

Proposal to San Diego Unified Port District

Reactive Underwater Caps for Impacted Sediments Management: Bench Applicability to San Diego Bay and Scale Testing

San Diego, CA

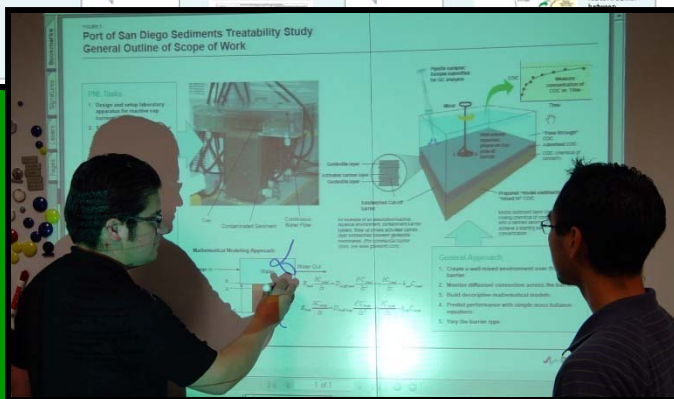
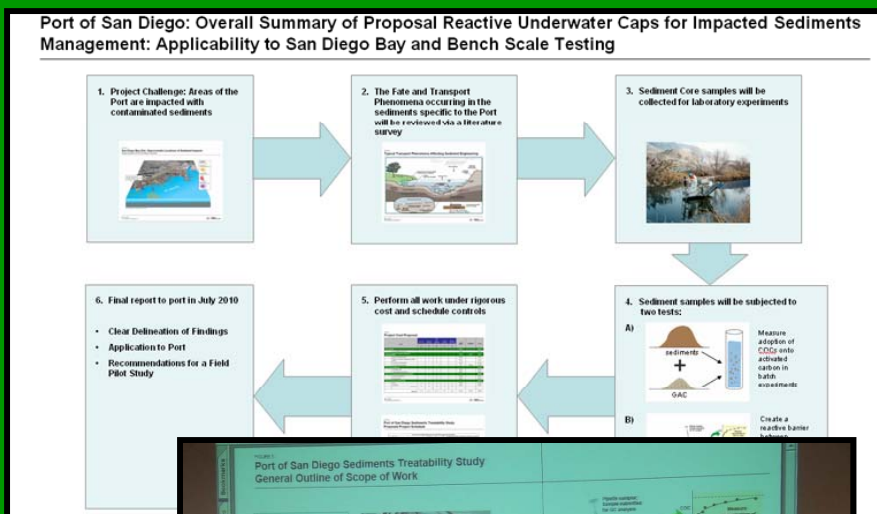
May 4, 2009

Submitted to

Eileen Maher
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Submitted by

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4 May 2009

To: **Ms. Eileen Maher**
Environmental Services Department
Port of San Diego
3165 Pacific Highway
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From: Ian A. Webster

Subject: **Proposal to San Diego Unified Port District**
Reactive Underwater Caps for Impacted Sediments Management:
Bench Scale Testing and applicability to San Diego Bay

Project Navigator, Ltd., in partnership with the Department of Chemical Engineering at University of Southern California, and two industrial in-kind co-sponsors (FMC Corporation and Chevron Corporation) is pleased to submit the above referenced proposal to test the applicability of reactive cap barriers to manage Port sediments. Summary information, as requested in the RFP, includes:

Project Title: Reactive Underwater Caps for Impacted Sediments Management: Bench Scale Testing and applicability to San Diego Bay

Project Description: Demonstrate the ability of underwater reactive cap technology to contain, treat and remediate contaminated sediments at the Port of San Diego

Project Manager: Dr. Ian A Webster
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Grant Funding Request: Environmental Projects Benefiting San Diego Bay

Total Value of Proposal: \$181,015
Funding Sought from Port: \$101,015
Matching and In-Kind Funding: \$80,000

Project Timeline: July 7, 2009 -- July 19, 2010

Benefits of Project: The development of a cost effective in-situ method for the remediation of contaminated sediments. Literature review will assess the applicability of the approach to the specific sediments impacts which exist at the Port. Subsequent bench scale testing at USC will provide proof of concept and allow key design criteria to be established.

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1.0 INTRODUCTION AND BACKGROUND

Project Navigator, Ltd. (PNL) and the Mork Family Department of Chemical Engineering and Materials Science at the University of Southern California (USC) are pleased to team to submit a proposal to The San Diego Unified Port District (Port) Environmental Advisory Committee to perform *research* on methods and technologies to *manage, contain and treat environmentally impacted harbor sediments*¹.

The proposed work is of immediate direct relevance to the Port. Eastern areas of the San Diego Bay marine sediments experience elevated levels of pollutants above San Diego Bay background levels. These elevated zones have been shown to exist from the Sampson Street extension in the north to the Chollas Creek in the south.

The use of underwater reactive caps or barriers to prevent the slow, sustained, release of chemicals of concern (COCs) into the aquatic environment is growing in importance and extent of application². This approach may present a cost-effective way to manage and treat impacted sediments releases in San Diego Bay. The proposed work in our program involves detailed study planning, literature research, experimental design, harbor sediments sampling, bench top treatability experimentation and the final reporting of practical and actionable results and recommendations to the Port.

We believe that the proposed program can develop the groundwork to validate the concept that east Bay sediments do not need to be dredged, but rather, can be equally effectively managed in place, thereby eliminating eliminate any long-term effects to human health and the environment. In place management is more cost-effective than dredging and land disposal, by an order of magnitude.

An overall summary of the proposed program is shown in **Figure 1** In summary, after an in-depth assessment and planning stage, Bay sediments samples will be collected and used in bench scale treatability studies at USC. The experiments will be designed to measure the effect of reactive agents on the extent and rate of adsorption or degradation of the sediments chemicals of concern (COCs), including metals (arsenic, lead, copper, mercury and zinc) and organics (PCBs and PAHs). **Figure 2** is an illustrative PNL graphic showing the locations of known metals impacts at one eastern locale of San Diego Bay. The tenants which are highlighted operate on land owned by the Port.

The proposed program will focus on the growing belief that simple high surface area adsorbents, such as granular activated carbon, can effectively adsorb and contain COCs, thereby rendering them non bio-available. Of even greater relevance, is the promise of being able to incorporate

¹ Highlighted to demonstrate direct responsiveness to the Port's selection criteria.

² Reible, D.D., Lampert, W.D., "Active Capping Demonstration in the Anacostia River, Washington DC" Remediation, The Journal of Environmental Cleanup Cost, Technologies, and Techniques, Vol. 17, No. 1, pp. 39-53, Winter 2006
Reible, D.D., "Organoclay Laboratory Study – McCormick & Baxter Cresoting Company Portland, Oregon" Report Submitted to the State of Oregon Department of Environmental Quality Sep 2005
Luthy, R., Ghosh, U., "Addition of Activated Carbon to Sediments to Reduce PCB Bioaccumulation by a Polychaete" Environ. Sci. Technol. 2005 39, 2880-2887
Luthy, R., Ghosh, U., "PCB and PAH Among Particles Types in Contaminated Harbors Sediments and Effects on PAH Bioavailability" Environ. Sci. Technol. 2003, 2007, 2209-2217

such “reactive agents” into underwater caps. These “tailor made, COC mobility restrictive, engineered semi-permeable sandwiches” have the potential to be laid down on the Bay floor thereby “isolating” (and slowly “treating”) the impacts of the past from new clean deposited sediments.

