RESEARCH ON USAGE OF VETIVER GRASS FOR PHYTOREMEDIATION & SEDIMENT CONTROL FOR THE SAN ANTONIO RIVER AUTHORITY IN CONVERSE, SAN ANTONIO, TX, USA

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Planting the Seed of Environmental Success

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INTRODUCTION

Hydromulch International operates out of South Africa, has been proactive in Vetiver marketing, propagation and environmental contracting for some five decades working extensively in West, Central & Southern Africa, the Indian Ocean Islands, Jamaica and even in the USA.

Environmental Bio-Solutions LLC was registered in South Carolina, USA in 2015 with a view to jointly, with Hydromulch South Africa, expanding its knowledge and interest in the promotion of the Vetiver system for environmental processes in the USA.

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Introduction…..

Two test sites were initiated in Florence, SC and in Converse, TX during 2015 and were worked on concurrently. However, this paper deals with the studies carried out by Dr. Rob Wayne, at the Converse, TX compost facility for the San Antonio River Authority (SARA).

History of Vetiver in the United States of America

Vetiver grass, as far as can be established, was first introduced into the USA during the early 1900's.

The first commercial establishment for the production of Vetiver started during the 1930's in Hammond, Louisiana by a certain Mr. Jennings.

Evidence suggests that sachets of Vetiver dried root plant material removed from a seven-acre field grown in Hammond, LA was used as a fragrance placed amongst lingerie, clothing and linens by housewives, hotels & department stores in addition to extracting essential oils for commercial usage.

The Vetiver Phytoremediation Research Study

The use of Vetiver grass in a phytoextraction study by the USDA Forest Services in 2002 to extract lead from contaminated soils (300-4,500ppm/kg) collected from an active firing range on the Savannah River Site (SRS) was dried, placed in pots & used as a medium for growing transplanted Vetiver grass plants in a greenhouse. Results concluded significant accumulation of lead in the Vetiver roots with little in the leaves.

The use of Vetiver grass coupled with selected amendments has considerable potential for use as a remedial strategy for lead contaminated soils.

Chelating agent EDTA (ethylene- diaminetetraacetic acid) increased lead extraction up to 1390-1450ppm/kg.

https://www.fs.usda.gov › fsbdev2_042053 (PDF) Vetiver grass removes Lead from Firing Range Soil

San Antonio River Watershed

The San Antonio River Watershed is threatened by stormwater pollutant runoff, transporting sediment from fields and construction sites, nutrients from fertilizers, chemicals (insecticides and herbicides), fuel and oil from vehicles or industrial facilities.

E. coli bacteria is the major pollution problem which accumulates from bird droppings, pet or other animal fecal wastes, spills and overflows from sewage lines leaking thousands of gallons of raw sewage into the river.

Urban development and commercial farming activities are also major pollution contributors, destroying wildlife habitats and causing animals to move into riparian areas.

