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September 21, 2007

RE: Petaluma Trestle Evaluation

Dear Mr. Delp:

I am writing in regards to the limited examination and evaluation of the timbers and piles supporting the railroad trestle along the waterfront in downtown Petaluma. The piles supporting the structure were examined during site visits on August 27 and 28, 2007.

INTRODUCTION: The general layout of the trestle was East to West, but the piles were numbered from West to East, starting with the bent adjacent to Abutment 1 (Bent 0) at the bulkhead. The trestle was retired from use and had been fenced off for a number of years. Structural panels covered most of the upper surface in an apparent attempt to make it safer, by covering openings in the structure. Several plans were being formulated for rehabilitation and reuse of the structure and an assessment of the general condition was requested.

PROCEDURES: The trestle was examined visually and the analysis of any damage noted during this investigation was made by probing of suspect wood components, by sounding, and by the pick test. The inter-tidal region of a number of piles and other elements were scraped to remove barnacles and other growth so that they could be examined for the presence of marine borers. Sounding involves hitting the wood members using a uniform force and listening for changes in tone. Areas that were soft when probed, were further evaluated by the pick test. The

pick test involves manually breaking a section of the latewood in the suspect region. The mode of failure was then analyzed and the presence of damage determined.

The findings from the evaluation and the general condition of various elements are presented in **Table 1**. In general, the condition of the various components was fairly consistent, with "patterns" of degradation observed. Many of the wood components were also evaluated, by engineers with Creegan + D'Angelo, using a Resistograph.

RESULTS: A number of wood components were sampled for identification purposes. A specimen from Pile E in Bent 19 was identified as coastal redwood (*Sequoia sempervirens*). A specimen from fender pile adjacent to Bent 17, a specimen from the pile cap in Bent 31, and a specimen from the outrigger supporting the water side (North) walkway along the trestle were each identified as Douglas-fir (*Pseudotsuga menziesii*). The presence of incisions on some of the wood components, and exudate from these materials, indicates that they were pressure treated with a wood preservative, such as creosote. The hardware was rusted and its integrity should be evaluated.

A number of the bents were visually out of alignment, apparently due to soil movement adjacent to and beneath the structure. The pile caps did not squarely meet the tops of a number of piles, especially between bents 12 and 30. A gap was visible between the outer (water side) edge of the piles and the caps and most gaps were filled with shims. Shims of various types (solid wood and plywood) were common in this structure and the condition of these components varied.

Piles: Surface degradation was observed in the inter-tidal zone of the piles. A "dimpled" surface remained in this zone where marine borers had attacked. The top surfaces of the piles in the structure were partially covered by a cross member "cap" timber, limiting access to the upper surface. The piles in this structure typically had a notch mechanically carved out of them above the high tide level. The purpose of this feature was not known, but it tended to expose the more porous end grain of the wood to the elements. The loss in cross section within the inter-tidal zone was generally greater than the depth of the notches into the piles, but its presence should be noted.

The redwood piles were not incised and did not appear to be treated with any preservative. It appeared that the sapwood and the outer portion of the heartwood in the piles was being attacked, but

the extractives in the center of these piles continued to offer some protection. Most of the piles were considered in a fair to poor condition, but still had a core of sound material. The tops of numerous piles were decayed beneath the cap. Repairs appeared to have been made in some areas where shorter (cut) piles had an additional cap section installed over the tops of them.

The outer surface of many piles was de-fiberized, or pulped, with loose wood fibers covering the surface to this depth. Some weathering, algal growth, and defiberization had loosened fibers to a depth of approximately ½ to 1 inch (up to 2 inches of diameter loss, because damage encircled the piles). The cause of this defiberization was not determined. Treatment with phosphates has been shown to cause similar issues and so has the formation of crystals within the cells of the wood as the material that has been wetted with salt water dries out and the salts recrystalize out of solution within the wood fibers.

Fender Piles: The fender piles in many locations had evidence of degradation, with pockets of decay beneath rusted top flashing and checks or voids evident in other areas. The intertidal zone was typically degraded. These members were preservative treated and the envelope of treatment was breached in numerous instances.

Deck: The deck assembly suffered fairly extensive damage. This included the panels placed as a temporary covering on the top surface. The panels were decayed to the extent that they no longer had structural integrity or could provide protection to people walking on the surface. The panels now actually make the trestle more dangerous, because they limit visibility of the gaps between ties and structural members beneath. Holes through this material were evident where it appeared that someone had stepped through the panels in a number of locations. The dimensional deck boards were also degraded and replacement would be prudent.

