COCOLOGIX
bank stabilization systems

DESIGN GUIDE

COCOLOGIX

CONTENTS

WHAT IS COIR?

Coir is a natural fiber from the husk of a coconut (the material between the hard, internal shell and the outer coat of a coconut). It is traditionally used to make floor mats, doormats, brushes, mattresses, upholstery padding, sacking, rope, nets, erosion control products, and much more. Each fiber cell is approximately 0.04 inch and 10 to 20 µm (0.0004 to 0.0008 in) in diameter. Individual fiber cells are joined to form fibers 4 to 12 inches in length. Coir fibers are hollow and have narrow cellulose walls. This void space within the cellulose walls is an essential physical property as shown later in this document. There are two different types of coir: white and brown. White coir fibers are harvested from the coconuts before ripened while brown fibers are harvested from fully ripened coconuts. White fibers tend to be smoother and finer making them perfect for the yarn used in mats or rope. The brown fibers are thick, strong, and have a high abrasion resistance. These fibers are typically used in mats, brushes and sacking. Coir fiber, either white or brown, is relatively water-proof and is one of the few natural fibers resistant to salt water damage.

Brown Coir Lightly Misted for Log Production

Coir Logs contain the brown coir compacted in to a tubular or rectangular net as shown above

HISTORY

In the early 1990's, coir fiber logs were introduced to the United States by Mr. Lothar Bestmann of Bestmann Green Systems, Germany. Mr. Bestmann developed and perfected many techniques to stabilize high energy reservoir shorelines, shipping lanes, and waterways & rivers utilizing vegetation as the primary stabilizing mechanism. Inspired by "wattles" or "live fascines", Mr. Bestmann developed coir fiber logs. Wattle or live fascine practice entails the use of live and/or dead plant parts (stems, branches, and dormant cuttings) which are inserted, driven, buried, or otherwise placed on the ground in specified orientations to control erosion, minimize shallow sliding, initiate sedimentation, protect structures, and provide a favorable environment for the establishment of a permanent vegetative cover. The manufactured version of the wattle or live fascine was comprised of long coir fibers, tightly machine compressed to a density of 9 lbs/ft^3, contained in a highly UV stabilized knotless 100% virgin polypropylene net. The manufactured version of the wattle or live fascine expanded the utility of this soil biotechnical practice more quickly and uniformly.

The invention of coir fiber logs has eliminated many challenges associated with live fascine practice such as proper plant identification, highly trained labor performing field fabrication, dormant season installation and harvesting. Coir fiber logs, as invented by Mr. Bestmann, changed the seasonality of live fascine practice by extending its use to all seasons. Additionally, the species of plants utilized for live fascine practice dramatically increased to include, not only woody species, but also herbaceous sedges, grasses, rushes, and forbs.

HOW ARE COIR LOGS USED?

There are two types of coir logs in the civil engineering industry: plain or vegetated.

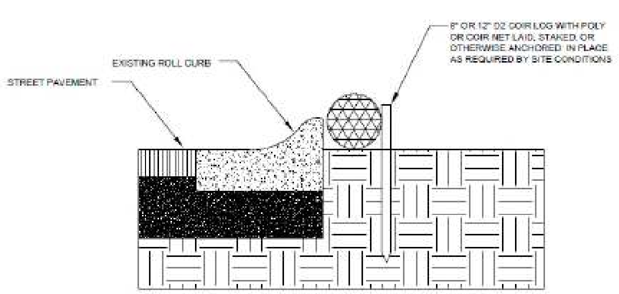
Plain coir logs, or logs without vegetation, can be used for perimeter sediment control in lieu of silt fences. The coir log is placed directly on the sub-grade and is staked (wood only) every three feet minimizing soil disturbance.

Benefits of coir logs used for sediment control include:

- Permeable product that allow flow to go through it while filtrating rather than ponding or eroding around/below the sedimentation device (for permeability rate see the *Design Section*)
- Placed on the existing sub-grade without trenching
- Flexible product that can be easily wrapped around inlets
- Low profile product that can be **occasionally** driven across
- Re-usable (4-6 times)

Perimeter Protection

Inlet Protection



Plain coir logs can also be used in areas as temporary erosion control where native plants are not desired (golf course ponds or similar). In these project sites, erosion is the primary focus without establishing an existing root structure to prevent future erosion. Turf grass is usually being used to the edge of the water body in these types of applications. Turf grass has a very shallow root system; therefore, cannot withstand the shear stresses and/or wave action of the water body. Hence, some type of erosion control device is required. It should be noted that the life of the coir log is only seven to ten years and will need replacement; otherwise, erosion will eventually take effect. A maintenance schedule should be created to ensure proper repairs.

Water's Edge Vegetated with Bent Grass at a Private Residence in Carmel, Indiana (9 years old)

The most common form of coir logs are vegetated to ensure the establishment of nature's best protection against erosion: root stabilization. The type of vegetation grown at a site changes its resistance to erosion drastically. Root systems enhance the soil strength by reinforcing the soil similar to rebar in concrete. The shear stress of the soil is transferred to the plant roots which have a stronger tensile strength. Depending on the type of vegetation, resistance can be increased by a factor of 18.5 (Goldsmith 1998). D2 strongly recommends pre-vegetating coir fiber logs for this purpose. When discussing vegetated coir logs, two options exist: pre-vegetated or vegetated and on-site vegetating. Pre-vegetating coir fiber logs allow for existing roots to be fully established prior to installation, making rooting quickly attainable, and ensuring the introduction of a native plant community on difficult sites.

Vegetated coir logs provide the following:

- Flowing waters or waves **will not** dislodge the seeds or plant community as they are protected by the coir fibers
- Mild prolonged periods of inundation **will not** suffocate the plant community
- Sediment deposition upon flooding **will not** suffocate plant community as the coir log provides additional void space for oxygen
- Algae colonization on leaves during mild prolonged periods of inundation **will not** suffocate the plant community
- Vegetated coir fiber logs have significant stored food reserves in the roots that are pre- established
- Limited maintenance is required if any
- Introduction of a native plant community that has enough strength to successfully compete with invasive species
- A site specific plant community can be successfully introduced on difficult sites by any level of trained labor
- A successful planting will occur any time of the year.
- Planting in this manner minimizes unsuccessful plantings avoiding costly repairs
- Protection from debris on large bodies of water
- Enable vegetative solutions to aid in successful permitting by governmental agencies

The following conditions can occur with young seedlings (or plant plugs):

- Flowing waters or waves can dislodge seeds, young seedlings or plugs
- Mild prolonged periods of inundation can suffocate seedlings and plugs
- Sediment deposition upon flooding will suffocate seedlings and plugs
- Algae colonization on leaves during mild prolonged periods of inundation will suffocate seedlings and plugs
- Predation by wild life quickly exhausts seedlings and plugs stored food reserves
- Lack of maintenance after installation leads to 50-60% mortality rate of young seedlings and plant plugs
- Competition from invasive species significantly hinders a successful introduction of a specific native plant community
- Successful installation and establishment from seed or plugs is seasonally limited

Coir Log Shipment

Vegetated coir logs are ready for shipment upon the roots protruding through the bottom of the log as shown above. Special note should be taken that these coir logs should be 9 lbs/ft³ density unless on low energy sites, sediment control, or special conditions apply as noted in the *Design Section*. In order to provide a cheaper solution, D2 will see some manufactures offering 7 lbs/ft³ density log, which are more often not appropriate.

On low energy sites, water velocity less than 3 ft/s, "plugging" or on site vegetation is acceptable. Refer to the list above for any concerns and if multiple concerns apply to your project site, pre-vegetation may be your best option. The 3 ft/s velocity limit will be clarified in the *Design Section* of this document.

SHAPES AND SIZES

Coir logs can be either round or rectangular. Round coir logs are traditionally 8, 12, 16, or 20 inches in diameter with densities of 5, 7, or 9 lbs/ft³. Rectangular coir logs are either 12 inches 6 by 10 inches or 16 inches by 10 inches with 7 or 9 lbs/ft³ density. Information on how to select the proper size and density is discussed in the *Design Section*.

D2 provides 7.5', 10' and 20' standard log lay lengths. Generally, contractors prefer to work with 7.5' or 10' lengths as the weight of the coir logs greatly increase with 20' length. 7.5' lay length logs can be palletized making them cheaper for larger projects or shipment. If outside of Indiana, 7.5' lengths are optimal for cost effectiveness. Customized lengths can be manufactured, but proper lead time is required.

NETTING OPTIONS

There are two netting options used in manufacturing coir logs: natural fiber nets and polymeric nets.

Natural Fiber Net

Polymeric Net

Natural nets are comprised of coir fibers, hand twisted into yarns, and hand woven into tubular nets. Natural coir fiber nets vary widely in consistency, strength, uniformity, and durability. Furthermore, natural fiber nets begin to deteriorate as soon as the product is made and stored. The rate of degradation varies with the raw fiber's water content, length of storage time before use, and storage location. Having imported coir fiber logs and natural coir fiber nets since 1994, one constant remains: 20 to 25% of the imported logs or nets are damaged when unloaded from the shipping container. When natural net coir fiber logs are stored for any length of time, whether indoors or outdoors, Asia or North America, the nets begin degrading in the inventoried pile (especially without the proper ventilation). The nets at the bottom of the pile are the last ones to be shipped yet have been sitting in storage the longest. When imported tubular coir nets are pressed into coir fiber logs domestically, stored in a temperature controlled environment, and cross stacked to facilitate air flow, the coir fiber exterior nets still degrades more quickly than its polymeric counterpart. D2 no longer inventories natural net coir fiber logs but rather only manufacture these logs to order. It should be noted that even manufactured to order natural net coir fiber logs can be damaged during loading, shipping, unloading, and installation operations.

