

Underwater Bridge Inspection for Engineers

Underwater elements are out of sight and often out of mind. This course explains when underwater inspection is required, how it is performed, and how engineers should read the results.

Learning objectives

- Explain when underwater inspection is required
- Compare diving and wading inspection levels
- Interpret underwater findings and soundings
- Set underwater intervals per the NBIS

When underwater inspection is required

The NBIS defines underwater inspection as inspection of the underwater portion of a substructure and surrounding channel that cannot be inspected visually at low water or by wading or probing, generally requiring diving (23 CFR 650.305). Owners must identify such locations in the bridge files and perform the first underwater inspection within 12 months of opening (650.313(e)). The regular interval is up to 60 months, reduced to 24 or extended to 72 under the criteria in 650.311(b).

Inspection levels

FHWA's *Underwater Bridge Inspection* manual (FHWA-NHI-10-027) describes three intensity levels:

- **Level I** — visual/tactile, swim-by inspection to detect obvious damage, usually covering 100% of the element.
- **Level II** — detailed inspection with partial cleaning of marine growth at selected areas to detect damage hidden by growth.
- **Level III** — highly detailed inspection, often with NDE or partially destructive testing, at limited locations.

What divers look for

- Scour holes, undermining and exposed piles or footings.
- Section loss on steel piles; concrete deterioration and exposed reinforcement; timber pile marine borers and decay.
- Debris accumulation (drift) that increases scour and lateral forces.
- Riprap displacement and countermeasure condition.
- Channel bottom profile soundings around piers for comparison over time.

Diver qualification and safety

An underwater bridge inspection diver must complete FHWA-approved underwater inspection training with a 70% end-of-course score (23 CFR 650.309(e)). Commercial diving safety standards apply (OSHA 29 CFR 1910 Subpart T for commercial diving operations). Plans must address current, visibility, boat traffic and hazards.

Reading the report as an engineer

Compare channel cross-sections with the previous inspection and the design or as-built streambed. Check whether observed scour approaches the foundation's estimated critical elevation from the scour evaluation or plan of action. Review pile section loss for substructure load rating. Underwater findings of channel or scour condition 3 or less trigger 24-month underwater intervals; 2 or less are critical findings.

Part A — Learning objectives and how to use this course

This course is written for engineers who plan, contract, review or rely on underwater bridge inspections, not for divers learning to dive. By the end you should be able to:

- Explain what the NBIS means by an underwater inspection and when one is required.
- Describe the NBIS underwater inspection intervals and the diver qualification requirement.
- Distinguish the levels of underwater inspection effort described in FHWA's Underwater Bridge Inspection manual and choose the right mix for a bridge.
- Recognize the deterioration and scour conditions that underwater inspections are meant to find, by material.
- Understand the tools available, including diving, probing and acoustic imaging, and their limitations.
- Read an underwater inspection report critically and connect its findings to substructure, channel and scour ratings, the scour Plan of Action and load rating.
- Recognize the findings that need immediate engineering action.

The core references are 23 CFR 650 Subpart C (NBIS), the Specifications for the National Bridge Inventory (SNBI), FHWA's Underwater Bridge Inspection manual (FHWA-NHI-10-027), the Bridge Inspector's Reference Manual (BIRM), HEC-18, HEC-20 and HEC-23 for scour and countermeasures, and the AASHTO Manual for Bridge Element Inspection. Diving operations themselves are governed by occupational safety rules, such as OSHA's commercial diving standard (29 CFR 1910 Subpart T), and by owner and contractor dive safety programs. This course does not train or certify divers.

Part B — What counts as an underwater inspection

The NBIS defines an **underwater inspection** as the inspection of the underwater portion of a bridge substructure and the surrounding channel which cannot be inspected visually at low water or by wading or probing, and generally requiring diving or other appropriate techniques (23 CFR 650.305). Two ideas follow from that definition.

First, underwater inspection is about what cannot otherwise be seen. A pier in a shallow creek that can be waded and probed at low flow is inspected during the routine inspection; a pier in deep or murky water, or with a footing below the bed, needs underwater methods.

Second, it covers the *channel* as well as the structure. The bed around the foundation, scour holes, countermeasures and debris are all part of the underwater inspection scope.

