KENTUCKY
HEARTWOOD

ADVOCATING FOR KENTUCKY'S WILD PLACES

Tim Reed, District Ranger
Stearns Ranger District
Daniel Boone National Forest
3320 Highway 27 North
Whitley City, Kentucky 42655

RE: Jellico Vegetation Management Project Draft Environmental Assessment

May 24, 2024

Dear District Ranger Reed and Mr. Hull,

The following are comments from Kentucky Heartwood in response to the Draft Jellico Vegetation Management Project Environmental Assessment. Kentucky Heartwood has made a good faith effort to provide information throughout the development of this project. The comments here respond to the analysis and currently available data. We may have further comments and input if more information becomes publicly available, such as through FOIA responses, additions to the EA, or other mechanisms. There is a great deal of information that is not included in the currently available documents, and this stymies our ability to provide as much substantive analysis as we would like. There are also issues raised in our scoping comments which we have not repeated here, or have otherwise abbreviated, as repetition should be unnecessary.

A. Slope stability and landslide risks

Kentucky Heartwood raised concerns regarding landslides and slope stability in our scoping comments. "Slope instability and landslides are an ongoing concern in the Jellicos. The combination of steep slopes, highly erodible soils, and the hydrologic properties of coal seams predispose the landscape to mass wasting events. Road construction (including skid roads) and timber harvest can substantially increase the likelihood of a mass wasting event to occur."[1] The Draft EA and associated Soils report purport to address this issue but fall far short of what is necessary to make reasonably informed, site-specific decisions that will protect soil and water resources during the Jellico project implement. Landslides and other forms of mass wasting could significantly impact soil and water resources in the project area, including federally-listed aquatic species and designated critical habitat.

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[1] See Kentucky Heartwood scoping comments, p19

It is crucial to point out that extreme precipitation events are increasing in frequency and severity, and that trend is anticipated to increase in eastern Kentucky and the Appalachian region. Flooding, including flash-flooding, landslides, and siltation, are major concerns for area residents and should be a priority for the U.S. Forest Service.

The recent report, "Flood Resilience in Appalachia: Policy Recommendations" (2024) states[2]:

> The American Communities Project has stated that "Appalachia is ground zero for rainfall," the risk of increasingly extreme rainfall is particularly high for Kentucky, West Virginia, and Ohio. New precipitation frequency modeling by researchers at First Street Foundation found that extreme events (e.g. 1-in-100 year flood events) are likely to occur much more frequently than every 100 years, especially for the Ohio River Basin.
> But rather than a futuristic scenario, these extreme rainfall and flooding events are already affecting our region. Over the last decade (2013 - 2023), there have been nearly 20 federally declared flooding disasters across Kentucky, Pennsylvania, Virginia, West Virginia, Tennessee and Ohio. The majority have occurred in Kentucky and West Virginia, often also affecting parts of Virginia. Total Federal Emergency Management Agency (FEMA) spending on these events totals nearly $1 billion and at least 230 lives have been lost due to flash flooding.

National Forest land in the Jellico project represents a critical headwaters area that directly affects many families and landowners in the immediate vicinity - and many more downstream. The extent to which the Forest Service has, and continues, to downplay or ignore the relationship between logging and landslides, as well as overall flood risks, has gone well beyond any disagreements about science, methods, or even risk assessment.

To expand on our previously voiced concerns, and respond to the Draft EA specifically, we are incorporating into this comment letter two documents authored by geological and geohazards consultant Dr. Bill Haneberg. Dr. Haneberg was state geologist and Director of the Kentucky Geological Survey from 2016 through 2023 and is a nationally recognized expert in landslide-related issues with specific expertise in landslide hazards in eastern Kentucky.

The first document, "**Recommended Best Management Practices to Minimize the Likelihood of Sediment Delivery to Streams by Logging Induced Landslides in Eastern Kentucky**," is included as **Appendix A**. This document was prepared for the Appalachian Citizen's Law Center, Kentucky Heartwood, and the National Wildlife Federation as part of an effort to inform federal flood policy in Appalachia in an era of climate change.[3] Dr. Haneberg's report describes the various factors affecting landslides and landslide susceptibility in eastern Kentucky, focusing on how logging and logging-related practices can significantly destabilize slopes for years, decades, or longer. Many of the issues raised by Dr. Hanberg reflect information that Kentucky Heartwood previously provided to the Forest Service during the Jellico project analysis and, more extensively, through our various comments, letters, and litigation over the South Red Bird project. The report also includes recommended Best Management Practices (BMPs) aimed at

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[2] See the report "Flood Resilience in Appalachia: Policy Recommendations" (2024)

[3] *Id.*

reducing the risk of landslides, including specific analytical methods relevant to land management planning. The Forest Service needs to incorporate the science and methodology and adopt the recommended BMPs into the Jellico analysis and any final approved action.

The second document prepared by Dr. Haneberg is **"Review of the Daniel Boone National Forest "Jellico Vegetation Management Plan Project Soil Effects Analysis" Document."** This review was prepared under contract for Kentucky Heartwood. Included below is the "Summary Comments" portion of Dr. Haneberg's review. The entire review and Dr. Haneberg's comments are incorporated in full as **Appendix B.**

> **SUMMARY COMMENTS**
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> The Forest Service assessment of potential slope stability problems associated with proposed logging in the Jellico project plan area, as described in the soil effects analysis report, relied primarily on identification of plastic soils using data from a nationwide Web Soil Survey. The report states that Forest Service staff also used lidar, slope, and geology to identify areas of slope stability within project unit boundaries and subsequently verified them in the field. However, the report includes no details about the lidar, slope, and geology-based identification process or project-wide landslide occurrence or susceptibility maps beyond those showing plastic soil occurrence included. In those regards**,** the report falls short of expectations for a robust regional or watershed-scale landslide hazard assessment prepared in support of land management decisions.
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> Table 3 in the soil effects report lists several known landslides as "watch outs" but the report contains neither synoptic nor detailed maps documenting the locations of past and/or currently active landslides or defining the potential susceptibility of logged areas to future landslides (either natural or as a consequence of logging). Locations of the landslides listed in Table 3 are given only at the stand level. There appear to be no properly georeferenced landslide polygons or even landslide centroids that can be used to locate the landslides; if those data exist exist, excluding them from the report was a significant omission. The lack of sufficiently detailed and properly georeferenced maps depicting landslide occurrence and susceptibility on a project-wide scale is a major deficiency of the report.
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> Interpretation of freely available high-resolution lidar digital elevation models and derivative maps covering two areas in which landslides had been reported to the Forest Service as public comments showed the areas to have complex geomorphology, significant indications of past slope instability, and thus a potential for future slope instability (especially if subjected to roadbuilding, logging, or other disturbances). The soil effects report states that one of the locations was visited but no evidence of a landslide was found and that a landslide at the second location, which may or may not have been visited, was not confirmed. It is not clear from the report language whether "not confirmed" means that the site was visted and no evidence could be seen or that confirmation was not attempted. The compelling evidence for slope instability at those two locations, illustrated further on in this review, casts doubt on the ability of the Forest

Service to understand the prevalence of unstable and potentially unstable slopes in one of the most landslide-prone regions in the country.

Although information about soil plasticity can be a useful component of landslide susceptibility studies, the use of soil map units and highly generalized physical properties from a nationwide database is insufficient in the context of the soil effects report and falls far short of the methods routinely used for such work in Kentucky and elsewhere. The Kentucky Geological Survey, for example, has developed a peer-reviewed approach based upon lidar-based landslide inventory mapping by trained geologists, statistical analysis of the regionally significant geologic and geomorphological variables associated with landslide occurrence, and use of modern geospatial processing methods like logistic regression to extend those rigorously developed association across large areas. It is important to know where landslides have occurred; however, it can be equally or even more important to understand where they may occur in the future, especially in the context of land-use planning and environmental impact assessment. As such, the use of modern GIS-based computational tools to predict landslide susceptibility is essential.

Throughout the report, suggestions that plastic soils are uniquely susceptible to rapid pore-water pressure increases—and thus instability—ignore the basic mechanical principles of landslide initiation, dangerously implying that other kinds of soils are not susceptible and need not be considered. That is untrue. A discussion in the report about the increased unit weight of wet plastic soils as a driver of slope instability is similarly naïve and, likewise, dangerously misleading because it appears to suggest the primary potential cause of landslides in the project area will be heavy equipment traffic across wet and heavy plastic soil. The focus on plastic soils and equipment traffic ignores the substantial body of peer-reviewed scientific literature showing a strong relationship between tree removal per se and subsequent landslides due to decadal-scale post-logging tree root cohesive strength decreases and pore-water pressure increases. Nowhere in the soil effects report is the impact of tree removal per se on slope instability considered. Likewise, the report limits the potential impacts of slope instability to plastic soil deformation, reduced water capacity, and issues related to aeration, mineralization, and vegetation growth. The potentially significant water quality and ecological impacts of landslides and debris flows—which in many cases mobilize from landslides—as agents of sediment delivery to streams and water quality degradation is ignored. The report's focus on soil plasticity and equipment traffic while ignoring the potential effects of tree removal on forest slope stability, sediment delivery, and water quality is a major deficiency.

Finally, the report consistently uses a non-standard definition of full-bench roads. Full-bench roads, in which all excavated material is hauled away from a cut, are typically the recommended option when roads must be built across steep and/or potentially unstable ground. Full-bench roads stand in contrast to side-cast or balanced section roads in which some of the excavated material is placed downslope to develop the road prism, thereby loading the slope below the road and decreasing stability. Admonitions to avoid full-bench roads (if understood as conventionally defined) imply that options like side-cast roads are safer options, when they will in fact almost certainly reduce slope stability.

B. Cerulean warbler/ Forest Plan consistency

Forestwide Objective 1.1.B in the Forest Plan directs the Forest Service to “Create and maintain at least one approximately 7,400-acre area of cerulean warbler habitat in the Licking River Management Area, Upper Kentucky River Management Area, and the Jellico Mountains of the Cumberland River Management Area.

> **Objective 1.1.B.** Protect or enhance habitat for species identified by Partners in Flight (PIF) as well as others that need special attention. Management activities should:
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> a) Provide artificial cavities and nest boxes for species that may be limited by cavity availability.
> b) Create and maintain at least one approximately 7,400-acre area of cerulean warbler habitat[3] in the Licking River Management Area, Upper Kentucky River Management Area, and the Jellico Mountains of the Cumberland River Management Area. Each 7,400-acre area can be composed of tracts at least 618 acres in size connected by corridors of either upland hardwood forest or riparian areas. Upland hardwood forest corridors should be no more than two miles long, and at least ¼-mile wide (see Figure 2 - 1 for example of possible pattern).

Footnote (3) for Objective 1.1.B states:

> Predominantly mature (age≥70), open (60 BA and up) contiguous upland hardwood or riparian forest (canopy with moderate to dense shrub/midstory layers, large grapevines are required in the mix; Buehler and Nicholson 1997), with some trees >20 in.; can be upland or bottomland/riparian. Contiguous is defined as having no more than 5 percent of the area in grassy openings, regenerating forest with less than 40 BA canopy, or roads greater than 50 ft. in width; tracts may be composed of blocks of minimum 618 acres in size connected by upland hardwood corridors approximately 0.25 mile wide or riparian corridors at least 100 ft. wide, neither of which is more than 2 miles long.

Figure 2-1 in the Forest Plan provides an illustration of how cerulean warbler habitat may be spatially arranged.

The Forest Plan envisions only three such areas across the entirety of the Daniel Boone National Forest for meeting this objective, and meeting this objective in the Jellico Mountains is directly specified. The Jellico project Draft EA makes no mention of Forestwide Objecive 1.1.B., nor does it describe how the Proposed Action or Alternative 1 will help or hinder meeting this Objective. The Forest Service cannot simply brush aside this forestwide direction without substantial analysis and robust reasoning as to why it can be ignored. Such an analysis is required under NEPA, and it must establish that the project will not interfere with the accomplishment of the objective for cerulean warbler.[4]

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[4] *See* 36 C.F.R. § 219.15(d).

The Biological Evaluation includes a brief discussion of Cerulean warbler (*Dendroica caerulea*) as Management Indicator Species (MIS). Cerulean warbler is used as an indicator species for "Closed Canopy, Mature Forest Species."[5] The Report argues that the approximately 5,200 acres of regeneration harvests in the Proposed Action – which remove suitable habitat for the cerulean warbler – will result in nearly three times as much suitable habitat as Alternative 1, which would approve regeneration harvests on 1,122 acres. This does not make sense and is misleading. Table 11 states for "Proposed Action-Current" that "4,301 ac of potentially suitable habitat is widespread in the Proposed Action Area," and anticipates "3,425 ac of potentially suitable habitat widespread in the proposed Action Area" following implementation of the Proposed Action. But Table 12, presenting information for Alternative 1, states that "1,311 ac of potentially suitable habitat is widespread in Alternative 1 Action Area," and "1,173 ac of widespread potentially suitable habitat is anticipated" following implementation.

First, it is unclear how the current acres of suitable habitat could be *both* 4,301 acres *and* 1,311 acres. And while the differing temporal frames for the Proposed Action and Alternative 1 make projections complicated, it does not make sense to argue that regeneration harvests on ~5,200 acres would result in more closed canopy, mature forest habitats than regeneration harvests on 1,122 acres. The presentation implies that significantly more regeneration cuts will result in nearly three-times the acres of suitable habitat for the Cerulean warbler. While we recognize that the timeframe for the Proposed Action is 40 years and the analysis for Alternative 1 is for 10 years[6], this creates an apples-to-oranges comparison. Alternative 1 does not anticipate future logging following implementation. To evaluate and compare the environmental effects between these two alternatives, the Forest Service needs to look at the effects on the same timeframe.

Footnote 6 to Table 11 also states that "Cerulean Warbler, however, is known to utilize two-aged shelterwood cuts and other treatments of similar structure." This only partially true. For example, Boves et al. (2013) [7] report increases in habitat use by territorial males following "Intermediate treatments" that reduced basal area and canopy cover by approximately 40% (BA = 14 m^2/ha or 60 ft^2/ac). In some studies and practices this may be considered a "shelterwood" harvest, but in the context of the Jellico project is on the high end of retention following a thinning and leaves around 4 times more trees than the Jellico shelterwood prescription. In that study "Heavy treatments" were defined as reducing basal area and canopy closure by approximately 75% to a residual basal area of 6 m^2/ha (26 ft^2/ac), which is still more retention than the shelterwood harvests proposed for the Jellico project. Cerulean warbler habitat use for heavy treatments in this study was much less than for intermediate treatments. Generally, the authors found that Cerulean warblers benefited from intermediate levels of disturbance which (though not noted by the authors) is consistent with disturbance regimes most beneficial to oak reproduction.

A report by Wood et al (2013) for the American Bird Conservancy[8] provides similar insights. The report states that "Heterogenous stand structure including large trees, canopy gaps, and

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[5] Biological Evaluation and Specialist's Report, Table 10 (p 63)

[6] Biological Evaluation and Specialist's Report, footnote 3 to Table 11

[7] Boves TJ, Buehler DA, Sheehan J, Wood PB, Rodewald AD, et al. (2013) Emulating Natural Disturbances for Declining Late-Successional Species: A Case Study of the Consequences for Cerulean Warblers (Setophaga cerulea). PLoS ONE 8(1): e52107. doi:10.1371/journal.pone.0052107

[8] Wood, P.B et al. 2013. Management guidelines for enhancing Cerulean Warbler breeding habitat in Appalachian hardwood forests. American Bird Conservancy. The Plains, Virginia. 28 pp.

understory vegetation promote density and reproductive success of ceruleans." The authors further state that:

> Before extensive clearcutting in the late 19th and early 20th century, tree mortality from old age, windthrow, ice storm damage, and fire contributed to the development of structurally complex and relatively open stands in which oaks were dominant. In the even-aged stands that developed following those extensive harvests, natural canopy disturbances tended to be unevenly distributed and relatively small thereby creating a relatively homogenous canopy structure (e.g., a closed canopy forest with an undeveloped understory and/or midstory).

And that:

> Ceruleans favor the complex canopy structure characteristic of unevenaged stands and old growth forest. Canopy gaps allow mid- and uppercanopy trees the growing space to form long horizontal branches and develop dense foliage. Tree species composition is relatively diverse with shade-intolerant species abundant in the overstory.

The authors add that Cerulean warblers "preferentially use canopy gaps ~400-1000 ft^2 in size" and highlight the importance of grapevines, stating that "Cerulean nest success was positively associated with density of grapevines (*Vitis spp.*) in Ohio."

Forests in the Jellico mountains have a notable amount of very large grapevine. The Proposed Action proposes to use herbicides to control grapevine on "up to a total project acreage of 9,537 acres."

The Report goes on to describe the The Cooperative Cerulean Warbler Forest Management Project (CWFMP) which implemented a series of studies in Tennessee, Ohio, Kentucky, and West Virginia. The study implemented harvests and controls that appear to be the same as in Boves et. al (2013). In the CWFMP study, harvests resulted in stands with a residual basal area of 93 ft^2/acre (light harvest), 62 ft^2/acre (intermediate harvest), and 27 ft^2/acre (heavy harvest), along with controls. The investigators found that "The largest and most consistent increases occurred when RBA was between ~40 and 90 ft^2/ac." Nest success has highest in unharvested controls, and next highest in the medium harvest treatment. For management considerations, the report states that "The results from the CWFMP indicate that retaining RBA levels of ~40-90 ft2/acre after harvesting trees in 25-acre harvest units in oak-dominated stands creates a forest structure that is generally favorable for ceruleans."

Contemporary research demonstrates that Cerulean warblers benefit from intermediate disturbance in mature forests with large trees. While they can, and do, use forests subject to "heavy" logging treatments, these habitats are less than optimal. Furthermore, the shelterwood prescriptions proposed in the Jellico project exceed the amount of harvest applied in the "heavy" treatments in the available literature. It is worth noting that "APPENDIX A. Cerulean Warbler Technical Group Forest Management Research Project Treatment Implementation Guidelines, May 3, 2005" in Hartman (2006)[9] states:

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[9] Hartman, Patricia J., "HABITAT SELECTION OF THE CERULEAN WARBLER IN EASTERN KENTUCKY" (2006). University of Kentucky Master's Theses. Paper 285.

> Intermediate Treatment: Between July 15, 2006 and April 1, 2007 this stand should be harvested by removing enough of the overstory to leave **approximately 55 sqft BA/acre** (12.6 m^2/ha). The removal should be conducted such that the residual stand is comprised almost entirely of well-spaced dominants and co-dominants. All other commercial stems (i.e., > 6" DBH) should be felled. The marking objective should be designed **to roughly mimic a shelterwood harvest as commonly practiced in the region in question**. (Emphasis added).

The recurring use of "shelterwood" by the Daniel Boone National Forest to describe harvests that remove substantially more timber than is typical under this terminology continues to create confusion and allows for the misapplication of research regarding the effects of "shelterwood" harvests on species and habitats. The U.S. Forest Service needs to start using terminology in a manner that is consistent with regional science and practice.

C. Timber targets

The Draft EA fails to disclose the relationship between the Jellico project and the mandated timber targets assigned to the DBNF and the Stearns District. These timber targets have included a more than 400% increase in the volume harvested on the DBNF over the past 20+ years. FOIA documents show that the DBNF is prioritizing these harvest volume mandates over other forest needs, including recreation, forest health, water quality, and other issues. According to FOIA response documents, meeting these targets is directly tied to performance reviews for DBNF staff.

For example, a May 25, 2023 email from Brian Emerson to District Rangers states[10]:

> We are significantly behind on our target execution. I know everyone is diligently working, but I think it is time for us to discuss
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> We have received a significant amount of support from the RO this year and it is critical for us to produce in order to continue to receive support.

A document titled "Daniel Boone NF Timber Sale Schedule Expectations" including volumes and acreages expected by the Stearns Ranger District for the years 2017 through 2026 states[11]:

> **PERFORMANCE** – This schedule is used as a performance element for line officers, IDT members, and others

This document assigns a goal of 6,300 CCF to be sold from the Stearns District annually, and an "Approximate acres to plan using 2-aged shelterwood at 15 ccf/ac" on 400 acres annually.

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[10] See: FOIA request 2024-FS-R8-00752-F response document "PDF-2", page 170 of the PDF

[11] See: FOIA request 2024-FS-R8-00752-F response document "Release in Full 2024-FS-R8-00752-F", page 77 of the PDF document. Multiple versions of "Daniel Boone NF Timber Sale Schedule Expectations" are found in in the document. Note also that this PDF one of several relating to this FOIA and is not the release in full as the file name indicates.

Another document titled "DBNF SALES PROGRAM" prescribes an annual harvest volume for the Stearns District of 7,500 CCF through at least fiscal year 2028.[12]

FOIA documents, including notes from so-called "Timber Target Meetings," show that Forest Service staff intend to use the Jellico project to meet at least some of these required targets. At the very least, the Forest Service has started the project with a predetermined volume of timber that will be produced. *See* FSM 2432.15 (requiring, at Gate 1, certification of estimated volume for the project). That information has not been provided to the public, nor has the agency explained how its hidden purpose is influencing its range of alternatives.

In effect, the Forest Service has already locked itself into an alternative that will provide timber volume to meet mandated timber targets. That directly contravenes the requirement to prepare a NEPA study "early enough so that it can serve as an important practical contribution to the decision-making process and *will not be used to rationalize or justify decisions already made*." 40 C.F.R. § 1502.5 (emphasis added); *see also Metcalf v. Daley*, 214 F.3d 1135, 1145 (9th Cir. 2000) (agency violated NEPA by agreeing to a support a gray whale harvest quota before studying the impacts of that decision in an EA).

Predetermining that the Jellico project would be used to satisfy timber targets on which staff performance is measured likely infected numerous aspects of the Forest Service's EA. To start, it may have influenced the range of reasonable alternatives the agency was willing to consider. Though Kentucky Heartwood suggested numerous project alternatives during scoping, the Forest Service rejected nearly all of them because they "would not meet the purpose and need of this specific project." Draft EA at 11. In addition, "[i]t is highly likely" that since the Forest Service (1) has already decided to use the Jellico project to meet its mandated timber targets, and (2) Forest Service staff have a vested interest in seeing those targets achieved, that "the [draft] EA was slanted in favor of finding that the [Forest Service's] proposal would not significantly affect the environment."[13]

By neglecting to disclose the effects of mandatory timber targets on project design, the Forest Service also failed to consider and disclose an important aspect of the problem. If the agency's discretion to design and choose a project alternative is being influenced by the need to meet timber targets, then it must disclose that information to the public. *See N.C. Wildlife Fed'n v. N.C. Dep't of Transp.*, 677 F.3d 596, 604–05 (4th Cir. 2012) ("When relevant information "is not available during the [NEPA] process and is not available to the public for comment[,] ... the [NEPA] process cannot serve its larger informational role, and the public is deprived of [its] opportunity to play a role in the decision-making process.").

The Forest Service's failure to disclose the impact of timber targets on project design violates NEPA and the APA.

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[12] See: FOIA request 2024-FS-R8-00752-F response document "PDF-2", page 82 and 106 of the PDF (and other pages)

[13] *Metcalf*, 214 F.3d at 1144.

There is also a direct relationship between the Forest Service's goal of meeting timber targets and the *prescriptions* included in the project. As we've expressed to the DBNF on many occasions, the use of "shelterwood" to describe cuts with a residual basal area of 10 to 15, or even 10 to 20 ft^2/acre deviates substantially from the normal use of the term in regional forestry. The Forest Service cannot have it both ways: it can implement shelterwood harvests with retention consistent with the literature, in which case it might be better justified in assuming benefits for oak regeneration or cerulean warbler habitat, or it can acknowledge that it is using heavier harvest methods to extract more volume per acre in service of a timber target. The tradeoffs of using these prescriptions (volume versus other benefits) must be disclosed under NEPA.

D. Tree of Heaven

Kentucky Heartwood described in detail issues with tree of heaven (*Ailanthus altissima*) in the Jellico project area. Tree of heaven is a highly invasive, ecologically destructive non-native invasive plant species (NNIP), and its occurrence in the Jellico project area is extensive. As we previously described, in addition to its occurrence along roadsides, we have seen numerous stands that were regenerated in the 1980s or 1990s where tree of heaven represents a significant component of the forest canopy. In some locations it is a dominant species. This is a pattern widespread across all portions of the project area. The Forest Service's failure to engage in responsible stewardship of these stands during the decades since the timber was sold has allowed tree of heaven to develop to reproductive maturity in forest canopies and produce vast amounts of seed to further infest the forest.

The Vegetation Report, under Direct and Indirect Effects for Alternative 2 – No Action states:

> Without treatment, invasive species abundance would be expected to increase thereby impacting species composition in affected stands. Specifically, during field reconnaissance tree of heaven was noted to be thriving in canopy gaps created by single tree and small group mortality.

This is highly selective and misleading by omission. Tree of heaven will establish in forest understories and take advantage of canopy disturbance. But the greatest abundance of tree of heaven in the project area is in stands that the Forest Service cut and then abandoned. It is these mismanaged stands – distributed across the project area – that have allowed for an extraordinary seed source to invade and establish in mature forests. Instead, the Vegetation Report portrays tree of heaven as primarily a problem of mature forests that were not harvested in recent decades.

The Biological Evaluation and Specialist's Report provides a better discussion of tree of heaven specifically, as well as other problematic NNIPs:

> (T)hinning and regeneration activities are likely to increase the population sizes of tree-of-heaven, princesstree and Amur honesuckle if existing individuals are not treated during or prior to activities. These three species have a high potential to interfere with tree regeneration.

Since scoping, concerns about the spotted lanternfly (*Lycorma delicatula*) have become more pressing after it became documented in Kentucky in October 2023. It is understood that tree of heaven is its primary host species. Spotted lanternfly will preferentially feed on tree of heaven, and may induce declines in the species. But tree of heaven also attracts spotted lanternfly to forested areas where it also impacts native species. Reproductive success of spotted lanternfly facilitated by the abundance of tree of heaven is likely to cause a population explosion that will increase pressure on native tree species throughout the project area. Controlling tree of heaven at a landscape scale, and rapidly, is arguably the most pressing forest health issue affecting the Jellico project area.

The Draft EA and BE describe how NNIPs, including tree of heaven, will be treated as part of other management actions, especially commercial timber harvest. The BE states:

> Nonnative invasive plants in the general project area would likely respond to the disturbance with increase of current population sizes and increased establishment of new populations. At the same time, for some species such as tree-of-heaven, princesstree, Amur honeysuckle, multiflora rose, and Japanese honeysuckle, increased extent of management activities would make treatment easier by improving detection of and increasing access to interior populations.

However, the BE also states that Alternative 1, with a reduction in harvest acres, would result in fewer acres of tree of heaven and other NNIPs being treated:

> As a more limited area will be affected by management activities, infestations are likely to be missed allowing them to continue producing propagules.

For Alternative 2- No Action, the BE states that the lack of timber harvest may result in reduced spread of tree of heaven (and princess tree) but also allow for “These species (to) continue to produce and disperse seed throughout the general area increasing population size and difficulty to control.”

The Forest Service needs to commit to a concerted effort across the Jellico project area to treat and control tree of heaven. This includes all areas, regardless of planned timber harvest or other management. The EA and associated documents describe a situation where the only way that the Forest Service will commit to addressing this exceptional forest health issue is if it is paired with commercial timber management, with fewer commercial sales meaning less control of tree of heaven, and no commercial sales meaning that the Forest Service won’t address it.

E. Old-growth assessments and specific old-growth sites

The need to manage for current and future old-growth, including specific old-growth and potential old-growth (POG) sites was an issue of importance raised by Kentucky Heartwood in our scoping comments. Those concerns are further elevated by the Biden administration’s executive order aimed at conserving and promoting mature and old-growth forests (MOG) and the Forest Service's proposed national forest plan amendment.[14]

Yet the Jellico Project prescribes regeneration harvest in areas that Kentucky Heartwood and the Forest Service know to meet POG and MOG conditions with little to no analysis or discussion of why and how these stand-level decisions were made. The sparse analysis of stand-specific information in the Draft EA is in direct contravention to both NEPA and the Forest Service's most updated technical guidance on old-growth management.

Without stand-specific analysis describing how and why the agency made the prescription selections in this project, the Draft EA is defective with respect to *both* of NEPA's aims. The Forest Service neither had the opportunity to "consider the environmental impacts of their actions" nor to keep the public informed about environmental concerns related to government decision making.[15] This must be rectified before the project can continue.

Moreover, the absence of stand-specific analysis in this Draft EA also disregards the Forest Service's most current technical guidance for silvicultural prescriptions in old-growth forests, which requires that "even-aged methods (seed tree cutting and clearcutting) should be considered as the last resort" for old-growth areas, and "should be used when they are the only option left to move the stand toward desired conditions and/or improve ecological integrity."[16] The Forest Service must explain why such prescriptions were necessary for the old-growth stands described below.

The Draft EA states that "The original project proposal included approximately 177 acres of existing old growth being considered for regeneration… To align with the intent of the NOI, these four stands were removed from consideration."[17] The Vegetation report expands on this, stating:

> Possible Old Growth (POG) criteria are presented in Table 3-25 of the Environmental Impact Statement for the Forest Plan (USDA 2004b). Data were analyzed to determine if any of the areas proposed for treatment met the criteria for POG. Approximately 316 acres proposed for treatment met the minimum age criteria for POG. Those stands where inventoried for old growth features and approximately 177 acres were determined to be Existing Old Growth (EOG) according to Guidance for Conserving and Restoring Old-Growth Forest Communities on National Forests in the Southern Region (Gaines, et al. 1997).

A careful review of the included maps allows the public to see which stands were removed from the Proposed Action. However, the Draft EA does not disclose which stands were analyzed, what determination was made, and why. Several other sites that appear to meet POG and EOG criteria

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[14] *See* Executive Order 14072, 87 Fed. Reg. 24851 (2022); Land Management Plan Direction for Old-Growth Forest Conditions Across the National Forest System, 88 Fed. Reg. 88042 (2023).

[15] 40 C.F.R. § 1500.1(a) (2020); see also 40 C.F.R. § 1500.1 (a), (b) (1978).

[16] USDA Forest Service, Technical Guidance for Standardized Silvicultural Prescriptions for Managing of Old-Growth Forests (Mar. 2024) at 5.

