Assisting Glacier National Park in Achieving Full International Dark Sky Park Status

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Abstract

The purpose of this project was to assist Glacier National Park with advancing from a provisional International Dark Sky Park (IDSP) status to a full IDSP status. To accomplish this, the park's lighting inventory, dark sky educational programs, and night sky quality were evaluated. We determined that Glacier National Park's sky quality has improved since becoming a provisional IDSP and we created resources to facilitate and expand the park's dark sky educational outreach programs. Our analysis determined that the park is on track to achieve its IDSP goals by March of 2021. A set of recommendations was compiled and presented to park staff.

Acknowledgements

We would like to give a special thanks to the people who helped make this project successful. Given the transition of this project to a remote format due to COVID-19, it could not have gone smoothly without the help we received from Glacier National Park staff members. We would like to thank the following members of Glacier National Park staff:

- **Tara Carolin**, our head liaison, who made this project possible through the Crown of the Continent Research Learning Center.
- Park Ranger **Mark Biel**, who spearheaded the IDSP efforts at Glacier National Park, provided us with the park's lighting compliance documents, and organized sky quality measurements throughout the park.
- **Iree Wheeler**, a Glacier National Park intern, who supplied us with initial information during the planning stages of our project.
- Park Astronomer **Lee Rademaker**, who helped us with information about the Dusty Star Observatory and took sky quality measurements on the east side of the park.
- Park Ranger **Ed Eberhardy**, who took sky quality measurements on the west side of the park.

Along with Glacier National Park staff, we would like to thank the IDA program manager, **Adam Dalton,** who provided us with resources and was always open to questions to keep this project on track. We would also like to thank **Bettymaya Foot**, the IDA Director of Engagement, who helped to distribute our infographic to its target audience.

Most importantly, we would like to thank our project advisors, **Frederick Bianchi**, and **Fred Looft**, or as we call them, the Freds. Both advisors provided invaluable guidance and helped to course correct us with the twists and turns that arose. Their guidance allowed our project work to excel in its remote setting.

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Executive Summary

Introduction

Excessive use of artificial lighting, known as light pollution, has harmful effects on human health, the environment, and wildlife. In the future, light pollution is expected to increase and affect more of the world as human development expands, and consequently, our view of a natural, starry night sky continues to be obstructed over every populated area. Fortunately, light pollution is easily reversable with the use of proper light fixtures. Figure 1 shows an ordinary light fixture compared to a dark sky-complaint light fixture.

To reduce light pollution, the International Dark Sky Association (IDA) was formed. The organization's mission is "to preserve and protect the nighttime environment and our heritage of dark skies through environmentally responsible outdoor lighting" (IDA, n.d.-a). The IDA designates parks as International Dark Sky Parks (IDSPs) through a certification process.

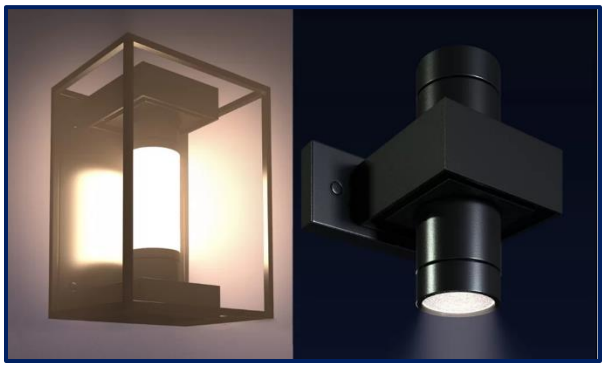

Figure 1: A non-dark sky-compliant light (left) and a dark sky-compliant light (right). (Wayfair, 2020).

Glacier National Park (GNP) was designated by the IDA as an IDSP with provisional status in 2017. This designation signifies that GNP is committed to night sky preservation. Given the park's provisional status, its current goal is to achieve full International Dark Sky Park status: a more prestigious title of night sky protection. The IDA has established an extensive list of objectives that must be met before the full IDSP designation is awarded, including:

1. Update at least 67% of the park lighting with lights and fixtures that meet IDA compliance standards for reducing light pollution.
2. Record sky quality measurements before and after compliance upgrades to ensure that the park meets the minimum darkness level.
3. Educate the public about light pollution and dark sky preservation.

The IDA has a specific timeline for achieving full IDSP status. GNP has until March 2021, three years after its initial application to reach 67% compliance. If the park does not meet the deadline, it loses its IDSP designation. Beyond 67% compliance, the park has until October 2022 to reach 90% compliance, and until 2027 to reach 100% compliance.

Goals and Objectives

The goal of this project was to assist Glacier National Park in achieving full gold tier International Dark Sky Park status by evaluating the park's night sky quality, lighting compliance advancement plans, and educational programs to identify ways to ensure achievement of full IDSP status in the timeframe given by the IDA. The following objectives were developed to help us meet the goal of our project:

1. Evaluate GNP's lighting management plan and sky quality readings to suggest strategies to reach 100% IDA compliance within the IDA specified timeline.
2. Create an external website to facilitate GNP's Outreach, provide educational content, spread dark sky awareness, and store archived images from the Dusty Star Observatory.
3. Complete a draft of Glacier National Park's 2020 annual progress report to the IDA.
4. Create an infographic that explains how to become an International Dark Sky Park.

These objectives fall under the three pillars of the IDA's goals for IDSPs: sky quality, lighting compliance, and educational outreach. By improving in each area, GNP more effectively preserves the night sky and reduces light pollution.

Methodology

The following material addresses each of these project objectives and the corresponding methods we used to achieve them.

1. Evaluate GNP's Lighting Management Plan and Sky Quality Readings to Suggest Strategies to Reach 100% IDA Compliance Within the IDA Specified Timeline.

Before analyzing GNP's current Lighting Management Plan (LMP), we first sought to gain an understanding of what is contained within an LMP. This research was meant to identify and obtain secondary sources, such as LMPs from other IDSPs. The LMP evaluation was intended to verify lighting changes throughout the park and update the lighting inventory as needed.

To determine the impact of lighting upgrades and to demonstrate sky quality improvements, sky quality measurements must also be included in the annual report to the IDA. The measurements for the 2020 annual report would be conducted in the same location as the 2016 measurements. Astronomical calendars and IDA sky quality survey guidelines would be used to determine the optimal times to take sky quality measurements.

2. **Create an External Website to Facilitate GNP's Outreach, Provide Educational Content, Spread Dark Sky Awareness, and Store Archived Images from the Dusty Star Observatory.**

While researching Glacier's Dark Skies, we found that information about educational programs and general dark sky awareness was scattered across many sources. To help centralize educational programs and dark sky awareness information, we decided to create a website that presented all of GNP's outreach programs and dark sky awareness in one easily accessible location. We determined that this website would also contain educational information about GNP's Dusty Star Observatory, including a page dedicated to collecting telescope viewing requests.

3. **Complete a Draft of Glacier National Park's 2020 Annual Progress Report to the IDA**

As an IDSP, GNP is required to submit annual reports to the IDA. These reports detail the progress that the park has made to increase lighting compliance and outline the park's plans for future improvement. As of October 2020, GNP has submitted two annual reports: one in 2018 and another in 2019. We decided that our draft of GNP's IDA annual report would include specific information on the progress made to GNP's sky quality, lighting compliance, and educational outreach.

4. **Create an Infographic that Explains How to Become an IDSP**

The IDA guidelines that describe the process of becoming an IDSP is daunting. The document contains an overwhelming amount of definitions, minimum requirements, examples, and processes. To make things easier for prospective parks, we decided to create an infographic. The infographic would outline each step of the IDSP application process and would help encourage qualified locations to take the first step towards becoming a dark sky park.

Results

This section presents the results for each of our project's objectives.

1. **Evaluate GNP's Lighting Management Plan and Sky Quality Measurements to Suggest Strategies to Reach 100% IDA Compliance Within the IDA Specified Timeline.**

Upon analyzing the Lighting Inventory spreadsheets, we determined that, as of Fall 2020, GNP has a 61% lighting compliance. The park is on track to meet its IDA lighting compliance goals by March of 2021. After analyzing the inventory spreadsheets, we returned the spreadsheets to the park with annotations detailing missing components.

For sky quality measurements, we compared the 2020 measurements with the 2016 measurements. Our analysis determined that the sky quality in GNP improved from an average of 21.66 mpsas in 2016 to an average of 21.82 mpsas in 2020, an increase of 0.16 mpsas. The increase advanced GNP's sky quality average into gold tier status.

2. **Create an External Website to Facilitate GNP's Outreach, Provide Educational Content and Dark Sky Awareness, and Store Archived Images from the Dusty Star Observatory.**

During our research, we found that GNP had minimal online information about the dark sky-related educational activities that the park offers. To expand GNP's online public outreach and establish a central location for information about the park's dark sky efforts, we designed and created an educational website. The goal of this website was to facilitate dark sky outreach and educational information relative to GNP. To achieve this goal, we organized the website into five distinct webpages: Activities, Dusty Star Observatory, Education and Awareness, Consortium, and About Us. The webpages contain graphics, interactive features, and educational information to teach the public about light pollution.

3. **Complete a Draft of Glacier National Park's 2020 Annual Progress Report to the IDA**

After a meeting with GNP Ranger Mark Biel, we discovered that Waterton Lakes National Park wrote and submitted the joint Waterton-Glacier 2020 Annual Report to the IDA on October 5th, 2020. As a result, we created an addendum to submit to the IDA as an addition to the Waterton-Glacier 2020 Annual Report. The addendum included information on our website, an infographic, and a summary of our lighting inventory analysis.

4. **Create an Infographic That Explains How to Become an IDSP.**

We created an infographic that overviews the IDSP application process. The infographic is a visually appealing and concise summary of the IDA application guideline document. It is intended to make the IDSP application process easy for prospective parks to begin. Created in the web-based application Piktochart, the infographic was sent to multiple individuals for feedback. Once the final draft was completed, the infographic was embedded in our website, and it was sent to multiple contacts in the NPS and the IDA for further distribution.

Recommendations

Based on our findings, we developed several recommendations for the park. Each recommendation is detailed below.

1. GNP Should Increase How Often Sky Quality Measurements Are Taken.

The IDA requires a quantitative update of the sky quality for each lighting compliance deadline (3, 5, and 10 years from attaining provisional status). Annual reports between these years are strengthened by including up to date SQM measurements. The four-year gap between the 2016 and 2020 SQM measurements in GNP caused uncertainty about how lighting retrofits impacted light pollution.

We recommend that the park increase SQM measurement frequency to at least monthly when the park is open. There are three options to achieve this: install permanent sky quality meters, have park staff manually conduct SQM measurements, or have a third party such as a community college or citizen science group take measurements on behalf of the park.

2. GNP Should Livestream All Dark Sky Related Activities.

There is currently an emphasis on online and remote communication due to the 2020-21 COVID-19 pandemic. Also, in an interview with Lee Rademaker, the lead ranger for the Dusty Star Observatory, he expressed a desire to expand the online presence of the park's dark sky programs, especially the observatory telescope. the

When the observatory is connected to the internet, we recommend that the feed on the television screens be broadcast live onto social media platforms such as YouTube and Facebook. The livestreams can be accompanied with information about the celestial object being displayed. Scientists can also give scheduled livestream talks using telescope images from the Dusty Star Observatory. As shown in Figure 2, GNP already has established programs, such as Logan Pass Star Parties, that would be well suited for livestreams. Additionally, since bringing an internet connection to the observatory is already planned and popular streaming software is free, there would be little logistical cost to establishing a stream to social media.

Figure 2: A dark sky educational program at Glacier National Park.
(Glacier National Park, 2019)

3. **GNP Should Create a Detailed Astronomical Calendar to Streamline and Expand Telescope Imaging Request Capabilities.**

Our website's Telescope View Requests webpage currently has a browser-based planetarium, an Interactive Night Sky Simulator, and a calendar that details when certain celestial objects are viewable. This information is intended to show the user which objects will be viewable to make an informed telescope request; however, it does not include all objects that the telescope can see, and it is not user friendly.

We recommend that the webpage be updated with a more comprehensive astronomical calendar and an improved user interface. The interface could have a single list of all the objects viewable by the telescope, with information about when each object can be observed from the telescope's location. This would alleviate any burden by the visitor to determine optimal viewing times for themselves.

4. **GNP Should Create a Dark Sky Consortium to Facilitate Communication Between National Parks Regarding Dark Sky Matters.**

The purpose of the IDSP program is to preserve and protect the night skies for future generations. This means IDSPs should assist other parks attempting to also gain IDSP status, which is something that many parks have fallen short of. We recommend forming a consortium for IDSPs to learn from one another, and to help more new parks achieve an IDSP designation themselves.

To help get the consortium started, we created an infographic that can serve as a foundation for future communication between IDSPs. For assistance in forming an IDSP consortium, we recommend reaching out to the Consortium for Dark Sky Studies (CDSS), a coalition of universities that are dedicated to scientific research within the dark sky field. As for in-person communication, we recommend taking advantage of the Annual IDA Conference and using our website to schedule the consortium's own meetings.

Authorship

Report Section	Writer(s)	Editor(s)
Abstract	EB, LO	ALL
Acknowledgements	CG	ALL
Executive Summary	ALL	ALL
Introduction	ALL	ALL
Background		
Glacier National Park	EB, LO, SM	ALL
Glacier National Park Conservancy	BW	ALL
International Dark Sky Association	EB, SM	ALL
Light Pollution	CG, EB, LO	ALL
Dark Sky Outreach	CG, EB	ALL
Financial Aspects	EB, BW	ALL
Methodology		
Objective 1: Evaluating GNP's LMP	LO, CG, SM	ALL
Objective 2: Create a Website	CG, LO	ALL
Objective 3: Draft of IDA Report	EB, SM	ALL
Objective 4: Creating IDSP Infographic	BW	ALL
Results		
Objective 1: Evaluating GNP's LMP	EB	ALL
Objective 2: Create a Website	CG, EB	ALL
Objective 3: Draft of IDA Report	LO	ALL
Objective 4: Creating IDSP Infographic	BW	ALL
Recommendations		
Increase SQM Testing Frequency	EB, LO	ALL
Create detailed Astronomical Calendar	LO	ALL
Create a Dark Sky Consortium	EB, BW	ALL
Livestream Dark Sky Activates	CG, LO	ALL
Summary and Conclusion	ALL	ALL
Appendix C: Sky Quality Meters	CG	ALL
Appendix D: Rise/Set Times for the Sun and Moon	CG	ALL
Appendix E: Lighting Replacement Totals	SM	ALL
Appendix F: Lighting Inventory	SM	ALL
Appendix G: SQM Data Analysis	CG	ALL
Appendix H: Website Technical Details	CG	ALL
Appendix I: IDSP Infographic	BW, CG	ALL
Appendix J: IDA Report Addendum	ALL	ALL

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1. Introduction

Did you know that the Milky Way can be seen with the naked eye? Unfortunately, most people in the United States have never seen the Milky Way because they live in an area affected by light pollution. Caused by artificial light that shines into the night sky, light pollution obscures the Milky Way for over 80% of the US population (Falchi et al. 2016). If lighting practices do not improve, it is estimated that light pollution will obscure almost all dark skies around US population centers by 2025 (Falchi et al. 2016). Fortunately, measures can be taken to decrease light pollution and maintain the starry sky.

Excessive nighttime lighting adversely affects human health, the environment, and wildlife. Regarding human health, nighttime lighting disrupts the circadian rhythm and melatonin production, which induces sleep (National Geographic Society, July 23, 2019). The environment is affected by light pollution due to the amount of energy wasted on illuminating the sky. Reducing light pollution could help reduce humanity's carbon footprint. As for wildlife, hundreds of millions of animal deaths are credited to light pollution annually (The Commission for Dark Skies, n.d.). Light that obscures the stars disorients animals and disrupts natural behaviors.

To address the issue of light pollution and its consequences, an organization called the International Dark Sky Association (IDA) was founded. The mission of the IDA is to "to preserve and protect the nighttime environment and our heritage of dark skies through environmentally responsible outdoor lighting" (IDA, n.d.-a). Formed in 1988, the IDA designates parks as International Dark Sky Parks (IDSPs). Earning such a title signifies a park's commitment to dark sky preservation. IDSPs can receive a full or provisional status with a gold, silver, and bronze tier designation, gold being the most prestigious.

In 2017, Glacier National Park (GNP) was designated as an International Dark Sky Park with provisional status. This designation, awarded by the IDA, signifies that GNP is committed to night sky preservation. Given the park's provisional status, its current goal is to achieve full International Dark Sky Park status: a more prestigious title of night sky protection. The IDA has established an extensive list of objectives that must be met before the full IDSP designation is awarded, including:

1. Update at least 67% of the park lighting with lights and fixtures that meet IDA compliance standards for reducing light pollution.
2. Record sky quality measurements before and after compliance upgrades to ensure that the park meets the minimum darkness level.
3. Educate the public about light pollution and dark sky preservation.

GNP has until March 2021 to achieve these objectives for a full IDSP designation or else the park's current provisional status will expire.

GNP's 2020 IDA annual report was subject to several unforeseen setbacks, including the ongoing COVID-19 pandemic and wildfire smoke that obstructed the parks skies. It is because of these and other issues that progress on the 2020 lighting compliance plan was delayed. The goal of this project was to take these delays into account and assist GNP in achieving full gold tier International Dark Sky Park status by evaluating the park's night sky quality, lighting compliance advancement plans, and educational programs to identify ways to ensure achievement of full IDSP status in the timeframe given by the IDA.

2. Background

This chapter introduces Glacier National Park (GNP), the Glacier National Park Conservancy, the International Dark Sky Association (IDA), and the idea of dark sky preservation. The first section explores the history of the park's land and native people as well as the park's goal of night sky preservation. The next section details the Glacier National Park Conservancy and its role in funding GNP's dark sky upgrades and IDA required programs. The IDA segment focuses on the goals and objectives of the association. It also describes the requirements an organization must meet to receive an IDA designation. The following Light Pollution section describes what light pollution is, why it is harmful, and how it is measured. This section also explains how to reduce the amount of light that is directed up towards the sky. The next and final section addresses cost and explains how GNP raises money for programs and projects. An analysis of the feasibility of park upgrades by looking at GNP's lighting management plan is also presented in this final section.

2.1. Glacier National Park

Glacier National Park is the United States' 10th national park. As shown in Figure 3, the park is located in northwestern Montana, and it meets the US-Canada border along its northern edge. Established in 1910 by President Howard Taft, GNP was founded six years prior to the National Park Service itself (NPS, 2016). With approximately 3.05 million visitors in 2019, GNP visitation has increased every year since 2015 (NPS, 2019). The park celebrated its 100 millionth visitor in June 2015. Despite the increasing park attendance, interest in the park land is not new; there is evidence of human activity in the current park boundaries for over 10,000 years.

