Date: August 8, 2018
To: Bureau of Land Management
From: Donald A. (Skip) Walker
Ph.D. & Professor, Department of Biology & Wildlife, and Institute of Arctic Biology, University of Alaska Fairbanks
Re: Comments on the BLM's planned Environmental Assessment for the conducting a seismic survey in the 1002 Area of the Arctic National Wildlife Refuge
Email to: blm_ak_coastal_plain_seismic_ea@blm.gov

Introduction

This letter addresses the Bureau of Land Management's (BLM's) plan for a seismic survey in the 1002 Area of the Arctic National Wildlife Refuge (ANWR)[1]. I am an arctic vegetation scientist and ecologist at the University of Alaska Fairbanks. I have been involved with vegetation research and tundra disturbance-and-recovery studies in arctic Alaska and the circumpolar Arctic for 49 years[2]. I mapped the vegetation of the 1002 Area in 1981–82[3]. In 2001–2003, I served on the National Research Council's Committee on Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope[4]. I am currently principle investigator of a project at Prudhoe Bay titled "Cumulative effects of arctic oil development – planning and designing for sustainability", funded by the National Science Foundation[5]. I am also principal investigator of a similar project in Russia sponsored by the National Aeronautics and Space Administration titled "Yamal synthesis: remote-sensing studies, ground observations and modeling to understand the social-ecological consequences of climate change and resource development on the Yamal Peninsula, Russia, and relevance to the circumpolar Arctic"[6],[7].

A recent description of BLM's planned review process for the seismic survey in the 1002 Area indicates that instead of an Environmental Impact Statement (EIS), as would normally be required for such a large-scale activity on public lands, BLM is planning a much shorter Environmental Assessment (EA) under the assumption that the action is "categorically excluded" from a more detailed environmental analysis because the action does not have a significant effect on the human environment[8].

After reviewing the proposed BLM seismic action plan, my expert opinion is that the finding of "no significant impact" is contrary to evidence from a variety of sources that I outline below. Although the full long-term effects of 3D seismic exploration are not well studied, there is overwhelming evidence that the proposed plan will clearly have significant long-lasting impacts. Before such a major action is permitted in one of the premier protected areas of the world, a comprehensive baseline study and a full Environmental Impact Statement (EIS) should be conducted. This would be consistent with national policy and precedent. The National Environmental Protection Act of 1970 requires federal agencies to prepare an EIS if a proposed major federal action is determined to significantly affect the quality of the human environment.[9] This letter should make it clear that there will be wide-ranging direct, indirect, and cumulative environmental impacts. I urge BLM to extend the 30-day public comment period and conduct a full EIS.

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[1] Bureau of Land Management (BLM). (2018). Seismic Exploration of the Coastal Plain. https://eplanning.blm.gov/epl-front-office/projects/nepa/111085/151625/185842/Seismic_Proposed_Action.pdf.

[2] Example tundra disturbance-and-recovery publications include: (1) Abele, G., Walker, D. A., Brown, J., Brewer, M. C., & Atwood, D. M. (1978). *Effects of low ground pressure vehicle traffic on tundra at Lonely, Alaska*. *CRREL Special Report 78-16* (p. 63). Hanover, NH: U.S. Army Cold Regions Research and Engineering Laboratory; (2) Walker, D. A., Webber, P. J., Binnian, E. F., Everett, K. R., Lederer, N. D., Nordstrand, E. A., & Walker, M. D. (1987). Cumulative impacts of oil fields on northern Alaskan landscapes. *Science*, *238*(4828), 757–761. http://doi.org/10.2307/170035; (3) Walker, D. A., Cate, D., Brown, J., & Racine, C. (1987). *Disturbance and recovery of arctic Alaskan tundra terrain: a review of recent investigations*. U.S. Army Cold Regions Research and Engineering Laboratory CRREL Report 87-11; (4) Walker, D. A. (1997). Arctic Alaskan vegetation disturbance and recovery: a hierarchic approach to the issue of cumulative impacts. In R. M. M. Crawford (Ed.), *Disturbance and Recovery in Arctic Lands* (pp. 457–479). Dordrecht: Kluwer Academic Publishers. (5) Walker, D. A., Shur, Y., Kanevskiy, M., Raynolds, M., Kofinas, G., Romanovsky, V., et al. (2018 submitted). Cumulative effects of infrastructure and a warming climate to permafrost and arctic ecosystems. *Frontiers in Ecology and the Environment*.