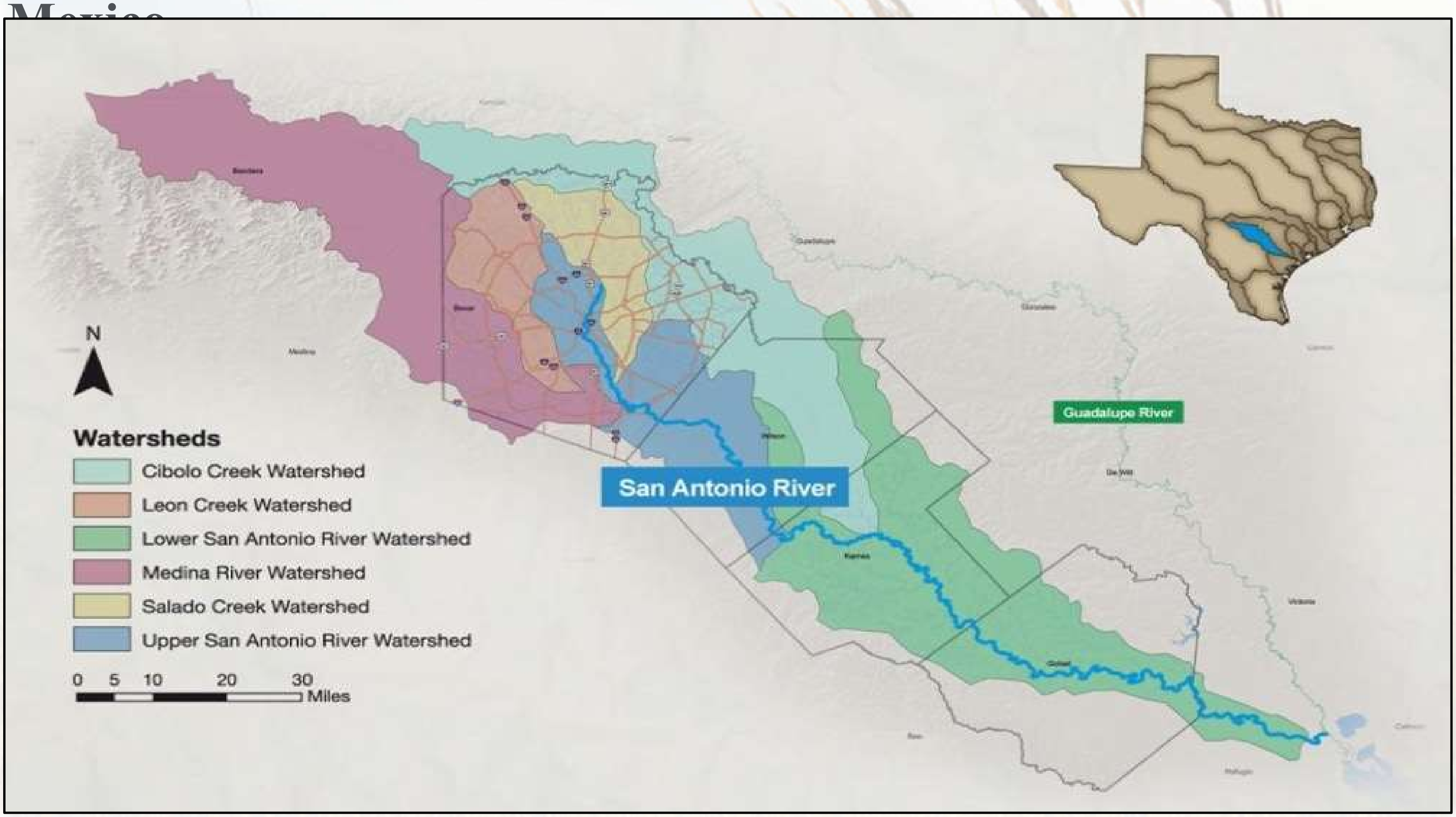
Background History

The phytoremediation capability of Vetiver grass (*Chrysopogon zizanioides*) was introduced to San Antonio River Authority (SARA) during October 2013 at a presentation (*Use of Native Vegetation for establishing vegetation under difficult conditions in semi-arid areas*) by Roley Nöffke of Hydromulch, South Africa.

Further discussions with Mr. Jim Doersam, Chief Engineer for SARA paved the way for Vetiver phytoremediation trials at the Martinez Creek Water Treatment Facility in Converse. TX, where inflated BOD levels & leachate discharge into the Martinez creek impacted on its discharge water quality.

The San Antonio River Basin

The basin drains a land area of 4,180 miles² (10 826 km²) containing over 8 800 miles (14 000 km) of streams. The San Antonio River flows 240 miles (384km) from San Antonio/Bexar County into the Guadalupe River in Refugio County, from where it eventually drains into the San Antonio Bay and Gulf of Mexico.



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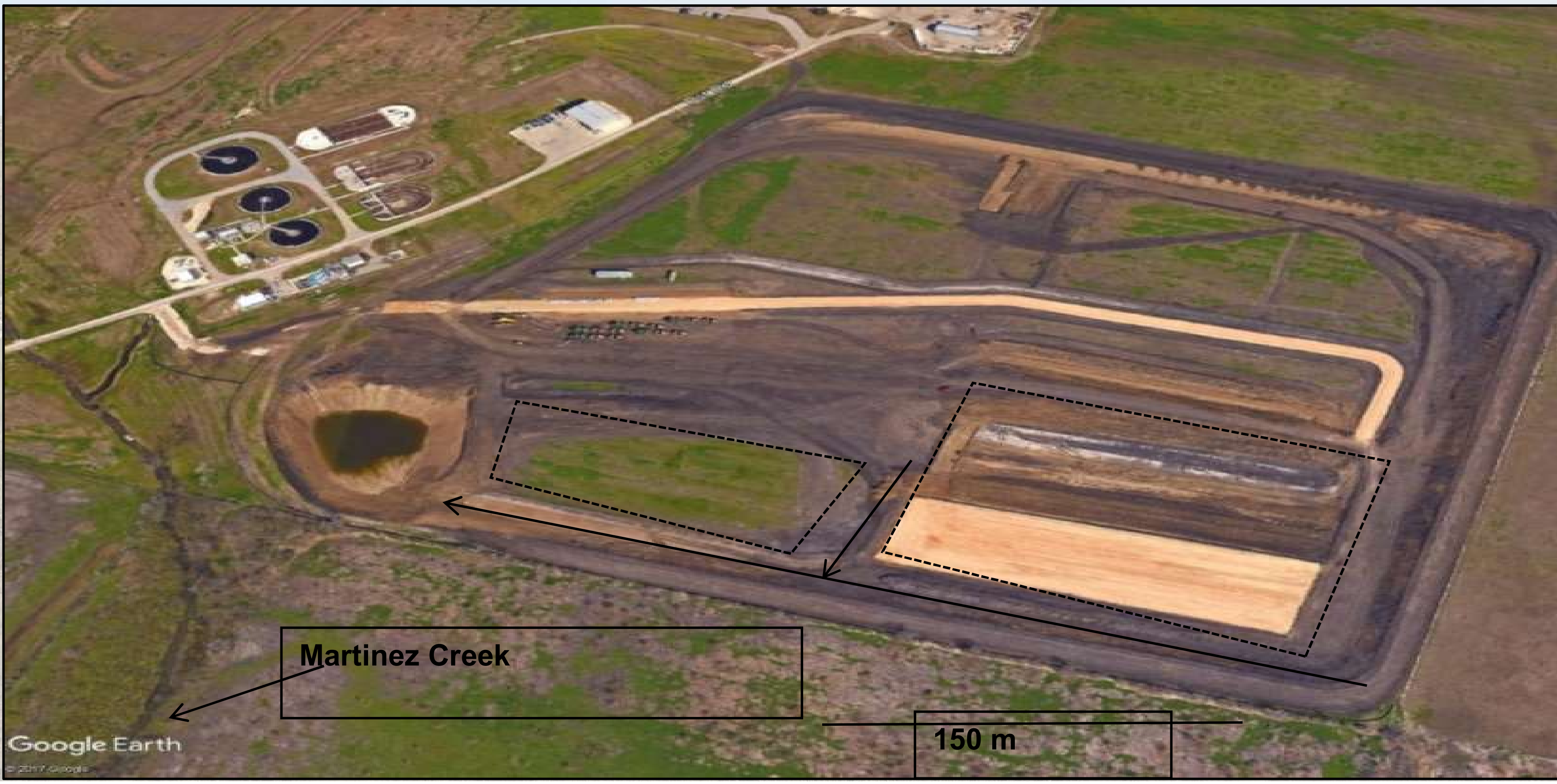
Site Description

The 52-acre Martinez II site is situated 16 miles N-E from the San Antonio River. It includes a 6-acre compost pad where various materials consisting of chipped yard trimmings, biosolids, liquid, solid food waste, animal carcasses & manure, paper and other materials are processed and placed in windrows as allowed under the Texas Commission on Environmental Quality (TCEQ) composting rules.



