From:	Stahl, Megan D.
To:	Lennon, Tiernan
Subject:	RE: MVP BA
Date:	Thursday, December 22, 2016 1:52:45 PM
Attachments:	Appendix_C_take_models_and_methods

Tiernan,

Appendix C is attached. Please let me know if you need anything else.

Also, I touched base with Jen Stanhope and Sumalee Hoskin earlier today regarding mitigation. They provided some initial thoughts their office has regarding mitigation but said that they would like to speak with you, and we also discussed setting up a meeting in January so that we can all discus the topic together. Please let me know once the two field offices have touched base so we can schedule a meeting that I convenient for the whole group to discuss.

Thanks! And I hope you enjoy the holidays!

Megan

From: Lennon, Tiernan [mailto:tiernan_lennon@fws.gov]
Sent: Thursday, December 22, 2016 12:12 PM
To: Stahl, Megan D. <MStahl@eqt.com>
Subject: MVP BA

Hey Megan - Can you send me a word version of Appendix C: Estimate of Take for Federally Listed Species? Thanks!

-Tiernan

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APPENDIX C
ESTIMATE OF TAKE FOR FEDERALLY LISTED SPECIES
MOUNTAIN VALLEY PIPELINE PROJECT
WEST VIRGINIA AND VIRGINIA

BIOLOGICAL ASSESSMENT TO ADDRESS POTENTIAL EFFECTS ON FEDERALLY LISTED SPECIES FOR THE MOUNTAIN VALLEY PIPELINE PROJECT IN WEST VIRGINIA AND VIRGINIA

October 2016

CONTAINS PRIVILEGED INFORMATION – NOT FOR RELEASE

Prepared by:
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1.0 Introduction

This appendix outlines the methods used to assess direct effects of the Mountain Valley Pipeline, LLC (MVP; Project) on the Indiana bat (*Myotis sodalis*), northern long-eared bat (*Myotis septentrionalis*), and Roanoke logperch (*Percina rex*) and is intended to supplement the Biological Assessment (BA) for the Project. Where appropriate, references are made to the BA itself. In addition to the effects methods, this document presents the methods and results of the hydrologic analysis of sedimentation which was used to calculate take for the aquatic species within the Action Area. Methods for direct effects to habitat and indirect effects are contained within the BA (see Section 5 of the BA). Because no harm or harassment is expected for the James spinymussel (*Pleurobema collina*), clubshell (*Pleurobema clava*), and snuffbox (*Epioblasma triquetra*), these species are not covered below; however, each species and their respective effects determination is discussed within the BA. Additionally, plant species are not covered within this appendix. Effects analyses for these species can be found in Section 5.0 of the BA.

2.0 Tree Clearing Schedule

One component of the Indiana and northern long-eared bat effects analysis is a spatialization of the tree clearing schedule provided by MVP. Tree clearance is projected on a monthly basis and will be performed simultaneously across 11 different spreads from the months of September through April with only one spread continuing into the beginning of April. This schedule is made based on the following assumptions: a clearing rate of 762 linear meters (2,500 ft) per day, clearing will not occur between Thanksgiving and New Years day, and a total of 19 days of tree clearing will be conducted per month. A visualization of this schedule in relation to known and potentially occupied bat winter habitats is available in Figures 17 and 18 of the BA.

3.0 Indiana Bats

3.1 Areas for Potential Impacts

Although no Indiana bats were captured during summer mist netting for the Project, the Project Area intersects buffers of three known, occupied localities for Indiana bat where the species is assumed present. These areas include both summer and winter habitats. Summer habitats include a 5-mile (8-km) radius buffer surrounding the capture location of a pregnant female in 2010 near Smithfield, WV, and winter habitats include two 5-mile radius buffers surrounding two known hibernacula: Greenville Saltpeter and Tawney's caves (see Figure 17 in the BA). In addition to these areas, several miles of the route fall within areas of assumed presence for northern long-eared bats. At the time of bat surveys, it was assumed that mitigation would be needed for both Indiana and northern long-eared bats; thus, areas within the buffers surrounding captures of northern long-eared bats were assumed present by Indiana bat as well. Note that as mist net surveys were being completed for the Project (see Section 1.4.1.1 of the BA), if a northern long-eared bat was captured, the area surrounding the capture was buffered by either 1.5 miles (2.4 km) surrounding a located roost tree or 3 miles (4.8 km) if no roost was located. These buffered areas were not sampled, but rather Indiana and northern long-eared bats were assumed present within these buffers. In lieu of a mist net survey, a detailed habitat assessment was performed in these areas of assumed presence and is used in conjunction with previous survey information as well as literature on the species to assess Project impacts.

In addition to surveys for summer habitat, field searches for undocumented cave or mine openings (portals) were performed and found 48 features, including Tawney's Cave a known hibernacula for both northern long-eared and Indiana bats, within a 300-foot wide survey corridor centered on the limits of disturbance (LOD). Initially 20 of these portals were determined to be potentially suitable for hibernating bats; however, four suitable portals have since been destroyed by an ongoing mining project (see Table 8 of the BA), leaving 16 suitable portals documented through field efforts. Surveys, using harp trap, were completed at 10 of the 16 suitable feature in September and October 2015, but no Indiana bats were captured (see Section 4.0 of the BA). Thus, these 10 features were considered to be unoccupied for the effects analysis for Indiana bat. One of the six suitable but unsampled portals, Canoe Cave, was recently surveyed by the VDCR-DNH, and no Indiana bats were observed (K. Powers, pers. comm. April 1, 2016). Given this result, this feature was considered to be unoccupied for the effects analysis for Indiana bat, leaving five suitable features with the potential for Indiana bats, including Tawney's Cave.

Based on desktop analyses, an additional 127 portal features were identified outside the survey corridor but within the vicinity of the Project (i.e., within 5-miles [8-km] of the Action Area). These features were compiled from requests made to the Virginia Speleological Survey, West Virginia Speleological Survey, Draper Aden Associates, and FERC comments. Fifty-eight of these features are within the Action Area of the Project. These portals lack information regarding occurrence of Indiana bats or a determination of the suitability to host cave dwelling bats. Because these features have the potential to host Indiana bats and may be impacted by Project activities, these portals are treated as potentially occupied for this analysis.

3.2 Site-specific Estimates of Abundance

3.2.1 Winter Population Sizes

As mentioned above, there are 133 features within the vicinity of the Project that have the potential for impacts from Project construction. These include two priority 3/4 winter hibernacula: Greenville Saltpeter Cave and Tawney's Cave. The maximum population estimate of Indiana bats in Greenville Saltpeter Cave is 300 (USFWS 2007); however, a recent (2012) in-feature count of Indiana bats within the cave only found 6 individuals. The maximum population estimate of Indiana bats in Tawney's Cave is 14 (USFWS 2007), but more recent in-cave winter surveys conducted in 2009, 2011, and 2013 yielded zero hibernating Indiana bats (Powers et al. 2015), suggesting this cave is no longer occupied by this species during winter. However, to be conservative, an estimate of 2.007 individuals was used for the effects analysis. This estimate was derived based on the modeling described in Section 3.2.1.4 below.

To account for the potential occurrence and abundance of Indiana bats within the remaining four suitable, un-surveyed portals as well as the 127 features with unknown suitability, an abundance estimate that reflected the best available information of the occurrence and abundance of Indiana bats in portals was derived from surveys conducted by Dalton (1987), Gates and Johnson (2006), and Powers et al. (2015), along with previous portal surveys conducted by Environmental Solutions & Innovations, Inc. (ESI) for various projects. Because many of these sources only documented capture of bats using portal trapping (e.g., harp traps), an effort was undertaken to correct for the general undersampling of the population (i.e., the entire population is not exposed to portal traps). The methods and results of this effort are outlined below.

3.2.1.1 Data Description and Model Development

Information from available ESI projects, as well as other studies (e.g., Whitaker and Rissler 1992, Brack et al. 2005), were compiled to create a dataset to estimate the relationship between portal-trap results and in-cave counts. Counts were compiled for six different bat species (*Eptesicus fuscus*, *Myotis lucifugus*, *M. septentrionalis*, *M. sodalis*, and *Perimyotis subflavus*) at 41 separate localities (34 from Indiana, 6 from Virginia, and 1 from West Virginia). At each of these localities, at least one in-cave count and one portal-trap sample was available that were close in temporal proximity (i.e., within 1 year). Although the majority of features only had a single winter in-cave count, the number of portal-trap samples varied dramatically among feature localities with a mean of 3.8 and a maximum of 29 samples.

Four general outcomes were observed in the compiled dataset:

- No winter population of the species existed at the locality based on in-feature counts, and no individuals of the species were caught in portal-traps (61%);
- No winter population of the species existed at the locality based on in-feature counts, but individuals were captured during portal-trap events (16.6%);
- A winter population existed and was greater than the maximum number of individuals caught in portal- traps (19.5%); and
- A winter population existed but was less than the maximum number of individuals caught in portal-traps (2.9%).

These findings suggest that: 1) the number of bats caught in a portal-trap does not represent an estimate of winter population size, 2) an absence of captures during portal-trapping events does not represent an absence of a winter population, and 3) capture of bats in a portal-trap does not necessarily represent the presence of a winter population.

In spite of these findings, portal-trap results may provide a reasonable index of winter population size if both occurrence and expected abundance are correlated with captures of bats during portal-trapping events.

A specific class of regression models known as hurdle models (Zuur et al. 2009) has been developed to account for such scenarios, where occurrence and abundance are a function of different processes. Due to the large number of zero counts found in ecological data, hurdle models break up counts into a binary process of occupancy and a count-based process (e.g., Poisson) of abundance. In the case of winter population of bats, the occurrence of a winter population (i.e., $\Pr[N > 0]$) is modeled using logistic regression. Given that a portal is occupied (i.e., $N > 0$), winter abundance in the portal feature can be modeled using a variety of distributions suitable for counts (e.g., log-normal, Poisson, negative binomial). Using these two separate models, it can be shown that the expected value (i.e., number of expected bats; E) of the winter population size (N) given portal trap results H (i.e., $\mathrm{E}[N|H]$) is:

$$\mathrm{E}[N_i|H] = \Pr(N_i > 0|H)\mathrm{E}[N_i|N > 0, H]. \quad \text{Eq. 1}$$

Although hurdle models provide an estimate of winter abundance given portal trap results, their use for some species of bats may not be applicable. This is particularly the case for northern long-eared bat (*M. septentrionalis*), which is hypothesized to hibernate in small crevices making it difficult to get accurate winter population size estimates. Because of this problem, as well as the small sample size of Indiana bat presences and counts within the dataset, a multispecies hurdle model that omits data from northern long-eared bats may be most appropriate. In this approach, both the logistic regression component and the abundance component of the model are expanded to estimate parameters for all species studied ($n = 5$ [omitting northern long-eared bat]) simultaneously using a mixed effect formulation (Zuur et al. 2009). This approach recognizes that the species specific relationship between portal-trap counts and winter counts may be different for each species studied but likely share a common pattern among species. The advantage of this approach is two-fold:

- Estimates can be made for each species, even when data is limited (e.g., Indiana bat), due to the ability to 'borrow' information across species, and
- The mean relationship can be used to create relationships for species not contained within the model training process. This is useful because it is difficult to get a winter estimate for northern long-eared bats.

3.2.1.2 Data Analysis

Hurdle models are constructed using the R package glmmADMB which utilizes the Automatic Differentiation Model Builder (ADMB) to fit generalized linear mixed models (GLMMs). Occurrence models are fit using hierarchical logistic regression with the species treated as a random effect. Note that all harp trap counts are square-root transformed to improve model fit and optimization. Four separate models are fit:

- A random intercept model using the ***mean*** portal-trap count for each species at each portal. This approach recognizes that mean occurrence varies by species but the relationship between portal-trap counts and occurrence is common.

- A random intercept model using the ***max*** portal-trap count for each species at each portal. This is similar to the approach taken in the previous model.
- A random slope model using the ***mean*** portal-trap count for each species at each portal. This approach recognizes that mean occurrence and the relationship between portal-trap counts and occurrence varies by species.
- A random slope model using the ***max*** portal-trap count for each species at each portal. This is similar to the approach taken in the previous model.