[17] Draft EA at 8

were left in the proposed harvest plans, including sites that Kentucky Heartwood provided specific data for during scoping. No rationale or data have been provided for why these other stands have remained in regeneration prescriptions in the Proposed Action.

Again, this paucity of analysis is incompatible with NEPA. The Forest Service must include a discussion of how and why harvest prescriptions were assigned to various stands which meet old-growth criteria in the Jellico Project, both for the agency's own inspection and for informed public comment. Where analysis of a project's impacts lacks this level of specificity, the NEPA documents are inadequate. *See, e.g., Klamath-Siskiyou Wildlands Ctr. V. U.S. Forest Serv.*, No. 2:05-CV-0299, 2006 WL 1991414, at *9–10 (E.D. Cal. July 14, 2006) (invalidating the use of an EA without site-specific analysis for project locations). And to conform with the Forest Service's own technical guidance, the Forest Service must explain why no other harvest method was appropriate for the old-growth stands described herein.[18]

Kentucky Heartwood cited stands 6267-04 and 6267-02 as meeting the minimum age threshold and having significant old-growth characteristics. Both sites have a "year of origin" of 1878 in the FSVeg database, making them 148 years in 2024. These stands would be categorized as "Dry-mesic oak forest" under the Forest Plan and Region 8 old-growth guidance, which has a minimum age threshold of 130 years for consideration as POG. Tree coring of those sites by Dr. Justin Maxwell of Indiana University, under a permit issued by the DBNF, confirmed that these sites included a significant amount of very old trees. While many of the trees were hollow, the sampled trees clearly show that the oldest age class exceeds the POG age requirements.

Species	Number	Inner Ring Year (visible)	Hollow	DBH (cm)	Core Length (cm)	Minimum Age
LITU	1B	1892	Hollow	76	44.5	129
LITU	2B	1875	Hollow	110	39	146
LITU	3A	1800		82.5	29	221
NYSY	1A	1770	Hollow	64	28	251
QUAL	1A	1848		85	38	173
QUAL	1B	1956	Hollow	101	13	65
QUAL	2A	1906		75.5	33	115

Tree ages of old trees in stands 6267-04 and 6267-02

These stands do not appear to have any major anthropogenic effects that detract substantially from their old-growth condition. Regardless, the Forest Service has kept these stands in the Proposed Action under a deferment harvest prescription. These stands should be considered as old-growth subject to the technical guidance on developing old growth prescriptions. The Forest Service needs to explain in detail how these sites were evaluated for their old-growth condition and why they were excluded from designation as old-growth.

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[18] *See* USDA Forest Service, Technical Guidance for Standardized Silvicultural Prescriptions for Managing of Old-Growth Forests (March 2024).

Another stand of concern is 6747-07 on Ryans Creek Mountain. The FSVeg database provides a "year of origin" of 1886 making this stand 138 years old in 2024. The stand should be considered as Dry-mesic oak for the purpose of old-growth evaluation. Even if the stand were categorized as mixed mesophytic (with a minimum POG age of 140 years) it is likely that sufficient tree coring would demonstrate that the oldest age class exceeds 140 years. The stand has experienced some significant natural canopy disturbance, yet exhibits significant old-growth characteristics. The Forest Service has kept this stand in the Proposed Action and Alternative 1, prescribed for shelterwood harvest. This stand should be excluded from harvest and designated as old-growth. The Forest Service should make available any information or analysis considering this stand, including its reasoning for rejecting it from old-growth designation.

Kentucky Heartwood endeavored to survey other sites with ages in the FSVeg database indicating POG, or otherwise exhibiting structural characteristics strongly indicative of old-growth condition. We worked with Rob Messick[19], a long-time and well-respected old-growth expert to examine several more sites in the Jellico project area. Stands exhibiting old-growth characteristics and needing further investigation or exclusion from harvest include: 6249-01, 6249-03, 6251-18, 6251-23, 6251-24, 6251-25, and 6251-30. Summaries and descriptions of each of these sites are included in these comments as **Appendix C**.

Under NEPA, the Forest Service needs to provide clarity and data describing which stands received were analyzed as POG, what the specific findings were, and whether or not these stands were reviewed by the USFS Washington Office as required under the December 18, 2023 memo to Regional Foresters entitled "Review of Proposed Projects with Management of Old Growth Forest Conditions." If they were not, then they cannot move forward with them because WO review is mandatory. If they were, then the Forest Service must disclose the reasons for keeping them in the project despite their old-growth characteristics. Further, the Forest Service must explain why it could not pursue a reasonable alternative that would not involve the harvest of old-growth. Old-growth harvest is a significant impact requiring an EIS and consideration of alternatives.[20] At the very least, the Forest Service's current efforts show that whether to harvest old-growth is an "unresolved conflict" that requires consideration of alternatives under NEPA.[21]

Another deficiency in the proposed action and Draft EA relates to old-growth assessments and the 40-year implementation timeframe of the proposed action. We described this issue in our scoping comments. Based on the tables in the Vegetation report, after 40 years the Proposed Action would result in 5,960 acres of forest over 130 years (the minimum POG age threshold for most forest communities in the project area). The No Action alternative would result in 11,103

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[19] Rob Messick is based in North Carolina but has extensive experience in old-growth identification throughout the southern Appalachian region, including Kentucky. He is author of the recent "Global Importance of Imperiled Old-Growth Forests With an Emphasis on the Southern Blue Ridge Mountains" in "Imperiled: The Encyclopedia of Conservation" (2022) and among those thanked by the Region 8 Old-Growth Team in their acknowledgements in the June 1997 Report of the Region 8 Old-Growth Team.

[20] *See Curry v. Forest Service*, 988 F. Supp. 541 (W.D. Pa. 1997); *Lands Council v. Cottrell*, 731 F. Supp. 2d 1028 (D. Idaho) (R&R adopted 731 F. Supp. 2d 1074); *Neighbors of Cuddy Mountain v. Forest Service*, 137 F.3d 1372 (9th Cir. 1998); *Idaho Sporting Cong. v. Alexander*, 222 F.3d 562 (9th Cir. 2000) (overruled on other grounds); *Wildwest Inst. v. Austin*, 2006 WL 8435846, at *1 (D. Mont. 2006).

[21] 42 U.S.C. § 4332(H).

acres of POG. This means a reduction in POG of 5,143 acres through implementation of the project. Another way of looking at this is that around 5,000 acres of forest will meet POG minimum age thresholds over the implementation timeframe but be exempt from review as EOG (existing old-growth) because they were filtered out years or decades before being logged. This is a violation of the Forest Plan. For example, a stand that is 120 years old in 2024 would not be reviewed for old-growth characteristics because of its current age – and structurally may not be old-growth – but would be harvested in 2054 when it is 150 years old and meeting old-growth criteria. And yet the stand would never receive an old-growth evaluation because it was approved for harvest decades earlier. This is an end-run around the clear direction in the Forest Plan (and the proposed national Forest Plan amendment). Again, these decisions warrant a consideration of alternative impacts, and the Forest Service cannot obfuscate this duty by approving these activities before old-growth criteria fully manifest.

We also point to the mischaracterization in the effects analysis where the Vegetation report states that, for Alternative 1, "Impacts to FOG, POG, and EOG would be the same as those described in the Proposed Action."[22] This is only true if the Forest Service assumes subsequent approval of the timber project over the subsequent three decades to implement – in essence – the Proposed Action. If the Proposed Action and Alternative 1 are compared over the same time period (40 years), the Proposed Action will result in 5,960 acres of forest over 130 years in age, while Alternative 1 will result in 10,271 acres of forest over 130 years in age. Based on the data in the Vegetation Report, the Proposed Action will result in 4,311 fewer potential old-growth acres than Alternative 1. The effects are not the same.

The Forest Service must correct these violations of NEPA and revise these inconsistencies with the agency's own internal guidance before proceeding with the Jellico Project.

F. Roadless Areas analysis

Since the publication of the scoping document, examination of the Ryans Creek Mountain section of the Jellico Project area has revealed a significant area that should be designated and managed as a Roadless Area under the Forest Plan. The area (illustrated below) includes 2,115 acres of national forest land within a larger, 2,419-acre roadless area polygon that includes adjacent private lands meeting roadless area criteria. This acreage exceeds the minimum acreage necessary for evaluation as a Roadless Area under the Forest Plan.

The Forest Plan cites FSH 1909, Chapter 7, section 7.11b, Criteria for Roadless Areas in the East in its evaluation (and elimination) of potential Roadless Areas[23]:

> 1) The area contains no more than one half-mile of improved road for each 1,000 acres, and the road is under Forest Service jurisdiction.
> 2) The area contains only a few dwellings on private lands and the location of these dwellings and their access needs insulate their effects on the natural conditions of federal lands.

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[22] Vegetation Report at 17

[23] See: Forest Plan FEIS Appendix C, Roadless Evaluation

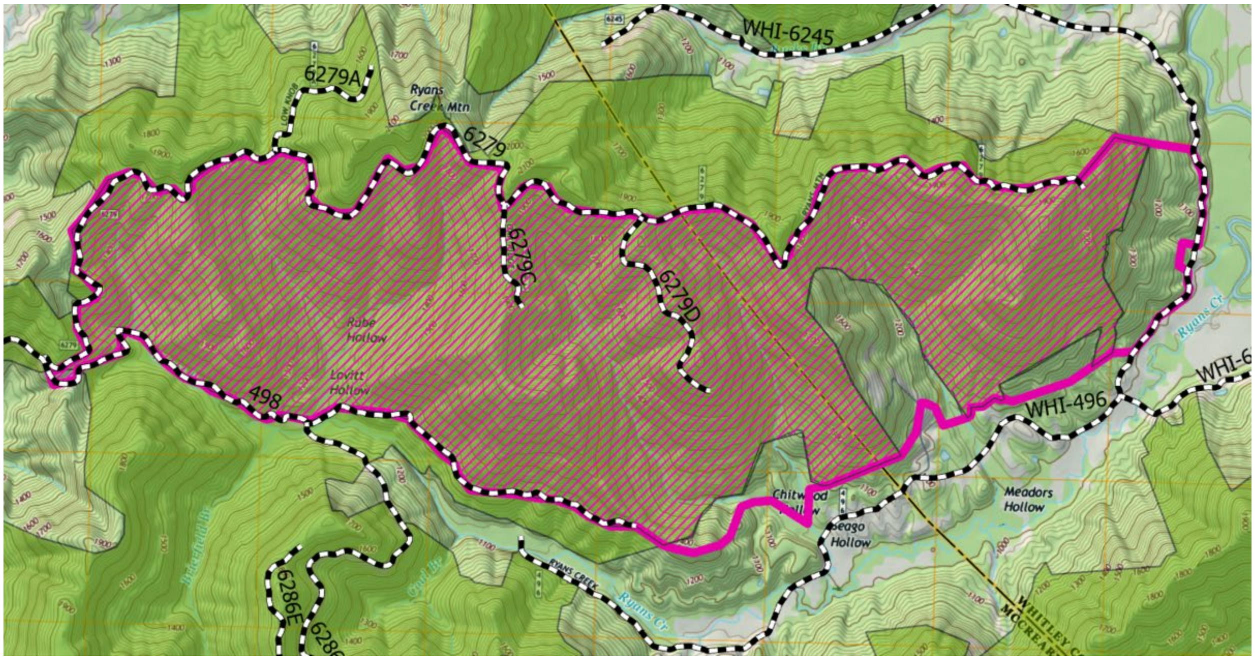
The area does include two road segments (NFSR 6279C and NFSR 6279D). In the DBNF Roads GIS data available to us these roads are designated as Operational Maintenance Level 2 – High Clearance with a total length of 1.27 miles. This amounts to 0.6 miles per thousand acres of federal land, and 0.5 miles per thousand acres of full polygon. While the former appears "on paper" to exceed the requirement that "The area contains no more than on half-mile of improved road for each 1,000 acres," the reality on the ground is that much of the distance accounted for in the GIS data fails to meet any reasonable definition of "improved road."

To further support this point, FSH 1909.12 Chapter 70 – Wilderness, directs the Forest Service to include in any Wilderness inventory

> d. Areas in Forests, Grasslands, Prairies, and other Administrative Units east of the 100th meridian with forest roads maintained to level 2 that are identified as closed to motor vehicles yearlong in a previous decision document, or as identified in a travel management plan (36 CFR 212.51) or a travel analysis (36 CFR 212.5(b))[24]

The aforementioned roads are maintained at level 2 and are closed to motor vehicles yearlong and therefore meet this criterion.

The Forest Service should have considered this area in the analysis for the Jellico project. The Draft EA needs to be corrected by conducting an appropriate Roadless Area analysis for the areas on the south side of Ryans Creek Mountain.



Candidate Roadless Area on Ryans Creek Mountain

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[24] See: FSH 1909.12 – Land Management Planning Handbook, Chapter 70, 71.22a – Road Improvements

G. Oak recruitment and oak regeneration

The Draft EA, in its description of the Proposed Action, states that "Forest community impacts would consist of either maintenance of the existing community or a shift from the existing community towards oak and hickory dominated forest communities as competing and invasive species are removed or eliminated through harvests and intermediate treatments."[25] For Direct and Indirect Effects, the Vegetation Report states:

> Direct impacts to forest communities in stands proposed for treatment would occur immediately after treatments and consist of either maintenance of the existing community or a shift from the existing community towards oak and hickory dominated forest communities. Specifically, all harvest methods and intermediate treatments are designed to favor desired species, namely oak and hickory. With the removal of undesirable species, such as red maple, the percent stand composition (i.e. trees per acre expressed as a percentage) of desired species would increase immediately.[26]

Kentucky Heartwood raised concerns in our scoping comments regarding the efficacy of oak regeneration following the Forest Service's proposed regeneration cuts in the Jellico project area. We reiterate all of the concerns and information included in our scoping comments. The bottom line is that stands in the Jellico project area do not have sufficient advance oak regeneration to result in a new cohort of oaks following regeneration cuts. The Draft EA states:

> Recent stand data and reconnaissance indicate high stem densities (i.e. over 2,500 stems per acre) of sugar maple in stands that are oak dominated suggesting that forest communities are shifting from dry-mesic and dry-xeric oak to mixed mesophytic.[27]

This statement, describing how maples dominate understories in many oak stands in the Jellico project area, does not assert that there is sufficient advance oak regeneration to make a regeneration harvest successful with oaks. Our observations in the field indicate that there is little advance oak regeneration in these stands. We note that the Center for Biological Diversity has submitted two FOIA requests for CSE (Common Stand Exam) reports that would provide these data, but the Forest Service has only responded with data from a few stands, most of which have been dropped from harvest plans.

It is also a basic fact of forest ecology that increasing abundance of maples under an oak or oak-hickory understory does not indicate a community shift from dry-mesic and dry-xeric oak to mixed mesophytic forest types. It is a different, distinct phenomenon. While the term "mesophication" is sometimes used to describe this understory compositional shift, mixed mesophytic forests represent a different forest assemblage than just oak forests with maple incursion.

Without sufficient advance oak regeneration, the proposed regeneration harvests (especially shelterwood and clearcut) will serve to reduce or eliminate the oak component of many stands,

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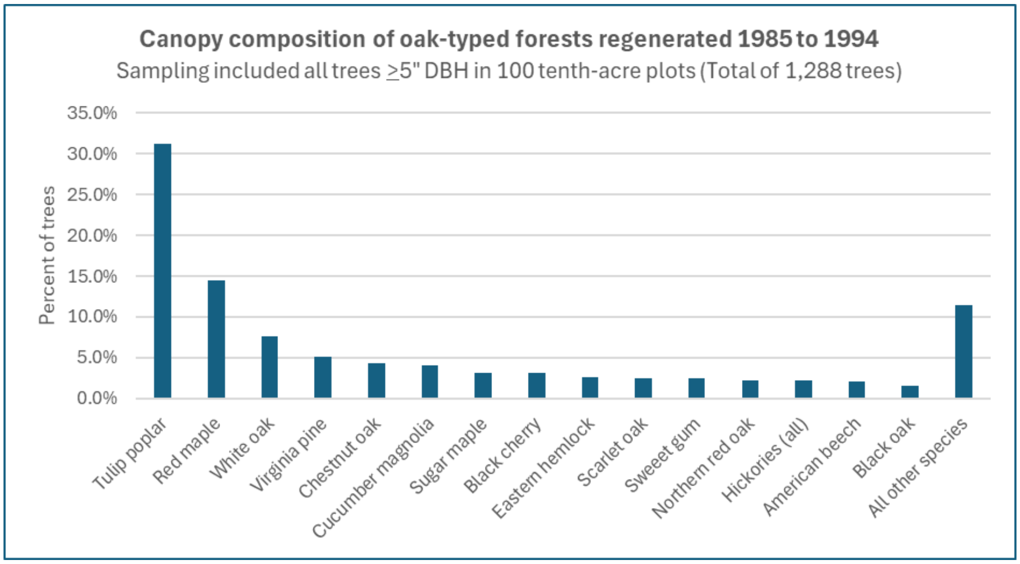
[25] Draft EA at 13
[26] Vegetation Report at 9
[27] Draft EA at 4

which is contrary to the purpose and need of the project and the Forest Service's requirements for assuring adequate stocking of desirable species.

Kentucky Heartwood collected canopy tree species data in 2019 in 100 tenth-acre plots in oak-typed stands that were subjected to regeneration cuts on the Daniel Boone National Forest from 1985 through 1994. Plots were distributed across all four DBNF Ranger Districts, though no plots were located in the Jellico project area. All trees ≥ 5" DBH were recorded by species in order to assess which species appeared dominant or poorly represented. In particular, we were interested in determining whether or not these stands, which were typed as oak forests in the FSVeg database, remained oak forests three decades after regeneration. While we have yet to perform statistical analysis, the raw data demonstrate that regeneration cuts on the DBNF have largely failed in reproducing. Instead, the cuts have accelerated the loss of oak species and conversion to tulip poplar and red maple-dominated forests.



The results of this sampling reflect years of observations of the Forest Service's failure to reproduce or regenerate oak through clearcutting and shelterwood methods – as is proposed in the Jellico project. The science is well-established. Oak reproduction and regeneration require multiple episodes of intermediate disturbance for advance oak reproduction to establish (regardless of whether or not overstory removal is desired). But the Forest Service continues to jump to the end of the process, against all science and best practices, conducting regeneration cuts (especially seed tree cuts incorrectly described as shelterwood cuts) before managing for advance oak regeneration in the understory.

The White Oak Initiative produced the report "Restoring Sustainability for White Oak and Upland Oak Communities: An Assessment and Conservation Plan." The report is undated but appears to be from 2023. The U.S. Forest Service is listed as a partner and financial contributor to the White Oak Initiative. The report includes a section on "Upland Oak Management Techniques."

> As a part of the White Oak Initiative, Dr. Jeff Stringer at the University of Kentucky coordinated leading oak researchers and practitioners in the development of a suite of 10 management practices to sustainably manage oak over the wide range of stand ages and conditions that occur across the region. Where appropriate, specific recommendations were provided for white oak.
>
> The management guidelines that have been developed for each practice include specific information on when and under what conditions to apply the practice, and details of how to implement and monitor the practice to ensure oak success in upland hardwood stands. Because of white oak's importance, specific information on how to apply the practice to enhance white oak is also provided.[28]

Under "Harvesting" the report states:

> Several practices are designed to do this. A shelterwood harvest retains approximately 50 percent of the overstory, delivering an appropriate amount of reduced sunlight that favors the oaks while slowing competitors such as yellow poplar that grow quickly in full sunlight.[29]

Note here that the report describes shelterwood as retaining "approximately 50 percent of the overstory," while the Jellico project uses the term "shelterwood" to describe harvests that remove 85 to 90 percent of the overstory ("Similar to a clearcut, this treatment would remove most trees; however, approximately 10-15 percent of the residual stand would be retained"[30]). What the report describes as "shelterwood," as an effective component of oak management, is what the Forest Service describes as "thinning" in the Draft EA ("This treatment would remove approximately 40-60 percent of the trees and retain 40-60 percent")[31].

Note also that the report describes how retaining 50% of the overstory allows for an appropriate environment "that favors oaks while slowing competitors such as yellow poplar that grow quickly in full sunlight." Kentucky Heartwood discussed this issue in detail in our scoping comments – namely that intensive cuts, like the proposed shelterwood and clearcut prescriptions, serve to bolster oak competitors at the expense of oaks.

The report also recommends group cuts:

> At times, group openings or gap cuts, one-half to two acres in size, can be harvested. The edge around the openings is partially shaded from the adjacent unharvested forest, encouraging oak growth while slowing shade-intolerant competitors.[32]

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[28] Restoring Sustainability for White Oak and Upland Oak Communities: An Assessment and Conservation Plan at 40

[29] *Id.* at 42

[30] Draft EA at 11

[31] *Id.*

[32] Restoring Sustainability for White Oak and Upland Oak Communities: An Assessment and Conservation Plan at 42

Kentucky Heartwood discussed the efficacy of small group selection harvests over larger regeneration systems in our scoping comments. We note that, as described in the response to comments document, the Ruffed Grouse Society also suggested expanding gap (femelschlag) systems in the Jellico project. Harvests of this type are far less impactful with regard to many of the resource concerns that Kentucky Heartwood and others have voiced (e.g., landslide hazards, conservation of interior forest blocks, etc.). However, these types of harvests have not been included in the project.

The report also describes how and when a deferment harvest can be used, and offers a distinctly different definition and practice than the Forest Service is using in the Jellico project:

> A third type of harvest, called a two-age deferment harvest, can be used to help with long-term oak sustainability if a harvest is required when limited advance regeneration or stump sprouters are present. This practice retains scattered, long-lived overstory oaks (reserve trees) while all other overstory trees are removed.
>
> A regenerating age class will start to grow beneath them but without any oaks, due to the lack of advance regeneration or stump-sprouters. The oak reserve trees are kept to ensure that acorns continue to be produced in the stand. While the rapidly developing regenerating class will be devoid of dominant oaks, the reserve trees will continue to produce acorns. As the regenerating stand develops below the reserve trees, the acorns produced will start to establish seedlings that can be cultivated and initiate the development of advance regeneration that can be used to establish oak in the next generation 50-70 years in the future, when the forest will be harvested again. This practice is used to "life-boat" oaks in the stand. If the oak regeneration potential is low or nonexistent when a harvest occurs and the overstory oaks are removed, there is little chance of easily reintroducing oak back into the stand. The two-age deferment harvest ensures that long-lived oak species such as white oak can be maintained in the stand for future regeneration.

There are several things to note in this section. First, this description of how a deferment harvest is to be used to support oak reproduction does not include an overstory removal after 10 to 15 years, as described in the Jellico project. Under the system recommended by the White Oak Initiative, overstory trees are retained throughout the development of the regenerating understory until "50-70 years in the future, when the forest will be harvested again."

And perhaps most importantly, is the statement that "***If the oak regeneration potential is low or nonexistent when a harvest occurs and the overstory oaks are removed, there is little chance of easily reintroducing oaks back into the stand***." This is critical. This is also completely known and understood. It does not matter that the Forest Service plans to use herbicide and other tools to kill competing vegetation. Without advance oak regeneration, jumping to overstory removal will knock out oaks for the long-term.

The Forest Service and others have begun to advance artificial regeneration (planting) following harvest as a means of establishing oak after a harvest when advance oak regeneration is insufficient. This is not proposed in the Jellico project. If the Forest Service plans to using planting as part of its strategy then this needs to be made explicit. Regardless, the White Oak Initiative report describes the difficulty of this technique:

> Enhancement/enrichment planting can be used directly before or after harvesting to establish oaks. This practice requires planting oak seedlings and using appropriate competition control measures to "enhance or enrich" the naturally regenerating age class that is deficient in oaks. ***While this practice of planting oak seedlings directly before or after a harvest seems like a direct means of regenerating oaks, it has significant hurdles***. Browsing by wildlife of the planting seedlings is common and is exacerbated by the high level of nutrients in seedlings from tree nurseries. Protection for the seedlings can be required, adding cost to the practice. Also, practices needed to adequately control competing species can be significant and costly. Plastic mulch, tree shelters, herbicides, or mechanical controls of competing species may be required. ***The high cost and degree of risk involved in planting oak seedlings in natural forests currently precludes the widespread use of this practice.***[33] (Emphasis added)

The report ranks its "Ten Suggested Upland and White Oak Management Practices," with intermediate treatments – and not significant regeneration harvests as proposed in the Jellico project – as being the priority tools for supporting oaks.

The Jellico project would advance practices and systems that, under current conditions, will serve to reduce oaks in the Jellico mountains. Is the DBNF emphasizing high-volume timber sales over science and best practices to meet timber quota objectives? If not, then what reasoning is there for ignoring this well-known science?

H. Socioeconomic analysis

The socioeconomic analysis for the Jellico project is decidedly one-sided and avoids a reasonable, unbiased accounting of costs and benefits. Incorporated into these comments as **Appendix D** is a review of the Socioeconomic Analysis: Jellico Vegetation Management Project conducted by Zachary Christin, Research Economist with Equilibrium Economics. The conclusion reached by this analysis is that:

> Results show that, for the Proposed Action, clearcutting and two-age shelterwood practices will induce costs between $5.0M to $18.5M in just the first year. Likewise, under Alternative 1 option of only two-stage shelterwood practices, practices will induce costs between $2.1M to $12.7M in just the first year.
>
> It is worth highlighting that costs are not limited to the first year and will continue to be incurred each year until the first succession species replace this value, likely in a diminished capacity. **It is also worth highlighting that the Year 1 costs highlighted here negate the net benefits identified in the Socioeconomic Analysis of $1.4M over the life of the project**.[34] (emphasis added)

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[33] *Id* at 44

[34] Christin, Zachary. Appendix D. Response to Socioeconomic Analysis

Thank you for the opportunity to submit these comments. If you have any questions or need clarification on any issues we have raised please do not hesitate to reach out. Kentucky Heartwood and our members are very invested in, and concerned, over the future of the Jellico section of the Daniel Boone National Forest. We encourage you to take these and others' comments into serious consideration and look forward to future dialogue over the future of these forests.

Sincerely,

Lauren Kall

Lauren Kallmeyer, Executive Director
Kentucky Heartwood

Appendix A

Recommended Best Management Practices to Minimize the Likelihood of Sediment Delivery to Streams by Logging Induced Landslides in Eastern Kentucky

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April 26, 2024

SCOPE AND PURPOSE

This document was prepared at the request of the Appalachian Citizens' Law Center, Kentucky Heartwood, and the National Wildlife Federation. Its purpose is fourfold:

- To summarize the occurrence of landslides and current state of publicly available landslide information in Kentucky.
- To summarize the large body of existing scientific literature on the relationship between logging and landslides.
- To summarize selected state logging best management practices (BMPs) dealing with the assessment and avoidance of sedimentation problems related to logging-induced landslides.
- To propose a set of best management practices (BMPs) intended to reduce the likelihood of logging-induced landslides, consistent with the geologic setting and data availability in Kentucky, and with consideration of potential adaption in other Appalachian states.

Throughout this document, "landslide" is used it its broadest sense to include downslope movement of earth materials by sliding or flowing under the influence of gravity at a rate greater than soil creep, including rockslides, mudslides, mudflows, debris flows, earthflows, slumps, slips, and similar phenomena.

LANDSLIDES IN EASTERN KENTUCKY

The Appalachian Mountains, including eastern Kentucky, have long been recognized as one of the most landslide-prone regions of the United States (Radbruch-Hall et al., 1982; Mirus et al., 2020). Systematic efforts to characterize Appalachian landslide occurrence and susceptibility date back to a U.S. Geological Survey program of mapping existing features and qualitatively evaluating landslide and debris flow hazard susceptibility for hundreds of 7.5-minute topographic quadrangles during the 1970s and 1980s, which resulted in the production of hundreds of hand-drawn open-file maps and more formal publications. Since then, landslide occurrence and susceptibility mapping in Appalachia has been largely left to state geological surveys or governments.

In Kentucky, the Kentucky Geological Survey (KGS) has assembled a statewide landslide database that includes a regularly updated list of known historical landslide locations and any other available information, landslides shown on existing 1:24,000 scale geologic maps in Kentucky, landslides identified from interpretation of airborne lidar coverage, landslides identified from aerial photographs by U.S. Geological Survey scientists, and areas susceptible to debris flow as inferred by U.S. Geological Survey scientists (Crawford, 2014).

KGS has also started to produce a series of FEMA-funded landslide susceptibility maps for individual counties using machine learning methods applied to lidar-based landslide inventory maps. At present, susceptibility maps are available for the five counties comprising the Big Sandy Area Development District (Pike, Martin, Magoffin, Johnson, and Floyd). Maps for the counties comprising the Kentucky River Area Development District (Breathitt, Knott, Lee, Leslie, Letcher, Owsley, Perry, and Wolfe) are in preparation. The KGS landslide database layers and susceptibility maps are available as an interactive online map at:

https://kgs.uky.edu/kygeode/geomap/?layoutid=25.

Each of the susceptibility maps is also available as a PDF document with explanatory text (Crawford et al., 2022 a,b,c,d,e) that can be freely downloaded from the KGS website.

The Kentucky susceptibility map creation workflow has been described in the peer-reviewed scientific literature (Crawford et al., 2021; also see Crawford et al., 2022 f). It uses a logistic regression model including eight topographic variables associated with landslides identified on high-resolution lidar topographic maps and their derivatives (e.g., lidar-derived hillshade images). Woodard et al. (2023) include Kentucky Geological Survey results from Magoffin County in an assessment of difficulties in developing modern landslide susceptibility maps over large regions for which limited data are available.

In addition to the topographic variables used to generate the susceptibility maps, KGS research has shown that weak strata such as shale, coal, and underclay layers can localize landslides (Crawford, 2014; Chapella et al., 2019).

