PORT of vancouver | Vancouver Fraser Port Authority

# BC Ferries Quiet Vessel Ferry Design case study – Phase 1

## ECHO Program summary

The Vancouver Fraser Port Authority (VFPA)-led Enhancing Cetacean Habitat and Observation (ECHO) Program is a collaborative regional initiative that seeks to better understand and reduce the impacts of commercial shipping activities on at-risk whales throughout the southern coast of British Columbia. To promote the uptake of underwater noise reduction solutions with ship owners and operators, the ECHO Program reviewed the approach that BC Ferries – one of the world's largest ferry operators – took in setting underwater radiated noise reduction goals through the design and construction of its new major ferries replacement program.

## What was the objective of the case study?

The case study outlines the key steps undertaken and challenges experienced by BC Ferries in the initial phases of the major vessel replacement program, highlighting lessons that may benefit other ship owners who are considering the inclusion of underwater radiated noise reduction targets in new vessel builds.

## Who conducted the project?

The ECHO Program retained West Pacific Marine to work directly with personnel at BC Ferries and summarize key learnings into a case study report.

## What methods were used?

West Pacific Marine compiled information through a combination of:

- Background documents provided by BC Ferries
- A series of six interviews led by West Pacific Marine with BC Ferries personnel involved in the major ferries replacement program in both management and technical roles
- Online research on underwater radiated noise; the role of classification societies in underwater radiated noise reduction; BC Ferries' publicly available documents; and shipyard risk management systems

## What areas of underwater radiated noise reduction solutions did the case study address?

The case study looked at the full history of BC Ferries' efforts to better understand and prioritize the reduction of underwater radiated noise, including what steps were taken to develop the underwater radiated noise reduction goals for their organization and targets for their new major vessel replacement program.

The case study also looked at the steps taken by BC Ferries to assess the noise signature of its existing fleet and understand the potential impacts of the fleet's underwater noise spectrum on the local endangered southern resident killer whale population.

The case study examined steps that BC Ferries took to engage a third-party expert in underwater noise to aid in evaluating noise reduction techniques and new build specifications that could help reduce underwater radiated noise.

Through interviews with BC Ferries, West Pacific Marine examined how underwater radiated noise reduction targets may complement or potentially impact other performance or design requirements for BC Ferries' new major vessel replacement program. This review highlighted the technologies or design modifications that showed the greatest promise in potentially reducing underwater radiated noise.

## Lessons learned

While BC Ferries' new major vessel replacement program is still ongoing, the initial phases of work have led to some key learnings which other vessel operators may find helpful when  considering setting underwater radiated noise reduction goals for new vessel builds:

- Underwater radiated noise is gaining attention for its negative impacts on marine life. In the Canadian context, the *Species at Risk Act* places an onus on the marine industry to incorporate underwater radiated noise reduction into environmental policies.
- The application of underwater noise reduction technology in the commercial shipping and shipbuilding industries is still in its infancy and therefore research is limited due to perceived risk, low demand and uncertainty in financial return. This gap in research means that solutions will need to be developed and financed by early adopters.
- Meeting underwater radiated noise reduction targets for a new vessel is not always complementary to other performance specifications, such as vessel speed and efficiency, which presents some design challenges and consideration of trade-offs.
- As underwater radiated noise is a function of many complex interactions within a vessel, it is important to design the propeller and propulsion systems in concert with the hull design to ensure that functional requirements are accounted for.
- Engaging an underwater radiated noise expert to assess design impacts and conduct trade-off analysis is valuable, as well as ensuring that the expert works closely with the selected shipyard throughout the design optimization and build process.
- While shipping classification societies have developed underwater radiated noise notations, the lack of a standardized approach to vessel design guidelines for such notations poses challenges to vessel operators exploring the development of underwater radiated noise targets.

# FINAL REPORT

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# BC Ferries Quiet Vessel Ferry Design

# A Case Study

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Revision: A

## 1.0 Executive Summary

In 2018 it was announced that BC Ferries was to enter a new phase of modernization with the launch of the Major Vessel Replacement Program (MVRP). For the first time in the company's history, Underwater Radiated Noise (URN) management was written into the Statement of Requirements (SOR) for this new class of vessels in the Request For Proposals (RFP) circulated to shipyards. While, at the time of this report, the MVRP is delayed due to the significant impact of COVID-19 on the company's capital project planning, the objectives related to URN remain. Meanwhile, the company is also assessing options for modification to existing vessels to achieve URN reduction without sacrificing fuel efficiency.

BC Ferries initially engaged directly with the problem of URN in 2014 to understand the potential impacts of its ferry route operations on species at risk. It became clear that URN was going to be a significant matter for the BC Ferries operations into the future and had to be addressed in operational and technical policies.

The company initiated a series of URN measurements on differing classes of vessels across the fleet in order to be better informed, and to increase internal awareness of the issue. As a result of this work, BC Ferries was able to establish and articulate a general baseline that a ferry at service speed is typically emitting URN at a broadband sound intensity of 185 dB radiated noise level (RNL). Operating a large fleet in the Salish Sea, the company set a goal to strive for a 50% reduction of overall URN emission into this habitat. In order to reach this goal, new vessels would need to be significantly quieter than vessels being retired and options examined to reduce noise from vessels part way through a 45 year average lifespan.

The introduction of URN requirements into the MVRP did not substantially alter processes in BC Ferries' Design-Build contracting methodology. The company applies risk mitigation strategies to adapt novel requirements, as it did in 2015 with the introduction of Liquefied Natural Gas (LNG) as a primary fuel. This includes partnering with an expert 3rd party outside of a build contract, investing in research that would build confidence in a design concept or discount it, and engagement with potential major vendors whose equipment might have significant impact on the outcome. This adds cost at the front end for feasibility but, if correctly applied, eases the way for a successful implementation.

BC Ferries needs to understand and be prepared for the trade-offs that will be encountered in the design and construction of a new vessel in the effort to reach URN reduction goals. The new build target of 175 dB (RNL) is a significant reduction that cannot be at the expense of energy efficiency, speed, maneuverability, lifecycle cost, and the various other technical requirements of a new class of major ferries. The contracting process and BC Ferries' major project approval process accounts for URN in relationship to other requirements based on weighted criteria.

Marine industry expertise in URN reduction is a work in progress, and BC Ferries is taking an important lead from which others will benefit. There is a high expectation that the burden of development will in due course be shared with other sectors, in particular the cruise industry as the attraction of expedition cruise ships grows and the demand for URN reduction drives solutions.

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## Acronyms and Definitions

| Acronym | Definition |
|---|---|
| ABS | American Bureau of Shipping |
| BV | Bureau Veritas |
| CMAC | Canadian Marine Advisory Council |
| CFD | Computational Fluid Dynamic |
| CORI | Coastal Ocean Research Institute |
| CPP | Controllable Pitch Propeller |
| CSR | Corporate Social Responsibility |
| dB | Decibel |
| DFO | Department of Fisheries and Oceans |
| DSIP | Delegated Statutory Inspection Program |
| DNV | Det Norske Veritas |
| ECHO | Enhancing Cetacean Habitat and Observation Program |
| FMP | Fleet Master Plan |
| FPP | Fixed Pitch Propeller |
| GHG | Greenhouse Gas |
| ISO | International Standards Organization |
| IMO | International Maritime Organization |
| LOA | Length of Vessel |
| LNG | Liquefied Natural Gas |
| LR | Lloyds Register |
| MEPC | Marine Environmental Protection Committee |
| MTRB | Marine Technical Review Board |
| MVRP | Major Vessel Replacement Program |
| R&D | Research and Development |
| RFEOI | Request for Expressions of Interest |
| RFP | Request for Proposal |
| RFPQ | Request for Pre-Qualification |
| RINA | Registro Italiano Navale |
| ROPAX | Roll-on/roll-off Passenger Ferries |
| RNL | Radiated Noise Level |
| RFP | Request for Proposals |
| RFPQ | Request for Pre-Qualification |
| SOR | Statement of Requirements |
| SRKW | Southern Resident Killer Whale |
| TC | Transport Canada |
| TCMS | Transport Canada Marine Safety |
| UNMP | Underwater Noise Management Plan |
| URN | Underwater Radiated Noise |
| VFPA | Vancouver Fraser Port Authority |
| WRAS | Whale Report Alert System |

## 2.0 Background

The emergence of Underwater Radiated Noise (URN) as a relatively new environmental issue for the marine industry to address was first signalled at the International Maritime Organization (IMO) in 2004. Thereafter, in 2008 the IMO Marine Environmental Protection Committee (MEPC) agreed to develop non-mandatory technical guidelines in order to raise the profile of the discussion.

In 2014 the IMO approved the issuance of a set of guidelines, “On Reducing Underwater Noise from Commercial Shipping to Address Adverse Impacts on Marine Life.” The document focused on four key themes:

- Propeller design.
- Hull form.
- Onboard machinery selection and installation.
- Maintenance including hull cleaning.

However, the guidelines noted that there are significant knowledge gaps and complexities related to the study of vessel generated underwater noise, which requires additional research. For this reason, the IMO was reluctant to enter into discussions related to the setting of targets for URN reduction at that time.

British Columbia has a productive coastal ecosystem that sustains numerous populations of whales that are designated as at-risk under Canada’s *Species at Risk Act*. Ships calling at the Port of Vancouver transit through designated critical habitat for the endangered Southern Resident killer whale (SRKW) population, which has just 75 individuals remaining. The Killer Whale Recovery Strategy published by Fisheries and Oceans Canada in 2008 identifies acoustic disturbance from vessels as a key threat impeding the recovery of the species.

The Vancouver Fraser Port Authority (VFPA) is responsible for the stewardship of the federal port lands and waters that make up the Port of Vancouver in and around Vancouver. Recognizing that commercial marine activity in the region has the potential to impact at-risk whales, the port authority launched the ECHO Program in 2014. The goal of the program is to work collaboratively with regional partners to better understand and reduce the cumulative effects of shipping on whales, with a particular focus on reducing underwater noise from large commercial vessels and supporting the recovery of the SRKW population.

In 2018, the MEPC noted several submissions related to URN, including a presentation from the Canadian delegation. However, several delegations pressed the need for further research into URN sources in order to better inform members prior to consideration of new regulatory measures at the international level.

