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Cover photograph:

Maryland wetland mitigation project – Crew installs live willow branches to provide bank stabilization and enhance aquatic habitat.

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CONTENTS

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WETLAND MITIGATION AND STREAM RESTORATION[1]

by Susan D. Bitter and Keith J. Bowers[2]

Mixing concrete and steel with buttonbush and bulrush may be more common than one might think. All across the country, local, state, and federal agencies are increasing their regulations to protect, replace, and restore wetlands and streams that are filled and altered for road construction. These same regulations often require that impacts to these resources be mitigated to replace lost ecosystem values and functions. As a result, state highway and public works agencies are often charged with designing and constructing wetlands and streams along with their roads and bridges.

Over the past 8 years, we have designed over 50 wetland and stream restoration/mitigation projects for various county, state, and federal agencies on the east coast. Much of our work stems from the need to mitigate and restore impacts resulting from public works projects including highways, utilities, and channel dredging.

As part of an 11-acre Maryland wetland mitigation project, crew installs live willow branches in a streambank to provide bank stabilization and enhance aquatic habitat.

The restoration challenge is straightforward: plan, design, and construct a mitigation project that complies with all permit conditions, satisfies neighborhood and community associations, meets budgetary and scheduling constraints, and replicates nature. Sound somewhat complex, if not formidable? Well, yes it is—especially the replication of nature. However, there are some important premises to respect and apply that will facilitate the design, construction, and maintenance of a successful mitigation project.

Art vs. Science

Wetland and stream restoration and creation is not an exact science, but an evolving art based on scientific theories and successful experiments. Current technology and knowledge do not afford us the opportunity to completely plan, design, construct, and manage all the biotic and abiotic resources that comprise a

[1] Reprinted with permission from the Editor, Public Works, October 1993 issue.

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wetland or a stream. Furthermore, like all landscapes, wetland and stream systems evolve and change over time, and are subject to a host of changing land use activities throughout a watershed. At best, one can plan, design, and construct for the fundamental wetland components: hydrology, hydric soils, and hydrophytic plants; and basic stream morphology components: discharge, gradient, sinuosity, width/depth ratio, channel material and size, soil stability, channel entrenchment, and valley confinement. As form follows function, art follows science. The rule of thumb in restoration/mitigation is "Use what you do know and build upon that foundation through application," but be aware of the "dynamic equilibrium" inherent in all natural systems.

The Landscape Is a Continuum

Streams and wetlands are complex ecosystems that we are still trying to understand and comprehend. To say we can "create" a wetland or a stream sounds a bit egotistical, and perhaps naive, but to give into the complexity of the undertaking and do nothing at all may be more of a disservice to our landscape than attempting to do something constructive. Wetland mitigation and stream restoration must be approached with caution and an affirmation that Mother Nature is the best instructor.

The restoration ecologist must look at the whole system and then analyze the parts. For example, if contemplating stream restoration, look at the top of the watershed and attempt to understand what makes the stream look and behave as it does. Travel downstream and learn what happens when that water leaves your site. Not only are these systems connected geographically, but are bridged by time as well. Your actions today will trigger events in the future, some predictable and some not. Everything that is done to manipulate and change a stream will have some effect on that system either downstream or upstream. Be sure to understand to the fullest extent possible the consequences of your actions and how they may affect the surrounding landscape.

Setting a Goal

Mitigation of wetlands and streams must begin with a goal. The goal must be achievable and at the same time meet the expectations of all project participants. Goals are often established based on the lost values and functions of the resource(s) being impacted. The goal may be as simple as reconstructing a streambank to arrest erosion or as elaborate as re-creating the exact habitat of a rare plant. Goals can also combine resource values and functions with cultural and economic factors. It may not be enough to just stabilize a streambank, but to stabilize the streambank while increasing trout habitat and enhancing water quality. Furthermore, the goal must be a result of a consensus between all interested parties. Once the goal is determined, a mitigation or restoration plan can be set into action. We have found it advantageous to meet with the client and regulatory agencies before beginning design concepts and develop a goal, or set of goals, that meets the expectations of all parties involved with the project.

It Takes a Team

Preparing and constructing a wetland or stream mitigation project is one of many steps in the regulatory process and often involves the expertise of a multi-disciplinary team of natural resource scientists, restoration ecologists, engineers, and collaboration with the regulatory agencies and the permit applicant. Very few successful projects are the result of individual efforts. Restoration ecologists are still learning a great deal about wetland and stream ecosystems and how they function, not to mention how to put them back together again, and the expertise of many people and disciplines are needed.

When team building, do not forget to include the input of concerned citizens and local neighborhood and environmental organizations. Often their insight into a particular site and their knowledge of local ecological processes and resources will provide valuable information for design and construction. Also consider including a wetland or stream restoration contractor on your team. Their expertise about construction techniques, plant availability, access considerations, and logistics can result in substantial cost savings not only during construction, but throughout the maintenance period.

Water, Water Everywhere

The long-term success of any wetland mitigation and stream restoration project depends on restoring or creating the appropriate water budget (hydrology). Unfortunately, for nontidal wetland creation, this is one of the most difficult variables to manage. Groundwater levels must be monitored, surface runoff and flood flows must be modeled, precipitation and evapotranspiration must be calculated, and a water budget must be created. The water budget determines the amount and duration of water moving in, through, and out of the wetland. Water budgets govern the final elevations and grade of the wetland, dictate plant selections, and define specific wetland values and functions. Without reliable, long-term monitoring date, accurate planning and design for specific water budgets is limited at best. Likewise with streams, water controls all other ecological processes. Whether it be sediment transport, streambank erosion, or trout habitat, water is the key to defining stream values and functions.

Know your water budgets and hydrology. Know how water gets to the site and how it leaves the site. Apply field experiments and set up monitoring devices to record streamflows, groundwater levels, and surface runoff. Remember the three main principles of a successful wetland and stream restoration project: hydrology, hydrology, and hydrology.

Build a Stable Foundation

Wetland soils are the primary medium for many chemical transformations that support wetland plants, and are a reservoir for minerals and nutrients required by both plants and many other biotic resources. When designing and constructing a wetland or stream, soil properties must be considered in response to the anticipated hydrologic regime. Soil characteristics that must be contemplated include texture, organic matter, pore space, and chemical properties such as pH. In most cases, a soil's chemical and physical properties must be managed or altered to attain an optimum foundation for hydrophytic plant growth, chemical transformations, and mineral and nutrient cycles. Without a stable base from which to build, desired plant communities and wildlife habitat are a guess at best.

Like hydrology, know thy soils. Learn both the physical and chemical parameters of the site's soils and how these parameters will affect the desired plant community. Of equal importance is knowing everything about any soils imported onto the site too.

Green Side Goes Up

If the hydrology is predictable and the appropriate soils are in place, wetland and riparian plant selections can then be made. Wetland and riparian plants can grow in an environment that is typically inundated periodically throughout the growing season. The tolerance to inundation, which includes both the frequency and duration of water contact, varies depending on the physiology of each plant species. Some plants may require constant inundation of water to survive (e.g., cattails) where others may tolerate only short periodic inundations (e.g., ash). Plant survivability is not only dependent on hydrology and soils, but also on microclimate, topography, solar radiation, orientation, and biological interaction.

Native plant species found growing in environments similar to the created wetland provide a reliable source for plant design selection. Additionally, the use of *local* native species provides a genetic advantage for plant adaptation and survivability. Plant selection in mitigation and restoration projects must also take into consideration plant availability and costs, estimated mortality, reproduction rates, sizes and spacing requirements, pests and diseases, and biotic interactions.

Four months after installation, willows have leafed out. Roots growing into the streambank prevent erosion and protect the bank from storm events.

Start Early and Stay Late

Successful wetland mitigation and stream restoration projects are often incorporated into the project early in the planning and design process and are a part of the project for up to 5 years after completion. By analyzing wetland and stream impacts early in the planning stages of a highway, it is possible to avoid impacts by altering alignments and minimize impacts by changing design details. Why do wetland mitigation and stream restoration when you do not have to?

