Mapping redox gradients in a living levee

Unit process wetlands

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Re-Inventing the Nation’s Urban Water Infrastructure (ReNUWIt)

Background

Wastewater treatment plants are considering the use of wetlands for additional treatment of municipal wastewater effluent due to cost-effectiveness and capacity of natural processes to remove nutrients that can cause eutrophication and other contaminants. By placing wetlands between existing flood control levees and the tidal mud flats, we expect to gain three key benefits: improving water quality, protecting coastal urban infrastructure against storm surges, and providing a wildlife habitat to native living organisms (Fig. 1).

Fig. 1. Some birds are seen at Oro Loma Living Levee in May 2018.

In the Oro Loma Sanitary District, an experimental system (the living levee) was constructed (Fig. 2).

- Generally, gravel and non-native plants are used in constructed wetlands to remove contaminants.
- The living levee mimics natural wetlands composed of fine sediments in which reducing conditions dominate
- Mapping redox gradients is an initial step to study removal mechanisms.

Research Goals

- Observe how the temporal reduction sequence has developed spatially
- Verify if the temporal reduction sequence varies over seasonal scales

Fig. 2. Top view of the Oro Loma Living Levee in May 2018

Approach

Sampling Methods

- Pore water samples were collected using Pushpoint samplers
- At cell G, the samples were taken along 2D transects at four different depths (Fig 5)
- We took two sampling trips, one in early spring (March) and one in late spring (May) to compare variation in seasons
- Samples were collected in triplicate

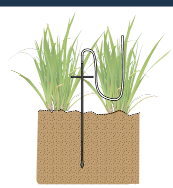


Fig. 3. Pushpoint sampler is inserted in a wetland.

Fig. 4. Pore water sampling at the Oro Loma Living Levee

Analytical Methods

- Nitrate, phosphate, sulfate and chloride concentrations were measured using Ion Chromatography
- Iron and Manganese concentrations were measured using ICP-MS

- Collecting samples from all of the cells A-L is an ideal situation
- Due to limited time and labor, our samples were collected from cell G (Fig. 5) because this cell has been characterized better than other cells.

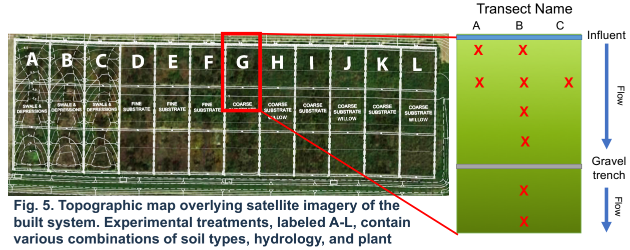


Fig. 5. Topographic map overlying satellite imagery of the built system. Experimental treatments, labeled A-L, contain various combinations of soil types, hydrology, and plant communities. Sampling map is pictured on the right.

Results

Distance from inlet (ft)

Depth (in)	0			9		15		21								45		54		60
0	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7
2	26.7	24.5	22.3	20.1	19.1	18.1	19	19.9	19.7	19.6	19.4	19.2	19.1	18.9	18.7	18.6	21.3	24	23.9	23.8
4	26.7	22.3	17.9	13.5	11.6	9.63	11.4	13.1	12.8	12.5	12.1	11.8	11.5	11.2	10.8	10.5	15.9	21.3	21.2	21
6	26.7	20.1	13.5	7.0	4.04	1.12	3.75	6.39	5.89	5.39	4.89	4.4	3.9	3.4	2.9	2.41	10.5	18.7	18.5	18.2
8	26.7	19.7	12.7	5.79	3.25	0.71	1.96	3.21	2.96	2.71	2.46	2.22	1.97	1.72	1.47	1.22	3.85	6.49	9.12	11.8
10	26.7	19.3	12	4.6	2.46	0.29	0.17	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	1.35	2.66	3.98	5.29
12	26.7	19	11.4	3.72	2.01	0.29	0.17	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	1.39	2.75	4.1	5.46
14	26.7	18.7	10.8	2.81	1.55	0.29	0.17	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	1.43	2.83	4.23	5.62
16	26.7	18.4	10.2	1.91	1.1	0.29	0.18	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.03	1.47	2.91	4.35	5.79
18	26.7	18.1	9.55	1	0.64	0.28	0.18	0.08	0.07	0.07	0.06	0.05	0.05	0.04	0.04	0.03	1.51	2.99	4.47	5.95
20	26.7	17.8	8.95	0.1	0.19	0.28	0.18	0.09	0.08	0.07	0.07	0.06	0.05	0.05	0.04	0.03	0.08	0.12	3.12	6.12
22	26.7	17.8	8.95	0.1	0.16	0.22	0.14	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.03	0.09	0.15	2.12	4.08
24	26.7	17.8	8.95	0.1	0.13	0.17	0.11	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.1	0.18	1.11	2.04
26	26.7	17.8	8.95	0.1	0.1	0.11	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.12	0.21	0.11	0.01

