OTC 24545

Arctic Operations Handbook JIP

Ed Wiersema /Heerema Marine Contractors, Frank Lange /Shell, Gus Cammaert, Frank Sliggers /TU Delft, Wim Jolles /Canatec, Clemens van der Nat /Bluewater

This paper was prepared for presentation at the Arctic Technology Conference held in Houston, Texas, USA, 10-12 February 2014.

Abstract

The Arctic Operations Handbook Joint Industry Project (JIP) was set up in 2012 with a focus on the operational activities for transport and installation of fixed, floating and subsea units, as well as for dredging, trenching, pipe laying and floating oil and gas production in Arctic and cold weather conditions. The prime purpose of the JIP was to identify gaps in the existing standards and guidelines. Specific recommendations were subsequently proposed which will hopefully contribute to the development of internationally accepted standards and guidelines.

The project addressed safety and sustainability of offshore operations in the Arctic. This investigation into existing rules, regulations, standards and guidelines was intended to provide a common understanding for the offshore industries. Work groups were formed to execute work packages which were judged to be of prime importance.

Taking into account numerous aspects of the impact of the Arctic on various operations it was considered that the overall risk levels for such operations can be reduced by adopting the outline recommendations including, for instance, those related to weather monitoring and forecasting, environmental impacts, logistics, equipment preparation, vessel operations, training and health and safety management.

Abbreviations

The following abbreviations are referred to in this paper:

ABS	American Bureau of Shipping
AMO	Arctic Marine Operations Challenges & Recommendations Report
AOH	Arctic Operations Handbook JIP
DNV	Det Norske Veritas
IM	Ice Management
IMO	International Maritime Organization
ISO	International Organization for Standardization
JIP	Joint Industry Project
NGO	Non-Governmental Organization
SC	Steering Committee
TC	Technical Committee for Standardization

Figure 1 - Arctic Operations (Source: V. Miettinen)

Introduction

The Arctic Operations Handbook JIP was set up by 15 participating companies in February 2012, consisting of offshore contractors, engineering companies, knowledge institutes and Arctic consultants, under a subsidy from the Dutch Ministry of Economic Affairs. The budget was 500.000 euros. The project ended in December 2013.

The JIP was intended to contribute to the international Arctic community by providing recommendations for guidelines to enhance safe, reliable and sustainable operations in the Arctic. The focus of the JIP was on the operational activities for

transport and installation of fixed, floating and subsea units, as well as for dredging, trenching, pipe laying and floating oil and gas production. It also concentrated strongly on related aspects common to all Arctic operations of this type such as, weather monitoring and forecasting, environmental impact assessment, logistics, equipment preparation, vessel operations, training and health and safety management.
The objective of this paper is to present the findings of the JIP. These are collected in the Arctic Marine Operations Challenges & Recommendations Report (AMO) [8] and are summarized here. The AMO report was made public towards the end of 2013 and gives a good overview of what is required to prepare for and to perform transport, installation and production operations in Arctic environments.
The identified gaps and recommendations from the report could provide further support for the work of such groups as ISO/TC67/SC8 (Arctic Operations), ISO 19906 [6] SC7 (Offshore Structures), ISO 19901-6 [5] (Marine Operations) and future JIP's.
During the JIP, a gap analysis workshop was first performed. Work groups were then established to further investigate the gaps and provide recommendations to bridge them. As a result of the gap analysis three pilot projects were identified and executed. These addressed ice floe simulation, accretion of marine icing and the impact of operations on the environment. The results of the JIP were assembled in the AMO report which was thoroughly reviewed by all participating companies and made public through the website www.arctic-operations-handbook.info.

