STATE OF COLORADO

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TO: Colorado Water Conservation Board Members

FROM: Joe Busto, Watershed and Flood Protection Section

DATE: January 10, 2012

SUBJECT: **Agenda Item 11, January 23-24, 2012 Board Meeting**
South Platte River Boat Chute Modification

Background

The CWCB is the non-federal sponsor of a flood control project along four miles of the South Platte River through the Denver metropolitan area known as the Chatfield Downstream Channel Improvement Project. In 1979, the CWCB was authorized to partner with the Corps of Engineers to purchase land, straighten the river, and armor the banks to accommodate maximum flood releases from Chatfield Reservoir. As part of this overall flood control project, the CWCB sponsored a project in 1990 to redesign an existing thirteen foot drop into a series of seven more gentle drops. In 2007, a letter from South Suburban Park Foundation asked the CWCB to address public safety concerns regarding two recent drownings by recreationists at or near these chutes. A safety study was completed that identified elements of Union Avenue Boat Drop #1, adjacent to the Englewood water diversion intake, as potential public safety hazards. CWCB staff then moved forward with seeking Corps approval of designs, funding and contracts with UDFCD, and access and permanent agreements with Englewood around the project. In late 2011, Naranjo Civil Engineering completed the project.

Discussion

The primary driving force in this project was the well-publicized 2007 drowning of a 28-year old man who left behind two children. Following this death, site visits and interviews were conducted with fire, police, and ambulance responders from Sheridan, Littleton, and Arapahoe County. According to reports, the man's children waded out to Union Drop #1 and became trapped in the currents. In an effort to save them, the man entered the river and rescued both children, but then drowned while trying to exit the river. Because the incident occurred at low flows, it was determined that the problem was not dangerous flows, but rather access and escape issues. In 2008 McLaughlin Whitewater Design Group (MWDG) conducted a facility safety evaluation and wrote a report summarizing the meetings and made recommendations to address public safety. A phased project approach was recommended that prioritized the most valuable safety modifications to be completed first. MWDG identified impaired egress/ingress from the pool downstream of Union Avenue Drop #1 due to vertical walls and high eddy current velocities as safety issue to be addressed with the first phase of work. Two vertical walls extending into the pool downstream of Drop #1 were removed and boulder islands installed near both river banks to improve ingress/egress and reduce eddy currents in the pool. Should evidence exist that further safety modifications are needed, these would be completed in subsequent phases. Staff believes the completed project successfully addresses the concerns that existed prior to the redesign.

Staff Recommendation

This in an informational board memo with no board action requested.

Whitewater Courses & Parks 2010
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WHITEWATER ON THE SOUTH PLATTE RIVER SAFETY AND PERCEIVED SAFETY FOR THE NON-BOATING PUBLIC

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Union Avenue Boat Chutes are on the South Platte River in Englewood, Colorado. These chutes have had and continue to have an interesting history that has left an impact on the planning and design for recreational whitewater. Originally, a low-head dam with a thirteen foot drop was built in 1984 as a part of a water diversion structure for the City of Englewood. After several drownings occurred, the dam was modified in 1992 to be a series of seven drops and pools downstream that created the present day whitewater park.

Over the following years, various park improvements were made including an adjacent parking lot, landscaping, and several structural in-river improvements. Since then, in the past five years, three drownings have occurred. This sparked concern from a number of entities and led to a review of this whitewater park. The resulting effort identified, among other things, that the hydraulics are relatively benign, the drownings occurred at low river flows, and the victims were non-boaters.

This paper looks at this venue as a case study of facility management and design issues related to safety in urban whitewater parks. It has an emphasis on safety related to the non-boating public. Topics presented will include hazard assessment, physical safety, perceived safety, river ingress and egress, river hydraulic factors, public access, public awareness, and signage.

1. INTRODUCTION

Three drownings occurred at the Union Avenue Boat Chutes Whitewater Park between 2005 and 2007 which raised concern from a number of entities and led to the safety review of the whitewater facility. McLaughlin Whitewater Design Group (MWDG) was hired by the Colorado Water Conservation Board (CWCB) and Urban Drainage and Flood Control District (UDFCD) to review the safety of this facility, develop hazard reduction recommendations, and design safety improvements. This project will be used as a case study of facility management and design considerations for reducing hazards in urban whitewater parks for non-boating users. Specifically, the material will focus on hazard evaluation and design of whitewater park safety improvements using both “physical” and “perceived” safety concepts.