[3] Walker, D. A., W. Acevedo, K.R. Everett, L. Gaydos, J. Brown, and P.J. Webber. (1982). Landsat-assisted environmental mapping in the Arctic National Wildlife Refuge, Alaska. U.S. Army Cold Regions Res. And Eng. Lab. CRREL Report 82-37. 68 pp.

[4] National Research Council (NRC). (2003). Cumulative environmental effects of oil and gas activities on Alaska's North Slope. Washington, DC: National Academies Press.

[5] Walker, D. A., et al. (2018 submitted, cited in footnote 2).

[6] Walker, D. A., Epstein, H. E., Šibík, J., Bhatt, U., Romanovsky, V. E., Breen, A. L., et al. (2018). Vegetation on mesic loamy and sandy soils along a 1700-km maritime Eurasia Arctic Transect. *Applied Vegetation Science*.

[7] Walker, D. A., Forbes, B. C., Leibman, M. O., Epstein, H. E., Bhatt, U. S., Comiso, J. C., et al. (2011). Cumulative effects of rapid land-cover and land-use changes on the Yamal Peninsula, Russia . In G. Gutman, A. Reissell, Reis (Eds.), *Eurasian Arctic Land Cover and Land Use in a Changing Climate* (pp. 207–236). Dordrecht: Springer.

[8] Public Broadcasting Service (PBS), July 27, 2018, https://www.alaskapublic.org/2018/07/27/blm-projects-insignificant-impact-from-seismic-work-in-anwr/).

[9] NEPA, the Environmental Quality Improvement Act of 1970, as amended (42 U.S.C. 4371 *et seq.*), sec. 309 of the Clean Air Act, as amended (42 U.S.C. 7609), and E.O. 11514 (Mar. 5, 1970, as amended by E.O. 11991, May 24, 1977) and Council on Environmental Quality (40 C.F.R. 1508.14).

I've limited the concerns expressed here mainly to those related to my major area of expertise – the land and vegetation of northern Alaska and the 1002 Area. I've divided the letter into five sections: (1) Summary of the BLM seismic plan; (2) Rebuttal including: (i) 2003 NRC study, (ii) the "seismic checkerboard", (iii) terrain considerations, (iv) hydrology and permafrost considerations, (v) vegetation considerations, (vi) climate-change considerations, (vii) multi-scale impacts, (viii) cumulative impacts; and (3) Conclusion.

Summary of the BLM seismic plan

The seismic survey by Texas-based SAExploration Inc. would be in advance of a planned lease sale for oil and gas drilling and production in the 1002 Area, which was authorized under Title II of the 2018 Tax Cuts and Jobs Act[10]. The entire approximately 6734 km^2 (2,600 mi^2, or 1.7 million acres) of the 1002 Area would be surveyed using a technique called 3 Dimensional (3D) seismic. The proposed survey would be conducted during the winters of 2018–19 and 2019–20 if needed. Vehicles mounted with seismic vibrators will generate acoustic waves that will be picked up by receiver sensors as the waves bounce off subsurface formations. From this information, images will be created that show in great detail subsurface topography and formations, including areas of potential hydrocarbons.[11] The proposed techniques require driving seismic generator and receiver vehicles over the tundra surface in sets of seismic lines spaced 200–400 m (660–1320 feet) apart. It also requires portable housing and support facilities for approximately 300 workers that need to be moved every 2–3 days. These facilities would be contained on approximately 100 trailers mounted on steel sleds pulled by some 30 vehicles, which would move the mobile camps.

BLM indicates that there is no plan to do an Environmental Impact Statement for the proposed seismic surveys. A much shorter Environmental Assessment is planned.

> "We felt that there would be insignificant impact, so we're planning on doing an environmental assessment and when that is available we'll post that environmental assessment, with a draft finding of no significant impact….At the end of the 30-day public comment period if we don't receive substantial input to change our finding of no significant impact, we would issue a decision record, and then the activity could be authorized."[12]

Rebuttal

The BLM's proposed action plan is only seven pages long, and the proposal by SAExploration[13] was 33 pages long, remarkably short for such a substantial and complex project. For example, the BLM plan offers no justification for why 3D is necessary or any comparative analysis of the variety of equipment or grid spacing that could be employed as a function of destructive potential, terrain type, data utility, etc. It contains no information regarding the total length of trails or total area impacted by the proposed seismic tracks. Nor does it include proposed locations of camps and airstrips or routes for fuel hauling. The plan is missing a realistic proposed timeline and itinerary to carry out the survey. The trails left by camp moves in past seismic surveys have been the most damaging to the tundra, but there do not appear to be substantially different methods proposed for camp moves. The statement regarding "insignificant impacts" justifying a short environmental assessment process is contrary to evidence from previous seismic surveys and the opinion of nearly everyone who has worked or recreated in the ANWR. The full long-term effects of 3D seismic exploration are not well studied, and multiple lines of evidence, outlined below, indicate that the seismic plan as proposed will have many major impacts.

