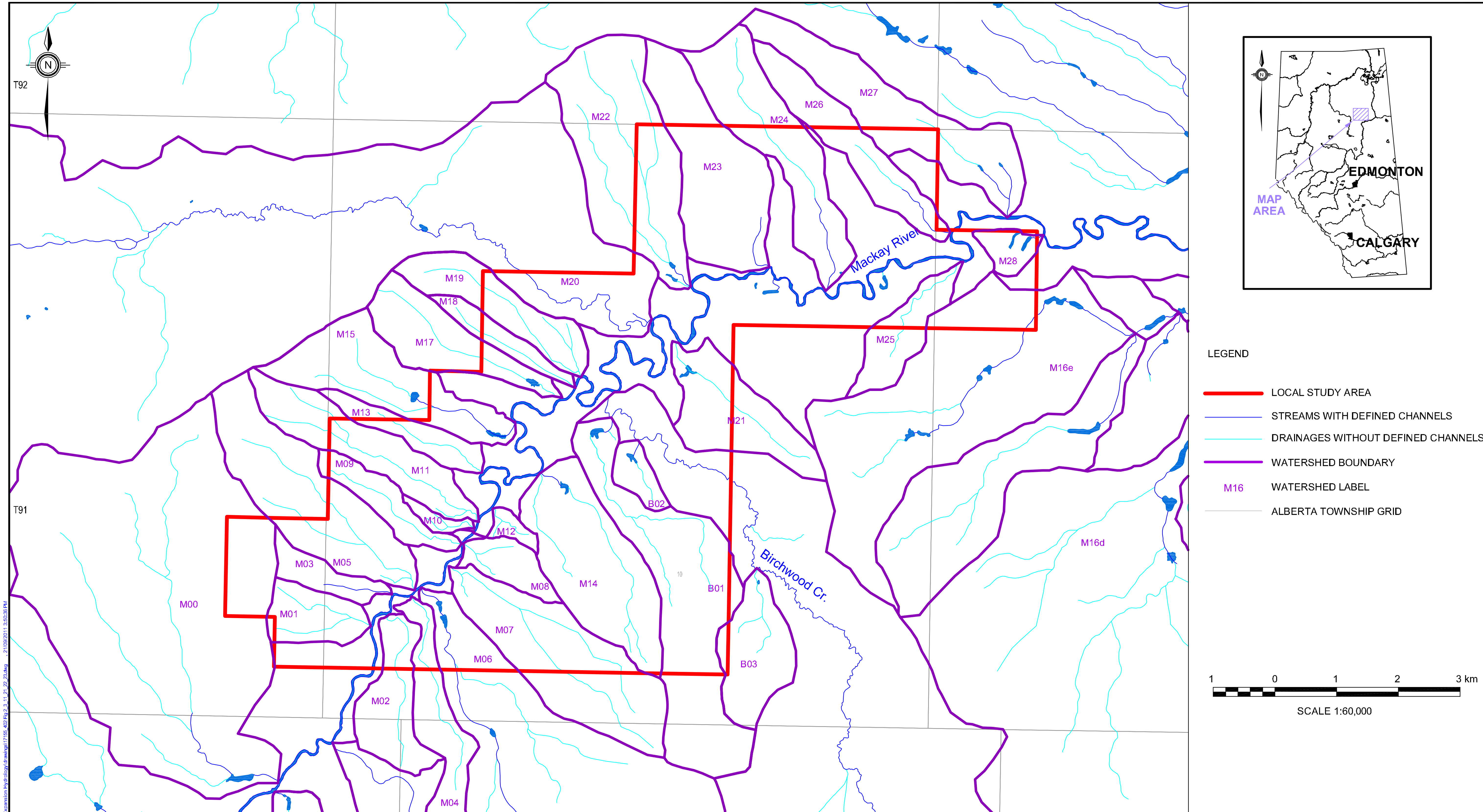

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STP McKAY THERMAL PROJECT - PHASE 2

LOCAL HYDROGRAPHY

Dwg. 7471-405	21 September 2011	**Figure 11**

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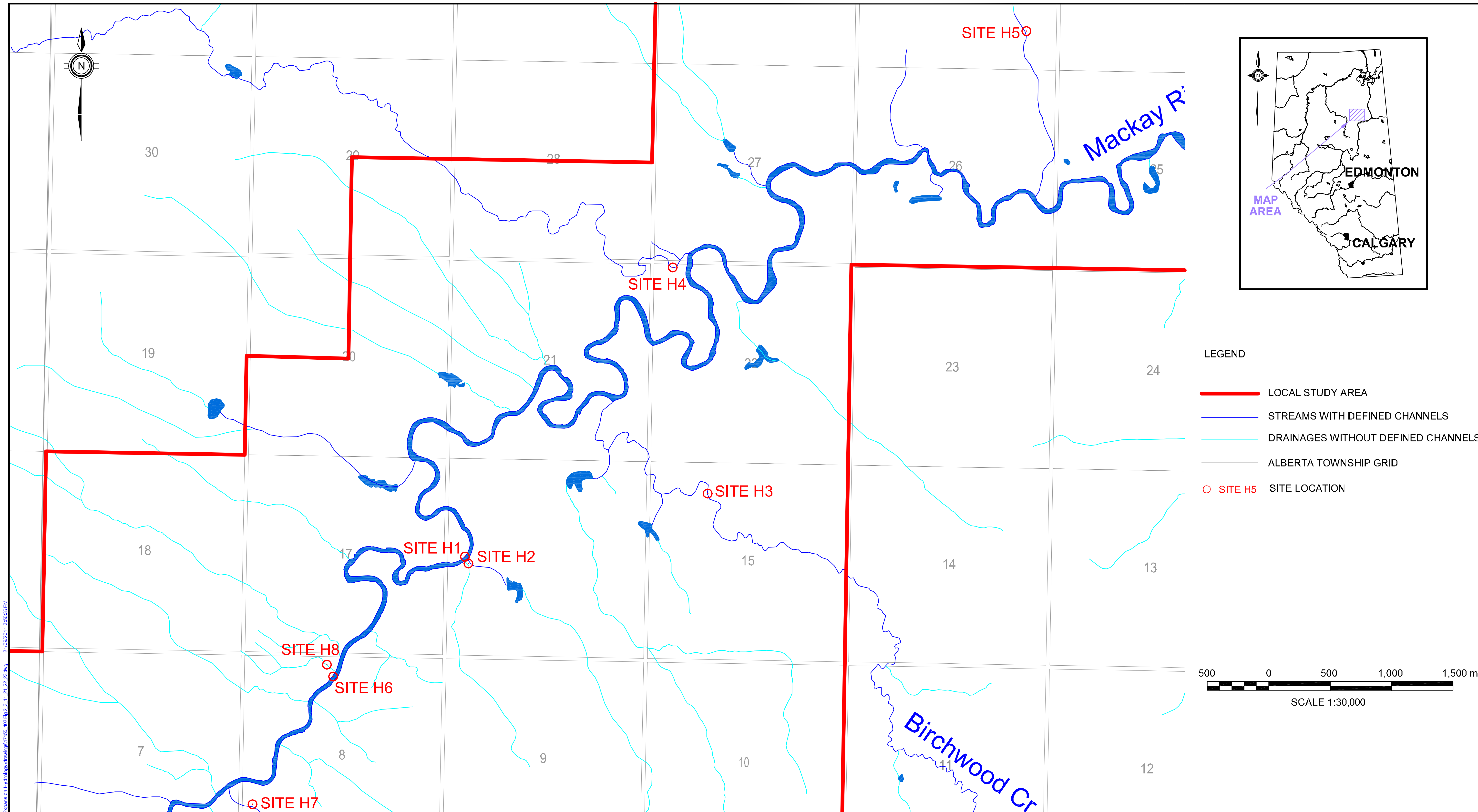

