CHAPTER 5. URBAN STREAM RESTORATION TECHNIQUES ON THE WAUKEGAN RIVER

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The Waukegan Park District has implemented an innovative stream restoration program with funding from the 319 nonpoint pollution program of the Illinois EPA and USEPA. The stormwater runoff had created severe bank erosion so that city sewer lines were exposed, park bridges were destroyed, and public access to downstream lands was limited (Figure 5-1).

Stream channel erosion in city parks results when stormwater runoff from streets, parking lots, and buildings enters the steep stream channel on the Lake Michigan bluff. The river falls from 730 msl to 580 msl, with the steepest lands located in Washington and Powell Parks.

The Waukegan River has a largely urbanized 7,640-acre watershed (Figure 5-2). Over 80 percent of the City of Waukegan lies in the watershed. With a population of 60,000, Waukegan has the greatest population density in Lake County. Washington Park and Powell Park are located in the older, highly urbanized area. As with many older cities, very few stormwater detention basins were constructed before 1970.

The Waukegan Park District requested that the Illinois State Water Survey develop stream stabilization practices to protect city infrastructure and restore the recreational and environmental benefits of park lands. The Water Survey chose biotechnical bank stabilization where riparian revegetation is combined with structural stabilization. The structural elements tested were bank covers (lunkers) and interlocking concrete jacks (A-jacks) as seen in Figure 5-3. These urban stream restoration techniques were chosen to resist high velocity runoff while increasing riparian habitat for stream fisheries.

Projects on the North Branch of the Waukegan River

Lunkers and A-jacks were installed in Powell Park in May 1991. Lunkers with stone were installed on the North Branch of the Waukegan River in Washington Park in August 1991 (Figure 5-4). On both lunker installations, willows, dogwood, grasses, and wetland plants were planted in lower, middle, and upper zones of the streambank. In October 1992, lunkers, stone, dogwoods and willows were installed where channel erosion had damaged the access road to Washington Park.

Projects on the South Branch of the Waukegan River

In September 1994, a severe bank erosion site on the South Branch of the Waukegan River in Washington Park was stabilized with lunkers, A-jacks, stone, dogwoods, willows, and grasses during the Second National Nonpoint Pollution Conference Workshop in Chicago. Smaller bank erosion sites on the south branch were stabilized with coir coconut fiber rolls, willows, and grasses.
Figure 5-1. A major erosion site in Powell Park
Figure 5-3. Lunker and A-jack structures
Figure 6-4. Installations of lunkers, stone and woody species
After monitoring the South Branch for two years following the National Watershed Monitoring Protocols of the USEPA, aquatic biota were still found to be limited by a lack of water depth in pools, limited cobble substrates, and limited stream aeration, even though the streambanks were stable and vegetated.

In 1996, a series of six pool-and-riffle complexes were recreated on the South Branch by the construction of low stone weirs in this channelized reach. In two locations, the weirs were placed over main sewer lines where channel incision had exposed the concrete culverts.

The National Watershed Monitoring Protocols are being followed in the continued monitoring of the South Branch to determine the environmental benefits resulting from the formation of pools and cobble riffles. The initial results of the 1996 monitoring reveal a doubling of pool depth, increased boulder substrate, and greater fishery diversity.
BIOTECHNICAL STREAMBANK PROTECTION A-JACK BANK REVETMENTS

Stream bank erosion in Powell Park was increased by hillside seeps which saturated bank soils. The saturated soils were very susceptible to floodwater scour at the apex of the meander (Figure 5-5). Stream meander migration was moving the stream channel from the floodplain into the high bluff, which would have drastically increased the cost of stabilization. In addition, the vertical bank collapsed easily from internal water pressure after the rapid lowering of flood water stage in this flashy urban stream.

A-Jack Revetment Design

This urban stream practice consisted of structural bank reinforcement (revetment) at the underwater base (toe) of the eroding bank with revegetation of the sloped saturated soils. Structural reinforcement of the bank toe consisted of small concrete jacks (A-jacks).