The drowning victims and circumstances of their accidents shared multiple common characteristics. All victims were non-boaters, they were not wearing personal floatation devices (PFDs) or other safety equipment, the river flow was relatively low, kayakers (boaters) were not present at the time of the accidents, and all occurred after the construction of a new park and parking lot adjacent to the facility. In general, the victims appear to represent the general non-boating public user. This type of user is perhaps the most common for an urban whitewater park and therefore should be the focus in safety related design aspects of these facilities.

As in many facets of life, safety related to a whitewater parks can be real (“physical”) or “perceived”. Physical safety relates to the actual risk that is incurred related to what is in and immediately adjacent to the river affecting the hydraulics and ability of users to enter and exit the river. Examples include

structures or rocks in the river, such as hydraulic jumps (holes or waves) and service eddy rocks, river contouring creating pools, eddies, and rapids, and river bank materials and steepness. Perceived safety is how dangerous or safe the reach of river appears to the user. This can be derived from warnings/reputation, signage, physical observation, and the skills or ability a person thinks they have. Based upon the perceived safety, a user can make an educated decision to avoid or enter the water. Perceived safety also includes how the general public, facility owners, or government officials view the facility.

The importance of addressing both physical and perceived safety in design of whitewater parks cannot be understated - both for the individual user, and for the general public and stakeholders. It is obvious that if physical hazards exist and a user is not aware of such hazards, a dangerous situation can be created. Another concern is that if the general public and/or government officials deem whitewater parks dangerous based on drowning and accidents at some whitewater parks, the ability to implement future facilities is jeopardize. Nobody wants a hazard in their community. It is therefore crucial to address physical and perceived hazards into the design and modification of whitewater parks.

2. PROJECT BACKGROUND

The Union Avenue Boat Chutes are located ¼ mile west of Sante Fe Boulevard at the Union Avenue Bridge over the South Platte River in Englewood, Colorado. The facility includes a series of seven hydraulic drop structures and pools stretching approximately a ¼ mile downstream of the Union Avenue Bridge. The structures are constructed of steel reinforced concrete and grouted boulders. Pools between drops consist of native sand and cobble alluvium bed material. A paved trail runs along the west bank of the river with multiple trail offshoots providing access to the boat chutes and pools.

Following the major flood in 1965 on the South Platte River, the United States Army Corps of Engineers (USACE) proposed to build infrastructure to control future flooding. The CWCB as the statewide floodplain management program in Colorado agreed to implement the project with matching funds from the federal government. The project included constructing three dams, straightening the natural river channel, and lining the river with riprap. Chatfield, Cherry Creek, and Bear Creek dams were constructed as upstream flood control storage facilities for the Denver Metro area. After the construction of Chatfield dam the state and federal government together purchased the land on both banks of the South Platte River for six miles downstream of Chatfield dam. This reach was straightened to increase the flow capacity and lined with riprap for channel stabilization. In 1992, the CWCB agreed to take ownership, maintain, and operate this six mile reach of river. The Union Avenue Boat Chutes were part of this agreement.

The CWCB partners with UDFCD to complete various maintenance projects on the South Platte River. The UDFCD is an entity that specializes in the execution of construction projects for maintenance and enhancement of drainage ways throughout the Denver Metro area. In 2007, after the third drowning in three years at the Union Avenue Boat Chutes, the CWCB and UDFCD initiated this safety modification project.

3. UNION AVENUE BOAT CHUTES HISTORY

In the early 1980's the USACE built a low head dam to create a raw water diversion for the City of Englewood. The project included an ogee crest type dam structure with a 13 foot vertical drop, abutment walls on both sides of the river at the dam crest, concrete wing walls extending downstream of the dam, buried riprap, and a sluicing radial gate. Shortly after completion of the project, multiple drownings occurred resulting in the removal and redesign of the diversion.

Figure 1: Original Diversion Dam at Union Avenue Circa 1984

In 1992 the original dam diversion was modified and replaced by seven boatable drop structures and pools stretching a ¼ mile downstream. The six drop structures downstream of the dam have approximately two to three feet of vertical drop. The modified original dam structure has slightly more hydraulic drop at higher flows. Two modifications were made in 1998 and 2005. These entailed adding sloped riprap and a concrete chute to the most downstream drop.