Also, in 2018, the Government of Canada announced the $167.4 million “Whales Initiative” to protect and support the recovery of the Southern Resident killer whale (SRKW), the North Atlantic right whale, and the St. Lawrence Estuary beluga. An additional investment of $61.5

million was also made to implement new measures aimed specifically at strengthening the protection of the SRKW.

As a founding member of the ECHO Program Advisory Working Group, BC Ferries has taken numerous steps to consider the company's own contribution to the generation of URN and how it can be reduced, particularly on primary routes transiting through SRKW critical habitat.

The ECHO program commissioned this Case Study document in an attempt to capture the steps taken by BC Ferries in the decision to build a quieter vessel with URN targets, to describe the processes undertaken to achieve that goal and how they differ from a standard shipbuilding process. It is hoped that this study will help inform other ship owners who may be considering designing and building a quieter vessel.

# 3.0 Scope of Work and Methodology

The BC Ferries Major Vessel Replacement Program (MVRP) Case Study is intended to inform the reader to the context, procurement process, technical and construction considerations, as well as the external support and risk management involved in the incorporation of Underwater Radiated Noise (URN) target in new vessel builds. This includes internal processes related to the determination of URN targets including the identification of knowledge gaps and focus from corporate governance as well as the methods that URN targets are assigned and managed between the vessel owner and shipyards involved in a design build program that includes URN targets.

## 3.1 Case Study Scope of Work

The scope of work for the Case Study may be summarized as follows:

- Provide an explanation of the rationale for the construction of quiet vessels.
- Provide an explanation for the development of URN targets for BC Ferries MVRP and the basis on which they were developed.
- Provide a summary of the workflow in the development of the MVRP with the inclusion of MVRP targets and how that may differ from a conventional Design-Build contract.
- Identify any additional costs for URN reduction, impacts on construction schedule and allowance for contingencies.
- Describe the process of design evaluation and the technologies that have been considered in the MVRP as they relate to URN targets.
- Describe the management of all forms of risk by the key stakeholders to the project.
- Describe the project approval and RFP processes and how the inclusion of URN targets impacted this process.
- Provide a summary of key learnings from the Case Study.

## 3.2 Methodology

The Case Study's assembly of information was achieved through a combination of:

- Shared background documents
- Following an introductory meeting including VFPA, a series of six Interviews were held with BC Ferries management involving senior technical and experienced naval architecture personnel.
- On-line research into:
    - URN and the mitigation of same
    - BC Ferries publicly available documents and announcements
    - The role of Classification Societies in URN reduction
    - The management of shipyard risk

## 4.0 BC Ferries

British Columbia Ferry Services Inc. operates as an independent, regulated, self-financing company providing passenger and vehicle ferry service to ports of call throughout coastal British Columbia. The Coastal Ferry Act has transformed BC Ferries into a customer-focused and financially stable marine transportation system.

The company provides frequent year-round ferry transportation services to the West Coast of Canada on 25 routes, supported by 35 vessels and 47 terminals, and also manages other remote routes through contracts with independent operators. BC Ferries is a vital sea link between the British Columbia mainland, Vancouver Island and the smaller islands dotted along the coast of Canada's most westerly province.

BC Ferries' fleet ranges in size up to the Spirit class vessels, which have a rated capacity of 358 cars and 2,100 passengers. As one of the largest ferry operators in the world based on passengers transported annually and transportation infrastructure, the company carries more than 22 million passengers and 8 million vehicles annually and employs more than 4,500 British Columbians.

## 5.0 Rationale for Building Quiet Vessels

The coastal waters of southern British Columbia are host to Canada's largest port, namely the Port of Vancouver. The port hosts approximately 3000 calls per annum of deep-sea ships engaged in the intermodal, bulk, break bulk, auto, cruise and tanker sectors. The port also hosts a vibrant domestic industry engaged in short sea trades moving refined products between Washington State and Vancouver in addition to servicing a network of critical coastal supply lines.

As described in Section 2.0, the context for and rationale behind the decision of BC Ferries to build quiet vessels is driven by a combination of increased global marine awareness of the impacts of URN, federal legislation (*Species at Risk Act,* Marine Mammal Regulations), regional collaborative research efforts and voluntary actions to support SRKW recovery, BC government and public sensitivity to the status of the iconic SRKW, and a high level of environmental stewardship.

It has also not gone unnoticed that TC has imposed a mandatory seasonal speed restriction of 10 knots on vessels of more than 20m in the Gulf of St. Lawrence in support of preserving the endangered North Atlantic right whale. The measure is supported by a potential fine of up to C$25,000 for non-compliance, which even the Canadian Coast Guard has run afoul of. More recently, a voluntary speed restriction has also been enacted in Cabot Strait.

Given all of the above, there should be no surprise that BC Ferries has made a strong commitment to the Government of Canada, the Government of British Columbia and to the people of British Columbia that the company will play its part in forging internal initiatives and supporting the efforts of others in favour of recovering the SRKW, a central driver in the inclusion of URN considerations for the MVRP.

## 6.0 Developing a Road Map to URN

As a founding member of the ECHO Program Advisory Working Group and the related Vessel Operators Committee, BC Ferries had a front row seat and an active role in lending its expertise in the development of voluntary underwater reduction operational initiatives between 2017 and 2020.

In parallel with the implementation of the first ECHO Program voluntary slow down trial in 2017, BC Ferries was engaged in the development of a road map to meet its own URN reduction objectives. Following on from a series of URN trials in the Swanson Channel (also in 2017), a Long-Term URN Mitigation Plan was presented at the company's 2018 Annual General Meeting. Therein, the company conveyed a commitment from all levels of the organization to invest the necessary resources to achieve URN reduction in the impacted SRKW sensitive areas, including an ambitious target to reduce overall noise by 50% against a 2016 baseline without compromise to service reliability or efficiency.
The main points of the Plan may be summarised as (BC Ferries, 2019a):

- Build and operate quieter vessels and terminals.
- Develop enhanced operational planning combined with bridge team education.
- Examine the feasibility of reducing propeller cavitation at the higher frequencies.
- Take steps to reduce hull noise and propeller wash.
- Dampen engine noise and other noise emitting sources.

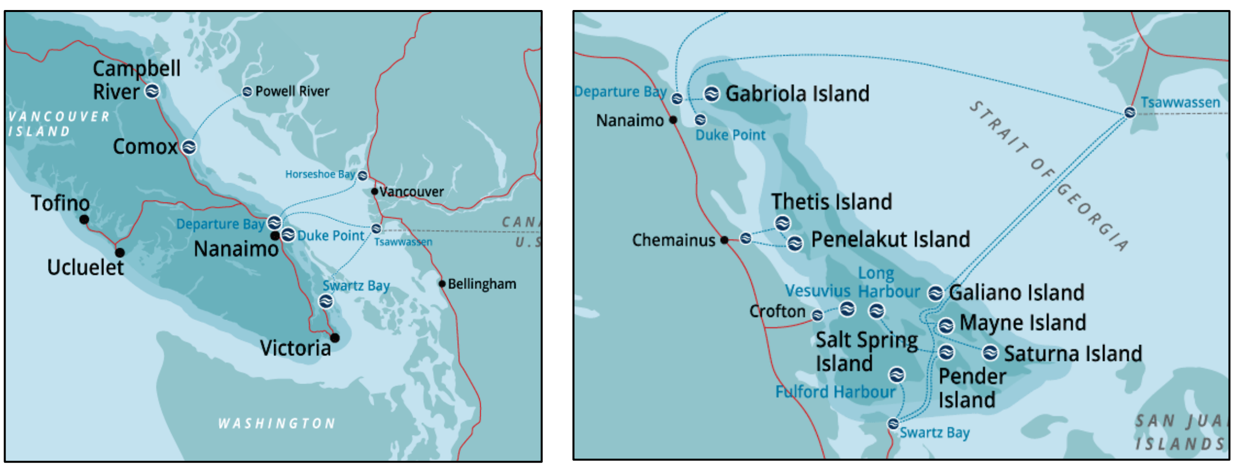



*Figure 1: BC Ferries service routes intersecting primary SRKW habitats*

The commitment of BC Ferries towards playing its part in the broader effort to mitigate and reduce the impacts of shipping generated URN through the MVRP is in many respects ground-breaking. In the absence of a broad international effort beyond the aspirational guidelines provided by the IMO in 2014, research and development (R&D) into URN has become a largely regional issue albeit now, also with the support of Washington State where the SRKW is also listed as a Federal endangered species.

## 6.1 Pathway to Setting URN Targets

As previously described in Section 2.0, the IMO's April 2014 issuance of MEPC.1/Circ.833 Guidelines for the Reduction of Underwater Noise from Commercial Shipping to Address impacts on Marine Life triggered at least general awareness of the negative impacts of URN. In that same timeframe, the ECHO Program was launched to bring regional stakeholders together to better understand and reduce the cumulative effects of shipping on whales, with a particular focus on reducing underwater noise from large commercial vessels and supporting the recovery of the SRKW population. The ECHO program is guided by input from a diverse range of advisors who help the program focus efforts, set goals and implement threat reduction measures. BC Ferries is a founding members of the ECHO Program Advisory Working Group.

### 6.1.1 BC Ferries URN initiatives in 2015

Given the absence of detailed requirements, URN research, technology or supporting science, BC Ferries elected to become proactive in advancing URN research rather than waiting for developments to unfold. Therefore, the company has been an early and active participant in the BC Cetacean Sighting Network, led by the Ocean Wise, which provides information on the abundance and distribution of marine species (such as the at-risk SRKW). BC Ferries developed the first Vessel Operation and Marine Mammal Policy (in North America) and was to be adopted by other operators. Likewise, the company collaborated with the Department of Fisheries and Oceans (DFO) in the installation of hydrophones in support of mammal detection and research data collection within ferry terminal approaches.

Sound range trials of the *Coastal Celebration* were conducted in Patricia Bay on Vancouver Island. The trials resulted in a complete and comprehensive measurement of the vessel's URN signature. Not only did the study quantify the underwater noise levels at various speeds, modes, and maneuvers, it was concluded that the vessel had an atypical speed to noise relationship. In other words, there was an increase in underwater noise at reduced speed. It was therefore determined that speed reduction was not an effective URN mitigation measure for this vessel and the two other *Coastal* Class ferries.