A-jack installations are structural bank revetments, which provide enough soil-filled voids for dense woody growth above the normal stream base flow. A-jacks are a concrete jack with three 24-inch axes (six 12-inch legs). The jack has two identical 45 pound halves, which slide together to form a single jack (Figure 5-6). This product was originally designed in larger sizes (10 ft diameters) for energy dissipation in ocean breakwaters.

Transportation

The two halves of each A-jack arrive on site in pallets of 36 A-jacks. A large lift truck or backhoe with forks is necessary to remove the pallets from the truck and transport them to the site (Figure 5-7). Where stream access is difficult, the A-jack halves can be offloaded into small All Materials Transport (AMT) and assembled on site. The bucket of the excavator can be very helpful when moving assembled A-jacks from the assembly point on the top of the bank to the installation point at the base of the bank.

Trench Excavation

Installation of A-jacks is similar to installation of a riprap bank with toe protection. On small urban streams, streambed material is excavated out of a shallow trench at the base of the eroding bank with a track hoe (Figure 5-8). The base elevation of the trench is below the elevation of the streambed. The bed of the trench is uniformly graded to ease A-jack installation.

The installation occurs during base streamflows so that flow can be diverted to the opposite bank. A small trash pump is helpful to keep water levels low in the toe trench during A-jack installation.

Assembly

Assembly consists of sliding one half into another half, on the ground. This junction is not normally grouted as the length of overlap on the A-jack halves will keep the jack together during handling.

Rows of A-jacks are assembled to interlock horizontal and vertical directions (Figure 5-8). On small streams, two rows of A-jacks interlock on the bed of the toe trench to form the base.
Site before A-jack construction

A-jack site two years later

Figure 5-5
Figure 5-6. A-jack formed by sliding two identical sections together
1. Designate and clear staging area to unload flatbed trailer.

2. Transfer A-jacks to assembly areas near bank.

3. Assemble A-jacks.

Figure 5-7. A-jack staging and transport.
4. Excavate toe trench along base of eroding bank and use trash pump where necessary.

5. Interconnect assembled A-jack in rows along toe trench.

6. Place willow cuttings or stock in voids between and behind A-jack rows to a depth equal to the water table.

Figure 5-8. Trench excavation and A-jack installation
of A-jack bank revetment. On large streams, three rows of A-jacks may be needed to form a stable base for the revetment.

On small streams, an upper row of jacks is interlocked with the base rows along the vertical earth bank. A geotextile material is placed between the A-jacks to reduce removal of fine soils while roots systems are developing. Both Fiberdam, a synthetic material, or curlex wood fibers have been used successfully (Figure 5-9).

Planting

Both rooted dogwood stock and willow cuttings are planted between A-jacks. Plant materials should extend into the water table. Additional cuttings and root stock are placed behind the A-jack rows along the earth bank.

Backfilling

The excavator places sediment from the toe trench into rows of A-jacks. Normally this fluid mix will enter the voids of the jacks. The excavator slopes the vertical streambank down over the jacks and compacts the soil with the back face of the bucket (Figure 5-9).

Seeding

Where streamside grasses are preferred, a geotextile fabric or coir fiber should be incorporated for erosion control. After the soil is compacted and seeded, the fabric is placed over the soils and the upper edge is staked in a shallow trench.

The plant materials should be checked weekly for insect damage or drought. Both insect spraying and irrigation are necessary during dry springs when plant stresses are high. Bank areas devoid of plant growth should be replanted. A high-pressure water pump and a long metal nozzle are useful to form holes in the soil for additional cuttings without damaging the A-jacks.