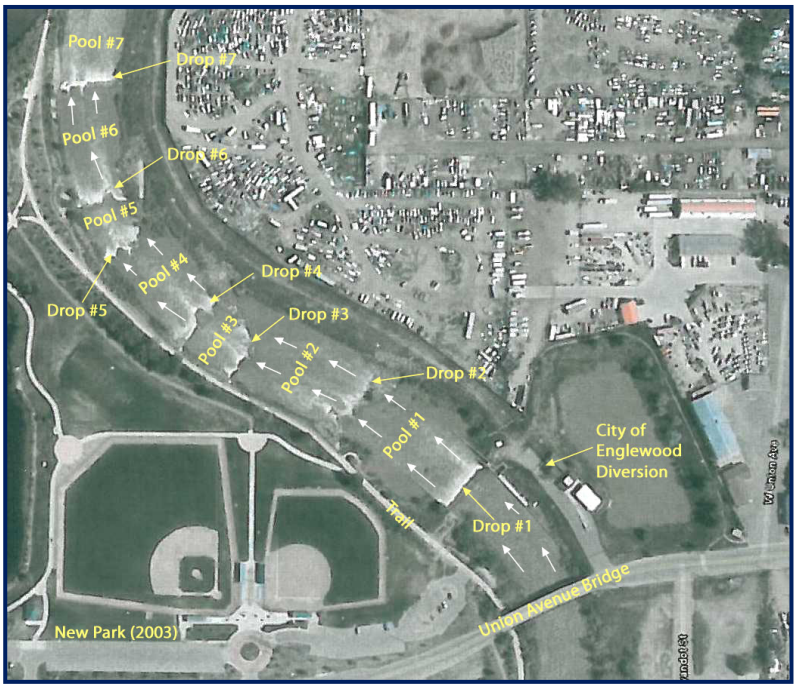

Figure 2: Union Avenue Boat Chutes Present Day

In 2003 a park was constructed adjacent to the whitewater park. The improvements included softball and baseball fields and a parking lot. Most importantly to this project, the parking lot increased access to the boat chutes by connecting to the paved trail along the west bank of the South Platte River just upstream of the City of Englewood's diversion (original dam site).

4. PROJECT APPROACH

MWDG was hired by the CWCB and UDFCD to review the facility for safety and design improvements to reduce existing hazards. The project approach included hazard assessment and reconnaissance, improvement recommendations, analysis, design of improvements, development of construction plans, and new signage.

4.1. Hazard Assessment

Hazard assessment and reconnaissance are critical activities for identifying physical and perceived safety hazards of a whitewater park. It is also important in defining recommendations and design criteria for new improvements. Assessment for this project was accomplished by research, meetings with government officials and emergency responders, site visits, and surveying. First, research was performed into the history of the boat chutes, drowning incidents, recent improvements, and other recreational whitewater facilities nationwide. Following research, a meeting was held with representatives from the CWCB, UDFCD, South Suburban Parks and Recreation, the City of Englewood, and local emergency responders to gather information on past incidences and to collaborate on potential improvements. Multiple site visits were conducted at varying river flows to observe potential hazards. Lastly, a detailed survey was performed to map existing structures, river banks, and the river bottom. Information from these sources was compiled and analyzed to develop safety improvement recommendations.

Site visits and physical observation of a facility is arguably the most powerful tool in evaluating potential hazards. The project team conducted multiple site visits and a field survey. The following issues were evaluated to determine potential hazards at the Union Avenue Boat Chutes. This list may also be applicable for other whitewater parks.

- Overall hydraulic functioning of whitewater park: gradient, size of drops, eddies, hydraulic jump types
- Functioning of recovery pools
- Retentive or recirculating hydraulics, under tow, eddy currents – particularly deceptively looking currents such as those associated with low-head dams.
- Submerged hazards
- Structural failures- large cracks, movement of rocks or concrete
- Obstructions or debris in boat chutes or pools- vegetation, rocks, trash, depositing of structural debris downstream
- Foot or hand entrapment hazards
- Ingress and egress access - the ability for users and emergency responders to enter and exit the river; including: bank configurations, bank slope, structures and walls that restrict access, underwater drop-offs, cut banks, pool lengths, river currents, etc.
- Existing signage- location, verbiage, size, clarity
- Public access- primary users, facility management, changes in access, effect of access on facility use

It is important to implement a comprehensive approach to hazard assessment. More sources of information provide a stronger basis for improvement recommendations and design criteria that will maximize safety and minimize costs. The ultimate objective is to efficiently use resources to address safety issues.

4.2. Hazard Assessment Conclusions

The following are the conclusions resulting from the hazard assessment and reconnaissance activities for the Union Avenue Boat Chutes.