This proposed program will be an important step to assessing the applicability of adsorbents and reactive caps as technologies which can improve the environmental quality of the Port.

The proposed work also has great relevance to the Port from a “beyond compliance and mitigation³” perspective. The Port’s RFP criterion can be interpreted in two ways, both of which justify positive action on this proposal.

First, at a technical level, it is expected that the containment and treatment effects of the reactive caps will continue for a long duration (greater than a decade) thereby reducing the COCs to levels far below any regulatory cleanup standards.

Second, at a regulatory level, the California Regional Water Control Quality Board (RWCQB) is considering how to enforce a draft Cleanup and Abatement Order⁴ for the alleged discharges of metals and other pollutant wastes to the Bay. At this time, RWQCB has stated that it looks to the Ports’ lessees as being responsible for the sediments impacts, but has documented its fall back position of seeking assistance from the Port should the tenants not comply. It is seemingly in the Port’s and public’s interests to better understand how the sediments impacts could be cost-effectively managed.

2.0 PROJECT NARRATIVE

The overall objective of the proposed project is to evaluate the extent to which COCs present in the impacted sediments at San Diego Bay can be either adsorbed onto or selectively degraded by reagents such as granular activated carbon⁵. If successful reagents can be identified, then in a subsequent phase the reagent will be incorporated into a reactive barrier/underwater cap which will be tested a bench top level at USC.

The project has the following distinct steps, and all have been scheduled in **Figure 3**. The overall program is expected to take about one year. The greatest time allocations (approximately 8 to 9 months) are for running the bench scale experiments at USC. The project is sequenced, as follows:

1. Convene a kickoff meeting and site visit with the Port personnel.
2. Perform detailed design and setup a laboratory system for reactive cap bench-scale experiments.
3. Collect sediments samples from the Port of San Diego.

³ The RFP is very clear that proposed projects must be for topics which have a “beyond compliance and mitigation” benefit to the Port.

⁴ Draft tentative Cleanup and Abatement Order No. R9-2005-0216, April 29, 2005, California Regional Water Quality Control Board, San Diego Region, San Diego, CA.

⁵ We will also consider impregnating the activated carbon with an oxidizing agent, which could react with, for example, PAHs and destroy their toxicity.

4. Perform laboratory experiments from sediments to identify optimal reactive material using Granular Activated Carbon (GAC) and KlozurCR⁶.
5. Perform laboratory experiments to test the feasibility of incorporating the reactive component into an underwater cap, and measure the systems' effectiveness.
6. Perform laboratory experiments simulating temperature and water flow rates.
7. Submit quarterly reports on status of project.
8. Prepare a Final Report outlining conclusions and recommendations.
9. Present results to BPC, Port EC and The Environmental Services Department.

The project will commence with a kick-off meeting with the Port of San Diego to discuss goals, schedule, technical methodology, anticipated project challenges and key personnel. This session will also allow PNL, beyond the formality of this proposal and the interview, to better understand the Port's specific interests in the proposed project and any unique drivers. Any modifications to the general project plan can also be made at this stage. PNL will prepare a press release and a lobby display of the proposed project for the Port⁷. Then using existing data on San Diego Bay sediments impacts, PNL with input from the Port, will identify areas where sediments are contaminated with PCBs, PAHs and metals. Sediment cores will be collected following internal protocols which PNL has developed for sediments sampling on other projects⁸. Following a rigorous chain of custody, the samples will then be sent to a laboratory at the University of Southern California for holding and bench scale testing.

The goal of the bench scale experiments is to simulate the complex physio-biochemical phenomena occurring in the aquatic environment. These events are shown in **Figure 4**. Exposure from contaminated sediments occurs because of the release of COCs from the sediments back into the aqueous environment. Improved protection of the environment will occur if this "release phenomena" or "pathway" is eliminated. The transport of COCs to the flowing water environment can be engineered via the installation of a semi-permeable reactive barrier that destroys COCs which try to pass across it, while simultaneously allowing the transverse diffusion of oxygen that maintains an active biological zone immediately under the cap. The ideal location of the engineered cap is shown in Figure 4.

Figure 5 shows the experimental apparatuses that will be utilized to perform laboratory experiments to simulate the San Diego Bay transport situation described in Figure 4. The first two experiments will consist of utilizing two different reactive cap materials to study the degradation rates of various chemicals of concern. These two experiments will be conducted for a period of three months. We anticipate two months to be the typical time frame based on our experience. When these experiments are concluded the type of reactive material will be selected to be incorporated into the reactive cap design.. The selection of a reactive material(s) and the design of the reactive cap will be based on the effectiveness the reagent displayed in reducing the concentrations of contaminated sediments in the first test.

⁶ KlozurCR is a solid phase oxidant made by FMC Corporation. Testing by FMC at other sediment sites on the east coast has shown that the reagent may have the long-term potential to degrade, in situ, PAHs and TPH.

⁷ PNL has excellent capabilities to produce graphical illustrations to explain technical work. See more at www.Visual-Navigator.com.

⁸ PNL Sediments Sampling and Analysis Plan (SAP) previously prepared and used at projects such as Ascon State Superfund Site, Huntington Beach, CA, 2008.

The third experiment will consist of investigating the stability of the cap by simulating field conditions in a bench-scale model. This experiment will determine the required thickness of the cap and allow an evaluation of the type of armor layer that is best suited to the specific hydrodynamic conditions at the Port⁹.

Once all the laboratory experiments have been performed a detailed report of the findings will be submitted to the Port. The report will focus on the *application of the findings specifically to addressing sediments impacts at the Port*. That is, while the fundamental science and engineering implications will be documented, the report will also focus on providing the Port with implementable recommendations which could be carried forward into further field testing. PNL will also formally present the findings of the project to Port personnel.

The grant monies will fund the engineer performing the experimental design, laboratory work, analysis and interpretation of the results, production of the reports (quarterly and final), and participation in meetings with the Port.

The proposed project is important to the Port of San Diego since the program bench tests and measures the effectiveness of a reactive, *In-Situ*, cap to manage sediments which are impacted with metals, PAHs, and PCBs. This “containment approach” to environmental risk reduction is a more cost-effective alternative than sediments dredging, dewatering and offsite disposal.

PNL will be assisted by the University of Southern California in performing the laboratory experiments. The Department of Chemical Engineering and Materials Science at the University of Southern California is a recognized research institute with state of the art facilities to conduct sediment cap design and experimentation. Dr. Theodore Tsotsis, Chair of the Department of Chemical Engineering, will provide expert advice to the program. Dr. Tsotsis is an expert in catalytic reactive barriers and membranes, having authored more than 50 peer reviewed publications on the topic. We also referred earlier to the idea of including an oxidizing reactive component in the reactive cap. Dr. Phillip Block of FMC Corporation, who is an expert in reagents that biodegrade PCBs, PAH, has offered his consulting services and reagents to the program at no cost.

