Susitna–Watana Hydroelectric Project
(FERC No. 14241)

Wood Frog Occupancy and Habitat Use
Study Plan Section 10.18

Study Completion Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

ABR Inc.—Environmental Research & Services

Forest Grove, Oregon and Fairbanks, Alaska

October 2015

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
ADF&G	Alaska Department of Fish and Game
AEA	Alaska Energy Authority
AICc	Akaike's Information Criteria, corrected for small sample size
AKNHP	Alaska Natural Heritage Program
APA	Alaska Power Authority
Bd	*Batrachochytrium dendrobatidis* (amphibian chytrid fungus)
C.I.	confidence interval
CIRWG	Cook Inlet Region Working Group
d	degrees of freedom
EC	electrical conductivity
FERC	Federal Energy Regulatory Commission
ft	foot, feet
GIS	Geographic Information System
GPS	Global Positioning System
ILP	Integrated Licensing Process
ISR	Initial Study Report
kph	kilometers per hour
m	meter
min	minimum
mph	miles per hour
n	sample size
n/a	not applicable
NHD	National Hydrography Dataset
NWI	National Wetlands Inventory
p	detection probability
pH	a measure of the acidity or alkalinity of a solution
PLP	Pebble Limited Partnership
Project	Susitna-Watana Hydroelectric Project
qPCR	Quantitative Polymerase Chain Reaction
RSP	Revised Study Plan
S.E.	standard error
SPD	Study Plan Determination
USFWS	United States Fish and Wildlife Services
USGS	United States Geological Survey

1. INTRODUCTION

The work described herein for the Wood Frog Occupancy and Habitat Use Study (Wood Frog Study, for short) was conducted according to Section 10.18 of the Revised Study Plan (RSP) approved by the Federal Energy Regulatory Commission (FERC or Commission) for the Susitna–Watana Hydroelectric Project, FERC Project No. 14241. The Wood Frog Study focused on auditory surveys of calling male wood frogs (*Rana* [*Lithobates*] *sylvatica*), including deployment of acoustic monitors, during the spring breeding season and on habitat occupancy modeling using the results of those surveys.

A summary of the development of this study, together with the Alaska Energy Authority's (AEA) implementation of the study through the 2013 study season, was presented in the Initial Study Report (ISR) that was filed with FERC in June 2014 (ABR 2014a, 2014b, 2014c). As required under FERC's regulations for the Integrated Licensing Process (ILP), the ISR described AEA's "overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule" (18 CFR 5.15(c)(1)).

Since filing the ISR in June 2014, AEA has continued to implement the FERC-approved plan for the Frog Study. For example:

- A second year of auditory surveys and acoustic monitoring of calling male wood frogs was conducted in spring 2014, followed by habitat occupancy modeling.

- On October 21, 2014, AEA held an ISR meeting for the Wood Frog Study and the other studies in the wildlife program.

In furtherance of the next round of ISR meetings and FERC's Study Plan Determination (SPD) expected in 2016, this report contains a comprehensive discussion of results of the Frog Study from the beginning of AEA's study program in 2013 through the end of calendar year 2014. It describes the methods and results of the Frog Study and explains how the study objectives set forth in the FERC-approved Study Plan have been met. Accordingly, with this report, AEA has now completed all field work, data collection, data analysis, and reporting for this study.

2. STUDY OBJECTIVES

The goal of the Wood Frog Study is to characterize the use of the Project area by breeding wood frogs to facilitate an assessment of potential impacts on wood frogs from development of the proposed Project.

The study has four objectives, as outlined in RSP Section 10.18.1:

- Review existing data on habitat use and distribution of breeding wood frogs in a broad region surrounding the study area.
- Estimate the current occupancy rate for breeding wood frogs in suitable habitats in the study area through a combination of field surveys and habitat-occupancy modeling.

- Collect information on current habitat occupancy and habitat use to enable estimation of the habitat loss and alteration expected to occur from development of the Project.
- Sample frogs opportunistically for the presence of the chytrid fungus that has been linked to amphibian population declines. (At the request of state and federal management agencies, AEA agreed to sample for the chytrid fungus to opportunistically take advantage of planned fieldwork and thereby provide some baseline information on the potential occurrence of the fungus in the study area before development.)

3. STUDY AREA

As established by RSP Section 10.18.1, the study area included those water bodies and suitable wetland habitats in the proposed Project area in which habitat loss, habitat alteration, and disturbance could potentially occur. The study area encompassed the reservoir inundation zone, associated areas for the dam and camp infrastructure, and the potential access-road corridors (Gold Creek, Chulitna, and Denali corridors) and material sites (Figures 3-1 and 3-2). Field sampling in 2013 was focused on the reservoir zone, dam and camp area, Chulitna Corridor, and a small portion of the Denali corridor (ABR 2014a). In 2014, field sampling was focused on the Gold Creek corridor and on the Denali West and Denali East corridor options (ABR 2014c).

3.1. Study Area Variance

As described in Section 1.4 of the ISR Overview, when the ISR was filed, AEA explained that it had decided to pursue the study of an additional alternative north/south-oriented corridor alignment for transmission and access from the Denali Highway to the proposed dam site. Referred to the "Denali East Option," this area was added to the Wood Frog Study area in May 2014 (Figure 3-2). The Denali Corridor surveyed in 2013 and reported on in the ISR and in 2013 figures and tables in this report is essentially equivalent to the Denali West Corridor surveyed in 2014.

In addition, Section 1.4 of the ISR noted that AEA was considering the possibility of eliminating the Chulitna Corridor from further study, so no surveys were conducted in that corridor in 2014 for the Wood Frog Study. In September 2014, AEA filed with FERC a formal proposal to implement this change. Thus, this report reflects a change in the study area to no longer include the Chulitna Corridor (Figure 3-2). Removal of the Chulitna Corridor resulted in minor changes to the 2014 study area buffer around the Gold Creek Corridor. Although the Chulitna Corridor was dropped from further study in 2014, lakes within the Chulitna Corridor that were surveyed for the APA Project in the 1980s were surveyed again in 2014 and those data are included herein for comparative purposes.

4. METHODS AND VARIANCES

The methods for each of the components of the Wood Frog Study are presented in this section.

4.1. Auditory Field Surveys

AEA implemented the methods described in the Study Plan (RSP Section 10.18.4.1), with the exception of the variances explained below (Section 4.1.1) and previously in Section 4.1 of ISR 10.18 Part A (ABR 2014a).

As indicated in the Study Plan, because the study area is large and the calling period of breeding male frogs is short, this study did not involve a comprehensive survey of all potential frog breeding habitat present in the study area. Instead, observers surveyed for frogs in suitable habitats that were stratified into two habitat types (water bodies and wetlands). The study team used a Geographic Information System (GIS) to compile the full list of possible sampling locations (148 in 2013 and 221 in 2014) by reviewing available information from existing GIS data layers (National Hydrography Dataset [NHD] and National Wetlands Inventory [NWI]) and by conducting additional interpretation of aerial imagery for portions of the study area for which recent imagery was available. The study team selected suitable individual water body and wetland habitats for auditory sampling by (1) identifying areas with emergent vegetation; (2) removing shoreline wetland polygons adjacent to water bodies (and just including the water bodies); (3) removing locations within 250 m of another suitable location; (4) including sampling locations on Cook Inlet Region Working Group (CIRWG) lands in 2014, for which access was not permitted in 2013; and (5) including high-elevation areas in 2014 that were frozen during the field-sampling period in 2013. Next, the study team selected sampling locations (120 in 2013 and 131 in 2014) by stratifying equally by area (access road or dam/camp area/reservoir zone [2013 only]) and then randomly selecting approximately equal numbers of each habitat type (water body, wetland) within each area. In 2014, sampling locations were stratified by access corridor (Gold Creek or Denali), except that all available water bodies and wetlands in the Denali East and West access corridor options were selected because relatively few were available in those corridors. The study team included the remaining locations (28 in 2013 and 90 in 2014) as alternative sampling locations, if needed.

The study team conducted ground-based auditory surveys of the randomly selected water bodies and wetlands in the study area during the early spring breeding season for wood frogs, the accepted survey time for this species (Gotthardt 2004; PLP 2011). Before the surveys began, observers trained by listening to digital audio files of the breeding calls of male wood frogs. Up to three replicate surveys were made by trained observers at each water body or wetland during May 30–June 8, 2013, and May 20–29, 2014. In addition to these surveys, incidental detections of wood frogs were documented during data collection efforts for other studies (mainly ground-based bird surveys), which provided additional information on the occurrence of frogs in the study area. The study team reached the survey sites by helicopter and then on foot by navigating to predetermined sample sites using hand-held Global Positioning System (GPS) receivers. The field observers listened for calling frogs during 5-min sampling periods along the margins of each water body or wetland sampled to determine whether or not frogs were calling. At small water bodies and wetlands, a single observation point was sufficient to detect calling frogs, but for large water bodies and wetlands, multiple observation points were needed to discern whether frogs were calling. Up to four observation points were located and sampled for large water bodies and wetlands, with distances of up to 500 m (1,640 ft) being designated between adjacent sampling points to achieve adequate survey coverage.

Due to variability in the calling frequency of male wood frogs even during the peak of the breeding season (PLP 2011), at least two, and occasionally three, visits were needed to detect frogs at some water bodies. The second or third surveys at each site were conducted by a different observer who generally did not have knowledge of the survey results from the first survey. Because this study involved the use of a “removal design” to estimate occupancy, however, additional surveys were not needed if frogs were detected on the first survey (i.e., that site was removed from further sampling; Mackenzie and Royle 2005). Surveys were conducted only under favorable weather conditions (e.g., light rain or no rain, air temperature higher than 4° C [39° F], and wind speed ≤25 kph [15 mph]). Observers spent a minimum of 5 min at each survey location listening for calling frogs, but terminated the survey sooner if frogs were detected.

Habitat and environmental characteristics (size and depth of water body or wetland, substrate, presence and type of emergent aquatic vegetation, water quality characteristics [pH level, dissolved oxygen, specific electrical conductivity (EC)], ice cover, surrounding terrestrial vegetation, water and air temperature, precipitation, cloud cover, wind speed, time of day, beaver activity) were recorded during the field surveys for use in the development of a Project-specific model to estimate occupancy based on the habitat characteristics of the occupied water bodies or wetlands.

4.1.1. Variances

The Study Plan (RSP Section 10.18.4.1) proposed that the potential water bodies and wetland habitats to be sampled would be identified from interpretation of aerial photos or remote-sensing imagery and from the preliminary mapping of vegetation, wildlife habitats, and wetlands. From that set of water bodies and wetlands, habitats were to be categorized as having a high or low probability of supporting breeding frogs (based on likelihood of supporting fish and presence of emergent vegetation). Lastly, the Study Plan proposed to select 10 sampling regions, two in each of the three potential access-road corridors and four in the reservoir zone and dam and camp facilities area. In each sampling region, 12 potential water bodies or wetlands were to be selected through a stratified random process.

Several factors affected the study team’s ability to implement the sampling approach described in the Study Plan: (1) current mapping of vegetation and wildlife habitats was not yet available before the 2013 and 2014 field seasons began; (2) existing wetland information (e.g., NWI mapping) did not cover the entire study area and was not of sufficient accuracy and resolution for the study; (3) data were not available regarding the presence of fish in water bodies and wetlands before field surveys began; and (4) permission for access to CIRWG lands was not granted in 2013, precluding sampling in most of the Gold Creek Corridor and parts of the Chulitna Corridor and the western portion of the reservoir zone in 2013. Therefore, the study team devised an alternative approach to selecting sampling locations (120 in 2013 and 131 in 2014) that still incorporated random selection of suitable sampling sites, as described in Section 4.1 above. This selection process fulfilled the original intent of the study plan to select sampling locations in a random manner throughout the study area.