Finally, in 2015, the combined efforts of the ECHO Program, JASCO Applied Sciences, Ocean Networks Canada and TC led to the installation of an underwater listening station in the Strait of Georgia, which was capable of accurately measuring URN signatures from vessels.

### 6.1.2 BC Ferries URN Initiatives in 2016-2017

Through 2016 and 2017, BC Ferries continued measuring and analyzing the underwater noise levels of the fleet at the Strait of Georgia underwater listening station. In 2017 BC Ferries contracted the two week deployment of a JASCO acoustic recorder for continuous measurement of fleet vessels passing through Swanson Channel. This study provided URN signatures for eight BC Ferries vessels in various controlled speed conditions. With previous data an overall source Radiated Noise Level (RNL) baseline at service speed for many of the existing fleet vessels could be realized.

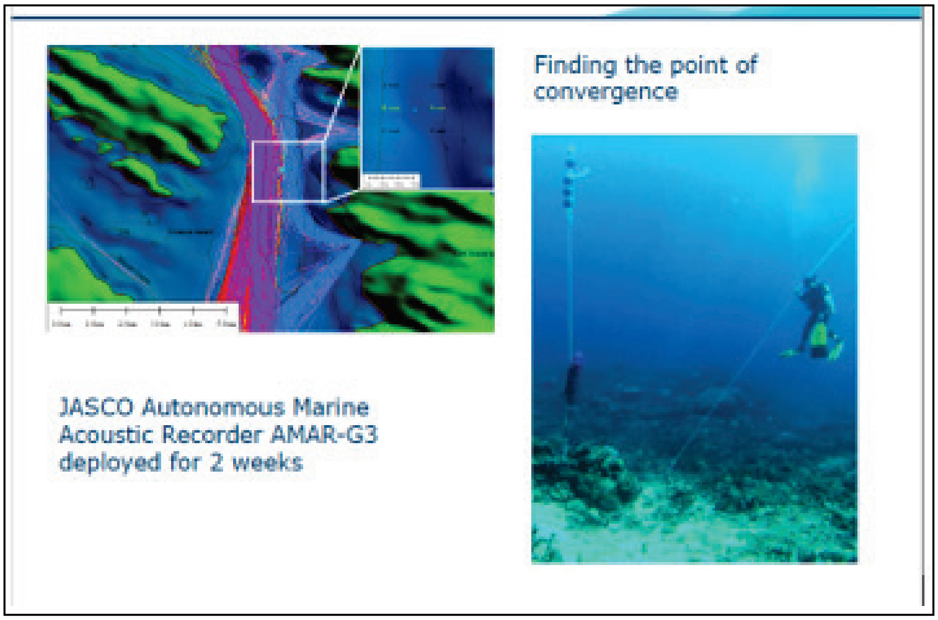



*Figure 2: JASCO Autonomous Marine Acoustic Recorder AMAR-G3*
*Source: BC Ferries CMAC presentation (2017)*

In addition to the establishment of a baseline, the 2017 research defined the noise assessment metrics for the SRKW. In May of that year, an expert workshop convened in Vancouver resulted in the publication of the *Proposed Metrics for the Management of Underwater Noise for Southern Killer Whales* research paper. This provided BC Ferries with data to confirm SRKW sensitive hearing frequencies which would serve to guide and refine the company's noise reduction strategy.

The establishment of a RNL baseline in conjunction with defining the underwater noise assessment metrics resulted in the development of an initial strategy to guide the company's underwater noise reduction plan. In July 2017, the company began development of an Underwater Noise Management Plan (UNMP), which considered the introduction of SRKW relative frequencies into quiet vessel design.

### 6.1.3 BC Ferries URN Initiative in 2018-2020

By 2018, just four years from the release of the IMO guideline, BC Ferries' commitment to proactively reduce its underwater noise contributions was further demonstrated through the company's contribution to the development of a number of tutorials, outreach, guidance, formalized agreements, procedures and policies, including:

- Mariner's Guide to Whales
- Whales in our Waters Tutorial
- Whale Report Alert System (WRAS)
- Green Marine Certification Performance Indicator for URN

- Conservation Agreement
- *Educating Mariners: Whales in our Waters Tutorial*. Journal of Ocean Technology, Volume 14, No 2.
- *Next Not Best Practises: Transboundary Collaboration to Ferry Services Addressing Species at Risk*. Journal of Ocean Technology, Volume 14, No 3.
- Whale Trail signage at terminals in SRKW critical habitat

BC Ferries also provided input to the development of Classification Society Notation Guides for URN.

## 6.2 Fleet Master Plan Design Directives

By August 2018, a BC Ferries UNMP was finalized with URN targets which were incorporated into a Fleet Master Plan (FMP). The FMP aligns corporate strategic goals with fleet design and development. It provides high-level direction for planning decisions, procedures, standards and actions. The fleet design directives are mandatory tactical direction governing standards and design requirements for fleet investments. The FMP is reviewed, updated and approved by the BC Ferries' Executive annually.

A URN Target of 175 dB RNL was added to the FMP design specifications for future build programs of the Island Class, the Salish Class, and the MVRP platforms.

### 6.2.1 Setting the Limiting Value of URN at 175 dB

With reference to the 2016 baseline, a ferry at service speed is typically emitting URN at a broadband sound intensity of 185 dB. A 50% reduction (3 dB) for one vessel is substantial and yet it will be insufficient to significantly reduce the typical noise emissions of many ferries transiting the Salish Sea. With a 45-year construction life, the age profile of the active fleet means that these 185 dB vessels will continue to operate for decades to come.

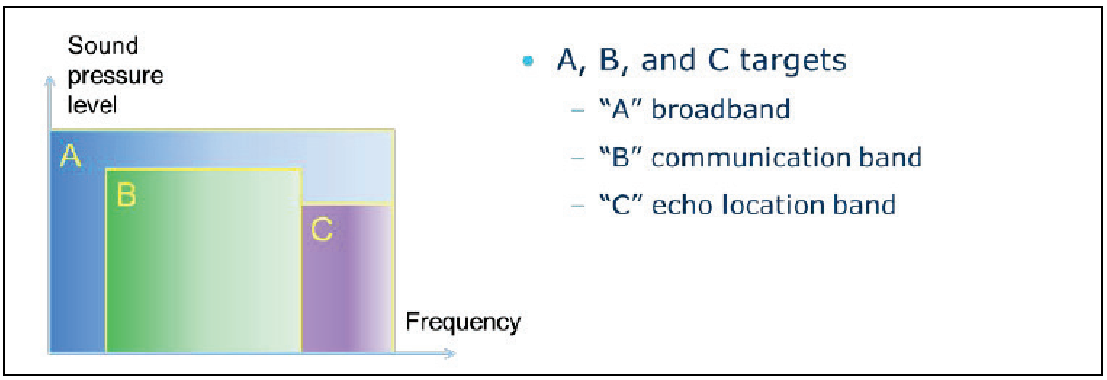
Most vessels (not just ferries) measured during transits in the Salish Sea are emitting between 180 to 190 dB RNL at service speed. The typical URN levels from this population of vessels will decrease with time and attention to the problem. A new vessel target of 175 dB provides reasonable assurance that a long-life vessel will not become a predominant noise maker as other vessels operate quieter through a variety of tactics, including slowing down.

To maintain fixed departure time schedules, a ferry relies on service speed. BC Ferries policies for operating in marine mammals' presence require stand-off distances to be achieved by course alteration or speed reduction. URN intensity dissipates over distance at varying rates dependent upon a number of factors, one of which is frequency. At 175 dB RNL, the stand-off distances will likely be an effective measure to mitigate vessel noise interference with SRKW communications.

### 6.2.2 Target Frequency Bands

BC Ferries has also accepted the framework of impact-focused underwater noise metrics derived from the *Proposed Metrics for the Management of Underwater Noise for Southern Killer Whales (2017)*, as developed by the Coastal Ocean Research Institute (CORI) of the Vancouver Aquarium. The framework identifies the three principal impacts of URN from motorized vessels and their associated underwater noise frequencies to SRKW.

- The first is the Broadband frequency band (10 Hz to 100 kHz), which impacts physiological stress, disruption of resting and foraging, avoidance behaviours, and hearing sensitivity threshold shifts.
- The second is the communication frequency band (500 Hz to 15 kHz), which impacts group cohesion and coordination and interferes with critical social behaviours.
- The third is the echolocation frequency band (15 kHz to 100 kHz), which reduces foraging efficiency and may impair navigation, orientation, and hazard avoidance.



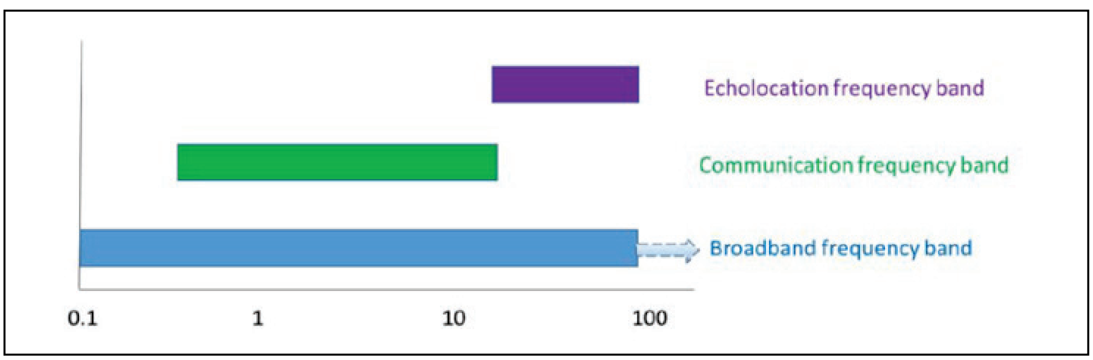




*Figure 3: SRKW Sensitivity Ranges*
*Source: BC Ferries Technical Memo URN Targets for New Vessels (2019)*

### 6.3 Achieving a 175 dB Limiting Value at Various Speed Configurations

A reduction of RNL to 175dB, not only at the SRKW sensitive frequencies, but for a range of vessel speeds, poses a significant challenge for the MVRP. As shown below, using BC Ferries' quietest vessels as a baseline, the required RNL reduction can be as low as 5 dB at certain speeds and as high as 18 dB in others. The reason for this is that the quietest existing ferries, when measured at service speed, are the noisiest when measured at reduced speeds. This is a circumstance related to the optimization of the propulsion system in these vessels discussed further in section 6.4. The negative speed to noise trend is a factor that will be addressed in future vessel design.