3.0 QUALIFYING EXPERIENCE

PNL is uniquely qualified to lead the proposed program. Our overall capabilities are shown in **Figure 6**, where we highlight our experience in working on large acreage, high impacted volume sites such as San Diego Bay. We are a 12-year old environmental engineering company based in Brea, CA. Our company has been built working with clients to solve complex remediation problems. Our problem solving work culture is a blend of practical engineering experience, which however, relies on an understanding of the fundamental scientific phenomena which drive environmental exposure scenarios. As such, we have collaborated extensively with USC environmental scientists and engineers and have access to laboratory space in the Department of Chemical Engineering and Materials Science.

⁹ If time and budget allows, there are some other bench scale test which may prove to be of value. For example the temperature of the experimental apparatus can be varied to simulate seasonal water temperature changes and their effect on degradation.

PNL manages environmental remediation efforts at more than 20 major Superfund sites, nationwide. Some examples are shown in **Figure 7**. We are also intimately involved with major projects where cumulatively there are millions of cubic yards of impacted sediments. Some examples are shown in **Figure 8**. At these sediments projects PNL is working with clients to formulate and evaluate the range of remedial solutions.

For example at the 6-square mile Newark Bay Site by Newark, N.J., we are working for a group of Fortune-100 companies to evaluate millions of lines of sediments constituents data, visualize the impacts and devise a range of possible solutions which would eliminate any possible exposure pathways. **Figure 9** depicts some recent analytical and data visualization work by PNL showing the geospatial location of sediments impacts at Newark Bay, N.J. Further general information on PNL is at www.ProjectNavigator.com. More on our capabilities and experience at sediments projects is at www.SludgesandSediments.com.

4.0 OBJECTIVE OF GRANT PROPOSAL

The objective of this proposal is to assist the Port of San Diego in the development of underwater reactive caps or barriers for impacted sediments management. Such caps can be used to cost-effectively stop the release of chemicals of concern (COCs), which presently exist in the sediments, back into the Bay water and subsequent health exposure pathways. With reference to the RFP, which requires the identification of "specific, measureable, and time-limited statements of purpose" which can be evaluated on the pathway to attaining the ultimate goal, we propose the following milestones:

1. Work to initiate project work by 14 July, 2009.
2. Achieve project goal alignment with Port staff by August 1, 2009.
3. Complete design of the experimental program, collect sediment samples and have issued one report to the Port by 14 September, 2009.
4. Conduct bench scale testing work at USC over a period of approximately 200 days from September 2009 to June 2010.
5. Submit draft report of findings and recommendations to Port by 21 June 2010.
6. Submit final report and deliver verbal presentation to Port on 19 July 2010.

5.0 COST PROPOSAL

Table 1 shows a detailed cost breakdown for the project. As requested in the RFP, the listed hourly rates are fully burdened.

We forecast that the entire project will be **\$181,015**.

The project will also receive funding in the form of a dollar contribution from PNL, (\$25,000); in-kind contributions from interested industrial companies such as FMC Corporation and Chevron Corporation (\$20,000); and donated professional consulting services and laboratory space from Department of Chemical Engineering at University of Southern California (\$35,000).

The industrial funding sources include FMC Corporation (who have already committed staff time in kind via Dr. Block (see Section 2), and Chevron Environmental Management Company (EMC) of San Ramon, CA. PNL works extensively with EMC on many sediments remediation projects. EMC is willing to commit exploratory funds, but cannot fully pre-commit until the Port indicates its interest in funding this proposal.

Professor Theodore Tsotsis of University of Southern California is a chemical and environmental engineer who is an expert in catalytic membrane barriers, solute transport and reactive caps. PNL and Dr. Tsotsis have worked extensively on fundamental scientific issues which affect site remediation for more than a decade. Dr. Tsotsis will act as a technical advisor on this project and provide laboratory space for the bench tests. His time and the availability of laboratory space are being donated at no charge. As noted, we estimate this in-kind contribution to be valued at approximately \$35,000.

In summary, the program is seeking funding to the level of \$101,399 from the Port. The program will also benefit from approximately \$80,000 from other funding sources. These matching funds in the form of both cash and in-kind contributions represent 44% of the total funding. As per the RFP, no request is being made for equipment maintenance, computers or travel.

6.0 PERSONNEL

Figure 10 shows the organization of the proposed team to perform the work described in Section 2.

Key participants include:

1. Dr. Ian A. Webster will lead the program and be responsible for project innovation and quality work product delivered on time and on budget. Ian is a chemical engineer with more than 25 years experience working on environmental remediation programs. During the last decade he has devoted considerable time to problem solving at major bay and waterway sediments projects, including Newark Bay, N.J. Ian led a day long teaching seminar on sediments site characterization and management, for oil and chemical company project managers in 2008. Ian holds a Sc.D. (chemical engineering) from MIT and is President of Project Navigator, Ltd.
2. Dr. Raudel Sanchez is the project's staff engineer. Raudel has 6 years experience in experimental design and sediments transport modeling. Raudel holds a Ph.D. (chemical engineering) from University of Southern California.
3. Mr. Josh Teves will act as project manager and also as the project's staff hydrogeologist. Josh will be responsible for day to day project logistics, accountability and budgetary controls. Josh holds a B.S. (civil engineering) from University of California, Berkeley.
4. Dr. Halil Kavak will assist as required to prepare project and data explanation graphics using GIS systems. Halil has a Ph.D. (chemical engineering) from University of Southern California.
5. Professor Theodore Tsotsis is Chair of the Department of Chemical Engineering and Materials Science at University of Southern California. Dr. Tsotsis has vast experience in the experimentation and the measurement of diffusive and convective transport across reactive barriers. He is one of the area's leading experimentalists, worldwide, and has written extensively on the topic. Theo will provide laboratory facilities for the proposed work. Theo holds a Ph.D. (chemical engineering) from the University of Illinois.

Dr.'s Tsotsis and Webster have been collaborating on experimental transport research since 1985.

7.0 SUBCONSULTANTS

No subconsultants will be used.

8.0 NON-PROFIT STATUS

Project Navigator, Ltd. is a registered, for profit, California Corporation, headquartered in Brea, California, with offices in Pleasant Hill, CA, Houston, TX and Malvern, PA.

9.0 APPLICATANT DISCLOSURE

Project Navigator, Ltd. has never received any citations for environmental non-compliance since our founding in 1997.

10.0 AGREEMENT

Project Navigator, Ltd. agrees to the terms and conditions as described in the sample agreement. PNL accepts the insurance and indemnification clauses.

11.0 CONFLICT OF INTEREST

Project Navigator, Ltd. has no work with other parties which would cause a conflict of interest if selected to perform the work described in this proposal. Also, if selected to perform the proposed work, PNL will not perform services for others which could conflict with the work contained in this proposal.

12.0 ADDITIONAL INFORMATION

None provided. Project SOQ information was described in Section 3. More on PNL and the company's capabilities are available at a number of websites including: www.ProjectNavigator.com, www.SludgesandSediments.com and www.SafetyMoment.org.

