Appendix N

Biological Resources: *Humboldt Wind Energy Project Marbled Murrelet Radar Survey Report, Humboldt County, California, April 2018–September 2018*

Humboldt Wind Energy Project

Marbled Murrelet Radar Survey Report

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Acronyms and Abbreviations

Ft	foot/feet
gen-tie	generation transmission line
M	meter
Mi	mile
SODAR	sonic detection and ranging

Note:

Often, agency suggestions and guidelines are provided in US units of measure (e.g., acres [ac] feet [ft], or miles [mi]), and in other instances, agency guidance is provided in metric (aka SI, or System International) units (e.g., meters [m] or kilometers [km]). To convert an otherwise readily recognized agency standard (e.g., 10 mi or 1 km) to the other system may result in confusion. Accordingly, we provide measures in either system, using the original agency suggestion unchanged, and provide conversion to the other standard only when it makes sense to do so.

Executive Summary

Humboldt Wind, LLC plans to permit, build, and operate a wind energy project in Humboldt County, California. As one part of the studies to support review of the project pursuant to state and federal regulations, Stantec Consulting Services Inc. (Stantec) conducted marbled murrelet (*Brachyramphus marmoratus*) radar surveys between April 17, 2018, and September 27, 2018.

We sampled marbled murrelet activity from seven radar stations located along the Bear River and Monument ridges and one low-elevation station located near the Eel River. All radar stations were sampled approximately every 3 weeks for a combined effort of 144 sampling sessions, which included 209 hours of morning surveys and 132 hours of evening surveys.

We documented 136 murrelet radar targets during the 341 hours of radar sampling. Activity was greatest at the low elevation site along the Eel River followed by radar station M5, which is the easternmost and lowest elevation ridgeline radar station.

Murrelet activity was greatest in July followed by May and June, and inbound flights were more common (79% of all flights) than seaward flights. We recorded more morning flights (83% of all flights) than evening flights across the sampling period. Murrelet flights were also concentrated along the Eel River and in the lower altitudes of the Eel River valley. Our results are consistent with known flight patterns in the area.

Our study documented murrelets crossing the project area ridgelines: 31 murrelet radar tracks created 35 ridge crossing events. Vertical radar data indicated that most of these events included birds that were flying below the radar elevation, hence below the crest of the ridge, and that likely increased their flight height to cross the ridges at very low (tree top) heights.

We measured murrelet activity from before sunrise, after sunrise, and during evening hours. After sunrise measurements are not typically reported for murrelet radar surveys due to the contamination of the radar data with non-target species during daylight hours. These results may include non-murrelet targets and thus may overestimate murrelet activity in the area. Lastly, we conducted surveys during mid-day to search for murrelet targets but detected none.

1.0 INTRODUCTION

Humboldt Wind, LLC (Humboldt Wind) is planning to construct and operate the Humboldt Wind Energy Project (project) in south-central Humboldt County, California (Figure 1). The project would consist of up to 60 wind turbines and associated facilities including meteorological towers, electrical collection system, access roads, construction staging areas, a substation, an operations and maintenance facility, up to a 25-mile (mi) generation transmission line (gen-tie) and expansion of the Bridgeville substation (point of interconnect). The project would have a nameplate generating capacity of up to 155 megawatts. Proposed turbine locations are situated on two prominent ridgelines, Bear River Ridge and Monument Ridge, 4.7 mi south and southwest of Scotia, in Humboldt County, California (Figure 1).

The project area encompasses areas of potential activity and includes a 1,000-foot-(ft-) wide corridor centered on proposed turbine locations; a 200-ft-wide corridor centered on project roads, the electrical collection line, and the gen-tie; and a 500-ft-wide buffer around proposed staging and temporary impact areas and project substations, encompassing 2,241 acres (Figure 2).

Stantec Consulting Services Inc. (Stantec) prepared a Draft Biological Resources Work Plan (Draft Work Plan) detailing biological resource surveys designed to support project planning (Stantec 2018). Included in the Draft Work Plan was a radar survey of marbled murrelet (*Brachyramphus marmoratus*) (hereafter murrelet) activity. Those surveys began in April 2018 and this report describes those survey efforts.

Our project team met with the United States Fish and Wildlife Service and the California Department of Fish and Wildlife to discuss the methodology and progress of field surveys for the project, including the murrelet radar survey, on January 24, March 7, April 6, June 21, and October 24, 2018. The initial meetings in January and March focused on the study design and scope presented in this report prior to initiation of the work in April. Subsequent meetings included two site visits to observe radar survey locations and operations.

The purpose of this radar survey was to document the activity of murrelets in the project area as they travel between their nearshore ocean foraging areas and their inland nesting sites. Specific objectives included documenting the number of murrelets that intersect the project area and their flight paths. Further, these flights were stratified into morning and evening activity periods. This provides quantitative information on ridge crossing flight data (location, timing, height) that will be used in a collision risk model that will be submitted in a separate report.

2.0 ENVIRONMENTAL SETTING

Humboldt County is within the Klamath/North Coast bioregion and features a rocky coastline, montane forests, and small and sparsely populated settlements. Cool, moist climate is typical on the coast but becomes progressively drier, warmer, and more variable but remaining mild inland. Humboldt County features several biological communities; the most abundant is coniferous forest comprising Douglas-fir, redwood, and pine forests, followed by oak woodlands, and grasslands. Less abundant habitats include coastal beach dune vegetation, northern coastal scrub, chaparral, salt marsh, riparian, and freshwater marsh. Humboldt Bay, located about 16 mi north of the project, is the second largest estuary in California. As such, the Bay and coast of Humboldt County coast have high biodiversity and support many species of resident and migratory wildlife with high seasonal and year-round abundance. Six rivers run through the county, providing habitats for fish and wildlife as well as important water resources.

Humboldt County spans two geologic provinces. The Coast Ranges Province in the county's center and southwest comprises mainly the Franciscan Complex, with schists, sand, and other alluvial deposits associated with the coast. The Klamath Mountains Province in the northeast features older sedimentary rock including sandstone, chert, slate, and schist.

The average July temperature in Humboldt County is typically in the 60s (Fahrenheit). While rain can occur throughout the year, about 90% of the annual rain results from Pacific Ocean storms and falls between October and April. Seasonal totals average more than 40 inches in the driest areas and exceed 100 inches in the wettest zones. Moisture and moderate temperature combined create high average relative humidity.

The project is on privately owned and managed lands in rural, unincorporated south-central Humboldt County, 10 mi southeast of Ferndale, 20 mi south of Eureka, and 22 mi north of Garberville, California. Most of the project would be located on two prominent ridgelines that are located south and east of the town of Scotia. Monument Ridge is located south and west of Highway 101 and the Eel River, and Shively Ridge is located north and east of Highway 101 and the Eel River.

The project area consists primarily of managed timberlands that are dominated by redwood and Douglas-fir forests, with annual grassland, hardwood, and chaparral inclusions. In addition to timber production, some areas of the project site are managed for cattle grazing. The topography is diverse and steep in places, and elevation ranges from nearly sea level in river bottoms to just over 3,000 ft.

3.0 MARBLED MURRELET NATURAL HISTORY

The marbled murrelet is a small coastal Pacific seabird ranging from central California to northern Alaska (Carter and Erikson 1992, Piatt and Naslund 1995). This species was listed as federally Threatened in 1992 (Federal Register 57 FR 45328) and also listed as State Endangered in California in 1992 (USFWS 1997).