Natural fiber nets for coir logs also have a limited manufacturing fiber density of 7 lbs/ft³ due to its lower tensile strength (100 lbs. of natural fiber nets verses 250 lbs. of polypropylene nets per ASTM D-4632). When you truly pack coir fiber to a density of 9 lbs/ft³ into a natural fiber net, the nets will break during the manufacturing process. The import community professes to provide a 9 lbs/ft³ coir fiber density natural net coir fiber log but in reality it simply is not practical. Often the confusion lies with coir fiber density per cubic foot versus coir fiber log weight per lineal foot. For example, a 12" diameter coir log with a coir fiber density of 9 lbs/ft³ weighs 7 lbs/lft thus making it a conversion misunderstanding. Even when properly manufactured to a fiber density of 7 lbs/ft³, natural net coir fiber logs are not as strong and durable as their 9 lbs/ft³ poly net counterpart. See *Design Section* – Weight for more information.

Attempt to Compact 12" Natural Coir Net to 9 lbs/ft³ Density

Inconsistent Netting

When Mr. Bestmann, noted in the *History Section*, started to evaluate high energy sites wanting to utilize vegetation as a stabilizing mechanism, it is now easy to understand why he chose to use a highly UV stabilized, knotless polypropylene net for its strength, durability, and longevity. Remembering that live fascines work due to their survival during fabrication, storage, handling, and installation, proper net selection is critical. It should also be noted that this replica of a live fascine must perform long enough to ensure the establishment of a local plant community. Unbound coir fiber has a long life expectancy, but only coir fibers secured into a dense tubular or rectangular shape will perform the functions of a live fascine. To this day, more than 45 years after their invention, coir fiber logs utilized in Europe remain predominantly comprised of long coir fibers, tightly machine compressed to a density of 9 lbs/ft³, and contained in a highly UV stabilized knotless polypropylene net.

D2 Land & Water typically recommends the highly UV stabilized knotless 100% virgin polypropylene net, the same as Mr. Bestmann.

OUR PRODUCT

Site geometry, water velocity, wave height, water level fluctuations & durations, soil type, and plant community are all key components to properly specify a coir log.

Side Slope

Site geometry can affect the size of coir log to be used. As the steepness of the side slope increases, the coir log at the toe will need to increase accordingly. The **toe of slope log size** should be as follows:

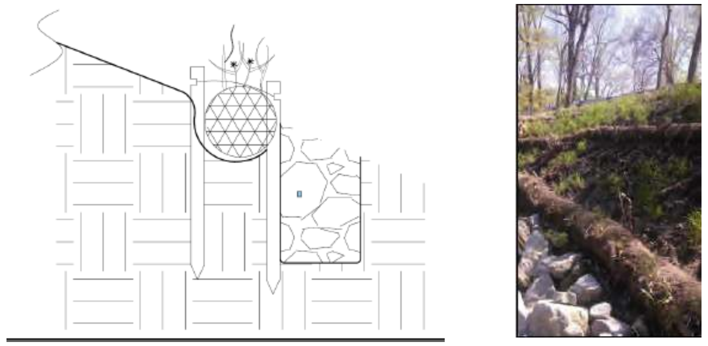
Slope	Diameter of Coir Log (in)	Rectangular of Coir Log (in x in)
X ≥ 2:1 Steeper	20	16 x 10
2:1 > X ≥ 3:1	16	16 x 10
X ≤ 3:1 Flatter	12	12 x 10

Note the diameter size can change when placed next to riprap or other system designs.

Comparison to RipRap

When evaluating coir logs, it is often being compared to the size of the riprap protecting the toe, which the coir log is adjacent to; therefore, to properly select the diameter size of the coir log, see the guidelines below:

Rip Rap Size	Diameter of Coir Log (in)	Rectangular of Coir Log (in x in)
$D_{50} \leq 12"$	12	12 x 10
$12" < D_{50} \leq 24"$	16	16 x 10
$D_{50} \geq 24"$	20	N/A - or Stacked Systems

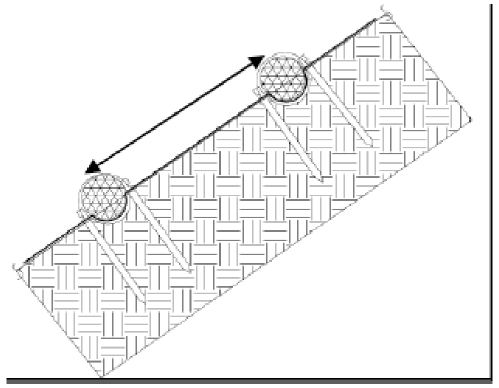


Example 12" Riprap Trench with 12" Coir Log

Interval Spacing

The length of slope and insurance of vegetation growth determines the coir log spacing along the side slope. Coir logs break up the slope minimizing the chance of erosion. As the length of a slope increases, flow becomes channelized increasing its shear stress which results in erosion. The void space within the coir logs itself and the hollow coir fibers act as a pipe retaining and moving water perpendicular to the slope. Coir logs should be placed in the following intervals:

Slope	Interval Spacing (ft)
1:1	5-10
2:1 > Slope > 1:1	10-20
4:1 > Slope > 2:1	20-40



Interval Spacing Along

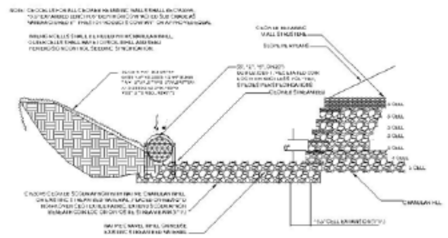
The above chart is based on D2's experience and ranges published by the EPA. D2 strongly recommends that the coir logs be placed at the overlap locations of blankets or turf mats. The coir logs will help secure the rolled goods during the "grow-in" period as well as aid in getting vegetation through this denser overlap area.

Velocity

Projects with velocities greater than 3 ft/s require a 9 lbs/ft^3 density, anything less will result in a loss of fiber. Most creek project sites will have velocities exceeding 3 ft/s; therefore, coir logs with a 9 lbs/ft^3 density are generally specified.

According to the EPA, coir logs can be used in bodies of water with a velocity of 8 ft/s or less. This is considered to be the moderate to high level of susceptibility range. D2 has seen coir logs with a coir fiber density of 9 lb/ft3 contained within a polymeric net be successfully installed and withstand velocities in excess of 10 ft/s. Literature from Bestmann Green Systems suggests coir fiber logs with a coir fiber density of 9 lb/ft3 contained in a polymeric net can withstand velocities up to 12 ft/s with the appropriate plantings.

It should be noted that coir logs aid in the protection of the vegetation during the "grow in" period. The site should be evaluated for when the coir log has degraded leaving nothing behind but what is below the coir log plus established vegetation. For example, if a turf reinforced mat is used at the project site, the driving factor will be if fully grown vegetation can withstand the shear stress of the water with the aid of the mat. Turf reinforced mats come in many different grades and materials, so be sure to check with each specific manufacture for shear stress capacities and permissible limits.



Example of Coir Log Stream Bed Detail

Richmond, Indiana Storm Event 10 ft/s

Inundation

Another item to consider is the inundation time at the site. Inundation is the period of flooding of which an overflow of water submerges land that is normally dry. General rules are as follows when pertaining typical inundation periods at a project site:

- Slope ≤ 2:1 &/or less than one week of inundation — Use 12" diameter coir log or equivalent
- Slope > 2:1 &/or less than one week of inundation — Use 16" diameter coir log or equivalent

Inundations longer than one week need to be evaluated for species type in addition to coir log size. Please seek the assistance of a D2 representative.

Permeability

Permeability is a measurement of the ability of a material to allow fluids to pass through it. Per ASTM D-2434 testing, a 9 lb/ft3 density coir log has a permeability rate greater than $16.3 cm/sec.^{-1}$. As the 9 lb/ft3 density coir log is the densest coir log produced, anything lighter log would have a higher permeability.

Weight

One of the most commonly misunderstood details of coir logs is its density verses weight. The weight of each coir log depends on three factors: diameter, density, and moisture content. During the manufacturing, the coir fibers are only lightly misted (under 15% moisture content) and must the compacted to the proper density. Below is a chart correlating coir diameter, density, and weight. **Special attention should be given to whether a specification is referencing the density (lbs/ft3) or the weight of the coir log (lbs/lft)**. These values are often confused in the marketplace and can cause failures after installation if not properly specified or delivered to the site. For example, a 12" diameter coir log with a density of 9 lbs/ft3 has a weight close to 7 lbs/ft. If the weight is misunderstood to be the density, or the 7 lbs/ft is understood to be 7 lbs/ft3, a lower grade coir log is designed/used rather than what is required.

The weight of coir logs can vary even more once pre-vegetated depending on the time of the year and exposure to water. Individual coir fibers are narrow and hollow allowing them to retain four to six times their weight in water increasing the logs weight. On average, a vegetated coir logs will weigh twice its dry weight, but can weigh up to six times its dry weight.

