THE APPLICATION OF NATURAL CHANNEL DESIGN METHODS FOR RESTORING WATERSHED HYDROLOGY AND FUNCTIONAL RIPARIAN ECOSYSTEMS AFTER MINING

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Mosaic

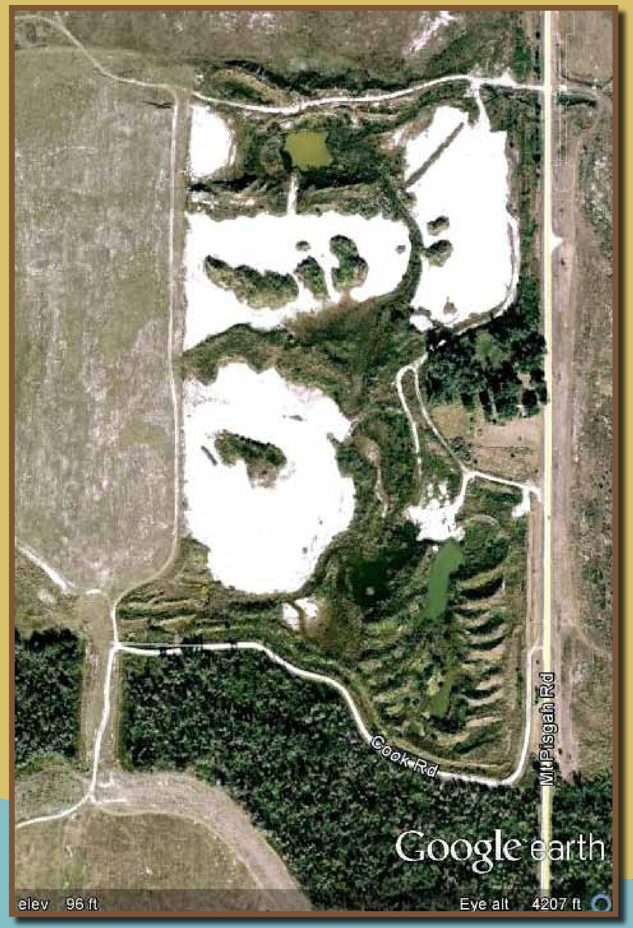
PROJECT BACKGROUND

Mosaic Fertilizer LLC mines phosphate rock in the West-Central Florida phosphate region. Following mining, Mosaic reclaims the mined land to replace natural wetland, terrestrial, and riparian ecosystems; maintain natural hydrology; and return the land to other useful purposes such as agriculture, recreation, and community development.

Streams are the natural conduit for draining the land and, in Florida, providing fresh water to coastal marine ecosystems. Stable and functional streams provide the full spectrum of ecological services. Stable, functional streams provide:

- Critical habitat for wildlife and aquatic biota
- Serve as travel corridors for wildlife
- Process and transport organic matter and nutrients
- Transport sediment
- Convey water from the landscape

Mosaic reclaimed reclamation unit SB-1 at its South Fort Meade mine located in Hardee County Florida in 2010, creating emergent wetlands, forested wetlands, and 1,385 feet of first and second-order streams. The landscape drains to Stephens Branch, a preserved second-order tributary of the Peace River. The Peace River is one of Florida's major river systems. The river flows north to south through the heart of Florida's phosphate region and provides fresh water to Charlotte Harbor, a National Estuary. The Peace River also provides fresh drinking water to coastal communities. Natural channel design and construction approaches were used to create the stable, functional streams. Monitoring has demonstrated morphological stability and natural hydrological behavior.



SB-1 before reclamation

Florida headwater stream

NATURAL CHANNEL DESIGN

Natural channel design was based on hydraulic geometry data obtained from a morphological reference stream (Figure 1A/B).

FIGURE 1A. Location of morphological reference stream relative to reclamation unit SB-1

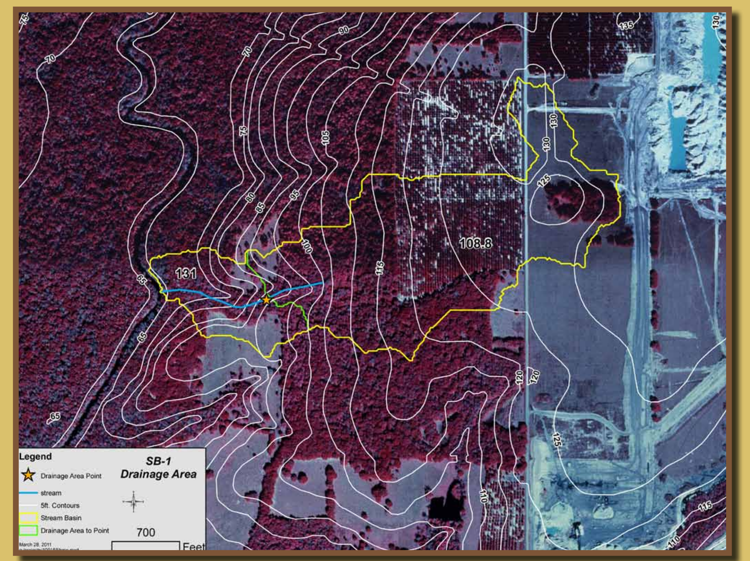


FIGURE 1B. Reference stream drainage basin and reference reach location – pre-mining site conditions

