WATER QUALITY IN STREAMS RECLAIMED AFTER MINING

Anthony Janicki, Ph.D.
Janicki Environmental, Inc.

BACKGROUND

The mining of phosphate ore in central Florida has significantly altered the landscape in that area. Many land features are altered, no more so than stream channels. Over the years many miles of streams have been affected to varying degrees, including most severely the removal of lower order streams. Many streams have not been reclaimed and those that have been possess a unique signature with respect to their hydrology, geomorphology, chemistry, habitat, and biota. The purpose of this document is to summarize some of the water quality data that have been gathered in reclaimed streams to assess the likelihood of successfully reclaiming streams that are proposed to been mined in the future.

The process of mining clearly disrupts the landscape, including the topography, vegetation, and soils, both during and after mining has occurred. In the most extreme cases, stream channels are removed by the mining process. Such changes in the landscape can significantly alter water quality in the remaining stream channels, even after reclamation.

Stream water quality is a product of the interaction of rainfall with the vegetation, soils, and underlying geology in the watershed. With regard to the vegetation, stemflow and throughfall can significantly alter the chemistry rainfall on its pathway to the stream channel. The topography controls the time of contact between the rainfall that passes through the vegetation and reaches the land surface of the watershed. The physical and chemical nature of that surface is a function of any organic layer that may exist and the characteristics of the soils beneath that organic layer. Finally, the quality of the water that infiltrates the organic and soil layers and enters the underlying groundwater will be influenced by the chemical nature of the materials that this water contacts before entering the stream as baseflow.

Observations of conditions in streams and the immediate area draining to the streams that have been reclaimed after mining lead to several general conclusions. First, the vegetation in these areas is atypical. Secondly, the soils have been severely disrupted. Thirdly, the hydrology of these streams is also atypical. It is not surprising given these observations that the water quality observed in reclaimed streams also significantly differs from that observed in streams unaffected by mining.

The following summarizes some of the water quality data that have been collected in recent assessments of reclaimed streams. The information summarized comes from three primary sources:

1. A study of reclaimed streams conducted by the University of South Florida for the Florida Institute for Phosphate Research,

2. A series of reports prepared by Florida Department of Environmental Protection (FDEP) staff on conditions in first order streams in central Florida, and

3. Recent results from sampling in a six reclaimed streams, including acute and chronic toxicity tests.

RESULTS

In 1993-1994, the University of South Florida conducted a study, *Meiofauna and Macrofauna in Six Headwater Streams of the Alafia River, Florida,* that entailed an assessment of the physical, chemical, and biological characteristics of the six streams. The following conclusions were drawn by this study:

- Reclaimed headwater streams are more similar to each other than to the natural headwater streams in the same area.

- Conductivity and iron and manganese concentrations are higher in reclaimed headwater streams than in the natural headwater streams in the same area.

- Large populations of the iron bacterium *Leptothrix ochracea* were found in Hall's Branch, a reclaimed headwater stream. USF investigators concluded that this organism may have toxic effects on benthic macroinvertebrates.

- The reclaimed headwater streams had appreciably less deciduous tree cover than in the natural headwater streams in the same area.

- The amount of organic matter in the bottom of reclaimed headwater streams was significantly higher than in the natural headwater streams in the same area.

- Low flow rates and the absence of spates (high flow events) failed to remove the large quantities of particulate organic matter which causes low dissolved oxygen conditions.

