American Galvanizers Association
Protecting Steel for a Sustainable Future

ZINC | international zinc association

Runoff from Zinc-Coated Construction Materials: Risk Assessment Supports Aquatic Safety

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Disclaimer

Introduction

In the Pacific Northwest, zinc runoff is seen as a persistent environmental concern. The concern stems from wanting to protect bodies of water that are considered sensitive due to their ecosystems (e.g. salmonoids) or are considered impaired and do not meet water quality standards set by the US Environmental Protection Agency (USEPA) or state regulatory authorities.

When the Washington State Department of Ecology (Ecology) identified zinc as a 'chemical of concern' and a top five pollutant in Puget Sound in 2017 due to its potential to harm aquatic life, extensive studies and reports on the sources and impacts of zinc soon followed. In response to this report, engineers began limiting the use of hot-dip galvanized (HDG) steel near impaired waters, often opting for duplex systems (painting over galvanizing) as recommended in Ecology's *2008 Suggested Practices.* However, a less-publicized report from Ecology in 2019 revealed zinc contributions from building materials presented in the 2017 report were significantly overestimated. Additional caution also has been influenced by the National Marine Fisheries Service (NMFS)/National Oceanic and Atmospheric Administration (NOAA) Fisheries Salmonoid Design Manual, which states HDG steel "can be toxic to fish" but does not necessarily prohibit it. This combination of early studies and precautionary guidance has contributed to ongoing uncertainty around the application of hot-dip galvanizing for asset protection from corrosion in environmentally sensitive areas throughout the region.

To address these concerns and misconceptions, the American Galvanizers Association (AGA) published a white paper, *HDG Steel's Contribution to Zinc Levels in the Water Environment*, demonstrating zinc released from HDG structures (e.g., bridges and docks) under stormwater conditions does not exceed hardness-based water quality criteria (WQC). As a result, individual HDG structures are not likely to result in water impairments due to zinc. Despite this information, engineers continue to express hesitancy when specifying exposed HDG steel near sensitive waters, citing a lack of detailed, project-specific case studies in Washington State.

In response to this feedback, the AGA and the International Zinc Association (IZA) conducted four desktop analyses to evaluate potential zinc runoff impacts from HDG steel in specific applications. This white paper summarizes the findings of the following application scenarios:

- A hypothetical bridge project along US 2 over sensitive/salmon waters at Barclay Creek – a tributary to South Fork Skykomish River (*Figure 1 & Figure 2*).
- A hypothetical bridge project along US 101 over sensitive/salmon waters at Nolan Creek – a tributary to Hoh River (*Figure 3*).
- A hypothetical utility line installation along the Lowell Snohomish River Road near a sensitive water body – Snohomish River.
- An architectural application in downtown Seattle – National Nordic Museum (*Figure 4*).

Figure 1: Barclay Creek Bridge

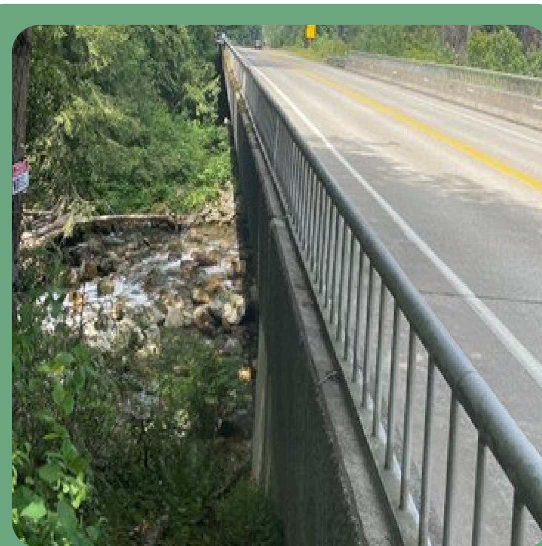

Figure 2: Barclay Creek Bridge Rail

Figure 3: Nolan Creek Bridge

Figure 4: National Nordic Museum

Methodology

Estimated surface water zinc concentrations (*Appendix, Table A.1*) at each location were compared against acute WQC to assess potential risks to aquatic life. While both the USEPA and Ecology currently employ a hardness-based approach to derive WQC, more accurate and advanced methodologies are under consideration. Through a Cooperative Research and Development Agreement (CRADA), the USEPA and IZA evaluated several WQC models incorporating zinc bioavailability, including multiple linear regression (MLR) and biotic ligand model (BLM) approaches (see Metals CRADA Phase 1 Report). These models provide a more accurate assessment of ecological risk by accounting for the influence of local water chemistry on the amount of zinc that can be absorbed by aquatic organisms.