| **VESSEL > 115 m LOA** | | **SPEED Configuration and LIMITING RNL Values** | | | | |
|---|---|---|---|---|---|---|
| Integral (broadband) dB | Frequency Range | HS | R4 | R2 | **SS** | FA |
| *Full Spectrum* | 10 Hz to 64 kHz | 175 | 175 | 175 | **175** | 175 |
| *Communications band* | 500 Hz to 15 kHz | 170 | 170 | 170 | **170** | 170 |
| *Eco-Location band* | 15 kHz to 64 kHz | 160 | 160 | 160 | **160** | 160 |
| | | **Estimated Reductions from Typical Major Vessel** | | | | |
| *Broadband* | 10 Hz to 64 kHz | | 18 | 17 | 10 | 10 |
| *Communications band* | 500 Hz to 15 kHz | | 15 | 14 | 8 | 6 |
| *Eco-Location band* | 15 kHz to 64 kHz | | 18 | 18 | 8 | 5 |

**FA – Full Away, SS – Service Speed, R2 – SS less 2 knots, R4 – SS less 4 knots, HS – Half Speed**

*Figure 4: BC Ferries Limiting RNL Values @ Various Speed Configurations*
*Source: BC Ferries*

## 6.4 Overcoming the Negative Underwater Noise Signature

Within the company’s existing fleet, vessels of LOA >115 meters have a flat, and in some cases, a negative underwater noise slope (BC Ferries, 2019c). This means that the vessel’s noise level stays the same or will become louder as vessel speed is reduced. Speed reduction as a URN mitigation measure is therefore counter productive.

This atypical response is due to the arrangement of the CPP operating with constant rotational speed. In other words, blades continue turning at maximum velocity even when thrust is reduced and reversed, which increases cavitation due to the increased pressure differential between the front and rear of the blades.

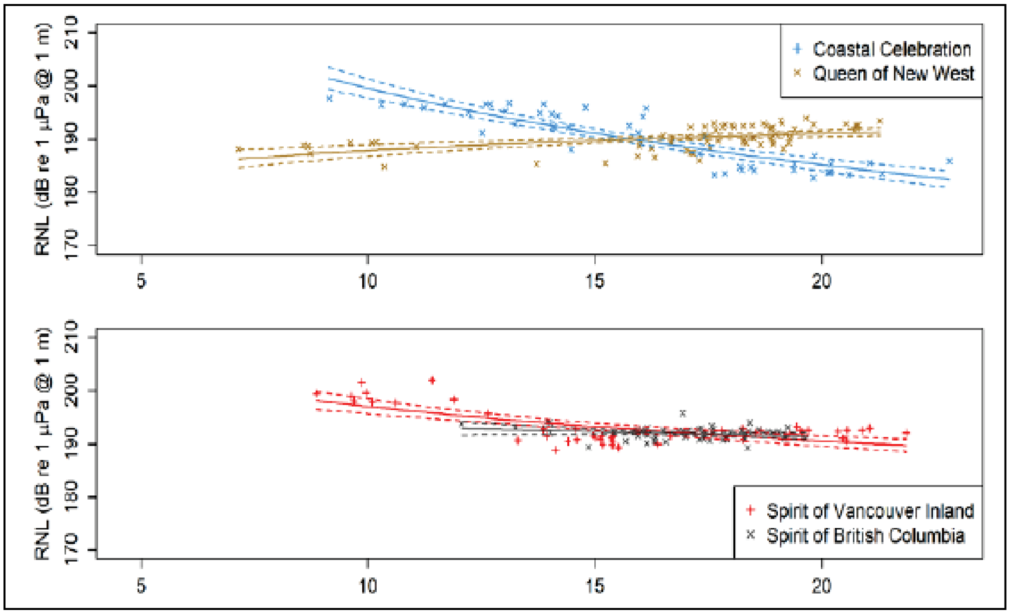



*Figure 5: BC Ferries' Negative Noise versus Speed Characteristic*
*Source: BC Ferries*

In summary, the BC Ferries' strategic objective is a 50 percent reduction in the overall noise contribution into the SRKW critical habitat against the 2016 baseline. The URN targets for the MVRP are established at 175 dB set at the SRKW ranges of sensitive frequencies for all speed configurations.

Given the URN signatures of existing vessels and the URN signature being targeted, there are significant challenges of design, technology and operating efficiency that will influence the procurement process leading to an eventual Design-Build contract along with validation of outcomes. That said, the work being undertaken will also play an important role in informing others, both nationally and internationally.

## 7.0 Noise Control Program

Having explored a number of options, BC Ferries UNMP concluded that: there *"…are no "ferry-ready" solutions on the market to achieve the URN reduction targets necessary for our longer term goal. Expert guidance from noise control specialists and an innovative approach shall be necessary".*

In May 2019, BC Ferries published a URN Control Program Support RFP seeking an expert partner to assist in achieving significant reductions in URN emissions without sacrificing other optimized and primary vessel performance criteria, including maximum fuel efficiency (GHG reductions), maneuverability, and interoperability.
The RFP identified three key areas where BC Ferries would be seeking support:

- Assistance in developing the requirements for new vessels under the MVRP.
- Documenting and recommending measures for the existing BC Ferries Fleet and Terminals.
- Assistance with research and development on URN, including attracting external funding and supporting Joint-Industry Projects.

Additional requirements related to new vessel construction include the options:

- To serve as a URN expert consultant.
- Provide guidance in the specific aspects of design to achieve URN limits and verification of performance.
- To provide front end analysis of new vessel design and specification.
- Develop specification of low URN requirements for URN emitting equipment and systems.
- Advise in identification of URN mitigation in construction and outfitting.
- Provide predictive modelling of URN levels.
- Provide cost benefit analysis for URN mitigations.
- Provide documentation of delivered noise control features.
- Advise in the development of a noise and vibration monitoring system/program.

A partnership was established in 2019 with a small URN specialist team within Det Norske Veritas (DNV) to help BC Ferries in some of the URN specific tasks noted above. None of the new construction options were undertaken before the MVRP was halted.

## 8.0 Major Vessel Replacement Program (MVRP)

In July 2018, BC Ferries announced plans to build five new large vessels for the major routes serving Metro Vancouver. The vessels to be replaced were listed as the five C Class vessels (BC Ferries, 2018a):

Queen of Alberni built 1976
Queen of Coquitlam built 1976
Queen of Cowichan built 1976
Queen of Oak Bay built 1981

| Vessel Particulars | New Major Vessels | C Class vessels to be replaced |
|---|---|---|
| Vessel type | Double ended ROPAX | Double ended ROPAX |
| LOA | 167-172m | 139m |
| Beam | 29.2m | 27.1m |
| Speed | TBD | 20.5 knots |
| Main engine | LNG/electric | MAK Diesel with Gearbox |
| Propulsion options | • Controllable Pitch Propeller (CPP) or Fixed Pitch (FPP)<br>• Azimuth thruster/pod | Kamewa Controllable Pitch Propellers (CPP) at each end with combinator opitmization |
| Capacity | 360 autos + 2100 passengers and crew | 315 autos + 1494 passengers and crew |
| URN level | 175 dB | 189 dB |

*Figure 6: Vessel Particulars – New Major Vessels vs. C Class vessels*

**For a list of BC Ferries Modern Fleet Propulsion Systems, please refer to Appendix B.*

The MVRP is the first program within BC Ferries where specific URN criteria were included as performance objectives within the planned work. The targeted reduction in URN levels represents a decrease of 97% of the noise radiated power emitted despite being the New Major Vessels being substantially larger than the C-Class ferries they are scheduled to replace. However, advanced design practices could make this achievable.

The stated objective at the time of the 2018 press release was to move forward with the approval, procurement and construction processes to have the first of the five vessels in service by 2024. The Shipyard RFP issued in 2019 in support of the project qualified the above announcement by stating that the initial order would be four vessels.

The MVRP was at an advanced stage of the RFP process in 2020 when the company's ridership levels and finances were impacted by the COVID-19 pandemic resulting in a decision by the BC Ferries Board of Directors to delay the program by five years. Effectively, the process will resume from scratch in 2021/22.

Some aspects of the procurement and approval processes described in the following sections run concurrently and were in progress at the time the program was halted. In the context of procuring a quiet vessel, it can be said that:

- The Statement of Requirements for the MVRP was approved at all levels.
- BC Ferries' expectations and URN target were explicitly stated in a detailed SOR (see Figure 10, page 28) to a pre-qualified pool of shipyards invited to make a bid through the shipyard RFP.
- The shipyard bids included proposals for URN limitation.
- A final proposal was not reached before the process was suspended by the pandemic.

# 9.0 BC Ferries Project Initiation and Approval Process

The timing of development of any new vessel Class within BC Ferries will be initiated by several considerations, including but not limited to:

- Replacement of ageing and inefficient vessels
- Response to changes in safety and environmental regulations
- The development and availability of new technologies
- Response to evolving customer demand and service expectations
- Financing

The vessel replacement strategy is overseen by the BC Ferry Commission Regulatory Review, which points to the desirability of standardization and interoperability of vessels and terminals, flexible deployment of equipment, and pursuit of more fuel-efficient systems. To date, the Commission has not placed a specific requirement for URN reduction.

## 9.3 Design-Build Procurement Process

In 2019, BC Ferries issued a global "Request for Expressions of Interest" (RFEOI) for the MVRP. The RFEOI served to notify the marine industry of the opportunity and to solicit their interest, capacity and capability to be considered for the procurement. While there is no limitation on the geographical range of shipyards from which a response to the initial RFEOI is expected, there are only a limited number of shipyards with experience in the construction of double ended ferries.

