# APPENDIX J.

## AN ASSESSMENT OF THE IMPACT OF POTENTIAL MINING OPERATIONS AT THE ALTON COAL TRACT ON THE DARK SKIES OF BRYCE CANYON NATIONAL PARK AND CEDAR BREAKS NATIONAL MONUMENT, ORIGINAL REPORT (2009) AND PART II (2014)

# APPENDIX J CONTENTS

# J.1. An Assessment of the Impact of Potential Mining Operations at the Alton Coal Tract on the Dark skies of Bryce Canyon National Park and Cedar Breaks National Monument

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# AN ASSESSMENT OF THE IMPACT OF POTENTIAL MINING OPERATIONS AT THE ALTON COAL TRACT ON THE DARK SKIES OF BRYCE CANYON NATIONAL PARK AND CEDAR BREAKS NATIONAL MONUMENT

NIGHT SKY FROM YOVIMPA POINT, BRYCE CANYON NATIONAL PARK
(NPS NIGHT SKY TEAM IMAGE)

# FINAL REPORT

**Prepared by Dark Sky Partners, LLC**
for
**SWCA Environmental Consultants**

**April 2009**

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## EXECUTIVE SUMMARY

This study presents results from computer calculations of the sky brightness due to mining operations in the Alton Coal Tract when viewed from Yovimpa Point in Bryce Canyon National Park and from Brianhead Peak near Cedar Breaks National Monument. Two scenarios were suggested by Alton Coal Development for analysis, one for *typical* lighting and one for *brightest* expected lighting. The calculations show that, under the *typical* lighting scenario, the lighting would not produce a sky glow visible above the horizon from Yovimpa Point; any sky glow would be seen only when looking just above the mine site and just below the distant horizon. The predicted sky glow would be less than that produced by several small towns in the general area that are usually not discernable according to the National Park Service, and significantly less than the visible glow arising from the distant large cities of St.George and Cedar City, Utah. Under the *brightest* lighting scenario described in this report, the sky glow seen from Yovimpa Point is found to be comparable to that produced by small, local towns but still less than that of the larger distant towns.

From Brianhead Peak, the analysis shows that the mine lighting under the *typical* lighting scenario would produce less sky glow than that produced by nearby towns. Under the *brightest* lighting scenario the sky glow would be comparable with that produced by several nearby towns

A separate analysis by SWCA shows that intervening terrain would prevent direct visibility of lights in the Alton Coal Tract from Yovimpa Point, but the same does not hold true for Brianhead Peak. If visible, the unshielded 1000 watt metal halide lights suggested for potential use at the active mine site are likely to be the brightest artificial lights visible in the night landscape and would look significantly brighter than the planet Venus.

Options that could reduce the sky glow and direct fixture brightness associated with lighting in the Alton Coal Tract lighting are presented.

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## I. INTRODUCTION

Dark night skies are increasingly recognized as one of the premier attractions of National Parks and Monuments, particularly those in the western U.S. Bryce Canyon National Park (BCNP) and Cedar Breaks National Monument (CBNM) are two premier dark sky sites; BCNP in particular attracts many thousands of visitors annually to enjoy a nearly pristine dark sky experience. Unfortunately, many other dark sky sites have been adversely affected by light pollution, from the intrusion of visible light sources into the naturally dark night landscape, the direct illumination of the park or portions of the park by lighting located within or outside of the park, and artificial sky glow arising from light emitted directly from fixtures or reflected from the ground and scattered (re-directed) toward the ground by atmospheric molecules and aerosols. Increasingly, proposed developments that could impact dark sky sites are now being required to address the potential impact of new outdoor lighting on dark skies as part of the environmental assessment process.

This study examines the sky glow that would arise from surface coal mining operations in the Alton Coal Tract (ACT) south of Alton, UT. The Tract is shown in Figure 1, along with nearby Bryce Canyon National Park and Cedar Breaks National Monument. Details of the ACT, showing the potential areas for mining as well as those for the mine headquarters, are shown in Figure 2. The sky glow created by the lighting described in this report is calculated using a sophisticated model describing the interaction of light emitted near the ground and interacting with objects and surfaces near the ground, the atmosphere of molecules and aerosols over the mine site and between the mine site and points of observation. These models are described in detail in published papers by Garstang (1986, 1989, 1991) and by Luginbuhl et al. (2009b). These models have been incorporated into a computer program by Dark Sky Partners LLC (DSP).

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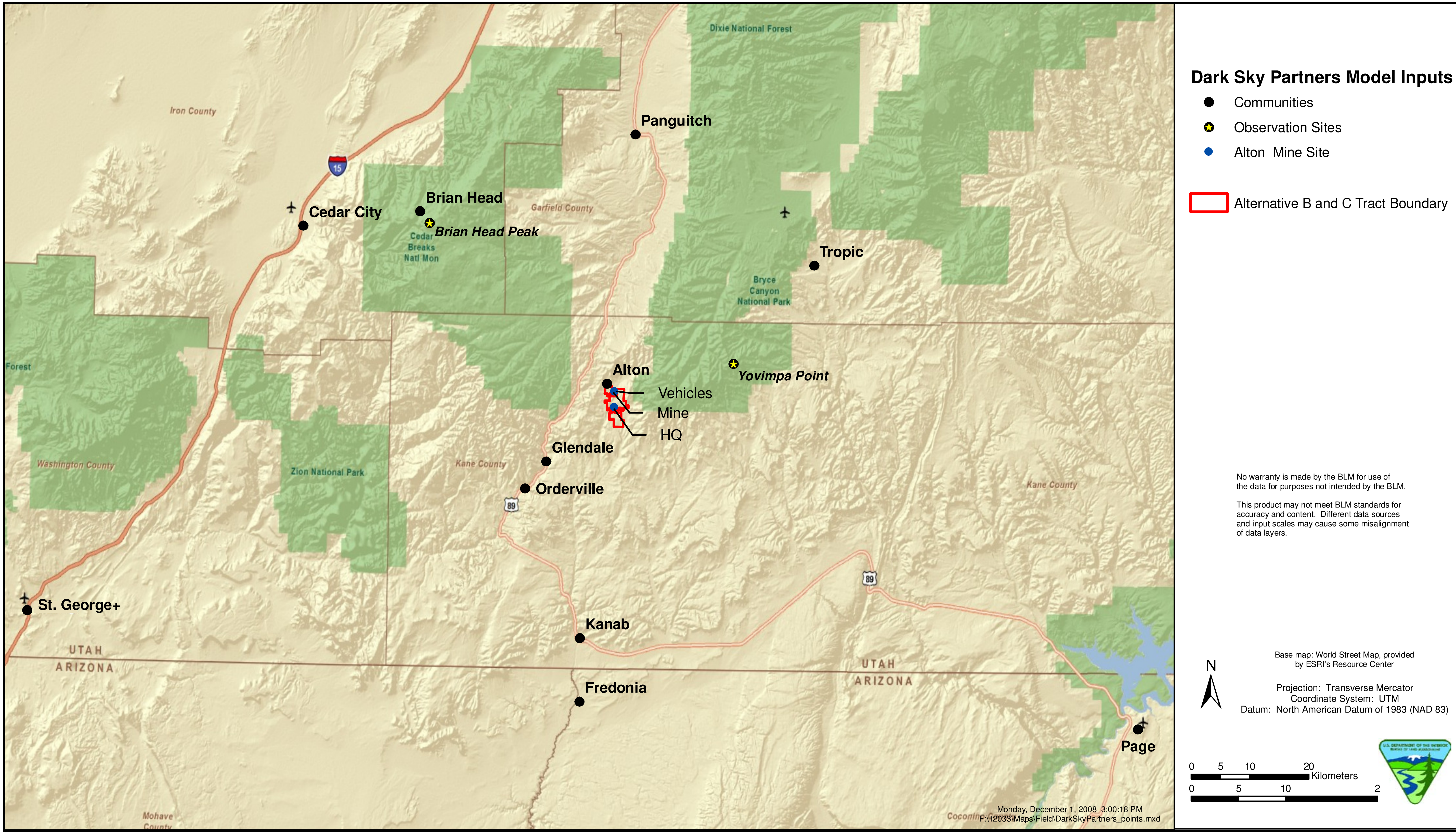


**Figure 1. The location of the Alton Coal Tract, Yovimpa Point and Brianhead Peak, together with regional towns and cities included in sky glow models.**

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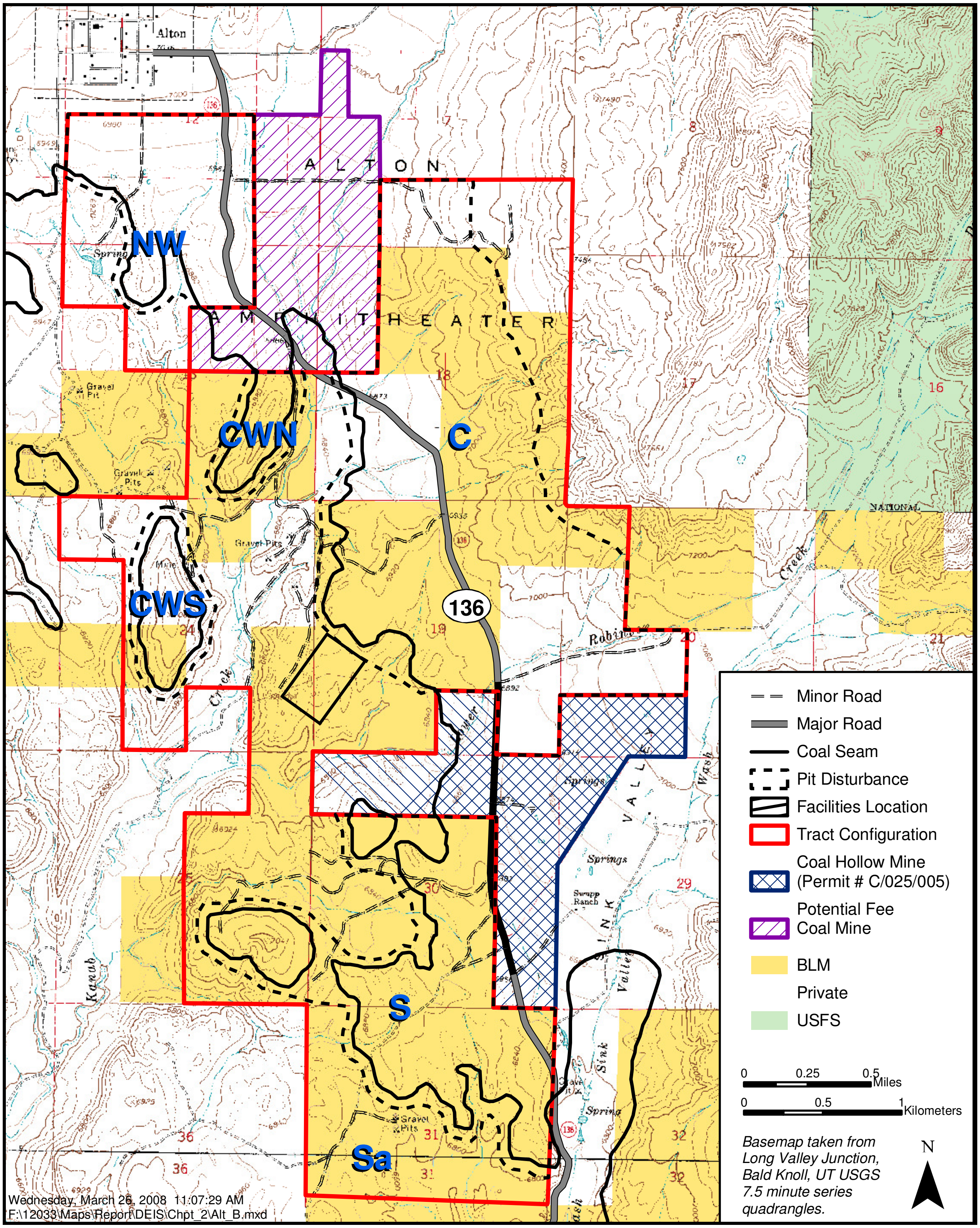


**Figure 2. Details of the Alton Coal Tract and potential headquarters (facilities) site.**

## II. STUDY METHODOLOGY

### A. The Numerical Model

R. Garstang (Garstang 1986, 1989, 1991) developed and published a model for calculating sky brightness arising from artificial outdoor lighting. This model has been recently improved by Luginbuhl et al. (2009b) to include effects on light propagation caused by blocking of the light emissions by objects near the ground, such as buildings, vegetation and terrain, an improvement essential to accurately connect light emissions measured at the light sources (lamps) with the resultant sky glow. A computer program based on this improved model, developed by Dark Sky Partners LLC, calculates the sky brightness observable from any location and toward any viewing direction due to light emitted from cities and towns or any specific light source or sources (i.e. fixtures). This program allows modeling of specific sources of artificial lighting such as shopping centers, housing developments or industrial projects, with the capability of specifying details such as amounts, spatial distribution, and shielding characteristics of lighting sources (Davis et al. 2006). This computer program was used to assess the impact of lighting at potential ACT mining operations on dark skies of BCNP and CBNM.

### B. Data Input for the Model

The inputs for the computer model include parameters describing the atmosphere and ground reflectivity, the location and amounts of light emitted (measured in lumens), the fraction of this light that escapes directly upward into the night sky (the uplight fraction), and the locations from which the sky is observed.

*Atmosphere and Ground*

Table 1 shows the parameters characterizing the atmosphere and ground; these values were kept constant for all locations. The parameter that describes the amount of aerosol (particulates) or clarity of the atmosphere, K, was set to 0.05. This is lower than the value used by Garstang for typical western cities (K=0.5), but is based on observations made by the National Park Service (NPS) Night Sky Team at CBNM and describes the 90th percentile (i.e. the K value was observed to be larger than this 90% of the time), and was recommended by NPS as the most appropriate condition for the analysis. Such a low value is not entirely unexpected due to the extreme clarity of the air in this region and at these altitudes. (It is important to recognize the modeling does not account for increased aerosols that may result from some weather conditions, air pollution, or the mining operations themselves.) The $E_b$ and $\beta$ parameters describe blocking of light emitted from light fixtures due to near-ground factors (vegetation, terrain), and affect both the amount of light escaping into the sky as well as the angular distribution of this upward-directed light. The values indicated for these parameters produced the best agreement between the model calculations and sky brightness measurements in the work described by Luginbuhl et al. (2009b), except that for this study the $\beta$ parameter has been increased from their best value of 0.0 to 0.1 to compensate for the relatively un-vegetated and open nature of the near-ground environment in this region. The ground reflectivity of 0.15 is typical of a wide variety of surfaces (except snow) including terrain, vegetation, dirty concrete and aged asphalt hardtop, and has been found to adequately characterize ground reflectivity for all warm season light pollution modeling efforts to date (Garstang 1986, 1989, 1991, Luginbuhl et al. 2009b and references therein).

These atmospheric parameters describe very clear conditions and will lead to modeling results that will show smaller impacts from potential lighting in the ACT as well as from nearby towns than will typically be the case. The NPS night sky team purpose in recommending these clear conditions for the analysis is to show what the impacts would be during the "best" observation nights, when the air is clearest and the stars most visible. It is important to recognize that 90% of the time the air will be less clear, and the impacts larger.

Some of the towns in this region lie within narrow valleys or canyons, and thus light emitted from them would suffer, in some directions, considerably greater blocking by the terrain. There has been no attempt to model this effect on a town-by-town basis in this study.

**Table 1. Atmospheric and Ground Parameters**

| Parameter | Value |
|---|---|
| K | 0.05 |
| $E_b$ | 0.40 |
| β | 0.10 |
| Ground Reflectivity | 0.15 |

*Alton Coal Tract Lighting*

The number and types of lights to be modeled as representative of lighting in the ACT were discussed and agreed to through telecoms with Alton Coal Development (ACD), SWCA, NPS, and BLM on September 25 and 30, 2008 and subsequent emails. The parameters listed in Tables 1 through 4 were distributed to these agencies for review and final approval.

Lighting required for nighttime mining operations on the tract would consist of three types of lights: 1) fixed lights at the mine headquarters for parking, walkway, security and general nighttime activity; 2) portable light towers with individually aimable fixtures located at the active mine site that would be moved as the mining operations shift; and 3) lighting (i.e. headlights) on mining vehicles, also assumed to be located at the active mine site.

The fixed lights at the headquarters buildings would utilize 250 watt metal halide lamps producing 25,000 lumens each, contained within fully shielded fixtures, i.e. none of the light is emitted directly upward. The portable lights would utilize 1000 watt metal halide lamps producing 110,000 lumens each. These fixtures are mounted with adjustable gimbals, allowing the fixtures to be aimed in different directions and at different angles relative to the horizon (see Appendix A). Although DSP contacted Baldor Electric Company, a manufacturer of a potential portable lighting system suggested by ACD representatives, the representatives of Baldor were unable to produce the photometric information needed to accurately evaluate the fraction of light directed upward as a function of aiming angle of the fixtures. Therefore, for this study DSP is forced to estimate this fractional uplight value. We assume that they would typically be aimed at 30° below the horizon and direct 30% of the light upward, but they may at times be directed essentially straight sideways toward the horizon, as is often observed when such lights are used on construction sites. The *typical* case (see Tables 2 and 3) is intended to represent most of the mining operations while the *brightest* case, utilizing the larger number of lights indicated, is for occasional intense activities, described by ACD representatives as expected to occur less than 10% of the time. The *brightest* case scenario also considers that the portable lights are aimed horizontally, producing a larger uplight fraction (0.50). These figures are summarized in Table 2.

For the vehicular lighting we have no specific information either on the manufacturers and types of the mining vehicles to be used, nor for the lighting that would be installed on this equipment. To estimate the light output from the vehicles, we scale the lumens from values typical of automobile headlights. From Schoettle et al. (2004), car headlights average 3786 effective lumens/vehicle with an uplight fraction of 0.11. We assume the same uplight fraction, but increase the light output from each mine vehicle to 10,000 lumens, about three times that of a typical car. All vehicular lighting is assumed to be located at the active mining site, i.e. no attempt has been made to model lighting produced when the vehicles are transporting materials on roadways.

Table 2 gives the details of how the total lumens were calculated for the mine lighting sources, while Table 3 gives the locations and lighting associated with all modeled light sources, including both scenarios detailed for the ACT as well as 11 towns and cities expected to be contributors to sky glow in the region (see below). Though there is a specific location indicated for the active mine site in Table 3, it is expected that active mining would occur at many sites within the tract. This location is chosen to provide specific inputs to the model and to give results representative of the lighting impacts of potential mining operations within the ACT.

**Table 2. Details of Alton Coal Tract Lighting (MH=metal halide; INC=incandescent).**

| Description | Lamp | lumens each | Number | total lm | fraction up |
|---|---|---|---|---|---|
| **Typical Case** | | | | | |
| Fixed lighting | 250W MH | 25000 | 4 | 100000 | 0.00 |
| Portable towers | 1000W MH | 110000 | 4 | 440000 | 0.30 |
| Headlights | INC | 10000 | 20 | 200000 | 0.11 |
| **Brightest Case** | | | | | |
| Fixed lighting | 250W MH | 25000 | 6 | 150000 | 0.00 |
| Portable towers | 1000W MH | 110000 | 12 | 1320000 | 0.50 |
| Headlights | INC | 10000 | 36 | 360000 | 0.11 |

*Towns*

The light outputs for all towns included in this study were calculated assuming 2500 lm per capita with 10% uplight fraction. These are typical values for communities without any outdoor lighting controls (Luginbuhl et al 2009a and references therein).

*Observation Points*

The observation sites listed in Table 4 were set in consultation with NPS and BLM representatives. These sites were chosen to provide a representative evaluation of the sky glow impacts of lighting in the ACT for visitors to BCNP and CBNM. For further discussion of the observation points see below and the memo presented in Appendix B.

All calculations are for the Johnson V bandpass, an astronomically defined wavelength vs. sensitivity response similar to the dark-adapted human eye. Though the system is not strictly equivalent to the sensitivity function for the human eye, it is reasonably close and has become the standard for both astronomical measurements of sky brightness and those produced by the National Park Service (Duriscoe, Luginbuhl & Moore, 2007).

**Table 3. Light Source Locations and Outputs.**

| | Latitude | Longitude | Elevation | Azimuth[1] | Distance[1] | | Typical | | Brightest | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | dms | dms | m | deg | km | Population | lumens | uplight | lumens | uplight |
| **Alton Tract** | | | | | | | | | | |
| HQ | +37 24 11 | –112 28 05 | 2090 | 249/134 | 21.5/44.5 | | 100000 | 0.00 | 150000 | 0.00 |
| mine | +37 25 37 | –112 28 06 | 2110 | 256/131 | 20.7/42.6 | | 440000 | 0.30 | 1320000 | 0.50 |
| vehicles | +37 25 37 | –112 28 06 | 2110 | 256/131 | 20.7/42.6 | | 200000 | 0.11 | 360000 | 0.11 |
| **Towns** | | | | | | | | | | |
| Alton | +37 26 21 | –112 28 59 | 2156 | 260/131 | 21.7/40.8 | 141 | 352500 | 0.10 | | |
| Brianhead | +37 41 55 | –112 50 58 | 2993 | 295/319 | 59.3/2.6 | 125 | 312500 | 0.10 | | |
| Cedar City | +37 40 22 | –113 04 28 | 1777 | 287/268 | 76.8/21.5 | 27823 | 69557500 | 0.10 | | |
| Fredonia | +36 57 00 | –112 31 35 | 1426 | 204/162 | 63.3/85.6 | 1096 | 2740000 | 0.10 | | |
| Glendale | +37 19 05 | –112 35 50 | 1763 | 242/153 | 35.9/45.3 | 336 | 840000 | 0.10 | | |
| Kanab | +37 02 50 | –112 31 39 | 1512 | 208/159 | 53.7/75.4 | 3769 | 9422500 | 0.10 | | |
| Orderville | +37 16 33 | –112 38 15 | 1661 | 238/159 | 41.3/48.2 | 599 | 1497500 | 0.10 | | |
| Page | +36 54 57 | –111 27 26 | 1321 | 131/125 | 92.9/148.3 | 6904 | 17260000 | 0.10 | | |
| Panguitch | +37 49 22 | –112 26 08 | 2019 | 336/65 | 42.6/38.1 | 1473 | 3682500 | 0.10 | | |
| St. George[2] | +37 06 04 | –113 34 31 | 895 | 251/226 | 125.1/92.1 | 121356 | 303390000 | 0.10 | | |
| Tropic | +37 37 30 | –112 05 13 | 1933 | 38/95 | 21.7/65.8 | 464 | 1160000 | 0.10 | | |

[1] Azimuth and distance from Yovimpa Point/Brianhead Peak

[2] Includes towns of St George, Ivins, Santa Clara, Springdale, Washington, Hurricane, LaVerkin, Toquerville

**Table 4. Observation Sites**

| | Latitude | Longitude | Elevation |
|---|---|---|---|
| **Observation Site** | dms | dms | m |
| Yovimpa Point | +37 28 20 | –112 14 25 | 2770 |
| Brianhead Peak | +37 40 52 | –112 49 50 | 3446 |

## III. IMPACT OF POTENTIAL ALTON COAL TRACT LIGHTING ON NIGHT SKY BRIGHTNESS

We calculated predicted sky brightness for both the *typical* and *brightest* ACT lighting (see Tables 2 and 3) as seen from the two observation points listed in Table 4. For each case, we calculated the sky brightness from the horizon directly above the mine site (zenith angle of 89°) to the horizon directly opposite (zenith angle of –89°), passing through the zenith. We show both the total sky brightness in nanoLamberts[1] (nL) and the fractional increase in sky brightness due to lighting as listed in Table 3. Though the ACT appears about 1.8° below the true horizon or at about 91.8° zenith angle from the two observation points of Table 4 (see e.g. Appendix B), the calculations do not extend beyond 89° zenith angle due to model limitations (see discussion below).

For reference, we compare these predicted profiles to the artificial sky brightening predicted toward each of the eleven nearby towns and cities identified in Figure 1 and Table 3. Fractional brightness increases for all town calculations are as compared against the natural condition, i.e. to the sky with no towns present. The fractional brightness increases for all ACT calculations are as compared with the current condition, i.e. including any towns or cities whose sky glow may overlap with that produced by the tract lighting. This is the most appropriate way to judge the impacts, as the sky glow arising from towns is viewed against a (generally) unpolluted horizon, while the sky glow produced by lighting installed in the ACT would be added to that already present.

To understand the visual impact of the numbers and ratios described in the following two subsections, readers should be aware that a brightness ratio of 1.1:1 (or 10%) is only just perceptible to most people when the two sources of light can be directly compared, with one appearing directly adjacent to the other. In this sense a 10% brightening may seem to be likewise only just perceptible. A brightness ratio of 50% (1.5:1) would be perceptible to most observers. However, a natural visual reference for the sky brightness impacts described here is the natural largely un-polluted night skies in this region. Here, the impact of a sky glow "dome" comparable to, say, the sky glow produced by a town already visible from the observation point may be best judged by considering the impacts this other town or towns have on the night landscape. For this purpose we have included the sky glow predictions for the eleven towns listed in Table 3.

### A. Bryce Canyon National Park

The observation point chosen to examine impacts at Bryce Canyon National Park is Yovimpa Point, located near the southern end of the park and relatively close (21 km) to the mine site. Yovimpa Point is also used by the park for night sky observation and interpretation.

Figure 3 shows the variation in sky brightness along the semi-circle passing through the mine site (right side of the graph), the zenith (middle of the graph) and ending at the horizon opposite the mine site (left side of the graph). The lowest curve shows the natural condition, i.e. the sky glow that would be observed without any artificial light in the region.

The predicted current sky glow arising from natural air glow plus artificial sky glow from the 11 cities and towns listed in Table 3, as well as the effect of the two lighting scenarios at the mine site,

[1] A nanoLambert (nL) is a unit of luminance or surface brightness. 1 Lambert = 1 lumen/sq cm for a uniformly diffusing surface. An naturally dark sky has a brightness of about 54 nL at the zenith, rising (due to natural causes) to approximately 100 nL 10° above the horizon (see the lowest curve in Figure 3).

are shown as the three increasingly brighter curves lying above the natural curve and distinguishable particularly toward the ACT (right side of the graph). This figure shows that there is essentially no increase in sky brightness from the zenith to the horizon opposite the tract location.

To more clearly display the effects of the ACT lighting on the night sky, Figure 4 displays fractional sky brightness increases, i.e. ratios of the predicted sky brightness to either the current or natural condition. The two ACT lighting scenarios are displayed as ratios of the predicted brightness along this semi-circle to the brightness already there, i.e. the current condition. For comparison, the ratios of brightness produced by the towns and cities listed in Table 3 are compared to the natural condition, i.e. the sky glow that would be present with no other artificial light sources. This figure displays only zenith angles from 80° – 89° to the horizon in the direction of the light source. A value of 1.10 means that the indicated condition is 10% brighter than the reference condition; 1.05 is 5% brighter.

From Figure 4 and Table 5 it can be seen that the *typical* lighting condition would brighten the sky by about 1% at a zenith angle of 80° (or an altitude of 10° above the horizon), increasing to 10% at a zenith angle of 89° (1° above the horizon). At zenith angles of less than 71°, the sky brightness increase is less than 1%. Under the *brightest* lighting condition the sky would brighten by about 3% at zenith angle of 80°, and by 31% at a zenith angle of 89°. This increased sky brightening falls to less than 1% at zenith angles less than 45° in the direction of the ACT. Looking at the other cities and towns included in Table 3, we see that the lighting at the ACT is superimposed fairly closely on the sky glow produced by Alton town and St. George, Utah (see further discussion below). At 85° zenith angle, these two towns contribute an approximate 10% and 35% brightening over the natural condition, respectively, though the brightest centers of these sky glow domes are located a few degrees right and left of the site analyzed here.

Here we must point out that the model predictions for angles within 10° of the horizon must be considered with caution. Localized and unpredictable variations in very low altitude atmospheric dust content, caused for example by low-level winds or by the mining operations themselves, and blocking by vegetation or terrain, including (variable) terrain relief produced by the mining operations, can make these values much larger or much smaller than predicted here. The values indicated in the study should be taken only as a general indication, useful for comparing one lighting scenario to another or for comparing one town to another, but not likely accurate to better than 50% in predicting absolute sky brightnesses for any given night. Because of these uncertainties calculations were not made for angles greater than 89° from the zenith or 1° altitude.

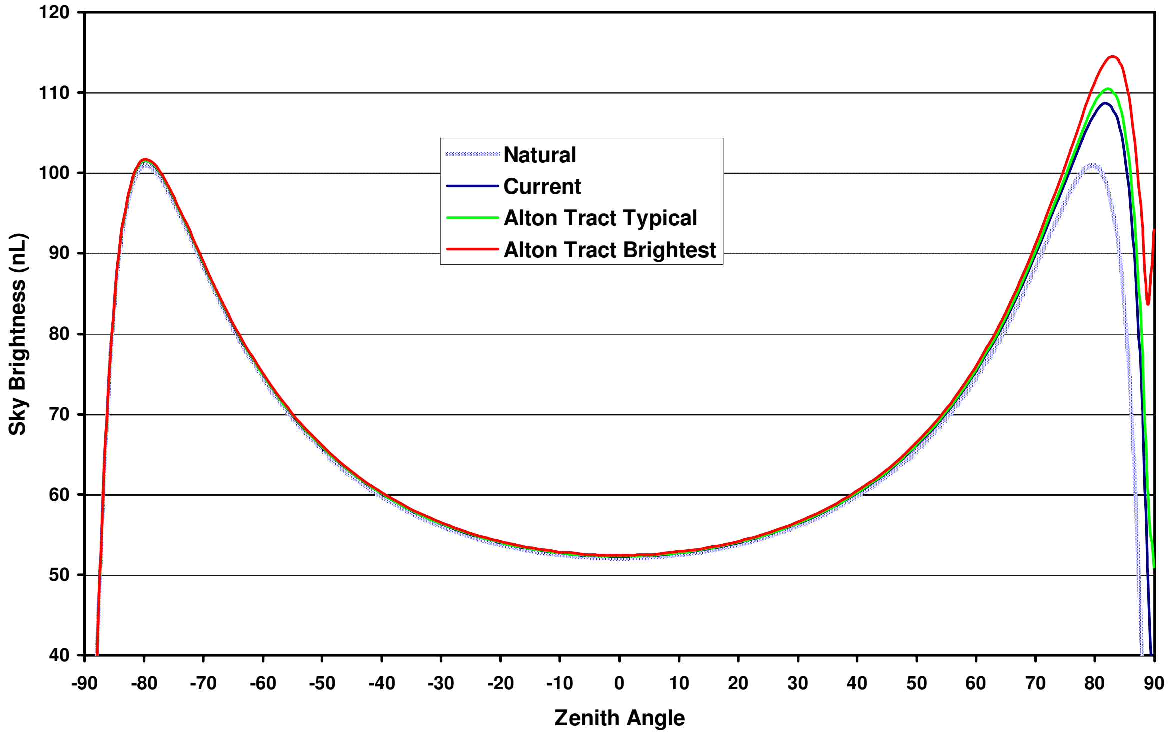


**Figure 3. Horizon to horizon sky brightness at Yovimpa Point on the semi-circle originating toward the Alton site (azimuth 256°, zenith angle 90°) and ending at the point on the horizon opposite (azimuth 76°, zenith angle –90°). The blue line shows the predicted current sky brightness profile arising from the 11 existing cities and towns listed in Table 3; the green and red lines show the predicted additional contributions of the two Alton tract lighting conditions described in the text.**

With these uncertainties in mind, Figure 4 shows that the greatest sources of sky glow at this site arise from Cedar City and St. George, Utah, located 77 km and 125 km distant at azimuth 287° and 251°. At 5° above the horizon in the direction of either of these two cities the sky appears about 35% brighter than the natural condition. The predicted sky glow produced by the *typical* mine lighting scenario does not reach this level at any calculated point, rising to 20% above the natural condition when viewed 1° above the horizon in the direction of the site (azimuth 256°). The impact appears to be smaller than the sky glow predicted for all of the towns and cities in this region, and by coincidence would be more difficult to discern due to its chance alignment with the brighter sky glow a rising from St. George. The *brightest* lighting scenario would produce a larger impact, rising to almost 70% brighter than the natural condition when viewed 1° above the horizon toward the mine, and 30% when viewed 2° above the horizon. The increase does not fall below 10% until the viewing angle increases to about 5° above the horizon. Under this condition the sky glow appears comparable to that visible from the towns of Orderville and Fredonia, and to that produced by a distant cities of Kanab and Page, Arizona. NPS personnel (Moore, personal communication) indicate that some of these towns do not produce a visible sky glow from this location. This may be due to terrain blocking by the nearby valley walls.

An important consideration, decreasing the likely visibility of above-horizon sky glow from both lighting scenarios within the ACT, is that the site detailed in Table 3, at azimuth 256°, is coincidentally closely aligned with St. George from this viewing location. However, since the ACT appears about 1.5° below the distant horizon, any artificial "sky" glow appearing immediately above the mining operations would appear projected against the landscape, below and distinct from the distant St. George sky glow, and thus more visible.

