# APPENDIX G: METHOD FOR SOUND MODELING AND ANALYSIS OF AIRCRAFT SOUND IMPACTS

The Federal Aviation Administration's Integrated Noise Model version 6.2a was used to evaluate aircraft sound associated with the existing operation of the Jackson Hole Airport (airport), and impacts on the natural soundscape in Grand Teton National Park that would result from each alternative. Integrated Noise Model version 6.2a includes the ability to assess aircraft sound audibility in areas such as national parks where impacts on natural soundscapes are a growing concern.

The Integrated Noise Model version 6.2a (the model) was used to estimate the percent-time audible, the maximum sound level, the time above 60 dBA, and the Leq (energy-average sound level) from aircraft arrivals and departures from the Jackson Hole Airport. The model estimated aircraft sound impacts using A-weighted and one-third octave band decibel levels. The Federal Aviation Administration and John A. Volpe National Transportation Systems Center (the author of the model and part of the U.S. Department of Transportation's Research and Innovative Technology Administration) provided technical consultations throughout the modeling process. The airport's control tower staff furnished key inputs, including actual aircraft flight tracks for the Jackson Hole Airport.

At the time of this analysis, the Integrated Noise Model version 6.2a was the best available model for estimating sound caused by aircraft. The model was developed, distributed, and sanctioned by the Federal Aviation Administration, and is used worldwide assess impacts associated with airport operations. However, all computer models have limitations in accurately representing reality. Formal model validation not was conducted in this study, but the model results were compared to field measurements at a number of sites. This comparison suggests that the model did a good job of estimating aircraft audibility of current conditions (see more details below).

Nevertheless, models are best used to evaluate the relative effects of alternatives rather than to make absolute depictions of reality. Therefore, the current condition of the park's soundscape based on modeled results of recent airport operations (described in the "Affected Environment" section), rather than actual field measurements, provided the best comparison for predicting changes in the soundscape that would occur with the airport operations that were forecast for each alternative.

## MODEL INPUTS

Integrated Noise Model 6.2a required specific information to forecast sound impacts of the alternatives. Model inputs included the following:

### Aircraft Fleet Mix and Numbers of Operations by Aircraft Type for Each Year Modeled

A list of aircraft types that fly into and out of the airport was developed. Data included aircraft type, departures, arrivals, number of daytime operations, nighttime operations, and flight length of departing flights (stage length).

Daily averages of these factors on an all-year basis were developed from the Federal Aviation Administration's records of actual operations at the Jackson Hole Airport from October 2004 through September 2005.

The months of July, August and September were defined as the peak season for airport use. Daily averages during the peak season were developed based on the 2005 airport-use records.

### Flight Track Information, including Aircraft Arrival and Departure Paths

Flight tracks are the aerial paths used by the aircraft that fly into and out of the airport. Arrivals, departures, and touch-and-go patterns were developed geographically from interviews with air traffic control tower staff. Each aircraft operating on a flight track also has an associated arrival and departure profile that is used within the Integrated Noise Model to define the altitude of the aircraft along the flight track. Thirteen arrival tracks and eight departure tracks were used to model the airport operations.

The Federal Aviation Administration's Air Traffic Control Beacon Interrogator-6 (BI-6) aircraft tracking system, which was installed at the Jackson Hole Airport in 2008, has improved the ability to map flight tracks at the Jackson Hole Airport. Flight tracks for a random sample of jet aircraft arriving at and departing from the Jackson Hole Airport during the period from January through July 2010 are provided in Figures G-32 and G-33. The BI-6 data were not incorporated in the model because this system was not operational when the modeling was done, but they show good correlation with the flight tracks that were developed for actual aircraft operations from October 2004 through September 2005.

### All-Year and Peak-Season Natural Ambient Sound Levels, in One-Third Octave Frequency Bands

Aircraft sound audibility is a function of the background or ambient sound levels within an environment. *Management Policies 2006* (NPS 2006a) states that noise impacts to park natural soundscape must be compared to the natural ambient sound level. The natural ambient sound level is the level of sound that occurs in an area without intruding sounds from non-natural sources. Long-term ambient sound measurements have been collected in the park by the National Park Service since 2003. From these extensive measurements, natural ambient data sets were prepared by the National Park Service for all-year average natural ambient and for peak-season natural ambient sound levels. These data sets, which are summarized in Table G-1,) were approved by the Federal Aviation Administration. The John A. Volpe National Transportation Systems Center, which is part of the U.S. Department of Transportation's Research and Innovative Technology Administration, prepared an ambient binary file from the NPS measurement data that was used to enable the audibility metrics within the Integrated Noise Model. See additional details below.

### Ground Surface, Temperature, and Humidity

Average meteorological data were used for the airport area, including a temperature of 55 degrees Fahrenheit, a barometric pressure of 20.92 inches of mercury, and a standard headwind of 8 knots. These were used for both all-year and peak-season computations.

### Topography

Topographical terrain data for the airport, the surrounding land areas, and all of the park was obtained from the U.S. Geological Survey data distribution system. Medium resolution data were downloaded from the Internet and used within the Integrated Noise Model to determine the distance of aircraft from ground positions.

Integrated Noise Model 6.2a also can use terrain data to compute the sound reduction caused by topographical features that block the line-of-sight to aircraft when viewed from certain positions on the ground. However, because of the extremely long computation time required when this option is selected in the model, the block-line-of-sight option was used only on the percent-time audible computations. The "soft ground" option was employed as an input.

### Sound Footprints for Each Aircraft Used in the Model

As shown in Figure 14, the takeoff and landing sound footprints among classes and models of aircraft vary widely. Therefore, it was important for model inputs to include the best possible estimates of the numbers and models of aircraft that will be using the Jackson Hole Airport during the modeled period.

The aircraft fleet mix and use rates that were used for modeling the alternatives in 2015 and 2025 were based on *Jackson Hole Airport Aircraft Operations Forecast: 2010-2025*, which was prepared by The Boyd Group, Inc. (2007a). Supplemental information on fleet mix was provided in an email (The Boyd Group, Inc. 2007b). However, some of the aircraft identified by The Boyd Group, Inc. were not among the selections available within the model. Therefore, the Federal Aviation Administration was contacted to identify appropriate surrogates.

The resulting aircraft types and use rates that were used in modeling of Alternative 2 are presented in Table 33. Alternative 1 used the same data except that operations associated with scheduled passenger service (that is, air carrier and regional carrier operations) were eliminated because they would not occur under this alternative. See additional details of the aircraft forecasts on in the related discussion in Chapter 4.

## LIMITATIONS OF THE MODEL

### Model Inputs

Most of the model inputs are averages or median values rather than the actual constantly varying values. These averages, such as aircraft operations, fleet mix, flight routes, temperature, humidity, and natural ambient sound level, by definition create model results based on average conditions. Individual hours, days, or other time periods will depart from these average conditions; half higher and half lower than the average values. Other factors that affect sound propagation or attenuation, sometimes strongly, are not included in the model. Examples of these factors include temperature inversions and vegetation. During temperature inversion sounds from the ground or near ground operations at the airport would propagate farther distances, sometimes substantially farther, than during non-inversion periods.

The model also did not consider the effects of major social shifts, such as population segments massively entering or leaving the Jackson housing (and travel) market, or large changes in fuel costs that could affect recreational travel. The model results must be interpreted with the understanding that these types of factors could alter the findings.

### Overlapping Aircraft Events

In calculating percent-time audible, the model used an unrealistic, though necessary, input that aircraft operations occur at evenly spaced intervals throughout the daily 15-hour time period and that the sound associated with each operation is a unique event. In practice, aircraft operations may be clustered. During busy periods, sounds from two or more aircraft may overlap and would reduce the percent of time during the day that aircraft sound is audible. Therefore, the actual percent-time audible could be lower.

The overlap of sound from more than one aircraft could also produce a higher sound level than either plane alone. As a result, the maximum sound levels (Lmax) calculated by the model sometimes could be underestimated. However the combined sound level would be no more than 3 dBA greater than the louder sound alone.

### Masking

Most aircraft operations occur during the day when there are many other human-caused sounds that could potentially obscure or mask sounds from aircraft. Examples include sounds from road vehicles, building utilities, and human voices. These other human-caused sounds are not accounted for in the model and, whenever they were present, they would mask aircraft sounds and reduce the percent-time audible for aircraft using the airport. Impacts from other sources of human-caused sounds are addressed qualitatively in the cumulative impacts discussion for each alternative.

Some areas of the park, particularly sites in windy locations or along rivers or creeks, would naturally mask aircraft sounds. Transient natural sounds, such as rain and thunder, also occur. In these circumstances, the modeled percent-time audible values for aircraft would be overestimated. In areas of the park that are much quieter than the average natural ambient sound level used in the model, the model would underestimate the aircraft percent-time audible.

### Other Non-Airport Aircraft

The airspace over the park is regularly used by aircraft ranging from general aviation aircraft making local flights a few thousand feet above the ground to transcontinental aircraft flying at an elevation of several miles. The controlled airspace is within 3,000 feet above the ground and within 5 miles of the tower. The model does not account for flights by transient aircraft not associated with operations at the airport. Instead, the effects of transient aircraft are included in the discussion of other human-caused sound in the cumulative impacts for each alternative.

### Daily Averages Rather than Hourly

Eight model runs were used to evaluate the alternatives. These include four runs to determine daily averages for all-year and peak-season conditions in 2015 and 2025 for the no action alternative, and four similar runs for the action alternative. Modeling used a 15-hour day (7 A.M. to 10 P.M.). Hourly, rather than daily, estimates would have produced a more precise representation of actual conditions, but would have required many additional model runs. It was decided that such an approach would not substantially change the understanding of impacts from the alternatives.

### New Technology

The model does not account for new technology, such as quieter engines, that could reduce aircraft sound by 2015 or 2025, or major advances in aircraft technology because there is no known method for accurately estimating the reductions. It also did not incorporate possible future navigational advances, such as those described in Chapter 2 under "Mitigation Measures Common to Both Alternatives.” As stated by The Boyd Group, Inc. (2007a) in their forecast of airport operations, new technologies "may render historical data and assumptions . . . useless in forward-looking projections."

### Fleet Mix Forecast

In August 2007, the Boyd Group (2007a and 2007b) provided an updated forecast of aircraft operations and aircraft types for the periods 2010, 2015, 2020, and 2025 for the Jackson Hole Airport. The forecast addressed commercial, regional, business, and general aviation categories. These forecasts were used as the basis for modeling aircraft sound profiles and emissions in 2015 and 2025 and have inherent assumptions that were described under the heading, ” Assumptions Used in Developing Airport Operations Forecasts” in Chapter 4.

### Aircraft Operating outside Modeled Period

This item is not actually a model limitation, but a limitation of how we implemented the modeling. The 15-hour day between 7 A.M. and 10 P.M. was used for the modeling of aircraft sound impacts. The rationale was that the vast majority of aircraft operations occur within this time period. Averaging a longer time period would tend to dilute the resulting impacts, i.e., the metrics would be average over a longer period, thereby appearing to be smaller.

### Conclusion

It was concluded that the limitations and assumptions of the model identified here do not invalidate the results, particularly because the analysis involves comparing existing conditions and alternatives that were all modeled within the same limitations. The individual assumptions and limitations variously may have over or under-estimated the impacts on the park’s soundscape which would have likely cancelled strong bias in either direction. Based on the comparison between the model results and field measurements, the model did a good job of estimating audibility.

## MODEL PRODUCTS

Four sound metrics were selected by the National Park Service to analyze natural soundscape impacts that would result from the alternatives. Each sound metric was based on a 15-hour day from 7 A.M. to 10 P.M. that reflected actual operations that result from the voluntary curfew and the absence of tower staffing and runway maintenance after the last scheduled passenger flight of the evening. Descriptions of these sound metrics are as follows:

**Percent of Time Audible**. This metric indicates the percent of time that aircraft sound is audible at a ground location within the park. This metric is cumulative of all aircraft operations occurring during the daytime period. Actual peak-season and all-year natural ambient sound measurements were used in the Integrated Noise Model, respectively with the peak-season flight operations and all-year operations, to compute the percent audibility. If the percent-time audible value is multiplied times the number of minutes in 15 hours (900), it provides the actual time in minutes that aircraft sound is audible at a ground location.

**Maximum A-Weighted Noise Level**. This metric indicates the highest sound level that would occur at a ground location caused by aircraft during an approach or departure operation. The maximum sound level is caused at a moment in time by a single aircraft, but may occur multiple times throughout the day from various aircraft or multiple operations of the same type of aircraft. This metric is not cumulative and, therefore, is the same during the peak-season and all-year operations and during operations in 2015 and 2025. The model cases where the maximum sound level would change was for Alternative 1 where the types of aircraft using the airport were restricted to general aviation.

**Time Above 60 dBA**. This metric shows the cumulative number of minutes in which aircraft sound is greater than 60 dBA. Because this metric is cumulative, peak-season operations at the airport generate higher values than the all-year operation, and alternatives with more operations generate higher values than alternatives with fewer operations.

**Leq (15-hour Leq, loosely equivalent to a day-night average sound level [variously abbreviated as DNL or Ldn]**). This metric is an energy-averaged sound level that represents the total sound exposure over a specified period of time. The 15 hours between 7 A.M. and 10 P.M. were used for this analysis to represent the operations of the Jackson Hole Airport, where night operations are controlled by a voluntary curfew.

There were a total of 659 modeling points inside and outside Grand Teton National Park. The points, all of which are the section corners from the U.S. Geological Survey topographic maps of the area, are on a 1-mile grid. The locations of the modeling points were provided in Figure 8 in Chapter 3 of the environmental impact statement.

- A total of 489 modeling points are inside the park boundary. All four sound metrics were modeled for each of the points in the park.
- Another 170 modeling points were outside the park within a 10-mile radius of the runway center-point. The maximum sound level (Lmax), time above 60 dBA, and Leq sound (15-hour Leq) were modeled for points outside the park.

Results for the 659 points were summarized as tables that are available on the Grand Teton National Park Internet site **at <www.nps.gov/grte/parkmgmt/planning.htm>. Th**e Integrated Noise Model produced quantitative values for the following conditions:

- Existing conditions (using 2005 as the baseline) for all-year and peak-season conditions.
- Alternative 1 for 2015 and 2025 for all-year and peak-season conditions.
- Alternative 2 for 2015 and 2025 for all-year and peak-season conditions.

For the modeling points in the park, the sound metrics derived from the Integrated Noise Model were compared to natural soundscape impact threshold criteria to estimate the effects of aircraft sound emissions under both all-year and peak-season conditions.

## NATURAL AMBIENT DETERMINATION AND VALUES USED FOR GRAND TETON

*What is the natural ambient sound level?*

The natural ambient sound level is the level of sound which occurs in an area without intruding sounds from non-natural sources. *Management Policies 2006* (NPS 2006a) mandate that noise impacts to park natural soundscape be compared to the natural ambient sound level.

*How is natural ambient determined?*

The natural ambient sound level can be measured directly in areas free from human-caused sounds and often is constantly varying over time and is dependent on habitat type and location. To compare proposed noise impacts to this highly variable natural condition it is necessary to simplify this natural sound level environment. To do this, the natural ambient is defined by a single decibel level (composed of the associated 1/3 octave band frequencies that are used in the model) that serves as an analog of the natural ambient condition.

*How are natural ambient levels calculated in environmental analyses?*

Over the past several decades the natural ambient (or background level) has been described by several governmental agencies (including the National Park Service, U.S. Environmental Protection Agency, and by state agencies in Massachusetts, Illinois, and Connecticut) using L90 as an analog. The L90 is the sound level (in A-weighted decibels) that is exceeded 90% of the time.

In recent years, several alternative measures of the natural ambient have been explored and tested. For air tour planning the NPS Natural Sounds Program suggested using the median (L50) levels of each of the 1/3 octave band frequencies from sound levels without the presence non-natural sounds. [The overall A-weighted decibel level can then be calculated by the sum of these 1/3 octave band frequencies]. When there are non-natural sounds present, the percent time they are audible can be documented and that percentage of the highest sound levels can be removed. Then the natural ambient is defined as the median value of the remaining sound levels. This technique requires knowledge of the percent time non-natural sounds are audible and assumes that the highest sound levels are from non-natural sources. This technique is currently being used by the NPS Natural Sounds Program and the Federal Aviation Administration in air tour management planning.

*How did the National Park Service choose natural ambient sound levels for the Jackson Hole Airport environmental impact statement?*

Given that we did not have known percent-time audible of non-natural sounds at all sites and at all time we used the L90 as an analog of the natural ambient sound level.

*What natural ambient levels did the National Park Service use?*

Because most aircraft operations at Jackson Hole Airport and most visits to the park occur during the summer, the peak summer months of July through September were used as the basis of most soundscape impact analyses. Natural ambient levels were calculated for both peak-season and all-year conditions. Because natural ambient conditions differ depending on habitat type and structure, natural ambient levels were calculated for both open and forested habitats.

*What data were available to calculate natural ambient sound levels?*

Although noise specialists at Grand Teton National Park have acoustic data from many monitoring sites, few locations had data for the entire peak and all-year time periods. The L90 sound levels (7 A.M.to 10 P.M.) from those sites and times that represented open and forested habitats during the peak (2,500 hours of monitoring data) and all-year (13,000 hours of monitoring data) time periods were used for the four L90 A-weighted decibel levels (Table G-1) (along with the associated the 1/3 octave band L90s model inputs for the frequencies from 50 Hz to 10,000).

*How did natural ambient sound level values differ by using the L90 versus using the calculated percent time audible method?*

Unless non-natural sounds are present more than 80% of the time, the L90 method will be slightly more conservative, i.e., lower decibel values. At the level of non-natural sounds present in Grand Teton, the L90, on average, will be about 1-2 dBA lower than the natural ambient sound level calculated by using the percent-time audible method.

**TABLE G-1: NATURAL AMBIENT SOUND LEVELS USED AS INPUTS IN COMPUTER MODEL**

| Freq **dBA** | Open Zone **Peak Season Lnat** 28.3 | Forested Zone **Peak Season Lnat** 25.8 | Open Zone **All year Lnat** 26.4 | Forested Zone **All Year Lnat** 24 |
|---|---|---|---|---|
| 50 | 28.8 | 28.3 | 26.4 | 24.3 |
| 63 | 28.5 | 27.8 | 26 | 23.7 |
| 80 | 27.7 | 26.3 | 25 | 21.2 |
| 100 | 25.4 | 23.9 | 23.3 | 19 |
| 125 | 22.6 | 21.6 | 21 | 17.1 |
| 160 | 20.8 | 19.7 | 19.8 | 16 |
| 200 | 20.3 | 18.8 | 19.2 | 15.4 |
| 250 | 20.6 | 17.7 | 19.3 | 14.5 |
| 315 | 21.6 | 17.1 | 19.7 | 14.5 |
| 400 | 22 | 17.1 | 19.7 | 14.7 |
| 500 | 21.4 | 16.7 | 19.2 | 14.5 |
| 630 | 20.4 | 16.2 | 18 | 14 |
| 800 | 19 | 15.9 | 16.3 | 13.2 |
| 1000 | 17.1 | 14.6 | 14.1 | 11.5 |
| 1250 | 14.3 | 12.2 | 11.4 | 9.2 |
| 1600 | 11.5 | 9.8 | 8.5 | 7 |
| 2000 | 9 | 8.3 | 6.6 | 6.1 |
| 2500 | 7.8 | 7.5 | 6.1 | 6 |
| 3150 | 7.3 | 7.5 | 6.1 | 6.3 |
| 4000 | 7.3 | 7.5 | 6.5 | 6.8 |
| 5000 | 7.8 | 7.9 | 7.2 | 7.4 |
| 6300 | 8.5 | 8.6 | 8.1 | 8.2 |
| 8000 | 9.7 | 9.3 | 9.4 | 9.2 |
| 10000 | 10.7 | 10.3 | 10.6 | 10.6 |

## MODEL RESULTS COMPARED TO FIELD MEASUREMENTS

Acoustic computer modeling was included in environmental analyses for this environmental impact statement. The purpose was to estimate the sound impacts from aircraft associated with Jackson Hole Airport under two alternatives and three time periods (2005, 2015 and 2025).