Murrelets spend much of their life at sea. They forage in the near-shore waters for small fish and invertebrates (Burkett 1995, Golightly et al. 2004, Peery and Golightly in prep). Like all seabirds, murrelets must return to land to nest. However, in contrast to most seabirds, which nest on offshore rocks and islands, marbled murrelets typically nest high above the ground on large branches of old-growth and late-successional coniferous trees. They lay a single egg on the branch of an old tree as far as 88 km inland from the coast (Raphael et al. 2016). Pairs are thought to persist through time, often reusing the same nest or nest stand year after year (Golightly and Schneider 2011, Plissner et al. 2015). While nesting, marbled murrelets forage at-sea and remain near nests, traveling an average of 1.4 kilometer (km) off-shore and as far as 99.1 km along-shore in northern California (Hébert and Golightly 2008).

In northern California, redwoods are the most common conifer available for nesting, and branches used for nesting averaged 29.2 centimeters in diameter at the location of the nest (Golightly et al. 2009). Generally, only very large, older trees contain such platforms, and thus, murrelets are "closely associated with old-growth and mature forests for nesting" (Nelson and Wilson 2001 Evans Mack et al. 2003). Average diameter at breast height of nest trees in northern California was reported as 266 centimeters (Golightly et al. 2009). Murrelet nests are also generally associated with contiguous stands of mature old-growth forest that exceed 0.5 km^2 (124 ac) (Meyer et al. 2002, Meyer et al. 2007).

In Oregon and northern California egg laying generally begins between mid-April and June, depending on variation in ocean conditions, and incubation lasts for 28 to 30 days. During incubation, each adult murrelet alternates between nest attendance, and making a single transit between land and sea each morning around sunrise (45 minutes prior to and 75 minutes following sunrise) (Evans Mack et al. 2003). After the chick hatches, murrelets continue to make this early morning transit each day to deliver a fish to their chick and they often embark on an additional flight to feed chicks in the evening around sunset (with the average flight occurring 23 minutes before sunset) (Hébert and Golightly 2006). The chick is fed by the parents for another approximately 28 days until it fledges and flies to the ocean. Outside of the breeding period, murrelets will periodically travel inland at dawn (Naslund 1993, Sanzenbacher et al. 2014) for unknown reasons that may include maintaining pair bonds, examining future nesting areas, or engaging in other social activities (Carter and Sealy 1986, Carter and Erickson 1992, Naslund 1993). When transiting between foraging and nesting habitats, murrelets can fly 50 mi per hour (81 km per hour) and they have been documented flying as fast as 95 mi per hour (154 km per hour) (Nelson 1997, Elliott et al. 2004).

4.0 SURVEY METHODS

4.1 SURVEY LOCATIONS AND SITE SELECTION

The methods for this survey followed established survey protocols (Burger 2001, Cooper and Hamer in Evans et al. 2003, Evans Mack et al. 2003, Burger et al. 2004) and more recent work conducted specifically for wind projects in Humboldt County (Cooper and Sanzenbacher 2006, Sanzenbacher and Cooper 2007) and Washington state (Cooper and Mabee 2010). We established eight radar stations to monitor murrelet movements within the project area. These included seven stations along Monument Ridge (5 stations: M1–M5) and Bear River Ridge (2 stations: BR1 and BR2) as well as a lower elevation station near the Eel River (ER) that has been previously surveyed as part of long-term murrelet monitoring efforts (Table 1 and Figure 3).

We spaced the seven ridgeline radar stations as evenly along the project area ridgelines as site conditions allowed. Our criteria for selecting the locations included sites that offered 360-degree views when possible, proximity to the area of interest (ridgeline areas slated for turbine development and the upper valley on either side), and the potential to use the surrounding topography and vegetation to maximize the recordable surrounding airspace (viewshed). Preliminary radar station locations were selected by using desktop mapping procedures and the final locations were selected during field reconnaissance efforts in February and March 2018.

At several sites where the topography or vegetation would reduce the recordable airspace, and to facilitate simultaneous sampling at two stations with available equipment, we erected construction scaffolding and installed a radar antenna at the top of the scaffolding, approximately 3 to 5-m above the ground, to increase the radar's view of the surrounding airspace. Four of the seven ridgeline stations include the construction scaffolding deployment.

Table 1. Location and elevation of marbled murrelet radar stations used at the Humboldt Wind Energy Project, Humboldt County, California, April 17, 2018–September 27, 2018.

Radar Station	UTM Coordinates		Elevation (m above sea level)
	North	West	
M1	4475115.348	404551.0226	908.64
M2	4475078.614	407109.1659	920.14
M3	4473942.038	409060.7878	846.28
M4	4472044.059	410468.1494	757.02
M5	4474359.04	413210.5274	590.8
BR1	4477942.362	403240.6463	672.77
BR2	4478655.068	399412.7557	663.89
ER	4477897.842	411813.48	74.56

4.2 SURVEY PROTOCOL

We initiated radar surveys on April 17, 2018, and sampling events occurred approximately every three weeks until September 27, 2018. During each survey event, we completed a radar survey at all eight radar stations for one evening and one morning. Two radar stations were surveyed simultaneously during each morning and evening survey. Morning surveys occurred from 90 minutes before to 75 minutes after sunrise, while evening surveys occurred from 60 minutes before to 60 minutes after sunset. Evening surveys at a radar station were typically completed the night before the morning survey was completed. The dates each radar station was operated are provided in Table 2. We discontinued the evening surveys following the first of the two September survey events, as fledged young should have left nesting areas and evening flights by adults should have ceased (Golightly pers. comm. April 2018).

We also completed five mid-day surveys at several of the ridgeline radar stations. We completed those surveys, of varying durations and times of day, in June and August. The mid-day surveys allowed for the visual correlation of non-murrelet radar targets and species identity. Confirmed radar target signatures were used during data analysis to assist in identification of murrelet and non-murrelet targets observed during dark and low-light sampling hours.

Table 2. Survey dates for marbled murrelet radar sampling at the Humboldt Wind Energy Project, Humboldt County, California, April 17, 2018 - September 27, 2018.

Radar Station	Morning Surveys	Evening Surveys	Mid-day Surveys
M1	4/22, 5/1, 5/5, 5/23, 6/18, 7/8, 7/25, 8/18, 9/8, 9/24	4/21, 4/30, 5/4, 5/22, 6/17, 7/7, 7/24, 8/17, 9/7	8/13, 8/14
M2	4/22, 5/1, 5/5, 5/23, 6/16, 7/9, 7/11, 7/26, 8/17, 9/9, 9/25	4/21, 5/4, 5/22, 6/15, 7/8, 7/25, 8/16, 9/8	

M3	4/19, 4/30, 5/6, 5/24, 6/20, 7/9, 7/26, 8/17, 9/9, 9/25	4/18, 4/29, 5/5, 5/23, 6/19, 7/8, 7/25, 8/16, 9/8	6/19
M4	4/20, 4/28, 5/4, 5/27, 6/16, 7/7, 7/28, 8/19, 9/10, 9/26	4/19, 4/27, 5/3, 5/27, 6/15, 7/6, 7/27, 8/18, 9/9	
M5	4/21, 4/26, 5/2, 5/25, 6/17, 7/10, 7/27, 8/14, 8/16, 9/12, 9/27	4/20, 4/25, 5/1, 5/26, 6/16, 7/9, 7/26, 8/15, 9/11	8/13
BR1	5/24, 6/17, 7/8, 7/25, 8/18, 9/8, 9/24	5/23, 6/16, 7/7, 7/24, 8/17, 9/7	6/20
BR2	5/26, 6/18, 7/7, 7/28, 8/19, 9/10, 9/26	5/24, 6/17, 7/6, 7/27, 8/18, 9/9	
ER	4/18, 4/27, 5/2, 5/22, 6/15, 7/10, 7/27, 8/20, 9/7, 9/12, 9/27	4/17, 4/26, 5/1, 5/21, 6/14, 7/9, 7/26, 7/28, 8/19, 9/6, 9/11	

4.3 RADAR EQUIPMENT AND DATA COLLECTION

We used X-band marine surveillance radar equipment, like that described by Cooper et al. (1991). Each radar station consisted of two separate radar units; the first radar unit was installed with the antenna in a normal, horizontal orientation and the second radar unit was installed with the antenna in a vertical orientation. The horizontal orientation allows us to record the flight path and direction of individual targets as well as measure target speed, while the vertical orientation allows us to record the flight height of airborne targets relative to the location of the radar. We aligned the vertical radar unit in a direction that likely would intersect passing murrelets, based on their known ocean-to-inland flight patterns and past evidence of flight directions in the area.

