5.4 Underwater Inspection Procedures

Underwater inspections supplement above-water inspections, focusing on substructure bridge elements and channel conditions that cannot be visually inspected during routine inspections because of excessive water depths or turbidity. The Underwater Investigation Program performs underwater inspections when site conditions preclude a wade and probe inspection during the routine inspection by the ABME/Inspector.

Underwater inspections are performed primarily by an in-house dive team consisting of engineers and engineering technicians. A qualified NBIS Team Leader shall be present during all Underwater Inspections. All Bridge divers shall meet the requirements of the NBIS section 650.309 (d). All specialty underwater inspections, final review and approval of underwater inspection reports are under the supervision of the Underwater Inspection Program Manager.

Inspection planning, report writing (documentation), inventory management as well as other procedures related to the underwater inspection program are found in other sections of this manual devoted to those topics. Caltrans recognizes the ***FHWA publication FHWA-NHI-10-027, Underwater Bridge Inspection (June 2010)*** as the industry standard for procedures related to underwater inspection of bridges. These underwater inspection procedures follow guidance presented in the FHWA publication.

Underwater Inspection Plans

The underwater inspection plan provides a summary of information related to inspection scope, access, staffing requirements, special tools required, structure specific contacts, previous inspection text, scour determinations and general structure information. The requirements for UWI plans are detailed in ***Section 4.4 – Preparation for Underwater Inspections*** of this manual.

The information presented in the underwater inspection plan, along with the group bridge list, vicinity map, structure plans and layout sheets for each pier shall be reviewed by the inspection team as part of the inspection planning process.

Underwater Inspection Intensity Levels

The designations of standard levels of inspection originated in the U.S. Navy and offshore diving industry and have been adopted for bridge inspections. The three diving inspection intensity levels are defined below:

Level I

Visual or tactile inspection of underwater components without the removal of marine growth.

A Level I inspection consists of a "swim-by" within arm's length of the total exterior surface of each underwater element. It must be detailed enough to detect obvious major damage, deterioration, scour and undermining. A Level I inspection provides a general overview of the substructure condition and verification of the as-built drawings. The Level I inspection can also indicate the need, extent, and location for Level II or III inspections.

When visibility is limited or zero, the diver will perform a tactile Level I inspection by "feeling" for damage.

Level II

Visual or tactile inspection of a clean representative sample, a minimum of 10% of all components.

Level II inspection is a visual or tactile examination of sufficient detail to identify damage and deterioration including but not limited to abrasion/wear, cracks, delaminations, spalls, voids, exposed reinforcing steel, rock pockets, section loss, checks and rot. When necessary, portions of the structure are cleaned of marine growth. A Level II inspection is performed on at least 10% of all underwater elements.

In some cases, especially large structures in coastal environments, cleaning is time consuming, difficult work, and should be performed by contract divers prior to a bridge inspection.

Most bridges over inland fresh waterways are relatively free of marine growth and require little extra effort from the diver other than some light wiping or scraping. In these cases, the Level II inspection usually covers substantially more than 10% of the substructure elements.

Level III

Nondestructive testing (NDT) or partially destructive testing (PDT) of a representative sample of all components. May consist of PDT of timber and remaining thickness of steel components.

A Level III inspection is a highly detailed inspection of a critical structural element to help identify a member that may need extensive repairs or replacement. The purpose of a Level III inspection is to detect hidden or interior damage and determine the remaining cross-sectional area. This type of inspection includes extensive cleaning, detailed measurements, and selected nondestructive and partially destructive testing techniques such as ultrasonic, sample coring or boring, physical material sampling, and hardness testing. Testing locations may be limited to a localized area of deterioration or random locations to establish measurement baselines.

Underwater Inspections for Bridge Scour

There are two main objectives for an underwater inspection with respect to scour:

- To accurately record the present condition of the substructure and channel.
- To identify conditions indicative of potential problems with scour and stream stability for further review and evaluation by others.

During an underwater inspection, the diver reports bottom conditions such as local scour or the presence of debris adjacent to the submerged foundation elements to the inspection team leader. The diver also reports the type of bottom material, the presence, location, and size of rip-rap, exposure and undermining of footings. The quantity and condition of exposed piles under a footing is reported when there is enough space for a diver to maneuver safely.

Inspection Scope

The underwater team typically performs an underwater inspection on all substructure elements that are at, under, or immediately above the waterline at the time of the inspection as noted in the UWI plan.