Count models are fit using a similar approach, but three separate distributional assumptions are tested. Models are first fit using a zero-truncated Poisson distribution. Since count models only incorporate data where winter population size is greater than zero, the zero-truncated Poisson distribution eliminates zero from the probability density function. Note that given present overdispersion within the dataset (i.e., greater variability than expected by the statistical distribution), an overdispersed zero-truncated Poisson is fit by adding a random effect for each observation within the dataset. This approach essentially adds an additional variance component to the model to deal with overdispersion. In addition to the zero-truncated Poisson, a zero-truncated negative binomial is also fit. The negative binomial is less sensitive to overdispersion because it includes a scaling parameter for additional variance. Finally, abundance is also modeled using a log-normal distribution. For each distribution, four models are fit using the random intercept or random slope formulations described above for regressing against the mean or max portal-trap counts made at each feature.

The weight of evidence for each of the models is judged using Akaike's Information Criterion (AIC) (Akaike 1974) as corrected for small sample size (AICc) (Hurvich and Tsai 1989), and the models with the lowest AICc are used to predict the expected number of wintering bats given portal trap results.

3.2.1.3 Application to Portal Trapping Dataset

Although the above analysis provides a relationship to link portal-trapping results to winter population sizes, it does not provide an estimate of the expected number of bats present in an unsampled portal or feature. The major issue with applying the estimated values from the model above is that they are biased by the fact that each feature was known to host at least one bat during winter, and these portals were trapped with the high expectation of finding bats. Ideally, an estimate of the expected number of bats in unsampled features would come from a designed study of randomly sampled features that demonstrate suitability for bats; however, no such study is available. Instead, results are available from several purposeful studies and reports involving either in-cave counts of bats or counts from portal–trapping. Although these results do not represent a true random sample, they are the best-available information regarding the presence and abundance of Indiana and northern long-eared bats in a random but suitable portal (excluding Priority 1 or 2 features).

In an attempt to estimate the expected number of bats in unsampled features, data from surveys conducted by Dalton (1987), Gates and Johnson (2006), and Powers et al. (2015) as well as surveys conducted for previous ESI projects were compiled into a database. In total, this database contained samples from 527 unique features (290 from Pennsylvania, 172 from Virginia, 23 from West Virginia, 20 from Ohio, 20 from Kentucky, and 2 from New Jersey) with 408 features containing only portal-trapping results and 119 features containing results from in-feature counts. For surveys that only had counts from portal-trapping, an estimate of the winter population size is made using the product of the expected probability of presence times the expected abundance given occupied (as in Eq. 1). For portals where in-feature counts were available (e.g., Dalton 1987), no adjustment is made. Using this approach, the expected number of bats in an unsampled feature is estimated as the mean winter population estimate from these sources.

3.2.1.4 Estimates of Winter Population Size

Models for presence of a winter hibernating population given presence of bats in autumn or spring (i.e. $Pr[N > 0|H]$) showed strong support over the null hypothesis that no relationship existed (i.e., $Pr[N > 0]$). Based on AICc, the best supported model was one that related the presence of a winter population to the maximum observed number of individuals of the species during portal-trapping. Based on the estimated regression coefficients, for every one unit increase in bat captures on the square root scale (e.g., 0 to 2, 2 to 4, 4 to 9, etc.), the presence of a winter population is 1.78 times more likely.

Similar to the results for presence of wintering populations, count models for population size showed strong support for the hypothesis that winter population size was correlated to the maximum number of individuals captured during portal-trapping. Based on this relationship, for every one unit increase in bat captures on the square root scale (e.g., 0 to 2), we expect the size of the population to be 60% larger.

Using the best-supported models for presence and population size when present, along with in-feature counts, the expected number of Indiana bats in an unsampled but suitable feature is 2.007 bats. For northern long-eared bats, this value is 7.017 bats. However, these estimates are based on ***suitable*** features. Thus, these estimates are applicable for the 4 suitable portals discovered during field surveys as well as a conservative estimate of Indiana bats present within Tawney's Cave, but 127 features within the vicinity of the Project lack information regarding the suitability for hibernating bats. For these features, the abundance estimate above can be multiplied by the proportion of features that are expected to be suitable within the region. Without better information, this proportion is estimated using survey information performed for the Project. In total 48 features were discovered within the 300-ft survey corridor for the Project. Of these 48 features, 20 were deemed suitable. Thus, it is expected that 41.67 percent of portal features are likely to be suitable for hibernating bats, and thus a population estimate of 0.8363 Indiana bats and 2.9238 northern long-eared bats is made for each of the features with unknown suitability within the vicinity of the Project.

3.2.2 Summer Population Sizes

Field studies conducted in support of the BA failed to provide evidence of occupation by Indiana bats during the summer season of reproduction (see Section 1.4.1.1 of the BA).

However, the Project intersects an area of known, occupied summer habitat from Project MP 0.0 to MP 10.3. In this area, and other areas of assumed presence, including near previously known hibernacula (i.e., Greenville Saltpeter and Tawney's cave) and areas not sampled by ESI (e.g., areas excluded due to captures of other endangered bat species), harm and harassment are possible.

To estimate harm and harassment during the summer season of reproduction, average densities of the species are calculated for both Virginia and West Virginia. According to USFWS (2015), there are 2,373 Indiana bats in West Virginia's 11,749,842 estimated acres of forest and 597 within Virginia's 15,765,700 acres. For West Virginia, where the species is distributed across most of the state, density estimates can be made by dividing the number of bats by the number of forested acres (i.e., 2,373 bats /11,749,842 forested acres), which gives the number of bats expected per forested acre (0.000202 bats/forested acre). In Virginia, the species is not known throughout the entire state, making the calculation slightly more difficult. Based on a georeferenced version of the Indiana bat distribution taken from the *Bats of Illinois*, just over half (0.519) of the state of Virginia is within the distributional range of the species. Thus, density can be calculated by dividing the number of bats by the number of forested acres times the proportion of the state within the range (i.e., 597/[15,767,700*0.519]). Based on this calculation Indiana bat density within Virginia is 0.00007 per forested acre.

3.3 Impact Approach

Biologically, there are four ecologically distinct components of the annual life cycle of Indiana bats: winter hibernation, spring staging and autumn swarming, spring and autumn migration, and the summer season of reproduction. The assessment of effects focuses on impacts to these different life cycle components, and in each component, effects are quantified and categorized into the expected number harmed ($HARM$) and the expected number harassed ($HARASS$). As discussed within the BA (see Section 5.1 of the BA), impacts to individuals and habitat are believed to be possible for all four components. Methods and results of impacts to individuals can be found below, and impacts to habitat are within Section 5.1.2 of the BA.

3.4 Direct Effects to Individuals

3.4.1 Winter Season of Hibernation

Although harm from destruction of winter habitat is unlikely to result from Project actions, potential effects from changes in the soundscape near the Project are possible. The Action Area is defined as extending 0.6 miles (0.97 km) from the edge of the Project Area, based on the distance to which Project sounds during construction would be above an intensity rated as quiet for human hearing. There are 62 portal features with the potential to host Indiana bats within this distance: one feature that has been identified as previously occupied by the species, Tawney's Cave; 3 features that have been deemed suitable but remain unsampled for bats (i.e., Fred Bulls Cave, Homer Williams Cave, and Overlooked Cave); and 58 features that have not been assessed for suitability or occurrence of Indiana bats. For Tawney's Cave and the 3 suitable portals a population estimate of 2.007 bats is used for impact assessment, but for features with unknown suitability an estimate of 0.8363 bats is used (i.e., $2.007 \times [20/48]$; see Section 3.2.1 above). Individuals, if present, within these portals have the potential to be harassed during hibernation. Thus, an expected number of harassed bats can be made by multiplying the 4 suitable features (including Tawney's Cave) by 2.007 bats and adding the product of the 58 features and 0.8363 bats ($56.53 = 4\times2.007+58\times0.8363$). Thus, rounding up, 57 individuals are expected to have the potential to be harassed by the Project during the winter season of hibernation.

Because bats also have potential to be harassed from noises during operations of the Project, the analysis also included an assessment of hibernacula surrounding potential locations of permanent aboveground facilities (i.e., compressor stations); however, there are no (0) hibernacula (known or potentially occupied) within 0.6 mile of a compressor station location.

3.4.2 Autumn Swarming and Spring Staging

After emerging from hibernation, Indiana bats are thought to participate in a process known as spring staging, where bats remain near the hibernacula for a short time (e.g., couple of days) before migrating to summer maternity areas. A similar process occurs in autumn but over a longer time period, with most bats roosting in forested habitat within 5 miles (8-km) of the cave entrances. As described in Section 3.4.1, the Project is within 5 miles (8 km) of two known Indiana bat hibernacula, 4 field documented suitable features (including one outside the Action Area) that have the potential to harbor Indiana bats, and 127 features that have unknown suitability for bats.

Project construction could directly harm or harass individuals during spring staging and autumn swarming in two primary ways. First, removal of wooded habitat associated with Project construction creates the potential for both injury and mortality. Second, individuals may be forced to expend additional energy to locate replacement roosts due to construction sound or active clearing of a tree where a bat is roosting.

To estimate impacts to individuals during spring staging, information on the activity levels of bats in different months during spring is derived from the literature. Based on information provided in Cope and Humphrey (1977), it is expected that the nearly all individuals remain in hibernation before March 14; however, a few individuals may remain active throughout the winter. The study also demonstrated that beginning in late March, individuals begin to emerge, and by March 30, 64 percent of individuals captured within the spring had emerged. That number increased to 95 percent by April 14, and after April 23 emergence had ceased. Based on this information, the likelihood of harm and harassment during staging is greatest within March and April. Using the observations of Cope and Humphrey (1977), 64 percent of bats within a winter habitat likely emerge and participate in staging during March, and 36 percent are likely to emerge and stage in April.

In addition to the temporal aspects of staging, the spatial configuration of roost tree use during spring is derived from the literature. To determine where bats may be present during staging, the kernel home ranges derived in Gumbert et al. (2002) are used to create concentric bins surrounding known or potentially occupied portal features. Based on this information, it is expected that 50 percent of the population is found within 0.67 kilometer (0.416 mi) of the hibernacula, 25 percent between 0.67 (0.416 mi) and 1.34

kilometers (0.833 mi), 20 percent between 1.34 (0.833 mi) and 2.37 kilometers (1.473 mi), and 5 percent between 2.37 and 7 kilometers (1.473 and 4.35 mi, respectively). These bins are then used to predict the density of bats surrounding each of the 133 features using the population estimates provided in Section 3.2.1.

Using both the temporal and spatial aspects of staging derived from Cope and Humphrey (1977) and Gumbert et al. (2002), respectively, the number of staging bats in a bin surrounding a potential hibernacula is calculated as the product of 1) the number of individuals expected in the feature as derived in Section 3.2.1, 2) the proportion expected to be participating in staging within the month based on Cope and Humphrey (1977), and 3) the proportion expected to be found within the distance bin based on Gumbert et al. (2002). This estimate is then used to calculate the potential harm and harassment from 1) tree felling and 2) construction disturbance.