Our radar stations included two different configurations (Photograph 1). Four stations (M1, M3, M4, and M5) consisted of the horizontal radar antenna deployed on top of construction scaffolding and the vertical radar antenna mounted on a deployable mast on a pick-up truck (“stationary” system) and 4 stations (M2, BR1, BR2, and ER) consisted of both radar units installed on top of a custom-built utility trailer (“mobile” system).

Photograph 1. Stationary (left, station M3) and mobile (right, station BR1) radar stations used at the Humboldt Wind Energy Project, Humboldt County, California, April 17, 2018–September 27, 2018.

The stationary systems were powered by a 1000-watt generator. The radars at the stationary systems were Furuno model FR1510MK3, manufactured by the Furuno Electric Co., LTD. in Nishinomiya City, Japan. The FR-1510-MK3 is a 12-kilowatt peak-power radar unit. These are X-band radars and we used a 2-m-long antenna, with a 20-degree beam width, to transmit pulses at 9,410 megahertz. The radars were set to sample at a range of 1.4 km (0.75 nautical mile) and to use a pulse length of 0.07 microseconds. This pulse length allows for an appropriate balance between a strong radar echo at further distances and a better ability to discriminate between individual targets that may be close to each other.

The mobile system was a covered utility trailer with the radar antennae mounted on top of the trailer, and the power, electronics and recording devices contained within the trailer. The radars were Furuno model FAR-1518-BB. These radar units have identical peak-power, waveguide, and transmission rate specifications as the FR-1510-MK3. The mobile radar units were also set to a range of 1.4 km. Both radar antennae on the mobile system were mounted onto automated brackets that allowed us to trim either antenna into its operating position such as fully vertical, for the vertically-sampling radar, or at slight angles for the horizontal radar, to account for any slope that the trailer was parked on or surrounding vegetation and topography.

When the pulses transmitted by the radar are reflected off objects (e.g., birds, vegetation, ground) the resulting echoes are displayed on-screen. The unwanted echoes from the ground, trees, and other non-bird objects are referred to as “ground clutter” or simply “clutter;” this can affect how the radar displays bird data on-screen. At each site, we minimized clutter by using the surrounding vegetation and/or topography to essentially cut-off the bottom of the radar beam (fencing). This fence protects the beam from returning echoes from unwanted objects and allows the display to show birds flying above the area. For further discussion of radar fences see Eastwood (1967), Williams et al. (1972), Skolnik (1980), and Cooper et al. (1991). Figure 3 provides the location of our radar stations and shows the blind spots of each radar station, which include areas where the radar view is either blocked by tall vegetation or areas where ground clutter from vegetation and hillsides obscures the tracks of bird targets flying over those areas.

Field biologists experienced in application of radar studies were on-site to provide continuous oversight during all radar sampling: they collected site-specific data on radar operation, recorded ground-level weather conditions (e.g., sky condition, and wind speed and direction) and made notes on radar target activity, including murrelet and non-murrelet targets. Biologists also attempted visual and audio confirmation of murrelet and non-murrelet targets, as ambient light conditions allowed.

The video data output from each radar system was captured during each sampling event using an Epiphan VGA2USB converter that uses the VGA radar display output and converts it into a digital feed. The feed from each radar was then input into two laptops; one for each radar; and recorded using My Screen Recorder Pro. This provided for the continuous recording of each radar during each sampling period. Radar video data were backed up after each sampling event and post-processed into one-minute samples for data analysis.

4.4 DATA ANALYSIS

After the survey session, we evaluated and analyzed the recorded radar video files to identify targets that appeared to be traveling fast enough to be murrelets and which had radar signatures characteristic of murrelets. To complete this we measured radar target speed, which is equivalent to ground speed (distance/time). We then corrected ground speed using the target flight direction and on-site wind data (wind speed and wind direction) to obtain the airspeed of the bird(s) creating the radar target. On-site wind data were obtained from several Triton sonic detection and ranging (i.e., SODAR) units distributed across the project area (Figure 3). Data from the SODAR unit nearest to each radar station was used to correct the radar target flight data from that station to obtain airspeed.

We distinguished murrelets from other species based on a combination of radar data characteristics, ecological considerations, and visual confirmation of murrelet and non-murrelet targets. Initially, the combination of airspeed (greater than 64 km/hour) and radar target signature was used to identify potential murrelet targets. We based our target signature on the signatures of radar targets for which we obtained direct visual confirmation as murrelets while conducting this survey. Importantly, we also used visual identification from non-murrelet targets to identify those signatures that were likely other than murrelets. These visual confirmations typically consisted of band-tailed pigeons (*Patagioenas fasciata*), which have a flight speed very similar to murrelets but often create squared and rectangular target signatures both as single birds or when traveling in small flocks, which also break apart and recombine.

Historically, surveys of murrelet activity in the region (Burger 2001, Berger et. al, 2004, Cooper and Sanzenbacher 2006, Sanzenbacher and Cooper 2007, Cooper and Mabee 2010, Sanzenbacher et al. 2015) report only data collected before sunrise to avoid contamination of the radar data sets with non-murrelet targets, which are more prevalent after sunrise. We wanted to have empirical site-specific information on flights after sunrise, rather than use data extrapolated from other times or places. Consequently, we included targets from the full survey period in our analysis. To evaluate if a radar target trail was ecologically consistent with murrelets, we used flight timing and direction (inbound or seaward) with respect to patterns in their flight and nesting behavior. Potential murrelet activity (e.g., non-breeder flights during the early nesting season, extra food delivery flights late in the nesting season, and timing of fledged chicks from nests late in the season) were considered during this process. To be conservative and inclusive, those targets that reasonably fit within the patterns of murrelet flight and nesting behavior were considered to be murrelets and were retained in the dataset.

We evaluated ridge crossing behavior by assessing the flight direction of murrelet targets relative to the ridgeline corridors where turbines have been proposed[1]. For targets recorded crossing the ridgelines, we generated the

[1] In this report, we provide the number of murrelet radar targets crossing only those sections of ridgelines where turbines are proposed. The collision risk modeling for the project will include murrelet radar tracks crossing those same areas, plus a buffer zone. Therefore, the number of targets reported to be crossing areas of perceived risk may differ between the two documents.

location of the crossing using a geographic information system (GIS). For targets that created shorter flight paths that angled toward or away from the ridgeline, we considered the flight trajectory, distance from the ridgeline, and any patterns in other flights recorded in that vicinity. For any of these targets determined likely to be crossing the ridgelines, we projected the target trail forward (or backward if it came from the ridge) and generated a crossing location by GIS.