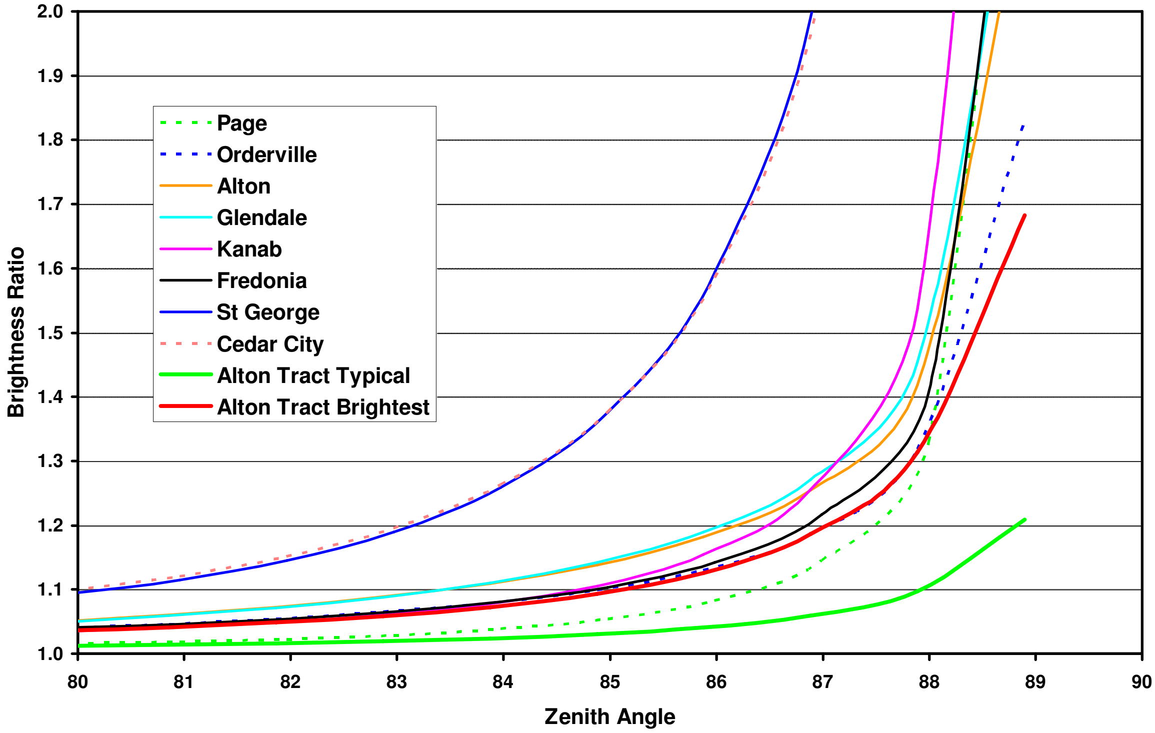


**Figure 4. Brightness ratio as viewed from Yovimpa Point toward the Alton site as well as toward a selection of regional towns/cities indicated in the key. The Brightness Ratio display for the towns is as compared to the natural condition (i.e., no towns): the Brightness Ratio for the Alton tract conditions is to the current condition (i.e., including sky glow from St. George, Kanab, etc.).**

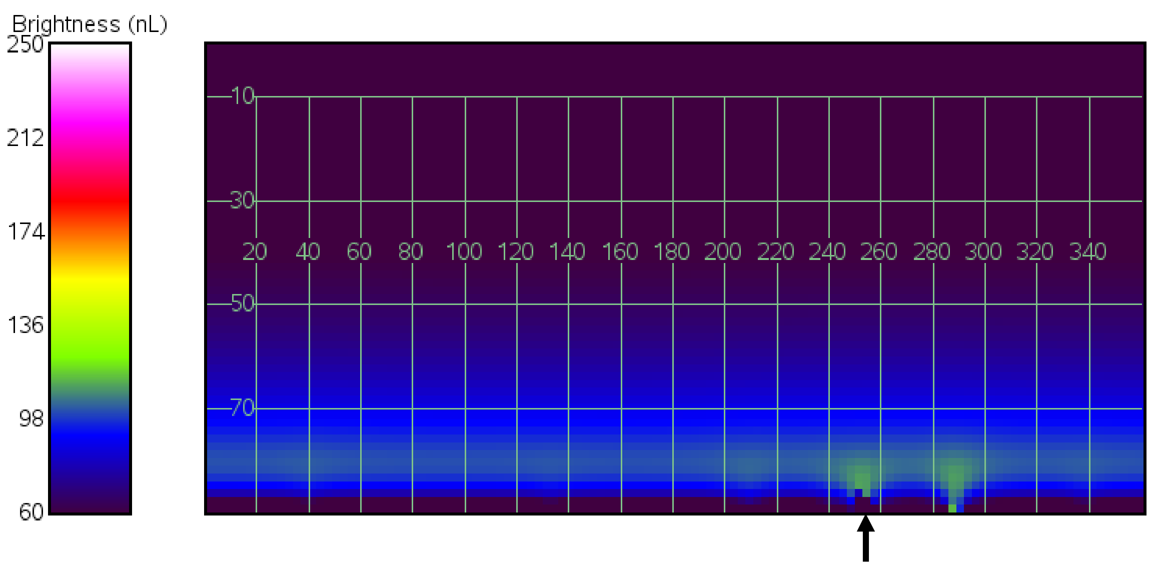


**Figure 5. An all-sky false-color panoramic map of the predicted current sky glow visible from Yovimpa Point. The grid and numbers on this and the following images indicate altitude and azimuth; the arrow indicates the azimuth of the Alton mine site in Table 3.**

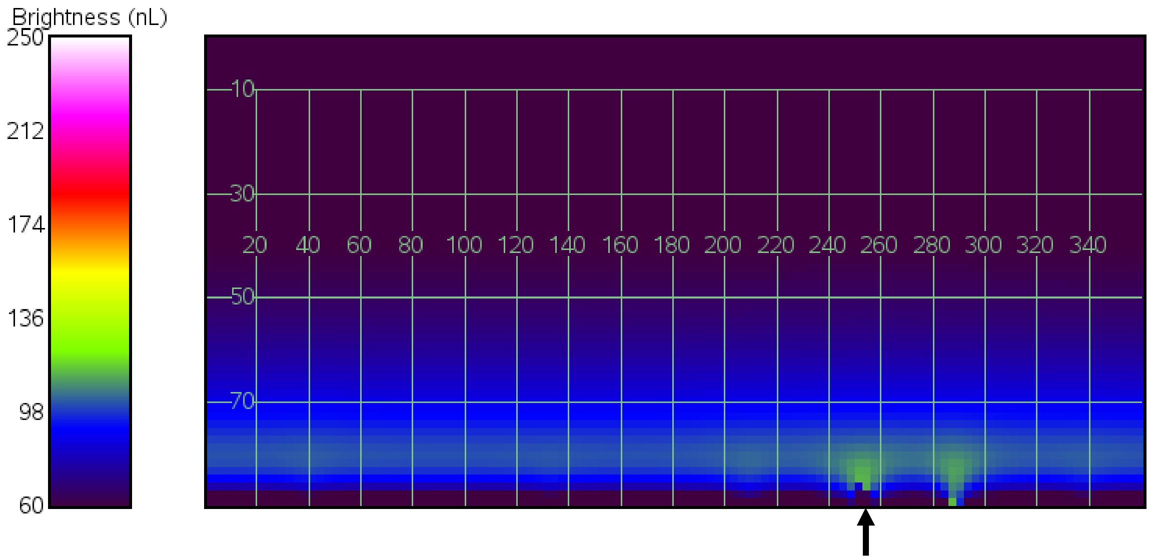


**Figure 6. As Figure 5, with *typical* lighting at the Alton tract.**

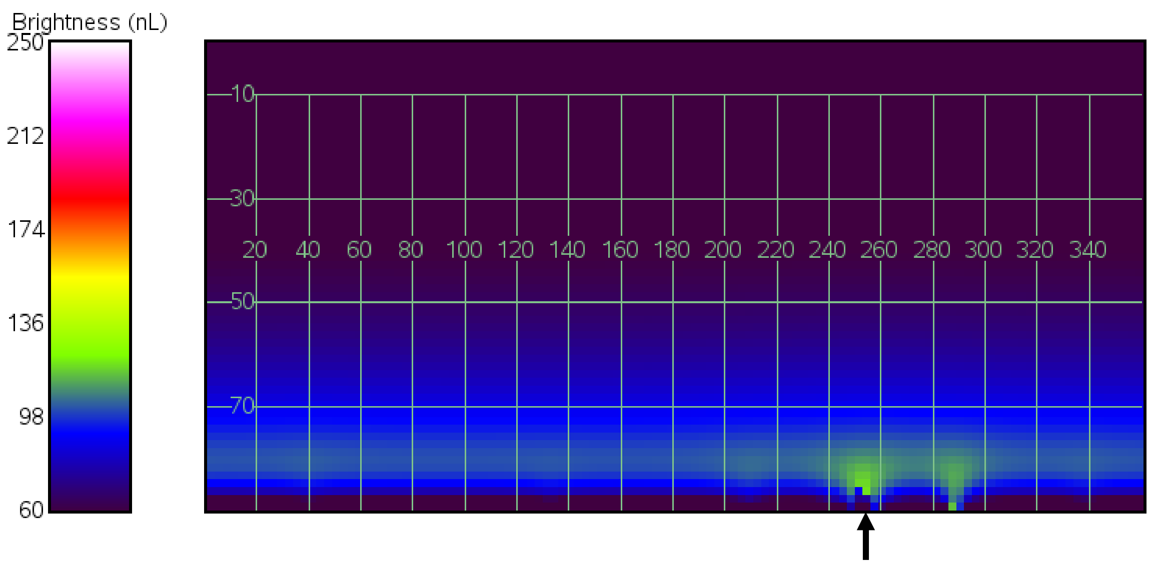


**Figure 7. As Figure 5, with *brightest* lighting at the Alton tract.**

Figures 5, 6 and 7 are false-color maps showing sky brightness over the entire sky as viewed from Yovimpa Point. Figure 5 shows the current condition, while Figures 6 and 7 show the addition of the *typical* and *brightest* lighting scenarios at the mine site. An increase in the sky glow above the ACT site (azimuth 256°, indicated by the arrow) is discernible in Figures 6 and 7, though this relatively nearby lighting is viewed against the distant and brighter sky glow arising from St. George at azimuth 251° and a small contribution from Alton town at azimuth 260°. The other distinct sky glow dome at azimuth 287° arises from Cedar City.

**Table 5. Sky brightness ratios as viewed from Yovimpa Point at selected zenith angles toward the Alton site**

| Zenith Angle (degrees) | Brightness Ratio (predicted/current) Typical | Brightest |
|---|---|---|
| 0 | 1.00 | 1.00 |
| 45 | 1.00 | 1.01 |
| 60 | 1.00 | 1.01 |
| 80 | 1.01 | 1.03 |
| 85 | 1.02 | 1.07 |
| 87 | 1.04 | 1.13 |
| 89 | 1.10 | 1.31 |

## B. Cedar Breaks National Monument

The observation point chosen to examine impacts at Cedar Breaks National Monument was the subject of some additional consideration (see Appendix B.). Brianhead Peak, located approximately 1.5 kilometers north of the park boundary in the Dixie National Forest, was chosen for its proximity to CBNM and the availability of NPS night sky team data for this site.

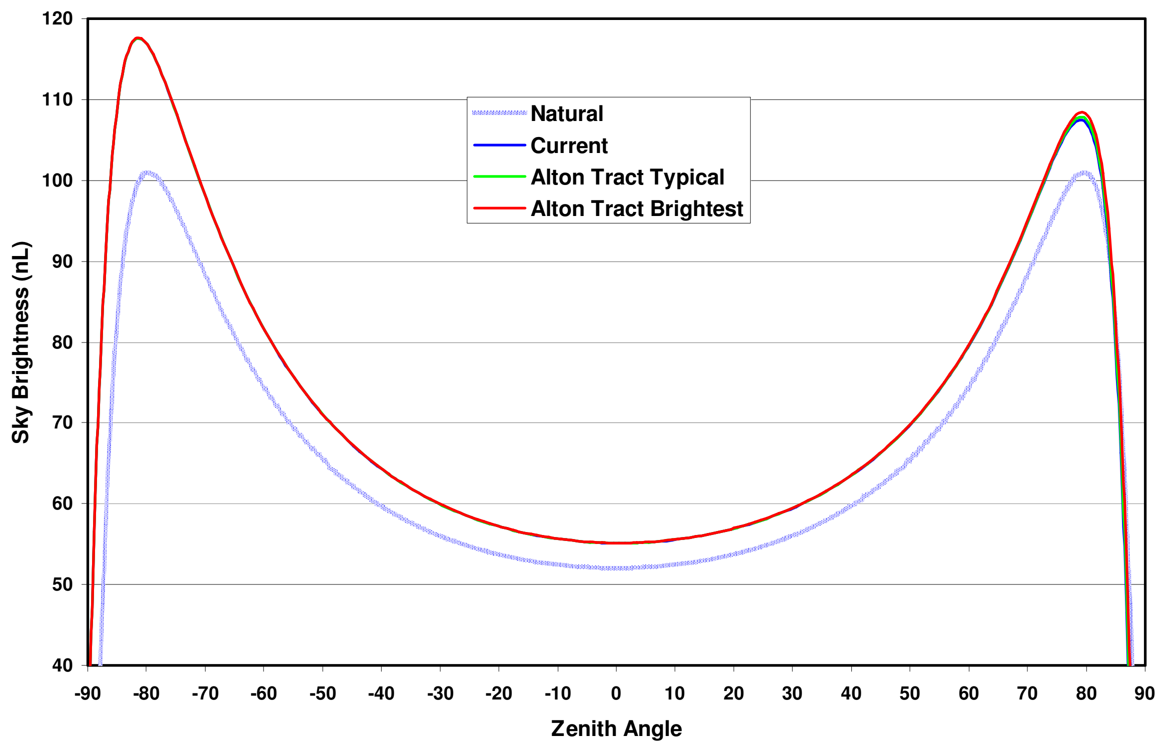


**Figure 8. Horizon to horizon sky brightness at Brianhead Peak on the semi-circle originating toward the Alton site (azimuth 131°, zenith angle 90°) and ending at the point on the horizon opposite (azimuth 311°, zenith angle –90°). The green line shows the predicted current sky brightness profile arising from the 11 existing cities and towns listed in Table 3; the blue and red lines show the predicted additional contributions of the two Alton tract lighting conditions described in the text.**

Figure 8 shows the sky brightness along the semi-circle originating at the ACT site (right side of the graph), passing through the zenith and ending up at the horizon opposite the mine site (cf. Figure 3). From this figure is clear that this is a much more heavily light-polluted site due mostly to the proximity of Cedar City and St. George, Utah, with the zenith appearing approximately 6% brighter than the natural condition with or without lighting at the ACT. This brightening rises to approximately 25% and 80% above natural condition when viewed 10° above the horizon toward St. George and Cedar City, respectively (see Figures 9 and 10).

Figures 9 and 10 display the fractional sky brightness increase over the current condition for the two ACT lighting scenarios, and over the natural condition for the semi-circles toward the indicated cities and towns. Here we can see that sky glow produced by the *typical* ACT lighting scenario is fainter than from all other sources in the study. Seven light domes are calculated to be brighter than that predicted for the *brightest* lighting scenario at the mine site, including, in decreasing order (name@azimuth), Cedar City @268°, St. George @226°, Brian Head @319°, Orderville @159°, Panguitch @65°, Fredonia @162°, and Glendale @153°.

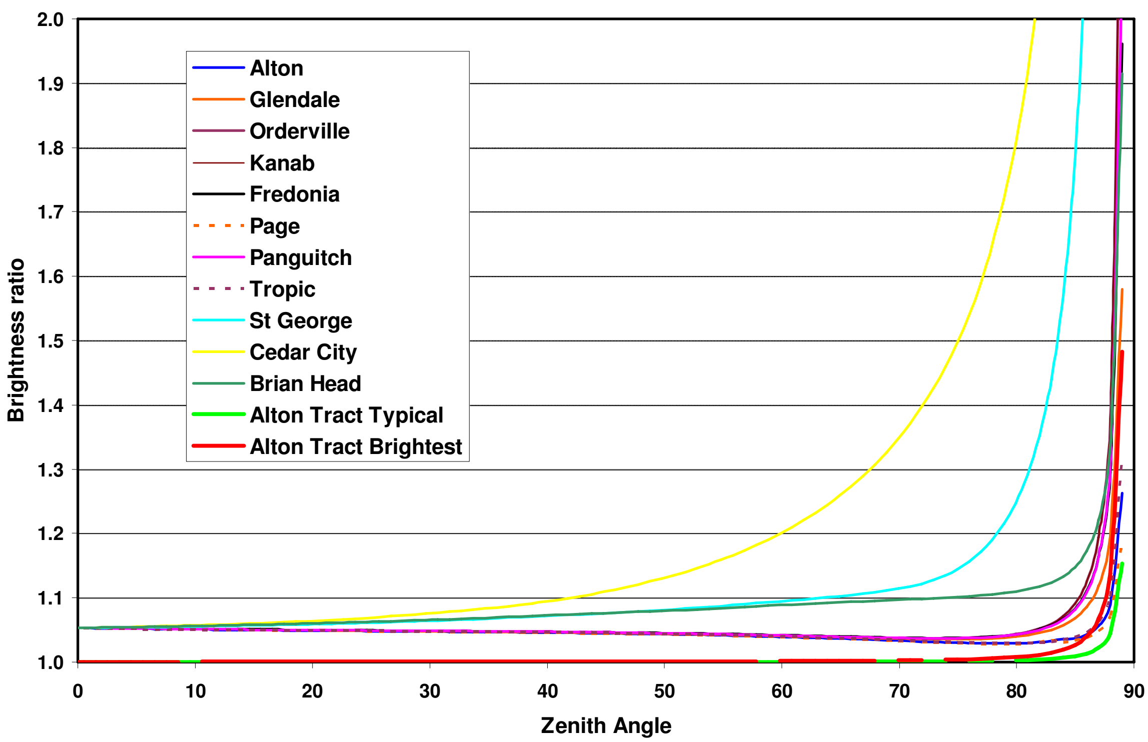


**Figure 9. Brightness ratio as viewed from Brianhead Peak toward the Alton site as well as toward a selection of regional towns/cities indicated in the key. The Brightness Ratio display for the towns is as compared to the natural condition (i.e., no towns): the Brightness Ratio for the Alton tract conditions is to the current condition (i.e., including sky glow from cities and towns). Zenith angles from 80°–90° are detailed in Figure 10.**

Figures 11 and 12 show false-color maps of sky brightness over the entire sky as viewed from Brianhead Peak; Figure 11 represents the current condition, while Figure 12 includes the addition of the *brightest* lighting at the ACT. This representation does not show any discernible increase in sky glow above the ACT (indicated by the arrow).

