Accomplishments

* What are the major goals of the project?

Cumulative Effects of Arctic Oil Development -- Planning and Designing for Sustainability

Goals of the Project:

Developing arctic oil & gas resources requires extensive networks of roads, pipelines and other forms of infrastructure. The cumulative environmental and social effects of expanding developments are difficult to assess and impossible to predict — especially in the face of rapid climate change and unpredictable politics, oil markets, and social and economic changes. Previous analyses of the cumulative effects (CE) of oil and gas development in northern Alaska have recommended comprehensive adaptive planning approaches to 1) minimize the spread of infrastructure across land that is used by indigenous people for subsistence, and 2) reduce the indirect effects of infrastructure that result in the thawing of ice-rich permafrost. A sustainable approach to CE requires collaboration between indigenous people, industry, and scientists from a broad spectrum of disciplines to address these infrastructure-related concerns. This project does that with detailed ground studies, local community input, industry involvement and an international perspective. A project has three major components:

1) Case study of the cumulative effects of industrial infrastructure at Prudhoe Bay, Alaska. This component focuses on infrastructure-related effects associated with gravel mines, roads and other areas of gravel placement. The study includes ground-based studies, an examination of infrastructure and landscape change at multiple scales, and a human dimension component that includes evaluation of adaptive management planning for infrastructure in northern Alaska and CE studies associated with the Inupiat village of Nuiqsut. The study is developing a process-based understanding of infrastructure-related permafrost/landform/vegetation succession in terrain undergoing thermokarst formation (the development of highly eroded landforms that result from the thawing of ice-rich permafrost). The study will help to answer the questions “What will these areas look like in 50-100 years?” and “Can adaptive management methods address the complex issues related to placement, usage and decommissioning of infrastructure in Northern Alaska?”

2) Arctic Infrastructure Action Group: Rapid Arctic Transitions due to Infrastructure and Climate (RATIC). The goal of RATIC is to bring cumulative-effects-of-infrastructure issues to greater prominence within the international Arctic research community and encourage research on the joint effects of climate change and expanding infrastructure in the Arctic. The initiative was developed during the Climate Change 2014 Conference in Ottawa and the Third International Conference on
Arctic Research Planning (ICARP III) in Yohama, Japan. RATIC consists of permafrost scientists, ecologists, hydrologists, engineers, social scientists and educators seeking to develop adaptive management strategies that address the unique issues related to networks of infrastructure in arctic permafrost environments.

3) Education/outreach component. A new field course is training students in arctic system science and introducing them to the issues of industrial development and adaptive management approaches. The 21-day course includes a 16-day expedition along the Elliott and Dalton highways in Alaska. The course includes a visit to Minto, an Athabascan village on the Tolovana River; Wiseman, an old mining community along the Dalton Highway; and the Prudhoe Bay Oilfield, where they learn firsthand about the issues with oilfield infrastructure, its impacts and the oil industry's ecological monitoring and vegetation rehabilitation practices.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities:

1. Analysis of historical changes in infrastructure, landscapes and vegetation in the Prudhoe Bay Oilfield. We published two key papers describing the historical trends of infrastructure- and climate-related changes in northern Alaska: 

The first paper, published in Global Change Biology (Raynolds et al. 2014), documented the cumulative geoecological effects of 62 years (1949–2011) of infrastructure- and climate-related changes in the Prudhoe Bay Oilfield, the oldest and most extensive industrial complex in the Arctic, and an area with extensive ice-rich permafrost that is extraordinarily sensitive to climate change.

The second paper, published in Environmental Research Letters (Raynolds et al. 2016), used Landsat TM and ETM+ data between 1985 and 2011 to examine trends in the Normalized Difference Vegetation Index (NDVI) and tasseled-cap transformation indices, and related them to high-resolution aerial photographs, ground studies, and vegetation maps.