Harm and harassment from tree felling is calculated using the estimate of the number of staging bats in bins surrounding potential and known hibernacula (Table 1). Expected harm of staging bats within each bin surrounding a potential hibernacula is calculated as the product of 1) the number of bats expected in the bin, 2) the proportion of the bin within the LOD cleared during months with staging bats present, and 3) the expected harm rate (0.25). This harm rate is based on the expectation that a large proportion of bats is able to escape when a tree is felled or disturbed. Previous studies have observed mortalities of 10, 16, and 9 percent (Mumford and Cope 1964, Cope et al. 1974, Belwood 2002). However, the sample size in these studies was fairly low and only includes mortality. To offset this low sample size and the potential for additional injury, a value of 0.25 (or 25 %) is chosen. All bats present within the proportion of the bin within the LOD are assumed to harassed (i.e., harassment rate=0.75). For example, harm and harassment for the Greenville Glenray Cave (Table 1) is calculated as follows. The cave is a potential hibernacula for the species but has unknown suitability, and it is estimated that 0.8363 Indiana bats use the feature for winter hibernation (see Section 3.2.1). Only the concentric bins for 0-0.67 kilometer (0-0.42 mi) and 0.67-1.34 kilometer (0.42-0.83 mi) intersect the area cleared within the LOD during the month of March, and no concentric bins intersect the area cleared within the LOD during the month of April. Broken up by bin, it is expected that during March, 0.2676 bats are within 0.67 kilometer (0.42 mi) (i.e., 0.8363*0.64*0.5, where 0.64 is the proportion of bats that are expected to emerge during March [Cope and Humphrey 1977] and 0.5 is the proportion of bats that are expected within 0.67 kilometer of a hibernacula [Gumbert et al. 2002]), and 0.1338 bats are within 0.67 to 1.34 kilometers (0.42-0.83 mi) (i.e., 0.8363*0.64*0.25, where 0.25 is the proportion of bats that are expected within 0.67 to 1.34 kilometers of a hibernacula). Harm within each bin is calculated as the product of 1) the number of individuals present (e.g., 0.2676 bats), 2) the proportion of the bin within the LOD that is being cleared in March (e.g., 0.0225), and the harm rate (0.25). Harassment is calculated by replacing the harm rate with the harassment rate (i.e., 0.75). Thus, 0.0015 (i.e., 0.2676*0.0225*0.25 where 0.0225 is the proportion of the bin within the LOD) and 0.005 (i.e., 0. 2676*0.0225*0.75) bats are expected to be harmed or harassed, respectively, within 0.67 kilometer (0.42 mi) of the feature. Similar calculations are made for all other bins, and the total number of individuals harassed or harmed is summed across all bins and all potential or known hibernacula (Table 1).

Table 1. Potential areas for harm and harassment of spring staging Indiana bats from tree felling.

Feature	Occupancy Status*	Winter Abundance Estimate	Month of Disturbance†	Distance Bin‡	Prop. of Bin in LOD**	Harm	Harass
Bear Hole	Suitability Unknown	0.8363	March	1.34-2.37km	0.0005	<0.0001	<0.0001
			March	2.37-7km	0.0021	<0.0001	<0.0001
Blankenship Cave	Suitability Unknown	0.8363	March	2.37-7km	0.021	<0.0001	<0.0001
Dixie Annex Cave	Suitability Unknown	0.8363	March	1.34-2.37km	0.0002	<0.0001	<0.0001
			March	2.37-7km	0.0021	<0.0001	<0.0001
Dixie Caverns††	Suitability Unknown	0.8363	March	1.34-2.37km	0.0002	<0.0001	<0.0001
			March	2.37-7km	0.0021	<0.0001	<0.0001
Elliston Cliff Cave	Suitability Unknown	0.8363	March	2.37-7km	0.0022	<0.0001	<0.0001
Garrisons Cave	Suitability Unknown	0.8363	March	1.34-2.37km	0.0006	<0.0001	0.0001
			March	2.37-7km	0.0021	<0.0001	<0.0001
Givens Cave	Suitability Unknown	0.8363	March	1.34-2.37km	0.0035	0.0001	0.0003
			March	2.37-7km	0.0018	<0.0001	<0.0001
Greenville Glenray Cave	Suitability Unknown	0.8363	March	0-0.67 km	0.0225	0.0015	0.0045
			March	0.67-1.34km	0.0044	0.0001	0.0004
Greenville Saltpeter	Known	0.8363	March	2.37-7km	0.0003	<0.0001	0.0001
Hans Creek Cave	Suitability Unknown	0.8363	March	1.34-2.37km	0.0012	<0.0001	0.0001
			March	2.37-7km	0.0002	<0.0001	<0.0001
Kays Cave	Suitability Unknown	0.8363	March	1.34-2.37km	0.0001	<0.0001	<0.0001
			March	2.37-7km	0.0021	<0.0001	<0.0001
New Dixie Cave	Suitability Unknown	0.8363	March	1.34-2.37km	0.0015	<0.0001	0.0001
			March	2.37-7km	0.002	<0.0001	<0.0001
Pedlar Hills Cave	Suitability Unknown	0.8363	March	2.37-7km	0.0022	<0.0001	<0.0001
Poor Mountain Cave	Suitability Unknown	0.8363	March	2.37-7km	0.0012	<0.0001	<0.0001
Psuedo-Garrisons Cave	Suitability Unknown	0.8363	March	1.34-2.37km	0.0004	<0.0001	<0.0001
			March	2.37-7km	0.0021	<0.0001	<0.0001
Rebel Yelp Cave	Suitability Unknown	0.8363	March	2.37-7km	0.0022	<0.0001	<0.0001
Salem Quarry Cave	Suitability Unknown	0.8363	March	0.67-1.34km	0.0002	<0.0001	<0.0001
			March	1.34-2.37km	0.0063	0.0002	0.0005
			March	2.37-7km	0.0014	<0.0001	<0.0001

*Occupancy status refers to the categorical classification of portal features from Section 3.2.1. Potential options are: Known, Suitable, and Suitability Unknown. Abundance estimates are made from these different classifications.
†The month of disturbance refers to months during the spring with the potential for harm and harassment from tree clearing.
‡Distance bins are the concentric bins surrounding hibernacula where densities of Indiana bats are though to vary. Bins were constructed from Gumbert et al. (2002).
**Proportion of distance bin within the limits of disturbance (LOD). Note only the proportion of the bin cleared within the respective month is shown.
††Multiple entrances used

Based on these calculations and the tree clearing schedule, the probability of a staging Indiana bat being harmed or harassed due to tree clearing is low but possible. Estimated harm is 0.0023 bats, and estimated harassment is 0.0068 bats.

Although the estimates of harm and harassment of staging bats from tree clearing are low, there is a much greater potential for disturbance from noise, sound, or dust from construction. Such harassment can be calculated for each feature as the product of 1) the proportion of staging bats within each concentric bin as derived from Gumbert et al. (2002), 2) the proportion of the bin within the Action Area (not including the LOD), and 3) the winter population size for the feature (see Section 3.2.1). Note that no temporal dynamics are incorporated within this estimated because it is assumed that all bats that participate within staging within 0.6 miles (0.97 km) of the Project (as defined by the Action Area) will be harassed. Using this approach, it is expected that within 0.67 kilometer (0.42

mi) of all features 26.9213 Indiana bats will be harassed; likewise, within 0.67 to 1.34 (0.42-0.83 mi), 1.34 to 2.37 (0.83-1.47 mi), and 2.37 to 7 km (1.47-4.35 mi) 9.5745, 6.2315 and 1.10 Indiana bats will be harassed, respectively.

Cumulatively, it is expected that 43.5340 and 0.0023 Indiana bats will be harassed or harmed, respectively, during spring staging. This harassment estimate combines harassment due to 1) the clearing of a tree with a bat occupying it but the bat escaping unharmed (0.0068) with 2) the potential harassment due to clearing and construction noises within a 0.6-mile radius of the Project (43.5272). As with the estimates for winter take, these estimates are rounded up to 44 individuals harassed and 1 individual harmed.

In addition to these estimates for spring staging, harm and harassment during autumn swarming is also possible via the same mechanisms listed for staging individuals. However, the temporal dynamics of swarming are not as well documented. Based on information provided in Cope and Humphrey (1977) and Humphrey et al. (1977), female Indiana bats begin migrations from summer ranges around early to mid-August and begin to arrive at caves around August 20. Several studies suggest that female Indiana bats enter torpor soon after arriving at the hibernacula (Cope and Humphrey 1977, Humphrey et al. 1977, LaVal and LaVal 1980, Richter et al. 1993, Johnson et al. 1998), and based on the information provided in Humphrey et al. (1977), females begin hibernation around September 10. Patterns of male Indiana bats are not as well documented, but males are thought to arrive prior to female individuals, and some males remain active as late as November (Cope and Humphrey 1977, Richter et al. 1993).

In addition to these arrival and hibernating timelines, several studies have documented that swarming may occur during several peak periods in the fall. LaVal and LaVal (1980) documented two peaks, one in mid to late August with both males and females and one in late September or early October dominated by males. Cope and Humphrey (1977) also documented two peaks, one in early September and one in early October, with the second dominated by males.

Based on this information, a few assumptions can be made about the temporal dynamics of swarming: 1) 50 percent of females are likely to swarm between August 15 and September 15, and 50 percent are likely to swarm between September 15 and October 15. This can be broken up into 15 day intervals with 25 percent within each period between August 15 and September 1, September 1 and September 15, September 15 and October 1, and October 1 and October 15. The timeline for males is less well-documented, and thus, it is assumed that 100 percent of individuals are swarming between August 1 and November 1.

Similar to the approach taken for staging, it is assumed that swarming individuals are distributed among different distance bins derived from Gumbert et al. (2002) above. Thus, the number of swarming bats in a bin surrounding a potential hibernacula is calculated as the product of 1) number of individuals expected in the feature as derived in Section 3.2.1, 2) the proportion expected to be participating in swarming within the month based on the assumptions made above, and 3) the proportion expected to be found within the distance bin based on Gumbert et al. (2002). This estimate is then used to calculate the potential harm and harassment from 1) tree feeling and 2) construction disturbance. Using this approach, it is expected that 0.0725 and 0.2176 swarming bats will be harmed or harassed from tree clearing, respectively, and 43.5295 bats will be harassed from construction disturbances (e.g., noise). Rounding up, the cumulative expected number of swarming Indiana bats harmed or harassed by the Project is 1 and 44, respectively.

3.4.3 Summer Season of Reproduction

Field studies conducted in support of the BA failed to provide evidence of occupation by Indiana bats during the summer season of reproduction (see Section 1.4.1.1 of the BA). However, the Project intersects an area of known, occupied summer habitat from Project MP 0.0 to MP 10.3. In this area, and other areas of assumed presence, including near previously known hibernacula (i.e., Greenville Saltpeter and Tawney's cave) and areas not sampled by ESI, harm and harassment are possible. Harm is only possible within forested areas cleared in April, May, and September that intersect these areas of assumed presence. In total, this area represents approximately 149.205 acres in Virginia and 444.173 acres in West Virginia (Table 2). However, harassment is possible within both the LOD and Action Area from tree clearing and construction disturbance. Available data from sites in Indiana (Humphrey et al. 1977, Brack 1983, Sparks et al. 2008, Whitaker and Sparks 2008) suggest that bats begin to arrive on the summer grounds approximately April 1, and the majority of individuals arrive by May 15, although a few stragglers continue to arrive into early June. Note that this is a pattern observed in female individuals, but adult males are thought to follow a similar pattern though are not as well studied. It is also important to note that males are thought to occupy different habitat than females during summer, often centered on hibernacula. Without knowledge of the location and number of individuals present within each hibernacula within West Virginia, Virginia, and surrounding states, it is assumed that all forested areas have an equal chance to host a male or female individual. Based on the arrival periods from the sources listed above, it is expected that within the spring 5 percent of residents will arrive within the MVP LOD between April 1 and April 15, 40 percent of residents will arrive between April 16 and April 30, 50 percent of residents will arrive between May 1 and May 15, and 5 percent will arrive from May 16 to June 1.

Departures of Indiana bats from summer habitats are not as well documented, but several aspects are known. According to Humphrey et al. (1977), females begin migrations from summer ranges around early to mid-August and begin to arrive at hibernacula around 20 August. Males, conversely, likely begin congregating at hibernacula prior to the arrival of females. Based off this information and the assumptions made in Section 3.4.2, a few assumptions can be made. First, it is assumed that between 25 and 75 percent of females are likely to remain in the summer range in September, depending on the time of month. Given this wide range it is assumed that 75 percent are on the landscape in September. This assumption likely over estimates the number of individuals present on the summer range in September because it does not consider migrations. Second, nearly all males are centered on hibernacula by August 1.

Based on these arrive and departure times, a time-variant population size within the MVP LOD can be made for the months of April, May, and September where tree clearing is expected and summer roosting bats may be present. This population estimate is based off the summer densities estimated in Section 3.2.2. In short, the number of bats expected per forested acre is 0.000202 bats in West Virginia and 0.00007 in Virginia. As described in Section 3.4.2, harm and harassment rates from tree felling are estimated at 0.25 and 0.75, respectively. Using these rates, MVP's proposed tree clearing schedule, and the time-variant population size estimates within the MVP LOD, the number of individuals expected to be harmed and harassed during tree clearing activities (not including sound, light, or dust disturbance; see below) is 0.022 and 0.065 (Table 2), respectively, which is rounded up to 1 individual harassed and 1 individual harmed.