If wetland mitigation or stream restoration is required, assign it a prominent role in the design process. Often mitigation and restoration requirements can be satisfied and incorporated into the design of a highway with minimal additional costs and time. Furthermore, integrating the design of wetland mitigation and stream restoration with the rest of the project will help ensure its long-term success.

The other critical time often ignored by agencies and permit applicants is the post-construction period. No matter how well planned and executed, *all* mitigation and restoration projects *need* maintenance. Remember, ecological systems change over time and space, often in unpredictable ways. Federal and state agencies are now requiring maintenance and warranty of wetland mitigation and stream restoration projects for up to 5 years, and longer in some cases.

Maintenance must be incorporated into the project to reach and satisfy the goals of the project. Maintenance activities may include wildlife predation protection, dead and diseased plant removal and replacement, exotic plant eradication, trash and debris cleanup, soil supplements, and hydrologic modifications. Additionally, plant material often needs watering throughout the establishment period, primarily throughout arid regions of the country. A successful mitigation and restoration project has a contingency plan(s) to handle unexpected situations.

Landscaping vs. Ecological Restoration

The failure of many past projects can be directly attributed to the inexperience of the construction/landscape contractor combined with the lack of proper supervision. In mitigation and restoration projects it is impossible to design for all conditions at all times. Consequently, it is imperative that the contractor or a construction manager be able to make intelligent field changes to ensure the success of the project. This requires a thorough understanding of the project goal and thorough knowledge of project components including plant hydrologic regimes, plant material, soil conditions, and surrounding potential influences. Manipulating the final grade 3 inches or moving a specific plant 3 feet may mean the difference between a successful project and a failure.

Ecological restoration construction firms should possess the skills and experience to make sure the project is installed and maintained properly. If you contract with a standard landscape contracting firm that does not possess the required expertise, make sure you retain the design consultant or a construction manager with the right qualifications that can supervise the project.

Scruples

Ecological restoration is an attempt to reverse the trend of unsustainable development. Everything we do to the landscape affects the capacity of the landscape to sustain an environment suitable for life as we now know it. The use of exotic plant material, unnecessary fertilizers and pesticides,and other high maintenance "improvements" will ultimately limit the earth's capacity to support life. Ecological restoration represents a significant step in reversing this trend to restore and create sustainable landscapes.

William McDonough stated our ethical responsibility rather succinctly, "Nature doesn't have a design problem, after all; human beings have a design problem." A few sustainable design and construction points to follow include:

- Minimize the destruction of one habitat for the benefit of another. (Remember, peat moss is mined from wetlands. Specify alternatives if available.)

- Advocate the minimization of extremely invasive procedures to native landscapes including wholesale regrading, major changes in drainage patterns, and replacement of native plant material for non-indigenous plants.

- Emphasize landform and grading to create design, rather than hard structures and surfaces. Balance cut and fill.

- Do not plant any species that may become invasive and decimate native habitats. A few plants that should not be planted include Norway maple, Russian olive, Amur and Tartarian honeysuckle, multiflora rose, kudzu, common reed, purple loosestrife, and red fescue.

Aldo Leopold, one of the great naturalists said, "Things are wrong, morally wrong, whenever our biotic community is degraded." Ecological restoration can be a powerful mechanism to reverse global ecological degradation.

Editor's Note: This article on contracting for underwater inspections should be useful to offices that need dive services on hydraulic structures.

BRIDGE DIVING INSPECTION AND THE COMPETITIVE BID SYSTEM: PROBLEMS AND PITFALLS[1]

by Michael J. Ganas, P.E. and Stephen T. Boswell, Ph.D., P.E.[2]

Nearly 6 years have now passed since the Federal Highway Administration (FHWA) mandated that all states implement programs for periodically inspecting the substructures of bridges spanning waterways. The primary objective of this requirement was to ensure public safety by preventing catastrophic collapses such as the Chickasawbogue Creek Bridge in 1985, or the Schoharie Creek Bridge in 1987 in which 10 persons died.

Since that proclamation, at least two more major collapses have occurred, and until each state has fully implemented a well-founded, comprehensive program for selecting qualified and competent firms that perform bridge diving inspections, the possibility exists that other lives will be claimed as a result of more collapses that might have been avoided.

A responsible dive team takes backup units of all necessary gear into the field.

In deeper waterways where wading and probing techniques cannot be used, diving techniques will generally be employed to determine the structural integrity of submerged bridge members. While other specialized equipment can sometimes be used in place of a diver, such as remotely operated vehicles with underwater video cameras, their applicability to bridge inspections is usually limited by swift currents, poor underwater visibility, and complex substructure configurations. And while other types of equipment, such as fathometric depth sounders, side scan sonar, and sub-bottom profilers, can also be utilized to assess developing scour patterns of bridge footings or evolving streambed elevations, their usefulness often supplements a diving inspection.

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1 Reprinted with permission from the Editor, Public Works, December 1993 issue.

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Levels of Effort in Underwater Inspection

Guidelines of the National Bridge Inspection Standards (NBIS) recognize three levels of underwater inspections that apply to bridges:

Level I. – Commonly known as a swim-by inspection, it is specifically intended to cover the entire exterior surface of all submerged components with the objective of locating defects and developing structural compromise. Although visual observations are used where possible to locate discontinuity of members of other deficiencies, such as footing exposure or undermining, tactile examination is often required where zero underwater visibility is encountered.

Level II. – This is more detailed in nature than a Level I inspection and requires partial cleaning of the substructure components, normally involving the removal of fouling marine growth that may reveal hidden deterioration. On steel members, it may involve the scraping away of oxidized metal or rust to assess the remaining cross-sections. A Level II inspection usually includes measurements intended to document the size and location of deteriorated areas. It may also involve the technique of tapping and sounding with a hammer to identify weakened sections of steel or concrete, or hollow areas in wood members that have been eaten away by marine borers. Sometimes a simple penetration test may be employed using an ice pick or awl to determine if timber components are undergoing rot. Where large amounts of hard-to-remove biofouling encrust substructure surfaces, it may be necessary to use a waterblaster to expose hidden damage and to expedite the inspection.

Level III. – This is highly detailed inspection that may employ both nondestructive testing and partially destructive testing methods intended to detect hidden or interior material section loss and deterioration. These techniques will generally be focused on suspected areas of representative or critical structural members. A Level III inspection often requires extensive cleaning, detailed measurements, and the use of ultrasounding techniques to evaluate material homogeneity. It may also involve in-situ hardness testing and physical material sampling techniques in which timber or concrete corings are removed for laboratory analysis.

NBIS guidelines mandate that as a minimum, bridge owners conduct routine underwater inspections requiring 100 percent Level I and 10 percent Level II efforts at least once every 5 years. A scour investigation, which involves the plotting of waterway bottom profiles adjacent to the bridge, is also conducted to supplement the inspection, but does not necessarily have to coincide with the underwater inspection. Routine inspection intervals, however, can be less than 5 years and are typically influenced by such factors as the occurrence of unusual floods or ice floes, high concentrations of corrosive chemicals in the water, prop wash from heavy boat traffic, vessel impact against the structure, the degree of economic importance to the community, recent earthquakes of significant magnitude, the prevalence of marine borer activity, the design of the substructure, susceptibility of the waterway bottom material to scour, the age and maintenance history of the structure, high water velocity, and the proximity of dams.

The need for more time-consuming indepth inspections involving Level II and Level III efforts on a particular bridge may arise as a result of a routine underwater inspection that indicates some evidence of more extensive hidden damage. In addition, in-depth inspections involving Level III efforts on a major scale are very often governed by the need to determine which substructure components are still reusable for a planned rehabilitation of the bridge. NBIS criteria for distinguishing between the need for a routine or in-depth inspection are not clear cut. In this respect,bridge owners are given considerable latitude that hinges on a subjective elevation of many factors. However, the costs associated with an underwater inspection are directly related to the size of a bridge substructure and the level of effort requirements of the owner. The cost is also sensitive to adverse environmental conditions such as swift currents, polluted water, poor underwater visibility, and water depth, which will slow down the inspection process and thus escalate the cost. Special equipment requirements, such as hydraulically powered wood coring tools, oscilloscopes for ultrasonically interpreting remaining thickness of steel members, waterblasters, workboats, underwater video cameras systems, and recompression chambers will further contribute to the cost.