Gap Analysis

At the start of the project a significant effort was spent on identifying gaps in existing guidelines. The boundaries for the study were set up early and a framework was defined to assist with identifying key aspects of safe Arctic operations. Considerable effort was spent to align th e knowledge and definitions of weather conditions. The Arctic conditions and their severity were generically defined within the project and are listed in the report. The definitions of conditions were used consistently throughout the gap analysis.
The offshore operations were divided into sub activities so that more specific conclusions and recommendations were developed, instead of only high level generic comments. As an example, see figure 2, the (sub) activities for firefighting included the awareness stage, sounding alarm, situation assessment, mobilizing a fire team and so on. The severity was indicated in red for major challenges and pink for minor challenges, as judged by the JIP participants.
A next important step was to identify for each (sub) activity the potential risks which may arise due to specific Arctic conditions. By adding the condition/severity consideration, a much better understanding was obtained of the operational challenges involved.
For the identified combinations of activity and Arctic conditions, the available guidance referred to existing rules, regulations, standards, guidelines and own experience. In addition, relevant literature was gathered and reviewed by the expert work groups. It was concluded that significant work would be needed to close all of the gaps. Hence the gaps were prioritized in order to focus the JIP efforts in these specific areas.

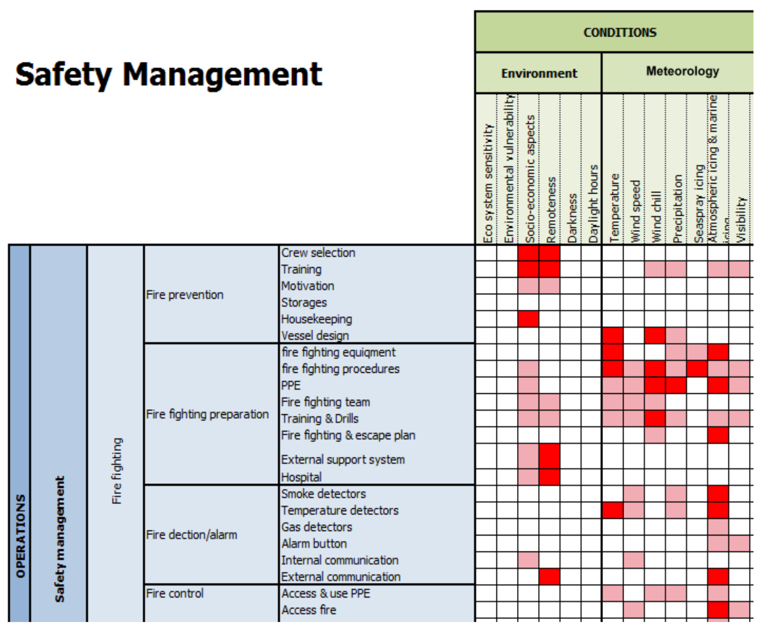

Figure 2 - Gap analysis example Safety Management (Source: AOH)

Arctic Marine Operations Challenges & Recommendations Report

The Arctic Marine Operations Challenges & Recommendations Main report is the first volume of the report. The other volumes of the report contain the results of the gap analysis and of the three pilot projects.
The report addresses the impact of Arctic conditions on operations, identifies gaps in operational guidance and provides recommendations to bridge the gaps. First general aspects like; weather condition monitoring and forecasting, vessel operations, equipment preparation and health and safety management are addressed. Then secondly in the offshore service operations section the contractor related operations are addressed.
Due to time and budget constraints not all operational aspects could be investigated in detail, hence these were considered in general terms only. It concerns; loadout, construction and outfitting afloat, offshore installation operations, lifting operations and decommissioning and removal.

Weather Condition Monitoring and Forecasting

The benchmarks for this work included the Barents 2020 project [2] and the ISO 19906 [6] and ISO 19901-6 [5] standards. The working group first defined gaps in operational standards and codes and then assessed priorities for each of the defined gaps. The report reflects those items which were given a score of high importance.