Upon request by the ABME and approval by the UWI program manager, the underwater inspection may also include elements which cannot be evaluated during the routine inspection from the shore or other access methods such as kayak, float tube, boat, UBIT, or catwalks. Such inspections by the UWI Team are limited to elements that can reasonably be inspected by the diver from the water or the inspection team from the dive setup location. Due to the need for partially destructive testing, the ELI condition states for timber elements that are not within arm's reach are not determined during the underwater inspection. These elements must be inspected by the ABME using another access method.

The underwater inspection team leader ensures the scope of inspection listed in the UWI plan is followed. Supports listed in the UWI plan that are in the dry should be inspected unless the routine report specifically notes that the support was inspected during that inspection.

Appropriate action will be taken when obvious major damage or deterioration is noted for elements that are not designated in the UWI plan but are plainly visible to the underwater team during the UWI.

The inspection team leader shall record inspection notes indicating:

- The supports in the water that were inspected.
- The maximum water depth at each support.
- The limits of the inspection when an entire element was not inspected.
- The submerged elements that were not inspected and the reason why.
- The portions of slope protection and other non-submerged portions of the structure such as the soffit, girders, etc. that were inspected.

5.4.1 Field Documentation

The following defines what is required for proper documentation of distress observed during all underwater inspections:

For all Damage/Deterioration

- The locations and limits of all damage or deterioration.
- Any signs of distress in adjacent elements or members.
- Photos or video, when conditions allow. Otherwise, detailed sketches of the location, shape, and size of deficiencies.
- When significant adverse conditions such as damage, advanced deterioration, section loss, significant increases in dead load, extensive scour, or element defects in Condition State 4 are discovered during a bridge inspection, which affect the primary load path elements, follow the procedures of ***Section 7.9 – Load Rating Responsibilities*** to contact the load ratings branch.
- When critical structural or safety-related deficiencies are found, follow the procedures of ***Section 5.8 – Critical Finding Procedures***.

Concrete Deterioration

- The location of the beginning and end of cracks and intermediate points as needed to define patterns.
- The maximum crack width and penetration depth.
- The height, width, and penetration of spalls or voids, including the number, size, exposed length and approximate section loss or other condition of any reinforcing steel.
- Note the degree of abrasion/wear on concrete.
- The location, height and width of delaminated areas.

Steel Members

- Routine Level III steel thickness testing (locations and results).
- The location and limits of any buckling, bulges, cracks and significant loss of section in steel members.
- The measurement and detailing of remaining member section, when significant corrosion is present.
- The locations and approximate quantities of areas with suspected microbial induced corrosion (MIC).
- Thickness measurements comparing MIC and non-MIC section loss.

- Note damage at connections.
- Paint or other coating condition as appropriate.

Timber Members

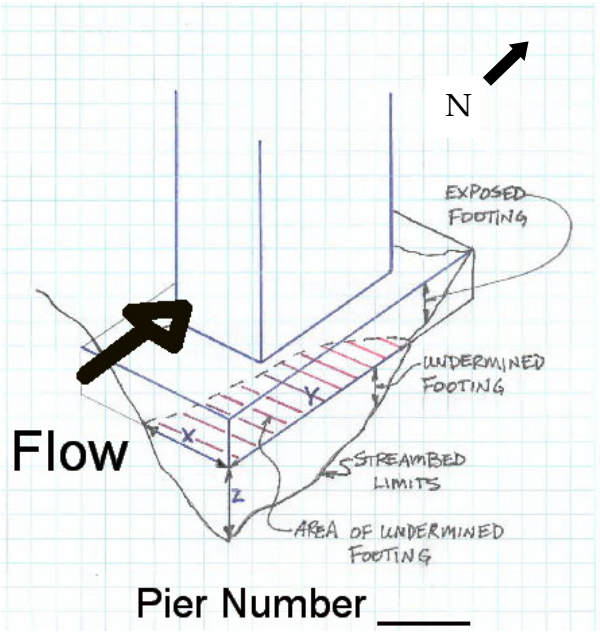
- The location and results of Level III timber auger testing.
- The field measured diameter of timber piles selected for Level II or Level III inspection.
- The extent, width and penetration of checks, and any rot.
- The measurement and detailing of remaining section, when significant element decay is present.

Column and Pile Exposure and Footing Undermining

- Measurements to determine the unbraced length of columns and piles when scour has occurred.
- Measurements and sketches documenting exposed and undermined footings.

All undermining descriptions shall note the length along the footing "Y", the vertical dimension "Z" from the bottom of the footing to the channel, and the horizontal distance "X" under the footing. An approximate undermined area should be sketched in the field.

Refer to the sketch below for an example.