Conditions Causing Poor Quality Underwater Inspection

Because underwater bridge inspections are highly covert in nature, diver observations and descriptions must be accepted at face value. If a critical structural deficiency on a bridge substructure goes undetected or is misinterpreted by an inspection diver or the team leader supervising the inspection, structural failure may result a short time later. There are four primary conditions which can cause an imminent failure condition to be missed during an underwater inspection.

Condition #1. – The diver is technically unqualified to recognize the impending failure condition.

Condition #2. – The diver is too inexperienced with hostile underwater conditions to give the inspection his/her full attention.

Condition #3. – The diver is improperly and/or insufficiently equipped to effectively execute the inspection.

Condition #4. – The diver spends insufficient time inspecting the structure.

Although any one of these conditions can lead to a poor diving inspection, unrealistic price proposals during the selection process have the potential of instigating them. In essence, bridge owners having a selection criteria based solely or primarily on low price take a substantial risk since such a policy inadvertently proliferates the potential for erroneous bridge condition surveys.

Several cost components determine a price proposal—direct labor, overhead, profit, and out-of-pocket expenses. The cost of direct labor is controlled by both the total man-hours estimated to conduct the work and the wage rates of the various personnel who would be assigned to the inspection project. Unrealistically low wage rates can often give rise to conditions #1 and #2, while too few labor man-hours can spawn condition #4.

In addition, too low an overhead rate or estimated out-of-pocket expenses may be indicative of insufficient or poorly maintained equipment to adequately conduct an inspection, thus bringing on condition #3.

While executing the work, a firm that recognizes it has underestimated the required labor to perform an underwater inspection consistent with NBIS guidelines usually has two options—either shortcut the inspection or absorb the additional cost of labor. Thus, assuming a firm's wage rates, overhead, profit, and expenses are not dramatically out of line with industry averages, it is easy to conclude that a very low price reflects a low man-hour estimate. One can further conclude that firms consistently low-balling their anticipated labor do so with the intention of shortcutting the underwater inspections. Herein lies one of the major abuses within the engineering profession and one of which all bridge owners should be aware.

A more detailed examination of conditions #1 and #4 and their relationship to NBIS guidelines for the underwater inspection of bridges is as follows:

<u>Condition #1</u>: Technically Unqualified Divers. – NBIS requirements for divers, as presented by the FHWA Manual on Underwater Inspection of Bridges, are nonspecific. Minimum acceptable requirements are left to the discretion of the particular state in which bridge diving inspections will take place. Some states stipulate that each inspection diver must have at least 3 years of underwater inspection or construction experience, while others require that this experience be supplemented by a bridge inspection training course. However, NBIS recommends that all bridge inspection divers work under the direct supervision of a fully qualified bridge inspection team leader.

According to National Bridge Inspection Standards (NBIS), there are four acceptable avenues which qualify a diver for certification as a bridge inspection team leader:

- Registration as a professional engineer
- Eligibility for registration as a professional engineer
- Completion of a comprehensive course in bridge inspection and a minimum of 5 years of bridge inspection experience
- Level III or Level IV certification under the National Society of Professional Engineers' National Institute for Certification of Engineering Technologies program.

The basic goal of these requirements is to ensure that the bridge inspectors have a basic knowledge of the effects of deterioration on the safe loading capacity of bridge structures. Engineers who are proficient and experienced divers usually satisfy this requirement better than a non-engineer.

It has been argued that the use of "real time" video tape documentation of the underwater inspection will relieve the diver of the need to be technically literate. While some bridge agencies and engineering consultants believe that only a qualified bridge inspection team leader stationed topside at the video monitor is all that is required during video taping of the substructure, the reliability of such a procedure for detecting conditions of developing structural compromise is often constrained by the ability of the diver to first locate and then point the video camera at the condition. In addition, variations of depth, contrast, and color on the video monitor may actually mislead the topside observer's perception of what is being viewed. Poor underwater visibility can compound this, greatly limiting the ability of the topside observer to make an accurate structural assessment.

There has also been much argument that supports the use of technically deficient divers under the direct supervision of an on-site professional engineer, even if real time video taping is not used. Such a line of reasoning places absolute faith in the judgment of the professional engineer to carefully question the diver in order to build an accurate picture of the submerged bridge structure. Consulting engineering firms lacking in-house diving capabilities are usually the biggest advocates of this philosophy and will often contract the services of a diver or diving contractor offering the cheapest price who will then work under their on-site supervision. It was this type of belief that led to a very costly mistake some years ago during the substructure inspection of a large bridge located in the northeast. The engineering consultant responsible for producing the rehabilitation design subcontracted with a sport scuba diver to provide them with the deteriorated configuration of the pier footings. After the work went out for bid, the marine contractor discovered that the contract plans did not even remotely match the existing conditions. The added cost of additional inspection, re-engineering, and extra work totaled nearly $1 million.

<u>Condition #2</u>: Inexperienced Divers. – Of equal importance alongside technical qualifications, an underwater inspector should be experienced and proficient as a diver in order to perform bridge inspections under hostile environmental conditions. Quite frequently, a diver must cope with swift currents that occur as a result of a bridge having been constructed at the narrowest gap in a channel where water velocity is at a maximum. Obstructions to the flow, such as bridge piers and abutments, can compound this condition by inducing various types of swirling vortices that can make diving very difficult and hazardous. Poor underwater visibility will often accompany these conditions, forcing the diver to rely on tactile, rather than visual, perceptions about the condition of a submerged structure.

Construction debris is in the form of cables, H-piles, pipes, and other items commonly exist around bridge footings, posing a diver hazard. Submerged driftwood and tree limbs can also hamper a diver, catching and entangling an umbilical hose.

Cold water is another environmental factor that commonly comes into play. Because most bridge owners have strict bridge inspection timetables to maintain, a contract awardee may not always have the luxury of conducting inspections when conditions are most ideal. Even during the summer months, a diver can encounter a thermocline on most lakes spanned by bridges, and if not properly equipped, may become quickly subjected to the effects of hypothermia.

Conducting inspections under any one of these adverse conditions places a significant physical and psychological demand on the diver. If not properly trained and experienced in coping with these factors, and if not in excellent physical shape, an underwater inspector may spend too much time adapting to inclement conditions to perform an effective inspection, no matter how technically qualified. Even a recreational sport diver, having logged hundreds of dives, may not be fully prepared to adjust to the conditions commonly encountered under many bridges since their experience may have been consistently restricted to open water settings much less adverse and thus much less physically demanding. In such a scenario, a diver may actually endanger himself/herself. All too often, such conditions will cause an inexperienced diver to rush an inspection in order to exit the water as soon as possible. This increases the probability that important structural information will be missed.

Condition #3: **Improper and/or Insufficient Equipment.** – The type of equipment needed to execute an underwater inspection is normally dictated by the level of effort required, the environmental conditions (such as water velocity, depth, and temperature), and the bridge design. The most important equipment, however, is the diver's life-support gear that provides the breathable air. SCUBA (self-contained underwater breathing apparatus) and lightweight surface-supplied air are the two basic vehicles used by a diver to go underwater.

Although there are advantages and disadvantages in the use of each, surface-supplied air in which the air is channeled to the diver from the surface through an umbilical hose, has proven to be safer and more practical under adverse conditions. In addition, umbilical air hose characteristically utilizes diver-to-surface audio communication whereby diver measurements and observations can be readily documented by topside personnel, especially on excessively deteriorated structures, making recorded information much more accurate and reliable. Surface-supplied air equipment, commonly called hard hat gear, also works well with underwater video tape systems that employ real time surface monitors since the video cable can be married to the diver's umbilical air hose. Recordings of the diver's verbal descriptions and questions by topside personnel can also be documented on the video tape.