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HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

HYDROLOGY SITE LOCATIONS

Dwg. 7471-405	21 September 2011	Figure 12

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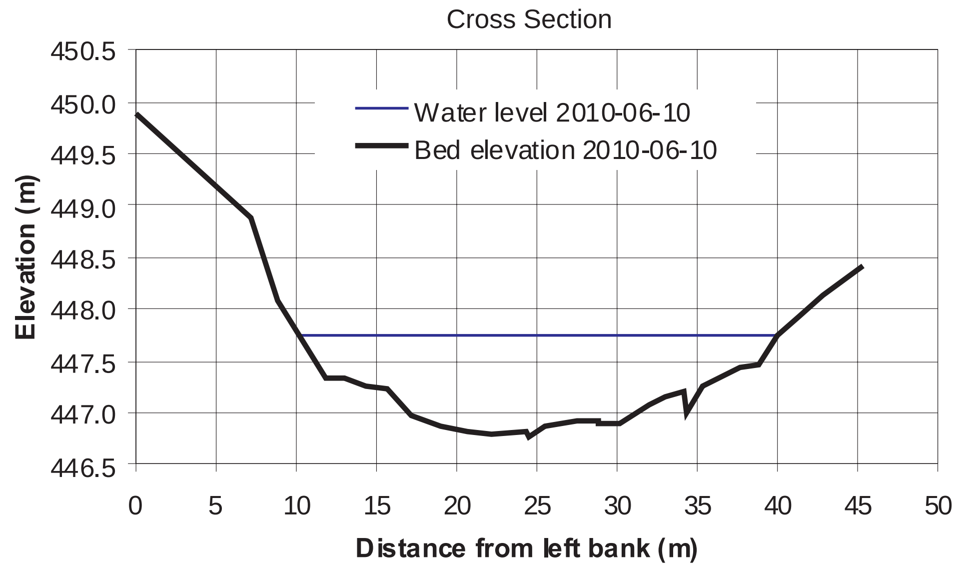
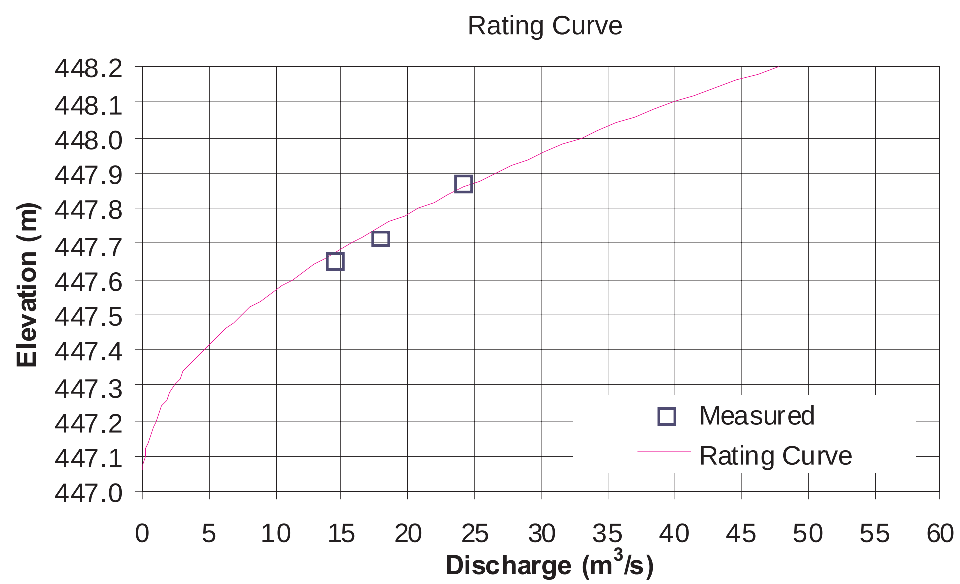