2. Ground-level investigation of changes associated with intensive thermokarst along roads. We conducted field studies adjacent to two of the oldest and most heavily traveled roads in the Prudhoe Bay region, the Spine Road (Lake Colleen Site A) and the Dalton Highway (Airport Site) during four field campaigns, 1-15 Aug 2014, 3-15 Jul 2015, 26 Mar-1 Apr 2016, and 15-19 Aug 2016. These included two midsummer campaigns to establish field plots and transects on both sides of the roads to measure vegetation, soil, microtopography, water, and permafrost characteristics. A late winter campaign measured and described snow along both transects, and a late summer campaign collected iButton® temperature loggers and measured active layer and water depths along the road transects. The results of the field studies are being published in three data reports (Walker et al. 2015, 2016 in prep., 2017 in prep.), conference presentations (Shur et al. 2016, Kanevskiy et al. 2016, Walker et al. 2016) and several papers in preparation (Kanevskiy et al. in prep., Walker et al. in prep.)

3. Human dimensions studies. Interviews of local people and industry personnel are being used to determine their perceptions of change, implications to their livelihoods, and assessment of adaptive management for infrastructure in Northern Alaska. Fifteen BP Exploration Alaska, Inc. staff were interviewed in September and December, 2015, to document oil industry perspective on cumulative effects management of North Slope of Alaska oil fields. Respondents' roles are primarily focused on environmental management. Interviews took place in Anchorage Alaska, lasting 45 minutes to one and a half hours. Respondents were asked to report on their criteria of successful management of the environmental conditions in North Slope oil development, the challenges associated with development, BP's approaches to environmental adaptive management, and cumulative effects. Respondents commented on specific issues, such as thawing permafrost and ecosystem fragmentation, and evaluated their professional relationship with agencies and academic researchers. Industry staff interviews are the first of three groups to be included in the study. We are now
analyzing the results of interviews with industry staff people and all results at this point are preliminary. Respondents reported that major challenges to environmental management on the North Slope of Alaska included balancing cost with sound environmental management, aging infrastructure, and increasing complexity of the regulatory environment. BP staffers did not commonly reference the terms “cumulative effects” and “adaptive management”, now used extensively in the academic literature of resilience theory and adaptive governance. However, respondents did report many examples of “learning by doing” through on-going monitoring activities and long-time experience. They also noted that BP has instituted company policies that are similar to adaptive management principles. Examples of learning by doing included improved methods for habitat remediation, and improvements to drilling technology leading to a smaller operating footprint. Respondents also noted that the motivation to try new approaches was often driven by opportunities for cost savings. Most said that there is currently little collaboration between industry and academia and while some respondents had strong feelings that there should be more collaboration, others did not see a value in it, given the groups’ different interests. Respondents also mentioned that their interactions with agencies were mostly related to regulation. As well they reported that there was not much collaboration with competitors (i.e., other large oil companies). Some people felt research initiatives would be more productive if there was. We also interviewed 28 residents of Nuiqsut, documenting their perceptions of environmental change in their homeland on the central North Slope of Alaska, including aspects of oil development and climate change. Interviews asked residents if change had occurred in specific areas and if so, how change had occurred. We also asked how changes were occurring, if they were affected livelihoods and where and or how they had received information on the change. Most interviews were completed as face-to-face questioning, using a recorder and a touch screen map to capture spatial data on local knowledge. We also distributed a mail-out survey to add to our sample, but few people responded to the survey. Data have been entered and analyzed. We are also making an Endnote annotated bibliography regarding the topics of cumulative effects and adaptive management. Future interviews will target agency staff and leaders of Alaska Native organizations.

4. Arctic Infrastructure Action Group: Rapid Arctic Transitions due to Infrastructure and Climate (RATIC). The RATIC initiative is a new forum for developing and sharing new ideas and methods to facilitate the best practices for assessing, responding to, and adaptively managing the cumulative effects of Arctic infrastructure and climate change. The initiative is being developed through the International Arctic Science Committee (IASC). The primary activities this past year were publication of a white paper has been produced that describes five international case studies, conclusions, and recommendations for steps to develop scientific research plans aimed at sustainable infrastructure development (Walker et al. 2015) and presentations of the RATIC initiative to the 2015 AGU meeting (Walker et al. 2015b), Arctic Science Summit Week 2015 and 2016, the Eleventh International Conference on Permafrost (Walker et al. 2016c), and the Interagency Arctic Research Policy Committee, and Polar Research Board.