Span_____

5.4.2 Underwater Inspection Procedures

The inspection team will perform an inspection following these procedures and the Underwater Inspection intensity levels outlined in the beginning of this section. Where appropriate, elements will be evaluated in accordance with the ***Caltrans Bridge Element Inspection Manual***.

Level I - Inspection Procedures

The diver will perform a 100% Level I inspection on all submerged bridge and culvert elements to confirm the integrity and continuity of all substructure elements and determine the limits of scour, footing exposure and undermining.

Divers shall follow inspection patterns established from well-defined reference points. Typical inspection patterns include:

- Circular or semicircular horizontal sweeps around piers or abutments beginning at the base, moving up a specified increment, and repeating until finished.
- Down one side and up the other for piles (or inspecting in a spiral pattern).
- For deep columns descend to deepest depth, sweep as ascending.

The diver typically performs a tactile inspection using sweeping motions of the divers' hands and arms to cover the entire submerged structure when visibility is limited.

The paint condition of any substructure elements within the scope of inspection is noted when appropriate. This includes substructure components immediately above the water surface elevation and any below the water surface. Photos should be taken of all areas experiencing paint deterioration when conditions allow.

Level II - Inspection Procedures

The diver will perform a Level II inspection on a minimum of 10% of the substructure elements.

When cleaning with tools is required to perform the Level II inspection, the inspection team leader will select a minimum of 10% of the substructure elements for the Level II inspection. The elements selected should typically rotate from inspection to inspection and shall be specifically noted in the UWI report.

On structures covered in light marine growth that can be wiped easily with the divers' hand, significantly more than 10% of the substructure elements will be inspected and it is not necessary to either select specific elements for the Level II inspection or note all Level II inspection locations in the report. Marine growth coverage that meets this requirement is typically noted in the last UWI text and shall be verified by the diver and relayed to the underwater inspection team leader at the beginning of the dive.

Cleaning for Level II investigations will meet or exceed these following standard procedures outlined by FHWA guidelines:

- For all structures, cleaning levels are near the low waterline, near the mud line, and midway between these levels.
- For columns and piles, a 6 to 12 inch high band is cleaned at each level. The cleaning includes at least three sides of a rectangular pile, six sides of an octagonal pile and at least three fourths of the perimeter of a round pile. On an H-pile, a minimum of both outside faces of the flanges, one inside face of a flange and one side of the web is cleaned. Columns and piles greater than 24 inches in diameter may follow guidelines for large solid faced elements below.
- On large solid faced elements such as piers, abutments, and columns and piles greater than 24 inches in diameter, a minimum 1-foot by 1-foot area is cleaned at each level on each exposed face. Cleaning locations will be spaced approximately 50 feet apart for faces longer than 50 feet.

Level III - Inspection Procedures

The inspection team leader will direct the diver to perform a Level III inspection when a particular condition is suspected in advance or when the results of a Level I or II inspection indicate the need.

The two most common Level III inspection techniques performed on bridges are soundness checks of timber elements using an auger, and ultrasonic testing of steel elements to measure remaining section.

The initial sample for these Level III inspections is one set of borings or set of section loss measurements on the 10% of the elements selected for a Level II inspection. For structures with light marine growth where specific elements were not identified for a Level II inspection, the inspection team leader will select 10% of the elements for the Level III inspection based on structural significance and access. Typically, the worst areas of deterioration are found near the low water line or within the tidal zone and these areas are always sampled for section loss. When deterioration is noted in other areas, then these areas are sampled as well.

The basic Level III inspection for timber columns or piles consists of one auger boring at each level tested (three bores per element) for all elements sampled.

The basic Level III inspection for steel elements consists of one set of thickness measurements for each level tested for all elements sampled. A set of thickness measurements is defined as follows: On round members, a minimum of two measurements are taken; and on H-piles, one measurement is taken on each flange and one on the web, except as noted below.

When deterioration or section loss is found; sufficient measurements to determine the remaining section of the member are required and will vary based on the shape of the member and level of deterioration. Based on the results of the initial 10% sample, the

inspection team leader may expand testing to other elements in order to gather enough data to determine the capacity of the structure.

Basic Scour Inspection Procedures

A basic scour inspection is performed as part of all underwater inspections. This inspection records the condition of the bridge and channel and identifies conditions indicative of potential problems with scour and stream stability for further review and evaluation by the SM&I State or Local Hydraulics Branches.

