

CHAPTER 7

Implementation of Safety Barriers and Devices



Chapter 4 presented a summary of safety barriers and devices that could potentially be used to improve the safety of the Walnut Creek Channel and Drop Structure 2. Of those barriers and devices, the CCCFCWCD is already using the following items, and consequently they do not require additional analysis:

- Fencing
- Vehicle Guard Rails
- Warning Signs

This chapter presents a summary of how the following safety barriers and devices could be implemented to improve the safety of the Walnut Creek Channel and Drop Structure 2.

- Escape Ladders
- Safety Racks
- Safety Nets
- Safety Cables
- Tension Diagonal
- Thermal Imaging

7.1 ESCAPE LADDERS

7.1.1 Implementation

There are a few existing safety ladders in the Walnut Creek Channel, but they are at irregular intervals, additional escape ladders could be installed on the vertical walls and steep side slopes of the flood control channel to achieve a 200 foot spacing between each ladder (400 feet between ladders on a single channel side). The ladders would be installed from the upstream side of the Drop Structure 2 to Treat Boulevard. The ladders would be fabricated from stainless steel and bolted into place. The bottom rung of each ladder would be 12-inches vertically above the channel invert. There would also be 3-foot wide yellow stripes painted at the channel walls on both sides of the ladder to provide better visibility of the ladders. An example of a flood channel safety ladder was shown in Figure 4-5. For the 3,700 foot segment of channel from Treat Boulevard to Drop Structure 2, 10 ladders would be installed on each side of the channel at a spacing of about 400 feet and yellow stripes would be painted on the channel walls on each side of the ladders.

7.1.2 Evaluation

At a flow of 18,000 cubic feet per second (cfs), the water velocity in the rectangular, concrete channel would be 27.8 feet per second, which is equal to 19 miles per hour. At a flow of 10,000 cfs the water velocity would be 23.1 feet per second (15.7 miles per hour). At a flow of 5,000 cfs the water velocity would be 18.2 feet per second (12.4 miles per hour). At a flow of 1,000 cfs the water velocity would be 10.0 feet per second (6.8 miles per hour). For comparison, a highly trained athlete running as fast as they can runs at about 18 feet per second (1,000 meter race in 3 minutes).

For someone trapped in the flowing water (at 5,000 cfs) to grab and hold onto a safety ladder (and self-rescue) would be equivalent to someone being able to run as fast as they can and then instantly stop themselves by grabbing a ladder. Additionally, if a person could grab and hold onto the ladder, the force of the flowing water would wash their body and legs downstream of the ladder, and it would be very difficult to get their feet onto the ladder in order to climb up the ladder. However, the water velocity would be slightly slower at the channel walls than in the center of the channel, but, it would still be very difficult for someone to grab and hold onto a safety ladder.

Safety ladders would provide only a limited increase in safety because of the difficulty of self-rescuing with a ladder. Ladders, however, also provide a means of unauthorized entry into the channel. The limited value of ladders must be balanced against the potential risk of increased unauthorized entry into the channel using the ladders.

Safety ladders would not significantly disrupt the flow in the channel. Even if debris accumulated on the ladders, only a small amount of the channel could be blocked. Consequently, the use of safety ladders would not significantly decrease the flow capacity of the channel or cause an increase in the water level in the channel.

During a storm event, safety ladders would not require a significant Operations and Maintenance (O&M) effort. Safety ladders can be damaged by debris in the channel flow and during maintenance with heavy equipment. Consequently, safety ladders would require routine O&M to remove the small quantities of debris that accumulates and for routine inspection of the ladders.

There would be no significant community or environmental impacts or benefits from the installation of escape ladders.

7.1.3 Cost Estimate

The estimated cost to manufacture and install a ladder would be about \$1,000 each, for a total estimated cost of \$20,000 for 20 ladders.

7.2 SAFETY RACK

7.2.1 Implementation

For the Walnut Creek Channel, a safety rack would be installed upstream of Drop Structure 2, in the straight section of channel between the drop structure and Bancroft Road. The safety rack would have slope of 4H:1V. The rack would have bars one inch wide centered every six inches. The rack would be connected to winches that would lower it into place only when a victim was trapped in the channel (see Thermal Imaging discussion below). The winches would be enclosed in small masonry buildings to protect them from weather and vandalism. The winches would be operated by rescue personnel either remotely (from a fire station) or on-site by rescue personnel. Along the top of the rack would be a single lane bridge suitable for a victim to climb onto from the rack (and suitable for performing O&M of the rack). There would be cross bars along the rack to provide structural strength to the rack. A victim trapped in the channel would reach the safety rack and then be washed up the rack to the level of the water surface. The victim would then either have to be rescued or perform a self-rescue.