Diameter of Coir Log (in)	Density (lb/ft^3)	Weight (lbs/ft)
8	5	1.75
12	5	3.95
16	5	7.00
20	5	10.90
8	7	2.45

Diameter of Coir Log (in)	Density (lb/ft^3)	Weight (lbs/ft)
12	7	5.50
16	7	9.75
20	7	15.30
8	9	3.15
12	9	7.10
16	9	12.60
20	9	19.65

Rectangular Coir Log (in x in)	Density (lb/ft^3)	Weight (lbs/ft)
12 x 10	7	5.85
16 x 10	7	7.80
12 x 10	9	7.50
16 x 10	9	10.00

Note that the weights above can vary based on the conditions listed above. The above weights are the actual weights of logs produced at the D2 facility in Indianapolis, Indiana.

Life Expectancy

The type of net and fiber density is directly related to a coir log's life expectancy. Coir logs with polymeric net and a density of 9 lbs/ft^3 can anticipate a life expectancy of 7- 10 years or greater in the Midwest. Coir logs encompassed by polymeric net and a fiber density of 7 lbs/ft^3 or less have a lower life expectancy of 3-5 years. Finally, coir logs contained in polymeric fiber density of 5 lbs/ft^3 are useful only for temporary applications such as sediment control or dewatering.

Natural nets will have a life expectancy of 2-3 years if arriving and surviving the installation process intact. Please see *Design-Netting Options* for more information on natural nets.

Plantings

The question often arises of what types of plants should be used to vegetate coir logs. The following items should be discussed for each project site to determine the proper plantings:

- Soil type
- Local genotype
- Sun exposure (full sun vs. partial sun vs. full shade)
- Maximum inundation periods & frequency
- Location on the bank (low vs. middle vs. high)
- Exposure to flowing water, wave action or still water
- Aesthetics

Specifications typically call out twelve to eighteen plant species with a minimum of five to seven being required. This allows the nursery to account for unforeseen difficulties of plant acquisitions or growth. Plant specifications should be site specific to ensure a successful, sustainable colonization. As a special note, native plant communities often take 2-3 years (or more) to fully develop. Comprehensive specifications should address the maintenance required during the 2-3 year "grow-in" period. D2 is willing to aid any designer with such specifications working with our expert local native plant specialists.

When vegetating a coir log, D2's logs will have the following plant spacing at a 6"-8" depth:

Coir Log Size	# Plants per Linear Foot
8" Diameter	1
12" Diameter	2
12" x 10" Rectangular	2
16" Diameter	3
16" x 10" Rectangular	3
20" Diameter	5

Wave Action

Sites with exposure to wave energy should only utilize poly net coir fiber logs with a fiber density of 9 lbs/ft³. The fill material placed behind the coir fiber log will migrate through the coir fiber logs with a density of less than 9 lbs/ft³.

A vegetated buffer can dissipate wave energy thus reducing erosive potential. A rule of thumb is as follows: bed slope gradient of 10:1 or less with a 5' wide buffer can dissipate a 12" wave, 15' wide buffer can dissipate a 24" wave and 30'wide buffer can dissipate a 36" wave. If there is wave action concern with a gradient of >10:1, additional hard armoring **will be** required in addition to a vegetated buffer. These rules were determined by the original coir log manufacturer Bestmann Green Systems. To date, D2 had found these guidelines to be precise.

Shore Line Protection at Lake Lemon, Indiana (One Month Old)

16" Vegetated Coir Log with Rock Roll Chambered Revetment

CONSTRUCTION

Step by Step Installation Instructions

Coir logs are simple to install. Just follow these steps:

1. Excavate and/or reshape the area where the log will be placed
2. Place coir mat, ECB, TRM and/or other natural seeding with the proper staple pattern per specification
3. Lay coir log on prepared bed burying 1/3 the log unless otherwise noted
4. Connect all logs end to end
5. Apply the proper anchor detail per the plans
6. Bury all upstream and downstream end treatments into the bank to smoothly transition the existing bank to the coir log system
7. Backfill areas next to the coir log as shown in the plans

Additional steps may be required, but the above is a general guideline.

Anchoring Details

There are many anchoring methods that can be used with coir logs with varying degrees of associated costs. One of the most simplistic, yet efficient method, is utilizing 36" or 48", 2" x 2", hardwood stakes with rope lashing. The natural or nylon rope shall be a minimum of ¼" in diameter and notched into the wooden stakes. The wooden stakes are staggered 2' on center each side (or 1' on alternating sides). Stakes should be driven flush with the top of the coir log or at a minimum depth of 1.5 times the height of the coir log and cut off if soils refuse further embedment. Actual lacing can be done in either fashion shown below. This very cost effective method is recommended as much as possible.




Coir Logs with Standard Staking & Lacing

Another method appropriate on low energy sites is burying the coir log to a depth equal or greater than half the coir log diameter (in lieu of one-third of the coir log diameter) or wedging the coir logs in rock.

Securing vegetated coir logs to a rock revetment structure with rope lashing is yet another approach.

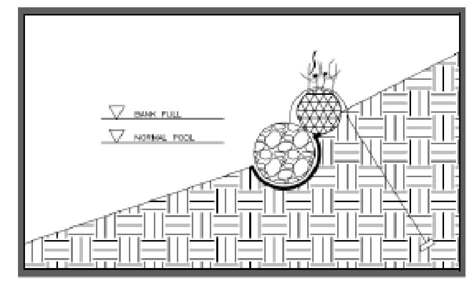
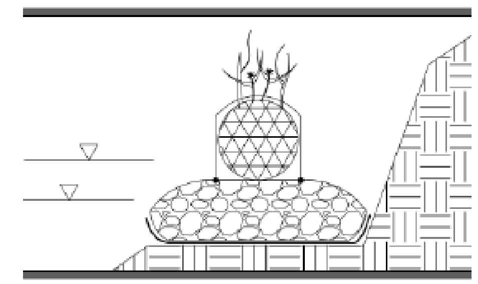
Buried Coir Log at 50%

Wedged Coir Log between Logs

Coir Log between Glacial Stone

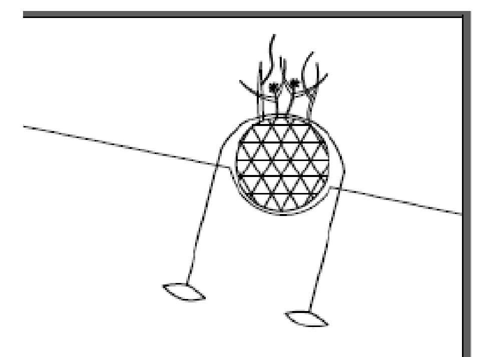
Coir Log Tied to Revetment Structure

Coir Log Tied to Geogrid

In fill applications, lacing the poly net at the bottom of the coir log to a geogrid with a minimum embedment length of three feet is the preferred method. The embedment length should always be separately evaluated if specific soil stabilization is required at the site. Always refer to the project geotechnical engineer. Anchoring with a geogrid is a simplistic installation and provides additional strength to the slope through soil reinforcement. Either uniaxial or biaxial geogrid can be used; however, specific attention needs to be given when utilizing uniaxial geogrid. Uniaxial geogrids need to be placed in the proper direction (i.e. ribs being developed into the slope). Only grids with high junction strength should be used for this anchoring method.

Helical Anchor Tie Back



Duckbill Anchor around Coir Log

Duckbill or helical earth anchors can be utilized, but this approach is more expensive. To decrease the costs of such installations, 1"- 1 ½" galvanized metal pipe can be installed to bridge the sections between duckbill, or helical, anchors to reduce the number of anchors. This method is often installed in larger cut/fill or poor soil applications.

Please refer to a D2 Sales Representative to ensure the proper method is installed at your product site.

Helical Anchor

Duckbill Anchor

End to End Connections

When installing coir logs in a vegetative system, the logs should be laced from one end to another as depicted below.

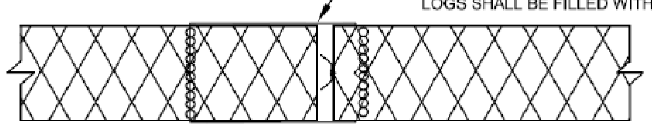
An alternative to lacing the coir logs end to end is a newer technique developed by D2. One end of the coir log has a prefabricated coupler system attached and netting to one end of the coir log. Like most construction products, there is a male and female end. The female end has a net extension of sufficient length to extend beyond the male end. Two 9GA aluminum "hog rings" are used to close the netting around the first coir log, which is folded back. As the second coir log is laid adjacent to the first coir log and extra coir fiber is placed between the logs making them seamless. Stainless steel ¾" "hog rings" will be placed no further than 1 ¾" from the coupler end of the coir log to ensure a second secure coupling of the continuous log unit.

Visual representation seen in figure to the right.

Last but not least, the coir logs can be staked at each end. Note that this does not make a seamless end to end connection; however, it can be every effective in areas with fewer inundation periods.