Fig. 6. Nitrate concentration heat map. Samples were collected at four depths (~6, 10, 20 and 26 inches) at 6 locations along the middle transect. Concentrations at other locations were estimated via linear interpolation. Darker green is higher nitrate concentrations (mg/L). The gray line is the position of the gravel intermediate trench.

- We expect nitrate concentration should decrease with an increase in depth and distance from the influent.
- Figure 6 shows that nitrate concentrations mostly follow this trend except at the farthest distances, which are likely influenced by the gravel trench (Fig 5)

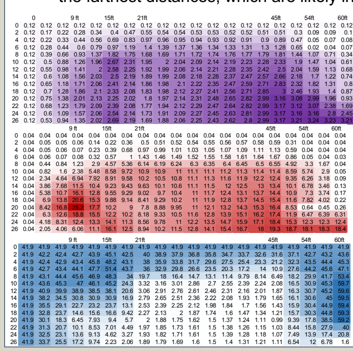


Fig. 7. (left) Manganese (purple), Iron (red) and Sulfate (blue) concentration heat maps show general depth and transect trends.

- Mn and Iron are released in the subsurface
- Sulfate is reduced at deeper depths than nitrate

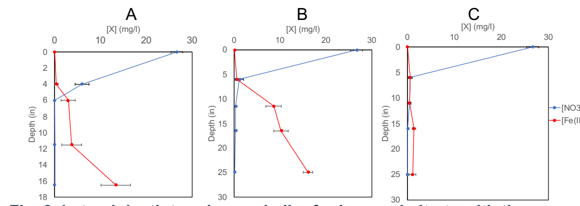
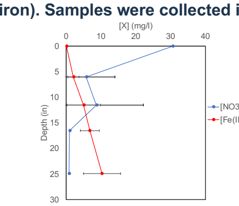


Fig. 8. Lateral depth trends are similar for iron and nitrate with the exception of point C (iron). Samples were collected in May



- No huge seasonal variation was observed.
- The denitrifying zone does not increase significantly during the winter months unlike expected.

Fig. 9. Sampling location 2 (Winter)

Conclusions

- Redox gradient mapping matches with the temporal reduction sequence in the living levee
- Spatial variations in concentrations do not vary much seasonally.
- The denitrifying zone was not expanded as much as anticipated in the winter.
- Significant portions of the slope are dominated by iron and manganese reducing microorganisms, which may have significant implications for the biogeochemistry of this system.

Next Steps

- Continue redox mapping in other cells to observe any peculiarity or variation between cells since each cell in the system has various combinations of soil types, hydrology, and plant communities.
- Explore possible reasons for observed variations and unexpected trends in the data.

Acknowledgements

I would like to thank my mentors, Aidan and Angela for patiently guiding me throughout this project and for their invaluable academic and professional advice. I would also like to thank Professor David Sedlak for accepting me to his lab and introducing me to Aidan and Angela.

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Supported by the National Science Foundation at: