BEAUFORT REGIONAL ENVIRONMENTAL ASSESSMENT

Second Annual Progress Report 2012–2013

Canada

April 2014

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Beaufort Regional Environmental Assessment

Building a strong knowledge base to support regulatory decisions on offshore oil and gas activity

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Introduction

The Beaufort Regional Environment Assessment (BREA) is a multi-stakeholder initiative that provides an opportunity for Inuvialuit communities, industry, federal and territorial governments, academia, and regulators to prepare for oil and gas activity in the Beaufort Sea. The primary objectives of BREA include building a regional socio-economic and scientific knowledge base that fills regional information and data gaps related to offshore oil and gas activities, as well as supporting efficient and effective regulatory decision-making.

BREA consists of a research program and multiple working group activities to address priority issues in the region. Twenty-three research projects have been funded, based on priorities identified in earlier analyses (Environmental Studies Research Fund Report #163 and the 2011 *BREA Data Mining Project* report prepared by ArcticNet for Aboriginal Affairs and Northern Development Canada (AANDC)), and subsequently refined collaboratively through multi-stakeholder committees. All projects were selected based on their relevance to the priority research areas, as well as their contribution to regulatory efficiency and community preparedness.

Separate working groups are addressing issues related to climate change; cumulative effects; information management; oil spill preparedness and response, social, cultural, and economic indicators; and waste management.

This second annual report on BREA activities covers the period between April 1, 2012 and March 31, 2013. The report includes a summary of the research projects funded this year, their progress, as well as descriptions of the six working groups and an update on their progress.

As part of the progress made during the first year of BREA, two projects were completed: “Polar Bears in the Deep Offshore Regions of the Beaufort Sea: A Preliminary Study to Estimate Distribution and Density in Previously Under-Surveyed Areas” (N. Snow, Joint Secretariat) and “Delineation of Extreme Ridges in High Resolution Satellite-Based Radar Imagery” (D. Powers, C-Core). These projects are not discussed in this report.

Project metadata and data will be posted to the Polar Data Catalogue (www.polardata.ca) as they become available, while the BREA website (www.BeaufortREA.ca) serves as a portal for all BREA projects. Communications and community outreach are an important component of BREA, a summary of activities is presented in this report, including the BREA Results Forum in Inuvik, February 2013.

Finally, the strength of BREA is in its many partnerships between government, Inuvialuit, industry, and academia. These partners are listed in the last section of the report.

Research Program

BASELINE FISH INFORMATION

Active Acoustic Mapping of Fish in the Beaufort Sea, 2011–2015

Lead: Louis Fortier (ArcticNet)

This cutting-edge project, led by ArcticNet, uses state-of-the-art fisheries sonar technology to map the distribution and abundance of Arctic cod and other fish in the offshore Beaufort Sea during the summer months. Arctic cod is the main food source for seals, whales, and birds in the Beaufort Sea Region and this study is important to supplement existing research into the winter distribution patterns of Arctic cod.

Progress: Building on the work of the first year, researchers installed and calibrated an EK60 echosounder on board the *F/V Frosti* as part of their collaboration with the "Fishes, Habitats, and Ecosystem Linkages to Oil and Gas Development in the Beaufort Sea" project (led by Fisheries and Oceans Canada in Winnipeg). The echosounder recorded 658 hours of hydroacoustic data in the Canadian Beaufort Sea between August 6 and September 3, 2012. Validation of the echograms with ichtyoplancton nets, mesopelagic, and benthic trawls confirmed the following:

1. Arctic cod (*Boreogadus saida*) represents >97% of the pelagic adult fish and >65% of the young-of-year fish.
2. The young-of-year fish are distributed in the first 100 m of the water column during the ice-free season.
3. Age 1+ Arctic cod occupy the lower part of the Pacific Halocline and the upper part of the Atlantic layer (200–400 m) during the same period.

The top layer of the young-of-year was continuously observed during the Mackenzie shelf and slope transects (from 20 m to 1,400 m bottom depth). The deeper aggregation of Age 1+ Arctic cod was present over the entire slope (from 200 m to 1,400 m bottom depth), but higher biomass values were observed at 350 and 1,000m bottom depths. Preliminary analyses based on hydroacoustic data suggest a maximum integrated biomass of 30 $g \cdot m^{-2}$ within the Age 1+ fish aggregation and 3.6 $g \cdot m^{-2}$ within the young-of-year aggregation. These aggregations overlap several oil and gas lease blocks in the region.

Fishes, Habitats, and Ecosystem Linkages to Oil and Gas Development in the Beaufort Sea, 2011–2015

Lead: Jim Reist (Fisheries and Oceans Canada)

Fisheries and Oceans Canada, in collaboration with six Inuvialuit communities, are conducting a four year study that will include a fishing survey in deeper waters (100–1,000 m) of the outer continental

shelf as well as slope areas of the Beaufort Sea. Researchers are studying both bottom-dwelling and mid-water fish species, documenting the size of their populations, habitats, diets, roles in the food chain, and migratory patterns—something which has never been done before. Increased understanding of the ecosystems on which fish species depend will support environmental assessments and sound decision-making regarding fish habitat and offshore oil and gas activities.

Progress: The 2012–2013 field seasons aboard the *F/V Frosti* proved to be a success. This year's accomplishments include the following:

1. The first-ever offshore fish trawling survey in deeper waters of the Canadian Beaufort Sea aboard the *F/V Frosti*. Four sections (75–150 linear km), each with seven stations (20–1,000 m depths), were sampled with benthic trawls (fish and epibenthic invertebrates), box cores (sediment, infauna), pelagic nets (plankton), and by water column measurements (salinity, temperature, nutrients).
2. A hydroacoustics survey of the sampled transects and a separate focal transect (a total of 481 linear km and 388 linear km, respectively) was performed (and verified using mid-water trawling) in order to determine pelagic biomass and to identify targets (linkage to "Active Acoustic Mapping of Fish in the Beaufort Sea" project).
3. Collaborative sampling of fish was conducted, and basic oceanographic, habitat, and ecosystem parameters were collected at six coastal locations (linkage to "Regional Coastal Monitoring in the Inuvialuit Settlement Region: Ecosystem Indicators" project).

Approximately 9,258 fish (representing 11 taxonomic families) were captured. All related habitats (water column and bottom) were determined as well as the sampling of non-fish biota. All related data was accumulated to establish biotic and habitat diversity, as well as connectivity among ecosystem components and among offshore and coastal ecosystems. Continued analyses will contribute to establish baselines of biotic diversity, habitats, and key contaminants (linkage to "Baselines, Accumulation, Cycling, and Potential Effects of Hydrocarbons in Beaufort Sediments and Biota" project). Connectivity (food-web, ecosystems) will be determined through gut contents, stable isotopes, fatty acids, and calorimetry. New information was acquired on fish distributions in previously unsampled areas (especially deepwater habitats), and at least six new fish species were added to the regional pool.