The umbilical line used by hard hat divers often includes a pneumofathometer air hose that can measure water depths which can be read from a dial gauge mounted on the surface. Such a tool is highly useful in obtaining waterway bottom elevations along bridge pier faces, a requirement of most bridge owners during bridge diving inspections and scour investigations.

Generally, an air compressor with a volume tank is needed to provide the diver with air whenever surface-supplied equipment is utilized. A secondary or backup source of breathing air using several 250-ft^3 cylinders of compressed air should also be incorporated into the dive station by means of a throw valve.

A fully equipped boat is used to inspect bridges over large waterways.

For cold water diving, dry suits are generally used to protect the diver against hypothermia. For prolonged submergence, a hot water suit is often employed to keep the diver warm.

On bridges spanning large waterways where shore access to the substructures is not possible, a boat is often needed to conduct an inspection. The size and configuration of the boat is dictated by the number of personnel carrying out the inspection, the particular equipment requirements, and the environmental conditions.

Assorted hand tools such as scrapers, hammers, awls, wire brushes, survey rods, and rulers are invaluable to the diver for cleaning, measuring, and assessing the condition of various material components. Underwater cameras with electronic flash are extremely important in documenting typical and atypical conditions, especially all structural deficiencies. Because underwater visibility is commonly limited under most bridges, a super wide angle lens (i.e., 15-mm or less) should be employed for closeup photography. Under low light conditions, underwater lights are often needed to visually illuminate structural components. Cameras, lights, and hand tools should be secured to the diver by a lanyard or string to avoid loss.

If a Level III effort of inspection is required, specialty equipment may be needed such as a waterblaster for cleaning large surface areas, or hydraulically powered coring tools for taking timber samples to assess marine borer intrusion.

Whatever the equipment requirements are, it is important that all gear be in good operating condition so as not to delay the inspection. As a precaution against the possibility of malfunctioning equipment, backup gear and spare parts should be routinely taken into the field, especially the diver support equipment. An efficient and responsible dive team will have on hand at least two units of all the necessary primary gear—diving helmets, air compressor, dry suit, wet suit, diver radio, umbilical hose, underwater camera, underwater light, hand tools, etc. If there is a requirement for underwater video tape documentation, such as mandated by the New York State Department of Transportation on all of their bridge diving inspections, a backup video system should be available.

A wide assortment of equipment, including backup, requires a sizeable capital investment. It is often the case that financially unstable firms do not possess the capital resources to consistently maintain and replace equipment, thus sending inspection teams into the field with marginally operating gear. Such a scenario lends itself to bridge inspections being rushed or cut short.

<u>Condition #4</u>: **Insufficient Time Spent Inspecting the Substructure.** – Various types and combinations of diving conditions encountered can directly affect the amount of time required to inspect a bridge substructure in a manner that conforms with NBIS guidelines. Swift currents and vortices will hinder the inspection and will quickly sap a diver's strength. Cold water can also slow the inspection and will constrain a diver's water time before the effects of hypothermia create mental confusion and drain the diver's energy. Deep water will limit bottom times because of dissolved nitrogen buildup in the tissues. Note that a diver working as deep as 60 feet is limited to 60 minutes in the water without having to undergo decompression. This time restriction becomes more severe with increasing water depth. Additionally, poor underwater visibility can easily cause a diver to become disoriented.

Generally speaking, the more adverse the conditions, the less time a diver can realistically spend performing an inspection before he/she becomes ineffectual or endangers himself/herself. For this reason, more frequent diver changeover is needed to continue the inspection. Because of this, one or more additional divers may be required to conduct the inspection in a safe, efficient, and reliable manner.

According to Occupational Safety and Health Administration (OSHA) Diving Standards, Subpart T—Commercial Diving Operations, there are specific procedures that should be complied with, depending on the type of diver support equipment that is used during the diving operation. Based on the gear used, these are as follows:

SCUBA:

- Should not be used beyond 130 feet of seawater (fsw).
- Should not be used against currents exceeding one knot unless the diver is line-tended from the surface.
- Regardless of water velocity, the diver must be line-tended unless accompanied by another in-water diver who is in continuous visual contact during the dive.
- A standby diver shall be available while a diver is in the water.
- For dives exceeding 100 fsw or outside the no-decompression limits, a decompression chamber must be readily available for use.

Surface-Supplied Air Diving (excluding heavy deep sea gear):

- Should not be used on dives exceeding 190 fsw unless bottom times do not exceed 30 minutes, in which case the maximum depth can be extended to 220 fsw (beyond which mixed-gas must be used).
- Another diver shall be stationed at the underwater point of entry (for purposes of tending the primary diver's hose) whenever diving is conducted in enclosed or physically confining spaces.
- Each in-water diver shall be continuously tended from the surface.
- A bell shall be used for dives with an in-water decompression time exceeding 120 minutes.
- For dives exceeding 100 fsw or exceeding the no-decompression limits (1) a standby diver stationed topside shall be available while a diver is in the water; (2) a separate dive team member shall continuously tend each in-water diver; and (3) a decompression chamber shall be readily available for use at the dive station.

Based on these safety requirements, it is obvious that a bridge inspection dive team using SCUBA must have, as a minimum, three persons—two in-water divers and a standby diver if line-tending is not used; or one in-water diver, one surface tender, and one standby diver if line-tending is used. However, some advocates of SCUBA will erroneously argue that the tender can also serve as the standby diver, thus justifying the use of a two-man dive inspection team to be in conformance with OSHA regulations (assuming the bridge inspection team leader is one of two people comprising the team). This simply is not the case and should be avoided.

A major shortcoming of SCUBA is the limited time it permits the diver to stay submerged. On a fairly large pier substructure, there is always the temptation to rush the inspection in order to avoid having to change air tanks. In addition, unless SCUBA bottles are used in conjunction with a band mask or diving helmet that incorporates diver-to-surface communication, the diver must keep coming to the surface to report observations and measurements to topside personnel.

When using surface-supplied air, however, the minimum manpower requirement is two persons—one diver and one tender—if the diving operation is conducted in water depths of 100 fsw or less. If, when using surface supplied-air, the water depth exceeds 100 fsw, then at least three team members would be needed—one diver, one tender, and one standby diver. Of course, these minimum personnel requirements assumes the bridge inspection team leader is one of the dive team members.

Unfortunately, it is often the case that a low bid awardee will understaff a bridge inspection project, thereby violating OSHA practices. To go a step further, if adverse diving conditions exist, but were either unanticipated or disregarded during the bid proposal process, the diving contractor may very likely have insufficient manpower to execute a quality inspection, thus burning out his/her diver or divers all too quickly. At this point, the contractor has two choices—either shortcut the inspection requirements and make profits, or fulfill the inspection requirements and suffer monetary losses. Because of this problem, there is no telling how many bridge structures have been erroneously reported as being in sound condition under a competitive bid contract when adverse conditions exist.

As a rule of safety, and to assure the quality of the inspection, all bridge inspection team members should be qualified inspection divers whenever adverse conditions are present so that frequent diver changeovers are possible.

Additional factors that can lead to a rushed or shortcut inspection are the following:

- The inspection diver or divers were not prepared for, or too inexperienced to cope with, adverse diving conditions encountered.

- Although having adequately staffed the project, even for frequent diver changeovers, the low bid awardee either intentionally or mistakenly underestimated the minimum amount of time needed to conduct a quality inspection.

- The contractor planned the diving operation poorly in the way of equipment requirements and failed to have adequate tools for executing the work.

- Boat access was necessary to reach some or most of the bridge substructures, but the contractor did not plan to use one.

or

- The contractor mobilized poorly maintained, marginally operating equipment with insufficient backup.

Unrealistic Bid Prices

As a general rule, proper underwater bridge inspections are expensive and require considerable effort to execute. Quite often, bidders will submit price proposals under a competitive bid system without ever having made a site reconnaissance of the structures requiring inspection. Unless underwater video tape documentation is required, the actual diving work remains highly covert in nature whereby inspection findings must be accepted on good faith.

