MOTT MACDONALD

Key Allegro Preliminary Bulkhead Repair Engineering Analysis

Technical Memorandum

October 17, 2017

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Contents

Executive summary

The purpose of this document is to detail the findings of Mott Macdonald's assessment of the bulkheads within Key Allegro as well as to provide guidance for homeowners to aid in the selection of repair options. This document categorizes and ranks typical bulkhead conditions and failure modes observed throughout Key Allegro canals and presents potential alternatives to homeowners for repair of deteriorated and/or failing bulkheads.

This document is for preliminary planning purpose only and shall not be used for construction. Each damaged bulkhead section needs to be evaluated on its own merit, one size might not fit all given that the failure/damage along each bulkhead varies. Also, some field exploration work such as diving or excavation is likely needed to assess the extent of the damage on some of the areas prior to disturbing the site to install any repair solutions.

Preliminary repair alternatives have been identified for repair of the various bulkheads depending on their mode of failure, and preliminary cost estimates are included in this document. A preliminary design for repair of the storm water outfalls through bulkheads, where applicable, has also been provided in this document. Repairs or replacement will need to be performed based on structural performance criteria developed in coordination with the KACOPA to define loading demands on the bulkheads instead of repairing or replacing in kind without an understanding of the loading demand for the site, both from existing structures (decks, docks, homes, etc.) and from the site (tides, surge, relative sea level rise, etc.).

Finally, a flow chart has been provided to aid homeowners in identifying whether repair is necessary and which repair alternative is preferred for their bulkheads.

1 Introduction

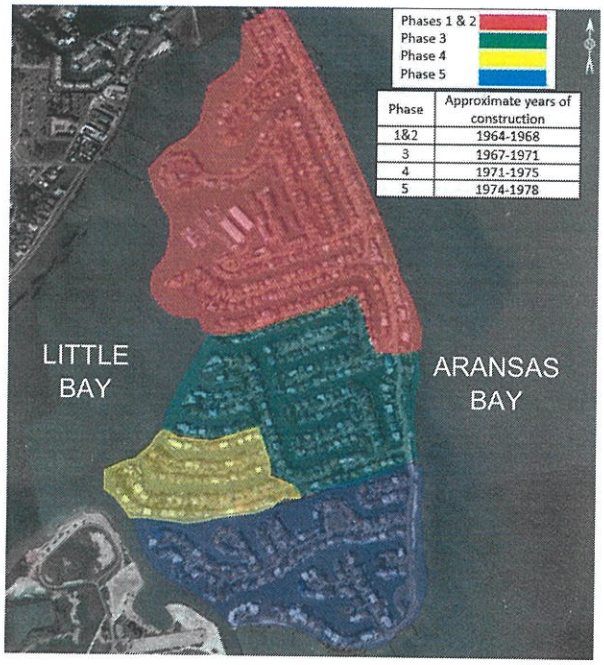
The Key Allegro Canal Property Owners Association (KACPOA) has requested that Mott MacDonald evaluate the condition of bulkheads throughout Key Allegro and develop preliminary alternatives for their repair. This document summarizes the results of the assessment and provides preliminary alternatives for repairs of bulkheads throughout Key Allegro. In addition, Mott MacDonald has developed a general flow diagram to aid homeowners in the selection of a suitable repair alternative. The information presented herein is for planning purposes only and shall not be used as a final solution and construction of bulkhead repairs.

1.1 Project Background

Key Allegro is a coastal community located on a triangular peninsula in Aransas Bay between Rockport and Fulton, Texas (Figure 1).

Figure 1: Project Location

The community is comprised of a series of canals and waterfront properties approximately constructed between 1962 – 1978. Construction work included dredging of the canals, filling adjacent lots with dredged material to raise their elevation, and installing concrete bulkheads to protect against erosion. Construction of the community occurred from North to South over a series of five phases with each phase taking approximately 3-4 years to construct. Figure 2 depicts the project location and approximate outline of the five phases (Key Allegro Canal and Property Owner's Association, 2016).



Phase	Approximate years of construction
1&2	1964-1968
3	1967-1971
4	1971-1975
5	1974-1978

Figure 2: Depiction of Key Allegro Construction Phases

The KACPOA bylaws require that all bulkheads maintain a minimum freeboard of 1 ft above MSL, but a higher design elevation may be preferred to protect property from the effects of storm surge and relative sea level rise. Regional and local land subsidence over the past 50 years has caused the existing concrete bulkheads to subside to an elevation below this requirement. The recent passing of Hurricane Harvey has caused widespread damage to Key Allegro, which may also include damage to the aging bulkheads. Per KACOPA requirements, it is the responsibility of the homeowners to maintain and repair the bulkheads on their property which do not meet the KACPOA freeboard requirement.

2 Bulkhead Condition Assessment

2.1 Review

A visual review of the current state of Key Allegro bulkheads took place during a site visit by Mott MacDonald on August 10, 2017. The review, conducted by land and by boat as shown in Figure 3, primarily focused on bulkheads constructed during phases 1-3, the oldest bulkheads in Key Allegro. Storm water outlet penetrations through aging and failed bulkheads present additional difficulties for bulkhead repairs around Key Allegro. Several storm water outlet locations were inspected and will be included in the repair alternatives.

Figure 3: Reviewed bulkheads

The results of this assessment are presented in the Memorandum of Project Understanding submitted previously.

2.2 Observed Failure Modes

The failures discussed herein are representative of the conditions observed throughout Key Allegro. Many of the bulkheads within Key Allegro exhibit a combination of different failure types. Bulkheads exhibiting any of these types of failure will need to be repaired or replaced as described in this report. The following modes of failure have been observed throughout Key Allegro.

2.2.1 Cap Deterioration

As the concrete cap reaches the end of its design life; loss of strength in the concrete and/or reinforcement corrosion causes the cap to crack. Minor cracks should be monitored frequently while major cracks may require repair or replacement of the caps. The cap in Figure 4 is severely cracked and the enclosed reinforcing (steel rebar) has been exposed and begun to corrode. Due to the extent of damage to this cap, it should be replaced. The bulkhead has also begun to subside at this location which will require additional repairs.

Figure 4: Deteriorating bulkhead cap

2.2.2 Tie-back Failure

Due to the age of the bulkheads, tie-back failure should be expected. A tie-back is a horizontal rod typically secured to the bulkhead on one end and concrete anchor (deadman) driven into the ground on the other end. The tie-backs in Figure 5 have been severely corroded due to their age and exposure to a corrosive environment. Tie backs have also been cut in some locations by property owners to allow installation of other structures such as swimming pools. Once tie-back failure is severe or tie-backs are cut the bulkhead will begin to lean forward as shown. Tie backs shall be inspected prior to undertaking a repair of the bulkhead as failure of these will result in failure of the entire structure. Due to the advanced age of the bulkheads and tie-backs, Mott MacDonald recommends all tie backs be replaced during bulkhead repair.

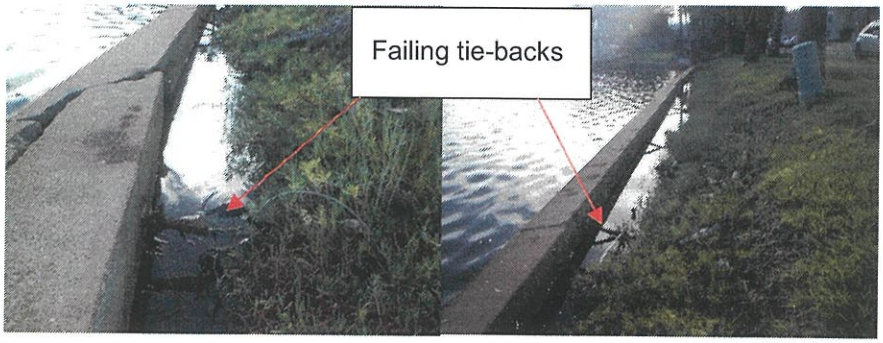


Figure 5: Exposed tie-backs showing failure

2.2.3 Bulkhead and Cap Subsidence

Several bulkheads throughout Key Allegro have subsided below +1' MSL, and in some locations the top of the cap has become partially submerged. This subsidence exposes the bulkhead to overtopping which can erode that land behind the structure, corrode the wall anchor tie backs, and lead to total failure of the structure and loss of land behind the bulkhead.

Figure 6: Examples of subsided bulkheads with limited freeboard

2.3 Repair Considerations

Mott MacDonald observed several factors which may exacerbate the degree of structural failures and complicate repairs that must be considered by the homeowners. The following items will require extra attention by homeowners and may result in increased repair costs for the failed bulkheads.

2.3.1 Structures over bulkheads

In several locations, homeowners have built structures over existing bulkheads. Small structures such as decks and docks should have a limited impact on the bulkhead, but may need to be temporarily removed in order to access the bulkhead for repair. Such a structure is shown in Figure 7.

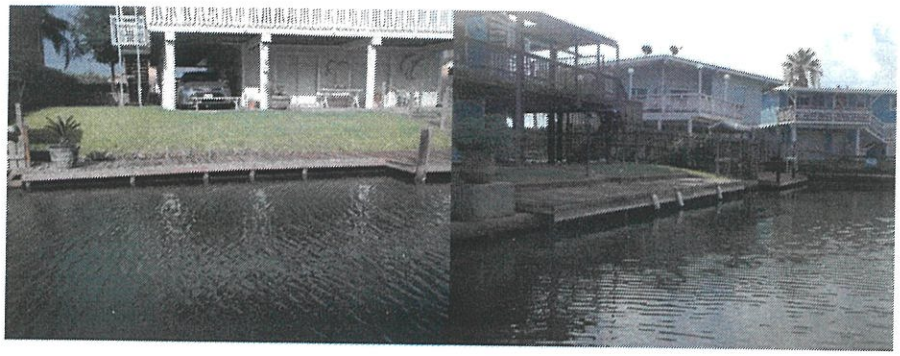


Figure 7: Decking constructed over existing concrete bulkhead

In some locations, concrete slabs and other structures of significance have been built on top of the bulkheads by homeowners to address the subsidence of the existing wall and provide additional freeboard to the structure. This should be avoided as, although they temporarily increase the cap elevation above the KACOPA minimum requirement, the structures create additional surcharge loads which the bulkhead was not designed to support, or may not presently have the structural capacity to support. Combined with an aging bulkhead, these structures are more likely to accelerate the failure of the bulkhead over time if the necessary repairs are not performed and designed to support the additional load prior to building of the structures. Owners should ensure that their bulkhead is in good condition and of adequate structural capacity to withstand the additional load prior to building directly over or adjacent to their bulkheads.

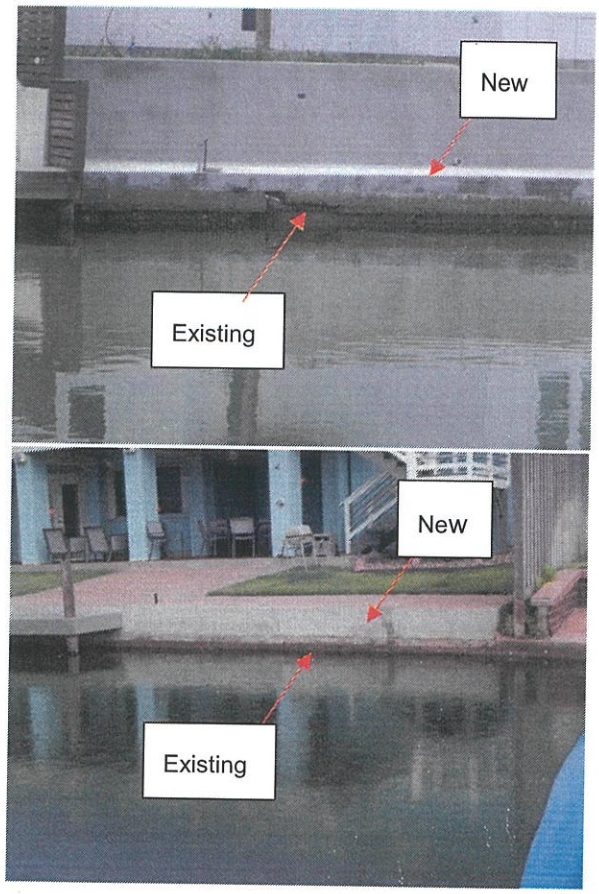


Figure 8: Concrete platforms constructed on top of existing bulkhead

Such structures also complicate the inevitable repair of the bulkheads as they may need to be removed in order to access the failing tie-back anchors, concrete caps, and sheet pile. In addition, if such structures are to remain or are to be constructed, the bulkhead repair shall be of sufficient capacity to withstand the additional load from the structures. Alternative options for tie-back installation may be necessary in locations where structures have been constructed where normal tie-backs and anchors would need to be installed. Anchor tie-back options such as helical anchors, grouted anchors, and tie-backs may be preferred in these locations to avoid impacting existing structures.