Field measurements (acoustic monitoring) have occurred in Grand Teton National Park since the winter of 2002-2003. The measurements were not specifically designed to compare to the computer modeling results but, with caution, can be useful for that purpose.

The computer modeling provided several acoustic metrics, including percent-time audible, for each of 489 points (intersection of a 1 x 1 mile grid pattern) in Grand Teton National Park. Field measurements were collected at 21 locations for varying periods of time from several days to two and half years. The percent-time audible values from those monitoring sites were compared to the modeling percent-time audible values at the closest grid point (Figure G-31).

The computer model estimated percent-time audible at each grid point for both an all-year and for a peak-season (July through September) average. For field measurement time periods less than for an entire year or peak season, the appropriate time period was compared. For example if field measurements were only collected during August, the modeled peak-season audibility values were used. Likewise, if field measurements were only collected from January to March than the modeled annual season values were compared. The comparison between field measurements and computer modeling was the most appropriate for most analogous time periods and those locations with the largest sample sizes. The more dissimilar the time periods the less dependable the comparisons.

Several issues need to be considered while comparing the percent-time audible results from field measurements and computer modeling. Field measurements included aircraft associated with the Jackson Hole Airport as well as itinerant aircraft not associated with the airport (estimated to be audible about 5% of the time between 7 A.M. and 10 P.M.). The computer modeling only included airport-related aircraft, therefore if all else was equal, field measurements would result in higher percent-time audible values for aircraft. Unfortunately, however, all else is not equal.

Ambient environmental conditions are highly variable and have an instantaneous direct effect on field measurements. A subset of environmental factors, including humidity, temperature, ground effects, topography, and natural ambient sound level, were included in the computer model, but only as a static, average condition. Therefore, conditions measured in the field that depart from the average will differ, sometimes substantially, from those used in the computer model.

Two examples will illustrate these differences. First, field measurements were collected 100 feet from the Teton Park Road and from 150 feet from the Snake River. During the peak-season period, the ambient sound levels at these sites were much higher than the average natural ambient sound level used in the computer model. These higher ambient sound levels would mask or cover up the distant aircraft sounds and thus, the computer model would tend to overestimate the percent-time audible of aircraft compared to the field measurements. Second, the natural ambient sound levels in the backcountry during calm periods in the winter are often substantially below the average natural sound levels used in the computer model, therefore field measurements collected during these time periods would tend to result in higher percent-time audible values of aircraft compared to the computer model.

Given these inherent obstacles to a direct comparison between field measurements and computer modeling the two agree remarkably well (Figure G-31). For the three measurement sites with all-year data (Teton Park Road, White Grass Ranch, and Jackson Lake Cow Island) the average field measured percent-time audible value was 14% compared to the modeled 11% (maximum difference was 7%). For another ten measurement sites (not all shown) with at least seven days of measurement data the measured average percent-time audible value was 15% compared to the modeled 12% (maximum difference 10%). The comparisons are nearly as favorable for an additional nine measurement sites (not all shown) with sample sizes of fewer days.

For each comparison, an understanding of the attributes of the measurement site and the typical ambient sound levels (to evaluate the potential masking of distant aircraft), the time period of the field measurements (how analogous it is to the computer modeled time period), the annual pattern of aircraft operations at the airport, and other potential complicating factors provides a plausible explanation for the differences between the field measured values and the computer modeled values for percent-time audible.

The following is a discussion of those locations compared in Figure G-31. Grassy Lake and Flagg Ranch were in the most northerly area of the park area where there was little to no Jackson Hole Airport aircraft traffic. Likewise, Jackson Lake Cow Island, though more southerly, was removed from the typical flight routes of Jackson Hole Airport. Snake River Spread North had natural occurring flowing water sounds from the Snake River that created a nearly constant locally higher natural ambient sound level than what was used in the model. This resulted in natural sounds masking aircraft sounds. Similarly, during the summer Teton Road Lagoon had nearly constant sounds of traffic that masked aircraft sounds. All-Year Teton Road Lagoon included the winter months that had no nearby traffic sounds and the field measurements show 5% more aircraft sounds than the modeling; consistent with the addition of transient, not modeled, aircraft.

Both Timbered Island and White Grass had many non-natural sounds audible in the field measurements. These sounds were often difficult or impossible to attribute to vehicular traffic or aircraft, so were coded as unknown motorized sounds. An unknown proportion of these were aircraft, but were not included in the field measurement totals. To a lesser extent, the Jackson Hole Airport location, suffered from the same phenomenon, but only for the transient aircraft, for the airport related aircraft was generally readily identified because of their high sound levels.

Taken as a whole, the field measurements provide strong evidence that the aircraft percent-time audible values derived from the computer modeling of current conditions are reasonable estimates of actual current aircraft percent-time audible.

## POTENTIAL ACOUSTIC METRICS

The science of measuring and evaluating acoustical impacts in natural areas is a relatively new and evolving field. Traditional measures for airport noise relied on community annoyance standards using day-night average sound levels (DNL). In contrast, the National Park Service needs to assess chronic and transient acoustic impacts on park visitors, park wildlife and other natural resources. Non-natural sounds have many attributes and there are multiple metrics that can be used including sound level, audibility, frequency components, duration, timing, sound quality, etc.

The analysis used a combination of the energy-based metrics of Leq and the Maximum Sound Level, the time-based metrics of percent-time audible and time above 60 dBA, and the area-based metric of percentage of the park affected by audibility. Additional metrics that are beginning to be used in other environmental analyses, such as time above 45 dBA and 52 dBA, alerting distance and listening area reduction, would provide additional details of the park's soundscape. The following section describes the acoustic metrics that were considered for this analysis, some advantages and disadvantages of each, and which metrics were selected for use.

### Percent of Park Affected by Time Audible Greater than 10%

This metric includes a spatial component and is easy to understand. It includes many aspects of the sound source and listener capabilities: natural ambient sound level, frequency content of source and ambient environment, and hearing ability of the listener. Audibility is the only metric listed here that takes into account the frequency content of sound. Human audibility is a good proxy for many other animals, but not all.

This metric does not distinguish between sound levels. For example, all audible sounds could be very low but still audible, hence misleading, or alternatively they could be very high. Different species can have different audibility.

Metric can be derived from Integrated Noise Model 6.2a output

This metric was used to assign impact designation for this impact analysis.

**Percent-Time Audible**

This metric is easy to understand. It includes many aspects of the sound source and listener capabilities: natural ambient sound level, frequency content of source and ambient environment, and hearing ability of the listener. Audibility is the only metric that takes into account the frequency content of sound. Human audibility is a good proxy for many other animals, but not all.

This metric does not distinguish between sound levels. For example, all audible sounds could be very low but still audible, hence misleading, or alternatively they could be very high. Different species can have different audibility.

Integrated Noise Model 6.2a can calculate this metric directly.

This metric was used for descriptive purposes in this impact analysis.

**Maximum Sound Level ($L_{max}$)**

This metric is easy to understand. It can be used to set the upper bounds of acceptable sound levels. Some sound sources have NPS maximum sound limits already established, but not aircraft.

This metric cannot distinguish between one or many events at the maximum sound level threshold. Many events could be just below allowable level and would not be captured. A single event at or above the $L_{max}$ could falsely imply high impacts.

Integrated Noise Model 6.2a can calculate this metric directly.

This metric was used for descriptive purposes in this impact analysis.

**Sound Level Equivalent ($L_{eq}$)**

This metric is based on the average energy over a set period of time. It is an accepted metric in the acoustic community and is used as the basis for calculating day-night average sound level (DNL) (below). Short, but loud event captured as well as frequent quiet sounds.

It is impossible to assess actual instantaneous acoustic conditions based on this metric. Continuous but low level events could be present, but misinterpreted.

Integrated Noise Model 6.2a can calculate this metric directly.

This metric was used for descriptive purposes in this analysis.

**Day-Night Average Sound Level (DNL or Ldn)**

This is one of the metrics used in Jackson Hole Airport noise mitigation plan. It has a long history of providing a reasonable assessment of community annoyance around airports.

This metric is difficult to understand. It was not designed or is appropriate for use in quiet natural areas such as national parks. The National Park Service seeks to provide excellent visitor experiences, not manage at a level just below annoyance.

Integrated Noise Model 6.2a can calculate this metric directly, but because of the hours used in this analysis, a 15-hour $\mathbf{L_{eq}}$, not a DNL, was calculated. However, the difference between the calculated 15-hour $\mathbf{L_{eq}}$ and a DNL would be small. The Jackson Hole Airport Board's annual reports include DNL contours that closely resemble the 15-hour $\mathbf{L_{eq}}$ contours that were derived from the Integrated Noise Model 6.2a output.

### Time above (60 dBA, 52 dBA, 45 dBA, 35 dBA, $\mathbf{L_{natural}}$)

These metrics are easy to understand. Time above 60 dBA and Time above 52 dBA can estimate amount of human speech interference. Time above 45 dBA can estimate human sleep interruption. The NPS mandates using the natural ambient as the base condition for assessing sound impacts so Time above $\mathbf{L_{natural}}$ (natural ambient) could be useful.

These metrics do not distinguish between just above or far above threshold. They do not provide maximum allowable level, for example, a sound could be above 45 dBA for a short time, but also above 100 dBA. And a continuous level just below cutoff would not be captured.

Integrated Noise Model 6.2a can calculate these metrics directly.

Time Above 60 dBA was used in this analysis for descriptive purposes.

### Percent-Time Audible and Time above 60 dBA Model Results

Figures G-1 through G-10 illustrate the model results of percent-time audible for aircraft using the Jackson Hole Airport for current conditions (based on October 2004 through September 2005 aircraft operations) and predicted audibility for 2015 and 2025 for Alternatives 1 and 2. Time above 60 dBA is illustrated in Figures G-11 through G-20). The figures represent the 15-hour time period from 7 A.M. to 10 P.M.

These figures show that aircraft impacts are widespread in the park, but are most intense close to the airport in the southern part of the park. In some areas of the park, aircraft may be audible more or less than illustrated in these figures because of the modeling limitations described earlier in this appendix. Therefore, the figures should be used for comparing the alternatives, seasons, and years, rather than as absolute values.

## 15-HOUR Leq MODEL RESULTS

The 15-hour energy average sound level (Leq) is shown in Figures G-21 through G-30. These illustrate the extent of sound energy by five-decibel increments (contours) around the airport.

