Napa County Flood Control and Water Conservation District

804 First Street
Napa, California 94559

MEMORANDUM

DATE: **July 17, 2014**

FROM: **Andrew Butler, Associate Engineer** AB

SUBJECT: **Feasibility Review of Railway Flood Closure Structures**

The attached report was created to document the feasibility level review of flood closure structures at the Napa Pipe redevelopment site. The report was prepared on behalf of Napa County Flood Control and Water Conservation District (NCFCWCD) staff. It concludes that there are six feasible options for closure structures at the site and ranks these according to several criteria. NCFCWCD staff concur with these conclusions.

NAPA PIPE REDEVELOPMENT

FEASIBILITY REVIEW OF RAILWAY FLOOD CLOSURE STRUCTURES

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Signed 6-25-14

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Purpose

The following is a limited technical feasibility review of alternatives for the proposed north and south railroad flood closures currently proposed in support of the Napa Pipe Redevelopment. HDR has reviewed the drawings entitled "Tentative Map Napa Pipe Redevelopment Napa County California" developed by Riechers Spence Associates, Inc. (RSA). Additionally, we have further investigated other commonly used flood closure systems used at railways and have provided information on the advantages and disadvantages of each.

Area of Proposed Flood Mitigation

Figure 1 depicts the proposed flood gate locations which serve to prevent inundation of the railroad tracks with the goal of maintaining unobstructed emergency road access to the west side of the railroad tracks. The flood gates would span across the railroad tracks to form a barrier between a proposed earthen berm to the east and a proposed retaining wall to the west.

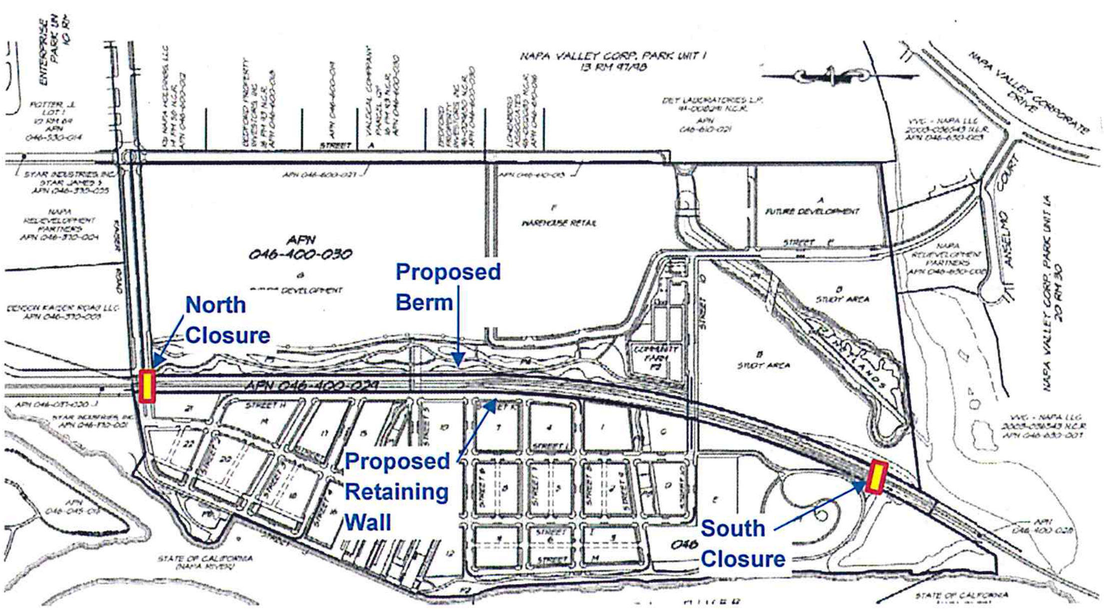


Figure 1. Railway Flood Gate Locations Proposed by Riechers Spence & Associates.

Figure 2 depicts the typical post development section across the railroad tracks with the earthen berm to the east of the railroad tracks and the retaining wall on the west side. This section depicts an approximately 80-foot wide railroad right-of-way (ROW) with a earthern berm to the east of the ROW and a retaining wall to the west of the ROW. Both the earthen berm and the retaining wall are to be designed to hold back floodwaters of the design flood.

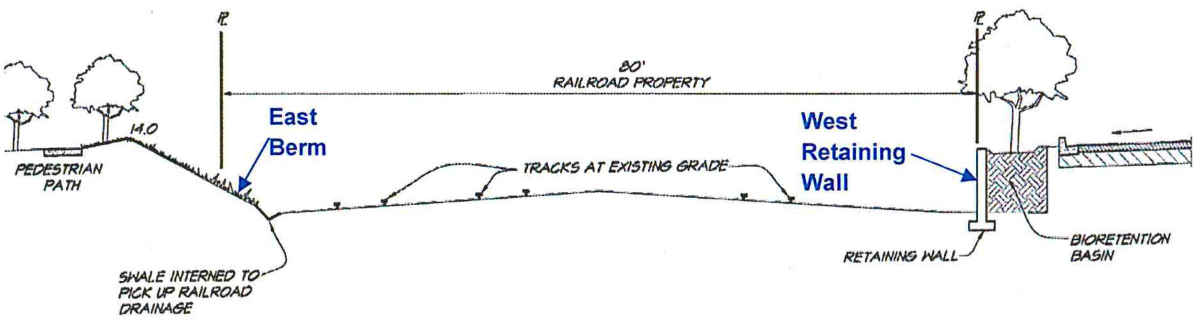


Figure 2. Typical Section Across the Railroad Tracks.

According to information presented in *Geotechnical Feasibility Study – Napa Pipe Facility Site* prepared by Treadwell & Rollo dated January 23, 2007, the site is underlain by compressible marine deposits that will further consolidate in response to the placement of new overlying fill. The construction of the proposed berm and fill to be retained by the the proposed retaining wall will experience on the order of three to six inches of settlement depending upon the final thickness of the new fill. The potential for differential settlement between the railroad right-of-way land area and the adjacent berm/retaining wall construction must be accounted for in the design of the flood gate closure structure.

The post development flood areas with no flood barriers (proposed flood gates open) are shown in Figure 3, in blue, with a maximum flood elevation of 8.40-feet MSL. Under this condition, the railroad tracks are inundated from Kaiser Road to the north to the lower-laying wetland area to the south. The proposed berm to the east and retaining wall to the west of the railroad tracks prevents flooding on either side of the railroad right-of-way.

Figure 4 depicts the intended flood barrier result with the proposed flood gates closed. The flood barrier prevents flood water from the Napa River from inundating the railroad tracks in the proposed development area; however, approximately 700 feet of railroad track to the south of the development area will still be flooded.

The 100 year floodplain boundary shown crossing the railroad track to the north appears to be located just south of the proposed north flood gate location. It may therefore appear that the north flood gate may be thought of as optional. We believe the north flood gate serves the important role of preventing a flood from outflanking the flood barrier system.

