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of the Northern Territories Water and Waste Association

Resiliency in Northern Water Infrastructure

NTWWA

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Serving NWT & Nunavut

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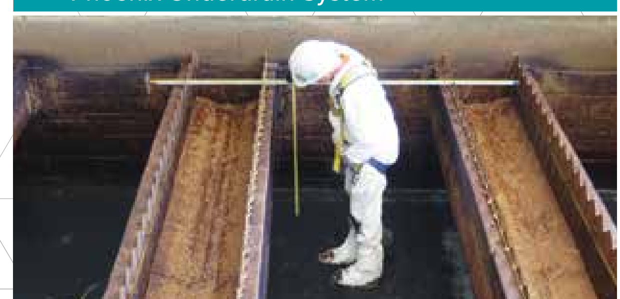

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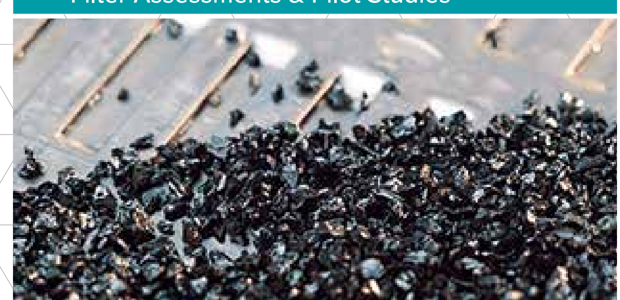

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Editor's Notes
KEN JOHNSON

Editor visiting grave site of Uncle Albert in Aklavik, NWT.

Writing this article finds me just returning from the Second Congress of the University of the Arctic (UArctic) in Finland, as a participant in the WAter Sanitation and Hygiene (WASH) network within the University of the Arctic.

The UArctic Congress, and the UArctic itself, is an opportunity for Canadian Arctic water practitioners to further advance the professional connections we have made with Greenlanders and Danes over the past several years. These connections had their beginnings with the Canadians who attended the ARTEK (Arctic Technology Centre) water conference in Sisimiut, Greenland in 2016 (http://www.artek.byg.dtu.dk/english/AIC-ARTEK-International-Conferences/AIC_2016), and reciprocal attendance by Greenlanders at the NTWWA conferences in 2016 and 2017. The growing Greenlandic and Danish connections were reflected in the abundant water articles in the 2017 issue of the *Journal* – many thanks to the Greenlanders and Danes for their efforts. Canadian Arctic water practitioners also have some well-established Alaskan connections that go back decades in some cases. It is time - and timely - for Canadian Arctic water practitioners to reach out to the European Arctic to mutually share our knowledge and expertise on WASH through the UArctic WASH network, and any other related information resources.

The magazine theme of resiliency is very timely to some serious water issues that are developing across the north. These water issues have required some serious attention, most recently with the emergency water resupply for the City of Iqaluit. Our members were well postured with experience and expertise to respond to this emergency. The *Journal* has reported on other water supply emergency situations in Grise Fiord (*Journal* article 2008), and Arviat (*Journal* article 2013).

Many thanks to Pearl Benyk, once again, for her editorial assistance, which raises the bar on the quality of the articles in the *Journal*. As always, I would encourage *Journal* readers to contact me about any Arctic water issues they have, or help they need, at 780-984-9085 (cell or text) or email (ken.johnson1@aecom.com or cryofront@shaw.ca).


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Hauling ice blocks to a community six kilometres away.

GRISE FIORD, NUNAVUT: A RESILIENT AND ADAPTIVE COMMUNITY

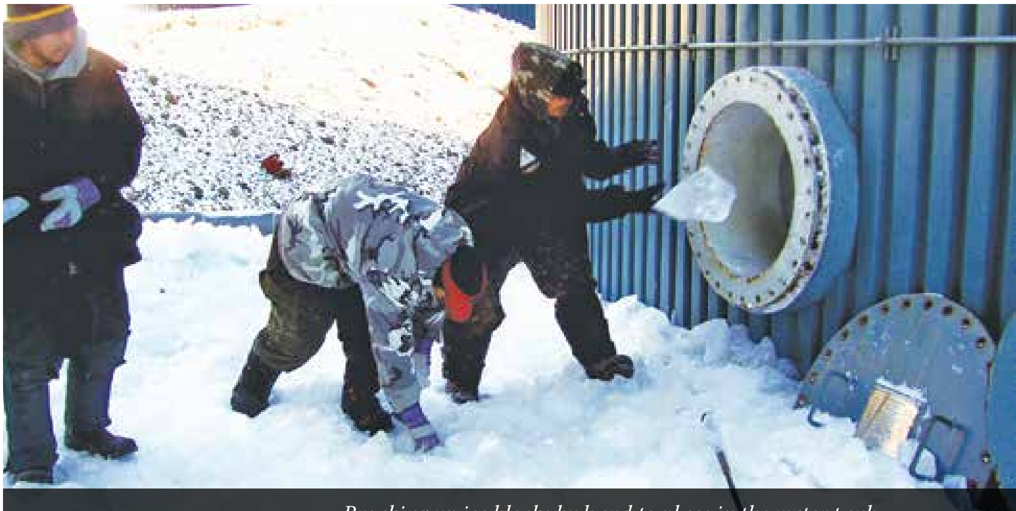
Grise Fiord is Canada's most northern community at 76° 25' 08" North latitude, a mere 1,500 kilometres from the North Pole. Grise Fiord must be differentiated from the weather stations further north such as Eureka and Alert because it is the permanent home of 130 Canadians. Community infrastructure is tough to maintain at this latitude, and it was made "tougher" over the past decade with water resupply challenges. This challenge was written about in the 2008 *Journal* after an occurrence in the spring, when residents of the community were forced to use icebergs as their potable water supply to deal with a severe water shortage.

The residents of Grise Fiord have a history of resiliency and adaptation, quite apart from their water supply problems. The creation of Grise Fiord was a social experiment by the Government of Canada that was perpetrated on a handful of ill-prepared families from northern Quebec in the 1950s. Most of the relocated Inuit had never experienced 24-hour darkness nor seen a muskox before, and their first few years in their new home were extremely difficult. Some families eventually returned to Northern Quebec, and others made a life in Grise Fiord despite being tethered to the air-supplied government assistance common to almost any remote fly-in community. Those who stayed demonstrated a resiliency and adapted to a new climate decades before these terms became common in the vocabulary of the far north.

Grise Fiord is finding out firsthand that water – described as the bloodstream of the biosphere, and the determinant of a community's future – is the one of the most significant aspects of climate change.