- The majority of drownings occurred at the upper most hydraulic drop and pool (Drop #1/Pool #1).
- The victims were non-boaters and were not wearing PFDs or other safety equipment.
- The drownings occurred at relatively low flows 400 cubic feet per second (cfs) or less.
- Kayakers or boaters were not present at the time of the drownings.
- Emergency personnel have responded to additional non-fatal incidents at the site.
- There has been confusion as to the exact location of incidents by emergency callers and responders resulting in more distant fire departments responding.
- The whitewater hydraulics at these flow rates are relatively benign.
- There are no apparent structural failures, unusual hand or foot entrapment hazards, debris, or obstructions.

- Ingress and egress appears restricted due to vertical concrete wing walls downstream of Drop #1 along both banks.
- An eddy exists at river right between Drop #1 rapids and a vertical concrete wall. Pool depths at this location are over six feet.
- Existing signage is in need of maintenance/ replacement.
- Adjacent access improvements most likely increased the usage of the whitewater park by boaters and non-boaters.

4.3. Safety Improvement Recommendations

Safety improvement recommendations were developed using conclusions from the hazard assessment and reconnaissance activities. Recommendations provided the basis for design of safety improvements. It was determined that most accidents occurred at Drop #1 and Pool #1, therefore the safety improvements were focused in this area.

The following recommendations were made to address "physical" safety issues at Drop #1 and Pool #1.

- Improvements need to focus on non-boater users (such as tubers) while not adversely affecting boatability.
- Improvements should target flows during expected usage- approximately 200 – 2000 cfs.
- Remove vertical concrete wing walls downstream of Drop #1 to improve ingress and egress access.
- Add rock structures along both river banks in Pool #1 to reduce eddy velocities and improve egress.

The following recommendations addressed the "perceived" safety at Drop #1 and Pool #1.

- Install new signage at existing and new locations. Improve sign language and clarity.
- Include information to help emergency responders identify closest fire department and location of incident.

The following design sections address and discuss the safety improvement recommendations in greater detail.

4.4. Physical Safety Improvements Design

As defined previously, "physical safety" relates to the actual risk that is incurred related to what is in and immediately adjacent to the river affecting the hydraulics and ability of users to enter and exit the river. These are the most straight forward safety design criteria because they are mostly controlled by engineering principles and hydraulics. Improvements were designed to address the recommendations discussed in the previous section. This project included the partial removal of two existing walls and installation of two rock structures to attenuate eddy velocities. Both of these elements improve access from the hydraulic feature to the banks and access paths. Analysis was performed and construction plans were developed as part of the design of the physical safety improvements.

Analysis was an important component in the design of the physical safety improvements. Hydraulic analysis was performed to evaluate headwater and tailwater elevations, velocities, shear stresses, scour depths, riprap, and structure sizes. Compound weir calculations and data from a United States Geological Survey (USGS) gauge station at Pool #1 were used to develop the headwater and tailwater curves at Drop #1 and Pool #1. Water surface elevations over the range of design flows were used to set boulder structure elevations. A HEC-RAS model was created using water surface elevations from the compound weir calculation and survey mapping data collected as part of the hazard assessment activities. The model determined water velocities, which were used to size rock structures, size riprap, and calculate scour depths for multiple design alternatives. Structure size and costs determined from model results were used to evaluate design alternatives and select the final improvements.

Removal of the existing concrete walls in Pool #1 is an integral part of this project. The walls were constructed in 1984 as part of the original USACE diversion dam project. Their primary function was to provide erosion protection for the banks along the downstream pool. Although the walls still provide erosion protection today, they are excessive since the modification of the original dam in 1992 reduced the drop height by approximately 10 feet. The walls have a total height of twenty feet, which is mostly buried below the river bottom. Exposure of the walls varies depending on sedimentation. At the time of survey for this project, wall exposure at river right and river left were approximately 9.5 and 6 feet, respectively. A sluicing gate exists at the crest of Drop #1 at river right which discharges along a wall section to be removed.

Figure 3: Concrete Wall Downstream of Drop #1 River Right

The primary objective of the wall removal design was to improve the ingress and egress at Pool #1. An eddy exists between the rapid from Drop #1 and the concrete wall at river right. This creates an impediment to exiting the water due to an induced recirculating current and the obvious difficulties with climbing a vertical wall. In addition, the river is greater than six feet deep at this location during low flows. Removal of the wall will expand the eddy out along the bank where it is shallower and exiting the river is less difficult. At higher flows the wall at river left would also hinder egress from Pool #1, therefore removal of a section of this wall was designed.