## List of Figures

Figure G-1: 2005 Percent Time Audible
For Average-Annual Condition

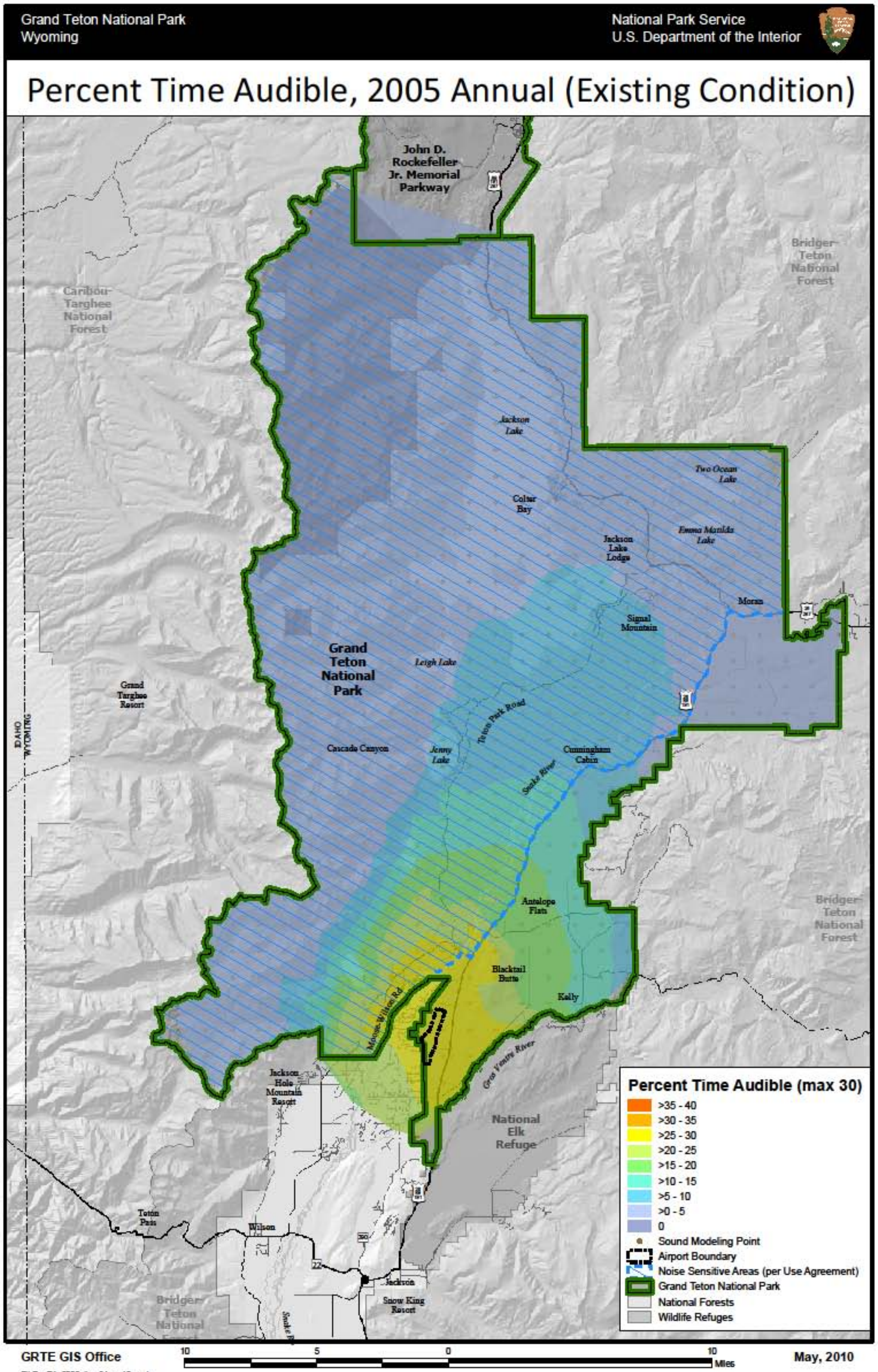


Figure G-2: 2015 Alternative 1 Percent Time Audible
For Average-Annual Condition

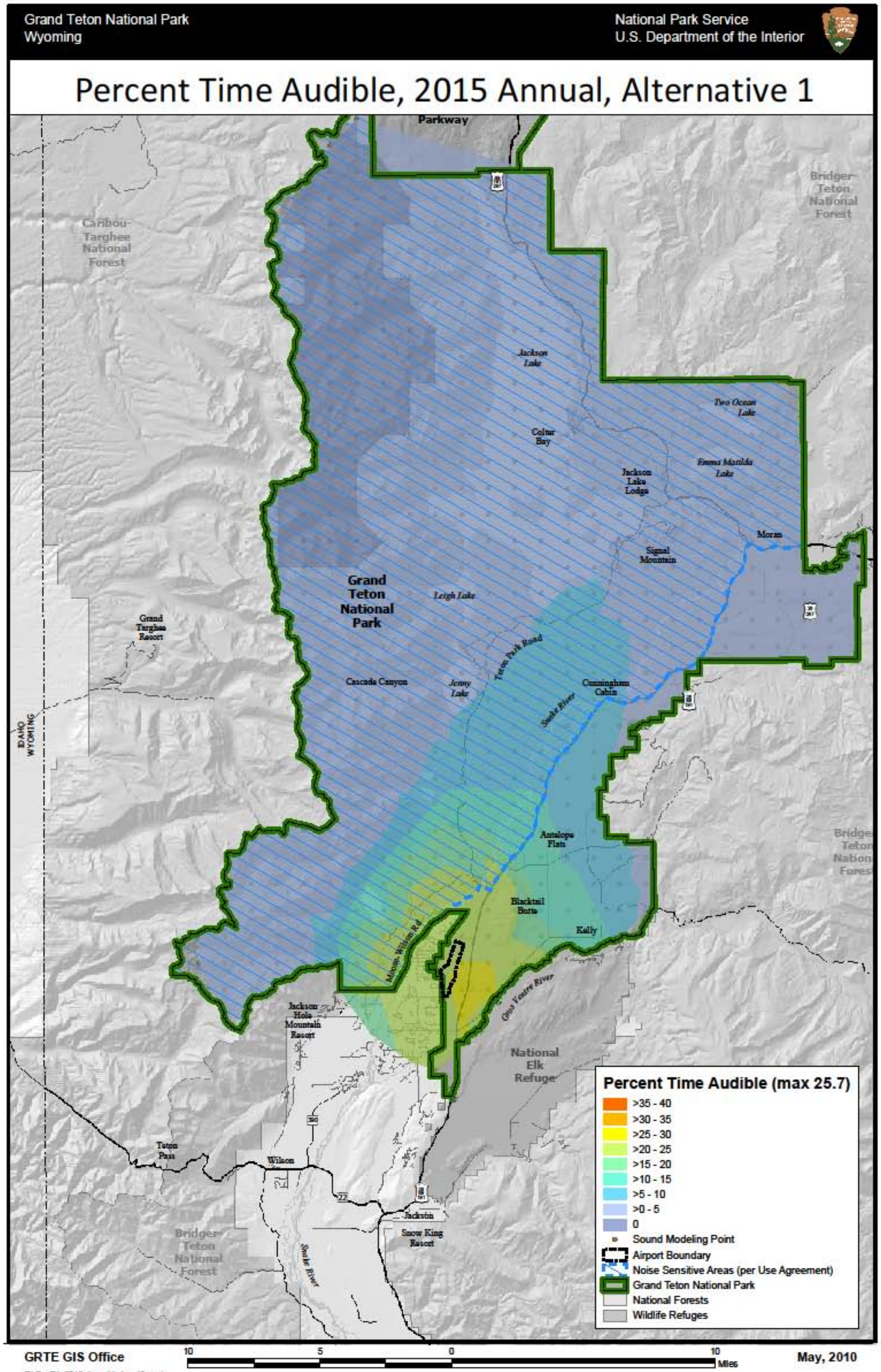


Figure G-3: 2015 Alternative 2 Percent Time Audible
For Average-Annual Condition

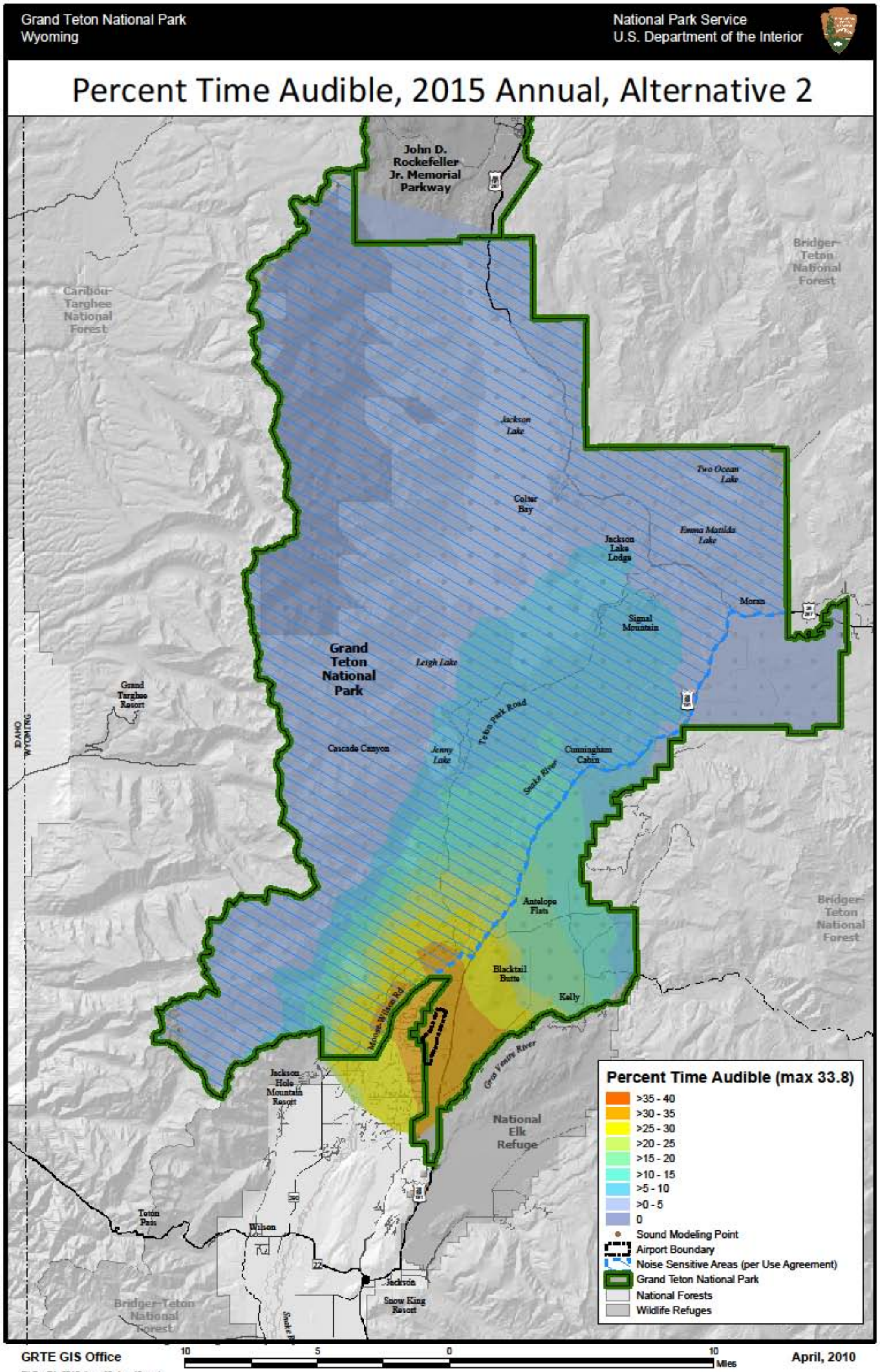


Figure G-4: 2025 Alternative 1 Percent Time Audible
For Average-Annual Condition

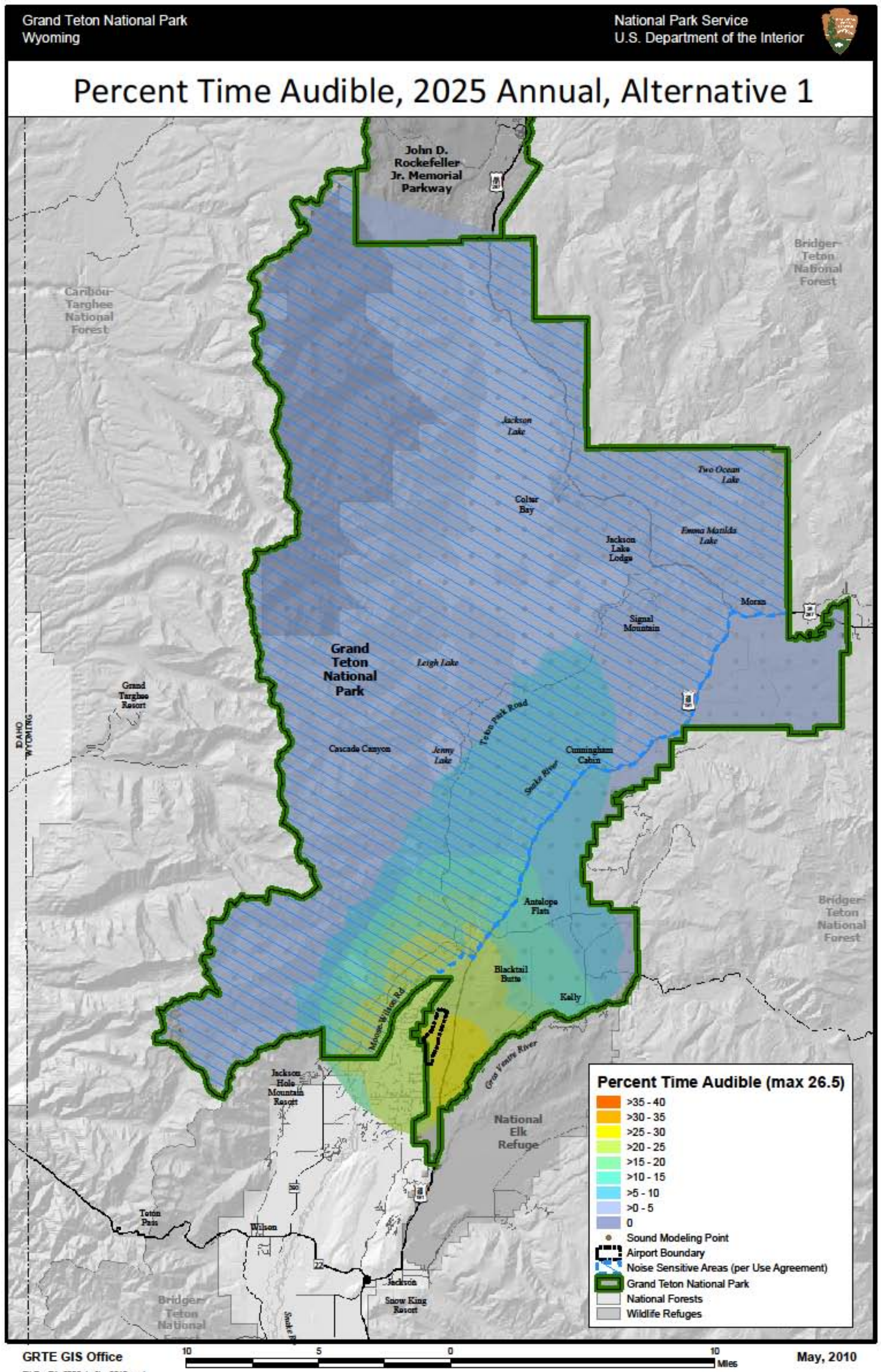


Figure G-5: 2025 Alternative 2 Percent Time Audible
For Average-Annual Condition

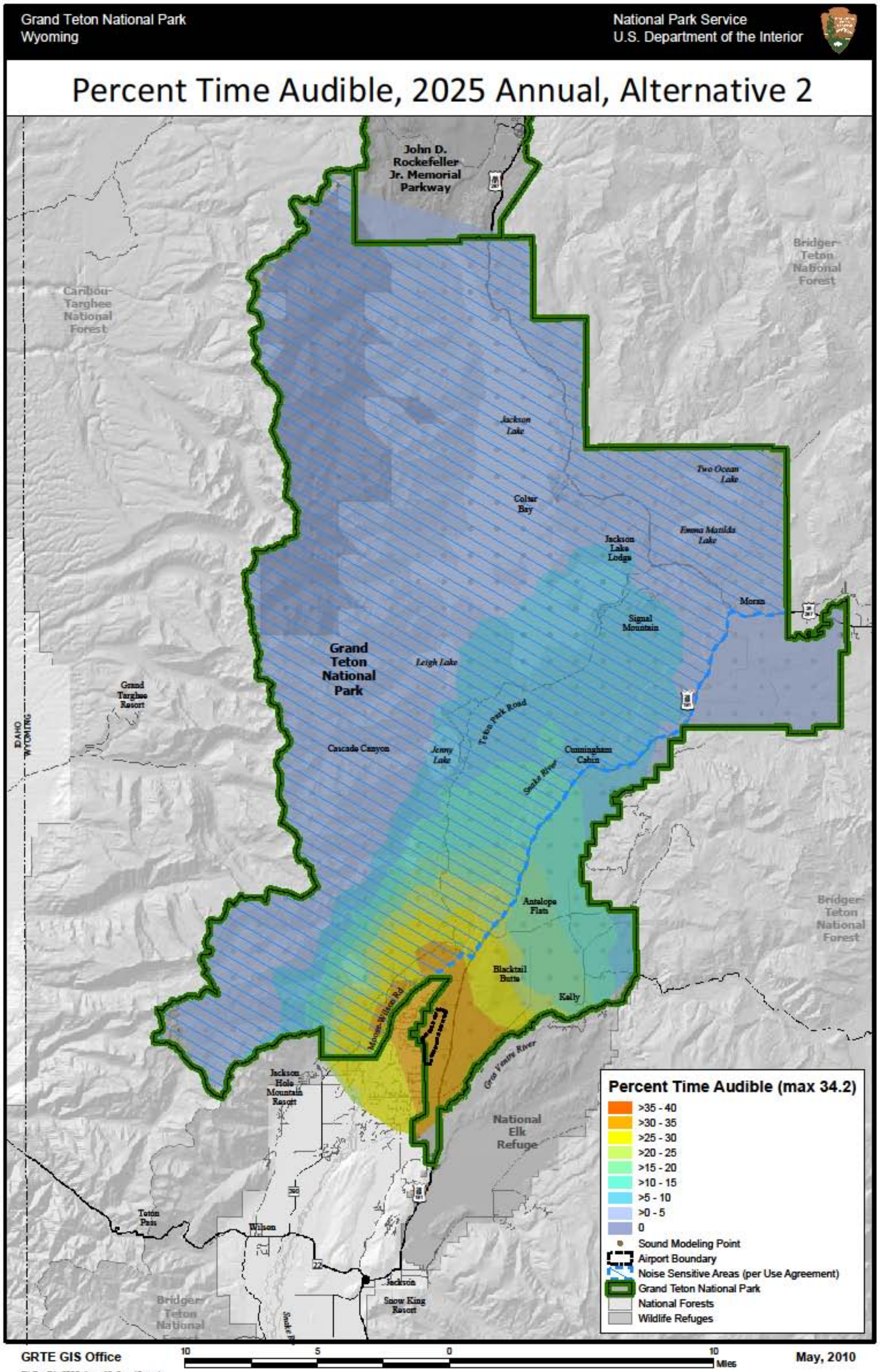


Figure G-6: 2005 Percent Time Audible
For Peak-Season Condition

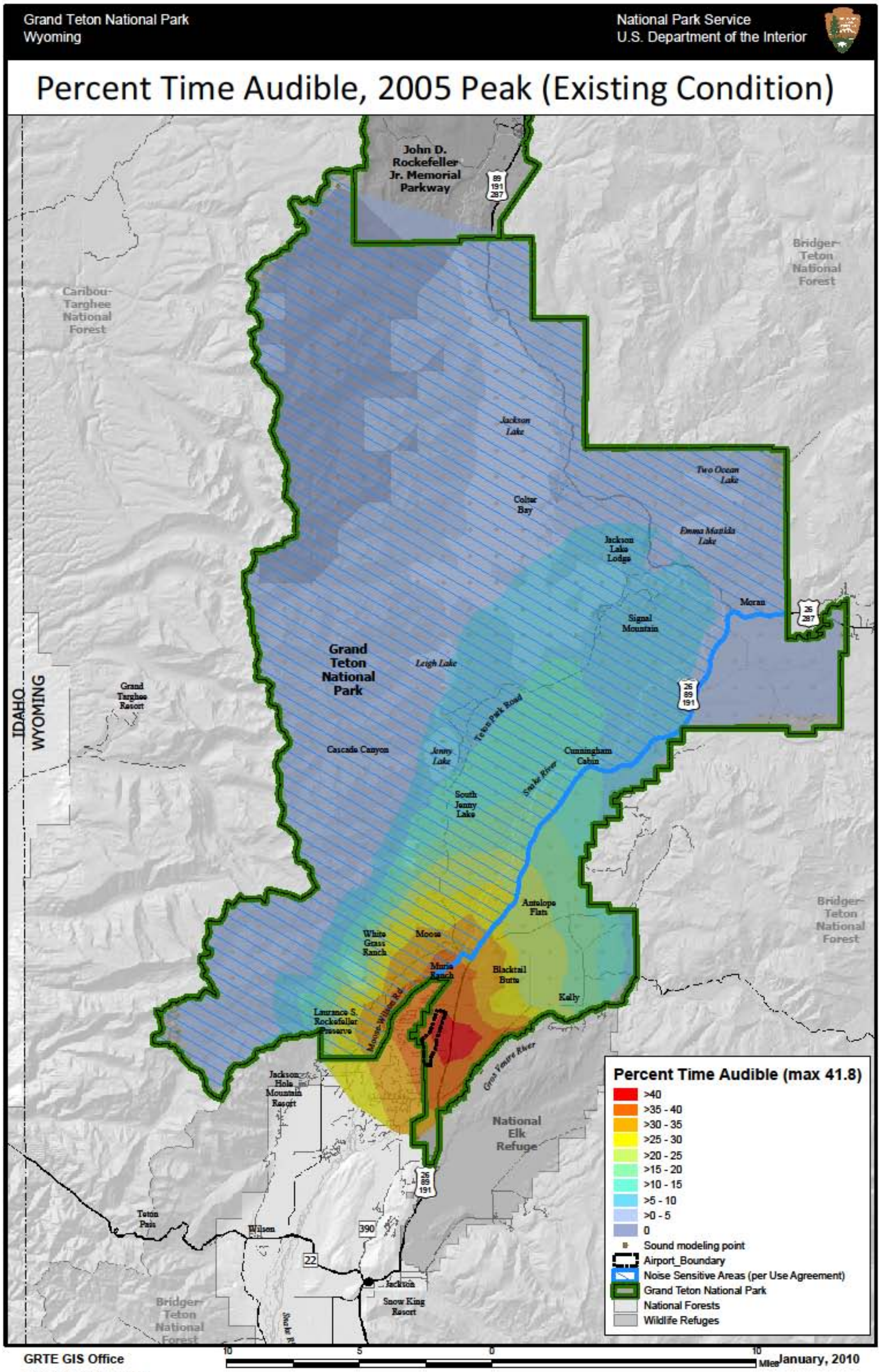


Figure G-7: 2015 Alternative 1 Percent Time Audible