2.3.2 Previous Repair Efforts

Some homeowners throughout Key Allegro have already taken steps to repair failing bulkheads. These have ranged from installing vinyl sheet piles in front of the bulkheads, installing timber piles to shore up the failing bulkheads, and placing concrete bags over the subsided bulkhead to increase the freeboard of the structure. Such repairs need to be considered when assessing the bulkheads. The most effective repairs are those that stabilize the existing bulkhead while meeting the repair criteria specified by the KACPOA.

Repairs that do not address the displacement of the bulkhead due to anchor tie-back failure and subsidence should be considered as a temporary solution and will need to be replaced frequently as the structure continues to shift.

Installation of sheet pile behind the existing bulkheads is not recommended as tie-backs on the existing bulkhead will need to be removed to complete this process. Although this process removes all load on the existing bulkhead, the existing bulkhead is no longer anchored and is likely to fall into the adjacent canal as the structure deteriorates, this failure could occur in a catastrophic manner (suddenly) depending on the condition of structure and exposure to unforeseen or excessive loads.

Existing repairs will also affect future repairs as the previously installed repairs may need to be removed or may have damaged the existing bulkhead to a point where it will need to be replaced. These previous repairs may increase the cost of future repairs as more effort may be required to remove or repair the existing bulkheads.

2.3.3 Storm Drain Outfall

Several sections of bulkhead throughout Key Allegro have an outfall through the wall with allows storm water to drain into the canal. These drains are critical for Key Allegro as they allow excess rain to drain from roads during storm events. In some locations, these outfalls have been damaged due to shifting of the bulkheads. One outfall observed had previously failed, allowing material behind the bulkhead to flow out of the structure and into the canal. Due to the age of the structures it is likely that several of the outfalls throughout Key Allegro have failed in a comparable manner. Homeowners can identify damaged storm water outfalls by the formation of sinkholes behind the bulkhead at the storm water drain location. When repairing the bulkheads, the design must incorporate these outfalls where necessary to ensure proper storm drainage in Key Allegro.

2.3.4 Construction Access

Due to the limited access within property lots for heavy equipment, most repair work will likely need to be performed from the water using barge mounted equipment. Working from a barge limits disturbance to the upland property but may be costlier. The barges may also restrict traffic within the canal adjacent to where the work is taking place. Homeowners shall also coordinate with the KACPOA during construction to avoid any interference to navigation within the Key Allegro Canals from heavy marine equipment.

Close to 50% of homes in Key Allegro have been damaged by hurricane Harvey and may be demolished or not permitted for reconstruction under current building codes. Prior to reconstruction of a home, homeowners should consider replacing or repairing failed bulkheads and deadman tiebacks, as open lots will allow contractors to access the bulkheads by land; significantly decreasing construction costs for the bulkhead work.

3 Bulkhead Repair Alternatives

3.1 Introduction

The repair alternatives discussed in this section are preliminary based on observations of the project site. Final repair options should be evaluated on a case by case basis to determine the appropriate repair solution required. Repairs or replacement will need to be performed based on structural performance criteria developed in coordination with the KACOPA to define loading demands on the bulkheads instead of repairing or replacing in kind without an understanding of the loading demand for the site both from existing structures (decks, docks, homes, etc.) and from the site (tides, surge, relative sea level rise, etc.).

In order to facilitate construction and potentially reduce cost, it is recommended that homeowners with adjacent bulkheads coordinate their repair efforts to avoid any issues tying in the repairs to adjacent bulkheads. Also, constructing repairs throughout several properties is more cost effective as construction costs per linear foot decrease for longer sections of bulkhead.

3.2 Repair Criteria

As mentioned previously, bulkheads with a cap elevation below +1' MSL must be repaired. Repairs shall raise the cap elevation above the minimum requirement and shall not reduce effective channel widths adjacent to the structure. When selecting the final cap elevation, homeowners shall consider tidal fluctuations in the area relative to constructability. The caps shall be high enough so that they can be formed and poured under normal tidal conditions to avoid any potential delays during construction.

The length of the bulkhead panels depends on several factors such as geotechnical conditions at the site, mudline elevations, and potential surcharge loads. A typical rule of thumb for estimating the length of sheetpile necessary for a conceptual design of a bulkhead is that 50%-65% of the total sheet length be embedded in the soils. Further wall design is recommended as embedment conditions are site specific due to varying soil and design conditions across properties throughout Key Allegro.

3.3 Repair Urgency

Repair urgency varies on a case by case throughout Key Allegro. High priority bulkheads are those that show signs of failure, such as low crest elevations, leaning (displaced) bulkheads, severely damaged concrete caps, and severe erosion behind the bulkheads. Several bulkheads within phase 1 and 2 that have not been repaired may fall within these criteria as they are the oldest and approaching the end of their design life.

Medium priority bulkheads are approaching the end of their design life and show signs of damage, but have not failed. These structures may have minor damage to the concrete caps but are not showing signs of failure such as leaning or severe cracking of the concrete. Structures that were recently repaired, but did not address the condition of the anchor tie-backs also fall under these criteria.

Low priority bulkheads are those approaching the end of their design life but show no visible signs of damage or failure. The concrete caps are in good condition, the wall is stable, and there are no signs of erosion behind the bulkhead. The concrete cap is also at or above +1' MSL.

Bulkheads that do not require repair are those that have been recently repaired and are in general good condition. Repairs must have addressed the anchor tie backs and the cap elevation must be at or above +1' MSL.

An example repair urgency scale is shown in Table 1, with the majority of the bulkheads within Key Allegro in the high or medium category.

Table 1. Bulkhead repair urgency scale.

Urgency	Priority Level	Timeframe
	High	Immediate action required
	Medium	1-5 yrs.
	Low	5-10 yrs.
	None at this time	-

3.4 Alternatives

A full range of alternatives was reviewed for repair of the bulkheads. This broad view of alternatives was compiled from previous Mott MacDonald experience and observations of other existing structures in the area. Advantages and disadvantages were evaluated and several solutions were chosen based on applicability to certain bulkheads within the project area. Figures for the repair alternatives can also be found in Appendix A. Mott MacDonald has developed a process flow diagram for determining which repair alternative should be used depending on the type of bulkhead failure which is included in Appendix B.

3.4.1 Alternative 1

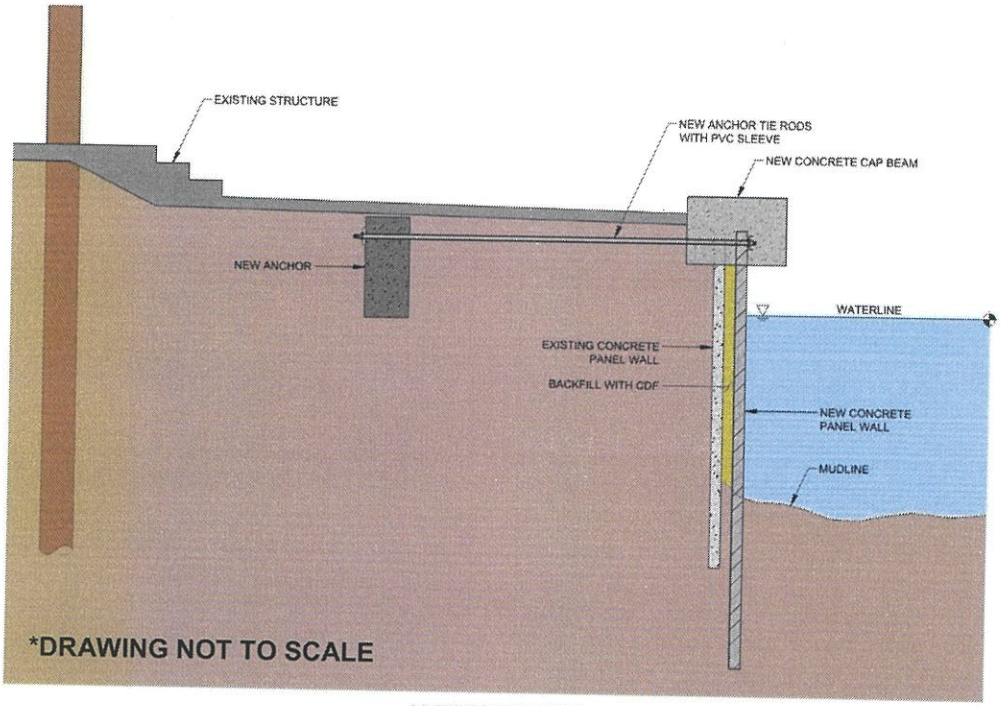


Figure 9. Repair Alternative 1

Alternative 1 consists of removing the existing concrete cap, installing longer concrete panels in front of the existing bulkhead, and installing new anchor tie-backs and a new concrete cap at least 2' thick and 3' wide. The void between the new and existing sheetpile should be filled with Controlled Density Fill (CDF). CDF is a self-compacting cementitious material which can be pumped into the void as a flowable liquid which hardens rapidly once in place; it is typically composed of water, Portland cement, and fly ash or slag cement.

This alternative can only be installed in locations where the bulkhead is not leaning over as the new panels will need to be flush against the existing bulkhead. Mott MacDonald estimates that this alternative would cost approximately $650 to $850 per linear foot of bulkhead repaired. This does not include the cost of any backfill that may be required.

The sequence of construction is up to the contractor's discretion and will be site specific, but the following is an example of the typical sequence expected for construction of this alternative:

1. Partially demolish existing concrete cap to allow installation of new concrete panel wall and anchor tiebacks. All debris shall be collected and disposed of offsite.
2. Install new concrete panels. Panels may be cast onsite to reduce transportation costs.
3. Install new deadman anchors and tiebacks.
4. Demolish remainder of concrete cap, existing anchors may be removed or left in place at this point.
5. Install Controlled Density Fill (CDF) between the existing and new bulkhead.
6. Pour new concrete cap.