13.0 CONCLUSION

Project Navigator, Ltd.'s proposal describes a planning and experimental program to evaluate the applicability and performance of underwater reactive cap barrier systems to prevent the release of sediments COCs to the environment. The work can be cost-effectively performed by a highly qualified team for less than \$80,000 in about one year. PNL is teamed with USC. The program will make use of experimental facilities at USC.

Results will be delivered to the Port in a format that will permit the program to move from bench top testing to field piloting.

Port of San Diego: Overall Summary of Proposal Reactive Underwater Caps for Impacted Sediments Management: Applicability to San Diego Bay and Bench Scale Testing

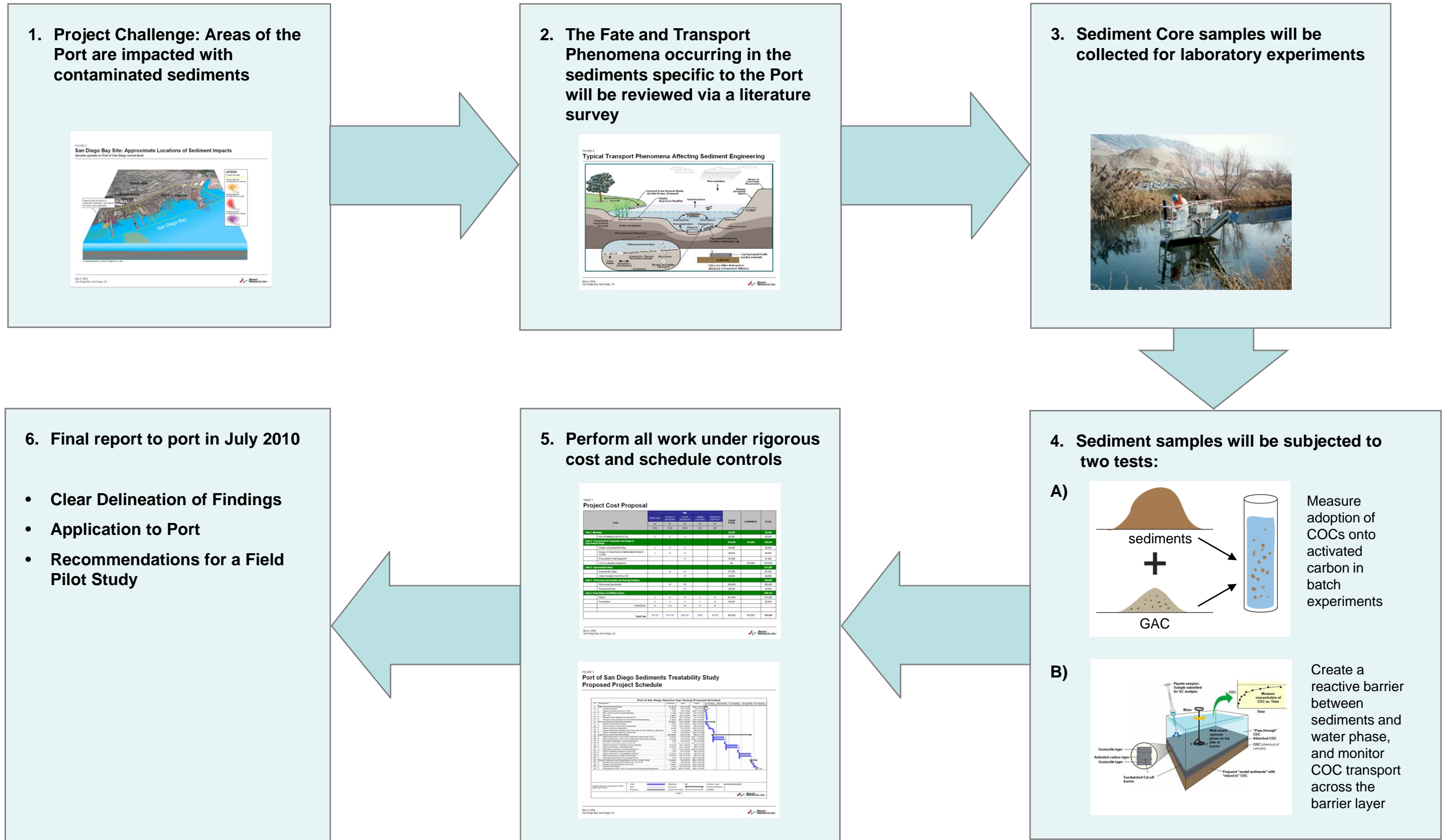


FIGURE 2

San Diego Bay Site: Approximate Locations of Sediments Impact

(Tenants operate on Port of San Diego owned land.)



