IALA

IALA GUIDELINE

G1175

OPERATION AND MANAGEMENT OF ATON IN EXTREME ENVIRONMENTAL CONDITIONS

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DOCUMENT REVISION

Revisions to this document are to be noted in the table prior to the issue of a revised document.

Date	Details	Approval
December 2022	First issue	Council 76
December 2024	Edition 2.0: Three guidelines (G1175,G1108 and G1136) have been merged and completely updated. Guideline G1175 now incorporates and replaces G1108 and G1136.	Transition Council 3

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1. INTRODUCTION

The role of a Competent Authority (CA) under SOLAS Chapter V is to provide such Marine Aids to Navigation (AtoN) as the degree of risk and volume of traffic requires, in order to facilitate safe navigation.

It is important, as part of this AtoN provision, that the CA considers the effects of environmental variables on Aids to Navigations systems. This includes:

- Capturing and utilising environmental information to inform design.
- Designing and providing appropriate AtoN that can operate in the relevant environmental conditions.
- Monitoring AtoN performance and position.
- Promulgating information to all concerned.
- Implementing emergency planning procedures.

This Guideline assists the AtoN manager to identify the negative impact of adverse environmental conditions can generate on Aids to Navigation performance and also understand how it may be possible to mitigate those effects. It is anticipated that it will also assist in prompting further research and the design of AtoN equipment appropriate for adverse environmental conditions.

2. SCOPE

The purpose of this document is to provide guidance to IALA members on aspects related to the definition, installation, operation and maintenance of Aids to Navigation in extreme environmental conditions, in the context of promoting safety of navigation, protection of the maritime environment and efficiency of maritime traffic.

Specific information from other guidelines has been identified and incorporated as several existing documents address how extreme weather conditions amongst other variables, can affect AtoN performance.

This includes:

- Information on the effects of extreme environmental conditions that could be experienced.
- Factors to consider when designing and implementing AtoN to mitigate those effects.
- Negative impact on AtoN devices.
- Human Resources and Environmental considerations.
- Others.

This new edition of the guideline is an update and amalgamated three Guidelines:

- G1136 – Providing AtoN Services in Extremely Hot and Humid Climates.
- G1108 – The Challenges of Providing AtoN Services in Polar Regions.
- G1175 – AtoN Equipment and Structures Exposed to Extreme Environmental Conditions.

3. ATON MANAGEMENT

AtoN management under extreme environment, requires specific processes and solutions to ensure the services are delivered to the appropriate standards. This may result in a degree of specialized engineering;

redundancy and innovative management solutions to ensure these AtoN meet their availability criteria and reliably provide appropriate information to the mariner.

This inevitably impacts cost and delivery time and must be factored into planning and budgeting. Failure to consider this in all stages of the AtoN process, including but not limited to design, specification, installation and maintenance will result in a reduced in-service life, poor AtoN delivery standards and in general, a negative impact on service delivery and availability.

Due the extent of some of these challenges, and the need for "above standard" solutions, there may be an incentive to identify and standardize regions with extreme ambient conditions, in order to enable authorities and manufacturers to agree on relevant operating specifications and standards for AtoN.

4. EXTREME ENVIRONMENTAL CONDITIONS

AtoN operation is affected by external forces, including environmental conditions. If these conditions become extreme, they can adversely affect:

- AtoN design.
- Installation and maintenance plan.
- Expected AtoN operation.
- AtoN service management.
- AtoN's lifespan.
- Quality control.
- Safety workers conditions.

This document identifies and describes these negative effects as follows:

- Heeling, shifting affecting vertical divergence.
- Reduced performance and lifespan.
- Stability of the AtoN and damage to the structure.
- Damage of the AtoN and its equipment.

Annex A contain a matrix developed to allow users to quickly identify the interrelation between the occurrence of extreme weather events (variables) and their impact on AtoN and their components.

Annex B summarizes the suggestions contained within the Guideline for best practice operation to reduce the impact of the effects of extreme environmental conditions on AtoN.

Here's a list of main extreme environmental conditions:

- Wind
  - Tropical cyclones
- Waves
  - Tsunamis
- Tides
  - Extreme tide
  - Extreme lowest astronomical tide

- Flooding
- Currents
  - Superficial currents
  - Tidal currents
- Temperature
- Ice

These extreme conditions can significantly alter natural and human systems, emphasizing the need for effective adaptation and mitigation strategies to deliver AtoN services as efficient as practically passible.

4.1. WIND

Wind has particular impact on AtoN performance since, depending on its speed and direction, it generates a "swell effect" which modifies the behaviour of hydrostatic buoys.

In floating AtoN, this effect has a great direct impact on the loads imposed on the mooring system, the buoy position, vertical divergence of the lantern, and the mooring chain deterioration rate. Due to these factors, it is necessary to consider the waves as another variable in the floating AtoN design process.

For fixed AtoN wind loads are also a significant consideration in the design process and material selection.

4.1.1. TROPICAL CYCLONES

A tropical cyclone is a generic term used for low atmospheric pressure systems formed in the oceans generally in homogeneous weather conditions and tropical zones. It is associated with a wide area of clouds, rain and electric storms, along with a superficial wind circulation, which is counter clockwise in the north hemisphere and clockwise in the south hemisphere.

Cyclones are usually called typhoons in the Northwest region of the Pacific Ocean and hurricanes in the Northeast Pacific and North Atlantic Ocean regions.

Depending on the geographical region, there is a scale of wind speed to define cyclone conditions. For example, the Australian Bureau of Meteorology categorizes wind speeds for cyclonic conditions as per the Australian Tropical Cyclone Intensity Scale. Another example is the Saffir–Simpson (Table 2) hurricane wind scale, which is used officially only to describe hurricanes that form in the Atlantic Ocean and northern Pacific Ocean east of the International Date Line. It is essential that the scale appropriate to the CA region should be used in the design of AtoN.

According to the Saffir-Simpson scale a hurricane is defined in five categories by wind speed:

Table 1 Wind scale – Saffir – Simpson (displayed as an example only)

Category	Maximum sustained wind speed (km/h)	Damages
1	119 – 153	Minimum
2	154 – 177	Moderat
3	178 – 209	Extended
4	210 – 249	Extreme
5	>250	Catastrop

In a hurricane, the destructive effect of the wind is directly related to its speed. While tropical depression winds generally will only cause damage weak structures, any system exhibiting speeds of over 170 km/h can seriously affect structures. AtoN have been known to lose their solar panels, top/day marks, marine lanterns and power systems can also be affected. Structures could also be damaged if their design is not suitable to withstand the effect of the winds or depending on their maintenance condition. Wind gusts are especially dangerous as they increase from 1.2 to 1.5 times the effect of the wind during 2 or 3 seconds.

Hurricanes and typhoons are meteorological events causing damage to AtoN annually. Their effects could cause the closure of the waterways by the competent authority for several weeks or at least lead to delays in operations.

Figure 1 AtoN affected by hurricanes

A short-term option to minimize the destructive effects of cyclones on AtoN could be the deactivation and the removal of AtoN components and other accessories for their preservation. This may avoid the loss of valuable equipment providing at the same time the opportunity to recommence operations with minimal delay after the cyclone has passed. This should be undertaken following an organized protocol including provision of timely information to the maritime community in compliance with Regulation 13, Chapter V of SOLAS.

Annex D provides an example of a demobilization protocol in preparation for cyclonic weather conditions (see also Guideline G1120).

When planning fixed AtoN construction in a cyclone prone region, consideration should be made to designing a structure resilient to cyclonic effects. This can be achieved by following the appropriate structural design standards and recommendations for the region.

For floating AtoN and mooring systems, design load values for extreme environmental factors such as current, waves and wind during the design return period (gap between one event and the other of the same kind or category) should be used, appropriate to the specific geographic area.

An example of a practical solution to provide more resilient AtoN against extreme wind could be the use of lattice design for towers, daymarks and topmarks. (see Guideline G1094 and Guideline G1165).

Figure 2 Front leading light with daymark lattice design

4.2. WAVES

he amplitude (height) and period (frequency) of waves can affect AtoN performance.

The wave characteristics can be predicted by means of simulations, weather forecast, or can be measured by special buoys which measure the energy transmitted by the wave to interpret the vicinity wave profile. The following parameters are used to determine wave profiles:

- Significant wave height (Hs).
- Mean direction.
- Peak period (Tp).

4.2.1. TRANSMITTED FORCES ON FLOATING ATON

Wave impact can have negative consequences on AtoN which should be considered during design. These consequences are different depending on whether the AtoN are fixed or floating.

In floating AtoN, the waves directly affect the motion of the buoy and, as a result, the vertical divergence of the lantern. If the mooring chain abruptly reaches its end, even in shallow waters, the floating AtoN experiences high peaks of force.

Another parameter to consider is where a wave may break compared to the water depth, which will determine the best location of the AtoN. It is necessary to obtain the parameters of the wave height at break (Hb) and the depth of break (hb). Obtaining these parameters reduces the uncertainty in the selection of location for the installation of the AtoN.

Wave break criteria that allow estimation of Hb (in the case of regular waves) are based on the characteristics of the waves (Hs, Tp and mean direction) and the profile of the seabed. However, given that in nature the waves are irregular, it is necessary to refer to historical breaking criterion that best suits the study environment. It is important to note that the breaking of the waves transmits a large force to the buoy and the mooring. This event can lead to chain breakage or cause the sinker to shift its position. The use of elastic moorings is a solution to this scenario (see G1066 The Design of Floating Aid to Navigation Moorings).

According to Sánchez-Arcilla and Lemos (1990), there are basically two types of breaking criteria (for waves at shallow and intermediate depths):

- Criteria that express the breaking conditions as a function of local parameters of the wave and bathymetric characteristics (seabed profile).
- Criteria that specify the wave height at break as a function of bathymetric characteristics (seabed profile) and wave super elevation in the offshore zone (H0 / L0).

The mooring of a buoy has two contradictory functions. Firstly, it keeps the buoy in position, but also, the mooring has to follow the wave dynamics in order to be able to reduce the loads on the mooring, to absorb the energy created by the movements of the buoy and to compensate for the differences between tide levels, waves, etc. (see Guideline G1099 Hydrostatic Buoy Design).

4.2.2. TRANSMITTED FORCES ON FIXED ATON

Wave impacts on fixed AtoN e.g., beacons and lighthouses placed on rock outcrops, causes deterioration of the structures particularly in assets approaching the end of their design life.

Trinity House, the Northern Lighthouse Board and the Irish Lights have supported the EPSRC-funded research project STORMLAMP, undertaken by a number of organisations (University of Plymouth, University College London and the University of Exeter University) to investigate the structural response of heritage rock lighthouses to wave loading during storms. They have estimated the wave loading on a number of vulnerable lighthouses using Bayesian-based statistical forecasts, empirical approaches, physical experiments and computational fluid dynamics.

The resulting structural response has been monitored through lighthouse-based instrumentation, and modelled using detailed structural analysis, validated using data obtained in field modal testing. On the basis of the investigations, they have been able to predict the structural vibrations and the survivability of the lighthouses into the future, providing crucial information for operational purposes and maintenance planning (Raby et al., 2019; Antonini et al., 2019).

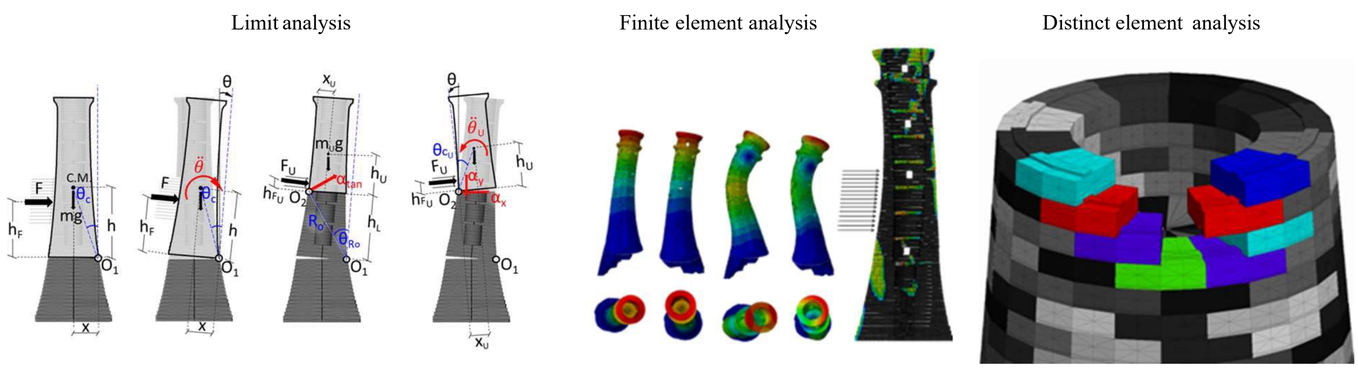


Figure 3 Examples of structural modelling techniques

Tropical cyclones also generate very large waves called swells that can affect 150 to 200 km of coastline and lasting for a few hours. These waves are caused by strong winds and a drop of atmospheric pressure in a shallow water area and can reach up to six metres height.

The combination of swells with astronomic tide when a cyclone is affecting a specific area produces the highest water level at a high tide. This effect is increased by waves moving over this already elevated water level.

4.2.3. TSUNAMIS

Tsunamis are typically caused by undersea earthquakes, submarine/subaerial landslides including island flank collapses, volcanic eruptions and meteorological conditions. There is also some evidence for generation by meteor strikes. Locations affected by tsunamis therefore tend to be close to plate boundaries e.g., the Pacific "Ring of Fire", although the effects of tsunamis may be experienced at large distances from the source.

The effects of tsunamis are generally not severe in deep water, where their height might only be of about 1 m. However, in shallow water where the wave height increases due to the shoaling effect, they may cause extensive damage due to:

- Rising/falling water levels.
- Large wave fronts, which can exceed 10 metres.

AtoN in deeper water will therefore probably be unaffected by tsunamis. However, damage is likely on structures such as rock lighthouses or operational facilities on or near the shoreline.

The following provide examples of AtoN damage due to tsunamis:

- Navigation buoys and the Great Basses Light and Little Basses lighthouses in Sri Lanka following the 2004 tsunami, where navigational buoys were lost around the coastline, and damage to lighthouses including that to the fuel tanks and glazing.
- The five-storey high Scotch Cap lighthouse on Unimak Island, Alaska was completely destroyed in the 1946 Aleutian tsunami with the loss of 5 men (Patel and Patel, 2012).

A high magnitude and long-lasting earthquake closer to the epicentre may result in a major disaster damaging infrastructure, affecting utilities and may even cause injuries and deaths.

An earthquake may also lead to a tsunami that could damage floating and land based AtoN, port infrastructure and facilities. Although both events, separately, are particularly destructive, their effects can be combined or individual.

The waves of a tsunami can be extremely dangerous and devastating to low-lying coastal areas as they enter shallow water at high speed and hit the shoreline in a short period. Tsunami impact time depends on the distance between the epicentre and the coast, ranging from tens of minutes to hours, and this propagation pattern will affect the areas near its origin.

Competent authorities should apply their knowledge and experience in order to define solutions for each situation taking into account specific extreme environmental conditions or events, such as tsunamis or hurricanes.

Further information regarding the structural design of fixed AtoN is given in Guideline 1165 Sustainable Structural Design of Marine AtoN. This document provides information on the AtoN structural design process and helps the AtoN manager understand how to ensure environmental loads such as wind, wave and current are incorporated adequately into the design.

Emergency preparedness and AtoN system resilience is key to minimize the impact of a tsunami on AtoN systems.

Annex E contains an example of the Chilean experience in dealing with Tsunami events and contains an example of an emergency AtoN plan.

4.2.4. TIDES

The astronomic tide is the variation of the hydrometric level as a response of the gravitational interactions between the sun, the moon and the earth, and it can be predicted with acceptable accuracy. Tidal level predictions are published by local maritime authorities in a document referred to as tide tables. The tidal range can be measured as the vertical difference between a high and a low tide. The largest differences in monthly astronomic tidal values occur according to the lunar phase (full or new moon), when the gravitational force of the sun and the moon are in phase. This kind of tide is known as a spring tide.

Conversely, the meteorological tide has its origins in the daily or seasonal variations of the weather conditions which can occur periodically and can also to a certain extent be predicted.

In river floodplain areas, an extreme tidal event can be caused by an increase in upstream rainfall coinciding with tidal events. Such events can also be linked to climate change as sea levels rise due to global temperature changes

Tides do not usually affect the performance of AtoN, due to tidal height being a parameter considered during design. In the case of extreme tides floating and fixed AtoN can be affected, especially their position when marking a narrow channel where tidal flows are "funnelled" through the channel causing local increases in water level.

4.2.5. EXTREME TIDES

An extreme tidal event is associated with sea level rise or fall created by the simultaneous occurrence of a high astronomic tide and a meteorological event (e.g. storm surge) and their occurrence can also be predicted.

Table 2 Extreme tidal values

Location	Country	Tidal Range (feet)	Tidal Range (metres)
The Bay of Fundy	Canada	38.4	11.7
Ungava Bay, Quebec	Canada	32	9.8
Avonmouth / River Severn	England	31.5	9.6
Cook Inlet, Alaska	USA	30.3	9.2
Rio Gallegos	Argentin	29	8.8
Hudson Bay	Greenla	28.5	8.7
Granville	France	28.2	8.6
Magellan Strait	Chile	28	8.5
Cancale	France	27.8	8.5
Iles Chausey	France	26.9	8.2

Source: Extract from National Oceanic and Atmospheric Administration (NOAA)

4.2.6. EXTREME LOWEST ASTRONOMICAL TIDE

The Lowest Astronomical Tide (LAT) is a rare event which occurs when the sea moves away from the shore. This rare natural phenomenon occurs together with the gravitational force during a particular lunar phase (full moon) acting on the water mass and the climatic conditions. When LAT occurs, in some situations (e.g. narrow channels), the low tide can cause floating aids to move transversely narrowing the channel further. This effect can be further magnified when coupled with adverse wind speed and direction.

4.2.7. FLOODING

The sustained and gradual increase of water volume in inland waterways can result in damage to AtoN due to floating debris (e.g., influx of aquatic vegetation or logs) causing impact damage and entanglement in the mooring system. This can result in a floating AtoN sinker dragging, the possible rupture of the moorings or even the loss of or sinking of the AtoN. Floating vegetation can also become entangled in ship's propellors and rudders which will reduce the ship's manoeuvrability especially with the higher current speeds in flooded waters.

In addition, floating vegetation and the changing coastline may introduce hazards which can cause confusion for the mariner by creating unchartered references through distortion of the visual marks and the radar image.