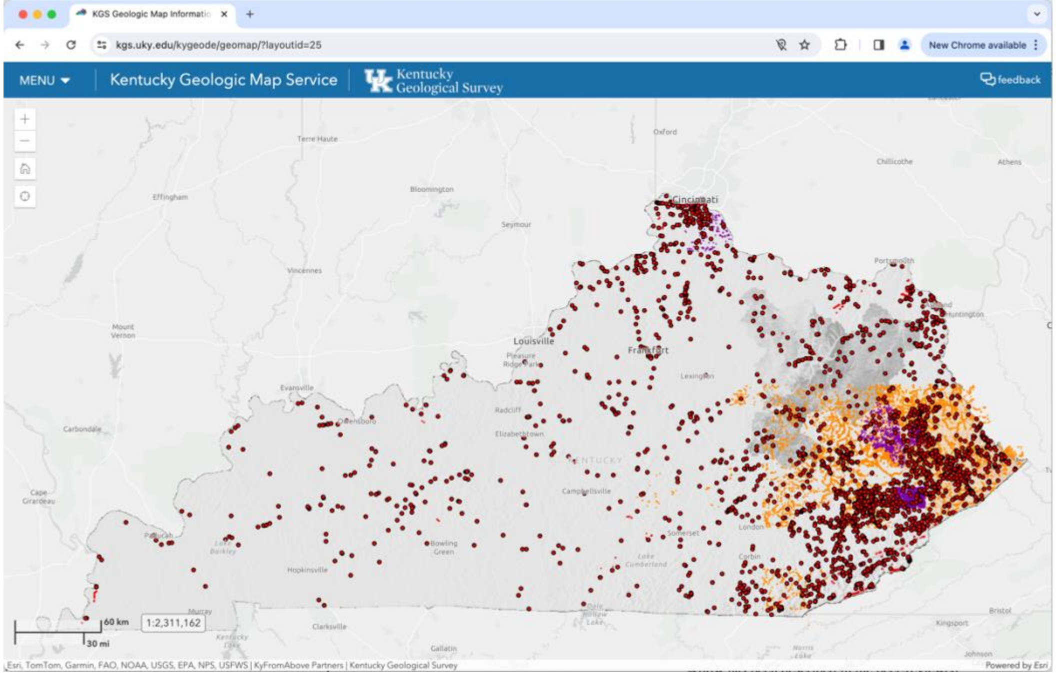

Figure 1—Screen capture from the Kentucky Geological Survey map service displaying landslide location information.

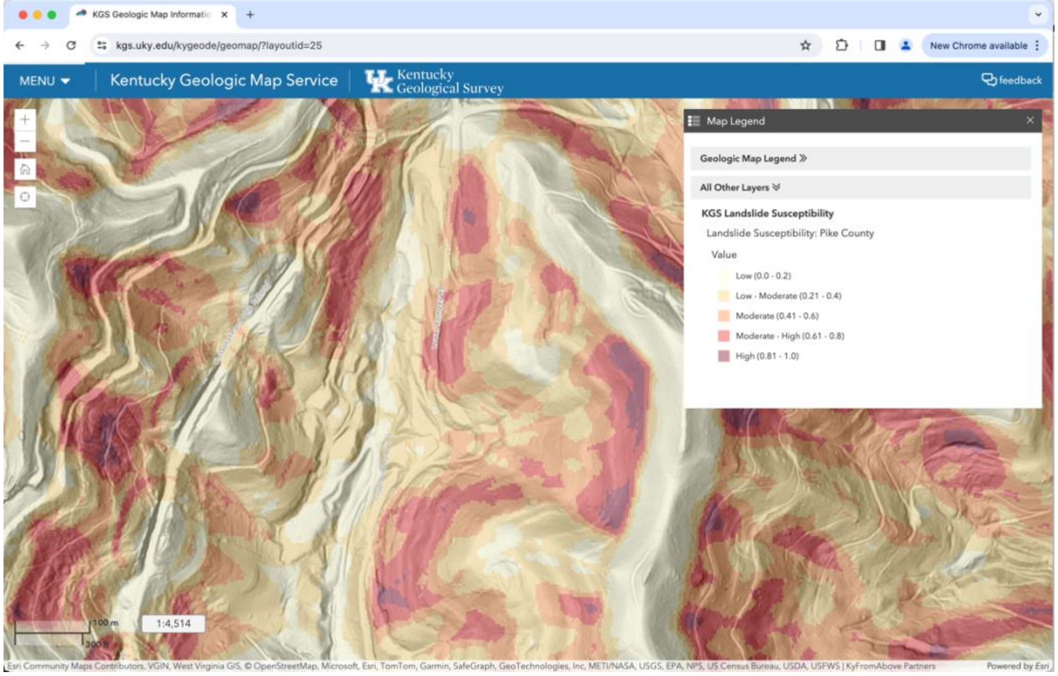

Figure 2—Screen capture showing a portion of the Kentucky Geological Survey landslide susceptibility map for Pike County draped over a 5-ft lidar multidirectional hillshade image of the area.

Neighboring states have also undertaken landslide susceptibility assessment and map production. Of particular note, Lessing et al. (1976) and Lessing et al. (1994) produced a series of landslide susceptibility maps for West Virginia. Those legacy maps, along with previous U.S. Geological Survey maps, were key components in the development of modern lidar-based landslide inventory, susceptibility, and risk maps available through the West Virginia GIS Technical Center (https://wvgis.wvu.edu). Like the Kentucky susceptibility maps, the West Virginia susceptibility maps leverage machine learning methods to determine susceptibility based upon the characteristics of landslides inventoried using airborne lidar coverage. Development of the model is described in a document available from the West Virginia GIS Technical Center (WV GIS TC, 2022). The North Carolina Geological Survey has also developed an interactive landslide website (https://experience.arcgis.com/experience/b55c8497d115400aa09d9cb7a27f5dc8/page/page_7/) with the ability to display known landslide points and polygons, landside deposits, and landslide susceptibility maps for some counties in western North Carolina.

LOGGING AND LANDSLIDES IN STEEP FORESTED WATERSHEDS

The effects of logging on the landscape are well established in the scientific literature. Charles Lyell wrote about the evidence of post-logging erosion, valley incision, and ground cracking he observed in Georgia and Alabama during 1846 in an 1853 revision of his three-volume *Principles of Geology*, which is widely recognized as a foundational document of modern geology (Wool, 2001). Although he did not refer specifically to landslides in his 1846 account of logging consequences, Lyell (1853) refers repeatedly to the importance of landslips, as he described them, in the enlargement of ravines and valleys such as those he described as consequences of logging. Nearly a century later, Hirata (1939) wrote, “Landslides, many of which are caused by heavy rains or earthquakes, land creep, and surface erosion, are specially frequent in deforested areas." He also observed that Japanese cedar plantations and bamboo forests offered less protection against landsides than broadleaved deciduous virgin forests. Swanston (1974) provided an early assessment of landslides related to logging in the western United States, including citations to work going back as far as 1950. DeGraff (1979) demonstrated that vegetative type conversion (which he defined as conversion of tree and brush cover to grassland cover) increased visible landslide activity by 300 percent in a Utah watershed and wrote "Vegetative-type conversion apparently has a landslide-inducing potential similar to that of clear-cutting and road building."

In a comprehensive modern review of landslides and their relationship to land use, Sidle and Ochiai (2006) describe in detail the relationship between trees and landslides on forested slopes. They state that the effect of trees on slope stability is a combination of 1) root strength that is generally considered a component of the cohesive strength of soil and 2) a reduction of soil wetness through a combination of canopy interception and evapotranspiration. Of the two, they consider root strength to be the more significant agent of stability. Sidle and Ochiai (2006) go on to summarize numerous studies demonstrating the role of logging on landslide generation in forested watershed, including the gradual loss of root strength in the years after logging. Sidle (1992) developed a mathematical model to evaluate the effects of logging on slope stability, concluding that alternating thinning and clear-cutting and clear-cutting along reduce slope stability more than shelterwood and partial logging.

There do not appear to be any published studies specifically investigating the relationship between logging and landslides in Appalachia, including eastern Kentucky, although Wooten et al. (2016) write with reference to their work in North Carolina, "Forest cover is an important stabilizing factor on hillslopes by intercepting precipitation, increasing evapotranspiration, and reinforcing roots" and "Anthropogenic influences have increased the frequency of mass wasting for a given storm event above natural historical levels through changes in vegetation and disturbances on mountain slopes".

The published scientific literature on the relationship between logging and landslides around the world is too extensive to review completely in this report. Google Scholar searches using the keywords "logging" and "landslides" and, separately, "logging" and "slope instability" yield about 59,500 and 45,400 results, respectively. The paragraphs below summarize a small selection of the relevant literature to demonstrate the near universality of logging as a potential cause of landslide problems.

In a study of the effects of clear-cutting and road construction on landslides in the Cascade Range of Oregon, Swanson and Dyrness (1975) concluded that landslide activity along logging roads and clear-cut areas increased by a factor of about 5 over a 20-year period. Reid and Keppeler (2012) analyzed landslide activity after second-entry partial clearcut logging in northern California and found that large landslides occurred at rates 10 times higher in logged areas and 100 times higher along roads, and that the volume rate of landslide activity associated with roads in logged areas was more than 3 times that from roads in not-logged forested areas. They also found that the largest slides occurred 9 to 14 years after logging and within "a few years" of pre-commercial thinning. Montgomery et al. (2000) analyzed 3224 post-logging landslides on commercial timberlands in Oregon and Washington, concluding that landsliding in their study area occurred at 3 to 9 times the regional background rate. They also concluded that landslides in their logged study area could be triggered by 24-hour rainfall events with recurrence intervals as small as 4 years.

Based on an analysis of 1004 landslides in British Columbia, Jakob (2000) concluded that the frequency of landslides in logged areas was 9 times higher than that in undisturbed forests and that logging-related landslides occurred on gentler slopes than natural landslides (in part because exceptionally steep slopes were not logged). He reported that most of the landslides resulted from road fill failures and within harvest areas. In a study evaluating 61 years of data from British Colubmia, Wolter et al. (2010) likewise found that logging related landslides required lower slopes to initiate than natural landslides and that, overall, the logging-related landslide rate was 9 times the natural rate. Guthrie (2002) found that the number of landslides following logging increased by factors of 3 to 16 in three different watersheds and 2 to 12 times more landslides reached streams after logging than before logging.

Imaizumi et al. (2007) studied an area in central Japan that had been subjected to rotational forest management since 1912 and found that the direct effect of clearcutting on landslide activity was in stands clearcut 1 to 10 years earlier with effects continuing up to 25 years after logging, an increase of 4 times the amount observed in control areas, which they attributed to a decay of root strength after logging. They also found that landslides continued to supply sediment for 45 years after logging in one watershed. Sato et al. (2023) studied landslides on plantation forests in Japan and concluded that the return period of landslides in their mature forest study area (> 40 years old) was 3 times higher than that for landslides in their immature forest study area (10 to 30 years old).

Steinacher et al. (2009) performed a numerical study in which they quantified the contributions of both tree roots and tree strength to slope stability for seven different hypothetical slopes. They showed that even for small amounts of root cohesion, deforestation decreases slope stability in the long term as roots decay. Hruška et al. (2023) conducted geophysical investigations at two locations in Moravia and the Czech Republic, concluding that logging led to incipient soil/rock movement and significant increases in wetness that they attributed to post-logging development of new rainfall infiltration pathways.

An important thread running through all of the cited landslide studies is that they demonstrate increased landslide activity was associated with specifically with logging and not simply a homogeneous regional response to factors such as rainfall; otherwise, there would have been little difference in landslide occurrence between logged and not-logged areas subjected to essentially the same amount of rainfall.

STATE LOGGING BMP AND FOREST PRACTICE DOCUMENTS

This section summarizes a subset of existing state BMP and forest practice documents with specific reference to landslides for two groups of states: The first group comprises Kentucky and neighboring states, reflecting current practices in central Appalachia and the eastern midcontinent. The second group comprises states that have adopted more rigorous and stringent practices up to and including promulgation of detailed forest practice rules specifically addressing the geologic evaluation of potentially unstable slopes.

Kelly and Crandall (2022) published an overview of the variety of state forestry practice policies across the United States and wrote, "Some states have codified BMPs into regulations, frequently by incorporating them into Forest Practices Acts; other states have maintained entirely voluntary BMPs and have focused on landowner and logger education to ensure BMPs are adopted." Although dated, Laird (2001) provides a useful summary of the integration of geologic assessments with timber harvest plans in the Pacific Northwest shortly after the adoption of existing forest practice rules.

Table 1 lists the states for which existing BMP, forest practices rules documents, and forest practices acts were reviewed; provides URLs for the documents reviewed; indicates whether the documents specifically reference landslides in relation to logging activities; and indicates in its fourth column whether detailed prescriptive BMPs related to landslide prevention are codified in the forest practice acts or regulations, as opposed to generic requirements or recommendations to avoid situations that could deliver sediment to streams.

Logging on federal land is generally exempt from state mandated BMPs; however, federal land managers may choose to follow BMPs developed for the states in which the managed lands are located.

Table 1. Logging best management practice and forest practice documents reviewed for this report. To avoid duplication and because of their wide variety of formats and authorship, the documents linked below are not included in the reference list at the end of this report.

State	Forest Practice or BMP Document URL	Mentions Landslides	Codified Landslide BMPs
Kentucky	https://eec.ky.gov/Natural-Resources/Forestry/ky-master-logger-program/Documents/Forest%20Conservation%20Act%20Statutes.pdf https://eec.ky.gov/Natural-Resources/Conservation/Agriculture%20Water%20Quality%20Act%20Documents/Ky%20Ag%20Water%20Quality%20Plan%20December%202020.pdf https://eec.ky.gov/Natural-Resources/Forestry/Kentucky%20Forest%20Conservation%20Act%20Information/Kentucky%20Logging%20BMP%20Field%20Guide%20FOR%20130.pdf	No	No
Virginia	https://dof.virginia.gov/wp-content/uploads/VAs-Forestry-BMP-Field-Guide_pub.pdf	No	No
West Virginia	https://code.wvlegislature.gov/pdf/19-1B-1/ https://wvforestry.com/pdf/DOFbmpManual2018.pdf	No	No

Tennessee	https://www.tn.gov/content/dam/tn/agriculture/documents/forestry/2023/Forestry-BMP-Guide.pdf	Yes	No
Ohio	https://dam.assets.ohio.gov/image/upload/ohiodnr.gov/documents/forestry/factsheets/BMPsErosionControlLogging.pdf	No	No
Indiana	https://www.in.gov/dnr/forestry/files/BMP.pdf	No	No
Missouri	https://mdc.mo.gov/sites/default/files/2020-09/woody_biomass_bmp_book.pdf	No	No
Pennsylvania	https://extension.psu.edu/best-management-practices-for-pennsylvania-forests	No	No
North Carolina	https://www.ncforestservice.gov/publications/BMP2021/2021NCFSBMPManual.pdf	No	No
Colorado	https://csfs.colostate.edu/wp-content/uploads/2020/08/2018_BMP_Audit.pdf	No	No
Wyoming	https://wsfd.wyo.gov/forest-management/bmp-s	Yes	No
Montana	https://dnrc.mt.gov/_docs/forestry/FinalBMP_VersionForWeb10_1_15.pdf	Yes	No
New Mexico	https://www.emnrd.nm.gov/sfd/wp-content/uploads/sites/4/19-20-4_NMAC_eff09142007.pdf https://www.emnrd.nm.gov/wp-content/uploads/sites/4/ForestPracticesGuidelines2008.pdf	Yes	No
Washington	https://www.dnr.wa.gov/about/boards-and-councils/forest-practices-board/rules-and-guidelines/forest-practices-board-manual	Yes	No
Oregon	https://knowyourforest.org/learning-library/forest-protection-laws https://www.oregon.gov/odf/documents/workingforests/fp-technical-guidance-identifying-slope-retention-areas.pdf	Yes	Yes
California	https://bof.fire.ca.gov/media/qs5p1yk4/2024-forest-practice-rules-and-act-final.pdf https://www.conservation.ca.gov/cgs/Documents/Publications/CGS-Notes/CGS-Note-45.pdf https://www.conservation.ca.gov/cgs/Documents/Publications/CGS-Notes/CGS-Note-50.pdf	Yes	Yes
U.S. Forest Service	https://geodata.geology.utah.gov/pages/view.php?search=&k=&modal=&display=list&order_by=field87&offset=9150&per_page=48&archive=0&sort=DESC&restypes=&recentdaylimit=&foredit=&ref=2550	Yes	Yes

All of the logging BMP or forest practice rule documents reviewed addressed steep slopes in the context of stream management zones, erosion, and runoff management. Only 7 out of 15, however, specifically mention landslides.

Some of the documents include language that can be broadly interpreted to include landforms or conditions characteristic of landslides or landslide-prone slopes. The Indiana BMP document, for example, includes the statement “Use soil, topographic, and aerial maps to locate poorly drained, high erosive, or wet areas to avoid” among its planning practices and “Minimize steep slopes and poorly drained areas as log-landing locations” among its items of caution. Poorly drained and wet areas on slopes can be indications of active or potentially active landslides, but the Indiana document does not specifically mention landslides or offer any additional detail. The Missouri document states, “Soil needs to be managed based on site-specific characteristics” but does not specifically state that the site-specific characteristics might include landslide susceptibility.

The Kentucky Forest Conservation Act (KRS 149.330 through 149.355) states, “No logger or operator shall conduct any timber harvesting operations in a manner that is causing or will likely cause water pollution.” The Kentucky Agriculture Water Act (KRS 224.71-100 through 224.71-140) further mandated development of a statewide agricultural water quality plan. As developed, the plan has silvicultural provisions including the minimum requirement that “Practices shall be implemented to control erosion that can deliver sediment to streams or channels from disturbed ground other than roads, trails, and landings.” Table 1 includes hyperlinks to the Kentucky Forest Conservation Act, Kentucky Agriculture Water Quality Plan, and the Kentucky Logging BMP Field Guide.

Although the Kentucky Forest Conservation Act, Agricultural Water Quality Act, and Logging BMP Field Guide do not specifically mention landslides, delivery of soil and rock to a stream by way of a landslide or debris flow developed from a landslide is a form of sediment delivery that constitutes water pollution. The Kentucky Logging BMP Field Guide refers to “steep slopes that may or may not be too steep to log” in the description of a harvest planning map and “steep areas were verified as being too steep to skid or safely fell timber” in the description of a harvest planning walkthrough; however, it does not provide additional details or guidance about the definition or consequences of “too steep”. Like other BMP documents, the Kentucky document addresses stream management zones (SMZs) with requirements that 50 percent of the overstory be retained near perennial streams and 75 percent near cold water aquatic habitats. The width of stream buffers within which overstory must be retained range from 25 feet (slopes < 15%) to 50 feet (slopes > 16%) for perennial streams and 100 feet regardless of slope for cold water aquatic habitats. The Kentucky BMP document also specifies setbacks of 50 feet to 100 feet for roads, trails, and landings, depending on the slope and stream type. The document also provides BMPs for “sinkholes with openings and other naturally occurring openings in the ground” aimed at preventing runoff, soil, and logging debris from entering sinkholes and giving rise to water quality problems. Although the Kentucky BMP document does not specifically include landslides, it does (1) state that some slopes may be too steep to log, (2) recognize the importance of retaining trees in some classes of sensitive areas, and (3) emphasize that sinkholes—which are, like landslides, geologic features—need to be considered when planning logging operations.

The Tennessee logging BMPs list landslides as a type of sensitive area, which the document defines as "site-specific natural or topographic features of consequence to aquatic resources…". The Tennessee BMP document states that skidding and road location should be avoided within sensitive areas, runoff should not be directed into sensitive areas, and soil exposure and compaction and should be limited in sensitive areas. The document does not include any guidance specifically regarding identification or assessment of landslides or landslide prone slopes.

The Virginia document states, "Tall cut slopes may require back-sloping to achieve stability and successful revegetation. Slopes of 1:1 or flatter are preferred if the terrain permits." It does not address landslides that may exist or develop in areas that are not cutslopes.

The Wyoming document includes a photograph of a landslide in a section titled "Naturally Caused Sediment" and a statement that "Sediment originates from mudslides…"

The Montana document mentions landslides three times in the context of forest ecosystem disturbance and sediment sources, and states "…events such as landslides and floods have had considerable influence on forest and watershed function." The document does not include any guidance regarding identification or assessment of landslides or landslide prone slopes in relation to logging.

Although the New Mexico logging BMPs do not specifically include the word landslide, they do state that "Road location, design, and construction shall address…the stability of slopes where roads are cut" and include topography and slope stability among the items on a planning and design checklist, which can be interpreted to include landslides and landslide-prone slopes. New Mexico defines "excessive slope" as a slope of more than 40 percent over a distance of 80 yards, requires identification of excessive slopes within cutting units, and requires a description of the ways that forest harvest practices standards will be met, as part of forest harvest plans.

Washington has a comprehensive approach to forest practices that explicitly considers landslides and their relationship to logging, based on its Forest Practices Act as implemented through rules adopted by its Forest Practices Board. The word "landslide" occurs 94 times throughout the 457-page Forest Practices Board Manual, which includes a 93-page section titled "Guidelines for Evaluation Potentially Unstable Slopes and Landforms". That section includes detailed examples of landslides, a review of office and field methods used to identify potentially unstable slopes and landforms, and advanced topics such as lidar processing and debris flow runout modeling. The document distinguishes between situations that can be adequately addressed by general practitioners and those that require extra attention from qualified experts. General practitioners can be landowners, foresters, and company engineers or consultants (including licensed geologists). A qualified expert is defined by state law as "…an engineering geologist or as a hydrogeologist (if the site warrants hydrologist expertise), with at least three years of field experience in the evaluation of relevant problems in forested lands". The state Department of Natural Resources maintains a register of experts appropriately licensed and qualified to practice geology related to forest activities. [1]

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[1] Like Kentucky, Washington and 28 other states license or otherwise regulate professional geologists. Washington additionally offers specialty endorsements in engineering geology and hydrogeology that require knowledge and

Oregon likewise has a comprehensive Forest Practices Act and a guidance document for identifying designated sediment source areas likely to experience landslides that will trigger debris flows capable of delivering sediment to streams; trigger source areas within sediment source areas that are most likely to generate high-volume debris flows; and debris flow traversal areas. The guidance document, which went into effect in January 2024, prescribes a four-step office- and field-based process undertaken before commercial logging is allowed to begin, including specific geologic, geomorphologic, hydrologic, and sylvicultural criteria used to identify areas of concern. The state has developed a topographic "slopes model" to identify slopes with a high likelihood of generating landslides and/or debris flows that might impact fish-bearing streams. The slope model information, including designated sediment source and debris flow traversal areas, is available through an interactive online map service. Oregon requires that at least 50 percent of designated sediment source areas in each harvest unit be left unharvested; the unharvested areas are known as slope retention areas (SRAs). The Oregon Forest Practices Act also includes a provision for the State Forester to certify practitioners who have "…completed training and demonstrated sufficient knowledge to determine the field delineation of the final boundaries for slope retention areas." There is separate technical guidance for landslide hazard areas that have downslope public safety risks.

California annually updates a 400+ page set of forest practice rules and has a multi-stage timber harvest plan review process that includes input from the California Geological Survey. The rules define different kinds of landslides and landforms associated with landslides (e.g., headwall swales) as well as unstable areas and soils. Specifically, the rules include unconsolidated[2], non-cohesive soils and colluvium as unstable soils. The rules state, "Such soils are usually associated with a risk of shallow-seated landslides on slopes of 65% or more, having non-cohesive soils less than 5 ft. deep in an area where precipitation exceeds 4 in. in 24 hours in a 5-year recurrence interval." "Continuing landslide or soil erosion problems related to past or ongoing land-use activities" are one of the criteria that can justify classification of watersheds as sensitive to further logging in which further logging would have a potential "…to cause, or contribute to ongoing, significant adverse cumulative effect(s)". Drainage measures are to be implemented such that they avoid "…concentration of flow onto unstable or potentially unstable areas, such as known active landslides, hummocky ground, concave headwalls, or steep fillslopes." The California Geological Survey has additionally published two documents relevant to landslides and logging: Guidelines for Geologic Timber Harvesting Plans (CGS Note 45) and Factor Affecting Landslides in Forested Terrain (CGS Note 50). Table 1 includes links to both of those CGS reports.

US FOREST SERVICE SLOPE STABILITY GUIDANCE DOCUMENTS

As the result of an ambitious multi-decadal program of applied research and professional practice refinement to support science-based resource management, the U.S. Forest Service published a 3-volume slope stability reference guide for national forests (Hall et al., 1994).

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experience above and beyond those required for a basic geologist license. Oregon and California offer specialty endorsements for engineering geologists.

[2] "Unconsolidated" is used differently by geologists and geotechnical engineers. In this context, it is the geological meaning synonymous with "unlithified" or "uncemented".

Although now 30 years old and written before the existence of modern technologies like lidar and easily used GIS software to facilitate detailed spatial analyses, and not strictly a BMP document, the guide remains one of the best available references about the technical aspects of evaluating the stability of steep forested slopes in the context of resource management. It is essentially a best professional practice document for forest slope stability investigations that is readily adaptable to current technologies, for example the use of high-resolution lidar images rather than aerial photographs or topographic contour maps to identify landslide-prone slopes.

The U.S. Forest Service slope stability reference guide (Hall et al., 1994) is notable for its cross-disciplinary integration of engineering geology with geotechnical engineering and its formalization of a three-level approach to slope stability evaluation, as described here:

- Level I slope stability investigations are conducted for "…watershed analysis, ecosystem management support, and timber sale area planning" and can include office evaluation of existing geological and geotechnical information, field reconnaissance to verify preliminary office interpretations, and delineation of geomorphic zones for evaluation of the potential for slope instability from natural processes and forest management activities such as logging (Hall et al., 1994). Level I slope stability investigations can include quantitative deterministic or probabilistic slope stability analyses, as described below, to evaluate current slope stability and changes likely to occur as the result of activities such as logging.

- Level II slope stability investigations build upon the results of Level I investigations and are intended to evaluate slope stability along roads or other corridors; they include definition of road design segments based on soil and rock types, drainage, and geologic processes in each segment. Level II investigations specifically and quantitatively address changes in slope stability as a result of building roads across potentially unstable slopes.

- Level III slope stability investigations are detailed site-specific investigations used to support design of engineered stabilization measures, including preparation of field-developed engineering geologic cross-sections, sampling and measurement of relevant geotechnical properties, installation of monitoring devices such as piezometers, and advanced or design-level slope stability analysis.

QUALITATIVE AND QUANTITATIVE EVALUATION OF FOREST SLOPE STABILITY

Landslides and landforms indicative of landslide susceptibility in forested terrain are best mapped using airborne lidar-based topographic maps and their derivatives, followed by field checks to confirm interpretations made in the office.

Kentucky has had freely available statewide lidar coverage available through its KyFromAbove program (https://kyfromabove.ky.gov) since early 2017. The available products include hydro-corrected 5-ft digital elevation models (DEMs), multidirectional hillshade images, contours, and classified lidar pointclouds. Some of the initial lidar coverage, including mountainous portions of eastern Kentucky, met U.S. Geological Survey (USGS) lidar quality level QL3 rather than QL2 or above as required for inclusion in the USGS 3DEP national elevation program. Statewide coverage at quality level QL2 should be completed in 2024, allowing for production of a more resolute 2-ft statewide lidar DEM. The USGS anticipates 2025 availability of nationwide high-resolution lidar-based digital elevation model meeting its 3DEP standards (with interferometric radar coverage in Alasks).

The grid spacing, cell size, or raster size of a lidar DEM—sometimes incorrectly referred to as the DEM resolution—is important because it places limits on the size of features that can be interpreted by geologists. To illustrate the nature of resolution, Keaton and Haneberg (2013) resampled a lidar DEM depicting an obvious landslide to different raster sizes. They suggested the ability of a DEM to resolve a geologic feature such as a landslide is about 10 times its raster size. In other words, the smallest landslide that an experienced geologist might expect to resolve using a 5-ft DEM would be on the order of 50 ft by 50 ft (or 2500 ft^2). A 2-ft DEM would improve the minimum resolvable size to about 20 ft by 20 ft (or 400 ft^2). Keaton and Haneberg (2013) also discussed reasons why landslide maps, which are inherently subjective even under the best conditions, made by different geologists may differ in important respects.

Chapella et al. (2019) and Crawford et al. (2021) described a set of uniform criteria and confidence ratings used to reduce landslide mapping subjectivity on Kentucky Geological Survey projects. Crawford (2012) provided examples of visualization techniques useful for mapping landslides from lidar coverage of northern Kentucky (Figure 3). Although not focused specifically on Kentucky, Haneberg (2017) also summarized technologies and techniques useful for landslide hazard assessment. Useful techniques include combinations of multiple hillshade images with different illumination directions, multidirectional hillshade or slopeshade images, topographic contours draped over hillshade images, and use of derivative maps quantifying slope steepness, roughness, and/or curvature viewed within GIS software so that multiple map layers can be combined as necessary to support the best possible interpretation of the landscape.

Landforms indicative of landslide occurrence or susceptibility visible on lidar-derived images include concave headwalls or headscarps, convex toes or zones of accumulation, lateral scarps, and hummocky terrain. Some landslides mobilize into debris flows characterized by concave sediment source areas, levees, and depositional lobes. Not all those landforms may be visible in any specific instance, nor are all required to confidently identify landslides. Confidence ratings such as those described by Chapella et al. (2019) and Crawford et al. (2021) can be used to convey uncertainties in landslide-related feature identification. In many cases, especially for older landslides whose topographic expression may have degraded over time, indications of landslides may be subtle and require interpretation by a geologist experienced in landslide mapping. Field confirmation of office-mapped landslides is important because it can yield important additional information such as the locations of springs or seeps, vegetation changes, abnormally distorted or pistol-butted trees, and open cracks that may not be visible on lidar images or aerial photographs.