For Peak-Season Condition

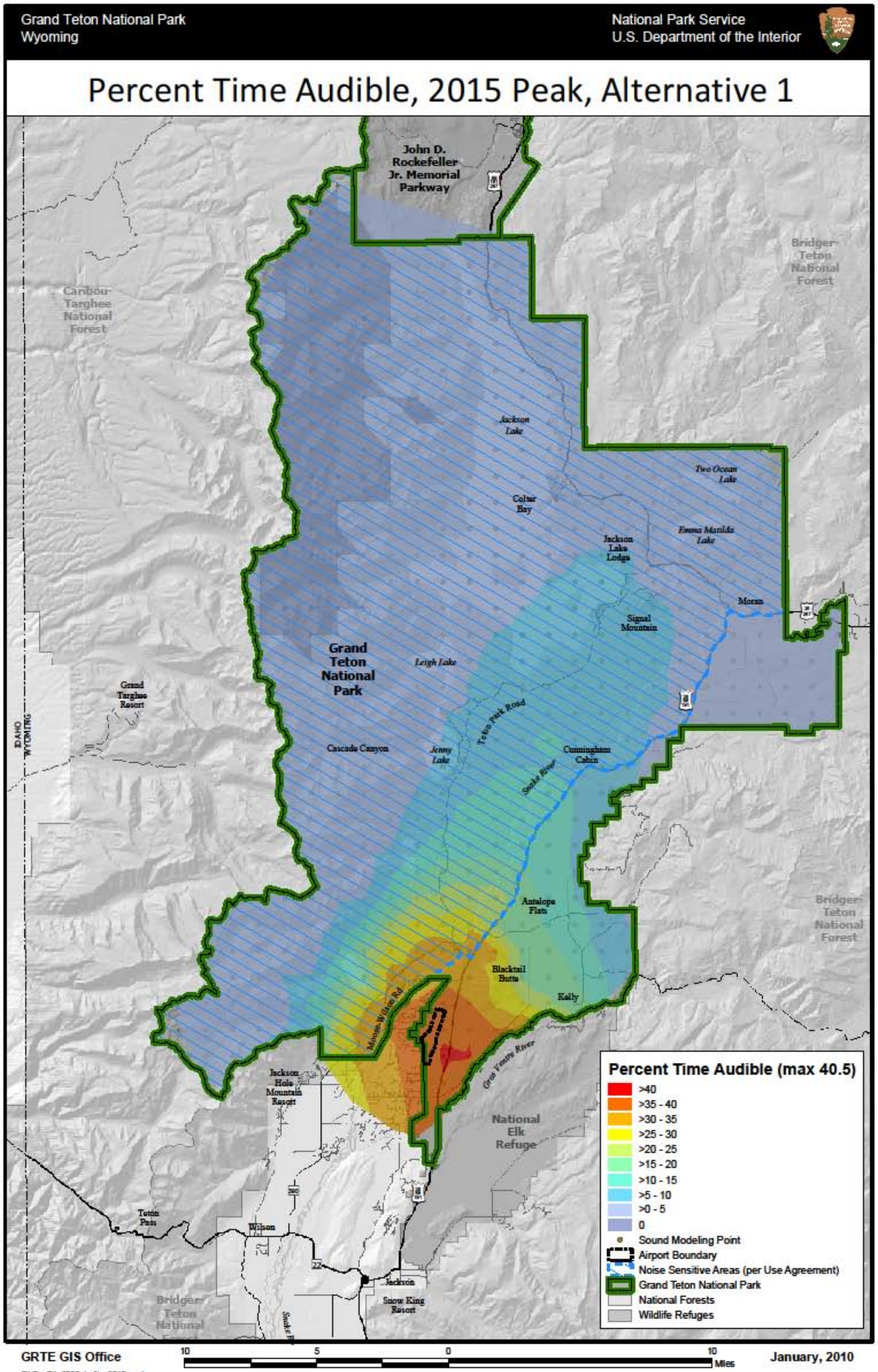


Figure G-8: 2015 Alternative 2 Percent Time Audible
For Peak-Season Condition

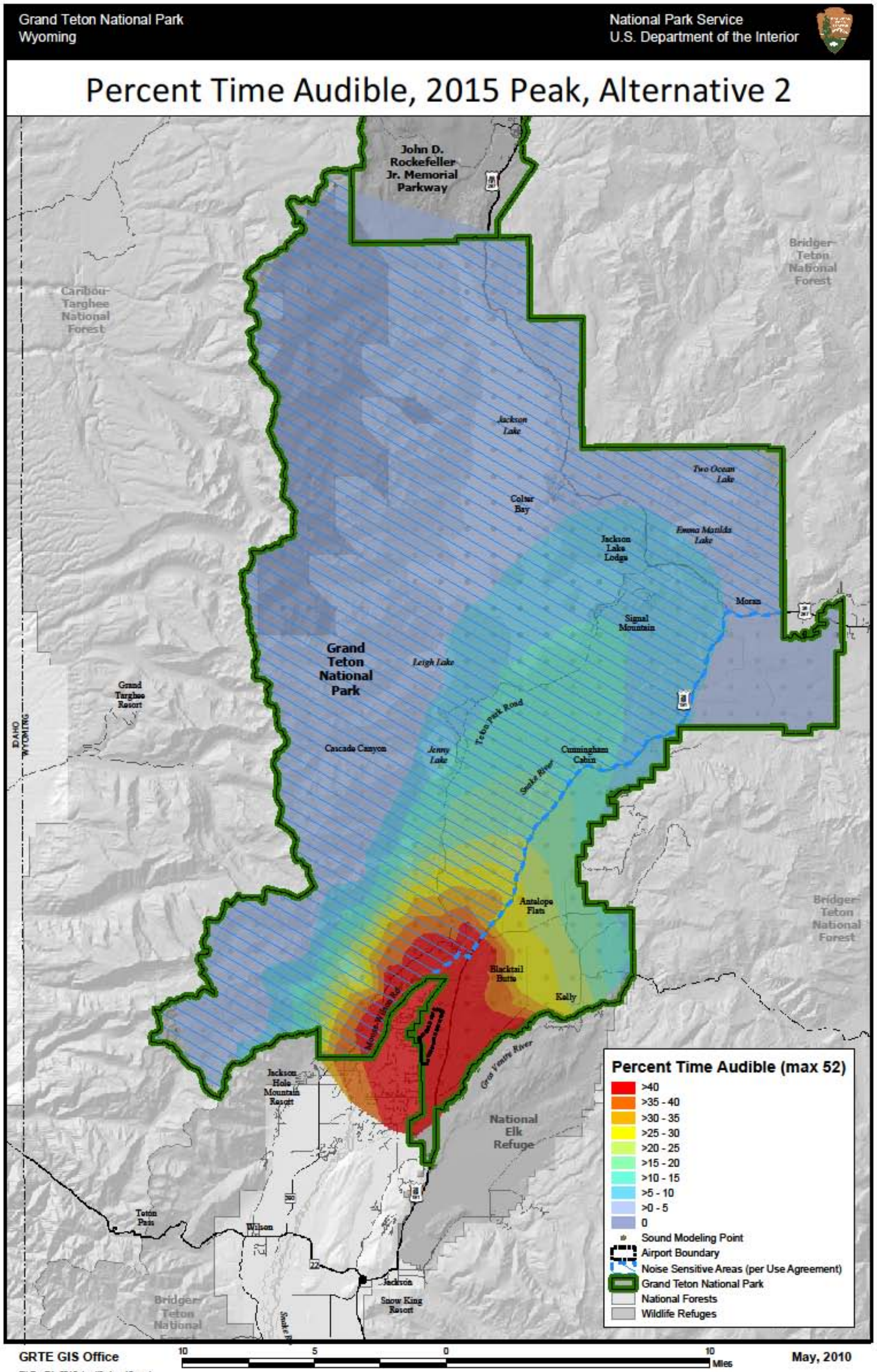


Figure G-9: 2025 Alternative 1 Percent Time Audible
For Peak-Season Condition

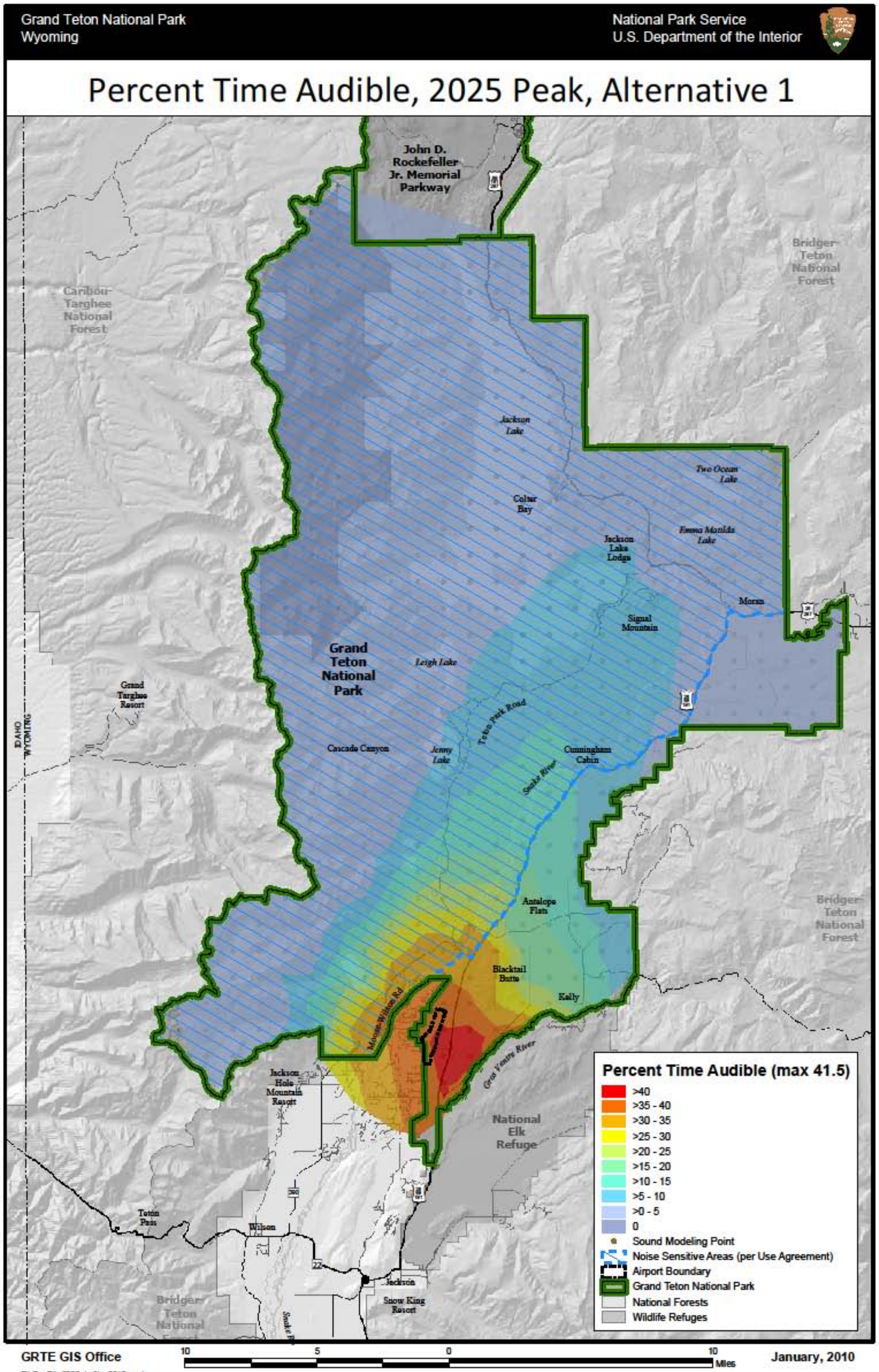


Figure G-10: 2025 Alternative 2 Percent Time Audible
For Peak-Season Condition

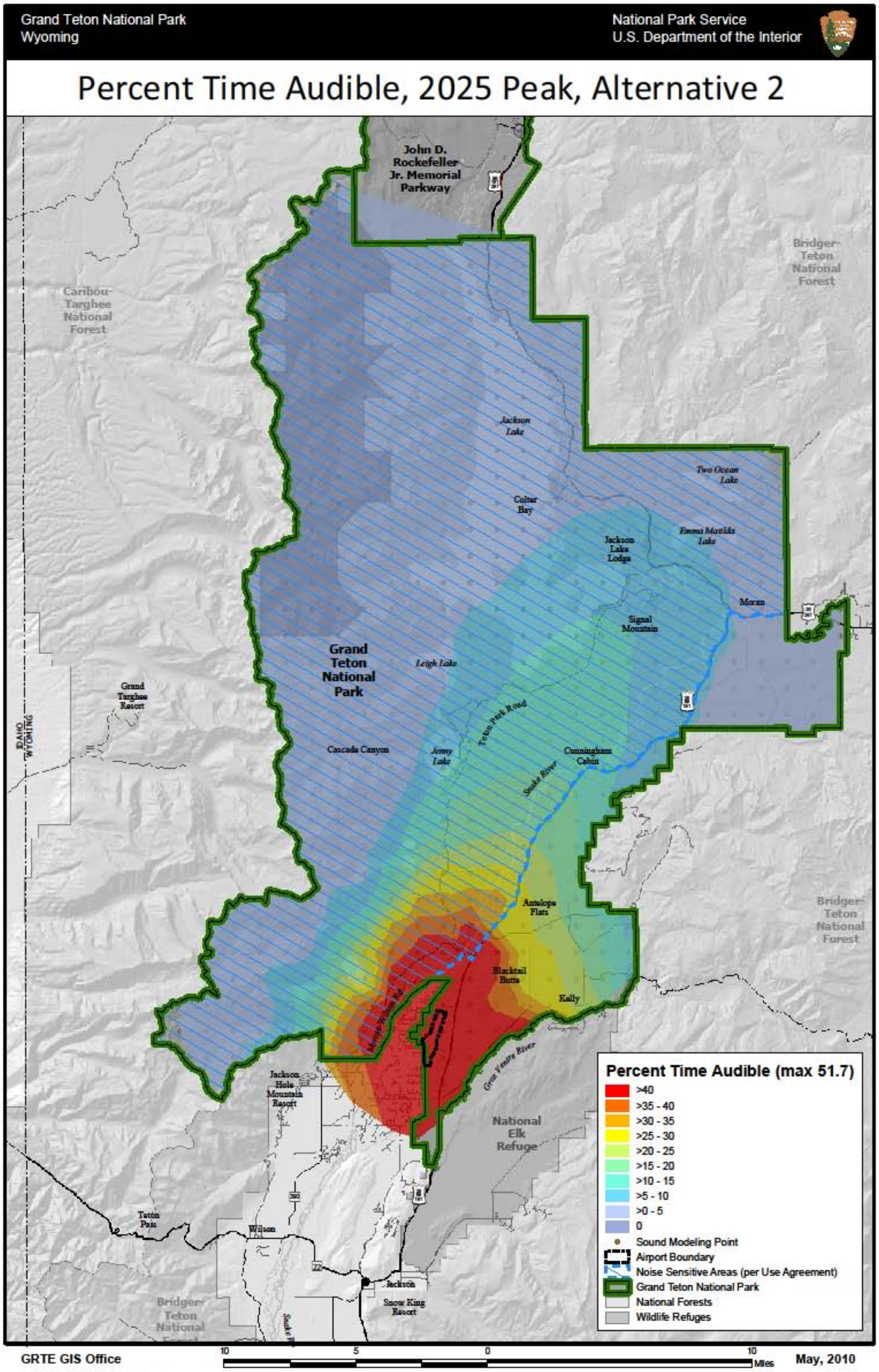


Figure G-11: 2005 Time Above 60 Decibels (60 dBA)
For Average-Annual Condition

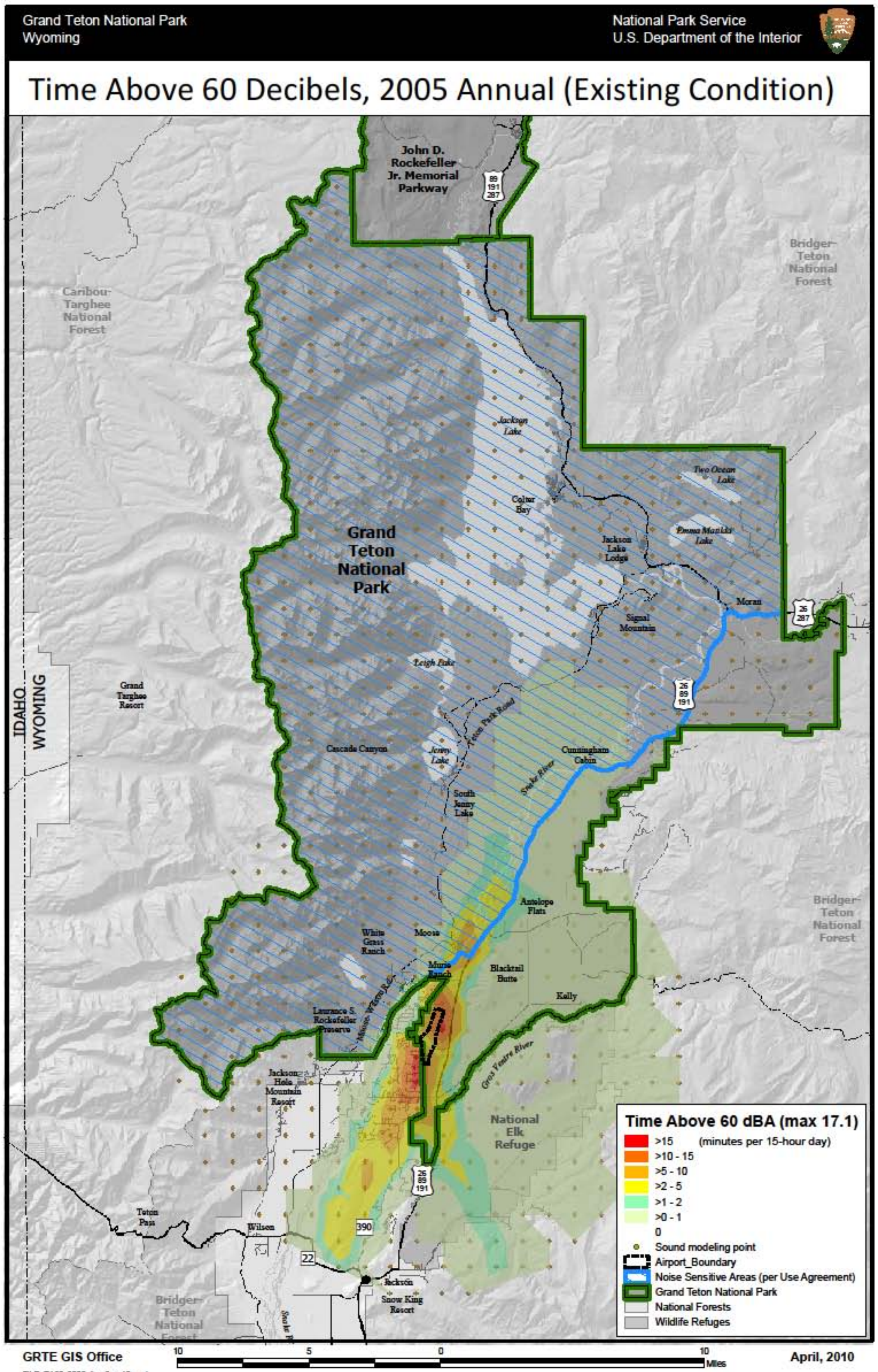


Figure G-12: 2015 Alternative 1 Time Above 60 Decibels (60 dBA)
For Average-Annual Condition

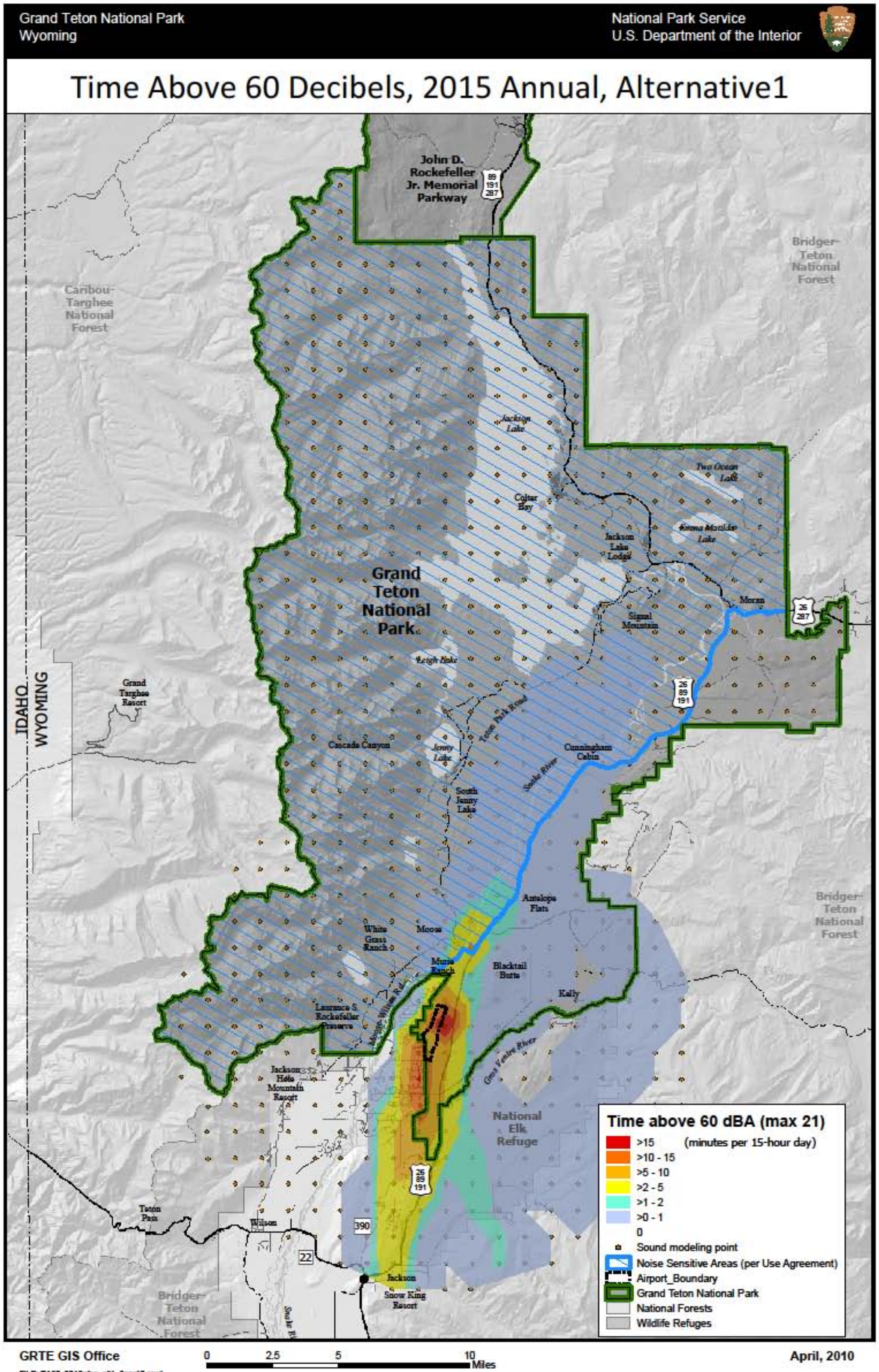


Figure G-13: 2015 Alternative 2 Time Above 60 Decibels (60 dBA)
For Average-Annual Condition