Figure 4 Negative effect of floating vegetation

The excess water can also cause instability to the area where fixed AtoN may be located due to erosion or collapse of the coastline. These effects should be considered during the design and selection of AtoN in flood prone area.

Figure 5 River coast flooded

4.3. CURRENTS

The movement of a mass of water is called current which is defined by its direction and speed. Some of the factors affecting currents are density variations within the water, winds and tides.

Extreme water current can affect AtoN in the following ways:

- Stability of fixed AtoN structures through erosion.
- Verticality of floating AtoN.
- Wear on mooring systems.
- Reduced window for safe access.
- Sediment or erosion local process.

4.3.1. SUPERFICIAL CURRENTS

The breaking of the waves generates a current parallel to the coastline. This current is a function of the angle with which the waves approach the coastline and of its wave height, called a superficial current.

AtoN, mainly buoys could also be affected by the increment of the superficial current. The effects differ depending on their design. They may be driven to the extent of the mooring length or tilted to the point where they could lose their verticality, which will affect the AtoN published characteristics (e.g., visual, luminous and radio propagation ranges).

4.3.2. TIDAL CURRENTS

A tidal current is generated with the rise and fall of the tide in locations near the coastline. The current is created by the vertical movement of the tide near the shore, also causing the water to move horizontally. When the current floods, the tide moves towards the land and away from the sea; when the current ebbs, the tide moves towards the sea and away from land.

In some specific places, the tidal currents can move at very high-speed creating eddies that can be seen on the water surface. When this occurs, mariners must follow the sailing directions and MSI published by the local maritime authorities while navigating these waters.

Places like the Chacao Channel, which separates the Chiloe Island from mainland Chile, experience tidal currents with an average of 8 to 10 knots in the middle of the channel. In the Kirke Channel, near Puerto Natales, tidal currents have also been registered with an average of 10 knots during flood and ebb periods. In this place, in 2014, the MV “Amadeo I” wrecked after crashing into sea bottom rocks due to the fast currents, among other factors.

In 2019, the Chilean Maritime Authority installed a current meter which sent, through VHF Channel, meteorological and current information transmitted by voice and AIS to enhance navigation safety through the channel.

Figure 6 Kirke channel and Amadeo ferry

4.4. TEMPERATURE

The effect of the temperature on the AtoN and its components are widely known, and its impact depends on the range of magnitude. In order to assess the effects that the extreme temperature can cause to AtoN, several guidelines have been published to assist AtoN selection.

At this guideline has fusion Guideline G1136 Providing AtoN Services In Extremely Hot and Humid Climates and guideline G1108 Providing AtoN Services in Polar Regions, to be easy and friendly find the specific data about the effect on Aton of extreme temperature.

Also, there are others current guidelines:

- G1067-0 Selection of Energy Systems for AtoN and Related Equipment.
- G1067-3 Energy Storage for AtoN.

Under normal conditions, selection of AtoN power supply systems may allow a choice of options, however in areas of extreme temperatures, options may be limited. Guidelines G1067-0 and G1067-3 recommend when mains power is not available, renewable energy should be considered, and where renewable energy sources are not feasible, primary batteries should be used instead. Also contained in these guidelines are tables which serve to guide on the selection of the power supply system and for the recommended storage system which consider extreme temperatures as one of the variables.

These alternative power supplies will be affected by the extreme temperature values. Extremely low or high temperatures can affect the performance of the external equipment; it can shorten the expected useful life of the equipment and make certain materials fragile, compromising the water ingress protection index (IP##) provided by the manufacturer or even the structural integrity. The selection of lubricants to be used in movable parts should also be considered.

Other examples of effects are as follows:

- Batteries will freeze and display poor performance and therefore the type of battery should be carefully selected.
- Freezing of the axis of the wind generators.
- The formation of ice in antennas and the concentration of snow can cause several problems in different systems and make some materials brittle.
- Low performance of the components of power supply system due to low temperatures and can also generate progressive layers of ice.
- High temperatures can affect the useful life of the battery and can affect its stability during operation.
- Extreme high and low temperatures will affect the normal operation of lubricated systems, such as wind generators, anemometers, or other mobile sensors.
- Extremely high temperatures can negatively affect the performance of AtoN equipment, including power supplies, lanterns, fittings, and other electronics. Steel buoys, towers, other structures and the installed equipment can reach temperatures that make access and handling very dangerous.
- Installing, maintaining or working on AtoN in extreme temperatures can also significantly increase the safety and health risks to AtoN technical staff.

4.4.1. ENERGY SOURCES AND STORAGE CAPACITY

In the majority of applications, and due to the remote or isolated nature of AtoN some form of energy storage system, usually in the form of a battery, is required. In these cases and particularly in the case of AtoN in extreme conditions great care should be exercised in the selection of the battery. The following section highlights some of the considerations that authorities / service provider or manufacturers should take into account. For more details, refer to Guideline G1067.

There are a number of different battery technologies including:

- Lead Acid (various technologies).
- Nickel Cadmium.
- Nickel Metal Hydride.
- Lithium Ion.
- Developing technologies.

Each technology has its advantages and disadvantages, will be less suitable to operation in extreme climates and someone could have safety issues under extremely hot conditions.

Lead-acid battery technologies are typically used for AtoN energy storage because of their low cost, adequate energy density and general suitability for solar charging applications (in terms of the random energy supply from solar panels).

Any battery technology will require compensation factors to be applied according to its predicted performance in an extremely climate. For example, lead-acid technologies display significant reduction in capacity at temperatures above 25°C and a compensation factor for this characteristic will likely be necessary and similar effect occur operating with low temperatures, under 0 °C.

Authorities/Service provider might need to take into account the extreme temperatures values to apply the method of battery autonomy calculation used in their or manufacturers' calculators. (See Guideline N° 1039 for develop the calculators photovoltaic system, take into account the consumption and geographical location).

4.4.2. POWER SUPPLIES

Accessibility of power supplies to technicians should be a consideration in these environments. This includes the size, location and storage method. Difficulties with climbing, manual handling and access in general can be magnified when working in extreme climates.

Testing and handling protocols and procedures in extreme climates may require specific testing methods and precautions. High humidity and sweat or with ice or snow presence can increase the risk of electrocution. Isolation of battery bases, the use of appropriately rated, water resistant and UV protected cables and the protection of terminals may reduce this risk also.

4.4.2.1. Mercury handling

Handling mercury in high temperatures is very hazardous due to the evaporation of mercury vapour. To reduce risk to the health of personnel the following must be considered as well as the standard controls to mitigate mercury risks.

- Air circulation must be adequate.
- Limit the working time during periods of intense heat.
- Where humidity is an issue, be careful of any slippery conditions which may cause slipping or mishandling of mercury.

4.4.2.2. Storage / structures

There are a number of factors that affect the suitability and issues of AtoN structures in extremely aggressive environments.

Battery ventilation is very important in hot climates, to avoid generation of heat, to allow air flow and to allow heat dissipation. This is generally applicable to most electrical equipment in these environments. Some protection from heat and humidity is critical.

A poorly ventilated structure in a hot climate may also contribute to equipment failure, due to poor heat distribution or the build-up of moisture and condensation.

In some applications, air conditioning may be possible and is an effective way of regulating internal temperatures.

The colour of the structure is also important, as certain colours (such as white) will allow better thermal protection. Darker colours should be avoided for an AtoN structures and equipment enclosures as these promote heat absorption.

An example of colour selection and effects on temperature can be seen in Figure 4, which shows results of recorded temperatures in white and black battery boxes.

Table 3 Measurement of Temperature vs. different surface colours

Battery box colour	Black	Amb Temp	White
Temperature sample (Celsius degree)	57.9	33	40.6
Percent of influence	175%	100%	123%

4.4.2.3. Battery operating temperatures

The range of temperature experienced by the battery during operation will considerably affect its useful life and it is a significant factor in the selection of the battery.

Batteries should operate at the specified temperatures stated by the manufacturer. Their operation outside these ranges will have a secondary effect on its capacity and useful life (life cycle), and it can also be hazardous.

Calculating battery life depends on several factors such as maintenance, percentage of discharge, battery temperature, number of times the battery is discharged, etc.

High temperature of the cell can be generated by the environmental temperature or alternatively, by an excessive charge. In both cases the possible effects can occur:

- Ageing acceleration.
- Spontaneous sulphation.
- Active matter dissolution.

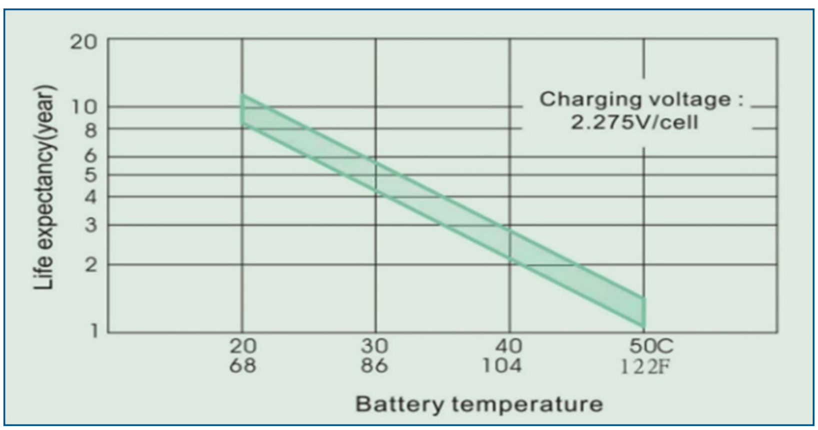


Figure 7 Lead acid battery ageing curve in relation to the temperature

The cold climate limits the number of possible energy storage technologies. Currently the most widely used solution is based upon Ni-Cd battery technology because of its well documented performance in extremely low temperatures. The reduced usable capacity in low temperatures has to be considered when calculating the battery size. Other criteria to consider include service intervals and expected lifespan.

It has been found that fibre plate Ni-Cd batteries perform much better in extremely cold regions than tubular plate Ni-Cd. Electrolyte with a crystallization point of - 40°Celcius should be used. Stronger electrolyte is available but will reduce the lifetime of the battery.

Present generation lithium batteries do not operate well at temperatures of less than -10°C and above 50°C.

4.4.2.4. Solar panel performance

The effects of the direct sun light (UV) and the high temperatures damages solar cells thus reducing performance. The life span of a standard solar panel is around 15 years with an average output of at least 70% to 80%. However, in hot climate regions an average of 40-50% over is achieved over a 10 year cycle. The reduction in output of the solar panel means that the charging current is insufficient, thereby reducing the battery life cycle. Units need to be replaced more frequently. The general AtoN performance and availability will be affected and operational costs may increase dramatically.

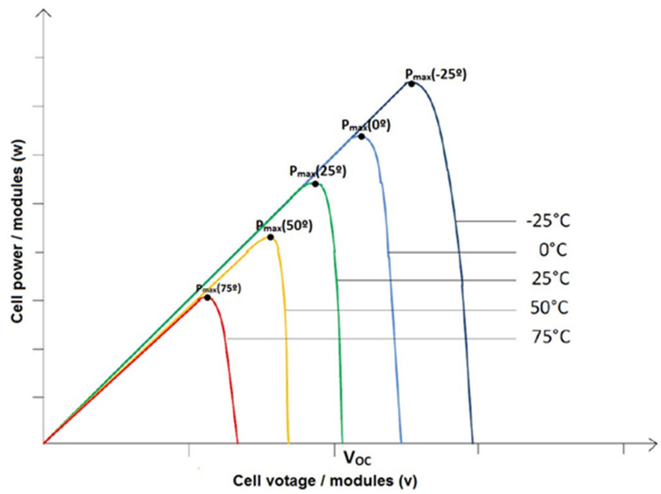


Figure 8 Lead Impact of temperature in the power of a solar panel

As can be seen in figure, increases in temperature can result decrease in power. Considering that manufacturers generally set maximum voltage values and photovoltaic module power for temperatures at around 25 ºC (Celsius degrees), it is necessary to take into account its energetic deficit for temperatures that may be up to twice as high. It may require over compensation in the design phase, which has it's a consequential increase in cost.

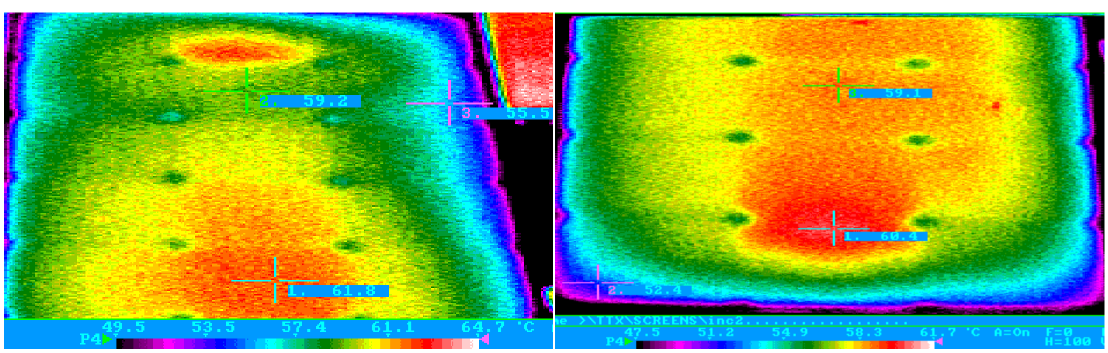


Figure 9 Thermal image of two photovoltaic modules being used in an extreme heat environment.

As observed above, the temperatures are not uniform across the entire module, caused by the border effect and a coating factor.

The output theoretical power of the solar unit is the term usually used to refer to the panel size or capacity, which does not always represent normal conditions because this value has been measured under Standard

Test Conditions (STC): 1.000 W/m^2 irradiation, and 25° C ambient temperature. These conditions are rarely experience during AtoN operation.

It is established as global standard that for every 1° C above 25° C (77° F) – temperature set by manufacture for the technical operations-the unit will show a 5% fall in voltage.

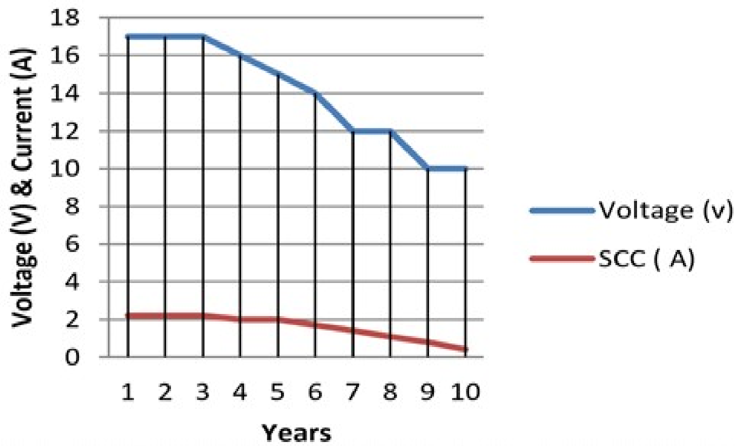


Figure 10 Power reduction over time of a solar panel deployed in an extreme heat environment

Consequently, solar panels could need derating for instantaneous performance under extremely environment conditions and additionally for the effects of long-term degradation in order to meet system requirements and to reduce negative effects on battery lifetime.

Competent authorities and service providers are recommended to implement a solar panel performance-check plan as part of their regular maintenance cycle.

4.5. ICE

Given the poor survivability of buoys in winter ice conditions, it is unlikely that these are suitable in most circumstances, and fixed AtoN should be utilized wherever necessary. Where buoyage is used this should be either seasonal or designed for all-season survivability, both these options are expensive and do not guarantee good reliability.

In ports and waterways subject to channel ice, floating AtoN may suffer impact damage or even sink due to ice compression and movement. The light range and data transmission of floating and fixed AtoN components, and other day marks can be reduced to the effects of heavy snow.

To reduce the risk of damage to AtoN there may be seasonal deployment of floating AtoN, whereby they will be located during the winter season only at the key points of the fairway to reduce the probability of damage by ice. Alternatively, special designs can be used which generally withstand ice forces due to their shape and design. For example, conical or cylindrical buoy shapes with reinforced bodies. Topmarks may not be used as they can be damaged by the weight of ice accumulation. The choice of AtoN should reflect the specification of the CA, which should consider the extreme environmental conditions.

Figure 11 Effect of ice on buoys

Ice sheets grow and shrink with the seasons and ice-charts may need to be updated frequently. Consideration should be given as to how this information can be managed in an efficient and cost-effective manner to ensure the mariner uses the most up to date information.

The growth and reduction of the ice sheet can also result in land-based systems having to be installed on permanently stable, high ground which may potentially be at sub-optimal locations, distant from the area of navigable waterway being served.

Figure 12 Example of ice on AtoN structure

4.5.1. FIXED ATON ON LAND

- The mark could be covered by ice which deforms the visibility of the mark and light.
- Ice or snow accumulation on the glasses of lantern rooms may severely affect light visibility.
- Fixtures and aerials or other construction elements may be damaged by ice if they are placed near sea level.

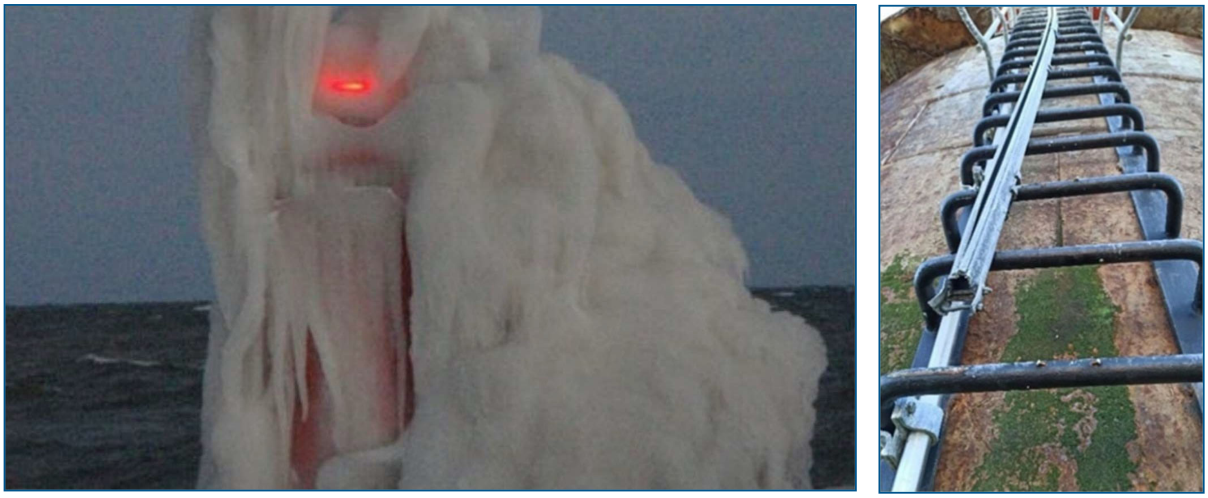


Figure 13 Port entrance mark covered by ice – safety rail bent by ice on Tallinnamadal lighthouse

Standard civil engineering best practices should be applied. Special considerations should be given to polar factors such as the presence of permafrost and seasonal ice conditions. To obtain the necessary information the design team should collect data from all available sources, notably local knowledge. Where data is not available it should be collected, for example, land and soil surveys or wind and ice measurements.