The NBIS also requires owners to develop and document inspection procedures for bridges needing underwater inspections, in accordance with the AASHTO Manual for Bridge Evaluation (650.313). Those bridge-specific procedures should identify which elements are underwater, the access and methods required, any special features, and the scour POA if one exists.

Why it matters

Foundations are out of sight, and many of the most serious threats to a bridge over water develop below the surface: local scour undermining a footing, marine borers destroying timber piles at the mudline, steel piles corroding through in the splash or tidal zone, or concrete piles cracking from impact. Some of the most serious bridge failures in the United States have involved scour of foundations. Underwater inspection is how owners find these problems between floods.

Part C — NBIS intervals and diver qualifications

Intervals

Under 23 CFR 650.311(b) Method 1, each bridge requiring underwater inspection must be inspected at regular intervals not to exceed 60 months. Owners must document criteria for reducing intervals below 60 months, and the interval must not exceed 24 months when any of the following is recorded in the NBI:

- The Underwater Inspection Condition item is coded 3 or less;
- The Channel Condition or Channel Protection Condition item is coded 3 or less; or
- The observed Scour Condition Rating is 3 or less.

Where those ratings are coded 3 or less because of localized deficiencies, the regulation allows a special inspection limited to those deficiencies at the reduced interval, with the complete underwater inspection at the regular interval. Extended intervals up to 72 months are allowed when the underwater condition, channel and channel protection, and scour condition are all coded 6 or greater, the bridge is stable for potential scour (Scour Vulnerability coded A or B), and the owner has documented an extended-interval policy and notified FHWA in writing. Method 2, a more rigorous risk assessment, is an alternative requiring FHWA approval. Always confirm the interval for a particular bridge in the owner's records.

Diver qualifications

Under 650.309(e), an Underwater Bridge Inspection Diver must complete FHWA-approved underwater bridge inspection training and score 70 percent or greater on an end-of-course assessment; prior completion of FHWA-approved comprehensive bridge inspection training or underwater bridge inspection training under the earlier regulations satisfies the intent of that requirement. The NBIS defines the diver as the individual performing the inspection of the underwater portion of the bridge. Team leader requirements under 650.309 also apply to the inspection. Dive safety qualifications are a separate matter governed by occupational safety rules and the dive program.

When contracting underwater inspections, engineers should verify both bridge-inspection qualifications and commercial diving qualifications, and ask for the dive safety plan.

Part D — Levels of inspection effort

FHWA's Underwater Bridge Inspection manual describes three levels of inspection effort, which most owners use when scoping work:

- **Level I:** a general visual and tactile inspection, without cleaning, over the whole underwater portion of each element, intended to detect obvious damage or deterioration and confirm the overall continuity of the structure. In poor visibility, the diver relies on touch.

- **Level II:** a detailed inspection that includes cleaning marine growth from selected areas to examine the surface closely, typically performed on a sample of each element. It gives more information on the extent and severity of deterioration and may include measurements.
- **Level III:** a highly detailed inspection, typically using nondestructive testing or partially destructive testing such as coring, ultrasonic thickness measurement or material sampling, used where detailed condition data are needed for evaluation or repair design.

A typical routine underwater inspection combines a Level I inspection of all underwater elements with Level II inspection of a sample. Level III effort is added where conditions or engineering needs call for it. The manual and the owner's procedures give the specifics, including the sample sizes the owner expects. When reviewing a report, check that it states which levels were performed on which elements.

Part E — Methods and tools

Diving

Diving modes include SCUBA and surface-supplied air. Surface-supplied diving provides continuous air from the surface and voice communication with the dive team, which is often preferred for bridge work in current, low visibility or near hazards. The choice depends on depth, current, visibility, contamination, and the owner's and contractor's safety programs. Dive operations require a dive team with defined roles, a dive plan, emergency procedures and coordination with navigation and traffic.

Wading and probing

In shallow water, inspectors wade and probe the bed with a rod to find soft material, voids and the depth of refilled scour holes. Probing is also used by divers to explore under footings and around piles.

Soundings

Soundings from the deck or a boat, with a weighted line, rod, or an echo sounder, define the channel cross-section and the bed elevation at the foundation. They should be referenced to a fixed datum or bridge feature and repeated at the same stations each cycle.

