

Appendix 8.2-A

Baseline Report on Dark Sky

AJAX PROJECT

**Environmental Assessment Certificate Application / Environmental Impact Statement
for a Comprehensive Study**



Baseline Report on Dark Sky

August 6, 2015
Rev 1

EXECUTIVE SUMMARY

KAM Mining Inc. (KAM) proposes to construct and operate an open pit copper-gold mine south of the city of Kamloops, British Columbia (the Project). The location was previously mined by Teck Cominco Ltd. From 1978 to 1997 with an interim shut down period due to low commodity prices. The proposed Ajax Project has a planned processing rate of 65,000 tonnes per day and a predicted mine life of 23 years.

This study assessed the pre-existing sky darkness in the area surrounding the Project. Baseline data was gathered on 16 different dates between June 2012 and October 2014 using a Sky Quality Meter (SQM). The objective was to sample only on clear and moonless nights; however, it was difficult to achieve this on a regular basis due to the timing of monthly new moons and variable atmospheric conditions. Sky Darkness levels around the Kamloops Astronomical Society (KAS) Stake Lake Observatory received special consideration during the development of this study and report due to specific concerns raised regarding potential effects of lighting on the observatory. At the observatory, five readings were gathered on each visit: one at zenith, and four at each cardinal direction. The goal of the cardinal directional readings collected was to provide information on horizon glow obtrusive light which could potentially impact astronomical observations.

A significant finding of this study was that obtrusive light from Kamloops has a measurable impact on areas beyond city limits. The rate at which obtrusive light decreases as distance from the city increases was also observable. Another finding is that outdoor lighting recently installed on the Stake Lake cross country ski trail network has a detrimental effect on sky darkness around the KAS observatory during winter months. Measurements show that the outdoor trail lighting during winter months reduced sky darkness at the observatory to levels typically observed in urban neighbourhoods. Light installation at Stake Lake began in 2010 and has continued periodically for the past four years. To date 4 km of trail lights have been installed. The Overlander Ski Club looks after the lighting system and has the ability to turn off the lights during KAS events (Overlander Ski Club, 2014).

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ABBREVIATIONS AND ACRONYMS

KAM	KGHM Ajax Mining Inc.
KAS	Kamloops Astronomical Society
SQM	Sky Quality Meter
mag/arcsec ²	magnitude/ arcsecond ²

1.0 INTRODUCTION

KAM Mining Inc. proposes to develop the Ajax Project (Project), an open pit copper-gold mine at the historic Afton Mining Camp, south of the City of Kamloops, British Columbia (BC). The Project is located in the South-Central Interior of British Columbia, southeast of the junction of the Trans-Canada Highway No. 1 and the Coquihalla Highway (No. 5), within the Thompson Nicola Regional District.

The Project lies in the traditional territory of the Secwepemc Nation. Within the Secwepemc Nation, the Tk'emlúps te Secwepemc and the Skeetchestn Indian Band are the Aboriginal groups in closest proximity to the Project. In a cooperative effort, the Tk'emlúps te Secwepemc and Skeetchestn Indian Bands have formed the Stk'emlupsemc te Secwepemc Nation (SSN), as a division of the greater Secwepemc Nation. The Ashcroft Indian Band and Lower Nicola Indian Band, whose members are part of the Nlaka'pamux Nation also assert their Aboriginal rights to the Project area- an area of common interest with the SSN.

The Ajax property includes two historic pits: the Ajax West Pit, and the Ajax East Pit. Both pits were formerly mined in the 1980s and 1990s. As many as 25 rock types have been recognized in the Project area, some of which are "hybrid" units resulting from the intermixing of multiple rock types.

Key Project facilities include the Tailings Storage Facility (TSF), which is planned as a conventional tailings storage facility; water management ponds; Peterson Creek diversion, and the Tailings Embankments, which will be constructed using mine rock; and four mine rock storage facilities (MRSFs). The four MRSFs include:

- the South Mine Rock Storage Facility (SMRSF),
- East Mine Rock Storage Facility (EMRSF),
- West Mine Rock Storage Facility (WMRSF), and
- the In-Pit Mine Rock Storage Facility (IPMRSF).

Several facilities that will be part of the operation phase but not remain after project closure include the:

- plant facilities and administration buildings,
- reclamation stockpiles,
- explosives facility,
- truck stop and fuel storage,
- power lines, and
- access roads

The mine plan for the Project predicts an operation based on a mill throughput of 65,000 tonnes of ore per day from the Ajax Pit with up to a 23 year mine life. The construction phase of the Project will be approximately two and a half years, and following the 23 year operation the decommissioning and

closure phase is expected to take up to 5 years. Over the mine life the Project will produce approximately 140 million pounds of copper and 130,000 ounces of gold annually with the concentrate shipped by truck to the Port of Vancouver.

1.1 PROJECT PLAN AND LOCATION OVERVIEW

KAM Mining Inc (KAM) proposes to construct and operate an open pit copper-gold mine south of the city of Kamloops, British Columbia (the Project). The newly proposed 65,000 tonne/day open-pit operation has a predicted mine life of 23 years. Figure 1.1.1 shows the footprint of major mine facilities. Within this footprint are an open pit, internal mine roads, plant and administration facilities, an ex-pit crusher and conveyor, explosive storage and magazine structures, water collection ponds, fence lines, dams, seepage collection ditches, water and tailings pipelines, a tailings storage facility (TSF), mine rock management facilities, ore stockpiles, as well as topsoil and overburden stockpiles.

The historic mine location has been used primarily for ranching purposes since closure of the Teck Cominco Operations in 1997. While there are many range roads and fence lines crossing the property, no outdoor mine light sources currently exist. Neighboring farms along Lac Le Jeune Rd, Goose Lake Rd, Long Lake Rd, and Edith Lake Rd currently utilize outdoor lighting systems and vary in distance to proposed facilities from 0.73 km to more than 3 km. The nearest outdoor lighting systems inside city boundaries are 1.75 km from the proposed mine facility.

The Stake Lake Observatory is located approximately 8.6 km straight-line distance southwest of the proposed southern mine border. The observatory is operated by the Kamloops Astronomical Society (KAS) – a local group that depends on dark skies for meaningful astronomical observations.

1.2 SCOPE AND PURPOSE

This study assessed the baseline (i.e. existing) sky darkness in the area surrounding the proposed Project. Fieldwork was conducted at 17 different times between June 2012 and October 2014. Sky darkness measurements are scheduled to continue through construction and operational phases to monitor impacts to sky darkness and guide mitigation measures.

Obtrusive light occurs as a result of anthropogenic night-time illumination systems that direct light horizontally and upwards, instead of directly down at an intended target. The potential impacts of obtrusive light on health, wildlife, as well as recreational activities such as star gazing and astronomy, have become a contemporary environmental management concern (Andrusiak, 2012; Royal Astronomical Society of Canada, 2012). The KAS' Stake Lake Observatory (UTM10 E678603 N5598470) near Stake Lake is located 13.4 km south of the mine processing plant, which is expected to be the primary outdoor light source for the Project.