Figure 14 Examples of a simple foundation which is preferred in Polar Regions to ensure a swift installation and to reduce the use of heavy equipment and large quantities of material[1]

4.5.2. FLOATING ATON

- The resistance offered by an AtoN and its mooring system caught in the drag of moving ice, when released, can produce highly accelerated oscillating movements, which could cause damage in the components (electronic devices, lanterns, etc).
- Floating AtoN may become submerged under ice and may not be visible to the mariner. MSI should be issued to notify mariners that availability targets may not be met in ice conditions.
- Ice may damage buoy lanterns and therefore special lanterns or ice protection is needed.
- Ice accumulation on floating AtoN may create problems with buoy stability.
- Moving ice or ice accumulation may significantly affect vertical divergence.

1 Refer to http://www.pws.gov.nt.ca/pdf/publications/GeotechnicalGuidelines.pdf for more information on Soil Investigation in Permafrost

- The internal buoy structure is critical to support the resistance to ice damage. Steel buoys can be reinforced with ribs and the empty voids in plastic buoys may be filled with closed cell foam.
- The coefficient of thermal expansion of polyethylene (PE) is approximately ten times bigger than steel. In plastic buoys with steel components this can lead to the development of pressure and resulting damage to the buoy hull.
- Empty compartments of plastic buoys can be damaged by pressure or a vacuum developing within the voids. The risk of this can also be reduced by filling the compartments with cell foam as mentioned above.
- Heavier sinkers are required to ensure the buoy remains in its position when subject to moving ice.
- In case of shallow waters with thick ice, the ice may touch the bottom of the seabed and move debris and objects (including anchors) that can move or impact floating AtoN
- Ice often scrapes off retroreflecting films and bird spikes used on buoys. An alternative to retroreflecting film is embedding or recessing of the luminous film within the body of the buoy.
- Retrieval of off station floating AtoN is sometimes impossible because buoy tenders are not able to operate in severe ice conditions.
- Sometimes it may be problematic to identify the colour scheme of a buoy in ice.

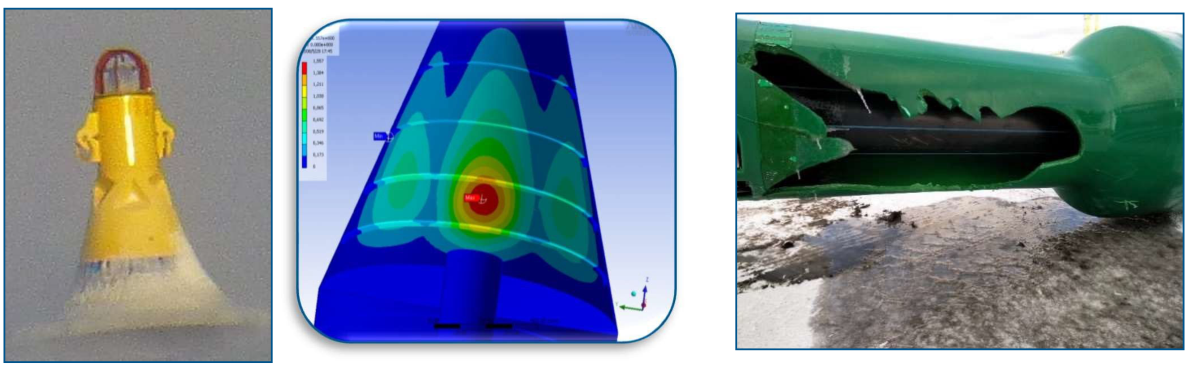


Figure 15 Various buoy conditions in ice

At figures shown (left to right) a buoy with ice protection over polycarbonate cupola, reinforcement ribs on a steel buoy and damaged plastic ice buoy without foam to support its structure.

Figure 16 Example of recessed retroreflective film

An example of a reinforced buoy for use in ice is one built with a “fishbone” stainless steel skeleton, and a streamlined three-section structure with a cylinder in the middle and a cone at both ends, using high polymer polyethylene material. The surface colour of the buoy does not fade or fall off even after long-term use under harsh conditions, and it can effectively resist the impact and collision of floating ice, and float under the ice surface passively when it meets large ice chunks.

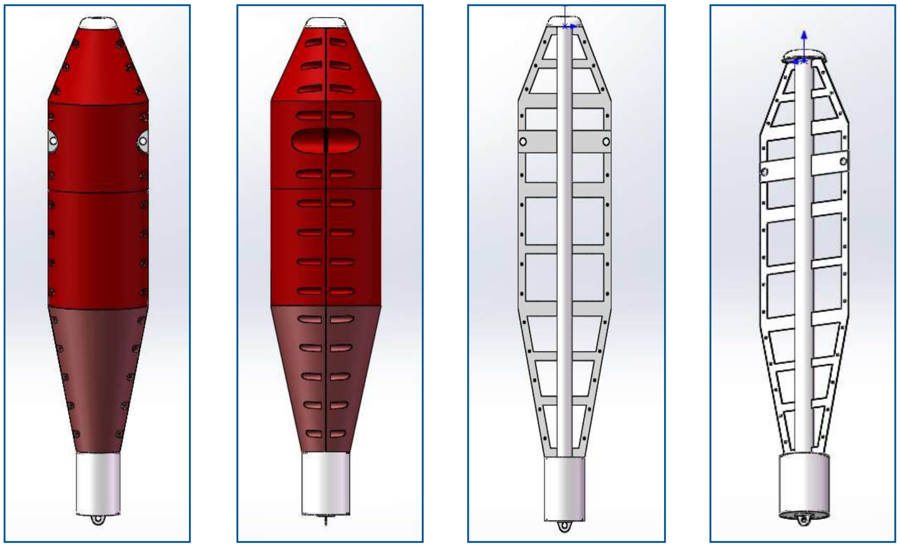


Figure 17 Appearance and skeleton

Unlit beacons and passive radar reflectors are particularly beneficial owing to their high reliability and low maintenance requirements, as opposed to powered AtoN, and are utilizable during polar summers where there is nearly three months of sunlight without a sunset. Electronic AtoN are also of high value owing to their usability in fog or poor visibility conditions, and power requirements for racons are minimized due to the low traffic volumes.

Development of virtual aids to navigation should be given strong consideration as an adjunct to conventional aids to navigation for use in Polar waters; however, provision of an effective virtual aids to navigation system depends on adequate hydrographic services as well as the provision of appropriate Maritime Safety Information (MSI) systems and communications infrastructure.

4.5.3. POTENTIAL FOR ICE DAMAGE

Dynamic ice flow has the potential to cause catastrophic failure of structures. Although not limited to floating AtoN, these are particularly susceptible to mooring damage or forced submersion. Static ice build-up on structures may also cause damage due to overloading and wind damage as a result of increased surface area.

4.5.4. ENERGY CONSUMPTION

Energy consumption of AtoN is a critical factor in AtoN in all areas and this applies equally in Polar Regions. Because of the long period of three months' darkness in winter and three months daylight in summer, all equipment needs to be rated for continuous operation on a 24 hour basis for three month periods.

4.5.5. ENERGY SOURCES

Provision of power supplies for electrical AtoN is particularly challenging, as the polar winter features long periods of darkness, when the AtoN may be required to be functional but the potential for solar-electric charging is negligible. This requires either large power reserves, although battery efficiency is reduced in cold conditions; or the potential for sourcing power from other means.

The remoteness of the location and cold climate impact the possible energy sources. Different kinds of energy sources are evaluated for use with AtoN in Polar Regions below.

- Public power supply: This is the ideal technology, based on reliability, however it is rarely available at planned AtoN sites.

- Solar: This is a proven reliable and robust technology. There are two main challenges. First ice and snow accumulation, which needs to be addressed when designing the site layout, capacity and redundancy. Second, the need for sunlight. Solar systems in Polar Regions must therefore be designed with much larger energy reserve to pass the long period of darkness.
- Wind: Each type has its own environmental (wind, ice) capabilities and limitations that need to be considered. The technology also has specific maintenance requirements that must be completed to ensure performance. Maintenance should be available locally to consider this technology a feasible option.
- Diesel: Is not suitable for small AtoN due to the maintenance frequency requirement, and the high cost of fuel transportation.
- Fuel Cells: Is a new unproven technology for use in Polar Regions and is therefore not currently recommended.
- Primary batteries: These are a proven and reliable power source with predictable capacity but require a robust maintenance programme to assure AtoN performance.
- Isotope nuclear thermoelectric generators have been used to provide heat and electric power. These generators use Strontium 90 as a fuel source and can operate unattended for long periods. However, they have not been totally reliable with risks of radiation contamination and susceptibility to theft. The environmental impact following an in-service failure, and disposal issues at the end of life, no longer make these units a recommended power source.

Solar power systems are probably the most suitable energy source for stand-alone AtoN applications in Polar Regions due to the simplicity, reliability and low maintenance requirements. Hybrid solutions may be an alternative where more energy is required.

5. OTHERS IDENTIFICATION OF EXTREME ENVIRONMENTAL CONDITIONS

Extreme weather events may include but is not limited to tropical storms, fog, monsoons, cyclones, sand/dust storms, seasonal winds, and an increased chance of lightning activity. These weather events present significant engineering and operational challenges and there may be design and installation requirements required in these areas that are not required elsewhere.

Others environmental conditions in extreme values should be considered on adversely effect on AtoN´s:

- Atmospheric conditions
  - Visibility
- Geophysical conditions
  - Soil and coastal morphology changes
  - Soil geomorphology
- Water conditions
  - Temperature and Quality
  - Corrosion
  - Abrasion
  - Marine growth
- Birds

- Mould
- Humidity and High ultra-violet levels.

5.1. ATMOSPHERIC CONDITIONS

5.1.1. VISIBILITY

Fog is an atmospheric phenomenon in which the visibility of the sky is reduced due to the high presence of smoke, dust or any other particles suspended in the air. According to the World Meteorological Organization the darkening on the horizon can be distinguished between mist, ice mist, vapour mist (steam), fog, smoke, volcanic ash, dust, sand or snow.

However, the turbidity can generally be measured by means of the Pollutant Standard Index (PSI) which states the air quality or the pollutant level in it. This index can vary according to the country which consults it, since different indexes are used all over the world, such as the Air Quality Health (reference).

At high latitudes it is dark for all or most of the day for half the year. Conversely, it is light for all or most of the day during the summer months. Both of these conditions impact on visual navigation.

Seasonal rain, high humidity, sandstorms and sand/dust laden air associated with extremely hot and humid climates all have a negative impact on visual navigation and need to be considered when providing AtoN services
in these regions. In regions of heavy rain, high humidity, fog and sandstorms, visibility can be significantly reduced. These climatic conditions may temporarily or more permanently affect atmospheric transmissivity, and these should be considered when determining minimum ranges for lit or unlit AtoN.

5.1.1.1. Difference between haze, fog, and mist

These three phenomena can result in reduced visibility due to climatic conditions (fog and mist) and in relation to the air pollution (haze). The main difference between these three concepts is that for fog and mist, these are formed by suspended drops of water, whereas haze can be formed by extremely small and tiny particles suspended within the air.

The natural phenomenon of mist occurs when hot air “crashes” against cold surfaces and the humidity “thickens” or condenses resulting in small amounts of water in the air.

Although, mist and the fog are similar phenomena, they are distinguished by the visibility distance, i.e., if the visibility distance is equal to or less than one kilometre, it is often named as mist, but if it is larger than a kilometre, it is called fog.

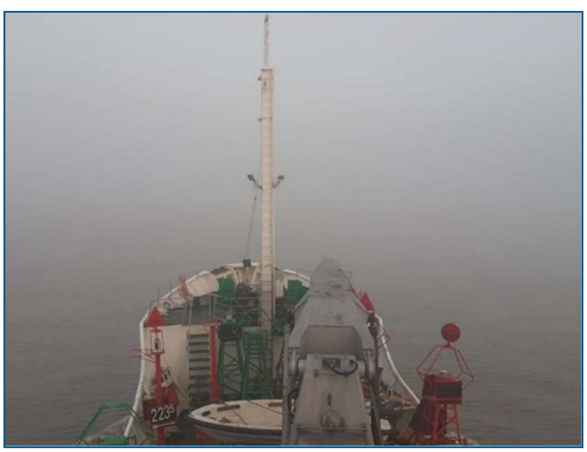



Figure 18 Presence of fog in a waterway

5.1.1.2. Dust

Dust is an issue in certain extremely hot environments and can cause a number of issues. Dust can cover lanterns and day marks, severely impacting the range, can cover solar panels thereby reducing the ability to charge batteries and its abrasive nature can accelerate deterioration of AtoN components. Dust can be of different physical properties, both industrial and natural, can cause different issues and require different controls and cleaning methods. Excessive dust also poses health and safety related risks to AtoN personnel.

The dust has impact on the AtoN's operational and physical properties. Dust can be as the result of industrial activity, as well as naturally occurring. It can interfere with the operation of lamp changers and cover day marks affecting the luminous and visual range, as well as the solar panels which, if covered in dust, can reduce their energy generation capacity. Furthermore, extreme dust also present risks related to health, such as respiratory problems. Dust is considered as a way of transporting pollutants and, can affect the health and safety of AtoN maintenance personnel.

In areas that are affected by dust, the service provider or competent authority should consider the frequency of maintenance visits. The visit interval should be adjusted to be practically and economically feasible.

Generally, sandstorms start as a dark orange cloud followed by heavy winds which can lead to the competent authority to impose restrictions on the navigation in channels, manoeuvring areas, entry to ports or harbours, amongst others.

Dust may cause visibility issues and accumulate on lantern fittings, particularly in Fresnel lenses. The use of Fresnel lenses without dust covers should be avoided or an alternative light source such as LEDs should be used.

Figure 19 Presence of dust on AtoN device

5.1.1.3. Fire and smoke

Fires can occur either due to extreme temperatures combined wind and a lack of rain or can be initiated through certain agricultural practices. Climate change effects are resulting in widespread fires in locations where previously such occurrence was a rarity.

Fires produce clouds of smoke which causes loss of visibility for the mariner, as well as affecting living beings inhabiting the area (fauna and humans). Fire can also destroy land based AtoN.

Figure 20 Presence of smoke in a waterway

Figure 21 Example of AtoN destroyed by fire

5.1.1.4. Impact on navigation

The main impact on navigation associated with the loss of visibility or limited visibility due to mist, haze, dust, sand or smoke, is the interruption of maritime operations.

Depending on the CA, the closure may not affect vessel traffic, or it may impose a restriction in navigation, such as delays in operations for a period of hours, to reopen again once the visibility conditions have improved.

The loss or reduction of visibility due to the presence of mist or fog does not affect the useful life of AtoN. However, it reduces the visual range and affects the safety of navigation. Visibility on navigation depends on the adjustment of the human eye or on the contrast between the darkness during the day in winter and the brightness during summer months; both factors affect visibility in navigation.

Guideline G1090 The Use of Audible Signs covers the loss of visibility due to the presence of mist and defines a requirement for:

"establishment of the considerations under which an audible signal can be used and the disadvantages of its use due to the complexity to identify the direction or vicinity from where the sound comes from, as well as stating the patterns in relation to usual range and nominal use."

At present, there exist electronic aids capable of warning the mariners in situations of low visibility. Their implementation, however, depends on cooperation and alignment of AtoN provision between the relevant maritime authorities. For example, it may be possible that the mariner is encouraged to navigate under a bridge during low visibility conditions because appropriate AtoN are installed but the final port destination may restrict operations in its area in low visibility and the vessel may be unable to berth. Criterion should be established and agreed between the maritime authorities regarding waterway operation during temporary periods of low visibility.

An example of how extreme fog can affect the operability of ports and the safety of navigation is the Port of San Antonio, a main Chilean port.

A fog bank is very common during the morning until after noon, while in the afternoon an anticyclonic margin is formed with winds from the SW, which generates the removal of the fog. However, when the fog clears it is accompanied by adverse sea state conditions. Both of these conditions exacerbate the challenge of navigation into the narrow port entrance channel. The hours authorized for entering the port are therefore reduced to night hours. In this situation, the port can utilise new technologies, such as marking the entrance channel with virtual AIS AtoN together with backup systems to support vessel coordination.

Figure 22 Fog bank at the Port of San Antonio

5.1.1.5. Impact on energy generation

Haze, fog, dust or smoke affects the performance of solar panels since the remaining insolation charging hours can be reduced where these extreme conditions occur during autumn or winter. Increased maintenance frequency may be required to reduce the impact on solar panels and other components.

5.2. GEOPHYSICAL CONDITIONS

5.2.1. SOIL AND COASTAL MORPHOLOGY CHANGES

The changes that take place in the seabed and river coastline require continuous bathymetry and topography survey on behalf of the competent authorities to keep nautical charts updated. It is also necessary for the mariner to ensure they are aware of the most up to date cartography and Marine Safety Information (MSI).

Eventually, the generation of sandbanks or the collapse of the coast associated with significant sedimentation and erosion processes, typical of river behaviour, can affect the stability of the fixed AtoN installed on the coastline. Positioning of AtoN in these areas should be carefully considered and a maintenance plan for proactive relocation of floating and fixed AtoN, where necessary and due to morphological changes is required.

Figure 23 Erosion process at the coast

Specifically, in buoy mooring systems, abrasion from sediment movement generally leads to a higher rate of wear in the mooring system.

5.2.2. SOIL GEOMORPHOLOGY

Currents carrying large quantities of sediments can bury a floating AtoN sinker making it difficult to lift for maintenance. The ship's crane or other lifting means may not be able to retrieve the complete mooring system resulting in the chain having to be cut. This could generate a new environmental condition or a navigational hazard to consider.

5.3. WATER CONDITIONS

The physical, chemical, and biological composition of marine waters can influence the rate of deleterious effects on both fixed and floating AtoN; such effects are discussed in the following paragraphs.

5.3.1. TEMPERATURE AND QUALITY

High water temperature in these environments can cause a number of issues. It can accelerate corrosion and result in an increased rate of marine growth. This is further complicated in environments where the water has high salinity. High water temperatures also create additional risks for workers, mainly those involved in underwater works. It can cause discomfort and reduces the amount of time that can be safely spent underwater. Warmer water environments also generally have a higher presence of marine organisms that can cause skin irritation or stings.