Grise Fiord must replenish its water supply during a brief three-week window in the summer when there is sufficient glacier melt flow to fill several large tanks with enough capacity to supply the community for 12 months. The tanks must then be heated, at considerable expense, for almost 12 months. Coupled with a population base that is too small to absorb the same base infrastructure costs borne by other communities, Grise Fiord has some of the highest water costs in the country, with a rate approaching five cents per litre. By comparison, the cost of water in Ottawa is approximately one-tenth of a cent per litre, making water in Grise Fiord about 50 times more expensive than in Ottawa.

Previous water shortages have occurred before. In 1997, the hamlet placed residents on half-rations of water in a bid to stretch dwindling supplies into midsummer. Conservation efforts began in April, when it became clear that the Hamlet's 5.9 million-litre res-



Breaking up ice blocks by hand to place in the water tank.

By Ken Johnson, Senior Environmental Planner and Engineer, AECOM

ervoir was being depleted faster than usual. The second tank stood empty because the river had frozen, at the end of the summer in 1996, before it could be filled.

Up until the late 1970s, iceberg ice was the community's sole water supply from late September until the end of June. At a community meeting in 1975, an engineering consultant doing a water supply study asked the community council what water supply improvements they would like to see. The council replied that they would like more tools like the one they had found in the school. They had found this tool to be ideal for harvesting chunks of ice off icebergs. Unfortunately, the tool they found in the school had now been lost and they didn't know the name of it. After much discussion, it was determined that the tool was a fire axe. The consultant sent them two fire axes.

Thirty years later, the community was once again reverting to this "old technology" to obtain an interim potable water supply. The community would normally have the two huge water tanks filled with enough glacial runoff to last them for 12 months after the tanks were filled in June of each year. Unfortunately, maintenance work and a lack of sufficient rain in the summer of 2007 left the tanks under-filled.

Grise Fiord officials issued an advisory urging residents to conserve water, while a six-kilometre ice road was built to the hamlet's new water source: a massive iceberg. Loaders were used to break blocks from the iceberg and haul them into the community, where four people chipped them into smaller pieces and put them into the tanks. It was estimated at the time that this emergency "fix" for the water shortage problem would cost about $60,000.

The federal budget tabled in March 2017 included $84 million over five years, beginning in 2018, to integrate traditional knowledge into understanding climate change. The budget proposal committed to investments in northern infrastructure to improve Indigenous communities' resilience to climate change, including the risks associated with flooding.

The traditional name for the community is Aujuittuq, which translates as "it (the glacier or the ice cap) never thaws", but the glacier which provides the yearly community water supply is no longer visible from the community. In 2017, for the first time, the hamlet's water supply was brown.

DEFINING, DESIGNING, APPLYING AND REFINING RESILIENCY IN NORTHERN WATER INFRASTRUCTURE

By George W. Thorpe, Senior Engineer, BI Pure; and Ken Johnson, AECOM, Senior Planner and Engineer

In spite of the abundance of water in Canada, it can be a scarce commodity, particularly in Northern communities that require a clean source of water year-round. Winter can last eight to 10 months of the year, and in winter, most of the surface water is covered with ice up to two metres thick. The north is also a desert, with most regions receiving less than 250 millimetres of annual precipitation, most of it as snow. Given these fundamental challenges, the supply of community drinking water and wastewater treatment in Nunavut are particularly challenging due to its geographic isolation, extremely cold climate, permafrost geology, extreme costs, limited level of services, and other unique northern community attributes.

These circumstances, as well as additional stressors, can move Nunavut's natural and human systems toward their tipping point and that may trigger extremely large responses. If these systems are networked or interconnected, the impact on them could be even greater.

By relying on a method called "design for resilience", the infrastructure and systems put into place in Nunavut communities can be such as to allow for a quick return to near normal levels of functioning even in cases of severe disturbances. The term resilience, or the ability to bounce back after being disturbed, has been used in many different contexts. However, in this case, it is used specifically to refer to the ability of critical infrastructure to

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FAQ's

Roles and Responsibilities

bounce back with reliability and robustness (strength) after a severe disturbance. Critical infrastructure includes processes, systems, and services that could cause death, discomfort, or destruction even if only momentarily disrupted.

A wide range of shocks and stresses can impact critical infrastructure. These events might include damage, loss of power, water, human access, and reduced control of infrastructure due to severe rain, flooding, high winds, lightning, earthquakes, other natural disasters, or even cyber attacks.

In the Arctic, there are additional issues with permafrost thaw, ground slumping, water shortages, distance between communities, and communication challenges. Longer-term climatic influences including sea level rise, floods, higher temperatures, severe storms, less permafrost, lower river levels and lower stored water levels will also have to be considered.

Measuring resilience is one of the most demanding tasks due to the complexity of the processes. Infrastructure and system health after severe disturbances were initially calculated by estimating and managing the risks. Design of infrastructure was thereby limited. Therefore, several years ago, this way of designing critical infrastructure evolved into "designing for sustainability" and has now advanced into a more comprehensive design for resilience.

Using a design for resilience involves combining stakeholder interaction with various engineering skills, as well as taking into account disaster experience, risk management, systems design and strategic planning. A major factor is covering the extra capital cost for these improvements. Some are skeptical about the value of resilience. Can the infrastructure life cycle be extended when integrating higher cost factors such as artificial intelligence, increased design safety factors, and system redundancies?

Figure 1 – Dynamic framework for planning and implementing resilient infrastructure.

Resilience of an engineered system can be improved through dynamic design principles. The science of designing for resilience is key to integrating the factors required for a successful future. It is therefore defined as the strategic design and construction of critical infrastructure systems to sustain required operations during and after the impact of severe disturbances, plus preventing, or adapting to, longer-term influences.

Substantial progress has been made in the science of designing for resilience for southern infrastructure, but to advance an understanding of the best detailed methodology for northern latitudes, major collaboration between institutions and stakeholders is required. Infrastructure resilience isn't easy to spot until after a severe disturbance when the full recovery time is recorded. Each system has a specific value that can be measured, and measuring these values is of key importance.

Design for resilience framework

The most cost-effective manner of achieving infrastructure resilience is by using an integrated set of engineering design guidelines based on collaboration between stakeholders and the use of engineering knowledge in many areas of expertise. The input of local stakeholders is an important part of the process.

Three attributes that can provide a resilient system are: adaptability, integrity, and tolerance. Resilient infrastructure and systems will have: 1) reduced probability of failure; 2) reduced consequences from failures, in terms of lives lost, damage, and negative economic and social consequences; and 3) reduced time for recovery (restoration of a specific system or set of systems to their "normal" level of functional performance). When resilience is not designed and built in, there will most often be no performance of the system or infrastructure after a severe stress, and it will take a significant amount of time to recover.