Relating to Arctic operations there is a lack of reliable long-term measurements resulting in uncertainty in weather forecasts. Tools and processes to accurately determine ice hazards and risks are not always available. Remoteness affects communication and data transfer capabilities. The unique ice conditions and seasonal variations must be taken into account. Other areas in which the Arctic differs from southern regions are visibility, extreme low temperatures, ice accretion, polar lows, variable sea ice and iceberg conditions. Large areas of open water, due to climate change, could lead to higher waves. The key recommendations in support of enhanced monitoring and forecasting are:

- Prepare procedures and associated operating manuals which define weather and ice data to be monitored and forecasted.
- Compare the suitability of the available forecasting models to the required timeframe and reliability.
- Consider the installation of temporary 'arctic-proof' weather monitoring stations which can be erected on various sites.
- Develop improved sea ice and iceberg data monitoring systems based on enhanced satellite imagery providing higher frequency, more coverage and better resolution.
- Provide centralized data base and decision support systems.
- Provide improved communication and data transfer systems.

Vessel Operations

Arctic and cold climate operations pose special challenges and risks due to the encountered Arctic conditions when using dredging and construction spreads, heavy lift and pipelaying vessels and moored floating production systems. Impact of these conditions on Arctic operations is mainly felt by lack of daylight and poor visibility, remoteness of the work location, impact of low temperatures and ice coverage and the effect of defense operations to keep vessels on station.

To mitigate these challenges and risks consideration should be given to;

- The selection of the best possible (ice class) vessel for the job.
- Operating performance, in terms of vessel speed or system uptime.
- Icebreaker support, type needed in normal operations and in emergencies.
- Operational windows (summer, extended summer and winter).
- Ice Management

The following vessel operations gaps have been identified;

- Safe speeds for non- or low- ice class ships sailing in open water conditions.
- Navigation and crew requirements for identification of hazardous ice conditions.
- Remote sensing and satellite imagery and the use of integrated surveillance systems.
- Applicable working season and the selection of safe start and end dates.
- Determination of icing loads on vessel, equipment and cargo.
- Ice effects on umbilical's and appendices such as pipeline stingers, drag arms, etc.

Depending on the project scope it is recommended to have an ice management plan and system in place to safeguard operations and extend operational windows. Ice Management (IM) may be necessary in all seasons. It can be divided in management for sea ice and for icebergs. Barents 2020 [2] lists a number of practical physical IM activities. The appropriate activities should be selected based on forecast weather and ice conditions, system performance, main installation vessel and ice management vessel characteristics, T-times (time required to Terminate an operation and safeguard the vessel), possible risks and hazards and the effectiveness of IM activities. On site monitoring and forecasting of weather and ice conditions is a key factor for safe IM. No single standard procedure can be provided for all possible IM scenarios and it is understood that ISO TC 67 SC8 (specifically Working Group 4, Ice Management) will be looking into this further.

Figure 3 - Greenland expedition 2012
(Source: S van der Werff)

It is recommended to look into the effects of marine icing on the vessels and their onboard equipment. These may experience sea spray icing and/or the freezing of deck areas. A state of the art review for marine icing on vessels has been performed and documented in the AMO report. However more field data is required to develop better prediction- and calculation models.

A number of navigation aspects could be considered, especially when operating with no or low ice class vessels in open water or light ice conditions. These aspects are the requirements for ice navigators or ice advisors, special navigational equipment like ice radar, adequate bridge watches, safe transit speeds and global ice charts supplemented with local ice charts. Information overload on the bridge can occur therefore the use of an integrated decision making system is recommended and will help reduce such problems and enhance the overall safety.

Equipment Preparation

Equipment preparations for Arctic conditions relate primarily to hull, shipboard and mission equipment used specifically for the actual offshore operations. For hull and shipboard equipment well established guidelines developed for Arctic shipping can be applied. These cover most of the guidelines related to equipment operations in Arctic environments, except those for station keeping systems, ice loads on hull and overboard structures passing through the splash zone, and icing loads. The main factors to be considered include the effect of extreme low temperatures, winterization requirements (especially those dealing with sea ice floes and icing) and remoteness with limited or no infrastructure for supply, repair or maintenance.