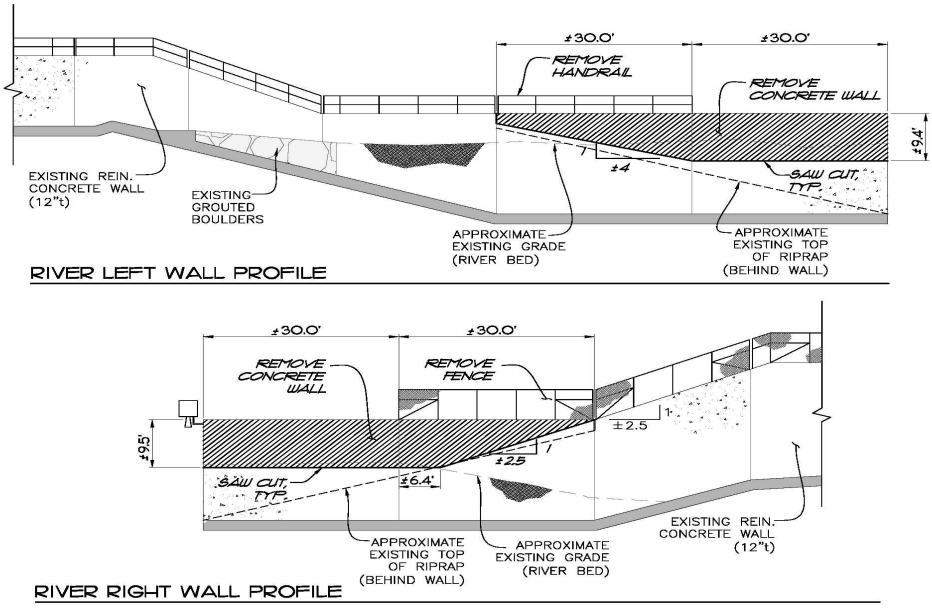

Figure 4: Proposed Wall Removal Profile Elevations

Another design objective for wall removal was to minimize impact to the existing structure. Record drawings from the original dam show existing 27-inch diameter buried riprap that extends from the bottom of the walls, twenty feet below, up at a 2 to 1 slope to the surface. The existing riprap was utilized as

erosion protection along the banks of Pool #1 in the new design. New top of wall elevations were set 3 feet below the next downstream boat chute (Drop #2) invert elevation so that the walls would always be below the water surface in Pool #1. Walls were designed with sloped transitions to match the elevation of the buried riprap and also match existing transitions from top of abutment walls. By leaving a majority of the buried walls in place the costs of removal was minimized. The remaining walls also provide toe protection for the existing buried riprap and new boulder structures.