7.2.2 Evaluation

This rack would screen a victim out of the flowing water. However, the rack cross bars would cause the risk of a person's arms or legs being caught and the person being trapped on the face of the rack. The rack could also present an "attractive nuisance" on which people might climb.

With this rack installed, assuming that it is clear of debris, the area available for flow would be five-sixths of the unobstructed channel. At the design flow of 18,000 cfs, the head loss through this rack would almost certainly result in the water level exceeding the concrete channel top. If the rack caused a hydraulic jump, the subcritical depth would be about 19.3 feet, which would overtop the concrete channel banks and would nearly exceed the top of the earthen channel banks (total depth of about 20 feet). If the hydraulic jump occurred, it could result in extensive scouring and erosion of the earthen channel and potentially damaging the concrete channel. Thus, the rack would significantly increase the risk of flooding and could also result in damage to the channel.

If the rack was left in place permanently, it would accumulate debris. Much of the debris would be pushed up the rack and accumulate near the top of the rack, leaving the majority of the rack clear. Nevertheless, the debris would increase the upstream water level, leading to an increased potential of a hydraulic jump. To keep the rack clear of debris would require significant maintenance during storm events. Also, large debris in the supercritical flow would impact the rack at a high velocity and thereby damage the rack.

During non-storm periods, the rack would require significant O&M effort. Debris that couldn't be cleared during a storm event would have to be cleared through post-storm O&M or routine O&M. Also the system would have to be inspected and operated periodically to ensure proper function during a storm event. The rack would have to be repaired when it was damaged by large debris.

The safety rack and winch enclosures could be constructed within the existing right-of-way of the channel. However, additional land would be required for access roads around the enclosures on each side of the channel (approximately 0.03 acres).

Safety racks are typically used in subcritical flow channels, and not in supercritical flow channels. Use of a safety rack in a supercritical flow channel would require extensive hydraulic evaluations to ensure proper function.

7.2.3 Cost Estimate

As shown in Table 7-1, the estimated construction cost of the safety rack system is \$1.8 million and the estimated total capital cost is \$2.4 million.

Table 7-1. Preliminary Cost Estimate for a Safety Rack

Item No.	Item Description	Unit of Measure	Estimated Quantity	Unit Cost	Total Cost
1	Galvanized Steel Rack	Square Feet	3,200	\$250	\$800,000
2	Single Lane Bridge	Square Feet	1,050	\$220	\$231,000
3	40 Ton Winches and Rigging	Each	2	\$150,000	\$300,000
4	Control System	Lump Sum	1	\$20,000	\$20,000
5	Winch Enclosure Buildings	Square Feet	400	\$200	\$80,000
6	Mobilization and Demobilization at 5 Percent	Lump Sum	1	\$72,000	\$72,000
Subtotal 1 (rounded)					\$1,503,000
Estimating Contingency (10%)					\$150,300
Subtotal 2 (rounded)					\$1,653,000
Construction Contingency (10%)					\$150,300
Total Estimated Construction Cost (rounded)					\$1,803,000
Design, Bidding, and Engineering Services during Construction Costs (10%)					\$180,300
District Costs (including Admin., Plan Check, etc.) (5%)					\$90,150
Construction Management (8%)					\$144,240
Environmental Documentation and Permitting Costs (5%)					\$90,150
Project Contingency (0%)					\$90,150
Land		Acre	0.03	\$700,000	\$21,000
Total Estimated Capital Cost (rounded)					\$2,420,000
Based on Engineering News Record 20-Cities Average Construction Cost Index of 9267 (March 2012)					
Assumes haul distance of 20 miles round trip					

7.3 SAFETY NETS

7.3.1 Implementation

For the Walnut Creek Channel, a safety net would be installed upstream of Drop Structure 2, in the straight section of channel between the drop structure and Bancroft Road. The net would be constructed of a mesh of steel cables mounted to a frame. The net and frame would be connected to winches that would lower it into place only when a victim was trapped in the channel (see Thermal Imaging discussion below). The winches would be set up to be operated by rescue personnel either remotely (from a fire station) or by on-site rescue personnel.

A victim trapped in the channel would reach the safety net and then have to climb up the net to above the water level. The victim would then either have to be rescued or perform a self-rescue.

7.3.2 Evaluation

Safety nets are typically used in subcritical flow channels, and not in supercritical flow channels. Use of a safety net in a supercritical flow channel would require extensive hydraulic evaluations to ensure proper function.

With a safety net, the flowing water would not necessarily push a victim up the net (like what would happen with a safety rack). Consequently, there is significant risk a victim becoming entangled in the net and drowning. A safety net is not a feasible solution in the supercritical flow channel upstream of Drop Structure 2. Consequently no additional evaluation of safety nets was prepared.

7.4 SAFETY CABLES

7.4.1 Implementation

Safety cables are ropes or cables with floats spaced periodically along the cable or rope. Safety cables could be installed across the channel along with escape ladders at each end of the cable. A victim would grab the safety cable, pull themselves to the edge of the channel and then self-rescue by climbing up the ladder.

7.4.2 Evaluation

As described above in the discussion of ladders, the water velocity in this supercritical channel is very fast. It would be difficult for a victim to successfully grab and hold onto the safety cable. Also, because the water level in the channel can vary by as much as 12 feet, either:

- The safety cables would have to have a significant slack so that it would float on the water surface at any water level. In this case, the victim would have to pull themselves along the cable and against the current to reach the escape ladder. It is unlikely that a person could pull themselves along the cable against the current.
- Cables would be installed at various levels in the channel. In this case, a victim could get trapped on a submerged cable and drown. Also the submerged cables would accumulate debris and could cause increased water levels.

Safety cables could be used in the subcritical flow channel section downstream of Drop Structure 2, specifically, in the stilling well between the existing baffles and the face of the drop structure. See Appendix 3C for a drawing of Drop Structure 2 and the sitting well. This cable would lead to additional cables along the stilling well walls that extend up the banks of the trapezoidal channel section. Also, an escape ladder would be placed up the banks of the trapezoidal channel. A second cable could be installed just downstream of the existing baffles. The second cable would also lead to the trapezoidal channel banks and the escape ladders.

Safety cables used below the drop structure would not prevent a victim from flowing over the drop structure and would not eliminate the submerged hydraulic jump that can entrain and drown victims. If the victim could successfully grab the safety cable and self-rescue, it would prevent the victim from being repeatedly submerged by the submerged hydraulic jump.

The safety cables would be constructed of marine rope, with floats every 3 feet. The safety cables would be connected to anchor bolts at 10 locations within the stilling well area.

7.4.3 Cost Estimate

The estimated cost to purchase and install the safety cables would be \$4,000 and the cost to install two escape ladders would be about \$4,000. The estimated total cost for this improvement would be about \$8,000.

7.5 TENSION DIAGONAL

7.5.1 Implementation

A tension diagonal consists of a rope or ropes (or cables) crossing the channel at a diagonal at the elevation of the water surface. The rope is tensioned so there is no slack. Rescue personnel are connected to the tension diagonal at the upstream end. As they enter the flowing water, the current pulls them along the rope. They stop themselves at the correct location in the channel to grab a victim floating in the channel. Then they allow the current to pull the rescuer and the victim to the other bank. At both the channel entrance and exit points there has to be an access ladder, ramp or other facility that provides safe entrance and exit from the channel.

For the WCFCCS, the tension diagonals would include extra-large ladders suitable for two rescue personnel, and a vertical bar onto which the tensional diagonal cables could be attached. When not in use, the tensional diagonal cables would be kept at the top of the channel above the water level. Additionally, several Anchor bolts would be installed in the channel top/walls for use as needed by the rescue personnel. Rescue personnel would slide the cables to the correct level when a rescue was underway.

Tension diagonals would be constructed at two locations along the channel. Two potential locations include the Treat Boulevard Bridge and the Bancroft Road Bridge. When a victim was discovered trapped in the channel, rescue personnel would be dispatched to both tensional diagonal sites. They would set the cable height and enter the channel at the Treat Boulevard site, and the first rescue attempt would be made at Treat Boulevard. If the first rescue was unsuccessful, the second attempt would be made at the Bancroft Road site (about 2 to 3 minutes later depending on the flow rate in the channel).