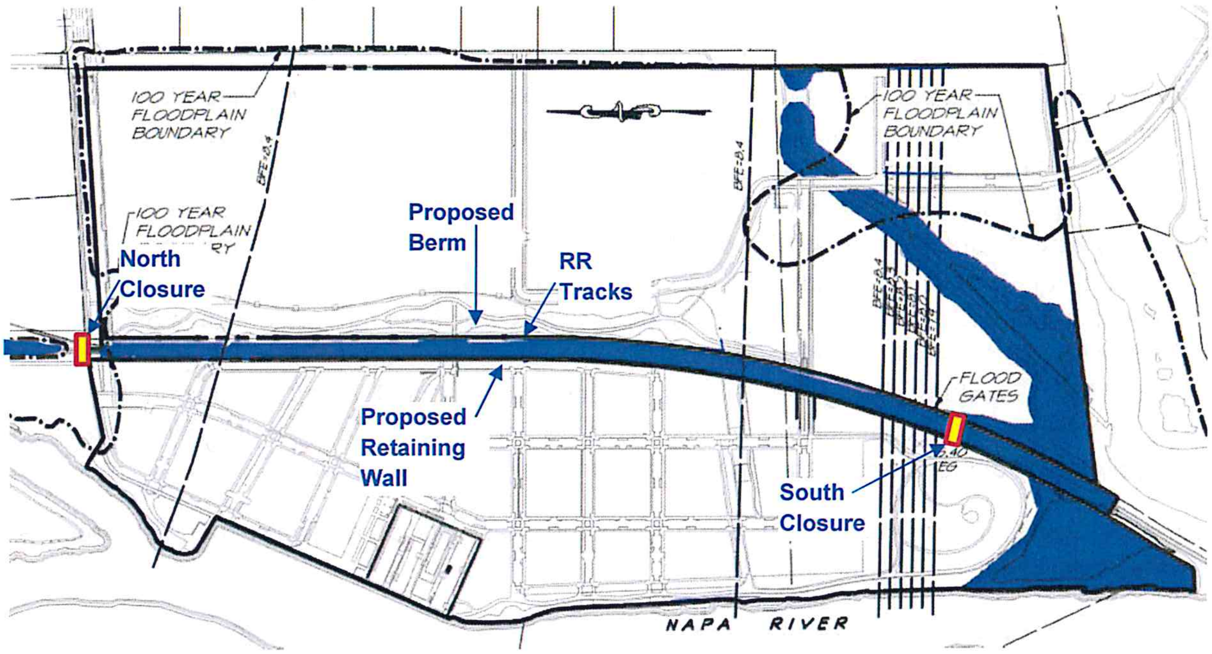


Figure 3. Flood Exhibit Post Development with Flood Gates Open.

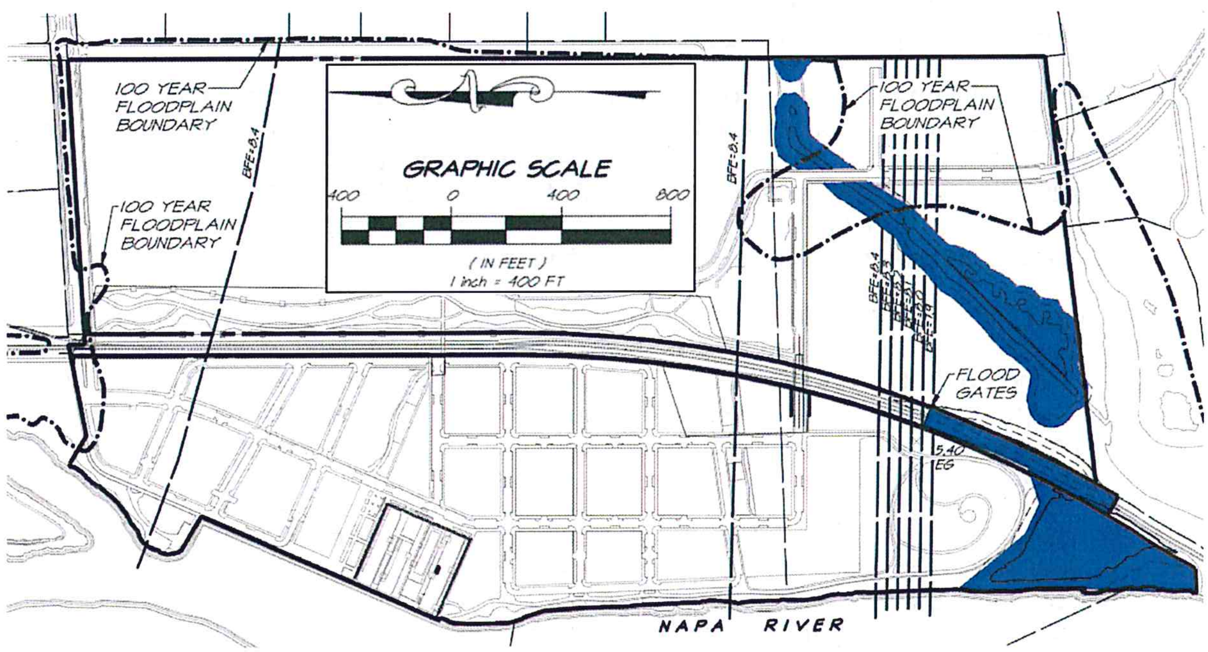


Figure 4. Flood Exhibit Post Development with Proposed Flood Gates Closed.

Railway Flood Barrier Objectives

The proposed flood gate locations for the current project serve to prevent inundation of the railroad tracks with the goal of maintaining unobstructed emergency road access to the west side of the railroad tracks. Closure structures in general are commonly used at openings in levee and floodwall systems when facilities such as railroads, road-ways, and pedestrian walkways pass through levee and floodwall systems at elevations below the level of protection provided by the project. The widths of openings for these facilities vary depending upon their functional purpose. Openings for railroads and roadways vary from moderate widths of 20 to 40-feet to widths of 100-feet or more. The US Army Corp of Engineers Engineering Manual EM 1110-2-2705, Structural Design of Closure Structures for Local Flood Protection Projects, provides information on commonly used flood barriers, including those spanning railroad tracks. The applicability of these barriers for the current project is discussed herein.

Important items of consideration in determining the feasibility of a closure barrier across a railroad right of way include the following:

1. Water Retention – water retention considerations include water-tightness and structural soundness of the closure barrier.
2. Underseepage – a major consideration for any flood barrier across a railroad right-of-way is preventing seepage through the underlying track ballast and supporting soil. Since the ballast is designed for drainage, a method of sealing the ballast is needed to prevent underseepage at the barrier location.
3. Interior Drainage – Flooding commonly occurs during inclement weather with heavy or sustained rains. A flood barrier system such as that proposed for the current development must be able of not only keeping water out, but provide a method of draining the water that is collected behind the flood barrier, which naturally leaks, to prevent internal ponding/flooding. Evaluation of interior drainage requirements was not specifically considered for the current proposed project.
4. Setup Time – The scheduled time for closure of structures should include a cushion to ensure that closure is completed well before the arrival of flood waters. The required lead time and the types of operating equipment and operations personnel available to the responsible agency, including the annual training of operations personnel, are the primary considerations in determining the type of closure structures suitable for particular applications.
5. Functional Requirements – Functional requirements for railroads affect the design of closure structures. Existing site topography and clearance requirements for railroads are primary functional considerations which must be incorporated into the design of closure structures. Minimum horizontal and vertical clearances must meet the requirements of the AASHTO (1989). The normal minimum width of opening provided for railroads is approximately 20-feet for each set of tracks involved in the closure. Clearances must be coordinated with and approved by the facility owner.
6. Maintenance – Proper maintenance of closure structures is essential to the continuous satisfactory performance of the structures. The required maintenance provisions must be included in the agreement with the responsible agency. Current agreements with responsible agencies require annual periodic inspections of the closure structures and

the adjoining levee or floodwall. Inspections must be thorough so that any deficiencies that are critical to the function of the project are detected and promptly corrected. Designs should incorporate materials, systems, and features which are economically feasible and require minimal maintenance.

