Intermittent Stream Reclamation

November 2013

About Mosaic Reclamation

> In carrying out its mission to help the world grow the food it needs, Mosaic couples recovery of phosphate resources with respect of the phosphate-rich land that fuels thriving communities, economies and American and global food production. While mining is a temporary use of the land, reclamation offers habitat and recreational benefits for generations to come. Land reclamation is the process of turning mined lands back into productive use and has been required by law in Florida since 1975. In respecting this important balance, Mosaic continuously improves its reclamation practices to create natural habitats blended with other land uses across the reclaimed landscapes.

Mosaic's dedicated team of reclamation scientists, engineers and biologists develop detailed reclamation plans for the productive use of mined lands years before any phosphate is extracted. With Mosaic reclaiming every acre or more that it disturbs, the reclamation plans focus on connecting preserved and reclaimed habitats to create a diverse and sustainable habitat network that is integrated into the larger regional ecosystem.

Connecting the Science

Reclaimed habitats contain streams and their associated floodplains, as well as connected and isolated wetland and upland natural environments. These include unique natural systems that are vital to the ecosystem of the Central Florida region, such as forested swamps and palmetto prairies. Reclamation also offers an opportunity to enhance the broader quality of lands that were drained or cleared for agriculture and other uses many years before mining was ever anticipated.

Mosaic designs its reclamation plans from a holistic perspective, centered on creating a variety of habitats to provide for a diversity of wildlife. This allows an ecosystem to survive and grow on its own, which is the essence of a sustainable environment, and the criteria for release approved by the state. <

Mosaic designs reclaimed streams to return the systems to a more natural state.

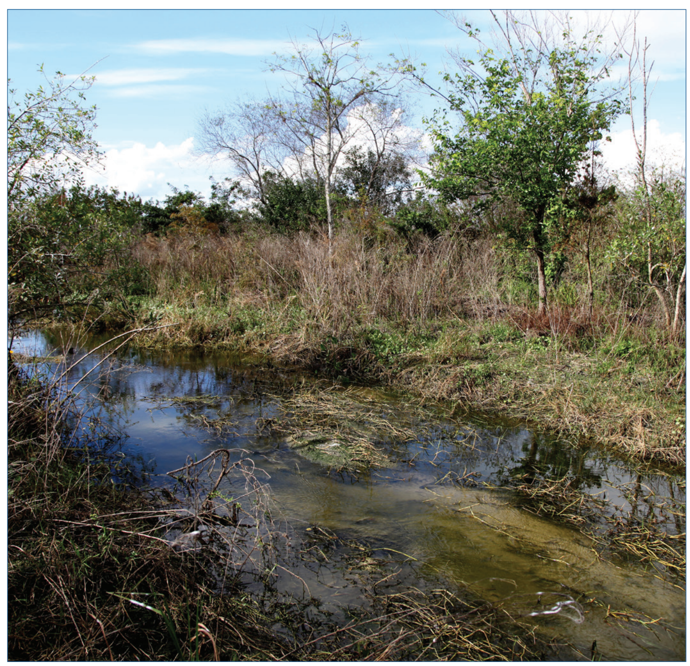
A Legacy of the Land

> Proper habitat connectivity requires a comprehensive understanding of the relationships among the environments within a watershed. Among other functions, streams and floodplains connect upstream and downstream habitats. Not only are streams responsible for delivering and maintaining the proper amounts of water at the proper times to surrounding habitats, but streams also create habitat for fish and aquatic insects. Additionally, streams provide other wildlife defined and valuable corridors that connect habitats and systems vital for their survival.

The two primary types of streams on Mosaic's land and in its reclamation portfolio are perennial and intermittent. Perennial streams flow continuously, while intermittent streams flow only during certain times of the year – typically during Florida's wet and rainy summer months. Most Central Florida streams are intermittent.

Whidden Creek and Stephens Branch are two streams Mosaic created on reclaimed landscapes in Polk County, Florida, that demonstrate the importance of reclaimed intermittent streams in connecting and supporting surrounding habitats. Whidden Creek, constructed in 1996, and Stephens Branch, constructed in 2011, are also case studies that exemplify how advancements in the science of reclamation over the last decade expedite the design, development and functionality of reclaimed stream systems. <

Each variety of wetland habitat contains unique plant species that require different amounts of water at the right times of year for support.



Mosaic enhances stream habitats by planting wetland sod along the banks to develop wetland floodplain systems that connect to adjacent uplands.