Figure 3: A map of Montana, with Glacier National Park shown in green.
(Mansbach, n.d.)

Native American tribes such as the Blackfeet, Pend d'Oreille, Salish, and Kootenai have had a presence in the general park area for centuries. The Blackfeet Tribe is the largest Native American tribe in Montana and 8th largest tribe in the United States (Blackfeet Nation, 2019; National Center for Education Statistics, 2008). Currently, the Blackfeet Tribe resides in a reservation east of GNP, sharing a border with the park, as shown in Figure 4. The Pend d'Oreille, Salish, and Kootenai Tribes are now located in the Flathead Indian Reservation, located southwest of GNP (Native Land, 2018).

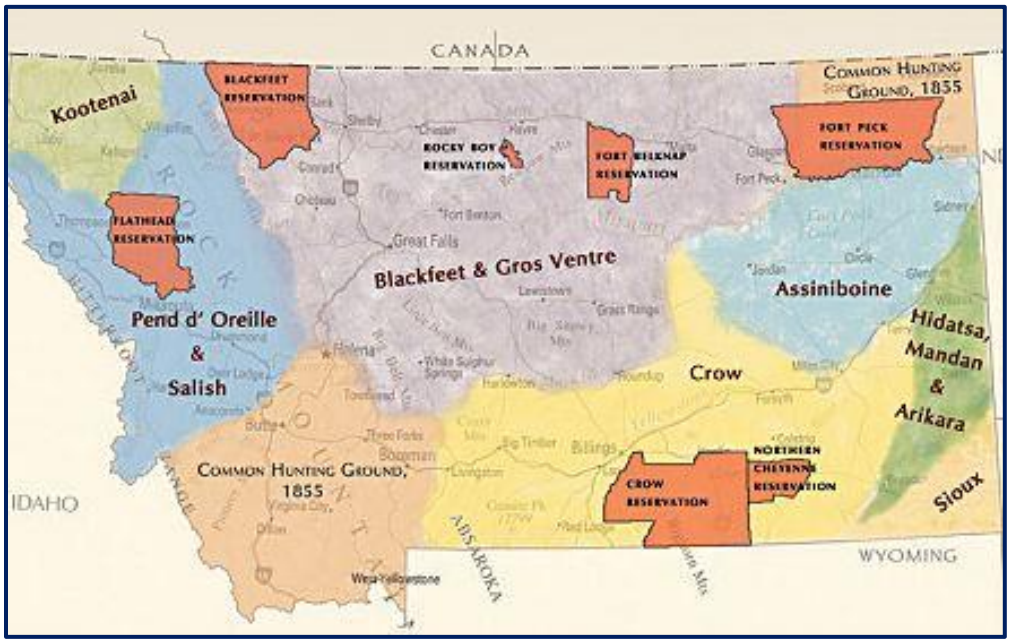

Figure 4: A map of all the reservations in Montana.

(Indian Country, 2020, May 12)

In 1932, GNP combined with Waterton Lakes National Park in Alberta, Canada, to form the Waterton-Glacier International Peace Park (UNESCO World Heritage Center, 2020). Defined as a protected area that spans the border of two or more countries, International Peace Parks preserve the environment and maintain peace in the area. As the world's first International Peace Park, the Waterton-Glacier International Peace Park was awarded the status of a United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Site in 1995 (UNESCO World Heritage Center, 2020). UNESCO establishes World Heritage sites to preserve significant international locations and structures, which includes the preservation of the night sky at these sites.

There are eight communities that serve as gateways into GNP as shown in Figure 5: Whitefish, Kalispell, Columbia Falls, West Glacier, Polebridge, East Glacier, St. Mary, and Babb. Home to roughly 24,000 people, Kalispell is the largest of these towns (US Census

Bureau, 2018). The smallest, St. Mary, has less than 50 full-time residents (US Census Bureau, 2018). These communities are hubs for adventurers and vacationers alike. They see a significant population increase during the summer season, which leads to the use of more outdoor lights.

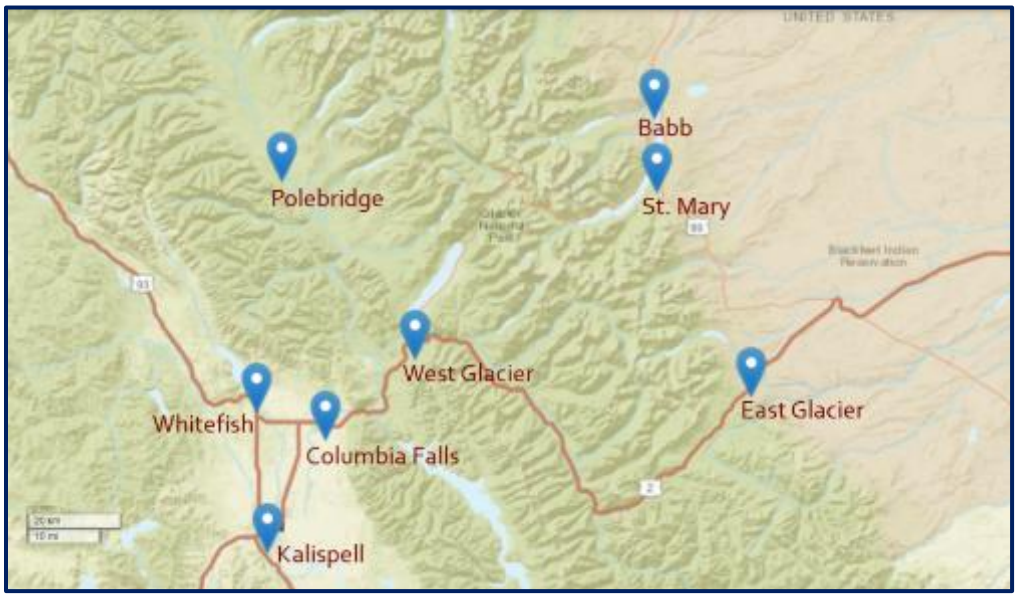

Figure 5: A map of the Glacier National Park gateway communities.
(NatGeo Mapmaker, Sept. 23, 2020)

In 1998, GNP created a Resource Management Plan that included a section about light pollution management. The plan states that "[w]hen local developments are planned, protection from night light intrusions should be discussed and negotiated prior to development [...] Where extensive light development intrudes upon the night scene, provisions should be made … for example, shields over lights" (IDA, 2017, p.15). Efforts to minimize light pollution have continued ever since. Current policies on light pollution in GNP have been defined based on regulations set forth by the IDA.

More recently, the Waterton-Glacier International Peace Park filed an application with the IDA to become an IDSP, a certification that emphasizes a park's continuing efforts in preserving their natural night skies. The two parks were jointly awarded gold tier provisional status in April 2017 based on their sky quality, 3-year Lighting Management Plan (LMP), lighting inventory, and outreach programs (IDA, 2018). The LMP is a guide to repair, replace, and install new lighting fixtures. The lighting inventory is a spreadsheet of all the fixtures and bulbs within the area administered by Waterton-Glacier. IDSP designations are coveted and considered important within the international conservation community (IDA, 2018).

2.2. Glacier National Park Conservancy

The Glacier National Park Conservancy is a non-profit organization that works with GNP to raise money for park upgrades, preservation efforts, and other projects. The Conservancy was formed in 2013 when the Glacier National Park Fund and Glacier National History Association merged, taking on the new name (GNP Conservancy, 2020). The Conservancy receives money through fundraising, merchandise sales, and philanthropy. To date, the Conservancy has funded park projects worth over $3.5 million (GNP Conservancy, 2020). Past and current projects have included trail maintenance, Native American cultural programs, citizen science research, and dark sky preservation. Recent dark sky projects include lighting upgrades and the construction of an astronomical observatory in the park.

2.3. International Dark Sky Association

The IDA is a leading authority on light pollution and night sky protection (IDA, n.d.-a). Founded in 1988, the IDA's mission is to "preserve and protect the nighttime environment and our heritage of dark skies through environmentally responsible outdoor lighting" (IDA, n.d.-b, para. 1). They accomplish this mission through four core tenets:

- Celebrate the Night
- Dark Sky Protection
- Lighting Where We Live
- Skyshed Restoration

Celebrate the Night is a program that raises awareness about the adverse impacts of polluted night skies. Dark Sky Protection allows the International Dark Sky Places certification program to be at the forefront of the IDA's efforts. Lighting Where We Live encourages residents to reduce light pollution through policy and practice. Finally, Skyshed Restoration focuses on reversing the rate of light pollution (IDA, n.d.-b).

The IDA has five designations for International Dark Sky Places. The designations are: International Dark Sky Communities, Parks, Reserves, Sanctuaries, and Urban Night Sky Places. To become an International Dark Sky Place, an organization must submit an initial application to the IDA that pledges their commitment to dark sky protection. A National Park IDSP application, for example, must include the following (IDA, 2018):

- A map of the park's boundaries
- A letter of nomination from a qualified IDA nominator
- A letter of support from an appropriate park administrator
- Documentation that demonstrates the importance of the park's dark sky resource
- A lighting management plan (LMP)

- A lighting inventory
- A proposed dark skies restoration project

After the application is accepted, the park is given provisional IDSP status and classified into one of the three tiers; the tier specifications are shown in the table in Appendix B. Provisional status expires after three years. The park is then given full IDSP status if 67% of its lighting fixtures meet IDA compliance requirements, such as fixtures that have proper shields and bulbs that minimize blue light. Full status, however, is not given in perpetuity. To maintain full IDSP status, the park must submit annual reports to the IDA and show that they are meeting the goals of their LMP (IDA, 2018). Reports are due to the IDA each year on October 1st. The IDA states that the goal for IDSPs is to reach 67% lighting compliance in three years, 90% in five years, and 100% in ten years.

2.3.1. National Parks as International Dark Sky Parks

The mission of the NPS is to conserve natural resources for the enjoyment and education of all (NPS, 2017). The night sky is recognized as a resource that the NPS vows to protect. In celebration of their centennial in 2016, the NPS published a report titled *A Call to Action*, which shared their vision for the organization's future. Point 27 of the report states that the NPS wants to "lead the way in protecting natural darkness as a precious resource and create a model for dark sky protection…" (NPS, 2015, p. 18). There are currently 12 US National Parks that have IDSP status (IDA, 2020).

2.4. Light Pollution

Light pollution is a result of artificial light obtrusively illuminating an area that would otherwise be dark. Light pollution is classified into four types: clutter, skyglow, light trespass, and glare (IDA, n.d.-e). Clutter, as shown in Figure 6, is bright and excessive groupings of light sources, such as streetlights that are spaced too closely together. Figure 7 shows an example of sky glow, the most prevalent type of light pollution. Skyglow occurs when an abundance of exposed artificial lights brightens the night sky over an inhabited area. In 2016, the journal *World Atlas of Artificial Night Sky Brightness* reported that "80 percent of the world's population lives under skyglow. In the United States and Europe, 99 percent of the public cannot experience a natural night" (IDA, n.d.-e, para. 7). Figure 8 shows light trespass, which occurs when light falls where it is not intended or needed, such as an outdoor light that shines through a home's window. Finally, glare, as shown in Figure 8, is excessive brightness that causes visual discomfort, such as headlight beams or the unintended shine from a streetlight.

Figure 6: An example of light pollution caused by clutter.
(Sunmaster Lighting Co., 2019)

Figure 7: Sky Glow over Los Angeles.
(Phys.org, 2019)

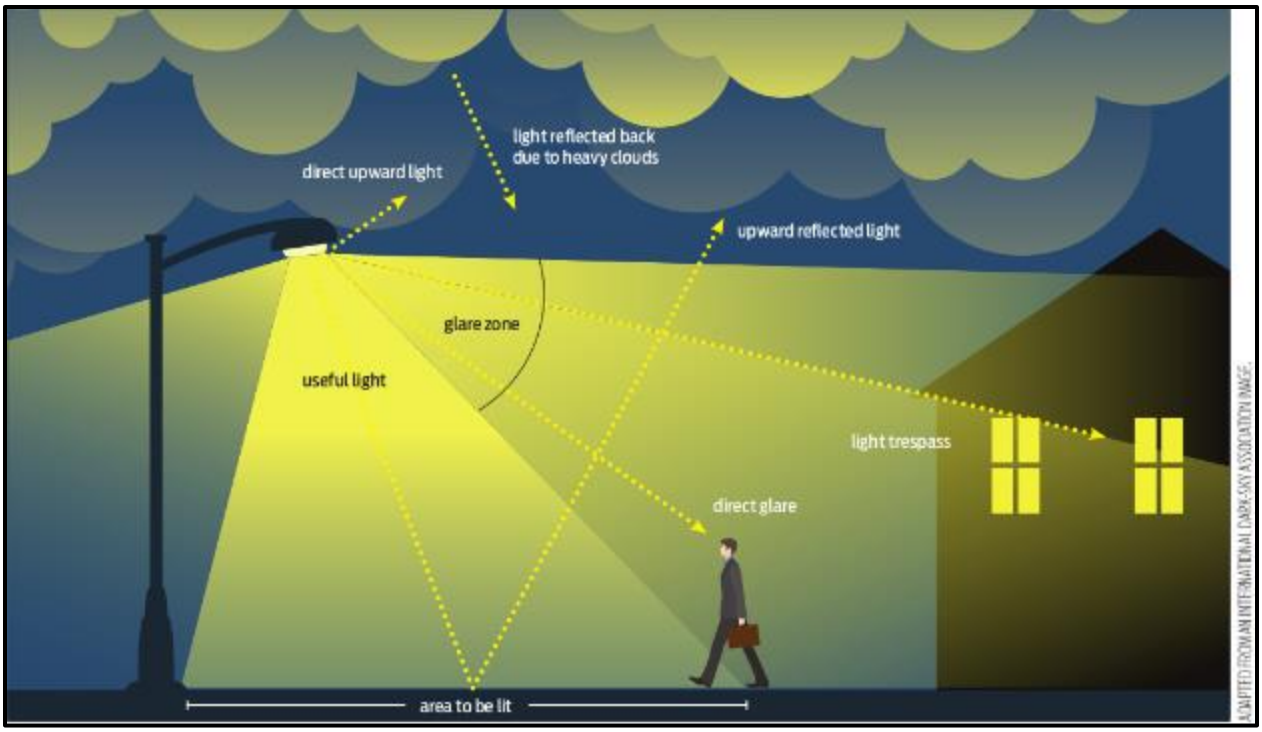

Figure 8: A visual example of the classifications of light pollution.
(Build Magazine, 2018)

2.4.1. Impact of Light Pollution

Light pollution not only hides our view of the night sky; it has negative consequences on human health, animal life, and the natural environment. In the United States alone, it is estimated that about $3.3 billion is spent on unnecessary outdoor lighting per year (IDA, n.d.-f). One impact of unnecessary lighting is that the natural dark sky becomes saturated with blue light. This disrupts the circadian rhythm: the natural sleep and wake cycle. (IDA, n.d.-g). In reaction, the body decreases production of melatonin, an important hormone that assists with sleep, maintains the immune system, and affects overall health. Disruption of these natural processes can lead to severe health issues such as sleep disorders and obesity (IDA, n.d.-g). Another impact of unnecessary outdoor lighting is that the energy wasted on excess lighting is estimated to release 21 million tons of carbon dioxide per year in the United States alone (IDA, 2020).

Those that defend light pollution argue that a brightly lit environment keeps people safe at night. Contrary to popular belief, a study on the effect of reduced lighting showed that crime increases in well-lit areas (Steinbach, et al., 2015). The study concluded that there is “little evidence of harmful effects of switch off, part-night lighting, dimming, or changes to white light/LEDs on road collisions or crime” (Steinbach, et al., 2015, para. 4). In fact, increased lighting can decrease personal safety because it makes potential victims easier to see (Steinbach, et al., 2015).

Decreasing light pollution is not just important for safety, but vital to the cultures of Montana's Native American tribes. For example, the Salish Tribe uses the stars to determine seasonal rounds (cultural equivalent of a year). The Blackfeet Tribe relies on the stars to tell legends and stories that impart life lessons to their children (Blackfeet, 2019).

A light-polluted sky disrupts the natural habits of animals and plants that depend on day and night cycles. Nearly half of the planet's wildlife species are nocturnal and rely on the darkness for protection, navigation, and natural behaviors. For example, birds rely on the stars to safely migrate. Without the stars, birds can become disoriented. Light pollution is credited with over 100 million bird deaths annually (IDA, n.d.-g). Hatching sea turtles are genetically compelled to crawl towards the brightest light they see. Without light pollution, the waves of the ocean reflect the moon and draw them to safety. In Florida alone, millions of sea turtle hatchlings die every year by wandering into parking lots or nearby streets and away from the ocean (IDA, n.d.-g).

2.4.2. Measuring Sky Quality

To measure the night sky's brightness, several tools can be used, ranging from photographs to sky quality meters (SQMs). As recommended by IDA (IDA, n.d.-d), at least two methods of measurement must be used during testing. One of these methods is photographic evidence. Photographic evidence, exemplified in Figure 9, uses photos taken at night to show the impact of light pollution on the sky and the surroundings. Astronomical photos should be taken with the horizon in the frame to get a sense of light pollution and the size of a city or town's light dome, the dome-like projection of skyglow over a city or town (IDA, n.d.-f). The camera settings should be included with each picture, since the settings affect how bright an image appears.

Figure 9: A photographer doing night photography.
(Canon Australia, Jun. 29, 2017)

Photographic evidence is often used in conjunction with the Bortle Scale Interpretation. Used for on-site testing, the Bortle Scale Interpretation (IDA, n.d.-a) assesses sky quality based on what an individual can see with their own eyes. The Bortle Scale uses nine classes, as shown in Figure 10, to rank different brightness levels. Class-1 on the Bortle Scale indicates an extremely dark sky, while class-9 indicates an extremely bright sky. The visibility of celestial objects such as the Milky Way and Andromeda Galaxies are used to determine the class under which the sky falls. The IDA uses a flowchart infographic for the Bortle Scale to determine the relative brightness of the sky (Appendix A). The Bortle scale can be subject to interpretation due to variations in eyesight from person to person. More exact measurements, such as the use of sky quality meters, can complement the findings of the Bortle Scale.