The potential impact of mine infrastructure and operations on the quality of sky darkness will be assessed in the environmental assessment of the Project. "Dark Sky" was selected as a valued component for the assessment because of the Project's proximity to the city of Kamloops, as well as stakeholder and public input and concerns regarding obtrusive light (including concerns raised by Kamloops residents during the public comment period of the Draft Application Information Requirements (dAIR) review (KAM, 2012)).

The purpose of this report is to describe the studies undertaken and the baseline conditions of sky darkness in the immediate vicinity of, and areas surrounding, the proposed Project, with particular emphasis on the KAS Observatory. This baseline information will be used to determine the potential effects of the Project on sky darkness, and appropriate obtrusive light mitigation measures, in the EA.

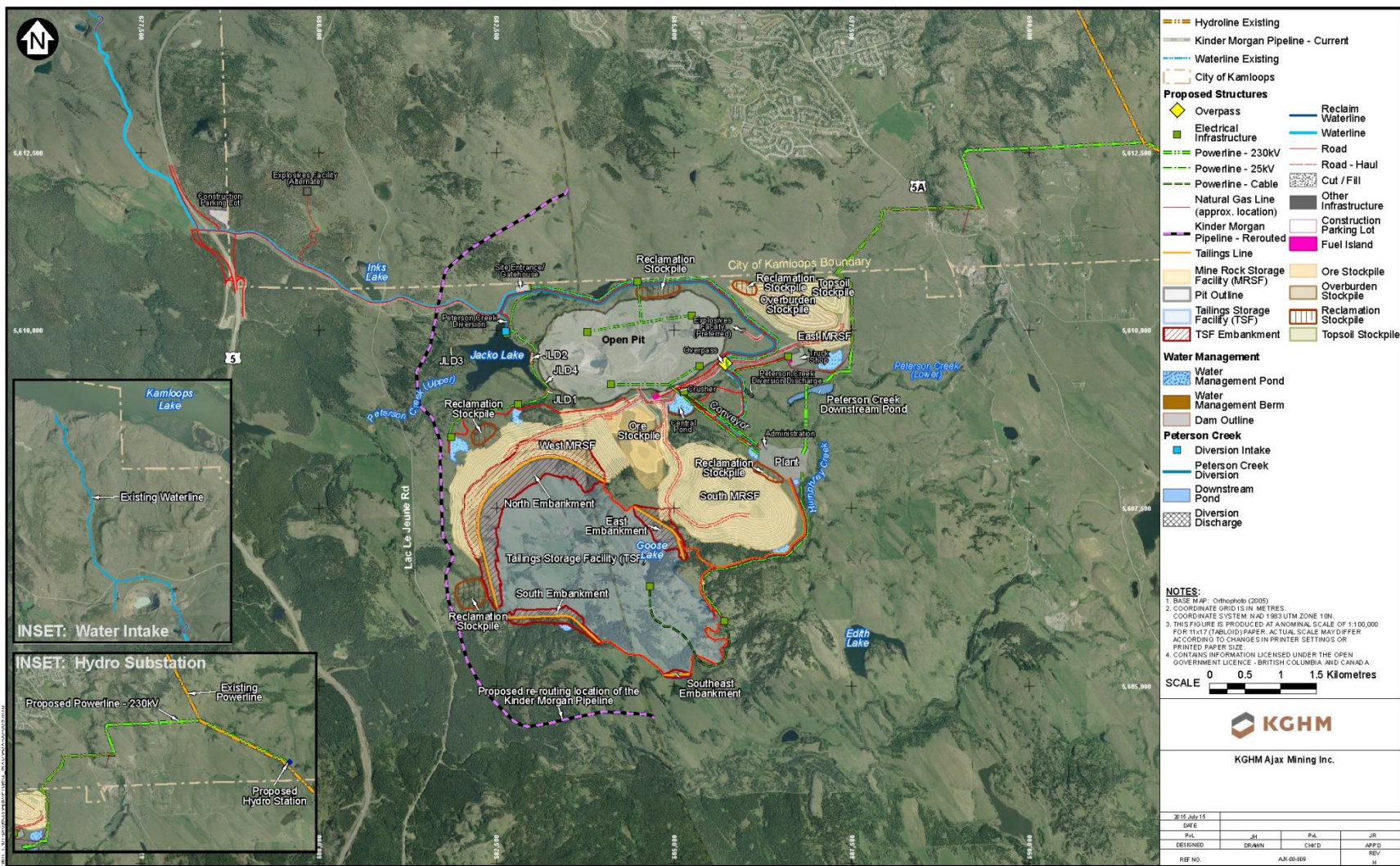


Figure 1.1.1: Location of Proposed Mine Facilities

2.0 SAMPLING METHODOLOGY

2.1 SKY QUALITY METER

The study used a Sky Quality Meter (SQM) made by Unihedron (Grimsby, Ontario, Canada) to measure sky darkness at 19 locations in and around the proposed Ajax Project, on 17 different occasions. The SQM (Figure 2.1.1) is a handheld device that measures visible light in units of magnitude/arcsec² and has been used successfully by both amateur astronomers and academics (KAS, 2012). Standard methodology does not exist for Dark Sky monitoring. The methodology used in this study was developed with assistance from the Kamloops Astronomical Society and Robert Dick, an expert in Dark Sky Preservation (KAS, 2012; Dick, 2012). The Project proponent (KAM) met and consulted with the KAS several times throughout the two-year sampling period to help identify useful sample locations, instrumentation, and literature related to the study. This included formal meetings prior to the start of sampling to finalize an agreeable methodology, as well as other periodic formal and informal correspondence and presentations during the sampling period.

Three readings were recorded at each location during each sampling period and then averaged during analysis. Sampling locations were marked using a GPS system to ensure that data were gathered in the same place repeatedly. All sites had measurements taken at the zenith. Data collected from the KAS's observatory near Stake Lake also included horizon glow measurements. Horizon glow was measured at an angle of 30 degrees towards the four specific azimuths of 90°, 180°, 270°, and 360°.

The SQM device provides a digital readout of sky brightness. Values range from 10-17 mag/arcsec² in brightly lit urban areas or during a full moon, to 17-23 mag/arcsec² for darker skies. Readings from the SQM were recorded manually on a custom log sheet (Appendix A). Research technicians documented:

- Light magnitude readings;
- Land cover (e.g. snow during winter);
- Meteorological conditions;
- Date and time; and
- Location.



Figure 2.1.1: Sky Quality Meter by Unihedron

2.2 SAMPLING SCHEDULE

Sky darkness samples were gathered once a month within three days of a new moon when natural light is at the lowest level of intensity. Sampling began in June 2012 and continued periodically through to June 2014, covering 25 months in total. The new moon schedule used to determine sampling dates is provided in Table 2.1.1. Sample dates were selected based on four factors:

- Safety concerns related to road and weather conditions;
- Date of the new moon;
- Staff availability; and
- Clear skies (i.e. weather).