In addition, the Study Plan (RSP Section 10.18.4.1) included the distribution of field survey times each day, which were originally planned for the period from approximately 12:00 to 22:00

but were conducted from approximately 09:00 to 20:00 (2013) and 09:30 to 19:30 (2014) instead, due to logistical challenges. The data from acoustic monitors showed that the sampling times were appropriate for the study, as is described below in Section 5.3. The acoustic monitors provided excellent results for evaluating the times of day when frogs were calling.

As explained above, the applicable study objectives were achieved with these modified approaches.

4.2. Occupancy Modeling and Habitat Associations

AEA implemented the methods described in the Study Plan (RSP Section 10.18.4.1) with no variances, as described previously in Section 4.2 of ISR 10.18 Part A (ABR 2014a).

Because frogs were not always detected during 5-min sampling sessions when they were present, the study team used occupancy modeling to adjust the observed occupancy rates for non-detections (Mackenzie et al. 2002). Occupancy modeling uses resurveys of the same locations to estimate a detection rate (p) and then uses the estimated detection rate to calculate an adjusted occupancy rate estimate (Ψ). The observed ("naïve") occupancy rate of frogs in water bodies and wetlands was adjusted to account for those frogs present but not detected, thereby producing a corrected occupancy rate for the water bodies and wetlands in this study.

Occupancy modeling also allows the user to compare various models with different specifications of detectability and occupancy parameters. The study team used a removal design in which locations were not revisited after frogs were detected, resulting in limited statistical power to estimate detectability parameters. It was assumed, therefore, that detectability was constant for all surveys in 2013. In 2014, the study team tested two model types for detectability: one assumed that detectability was constant for all surveys and the other assumed that detectability differed between corridors (Denali and Gold Creek); the latter was added to the analysis because of the large differences observed in seasonal phenology between the Gold Creek and Denali corridors in 2014. The study team compared four covariates for occupancy: (1) area (dam/camp area plus reservoir zone vs. access-road corridors) in 2013 or corridor (Denali vs. Gold Creek) in 2014; (2) water type (wetland or water body); (3) water depth (≤1.5 m [4.9 ft] or >1.5 m); and (4) percent of hibernation habitat (visual estimate of the percent of herbaceous cover, low shrubs, and tall shrubs within 50 m of the shoreline). Area was included in 2013 because the sample was stratified by area, whereas corridor was included in 2014 because the sample was stratified by corridor and the corridors had different elevation ranges. The other three covariates were chosen because they were expected to be the most biologically important, based on field observations and the results of other studies. With the available sample size, the analyses would only support a limited number of covariates.

The study team tested all possible combinations of these four occupancy covariates (without interactions), including an intercept-only model, and with two detectability models in 2014 (constant and corridor), resulting in a total of 16 different models for the 2013 results and 32 different models for the 2014 results. Model calculations were conducted with a desktop computer using the single-season analysis format and custom model-building features of the software program PRESENCE (Hines 2006).

The different models for each year were compared using information–theoretic methods (Burnham and Anderson 2002). For each model, the study team calculated the Akaike Information Criterion corrected for small sample sizes (AICc), which compares model fit and penalizes models for the number of parameters to determine the most parsimonious model (the best fit with the fewest number of parameters). The number of different locations was used as the effective sample size. The AICc values were used to calculate the Akaike weight (ωi), which is the probability that each model is the best model in the candidate set (Burnham and Anderson 2002).

4.2.1. Variances

No variances from the methods described in the Study Plan were implemented in 2013 or 2014.

4.3. Acoustic Monitoring

AEA implemented the methods described in the Study Plan (Section 10.18.4.1) with no variances.

The study team used Wildlife Acoustics Song Meter SM2BAT+ platforms with SMX-II microphones to record frog calls onto 32-GB (Class 4 SDHC) data cards. The monitors were internally powered with rechargeable D-cell batteries (Imedion 9,500 mAh). Five acoustic monitors were deployed to increase accuracy in calculating the detectability of calling frogs. The monitors were deployed at a subset of water bodies and wetlands on state, federal, and, in 2014 only, on CIRWG lands known to be occupied by frogs. Although the monitors were programmed to record full-spectrum audio recordings for the first 30 min of each hour around the clock, the study team analyzed only the first 10 min of each hour. Analytical results indicated that this subsampling adequately characterized the calling activity within the hour.

In 2013 the study team used the proportion of 5-min periods with frogs calling as an independent estimate of the ability to detect frogs at a given location, assuming that frogs were present. Due to battery failures for several monitors in 2014, however, it was not possible to derive a similar estimate for that year because of the small sample sizes obtained. The validity of this estimate relies on several assumptions: (1) individual observers were able to detect frogs calling at least as well as were the acoustic monitors; (2) the presence of observers did not lower the probability of frogs vocalizing; and (3) the locations chosen for acoustic monitoring were representative of all locations at which frogs were present. For each location surveyed, the study team determined the hour of the day in which the visit occurred and calculated the proportion of 5-min periods in which frog calls were heard on acoustic monitors during that hour. The study team then calculated the mean of all these proportions for each visit as a second, independent estimate of detectability.

4.3.1. Variances

No variances from the methods described in the Study Plan were implemented in 2013 or 2014.

4.4. Chytrid Fungus Bioassay

Sampling and laboratory assay methods for the chytrid fungus (*Bd*) were identified through consultation with U.S. Fish and Wildlife Service (USFWS) representatives in Alaska, who recommended that Tara Chestnut, an expert with the U.S. Geological Survey (USGS) in Portland, Oregon, be contacted for sampling protocols (Appendix A). Biologists wore fresh nitrile gloves and sprayed boots with a 10 percent bleach solution at each sampling location to prevent potential contamination among sites.

The study team captured seven frogs in 2013 by hand opportunistically and swabbed the skin of the abdomen, inner thighs, and undersides of foot webbing for a total of 25 times with a sterile cotton swab, after which the frog was released unharmed. Swabs were placed in tubes that were refrigerated until all seven samples were shipped on dry ice to the USGS Microbiology laboratory in Reston, Virginia. The lab analyzed the samples using a quantitative polymerase chain reaction (qPCR) technique to test for the presence of *Bd* fungus.

Sampling for the chytrid fungus (*Bd*) was not conducted in 2014 (see Section 4.4.1).

4.4.1. Variances

No variances from the methods described in the Study Plan were implemented in 2013.

Because of the small sample size obtained in 2013 ($n = 7$), opportunistic capture and swabbing of adult frogs to sample for the presence of amphibian chytrid fungus (RSP Section 10.18.4.2) was dropped from the field effort in 2014, as was discussed and agreed to in the technical meeting on March 6, 2014 (see meeting notes here: http://www.susitna-watanahydro.org/wp-content/uploads/2014/03/2014-03-06TT_Wildlife_MeetingNotes.pdf) and was discussed further with USGS (see Appendix A in ISR 10.18 Part A). Dropping the opportunistic sampling of frogs for the presence of *Bd* in 2014 was a study plan modification described in Section 7.1.2 of ISR 10.18 Part C (ABR 2014c); the study plan objective to sample frogs opportunistically was fulfilled in 2013.

5. RESULTS

Cumulative data developed in support of the Study Completion Report for 2013–2014 are available for download at http://gis.suhydro.org/SIR/10-Wildlife/10.18-Wood_Frogs/:

- FROG_10_18_2013_2014_ABR.gdb/FROG_2013_2014_AcousticMonitors
- FROG_10_18_2013_2014_ABR.gdb/FROG_2013_2014_IncidentalObs
- FROG_10_18_2013_2014_ABR.gdb/FROG_2013_2014_SamplingSites
- FROG_10_18_2013_2014_ABR.gdb/FROG_2013_StudyArea
- FROG_10_18_2013_2014_ABR.gdb/FROG_2014_Actual_Field_StudyArea
- FROG_10_18_Acoustic_Monitoring_2013_2014_ABR.xlsx.

5.1. Auditory Field Surveys

5.1.1. 2013 Sampling

As described in Section 5.1 of ISR 10.18 Part A(ABR 2014a), the study team surveyed a total of 90 different wetlands and water bodies for the presence of wood frogs in 2013 (Table 5.1-1, Figure 5.1-1). Additional water bodies and wetlands (n = 17) were visited but were excluded from the analyses for various reasons (e.g., water still frozen or insufficient water depth). Frogs were detected at 37 of the 90 locations (41.1 percent) on the first visit (Table 5.1-2) including 35 locations where frogs were heard calling and two locations where frogs were not heard but egg masses were found. The latter two locations were treated as non-detections in occupancy modeling, however, because frogs were not detected using the normal survey method. The study team conducted a second survey visit at 50 of the 53 locations where frogs were not detected on the first visit, producing detections at 8 more locations (16.0 percent). A third visit was conducted at five of the 42 sites where frogs were not detected on the first and second visits, producing detections at two more locations (40.9 percent). Overall, frogs were heard or egg masses were observed at 47 (52.2 percent) of the 90 locations sampled (Table 5.1-2, Figure 5.1-1). Therefore, the naïve estimate of frog occupancy (assuming 100 percent detectability) was 52.2 percent.

5.1.2. 2014 Sampling

The study team surveyed a total of 104 different wetlands and water bodies for the presence of wood frogs in 2014 (Table 5.1-3, Figure 5.1-2). Additional water bodies and wetlands (n = 31) were visited but were excluded from the analyses for various reasons (e.g., water still frozen or insufficient water depth). Frogs were detected at 14 of the 104 locations (13.5 percent) on the first visit (Table 5.1-4). The study team conducted a second survey visit at the 90 locations where frogs were not detected on the first visit, producing detections at 7 more locations (7.8 percent). A third visit was conducted at three of the 83 sites where frogs were not detected on the first and second visits, with no additional detections. Overall, frogs were heard or egg masses were observed at 21 (20.2 percent) of the 104 locations sampled (Table 5.1-4, Figure 5.1-2). Therefore, the naïve estimate of frog occupancy (assuming 100 percent detectability) was 20.2 percent across all locations sampled.

5.2. Occupancy Modeling and Habitat Associations

5.2.1. Occupancy Modeling

5.2.1.1. 2013 Sampling

The best model of frog occupancy contained only one variable: water depth. Based on the Akaike weight, this model had a 31.9 percent chance of being the best model in the candidate set (Table 5.1-5). The next three competing models contained water depth and one of the other variables but, in all cases, the 95 percent confidence interval (C.I.) for the other variable contained zero, suggesting that variables other than water depth added little to the model. After water depth was included, no statistical evidence was found to indicate that occupancy rates varied by area, by water-body type, or with increasing hibernation habitat.

The estimated detectability from the best model was 60.6 percent (95 percent C.I. = 34.8–81.6 percent; Table 5.2-1). The model results indicated that, if frogs were present in a pond, the study team would, on average, detect them 60.6 percent of the time with one visit, 84.5 percent of the time with two visits, and 93.9 percent of the time with three visits.

The estimated occupancy for shallow-water habitats was 36.8 percent (95 percent C.I. = 20.8–56.5 percent) and the estimated occupancy for deep-water habitats was 81.8 percent (95 percent C.I. = 44.4–96.2 percent; Table 5.2-1). As would be expected, these estimates were slightly higher than the naïve estimates of 31.0 percent and 70.8 percent, respectively. The sample included 42 shallow-water habitats (46.7 percent) and 48 deep-water habitats (53.3 percent). Assuming that this ratio is representative of the entire area sampled in 2013, the overall occupancy estimate was 63.4 percent (Table 5.2-1).

5.2.1.2. 2014 Sampling

The best model of frog occupancy contained only one occupancy variable (water depth, similar to 2013) and one detectability variable (corridor—Gold Creek Corridor or Denali Corridor options). Based on the Akaike weight, this model had a 16.5 percent chance of being the best model in the candidate set (Table 5.1-6). The second-best model, which contained the same variables plus hibernation habitat as an occupancy variable, had a 13.6 percent chance of being the best model in the candidate set. The confidence interval for hibernation habitat contained zero, however, suggesting that the variable added little to the model. The third-best model, which included water depth and corridor as occupancy variables and for which detectability was constant across all sites, had a 13 percent chance of being the best model in the candidate set.