The best configuration for the entrance and exit ladders, ramps, or other facilities at each site would be developed in cooperation with the rescue personnel. Also, there may be other locations farther upstream where tensional diagonals could be implemented.

7.5.2 Evaluation

Because the tension diagonal would only result in a cable, rope and rescue personnel being in the water, it would not significantly affect the flow of the water or cause a hydraulic jump. Because it would only be lowered into the channel when required for a rescue, it would not accumulate debris. Tension diagonals have been used successfully in other supercritical flow channel systems.

If ladders were used for the tension diagonal entrance and exit, no additional land would be needed. There would be no significant environmental impacts or benefits (like fish passage) from the facilities.

The ladders would not require additional O&M during storm events. The ladders and bars might accumulate some debris, which would have to be cleared through routine O&M. The tension diagonal ladders, bars and cables would require routine inspections.

7.5.3 Cost Estimate

The estimated construction cost for each set of the tensional diagonal entrance and exit ladders, bars, and cables is about \$25,000. If access ramps were constructed, capital cost for each tension diagonal site would be about \$600,000 to \$700,000.

7.6 THERMAL IMAGING

7.6.1 Implementation

Several thermal imaging cameras would be located at strategic locations upstream of Drop Structure 2. The system of cameras and associated electronics would operate continuously, and if the thermal imaging camera detected a warm body in the cold water, the system would send an alarm and the image causing the alarm to the fire department dispatcher. The dispatcher would check the image to ensure that the warm body was in fact a person (not animal or other debris). For each camera location, the approximate time for the victim to flow from the camera location to a predetermined rescue location (like the tension diagonal locations) would be known. If it is a person in the channel, the dispatcher would then dispatch rescue personnel to the appropriate locations to perform the rescue (see the discussion about tensional diagonals above).

There are several types of thermal imaging cameras available with different sensitivities, and widths and depths of image field. There are outdoor cameras available that will function in all weather conditions. In fact, there are cameras with “windshield wipers” available to ensure they work correctly even in heavy rainfall. The cameras need to be connected to the internet. The connection could be wireless or wired.

This discussion is based on conversations with Flir Systems Inc. and Movitherm staff who are knowledgeable about thermal imaging, including:

David Shahan (800-853-8331)

Greg Cortina (661-965-1100)

Bill Lehmanowsky (866-477-3687)

Marcus Tarin (949-699-6600 x111)

The local Flir Systems Inc. representative is Eric Hughes (866-537-3245), who would be available to discuss this application, attend a site visit, recommend specific cameras, and associated systems, and provided refined costs.

7.6.2 Evaluation

The likely points of entry into the Walnut Creek channel system are from the trapezoidal channel segments at Civic Park and just upstream of Rudgear Road and west of Interstate 680. The distance from Civic Park to Drop Structure 2 is about 11,600 feet. The water velocity in the channel is dependent on the flow rate, and ranges from about 10 feet per second (flow of 1,000 cfs) to 27.8 feet per second (flow of 18,000 cfs). If one camera was installed just downstream of Civic Park on the Iron Horse Regional Trail Bridge, then at a flow of 18,000 cfs there would be almost 7 minutes from when a victim was detected in the water to when the victim would reach Drop Structure 2, and at a flow of 1,000 cfs, there would be almost 20 minutes. If one camera was installed at Rudgear Road, then at a flow of 18,000 cfs there would be almost 13 minutes from when a victim was detected in the water to when the victim would reach Drop Structure 2, and at a flow of 1,000 cfs, there would be about 37 minutes. For most storms, this would provide adequate time for the rescue personnel to be dispatched to the tension diagonal rescue locations.

Use of thermal imaging cameras would not impact the flow of water in the channel. There would be no hydraulic impacts from a thermal imaging system. The cameras would be installed on existing bridges or other structures, and no new structures would be needed. Consequently, there would be no significant community impacts. There would be no significant environmental impacts or benefits from the thermal imaging camera systems. The camera system would not require additional maintenance during storm events; however, they would require routine maintenance.

7.6.3 Cost Estimate

Depending on the camera selected, the cost for each camera would probably be about \$17,000. The associated electronics would cost about \$20,000. There would also be installation costs that would vary greatly depending on the specific location. For this analysis, installation costs are assumed to be up to \$23,000 per site. The estimated total cost per camera site would be \$60,000. If camera systems were implemented at four locations, the total cost would be as much as \$240,000.