Acoustic imaging

Sonar systems can image the bed and the submerged structure where visibility is poor or currents are dangerous for divers:

- **Single-beam echo sounders** measure depth along a track.
- **Side-scan sonar** produces images of the bed and objects on it.
- **Multibeam sonar** produces detailed bathymetric surfaces around foundations.
- **Scanning or imaging sonar** deployed from a fixed point can image a pier face and the bed around it.

Acoustic methods are excellent for mapping scour and channel geometry and for planning dives, and some owners use them for monitoring. They do not replace tactile inspection of structural surfaces for cracks, section loss or timber decay. Results depend on equipment, operator and conditions; reports should say what system was used and how it was positioned.

Remotely operated vehicles

ROVs with cameras or sonar can reach places that are hazardous for divers. They are limited by visibility, current and tether management, and they cannot feel the surface. They are best treated as a supplement.

Underwater NDE

Ultrasonic thickness gauges for steel, coring and rebound or other tests for concrete, and increment boring for timber can be adapted for underwater use. Cleaning to bare surface is usually required.

Part F — What underwater inspections look for, by material

Scour and undermining

The most important finding is often in the bed, not the structure: local scour holes at pier noses, exposed footings and piles, voids under footings, loss of countermeasure material, and changes in the channel profile compared with prior cycles. Divers probe under footing edges and measure penetration into voids. The underwater inspection should feed the channel, channel protection, scour condition and substructure items, and the scour appraisal.

Concrete

Abrasion and erosion of the surface at the waterline and near the bed, cracking, spalling and exposed reinforcement, honeycombing from tremie placement, and impact damage from vessels and debris. In cold climates, freeze-thaw damage is concentrated near the waterline. Cracks in concrete piles, especially prestressed piles, and deterioration at pile-to-cap connections are significant.

Steel

Corrosion is heaviest in the splash and tidal zones and just below the mudline. Measure remaining thickness ultrasonically on cleaned spots and record holes. Look for buckled or broken bracing and damaged pile jackets.

Timber

Timber piles in salt or brackish water can be attacked by marine borers. Damage can be severe and is often concentrated near the mudline, sometimes leaving an hourglass-shaped section that is hard to see under growth. Freshwater piles can decay near the waterline. Divers sound and probe, and remove growth as needed to see the section.

Masonry

Mortar loss, displaced or missing stones and undermining at the base, which can let fill wash out from inside or behind the unit.

Other items

Debris accumulations, fender and dolphin systems, pile jackets and encasements, and utilities attached below water.

Part G — Planning and scoping an underwater inspection

Engineers often write the scope for underwater inspections and manage the consultants who perform them. A good scope prevents most of the problems reviewers find later.

Before scoping

- Identify every substructure unit in water, its foundation type, the design footing and pile tip elevations where known, and any unknown foundations.
- Pull the previous underwater reports, soundings and photos, and the scour appraisal and POA.
- Note navigation, ice, debris, current, tide and seasonal flow patterns. Many owners schedule underwater inspections for low-flow seasons.
- Note contamination concerns, such as discharges or sediments, that affect diver safety and equipment.

What a scope should specify

- Units and elements to be inspected, and the level of effort for each (Level I on all, Level II on a defined sample, Level III where needed).
- Channel cross-sections: stations, reference points, extent upstream and downstream, and the method.
- Probing requirements around footings and piles.
- Whether acoustic imaging is to be used, and what deliverables (images, surfaces, plots) are required.
- Element quantities and condition states per the MBEI and owner guidance, and the SNBI items to be recommended.
- Photo and video expectations, recognizing that underwater visibility may limit them.
- Notification procedures for critical findings during the fieldwork, not just in the final report.
- Qualifications: the NBIS team leader and diver requirements and the commercial dive qualifications.
- Safety: dive plan, emergency procedures, navigation coordination and traffic control.

Timing and conditions

Water level, current and visibility at the time of inspection affect what can be found. Reports should state them. Inspections immediately after high flows may find scour that later refills, but can be dangerous; follow the dive safety plan and the owner's POA.