3.4.2 Alternative 2

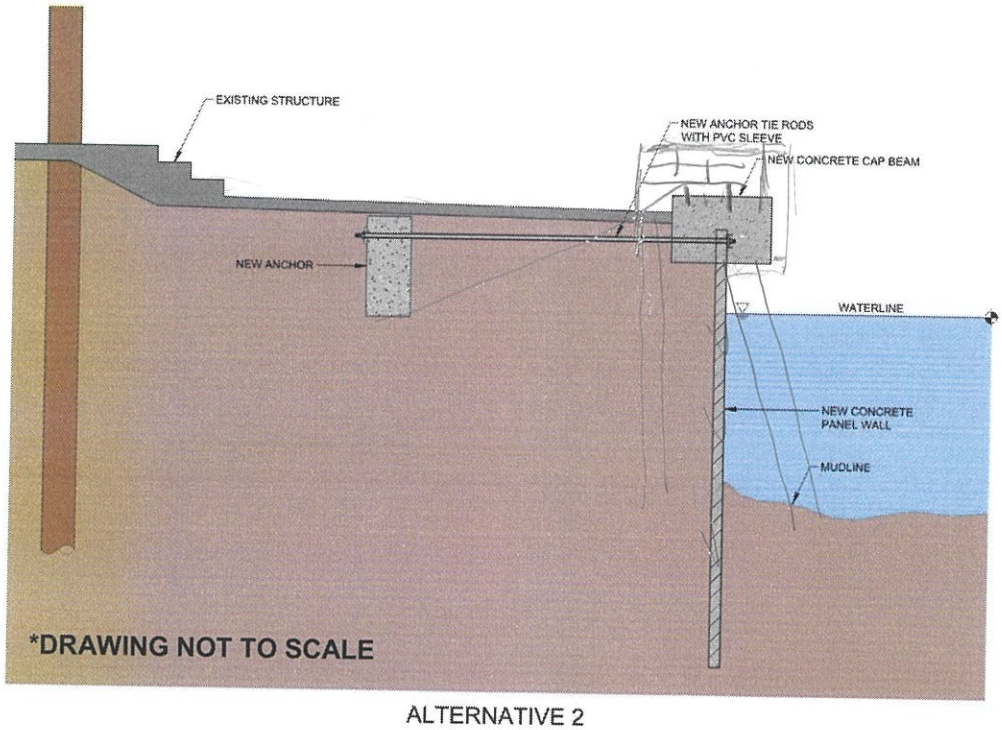


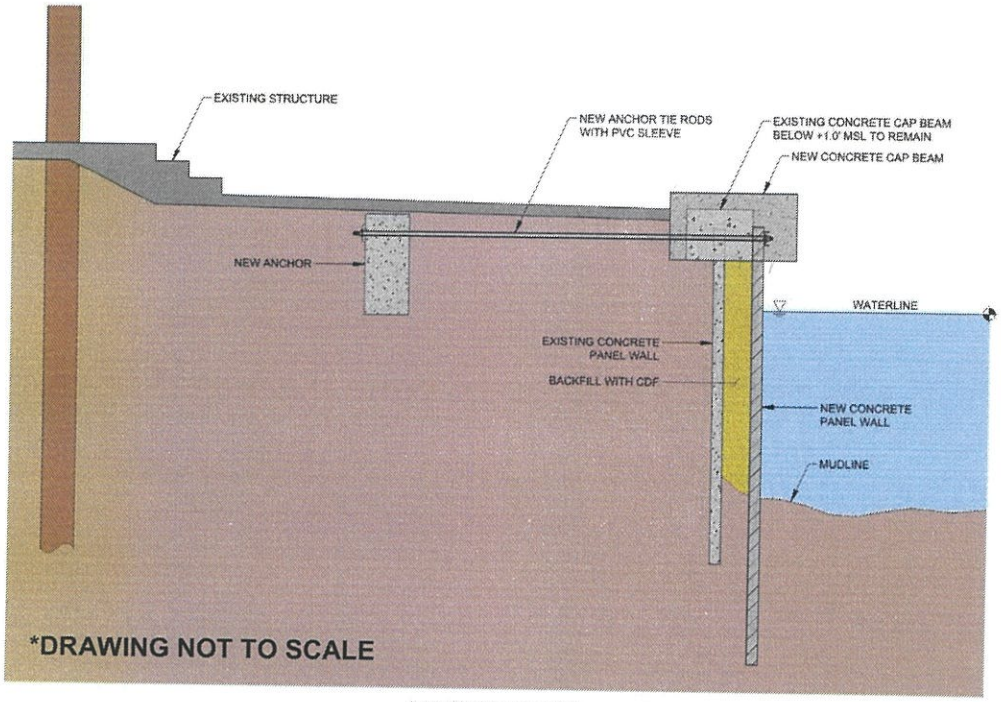
Figure 10. Repair Alternative 2

Alternative 2 consist of completely removing the existing bulkhead (cap and panels) and installing new longer concrete panels, a new cap at least 2' thick and 3' wide, and installing new anchor tie-backs. This alternative can be implemented anywhere throughout Key Allegro and would have the most longevity of any of the alternatives proposed, but it is also the costliest at an estimated cost of approximately $750 to $950 per linear foot of bulkhead installed.

The sequence of construction is up to the contractor's discretion and will be site specific, but the following is an example of the typical sequence expected for construction of this alternative:

1. Demolish existing bulkhead and cap. Wall anchors can be removed or may be left in place. All debris shall be collected and disposed of offsite.
2. Install new concrete panels. Panels may be cast onsite to reduce costs due to transportation.
3. Attach anchor tiebacks to panels and install new anchors.
4. Install concrete cap.
5. Backfill as necessary.

3.4.3 Alternative 3



ALTERNATIVE 3

Figure 11. Repair Alternative 3

Alternative 3 consists of installing new longer concrete panels in front of the existing panels, installing a new cap 2' thick, wide enough to encapsulate the existing concrete cap, and installing new anchor tie-backs. This alternative can only be installed in locations where the bulkhead is not leaning over as the new panels will need to be flush against the existing bulkhead. The existing concrete cap must also be high enough above the water to allow for proper forming and pouring of the concrete cap. Mott MacDonald estimates that this alternative would cost approximately $700 to $900 per linear foot of bulkhead repaired. This does not include the cost of any backfill that may be required. Owners should consult with the KACOPA prior to selection of this alternative as it may encroach into the channels past acceptable limits in some locations.

The sequence of construction is up to the contractor's discretion and will be site specific, but the following is an example of the typical sequence expected for construction of this alternative:

1. Install new concrete panels in front of the existing bulkhead. Panels may be cast onsite to reduce costs due to transportation.
2. Install Anchors and Tiebacks. Drill through the existing concrete cap to allow attachment of the tiebacks to the new concrete panels. Existing anchors may be removed once tiebacks are installed.
3. Fill area between the existing and new wall with CDF.
4. Install new concrete cap wide enough to encapsulate the existing cap.

3.4.4 Alternative 4

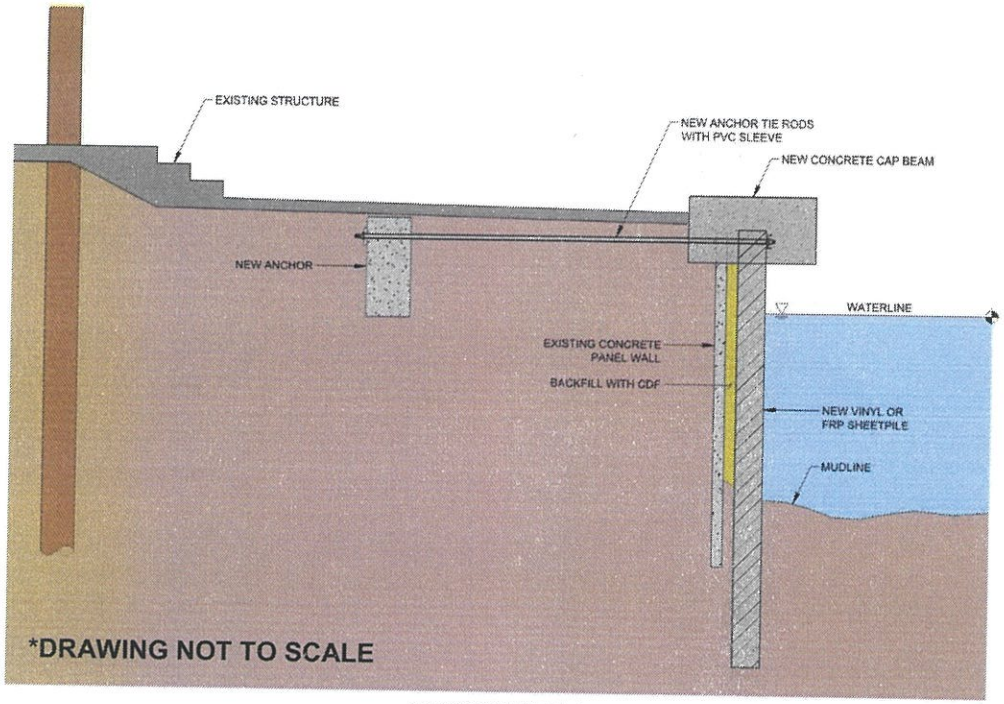


Figure 12. Repair Alternative 4

Alternative 4 consists of removing the existing concrete cap, installing sheet piles (Vinyl or Fiber Reinforced Plastic) in front of the existing bulkhead, and installing new anchor tie-backs and a new concrete cap at least 2' thick and 3' wide. This alternative can only be installed in locations where the bulkhead is not leaning over as the new sheet piles will need to be flush against the existing bulkhead. This alternative is identical to Alternative 1, but the use of a composite sheet pile would reduce the cost to approximately $600 to $800 per linear foot of bulkhead repaired. This does not include the cost of any backfill that may be required. Owners should consult with the KACOPA prior to selection of this alternative as it may encroach into the channels past acceptable limits in some locations.

The sequence of construction is up to the contractor's discretion and will be site specific, but the following is an example of the typical sequence expected for construction of this alternative:

1. Partially demolish existing concrete cap to allow installation of new composite sheetpile wall and anchor tiebacks. All debris shall be collected and disposed of offsite.
2. Install new composite sheetpile in front of the existing bulkhead.
3. Install new deadman anchors and tiebacks.
4. Demolish remainder of concrete cap, existing anchors may be removed or left in place at this point.
5. Install Controlled Density Fill (CDF) between the existing and new bulkhead.
6. Install new concrete cap.