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Dr. E. W. (Rob) Wayne

A science researcher with extensive background in plant and animal physiology, taxonomy and training in geology. Well versed in research methodology, experimental design and analysis, and has a proven record in reporting and publishing scientific discoveries.

- **Adjunct Faculty**
  University of the Incarnate Word
  San Antonio, TX
- **Visiting Assistant Professor**
  Texas A&M University
  San Antonio, TX

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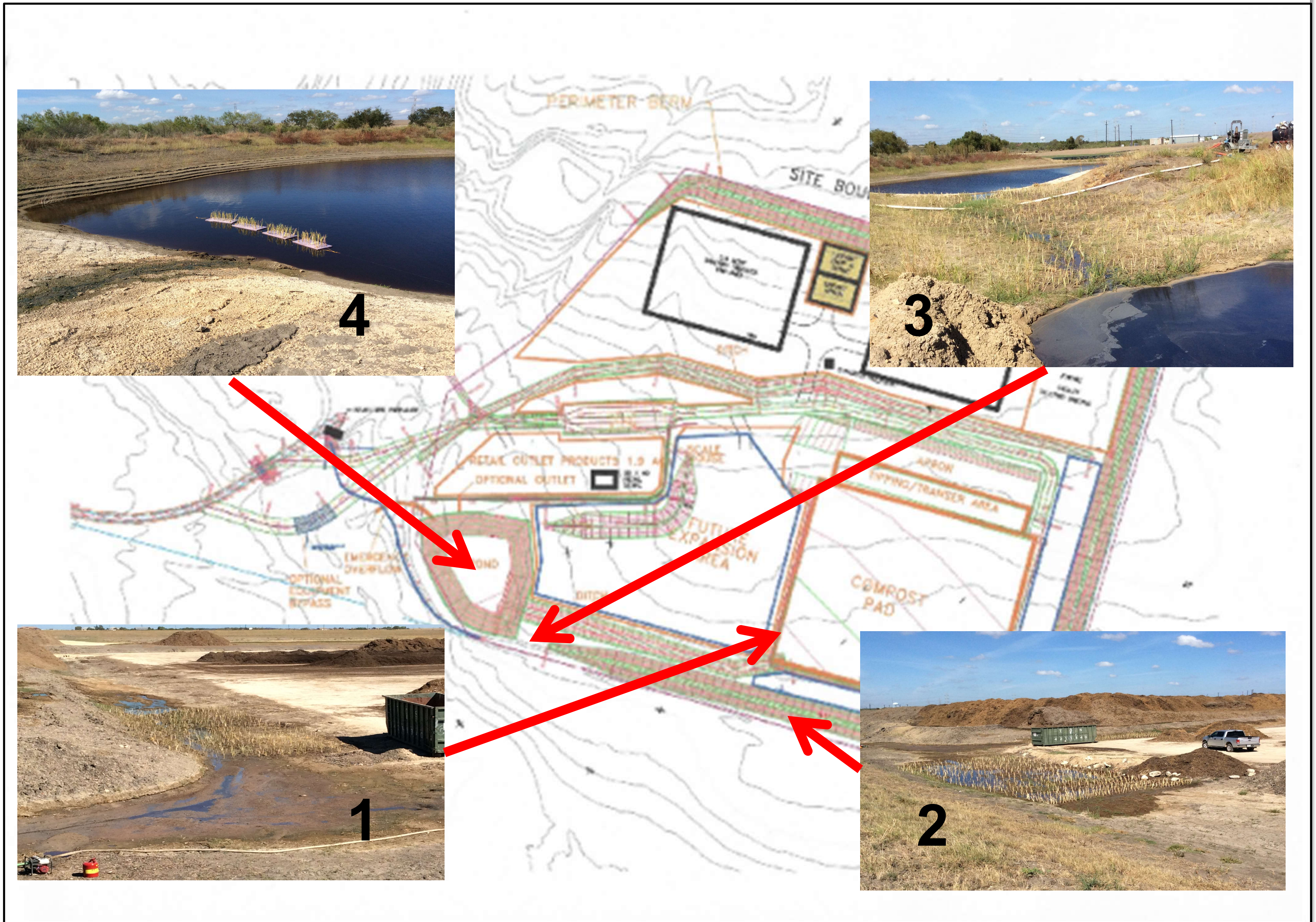
Monthly Rainfall Totals from 2015 to 2018 Seasons