Part H — Dive safety in brief

Engineers do not run dive operations, but they should recognize what a safe operation looks like and why some requests are refused. Bridge diving involves current, poor or zero visibility, entanglement hazards from debris and reinforcement, boat traffic, cold water and sometimes contaminated water. Recognized practice includes a written dive plan, a dive team with a supervisor, a standby diver, tending and communications, emergency procedures and equipment, and limits on conditions such as current and depth. OSHA's commercial diving operations standard (29 CFR 1910 Subpart T) applies to many operations, and some agencies apply other programs such as the U.S. Army Corps of Engineers safety manual EM 385-1-1. A dive supervisor who stops a dive because of current or debris is doing the job correctly; the engineer's role is to adjust the schedule or methods, for example by using acoustic imaging, rather than pressing the team.

Part I — Reading an underwater inspection report

An underwater report should let a reader who has never been in the water understand the foundation condition and the channel. When reviewing one, check that it includes:

1. **Conditions:** date, water level referenced to a datum or bridge feature, current, visibility, water temperature, and the methods and equipment used.
2. **Scope performed:** which units and elements, which levels of effort on each, and any element not inspected and why.

3. **Channel data:** cross-sections at defined stations, plotted with previous cycles; bed elevations at each pier face; any scour holes with dimensions.
4. **Foundation exposure:** exposed footings and piles, with measured exposure; probing results under footing edges, with penetration depths.
5. **Structural findings:** defects by element with location (unit, face, elevation), size and severity, and measurements such as steel thickness or timber section.
6. **Element quantities and recommended ratings** for the underwater inspection condition, channel, channel protection, scour condition and substructure items, consistent with the findings.
7. **Photos, video and sonar images** referenced to locations, with an explanation where visibility prevented useful images.
8. **Recommendations**, prioritized, including repairs, countermeasures, monitoring and follow-up inspections.
9. **Critical-finding notifications** made during fieldwork, with dates and recipients.

Red flags

- A cross-section that cannot be compared with prior cycles because stations or references changed.
- Ratings that do not follow from the narrative, such as a scour condition of 7 next to a described undermined footing.
- Statements like "no significant scour" without soundings or probing.
- Missing elevation references, so exposures cannot be compared with design footing elevations.
- Recommendations without priority or location.

Part J — Connecting findings to ratings, the POA and load rating

Underwater findings feed several decisions:

- **SNBI items:** underwater inspection condition, channel, channel protection, scour condition and substructure. Under 650.311(b), coding any of the first four of these as 3 or less (as applicable) triggers the 24-month underwater interval, and coding underwater, channel and scour all 6 or greater, with stable scour vulnerability, is part of the extended-interval criteria.
- **Critical findings:** under 650.313(q), minimum triggers include channel or scour condition rated 2 or less and a substructure rated 2 or less, as well as conditions warranting closure. NHS bridges with findings warranting closure require FHWA notification within 24 hours.
- **Scour appraisal and POA:** observed scour is one input to the scour appraisal, which the NBIS defines using the least stable result of observed scour or estimated scour. If observed scour approaches or exceeds what the appraisal assumed, the appraisal should be revisited and the POA followed.
- **Load rating and structural evaluation:** section loss in piles, loss of pile embedment, or undermining may affect capacity. Under 650.313(k), a change that warrants re-rating starts the 3-month load rating clock.
- **Maintenance and countermeasures:** riprap restoration, debris removal, pile jackets and other repairs from HEC-23 and owner practice.

The engineer who receives the underwater report is often the person who makes these connections. Make them explicitly and in writing.

Part K — When to act immediately

Some underwater findings cannot wait for the final report:

- Undermining of a spread footing, especially beneath the leading edge or a large fraction of its width.
- Exposed piles beyond design expectations, piles with lost embedment, or piles broken or severely reduced in section.
- Marine borer damage that has severely reduced timber pile sections.
- Large scour holes at piers, particularly where the foundation depth is unknown.
- Displacement or tilt of a unit, which may be confirmed by observations above water.
- Major vessel impact damage.

The dive team should notify the owner's designated contact from the field per the critical-finding procedure, and the engineer should decide promptly on actions such as closure, load restriction, monitoring under the POA, or emergency countermeasures. Document all notifications and decisions.

