At your request, Moffatt & Nichol (M&N) has reviewed a variation of the fill alternative proposed for the City of St. Petersburg Pier in the circa 2003 and 2006 reports prepared by Parsons Brinckerhoff. The alternative discussed in this document is a solid fill structure constructed around the limits of the existing pile-supported pier. The width of the access roadway segment was set at 150 feet and the overall impact area set at 291,000 square feet to match Alternative 1 as proposed in the Pier Advisory Task Force study prepared by Bermello Ajamil & Partners, Inc.

The existing City of St. Petersburg Pier consists of an asphalt roadway and brick paver sidewalks supported by concrete slab, beams, pile caps and piles to support pedestrian and light vehicular traffic loading. This structure was built circa 1920 providing access to a Mediterranean-style building at the end of the pier. In the 1970s, this Mediterranean building was removed and replaced by the current ‘inverted pyramid’ building. To resist the loads from the new building, an independent foundation system was constructed consisting of solid fill caissons.

The following is a discussion of the design and construction methodology of two types of soil retaining structures that would be appropriate for this project. Options evaluated for the solid fill structure included parallel concrete or steel sheet pile bulkheads and cellular cofferdams. These alternatives, as well as an order of magnitude opinion of probable construction costs, are presented. Additionally, demolition of the pier superstructure is considered versus leaving it in place.

**Solid Fill Structure Types**

The first retaining system considered is a sheet pile wall system. This system involves driving sheet piles to provide a continuous retaining structure. Bulkheads of this height and loading require anchorage which is typically provided by steel tie rods connected to a deadman anchor. A deadman anchor utilizes soil pressure to provide stability to the sheet piles. In order for the deadman anchorage system to be effective, it must be located far enough away from the sheet piles to fully develop soil pressure resistance without influencing the bulkhead. See Figure 1. In a parallel sheet pile wall system, the opposing walls act as the deadman for...
each other as the tie rods are installed across the fill structure. See Figure 2. To create a uniform structural system, a concrete pile cap is constructed on the top of the sheet piles. Either concrete or steel sheet pile can be used for this type of structure. However, steel sheet piles are more common for this application due to the water depths and pace of construction as long concrete sheets are heavy and difficult to maneuver.

A cofferdam system consists of interlocking steel sheet piling driven as a series of interconnecting cells. The cells may be of circular type or of straight-wall diaphragm type. See Figure 3. The cells are filled with well compacted sands or gravels. External forces on the structure are resisted by the mass of the cofferdam. Cofferdams are gravity structures and must be installed on a bearing stratum capable of resisting the mass of the structure to be stable. Cofferdams are common for locations where there are large lateral loads, where there is shallow rock, or where the inherent stability of the cells is needed to progress construction into the water and allow top down construction.

**Structural Fill**

For a solid fill structure, the type of soil fill selected plays a critical role in cost, timeline and feasibility of the project. Not only the type of backfill material, but the method of placement and densification also must be considered. Achieving a well-consolidated soil that is resistant to long-term settlement is a critical objective.

Fill options include select fill from land based borrow sites and quarries or hydraulic fill from dredge spoils. Select fill typically consists of granular material such as well graded sand or gravel. Select fill has a higher material and placement cost but is more economical due to the relatively short construction timeline required. Alternatively, hydraulic fill has a less expensive initial cost in place but typically consists of poorly graded silts and clays from dredge spoils which require extensive dewatering and compaction programs to provide a soil system that is resistant to long term settlement. Hydraulic fills expand when wet and have low strength complicating the construction of waterfront structures. A key disadvantage for hydraulic fill is that adequate consolidation is not achievable when the fill is placed below the waterline. The use of poor quality soil also increases the size of structural members. A solid fill structure relies on soil structure interaction; if the soil is weak, the structure must be stronger to compensate.
When soil is moved, its volume increases because of the addition of air or voids in between the soil particles. Unconsolidated soil has numerous voids in it. Consolidation is the process by which the voids are removed and the soil packs closer together, typically when pressure is added to the soil. The presence or absence of soil water can have a considerable effect on soil strength and settlements. Submerged soil particles do not compact. However, free draining soils above the water table can be compacted. Compaction is the method by which soil is consolidated above water.

Compaction alternatives for granular soils include static and vibratory methods. Static methods include kneading and pressure compacting. This type of compaction involves using the dead weight of a machine to apply a downward force on the soil and is typically used only on upper layers of soil. Vibro compacting can be either rotary or impact. It can be accomplished with a probe to essentially mix and densify the soil or with a roller on the upper layers of soil. Impact compacting, another form of vibratory compacting, is completed by having a hammer deliver a rapid sequence of blows to the soil. Vibro compacting is the most common type of compaction for dry, granular soil layers. Probe vibro consolidation is frequently used to facilitate consolidation underwater.