The first, second, and third-best models all included depth and corridor as variables, but the first and second models assumed that detectability differed between corridors and occupancy was the same, whereas the third model assumed that detectability was the same between corridors and occupancy differed (Tables 5.2-2, 5.2-3). Because the two groups of models gave different occupancy estimates, one estimate from each group (best model and third-best model) is presented to acknowledge this difference in interpretation (Tables 5.2-2, 5.2-3).

The estimated detectability from the best model, for which detectability differed between corridors, was 56.6 percent (95 percent C.I. = 14.5–90.9 percent; Table 5.2-2) in the Gold Creek Corridor. This model indicated that, if frogs were present at a sampling site in the Gold Creek Corridor, the study team would, on average, detect them 56.6 percent of the time with one visit, 81.2 percent of the time with two visits, and 91.8 percent of the time with three visits. In contrast, detectability was estimated to be just 16.0 percent (95 percent C.I. = 5.5–38.7 percent; Table 5.2-2) in the Denali corridors (West and East options combined). The model indicated that, if frogs were present at a sampling site in the Denali corridors, the study team would, on average, detect them 16.0 percent of the time with one visit, 29.4 percent of the time with two visits, and 40.7 percent of the time with three visits.

The estimated detectability from the third-best model, with constant detectability in both corridors, was 54.6 percent (95 percent C.I. = 22.6–83.2 percent; Table 5.2-3). The model results indicated that, if frogs were present at a sampling site, the study team would, on average, detect them 54.6 percent of the time with one visit, 79.4 percent of the time with two visits, and 90.6 percent of the time with three visits.

Based on the results of the best model with different detectability between corridors, the estimated occupancy for shallow-water habitats was 17.9 percent (95 percent C.I. = 5.9–43.1 percent) and the estimated occupancy for deep-water habitats was 71.9 percent (95 percent C.I. = 19.2–96.5 percent; Table 5.2-2). As would be expected, these estimates were higher than the naïve estimates of 8.6 percent and 34.7 percent, respectively. The sample included 58 shallow-water habitats (55.8 percent) and 46 deep-water habitats (44.2 percent). Assuming that this ratio is representative of the entire area sampled in 2014, the overall occupancy estimate based on the best model was 39.3 percent (Table 5.2-2).

Based on the results of the third-best model, with constant detectability between corridors, the estimated occupancy for shallow-water habitats was 21.5 percent (95 percent C.I. = 7.4–49.5 percent) in the Gold Creek Corridor and 4.9 percent (95 percent C.I. = 1.4–16.2 percent) in the Denali corridors. The estimated occupancy for deep-water habitats was 68.2 percent (95 percent C.I. = 32.5–90.5 percent; Table 5.2-3) for the Gold Creek Corridor and 28.7 percent (95 percent C.I. = 12.0–54.3 percent) in the Denali corridors. The sample included 21 shallow-water habitats (55.3 percent) and 17 deep-water habitats (44.7 percent) in the Gold Creek Corridor and 37 shallow-water habitats (56.1 percent) and 29 deep-water habitats (43.9 percent) in the Denali corridors. Assuming that these ratios are representative of the entire area of both the Gold Creek and Denali corridors, the overall occupancy estimates based on the third-best model is 40.8 percent in the Gold Creek Corridor and 11.3 percent in the Denali corridors (Table 5.2-3).

5.2.2. Habitat Associations

5.2.2.1. 2013 Sampling

Occupancy modeling was the primary tool to assess habitat associations with breeding male wood frogs and water depth was the most important habitat variable. Frogs were detected at a total of 13 of 42 (31.0 percent) locations with shallow water (≤1.5 m) and 34 of 48 (70.8 percent) locations with deep water (>1.5 m). The remaining habitat variables were summarized by locations where wood frogs were detected, not detected, and across all sampling locations (Table 5.2-4). The only other variable that exhibited a significant association was dissolved oxygen (mg/L), with lower levels being found where frogs were detected (Table 5.2-4).

5.2.2.2. 2014 Sampling

Occupancy modeling was the primary tool to assess habitat associations with breeding male wood frogs and water depth was the most important habitat variable, as in 2013. Frogs were detected at a total of 5 of 58 (8.6 percent) locations with shallow water (≤1.5 m) and 16 of 46 (34.8 percent) locations with deep water (>1.5 m). The remaining habitat variables were summarized by locations where wood frogs were detected, not detected, and across all sampling locations (Table 5.2-5). The only other associations of significance were water-body type (more frogs detected at small ponds with emergent vegetation than other water-body types); dissolved oxygen (higher levels were found where frogs were detected, which was the opposite of the pattern observed in 2013); and specific EC (lower levels were found where frogs were detected;

Table 5.2-5). Although substrate type and emergent vegetation type did not exhibit statistically significant differences in wood frog presence ($P > 0.05$), almost all detections were in areas with emergent sedges (90.5 percent) and all detections were in areas with organic substrates (Table 5.2-5).

5.3. Acoustic Monitoring

5.3.1. 2013 Sampling

Acoustic recordings from the five monitors provided a sample of 2,015 5-min intervals that were used to quantify when frogs were heard calling. Calling activity varied by date and time of day (Figure 5.3-1). The results demonstrated that the surveys were well-timed to capture the peak of calling activity in the study area; frogs were calling when the acoustic monitors were deployed on May 31 and calling activity was declining by the end of the survey period on June 8 (Figure 5.3-1 [top]). A very strong diurnal pattern of calling activity was evident. Calling activity peaked near 01:00, then activity dropping dramatically to a low early in the morning (05:00) and increased throughout the remainder of the day (Figure 5.3-1 [bottom]).

Based on the time-specific results from the acoustic monitors, the site visits should have had a detectability of 60.8 percent, which was essentially identical to the estimate of 60.6 percent from the occupancy modeling. This concurrence provides additional evidence that the occupancy modeling provided a reasonable estimate of detectability and indicates that occupancy rates were adjusted appropriately.

5.3.2. 2014 Sampling

Acoustic recordings from the five monitors provided a sample of 442 5-min intervals that were used to quantify when frogs were heard calling. Unfortunately, four monitors experienced battery malfunctions during most of the sampling period, substantially reducing the overall sample size in 2014. As in 2013, calling activity varied by date and time of day (Figure 5.3-2). Although the data on seasonal changes in calling rates were sparse, the results demonstrated that the surveys were well-timed to capture the peak of calling activity in the study area; frogs were calling when the acoustic monitors were deployed on May 20 and calling activity declined by the end of the survey period on May 29 (Figure 5.3-2 [top]). As in 2013, a strong diurnal pattern of calling activity was evident, with the lowest rates of calling occurring in the morning (05:00–10:00; Figure 5.3-2 [bottom]) when air temperatures were low (Figure 5.3-3), followed by increasing calling rates during the late morning and early afternoon (Figure 5.3-2 [bottom]) as air temperatures increased (Figure 5.3-3). Because of the small sample size of recordings obtained in 2014, the acoustic monitoring results were not used to calculate detectability.

5.4. Chytrid Fungus Bioassay

Swab samples collected from seven frogs captured opportunistically in 2013 were sent to the USGS Reston Molecular and Environmental Microbiology Laboratory in Reston, Virginia, and tested for the presence of chytridiomycosis (*Bd*) using standard qPCR protocols (Boyle et al. 2004). All seven samples tested negative for *Bd*. No samples were collected in 2014 (see Section 4.4.1).

6. DISCUSSION

Amphibian populations appear to have been declining worldwide for several decades (Blaustein and Wake 1990; McCallum 2007), leading to elevated levels of concern about the conservation status of a large number of amphibian species. Although populations appear to be healthy in Alaska (Gotthardt 2004, 2005), concern has been expressed about the conservation status of wood frogs in Alaska (ADF&G 2006). Because amphibians were not included in the original Alaska Power Authority Susitna Hydroelectric Project (APA Project) environmental study program in the 1980s, information on the occurrence of wood frogs in the upper Susitna drainage was lacking and their status in the study area was unknown at the time this study began.

6.1. Distribution and Habitat Use

A review of the literature shows that wood frogs are widely distributed throughout northern North America and that, in Alaska, they occur from Southeast Alaska throughout central Alaska to the crest of the Brooks Range (MacDonald 2010). Closer to the study area, they have been documented in Denali National Park and Preserve, near Healy, and in the lower Susitna drainage (Cook and MacDonald 2003; Anderson 2004; Gotthardt 2004, 2005; Hokit and Brown 2006).

Wood frogs were widely distributed throughout the areas sampled in 2013 and throughout the Gold Creek Corridor in 2014. The distribution of frogs at higher elevation sites in the Denali East and West corridor options was more dispersed, however. Wood frogs may be reaching their elevational limits in this region because of the limited time available for breeding. The highest potential sampling sites (approximately 900–1,100 m [2,953–3,609 ft] above sea level) were still covered by snow and ice during the 2014 survey period and thus were unavailable for sampling.

Wood frogs occurred in a variety of habitats sampled in 2013 and 2014, ranging from alpine tundra to forested wetlands (see photographs in Appendix B). Wood frogs are known to inhabit diverse vegetation communities in Alaska, including tundra, open forests, grassy meadows, and muskeg (MacDonald 2010). Not surprisingly, the habitat associations of wood frogs are diverse, so a summary of known habitat associations is presented below and related to the findings of this study and other similar studies.

Water-body types in the study area ranged from those having adequate water to sample, but insufficient water depth to allow frog larvae to metamorphose (i.e., the ponds or wetlands would dry out too early in the season) to deep-water lakes. More frogs were detected at small ponds with emergent vegetation than at other water-body types in 2014, likely because emergent vegetation is important for the attachment of egg masses (France 1997).

Water depth was the most important habitat factor analyzed in this study in 2013 and 2014, which was consistent with the results of a similar study in southwestern Alaska, in which water depth was an important habitat factor (PLP 2011). In both studies, calling male frogs were detected more frequently in habitats where water was deeper than 1.5 m.

Water depth may be important because deeper water bodies retain water and often maintain more consistent water-quality characteristics during the egg and larval growth stages (Knapp et al. 2003). In Denali National Park, Hokit and Brown (2006) found that wood frogs had the highest breeding activity (defined as eggs or larvae) in sites with 51 to 75 percent of the site < 50 cm (1.6 ft) deep, but with a maximum depth of 1 to 2 m (3.3 to 6.6 ft). Differences in sampling methods, sampling times, and characterization of water body depths, however, make direct comparison of their results with this study difficult. Water depth may be one of many factors influencing where wood frogs choose to breed, judging from the findings of Herreid and Kinney (1966), in which 96 percent of wood frog eggs and larvae died before reaching metamorphosis because of lack of fertilization, freezing, desiccation of eggs, temperature-related abnormalities, and predation.

Hibernation habitat (herbaceous, low shrub, and tall shrub vegetation within a 50-m radius of the shoreline) was not associated with frog detectability in this study in 2013 or 2014, in contrast to the results reported by PLP (2011), in which wood frog occupancy increased as surrounding hibernation habitat increased. Increased availability of vegetation that provides suitable habitat for hibernation within 50 m of breeding ponds may be an important factor influencing occupancy of water bodies in some areas, although seasonal movements of wood frogs up to 300 m or more away from breeding ponds have been documented in Maine (Vasconcelos and Calhoun 2004, Baldwin et al. 2006). The PLP (2011) study was conducted in a tundra area with much less tree cover than in this study area. Differences in habitat occupancy and vegetative cover may help to explain this difference between studies.