Operations List (Figures 5-7 to 5-10)

1. Designate and clear staging area for the unloading of flatbed trailer
2. Transfer A-jacks to assembly areas near bank
3. Assemble A-jacks
4. Excavate toe trench along base of eroding bank and use trash pump where necessary
   Follow State guidelines on the timing of in-stream construction to protect fish spawning and sensitive species (where possible, divert streamflow from the work area)
5. Interconnect assembled A-jacks in rows along the toe trench
6. Place willow cuttings or rooted stock in the voids between and behind A-jack rows to a depth equal to the water table
7. Fill voids with fibredam or similar geotextile
8. Backfill sediment from toe trench over the rows of A-jacks

9. Back slope vertical bank over the A-jacks and compact soils

10. Seed bank and cover with excelsior blanket: grass applications can range from native prairie seeds and sprigs to turf grass sod, depending on landowner desires and the extent of foot traffic

11. Plant rooted stock of red osier dogwood or riparian trees as landowner desires
7. Fill voids with fiberdam or similar geotextile

8. Backfill sediment from toe trench over the rows of A-jacks

9. Back slope vertical bank over the A-jacks and compact soils

Figure 5-9. A-jack backfill and bank sloping
10. Seed bank and cover with excelsior blanket (Grass applications can range from native prairie seeds and sprigs to turf grass sod depending on landowner's desires and extent of foot traffic)

11. Plant rooted stock of red osier dogwood or riparian trees as landowner desires

Figure 5-10. A-jack bank revegetation
BANK COVER (LUNKER) REVETMENTS

Lunker installations are structural bank revetments, which provide a stable undercut bank for gamefish (Figure 5-3). Lunkers are a modular type of bank cover developed by the Wisconsin Department of Natural Resources for trout habitat enhancement. This bank cover design is similar to a cargo pallet, 8 ft long by 2 ft wide with 1.5 ft between the double layers of the pallet. The pallet layers are constructed of 2-inch by 8-inch planks. Three 4 ft planks extend across the lunker width into the streambank. Figure 5-11 is the S1 lunker site on the South Branch of the Waukegan River before and after stabilization.

Transportation

A large lift truck or backhoe with forks is necessary to remove the lunkers from the truck and transport to the site (Figure 5-12). Where stream access is difficult, lunkers can be offloaded into small AMTs. The excavator bucket and chains help move lunkers from the top of the bank to the installation point at the base of the bank.

Toe Trench

Stream channel excavation normally requires a track excavator or a large backhoe. Since lunkers trucked to the site on a flatbed truck, a backhoe with forks is very useful in unloading the truck.

Installation of lunkers is similar to installation of a riprap bank with toe protection in a sandbed stream. On small urban streams, streambed material is excavated out of a shallow trench at the base of the eroding bank (Figure 5-13). The base elevation of the trench is at the elevation of the streambed. The bed of the trench is uniformly graded to ease lunker installation.

The installation occurs during base streamflows so that flow can be diverted to the opposite bank. A small trash pump is helpful to keep water levels low in the toe trench during installation.

Installation

When the lunker is positioned in the trench along the vertical bank, the nine rebar are driven through the lunker into the streambed. All rebar are bent over flat against the upper wooden surface behind the blocking board (Figure 5-14).

The coir fiber roll is attached to the lunker behind the blocking board to further protect bank soils and grasses at the base flow line of the stream.

Planting

Both rooted stock as dogwood and cuttings as willows are planted behind the lunkers. Plant materials should extend into the water table (Figure 5-15).

Backfilling

The excavator places riprap over and behind the lunkers and sediment from the toe trench over the riprap and lunkers. The streambed material will fill the larger voids in the riprap.
Site before lunker construction

Lunker site after 1 year

Figure 5-11. The S1 lunker site before and after rehabilitation
1. Designate and clear site for unloading of flatbed trailer.

2. Transfer lunkers, riprap, and rebar to construction areas near bank site.

Figure 5-12. Staging for lunker installations
3. Place rebar in drilled holes in the lexker

4. Excavate toe trench along base of eroding bank and use trash pump where necessary

Figure 5-13. Trench excavation and leunker check
5.

Lower lunker by backhoe into toe trench

5a.