The Underwater Inspection Team Leader will ensure the following is performed for all scour inspections and the findings included in the field inspection notes:

- A review of as-built plans for foundation details and scour countermeasures.
- A review of documentation of the current NBI scour critical code (Item 113). Determine and record the date of the evaluation that determined the 113 coding.
- A review of the Scour Plan of Action (POA) for scour critical and unknown foundation bridges. Determine if any actions were specified for an underwater inspection, review any critical elevations.
- A comparison of existing conditions at the bridge and the current Item 113 coding, noting any inconsistencies.
- All submerged footings and pile caps are inspected for exposure and undermining, quantifying any found.
- At foundations where loose sediment is present, the bottom material is probed to estimate the depth of any area subject to infill or to check for footings which may be covered with a thin layer of sediment.
- An evaluation of NBI channel and channel protection (Item 61), and Element Level Inspection scour defects of underwater designated elements.
- Channel section measurements in the bridge area are measured and typically consist of depth measurements (by diver's pneumofathometer) to mudline or channel liner at each support. For use by others performing scour evaluations or if there is a need to generate a channel cross section, a fixed point on the structure is referenced by one of the following typical methods:

    1. One reference measurement from the water surface to a known point on the bridge shall be recorded and included in the text of the BIR. When the water surface elevation fluctuates significantly over the course of the inspection, more than one reference measurement to the structure is taken.
    2. Measurements from the bridge deck to the water surface and channel bottom, when traffic allows. The channel cross section, included with the pre-inspection report, can be used as a template using the same measurement locations and elevation references for the new measurements.

- Gather sufficient information to compare the current conditions to past channel cross sections for scour critical and unknown foundation bridges.

After the Inspection:

- For scour critical and unknown foundation bridges, a comparison of the current channel cross section measurements to past measurements is to be performed for each inspection. Document the results in the "Waterway" section of the inspection report and notify the SM&I State or Local Hydraulics Branches via a work request of any concerns.
- A determination of the amount of footing cover for all the submerged supports. (When sufficient information is available on as-built plans.)
- For bridges which are not scour critical and do not have an unknown foundation, a review of the depth sounding information gathered during the inspection. Any significant changes that may affect the foundations are submitted to the SM&I State or Local Hydraulics branches via a work request.

Underwater Inspection Team Leader and Diver Responsibilities

The *Team Leader* will ensure that the following information is captured during the inspection and reported in the inspection report:

- All relevant inspection information reported by the diver.
- A profile photo from the water (for boat access bridges) of each distinct substructure support configuration appropriately labeled.
- Locations of Level II inspection when cleaning with tools is required.
- Tools used for the inspection such as drill, scrapers, ultrasonic testing etc.
- A measurement from the water surface to a fixed reference point on the bridge.
- Any noticeable adverse conditions when heavy vehicles traverse the bridge, such as noticeable deflection.
- The Team Leader is also responsible for taking the appropriate action in the event of significant damage, such as posting or closing a bridge and submitting a ***Record of Critical Finding***.
- Obvious out of plumb conditions for primary elements.

Prior to the diver entering the water for the inspection, the Underwater Inspection Team Leader should brief the diver and dive crew on the following:

- The structure layout.
- Numbering convention.
- Previously noted defects or scour conditions.

- Outstanding work recommendations within the scope of inspection.
- Locations for Level II inspections.
- Other structurally significant underwater elements/conditions.

The Diver will systematically report the following information for each support location to the team leader during the inspection:

- Any damage, deterioration or scour observed.
- Water velocity and visibility.
- Marine growth conditions, including suspected microbial induced corrosion; thickness and percent coverage, cleaning requirements.
- Channel material classification and consistency at each support.
- Water depths at supports.
- Condition and limits of slope/scour protection.
- A rough quantification of drift (floating) and debris (sunken) material that has been lodged against the upstream face or edge of supports or deposited from construction activities.
- The condition of previous repairs or rehabilitation.
- A determination if outstanding work recommendations have been completed.
- Any displacements of primary elements.

5.4.3 Special Inspection Procedures

Inspection of Superstructure Elements

When an inspection of the superstructure is performed, the team leader shall assess and record the condition, including the numbers, quantities and defects of the elements, of the superstructure and the soffit of the deck in each span and bay, where applicable. Photos are required of typical cracks and all damage/deterioration consistent with procedures outlined in ***Section 7.5 – Inspection Photographs***.

Underwater Inspection of Posted Bridges

The underwater inspection team leader shall review bridge records to determine if an underwater inspection is being performed on a posted bridge. When the controlling member is within the scope of the underwater inspection, the posting calculations shall be reviewed to determine the level of inspection required to verify any changes to bridge elements that may affect the load capacity. For all inspections of posted bridges, the bridge site shall be inspected for the presence of the posting signs. The signs shall be photographed and included with the bridge inspection report.