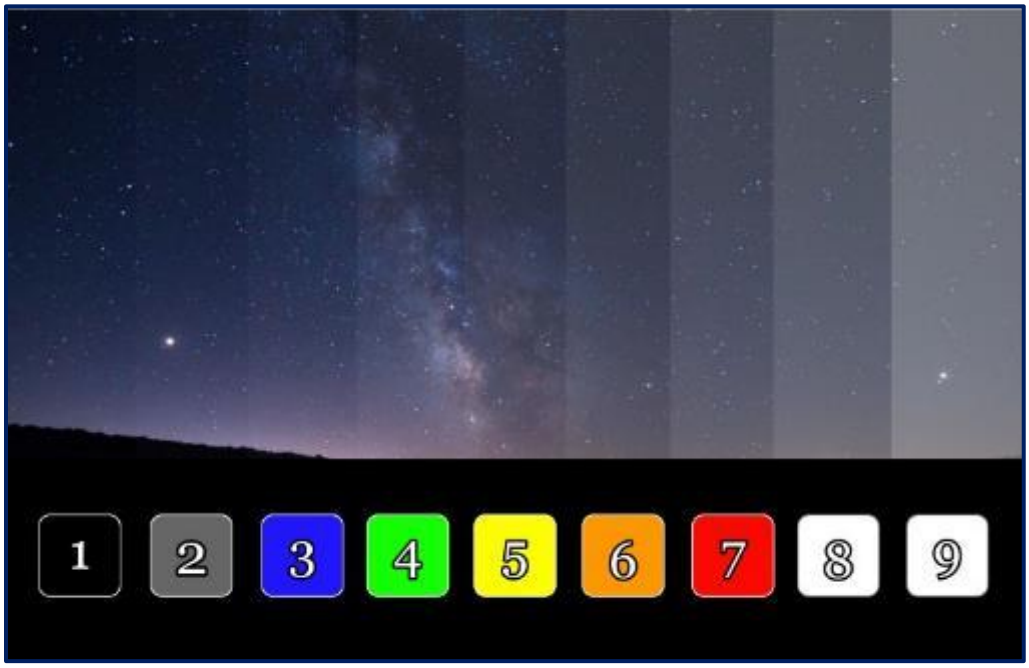

Figure 10: An image illustrating the classes of the Bortle Scale.
(Night Sky Pix, 2020)

Sky quality meters (SQMs) are the most accurate tool for measuring sky quality (Unihedron, n.d.). Figures 11 and 12 show examples of SQMs. An SQM measures the visible brightness of the sky in magnitudes per square arcsecond (mpsas) and filters out non-visible forms of light, such as infra-red. A magnitude is a unit of brightness used in astronomy, while an arcsecond is 1/3600th of a degree. The darkest skies read 22.0 mpsas on an SQM.

A past WPI IQP utilized SQMs to obtain data readings for Acadia National Park (D'Agostino, Stapleton, Rosenfeld, Lund, Curtis & Lapierre, 2017). This IQP utilized the SQM Model SQM-LU-DL, pictured in Figure 11, to take sky quality measurements in and around Bar Harbor, Maine, to determine the feasibility of Acadia becoming an International Dark Sky Community. The SQM-LU-DL requires a USB connection to a computer or laptop to function. This makes the SQM-LU-DL not suitable for use in GNP because the remoteness of the measurement locations makes it difficult to recharge a laptop. Both the USB and stand-alone models have the same technical specifications for taking measurements, meaning the quality of collected data should not vary between the two models. Based on this, the Unihedron SQM models SQM and SQM-L are the most suitable for use throughout GNP. For a more in-depth explanation of the differences in SQM models, see Appendix C.

Figure 11: An SQM-LU-DL mounted to a tripod
(Unihedron, n.d.)

Figure 12: The standard model SQM.
(Unihedron n.d.)

2.4.3. Previous WPI Light Pollution Projects

The first WPI Dark Sky-related research project was a 2013 IQP based in Acadia National Park, Maine (Larson, Morse, Rolon, & Roth 2013). The project used the Bortle scale to create heat maps of light levels across Mount Desert Island. The following year, a new team of WPI students recorded SQM measurements across Acadia National Park and made heat maps of the results. The 2014 group also enhanced Acadia National Park's dark sky educational programs to help prepare Acadia National Park for an IDSP application (Carello, Carmichael, Hedberg, & Plenefisch, 2014). This work was continued in 2015 by another WPI team that wrote Acadia National Park's first draft of the IDSP application (Sinkler, Ogren, Muntz, & Alsoby, 2015). A plan for Acadia National Park to reach silver-tier Dark Sky Park status was developed one year later by a different WPI team (Jacobson, Shira, Diamond, & Reuter, 2016). The most recent Dark Sky project was in Acadia National Park in 2017, with the creation of new sky quality heatmaps and remeasured SQM readings. This IQP determined that Acadia National Park remained in silver tier status with a 66% lighting compliance (D'Agostino et al., 2017). The past WPI research projects can help guide the present project in GNP, particularly since the project described in this document represents the work of the first WPI team to undertake a dark sky project in GNP.

2.4.4. Reducing Light Pollution

The IDA website states that to effectively reduce light pollution, outdoor lighting should (IDA, n.d.-h):

- Only be on when needed
- Only light the area that needs it
- Be no brighter than necessary
- Minimize blue light emissions
- Be fully shielded (pointing downward)

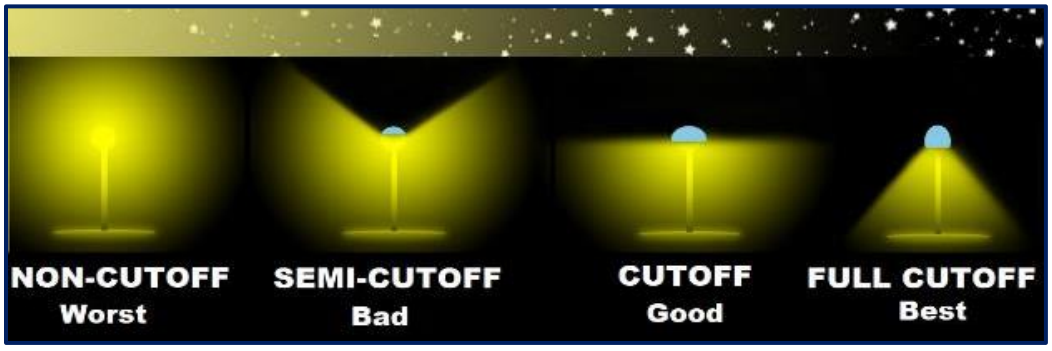

Figure 13: The effects of various lighting shield on the night sky.
(Blanco County Friends of the Night Sky, 2019)

GNP has addressed the light pollution issue primarily by replacing old outdoor light fixtures and light bulbs with shielded models. These IDA-approved fixtures and bulbs are designed to direct light towards the ground, where it is intended to fall, and prevent light from escaping into the sky. An effective shield must fully cut off the light so that only a deliberate area of the ground is illuminated (IDA n.d.-h). Figure 13 shows the effect that a shielded light has on the quality of the night sky. The two fixtures that GNP has used for most of its lighting replacements are shown in Figure 14: the Raymond RB-8W and the Progress P5695-16. Additionally, GNP has utilized shielded lightbulbs. Buildings with these light bulbs and light fixtures are considered IDA-compliant.

Figure 14: The Progress RB-8W (left) and Raymond P5695-16 (right).
` (Progress Lighting, 2020 & Affordable Lamps, 2020).

In addition to shields, the light's color is crucial for a light to be dark sky compliant. Outdoor lights must minimize blue light by being "warm" in color. This corresponds to a light temperature of less than 3000 Kelvin and a yellow or amber hue. GNP has followed the IDA's guidelines by using warm-colored light bulbs, such as the shielded PAR-30 bulb.

Since submitting their IDSP application in 2017, GNP has begun implementing its Lighting Management Plan (LMP). The LMP outlines the park's plans "to provide visitor safety in park developed areas while preserving GNP dark sky views for future enjoyment" (IDA, 2017, p. 31). This means that GNP is removing and retrofitting lighting fixtures in the park. According to the 2018 and 2019 annual reports, GNP has retrofitted lighting fixtures in amphitheaters, campgrounds, maintenance buildings, housing, and concessions. Furthermore, Flathead Electric Cooperative, the company that maintains streetlights in the park, agreed to replace the lighting fixtures in multiple roads and parking lots with dark sky compliant lights (IDA, 2018). However, since their agreement with GNP in 2018, Flathead Electric has not responded to calls from the park and has not made any progress on replacing streetlights in GNP. Additionally, when the contract with the park's concessionaire came up for renewal in 2019, the requirement for dark

sky compliant fixtures on all buildings operated by the Concessionaire was approved (IDA, 2019).

GNP has encountered several challenges in reaching full dark sky compliance. Any changes to historic locations must be approved by The Montana State Historic Preservation Office (SHPO), the authority on all 375 historic locations and six landmarks throughout the park. Non-compliant light fixtures on historic properties need their historic significance accounted for when changes are implemented. Both the Raymond RB-8W and the Progress P5695-16 fixtures are deemed historically compliant for GNP buildings constructed within a specific time frame. The park also relies on donations made to the GNP Conservancy for lighting upgrades, as the compliancy upgrades are expensive. Once the challenges of lighting fixture upgrades are addressed, the only way to prove a reduction in light pollution is to measure the quality of the night sky.

2.5. Dark Sky Outreach Programs

To maintain International Dark Sky Park status, the IDA requires that parks host educational outreach programs. Outreach programs must be offered at least four times annually and help protect the night skies for present and future generations. If a park cannot hold a program, then extensive marketing can substitute for outreach (IDA, 2018-c). As of 2020, GNP offers a variety of dark sky education programs that attract upwards of 30,000 visitors per year (Glacier National Park, 2020, September 2).

The most popular outreach program offered by GNP is the *Logan Pass Star Party*. Held monthly from July to September, Star Parties attract up to 500 visitors per event (Glacier National Park, 2020, September 2). At the event, visitors travel to Logan Pass, where they can look through telescopes and observe the night sky in the least light-polluted areas of GNP. Figure 15 shows a 2019 Logan Pass Star Party.

Figure 15: Ranger Lee Rademaker gives a presentation at a Star Party.
(GlacierNPS, August 3, 2019)

GNP has also established dark sky-related programs, called sky tours, that are offered from late June to early September. These events occur several times per week on both the east side (St. Mary) and west side (Apgar) of the park (NPS, 2019-c). The west side program, called *Glacier's Night Sky Astronomy*, educates participants on basic astronomy, and gives the opportunity to look at the night sky through telescopes and astronomical binoculars. The east side program, called *Half the Park Happens After Dark,* was launched by the Glacier National Park Conservancy in 2016. This program explains the importance of dark skies to Native American peoples, the National Park Service, researchers, and wildlife. Participants also get the opportunity to look through telescopes, including the park's observatory telescope. Figure 16 shows the average attendance of the park's dark sky outreach programs from 2016 to 2019.

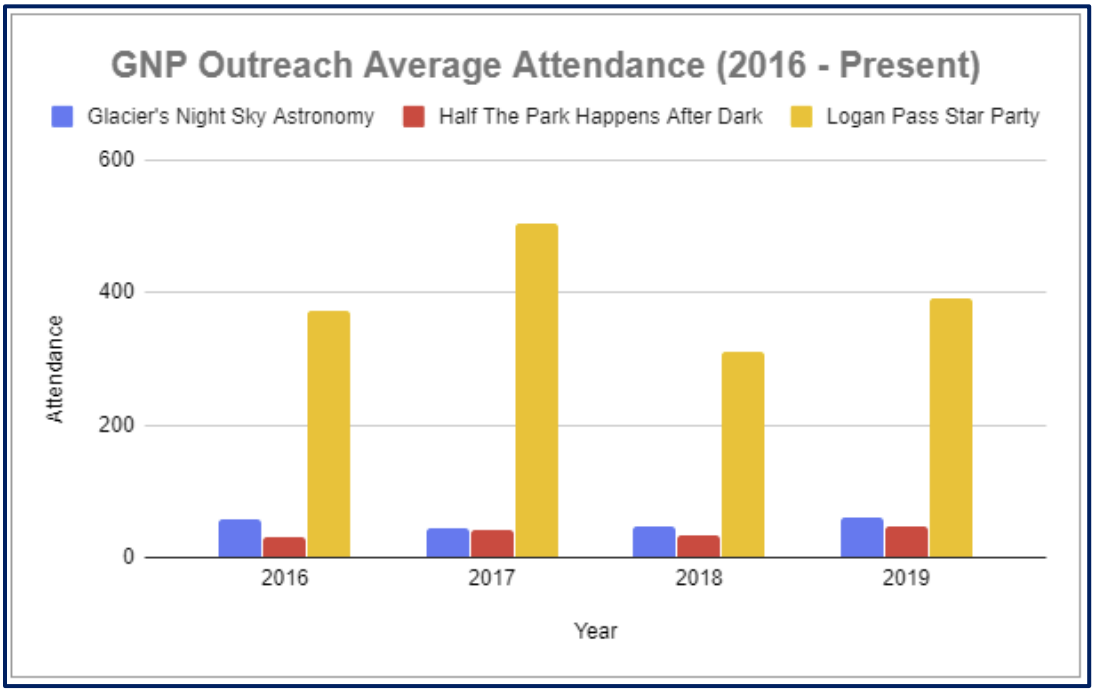

Figure 16: The average attendance per event for GNP's dark sky outreach programs.
(Rademaker, 2020).

2.5.1. The Dusty Star Observatory

The east side of the park is home to the Dusty Star Observatory. Located in the St. Mary's Visitor Center parking lot, the observatory was completed in 2019. The Glacier National Park Conservancy raised $200,000 for the observatory and its educational programs. Shown in Figure 17, a Planewave 20-inch Dall-Kirkham telescope is housed inside the observatory. The telescope has a computerized image focuser that attaches to a camera and can display the camera image on a computer screen. The telescope is housed inside a moveable dome to protect it from GNP's harsh weather.

Currently, the telescope is set up for in-person use by park rangers only. In the past, the observatory has sent videos and pictures to local schools. These pictures and images were intended for educational use and were not fit for scientific research (Interview with Lee Rademaker, 2020, September 03). Unfortunately, the telescope currently (Fall 2020) has limited internet access, making remote access difficult.

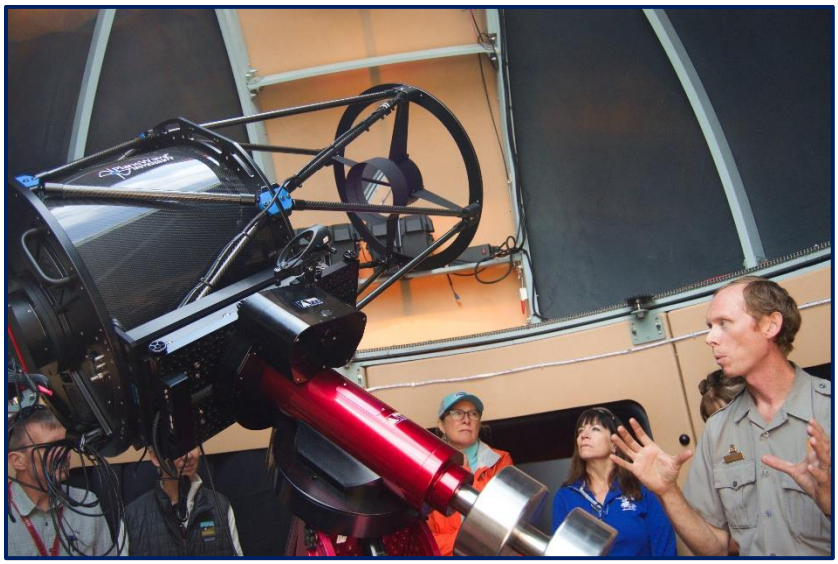

Figure 17: A ranger showing the telescope to observatory visitors.
(Glacier Conservancy, 2019)

During the day, the telescope attracts wandering visitors and offers them a chance to observe solar events, such as sunspots. At night, the telescope is used for sky tours to give visitors a deeper look into space (NPS, 2019). The observatory has also become a major component of *Half the Park Happens After Dark*. To view the observatory telescope, the park installed two TV screens on the exterior of the observatory. The exterior of the observatory is shown in Figure 18.

Figure 18: The Dusty Star Observatory.
(Glacier National Park, 2019, August 22).

2.6. Financial Aspects of the Dark Sky Project

To determine the financial feasibility of light fixture replacement and maintenance for the Dark Sky Project, GNP's finances must be understood. The park receives revenue from several different sources, such as donors, partners, visitor fees, and merchandise sales. The park's largest source of revenue comes from the GNP Conservancy. The Conservancy operates independently from GNP but exists solely to support the park. In 2020, the Conservancy planned on donating $84,720 to replace light fixtures and support dark sky educational programs (GNP Conservancy, 2019). The Conservancy is responsible for funding 100% of the overall GNP dark sky compliance project.

One financial consideration of an IDSP is the cost of purchasing compliant light fixtures. The IDA website contains an inventory of all fixtures certified as IDA-compliant, including brand name, technical specifications, and stores where each fixture can be purchased. According to this list, smaller wall-mounted fixtures range from around $20-$400. The most expensive fixtures, such as streetlights, cost approximately $2,000-$3,000.

Despite the initial cost of purchasing new light fixtures, increased Dark Sky compliance will save the park money in the long run. Keeping lights turned off, on timers, and at lower brightness levels will consume less power (IDA, n.d.-e). In addition to power savings, night sky-related events could be a source of revenue, because they increase park visitation. These events consistently draw in over 600 visitors per night during the spring and summer months (Gardner, 2019), and each vehicle is required to pay a $30 park entry fee. With greater Dark Sky compliance, the park could potentially entice more visitors to attend Star Parties, astronomy viewings, and other nighttime activities.

3. Methodology

The goal of this project was to assist Glacier National Park (GNP) in achieving full gold-tier International Dark Sky Park (IDSP) status by evaluating the park's night sky quality, lighting compliance advancement plans, and educational programs to identify ways to ensure achievement of full IDSP status in the timeframe given by the IDA. The following list of objectives was developed to help us meet the goal of this project.

1. Evaluate GNP's lighting management plan and sky quality readings to suggest strategies to reach 100% IDA compliance within the IDA specified timeline.
2. Create an external website to facilitate GNP Outreach, provide educational content, spread dark sky awareness, and store archived images from the Dusty Star Observatory.
3. Complete a draft of Glacier National Park's 2020 annual progress report to the IDA.
4. Create an infographic that explains how to become an International Dark Sky Park.

The following material addresses each of these project objectives and the corresponding methods we used to achieve them.