Part L — Unknown foundations and scour monitoring

Many older bridges over water lack plans showing foundation type and depth. The NBIS defines unknown foundations for bridges over waterways where complete foundation information is not available, and it requires a scour POA for bridges that are scour critical or have unknown foundations. For these bridges, underwater inspections take on extra importance: without design elevations, the only evidence of scour vulnerability may be the observed bed and exposure history.

Owners may investigate unknown foundations with methods such as borings, probing, or nondestructive tests that estimate pile length. Until the foundation is known, the POA may rely on monitoring. Monitoring can be:

- **Periodic:** more frequent inspections or soundings, especially after defined flood events.
- **Fixed instrumentation:** devices such as sonar or other scour monitors mounted on the bridge, which report bed elevation.
- **Flood watch:** closure or observation protocols triggered by stage, discharge or rainfall thresholds defined in the POA.

HEC-23 treats monitoring as a countermeasure in its own right, and the NBIS explicitly allows monitoring as a scour countermeasure within a POA. The underwater inspection report should note any monitoring instruments, their condition, and whether readings agree with observed bed elevations.

Part M — Worked examples

Example 1 — A cross-section that changed references

A consultant's report shows the bed at pier 3 two feet lower than the previous report. On review, you find the previous survey measured from the top of the rail and the new one from the deck edge, which differ in elevation. *Discussion:* The apparent scour may be partly or entirely a reference difference. Ask for the measurements to be reduced to a common reference and replotted with prior cycles. Make the reference requirement explicit in the next scope.

Example 2 — Undermined footing found by probing

The diver reports that the bed at the upstream nose of a spread-footing pier is near the footing bottom and a probe penetrates horizontally under the footing about 3 ft. Visibility was near zero. *Discussion:* This is a potential loss of support and should have been notified from the field. Confirm that notification occurred, review the POA, and consider immediate actions such as monitoring, load restriction or closure, and emergency countermeasures. The channel, scour condition and substructure items should reflect the finding. A follow-up inspection to define the extent, possibly with acoustic imaging, may be warranted.

Example 3 — Timber piles in brackish water

A Level II inspection on a sample of timber piles finds several with significant section reduction near the mudline from marine borer activity, discovered after growth was removed. The Level I inspection on the rest found heavy growth and no obvious damage. *Discussion:* Because the sample showed significant damage hidden under growth, the Level I results on the remaining piles may not be reliable. Recommend extending the detailed inspection to all piles, measuring remaining section, and engineering evaluation. Consider load rating and posting implications.

Example 4 — Steel H-piles with thickness readings

Ultrasonic thickness readings on cleaned spots show flange loss concentrated in the tidal zone at most piles in a bent. *Discussion:* Ask for readings by pile, flange and elevation, with original thickness from plans. Refer to the load rater. Recommend repair options such as jacketing or encasement as an engineer specifies, and consider whether the reduced interval criteria apply based on the underwater inspection condition.

Example 5 — Sonar shows a deep hole, diver cannot reach it

Multibeam sonar shows a scour hole at a pier in fast current. The dive supervisor declines to dive due to current. *Discussion:* The sonar data are valuable and may be enough to recognize a serious condition. Compare the hole bottom with the foundation elevations if known. Notify the structural engineer, follow the POA, and schedule tactile inspection when conditions allow. Do not pressure the dive team to dive outside their limits.

Example 6 — Debris and riprap

A debris accumulation on a pier extends to the bed, and riprap placed as a countermeasure is partially displaced downstream. *Discussion:* Debris increases local scour and lateral load; displaced riprap means the countermeasure may no longer protect the foundation. Recommend debris removal, a post-removal bed survey, and riprap restoration consistent with HEC-23 design guidance. Record channel protection condition accordingly.

Part N — Element data and consistency

The MBEI applies the same substructure elements underwater as above water, with quantities distributed among condition states. The underwater portion of a pier, column or pile is part of the same element as the portion above water, so the underwater findings must be merged with the routine inspection's findings for the element. Coordinate the two reports. A common QC problem is two reports for the same bridge, months apart, with inconsistent element quantities or ratings because no one reconciled them. The bridge file should show how the underwater findings were incorporated into the element data and the component ratings.