Install lunkers along the toe trench and drive rebar into streambed

Figure 5-14. Lunker installation
6. Place cuttings or rooted stock in the voids between and behind lunkers to a depth equal to the water table.

7. Place riprap behind lunkers and over the submerged surface.

Figure 5-15. Installation of cuttings and riprap.
excavator slopes down the vertical streambank over the lunkers and compacts the soil with the back face of the bucket (Figure 5-16).

**Planting Inspection**

The plant materials should be checked weekly for insect damage or drought. Both insect spraying and irrigation are necessary during dry springs when plant stresses are high. Bank areas devoid of plant growth should be replanted. A high-pressure water pump and a long metal nozzle are useful to form holes in the soil for additional cuttings without damaging soil structure (Figure 5-17).

**Operations List**

1. Designate and clear staging area for the unloading of flatbed trailer.
2. Transfer lunkers, riprap, and rebar to construction areas near bank site.
3. Check predrilled holes in lunkers with rebar.
4. Excavate toe trench along base of eroding bank using trash pump where necessary.
   
   Follow state guidelines on the timing of construction activities to protect fish spawning seasons and sensitive species (where possible, divert streamflow from the work area during construction).
5. Install lunkers along the toe trench and drive rebar into streambed.
6. Place willow cuttings or rooted stock in the voids between and behind A-jack rows to a depth equal to the water table.
7. Place riprap behind lunkers and over the submerged surface.
8. Backfill sediment from toe trench over the lunkers and riprap.
10. Seed bank and cover with excelsior blanket (grass applications range from native prairie seeds and sprigs to turf grass sod depending on landowner desires and the extent of foot traffic).
11. Plant rooted stock of red osier dogwood or riparian trees as landowner desires.
8. Backfill sediment from toe trench over the lunkers and riprap

9. Back slope vertical bank over the lunkers and compact soils

Figure 5-16. Trench fill and bank sloping

S-23
10. Seed bank and cover with excelsior blanket (Grass applications can range from native prairie seeds and sprigs to turf grass sod depending on landowner desires and the extent of foot traffic)

11. Plant rooted stock of red osier dogwood or riparian trees as landowner desires

Figure 5-17. Bank revegetation on N1 and S1 lunker sites
POOL AND RIFFLE RESTORATION

Dr. Newbury has based his stream restoration methodology upon duplicating the stream characteristics of a high-quality stream in a reference watershed from the same geographic region as the project. This restoration or rehabilitation strategy allows the complex climate and geological watershed effects on stream evolution to be observed and documented. When applied to geographic regions within a state, the physical goals of the stream restoration program can be directly observed and measured.

With Dr. Newbury's 10-step method of stream analysis, reference streams and watersheds can quickly and practically define the physical criteria necessary for stream restoration efforts. These criteria have been determined for some regions in Manitoba, British Columbia, and Ontario. Fortunately, many states, including Illinois, have such databases of stream geometry and streamflow.

As a consequence, Dr. Newbury's evaluations are often based upon national averages for the United States. This approach has limitations within urban watersheds where intense watershed development has modified stream geometry and drastically increased stormwater runoff.

Waukegan is an older city with the highest population density in Lake County. Few stormwater detention basins were constructed before 1980. As a consequence, the Waukegan River allows a test application of Dr. Newbury's methodology in an urban Midwestern watershed.

TEN-STEP WATERSHED ANALYSIS

Step 1. Watershed Size

Watershed size is determined from 1:24,000 USGS topographic maps (Figures 5-18 and 5-19). For the Waukegan River, the South Branch has a watershed area of 2.3 square miles. The upper reaches of the South Branch are confined in large stormwater culverts before reaching the ravine on the Lake Michigan bluffs above Washington Park.

Step 2. Stream Profiles

Large culverts carry the stream under Waukegan streets to Lake Michigan. These culverts limit the floodwater discharge and raise flood heights in the ravine valleys of park lands. The culverts maintain streambed elevations at fixed points. Channel incision occurs between street culverts when initiated by stream channelization or watershed increases of stormwater runoff.