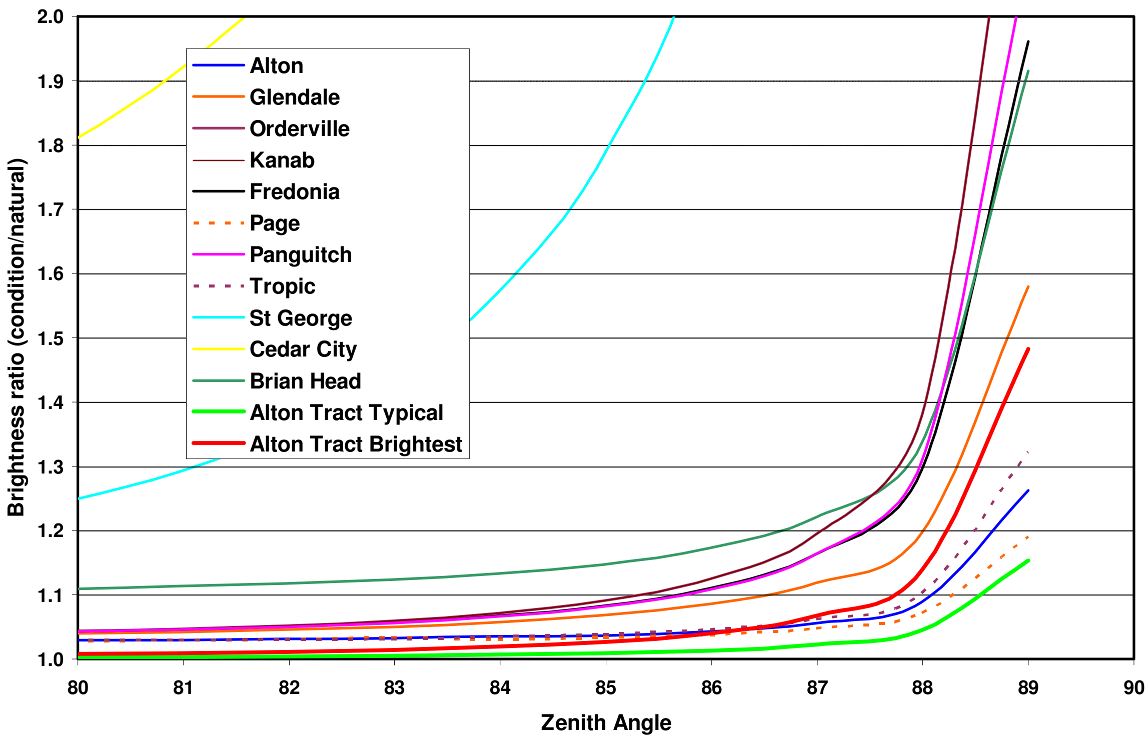


**Figure 10. As Figure 9, from zenith angles 80°-90°.**

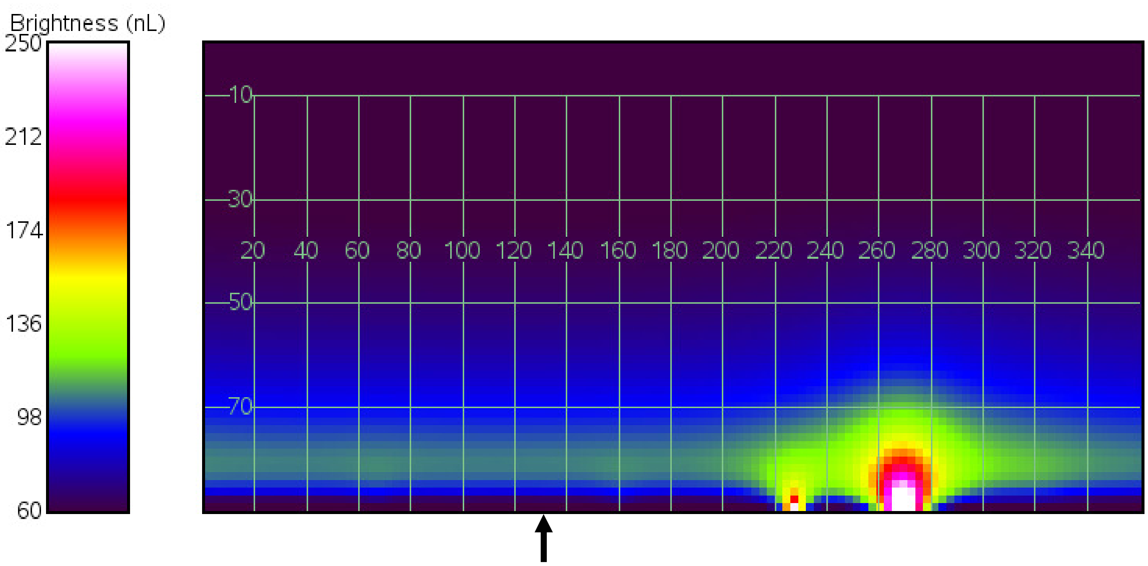


**Figure 11. An all-sky false-color panoramic map of the predicted current sky glow visible from Brianhead Peak. The grid and numbers on this and the following image indicate altitude and azimuth; the arrow indicates the azimuth of the Alton mine site in Table 3.**

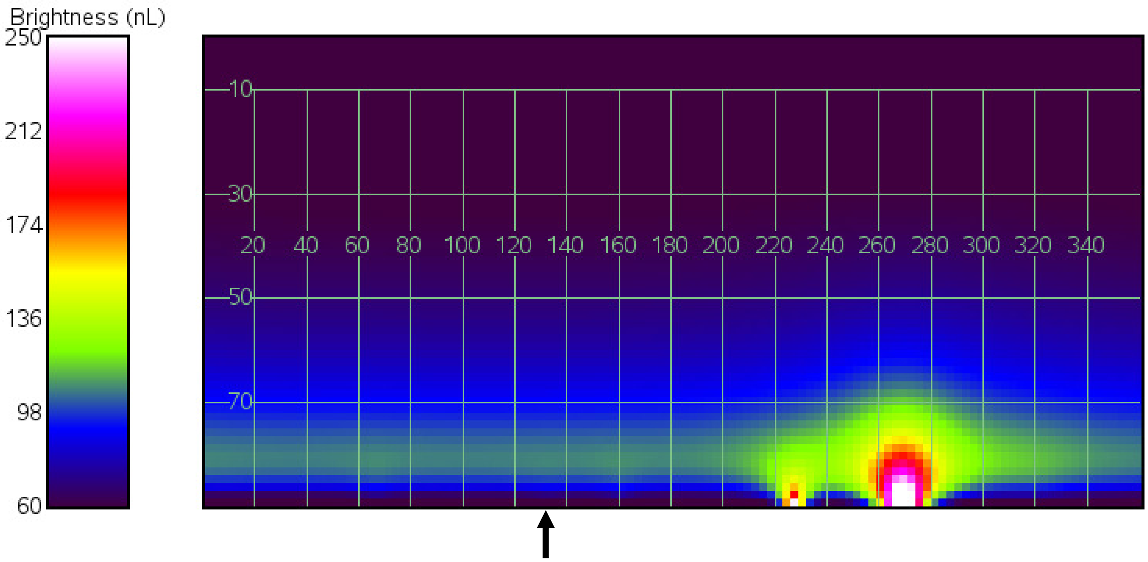


**Figure 12. As Figure 11, with *brightest* lighting at the Alton tract.**

**Table 6. Sky brightness ratios as viewed from Brianhead Peak at selected zenith angles toward the Alton site**

| Zenith Angle (degrees) | Brightness Ratio | |
|---|---|---|
| | Typical | Brightest |
| 0 | 1.00 | 1.00 |
| 45 | 1.00 | 1.00 |
| 60 | 1.00 | 1.00 |
| 80 | 1.00 | 1.01 |
| 85 | 1.01 | 1.03 |
| 87 | 1.02 | 1.06 |
| 89 | 1.13 | 1.42 |

## IV. Impact of Potential Alton Coal Tract Lighting on the Viewshed

Though not directly apart of the analysis forthis report based on DSP sky brightness modelling, the question has been raised of the potential direct visibility of light fixtures in the ACT from BCNP and CBNM. To address this concern SWCA performed a viewshed analysis to determine what parts of the ACT might be directly visible from the observation points of Table 4 (see Appendix C) and conversely what parts of BCNP and CBNM might be visible from within the ACT.

The results of this analysis show that no part of the ACT is directly visible from Yovimpa Point or any part of BCNP due to intervening terrain, and thus no light fixtures used in the ACT would be directly visible from BCNP.

The analysis shows however that a portion of the potential mining sites in the ACT are directly visible from Brianhead Peak near CBNM and more importantly from portions of the Markagunt Plateau in the northeast portion of CBNM itself. Light fixtures used in these portions of the ACT could therefore be directly visible from within CBNM. The unshielded portable fixtures particularly, using1000 watt 110,000 lumen lamps, would almost certainly be the brightest artificial light sources visible in the night landscape. Though a precise calculation of the brightness of these lights would require detailed specification of the fixtures' photometric properties, aiming configuration and other details, an order-of-magnitude calculation yields that the lights would appear significantly brighter than the planet Venus, the brightest object in the night sky after the moon. This calculation assumes the Brightest Case lighting described in Table 2 and that the lights are pointing toward Brianhead Peak.

## V. Potential Mitigation Strategies

In rough order of importance or mitigation effectiveness, the following strategies could be employed to decrease the impacts of the lighting used at the Alton Coal mine site on BCNP and CBNM.

### A. Hours of operation

Performing mining operations during daylight hours only would allow the elimination of 86%-92% of the total lighting, and completely eliminate all unshielded lighting. The sky glow reduction arising from the ACT would be reduced by somewhat more than this figure due to the elimination of unshielded floodlighting at the ACT site. Alternatively, mining activities could be reduced during hours of night visitor use.

### B. Lamp type

All of the lighting suggested for the mine operations, excepting only that on the mining vehicles themselves, is to be provided by metal halide lamps. For the *typical* scenario 73% of the lighting would come from metal halide lamps, while in the *brightest* scenario this figure would be 88% (see Table 3). Luginbuhl et al. (2008) have shown that, at small zenith angles (i.e. near the zenith) and under clear atmospheric conditions appropriate to this region, the visible sky glow produced by metal halide lighting is approximately 3 times that produced by high-pressure sodium lighting, and 12 times that produced by low-pressure sodium lighting, on a lumen-for-lumen basis. At high zenith angles (i.e. at viewing angles more directly toward the light sources) this effect would decrease. Nonetheless, a reasonable way to decrease sky glow impacts from lighting in the ACT would be to use low-pressure sodium lighting at the mine headquarters and high-pressure sodium for the portable floodlights used at the active mine site.

### C. Portable fixture shielding

The uplight fraction from these very poorly shielded fixtures could be improved with the addition of shields on the upward portion of the luminaires, conceptually following the huge improvements in sports lighting technology seen in the last five to 10 years. If the shields are not available from the manufacturer, it may not be an unreasonable number to have manufactured. It may be possible to entirely replace the stock flood light fixtures with higher quality partially shielded or completely shielded floodlights generally used for sports lighting (see Appendix C for an example). Though the precise reduction in sky glow and the brightness of directly visible light fixtures is difficult to precisely quantify, a reduction of sky glow under the *typical* lighting scenario of three quarters (75%), and the intensity of directly visible fixtures by an order of magnitude (10 times) could be easily expected. The sky glow and direct fixture brightness reduction under the *brightest* scenario would be greater.

### D. Portable fixture aiming

Keeping the portable light fixtures located at the active mine site aimed as far as possible below the horizon and away from the directions toward these parks could substantially reduce sky glow and direct visibility impacts. Without specific photometric information for the fixtures or information on aiming constraints the improvements expected cannot be quantified, and practically assuring that such aiming is maintained could be problematic.

## E. Dust reduction

Methods to mitigate dust reduction such as paving heavily used roads, wetting the ground or limiting operation during windy conditions can considerably decrease aerosol/dust concentrations in the lower atmosphere and therefore light scattered toward the observation points from the mine site. The sky glow reductions from this mitigation are unknown.

## F. Headquarters lighting

Depending on activity expected at the headquarters building during nighttime hours, it may be possible to reduce or eliminate much of the lighting planned in this area, which amounts to 8%-14% of the total lighting. Particularly lighting used for security purposes can be reduced or eliminated by limiting access to the site through physical means such as fences and gates or security patrols.

## VI. Discussion and Conclusions

The calculations performed for this study indicate that the outdoor lighting for mining operations within the ACT would produce a detectable sky glow when viewed from Yovimpa Point in BCNP for only the *brightest* lighting scenario analyzed. Under this scenario, sky glow produced by lighting in the ACT would appear similar to that produced by the towns of Orderville, Utah, and Fredonia and Page, Arizona, but less than that produced by the distant large cities of St. George and Cedar City, Utah.

Though sky glow produced by ACT lighting under the *typical* scenario might otherwise be visible from Yovimpa Point, the chance alignment of the ACT site and the distant city of St. George would likely render the predicted small increase visually undetectable against the brighter sky glow arising from St. George.

From Brianhead Peak near CBNM the *typical* lighting scenario produces a sky glow fainter than any nearby town, and we judge it unlikely to be visually detectable above the horizon. The *brightest* scenario produces a sky glow comparable to nearby small towns, and would likely be visible under some conditions and by some observers when looking at or above the horizon.

A viewshed analysis indicates that light fixtures used in some areas of the ACT would probably be directly visible from both Brianhead Peak and from some locations within CBNM. There would be no direct visibility of fixtures within the ACT from BCNP. If visible, the unshielded 1000 watt metal halide lights suggested for potential use at the active mine site would probably be the brightest artificial light sources visible in the night landscape.

Though the sky glow impacts of the potential lighting appear small, particularly when considering the *typical* lighting expected to be used 90% of the time that the mine is active, the unusually pristine nature of the nighttime landscapes in this region, combined with the high resource value attached to natural nightscapes by BCNP mean that even small impacts may be of concern.

Options that could produce significant reductions in these impacts are available. Though restriction of mining operations to daylight hours may be unlikely, improved shielding and restrictions on vertical aiming angles and azimuths for the portable mine lighting, combined with the potential to use yellow light sources such as high-pressure and low-pressure sodium instead of metal halide lamps could reduce impacts substantially.

## VII. References


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# Appendix A:
# Portable Light Tower for Potential Use at Alton Coal Tract

## VIII. Appendices

### Appendix A. Portable light tower for potential use at the Alton Coal Tract

**BALDOR** **PL6000K**

# Baldor POW'R LITE Light Tower

Baldor's compact mobile light tower provides 4000 watts of light anywhere you need it: Construction, Emergency, Industrial, Mining, Civil Engineering and Event Lighting. With metal-halide lamps the Baldor POW'R LITE models will provide light coverage for over 5-7 acres.



- **Baldor's 6kW Generator –** powered by an 1800 RPM liquid-cooled Kubota diesel engine. The Baldor Generator and Kubota engine arebacked by a 3-Year Limited Warranty.
- **Baldor's new elliptical light fixtures –** provide a more efficient light pattern than conventional round fixtures. The 4 – 1000 Watt metal halidelamps are supported on both ends to enhancedurability and long life.
- **Corrosion resistant aluminum enclosure –** heavy duty 12 gauge side panels and lockable doors. Durable powder coat finish.
- **Convenience outlets –** 2000 watts, 120 VAC and 240 VAC.
- **Designed for easy service –** the side fender and side panel are easily removed allowing full access in minutes for engine/alternator service.
- **Mast and outriggers –** zinc plated for long life.
- **30' extended light tower –** Tower rotates 360 degrees
- **4-section mast –** allows for compact trailering length. Coiled mast cords.
- **Dual forklift pockets –** located on light mast and bottom of trailer for easy lifting.
- **Internal control panel –** protects against elements. Hour meter and keylock standard.
- **Engine shutdown –** low oil/high temperature shutdown protection.
- **50 Gallon fuel tank –** provides 100 hours of runtime and outside fill cap.
- **Radiator fill –** easily accessible from end panel cutout.
- **Battery included.**

## Mast/Enclosure

| | |
|---|---|
| Lighting Coverage | 5-7 Acres @ 0.5 foot candles |
| Mast Height | 30' |
| Mast Material | Zinc Plated |
| Mast Sections | 4 |
| Tower Rotation | 360 Deg |
| Mast Cord | Coiled |
| Enclosure Material | 12 Gauge |
| Finish/Coating Enclosure | Powder Coat |
| Finish/Coating Hardware | Zinc Plated |
| Lockable Doors | Yes |
| Hinge Material | Aluminum |
| Fenders | Steel |
| Outrigger System | 3 Point |
| Forklift Pockets | Standard |
| Maximum Wind Load | 65 MPH |

## Engine Specifications

| | |
|---|---|
| Manufacturer | Kubota |
| Model | D905E |
| Cylinders | 3 |
| Induction System | Naturally Aspirated |
| Displacement, cc (cu. in.) | 898 cc (54) |
| EPA Emissions Level | Tier 2 |
| HP @ Rated Speed | 17 |
| RPM | 1800 |
| Bore and Stroke | 2.83" x 2.90" |
| Lubrication Capacity (with filter) | 5.4 Qts |
| Battery Recommendation (min. cold cranking amps) | 525 |

- Battery, battery rack, and cable supplied
- Spin-on oil filter
- Thermostat controlled liquid cooling system
- Glow plugs
- 12V engine alternator
- 12V starter motor

## Trailer

| | |
|---|---|
| Standard Hitch | 2" Ball |
| Trailer Tongue | Removable |
| Trailer Lights | DOT Approved |
| Transport Tie-downs | Standard |
| Tires | 205 / 75D14 |
| Towing Speed (MPH) | 60 |

## Fuel System Specifications

| | |
|---|---|
| **Fuel Consumption** | **GPH** |
| Full Load | 0.5 |
| **Approximate Run Time** | **Hours** |
| Full Load | 100 |
| **Fuel Capacity** | |
| Gallons | 50 |
| Fuel | Diesel |

## Weights and Dimensions

| | |
|---|---|
| Weight Without Fuel | 1800 |
| Dimensions Stowed (L x W x H) | 162" x 54" x 73" |
| Dimensions Extended (L x W x H) | 106" x 122" x 396" |

## Sound Level

| | |
|---|---|
| Sound level dB(A) | 72 |

Measured @ 7 meters, full load

## Engine, Generator Instrumentation

Digital controller with integral hour meter, operator keylock, engine preheat, and engine start selection. Low oil, high temperature, low battery, and overspeed protection with LED indicators.