Newly acquired information and understanding will be integrated with existing knowledge to establish the regional context for marine fish in the Canadian Beaufort Sea.

Baselines, Accumulation, Cycling, and Potential Effects of Hydrocarbons in Beaufort Sediments and Biota, 2012–2014

Lead: Gary Stern (Fisheries and Oceans Canada)

The purpose of this project is threefold: (i) to establish the background levels of hydrocarbons in sediment, zooplankton, benthic invertebrates, and fish, (ii) to establish baseline concentrations of hydrocarbon metabolites in fish, and (iii) to establish background values for indicators of fish health against which the magnitude and extent of potential environmental perturbations can be assessed.

Progress: To date, this work has established background levels of hydrocarbons (polycyclic aromatic hydrocarbons (PAH) and alkanes) in sediments across all oil and gas lease areas in the Beaufort and across a significant gradient in water depth (0–1,000 m), ranging from near the coast to the continental basin. Twenty-four surface sediment samples have been analyzed from four transects collected from the *M/V Frosti* cruise in summer 2012 for PAH and alkanes (~70–72°N and 130–141°W). Results show that the Beaufort Sea is a highly petrogenic (fossil carbon-rich) as opposed to pyrogenic (combustion carbon-rich) system, indicating that eroded coal outcrops, peat, and natural oil seeps dominate the PAH signal relative to forest fires and industrial and vehicular activity. This is distinct from most other river-dominated seas worldwide, including most other major Canadian sites.

These same 24 surface sediment samples have been analyzed for mercury, other metals, and organic carbon forms (Rock-Eval analyses) to determine the source of the mercury to the sediments. Interestingly, mercury and most metals increase with water depth and distance offshore, which may be related to higher organic matter input, perhaps due to a combination of greater aquatic (marine) primary productivity and lower (geological) sediment input. Pelagic (water column) zooplankton have also been analyzed for mercury at each site, and where sufficient sample existed, for methyl mercury (the more toxic and bioaccumulative form of mercury). In general, higher mercury concentrations were observed going from west to east, and the highest concentrations were often found at sites where the water was 200–400m deep, along the continental slope. This is likely related to upwelling of nutrients from the mixed layer between the Pacific and Atlantic water masses, and will be examined in greater detail in 2013–2014. Benthic invertebrates have also been analyzed for mercury. Concentrations were on average much higher in the benthic invertebrates relative to the pelagic zooplankton (up to 3 mg/kg and up to 0.5 mg/kg, respectively), and there were clear, increasing trends between sedimentary mercury and benthic invertebrates for most species (starfish were the exception, decreasing with increasing sedimentary mercury concentrations). These data show that the benthic invertebrates are likely accumulating mercury from the sediments.

COASTAL AND MARINE BIRDS

Bird Usage of the Coastal Regions of the Canadian Beaufort Sea, 2011–2013

Lead: Myra Robertson (Environment Canada)

The Beaufort Sea Region provides marine and coastal habitat for hundreds of thousands of migrating and breeding birds. This project is identifying important nearshore and coastal nesting, feeding, and migration areas. The study is compiling existing information on coastal bird usage and identifying species, numbers, and distribution of birds. A digitized GIS is used to identify bird sensitivity areas in the Beaufort Sea based on available information. The information will be valuable to oil and gas developers and regulators through the environmental assessment process to ensure that negative impacts of development on birds are minimized.

Progress: Work in 2012–2013 focused on preparing the report for publication, and getting the bird information ready for a publically available online mapping tool. It was found that some additional analyses and mapping needed to be done, which has delayed the production of the hard copy report and posting on the online mapping tool until 2013–2014. This work complements the "Birds of the Offshore Canadian Beaufort Sea" project being led by Upun-LGL Limited.

Birds of the Offshore Canadian Beaufort Sea, 2011–2013

Lead: Ross Harris (Upun-LGL Limited)

This project is synthesizing existing information on offshore bird populations in the Beaufort Sea into a geo-referenced database. The database will include information on the offshore occurrence of birds, species, gender, age, date, location, movement, and the data source.

Progress: This project produced a geospatial database and report using 25 sets of data amalgamated from various contributors. These contributors include Devon Canada, Fisheries and Oceans Canada, GX Technology, ArcticNet, Imperial Oil, British Petroleum, Natural Resources Canada, and Chevron. The data sets span the years of 2002–2012. The areas covered include offshore lease areas such as Ajurak, Pokak, and Sirluaq and ice-free waters. The least reported areas were the Spring migration in offshore leads in and near the pack ice. This work complements the "Bird Usage of the Coastal Regions of the Canadian Beaufort Sea" project being led by Environment Canada.

BIRDS, FISH, AND MARINE MAMMAL INFORMATION

Biological Data to Assess the Net Environmental Benefits and Costs of Dispersants and *In Situ* Burning in Oil Spill Response, 2011–2013

Lead: Ken Trudel (SL Ross Environmental Research Limited)

An important part of oil spill response planning is to develop tools to assist in assessing the risks from oil spills and the benefits of countermeasures (e.g., dispersants, *in situ* burning) used to fight them. This project is examining traditional knowledge to identify Inuvialuit environmental protection priorities in the Canadian Beaufort Sea. Traditional knowledge will be combined with scientific data to (i) describe Inuvialuit harvesting and other activities; (ii) describe the fish, bird, and marine mammal populations upon which these activities depend; and (iii) assess the vulnerability of all of these to effects of spills and countermeasures. Using realistic spill scenarios, this information will be used to illustrate the use of Net Environmental Benefit Analyses to assess the merits of dispersants and *in situ* burning in responding to oil spills in the Beaufort Sea.

Progress: Prioritized lists of Valued Components (VCs) (bird, mammal, and fish species, as well as Inuvialuit harvesting and other activities) have been assembled that would (i) be vulnerable to effects of oil spills into the marine environment occurring in the Canadian Beaufort Sea; and (ii) drive spill response planning, policy, and decision-making in the Beaufort, including decisions about dispersants

and *in situ* burning. Oil spill vulnerability profiles have been created in a well-formatted and easy to use database for the priority VCs that clearly identify the characteristics of these species and Inuvialuit activities. Workshops to assemble traditional knowledge concerning priority VCs were held in order to conduct and document an example Net Environmental Benefit Analysis for a typical exploration spill scenario to illustrate the use of vulnerability profiles for undertaking Net Environmental Benefit Analyses.

WORST-CASE ENVIRONMENTAL DESIGN LIMITS FOR ICE

Overwintering in the Beaufort: Assessing Damage Potential to Vessels, 2011–2013

Lead: Anne Barker (National Research Council)

Vessels containing and/or storing fuel are frozen into ice that is anchored to the shoreline (land-fast ice) throughout the Beaufort region over the winter months. The practice, called over-wintering, has raised concerns in some Northern communities about the potential for fuel spills. This project is assessing whether vessels or barges experience any significant damage when overwintering in land-fast ice, which could pose environmental risks. The information will be used to make recommendations to Inuvialuit communities and regulators on the best ways to reduce the likelihood of damage to vessels overwintering in ice in the nearshore region of the Beaufort Sea.