In nine of the 25 months, sampling was prevented due to a variety of reasons. There were a number of nights where overcast skies persisted for several days either side of a new moon and sampling was therefore not carried out. Staff availability due to unfavorable weather conditions and safety concerns associated with sampling on unsafe terrain at certain times of the year also prevented sampling at some times. However, sampling did occur on occasion when light-to-moderate cloud cover was present in the area and covered all four seasons under various ground cover conditions. In total, dark sky readings were taken over 16 fieldwork nights. The details of specific sampling dates are provided below in Table 3.3.2.

Table 2.1.1: New moon schedule w/ Sunset Time

Month	2012			2013			2014		
	New Moon Date	Sampling Date	Sunset	New Moon Date	Sampling Date	Sunset	New Moon Date	Sampling Date	Sunset
January	-	-	-	11	11 th	4:19	30	30 th	4:06
February	-	-	-	10	12 th	5:07	-	-	-
March	-	-	-	11	13 th	6:58	1	4 th	5:41
April	-	-	-	10	-	7:47	28	4 th	8:16
May	-	-	-	10	-	8:33	28	1 st	8:59
June	19	19 th	9:17	8	-	9:11	27	4 th	9:18
July	19	18 th	9:06	8	-	9:14	-	-	-
August	17	16 th	8:19	6	-	8:39	-	-	-
September	15	17 th	7:16	5	11 th	7:39	-	-	-
October	15	16 th	6:10	4	10 th	6:34	-	-	-
November	13	15 th	4:18	3	-	4:34	-	-	-
December	13	-	3:56	3	-	3:59	-	-	-

2.3 SAMPLE LOCATIONS

The study began with 15 sample locations. Four locations were added throughout the program as changes to the Project footprint occurred, for a total of 19 sampling locations. These include residential areas of Sahali, Pineview, Aberdeen and Knutsford, surrounding rural roadways located to the south of the proposed Project, as well as the Kamloops Astronomical Society Observatory. Sample locations were chosen based on accessibility, feedback from stakeholders such as the City of Kamloops and KAS, topographic influences and distance to existing light sources. The complete list of sampling locations can be found in Table 2.2.1. These 19 baseline monitoring locations will be sampled throughout construction and operations to continually monitor changes to sky darkness.

In addition, SQM readings were gathered from 40 locations on September 27, 2014 and combined with mean values from the original 19 sites to produce a more detailed baseline thematic map (Figure 3.3.1). Spatial analysis GIS tools were used to extrapolate sky darkness zones and illustrate a general regional trend in existing sky quality from downtown Kamloops to Lac Le Jeune. Figure 2.2.1 illustrates the location of all 59 sample locations relative to proposed mine facilities and the City of Kamloops.

Table 2.2.1: List of Sampling Locations and Average Reading

Location ID	Coordinates		Average SQM Reading	Location ID	Coordinates		Average SQM Reading
	X	Y			X	Y	
1	687486	5613665	20.05	32	678983	5610170	20.74
2	685912	5612632	19.97	33	680802	5610324	20.72
3	684102	5614222	19.28	34	680053	5614030	20.48
4	680434	5610403	21.23	35	681172	5614831	20.31
5	678608	5598433	21.54	36	683249	5614803	19.92
6	681695	5603940	21.45	37	684887	5614598	19.52
7	684700	5605929	21.36	38	682380	5615908	19.29
8	688918	5609811	21.09	39	684549	5615716	19.79
9	685680	5609366	21.12	40	685880	5614958	18.59
10	683426	5610902	19.58	41	685711	5616611	19.23
11	683239	5612758	19.96	42	686022	5617429	19.42
12	684683	5612151	20.17	43	687104	5616045	13.65
13	684665	5612000	20.44	44	686858	5615029	19.46
14	685001	5611736	20.35	45	687854	5615083	19.39
15	678410	5611393	21.14	46	686767	5613882	19.68
16	680434	5610403	20.66	47	687471	5612848	19.92
17	689683	5608208	21.05	48	688640	5611413	20.47
18	675084	5612670	20.16	49	689920	5606623	21.00
19	687451	5605855	21.05	50	689747	5607747	20.93
20	678069	5595786	21.55	51	687602	5607560	20.94
21	680330	5612922	50.58	52	689497	5609103	20.82
22	680979	5611576	20.75	53	687240	5609370	20.73
23	680988	5609000	20.86	54	686607	5609138	20.75
24	681746	5605608	21.01	55	685522	5609158	20.76
25	680941	5601814	21.11	56	685252	5608846	20.79
26	678689	5599473	21.12	57	684827	5608552	20.85
27	677711	5596466	21.15	58	684929	5607906	20.86
28	675328	5595676	21.16	59	685074	5607552	20.90
29	675994	5595979	21.03	60	684717	5607073	20.95
30	678233	5598344	21.00	61	679355	5613061	20.78
31	670708	5603721	20.89				

*Red highlight indicates sites that were removed due to GPS malfunction equating to 59 usable sites