Emergent and aquatic vegetation in water bodies provides a substrate for frog egg masses and escape cover from aquatic predators, as well as helping to increase dissolved oxygen in the water (France 1997; Babbitt and Tanner 1998). Although the extent of emergent vegetation did not differ significantly between ponds with and without frog detections ($P = 0.10$) in 2014, frogs were never detected at locations without emergent vegetation and were nearly always detected (90.5 percent) at locations with emergent sedges. Dissolved-oxygen levels (8.53 mg/L) were similar between sites occupied and those not occupied by frogs in 2013, whereas in 2014 they were higher at occupied (8.63 mg/L) vs. unoccupied (7.28 mg/L) sites. The levels in this study were similar to those observed in a study in Southeast Alaska (approximately 9.0 mg/L; Carstensen et al. 2003) and were within the range of mean values from new (4.9 mg/L) and old (10.5 mg/L) beaver ponds in Alberta (Stevens et al. 2006). Increased concentrations of dissolved oxygen were thought to be important in the latter study because they were correlated with enhanced larval growth rates of wood frogs in old beaver ponds, although the authors cautioned that this may have been an artifact of other landscape features (Stevens et al. 2006).

Other aspects of water quality such as pH may be important for breeding-site selection by wood frogs. A study in Quebec reported that egg mass density and hatching success were negatively correlated with pH, although hatching success was still fairly high (47 and 80 percent in ponds with pH of 4.3 and 4.7, respectively; Gascon and Planas 1986). Another study near Juneau, Alaska, measured pH levels ranging from 4.5 to 5.5 in ponds where larval wood frogs were present (Carstensen et al. 2003). New and old beaver ponds in Alberta containing wood frogs had pH levels of 7.6 and 7.8, respectively (Stevens et al. 2006). The pH values in the study were very consistent throughout the sampling locations (5.73 at occupied sites and 5.72 at unoccupied sites in 2013; 6.55 at occupied sites and 6.51 at unoccupied sites in 2014), within the range of other studies where wood frogs bred successfully.

Electrical conductivity, a measure of water quality related to salinity, was found to be statistically significant in this study in the 2014 results, but these differences evidently were not biologically meaningful. The difference between sites where frogs were detected and were not detected was <1 uS/cm, and it is thought that conductivity should not limit tadpole presence at values <3,000 uS/cm (Smith et al. 2006).

Other habitat variables measured in this study did not show clear relationships with frog occupancy, including beaver activity, substrate, ice cover, and water temperature. Fish are known predators of frogs (Hecnar and McCloskey 1997), but data on fish presence and distribution in the water bodies and wetlands sampled in this study were not available for analysis.

6.2. Occupancy Modeling

Accurate habitat occupancy estimates are adjusted for the detectability of organisms in the environment. Detectability in this study was high in 2013, at 60.6 percent from the best model and 60.8 percent from the acoustic monitors (see Section 6.3 below). Detectability was variable in 2014, at 56.6 percent in the Gold Creek Corridor and 16.0 percent in the Denali corridors from the best model, or at 54.6 percent overall from the third-best model. The estimated detectability in a study in southwestern Alaska (26.6 percent; PLP 2011) was lower than this study and may have resulted from differences in frog density, habitat characteristics, survey conditions, or the timing of surveys between studies.

The high detectability in this study during 2013 indicates a robust study design: if frogs were present at a sampling site, the study team would detect them 60.6 percent of the time with one visit, 84.5 percent of the time with two visits, and 93.9 percent of the time with three visits (based on the best model). Similarly, in 2014, if frogs were present at a sampling site the study team would detect calls in the Gold Creek and Denali corridors, respectively, 56.6 and 16.0 percent of the time with one visit, 81.2 and 29.4 percent of the time with two visits, and 91.8 and 40.7 percent of the time with three visits (based on the best model). Based on the third-best model, frogs would be detected 54.6 percent of the time with one visit, 79.4 percent of the time with two visits, and 90.6 percent of the time with three visits.

The best models of frog occupancy in this study in 2013 and 2014 contained only the variable water depth, with deeper water types having higher occupancy. The estimated occupancy in 2013 for shallow-water habitats (36.8 percent), deep-water habitats (81.8 percent), and all locations (63.4 percent) suggest a widespread distribution of frogs in the areas surveyed in 2013 (dam and camp area, reservoir inundation zone, Chulitna Corridor, part of the Denali corridors). In the Gold Creek and Denali corridors in 2014, respectively, the estimated occupancy was 21.5 and 4.9 percent in shallow-water habitats, 68.2 and 28.7 percent in deep-water habitats, and 40.8 percent and 11.3 percent for all locations. The third-best model suggested a widespread distribution of frogs in the Gold Creek Corridor and a more limited distribution in the Denali corridors.

The study team detected fewer frogs in 2014 in the Denali corridors than in the Gold Creek Corridor. Occupancy modeling provided two different interpretations of the 2014 data, both of which had statistical support but for which occupancy estimates differed. The best model had very different detection rates between corridors (perhaps because of differences in the timing of surveys), resulting in occupancy rates that just varied with water depth. The third-best model had constant detectability between corridors but different occupancy rates, both by water depth and corridor (perhaps because of differences in habitats by corridor). Although it is not possible to reach a definitive conclusion about which interpretation is correct because of the limited number of detections in the Denali corridors in 2014, it is clear that water depth is very influential on the occupancy rate of wood frogs in this study.

Few studies have estimated occupancy rates of wood frogs in Alaska. The naïve occupancy rate in Denali National Park and Preserve was estimated at 45 percent (Hokit and Brown 2006), which was generally similar to an adjusted occupancy estimate of 49.5 percent in southwest Alaska (PLP 2011), although adjustment of the Denali Park estimate would likely have resulted in a higher occupancy rate. In comparison, the adjusted overall occupancy rates in this study ranged from 39.3–40.8 (2014) to 63.4 percent (2013), bracketing the results from those other studies in Alaska.

6.3. Acoustic Monitoring

The use of acoustic monitoring devices allowed the study team to collect information to characterize the calling activity of breeding male wood frogs throughout the survey period and throughout all hours of the day. Frogs called throughout the survey period (May 30–June 9, 2013; May 20–29, 2014) and incidental observations by other wildlife field crews noted calling frogs (May 28–June 14, 2013, and May 26–June 14, 2014). These results indicated that the auditory surveys were well-timed, at least for locations at lower elevations in 2013 (dam and camp area, reservoir zone, and most of the Chulitna Corridor) and 2014 (Gold Creek Corridor). Locations at higher elevations in the Denali corridors, however, still were snow-covered and many water types were either frozen or just beginning to thaw during the survey period in each year, although much more water was open in 2014 than in the unusually late spring in 2013.

Supplemental data from acoustic monitors deployed in both corridors between May 30 and June 8, 2014, showed a decline in calling activity for detectors in the lower-elevation sites (i.e., Gold Creek Corridor) and a decreasing or variable rate of calling activity in the Denali corridors. Egg masses in the early stages of development (n = 5 locations), along with young tadpoles (n = 1) were discovered in the Gold Creek Corridor, also suggesting that the auditory surveys were well-timed to detect calling frogs in that corridor.

The information for the higher-elevation sites in 2014 (Denali corridor options) is less clear, however, for several reasons: (1) the two acoustic detectors deployed there were installed at later dates (May 24 and 26) than in the Gold Creek Corridor because it was necessary to sample the lower-elevation sites first and allow the higher-elevation sites to thaw; (2) the detectors collected limited data during the auditory survey period because of battery failures, and most data were obtained during May 30–June 8, after the auditory surveys were completed; and (3) the two detectors in the Denali corridors produced disparate results, in that calling frequency decreased over time at one detector and was variable over time at the other, making it unclear whether the Denali corridors were sampled when most frogs were calling.

Diurnal patterns of frog calling activity in 2013 showed a pattern of high calling rates throughout the late morning and afternoon, with peak calling activity occurring between 01:00 and 02:00. Frog calling activity in 2014 showed a diurnal pattern of high calling rates throughout the early afternoon and evening, although all of the data for the period of 00:00–15:00 came from a single detector located in the Gold Creek Corridor. Additional data obtained after the auditory surveys finished in 2014 (May 30–June 8) reinforced this pattern, which was similar in overall shape to that from 2013, although 2014 values were generally at lower levels (lower percentages). The lowest rates of calling activity in 2014 correlated with some of the lowest temperatures of the day, which occurred before acoustic surveys began.

The auditory survey sampling times between approximately 09:00 and 20:00 in 2013 mainly fell within the period of high calling activity, helping to explain the high detectability of the surveys that year. The survey times between approximately 09:30 and 19:30 in 2014 fell within both low and high periods of calling activity observed in 2014, with later sampling times having a higher percentage of calling frequency. The low frequency of frogs calling in the morning and early afternoon in 2014 may help to explain the lower detectability values obtained in 2014 than in 2013.

An additional use of the 2013 acoustic monitoring data was to calculate the detectability (60.8 percent) of frogs calling when the study team actually sampled and compare that to the estimate from occupancy modeling (60.6 percent). Concordance between these results provided strong evidence that the occupancy modeling provided a reasonable estimate of detectability and that the occupancy rates were adjusted appropriately. This concordance is key to producing meaningful habitat occupancy results for eventual use in estimating the potential habitat loss and alteration that may occur from development of the Project.

6.4. Chytrid Fungus

Bd is a chytrid fungus that causes the disease chytridiomycosis in amphibians. Since it was first discovered in amphibians in 1998, it has devastated amphibian populations around the world, including in North America (Adams et al. 2007, Olson et al. 2013). *Bd* is sometimes a nonlethal parasite and some amphibian species and some populations of susceptible species are known to survive infection. The fungus is widespread and ranges from lowland forests to cold mountain tops, and is typically associated with host mortality in high altitude environments and during winter, with greater pathogenicity at lower temperatures. *Bd* is believed to spread mainly through contact between infected frogs or with infected water. USFWS originally requested that opportunistic sampling for the presence of *Bd* be added to the Study Plan out of concern for the potential spread of the fungus through increased road access in the study area.

Wood frogs have been identified as a species susceptible to infection by *Bd*, and it was first detected in Alaska in a dead wood frog found in the Kenai National Wildlife Refuge in 2002 (Reeves and Green 2006, Reeves 2008). Another positive detection of *Bd* occurred near Dyea in Southeast Alaska in 2006 and was associated with the apparent die-off of western (boreal) toads in that region (*Juneau Empire*, May 21, 2006). *Bd* was documented in boreal toads (*Bufo boreas*) and red-legged frogs (*Rana aurora*) in another study in western Canada and Southeast Alaska (Adams et al. 2007). Although *Bd* was not detected in this study, the small sample size of swabs obtained in this study is considered inadequate to confirm its absence unequivocally.

7. CONCLUSION

During 2013–2014, AEA completed auditory surveys and acoustic monitoring of calling male wood frogs to document the distribution, habitat use, and occupancy of wood frogs in water bodies throughout the study area during the spring breeding season. The status of wood frogs in the Project area was unknown prior to this study and few studies have established occupancy rates of wood frogs in Alaska. A total of 90 randomly selected wetlands and water bodies were surveyed for the presence of wood frogs in 2013 and 104 wetlands and waterbodies in 2014. Frogs were found to be widely distributed in the areas surveyed over a variety of habitat types from tundra to forested wetlands. The field work, data collection, data analysis, and reporting for the Wood Frog Study successfully met the first, second, and fourth study objectives in the FERC-approved Study Plan; the third objective will be addressed in the draft license application for the Project, using information obtained in this study. The results of the Wood Frog Study are reported herein and earlier by AEA (ABR 2014a, 2014b, 2014c). With this report, AEA has now completed Study 10.18, Wood Frog Occupancy and Habitat Use.

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9. TABLES

Table 5.1-1. Number of Frog-survey Visits to Water Bodies and Wetlands in the 2013 Study Area.

Location	First Visit	Second Visit	Third Visit
Dam/Camp Area and Reservoir Zone			
Water body	28	9	0
Wetland	21	9	0
Total	49	18	0
Corridors			
Water body	28	21	4
Wetland	13	11	1
Total	41	32	5
Grand Total	90	50	5

Table 5.1-2. Frog Detection in Shallow- and Deep-water Habitats in 2013.