Month	2018	2017	2016	2015
January	3.38"	14.74"	5.44"	0.82"
February	0.57"	3.89"	0.62"	1.61"
March	6.26"	0.74"	2.54"	0.32"
April	0.02"	0.09"	0.86"	0.41"
May	0.39"	0.06"	1.59"	0.01"
June	0.00"	0.01"	0.01"	0.00"
July	0.07"	0.00"	0.79"	0.00"
August	0.02"	0.00"	0.00"	0.79"
September	0.28"	0.19"	1.20"	0.01"
October	0.09"	.53"	1.07"	0.07"
November	0.00"	0.67"	0.41"	1.18"
December	0.00"	6.00"	1.30"	4.65"
Total/year	**20.31"**	**16.92"**	**9.53"**	**11.15"**

Does not record 6.5 inches rainfall on 24 June 2015 ?

The diagram below showing the Site location 1, 2, 3 & 4 for the Vetiver trials at the Martinez site, Converse, TX.



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June 2015 – SARA Vetiver Trials

Trial set up to determine Vetivers' ability to trap sediment & to absorb minerals leaching from the composting facility & dissipating into the downstream retention pond. Seven lines of 2 rows each were set out along the pond canal at 5 plants per linear yard.

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The June 2015 Vetiver trials were subjected to extreme dry & hot conditions. Most of the planted Vetiver grass did not survive as a result of the extensive and intense heat (103˚F). Excessive ponding of the discharge canal from a 6.5-inch rainfall storm on 24 June, submerged the plants for around 10 weeks.

Replanting of the affected areas was carried out in October 2015.

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July 2015 - Submerged Vetiver rows in canal
Replanting of the affected areas was carried out
In October 2015.

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October 2015 – Replanting Vetiver Buffer Areas

Three (3) new Vetiver grass buffer zones were planted in October 2015 to replace the damaged June planting.

Site 1, 2 & 3 – 5 by 10 yards each.

Sites 1 & 2 planted along the canal discharging leachate from the compost stockpiles into the canal leading into the retention pond.

Site 3 planted downstream at the canal discharge end leading into the retention pond

February 2017 – Maintenance of Vetiver Sites

Site 1 & 2 after mowing & removal of thatch. Paddock area well established after grass dormancy requiring removal of harvested material

Site 3 before mowing. Paddock area well established and functional but requiring harvesting

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September 2017 - The Vetiver grass had established well with regular maintenance over the 2016 & 2017 growing period. A wet September further assisted in plant growth.

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Second Water sample collection – October 2017

Water Analysis - Collection Protocol (Dr. Rob Wayne)
Samples collected by Dr Rob Wayne on 25 October 2017 and stored in containers provided by SARA laboratory.
A submersible hand pump was used to pump water into a bucket. Samples were poured into separate containers provided by SARA for lab analysis.

Samples stored on ice & delivered within 3 hours of collection to the SARA Regional Environmental Laboratory, 600 East Euclid San Antonio TX, 78212.
Samples numbered S1, S2 & S3

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Water Sample Analysis

Water samples were analyzed for:

- **E. coli**
- **Ammoniacal nitrogen (NH_3-N)**
- **Nitrate (NO_3-N)**
- **Total Kjeldahl Nitrogen (TKN – proxy for protein in water)**
- **pH**
- **Total dissolved solids (TDS)**
- **Total suspended solids (TSS)**
- **Phosphorous (P)**
- **Aluminum (Al)**
- **Copper Cu)**
- **Iron (Fe)**
- **Magnesium (Mg)**
- **Manganese (Mn)**
- **Zinc (Zn)**
- **Calcium (Ca)**
- **Sodium (Na).**

October 2017 - Water Quality Data

Reported water quality values for sample positions 1, 2 & 3 at the Martinez Creek Water Treatment Facility.