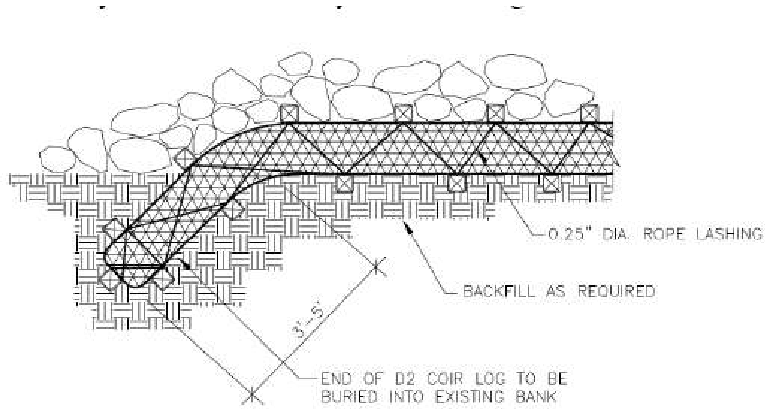
Top View of Laced Coir Logs End to End

Side View of Laced Coir Logs End to End



End Treatments

Attention should be given to the upstream and downstream ends of the coir log system. The end logs need to be smoothly transitioned and keyed into existing stream bank.



Installation Timing

Installations can occur anytime of the year. With the proper attention to detail, logs, mats and seeds can all remain in place and work synergistically to yield the desired results. Past experiences on several sites have resulted in successful installations during the winter with germination developing in the spring.

Examples of challenges during winter construction are as follows:

- Lowest elevation of the system being below the seasonal waterline
- Fill soils being too wet too pass 95% proctor
- Difficulty grading or driving anchor devices into frozen soils
- Seasonal high water or flooding from snow melt
- Stock pile materials can freeze to the ground if not properly handled for winter installations

COMMON QUESTIONS

QUESTION 1: What are some of the advantages of utilizing coir logs?

ANSWER:

- Coir logs allow native vegetation to root, stabilizing nature's best protection against erosion.
- Seeding by itself can be dislodged during water fluctuations. Vegetated coir logs can minimize these occurrences.
- During water fluctuations, silt and/or algae film can be deposited on the newly planted seedlings depriving them of the proper oxygen to grow. Coir logs have approximately 85% void space allowing plants to continue growth until protrusion can occur.
- Maintain valuable nutrients on site that may otherwise discharge into the waterway.
- Expedite vegetative cover due to the proper selection of native plants with protective measures.
- Allows for proper transition from hard armor systems to soft armor systems.

QUESTION 2: What is the most common use of coir logs in erosion control applications?

ANSWER:

Biodegradable Erosion Control Blankets (ECBs) and Permanent Turf Reinforcement Mats (TRMs) are designed to stabilize slopes, shorelines and waterways; however, when blankets or mats are used adjacent to "live" water (water constantly flowing) the termination detail of these products can be difficult to secure prior to establishing vegetation. Coir logs act as a protective piece from the moving water with erosive forces to blankets or mats, which are mechanically anchored. An additional feature of coir logs is their ability to encourage the deposition of sediment behind the log maintaining valuable nutrients while resulting in a bank backfilling zone upon decomposition of the coir log in lieu of a void space.

Coir logs are also a transitional piece from hard armor products to rolled erosion control products (RECPs). This transitional location is often located above the low flow elevation where vegetation can be reinforced and sustain inundation up to 14 days. This elevation is often located at two-thirds bank full. Turbulent forces are increased where rough, smooth surfaces meet and coir logs bridge the gap between these dissimilar materials while encouraging vegetative growth.

Coir Log with PolyNet (9 lb/ft3Density) after 5 Years

QUESTION 3: Because a coir log is being utilized along a shore line to reduce wave action energy, could the turf reinforced mat be eliminated to save money?

ANSWER:

Remember that coir logs are biodegradable and are typically not used to dissipate wave energy by them self but to establish vegetative growth to prevent erosion during the vulnerable "grow in" time period. Coir logs may be used in conjunction with other materials to create a system capable of stabilizing soils prone to wave energies but cannot be used to eliminate other stabilizing products with specific design characteristics. Coir logs are a temporary measure and cannot be considered as a permanent structure. TRMs (permanent turf reinforcement mats) are used to increase the shear stress capacity of the vegetation. Utilizing a vegetated coir log with TRMs increases plant survival on sites where erosive forces during the "grow in" period would have previously failed.

QUESTION 4: When should a vegetated coir log be ordered to ensure its ready in time for the project installation?

ANSWER:

Depending on climatic region and time of year, coir logs require a lead time of a minimum of 2 months to be properly pre-vegetated and have roots protruding through the bottom of the log. If within a 500 mile radius of Indianapolis, IN and placing an order between April 1st and September 1st, the two month lead time is adequate. Due to the climatic zone, being outside of this time frame requires additional time. Outside the 500 mile radius of Indianapolis will also require additional time. Please consult with your D2 representative to get specifics on ordering vegetated coir logs.

QUESTION 5: Have you seen successful installation incorporating various reinforcement products in lifts to establish a stabilized vegetative slope?

ANSWER:

Bioengineering is the term often used to describe the use of vegetation in the construction of civil engineering projects. As designers, we tend to explore the limits of manufactured products and do the same for vegetative growth as well. Vegetation is nature's best protection against erosion, but the "danger" time is the period prior germination and plants rooting. Construction is stressful on plants and the need for outside products to encourage rapid growth should be considered. The biggest question is whether temporary products or permanent products are required.

Temporary products should be used in applications where vegetation only needs moderate assistance to successfully establish a plant community. When evaluating a slope, or similar system, placing temporary products above water fluctuation zones are general adequate if the slope is stable. Other considerations should always be given to the following whether the vegetation will have enough time to fully develop prior to temporary products degrading:

- Velocity of the waterway
- Energy of the waterway
- Sun exposure or lack of
- Site geometry
- Steepness of slope (General Rule of Thumb: Less than or equal to 3:1)
- Period of inundation
- Number of wet/dry cycles
- Proximately to septic systems
- Soil physical structure and chemical characteristics

One needs to be sensitive to all items listed above in making decisions on temporary products. If in doubt, utilizing a permanent product is encouraged. Permanent products are suggested in areas below OHWM as well as for areas when full vegetated systems cannot sustain by themselves.

System Solution of TRM, Coir Log & Riprap

As long as each slope is carefully analyzed, vegetative slopes can be successfully installed in a wide range of applications.

QUESTION 6: What size of coir log should be used for sediment control applications?

ANSWER:

Coir logs for this application require a density of 5 lbs/ft^3 and typically have diameters of 8 or 12 inches; however, diameters could be larger depending on site design. Local regulations should be checked for the placement of coir logs. Typically, the coir logs are placed at the same location as silt fences or other alternative products. Sediment should be removed when deposits reach one-half the height of the log. The table listed above for slope interval spacing in the *Design Section* can also be used for sediment control intervals.

QUESTION 7: What is slope contouring?

ANSWER:

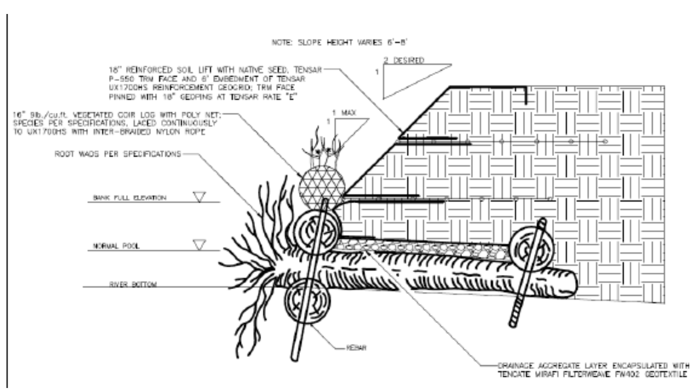
As mentioned in the *Design Section* -Interval Spacing of this document, coir logs are sometimes used to break up the length of slope to minimize the potential for erosion. This concept is known as slope contouring. For most applications of slope contouring (or live staking), a 7 lbs/ft^3 density coir log is utilized as flow is minimized at these locations.

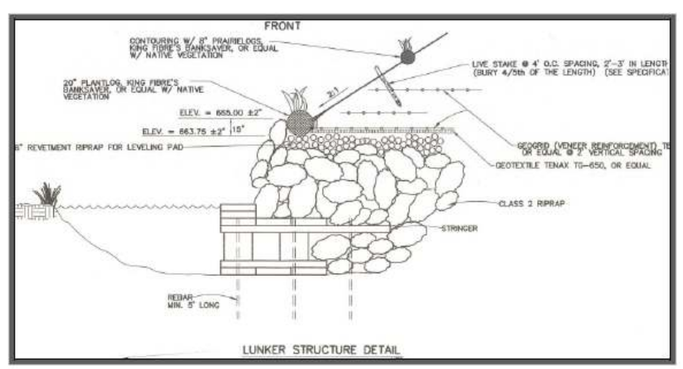
Example of Slope Contouring

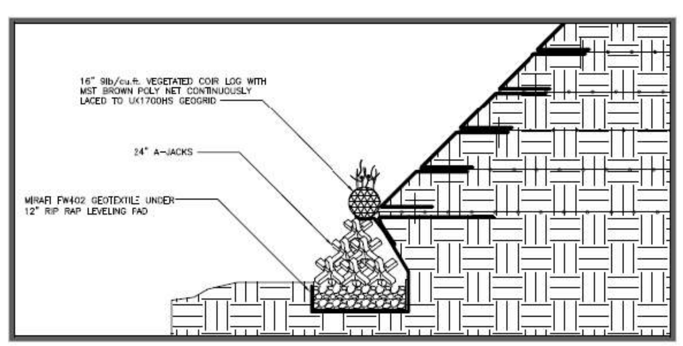
QUESTION 8: Can coir logs be used in soil lifts?