7. Aesthetics – Since the proposed flood barriers are located in a populated area, visual aesthetics must be incorporated into the design.

8. Safety – The design of closures must include safety provisions for the public and the operations personnel. The responsible agency is responsible for the safe operation of closure structures; therefore, designers must coordinate with the agency so that the appropriate design provisions are incorporated to ensure safe operation. General safety provisions include providing railings on the top of gates and adjacent walls for public protection and providing ladders for access by operations personnel. Additional safety features could include warning signs and barriers which prevent access by unauthorized persons.

9. Security – The design of closure structures must include security provisions which prevent vandalism and the impairment of operating capability. Locked storage facilities which are inaccessible to the public should be provided for the storage of stoplogs, removable posts, and other unsecured parts of closure structures. In areas subject to vandalism, masonry buildings should be used. Latching devices which hold gates in the stored position should be provided with adequate locks.

10. Construction – Construction procedures and methods should be considered during design to facilitate the general constructability of closure structures. All phases of construction and erection procedures, particularly for gated closure structures, should be considered and design details developed which minimize complexities.

11. Cost – The costs of previously constructed closure structures vary according to the closure type and opening size. These variations should be considered in making cost-effective decisions in the selection of the closure type and the design of closure structures.

Flood Barrier Common Features

There are two design considerations that will be common to each of the flood barriers under consideration; these are underseepage and interior drainage.

Underseepage

As discussed previously, underseepage through the underlying track ballast and supporting soil is a major consideration for a functional flood barrier. Underseepage prevention methods to be considered could include: concrete foundations, thin slurry walls (bentonite-cement-slurry), jet grouting, secant pile walls from concrete of slurry, injection walls, or sheet pile walls.

To construct the underseepage barrier, a railroad segment would have to be temporarily removed from service for construction. Once the underseepage barrier has been constructed at the needed depth below the railroad ballast and supporting soil interface, a concrete structural section could be used under the tracks for a short length in place of the ballast. The interface of the underseepage barrier and the concrete section would be designed to prevent leakage.

Interior Drainage

Water collecting behind the flood barrier due to rainfall or inadvertent floodwall leakage will have to be removed by gravity drainage or by pumping. For gravity drainage, piping or other means of conveyance would have to be constructed under or through the flood barriers into the downstream storm water collection system. Pumping would require the construction of sumps and a level-controlled automatic pumping system. The advantages and disadvantages of each interior drainage system are as follows:

Drainage Piping/Conveyance

Advantages
- Passive system
- Minimal maintenance

Disadvantages
- Difficult to connect to existing drainage system
- May require upsizing existing downstream facilities to accommodate additional flows
- During a flood, downstream facilities may not be effective in receiving drained flows (they may be flooded out)

Pumping

Advantages
- Quickly/automatically activated
- Can direct flow anywhere

Disadvantages
- Regular maintenance required
- May be more expensive to construct than drainage piping
- Reliability would require a redundant power supply

Closure Types

Closure structures are required at openings in levee and floodwall systems when facilities such as railroads, roadways, and pedestrian walkways pass through levee and floodwall systems at elevations below the level of protection provided by the project. The widths of openings for these facilities vary depending upon their functional purpose. Openings for railroads and roadways vary from moderate widths of 20 to 40-foot to widths of 100-foot or more.

There are several types of floodgate closures that have been used that are applicable to railroad crossing closures. These include:

1. Stoplogs

Stoplog closure structures usually consist of one or more sets of horizontal aluminum or steel beams, stacked vertically in the closed position. Aluminum stoplogs weigh less than steel stop-logs of the same size but do not have the same strength. For narrow openings, one set of beams or logs may span between support slots constructed at the edge of openings. For wider openings, intermediate, removable support posts are required as shown in Figure 5. Seals are not normally attached to the stoplogs; however, plastic sheeting, sandbags, or other available means should be used to reduce leakage through the stoplog closure structure. Storage facilities must be provided for the stoplogs, removable posts, and accessories. When secured areas are available, closure items may be stored on uncovered storage concrete pedestals or slabs; otherwise, a storage building must be provided.

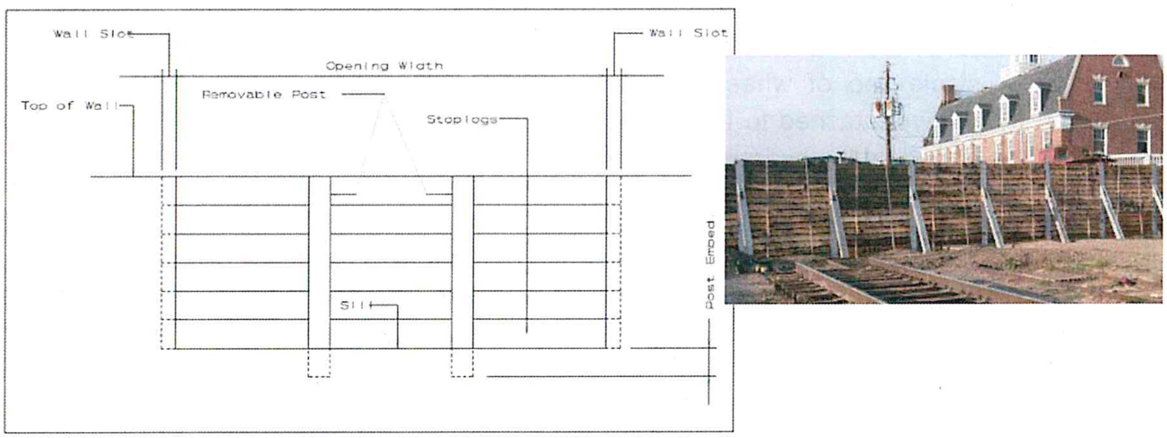


Figure 5. Stop-log Closure Structure

Advantages

- Fabrication methods are simple and economical
- Initial cost is usually less than for other closures, such as gated closures
- Is easily operated for narrow and low openings

Disadvantages

- Intermediate support posts or wide stoplogs are required for wide openings which usually require special lifting equipment for installation
- Accurate long-range weather forecasting is needed since a relatively long lead time is required to mobilize personnel and equipment for installation
- Installation time is usually increased to allow cleaning of the post sockets during installation
- Installation time is longer than required to close gated closures
- A storage building is required for stop logs to prevent damage by vandalism or loss by theft

2. Rolling Gates

Rolling gates are composed of a structural steel frame covered with a water barrier skin plate. The gates are supported by wheels that roll on tracks embedded in the sill across the closure opening and the storage area. J-seals are attached to the ends and bottoms of the gates to form a water-tight seal between the gates and the plates embedded in the end supports and the bottom sill. The gates are sometimes operated by a cable attached to a truck motorized winch; however, the cable could also be connected directly to a truck which pulls the gate open or closed. Alternately, the design may consist of a winch mounted at the site for gate operations. Latches should be provided to secure the gates in the stored and closed positions.