3.1. Objective 1: Evaluate GNP's Lighting Management Plan and Sky Quality Readings to Suggest Strategies to reach 100% IDA Compliance within the IDA Specified Timeline.

To become an IDSP, a park must have a plan to achieve 90% compliance within five years of the initial application and must achieve 100% compliance within ten years. GNP's initial application was accepted in 2017, which means the park needs to achieve 90% compliance by 2022 and 100% compliance by 2027. To help GNP achieve the 100% compliance objective, we decided to review the park's 2017 LMP to ensure it was as effective as possible.

3.1.1. Analyze the 2017 Lighting Management Plan

Before analyzing GNP's current LMP, we first sought to gain an understanding of what is contained within an LMP. We researched primary sources, including official IDA documents, graphics, and descriptions of LMP formats and requirements to determine how to properly compose an LMP. This research was also meant to identify and obtain secondary sources, such as lighting management plans from other IDSPs.

3.1.2. Evaluate the Changes to GNP's 2017 Lighting Management Plan

To properly evaluate the lighting fixtures changes since GNP's IDSP application was initially submitted in 2017, we decided to perform a multi-criteria evaluation of both the application's Lighting Inventory and the 2020 Lighting Needs Spreadsheet. The 2017 Lighting Inventory was a spreadsheet that included information on the fixtures and bulbs of each park building. An excerpt from the Lighting Inventory is shown in Table 1.

Developed area	# Buildings	# Fixtures	% of park total fixtures	# Compliant	% Compliant	# of replacements recommended	Total equipment needed (bulbs and fixtures)
Totals	429	1550	100	938	61%	612	733
Apgar Campground	12	45	3	18	40%	27	39

Table 1: A selection of rows from the 2020 Lighting Needs Spreadsheet.

The 2020 Lighting Needs Spreadsheet was provided to us by Iree Wheeler, a GNP intern working on the Dark Skies Project. The 2020 Lighting Needs Spreadsheet is a detailed report on light fixtures that are needed, where they are required, and what has already been replaced. The spreadsheet lists the type of fixtures and bulbs on each building and denotes fixtures that need to be replaced. The LMP evaluation was intended to verify lighting changes throughout the park and update the lighting inventory as needed. We proposed that this information could be used to create a side-by-side comparison of the 2017 and 2020 documents. The comparison would highlight the progress GNP made over this time span.

3.1.3. Analyze the Cost of Lighting Upgrades

GNP relies heavily on the GNP Conservancy to fund projects. The GNP Conservancy is an independent organization and GNP's sole fund-raising partner. The Conservancy, which runs completely on donations and sales, funds GNP's projects and programs. For example, one of these projects is to retrofit all of GNP's lighting fixtures to be IDA-compliant. For a project as large as ours, having a feasible funding plan is essential. We proposed to conduct a cost analysis of the current LMP to determine if any changes to the LMP needed to be made. We also decided to perform an interview with Iree Wheeler to receive financial information about lighting upgrades. To update the information, we planned to revise the financial plan to reflect the current state of upgrades within the park. To accurately estimate the total cost, the group members decided to research the prices of each compliant light fixture type to be installed, as well as the estimated cost of the electrician hired to replace the fixtures. We proposed to use the 2020 Lighting Needs Spreadsheet to find the exact number of each type of fixture the park still needs to purchase to calculate the total cost. The purpose of acquiring this information was to evaluate whether the current LMP is feasible, given the IDA deadline of five years to replace 90% of the lighting fixtures with IDA-compliant fixtures.

3.1.4. Measure Sky Quality

Figure 19: A Unihedron SQM sky quality meter.
(Unihedron, n.d.)

To accurately measure the sky's brightness, certain criteria had to be met when taking measurements with a Unihedron sky quality meter (SQM) (Unihedron, n.d.). Sky quality meters are a device used to measure the brightness of the sky in magnitudes per square arcsecond, a unit of brightness over one arcsecond of the sky. Figure 19 shows the SQM, the specific model that park staff should use while taking measurements for this project. Since a full moon can produce enough light to cast shadows, it was critical that SQM measurements were taken when the moon was not polluting the sky with light. A new moon is the first lunar phase that occurs when the Moon, Earth, and Sun's alignment leaves the Moon in complete darkness from the perspective of Earth. To collect data in the darkest possible conditions, GNP staff took measurements within 48 hours of a new moon when less than 10% of the Moon is illuminated by the Sun.

Additionally, SQM measurements were proposed to be taken during astronomical darkness. Astronomical darkness is when the Sun is more than 18 degrees below the local horizon, as shown in Figure 20. Taking measurements during this time span would ensure that the horizon is not lit at all by the rising or setting Sun, and the sky directly overhead is at its darkest. SQM measurements were taken with the device pointing directly at the zenith in an open area with minimal artificial light.

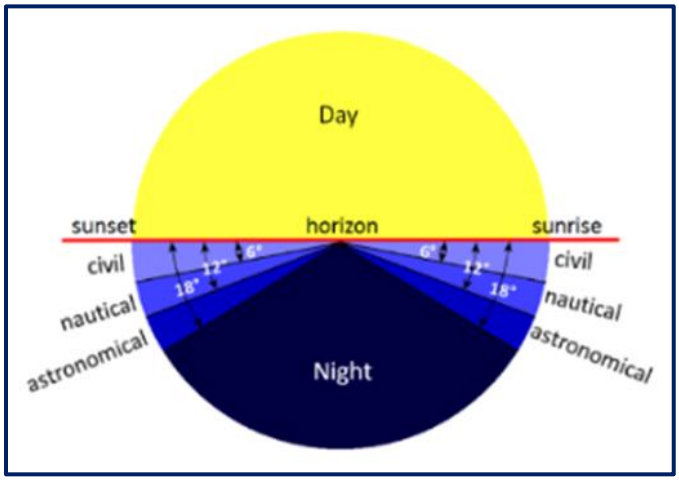

Figure 20: A diagram of the different classifications of nights.
(US Department of Commerce, 2015, March 16)

To determine when the optimal SQM measurements should be taken, we needed to create a chart that represented the rise and set times of the Sun and the Moon for September 2020. We did not consider August and October due to the full moons that occurred during both months. Table 3 in Appendix D displays the rise and set trends for the Sun (time and date, n.d.-a) and Moon (time and date, n.d.-b) throughout September 2020. Using the results from Figure 21, we determined that the ideal data collection time was after 10 PM and before 4 AM throughout the month. After factoring in the orbit and phases of the Moon, we determined that the optimal testing range lied between September 15th and 19th.

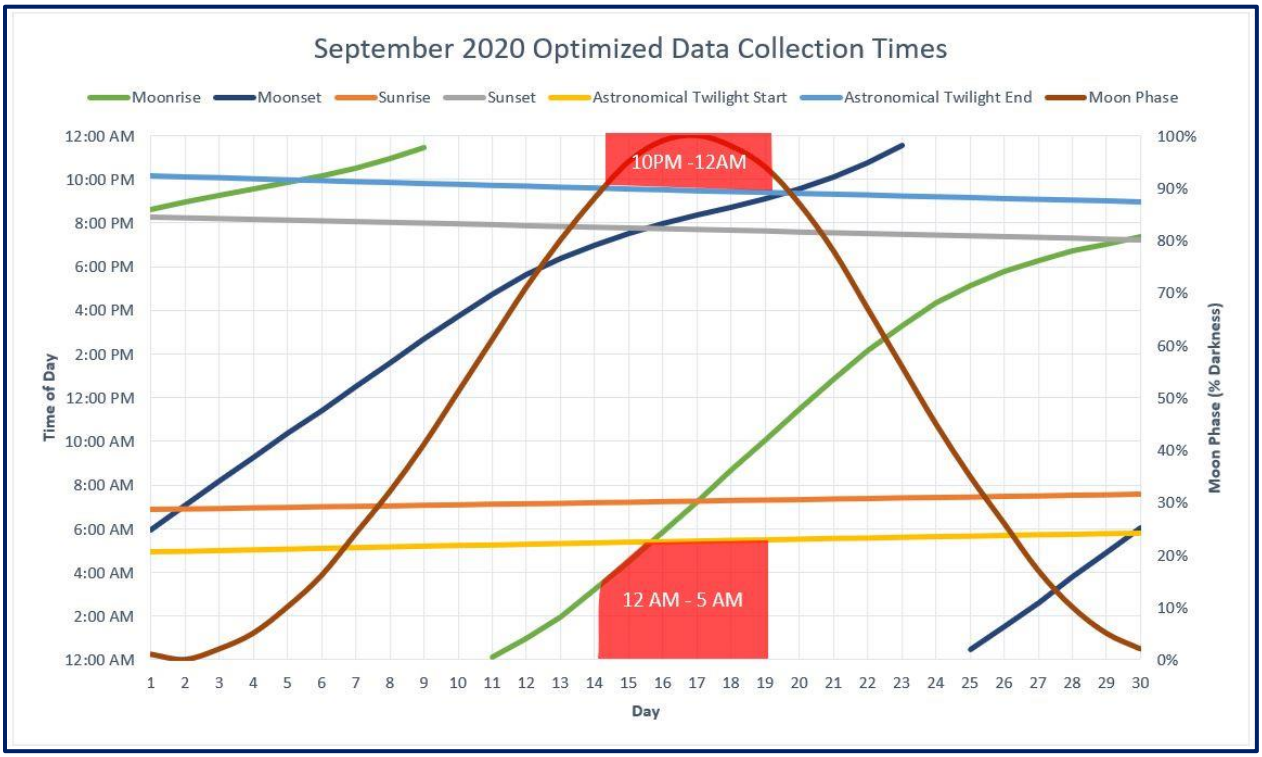

Figure 21: The optimized data collection times for September 2020.

Since no SQM measurements had been taken in GNP since 2016, park staff were unsure about the status of their sky quality. To determine if the sky quality over GNP had changed, we proposed that park staff take measurements at each test site again. GNP's 2017 IDSP application included SQM measurements from eight collection sites, six from 2016 and two from a 2009 Night Sky Quality Monitoring Report (NSQMR). We suggested that park staff take new measurements at each location using the SQM-L. The following data collection sites, which are mapped out in Figure 22, were proposed:

2016 Measurement Locations:

1. 48.58.54 -113.36.60, Park Boundary, Chief Mountain International Peace Park Highway
2. 48.49.75 -113.31.47, Many Glacier Valley at Sherburne Lake dam/park boundary
3. 48.44.23 -113.27.48, Going-to-the-Sun Road at mile one gate near St. Mary
4. 48.629 -113.869, Lake Mcdonald Lodge, on the beach near the river inlet
5. 48.528 -113.985, Apgar Village, on dock
6. 48.783 -114.280, Polebridge Entrance Station

2009 NSQMR Locations:

7. 48.60 -114.14, Huckleberry Mountain
8. 48.74 -113.44, St. Mary's Visitor Center

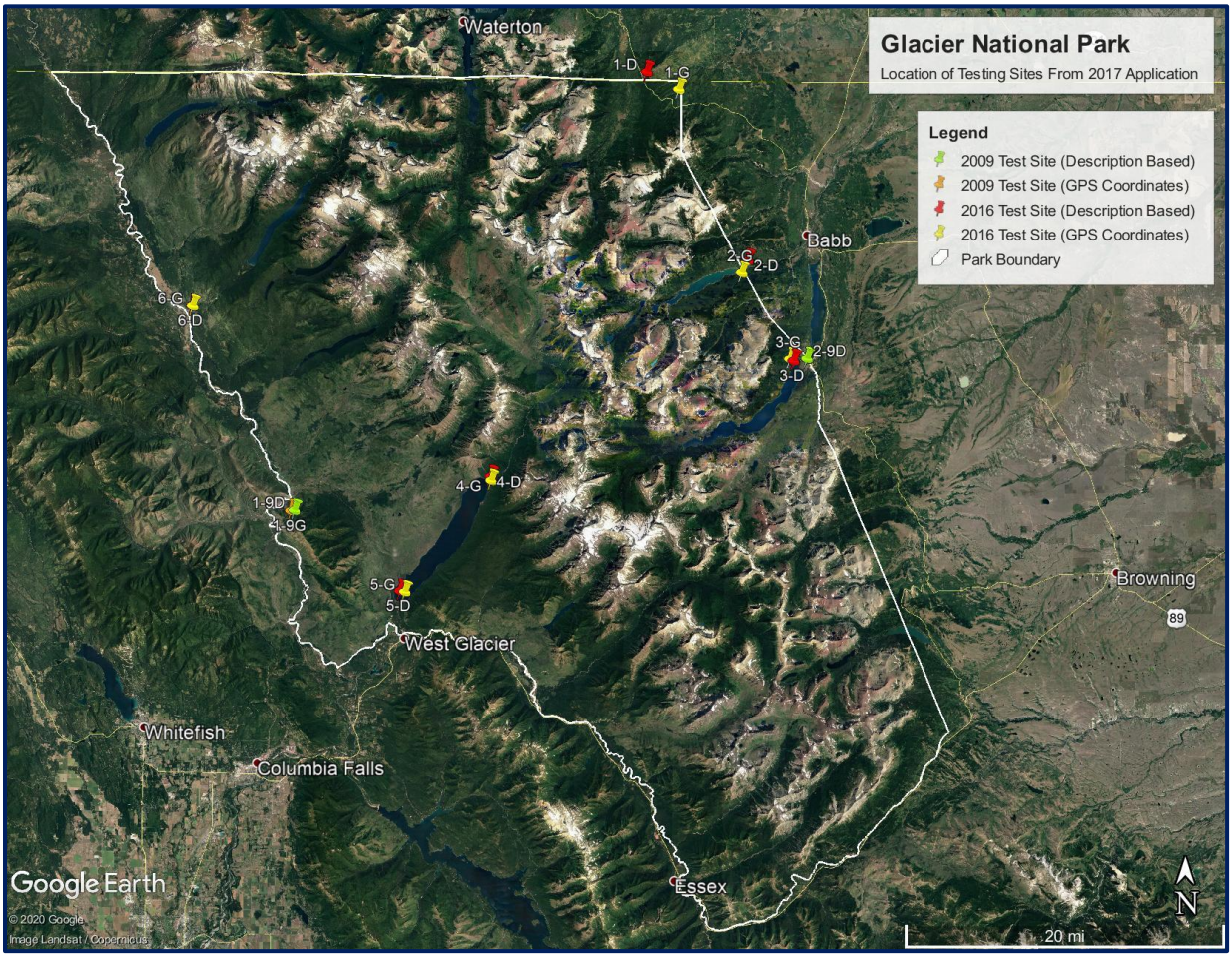

Figure 22: A map of all the past SQM measurement locations.

To produce the most accurate results, we recommended that six readings be taken at each collection site, with the first one being discarded (IDA, n.d.-d). After each measurement, the employee would have to log each SQM reading. Measurements would be combined into a Microsoft Excel spreadsheet with the time, location, reading, and conditions for each collection site. Figure 23 shows a theoretical measurement recording.

SQM Measurements							
Collection Site #	Reading #	GPS Coordinates		Time (± 15 min.)	Weather / Conditions	SQM Reading Mpsas	Additional Notes
		Latitude	Longitude				
1	1	48°31'43.45"N	113°59'31.17"W	2:00	Clear	21.66	Darkest Area
	2	"	"	"	Clear	21.74	"
	3	"	"	"	Clear	21.84	"
	4	"	"	"	Clear	21.33	"
	5	"	"	"	Clear	21.48	"
	6	"	"	"	Clear	21.59	"
					Avgerage Reading:	21.60	

Figure 23: A theoretical SQM measurement.

3.1.5. Compare SQM Measurements to Measurements from Previous Years

To determine if the park's lighting upgrades continue to meet the IDA's Gold Tier IDSP requirements, we proposed to compare the SQM measurements taken by park staff in 2020 to the measurements taken in 2016. A Microsoft Excel spreadsheet would be used to compare readings. If the SQM measurements for each site were higher, the skies above that location darkened from 2016 to 2020. A lower measurement indicated brighter skies. Using the updated lighting inventory, we would also analyze the lighting upgrade locations to determine if there was a correlation between compliancy upgrades and improved sky quality measurements.

3.2. Objective 2: Create an External Website to Facilitate GNP Outreach, Provide Educational Content, Spread Dark Sky Awareness, and Store Archived Images from the Dusty Star Observatory.

To maintain its IDSP designation, GNP must host dark sky related outreach programs. However, we found that information about these programs was scarce and scattered across many sources. We determined that one of the project's objectives should be to create a website to serve as a clearinghouse of information about GNP's outreach programs and dark sky awareness.

The proposed website would contain educational information about the telescope in GNP's Dusty Star Observatory. A page on the site would have information about which celestial objects are visible by the telescope, when they can be viewed, and would provide access to images from the Dusty Star Observatory of these objects captured by the telescope. Additional sections of the website would describe GNP's outreach programs to potential park visitors. Another page of the site would educate visitors on the impact light pollution has on our view of the night sky by providing comparative photographs of celestial objects with and without light pollution. Information for the website would be obtained from current online resources, documents obtained from the project sponsor, and interviews that we would regularly hold. Figure 24 shows an early draft of the website layout flowchart.