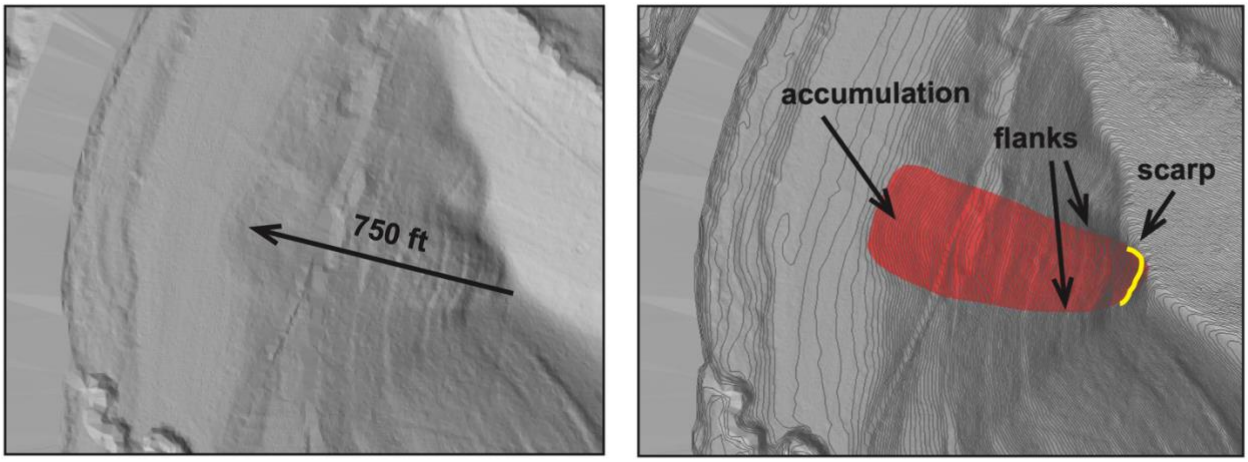

Figure 3—Example of a subtle northern Kentucky landslide identified from airborne lidar hillshade imagery and topographic contour patterns. Left: Hillshade image. Right: Hillshade superimposed with 2-ft topographic contours and annotated with landslide features. Source: Crawford (2012).

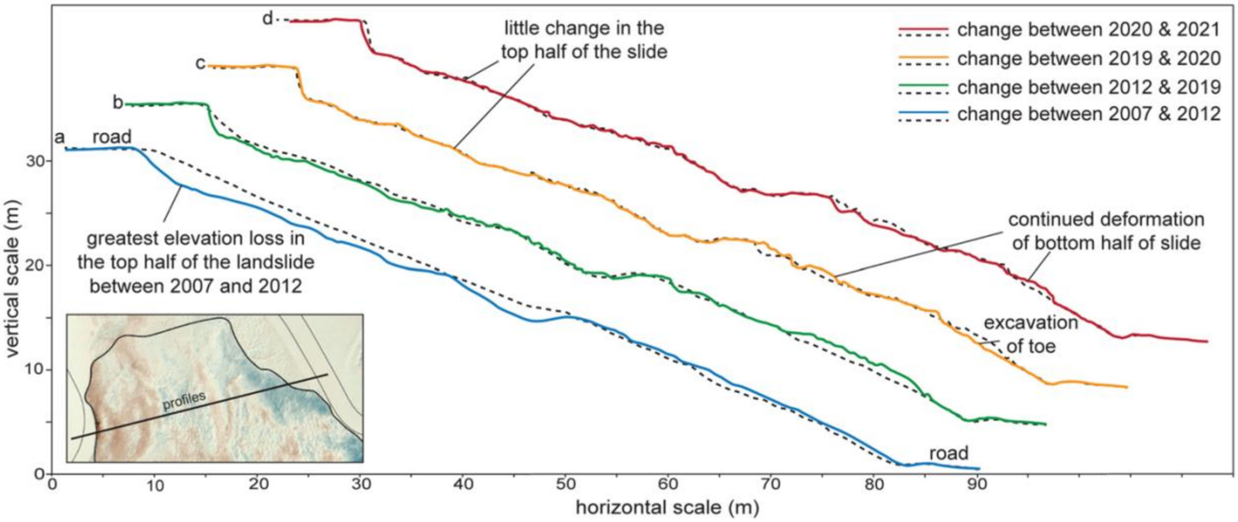

Figure 4—2007 through 2021 surface elevation changes of a northern Kentucky landslide calculated from DEMs produced from three different technologies. Inset map shows areas of elevation gain (blue) and loss (brown). Source: Johnson et al. (2023).

In situations where multiple high-resolution digital elevation datasets are available, DEM differencing may help to define areas of ongoing landslide movement. Experience has shown, however, that several steps may be necessary to account for systematic differences in DEMs produced using different technologies, with different cell sizes, and at different times. The best solution is to tie the DEMs to benchmarks surveyed immediately before or after each data collection campaign. If benchmark survey data are not available, which often occurs in cases of practical interest, comparison of elevation values in areas where is can be reasonably inferred that no change has occurred may be used as a proxy. Johnson et al. (2023) described how to correct for mismatches between DEMs produced at different times using different technologies and cell sizes and documented the decadal activity of a slow-moving landslide in northern Kentucky. Even after basic corrections are applied, DEM difference maps should always be evaluated critically with respect to the best available (typically the most recent) dataset. DEMs produced by digitizing topographic contours produced using pre-GPS analog photogrammetry, especially in steep forested terrain susceptible to landslides, can also have horizontal positional errors that require advanced rectification techniques before they can be directly compared to modern lidar DEMs (Zhu et al., 2022). In eastern Kentucky, the horizontal error between photogrammetrically derived 10-m legacy DEMs and modern lidar DEMs is in many cases 100 ft or more.

The effect of logging on slope stability can be quantitatively evaluated with the 1-D limit equilibrium slope stability equation used by the U.S. Forest Service in its watershed-level slope stability evaluation guidance document and software (Hammond et al., 1992; Hall et al., 1994; also see Haneberg, 2004 a):

$$FS = \frac{c_r + c_s + [q_t + \gamma_m D + (\gamma_{sat} - \gamma_w - \gamma_m) H_w D] \cos^2\beta \tan\phi}{[q_t + \gamma_m D + (\gamma_{sat} - \gamma_m) H_w D] \sin\beta \cos\beta}$$

where FS is the factor of safety against sliding; c_r and c_s are the root and soil cohesive strengths; q_t is the surcharge exerted by the weight of trees; γ_{sat}, γ_m, and γ_w are the unit weights of saturated soil below the phreatic surface, moist soil above the phreatic surface, and water; H_w is the height of the phreatic surface above a potential landslide slip surface; D is the thickness of soil above a potential landslide slip surface; β is the slope angle (in degrees); and ϕ is the effective angle of internal friction of the soil. The factor of safety, FS, is the ratio of resisting to driving forces acting within the slope. Values of $FS < 1$ indicate an unstable condition whereas values of $FS > 1$ indicate a stable condition. A value of exactly $FS = 1$, which is virtually never encountered in practice, represents a critical or limiting state of equilibrium within the slope. The FS equation can be solved in a variety of ways, from simple deterministic spreadsheet calculations computationally intensive probabilistic simulations that treat the input variables as probability distributions to account for inherent uncertainties. The U.S. Forest Service published a probabilistic computer program named LISA—for Level I Stability Analysis—that is well-documented and remains publicly available (Hammond et al., 1992). It performs calculations for a specific slope or location and is not readily applied for area-wide map-based analyses. The LISA documentation is available at:

https://forest.moscowfsl.wsu.edu/cgi-bin/engr/library/searchpub.pl?pub=1992a

and an executable MS-DOS LISA program file is available at:

https://forest.moscowfsl.wsu.edu/engr/lisa0.html

Haneberg (2004 a) developed a computationally efficient first-order, second-moment approach that allows the FS equation to be easily applied across entire watersheds using digital elevation model, soil geotechnical unit, and forest stand maps (Windows and Apple OS X versions of the FORTRAN computer program PISA-m, an acronym for Probabilistic Infinite Slope Analysis for Maps, are available from him upon request). Escobar-Wolf et al. (2021) subsequently developed an ArcPy implementation of the PISA-m algorithms that allows the calculations to be performed within GIS software.

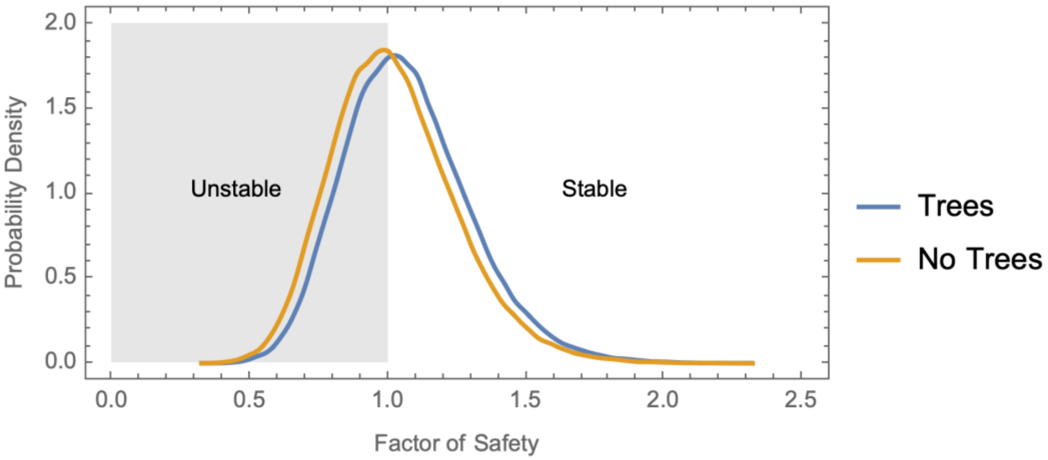

Figure 5—Results of iterative probabilistic slope stability calculations to illustrate the destabilizing effect of removing tree weight and root strength from a hypothetical slope.

As an illustration of the way the *FS* equation can be used to evaluate the effects of logging and subsequent root decay on slope stability, Figure 5 shows the results of an iterative Monte Carlo evaluation of the equation using a published sample data set from a U.S. Forest Service slope stability guidance document (Hall et al., 1994; also see Haneberg, 2004 a,b). Appendix A of this report includes the Mathematica commands used to produce the plot. For each of two scenarios—one with tree root cohesion and surcharge and the other without tree root cohesion and surcharge—the *FS* equation was solved 100,000 times with the variables for each iteration randomly selected from pre-specified probability distributions reflecting input uncertainty. Using a probabilistic formulation allows input parameter uncertainty, which is ever present and unavoidable, to be explicitly incorporated into the calculation.

In Figure 5, the blue line represents the ensemble of *FS* values calculated for the forested slope and the gold line represents the ensemble of *FS* values calculated for the unforested post-logging slope. Removing root strength and tree surcharge decreases the mean factor of safety from 1.07 to 1.02, very near the limiting state of equilibrium. The probability of sliding, Prob [$FS < 1$], for each condition is the area under its curve for values of $FS < 1$ (indicated by the gray area in Figure 5). Removal of root strength and tree surcharge from the *FS* equation in this case increases the probability of sliding from 41 percent to 50 percent. Increased pore water pressure because of logging, which is not included in the calculations, would further reduce the factor of safety and increase the probability of sliding.

The values used in this example are not intended to represent any specific or generalized Kentucky hillside; rather, they were chosen because of their previous use to illustrate the application of the method by Hall et al. (1994) and Haneberg (2004a). Use of the *FS* equation for evaluation of land management or public safety options should be overseen by appropriately licensed professional geologists and/or engineers with experience in the evaluation of steep forested slopes, particularly with regard to selection of shear strength parameters and estimation of pore water pressures likely to develop during the analysis period. Design of any remedial measures should be overseen by an appropriately licensed engineer.

Application of the logistic regression model developed by Crawford et al. (2021) to produce the Kentucky Geological Survey county-wide landslide susceptibility maps requires a level of GIS expertise impractical for application individual logging operations in Kentucky. A simplified version of the model that accounts only slope steepness, however, can be used as an approximate indicator of landslide susceptibility. If all variables except slope angle are set to zero, equation (4) in Crawford et al. (2021) becomes:

$$z = -2.0158 + 0.093\, S_{min}$$

where S_{min} is the minimum slope angle (in degrees) within an appropriately sized moving window and landslide susceptibility is given by the probability, P, as

$$P = \frac{1}{1 - e^{-z}}$$

Figure 6 is a plot of P over a realistic range of S_{min} values. Exceptionally steep slopes (above 45° or 100%) are unlikely to accumulate the soil necessary for landslides to occur, although they may be susceptible to rock falls or rock topples unlikely to deliver sediment to streams.

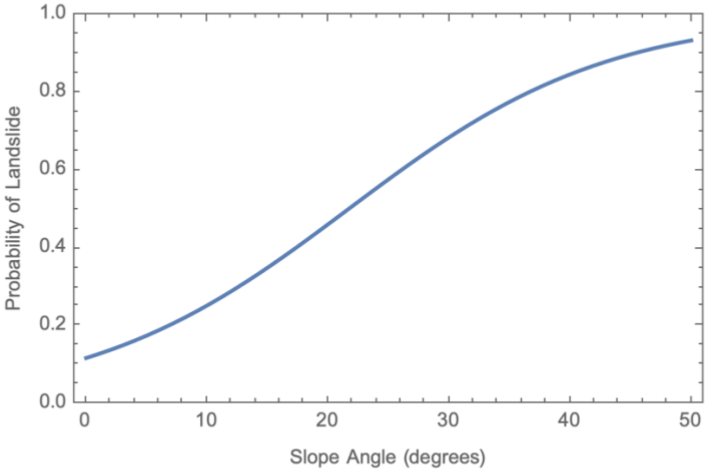

Figure 6—Plot of landslide probability as a function of minimum slope angle within a moving window alone, ignoring other geomorphological factors (cf. Crawford et al., 2021)

RECOMMENDED BEST MANAGEMENT PRACTICES

Landslides can be naturally occurring events triggered by rainfall, snowmelt, and seismic shaking. In that regard, they can be important elements of natural landscape evolution. The extensive body of literature described in this report and practical experience, however, shows that logging related activities can also increase landslide activity through loss of root strength, increases in soil moisture or pore water pressure, and roadbuilding. The BMPs described below are intended to reduce the human-driven component of landsliding in logged watersheds.

The landslide-related BMPs recommended in this section are based on a synthesis of state-of-the-practice documents from Oregon, Washington, and California (listed in Table 1) and the U.S. Forest Service slope stability reference guide (Table 1 and Hall et al., 1994), modified to account for current technology (e.g., freely available lidar digital elevation data and GIS software), regional geologic characteristics, and the current state of geologic practice in Kentucky.

Current Kentucky BMPs (Kentucky EEC, 2022) "…are designed to prevent and minimize nonpoint water pollution primarily from timber harvesting." The BMPs recommended in this section complement—not replace—existing Kentucky BMPs by providing the guidance necessary to prevent or minimize potentially significant impacts to water quality by sediment delivery from landslides.

Although these BMPs were developed in the context of eastern Kentucky topography, geology, and landslide processes, they can be adapted to other states if local factors are given proper consideration. If these recommended BMPs are adopted beyond Kentucky, it should be done in collaboration with qualified and appropriately licensed geologists and engineers to ensure that the practices are appropriate relative to regional and local geologic and geotechnical contexts. There may be justification for modifying slope angle thresholds, including or excluding locally specific geological features such as coal beds, and using different shear strength values for slope stability calculations.

The BMPs elaborated below are in a format that can be incorporated into the existing Kentucky Logging BMP Field Guide and are written at a level of specificity intended to reduce ambiguity and clarify expectations, as opposed to more general statements about avoiding landslide-prone areas.

National forests, including the Daniel Boone National Forest in Kentucky and, more broadly, in central Appalachia can incorporate the recommended BMPs (or similar regionally-tailored BMPs) into their Land and Resource Management Plans ("Forest Plans") as specific forest-wide standards through an amendment or revision process.

BMP 1: Forest landslide susceptibility and other slope stability investigations should be performed by qualified and experienced geologists and/or geotechnical engineers.

- For work on state or private lands, "qualified professional" in the context of these BMPs means a state-licensed professional geologist or civil engineer with specialized experience evaluating the geomorphology and stability of steep forested slopes.

- Employees of federal agencies such as the U.S. Forest Service are exempt from state licensing requirements but, if they do not hold active professional licenses, should otherwise be qualified through a combination of formal education, work experience, peer-reviewed publications, and/or credentials such as a Certified Professional Geologist designation from the American Institute of Professional Geologists.

- Not all states license professional geologists. If similar BMPs are adopted in a state that does not license professional geologists, qualifications should be demonstrated through a combination of formal education, work experience, peer-reviewed publications, and/or credentials such as a Certified Professional Geologist designation from the American Institute of Professional Geologists.

- Engineering design—for example, road prism, retaining structure, or slope drainage system design—should be performed under the supervision of an appropriately licensed engineer. Site investigations in support of engineering design work require collaboration of qualified geologists and engineers to ensure that data collected are both geologically representative of site conditions and provide information sufficient for design needs.

- Professionals such as foresters, hydrologists, soil scientists, biologists, or environmental scientists will generally not meet the geologist or engineer qualification, experience, and subject matter expertise expectations laid out in this BMP. If they perform the kinds of investigations outlined in these BMPs, it should be under the supervision of a qualified geologist or engineer.

BMP 2: Timber harvest planning should begin with production of a slope steepness map using the best and most current topographic data available for the watershed in which logging is anticipated.

- Unless a landowner or logging operator has collected more resolute data, the best available data for slope maps in Kentucky will generally be the most recent 2-ft DEMs from the KyFromAbove program (https://kyfromabove.ky.gov). As of April 2024, most of Kentucky is covered by airborne lidar topographic data meeting USGS quality level QL2 or better, but some areas in eastern Kentucky are currently covered only by older 5-ft lidar data that only meets QL3 requirements. The lower 48 states should have complete QL2 or better DEM coverage available in 2025 through the USGS 3DEP cooperative program (https://www.usgs.gov/3d-elevation-program).

- DEMs, especially high-resolution lidar DEMs, can sometimes benefit from gentle smoothing before derivatives like slope steepness are calculated. To preserve essential landforms, moving windows larger than 5 by 5 raster cells should be avoided if a DEM is smoothed prior to slope steepness map production. The slope steepness map and its metadata should also include a description of any kind of filtering or smoothing used (e.g., moving mean, median, or gaussian smoothing window).

- Ground surface slope angles should be calculated using a standard GIS slope function using a 3 by 3 cell moving window applied to a high-resolution lidar DEM with minimal smoothing as described it the previous bullet point.

- The slope map should clearly indicate whether the steepness is given in percent (common in agriculture and forestry) or degrees (common in geology and engineering) to avoid confusion.

- Manual estimation of slope from printed contour maps at a limited number of points or reliance on manually prepared topographic profiles is insufficient given the easy availability of high-resolution lidar DEMs.

BMP 3: For individual harvest units or road corridors in which more than 10% of the area has a ground surface slope greater than 20% (11°), a qualified professional with experience in steep forested watershed geomorphology and landslide mapping should perform an office review and site visit with a written summary report to identify areas that show evidence of past, current, or potential future landslide activity.

- The percentage of the area exceeding the 20% (11°) threshold should be calculated using all slope values within the area as described in BMP 2, either empirically from a histogram or analytically from the cumulative distribution function of a theoretical probability distribution (e.g., normal, log-normal, beta) appropriately fitted to the slope values. The written report should include slope histograms and, if used, details of the best fit probability distributions used to support the determination.

- In addition to the written report, all available data should be compiled in a GIS project using standard file formats to support the best possible interpretation and integration of information providing insights about slope stability or instability in relation to potential logging activities.

- The ensemble of information should minimally include a lidar DEM and derivatives (topographic contours, multiple hillshade and/or slopeshade images, roughness and curvature maps, and a slope map) to support multilayered geomorphological interpretation of the watershed. The written report and/or GIS metadata should include data sources and any processing or calculations done to produce each layer. Landslide susceptibility or occurrence maps and coal seam arcs available through the Kentucky Geological Survey or U.S. Geological Survey—or equivalent information available in other states—should be included as layers in the GIS project. (Information about KGS map services and GIS data availability can be found at https://kgs.uky.edu/kgsweb/main.asp)

- The compiled information should be used for office-based mapping of landforms potentially related to landsliding (e.g., concave headwalls, cove landforms, headscarps, or source areas; convex or bulked toes; lateral or internal scarps; atypically rough or hummocky topography; visibly offset roads or stream channels). It is not sufficient to simply list the coordinates of a point representing a landslide-related landform. Office mapping should be followed by field reconnaissance to verify the maps and add features such as seeps, areas of anomalous vegetation, or open cracks not visible on lidar-based layers. This is equivalent in scope and intent to a Level I slope stability analysis as described by Hall et al. (1994) as well the procedures outlined in the Oregon and Washington forest practice rule documents listed in Table 1.

- The 20% (11°) threshold is a limiting value calculated using an infinite slope factor of safety equation with a typical Appalachian sedimentary rock colluvium residual friction angle of 22°, no cohesive strength, slope parallel seepage, and a phreatic surface coincident with the ground surface. The limit is also the slope that yields 25% probability of landslide occurrence using the Crawford et al. (2021) landslide susceptibility logistic regression equation evaluated using only slope angle (all other variables set to zero), rounded to the nearest 10%. Landslides are unlikely to occur on slopes less than the threshold even if the ground is completely saturated and root strength eliminated. These values may be modified based on local experience if the BMPs are adopted in other states.

BMP 4: Within harvest units or road corridors in which more than 10% of the area has a ground surface slope greater than 20% (11°), areas susceptible or highly susceptible to landsliding should be delineated.

Portions of harvest units or road corridors should be considered **susceptible areas** if they meet one or more of the following criteria:

- Fall within an area of moderate or higher susceptibility on Kentucky Geological Survey landslide susceptibility maps (currently available only for counties in the Big Sandy Area Development District) or similar susceptibility maps in other states.

- Fall within a 100-ft buffer of a landslide polygon shown on Kentucky Geological Survey landslide occurrence maps (landslides shown on 1:24,000 geologic quadrangle maps, landslides mapped from aerial photographs, or landslides mapped from lidar) or within a 200-ft buffer of a point location in the Kentucky Geological Survey landslide database (or equivalent databases and maps that may be available in other states). The level of coverage of the maps varies across eastern Kentucky.

- Fall within a 100-ft buffer of a coal seam depicted on Kentucky Geological Survey 1:24,000 geologic quadrangle maps or in associated GIS databases. This criterion would not necessarily be applicable in areas outside of Kentucky for which relationships between coal beds and landslides do not exist.

- Fall within a 100-ft buffer of any landslide-related landform identified during office mapping and verified during field reconnaissance or initially identified during field reconnaissance.

- Have a ground surface slope between 40% and 50% (22° and 27°) based on a slope map prepared per BMP 2. These limits are based on slopes that yield 50% and 75% probability of landslide occurrence using the Crawford et al. (2021) landslide susceptibility logistic regression equation evaluated using only slope angle (all other variables set to zero), rounded to the nearest 10%.

Portions of harvest units or road corridors should be considered **highly susceptible areas** if they meet one or more of the following criteria:

- Fall within an area of high susceptibility on Kentucky Geological Survey landslide susceptibility maps (currently available only for counties in the Big Sandy Area Development District) or similar susceptibility maps in other states.

- Intersect with any landslide polygon shown on Kentucky Geological Survey landslide occurrence maps or 100-ft buffer of a point location in the Kentucky Geological Survey landslide database (or equivalent databases and maps that may be available in other states).

- Intersect with a coal seam depicted on Kentucky Geological Survey 1:24,000 geologic quadrangle maps or in associated GIS databases. This criterion would not necessarily be applicable in areas outside of Kentucky for which relationships between coal beds and landslides do not exist.

- Intersect any landslide feature identified during office mapping and verified during field reconnaissance or initially identified during field reconnaissance.

- Have an average ground surface slope greater than 50% (27°). This limit is based on slopes that yield greater than 75% probability of landslide occurrence using the Crawford et al. (2021) landslide susceptibility logistic regression equation evaluated using only slope angle (all other variables set to zero), rounded to the nearest 10%.

BMP 5: Take steps to minimize the likelihood of sediment delivery to streams—or other undesirable consequences such as road or structural damage, oil or gas pipeline rupture, or habitat loss—from landslides triggered by logging activities in susceptible or highly susceptible areas.

- Within **susceptible areas**, regeneration harvests should be avoided and at least 50% of the basal area should be left uncut OR it should be demonstrated, using quantitative slope stability analyses based on representative values for the site and reviewed by a disinterested qualified geologist or geotechnical engineer, that logging will not reduce the long-term stability of the slope below a deterministic factor of safety of $FS = 1$ or a probabilistic value of Prob $[FS < 1] = 0.50$. This will generally entail the use of a representative residual, not peak, angle of internal friction, no soil or root cohesion, and a conservatively high phreatic surface. It is recommended that the analysis assume the phreatic surface will at some time reach the ground surface during the decadal period before root strength has recovered unless other supporting data are available.

- Cutting, filling, and other earth moving for roads, landings, or other aspects of logging operations in **susceptible areas** should be subject to review and approval by a licensed engineer to ensure they will not contribute to increased instability (including design and implementation of any necessary stabilization measures).

- Logging operations in susceptible areas should be suspended during times when the ambient moisture content exceeds the plastic limit of the colluvium, residuum, or other geologic deposits on the slope.

- In **highly susceptible areas**, 100% of the area should be left uncut.

- The percentages of area left uncut should be applied to each susceptible or highly susceptible area within each harvest unit, not averaged over a group of larger areas.

- Cutting, filling, and other earth moving for roads, landings, or other aspects of logging operations should be avoided entirely in **highly susceptible areas**.

BMP 6: Implement a plan for long-term monitoring of susceptible and highly susceptible areas that intersect harvest units through the period of post-logging root strength loss and recovery, which may be on the order of a decade or more.

- A qualified geologist, geotechnical engineer, hydrologist, or soil scientist should perform at least annual field visits to inspect for signs of ongoing or incipient slope movement.

- If signs of ongoing or incipient movement are detected, consult with a qualified geologist, geotechnical engineer, hydrologist, or soil scientist to 1) determine the risk of sediment delivery to downslope streams and 2) develop a monitoring program that may include frequent field inspections, repeat surveys of monuments located to adequately characterize any slope movement, displacement gauges or transducers, piezometers and/or soil moisture sensors.

- In some cases, and depending on available resources, repeat lidar surveys (including drone-borne lidar) or interferometric synthetic aperture radar (InSAR) monitoring may be useful.

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Appendix A

Monte Carlo simulation of the Hammond et al. (1992) infinite slope stability equation

William C. Haneberg
April 9, 2024

This is a Mathematica 13 notebook with a set of commands to perform and display the results of Monte Carlo simulations of the infinite slope stability equation used in the U.S. Forest Service computer program LISA (Hammond et al., 1992). The input probability distributions are those used as an example in Hall et al. (1994) and Haneberg (2004 a) and are not intended to represent any actual slope in Kentucky. Two ensembles of results are calculated: one using the complete input dataset and a second with the tree surcharge and root cohesion values set to zero to simulate the effects of deforestation. Additional complications could be added, for example allowing the phreatic surface height and/or root strength to vary over time. Likewise, additional statistics beyond the arithmetic mean and Prob[FS < 1] could be easily added to the calculations. The primary purpose of this notebook is to demonstrate how Figure 5 in the report was produced.

```
In[1]:= (*
        First, define the function FS to calculate the Hammond et al. (1992)
         infinite slope factor of safety against sliding. Descriptions
         of the variables are in the main text of the report.
        *)
```

```
In[2]:= FS[cr_, qt_, cs_, ϕ_, γsat_, γm_, γw_, T_, Hw_, β_] :=
         cr + cs + (qt + γm T + (γsat - γw - γm) Hw T ) Cos[β]^2 Tan[ϕ]
         ─────────────────────────────────────────────────────────────
                 (qt + γm T + (γsat - γm) Hw T ) Sin[β] Cos[β]

        (* Set random seed to ensure reproducibility of the probabilistic results *)

        SeedRandom[1234];

        (* Set number of Monte Carlo iterations *)
```

```
nsteps = 100 000;

(*
Iterate the FS function nsteps times
 both with and without tree surcharge and cohesion
*)

results = Reap[
    Do[
     Module[{},
      T = RandomVariate[
        NormalDistribution[
         Mean[{1.68, 4.42}], (4.42 - 1.68) / 6
        ]
       ];
      β = RandomVariate[
        NormalDistribution[
         Mean[{19., 33.}] , (33. - 19.) / 6
        ]
       ];
      qt = RandomVariate[
        NormalDistribution[
         Mean[{0.72, 2.15}], (2.15 - 0.72) / 6
        ]
       ];
      cr = RandomVariate[
        NormalDistribution[
         Mean[{0.24, 1.68}], (1.68 - 0.24) / 6
        ]
       ];
      cs = RandomVariate[
        NormalDistribution[
         Mean[{0.24, 1.68}], (1.68 - 0.24) / 6
        ]
       ];
      ϕ = RandomVariate[
        NormalDistribution[
         Mean[{17., 47.}] , (47. - 17.) / 6
        ]
       ];
      γm = RandomVariate[
        NormalDistribution[
         Mean[{16.2, 21.3}], (21.3 - 16.2) / 6
        ]
```

```
         ];
        γsat =  RandomVariate[
          NormalDistribution[
           Mean[{19.2, 22.0}], (22.0 - 19.2) / 6
          ]
         ];
        Hw = RandomVariate[TriangularDistribution[{0.3, 0.7}]];
        Sow[
         {FS[cr, qt, cs, ϕ Degree, γsat, γm, 9.81, T, Hw, β Degree],
          FS[0.0, 0.0, cs, ϕ Degree, γsat, γm, 9.81, T, Hw, β Degree]
         }
        ]
       ], {i, nsteps}
      ]
    ]⟦2, 1⟧;

(* Put the results into more convenient lists for clarity and plotting *)

results = Transpose[results];
resultsTrees = results⟦1⟧;
resultsNoTrees = results⟦2⟧;

(* Calculate mean values for each ensemble of results *)

Print["Mean FS trees = ", Mean[resultsTrees]]
Print["Mean FS no trees = ", Mean[resultsNoTrees]]

(* Calculate Prob[FS < 1] by simple counting for each ensemble of results *)

Print["Prob[FS < 1] trees = ", Length[Select[resultsTrees, # < 1 &]] / Length[resultsTrees] // N]

Print["Prob[FS < 1] no trees = ", Length[Select[resultsNoTrees, # < 1 &]] / Length[resultsNoTrees] // N]
Print["\n"]

(*
Display a plot showing smooth kernel histograms for each ensemble of results
  and a gray area showing the portions of the curves with FS < 1
 *)

Show[Graphics[{GrayLevel[0.9], Rectangle[{0, 0}, {1, 2}]}],
  PlotRange → {{-0.1, 2.6}, {-0.1, 2.1}}, Frame → True, AspectRatio → 1 / 2,
```

```
  FrameLabel → {"Factor of Safety", "Probability Density"}];

SmoothHistogram[{resultsTrees, resultsNoTrees}, Automatic, "PDF",
  Frame → True, PlotRange → {0, 2}, PlotLegends → {"Trees", "No Trees"}];

Show[%%, %,
 Epilog → {Inset[Text["Unstable"], {0.45, 1}], Inset[Text["Stable"], {1.75, 1}]}]
```

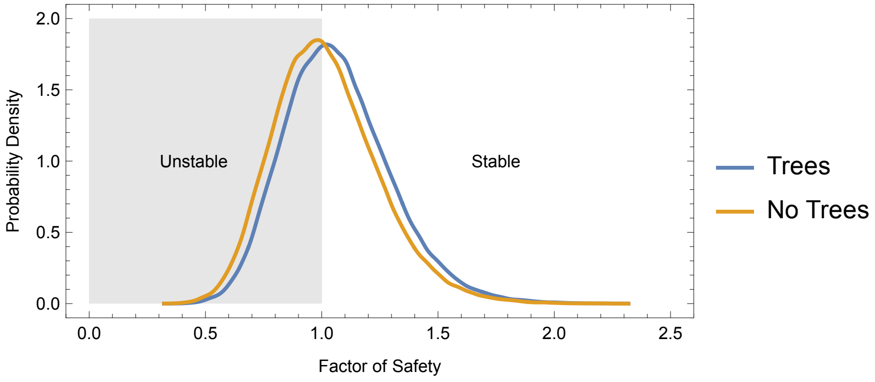
```
Mean FS trees = 1.06845

Mean FS no trees = 1.02089

Prob[FS < 1] trees = 0.40976

Prob[FS < 1] no trees = 0.49664
```

Out[16]=



Appendix B
Review of the Daniel Boone National Forest “Jellico Vegetation Management Plan Project Soil Effects Analysis” Document

William C. Haneberg, Ph.D., C.P.G., P.G.