Progress: This project concentrated on the nearshore Beaufort region, stretching from Herschel Island through the MacKenzie Delta region, Tuktoyaktuk, and up to McKinley Bay. Some minor investigations were carried out in the Mackenzie River area. As the 2012–2013 year is the final year of the project, the goals were to establish site visits and the creation of a final report. Meetings were held with the representatives of the Inuvialuit Joint Secretariat, the Inuvialuit Game Council and the Fisheries Joint Management Committee, Horizons North, and Transport Canada. A site visit was conducted in both Tuktoyaktuk Harbour and McKinley Bay, as these are key overwintering locations in the region (weather prevented a planned visit to Herschel Island).

A final report is available that summarizes the historical overview of the practice, calculation methods for determining appropriate ice loads for overwintering vessels, key considerations for the practice of overwintering, as they pertain to ice, and a framework for a methodology for site selection for overwintering vessels. Meetings were conducted with Industry members to discuss the results of the project. On-going discussions with Transport Canada will continue for the inclusion of some of the results from this project into their upcoming Guidelines for Overwintering, which will be applied across the Arctic. The report was mailed to local representatives of the local communities, and a copy of the report was also left with the Aurora Research Institute's library for inclusion therein. In addition, the full report is available through the BREA website.

SEA ICE TYPES AND EXTREME FEATURES

CanICE: A Sea Ice Information Database and Web-Based Portal, 2011–2014

Lead: Lina Assad (Environment Canada)

Sea ice exerts important seasonal effects on weather and climate, marine ecosystems, the safety of marine transportation, northern communities, and offshore resource development and exploitation. Whether preparing policy or regulations, assessing the impacts of activities on ecosystems, designing sustainable infrastructure, or planning and conducting safe and secure shipping, information about sea ice conditions is vital given the variable and harsh Arctic marine environment. Environment Canada, in partnership with several universities, is creating a publically accessible database that captures existing information on BREA-relevant sea ice features including extent, concentration, type, characteristics, and extreme ice hazards. Access to the database will be through the Polar Data Catalogue. The quality-controlled, interoperable database will enable online, open access to historical and current sea ice information, and will allow others with sea ice information to add data to this central information source.

Progress: The Canadian Ice Service has built a new BREA sea ice database, and added over 200,000 old paper and microfilm ice charts to the Canadian Ice Service database. The new Canadian Ice Service sea ice chart production system for the entire Canadian Arctic will be compatible with the BREA database. The Universities Waterloo, Laval, and Ryerson have also aided in this endeavour.

The University of Waterloo is building a new server to host the web and map tools and, in collaboration with the Canadian Ice Service, is setting up a connection to the Polar Data Catalogue. Significant improvements to the Polar Data Catalogue Geospatial Search application and the Polar Data Catalogue database have been ongoing to enhance services, to facilitate inclusion of the SOLAP and GIS tools from the CanICE partners, and support web services and interaction with the Canadian Ice Service as well as other data portals with Beaufort and Arctic interests.

Université Laval is developing web tools for complex analysis of CanICE data maps, Polar Data Catalogue metadata, web traffic, and Canadian Ice Service Egg Codes. A fully working web-based prototype has been developed with Map4Decision using Egg Code data provided by the Canadian Ice Service for a pilot zone and time period. These data can be explored interactively and users can instantly display maps, tables, and statistical charts for the entirely covered zone, for an arctic region, for a sub-region, and for smaller bathymetry-delineated spatial units (<200 m, 201–500 m, 501–2,500 m, >2500 m). Similarly, users can explore data by weeks, months, seasons, years, and multi-years.

Alongside them, Ryerson University has completed a spatiotemporal database model for all historical and continuously retired ice data. New functionality of the web-based sea ice archive portal includes a new user interface and interactive thematic ice charts that can filter different types of ice; two types of ice archive data animation to visually assess how ice changes over time; user registration and preferences setup; online printing and social media sharing; manually user defined areas that can be

synchronized to server and viewed again on client after user login; an improved icegraph generation method; and an ice archive data downloading function.

Beaufort Sea Engineering Database, 2011–2013

Lead: Ivana Kubat (National Research Council)

Over the years, a significant amount of data has been collected in the Beaufort Sea, but it is widely scattered. Searching for the best available datasets is often difficult. Downloading, extracting, and visualizing the information from various sources and file formats is even more challenging and time consuming. The National Research Council of Canada is developing an integrated database for the storage, query, and visualization of all key relevant environmental data for engineering design purposes in the Beaufort Sea. This single-window information source will give regulators access to definitive regional environmental information. The database will be used to determine design ice loads for offshore platforms and marine operations.

Progress: Phase 2 of the project seeks to link all available Beaufort Sea environmental datasets of interest and implement further features requested by Joint Industry Partners (JIP) partners. During the second year of Phase 2, several tasks have been accomplished. The Beaufort Sea Engineering Database (BSED) interface has been modified to include 64 datasets which JIP partners selected for the inclusion. Functionalities requested by project partners were built and implemented in the BSED. The development of multi-year and ridged ice databases within BSED has been completed. Ice Islands Drift database have been developed and included in BSED. Training was provided in October 2012 on how to run and use the BSED. A final user manual was prepared and distributed to JIP partners. An FTP site was established for updating and maintenance of the BSED. The update and maintenance will be done as part of Phase 3 of the project. This completes the portion of the project supported by BREA.

Quantifying Sea Ice Dynamics in the Beaufort Sea, 2012–2015

Lead: Chris Derksen (University of Waterloo)

Sea ice within the Beaufort Sea region circulates according to the predominantly anti-cyclonic Beaufort Gyre, but very little quantitative information about sea ice motion exists. This project is deriving sea ice motion products for the Beaufort Sea region using the Canadian Ice Service's operational archive of RADARSAT-1 and RADARSAT-2 imagery and Environment Canada's new sea ice motion tracking algorithm. The results of this analysis will establish a baseline sea ice motion dataset which can be used to plan and support future offshore operations. Results will also provide BREA with information on regional changes in sea ice dynamics that have occurred within the context of changes in the sea ice regime of the Beaufort Sea region during recent decades, marked by pronounced warming trends in the region. In addition, the ice motion products will serve as validation for a new state-of-the-art atmosphere-ice-ocean model for operational sea ice forecasting in the Beaufort Sea, currently under development at Environment Canada.

Progress: The primary task for the first year of this project was RADARSAT image acquisition over the Beaufort Sea region, and image pre-processing. This activity has since been completed. RADARSAT-1 and RADARSAT-2 ScanSAR wide imagery were acquired for the Beaufort Sea over the 1997–2012 time period. The study area was subdivided into five regions to facilitate ice-flux calculations (Figure 1).