3.4.5 Alternative 5

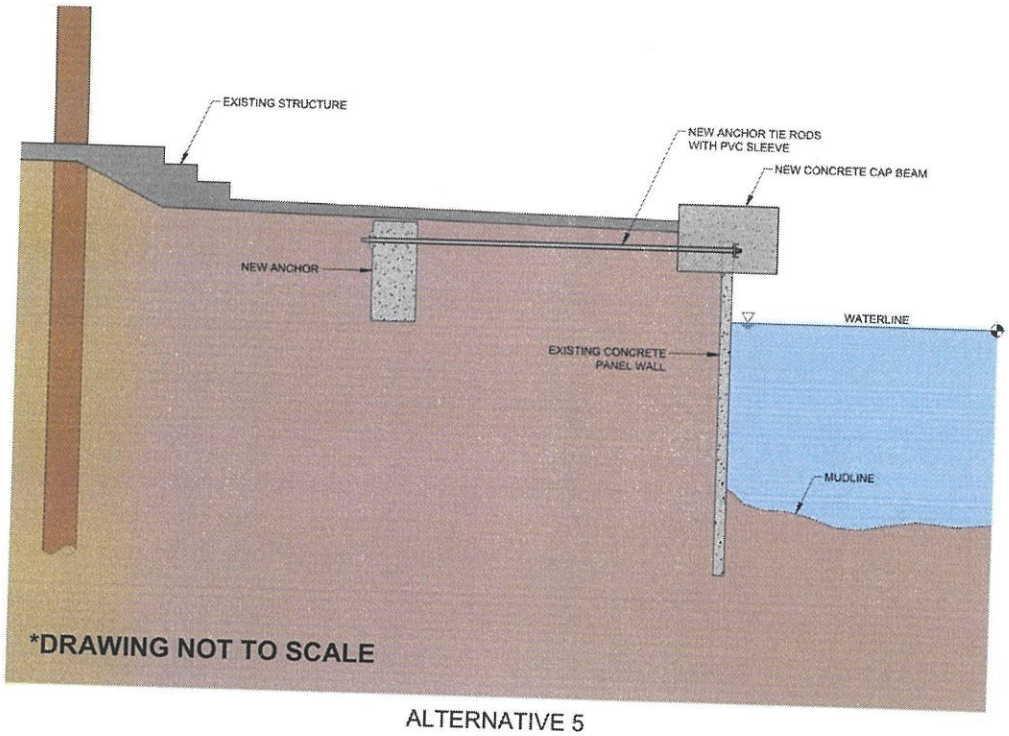


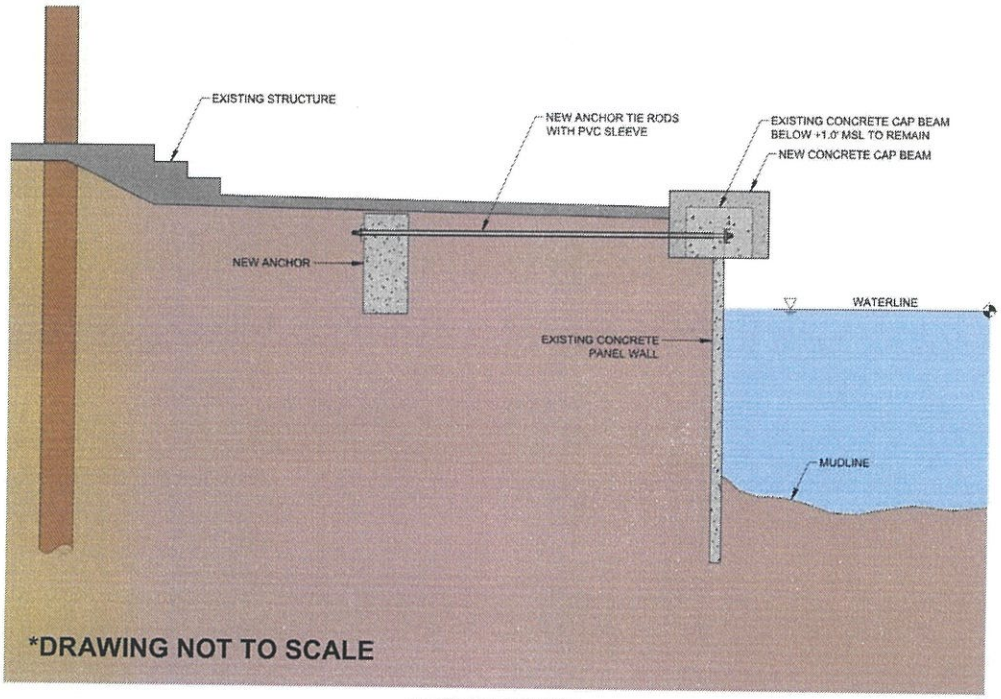
Figure 13. Repair Alternative 5

Alternative 5 consists of removing and replacing the existing concrete caps and anchor tie-backs. The replacement cap would need to be at least 2' thick and 3' wide to match the dimensions of the existing caps. This alternative assumes that the existing concrete panels are in good condition and have not subsided. The top of the wall would need to be high enough above the water for proper forming and installation of the concrete cap. Due to the current age of existing bulkheads, this alternative is not recommended for most cases and shall only be used in locations where the concrete panels are in excellent condition. Mott MacDonald estimates that this alternative would cost $300 to $500 per linear foot of cap repaired.

The sequence of construction is up to the contractor's discretion and will be site specific, but the following is an example of the typical sequence expected for construction of this alternative:

1. Demolish the existing concrete cap.
2. Install new deadman anchors and tiebacks. (can replace one at a time to avoid leaving the wall unsupported).
3. Install new concrete cap.

3.4.6 Alternative 6



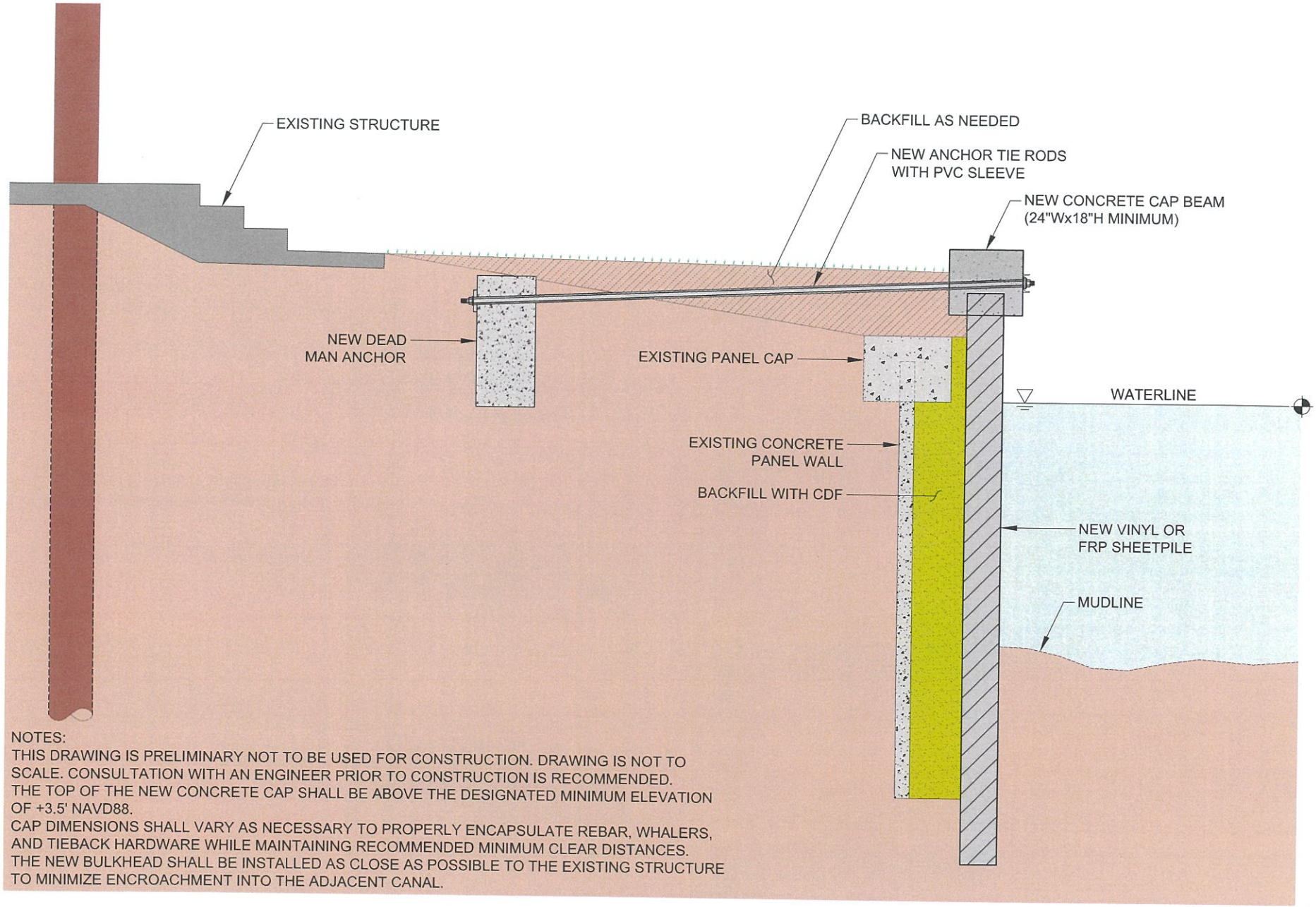
ALTERNATIVE 6

Figure 14. Repair Alternative 6

Alternative 6 consists of installing a new 2' thick concrete cap wide enough to encapsulate the existing cap and installing new anchor tie-backs for the existing concrete panels. This would only be performed in areas where the existing panels are in good condition and have not subsided. The existing concrete cap must also be in good enough condition to support the additional concrete installed. This alternative would not be appropriate for bulkhead sections where excessive damage to the concrete cap is evident. This alternative does not address the condition of the existing bulkhead panels which are approaching the end of their design life and may need to be replaced. Mott MacDonald estimates that this alternative would cost $200 to $400 per linear foot of cap repaired.

The sequence of construction is up to the contractor's discretion and will be site specific, but the following is an example of the typical sequence expected for construction of this alternative:

1. Install new deadman anchors and tiebacks.
2. Remove existing anchors and tiebacks or leave in place.
3. Install new concrete cap over existing cap.



NOTES:
THIS DRAWING IS PRELIMINARY NOT TO BE USED FOR CONSTRUCTION. DRAWING IS NOT TO SCALE. CONSULTATION WITH AN ENGINEER PRIOR TO CONSTRUCTION IS RECOMMENDED.
THE TOP OF THE NEW CONCRETE CAP SHALL BE ABOVE THE DESIGNATED MINIMUM ELEVATION OF +3.5' NAVD88.
CAP DIMENSIONS SHALL VARY AS NECESSARY TO PROPERLY ENCAPSULATE REBAR, WHALERS, AND TIEBACK HARDWARE WHILE MAINTAINING RECOMMENDED MINIMUM CLEAR DISTANCES.
THE NEW BULKHEAD SHALL BE INSTALLED AS CLOSE AS POSSIBLE TO THE EXISTING STRUCTURE TO MINIMIZE ENCROACHMENT INTO THE ADJACENT CANAL.

ALTERNATIVE 7

3.4.7 Anchor Tieback Repair

When repairing the anchor tiebacks, care should be taken to ensure the existing wall or ground is not displaced. This is done by avoiding placing heavy equipment adjacent to the bulkhead and minimizing any surcharge loads near the structure. For alternatives where the existing wall is to remain while the tiebacks are replaced, there will be a short period of time when the wall is unsupported during the repair. It is unlikely that the wall will be displaced over such a short time, but if there is a concern of the wall falling over, contractors should temporarily brace the structure while repairs are taking place.

Tieback spacing and deadman anchor locations shall be determined on a case by case basis through structural analysis and design. Typically, tiebacks spaced at a maximum distance of 10' along the length of the wall with anchors approximately 25' landward of the bulkhead are sufficient for residential applications. Alternative, more robust anchoring methods, such as anchor piles or helical anchors, may be required in locations where existing structures, such as swimming pools, limit the installation of new anchor tiebacks and deadmen. In locations with swimming pools, helical anchors may be the best option as they can be drilled in place under the structure without disturbing the ground. Additional analysis and design will be necessary for designing anchoring solutions for those locations.

3.4.8 Summary of alternatives

Alt	Demolition	Bulkhead	Cap	Tie-backs	Est. Cost per Linear Foot
1	Remove existing concrete caps	Install New Longer Concrete Panels in front of existing panels	Install a new 2'+ thick and 3' wide cap	New Anchor Tie-backs	$650-$850
2	Remove existing concrete caps and panels	Install New Longer Concrete Panels	Install a new 2'+ thick and 3' wide cap	New Anchor Tie-backs	$750-$950
3	None	Install New Longer Concrete Panels in front of existing panels	Install a new 2'+ thick cap wide enough to encapsulate existing cap	New Anchor Tie-backs	$700-$900
4	Remove existing concrete caps	Install Vinyl or FRP Sheetpile in front of existing concrete panels	Install a new 2'+ thick and 3' wide cap	New Anchor Tie-backs	$600-$800
5	Remove existing concrete caps	None	Install a new 2'+ thick and 3' wide cap	New Anchor Tie-backs	$300-$500
6	None	None	Install a new 2'+ thick cap wide enough to encapsulate existing cap	New Anchor Tie-backs	$200-$400

Notes:

1. The estimates provided herein do not include permitting, demolition, and contractor mobilization costs.
2. Helical and grouted anchors may be another cost-effective alternative, such costs may be compared based on the particulars of the bulkhead repair or replacement.
3. All costs are in 2017 Dollars.
4. Costs assume most of the work will take place from the water using barge mounted heavy equipment.
5. Due to the extent of the damage from Hurricane Harvey, coastal contractors and equipment may be difficult to obtain due to high demand from ongoing repair efforts and costs may vary as a result.

3.5 Storm Water Outfall Alternatives

Storm Water Outfall repair consists of installing a cast in place reinforced concrete collar on the backside of the bulkhead at the location of the outfall. This option can be applied to all of the repair alternatives discussed previously. A hole must be cut through the bulkhead large enough for the HDPE pipe to fit through the bulkhead if new sheet pile or concrete paneling is installed. Watertight "Anaconda Gaskets" are to be installed on the pipe where it passes through the center of the reinforced concrete collar and shall be grouted using non-shrink grout. The grout

shall be installed sufficiently to create a water tight seal between the pipe, bulkhead, and concrete collar as shown in Figure 15.