Near the upstream culverts, stormwater creates a large scour pool. The streambed will degrade upstream into the scour pool so that the upper stream channel is deepened with vertical banks. Where the stream channel was repositioned along the bluffs during channelization, the valley bluff has collapsed into the channel. Bluff erosion has increased sediment loadings (especially bedload). The stream channel fill with bedload material where the downstream culvert restricts stormwater discharge.
Figure 5-18. Topography of Waukegan River watershed
Enlarged View of Waukegan River Watershed Map Inset

Figure 5-19. Topography of South and North Branches of Waukegan River in Washington Park
The stream channel in the middle reach has less gradient and an increased tendency to meander. The largest bank erosion sites are located in these middle stream reaches of both Washington and Powell Parks.

The stream profile indicates these stream culverts as sharp breaks in stream gradient as at Belvidere Road (Figure 5-20). The stream slope is about 0.005 in Washington Park and about 0.01 on the steepest reach above Washington Park.

**Step 3. Streamflow**

Prepare a streamflow summary for the rehabilitation reach from an existing gage on the stream or a nearby stream. The "bankfull" or "channel maintenance" flow is determined from the tabulation of all gaged annual floods for the stream or a nearby stream in a similar watershed. Stream channels are the result of moderate floods, which transport the greatest percentage of floodwater and sediment over the long term. Such floods are not the very largest floods, but large floods which occur with enough frequency to "maintain" the stream channel dimensions of width, depth, and cross-sectional area.

The discharge of the "bankfull" flood can be estimated by ranking the peak annual floods in a gaged station. Each annual flood is ranked by its peak discharge. The peak discharge of each annual flood is given a probability of occurrence. The probability of occurrence is estimated by dividing each ranked flood discharge by the total number of annual peak floods plus 1. Plotting the frequency of ranked annual peak floods on log-probability graph paper will determine the "cumulative probability of exceedance" of each annual flood.

If the gaging station has 19 years of record, the largest flood discharge will have a 5 percent probability of occurrence (P probability = rank/n+1 x 100%). N is the total number of annual flood peaks. The next largest annual flood discharge will have a 10 percent probability of occurrence.

On log-probability graph paper, the plot of a straight line through graph points assumes that logarithms of the annual flood discharges is normally distributed. Watersheds in natural conditions usually have such a distribution but urban watersheds often do not.

For the streamgage station, the magnitude of the bankfull or channel maintenance flood is estimated by the flood magnitude occurring with a 67 percent frequency. When divided by the watershed area, the bankfull flood flow at the gaging station can give an estimate of bankfull flow for smaller subwatersheds on the gaged stream or nearby streams with similar land use and geology.

The nearest gaging station to the Waukegan River was on the Des Plaines River near Gurnee. The bankfull flow was estimated at 1700 cfs for the 215-square-mile watershed. The bankfull flow is generated at 7.9 cfs per square mile of watershed from the Des Plaines River gage.

The Gurnee gage will underestimate the bankfull flood discharge on the Waukegan River because of the more intense residential and industrial development on the Lake Michigan bluffs. Dr. Newbury's estimate of bankfull flow on the South Branch was 40 cfs.
Figure 5-20. South Branch of Waukegan River, channel profile
Figure 5-20. South Branch of Waukegan River, channel profile
Step 4. Reference Stream Channel Geometry Surveys

Illinois has not established a regional database to define the relationships of stream channel geometry to watershed size and bankfull discharges. Such data would define the frequency of riffle locations, the bankfull width, and meander frequency from field observations.

Therefore bankfull width of the Waukegan River was determined by surveys of the most stable areas within Washington Park. Field reconnaissance of the South Branch found the bankfull widths ranging from 15 to 26 feet. An average bankfull width of 20 feet was chosen based upon these observations.

Dr. Newbury checked these observations with national rating curves developed by Dunne and Leopold (1978). A 5-square-mile watershed would maintain a stream with bankfull width of 20 feet and a bankfull depth of 2 feet.