What is the best methodology for planning for resilience and then building resilience? Figure 1 shows a framework which starts with planning – determining the current threats and hazards and characterizing and analyzing the risks until the resilience options are developed. The plan then needs to have the resilience actions prioritized and implemented. Moving into the building phase, the key is funding these activities, which is a proactive investment for harm reduction. The detailed design for resilience then takes place, followed by construction and monitoring of these improvements in order to learn from the things that went wrong or slowed things down. Refining and improving the loop of planning for resilience and then building for resilience can continue with new knowledge and an improved methodology.

The Canadian Standards Association is working to assist in the improvement of northern infrastructure by providing detailed documentation for designs to withstand a changing climate. The first five standards deal with drainage, permafrost, and snow load. Under development are several more standards covering wastewater and erosion. These standards will assist with the establishment of Canadian infrastructure for an uncertain future.

Conclusion

As the impacts of climate change on the North are increasing in frequency and severity, the new climate reality must be confronted with urgency. The process of accelerating and promoting the establishment of resiliency in the North should:

- Mobilize existing knowledge by teaming up, and collaborating, with stakeholders;
- Research known unknowns with a cross-functional team in order to build capacity;
- Transform existing infrastructure and systems by making funds available for resilience efforts; and
- Build new climate resilient and cost-effective infrastructure.

The design for resilience methodology is advanced enough to allow a theoretical foundation for understanding best practice. It will continue to evolve as it is refined by adapting and applying new scientific practices and knowledge. To achieve northern critical infrastructure resilience goals, experimentation, iterative learning, and discovery by stakeholders is required.

THE LIVING BUILDING CHALLENGE

Rethinking Water & Wastewater Management

The Intergovernmental Panel on Climate Change (IPCC) is warning the world that we need negative carbon emissions in order to stay below two degrees Celsius of global warming. However, besides controlling global warming, there's a need for increased community resiliency, as the effects of climate change are inducing more uncertainty in the natural world.

Ecology North is currently spearheading a project to construct a Northern Centre for Sustainability (NCFS) in Yellowknife.

The proposed facility is targeting a "Living Building Challenge" certification, globally recognized as the most stringent green building certification. The space will host Ecology North's offices and community education space.

The Centre, in association with Ecology North, the Yellowknives Dene First Nation, Concordia University and the University of Alberta, will demonstrate proven pre-commercial technology for green buildings. The intent is to transfer the demonstrated knowledge and skills to northern communities. The first demonstration Living Building in Canada's North will be energy-positive, carbon-negative, water-positive, waste-positive and, most importantly, people-positive. It will actively promote technology replication, job creation and the reduction of greenhouse gas emissions through the Building Retrofit Economy.

The living building challenge

In contrast to Leadership in Energy and Environmental Design (LEED), the Living Building Challenge (LBC) is intent-based and aims for net positive impacts in its seven categories (Energy, Water, Materials, Place, Health & Happiness, Beauty, and Equity), which allows for more design freedom. The imperatives include but are not limited to: on-site renewable energy production of 105 per cent of the building's annual energy needs; a strict list of prohibited materials; carbon-neutrality construction and operation; and communication of the various aspects of the challenge.

Water, wastewater and related requirements

Project water use and release must work in harmony with the natural water flows of the site and its surroundings. One hundred percent of the project's water needs must be supplied by captured precipitation or other natural closed-loop water systems, and/or by recycling used project water, and

by William Gagnon, Green Buildings Specialist, Ecology North

must be purified as needed without the use of chemicals. All storm water and water discharge, including grey and black water, must be treated onsite and managed through reuse, a closed loop system, or infiltration. Excess storm water can be released onto adjacent sites under certain conditions.

The use of chlorine and calcium hypochlorite are not permitted in association with the LBC due to the toxicity and other potential harmful attributes, leaving designers with limited options for water disinfection. Ultraviolet lamps usually contain mercury and are therefore banned if compliance with the materials objective is intended; ozone may be an appropriate option, but an in-line carbon filtration device is suggested to avoid any potential health threats.

Alternatives to Polyvinyl Chloride (PVC) piping material, which has been identified as containing carcinogenic material, include: high-density polyethylene (HDPE); polypropylene; cross-linked polyethylene (PEX); vitrified clay; concrete; Acrylonitrile Butadiene Styrene (ABS); copper; steel; and iron.

Connection to a municipal sewage system is allowed for the project, but only provided that the system has a biological treatment process without chemicals, is within 500 metres or in the same watershed as the project, and treats water to tertiary levels with return of the water to the project. In that case, the project must show a balance between water inputs and outputs; must not put an additional burden on an existing combined sanitary and storm system; must not be separated from the plant by a lift station; and must include all energy requirements (production and pumping) into the equation.

The price of carbon and the opportunity for innovation

Carbon pricing will change the approach to design from system to system. The water treatment plants (regardless of scale or type) can be used to reduce the peak energy demand, and the water treatment operations can be turned on during times of low energy demand to reduce energy cost. The integration of these systems at the building level will facilitate the integration of renewable energy technologies that are usually less reliable.

The City of Yellowknife's water utility stations have been responsible for 21 per cent (660 tonnes) of the City's greenhouse gas emissions. In principle, these 660 tonnes of emissions equal a $30,000 annual carbon tax based upon a price of $50 per ton for carbon emissions that could emerge from Federal legislation. Carbon pricing will bring radical changes in how systems are designed, which will demand more innovative designs and the creation of "systems of systems" that inherently function as part of a big environmental re-generation machine.

Transforming industry into an environmental regeneration advocate

The LBC allows for exceptions, provided they help the industry shift slowly toward more sustainable practices. If the municipality requires that all buildings be connected to a municipal potable water supply, the design team must demonstrate that their drawings were submitted to the authorities having jurisdiction and that all regulatory appeals, short of legal appeals, have been exhausted. The intent of this is to create advocacy capacity for greener practices within the construction community.

BETWEEN A HONEY-BAG AND LAGOON: POTENTIAL DECENTRALIZED WASH SOLUTION FOR REMOTE/INDIGENOUS COMMUNITIES

The issue at hand

Most urban drinking water and wastewater infrastructure employs centralized systems, which consist of piped collection and conveyance systems for wastewater and water. Similar systems have been adapted for the far north and installed in certain communities. However, the cost of these systems, particularly the construction cost, remains a very expensive means of providing adequate water, sanitation, and hygiene (WASH) infrastructure to remote northern communities. The application of de-centralized or on-site WASH infrastructure is not new in its application and has provided a means for cost effective development in a rural southern context for decades.

De-centralized wastewater infrastructure has been gaining more attention given its relatively low capital and potential operational savings when compared to centralized systems. Additionally, recent studies have estimated that the greenhouse gas emission (GH) reductions for de-centralized systems are at least 40 per cent less than centralized services. Here, we propose a broad framework for the development of de-centralized WASH infrastructure for expanding communities, with a focus on remote Indigenous northern communities.