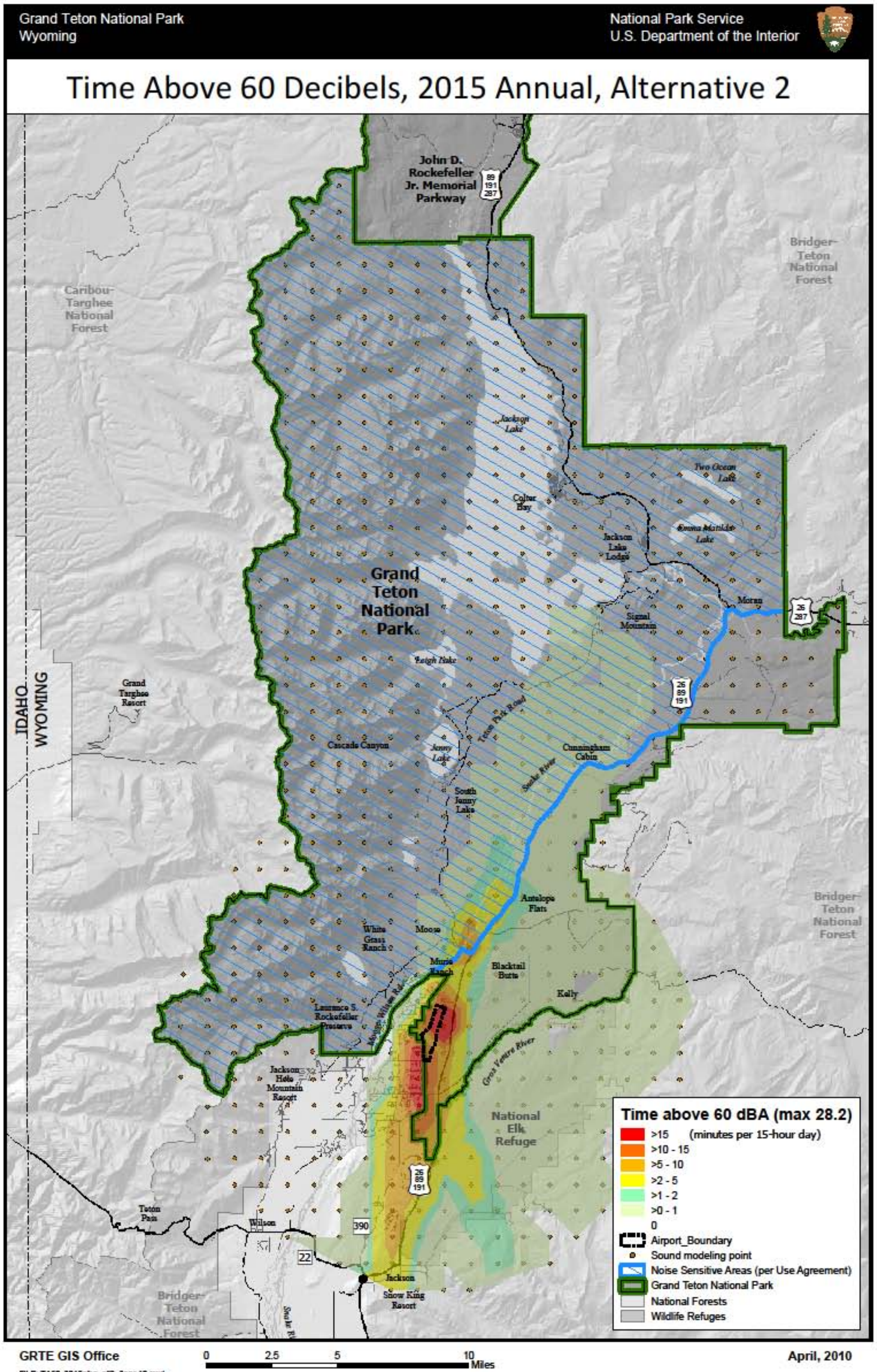


Figure G-14: 2025 Alternative 1 Time Above 60 Decibels (60 dBA)
For Average-Annual Condition

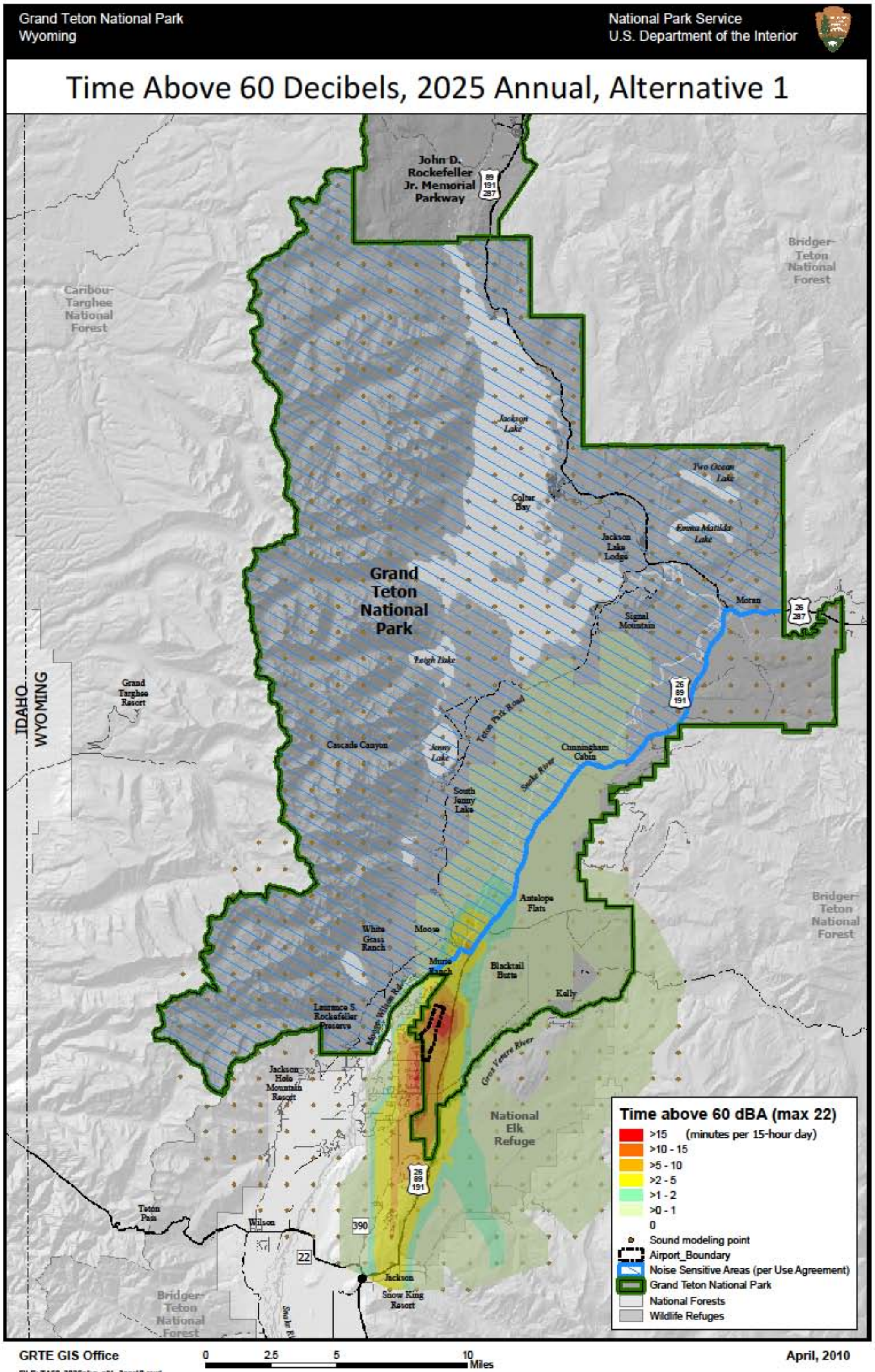


Figure G-15: 2025 Alternative 2 Time Above 60 Decibels (60 dBA)
For Average-Annual Condition

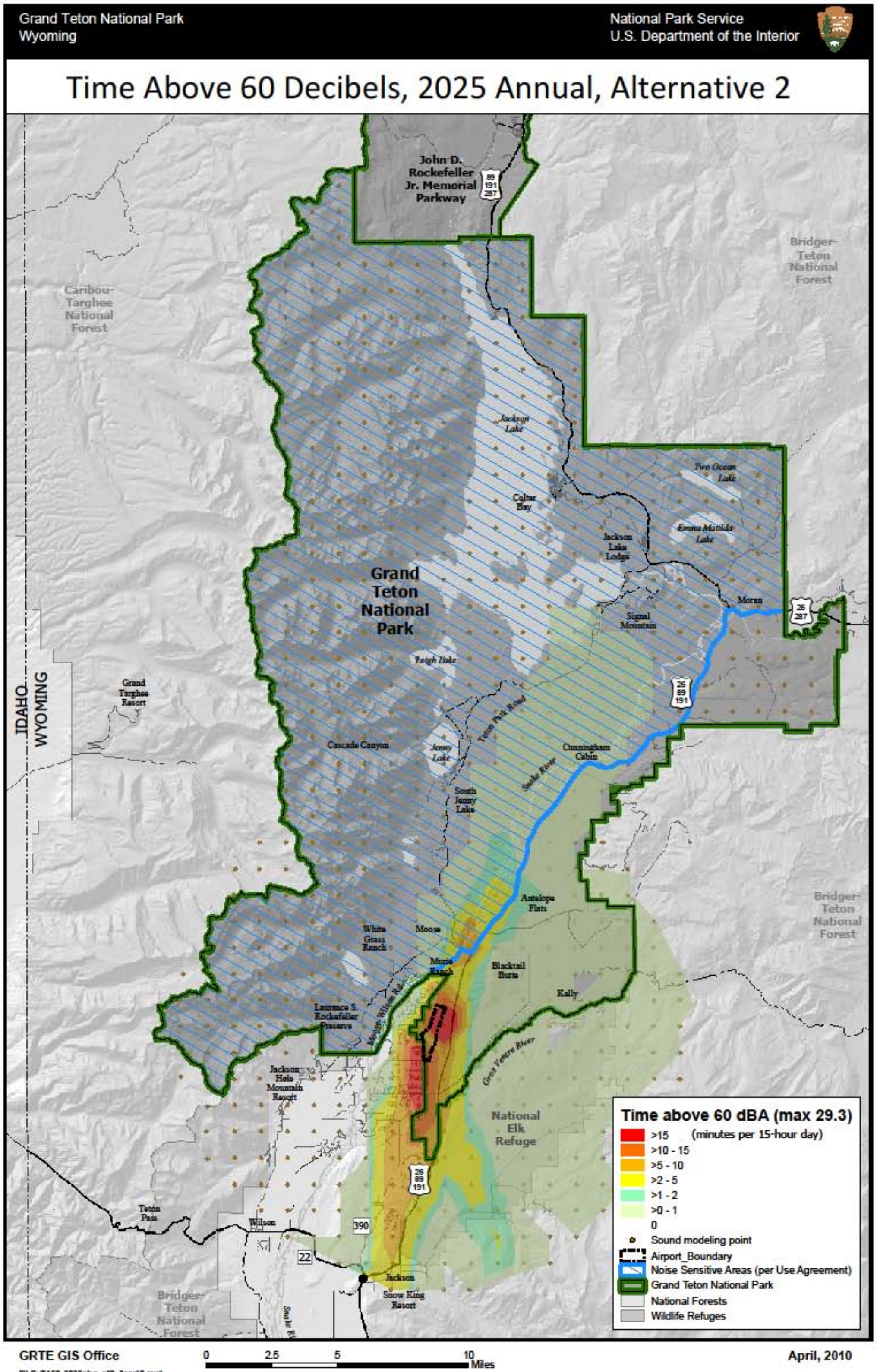


Figure G-16: 2005 Time Above 60 Decibels (60 dBA)
For Peak-Season Condition

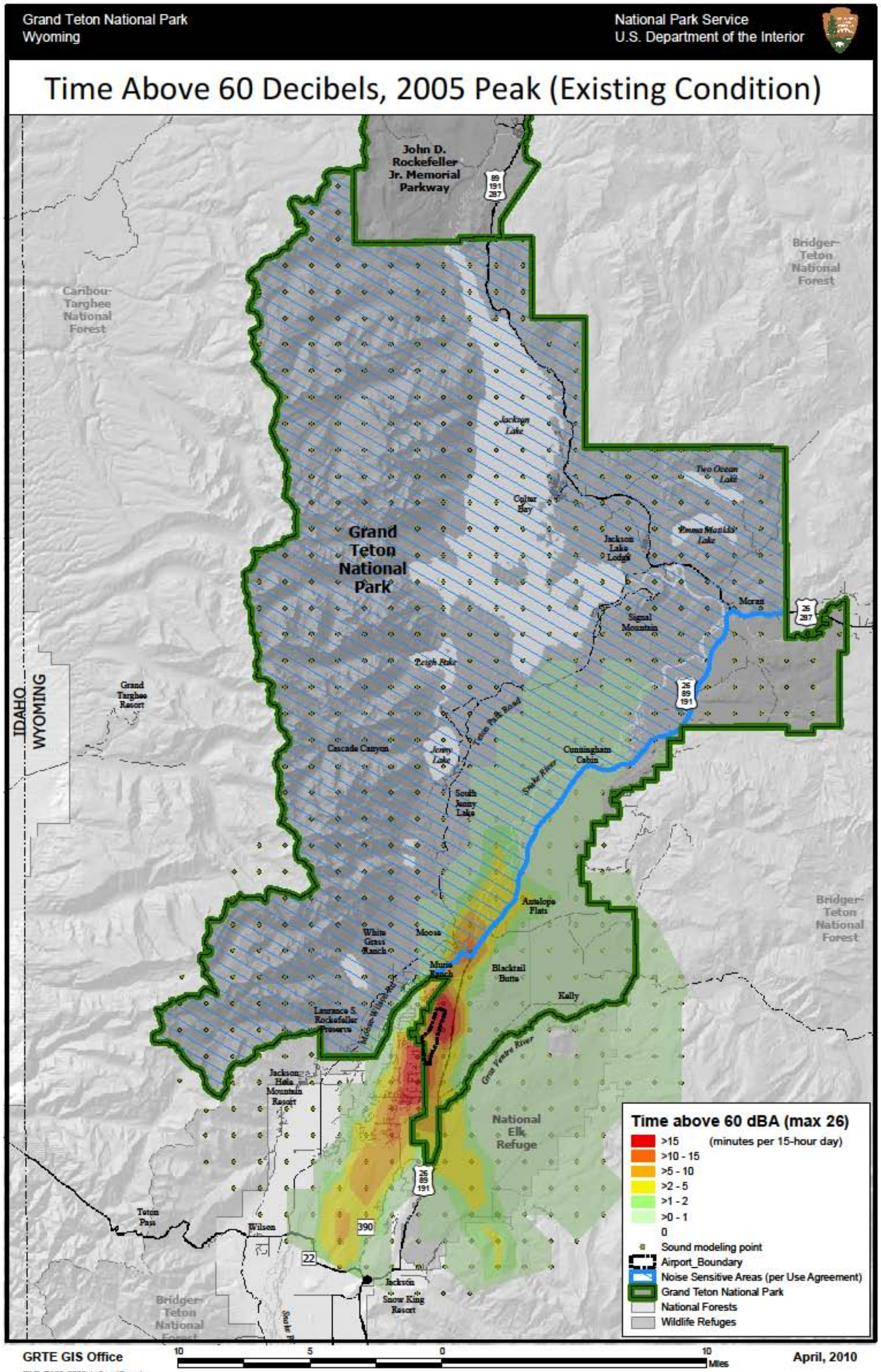


Figure G-17: 2015 Alternative 1 Time Above 60 Decibels (60 dBA)
For Peak-Season Condition

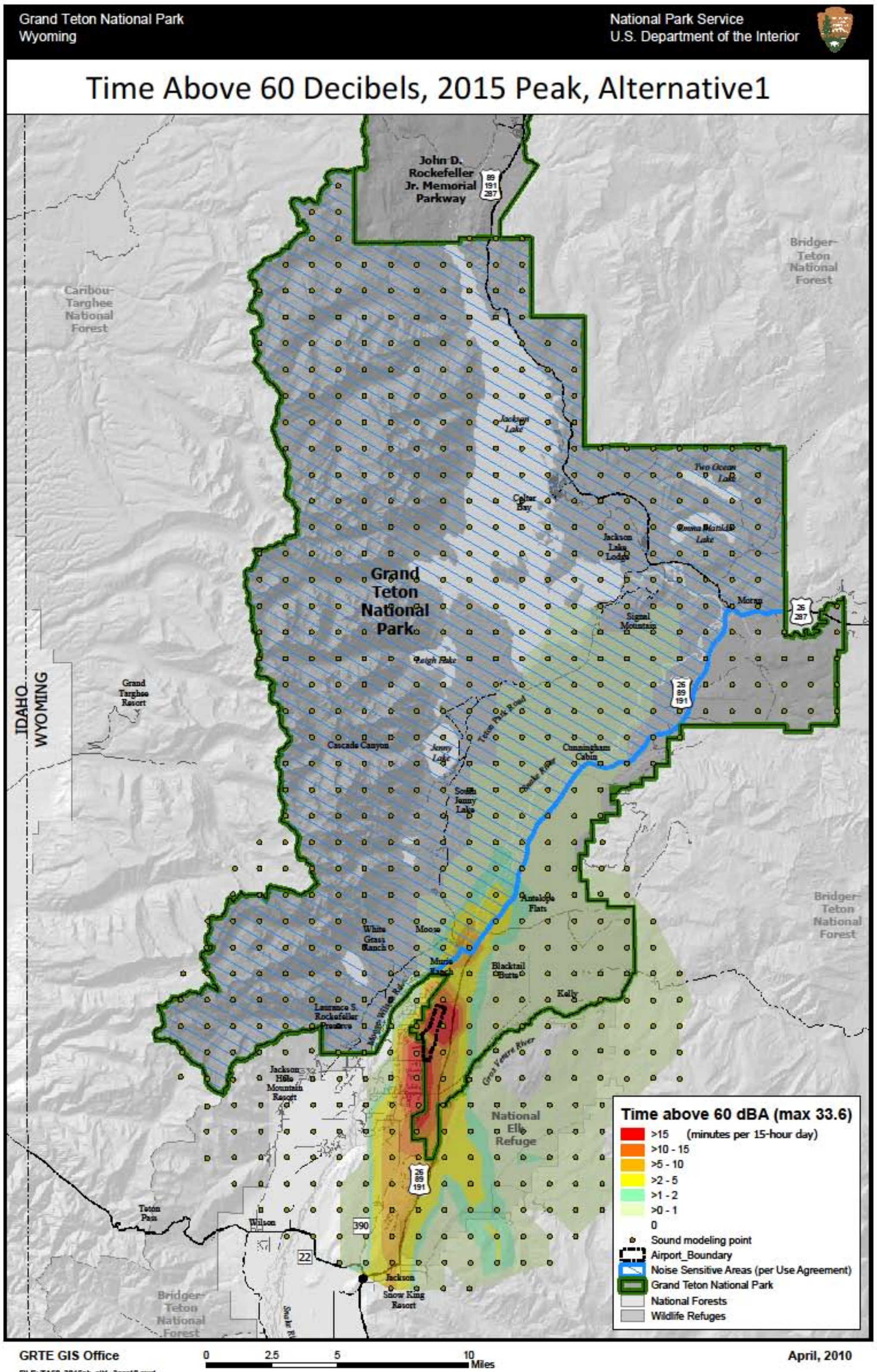


Figure G-18: 2015 Alternative 2 Time Above 60 Decibels (60 dBA)
For Peak-Season Condition