Rolling gates stabilized with two lines of wheels are composed of: horizontal girders, vertical intercostals, vertical end and intermediate plate diaphragms, a skin plate, and two lines of support wheels as shown in Figure 6. The wheels support and stabilize the gate against overturning. The wheels are usually V-grooved castings and roll on tracks that are usually inverted angles with embedded anchorages. The depth of the bottom girder is usually governed by the required transverse spacing between the supporting wheels rather than the hydrostatic load. A girder depth of 30 to 36-inches is normally required to accommodate the spacing between the two lines of wheels to provide stability of the gate during opening and closing operations.

Rolling gates with single line of wheels and stabilizing trolleys are usually composed of a trussed steel frame covered with skin plate or bridge planks. The gates are supported at the bottom by a single line of wheels and are stabilized laterally by an extended top girder supported by trolleys attached to the top of the floodwall as shown in Figure 7. Girder depths are usually governed by the hydrostatic loading on the gate.

Rolling gates with L-frames are usually composed of a series of L-shaped structural steel frames interconnected by horizontal and diagonal members. The gates are supported at the bottom by two lines of wheels as shown in Figure 8. Hooks attached to the heel of each of the L-frames engage anchorages embedded in the concrete sill structure to stabilize the gate against hydrostatic loadings.

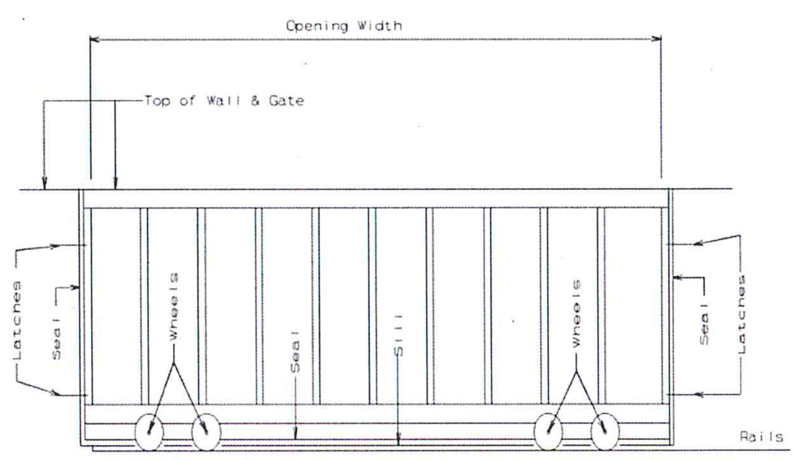


Figure 6. Rolling Gate Stabilized with Two Lines of Wheels

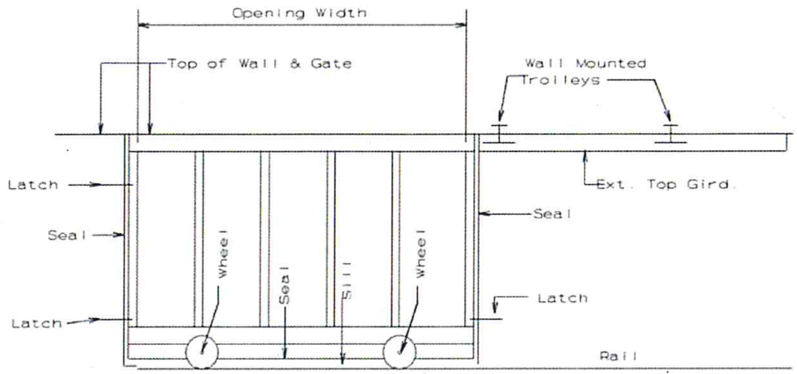


Figure 7. Rolling Gate - Single Line of Wheels and Stabilizing Trolleys

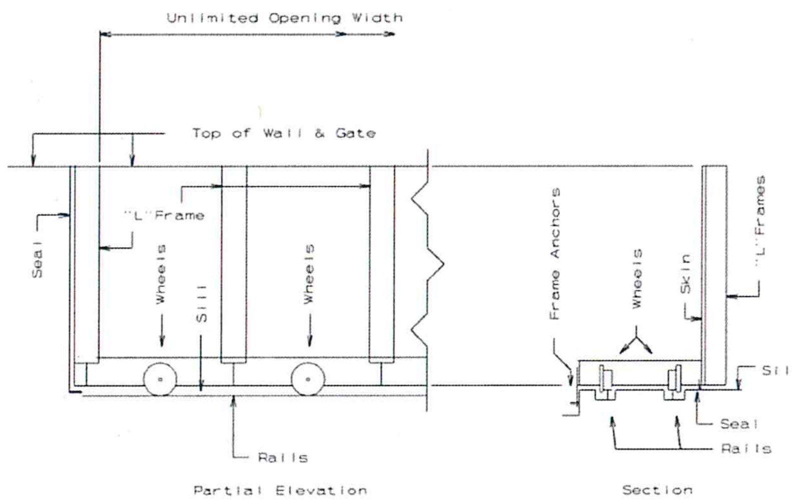


Figure 8. Rolling Gate - L-frame Stabilized by Hooks

Figure 9. Rolling Gate with Screw-down Seal Connections and Concrete Barrier in Railroad Ballast (New Orleans, LA)

<u>*Advantages*</u>	<u>*Disadvantages*</u>
Rolling Gates – Two Lines of Wheels • Adaptable to wide openings • Closure can be made quickly without the use of skilled personnel • A storage building is not required • Small storage footprint	• Requires a retractable bottom seal to accommodate non-level sill surfaces • Unless wheel assemblies are designed to accommodate the lateral bottom girder deflection, jacks must be provided to lift the wheel assemblies from the tracks when the gate is in the closed position • Requires level storage area immediately adjacent to the closure opening
Rolling Gates – Single Line of Wheels • Practical for closure widths up to 30-feet • Closure can be made quickly without the use of skilled personnel • A storage building is not required • Small storage footprint	• Requires a retractable bottom seal to accommodate non-level sill surfaces • Requires level storage area immediately adjacent to the closure opening
Rolling Gates – L-Frame • Can be designed for any opening width • Can be shop-fabricated in sections to simplify handling and storage • Closure can be made quickly without the use of skilled personnel • A storage building is not required	• Requires a retractable bottom seal to accommodate non-level sill surfaces • Requires level storage area immediately adjacent to the closure opening • Requires wide sill to accommodate the installation of tracks and hook anchorages

3. Leaf Swing Gates

Leaf swing gates are composed of two or more horizontal girders, vertical intercostals, vertical end diaphragms, a skin plate, and diagonal braces. Swing gates are supported on one side by top and bottom hinges attached to a support structure as shown in Figure 10. In most cases, swing gate closures consist of a single swing gate leaf. However, double leaf gates are used for wide openings. Double leaf gates must be stabilized by a removable center post or diagonal tie-back linkages as shown in Figure 11. One end of the diagonal linkage rods shall be permanently attached to the free ends of each gate leaf. The other end of the each linkage rod is attached to the support structure when the gates are closed. A support jack is provided beneath the gate to withstand the vertical component of load from the linkage rods. Rubber J-seals are attached to gates to form a continuous water-tight seal between the gates and supporting walls and sill of the opening. Closure provisions should include the use of winches or motor vehicles to accomplish closure during strong winds.