Figure 1 – Risk (Hazard, Exposure & Vulnerability), Resilience (Hazard, Exposure & Intrinsic Resilience).

Shifting the paradigm

In most northern communities, the current WASH solution is trucked water and sewage. Sewage is most often disposed in lagoons, resulting in the loss of potential for resource recovery. Here, we suggest an alternative to the present management of household wastewater in remote northern communities (Figure 1).

Decentralization

The core piece to our proposed WASH framework is based around decentralized energy and nutrient recovery from wastewater for remote communities. While this can look different across communities, the concept is simple: investing in smaller community-scale recovery systems, giving communities the ability to treat wastewater on-site to potable quality if need be. Such an approach eliminates the need for transporting wastewater to lagoons or treatment plants. Rather, the contents from toilets are conveyed to a small community anaerobic digester for methane energy production and struvite (ammonium-magnesium-phosphate) nutrient recovery for local agricultural uses such as green houses.

Source diversion

By using a resource-recovery decentralized approach we will have the freedom to more easily implement household source-diversion of toilet/food residual "blackwater" from other washing-generated (greywater) household wastewater. There is a growing awareness that source-diversion of wastewater allows for more efficient treatment -- blackwater contains nutrients (ni-

By David C. Shoults & Nicholas J. Ashbolt, University of Alberta

Figure 2 – Dynamic framework for planning and implementing resilient infrastructure

trogen and phosphorus) and produces local biogas (methane), while greywater has good potential for heat recovery and water reuse. Greywater from washing and laundry, which accounts for approximately 70 per cent of traditional domestic wastewater, is more readily treated to enable fit-for-purpose reuse than toilet/food residual blackwater.

Recent improvements in compostable self-sealing bags within toilets (such as in the Loowatt, Figure 2) allow for easy and safe collection of nearly all the nutrients and biogas substrates generated within a household. Hence, separating blackwater allows for greywater collection within homes and treatment for use as wash water. Treating greywater for safe reuse is critical but readily achievable with a range of approaches at the household level. Overall, handling separate wastewater streams within homes allows for more efficient treatment and resource (heat, nutrient, and water) recovery and could provide safe wash-water to reduce the burden of microbial diseases.

Advanced biosolids treatment

With our changing climate, there has been an increased awareness of the need to reduce greenhouse gas emissions where possible. We have also realized the opportunity to produce nutrients for the growing interest in local food production in community greenhouses. Advanced blackwater treatment through anaerobic digestion (AD) for methane recovery is a net-positive process which has the capacity to not only recover the energy required to operate a local treatment facility but generate excess heat/power. With this shifting paradigm and innovation in the field of sanitation, the use of waterless toilets is not only feasible, but provides tangible advantages. A waterless toilet (Fig. 2) provides home owners with a toilet solution which does not require any piping in or out. After use, contents in the toilet are sealed into an air tight, biodegradable film which can be emptied every few days into a community digester (along with food residuals), which then provides power for this community function.

Greywater treatment, reuse, and heat recovery

Supplying large amounts of potable water to remote northern communities for all household uses is very costly; but what if we could reduce the amount of water needed while increasing the amount of water available for use? By treating greywater to a level fit for non-potable reuse, importing water for household uses could be reduced by 70 per cent, depending on end-uses. The benefits are twofold: less energy to produce potable water and minimal generation of wastewater (e.g. no need for lagoons).

Additional considerations

Of course, implementing a new paradigm of WASH infrastructure is easier said than done. Capital cost, operation and maintenance costs, accessibility, climate, and community capacity must all be considered. Decentralizing will require a change in industry as individuals trained to operate these treatment facilities are needed. Centralized treatment facilities have the obvious advantage of being able to handle all the wastewater in one facility, thus simplifying the process in many ways. However, by decentralizing wastewater treatment plants, there is an opportunity to create new jobs and put the ownership of water distribution back into the hands of these communities, where community members are not relying on external sources for their water.

The final step needs to come first

With the advancement of water treatment technology in recent decades, efficient treatment of greywater to potable quality exists; however, there is a potential social barrier if communities are not engaged with deciding on a reuse strategy. Historically, First Nations, Metis, and Inuit communities have rarely been engaged in the design process and instead have been provided with solutions that may not have been appropriate for their communities. With the current paradigm on wastewater, many people are neither comfortable with, nor aware of, direct treatment/reuse of greywater. Therefore, community consultation, focus groups, and ongoing education are essential first steps, not last steps, for this to be successful. It is essential that government bodies and consultants work hand-in-hand with communities to co-create a solution suitable for each community. Water is the most important resource we have; it is important for the public to understand how it is managed and what risks are involved. However, it is equally important that those seeking to implement a solution are aware of the needs of the community. Ultimately, treating our wastewater as a resource and co-creating with stakeholders is an important next step to a more sustainable future.

The largest solar array in Manitoba will offset the power required by the plant, helping the community move away from the diesel fuel that creates the contamination issues that the plant is also helping to resolve. PHOTO CREDIT: BOKE CONSULTING

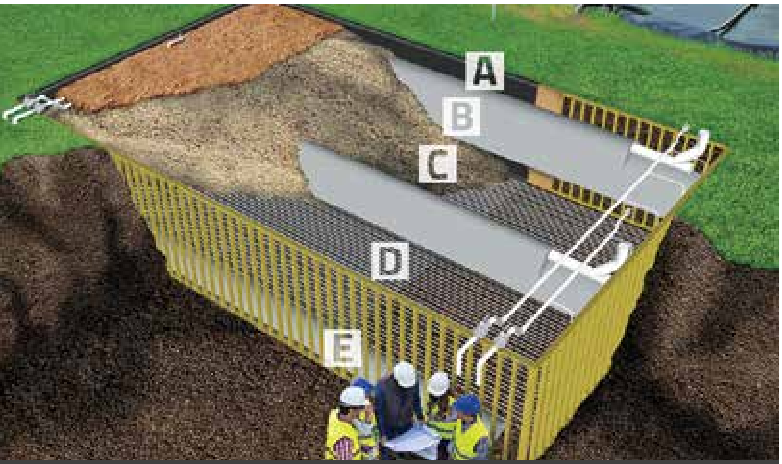
NORTHLANDS DËNESųŁINÉ FIRST NATION SUSTAINABLE WASTEWATER TREATMENT PLANT

"The North is the North," Ken Mattes begins. "You get down to 40-below, you discover all sorts of things that can go wrong."

Mattes is the long-time Manitoba coordinator for an Indigenous Services Canada (formerly INAC)-funded, West Region Tribal Council-facilitated circuit rider program, working with wastewater treatment operations on First Nations.