Railroad Ties: The ends of the railroad ties were visible from the dock, but could not generally be probed because they were inaccessible. Most of the ends of these members appeared sound, with few checks or indication of degradation observable. The top surface of a number of these ties were probed near the rails and some degradation was evident. It was estimated that approximately 20 percent of the ties would need replacement, but a more thorough survey should be completed when the overlay material (panels) is removed and the ties are visible and accessible.

Stringers: The stringers could be reached from above and/or below in some areas. The stringers were in two groups of three (one group under each rail). Records indicated that many of the stringers were replaced during repairs to the structure in 1969. The stringers from bents 17 through 30 were reportedly replaced at that time. The shore side stringer between bents 32 & 33 was heavily decayed, with a large void within it. Decay damage was noted in the top surface of stringers in other areas and resistograph readings indicated the presence of degradation at the interface or joints between members in other areas. Holes were observed in numerous stringers in this structure. They were apparently drilled for hardware that was either not used in these locations or was no longer present.

Cap members: Most of the horizontal cap members appeared to be sound, although some issues were observed. End splits were observed adjacent to hardware on some members. Repairs to the structure appeared to include cutting the tops of some piles and insertion of a second section of horizontal cap material to fill the space.

Cross Members: The cross members in each bent included one diagonal (cross-bracing) and one horizontal member (sill) on each side of each bent. The condition of these members varied by location and the amount of exposure. The extent of degradation was randomly evaluated in these components. Additional inspection of these elements will be required.

Walkway Outriggers: These members were treated Douglas-fir and many suffered decay damage or were split by large fasteners. The number affected was not readily evident and a survey should be completed after the material on their upper surface are removed.

DISCUSSION: The inter-tidal zone of the piles showed damage resulting from attack by marine borers, commonly called the "termites of the Sea." Evidence of attack by shipworms, pholads, and limnoria (gribbles) was observed, but other pests are also present in the area. ***Attachment 1*** provides a general discussion of marine borers.

There are two general types of marine borers, the mollusks and the crustaceans. The primary species of mollusks that attack wood in the San Francisco Bay area are Bankia (formerly known as Xylotria), Teredo (***T. navalis*** and ***T. diegenesis***), and Martesia (pholads). Crustaceans active in this area include Limnoria (gribbles), and Sphaeroma. The actions of each are somewhat different.

The mollusks attach themselves to the wood and live in tunnels through most of their life cycle. Bankia and Teredo, or shipworms, living in the wood can attain a size of 1 inch in diameter and can be up to 4 feet in length, creating large voids within the piles. Shipworms can create a network of tunnels through the wood and may not be readily seen from the outside, often leaving the pile with a sound appearance. Damage can also occur below the inter-tidal zone. Pholads are mollusks with a clam-like appearance and generally grow to a length of approximately 2-2 ½ inches and 1 inch in diameter. While the shipworms line their burrows with a pearly material, the Pholads do not. An early report discussing the activity of Bankia, the 1921 San Francisco Bay Marine Piling Survey (SFBMPS), cites the destruction of piles near Alameda in approximately 21 months and those near the Golden Gate in six months.

The crustaceans are much smaller and they remain motile, creating numerous relatively shallow burrows into the wood, but they do so in great numbers and can cause a great deal of damage in a short amount of time. Damage by these organisms typically occurs in the inter-tidal zone. Limnoria, or gribbles, is a particularly aggressive pest and cracks or other breaches in the barrier protecting the pile (or checks or holes in the envelope of preservative treatment in exposed piles) can allow these organisms in. The 1921 SFBMPS report cited earlier notes that untreated pilings can be destroyed by this organism in six months to two years. Sphaeroma (the pill bug borer) is another crustacean that can affect the piles in this area, but the activity of this pest is not considered as significant as that of the other marine borers noted.

Other sections of the trestle suffered from the effects of fungal degradation. The spores of wood decay fungi are normal in the air so prevention and control of this microorganism in marine structures typically relies on the use of fungicidal preservatives.

CONCLUSIONS: The trestle has suffered a significant amount of degradation and will require repair for either proposed use. The extent of repair will vary with the intended use and loading that will be anticipated. If the trestle is to be used for a trolley service it will require more work and reinforcement than if it is used only for pedestrian loading. If it is left "as is" for any period of time the amount of degradation will continue to increase along with the amount of repair required.

RECOMMENDATIONS: The pressure impregnated components have a shell of preservative treated material around the outer surface and a core of untreated material in the center. When the outer treated zone is breached, the untreated core will become exposed and the wood becomes increasingly susceptible to degradation.