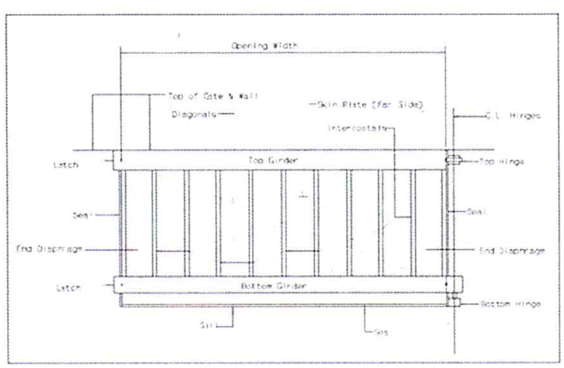
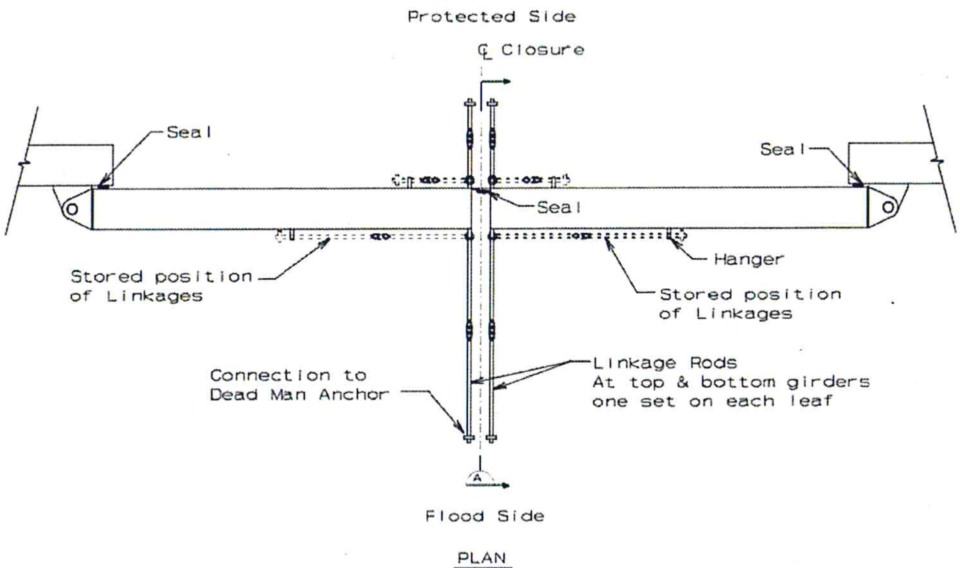


Figure 10. Single Leaf Swing Gates



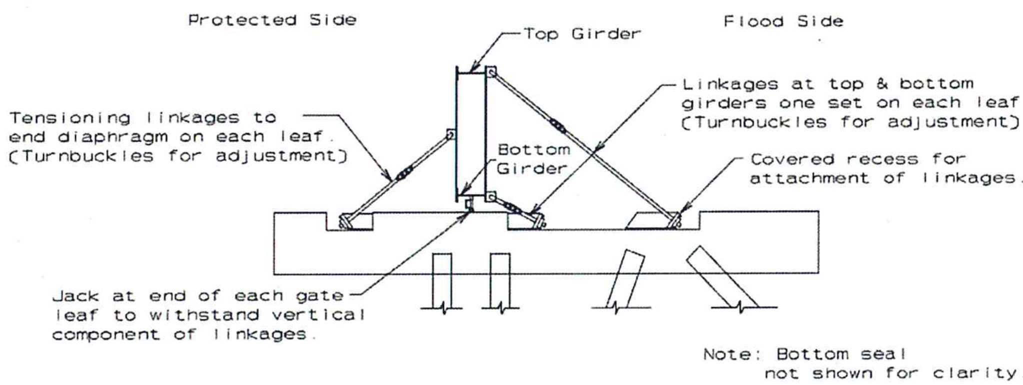


Figure 11. Double-Leaf Swing Gates with Tie Back Linkage

Figure 12. Dual swing gates across a railroad, Harlem City, NY

Advantages

- Single leaf swing gates are more practical for opening widths up to 40-feet
- Skilled personnel or equipment are not required for operation except when removable intermediate support posts are used with double leaf gates
- A short lead time is required for making closure except when removable intermediate support posts are used with double leaf gates

Disadvantages

- Requires right-of-way area for operating
- A storage facility is required when removable intermediate support posts are used with double leaf gates
- Maintaining a seal at the bottom of the gate can be challenging
- Requires a retractable bottom sill to accommodate non-level sill surfaces
- Is difficult to operate during high winds

4. Trolley Gates

Trolley gates are usually composed of top and bottom horizontal girders, other secondary framing members, and a skin plate. Trolley gates are suspended from trolleys running on an overhead rail and beam supported by the floodwall as shown in Figure 13. The gates are opened and closed by a winch arrangement similar to that used for rolling gates.

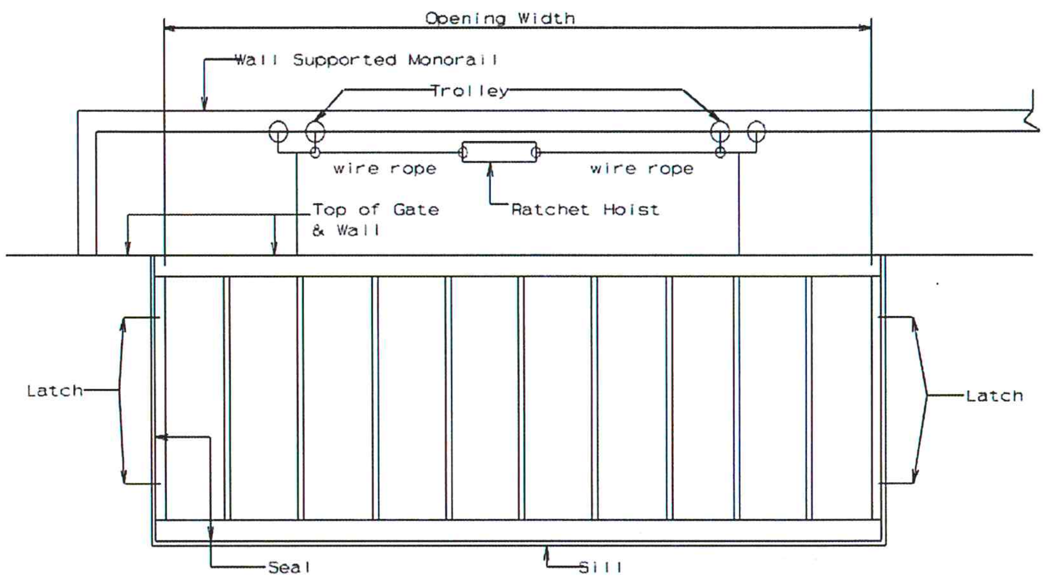


Figure 13. Trolley Gate

Advantages

- Practical for closure widths up to 60-feet
- Skilled personnel or equipment are not required for operation except when removable intermediate support posts are used with double leaf gates
- Can obtain a good seal against irregular sill surfaces
- A storage building is not required
- Small storage footprint
- Suitable for railroad closures because required vertical clearances for railroads are fixed

Disadvantages

- Slope of the ground adjacent to the closure opening must allow adequate clearance to open the gate
- May be rendered inoperative due to permanent overhead support members being damaged by vehicles or other sources, or removable overhead support members or their anchorages being damaged during removal or placement operations
- A guide member at the base of the gate may be required to support the gate against wind loads during opening and closing operations

5. Passive Hydraulically Positioned Barriers

Passive flood barriers automatically deploy, lifted by the floodwaters, should a flood event occur. During dry times, the gate returns to its hidden position allowing unimpeded access. Two options are available for the railroad rails:

- For modest flood depths rails mount on the barrier and stay on the barrier during flood event. After the flood event, the barrier closes with rails returning to surface grade.
- For greater flood depths rails mount on the barrier and are demounted prior to the flood event allowing the passive automatic barrier to close without rails. After the flood event, the barrier returns to surface grade and the rails are remounted. This option would require operator intervention before and after the flood event.