5.3.2. CORROSION

Salinity, sulphate content, temperature, dissolved oxygen, and pH can all separately, and in combination, influence the corrosion of steel AtoN. Generally, higher temperatures as experienced in tropical waters, and higher levels of dissolved oxygen will combine to increase corrosive mechanisms.

The corrosion of steel in seawater is an electrochemical process, which is exacerbated by increased salinity.

pH of the water also has a variable effect on corrosion. Typically, corrosion rates are high at lower pH due to acidic corrosion and at a higher pH, the corrosion can be caused due to a reaction known as caustic embrittlement. pH of waters can be locally affected by artificial influences such as discharges from oil refineries and chemical plants.

Accelerated low water corrosion (ALWC) of steel structures is found in certain regions. ALWC is an aggressive form of microbially influenced corrosion that may occur on steel in estuarine and marine structures. The rate of corrosion caused by ALWC can be ten times the normal rate of seawater corrosion. Sulphate reducing bacteria, which can thrive under marine growth, are a contributory element. ALWC is characterised by bright orange surface deposits underlain by black slime. The effects are most prevalent in tidal waters and ALWC is often observed around the low water level.

Marine organism can also be the cause of bio-corrosion of steel parts. This bio-corrosion affects both the submerged parts of the buoy and the mooring chains.

Cathodic protection is a means of reducing corrosion in metallic structures and major components exposed to seawater. The system provides sacrificial anodes that corrode in place of the metal. This can reduce the rate of corrosion.

Figure 24 Sacrificial anodes before and after of spar buoy installation

AtoN structures can be painted, wrapped with a bituminous tape or sheathed in a protective jacket to minimise the contact of seawater with the structure.

5.3.3. ABRASION

Mobile sediments made up of abrasive sand such as basalt, can have an abrasive effect on all submerged materials including fixed, marine based AtoN foundations and floating AtoN mooring chains. Abrasive sediments can be moved by the mass of water in stormy weather or speedy current tide and can damage protective coatings and abrade the AtoN material. In steel, this can lead to an entry point for corrosion of bare metal.

5.3.4. MOORINGS

Steel mooring chains can be damaged by the grinding of granular sediments between the chain links and can undergo abrasion when in contact with the seabed they affect the lower slice of the mooring line. In quiet sea conditions, it is the movement of the ground mooring chain on the sea bottom that undergoes this abrasion while the buoy moves.

Abrasive particles in suspension in the water can damage mooring lines made of steel chains or synthetic ropes. This situation is generally encountered in rivers or estuaries, carrying these particles. Extremely turbid waters can also make inspection and maintenance of fixed, marine AtoN difficult and may require the use of specialist divers who are familiar with the structure.

Figure 25 Chain wear

Maintenance operations will gather information over time regarding the rate of corrosion of steel chains and other mooring components. This allows the material thickness to be sized accordingly, allowing for sacrificial loss of material. This may necessitate more regular replacement of the mooring system or at least more regular inspections. Type of mooring selection should take this factor into consideration. An alternative mooring in these locations may reduce the corrosion, subsequent maintenance and increase the lifespan. This may include heavier moorings, different material types (steel grades, synthetic etc.) and should be chosen to suit the site.

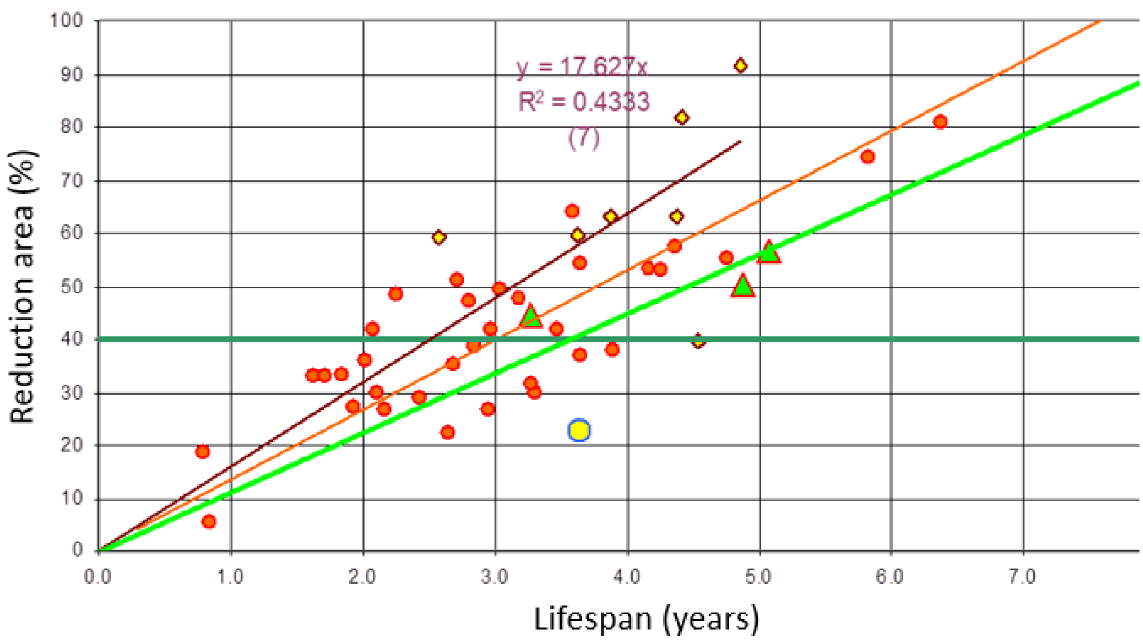


Figure 26 Statistical measurement of chain wear

5.4. ECHOLOGICAL IMPACTS

Extreme environmental conditions, such as heatwaves, severe storms, prolonged droughts, level water saltation and density have profound ecological impacts on AtoN elements/systems.

These conditions can lead to habitat degradation, loss of biodiversity, and shifts in species distribution, in other hand might rapidly growth of sea growth and moulds.

For instance, rising temperatures can stress ecosystems, making it difficult for some species to grow rapidly, while altering plant growth patterns and affecting AtoN.

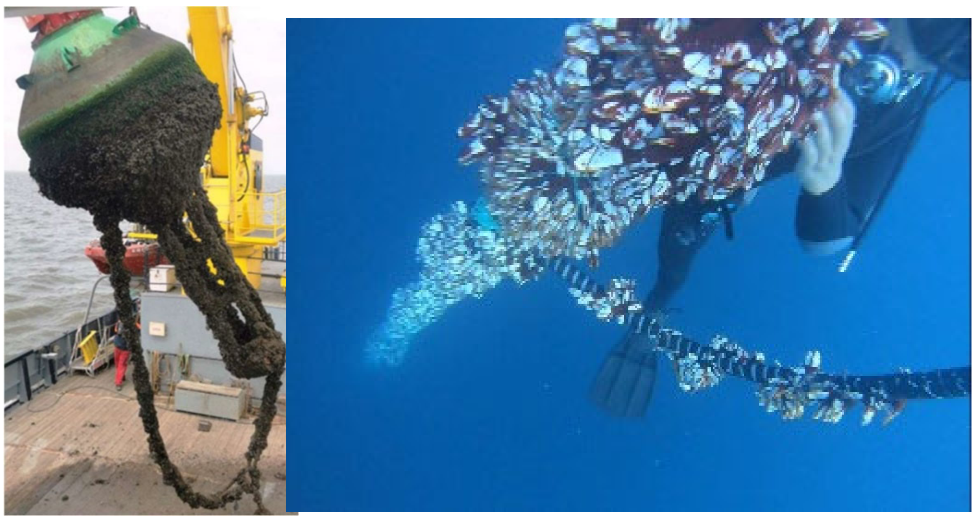
Extreme weather events can also disrupt ecological processes, such as marine growths and Moulds, leading to cascading effects throughout the AtoN structure.

Understanding these impacts is essential for effective conservation and management strategies in the face of provision AtoN services.

5.4.1. MARINE GROWTH

Very warm seawater, associated with extremely hot and humid climates, can cause the rapid growth of dense and sometimes destructive marine organisms on both buoy moorings and the foundations of fixed structures. This can increase the frequency and cost of maintenance, can adversely impact buoyancy and accelerate corrosion.

Fouling from marine growth may be so severe that the buoy will have to be lifted and cleaned at increased regular intervals. During servicing, fouling should not be removed with mechanical scrapers as these can cause serious damage to the protective coating and shorten the life of the paint system. Marine growth should be removed with water jetting using a suitable pressure that will not damage the protective coating (see Guideline



G1077).

Figure 27 Marine growth

Guideline G1036 describes the impact that AtoN have in the environment and establishes the general recommendations for the management of waste, acoustic and luminous pollution, and the protection of habitats, flora and fauna, amongst others.

5.4.2. BIRD FOULING

Bird fouling is an issue affecting all AtoN, causing accelerated corrosion and deterioration of surface colour in all types of materials, and but in extremely hot and humid environments the combination of heat and UV can harden it and make it particularly difficult to clean remove.

Bird fouling (guano) derives primarily from birds landing and roosting, or attempting to land and roost, on an AtoN site. The discharge of faecal matter is the primary contaminant, but it can also be related to shedding of feathers, nesting debris and presence of rotting food. Bird fouling can have, among others, the following detrimental effects on AtoN sites:

- Excessive guano coverage on lanterns or optics, causing obstruction of the light source, resulting in reduced nautical range or in severe cases, total outage of the AtoN.

- Excessive guano coverage of solar panels, reducing the active area of the panel and severely limiting battery charging capacity, which can lead to negative effects on night-time signalling functions of the lantern and may eventually lead to total battery discharge and subsequent outages of the AtoN.
- Guano coverage on lighthouses or other daymarks can cause a change in the colour, severely affecting the ability of that AtoN to provide clear information to the user.
- Guano is highly caustic and can increase corrosion rates on AtoN structures, fittings and components, resulting in accelerated deterioration and reduced life span, higher maintenance costs and unsafe structures.
- Bird fouling on any site generally pollutes and contaminates, causing a number of associated issues for maintenance teams.

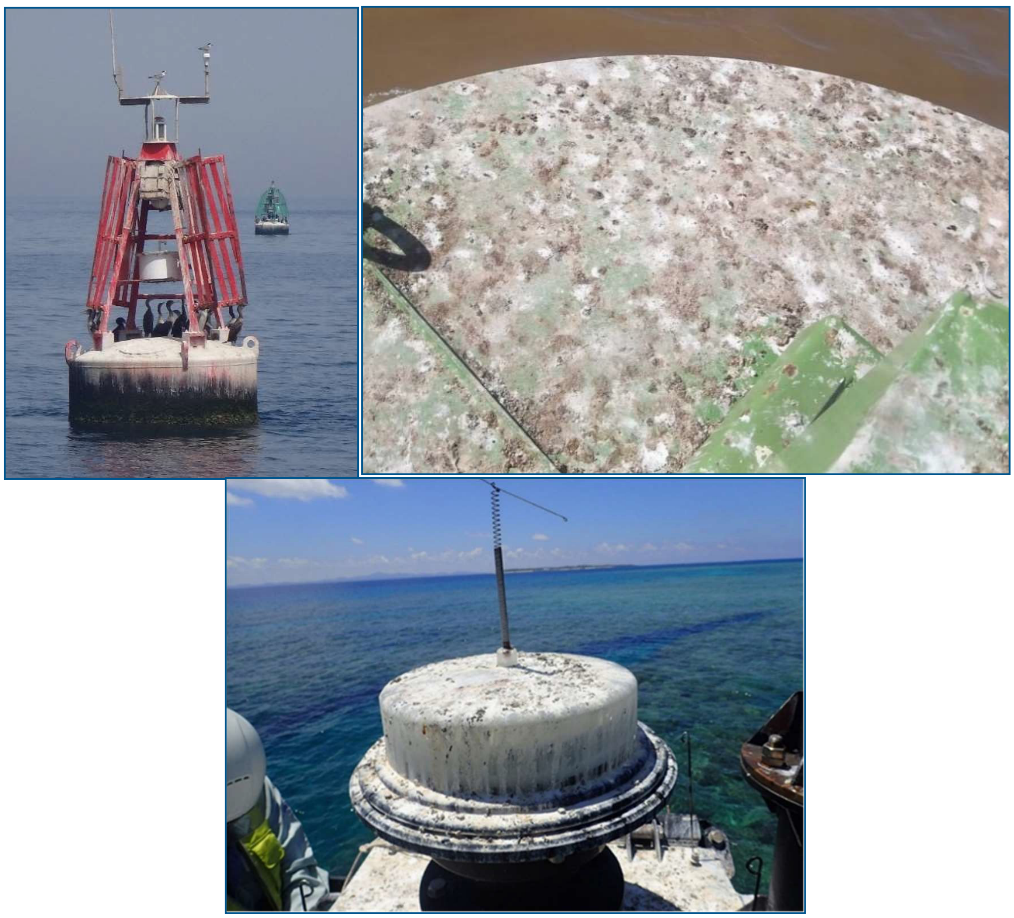


Figure 28 Bird fouling on buoys and lanterns

Guideline G1091 Bird deterrent and bird fouling solutions describes methods to mitigate bird fouling on AtoN structures, such as implementing commercial products and deterrent systems, the application of engineering solutions, structural changes or revised installation methods where it is impossible to deter bird colonies. The exact method should be tailored to suit a particular site, situation and, in some cases, may need to be designed to suit the visitation habits of a particular species of bird.

A further consideration is that in hot climates is that guano can be baked on due to the extreme heat, making it very difficult and time consuming to remove. Intensive cleaning can create dust which poses inhalation related health and safety risks to workers. Bird deterrents should be used wherever possible to prevent this problem.

Some ways used to prevent this effect:

- Install the most appropriate bird deterrent for the location and bird species – this action prevents the bird fouling.
- Paint over the surface colour with a special ant graffiti product – this action will not prevent the bird fouling but ensure it is easier to remove with water pressure.

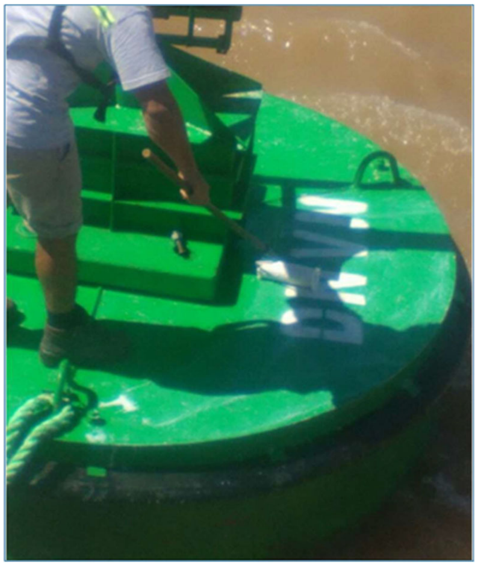


Figure 29 Anti-graffiti product application and Example of AtoN configuration to deter bird roosting

5.4.3. Mould

Mould can be an issue experienced in high humidity environments. Mould can affect conspicuity of structures and daymarks, can cause deterioration of equipment and can cause slippery and unsafe conditions for workers. Mould can be combated by the use of high-gloss paint systems. In some cases, the only suitable control measure is more regular cleaning. Adequate air flow and ventilation can also help reduce mould.

5.5. HIGH ULTRA-VIOLET LEVELS

High Ultraviolet (UV) light levels in prolonged periods of strong sunlight can cause degradation of material properties including colour retention, plastic lenses, steel and plastic buoys, structures, coating systems and electrical/electronic equipment and fixtures. UV exposure can also be a significant risk to workers and requires careful management and specific mitigation controls.

Careful design considerations should be made when using plastic buoys in very hot climates (equatorial regions) as some effects could severely impair the performance of the equipment. The following are examples of problems that may result from prolonged exposure of plastic material to high temperature. They should be considered to help determine if the design is suitable for the application (this list is not intended to be exhaustive):

- Parts bind or corrode from differential expansion of dissimilar materials.
- Materials change in dimension, either totally or selectively.
- Packing, gaskets, seals, etc. become distorted, bind, and fail causing mechanical or integrity failures.

- Gaskets display permanent set.
- Closure and sealing strips deteriorate.
- Shortened operating lifetime.
- Colour fading, cracking or crazing of plastic materials.

Figure 30 High Ultraviolet effect on red buoy

The high rates of solar radiation (UV) in these regions can cause surface temperatures to increase by 15 to 30°C above ambient temperatures and surface temperatures can reach 80°C. As a result, it is important to consider studies made by various manufacturers comparing material degradation, reaction and resilience under these extreme conditions (see Guideline G1006). Maintenance of lanterns should include inspection to re-verify the light range as this can be affected by high UV.

5.5.1. CHOICE OF MATERIALS RELATING TO UV AND SAND-BLASTING EFFECTS

Ultra-violet radiation can affect the properties of both external and internal materials of an AtoN. The effects can result in a reduction in performance and/or lifetime of an AtoN.

Appropriate product selection and addition of redundancy might both need to be considered where the effects of UV radiation or surface abrasion by sandstorms could be significant. UV radiation could affect AtoN properties such as surface colour or optic transmissivity and might also degrade internal components of the optic head. Sand- storm abrasion could damage surfaces, such as those of optic elements, also leading to reduced optic transmissivity.

5.6. HUMIDITY AND PRECIPITATION

High humidity environments present issues to both AtoN equipment and personnel. Water ingress and the effect of humidity and the build-up of condensation in AtoN equipment can cause electronic failure, thereby negatively impacting availability, reducing reliability and impacting service life. Increased humidity can also have a negative effect on the worksite, worker comfort and output efficiency, thereby increasing the risk of incidents and impacting quality.

In order to protect the integrity of the equipment installed in areas of extreme humidity, increase its lifespan and ensure its reliability, it is necessary to prevent the condensation cycle from starting during the installation process. In order to achieve this, an IP (Ingress Protection) level should be specified

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impacting availability, reducing reliability and impacting service life. Increased humidity can also have a negative effect on the worksite, worker comfort and output efficiency, thereby increasing the risk of incidents and impacting quality.

Highly humid and saline environments cause corrosion of the AtoN structure and its components increasing the probability of malfunction. It is essential to guarantee the water tightness of enclosed AtoN devices to avoid the generation of condensation cycles that can damage the components.

5.6.1. WATER INGRESS

AtoN operating in extremely hot climates are susceptible to moisture and water ingress due to a number of factors. These include poor sealant design, inappropriate material selection, mishandling of AtoN or poor assembly procedures.