For mine-wide application, natural channel design relies on site-specific "regional" curves (Figure 2) relating bankfull cross-sectional area to drainage area. The curves are used in design to size restored stream channels.

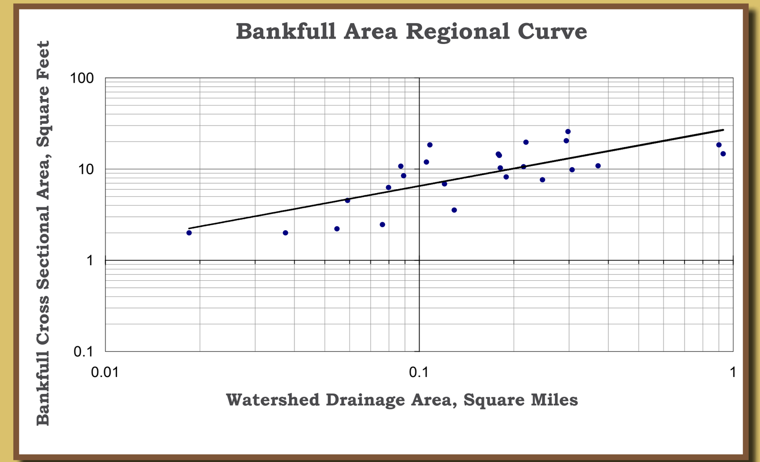


FIGURE 2. Typical site-specific "regional" curve relating bankfull cross-sectional area and drainage area

The hydraulic geometry data are used to develop dimensionless ratios (Table 1). The dimensionless ratios are used to scale the restored stream dimensions to its drainage area using the established bankfull cross-sectional area.

Native riparian vegetation communities are established along the restored stream corridors according to Mosaic's overall restoration goals. Plant communities reflect the natural character and distribution of communities associated with the stream prior to mining such that the biological, chemical, and physical functional influences of riparian interactions are maintained.

Dimensionless Ratio		Mean	Minimum	Maximum
Drainage Area Ratio	$[DA/A_{bkf}]$	26.91	17.38	39.02
Riffle Width Depth Ratio	$[W_{bkf} / D_{bkf}]$	10.4	9.6	12.9
Riffle Max Depth Ratio	$[RD_{max} / RD_{bkf}]$	1.5	1.3	1.8
Pool Width Ratio	$[PW_{bkf} / RW_{bkf}]$	1.2	0.8	1.5
Pool Max Depth Ratio	$[PD_{max} / RD_{bkf}]$	1.4	1.2	1.7
Meander Radius Ratio	$[R_m / RW_{bkf}]$	1.7	1.5*	2.8
Meander Length Ratio	$[L_m / RW_{bkf}]$	5.0	2.60	6.2
Meander Beltwidth Ratio	$[BW_m / RW_{bkf}]$	6.7	--	--

TABLE 1. Dimensionless ratios used to scale stream dimensions

Constructed stream channel showing natural planform and early growth of planted riparian wetland vegetation

MORPHOLOGY

The purpose of monitoring the restored streams in reclamation unit SB-1 is to document development and maintenance of aquatic habitat; natural, stable stream morphology sized to its watershed; and natural stream hydrology.

The longitudinal profile (bed and banks) and six cross-sections were surveyed over a 100-meter reach to measure the planform, profile, and dimensions of the restored channel.