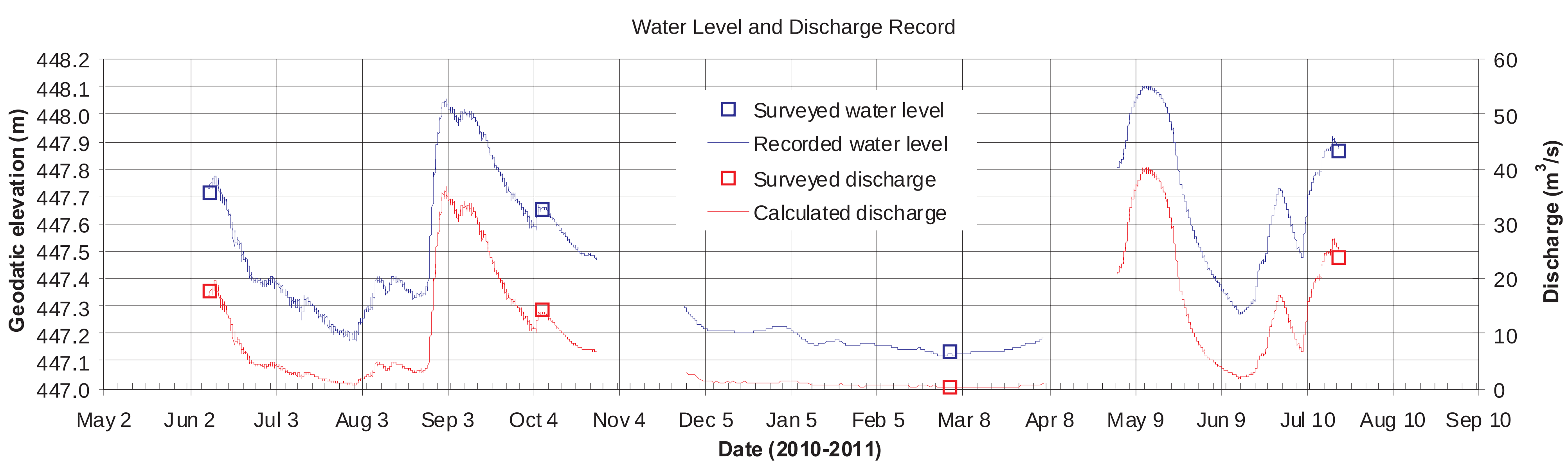
View upstream of cross section

View downstream of cross section



View of cross section from left bank

Aerial view of cross section



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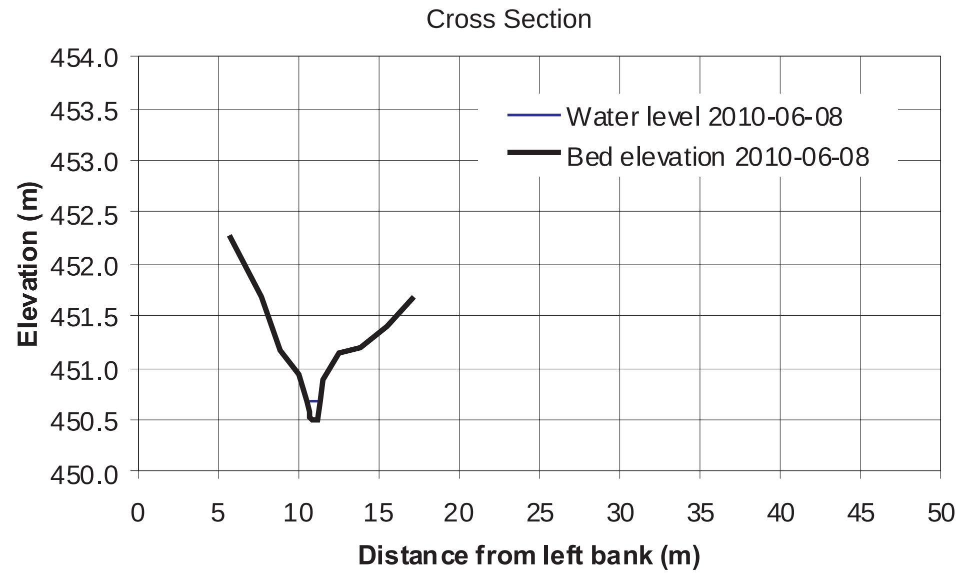
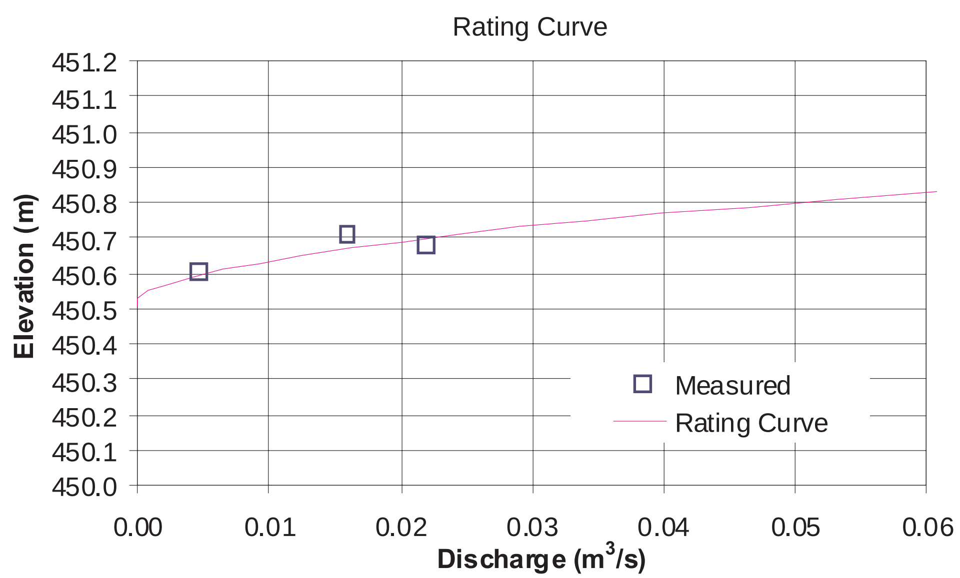
HYDROLOGY ASSESSMENT FOR STP McKAY THERMAL PROJECT - PHASE 2		
CHANNEL CHARACTERISTICS AT SITE H1		
Project 17471	22 Sep 2011	**Figure 13**
northwest hydraulic consultants		



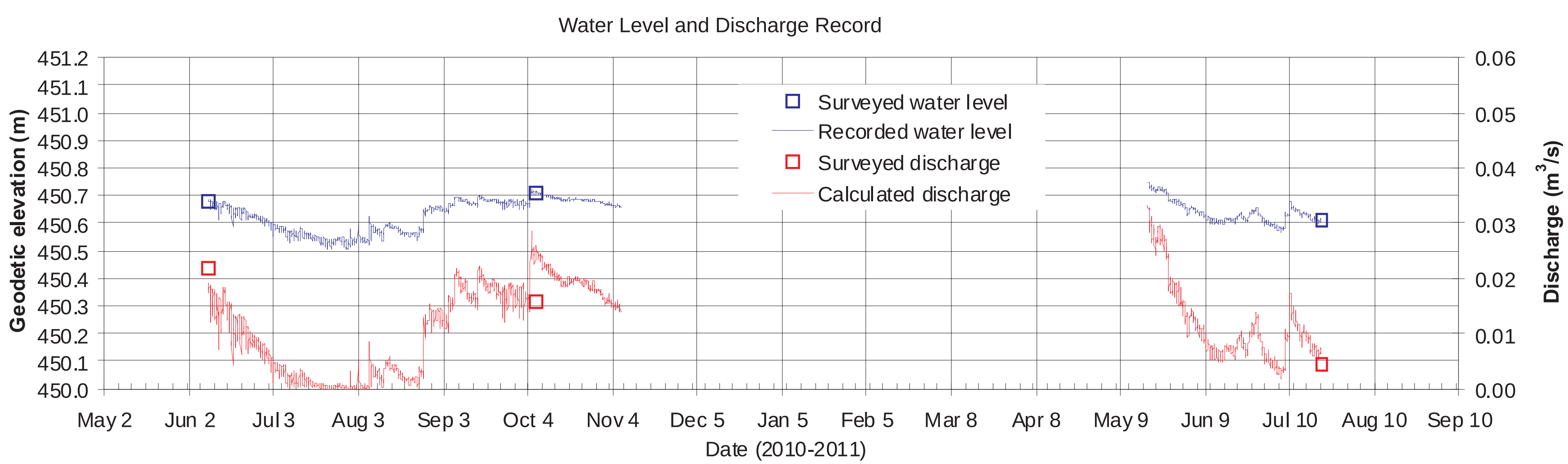

View upstream of cross section


View downstream of cross section




View of cross section


Aerial view of beaver ponds upstream of cross section



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HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

CHANNEL CHARACTERISTICS AT SITE H2

Project 17471	22 Sep 2011	**Figure 14**

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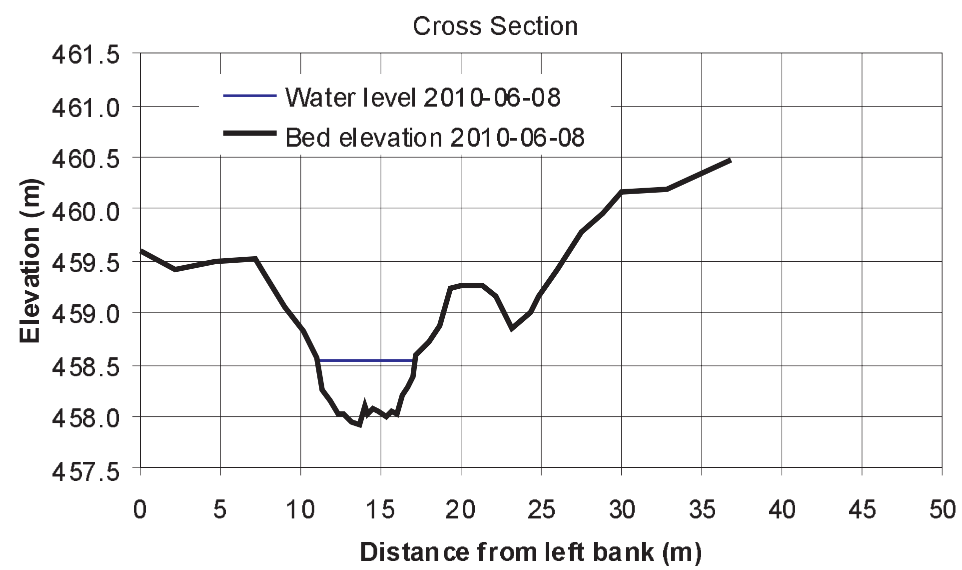
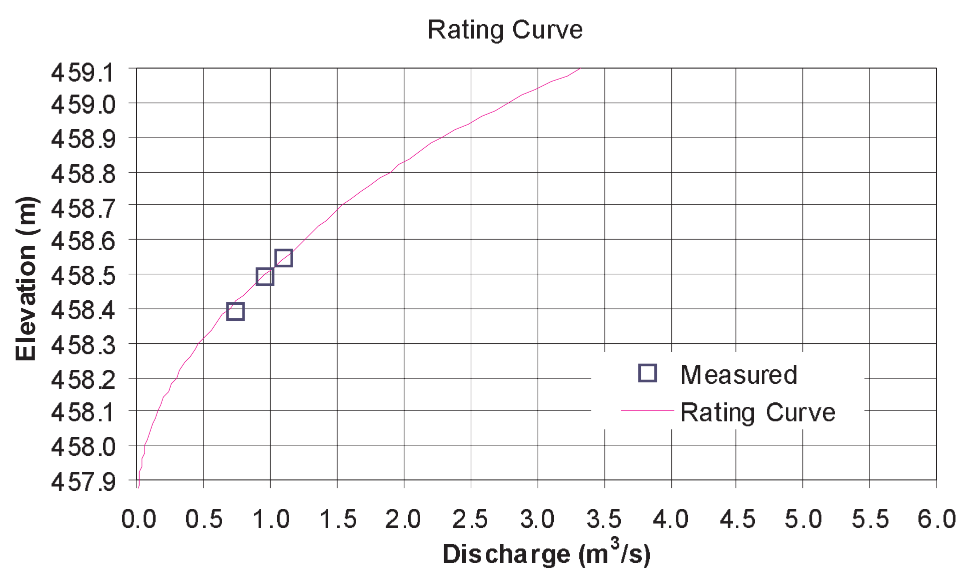