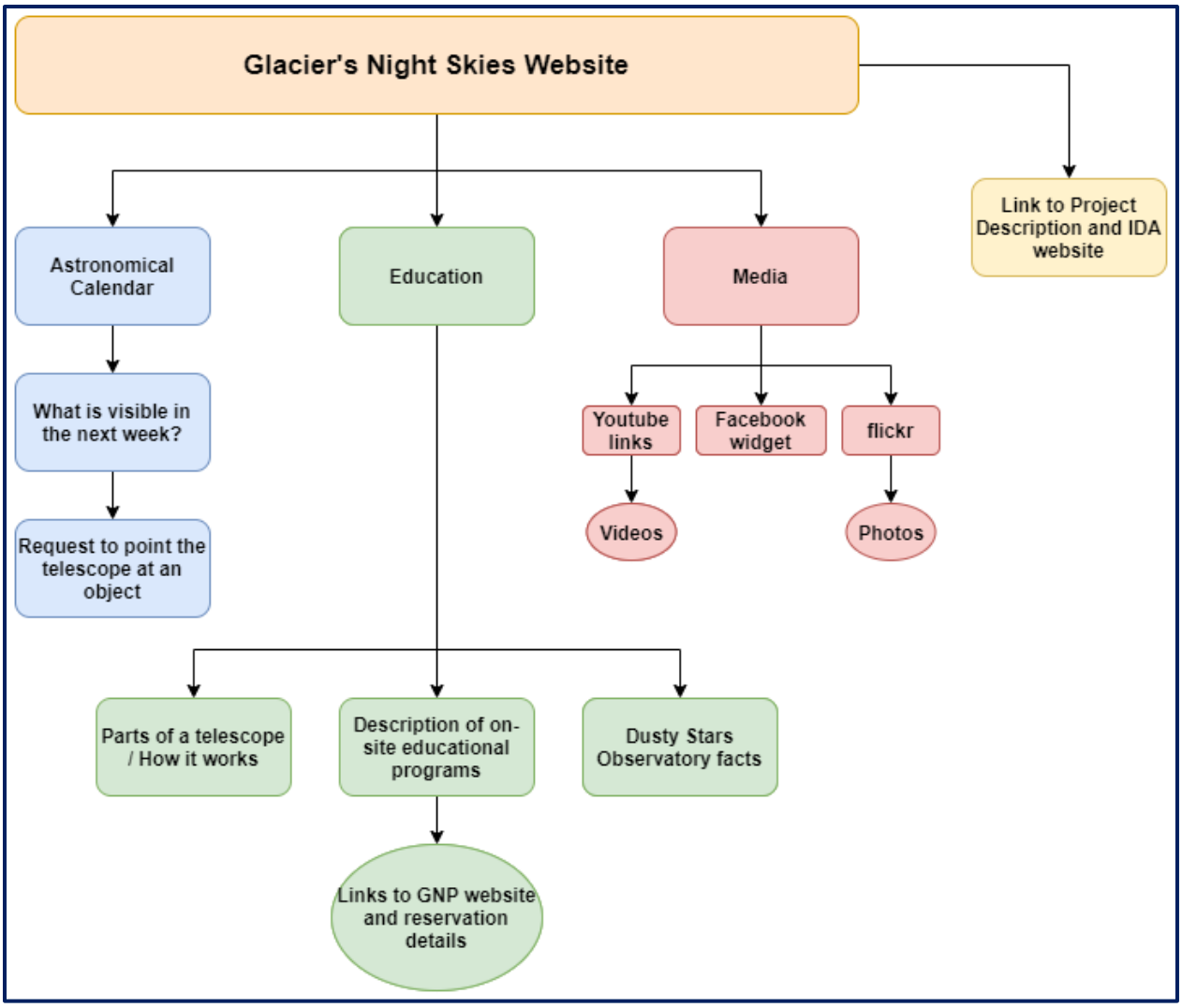

Figure 24: The initial flowchart for the dark sky website.

3.2.1. Create a Website to Collect Telescope Viewing Requests

One major limitation of the observatory was the inability for most people to see through the telescope. The telescope is set up for in-person observation only, which means people can experience the telescope only through the *Half the Park Happens After Dark* program. Due to limited outreach for the telescope, we proposed to dedicate a page of our external website to assist the park's Dusty Star Observatory. One purpose of creating the webpage would be to receive public requests to aim the telescope at specific celestial objects such as planets, galaxies, and nebulae. Due to federal regulations, the National Park Service cannot directly collect information from members of the public, making a request system very difficult to achieve. A website not operated by the National Park Service can circumvent these regulations, so the necessary information can be collected. It was decided as part of this objective to design a form

that collects an email, organization name (such as a school or museum), and several objects the organization would like to view. Since the visibility of celestial objects can vary from day to day, the website would provide information on what objects are currently visible. Once the telescope has observed the object, the video or pictures would be uploaded to the website for anyone to access.

3.2.2. Make Past Telescope Content and Media Accessible

Another section of the website is an archive of previously recorded telescope media. This media includes videos and pictures of what was viewed through the telescope. Currently, there are no publicly accessible video recordings of observations from the telescope. We decided to use WPI's computing and storage resources to enable members of the public to download the photos and videos provided by the observatory.

3.2.3. Create a Webpage About the Telescope and Dark Sky Education

We planned on creating a page dedicated to education about the telescope and the importance of dark skies. We proposed to include information about the history of the telescope, facts about telescopes and astronomy, and a description of how the telescope works. Facts about the telescope and how it works were presented as an interactive image with pop-outs. Another proposed aspect of the webpage is to offer a plethora of activities. We plan to include links to resources that provide lesson plans for teachers and at-home activities for parents to do with their kids. It was also decided that widgets would be added that act as windows to GNP social media pages so readers can stay up to date on any information, virtual events, and challenges GNP offers. The goal of this page is to educate and excite people about astronomy and dark sky preservation.

3.3. Objective 3: Complete a Draft of Glacier National Park's 2020 Annual IDA Progress Report.

As an IDSP, GNP is required to submit annual reports to the IDA. These reports detail the progress that the park has made to increase compliance and outline their plans for future improvement. So far, GNP has submitted two annual reports, in 2018 and 2019. We made it an objective to draft GNP's 2020 IDA report with improvements based on other parks' reports.

3.3.1. Suggested Content and Format for an IDA Annual report

The IDA has guidelines for how an annual report should be formatted. The IDA suggests that the report includes sections about funding, lighting, sky quality, conservation and research, education, outreach, and community relations. The suggestions also include brief guidelines on what the IDA looks for in each section. For instance, the lighting section should provide a summary of the progress that the IDSP has made in their LMP (IDA, "Annual Report Content Guidelines," Apr. 8, 2020). The IDA deems these reports as an important resource because they "use the contents of IDSP Annual Reports to measure the program's effectiveness as a dark sky conservation and outreach tool, to inform the larger IDA audience of International Dark Sky Place's impact on the dark sky movement, and to ensure the integrity of the IDSP Program" (IDA, "Annual Report Content Guidelines," Apr. 8 2020).

3.3.2. Compare GNP's IDA Annual Reports to Other Park's IDA Reports

While there are guidelines for composing an IDA annual report, there are no explicit requirements. This means that IDSPs have the freedom to tailor their reports to focus on their strengths. For example, Grand Canyon National Park includes a "next phases" section but adds nothing about community and media relations (IDA, 2018). Meanwhile, GNP does not mention their next phases in their 2018 and 2019 annual reports, but they go into detail about social media presence and promotion. We would evaluate annual reports from Capitol Reef National Park, Great Basin National Park, Grand Canyon National Park, and Petrified Forest National Park. This multi-criteria evaluation would determine what is unique about each park's reports and what their strengths are regarding formatting and data. From this analysis, suggestions would be made to improve GNP's annual reports.

3.4. Objective 4: Create an Infographic That Explains How to Become a Dark Sky Park.

The IDSP application process is outlined by the IDSP Guidelines document. This 20-page document contains an overwhelming amount of definitions, minimum requirements, examples, and processes. This document is extremely hard to navigate, especially for someone not already familiar with the IDA. We sought to make an infographic to present the guideline information in a more visually appealing, easy to understand format. The infographic would be submitted to the IDA, with the intent to inspire more parks to apply to be IDSPs.

3.4.1. Create an Infographic for Use by Other Parks

We proposed to create an infographic to encourage qualified locations to become IDSPs and make the Dark Sky application process easier. The proposed infographic would include information about the benefits of becoming an IDSP, the preliminary requirements of IDSPs, the application process timeline, and the post-designation requirements. This information was gathered using the IDA 2018 Guidelines. By using an infographic to advertise the IDSP process, more parks can apply to become IDSPs, which would reduce global light pollution. The infographic also counts as a form of outreach to other parks, further satisfying the IDA's outreach and educational requirements.

To create the infographic, we chose to use the website Piktochart. It was determined that working copies of the infographic should be sent out to groups of students on campus to get feedback during different stages of creation. We also decided that we would meet with Michael Hamilton, the instructional technology specialist at WPI, to get specific feedback on the infographic.

4. Results

This chapter describes our findings and accomplishments. We evaluated the park's SQM Measurements, suggested improvements to the Glacier National Park (GNP) Lighting Management Plan (LMP), created a website to promote the park's outreach programs and general dark sky awareness, and designed an infographic to encourage other locations to become IDSPs. In doing so, we successfully completed each of the project's objectives.

There were delays to the original timeline due to the global COVID-19 pandemic. These delays included the GNP electrician taking a hiatus and GNP employees working overtime to ensure the park stayed safe during the pandemic. As a result, the Dark Sky project was made a lower priority compared to other park improvement and maintenance needs, and lighting upgrades were not accomplished. Due to these delays, GNP applied to the IDA for a deadline extension in April 2020. The request was granted, and the deadline for the annual report and 67% lighting compliance was extended from October 1st, 2020 to March 31st, 2021.

4.1. Objective 1: Evaluate GNP's Lighting Management Plan and Sky Quality Readings to Suggest Strategies to reach 100% IDA Compliance within the IDA Specified Timeline.

We received GNP's most recent Lighting Inventory from Mark Biel, the Park Ranger in charge of GNP's dark sky program. Upon analyzing the Lighting Inventory spreadsheets, we determined that as of Fall 2020, GNP has a 61% lighting compliance.

Additionally, GNP staff recorded SQM measurements at seven sites in September 2020. We analyzed the measurements and concluded that the GNP sky quality had improved since the park's initial IDSP application.

4.1.1. Sky Quality Measurements

Since no SQM measurements had been taken in GNP since 2016, park staff were unsure about the park's sky quality. To determine if the sky quality over GNP had changed, we proposed that park staff take new measurements at each of the 2016 test sites. The park's 2017 IDSP application included SQM measurements from eight collection sites: six from 2016 and two from a 2009 Night Sky Quality Monitoring Report (NSQMR).

Following the IDA's recommended procedure, the park staff took six readings at each collection site, with the first one being discarded (IDA, n.d.-d). After each measurement, the time, location, weather, and site description were recorded in an excel spreadsheet. The 2009 test site at Huckleberry Mountain was not tested due to accessibility issues. Photographic evidence was not collected because GNP staff did not have the camera equipment or the time for night sky

photography. Table 2 shows the results of the new 2020 sky quality measurements. The rest of the testing spreadsheet used by the park can be found in Appendix G.

Site Number	Description	2016 Measurements	2016 Avg	2020 Measurements	2020 Avg	Status
1	Park Boundry, Chief Mountain International Peace Park Highway (48°58'54" N, -113°36'60" W)	No Reading 21.73 21.77 21.82 21.82 21.82	**21.792**	21.60 21.84 21.73 21.67 21.84 21.79	**21.77**	Lighter
2	Many Glacier Valley at Sherburne Lake Dam / Park Boundry (48°49'75" N, -113°31'47" W)	No Reading 21.80 21.80 21.80 21.83 21.83	**21.81**	21.55 21.74 21.93 21.66 21.67 21.67	**21.73**	Lighter
3	Going to the Sun Road at one mile gate, near St. Mary (48°44'23" N, -113°27'48" W)	No Reading 21.82 21.80 21.81 21.81 21.83	**21.81**	21.70 21.69 21.78 21.89 21.81 21.70	**21.77**	Lighter
4	Lake McDonald Lodge On the beach near the river inlet (48.629 N, -113.869 W)	No Reading 21.60 21.41 21.68 21.68 21.58	**21.59**	21.92 21.94 21.88 21.90 21.90 21.88	**21.90**	Darker
5	Apgar Village, on dock (48.528 N, -113.985 W)	No Reading 21.44 21.57 21.57 21.49 21.50	**21.51**	21.88 21.88 21.90 21.85 21.83 21.86	**21.86**	Darker
6	Polebridge Entrance Station (48.783 N, -114.28 W)	No Reading 21.52 21.49 21.52 21.57 21.58	**21.54**	22.12 22.18 22.11 22.09 22.13 22.15	**22.13**	Darker
7	Huckleberry Mountain (48.6 N, -114.14 W)	No Reading 21.65 21.65 21.65 21.65 21.65	**21.65**	0.00 0.00 0.00 0.00 0.00 0.00	**21.65**	No Change
8	St. Mary Visitor Center (48.74 N, -113.44 W)	No Reading 21.56 21.56 21.56 21.56 21.56	**21.56**	21.59 21.56 21.59 21.56 21.53 21.68	**21.58**	Darker
		Avg	21.66		21.82	

Table 2: A comparison of the 2016 and 2020 SQM Measurements.
The gold and silver shaded boxes represent their corresponding IDA tiers.

Table 2 consists of eight columns: site number, site description, 2016 measurements, 2016 average, 2020 measurements, 2020 average, and status. The site number corresponds to the order listed in the IDSP application. The final column shows the change between the 2016 and 2020 measurements. The status column has three possible values: lighter, darker, or no change.

Individually, three of the eight test sites from the 2016 application were categorized under the gold tier sky quality status. These sites were the park boundary at Chief Mountain (1), Many Glacier Valley (2), and the Going to the Sun Road (3). All other testing sites fell under the silver tier category. Based on the 2020 measurement data, we found that four test sites switched

tiers. Site 2 at Many Glacier Valley lightened and dropped to a silver tier. However, the sites at Lake McDonald (4), Apgar Village (5), and Polebridge (6) were darker and achieved gold tier status. Based on these changes, five of the eight test sites now fall under gold tier sky quality.

The data show that sky quality measurements generally improved. As shown in Figure 25, the average SQM measurement on the 2016 IDSP application was 21.66 mpsas. The average 2020 sky quality measurement was 21.82 mpsas. Excluding Huckleberry Mountain, the average SQM measurement changed by +0.16 mpsas. As a result, the average sky quality measurement now surpasses 21.75 mpsas, exceeding the sky quality requirement for gold tier IDSP status.

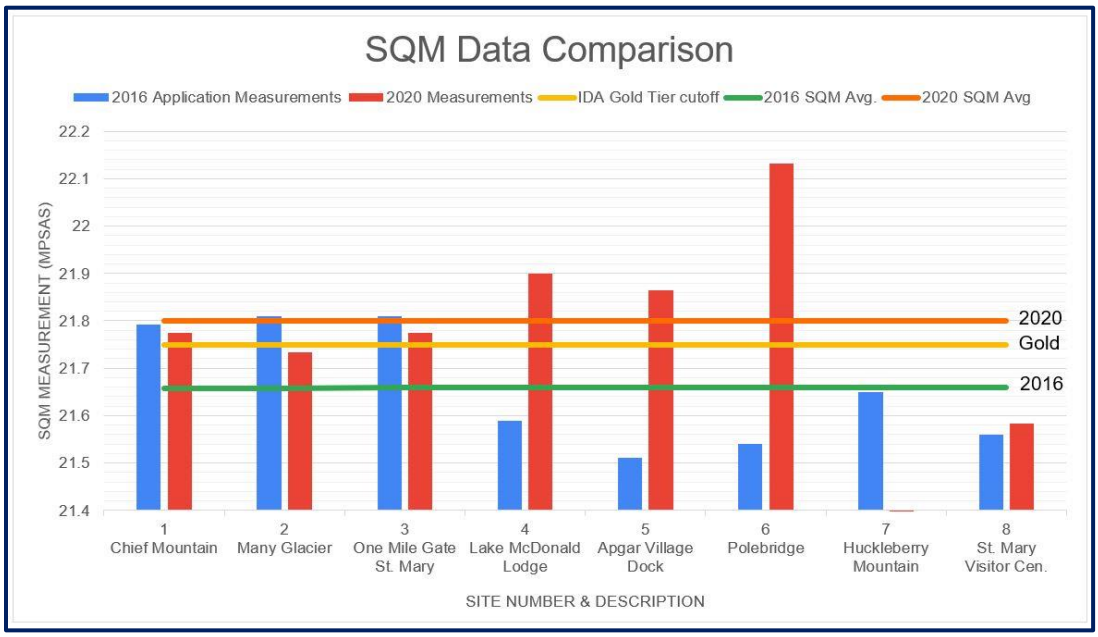

Figure 25: A graph comparing SQM measurements, averages, and the IDA gold tier cutoff.

Some sites, however, increased in brightness. These sites brightened because of changes to lighting outside of the park in the surrounding towns. For example, St. Mary has recently upgraded public works buildings, which increased light pollution (Biel, 2020). Other factors that contribute to a perceived decrease in sky quality at these sites could include the SQM itself. Improper calibration of the SQM can affect the measurement. The lingering wildfire smoke in the atmosphere at the time of measurements could have also led to brighter skies. More sky quality measurements would need to be taken to average out the data set.

4.2. Objective 2: Create an External Website to Facilitate GNP Outreach, Provide Educational Content, Spread Dark Sky Awareness, and Store Archived Images.

During our research, we found that GNP had little information published online about dark skies and the related activities that the park offers. To expand GNP's public outreach and create a location for information regarding the park's dark sky efforts, we designed and created an educational website.

Before we created the website, we had to consider the technical details and design considerations of the website. For technical details, see Appendix H. The final version of the website can be found at https://wp.wpi.edu/darksky2020.

The main goal of the website is to facilitate dark sky outreach and educational information relative to Glacier National Park. The website creates a platform that the park or future WPI project teams can expand upon. When creating our website, we found that the structure of the website would benefit from having several changes from our initial outline.

Initially, we proposed creating four main webpages: an astronomical calendar for telescope requests, dark sky activities, a telescope image gallery, and information about our project and the IDA. We quickly realized that an astronomical calendar and telescope gallery could fall under one observatory webpage. We also wanted to have a more equal focus on GNP's outreach programs, not solely on the observatory. Additionally, explanations of the park's dark sky programs did not fit within an education webpage. To address these issues, we divided education and activities into two separate webpages. Figure 26 shows the final flowchart of the website, with the five main webpages. Below, the content and focus of each of the main web pages are described.

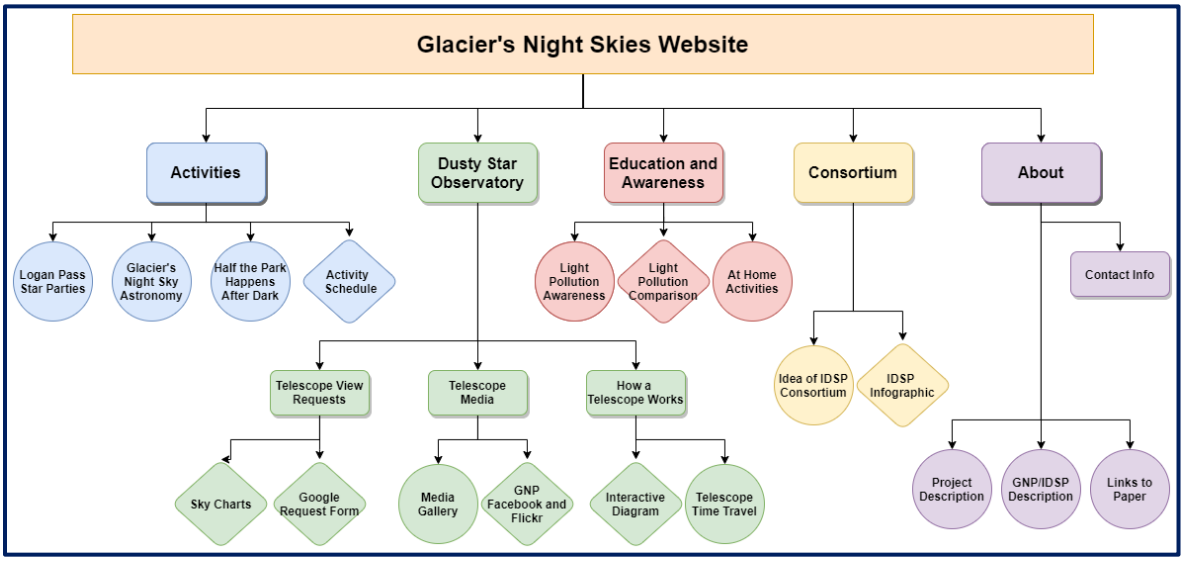

Figure 26: The final flowchart for the website.