"Northlands [Dënesųłiné First Nation] had a Sequencing Batch Reactor-based mechanical system with a lot of problems thanks to the cold." Mattes rattles off a laundry list of issues: balancing sludge, pipes that had overheated and melted, even a door that didn't close right that had let in freezing cold air.

Northlands knows cold – located at 58° 36' N on the shores of Lac Brochet, even the average winter day features temperatures near -30°C. There's a tendency to view the cold as an added complication, and to contend with it, additional systems must be put into place. But as Mattes speaks, it becomes clear that the solution involves not more complexity, but increased simplicity and sustainability.



Cutaway view of a SAGR. A: Plastic liner preventing infiltration covers the sacrificial walls. B: Influent distribution chamber. C: Clean stone provides surface area for nitrifying bacteria. D: Linear aeration system creates fully-aerobic conditions. E. Effluent collection chamber. Photo credit: Nexom

Simplicity

"Simple in maintenance and simple in operation," agrees Liliya Chunderova, speaking of the new Northlands Dënesųłiné First Nation wastewater treatment lagoon she and her colleagues at Tetra-Tech designed. Even the process train is simple: "A new lift station, a new force main, the two aerated lagoon cells, followed by two SAGR cells discharging continuously."

Chunderova is referring to Nexom's Submerged Attached Growth Reactor (SAGR) post-lagoon cold water nitrification system, a made-in-Manitoba innovation. The SAGR is an in-ground, fully-aerated, horizontal-flow rock media bed that uses a patented process to grow multiple sets of the biomass that reduce ammonia in wastewater to non-detect levels, even in lagoon effluent that can fall below 1°C.

"In the extreme cold conditions at Northlands, a facultative lagoon would need a bigger footprint and still wouldn't meet Wastewater Systems Effluent Regulation (WSER) requirements," explains Chunderova, "but an aerated lagoon with SAGR for nitrification will."

"The ease of operating and maintaining a SAGR really sets it apart," says Mattes. "If you get into Level 3 plants, you need two years of post-secondary education just to operate it. But with the SAGR, the sewage goes into the lagoon, and clean effluent comes out with very little effort."

The SAGR is an in-ground, fully-aerated, horizontal-flow rock media bed that uses a patented process to grow multiple sets of the biomass that reduce ammonia in wastewater to non-detect levels, even in lagoon effluent that can fall below 1°C.

Yet what truly sets this treatment plant apart – possibly from any other on earth – is the SAGR's role in enabling the community to achieve greater sustainability.

By Philip Wiebe, Marketing & Communications Manager, Nexom

Sustainability

"Northlands is one of four Manitoba First Nations dependent on diesel for power, and they hate it," says Bruce Duggan, owner of Boke Consulting, a green-energy consultant on this project.

Getting sustainable is a big part of the new wastewater treatment plant on two fronts. The first is offsetting the site's power draw through a 282-kilowatt solar array. "It's the largest such array in Manitoba," says Duggan, "with over 1,000 solar panels, each measuring one metre by three metres." During the long summer days, and even in the shorter days in winter, the solar cells will help power Northlands' grid, contributing enough energy to offset the 270,000 kilowatt hours per year it will take to aerate the plant's lagoons and SAGR. The array will also power two new alternative-energy heating systems, which are a new biomass heating system at Northlands' school and a new geothermal heating system for several buildings and houses at the former federal school contaminated site.

But the wastewater plant does more than just generate its own power. In addition to treating the municipal wastewater, the new wastewater system is being used to treat contaminated soil and groundwater.

"No matter how careful you are with diesel, it will get into the ground, and when your community is built on an esker – a sand and gravel ridge – leaked diesel plumes." A small leak, Duggan notes, may seep down three metres but have a 10-metre spread. "Rather than 'digging and dumping' each incidence of diesel contamination, each of which could cost anywhere from $50,000 to over a million dollars to remediate, we're lancing the contaminated soil," says Duggan. Lancing is a process in which steel rods are pushed into the ground. Oxidizers and surfactants are injected to break down and free the diesel from the sand and gravel particles, and then the diesel and contaminated groundwater is pumped out through small wells.

"Then, by using the treatment plant's lagoon and SAGR instead of consumable carbon filters [for the leachate], we will be able to break down the diesel and associated chemicals and return the cleaned groundwater back to the ecosystem," Duggan says. He and others involved believe that the dual-purpose wastewater and diesel contamination treatment system used here is indeed the first time it has been done anywhere.

Ultimately, credit for the innovative plant belongs to the community.

"In southern communities, you face a lot of skepticism," says Duggan, "but in Northlands, people are determined to take care of their lands. They've lived here for thousands of years. We did not have to convince anyone of anything."

"It's a thrill to be involved in this project because of the difference it'll make," says Mattes, "not only for the template it could provide to protect the environment in northern Canada, but for Alphonse, the operator at Northlands, and his community specifically."

Water treatment, storage and truckfill facility in Cambridge Bay, Nunavut.

EMERGING CLIMATE CHANGE ISSUES AND CHALLENGES FOR WATER SYSTEMS IN THE ARCTIC

Introduction

Many factors influence the engineering practices associated with water infrastructure in the Canadian Arctic. These factors include the extreme cold conditions that infrastructure must withstand, ground-related conditions, extreme construction, operation and maintenance costs, the short construction season, challenges of transporting construction material, delays in procuring specialized equipment, and an undersupply of labour.

It has been observed that Arctic water is abundant, but in short supply for communities that require a clean source of water year-round. Ten-month winters, by themselves, limit water supply because water can freeze to a depth of two metres. The Arctic is also a desert with some most regions receiving less than 250 millimetres of annual precipitation, falling mostly as snow.

Water treatment processes have become complex with the application of membrane technology, which involves high capital and operation and maintenance costs. This technology is generally designed for "targeted" treatment, which may not be easily adjusted to accommodate changes in the source water quality.

Ongoing research is showing that climate change is altering the fragile thermodynamic relationships of northern ecosystems by shifting the seasonal transitions, and altering precipitation regimes, including the rainfall events and the snowfall accumulations. Snowmelt is a crucial source of water for shallow Arctic lakes, and snowfall is projected to decrease in some regions. What this means is

By Ken Johnson, AECOM

that the targeted treatment systems may be unable to achieve the required water treatment because of changing conditions.

A recent compilation of specific occurrences potentially related to climate change issues for water and sewer systems (NWT and Nunavut) identified 17 occurrences. Of these 17 occurrences, 11 were associated with water supply and treatment, and seven of the 11 were associated with water quality.

Attributes of water infrastructure not suited to change

The water infrastructure in the Arctic has three significant attributes which cause limitations for climate change adaptation. The attributes are design life, a non-portable configuration, and complexity. The design life limits the infrastructure because it is designed to last a generation (20 to 30 years), which means that a community is burdened with whatever infrastructure is built for a 20- to 30-year period, with limited or no opportunity for changing the infrastructure. The non-portable attribute limits the infrastructure because it

Water treatment, storage and truckfill facility in Cape Dorset Nunavut has a fixed location with a limited possibility for relocation.