2003 NRC study

The most relevant information that addresses the impacts of seismic surveys on Alaska's North Slope comes from the National Research Council's 2003 review of the cumulative effects of oil and gas development in northern Alaska[14]. A prior 2D seismic program conducted in the 1002 Area during 1984–1985 resulted in significant surface disturbance including long-term effects to tundra vegetation and permafrost thaw that have lasted over 30 years[15]. Impacts similar to those reported in the 1002 Area have been reported from recent (2-year-old) and 20–30-year-old trails in Canada[16,17]. I quote at length from the portion of the NRC report describing results from surveys in the 1002 Area:

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[10] U.S. Congress. Public Law No. 115-97 (2017). Short title: Tax Cuts and Jobs Act (An act to provide for reconciliation pursuant to titles II and V of the concurrent resolution on the budget for fiscal year 2018). https://www.congress.gov/115/plaws/publ97/PLAW-115publ97.pdf

[11] BLM (2018, cited in footnote 1).

[12] Public Broadcasting Service (PBS), July 27, 2018, https://www.alaskapublic.org/2018/07/27/blm-projects-insignificant-impact-from-seismic-work-in-anwr/).

[13] See permit application linked to Washington Post, Companies take first steps to drilling for oil in Arctic National Wildlife Refuge, June 1, 2018: https://assets.documentcloud.org/documents/4489227/SAExploration-s-Plan-for-Seismic-Drilling-in-the.pdf; also https://www.washingtonpost.com/business/economy/companies-take-first-steps-to-drill-for-oil-in-arctic-national-wildlife-refuge/2018/05/31/8f133464-643a-11e8-a768-ed043e33f1dc_story.html?utm_term=.a0f83dbd77b5.

[14] NRC. (2003, cited in footnote 4). p. 81-88.

[15] Jorgenson, J.C, J.M. VerHoef, and M.T. Jorgenson. (2010). Long-term recovery patterns of arctic tundra after winter seismic exploration. Ecological Applications, 20(1): 205-221.

[16] Kemper, J. T., & Macdonald, S. E. (2009a). Directional change in upland tundra plant communities 20-30 years after seismic exploration in the Canadian low-arctic. *Journal of Vegetation Science*, *20*(3), 557–567. http://doi.org/10.1111/j.1654-1103.2009.01069.x

[17] Kemper, J. T., & Macdonald, S. E. (2009b). Effects of contemporary winter seismic exploration on low arctic plant communities and permafrost. *Arctic, Antarctic, and Alpine Research*, *41*(2), 228–237. http://doi.org/10.1657/1938-4246-41.2.228.

"Effects were estimated from an aerial photo survey that examined a random sample of 20% of the trails a year after disturbance. About 14% of the trails had no detectable disturbance; 57% had low disturbance; 27% had moderate disturbance; and 2% had high disturbance[18]. Eight years after the exploration, only about 4% of the seismic and receiver line trails were still disturbed, but *camp-move trails showed more disturbance – about 15% were disturbed, including 4% that showed medium disturbance and 1% that showed high disturbance* [italics are mine to emphasize points made elsewhere in this letter][19]….Although the typical effects of individual seismic trails in the Arctic National Wildlife Refuge generally were minor, they were extensive and varied greatly with vegetation type, vehicle type, operator vigilance, and *amount of snow cover*. Minor effects and rapid recovery occurred in flat areas of wet tundra…*Damage was greater in areas with more microrelief and in areas with taller shrubs that were not covered by snow, which is more common in hilly portions of the North Slope. Tussock tundra and frost-boil tundra were particularly susceptible because of the higher microrelief*. The greatest damage occurred where the vegetative mat was destroyed, and the underlying soil was exposed. This was infrequent and usually resulted from tracked vehicles or sleds on skids cutting into hummocks or other raised areas or from Caterpillar operators making a tight turn or dropping the blade too deeply into the snow. High disturbance also occurred where vehicles became mired in deep snow and their operators tried to extricate the equipment instead of being pulled out[20]….

"In 1998, *14 years after the original survey, 7% of the plots assessed on the ground were still disturbed, and 15% showed disturbance that was visible from the air*[21]. The active layer [depth of summer thaw of the soil] was deeper on about 50% of the disturbed plots than it was on adjacent control areas after 10 years (1984–1994)….Overall, the vegetation recovery reaches a plateau after about 8 years. *Some trails are likely to be visible from the air for decades after that*[22].