Also check that the Underwater Inspection Condition item and the substructure rating tell a consistent story. A severe underwater finding usually affects both, and the narrative should explain any difference.

Part O — Frequently asked questions

Can sonar replace divers?

Not for structural condition. Sonar is excellent for scour and channel geometry and for monitoring, but it cannot feel cracks, measure steel thickness or probe timber. Many owners use both.

If a creek can be waded at low water, does it need an underwater inspection?

If the underwater portion and surrounding channel can be inspected visually at low water or by wading or probing, the NBIS definition of underwater inspection does not apply, and the routine inspection covers it. Owners should document which bridges need underwater inspection and why.

What if the underwater inspection is late because of high water?

The NBIS sets interval tolerances in 650.311(e): up to 2 months past the due month for intervals under 24 months, and up to 3 months for intervals of 24 months or more. Exceptions for rare and unusual circumstances must be approved by FHWA in advance of the due date plus tolerance. Record the reason and reschedule at the first safe opportunity, and use the POA and other monitoring in the meantime.

Who decides the level of effort?

The owner, through its procedures and the bridge-specific underwater inspection procedures, with the team leader adding effort where conditions warrant.

Does this course qualify me as an underwater bridge inspection diver?

No. The NBIS requires FHWA-approved underwater bridge inspection training with a passing end-of-course assessment (650.309(e)). This course is supplemental PDH for engineers.

Part P — Summary checklist and glossary

- Know which bridges need underwater inspection and why, per the NBIS definition.
- Track the interval: 60-month regular, 24-month when underwater, channel, channel protection or scour items are coded 3 or less, and up to 72 months only when all extended-interval criteria and owner policy steps are met.
- Verify NBIS diver and team leader qualifications and commercial dive qualifications.
- Scope Level I, II and III effort explicitly, along with cross-sections, probing and sonar deliverables.
- Require fixed references for soundings and compare every cycle.
- Expect field notification of critical findings.
- Connect findings to SNBI items, the scour appraisal and POA, load rating and maintenance.
- Reconcile underwater and routine element data.

Glossary. *Underwater inspection:* inspection of the underwater portion of a substructure and surrounding channel that cannot be inspected visually at low water or by wading or probing. *Level I, II, III:* FHWA's levels of underwater inspection effort, from general visual and tactile, to detailed with cleaning, to highly detailed with testing. *Surface-supplied diving:* diving with air supplied from the surface through an umbilical. *Multibeam sonar:* acoustic system producing detailed bed surfaces. *Unknown foundation:* a bridge over a waterway without complete foundation information. *Marine borers:* organisms that attack timber in salt or brackish water.

Part Q — Trend analysis across inspection cycles

A single underwater inspection is a snapshot. The real value comes from comparing cycles. Scour at a pier may fill in after a flood and reopen in the next, so a bed elevation that looks stable between two inspections can hide a much deeper scour during the flood itself. Conversely, a slow, steady lowering of the bed across several cycles can indicate long-term degradation of the channel, which HEC-18 and HEC-20 treat as a component of total scour separate from local and contraction scour.

For each underwater bridge, the bridge file should let a reviewer see, in one place:

- Bed elevations at each pier face and at defined cross-section stations, for every cycle, referenced to a consistent datum or bridge feature.
- Foundation exposure measurements over time.
- Any countermeasures placed, with dates, and their observed condition each cycle.
- Flood events between inspections where known, and any post-flood observations.
- Changes in the ratings for channel, channel protection, scour condition and underwater inspection condition.

Plotting cross-sections from several cycles on one sheet is one of the simplest and most effective review tools. It reveals lateral channel migration toward an abutment, aggradation that may reduce waterway opening, and progressive lowering at a pier. HEC-20 describes stream stability assessment methods that use this kind of history together with aerial imagery and field observations of bank erosion, bars and the planform of the stream.

Trend analysis also informs the inspection interval. Under 650.311, the interval and level of effort are owner decisions within the regulatory limits, and a bridge with a worsening trend is a poor candidate for an extended interval even if its current ratings meet the minimum criteria. Conversely, a long history of stable conditions, documented with consistent soundings, supports a risk-based decision.