In consideration of the USEPA's ongoing development of models to be used to update the zinc WQC as well as IZA's technical assistance to the California Water Boards in development of models to support site-specific water quality objectives (SSWQOs), the current analysis evaluated four methodological approaches to criteria development:

1. USEPA – Hardness-based (last updated in 1995)
2. WA Ecology – Hardness-based (updated in 2024)
3. MLR-based – Deforest et al. (published in 2023 to support CRADA efforts)
4. BLM-based – Ryan et al. (currently in review for publication to support California SSWQOs)

Among these, the WA Ecology WQC was identified as the most stringent, exhibiting WQC that were 1.7 times lower than the national criteria established by USEPA.

To evaluate potential environmental impacts, a desktop analysis was conducted on four representative projects. Three non-galvanized projects – two bridges over sensitive waterways and an existing wood pole distribution utility line near the Snohomish River – were analyzed under a hypothetical scenario in which they were constructed using HDG materials (*Table 1*).

Table 1: Descriptions of Hypothetical HDG Bridge and Utility Pole Projects

HYPOTHETICAL PROJECT	DESCRIPTION
HDG Bridge Project at Barclay Creek	173 ft straight, single span steel girder bridge; 177 ft of standard handrail design; HDG according to ASTM A123 for plate, structural steel, pipe/tube
HDG Bridge Project at Nolan Creek	170 ft straight, single span steel girder bridge; HDG according to ASTM A123 for plate, structural steel, pipe/tube
HDG Utility Pole Project near Snohomish River	5.7 miles along Lowell Snohomish River Road; 40 ft long universal steel distribution poles; HDG according to ASTM A123 for plate & pipe/tube

Additionally, the National Nordic Museum project in downtown Seattle, which includes pre-weathered rolled zinc siding, was reassessed using data from a 2016 pre-construction study (Van Genderen). *Figure 1* shows the locations of all four projects.