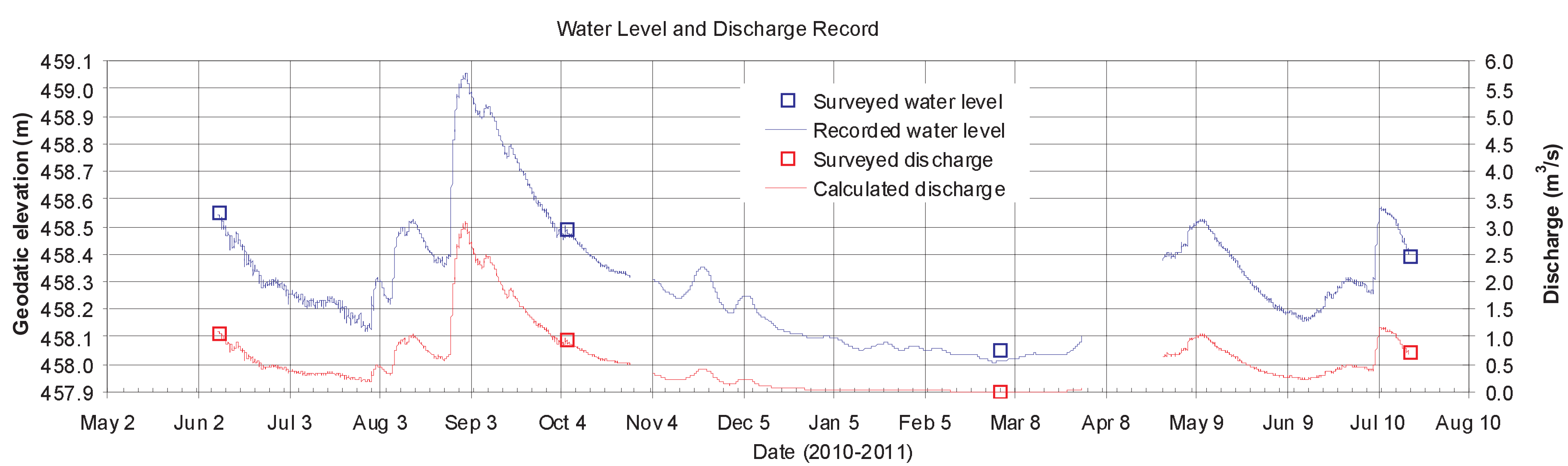
View upstream of cross section

View downstream of cross section



View of cross section

Aerial view of cross section from upstream



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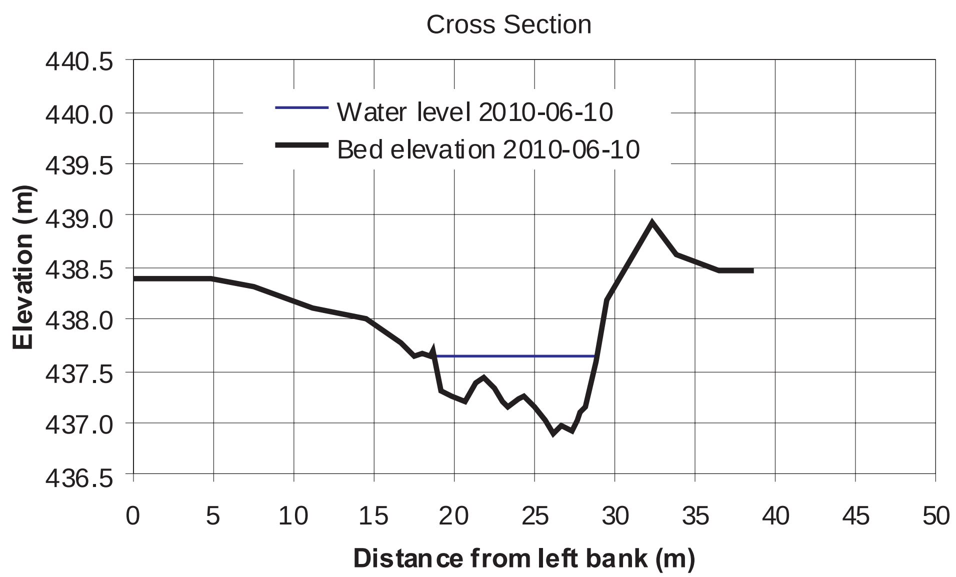
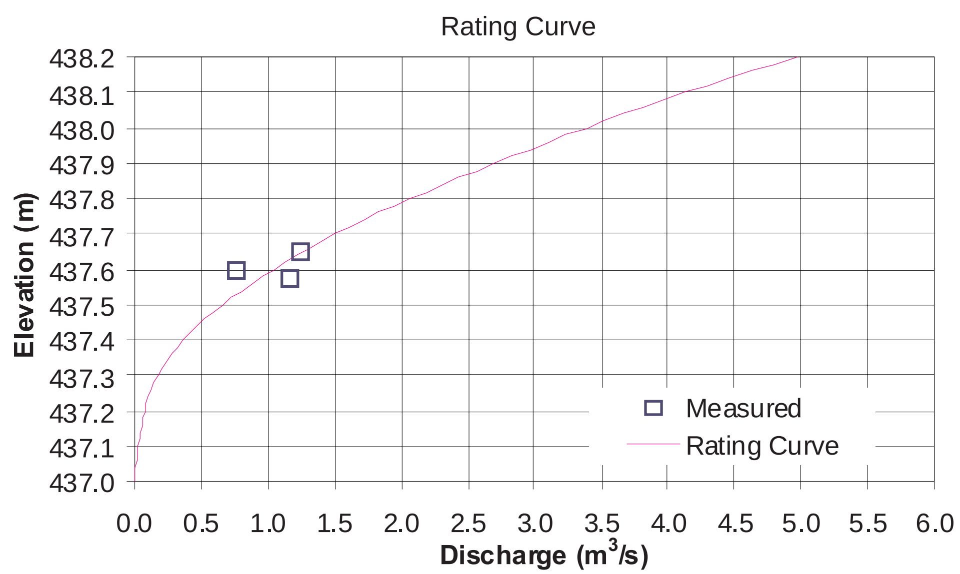
HYDROLOGY ASSESSMENT FOR STP McKAY THERMAL PROJECT - PHASE 2		
CHANNEL CHARACTERISTICS AT SITE H3		
Project 17471	22 Sep 2011	**Figure 15**
northwest hydraulic consultants		



