PROJECT: "Factors responsible for limiting the degradation rate of Exxon Valdez oil in Prince William Sound beaches".

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The Temple University conducted studies on six beaches in Prince William Sound as specified in the proposal. The beaches are: EL056C and EL058B (Eleanor Island), KN109 and KN114A (Knight Island), SM006B and SM006C (Smith Island).

In Summer 2007, the studies were conducted on EL056C and EL058B (Eleanor Island). In Summer 2008, the studies were conducted on KN109A and KN114A (Knight Island) and SM006B and SM006C (Smith Island). In Summer 2009, studies were conducted on a subset of the initial beaches, which was EL056C and SM006C.

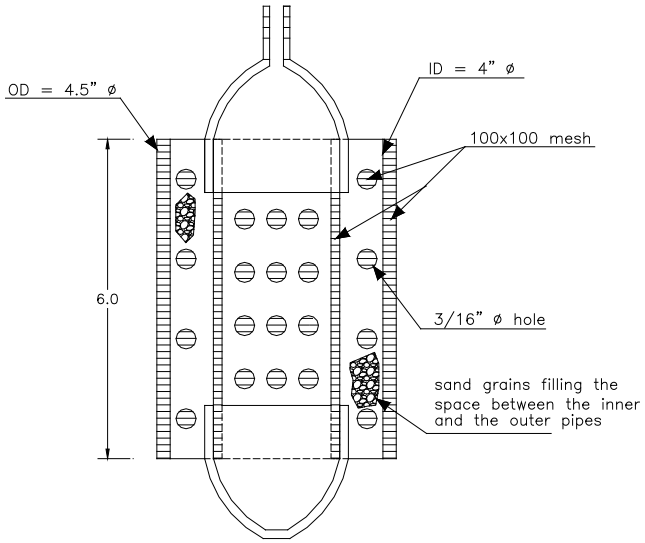
Findings from the studies in 2007 and 2008 motivated the work conducted in 2009. These findings are:

1) The beaches can be viewed as consisting of two layers, an upper layer with a very large permeability and a lower layer with a very small permeability. The contrast in permeability between the layers was found to be around a thousand folds.
2) The dissolved nutrient concentration in the beaches is much smaller than that needed for maximal growth of micro-organisms and the subsequent consumption of oil.
3) The oil persisted at locations where the freshwater groundwater flow (moving seaward) was small.
4) Temperature of pore water within the beaches was higher than 12^{o}C in the summer months suggesting that biodegradation is likely unhindered by temperature.
5) Modeling studies using the software SUTRA (USGS) and MARUN (Boufadel et al., 1999) confirmed the two layers' configuration and suggested that the concentration of dissolved oxygen in the lower layer is most likely too low to sustain aerobic biodegradation.

During the Summer 2009, the Temple University team was in Prince William Sound during two period: June 18 through 25^{th} and August 19 through 27^{th}. During the June period, various sensors were placed into the beach along with systems for high pressure injection and systems for low pressure injection. The tracer was lithium bromide, where lithium is the conservative tracer. A bromide electrode was used in the field to provide preliminary information on the extent of spreading of the tracer. All measurements were conducted during the August period along with testing of the high pressure (injection)

wells and the slow release systems (low pressure systems). The preliminary findings from the 2009 field studies are the following:

1) It takes between a month and two months for the two layers configuration to be reached after excavation and filling of pits.
2) The dissolved oxygen was measured in situ using an optical sensor after extraction of water from the sampling boxes (Figures 1 and 2). The concentration of dissolved oxygen was found to be less than 1.0 mg/L in the oiled transects. It was in general higher than 3.0 mg/L in the clean transects.
3) Pore water samples (around 400 samples) were stored in 25 ml high density polyethylene bottles and shipped to Temple University while frozen for nutrient analysis. Other pore water samples (around 450 samples) were kept in 100 ml polypropylene bottles and shipped to Temple University for analysis of tracer concentration. Analysis of these samples is under way at Temple University.
4) On Beach EL0056C where high pressure injection was conducted, a test well was attempted first and it was found that the pressure buildup reaches around 26 psi before "blowout", which occurred when the pressure dropped significantly. The flow rate prior to blowout was around 3.0 liter/minute (around 0.8 gpm). For the tracer injection test, the diameter of influence was larger than 3.0 m, and the injected flow rate was around 2.0 liter/minute (around 0.53 gpm).
5) On Beach SM006C where the tracer was released under low pressure, two horizontal manifolds, each around 0.9 m long (3 feet) were placed approximately 0.9 m (3 feet) deep. The tracer reached around 2.0 m (6 feet) seaward in about 24 hours. The tracer also moved around 0.3 m (1.0 foot) landward during the same duration.



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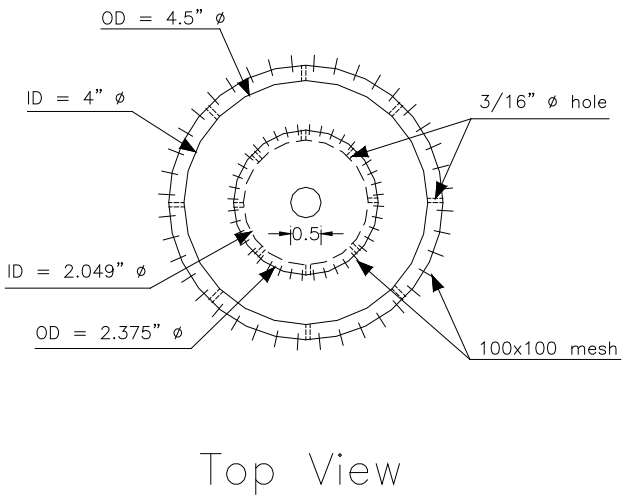

Figure 1: Schematic of the "Sampling Box" used to extract water from the lower layer.

Figure 2: Placement of two Sampling Boxes, a multiport sampling well, and water level well (the white PVC pipe) in a pit.

Boufadel, M. C., M. T. Suidan, and A. D. Venosa, "A numerical model for density-and viscosity dependent flows in two-dimensional variably-saturated porous media", *J. of Contaminant Hydrology*, Vol. 37, p 1-20, 1999.

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