"*Few studies have examined the effects of current three-dimensional (3-D) seismic methods*. One study of the Colville River delta detected the trails left from repeated 2-D exploration in 1992, 1993, and 1995 and from 3-D work in 1996[23]….High disturbance occurred on only 1% of the sites surveyed, mostly dry dune areas. *Maps of those survey lines show the much higher density of trails associated with the 3-D operations, which can be spaced as close as 200 m (660 feet), or rarely even closer*. It was difficult to quantify the number of random stray trails that were not part of the seismic lines or camp move trails….*Some areas were surveyed several times by different companies, resulting in a maze of seismic trails, camp trail, and ice roads, which are difficult to identify by type and year of origin.* Some repetition is caused by the need for a new or better seismic information, but it also occurs because the data are proprietary, and companies will not share information that might help competitors, thus setting the stage for each to gather data and conduct analyses independently."

Clearly, despite regulations and permit stipulations developed to minimize impacts, significant impacts occur in tundra landscapes during seismic surveys. The NRC study noted that even though improvements have been made in the seismic vehicles since the 1984–1985 2D surveys, denser networks of modern 3D seismic trails, and larger camps with more vehicles, increase the risks of damage to the tundra, often because the impacts from numerous surveys overlap and take place prior to the tundra recovering from earlier surveys.[24] The NRC report also noted that as seismic exploration moves into new areas, such as the Brooks Range foothills of the 1002 Area, which has substantially different terrain from areas of current activity, the current technology and government regulations will not prevent damage to the tundra. One of the primary recommendations of the NRC study was that future developments should be done with comprehensive planning that includes that latest scientific knowledge of the system to be impacted.

The "seismic checkerboard"

To demonstrate the density and extent of the proposed seismic trails, Dr. Matt Nolan recently generated an image of the proposed seismic grid required to fully survey the entire 1002 area with seismic lines spaced at approximately 200-m (656 ft) intervals between grid lines (the spacing suggested by SAExploration)[25]. The resulting checkerboard of tracks resulted in approximately 32,000 km (20,000 miles) of trails. Matt Nolan calculated the area impacted by various densities of trails. He measured existing 3D trails west of the Canning River to be 10–20 m wide. For 200-m x 200-m trail spacing (a density used in a 3D seismic survey immediately adjacent to the 1002 Area), a 1-km square area of tundra would have 5 x 5 trails per km^2. This would impact between 100,000 m^2 and 200,000 m^2 per 1,000,000 m^2 of tundra, or about 10% – 20% of each square kilometer mapped, or between 673 km^2 and 1347 km^2 of the 6734 km^2 1002 Area. Of that, some fraction will certainly become permanently visible. Even if that is only 2% (the percentage having high levels of disturbance after the 1984–1985 2D surveys), that is still 13 km^2 to 26 km^2 of the 1002 Area.

Nolan also examined recent 3D tracks just outside the western boundary of the 1002 Area using his personal aircraft and an advanced digital photogrammetric technique called "fodar" to create high-resolution digital elevation maps. These show that the

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[18] Felix, N. A., & Raynolds, M. K. (1989a). The effects of winter seismic trails on tundra vegetation in northeastern Alaska, U.S.A. *Arctic and Alpine Research*, *21*, 188.

[19] Emers, M., Jorgenson, J. C., & Raynolds, M. K. (1995). Response of arctic tundra plant communities to winter vehicle disturbance. *Canadian Journal of Botany*, *73*(6), 905.

[20] Schultz, G. 2001. Inspection of PGS Seismic Operation. Memorandum from G. Schultz, State of Alaska, Department of Natural Resources, to . Rader, State of Alaska. Department of Natural Resources, Fairbanks, AK. 6 Aug 2001.

[21] J. C Jorgenson. FWS. (2001, cited in NRC 2003). Personal communication.

[22] J. C. Jorgenson. FWS. (2001, cited in NRC 2003). Personal communication.

[23] Jorgenson, M. T. & J. E. Roth. Reconnaissance survey and monitoring of seismic trail impacts on the Colville River Delta, 1997-1998. Prepared for Phillips Alaska Inc., Anchorage, AK, by ABR, Inc. Fairbanks, AK. (pp. 41).

[24] NRC (2003, cited in footnote 4). p. 157.