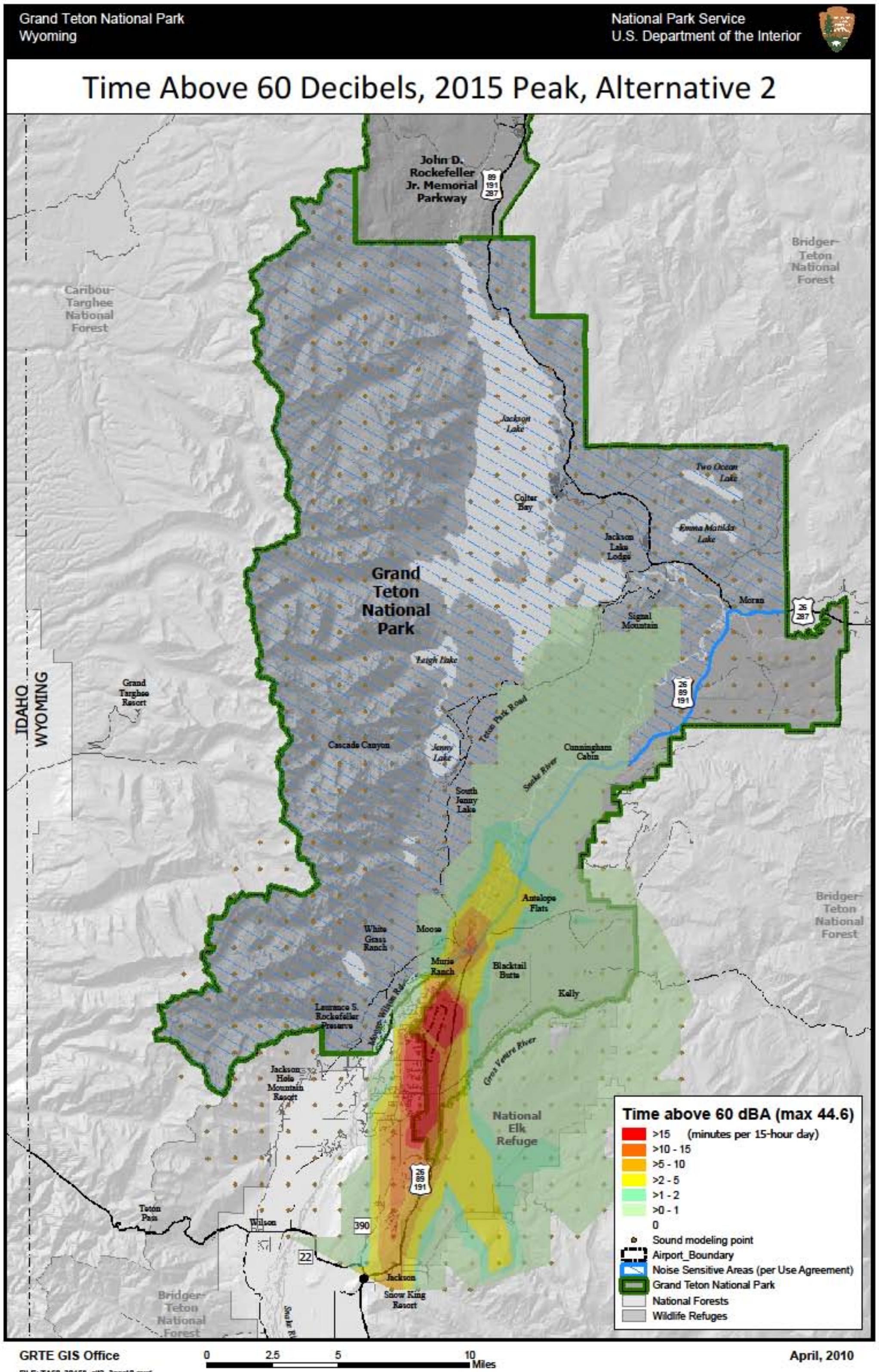


Figure G-19: 2025 Alternative 1 Time Above 60 Decibels (60 dBA)
For Peak-Season Condition

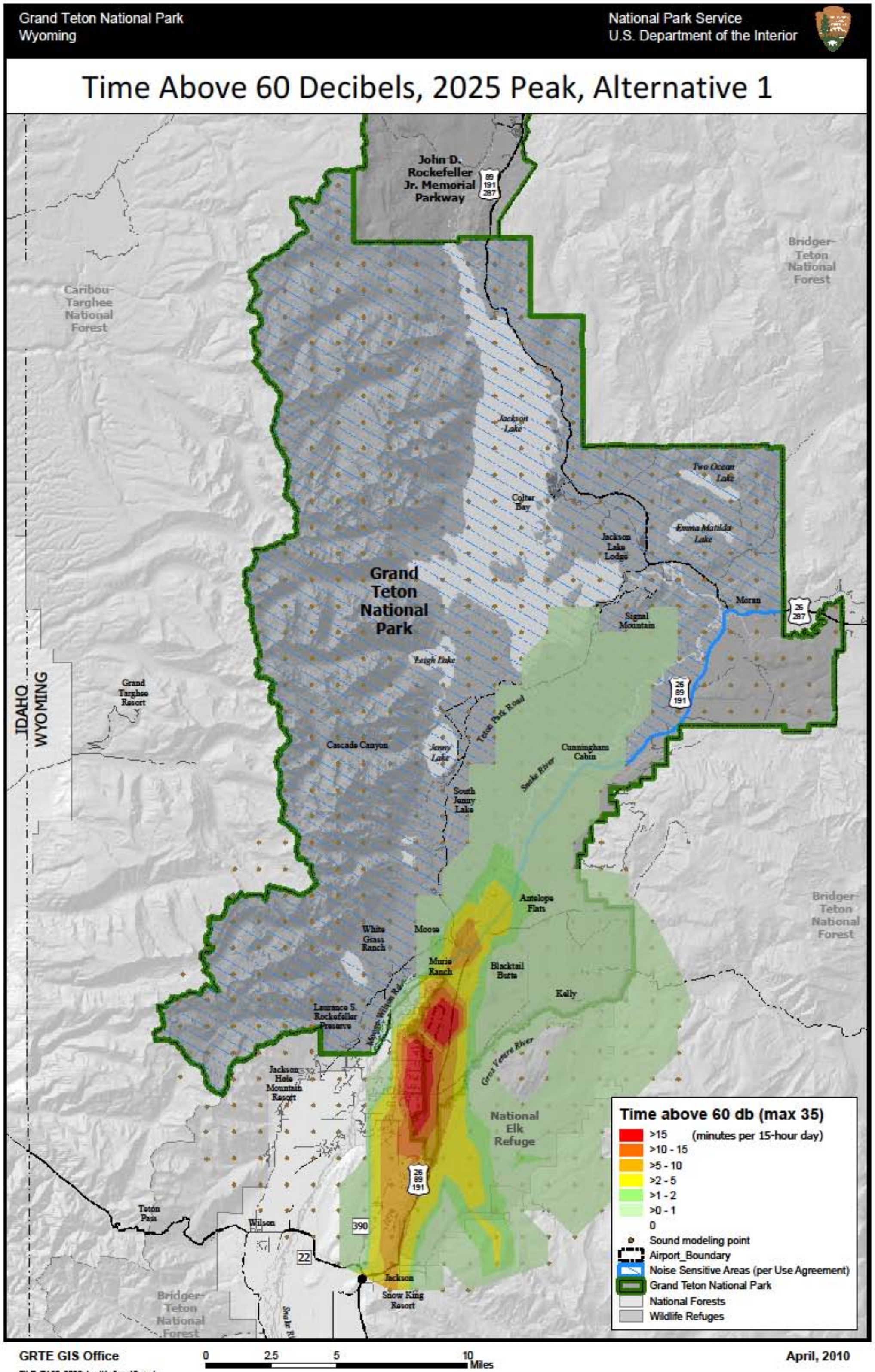


Figure G-20: 2025 Alternative 2 Time Above 60 Decibels (60 dBA)
For Peak-Season Condition

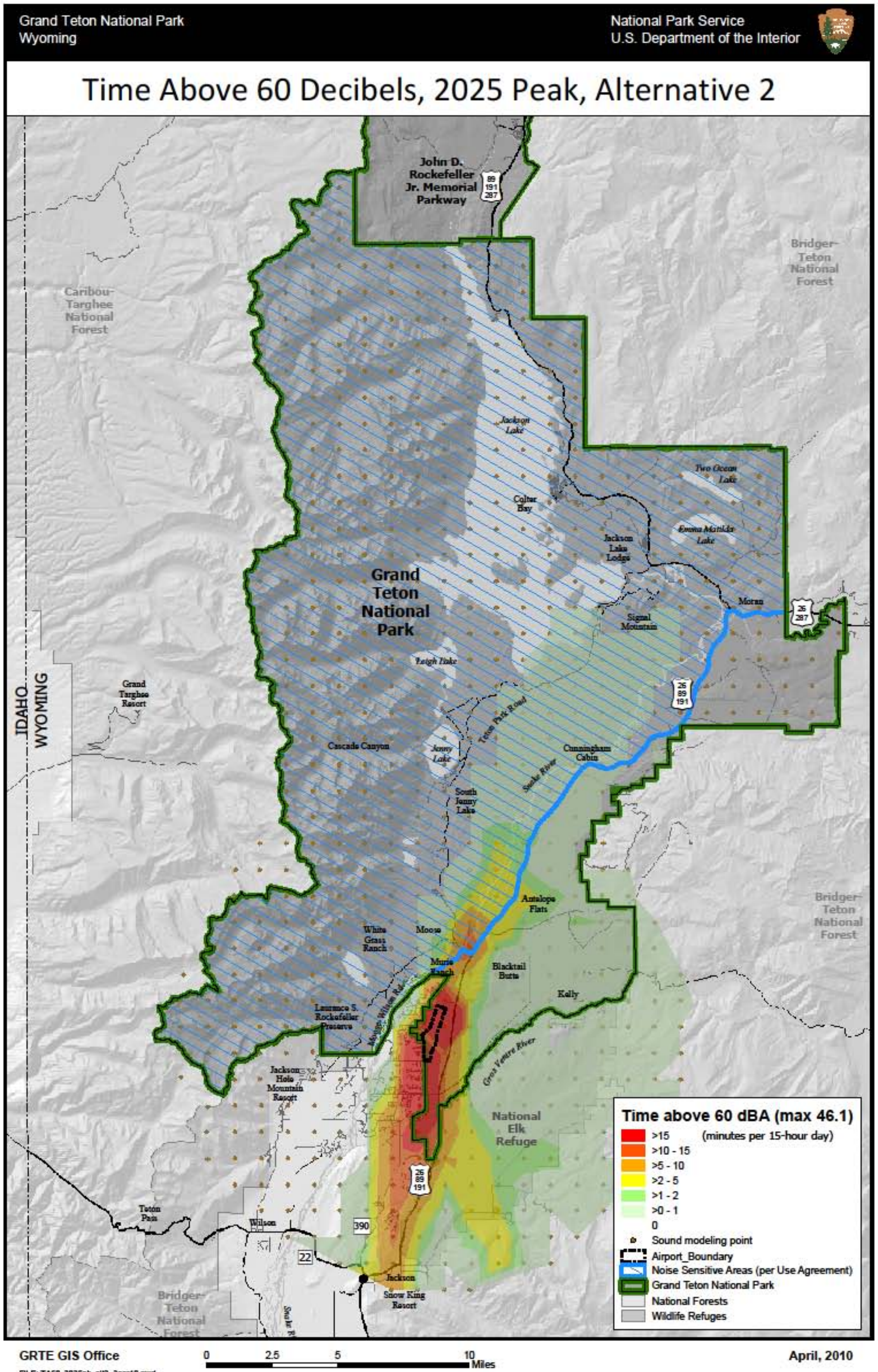
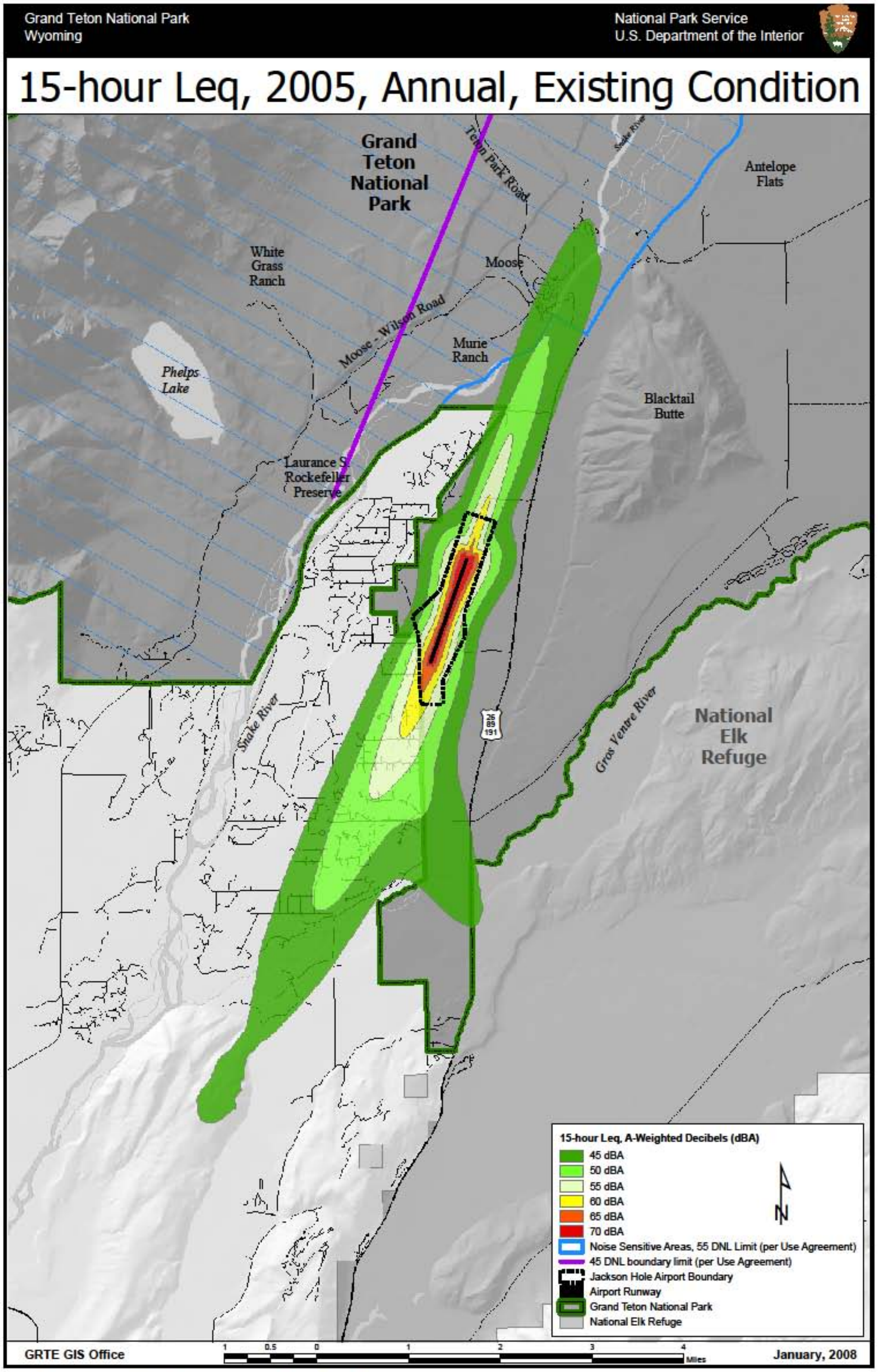


Figure G-21: 2005 15-Hour Sound Energy Level (dBA)
For Average Annual Condition



Q:\GIS_Data\Map_files\Planning\Airport_EIS\2008_maps_updates\DNL All Year 2005 Existing Condition 29jan2008.mxd

Figure G-22: 2015 Alternative 1 15-Hour Sound Energy Level (dBA)
For Average-Annual Condition

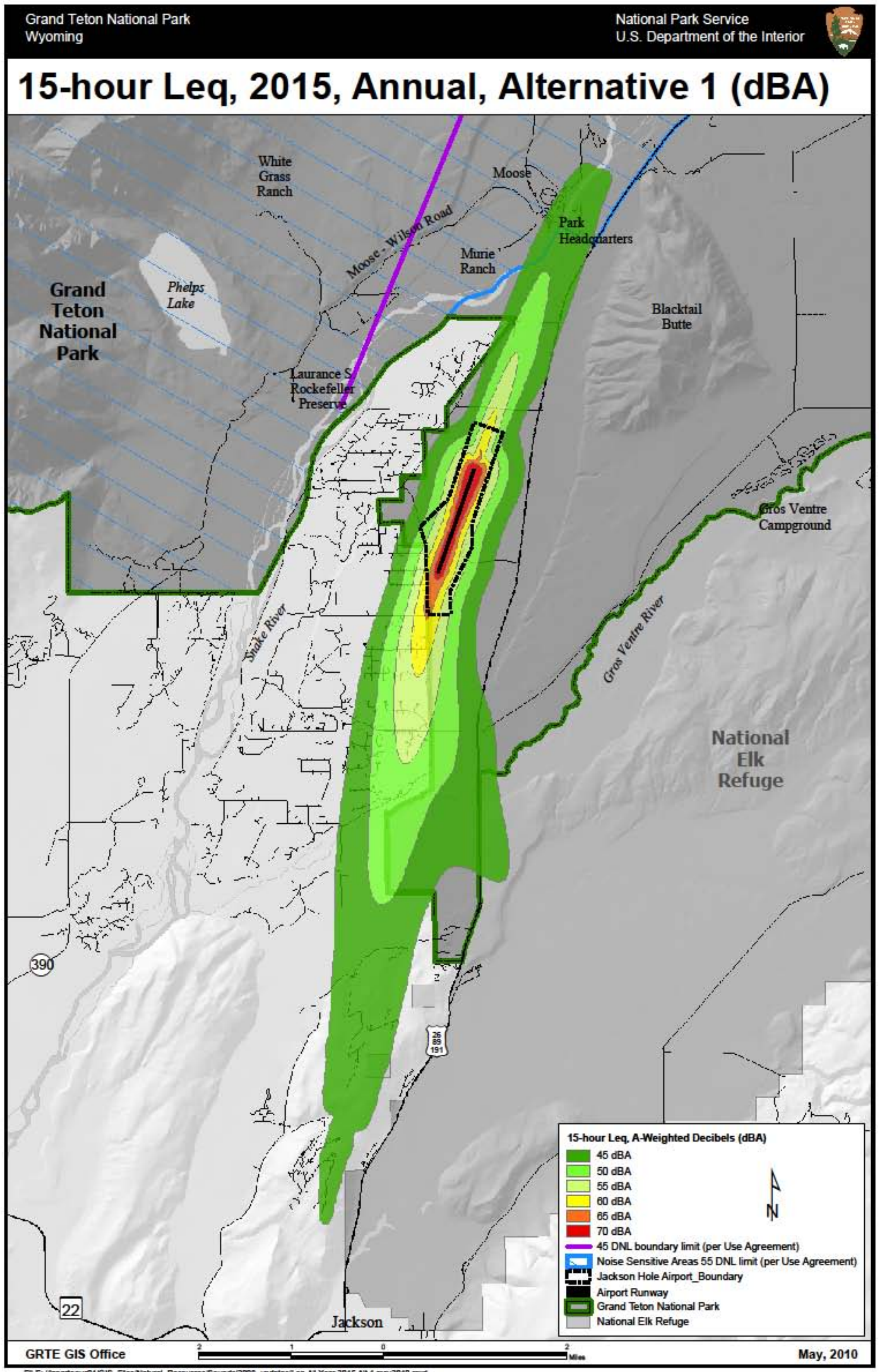


Figure G-23: 2015 Alternative 2 15-Hour Average Sound Energy Level (dBA)
For Average-Annual Condition