Activities The activities webpage contains information relevant to the outreach programs offered by the park: *Logan Pass Star Parties, Half the Park Happens After Dark,* and *Glacier's Night Sky Astronomy*. The page describes each program, displays images of each, and contains an embedded calendar of when each program occurs. The calendar was provided to help visitors determine which events are available on a given night.

Observatory The Dusty Star Observatory webpage was created to enhance GNP's outreach capabilities. We interviewed park ranger, astronomer, and lead interpreter Lee Rademaker several times to determine appropriate content for this webpage. We found that despite having an observatory on-site, the IDA and the Glacier Nation Park Conservancy had published scarce information about it. The Dusty Star Observatory page has three subpages, those being Telescope View Requests, Telescope Media, and How a Telescope Works.

Requests The Telescope View Requests page enables members of the public to submit a Google form request for the observatory staff to capture images of celestial objects. Possible objects include planets, stars, galaxies, and nebulae. To determine what is visible from the park, we embedded several interactive sky guides and an astronomical event calendar, as shown in Figure 27. If the observatory captures a requested image it will be uploaded to the Telescope Media webpage.

Figure 27: One of the night sky simulators used on the website displaying M31.

How a Telescope Works The How a Telescope Works page explains how the telescope works and features an interactive diagram of the telescope with callouts and descriptions for each telescope component. Figure 28 shows a SolidWorks CAD model of the telescope that was created for the interactive diagram. When interviewing Lee, we were told that the *Half the Park Happens After Dark* educational program talks about the concept of distance and time through space. We thought it would be appropriate to finish the telescope webpage with an explanation of a telescope's ability to see back in time due to distance and the speed of light.

Figure 28: The CAD render used for the website.

Education and Awareness The Education and Awareness webpage pertains to the purpose of IDSPs: the conservation and protection of the night skies. It includes basic information on light pollution, such as images and descriptions of its four different classifications. The external website *underluckystars.com* was embedded to highlight the effect of light pollution. Shown in Figure 29, this feature compares a natural night sky to a light-polluted night sky across the planet. The webpage also provides ways that the public can reduce light pollution, such as turning off unnecessary lighting.

Figure 29: The underluckystars.com slider displaying New York City's light pollution.

Consortium The consortium webpage provides an outline and starting point for our consortium recommendation, as described in Section 5.4. The page currently includes an outline of the recommended formatting for the webpage as well as our "Becoming an International Dark Sky Park (IDSP)" infographic.

About Us The About Us page contains a description of our project and how it relates to the mission of reducing light pollution. The page contains links to the IDA website, our research proposal, and our final paper. It also contains contact information for the park and project team. Brief descriptions explain our project, the park's IDSP history, and the park's future lighting status goals. Finishing the website off with this information bridges the gap between visitors across the country and those in the park. We hope that the website provides a basis for the park's Dark Sky program to expand upon.

4.3. Objective 3: Complete a Draft of Glacier National Park's 2020 Annual IDA Progress Report.

As per the IDA requirements, the 2020 IDA annual report had to demonstrate that GNP met all the conditions to become a full IDSP. To draft the report properly, we conducted a multi-criteria evaluation of previous IDA annual reports from Capitol Reef National Park, Great Basin National Park, Grand Canyon National Park, Petrified Forest National Park, and GNP to determine how GNP's IDA report could be improved. The report criteria we evaluated include the description of outreach programs, the amount of detail provided in each section, and progress in lighting compliance upgrades. IDA annual report improvements included using quantitative data on the lighting inventory and SQM measurement data to provide an exact measure of the park's progress in its lighting management plan. We also included information about our project, and specifically our website, as a new component to GNP's outreach programs. The final annual report was comprised of five sections:

- Visitation data
- Lighting upgrades in the past year
- Outreach programs
- The observatory
- SQM measurements

4.3.1. Changes to Objective Three

After a meeting with GNP Ranger Mark Biel, we discovered that Waterton Lakes National Park wrote the joint Waterton-Glacier 2020 Annual Report to the IDA and submitted it on October 5th, 2020. After reviewing the finished report, we noticed the sections describing GNP's progress lacked important details. This project and its deliverables were not mentioned. Additionally, the previous Annual Reports did not include hard numbers and details about lighting upgrades and SQM measurements.

As a result, we created an addendum to submit to the IDA as an addition to the Waterton-Glacier 2020 Annual Report. The addendum included information on our website, the infographic, and a summary of our lighting inventory. The addendum will also be used as a resource for GNP to write its 2021 IDA Annual Report. See Appendix J for the addendum we submitted to Glacier National Park.

4.4. Objective 4: Create an Infographic That Explains How to Become a Dark Sky Park.

We created an infographic that overviews the IDSP application process. The infographic is a visually appealing, concise summary of the IDA application guideline document and it is intended to make the IDSP application process easy for prospective parks to begin. The infographic was included in GNP's 2020 IDA Annual Report Addendum and was distributed throughout the Dark Sky community. It is organized into the following blocks:

- What is an IDSP
- Requirements for Provisional IDSP status
- The IDSP Application Process
- Post Designation Requirements
- Conclusion

Created using the web-based application Piktochart, each section featured a theme relevant the IDSP application process. The infographic was sent to the IDA Director of Engagement, Bettymaya Foott, for feedback. We also met with Mike Hamilton, the WPI instructional technology specialist, for advice regarding the content and layout of the infographic. There were three rounds of feedback, each producing a new draft of the infographic. Once the final draft was developed, we distributed the infographic. We emailed the infographic to employees of both the NPS and the IDA. These contacts included Bettymaya Foott and Renata Harris, the GNP Science Communication Technician. Renata provided us with a list of individuals that are essential to communication between National Parks and IDSPs. The infographic resides on the Consortium page of our website. It can also be found in Appendix I.

5. Recommendations

Based on the results of our lighting inventory analysis and our experiences from working on the website, annual report, and infographic, we created recommendations to help guide GNP with its future dark sky efforts. Our recommendations focus on promoting, preserving, and protecting dark skies at GNP within the context of the park achieving Full International Dark Sky Park status. We also recommend possible ways for future IQPs to expand upon our work.

5.1. Increase SQM Measurement Frequency to at Least Monthly when Glacier National Park is Open

The IDA requires a quantitative update of the sky quality for each lighting compliance deadline (3, 5, and 10 years from attaining provisional status). Annual reports between these years are strengthened by including up to date SQM measurements. The four-year gap between the 2016 and 2020 SQM measurements in GNP caused uncertainty regarding how well lighting retrofits impacted light pollution.

We recommend that the park increase SQM measurement frequency to at least monthly when the park is open. There are three options to achieve this: install permanent sky quality meters, have park staff conduct manual SQM measurements, or have a third party such as a community college or a citizen science group take measurements on behalf of the park.

Unihedron offers SQMs capable of continuous measurements, such as the SQM-LU-DL, with a memory capacity of over 1 million recordings. The SQM can be purchased with weatherproof housing capable of protecting it from the conditions it will experience outdoors in GNP. The device can be plugged into a computer or laptop. Included with the purchase is a CD that contains software to display the measurements and to allow the user to change the frequency of the measurements.

With its included 3AH (Amp Hour) external battery pack, an SQM-LU-DL measuring every five minutes has a battery life of approximately 2.5 months. However, the battery life is dependent on the frequency of measurements, meaning that if GNP staff wanted to check the device less often, they could decrease the frequency of measurements. The combined listing price for the SQM, protective housing, software CD, and USB cable is $289.94. The total cost of monitoring all 7 sites tested in 2020 would be approximately $2029.58. The meter location would need to be regularly monitored to ensure it is still positioned and functioning correctly. Additionally, Ikarus Imaging sells a kit for £359 (about $468) that includes an SQM-LU-DL, a solar charger, and waterproof housings for both the SQM and solar charger. This option is more expensive but allows for the SQM to be deployed for longer periods of time with less upkeep.

An alternative to the SQM-LU-DL is for GNP staff to take manual sky quality measurements with the SQMs currently on hand. This may be a lower cost option, as no new equipment would need to be purchased. However, it would be the more time-consuming and labor-intensive choice, as each site needs to be measured individually at specific dates and times. The final alternative is for GNP to reach out to the conservancy, a local college, or a citizen science group to find volunteers to take the SQM measurements.

The GNP staff's awareness of their sky quality status will help ensure successful future IDA reports by gathering consistent sky quality data as retrofitting occurs. This will allow the park to implement changes well before an annual report deadline.

5.2. Livestream Astronomical Activities and Dusty Sky Observatory Programs to Social Media Platforms

There is currently an emphasis on online and remote communication due to the COVID-19 pandemic. This presents a challenge to the dark sky activities that GNP offers. On-site events are not recorded or published online, and the park's dark sky activities are only accessible to on-site visitors. In an interview with Lee Rademaker, the lead ranger for the Dusty Star Observatory, he expressed a desire to expand the park's dark sky programs presence online, especially the observatory telescope.

When the observatory is connected to the internet, we recommend that the feed on the television screens be broadcast live onto social media platforms such as YouTube and Facebook. GNP already has established YouTube and Facebook pages with large followings, which would be ideal for livestreams. The livestreams can be accompanied by information about the celestial object being displayed. Scientists can also give scheduled livestream talks using telescope images from the Dusty Star Observatory. Since bringing an internet connection to the observatory is already planned and popular streaming software is free, there would be little logistical cost to establishing a stream to social media. GNP can expand its educational outreach as an IDSP by teaching and inspiring an audience about dark skies that may not be able to visit the telescope in person.

The observatory telescope was established in September 2019 and has been integrated into outreach programs such as *Half the Park Happens After Dark*. However, the telescope is an underused resource because it is only accessible in person. Livestreams from one of the most powerful telescopes in Montana in an International Dark Sky Park would be a great resource for the public.

In addition, we recommend exploring the feasibility of virtual star parties. Due to the COVID-19 pandemic, national parks across the country were forced to cancel events and

activities in 2020. However, Grand Canyon National Park, also an IDSP, decided to hold their annual star party virtually on Facebook and YouTube. The virtual star party was reported as reaching up to 600,000 followers and was regarded as one of the largest star parties of its kind (Grand Canyon National Park, 2020). Their event included several guest speakers, followed by a virtual telescope viewing session. Based on the popularity of GNP's star parties and their desires to stream the observatory online, virtual star parties have great potential to expand GNP's dark sky outreach.

5.3. Create a Detailed Astronomical Calendar to Streamline and Expand Telescope Imaging Request Capabilities

The Telescope View Requests webpage on our website currently has a browser-based planetarium provided by the Las Cumbres Observatory and an Interactive Night Sky Simulator provided by Stellarum. There is also a calendar that details when additional celestial objects are viewable, compiled by In-The-Sky.org. This information is intended to show the user which objects will be viewable to make an informed telescope request; however, it does not include all objects the telescope can see and is not user friendly.

We recommend that the webpage be updated with a more comprehensive astronomical calendar and an improved user interface. The interface could have a single list of all the objects viewable by the telescope with information about when each object can be observed from the telescope's location. This would alleviate any burden of the user to determine optimal viewing times for themselves.

5.4. Create a Dark Sky Consortium to Facilitate Communication Between National Parks Regarding Dark Sky Matters

The purpose of IDSPs are to preserve and protect the night skies for future generations. This means an IDSP should assist parks attempting to also gain IDSP status, which is something that many parks have fallen short of. We recommend forming a dark sky consortium of IDSP National Parks as a group for IDSPs to learn from another and to help more new parks achieve IDSP status themselves.

Being a part of a consortium has many benefits. It is easier to share resources and best practices, such as how to construct annual reports. A consortium could also establish connections between parks that otherwise do not communicate. The best solutions to dark sky issues could easily be found through collective brainstorming of IDSP employees from all over the country. Having contacts in parks across the globe would open doors for new ideas and to improve upon existing operations. Forming a consortium would also be a great way to gain media exposure. Attention on news outlets and social media platforms would be a great way to spread knowledge of dark skies and to increase awareness about the harms of light pollution.

To help get GNP started, we created an infographic that can serve as a foundation for future communication between protected areas. The infographic was distributed throughout the dark sky conservation community by Bettymaya Foott. GNP could follow up with these locations about the prospect of creating a consortium.

For assistance in forming an IDSP consortium, we recommend reaching out to the Consortium for Dark Sky Studies (CDSS), a coalition of universities that are dedicated to scientific research within the dark sky field. Based at the University of Utah, members of this consortium have published research on the effects of light pollution on human health, as well as data on modeling and measuring light pollution. Contacting the CDSS would be a great way to gain insight into what forming a consortium involves. GNP and the CDSS could consider partnering and to make IDSPs a subgroup of the existing consortium.

As for in-person communication, we recommend taking advantage of the Annual IDA Conference and using our website to schedule meetings of the consortium's own. Each year, the IDA holds a general meeting in which members of the IDA from all over the world gather to discuss their findings on dark skies. This global conference is a great opportunity to spread the word of an IDSP consortium. Meetings can be organized on the website created during this project. The Glacier's Night Skies website contains a webpage titled "Consortium," which was created as a seed for the consortium. The webpage is currently a template that contains recommendations on how to grow the page. One of the recommended subsections is titled "Scheduled Meetings." We recommend including a calendar of scheduled future meetings as well as minutes from previous meetings so that both current and aspiring IDSPs can benefit from the consortium.

6. Summary and Conclusion

The goal of this project was to assist Glacier National Park in achieving full gold tier International Dark Sky Park status by evaluating the park's night sky quality, lighting compliance advancement plans, and educational programs to identify ways to ensure achievement of full IDSP status in the timeframe given by the IDA. We conducted a thorough analysis of Glacier National Park's lighting management plan with respect to the IDA guidelines and have determined the park is positioned to achieve full IDSP status by March 2021. Additionally, future WPI teams in GNP have the potential to go above and beyond the IDA requirements by utilizing the resources created over the course of this project, such as the website, IDA annual report addendum, and the infographic. With these results, GNP has a direction for further expansion of its Dark Sky outreach to both the public and to other national parks and is on its way towards achieving full International Dark Sky Park status.

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Appendix A: IDA Bortle Scale Flowchart

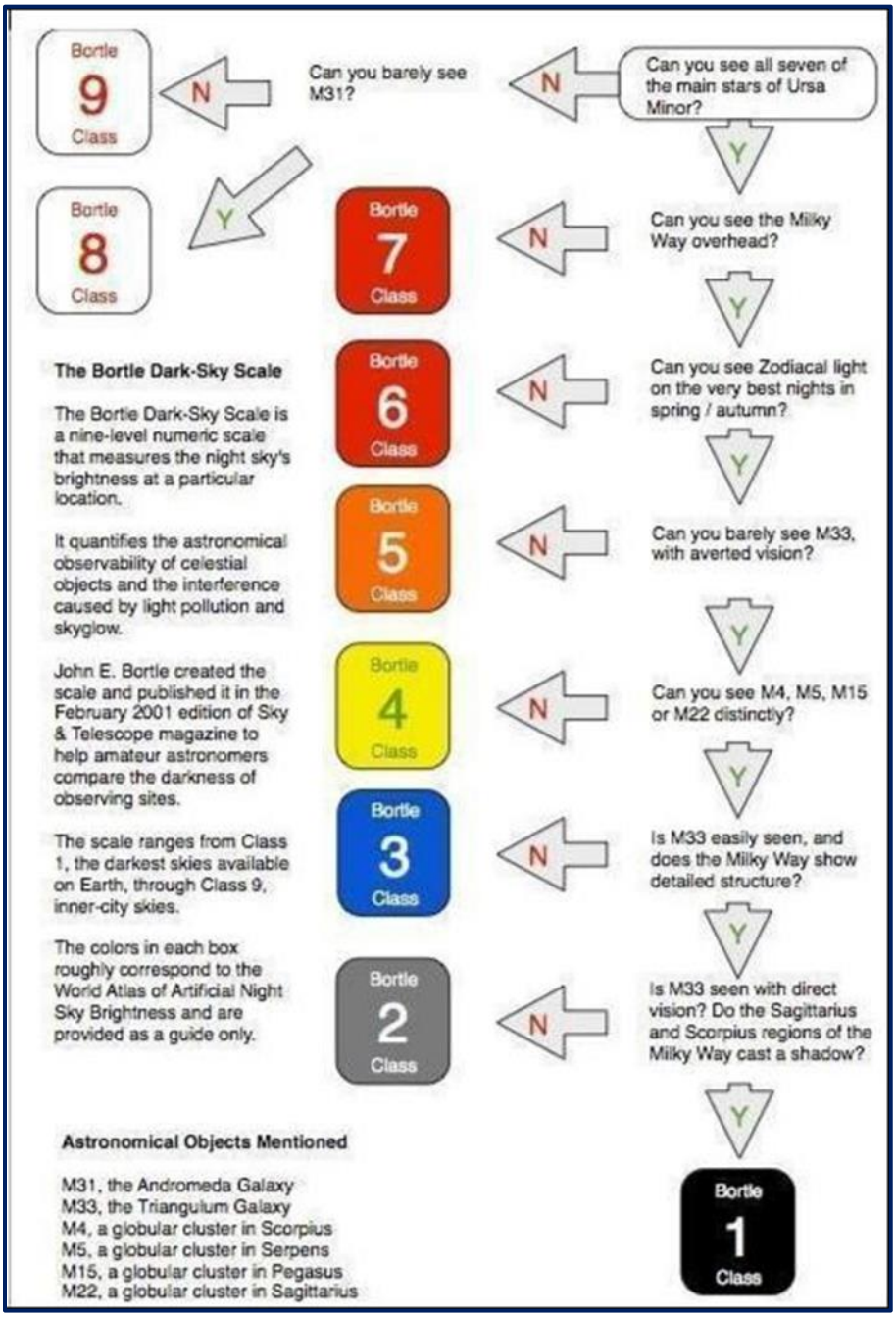


Figure 30: The IDA Bortle Scale flowchart.
(IDA, n.d.-a)

Appendix B: IDA Tier Designations

Indicator	Gold	Silver	Bronze
Philosophy	Nighttime environments that have negligible to minor impacts from light pollution and other artificial light disturbance, yet still display outstanding quality night skies and have superior nighttime lightscapes.	Nighttime environments that have minor impacts from light pollution and other artificial light disturbance, yet still display good quality night skies and have exemplary nighttime lightscapes.	Areas not meeting the requirements of *Silver*, yet still offering people, plants, and animals a respite from a degraded nocturnal environment and suitable for communicating the issue of light pollution and connecting people with the many aspects of the night sky.
Artificial Light and Skyglow	Typical observer is not distracted by glary light sources. Light domes are only dim and restricted to sky close to horizon.	Point light sources and glary lights do not dominate nighttime scene. Light domes present around horizon but do not stretch to zenith.	Areas with greater artificial light and skyglow than *Silver*, but where aspects of the natural sky are still visible.
Observable Sky Phenomena	The full array of visible sky phenomena can be viewed—e.g. aurora, airglow, Milky Way, zodiacal light, and faint meteors.	Brighter sky phenomena can be regularly viewed, with fainter ones sometimes visible. Milky Way is visible in summer and winter.	Many sky phenomena cannot be seen. Milky Way is seen when pointed out to the average person, as is the Andromeda Galaxy.
Nocturnal Environment	Area is devoid of obvious lights that can cause wildlife disorientation. Artificial light levels are thought to be below the threshold for plant and animal impact. Ecological processes related to nocturnality are unaltered. No lighting atop towers or buildings within Park boundary.	Areas that have minor to moderate ground illumination from artificial skyglow. Lights that may cause disorientation to wildlife are distant. Disruption of ecological processes is minor with no impairment to plants or wildlife.	Areas with greater nocturnal impact than *Silver*, but where ecosystems are still functional.
Visual Limiting Magnitude	Equal or greater than 6.8 under clear skies and good seeing conditions	6.0 to 6.7 under clear skies and good conditions	5.0 to 5.9 under clear skies and good seeing conditions
Bortle Sky Class	1-3	3-5	5-6
Unihedron Sky Quality Meter	> 21.75	21.74-21.00	20.99-20.00

Figure 31: The descriptions of the IDA tiers.
(IDA, 2015.)