Table 2. Potential areas for harm and harassment of summer roosting Indiana bats from tree felling.

State	Month	Acres Cleared	Harm	Harassment
Virginia	September	149.2051	0.0024	0.0071
West Virginia	April	11.694	0.0003	0.0008
West Virginia	September	432.48	0.0191	0.0573

In addition to this harm and harassment from tree clearing, harassment due to construction noises, light, and dust is also possible. It is assumed that an individual can only be harassed once; thus, harassment was estimated by the mechanism that has the largest area of impact, noise. As discussed in Section 3.1.3 of the BA, it is believed that sound may harass individuals within 0.6 miles (0.97 km) of active construction. Thus, to calculate the number of individuals potentially harassed during summer roosting, the density estimates from Section 3.2.2 were multiplied by the number of forest acres expected to be disturbed during active construction within each state (i.e., areas within 0.6 miles ([0.97 mi] of the LOD). Note that these acres were adjusted to remove areas where sufficient sampling was performed to claim probable absence as well as the LOD for the Project. Using the National Land Class Database (NLCD) in conjunction with land use classifications from the detailed habitat assessments, it is expected that 129,639 and 40,457.62 acres of forest within West Virginia and Virginia, respectively, that remain unsampled for Indiana bat will be within the range of potential disturbance from MVP construction. Based on these estimates 29.13339 bats (i.e., 0.000202 bats/acre × 129,639 acres + 0.000073 bats per acre × 40,457.69 acres), rounded up to 30 bats, during the summer season of reproduction will be harassed during Project construction.

3.4.4 Spring and Autumn Migration/Transient Period

Relatively little is known about the timing or use of habitat during the migratory/transient period. Typically, roosting habitat suitable for use in summer is assumed to be suitable for migrating bats. One aspect of migration that has been relatively well studied is the time bats arrive from and depart from both the summer and winter ranges (e.g., Humphrey et al. 1977, Cope and Humphrey 1977). Based on information from available studies, the first bats are thought to arrive on the summer grounds approximately April 1 with most bats present by May 15, although a few stragglers continue to arrive into early June.

Because there is potential to remove forested habitat during portions of April, May, and September, a direct take of migrant individuals by harm (killing or injury) or harassment is possible via active tree clearing. Given that migrants are expected to occur for only a brief amount of time within the Action Area (e.g., 1 day), it is assumed that disruptions from construction via noise, light, or dust would not significantly increase the stress or energetic costs of the species during this short time period. Under these assumptions, harassment and harm is only possible within the LOD in forested areas where trees are actively being cleared.

Because no information is available regarding the paths or densities of migrants during the spring and autumn, summer densities of bats may provide the most reasonable surrogate to estimate take of migrants. As discussed in Section 3.2.2, estimates for summering individuals within Virginia and West Virginia are 0.0002 and 7.295 $x10^{-5}$ bats per acre, respectively. These densities were specified for migrants in order to provide a conservative estimate of the potential for take. In reality, true migrant densities are likely smaller and more variable across time during the months of April, May, and September. Similar to the approach taken for summering individuals, harassment and harm was calculated by multiplying respective densities of migrant individuals by the acres being cleared within the months of April, May, and August to get a total number of expected bats. Note that this was not restricted to areas of assumed presence. This total number was then multiplied by 0.25 to get an estimate of harmed individuals, and all other individuals are assumed to be harassed. In West Virginia, it is expected that 718.714 forested acres will be cleared in the months of April, May, and September. Likewise, 220.336 acres will be cleared within Virginia within that same time frame. Thus, we expect 0.1452 bats to be present in these areas of the LOD in West Virginia (i.e., 718.714 acres $\times$ 0.000202 bats/acres) and 0.0161 bats in Virginia (i.e., 220.3364 acres $\times$ 7.295 $x10^{-5}$ bats per acre). Multiplying the sum of these estimates by 0.25 provides an estimate 0.04 bats harmed, and multiplying the sum by 0.75 provides an estimate of 0.121 bats harassed. Because it is impossible to harass or harm a proportion of an individuals, each of these estimates is rounded up to 1. Thus, 1 migrant individual is expected to be harmed, and 1 individual is expected to be harassed from Project construction.

In addition to these construction impacts, operational effects are also possible around compressor stations. Three compressor stations are currently proposed for the Project. Using the same approach adopted for construction impacts, take, in the form of harassment from noise, is calculated using the acres of forest surrounding the compressor stations. These acres are then multiplies by the number of bats expected per acre within West Virginia. Based on this approach, it is expected that during the first year of operations at the compressor station facilities 0.3759 bats will be harassed, which is rounded up to one.

3.5 Summary of Take

Cumulatively, the estimates suggest that total take from the Project will be 181 Indiana bats. This includes both construction and operational take. The majority of this take will be to individuals participating in winter hibernation during construction (57), which have the potential to be disrupted due to construction noises (a form of harassment). Such disturbances (including dust, noise, and light) also account for the majority of take within other annual stages, including 29.1334 individuals during summer, 43.5272 individuals during spring staging, and 43.53 individuals during autumn swarming. Operational effects are also expected to 0.3759 summer individuals via noise disturbance from compressor stations. In addition to these disturbances, active tree felling is expected to harass and harm individuals during spring staging, summer reproduction, autumn swarming, and migration. Harassment from tree clearing during the spring, summer, autumn, and migrant periods is estimated at 0.0068, 0.065, 0.2176, and 0.121, respectively. Harm via the same mechanism during the spring, summer, autumn, and migrant periods is estimated at 0.0023, 0.022, 0.0725, and 0.04, respectively. Rounding up, cumulative estimates of harassment for winter, spring, summer, autumn, and migrant periods are 57, 44, 31, 44, and 1. Cumulative harm estimates are 1 individual per season except winter when no potential harm is thought to occur (i.e., spring, summer, autumn, and migrant seasons).

4.0 Northern Long-eared Bats

4.1 Areas for Potential Impacts and Impact Approach

Analysis of effects to northern long-eared bats as a result of Project construction and operation are restricted to areas of known or potentially occupied habitat where the species is presumed to be present. This area includes maternity roosts and trees within 150 feet of each roost as well as areas within 0.25 mile surrounding known or potentially occupied hibernacula (USFWS 2016). Clearing of forested habitat within the Project Area is anticipated to occur September through December in 2017 and from January through April in 2018. Given this schedule, analysis of effects to individuals only considers impacts to this species within the 0.25-mile buffers surrounding hibernacula where individuals may be impacted during hibernation, spring staging, autumn swarming, or migrant time periods. Within these areas, timber clearing, and construction noise pose the greatest threats to individuals. Methods and results of impacts to individuals can be found below, and impacts to habitat are within Section 5.2.2 of the BA.

4.2 Direct Effects to Individuals

4.2.1 Winter Season of Hibernation

Although harm from destruction of winter habitat is unlikely to result from Project actions, potential effects from changes in the soundscape near the Project are possible. The Action Area is defined as extending 0.6 miles (0.97 km) from the edge of the Project Area, based on the distance to which Project sounds during construction would be above an intensity rated as quiet for human hearing. There are 64 portal features with the potential to host northern long-eared bats within this distance: two feature that have been identified as previously occupied by the species, Tawney's Cave and Canoe Cave; one feature where a northern-long eared bat was captured for the Project, PS-WV3-Y-P1 in Braxton County, West Virginia; three features that have been deemed suitable but remain unsampled for bats; and 58 features that have not been assessed for suitability or occurrence of northern long-eared bats. For Tawney's Cave and the 3 suitable portals, a population estimate of 7.017 bats is used for impact assessment (see Section 3.2.1). Canoe Cave was not surveyed for this Project but was recently surveyed by the VDCR-DNH. No northern long-eared bats were observed by VDCR-DNH, but historic records indicate the observation of a single hibernating northern long-eared bat from 1982. To be conservative, this record was used as a population estimate for the cave. Given the results of harp trapping at PS-WV3-Y-P1, an estimate of 1.293 bats was used for impact assessment at this feature. This estimate was based off of the analysis performed in Section 3.2.1. For features with unknown suitable an estimate of 2.9238 bats is used (i.e., 7.017*[20/48]; see Section 3.2.1). Individuals, if present, within these portals have the potential to be harassed during hibernation. Thus, an expected number of harassed bats can be made by summing the number of individuals expected in each of the 64 features (i.e., 3 suitable features * 7.017 individuals + 1.293 individuals in PS-WV3-Y-P1 + 7.017 individuals from Tawney's Cave + 58 features with unknown suitable * [7.017*(20/48)]). Based on the abundance estimates above, 220 (rounded up from 199.9385) bats have potential to be harassed due to noise during tree clearing and construction.

There are no known or potentially occupied hibernacula within 0.6 mile of a proposed compressor station; therefore, no impacts to hibernating northern long-eared bats from noise during operations is expected.

4.2.2 Autumn Swarming and Spring Staging

After emerging from hibernation, northern long-eared bats are thought to participate in a process known as spring staging, where bats remain near the hibernacula for a short time (e.g., couple of days) before migrating to summer maternity areas. A similar process, of longer duration occurs in autumn with large numbers of bats roosting in nearby forested habitat. The Project Action Area includes two northern long-eared bat hibernacula and one feature where a single individual was caught during an autumn harp trap survey. However, few hibernating northern long-eared bats have been observed with the previously documented hibernacula during recent surveys. Along with these three features, there are an additional three field documented, suitable, potentially occupied features within the vicinity of the Project and 58 features with unknown suitability that may also be occupied. All of these features are treated as potentially occupied by the species within this document.

Project construction could directly harm or harass individuals during spring staging in two ways. First, removal of wooded habitat associated with Project construction within a 0.25-mile radius has the potential for both injury and mortality. Second, individuals may be forced to expend additional energy to locate replacement roosts due to construction sound or active clearing of a tree in which a bat is roosting.

Combined, approximately 72.63 acres of forested habitat within the protective buffers (0.25-mile radius) surrounding the known or potentially occupied portals will be cleared during Project construction, which could potentially harm or harass individuals participating in spring staging or autumn swarming.

To estimate impacts to individuals during spring staging, information on the activity levels of bats in different months during spring is derived from the literature. Whitaker and Rissler (1992) documented that northern bats emerge from hibernation early in the season. Large numbers of bats were observed exiting from Copperhead Cave in Indiana when the temperature approached 10 degrees Celsius, which typically occurred between the second week of March and April each year. During May and early June, few northern long-eared bats were active at Copperhead Cave. Six were captured in May, and three were captured on June 2. Given this information, it is expected that 50 percent of the population is likely to emerge and stage within March, and 50 percent of the population is likely to emerge and stage within April.

Since no information is available regarding the distribution and abundance of individuals around hibernacula during staging, it is assumed that northern long-eared bats demonstrate a similar pattern as the Indiana bat. Based on kernel home ranges derived in Gumbert et al. (2002), the proportion of the staging population is broken up into concentric circles with: 50 percent of the population within 0.67 kilometer (0.416 mi) of the hibernacula, 25 percent between 0.67 and 1.34 kilometer (0.416 and 0.833 mi, respectively), 20 percent between 1.34 and 2.37 kilometer (0.833 and 1.473 mi, respectively), and 5 percent between 2.37 and 7 kilometer (1.473 and 4.350 mi, respectively). Under the 4(d) ruling (USFWS 2016), non-exempt take of staging individuals is only possible within 0.25 mile (0.4 km).

Using both the temporal and spatial aspects of staging derived from Whitaker and Rissler (1992) and Gumbert et al. (2002), respectively, the number of staging bats within 0.25 mile surrounding a potential hibernacula is calculated as the product of 1) the number of individuals expected in the feature as derived in Section 3.2.1 and listed above, 2) the proportion expected to be participating in staging within the month based on Whitaker and Rissler (1992), 3) the proportion expected to be found within the distance of 0.67 kilometer (0.416 mi) (based on Gumbert et al. (2002), and 4) the proportion of the 0.67 bin that is within 0.25 mile (0.4 km) of the hibernacula (0.360602). This estimate is then used to calculate the potential harm and harassment from 1) tree felling and 2) construction disturbance.