Conceptual graphic by Project Navigator Ltd., 2008

FIGURE 3

Port of San Diego Sediments Treatability Study Proposed Project Schedule

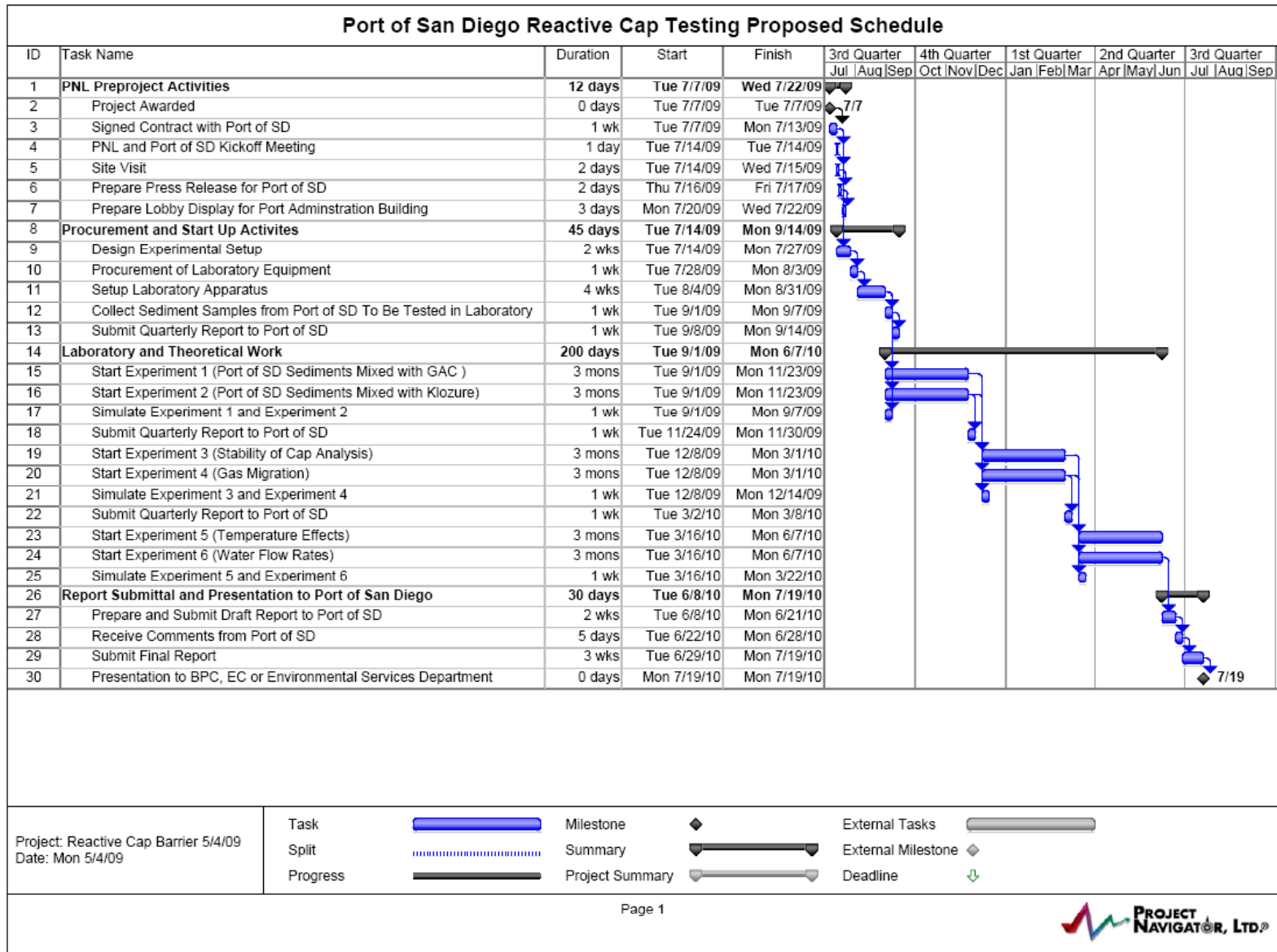
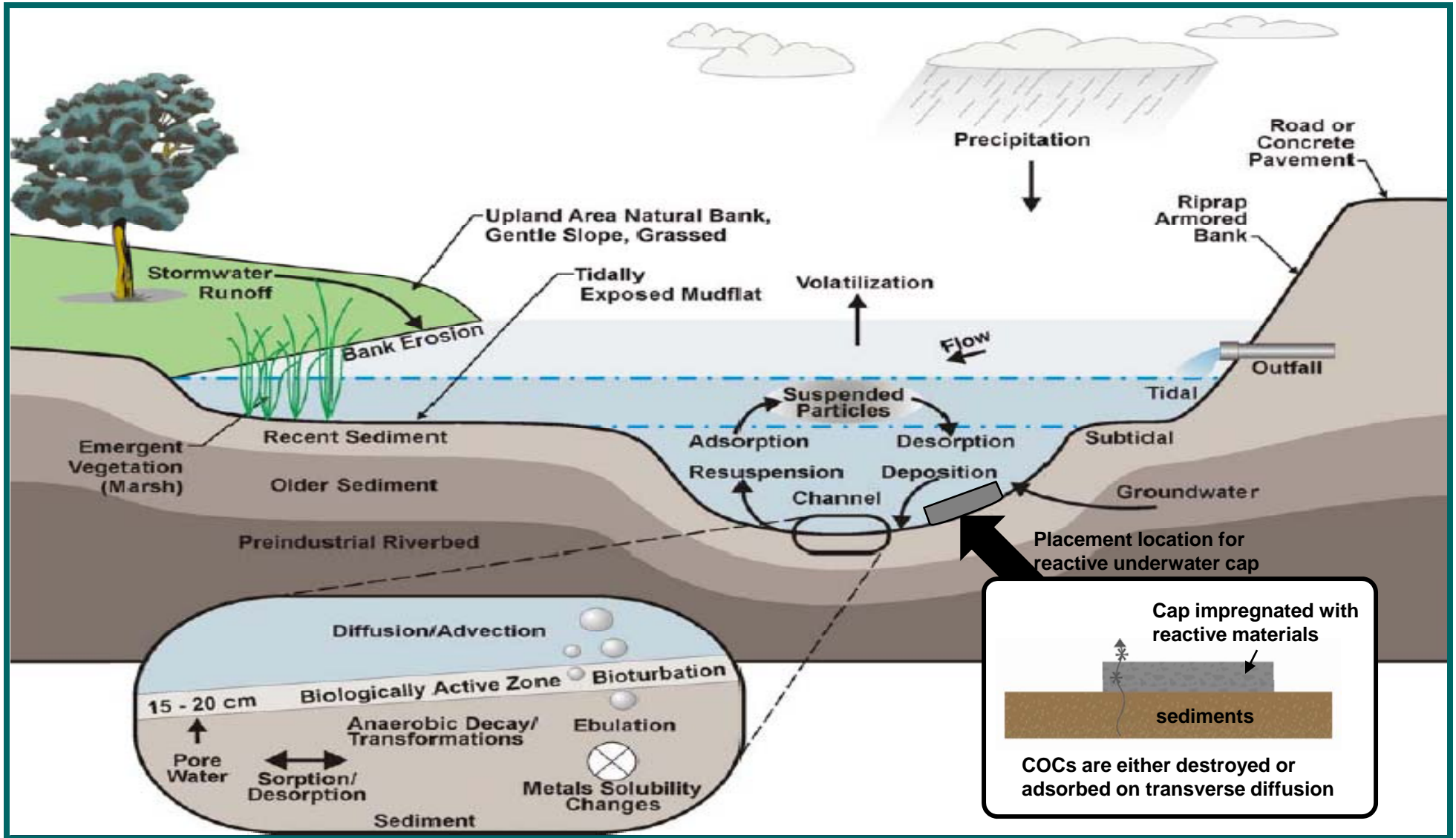


FIGURE 4

Typical Transport Phenomena Affecting Sediment Engineering



Port of San Diego Sediments Treatability Study

General Outline of Scope of Work

PNL Tasks

1. Design and setup laboratory apparatus for reactive cap barriers.
2. Simulate transport phenomena throughout cap and sediment region to optimize design.
3. Work with USC personnel on conducting lab experiments
4. Collect contaminated sediments from Port of SD
5. Submit final report to Port of SD