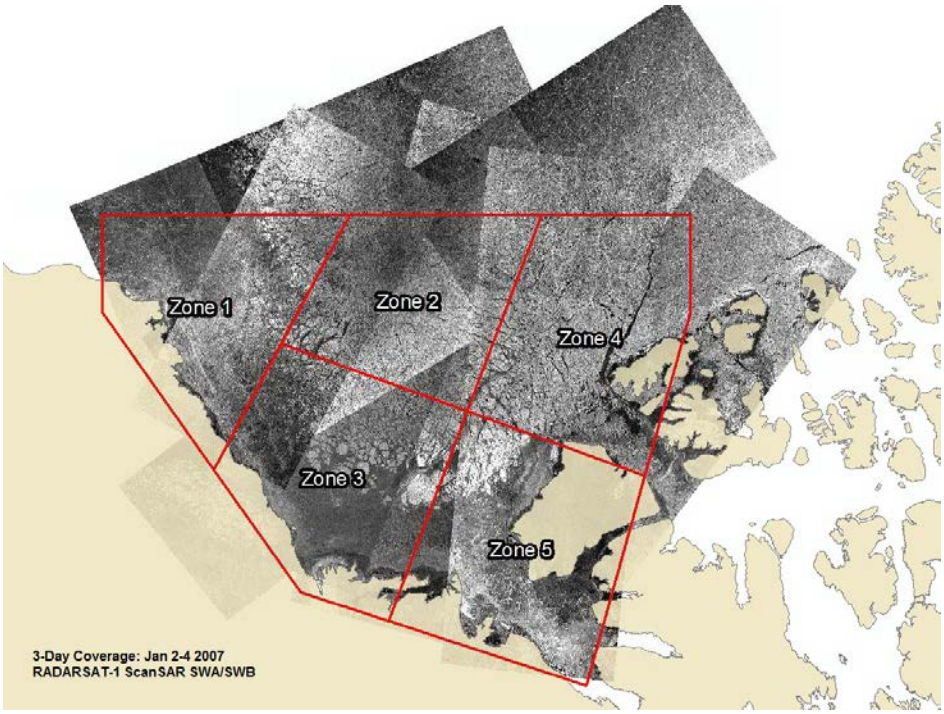

Figure 1. Ice motion study area sub-divided into five zones.

Using 2007 as an initial test year, the Canadian Ice Service Automated Sea Ice Tracking System was utilized to produce ice motion fields from pairs of RADARSAT imagery (Figure 2). Averaging procedures are currently being evaluated for the derivation of monthly ice motion composite maps. Sea ice exchange between the zones shown in Figure 1 will be derived at three to four day and monthly time steps. Current emphasis is on the quality control and assessment of the 2007 ice motion estimates (using available ice beacon and buoy data). Once the researcher is satisfied with the output for 2007, the remaining 16 years of the time series will be processed in an automated fashion as well.

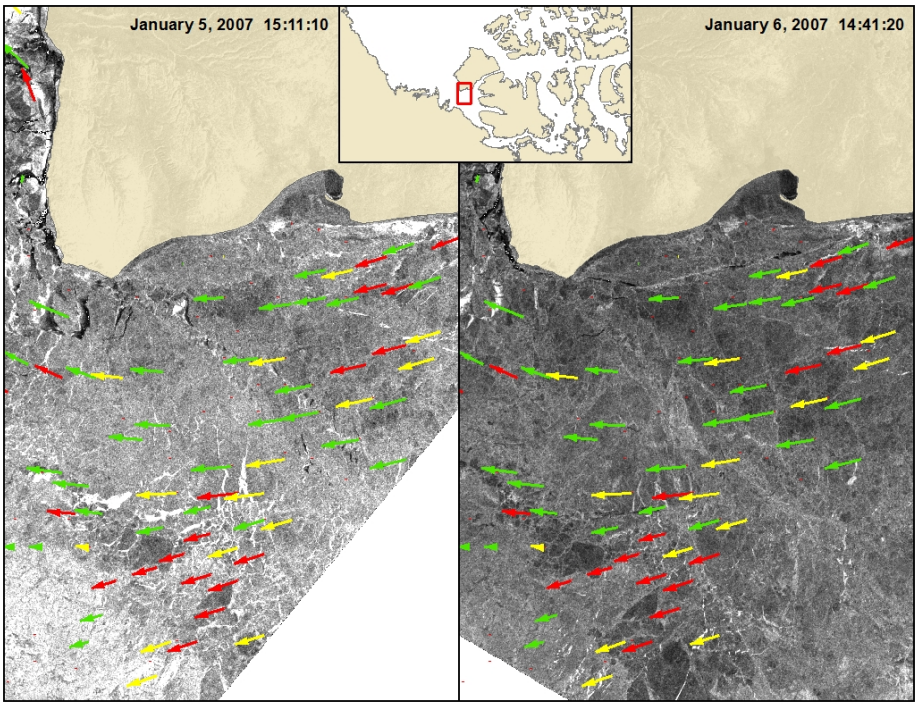

Figure 2. Example ice motion vectors between January 5 and 6, 2007. Arrow colours indicate confidence levels in the motion estimates (green = high; red = low).

Characterizing Deformed Multi-Year Ice in the Beaufort Sea, 2011–2015

Lead: Michelle Johnston (National Research Council)

Although there is growing evidence that the polar pack is decreasing in extent and thickness, icebergs, ice islands, and thick, deformed multi-year ice continue to pose a hazard. This project, led by the National Research Council of Canada, is describing the thickness and strength of extreme ice features in the Beaufort Sea at ice depths of up to 12 m, where no information currently exists. The research will provide information needed to better engineer structures to withstand the impacts of deformed multi-year ice. Increased knowledge of dangerous ice features will also enhance the decision-making capacity of regulators and industry.

Progress: During the May 2012 field program, equipment newly developed during the first year was tested on hummocked multi-year ice to ensure that it performed well. Three people from the National Research Council traveled to Resolute to conduct the first field program of this four-year project from May 3 to 20, 2012. Measurements were constrained to one hummocked multi-year ice floe for the purposes of testing the equipment. Ice cores were extracted from two boreholes to document the temperature and salinity of the ice to a maximum depth of 12 m. *In situ* strength tests were conducted in both boreholes at depth intervals of 30 cm to document changes in strength versus depth, and to relate this information to the ice temperature and salinity. Ice thicknesses were measured at a total of 20 holes using drill hole and steam hole techniques. Measurements from the 2012 field program are

unique because they provide the only available information about the keel strength of thick, hummocked multi-year ice below a depth of 10 m. Material from the 2012 field season was presented at the BREA Results Forum (February 2013, Inuvik, Northwest Territories).

Distribution and Thickness of Different Sea Ice Types and Extreme Ice Features in the Beaufort Sea, 2011–2015

Lead: Christian Haas (York University)

Among the most serious challenges to operating in the Beaufort Sea are widely varying sea ice types and severe ice conditions. This project is using electromagnetic surveys and drift beacons to perform large-scale airborne ice thickness surveys to quantify the thickness and regional distribution of multi-year ice and extreme ice features in the Southern Beaufort Sea. The results of this research will improve understanding of how sea ice moves in response to winds and currents, and will contribute to the development of tools to predict ice drift. Being prepared for any and all eventualities is one of the realities facing regulators and industry contemplating offshore oil and gas exploration and drilling.