Following a successful RFEOI there was a two-stage procurement process (BC Ferries, 2018a):

a) Request for Pre-Qualification (RFPQ)
An RFPQ is issued to a range of shipyards identified through the RFEOI process and determines the pool of shipyards invited to submit a bid for design and construction. At this stage, BC Ferries assessed the suitability of the shipyard to the requirements of the MVRP,

b) Request for Proposals (RFP)
This 2nd stage of the standard procurement process involved an invitation to pre-qualified proponents that are identified through the RFPQ process to submit an MVRP project plan and firm pricing. Because this was a first in class vessel, a preliminary design was also required. In this design-build process, the bid is not based on a specification but rather on a preliminary design provided by the proponent that is intended to meet the SOR. Ferry operations by nature require more customization in design, i.e., to optimize for routes, traffic, passenger needs and terminal facilities. It is only after contract award that the shipyard initiates the design phase to produce a detailed design and specification for construction.

These final steps were not reached in the MVRP. The process was halted at the final shortlisting of shipyards. However, it is believed that the inclusion of URN targets in the SOR did not affect the contract process flow.

Figure 8 below shows the process flow from the shipyard perspective.

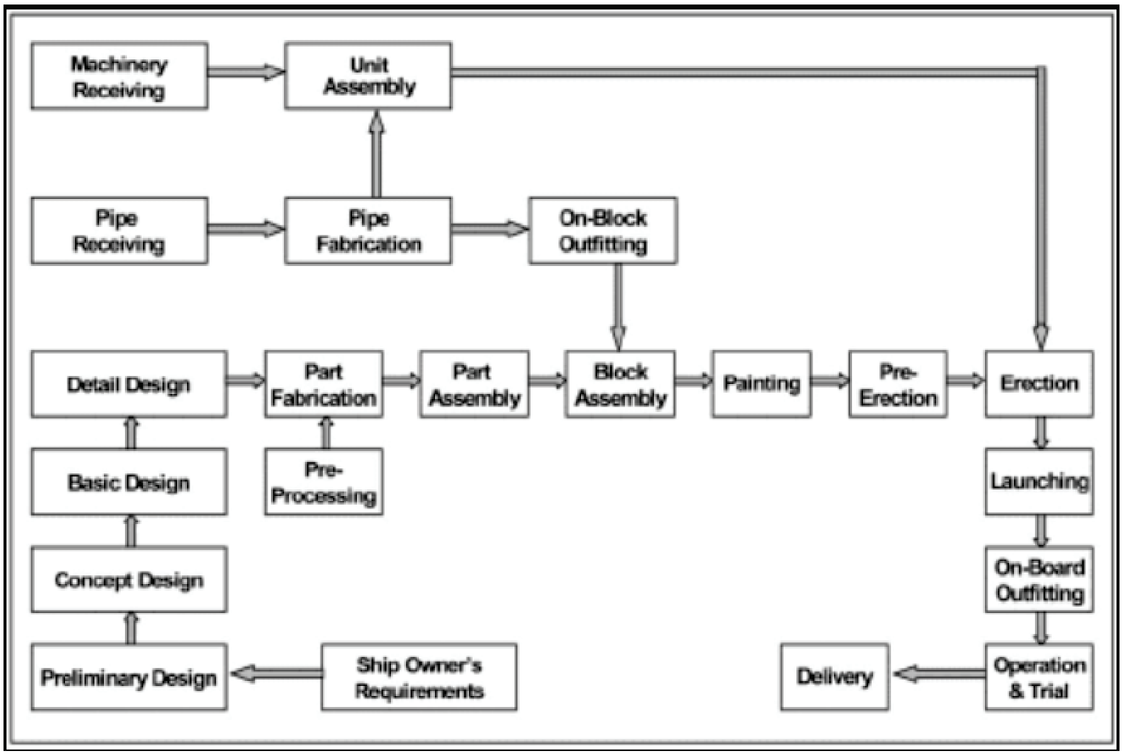



*Figure 7: Flow of Shipbuilding Process*
*Source: Kim (2002)*

The URN requirements (detailed further in section 9.5) is a design problem that can not be resolved until the detailed design process, in what is known as the "Design Spiral[1]". The RFP process was halted before the application of this detailed design process to the URN requirements could be contracted with a shipyard.

[1] Note: In the world of naval architecture, the Design Spiral is commonly defined as the systematic approach to achieving near perfect designs for a given design problem. As progress is made through the spiral to its core, there is a transition from less information to specific requirements in the construction of a ship – also known in the trade as "realization of the design into a product" (Naval Architecture, 2014).

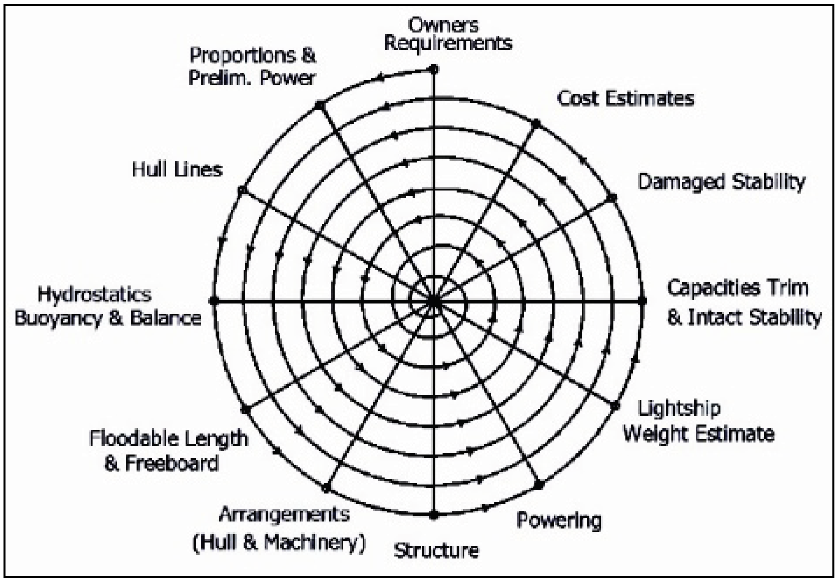



*Figure 8: Design Spiral*
*Source: Naval Architecture (2014)*

## 9.5 Statement of Requirements (SOR)

The MVRP statement of requirements includes Underwater Radiated Noise not to exceed the BC Ferries specified criteria and the noise measurements at delivery are to comply with the ABS UWN(Q) Class notation.

| | | Noise Criteria Limits at Speed [RNL value @ 1m] | | | |
|---|---|---|---|---|---|
| | Frequency Range | Half Ahead | Service Speed (Route 1) | Service Speed (Route 2) | Service Speed (Route 30) |
| A | 10 Hz to 64 kHz | 175 | 175 | 175*/185 | 175*/185 |
| B | 500 Hz to 15 kHz | 170 | 170 | 170*/175 | 170*/175 |
| C | 15 kHz to 64 kHz | 160 | 160 | 160*/165 | 160*/165 |

where:

a) Frequency Range “A” corresponds to the full broad band spectrum; and frequency ranges “B” and “C” correspond to critical noise bandwidths affecting local marine mammal activity.
b) For Route 2 and 30, which are outside the critical marine mammal habitat, the *value represents a target, and the larger value the maximum acceptable URN value.

Measurement method is to satisfy the Grade-C requirements of vessel radiated noise standard ANSI S12.64 (2009).

Once built and delivered, the new vessel will have a measured URN characteristic that includes a range of operational settings. The URN measurements will determine the quietest operating configuration which will then be defined into operational policy so that the vessel’s crew can easily configure the vessel (speed and machinery settings) to a quiet mode of operation when required.

Currently, there are multiple URN measurement standards in use:

- American National Standards Institute: ANSI S12.64 (2009) – Quantities and Procedures for Description and Measurement of Underwater Sound from Ships.
- International Organization for Standardization: ISO 17208-1,2,31 (2016, 2019b, estimated 2023) – Underwater acoustics – Quantities and Procedures for Description and Measurement of Underwater Sound from Ships.
- The individual standards applied by the Classification Societies that offer quiet vessel certifications:
    - Det Nortske Veritas (DNV)
    - American Bureau of Shipping (ABS)
    - Registro Italiano Navale (RINA)
    - Lloyds Register (LR)
    - Bureau Veritas (BV)

The measurement data from each of the standards identified above are not compatible and cannot be cross referenced with the other. For this reason, the BCF statement of requirements defines ANSI S12.64 (2009) as the measurement standard that corresponds to the 175 dB RNL target.

## 9.6 Role of the Classification Society (Responsible Organization)

It is normal process with a BC Ferries new vessel construction to select the Classification Society for the new class of vessels in the early stages of the project. American Bureau of Shipping (ABS) was selected in 2018 as the Classification Society and Recognized Organization for the MVRP. ABS is therefore extensively referenced in the Shipyard RFP issued in 2019. The role of ABS in the MVRP is to act both as a Classification Society approving materials and construction to ABS rules and standards, but also on behalf of TC under the guidelines of the Delegated Statutory Inspection Program (DSIP).

In the role of a Classification Society, ABS was also able to offer an Underwater Noise Notation for the MVRP. The ABS notation UWN (Q) sets underwater noise criteria for low-speed operation in environmentally sensitive areas. ABS also provides prescriptive guidance on URN test protocols, the development of a Measurement Plan and sea trials procedures that must be met, including (ABS, 2020):

- Engagement of an ABS Recognized External Specialist for Underwater Noise Measurement
- Test site requirements
- Measurement of background noise
- Distance measurement
- Weather and sea surface conditions
- Test sequencing
- Vessel condition

- Processing and analysis of measured data

A Class Notation provides an established standard that the shipyard can apply without the additional effort of having to develop one with BC Ferries thus increasing certainty in the certification process for both the ship owner and the shipyard. In addition, the Class surveyor can be readily available to ensure that the standard is properly applied to the MVRP. The caveat with the use of a Class Notation is that the standard may not be suitable for the vessel type or match well with the owner's requirements.

For the MVRP, the ABS Notation was reviewed by BC Ferries after ABS was selected for general Classification services. It was determined that the Notation had sufficient match to the BCF URN requirements and could be added to the SOR for the new vessel.

# 10.0 Risk Mitigation

## 10.1 Underwater Noise

URN measurements will be performed at acceptance sea trials, leaving little opportunity for the shipyard to apply corrective solutions if the targets are not achieved. In addition, because the primary source of URN is the design and arrangement of the propeller and hull form, a low noise design solution is likely to touch on critical design aspects necessary to meet vessel speed and fuel efficiency requirements.