Three reports have recently been produced by FDEP including:

- *Ecological Assessment of Reclaimed Streams – Polk, Hillsborough & Hardee Counties – July 2000*

- *Ecological Assessment of 1st Order Reference Streams – Manatee & Hardee Counties – July 2000*
- *Reclaimed Streams Study – April 1999*

The following streams were examined in these studies:

- Reclaimed streams
  - Bryants Branch
  - Mill Branch
  - Hall's Branch
  - JP Creek
  - Mickey Mouse Wetland
  - Big Marsh
  - Hickey Branch
  - McCullough Creek
  - George Allen Creek
  - Dogleg Branch

- Reference streams
  - Wildcat Slough
  - Bud Slough
  - Plunder Creek

- Other streams
  - Horse Creek

Table 1 presents a summary of the water quality data collected during these studies. These data demonstrate that the water quality in reclaimed streams typically have elevated conductivity and pH, and higher concentrations of phosphorus, nitrogen, suspended sediment, and turbidity than observed in the reference streams and Horse Creek. Such conditions are indicative of an impaired stream system.

These streams, chosen from a list of reclaimed streams provided by IMC Phosphates as examples of the stream reclamation planned for the Ona Mine, were:

- The Pickle
- The Tadpole
- Hall's Branch
- Jamerson Jr.
- Dogleg Branch
- Lizard Branch

Table 2 presents the water quality results from these samples.

In addition to these samples, water quality samples were also collected from a series of eight sites previously visited by IMC consultants to characterize the water quality in the area generally known as the proposed Ona Mine area. Table 3 presents the results from these samples.

Comparison of the data presented in Tables 2 and 3 shows that the water quality in the reclaimed streams differs from that observed in the Ona stream sites. Clearly, much higher nutrient concentrations are observed in the reclaimed streams. Also, higher turbidity and suspended sediments are common in these streams. Most notable perhaps are the elevated metal concentrations, particularly iron, selenium, lead, and copper, in the reclaimed streams. Also, the base cations (calcium and magnesium) are in higher concentrations in the reclaimed streams. Examination of the results for individual streams shows that water quality in Hall's Branch and Jamerson Jr. is most impaired.

In addition to the water quality sampling reviewed above, acute and chronic toxicity tests were performed on water collected from the six reclaimed streams. Toxicity tests can be very informative since they provide an assessment not only of the potential synergistic effects of pollutants, but also of the potential impact of other water quality variables that may affect the ability of test organisms to survive or reproduce.

No acute toxicity was observed in any of the waters collected. However, significant chronic effects were obtained from two of the six streams: Jamerson Jr. and Lizard Branch. Table 4 presents the chronic toxicity results from all six streams. Clearly, the number of neonates/female *Ceriodaphnia dubia* (the commonly used invertebrate in such toxicity tests) was reduced with increasing concentrations of test water as compared to the control, with the differences observed in Jamerson Jr. and Lizard Branch being statistically significant.

CONCLUSIONS

Data from these three studies support the contention that water quality in streams that have been reclaimed after phosphate mining differs from that in streams that have not been affected by mining. Also, these differences are sufficient to apparently affect the reproductive capacity of a test organism. Perhaps more importantly, these results also agree with the observation that the benthic macroinvertebrate communities in reclaimed streams are altered from those observed in streams unaffected by mining.

With respect to the pending permits regarding the proposed IMC Phosphates Ona Mine, these results indicate that if the lower order streams in the area to be mined are to be reclaimed in much the same manner as those examined above the following could be expected:

- The reclaimed streams will not provide the similar functions with respect to water quality and habitat for the aquatic biota as they currently provide. Specifically, the loadings of nutrients and other pollutants to downstream waters will be higher than at present.
- The reclaimed streams will not meet the reclamation standards as set out in FAC 62C-16.0051.

- Reasonable assurance is not provided with respect the Basis for Review for Environmental Resource Permits Sections:
  - 3.2.1 – the degree of impact to stream functions can not be mitigated.
  - 3.2.2 – adverse impacts to the abundance and diversity of fish, wildlife, and listed species and to their habitats.
  - 3.2.3 – the conservation of fish and wildlife and their habitats will be adversely affected; fishing or recreational values, and marine productivity will be adversely affected; the current conditions and relative value of functions will be adversely affected.
  - 3.2.4 – water quality standards will not be met.
  - 3.2.8 – unacceptable cumulative impacts will occur.