One or more birds flying close together on the same flight path can appear as one echo, or target, on the radar screen. However, if their flight distances vary enough, the radar target signature can change shape and provide an indication that more than one bird may be present. Consequently, each murrelet radar target was examined for the full time it was tracked to determine whether it represented one or more than one bird.

For each target determined to be a murrelet, we recorded:

- Date
- Time
- Flight location
- Flight direction (both the azimuth and as inbound or seaward)
- Ridge crossing behavior and coordinates of the crossing location
- Flight altitude, when available, for targets observed or projected to have crossed the ridge
- Indication of being more than one bird
- Whether it was confirmed visually or audibly by a technician at the radar station.

5.0 RADAR SURVEY RESULTS

5.1 SURVEY EFFORT

We completed 144 radar sampling events between April 17 and September 27, 2018. This included from 7 to 11 morning and 6 to 10 evening surveys at each of the 8 radar stations. Overall, we sampled 209 hours during the mornings and 132 hours during evenings (Table 3). The number of morning survey hours per station ranged from 19.25 hours at the Bear River Ridge stations to 30.25 hours at the M2 and Eel River stations, while the total number of evening survey hours ranged from 12.00 hours at the Bear River Ridge stations to 19.50 hours at the M5 station (Table 3).

Table 3. Marbled murrelet radar survey effort (hours) conducted at the Humboldt Wind Energy Project, Humboldt County, California, April 17, 2018–September 27, 2018.

Radar Station	April		May		June		July		August		September		Total by Station	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
M1	2.75	4	8.25	4	2.75	2	5.5	4	2.75	2	5.5	2	27.5	18
M2	2.75	2	8.25	4	2.75	2	8.25	4	2.75	2	5.5	2	30.25	16
M3	5.5	4	5.5	4	2.75	2	5.5	4	2.75	2	5.5	2	27.5	18
M4	5.5	4	5.5	4	2.75	2	5.5	4	2.75	2	5.5	2	27.5	18
M5	5.5	4	5.5	4	2.75	2	5.5	4	2.75	3.5	5.5	2	27.5	19.5
BR1	0	0	2.75	2	2.75	2	5.5	4	2.75	2	5.5	2	19.25	12
BR2	0	0	2.75	2	2.75	2	5.5	4	2.75	2	5.5	2	19.25	12
ER	5.5	4	5.5	4	2.75	2	5.5	4	2.75	2	8.25	2.5	30.25	18.5
Total by Month	27.5	22	44	28	22	16	46.75	32	22	17.5	46.75	16.5	209	132

All tallies are rounded to the nearest quarter hour.

5.2 MARBLED MURRELET ACTIVITY

We documented 136 murrelets (including murrelets flying parallel to the ridges, both near and far, and crossing the ridges) during the 341 hours of radar sampling in 2018 (Table 4, Appendix A). The greatest number of targets were detected at station ER (41) followed by station M5 (27), and the fewest were detected at stations M3 and BR1 (9 each). Murrelet activity was greatest in July (38 murrelets) followed by May and June (33 murrelets each). Inbound flights accounted for approximately 79% (107) of all flights and seaward flights represented approximately 21% of flights (Appendix A).

Mean detection rates by sampling time (number per morning and evening) varied between sites across all survey events. Detection rates were generally greatest in June, followed by May and July (Table 5). No murrelets were detected during mid-day surveys.

We recorded two visual confirmations of murrelets during the radar sampling; one of two murrelets and the other of a single murrelet. The first occurred three minutes before sunrise on June 17, 2018, at radar station M5. The observer saw the two murrelets that created a radar target flying seaward approximately 600 m north of the radar station. The radar target signature for this observation included both single and split targets as the birds moved closer and further from each other during their flight. The second observation occurred 45 minutes after sunrise on August 20, 2018, at station ER. A single murrelet was observed flying inbound northeast of the river.

Nearly all murrelet targets (127 of 136, or 93.4%) appeared as a consistent radar target signature indicative of a single bird in flight, while 6.6% of targets included some target characteristics indicating that more than one bird could be represented by the radar target.

We observed 31 murrelet radar targets making 35 flights over those portions of the project area ridgelines where turbines have been proposed; four of the targets crossed the ridgelines at an angle that caused them to intersect two different strings of turbines. Vertical radar data indicated that four of the 35 events occurred approximately 230 m or more above the ridge. Twenty-eight ridge crossing events consisted of targets either passing approximately 60–130 m over the ridges or flying below the radar station. For these latter targets, the target trail was lost before the bird crossed the ridgeline (or was detected only after it crossed), and we assumed the birds crossed the ridge at relatively low, tree-top, height. Three observed ridge crossing flights did not have any vertical data available.

Table 4. Total number of marbled murrelets detected by radar at the Humboldt Wind Energy Project, Humboldt County, California, April 17, 2018–September 27, 2018.

Station	April		May		June		July		August		September		Total by Station	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
M1	0	0	3	0	4	2	4	1	0	0	1	0	12	3
M2	0	0	2	0	1	0	3	4	1	0	0	0	7	4
M3	0	1	1	0	4	1	2	0	0	0	0	0	7	2
M4	0	0	6	2	1	0	0	1	0	0	0	0	7	3
M5	3	0	4	1	7	0	8	2	2	0	0	0	24	3
BR1	N/A	N/A	0	0	2	0	1	1	3	1	1	0	7	2
BR2	N/A	N/A	7	0	1	0	4	1	0	0	1	0	13	1
ER	6	0	7	0	10	0	3	3	5	2	5	0	36	5
Total by Month	9	1	30	3	30	3	25	13	11	3	8	0	113	23

Table 5. Mean number of murrelets detected per sampling session during morning and evening surveys at the Humboldt Wind Energy Project, Humboldt County, California, April 17, 2018–September 27, 2018.

Radar Station	April		May		June		July		August		September	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
M1	0.00	0.00	1.50	0.00	4.00	2.00	2.00	0.50	0.00	0.00	0.50	1.00
M2	0.00	0.00	0.67	0.00	1.00	0.00	1.00	1.33	1.00	0.00	0.00	0.00
M3	0.00	0.50	0.50	0.00	4.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
M4	0.00	0.00	3.00	0.67	1.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00
M5	1.50	0.00	2.00	0.50	7.00	0.00	4.00	1.00	2.00	0.00	0.00	0.00
BR1	--	--	0.00	0.00	2.00	0.00	2.00	0.50	3.00	1.00	0.50	0.00
BR2	--	--	7.00	0.00	1.00	0.00	2.00	0.50	0.00	0.00	0.50	0.00
ER	3.00	0.00	3.50	0.00	10.00	0.00	1.50	1.50	5.00	2.00	1.67	0.00

6.0 DISCUSSION

We placed radar stations evenly across the project area to monitor murrelet activity as consistently as possible along the project area ridgelines. Topography and vegetation, however, impact how effectively radars monitor the airspace surrounding them, and blind spots were associated with each station (Figure 3). Our westernmost ridgeline radar stations (BR1–2 and M1–2) included terrain features and a lack of significant forest cover that allowed the radars to provide nearly full 360-degree views. Each of these stations had ground clutter on the radar screens but we were able to track targets across the ridgelines at all four sites. Stations M3 and M4 were placed in areas of recent forest harvesting, so we were able to take advantage of views in several directions that would have normally been blocked by vegetation. Although some sections of ridgeline at these two sites were located within ground clutter on the radar screen, we were able to detect targets flying toward or away from those ridgeline areas. For station M5, only slightly more than 50% of the radar screen was clear to view and track targets. Based on radar station spacing and viewsheds at each station, we believe we sampled approximately 75% of the ridgeline sections proposed for turbines.