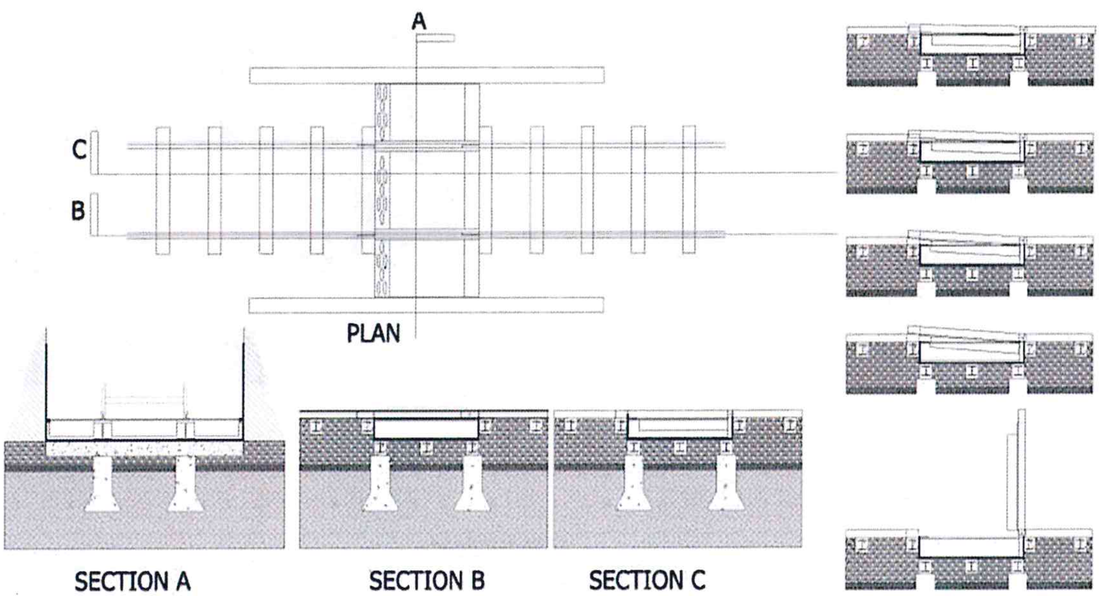


Figure 14. Passive Automatic Flood Barrier Across Railroad Tracks.

Advantages

- Uses hydrostatic pressure without power or equipment to set up
- For the option of rail mounts on the barrier, no human interaction is needed for the system to operate

Disadvantages

- For the option of rail mounts on the barrier, maintaining track rail alignment may be a challenge and would need special permitting with the railroad
- For the option of demounting the rails from the mounts, operator intervention would be required both before and after a flood event.
- Proprietary system (FloodBreak® Automatic Floodgates | Passive Flood Barriers) without extensive history of usage on railroad projects

6. Water-Filled Bladder Dams

Water-filled bladder dams are made of flexible tubes that can be rolled out and filled with water to create a temporary dam to control flood waters. After the flood event, the dam is drained and rolled up for storage. Because the bladder tubes are flexible, they can span and rails and ties with a good seal without special preparation of the ground surface. Bladder dams do not require special retaining walls or abutments at their ends to operate and would work well to span the existing topography at the northern closure; however, they work well in concert with these features if they are already present, such as at the south barrier. Underseepage issues would still need to be addressed in using bladder dams. Figure 15 shows a sketch of bladder dam, as well as pictures of such dams in operation.

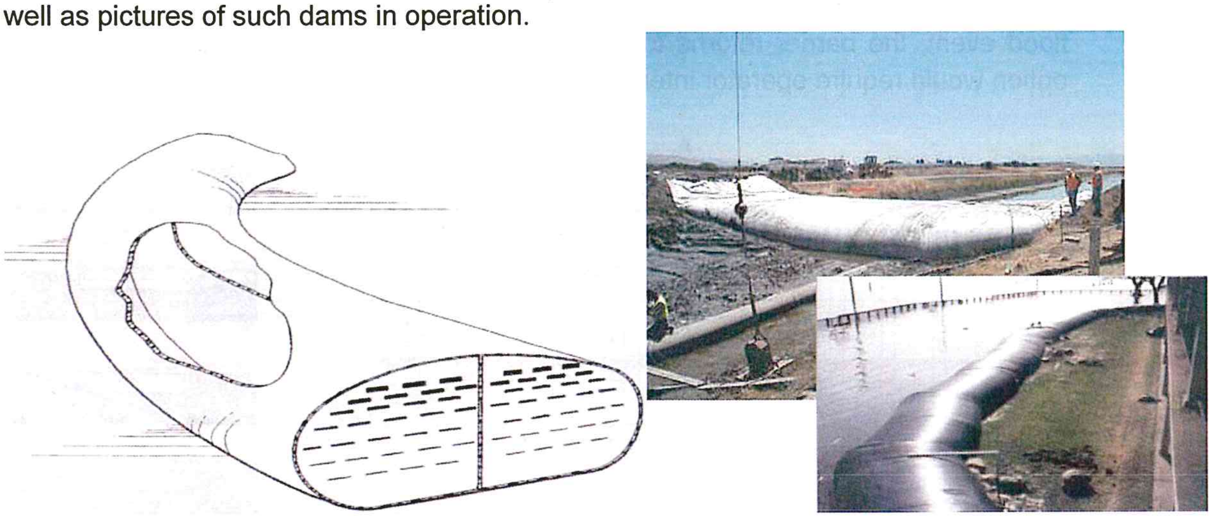


Figure 15. Bladder Dam

Advantages

- Easy to set up, simply roll out to position across the railroad ROW
- Flexible bladder tube seals irregular ground surfaces without special provisions

Disadvantages

- Needs a water source such as a fire hydrant to fill the dam
- May need mechanical equipment to position before rolling out
- Needs storage facilities
- Fill time could be an issue unless adequate water supply is provided

Closures Proposed By Riechers Spence & Associates

Riechers Spence & Associates (RSA) proposed two flood barrier options for each of the two flood closure locations (North Flood Barrier and South Flood Barrier). The barrier options are conceptual in nature and as such specific information is not provided about various issues that will have to be addressed to finalize the design. For example, sealing the railroad ballast or drainage provisions are not specifically addressed for any of the options. These details, as well as each of the objectives listed under

Railway Flood Barrier Objectives, would be addressed in the final design.

Option 1 – Both North and South Flood Barrier

This option is to construct a stoplog flood barrier with removable intermediate posts across the railroad ROW.