Harm and harassment from tree felling is calculated using this estimate of the number of staging bats within 0.25 mi of potential and known hibernacula. Expected harm of staging bats within this buffer is calculated as the product of 1) the number of bats expected within the buffer, 2) the proportion of the bin within the LOD cleared during months with staging bats present, and 3) the expected harm rate (0.25). Note that this harm rate was developed for Indiana bats (Section 3.4.2), but is assumed to be applicable for northern long-eared bats as well. All bats present within the proportion of the bin within the LOD that are not expected to be harmed are assumed harassed (i.e., harassment rate=0.75). Using this approach, harm and harassment are possible near two features: Greenville Glenray Cave and PS-WV3-Y-P1. Cumulatively, it is expected that 0.004 individuals will be harmed and 0.012 individuals will be harassed from tree clearing.

Although the estimates of harm and harassment of staging bats from tree clearing are low, there is a much greater potential for disturbance from noise, sound, or dust from construction. Such harassment can be calculated for each feature as the product of 1) the proportion of staging bats within 0.25 mi as derived from Gumbert et al. (2002), 2) the proportion of the bin within the Action area (not including the LOD), and 3) the winter population size for the feature (see Section 3.2.1). Note that no temporal dynamics are incorporated within this estimate because it is assumed that all bats that participate within staging within 0.6 miles (0.97 km) of the Project (as defined by the Action Area) will be harassed. Using this approach, it is expected that within 0.25 mile (0.4 km) of all features, 11.4438 bats will be harassed. Rounding up, the cumulative expected number of staging northern long-eared bats harmed or harassed by the Project is 1 and 12, respectively.

In addition to these estimates for spring staging, harm and harassment during autumn swarming is also possible via the same mechanisms listed for staging individuals. Based on information provided in Whitaker and Rissler (1992), male individuals begin arrive at hibernacula in late July, and females come soon after. Using the Whitaker and Rissler (1992) study, the following assumptions are made regarding northern long-eared bat swarming: 6 percent of bats arrive at hibernacula before August 1, 54 percent of bats arrive in August, 25 percent of bats arrive in September, and the remaining 15 percent mostly arrive before November (13%), but individuals may be active until mid to late November (2%).

Similar to the approach taken for staging, it is assumed that swarming individuals are distributed among different distance bins derived from Gumbert et al. (2002) above. Thus, the number of swarming bats with 0.25 mile surrounding a potential hibernacula is calculated as the product of 1) number of individuals expected in the feature as derived in Section 3.2.1, 2) the proportion expected to be participating in swarming within the month based on the assumptions made above, and 3) the proportion expected to be found within the distance bin based on Gumbert et al. (2002). This estimate is then used to calculate the potential harm and harassment from 1) tree feeling and 2) construction disturbance. Using this approach, it is expected that 0.0144 and 0.0432 swarming bats will be harmed or harassed from tree clearing, respectively. In addition, 11.438 bats are expected to be harassed from construction disturbances (e.g., noise). Rounding up, the cumulative expected number of swarming northern long-eared bats harmed or harassed by the Project is 1 and 12 respectively.

4.2.3 Summer Season of Reproduction

Studies conducted in support of this BA provided evidence of occupation of the Project Area by the northern long-eared bat during the summer season of reproduction (Section 1.4.1.1). The final 4(d) rule published January 14, 2016 prohibits incidental take of northern long-eared bats through removal of known maternity roosts and any trees within 150 feet from June 1 through July 31, when non-volant young are present within the roosts. Woodland habitat will not be removed during June or July, and therefore a direct take via harm of individuals is exempt.

Potential effects of changes in the soundscape as a result of construction and operation of the Project are addressed in Section 3.1.3. The final 4(d) rule does not prohibit incidental take of northern long-eared bats via harassment as a result of changes in sound levels or air quality in their summer range.

4.2.4 Spring and Autumn Migration/Transient Period

Relatively little is known about the timing or use of habitat during the migratory/transient period. For northern long-eared bats, the spring migration period likely occurs from mid-March to mid-May, and the fall migration period from mid-August to mid-October (USFWS

2016). Given that the final 4(d) rule does not clearly define or prohibit take of migrating individuals on the summer landscape (e.g., no migrant roosts are known in the Project Area), any non-exempt impacts would be restricted to quarter mile buffers surrounding known hibernacula and potentially occupied portal features. Migrants occurring within this radius could potentially be harassed during tree clearing in March, April, May, and August.

Given that migrants are expected to occur for only a brief amount of time within the Project Area (e.g., 1 day), it is assumed that disruptions from construction via noise, light, or dust would not significantly increase the stress or energetic costs of the species during this short time period. Under these assumptions, harassment and harm are only possible within the LOD in forested areas where trees are actively being cleared. Because information regarding the flight paths and densities of migrants during the spring and autumn is lacking, a quantification of take from tree felling is not feasible. However, given that harm and harassment estimates from tree felling were less than one for both Indiana bat and northern long-eared bat for each respective life stage, it is likely that take of migrants from tree felling will be equally small. Thus, it is assumed that 1 migrant individual may be harmed and 1 individual may be harassed from Project construction.

4.3 Summary of Take

Cumulatively, our estimates suggest that total take from the Project will be 228 northern long-eared bats. This includes both construction and operational take. The majority of this take will be to individuals participating in hibernation during construction (199.94), which have the potential to be disrupted due to construction noises (a form of harassment). Construction noises, as well as dust and lights, also account for the majority of take within other annual stages, including 11.444 individuals during spring staging and 11.438 individuals during autumn swarming. No operational effects are expected to occur based on the 4(d) ruling. In addition to these disturbances, active tree felling is expected to harass and harm one individual or less in each of the following periods: spring staging, autumn swarming, and migrant. Rounding up, cumulative estimates of harassment for winter, spring, summer, autumn, and migrant periods are 200, 12, 0, 12, and 1. Cumulative harm estimates are 1 individual per season except winter and summer when no non-exempt harm is thought to occur (i.e., spring, autumn, and migrant seasons).

5.0 Hydrologic Analysis of Sedimentation

The introduction of excess sediment into waterways may result in significant changes to water quality and potentially impact aquatic biota, including federally listed species in the vicinity of the Project Area. MVP will implement specific conservation measures (i.e., erosion and sediment controls) (outlined in Section 2.6.1 of the BA) to minimize impacts to waterways; however, these measures are unlikely to prevent all excess sediment inputs. Although sedimentation of streams by erosion is a natural process, land development and disturbance may accelerate this process. Exposure of bare soils during land development increases the potential for detachment of soil particles, thus increasing the likelihood of deposition within adjacent and nearby waters.

To assess potential impacts of sedimentation within streams as a result of Project activities, a hydrologic analysis of sedimentation is performed. The spatial extent of this analysis is contained within the intersecting U.S. Geological Survey's (USGS) 4-digit subregional hydrologic unit codes (HUC) and includes the Roanoke-Chowan, Kanawha, Lower Chesapeake, Monongahela, and Upper Ohio subregions. Given this large extent, the analysis is further constrained to intersecting 8-digit, 10-digit, or 12-digit HUCs, and is dependent on the spatial area within the HUC crossed by the Project and the location of the Project relative to upstream areas (see Section 5.2 below).

The Revised Universal Soil Loss Equation (RULSE) is used for the hydrologic analysis of sedimentation (Renard et al. 1997). The RUSLE was chosen over similar models (e.g., Modified Universal Soil Loss Equation) due to published guidelines for its application on construction sites (Galetovic 1998). This equation provides generalized annual estimates of erosion rates and sediment loads based on climate, soil, topography, and land use/management factors and can be used to determine sediment loads and yields for stream catchments within the vicinity of Project construction. However, because sediment routing is not incorporated into the RUSLE, the fate and deposition of displaced sediment remains unknown and is largely assumed to continue downstream until the first hydrologic barrier (e.g., dam) is encountered.

The RULSE simply takes the product of several derived metrics in order to estimate expected soil loss under different land use, management, topographic, and climatic conditions. Sediment load (A) is estimated at a rate of tons year^{-1} using the following equation:

$$A = R \times K \times (L \times S) \times C \times P, \qquad \text{Eq. 2}$$

where R is the erositivity index, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is a cover-management or landuse factor, and P is a support practice factor. These factors, along with their respective derivations are discussed further below in Section 5.3.

5.1 Impact Approach

The following approach is taken to estimate soil loss rates expected from Project construction. The RUSLE, as described below, is used to estimate the sediment load (ton yr^{-1}) and sediment yield (ton/mi^2 yr^{-1}) for the catchments of all streams within the 1:24,000 National Hydrography Dataset (NHD) within the study area. These calculations are made using both current and expected land use classes. Current sediment loads and yields are considered baseline conditions, and provide a measure of the present sediment load and yield within each subwatershed in the vicinity of the Project. These baseline conditions are then used to assess increases of soil loss expected during construction.

In order to simulate construction impacts, all areas within the construction ROW are reclassified to bare-soil land uses (see Section 5.3.4 below) (Galetovic 1998), which have higher predicted soil loss rates than any other land class used in the analysis. The model is then reapplied and results are compared to baseline conditions to assess the potential impact of Project construction. This analysis exclusively focuses on sediment increases due to pipeline construction, but soil losses after the land has been revegetated are expected to be similar to those of a shrub/scrub or herbaceous landscape.

Unfortunately, a nationally-accepted sedimentation standard or exceedance threshold is not available. Attempts to establish such a standard have been stymied by five ecological realities (Kemp et al. 2011): 1) the amount of sediment inputs to streams exhibits substantial natural variation, 2) sedimentation regimes may differ in portions of the same stream based on highly localized factors such as riparian land cover, 3) sediments from different geological sources may have different physical properties and biological effects, 4) even closely related aquatic taxa may respond in markedly different ways to similar levels of sediment, and 5) different life stages of a single species may respond in markedly different ways to similar levels of sediment. Without a nation-wide standard, different regulatory entities use a wide variety of metrics, such as turbidity and total suspended solids, to assess potential changes associated with sedimentation. Threshold values may vary widely among state and tribal agencies (USEPA 2003), and metrics such as turbidity are sensitive to a variety of chemical and biological factors (such as algae and tannins) and may not clearly represent conditions related specifically to sediment inputs. Despite these inconsistencies, one commonly used impact threshold is one in which the metric of impact is increased by 10 percent or more (USEPA 2003). This approach recognizes the biological reality that even a relatively small (in absolute terms) amount of sediment may degrade a pristine stream, while a larger amount might be needed to further degrade a historically impacted stream. Given that the mechanisms of sediment impact are related to either deposition and/or suspension, total sediment load provides a reasonable impact metric as it encompasses both suspended and deposited sediments within a stream channel. Using this method, a significant impact is defined as anything that raises current total sediment load by more than 10 percent. It should be noted, however, that the magnitude of impact is also related to both the duration and frequency of the elevated sediment load. Longer and more frequent periods of sedimentation are likely to be more harmful to aquatic ecosystems.

5.2 Hydrologic Study Area

The study area for the hydrologic analysis of sedimentation is contained within: one 4-digit HUC subregion (Kanawha [0505]), five 8-digit HUC subbasins (West Fork [05020002], Little Kanawha [05030203], Elk [05050007], Upper Roanoke [03010101], and Banister [03010105]), and five 10-digit HUC watersheds (Headwaters Middle Island Creek [0503020104], Fishing Creek [0503020102], Johns Creek [0208020111], Upper Craig Creek [0208020110], and Lower Craig Creek [0208020112]) (Figure 1). These areas and their various sizes are chosen with the intent to encompass all possible sediment effects downstream of the Project Area. Note that if results demonstrate

Figure 1. Hydrologic study area for effects analysis of the Mountain Valley Pipeline Project in West Virginia and Virginia.

possible sediment impacts outside of these areas, the hydrologic study area is extended to include all downstream effects as well.

5.3 RUSLE Parameters

All RUSLE parameters are developed within a Geographic Information System (GIS) environment (i.e., ArcGIS 10.3; ESRI, Redlands, CA) and are projected into the Universal Transverse Mercator Zone 17 North coordinate system. Rasters are aligned to a 0,0 registration point (with all rasters using the same alignment).