	First Visit		Second Visit		Third Visit		Overall	
Location	**Detected**	**Not Detected**	**Detected**	**Not Detected**	**Detected**	**Not Detected**	**Detected**	**Not Detected**
Shallow water (<1.5 m)[a]	8	34	3	29	2	3	13	29
Deep water (>1.5 m)	29[b]	19	5	13	–	–	34	14
Total	37	53	8	42	2	3	47	43

Notes:

a. 1.5 m = 4.9 ft.

b. Two locations were included where egg masses were observed but no frog calls were detected.

Table 5.1-3. Number of Frog-survey Visits to Water Bodies and Wetlands in the 2014 Study Area.

Location	First Visit	Second Visit	Third Visit
Gold Creek Corridor			
Water body	18	14	0
Wetland	20	15	0
Total	38	29	0
Denali Corridor Options			
Water body	54	49	0
Wetland	12	12	3
Total	66	61	3
Grand Total	104	90	3

Table 5.1-4. Frog Detection in Shallow- and Deep-water Habitats in 2014.

Corridor	Location	First Visit		Second Visit		Third Visit		Overall	
		Detected	Not Detected	Detected	Not Detected	Detected	Not Detected	Detected	Not Detected
Gold Creek	Shallow water (<1.5 m)[a]	1	20	2	18	0	0	3	18
	Deep water (>1.5 m)	8	9	2	7	0	0	10	7
	Total	9	29	4	25	0	0	13	25
Denali	Shallow water (<1.5 m)[a]	1	36	1	35	0	3	2	35
	Deep water (>1.5 m)	4	25	2	23	0	0	6	23
	Total	5	61	3	58	0	3	8	58
Total	Total	14	90	7	83	0	3	21	83

Notes:

a. 1.5 m = 4.9 ft.

Table 5.1-5. Occupancy-model Selection Results for Presence of Wood Frogs in 2013.

Model[a]	–2*LL[b]	K[c]	AICc[d]	ΔAICc[e]	ω_i[f]
Ψ (Water Depth), *p* (.)[g]	162.35	3	168.63	0.00	0.348
Ψ (Water Depth, Habitat), *p* (.)	161.71	4	170.18	1.55	0.160
Ψ (Water Depth, Water Type), *p* (.)	161.97	4	170.44	1.81	0.141
Ψ (Water Depth, Area), *p* (.)	162.00	4	170.47	1.84	0.139
Ψ (Water Depth, Water Type, Habitat), *p* (.)	161.51	5	172.22	3.59	0.058
Ψ (Water Depth, Area, Habitat), *p* (.)	161.61	5	172.32	3.69	0.055
Ψ (Water Depth, Area, Water Type), *p* (.)	161.84	5	172.55	3.92	0.049
Ψ (Global), *p* (.)	161.48	6	174.49	5.86	0.019
Ψ (Habitat), *p* (.)	168.78	3	175.06	6.43	0.014
Ψ (Water Type, Habitat), *p* (.)	168.53	4	177.00	8.37	0.005
Ψ (Area, Habitat), *p* (.)	168.75	4	177.22	8.59	0.005
Ψ (Area, Water Type, Habitat), *p* (.)	168.48	5	178.87	10.24	0.002
Ψ (Area), *p* (.)	172.59	3	179.19	10.56	0.002
Ψ (.), *p* (.)	175.18	2	179.32	10.69	0.002
Ψ (Area, Water Type), *p* (.)	171.93	4	180.40	11.77	0.001
Ψ (Water Type), *p* (.)	174.81	3	181.09	12.46	0.001

Notes:

a. Ψ = occupancy variable; *p* = detection probability; Water Depth = 1 if depth > 1.5 m (4.9 ft); Habitat = proportion of shoreline containing hibernation habitat; Water Type = water body or wetland; and Area = dam, camp, and reservoir area or road corridors.

b. Negative 2 times the log-likelihood value.

c. Number of estimable parameters in the approximating model.

d. Akaike's Information Criterion, corrected for small sample size.

e. Difference in value between the AIC_c of the current model and that of the best approximating model.

f. Akaike Weight = Probability that the current model (i) is the best approximating model in the candidate set.

g. *p* (.) indicates that detection probability was held constant across all locations in the model.

Table 5.1-6. Top Occupancy-model Selection Results for Presence of Wood Frogs in 2014.

Model[a]	–2*LL[b]	K[c]	AICc[d]	ΔAICc[e]	ω_i[f]
Ψ (Water Depth), p (Corridor)	112.25	4	120.65	0	0.1645
Ψ (Water Depth, Habitat), p Corridor)	110.42	5	121.03	0.38	0.1360
Ψ (Corridor, Water Depth), p (.)[g]	112.72	4	121.12	0.47	0.1300
Ψ (Water Type, Water Depth, Habitat), p(Corridor)	108.55	6	121.42	0.77	0.1119
Ψ (Water Type, Water Depth), p (Corridor)	111.19	5	121.80	1.15	0.0925
Ψ (Corridor, Water Depth, Habitat), p (.)	111.70	5	122.31	1.66	0.0717
Ψ (Corridor, Water Type, Water Depth), p (.)	111.97	5	122.58	1.93	0.0627
Ψ (Corridor, Water Depth), p (Corridor)	112.25	5	122.86	2.21	0.0545
Ψ (Corridor, Water Depth, Habitat), p (Corridor)	110.36	6	123.23	2.58	0.0453
Ψ (Corridor, Water Type, Water Depth, Habitat), p (.)	110.53	6	123.40	2.75	0.0416
Ψ (Corridor, Water Type, Water Depth, Habitat), p (Corridor)	108.53	7	123.70	3.05	0.0358
Ψ (Corridor, Water Type, Water Depth), p (Corridor)	111.19	6	124.06	3.41	0.0299
Ψ (Water Depth), p (.)	120.24	3	126.48	5.83	0.0089
Ψ (Water Type, Water Depth), p (.)	119.97	4	128.37	7.72	0.0035
Ψ (Water Depth, Habitat), p (.)	120.17	4	128.57	7.92	0.0031
Ψ (Corridor, Water Type), p (.)	121.98	4	130.38	9.73	0.0013

Notes:

a. *Ψ* = occupancy variable; *p* = detection probability; Water Depth = 1 if depth > 1.5 m (4.9 ft); Habitat = proportion of shoreline containing hibernation habitat; Water Type = water body or wetland; and Corridor = Gold Creek or Denali Corridors.

b. Negative 2 times the log-likelihood value.

c. Number of estimable parameters in the approximating model.

d. Akaike's Information Criterion, corrected for small sample size.

e. Difference in value between the AIC_c of the current model and that of the best approximating model.

f. Akaike Weight = Probability that the current model (i) is the best approximating model in the candidate set.

g. *p* (.) indicates that detection probability was held constant across all locations in the model.

Table 5.2-1. Model Estimates of Wood Frog Occupancy and Detection Probability in 2013 from the Best Model.

Variable	Estimate	S.E.	95% C.I.
Occupancy			
Shallow water (<1.5 m deep)[a]	0.368	0.095	0.208–0.565
Deep water (>1.5 m deep)	0.818	0.131	0.444–0.962
Overall [b]	0.634	n/a	n/a
Detection Probability			
Overall	0.606	0.129	0.348–0.816

Notes:

a. 1.5 m = 4.9 ft.

b. Occupancy based on weighted average of parameter estimates.

Table 5.2-2. Model Estimates of Wood Frog Occupancy and Detection Probability in 2014 from the Best Model.

Variable	Estimate	S.E.	95% C.I.
Occupancy			
Shallow water (<1.5 m deep) [a]	0.179	0.093	0.059–0.431
Deep water (>1.5 m deep)	0.719	0.245	0.192–0.965
Overall [b]	0.393	n/a	n/a
Detection Probability			
Gold Creek Corridor	0.566	0.256	0.145–0.909
Denali Corridor	0.160	0.082	0.055–0.387

Notes:

a. 1.5 m = 4.9 ft.

b. Occupancy based on weighted average of parameter estimates.

Table 5.2-3. Model Estimates of Wood Frog Occupancy and Detection Probability in 2014 from the Third-best Model.

Corridor	Variable	Estimate	S.E.	95% C.I.
	Occupancy			
Gold Creek	Shallow water (<1.5 m deep) [a]	0.215	0.106	0.074-0.495
	Deep water (>1.5 m deep)	0.682	0.165	0.325-0.905
	Overall [b]	0.408	na	na
Denali	Shallow water (<1.5 m deep) [a]	0.049	0.031	0.014-0.162
	Deep water (>1.5 m deep)	0.287	0.113	0.120-0.543
	Overall [b]	0.113	n/a	n/a
	Detection Probability			
Overall	Overall	0.546	0.179	0.226-0.832

Notes:

a. 1.5 m = 4.9 ft.

b. Occupancy based on weighted average of parameter estimates.

Table 5.2-4. Habitat Characteristics of Water Bodies and Wetlands where Wood Frogs were Detected and Not Detected in 2013.

Habitat Type / Variable	Description	Wood Frog Detection [a]			*P*-value
		Detected	Not Detected	Overall	
Water-body Structure					
Water-body type (%)	Big lakes (> 20 acres)	2.1	2.3	2.2	0.158 [b]
	Small ponds w/o emergents	27.7	11.6	20.0	
	Small ponds w/ emergents	44.7	41.9	43.3	
	Seasonally flooded ponds	25.5	44.2	34.4	
Beaver activity (%)	No	91.3	76.7	84.3	0.157 [b]
	Yes	8.7	23.3	15.7	
Aquatic Habitat Characteristics					
Emergent and submergent vegetation (%)		22.6 (4.2)	32.7 (5.2)	27.5 (3.3)	0.132
Emergent vegetation (%)	Grass	6.4	14.0	10.0	0.158 [b]
	Sedge	80.9	62.8	72.2	
	None	12.8	23.3	17.8	
Substrate (%)	Boulder	4.3	2.3	3.3	0.179[b]
	Gravel	0.0	7.0	3.3	
	Mud/silt	14.9	23.3	18.9	
	Organic	80.9	67.4	74.4	
Aquatic Features					
Ice cover (%) [c]		36.7 (5.6)	26.1 (5.0)	31.7 (3.8)	0.165
Water temperature (%) [c]		7.0 (0.6)	5.7 (0.8)	6.4 (0.5)	0.175

Habitat Type / Variable	Description	Wood Frog Detection [a]			*P*-value
		Detected	Not Detected	Overall	
Water depth (%)	Shallow (≤ 1.5 m)	27.7	67.4	46.7	<0.001[b]
	Deep (> 1.5 m)	72.3	32.6	53.3	
Water Quality					
Dissolved oxygen (%) [c]		64.77 (2.77)	70.63 (3.50)	67.57 (2.22)	0.193
Dissolved oxygen (mg/L)		7.96 (0.38)	9.16 (0.46)	8.53 (0.30)	0.047
Specific EC [c]		0.039 (0.006)	0.040 (0.008)	0.039 (0.005)	0.950
pH [c]		5.73 (0.10)	5.72 (0.12)	5.73 (0.07)	0.932
Terrestrial Habitat within 50-m Radius					
Herbaceous (%)		18.0 (1.9)	26.4 (3.2)	22.0 (1.9)	0.029
Dwarf shrub (%)		12.7 (2.2)	11.4 (2.6)	12.1 (1.7)	0.709
Low shrub (%)		21.2 (2.1)	22.4 (2.4)	21.8 (0.6)	0.709
Tall shrub (%)		28.5 (2.3)	27.7 (3.6)	28.1 (2.1)	0.847
Trees (%)		19.0 (2.6)	12.8 (3.1)	16.4 (2.0)	0.130

Notes:

a. Parenthetical values in table cells indicate 1 S.E.

b. *P*-value from chi-square test (other *P*-values are from t-tests for two independent samples).

c. Measured on first visit.

Table 5.2-5. Habitat Characteristics of Water Bodies and Wetlands where Wood Frogs were Detected and Not Detected in 2014.