## Receptacle Specifications

| | |
|---|---|
| 120 Volt 20 Amp Duplex GFCI | 1 |
| 120/240 Volt 30 Amp Twistlock (L630R) | 1 |
| Voltage Regulation | ± 5% |
| Frequency | 60 Hz |

Baldor reserves the right to implement specifications or design changes without notice.

**WARNING:** Do not connect generator to any building's electrical system unless a disconnect switch has been installed.

Distributed by:

BALDOR

Baldor Electric Company
P.O. Box 2400 • Fort Smith, AR 72902-2400 U.S.A.
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# Appendix B:
# Discussion for Second Observation Point,
# Alton Coal Tract Night Sky Aesthetic Analysis

**Appendix B. Discussion of second observation point, Alton Coal Tract night sky aesthetic analysis**

9/26/2008

TO: Ben Gaddis, SWCA Environmental Consultants, and discussion group

FM: Chad Moore, NPS Night Sky Program Manager

RE: Discussion of second observation point, Alton Coal Mine night sky aesthetic analysis

Three National Park Service sites have the potential to be impacted by the proposed Alton Coal Mine— Bryce Canyon National Park, Cedar Breaks National Monument, and Zion National Park. Bryce Canyon has the most pristine night skies of the three, and is the closest to the Alton project site. Clearly that is the most important park to analyze impacts to, and there appears to be agreement that Yovimpa Point near the southern end of the park is appropriate for an observation point. This observation point will be modeled by Dark Sky Partners LLC in order to assess night sky aesthetic impacts.

The NPS Night Sky Program recommended today during a teleconference that a second observation point be established. Of the other two parks, Cedar Breaks is more likely to be impacted than Zion. Zion National Park has a slightly brighter (ie. More light polluted) night sky than Cedar Breaks and the majority of the park is at a lower elevation. This lower elevation will minimize potential light pollution from the Alton site due to terrain shielding, and any perceived impact will be proportionally less as compared to the existing sky. Night sky brightness data does exist at two potentially useful sites within Zion— at Lava Point and near the east entrance; so if desired, Zion National Park could be included in Dark Sky Partner's analysis.

Cedar Breaks has several panoramas along the rim, though none of them offer 360 degree views. Because of this, the NPS Night Sky Program chose Brianhead Peak as a representative site. Brianhead allows the NPS system to capture the entire 360 degree panorama from one location, but it is located on Dixie National Forest land approximately 1 mile away from and 1000' above the park boundary. If the modeling by Dark Sky Partners was based on a second observation point at Brianhead, there was concern that results might not be representative of conditions at Cedar Breaks.

The difficulty with using a site within Cedar Breaks is that no all-sky brightness data exists there. With winter approaching, it is unlikely that suitable data could be acquired there before June 2009. While models produced from an observation point within the park (as opposed to at Brianhead Peak) would be slightly more accurate, the portion of the impact to the current condition would be less accurate since no data exists.

To further the discussion, a rough map and sight profile was created for the proposed observation points. Comparing Brianhead with Point Sublime within Cedar Breaks shows that Brianhead has an elevation above the proposed Alton Coal Mine of 4407', while Point Sublime is 3450'. Higher elevation observation points tend to be more exposed to light pollution, though the difference is relatively minor. Brianhead peak has a slightly higher angle of view to the project site, 1.8 degrees vs. 1.6 degrees from Sublime Point. This is a very small difference and unlikely to have an impact on the modeled sky brightness in my opinion. The third difference is that Brianhead peak is further away, roughly 26.5 miles vs. 24 miles. Using the approximation of Walkers Law, this should result in Brianhead having 22% greater attenuation in light from the project site than Sublime Point; in other words showing less impact. Keep in mind that Cedar Breaks covers a area that ranges from 23 miles to 27 miles distant, so no single observation point will be representative of the entire park. Fourth difference is that Brianhead has slightly less terrain blocking than the Sublime Point observation site. The exact difference between the two will require a far more detailed analysis than is provided here. However, at 1000' above the project site, both sites have a clear view. Since the model employed by Dark Sky Partners begins at the horizon extending upward, I suspect that the terrain blocking issue is moot (though it is certainly a parameter that should be adequately modeled at the Yovimpa Point site at Bryce Canyon). A fifth and final difference between the two sites is that the Brianhead site is likely to have more light pollution than the Cedar Breaks site due to the proximity of the small town of Brian Head. This should result in any analysis at Brianhead showing proportionally less impact to the entire sky.

Either approach has some drawbacks. However, I do not believe that an analysis at Brianhead would overestimate impacts at the nearby park. It appears with this cursory analysis to be more likely to underestimate impacts. The preference of the National Park Service is to exercise the model at a point where we have data and then to be as transparent as possible about how this is extrapolated to represent conditions across a park.

See the graphic attachment (Fig. B-1).

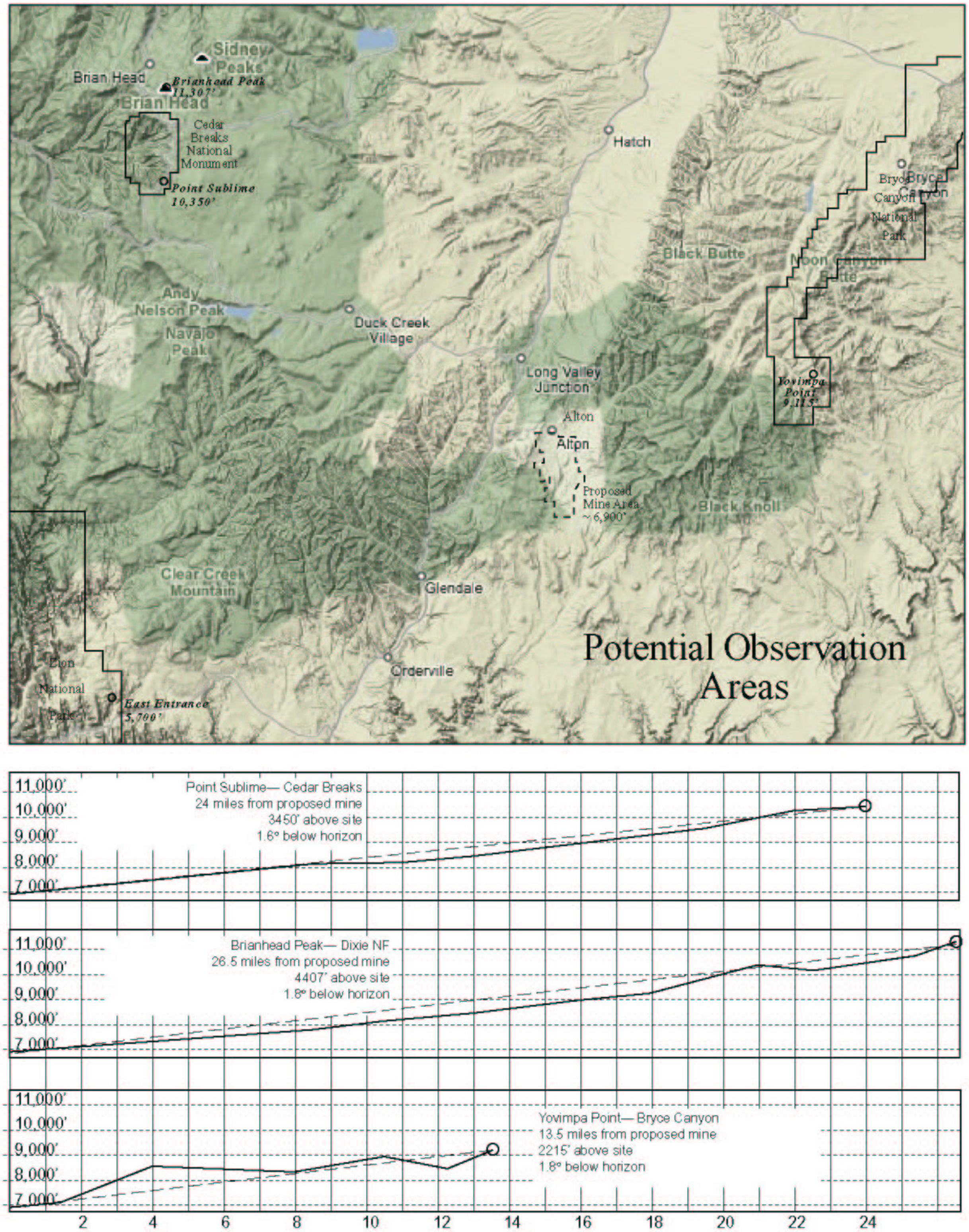


**Figure B-1. Observation points and lines-of-site**

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# Appendix C:
# Viewshed Analysis

## Appendix C. Viewshed Analysis

The following viewshed analysis is provided by SWCA.

### *Methods*

The viewshed analyses were performed on a mosaic of 5-meter Digital Elevation Model (DEM) datasets using the Spatial Analyst tool within ESRI ArcGIS Desktop. The DEM has a vertical Root Mean Square Error (RMSE) of 4 meters. To account for this potential error plus the height of an observer, the observation points were offset above the DEM by 6 meters. The model accounts for the curvature of Earth, but not tree-cover/obstruction or atmospheric conditions. This provides a conservative estimate of visibility.

One analysis was conducted to model a viewshed as "seen" from 11 observation points within the tract (Figures C-1 and C-3). It indicates any area that may be visible from at least 1 of the 11 points. Ten of the points are within the pit disturbance areas, each representing a location with the greatest local elevation or a location at/near the perimeter of the potential disturbance area. One point represents the center of the area proposed for the facilities location. The extent of the analysis includes both Bryce Canyon National Park and Brian Head Peak.

A separate analysis was conducted to model the viewshed from the highest point of Brian Head Peak, and indicates areas that may be visible from that 1 observation point (Figures C-2 and C-4).

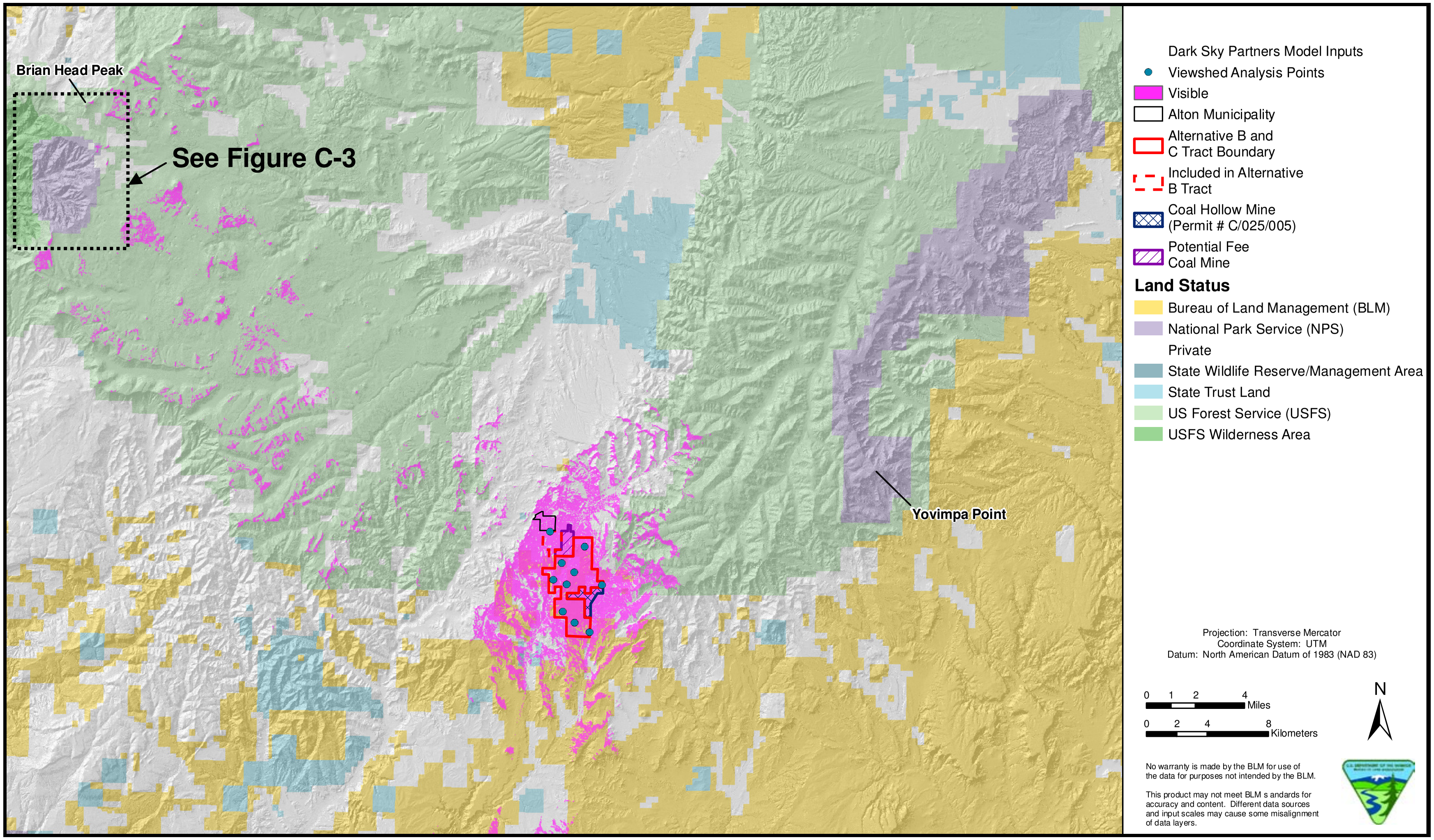


**Figure C-1. Points visible (line of sight) from select locations within the Alton Coal Tract (indicated in pink). For detail within Cedar Breaks National Monument see Figure C-3.**

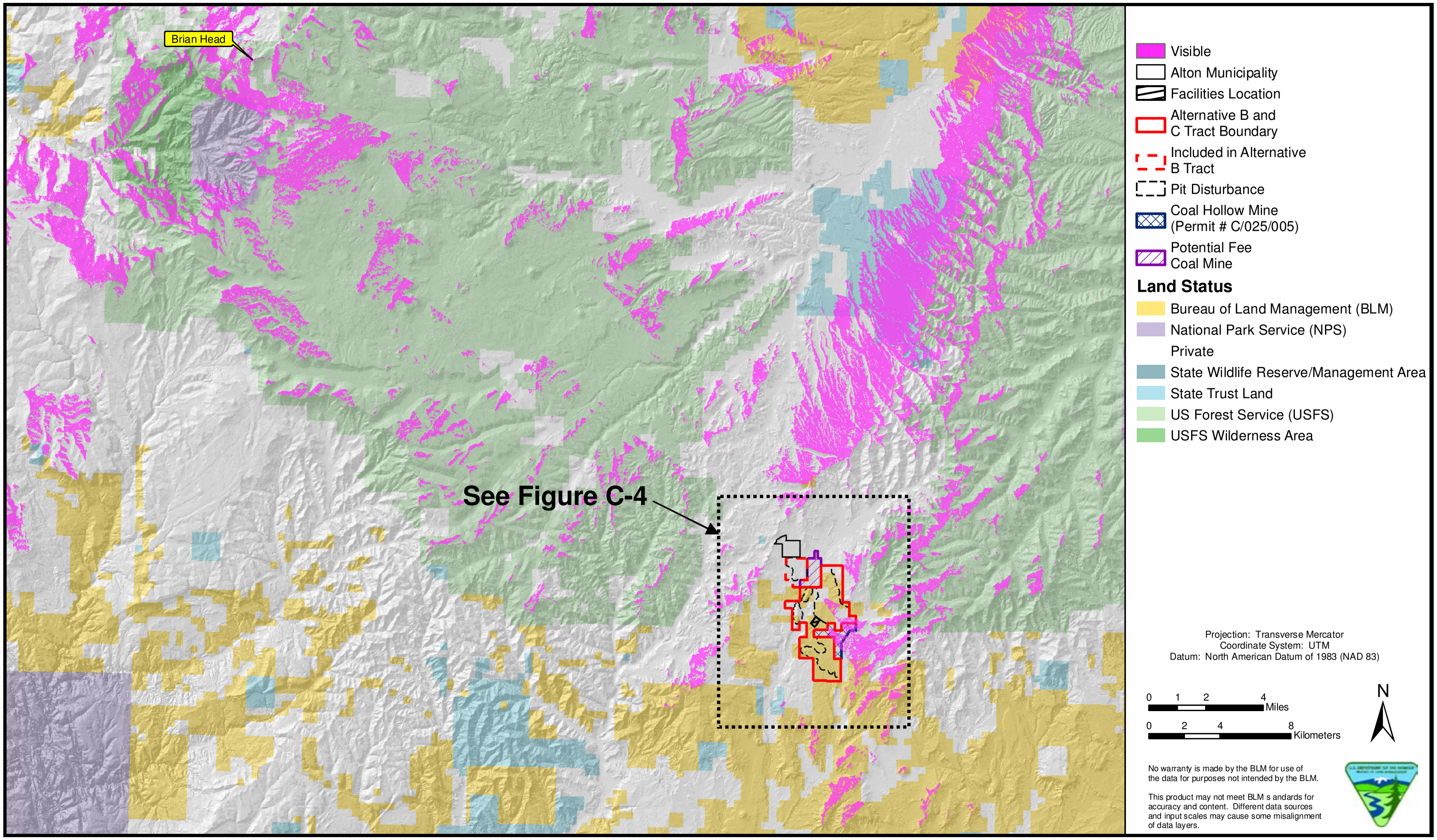


**Figure C-2. Points visible (line of sight) from Brianhead Peak (indicated in pink). For detail within the Alton Coal Tract see Figure C-4.**