5.3.1 R-Factor

Because the RUSLE does not directly model hydrology, runoff estimates are not available to simulate erosion; instead, a rainfall erosivity factor is calculated that characterizes the potential effect of runoff on soil erosion. To calculate R, average annual precipitation estimates (PRISM Climate Group 2012) from 1981 to 2010 are used within the following formula:

$$R = 0.059 \times 0.04830 \times P^{1.610}, \qquad \text{Eq. 3}$$

where P is precipitation expected within a raster cell (in millimeters) and R is the rainfall erosivity in hundreds of foot-ton-inch acre^{-1} hour^{-1} year^{-1} (Renard and Freimund 1994). In this equation, 1.610 and 0.04830 are estimated regression coefficients from Renard and Freimund (1994), and 0.059 is a conversion factor to U.S. customary units. Note that in this approach, annual estimates are used due to the complexity of integrating the RUSLE into the GIS environment (see below); however, rainfall changes seasonally, thus sedimentation impacts may depend on the season in which construction takes place.

5.3.2 K-Factor

The soil erodibility factor accounts for variability in the inherit erodibility of soils and is a function of integrated influences, including infiltration, rainfall, composition, and overland runoff. Fortunately, this metric is currently available within the Natural Resources Conservation Service's SSURGO (Soil Survey Staff 2015a) and STATSGO2 (Soil Survey Staff 2015b) soil databases. Note that although the K-factor is available in these datasets, it needs to be aggregated among soil components and horizons. To accomplish this, the kwfact parameter (K Factor, Whole Soil) from the dominant condition among components is used, and no aggregation is made among horizons but rather the surface layer is used instead.

In most areas within the hydrologic study area, the more detailed SSURGO dataset is used. However, aggregation and rasterization of this detailed dataset is time intensive. Therefore, in some areas the kwfact is calculated with STATSGO2 K-factors, which have lower resolution but sufficient correspondence with SSURGO factors (Breiby 2006). Because of the large geographical extent, STATSGO2 data is exclusively used within the Kanawha subregion, with the exception of the Elk River subbasin. In the case of the Elk River subbasin, the Project is sufficiently close to populations of endangered mussels to warrant the more detailed SSURGO dataset.

5.3.3 L and S Factors

The L and S factors individually represent slope length and steepness, respectively, but combine to form what is known as a topographic factor. This topographic factor is a function of the landscape terrain. Following Moore and Wilson (1992), LS for each raster cell i is calculated as:

$$LS_i = \left(\frac{A_{s_i}}{22.13}\right)^m \times \left(\frac{\sin\beta_i}{0.0896}\right) \times (m+1), \qquad \text{Eq. 4}$$

Commented [GA1]: This equation might be missing an exponent n.

where A_{s_i} is the specific catchment area or the upslope contributing area per unit width of contour, β is the slope angle in radians, and m and n are constants. Both A_{s_i} and β_i are calculated using the standard Spatial Analyst functions within ArcGIS; however, to ensure alignment with the NHD, elevation data is adjusted to calculate A_{s_i}. In this process, elevation data (derived from the 1/3 arc-second seamless digital elevation model available from the USGS 3D Elevation Program) is adjusted by burning in the NHD, and a flow direction and flow accumulation process is performed on this adjusted elevation data. The specific catchment area is then calculated as the product of the flow accumulation estimate and the cell resolution (i.e., 10 meters) and results in the units of m^2 m^{-1}. As suggested in Galetovic (1998), the slope length component of this equation is truncated at 400 ft (121.9 m). Values of m and n can vary among different terrains, but typically range from 0.4 to 0.6 and 1.0 to 1.4, respectively. For this analysis, m and n are set at 0.4 and 1.0, respectively. These values are chosen because of the high forest cover and complex topography (Oliveria et al. 2013).

Similar to the approach taken for K factors, two separate resolutions of elevation data are used for the analysis. In all portions of the study area except for the Kanawha the higher resolution (10-meter [32.8 ft] resolution) elevation data is used to derive the topographic factor, but due to the large geographical extent of the Kanawha subregion, 30-meter (98.4 ft) resolution data is used.

5.3.4 C-Factor

The cover and management factor (C) accounts for the effects of vegetation, management, and erosion control practices on soil erosion. This factor is derived by reclassifying: the 2011 NLCD (Homer et al. 2015); land use classifications made during detailed habitat assessments and wetland and stream surveys; and known preexisting road types derived during civil surveys. Reclassifications are conducted using the values from Table 3, which are taken from several literature sources, including Dissmeyer and Foster (1980), Galetovic (1998), Mitasova et al. (2001), MTDEQ (2006), Gaffer et al. (2008), Litschert et al. (2014).

Table 3. Conservation management factors applied for different land uses within the study area.

Vegetative Cover Type[1]	Management Factor (C)
National Land Cover Classes	
Deciduous Forest	0.003
Evergreen Forest	0.003
Mixed Forest	0.003
Woody Wetlands	0.006
Developed Open Space	0.003
Developed, Low Intensity	0.001
Developed, Medium Intensity	0.001
Developed. High Intensity	0.001
Shrub/Scrub	0.010
Emergent Herbaceous Wetlands	0.003
Cultivated Crops	0.240
Pasture/Hay	0.010
Grassland/Herbaceous	0.010
Open Water	0.000
Barren Land	0.001
Preexisting Roads	
Paved Roads	0.001
Unpaved Roads	0.250
Pipeline Construction	
Access Road	0.450
Additional Temporary Work Space	0.450
Ancillary Site	0.450
Pipeline ROW	1.000

Note that soil loss from pipeline construction and practices are estimated by applying a C factor of 1 to all areas of the pipeline ROW and a factor of 0.45 for all other temporary work-spaces (e.g., access roads, ancillary sites, laydown yards). This approach recognizes that all areas of temporary disturbance from the Project will likely have increased erosion and sedimentation over baseline conditions, but erosion rates within the pipeline ROW are likely higher than other temporary work-spaces due to filling activities (Galetovic 1998).

5.3.5 P-Factor

The support practice factor is incorporated into RULSE to account for conservation practices and erosion and sediment control measures. According to a review conducted by the United States Environmental Protection Agency (USEPA 1993), soil containment on construction sites may average as high as 85 percent under proper application of soil and erosion control best management practices (BMPs); however, estimates of containment rates, especially those made for silt fences, vary widely among numerous studies and are dependent on the study design. Most laboratory studies conducted using flumes show high rates of containment. For example, Farias et al. (2006) demonstrated sediment reduction between 93 and 96 percent, and Risse et al. (2008) evaluated containment at varying slopes, up to 58 percent, and found that containment remained upwards of 80 percent across all trials. Bench scale testing studies have also suggested high efficiencies, ranging from 72 to 89 percent containment (Faucette et al. 2008). Because of the uncontrollable nature of real storms and rain events on the landscape, containment studies involving field testing are difficult and have had mixed results. An alternative approach is field scale testing. A recent study conducted by Dubinsky (2014) found that overall average projected performance efficiency ranged from 48 to 97 percent with a mean and median of 79 and 86 percent, respectively. Furthermore, Dubinsky (2014) evaluated containment at a variety of slopes and rainfall events. Based on these findings, a 79-percent containment rate is applied during the sedimentation analysis for this Project.

5.4 Estimating Sediment Delivery

The RUSLE provides an estimate of the expected soil loss per unit of interest for the entire study area; however, not all sediment is expected to continue into downstream areas. The proportion that does continue downstream is expected to vary with catchment size, with the headwaters producing relatively more sediment than lower, flatter portions of the watershed. Based on this concept, sediment delivery ratios are used to predict the proportion of sediment expected to reach the outlet of each catchment. More specifically, the sediment delivery ratio is modeled using Boyce (1975)'s upland theory as:

$$SDR_w = 0.417762 \times A_w^{-0.134958} - 0.127097, \qquad \text{Eq. 5}$$

where A_w is the area of the catchment (i.e., watershed draining to a stream segment) in square-miles and SDR_w is the estimated sediment delivery ratio (NRCS 1983). Thus, to calculate the expected sediment load for any given stream segment (L_w), the following equation based on Fernandez et al. (2003) is used:

$$L_w = \sum_{i=1}^{n} SDR_w \times A_i * a, \qquad \text{Eq. 6}$$

where i indexes the n raster cells within the catchment, A_i is the expected sediment loss for cell i based on Eq. 2, and a is a conversion factor of square meters to acres that depends on the resolution of the data.

Calculating sediment loads in this manner assumes that sediments are continually transported downstream; however, most sediments will likely stop at the nearest dam. Although the ultimate fate of anthropogenic sediments are estuarine and/or marine environments (e.g., Gulf of Mexico), instream impoundments (e.g., mill, low-head, reservoir, etc.) can arrest the majority of these sediments (Maneux et al. 2001). To account for this phenomena, two types of upstream catchments are delineated: (1) total catchment area and (2) catchment area below impoundment. The first type of catchment area is used to estimate the sediment delivery ratio (i.e., SDR_w) in Eq. 5, but only cells that are members of the catchment area below impoundment can contribute to the sediment load calculation in Eq. 6. Both total catchment area and catchment area below impoundment are calculated using ArcHydro, which utilizes both raster information (e.g., flow direction grid) and vector networks (i.e., NHD) to delineate catchments and adjoining catchments. To account for impoundments within the stream network, the NHD waterbodies layer is used; however, only features with the FType of ‘Lake’, ‘Pond’ or ‘Reservoir’ are used as potential impoundments. Although this layer represents an underestimate of the number of impoundments present within a given stream network (compared to the National Inventory of Dams ([NID]); the NHD waterbodies are georeferenced to the NHD and provide common identifiers to join the two feature layers together.

Using the sediment load calculated in Eq. 6, a sediment yield is calculated by dividing the load by the catchment area.

5.5 Results

Analysis using the RUSLE identified the boundaries associated with a 10 percent increase in sediment load. Detailed maps of streams with a 10 percent increase in sediment load can be found in Appendix B of the BA. Project-wide, greater than 1,445 stream kilometers (898 mi) are expected to have a 10 percent increase or greater at a limited temporal scale. Although the majority of these stream reaches are closely associated with the boundaries of the Project Area, there are several exceptions (see Maps 8 and 9 in Appendix B of the BA), and the farthest extent observed was approximately 11 kilometers (6.84 mi) downstream of the Project in Sand Fork, a tributary to the Little Kanawha River in West Virginia.

6.0 Roanoke Logperch

Roanoke logperch are known to occur in several disparate populations in widely separated segments within the Chowan and Roanoke river basins. All of the populations are geographically small and no genetic exchange occurs among them because they are separated by large impoundments and wide river gaps of apparently unsuitable habitat (USFWS 2003). The Project traverses four major drainages in the Roanoke basin including the upper Roanoke River, Blackwater River, Pigg River, and Banister River. Roanoke logperch are not known or recognized to occur in the Banister River subbasin (HUC 03010105); therefore, the species is determined to be absent from waterbodies in this subbasin for this impact analysis. In contrast, Roanoke logperch have not been observed in the Blackwater River drainage; however, this drainage is nested within the currently-known range extent of the species and therefore has the potential to host the species. Thus, waterbodies within the Blackwater River drainage that exhibit potentially suitable habitats are included in the impact analysis within this document.

6.1 Population Estimates and Occurrence

Population sizes have been previously estimated for Roanoke logperch in both the upper Roanoke and Pigg river drainages (Roberts 2012); however, these estimates were limited to reaches within the documented extent of the species (i.e., known occurrences), and thus may not incorporate all areas where the species may occur. Recognizing that the species may occur in other smaller, less sampled waterbodies, Lahey and Angermeier (2007) developed a screening model to determine the potential for Roanoke logperch occurrence in these waterbodies. The Lahey and Angermeier (2007) model consists of four metrics that are thought to determine logperch occurrence within the Roanoke drainage: Strahler order (range=2-6), Shreve link (range=3-372), gradient (range=0-10.2 m km^{-1}), and elevation (181-488 m). Note that both Strahler order and Shreve link are based on the 1:100,000 NHD within the Lahey and Angermeier (2007) model. For the purposes of the BA, all areas that meet these conditions are considered potentially occupied by the species, unless site specific field assessments suggest otherwise.