Habitat Type / Variable	Description	Wood Frog Detection [a]			*P*-value
		Detected	Not Detected	Overall	
Water-body Structure					
Water-body type (%)	Big lakes (> 20 acres)	4.8	1.2	1.9	0.016 [b]
	Small ponds w/o emergents	0	18.1	14.4	
	Small ponds w/ emergents	95.2	65.1	71.2	
	Seasonally flooded ponds	0	15.7	12.5	
Beaver activity (%)	No	76.2	68.7	70.2	0.501 [b]
	Yes	23.8	31.3	29.8	
Aquatic Habitat Characteristics					
Emergent and submergent vegetation (%)		16.0 (5.6)	21.2 (3.0)	20.1 (2.6)	0.097
Emergent vegetation (%)	Grass	4.8	9.6	8.7	
	Sedge	90.5	67.5	72.1	
	Shrub	4.8	2.4	2.9	
	None	0	20.5	16.3	
Substrate (%)	Boulder	0	4.8	3.8	0.080 [b]
	Gravel	0	1.2	1.0	
	Mud/silt	0	21.7	17.3	
	Organic	100.0	69.9	76.0	
	Sand	0	2.4	1.9	
Aquatic Features					
Ice cover (%)[c]		6.2 (4.4)	8.6 (2.3)	8.1 (2.0)	0.625
Water temperature (%)[c]		8.6 (0.8)	7.7 (0.4)	7.9 (0.3)	0.273

Habitat Type / Variable	Description	Wood Frog Detection [a]			*P*-value
		Detected	Not Detected	Overall	
Water depth (%)	Shallow (≤ 1.5 m)	23.8	63.9	55.8	0.001 [b]
	Deep (> 1.5 m)	76.2	36.1	44.2	
Water Quality					
Dissolved oxygen (%) [c]		74.3 (3.71)	61.58 (2.36)	64.1 (2.08)	0.006
Dissolved oxygen (mg/L)		8.63 (0.42)	7.28 (0.29)	7.55 (0.25)	0.011
Specific EC (uS/cm) [c]		0.042 (0.005)	0.058 (0.005)	0.055 (0.004)	0.023
pH [c]		6.55 (0.08)	6.51 (0.08)	6.53 (0.06)	0.761
Terrestrial Habitat within 50-m Radius					
Herbaceous (%)		26.9 (3.8)	28.1 (1.9)	27.9 (1.7)	0.775
Dwarf shrub (%)		10.5 (2.3)	10.5 (1.5)	10.5 (1.2)	0.983
Low shrub (%)		23.6 (5.0)	23.9 (22)	23.8 (2.0)	0.956
Tall shrub (%)		33.0 (5.0)	30.7 (2.5)	31.1 (2.2)	0.679
Trees (%)		6.0 (3.4)	6.6 (1.5)	6.5 (1.4)	0.877

Notes:

a. Parenthetical values in table cells indicate 1 S.E.

b. *P*-value from chi-square test (other *P*-values are from t-tests for two independent samples).

c. Measured on first visit.

10. FIGURES

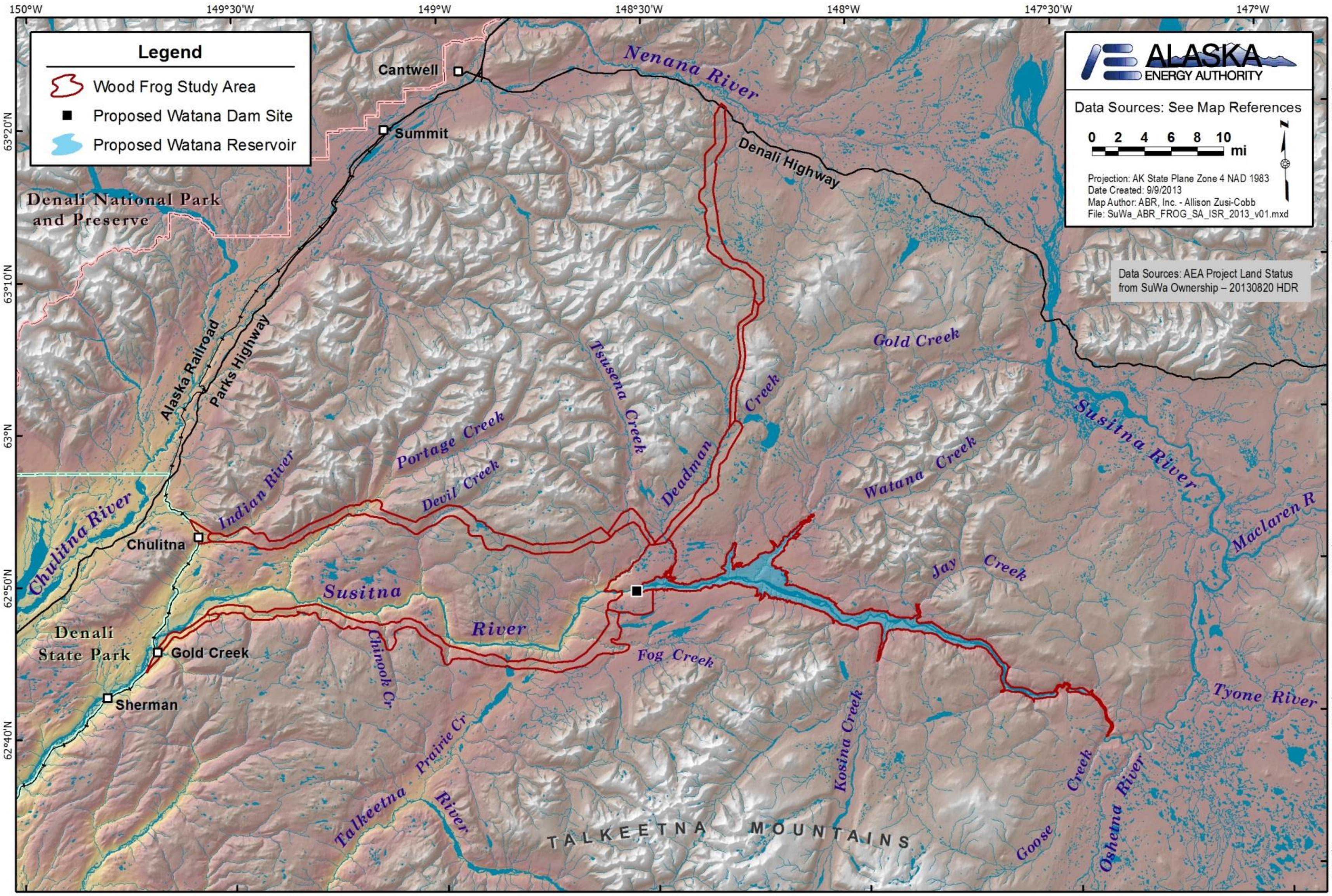

Figure 3-1. Wood Frog Study Area for the Susitna–Watana Hydroelectric Project in 2013.

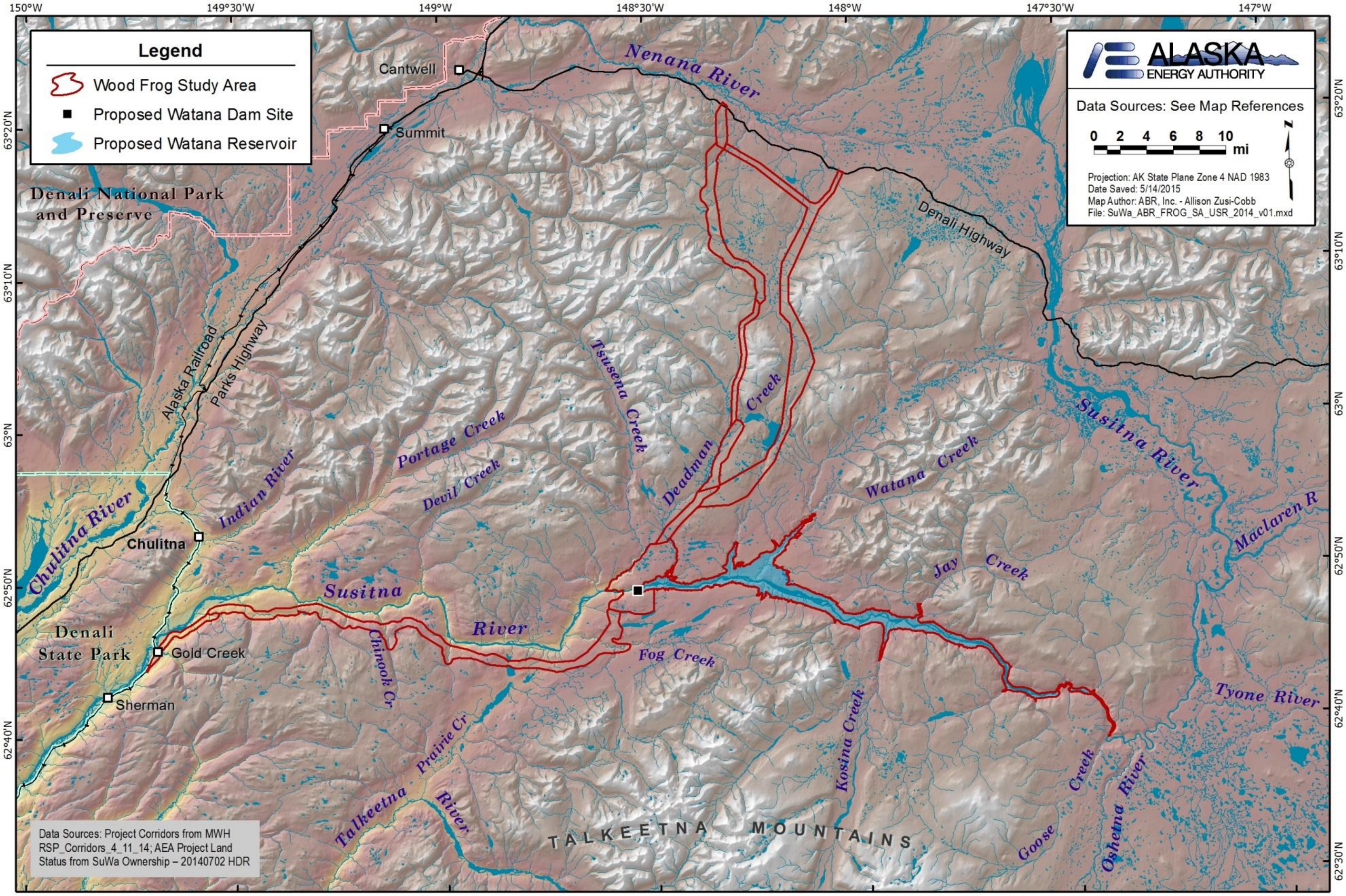

Figure 3-2. Wood Frog Study Area for the Susitna–Watana Hydroelectric Project in 2014.