ANSWER:

Coir logs are often used in soil lifts on various types of slope/wall construction projects. Each project is site specific; therefore, each site is designed independently. A few examples utilized in past projects include:







QUESTION 9: Won't the polymeric net be a threat to animals once the coir has decomposed and is exposed?

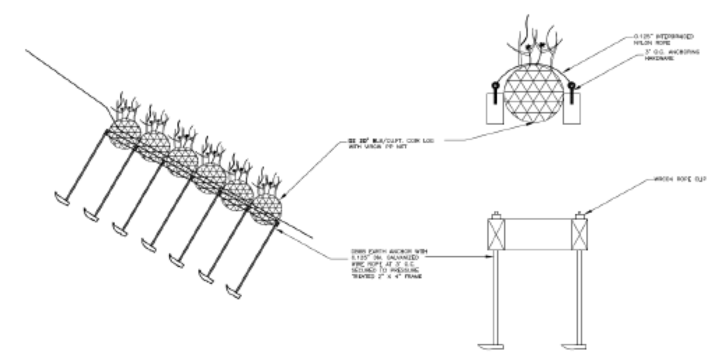
ANSWER:

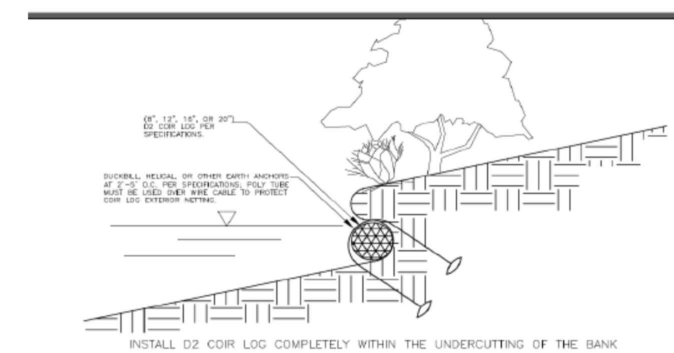
Coir logs encourage the deposition of sediment behind the log maintaining valuable nutrients while resulting in a bank backfilling zone upon decomposition of the coir log. As this process takes place the sediment covers up the net and plants are growing over entire coir log space. Once the coir logs have completely deteriorated, the polymeric net will not be on the surface of the slope, but rather buried.

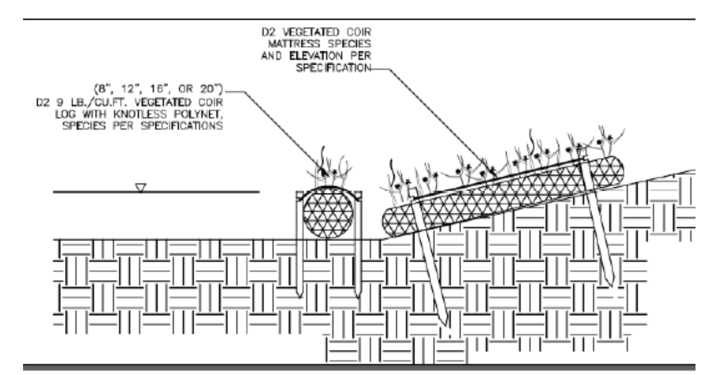
QUESTION 10: Can coir log vegetative systems be used in coastal applications?

ANSWER:

Yes. There are two major differences when working on coastal applications. The first is utilizing different anchoring mechanisms for the sand base and resistance against increased wave action. The second difference is the types of plants used in pre-vegetation. Plants used in coastal applications need to be water tolerable, salt tolerable and deep rooting. Coir log projects have been on the East Coast as well as Southern United States. Projects have included erosion protection for boardwalks, sidewalks, roadways, and loss of usable land. Some example cross sections used in the past are shown below.







PROJECT PROFILES

TIBBS AND BANTA LANDFILL

In the winter of 2002, the City of Indianapolis faced a critical situation. River bank erosion had exposed landfill waste and threatened to expose a petroleum pipeline, jeopardizing public safety and private property. EPA funding for design would not be available for 2-3 years; therefore, in order to protect the public and private property, as well as avoid a potential legal action, the city needed a quick, cost effective solution.

Naren Patel, PE, VS Engineering, Inc., was shown the site by the City in a canoe on the White River. When asked if he would help the City find a solution, Mr. Patel enthusiastically replied, "I will as long as you never make me ride in a canoe in winter on the White River again!" Mr. Patel discussed the possibilities of utilizing a hybrid soil biotechnical solution with local industry representative Jim Blazek. Mr. Patel explained that environmental compatibility, cost effectiveness, call for immediate action, quick permitting, and the difficulties associated with public "low bid" work were all challenges to be considered. Additionally, the system would need to be built year round and withstand potential flooding not only during, but immediately upon construction.

A hard armor solution was investigated and D50 = 30" was an appropriate design. The estimate for constructing this hard armor riprap solution along the affected area was $3,000,000. A second analysis was conducted to determine if soils colonized by synthetically reinforced indigenous vegetation soft armor would adequately protect the landfill and pipeline from exposure. A detailed design analysis was performed and a hybrid system was proposed. The installed estimate for the hybrid system was $2,200,000. Considering the project's challenges and budgetary analysis, VS Engineering, Inc. proceeded with the hybrid design.

Looking Downstream at Site April 2003

August 2003

Looking Upstream after First Flood May 2003

December 2003

The hybrid design approach included a riprap wing deflector at the upstream end of the project as the affected river bank was approximately at a 30 degree skew to the river's thalweg or primary deep channel. A riprap "aggregate raft" was constructed along the entire toe of slope composing of Tensar UX Geogrid and 1160N Mirafi non-woven geotextile. The aggregate raft design was utilized to minimize scour and differential settlement. It was constructed from three feet below the normal pool to a top elevation of two feet above normal pool. The top elevation coincides approximately with the two-thirds of bank full elevation, which is the typical transition point to the vegetated or "soft armor" solutions. A non-woven separation geotextile was laid on top of the aggregate raft to prevent the backfill from migrating through the stone's void space. A 2:1 fill slope was constructed over the aggregate raft in front of the landfill waste and the pipeline. The backfill was reinforced with Tensar BX Geogrids in 18" vertical lifts. Indigenous seeds were sown on the constructed slope and then covered with North American Green P-550 permanent reinforcement mat. The bottom of slope included a 20" diameter, 9 lbs/ft3 density, prevegetated coir log, with site specific species. The coir log was placed on top of the P-550 at the transition to the vegetative system. Eight inch diameter, 9 lbs/ft3 density, vegetated coir logs were also placed to secure the overlap locations of the P-550 mat. The coir logs were used to ensure the successful introduction of over twenty indigenous plants species throughout the slope.

The project's installation began in April 2003 and was completed by the end of October 2003. The first flood took place less than thirty days after the first four hundred feet of the project was installed (two thousand linear feet total). The last eight hundred feet was installed dormant waiting for Spring 2004 to germinate. The system withstood six flood events during the 2003 installation, with inundation periods up to seven days and a record setting nine inch "Labor Day 2003" rain event. The system has been monitored yearly since 2003 and continues to perform meeting all design expectations.

March 2005

August 2005

May 2004

August 2005

CAMPBELL'S DITCH

When designing CR 200 South in Tipton County, Indiana, USI Consultants had a potential long term cost savings measure for the County. Campbell's Ditch, a legal drain, originally crossed CR 200 South discharging into Buck Creek 300 yards downstream of the road crossing. By relocating 1400' of Campbell's Ditch to the north side of the road and keep Campbell's Ditch discharging into Buck Creek, USI would save the County the costs associated with the replacing the existing structure and all future maintenance costs associated with the structure itself.

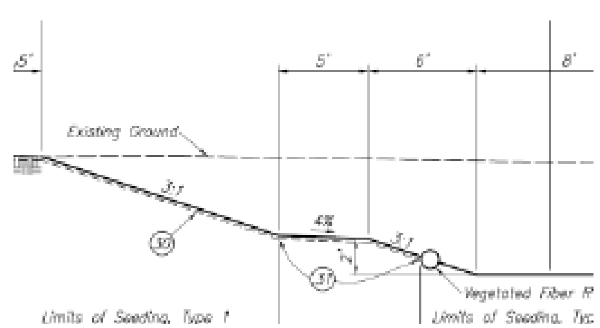
Knowing that relocating the ditch could be difficult during the permitting process, USI looked for alternative vegetated solutions in lieu of the standard riprap details. In doing so, USI seek expertise from local erosion control specialist, D2 Land & Water Resource. The ditch's minimal velocity allowed a 12" diameter, 9 lb/ft3 density coir log to be placed at the toe-of-slope with a permanent turf reinforcement mat, North American Green's SC-250, on the side slopes. The upper bank was protected with a biodegradable blanket, S150BN, to allow the vegetation to develop. This design was approved by the Indiana Department of Natural Resources for a Construction in a Floodway Permit, Indiana Department of Environmental Management for an Individual Section 401 Permit, and Army Corp of Engineers for a Section 404 Permit.

The design has successfully withstood several flooding events including the storm documented in April 2013 shown below. By the May 2013 picture, you can see that major flooding is no problem for this reinforced vegetative system!