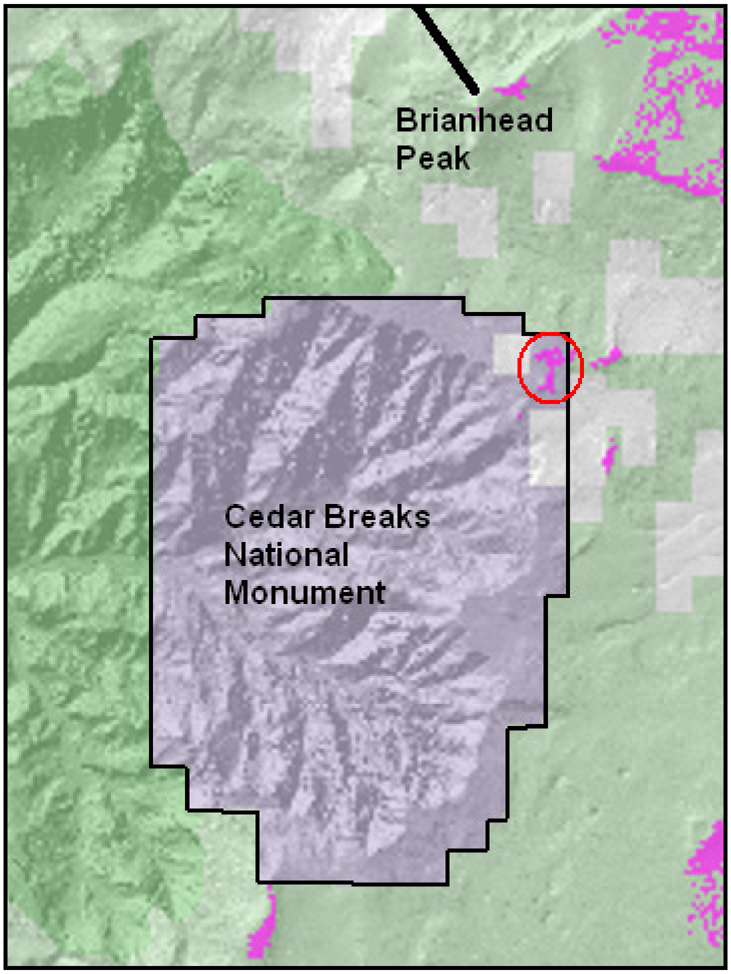


**Figure C-3. Portion of Figure C-1 showing Cedar Breaks National Monument (CBNM). The red circle shows a portion of the Markagunt Plateau within CBNM that potentially has direct line-of-sight to portions of the Alton Coal Tract.**

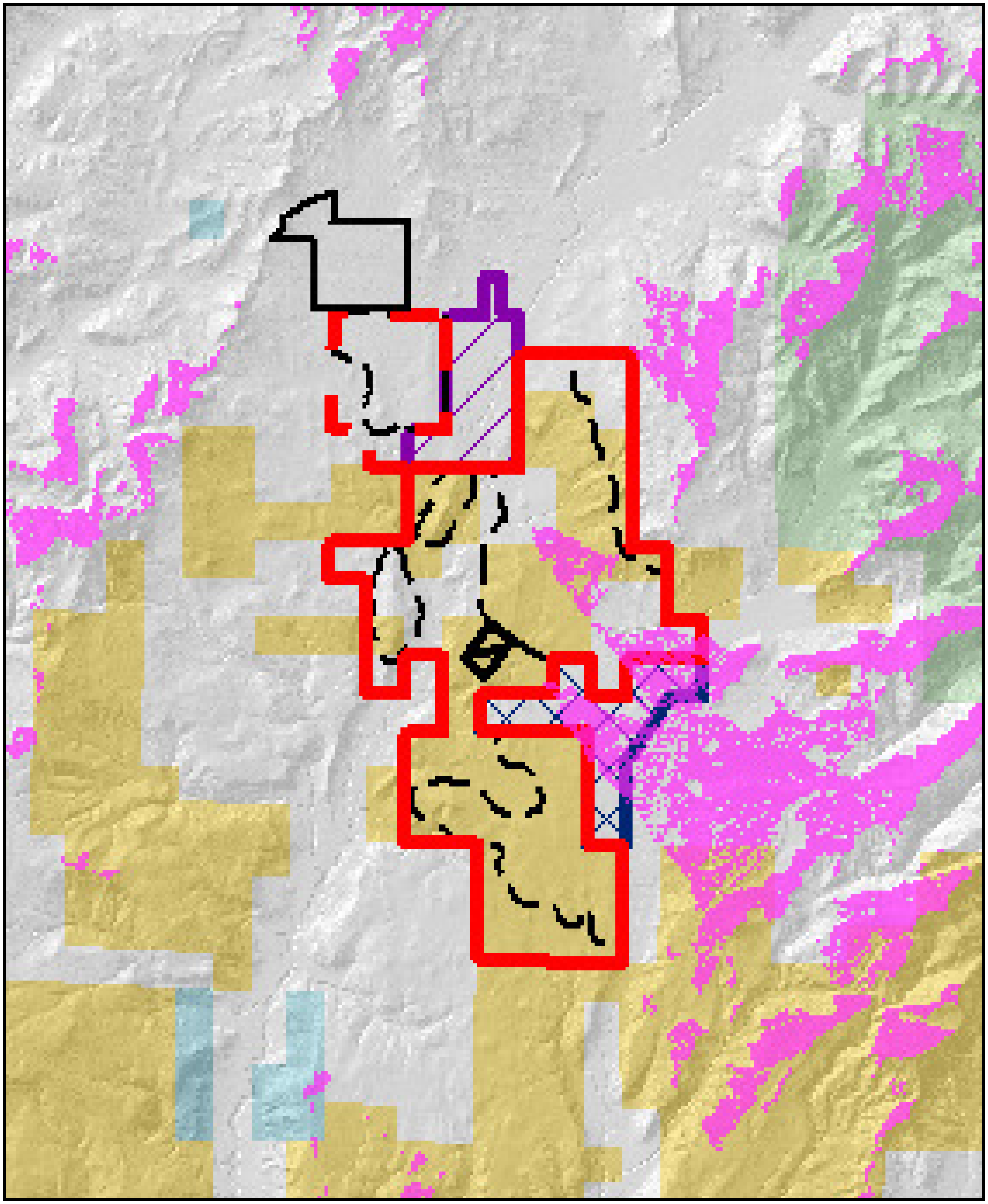

**Figure C-4. Detail of Figure C-2 covering Alton Town and the Alton Coal Tract.**

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# Appendix D:
# Shielded Floodlight Fixtures

**Appendix D. Shielded floodlight fixtures**

**MUSCO Lighting**
100 1st Avenue West
P.O. Box 808
Oskaloosa, Iowa 52577

800/825-6030
641/673-0411
Fax: 641/673-4852

**LSG product**

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## *ATTACHMENT 1.*

### 3/26/2008 MEMO FROM NATIONAL PARK SERVICE NIGHT SKY PROGRAM MANAGER TO SWCA PROJECT MANAGER: DISCUSSION OF SECOND OBSERVATION POINT, ALTON COAL MINE NIGHT SKY AESTHETIC ANALYSIS, AND GRAPHIC ATTACHMENT ACCOMPANYING MEMO

**9/26/2008**

**TO: Ben Gaddis, SWCA Environmental Consultants, and discussion group**

**FM: Chad Moore, NPS Night Sky Program Manager**

**RE: Discussion of second observation point, Alton Coal Mine night sky aesthetic analysis**

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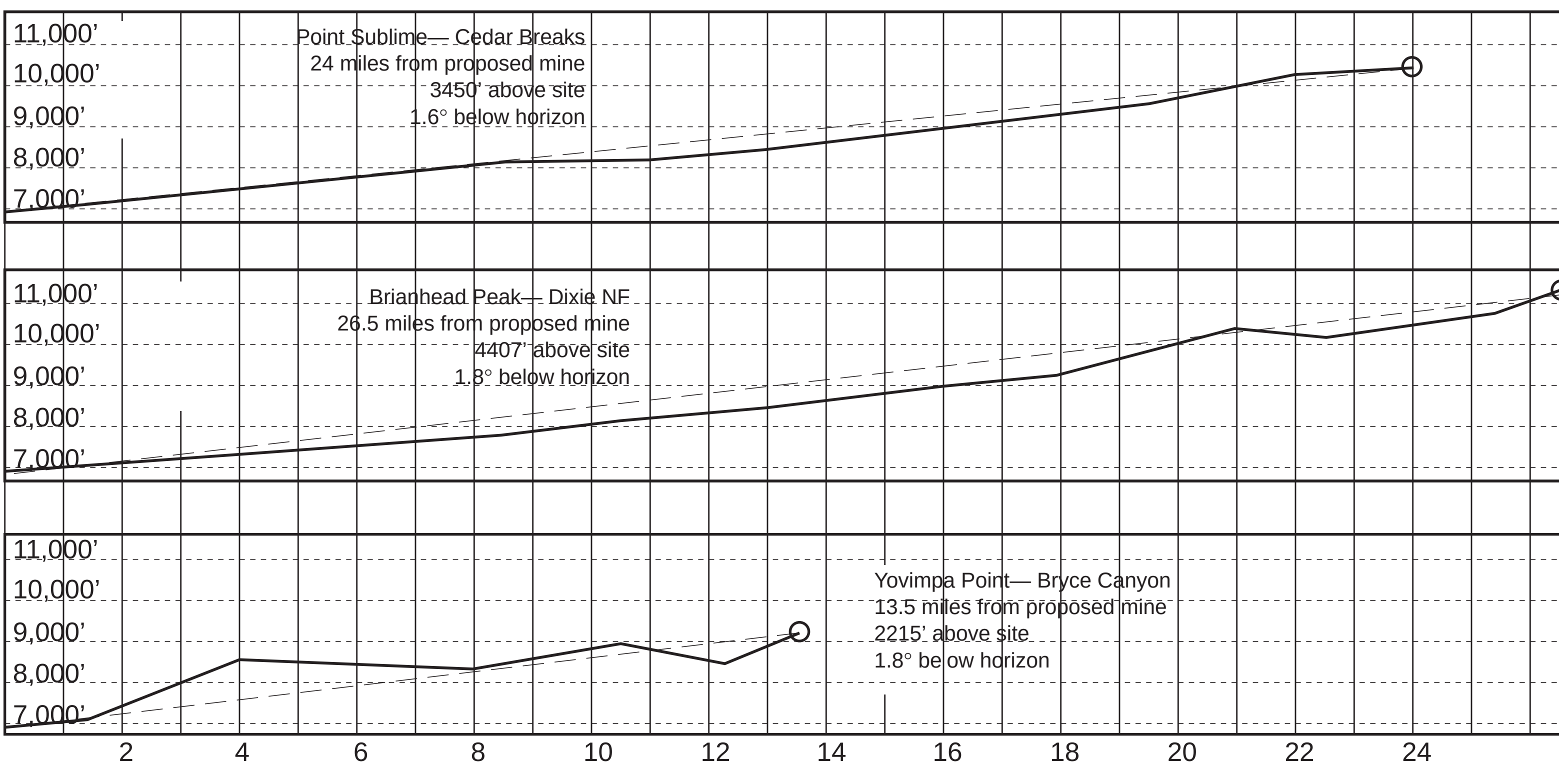
See the graphic attachment


Potential Observation Areas
Sidney Peaks
Brian Head
Brianhead Peak
11,307’
Brian Head
Cedar Breaks National Monument
Point Sublime
10,350’
Hatch
Bryce Canyon National Park
Bryce Canyon
Black Butte
Moon Canyon Butte
Andy Nelson Peak
Navajo Peak
Duck Creek Village
Long Valley Junction
Yovimpa Point
9,115’
Alton
Alton
Proposed Mine Area ~ 6,900’
Black Knoll
Clear Creek Mountain
Glendale
Orderville
Zion National Park
East Entrance
5,700’


11,000’
10,000’
9,000’
8,000’
7,000’
Point Sublime— Cedar Breaks
24 miles from proposed mine
3450’ above site
1.6° below horizon
Brianhead Peak— Dixie NF
26.5 miles from proposed mine
4407’ above site
1.8° below horizon
Yovimpa Point— Bryce Canyon
13.5 miles from proposed mine
2215’ above site
1.8° below horizon
2
4
6
8
10
12
14
16
18
20
22
24

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## *ATTACHMENT 2.*

### *4/28/2009 CORRESPONDENCE BETWEEN NATIONAL PARK SERVICE AIR RESOURCES DIVISION AND BLM PROJECT MANAGER RE: ALTON COAL MINE LIGHTSCAPE ANALYSIS*

United States Department of the Interior
NATIONAL PARK SERVICE
Air Resources Division
P.O. Box 25287
Denver, Colorado 80225

4/28/2009

Keith Rigtrup
BLM Project Manager, Alton Coal LBA EIS
BLM Color Country District
176 East DL Sargent Drive
Cedar City, UT 84721

Subject: Alton Coal Mine Lightscape Analysis

Keith,
The mission of the National Park Service includes the mandate to protect scenery. The protection of scenery extends across both day and night, horizontally as viewed from within parks, as well as upward to the sky. Natural Lightscapes are important to national park visitors and are also an element of a natural ecosystem. Such lightscapes are under substantial threat and modification by outdoor lighting. If not properly contained and controlled, light can impact lightscapes up to 300 kilometers away, as has been observed with the impact of large cities on remote parks. Even a small number of lights can potential cause an impact if they are proximal to natural areas.

Through discussion with the BLM and SWCA Environmental Consultants, it was determined that the proposed development of the Alton Coal Mine had the potential to impact natural lightscapes at three national park units— Bryce Canyon National Park, Cedar Breaks National Monument, and Zion National Park. Bryce Canyon has the most pristine night skies of the three, is the closest to the Alton project site, and this resource is highly valued by park visitors and park management. It was decided that Zion would be omitted from the technical analysis since impacts were expected to be the least among the three parks and impacts could likely be extrapolated from Cedar Breaks and Bryce Canyon data. Midway through the technical analysis process, it was determined that both the indirect impact to the night sky (skyglow) and the direct impact to the nighttime viewshed (glare) should be considered. The National Park Service coordinated with Dark Sky Partners LLC (DSP) who were contracted to produce a computer model predicting the impact of the proposed mine lighting. The following is a response to the modeling report "An Assessment of the Impact of Potential Mining Operations at the Alton Coal Tract on the Dark Skies of Bryce Canyon National Park and Cedar Breaks National Monument" and suggested impact findings.

The National Park Service worked with DSP to verify the model input parameters, particularly the atmospheric clarity or "K" factor. The assumptions about light fixture output, position, and pointing appear to be reasonable and the NPS has confidence in the computer model performance based on past collaborations.

The NPS Night Sky Program is working toward a comprehensive and peer-reviewed framework for assessing lightscape impacts, however this product is not yet available and likely more than a year away from fruition. We present here a simple method of weighting the impact of the proposed mine lighting.

### *Bryce Canyon*

Yovimpa Point at the southern end of Bryce Canyon National Park was chosen for the analysis. This site is important from a visitor perspective, and has several night sky brightness data sets collected from there. From this location, given the typical pit location within the mining tract, the light pollution generated by the proposed project is superimposed in the sky against the existing glow from St. George. For this impact analysis, we considered the impact as if the mine skyglow was shifted to the side of the existing St. George glow. This was done for four reasons. 1) The NPS guidance on environmental impact analysis directs us to measure against natural background conditions, 2) small changes in the viewing location from within the park would shift the light dome left or right, 3) changes in the light source within the mine complex would have a similar directional shift, and 4) other light pollution sources have the potential to reduce their light pollution and thus their impact on the parks. In fact, many suburbs of St. George are in the process of changing streetlights to become more night-sky friendly.

The *typical* scenario as modeled by DSP shows that the brightness ratio would only exceed 10% over natural conditions in the lowermost 2 degrees of sky. In the experience of the Night Sky Program and in relative comparison to the other small population centers brightness ratios, such a change to the natural lightscape is unlikely to be noticed by a casual observer, but would likely be noticeable to a keen or trained observer. The extent of the light dome would be well restricted to the lowermost section of sky, and would be less than the glow from almost all small towns surrounding the park. These factors lead us to conclude that the impact prescribed to the mine lighting would not be annoying or measurably reduce the perceived aesthetic quality of the night sky. As such, the impact of the *typical* lighting scenario should be **negligible**.