Specific Objectives:

1. Cumulative effects of development and climate change. In the GCB paper (Raynolds et al. 2014), we demonstrated that thermokarst has recently affected broad areas of the Central North Slope Arctic Coastal Plain, and that a sudden increase of thermokarst began shortly after 1990 corresponding to a rapid rise in regional summer air temperatures and related permafrost temperatures. We also present a conceptual model that describes how infrastructure-related factors, including road dust and roadside flooding contribute to extensive thermokarst in areas adjacent to roads and gravel pads. We mapped the historical infrastructure changes for the Alaska North Slope oilfields for 10 dates from the initial oil discovery in 1968–2011. By 2010, over 34% of the intensively mapped area was affected by oil development. In addition, between 1990 and 2001, coincident with strong atmospheric warming during the 1990s, 19% of the remaining natural landscapes (excluding areas covered by infrastructure,
Key outcomes or Other achievements:

* What opportunities for training and professional development has the project provided?

1. The project has supported the PhD studies of Tracie Curry, who is pursuing her degree in Natural Resources and Sustainability in the School of Natural Resources and Extension at UAF. Tracie has participated in Scenario Workshops of the North Slope Science Initiative, traveled to Native villages where she has interacted with local residents and Tribal leaders and presented to these groups.
2. Seven students were trained in Arctic System Environmental Change in 2016 during the summer field course, bringing the total trained during the project to 21.
3. A post-doctoral student, Dr. Marcel Buchhorn, was trained and accepted a job offer from VITO in Belgium, a leading
European independent research and technology organisation in the areas of clean technology and sustainable development.

4. Funds from the ArcSEES project were used to help involve Arctic Polar Early Career Scientists to the RATIC meetings in Canada and Japan during the past year.

5. Dr. Jozef Sibik, a visiting scientist from the Slovak Republic, and his graduate student, Silvia Chasnikova, visited for 5 months to receive training in our methods of data collection and analysis methods, and background in projects including our ArcSEES project.

6. Dr. Ksenia Ermokhina, a visiting scientist from Moscow State University and the Russian Academy of Science Earth Cryosphere Institute, visited for 2 months in August and September 2016 to be trained in methods of vegetation archiving and analysis and visited the ArcSEES research site at Prudhoe Bay.

* How have the results been disseminated to communities of interest? If so, please provide details.

1. We have made presentations about the project to several groups in Alaska, including The North Slope Borough Wildlife Management Department, to graduate students at UAF, community organizations in Nuiqsut and Wainwright, Interagency Arctic Research Policy Committee (IARPC), the Bureau of Land Management's new cumulative effects of development initiative, and the Polar Research Board, and a public lecture at the UAF Institute of Arctic Biology's seminar series.

2. Two new websites archive information and provide all project details from the project. One provides general information from the ArcSEES project with information on the projects goals, proposals, annual and other reports, publications, workshops, and key data (http://www.geobotany.uaf.edu/arcsees/). The other is a Geocological Atlas is being developed in collaboration with a NASA ABoVE (Arctic and Boreal Vulnerability Experient) project (http://geobotanical.portal.gina.alaska.edu). This site contains all the map and plot data produced by this project and others that the Arctic Geobotany Center has been involved with during its 45-year history.

3. The new AGC publication series provides web and hard copy data reports from the project. Copies of three of these reports are included in the supporting files.

4. Special RATIC Session at the the Arctic Change 2014 meeting in Ottawa, Canada. The workshop included 40 participants, who presented a variety of case studies from around the Arctic. Two topical sessions included 10 oral presentations and 17 posters, with first authors from the U.S. (9 papers, Russian (9 papers), Canada (6 papers), Finland (2 papers), and Norway (1 paper).

