

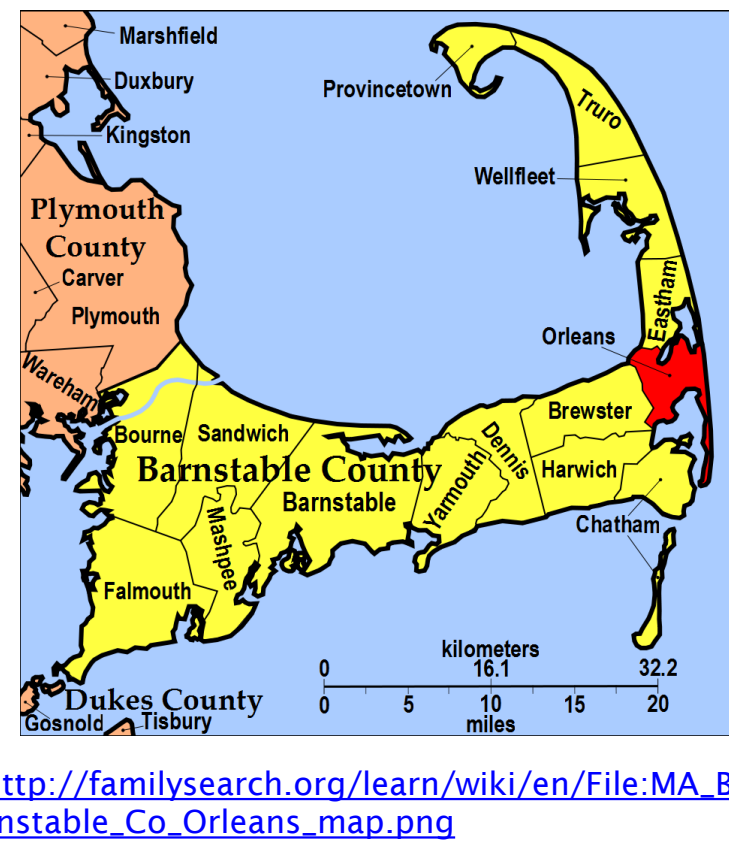
## Abstract

Nitrogen runoff in locations that rely almost exclusively on septic systems for wastewater management is causing water quality issues in local bodies of water, like ponds, lakes and watersheds. This excess nitrogen causes plant life to die, allows bacteria and algae to thrive and gives bodies of water a murky green discoloration. Orleans, Massachusetts has drafted several plans to solve this problem, but they keep getting voted down at town meetings due to high costs. The purpose of this project is to find and develop efficient and cost effective methods to augment these drafted plans and reduce costs to a level which meets public approval. The method we recommend is the use of microbial fuel cells (MFCs). These cells clean wastewater, remove between 60 and 90 percent of the nitrogen, use little energy to operate, and create some electricity in the process. This means when implemented in a centralized treatment plant, MFCs can significantly reduce the long term cost of a wastewater treatment project.

## Focus: Orleans, Massachusetts

### Why Orleans?

- Communication: Austin Higgins' hometown is Orleans, so getting information and opinions is easy.
- At least 85% of the town's wastewater infrastructure is septic based.
- Plans for waste management infrastructure have been repeatedly voted against by the Orleans community, due to cost.



## Background

- Individual septic systems used in Orleans were not designed to remove nitrogen, and the sandy Cape Cod soil allows nitrogen to travel quickly through the ground, so large concentrations of nitrogen have been getting into ponds and the ocean.
- Nitrogen content in the water around Orleans is causing an overabundance of algae and seaweed, harming water life and making ponds murky.
- Orleans is a tourist destination, one of its largest draws are the ponds and lakes it has to offer.
- Despite the severity, Orleans has yet to pass a plan to resolve this problem as the high cost of infrastructure projects keeps causing votes to fail.

## Interviews

### Harbormaster Dawson Farber:

- His part in the plan: not very involved.
- Overall thoughts on the current plan: "100% in support of the need to address our wastewater issues" – thinks a combined centralized and decentralized plan will be used in the end.
- Other points: some people think a large scale project is not necessary, some don't want to have to pay the bill.

### Town Planner George Meservey:

- His part in the plan: very involved - responsible for planning for the town, both short and long term.
- Overall thoughts on the current plan: it's a "good plan," and will remove enough nitrogen to protect the environment.
- Other points: The plan has a lot of support, but not quite enough to reach a two-thirds majority.