**Sites 21 to 61 were used solely for thematic mapping purposes

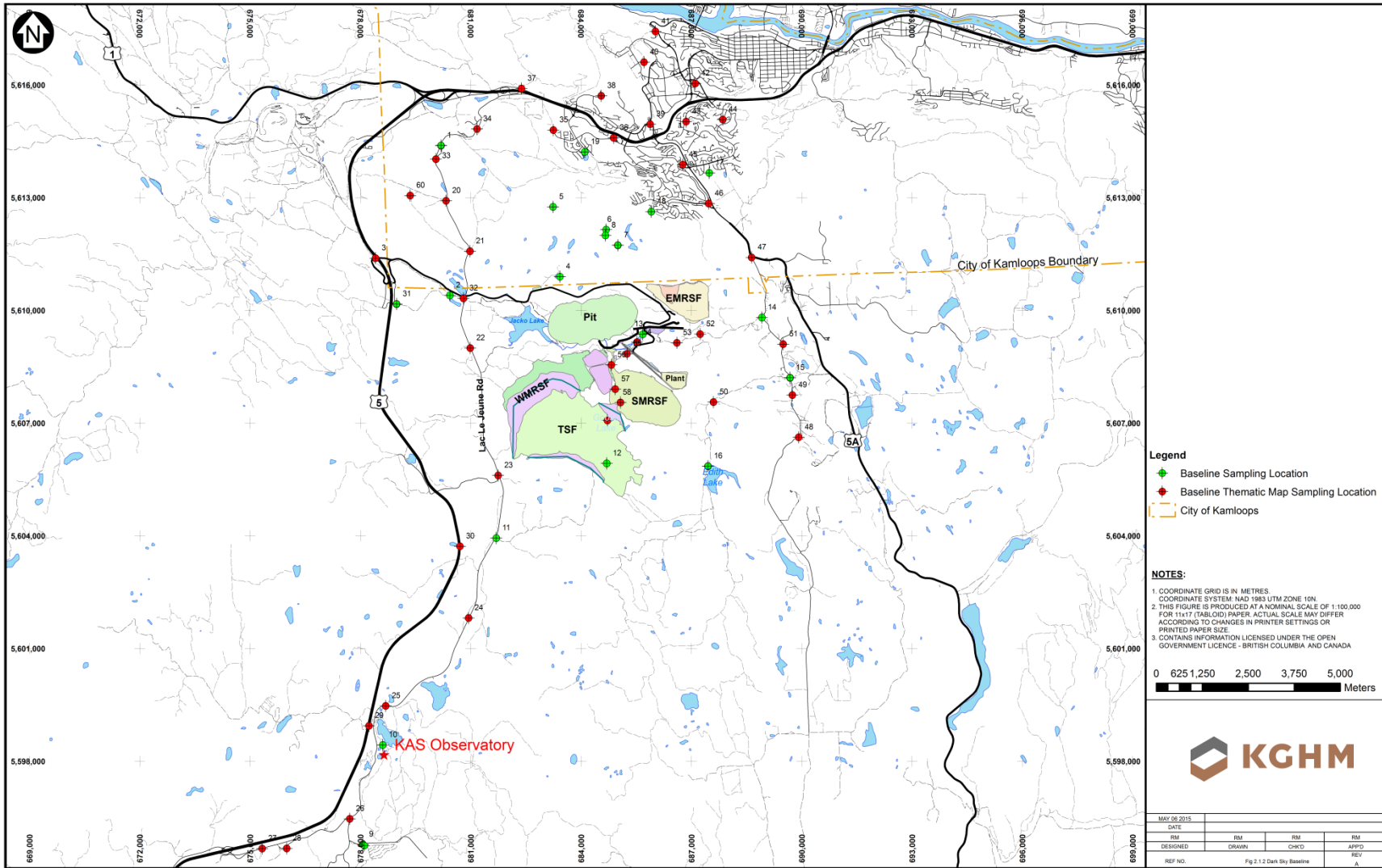


Figure 2.2.1: Sample Locations Relative to Proposed Facilities and City of Kamloops

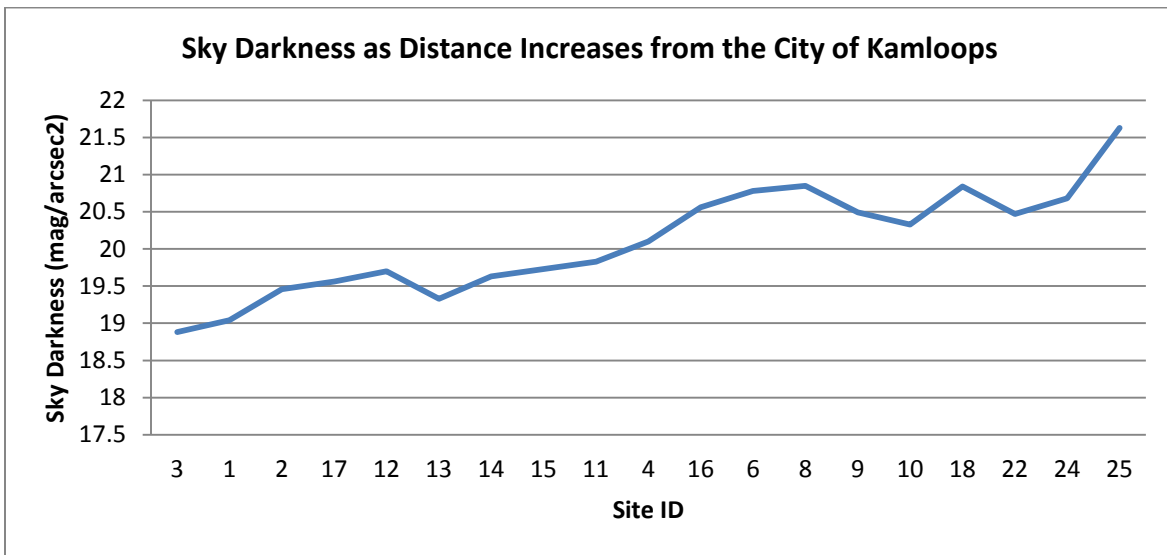
3.0 DARK SKY ANALYSIS AND RESULTS

3.1 BASELINE RESULTS SUMMARY

A total of 16 fieldwork nights occurred under various sky and ground cover conditions. The goal was to sample only on clear nights; however, it was difficult to achieve this on occasion due to the timing of monthly new moons and variable atmospheric conditions. Sampling results show that the existing quality of sky darkness is greatly influenced by cloud cover and resulting light scattering. On nights with light to moderate cloud cover, sky darkness readings were, on average, 1.5 orders of magnitude lighter than on cloudless nights.

The level of darkness also increased with distance away from the city of Kamloops, indicating a noteworthy baseline level of urban obtrusive light in the rural areas near the proposed mine site (Figure 3.1.1). This observation is confirmed by the empirical sampling of this study, as well as the World Atlas' Global Obtrusive light mapping project (World Atlas, 2000). A map completed by the World Atlas illustrates the current (pre-Project) level of regional obtrusive light caused by the City of Kamloops, the City of Merritt, urban developments in the Okanagan Valley, industry and transportation infrastructure (Figure 3.1.2).

Figure 3.1.3 and 3.1.4 illustrate sky darkness using the Bortel Classification System and Sky Quality Meter units of mag/arcsec², respectively. The darkest samples were routinely gathered from the KAS observatory near Stake Lake. The darkest baseline reading of 21.76 mag/arcsec² was taken at the KAS observatory in June 2014 with average readings throughout the sampling period of 20.84 mag/arcsec². However, when the effects of an outdoor ski lighting system are combined with homogenous snow cover on the surrounding winter landscape, readings at the Observatory were reduced to 18.00 to 18.58 mag/arcsec², which is comparable to well-lit urban neighbourhoods (Figure 3.1.4). The outdoor lighting system was installed in phases beginning in 2010. To date there are approximately 40 lights over a distance of 4 km of trails (Overlander Ski Club, 2015). Trail lights are turned on by sensors at dusk and turned off by timers at 10:00 PM throughout the winter. The Ski Club also has the ability to turn off lights during KAS events to avoid disruptions to star gazing.