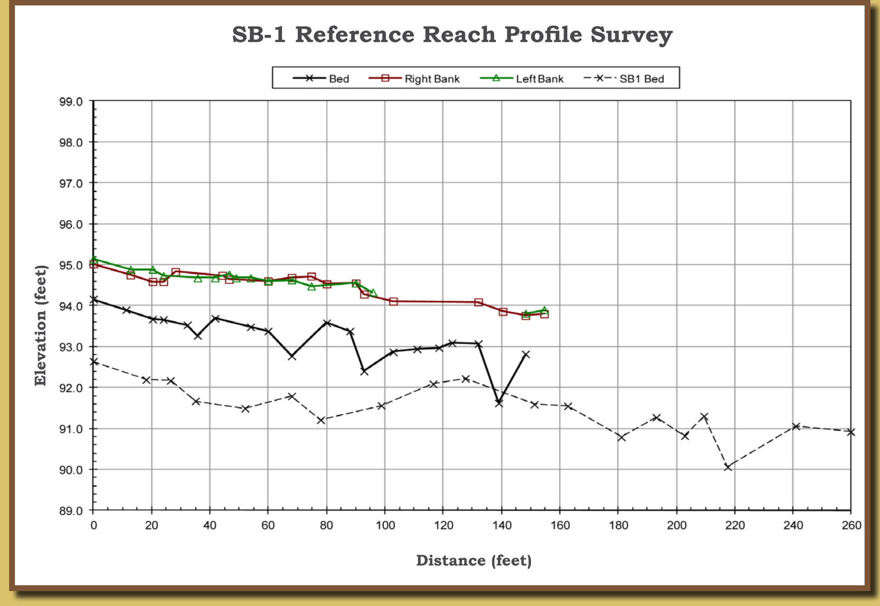


FIGURE 1. Bed profile survey of the restored stream channel compared to the reference stream profile

The restored stream channel bed profile contains bed features similar to the reference stream (Figure 1). The developing pool habitat and bed diversity provide good aquatic habitat. The planform survey (Figure 2) indicates that the channel has remained stable, lacking migration and channel avulsion, despite dimensional adjustments. The channel dimensions have increased slightly from design (Table 1) with increasing dimensional diversity.

Design			2012		
Mean	Min	Max	Mean	Min	Max
4.6	3.0	6.6	5.0	2.5	6.9

TABLE 1. Channel cross-sectional area design values versus 2012 monitoring

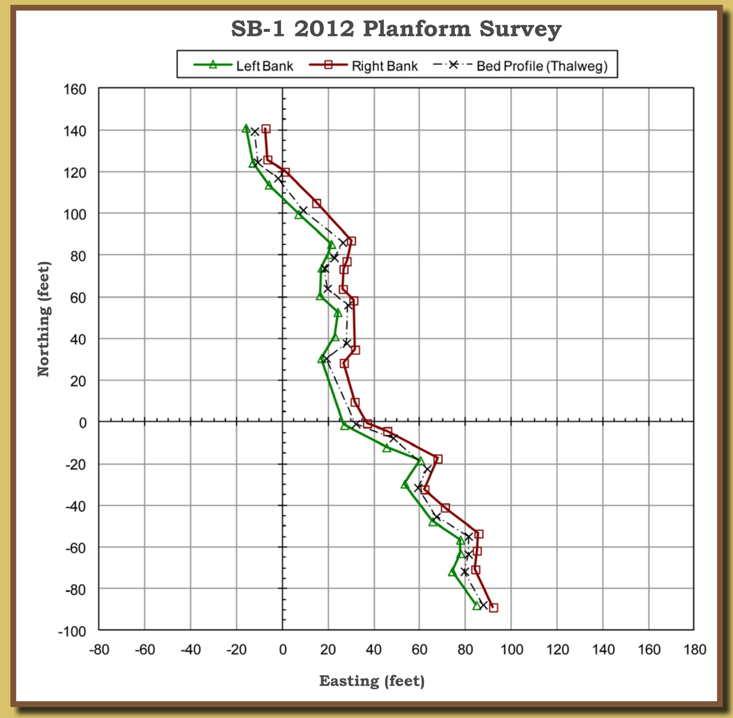


FIGURE 2. Channel planform

Installed large woody debris and associated scour pool formation

Restored stream in 2011 during first full growing season

HYDROLOGY AND WATER QUALITY

An environmental radar and linked data logger were used to record water stage. The environmental radar is a Campbell Scientific CS475-L25. It is paired with a Campbell Scientific CR200X data logger that provides power to the radar through a 6-volt rechargeable battery, provides instrument communication, and stores instrument readings. Once installed (Figure 1) the radar measures the distance from the radar to the water surface (or bed if dry) at 15-minute intervals based on radar signal time-of-travel. Distance measurements were converted to elevation data using the height of the instrument above the bed as a fixed reference point.

FIGURE 1. Water stage environmental radar station

The radar was mounted over a control section installed in the bed of the reclaimed stream (Figure 1). The control section allows for more accurate flow measurements, which is important considering the low flows, and fixes the channel dimensions. Manual flow measurements are being used to calibrate a flow rating curve created using Manning's equation.