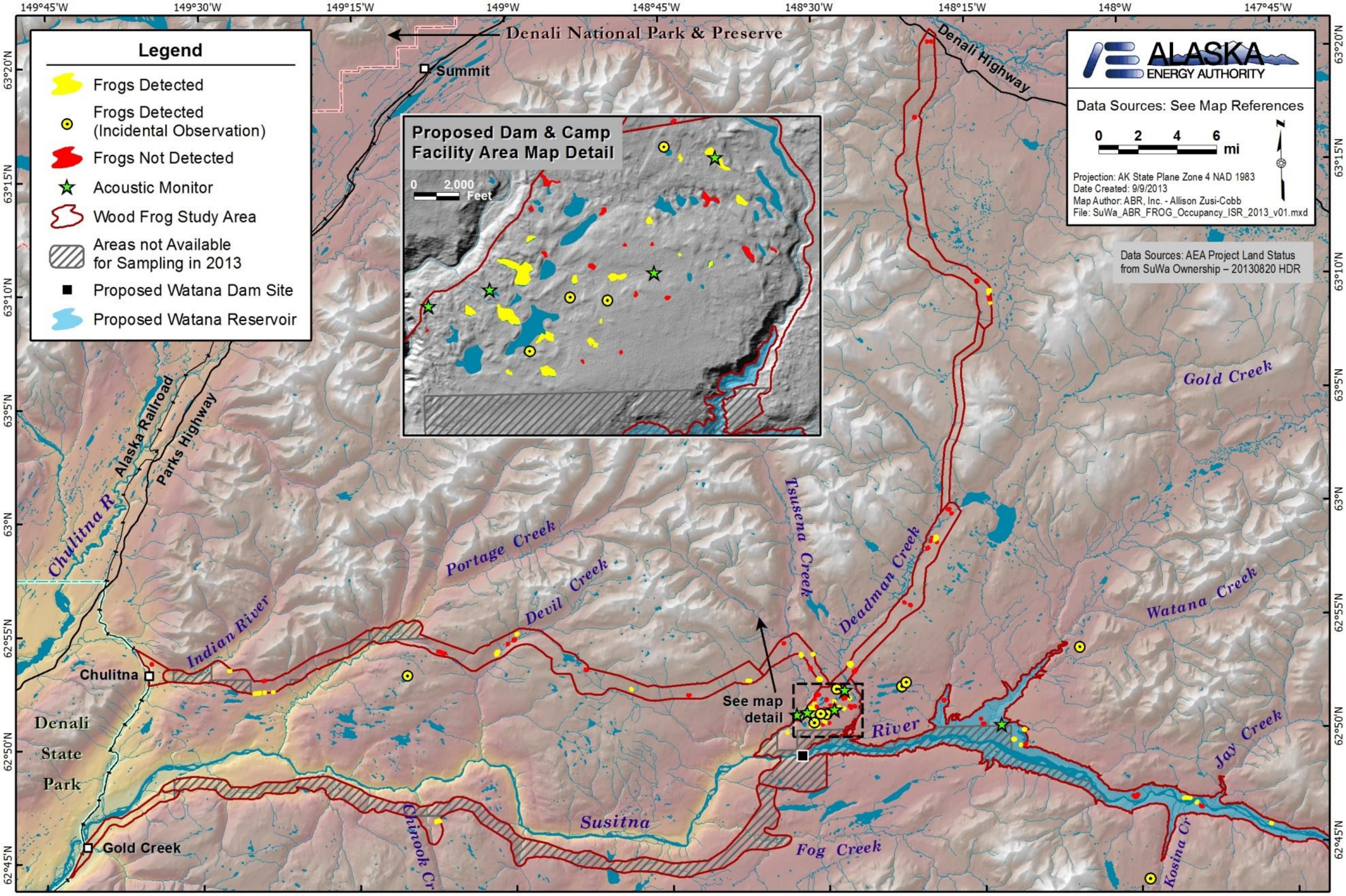

Figure 5.1-1. Locations where Wood Frogs were Detected during Auditory Surveys, plus Incidental Observations from Other Wildlife Surveys, in 2013.

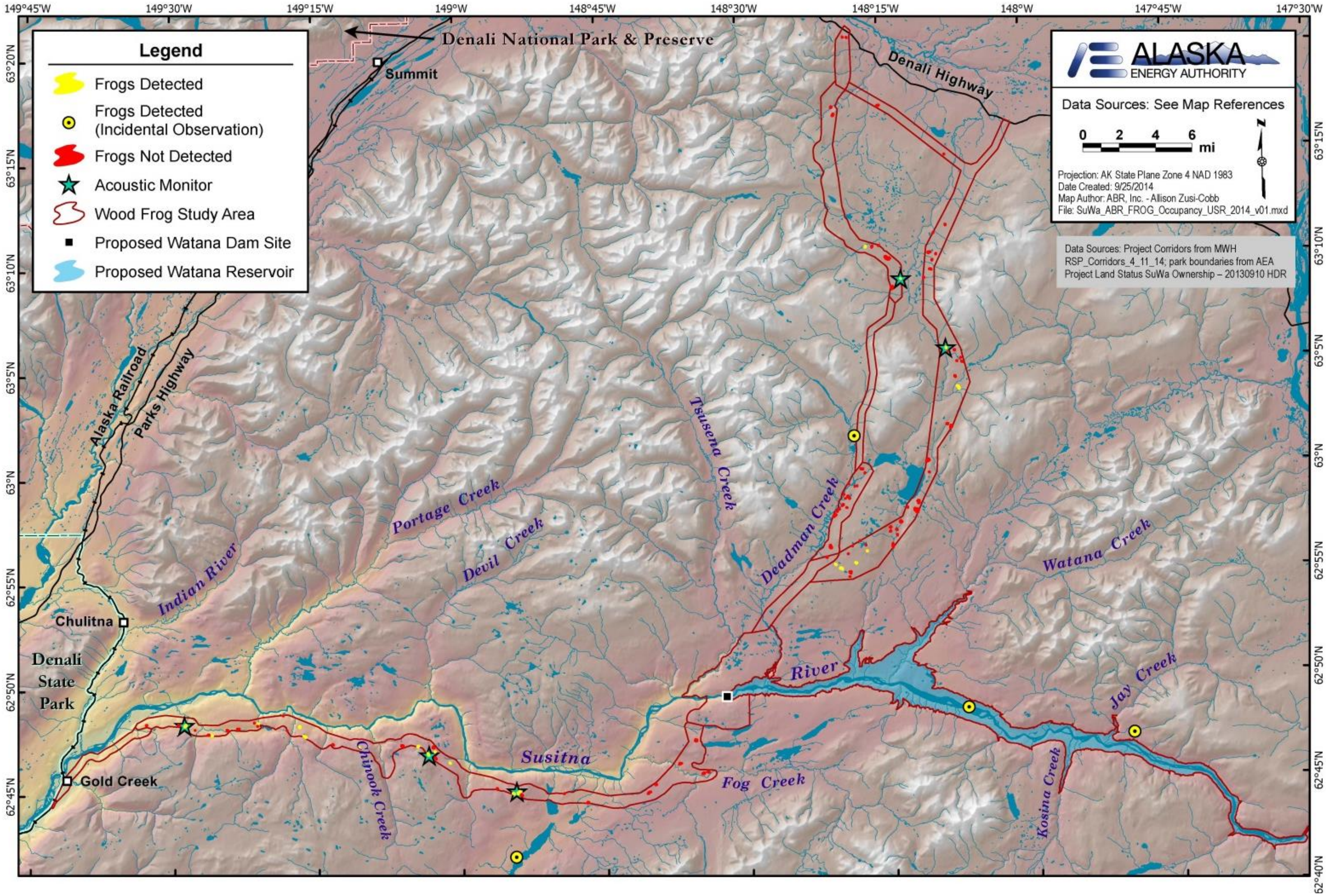

Figure 5.1-2. Locations where Wood Frogs were Detected during Auditory Surveys, plus Incidental Observations from Other Wildlife Surveys, in 2014.

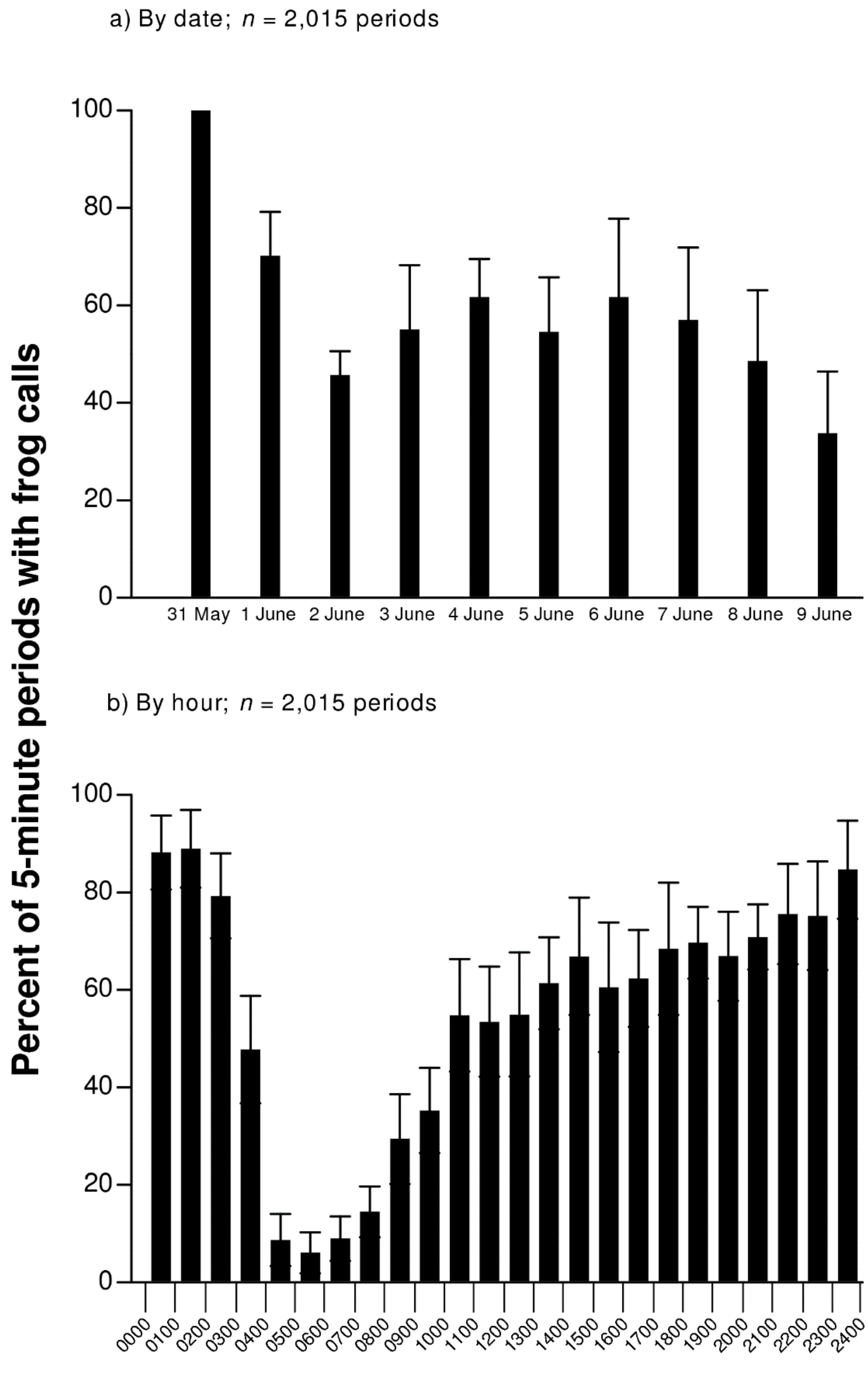

Figure 5.3-1. Wood Frog Calling Activity by Date and Hour in 2013 (error bars depict 1 S.E.).