Progress: In April 2012, researchers successfully performed an ice thickness survey out of Inuvik, including several multi-year hummock fields and an ice island. Some of these features were marked by GPS beacons and were subsequently tracked into the summer when they disintegrated. Results show that the multi-year ice edge is very variable and retreats further north. Multi-year ice in the Beaufort Sea can still be very thick with mean thicknesses ranging between 4 and 6 m over 1 km intervals. However, first-year ice in proximity to the nearshore fast ice edge can be very deformed as well, and hummock fields were encountered which were thicker than several multi-year hummock fields. These show that the multi-year ice may not be the most hazardous ice at all during winter and spring. Researchers have been successful in completing integration and testing of a new airborne ice thickness observing system using a Kenn Borek Air BT67, and have finalized plans for another survey and buoy deployment out of Sachs Harbor and Inuvik between April 11 and 15, 2012. A field plan has been prepared and is available on the BREA website.

RADARSAT Mapping of Extreme Ice Features in the Southern Beaufort Sea, 2011–2015

Lead: David Barber (University of Manitoba)

There is growing global interest in marine shipping and oil and gas development in the Southern Beaufort Sea as ice cover in Arctic waters diminishes over the summer months. However, hazardous ice remains a risk to industrial operations in the region. This research is providing regionally relevant information on extreme ice features along the northwestern flank of the Canadian Arctic Archipelago. The University of Manitoba is leading a team of investigators that is using RADARSAT technology to detect, monitor, and eventually model the distribution and motion of hazardous ice features and their movement over significant oil and gas exploration licenses in the area. This scientific knowledge will be

married with information collected by local residents participating in a new community-based pilot program to monitor sea ice thickness.

Progress: Progress was made on all four of the University of Manitoba components of the Integrated Sea Ice Project:

1. Ice thickness: Eleven multi-year floes and one ice island were visited. Ice thickness data were collected from representative floes by electromagnetic induction (EMI), including ground penetrating radar data on the ice island. This high resolution data is intended to supplement data collected by Dr. Christian Haas (regional-based EMI surveys). Mean ice thicknesses obtained by the EMI ranged from 4 to 7 m for the multi-year ice, while the ice island was estimated at 33 m thickness. Complimenting this data is mooring data in the Beaufort Sea which will provide near continuous data on ice motion, ice keel depths, and ocean currents from 2009 to 2011 (data provided by ASL).

   Ice thermodynamics: Two ice mass balance buoys were deployed; one failed after five days, the other lasted from April to the end of July 2012. These devices provide temperature profiles of the sea ice, a variable linked to ice strength. This data will be integrated with the "Characterizing Deformed Multi-Year Ice in the Beaufort Sea" project.

2. Sea ice motion (dynamics): Thirteen position-only beacons were deployed, 11 on multi-year floes and two on either end of an ice island (tabular iceberg). These were deployed as triplets to enable the measurement of convergence and divergence of ice (April through July 2012). This hourly data is used to track ice relative to local and regional winds. The hourly data is combined with regional ice motion using RADARSAT data. To help understand the relative significance of ocean versus atmospheric forcing *in situ* current profiler data and wind data were collected. Current direction and speed was recorded and surface winds were measured at the same site, all data was corrected to account for floe rotation. The instruments lasted from early April to the end of July 2012 when the floes broke up.

3. RADARSAT mapping of hazardous ice features: Weekly RADARSAT data was collected from March 15 to August 3 2012. This data is used to map ice concentrations, ice motion, and local wind speed (in open-water areas). This data is also used to identify ice types within the study area and the seasonal evolution of microwave backscatter of first year ice, multi-year ice, and ice islands (tabular ice bergs). Changing backscatter signatures have significant impact on the ability to identify hazardous ice features.

4. Community-Based Monitoring: This program was very successful. Three community members were trained to operate an EMI system to measure ice thickness. This instrument was designed to be towed by snowmobile. Local ice thickness was mapped along transects near Sachs Harbour. This data was supplemented by ground confirmation data (ice thickness, free board, and snow thickness measurements) and conductivity, temperature, and depth profiles under the ice. The program lasted from April 22 to May 29, 2012, when the ice became too dangerous to measure.

COUPLED OCEAN-ICE-ATMOSPHERE MODELING AND FORECASTING

Southern and Northeastern Beaufort Sea Marine Observatories, 2011–2014

Lead: Martin Fortier (ArcticNet)

This initiative is establishing three oceanographic observatories, each composed of two moorings, to collect year-round marine observations of the Beaufort Sea using state-of-the-art instruments, including Doppler current meters, sediment traps, ice-profiling sonars, conductivity-temperature sensors, and turbidity meters. Researchers are monitoring and interpreting the information generated on sea ice, ocean circulation, and biogeochemical fluctuations throughout the region. The four-year project, led by ArcticNet and IMG-Golder (an Inuit-owned environmental and engineering company), is collecting data to gauge the physical conditions and variability of the Canadian Beaufort Sea year over year. This information will provide previously unavailable scientific evidence of oceanic and sea ice conditions, enabling regulators to make informed decisions about potential environmental effects of exploration drilling in the Beaufort Sea.

Progress: In September 2012, using the Canadian Coast Guard icebreaker *CCGS Sir Wilfred Laurier,* the four moorings deployed in 2011 were successfully retrieved and redeployed. A fifth mooring (BR-01) has been deployed in the Mackenzie Trough to complete the second BREA oceanographic observatory. Data recovered from the four moorings included quality year-round measurements of the following: currents; ice draft and velocity; water level, temperature, salinity, and turbidity; chlorophyll; suspended particulate size and concentration; and vertical carbon flux. The final pair of moorings (BR-03, BR-04), representing a third observatory to be deployed in 2013, will be located off the northwest coast of Banks Island, starting a time series in the north-eastern Beaufort Sea where year-round measurements have rarely been obtained. The three oceanographic observatories will address a large gap in monitoring of oceanic and sea-ice conditions in the Beaufort Sea, providing essential data for ground-truthing of ocean circulation models, oil spill trajectory models, and future environmental (biophysical) assessments.

Forecasting Extreme Weather and Ocean Conditions in the Beaufort Sea, 2011–2015

Lead: Fraser Davidson (Fisheries and Oceans Canada)

Drilling operations in the Beaufort Sea are increasingly focused on the shelf break between the deep and shallow parts of the Sea—an area characterized by extreme weather events, ocean currents, and waves. This research will develop and implement an integrated ocean-wave-ice-atmosphere prediction system to forecast the changing marine weather, sea ice, and ocean conditions. This invaluable information will support the Global Maritime Distress Safety System's warnings and information services for the Arctic. It will be equally vital to oil and gas exploration and development by providing forecasts that will inform operations in the Beaufort Sea.