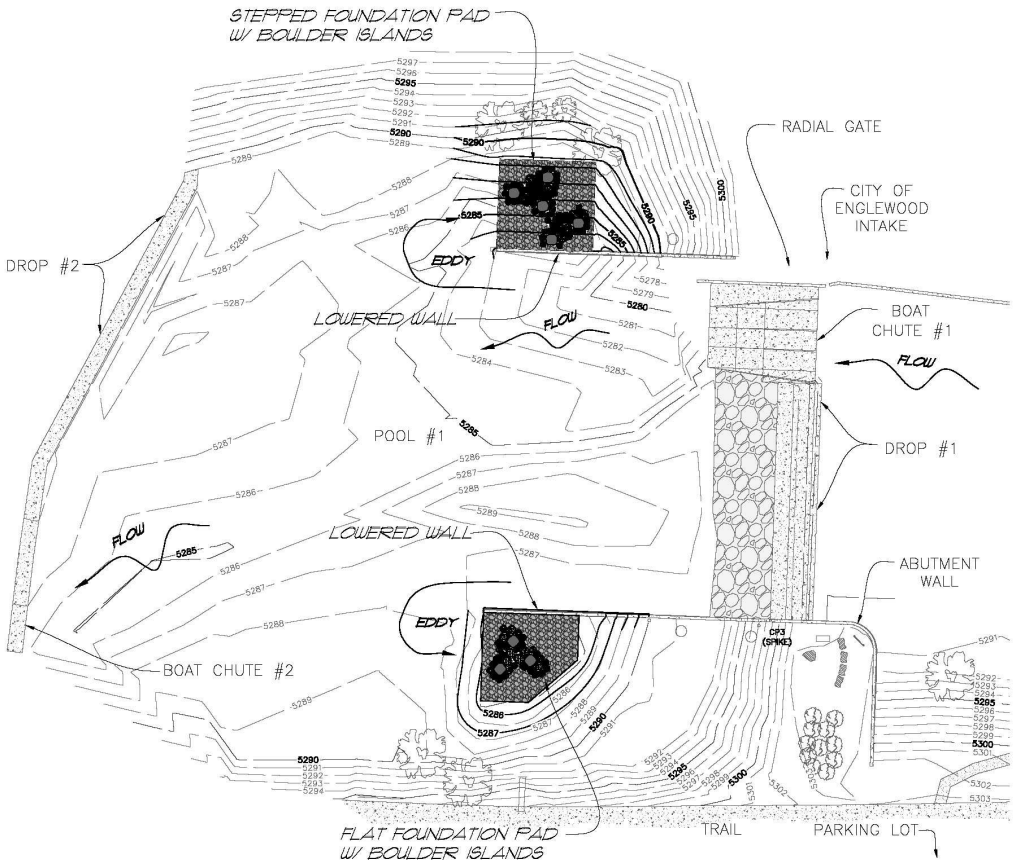

Figure 5: Proposed Safety Improvements Plan View

Boulder structures were designed along both river banks in Pool #1 to reduce eddy velocities and improve egress. The design concept is to reduce the recirculating eddy velocities by restricting upstream flow along the banks. This is accomplished with boulder islands (jetties) and by directing flow through notches in the islands that are shallow, allowing a person to grab on to the rocks or stand up. The islands (jetties) were generally located based on rules of thumb for jet expansion of flow and site conditions. Boulders with diameters ranging from 2 feet to 5 feet were selected for the structures. The island at river left is made up of three interconnected stacks of boulders of varying heights. Five interconnected stacks of boulders at varying heights were designed for the island at river right. Height variation allows the islands to function during a range of flow conditions and pool water surface elevations. At lower flows, lower portions of the islands will be more effective at breaking the eddy current. Similarly, at higher flows the portion of the islands placed at higher elevations will be more effective. By staggering the island heights the likelihood of eddies forming between the rapid and the islands is also reduced.

4.5. Perceived Safety Improvements Design

Safety improvements were also designed to address the “perceived” safety of the whitewater park. Perceived safety is how dangerous or safe the facility appears to the user or observer. An inadequate perception of the risks of whitewater (and even flat-water) recreation typically leads to the absence of personal floatation devices and other safety equipment used by a properly equipped recreationalist.

Improved signage at key locations was recommended for improving public awareness. MWDG conducted research to determine if national or regional signage standards existed. The research showed that many whitewater facilities use signage, but for the most part language and symbols were unique for each project. Standard signage criteria, such as the Manual for Uniform Traffic Control Devices (MUTCD) used for highway signs, simply do not exist for recreational whitewater parks. As a result, MWDG researched other whitewater facility's signage and obtained input from the CWCB and UDFCD to develop multiple sign language and symbol alternatives. A committee made up of representatives from the CWCB, UDFCD, South Suburban Parks and Recreation, State Attorney General's office, and other local government agencies, will review the alternatives and decide on final sign language, symbols, size, and location.

Suggested signage issues and objectives included:

- Size of signs, lettering, and symbols- large enough to see easily
- Location - at entrances to whitewater park, along river trail, on Union Avenue Bridge over river upstream of park, at east bank of Pool #1 near the City of Englewood raw water diversion.
- Language- clear, concise, comprehensive
- Content - history of past accidents, recommended safety equipment, warnings of hazards, "in case of emergency", recommended usage
- Portage - exit information for river users upstream of the whitewater park
- Symbols- to improve communication to the illiterate and non-English speaking
- Other information- respect for others, no glass containers

Figure 6: Example Signage Alternatives

5. CONCLUSION

The safety improvement project at the Union Avenue Boat Chutes provides a case study into facility management and the design of safety improvements for urban whitewater parks. Although this project was a retrofit of an existing facility, aspects of the project approach and methodologies are applicable to the design of new urban whitewater parks. Designing and evaluating facilities based on expected users is crucial to minimize hazards. At urban whitewater parks, less-experienced users must be considered. Research and hazard assessment are important in evaluating hazards and developing design recommendations. Both physical and perceived safety concepts for users should be incorporated in the design. A comprehensive evaluation and design approach for safety at urban whitewater parks will ensure successful operation and allow implementation of these facilities in the future.