Geological and Geohazards Consultant
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AIPG Certified Professional Geologist 10311
Kentucky Professional Geologist 171390

May 13, 2024

PURPOSE AND SCOPE

This document is a technical review of the Effect 2 (slope stability) aspects of the Daniel Boone National Forest document "Jellico Vegetation Management Plan Project Soil Effects Analysis", subsequently referred to as "the report", prepared by Dr. Claudia Cotton and dated April 4, 2024.

The review was undertaken for Kentucky Heartwood, which provided a PDF copy of the Forest Service report. Three KyFromAbove airborne lidar digital elevation model (DEM) tiles were additionally downloaded, processed, and interpreted as part of the review to demonstrate the occurrence of landforms indicative of past and potential slope instability in two areas referenced in the report. No other data were produced, additional analyses performed, or documents reviewed.

The review does not cover the Effect 1 (erosion from exposed bare or mineral soil) or Effect 3 (herbicide dissipation in soil) of the report; however, the potential for contribution of sediment to streams is discussed within the context of slope instability. The terms slope instability and landslide are used interchangeably throughout, with landslide understood to generically include a range of downslope mass movements such as earthflows, slumps, rotational landslides, translational landslides, and debris flows.

SUMMARY COMMENTS

The Forest Service assessment of potential slope stability problems associated with proposed logging in the Jellico project plan area, as described in the soil effects analysis report, relied primarily on identification of plastic soils using data from a nationwide Web Soil Survey. The report states that Forest Service staff also used lidar, slope, and geology to identify areas of slope stability within project unit boundaries and subsequently verified them in the field. However, the report includes no details about the lidar, slope, and geology-based identification process or project-wide landslide occurrence or susceptibility maps beyond those showing plastic soil occurrence included. In those regards, the report falls short of expectations for a robust regional or watershed-scale landslide hazard assessment prepared in support of land management decisions.

Table 3 in the soil effects report lists several known landslides as "watch outs" but the report contains neither synoptic nor detailed maps documenting the locations of past and/or currently active landslides or defining the potential susceptibility of logged areas to future landslides (either natural or as a consequence of logging). Locations of the landslides listed in Table 3 are given only at the stand level. There appear to be no properly georeferenced landslide polygons or even landslide centroids that can be used to locate the landslides; if those data exist exist, excluding them from the report was a significant omission. The lack of sufficiently detailed and properly georeferenced maps depicting landslide occurrence and susceptibility on a project-wide scale is a major deficiency of the report.

Interpretation of freely available high-resolution lidar digital elevation models and derivative maps covering two areas in which landslides had been reported to the Forest Service as public comments showed the areas to have complex geomorphology, significant indications of past slope instability, and thus a potential for future slope instability (especially if subjected to roadbuilding, logging, or other disturbances). The soil effects report states that one of the locations was visited but no evidence of a landslide was found and that a landslide at the second location, which may or may not have been visited, was not confirmed. It is not clear from the report language whether "not confirmed" means that the site was visted and no evidence could be seen or that confirmation was not attempted. The compelling evidence for slope instability at those two locations, illustrated further on in this review, casts doubt on the ability of the Forest Service to understand the prevalence of unstable and potentially unstable slopes in one of the most landslide-prone regions in the country.

Although information about soil plasticity can be a useful component of landslide susceptibility studies, the use of soil map units and highly generalized physical properties from a nationwide database is insufficient in the context of the soil effects report and falls far short of the methods routinely used for such work in Kentucky and elsewhere. The Kentucky Geological Survey, for example, has developed a peer-reviewed approach based upon lidar-based landslide inventory mapping by trained geologists, statistical analysis of the regionally significant geologic and geomorphological variables associated with landslide occurrence, and use of modern geospatial processing methods like logistic regression to extend those rigorously developed association across large areas. It is important to know where landslides have occurred; however, it can be equally or even more important to understand where they may occur in the future, especially in the context of land-use planning and environmental impact assessment. As such, the use of modern GIS-based computational tools to predict landslide susceptibility is essential.

Throughout the report, suggestions that plastic soils are uniquely susceptible to rapid pore-water pressure increases—and thus instability—ignore the basic mechanical principles of landslide initiation, dangerously implying that other kinds of soils are not susceptible and need not be considered. That is untrue. A discussion in the report about the increased unit weight of wet plastic soils as a driver of slope instability is similarly naïve and, likewise, dangerously misleading because it appears to suggest the primary potential cause of landslides in the project area will be heavy equipment traffic across wet and heavy plastic soil. The focus on plastic soils and equipment traffic ignores the substantial body of peer-reviewed scientific literature showing a strong relationship between tree removal per se and subsequent landslides due to decadal-scale post-logging tree root cohesive strength decreases and pore-water pressure increases. Nowhere in the soil effects report is the impact of tree removal per se on slope instability considered. Likewise, the report limits the potential impacts of slope instability to plastic soil deformation, reduced water capacity, and issues related to aeration, mineralization, and vegetation growth. The potentially significant water quality and ecological impacts of landslides and debris flows—which in many cases mobilize from landslides—as agents of sediment delivery to streams and water quality degradation is ignored. The report's focus on soil plasticity and equipment traffic while ignoring the potential effects of tree removal on forest slope stability, sediment delivery, and water quality is a major deficiency.

Finally, the report consistently uses a non-standard definition of full-bench roads. Full-bench roads, in which all excavated material is hauled away from a cut, are typically the recommended option when roads must be built across steep and/or potentially unstable ground. Full-bench roads stand in contrast to side-cast or balanced section roads in which some of the excavated material is placed downslope to develop the road prism, thereby loading the slope below the road and decreasing stability. Admonitions to avoid full-bench roads (if understood as conventionally defined) imply that options like side-cast roads are safer options, when they will in fact almost certainly reduce slope stability.

DETAILED COMMENTS

p. 1: The Effect 2 description states "Slope disturbances produced by construction of roads, skid roads, and log landings, etc., can potentially initiate or accelerate existing soil mass movement by undercutting or loading a slope or disrupting established drainage patterns" but does not include tree removal per se as a potential cause of mass movement (i.e., landsliding). However, the text goes on to state "Internal soil strength and external factors (e.g., root systems, ground water supplies, bedrock type) are important aspects of slope stability", which implies that tree removal and subsequent decay of root strength can be a potential cause of mass movement (as is also documented extensively in the peer-reviewed scientific literature). The text needs to be revised to include tree removal per se, not just secondary effects of logging like road or landing construction, as a factor that can contribute to or cause slope instability.

p. 1: The Effect 2 statement "These shale's [sic] weather to plastic clays, which increases the risk that soils will slump when subjected to a rapid rise in groundwater or concentrations of overland flow" is misleading for three reasons:

- First, potentially destabilizing pore-water pressure increases—as "rise of groundwater" is used in this context—are not unique to plastic clays. Although the presence or absence of plastic clays can be an element of landslide hazard assessment, classification of potentially unstable areas based solely or primarily on the presence of plastic clays because of a presumed susceptibility to pore-water pressure increases is insufficient. Slope stability researchers and practitioners have known for decades that destabilizing pore-water pressure increases can occur in any kind of soil, surficial deposit, or fractured rock if free pore water accumulates more rapidly than it can be dissipated, which is a function of the hydraulic conductivity of the material, pre-storm soil moisture conditions, depth to a lower permeability layer that may impede infiltration, slope steepness, and rainfall intensity, and rainfall periodicity.

- Second, the rate of pore-water pressure increase is insignificant; it is the magnitude of the increase that is important. A slow increase can be just as destabilizing as a rapid increase.

- Third, concentration of overland flow per se does not lead to an increase in risk (hazard is the correct term in this context). It is infiltration of water associated with concentration of overland flow that can increase the likelihood of slope instability. Concentrated overland flow, if adequately controlled and routed so that infiltration into potentially unstable areas does not occur, will not contribute to slope instability.

p. 2: Use of soil survey maps supplemented by USGS 1:24,000 "geologic topoquads" is generally insufficient for assessment of past, present, and potential future slope instability at a level appropriate for assessing project actions. It is not clear how lidar coverage, which is substantially more resolute than USGS 1:24,000 topographic maps, was used in combination with slope and geology in GIS to assess the potential for slope instability per the report. The report states only

"Slope stability was analyzed using the same methods as above with the addition of the USGS 1:24,000 geologic topoquads..." The methods and GIS layers used to support office-based slope stability assessment need to be described in more detail. It is also not clear if the office-based assessment and subsequent field verification were performed by specialists with experience in landslide hazard mapping and evaluation; the Methodology section refers only to "DBNF personnel".

p. 5: Inclusion of plastic soils and susceptible geologic formations as the only two indicators in Table 1 is insufficient for assessment of past, present, and potential future slope instability. This is particularly true if the susceptible geologic units are limited to those listed on p. 1 of the report under review (i.e., Beattyville, Hartselle, Magoffin, Pennington, Nada-Cowbell, and Nancy), which is not clear. This criterion needs to be expanded to minimally include the presence of diagnostic landforms, seeps, and vegetation anomalies as indicators. The assessment should also include modern quantitative methods such as those employed by the Kentucky Geological Survey produce landslide susceptibility maps in eastern Kentucky, which represent the current local state of practice in areal slope stability assessment.

p. 11: Table 3 makes repeated reference to full-bench roads, but the use of the term and/or recommendation is inconsistent with generally accepted terminology. Full-bench roads, as opposed to side-cast or balanced section roads, are typically preferred in steep and potentially unstable terrain if roadbuilding is necessary. This is because full-bench road construction requires removal of excavated material from the cut instead casting it aside and loading the slope.

p. 11: The "watch outs" in Table 3 need to include specific point locations or, preferably, footprints of known landslides, previous landslides, or other signs of potential instability. For example, the "watch out" for stand 6265012 is simply "Known landslide off FSR 213", which does not allow the potentially problematic area to be easily identified and avoided. The "watch out" for stand 6263001 is "Reported landslide at bottom of stand, not confirmed". Although logging is currently not proposed in that stand, the existence of a possible landslide should be confirmed so that the information is available in the future.

p. 13: The report states that none of the susceptible geologic formations listed in a previous section occur in the area; however, there is no discussion of formations and other geologic features that do appear in the area, even though that information is freely available. This is a major omission. The report should include at the least a textual description, if not a geologic map, of the geology of the area under study.

p. 14: Coal seams and topographic benches should likewise be shown on a study-wide map.

p. 15: As previously discussed, soil plasticity is one of several factors that may influence slope stability. The implied degree of association of soil plasticity with rapid pore-water pressure increases is misleading and suggests that the mechanisms of slope instability are not well understood by the report authors. Also, the section of the forest plan quoted on p. 15 clearly includes logging as an activity separate from road construction that is capable of destabilizing slopes. However, nowhere in the report is tree removal per se evaluated for its potential to decrease slope stability, despite the well-established destabilizing effects of tree removal in steep forested watersheds. Instead, concern is limited to heavy equipment traffic during times when the water table is within a foot of the ground surface. While it is important to consider potential impacts of heavy equipment operations under those conditions, it is insufficient to consider equipment traffic alone.

p. 15: Roy and Bhalla (2017), which is cited on p. 15 and p. 18, is not included in the reference list at the end of the report.

p. 18: The role of Dr. Crawford's participation needs to be clarified to include details of time and effort expended, the nature of the cooperative agreement between the Forest Service and the Kentucky Geological Survey, and, most importantly, whether Dr. Crawford's involvement is intended to represent KGS endorsement of Forest Service findings or recommendations.

p. 18: The report states that a field visit by Forest Service personnel and Dr. Crawford did not find any evidence of a landslide at 36.60711272° N, 84.2007211° W that had been reported by the public. Although there may have been no obvious signs of an active landslide at that exact location at the time of the visit, a review of freely available KyFromAbove airborne lidar coverage of that area shows the slope to be geomorphologically complex, with evidence of previous instability including landslides, debris source areas, and debris deposit lobes as illustrated in Figure 1. There is also an approximately 18-acre area of anomalously rough topography that may represent an older and more extensive potentially unstable area. The landforms shown in Figure 1F were identified by qualitative interpretation of the lidar imagery and derivative maps (i.e., hillshade and slopeshade images, topographic contour maps, residual topography maps, and topographic roughness maps), in particular the existence of concave headwall areas and headscarps, convex toes, diagnostic contour and residual elevation patterns showing downslope changes from concave to convex topography, and topographic roughness anomalies. Even if there were no obvious indications of a currently active landslide that the time of the Forest Service field visit and some of the landforms delineated in Figure 1 are subtle and subject to interpretation, stating that there is no evidence of a landslide at that location misrepresents the geomorphological complexity and abundant evidence of past—if not current and potential future—slope instability in the immediate vicinity. The report does not state whether or how existing airborne lidar coverage was used by Forest Service experts to support geomorphological interpretations of the site and/or inform the field visit (e.g., by targeting specific areas for field reconnaissance). For example, what criteria were used to identify previously or currently unstable areas? How was confidence evaluated? The failure of the Forest Service to have a geologist experienced with modern methods of lidar interpretation for landslide mapping perform a project-wide assessment using methods similar to those used to produce Figure 1, preferably before the field visit, for inclusion in the report would be a significant omission.

p. 18: Similarly, the report states "Another landslide was reported by the same party in late March 2023, located in stand 6263001 at 36.6036659, -84.2716495. This landslide was not confirmed, and this stand is not part of the project. No action will take place in this location." It is not clear from the report what "not confirmed" means; that is to say, whether there was no effort made to confirm the landslide because it is not in an area to be logged or an attempt was made and no evidence was observed. Regardless, interpretation of available lidar imagery and maps shows that the area around the reported location is, like the area shown in Figure 1, gemorphologically complex with abundant evidence of past slope instability that would have a bearing on a landslide hazard assessment of the area (Figure 2).

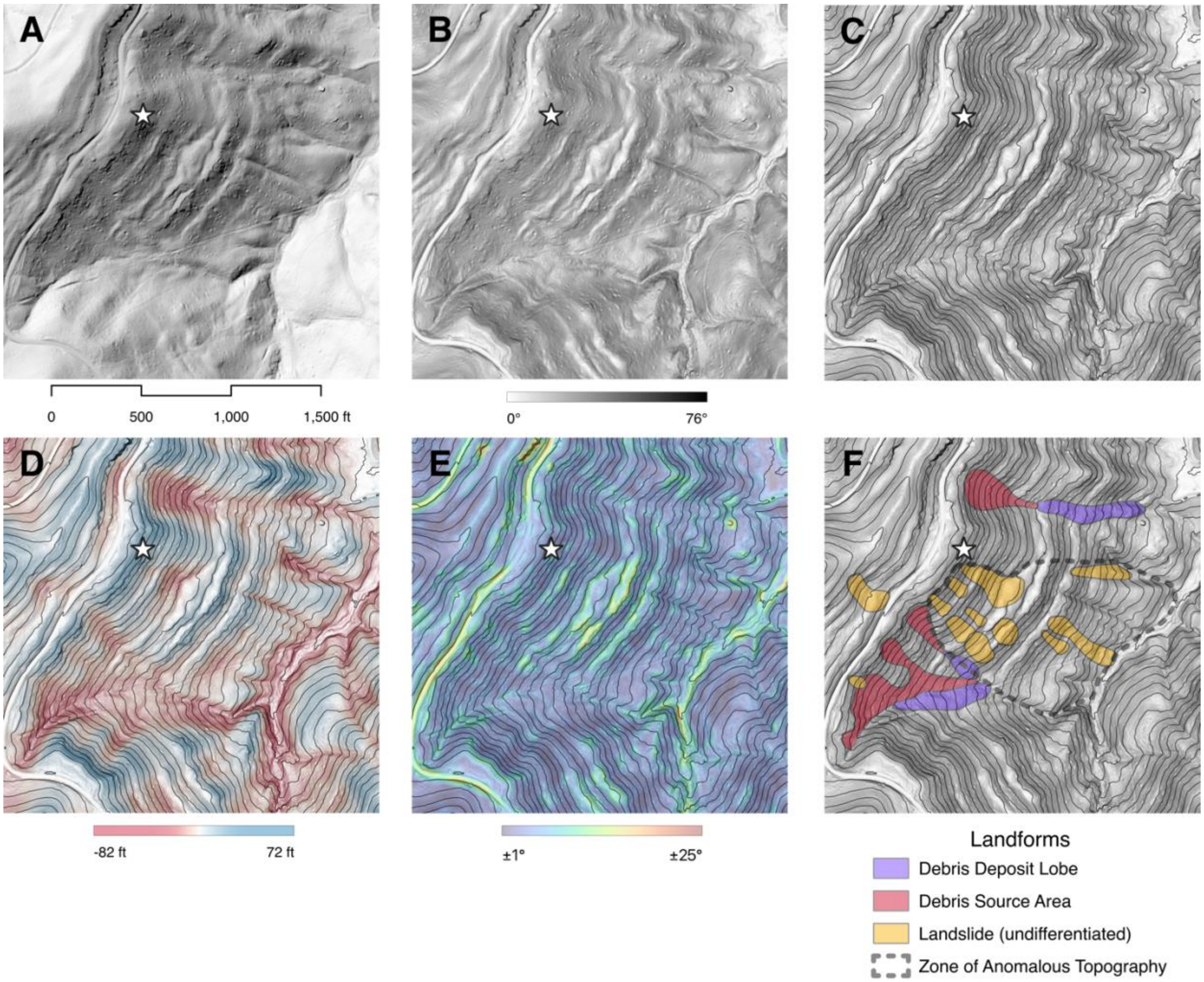

Figure 1. Lidar-based images and maps of the area around 36.60711272°, -84.2007211° (indicated by star) for which the Jellico Soil Effects Analysis states that no evidence of a landslide was found during a field visit. Map scale and extent are identical for all six panels. A) Hillshade image with simulated illumination from an azimuth of 045° and an inclination of 45°. B) Slopeshade image with steepness as indicated by scale bar. C) Slopeshade image draped with 20-ft lidar-derived topographic contours. D) 201-cell residual topography and 20-ft topographic contours draped over slopeshade image with magnitude as indicated by scale bar. E) Topographic roughness as the standard deviation of slope angle within a 25-cell moving window with magnitude as indicated by scale bar. F) Interpretive map showing landforms suggesting past and potential future slope instability. Lidar source: http://kyfromabove.ky.gov , tile N196E320, Phase 2 DEM (2-ft).

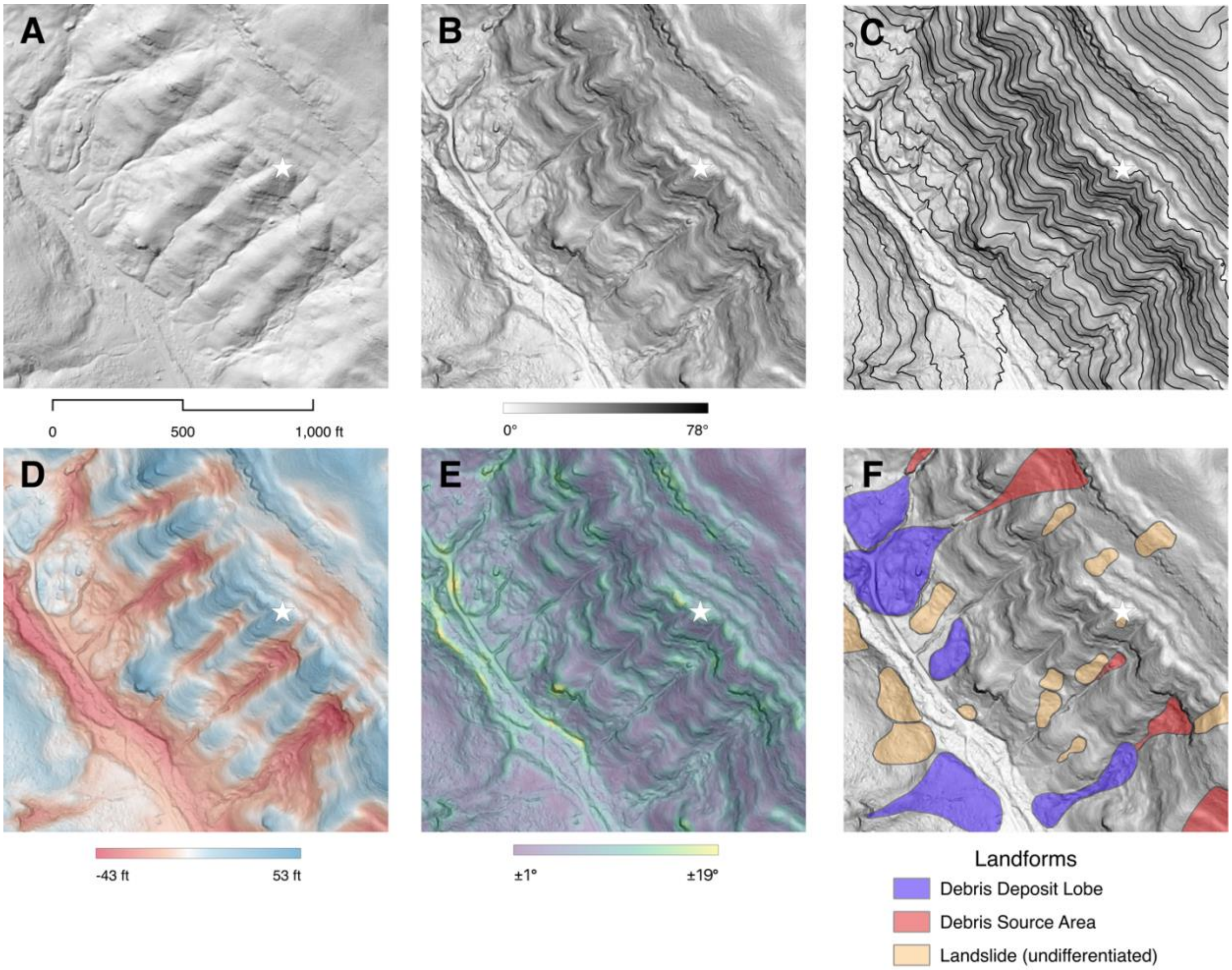

Figure 2. Lidar-based images and maps of the area around 36.6036659°, -84.2716495° (indicated by star) for which the Jellico Soil Effects Analysis states that no evidence of a landslide was found during a field visit. Map scale and extent are identical for all six panels. A) Hillshade image with simulated illumination from an azimuth of 315° and an inclination of 45°. B) Slopeshade image with steepness as indicated by scale bar. C) Slopeshade image draped with 20-ft lidar-derived topographic contours. D) 201-cell residual topography and 20-ft topographic contours draped over slopeshade image with magnitude as indicated by scale bar. E) Topographic roughness as the standard deviation of slope angle within a 25-cell moving window with magnitude as indicated by scale bar. F) Interpretive map showing landforms suggesting past and potential future slope instability. Lidar source: http://kyfromabove.ky.gov , tiles N196E315 and N196E316, Phase 2 DEM (2-ft).

p. 19: The report states "Additional comments regarding landslides were received from initial scoping and voiced at the town hall meeting in Williamsburg, KY, on November 30, 2022. Comments mentioned interpretations from the Web Soil Survey (Soil Survey Staff, 2023). Web Soil Survey is the primary tool for soils data; as such, it provides interpretations and ratings for various activities. These interpretations serve as a first approximation of site conditions, but like any model, they need to be field verified due to the coarseness of the data, especially in forested environments where multiple soils are grouped into complexes due to the spatial complexity and heterogeneity of the soil resource." Although the Web Soil Survey provides information useful for many aspects of land-use planning, and some soil properties such as plasticity can be useful as one element of a landslide hazard assessment, it is insufficient to use the Web Soil Survey as a primary or sole tool to identify areas susceptible to landslides as an effect of land-use decisions. Modern landslide susceptibility maps, such as those produced by the Kentucky Geological Survey using peer-reviewed workflows, are based on inventories of landslides identified from lidar coverage by trained geologists, statistical analysis of the geomorphological and geological factors associated with landslide occurrence, and extrapolation of the statistical relationships across the landscape using quantitative landslide susceptibility models based upon established techniques like logistic regression.

p. 19: The report states "A team of resource managers have [sic] been surveying proposed units for evidence of slope instability since 2020. The results have been shared with the district. This information has helped refine the project actions and identify where they can occur on the landscape without causing resource damage." This information, including both a description of methods used and findings, should have been included in the report. Without it, it is impossible to assess the qualifications of the people performing the work (e.g., were they trained geologists experienced in landslide hazard mapping and assessment), the methods used, or the veracity of their conclusions.

p. 20: The project actions listed as potentially detrimental to slope stability are limited and insufficient on several counts. The "watch outs" listed in Table 3 are vaguely defined and not shown on any maps provided with the report; it is not clear how the extent of those "watch outs" was determined or will be conveyed to logging operators. Based on examination of the two areas illustrated in Figures 1 and 2, there is abundant evidence of past slope instability—and thus potential for future instability, particularly as a consequence of logging—in areas that Forest Service staff have implied have no evidence of landsliding (or, at least, no confirmation of the evidence). Thus, there is a reasonable likelihood that the "watch outs" listed in Table 3 are an incomplete and misleading representation of the ubiquity and severity of slope instability problems in the project area.

p. 21: The temporal effects associated with slope instability due to equipment operation on plastic soils are limited to soil deformation, reduced water capacity, and issues related to aeration, mineralization, and vegetation growth. There is no mention of the significant potential for sediment delivery to streams that can potentially impact surface water quality.

p. 22: See previous comment regarding slope instability effects including sediment delivery and water quality degradation.

p. 21-22: Although Table 7 and Table 8 consider slope instability in the context of equipment operation on plastic soils, neither considers decadal reductions in soil cohesive shear strength and increases in pore water pressures (i.e., reduction in frictional strength) as a consequence of tree removal, despite the fact that those effects have been well-documented in the peer-reviewed scientific literature.

p. 23: Under the heading "Slope stability", and as previously discussed, using a lack of specific geologic formations and presence of plastic soils identified on soil survey maps is an insufficient assessment of landslide susceptibility given the availability of high-resolution lidar topographic data and the standards of practice employed by agencies such as the Kentucky Geological Survey.

Limitation of the discussion of potential effects to equipment operation on plastic soils, as discussed above, ignores the well-known effects of decadal reductions in soil cohesive shear strength and increases in pore water pressures (i.e., reduction in frictional strength) as consequences of tree removal.

p. 23: The discussion of the weight of wet vs. dry plastic soils and its implications for slope stability is naïve and misguided. The difference between the unit weights of wet and dry clayey soils is typically of little consequence in quantitative slope stability analyses. The reduction of effective normal stress in the soil by saturation (positive pore-water pressure development) is in most cases a far more important factor. Changes in slope geometry, plasticity, and decadal post-logging reductions in soil shear strength due to tree removal are likely to be far more significant than increases in soil weight.

p. 24: In the discussion of coal seams and weathering, it is insufficient to rely on descriptions of geologic formations from general-purpose geologic maps produced 45+ years ago (the Kentucky statewide geologic mapping program took place 1960-1978). This supposition should have been evaluated using modern lidar topographic data and field observations.

p. 26: The report states “No increase in slope instability on side slopes or terraces is expected unless concentrated flow and channels form from disturbance, a wet coal seam is cut by heavy machinery, and/or plastic soils are disturbed during times of high soil moisture.” That statement is incomplete because it does not consider decadal post-logging reductions in soil shear strength (decrease of cohesive strength due to root decay and frictional strength due to increased pore-water pressure) due to tree removal.

Appendix B

Curriculum Vitae of William C. Haneberg, Ph.D., C.P.G., P.G.

William C. Haneberg

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EDUCATION

Ph.D., 1989, Geology, University of Cincinnati. Primary emphasis: geomechanics. Secondary emphasis: engineering geology and hydrogeology. Advisor: Arvid M. Johnson.

M.S., 1985, Geology, University of Cincinnati. Primary emphasis: structural geology.

B.S. cum laude, 1982, Geology, Bowling Green State University.

EMPLOYMENT

William C. Haneberg, LLC, Albuquerque, New Mexico

Independent consultant specializing in geohazard and risk assessment, climate impacts, and use of geoscience information to support policy decisions, 7/23 – present.

University of Kentucky, Lexington, Kentucky

State geologist and director, Kentucky Geological Survey and research professor, Earth and Environmental Sciences Department, 9/16 – 6/23.

Fugro Marine GeoServices (formerly Fugro GeoConsulting), Houston, Texas

Senior consultant and quantitative geohazards team leader, 1/15 – 8/16. Previously consultant and quantitative geohazards team leader, 10/11 -12/14.