+

USC Tasks

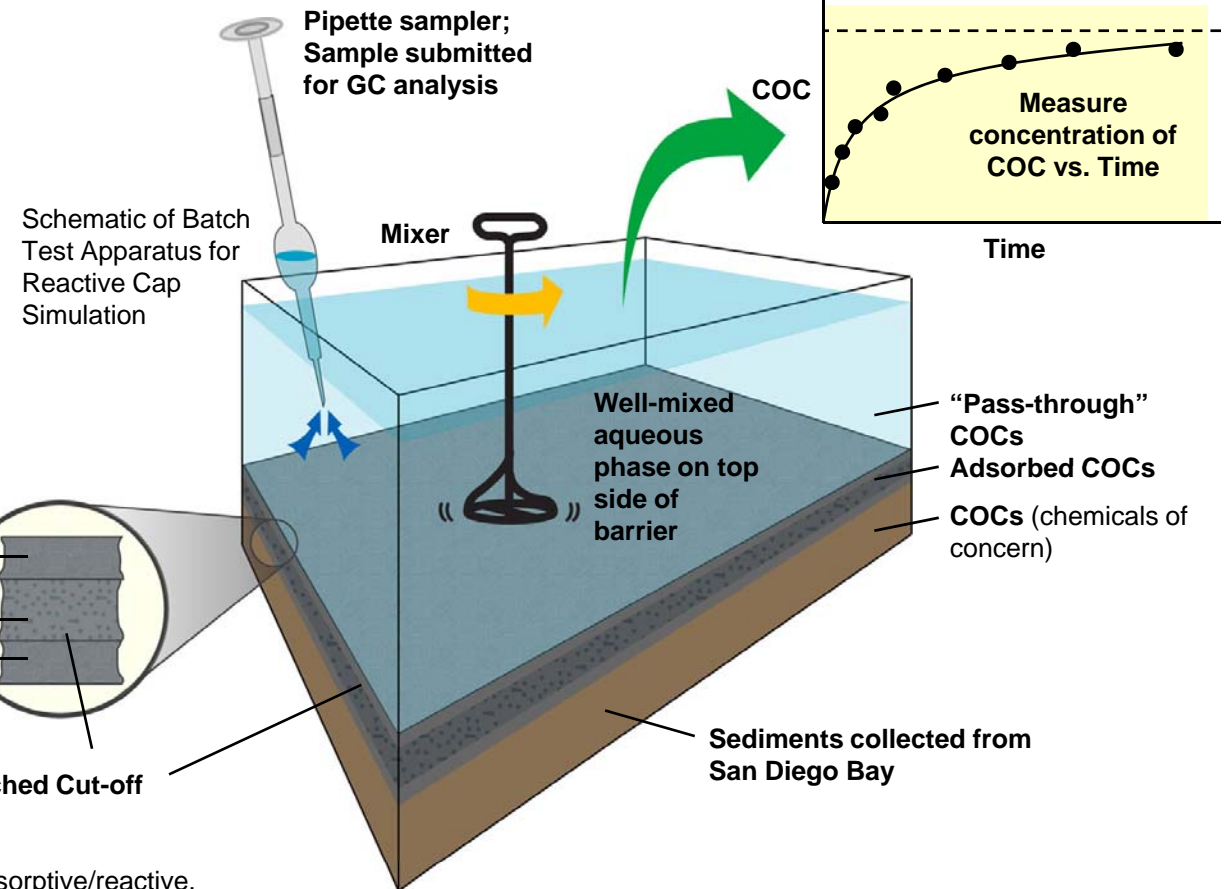
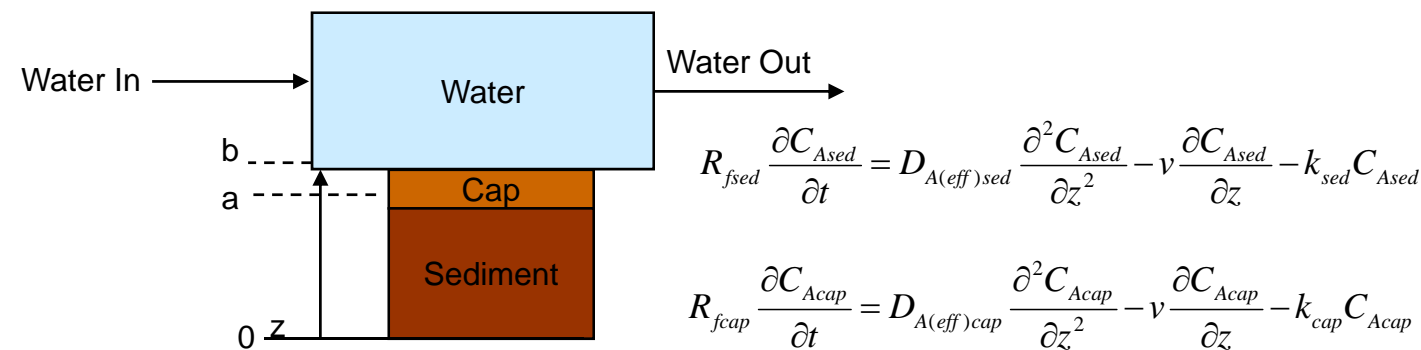
1. Provide laboratory and equipment to conduct experiments.
2. Provide technical support on mathematical modeling of system
3. Provide graduate student to assist in lab setup and perform lab experiments
4. Provide computational resource to conduct simulations



Photograph of Reactive Cap Barrier over Sediments Test Apparatus

Cap
Contaminated Sediment
Continuous Water Flow

Mathematical Modeling Approach



An example of an adsorptive/reactive, aqueous environment, containment barrier system. Blow up shows activated carbon layer sandwiched between geotextile membranes. (For commercial barrier types, see www.gseworld.com).

General Approach

1. Create a well-mixed environment over the cut-off barrier.
2. Monitor diffusion/ convection across the barrier.
3. Build descriptive mathematical models
4. Predict performance with simple mass balance equations
5. Vary the barrier type

FIGURE 6

Project Navigator, Ltd. Specializes in Environmental Planning, Engineering and Remediation

Stakeholders
Vision
Creativity
Solutions
Success

What We Do

- Site Project Management
- Sediments Sites Engineering
- Experimental Design
- Project Strategy and Planning Services
- Design and Construction Oversight
- Risk Management and Remediation
- Technically Rigorous Visualizations and 3D

www.projectnavigator.com
www.sludgesandsediments.com

Project Navigator has five main offices.

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• Malvern, PA
(610) 251-6851

• Raleigh, NC
(919) 539-1928

FIGURE 7

Summary of Key Elements of Project Navigator Ltd.'s Skills for the Port of San Diego Proposal