Progress: A phased approach is currently underway with the use of the Regional Ice Prediction System in the Beaufort. This will be updated by adding ocean dynamics to the ice prediction developed in this

project. In 2015, atmosphere-ocean-ice coupling will be implemented in operations. In pursuing the ocean model development, four historical hindcasts have been prepared from 2003 to 2010. Additionally the first ocean forecast version has been tested for the Beaufort Sea and Arctic Ocean for a one-year test period. A validation test package is currently being assembled for the model hindcasts, and near real time validation scripts are being run for the Global and Regional ocean model forecasts. A test website of ocean circulation in the Beaufort Sea has been implemented on computer infrastructure that will be accessible to the public. Various formats (visual and numeric) of the ocean forecasts will be available to download on demand by the end user.

Seasonal Forecasting of Ocean and Ice Conditions in the Beaufort Sea, 2011–2015

Lead: Gregory Flato (Environment Canada)

Predicting the weather days in advance is standard fare in most parts of the country. However, for oil and gas companies considering exploration and drilling activities in the Arctic, anticipating what the weather will be like over the coming year is extremely important. This project, led by Environment Canada, is creating a high-resolution forecasting system capable of predicting ocean and sea-ice conditions in the Beaufort Sea region from one to twelve months in advance. The research is providing enhanced regional detail in operational seasonal predictions and contributes directly to the development of improved climate prediction products. This will serve both regulators' and industry's operational needs, now and in the future.

Progress: During 2012–2013, work on evaluating the skill of the Canadian Seasonal to Interannual Prediction System (CanSIPS) has progressed, with two peer-reviewed papers published on the analysis of skill in seasonal prediction of Arctic sea-ice area. Monthly and daily sea ice fields including concentration, thickness, and zonal and meridional velocities from CanSIPS historical forecasts initialized every month in 1979–2010 for each of 20 ensemble members were processed and made available on the Canadian Centre for Climate Modeling and Analysis's data server. These fields were provided on a standardized grid for the international Climate-system Historical Forecast Project, and work is underway to also provide this data on the original model grid in response to user requests.

Modeling of Freshwater Flows to the Beaufort Sea for Improved Offshore Prediction by the Metarea Ocean Forecast System, 2012–2015

Lead: Philip Marsh (Environment Canada)

With potential development in the Beaufort Sea offshore, there is a need to implement an operational ocean-ice-atmosphere model that includes the Beaufort Sea in order to plan and carry out development in this area in a sustainable fashion. Consideration of the complex interactions between the Mackenzie Delta and the Beaufort Sea is necessary in the development and implementation of a robust ocean-ice-atmosphere model (CONCEPTS OIA). This study is building on activities funded under the International Polar Year and the Program for Energy Research and Development and is developing a hydraulic model of the Mackenzie Delta and link this model to the CONCEPTS OIA model under development by

Environment Canada and Fisheries and Oceans Canada. These linked models will be used to consider the interactions between the Mackenzie Delta and the Beaufort Sea under both open-water and ice-covered conditions.

Progress: This project has made significant progress on all planned aspects of this study, and is ahead of schedule on certain aspects of the project. The following activities were completed in 2012–2013:

1. Analysis of LiDAR data. This is required for the determination of off-channel water storage.
2. Off-channel water storage model, which is required for hydraulic modeling of the Delta. This work demonstrated that off-channel storage is a significant component of total Mackenzie River flow, and confirmed that off-channel storage must be included in the hydraulic modeling of the delta to determine time dependent river flows to the Beaufort Sea as needed by the ocean model.
3. Mackenzie Delta Hydraulic Model, which is required for provision of boundary conditions to the Beaufort Sea model. Continued advances were made on the Delta hydraulic model with successful low-flow calibration runs completed. This sets the stage for additional work next year.
4. NEMO Beaufort Sea Modeling. Continued advances were made using the NEMO ocean model and preparing for interactively modeling the coupled river-ocean system.

OFFSHORE GEOHAZARDS AND COASTAL PROCESSES

Regional Assessment of Deep Water Seabed Geohazards for Oil Spill Prevention, 2011–2015

Lead: Steve Blasco (Natural Resources Canada)

Oil and gas exploration in the deep waters of the Beaufort Sea requires knowledge of seabed stability conditions to ensure safe drilling practices. Under this initiative, the Geological Survey of Canada is conducting a regional assessment of seabed instability conditions, such as mud volcanoes, gas vents and faults, subsea permafrost, and the severity of these geohazards. Seabed geohazard research provides baseline knowledge in support of spill prevention and contributes to the preservation of the marine ecosystem and protection of renewable resources. Research findings from this regional assessment are essential for environmental impact assessments and support informed decision-making in the development of an effective regulatory regime.

Progress: The research conducted for 2012–2013 year was based in the Beaufort Sea outer shelf and upper continental slope. The research focused on acquiring data to feed seabed geohazard assessment in deep waters. Partnership was made with the Program of Energy Research and Development and the Environmental Studies Research Funds, and BREA contributed to data acquisition. Through BREA funding, data was acquired on the *CCGS Amundsen* in 2011 using multi-beam and sub-bottom profile data that was imported, cleaned, edited, and put into a database for analysis of geohazards to 100m below sea bed. Industry multi-channel seismic data that was acquired was also put into a database and processed for analysis and interpretation of geohazards greater than 100m below sea bed. Sediment

sample data was acquired imputed into a database and processed for age and rates of activity of seabed failures including submarine slides, mud volcanoes, and other activities.

Regional Synthesis of Coastal Geoscience for Management of Beaufort Oil and Gas Activity, 2012–2014

Lead: Dustin Whalen (National Research Council)

The purpose of this project is to provide an inventory of existing knowledge pertaining to regional scale coastal processes affecting the siting, planning, and management of coastal infrastructure (from the Alaska/Yukon border to Cape Dalhousie) in support of Beaufort Sea oil and gas activity.

Progress: Targeted datasets from 40 years of coastal geoscience research by the Geological Survey of Canada were compiled and analyzed to define data gaps and future data needs. Synthesis of these datasets includes the validation of hard copy and digital data sources and conversion of these data into a GIS format. Additional deliverables for this year include (i) GIS layers from the Coastal Information System database describing shore-zone form, material, and coastal classification (primarily from aerial video imagery); (ii) over 1,000 coastal photographs spanning the last 40 years; (iii) a complete digital surficial geology layer; and (iv) preliminary compilation of project-relevant grey literature. A small field program was conducted in the summer of 2012 to update rates of coastal change at a number of sites along the Yukon, Richards Island, and Tuktoyaktuk Peninsula coast. These precisely positioned RTK-GPS ground measurements are being used to update the coastal monitoring database and highlight processes of change at specific sites. Work is ongoing to provide appropriate standardized metadata for nearshore high-resolution multi-beam mapping, coastal LiDAR, and coastline vectors that will enable us to highlight up to 60 years of coastal change (using historical air photos). Despite the challenges of combining several decades of data derived from different sources and equipment, this ongoing activity has successfully helped to identify data gaps and will contribute to an improved knowledge of coastal processes for the Beaufort Sea region. A number of hard-copy mapping products have been produced to show the synthesis of data layers across a regional scale.