## Potential Solutions

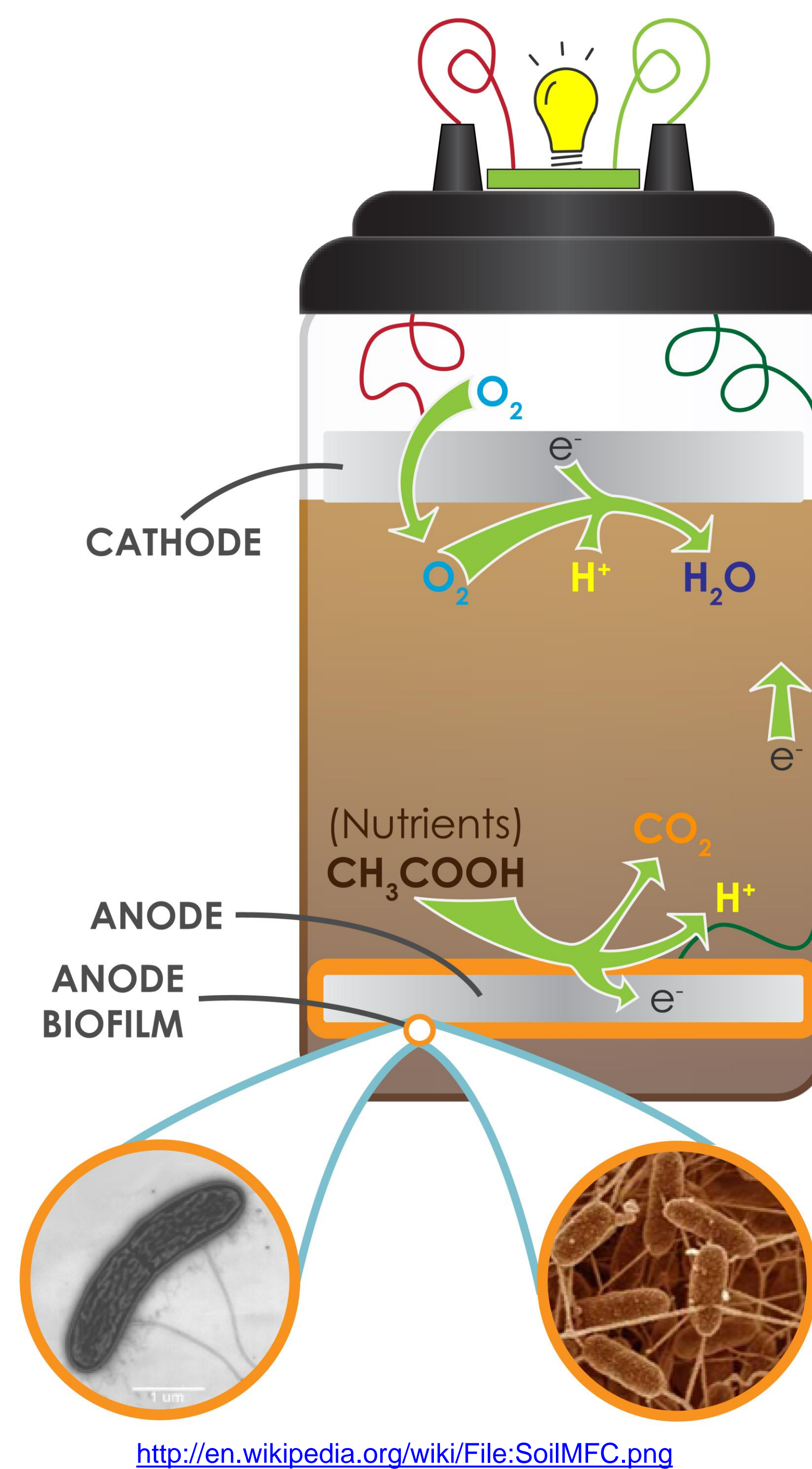
### Duckweed

- Absorbs nitrogen and is edible by fish, but would require a new plan to be implemented for the plant, and the reliability of the plant in coastal and cold waters is low.