Part R — Coordinating with hydraulic engineers

Underwater inspectors observe; hydraulic engineers predict. The scour appraisal for a bridge combines both, and the NBIS definition of scour appraisal uses the least stable result of observed scour and estimated scour. Good coordination means:

- The hydraulic engineer receives the underwater report and reviews observed bed elevations against the calculated scour depths and the foundation elevations.
- The inspector receives the key results of the scour evaluation, such as which piers are most vulnerable and what bed elevations would be of concern, so that field effort can be focused there.
- Changes in the channel, such as a new bar deflecting flow toward a pier, a headcut moving upstream, or bank failure near an abutment, are reported in terms the hydraulic engineer can use, with location and photos.
- Debris accumulation and its effect on flow are described, since debris can increase local scour.

When observed scour exceeds the values used in the scour evaluation, or approaches the foundation in a way not anticipated, the evaluation should be revisited. The POA should identify who is responsible for that review and for any change in scour critical status.

Part S — Post-flood and event-driven inspections

Floods are when scour happens. Many owners' POAs define flood thresholds, often in terms of stream stage, discharge or rainfall, that trigger closure, monitoring, or an inspection after the water recedes. These are typically special or damage inspections under owner procedures rather than the scheduled underwater inspection. The NBIS defines a damage inspection as an unscheduled inspection to assess structural damage resulting from environmental factors or human actions, which can include flood damage.

Practical considerations for post-flood inspections:

- Safety first. High water, fast current and floating debris may make diving unsafe for days or weeks. Sonar from a boat or from the bridge deck, where practical, may provide early information.
- Look above water for indirect evidence: settlement or tilt of piers, misalignment of railings or joints, new cracks, displaced bearings, or approach embankment loss.
- Record the high-water mark and debris lines, which help hydraulic engineers relate the event to design conditions.
- Recognize that refilling may mask the maximum scour depth. Probing may detect loose infill material in a scour hole.
- Follow the POA and notify as required if a critical finding is identified.

Part T — Quality control and quality assurance for underwater work

The NBIS requires owners to maintain documented quality control and quality assurance procedures (650.313(p)). For underwater inspections, QC by the inspecting team and QA by the owner can include:

- Review of the report for completeness against the scope, including all units and all requested levels of effort.
- Checking that ratings follow from the narrative and measurements, and that element quantities are reconciled with the routine inspection.
- Verification of team leader and diver qualifications on file.
- Comparison of soundings with prior cycles and with the scour evaluation.
- Independent review dives or sonar surveys on a sample of bridges, as some owners practice.
- Verification that critical findings were reported and tracked to resolution.

QA findings should be fed back into scopes, training and procedures. Repeated issues, such as missing references or inconsistent ratings, usually point to a procedure gap rather than a single inspector's error.

Part U — Communicating findings to decision makers

Underwater findings often reach managers who will never see the substructure. Communicate them clearly:

- Lead with the consequence: whether the foundation support is adequate, uncertain or compromised.
- Use a simple sketch of the pier, the bed line and the footing or pile tips, with the current and prior bed lines.
- State what is known and unknown, especially for unknown foundations or where visibility limited the inspection.
- Give a prioritized recommendation with a time frame, and link it to the POA actions where applicable.
- Record who was told, when, and what was decided.

Clear communication is part of the inspection. A correct finding that does not lead to the right decision has not protected the public.

Part T2 — Preparing for a review meeting with the dive contractor

A short review meeting after fieldwork and before the final report helps avoid surprises. Useful agenda items include: any critical or urgent findings and the notifications made; units or elements not inspected and why; conditions that limited the work, such as current, visibility or debris; preliminary recommended ratings for the underwater, channel, channel protection and scour items; comparison of soundings with the previous cycle; whether sonar data revealed areas needing tactile follow-up; and the schedule for the draft report. Ask the team leader to walk through representative photos or video and sketches for each unit. Capture decisions in meeting notes and put them in the bridge file. For the owner, this meeting is also a chance to check that the scope was understood, that the requested level of effort was delivered, and that the contractor has the

information needed from prior reports. For the contractor, it is a chance to raise concerns about access, safety or scope that should be fixed before the next cycle. Over several cycles, these meetings build a shared understanding of each bridge that no single report can capture, and they are an inexpensive part of the quality program that the NBIS requires owners to document.