WEB-BASED GEOSPATIAL ANALYSIS TOOL

Web-Based Geospatial Analysis Tool, 2012–2013

Lead: Jason Duffe (Environment Canada)

The BREA Toolkit GIS applications are universal to record baseline information and for map production. However, increasingly advanced GIS capabilities such as scenario analysis and cumulative effects analysis are being included in Regional Environmental Assessments. The main geospatial tools of interest to Regional Environmental Assessments in general are digital mapping, spatial analysis/assessment, and spatial modeling. A web-based GIS tool has the potential to enhance transparency and public participation and be an effective way of communicating to decision-makers and the public.

Progress: This project designed and developed a state of the art web-based digital mapping and spatial analysis/assessment toolkit for BREA. The BREA Toolkit includes baseline information and research data on a number of environmental factors including flora and fauna, water, air, and climatic factors, ice and geohazards as well as cultural, sociological, and infrastructure information. The web-based GIS toolkit developed includes a variety of tools for the display and analysis of existing and new research information to support the BREA implementation. Spatial analysis tools to aid in environmental assessments include such operations as proximity analysis, weighted overlays, and map calculations, as well as the ability to convert between vector (points, lines, and polygons) and raster. This project has the potential to support a number of BREA topics including integrating research outputs, assessing cumulative effects, facilitating information management, and engaging communities in oil spill preparedness. In addition, it will help to inform regional-level decision-making as well as improve project-specific regulatory information to inform oil and gas development in the Beaufort Sea.

COMMUNITY PRIORITIES

Regional Coastal Monitoring in the Inuvialuit Settlement Region: Ecosystem Indicators, 2012–2015

Lead: Vic Gillman (Fisheries Joint Management Committee) / Frank Pokiak (Invialuit Game Council)

This project is building a baseline understanding of ecosystem structure and function of the Beaufort Sea coastal food-web. The project uses food-web biomarkers at a regional scale that captures both estuarine and marine coastal ecosystems in the Inuvialuit Settlement Region (ISR). Community relevant coastal programs have been developed to focus on key valued ecosystem components that include (i) coastal fish, (ii) beluga, and (iii) their supporting ecosystem (habitat) at harvest/hunt sites for each of the six ISR communities. While species monitored may differ among sites, the methods employ a standardized approach by using common indicators that define trophic interactions.

Progress: Laboratory analytical analysis was conducted on food-web biomarkers, specifically stable isotopes and fatty acids, from key species collected at monitoring sites. Fish and beluga samples were received from all six ISR communities and were processed for analyses. A total of 951 fish from coastal sites were processed for full morphometrics and prepared for stable isotopes and fatty acids. A total of 654 fish from estuarine sites and 297 fish from marine sites that spanned across 22 species were analyzed. A total of 58 beluga samples were prepared analyzed, where liver and muscle samples were processed for stable isotopes, and blubber was processed for fatty acids. Approximately 80% of the stable isotopic data has been received and entered into an access database. All beluga fatty acid extractions and data integration is complete. Fatty acids for the fish are 70% completed.

Working Groups

Climate Change

The BREA Climate Change Working Group was formed to support efficient and effective environmental assessment and regulatory decision-making as related to aspects of climate change of relevance to offshore oil and gas activities in the Beaufort Sea. Working Group activities are assisting to identify and recommend actions to fill information and data gaps related to climate change in the region.

Progress: The BREA Climate Change Working Group funded a contract to produce the *Oil and Gas Exploration and Development Activity Forecast: Canadian Beaufort Sea 2012–2027*. This forecast, although spanning a medium time frame of fifteen years was created to aid in the future for oil and gas activities occurring in the Beaufort Sea and the implications therein. The Forecast was updated to encompass 2013–2028 and can be found on www.BeaufortREA.ca for further review and information. Additionally, the Working Group held a climate change workshop in Inuvik from November 19–21, 2012 and a comprehensive report with recommendations to decision-makers was submitted in January 2013.

Waste Management

The Waste Management Working Group is facilitating the development of a Regional Waste Management Framework for the Inuvialuit Settlement Region (ISR). The framework clearly maps out regulatory requirements and jurisdiction, identifies gaps, and fully characterizes current problems in waste management. The report also presents options for their resolution, through guidance on best practices and the determination of requirements for new or improved waste management processes/facilities including the identification of regional economic opportunities in the area of waste management.

Progress: The Waste Management Working Group issued a contract to produce a framework and development plan for a Regional Oil and Gas Waste Management Strategy (RWMS) for ISR. This RWMS Framework was delivered March 31, 2013.

Cumulative Effects

The Cumulative Effects Working Group is working towards developing a regional framework that will enable all stakeholders to participate and support the process. The framework will establish a cumulative effects assessment method that addresses regional concerns based on identified Valued Components (VCs) and their associated stressors. A regional collaborative approach to developing the assessment framework will provide a consistent approach in project assessments and provide a better means for regulators to ensure that cumulative effects are being addressed.

Progress: The Cumulative Effects Working Group focused on furthering the Pilot project discussed in the *2011–2012 BREA Annual Progress Report*. The Working Group reaffirmed the need for regular

engagement of stakeholders throughout framework development and formulated a plan for the progression of the framework.

Information Management

The Information Management Working Group supports coordinated data and information management for BREA. The Working Group focuses on making historical and new information generated on the Beaufort accessible to stakeholders.

Progress: The Information Management Working Group was able to catalogue BREA publications on the Hydrocarbon Impacts database, the Polar Data Catalogue as well as create a Data and Information Management Policy that are all publicly accessible.

Oil Spill Preparedness and Response

The Oil Spill Preparedness and Response Working Group was established to improve the ability of government, the Inuvialuit, and Industry to respond to a significant spill related to oil and gas activities in the Beaufort Sea.

Progress: Building on the Dispersant Use Workshop in Year 1, the Working Group followed up on recommendations and initiated a training needs analysis and the development of a report entitled *Inuvialuit and Federal and Territorial Government Mandates and Roles for a Tier 3 Beaufort Sea Oil Spill Response*.

Social, Cultural, and Economic Indicators

The Social, Cultural, and Economic Indicators Working Group was established to develop social, cultural, and economic baseline data and indicators for the ISR to identify the impacts associated with oil and gas activity.

Progress: The Social, Cultural, and Economic Indicators Working Group completed the Indicators Project for BREA in partnership with the Northwest Territories Bureau of Statistics as well as advanced social policy research on many topics. The working group helped fund and conduct the Addictions and Mental Health Study (completed in 2010) as well as the Social Housing and Income Support among other social policy concerns. They also created the Beaufort Delta Agenda and Mackenzie Gas Project Impact Fund Investment Plan while implementing current the Inuvialuit Regional Corporation Strategic Plan, Wellness Plan, and Beaufort Sea Integrated Oceans Management Plan.