aFigure 3.1.1: Sky Darkness increases with increasing distance from Kamloops, BC

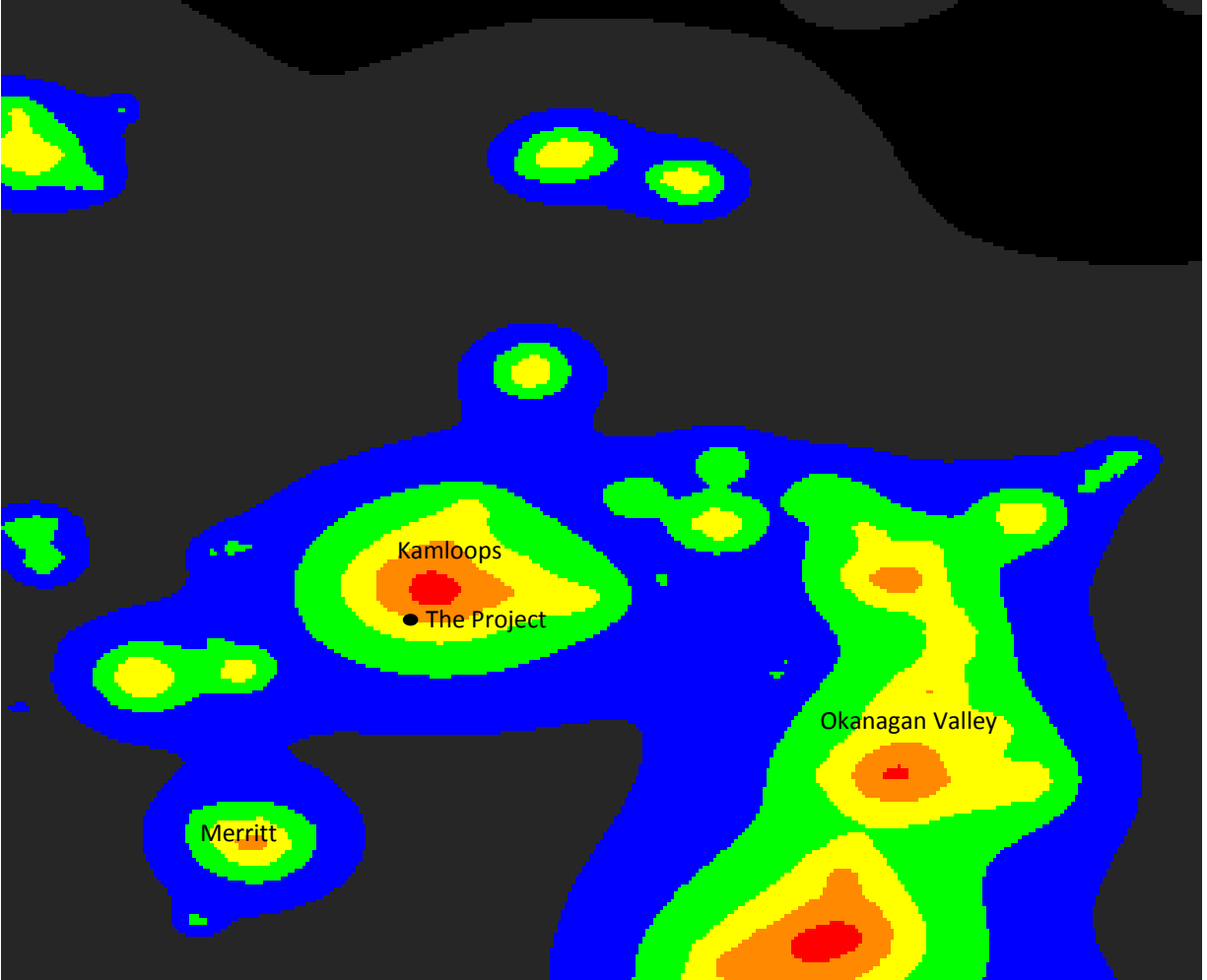


Figure 3.1.2: Existing Regional Obtrusive light – Kamloops Region (World Atlas, 2000)

Corresponding Sky Darkness Key

Color	Bortle	Sky Brightness	
Magnitude	Class	mag/arcsec ²	Artifi./Natural
7.6 - 8.0	1	>21.90	<0.01
7.1 - 7.5	2	21.90 - 21.50	0.01 - 0.11
6.6 - 7.0	3	21.50 - 21.30	0.11 - 0.33
6.3 - 6.5	4	21.30 - 20.80	0.33 - 1.00
6.1 - 6.3	4.5	20.80 - 20.10	1.00 - 3.00
5.6 - 6.0	5	21.1 - 19.10	3.00 - 9.00
5.0 - 5.5	6,7	19.1 - 18.00	9.00 - 27.0
<4.5	8,9	<18.00	>27.0