Naturally Advancing

> Stream restoration and design has progressed significantly in recent years because of the advancement of land-restoration science and improvements in digital mapping, measuring and modeling technologies. Today, reclaimed stream design calls for an increased level of precision. This includes providing in-stream habitat for fish and aquatic insects and corridors for connecting other habitats – natural and reclaimed – to allow for wildlife passage. The design is further supported by applying sophisticated computer models that predict when and how the water will flow.

Use of the Rosgen classification system is one example of the stream restoration and design advancements that Mosaic utilizes. Rosgen is a formal classification system that supports the modeling of reclaimed streams by identifying a stream's ideal channel dimensions, bed materials and size.

When Whidden Creek was constructed, the practice was to grade a stream valley/floodplain area, along with the land that would drain into it, which is also known as the watershed. Then, rainfall runoff onto the watershed would flow into the stream valley and "naturally carve" the channel over many years. Today, this process has been accelerated by pumping water in a recirculating manner to simulate storm events and "hydraulically carve" the stream channel in a few months.

The other method for creating functional streams is through mechanical construction. This method consists of excavating the meandering channel to the design dimensions in the stream valley and stabilizing the banks with vegetation and biodegradable fabric. The channel meanders and design dimensions are determined by classifying and assessing existing streams in order to mimic natural conditions, known as the reference-reach method.

Monitoring has also documented that the streams are properly sized to match the flow patterns generated by their watersheds and store floodwaters to reduce downstream flooding. <

Rosgen stream design techniques and/or simulated flood flows ensure reclaimed stream systems provide both proper hydrological function to the systems they connect as well as valuable wildlife habitat and corridors.

Intermittent Stream Design At-a-Glance

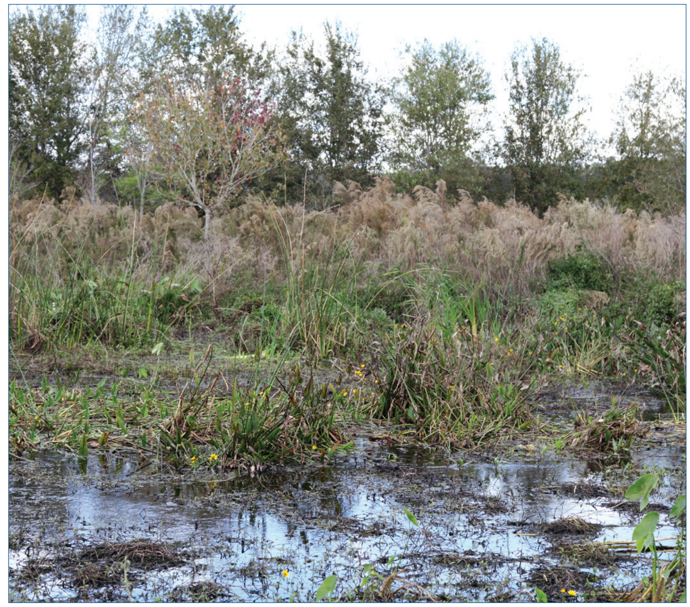
Design Components	Whidden Creek (1996)	Stephens Branch (2011)
Pre-mining Condition	• Shrubby, transitional, marsh system with a poorly defined channel.	• 14-acre mixed hardwood forested wetland with large cattle pond. • Permeable, sandy soils with variable organic matter content.
Project Timeline & Milestones	• Mining occurred during 1992 and 1993. • Reclamation occurred during 1998. • Reconnected to state waters in 2002. • Released by state of Florida in 2012.	• Mining operations completed in 2007. • Preconstruction soil and hydrology monitoring and modeling to confirm design requirements (2008-2010). • Reclamation complete in 2011. • Reconnected to state waters in 2012. • Currently monitoring to support future state release request.
Design Methods	• Naturally carved stream.	• Mechanically constructed. • Utilized reference reach and Rosgen design methods.
Connectivity Aspects	• Headwater stream flowing into Whidden Creek, a tributary of the Peace River, and then into Charlotte Harbor.	• Headwater wetland flows into Stephens Branch. • Stephens Branch flows into preserved tributary of the Peace River and then into Charlotte Harbor.
Drainage & Hydrology	• Surrounding lakes and marsh feed the stream. • Limited to surface runoff modeling.	• Forested headwater wetland design based on integrated surface-groundwater modeling. • Groundwater monitoring to confirm design. • Drainage area, Rosgen channel and design valley slope similar to reference stream.
Vegetation	• 12 acres of forested wetlands surrounding more than 25 acres of marsh.	• 28-acre forested headwater wetland flows into Stephens Branch. • Contains upland forested buffer.