We differentiated targets in a manner similar to other recent radar studies of murrelet activity. Accuracy of differentiating murrelet targets from other species decreases during the day because more fast flying birds such as band-tailed pigeons and some waterfowl become active and, unless they are observed visually, they cannot reliably be removed from the data set in a consistent and through manner. We accounted for this by removing targets that we visually observed to be of species other than murrelets.

Studies evaluating murrelet activity have typically only reported the targets detected before sunrise, even when radar surveys extend beyond sunrise. Collision risk assessments for other proposed wind projects have used pre-dawn data only and applied correction factors to characterize murrelet activity in an area during the day and evening time periods (Cooper and Sanzenbacher 2006, Sanzenbacher and Cooper 2007, Cooper and Mabee 2010, Sanzenbacher et al. 2015). However, this results in reducing the total usable sample size, which is a concern for rare species or limited observations. As such, we elected to provide the entire data set. It is likely that some of our reported murrelet targets are of other species, and our reported activity results are therefore likely an overestimate murrelet activity in the project area.

Our pre-dawn data (Table 6) can be used for comparison to other studies, particularly the radar surveys completed on Bear River Ridge by Cooper and Sanzenbacher (2006) and Sanzenbacher and Cooper (2007). Of the 113 total murrelet targets detected during morning surveys, 87 (77%) occurred during pre-dawn hours. The distribution of those pre-dawn observations generally follows that observed for the full morning sampling hours, with the most murrelet targets observed at the Eel River station (30, 35%) followed by station M5 (18, 21%). Stations M3 and BR1 had the fewest pre-sunrise murrelet targets, with two and three targets identified, respectively.

Pre-dawn detection rates at ridgeline stations varied from 0.20 murrelets per morning at station M3 to 1.80 murrelets per morning at station M5. Pre-dawn detection rates for all seven ridgeline stations combined was 0.88 murrelets per morning. While data from Bear River Ridge (Cooper and Sanzenbacher 2006, Sanzenbacher and Cooper 2007) are reported using slightly different metrics, detection rates were generally consistent with our survey results.

Table 6. Number of pre-sunrise marbled murrelet targets documented at the Humboldt Wind Energy Project, Humboldt County, California, April 17, 2018–September 27, 2018.

Radar Station	April	May	June	July	August	September	Total by Station	Number per Morning
M1	0	3	4	4	0	1	12	1.20
M2	0	1	1	2	1	0	5	0.45
M3	0	0	2	0	0	0	2	0.20
M4	0	4	1	0	0	0	5	0.50
M5	3	4	7	4	0	0	18	1.80
BR1	0	0	2	1	0	0	3	0.43
BR2	0	6	1	4	0	1	12	1.71
ER	5	6	8	3	4	4	30	2.72
Ridgeline Stations	3	18	18	15	1	2	57	0.88
Total	8	24	26	18	5	6	87	1.15

We documented murrelet movement that was consistent with known flight patterns in the area. Murrelets nest predominantly in old growth trees (Golightly et al. 2009) such as Humboldt Redwoods State Park, and the Eel River is known to be the primary travel route between the ocean and such nesting stands (Bigger et al. 2006). Murrelet activity was greatest at station ER, where nearly one-third of all targets (30%) consistently traveled parallel to the river. Station M5, which was located 3.8 km south-southeast station ER documented the second largest number of murrelet flights (24 targets); combined, these two stations accounted for 50% of all murrelet activity in 2018.

Activity at station M5 was concentrated to the north and northeast of the radar, over a lower ridgeline extending from the eastern end of the project's proposed turbine arrays. Despite that the greatest number of murrelet flights of all the ridgeline sites occurred at station M5, we did not observe murrelet target trails flying directly toward or away from the areas of proposed turbines in that location. While that section of the ridgeline is within a blind spot, the radar view would have allowed us to observe targets flying toward or from area, particularly where the eastern most two turbines are proposed. Rather, murrelets were flying in a concentrated band northeast of the radar site, in east-southeast (for inbound flights) or west-northwest (for seaward flights) directions and generally parallel to the alignment of the Eel River. Interestingly, the lower ridgeline over which murrelets were consistently observed flying is the last ridge (when traveling inland) before the Bear Creek valley, which leads southward to Humboldt Redwoods State Park.

With some exceptions, most murrelet activity that we observed was generally traveling parallel to the project area ridgelines. Flights we observed crossing the ridgelines typically did so where curves in the ridgelines were perpendicular to the general east-southeast/west-southwest flight tendency, such as near station M3. These crossing events also typically occurred at or near saddles in the ridgelines.

We did observe some concentrations of flight paths parallel to the ridgeline within the Bear River valley but out away from the ridge. In particular, at stations BR2, M1, and M4 we observed murrelet flight paths (4 to 11 targets) running parallel to the ridgelines and concentrated in bands centered approximately 0.75 km south of the ridges. These murrelets were flying at higher altitudes than what we observed in the Eel River valley, as we did not observe any similar concentration of flights to the north of the ridges.

Sanzenbacher and Cooper (2007) reported a general trend of greater murrelet activity at their radar sites further inland along the Bear River Ridge. Flight patterns observed during our surveys were consistent with this, as the greatest number of targets observed among our radar stations was documented at station M5..

Our 2018 surveys documented flight activity and patterns of marbled murrelets near the proposed project. We documented general trends in murrelet abundance and flight that are consistent with results of other surveys completed near the project. These results have provided additional insight on murrelet movements along Bear River Ridge and Monument Ridge, an area previously not intensively monitored for murrelet activity with radar, and which will be used in quantitative murrelet collision risk modeling for the project.

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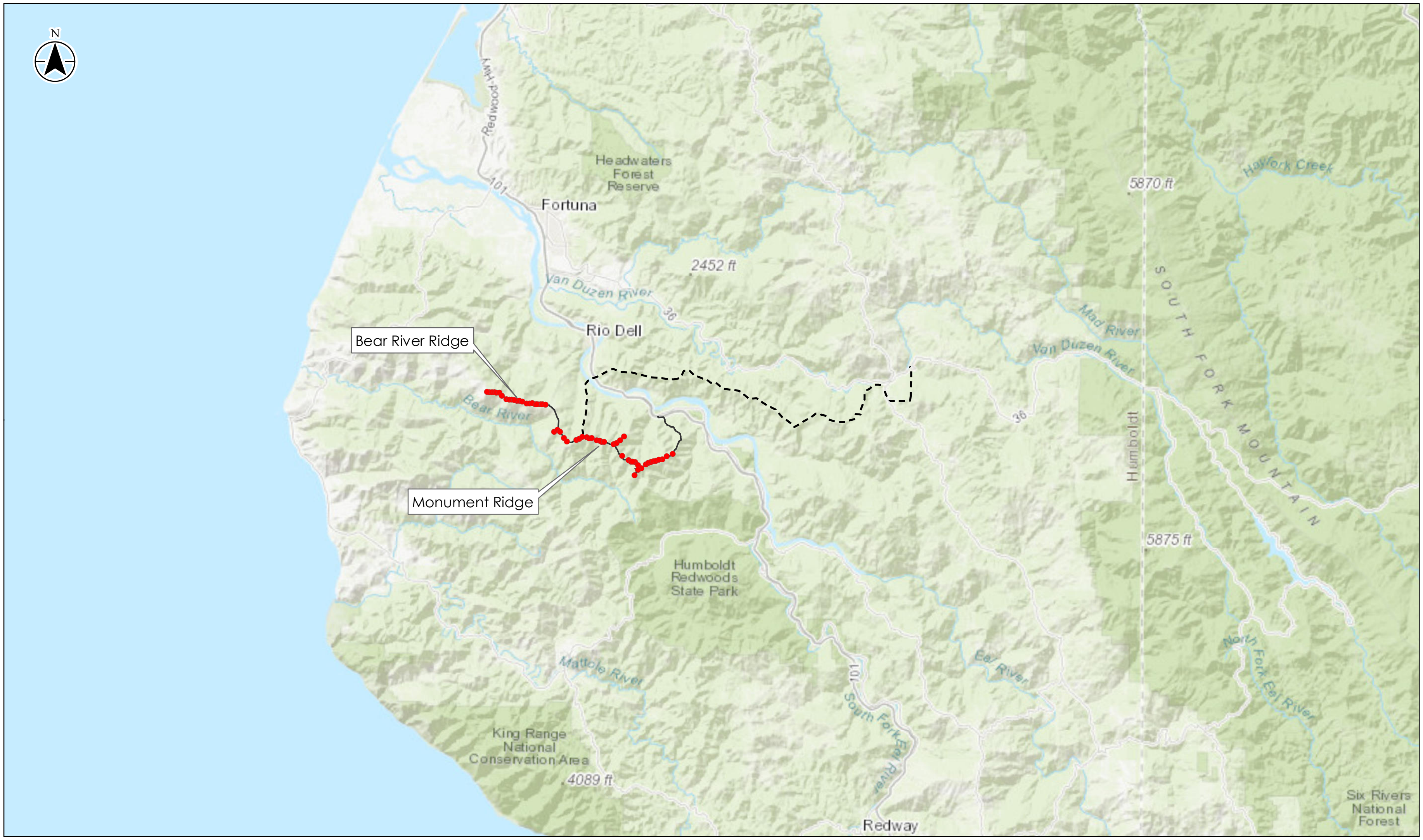
FIGURES