The suitability of existing units and their systems for Arctic operations and the modifications that would be required is an essential consideration.

In the AMO report a methodology is developed to evaluate the equipment against the requirements of a specific operation in a specific area in a specific period. The main principle is that the equipment's limitations are determined, analyzed for the operational conditions and judged on acceptability. If the equipment is not acceptable, either other equipment can be selected, or the operational profile adjusted to allow the equipment to be used, or modifications to the equipment can be applied. The proposed methodology is based on ISO 19905 (Site Specific Assessment) and made specific for Arctic operations.

Winterization measures should generally be applied in accordance with classification rules. For mission equipment these guidelines are generally less detailed or not always practicable and usable. Hence, the equivalency method for equipment which is not related to the safety of the operation and/or critical for the operations could be used. Alternatively, a risk based approach could be applied for equipment which is critical to the safety and/or continuity of the operation.

To determine the equivalency of winterization for mission equipment, the DNV rules for classification of ships, part 5 chapter 1 are recommended. Three categories are defined requiring different levels of anti- and/or de-icing provisions; Category I - keep the equipment or areas free from ice at all times, Category II - removal of accreted ice within a reasonable period of time (4 to 6 hours), Uncategorized - installations requiring no anti- or de-icing.

Redundancy is an important aspect in Arctic and remote area operations. Redundancy is normally defined as finding another safe alternative to continue the operation and ultimately finding the ability to safely terminate operations. This philosophy is commonly applied to dynamic positioning and mooring systems, but for Arctic operations this should be applied to the complete unit and should include critical mission equipment, winterization and accommodation support systems.

Where lay-up is envisaged in Arctic operations, two main subjects need to be addressed - that of the selection and preparation of the lay-up site and the equipment preparation, monitoring and re-activation. Some useful references are provided by DNV Guidelines No. 22 – Lay-up of Vessels, ABS Rules for Building and Classing Steel Vessel Rules, Part 7, Rules for Survey After Construction and the Beaufort regional environmental assessment (Overwintering of Barges in the Beaufort – Assessing Ice Issues and Damage Potential, August 2012).

Although suitable guidelines have been found, it is recommended that further work should be carried out to prepare more detailed operational guidelines.

Offshore Service Operations

During the gap analysis no general rules, regulations or standards for dredging, trenching, pipelay and subsea operations were identified, let alone for Arctic environments. However, some scattered guidance for operations in Arctic environments can be found in ISO 19901-6 [5], ISO 19906 [6], DNV-OS-F101 [4], API RP 2N [1] BS 6349-5 [3] and GL Noble Denton Guidelines for Marine Transportations,0030/ND [7]. Additional information can be taken from the regular shipping rules and regulations / guidelines such as the IMO Polar Code with it's target completion date for DE in 2014.

Operator requirements and project specific operational manuals prescribe the environmental criteria under which the operation must be conducted. Operational guidelines are normally established on a project basis in the form of an Operations Manual. Taking into consideration all the project specific data, circumstances and the Arctic conditions the contractor will use general engineering practice to demonstrate suitability and safety of the intended operation. It is recommended not to focus on drafting Arctic guidelines, specifically for described operations, but to deal with these operations on a project-by-project basis.

Transport Installation and Logistics

Sea spray and atmospheric icing pose a threat to the weight and center of gravity of involved ships and structures during transport or installation operations in the Arctic. An additional contingency factor is advised for the weight of calculated icing volumes especially for smaller units. Increasing icing build-up should be closely monitored and mitigation approaches need to be defined in the transportation and installation manual.
A large number of recommendations regarding stability, ballast systems, and transport are given in ISO 19901-6 [5] which are also relevant for Arctic situations. In the AMO report it is recommended to supplement these with guidance from Arctic shipping guidelines as provided by classification societies and Noble Denton.
Logistics was identified as one of the important aspects in Arctic operations in areas of crewing, supplies, project cargos, repair and maintenance. A variety of current guidelines and rules has been discussed in the AMO report affecting each of these logistics operations. A site or operation specific approach is recommended.