The piles will need some remedial treatment and repairs. The top surface of a pile, beneath the cap (cross member), is more vulnerable because the end grain is more porous and vulnerable to decay. Pile damage in the inter-tidal zone should be protected so that the core is not further exposed. The original section from each pile, even those suffering from decay or attack, should be sound below the permanent water table, because an anaerobic atmosphere exists below this level and little degradation can occur in this environment.

The piles can be protected in several ways. The use of pile capping devices is discussed in ***Attachment 2*** and should be used on the tops of any accessible piles. Other remedial treatments include encapsulation with concrete jackets, impermeable high density polyethylene wraps, or fiber reinforced composite shells. These methods are discussed in ***Attachments 2 and 3***.

Fumigants would be an appropriate form of protection for many of the larger wood elements in the structure. These volatile chemicals are injected into the wood members and permeate it as they volatilize and pass through the wood. The presence of voids or openings into the wood can affect the longevity of the protection afforded. One available fumigant with a history of successful use is methylisothiocyanate (MITC). It is available in various strengths or concentrations for different uses. The strongest concentration available should be considered for use in this application. Discussion of the use of fumigants can be found in ***Attachment 4***.

Sincerely,

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Petaluma Trestle: Field Evaluation of Inter-Tidal Zone					
Bent	Member	Evaluation	------ C+E ------		
			Rating	Resistograph	
				(KAF Interp)	
Abut 1	Abutment 1	-			Bulkhead at the West end of the trestle, numbered Bent "1" in a previous report
Abut 1	A-D	Visual			Loss in xs @ mud line
Abut 1	E	Visual			Poor condition, decay, marine borers, checks
Abut 1	Diagonal	Visual			Deteriorated and failed
1	Cap	Visual			No degradation readily evident
1	A-B	Visual			Base in concrete
1	C-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
1	Diagonal	Visual			Both were in place and no degradation was readily evident
1	Horizontal	Visual			One member missing, other appears sound
2	Cap	Visual			Shims on cap decayed
2	A-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
2	A-B	Visual			2 piles w/base in concrete
3	Cap	Visual			Large end split @ bolt
3	A-E	Visual			Piles in "typical" condition, loss of outer material leaving the core intact
3	Diagonal	Visual			In place, no degradation evident
3	Horizontal	Visual			In place, no degradation evident
4	Cap	Visual			Decay damage was noted in the shim material (wedge) beneath the stringers above Pile D
4	A-E	Visual			Loss in cross section was typically 4-6 inches in these piles. Pile E appeared to have more degradation than the others.
5	Cap	Visual		5 Cap = OK	Appears to be sound, shims appear sound
5	A-E	Visual	5E = P	5E = Suspect	Typical degradation to outer portion of piles, loss of 4-6 inches more in Piles C & E
5	Diagonal	Visual			In place, no degradation evident
5	Horizontal	Visual			Obstructed from view
6	Cap	Visual			Cap split at through bolt.
6	A-E	Visual	6D = F	6D = Suspect	The piles at this location appeared to be in relatively poor condition, with Pile A completely gone.
7	A C & D	Visual			The piles at this location appeared to be in relatively poor condition.
7	B & E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
8	A-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
9	A-E	Visual			The piles in this bent were in a relatively poor condition with a loss of approximately 6 inches in diameter
10	Cap	Visual			A double cap was present in this bent.
10	A B C & E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
10	D	Visual			Pile D was somewht worse than the others.
11	A-D	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
11	E	Visual			A hole was evident in the intertidal zone of this pile and it was suspect
12	A-B	Visual			Connected & at least one appears failed
12	C-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
13	Cap	Visual		13 Cap = OK	A double cap was present in this bent.
13	A	Visual			This pile was square
13	B & D	Visual	13D = F	13D = Suspect	Typical degradation to outer portion of piles, loss of 4-6 inches
13	C & E	Visual	13E = BP	13E = Suspect	These piles appeared more heavily attacked
14	Cap	Visual			A double cap was present above pile B.
14	A-D	Visual			These piles appeared more heavily attacked
15	A-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
15	E	Visual			Cap not fully on pile (~1/2 off)
16	A-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
17	Cap	Visual		17 Cap = OK	A double cap was present above piles A- C
17	A-B	Visual		17C = OK	Piles were split
17	C-E	Visual	17C = F	17E = OK	Typical degradation to outer portion of piles, loss of 4-6 inches
18	Cap	Visual			A double cap was present above pile B. The small cap had a split.
18	A-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
19	Cap	Visual		19 Cap = OK	No degradation readily evident
19	A B C & E	Visual	19C = F	19C = 1/2" Void	Typical degradation to outer portion of piles, loss of 4-6 inches
19	D	Visual	19D = F	19D = Suspect	This pile appeared more heavily attacked
19	Stringer	Visual		Edge Decay	Not examined
20	A	Visual	20B = F	20B = Suspect	Typical degradation to outer portion of piles, loss of 4-6 inches
20	B-E	Cleaned	20E = P	20E = Suspect	Degradation affected the outer portion of these piles to a depth of approximately 4-6 inches, including defiberized zone.
21	A-D	Cleaned			Degradation affected the outer portion of these piles to a depth of approximately 4-6 inches, including defiberized zone.
21	E	No Access			Water too high