Perfect Timing

> Converting the designs of a reclamation plan into streams and associated habitats is accomplished by first modeling and then backfilling and grading the mined areas and developing the stream channels (mechanically or hydraulically). Next, the site is planted with native vegetation. From there, each site undergoes an extensive period of monitoring and maintenance until it is self-sustaining, meets the design criteria and can be released by the state.

Backfill and grading requirements to return the mined land to the design topography are determined using computer models and advanced digital aerial imagery. Most often, sand separated from the phosphate ore matrix is pumped to provide the necessary fill volumes and properly layered with the sub-soils excavated during mining and left on site to assure proper groundwater flow. This process is known as "sand tailings" fill. Earthmoving equipment, typically outfitted with GPS-based technology, is used to contour sand and overburden to approved vertical tolerances as narrow as three inches.

Once the foundation has been established, Mosaic often relocates topsoil from other wetland areas yet to be mined. Known as "muck," these topsoils contain diverse seed banks, which help establish desirable native vegetation and help prevent unwanted vegetation from emerging. Further, Mosaic relocates desirable native vegetation, when available, from donor sites permitted for mining. Trees and shrubs purchased from nurseries are planted and used to complete the vegetation process. Upland buffers are created surrounding stream systems to provide wildlife corridors and connectivity.



Placement of muck helps expedite the establishment of proper wetland function.

Once constructed, the stream channel bed and banks are further developed by installing biodegradable erosion-control matting, which enhances stream bank stability during the vegetation-establishment process. Additionally, shallow "pools" are excavated to provide habitat for fish. Logs, tree stumps and leaf litter from other streams are installed to provide aquatic insect habitat. Riffles are also constructed between pools to provide faster flowing segments to facilitate habitat creation in the channel.

With a working system in place, Mosaic then turns its stream-reclamation focus to the monitoring and maintenance of the site. Each stream and adjoining wetland is monitored to measure stream habitat and conditions, flow patterns, water quality, and the growth and development of the desirable vegetation. Removal of unwanted vegetation occurs as needed.

EXECUTION

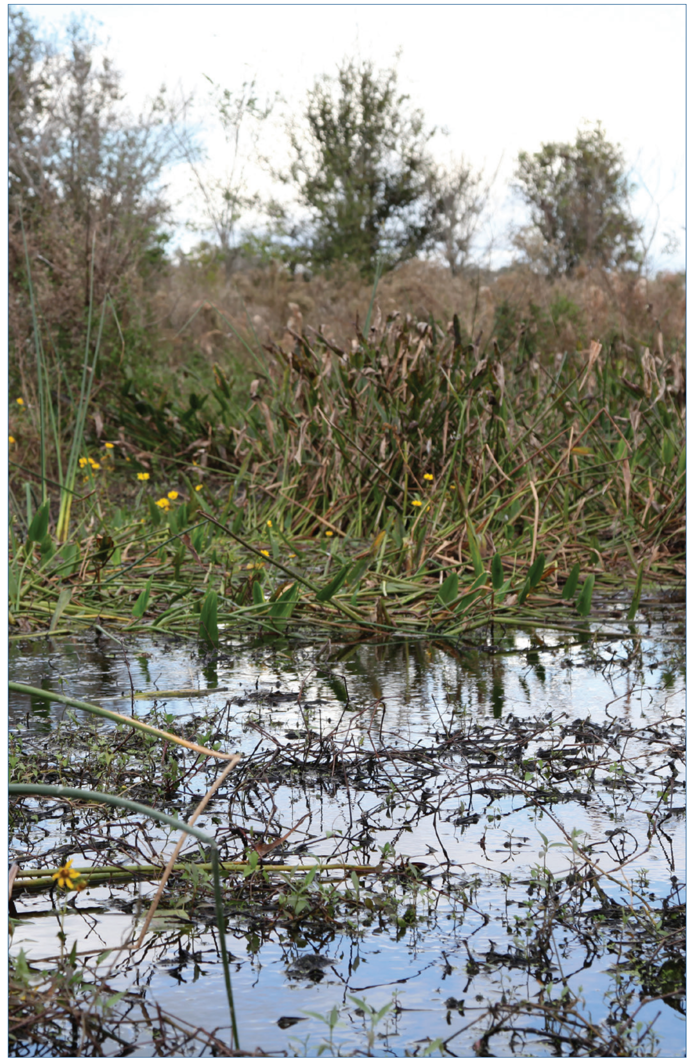
Over time, additional planting of trees, shrubs and groundcover is completed, if necessary, to enhance habitat creation and promote tree canopy formation, providing necessary shade for wildlife and plants.