Table 1. FDEP Water Quality Results

Stream	Conductivity (uS/cm)	pH	Turbidity (NTU)	NH3 (mg/L)	NOx (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
Wildcat Slough	703	5.68	2.8	0.028	0.01	0.68	0.069	6
Bud Slough	272	6.62	1.7	0.033	0.04	0.79	0.37	4
Plunder Creek	101	6.6	15	0.032	0.01	1.7	0.72	5
Horse Creek	80	6	2.5	0.021	0.01	1.5	0.31	4
Bryants Branch	290	6.19	6.3	0.065	0	0.62	0.23	10
Mill Branch	395	6.44	18	0.017	0.01	0.66	5.9	38
Halls Branch	375	7.17	36	0.26	0.03	1.5	0.64	17
JP Creek	345	7.02	1.7	0.017	0.01	0.74	0.35	4
Mickey Mouse Wetland	300	7.2	3.7	0.027	0	0.97	0.7	6
Big Marsh	135	6.7	1.3	0.021	0	1	1.4	4
Hickey Branch	356	7.09	7.7		0.01	0.73	0.59	9
McCollough Creek	216	6.83	35		0.29	1.2	1.4	40
George Allen Creek	302	6.34	21		0.03	0.36	0.59	12
Dogleg Branch	250	6.68	7.5		0.14	0.31	0.2	7

Table 2. Charlotte County Water Quality Results

Reclaimed Stream Sites, Hillsborough and Polk Counties, Florida

Analytes	Units	The Tadpole	The Pickle	Hall's Branch	Jamerson Jr.	Dogleg Branch	Lizard Branch
Conductivity	μS/cm	403	486	483	148	328	290
pH	Standard units	6.93	6.67	6.67	7.02	6.81	8.09
NH_3	mg/L	0.083	0.023	1.22	0.036	0.022	0.01
NO_2+NO_3	mg/L	< 0.004	0.023	< 0.004	0.084	0.26	< 0.004
TP	mg/L	2.46	1.73	0.614	0.181	0.26	0.56
TSS	mg/L	32	14	23	<2	3	31
Turbidity	NTU	190	30	70	2.8	2	9.3
DOC	mg/L	26.8	30.4	28.8	4.38	4.27	27.1
Ca/T/ICP	mg/L	41.3	39.6	53.6	23.5	37.2	26.3
Mg/T/ICP	mg/L	15.7	16	24.5	17.6	22.6	24
Na/T/ICP	mg/L	30.4	30.4	6.25	13.4	4.55	6.12
K/T/ICP	mg/L	2.49	2.93	0.35	6.58	1.13	1.97
Fe/T/ICP	ug/L	11300	4230	117000	583	325	547
Mn/T/ICP	ug/L	166	127	1880	136	41.1	70.8
Al/T/ICP	ug/L	669	107	226	391	160	445
Zn/T/ICP	ug/L	7.2	4.9	2.5	110	< 2.0	2.7
Se/T/ICP	ug/L	2.2	< 2.0	3.5	19.6	< 2.0	< 2.0
Pb/T/ICP	ug/L	< 2.4	< 2.4	8.2	20.3	< 2.4	< 2.4
Cu/T/ICP	ug/L	0.4	< 0.4	< 0.4	100	< 0.4	< 0.4
Cr/T/ICP	ug/L	3.3	1.4	2.1	105	0.9	1.3
Cd/T/ICP	ug/L	21.9	20.8	4	4.9	< 0.4	< 0.4
B/T/ICP	ug/L	9.9	9.3	16.6	114	15.8	7.5
As/T/ICP	ug/L	0.7	< 0.4	3.4	23.7	< 2.5	3.2