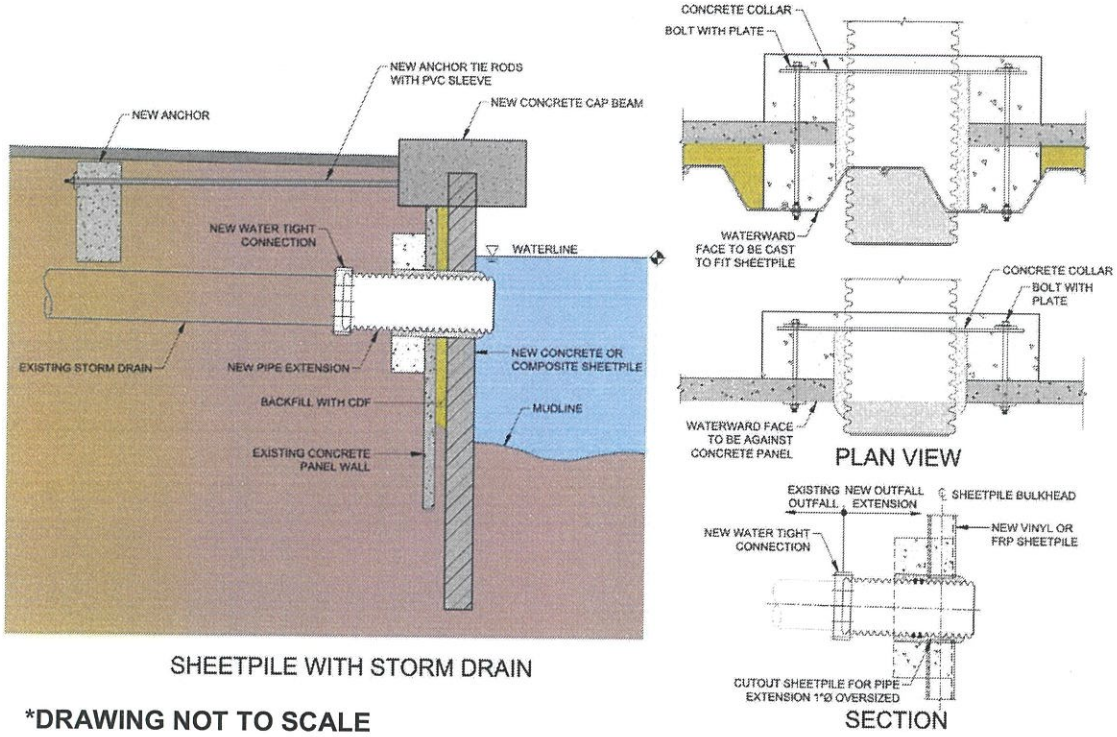


Figure 15. Storm Drain Outfall Repair Alternatives

Due to the potential movement of the bulkheads due to settlement it is recommended that the pipe through the bulkhead be of a flexible material such as HDPE. In areas where the existing concrete pipe has been damaged, it is recommended that the pipe be cut just above the location of the damage and spliced with the HDPE outfall pipe as shown in the Figure 15.

If Alternatives 5 and 6 are selected where an outfall is present, care must be taken to avoid damaging the aged concrete panels at the outfall location. It is recommended that a pipe smaller than the existing outfall hole be used to avoid cutting into the concrete and potentially damaging the panels. If alternative 2 is selected, the drain outfall may be installed on the panel prior to driving to facilitate installation. A small cofferdam or other dewatering method may be required to keep water out of the outfall during pouring of the concrete collar and grout.

The sequence of construction is up to the contractor's discretion and will be site specific, but the following is an example of the typical sequence expected for construction of this alternative:

1. Excavate area around drain to access pipe and outfall location.
2. A small cofferdam or form will need to be installed at the outfall to keep water out during the repair. It may also be possible to construct a small cap to encapsulate the outfall hole while repairs are being performed.
3. Cut existing storm drain pipe and remove from bulkhead. Cutout sheetpile if necessary to fit new outfall pipe.
4. Bolt steel plate with oversize pipe to sheetpile at outfall location.
5. Form and pour concrete for concrete collar.
6. Insert new corrugated pipe through collar and outfall and pour non-shrink grout between corrugated pipe and concrete collar.

7. Attach corrugated pipe to remaining storm drain pipe.
8. Backfill area behind the bulkhead.

3.6 Bulkhead Repair Alternative Selection Process

Appendix B shows a process diagram that may be used by homeowners to identify the best alternative for repair of their bulkheads. This diagram, coupled with the guidance provided herein shall aid homeowners during preliminary selection of the appropriate repair alternatives for their property. Homeowner's shall consult with qualified contractors or engineers prior to initiating repairs to their bulkheads.

4 Conclusion

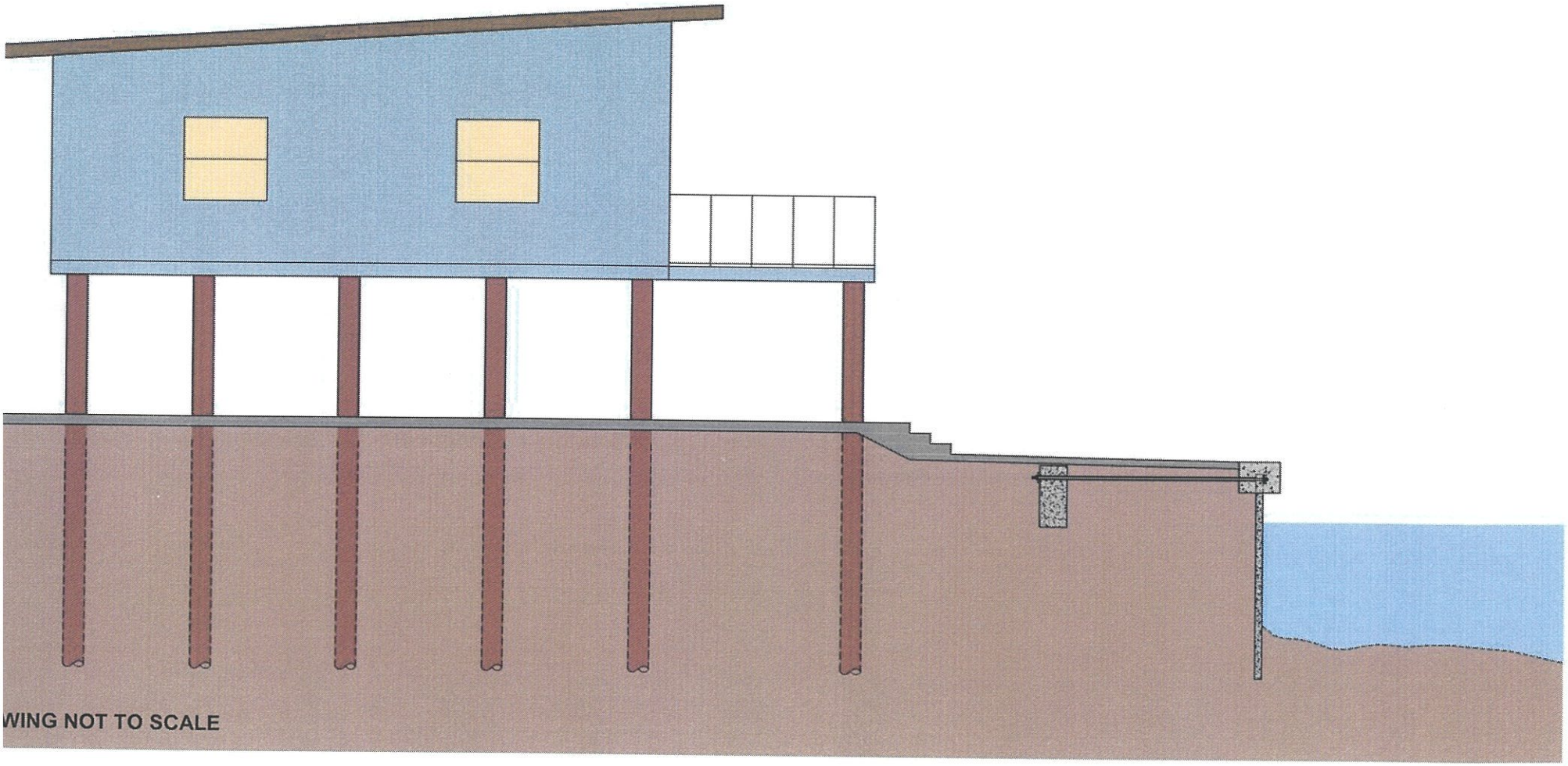
The assessment of bulkheads throughout Key Allegro has shown many failing structures that will need replacement or extensive repair. Existing structures adjacent to or over the bulkheads may complicate repair efforts and could lead to premature failure of the bulkheads due to increased surcharges on the structures. Also, previous repair efforts, when not performed correctly, only temporarily stabilize the structures and additional repair may be required.

Using the criteria specified for repair of the bulkheads, alternatives were developed to address the observed bulkhead modes of failure. These alternatives are preliminary and further investigation should be performed prior to executing repairs. Preliminary costs have been provided to aid homeowners in selecting the appropriate repairs. In order to facilitate construction and potentially reduce cost, it is recommended that homeowners with adjacent bulkheads coordinate their repair efforts to avoid any issues tying in the repairs to adjacent properties. Also, a coordinated effort is more cost effective as construction costs per linear foot decrease for longer sections of bulkhead, and if the same contractor is used and the work is performed concurrently a reduction in mobilization and overall costs may be achieved.

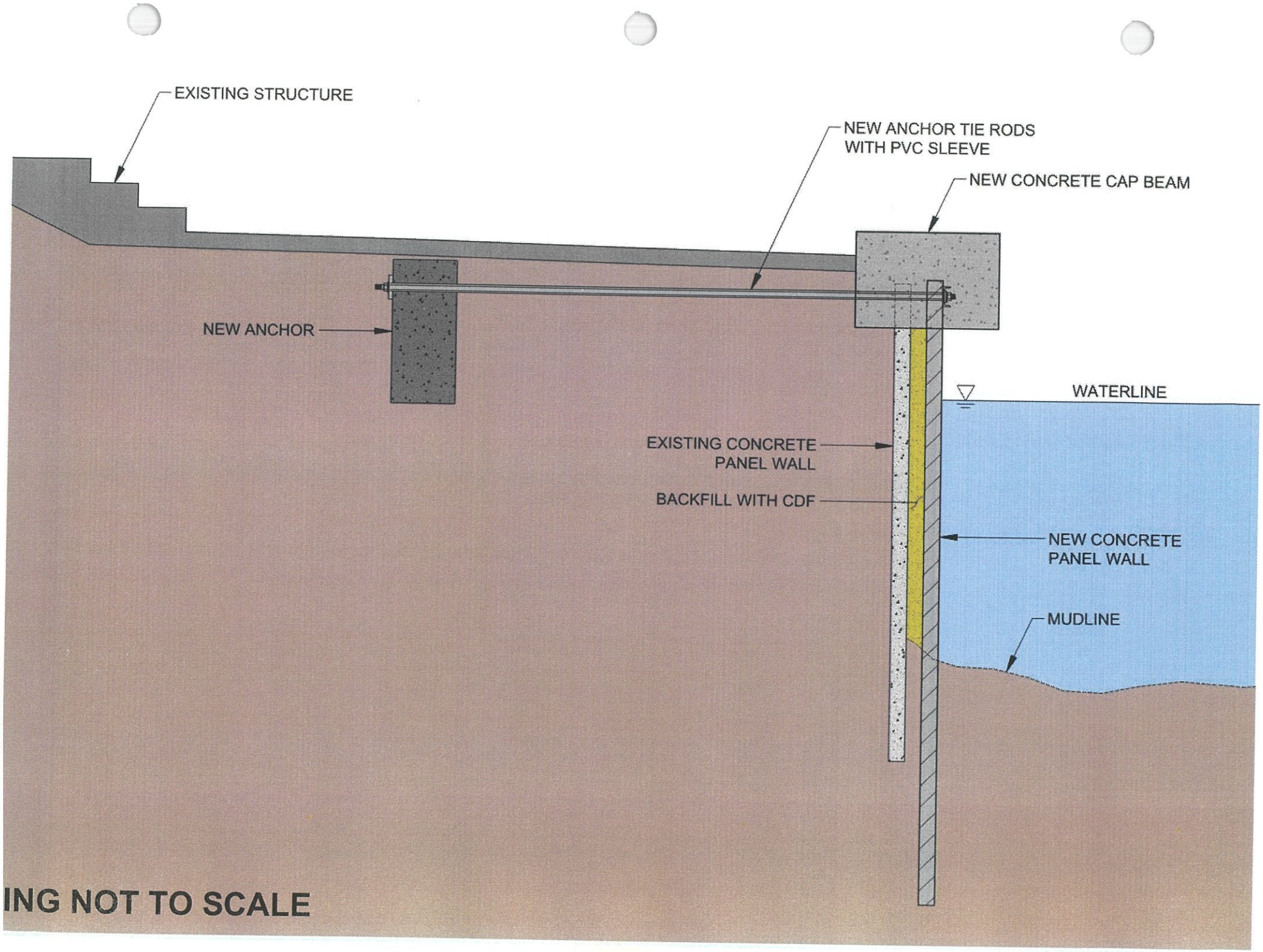
Finally, the flow chart provided in Appendix B coupled with the guidance provided herein shall be used to aid homeowners in identifying whether repair is necessary and which repair alternative is preferred for their bulkheads prior to final design of the bulkhead repair. Due to the advanced age of most bulkheads throughout Key Allegro, Mott MacDonald recommends Homeowners consider replacing the concrete panels or installing new panels in front of the existing bulkhead when performing repairs. Homeowner's shall consult with qualified contractors and engineers prior to initiating a repair on their bulkheads.