Compaction of cohesive soils typically found in hydraulic fill is most effectively completed using pressure or impact compaction. However, the high water content in this type of fill requires significant amounts of time to compact, months to years, depending on the soil properties. Wick drains can be used to assist in the compaction process. A wick drain is typically a segment of corrugated plastic pipe covered in filter fabric that is pushed into the soil. This allows a place for the water to collect and be conveyed to the surface. Again, this adds time to the construction schedule.

Retaining structures in general are heavy after back filling. They generally require stable subsurface conditions to provide an adequate foundation. The increased loads associated with the structure and backfill weight result in increased stress in the underlying soil which needs to be considered to prevent bearing failure, instability and intolerable settlements. Based on the soil profile shown in the as-built drawings for the Pier’s building foundation, the bearing stratum is approximately 70.0 feet below the waterline. Further geotechnical studies would need to be conducted to determine if there is a more stable layer above this.

**Construction Methodology**

Solid fill structures are installed in stages due to the reliance on the fill to create a stable structure. Sheet piles driven and not tied back or braced are susceptible to wave and wind forces. In order to maintain stability and alignment the construction of the structure is typically broken down into stages or manageable pieces where stability can be achieved and its strength used to facilitate construction of the next segment. On a structure requiring parallel bulkhead walls, the usual construction method is to install the walls for a predetermined distance, for example 100 feet, on both sides of the structure and an intermediate tie wall or diaphragm wall is then installed between the two bulkheads to form the perimeter. This is to establish the stability of the perimeter wall which cannot be done with dredge spoils. When the perimeter is in place the interior can be filled with the same coarse granular fill which does not need consolidation or dredge spoils can be used if properly dewatered and consolidated. The next step is to construct the pile cap followed by backfilling and compacting to grade. This procedure is then repeated until the structure is complete. This staged construction technique is important to maintain the overall stability of the structure.
Sheet pile cofferdams are installed using flat steel sheet pile. The circular type construction is more common in an open water environment because each cell can act as an individual stable structure. Driving templates are set up from a barge for accurate pile driving as there is a small driving tolerance to complete a closed loop. The closed loops are installed first, and then the interconnecting arcs are installed. A cellular cofferdam structure must also be filled in stages because excessive filling in an individual cell can cause failure due to stresses in the steel sheets. Additionally, if unsuitable soil is encountered above the bearing strata it must be removed from within the cells prior to filling. This will require an internal bracing system at an elevation near the bottom of the structure to maintain stability.

Open water construction for both of these structure types requires numerous barges. The piles will be driven by barge-mounted equipment accompanied by material barges for the piles and structure fill.

**Existing Pier Considerations**

Constructing a solid fill structure around the existing pier is challenging. As discussed above, construction of a sheet pile wall or cofferdam will necessitate diaphragm walls that cross under the pier footprint. These walls cannot be installed without partial demolition of the existing pier. The presence of the pier also restricts the placement and consolidation of the fill. The contractor can hydraulically place fill underneath the existing pier. However, adequate compaction is not achievable without partial demolition of the existing pier. The weight of material will compress the underlying in-situ soil stratum which consists of highly compressible material leading to excessive settlements.

The existing piles were driven into the soil and achieved capacity through friction on the sides of the pile. The placement of the fill will induce down drag forces into the piles as the soils compress. These forces can be mitigated above the bay bottom by wrapping the piles to reduce the friction forces. Since wrapping of the piles below the bay bottom is impractical, significant forces will be imparted to the piles in the compressible in-situ soil layers.

The weight of the fill material placed above the in-situ soil layers will cause long term settlement. This settlement is likely to be differential, leading to cracking of slab, beam and pile cap members. Grout can be pumped into the voids between the top of the newly placed fill and the underside of the existing structure to provide support to structural elements. However, this will create long term maintenance issues as the soils continue to compress over time beneath the deck where monitoring is extremely difficult. This will lead to excessive maintenance costs in monitoring and grouting. Additionally, there is potential liability to the City should there be a localized failure over an undetected void.

Because of the long term settlement issues, surrounding the piles with fill does not provide continuous support to all elements of the existing structure to resist loads and it makes the components inaccessible for inspection or repair. Regardless of the placement, consolidation, and settlement issues, the remaining service life of the existing structure is a concern. The reason for replacement of the pier is that it has exceeded its design life and repair costs will increase annually as the deterioration increases exponentially.
Permitting Considerations

The solid fill alternative presents a complex environmental permitting impediment. Solid fill structures are typically used for land reclamation or creation of new land and are generally prohibited by The U.S. Army Corps of Engineers (USACOE) and the Florida Department of Environmental Protection (FDEP). Section 230.10 of the Code of Federal Regulations (CFR) 40 states “no discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences.”