Table 3. Charlotte County Water Quality Results

Ona Mine Stream Sites, Hardee County, Florida

Analytes	**Units**	Hickory Creek SW-8	Oak Creek SW-7	Horse Creek SW-2	Brushy Creek SW-5	Horse Creek SW-3	West Fork Horse Creek SW-1	Brushy Creek SW-4	Oak Creek SW - 6
Conductivity	µS/cm	353	137	180	129	183	169	89	89
pH	Standard units	6.94	6.31	6.7	6.93	7.25	6.85	6.37	6.04
NH_3	mg/L	< 0.01	0.03	< 0.01	0.018	< 0.01	< 0.01	0.052	0.021
NO_2+NO_3	mg/L	< 0.004	< 0.004	0.016	0.047	0.062	0.057	0.02	0.016
TP	mg/L	0.389	0.504	0.372	0.469	0.514	0.415	0.656	0.312
TSS	mg/L	<2	6	4	4	4	2	2	10
Turbidity	NTU	1.7	4.8	1.3	4.2	3	2.3	1.8	3
DOC	mg/L	17.7	42.3	28.1	33	21.8	18.5	41.9	49.8
Ca/T/ICP	mg/L	32.1	12	12.8	13.2	19.5	12.1	7.4	7.82
Mg/T/ICP	mg/L	12.5	5	9.14	7.34	11.6	6.91	4.08	3.38
Na/T/ICP	mg/L	11.5	7.2	17.2	7.82	15.6	6.29	5.53	4.52
K/T/ICP	mg/L	8.87	3.32	1.89	3.89	5.26	6.24	0.82	3.17
Fe/T/ICP	ug/L	301	772	252	783	654	355	824	592
Mn/T/ICP	ug/L	70.9	26.9	5.5	32.6	10.6	7.1	19.2	35.3
Al/T/ICP	ug/L	25.3	128	74.1	252	194	134	171	160
Zn/T/ICP	ug/L	4.4	3.4	14.2	2.4	4.3	2	2.4	5.7
Se/T/ICP	ug/L	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Pb/T/ICP	ug/L	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4
Cu/T/ICP	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Cr/T/ICP	ug/L	0.5	2	0.9	1.2	1.6	0.7	1.2	0.9
Cd/T/ICP	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	22.6	17.2	< 0.4	< 0.4
B/T/ICP	ug/L	24.8	17.9	9.9	27.1	2.6	2.8	21.3	19.4
As/T/ICP	ug/L	3.9	4.4	< 2.5	3.3	< 0.4	< 0.4	< 2.5	< 2.5

Table 4. Charlotte County Toxicity Test Results			
	Percent Effluent	***C. dubia*** **Final Survival (%)**	***C. dubia*** **Reproduction (neonates/female)**
October 24, 2003 Pickle	Control	100	27.7
	6.25	100	28.2
	12.5	90	29.5
	25	100	28.3
	50	100	26.6
	100	100	28.3
	NOEC	**> 100%**	**> 100%**
October 24, 2003 Tadpole	Control	100	26.0
	6.25	100	28.2
	12.5	100	28.3
	25	100	26.9
	50	100	28.8
	100	80	21.1
	NOEC	**> 100%**	**> 100%**
October 25, 2003 Hall's Branch	Control	100	27.3
	6.25	90	24.6
	12.5	100	30.1
	25	90	28.3
	50	90	24.9
	100	100	25.5
	NOEC	**> 100%**	**> 100%**
October 25, 2003 Jamerson	Control	100	29.3
	6.25	100	27.8
	12.5	100	28.0
	25	100	27.8
	50	100	29.6
	100	100	24.2*
	NOEC	**> 100%**	**50%**
October 28, 2003 Dogleg	Control	100	22.9
	6.25	100	22.5
	12.5	100	23.0
	25	100	19.7
	50	90	18.8
	100	100	21.1
	NOEC	**> 100%**	**> 100%**
October 28, 2003 Lizard Branch	Control	100	22.3
	6.25	100	22.5
	12.5	100	20.7
	25	90	19.0
	50	100	17.1*
	100	100	11.8*
	NOEC	**> 100%**	**25%**

A * indicates a significant difference between the control and the sample for this endpoint.