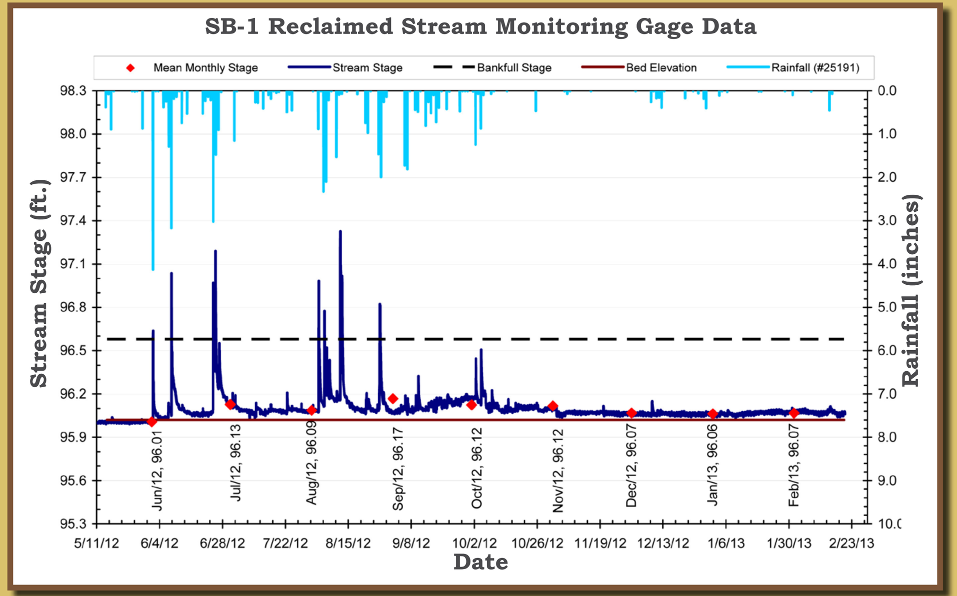


FIGURE 2. Stream stage hydrograph and rainfall data

Periods of no flow (i.e. dry bed) and flooding occurred in response to precipitation events (Figure 2). The stage hydrograph shows flashy, surface-runoff dominated hydrology, which is typical for this region. However, periods of extended baseflow occur as well due to shallow lateral flow and connected wetland discharge. Eleven flow events exceeding the bankfull stage occurred during Florida's wet season between June 1 and August 27, 2012. The stage-duration curve is also fairly typical for this region where flashy flows create a flat curve steep tails (Figure 3). The probability of flows exceeding bankfull stage is 1%, while the probability of no-flow is 7%. Flow monitoring to date indicates that stream hydrology is intermittent, which is consistent with design expectations. In addition, water quality conditions have been consistent with natural conditions for the region and meet water quality standards (Table 1).

Date	pH	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	Temperature (C°)	Turbidity (NTUs)
6/8/12	7.90	7.93	185	28.83	5.48
7/6/12	7.61	5.49	263	29.12	4.66
8/17/12	7.00	4.75	263	30.99	3.39
9/20/12	7.15	6.20	304	27.36	5.82
11/2/12	7.09	12.58	401	16.54	2.02

TABLE 1. Summer 2012 water quality data

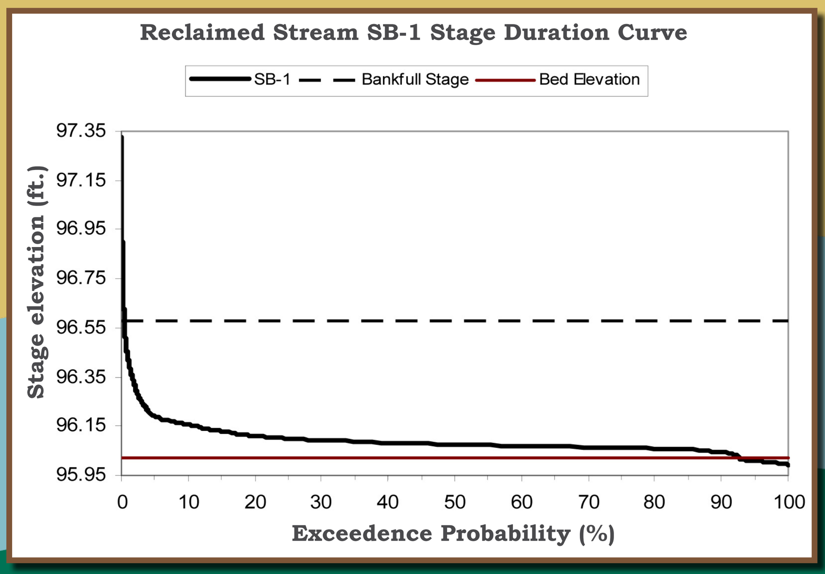


FIGURE 3. Stream stage duration curve