Installation - August 2007

May 2013

During April 2013 Flooding



HIDDEN VALLEY SUBDIVISION

Due to upstream development resulting in more intensive storms, erosion on an un-named regulated drain in Richmond, Indiana had started to expedite, threatening an already failing vinyl sea wall, exposing a 36" sanitary line and a roadway collapse. The creek ran through Hidden Valley Subdivision and was a featured part of the subdivision with many residences backing up to the creek's edge as a prominent feature. Design consultant, Butler, Fairmen & Seifert (BF&S), had a lot to consider while working within the complex tight easement. Part of their challenge was to find vegetative systems that would be not only more aesthetically appealing, but also minimize city's safety concerns of riprap in this residential area.

To meet these challenges, three different types of vegetative sections were developed based on the location of the creek with the roadway, residences, sanitary sewer line and existing sea wall. Where there was enough horizontal space to install a vegetative slope, the standard design of a sacked gabion at the toe of slope and coir log to transition to vegetation reinforced with a permanent turf reinforcement mat was utilized. The velocity of the drain was 10 ft/s; therefore, in the bend areas, a soil confinement mechanism, GeoWeb, was installed to maintain the soil bed to prevent erosion at the toe of slope or further movement of sediment. Other areas of the project were much more complicated than these gentle slopes.

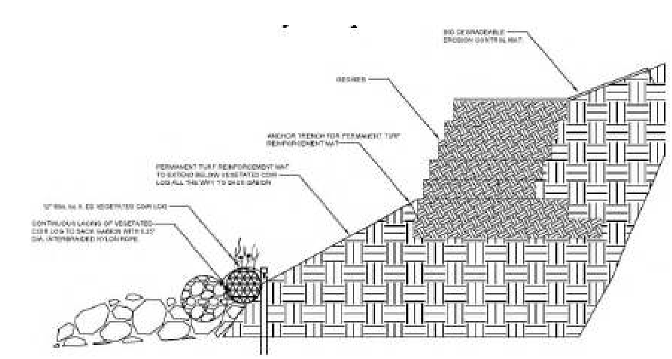
In the areas with limited space for grade changes, vegetative wall systems were investigated. The standard wall heights required were either 4' or 10' tall. After comparing several options, BF&S decided to pursue with a GeoWeb wall due to its superior drainage capabilities, natural appeal and limited future maintenance. Each wall was protected at the toe with a sacked gabion, 12" diameter 9 lb/ft3 density coir log and a permanent turf reinforcement mat.

The City of Richmond was extremely pleased with the ease of construction of these systems as well as finished appeal. Since construction, the systems have withstood several flood events without any complications.

Standard Coir Log Design Section Installed Dec. 2009 - Picture taken Aug. 2012

Standard Coir Log Design Section Installed December 2009

Overgrown 10' GeoWeb Wall with Coir Log at Toe of Slope - Aug. 2012



LICK CREEK

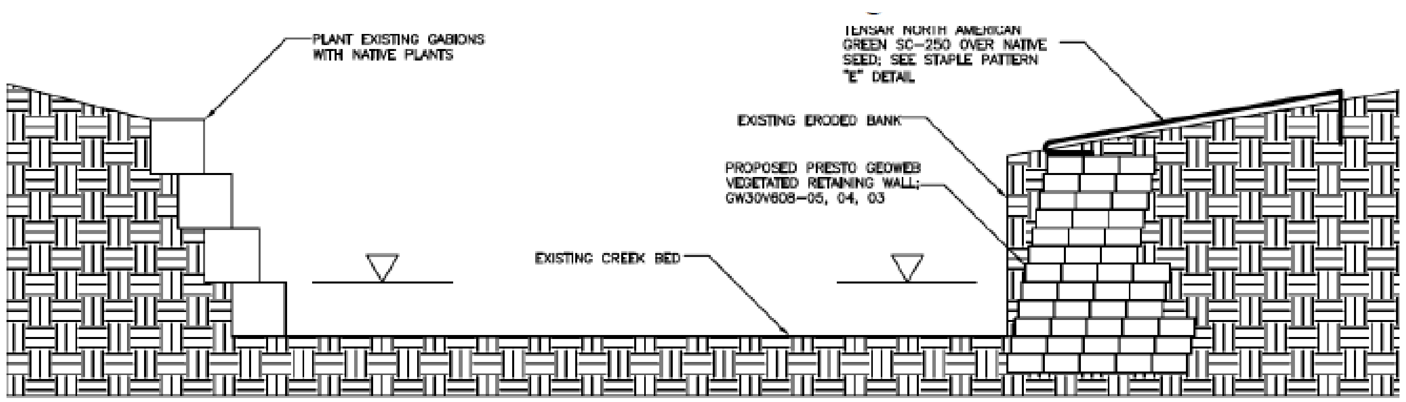
The City of Beech Grove, Indiana, located on the south side of Indianapolis, had some serious erosion issues in Sarah Bolton Park. Erosion of Lick Creek through the park was raising concerns of threating the roadway, eroding the foundation of an existing power pole, exposing a sewer line and losing three large trees. To find solutions to their problem, Beech Grove hired United Consulting to survey & permit the project and Christopher Burke Engineering for the design.

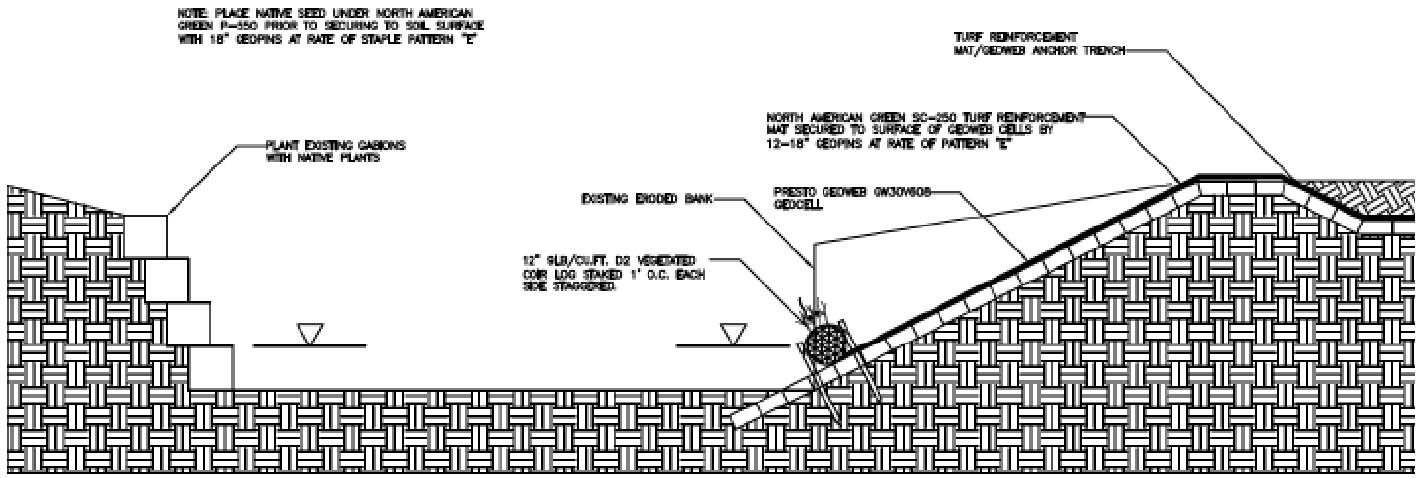
Three cross sections were developed at the project site. The determining factor on the type of cross section utilized along the bank was the available horizontal space to the soon-to-be protected obstruction. Erosion began downstream of a concrete bridge and continued for 750′. The furthest downstream cross section incorporated a vegetated soil confinement wall, GeoWeb, to protect the power pole from relocation. Above the wall, a permanent turf mat, North American Green SC-250, was used to protect the seeded area till germination and strengthen the vegetation during flood overtopping. The opposing side the creek had an already constructed gabion wall. The gabion baskets were repaired with new PVC coated galvanized steel baskets and live staked to increase vegetation.

Once past the power pole, the cross section could be slightly modified with the GeoWeb wall to lessen the steepness of the cross section. It should be noted that around the power pole a modified wall design was used. Helical anchors were used to reinforce the gravity wall to decrease the cut into the slope minimizing any impacts to the power pole.

Installation - August 2007

May 2013





Eventually, Christopher Burke was able to lay the slope back for a gentler cross section approaching the bridge while protecting the sewer line, tree roots and roadways. Due to the erodible soils, GeoWeb was once again used; however as a surface applied product in this cross section. A 12″ diameter, 9 lbs/ft3 density pre-vegetated coir log was placed at the Ordinary High Water Mark (OHWM) to assist in establishing the vegetation at this vulnerable location. The same permanent turf mat, North American Green SC-250, was used on top of the surface applied GeoWeb to increase the shear stress capacity of the system. Note the SC-250 was below the coir log, continued up the slope to the top of bank. The Parks Department was very specific on the types of plants to be incorporated into the design. As such, D2 worked with the Parks Department to pre-vegetate the coir logs appropriately and provide a seed mixture.

Next to the bridge, Christopher Burke was able to transition to the bridge with articulated concrete block mat, which was consistent with the existing design.

The project was an overall success and D2 will continue to monitor the site through the upcoming years.