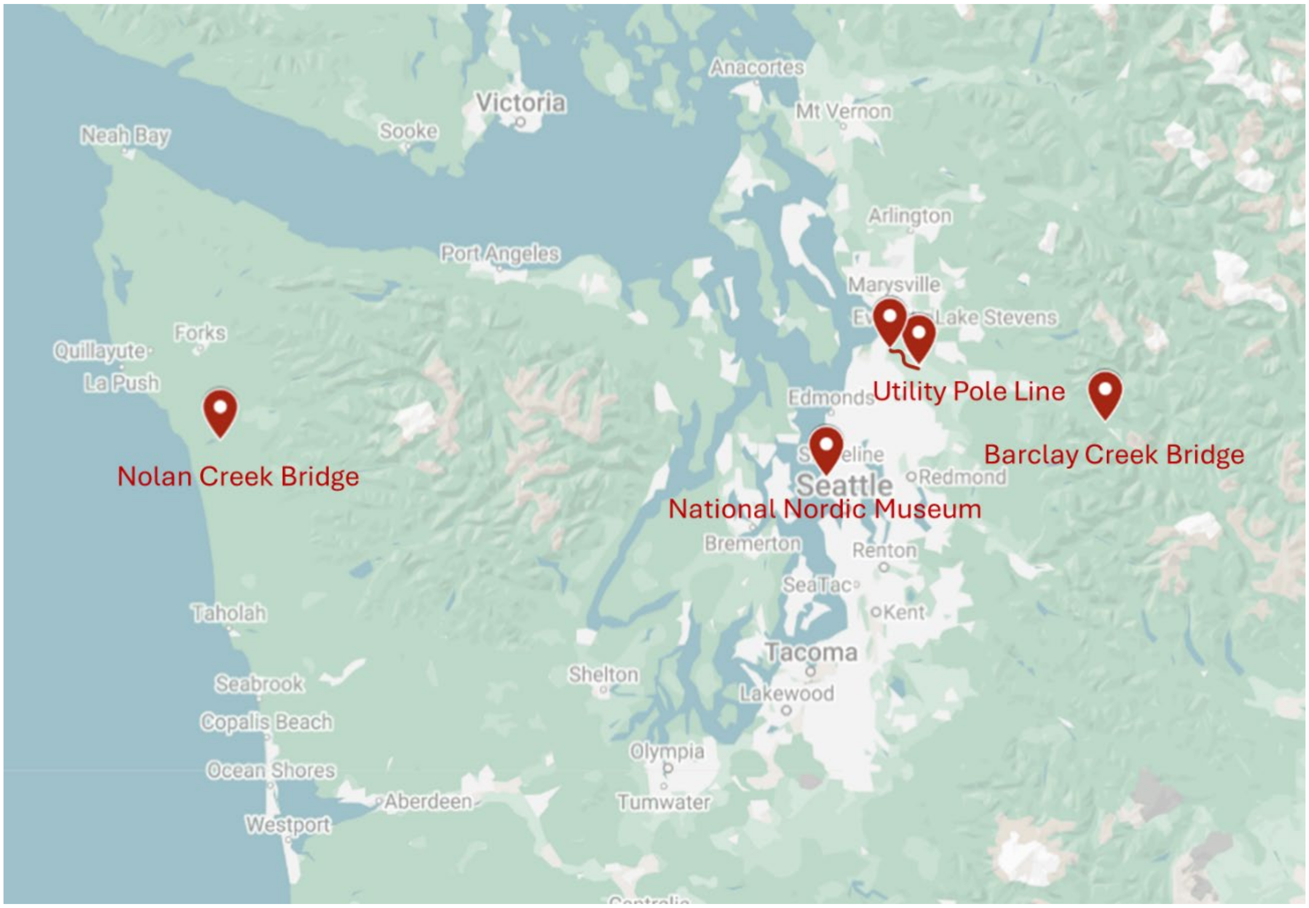

Figure 1: Locations of the four desktop stormwater risk evaluations of zinc in stormwater from zinc-coated or zinc-based construction materials in northwestern Washington state.

Data Collection

Site-specific information, including characteristics of each receiving water or close surrogate and atmospheric conditions known to affect corrosion, were compiled for each location. In general, weather and atmospheric information came from federal or local government sources. All information pertaining to the HDG steel structures (e.g., surface area, coating thickness, sheltering condition) was provided by the AGA and the National Nordic Museum data was obtained from the pre-construction assessment (Van Genderen, 2016). The Appendix (*Tables A.1 and A.2*) highlights relevant site- and structure-specific information used to estimate the zinc loads to receiving waters.

Assumptions

This analysis assumes a worst-case scenario where all zinc in runoff from fully exposed HDG steel surfaces enters surface waters. For the National Nordic Museum, a pre-construction estimate conservatively assumed 20% of zinc runoff reached surface waters (Van Genderen, 2016).

Note

Zinc runoff from zinc sheet is typically much lower than zinc corrosion rates (Wallinder et al.); if similar for HDG steel, zinc runoff estimates using the ZCLP are considered highly conservative. Zinc runoff is understood to decrease over time, reinforcing conservatism.

Key considerations in the desktop evaluation include:

- Background zinc concentrations in receiving waters were included in storm event estimates.
- The Zinc Coating Life Predictor (ZCLP) was used to estimate zinc runoff from HDG steel under typical atmospheric conditions.
- The Zinc Roof Assessment Tool for the Environment (Zn-RATE) was used to estimate zinc runoff from the museum site as it is specific for zinc sheet building materials.
- The dilution factors (2 for the river/creeks; 10 for Salmon Bay) applied are considered highly conservative.
- One-hundred year storm events were assumed, based on the lowest regional annual rainfall days. Rain events were modeled as lasting 8 hours, with some spanning consecutive days (NOAA).
- Water chemistry and flow data were sourced from the water quality portal (WQP) and US Geological Survey National Water Information System (NWIS) database.