By understaffing and/or under-equipping a bridge inspection dive team, a contractor can easily low-ball a bid price, even if good technical qualifications to conduct the work can be verified. Unfortunately, the risk to the public increases in direct proportion to such tactics. Because of problems such as these, the competitive bid system can actually proliferate poor quality underwater inspections. And until such a selection procedure is discarded in favor of a process based solely on technical merit, it is highly possible that more bridge collapses could occur as a result of imminent structural failure conditions that were missed.

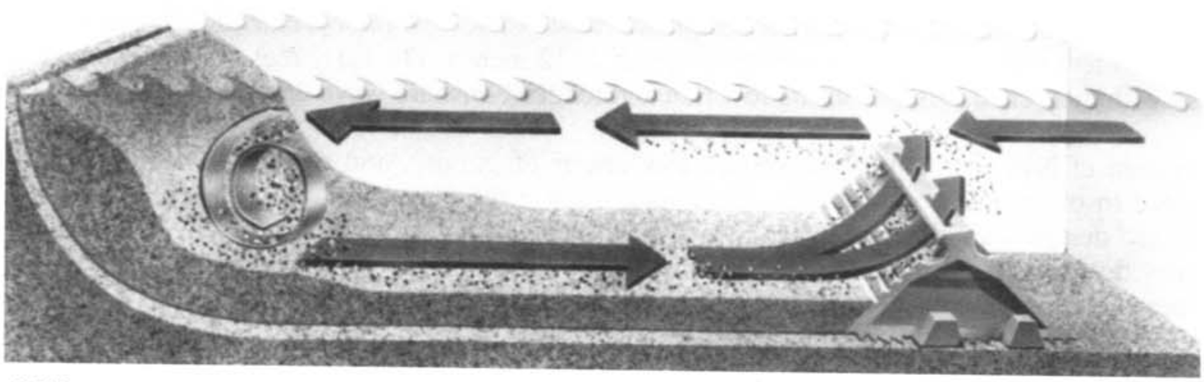
ARTIFICIAL REEF TESTED IN BEACH EROSION CONTROL PROJECT[1]

An unusual submerged reef designed to control beach erosion was installed 250 feet offshore last summer at Avalon, New Jersey. Giant 21-ton concrete modules were lowered into the water from a barge-mounted heavy crane and guided into position on the ocean floor by divers. The modules were shipped by barge from their manufacturing site at Port Monmouth, near Sandy Hook, New Jersey.

The Avalon reef was the first part of the New Jersey Pilot Reef Project, which combines construction of specially designed reefs with sand nourishment programs to extend the life expectancy of beach replenishment. The project involves installation and intensive scientific monitoring of the reef in about 1,000-foot lengths at three shore locations. The three sites are the border of Belmar and Spring Lake, on the headlands or mainland; Avalon, located on a barrier island adjacent to an inlet; and Cape May Point, at the tip of New Jersey where strong cross-currents result from the convergence of Delaware Bay and Atlantic Ocean waters.

Belmar/Spring Lake, Avalon, and Cape May Point each offer a distinctly different environment that will yield a wealth of data vis-a-vis the performance of the reef under various wave and current conditions, near-shore slopes, and sand grain sizes. Specifically, the project will quantify the degree to which the reef extends the life span of a nourished beach, thereby protecting that beach and acting as a hazard mitigation device during storm events. Funding for the $2.1 million project is being shared by state, federal, and local governments.

The 1,000-foot Beachsaver® manmade reef was designed and manufactured by Breakwaters International Inc., Flemington, New Jersey. The Avalon reef took about 2 weeks to complete. Derived from a simple emergent breakwater design, the reef is positioned parallel to the shoreline and submerged below the level of mean low tide by about 6 feet. It is placed several hundred feet offshore, depending upon water depth, where its location is marked by navigation buoys. The reef is modular and can be extended to varying lengths, depending upon the beach that requires protection.



Offshore current channels through the Beachsaver backwash flume (top right) creating an upward flowing curtain of water that lifts sand over the reef. Incoming waves then carry the suspended sand back onshore.

[1] Reprinted with permission from the Editor, Public Works, December 1993 issue.

Module Composition

Each module is 10 feet long by 15 feet wide by 6 feet high. Modules are made of precast concrete enhanced with W. R. Grace's (Cambridge, Massachusetts) "Force 10,000" microsilica additive. The composition increases impact strength tenfold and salt resistance twentyfold over regular concrete. In addition, it withstands freeze-thaw cycles better. Each module weighs around 21 tons; each 1,000-foot reef weighs 4 million pounds. The life of the reef in the ocean is expected to exceed 50 years. Within 18 months, the device will act as a natural reef, providing a protected breeding ground for millions of marine organisms within its internal cavity and attracting sport fish to the area.

The cross section of the reef module includes several notable features. The modules interlock by a mortise-tenon joint that prohibits lateral, vertical, and horizontal movement. The ridged, seaward sloping face of the structure dissipates up to 30 percent of the incident wave energy while avoiding the production of significant reflected wave energy. This feature, in addition to submergence, greatly reduces both the wave-induced force on the structure and the amount of scouring at the seaward toe. The patented system of ridges effectively eliminates toe scour by returning small amounts of sand to the toe of the structure as each wave passes.

The crest of the structure is curved upward on the landward side so as to channel wave-induced return flow vertically toward horizontal openings along the top of the reef. This configuration, known as the "backwash flume," is designed to direct a vertical jet of water upward during the return flow. This return flow is sediment-laden during storm events. The induced "curtain" of water inhibits the offshore migration of the beach berm during storms, essentially cycling the sand back onto the beach. Testing performed at New Jersey's Stevens Institute of Technology in Spring 1992 indicated that the reef limited the offshore movement of sand during periods of forceful waves and increased the likelihood of sand returning to the beach during periods of calm.

Extensive Testing

The first generation of these reefs was an emergent design that was tested on Long Island Sound in mid-1980's. An ocean test of this earlier design at Sea Isle City, New Jersey, extended the beach outward by 50 to 70 feet and raised sand levels by as much as 12 inches. The early reef systems were designed for use with their crests visible during low tide and reduced onshore wave energy.

The system utilizes its submerged weight, low center of gravity, and wide saw-toothed bottom for resistance to overturning and sliding. Wave tank tests at the University of Delaware established the submerged design's ability to withstand wave flows that surpass any found in nature. Those tests also determined that the reefs can reflect and dissipate wave energy by up to 30 percent. Staying within that limit keeps the reef in balance with natural forces.

Subsequent tests at Stevens confirmed the reef's ability to extend significantly the life span of a nourished beach and to reduce the offshore movement of sand, particularly during storm events. These encouraging laboratory results created great interest in an ocean environment demonstration project.

Breakwaters' latest reef design was tested at Stevens Institute of Technology's Davidson Laboratory. The laboratory, one of the world's best known hydrodynamic and ocean engineering research centers, (tested) the reef in a wave tank setting and found that it significantly mitigates the rate of beach erosion. The laboratory has advanced testing and research capabilities in beach erosion, shore protection, and coastal pollution.

Wave Tanks

Laboratory facilities include the largest wave tank complex of any United States university. One tank is 320 feet long, 12 feet wide, and 6 feet deep. The other is 75 feet long, 75 feet wide, and 5 feet deep. Both contain wave-making devices and the capability to simulate shallow water and sloping beach conditions through the use of false bottoms.

The laboratory also houses an electronic/instrumentation group, a machine shop with expertise in the fabrication of laboratory apparatus and models, and a photography lab capable of motion pictures and high-speed still photos of underwater laboratory and field experiments.