Tree Roots being Threatened by Erosion June 2012

Transition from Coir Log to GeoWeb Wall June 2013

Coir Log to GeoWeb Wall August 2013

MISHAWAKA RIVERWALK

In 2006, Lawson-Fisher and Rundell Ernstberger were retained to design a new upscale condo complex as well as the surrounding river walk on a brownfield site in downtown Mishawaka, Indiana. Part of the project included stabilizing and vegetating the banks of the St. Joe River, which included maintaining some of the natural habitat. The native plant community not only stabilizes the bank in front of the river walk wall, but also provides forage and cover to indigenous animals that use the river corridor. This design strategy was cost effective and appealing to the permitting agencies.

Rundell worked with D2 Land & Water Resource on three project site locations for vegetative system solutions. The north slope included two components. The upper section of the slope utilized un-vegetated coir logs for slope contouring. The 7 lbs/ft3 density coir logs were used to break up the length of slope. Channelized flow on banks can start rills in un-vegetated areas which lead to complex erosion issues. Coir logs minimize the potential for this erosion by diverting the water through the coir log and discontinuing channelized flow. The bank was also seeded and protected with an erosion control blanket till germination could take place.

The lower section of the north slope included aesthetic river rock to protect the toe, pre-vegetative 9 lbs/ft3 density coir logs to transition to the soft armor system of a permanent turf mat, North American Green P-550. This permanent turf mat was chosen to increase the shear strength of the vegetation on the slope to match the proposed conditions. The pre-vegetative coir log allows for a successful introduction of a plant community in a vulnerable zone where plugs tend to dislodged, suffocated, or erode prior to establishment. Coir logs help prevent all these failures as noted throughout the Design Guide created by D2. The third location, the south bank, was designed the same as the lower section of the north bank.

As the plant communities "grow up", the coir logs degrade, becoming part of the cover and are virtually unseen as shown in the August 2009 picture. This successful project is wonderful to look at on walk along on the riverwalk!

Upper Section of North Bank- 2007 Installation

Lower Section of North Bank- 2007 Installation

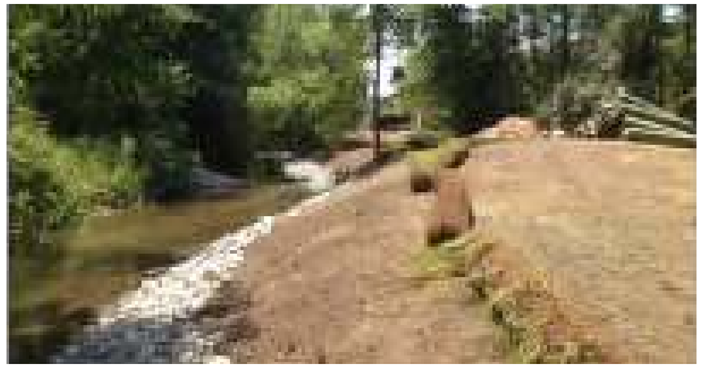
Upper Section of North Bank- August 2009

Lower Section of North Bank- August 2009

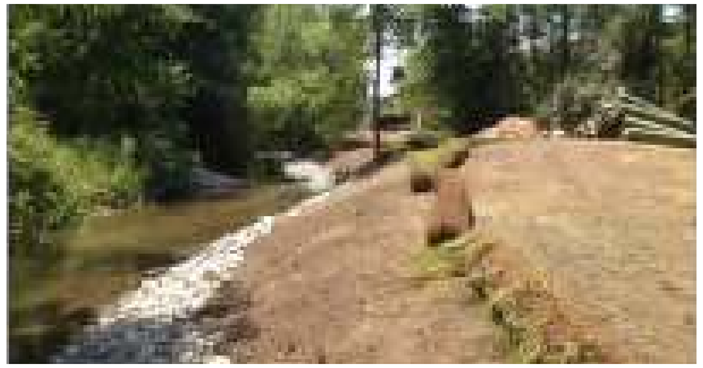
ELLER DITCH

The construction of the US 331 Road Reconstruction in South Bend, Indiana did not come without its environmental challenges and concerns. American StructurePoint was required to design a mitigation plan as part of the project. Eller Ditch, a St. Joseph County legal drain, was determined to be the perfect location to incorporate such a plan. The mitigation plan included the following coir log design: riprap placed at the toe of slope for stabilization, 12" diameter 9 lb/ft3 density coir log to transition to a soft armor vegetative system, a permanent turf reinforcement mat on the slope to increase shear stress capabilities of the vegetation.

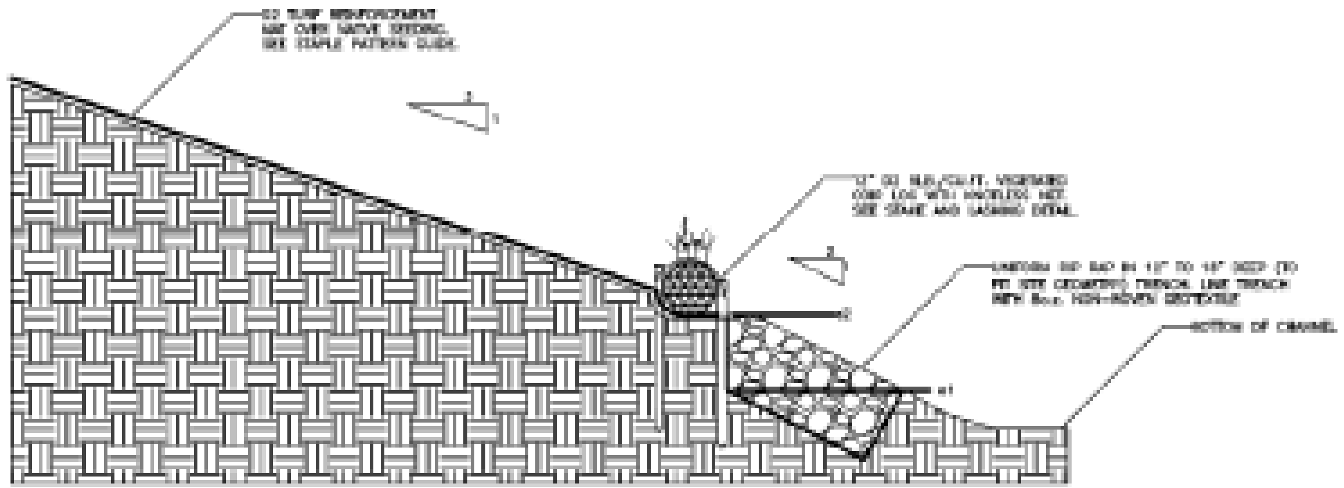
During the submittal, the Indiana Department of Transportation and the contractor had concerns regarding whether the design would hold during flooding conditions. Specifically, they were anxious the plants would suffocate during the wet season. This same design technique was used on a nearby Juday Creek, Indiana's only natural trout stream, without any problems. With the aid of D2 Land & Water Resource and recognizing similarities to the Juday Creek project, StructurePoint was able to convince all parties involved that the vegetative design was the appropriate solution. From the one year later installation, everyone can see they were correct! To date, the vegetation has successfully established without any further maintenance.



During July 2012 Installation



July 2013



WHITE RIVER CAMP GROUND

In 2007, the Hamilton County Parks Department had a serious erosion problem on the west bank of the White River Camp Ground located in Strawtown, Indiana. If the erosion continued, not only would an electrical and sanitary line be exposed, but the 10′ drop from the RV camp sites would continue to erode raising even further safety concerns. The Parks Department decided to locally fund the project and selected Indianapolis-based USI Consultants to perform the design. Due to their previous successes with vegetative systems, USI Consultants engaged D2 Land & Water Resource early in the design process.

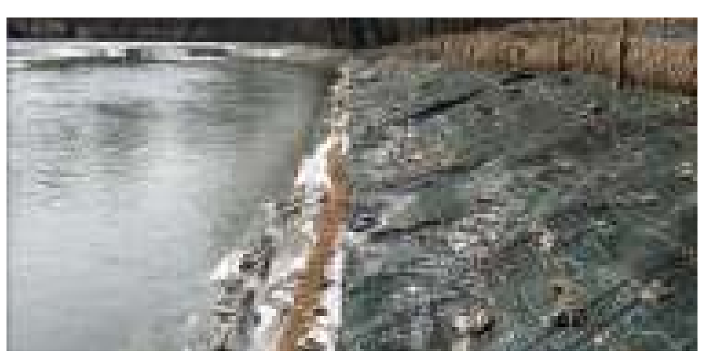
Two designs were proposed along the White River depending on the location of bank in reference to the utilities. The first design was at the lower bank or where the steepest slopes with erosion closest to the utilities were located. At the base of the slope extending to the Ordinary High Water Mark (OHWM), an aggregate raft was built utilizing Mirafi 180N geotextile, Miragrid 5T geogrid, and Class 1 riprap. A 20″ gabion sack was placed at the OHWM, where a 9 lb/ft3 density vegetated coir log transitioned to the soft armor system of permanent turf reinforcement mat. It should be noted that the coir log was secured (laced) to the gabion sack for stability.

The second cross section was designed for the area where only high bank restoration was required. In these areas, there was enough horizontal space in relationship with the utilities to properly slope the bank. Similar to the first cross section, another aggregate raft was built, but at the OHWM no gabion sack was used to transition to the coir log design due to the more gentle slope. The same 9 lb/ft3 density vegetated coir log was used to transition to the soft armor system. In the soft armor system of this section, Tensar BX100 geogrid was used to strengthen the newly backfilled surface slope as well as to secure the lower coir log to the bank. The sub sequential vegetated coir logs were stacked and laced at the TRM overlap locations.