* What do you plan to do during the next reporting period to accomplish the goals?


2. Archive data in the ARCSS Data Archive at NCAR/EOL.

3. Complete interviews on adaptive management and cumulative effects. Respondents will be selected through members of the North Slope Science Initiative Oversight Panel, who represent all organizations involved in North Slope land management.

4. Organize a regional workshop and panel at a conference on Arctic Alaska landscape change, undertaken in cooperation with EPSCoR Northern Test Case Project.

5. Organize a RATIC workshop at Arctic Science Summit Week 2017, Prague.

6. Use the Decision Theater North with North Slope stakeholders to make presentations to and have discussion. The process will be used to test the effectiveness of the visualization on roads in conveying information on the topic and informing decision making.

7. Conduct a 21-day field course entitled Arctic Alaska Environmental Change in Jun 2017.


- Cumulative effects of Arctic roads to the soils and vegetation after 45 years, Prudhoe Bay region, Alaska. Walker et al. To be submitted to *Applied Vegetation Science* or *Phytocoenologia*.
Comparing Indigenous Peoples with Oil and Gas development with climate change in Yamal Russia and North Slope Alaska Experiences of, Bruce Forbes and Gary Kofinas
PhD dissertation by Tracie Curry.

Products

Books
Walker, D. A., M. K. Raynolds, M. Buchhorn, and J. L. Peirce (Eds.). (2014). Landscape and permafrost change in the Prudhoe Bay Oilfield, Alaska. Alaska Geobotany Center, University of Alaska, AGC. University of Alaska Fairbanks. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; OTHER:

Book Chapters

Journals or Juried Conference Papers

https://reporting.research.gov/rppr-web/rppr?execution=e1s8


**Licenses**

**Other Conference Presentations / Papers**


**Other Products**

**Other Publications**


**Patent Applications**

**Technologies or Techniques**

**Thesis/Dissertations**


**Websites or Other Internet Sites**

**Participants/Organizations**

**What individuals have worked on the project?**

<table>
<thead>
<tr>
<th>Name</th>
<th>Most Senior Project Role</th>
<th>Nearest Person Month Worked</th>
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<tr>
<td>Walker, Donald</td>
<td>PD/PI</td>
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<td>Raynolds, Martha</td>
<td>Postdoctoral (scholar, fellow or other postdoctoral position)</td>
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<td>Matyshak, George</td>
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<tr>
<td>Peirce, Jana</td>
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<tr>
<td>Wirth, Lisa</td>
<td>Other Professional</td>
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</table>

**Full details of individuals who have worked on the project:**

**Donald A Walker**  
*Email:* ffdaw@uaf.edu  
*Most Senior Project Role:* PD/PI  
*Nearest Person Month Worked:* 4  

**Contribution to the Project:** Project management, Field research, author several papers and conference presentations  
**Funding Support:** UAF Salary 1 month  
**International Collaboration:** Yes, Russian Federation  
**International Travel:** Yes, Germany - 0 years, 0 months, 7 days; Canada - 0 years, 0 months, 5 days; Japan - 0 years, 0 months, 7 days

**Gary P Kofinas**  
*Email:* gary.kofinas@alaska.edu  
*Most Senior Project Role:* Co PD/PI  
*Nearest Person Month Worked:* 1  

**Contribution to the Project:** Co-PI, coordinate human dimension component, supervise graduate student  
**Funding Support:** Partial UAF support  
**International Collaboration:** Yes, Finland  
**International Travel:** No

**Yuri L Shur**  
*Email:* yshur@alaska.edu  
*Most Senior Project Role:* Co PD/PI  
*Nearest Person Month Worked:* 1  

**Contribution to the Project:** Co-PI, field research, project direction, paper writing, conference participation
Funding Support: Partial UAF support

International Collaboration: No
International Travel: Yes, Germany - 0 years, 0 months, 7 days