- Poor Sealant design: Consideration should be given to the differential thermal expansion rates of the various materials used in order to ensure good sealing integrity to reduce any moisture ingress. Thought should also be given to the protection of the electrical or electronic circuitry by the possible use of conformal coatings, resin gel together with the use of water-resistant connectors and glands. In the case of navigation lights, self-contained or stand-alone it is recommended that a minimum IP rating of IP 67 is requested from the supplier.
- Material and component Selection: When selecting materials to be used, consideration should be given to the maximum operating temperatures on site, the UV protection rating of the synthetic materials used, the coating or paint to be applied and the IP rating of the cabling glands.

It should be a consideration that during final assembly the atmosphere within the manufacturer's production facility be as dry and controlled as possible in order to reduce the trapping of humid, moist air inside the navigation equipment. Any on site assembly needs to carefully consider the cabling route in and out of the AtoN to ensure the manufacturers IP rating is maintained. This will reduce the incidence of water ingress via cable entry.

The UK and Irish General Light Authorities produced a detailed report *Building Conditioning of Lighthouses, Accommodation, Outbuildings and Associated Structures (IGC5 TASK GROUP REPORT, 2009)* that described these effects in some detail, with suggested monitoring approaches (see Guideline G1007 *Lighthouse Maintenance*).

6. SPECIAL FEATURES OF WORKING IN EXTREME ENVIRONMENTAL CONDITIONS OR REMOTE REGIONS

Working in extreme environmental conditions and remote regions presents unique challenges and opportunities. Professionals often face harsh weather, limited access to resources, and isolation, which can impact safety and well-being. However, these environments foster resilience and adaptability, encouraging innovative problem-solving and teamwork. Specialized training and equipment are essential, and the experience can lead to a strong sense of accomplishment and camaraderie among team members. Additionally, working in such settings can provide valuable insights into sustainability and the impact of climate change on ecosystems.

The following aspects illustrate the consideration which might assess to work on such challenging conditions.

6.1. LIFE CYCLE CONSIDERATIONS

A project in regions with extreme environmental conditions normally takes longer to develop and implement than it takes in more densely populated areas. The remoteness, the rarity of specialized resources, the lack of support infrastructure, the complexity of transportation, dangers from wildlife and the environmental conditions are many elements that need to be seriously considered for the successful delivery of a project.

In many cases, the delivery of a project may take more time before being finalized in remote areas with extreme environmental conditions depending on its complexity, location and size. Completion dates are vulnerable to postponement due to extreme weather conditions.

For this reason, it is important to analyse each activity required in the delivery of the project and ensure its feasibility in remote areas. Care should be taken especially with regard to the following elements:

- AtoN System selection.
- Land and soil survey.
- Authorizations and permits.
- System design (structure, power system, AtoN equipment…).
- Material acquisition.
- Quality control.
- Material and staff transportation.
- Staff welfare, lodging facilities, health and safety.
- Construction period.
- Equipment suitability to use during the task.
- Local material and resources availability.
- Operation and maintenance requirements.
- Hazardous materials management.

6.2. PROJECT PLANNING

Implementing projects in extreme environmental conditions is a challenge that requires a lot of planning. It is important to secure resources for critical activities well in advance of work. The solutions when something is not working as planned are either limited, or extremely expensive to implement. For this reason, it is recommended to refer to experienced people in that type of projects in remote locations for assistance in project planning. This includes personnel from the AtoN authority and also consulting firms and contractors when appropriate.

Using those resources does not guarantee that everything will go well but brings a higher level of confidence. The involvement of the people of the local communities is another way to improve the project outcome, considering their knowledge of the conditions that may affect the delivery of a project. They can normally help regarding the best construction period, the availability of local resources and the possibilities and challenges concerning transportation.

6.3. LOGISTICS

6.3.1. TRANSPORTATION

Remote region sites are difficult to access with few roads and airports. There are a limited number of local service providers. In order to access and construct an AtoN site, various means of transportation can be used; commercial service providers when available and more likely your internal organization's resources: ships, helicopters, small vessels, etc, but in remote regions, options are rather limited. Many areas can have access restrictions due to local environmental protection regulations such as species at risk, among other challenges.

Then, remoteness regions require more planning than other areas. Construction crews should ensure they understand the issues they may encounter.

6.3.2. OUTSOURCING

Outsourcing transport should ensure companies are qualified to operate in remote regions. The dangers and complexities need to be well understood. To make this option feasible, the requirements of the job must be very well understood and described in advance of tendering the job. This option is not generally recommended due to the shortage of local site information.

6.3.3. AVAILABILITY OF RESOURCES

Given the great distances and limited resources available in remote regions, it is not practical to provide Aids to navigation with the same density and coverage as is possible in zones closes to urban centres. It is therefore necessary to focus resources on providing maximum benefit for minimum cost, particularly in terms of maintenance requirements.

One cannot rely on sourcing the equipment or materiel locally. Supplies are limited in remote regions, and generally can only support the local community needs. The logistics plan should make allowances for the resources needed and contingency on each of these items. With respect to equipment, you should carry repair kits and spare parts to be able to perform repairs on site.

6.3.4. ABOUT FUEL, MATERIALS, ATON EQUIPMENT AND MANPOWER

- **Fuel**

In the preparation of any project in extreme environmental conditions, one should consider the limited availability of fuel. It is always important to consider the requirements and determine the best solutions to limit the quantity of fuel required during and after construction.

Depending on the conditions, transportation of fuel can easily cost 8 to 10 times the cost of the fuel itself. This factor may influence the way the project will be planned and implemented. Experience has also shown regular issues with the quality of the fuel in remote locations, so filtering the fuel prior to filling the vehicle tanks and having spare fuel filters for the machinery is advisable.

- **Materials**

It is sometimes possible to find raw material that would be suitable for construction not too far from the construction site. It is also good to investigate the availability of equipment in the area to limit the need to bring the heavy machinery from outside. Municipalities, local contractors and sometimes large contractors from outside doing work in close areas may already have what is needed and reduce your need to bring everything with you. They may also supply local manpower and reduce your need to bring your own workers.

One other possibility to reduce the need for fossil fuels is the pre-fabrication of the material. This way of working will limit the time required on-site thus the need for fuel for equipment and accommodation. However, this may increase the need for lifting equipment of higher capacity and require more space on board shipping vessels.

- **Spare parts**

Working in remote locations brings challenges that are not even considered in densely populated areas. Authorities should make sure the organization responsible for the site construction has brought sufficient spare parts and equipment should something go wrong. The lack of a spare part or tool will increase the cost to source spare equipment and cause delays in the delivery of the work. In order to reduce the level of risk associated with the lack of spare parts, a risk analysis of the equipment on-site, the work methods, the soil conditions, the various resources available in the area and the remoteness of the work should be done to determine what spare parts should be brought to the work site.

6.3.5. RELIABILITY AND REDUNDANCY CONSIDERATIONS

Due to the difficulty of accessing remotes sites, the implementation of redundant equipment needs to be considered for any active system. Many factors should be considered before making the decision to install redundancy, noting that each additional item of equipment, or electrical connection, introduces another potential point of failure. The importance of the aid to navigation in the AtoN system, the reliability of the planned equipment under normal conditions, the level of knowledge in terms of performance of this equipment in extreme climate, the required/expected availability, the capital and maintenance cost, and the impact of a failure are many elements to consider before making a decision to duplicate equipment or not.

Redundancy will come at an increased up-front cost but helps avoid the costly repercussions of AtoN system failures and repairs. It also ensures that availability is achieved and maintained despite the extreme environmental conditions.

The minimum standards for the performance of AtoN, AIS, remote monitoring and other electronic AtoN should be established with consideration to seasonal extremes environmental conditions, which can cause significant effects on performance.

Data and information on failures, reliability and other operational issues can prove critical to a competent authorities' future purchasing decisions and changes to procedures and methods of working.

6.4. REPAIR AND MAINTENANCE STRATEGIES

Repair by replacement – Due to the extreme conditions at the AtoN, consideration should be given in the design and installation to allow ease of component or module replacement to reduce the time required to spend on site.

Planned maintenance - The cost of repairs will be high due to the difficulties in access to the AtoN, therefore the cost of any planned maintenance can be offset by the reduction in the likelihood of a failure. Schedules to replace entire components more frequently than on an easily accessible AtoN should be considered.

6.5. MAINTENANCE AND WORK SCHEDULES

Maintenance and work intervals should be established by the responsible parties to suit their requirements or according to their asset strategy. Scheduling of these intervals should be managed to avoid extreme conditions wherever possible. In some regions, temperatures may be so extreme it is unsafe for workers to work on site in exposed conditions for long periods of time and it is therefore more appropriate to schedule site visits for more suitable seasons.

Likewise with seasonal wind or weather patterns, monsoons, cyclones or strong winds may cause dangerous sea states and conditions that make it unsafe to work on site. In these instances, work should be scheduled for seasons when sea conditions promote the safest working conditions. Alternative means of access, such as helicopter access, may be considered for these situations.

Heavy seasonal rains in some areas may make it impossible to work safely and efficiently on an AtoN site. Wet seasons often have an accompanying dry season, which could be utilized instead.

The impact of these environments on AtoN equipment may necessitate higher site visit frequencies than would normally be expected elsewhere in the world. Accelerated corrosion, lens degradation, higher rates of marine growth, dust coverage, the effect of heat on electronics, etc. are all issues that might require shortened site visit intervals. This obviously has cost implications, related to both frequency of visits and equipment replacement. The cost benefits need to be explored by the responsible parties.

6.5.1. INSTALLATIONS IN POLAR REGIONS

When work needs to be done on permafrost, it is important to take some precautions to prevent it from melting. Removing vegetation will immediately cause the soil to melt, especially if the work is conducted in summer where the sun shines almost 24 hours a day. This may impact the areas where roads need to be built as well as the work site. If the permafrost melts, the possibility of landslides increases drastically.

As the number of ships travelling in Polar Regions is limited, it is important to schedule and reserve ships to carry material early in advance. The shipping season in some areas is quite limited, so the lack of planning may mean a long delay in the project.

In some cases, winter transportation may be the only solution to reach some sites. Ice roads built on lakes and frozen ground may sometimes be the only solution to bring heavy machinery to construction sites.

A disadvantage of working in a Polar region is the short construction period which is sometimes limited to a few summer months. However, as the sun never goes below the horizon during that period, it is possible to plan the work on 2 or 3 shifts a day, giving more time to complete the work.

During the planning of the project, consideration should be given to the possibility of delays due to weather conditions. It is particularly true if the project requires the use of air transportation.

6.5.2. PERIODIC CHANGE OUT OF EQUIPMENT

Service periods for AtoN equipment may need to be reduced due to the negative effects of extreme environmental conditions. This could be due to a number of reasons, including but not limited to lens degradation (either by UV or sand/dust abrasion), water ingress and condensation in electronics. The issues may vary according to a region’s climate, or even macro-climate, and the service and change out periods should be adjusted to suit.

Wherever possible, selection of appropriate equipment should be used to reduce the maintenance required, which will reduce the costs associated with more frequent site visits. Upfront costs could be offset by reduced maintenance effort.

6.5.3. COMMUNICATION WITH THE SITE DURING CONSTRUCTION

During a project in remote regions, it is important to consider the availability of communications. It is generally required to stay in contact with the support team of engineers who may not be on-site, especially if something goes wrong. Voice communication is essential for safety reasons, however it may also be necessary to transfer data and satellite communications may offer a solution.

In the event the main communication system fails, there should be a back-up strategy to keep the site team in contact with the outside world, especially in the case of an emergency on site.

6.6. HUMAN FACTORS, HEALTH AND SAFETY CONSIDERATIONS

6.6.1. HUMAN FACTORS

Human factors in extreme environment are one of the most critical aspects of AtoN delivery. Human performance is severely affected in uncomfortable working environments and must be attended to in order to ensure safe and reliable delivery.

Existing legislation pertaining to workplace safety should always form the basis for safety management and worker welfare; however the conditions associated with these extreme environments do exacerbate risks and therefore require additional appropriate controls. In some parts of the world, the impacts of religious and cultural restrictions need to be taken into account. Guideline G1092 provides guidance on safety management concepts.

6.6.2. THE WORK ENVIRONMENT AND FATIGUE MANAGEMENT

It is important that workers understand the risks specific to working in extreme environments due to it accelerate and increase the risk of worker fatigue. Supervisors and team members should be able to identify and treat fatigue and there should be procedures in place to do so.

Fatigue management may be controlled by the following;

- Regular hydration. This may include water, oral rehydration salts or other means.
- Defined work and rest periods.
- Distribution of work during suitable hours and shift management.
- Rotation of staff.
- Awareness and communication on the risks associated with fatigue.
- Protection of solar radiation, ice, snow, cold weather, others.
- Provision of rest areas.

The extreme temperatures can be hazardous for works that require a strenuous and prolonged physical activity outdoors.

In zones where the AtoN maintenance task be made with hot climates, Heat index values may be a useful guide to managing work activities in these environments. The heat index value, also known as real feel, either in Celsius (ºC) or Fahrenheit (ºF) according to the country, measures the real feel when the relative humidity combines with the real air temperature.

In some countries, this heat index (or real feel) can be used to set work alerts when temperatures and humidity exceed certain levels. These alerts should be set according to any existing legislation or where that is not available, according to internally set thresholds.

6.6.3. AVAILABILITY OF PERSONNEL

Personnel should be suitably trained and competent to work in remote areas and be physically fit. Minimalist crew numbers are not recommended. Insufficient staff numbers could compromise the task whilst one too many will not – the task is too important and expensive to be put at risk by short staffing.

Accommodation will generally need to be provided for staff welfare, this may be on a ship or purpose built for the duration of the works.

6.6.4. TRAINING

Introduction of new services and new ways of operating requires training and familiarization, and this will need to be tailored to the special conditions in Regions with extreme environment.

All workers should be familiarized through training, induction and awareness programs, of the risks that work in extreme environments present to themselves and their co-workers.

There is some training available that contains components specific to working in these environments and this could be utilized where available, as an additional control.

Personnel nominated to work in these environments should be able to cope with the conditions and this may require acclimatization, especially if workers come from different locations.

Appropriate supervision and medical support (first aid kits, first aid officers) should be available on all work sites where extreme environment is an issue. These environments pose particular health risks and medical support should be appropriately equipped and trained.

6.6.5. SAFETY PLAN

A project safety plan should be developed initially that will cover activities during the design and construction phases, through to the “ready-for-operations” stage of the project.

Management during the operational phase should focus on procedural and administrative aspects. Hazard management techniques such as an effective permit to work system, job hazard analysis, environment, health and safety performance monitoring system and contingency planning should be implemented to address operation-specific hazards identified in formal risk assessment and safety engineering studies undertaken during the design phase.

Formal maintenance management systems should be established to ensure safe and environmentally sound operations of the facilities.

In the event that an external contractor performs the operation/maintenance activities, it is recommended that the contractor develops an operation and safety plan for his activities and this plan should be integrated in the project safety plan.

The development and implementation of a health and safety plan will ensure efficient and safe activities during all phases of the project, from concept, development through to construction, operations and abandonment.

The elements identified below could be considered during the development of this plan:

- Leadership/responsibilities/accountability.
- Managing risk.
- Emergency preparedness.
- Assuring competency.
- Conducting business responsibly.
- Ensuring contractor and supplier performance.
- Managing incidents.
- Documentation management.
- Reporting Health and Safety performance.
- Evaluating system effectiveness.
- Fuel transfer and storage.
- Garbage disposal.
- Leaks from machinery.
- Emergency response in case of fuel spill.

* Risk plan for wild animals.

For the activities in remote areas, emphasis should be placed on the Medical and First Aid services available on-site, the communications with medical services as well as medical evacuation from the work site.

* Medical/First Aid services on-site.
* Medical evacuation.
* Communications with emergency services.

6.6.6. PERSONAL PROTECTIVE EQUIPMENT (PPE)

PPE is a requirement on any worksite, regardless of conditions, however there are some special considerations in environments with extreme climates. PPE that may be conventional in other work environments may not be suitable for work places affected by extreme temperatures as they may increase worker discomfort.

Tool and equipment selection and storage is also an important consideration. Electrical tools may behave differently in extreme environmental conditions. Appropriate selection and storage may avoid these issues and contribute to avoid thermal stress.

6.6.7. OTHERS HUMAN HEALTH AND SAFETY IMPACTS

Dust and smoke have a harmful effect on people's health. They can cause eye irritation and nasal congestion; they can also affect lungs and cause severe headaches. Both phenomena can particularly affect those people with existing allergies and asthma and affect people's sense of smell.

Some hot and humid climates result in high vegetation cover and growth. The need to constantly control and clear excessive vegetation so that does it not obstruct the operation of an AtoN can be an issue in these regions.

The presence of dangerous fauna, such as marine stingers, snakes, scorpions, spiders, venomous insects, crocodiles and sharks can present serious risks to workers and the ability to safely access, operate and maintain AtoN.

Nesting birds can be aggressive and dangerous to maintenance workers when working at height.

The presence of protected species may require modification to maintenance plans and in some situations may preclude site visits for a temporary period.

Figure 30 Risks of AtoN maintenance associated with wildlife

7. ENVIRONMENTAL MANAGEMENT

Extremely environmental conditions are often characterized by specific environmental profiles and AtoN can be located in places of ecological importance. This should be taken into account when working in these areas. The Guideline G1036 Environmental Management provides guidance on how to manage environmental impact.

The increased maintenance needs of these environments does result in a higher frequency of visits and interactions with local habitats and therefore a higher level of impact. This can be considered during the design phase and when assessing risks and developing controls.

7.1. ENVIRONMENTAL PRECAUTIONS

When handling fuel transfer and storage, it's crucial to implement environmental precautions to minimize risks. Here are key considerations:

7.1.1. FUEL TRANSFER & STORAGE

Containment: Use double-walled tanks and spill trays to prevent leaks.

Monitoring: Regularly check for leaks and ensure proper ventilation.

Training: Provide training for personnel on safe handling practices.

7.1.2. GARBAGE DISPOSAL

Segregation: Separate hazardous waste from regular trash.

Disposal Methods: Use approved disposal methods for hazardous materials, such as recycling or incineration.

Documentation: Maintain records of waste disposal to ensure compliance with regulations.

7.1.3. Leaks from Machinery

Regular Inspections: Conduct routine checks on equipment to identify and fix potential leaks.

Maintenance: Keep machinery well-maintained to reduce the risk of leaks.

7.1.4. Emergency Response for Fuel Spills

Emergency Plans: Develop and communicate clear response plans for spills.

Training: Train employees on spill response procedures and the use of containment tools.

Equipment: Have spill kits readily available, including absorbent materials and protective gear.

Implementing these precautions helps protect the environment and ensures a swift response to incidents.

7.2. SECURE STORAGE OF MATERIAL

Depending on the timing and the method selected, it may be necessary to ship and store the material in advance to a close local community. It is important to ensure it is stored in a secure place. Sensitive equipment (e.g., lights, power systems, electronics …) may need to be protected from the environment and should not be stored outside without appropriate protection.