Petaluma Trestle: Field Evaluation of Inter-Tidal Zone					
Bent	**Member**	**Evaluation**	**------ C+E ------**		
			Rating	**Resistograph**	
				(KAF Interp)	
22	A-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
23	A	Visual			Cap not fully on pile (~1/2 off)
23	B-D	Cleaned			4-6 inch diameter loss plus 1 inch zone of defiberization
23	E	Cleaned			Degradation of 4-6 inches plus defiberization of 1 inch. Plant growing out of check indicates potential internal degradation.
24	Cap	Visual		24 Cap = OK	Cap was continuous over piles B-E, wider section extende from A to shore.
24	A-B	Visual	24A = G		Typical degradation to outer portion of piles, loss of 4-6 inches
24	C-E	Cleaned	24D = P	24D = Suspect	4-6 inch diameter loss, plus 1 inch zone of defiberization
25	Cap	Visual	24E = F	24E = Suspect	A partial double cap covered this widened bent.
25	A-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
26	Cap	Visual			Cap 1/2 off pile A, 1/4 off pile E
26	A	Cleaned			Mechanical damage to top, Dia. loss of 4-6 inches plus a defiberized zone of 1-2 inches, rusted fasteners
26	B-D	Cleaned			Dia. loss of 3-6 inches plus defiberized zone of 1-2 inches,
26	E	Visual			Top appeared poor
27	Cap	Visual			Cap 1/3 off pile A, shims decayed
27	A	Visual	27A = P	27A = OK	Top of pile split
27	B-E	Cleaned			Dia. loss of 3-6 inches plus defiberized zone of 1-2 inches,
28	A	Visual	28A = F	28A = OK	Typical degradation to outer portion of piles, loss of 4-6 inches
28	B-E	Cleaned			Dia. loss of 3-6 inches plus defiberized zone of 1-2 inches,
29	Cap	Visual			End split @ bolt, landslide knocked bent & deformed drift pin, cap off pile A
29	A-E	Visual	29A = P	29A = OK	Typical degradation to outer portion of piles, loss of 4-6 inches
29	Stringer	Sounding			No indication of degradation visually or by sounding
30	Cap	Visual			Incised
30	A-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
30	Stringer	Sounding			No indication of degradation visually or by sounding
31	Cap	Visual			Incised, end split
31	A-E	Visual	31B = F	31B = OK	Typical degradation to outer portion of piles, loss of 4-6 inches
31	Stringer	Sounding			No indication of degradation visually or by sounding
32	A-B & D-E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
32	C	Sounding			Square pile, poor condition due to powderpost beetle and other damage
32	Stringer	Sounding		Void evident	Heavy decay detected in shore side stringer - Remove & replace
33	Cap	Sounding		33 Cap = suspect	No indication of degradation visually or by sounding
33	A-C & E	Visual	33B = F	33 B = Suspect	Typical degradation to outer portion of piles, loss of 4-6 inches
33	D	Sounding	33D = G	33D = ok	Square pile, suspect at top
33	Stringer	Sounding		Edge Decay x2	No indication of degradation visually or by sounding
34	Cap	Visual		34 Cap = OK	No degradation readily evident
34	A	Sounding			Top and outer shell decay
34	B	Sounding	34B = F		Top and outer shell decay
34	C	Sounding			Outer shell deteriorated
34	D	Sounding			Incised, no indication of degradation
34	E	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
34	Stringer	Visual		2 Suspect, 1 OK	Not examined
35	Cap	Sounding			Incised, no indication of degradtion visually or by sounding
35	A	Visual			Typical degradation to outer portion of piles, loss of 4-6 inches
35	B	Sounding			Square pile, suspect at top
35	C	Sounding			Outer shell deteriorated, top suspect
35	D	Sounding			Outer shell deteriorated
35	E	Sounding			Top suspect by sounding, outer degradation at mud line
36	End - Steel @ bulkhead				
Other:					
16-17	Fender Pile			OK	Checks evident, treatment likely penetrated
19	RR Tie			OK	Not examined
34 - Walkway Outrigger				OK	Not examined