Once a site meets the criteria mapped out in the designs and permit requirements, it is ready for "release." This benchmark of success, decided by the state and federal regulatory agencies overseeing a given project or site, indicates a site's ability to support itself and surrounding habitats.

The time to complete these steps varies. For example, at Stephens Branch, five years elapsed between the time mining operations were completed and when the created stream met the criteria necessary to allow it to be connected to state waters. During this five-year period, the upland watershed was reclaimed, site hydrology data was collected to support final wetland and stream design, and the wetland and stream were graded and planted.

Only one year was required after channel construction to meet Florida Class III water-quality standards and reconnect Stephens Branch to state waters. <

In Mosaic reclamation projects, we connect stream systems with wetlands and lake systems, providing wildlife corridors and aquatic habitat to the mosquito fish and sailfin mollies seen here.



A stream's function in the watershed is quite complex, draining and delivering water to the wetland habitats it connects and providing water to plant species within those wetland systems.

Intermittent Stream Design At-a-Glance

Execution Components	Whidden Creek (1996)	Stephens Branch (2011)
Establishing the Site's Topography	• Sand tailings fill used to create required elevation. • Three-to-six inches of harvested muck topsoil.	• Computer modeling and digital aerial imagery are used before sand tailings fill volumes. • Muck topsoil in wetland.
Construction Methods & Techniques	• Creation of a large, low swale that mirrored the valley of the pre-mining stream, broadened to accommodate the development of the marsh system that would be located within the forested area. • Naturally carved stream over the course of several years, a very braided, winding and sinuous channel.	• GPS-enabled earthmoving equipment contoured wetlands and stream valley to narrow tolerances. • Sand placed in adjacent uplands to provide seepage to stream valley. • Stream channel location surveyed, depth and width mechanically constructed.
Stream Channel Development	• Overflow from the surrounding lakes supported the formation of the stream channel. • All water that flowed through the system to form the channel was put back into the site's water recirculation system until water-quality standards could be met.	• Use of biodegradable erosion control blanket to stabilize the new stream bank and silt fencing to keep upland material out of channel. • Excavated pools, constructed riffles and installed woody debris about every 50 feet to create a natural aquatic habitat.
Revegetation	• Combination of muck and planting resulted in high density of desirable herbaceous (nonwoody) plants, including fire flag, sagittaria, pickerelweed, hydrocotyle and polygonum. • Established a variety of wetland trees across the stream valley, including cypress, oaks, sugar berries, sweet gums and red maples. • Enhanced the function with upstream (reclaimed) buffer of coniferous pines.	• Used fast-growing seasonal grasses to quickly establish groundcover in adjacent uplands. • Planted more than a half million wetland plants to accelerate the establishment of native vegetation. • Wetland shrubs, groundcovers and trees native to the state of Florida and the South Fort Meade region were used. • Surrounding upland forest buffers to the stream include oaks, pines and shrubs.

Intermittent Stream Design At-a-Glance continued

Execution Components	Whidden Creek (1996)	Stephens Branch (2011)
Establishing Water Flow & Quality	• Packs of leaves collected from other forested flood plains were placed at the beginning of Whidden Creek to spur habitat development for healthy aquatic insects, which is indicative of healthy water quality. • The construction techniques used resulted in a naturally carved stream channel sized to carry the natural flow patterns from the contributing watershed.	• Headwater wetland design modeled to ensure flow into the stream at frequencies and volumes required to support high-quality stream habitat. • Flow measurement equipment was installed to provide data comparing actual flow frequency, duration and volume against design criteria.
Monitoring Water Quality & Vegetation	• Ongoing site management included vegetation and water-quality monitoring to document progression toward the reclamation objectives.	• Monitoring vegetation succession through annual surveys. • Water quality monitored using applicable state standards. • Stream channel stability monitored at permanent channel survey points.

Sustainable Success

> Success of any stream reclamation project is based on measurable attributes and conditions that are equivalent to its natural counterparts, known as reference streams. A successful stream must demonstrate that the site is a self-sustaining system that provides connectivity and supports dependent habitats and species, including upland buffers (to enhance wildlife use).