- Proposed Representative Wind Turbine Locations
- Generation Transmission line (gen-tie)
- Proposed Access Roads

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Miles
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Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Base map: ESRI World Topographic Map web mapping service.

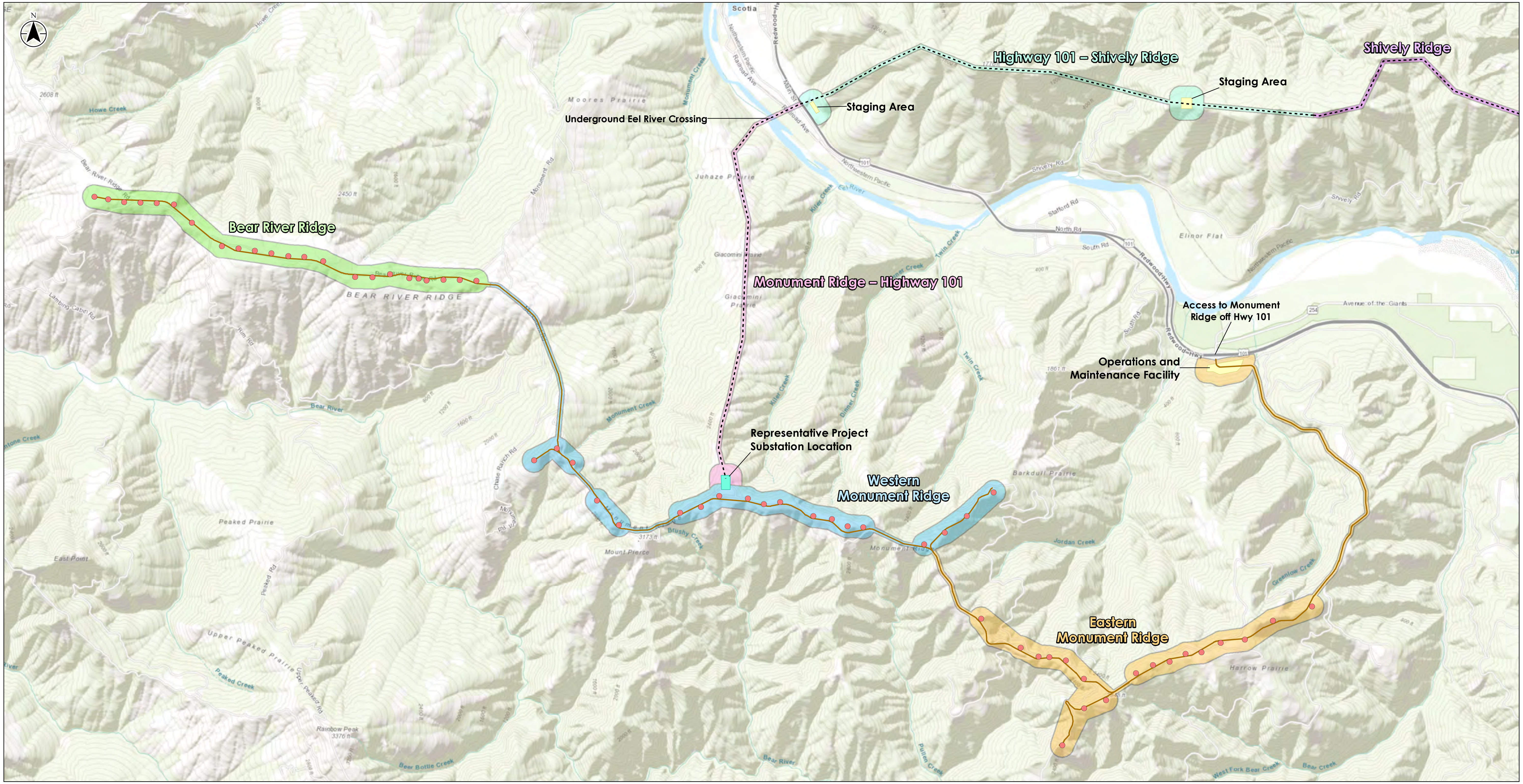
Stantec

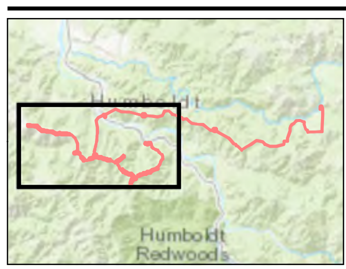
Project Location
Humboldt County, California
185703758
Prepared by PG on 2018-08-06
Technical Reviewed by YA on 2018-08-07
Independent Review by JD on 2018-08-07

Client/Project
Humboldt Wind, LLC
Humboldt Wind Energy Project

Figure No.
1

Title
General Overview





Project Area Segments

- Bear River Ridge
- Western Monument Ridge
- Monument Ridge - Highway 101
- Eastern Monument Ridge
- Highway 101 - Shively Ridge
- Shively Ridge
- Bridgeville

Project Components

- Proposed Representative Wind Turbine Locations
- Generation Transmission Line (Gen-Tie)
- Proposed Access Roads
- Substation
- Staging Area

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Miles
1:50,000 1 inch = 4,167 feet
(At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Base map: Esri World Topographic Map