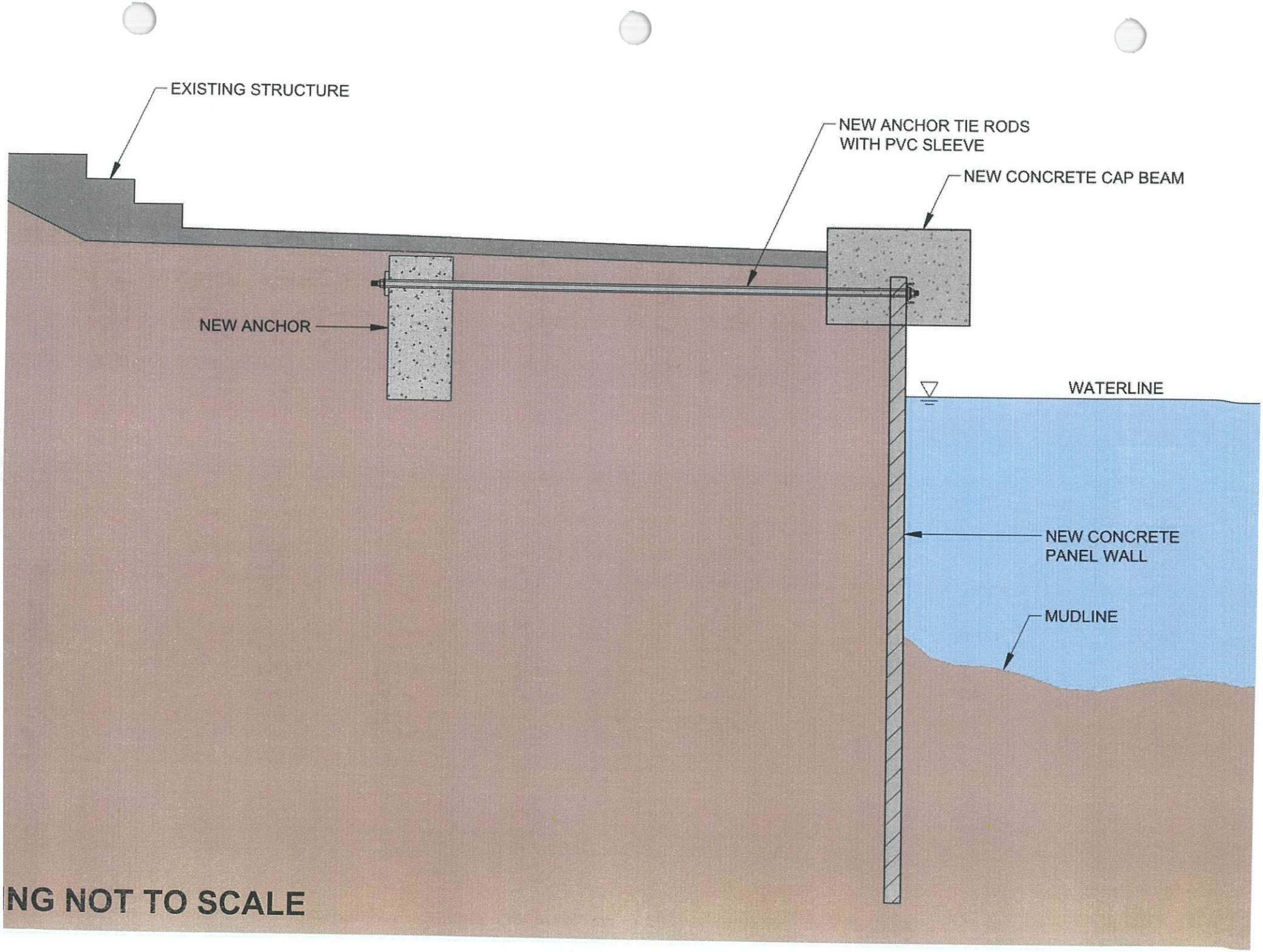
Appendices

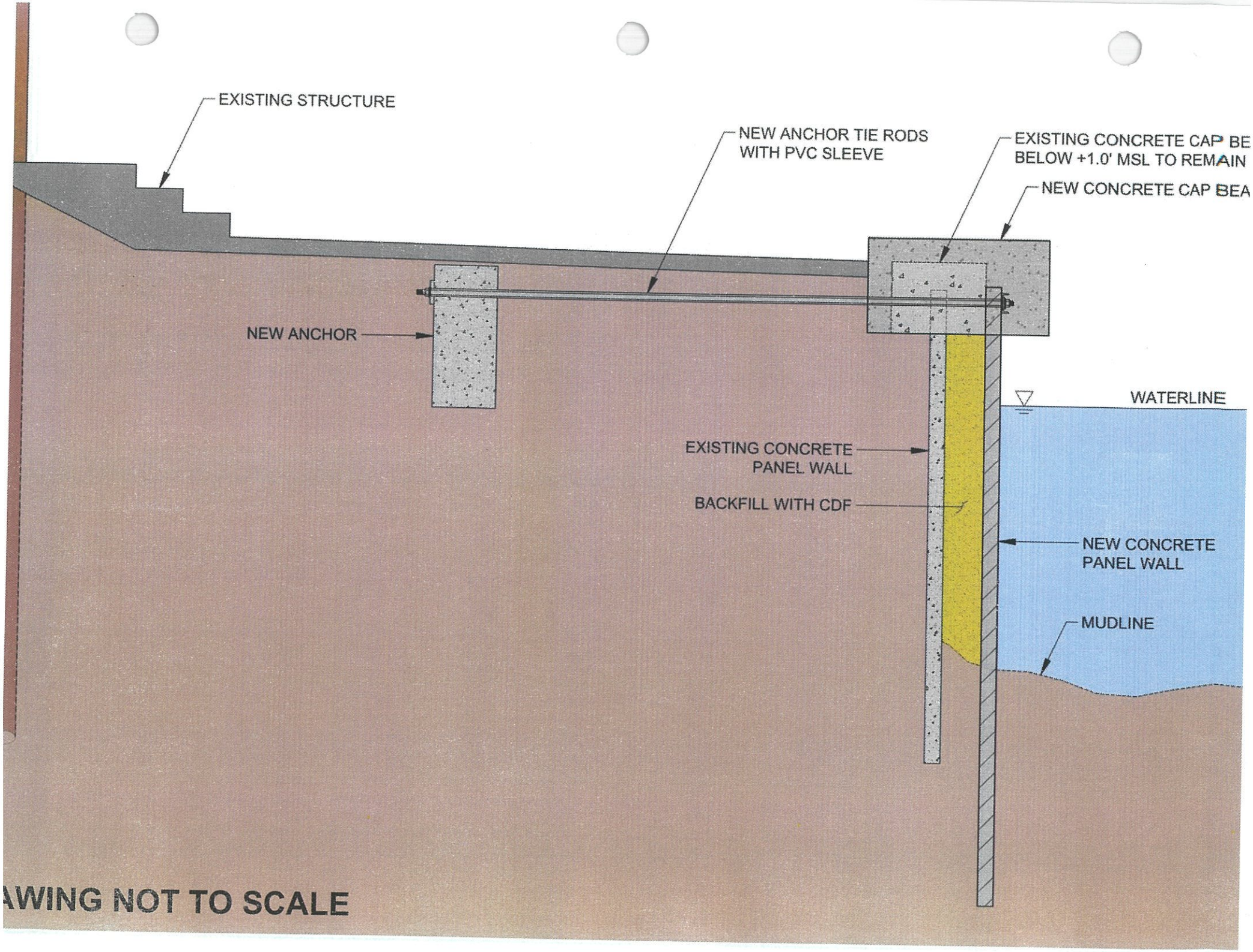
A. Bulkhead Repair Alternatives

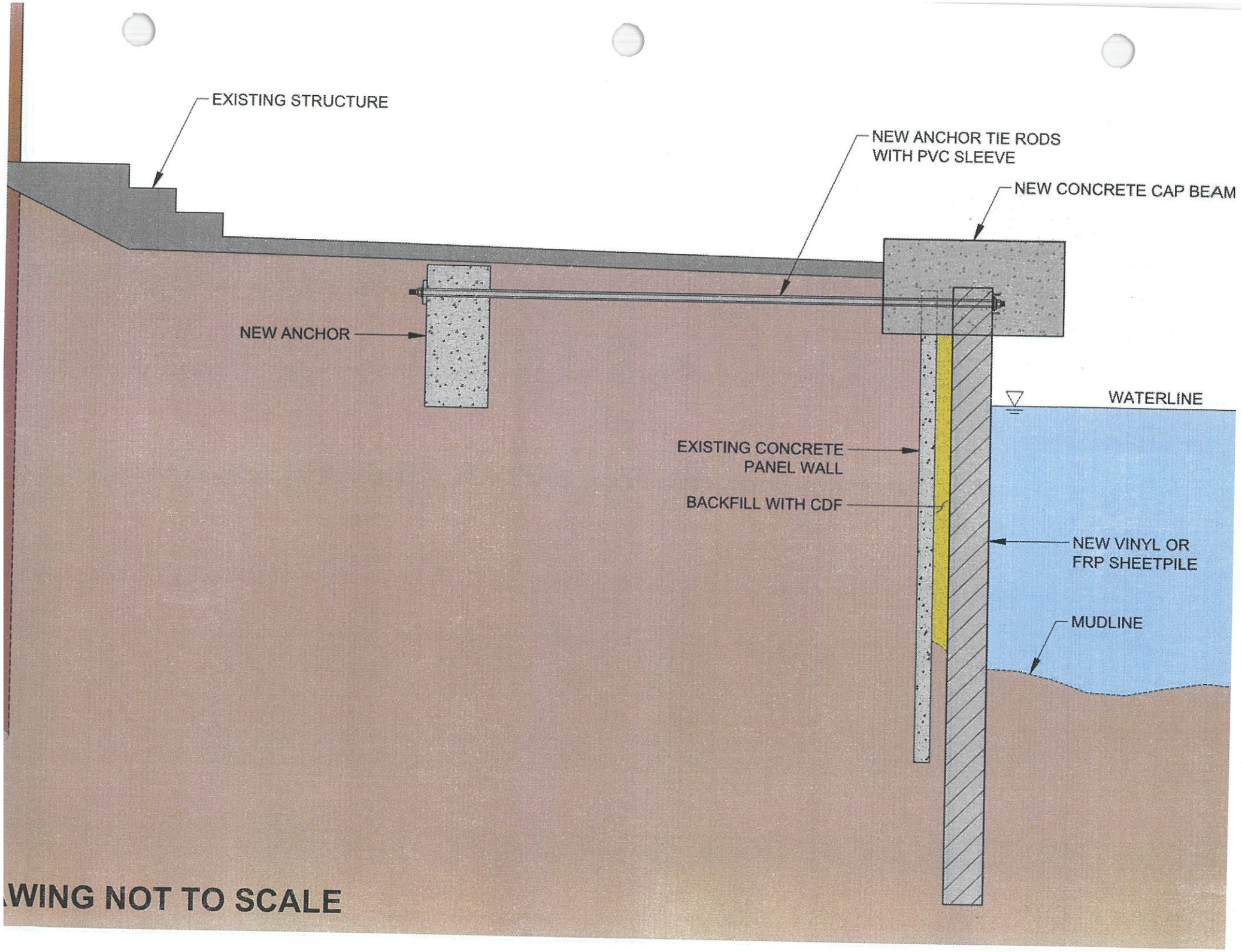


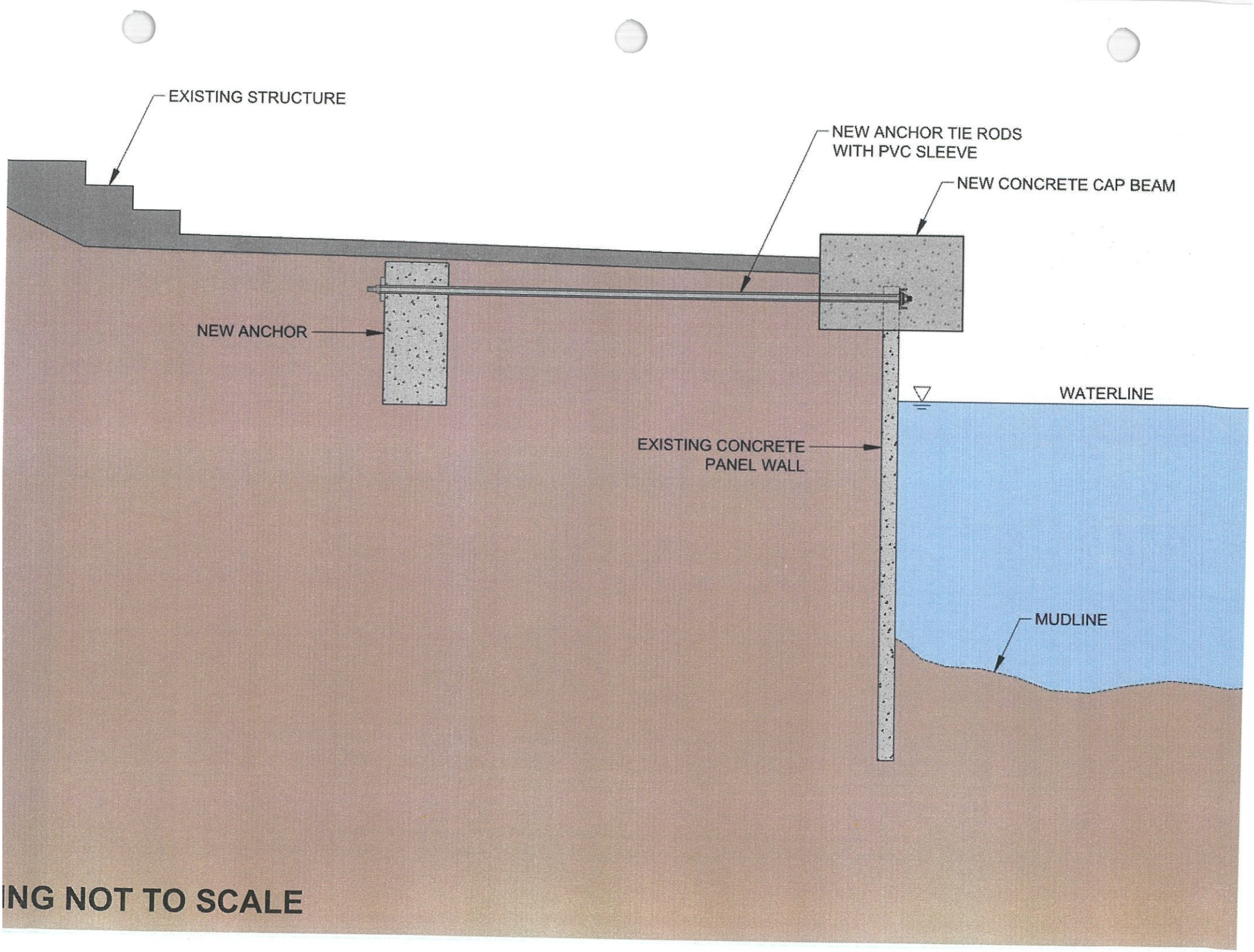
GENERIC OVERALL EXISTING SECTION

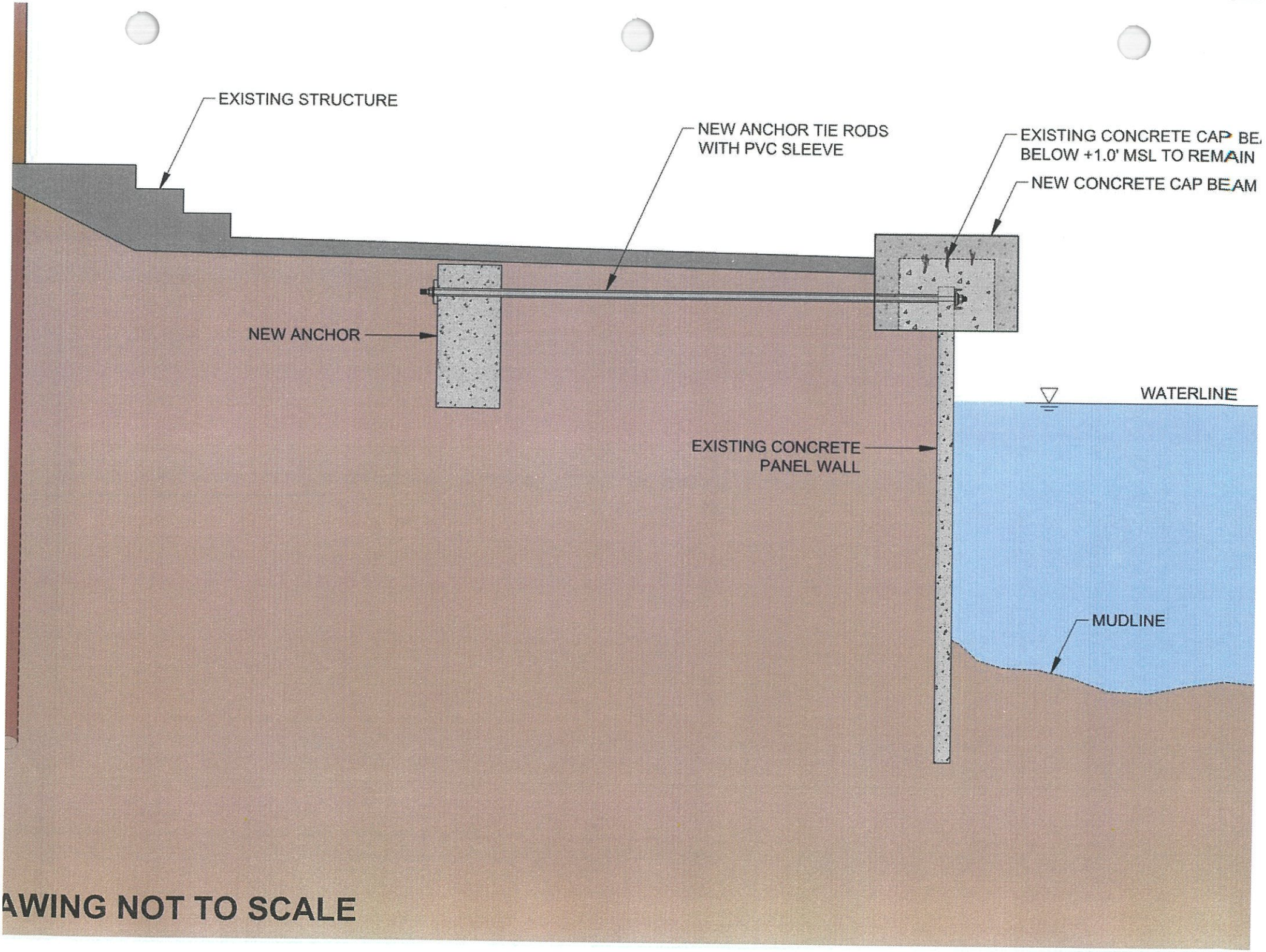

EXISTING STRUCTURE
NEW ANCHOR TIE RODS
WITH PVC SLEEVE