Missing posting signs constitute a critical finding and the procedures of *Section 5.8 – Critical Finding Procedures* shall be followed.

Inspection of Protection Devices

The inspection of the above water portion of bridge protective devices such as fenders and dolphins is the responsibility of the ABME/Inspector during routine inspections. During the UWI, portions of protection devices that are at or above the waterline are visually inspected for obvious deterioration and damage that may have occurred since the last routine inspection. The UWI team will perform an UWI of protection devices when condition found during the routine inspection warrant further investigation and a work request is submitted to the UWI program.

Channel and Waterway Inspection

The underwater inspection team shall inspect the waterway in the area immediately adjacent to the structure noting items such as:

- High water that has reached the superstructure.
- Flow that is potentially misaligned with the supports at high flows.
- Serious bank erosion that may threaten the abutments or approach roadways.
- Large depressed areas under the bridge.

Any of these conditions found that differ from previous inspections or have not been submitted to the SM&I State or Local Hydraulics Branches for evaluation shall be documented with photographs and referred to the hydraulics branches for evaluation via a SM&I work request. The work request shall be documented in the bridge inspection report.

Wade and Probe Inspections

Wade and probe underwater inspections are either performed by the ABME/Inspector as part of the routine inspection or by the UWI Team as part of a specialty investigation. See *Section 4.4.1- Responsibility for UW Inspections* for the criteria that determines responsibility of the inspection. The procedures outlined below shall be followed for all wade and probe inspections unless conditions exist that require a detailed underwater inspection plan.

Wade and probe inspections shall be limited to bridges with conditions that allow the inspector to determine with certainty that no scour or structural problems exist. Experience over many inspection cycles has shown that the majority of all defects for elements in water are at or above the low water mark and the portion of the element above the water level usually controls the element condition state. For this reason element condition states can be reasonably determined by the combination of a tactile probing inspection below the water surface and a visual/tactile inspection of elements in the vicinity of the water surface and above. Inspection of elements above the water surface follows routine inspection procedures.

When necessary, ABMEs/Inspectors follow ***Section 10.5 – Adding/Removing Structures in the Special Inspection Inventory*** to request the addition or removal of bridges or elements within a bridge to/from the UWI Inventory.

The following procedures shall be followed for all wade and probe inspections:

- Continuity of 100% of all elements shall be confirmed.
- The current water depth and extent of element exposure at all supports identified for a wade and probe inspection are recorded and compared to past conditions to determine if any scour conditions are present or have progressed. The extent of the exposure of columns, piles and footings shall be recorded as noted in ***Section 5.4.1***.
- When marine growth or crusted sediment hinders the inspection, a minimum of 10% of all elements shall be cleaned and inspected in the vicinity of the waterline.
- When section loss of steel members is confirmed visually or tactilely, the remaining section of the member shall be measured in the areas suspected of section loss on a minimum of 10% of the elements. The results shall be compared to as-built conditions if known and monitored during future inspections.
- The perimeter of footings or pile caps shall be probed for areas of vertical and horizontal undermining. The amount of undermining shall be estimated by probing and recorded.
- For bridges with spread footings, the limits of any horizontal undermining must be able to be determined with certainty by probing. If this cannot be accomplished, an Underwater Inspection using another mode such as surface supplied diving is required.
- For bridges with exposed piles under a pile cap, the condition of exposed piles under the pile cap must be ascertained by visual/tactile method or another inspection mode such as surface supplied diving is required.
- For bridges with submerged column to pile splices, the splice must be tactically inspected by hand.
- When drift or debris hinders a wade and probe inspection, the inspector shall take the necessary channel bed measurements surrounding the debris and review structure plans to determine if additional inspection effort is required. The bridge owner shall be notified to remove the material with the urgency that is appropriate for the situation.

5.4.4 Documenting the Inspection

All inspection reports shall use standard inspection commentary in accordance with ***Section 7.2 – Bridge Inspection Report Narrative*** of the SM&I Inspection Procedures Manual.

The inspection team leader shall record notes following standard bridge component numbering nomenclature using standard underwater inspection reporting nomenclature and abbreviations. For all elements within the scope of inspection, the inspection team leader shall verify that the total element quantity and description are correct and quantify the dimensions and locations of any defects, damage, or deterioration resulting in Condition States 2, 3 or 4.

For all elements within the scope of inspection, the inspection team leader is responsible for new work recommendations or marking existing work recommendations complete when appropriate.