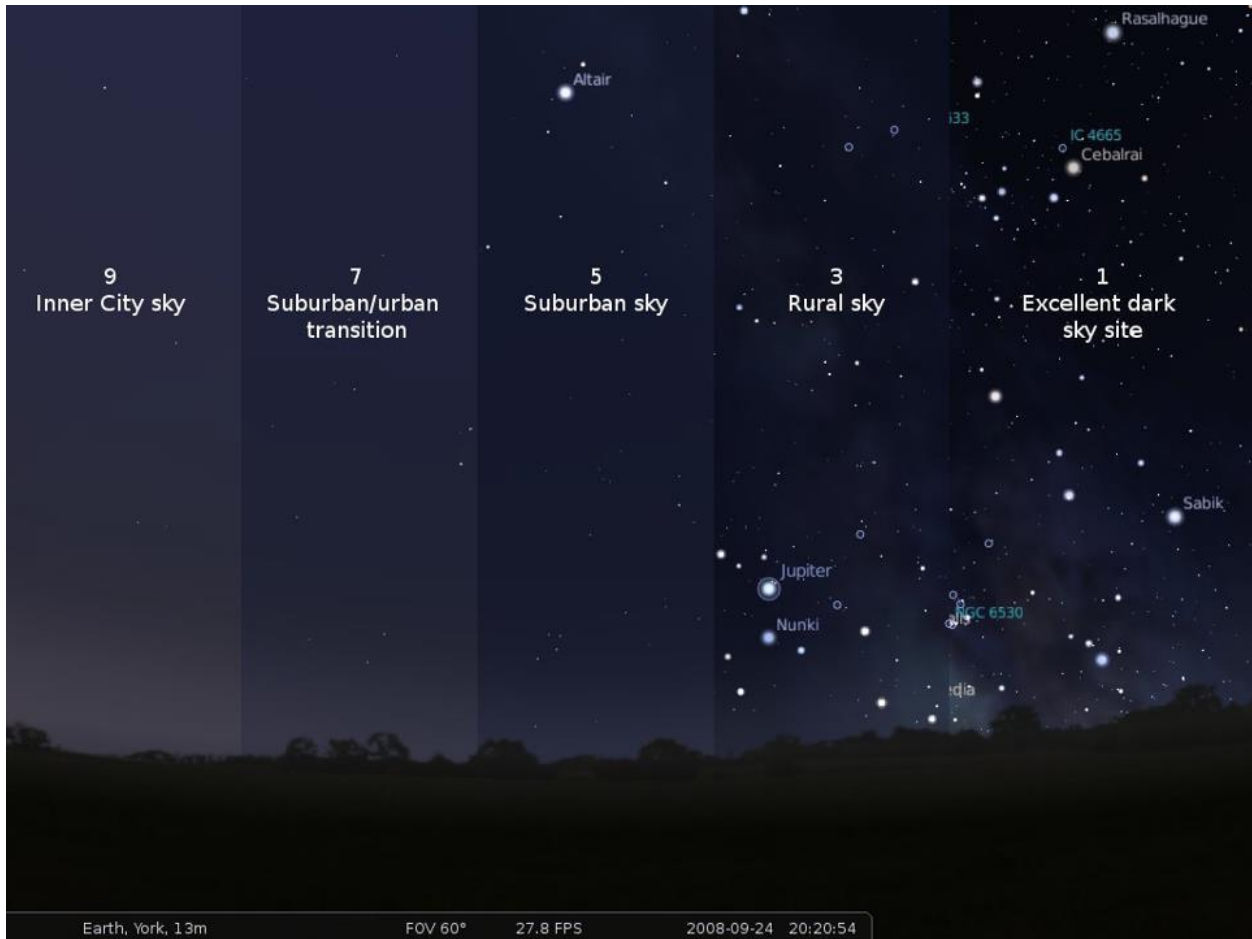


Figure 3.1.3: Visual Dark Sky Representation of Bortle Classification Ratings (Quarts to Quasars, 2014)

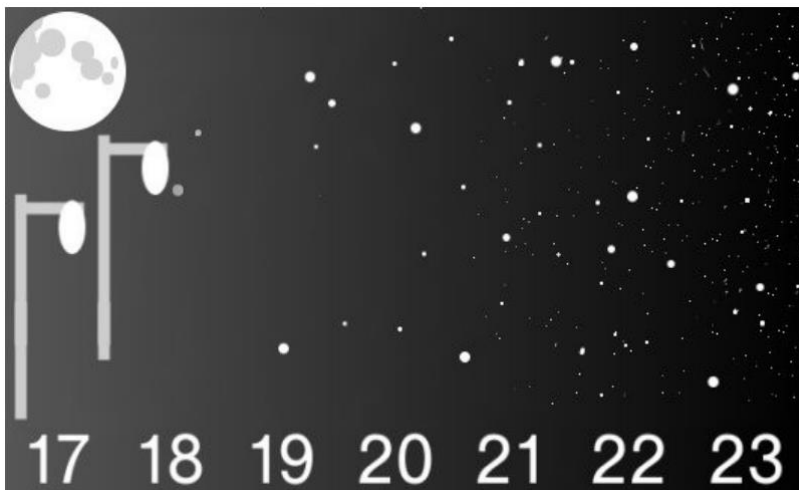


Figure 3.1.4: Visual Dark Sky Representation in units of mag/arcsec² (Unihedron, 2012)



Figure 3.1.5: KAS Observatory when outdoor lighting is in operation on ski trails with snow cover present

3.2 City of Kamloops Outdoor Lighting Improvements

On May 15, 2012 the City of Kamloops authorized additional funding to install adaptive LED lighting technology in the neighbourhoods of Sahali, Aberdeen, Bachelor Heights, and Juniper Ridge. The anticipated benefits to the city included reductions in CO₂ emissions, energy usage, solid waste, and nighttime sky pollution and disruptions to migratory birds (City of Kamloops, 2013).

A formal report and schedule of completion for the adaptive lighting project was not available from the City of Kamloops. However, the final phase of the project was completed in April 2014 (Fretz, 2014).

3.3 Descriptive Statistics and Interpolation Analysis

Table 3.3.1 provides a statistical summary of readings from the 19 sample locations as well as the four horizon glow readings from the KAS Stake Lake Observatory (Sample Locations 17 – 21). Mean and median values were calculated based on all readings gathered from each site over the 28-month period between June 2012 and September 2014. As noted in section 3.1, mean readings from the KAS Observatory decreased from 21.26 mag/arcsec² to 20.84 mag/arcsec² due to outdoor lighting systems installed for nighttime skiing on the Stake Lake cross country skiing trail network.

Table 3.3.2 provides a summary of results from each sampling event that occurred over the 28 month sample period as well identification of months where readings were not gathered due to atmospheric conditions, staffing availability, and or safety conditions. Tabulated results from the 40 samples gathered on September 27, 2014 for thematic mapping purposes are provided in Appendix B. Sites 24 and 25 were added late in the sampling program. Due to the limited number of samples gathered at these locations no meaningful descriptive statistics were attainable.

Figure 3.3.1 illustrates the impact of anthropogenic outdoor lighting sources on an area spanning from the City of Kamloops to the Lac Le Jeune – Highway 5 interchange. The figure was produced using 40 sky darkness readings taken on September 27, 2014 as well as average readings from the 19 sites that were sampled between June 2012 and September 2014.

Table 3.3.1: Summary Statistics in mag/arcsec²

Site ID	Purpose	Mean	Median	Standard Deviation
1	Zenith	19.04	19.41	1.13
2	Zenith	19.46	19.68	0.77
3	Zenith	18.88	19.17	0.99
4	Zenith	20.11	20.63	1.07
4	Zenith	20.84	21.19	1.10
5	Zenith	20.78	21.12	0.85
6	Zenith	20.85	21.05	0.56
7	Zenith	20.49	20.67	0.72
8	Zenith	20.33	20.62	0.73
9	Zenith	19.83	20.20	0.99
10	Zenith	19.70	19.96	0.90
11	Zenith	19.33	19.80	1.13
12	Zenith	19.63	20.06	1.24
13	Zenith	19.73	20.04	1.03
14	Zenith	20.56	20.77	0.58
15	Zenith	19.56	20.05	1.26
16	Zenith	20.60	20.70	0.85
17	Zenith	20.66	21.05	1.54
18	Horizon, 0°	20.80	21.13	1.16
19	Horizon, 90°	20.79	21.13	1.27
20	Horizon, 180°	20.47	20.76	0.79
21	Horizon, 270°	20.16	20.16	N/A
22	Zenith	20.68	21.05	0.91
23	Zenith	21.63	21.63	0.11