Figure 4 – Kigoriak icebreaker with drilling caisson tow in 1992 (Source: Canmar)

Temporary Mooring and Station Keeping

For a large number of operations temporary mooring and station keeping will be applied which requires different approaches than those for permanently moored structures.
Within the report the operational ice level has been defined as the ice action at which position of a stationary floating structure, temporary moored, may no longer be retained, due to structural or station keeping capability. The ice environment should not impose loads exceeding this level. This approach differs from the use of Extreme Level Ice Events which are related to a design return period and intended for designed permanent structures. The ice environment associated with operational ice level can occur in various ways. It is recommended to define these various ice environments using the 'egg code' including ice movement. The 'egg code' [9] describes basic ice data concerning concentrations, stages of development (age) and form (floe size) in a simple oval form.
When applying IM it is possible to change the ice environment with the intent to keep the ice action on the mooring and/or the structure within its capacity. Using the operational ice level in a project requires thorough preparation and monitoring and forecasting as indicated earlier.
Although it is anticipated that most operations, as defined within the context of the report, will be executed in open water conditions, it is recommended to anticipate the occurrence of ice fields, characteristic for the area to enhance the preparedness and safety of the operations.

Dredging and Trenching Operations

The selection of the dredging plant for operations in Arctic environment is not different than in other parts of the world, but the unique Arctic conditions with respect to soil conditions (permafrost and boulders), the workability and ice management system and the response to polar lows and coldness will result in Arctic favourable equipment or may result in special Arctic dredging tools.
Guidelines are required on how to deal with permafrost and seasonally frozen ground conditions. More information on these conditions is required. The focus should be on the uncertainty of the behaviour of the frozen and thawing ground, the changing conditions at the shoreline (extension of land into sea), the effects on dredger performance and what mitigation or precaution measures are to be taken.
The workability of dredgers should be determined for work in ice conditions, and guidelines are recommended for the implementation of ice management measures such as forecasting, definition of safety zones, ice sheltering and abandonment decision procedures.

Figure 5 - Dredging Operation (Source: Boskalis)

Under Arctic conditions transport of dredged material through pipelines needs to be re-evaluated. Experience shows that floating pipelines freeze after stoppage of work and that it is difficult to make couplings. Moreover, valves and control structures within the pipelines start to freeze during operations. New guidance is recommended on operability of discharge pipelines in Arctic conditions.
The presence of seabed permafrost and boulders will both affect the productivity and quality of the trenching works. In principle the production rates of the trenching works and the bottom roughness of the trench are negatively affected by them. The expected deep trenches required due to ice keel gouging may be difficult to achieve, sometimes even unachievable with the current trenching tools considering the mostly short weather windows.
Development of guidelines on how to deal with permafrost and boulders in the pipeline trench routing is recommended. A

project specific study on the iceberg scouring risk in the field area is recommended to be able to design optimum trench geometry and to develop adequate trenching equipment and procedures to deal with various soil conditions, soil depths and ecological effects. It is also recommended to investigate whether geological maps exist or need to be prepared that include areas where boulders may be abundant.

Pipelay Operation

The influence of cold climate will not directly affect the method of constructing and installing the pipeline on the seabed. The handling of pipe joints, connecting the joints to one continuous pipeline and the lowering to the seabed will be similar, irrespective of the climate. However the pipelay operations will have to account for the Arctic environment conditions.

The following technical adjustments or precautions could be made to mitigate or reduce the effects of Arctic conditions; protection of people and equipment through enclosed working areas, proper material selection, and a winterization regime. Pipeline, subsea structures and equipment lowered through the waterline should be protected from ice conditions. Protection could be provided by a moon-pool. Vessel performance can be significantly improved by considering the cold climate aspects in the design of the vessel or through proper preparation and winterization of the vessel.