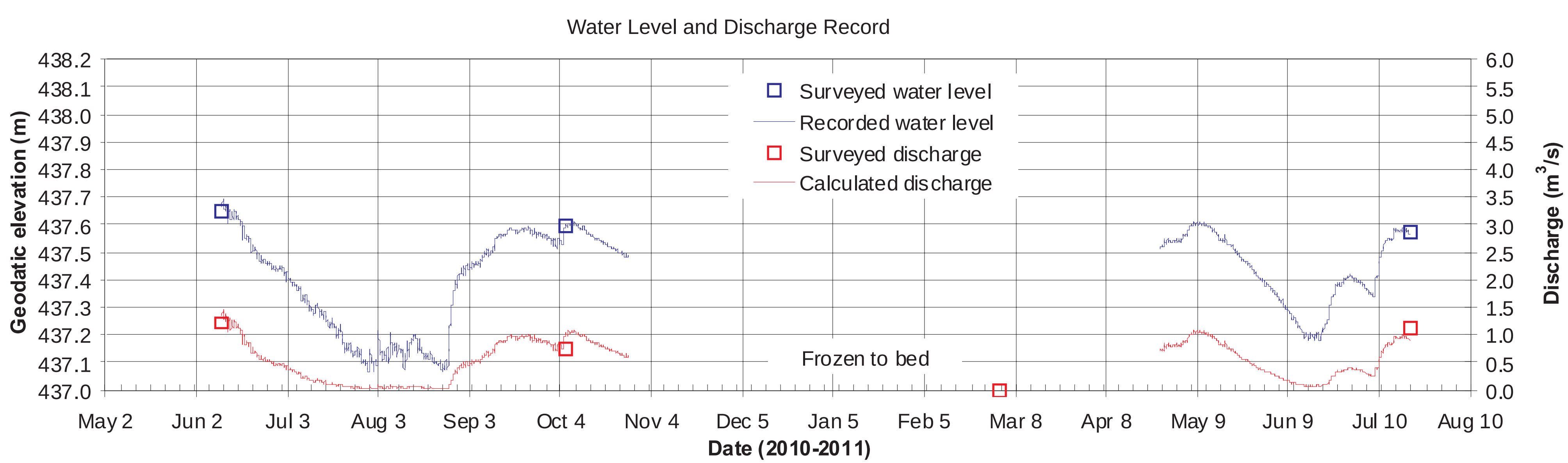

View upstream of cross section


View downstream of cross section




View of cross section


Aerial view of cross section from downstream



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HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

CHANNEL CHARACTERISTICS
AT SITE H4

Project 17471	22 Sep 2011	**Figure 16**

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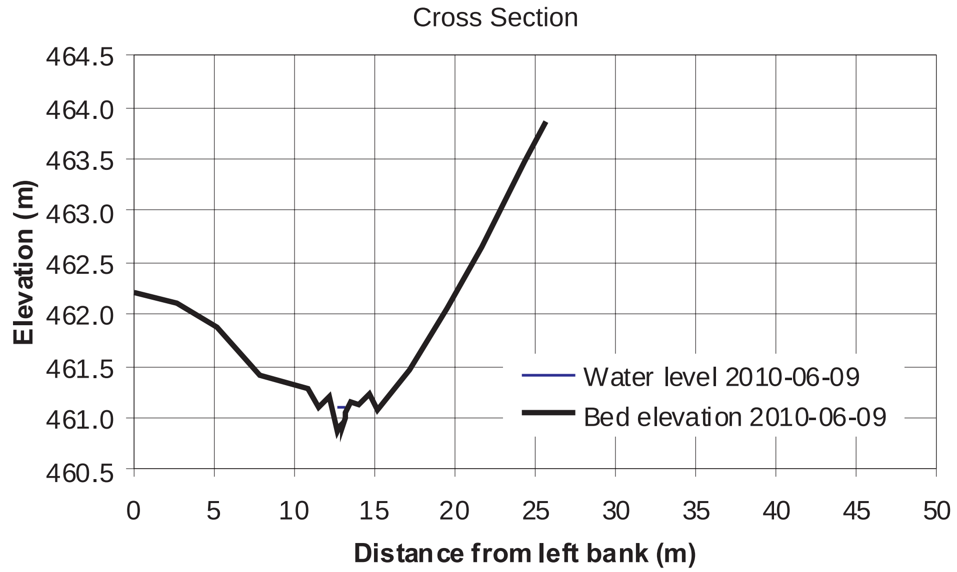
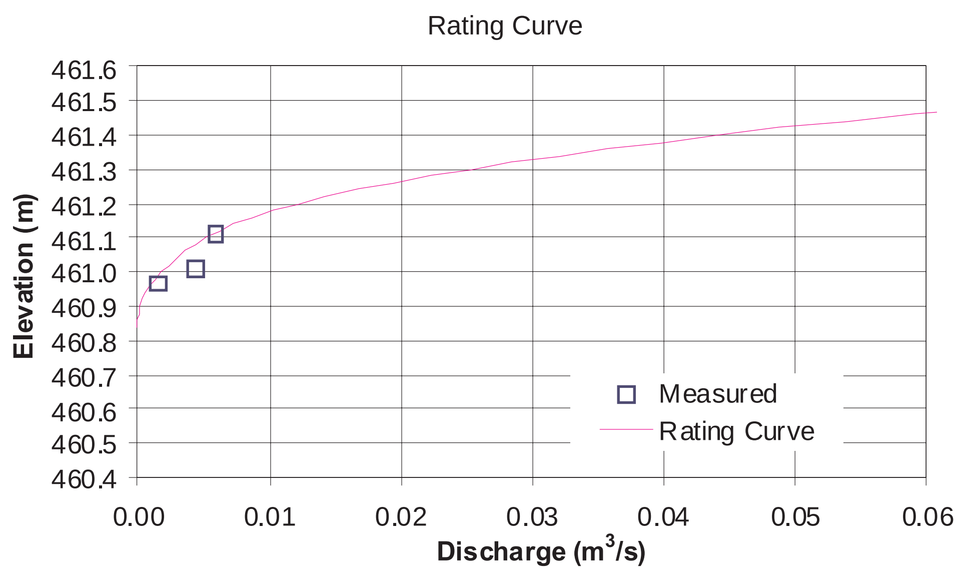


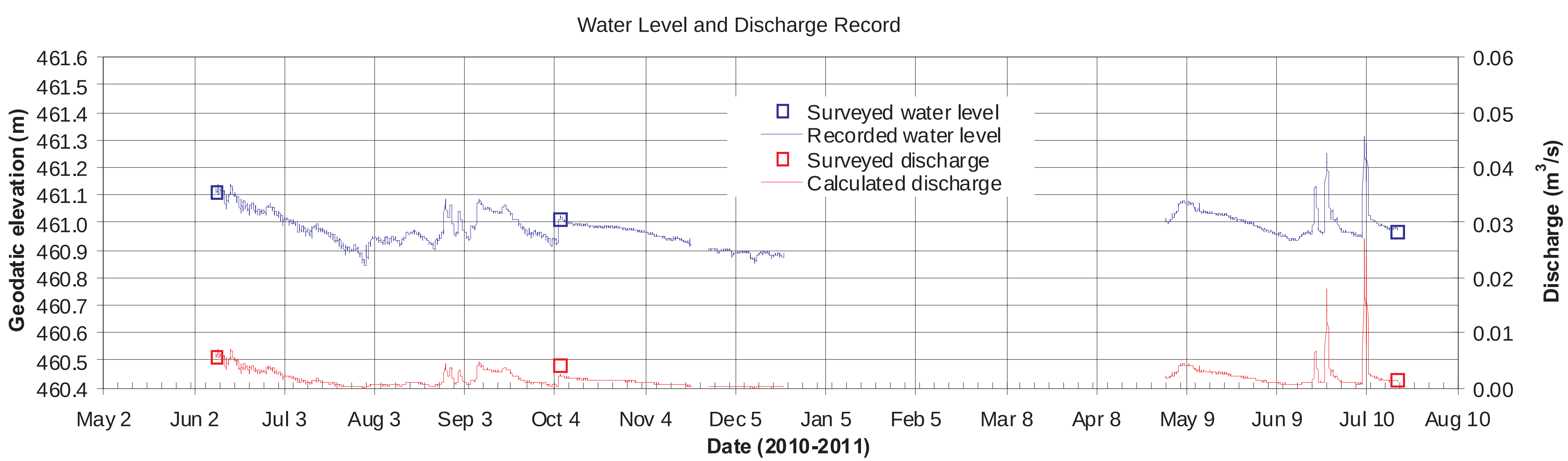
View upstream of cross section

View downstream of cross section



View of cross section

Aerial view of the beaver ponds upstream of cross section



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HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