Due to the size and impact of the project, all of the responsible regulatory agencies would require individual permit applications which have significant timeline and cost implications. For this project, a permitting timeline of 12 to 24 months or more should be expected. Furthermore, the agencies will require the following studies:

- Bathymetric Survey
- Environmental Resources Survey
- Wave Analysis
- Sediment Transport Analysis
- Hydraulic Model and Study for Water Quality

Justification for the environmental impact and a significant argument for why the pier could not be repaired or replaced in kind with less impact will be required. If allowed, the proposed loss of marine habitat associated with a fill structure would require mitigation for the impacted areas. The required amount of mitigation will be assessed during the permitting process. The quality of the submerged lands will be evaluated and a mitigation ratio determined by the FDEP. The mitigation requirements will be significantly impacted by the pier being located in the Pinellas County Aquatic Preserve. Typically the mitigation is expressed as a ratio which will dictate the amount of land the City will need provide for improvement and/or development into wetlands to offset the impacts. Should this land not be available it would need to be purchased and developed.

Permitting will be challenging and time consuming based on the Pinellas County, USACOE and FDEP rules and regulations; additionally, the attempt to permit will require environmental studies and proposed mitigation. The permit application is also challengeable by the public, which can significantly impact the timeline for the project, whereas a replace in kind alternative should be granted an exemption. A replace in kind alternative involves demolishing the existing structure and replacing it with one of the same footprint and similar structure type. The level of difficulty in permitting a replacement alternative varies with the amount of change to the existing design and configuration. The permitting process will be significantly more complex for the solid fill (land reclamation) alternative than it would be on a replace in kind alternative. Enlarging the footprint while keeping the structure type the same as the existing pier, as presented in Alternative 1 of the Bermello Ajamil & Partners, Inc. study will require aquatic studies and an individual permit application which is at least a 12 month process. Provided the agencies will consider a solid fill alternative, changing it to a solid fill structure will increase the required study effort and the time required to obtain the permit to approximately 24 months.
Additional Considerations

Solid fill structures are typically designed for a predetermined live load or allowable surcharge load, similar to a pile supported pier structure. This loading determines the size of the structural members and the depth to which the sheet piles are driven. Buildings on the pier will require independent pile-supported foundations for settlement and loading reasons.

Both structure types can be designed to achieve the same service life. The reinforced concrete in the pile supported pier and the steel sheet piles and reinforced concrete cap and fascia will deteriorate in the harsh marine environment and therefore will require bi-annual inspections and maintenance.

Opinion of Probable Construction Cost

Order of magnitude opinion of probable construction costs were developed for concrete and steel parallel sheet pile walls and for a cofferdam structure. The costs include demolition of the existing pier structure with cut-off of the piles at the waterline. Leaving the piles in place below grade will have minimal affect on the solid fill structure and is more cost effective than pile extraction. These estimates do not include demolition of the buildings constructed directly on the existing pier and reconstruction of the buildings and associated foundations. Mitigation costs are highly variable as discussed previously in this memo and they are not included in the values presented herein. All costs are for the structural components only and do not include considerations for electrical, mechanical, communications, landscaping, appurtenances or architectural features and are presented in 2010 dollars. It is recommended that a contingency commensurate with the level of concept development be added to the costs in the final computations prepared by the City.

The two large cost items for this type of structure are the sheet pile and the fill material. The length of sheet pile will vary depending on the results of a geotechnical evaluation of the soil conditions and the cost of fill assumes barging material from a Florida limestone quarry located north of St. Petersburg which provides FDOT-approved limestone. The material would be barged to St. Petersburg and unloaded by the contractor at an estimated cost of $35 per cubic yard. The summary of estimated construction costs are presented in the following table.

<table>
<thead>
<tr>
<th>Pier Replacement</th>
<th>Cost (per square foot)** (Total, Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier Replacement – Solid Fill – Steel Sheet Pile Retaining Wall</td>
<td>$121/sf $47M</td>
</tr>
<tr>
<td>Pier Replacement – Solid Fill – Concrete Sheet Pile Retaining Wall</td>
<td>$151/sf $60M</td>
</tr>
<tr>
<td>Pier Replacement – Solid Fill – Cofferdam</td>
<td>$227/sf $92M</td>
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</tbody>
</table>

*The values in this table do not include contingency costs which will be included in the final cost tabulations by the City. Additionally, land acquisition for mitigation, mitigation improvements, building demolition and replacement are not included in these costs.

**Cost is per square foot of land reclamation.