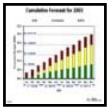
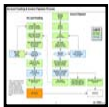
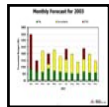
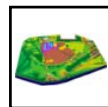
Project Navigator's Experience Relevant to the Port of San Diego Environmental Services RFP Requirements								
Project Name and Description	Patrick Bayou Superfund Site Texas City, TX  3 mile long bayou with impacted sediments	Tex Tin Superfund Site Texas City, TX  200-acre tin smelter with waste ponds	Ascon Landfill Site Huntington Beach, CA  40-acre oil and gas production waste landfill	Newark Bay Newark, NJ  Contaminated river and waterway	Major NE Sediments-Driven CERCLA Site  Former oil and tar storage and reclamation facility	Guadalupe Oil Field San Luis Obispo, CA  3000 acre site, ~8.5 million gallons of spilled petroleum	Avila Beach San Luis Obispo, CA  Pipeline petroleum leakage to impacted soil and groundwater beneath coastal beach	
PNL Personnel	Bob Piniewski	Bob Piniewski, Mark Landress	Ian Webster, Halil Kavak	Steve Werner, Ian Webster	Ian Webster, Halil Kavak	Paul Lundegard	Paul Lundegard	
PNL Role	<i>Project Manager</i>	<i>Project Manager</i>	<i>PRP Group Project Manager</i>	<i>PRP Group Project Manager</i>	<i>Information Management</i>	<i>Technical Leader</i>	<i>Technical Support</i>	
Experience	Project Navigator is the Project Manager for a multi-party PRP Group at this site. Our initial efforts were to assist the Group in AOC/SOW negotiations for the RI/FS and in selecting the RI/FS contractor. The RI/FS is ongoing and PNL provides oversight of the RI/FS and various specialty sediment, hydrodynamic, and risk evaluation contractors for the project. PNL is the primary interface with EPA, the state and other stakeholders. The project utilizes Adaptive Management Strategies to rapidly respond to new information on site conditions. PNL also manages the project budget for the Group..	The TexTin Site has a significant history, in that it was the only tin smelter in the U.S. during WWII. All contaminants are inorganic media: soils, sediments, sludge groundwater and waste products (slag). PNL conducted a fast-track streamlined design/build approach that saved >\$10MM. Tailored area by area remedy, where solution matched long-term development goals.	The Ascon Landfill Site contains significant quantities of oily drilling muds and sludges. The selected remedy, which will be performed possibly commencing 2007, will involve "treating" and removing these materials from the site. The volumes, which will require management, may exceed 1 million cubic yards. Project Navigator is presently helping the PRPs with all aspects of the project, including: planning, technology selection, negotiations and community relations.	PNL has been working at a major Federal Sediments Superfund site in the North East. In parallel with the ongoing traditional RI/FS, where data is being collected both onshore and in the adjacent river and waterway, PNL has been retained to further analyze and dissect the data for the purposes of devising an allocation. During the course of our work, we have performed extensive finger printing data analyses, devised a site conceptual model which is facilitating the allocation discussions and worked on the formulation of a global allocation strategy for our client.	PNL has recently been retained to assess decades of project information and historical data (both recent and decades old) at a large acreage superfund site on the east coast, with the aim of devising a remedial solution.	Provided technical guidance on a wide variety of assessment and remediation issues over a 13-year time period, including NRD assessment. Conducted field pilot tests of remediation options, including conventional and vacuum-enhanced recovery pumping, air sparging with horizontal wells, and thermally enhanced product recovery. Investigated natural attenuation of dissolved and residual petroleum, including the stability of groundwater plumes, rates of mass loss from source areas and groundwater plumes, and the sustainability of natural attenuation processes. Also Helped frame discussion of the level of threat posed by individual Source areas to surface water habitats.	Evaluated transport of contamination towards zones of intertidal groundwater discharge into the ocean and determined the effect of natural attenuation. Evaluated mobility of liquid petroleum in soil and conducted field pilot tests of in situ bioremediation.	
References	George Landreth <i>Shell Oil Products</i> (713) 241-5400 Meera Raghuram <i>Lubrizol</i> 440-347-2242 Juan Somoano <i>Glenn Springs Holdings</i> (972) 687-7510	Edgard Bertaut <i>Alleghany Technologies</i> (301) 526-1710 Earl Moran <i>ExxonMobil</i> (504) 589-9527	Glenn Anderson <i>Chevron</i> (925) 842-5280 David A. Giannotti (310) 203-2661	John Vidumsky DuPont (302) 892-1378 Bernie Reilly DuPont (302) 774-5445	Confidential Client	Gonzalo Garcia <i>Chevron</i>	Bill Sharrer <i>Chevron</i>	
PNL Support Service Capabilities	<ul style="list-style-type: none"> Project Navigator, Ltd. is fully capable of producing compelling, highly illustrative, project visuals for meetings and reports. Refer to www.visual-navigator.com for full details of our graphics, GIS, data management, and model building capabilities. Project Navigator, Ltd. operates a secure website, www.projecttoolbox.com, for the online storage of project information. 							
	Account Fund Management  Forecasting  Scheduling  Controls  Reporting			Presentation Graphics for Facilitating Decision-Making  GIS  Data Analysis  Concept Models  Illustrations  EVS  Scale Models				

FIGURE 8

Project Navigator Ltd.'s Sediments and Sludges Experience

The Project Navigator team is experienced in the formulation of remedial solutions at sites impacted with large volumes of sediments and sludges.



CASE STUDY	Newark Bay Federal Superfund Site NJ/NY	Patrick Bayou Federal Superfund Site Deer Park, TX	MAR Services State Superfund Site Cankton, LA	Tex Tin Federal Superfund Site Texas City, TX
DESCRIPTION	<ul style="list-style-type: none"> Newark Bay is ~ 6 miles long and 1 mile wide with impacted sediments 	<ul style="list-style-type: none"> 3-mile long bayou at the Houston ship channel with impacted sediments 	<ul style="list-style-type: none"> 80-acre site 3 major TPH-impacted sediment lagoons 300,000 cu.yd. of waste were managed 	<ul style="list-style-type: none"> 140-acre former tin smelter Historically significant, only tin smelter in U.S. during WWII Contaminants all inorganic; in soils, sediments, GW and waste
PROJECT METRICS	<ul style="list-style-type: none"> ~3.3 MM cu. yd. of impacted material will need to be addressed 	<ul style="list-style-type: none"> The volume of pollutants will be determined during the RI/FS 	<ul style="list-style-type: none"> \$5 MM design/build 1.5yr constr. schedule 	<ul style="list-style-type: none"> 9,600 cu.yd. of impacted sediments 52,000 cu.yd. of acid pond sludges
PNL ROLE	<ul style="list-style-type: none"> Project Manager Data Analysis and Project Strategy Formation Group Fund Management Remedy Formulation 	<ul style="list-style-type: none"> Project Manager AOC/SOW negotiations for the RI/FS Established a Remediation Trust Group Fund Management 	<ul style="list-style-type: none"> Project Manager Bidding & Contractor selection Design/construction oversight Scope negotiations 	<ul style="list-style-type: none"> Project Manager Leader of a remediate and dispose of sediments onsite, initiative Waste strengthening to permit further site development

More on Project Navigator Ltd.'s sediments experience and capabilities can be found at www.sludgesandsediments.com.

FIGURE 9

Newark Bay, NJ: Example of Sediments Mercury Data Assessment and Visualization by Project Navigator, Ltd.