7.2.1. Petroleum

If there is a need to store petroleum or any other chemical product, consideration should be given to the protection of the environment. Fuel drums for example should be stored on special pallets or in special containers to prevent any leak. National, regional and local regulations concerning the storage of petroleum products must be followed to prevent any possible litigation.

7.2.2. Paint

Paint and other coating systems are also often affected by extreme temperature and humidity, which can shorten lifetime and alter the properties and performance of paint, particularly mixed two-pot/two-part paints. The impact or deterioration is often not noticed until the time of application.

7.2.3. Batteries

Batteries suffer from ageing effects. Minimization of these effects requires appropriate storage and maintenance methods, with specific details dependent on the particular battery technology and the temperature of region. Similarly, self- contained lanterns should be provided the same considerations. Examples are following;

Example 1: Lead-acid GEL batteries retain maximum capacity during storage if maintained at or below the typical specification temperature of 25°C and if recharged at appropriate intervals. The required recharge interval dramatically reduces with a modest increase in ambient temperature.

Example 2: When storing self-contained lanterns, care is required to ensure that these are deactivated and therefore not discharging the internal battery. This is especially important in hot or humid climates, where the temperature may require more regular checks and charging of batteries.

In some cases the battery or self-contained lanterns warranty could be voided if the manufacturer's recommended storage and maintenance procedures are not complied with.

Another element to consider is the possibility that your material attracts large animals and be damaged before you return to the site. Additional physical protection may be required in that case. The curiosity of animals should never be underestimated. Bears can smash battery cabinets and the batteries inside them. Sea lions, seals, and bears have a penchant for chewing the insulation off unprotected electrical wires. Whenever possible an AtoN should be enclosed and the wires run within its construction or adequately protected.

7.3. CO-ORDINATION WITH LOCAL COMMUNITIES

In order to maintain good relationship with the local communities, the importance of communication cannot be understated. They should be informed of the goal of the project, the planned work, the immediate and long-term impact on their community and of any commitment the organization is willing to make (e.g., paying a rent for the use of the land or acquire the land).

Normally, permits are required before proceeding with any project concerning native lands or local government. All required permissions should be received before starting the work in order to ensure good collaboration and prevent confrontation. Explaining how this project will be beneficial to the navigation and indirectly to the communities should help getting the go ahead.

Consideration should also be made to ensure the project doesn't affect the lifestyle of those communities by negatively affecting the wildlife habits that may affect the subsistence of the local people. Examples may be blocking the passage of grazing animals or diverting the flow of a river affecting the fish habitat.

In many cases, being able to demonstrate that the implementation of aids to navigation will generate work for local people will help the discussions. Adding local acquisition to the project may also influence the time required to get the expected permits.

7.3.1. CONTRIBUTION OF LOCAL RESIDENTS (EMPLOYMENT, LOCAL KNOWLEDGE)

The knowledge of the local population may be an important success factor in the delivery of a project in the extreme environmental conditions regions. Involving the officials of the communities, local contractors or local engineering firms may facilitate the planning and construction of a project. In many cases, the local people know who has material, machinery and transportation capabilities in the area. Local acquisitions should be utilized wherever possible; this may reduce the need to import equipment and material at high cost.

This would also increase the employment in the local villages, which could affect positively the perception of a project in the community.

7.4. IMPACT DAMAGE

Macro-waste can be natural such as tree trunks or tree branches, or artificial such as drifting fishing nets or drifting steel cable. They are mainly carried by rivers. They can get caught in mooring lines made of chain and generate significant stress. They can also damage synthetic mooring ropes.

One solution on inland waterways is to deploy passive debris collectors (PDC) positioned appropriately on upstream channels to collect debris for removal.

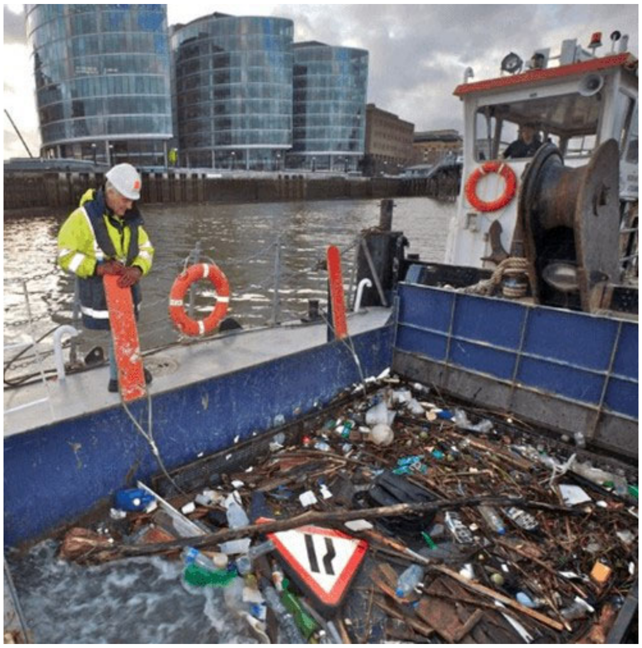

Figure 31 Example of passive debris collector positioned in waterway

8. QUALITY CONTROL

A robust quality control system is critical in extreme environmental conditions where conventional standards may not have taken into consideration in which the AtoN are installed and operated.

There are a number of considerations:

- The impact of human comfort and its effect on their performance, can compromise the quality of their work. This is a major factor in extreme climates. Preparation of equipment and installations in controlled environments, to minimize working on site under difficult conditions, can help mitigate this issue. Controlled conditions allow predictable quality, increased comfort for workers, and an overall cost efficiency.
- In the event it is not possible to undertake substantial preparation off-site, it may be possible to control the on-site workspace as much as practical in order to provide a more tolerant, stable and comfortable environment.
- Equipment ratings on 3rd party products should be scrutinized and verified before entrusted into the field. The specific extreme conditions in these environments may not have been factored into tests and some level of trialling is encouraged before a more extensive use in the field. The level of testing, and the conditions under which equipment is tested, must be relevant to the environment in which it is installed.
- Communication and feedback between manufacturer / suppliers, competent authorities / service providers and stakeholders / end-users is important in rectifying issues with equipment performance operating below extreme environmental conditions.

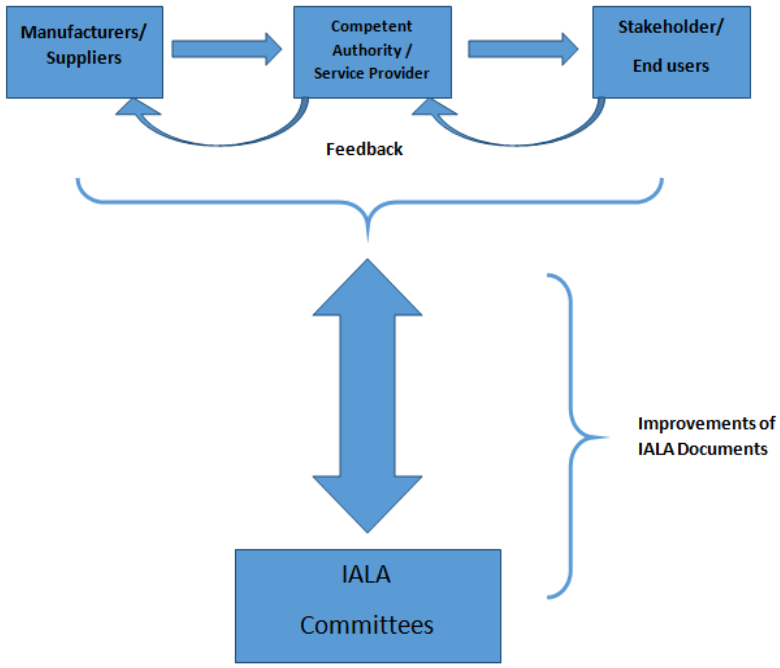

Figure 32 Communication and feedback between (Manufacturer/suppliers), (Competent Authority/ Service)

9. DEFINITIONS

The definitions of terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA dictionary) and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

10. ABBREVIATIONS

Ah	Ampere hour
AIS	Automatic Identification System
ALWC	Accelerated low water corrosion
App	Application
ASM	Application Specific Messages
AtoN	Aid(s) to Navigation
C	Celsius
Circ.	Circular (IMO document)
DMA	Danish Maritime Authority
DSC	Digital Selective Calling
GEO	Geo-stationary Orbit
GNSS	Global Navigation Satellite System
GPS	Global Positioning System (USA)
HAT	Highest astronomical tide
HEO	Highly Elliptical Orbit / High Earth Orbit

HF	High frequency (3 – 30 MHz)
Hydro.	Hydrography / hydrographical
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IMT	International Mobile Telecommunications
IP	Ingress protection
ITU	International Telecommunication Union
LAT	Lowest astronomical tide
LED	Light Emitting Diode
LEO	Low Earth Orbit
LNG	Liquefied Natural Gas
LRIT	Long Range Information & Tracking
LTE	Long Term Evolution (Standard)
MBS	Maritime buoyage system
MEO	Medium Earth orbit
Met	Meteorology / meteorological
MF	Medium frequency (300 kHz to 3 MHz)
MMSI	Maritime Mobile Service Identity
MSI	Maritime Safety Information
NAV	Sub-Committee on Safety of Navigation (IMO)
NAVTEX	Navigational Telex
NGO	Non-governmental organization
NiCd	Nickel Cadmium
NM	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration
PE	Polyethylene
PNT	Position, Navigation and Timing
QA	Quality assurance
SAR	Search and Rescue
SCC	Solar Charge Current
SD	Software defined
SOC	State of Charge
SOLAS	International Convention for the Safety of Life at Sea
STC	Standard Test Conditions
UV	Ultra-violet
VDES	VHF Data Exchange System
VHF	Very high frequency (30 MHz to 300 MHz)
VTS	Vessel Traffic Services
W	watt
WiFi	Local area wireless computer networking
WiMax	Worldwide Interoperability for Microwave Access
WWRNS	World-Wide Radio Navigation System

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[22] Specific standards for hot climates regions– e.g., STANAG 2895
[23] Reference for the Canadian Foundation Engineering Manual - http://www.cgs.ca/engineering- manual.php?lang=en
[24] CSA-S37 (Canada) Reference for the CSA standard: S37-01 (R2011) - Antennas, Towers, and Antenna- Supporting Structures - http://shop.csa.ca/en/canada/structures/s37-01-r2011/invt/27013452001
[25] Presentation on the Maritime Cloud and the Arctic WEB, Omar Frits Eriksson, the Challenges of Providing AtoN Services in Polar Regions, Ilulissat, Greenland, 30 September and 4 October 2013
[26] Ice Navigation and the Electronic Age, Captain Patrick R. M. Toomey, Canadian Coast Guard (retired), 21 June 2012

12. ANNEX

Annex A – Conditions and negative effects matrix.

Annex B – Potential mitigation of environmental effects on AtoN matrix.

Annex C – General considerations about Navigation in Polar Regions.

Annex D – Example of demobilisation protocol – Cyclones.

Annex E – Example of Chilean tsunami experience and demobilization protocol.

ANNEX A CONDITIONS AND NEGATIVE EFFECTS MATRIX

Table A 1 has been developed to allow users to quickly identify the interrelation between the occurrence of extreme weather events (variables) and their impact on AtoN and their components, the impact on navigation, channel access, staff health and safety, or port operations, between others. Competent Authorities should consider the effects and improve and develop a strategy to mitigate these negative effects.

Table A 1 Conditions and negative effects matrix

Section	Extreme environmental conditions	Negative effects on: Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply
4.1	Wind	• Stability • Position – swinging radius • Mooring system, e.g., size of chain, mooring length, etc. • Lifespan of protective Coatings	• Stability of structure • Access to structure • Lifespan of protective coatings	• Vertical divergence (Buoys) • Damage/orientation (antenna) • Transmission of data	• Wind generators • Solar panels • Cables and transmission lines
4.2	Waves	• Stability • Position – swinging radius • Seabed contact in shallow waters • Mooring system, e.g., size of chain, mooring length, etc. • Chain wear	• Transmitted forces on the structure • Seabed (scour causing instability) • Access to structure	• Vertical divergence (Buoys) • Damage/orientation (antenna) • Transmission of data	• Wind generators • Solar panels • Cables and transmission lines • Battery enclosure (inundation)
4.3	Tidal levels	• Mooring system, e.g., size of chain, mooring length, etc. • Seabed contact in shallow waters	• Access to structure	• Ground based components (sand inundation)	• Ground based components (sand inundation)

Section	Extreme environmental conditions	Negative effects on:			
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply
4.4	Currents	• Stability • Position – swinging radius • Seabed contact in shallow waters • Mooring system, e.g., size of chain, mooring length, etc. • Accelerates wear on mooring components • Lifespan of protective coatings • Structure (impact) • Access to structure	• Erosion of coastline • Lifespan of protective • coatings • Structure (impact) • Access to structure	• Vertical divergence (Buoys)	
4.5	High temperature	• Degradation of protective coating systems • Thermal mechanical force (deformation)	• Degradation of protective coating systems • Thermal mechanical force (deformation)	• Reduction in service life	• Reduction in service life

4.6	Ice and Snow	• Position – swinging radius • Structure – visibility – occasional immersions • Loss of retroreflecting film on AtoN • Buoyancy • Structural integrity • Damage by hail	• Structure stability – damage or loss of AtoN (exceptionally) • Structural integrity • Damage by hail	• Loss of lantern, racon, antennas, sensors, etc. (Buoys) • Piling on lantern • Visibility of light (blizzard) • Transmission of data • Damage by hail	• Damage to power supply (Buoys) • Reduction of capacity – piling on solar panels • Influence on battery life • Cables and transmission lines • Damage by hail
5.1.1.2	Dust	• Reduce the performance of day marks • Degradation of protective coating systems	• Reduce the performance of day marks • Degradation of protective coating systems	• Visibility of light • Reduction in service life	• Reduction in performance
5.1.1.3	Fire and smoke	• Access to structure	• Access to structure • Destruction of AtoN	• Visibility of light	• Reduction in performance of solar panels
5.2	Coastal morphology changes	• Accelerates wear on mooring components	• Stability – Position		
5.3	Water conditions	• Corrosion	• Corrosion	• Corrosion • Visibility of light	• Corrosion of contacts and frames

Section	Extreme environmental conditions	Negative effects on:			
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply
5.4.1	Marine growth	• Buoyancy • Bio-corrosion • Colour recognition • Accelerates wear on mooring components • Degradation of protective coating systems • Excess weight for lifting • Increased maintenance	• Bio-corrosion • Colour recognition • Degradation of protective coating systems • Access to structure	• Reduces sensor • performance	
5.4.2	Bird fouling	• Colour recognition • Corrosion • Health hazard • Increased Maintenance • Access to structure (slips)	• Colour recognition • Corrosion • Health hazard • Increased maintenance • Reduced time window for access • Access to structure	• Visibility of light • Reduction in the performance of the lens	• Reduction in performance of solar panels

5.5	High ultra-violet levels	• Loss of colour and degradation of material properties (plastic parts) • Degradation of protective coating systems	• Loss of colour and degradation of material properties • Reduction in service life	• Reduction in service life • Damage/loss of components	• Reduction in solar panels useful life
Section	**Extreme environmental conditions**	**Negative effects on:**			
		Floating AtoN	**Fixed AtoN**	**AtoN components e.g., lanterns, racons, etc.**	**Power supply**
5.6	Humidity	• Corrosion	• Corrosion	• Reduction in service life by condensation cycle	• Reduction in service life by condensation cycle • Corrosion of terminals
6.6.7	Bird and animal interference (Human health and safety)	• Nesting birds may obscure light or preclude maintenance visits	• Nesting birds may obscure light or preclude maintenance visits		• Destruction of cables and components

ANNEX B POTENTIAL MITIGATION OF ENVIRONMENTAL EFFECTS ON ATON

Table 2 summarizes the suggestions contained within the Guideline for best practice operation to reduce the impact of the effects of extreme environmental conditions on AtoN. The optimal solution will always depend on site specific conditions, but the table may provide the AtoN manager with ideas for consideration.

Table 2 Potential mitigation of environmental effects on AtoN

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
4.1	Wind	• Ensure wind induced wave variables are incorporated into design process • Select appropriate protective coating system • Select appropriate design of topmark and daymark • Consider redundancy within system	• Ensure appropriate wind design levels are incorporated into structure design • Select appropriate protective coating system • Consider temporary demobilization procedures • Consider more wind resilient design e.g., reduction in surface area • Consider redundancy within system	• Ensure appropriate wind design levels are incorporated into component design • Consider temporary demobilization procedures	• Ensure appropriate wind design levels are incorporated into power supply design • Consider temporary demobilization procedures	G1165 G1099

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
4.2	Waves	• Ensure wind induced wave variables are incorporated into design process • Install wave monitoring buoys to improve parameter understanding and inform site selection • Consideration of elastic moorings	• Ensure appropriate wave loads are incorporated into structure design	• Ensure correct ingress protection (IP) level specified • Consider redundancy within system • Select lanterns designed for the anticipated vertical divergence	• Ensure correct ingress protection (IP) level specified	G1065 G1066 G1099 G1165

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
4.3, 4.4, 5.2	Tidal levels, flooding, currents and coastal morphology changes	• Consider position monitoring to identify drifting AtoN • Ensure current flows are incorporated into design process • Install current monitoring buoys to improve parameter understanding and inform site selection • Consider use of skirt buoy to ensure vertical at low water • Select appropriate protective coating system	• Careful selection of location to reduce risk of undercutting or destabilisation • Ensure current flows are incorporated into design process • Select appropriate protective coating system	• Design for vertical divergence in accordance with relevant guidance • Ensure correct ingress protection (IP) level specified	• Ensure elevated position of generators to reduce risk of flooding and spillage of fuel and lubricants • Ensure correct ingress protection (IP) level specified	G1065 G1165 G1099

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
4.5	High temperature	• Ensure maintenance programme reflects potential for reduced design life • Ensure material selection is suitable for operating temperature	• Ensure construction materials are appropriate for construction phase temperatures • Ensure maintenance programme reflects potential for reduced design life • Ensure material selection is suitable for operating temperature	• Ensure products selected for anticipated operating temperature range	• Ensure appropriate choice of primary and back up supply • Ensure batteries stored less than 25 degrees C prior to deployment • Ensure maintenance programme reflects potential for reduced design life • Consider use of vented enclosures	G1065 G1067-1&3 G1039
5.5	High ultraviolet levels	• Ensure appropriate selection of product material for expected operating temperature range	• Ensure appropriate selection of product material for expected operating temperature range	• Ensure appropriate selection of product material for expected operating temperature range • Ensure checks within inspection programme to verify the light range of reused lanterns	• Ensure appropriate selection of product material for expected operating temperature range • Ensure maintenance programme reflects potential for reduced design life	G1006 G1136

4.6	Ice and Snow	• Consider seasonal and/or strategic deployment of buoys • Specify appropriately reinforced buoys • Ensure survey frequency reflects requirements of ice sheet extent • Consider appropriate mooring system to withstand ice movement • Consideration of virtual AIS • Ensure maintenance programme reflects potential for reduced design life • Consider use of topmarks and lateral daymarks or not depending on potential for ice accumulation • Ensure additional buoyancy requirements are incorporated into design process • Consider using other techniques to retroreflective film	• Ensure selection of AtoN location and type reflects risks of icing • Ensure risk of drifting ice is incorporated into design process • Ensure additional structural loads are incorporated into design process • Ensure construction materials are appropriate for construction phase temperatures	• Ensure selection of light location and type reflects risks of icing • Consider seasonal operation of lanterns • Consider redundancy of data transmission systems • Ensure products selected for anticipated operating temperature range • Ensure correct ingress protection (IP) level specified	• Ensure maintenance programme reflects potential for reduced design life • Ensure products selected for anticipated operating temperature range	

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
5.6	Humidity and precipitation	• Ensure adequate paint specification to resist water ingress • Ensure appropriate maintenance regime to reflect potential for moisture ingress and associated deleterious effects	• Ensure adequate paint specification to resist water ingress • Ensure appropriate maintenance regime to reflect potential for moisture ingress and associated deleterious effects • Consider cathodic protection	• Ensure correct ingress protection (IP) level specified • Use of water repellent products on terminals, contacts, etc.	• Ensure maintenance programme reflects potential for reduced design life • Use of water repellent products on terminals, contacts, etc.	G1136

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
5.1.1.2 5.1.1.3	Dust, fog and smoke	• Consider use of temporary operating instructions for visibility reduction • Adopt appropriate maintenance regime required for cleaning AtoN components • Consider supplementary audible warnings • Consider virtual AIS	• Consider use of temporary operating instructions for visibility reduction • Adopt appropriate maintenance regime required for cleaning AtoN components • Consider supplementary audible warnings • Consider virtual AIS	• Consider use of temporary operating instructions for visibility reduction • Adopt appropriate maintenance regime required for cleaning AtoN components • Ensure correct ingress protection (IP) level specified • Avoid using Fresnel lens without cover or use alternative light source, e.g., LED	• Ensure maintenance programme reflects potential for reduced design life • Consider supplementary power if solar is primary source	

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
5.3	Water conditions	• Ensure paint specification appropriate to withstand aggressive corrosion/abrasion • Adopt appropriate maintenance regime required for inspection of damage to paint system • Increase thickness of metal components to provide sacrificial layer • Deploy passive measures to capture water surface debris • Select appropriate protective coating system • Consider use of cathodic protection system	• Ensure paint specification appropriate to withstand aggressive corrosion/abrasion • Adopt appropriate maintenance regime required for inspection of damage to paint system • Increase thickness of metal components to provide sacrificial layer • Deploy passive measures to capture water surface debris • Select appropriate protective coating system • Consider use of cathodic protection system	• Ensure correct ingress protection (IP) level specified	• Ensure correct ingress protection (IP) level specified • Ensure maintenance programme reflects potential for reduced design life	G1036

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons,	Power supply	
5.4.1	Marine growth	• Ensure buoy and mooring design considers additional weight potentially imposed by growth • Ensure paint specification appropriate to withstand marine growth removal • Adopt appropriate maintenance regime required for cleaning buoy	• Ensure paint specification appropriate to withstand marine growth removal • Adopt appropriate maintenance regime required for cleaning structure			G1036

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
5.4.2	Bird fouling	• Use of bird deterrents, appropriate to the species • Consider bespoke top covers to reduce available landing surfaces • Apply appropriate paint system covering to facilitate removal of debris when cleaning. • Ensure paint specification appropriate to withstand bird fouling removal • Use of appropriate personal protective equipment (PPE) for maintainers	• Use of bird deterrents, appropriate to the species • Consider bespoke top covers to reduce available landing surfaces • Use of appropriate personal protective equipment (PPE) for maintainers	• Ensure correct ingress protection (IP) level specified	• Ensure correct ingress protection (IP) level specified	G1036 G1091

Section	Extreme environmental conditions	Potential mitigation for:				Relevant IALA publications
		Floating AtoN	Fixed AtoN	AtoN components e.g., lanterns, racons, etc.	Power supply	
6.6.7	Bird and animal interference (Human health and safety)	• Use of bird deterrents, appropriate to the species • Consider bespoke top covers to reduce available landing surfaces • Use of appropriate personal protective equipment (PPE) for maintainers	• Consider timing of maintenance programmes • Use of bird deterrents, appropriate to the species • Consider bespoke top covers to reduce available landing Surfaces • Consider audio and visual deterrents • Incorporate pest control in inspection and maintenance Programmes • Use of appropriate personal protective equipment (PPE) for Maintainers	• Ensure adequate sheathing and routing of cables	• Ensure adequate sheathing and routing of cables	G1036

ANNEX C GENERAL CONSIDERATIONS ABOUT NAVIGATION IN POLAR REGIONS

C.1. NAVIGATION IN ICE

Navigation in Polar Regions is particularly challenging for a number of reasons:

- The potential for collision with ice.
- Restricted manoeuvrability in ice conditions:
  - Extreme and dynamic weather conditions
  - Visibility often limited by fog, snow or low cloud
  - Limited weather forecasting over wide areas
  - Limited availability of survey reports to modern standards.
  - Differences in chart datum.
  - Use of different chart projections.
  - Limitations on usability of navigation and communications equipment.
  - Limited shore infrastructure, salvage and SAR facilities.
  - Response times (to incidents or AtoN failures) measured in days or non-existent.

The basic principle of navigation in the Polar Regions is to avoid ice whenever possible, even if this requires a substantial deviation, as navigation in ice is much slower than in open water.

In planning a voyage in polar waters, the open water voyage plan is adjusted, based on currently known ice conditions, which may be based on satellite, aerial or visual observations.

If it is necessary to enter ice, the ship's progress is continually re-assessed in view of prevailing local ice conditions. These considerations include the age and thickness of ice, movement of and changes in pressure on the ice floes, the identification of potentially dangerous floes and the effects of weather and tide.

C.2. EMERGING ROUTES IN POLAR REGIONS

There has been a longstanding interest in routing ships via the Polar Regions, as there is scope for significantly shortening trade routes between Pacific and Atlantic ports, with consequential savings in transit times and fuel use. The widely reported reduction of the Polar ice pack in recent years has increased the likelihood of ice-free routes in summer.

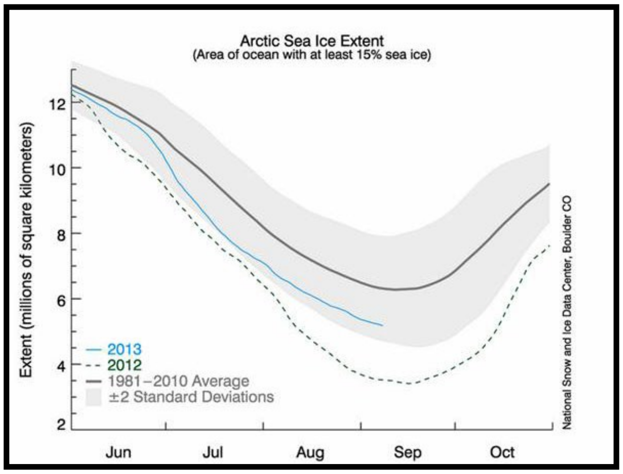

Figure C1 Arctic Sea ice extent in 2012 and 2013 compared with 1981

This has led to increases in transit traffic, and also in more localised traffic focussed on the exploitation of minerals, hydrocarbons and logging.

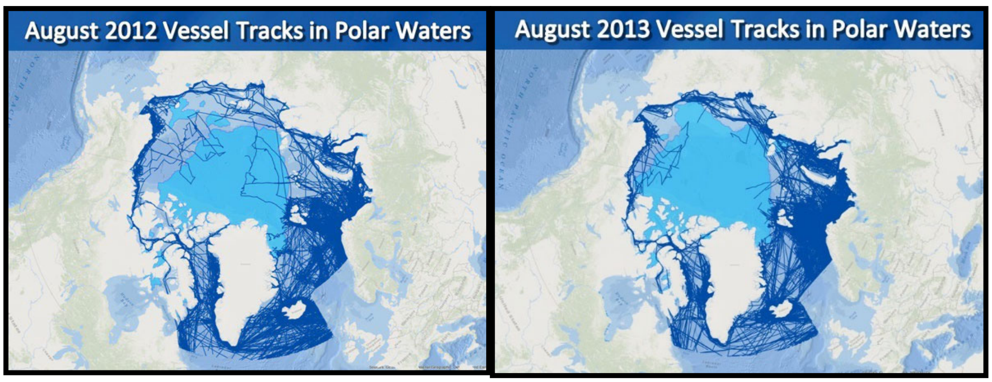

Figure C2 Vessel Tracks in Polar Waters in August 2012 and August 2013 (Courtesy ExactEarth)

C.2.1. NORTHERN SEA ROUTE

The Northern Sea Route (North East Passage) stretches approximately 2,800 kilometres along the Russian Arctic coast from Novaya Zemlya to the Bering Strait. It has been used intermittently for shipping, depending on shipping requirements and the degree of ice on the route, and peaked at 6.6 million tons in 1987. The route was closed by ice in 2007 but reopened the following year. Six ships transited the route in 2010, followed by 34 in 2011 and 46 in 2012. Most of these vessels are high capacity oil or gas tankers, benefiting from fuel savings as voyages from Korea to Rotterdam are reduced by some 4000 nautical miles.

C.2.2. NORTHWEST PASSAGE

The Northwest Passage is the sea route connecting the Atlantic and Pacific Oceans through the archipelago of Canada. The islands of the archipelago are separated from each other and the Canadian mainland by several waterways. The Canadian Arctic is mostly an area of destination for traffic calling at ports there. Shipping is nevertheless expected to increase in the years to come, not least since oil and gas activity in the Beaufort Sea is likely to expand. The Northwest Passage has also experienced intermittent use by cruise liners, and increased leisure usage.

C.2.3. Antarctic Routes

Although Antarctic waters are not generally used for transit by vessels, there are various vessels operating in the Antarctic, mostly offering cruises from South America to the Antarctic Peninsula.

C.2.4. Regulatory and User Requirements

SOLAS Chapter V requires each Contracting Government to provide such aids to navigation as the volume of traffic justifies and the degree of risk requires. Although volumes of traffic are low in the Polar Regions, the degree of risk is often high, with lack of salvage and SAR facilities an additional consideration.

AtoN are required to provide mariners with a means of confirming their ground-referenced position. There are a number of issues which add to the benefit of AtoN at known locations. These include the sometimes poor correlation between charts and electronic position fixing, and the difficulties of distinguishing between ice- covered sea and shoreline.

Physical AtoN provision should be such that the mariner is able to periodically confirm their position, rather than attempting to mark every hazard or turning point.

One approach is to identify offshore routes where the standard of hydrography can be of a higher quality than over the wider area, and chart and mark these routes to clearly identify the preferred routing. These routes can be used to identify areas where ice is less of an issue. A further benefit of this approach is that the routes can be selected to minimize the possibility of vessels drifting ashore, if beset by ice or loss of power or steering.

C.3. CHARACTERISTICS OF POLAR REGIONS

C.3.1. Moving Landscape

Ice sheets grow and shrink with the seasons and ice-charts may need to be updated frequently. Consideration should be given as to how this information can be managed in an efficient and cost-effective manner to ensure the mariner uses the most up to date information. The growth and reduction of the ice sheet can also result in land based systems having to be installed on permanently stable, high ground which may potentially be at sub-optimal locations, distant from the area of navigable waterway being served.

C.3.2. Sudden Severe Weather Events

Weather events in the Arctic often develop very quickly and are dependent upon barometric pressure changes, temperature differentials, and land/ice topography. Windstorms often include hurricane force winds, hail, and large amounts of precipitation. All of these things combined with a dearth of weather stations make weather prediction extremely difficult. For this reason, investments may need to be made to increase the number and density of fixed weather stations throughout the polar waters and ships transiting would greatly assist in this effort if they were able or required to report periodically on their local weather.

C.3.3. Natural Resources

It is expected that the Polar Regions will observe a growth in offshore industry, with associated increase in marine traffic and subsequent risk, as approximately 25% of undiscovered oil and gas resources are believed to be within this region.

C.3.4. Hydrography

Given the rapid changes expected to navigable areas due to moving ice and the ice shelf, the mariner will need up to date charts, referenced to an appropriate datum.

C.4. E-NAVIGATION AND POTENTIAL FUTURE DEVELOPMENTS IN POLAR REGIONS

C.4.1. Introduction to e-navigation in Polar Regions

E-Navigation is a concept for the future of maritime navigation, which would make the relevant information available to the user, on board and ashore, in a coherent and efficient way. It is particularly applicable to Polar Regions because many e-Navigation services can be made available remotely without additional infrastructure on the ground. However, whilst positioning is currently in place, it is lacking in resiliency which needs enhancing. In addition, adequate communications and information services have yet to be established.

The problems of Polar Regions that make operations there difficult, such as the environment – low temperatures, ice, storms, space weather effects; sparse or inaccurate surveys; lack of infrastructure – SAR/pollution control resources, can all be addressed to some extent by e-Navigation services.

The pressure to implement solutions is increasing with the effects on traffic and routes of more offshore exploration/onshore mining, with greater economic expectations and the severity of consequences of an accident.

The increasing number of ships using Northern routes brings an increasing requirement for services, to which is added the growth of tourism and cruises in these regions. However, the overall low density of general users affects the viability of services and the standards of vessels can be very variable.

The flexibility of providing e-Navigation services, using a range of information, communications and positioning systems has the potential to meet requirements more cost-effectively than with conventional, fixed infrastructure. However, it should be emphasized that e-Navigation will not replace physical aids to navigation and a mix of systems is always likely to be needed.

Some e-Navigation services could have applications in Polar Regions in the immediate future and so the subject has been treated in some detail here.

C.4.2. Information Systems

Conventionally Maritime Safety Information (MSI) is delivered via SafetyNet, NAVTEX, local NavWarnings and Notices to Mariners, using a range of frequency bands from MF, through HF and VHF to L Band satellites.

C.4.2.1. Digital MSI – ASM

Digital information systems are a core part of e-navigation. However, currently there is only one general purpose digital communication means universally available – AIS ASM. It is likely, that other systems will be developed to provide e-navigation solutions in the future. However, it is essential that these systems be standardized by the relevant bodies (IMO, ITU, IHO etc.).

C.4.2.2. The Maritime Cloud

Maritime Cloud is a concept being developed to connect all maritime actors in a communication framework with the aim of providing a single platform for all information exchange between all actors in maritime traffic. Its key components are:

- Geo-messaging: how to exchange data.
- Maritime Identity Register: how to identify actors and solve security concerns.
- Maritime Service Portfolio Register: how to locate providers of services.

In development of the Maritime Cloud, it is anticipated that the Internet will become an important communication channel in e-navigation. For realising the targets set for the Maritime Cloud, a new geo-aware messaging protocol is proposed, a private overlay network to the Internet. Geo-awareness makes it possible to send and receive messages that are relevant to the exact location of the vessel.

Maritime Identity Register gives each vessel a unique identity code, similar to call-sign or MMSI, tied to the "ship keel" for the lifetime of the vessel, not fixed to a specific role or technology.

In essence the Maritime Service Portfolio Register is an electronic meeting place where providers and users of services meet. Service providers maintain updated information of services and areas where the services are provided. Service users then make queries of services that they see relevant and valuable for them.

As a summary, the Maritime Cloud is based on the notion of e-navigation as an infrastructure and services as "apps". Services can be developed dynamically by any actor. The Maritime Cloud is built on existing proven technology and can therefore be cost effective.

The Maritime Cloud is currently used as the testbed infrastructure in the ACCSEAS project. The concept has also been submitted to the IMO e-navigation process as a proposed infrastructure supporting e-navigation.

C.4.2.3. Arctic Web

Arctic Web is a web based approach to providing e-navigation services and solutions. As such it is not limited to any specific equipment or carriage technology. It focuses specifically on the Arctic region, aiming at gathering all relevant information and services for the Arctic. This includes e.g., provisioning of AIS data, allowing for coordinated passage/voyage or location of emergency support in distant areas as well as information on ice conditions (thickness, concentration, type etc.).

Both the Maritime Cloud and the Arctic Web take advantage of not just the latest technologies but also latest development methods and tools. They are based on open source code and are available for anyone for further development of the platform itself and additional services.

C.4.3. INFORMATION SERVICES

The lack of traditional AtoN in the polar regions, makes up to date maritime safety information imperative to safe navigation. Maritime Safety Information (MSI) means navigational and meteorological warnings, meteorological forecasts other urgent safety-related messages, (IHO definition). A system should be developed to reliably deliver all of this information to the navigator in near real time. Methods of delivery are limited by the vast geographical distances and limited bandwidth available. Study should begin on methods to increase transmission distance and interoperability of systems to display the information.

Other examples of information services to be developed could be Sea Traffic Management – dynamic route planning, QA for hydrographic data, global sharing of maritime information, for example user-shared ice-routing (it's almost always easier to break up refrozen brash than to open a new channel).

Content of services – ice forecasts/warnings, met./hydro., space weather - all can be delivered in depth or detail tailored to and by the end user. Space should be made for user-created content i.e., a bulletin board of useful marine information.

Virtual AtoN – The IALA-organized Meeting on the Marking of Arctic Routes resolved that to "establish safe and efficient maritime transport corridors in Arctic waters there is a need to develop and implement electronic maritime navigation, communication and traffic monitoring infrastructure, including i.e., radio-navigation aids, GNSS, AIS satellite. Development of virtual aids to navigation is one solution that should be given strong consideration." It was recommended that IALA would support "the marking of polar routes and development of virtual aids to navigation".

The Report to IMO NAV59 *Policy & Symbols for AIS AtoN* noted that a:

"Virtual AIS AtoN is transmitted as a Message 21 representing an AtoN that does not physically exist. The competent AtoN authority should take every precaution to avoid confusion to the mariners. The AIS message should clearly identify this as Virtual AIS AtoN. Virtual AIS AtoN should not be used for permanently marking an object for which Physical AtoN would be possible, but, may be considered for marking an object or feature where it is difficult to establish a Physical AtoN due to environmental or economic constraints e.g., deep water, harsh sea conditions."