Figure 6 - Pipelaying in the Gulf of Finland (Source: Allseas)

In the Arctic the workability of the pipelay vessel is strongly affected by icing, sea ice or icebergs and by severe weather conditions such as polar lows. To elongate the working season and minimise the risk, an ice class notation for the vessel should be considered and the risks reduced by ice management.

The duration of the ice-free periods can be relatively short and unpredictable. In combination with the wish to extend the installation season as long as practically possible, the risk exists that the pipelay vessel will encounter some form of ice. Therefore the development and implementation of ice and/or iceberg management measures is recommended.

Floating Oil and Gas Production

Floating oil and gas production includes station keeping, disconnection and re-connection operations and oil offloading operations. Many existing guidelines and industry standards can be identified that support the floating oil and gas production activities in milder climates. Ice covered waters affect especially the station keeping systems and offloading systems as these operations may require the possibility to disconnect when ice loads are expected to exceed the station keeping capabilities or in an emergency. Evaluation of existing guidelines is recommended with respect to ice loading and the ability to predict real-time ice-loading as well as ice flows (around riser systems) from incoming ice fields.New guidelines are recommended with respect to ice loading and the ability to predict real-time ice-loading as well as ice flows (around riser systems) from incoming ice fields. Guidelines are also recommended for the reliability of the disconnection operations to ensure the integrity of the station keeping and offloading capability after later re-connection.

Various organizations have started to develop, within their existing guidelines, additional chapters on offloading operations in ice covered waters. However, fully developed guidelines can only be expected when proven operational experience becomes available, as best-practices from on-going operations.

Recommendations are provided to encourage the development of guidance on operational aspects such as:

- Minimum requirements to predict real time ice loads on the system including those on the offloading tanker
- Investigation of risk analysis models that support decisions on potential disconnection
- Availability and survivability predictions for mooring and hawser systems
- Minimum required maneuverability capabilities of offloading tankers in broken ice
- The impact of passive and/or active ice management on the workability of the station keeping and offloading operations
- The implementation of remote sensing techniques and risk based assessments using historical data in the decision support for potential disconnection.

Figure 7 - Offloading buoy at Sakhalin (Source: Sakhalin Energy)

Health, Safety and other considerations

The Arctic Operations Handbook work group considers it paramount to follow the recommendations of ISO 19901-6 Section 5 (General considerations, dealing with HSE plan and Risk management) [5]. Moreover, Arctic operations need special considerations and additional sections concerning Health, Safety Management and Training have been proposed in the AMO report.

Health

This section elaborates the importance of health in the Arctic. In particular, all employees should be informed in detail about nutrition in the Arctic.

In extremes of climate, good food and water can have a significant influence on how well people cope with the environment. Quality of food should be guaranteed from its source, through transport, storage and the cooking or preparation process. If ambient temperatures are high, extra vigilance is necessary to avoid deterioration or infection. Extra calories are required while working in the extreme cold. Fats consumed in the evening increase the body's temperature at night and improve sleep quality. Rapidly absorbed carbohydrates should be consumed when working and directly exposed to cold.

Safety

This section of the AMO report covers medical support, emergency response, fire fighting and operational manuals covering working conditions.

Medical support is always an important issue when working offshore but in the Arctic many parameters differ while new parameters may appear such as cold-related injuries. This section of the AMO report has focused on medical support standards and training on how to avoid cold related injuries and how to maintain a basic state of health.

In particular, on-board medical facilities are likely to require a greater degree of self-sufficiency given the distance to onshore medical facilities and the potential for delays in evacuating personnel for medical attention.

Training

Training is an important key for ensuring safety and performance standards when operating in the Arctic. For this goal to be achieved, the Guide has identified the gaps in existing guidelines for working offshore in the Arctic and gives useful recommendations for future operations.

