CREW CENTRE OF EXPERTISE FOR WATERS

**Project specification**
**CD2021_02**

# Understanding the increased risk of frazil ice blockages at water intakes in response to climate change in Scotland

**Research questions** to be answered:

*Over recent winters there have been increasing reports of frazil ice blockages at water intakes at Scottish Water's operational sites. This phenomenon is not unusual within a band of northern latitude countries covering parts of Scandinavia, Canada, USA and Russia, however with climate change the risks to water assets in Scotland are largely unknown. This project should therefore address the following research questions:*

1. *Is there an increasing risk that Scotland may be expose to more extreme weather patterns that result in the formation of frazil ice?*
2. *How does existing national/international research into frazil ice formation relate to ice blockage issues in Scotland? i.e., is existing research relevant to Scotland, and how might it inform the development of Scottish Waters risk management/mitigation strategy?*
3. *Is a more focussed programme of research required to understand the risk of ice blockages due to climate change in Scotland? E.g. Is the risk of ice blockages in the future less likely given climate change projections? Are there identifiable patterns of projected seasonal (winter & spring) water and air temperature and wind directions that increase the risk of ice blockages at water intakes?*
4. *Based on insights from the literature, and interviews with site operators, which Scottish Water and Scottish Hydro sites are most at risk to frazil ice blockages (hydrological, meteorological, and topographical conditions)?*
5. *What mitigation measures are available to enhance the resilience of Scottish Water and Scottish Hydro operations should frazil ice pose a problem in the future?*

## Background

Scottish Water has an obligation to ensure its assets are resilient to climate change in order to protect public water supplies. Frazil ice build-up at water intakes has been identified as a relatively recent issue, and as such there is limited information available on how climate change might affect the frequency of problem in Scotland and the impact on water and hydro assets.

Furthermore, little is known about the way frazil ice forms; how it is drawn down to the depths at which the intakes are located; and how to prevent frazil ice from fully blocking intakes. The main problem has been reported at reservoir intakes but it may also affect river intakes, especially if climate change influences the frequency of events that lead to ice blockage problems.

Currently, Scottish Water has no system in place for evaluating which assets are at the highest risk of ice blockages at intakes or how to assess the risk of climate change on water and hydro assets.

**Previous related work**

A number of studies have shed light on frazil ice formation etc., but research on the risks associated with climate change are few and far between. There are no existing programmes of research in Scotland or elsewhere in the UK, therefore a review of international published/grey literature and expert opinion will be necessary, and the resultant review should be framed/relevant to a Scottish context.

**Literature overview**

Frazil ice is a collection of loose randomly orientated ice crystals formed in supercooled (below freezing) turbulent water. The formation of frazil ice can occur in standing water (reservoirs/lochs) and rivers. In rivers the frazil ice formation is a factor of low water and air temperature (≤6°C), open water and clear nights; in standing waters strong winds also contribute by lowering water temperatures. Frazil ice is not buoyant and sinks to the waterbody bed, and ice crystals grow and 'stick' to any object including water intakes/rubbish screens and have an extremely high affinity to rusting water intakes.

Blockages of water intakes caused by frazil ice can result in the cessation of water provision to business and domestic households and can also potentially impact hydroelectric inlets. Much of the available information/data is linked to larger water bodies and less so small water bodies, but for the latter the smaller freezing actions maybe more extreme and contrasting.

Frazil ice has typically been associated with countries of colder climes e.g., Canada, USA, Antarctica, Scandinavia, however, with climate change, the incidences of frazil ice are increasingly being reported in Scotland from Scottish Water site operators and other observations (e.g., Pancake ice/frazil pans on the River Dee, Aberdeenshire).

Previous studies have emphasised the need for monitoring to help understand the river dynamics (water and air temperature, meteorological metrics, surface ice cover) linked to the occurrence of frazil ice, and the frequency of blockages, to inform effective prediction of occurrences. This would enable mitigation and management procedures to be mobilised. Other methods of 'coping' with frazil ice include the development of an ice cover (providing insulation), using heat to warm the water and /or intake, adding warm water (from other process associated in the industry) mechanical removal, use of different coatings on the inlet and/or rubbish screens structures (delays the onset of frazil ice), to name a few.