### MFCs

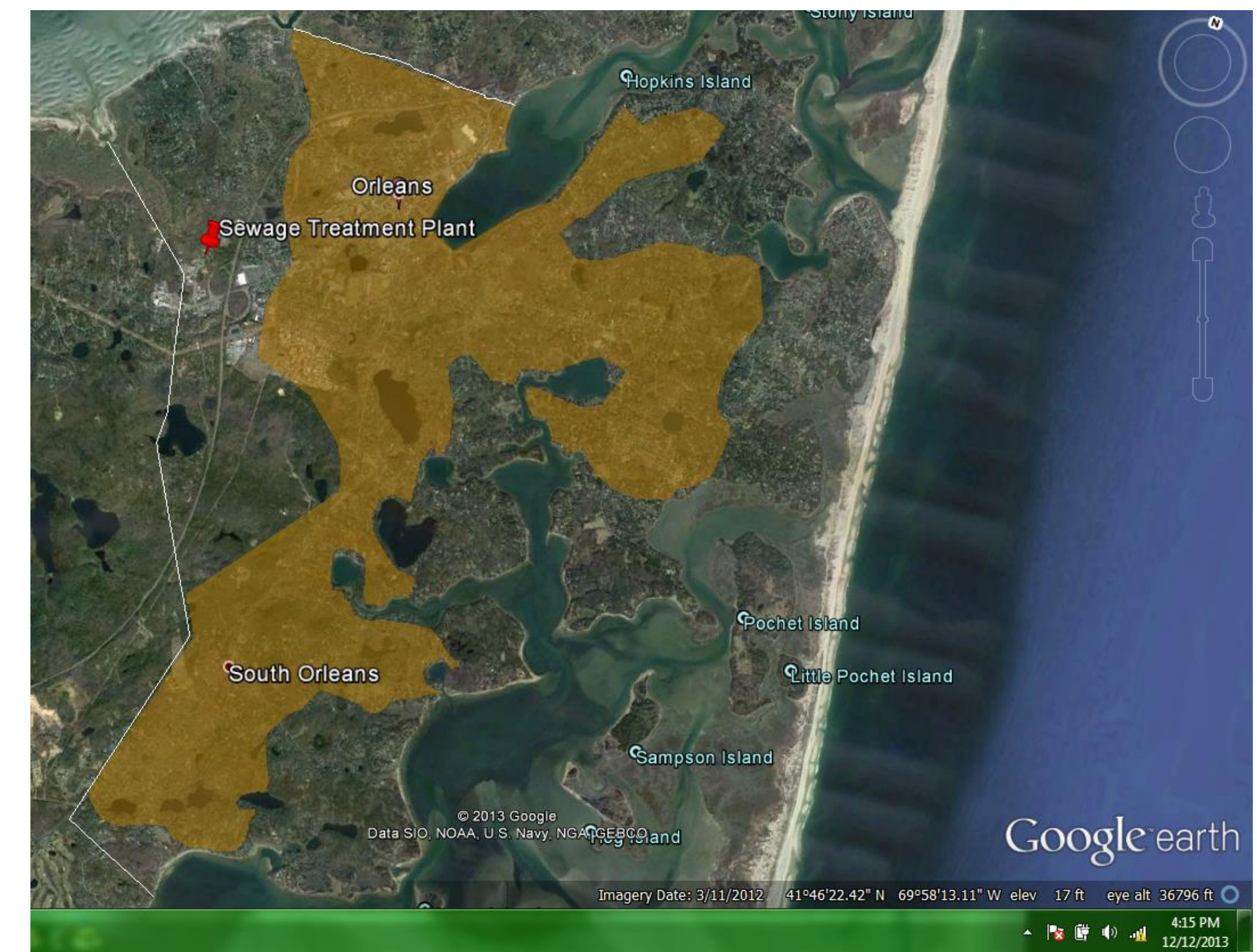
- High efficiency, but relatively new technology. There is a risk of a higher initial cost, depending on the depth of implementation, but little to no energy is needed to run them after initial setup which reduces maintenance costs.
- ### Comprehensive Wastewater Management Plan
- This is Orleans' current plan. This will solve the nitrogen problem, but involves digging up and newly paving many roads, and a very large cost. It has a lot of support, but not enough to pass.

## Microbial Fuel Cells



Shown above is an anodic biofilm based MFC, which converts a carbon-hydrogen solution into electron charge and water. The same concept can be applied to cathodic biofilm MFCs, which are used as electron donors to convert CODs (carbon-oxygen demand)  $\text{NH}_4$  into  $\text{N}_2$  and water.

- Two experiments have found that with an input of Acetate,  $\text{NH}_4\text{-N}$ , and CODs there is an output of much smaller concentrations of  $\text{NH}_4\text{-N}$ ,  $\text{NO}_2\text{-N}$  and  $\text{NO}_3\text{-N}$ .
- Nitrogen removal efficiencies were found to be from 20.3% to 67.5% from a 2008 study from The University of Queensland and University of Cagliari.
- $\text{NH}_4\text{-N}$  removal efficiencies were found to be as high as 81.8% to 95.1% from a 2011 study conducted by Tsinghua University, Beijing.



This image, created using Google Earth, displays the area affected by the centralized sewer system.

## Results

- MFCs efficiently remove enough nitrogen effluent to be viable in situations where there is little to no management system in place and also in systems where cost is an issue.
- When implemented as a supplement to a centralized sewer system, MFCs could improve the efficiency of the system and reduce the overall cost to building the system.

## Conclusions and Recommendations

- Orleans' current plan is too far along to be completely overhauled, but not far enough along to be unchangeable.
- To implement the MFCs, the town would have to add them to the current proposed treatment.
- Further studies on the effectiveness of MFCs to reduce the overall cost of the project, along with treating the wastewater, will be needed to evaluate the feasibility of the implementation of the fuel cells.

## Acknowledgements

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