Note: Gold is the most prestigious, whereas Bronze is the least Prestigious

Appendix C: Unihedron Sky Quality Meters

Unihedron makes several tethered and untethered models of the SQM. Their tethered models have the capability of remote or autonomous functions, along with continuous readings up to 80 seconds in length. These models all connect to a computer by a different form of communication (USB, Ethernet, RS232). The Unihedron untethered SQMs do not rely on being connected to a computer to take readings. Instead, each measurement is displayed on an LCD. They are battery powered, allowing for easy transportation. Unihedron sells two models of the untethered SQM: the SQM and the SQM-L. They both share the same specifications; however, the SQM-L has a narrower field of view. Based on the objectives of this project, the SQM-L was deemed sufficient and will be the SQM used for taking sky quality readings.

Due to the COVID-19 pandemic and our project being moved to an online format, we had to rely on the equipment that GNP staff had for sky quality measurements. They used the basic SQM model which has a wider field of view than the SQM-L.

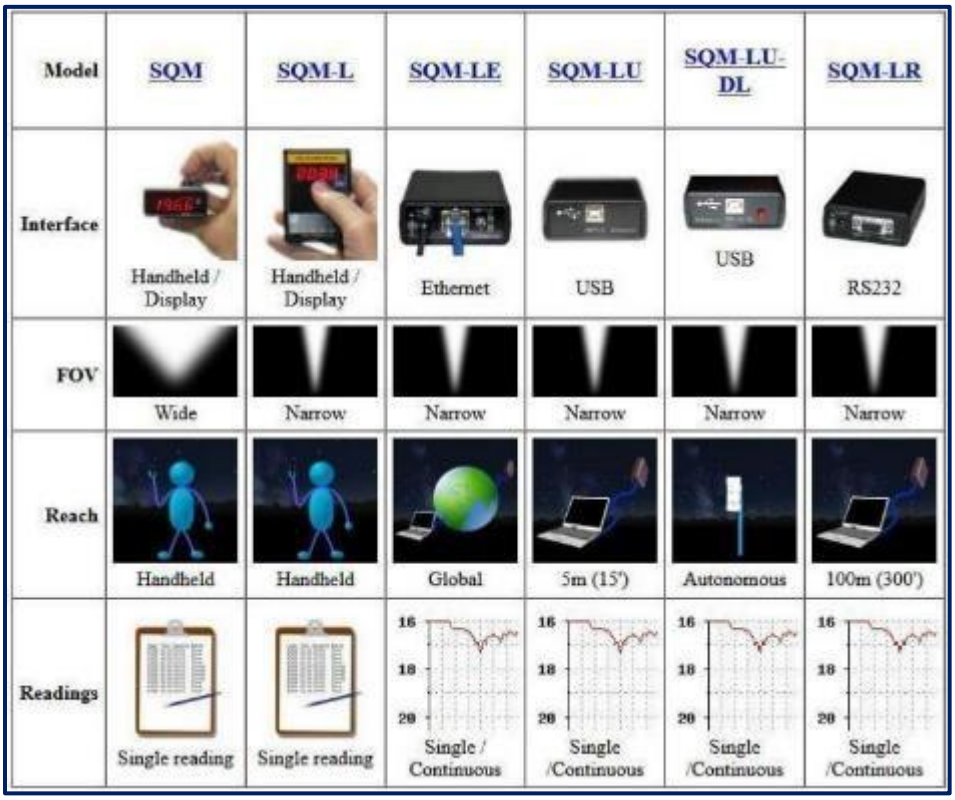
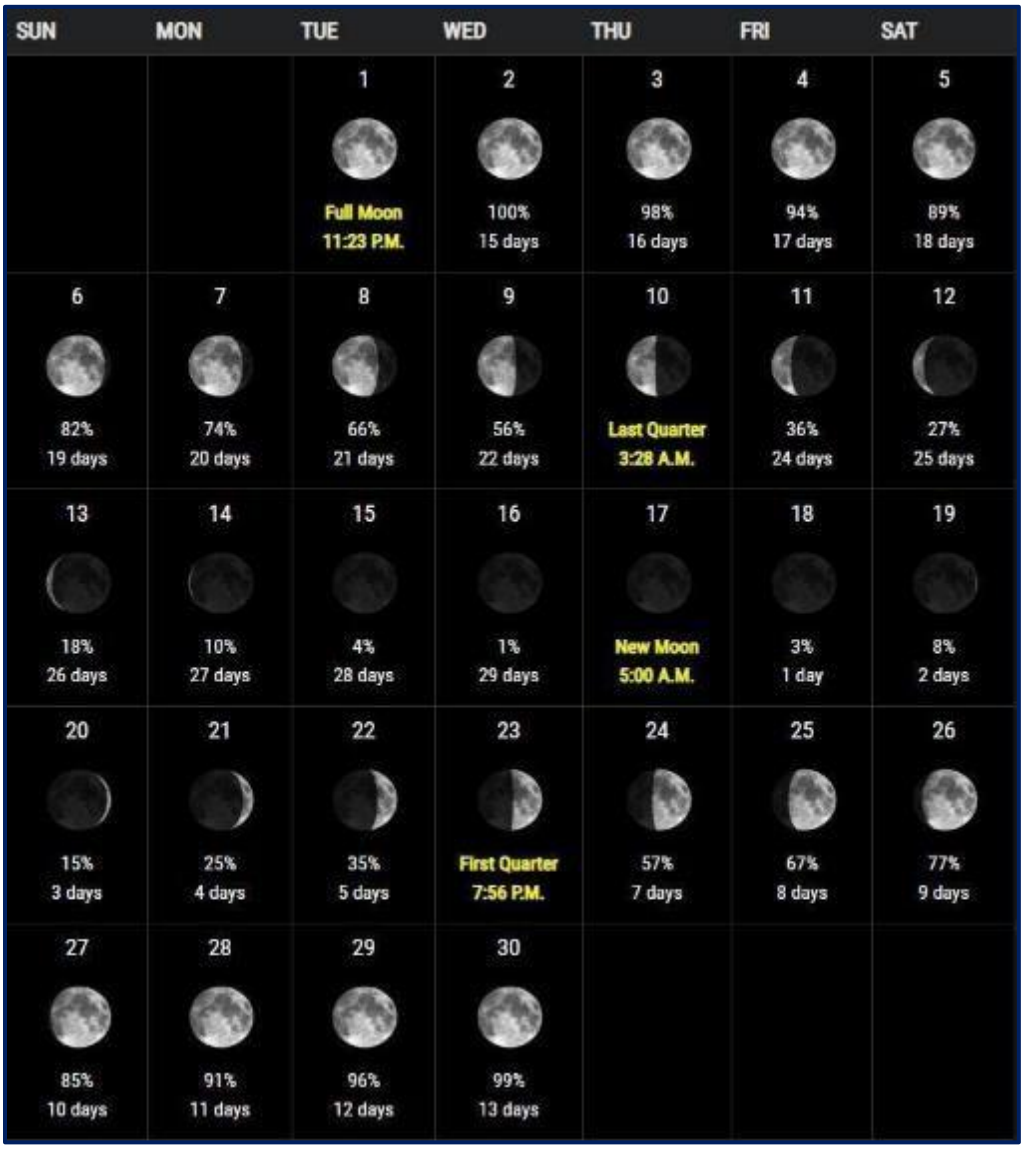


Figure 32: The different models of the Unihedron SQM.
(Unihedron, n.d.)

Appendix D: Rise/Set Times for the Sun and Moon



SUN	MON	TUE	WED	THU	FRI	SAT
		1 Full Moon 11:23 P.M.	2 100% 15 days	3 98% 16 days	4 94% 17 days	5 89% 18 days
6 82% 19 days	7 74% 20 days	8 66% 21 days	9 56% 22 days	10 Last Quarter 3:28 A.M.	11 36% 24 days	12 27% 25 days
13 18% 26 days	14 10% 27 days	15 4% 28 days	16 1% 29 days	17 New Moon 5:00 A.M.	18 3% 1 day	19 8% 2 days
20 15% 3 days	21 25% 4 days	22 35% 5 days	23 First Quarter 7:56 P.M.	24 57% 7 days	25 67% 8 days	26 77% 9 days
27 85% 10 days	28 91% 11 days	29 96% 12 days	30 99% 13 days			

Figure 33: The phases of the moon throughout September 2020.

(Moon Phase Calendar for 2020, n.d.)

		Sun		Astronomical Twilight		Moon		Phase	
Day	Time	Sunrise	Sunset	Start	End	Moonset	Moonrise	% light	% dark
1	1:00 AM	6:53 AM	8:15 PM	4:58:00	22:10:00	5:57 AM	8:37 PM	1.00%	99%
2	2:00 AM	6:54 AM	8:13 PM	4:59:00	22:07:00	7:05 AM	8:57 PM	0.00%	100%
3	3:00 AM	6:55 AM	8:11 PM	5:01:00	22:05:00	8:11 AM	9:16 PM	2.00%	98%
4	4:00 AM	6:57 AM	8:09 PM	5:03:00	22:02:00	9:17 AM	9:33 PM	5.00%	95%
5	5:00 AM	6:58 AM	8:07 PM	5:05:00	21:59:00	10:21 AM	9:51 PM	10.00%	90%
6	6:00 AM	7:00 AM	8:05 PM	5:07:00	21:57:00	11:25 AM	10:09 PM	16.00%	84%
7	7:00 AM	7:01 AM	8:03 PM	5:09:00	21:54:00	12:30 PM	10:31 PM	24.00%	76%
8	8:00 AM	7:02 AM	8:01 PM	5:11:00	21:52:00	1:36 PM	10:56 PM	32.00%	68%
9	9:00 AM	7:04 AM	7:59 PM	5:13:00	21:49:00	2:41 PM	11:28 PM	41.00%	59%
10	10:00 AM	7:05 AM	7:57 PM	5:15:00	21:47:00	3:45 PM		51.00%	49%
11	11:00 AM	7:07 AM	7:55 PM	5:16:00	21:44:00	4:45 PM	12:07 AM	61.00%	39%
12	12:00 PM	7:08 AM	7:52 PM	5:18:00	21:42:00	5:38 PM	12:57 AM	71.00%	29%
13	1:00 PM	7:09 AM	7:50 PM	5:20:00	21:39:00	6:23 PM	1:59 AM	80.00%	20%
14	2:00 PM	7:11 AM	7:48 PM	5:22:00	21:37:00	7:00 PM	3:11 AM	88.00%	12%
15	3:00 PM	7:12 AM	7:46 PM	5:24:00	21:34:00	7:31 PM	4:29 AM	95.00%	5%
16	4:00 PM	7:14 AM	7:44 PM	5:25:00	21:32:00	7:57 PM	5:52 AM	99.00%	1%
17	5:00 PM	7:15 AM	7:42 PM	5:27:00	21:29:00	8:21 PM	7:15 AM	100.00%	0%
18	6:00 PM	7:17 AM	7:40 PM	5:29:00	21:27:00	8:44 PM	8:40 AM	98.00%	2%
19	7:00 PM	7:18 AM	7:38 PM	5:30:00	21:25:00	9:08 PM	10:04 AM	94.00%	6%
20	8:00 PM	7:19 AM	7:35 PM	5:32:00	21:22:00	9:35 PM	11:27 AM	87.00%	13%
21	9:00 PM	7:21 AM	7:33 PM	5:34:00	21:20:00	10:06 PM	12:50 PM	78.00%	22%
22	10:00 PM	7:22 AM	7:31 PM	5:35:00	21:18:00	10:45 PM	2:08 PM	67.00%	33%
23	11:00 PM	7:24 AM	7:29 PM	5:37:00	21:15:00	11:32 PM	3:19 PM	56.00%	44%
24	12:00 AM	7:25 AM	7:27 PM	5:39:00	21:13:00		4:20 PM	45.00%	55%
25		7:26 AM	7:25 PM	5:40:00	21:11:00	12:28 AM	5:09 PM	35.00%	65%
26		7:28 AM	7:23 PM	5:42:00	21:08:00	1:31 AM	5:48 PM	26.00%	74%
27		7:29 AM	7:21 PM	5:44:00	21:06:00	2:38 AM	6:18 PM	17.00%	83%
28		7:31 AM	7:19 PM	5:45:00	21:04:00	3:47 AM	6:43 PM	10.00%	90%
29		7:32 AM	7:16 PM	5:47:00	21:02:00	4:55 AM	7:03 PM	5.00%	95%
30		7:34 AM	7:14 PM	5:48:00	20:59:00	6:02 AM	7:22 PM	2.00%	98%

Table 3: September 2020 Rise and set times for the Moon and Sun.
(timeanddate, 2020)

Appendix E: Lighting Replacement Totals

This Appendix consists of 2 Excel workbooks. These tables are located in the Lighting_Replacement_Totals folder and are labelled Lighting_Replacement_Totals.xlsx and Lighting_Needs.xlsx.

The Excel workbook Lighting_Replacement_Totals.xlsx delineates the area, the number of buildings in that area, the total fixtures in that area, the percentage of park fixtures in that area, the number of compliant fixtures in the area, the percentage of compliant fixtures in the area, the number of replacements recommended, the total number of equipment needed, and finally any notes for the area. The second worksheet only states which locations have streetlights.

The Excel workbook Lighting_Needs.xlsx has many more worksheets. First, the KEY worksheet provides a correlation between each color and the meaning of that color. Next, the Totals worksheet has 11 columns, those columns being:

- Developed area: which area the totals come from
- Total # of Bulbs: how many bulbs the area needs
- Total # of fixtures and bulbs: how many fixtures and bulbs the area needs to become 100% compliant
- Raymond RB-8W: the total number of Raymond RB-8W fixtures needed
- Progress P5695-16: the total number of Progress P5695-16 fixtures needed
- Wallpack: the total number of Wallpacks needed
- Calvin Wall Mount QS-2W: the total number of Calvin Wall Mount QS-2W fixtures needed
- Shielded PAR 16: the total number of Shielded PAR 16 bulbs needed
- Non shielded PAR 16: the total number of Non shielded PAR 16 bulbs needed
- PAR 30: the total number of PAR 30 bulbs needed
- Notes: any additional notes for the Area

One note is that the HQ areas are excluded from the totals on this sheet because the fixtures and bulbs are already in inventory.

The next 15 worksheets are all the same with one main difference per sheet: the worksheet is named with one of the areas in the totals sheet. The columns for this sheet are:

- Building #: the number of the building for the row
- Fixture Type: any specific notes for the building.
- Total # of items needed: the total number of bulbs and fixtures needed
- Raymond RB-8W: the total number of Raymond RB-8W fixtures needed

- Progress P5695-16: the total number of Progress P5695-16 fixtures needed
- Wallpack: the total number of Wallpacks needed
- Calvin Wall Mount QS-2W: the total number of Calvin Wall Mount QS-2W fixtures needed
- Shielded PAR 16: the total number of Shielded PAR 16 bulbs needed
- Non shielded PAR 16: the total number of Non shielded PAR 16 bulbs needed
- PAR 30: the total number of PAR 30 bulbs needed
- Notes: any additional notes for the building

One final note is that any changes to either workbook, outside of any formulas, is colored in blue font, as noted in the top of the “notes” column.

Appendix F: Lighting Inventory

This appendix consists of 17 Excel workbooks, located in the Lighting_Inventory folder and labelled with the name of an area. These workbooks consist of each individual building as a different worksheet. These worksheets are all named with the building number or building name. Furthermore, they consist of a wide picture of the building in question on the first row, then the subsequent rows are as follows:

- A wide picture of the fixture in question
- A detailed picture of the fixture in question
- The number of the light, numbered from 1 to n (n being the last fixture) sequentially
- The type of luminaire
- The light control mechanism
- Whether or not the light is shielded
- The wattage of the light
- The bulb type of the light
- The purpose or application of the light
- Whether or not the light is compliant
- Additional notes about the light
- The recommended replacement

This is repeated for each building in the area. Additionally, the workbook can contain a summary of the area, a template for the worksheet, and any streetlights present in the area.

Appendix G: 2020 SQM Data and Analysis

This document was uploaded with the appendices .zip file under the name WPI_SQM_Measurements_2020.xlsx and contains a spreadsheet with SQM data from 2016, 2020, and an analysis of the data.