For the north flood barrier, retaining walls would be constructed on the outer edges of the railroad ROW (west edge and east edge) and would diminish into the existing rising ground slope. The stoplogs would slide into special grooves in the retaining wall edges. Nine removable intermediate I-beam posts are placed at approximately 10 foot intervals (staggered to avoid placement between the rails of the railroad tracks) between the two retaining walls with stoplogs spanning the posts as shown on Figure 16.

For the south food barrier, the stoplogs would span between the proposed retaining wall and a concrete abutment, located on the west and east edges of the railroad ROW, respectively. The stoplogs would slide into special grooves in the retaining wall and abutment. Seven removable intermediate I-beam posts are placed at approximately 10 foot intervals (staggered to avoid placement between the rails of the railroad tracks) between the retaining wall and abutment with stoplogs spanning the posts as shown on Figure 17.

For both locations the removable I-beam posts have permanent concrete footings flush with grade with sockets to accept the I-beam posts. Both options shown on the RSA drawings indicate the use of I-beams alone to support the stoplogs, however in practice many stoplog barriers need bracing for adequate support (as is shown to the image to the right).

The configuration of Option 1 corresponds to the stoplog configuration discussed earlier. The advantages and disadvantages of Option 1 therefore mirror those discussed previously. Some of the considerations not depicted on the Option 1 figure include how the stoplogs will be sealed, especially at the interface between the bottom stop log and the railroad tracks. Storage facilities must be provided for the stoplogs, removable posts, and accessories.

A relatively long lead time is required to mobilize personnel and equipment for installation. The I-beam posts will probably be too heavy for personnel to put into place without the aid of lifting equipment. Depending on the stoplog material and the lifting height, lifting equipment will also be needed to install the stop logs.

Major design details remaining to be addressed for this option include underseepage control at the railroad ballast and retaining walls, drainage control, and storage facilities.

Option 2 – North Flood Barrier

This option is to construct a two-piece sliding gate, each gate section 50-feet long, which operators would slide into position and latch together at the midpoint prior to a flooding event, see Figure 16. Similar to Option 1 for the north barrier, the sliding gates would span between retaining walls, with the retaining walls on the outer edges of the railroad ROW, both west edge and east edge, and diminishing into the existing rising ground slope. The track rails would need to be modified to provide a gap for the grade beam onto which the sliding gate pieces would travel along, as shown on the Track Detail of Figure 16. The grade beam for the sliding gates is mounted on a concrete footing; therefore a section of railroad track at each crossing point would need to be removed to install the footing and grade beam. Once the sliding gate has been rolled into position and latched, several hinged support brackets would be flipped out on the dry side of the gate and secured to flush-to-grade concrete piers to provide lateral support behind the sliding gate.

This option corresponds to the rolling gate closure described earlier, although it is unclear whether single line or two lines of wheels would be used for the gate rollers. The option for two lines of wheels would be better operationally because of the length of travel. A retractable bottom seal is needed at the grade interface to seal the gate. Figure 9 shows a screw-down type seal that can be considered for gate sealing.

The lead time to set up this type of gate system would be less than that of the stoplog option. However, the gate panels would be heavy and therefore mechanical equipment would still be needed to roll the gate into position. Additionally, the roller and grade beam system would need to be regularly maintained to prevent jamming as the system ages and the grade beam would have to be kept clear of debris for the rollers to work properly.

Unlike the stoplog option, storage facilities would not be needed for system components; however, the gates and hinged supports would need to be secured to prevent tampering and vandalism.

Option 2 –South Flood Barrier

This option is to construct a two leaf gate system, each gate section 40-feet long, which operators would swing into position and latch together at the midpoint prior to a flooding event, see Figure 17. Similar to Option 1 for the south barrier, the gate would span between the proposed retaining wall and a concrete abutment, located on the west and east edges of the railroad ROW, respectively. Similar to Option 2 for the north barrier, once the swinging gates have been swung into position and latched, several hinged support brackets would be flipped out on the dry side of the gate and secured to flush-to-grade concrete piers to provide lateral support behind the sliding gate. The flush-to-grade concrete piers for the lateral supports would be constructed across the railroad ROW to avoid placement between the track rails.

This option corresponds to the double leaf gate closure described earlier. A retractable bottom seal is needed at the grade interface to seal the gate. Figure 9 shows a screw-down type seal that can be considered for gate sealing. Figure 11 shows a tie-back and jack linkage that could be used for sealing the gate. Unlike the rolling gate option, the track rails would not have to be permanently altered with gaps, but like all of the options, a section of the track rails would have to be temporarily removed to install the underseepage barrier and concrete base for sealing the base of the gate.

The lead time to set up this type of gate system would be less than that of the stoplog option and possibly less than the sliding gate option because the swing gates would probably not need special equipment to swing into place. However, the gate panels, depending upon size, could be difficult to maneuver in windy conditions.

Like the sliding gate option, storage facilities would not be needed for system components; however, the gates and hinged supports would need to be secured to prevent tampering and vandalism.