CHANNEL CHARACTERISTICS
AT SITE H5

Project 17471	22 Sep 2011	**Figure 17**

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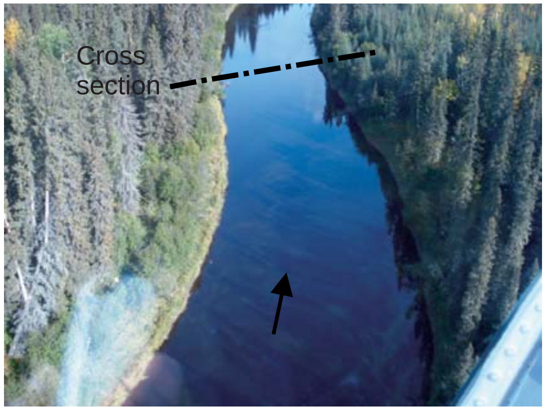
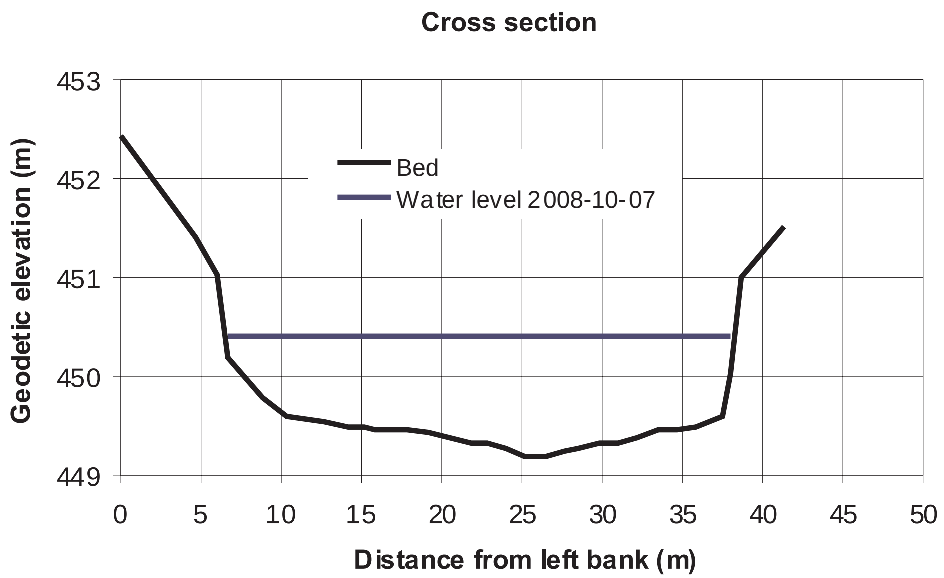


Aerial view of cross section from upstream


View upstream from cross section


View downstream from cross section



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HYDROLOGY ASSESSMENT FOR STP McKAY THERMAL PROJECT - PHASE 2 **CHANNEL CHARACTERISTICS AT SITE H6**		
Project 17471	22 Sep 2011	**Figure 18**
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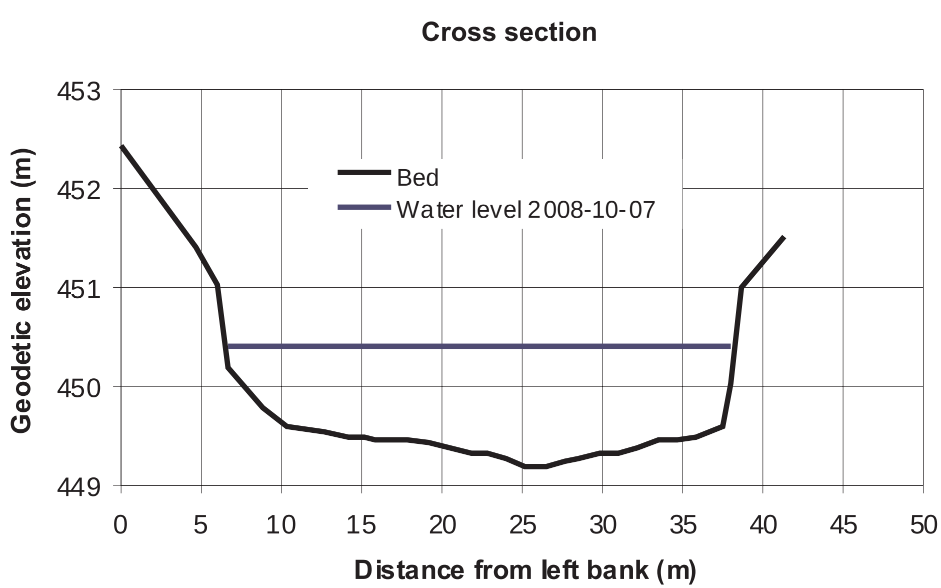
Aerial view looking upstream

View upstream from cross section

View downstream from cross section



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HYDROLOGY ASSESSMENT FOR STP McKAY THERMAL PROJECT - PHASE 2 **CHANNEL CHARACTERISTICS AT SITE H7**
Project 17471 | 22 Sep 2011 | **Figure 19**
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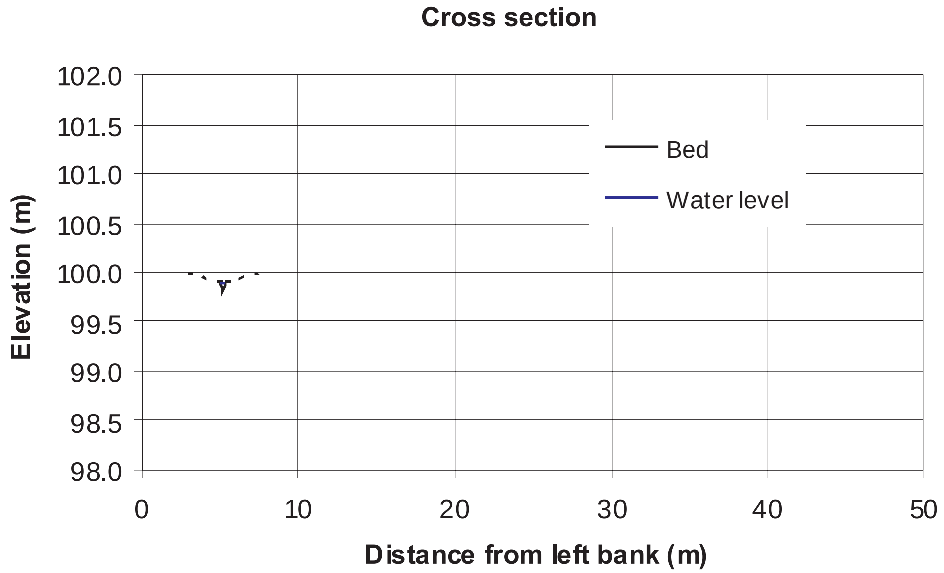
View upstream from cross section