[25] Nolan (2018) Latest view of 2018 seismic exploration impacts near the 1002 Area. posted 1 Aug 2018 http://fairbanksfodar.com/latest-view-of-2018-seismic-exploration-impacts-near-the-1002-area.

seismic trails, which are barely visible on some aerial photographs, are compressed several centimeters below the level of the original tundra surface. Aerial photographs taken in early summer show that the trails are clearly delineated by snow that remains in the track depressions. Late summer images of the same area show a grid of faint but clear trails.[26] I strongly recommend that BLM and others who are considering seismic in the 1002 Area view Nolan's web page and consider the question, "Do we want to be responsible for the legacy of a similar checkerboard across the entire landscape of the 1002 Area?"

Why do these small difference in microtopography matter? We know from previous studies that compressing tundra soils and vegetation will likely have major impacts to local hydrology, permafrost, soil, and vegetation regimes as discussed below.

Terrain considerations

The proposed surveys in the 1002 Area would be conducted in a very different landscape than the Prudhoe Bay and National Petroleum Reserve-Alaska regions where extensive 3D seismic has taken place to date.[27] The 1002 Area is a relatively narrow band of tundra wedged between the Brooks Range and the Beaufort Sea, consisting mainly of foothills (44%) and hilly coastal plain (22%), where slopes are generally greater than 5% grade, interspersed by river floodplains and deltas (24%) that form a dozen major riparian networks. Flat thaw-lake plains, similar to those near Prudhoe Bay, comprise only about 3% of the area; there is also a small amount of alpine terrain near Sadlerochit Springs (0.03%).[28],[29]. Hill tops and ridge areas are windblown and are rarely covered with sufficient snow to conduct a seismic survey without damaging the tundra vegetation, soils, and permafrost. Other areas along the many water tracks and streams have steep embankments where deep soft snow can trap the heavy seismic vehicles and require other larger vehicles to extract them. (Note: Some meso-scale questions related to terrain considerations that need to be answered before a decision to conduct the surveys is made are presented below under "Multi-scale impacts".)

Hydrology and thermokarst considerations

Improved vehicles for doing seismic surveys have lessened damage to tundra vegetation, yet even the seemingly small depressions caused by the newer vehicles can change the character of vegetated surfaces by compressing the tundra, leading to snow accumulation in the tracks (as seen in Nolan's photos), ponding of water on the tundra surface, and the channeling of water along the tracks, especially in early summer. This process of compression, snow accumulation, ponding, and channeling, can trigger more extensive landscape changes through "thermokarst," which results when ice in the permafrost melts and causes subsidence of the ground surface, resulting in irregular topography consisting of depressions, mounds, and ponds[30],[31]. Those who live and work in the Arctic know that thermokarst is hazardous to infrastructure and extremely difficult to predict or control. The effects of thermokarst are particularly evident near oilfield infrastructure such as roads, trails, and oilfield support facilities[32],[33].

Vegetation considerations

The long-term changes to vegetation in the 1002 Area following the 1984–1985 2D seismic surveys in the 1002 area have

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[26] Fountain, H. 2018. How oil exploration cut a grid of scars into Alaska's Wilderness. New York Times. https://www.nytimes.com/2018/08/03/climate/alaska-anwr-seismic-testing-tracks.html.

[27] NRC (2003, cited in footnote 4). p. 81–88.

[28] Walker, D. A., W. Acevedo, K.R. Everett, L. Gaydos, J. Brown, and P.J. Webber. 1982. Landsat-assisted environmental mapping in the Arctic National Wildlife Refuge, Alaska. U.S. Army Cold Regions Res. And Eng. Lab. Report 82-37. 68 pp.

[29] Garner, G. W. and P.E. Reynolds, eds. Dec 1986. Arctic National Wildlife Refuge Coastal Plain Resource Assessment, Final Report Baseline Study of the Fish, Wildlife, and their habitats. Section 1002C, ANILCA. See Fig. 1, Terrain types of the coastal plain of the Arctic National Wildlife Refuge (Walker et al. 1982) and discussion of terrain types pp. 46-67 based on Walker et al 1982 concluded by identifying data gaps: *"Future vegetation and habitat information needs for the study area will require the development of a base map of a higher degree of detail than is possible with Landsat data. A base map similar to the geobotanical atlas (1:12,000) of the Prudhoe Bay region should be developed for the study area. Adequate time should be allotted for ground-truthing and accuracy assessment to ensure the development of a reliable map. A base map at this scale is needed for habitat identification for various wildlife species. If further exploration and/or development occurs on the study area, this base map is essential to aid in site selection for facilities and related activities to minimize environmental impacts." (p.61)*

[30] Jones BM, Amundson CL, Koch JC, and Grosse G. (2013). Thermokarst and thaw-related landscape dynamics: annotated bibliography with an emphasis on potential effects on habitat and wildlife. *US Geological Survey Open-File Report* 2013-1161: 60.