For reclaimed intermittent streams, success is measured by the following factors: channel stability (to minimize erosion and sediment deposits); flow patterns and volumes (frequency and duration of flow); water quality (meeting state standards to protect fish and other species); stream habitat conditions (branches, logs and leaves to harbor aquatic insects); and floodplain development (appropriate vegetation density and species composition).

Streams constructed by Mosaic using both methods have been assessed and monitored by applying stream habitat and condition assessment methods developed by the Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection (FDEP). These assessments demonstrate that Mosaic's created streams provide optimal functionality, including flow patterns, flood storage capacity and transport of food for downstream inhabitants (fish and insects).

Specific reclamation and wetland/stream mitigation success criteria are defined by FDEP and the U.S. Army Corps of Engineers (ACOE). <

Seeds contained in the harvested topsoil will begin to sprout and produce a diverse and appropriate upland plant population.

Intermittent Stream Success At-a-Glance

Success Components	Whidden Creek (1996)	Stephens Branch (2011)
Connectivity	• Replaced transitional marsh and poorly defined channel with a forested stream corridor surrounded by an upland buffer to connect surrounding lakes and marsh with Whidden Creek, which flows into the Peace River and Charlotte Harbor.	• Replaced degraded wetland, excavated pond and outlet channel with a larger forested headwater wetland, stream and adjacent upland buffer. • Constructed segment of Stephens Branch connects the reclaimed wetland to the preserved segment of Stephens Branch, which flows into the Peace River and Charlotte Harbor.
Drainage & Hydrology	• Whidden Creek flows nearly continuously during the rainy season and less so during the dry season with periods of no flow, thereby meeting the definition of intermittent stream.	• Flow-monitoring data confirms Stephens Branch flow, frequencies, volumes and durations meet the definition of intermittent streams.
Site Performance	• Overflow from the surrounding lakes supported the formatting of the stream channel. • All water that flowed through the system to form the channel was put back into the site's water recirculation system until water-quality standards could be met.	• Use of biodegradable erosion control blanket to stabilize the new stream bank and silt fencing to keep upland material out of channel. • Excavated pools, constructed riffles and installed woody debris about every 50 feet to create a natural aquatic habitat.
Revegetation	• Successfully reached required 400 trees per acre as well as established a sustainable herbaceous understory and surrounding marsh wetlands. • The aggressive management of unwanted vegetation has significantly reduced any presence of the dominating vegetation at the site. • Formation of woody wetland and forested upland. • Organic material deposited from the woody vegetation supports additional layers of muck underneath the forested wetland, which helps maintain a healthy foundation for future growth.	• Met applicable state water quality standards in less than one year, allowing connection to the Peace River. • After first year, site has attained roughly 40 percent of target vegetation performance criteria. • Stream reached a Habitat Assessment score of 124 (optimal) within one year. • A total of 38 different wildlife species have been observed. They include birds, amphibians, reptiles and fish. Listed species are: blue heron, tricolored heron, wood stork, American alligator.

Fundamental Framework of Balance

> Mosaic's use of advanced design and construction tools expedites and enhances stream creation. Whidden Creek used the old technique – while a viable method – which achieves results at a slower rate. Stephens Branch is just one of several Mosaic streams that used the modern approach and exemplifies Mosaic's leadership in stream reclamation. These streams not only illustrate Mosaic's ability to design and construct viable stream systems, but also the company's ability to deliver self-sustaining systems that can support the larger watershed for generations to come.

Additionally, reclamation of streams successfully connects upstream and downstream reclaimed sites, as well as off-site natural habitat, providing benefits for the regional ecosystem with the creation of larger contiguous blocks of native habitats. Because much of Florida's remaining natural habitats are often small, fragmented and isolated patches surrounded by converted agricultural fields or developments that restrict wildlife movement migration, reclamation offers an opportunity to reverse this trend.

Today, public funding is unable to fully support expensive conservation land acquisition programs. Mining followed by reclamation of streams connecting native and reclaimed natural habitats in the manner practiced by Mosaic, many of which are protected against future disturbance by conservation easements, represents a unique concurrent scenario that contributes both to the regional economy and ecosystem. <

Modern reclaimed lands contain intricate stream systems that connect habitats and provide wildlife corridors.

All photos were taken at Whidden Creek, a stream system that Mosaic created on reclaimed landscapes in Polk County.