Sample position 1 (S1) is at the upstream gradient and receives effluent from the Vetiver barriers draining active compost piles.

Sample position 2 (S2) is upstream of the Vetiver barrier ahead of the retention reservoir (pond).

Sample position 3 (S3) is downstream prior to water release into the retention reservoir (pond).

EPA/TCEQ numeric values for contaminant action level are indicated.

October 2017 – Water Quality Indicators

	S1	S2	S3	Action level	MPN/100 ml	Change %
E. coli	1700	1300	1000	126		41.2
BOD - 5 day	12	10	4	10	ppm	66.7
Ammonia as N	0.395	0.921	0.351	1.5	ppm	11.1
Nitrate as N	<0.05	<0.05	0.056	10	ppm	
Nitrite as N	0.078	<0.05	<0.05	1	ppm	
Total Kjeldahl N	13.7	10.5	8.7		ppm	36.5
Total Phosphorus	2.37	2.17	1.16		ppm	50.6
pH	8.2	8.1	8	6.5 - 9.0	S.U.	
TDS	2610	1560	1600	750	ppm	38.7
TSS	61.5	64.2	27.5		ppm	55.3
Specific Conductance	3460	2091	2183	1.5	µmhos/cm	
Aluminum	681	1510	664	0.2	ppm	2.5
Calcium	323	156	170	200	ppm	47.4
Copper	18.7	9.3	12.4	1	ppm	33.7
Iron	0.79	1.39	0.8	0.3	ppm	+1.3
Magnesium	66.4	40.5	43.4		ppm	34.5
Manganese	187	180	146	0.05	ppm	21.9
Sodium	288	168	175		ppm	39.3
Zinc	19.3	<10	69.7	5	ppm	+261.4

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Water quality indicators………

TDS was highest at site 1 and lowest at site 2, but was only 40 mg/L lower than site 3. Overall TDS declined 43.1% through the Vetiver barriers.

TSS was marginally higher at site 2 (+2.7 mg/L) and lowest at site 3; decreasing by 55.3%.

E.coli exceeded biologic action levels of 126. However, there appears to be a substantial decrease (-41.2%) in bacterial counts as water filters through the final barrier.

BOD declined to a value that was 60% below toxic criteria.

The pH was relatively unchanged and was in an acceptable range for water quality.

Essential plant nutrients (Water)

Nitrogen was below criteria standards for NO_3, NO_2, and NH_3, and did decline at site 3 before water emptied into the detention reservoir. It must be noted that it is difficult to determine if a decline occurred through the vetiver barriers because these nitrogen parameters appeared substantially low.

However, total Kjeldahl nitrogen, the nitrogen component derived from organic sources, did decline by 36.5% (site 1 to site 3). The solute concentration for Kjeldahl nitrogen, ammonia, and phosphorus were highest at site 2. Elevated ammonia could be due to ammonification of dissolved nitrogen derived from either the leachate or perhaps anaerobic activity in the bottom sediment or lower portions of algal mats.

Another consideration is the drainage channel that is periodically inundated with water because of precautions taken to keep compost piles wet and heat abatement. Thus, the resulting flooding may stir up sediment in the retention pool causing elevated values.

Essential plant nutrients (Water)……..

Phosphorous decreased by 50.6%. Comparing data between sites 2 and 3 (Kjeldahl decreased by 17.1%, ammonia decreased by 61.9% and phosphorous decreased by 46.5%. It is possible to suggest that the final Vetiver barrier had an influence on nutrient reduction.

Solutes **(water)**

Aluminum and iron showed minimal change between site 1 and site 3; however, site 2 which is a small retention pool had elevated levels (121.2% and 75.6% respectively).

Zinc increased substantially, while copper, magnesium, and manganese decreased along the entire gradient. All solutes though were above toxic criteria.

Calcium and sodium also declined. Again, it is likely that periodic high-water flow is resulting in disturbance.

Overall impressions for October 2017 (Water)

Exclusive of *E. coli* it appears that the Vetiver barriers are having an effective role improving the water quality of the leachate that drains into the detention reservoir.