The *brightest* scenario shows that the brightness would exceed 10% over natural condition in the lowermost 5 degrees of sky. The glow would be comparable to Page, and somewhat less than the combined glow of Kanab and Fredonia. These towns are easily visible to a dark-adapted visitor at Yovimpa Point, and in several other locations in the park as well. Such city glows impact a small fraction of the sky— a much smaller fraction than the light domes from either St. George or Cedar City, and thus have relatively smaller impact. The impact upon the zenith or any area above 20 degrees angular elevation is likely to be unmeasureable and is certainly not noticeable at those higher angles. As pointed out in the analysis by DSP and discussions through the modeling process, the exact impact is highly dependent on very small variations of the placement of the mine lights and their aiming. These factors lead us to conclude that the impact prescribed to the mine lighting would be intermittently and infrequently noticeable and measurable, and would have a perceived impact upon the aesthetic quality of the night sky. As such, we suggest that under the *brightest* scenario, there would be an occasional **minor** impact, which would usually fall below the threshold of **negligible** at most times.

The mine would not be directly visible from Yovimpa Point nor any other area from within the park boundary. Thus, there should be no impact of direct glare from the proposed mine. If future expansions of the mine are proposed that are within the viewshed of the park, the impact of direct glare must be reconsidered and may become a substantial lightscape impact.

### *Cedar Breaks*

Night Sky Brightness data for Cedar Breaks was collected just outside the park boundary atop Brianhead Peak. Using off-site locations is often practiced by the NPS Night Sky Program in order to get a better view of light sources near the horizon. When most light sources are distant, this approach makes sense and introduces fairly little bias. Thus for assessing the impact of the Alton Mine lighting, Brianhead Peak was chosen.

Cedar Breaks and Brianhead Peak are further from the mine site than Yovimpa Point, and the modeling results show that the skyglow impact produced by both the *typical* and *brightest* scenarios are small. Based on comparisons with other light sources around the park, and the experience of NPS field personnel, a trained observer would likely be unable to detect the *typical* scenario, which of course would be invisible to a casual visitor. Both keen and casual observers would be likely to see the *brightest* scenario, but the impact would be restricted to the lowermost degree of sky and it is not likely to be perceived as annoying even if the light from Cedar City and St. George were removed. In almost all locations within the park, except for the NE corner which is open meadowland and slopes toward the Alton Mine, this skyglow would be obscured by trees or terrain. We suggest that the combination of the limited skyglow and infrequent spatial and temporal visibility combine to render both the *typical* and *brightest* scenarios as **negligible**.

The question of direct glare at Cedar Breaks was also assessed. When by chance pointed directly toward the park, the Alton Mine lights would be very bright. A rough calculation, assuming that 2 of the 4 lights on the portable stanchion were aimed at the park, they would appear as bright as a negative 4.3 magnitude star. This is roughly as bright as the planet Venus and would dominate the nocturnal landscape when looking SE, and is also likely to cast a faint shadow. If considered in isolation, this would be a worrisome impact, however, this lightscape change is only under the infrequent and intermittent *brightest* scenario. Additionally, only one small location within the park would be subject to this lightscape impact. This is the meadow area near the road junction of highways 143 and 148. This section is traveled by visitors at night, but it is not an area where visitors are likely to be seeking natural lightscapes among the occasionally headlights of oncoming cars. During infrequent occurrences at this one location the impact is likely to be **minor to moderate**, though the sum total impact to the park averaged over time and space should be **negligible**.

We would also like to point out that the direct glare from the Alton Mine lighting would often be visible (to varying degrees) from Brianhead Peak and from numerous other locations within the Dixie National Forest. Because the scope of the DSP report and this letter includes only NPS administered lands, this impact was not assessed.

### *Zion*

Though not analyzed, we can interpolate the lightscape impact to Zion national park based on the model runs from Yovimpa Point and Brianhead Peak. In both scenarios, and considering both skyglow and direct glare, the impact to Zion is expected to be **negligible**.

## Mitigation

The conditions above where impacts to national parks are not negligible can be effectively mitigated. The National Park Service concurs with the mitigations suggested in the report by Dark Sky Partners. Assuming that reducing hours of operation at night is impractical for the mine operators, reducing lamp intensities and shielding fixtures would in combination sharply reduce both skyglow and direct glare. Retrofitting the proposed portable lighting unit with shielded fixture heads is recommended (see Appendix D), as well as addressing fixed lighting throughout the site.

**Conclusions**

As presented, lightscape impacts to national parks will be negligible to minor. The intervening terrain blocks much light that would otherwise be a substantial problem for these two parks. The report by Dark Sky Partners has lowered our initial concern over the impact to the outstanding natural lightscapes found in Bryce Canyon, Cedar Breaks, and Zion national parks. However, the report also underscores the necessity to this kind of analysis, especially when in close proximity to parks and where terrain does not fortuitously block stray light. Though the environmental impact is relatively small, we encourage simple and relatively low initial cost mitigations that will sensibly reduce this project's environmental impact.

cc:
Benjamin Gaddis
SWCA Environmental Consultants

Eddie Lopez
Bryce Canyon National Park

Paul Roelant
Cedar Breaks National Park

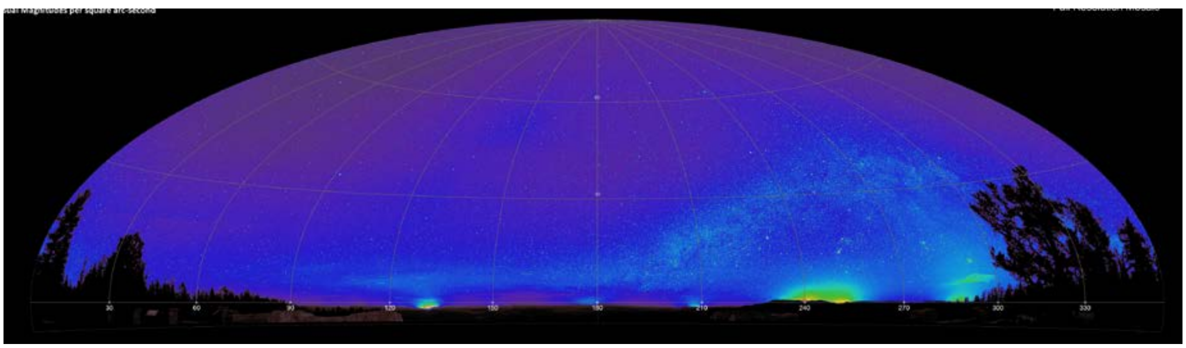
Jock Whitworth
Zion National Park

# J.2. An Assessment of the Impact of Potential Mining Operations at the Alton Coal Tract on the Dark Skies of Bryce Canyon National Park and Cedar Breaks National Monument

# Part II. An Additional Lighting Scenario, Dust Effects, Projected Future Increases in Skyglow due to Growth, and the Average Sky Luminance Parameter

# An Assessment of the Impact of Potential Mining Operations at the Alton Coal Tract on the Dark Skies of Bryce Canyon National Park and Cedar Breaks National Monument

## Part II. An Additional Lighting Scenario, Dust Effects, Projected Future Increases in Skyglow due to Growth, and the Average Sky Luminance Parameter



**NIGHT SKY FROM YOVIMPA POINT, BRYCE CANYON NATIONAL PARK**
**(NPS NIGHT SKIES PROGRAM)**

# FINAL REPORT

**REVISED**


**Prepared by Dark Sky Partners, LLC**
for
**SWCA Environmental Consultants**


**February 2014**

## EXECUTIVE SUMMARY

This report presents additional results from computer calculations of the sky brightness due to mining operations in the Alton Coal Tract when viewed from Yovimpa Point in Bryce Canyon National Park. This report is a follow-up report to the 2009 report *An Assessment Of The Impact Of Potential Mining Operations At The Alton Coal Tract On The Dark Skies Of Bryce Canyon National Park And Cedar Breaks National Monument*. The present work adds a third proposed lighting scenario to the two proposed Alton Coal Tract lighting scenarios used in the 2009 study, and analyzes the impact of mine-generated dust on skyglow as seen from Yovimpa Point. It also includes projections of the increased skyglow from population growth in the region through the year 2040. Finally, a new measure, the average sky luminance, is calculated; this measure can be compared with the value measured by the National Park Service Night Sky Team.

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## CONTENTS



## FIGURES



## TABLES

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# I. INTRODUCTION

The 2009 Dark Sky Partners (DSP) report A*n Assessment Of The Impact Of Potential Mining Operations At The Alton Coal Tract On The Dark Skies Of Bryce Canyon National Park And Cedar Breaks National Monument* (hereafter DSP 2009) describes the impact of proposed mining operations at the Alton Coal Tract (ACT or tract) on the night sky as seen from Bryce Canyon National Park (BCNP) and Cedar Breaks National Monument (DSP 2009). In the public comment period on the draft environmental impact statement (DEIS), issues were raised as to

- the impact on skyglow from dust generated by mining activities on the tract;
- increased skyglow over time as a result of projected population growth in the region; and
- the effects on the overall sky brightness as measured using the average sky luminance (ASL) measure.

These issues are addressed in this report. An Alton Coal Tract EIS Night Sky Working Group (NSWG) was formed, consisting of representatives from the Bureau of Land Management, National Park Service (NPS), SWCA Environmental Consultants, and DSP to address the above issues and to provide guidance on any further modeling work needed for the EIS. The reader is referred to DSP 2009 for a description of the study methodology and the details of the tract lighting.

In this supplementary report, predicted sky brightness is calculated for three ACT lighting scenarios. The DSP 2009 report analyzed two ACT lighting scenarios, called *typical* and *brightest*. To these scenarios this report adds a third scenario to describe an even brighter scenario. The three scenarios analyzed here are summarized as:

1. Scenario 1 (*typical* in DSP 2009) assumes the least lighting with one portable light tower (4 lamps), four fixed-position light towers, and 20 lamps from mobile light sources.

2. Scenario 2 (*brightest* in DSP 2009) assumes a mid-range of lighting with three portable light towers (12 lamps), six fixed-position light towers, and 36 lamps from mobile light sources.

3. Scenario 3 (not analyzed in DSP 2009) assumes the most lighting with six portable light towers (24 lamps), six fixed-position light towers, and 36 lamps from mobile light sources. Other than the increase in numbers of lamps, the characteristics of the sources in this new scenario are the same as for scenarios in DSP 2009.

# II. DUST IMPACTS

The methodology and lighting described in DSP 2009 are used to address the impact of mine-generated dust on skyglow. To investigate the impact of dust over the mine site, DSP modified the computer code to model the mine-generated dust as being in a cylinder over the mine pit, increasing the particulate component of the atmosphere within this cylinder relative to the surrounding atmosphere. The cylinder was assumed to be 1 kilometer in radius, reaching to 200 meters over the ground, and centered over the mine pit.

The parameter that describes the amount of aerosol (particulates) in the atmosphere, K, was set to 0.05throughout the region, including the mine site, in the DSP 2009 report. This value is representative of very clear air in the region, not the typical or average; an average western atmosphere is characterized with a K of approximately 0.3–0.5. The reasoning behind this choice of an atypical K value are discussed in DSP 2009. To determine a K value that characterizes the tract dust, data from the *Air Resources Impact*

*Assessment Technical Report for the Alton Coal Lease By Application Draft Environmental Impact Statement* (Appendix K in the DEIS) were used to provide the particulate mass loading (micrograms/m$^3$) for mining activities under the action alternatives. The last column of Table 1 gives the factor by which K should be increased to account for the increased mine-generated dust. Because the values listed under "background" describe average conditions in the region (i.e., K = 0.5, not K = 0.05 used in the DSP 2009 study), to be conservative, DSP adopted a K value of 4 × 0.5 = 2 within the cylinder, leaving K = 0.05 in the atmosphere outside of the cylinder.

**Table 1. Mine Dust and Background Dust, in mcg/m$^3$, for the Alton Coal Tract used to Model Dust Impacts on Skyglow**

| Scenario | Background | Mine Dust | Total | Ratio Total/ Background |
|---|---|---|---|---|
| $PM_{10}$, 200 feet, Alternative B and K1 | 72 | 83 | 150 | 2.1 |
| $PM_{10}$, 200 feet, Alternative C | 72 | 84 | 160 | 2.2 |
| $PM_{10}$, 300 feet*, Alternatives B and K1 | 72 | 86 | 160 | 2.2 |
| $PM_{10}$, 300 feet*, Alternative C | 72 | 93 | 160 | 2.2 |
| $PM_{2.5}$, 200 feet, Alternatives B and K1 | 8.6 | 19.3 | 30 | 3.5 |
| $PM_{2.5}$, 200 feet, Alternative C | 8.6 | 21.1 | 28 | 3.3 |
| $PM_{2.5}$, 300 feet*, Alternatives B and K1 | 8.6 | 22.7 | 31 | 3.6 |
| $PM_{2.5}$, 300 feet*, Alternative C | 8.6 | 24.5 | 33 | 3.8 |

*Notes*: $PM_{10}$ = particulate mass density of particles > 10 microns; $PM_{2.5}$ = particulate mass density for particles > 2.5 microns. For the $PM_{2.5}$, the 24-hour average as reported in Table 3.6 of the air resources report was used. "200-feet" and "300-feet"* indicate the amount of overburden removed.

*The 300-foot overburden removal scenario was eliminated from detailed analysis in the SDEIS. By lease stipulation, the successful bidder would not be permitted to surface mine at overburden depths greater than approximately 200 feet. The 300-foot overburden scenario is included here for completeness.

Figure 1 shows the predicted sky brightness (in nanoLamberts[1] [nL]) as seen from Yovimpa Point in BCNP for ACT lighting Scenarios 1 through 3 as described above. It also compares the skyglow with and without enhanced dust over the ACT. Figure 2 gives the predicted fractional change in sky brightness from mine dust. As seen from these figures, the addition of dust over the tract causes a slight decrease in the predicted sky brightness when viewing the sky slightly above the mine site, compared to the predicted increase without dust enhancement. This change is very small for all zenith angles (ZAs), reaching approximately 0.3–2% decrease at ZA 89º. The addition of dust results in a predicted reduction in the sky brightness increase at a zenith angle of 89º toward the tract from 10% to 9.7% (a decrease of 0.3%) for lighting Scenario 1, from 31% to 30% (a decrease of 1%) for Scenario 2 (cf. to DSP 2009 Table 5), and from 64% to 62% (a decrease of 2%) for Scenario 3.

[1] A nanoLambert (nL) is a unit of luminance or surface brightness. 1 Lambert = 1 lumen/square centimeter for a uniformly diffusing surface. A naturally dark sky has a brightness of approximately 54 nL at the zenith, rising (due to natural causes) to approximately 100 nL 10° above the horizon.

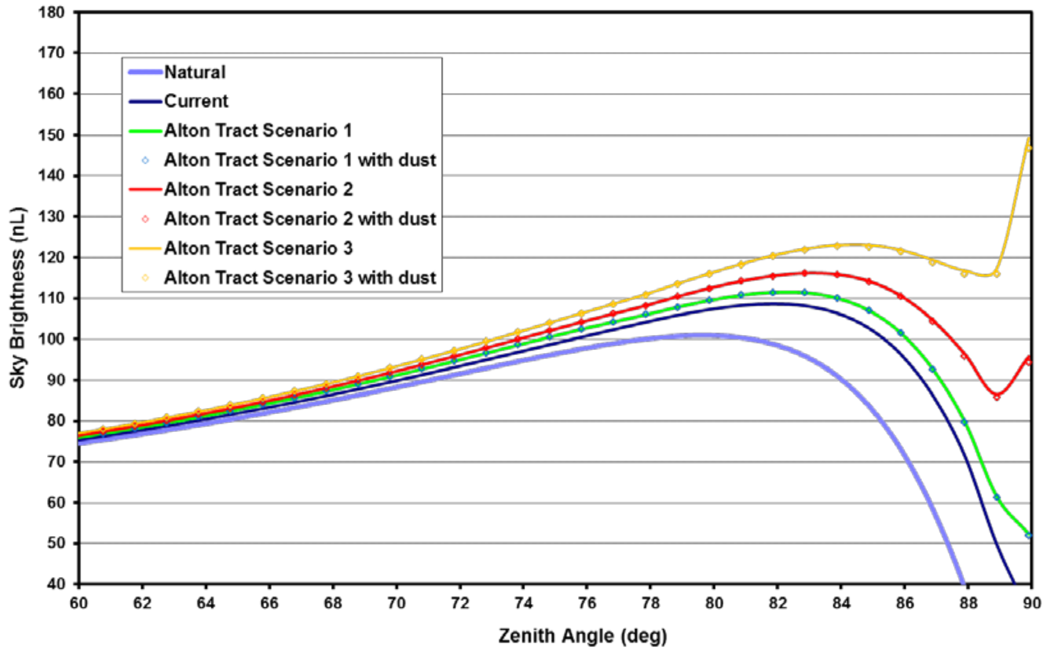


**Figure 1. Predicted sky brightness in nano-Lamberts (nL) as observed from Yovimpa Point toward the ACT, with and without enhanced dust over the ACT, for the three lighting scenarios considered for the ACT. Zenith Angle (ZA) in all figures refers to the angle between the zenith and the observation direction: 0º < ZA < 90º are at azimuth 256º, i.e. toward the ACT as observed from Yovimpa Point, and 0º > ZA > –90º refer to azimuth 76º, directly opposite the ACT.**

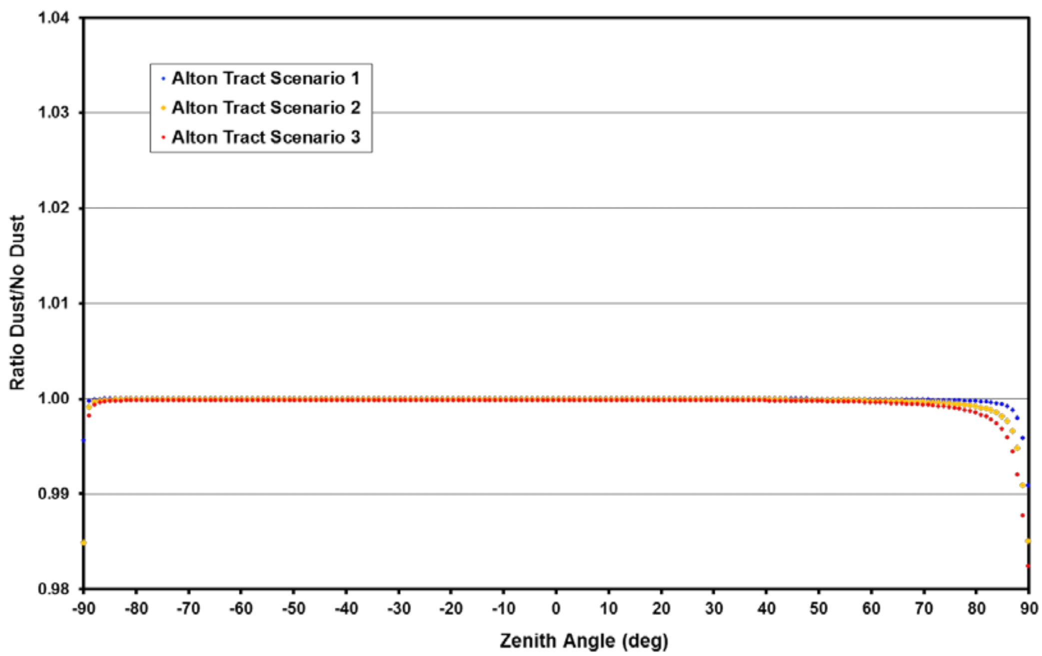


**Figure 2. Ratio of predicted Yovimpa Point sky brightness with enhanced (K=2) dust over ACT to brightness without enhancement for lighting scenarios 1 and 3.**

It is important to note that the tract appears 1.5º below the geometric horizon as viewed from Yovimpa Point, or at ZA 91.5º. Though DSP models do not provide predictions for ZA > 90º, it is to be expected that the dust over the mine site would increase the brightness of the site to observers at Yovimpa Point looking below the geometric horizon and into the dust layer directly over the mine site, due to increased scattering of light from dust generated by tract operations.