Part V — Additional worked examples

Example 7 — Extended interval request

A program manager asks whether a two-pier concrete bridge in a stable channel can move from a 60-month to a 72-month underwater interval. The last report codes underwater inspection condition 7, channel 7, channel protection 6, and scour condition 7, and the scour vulnerability is not yet assessed. *Discussion:* Under 650.311(b), the extended interval requires the applicable items coded 6 or greater and the scour vulnerability coded in the stable categories, plus a documented owner policy and FHWA notification. The missing scour vulnerability assessment means the bridge does not yet qualify. Recommend completing the assessment and reviewing the trend history before any change.

Example 8 — Reduced interval triggered

A new report codes channel protection 3 because riprap around a pier has been largely displaced. *Discussion:* A channel protection item of 3 or less triggers the 24-month underwater interval under 650.311(b), unless the owner uses a localized special inspection per its procedures where allowed. Update the schedule, review the POA, and program countermeasure repair. Confirm the scour condition coding is consistent with the observed bed.

Example 9 — Inconsistent reports

The routine inspection six months ago coded the substructure 6 based on above-water observations. The new underwater report documents significant section loss on several piles below water and recommends substructure 4. *Discussion:* The substructure rating should reflect the whole component, including underwater portions. Reconcile the ratings and element data in the bridge file, refer the section loss to the load rater, and check whether the change warrants re-rating within the regulatory time frame.

Example 10 — Low water opportunity

During a drought, a normally submerged pier footing is exposed and can be inspected by wading. *Discussion:* This is an opportunity to inspect and photograph the footing and bed directly and to probe beneath its edges. Document it as a special inspection per owner procedures, compare with prior underwater findings, and record bed elevations to the standard reference. It does not automatically replace the scheduled underwater inspection; follow the owner's policy on whether it satisfies the requirement.

Part W — Key takeaways

Underwater inspection protects bridges from the hazard most likely to cause sudden failure over water: loss of foundation support. The engineer's role is to define the right scope, make sure qualified teams perform it safely, read the report critically, compare it with history and the scour evaluation, and turn findings into ratings, intervals, POA actions, load ratings and repairs. The rules in 23 CFR 650 set the minimum: who may dive, how often, and when findings must be escalated. Remember too that much of the most important evidence is indirect: a sounding compared with an older one, a probe that slides under a footing, or a tilt seen from the deck. Treat each of these signals seriously, record it precisely, and make sure it reaches the people who can act on it. A careful record made today is what allows the next inspector, and the next engineer, to

recognize change before it becomes failure. Good practice goes further by keeping consistent references, plotting trends, coordinating with hydraulic engineers and communicating clearly to decision makers.

Key takeaways

- Underwater: first inspection within 12 months; 24/60/72-month intervals.
- Level I swim-by, Level II cleaned areas, Level III detailed/NDE.
- Divers need FHWA-approved underwater training.
- Compare soundings and scour to plan-of-action thresholds.

References

1. FHWA, Underwater Bridge Inspection, FHWA-NHI-10-027, 2010
2. 23 CFR Part 650, Subpart C — National Bridge Inspection Standards (final rule published May 6, 2022)
3. FHWA, Bridge Inspector's Reference Manual (BIRM), FHWA-NHI-12-049, 2012 (as revised)
4. FHWA, Specifications for the National Bridge Inventory (SNBI), FHWA-HIF-22-017, March 2022
5. AASHTO, Manual for Bridge Element Inspection, 2nd Edition, 2019
6. FHWA, HEC-18 Evaluating Scour at Bridges, 5th Edition, FHWA-HIF-12-003, 2012
7. FHWA, HEC-20 Stream Stability at Highway Structures, 4th Edition, FHWA-HIF-12-004, 2012
8. FHWA, HEC-23 Bridge Scour and Stream Instability Countermeasures, 3rd Edition, FHWA-NHI-09-111 and -112, 2009
9. AASHTO, The Manual for Bridge Evaluation, 3rd Edition, 2018 (with interim revisions)

Study text only; the final quiz is taken online. Verify all references against the edition your agency has adopted.