Haneberg Geoscience, Seattle, Washington and Cincinnati, Ohio

Independent consultant specializing in geohazard assessment, digital terrain modeling, and computational geology, 7/99 – 10/11.

New Mexico Institute of Mining and Technology, Socorro and Albuquerque, New Mexico

Senior engineering geologist and assistant director, New Mexico Bureau of Mines and Mineral Resources. Albuquerque satellite office manager. Previously engineering geologist and assistant director, and engineering geologist, 1/89 – 6/99. NMIMT tenure granted 1992.

Department of Geology, University of Cincinnati, Cincinnati, Ohio

Graduate assistant, Department of Geology, 9/82 - 5/85 and 9/86 - 5/88.

Hydrogeologist, Groundwater Research Center, 6/87 - 8/87.

Manitou Exploration Company, Granville, Ohio

Petroleum geologist, 6/85 - 7/86.

Bowling Green State University, Bowling Green, Ohio

Graduate teaching assistant, Department of Geology (summer field camp), 6/82 - 8/82.

Undergraduate research assistant, Department of Geology, 1/82 - 5/82.

ADJUNCT OR AFFILIATE FACULTY APPOINTMENTS

Adjunct Faculty, New Mexico Tech, Department of Mineral Engineering, 1/24 – present.

Adjunct Professor, University of Kentucky, College of Arts and Sciences (Earth and Environmental Sciences) and College of Nursing, 8/23 – present.

Faculty Affiliate, University of Kentucky, Appalachian Studies Program, 3/22 – present.

Adjunct Professor, University of Cincinnati, Department of Geology, 9/09 – 10/11.

Adjunct Associate Professor, Department of Geology, Portland State University, 9/00 – 12/00.

Adjunct Faculty, New Mexico Tech, Department of Earth & Environmental Sciences and Department of Mineral & Environmental Engineering, 1/90 – 9/05.

LICENSES AND CERTIFICATION

Professional Geoscientist, Texas, #11398

Professional Geologist, Kentucky, #171390

Professional Geologist, Wisconsin, #356

Licensed Geologist, Engineering Geologist, and Hydrogeologist, Washington, #501

Certified Professional Geologist, American Institute of Professional Geologists, #10311

PROFESSIONAL AFFILIATIONS

Fellow, Geological Society of America

Member, American Geophysical Union

Member, New Mexico Geological Society

PATENT

Automated Mapping of Features of Interest. United States patent application 17/271,138 filed 24 February 2021 (co-inventor with Christine Devine).

LITIGATION SUPPORT

Terbush v United States, United States Court for the Eastern District of California, Case No. 1:02-CV-05509-SMS. Deposed as expert for the plaintiffs regarding use of airborne LiDAR data to map rock discontinuities related to groundwater flow and a fatal rock-fall in Yosemite National Park. 2009.

Angeles et al v McKesson et al, United States Court for the Central District of California, Case No. 2:01-CV-10532. Deposed as expert for the plaintiffs regarding effect of surface loading from large rubble piles on shallow aquifer system compaction, groundwater flow, and contaminant transport. 2007.

Skow v State et al, Iowa Courts Case No. 08562 LALA004727. Deposed as expert for the plaintiffs regarding effects of highway embankment construction on earth movement and damage to an adjacent home. 2004.

Water Rights Hearing, New Mexico Office of State Engineer, SP 03919. Testified under oath as expert for the applicant (US Forest Service) regarding leach field effluent travel time calculations as pertinent to water rights return flow credit. 1994.

HONORS AND AWARDS

Invited Speaker, Pardee Keynote Symposium, Looking to the Future of Environmental and Engineering Geology: EEGD 75th Anniversary, Geological Society of America Annual Meeting, 9-12 October 2022.

Invited Speaker, Binghamton Geomorphology Symposium: Geomorphology in the Anthropocene, 15-17 October 2021 (remote presentation).

Invited Keynote Speaker, XIII Congress, International Association for Engineering Geology and the Environment, San Francisco, 17-21 September 2018.

Invited Keynote Speaker, 7th Technical Conference in Eastern Asia on Geo-Natural Disasters, Chengdu, China, 12-14 May 2018.

Invited Keynote Speaker, 3rd North American Symposium on Landslides, Roanoke, Virginia, 4-8 June 2017.

Outstanding Reviewer, *Environmental & Engineering Geoscience*, 2013.

Richard H. Jahns Distinguished Lecturer, Association of Environmental & Engineering Geologists and Geological Society of America, 2011.

Samuel Mayfield Distinguished Lecturer, Bowling Green State University, Department of Geology, 2010.

Claire P. Holdredge Award, Association of Environmental & Engineering Geologists, for *Computational Geosciences with Mathematica* as a publication judged to be an outstanding contribution to the advancement of the profession, 2006.

Meritorious Service Award, Geological Society of America, Engineering Geology Division, 2006.

Visiting Scholar, Western Michigan University, Department of Geosciences, 2006.

Presidential Citations, Association of Environmental & Engineering Geologists, 2004, 2006-2010, 2021.

Editor's Citation for Excellence in Scientific Refereeing, American Geophysical Union, 2002.

Certificate of Distinction from the New Mexico State Engineer for contributions made as a member of the Costilla Dam Independent Review Team resulting in the State's recovery of nearly $5 million in cost overruns associated with the reactivation of a dormant landslide, 1994.

Outstanding Teaching Assistant, Department of Geology, University of Cincinnati, 1985.

PROFESSIONAL SERVICE

BOARDS AND COMMITTEES

Advisory Committee on Landslides, US Geological Survey (appointment pending).

AEG Foundation, Board of Directors, member, 2023-present.

National Geospatial Advisory Committee, US Department of the Interior, member, 2020-2023.

Quarterly Journal of Engineering Geology & Hydrogeology, editorial board member, 2018-present.

Kentucky Geographic Information Advisory Council, ex officio member, 2018-2023.

University of Kentucky, Kentucky Water Resources Research Institute, ex officio advisory board member, 2017-2023.

University of Kentucky, Center for Applied Energy Research, ex officio advisory board member, 2016-2023.

Kentucky Board of Registration for Professional Geologists, ex officio member, 2016-2023.

Society for Underwater Technology, Houston Offshore Site Investigation & Geotechnics Committee, 2015-2016.

Environmental & Engineering Geoscience, Editorial Policy Board. Chair, 2007-2010. Member, 2001-2007. Joint AEG-GSA appointee, 2008-2010. GSA appointee, 2001-2007. Associate Editor, 1995-2001.

The Hillside Trust, Cincinnati, Ohio, Trustee, 2010-2011.

Geological Society of America, Engineering Geology Division, Chair, 2003-04. Previously vice-chair (2002-03), secretary (2001-02), and management board member-at-large (2000-01).

Association of Environmental & Engineering Geologists, Digital and Electronic Technology in Geology Technical Working Group, Chair, 2007-2011.

Geological Society of America. Professional Development Committee, Chair, 2004-2006. Committee member, 2003-2004.

Geological Society of America, Engineering Geology Division, Annual Meeting Joint Technical Program Committee Representative, 2002 and 2003.

International Association for Engineering Geology, Member, Commission No. 1 (Engineering Geologic Visualization and Characterization), 2007-present.

Geological Society of America, *Ad Hoc* Committee on Divisions. Member, 2006.

Association of Engineering Geologists, Shlemon Conference Operational Committee, 2004.

New Mexico State Engineer, Mid-Rio Grande Technical Advisory Committee, 1995-1999.

New Mexico Interstate Stream Commission, Regional Water Planning Work Group, 1996.

New Mexico Institute of Mining & Technology, Institute Senate Research Committee, 1992-1994.

Geological Society of America, External Awards Committee, Member, 1998.

Geological Society of America, Engineering Geology Division, E.B. Burwell, Jr. Award Panel, 1990-1992.

Western States Seismic Policy Council, State delegate from New Mexico, alternate years 1992 -1998.

U.S. Forest Service, National Advanced Resource Technology Center Faculty, April 1995.

New Mexico Institute of Mining & Technology, Institute Senate, Vice-chair, 1994-1995.

City of Cincinnati, Infrastructure Commission. Member, 1987.

PROFESSIONAL SERVICE

CONFERENCES AND SESSIONS ORGANIZED OR CHAIRED

Climate & Health. 2022 Spring Conference, Center for Clinical and Translational Science, University of Kentucky. (co-chair with E. Haynes).

From Global to Local—Why Geology Matters for Human Health. 2018 GSA Annual Meeting (with B. Overfield, A. Wolfe, S. Datta, and R.B. Finkleman).

Origin, Transport, and Fate of Geogenic Carcinogens. 2017 AGU Fall Meeting (with B. Overfield, G. Plumlee, and E. Hahn).

Advances in Quantitative Geohazard and Georisk Assessment. 2015 Offshore Technology Conference (with Z. Medina-Cetina).

Advances in Submarine Slope Stability. 2013 Offshore Technology Conference.

Working with Uncertainty and Complexity in Modern Engineering Geology. 2013 AEG Annual Meeting (with J. Keaton).

Mass Wasting in Disturbed Watersheds. AEG Shlemon Conference, Durango, Colorado, Spring 2006 (with S. Cannon, J. Coe, and P. Santi).

Fractured Rock Characterization in Applied Geology. Geological Society of America 2006 Annual Meeting.

Earth Fissures. AEG Shlemon Conference, El Paso, Texas, April 2004 (with J.R. Keaton).

GIS, GPS, and Remote Sensing Applications in Geologic Hazard Assessment. Geological Society of America 2004 Annual Meeting (with N. Levine).

Characterizing Complexity in Geomechanics, Engineering Geology, and Hydrogeology. Geological Society of America 2003 Annual Meeting (with E. Medley).

Humans as Geologic Agents. Geological Society of America 2002 Annual Meeting (with J. Ehlen and R. Larson).

Nothing Ventured, Nothing Gained: Geology and Risk Assessment in the 21st Century. Geological Society of America 2001 Annual Meeting (with S. Burns).

Faults and Subsurface Fluid Flow: Fundamentals and Applications to Hydrogeology and Petroleum Geology. Geological Society of America Penrose Conference, Taos, New Mexico, September 1997 (with J.C. Moore, L.B. Goodwin, and P.S. Mozley).

Quantifying Hazardous Natural Processes for Risk Assessment. Association of Engineering Geologists 1996 Annual Meeting (with J.R. Keaton).

Instability of Clay and Shale Hillslopes. Geological Society of America 1992 Annual Meeting (with R.W. Fleming).

PROFESSIONAL SERVICE

MANUSCRIPT OR PROPOSAL REVIEWER

Nature, Remote Sensing, *Radiation and Environmental Biophysics*, *GSA Bulletin*, *Geology*, *Earth Surface Processes & Landforms, Water Resources Research*, *Geomorphology, Journal of Geology*, *Journal of Geophysical Research*, *Bulletin of the Seismological Society of America*, *Landslides, Canadian Geotechnical Journal, International Journal of Rock Mechanics and Mining Sciences, Catena, Engineering & Environmental Geoscience*, *Engineering Geology, Hydrogeology Journal, Journal of Geotechnical Engineering, American Association of Petroleum Geologists Bulletin, Clays and Clay Minerals, Annals of Geophysics, Advances in Water Resources*, *Computers & Geosciences, Advances in Space Research*, *Heritage,* Kansas Geological Survey, U.S. Geological Survey, Columbia University Press, Oxford University Press, National Science Foundation, U.S.

Department of Energy, U.S. Geological Survey, Wyoming Water Resources Research Institute, Kentucky Water Resources Research Institute, Petroleum Research Fund.

CONFERENCE PANEL

Rhetoric, ethics, and knowledge coproduction: Engaging with discourses of transdisciplinarity (Chair: B. McGreavy; Panelists: N. Stormer, L. Cagle, **W. Haneberg**, K. Walker, P. Hernandez-Trujillo, C. Hinojosa, A. King-Kostelac). Rhetoric Society of America, Baltimore, Maryland, May 2022. https://rhetoricsociety.confex.com/rhetoricsociety/2022/meetingapp.cgi/Session/1519.

BOOKS

WRITTEN OR EDITED

Haneberg, W.C., 2004, *Computational Geosciences with Mathematica*: Springer, 381 pp.

Ehlen, J., **Haneberg, W.C.**, and Larson, R.L., editors, 2006, *Humans as Geologic Agents*: Geological Society of America Reviews in Engineering Geology, 158 pp.

Haneberg, W.C., Mozley, P.S., Moore, J.C., and Goodwin, L.B., editors, 1999, *Faults and Subsurface Fluid Flow in the Shallow Crust*: American Geophysical Union Geophysical Monograph 113, 220 pp.

Haneberg, W.C. and Anderson, S.A., editors, 1995, *Clay and Shale Slope Instability*: Geological Society of America Reviews in Engineering Geology 10, 160 pp.

PAPERS

PEER REVIEWED JOURNALS AND BOOKS

Johnson, S.E. and **Haneberg, W.C.,** submitted, Machine learning for mapping surficial geology. *Earth Surface Processes and Landforms*.

Haneberg, W.C., 2024, Precipitation patterns, mountaintop removal mining, and the July 2022 North Fork Kentucky River flood. *Environmental & Engineering Geoscience* (in press).

Hahn, E.J., **Haneberg, W.C.,** Stanifer, S.R., Rademacher, K., and Rayens, M.K., 2023, Geologic, seasonal, and atmospheric predictors of indoor home radon values. *Environmental Research: Health* 1(2), 025011, https://doi.org/10.1088/2752-5309/acdcb3.

Khabiri, S., Crawford, M.M., Koch, H.J., **Haneberg, W.C.**, and Zhu, Y., 2023, An assessment of negative samples and model structures in landslide susceptibility characterization based on Bayesian network models. *Remote Sensing* 15(12: 3200), https://doi.org/10.3390/rs15123200

Johnson, S.E., **Haneberg, W.C.**, Bryson, L.S., and Crawford, M.M., 2023, Measuring ground surface elevation changes in a slow-moving colluvial landslide using combinations of regional airborne lidar, UAV lidar, and UAV photogrammetric surveys: *Quarterly Journal of Engineering Geology and Hydrogeology* 56(2), https://www.doi.org/10.1144/qjegh2022-078.

Crawford, M.M., Dortch, J.M., Koch, H.J., Zhu, Y., **Haneberg, W.C.,** Wang, Z., and Bryson, L.S., 2022, Landslide risk assessment in eastern Kentucky, USA: developing a regional scale, limited resources approach: *Remote Sensing* 14(24), 6246*,* https://doi.org/10.3390/rs14246246.

Zhu, Y., Dortch, J.M., and **Haneberg, W.C.**, 2022, Non-affine georectification to improve the topographic fidelity of legacy geologic maps: *International Journal of Applied Earth Observation and Geoinformation* 115, 103127, https://doi.org/10.1016/j.jag.2022.103127.

Stanifer, S., Hoover, A.G., Rademacher, K., Rayens, M.K., **Haneberg, W.** and Hahn, E.J., 2022. Citizen science approach to home radon testing, environmental health literacy and efficacy. *Citizen Science: Theory and Practice* 7(1): 26, 1:13, https://doi.org/10.5334/cstp.472.

Haneberg, W.C., Johnson, S.E., and Gurung, N., 2021, Response of the Laprak, Nepal, landslide to the 2015 M_w 7.8 Gorkha earthquake: *Natural Hazards* 111, 567–584, https://doi.org/10.1007/s11069-021-05067-z.

Zhu, Y., Wang, Z., Carpenter, N.S., Woolery, E.W., and **Haneberg, W.C.,** 2021, Mapping fundamental site periods and corresponding amplifications for the Jackson Purchase region of western Kentucky, central United States: *Bulletin of the Seismological Society of America* 111(4), 1868–1884, https://doi.org/10.1785/0120200300.

Zhu, Y., Massey, M.A., Dortch, J.M., **Haneberg, W.C.,** and Curl, D., 2021, An intelligent swath tool to characterize complex topographic features: Theory and application in the Teton Range, Licking River, and Olympus Mons. *Geomorphology* 387, https://doi.org/10.1016/j.geomorph.2021.107778.

Crawford, M.M., Dortch, J.M., Koch, H.J., Killen, A.A., Zhu, J., Zhu, Y., Bryson, L.S., and **Haneberg, W.C.**, 2021, Using landslide-inventory mapping for a combined bagged-trees and logistic-regression approach to landslide susceptibility in eastern Kentucky: *Quarterly Journal of Engineering Geology and Hydrogeology* 54(4), https://doi.org/10.1144/qjegh2020-177.

Haneberg, W.C., Wiggins, A., Curl, D.C., Greb, S.F., Andrews, W.M., Jr., Rademacher, K., Rayens, M.K., and Hahn, E.J., 2020, A geologically based indoor-radon potential map of Kentucky: *GeoHealth* 4, e2020GH000263, https://doi.org/10.1029/2020GH000263.

Chapella H., **Haneberg W.,** Crawford M., Shakoor A., 2019, Landslide inventory and susceptibility models, Prestonsburg 7.5-min quadrangle, Kentucky, USA, *in* Shakoor A. and Cato K. (eds), *IAEG/AEG Annual Meeting Proceedings*, San Francisco, California, 2018 - Volume 1. Springer, Cham, p. 217-226.

Haneberg, W.C., 2018, Lidar, in P.T. Bobrowsky and B. Marker, editors, *Encyclopedia of Engineering Geology*: Springer Cham, https://doi.org/10.1007/978-3-319-12127-7.

Haneberg, W.C., 2017, Emerging trends and technologies in spatially distributed landslide hazard assessment, in J.V. DeGraff and A. Shakoor, editors, *Landslides: Putting Experience, Knowledge and Emerging Technologies into Practice*: AEG Special Publication 27, p. 21-32.

Westgate, Z.J., **Haneberg, W.C.**, and White, D.J., 2016, Modelling spatial variability in as-laid embedment for high pressure and high temperature (HPHT) pipeline design: *Canadian Geotechnical Journal* 53, p. 1853-1865, https://dx.doi.org/10.1139/cgj-2016-0091.

Haneberg, W.C., 2016, Incorporating correlated variables into GIS-based probabilistic submarine slope stability analyses, in G. Larmarche et al, editors, *Submarine Mass Movements and Their Consequences*: Springer, Advances in Natural and Technological Hazards Research 41, 529-536, https://doi.org/10.1007/978-3-319-20979-1_53.

Haneberg, W.C., Devine, C.A., Feregrino, D.N.V., and Calderón, M.O., 2015, Optimizing deep-water pipeline routes in areas of geologic complexity—an example from the Gulf of Mexico, in V. Meyer, editor, *Frontiers in Offshore Geotechnics III*: London, Taylor & Francis, p. 963-968 https://doi.org/10.4043/25785-MS.

Haneberg, W.C., 2015, Understanding the element of time in probabilistic submarine slope stability analysis, in V. Meyer, editor, *Frontiers in Offshore Geotechnics III*: London, Taylor & Francis, 957-962, https://doi.org/10.1201/b18442-140.

Haneberg, W.C., Kelly, J.T., Graves, H.L., and Dan, G., 2015, A GIS based multicriteria decision support approach to deep-water drilling hazard maps: *The Leading Edge* 34(4), 398-404, https://doi.org/10.1190/tle34040398.1

Murari, M.K., Owen, L.A., Dortch, J.M., Caffee, M.W., Dietsch, C., Fuchs, M., **Haneberg, W.C.**, Sharma, M.C., and Townsend-Small, A., 2014, Timing and climatic drivers for glaciation across monsoon-influenced regions of the Himalayan-Tibetan orogeny: *Quaternary Science Reviews* 88, 159–182, https://doi.org/10.1016/j.quascirev.2014.01.013.

Gurung, N., **Haneberg, W.C.**, Ramana, G.V., and Datta, M., 2011, Engineering geology and stability of the Laprak landslide, Gorkha District, Nepal: *Environmental & Engineering Geoscience* 17(1), 23-38, https://doi.org/10.2113/gseegeosci.17.1.23.

Haneberg, W.C., 2009, Improved optimization and visualization of drilling directions for rock mass discontinuity characterization: *Environmental & Engineering Geoscience* 15(2), 107-113, https://doi.org/10.2113/gseegeosci.15.2.107.

Haneberg, W.C., Cole, W.F., and Kasali, G., 2009, High-resolution LiDAR-based landslide hazard mapping and modeling, UCSF Parnassus Campus, San Francisco, USA: *Bulletin of Engineering Geology and the Environment* 68, 273-286, https://doi.org/10.1007/s10064-009-0204-3.

Adam, B., Dietsch, C., Owen, L.A., Caffee, M.W., Spotila, J.A., and **Haneberg, W.C.**, 2009, Exhumation and incision history of the Lahul Himalaya, northern India, based on (U-Th)/He thermochronometry and terrestrial cosmogenic nuclide dating techniques: *Geomorphology* 107(3-4), 285-299, https://doi.org/10.1016/j.geomorph.2008.12.017.

Dortch, J.M. Owen, L.A., **Haneberg, W.C.**, Caffee, M.W., Dietsch, C., and Kamp, U., 2009, Nature and timing of large landslides in the Himalaya and Transhimalaya of northern India: *Quaternary Science Reviews* 28, 1037-1054, https://doi.org/10.1016/j.quascirev.2008.05.002.

Haneberg, W.C., 2009, Simplified analysis of vibration induced rock toppling: *Environmental & Engineering Geoscience* 15(1), 41-45, https://doi.org/10.2113/gseegeosci.15.1.41.

Haneberg, W.C., 2008, Using close range terrestrial digital photogrammetry for 3-D rock slope modeling and discontinuity mapping in the United States: *Bulletin of Engineering Geology and the Environment* 67(4), 457-469, https://doi.org/10.1007/s10064-008-0157-y.

Haneberg, W.C., 2008, Elevation errors in a LIDAR digital elevation model of West Seattle and their effects on slope stability calculations, *in* R.L. Baum, J. Godt, and L. Highland, editors, *Landslides and Engineering Geology of the Greater Seattle Area, Washington*: Geological Society of America Reviews in Engineering Geology 20, 55-66, https://doi.org/10.1130/2008.4020(03).

Haneberg, W.C., 2006, Effects of digital elevation model errors on spatially distributed seismic slope stability calculations: an example from Seattle, Washington: *Environmental & Engineering Geoscience* 12(3), 247-260, https://doi.org/10.2113/gseegeosci.12.3.247.

Haneberg, W.C., 2004, Simulation of 3-D block populations to characterize outcrop sampling bias in block-in-matrix rocks (bimrocks): *Felsbau* 22(5), 19-26, http://bimrocks.com/wp-content/uploads/2010/07/HanebergFelsbau2004.pdf

Haneberg, W.C., 2004, A rational probabilistic method for spatially distributed landslide hazard assessment: *Environmental & Engineering Geoscience* 10(1), 23-47, https://doi.org/10.2113/10.1.27.

Haneberg, W.C., Bauer, P.W., and Chávez, W.X., Jr., 2002, Multilevel geologic hazard assessment mapping in the Rio Grande gorge, northern New Mexico, USA, *in* P. T. Bobrowsky, editor, *Geoenvironmental Mapping: Method, Theory and Practice*: A.A. Balkema, 75-91.

Haneberg, W.C., 2000, Deterministic and probabilistic approaches to geologic hazard assessment: *Environmental & Engineering Geoscience* 6(3), 209-226, https://doi.org/10.2113/gseegeosci.6.3.209.

Heynekamp, M.R., Goodwin, L.B., Mozley, P.S., and **Haneberg, W.C.**, 1999, Controls on fault-zone architecture in poorly lithified sediments, Rio Grande rift, New Mexico: implications for fault zone permeability and fluid flow, *in* Haneberg, W.C., Mozley, P.S., Moore, J.C., and Goodwin, L.B., editors, *Faults and Subsurface Fluid Flow in the Shallow Crust*: American Geophysical Union Geophysical Monograph 113, 27-50, https://doi.org/10.1029/GM113p0027

Whitworth, T.M., **Haneberg, W.C.**, Mozley, P.S., and Goodwin, L.B., 1999, Solute sieving induced calcite precipitation on pulverized quartz sand— experimental results and implications for the membrane behavior of fault gouge, *in* Haneberg, W.C., Mozley, P.S., Moore, J.C., and Goodwin, L.B., editors, *Faults and Subsurface Fluid Flow in the Shallow Crust*: American Gesophysical Union Geophysical Monograph 113, 49-158, https://doi.org/10.1029/GM113p0149

Haneberg, W.C., 1999, Effects of valley incision on the subsurface state of stress— theory and application to the Rio Grande valley near Albuquerque, New Mexico: *Environmental & Engineering Geoscience* 5(1), 117-131, https://doi.org/10.2113/gseegeosci.V.1.117

Haneberg, W.C., Gomez, P., Gibson, A., and Allred, B., 1998, Preliminary measurements of stress-dependent hydraulic conductivity of Santa Fe Group aquifer system sediments, Albuquerque Basin, New Mexico: *New Mexico Geology* 20(1), 14-20, https://doi.org/10.58799/NMG-v20n1.14

Haneberg, W.C., 1995, Steady-state groundwater flow across idealized faults: *Water Resources Research* 31(7), 1815-1820, https://doi.org/10.1029/95WR01178

Haneberg, W.C., 1995, Depth-porosity relationships and virgin specific storage estimates for the upper Santa Fe Group aquifer system, central Albuquerque Basin, New Mexico: *New Mexico Geology* 17(4), 62-71, https://doi.org/10.58799/NMG-v17n4.62

Haneberg, W.C., 1995, Groundwater flow and the stability of heterogeneous infinite slopes underlain by impervious substrata, *in* Haneberg, W.C. and Anderson, S.A., editors, *Clay and Shale Slope Instability*: Geological Society of America Reviews in Engineering Geology 10, 63-78, https://doi.org/10.1130/REG10-p63

Haneberg, W.C. and Friesen, R.L., 1995, Tilts, strains, and ground-water levels near an earth fissure in the Mimbres Basin, New Mexico: *Geological Society of America Bulletin* 107(3), 316-326, https://doi.org/10.1130/0016-7606(1995)107<0316:TSAGWL>2.3.CO;2

Haneberg, W.C. and Gökce, A.Ö., 1994, *Rapid water-level fluctuations in a thin colluvium landslide west of Cincinnati, Ohio*: U.S. Geological Survey Bulletin 2059-C, https://pubs.usgs.gov/bul/2059c/report.pdf

Haneberg, W.C. and Bauer, P.W., 1993, Geologic setting and dynamics of a rockslide along NM 68, Rio Grande gorge, northern New Mexico: *Bulletin of the Association of Engineering Geologists*, v. 30, p. 7-16.

Haneberg, W.C., Austin, G.S., and Brandvold, L.A., 1993, Soil lead distribution at an abandoned smelter site in Socorro, New Mexico: *Environmental Geology*, v. 21, p. 90-95.

Haneberg, W.C., 1993, Drape folding of compressible elastic layers– II. Matrix solution for two-layer folds: *Journal of Structural Geology*, v. 15, p. 923-932.

Haneberg, W.C., 1992, Drape folding of compressible elastic layers– I. Analytical solutions for vertical uplift: *Journal of Structural Geology*, v. 14, p. 713-721.

Haneberg, W.C., 1992, Geologic hazards in New Mexico– Part 2: *New Mexico Geology*, v. 14, p. 45-52.

Haneberg, W.C., 1992, Geologic hazards in New Mexico– Part 1: *New Mexico Geology*, v. 14, p. 34-41.

Haneberg, W.C., 1991, Pore pressure diffusion and the hydrologic response of nearly-saturated, thin landslide deposits to rainfall: *Journal of Geology*, v. 99, p. 886-892.

Haneberg, W.C., 1991, Observation and analysis of short-term pore pressure fluctuations in a thin colluvium landslide complex near Cincinnati, Ohio: *Engineering Geology*, v. 31, p. 159-184.

Haneberg, W.C. and Tripp, G., 1991, An irrigation-induced debris flow in northern New Mexico: *Bulletin of the Association of Engineering Geologists*, v. 28, p. 359-374.

Haneberg, W.C., 1990, A Lagrangian interpolation method for three-point problems: *Journal of Structural Geology*, v. 12, p. 945-947.

Haneberg, W.C., 1988, Some possible effects of consolidation on growth fault geometry: *Tectonophysics*, v. 148, p. 309-316.

Haneberg, W.C., 1982, A paradigmatic analysis of Darwin's use of uniformitarianism in *The Origin of Species*: *Compass*, v. 60, p. 89-94.

PAPERS

CONFERENCE PROCEEDINGS NOT PEER REVIEWED

Haneberg, W.C., 2018, Repeat AUV MBES surveys for deepwater seafloor change detection: 2018 Offshore Technology Conference, Paper OTC-28738-MS.

Haneberg, W.C., Brumley, K.**,** and Kucera, M.S., 2016, A GIS approach to quantitative ice gouge depth mapping, analysis, and prediction: 2016 Arctic Technology Conference, Paper OTC-27425-MS.

Devine, C.A. and **Haneberg, W.C.,** 2016, Optimization methods for Arctic pipeline route selection: 2016 Arctic Technology Conference, Paper OTC-27391-MS.

Zhang, Z., Wardlaw, S., and **Haneberg, W.C.**, 2016, Seismic AVO analysis for shallow hazard assessments in stratigraphically complicated areas in onshore Alaska locations. Society of Petroleum Engineers Western Regional Meeting, 23-26 May, Anchorage, Alaska, Paper SPE-180455-MS.

Devine, C.A., **Haneberg, W.C.**, Lee., H., Liu, M., and Chang, G., 2016, A sensible approach to subsea pipeline route determination—moving from hand-drawn routes to geologically constrained, least-cost optimized paths: 2016 Offshore Technology Conference, Paper OTC-26940-MS.

Trandafir, A.C. and **Haneberg, W.C**., 2016, Top-hole formation pore pressure assessment at deepwater well sites using a geotechnical approach: 2016 Offshore Technology Conference, Paper OTC-26994-MS.

Haneberg, W.C., Campbell, K.J., and Mackenzie, B., 2016, Concept stage site assessments, deepwater development risks, and long-term value preservation: Why getting it right the first time is more important than ever: 2016 Offshore Technology Conference-Asia, 22-25 March 2016, Kuala Lumpur, Malaysia, Paper OTC-26520-MS.

Haneberg, W.C., 2015, Stochastic incorporation of uncertainty and subjectivity in deepwater pipeline route optimization: Offshore Technology Conference, Paper OTC-25785-MS.