Appendix H: Website Technical Details

Website URL:

https://wp.wpi.edu/darksky2020/

Website Host:

WordPress through WPI edublogs. Access for the website is detailed in the Website_Admin_Access.txt file that was uploaded with the additional files.

Website Builder:

Since no group members had web development experience, we chose to utilize the Divi website builder. This builder takes a visual approach to designing webpages compared to more a more traditional coding approach. The builder also has multi-platform integration in mind with the ability to see the website as it would look on a computer, tablet, or smartphone.

Color Layout:

When designing the website color palette, we obviously had a theme of dark skies in mind. Using the google design development website material.io, we were able to create the following color pallet, as shown in Figure 34.

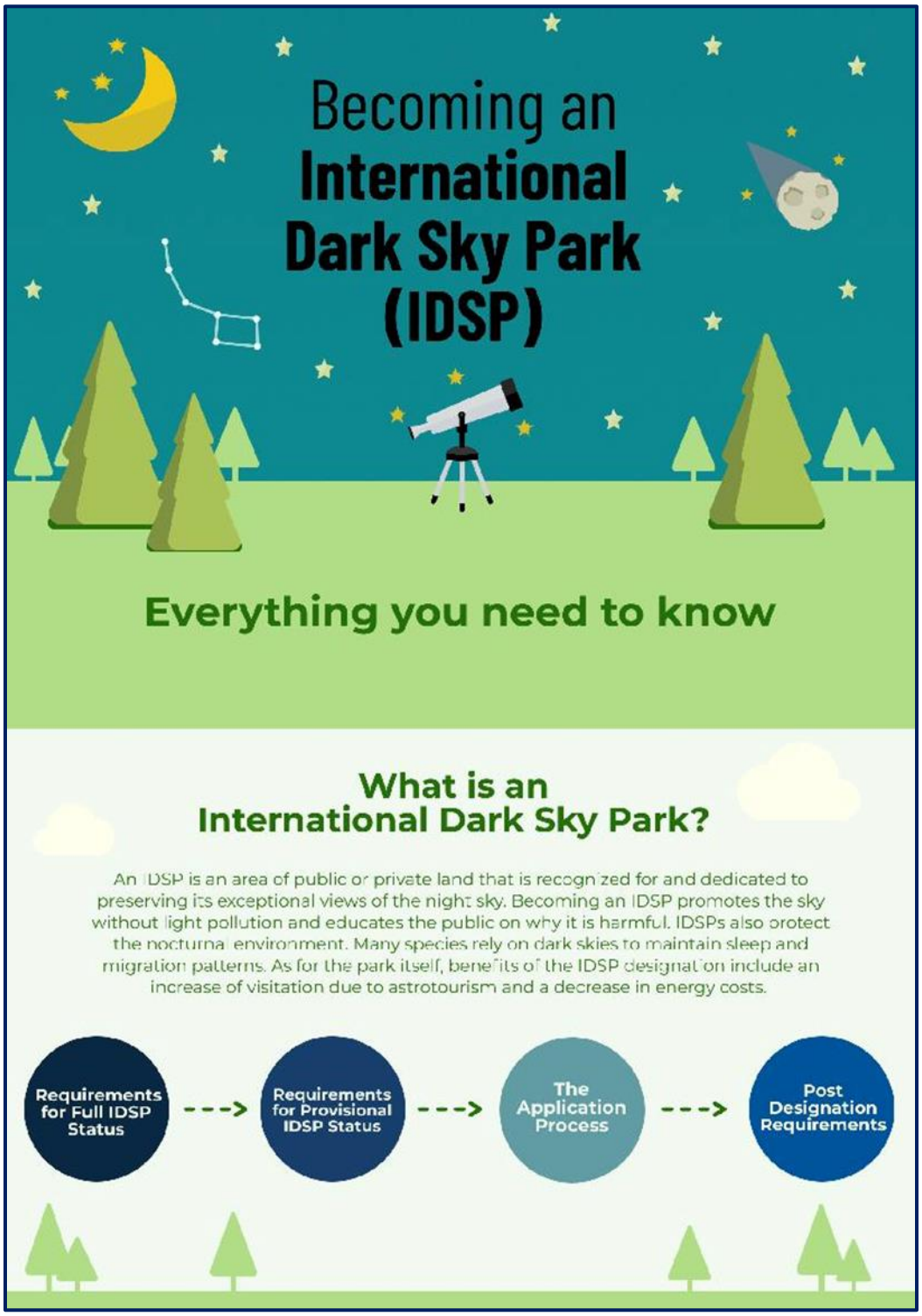
Figure 34: The website color pallet.

***Calendar and Google Form*:**

To facilitate the calendars and google form, we created a google account specifically for the website. We found that the google drive suite provided the best embeddable calendar and request form for our purposes. The email is *gnpdarksky@gmail.com*. Information regarding the login info was submitted with the additional documents folder.

Appendix I: IDSP Infographic

This document was also submitted with the additional materials as 2 PDFs, a long and a short version. Their names are IDSP_Infographic.pdf and IDSP_short_Infographic.pdf. It can also be found on the project website under the Consortium tab.




Requirements for Full IDSP Status
Refer to the IDA 2018 Guidelines for more detailed requirements.
Must be protected public or private with regular nighttime public access
Must create a Lighting Magagement Plan
Milky Way is Visible to the naked eye
Minimal light glare is present and any light domes are close to the horizon
Commitment to preserving Dark Skies
Must be able to set a leadership example in the conservation community
Requirements for Provisional IDSP Status
This designation is intended to help the park gain resources and support until full IDSP status can be achieved
Must create a lighting inventory
Must create a Lighting Management Plan
Must have made outreach efforts
Sky quality criteria is met


The Application Process
Refer to the IDA 2018 Guidelines for what to include in the application.
Reach out to the IDA to discuss getting started
Assign a manager to the project
Obtain a letter of nomination from an IDA qualified nominator
Write IDSP Application
Send application to IDA for review
Post Designation Requirements
Write a small annual report to show progress towards meeting the goals of the Lighting Management Plan
Thank you for celebrating the night sky and protecting our planet's resources!
References:
International Dark Sky Association. (2018). International Dark Sky Association Dark Sky Park Program Guidelines. Retrieved Apr. 9, 2020, from https://www.darksky.org/wp-content/uploads/2018/12/IDSP-Guidelines-2018.pdf

Appendix J: 2020 IDA Report, Glacier National Park Addendum

This file was also uploaded with the additional materials for this project. It starts on the next page to preserve the formatting of it. Since the report had already been submitted to the International Dark Sky Association, it serves as an addendum for Glacier National Park's portion of the report.

Waterton-Glacier International Dark Sky Park
2020 Annual Report Addendum

General

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This addendum details the results of a research project that was conducted in partnership with Glacier National Park but was not included in the 2020 annual report submission. A team of five students from Worcester Polytechnic Institute (WPI), Massachusetts, USA, worked with the park over a 7-week period from the end of August to mid-October. The purpose of their project was to assist Glacier National Park with advancing from provisional IDSP status to full IDSP status. To accomplish this, the team analyzed GNP's lighting inventory, dark sky educational programs, and night sky quality. They determined that sky quality has improved to gold tier status as of the 2020 measurements. They also created resources to facilitate and expand the park's dark sky outreach programs. The team's analysis determined that Glacier is on track to achieve its IDSP goals. A set of recommendations was compiled and presented to the park.

WPI Project Website: wp.wpi.edu/darksky2020

WPI Research Paper (found at bottom of webpage): https://wp.wpi.edu/darksky2020/about/

Lighting

The WPI team analyzed GNP's lighting inventory and determined that the park currently has a 61% lighting compliance. However, the park has the fixtures on hand to achieve 74% compliance, which would surpass the 67% lighting compliance needed by March 2021 (three years after initial IDSP application) to achieve full IDSP designation. The park plans to install these fixtures in the Many Glacier, St. Mary, and East Glacier areas before the March deadline. A list is currently being developed to detail the purchase of the same light fixtures for the remaining areas of the park.

Sky Quality

As mentioned in the main report, in September of 2020, Glacier National Park staff took sky quality measurements at 7 of the 8 locations included in the 2017 IDSP application. Due to accessibility issues, measurements were not taken at site 7, Huckleberry Mountain, but will be included in future years. The test site locations are as follows:

1. Park Boundary, Chief Mountain International Peace Park Highway
   (48°58'54" N, -113°36'60" W)
2. Many Glacier Valley at Sherburne Lake Dam / Park Boundary
   (48°49'75" N, -113°31'47" W)
3. Going to the sun Road at one-mile gate, near St. Mary
   (48°44'23" N, -113°27'48" W)
4. Lake McDonald Lodge
   (48.629, -113.869 W)
5. Apgar Village, on dock
   (48.528 N, -113.985 W)
6. Polebridge Entrance Station
   (48.783 N, -114.28 W)
7. Huckleberry Mountain [Not tested in 2020]
   (48.6N, -114.14W)
8. St. Mary Visitor Center
   (48.74N, -113.44W)

The WPI team compared the sky quality measurements from the 2017 IDSP application to the 2020 measurements. As shown in the table on the next page, the average of the sky quality measurements (excluding Huckleberry Mountain) rose 0.16 mpsas, to 21.82 mpsas. Several measurement locations also changed tiers; three advanced from silver to gold tier, and one site lowered from gold to silver tier. These changes now raise the park's sky quality average above 21.75 mpsas, the minimum requirement for gold-tier status.

Table 6: The highlight on the 2016 and 2020 Avg columns denotes what status the average measurement achieves, yellow denotes gold tier status and grey denotes silver tier status.

Site Number	Description	2016 Measurements	2016 Avg	2020 Measurements	2020 Avg	Status	Δ (mpsas)
1	Park Boundry, Chief Mountain International Peace Park Highway (48°58'54" N, -113°36'60" W)	No Reading	21.792	21.60	21.77	Lighter	-0.02
		21.73		21.84			
		21.77		21.73			
		21.82		21.67			
		21.82		21.84			
		21.82		21.79			
2	Many Glacier Valley at Sherburne Lake Dam / Park Boundry (48°49'75" N, -113°31'47" W)	No Reading	21.81	21.55	21.73	Lighter	-0.08
		21.80		21.74			
		21.80		21.93			
		21.80		21.66			
		21.83		21.67			
		21.83		21.67			
3	Going to the Sun Road at one mile gate, near St. Mary (48°44'23" N, -113°27'48" W)	No Reading	21.81	21.70	21.77	Lighter	-0.04
		21.82		21.69			
		21.80		21.78			
		21.81		21.89			
		21.81		21.81			
		21.83		21.70			
4	Lake McDonald Lodge On the beach near the river inlet (48.629 N, -113.869 W)	No Reading	21.59	21.92	21.90	Darker	0.31
		21.60		21.94			
		21.41		21.88			
		21.68		21.90			
		21.68		21.90			
		21.58		21.88			
5	Apgar Village, on dock (48.528 N, -113.985 W)	No Reading	21.51	21.88	21.86	Darker	0.35
		21.44		21.88			
		21.57		21.90			
		21.57		21.85			
		21.49		21.83			
		21.50		21.86			
6	Polebridge Entrance Station (48.783 N, -114.28 W)	No Reading	21.54	22.12	22.13	Darker	0.60
		21.52		22.18			
		21.49		22.11			
		21.52		22.09			
		21.57		22.13			
		21.58		22.15			
7	Huckleberry Mountain (48.6 N, -114.14 W)	No Reading	21.65	0.00	21.65	No Change	NA
		21.65		0.00			
		21.65		0.00			
		21.65		0.00			
		21.65		0.00			
		21.65		0.00			
8	St. Mary Visitor Center (48.74 N, -113.44 W)	No Reading	21.56	21.59	21.58	Darker	0.02
		21.56		21.56			
		21.56		21.59			
		21.56		21.56			
		21.56		21.53			
		21.56		21.68			
		Avg	21.66		21.82		0.16

Outreach

Websites

To enhance GNP's outreach and online presence, the WPI team developed a Dark Sky website called "Glacier's Night Skies". The educational website, located at http://wp.wpi.edu/darksky2020, is designed to facilitate all information regarding Glacier's Night Skies. A flowchart of the website can be found in Figure 4.

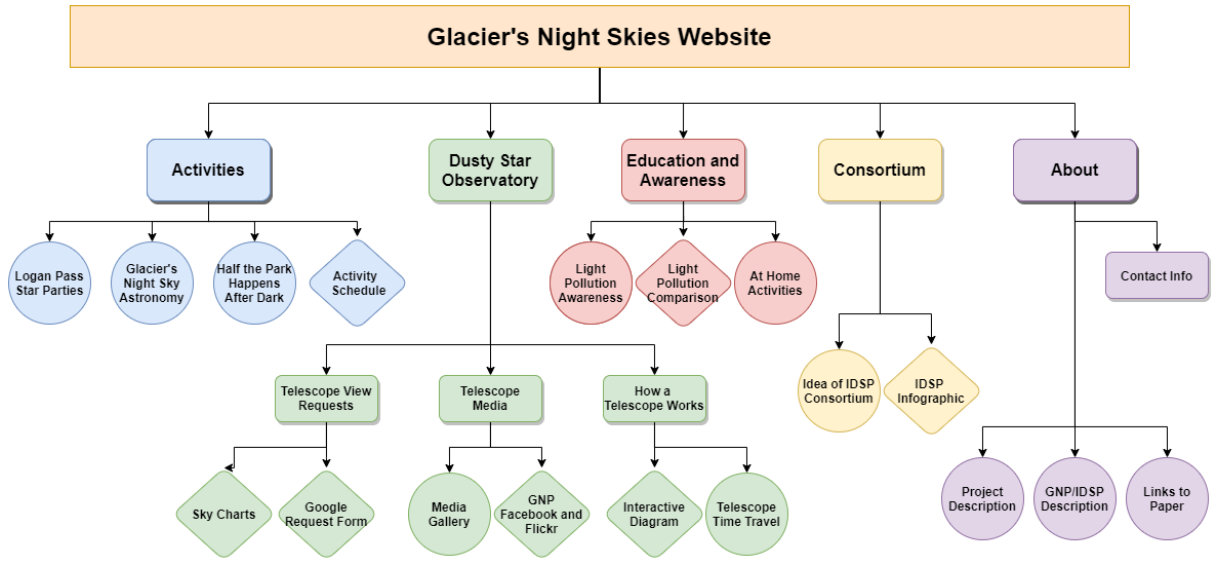

Figure 4: The flowchart for the Glacier's Night Skies website.

The website expands upon GNP's education and outreach by containing information about its three current outreach programs: *Logan Pass Star Parties, Half the Park Happens After Dark,* and *Glacier's Night Skies.* The website also contains a calendar that documents when each program occurs to simplify trip planning for visitors.

The website enhances the outreach of the Dusty Star Observatory, which opened in 2019 at St. Mary. The WPI team created a system where users can request an image taken through the observatory's telescope. Users can determine visible celestial objects by using the website's embedded calendars and interactive sky simulators. Images taken by the observatory can be uploaded to the website's media gallery. Lastly, the website contains information about how telescopes work, including an interactive feature that highlights each component of the Dusty Star Observatory Telescope.

A page of the website is dedicated to dark sky awareness, which explains the causes and classifications of light pollution, as well as how light pollution affects the environment, humans, and wildlife. At-home educational activities for children are also found on this page.

Infographic

The WPI team also created an infographic about becoming an IDSP. This infographic is meant to encourage and help qualified locations take the first step towards becoming an IDSP. Figure 5 shows a condensed version of this infographic. The full-sized infographic can be found on the Dark Sky website.

Figure 5: A condensed version of the IDSP infographic.

Social Media

For International Dark Sky Week 2020, Glacier National Park created a video titled "Glacier's Dark Skies". Statistics about the video are shown below for YouTube, Instagram, and Facebook. Note: The WPI team did not create the video but felt that it should be mentioned in the annual report.

Table 7: Summary of Glacier National Park Dark Sky Material on YouTube.

Date	Messaging	Likes	Dislikes	Views
April 23, 2020	Glacier's Dark Skies This video highlights the dark skies of Glacier National Park and describes the efforts taken to designate the park as an official International Dark Sky Park 	114	0	5,729

Table 8: Summary of Glacier National Park Dark Sky Material on Instagram.

Date	Messaging	Likes	Comments
April 20, 2020	Same as First Facebook Post	11,575	33
April 24, 2020	International Dark Sky Week continues! And to celebrate, we want to share our new video, "Glacier's Dark Skies." This beautiful film highlights Glacier's epic night skies and the efforts currently being made to establish Waterton-Glacier as an official International Dark Sky Park. We hope you enjoy the video, and don't forget to look up at the sky tonight! What is it you see? *https://www.youtube.com/watch?v=suXpf_tmkps* An audio described video is also available at https://youtu.be/4KJrTxt3uNk [image description: A bright, yellow-blue arches across the mountains, its reflection shines in the lake below.] 	13,538	50

Table 9: Summary of Glacier National Park Dark Sky Material on Facebook.

Date	Messaging	Likes	Reactions	Shares	Comments
April 20, 2020	It's International Dark Sky Week! This is a time to celebrate the shared heritage and stories of the stars, the science and discoveries of astronomy, the critters and creatures of the night, and a perfect opportunity for you to turn down/off an outdoor light, step outside, and look up. Glacier National Park is an International Dark Sky Park (provisional status) in conjunction with Waterton Lakes National Park across the border in Canada. In Glacier's nearly light pollution free skies we see more stars than we can count! Not to mention being able to view the distinct glow of our Milky Way Galaxy. With the aid of binoculars or a telescope, you can even see deep space objects like star clusters, galaxies, and colorful nebulae. So, tonight, take a moment to gaze at the sky above your home and know that the same beauty above Waterton-Glacier International Dark Sky Park is there, the only difference may be your porch light...maybe turn it off and see? And stay tuned! Later this week, we will promote our new Dark Sky video that highlights Glacier National Park's epic night skies and the efforts made to protect them! 	1,600	428	316	40

Date	Messaging	Likes	Reactions	Shares	Comments
April 24, 2020	International Dark Sky Week continues! And to celebrate, we want to share our new video, "Glacier's Dark Skies." This beautiful film highlights Glacier's epic night skies and the efforts currently being made to establish Waterton-Glacier as an official International Dark Sky Park. We hope you enjoy the video, and don't forget to look up at the sky tonight! What is it that you see? https://youtu.be/suXpf_tmkps An audio described video is also available at https://youtu.be/4KJrTxt3uNk 	857	228	294	33