Step 5. Survey of the Stream Rehabilitation and Control Reaches

The stream profile has a slope of 0.0043 over the 1200 feet reach which included the downstream rehabilitation area and upstream control (Figure 5-21).

Step 6. Preferred Habitats

The Waukegan River was channelized during construction of the main sewer lines and during park development. The South Branch of Waukegan River was positioned along the valley bluffs in the downstream rehabilitation reach. The physical characteristics of the channel resembled a ditch more than a natural stream.

With the exception of scour pools below street culverts, the stream pools were very shallow during summer low flows. The stream was largely shallow runs with slightly deeper water at bank erosion sites and at exposed sewer lines. Riffles were depositions of gravel at slightly raised elevations. Substrates of the runs and riffles were very similar.

Within this severely altered but typical urban stream, the physical habitat of a high-quality stream was to be reconstructed. The habitat restoration goals were modest: deeper stream pools and greater cobble substrate in the riffles. Localized increases in stream velocity were achieved by concentrating streambed drop on the cobble substrate of the weirs.

At the riffles, the faster flows are evident by the sound of trapped air bubbles releasing from the rushing waters on the steep cobble backface. Riffles with their attached macroflora and microflora assimilate dissolved nutrients and transform pollutants as ammonia to less toxic forms.

This aesthetically pleasing and environmentally necessary function is lost when streams are channelized. Channelized streams are ditches with a smooth streambed slope to maximize stormwater flow. The loss of concentrated flows on the coarse substrates of riffles limits the diversity of aquatic life.
Figure 5-21. Streambed elevations of South Branch of the Waukegan River through the S1 and S2 monitoring sites
Step 7. Locating and Sizing Rehabilitation Weirs

Siting Weir Locations

The distance between weirs was based upon the determination of bankfull width. Bankfull width has proven to be the most reliable indicator of the stream channel area required to move stormwater through the stream segment. Stream morphology studies have indicated that naturally formed grade controls or riffles occur about every six bankfull widths. This grade control may be located on straight or meandering stream channels. The majority of data sets ranged between five and seven bankfull widths.

Field reconnaissance of the South Branch found that the bankfull width was 20 feet (Harrelson et al., 1994). The distance between riffles was based upon the bankfull channel width, approximately six bankfull widths or 120 feet. The weir sites were adjusted during construction so that sewer lines could be protected at two sites (Figure 5-22).

Determining Weir Height

The relative height of each stone weir was determined by dividing the total streambed fall in the demonstration reach by the number of weirs to be located in the length of demonstration area. Streambed elevations were controlled at six distinct locations (Figure 5-22). Streambed fall is localized at each weir so that concentrated flow maintains deeper pools below the weirs.

The height of the uppermost weir was lowered to minimize upstream deposition of bedload since there would be no upstream weir to promote pool scour. The height of the last downstream weir was lowered to reduce downstream scour where no weir would provide a deeper pool to slow floodwater velocities.

Determining Weir Length

The stone backface of each weir extended downstream for a distance of 20 times the height of the crest stone above the streambed. The front face of the weir extended upstream four times the height of the crest stone.

Sizing Weir Stone

The size of the crest stone in the weir was determined by bankfull floodwater depth of floodwater at each weir elevation. In a broad channel with a high width: depth ratio, the hydraulic radius approximates bankfull depth. In that case, the tractive force is equal to the product of the average slope of the water surface, the water depth in feet, and the specific gravity of water - 62.4 lb/ft$^3$.

\[ t = 62.4 \times d \times s \]

where $t =$ tractive force
$d =$ water depth (ft)
$s =$ slope

For weirs with a 20:1 backslope and a bankfull depth of 2 feet,
Waukegan River, South Branch Data

- Drainage area: 5 mi²
- Mean annual flood: 4000 cfs
- Bankfull with: 20 ft
- Bankfull depth: 2 ft
- Slope: 0.0043
- Estimated channel capacity is 200 cfs
- (no backwater)