[31] Kanevskiy, M., Shur, Y., Jorgenson, T., Brown, D. R. N., Moskalenko, N., Brown, J., et al. (2017). Degradation and stabilization of ice wedges: Implications for assessing risk of thermokarst in northern Alaska. *Geomorphology*, *297*, 20–42. http://doi.org/10.1016/j.geomorph.2017.09.001

[32] Raynolds, M. K., Walker, D. A., Ambrosius, K. J., Brown, J., Everett, K. R., Kanevskiy, M., et al. (2014). Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska. *Global Change Biology*, *20*(4), 1211–1224. http://doi.org/10.1111/gcb.12500

[33] Romanovsky, V., Isaksen, K., Drozdov, D., Anisimov, O., Instanes, A., Leibman, M., et al. (2017). Changing permafrost and its impacts. In AMAP (Ed.), *Snow, Water, Ice and Permafrost in the Arctic (SWIPA) 2017* (pp. 65–102). Oslo, Norway: Arctic Monitoring and Assessment Programme (AMAP).

continued to be monitored up to the present [34],[35],[36],[37],[38],[39]. Many of the trails are still evident. Vegetation changes after five years varied in relationship to site and internal vegetation factors, including height of the microtopography, site moisture, snow status, vegetation type, species composition, and height of shrubs. Camp moves were most damaging to tundra and produced trails that depressed the tundra up to 40 cm (16 in.)[40]. Dry sites were most strongly affected and slowest to recover, whereas wet sites recovered relatively quickly. Moist tundra, including tussock tundra, the most common vegetation type in the 1002 Area, is susceptible to damage because of the considerable micro-topographic relief associated with the tussocks and requires variable amounts of snow to protect it depending on the height of the tussocks, which can be up to 25 cm tall (10 in.). Some vascular-plant and moss species appear to be particularly sensitive to compression of the "depth hoar" at the base of the snowpack[41]. Compression of the vegetation mat causes changes to the surface albedo and hydrology, often resulting in green trails that are slow to recover[42],[43]. The studies recorded measurable vegetation disturbance, even with as much as 45 cm (18 in.) of snow in tussock tundra and 72 cm (28 in.) in sedge-shrub tundra. Moderate disturbance occurred at snow depths to 25 cm (10 in.) in tussock tundra and 35 cm (14 in.) in sedge-shrub tundra.[44] The plant species with poor potential for recovery if damaged included cotton-grass tussocks (*Eriophorum vaginatum*), evergreen shrubs including Labrador tea (*Rhododendron decumbens*), low-bush cranberry (*Vaccinium vitis-idaea*), and mountain avens (*Dryas integrifolium*), deciduous shrubs such as dwarf birch (*Betula nana*) and dwarf willows (*Salix phlebophylla, S. reticulata*), some mosses (particularly *Sphagnum* and *Tomentypnum nitens*), and all lichens.[45] The NRC study described how thin snow cover increases the risks of damage from winter exploration and that the regulatory use of average snowpack and frost thickness to determine tundra travel opening and closing seasons is not sufficient to provide adequate protective cover because of high local and regional variability in snow cover, density and other factors that affect vegetation distribution and quality.[46]

To my knowledge, there has not been a comprehensive study of the effects of modern 3D arctic seismic surveys, nor have experimental studies included the effects of the large trains of heavy vehicles used for camp moves. An unpublished report prepared for the Alaska Department of Natural Resources (DNR) attempted to model the effects of several off-road vehicles commonly used in winter seismic operations, including a cleated-tracked Tucker Snowcat; a wheeled front-end loader; a rubber tracked Challenger; and a Caterpillar D-7 bulldozer[47]. The study was carefully designed and statistically rigorous, but the resulting model is difficult to apply to other areas outside where the model was developed. It provides useful insights to the difficulty of developing predictive models of real-world impacts for seismic surveys because of the large number of factors involved and their high natural variability. The long-term observations from the 1984–1985 seismic studies[48] remain the best and essentially the only source of information regarding the potential effects of seismic activity in the 1002 Area. The studies need to be updated with comparable studies of modern 3D methods. (Note: Some micro-scale questions related to hydrology, permafrost, and vegetation that need to be answered before a decision to conduct the surveys is made are presented below under "Multi-scale impacts".)