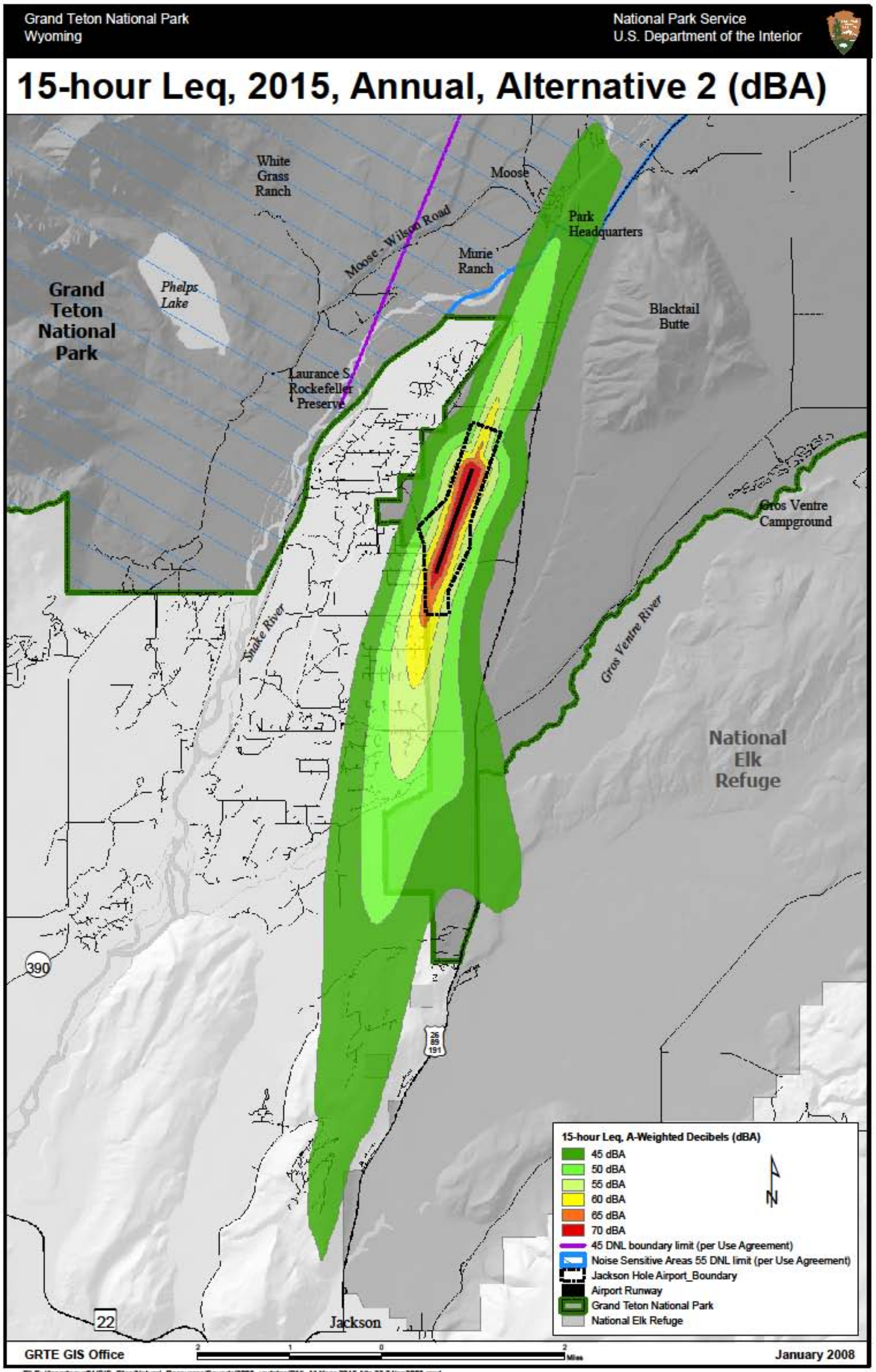


Figure G-24: 2025 Alternative 1 15-Hour Sound Energy Level (dBA)
For Average-Annual Condition

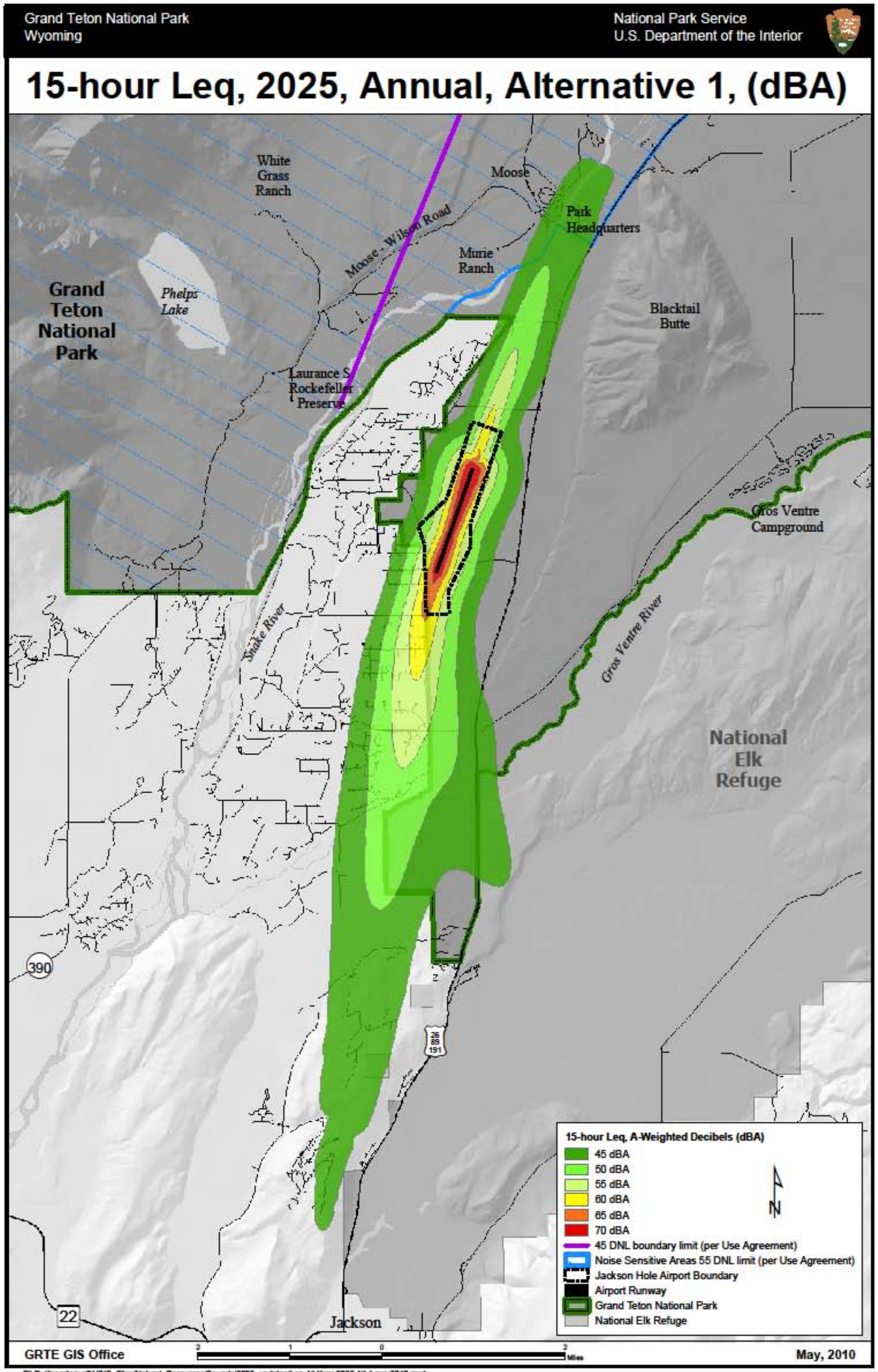


Figure G-25: 2025 Alternative 2 15-Hour Sound Energy Level (dBA)
For Average-Annual Condition

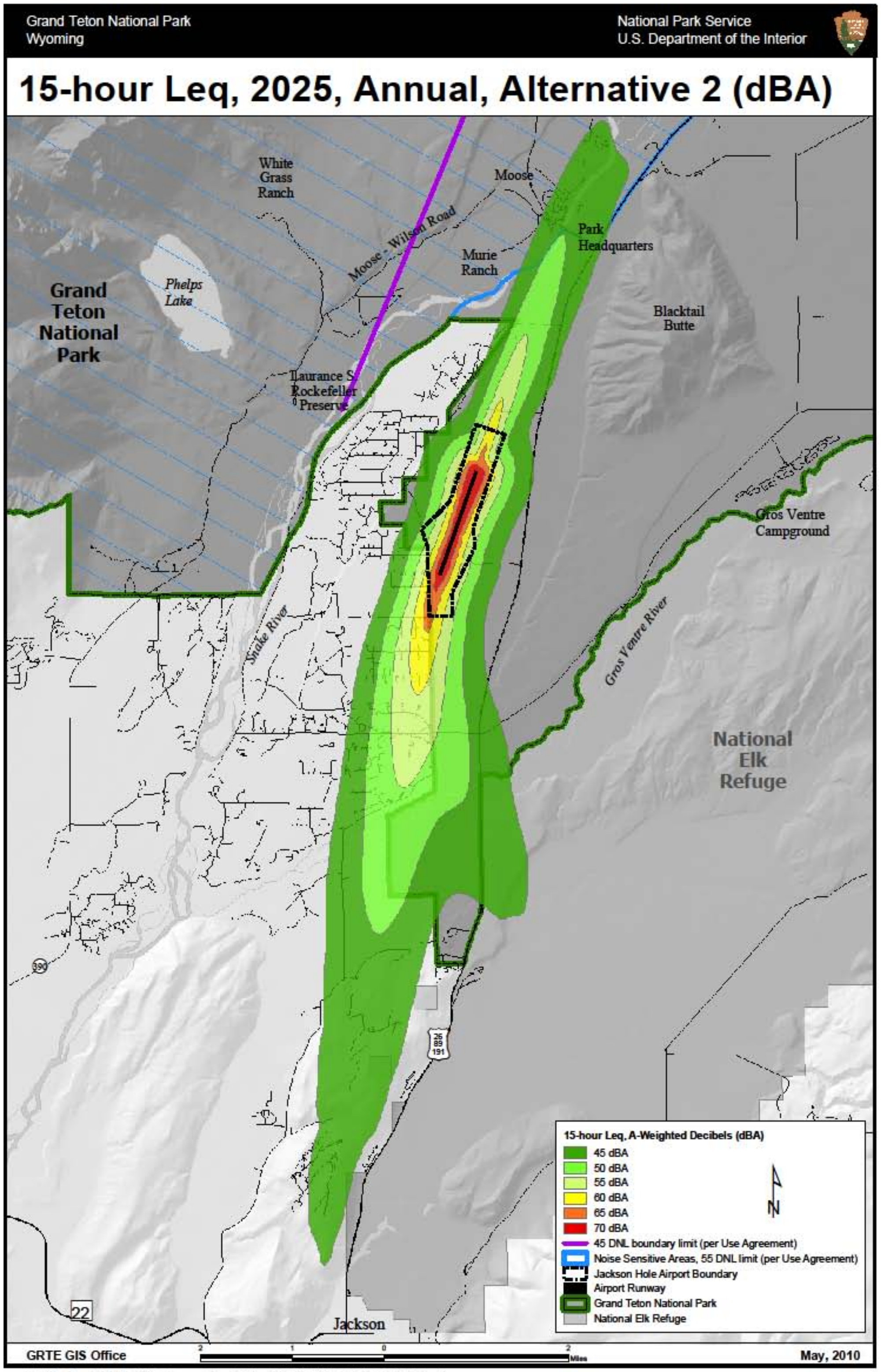


Figure G-26: 2005 15-Hour Sound Energy Level (dBA)
For Peak-Season Condition

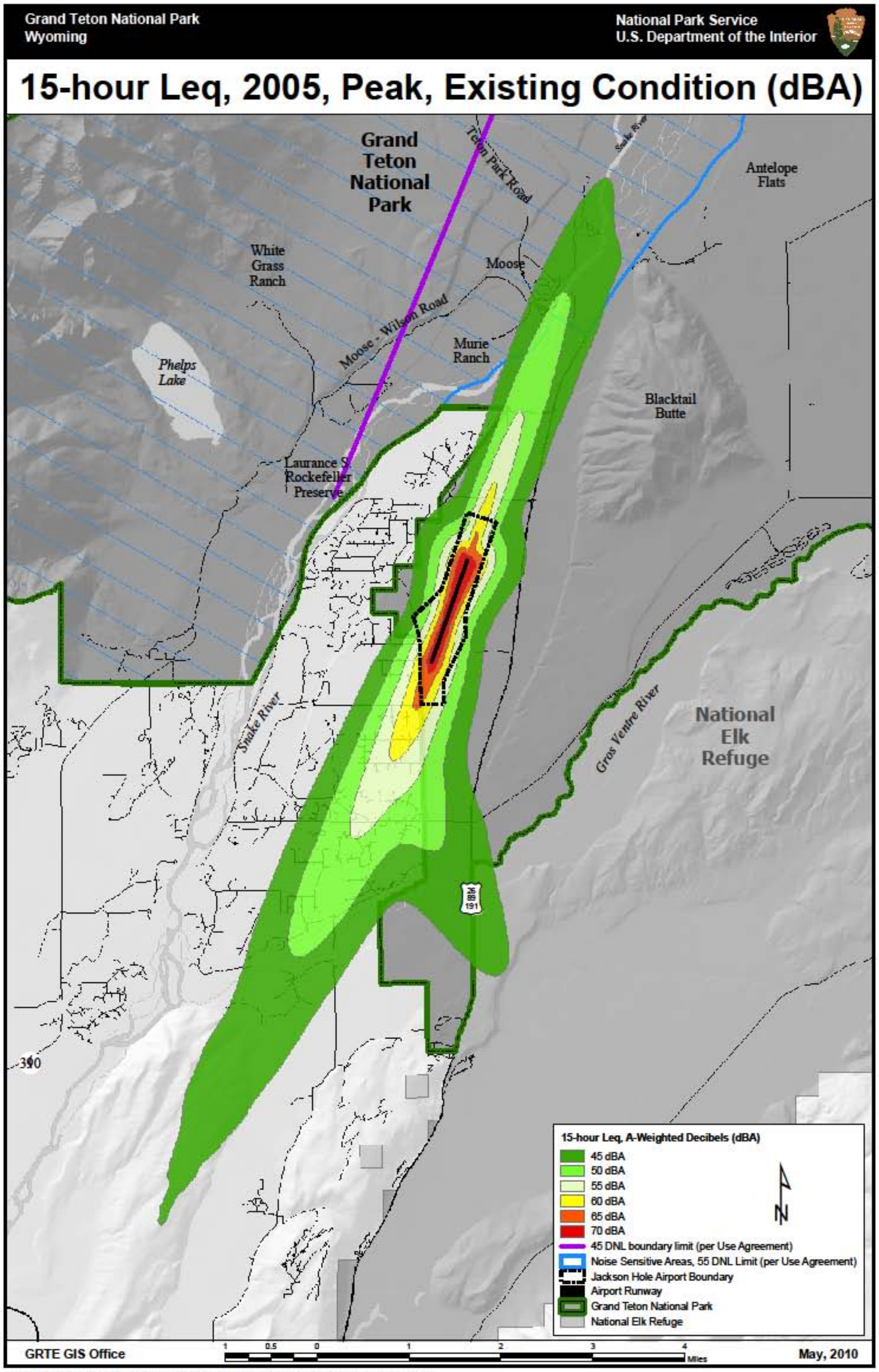


Figure G-27: 2015 Alternative 1 15-Hour Sound Energy Level (dBA)
For Peak-Season Condition

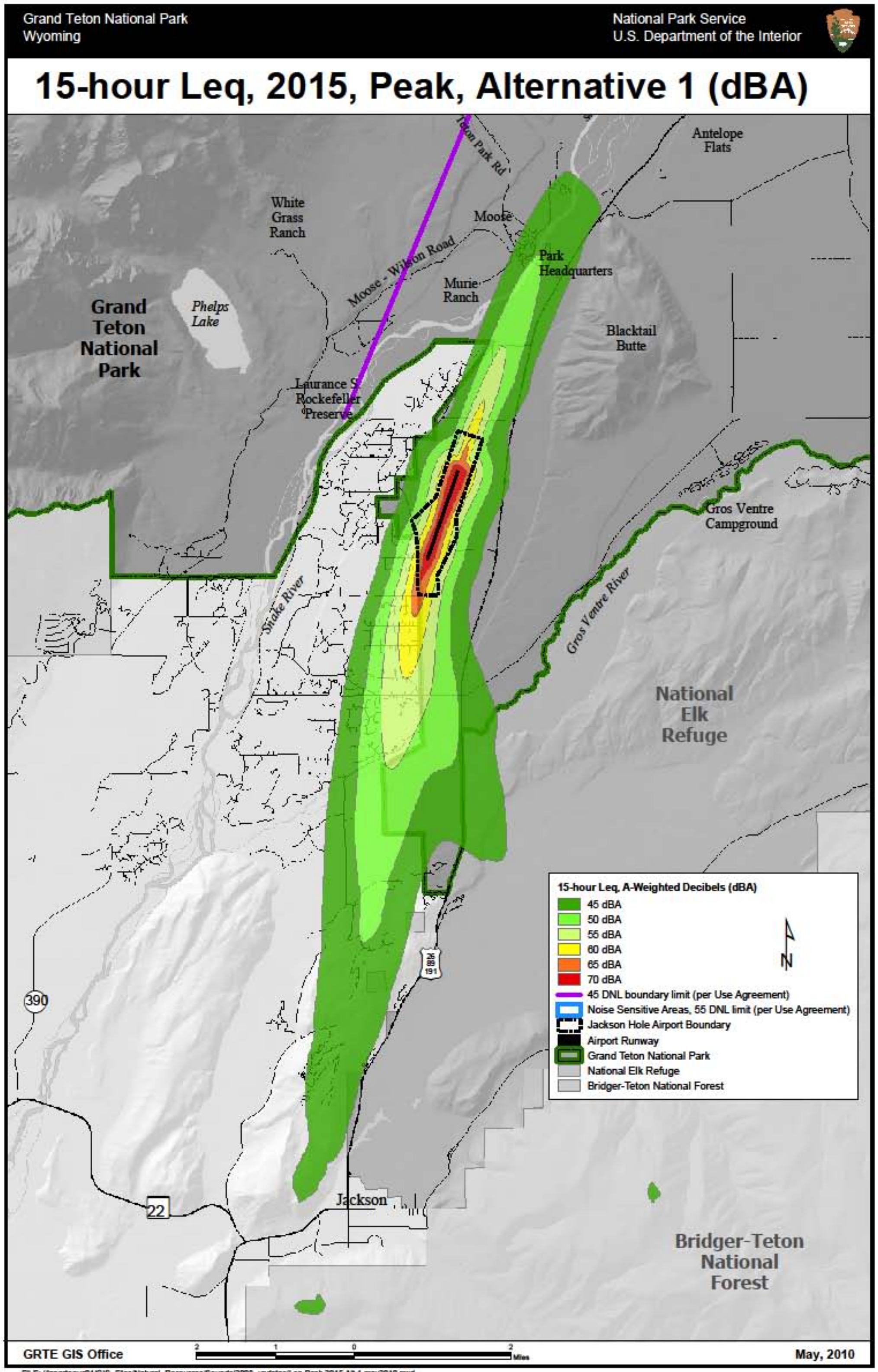


Figure G-28: 2015 Alternative 2 15-Hour Sound Energy Level (dBA)
For Peak-Season Condition