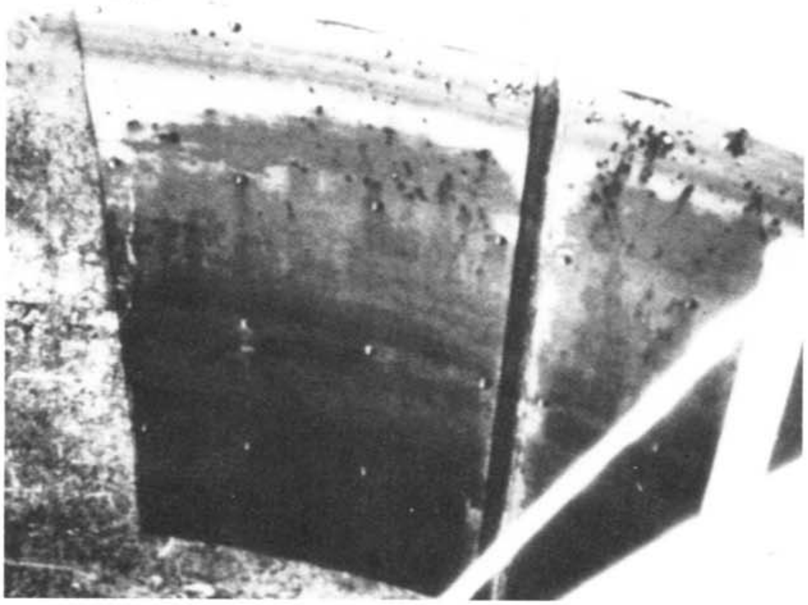
The laboratory is headquarters to The Alliance for Coastal Engineering, which works with local and federal government agencies to control beach erosion and coastal pollution. On its own, the Alliance undertakes research aimed at solving the problems of coastal communities.

SEEKING SOLUTIONS FOR ICING AT DAMS AND HYDROPLANTS[1]

by F. Donald Haynes[2]

Icing problems at hydroplants cause considerable loss of power generation, and thus revenue, every year. The Corps of Engineers is sharing information about solutions to the problem and researching new ways to eliminate ice.

Hydroelectric plant operators in the northern U.S. and Canada often encounter icing problems that interfere with normal operations. Icing can cause problems in machinery, valves, and gates, and frazil ice can block water intakes. (Frazil ice is a slightly super-cooled, slush-type ice commonly formed on northern rivers in a rapids area or any area without an ice cover.) Icing problems, especially blockage of water intakes, can shut down a hydropower plant and cause a considerable loss of power generation.



Installing high-density polyethylene (HDPE) sheets on miter gate recess walls at the Starved Rock Lock and Dam in central Illinois reduced ice buildup. Ice grows on the HDPE instead of the concrete and can be removed more easily. Although bolts are protruding from this HDPE sheet, the Corps' Cold Regions Research and Engineering Laboratory (CRREL) researchers suggest that the sheets be mounted onto the concrete wall with flush-mounted screws since ice can adhere to protruding screws and bolts.

The U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) surveyed hydroplant operators about icing problems experienced at their facilities and solutions to these problems. By sharing the survey results, CRREL researchers hope to spread solutions among operators and to identify those problems for which no solutions are currently known that require more research. CRREL researchers also are developing promising technology that may help to alleviate icing problems.

[1] Reprinted with permission from Hydro Review magazine, HCI Publications, Kansas City, Missouri, December 1993 issue.

[2] Don Haynes, P.E., is a mechanical engineer at the U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire.

Assessing and Solving Icing Problems

In 1991, CRREL sent a survey to all Corps of Engineers districts and divisions with sites affected by ice. These sites included hydropower dams, navigation dams, and locks.

The survey focused on three areas: dams, locks, and general ice problems. Survey participants were asked about the severity and methods of alleviation for a number of icing problems. Approximately 170 sites responded to the survey.

CRREL researchers defined icing to be a problem if it interrupts operations and 100 man-hours or more are required for normal operations to be restored. The following guidelines were furnished in the survey for classifying the severity of an icing problem: severity is high if the event happens every 5 years or less; medium if it occurs every 5 to 10 years; and low if it occurs every 10 years or more.

CRREL converted the severity responses from "high," "medium," "low," or "none" to a percentage rating. A 100 percent severity rating indicates a high, or serious, icing problem, a 67 percent severity indicates a medium icing problem, a 33 percent severity indicates a low icing problelm, and a 0 percent rating indicates no icing problem at the site. The mean value of the percent severities indicates the overall severity.

Figure 1 shows the most common icing problems at dams and the overall severity of each. Figure 2 shows the most common icing problems at hydro facilities in general.

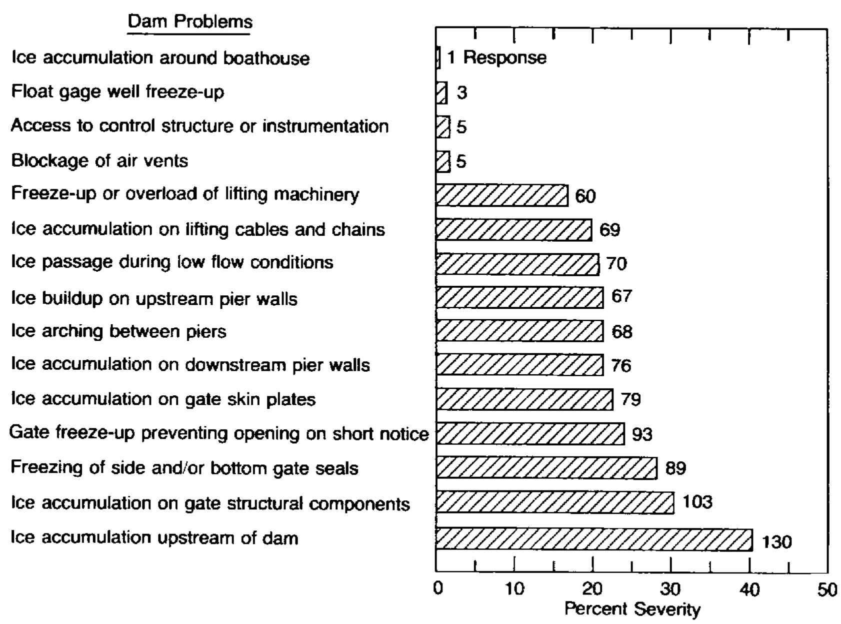


Figure 1. – A summary of the results of the CRREL survey shows the most common icing problems at dams, the number of respondents experiencing each problem, and the overall percent severity. For example, 130 respondents out of a total of 171 identified ice accumulation upstream of the dam as a problem and the overall severity based on these responses was 40 percent.

The survey results show that the frequency and severity of icing problems vary widely.

Survey respondents indicate success with several icing alleviation methods. These methods can be classified as operational, mechanical, heat-related, and manual.

Operational Solutions: Changing Procedures to Minimize Icing

Using operational methods to reduce icing can be cost-effective owing to the fact that additional hardware usually is not needed. According to survey respondents, the two most successful methods of dealing with ice accumulation upstream of a dam (the most common problem according to the survey) involve operational changes:

- Using a towboat to break ice so that it passes under gates or over submersible gates, and;
- Changing the position of tainter gates to prevent freeze-up during icing conditions and to ensure the ability to move the gates, if necessary.

Movement of dam gates, known as "exercising" the gates, is commonly done when air temperature drops below 0 °F. For example, at the Corps' Marseilles Lock and Dam in Illinois, tainter gates are moved about 6 inches every hour when air temperature is -10 °F. Dam operators report that pool level is unaffected by a change in gate position if two dam gates are moved concurrently in opposite directions for the same distance and at the same rate.

At some dams, an emergency bulkhead or stoplogs have been installed in front of the dam control gate. This creates a small waterfall and breaks up ice so that it can pass under the gate. Barges have been used upstream of a dam to deflect ice toward an auxiliary lock or a spillway. Some dam operators maintain the elevation of the reservoir at a maximum level in the winter. This can reduce icing of gate skin plates, walls, seals, structural elements, gate machinery, lift cables, and chains.