Climate-change considerations

The length of time for such a survey in the winter is tightly constrained by the depth of snow cover early in the survey season and the melt date of snowpack late in the survey season. The surface also needs to be frozen hard enough to support the heavy vehicles. Delayed winter seasons, earlier snow melt in spring, and late freeze up have already resulted in shortened ice road and tundra travel seasons.[49] The BLM plan does not consider how the seismic impacts will interact with the changing climate and may not allow sufficient time to complete the very large survey proposed because of increasingly short periods when off-road travel is permitted on the tundra. The plan also does not consider issues related to thawing permafrost. Numerous recent studies

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[34] Felix, N. A., & Raynolds, M. K. (1989a, cited in footnote 18).

[35] Felix, N. A., & Raynolds, M. K. (1989b). The role of snow cover in limiting surface disturbance caused by winter seismic exploration. *Arctic*, *42*, 62–68.

[36] Felix, N. A., & Jorgenson, M. T. (1984). *Effects of winter seismic exploration on the coastal plain of the Arctic National Wildlife Refuge, Alaska, 1984* (pp. 86). Fairbanks, AK: Fish and Wildlife Service.

[37] Felix, N.A, M.K. Raynolds, J.C. Jorgenson, and K.E. DuBois. (1992). Resistance and resilience of tundra plant communities to disturbance by winter seismic vehicles. Arctic and Alpine Research, 24(1): 69-77. See also NRC (2003) p. 84.

[38] Emers, M., et al. (1995, cited in footnote 19).

[39] Jorgenson, J.C. et al. (2010, cited in footnote).

[40] Felix, N.A, et al. (1992, cited in footnote 38). (p. 72).

[41] Walker, D. A. et al. (1987, cited in footnote 2), p. 24.

[42] Chapin, F. S. I., Fetcher, N., Kielland, K., Everett, K. R., & Linkins, A. E. (1988). Productivity and nutrient cycling of Alaskan tundra: enhancement by flowing soil water. *Ecology*, *69*(3), 693–702.

[43] Felix & Raynolds (1989a, cited in footnote 18).

[44] Felix, N.A. and M.K. Raynolds. (1989b, cited in footnote 36).

[45] See also NRC (2003, cited in footnote 4) p. 84.

[46] NRC (2003, cited in footnote 4). p. 85.

[47] Bader, H., & Guimond, J. (n.d.). *Tundra travel modeling project*. Alaska Department of Natural Resources. Retrieved from http://dnr.alaska.gov/mlw/tundra/TundraModelReport.pdf., 4 Aug 2018.

[48] Jorgenson et al. (2010, cited in footnote 15).

[49] NRC (2003, cited in footnote 4) p. 86.

in northern Alaska and elsewhere in the Arctic have revealed that recent warming of the Arctic is causing thermokarst to expand over extensive areas[50],[51], which exacerbates ponding caused by seismic surveys.

Multi-scale impacts
Impacts from the proposed 3D seismic surveys will occur at numerous spatial scales. Here is a sample of questions in a hierarchy of spatial scales that should be answered before proceeding with seismic surveys in the 1002 Area:

Micro-scale (plot-scale) questions: Micro-scale features include moss hummocks, bird mounds, frost-boils, water tracks, and ice-wedge-polygon elements (polygon troughs, rims, centers), all of which would be subjected to compression by 3D seismic vehicles. Micro-topography in permafrost terrain has a particularly strong effect on hydrology because the permafrost table prevents vertical drainage of surface water, which strongly affects drainage patterns, permafrost temperatures, soil, vegetation properties, and habitat for numerous animal species. Some ongoing ecosystem studies of patterned ground are currently being conducted by the Department of Energy's Next Generation Ecosystem Experiment (NGEE)[52], the National Science Foundation's Arctic Science, Engineering, and Education for Sustainability (ArcSEES) program[53], and other projects, but not in the context of how changes to micro-relief would affect biodiversity or total system function. Some key questions include: (1) What range of changes to micro-scale relief can we expect from 3D seismic? (2) How do impacts from 3D seismic affect hydrological properties, depth of the active layer, patterns of thermokarst, plant-species composition, vegetation productivity; and vice versa, how do the differences in micro-relief affect the severity of 3D seismic disturbance? (3) How does snow depth affect disturbances caused by 3D seismic? (4) How will the visibility of tracks due to their increased greenness change with time? (5) Do the micro-scale disturbances related to 3D seismic affect the distribution of key animal species, such as shorebirds that rely on micro-topographic features for display or nest sites.