Stakeholders

The aspect of stakeholder mapping is considered an essential aspect which is more complex in Arctic areas, given the importance of involving, among others, indigenous peoples and NGO's in alignment processes.

This guide recommends the use of ISO 26000 [10] (Guidance on Social Responsibility), as the primary reference for dealing with stakeholders. This standard offers guidance much broader than stakeholder issues alone and also covers socially responsible behaviour and possible actions.

However, the ISO 26000 standard makes no specific reference to Arctic developments. Its provisions are general enough to cover projects in any and all parts of the world. A particular aspect of stakeholder identification and engagement in an Arctic project is the special role accorded to indigenous (native) people. It could in fact be argued that indigenous stakeholders enjoy certain special privileges that might not be available to "regular" stakeholders, as covered in the UN declaration for the rights of indigenous peoples [11], for example.

Pilot Projects

The AOH identified the need to perform a number of detailed studies and three topics were investigated in so-called 'pilot projects'. The relevant results of the following pilot projects are included in the AMO report.

Ice Stream Pilot Project

The main aim of this project has been to develop a tool that can help build an appropriate physical model of an ice field around an operating vessel, based on visual observations and measurements of the conditions in the field. The study made use of the 'egg code' [9] to describe the thickness, size and concentration of ice floes in the ice field. It has been demonstrated that the 'egg code' can quite elegantly be used as a basis to establish a visualization of the level ice field. This basis may then be used as input to numerical models with which ice loads can be predicted on floating structures.

Figure 8 - Beaufort Sea Tow
(Source: W. Jolles)

Marine Icing Pilot Project

A state of the art review of the sources and distribution of marine ice accretion on vessels has been performed. Sea spray and atmospheric precipitation are the two principal sources of ice accretion.

Prediction of icing buildup rate is very complex. The physical processes of superstructure icing vary spatially and temporally on a ship, and icing rate is qualitatively related to ship size, speed, headway, air and water temperature, wind velocities and sea state. Today, modeling of ice accretion processes is still in its developmental phase. Several methods are now available for icing mitigation and removal, such as thermal, coating, chemical or mechanical means. Vessel design for anti-icing may increase design and construction cost, but can significantly increase workability and has potentially minimal operational costs.

The conclusions of this pilot project highlights that a number of different approaches are available, however there is no reliable common approach and no industry standard for marine icing calculations. The need for more field observations is strongly recommended so that improved prediction models to determine sea spray formation and icing accretion may be developed.

Environmental Impact Pilot Project

This project has developed an enhanced approach for understanding the environmental impact of offshore Arctic operations. In the pilot project report the proposed generic framework is described for environmental assessments and also includes a step-by-step procedure on how the framework should be used.

Application of such an approach is recommended to assess, evaluate and reduce the environmental impact of operations in Arctic and cold regions areas.

The methodology can be used in an early project stage to asses impacts in a semi-quantitative manner. The methodology uses an ecosystem-based approach in which both the intensity of pressures and the vulnerability of ecosystem components are incorporated (Figure 9) and includes interaction of linked ecosystem components.

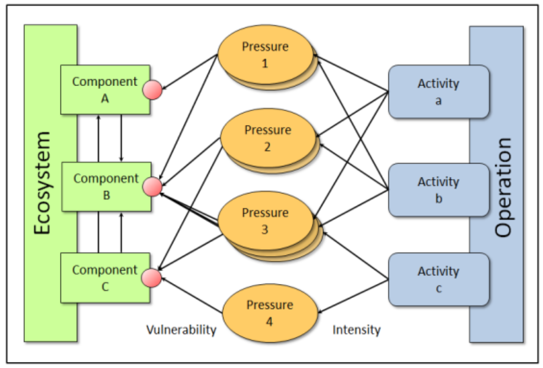

Figure 9 - Cumulative effect assessment including interrelationships of the ecosystem components (Karman & Jongbloed, 2008)