In anticipation of this challenge, the BC Ferries Noise Control Program prompted a joint industry project through TC known as the “Propeller Parameter Study.” The BC Ferries fleet technical team, the DNV URN specialists, and TC have completed Phase 1 of the Study Plan which involved 3D computer modeling and Computational Fluid Dynamic (CFD) analysis to:

- Design 6 different propellers differentiated by pitch distribution (camber).
- Confirm open water performance and propeller cavitation.
- Cavitation simulation and URN prediction.

The second phase of the study is underway to assess inefficiency in fuel consumption that might result from a propeller that is optimized for low URN.

This project work is not to design a low noise propeller for the MVRP but will be applicable to existing vessels in the fleet. However, the work will add new knowledge to the MVRP that will also be made available to shipyards. The study uses propeller models from the company’s most recently built double-ended Coastal Class vessels that have similar general particulars and specifications to the new major vessel.

## 10.2 Cost Benefit Analysis

URN reduction measures will be an additional cost during design and construction, but this is not visible in a fixed price design build contract such as the MVRP that includes so many other requirements. For this reason, extracting the cost benefit analysis for URN is not possible before or after construction of a new vessel class. The driver for investment is therefore as described in the “Rationale for Building Quiet Vessels.”

Globally, in the absence of a regulatory requirement, it is likely that ship owners will require incentives to invest in URN reduction unless this is tied to quantifiable operating efficiency gains. Otherwise, URN reduction will remain a consequence of design and technology enhancements rather than the driver of these. The unanswered question comes back to the acceptable level of sacrifice in vessel efficiency against an achievable level of URN reduction. How does a ship owner quantify the willingness to accept a likely unmeasurable operating premium to achieve URN given the uncertainty of outcomes? These considerations are further complicated by the potentially undefined level of risk to be assumed by the owner and the shipyard.

In summary, the company's approach to new vessel construction has a high degree of oversight through the progressive steps towards contracting with a shipyard. Within this process, the new and potentially novel requirement for achieving URN reduction targets for the MVRP is just one of many considerations. Risk mitigation tactics will be applied where necessary, as was the case in BC Ferries 2014-2017 project to construct the first LNG fueled vessels.

# 11.0 Design and Construction Considerations

## 11.1 URN Impact on Design Schedule

It is widely accepted that the three primary sources of URN are vessel flow noise, propeller generated noise and machinery noise. The inclusion of URN reduction technologies into the initial design would not however be expected to significantly impact the overall design schedule.

## 11.2 Hull Form

A well-designed hull form will require less power and provide more uniform inflow to propellers thus increasing propulsion efficiency and reducing URN caused by an uneven wake flow.

Double-ended ferries such as those of the MVRP are a specific class of ROPAX vessels which typically operate on short domestic routes and are assigned to purpose-built terminals. The primary advantage of the design is the minimization of terminal time (harbour maneuvering, berthing and loading & unloading). These requirements call for the specific symmetric hull form and propulsion system, allowing for hydrodynamic efficiency when sailing in either direction.

Testing of hull designs has evolved considerably with the emergence of specialized software and thereby reduced dependence on tank model testing to determine hydrodynamic efficiency, allowing in turn for selection of the optimum combination of MVRP hull design and propulsion system to balance URN, fuel consumption and speed requirements.

With a conventional hull form, the lines in the fore part of the vessel will be optimized to provide good bow flow properties and the aft lines must be optimized to have good stern flow properties. However, for the MVRP there is no dedicated bow and stern since both ends act as both bow and stern. Therefore, the hull form optimization must be a compromise of good stern and bow flow properties for the vessel to be efficient which will necessarily compromise wake flow and propeller inflow characteristics. This type of compromise is a typical consideration in vessel design between wake flow efficiency and operational requirements such as stability, resistance to heave and roll, as well as, in the case of BC ferries, double ended design requirements for vehicle roll-on/roll-off.

Investment in high quality hull silicone hull coatings for the MVRP and interim hull cleaning between dry docks will also both play a role in minimizing hull resistance and required power generation for a given speed.

## 11.3 Propeller

A propeller can be considered, in its most simple form, as a fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil shaped blade, and water is accelerated behind the blade due to this pressure differential which results in propulsion of the vessel. Propeller cavitation, where the pressure differentials developed reduce the static pressure of the liquid to below the liquids vapour pressure, leading to the formation of small vapour-filled cavities. When the pressure around these cavities starts to equalize the cavity will implode which can generate high intensity sound waves over long distances.

MVRP propeller design selection will therefore be driven by the need to achieve optimal efficiency under the most frequently operated conditions of speed and draft and to be optimized for the inflow of water influenced by the vessel hull as seen by the propeller. For commercial ships, it is hard to avoid cavitation for efficiency reasons, but cavitation can be controlled and maintained at moderate levels.

In terms of actual MVRP propeller design, including inflow characteristics from the hull form, the default consideration will be to optimise speed and fuel consumption. Any deviation from this principle will involve compromise and trade off. A propeller designed to reduce URN, may therefore sacrifice power or efficiency resulting in reduced speed and/or increased fuel consumption, further complicated by pressure on BC Ferries to further reduce GHG emissions.

As previously noted, the propulsion configuration options under consideration for the MVRP are:

- CPP propellers with variable frequency drive
- FPP propellers
- Azimuth thruster/pod

Regardless of which configuration option is selected, drives will be required on both ends to accommodate the doubled ended operational requirement.

CPP offer a number of advantages for the ferry industry and are widely used. They are operationally efficient since pitch can be varied to absorb the maximum power that the engine is capable of producing. By varying the propeller blades to the optimal pitch, higher efficiency is gained, thus saving fuel. A further consideration is that a vessel with a CPP can accelerate more rapidly from a standing start and can decelerate more effectively.

Feathering of CPP blades will reduce the drag of the forward propeller when not in use, a key consideration for doubled ended ferries such as the MVRP. The amount of feathering of the propeller is also used on the main drive engine to control the propeller thrust along the length of the vessel. In the case of fixed pitch propellers (FPP), this is achieved by modifying the shaft rpm to adjust the propeller thrust. However, a complication with CPP is that to reduce vessel speed it is necessary to decrease the propeller pitch, as the main engine maintains a constant shaft RPM. Decreasing the propeller pitch at the slowest speeds will tend to increase the level of URN as operating at a non-optimal angle can generate a cavitating vortex on the leading edge of the propeller blade, giving rise to increased broadband noise. For this reason, the application of a voluntary or regulated reduction in speed may become counterproductive for vessels with this design of propulsion in reducing URN.

A solution may lie in the development of a variable frequency drive in combination with a CPP such as is being proposed for the quarter life refit of BC Ferries Coastal Class vessels.

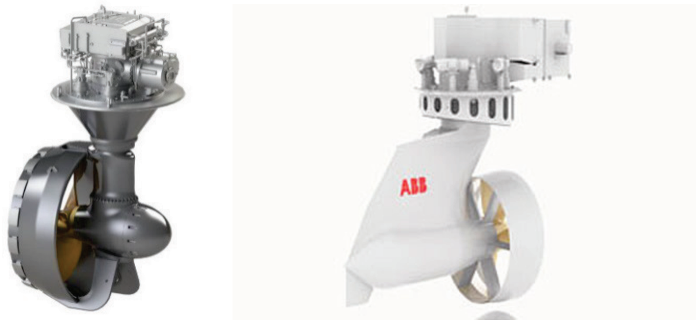



*Figure 9: Schottel Rudder Propellers (left) and ABB Azipod (right)*

Azipod thrusters can be designed in either CPP or FPP configurations and are unique in that the orientation of the thruster can be adjusted with respect to the centreline of the vessel allowing far greater control and maneuverability acting as both propeller and rudder. The choice of Schottel transverse thrusters for the four BC Ferries Salish and six Island Class vessels built by Remontowa in Poland and Damen in Romania, respectively, is indicative of the willingness of the company to adopt rudder propellers (or Azipods) as an alternative to conventional CPP or FPP propulsion systems. Schottel thrusters claim an efficiency rating of 8-10% over conventional propellers. The selection of an ABB Azipod for the new Wasaline ferry *Aurora Botnia*, which is to enter service in the Spring of 2021, is also an example of the growing adaptation of these units for the ferry sector.


*Figure 10: Aurora Botnia rendering*

Minimization of propeller cavitation is also achieved by a typically greater propeller draft ensuring that a propeller sees a higher hydrostatic force, which acts as a suppression to cavitation inception, when water depth permits. This is normally not an issue for ferries.

For Rudder Selection Options in Reducing URN, please refer to Appendix C.

## 11.4 Machinery

The MVRP engine room will be home to a complex array of equipment. In addition to the main engine, there are generators, pumps, motors, compressors all performing a multitude of tasks. Machinery transmits vibration into its mountings and along interconnected systems to generate noise which can travel far beyond a vessel's hull and thereby contribute to a vessel's URN footprint.

BC Ferries has for some time included a noise and vibration requirement in new vessel construction. In the MVRP the SOR called for the application of the ABS Comfort Class Notation. This implied the need for noise suppression mountings and absorbent material in vessel specification. The notation requires comprehensive onboard measurement of noise in air under a range of operating conditions during sea trials. It is expected that reducing vibration and onboard noise will have a benefit in also reducing URN.

Most Classification Societies offer a Comfort Class notation, essentially placing strict limits on noise and vibration. This extends to public spaces and passenger or crew accommodation, including noise between cabins, where relevant. Comfort ratings are categorized as:

- Level 1 – high
- Level 2 – acceptable
- Level 3 – comfort

It is anticipated that measures taken to reduce noise within the vessel will also have benefits in reducing underwater radiated noise.

# 12.0 Shipyard Oversight during Construction and Sea Trials

## 12.1 Construction Oversight

Shipbuilding can be a complicated and time-consuming process. There are many examples of projects that have resulted in late delivery and/or exceeded budget. Attention to maintaining a quality program is therefore of paramount importance but ship construction includes multiple tasks and sub processes that link to each other technically and through build schedules. Since URN is the product of many factors working in conjunction it is important that both the BC Ferries team and the shipbuilder understand the risks associated with URN and how to best mitigation these risks throughout the construction process.

## 12.4 Sea Trials

The execution of the MVRP sea trials will be conducted by a specialized shipyard team with BC Ferries, ABS and possibly TC in attendance. The initial round of sea trials will be the first opportunity to test the vessel in sea conditions with particular focus on those elements which cannot be tested or verified until this point. The primary focus is to record all necessary data to confirm that the vessel meets contractual requirements and performance objectives.