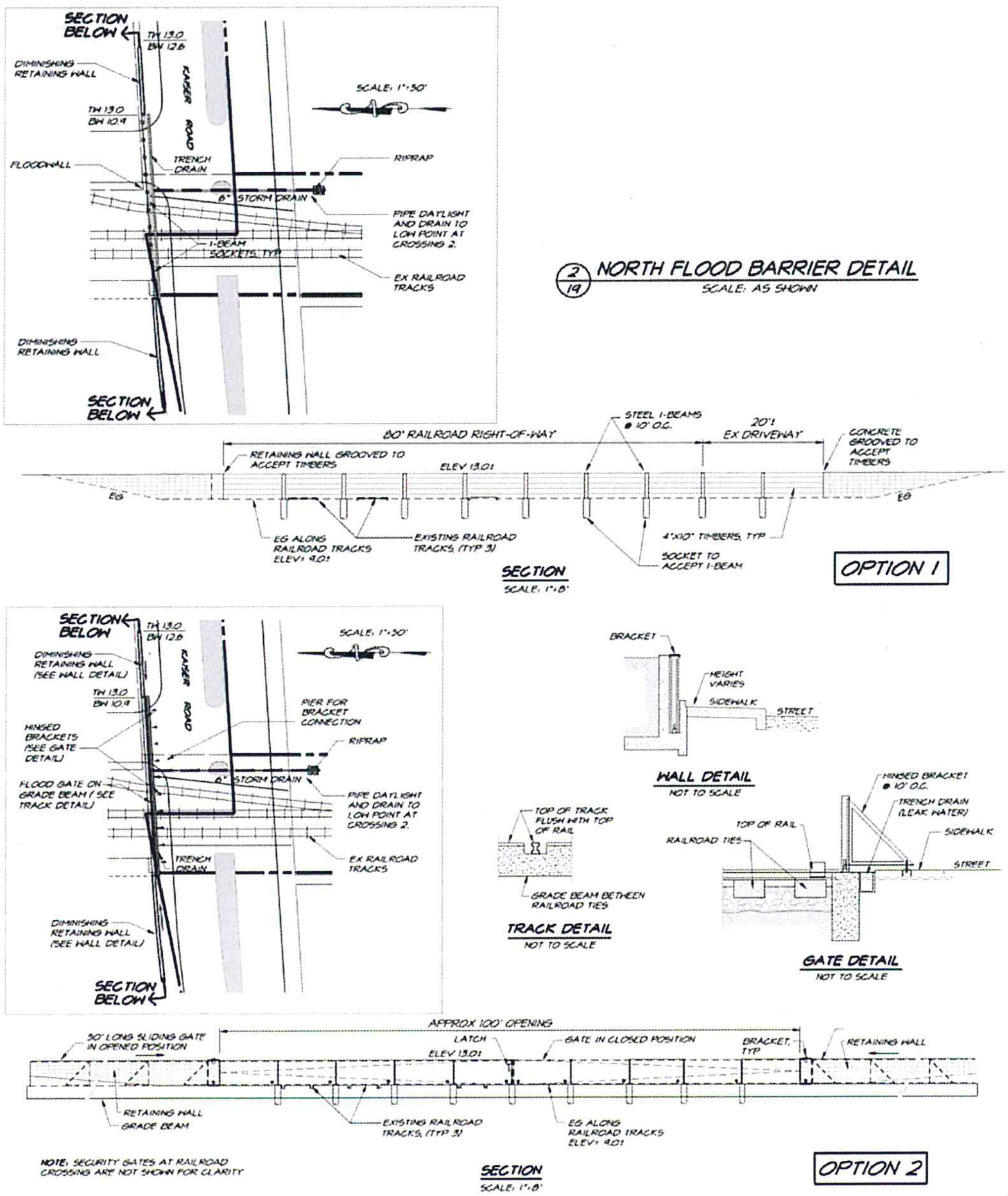


Figure 16. North Flood Barrier Options Proposed by Riechers Spence & Associates.

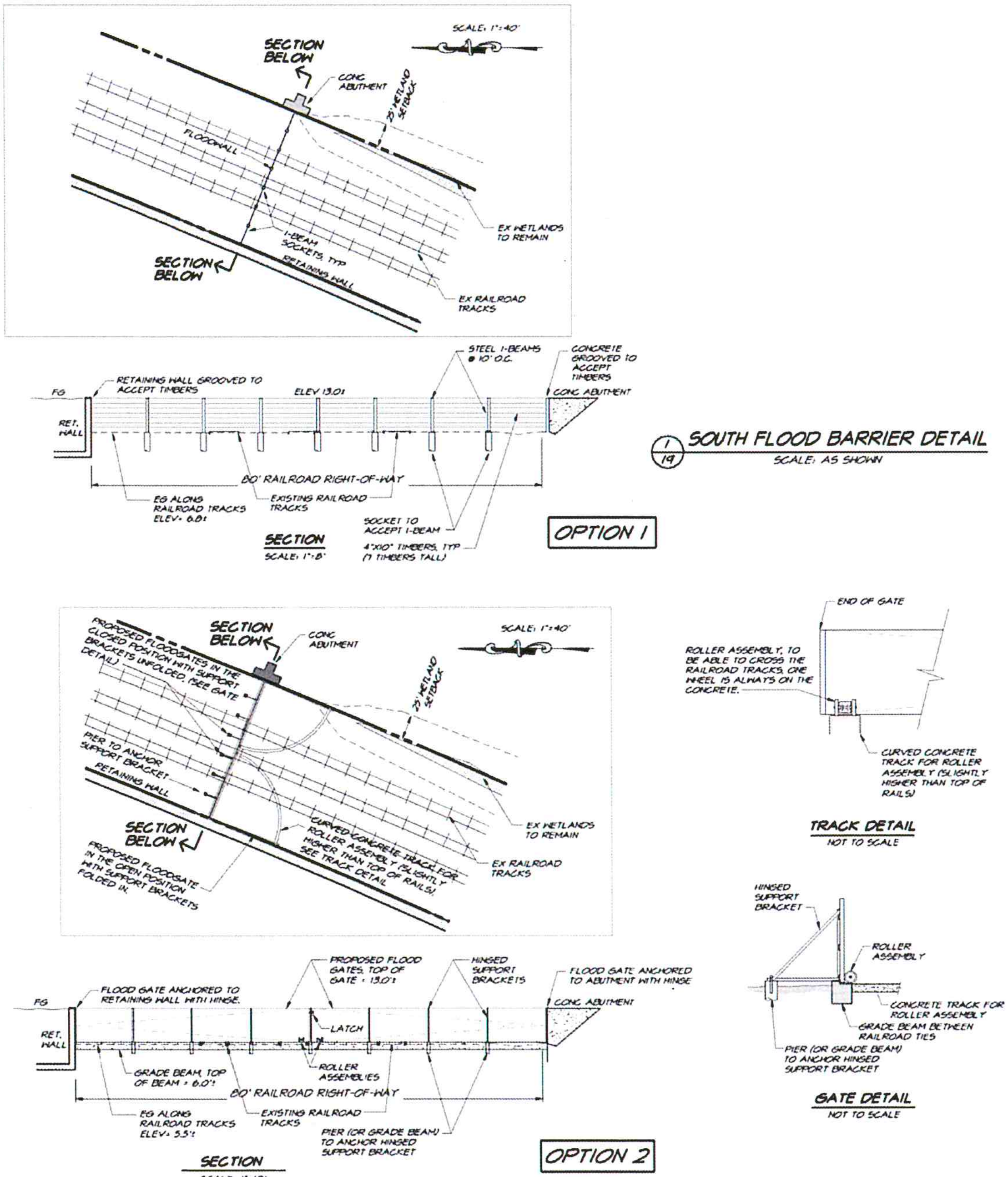


Figure 17. South Flood Barrier Options Proposed by Riechers Spence & Associates.

Scoring of Alternative Closure Barriers

The following matrix lists the gate options considered and quantifies the ability of the closure system to meet project objectives on the following scoring system: 0 – unacceptable; 1 – poor/difficult; 2 – acceptable; 3 – preferred. It should be noted that the scoring system does not consider some factors important to closure system selection, such as construction cost and permitting.

	Objective								
System	Water Retention	Setup Time	Maintenance	Aesthetics	Storage	Construction Difficulty	Score	Construction Cost	Total Cost of Ownership*
1. Stoplogs	2	1	2	2	1	2	**10**	$$	$$$
2. Rolling Gates	2	2	1	1	2	1	**9**	$$$	$$$$
3. Leaf Swing Gates	2	2	1	1	2	1	**9**	$$$$	$$$$
4. Trolley Gates	2	2	1	1	2	1	**9**	$$$$	$$$$
5. Passive Hydraulically-Positioned Barriers	2	3	2	3	3	1	**14**	$$$	$ - $$
6. Bladder Dam	3	2	2	2	1	3	**13**	$	$$$

* Order of magnitude cost, scale is independent of that shown for construction cost

Conclusion

As indicated in the scoring of alternatives above, the advantages and disadvantages of closure structure types 1 through 4 are grouped closely together with types 5 and 6 exhibiting notable advantages. Each of the closure structure types have characteristics capable of adequately addressing the important items, listed above in *Railway Flood Barrier Objectives*, to be considered for determining feasibility and it is HDR's opinion that each is suitable for use on the Napa Pipe Redevelopment Project site.

HDR recommends the project proceed into the preliminary design phase for the establishment of specific goals to identify preferred alternatives for which consideration will be given to long-term flood closure structure operation and maintenance costs, construction cost and railroad permitting.