Results

To provide a straightforward indicator of ecological risk, hazard quotients (HQs) were calculated to assess potential zinc effects by dividing predicted zinc concentrations in water by WQC (i.e., the maximum levels considered safe for aquatic life). An HQ value less than one strongly indicates zinc levels are very unlikely to harm aquatic organisms, while values greater than one indicate a potential risk. Worst case scenarios were analyzed, assuming all structures were fully exposed, all zinc runoff from HDG surfaces reached receiving waters, and 20% of zinc runoff from zinc sheet reached receiving waters (considered conservative for the National Nordic Museum).

Even for these worst-case scenarios which almost certainly overestimate the predicted zinc concentrations in the receiving water, HQs < 1 were calculated for all four locations, demonstrating zinc runoff from both the HDG steel structures and the National Nordic Museum zinc sheet poses no unacceptable risk to aquatic life (Table 2). HQs for all four locations remained <1 even when referencing different WQC methodologies, such as Ecology's more stringent hardness-based WQC, which results in HQs nearly double those of the three other standard assessments. Using the Zn-RATE tool as an independent methodological approach for the zinc sheet on the National Nordic Museum corroborated the results.

Table 2: Summary of desktop assessment indicating zinc-coated and zinc-based construction materials do not contribute adverse risk to sensitive surface waters in Washington state

WQC METHODOLOGY	BARCLAY CREEK (HDG BRIDGE & RAILING)	NOLAN CREEK (HDG BRIDGE)	SNOHOMISH RIVER (HDG UTILITY POLES)	SALMON BAY (PRE-WEATHERED ROLLED ZINC SIDING)
	ACUTE HAZARD QUOTIENT (HQ)	ACUTE HAZARD QUOTIENT (HQ)	ACUTE HAZARD QUOTIENT (HQ)	ACUTE HAZARD QUOTIENT (HQ)
USEPA Hardness-based	0.49	0.27	0.29	0.13
WA Ecology Hardness-based	0.86	0.48	0.50	0.23
MLR-Based (DeForest et al. (2023))	0.40	0.29	0.24	0.05
BLM-Based (Ryan et al. (in review))	0.49	0.38	0.31	0.02
Results: All Acute Hazard Quotients (HQ) < 1, Safe for Aquatic Life				

Conclusion

Zinc runoff from zinc-coated and zinc-based construction materials used near sensitive Washington State surface waters pose no significant threat to aquatic life; therefore, the use of duplex systems or restrictions on HDG materials, as suggested by Ecology's guidance, is unnecessary. These waters are among the most sensitive in the United States for zinc due to their soft water chemistry and low dissolved organic carbon concentrations. This conclusion is strongly supported by conservative worst-case estimates of zinc concentrations in receiving waters, which consistently remain below even the strictest acute WQC. Since these waters represent some of the most sensitive environmental conditions in the nation, it can be reasonably concluded that zinc is safe in the majority of other locations across the United States.

References

Background Studies

- Ryan, Adam. 2025. Desktop Risk Assessment of Stormwater Runoff from Selected Zn-coated and Zn-based Construction Materials in Washington State. Prepared for AGA. 11 February 2025.
- Washington Department of Ecology Copper and Zinc in Urban Runoff: Phase 1 – Potential Pollutant Sources and Release Rates (October 2017)
- Washington Department of Ecology Suggested Practices to Reduce Zinc Concentrations in Industrial Stormwater Discharges (June 2008)
- Washington Department of Ecology Copper and Zinc in Urban Runoff: Phase 2 – Rainwater Washoff Monitoring (June 2019)
- National Oceanic and Atmospheric Administration (NOAA) Fisheries West Coast Region Anadromous Salmonoid Passage Design Manual (2022)
- Van Genderen E. 2016. Desktop hazard assessment of stormwater runoff from the Nordic Heritage Museum, Seattle, WA. Prepared for Mihun/Pier 56. 14 November 2016. pp. 3.
- AGA's White Paper HDG's Steel Contribution to Zinc Levels in the Water Environment