Locate weir sites based upon bankfull width spacings

Streambed spread falls uniformly across the number of weirs to be constructed in demonstration reach

Figure 5-22. Weir siting (top) and elevations on South Branch (bottom)
\[ t = 62.4 \text{ lbs/ft}^3 \times 2 \text{ ft} \times 0.05 = 6.2 \text{ lb/ft}^2 \]

Lane (1955) found that noncohesive bed materials greater than 1 centimeter in diameter will begin to erode when the tractive force (lb/ft²) is double the diameter (inches) of the gravel or cobble. Therefore, stones on the Waukegan weirs should have a mean diameter of at least 1 foot or larger.

Step 8. In-stream Flow Regulation for Spawning or Baseflow Enhancement

In-stream flows were not regulated in any fashion as the upstream floodwater detention basin was not designed for such activities.

Step 9. Supervise Construction

All constructed weirs were placed approximately 30 feet upstream of Newbury’s design locations so that stone of the number 1 weir would cover the exposed sewer line downstream of the junction of the North and South Branches of the Waukegan River (Figure 3-10). Stone from the number 5 weir covered the exposed sewer line at the S1 monitoring site.

The distance between the number 2 and number 3 weirs was lengthened by 30 feet so that the weir would not be tied into the slipface in a large bluff collapse. As a consequence, the distance between weirs 3 and 4 was shortened to 90 feet. Figures 5-23, 5-24, 5-25 summarize weir construction.

Crest stone diameters averaged about 2.0 feet for the granite boulders but crest stones were highly variable. Smaller boulders had a median diameter of 1 foot (within the 1.5 to 0.5 foot diameter of stone specified by Dr. Newbury).

The majority of the stone was used in the initial January construction. Approximately 160 tons of granite boulders were purchased at $52 per ton for six weirs on the South Branch and one weir on the North Branch.

Of the 160 tons of granite boulders, 46 tons had an average diameter of 24 inches. The remainder of the tonnage had a median diameter of 12 inches. Downstream of the last weir, 18 tons of riprap were placed along an exposed sewer line below the junction of the South and North Branches.

Step 10. Monitor Project and Adjust Design as Necessary

An additional 30 tons of 12 inch diameter boulders were added in early May to adjust for backslope settling of the weirs 3 and 5.

TOTAL PROJECT COSTS

Granite Boulders

The cost for 190 tons of granite boulders for the seven stone weirs was $10,000. This quantity includes 30 tons for weir adjustments.
1. Excavate trench for crest stone in streambed and key into streambank

2. Place crest stone across stream in excavated trench

Figure 5-23. Crest stone placement for Waukegan weir construction
3. The crest stone forms a shallow "V" with the design elevation at the base of the "V".

4. The backface of the weir extend 20:1 downstream when compared to weir height.

5. Large stone is embedded in the back face of the weir.

Figure 5-24. Weir crest and backface construction, Waukegan River
The front face of the weir extends upstream at a 4:1 slope when compared to the weir height.

Erosion controls are installed around weir bank keys including revegetation and straw mulch.

Figure 5-25. Weir front face design and revegetation
Equipment

A large trackhoe was contracted for the majority of the weir installation at a cost of $1,350. The Waukegan Public Works Department contributed a track loader to transport the granite boulders down the steep ravine bluffs. The Waukegan Park District contributed a rubber tired backhoe for additional boulder transport to stream locations and some boulder placement in the stream channel. The track front end loader was used for 2.5 days at cost of $1,100. The backhoe was used for 4 days at a cost of $800.

Labor

Labor cost for a five-person crew was about $3,600 for one week of construction. One additional day of labor cost another $750 when stone was added to two weirs in May.

Total costs for material, equipment, and labor were $17,600. Figure 5-26 shows the S1 monitoring site before and after rehabilitation.

LITERATURE CITED


Figure 5-26. The S1 monitoring site before and after lunker and weir installation

5-39