## III. CUMULATIVE IMPACTS

In DSP 2009, the predicted skyglow profiles toward the ACT are compared to the artificial sky brightening predicted toward each of the 11 nearby towns and cities. Fractional brightness increases for all town calculations are compared against the natural condition, i.e., to the sky with no towns present. The fractional brightness increases for all ACT calculations are compared with the current condition, i.e., including any towns or cities where skyglow may overlap with that produced by the ACT lighting. This is the most appropriate way to judge the impacts, because the skyglow arising from towns is viewed against a (generally) unpolluted horizon, whereas the skyglow produced by lighting installed in the ACT would be added to that already present.

The NSWG requested a calculation of the fractional brightness increase due to ACT lighting in 2040, the expected end date for ACT mining operations. To assess this impact, DSP projected the increase in skyglow due to growth in the 11 towns included in the DSP 2009 calculation of the current sky brightness. Two lighting conditions for 2040 were considered. The first used the same 10% direct uplight assumed in calculating the current sky brightness. The second assumed that the direct uplight fraction would be cut in half (to 5%) to account for possible improvements in lighting technology and codes/ordinances (in terms of limiting light pollution) over time. Both used the same 2,500 lumens/capita used in DSP 2009. Table 2 gives the projected 2040 population and lumens used to calculate the 2040 sky brightness.

**Table 2. Projected Population in 2040 and the Associated Lumens Generated for the Cities and Towns used in the Cumulative Impact Analysis**

| Town/City | Population | Lumens |
|---|---|---|
| Alton town | 268 | 670,000 |
| Brian Head | 299 | 747,500 |
| Cedar City | 65,165 | 162,912,500 |
| Fredonia | 1,403 | 3,508,504 |
| Glendale | 669 | 1,672,500 |
| Kanab | 7,177 | 17,942,500 |
| Orderville | 1,156 | 2,890,000 |
| Page | 8,303 | 20,758,575 |
| Panguitch | 2,383 | 5,957,500 |
| St. George | 280,507 | 701,266,510 |
| Tropic | 752 | 1,880,000 |
| **Total** | **368,082** | **920,206,089** |

*Source*: GOPB (2012).

For comparison, the 2010 total population used in DSP 2009 was 164,086 and the total lumens were 410,215,000.

Brightness profiles as viewed from Yovimpa Point toward the ACT were calculated for the three ACT lighting scenarios with 2010 populations, as well as for ACT scenario 3 under both 2040 lighting conditions as described above. Results are shown in Figures 3 – 5.

After the cumulative impact figures were generated for this report, updated population projections were made available by the State of Utah. The revised population projections show a reduced growth rate in the region, particularly for St. George and Cedar City (See Section 4.19.2.1.4 of the SDEIS). The total population projected in 2040 was reduced to 272,964 from the previous estimate of 386,080 used in this analysis (GOPB 2013). Therefore, the results presented here are conservative compared to those that would be predicted using the more recent population projections, because the figures presented here are brighter overall, with the ACT therefore contributing a smaller fraction.

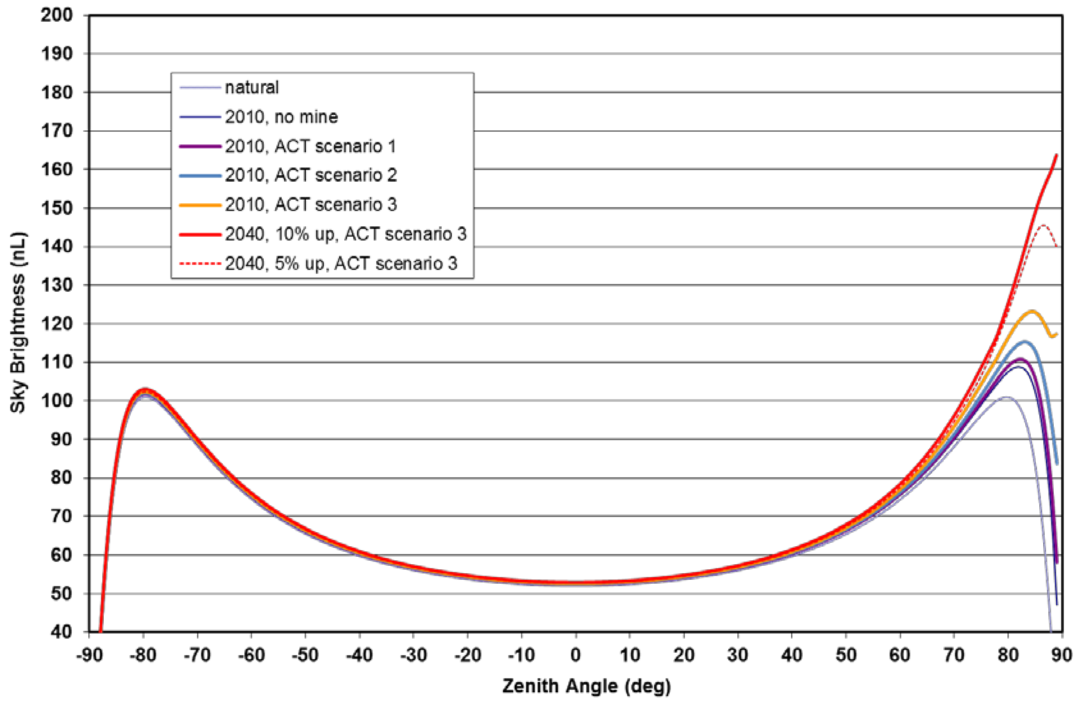


**Figure 3. Sky brightness as observed from Yovimpa Point at azimuth 256º toward the ACT (0º < ZA < 90º), comparing 2010 values with those using 2040 population projections and lighting scenario 3.**

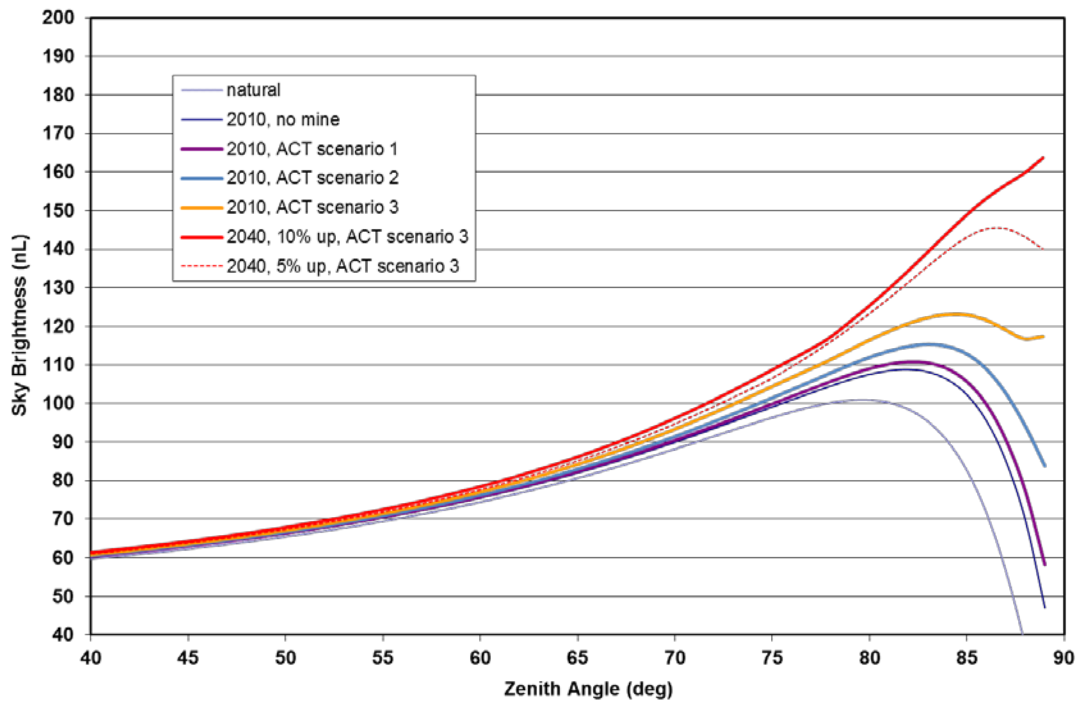


**Figure 4. Enlargement of the right part of Figure 3 showing the sky brightness for zenith angles from 40º to 89º in the direction of the ACT.**

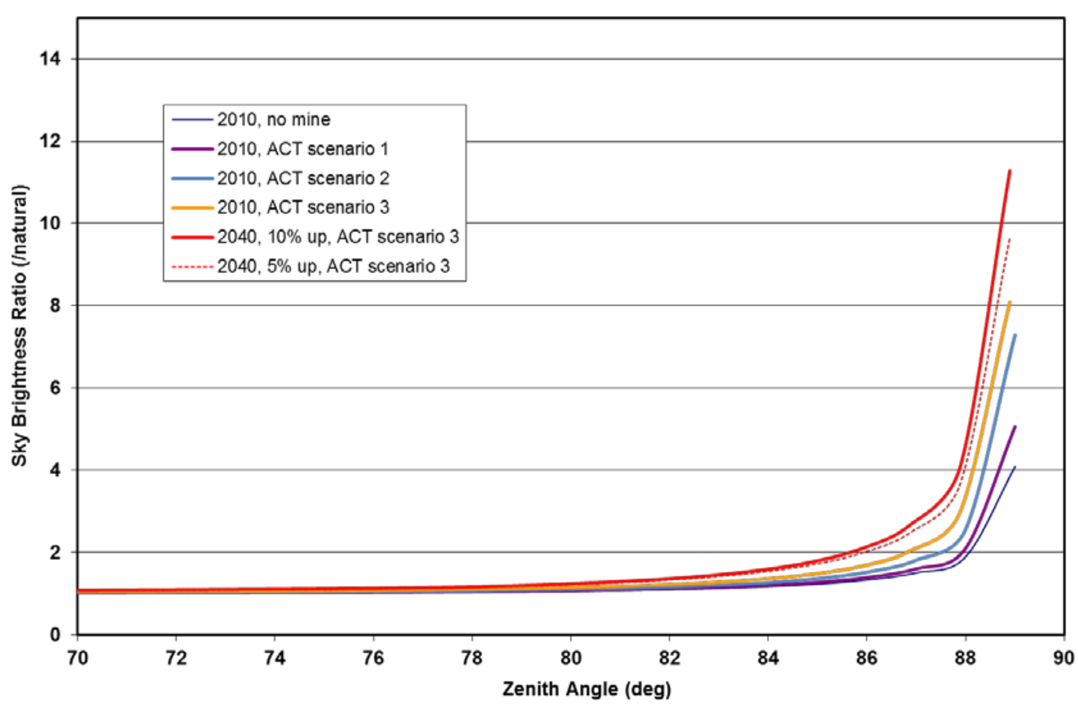


**Figure 5. The sky brightness ratio (Scenario/Natural) as viewed from Yovimpa Point close to the horizon toward the ACT for the five cases in Figure 3.**

# IV. AVERAGE SKY LUMINANCE

The NSWG requested that DSP provide a calculation of the predicted average sky luminance (ASL), both for total skyglow and artificial skyglow only. The ASL is the average luminance (or sky brightness) of the sky as seen from the observer's location. This parameter is useful as a single value describing the quality of the entire hemisphere of the sky instead of in a particular direction.

DSP developed new computer code based on the modeling algorithms described in DSP 2009 to calculate the ASL by calculating sky luminance on a grid of positions covering the hemisphere of the sky. A separate calculation then integrates over the grid to find the average sky luminance, the ASL. For the Alton (Yovimpa Point) calculations, the grid was set with 80 points uniformly spaced in azimuth (0–360 degrees) and 20 points in elevation (0–90 degrees), for a total of 80 × 20 = 1,600 points. The calculated ASL can be compared with one derived from measurements made by the NPS Night Sky Team as shown in Table 4. The results are shown in Table 3.

**Table 3. Average Sky Luminance in nanoLamberts for 2010 Conditions (no mine), Three Cases with Mine Lighting using 2010 Population Numbers, and Two Future (2040) Cases showing both Standard and Optimistic Parameters for 2040 Town Lighting.**

| Scenario and Parameters | Natural Lighting | Mine Lighting | Lighting from Towns | Total Artificial Lighting | Total Present Lighting | Total Percent Lighting Increase over Present | Total Percent Lighting Increase over Natural |
|---|---|---|---|---|---|---|---|
| 2010, no mine | 71.19 | 0.00 | 1.92 | 1.92 | 73.11 | 0.0% | 2.7% |
| 2010, ACT Scenario 1 | 71.19 | 0.14 | 1.92 | 2.06 | 73.25 | 0.2% | 2.9% |
| 2010, ACT Scenario 2 | 71.19 | 0.52 | 1.92 | 2.44 | 73.63 | 0.7% | 3.4% |
| 2010, ACT Scenario 3 | 71.19 | 0.99 | 1.92 | 2.91 | 74.10 | 1.4% | 4.1% |
| 2040, ACT Scenario 2, standard parameters | 71.19 | 0.52 | 4.01 | 4.53 | 75.72 | 3.6% | 6.4% |
| 2040, ACT Scenario 2 optimistic parameters | 71.19 | 0.52 | 2.91 | 3.43 | 74.62 | 2.1% | 4.8% |
| 2040, ACT Scenario 3, standard parameters | 71.19 | 0.99 | 4.01 | 5.00 | 76.19 | 4.2% | 7.0% |
| 2040, ACT Scenario 3 optimistic parameters | 71.19 | 0.99 | 2.91 | 3.90 | 75.09 | 2.7% | 5.5% |

The NPS estimate of the ASL due to artificial lighting at Yovimpa Point, made with the NPS camera system (Duriscoe et al., 2007), shows significant uncertainty due primarily to uncertainty in the natural sky glow (indicated by the range of values for the zenith air glow in column 3 of Table 4), which varies both temporally and spatially. Subtracting the natural sky glow model developed by the NPS from their Yovimpa Point observations to find the ASL contribution from towns gives values ranging from 1.13 nL to 5.24 nL, depending the estimate used for the natural airglow. These figures are summarized in Table 4. Hence, the DSP modeled value of 1.92 nL for the 2010 towns' contribution is within the range of the NPS estimate.

**Table 4. The Average Sky Luminance, in nanoLamberts, measured by NPS from Yovimpa Point (NPS, 2014).**

| Observation Date | Total ASL | Zenith Air Glow | Natural ASL | Artificial ASL |
|---|---|---|---|---|
| 14 March 2007 | 67 | 13 – 17 | 62 – 66 | 1.13 – 5.24 |

## V. REFERENCES

Dark Sky Partners. 2009. *An Assessment of the Impact of Potential Mining Operations at the Alton Coal Tract on the Dark Skies of Bryce Canyon National Park and Cedar Breaks National Monument.*

Duriscoe, D.M., Luginbuhl, C.B. and Moore, C.A. 2007. Measuring Night-Sky Brightness with a Wide-Field CCD Camera, Pub. Astron. Soc. Pac., 119:192

GOPB. 2012. Utah Governors Office of Planning and Budget, Subcounty Population Projections.

GOPB. 2013. Utah Governors Office of Planning and Budget, Subcounty Population Projections. Available at: http://governor.utah.gov/dea/projections.html. Accessed on 7.19.13

NPS. 2014. Email communication from D. Duriscoe to DSP dated 13 February 2014.