The final attribute is associated with the complexity of the design, and operation and maintenance. With these complexities, issues may develop with time that may be expensive and time consuming to correct. This is particularly true with the "modern" water infrastructure that has emerged which requires the application of complex technologies.

These three attributes do not align well with climate change because by its very nature climate change is creating an increasingly dynamic natural environment that the water infrastructure must respond to. Water infrastructure operation and maintenance in the Arctic can be difficult enough with "normal" day-to-day functioning, and quite likely very difficult, to impossible, with the anticipated changes in the quality and quantity of water.

A changing climate presents additional challenges to the design, development, and management of water infrastructure in the Arctic. Water infrastructure is "climate sensitive" because it is designed, built, and operated so as to provide useful service over decades within a range of site-specific criteria. The current water infrastructure – and the infrastructure that will be built in the next few decades – will be subject to climate conditions outside of historical experience, with changes likely intensifying over time. All infrastructure systems carry some risk of failure. However, unanticipated, and rapid, changes in the operating environment may increase this risk and overwhelm systems' coping capacity, with related financial losses, and health and safety risks.

Water engineering practices associated with climate change

The lack of system "redundancies" or backups, and the isolation of Arctic communities are key features that differentiate infrastructure systems in the Arctic from systems in the south. In the event of infrastructure failure, northern communities may not have access to the benefits of options that many southern communities take for granted, such as simple and convenient community access, piped and looped water systems, and local problem-solving resources.

This lack of options in emergency situations may require the mobilization of considerable resources, at great expense, to address an issue. For example, Arviat, Nunavut had a significant leak in the water reservoir, which prompted the need for an emergency water supply because a winter repair was not possible. After the consideration of alternate freshwater sources, it was concluded that seawater was the only reliable solution. This required the quick and expensive mobilization of a reverse osmosis treatment system.

A northern water engineering manual Good Engineering Practice (GEP) for Northern Water and Sewer Systems was originally

Water storage reservoir in Chesterfield Inlet, Nunavut.

published in 2004 by the Government of the Northwest Territories' Department of Public Works and Services. GEP highlights the conditions for Arctic water infrastructure which often require a different approach to design than what is commonly applied in the south. GEP has been revised and published as a second edition, and the revision includes a list of climate change influences associated with the engineering of water systems in the Arctic, along with several reference documents for further consideration.

There are planning reports addressing climate adaptation that have been developed for many Arctic communities, but water infrastructure is only highlighted in the context that change will likely occur, and adaptation will be needed. Ultimately the adaptation of water systems to a changing climate will be the responsibility of the individual communities, with the support available from the senior governments.

Closure

It is anticipated that the warming Canadian Arctic climate will influence the quantity and quality of community water. A significant number of Arctic communities are already experiencing water issues that may be related to climate change. The most recent climate change report stated that the entire Arctic Ocean could be largely ice free, in the summer, as early as 2030. Arctic temperatures are rising twice as fast as temperatures in the rest of the world, and, in the fall of 2016, mean temperatures in the Arctic were six degrees higher than average.

In response to climate impacts on water infrastructure, resiliency may be more appropriate than redundancy. Historically, the application of redundancy has meant having "more of the same" in order to be in a position to respond to critical facility issues, whereas "resiliency" refers to the ability of such infrastructure systems (including the interconnected systems and social systems) to absorb disturbance and still retain their basic function and capacity.

Most Arctic communities currently have a limited capacity for dealing with water issues, whether they are technical, financial, administrative, or human resources. Contrary to this limited capacity are the increasing demands on these same resources which are being driven by increasing regulatory demands and increasing sophistication in the technology associated with water in the Arctic. Climate change will demand new approaches to juggle these contrary issues.

Boring in Qaanaaq.

INFRASTRUCTURE RESEARCH IN QAANAAQ, GREENLAND

Introduction

Qaanaaq is the world's northernmost community with an indigenous population, and Greenland's poorest, with an average income markedly lower than the national average.

The primary business is still the hunting of marine mammals and polar bears, but the hunt is challenged by climate change, and it is becoming still more difficult to sell skins and ivory due to international regulations. To supplement their income, hunters are increasingly turning to fishing for halibut, but the infrastructure in the district is completely insufficient to support this necessary conversion. Thus, in recent years, there has been a focus on improving Qaanaaq's infrastructure and the living conditions of the inhabitants.

In 2017, the Arctic Technology Centre (ARTEK) was responsible for a series of research projects in Qaanaaq, which were carried out in cooperation with several partners. Their work included two months of field work in the community of Qaanaaq (620 inhabitants) and two of the district's settlements.

The research was financed by the Greenlandic Self-rule Government, the national power- and water-supply company Nukissiorfiit, and the Technical University of Denmark, and completed in cooperation with Qaasuitsup Kommunia (the municipality). The projects regarding water supply also received economic support from the Nordic Atlantic Cooperation (NORA).

Permafrost issues

Almost everywhere in Greenland, buildings are built on solid rock. Qaanaaq, how-

By Kåre Hendriksen, Arctic Technology Centre ARTEK, Technical University of Denmark

ever, is situated on sediment, containing permafrost, in an old riverbed, and consequently, many buildings are damaged due to settling foundations.

A systematic analysis of the geotechnical conditions in the area has never been carried out, and thus there is not sufficient knowledge about what kind of foundations buildings should have constructed in order to avoid damage from ground movement, or where the community may be expanded to minimize this issue. This is why a series of geophysical measurements and excavations were completed in and around Qaanaaq. Simultaneously, several holes, up to 20 metres deep, were bored and thermal sensors installed to monitor future thermal developments. The goal is to uncover the structure of the geology, map the ice contained in the ground, and assess how far much below the surface the bedrock is located.


Collecting ice bergs for melting.

Qaanaaq reef at low tide with supply ship off shore.

Limited water supply

The river in Qaanaaq contains only enough water to meet the community needs for about four months of the year. During this period, Nukissiorfiit also fills two water containers, each holding 2,000 cubic metres, which provides enough water for the community needs for the following four months. During the last four months of the year, Nukissiorfiit collects ice from icebergs trapped in the sea ice and melts this ice in a special melter connected to the water works (See article in 2017 edition of the *Journal*). This period when the water is being produced by melting sea ice is exactly the same time as the first sales of halibut. The lack of sufficient, economically priced water limits both the factory's processing and first sales. Simultaneously, the sea ice is getting thinner due to climate change, which makes collecting icebergs more dangerous.