NEW CONCRETE CAP BEAM
NEW ANCHOR
WATERLINE
EXISTING CONCRETE
PANEL WALL
BACKFILL WITH CDF
NEW CONCRETE
PANEL WALL
MUDLINE
ING NOT TO SCALE

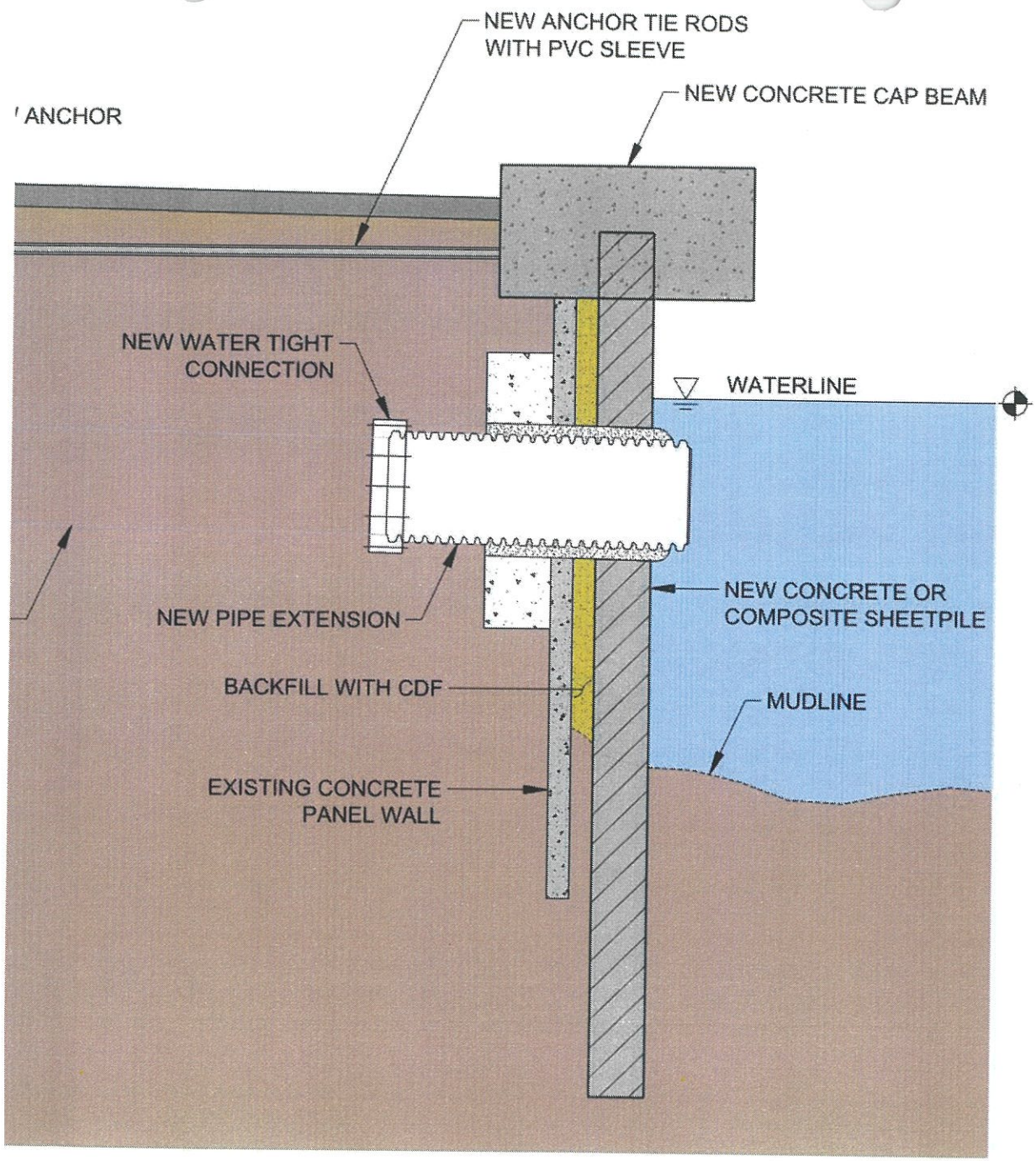

EXISTING STRUCTURE
NEW ANCHOR TIE RODS
WITH PVC SLEEVE
NEW CONCRETE CAP BEAM
NEW ANCHOR
WATERLINE
NEW CONCRETE
PANEL WALL
MUDLINE
NG NOT TO SCALE