The effects analysis for Roanoke logperch is broken up into impacts to adults and subadults (hereafter adult or Age-1+) and young-of-the-year (hereafter YOY or Age-0). Although these different life stages may occupy different micro and mesohabitats, it is assumed that all stream reaches suitable for Age-1+ individuals are also suitable for YOY individuals. Site specific abundance estimates for both life stages are made below.

6.1.1 Occurrence and Abundance of Age-1+ Roanoke Logperch

To get an estimate of abundance within occupied or presumed occupied reaches within the upper Roanoke, Pigg, and Blackwater river drainages, a site-occupancy modeling approach is taken; namely, N-mixture modeling (Royle 2004). The standard N-mixture model utilizes replicated captures of a species at multiple sites in order to decompose per individual detection probability (p) and site abundance (N). Using this approach, abundance can be regressed against covariates to test hypotheses regarding variation in abundance using the Poisson distribution:

$$N_i \sim \text{Poisson}(\ln(\beta_0 + \beta_1 \times x_i)), \quad \text{Eq. 7}$$

where β_0 and β_1 are regression coefficients and x_i is a variable hypothesized to be correlated with abundance (e.g., catchment area). Note that in this model N is not a known variable but is estimated in conjunction with a process component (i.e., per-individual detection). In most N-mixture models, detection and abundance are estimated simultaneously using replicated counts at a site. In the absence of such replication, prior information regarding Roanoke logperch capture rates is used to fix per-individual detection at 10 percent (i.e., p=0.1) (Roberts and Anderson 2013). Using this estimate, rather than estimating detection directly in the model, allows for the application of the model without replicated counts at a site.

The advantage of this model-based approach to estimate site abundances is that heterogeneity in abundance among populations and within populations can be modeled. Additionally, this approach can also be used to model abundance in watersheds and waterbodies where no captures of Roanoke logperch have been made but are assumed to be present (e.g., Blackwater River). This later advantage is accomplished by truncating the Poisson distribution to remove zero values. That is, abundance must always be greater than 0.

6.1.1.1 Data Description and Analysis

The approach described above is adapted to Roanoke logperch populations in the upper Roanoke subbasin. Within the upper Roanoke several fish collections are publically available from various reports, dissertations, theses, scientific papers, and databases, including: James (1979), Burkhead (1983), Simonson and Neves (1986), Ferguson et al. (1994), Stancil (2000), Lahey and Angermeier (2007), Roberts and Anderson (2013), VADEQ (2015), and Anderson and Angermeier (2015). In total, these collections provide 159 unique stream segments (i.e., reaches of stream between confluences of other streams) that have at least one sample event for fish. However, using the Lahey and Angermeier (2007) screening model, only 118 are within the possible distribution of the species.

Theses samples are used in conjunction with prior information on estimates of capture rates from Roberts and Anderson (2013) to estimate abundance in areas of assumed occupancy while accounting for heterogeneity among and within populations. More specifically, a few simplistic relationships using catchment area as a covariate of abundance are modeled. In addition to this covariate, a random effect is added to the model to account for differences in baseline abundance among the different watersheds (i.e., U.S. Geological Survey Hydrologic Unit Code 10) within the study area. In total, six different models are fit:

- A ***null model*** with no covariates or random effects for different watersheds. This model assumes that abundance is constant across all watersheds and all habitats within those watersheds (Figure 2a).
- A ***linear relationship*** with catchment area with no random effects for different watersheds. This model assumes that abundance increases with catchment area, and this relationship is the same for all watersheds within the study area (Figure 2b).
- A ***polynomial relationship*** with catchment area with no random effects for different watersheds. This model assumes that abundance increases with catchment area but decreases after some point (i.e., quadratic relationship), and this relationship is the same for all watersheds within the study area (Figure 2c).
- A ***random effect model*** with no covariates. This model recognizes that there might be variation in abundance among watersheds but abundance is constant within watersheds (Figure 2d).
- A ***linear relationship*** with catchment area with ***random effects*** for different watersheds. This model recognizes that there might be variation in abundance among and within watersheds and variation within watersheds is correlated with catchment area (Figure 2e).

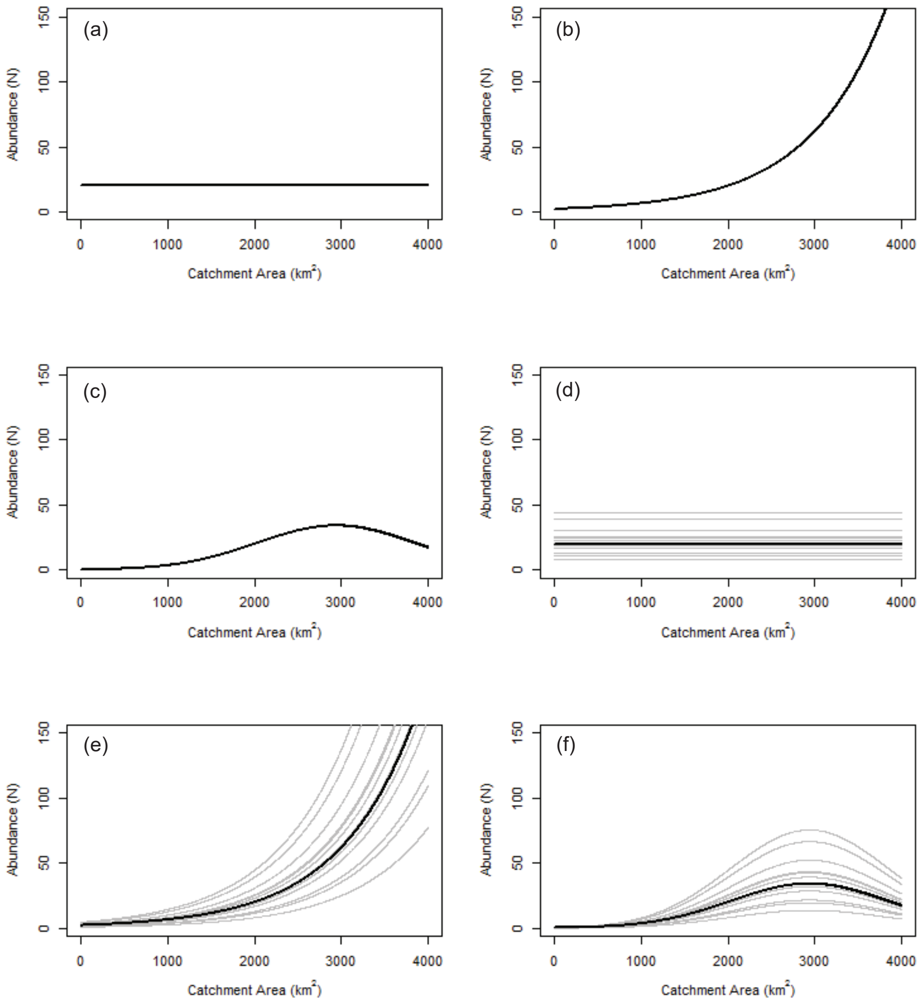

Figure 2. Six plausible models of Roanoke logperch abundance within the upper Roanoke River drainage. (a) A ***null*** model with no covariates or random effects for different watersheds; (b) a ***linear relationship*** with catchment area with no random effects for different watersheds; (c) a ***polynomial relationship*** with catchment area with no random effects for different watersheds; (d) a ***random effect model*** for different watersheds with no covariates; (e) a ***linear relationship*** with catchment area with ***random effects*** for different watersheds; and (f) a ***polynomial relationship*** with catchment area with ***random effects*** for different watersheds. Mean effects are shown as black lines, and watershed level effects are shown in gray. All relationships were simulated to demonstrate each model type.

- A ***polynomial relationship*** with catchment area with ***random effects*** for different watersheds. This model recognizes that there might be variation in abundance among and within watersheds and abundance increases with catchment area but decreases after some point (i.e., quadratic relationship; Figure 2f).

All models are fit using a Markov chain Monte Carlo approach to estimate parameters. This approach is chosen based on the presence of the random effects and prior information within the likelihood. The weight of evidence for each of these models is judged using the Watanabe-Akaike Information Criterion (WAIC) (Watanabe 2010). WAIC is a Bayesian analog to the Akaike Information Criterion (Akaike 1974) and is a penalized criterion of model performance that is based on model fit and the effective number of parameters in the model. Using this criterion, models that perform better are weighted higher but are penalized for their complexity. The model with the lowest WAIC is then used to predict the abundance of Roanoke logperch in suitable habitats within stream segments.

Note that the output of this model based approach is abundance within a suitable patch; thus, estimates are adjusted to derive fish densities (e.g., fish km^{-1}) by multiplying estimated abundance times the patch density estimates derived in Roberts (2012). Because no patch density was reported for the Blackwater drainage, the patch density estimate reported for the Pigg was used. This density is the highest of those reported in Roberts (2012).

6.1.1.2 Results and Application to Study Area

Out of the six different models for Roanoke logperch (Figure 2), the model containing a linear relationship with catchment area that included random effects for different watersheds showed the greatest support. Based on parameter estimates for this model, density estimates among the 12 crossings with suitable habitat (and thus assumed presence) vary from 4.29 to 423.05 Age-1+ Roanoke logperch per kilometer (0.621 mi). Note that Age-1+ density estimates are also made for all waterbodies potentially impacted by the Project where Roanoke logperch occur or are presumed to occur.

6.1.2 Occurrence and Abundance of YOY Roanoke Logperch

To get an estimate of the number of YOY logperch within occupied and potentially occupied reaches, information on population growth rates of the species is compiled from the literature. Traditional approaches for estimating YOY abundance require vital life history attributes of species (e.g., egg fecundity, hatching success, natural mortality, etc.) that are unknown for Roanoke logperch, and therefore, estimates cannot be made using these approaches. Alternatively, using population growth rates to estimate YOY abundance provides a potentially biased estimate of abundance, but capitalizes on the best currently available information. For Roanoke logperch, the growth rate is a 'realized' growth rate because it is derived using live individuals collected during sampling. The realized population growth rate includes naturally selective factors and includes individuals that might be recruited from other populations. One major constraint of this approach to estimate YOY population size is the inability to account for these additional temporal dynamics of the Age-1+ Roanoke logperch population. To estimate the number of YOY for any given year, information from the aforementioned Age-1+ estimate and an estimated maximum population growth rate (λ) estimate of 1.7205 from Roberts et al. (2016) is used. In this approach the density of YOY is calculated as:

$$D_{YOY} = D_{Adult} \times (\lambda - 1), \qquad \text{Eq. 8}$$

where D_{YOY} is the estimated YOY density and D_{Adult} is the estimated Age1+ population density. Based on the data presented, the density estimates among the 12 crossings with suitable habitat (and thus assumed presence) vary from 3.09 to 304.81 YOY Roanoke logperch per kilometer (0.621 mi). Note that YOY density estimates are also made for all waterbodies potentially impacted by the Project where Roanoke logperch occur or are presumed to occur.

6.2 Areas for Potential Impacts and Impact Approach

Analyses of effects to Roanoke logperch as a result of Project construction and operation are restricted to areas of known, occupied habitat where the species is presumed to be present as well as areas of potentially suitable habitat. Known, occupied habitats include the North Fork Roanoke, Roanoke, and Pigg rivers. Potentially suitable habitats (and assumed occupation) occur in North Fork Blackwater River, Blackwater River, Little Creek, and portions of Bradshaw, Bottom, Teels, Maggodee, Jonnikin, Jacks, Parrot, and Harpen creeks as well as an unnamed tributary to the Blackwater River.

Project activities with potential to affect Roanoke logperch include (but are not limited to) instream, benthic disturbances (e.g., use or operation of machinery and equipment within a stream, trenching, blasting, etc.), upland land disturbances (e.g., erosion, sedimentation), water-uses (e.g., hydrostatic testing, hydroseeding, dust control), ROW clearing (e.g., riparian removal), noise, and artificial lighting. Effects to individuals by life stage are addressed in the sections below. Effects are broken up into three spatial scales: 1) effects within the LOD, 2) effects downstream of the LOD, and 3) effects from sedimentation within upstream catchments.