Key to the sea trials is the recording of weather and sea conditions, air and seawater temperature, vessel speed and power data, maneuvering characteristics, vibration and noise levels. For the first time, measurement of URN was included in the sea trials of the Island Class vessels in the Black Sea. Similar sea trials will be conducted to ABS standards for vessels built under the MVRP, location as yet unknown.

Sea trials, for the MVRP, will also include specific underwater radiated noise measurements in accordance with the ABS Guide for the Classification Notation Underwater Noise – standard for Quiet Operation (Q)

Careful consideration from the program inception, including risk reduction studies on URN, retaining a 3rd party URN expect, such as DNV, to collaborate on the program and the fostering of a strong partnership with the shipyard through the design and build phases can mitigate the risk of failure to meet any of the performance objectives, including URN targets, set in the SOR.

## 13.0 Key Learnings and Conclusions

The pursuit of URN reduction is a complex issue for governments, Classification Societies, vessel owners, naval architects and shipyards to advance in isolation from one another or even collectively. The key learnings from the MVRP Case Study that would inform BC Ferries, along with other ship owners and marine stakeholders who are contemplating the procurement and construction of Quiet Vessels, are therefore summarised as follows:

### 13.1. URN Awareness and Education

- Despite publication by the IMO of *Guidelines for the Reduction of Underwater Noise from Commercial Shipping to Address the Impacts on Marine Life* in 2014, the underlying science and importance of URN reduction remains at an early stage of gaining international recognition.
- In a Canadian context, compliance with the *Species at Risk Act* places an onus on the marine industry on all coasts to incorporate URN reduction into environmental policies.
- On Canada's west coast, the threat to the existence of the SRKW remains serious, and the numbers are well below the level required to lift the designation of endangered species. For this reason, the issue of SRKW conservation will require continuing long-term research and collaboration across government and industry.
- The VFPA sponsored ECHO program has made an important contribution to national and international awareness of the plight of the SRKW but has also provided leadership to several initiatives designed to mitigate the impact of shipping on the species.

### 13.2. The Role of the Classification Societies

The Classification Societies have recognized the business opportunity represented by URN and have responded with the development of a series of URN related individual notations, however the challenge for BC Ferries is that there is no standardization in:

- URN quiet notations.
- Vessel design guidelines to qualify for URN notation.
- The conditions for conduct of URN measurement during sea trials or at a subsequent stage.

### 13.3. The Role of Shipyards

The majority of commercial shipyards are traditionally reluctant to invest in URN research since:

- The demand for solutions is still relatively low.
- The contractual risks are perceived to be too high.
- The financial returns are currently inadequate to justify the perceived level of business risk.

As more and more ship owners include URN targets into new build programs the knowledge base will continue to grow. Already, Ponant Cruise of France has obtained Bureau Veritas class notation NR614 for its cruise ship Le Jacque-Cartier as it sees environmental stewardship as a key to its ongoing brand. As the public and governments look to minimize the impacts due to URN, particularly in sensitive habitats it is expected that this trend will continue to grow.

### 13.4. Vessel Design and the Influence on Technology Adoption

The design profile of traditional double-ended ferry designs such as those operated by BC Ferries represents hydrodynamic compromise which does not readily lend itself to URN reduction. This translates to an increased MVRP design challenge since:

- Simplistic URN reduction will involve a reduction in vessel speed and/or a compromise in the design of the propulsion system and propeller for a loss of vessel efficiency, increased operating costs and increased emissions.
- The widespread adoption of the CPP in the ferry industry does not readily align with URN reduction, given that a reduction in speed through a tapering of the propeller blades will generally increase cavitation noise levels.
- The availability of enhanced vessel design software, in parallel with traditional tank model testing, presents an opportunity to refine design options in favour of URN reduction.
- BC Ferries has concluded that the design process for the MVRP will not be materially affected to any significant degree by the inclusion of URN criteria into the SOR.

### 13.5. Transfer of Technology.

The adoption of existing military or quiet running research vessel technologies to the MVRP has been explored by BC Ferries. Several options were considered under non-disclosure agreements, however no readily transferrable experience suited to the MVRP has been identified.

### 13.6. BC Ferries Leadership in URN Reduction

In the absence of regulation, BC Ferries has taken the lead, and potentially a few risks, in pursuit of a suite of proactive environmental stewardship objectives, including the setting of MVRP URN targets,

In order to make the case for a URN target to be included in the SOR for the MVRP, it was necessary for BC Ferries to invest time and money in a series of trials to measure URN levels of the existing fleet, thereby establishing a baseline from which to set the MVRP URN target.

The MVRP represents an opportunity to achieve a meaningful reduction in URN in a particularly sensitive geographical area for the SRKW on account of:

- Initial acceptance of URN reduction goals by responding shipyards of specific URN reduction goals within the Statement of Requirements included in the initial Request for Proposals circulated in 2019.

- Variable Frequency Drives coupled to a CPP(s) in addition to advances in propulsion systems are important technology developments to be measured against URN reduction.
- The delay in advancing the MVRP on account of the impact of the COVID-19 crisis on BC Ferries represents an opportunity to ensure that intervening advances in URN mitigation research are incorporated into the eventual Design-Build contract.
- There is no evidence that the adoption of URN will have a measurable cost differential. Discussion is about vessel performance (efficiency vs noise) and complexity of the work to get to a quieter new vessel.

Through the MVRP procurement process, BC Ferries is playing an important role in gaining the attention of shipyards internationally in the business opportunity presented by a regional URN reduction program which in due course seems destined to expand into a global pressure for more serious attention.

## 14.0 Closing Comments

We would like to extend our appreciation to the following for their time and patience through a series of virtual meeting in support of this Case Study:
Mr. Greg Peterson, Director Engineering Services, British Columbia Ferry Services Inc.
Mr. Bruce Paterson, Director Naval Architecture, Engineering, British Columbia Ferry Services Inc.
Mr. Chanwoo Bae, Engineering Manager of Naval Architecture, British Columbia Ferry Services Inc.

Without their guidance and free sharing of information, it would not have been possible to share the experience and technical knowledge that lies within BC Ferries in the study.

We would also like to thank the Vancouver Fraser Port Authority ECHO team leadership for the opportunity to develop this study.

We fervently hope that the report proves to be of value in raising awareness of the challenges, but also the opportunities, related to Underwater Radiated Noise reduction.

Capt. Stephen Brown
West Pacific Marine Ltd.

Mr. Jeff Melegrito
Melegrito Consulting Group

Final Draft Report dated March 31, 2021

# Appendix A: BC Ferries History and Development

Ferry services on the coast of BC have evolved considerably since the formation of the Union Steamship Company of British Columbia in 1889, followed by the Canadian Pacific Railway BC Coastal Steamship Service in the early 1900's. The Union Steamship Company maintained services until the mid 1950's when post war development and the demand for vehicle space overtook the company's fleet of conventional ferries. In 1958 the Provincial Government of the day to establish a government owned and controlled ferry service. The company's early years were a period of rapid expansion. A further expansion came in the 1980's when BC Ferries absorbed the coastal fleet of the BC Ministry of Transportation and Highways. In 2003 the decision was made to transform the Crown Corporation into a publicly owned, but independently managed, private corporation through the Coastal Ferry Act (Bill 18-2003). The Province of BC retains a single voting share through the BC Ferry Authority.

## Present day

**Routes and Terminals by Region**

| VANCOUVER ISLAND – MAINLAND | |
|---|---|
| ROUTE LABEL | TERMINALS |
| ROUTE 1 | SWARTZ BAY-TSAWWASSEN |
| ROUTE 2 | DEPARTURE BAY-HORSESHOE BAY |
| ROUTE 30 | DUKE POINT-TSAWWASSEN |

| SOUTHERN GULF ISLANDS | |
|---|---|
| ROUTE LABEL | TERMINALS |
| ROUTE 4 | FULFORD HARBOUR-SWARTZ BAY |
| ROUTE 5 | SWARTZ BAY-SOUTHERN GULF ISLANDS |
| ROUTE 6 | CROFTON-SALT SPRING ISLAND |
| ROUTE 9 | TSAWWASSEN-SOUTHERN GULF ISLANDS |
| ROUTE 12 | BRENTWOOD BAY-MILL BAY |
| ROUTE 19 | GABRIOLA ISLAND-NANAIMO |
| ROUTE 20 | CHEMAINUS-PENELAKUT ISLAND-THETIS ISLAND |

| NORTHERN GULF ISLANDS | |
|---|---|
| ROUTE LABEL | TERMINALS |
| ROUTE 21 | DENMAN ISLAND WEST-BUCKLEY BAY |
| ROUTE 22 | DENMAN ISLAND EAST-HORNBY ISLAND |
| ROUTE 23 | CAMPBELL RIVER-QUATHIASKI COVE |
| ROUTE 24 | QUADRA ISLAND-CORTES ISLAND |
| ROUTE 25 | PORT McNEILL-MALCOLM ISLAND-ALERT BAY |

| SUNSHINE COAST | |
|---|---|
| ROUTE LABEL | TERMINALS |
| ROUTE 3 | HORSESHOE BAY-LANGDALE |
| ROUTE 7 | EARLS COVE-SALTERY BAY |
| ROUTE 8 | BOWEN ISLAND-HORSESHOE BAY |
| ROUTE 13 | GAMBIER ISLAND-KEATS LANDING-LANGDALE-KEATS ISLAND WEST |
| ROUTE 17 | COMOX-POWELL RIVER |
| ROUTE 18 | POWELL RIVER-TEXADA ISLAND |

| MID & NORTH COAST | |
|---|---|
| ROUTE LABEL | TERMINALS |
| ROUTE 10 | PORT HARDY-NORTH COAST (McLOUGHLIN BAY, OCEAN FALLS, BELLA COOLA, SHEARWATER, KLEMTU) |
| ROUTE 11 | PRINCE RUPERT-SKIDEGATE LANDING |
| ROUTE 26 | SKIDEGATE LANDING-ALLIFORD BAY |
| ROUTE 28 | PORT HARDY-BELLA COOLA |
| ROUTE 28A | DISCOVERY COAST CONNECTOR SERVICE (McLOUGHLIN BAY, OCEAN FALLS, BELLA COOLA, SHEARWATER) |

*Figure 11: BC Ferries Routes and Terminals by Region*
*Source: BC Ferries annual report to BC Ferry Commissioner (2020)*

In the annual report to the BC Ferries Commissioner dated March 31, 2020, the company advised that coastal services were maintained on 25 designated ferry routes under the Coastal Ferry Services Contract. Other report highlights include:

- On a system-wide basis, BC Ferries delivered a total of 82,288.5 round trips during the fiscal year April 1, 2019 to March 31, 2020.
- In fiscal 2020, BC Ferries carried 8.8 million vehicles and 21.7 million passengers, decreases of 1% and 2.7% respectively when compared to the year prior.