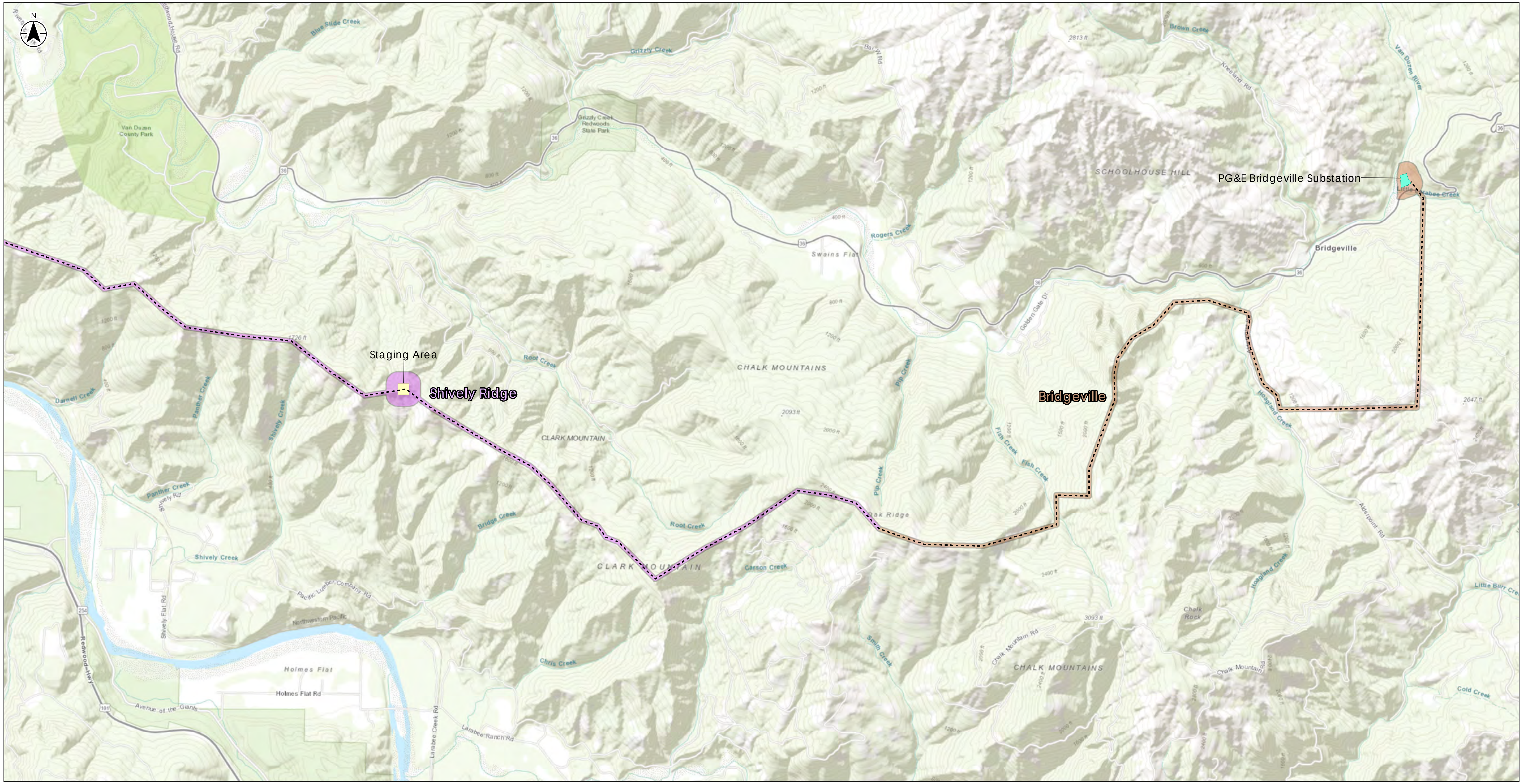
Project Location
Humboldt County, California

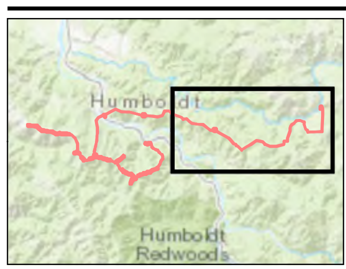
185703758
Prepared by PG on 2018-09-13
Technical Review by SC on 2018-09-13

Client/Project
Humboldt Wind, LLC
Humboldt Wind Energy Project

Figure No.
2

Title
Project Area





Project Area Segments

- Bear River Ridge
- Western Monument Ridge
- Monument Ridge - Highway 101
- Eastern Monument Ridge
- Highway 101 - Shively Ridge
- Shively Ridge
- Bridgeville

Project Components

- Proposed Representative Wind Turbine Locations
- Generation Transmission Line (Gen-Tie)
- Proposed Access Roads
- Substation
- Staging Area

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Miles
1:50,000 1 inch = 4,167 feet
(At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Base map: Esri World Topographic Map

Stantec

Project Location
Humboldt County, California

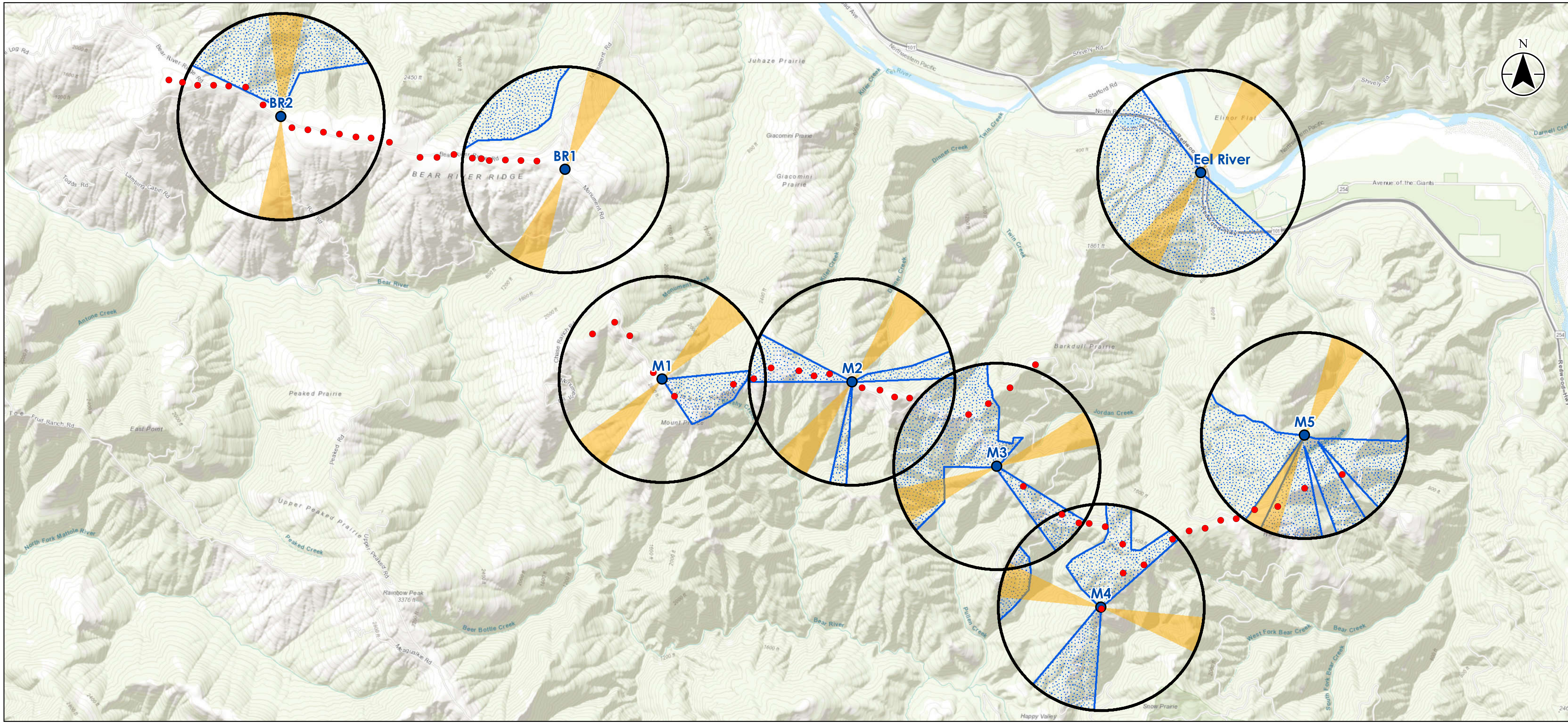
185703758
Prepared by PG on 2018-09-13
Technical Review by SC on 2018-09-13