EXISTING STRUCTURE
NEW ANCHOR TIE RODS
WITH PVC SLEEVE
EXISTING CONCRETE CAP BE
BELOW +1.0' MSL TO REMAIN
NEW CONCRETE CAP BEA
NEW ANCHOR
WATERLINE
EXISTING CONCRETE
PANEL WALL
BACKFILL WITH CDF
NEW CONCRETE
PANEL WALL
MUDLINE
AWING NOT TO SCALE

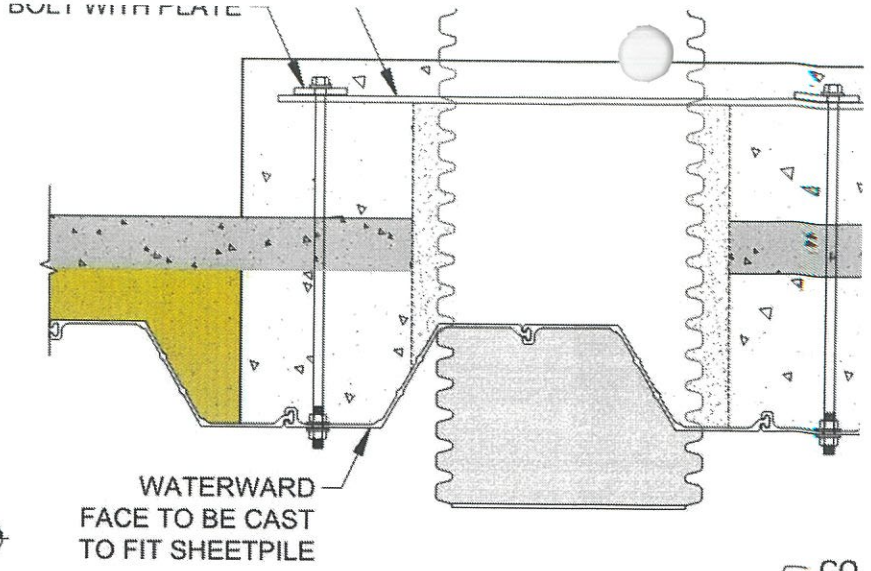

EXISTING STRUCTURE
NEW ANCHOR TIE RODS
WITH PVC SLEEVE
NEW CONCRETE CAP BEAM
NEW ANCHOR
WATERLINE
EXISTING CONCRETE
PANEL WALL
BACKFILL WITH CDF
NEW VINYL OR
FRP SHEETPILE
MUDLINE
WING NOT TO SCALE

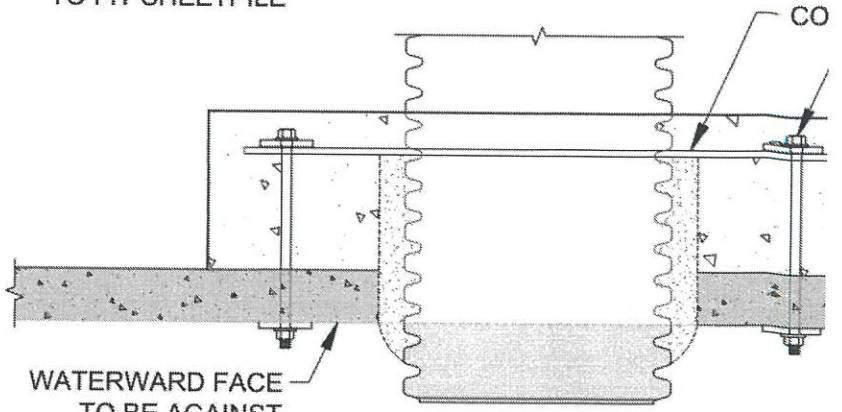

EXISTING STRUCTURE
NEW ANCHOR TIE RODS
WITH PVC SLEEVE
NEW CONCRETE CAP BEAM
NEW ANCHOR
WATERLINE
EXISTING CONCRETE
PANEL WALL
MUDLINE
ING NOT TO SCALE


EXISTING STRUCTURE
NEW ANCHOR TIE RODS
WITH PVC SLEEVE
EXISTING CONCRETE CAP BE
BELOW +1.0' MSL TO REMAIN
NEW CONCRETE CAP BEAM
NEW ANCHOR
WATERLINE
EXISTING CONCRETE
PANEL WALL
MUDLINE
AWING NOT TO SCALE

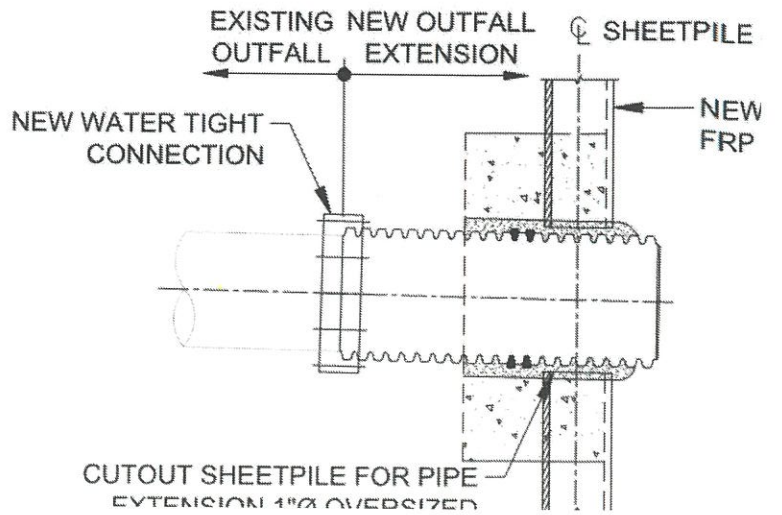


SHEETPILE WITH STORM DRAIN





PLAN VIEW



B. Bulkhead Repair Alternative Selection Flow Chart

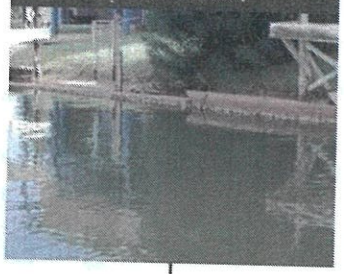
EGRO
nt Flowchart

Start here

Is the bulkhead damaged or below +1'MSL?

Yes

Is the damage severe? (cracking, erosion behind bulkhead, bulkhead undermined)



No

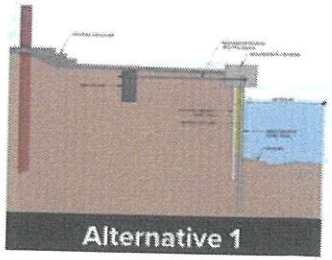
Is the bulkhead falling over?

No

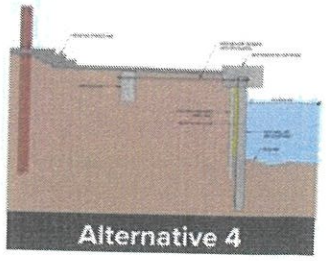
Is the concrete cap damaged?

Yes

Alt 1, 4



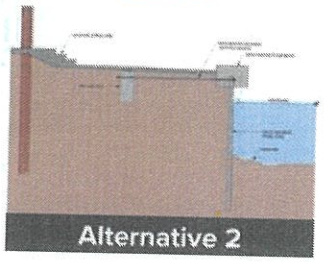
Alternative 1



Alternative 4

Yes

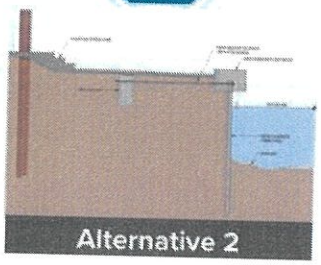
Alt 2



Alternative 2

Yes

Alt 2

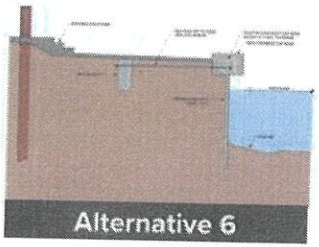


Alternative 2

damage severe?
g, exposed rebar)

No

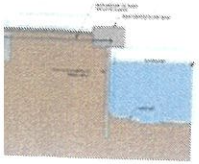
Alt 6

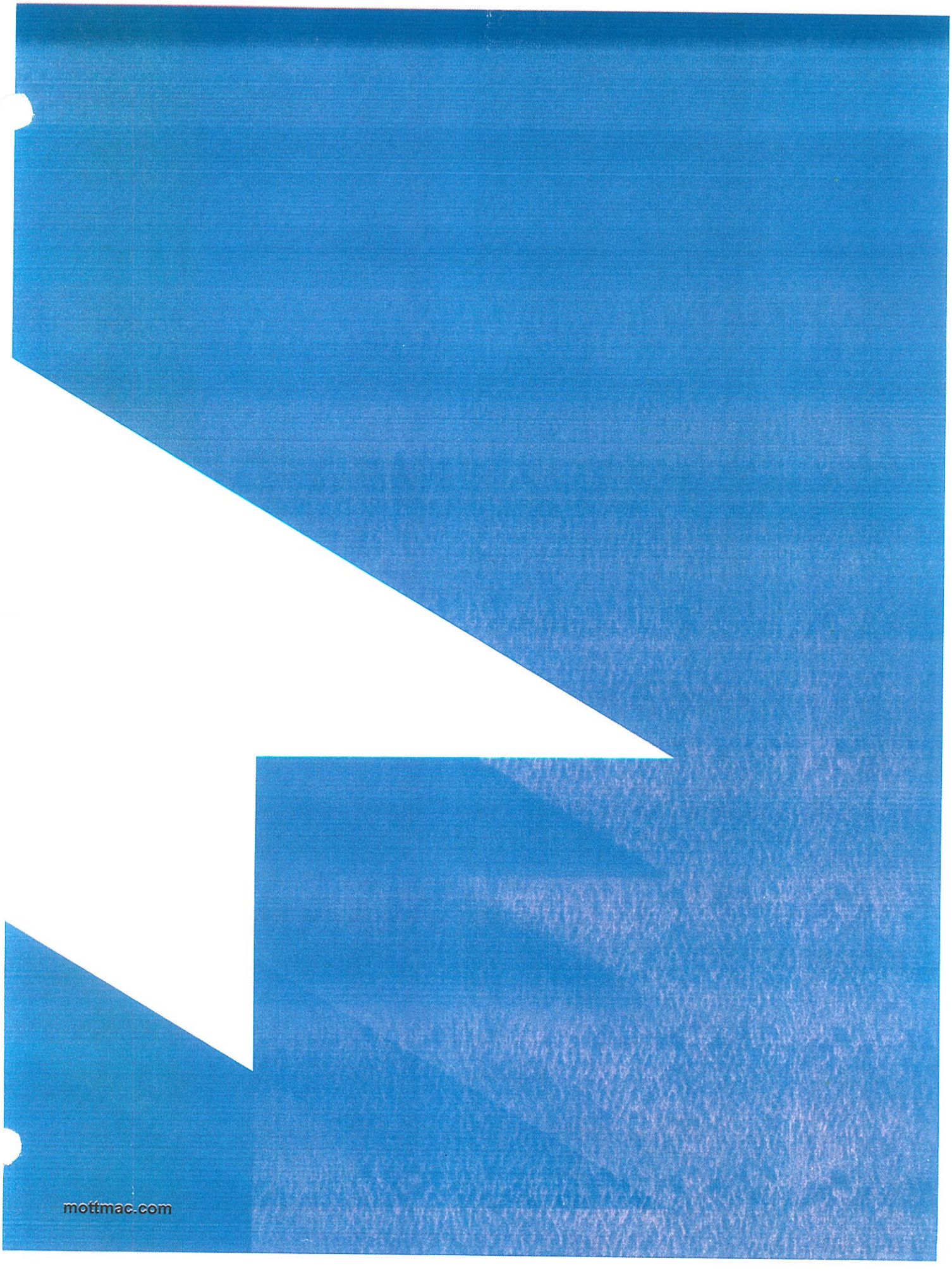


Alternative 6

Yes

Alt 5





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