The company's ridership has been significantly impacted by the COVID-19 pandemic which initially resulted in reduced service frequency on several routes. In the early stages of the pandemic, it was announced that the company was losing $1.5 million per day with ridership down by 42%.

## Current Fleet - in Transition to Standardised Vessel Strategy

| Replacement Class | Current vessel name | New Build | Year of Build | Target Retirement | Age at Retirement* |
|---|---|---|---|---|---|
| Northern | Northern Sea Wolf | | 2001 | 2037 | 36 |
| | Northern Adventure | | 2004 | 2043 | 39 |
| | Northern Expedition | | 2009 | 2049 | 40 |
| | | | | | |
| Major | Queen of Alberni | MVRP | 1976 | 2023 | 47 |
| | Queen of New Westminster | | 1964 | 2024 | 60 |
| | Queen of Cowichan | MVRP | 1976 | 2024 | 48 |
| | Queen of Coquitlam | MVRP | 1976 | 2025 | 49 |
| | Queen of Oak Bay | MVRP | 1981 | 2030 | 49 |
| | Queen of Surrey | MVRP | 1981 | 2031 | 50 |
| | Spirit of Vancouver Island | | 1994 | 2044 | 50 |
| | Spirit of British Columbia | | 1993 | 2045 | 52 |
| | Coastal Renaissance | | 2007 | 2052 | 45 |
| | Coastal Celebration | | 2008 | 2053 | 45 |
| | Coastal Inspiration | | 2008 | 2053 | 45 |
| | | | | | |
| Salish | Mayne Queen | new Salish | 1965 | 2021 | 56 |
| | Salish Orca | | 2016 | 2061 | 45 |
| | Salish Eagle | | 2017 | 2062 | 45 |
| | Salish Raven | | 2017 | 2062 | 45 |
| | | | | | |
| Shuttle | Queen of Capilano | | 1991 | 2037 | 46 |
| | Queen of Cumberland | | 1992 | 2038 | 46 |
| | Skeena Queen | | 1997 | 2042 | 45 |
| | Malaspina Sky | | 2008 | 2047 | 39 |
| | | | | | |
| Island | Island Discovery | | 2019 | 2065 | 45 |
| | Island Aurora | | 2019 | 2065 | 45 |
| | Bowen Queen | | 1965 | 2020 | 55 |
| | Powell River Queen | new Island<br>new Island | 1965 | 2021 | 56 |
| | Quinitsa | | 1977 | 2028 | 41 |
| | Quinsam | new Island<br>new Island | 1982 | 2029 | 47 |
| | Kahloke | | 1973 | 2030 | 57 |
| | Klitsa | | 1972 | 2030 | 58 |
| | Quadra Queen II | | 1969 | 2031 | 62 |
| | Tachek | | 1969 | 2031 | 62 |
| | Kuper | | 2006 | 2050 | 44 |
| | | | | | |
| Unique | Kwuna | | 1975 | 2027 | 52 |
| | Baynes Sound Connector | | 2015 | 2060 | 45 |
| | | | | | |

*Figure 12: BC Ferries Current Fleet and Replacement Strategy*

* Planned age of retirement was pre-pandemic and prior to delay of Major Vessel Replacement Program (MVRP)
Source BC Ferries

## Appendix B: BC Ferries Modern Fleet – Propulsion Systems

| Vessel Class | Year of Build | Propulsion System | Comments |
|---|---|---|---|
| | | | |
| Spirit Class | 1993-94 (LNG conversions 2017-19) | (post LNG conversion) 4 x Wartsila WBL 34DF dual fuel<br>Reduction gear Wartsila TCH 270-P58 CPP LIPS HPP 115 Twin Screw<br><br>2 x CPP bow thruster 750kW<br>Becker rudder | Operating on LNG |
| | | | |
| Coastal Class | 2007-08 | 4 × 8 cylinder MaK 8M32C diesel engines, total 16,000 kW<br><br>CPP screw, 1 fore & 1 aft, constant speed<br><br>Twist screw rudder with high lift section | Quarter life refits scheduled for 2022-24:<br>Install Variable Frequency Drive and new propellers.<br><br>Candidate for conversion to LNG in mid life |
| | | | |
| Salish Class | 2016-21 | 3 x Wartsila DF20 Dual Fuel 5,952 horsepower (4,438 kW) normally runs on 2 units<br><br>Azimuth Thrusters 2 x Schottel Twin Propeller (STP) 1515 FP with 3 bladed propellers at each end<br><br>Optimal power split 70% stern and 30% bow when underway | Operating on LNG with diesel as pilot fuel |
| | | | |
| Island Class | 2019-22 | 2 x Mitsubishi S16R2Generators 1500kW-T2MPTAW 900 kW azimuth thrusters, electric drive<br>Schottel 340 FP Propulsion unit<br>• 1 Schottel thruster with 2 x 3 bladed propellers at each end (same as Salish Class) | Operating on ultra low sulphur diesel with B5 biodiesel blend pending availability of supporting electric infrastructure |

*Figure 13: BC Ferries Modern Fleet – Propulsion Systems*

## Appendix C: Rudder Selection Options in Reducing URN

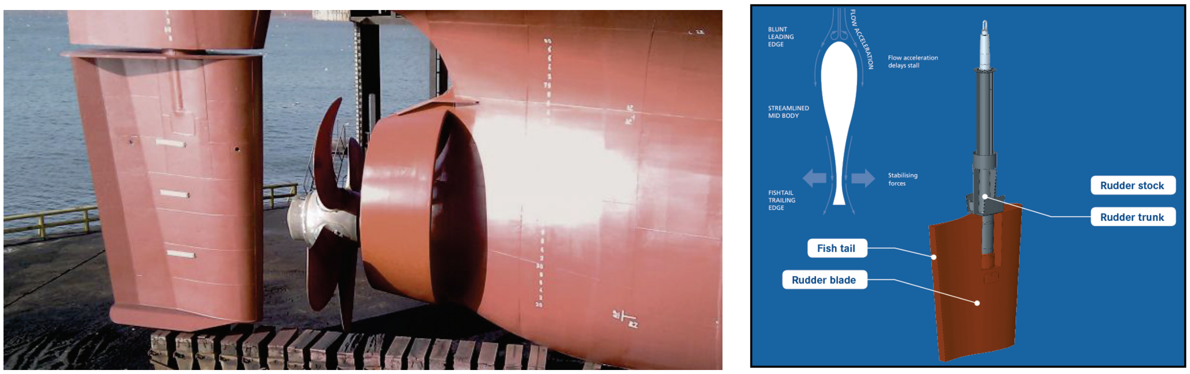



*Figure 14: Becker Schilling Rudder*
*Source: Becker Marine Systems (n.d.)*

Additional noise generated during manoeuvring is an important consideration in URN reduction. The reliance of cruise ships on bow thrusters to complement main Azipod or conventional propulsion systems is common and of course this is offset both practically and financially by avoiding the use of tugs. However, investment in high lift rudders such as the Becker Schilling rudder, one version of which is seen above, can also reduce reliance on tugs and their associated noise levels.

Quote from Schilling Becker (Becker Marine Systems, n.d.):

> *The rudder is one of the most heavily strained components on a ship. Water flow with a higher velocity and a slight angle over a rudder blade will, under certain conditions, result in cavitation which will increase fuel consumption and cause erosion on the rudder's surface. Conventional rudders are placed behind the propeller with the rudder cross section arranged symmetrically on the vertical rudder centre plane. However, this arrangement does not consider the fact that the propeller induces a strong rotational flow impinging on the rudder blade. This results in areas of low pressure on the blade, inducing cavitation.*
>
> The Becker Twist design equalises pressure distribution on the rudder blades. To avoid cavitation and to improve the manoeuvrability performance of a full spade rudder, Becker Marine Systems has enhanced the development of the Becker Twist Rudder. With the Becker Twist Rudder solution cavitation and gap cavitation are prevented, resulting in lower servicing and maintenance costs. In addition, the Becker Twist Rudder reduces noise caused by cavitation.

Another product is the relatively new Becker Cross Over Rudder seen below in Figure 20.

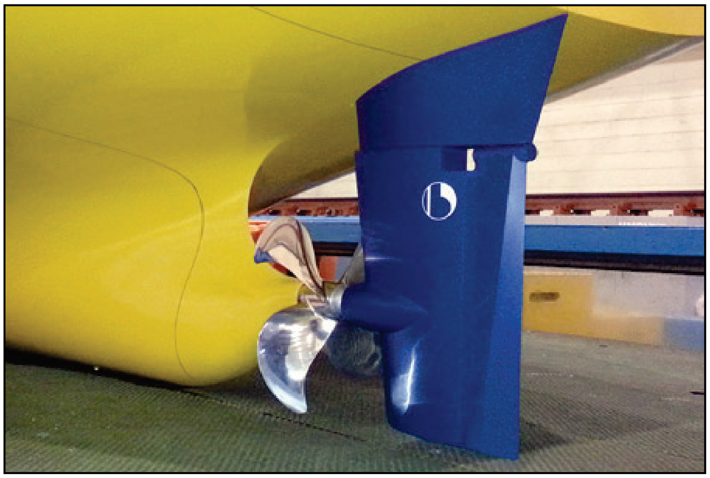


*Figure 15:* The new Cross Over Rudder - a new design featuring a rudder bulb and fairing cap
*Source: Becker Marine Systems Cross Over Rudder (n.d.)*

The primary benefits of the Cross Over Rudder are listed as:

- No propeller hub cavitation
- Designed specifically for feeder vessels and ferries
- Optional trailing edge flap available
- Fuel savings of up to 7%

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