Meso-scale (landscape-scale) questions: Many meso-scale questions are related to the unique closely-spaced checkerboard pattern of 3D seismic trails, which have never been studied: (1) How do we know the methods used in NPRA and flat portions of the Arctic Coastal Plain are safe to use in this much different geological area? For example, how will the perched wetlands of the 1002 area be affected by a gridwork of shallow seismic trails that will connect them all? (2) What can we learn from past 3D surveys outside the 1002 area, particularly those near the western boundary of the 1002 area? Where and when have these past surveys been conducted? (3) What will short-term and long-term effects of 3D seismic trails be to the wilderness experience of visitors to 1002 Area and adjacent designated Wilderness?

Macro-scale (regional- to global-scale) questions: These are broader scale questions that include regional and global environmental, economic, and social issues. Questions at this scale are difficult to address but need to be considered. They include: (1) Can we build realistic scenario models to project the long-term cumulative effects of oil-field exploration and development that includes seismic exploration as well as future oilfield infrastructure required to develop this area? (2) What are cumulative impacts of 3D seismic and climate change, such as those related increased shrub productivity[54], changes to vegetation greenness associated with changes in sea-ice distribution and land-surface temperature[55], and multi-scale changes related to snow, water, ice and permafrost regimes[56]. (3) Will 3D seismic exploration have long-term consequences to any of the fish and wildlife species that are of special concern (e.g., polar bears, caribou, wolverine, muskox, Dolly Varden/Arctic Char) or any other species that use of the 1002 area? (4) Will any aspect of the 3D seismic affect the quality of life for the Gwich'in and Iñupiat people who are reliant on this area for subsistence? (5) What are the global-scale economic and environmental impacts of developing the 1002 area?

Cumulative impacts
Cumulative impacts are the incremental impact of the proposed action added to other past, present, and reasonably foreseeable future actions[57]. Cumulative impacts are notoriously difficult to innumerate and predict but must be considered in documents prepared under the National Environmental Policy Act (NEPA) regulations. Cumulative impacts include consideration of the multi-scale impacts mentioned above, and the combined effects of different projects involved in the gradual "nibbling" of large

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areas of undeveloped land, such as the extensive infrastructure that will surely follow the discovery of new oil and gas deposits. Statements by proponents of drilling predict a total development footprint of only 2000 acres. These estimates are not based on realistic scenarios of how the oil is distributed and where facilities will need to be located to extract the oil, nor the many types of impact that will likely occur, including the direct impacts of new infrastructure (e.g., ice roads, gravel pads for new oil wells and oil field facilities, new roads, gravel mines, pipelines, and powerlines), and the indirect impacts (e.g., infrastructure-related flooding and thermokarst, road dust, and off-road vehicle trails, including seismic trails)[58]. More realistic scenarios of development need to be presented based on current knowledge.

Conclusion

In summary, it is hard to conceive that the proposed seismic surveys can be conducted without major impacts to the tundra of 1002 Area. Numerous lines of evidence from the 2003 NRC studies, prior studies of seismic surveys, knowledge of the unique terrain and size of the proposed action, likely interactions with climate change, and consideration of complex cumulative effects all lead to the conclusion that the BLM prediction of insignificant impact is not justified.

My experience in the 1002 area gave me an appreciation for what pristine tundra landscapes look like without the ubiquitous vehicle trails that now cover most of the North Slope. These untracked landscapes are breathtaking and are now a rare phenomenon because nearly all other undeveloped tundra landscapes outside the 1002 area on the Arctic Coastal Plain are covered with seismic trails and other tracks left by off-road vehicles. The proposed surveys would occur in one of the world's most pristine wildlife refuges and one of the most biologically diverse areas in the circumpolar Arctic. The analysis of potential impacts by BLM is inadequate. A thorough review, including the potential total direct, indirect, and cumulative impacts to the full ecosystem is needed. The analysis should include the impacts of various grid spacings and of 3D seismic compared with already existing 2D seismic. The issue is broader than the predictable direct impacts of the seismic trails. It includes the less predictable, multi-scale, long-term, cumulative impacts – the interactions between the impacts of the tracks, climate-related factors, and the direct and indirect effects of oilfield-infrastructure that will surely follow the seismic surveys.

Congress passed the tax reform bill that permitted oil development in the 1002 Area of the Arctic National Wildlife Refuge with assurances that the environmental quality of this region will be maintained. The area has immense value to the wildlife, the local people who depend on it for their livelihoods, and all Americans and global residents who care about this place. In order to insure proper stewardship of this important resource, BLM should do the right thing and produce a full Environmental Impact Statement of the expected consequences. To not do so would be an act of negligence of its responsibility.

Sincerely,
Skip Walker, Ph.D.
Professor, Department of Biology and Wildlife, University of Alaska Fairbanks
Director, Alaska Geobotany Center, Institute of Arctic Biology
Fairbanks, AK

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