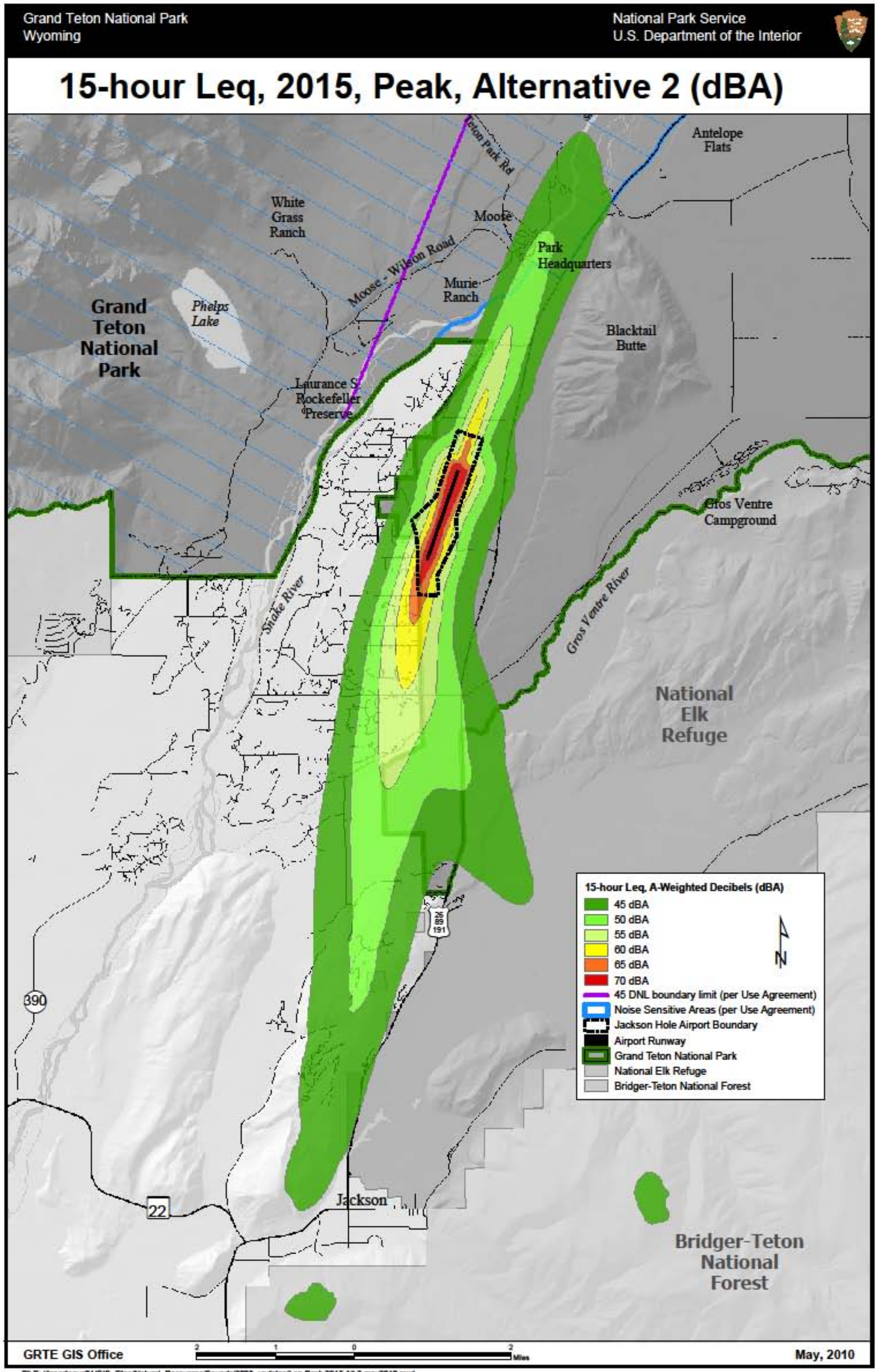


Figure G-29: 2025 Alternative 1 15-Hour Sound Energy Level (dBA)
For Peak-Season Condition

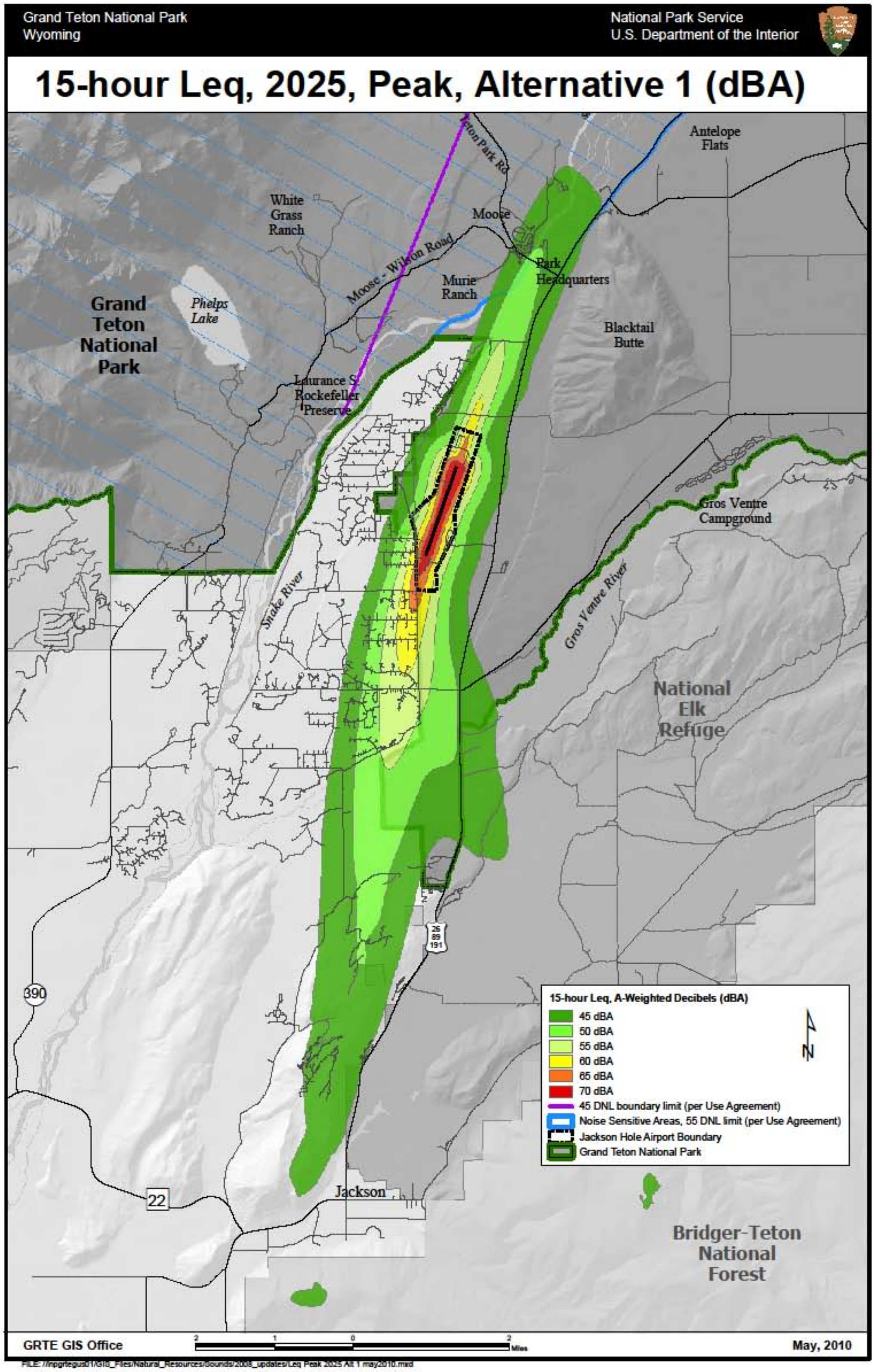


Figure G-30: 2025 Alternative 2 15-Hour Sound Energy Level (dBA)
For Peak-Season Condition

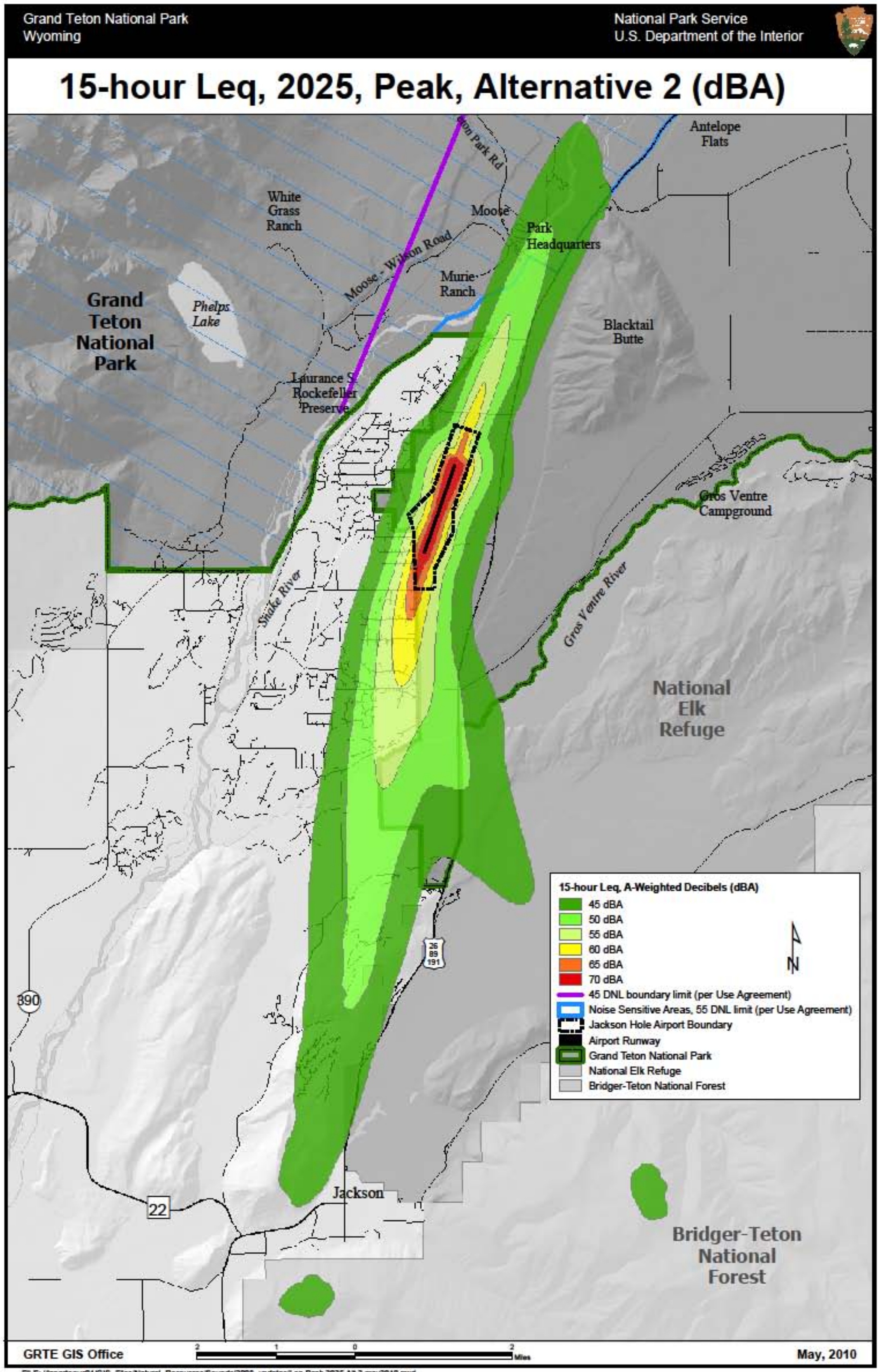
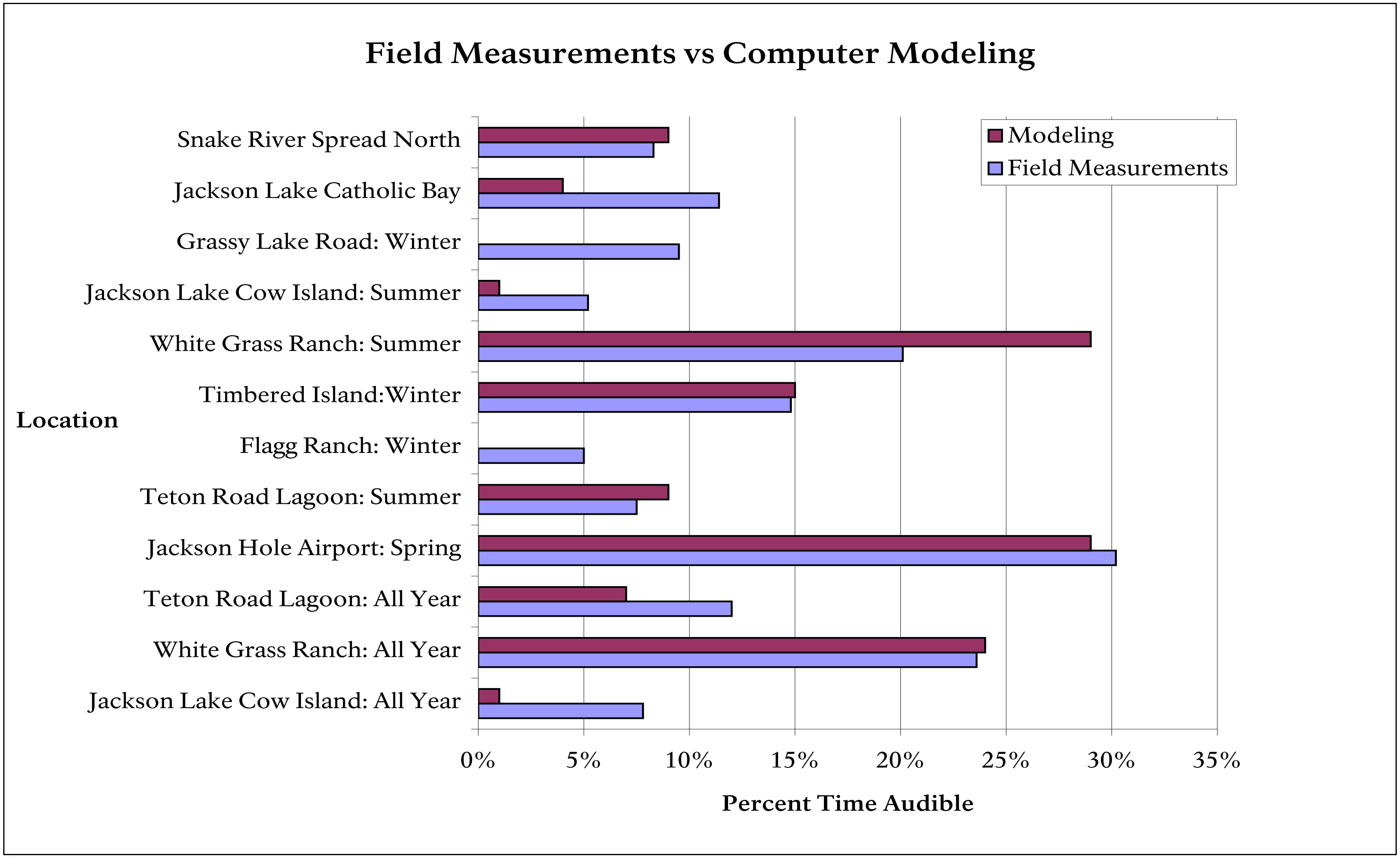


FIGURE G-31: COMPARISON OF FIELD MEASUREMENTS AND COMPUTER MODELING RESULTS AT SELECTED SITES [a/]




a/ Sites are ordered from smallest to largest sample size for field measurements. See text for details.

FIGURE G-32: TYPICAL FLIGHT PATHS FOR ARRIVALS TO THE JACKSON HOLE AIRPORT

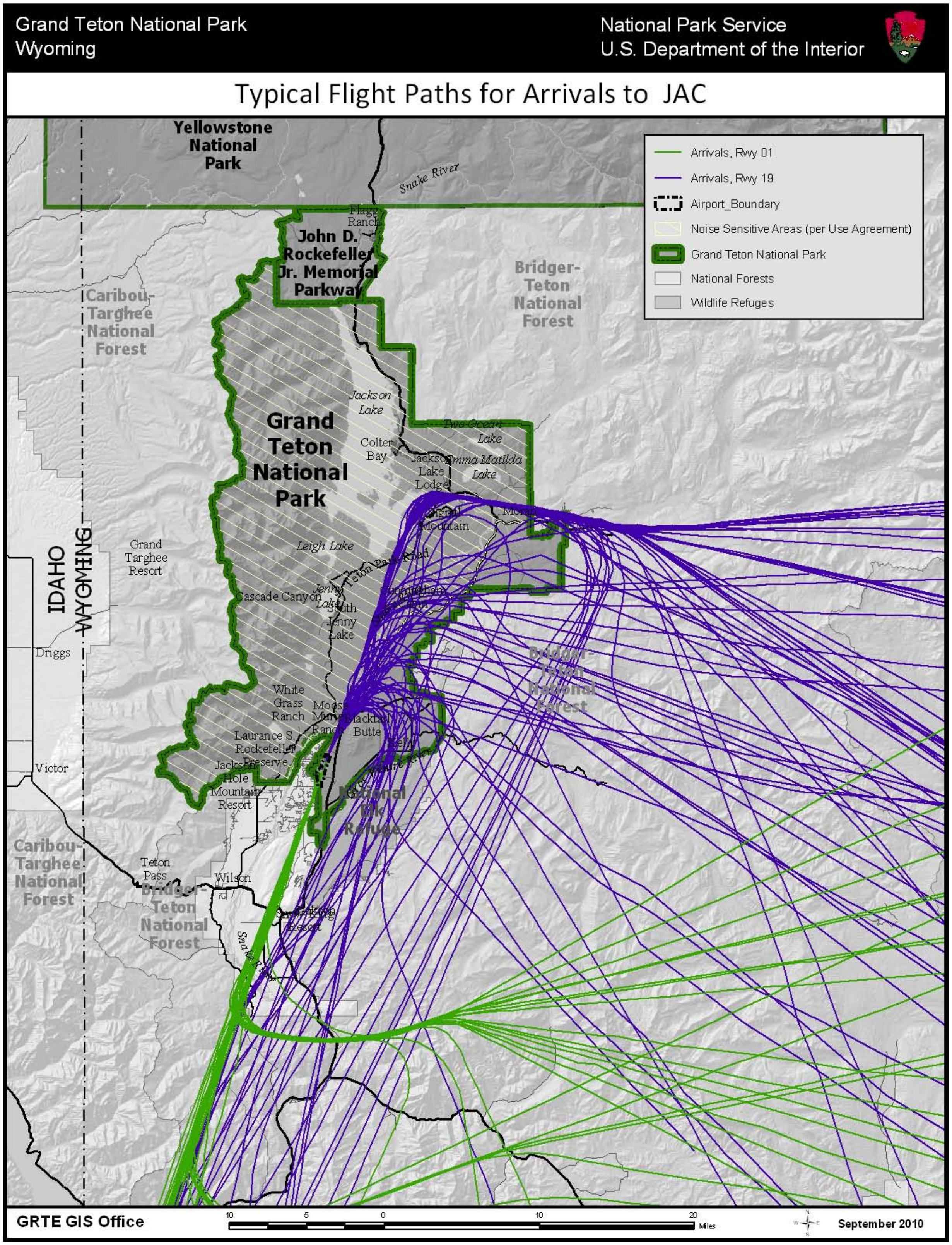


**FIGURE G-33: TYPICAL FLIGHT PATHS FOR DEPARTURES FROM THE JACKSON HOLE AIRPORT**