Additional water storage

An assessment of the possibility of extending the period when water is obtained from the river and finding a suitable location for the placement of two new large water containers were also included in the project. In the fall of 2017, Nukissiorfiit decided to establish two new water containers of 2,000 cubic metres each, which increased the total amount of water which could be stored to 8,000 cubic metres. The challenge of this decision is that it will only cover the community's current annual water consumption, not what future needs are estimated to be.

Partly, the problem is that Qaanaaq has the lowest per capita water consumption in Greenland, at just 40 litres per person, per day, when the national average is more than 100 litres per person per day. The low consumption in Qaanaaq is largely because houses are not connected to a piped water supply system.

The other problem is that a winter capacity of 8,000 cubic metres for four months is not enough for consumption by the households and the processing of fish in the community Added issues that must be considered are that the fishing for halibut is increasing, and there is massive unemployment in the community.

Reverse osmosis water treatment or additional storage

Currently, Nukissiorfiit is considering supplementing the winter water supply with a reverse osmosis facility. The issue with this is that 300 metres outside the city is a reef, and the city's grey waste water is released onto the land and ends up on the community side of the reef. Also, honey bucket bags are left at the community dump, which leads to black waste water (fecal matter) leaking out to sea and concentrating inside the barrier formed by the reef. This means that every winter, a salt water intake line would have to be placed well past the reef to ensure reasonably clean seawater. This would be complicated due to the large ice movements caused by the reef.

In consideration of the saltwater supply issue, the researchers recommended that the two new 2,000-cubic-metre water tanks being considered be replaced with 3,000-cubic-metre ones instead, because this option will be cheaper in the long run than installing an extra 2,000-cubic-metre tank in the future.

COLD REGIONS ENGINEERING – NEW MANUAL OF PRACTICE

By Jaime D. Goddard, Department of Municipal and Community Affairs, Government of the Northwest Territories

The Cold Regions Utilities Monograph (CRUM) was first published in 1979, and the current edition in 1996. It has been a mainstay of cold regions utilities design, covering topics such as planning, geotechnical considerations, drinking water systems, wastewater, solid and hazardous waste, fire protection, and energy management, with a focus on the challenges specific to the design of water, waste, and power systems in the circumpolar regions, Advances in research and technology, further practical experience in the operation of northern systems, and changes to government funding arrangements and operator training over the past 22 years mean that it is now in dire need of revision. Luckily, an update is now underway. Spearheaded by University of Alaska professor Aaron Dotson, the revision team includes both Canadian and American contributors from private industry, academia, and government. Several meetings have taken place to determine what should be cut, updated, combined, or moved, with the intent of narrowing the book's scope to more specifically address cold regions issues and remove general design methodologies when they are the same as southern practice.

Although the current book is a monograph, the new version is anticipated to be reformatted as a manual of practice. Writing and editing are currently underway, and publication of the new edition is anticipated to be in 2019. When complete, the updated manual of practice will incorporate recent research and experience gained in the field of cold regions engineering since the previous edition, as well as updating outdated information on pricing, available materials, and appropriate technologies. It will be available for purchase through the American Society of Civil Engineers (ASCE).

The team is looking for reviewers with cold regions utilities experience to form a Blue-Ribbon Committee for review of the revised chapters, with the intent of having each chapter reviewed by both a Canadian and an American reviewer to ensure both jurisdictions are properly represented. Anyone interested in becoming a reviewer should contact Aaron Dotson at addotson@alaska.edu.

Cape Dorset – depollution training.

CAPE DORSET METAL MANAGEMENT PROJECT

Solid waste is a challenge across most remote northern Canadian communities. Dumpsites in northern communities were often located out of convenience at a time when there was far less population, and far less waste per capita. These dumpsites predate current environmental regulations and are a burden on the communities. A report prepared in 2014 by EXP for the Government of Nunavut presented a clear picture that metal waste in Nunavut is a large problem.

In 2017, a demonstration project was launched in Cape Dorset to clean-up the metals dumpsite through a community-driven, train-the-trainer model led by Qikiqtaaluk Business Development Corporation (QBDC). QBDC, a subsidiary of Qikiqtaaluk Corporation (QC) is the development arm of Qikiqtani Inuit Association. Through this structure QBDC represents the approximately 14,000 Nunavut Inuit in the Qikiqtani Region. This project brings a multi-level government approach inclusive of federal, territorial, municipal governments, and the Regional Inuit Organization.

Cape Dorset – baling training.

The project structure is such to maximize local and Inuit training and employment and to build capacity at the municipal government level with support from their Regional Inuit Organization (QC & QBDC in this project instance).

The 2017 summer was a great success! The project provided funding to the municipality to subsidize the wages for six new casual positions devoted to the clean-up of the metals dumpsite. Six Cape Dorset residents were hired and trained in the health and safety aspects, and hands-on knowledge transfer for safe removal, handling and packaging of hazardous waste from waste metals. Scout Environmental supported the training of depolluting end-of-life vehicles and white goods. By the end of the summer, most vehicles at the dumpsite were depolluted and refrigerants recovered from about half the fridges and freezers. This was all completed in only a few short months of hard work. The next step was to compact the metal and prepare it for future backhaul for recycling. The Government of Nunavut made available their metal baler through in-kind project support. After two weeks of intense training, a local equipment operator was ready to start tackling the metal pile and in a few short weeks had baled about 600 tonnes of metal!

A late spring and equipment repairs de-

By Justine Lywood and Erin Mentink, plusArctic

layed the start-up of the baling work for the 2018 season, but that hasn't stopped the project from moving ahead. This year, QBDC and the municipality are working together to expand the scope to include a community clean-up to remove the derelict vehicles scattered around the hamlet and bring them to the metal dumpsite for depollution and baling. These derelict vehicles not only have negative visual impacts, they also pose a safety and environmental concern.

The desire for the community clean-up is driven in part by the exciting upcoming opening of the Kenojuak Cultural Centre and Print Shop. Cape Dorset has a thriving arts scene, and it is anticipated that with the opening of the Kenojuak Cultural Centre, tourism will see a considerable increase. The derelict vehicles are an eyesore and detract from enjoying the scenic community and encouraging tourists to walk around and meet the local artists as they work outside their dwellings. The community clean-up will support Cape Dorset in presenting an image that reflects the community – opening, welcoming, and inspirational.

The project in Cape Dorset is a demonstration of a new approach to delivering projects that truly prioritize capacity building and a social return on investment. This project scope has evolved, reflecting the unique needs of the community, and has supported the municipality to drive the project priorities.

Conversations are ongoing on ways to deliver a similar structured project in all Nunavut communities. The delivery of this project has been made possible through the financial contribution of Polar Knowledge Canada, Government of Nunavut Community Government Services, Department of Environment, and Economic Development and Transportation, Qikiqtaaluk Corporation, Kakivak Association, and the Municipality of Cape Dorset. Most importantly, this project would not have been successful if not for the dedication and hard work of Steven Pootoogook, Ashoona Ashoona, Pitseolak Koomwatook, Pitseolak Pudlaq, Tytoosie Pudlat, Itulu Qinnuajuak, and Mosha Ragea.