Haneberg, W.C., Bruce, B., Kelly, J.T., and Davis, L., 2015, A simple model for glory hole dredge spoil dispersion assessment: Arctic Technology Conference, 23-25 March,, Paper OTC-22606-MS.

Haneberg, W. C., 2014, Evaluating the effects of input cost surface uncertainty on deep-water petroleum pipeline route optimization, in G. Lolino, D. Giordan, K. Thuro, C. Carranza-Torres, F. Wu, P. Marinos, and C. Delgado, editors, *Engineering Geology for Society and Territory-Volume 6*: Springer International Publishing, 351-355.

Haneberg, W. C. and Campbell, K. J., 2014, Evolution of a submarine mass-transport complex in space and time, in G. Lolino, A. Manconi, J. Locat, Y. Huang, and M. Canala Artigas, editors, *Engineering Geology for Society and Territory-Volume 4*: Springer International Publishing, 205-208.

O'Leary, L., Spinewine, B., **Haneberg, W**., Clare, M., Thomas, S., and Wu., H., 2014, An integrated sediment mobility and scour assessment: characterization, calibration, and mitigation studies for a pipeline in the South China Sea: Offshore Technology Conference Asia, 25-28 March 2014, OTC -24872-MS.

Keaton, J.A. and **Haneberg, W.C**., 2013, Landslide inventories and uncertainty associated with ground truth, *in* F. Wu and S. Qi, editors, *Global View of Engineering Geology and the Environment*. London, Taylor & Francis, 105-110.

Haneberg, W.C., Bruce, B., and Drazba, M.C., 2013, Using qualitative slope hazard maps and quantitative probabilistic slope stability models to constrain least-cost pipeline route optimization: 2013 Offshore Technology Conference, OTC-23980-MS.

Haneberg, W.C., 2012, Spatially distributed probabilistic assessment of submarine slope stability, in P. Allan and 9 others (editors), *Offshore Site Investigation and Geotechnics*: Proc., 7th International Offshore Site Investigation and Geotechnics Conference, London, UK, 551-556.

Watts, C.F., Underwood, S.A., **Haneberg, W.C.,** and Rogers, J.D., 2012, Fully rationalized equations for incorporating joint water pressure in rock slope stability analyses at Glacier Point in Yosemite National Park, California, in E. Eberhardt, C. Froese, K. Turner, and S. Leroueil, editors, *Landslides and Engineered Slopes (Volume 2)*: Proc., 11th International & 2nd North American Symposium on Landslides, Banff, 3-8 June, 2012.

Gates, W.C.B. and **Haneberg, W.C.**, 2012, Comparison of standard structural mapping results to 3-D photogrammetric model results: Boundary Transformer Banks rockfall mitigation project, Metaline Falls, Washington: Proc., 46th US Rock Mechanics/Geomechanics Symposium, Chicago, 24-27, ARMA Paper 12-368.

Pate, K. and **Haneberg, W.C.**, 2011, Photogrammetric and LIDAR 3-D rock slope discontinuity mapping and interpretation surveys to improve baseline information for planning, design, and construction of capital improvement projects at hydroelectric facilities: Proc., 45th US Rock Mechanics/Geomechanics Symposium, San Francisco, CA, June 26–29, 2011 (ARMA 11-520).

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Sarah Johnson, *Applications of digital terrain modeling to address problems in geomorphology and engineering geology.* Ph.D. in Earth & Environmental Sciences, University of Kentucky, 2023. Principal advisor.

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Matthieu Sturzenegger, *An evaluation of rock slope characterization using digital photogrammetry and laser scanning techniques*. Ph.D. in Earth Sciences, Simon Fraser University, Canada, 2010. Committee member.

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Geoff Rawling, *Hydrogeologic characterization of the Sand Hill fault zone, Albuquerque Basin, New Mexico*. Ph.D. in Geology, NM Tech, 2001. Committee member.

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Michiel Heynekamp, *Controls on fault-zone architecture and fluid flow in poorly consolidated sediments: The Sand Hill fault, central New Mexico*. M.S. in Geology, NM Tech, 1998. Committee member.

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Garret Ross, *Environmental geologic maps of Santa Fe County, New Mexico*. M.S. in Mineral Engineering, NM Tech, 1992. Research advisor.

Valerie Rhodes, *Laboratory study of geogrid-reinforced sand-clay mixtures from Cenozoic basin-fill deposits, central New Mexico*. M.S. in Mineral Engineering, NM Tech, 1991. Research advisor.

TEACHING

UNIVERSITY

Geol 699	Geology Colloquium (University of Cincinnati, 2009, 10, 11)
Geol 331	Elementary Structural Geology (University of Cincinnati 2010, 11)
Geol 394	Digital Terrain Modeling (Northern Kentucky University, 2010)
Geol/Hydro 572	Mechanics of Earth Surface Processes (New Mexico Tech, 1997, 98)
Geol/Hydro 504	Hydrogeology (New Mexico Tech,, team taught, 1994)
Geol/Geoph 558	Mechanics of Earthquakes (New Mexico Tech, team taught, 1994)
Geol 571	Mechanics of Geologic Processes (New Mexico Tech, 1993)
Geol 391	Structural Geology (Portland State University, 2000)
Min Engr 540	Numerical Methods in Geotechnical Engrg (New Mexico Tech, 1990, 92)
Min Engr 581	Geologic Hazards (New Mexico Tech, 1991)
Min Engr 427	Site Investigation (New Mexico Tech, 1992)

TEACHING

PROFESSIONAL SHORT COURSES

Digital Terrain Modeling with Airborne LiDAR. Association of Environmental & Engineering Geologists Annual Meeting, Los Angeles, September 24, 2007.

Virtual Structural Mapping Using 3-D Digital Rock Slope Models*.* Association of Environmental & Engineering Geologists Annual Meeting, Los Angeles, September 25, 2007 (with J. Keaton, G. Poropat, and A. Gaich).

Introduction to Computational Hydrogeology: Developing Solutions to Groundwater Flow and Transport Equations. Northwest Environmental Training Center, Seattle WA, February 9-10, 2005.

Environmental Statistics for Site Managers, Northwest Environmental Training Center, Seattle WA, June 25-26 and August 21-22, 2003.

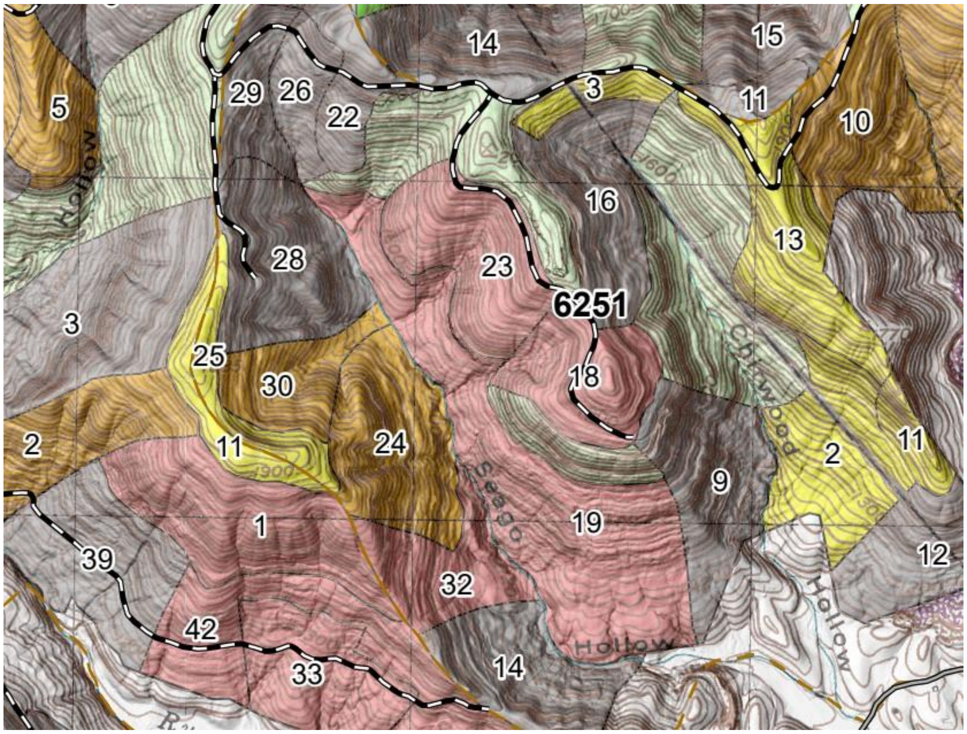
Applied Hydrogeologic Site Characterization for Environmental Professionals, Northwest Environmental Training Center, Seattle WA, May 29-30, 2003.

What are the Odds? An Introduction to Probabilistic Methods for Environmental and Engineering Geologists. AEG-AIPG 2002 Joint Annual Meeting, Reno, September 2002.

Appendix C

Stand 6249-1 Specifics for the Jellico Project

by Robert E. Messick Jr Visited 5/12/24 with Lauren Kallmeyer



Stand 6249 / 1

Dry Oak (or Dry and Xeric Oak Forest)

Geographic Location: on upland south and southwest facing slopes and on a shelf in the northern section of stand 1. This overlaps a bit with stand 11 (see WP #5). A rock edge exists near the border between stands 11 and 1. There are at least three shallow valley slopes that form in the upper sections of stand 1. They were not visited. More mesic forests may be present there?

Stand Prescription in EA of 2024: two-age shelterwood

Comparison with EVCode in FSVeg: listed as 'Chestnut Oak forest' in the database though old black gum and white oak trees were also present

Relation to R8G Age Minimums: black gum, chestnut oak, and white oak are likely the oldest trees in the stand, and codominant trees of these species would likely be well beyond the 110 year minimum in R8 Old Growth Guidance (see photos)

Range of Larger Trees: (see photos)

black gum: 81 - 55 cm dbh

chestnut oak: 60 to 55 to 50 cm dbh

white oak: 65.5 to 50 to 45 to 41 cm dbh

black oak: 47.5 cm dbh

red maple: 12.5 cm dbh

Associated Trees and Shrubs: sourwood was present though only in the understory. Patches of blueberry were present.

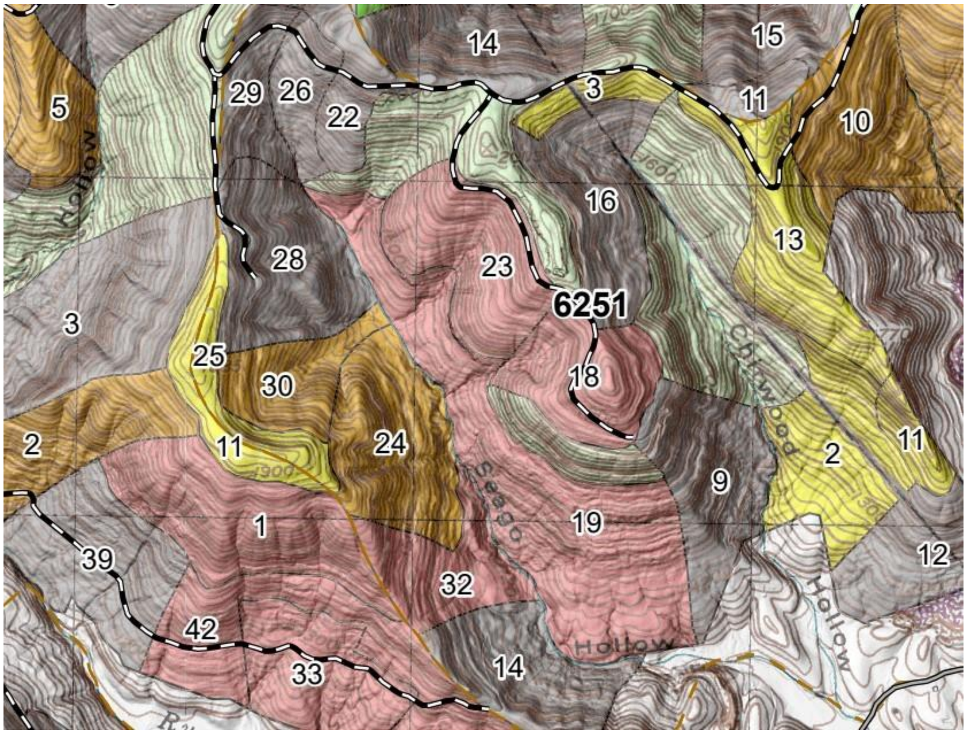
Herbs: sparse

Signs of Human Disturbance: some cut wood was spotted, mainly associated with previous logging on the main ridge (i.e. more related to stand 11)

Comments: core sampling could be done in stand 1. Fire scars at the base of some trees point to a previous fire episode – though fire char was not found on down wood.

Stand 6249-3 Specifics related to the Jellico Project

by Robert E. Messick Jr Visited 5/12/24 with Lauren Kallmeyer



Stand 6249 / 3 (not in the timber sale)

Dry Oak (or Dry and Xeric Oak Forest)

Geographic Location: on an upland west facing slope slightly downslope of FSR 6279C. See waypoints #1 and #2 west of the FSR.

Stand Prescription in EA of 2024: none (stand 3 is a large un-inventoried stand and experience in Pisgah NF shows that stands of this kind may contain old-growth forests). This stand, and parts of nearby stand 2, could use more examination to find edges. Stand 2 is in the timber sale, and upland coves there deserve examination.

Comparison with EVCode in FSVeg: ?

Relation to R8G Age Minimums: some codominant chestnut oak trees in this area would likely be well beyond the 110 year minimum in R8 Old Growth Guidance (see photos)

Range of Larger Trees:

chestnut oak: 103.5 - 78 cm dbh (see WP #2 for the location of the large chestnut oak)

A chestnut oak snag with a large burl (healed scar) was found in this area (see photo). Burls have also been found on some old trees in Pisgah NF.

Associated Trees: regenerating black oaks were found, though they were not in the canopy. Red maple and sassafras were in the understory. Black gum was also present.

Herbs: sparse

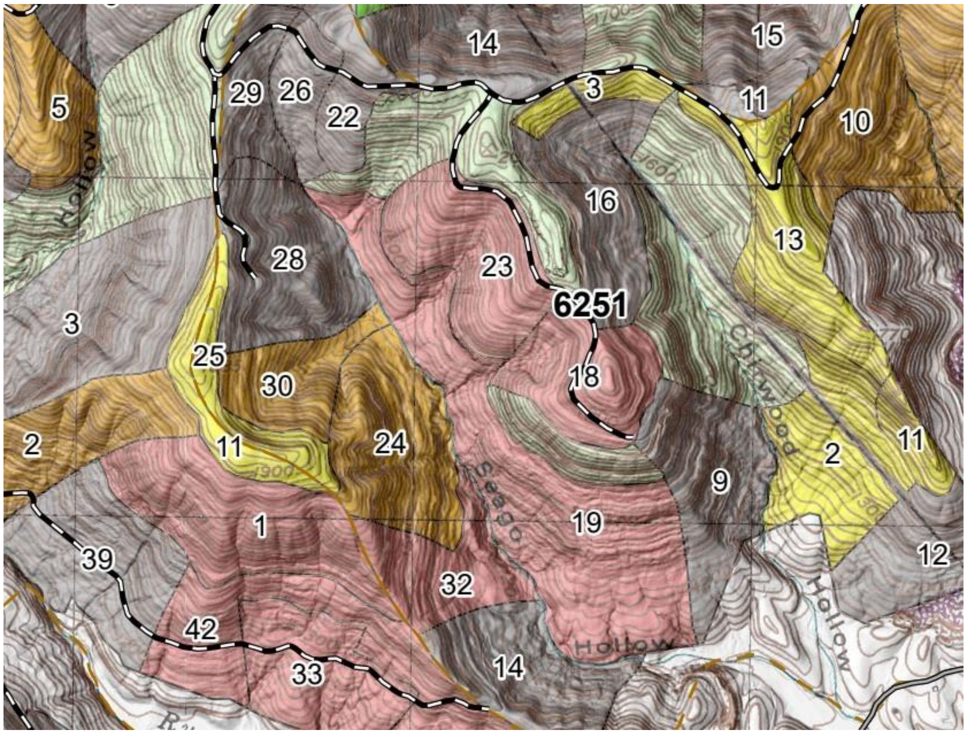
Basal Area: 150 sq ft/acre which could be considered above average for this forest type

Signs of Human Disturbance: the road on the ridge, and some logging activity associated with it, were the main forms of human disturbance. Signs of logging access were not found in the upland section of stand 3, though we did not go downslope to investigate edges.

Comments: this Dry Oak forest is somewhat similar to the same type found on the ridge slope between Tributaries A & B on 5/13/24. Rock outcrops were common, and the bedrock depth was shallow. The canopy was full though down wood had fallen randomly in the past.

Stand 6251-18 Specifics for the Jellico Project

by Robert E. Messick Jr Visited 5/13/24 with Dave Cooper



Stand 6251 / 18

Dry Oak Heath

Geographic Location: found on a relatively consistent southwest facing slope near 1700' on a shelf in Tributary B (see the map that names tributaries)

Stand Prescription in EA of 2024: two-age shelterwood

Comparison with EVCode in FSVeg: the database does not appear to recognize DOH

Relation to R8G Age Minimums: codominant chestnut oaks may reach or surpass minimums found in R8 Old Growth Guidance for Dry Oak.

Range of Larger Trees:

chestnut oak: nm (see a nearby measurement below)

shortleaf pine: 22.5 cm dbh (these were not common – only two were seen)

Mountain laurel was in bloom in the understory.

Herbs: very sparse, though an orchid (possibly pink lady slipper?) was spotted

Signs of Human Disturbance: no signs of skidders, cut wood, metal artifacts, or trash were found

Comments: Dry Oak (or ‘Chestnut Oak forest’) west of this Dry Oak Heath occurrence had chestnut oaks up to 86 cm dbh. Scars were found on some trunks but they survive.

-

Submesic Oak (or Dry-Mesic Oak Forest) (a.k.a. Montane Oak-Hickory forest)

This type could also be considered *Mesic Oak* (see the species composition)

Geographic Location: found in a shallow valley slope with a shelf in Tributary B between ~1740’ and 1600’. The aspects were mainly southwest and northwest. At 1700’ the stream flowed west / southwest.

Somewhat dryer oak forest, still likely submesic, was found upslope of 1740’ toward the gap there FSR 6279D exists. Some sizable n. r. oaks were spotted in this upland area.

Stand Prescription in EA of 2024: two-age shelterwood

Comparison with EVCode in FSVeg: the listing in the database appears to be wrong in assuming this is Dry Oak. It is possible some areas in Tributary B could be considered Mesic Oak - particularly with the presence of sugar maple, pawpaw relatively high in the understory, and some yellow buckeyes in the understory.

Relation to R8G Age Minimums: it is possible the larger codominant white oaks, northern red oaks, and some hickories would have age beyond the 130 year minimum for this type that is found in R8 Old Growth Guidance

Range of Larger Trees: (see photos)

northern red oak: 96.5 (buttressing) to 77.5 cm dbh

white oak: 100.5 to 80 to 78.5 cm dbh

tulip poplar: 88.5 to 72.5 to 60 to 57.5 to 55 cm dbh bitternut hickory: 75 - 72.5 cm dbh

shagbark hickory: 60 cm dbh

sugar maple: 42.5 cm dbh

Associated Trees: pawpaw (higher in the canopy than in Tributary A), redbud, and black gum were present near Tributary B. A few yellow buckeyes were present in the understory.

Herbs: mayapple, wild ginger (prolific), little brown jug (*Hexastylis arifolia*), violets, meadow rue, black cohosh, jack in the pulpit, white lettuce (*Prenanthese alba*), and rattlesnake plantain were present. Maple-leaved viburnum was present. A photograph of an unknown herb with bladed leaves and a long stalk was taken in this type.

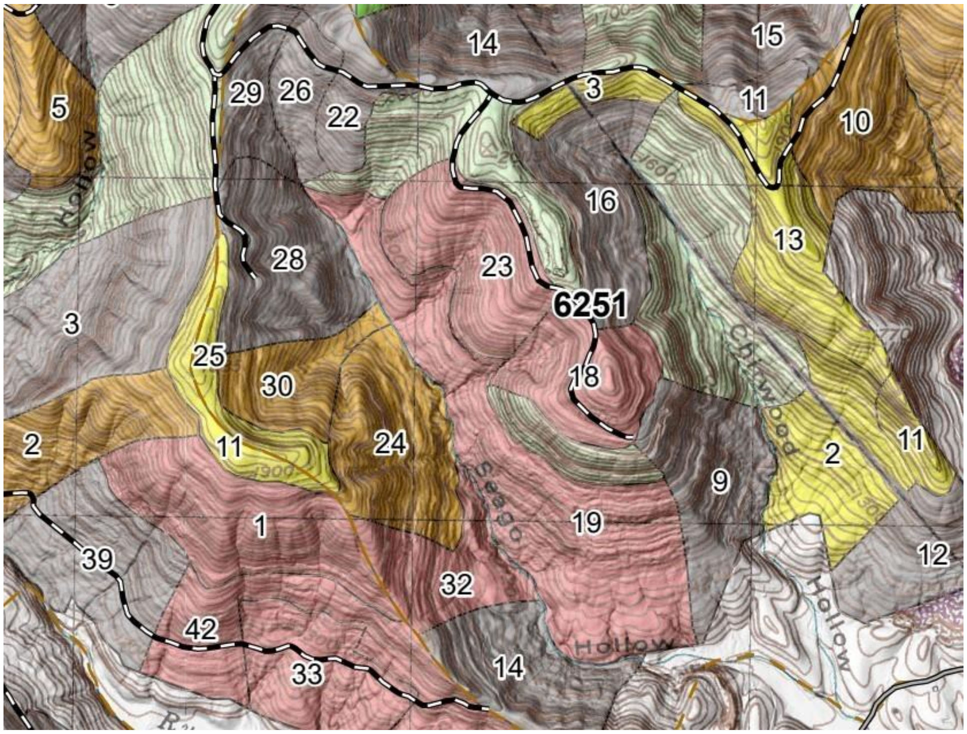
Signs of Human Disturbance: no signs of skidders, cut wood, metal artifacts, or trash were found. No sign of industrial access was found down to 1600' in this valley slope. Does this condition extend to stand 19 below?

Comments: different bird species were heard in this area compared to nearby Dry Oak and Dry Oak Heath forests. Randomly fallen down wood in many stages of decay was spotted in numerus sections of the valley slope. A few blown over trees with tip-up mounds were present. Pit and mound topography from older tip-ups was spotted in some areas in Tributary B.

Note: tree density appears to thin out (with less larger trees in the mix) below 1600', which is similar to conditions in lower sections of Tributary A, and in Tributary 1 on the west side of Seago Hollow. No signs of industrial access were found at 1600' in Tributary B.

Stand 6251-23 Specifics for the Jellico Project

by Robert E. Messick Jr Visited 5/13/24 with Dave Cooper



Stand 6251 / 23

Dry Oak (or Dry and Xeric Oak Forest)

Geographic Location: found in the upland section of Tributary A between ~1860’ and 1750’. This is downslope of FSR 2679D.

Stand Prescription in EA of 2024: two-age shelterwood

Comparison with EVCode in FSVeg: the database accurately lists Dry Oak, though the band of Submesic Oak described below does not appear to be recognized

Relation to R8G Age Minimums: larger codominant trees would likely have age beyond the 110 year minimum for this type that is found in R8 Old Growth Guidance

Range of Larger Trees:

chestnut oak: 85 cm dbh

white oak: 59.5 cm dbh

tulip poplar 50 cm dbh

Associated Trees: black gum (less than 60 cm dbh), sourwood, red maple, and a low frequency of sugar maple. Mountain laurel was present, though not in high concentrations.

Herbs: sparse

Signs of Human Disturbance: no signs of skidders, cut wood, metal artifacts, or trash were found

Comments: patches of greenbrier were common in this type. Rock outcrops were common, and the bedrock depth was shallow. Down wood in numerous stages of decay was present. Snags were present.

This forest is nearly submesic with a relatively lush understory. Northern red oaks were found by the ephemeral streambed. Oak regeneration was prolific. Birds were frequently heard.

Note: the un-numbered stand at the top of FSR 6279D appears to be *similar* old Dry Oak forest with chestnut oaks 76 cm dbh and above

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Submesic Oak (or Dry-Mesic Oak Forest) (a.k.a. Montane Oak-Hickory forest)

Geographic Location: found on a shelf at 1750’ in Tributary A (see the map that names tributaries)

Stand Prescription in EA of 2024: two-age shelterwood

Comparison with EVCode in FSVeg: submesic oak appears to be missing from this oversimplified and timber-oriented database related to stand 23

Relation to R8G Age Minimums: core sampling would have to be done to find out if codominant trees would reach or surpass the 130 year minimum for this type that is found in R8 Old Growth Guidance

Range of Larger Trees:

northern red oak: 62 – 60 cm dbh

white oak: 60 to 52 to 45 cm dbh

tulip poplar: 72.5 cm dbh

chestnut oak: 65 cm dbh

pignut hickory: 47.5 cm dbh

red hickory: 32.5 cm dbh

Associated Trees: sassafras was in the understory. Cucumber magnolia and sugar maple were regenerating in this type.

Herbs: ferns, poison ivy, and a small number of herbs were present

Signs of Human Disturbance: no signs of skidders, cut wood, metal artifacts, or hunter's trash were found. A party ballon had floated into the area, popped, and landed.

Comments: greenbrier patches were still present, though the understory was relatively open. Down trees related to a blow-down event were spotted in this type. An orange newt was spotted under a down log in this area.

-

Dry Oak (or Dry and Xeric Oak Forest)

Geographic Location: found somewhat below the shelf mentioned above at 1700' in Tributary A (see the map that names tributaries, and a photo taken at 1700').

This type extended downslope to 1600' in Tributary A. Tree height may have been between 80 and 100 feet at this low elevation. Nearby slopes were dominated by chestnut oak.

Stand Prescription in EA of 2024: two-age shelterwood

Comparison with EVCode in FSVeg: this matches the type listed in the database

Relation to R8G Age Minimums: it is possible some codominant trees would be older than the minimum for this type that is found in R8 Old Growth Guidance (i.e. 110 years)

Range of Larger Trees: (see photo with these two trees) chestnut oak: 67.5 cm dbh

black gum: 50 cm dbh

Associated Trees: relatively short pawpaws were found in a patch in the perking stream in this area of Tributary A. They were considerably shorter than those found in Tributary B. Sugar maple and flowering dogwood were present in the understory near the streambed in this area. Some black gums were present near the stream. Some azaleas were spotted.

Herbs: sparse, though maple-leaved viburnum was present

Basal Area: at 1600’ a BA reading was 110 sq ft/acre which is average or just below average for older Dry Oak forest. No northern red oaks or white oaks were present at this elevation. Black oak was regenerating, but no canopy trees of this species were present.

Signs of Human Disturbance: no signs of skidders, cut wood, metal artifacts, or trash were found

Comments: the stream perked in this area and a colored Upland Burrowing Crayfish was spotted in the streambed (see photo by Dave Cooper). A box turtle was spotted in this area. Rock outcrops were frequent, and two photos of a chestnut oak that had growth “lips” around a nearby rock were taken. This is a sign of continuity.

At 1600’ in Tributary A down wood had fallen randomly, and some of it was in advanced decay. Some pit and mound topography was present.

Link: https://www.facebook.com/kdfwr/posts/beautiful-crayfish-what-do-you-think-the-upland-burrowing-crayfish-ranges-in-col/10157968462758782/

-

Dry Oak (or Dry and Xeric Oak Forest)

Geographic Location: found at 1700’ on a shelf on the ridge slope between Tributaries A and B. No sign of an access road was spotted.

This type was also found between 1600’ and 1550’ on west / northwest facing steep slopes and a shallow valley slope (see two chestnut oak measurements and one photo from this area). This was the lowest point accessed in the Seago Hollow area.

Stand Prescription in EA of 2024: two-age shelterwood

Comparison with EVCode in FSVeg: these areas seem to match listings in the database

Relation to R8G Age Minimums: it is very likely these two areas have codominant trees that would surpass the minimum age requirement for this type in R8 Old Growth Guidance (i.e. 110 years)

Range of Larger Trees:

chestnut oak (on W/NW facing steep slopes): 95.5 - 88 cm dbh (the largest had a burl)

chestnut oak: some larger trees showed signs of buttressing

white oak: nm

black gum: 60 cm dbh

Associated Trees and Shrubs: smaller black gums and mountain laurel were present. A few cucumber magnolias were in the understory in this type.

Herbs: sparse

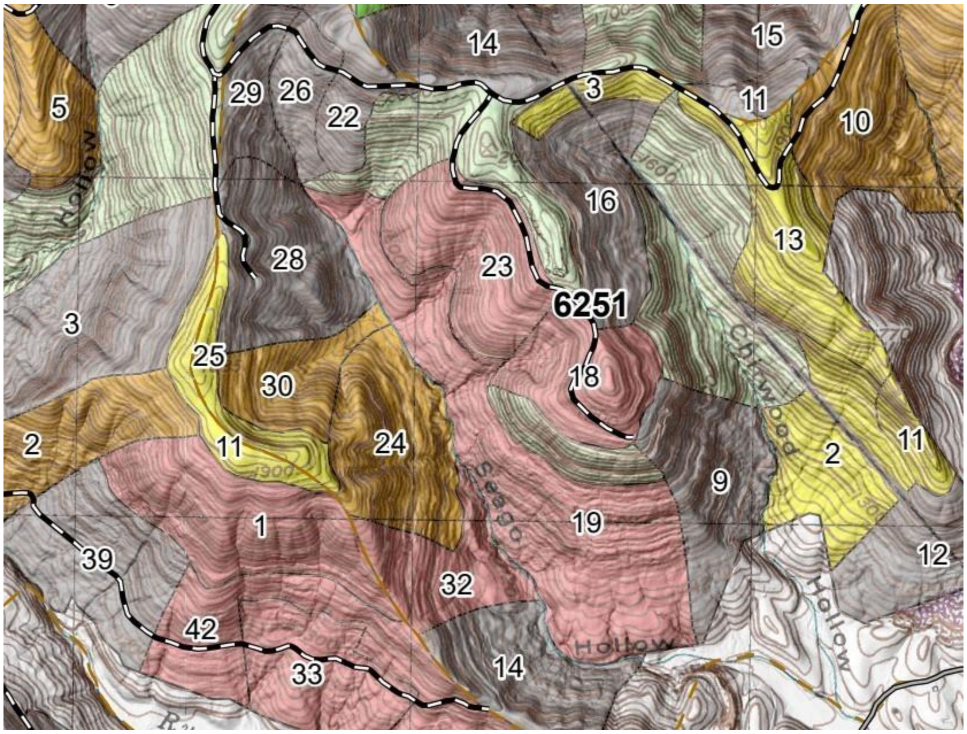
Basal Area: 150 sq ft/acre on the shelf at 1700’ which is above average for this type and is equivalent to the basal area measurement that was done in stand 6249-3 on 5/12/24.