View downstream of cross section

View of cross section



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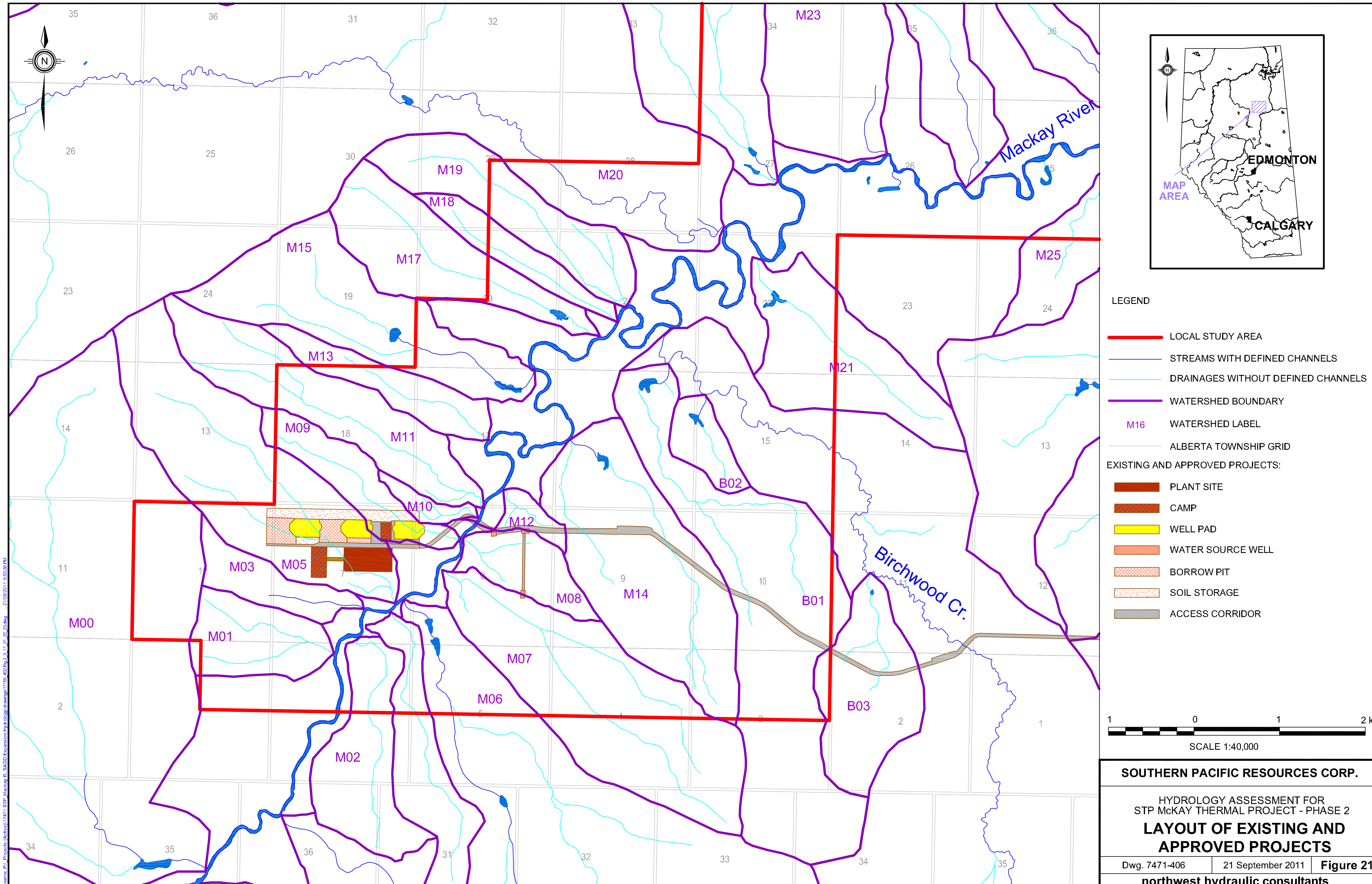
HYDROLOGY ASSESSMENT FOR STP McKAY THERMAL PROJECT - PHASE 2 **CHANNEL CHARACTERISTICS AT SITE H8**		
Project 17471	22 Sep 2011	**Figure 20**
northwest hydraulic consultants		


Mackay River
Birchwood Cr.
M00
M01
M02
M03
M05
M06
M07
M08
M09
M10
M11
M12
M13
M14
M15
M17
M18
M19
M20
M21
M23
M25
B01
B02
B03
EDMONTON
CALGARY
MAP AREA
LEGEND
LOCAL STUDY AREA
STREAMS WITH DEFINED CHANNELS
DRAINAGES WITHOUT DEFINED CHANNELS
WATERSHED BOUNDARY
M16 WATERSHED LABEL
ALBERTA TOWNSHIP GRID
EXISTING AND APPROVED PROJECTS:
PLANT SITE
CAMP
WELL PAD
WATER SOURCE WELL
BORROW PIT
SOIL STORAGE
ACCESS CORRIDOR
1 0 1 2 km
SCALE 1:40,000
SOUTHERN PACIFIC RESOURCES CORP.
HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2
LAYOUT OF EXISTING AND APPROVED PROJECTS
Dwg. 7471-406
21 September 2011
Figure 21
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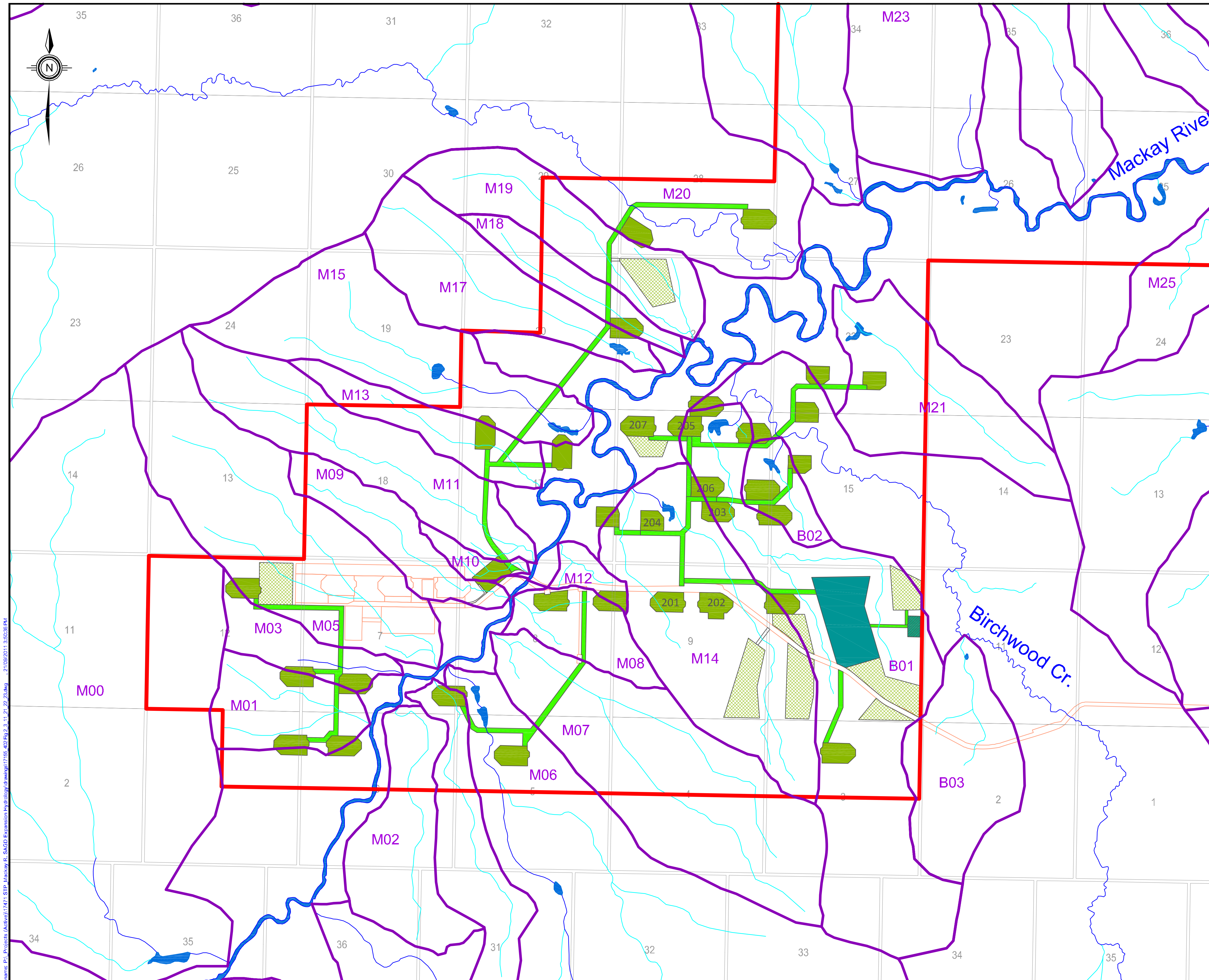