Water Quality Criteria Information

- Metals CRADA Phase 1 Report, USEPA Hardness-Based Water Quality Criteria, and Washington Department of Ecology Hardness-Based Water Quality Criteria.
- DeForest DK, Ryan AC, Tear LM, Brix KV. 2023. Comparison of Multiple linear regression and biotic ligand models for predicting acute and chronic zinc toxicity to freshwater organisms. Environmental Toxicology and Chemistry 42(2):393-413.
- Ryan AC, Santore RC, Schiff K. in prep. Updating the unified zinc biotic ligand model for protection of freshwater aquatic life and application for site-specific water quality objectives. Integrated Environmental Assessment and Management - to be submitted Q1 2025.

Site and Structure Specific Information

- Zinc Coating Life Predictor (ZCLP)
- Seattle DPD - Seattle 2035 Draft EIS 3-2 Air Quality Greenhouse Gas (May 2015)
- Zn-Risk Assessment Tool for the Environment (ZN-RATE)
- Reported values from NOAA
- Water Quality Portal – all chemistry data for the surface waters near the HDG steel structures
- U.S. Geological Survey National Water Information System (NWIS) database – flow estimates based on historical data for the surrogate locations.
- Hoh Tribe. 2016 State of our watersheds report: Hoh River basin.
- Wallinder IO, Verbiest P, He W, Leygraf C. 1998. The influence of patina age and pollutant levels on the runoff rate of zinc from roofing materials. Corrosion Science 40(11):1977-1982.
- Karlen C, Heijerick D, Wallinder IO, Leygraf C. 2001. Atmopsheric corrosion of zinc-based materials: runoff rates, chemical speciation and ecotoxicity effects. Corrosion Science 43:809-816.

Appendix

Table A.1: Site- and structure-specific information used to estimate zinc loads to receiving waters (hypothetical HDG structures)

PARAMETER (UNITS)	BARCLAY CREEK (HDG BRIDGE & RAILING)	NOLAN CREEK (HDG BRIDGE)	SNOHOMISH RIVER (HDG UTILITY)
Total Zinc Surface Area (m^2)	910	795	931
Corrosion Rate (µm/yr)	1.6	1.7	1.1
Source for Corrosion Rate	ZCLP	ZCLP	ZCLP
Runoff Rate (g Zn/m^2*yr)	11.3	12.0	7.8
Assumed Soil Attenuation Factor	0.0	0.0	0.0
Assumed Fraction Surface Exposed	1.0	1.0	1.0
Total Zinc Load (kg Zn/yr)	**10.3**	**9.5**	**7.2**
Event Zinc Load from Background (kg/h)	0.0133	0.0125	2.72
Event Zinc Load from Structure (kg/h) *total zinc load/hours of rain per year*	0.0129	0.0119	0.0090
Assumed Dilution Factor	2	2	2
Estimated Runoff Concentration from structure (µg Zn/L)	4.85	5.85	0.02
Estimated Receiving Water Concentration (µg Zn/L)	**9.85**	**12.00**	**6.69**

Table A.2: Site- and structure-specific information used to estimate zinc loads to receiving waters (existing Nordic Heritage Museum)

PARAMETER (UNITS)	SALMON BAY (PRE-WEATHERED ROLLED ZINC SIDING)
Total Zinc Surface Area (m^2)	4000
Rain (in/yr)	34
Inclination (°)	90
Source for Corrosion Rate	Zn-RATE
Runoff Rate (g Zn/m^2*yr)	0.09
Assumed Soil Attenuation Factor	0.8
Assumed Fraction Surface Exposed	1.0
Total Zinc Load (kg Zn/yr)	**0.1**
Background Zinc (µg/L)	4.9
Assumed Dilution Factor	10
Estimated Runoff Concentration from structure (µg Zn/L)	21.9
Estimated Receiving Water Concentration (µg Zn/L)	**2.7**

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