**Sites 17 through 21 are located at the KAS Observatory*

Table 3.3.2: Dark Sky Readings in units of mag/arcsec²

Year	Month	Weather	Surface	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2012	June	Scattered Cloud	Bare Earth	17.27	18.77	17.82	20.64		19.20	20.23	19.60	19.24	18.25	18.22	18.26	18.34											
	July	Clear Skies	Bare Earth	19.66	19.77	19.41	20.69	21.15	21.12	21.1	20.56	20.57	20.45	20.2	20.16	20.32	20.04	20.83	20.4	20.91	21.07	20.98	21.24				
	August	Clear Skies	Bare Earth	20.12	20.08	19.83	20.63	21.36	21.32	21.38	20.84	20.83	20.8	20.55	20.42	20.45	20.57	21	20.63	21.42	21.29	21.3	21.49				
	September	Clear Skies	Bare Earth	19.9	20.06	19.61	20.95	21.29	21.12	20.11	20.69	20.76	20.67	20.36	20.17	21.32	20.24	20.94	20.51	21.29	21.05	21.15	21.16				
2012	October	Overcast	Bare Earth	16.67	17.32	16.68	18.96	21.19	20.31	19.51	18.58	18.36	17.64	17.76	16.88	17.2	17.14	18.99	18.1	20.51	20.97	21.24	21.13	18.57			
	November	Mostly Clear	Snow	19.12	19.44	17.75	20.9	21.23	21.13	20.95	20.63	20.77	19.18	19.93	18.18	Inaccessible due to conditions		20.87	18.79	20.64	21.25	21.11	20.98	20.6			
	December	Unable to complete sampling																									
	January	Clear Skies	Snow	18.85	19.17	17.48	20.53	20.96	21.07	20.98	20.45	20.54	20.32	19.86	19.66	20.04	19.81	20.65	20.03	20.37	20.98	20.84	20.71	20.33			
	February	Skattered Cloud	Snow/Dirt	19.88	19.87	19.88	20.12	21.05	21.09	21.12	20.72	20.8	19.94	20.07	20.13	20.02	19.86	20.13	19.52	20.41	20.64	21.13	20.97	20.78	20.16		
	March	Scattered Cloud	Snow/Dirt	17.02	19.65	18.89	17.09	21.11	18.53	19.99	19.31	19.96		Inaccessible due to conditions				20.22	16.11	20.42	20.62	20.94	21.02	19.28			
	April	Unable to complete sampling																									
	May	Unable to complete sampling																									
2013	June	Unable to complete sampling.																									
	July	Unable to complete sampling.																									
	August	Unable to complete sampling																									
	September	Clear Skies	Bare Earth	19.89	20.22	19.62	Omitted	21.19	20.05	21.07	20.80	20.81		Inaccessible due to conditions			20.77	20.34	20.88	20.95	20.64	20.93	20.91				
	October	Scattered Cloud	Bare Earth	18.88	19.19	19.42	19.78	21.3	21.22	20.96	20.69	19.89	19.48	18.71	18.63	18.35	18.68	19.73	19.3	20.7	21.14	21.27	21.36	20.94			
	November	Unable to complete sampling																									
	December	Unable to complete sampling																									
	January	Mostly Clear	Snow	19.15	19.45	19.06	19.24	18.59	21.15	21.12	20.64	19.89	20.39	19.75	18.45	18.4	19.36	20.78	20.35	Omitted due to conditions				20.73			
	February	No New Moon in February, 2014																									
	March	Mostly Clear	Snow/Dirt	19.72	19.71	18.38	20.78	18	20.81	21.02	20.64	20.67		Inaccessible due to conditions			20.67	19	18.01	15.62	17	16.63	21.19				
2014	April	Clear Skies	Bare Earth	19.96	20.25	20.07	20.65	21.54	21.46	21.39	21.09	21.01	20.92	20.69	20.44	20.62	20.49	21.16	20.66	21.29	21.38	21.32	21.18	21.04		21.35	
	May	Scattered Cloud	Bare Earth	18.55	18.45	18.93	19.45	21.76	21.44	21.24	21.44	20.11	20.2	20.1	19.8	20.07	20.51	20.53	20.06	20.9	21.58	21.49	21.49	20.24		19.64	21.7
	June	Clear Skies	Bare Earth	20.05	19.97	19.28	21.23	Omitted	21.45	21.36	21.09	21.12	19.58	19.96	20.17	20.44	20.35	21.14			Omitted			21.05		21.05	21.55
	July	Unable to complete sampling																									
	August	Unable to complete sampling																									
	September	See Appendix for baseline thematic map data collected on September 27, 2014																									