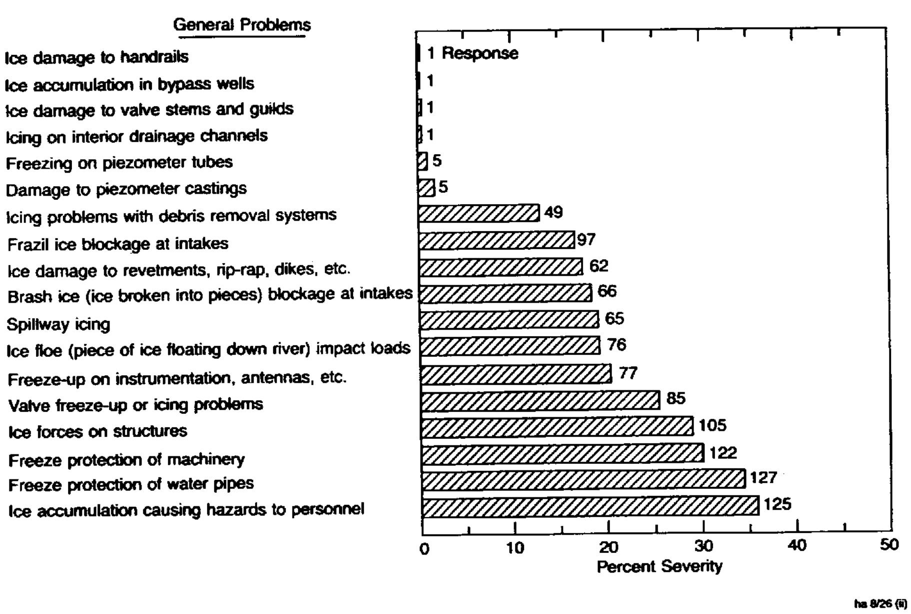
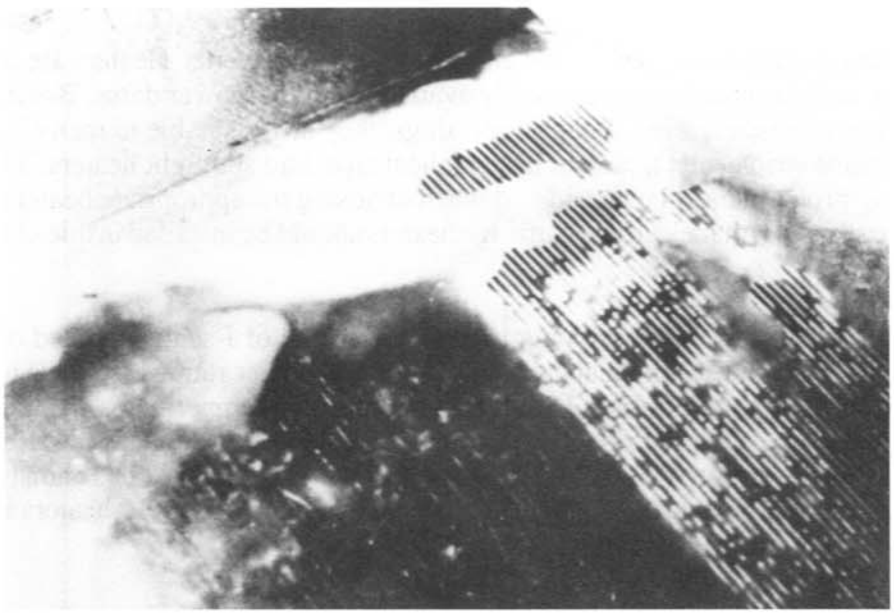


Figure 2. – CRREL survey respondents identified a number of general icing problems. The number of participants experiencing each problem is indicated on the chart and the overall percent severity is shown on the horizontal axis. Comparing the number of responses to the overall severity shows that the most common problems are not necessarily the most severe. For example, frazil ice blockage at intakes had a low severity compared to the number of responses. Frazil ice blockage was rated as low severity (every 10 years or more) at virtually all of the Corps of Engineers' plants responding to this question.

Mechanical Solutions for Reducing Ice

Although mechanical solutions often involve purchase and installation of hardware and equipment, the costs incurred can be offset by the large reduction in time required to handle ice problems.

One of the most common mechanical solutions is the installation of air bubblers. Bubblers help to prevent icing by moving water and by bringing warmer water from the bottom of the reservoir to the surface. Bubblers have been effectively used to alleviate spillway icing at the Corps' 121.5-MW Gavins Point and 5.18-MW Garrison hydroelectric projects on the Missouri River. They can be installed as either point-source bubblers or as air curtains. Operators using air bubblers report that they are reliable and easy to use. A bubbler system can be designed and operated to meet a variety of ice moving or ice melting requirements. Many dam operators rent 750-ft^3/min compressors for the winter to meet air requirements for these bubblers. (Bubblers used typically have an operating pressure of 100 lb/in^2.)



A heated trashrack was installed at a 140-Kw hydroplant in Piermont, New Hampshire. The heated trashrack on the right is mostly free of ice. Unheated racks on the left are blocked with ice.

Water jets (submersible electric motors with front propellers) have successfully reduced ice buildup. The jets bring slightly warmer water from the bottom of the reservoir to the surface and direct the water at the icing problem. Recently, heated water jets have been tested at CRREL for use in removing ice. This technique will be field tested at Starved Rock Lock and Dam in central Illinois in the winter of 1993.

Electrical cartridge heaters are placed in front of the propeller on the water jet to provide additional heat for melting ice. (Cartridge heaters are steel-encased, insulated resistance heaters about 1/2 inch in diameter and available in lengths of up to 20 feet.) To be effective, cartridge heaters should have at least three times the power of the water jet.

At lock and dams, an opening in the guide wall of the lock (called a drift pass) is normally used to sluice debris past the dam. The drift pass can sometimes be enlarged to enable easy passage of ice. This concept is used at the Corps' Lock and Dam 11 on the Mississippi River, CRREL researchers suspect that a water jet might increase flow through the drift pass.

High-density polyethylene (HDPE) sheets can reduce ice buildup on concrete walls. Ice will grow on HDPE as it does on concrete, but it can be removed cleanly and easily with about 30 times less force than is required to remove ice from concrete. CRREL researchers have found that it is important to mount HDPE sheets onto the concrete wall with flush-mounted screws—ice can tenaciously adhere to protruding bolts and studs.

Using Heat for Minimizing Ice

Heat can be used in several ways for controlling ice at dams. Like mechanical solutions, heat-based options may require purchase and installation of hardware.

Many dam operators use electrical heaters for alleviating icing problems. Heaters are usually easy to install and operate, and electrical power is readily available at hydropower dams. Because heaters are available in a variety of shapes, sizes, and power ratings, they are adaptable to many icing problems. Configurations include strip heaters, radiant heaters, heat tape, and spotlight heaters. The climate and severity of the icing problem must be considered when choosing the appropriate heater configuration. CRREL researchers suggest that electrical cartridge heaters should be installed inside of a slot or cavity for easy replacement.

Self-regulating heat cables have reduced icing in the hollow core of J-seals mounted on tainter gates at the Starved Rock Lock and Dam. Heat cables have typical power ratings from 10 to 40 watts per foot (W/ft). These heaters keep the rubber J-seals flexible at low air temperatures and thus enable them to maintain a tighter seal against the side plates. Infrared radiant heaters have been used for de-icing roller gate chain drives at the Corps' Lock and Dam 16 in Muscatine, Iowa. At this dam, two 3,000-watt heaters are suspended by adjustable steel cables above the chain drive. These heaters keep the chain drive ice-free at air temperatures of 0 °F.

Tainter gates can become inoperable if thick sheet ice grows on the skin plates. To free these plates of ice, operators at the Corps' Lock and Dam 2 in Hastings, Minnesota, have placed cartridge heaters, typically 100 to 200 W/ft, inside waterproof cavities at the water line. The cavities were added to the gates, covering the entire width and extending 2 feet high to accommodate possible water elevation changes. Further experience with such heaters at Lock and Dam 2 shows that the gates can be operable in 2 to 3 hours if 18 inches of ice is frozen onto them at an air temperature of -10 °F. Self-regulating cable heaters also have been placed between two aluminum sheets to easily shed ice from the sheets. These heated panels may be bolted onto concrete walls, such as miter gate recess walls.