Signs of Human Disturbance: no signs of skidders, cut wood, metal artifacts, or trash were found

Comments: down trees with no sign of cutting were common in this area, and yet the basal area was still relatively high. Tip-up mounds revealed tan to light orange subsoil. Birds were frequently heard in this area, and woodpeckers were present.

Stand 6251-24 Specifics for the Jellico Project

by Robert E. Messick Jr Visited 5/12/24 with Lauren Kallmeyer



Stand 6251 / 24 (and parts of stand 25)

Mixed Mesophytic (or Rich Cove forest)

Geographic Location: found from ~1600' to ~1700' in the small cove labeled Tributary 2, which is smaller than Tributary 1 and is on the west side of stand 24.

Stand Prescription in EA of 2024: deferment harvest (essentially leaving a basal area of 20 to 40 sq ft /acre of codominant trees and coming back 10 to 15 years later to remove the rest - all ephemeral stream zones retain a minimal basal area of 15 sq ft/acre).

Comparison with EVCode in FSVeg: the database for this large stand lists Submesic Oak, though it misses the importance of Tributary 2, the presence of a small patch of mixed mesophytic forest, and the presence of a listed plant that occurs there. Ascribing one forest type to a stand this large is inconsistent with ecological forest typing.

Relation to R8G Age Minimums: it would be necessary to core codominant trees to find out if this area reaches or surpasses the age minimum for this type that is found in R8 Old Growth Guidance (i.e. 140 years)

Range of Larger Trees:

yellow buckeye: 57.5 cm dbh

tulip poplar: nm

black walnut: 50 cm dbh

American beech: 45 cm dbh (and larger)

northern red oak: nm

Associated Trees: American basswood was present in the understory. Red hickory, pawpaw, and flowering dogwood were also present. Biltmore ash trees were snags in this area due to insect infestation.

Herbs: nodding trillium and patches of woods nettle were found in the streamway in this section of Tributary 2. A listed rare plant occurs frequently in this cove.

Signs of Human Disturbance: no signs of skidders, cut wood, metal artifacts, or hunter's trash were found

Comments: canopy gaps and naturally broken trees were common in the lower section of this cove in Tributary 2. Wind events likely occurred in the past. Down wood was in many stages of decay. Down wood had also fallen randomly, and pit and mound topography was present. Mushrooms were present.

-

Submesic Oak (or Dry-Mesic Oak forest) (a.k.a. Montane Oak-Hickory forest)

This type could also be considered *Mesic Oak* (see the species composition)

Geographic Location: found from ~1700' to ~1850' in the upland section of Tributary 2 as it becomes a slope. Some of this area overlaps with stand 6251-25 near the ridge.

Stand Prescription in EA of 2024: deferment harvest in stand 24 and clearcutting in stand 25

Comparison with EVCode in FSVeg: this appears to match the type listed in the database

Relation to R8G Age Minimums: codominant oak trees in this area would likely reach or exceed age minimums for this type in the R8 Old Growth Guidance (i.e. 130 years)

Range of Larger Trees: (see photos)

northern red oak: 95.5 - 78 cm dbh

white oak: 84.5 - 65 cm dbh

shagbark hickory: 65 cm dbh

Associated Trees: yellow buckeye, American basswood, and sugar maple were in the understory. Pawpaw, red hickory, and red maple were also present. Sizable Biltmore ash trees were snags in this area due to insect infestation.

Herbs: blue cohosh and darker A-horizon soils were found on upland slopes in this area. A listed rare plant also occurs in this higher section. On this slope in the range of 1800' wild cumfrey and solomon's seal were spotted.

Signs of Human Disturbance: downslope of logging disturbances on the ridge in stand 25 no sign of skidders, cut wood, metal artifacts, or hunter's trash were found. In the vicinity of 1900' or slightly below an obvious edge of past logging was encountered. Extensive logging activity had occurred on the ridge in the past.

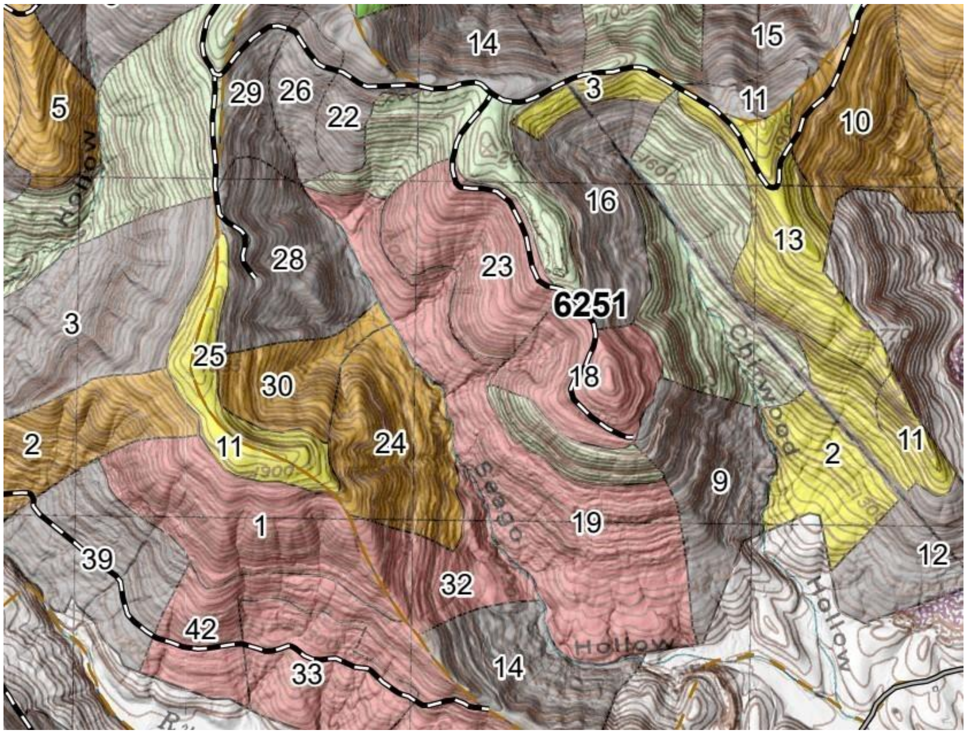
Comments: canopy gaps due to blow downs in the past were common. A large blowdown occurred near the ridge slope that forms the eastern edge of Tributary 2. It is possible to see into Seago Hollow from there, and the stream is audible. Other canopy gaps were spotted near the boundary between stands 24 and 25.

Note: old blue paint marks were found on a mid-size tree on the eastern ridge slope, which may mark boundaries before the national forests were acquired?

Note: an old gold-colored paint mark was found on a shagbark hickory tree higher up, closer to 1800'.

Stand 6251-25 and Stand 6251-30 Specifics for the Jellico Project

by Robert E. Messick Jr   Visited 5/12/24 with Lauren Kallmeyer



Stand 6251 / 25 and Stand 6251 / 30

Mesic Oak (Lucy Tyrrell et al., 1998)

Geographic Location: found in a small area at the top edge of Tributary 1 a little above 1900’. This changed to mixed mesophytic forest very quickly downslope.

Stand Prescription in EA of 2024: clearcut

Comparison with EVCode in FSVeg: the database lists Submesic Oak, however sugar maples and pawpaws were in the understory and this mesic oak forest with sizable trees is right next to mixed mesophytic forest

Relation to R8G Age Minimums: it is possible codominant trees in this area would reach or surpass the 120 year minimum for this type recognized in Tyrrell et al., 1998 (pgs 186-188)

Range of Larger Trees:

northern red oak: 110 cm dbh

tulip polar: 84.5 cm dbh (see photo)

Associated Trees: sugar maple, red maple, and pawpaw were present in the understory. Spicebush was common, as it was in mixed mesophytic forest below.

Herbs: bloodroot, blue cohosh, black cohosh, and mayapple were present

Basal Area: nm, but relatively high in this area

Signs of Human Disturbance: logging had occurred on the ridge, though it did not appear to proceed down the slope. Northern red oak trees often fill gaps and it would be interesting to see how old some of the larger ones are in this area.

-

Mixed Mesophytic (or Rich Cove forest)

Geographic Location: found from ~1900' to ~1650' in Tributary 1 in most of stand 30. The cove has a general northeast orientation.

Stand Prescription in EA of 2024: two-aged shelterwood

Comparison with EVCode in FSVeg: the database lists Submesic Oak, though this is clearly not an oak dominated forest. It is a variant of rich cove or mixed mesophytic forest with rock outcrops and some talus conditions.

Relation to R8G Age Minimums: it would be necessary to core numerous codominant tulip poplars in this area to find out if they reach or exceed minimum age requirements for mixed mesophytic forest found in R8 Old Growth Guidance (i.e. 140 years)

Range of Larger Trees:

tulip poplar: 85 cm dbh (see photo)

sugar maple: nm

black walnut: nm

American beech: 15 cm dbh

Associated Trees: the understory had a significant amount of pawpaw, sugar maple, and spicebush (see one of the photos). American basswood, redbud, American hornbeam, and umbrella magnolia were also present. Northern red oak was present below breast height, and suppressed under the canopy, though it was not frequently encountered. Similar dynamics were true for red and shagbark hickories. A dead white or Biltmore ash tree was spotted.

Herbs: blue cohosh (common), black cohosh, sweet cicely (carrot family), maidenhair ferns, and an unknown orchid species were present

Signs of Human Disturbance: two rock piles that may have been collected by humans in the past (?) were encountered. Talus conditions exist in this cove. Other than this no signs of skidders, roadbeds, metal artifacts, or trash were found.

Comments: tree height increased as we dropped from the ridge. Canopy gaps were common in this type. Down wood had fallen in a random way, and it was in numerous stages of decay.

Rock outcrops were frequent, and the bedrock depth was shallow, though soils were dark brown.

The lower section of stand 30, at about 1650’, had more open understory conditions. Tulip poplar was still in the canopy and sugar maple and American basswood were common in the understory. There were fewer large trees, though no obvious signs of industrial access were found. Small valley slopes joined near this elevation. Numerous birds were heard.

Appendix D. Response to Socioeconomic Analysis

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May 24, 2024

The following memo is in response to the Draft Jellico Vegetation Management Project Environmental Assessment (called the Jellico Management Project), specifically the Fitzsimmons Socioeconomic Analysis: Jellico Vegetation Management Project (called the Socioeconomic Analysis) prepared on 4/4/2024. It is the position of the organization listed above that this Socioeconomic Analysis considers only a portion of the costs and benefits associated with the Jellico Management Project, undercounting the actual costs associated with disturbance and removal of forest vegetation in the project area. This undercounting results in a skewed net benefit calculation that misleads the public on the return on investment of the Jellico Management Project, including alternatives.

This memo was prepared below by Zachary Christin of Equilibrium Economics (Batker Consulting). Mr. Christin has worked in ecological economics for 15 years focused on federal regulatory policy and advanced applications of benefit-cost analysis (BCA) with federal agencies such as FEMA, HUD, EPA, and USFS. Mr. Christin led research to incorporate environmental benefits for FEMA's BCA tool, resulting in FEMA Policy FP-108-024-01 (FEMA 2013). Christin also participated in HUD's National Disaster Resilience Competition as a Subject Matter Expert on Economics and BCA.

The remainder of this memo estimates additional costs associated with the Jellico Management Project that are omitted from the Socioeconomic Analysis. This information follows methods adopted by other federal agencies and should be used in conjunction with the content already presented in the Socioeconomic Analysis to recalculate the Net Benefits associated with the Jellico Management Project.

X. Overview of Methodology and Federal Acceptance

The methodology used in this memo to calculate costs associated with the Jellico Management Project uses an ecosystem goods and services (EGS) framework under a mixture of value estimation approaches called Benefit Transfer Method (BTM) and Function Transfer Method (FTM). This section discusses the EGS framework, how BTM and FTM are used to estimate value under the framework, and how federal entities currently use it.

In 2001, an international coalition of scientists, economists and policy makers assessed the effects of ecosystems on human well-being (MEA, 2005) The resulting Millennium Ecosystem Assessment classifies EGS into four broad categories according to how they benefit humans:

- Provisioning goods provide physical materials and energy for society from natural systems. Forests produce lumber, agricultural lands supply food, and rivers and aquifers provide drinking water.
- Regulating services are benefits obtained from the natural control of ecosystem processes. Intact ecosystems keep disease organisms in check, improve water quality, control soil erosion or accumulation, reduce disaster damage, and regulate climate.
- Supporting services include primary productivity (natural plant growth) and nutrient cycling (nitrogen, phosphorus, and carbon cycles). These services are the basis of the vast majority of food webs and life on the planet.
- Information services are functions that allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, and opportunities for scientific research and education.

Each category above can be defined by several EGS, and contributions that ecosystem services make to human well-being. Table 1 below the ecosystem services valued in this analysis within these four categories and the economic benefits provided to people.

Table 1. Ecosystem Goods and Services List and Description of Benefits to People

Ecosystem Goods & Services	Economic Benefits to People
Provisioning	
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy
Food	Producing crops, fish, game, and fruits
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Providing resources for clothing, jewelry, handicraft, worship, and decoration
Water Storage	Providing long-term reserves of usable water via storage in lakes, ponds, aquifers, and soil moisture
Regulating	
Air Quality	Providing clean, breathable air.
Biological Control	Providing pest, weed, and disease control
Carbon Sequestration & Stock	Supporting a stable climate at global and local levels through carbon sequestration.
Disaster Risk Reduction	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts.
Pollination & Seed Dispersal	Pollinating wild and domestic plant species via wind, insects, birds, or other animals
Soil Quality and Formation	Maintaining soil fertility and capacity to process waste inputs (bioremediation)
Soil Erosion Protection	Retaining arable land, slope stability, and coastal integrity.
Water Quality	Removing water pollutants via soil filtration and transformation by vegetation and microbial communities.
Water Supply	Regulating the rate of water flow through an environment and ensuring adequate water availability for all water users.

Temperature Regulation	Shade provided by forests can reduce local temperatures and provide energy savings
Supporting	
Habitat	Providing shelter, promoting growth of species, and maintaining biological diversity.
Nutrient Cycling	Movement of nutrients through an ecosystem by biotic and abiotic processes. Supports retention in the biosphere and the soil organic layer
Information	
Aesthetic Value	Enjoying and appreciating the scenery, sounds, and smells of nature.
Cultural Value	Providing opportunities for communities to use lands with spiritual, religious, and historic importance
Science & Education	Using natural systems for education and scientific research
Recreation & Tourism	Experiencing the natural world and enjoying outdoor activities.
Artistic Inspiration	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, and media

Overview of BTM & FTM

BTM is a widely accepted valuation method that has been used for many decades in the ecosystem service valuation field. Authors such as Freeman (1984) have been conducting benefit transfer since the 1980s, and in the early 1990s benefit transfer was broadly recognized as a distinct area of research (Rosenberger and Loomis, 2001). The BTM allows for the estimation of ecosystem service values by transferring values estimated in a previous study (i.e., study site) to a different location, to the area of interest, or target location (i.e., policy site).

FTM is a type of BTM that utilizes a value function estimated for an individual study site in conjunction with information on policy site characteristics to calculate the unit value of an ecosystem service at the policy site. This approach may provide a more accurate estimate of value for the policy site with the available on-the-ground data and particularly if limited studies exist which meet the criteria for a valid value for transfer.

Currently, multiple academic articles and federal agencies publish criteria and best practices to ensure valid benefit transfer. Criteria were first recommended by Boyle and Bergstrom (1992) which states that, under ideal conditions, the source and target sites, populations, and welfare measures are matched as closely as possible. Since then, guidelines have been proposed to ensure appropriate value transfer when variation in study and policy site is present. Later sections of this memo estimate costs of the Jellico Management Project via the loss of benefits due to clearcut and two-age shelterwood land management practices. Best practice criteria for BTM and FTM were used to estimate these costs.

EGS in Federal Agencies

Currently, the use of BTM economic values is used by several federal agencies. The EPA utilizes BTM in benefit-cost analyses related to proposed air and water quality regulations and is specifically discussed in the EPA's Guidelines for Preparing Economic Analyses (EPA, 2014). The U.S. Forest Service and U.S. Army Corps of Engineers both utilize BTM for estimating the economic value of recreation related to project activities and impacts (Johnston et al., 2015). FEMA allows the use of BTM valuation in their Hazard Mitigation Assistance Program and all other mitigation projects (FEMA, 2016). Some examples of administratively approved values include the U.S. Forest Service Resources Planning Act for recreation and other ecosystem services or the U.S. Water Resources Council's values for recreation (Richardson et al., 2015; Rosenberger et al., 2017).

The remainder of this document will focus on estimating the cost of the Jellico Management Project using the EGS framework and BTM/FTM methodology. The same BTM approach used in this memo is consistent with the approach cited above.

X. Economic Cost by Ecosystem Good and Service Category

This section summarizes the literature and data used to estimate costs of the Jellico Management Project. This section considers a subset of EGS shown in Table 1 above, consolidating some above categories into the following:

1. Water Quality, Storage, and Retention
2. Recreation and Aesthetic Value
3. Carbon Sequestration

Given the omission of the other ecosystem services due to data and time limitations, this analysis should be considered an underestimate of the full EGS cost of the Jellico Management Project.

Water Quality, Storage, and Retention Costs

The Daniel Boone NF functions as a critical headwaters region for the Cumberland River, significantly influencing water quality and hydrological storage. Figure 1 below shows the rivers surrounding the project area that eventually feed into the Cumberland River. The forest's vegetation and watershed systems regulate sedimentation, nutrient runoff, and erosion. Clearcutting and other silviculture activities in this area can adversely affect these regulatory mechanisms by increasing sedimentation and nutrient runoff, and by promoting erosion. Additionally, deforestation reduces the forest's capacity for water storage and controlled release, potentially disrupting natural flow regimes.

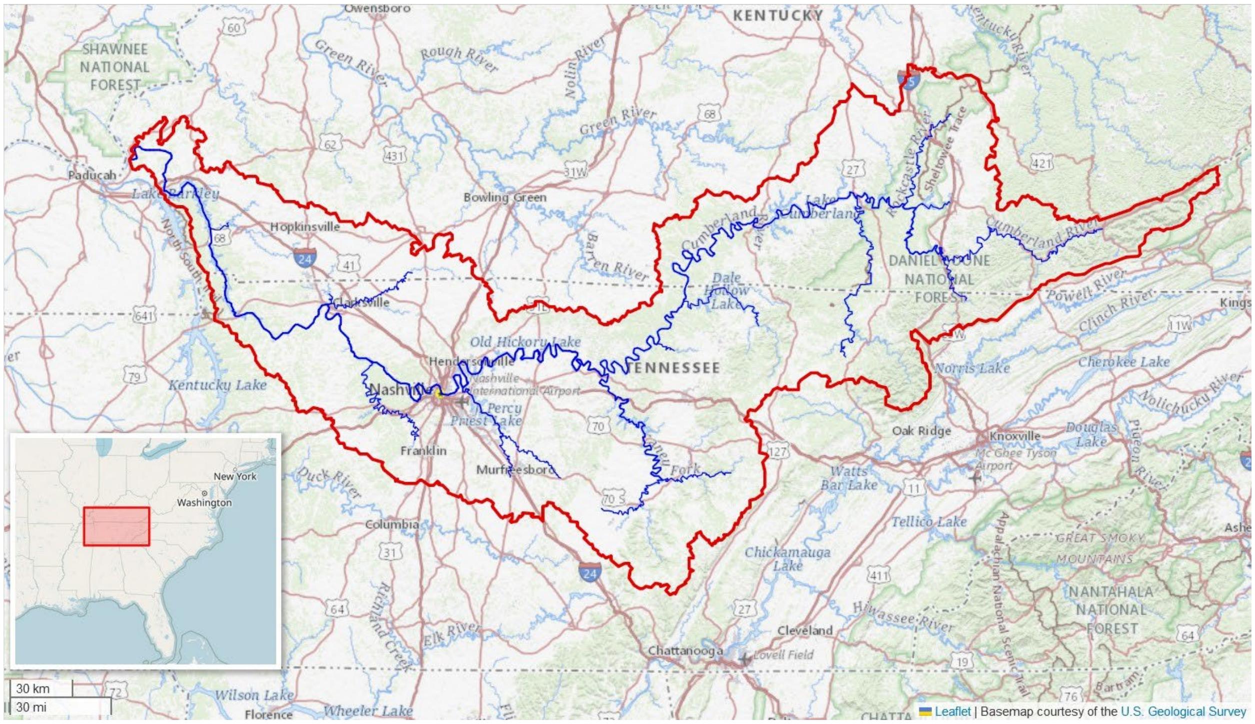

Figure 1. Map of Cumberland River and Tributaries

As addressed above, understanding the cost of clearcutting and two-stage shelterwood activities in this memo will require the use of BTM. Fortunately, published peer-reviewed literature shed light on this cost using data directly from the Daniel Boone NF. In one study, Hill et al. 2014 sampled over 10 different points in and directly outside of the Daniel Boone NF to understand the water related EGS provided by these upland forests.

Hill et al. found that upland forests provide between $1,563 to $1,726 in *annual* water quality benefits for each acre of forest. This accounts for sedimentation and nutrient runoff that would otherwise be released and eventually flow downstream in the event of a major disturbance such as clearcutting. The range in value accounts for multiple data points.

Likewise, Hill et al. found that upland forests provide approximately $156 in *annual* water storage and retention benefits for each acre of forest. This accounts for water stored and slowly released over time, relieving downstream pressure during heavy storm events. With the removal of upland forests, stormwater converts to surface water, more quickly accessing nearby rivers. The loss of these benefits is recognized as a cost for each acre clearcut or otherwise.

Table 2 below summarizes these costs. All figures were converted to 2023$/acre/year. This data was found appropriate for BTM to understand the costs of the Jellico Management Project, where clearcutting and other silviculture activities remove the value of forest as summarized in Table 2.

Table 2. Water Quality and Water Storage & Retention Annual Value per Acre ($2023)

EGS Category	**$ per acre per year**	**$ per acre per year**

Water Quality	$1,563	$1,725
Water Storage and Retention	$156	$156

Recreation and Aesthetic Opportunity Costs

The Daniel Boone NF receives over one million visitors each year; however, the Jellico Management Project area experiences little in the way of recreational visitors. Only a couple dispersed campsites exist with no managed trails in the project area. Despite this fact, the Jellico Management Project area in its current condition still provides recreational and aesthetic value to surrounding residents and visitors. The infrequently visited area serves as contiguous habitat for animal species that provide recreational opportunities (sightseeing, hunting, etc.) to people elsewhere in Daniel Boone NF and beyond.

Recreational and aesthetic value people derive from forests such as these can be measured using visitor data. For example, one study (Bowker et al. 2009) valuing camping and backpacking in national forests shows that people value these activities between $35 to $111 per day when converted to 2023$. Given data limitations on the Jellico Management Project area current visitation, the BTM approach is used to estimate this value.

A study by Moore et al. 2011 surveyed residents in a region surrounding rural private forests, asking residents their willing-to-pay to preserve these forests under threats of development and clearcutting. For each acre of the forest, the study found the surrounding community was willing to pay between $73 and $6,544 for the forest's preservation each year (converted to 2023$), the range reflecting variations in income and demographics of the population sampled. Table 3 summarizes this value below.

The conditions outlined in the Moore et al. study closely resemble the rural context of the southern region of Daniel Boone NF where the Jellico Management Project is proposed to take place. Residents and visitors retain comparable value knowing this area is left preserved for the opportunities to visit and experience habitat that migrate outside the area. This data was found appropriate for BTM to understand the costs of the Jellico Management Project, where clearcutting and other silviculture activities remove the value of forest as summarized in Table 3.

Table 3. Recreation and Aesthetic Annual Value per Acre ($2023)

EGS Category	$ per acre per year	$ per acre per year
Recreation and Aesthetic Value	$73	$6,544

Carbon Sequestration

Sequestered carbon biomass provides economic value by contributing to climate stability. Each year, upland forests in Daniel Boone NF sequester carbon which would otherwise be released into the atmosphere. To arrive at an annual dollar value per acre of carbon sequestration, total carbon biomass was combined with dollar values for each ton of carbon sequestered from forest types found in Daniel Boone NF.

One study published by the US Forest Service (Smith et al. 2006) was used to estimate carbon sequestration of regional forests in this memo. Multiple data points from this study were converted to annual metric tons of carbon sequestered per acre of vegetation types found specifically in the Daniel Boone NF. Table 4 summarizes this information below. The standing age of the forest was assumed to be between 40 years and 90 years, reflecting the survey conducted under the Jellico Management Project summary documents. The range in sequestration amounts below reflects this variation in assumed age.

Table 4. Carbon Sequestration per Ton by Forest Type

Forest Type	**Annual Carbon Sequestered Low (Tons)**	**Annual Carbon Sequestered Low (Tons)**
oak-hickory	0.782393449	0.939883855
oak-pine	0.737428309	1.005645373

A method must be selected to measure monetary value of each ton of carbon sequestered. One approach is using the social cost of carbon. This is defined as a dollar value that represents comprehensive estimate of climate change damages. It includes changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced heating costs and increased air conditioning costs (USEPA, 2016). The Center for Environmental Quality's Interagency Working Group on the Social Cost of Carbon published a report in 2011, indicating that the social cost of carbon ranges from approximately $46.05 to $142.33 per metric ton (Interagency Working Group on Social Cost of Carbon, 2013). This value has since been updated as recently as 2021, under the Biden administration, to $51 per ton of carbon (Fisher, 2024).

Table 5 below combined the carbon sequestered by forests and the social cost of carbon, estimating the value of carbon sequestration in upland forests of the study area to be $39.15 to $53.39 per acre per year. Values for tons of carbon sequestered were selected to represent the lowest and highest value from Table 4 above given the unknown forest type throughout the Jellico Management Project acre-by-acre.

Table 5. Carbon Sequestration Annual Value per Acre ($2023)

Tons C Low	**Tons C High**	**2021$ C**	**2023$/acre/year Low**	**2023$/acre/year High**
0.737428309	1.005645373	51	$39.15	$53.39

X. Total EGS Cost of the Jellico Management Project

According to the Jellico Vegetation Management Project (63037) 30-day comment period documentation provided by the USFS on April 23rd, silvicultural management is proposed west of I-75, including one proposed action and an alternative project that consist of the following:

- Proposed Action
  - 931 acres of clearcut
  - 1,805 acres of two-age shelterwood

  - 2,434 acres of deferment harvest
  - 4,367 acres of commercial thinning
- Alternative 1
  - 1,122 acres of two-age shelterwood
  - 1,811 acres of commercial thinning

For the scope of this memo, cost estimates will not include the impacts of commercial thinning. Furthermore, the use of "shelterwood" by the Daniel Boone National Forest to describe harvests has been shown to remove substantially more timber than is typically assumed under this terminology. Therefore, shelterwood is being treated as having the same impact as clearcut.

To understand the full impact of the Jellico Management Project, we must combine the annual per acre dollar values for each EGS identified above with the acres of clearcut and two-stage shelterwood management practices for each option. Table 6 summarizes this below, estimate the total annual impact to water quality, water storage & retention, recreation & aesthetic value, and carbon sequestration.

Table 6. Total Annual Cost by Jellico Management Project type and EGS

Proposed Action

Ecosystem Service	Acres Clearcut	Acres Two-Age Shelterhead	Per Acre Value Low	Per Acre Value High	Total Low	Total High
Water Quality	931	1,805	$1,563	$1,725	$4,275,005	$5,808,028
Water Storage and Conveyance	931	1,805	$156	$156	$426,332	$305,542
Recreation and Aesthetic Value	931	1,805	$73	$6,544	$200,578	$12,292,378
Carbon Sequestration	931	1,805	$39	$53	$107,117	$98,461
				total	***$5,009,032***	***$18,504,409***

Alternative 1

Ecosystem Service	Acres Clearcut	Acres Two-Age Shelterhead	Per Acre Value Low	Per Acre Value High	Total Low	Total High
Water Quality	0	1,122	$1,563	$1,725	$1,753,127	$4,630,038
Water Storage and Conveyance	0	1,122	$156	$156	$174,834	$199,115
Aesthetic and Recreation Value	0	1,122	$73	$6,544	$82,254	$7,822,567
Carbon Sequestration	0	1,122	$39	$53	$43,927	$61,995
				total	***$2,054,143***	***$12,713,714***

Results show that, for the Proposed Action, clearcutting and two-age shelterwood practices will induce costs between $5.0M to $18.5M in just the first year. Likewise, under Alternative 1 option of only two-stage shelterwood practices, practices will induce costs between $2.1M to $12.7M in just the first year.

It is worth highlighting that costs are not limited to the first year and will continue to be incurred each year until the first succession species replace this value, likely in a diminished capacity. It is also worth highlighting that the Year 1 costs highlighted here negate the net benefits identified in the Socioeconomic Analysis of $1.4M over the life of the project.

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X. Glossary

Benefit Transfer Methodology (BTM) – BTM is an ecosystem service valuation method that uses values derived from published studies for application in similar ecosystems. It resembles a house or business appraisal that is based on comparable characteristics of similar houses or businesses.

Ecosystem – An interacting system of living organisms, soil, and climatic factors. Forests, wetlands, watersheds, ponds, prairies, and communities are ecosystems.

Ecosystem Services – Benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, air, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling.

Ecosystem Services Valuation (ESV) – Ecosystem service valuation: Ecosystem service valuation is the quantification of the benefits that people derive from ecosystems, generally expressed as non-market values or market value equivalents.

Ecosystem Service Value - Measure of the benefit provided by an ecosystem using market proxies to infer a dollar value equivalent.