6.3 Direct Effects to Individuals

6.3.1 Effects within the LOD

The greatest potential for harm and harassment of individuals within the LOD is due to instream construction (LOD: 75 ft [0.02286 km] width at stream crossings). Individuals are susceptible to harm from being crushed by heavy equipment operations and construction in the stream. To minimize harm to individuals, all fishes, including Roanoke logperch (where present), are proposed to be removed from instream disturbance areas (including [but not limited to] coffer dam, dewatered areas, and/or pipeline construction footprint) immediately prior to instream construction activities. Depletion fish surveys will be performed via electrofishing techniques, seining, and installation of block nets at the upstream and downstream limits of construction. All collected fishes will be translocated to their stream of origin but a sufficient distance downstream of the construction area.

To calculate harm and harassment due to the fish removal, abundances of Roanoke logperch within the 22.86-meter (75-ft) LOD are estimated at crossings of known-occupied habitats (i.e., North Fork Roanoke, Roanoke, and Pigg rivers) as well as potentially-occupied habitats that are proposed to be crossed by the Project (i.e., Bradshaw Creek1, Bradshaw Creek AR, North Fork Blackwater River, Blackwater River3, Maggodee Creek1, Teels Creek4, Little Creek1.5, Little Creek2, and Harpen Creek1). Note pertinent information regarding four Project crossings:

- An existing access road ford crossing (i.e., North Fork Roanoke River1 AR) is located approximately 110 meters (361 ft) upstream of the MVP crossing of the North Fork Roanoke River and included in the Project LOD. The access road stream crossing is rerouted to traverse the North Fork Roanoke River at the pipeline crossing thereby eliminating unnecessary instream impacts. Any potential impacts to Roanoke logperch are accounted for at the pipeline crossing of the North Fork Roanoke River.
- The Project LOD includes using Reese Mountain Road as an access road during construction efforts. Reese Mountain Road traverses North Fork Roanoke River (Access Road2) via an existing bridge that spans the River. No instream construction activities are proposed and consequently no site-specific impacts to Roanoke logperch are anticipated.
- Two existing access road crossings are proposed for use at Bradshaw Creek and occur within 28 meters (92 ft) of the stream reach. One is a ford crossing and the other includes a multi-box, concrete culvert. Both stream crossings may be used during construction activities therefore the site-specific instream LOD is 28 meters (92 ft).
- Based on in-situ habitat delineations conducted for mussel surveys for the Project, the proposed crossing of the Roanoke River is completely contained with a suitable patch for adult and subadult Roanoke logperch.

Because the proposed crossing of the Roanoke River is completely contained within a suitable patch for adult and subadult Roanoke logperch, the expected abundance rate (N) derived in Section 6.1 is used rather than the expected density estimate. According to the N-mixture model, 181.57 individuals are expected in the suitable patch which is 1,311 square-meters (0.32 ac) large. The LOD for the crossing is estimated at 343 square-meters (0.09 ac). Thus, an estimate of the expected number of adult individuals within the LOD is made by multiplying the expected abundance (N) by the proportion of area of the patch that is covered by LOD (i.e., 81.57 × [343/1,311]). Using this approach, 47.5 adult or subadult individuals are expected within the LOD. However, given that riffle and run habitat is likely less suitable for YOY, a density estimate was used in conjunction with Eq. 9 to calculate the expected number of YOY within the LOD.

At all other crossings, estimates of the number of Age1+ and YOY Roanoke logperch within the LOD are made using the following equation:

$$N_{Age_{LOD}} = D_{Age} \times SL, \quad \text{Eq. 9}$$

where D_{Age} is the age-specific estimated density based on the approach taken in Section 6.1 (Table 4) and SL is the length of stream (in kilometers) impacted. In the case of the LOD, SL is 0.02286. For example, the number of adults (Age1+) expected to be within the LOD of the North Fork Roanoke River pipeline crossing is calculated as follows: 60.19 fish per kilometer × 0.02286 kilometers =1.376 Age-1+ individuals. The estimate from Eq. 9 represents the number of individuals for the age class that have the potential to be harmed or harassed within the LOD.

Individuals may be harassed by the physical act of collections, handling, temporary holding, translocating to alternative habitat(s), and subsequent isolation from previously occupied habitat. Individuals may be harmed by sustaining injury (e.g., internal hemorrhaging) or direct mortality as a result of electrofishing during depletion surveys. Note that these surveys are required to prevent the potential for greater harm if individuals remained within the LOD during construction. Harm rates of electrofishing for Roanoke logperch are unknown; however, Cooke et al. (1998) documented an 8 percent harm rate (e.g., direct mortality or internal hemorrhaging) in benthic stream fishes as a result of standard electrofishing techniques. Thus, it is assumed that 8 percent of individuals occupying the LOD, regardless of age, are harmed (Cooke et al. 1998) ($HARM_{Age_{LOD}}$), and the remaining number of individuals are harassed ($HARASS_{Age_{LOD}}$). These are calculated as followed:

$$HARM_{Age_{LOD}} = N_{Age_{LOD}} \times 0.08\,, \qquad \text{Eq. 10}$$

and

$$HARASS_{Age_{LOD}} = N_{Age_{LOD}} - HARM_{Age_{LOD}}\,. \qquad \text{Eq. 11}$$

Results from these calculations are available in Table 4.

Table 4. Estimated densities, expected number of individuals, and respective harassment and harm estimates at stream crossings for adult and young-of-the-year (YOY) Roanoke logperch.

Stream Name	County*	Adult Density (fish km^{-1})	YOY Density (fish km^{-1})	Expected Adults in LOD†	Expected YOY in LOD†	Adult Harassment†	Adult Harm†	YOY Harassment†	YOY Harm†
North Fork Roanoke River	Montgomery	60.19	43.37	1.38	0.99	1	1	0	1
Bradshaw Creek AR‡	Montgomery	53.17	38.31	1.49	1.07	1	1	1	1
Bradshaw Creek1	Montgomery	55.89	40.27	1.28	0.92	1	1	0	1
Roanoke River	Montgomery	423.05	304.81	47.51	6.97	44	4	6	1
North Fork Blackwater River	Franklin	19.45	14.01	0.44	0.32	0	1	0	1
Teels Creek4	Franklin	19.62	14.14	0.45	0.32	0	1	0	1
Little Creek1.5	Franklin	23.90	17.22	0.55	0.39	0	1	0	1
Little Creek2	Franklin	24.64	17.75	0.56	0.41	0	1	0	1
Maggodee Creek1	Franklin	31.65	22.80	0.72	0.52	0	1	0	1
Blackwater River3	Franklin	149.30	107.57	3.41	2.46	3	1	2	1
Pigg River	Pittsylvania	256.47	184.79	5.86	4.22	5	1	4	1
Harpen Creek1	Pittsylvania	4.29	3.09	0.10	0.07	0	1	0	1
					Total	55	15	13	12

* All counties listed are within Virginia.

† Expected number of adults and YOY within the Limits of Disturbance (LOD) were calculated using Eq. 2. Harassment and harm estimates were rounded up to the next integer.

‡ The LOD of Bradshaw Creek AR is 92 feet and all other crossings are 75 feet.

6.3.2 Effects Downstream of the LOD

To account for sedimentation and hydrologic alteration at each stream crossing as a result of direct instream construction, it is assumed that an 800-meter (0.5 mi) downstream buffer will receive elevated levels of sedimentation that could result in harassment of individuals. This spatial extent is derived from formal consultation with the USFWS in Virginia.

The 800-meter (0.5 mi) buffer is applied relative to the LOD downstream boarder. To calculate the number of individuals present within DS buffers, the same approach used to calculate effects within the LOD (Section 6.3.1) is used. Density estimates specific to the respective stream segment and age class are used to calculate the number of individuals present within each DS buffer based on the 1:24,000 NHD. Note that an 800-meter downstream buffer is added to all stream crossings regardless of the suitability for Roanoke logperch occupancy. If a buffer of a crossing with unsuitable habitat extended downstream into suitable habitat, harassment estimates are made for the portion of the buffer that was deemed suitable. When information is lacking from infield assessments of habitat suitability, the screening model developed by Lahey and Angermeier (2007) is used to remotely assess the potential for Roanoke logperch occurrence. Results from these calculations are provided in Table 5.

Table 5. Estimated harassment for adult and young-of-the-year (YOY) Roanoke logperch from impacts immediately downstream of pipeline and access road crossings.

Stream Name	Counties*	Stream Length (km)	Expected Adult Harassment	Expected YOY Harassment
North Fork Roanoke River	Montgomery	1.19	71.83	51.76
Bradshaw Creek	Montgomery	1.99	109.01	78.54
Roanoke River	Montgomery and Roanoke	1.02	440.17	317.14
North Fork Blackwater River	Franklin	0.80	15.84	11.41
Teels Creek	Franklin	0.39	7.56	5.45
Little Creek	Franklin	1.42	34.05	24.53
Blackwater River	Franklin	2.39	237.93	171.43
Maggodee Creek	Franklin	1.07	33.99	24.49
Jonnikin Creek	Pittsylvania	0.35	1.42	1.03
Pigg River	Pittsylvania	0.80	205.86	148.32
Harpen Creek	Pittsylvania	1.32	5.64	4.06
	Total:	**12.74**	**1,164**†	**839**†

* All counties listed are within Virginia.

† Cumulative harassment estimates were rounded up to the next integer.

6.3.3 Effects of Sedimentation from Catchments

Using the results of the RUSLE sedimentation model (Section 5.0), increased sediment loading rates (i.e., 10 % or greater over baseline) are expected to occur within numerous streams within the Roanoke River drainage. In total, it is expected that 73.88 stream kilometers (45.01 mi) with the potential to support Roanoke logperch will be temporarily impacted from increased sedimentation from upland Project construction. The majority (79%) of these impacts are within the Blackwater River system, including tributaries, where 58.14 stream kilometers (36.13 mi) are expected to be impacted. The sediment impact area within the Pigg and the upper Roanoke drainages are not expected to be as extensive with 8.32 and 7.42 stream kilometers (5.17 and 4.61 mi) predicted to be impacted, respectively. Within waterbodies with documented occurrences of Roanoke logperch (North Fork Roanoke River and Bottom Creek), sediment impacts are likely to extend for 3.42 stream kilometers (2.13 mi). All other impact reaches are areas where suitable habitat exists and therefore have the potential to host the species. Harassment of Roanoke logperch in these areas was calculated by multiplying the reach specific density estimates from Section 6.1 times the length of the stream length impacted by sediment. These calculations are made for each stream segment and then summed to get a total harassment estimate for each age class. Results from this calculation are in Table 6.

Table 6. Estimated harassment for adult and young-of-the-year (YOY) Roanoke logperch from impacts from increased sediment loads from upland construction.

Stream Name	Counties*	Stream Length (km)	Expected Adult Harassment	Expected YOY Harassment
North Fork Roanoke River	Montgomery	2.01	134.94	97.22
Flatwoods Branch	Montgomery	1.83	88.10	63.47
Bradshaw Creek	Montgomery	2.17	122.68	88.39
Bottom Creek	Montgomery	1.41	136.19	98.13
North Fork Blackwater River	Franklin	12.72	292.75	210.92
Little Creek	Franklin	12.54	269.29	194.02
Blackwater River	Franklin	32.88	3,421.84	2,465.43
Jacks Creek	Franklin	0.16	19.03	13.71
Parrot Branch	Franklin	1.74	201.84	145.43
Jonnikin Creek	Pittsylvania	3.65	15.01	10.82
Harpen Creek	Pittsylvania	2.77	11.97	8.62
	Total:	**73.88**	**4,714**†	**3,397**†

* All counties listed are within Virginia.
† Cumulative harassment estimates were rounded up to the next integer.

6.4 Summary of Take

Collectively throughout the Roanoke River basin, it is estimated that Project activities could potentially harass 10,182 individuals and harm 27 individual of all age classes (YOY and Age-1+ individuals). Harm estimates are calculated at 12 crossings (Table 4), with expected harm rates for YOY and Age 1+ Roanoke logperch of 1 individual for each age class at each crossing with the exception of the Roanoke River where 4 adult individuals are expected to be harmed. In addition to this harm, 68 individuals are expected to be harassed within the LOD. Impacts immediately downstream of the LOD are also likely to occur. Within an 800-m (0.5 mi) buffer of each stream crossing, cumulative harassment and harm is estimated at 2,003 individuals (including both YOY and Age-1+ individuals). Upstream disturbance is expected to result in the largest impact from the Project, with 8,111 individuals expected to be harassed.

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