There needs to be further study and standardization by IALA before moving forward with full implementation in the Arctic. Possibilities include terrestrial AIS via relays and satellite delivery. Issues include areas where charts are offset by a constant distance, or the incorrect datum is applied. In these cases, where does one put the virtual AtoN? Virtual AtoN need not be limited to marking points. Lines could be used to delineate channels or, dynamically, the limits of ice sheets.

Integrity monitoring of the information broadcast is essential as no acknowledgement is built in.

C.4.4. Communications Systems

This section looks at the existing systems as required by SOLAS for sea area A4. It then goes on to consider improved communication and dissemination of MSI (Maritime Safety Information) with ships operating in polar areas, through enhanced communication systems. These could be introduced over the next few years as part of e-Navigation.

C.4.4.1. Existing systems

According to SOLAS Chapter IV, the systems required for operation in Sea Area A4 are:

- VHF with DSC and distress alerting
- MF/HF radio installation
- SAR locating device
- MSI through HF direct-printing telegraphy
- Satellite EPIRB

And SOLAS Chapter IV reg. 19-1:

- LRIT Long-Range Identification and Tracking of ships.

For ships operating in Sea Area A4, HF radio remains the only viable system for communicating distress and safety information and MSI, because of limited coverage by recognized satellite systems. In spite of this and the fact that SOLAS requires that "each Contracting Government undertakes to make available appropriate shore-based facilities for space and terrestrial radiocommunication services, including services in the bands between 4,000 kHz and 27,500 kHz" (SOLAS Chapter IV, regulation 5), many administrations have closed down their HF radio stations, because of low traffic.

C.4.4.2. Future infrastructure needs

Convention ships are not permitted to operate beyond the coverage of systems in which continuous alerting is available. Beyond the coverage of satellites in the Inmarsat system only HF is capable of fulfilling this obligation today. There is therefore a need to re-establish reliable communication to and from ships operating in polar areas for safety reasons.

Efficient, seamless and automated delivery of MSI should be a key objective of such communication in order to minimize distress situations. It should be noted that some urgent safety situations may require higher bandwidth solutions than available using AIS.

It is imperative to monitor all shipping traffic in polar areas to ensure its optimum safety.

C.4.4.3. VDES (VHF data exchange system)

The future VDE (VHF Data Exchange) may become an efficient tool for communication and navigational safety in Polar Regions as well as other areas.

C.4.4.4. HF Data

A new data communication system using 10-20 kHz bandwidth for data rates up to 51 kbps, has been incorporated in the Recommendation ITU-R M. 1798-1. Appendix 17 to the Radio Regulations as revised at the World Radiocommunication Conference 2012 (WRC-12). The revision of AP17 will implement new digital bands for 3 kHz systems as well as wideband systems.

C.4.4.5. NAV Dat

NAV DAT is an MF radio system, for use in the maritime mobile service, operating in the 500 kHz band for digital broadcasting of maritime safety and security related information from shore-to-ship. It has the potential to transmit any type of text, graphs, pictures, data etc. with encryption if required, and automatic reception. The global architecture of NAV DAT is similar to NAVTEX and the coverage is approximately 250/350 NM from coast stations.

C.4.4.6. ELoran

The enhanced Loran (eLoran) system is an experimental system that provides a data channel modulated onto the 100 kHz signals. The formats for this data channel currently available offer data rates below 100 bps although higher rate concepts have been proposed and the system has very long range (1000 km).

C.4.4.7. Satellite AIS

Satellite AIS may provide part of the solution to the monitoring problem, but the ground infrastructure has still to be fully developed.

C.4.4.8. Polar orbiting communications satellites

As an alternative to HF, AIS, VHF and Inmarsat, which are required to be carried on SOLAS convention ships, polar orbiting satellite systems could be used as a tool for enhanced safety in polar areas.

Though there are no recognized satellite services defined for Sea area A4, non-GMDSS satellites are available (or planned).

C.4.4.9. Wifi/Wimax/IMT/LTE

Private and public networks could be used for communications in local port areas and other inhabited areas but would have limited coverage in polar regions and would not generally be available out of sight of land.

C.4.4.10. Need for generic SD receiver

In future it should be possible to provide a software defined receiver that will operate with various systems across several bands. Such a concept would need to be standardized in the normal way but could have operational and commercial advantages.

C.4.4.11. LRIT

The Long-Range Identification and Tracking (LRIT) system provides for the global identification and tracking of ships of 300 GT or more. General requirements are contained in IMO resolution A.694(17) for ship borne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids. In addition, the ship borne equipment should be capable of automatically and without human intervention on board the ship transmits the ship's LRIT information at 6-hour intervals to an LRIT Data Centre, Ref.: Resolution MSC.263(84), MSC.1/Circ.1307 and 1309.

The LRIT system is only accessible to nominated authorities.

C.4.5. POSITIONING SYSTEMS

Reliable positioning is essential to almost all e-Navigation services and reliance on electronic positioning could be greater in Polar Regions than in other parts of the world, simply because physical AtoN are few and far between.

This section looks at the possible limitations of GNSS in Polar Regions and the possible alternatives or backups that might be available.

C.4.5.1. Limitations of GNSS in polar regions

Global Navigation Satellite Systems, in particular GPS, have become the primary means of maritime navigation. However, GNSS are known to be vulnerable to interference, both deliberate and accidental. The inclined Medium Earth Orbits of the present GNSS can also result in poor geometry at high latitudes. The extent of these problems has been investigated and it can be concluded that accuracy is unlikely to be a problem for users in high latitudes. However, integrity (the ability of a system to warn of a malfunction) can only be provided by Receiver Autonomous Integrity Monitoring (RAIM) and this is not available on many maritime GNSS receivers currently installed. Space Based Augmentation System, such as WAAS and EGNOS rely on Geo-stationary orbit satellites, which are not generally visible above 75 degrees of latitude at sea level. There are some ground-based, medium frequency DGPS stations in Northern latitudes, but coverage is very limited.

The problem of interference to GNSS is not likely to be any worse at high latitudes, although solar storms can cause occasional scintillation, loss of lock and increased errors. Interference from faulty equipment is a general problem, but of course the consequences could be more serious if there are no alternatives available.

C.4.5.2. Receiver standards

Existing maritime receiver standards are more than ten years old and do not reflect current technology. In particular, they were formulated for individual, standalone systems, whereas modern receivers general employ two or more position sources. For these reasons and to support the concept of resiliency essential for e-Navigation, development of a multi-system receiver performance standard is underway at IMO. This should lead to a generic, “required navigation performance” approach that will meet the integrity requirements that are lacking in present day receivers.

C.4.5.3. Racons

Racons are receiver/transmitter devices operating in the maritime radar frequency bands (9 and 3 GHz) that enhance the detection and identification of certain radar targets.

A racon responds to the presence of a ship’s radar by sending a characteristic pulse train. The response appears as a coded mark (or “paint”) on the ship’s radar display that highlights the range and bearing of the racon and uses a Morse character for identification. Range is dependent on mounting height but is typically 20 NM.

It is likely that Racons will be able to operate in low temperatures and their shape will help prevent snow build up, however some additional protection may be needed.

Racons are used in the vicinity of Greenland and Svalbard and have operated there with no problems for many years. These Racons are powered via solar panels and battery banks; the power consumption is very low due to the limited number of passing vessels.

C.4.5.4. DGNSS

IALA Beacon DGNSS is the provision of non-encrypted differential corrections as well as integrity information to maritime users to improve accuracy and integrity of GNSS based determination of position, navigation and time data (PNT). The method of differential positioning was developed in the nineties, is internationally accepted and supported in most coastal waters, especially in areas of high traffic density. The differential corrections are determined at known positions of reference stations or a network of them.

Ranges of stations are generally 100-200 NM. There are a few stations operational in Northern Norway and some in Northern Russia, but not sufficient to provide complete coverage of Northern routes.

C.4.5.5. ELoran

Enhanced Loran (eLoran) is a terrestrial navigation system developed from Loran-C. It is a Positioning, Navigation, and Timing (PNT) service for use by land, sea and air navigation as well as other applications reliant on timing data.

eLoran is independent of and has dissimilar failure modes to GNSS and therefore complements GNSS use. Although offering reduced accuracy, it will allow GNSS users to retain the safety, security, and economic benefits of GNSS, even when their satellite services are disrupted.

eLoran provides positional accuracy in the region of 8 - 20 metres and time and frequency performance (to stratum-1 level) similar to current GNSS. Ranges of individual stations are in the region of 1000km.

None of the currently operating Loran-C stations covering Arctic waters has been converted to eLoran and their future is uncertain. However, in combination with the existing Chayka infrastructure in Northern Russia, there is the potential to cover substantial parts of the Northern routes.

C.4.5.6. Need to define requirements

The level of provision of radio-navigation systems in Polar Regions should be related to identified requirements – accuracy, availability, integrity, level of resilience.

C.4.5.7. Special features

Ice, stormy weather, darkness, lack of coastal infrastructure, need for self-sufficiency, all require specialized training.

C.4.5.8. Ice navigation

There is a need for sufficient knowledge of the area, weather, local communications, ice pilots – local knowledge, local competent person needed if not available among crew.

C.4.5.9. How should e-navigation systems be adapted to local/regional needs?

Location Based Services, such as the Arctic Web, can provide the information relevant to the user's needs for a particular area.

C.4.5.10. Sea Areas

Sea area A1 means an area within the radiotelephone coverage of at least one VHF coast station in which continuous DSC alerting is available, as may be defined by a Contracting Government.

Sea area A2 means an area, excluding sea area A1, within the radiotelephone coverage of at least one MF coast station in which continuous DSC alerting is available, as may be defined by a Contracting Government.

Sea area A3 means an area, excluding sea areas A1 and A2, within the coverage of an Inmarsat geostationary satellite in which continuous alerting is available.

Sea area A4 means an area outside sea areas A1, A2 and A3.

C.4.5.11. E-Navigation

E-Navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment.

C.4.5.12. Geostationary Earth Orbit (GEO)

Geostationary Earth Orbit (GEO) is in a circular orbit 35,786 km (22,236 mi) above the Earth's equator and rotates at the same speed as the earth's rotation. Because the Geostationary Earth Orbit satellite is over the equator, the typical communications coverage extends from approximately 70 degrees South to 70 degrees North. Depending on geographic location, the satellite coverage may extend further north and south. The only GEO satellites accepted by IMO as meeting the GMDSS requirements is the Inmarsat system.

C.4.5.13. Geocentric Orbit

Geocentric orbit is an orbit around the Earth and are usually classified by the satellite's altitude (i.e., Low Earth Orbit (LEO), Medium Earth orbit (MEO) and High Earth orbit (HEO)); the shape of the orbit (e.g., highly elliptical); and the area the orbit crosses (e.g., Polar orbit).

To provide effective, full-time communications over any given area, any LEO or MEO system requires a constellation of satellites. Some orbits, such as the Highly Elliptical Orbit (HEO) can be designed so that the satellite covers a region of the earth for a large fraction of its orbital period. For example, two HEO satellites could provide polar coverage.

C.4.5.14. Polar coverage

Two general types of satellite orbits that will provide Polar coverage: A constellation of satellites in low or medium earth orbit with sufficient number of satellites such that a satellite is in view at all times (e.g., Iridium) or a smaller number of satellites in a highly elliptical orbit (e.g., Molniya satellites used by Russia).

ANNEX D EXAMPLE OF DEMOBILISATION PROTOCOL – CYCLONES

D.1. CRITERIA FOR CONSIDERATION

Prior to the hurricane season, a detailed analysis regarding the priorities for the deactivation and further activation process must be conducted, preferably involving the criteria and expertise from the most relevant members of the maritime community such as pilots, maritime administrations, coast guards, navy, shipping companies, meteorological services, among other stakeholders.

For this purpose, the IALA Risk Management Toolbox could be extremely valuable when focused on the risk related to maritime operations that could be present before, during and after the occurrence of such events. Modelling and simulation techniques should be an advantage when performing this analysis to show the possible or forecasted scenarios that must be taken under consideration in a given maritime area or waterway.

This analysis should be run in a yearly basis as some elements related to the operational conditions of a waterway may vary, such as local maritime regulations, AtoN system modifications, among others.

The result of this analysis could be a plan to practically organize the deactivation and activation process, including:

- An Agreement and Cooperation Act to be signed by the process stakeholders, containing the list of AtoNs to be deactivated and activated according to the priorities determined in the analysis, and the means provided by each stakeholder to cooperate with the process.
- A table containing the number of AtoNs with real possibilities to be part of the process, sorted by type of AtoN.
- The composition of each Deactivation and Activation Brigade (DAB) to perform the procedure, means of transportation, waterways to be covered, departure point, trajectory, communications, storage facilities for the preservation of the luminous and power supply system and other accessories, among other practical details. Proper training for the DAB personnel based on local AtoN System conditions should be provided.

This Plan should be submitted for the approval of the competent authorities to ensure its compliance with national, territorial and local regulations.

The criteria to establish the priorities for the deactivation process may include, among others:

- The importance of the AtoN for the maritime operations in a given waterway: the demobilization of AtoN should be prioritized such that critical AtoN for vessel operations are deactivated last, prior to the arrival of the hurricane.
- The meteorological conditions: the deactivation process should start well in advance of the deterioration of the sea conditions in order that service vessels could work safely, especially on buoys. Up-to date information on the current position, trajectory, speed displacement and strength of the hurricane provided by local meteorological services is essential.
- The distance from the departure point of DAB to the farthest AtoN to be deactivated: it would be unpractical trying to deactivate AtoNs located too far away.
- The average time spent undertaking each demobilization, according to the complexity of the AtoN.
- After a hurricane has left an area or waterway, an evaluation of its AtoN system status should be made to assess the damages caused as soon as the meteorological conditions allows to do so, in order to determine the damages and to prepare all the necessary resources to repair or reactivate them.

Subsequently, the criteria to establish the priorities for the activation process may include, among others:

- The urgency to ready the most important waterways: those AtoNs meant to contribute to a safe navigation by these waterways must be activated first.

- The meteorological conditions: the activation process should start as soon as the weather condition allows the deployment of DABs.
- The use of most suitable and reliable equipment available in the AtoN maintenance station or preserved during the deactivation process to ready the most critical AtoN.

ANNEX E EXAMPLE OF CHILEAN TSUNAMI EXPERIENCE AND DEMOBILIZATION PROTOCOL

E.1. INTRODUCTION

A few minutes after the earthquake, the Pacific Tsunami Warning Center disseminates a tsunami warning to the Pacific Ocean, which will be issued to 53 countries across its basin, including Peru, Colombia, Panama, Costa Rica, Nicaragua, Antarctica, New Zealand, French Polynesia and the coasts of Hawaii.

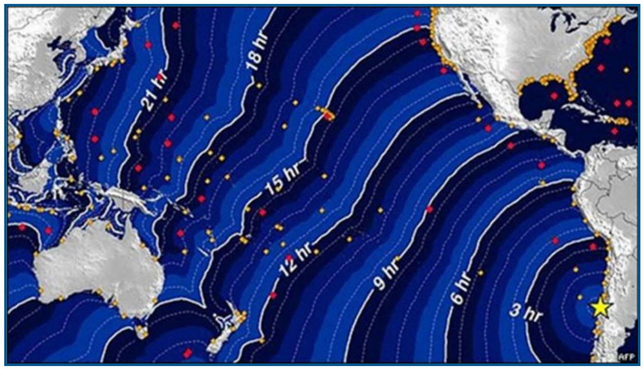

Figure E1 Expansive wave

The height of the wave train will vary upon the area and the impact on the coastline, and it will depend on the type of coastline, slope and other features of the shoreline.

Figure E2 Examples of destructive effects of tsunami

When such natural disasters occur, the personnel usually involved in navigational aid organizations, which in many countries are part of the Navy, is engaged in rescue tasks, community support and restoring basic services, as well as maintaining public order. This is therefore a critical scenario, where AtoN are not necessarily a priority.

Navigational aids located in the disaster area are also vulnerable to damage caused by an earthquake and subsequently a tsunami. However, it is possible to identify or prioritize those affected aids based on parameters, such as type and size of the structure and average height above sea level.

E.2. EMERGENCY AND CONTINGENCY PLAN

In countries with a seismic culture, such as Chile, Japan or Cuba, where based on experience, special plans have been developed to respond to all types of disasters, AtoN are considered critical infrastructure for their contribution to safety.

The following is an example of the general guidelines to be addressed in the event of extreme environmental disasters such as earthquakes, tsunamis, typhoons or hurricanes.

E.2.1. Suggested Actions

- Establish an emergency repairs unit made up by specialized personnel to inspect the affected area, in order to assess the condition of the navigational aids, according to the prioritization resulting from the variables of the structures and the average height above sea level.
- Once an initial assessment is completed, a basic corrective maintenance plan should be implemented using adequate equipment to restore damaged aids to normal.
- Provide a team of AtoN trained personnel equipped with the appropriate communications and personal protective equipment, and ready to operate in the event of an emergency.
- Keep written records with the following information:
    - List of personnel and their contact telephone numbers and addresses.
    - List of navigational aids installed at a certain maximum height above sea level, according to areas of action.
    - List of large navigational aids, mainly concrete, according to areas of action.
    - List of navigational aids powered by the public lighting network.
    - Paper charts with flooding plan for the main ports of the country.
    - Keep records of specific beacons.
- Provide operational VHF communications equipment and flashlights.
- Keep a lighthouse relighting kit, with minimum working tools to be shipped as quickly as possible.
- Stock minimum spares inventory and power supply for relighting of navigational aids.
- Implement consumables and spare parts warehouses to supply the necessary equipment.
- Provide a first aid kit.

E.2.2. Post-Event Evaluation

- Communication systems may be suspended right after an earthquake, and internet, mobile and landline services will not be available. VHF and HF should be considered as a reliable option.

- Radio and television may be the only means of communication available to learn about the status of the catastrophe in the early stages, which could be used as a starting point to respond to uncertainty among local people.
- In addition, both urban and interurban roads may be damaged partially or totally, and thus fuel supply may be affected. Basic services such as electricity, drinking water and gas, may remain unavailable during the first days, even weeks, depending on the existing operational capacities, also for safety reasons.
- Depending on the materials used in fixed navigational aids such as fiberglass or polyethylene towers or beacons, they may not be damaged by the seismic activity, but they will be potentially impacted by the tsunami, which may exceed ten metres upon sea front slope.
- Large old navigational aids made of concrete and iron, which have been manufactured prior to anti- seismic regulations and have been exposed to the effects of the marine environment, may be greatly damaged by the quake even resulting in complete destruction.
- It should be noted that personnel responsible for the maintenance of AtoN might be needed to perform support tasks to assist local citizens, and the navigational aids would not necessarily be an immediate priority.