* Green shaded sites indicate the KAS Observatory Sample Location

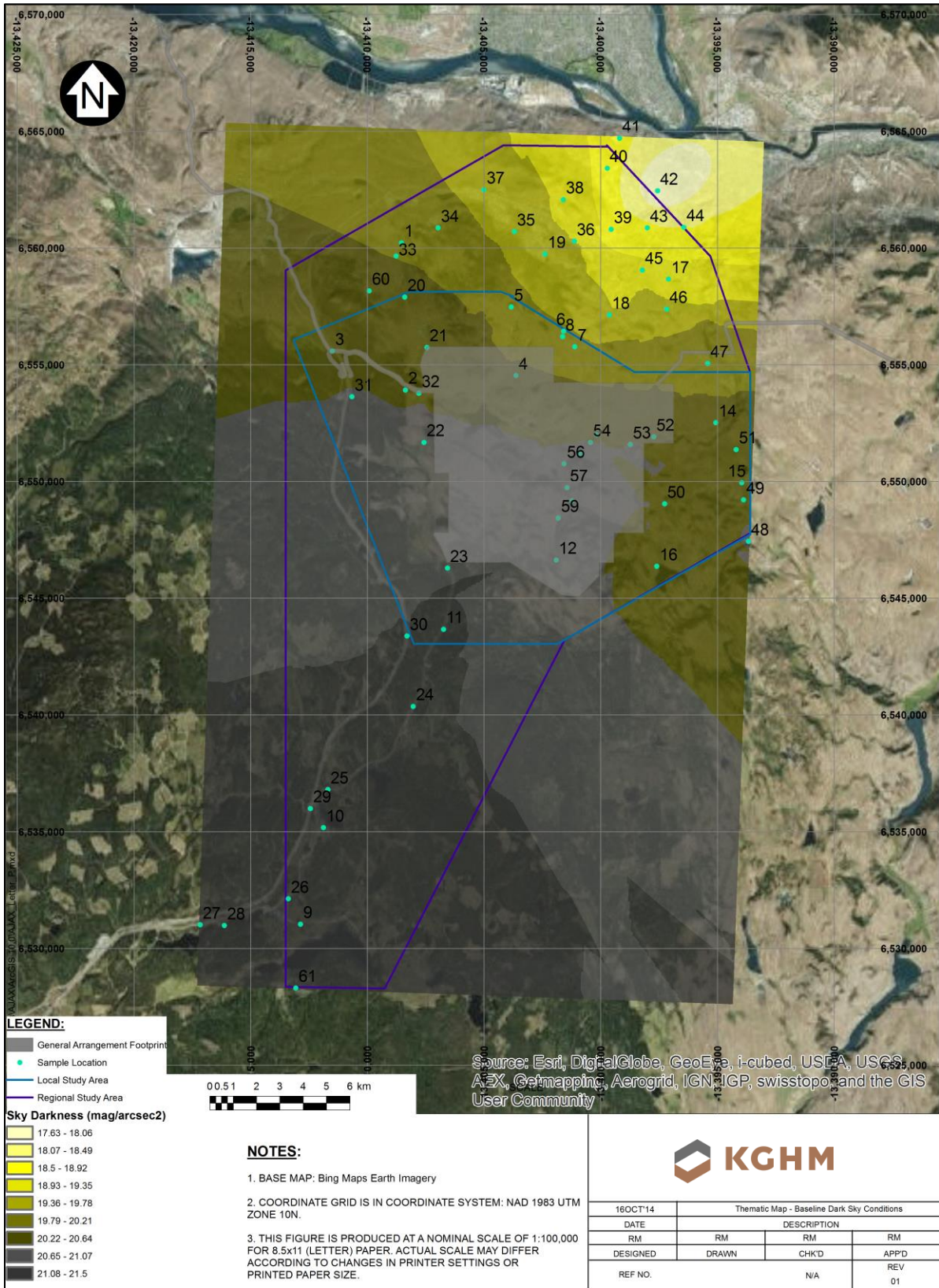


Figure 3.3.1: Interpolated Sky Darkness (Baseline) for Areas Surrounding the Proposed Ajax Mine Site

4.0 REPORT SUMMARY

Dark sky baseline measurements have been gathered from Kamloops and surrounding areas over a 28 month period spanning June 2012 to September 2014. A total of 17 sampling events took place over this period. Sampling covered 20 sites in the vicinity of the propose Project; an additional 40 sites were sampled on September 27, 2014 for thematic mapping purposes (Figure 3.3.1).

The urban readings were strongly affected by existing artificial lights found on city streets, homes, and businesses in and around the Kamloops' neighbourhoods of Sahali, Pineview, and Aberdeen. Dark sky measurements on the urban-rural periphery indicate that Coal Hill provides an effective topographic barrier and obtrusive light begins to decrease significantly beyond this point. Similarly, the elevation increases from the proposed mine site to the KAS Observatory from approximately 950 masl to 1320 masl. The topography between these two points is also variable. Hull Hill and McConnell Hill are situated between the Project and observatory and have elevations of 1452 masl and 1480 masl, respectively.

Sky darkness levels around the KAS Stake Lake Observatory received special consideration during the development of this study and report, due to the importance of dark skies for stargazing at the observatory. At the observatory location, five readings were gathered on each visit: one at zenith, and four at each cardinal direction. The goal of the cardinal directional readings was to provide information on horizon glow obtrusive light that could impact astronomical observations. Should the proposed Ajax Mine project proceed through permitting and approval into construction and operations, the horizon glow baseline readings at the observatory will provide a baseline against which changes as a result of Project lighting systems can be monitored, and help inform mitigation strategies throughout the mine life.

Another finding of this study is that outdoor lighting present on the Stake Lake cross country ski trial network has an effect on sky darkness around the KAS observatory during winter months. Measurements showed that the outdoor trail lights reduced sky darkness at the observatory to levels equivalent to urban neighbourhoods. However, the Overlander Ski Club has the ability to turn off lights near the KAS observatory at certain times when KAS has a scheduled winter event (Overlander Ski Club, 2015).

Sky darkness readings were shown to be strongly influenced by atmospheric conditions (i.e. the presence of cloud cover) and whether or not snow was present at the surface (See Table 3.3.2). Light to moderate cloud was shown to increase the presence of obtrusive light due to additional scattering and reflective influences by up to 1.5 orders of magnitude. The role of environmental features is also demonstrated by the fact that the City's adaptive lighting program (implemented in 2012/2013) resulted in minimal reduction to obtrusive light.

5.0 REFERENCES

- Andrusiak, 2012. Email Correspondence discussing obtrusive light impacts on wildlife, specifically nocturnal animals. January 10, 2012.
- City of Kamloops, 2013. *Report to the Chief Administrative Officer from the Public Works and Utilities Department on Adaptive and LED Street Lighting – Update*. January 9, 2013.
- Dick, R. Canadian Scotobiology Group, and Royal Astronomical Society of Canada. Email from June 6, 2012.
- Fretz, J. Sustainability and Environmental Services Manager. City of Kamloops. Completion of Adaptive Lighting Program. Personal Email. 1 August 2014.
- Kamloops Astronomical Society (KAS). Tracy Hendry: Representative of Kamloops Astronomical Society. Emails regarding public presentations and Dark Sky Methodology from July, 2012.
- KAM¹. 2012. Transcribed Public Comments from Environmental Workshop. Thompson Rivers University Campus Activity Centre. 28 June 2012.
- KAM². 2012. Ajax Copper-Gold Project Fact Booklet.
- Overlander Ski Club, 2015. Email correspondence discussing the installation of the Stake Lake Cross Country Ski Trail Lighting system. May 27, 2015.
- Quarts to Quasars. 2014. Bortle's Dark-Sky Scale. Retrieved from www.fromquarkstoquasars.com/dark-sky-scale/
- Unihedron, 2012. Sky Quality Meter Instruction sheet. Retrieved from http://www.unihedron.com/projects/darksky/Instruction_sheet.pdf
- World Atlas, 2000. *The World Atlas of the Artificial Night Sky Brightness*. Retrieved from the Obtrusive light Science and Technology Institute at www.lightpollution.it/worldatlas/pages/fig1.htm.

APPENDIX A - Dark Sky Logging Form

KGHM-Ajax Mining Inc.

Dark Sky Data Logging Form

Date: _____

Moon Phase: _____

Technician(s): _____

ID	Site Name	Time	mag/arcsec ²	Temp (°C)	Weather and Site Description
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

APPENDIX B – Thematic Mapping Data

ID	EASTING	NORTHING	Mag/ArcSec
1	680979	5611576	20.75
2	680988	5609000	20.86
3	681746	5605608	21.01
4	680941	5601814	21.11
5	678689	5599473	21.12
6	677711	5596466	21.15
7	675328	5595676	21.16
8	675994	5595979	21.03
9	678233	5598344	21
10	670708	5603721	20.89
11	678983	5610170	20.74
12	680802	5610324	20.72
13	680053	5614030	20.48
14	681172	5614831	20.31
15	683249	5614803	19.92
16	684887	5614598	19.52
17	682380	5615908	19.29
18	684549	5615716	19.79
19	685880	5614958	18.59
20	685711	5616611	19.23
21	686022	5617429	19.42
22	687104	5616045	13.65
23	686858	5615029	19.46
24	687854	5615083	19.39
25	686767	5613882	19.68
26	687471	5612848	19.92
27	688640	5611413	20.47
28	689920	5606623	21
29	689747	5607747	20.93
30	687602	5607560	20.94
31	689497	5609103	20.82
32	687240	5609370	20.73
33	686607	5609138	20.75
34	685522	5609158	20.76
35	685252	5608846	20.79
36	684827	5608552	20.85
37	684929	5607906	20.86
38	685074	5607552	20.9
39	684717	5607073	20.95
40	679355	5613061	20.78

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