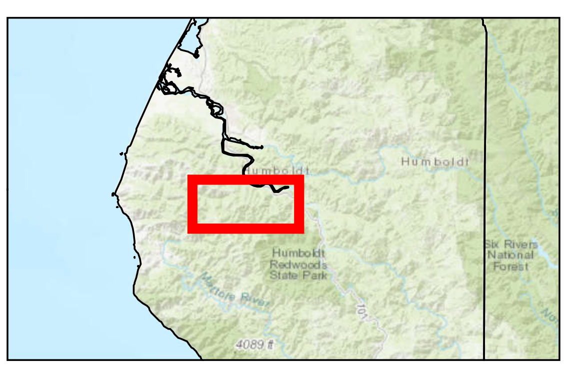
Client/Project
Humboldt Wind, LLC
Humboldt Wind Energy Project

Figure No.
2

Title
Project Area

Page 2 of 2





Legend

- Proposed Representative Wind Turbine Locations
- Radar Survey Location
- 1.4 km Radar Range Limit
- Radar Blind Spot
- Initial Vertical Radar Antenna Alignment

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1:54,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Base map: ESRI World Topographic Map

Stantec

Project Location 185703758

Humboldt County, CA

Prepared by GC on 2018-10-26
Reviewed by BR on 2018-10-29

Client/Project

Humboldt Wind, LLC
Humboldt Wind Energy Project

Figure No.

3

Title

Radar Survey Locations

Appendix A TOTAL MURRELET TARGET COUNT BY STATION

Appendix A. Total Murrelet Target Count by Station

Radar Station	Sampling Event Dates	Evening Survey			Morning Survey			Sampling Event Total
		Inland	Seaward	Total	Inland	Seaward	Total	
M1	4/21–4/22	0	0	0	0	0	0	0
	4/30–5/1	0	0	0	0	0	0	0
	5/4–5/5	0	0	0	1	1	2	2
	5/22–5/23	0	0	0	0	1	1	1
	6/17–6/18	1	1	2	3	1	4	6
	7/7–7/8	1	0	1	3	1	4	5
	7/24–7/25	0	0	0	0	0	0	0
	8/17–8/18	0	0	0	0	0	0	0
	9/7–9/8	0	0	0	1	0	1	1
	9/24	0	0	0	0	0	0	0
M1 Total	–	**2**	**1**	**3**	**8**	**4**	**12**	**15**
M2	4/21–4/22	0	0	0	0	0	0	0
	5/1	0	0	0	0	0	0	0
	5/4–5/5	0	0	0	2	0	2	2
	5/22–5/23	0	0	0	0	0	0	0
	6/15–6/16	0	0	0	1	0	1	1
	7/8–7/9	3	0	3	0	0	0	3
	7/11	0	0	0	2	0	2	2
	7/25–7/26	1	0	1	1	0	1	2
	8/16–8/17	0	0	0	0	1	1	1
	9/8–9/9	0	0	0	0	0	0	0
	9/25	0	0	0	0	0	0	0
M2 Total	**–**	**4**	**0**	**4**	**6**	**1**	**7**	**11**
M3	4/18–4/19	1	0	1	0	0	0	1
	4/29–4/30	0	0	0	0	0	0	0
	5/5 -5/6	0	0	0	1	0	1	1
	5/23–5/24	0	0	0	0	0	0	0
	6/19–6/20	1	0	1	2	2	4	5
	7/8–7/9	0	0	0	1	0	1	1
	7/25–7/26	0	0	0	1	0	1	1
	8/16–8/17	0	0	0	0	0	0	0
	9/8–9/9	0	0	0	0	0	0	0
	9/25	0	0	0	0	0	0	0
M3 Total	**–**	**2**	**0**	**2**	**5**	**2**	**7**	**9**
M4	4/19–4/20	0	0	0	0	0	0	0
	4/27–4/28	0	0	0	0	0	0	0
	5/3 -5/4	0	0	0	3	0	3	3
	5/27	1	1	2	3	0	3	5
	6/15–6/16	0	0	0	1	0	1	1
	7/6–7/7	1	0	1	0	0	0	1
	7/27–7/28	0	0	0	0	0	0	0
	8/18–8/19	0	0	0	0	0	0	0
	9/9–9/10	0	0	0	0	0	0	0
	9/26	0	0	0	0	0	0	0
M4 Total	**–**	**2**	**1**	**3**	**7**	**0**	**7**	**10**
M5	4/20–4/21	0	0	0	1	2	3	3
	4/25–4/26	0	0	0	0	0	0	0
	5/1–5/2	1	0	1	1	0	1	2
	5/25–5/26	0	0	0	2	1	3	3
	6/16–6/17	0	0	0	5	2	7	7
	7/9–7/10	2	0	2	4	1	5	7
	7/26–7/27	0	0	0	3	0	3	3
	8/14–8/16	0	0	0	2	0	2	2
	9/11–9/12	0	0	0	0	0	0	0
	9/25	0	0	0	0	0	0	0
M5 Total	**–**	**3**	**0**	**3**	**18**	**6**	**24**	**27**
ER	4/17–4/18	0	0	0	5	1	6	6
	4/26–4/27	0	0	0	0	0	0	0
	5/1–5/2	0	0	0	0	0	0	0
	5/21–5/22	0	0	0	5	2	7	7
	6/14–6/15	0	0	0	8	2	10	10
	7/9–7/10	0	0	0	0	0	0	0
	7/26–7/28	2	1	3	3	0	3	6
	8/19–8/20	0	2	2	5	0	5	7

Radar Station	Sampling Event Dates	Evening Survey			Morning Survey			Sampling Event Total
		Inland	Seaward	Total	Inland	Seaward	Total	
	9/6–9/7	0	0	0	0	1	1	1
	9/11–9/12	0	0	0	2	0	2	2
	9/27	0	0	0	0	2	2	2
ER Total	**–**	**2**	**3**	**5**	**28**	**8**	**36**	**41**
BR1	5/23–5/24	0	0	0	0	0	0	0
	6/16–6/17	0	0	0	2	0	2	2
	7/7–7/8	0	0	0	0	0	0	0
	7/24–7/25	1	0	1	1	0	1	2
	8/17–8/18	1	0	1	2	1	3	4
	9/7–9/8	0	0	0	0	0	0	0
	9/24	0	0	0	1	0	1	1
BR1 Total	**–**	**2**	**0**	**2**	**6**	**1**	**7**	**9**
BR2	5/24–5/26	0	0	0	7	0	7	7
	6/17–6/18	0	0	0	0	1	1	1
	7/6–7/7	0	0	0	3	0	3	3
	7/27–7/28	0	1	1	1	0	1	2
	8/18–8/19	0	0	0	0	0	0	0
	9/9–9/10	0	0	0	1	0	1	1
	9/26	0	0	0	0	0	0	0
BR2 Total	**–**	**0**	**1**	**1**	**12**	**1**	**13**	**14**
Survey Total	**–**	**17**	**6**	**23**	**90**	**23**	**113**	**136**