Crew.

Taloyoak water treatment facility.

WORKING TOWARD WATER RESILIENCE IN TALOYOAK, NUNAVUT

The design, build, and installation of a package water treatment plant always presents challenges, but few can match the project completed in Taloyoak, Nunavut. While water system resilience is still an evolving term in the far north, the Government of Nunavut has taken a leadership role in working to provide the northernmost settlement on mainland Canada with a self-contained, environmentally- sound, water treatment plant. The project objective was not only to generate clean water all year round, but also foster local development and reduce contributions to climate change.

The village of Taloyoak is an isolated community of 700 people located on the shore of the Arctic Ocean at 69° 32’ north latitude, 2,000 kilometres north of Edmonton. This distance creates accessibility challenges, in addition to challenges associated with the extreme cold. Added to these challenges were a “Triple Bottom Line” objective established by the Government of Nunavut. Usually cost is paramount, but the Taloyoak water treatment project also had equal weight given to social and environmental considerations. The Government of Nunavut requested a design with a minimal impact on the fragile northern environment.

Since there are no roads to Taloyoak, construction materials arrive each September on the annual sealift. An alternative – but considerably more expensive – delivery method is air freight, but this has significant size limitations. To further complicate matters, power generation in the high Arctic is normally provided by diesel generators, which means that fuel must also be transported to the community on the annual sealift.

To cut fuel emissions, reduce fuel supply costs, and meet the project’s environmental “bottom line”, the project team wanted to reduce dependence on diesel generators as much as possible. In response to these objectives, solar and wind energy were selected as the primary power sources, since they are renewable and non-polluting. A four-point approach was taken to utilize the advantages that each potential power source has to offer. The alternative sources of power for the community were community diesel-generated power, an onsite diesel generating system, solar power and wind power. The community diesel generated power provides added stability to the system, and a power supply for the periods without sun or wind. The onsite diesel power system is inside the water treatment plant and provides additional resiliency for emergency power.

The solar power component of the plant consists of 48 photovoltaic modules, 175 watts each, mounted on four support poles. Each bank of 12 solar modules is con-

By George Thorpe, BI Pure Water and Ken Johnson, AECOM

trolled by a sun-tracking device, allowing them to continuously follow the sun at an ideal angle. The combined solar modules have a total power rating of 8.4 kilowatts (kW), which, on a sunny summer day, produce nearly 40 kWh (kilowatt hours) of power.

Some of the solar power will be used to charge a battery bank made up of 48 batteries installed in the building. By using solar energy rather than relying solely on diesel generated power, more than 130 tonnes of carbon dioxide are not discharged into the environment each year. The entire on-site power consumption is 60 kWh per day, which translates into two-thirds of the total power supply potentially coming from solar energy.

To supplement the solar system, a small wind turbine was installed on a 21-metre-tall tower. Based on a mean wind speed in Taloyoak of approximately seven metres per second, the estimated wind power is 1.75 kW. Wind power generation does fluctuate, depending on wind speed and other variables, however, combined with energy storage batteries, it may provide a steady source of power.

The raw water supply for the treatment plant is Canso Lake, a 20-hectare lake 3.2 kilometres northeast of the community, which is seasonally recharged during the spring runoff. Despite ice thicknesses on the lake that may exceed two metres, the insulated and heated intake pipelines do not freeze.

The water treatment system process itself utilizes cartridge filtration with a 20-micron initial filter followed by a one-micron filter. Supplemental chlorination is used for disinfection and to provide a residual level of chlorine for the trucked water delivery system.

Providing Nunavut residents with relevant job skills was another key aspect necessary to meet the project's social ob-


Operation of truckfill system at Taloyoak water treatment facility.

jectives. The contractor worked closely with local labour resources for a successful construction phase. Operations training for the local staff followed the construction.

The training plan for the staff went beyond the normal expectations specified. A Remote Monitoring and Trending system was used throughout the warranty period. The system provided alarm reporting and data monitoring, as well as trending of important parameters such as chlorine levels, pressure differentials, pump speeds, flow, alarms and outputs from the turbidity and chlorine analyzer instruments. This information is available on computer screens in the Taloyoak operator's office, and at southern locations through the power of the internet. Ongoing training has been one of the results of using this system, with contractor resources available to help the operator diagnose problems in real time.

The water treatment system has been providing clean, safe water to the people of Taloyoak; however, operating alternate energy systems has been challenging because specialized maintenance knowledge is required. The alternate energy systems have had considerable downtimes as the "hiccups" of the new technology are worked through. Despite these hiccups, the Taloyoak water treatment facility is raising the bar for facility resiliency of water treatment systems in Nunavut.


Solar panel for water treatment facility in Taloyoak

NTWWA President's Report
OLIVIA LEE

To my friends, colleagues and members, it is my pleasure to write to you as the President of Northern Territories Water and Waste Association (NTWWA). Having participated with the organization for over 10 years, it has been an honour to watch its continued growth. I am grateful for this opportunity and deeply appreciative of the strong support provided by all our NTWWA members. I would like to thank our members for making efforts to engage new members and reconnect with those individuals whose membership has expired.

Over the past year, our association introduced a scholarship fund offering a training grant award and a campaign grant award each with an award amount of $1,500. Congratulations to the Iqaluit Inuksuk High School's Green Club, who are the very first recipients of the campaign grant award. They will be hosting their first water and waste symposium with the funding. The association is happy to support such a great initiative, and we wish them luck. Applications for the next round of scholarship funding can be found on our website and will be accepted until June 28th, 2019.

Thank you to everyone who was able to attend the 2017 conference in Iqaluit, Nunavut. Though economic times are tough, we had a full roster of 18 presentations, seven tradeshow booths and 60 delegates, of whom 24 participated in the operator's workshop. For the past few years, we have been lucky to welcome the participation of delegates from Greenland. They have been able to share with us some of the interesting things they are doing in the area of waste management, and we look forward to their continued participation.

As a not-for-profit organization, our success depends on the generosity of our sponsors, and I would like to express my deep appreciation to those sponsors. In addition, thanks to our conference planning committees, as well as Gerry Gusdal and Jean Soucy, for ensuring the operator's workshop was a huge success.

Thank you for your continued support of the NTWWA. With our continued effort, this organization can continue to thrive and grow. We are always looking for new and creative ideas to provide the best possible service to our membership. We welcome your thoughts and feedback.

We look forward seeing you in Yellowknife in November 2018. For additional information, please visit our website (www.ntwwa.com).