Community Outreach and Communications

From April 1, 2012 to March 31, 2013, the BREA project management office undertook activities to engage the Inuvialuit and Northerners in BREA, solicit their feedback on BREA initiatives, and ensure that community priorities are being addressed.

The BREA project management office, as well as BREA research project and working group leads, attended Inuvialuit Game Council, Beaufort Sea Partnership, and Beaufort Sea Integrated Oceans Management Plan Regional Coordinating Committee meetings to provide updates on BREA.

First Annual BREA Progress Report

The First Annual BREA Progress Report covers the period between April 1, 2011 and March 31, 2012 and is available on the Program website.

BREA Results Forum: First Two Years of Progress

The BREA Results Forum was held in Inuvik from February 19 to 21, 2013 at the Ingamo Hall Friendship Centre. Approximately 75 participants representing Inuvialuit communities and organizations, co-management bodies, the federal and territorial governments, industry, academia, and consultants attended the Forum to hear about the first two years of progress and discuss the results to date.

The Forum objectives were the following:

- To share BREA research and working group results to date with Inuvialuit organizations, communities, industry, governments, regulators, and academia.
- To provide participants with the opportunity to hear the results, pose questions, and engage in dialogue that will assist researchers in conducting any future work on their research projects, and assist working group leads in planning their future activities.
- To hear from participants how the information presented could help inform the final outcomes and contribution of BREA.
- To provide a venue to facilitate greater collaboration among the researchers and other partners as they share the research results to date.
- To enable working group leads to identify research directly relevant to their working group mandate and deliverables.

The Forum report is available for viewing in English and in French, as well as the presentations on www.BeaufortREA.ca.

Website

The Joint Secretariat continues to host the program website: www.BeaufortREA.ca. The website is updated regularly with project and working group reports and developments. It is a key communication tool for the Information Management Working Group.

Conclusion

Building on the first year of BREA implementation, considerable progress has been made in BREA's second year, with 15 of the original 17 research projects continuing, and six additional projects coming online. Of the 23 research projects, this year, nine are approaching the final stages of completion. Not to be outdone, the working groups made significant progress on their mandates with Climate Change, Oil Spills Preparedness and Response, and Waste Management delivering major components in 2012–2013.

The BREA Results Forum 2013 provided a legacy of connections, information, and networks that will continue long after BREA ends.

BREA offers an alternative forum to address regional concerns and research priorities raised by the Inuvialuit, Northerners, industry, and regulators not easily dealt within a strictly regulatory approach. Government's investment in the region will increase confidence in its preparedness for oil and gas activities, and reduce information gathering on project-specific reviews, while demonstrating its commitment to streamlining the regulatory process.

Annex : Governance and Partnerships

BREA is governed by a participatory governance structure that includes federal and territorial governments, industry, Inuvialuit, and academic organizations.

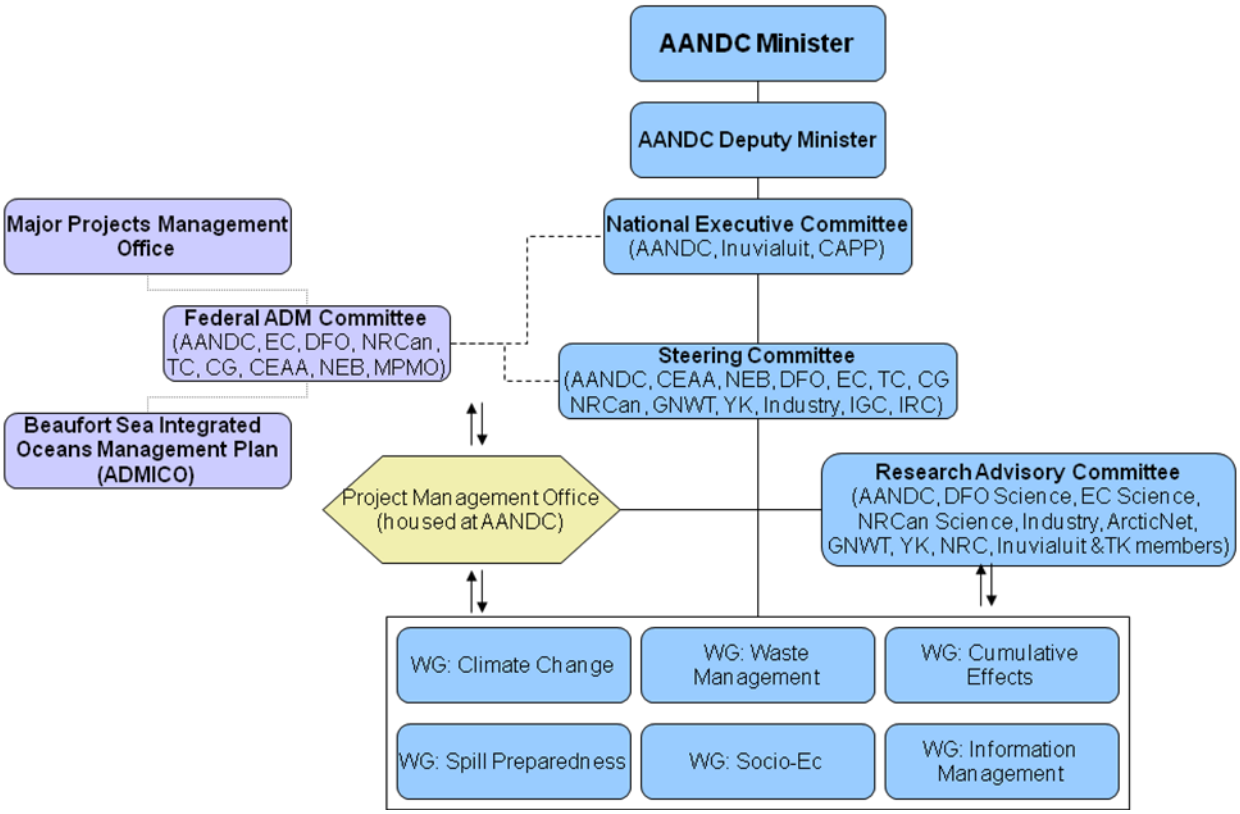

Figure 3. BREA Governance Structure. [Abbreviations: AANDC – Aboriginal Affairs and Northern Development Canada, CAPP – Canadian Association of Petroleum Producers, CEAA – Canadian Environmental Assessment Agency, CG – Coast Guard (Canada), DFO – Fisheries and Oceans Canada, EC – Environment Canada, GNWT – Government of Northwest Territories, IGC – Inuvialuit Game Council, IRC – Inuvialuit Regional Corporation, MPMO – Major Projects Management Office, NRC – National Research Council, NEB – National Energy Board, NRCan – Natural Resources Canada, PC – Parks Canada, TC – Transport Canada, TK – Traditional Knowledge, YK – Government of Yukon]