Key observations

The following key observations/guidance have been gathered within the scope of this JIP;

- It was noted from the gap analysis that there was limited general guidance for pipelay, trenching and dredging operations, especially for Arctic areas. The JIP decided to address best practices for these operations, with specific focus on the Arctic environment.
- Site specific operations should be considered when planning and carrying out operations.
- The report identified the importance of and provides requirements for monitoring and forecasting as well as the requirements for decision based tools.
- For the transportation and logistic aspects, input relied heavily on the existing guidance for Arctic shipping. This was further developed and transferred to recommendations for the specific operations covered in this report.
- The report provides guidance specific to aspects of health, safety and training.
- Specific attention was given to environmental impact assessments in early stages to ensure that impacts could be managed in the various project stages.
- Specific attention was given to the operation of disconnectable or temporary moored floaters in the Arctic.
- The state of the art on icing accretion is provided and this indicates the requirement to further study and develop guidance for icing load calculations.

Conclusions

The Arctic Operations Handbook JIP and its main deliverable the Arctic Marine Operations Challenges & Recommendations Report [8] provide the offshore industry an overview of identified gaps and proposes a large number of recommendations in order to close these gaps.

The identified gaps and recommendations could support the further development of ISO/TC67/SC8 (Arctic Operations), ISO 19906 SC7 (Offshore Structures) [6], ISO 19901-6 (Marine Operations) [5] and future JIP's.

The Arctic Marine Operations Challenges & Recommendations Report [8] provides an overview of the available guidance and gives recommendations which can be used for further development of standards. Due to its public availability it provides a level playing field and the incentive to cooperate, similar to how this JIP progressed, in order to establish safe and reliable guidelines and working principles in the Arctic.

The report is made public through the website www.arctic-operations-handbook.info.

Acknowledgements
The authors wish to express their appreciation to the Dutch Ministry of EL&I (Economic affairs, Agriculture & Innovation) for their subsidy within the framework of the Maritime Innovation Program.

The authors thank the following companies for their contribution to the Arctic Operations Handbook JIP;
Allseas Engineering B.V.
American Bureau of Shipping
Bluewater Energy Services B.V.
Canatec Associates International Ltd.
Delft University of Technology
Deltares
GustoMSC B.V.
Heerema Marine Contractors B.V. [Project Coordinator]
Huisman Equipment B.V.
Imares, Institute within Stichting Dienst Landbouwkundig Onderzoek
IntecSea The Netherlands
MARIN
IHC Merwede
Royal Boskalis Westminster N.V.
Shell Global Solutions International B.V.
TNO

Referenced Standards

[1] API RP 2N — Recommended Practice for Planning, Designing and Constructing Structures and Pipelines for Arctic Conditions, including Errata (2009)

[2] Barents 2020 — Assessment of International Standards for Safe Exploration, Production and Transportation of Oil and Gas in the Barents Sea – Final Report Phase 4 (2012)

[3] BS 6349-5 — Maritime structures. Part 5: Code of practice for dredging and land reclamation (1991)

[4] DNV-OS-F101 — Submarine Pipeline Systems (October 2013)

[5] ISO 19901-6 — Petroleum and natural gas industries – Specific requirements for offshore structures - Part 6: Marine operations 2009, Technical Corrigendum 1 (2011)

[6] ISO 19906 — Petroleum and natural gas industries – Arctic offshore structures (2010)

[7] 0030/ND — GL Noble Denton, Guidelines for Marine Transportations (2010)

[8] MAR11908-E/1133 — Arctic Marine Operations Challenges & Recommendations (2013)

[9] MANICE — Environment Canada - Weather and Meteorology - MANICE Chapter 3.4 The Egg Code

[10] ISO 26000 — Guidance on social responsibility (2010)

[11] UNDRIP — United Nations Declaration on the Rights of Indigenous Peoples (Sep 2007)