Marcel Buchhorn
Email: mbuchhorn@alaska.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Post-doc, field work, GIS/remote sensing lab manager, building new facility

Funding Support: This project plus NASA LCLUC Grant, and PreABoVE

International Collaboration: Yes, Germany
International Travel: No

Martha K Raynolds
Email: mkraynolds@alaska.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Field research, mapping, writing publications

Funding Support: This project

International Collaboration: No
International Travel: No

George Matyshak
Email: matyshak@gmail.com
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: Soils descriptions and analysis at field sites

Funding Support: travel support from this grant

International Collaboration: Yes, Russian Federation
International Travel: Yes, Canada - 0 years, 0 months, 7 days; Germany - 0 years, 0 months, 7 days

Jana L. Peirce
Email: jlpeirce@alaska.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 2

Contribution to the Project: Writing and editing reports, field work, data analysis

Funding Support: this grant

International Collaboration: No
International Travel: No

Lisa Wirth
Email: lisa@gina.alaska.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 2

Contribution to the Project: Mapping, GIS, web site, field work

https://reporting.research.gov/rppr-web/rppr?execution=e1s8
Funding Support: This project, NASA PreABoVE project

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

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<tr>
<th>Name</th>
<th>Type of Partner Organization</th>
<th>Location</th>
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<tr>
<td>Earth Cryosphere Institute</td>
<td>Other Organizations (foreign or domestic)</td>
<td>Tyumen, Russia</td>
</tr>
<tr>
<td>University of Eastern Finland</td>
<td>Academic Institution</td>
<td>Finland</td>
</tr>
</tbody>
</table>

Full details of organizations that have been involved as partners:

**Earth Cryosphere Institute**

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Tyumen, Russia

Partner’s Contribution to the Project:
Financial support
In-Kind Support
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Helping with RATIC workshop and Russian case study

**University of Eastern Finland**

Organization Type: Academic Institution
Organization Location: Finland

Partner’s Contribution to the Project:
Financial support
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Helping with the RATIC workshop and Russian case study

What other collaborators or contacts have been involved?
Nothing to report

Impacts

What is the impact on the development of the principal discipline(s) of the project?

New type of thermokarst described by Shur et al. provides major insight into how massive thermokarst erosion can occur in association with flooding events. Also how aufeis can be promoted by seismic activities in deltas of rivers.

What is the impact on other disciplines?

The RATIC is a strong cross-disciplinary initiative with major international collaborators in the social sciences, permafrost science, engineering, and education.

What is the impact on the development of human resources?
We are training numerous students during the summer field courses, and through exchanges with researchers in Russia, Slovak Republic, Germany. One Ph.D. Student (Tracie Curry) is funded by the project and developing innovative approaches to convey the results of the project to a broad range of user groups. One Post-Doc has been trained and recently accepted a top research position with TIVO in Belgium.

**What is the impact on physical resources that form infrastructure?**

Funding from this ArcSEES project helped us make major modernization of the GIS and remote sensing facilities.

**What is the impact on institutional resources that form infrastructure?**

Nothing to report.

**What is the impact on information resources that form infrastructure?**

Support from this project help us hire Jana Peirce, who has made many major contributions in helping to write, edit, and publish data reports, and communicate the results of the project to wide group of interested parties, and in developing the project web sites.

**What is the impact on technology transfer?**

Nothing to report.

**What is the impact on society beyond science and technology?**

The project has made a major contribution in helping direct more scientific attention to the issues related to development and infrastructure in the Arctic, particularly the interactions between climate change and infrastructure.

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**Changes/Problems**

**Changes in approach and reason for change**

Nothing to report.

**Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

**Changes that have a significant impact on expenditures**

Nothing to report.

**Significant changes in use or care of human subjects**

Nothing to report.

**Significant changes in use or care of vertebrate animals**

Nothing to report.

**Significant changes in use or care of biohazards**

Nothing to report.

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**Special Requirements**

Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.

Nothing to report.