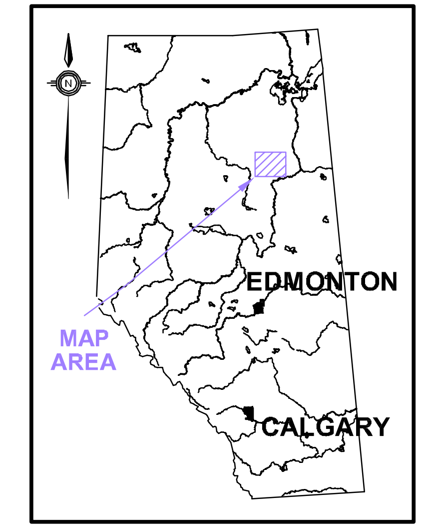

LEGEND

- LOCAL STUDY AREA
- STREAMS WITH DEFINED CHANNELS
- DRAINAGES WITHOUT DEFINED CHANNELS
- WATERSHED BOUNDARY
- M16 WATERSHED LABEL
- ALBERTA TOWNSHIP GRID
- EXISTING AND APPROVED PROJECTS

PHASE 2 DEVELOPMENT

- PLANT SITE
- CAMP
- WELL PAD
- BORROW PIT
- ACCESS CORRIDOR

1 0 1 2 km

SCALE 1:40,000

SOUTHERN PACIFIC RESOURCES CORP.

HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2

LAYOUT OF PHASE 2 DEVELOPMENT

Dwg. 7471-407	21 September 2011	**Figure 22**

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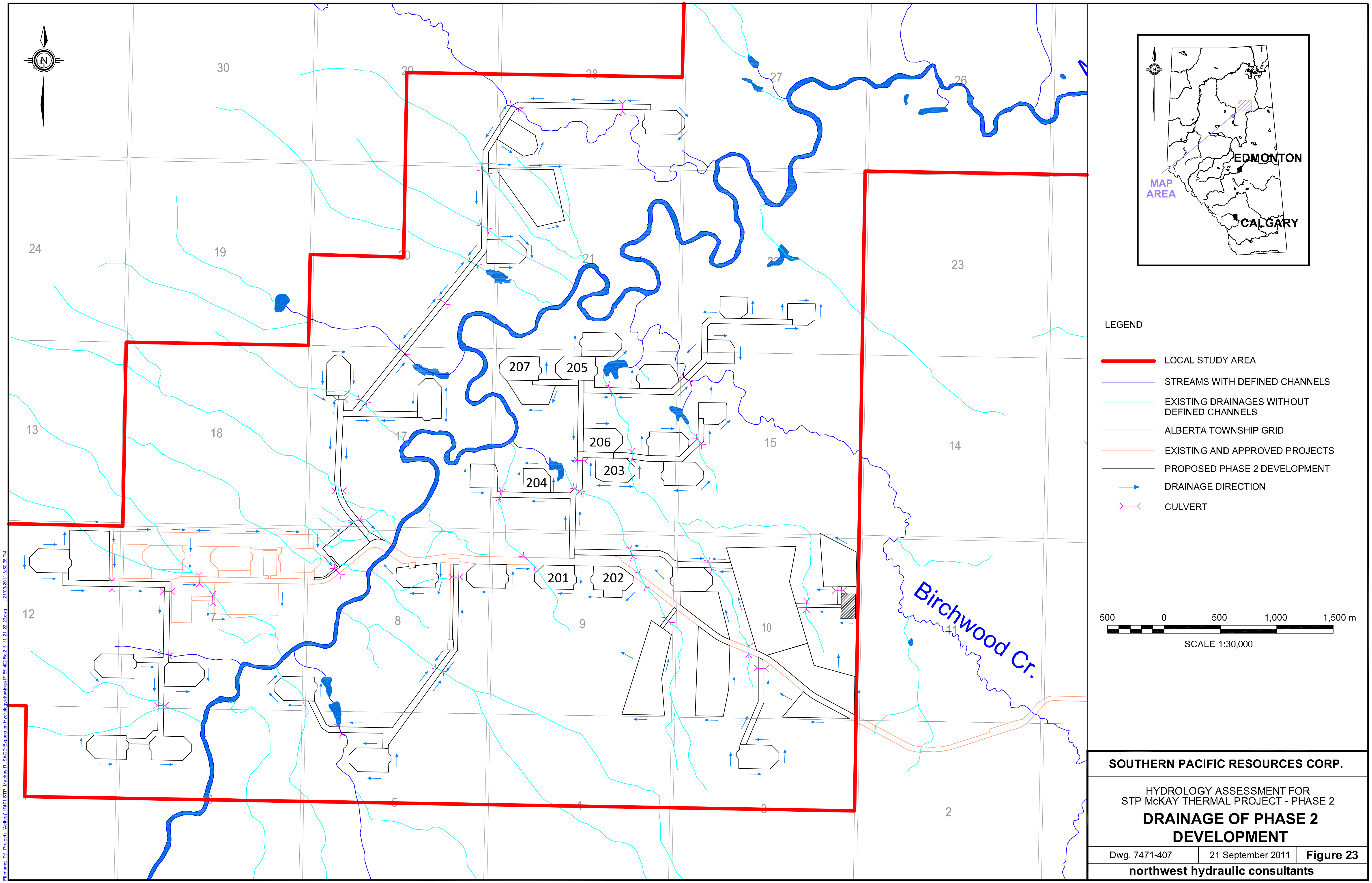
EDMONTON
MAP AREA
CALGARY
LEGEND
LOCAL STUDY AREA
STREAMS WITH DEFINED CHANNELS
EXISTING DRAINAGES WITHOUT DEFINED CHANNELS
ALBERTA TOWNSHIP GRID
EXISTING AND APPROVED PROJECTS
PROPOSED PHASE 2 DEVELOPMENT
DRAINAGE DIRECTION
CULVERT
500 0 500 1,000 1,500 m
SCALE 1:30,000
Birchwood Cr.
201
202
203
204
205
206
207
SOUTHERN PACIFIC RESOURCES CORP.
HYDROLOGY ASSESSMENT FOR
STP McKAY THERMAL PROJECT - PHASE 2
DRAINAGE OF PHASE 2 DEVELOPMENT
Dwg. 7471-407
21 September 2011
Figure 23
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