Historic and current literature is focused on the experiences and research in the countries mentioned above; the purpose of the literature review/scoping study is to understand the transferability of the information/data available to inform on frazil ice and its management in Scotland.

**Key References**

*https://apps.dtic.mil/sti/citations/ADA235724*

https://www.sciencedirect.com/science/article/abs/pii/S0165232X07001887
https://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9429(2006)132:8(814)
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## Hypothesis

*The broad hypothesis on the ice blockage phenomenon is that surface water temperatures drop below freezing, but surface ice is prevented from forming due to surface turbulence, possibly/probably wind driven. The super cooled water (just below freezing point) is then drawn into the intake, resulting in frazil ice blockages.*

## Aims, objectives, and impact

The overall aim of this project is to establish if this hypothesis is supported by the literature and to identify data sources (climate projections) that could be used to evaluate how the risk of ice blockages at Scottish Water and hydroelectric sites might change in the future due to climate.

The specific objectives are as follows:

I. *Establish the extent of the problem at Scottish Water/Hydroelectric sites through targeted interviews with operational managers.*
II. *Guide Scottish Water to relevant research and information relating to frazil ice, especially relating to its formation and how to evaluate the risks of potential icing problems at installations from a knowledge of the hydrological, meteorological, and topographical conditions which exist at Scottish Water and Hydroelectric sites.*
III. *Provide an insight into the potential climate change scenarios that could result in an increased frequency of frazil ice formation and ice blockages (Note: climate modelling is not requested as part of this project but published climate projection for Scotland should be referenced).*
IV. *Provide an insight into the reported frequency of meteorological conditions that influence frazil ice formation i.e. increased frequency in the pattern of events that result in frazil ice formation due to climate change and associated risks of frazil ice formation in Scotland as a consequence of climate change.*
V. *Evaluate the risk of ice blockages at Scottish Water and hydroelectric sites.*
VI. *Recommendations for further research, especially relating to how Scottish Water evaluates, monitors and manages risks due to climate change i.e. what programme of monitoring might be required to determine a change in risk due to climate change and how might Scottish Water determine sites at highest risk?*
VII. *Provide guidance on technical/engineering solutions to enhance the resilience of water intakes to frazil ice blockages (should that be an issue in the future).*

The anticipated impact of the project is as follows:

- ✓ *How exactly will project outputs be utilized?*
  The output of the project will a) allow Scottish Water (and Scottish Hydro) to better understand the risk of ice blockages at water intakes, b) help operators evaluate the risk from frazil ice and c) inform resilience planning and response under a suite of climate change scenarios.
- ✓ *Who or what will be the primary and secondary beneficiaries of project outputs?*
  The primary beneficiary will be Scottish Water, the secondary beneficiaries will be hydro plant operators and providers. The project outputs will help improved asset risk assessment for climate change resilience by adding greater certainty of investment needs to protect public water supplies and hydro production from frazil ice events.

## Outputs required

1. A literature review to allow Scottish Water to a) gain a clearer understanding of how frazil ice is formed and how it could impact drinking water and hydroelectric intakes and b) assess the risk to Scottish Water /Scottish Hydro operations from frazil formation as a consequence of climate change.
2. Guidance on technical/engineering solutions to enhance the resilience of water intakes to frazil ice blockages should that be an issue in the future.

**Format of project outputs**

☒ Report (20-30 pages)
☒ Executive summary (2-4 pages)
☒ Plain English summary[1] (1-2 pages)

**Projected key dates**

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|---|---|
| a. **Start-up meeting** | AUG 2021 |
| b. **Interviews (Site operators)** | SEPT-OCT 2021 |
| c. **Initial report** | END NOV 2021 |
| d. **Final report** | MID DEC 2021 |
| e. **Project completion** | DEC 2021 |

[1] A plain English summary is required for all CREW projects.

**Maximum funding available including VAT: c.£30k**

## Project Steering Group and Management

| Name | Organisation | Role |
|---|---|---|
| Graeme Moore | Scottish Water | Requestor/Steering Group |
| Rachel Philp | Scottish Water | Steering Group |
| TBC | Scottish Hydro | Steering Group |
| | | |
| Rachel Helliwell | CREW | CREW Manager/Project Manager |