A visual examination of the water clarity to depth further suggests a benefit of establishing a plant barrier system. Water clarity where the final barrier is located (retention pool) was dark, with floating mats of algae. At the final drainage beyond the final barrier the water was clear, but in addition as indicated above, the solute concentrations were mostly reduced.

A decline in TSS, which is a proxy for assessing water clarity, from leachate origin to final drainage reinforces this opinion that water quality is improved because of the Vetiver barriers.

Vetiver Root & Leaf analysis

Data was collected for Vetiver Root – Leaf (shoot) nutrient analysis from each of the buffer zones.

However, it is difficult to interpret the findings of the root – shoot analysis for several reasons:

- **Samples cut too high from ground level**
- **Collection of wet and dry weights for root and shoot were not obtained**
- **Thirdly only a single sample from each buffer zone was submitted.**

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Reported plant Root-Shoot Analysis for Vetiver grass (*Chrysopogon zizanioides*) collected in May 2017 at the Martinez Creek Water Treatment Facility in Converse, Texas. Values reported are based on 100% dry mass.

	Shoot Site 1	Root Site 1	Shoot Site 2	Root Site 2	Shoot Site 3	Root Site 3	
Nitrogen	1.15	0.65	1.35	0.92	1.08	0.78	%
Phosphorus	0.08	0.07	0.14	0.05	0.14	0.06	%
Potassium	1.76	1.10	2.49	0.68	1.33	0.39	%
Calcium	0.16	0.60	0.27	0.70	0.15	0.23	%
Magnesium	0.05	0.12	0.11	0.13	0.05	0.08	%
Sodium	690	704	186	2832	303	1878	ppm
Zinc	15	18	16	26	8	11	ppm
Iron	145	2337	248	3544	207	1093	ppm
Copper	5	24	14	15	7	13	ppm
Manganese	48	79	76	61	74	71	ppm
Sulfur	1234	1585	2426	3229	1057	1660	ppm
Boron	7	3	3	3	7	2	ppm
Chloride	6832	4647	10690	4011	3644	2447	ppm

Insitu Soil collection for analysis

Soil samples of insitu material collected in May 2017 in the vicinity of Site 1:

A1 sample obtained on the side of a berm made up of compost and soil.

A2 sample obtained from level ground (clay soils) within the Vetiver patch designated site 1.

	A1	A2	
pH	8.7	8.3	
Conductivity	4300	1060	µmhos/cm
Nitrate-N	3	15	ppm
Phosphorus	572	194	ppm
Potassium	7044	1684	ppm
Calcium	20928	11105	ppm
Magnesium	1005	704	ppm
Sulfur	319	183	ppm
Sodium	458	195	ppm
Organic matter	47.2	5.4	%

Regarding the soil data only two samples were collected. One was from the downslope side of a compost berm and the other was adjacent to the berm on level ground receiving effluent from the above position.

Differences in soil organic matter content may be related to the berm position composed principally of unincorporated compost and ground wood chips, while the lower elevation consists of compost blended with native soil.

The lower elevation may also have greater soil compaction due to heavy equipment frequenting this position.

Conclusion

- The Vetiver trials indicate that extraction of pollutants from water and/or soil can be achieved by using vegetation as a cost-effective mechanism.

- Maintenance, however, remains fundamental to ensure success as the harvesting of the leaves & roots is important for the removal of the toxic pollutants and heavy metals etc.

- Further testing on a broader scale is recommended to establish the potential of Vetiver grass for phytoremediation applications over extended surface areas particularly in ponds, dams and rivers.

Conclusion…….

- **The planting of Vetiver grass is expensive as compared to general seeding applications, but the plant is hardy, robust, increases in mass exponentially over time and can survive for decades with little or no invasive aggression.**

References : **Vetiver Grass Removes Lead from Firing Range Soil : https://fs.usda.gov>fsbdev2_042053**
Vetiver grass Plant guide : https://plants.usda.gov>pdf_chzi

Thank you

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