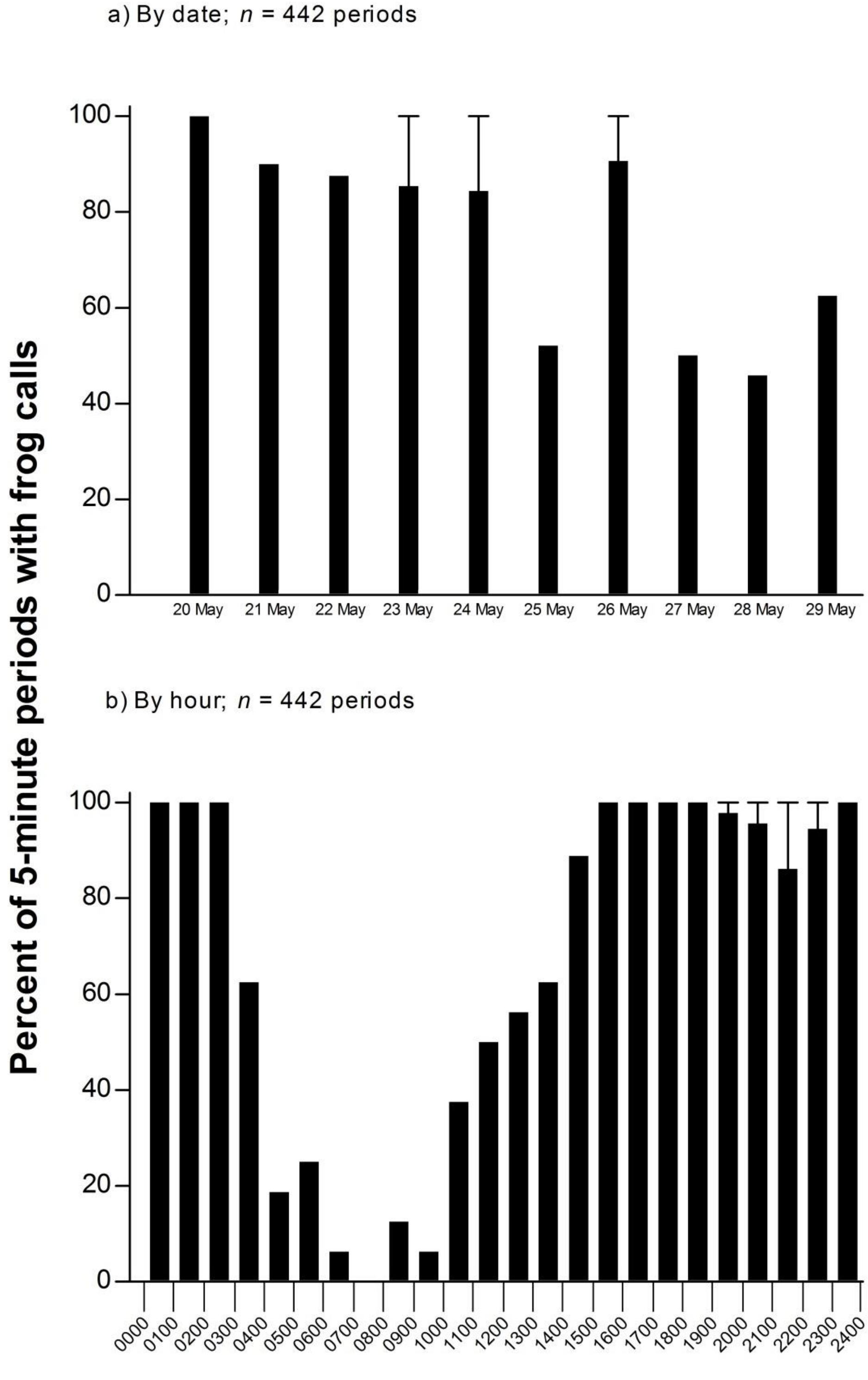

Figure 5.3-2. Wood Frog Calling Activity by Date and Hour in 2014 (error bars depict 1 S.E.).

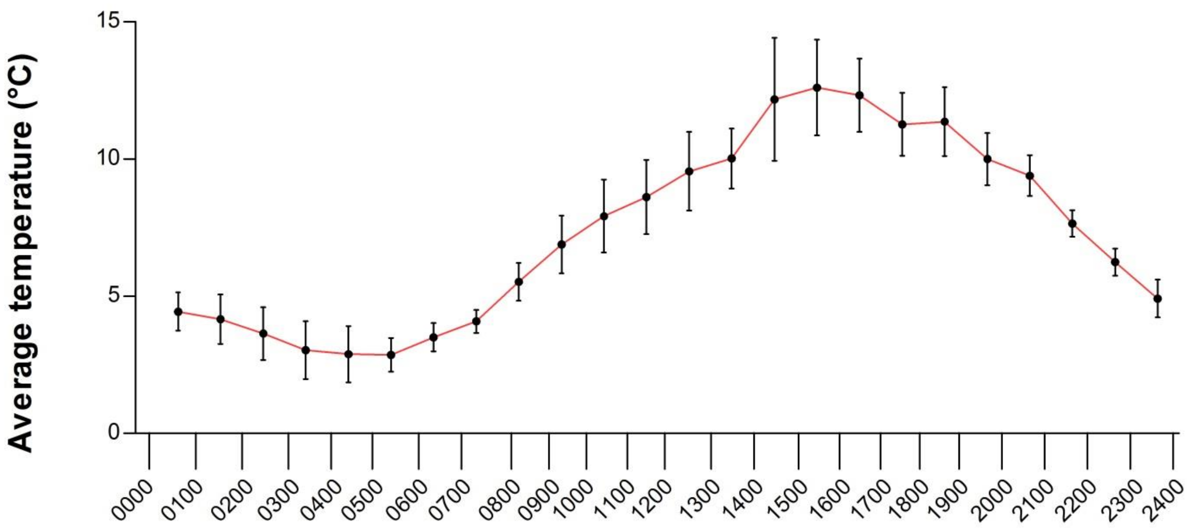

Figure 5.3-3. Average Hourly Air Temperatures Measured at Acoustic Monitor Stations during May 20–29, 2014 (error bars depict 1 S.E.).

APPENDIX A: RECORDS OF ADDITIONAL CONSULTATION IN 2014 WITH USGS REGARDING SAMPLING PROTOCOL AND ANALYTICAL METHOD FOR AMPHIBIAN CHYTRID FUNGUS.

SUSITNA-WATANA HYDROELECTRIC PROJECT

EMAIL RECORD

From: Todd Mabee tmabee@abrinc.com
Date: 4/4/14
To: Chestnut, Tara chestnut@usgs.gov

Hi Tara,

eDNA has been mentioned as an idea for sampling for Bd in Wood Frogs. Would this technique be an appropriate method to sample for Bd for Wood frogs? If so, how many samples would we need to obtain useful information? Do you have any idea on labs that process these samples and costs?

This may be easier to discuss on the phone, and if so, please feel free to suggest a time that would be convenient for you next week.

Hope you are well, and thank you!

Todd J. Mabee

Senior Scientist/Research Coordinator

ABR Inc., Environmental Research & Services

P.O. Box 249 Forest Grove, Oregon 97116

Work: (503) 359-7525 ext 110

Mobile: (503) 537-7749

Fax: (503) 359-8875

www.abrinc.com

From: Chestnut, Tara chestnut@usgs.gov
Date: 4/8/14
To: Todd Mabee tmabee@abrinc.com

Hi Todd,

Hmm... I would need to know more about the study goals and objectives. I generally recommend against sampling for Bd for the sake of sampling for it. We know it's widespread so we don't gain much information by collecting samples without specific questions. Can you tell me more about the details?

Thanks,

Tara

From: Todd Mabee tmabee@abrinc.com
Date: 4/8/14
To: Chestnut, Tara chestnut@usgs.gov

Hi Tara,

The idea was suggested specifically for the SuWa study by Dave Tessler of ADFG to detect whether Bd is present in this remote study area before any roads/transmission corridors are developed.

That's all the detail I have on this topic. Let me know if you want to discuss on the phone, might be easiest to talk through ideas and potential study options?

Thank you!
Todd

From: Brian Lawhead <lawhead@abrinc.com>
Date: Apr 8, 2014
To: Todd Mabee, ABR

Thanks, Todd. Please call her and tell her that it was an idea suggested specifically for the SuWa study by Dave Tessler of ADFG (whom she knows). And yes, it would be primarily intended to detect whether Bd is present in this remote study area before any roads/transmission corridors are punched in.

An idea of sampling intensity and sample analysis costs would be useful.

Please document these interactions using the appropriate contact log forms.

Thanks!
Brian

From: Todd Mabee
Sent: Tuesday, April 08, 2014 2:15 PM
To: Brian Lawhead
Cc: Todd J. Mabee
Subject: Fwd: eDNA sampling for Bd?

Todd Mabee <tmabee@abrinc.com>
Date: Apr 8, 2014
to Tara Chestnut, USGS

Hi Tara,

The idea was suggested specifically for the SuWa study by Dave Tessler of ADFG to detect whether Bd is present in this remote study area before any roads/transmission corridors are developed.

That's all the detail I have on this topic. Let me know if you want to discuss on the phone, might be easiest to talk through ideas and potential study options?

Thank you!

From: Todd Mabee <tmabee@abrinc.com>
Date: Apr 11, 2014
To: Tara Chestnut, USGS

Hi Tara,

Can we set up a time to talk on the phone next week? I'd like to get your thoughts on this latest sampling idea. I'm around most of the week, so just let me know if there would be a good time to talk.

Thank you!

From: Todd Mabee <tmabee@abrinc.com>
Date: Apr 14, 2014
To: Brian Lawhead, ABR

Hi Brian,

Had a good conversation with Tara, here's the summary. She thinks there is a high probability that Bd is in the SuWa area (and throughout AK) and that trying to answer the question of "is Bd there" is not a very useful one. Rather she thinks that it would be useful to understand how different strains of Bd affect the native populations of frogs. To answer this question you need swabs of frogs and their actual skin (therefore would need permit to collect frogs).

She thinks we could use the same approach as last year, except keep the frogs and send them to lab for sampling (@~$125/frog). We only got 7 samples last year, so this wouldn't be terribly expensive.

FYI, eDNA does not allow you to detect strains of Bd, but only would answer the question of "presence". It is also expensive and requires a lot of samples to have a high probability of detecting Bd.

SUSITNA-WATANA HYDROELECTRIC PROJECT

RECORD OF TELEPHONE CONVERSATION

AEA Team Member		Other Party	
Name:	*Todd Mabee*	**Name:**	*Tara Chestnut*
Organization:	*ABR Inc.*	**Organization:**	*USGS, Portland, OR*
Study Area:		**Phone Number:**	*503 251 3283*
Date:	*14 April 2014*	**Time:**	*1500*
Call Placed by:	[X] AEA Team	[ ] Other Party	

Others on Call: none

Subject: Environmental DNA (eDNA) sampling for chytrid fungus

Discussion:

- ADFG is interested in whether *Bd* is present in SuWa study area.

- Tara Chestnut (USGS expert on wood frogs and *Bd* in AK) thinks one should assume *Bd* is everywhere in Alaska, given its known occurrence in Denali SP, ANWR, & other locations. Doesn't think focusing on this question is very useful to advance the scientific knowledge of *Bd* in AK. Recommended that wood frogs be swabbed and captured, so that IF frogs tested positive for *Bd*, then the frogs could provide a strain of *Bd* that could be used in future experiments. She felt this would help advance the understanding of *Bd* in Alaska and elsewhere. Agreed that the small sample size obtained last year (7 samples) is inadequate to provide any level of certainty about the presence of *Bd* in the study area.

- eDNA technique can be used to determine if *Bd* is present but it can't isolate strains. It also is expensive: would need approximately 10 samples/wetland at a cost of approximately $70/sample; therefore, $700/wetland. This expense would be cost prohibitive at the scale of the SuWa project.

APPENDIX B: PHOTOGRAPHS FROM FIELD SURVEYS IN 2013 AND 2014.

Example of Water Body at which Wood Frogs were Detected in the Chulitna Access Corridor in 2013.

Example of Water Body in the Reservoir Inundation Zone at which Wood Frogs were Detected in 2013.

Example of Water Body with Emergent Vegetation at which Wood Frogs were Detected in 2013.

Wood Frog Egg Mass, 2013.

Example of Acoustic Monitoring Device used to Supplement Auditory Surveys in 2013.

Example of Wetland at which Wood Frogs were Detected in the Gold Creek Access Corridor in 2014.

Example of Water Body in the Gold Creek Access Corridor at which Wood Frogs were Detected in 2014.

Example of Water Body with Emergent Vegetation in the Denali West Access Corridor at which Wood Frogs were Detected in 2014.

Wood Frog Egg Mass, 2014.

Example of Acoustic Monitoring Device used to Supplement Auditory Surveys in 2014.

Wood Frog Adult, 2014.