Steam is often used to remove ice from surfaces and machinery. Steam can be supplied by an on-site or portable steam generator. Although effective, the application of steam can be time-consuming. Hot water is often used much like steam to remove ice.

Manual Ice Removal: A Last Resort

Removing ice manually is labor-intensive and time-consuming. Survey responses indicate that operators often resort to manual ice removal, especially when operational, mechanical, and heating methods are unsuccessful or unavailable.

When manual ice removal is needed, operators often use pike poles (long wooden or aluminum poles 1 to 2 inches in diameter and up to 20 feet long with a spike on one end). Using these poles is very labor-intensive and can be hazardous to personnel working in slippery conditions. Chipping ice, another common method, has the same disadvantages as pike poles. Ice rakes are used to remove ice from trashracks. Saws have been used to cut ice from walls. Compressed air lances are used to remove ice, but because no heat is used along with the air, this method is usually not very effective.

Sharing, Developing Ideas for Reducing Icing

Although operational, mechanical, heat-related, and manual methods help to alleviate many icing problems, the survey responses show that consistently applied solutions do not exist for many common icing problems. For example, most hydro operators reported that no alleviation method was known for the frequently cited problems of ice accumulation upstream of a dam, spillway icing, and ice accumulation on gate structural components.

CRREL researchers feel that many of the "no known method" responses to alleviation methods for specific icing problems are the result of poor communication. Survey creators hope that, as the results of this survey become more widespread,operators will try new methods that have been successful at other facilities and will communicate more about their methods.

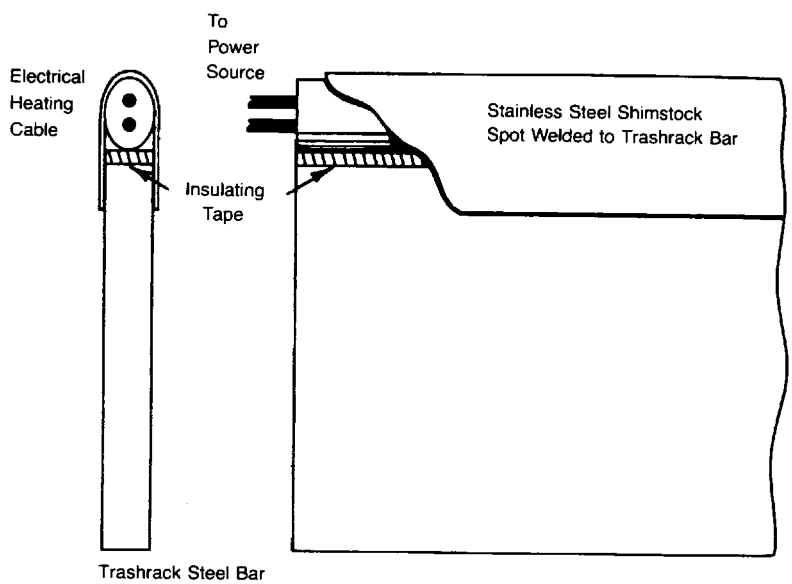


Figure 3. – In 1991, CRREL developed a trashrack design with a heated leading edge to prevent frazil ice from adhering to the bars. A cross section of one trashrack bar is shown on the left. The side view of the trashrack bar is shown on the right. A heated cable is placed on the upstream face of each trashrack bar and covered by a U-shaped shimstock that is welded onto the bar. By heating the upstream edge of each bar, the formation of frazil ice is prevented. Heated trashrack designs can be adapted to suit varying plant capacities and climates.

CRREL is helping operators deal with icing problems not only by spreading technology but also by working to develop promising new alleviation methods. In 1991, CRREL developed a new technique to prevent frazil ice from adhering to trashrack bars (reference " Note" at end of article). This technique is illustrated in Figure 3. The design rationale is to maintain a warm, 32.1 °F leading edge on the trashrack so that frazil ice cannot begin to stick to the bar. If frazil ice begins to stick to this leading edge, additional frazil ice can quickly accumulate and block the water intake. This leading edge heating method was field tested at the 130-kW Celley Mill hydropower plant in Piermont, New Hampshire. In the test, the heated rack remained free of ice while adjacent, unheated racks were clogged with frazil ice. The power requirement for this installation was 12 W/ft of bar length for a total of 2,500 W. The amount of heater capacity needed is based on the demands of the powerplant and climate.

CRREL also completed a heated trashrack design for the Niagara Mohawk Power Corporation's 28-MW Colton plant on the Raquette River in northwestern New York State. [Owing to contractual complications with the Corps, Niagara Mohawk engaged Acres International Corporation to design a similar trashrack, which will be installed and tested in the winter of 1993-94.—Ed.]

The technology used in the heated trashrack may have broader applications for the hydropower and other industries. For example, the city of Minneapolis is considering adapting this design to solve icing problems that affect the city's water supply intakes.

Increasing Efficiency by Minimizing Ice

Ice reduces the efficiency of hydroplants every year by blocking intakes and interfering with machinery, valves, and gates. Operators can minimize the effects of ice by considering alleviation methods used at other facilities and by sharing their methods with other operators. The CRREL survey began this sharing of technology. More research like CRREL's heated trashrack study is needed to solve icing problems for which no alleviation methods are currently known.

Mr. Haynes may be contacted at Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers, Lyme Road, Hanover NH 03755-1290; (603) 646-4184.

Note

Daly, S. F., F. D. Haynes, D. E. Garfield, and C. H. Clark, "Field Test of a Surface-Heated Trashrack to Prevent Frazil Ice Blockage," *Proceedings of the International Association for Hydraulic Researchers Symposium*, Volume 1, Banff, Alberta, 1992, pages 71-77.

AGING INFRASTRUCTURE REVITALIZED[1]

Historic Waterville, Ohio, is not unlike thousands of other municipalities large and small throughout the United States. The village's water system is aging, with as much as 35 percent of the potable water traveling through 50-year old cast iron pipes—some pipes are even older.

Over the years, microbiological activity has caused the pipes to scale with iron oxide deposits that reduce the pipe diameter. In some sections of the 6-inch waterline, the scale measures 3 to 4 inches, enough to seriously restrict waterflow and cause chronic red water discoloration. Replacing the old lines with plastic pipe would cost Waterville $35 per foot, not to mention the disruption caused to residents by time-consuming excavation and supplementary waterlines.

Instead of taking months to dig up and replace restricted lines, the village is phasing in a systematic chemical cleaning process that restores old lines to optimum flow at a fraction of the cost of replacing them.

Since January, Phases I and II of the project have been completed, with two lengths of scaled pipe brought back to normal operating flow conditions. There was minimum excavation, no costly replacement. The lines were flushed with Pipe-Klean, an organic bio-cleaner manufactured by Health Environmental Research Chemistry Incorporated (H.E.R.C.), Phoenix, Arizona. When mixed in solution of water and a small amount of acid, it rapidly dissolves oxides of calcium, magnesium, iron, and manganese scale, without attacking the base metal. Since the product is biodegradable, no special disposal methods are necessary.

Fifty years of scale accumulation was loosened and dissolved in a day.

According to Ken Blair, Waterville's director of public works, the first section of the distribution system to be treated, a 650-foot section of 6-inch main, had from 3 to 4 inches of scale and flow rate had been reduced to 558 gal/min. After two treatments with solution of Pipe-Klean, water, and muriatic acid, flow rate increased to 872 gal/min, an increase of 48 percent. Phase II of the reclamation project involved a 1,000-foot-long section of 6-inch main. An 8-hour treatment removed the scale from the line and increased the flow 60 percent, from 435 gal/min to over 700 gal/min.

[1] Reprinted with permission from the Editor, Public Works, December 1993 issue.

In both instances, it took less than 1 day for the solution to dissolve and loosen scale from the distribution line and restore normal flow. After the treatment, the bacteria count was low, and there has been no rust discoloration. A scaling process that took nearly 50 years to develop was rectified in less than a day.

"By making reclamation easy and affordable, villages such as Waterville will be more inclined to act quicker to reduce deposit buildup and increase their system's flow rate before a serious problem develops," Blair explained.

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