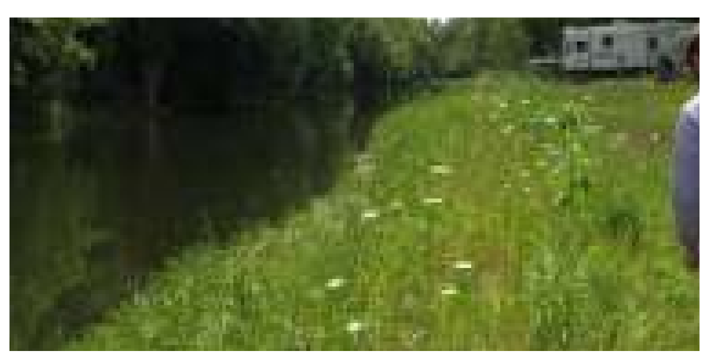
The construction of this site occurred from Nov. 1, 2007 to March 15, 2008. During this time, there was 67 flood days, all overtopping some part of the vegetative system. From July 2009 photo, it can be seen that the flooding did not affect the stability of the vegetative system.

November 1, 2007

Aggregate Raft



November 14, 2007

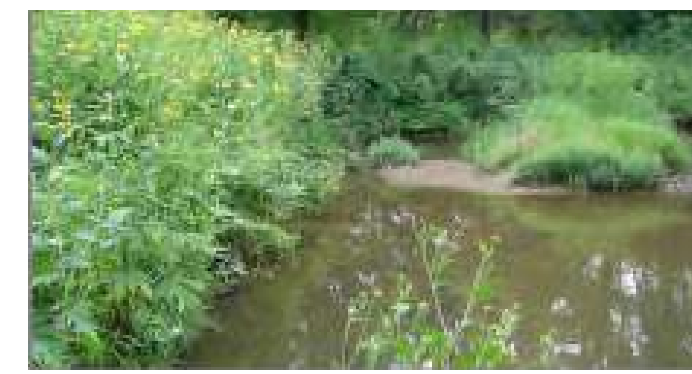


July 2009

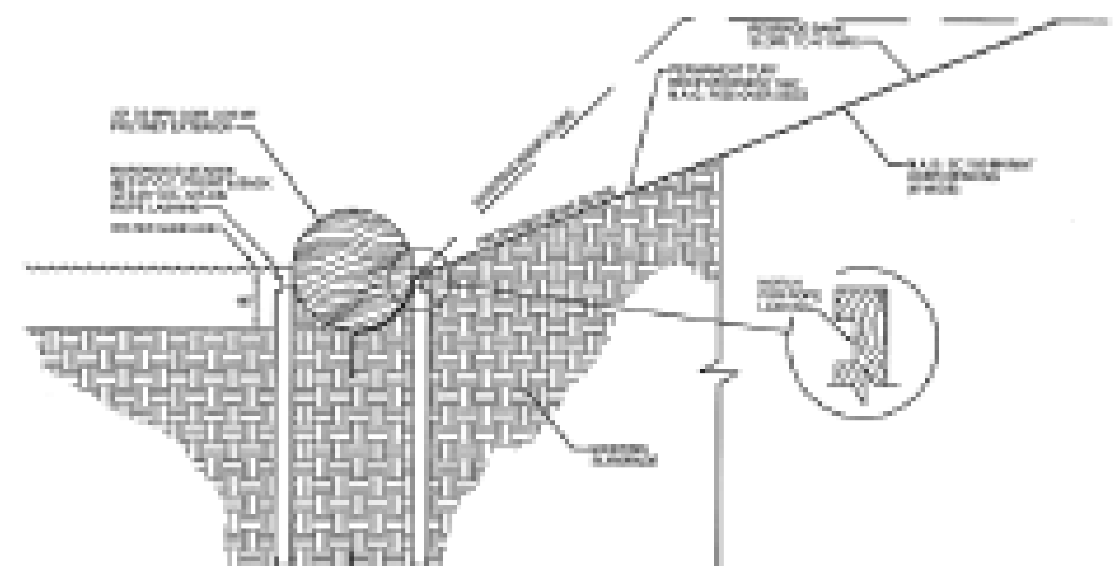
COOL CREEK STREAM RESTORATION

City of Carmel, just north of Indianapolis, has been under expansion the past several decades. The rapid urban and residential growth has led to increased run-off throughout the City, especially along its Cool Creek corridor, which is a tributary to the White River and a native riparian habitat. To satisfy the City's concern with another upstream residential development, a mitigation plan was developed by the engineer of Arden Townhomes. Many options were analyzed throughout the design process. The final design, agreed to by all, was a vegetated system to include a 20 inch coir log, North American Green (NAG) P550 permanent turf mat, and NAG SC 150 BN temporary erosion control blanket. The 20 inch coir log was pre-vegetated and placed at the toe of slope to aid native plants in taking root in this sensitive area. NAG P550 was installed over seeded soil in the wet to mesic areas to increase the vegetation's shear strength capacity to 14 lbs/sft. Finally, the temporary blanket was placed along the upper slopes where natural vegetation was sufficient to resist erosion once established. NAG SC 150 BN is a double-net straw and coconut fiber blanket with woven jute netting, which protects the soil up to 18 months during the establishment of vegetation. This vegetative system was designed as an equivalent to a 24 inch riprap section. By working with both the City of Carmel and design engineer, D2 Land & Water Resource was able to satisfy all the restrictions and provide a cost effective vegetative solution.

Installation



Four Years after Construction



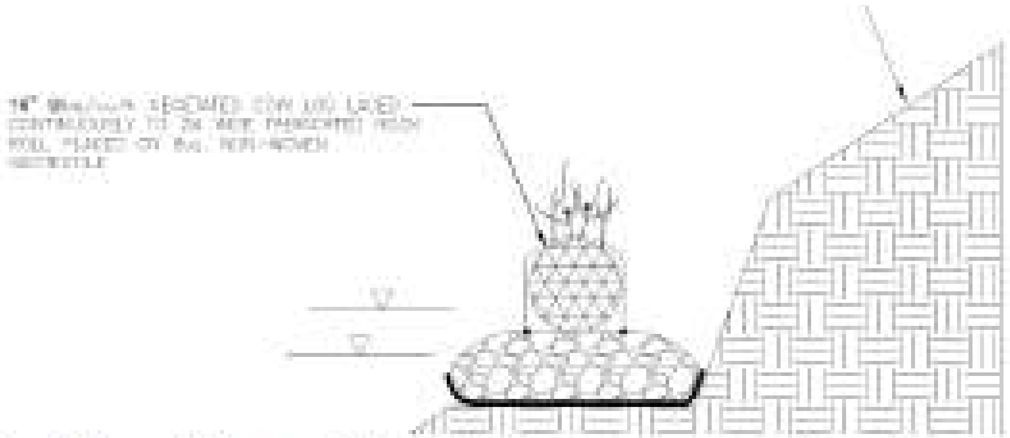
LAKE LEMON RESERVOIR

Lake Lemon is a reservoir formed by Lake Lemon Dam on Beanblossom Creek approximately 10 miles northeast of Bloomington, Indiana. Originally, the lake was built to control water levels for Bloomington's (and surrounding areas) drinking water supply. Today, Lake Lemon is mostly a recreational site. The constant wind and wave energy throughout the years had resulted in erosion along the entire shoreline. Compounded with the fluctuating water levels, the zone between well-established vegetated banks and the eroding toe of slope was expediting. The eroded bank consisted mostly of infertile subsoil and rock making re-vegetating the banks difficult. Any potential solution for the site would require all the following: create a wave break to dissipate the wind and wave energy, provide a specific plant community in the hostile growing environment and soils, allow for construction with very limited access, and require little to no long-term maintenance.

After the Lake Lemon Conservancy District (LLCD) received a LARE (Lake and River Enhancement) grant, they selected Donan Engineering to help administer the grant and address the shoreline erosion. Donan Engineering contacted D2 Land & Water Resource to evaluate the problems at Lake Lemon. After a site visit, D2 proposed the following design:

To combat the wave and wind energy, pre-fabricated 22 inch rock rolls filled with 4 to 6 inch riprap would be placed at the toe of slope. The rock rolls would provide the armor for boat and wind energy while creating an elevation for the introduction of vegetation. Upslope of the rock roll, a pre-vegetated 16 inch coir log with knotless brown polypropylene netting at a density of 9 lbs/ft3 would be installed. This type of coir log in terms of density and net type was selected for its proven performance history in waterway and shoreline bioengineering projects. The coir log would be pre-vegetated with native wetland species and provide a mechanism for controlled species introduction. The compressed coconut coir log, once pre-vegetated, can offer moisture and nutrients to the vegetation while establishing in its new location. This proposed cross section offered LLCD a low/no maintenance way to introduce these difficult plant species.

The results of this system were immediate. It provided a self-sustaining solution that allowed for sediment deposition behind the coir log for natural slope refilling, the rock toe allowed for energy dissipation and created an environment to allow the native species to establish. The site continues to be monitored, and even after nearly a decade in place, the system is still providing the erosion protection and habitat development.



**It should be noted that an additional 2 inch loose stone was top dressed over the rock rolls to fill the voids between the larger stones, to smooth the transition between the rock roll and the coir log, as well as to provide a natural aesthetic look.*

Installation July 2003

Completed Installation

August 2003, One Month after Installation

August 2008- 5 Years after Installation

COCOLOGIX

bank stabilization systems