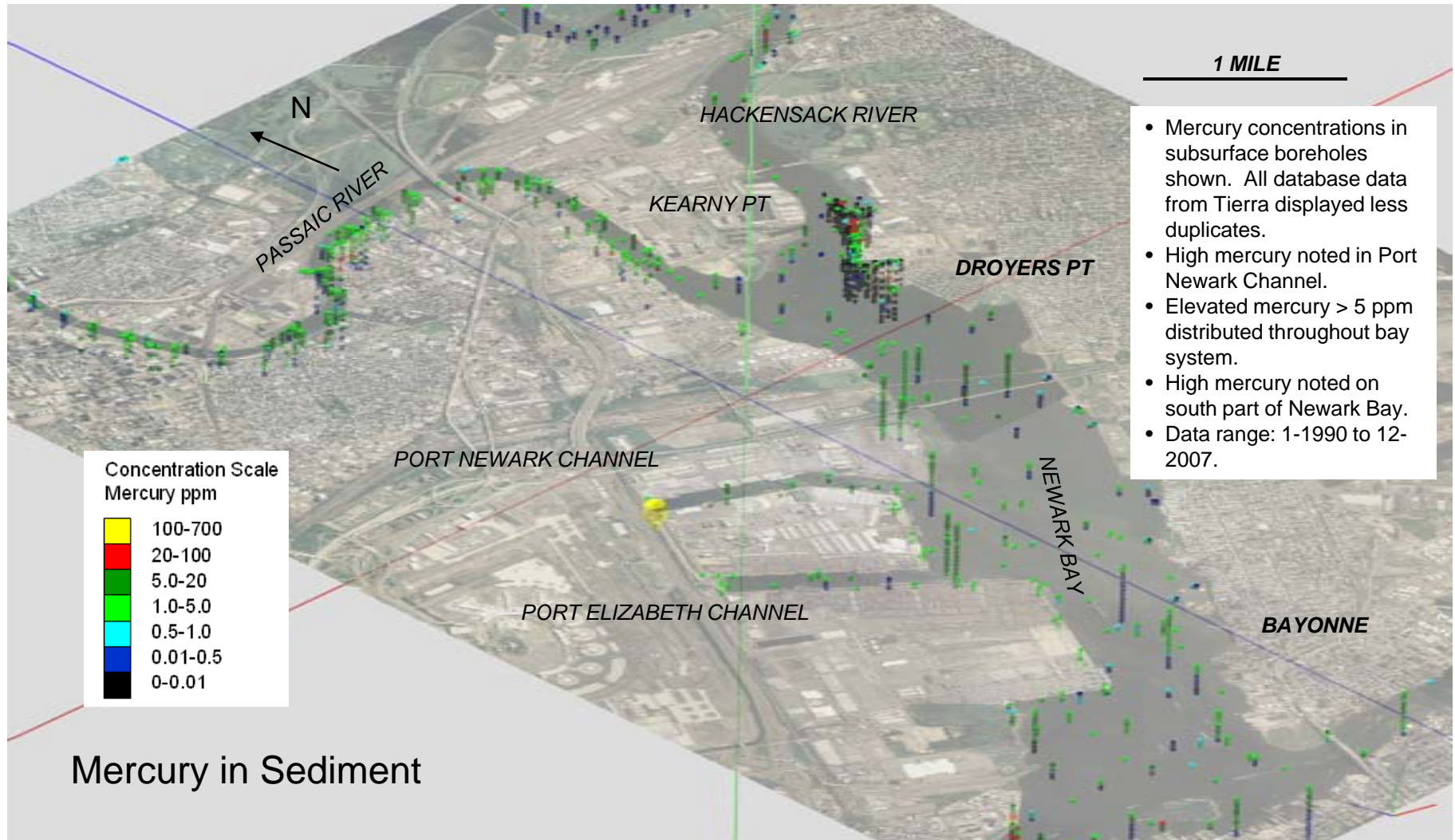
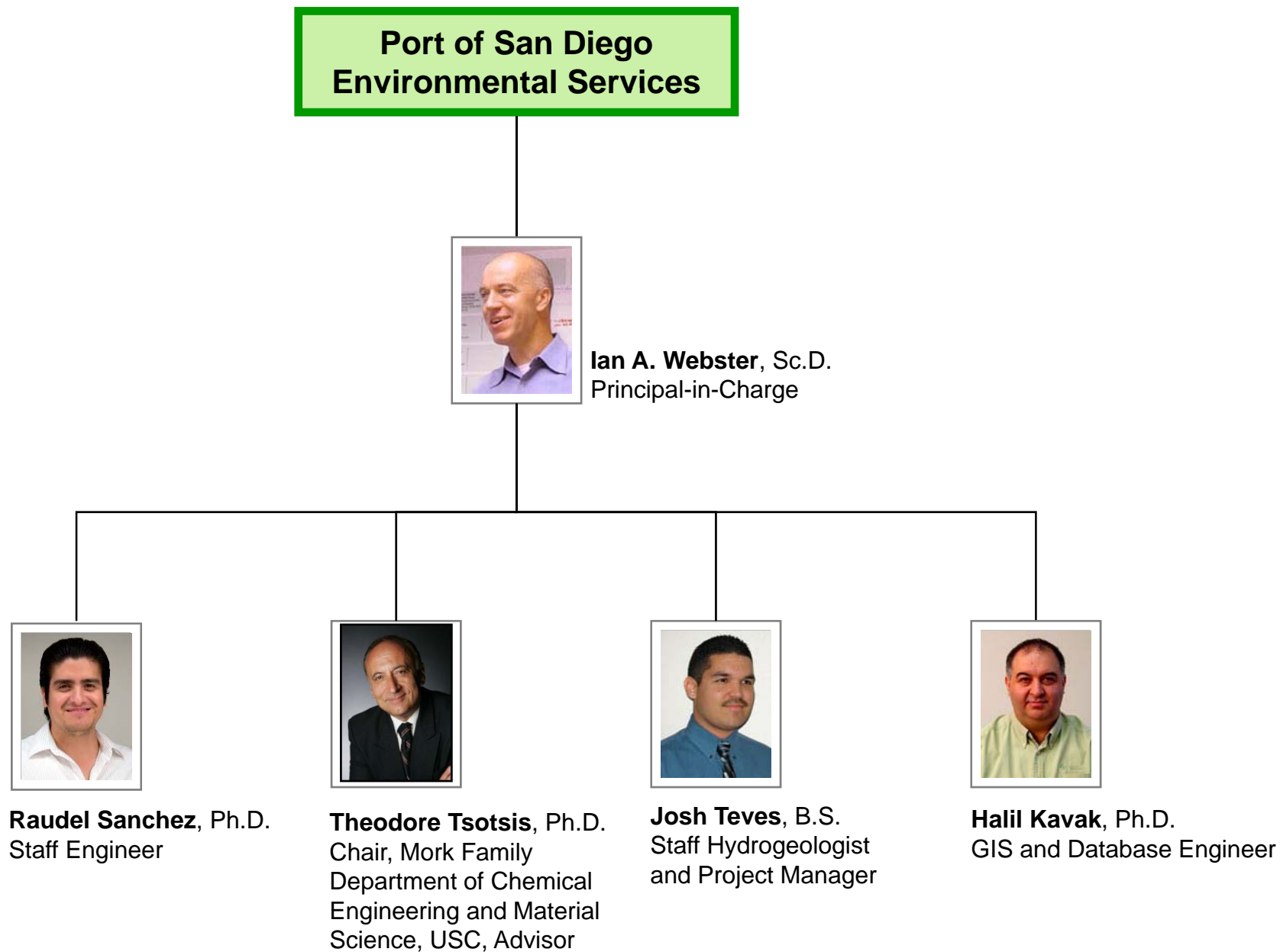


FIGURE 10

Port of San Diego Sediments Treatability Study: Proposed Project Organization Diagram



Proposed Project Team

Ian A. Webster, Sc.D., Proposed Principal-in-Charge

Dr. Webster has 22 years of experience working on all aspects of CERCLA sites, from site assessment to remediation and O&M. Ian has worked extensively on scores of Federal and State Superfund sites. Ian excels in experimental design and the derivation of remedies for complex sites. He holds an Adjunct Professorship in the Department of Chemical Engineering at USC

Raudel Sanchez, Ph.D., Staff Engineer

Dr. Sanchez has 3 years of experience in modeling transport and fate processes in caps and soil. Dr. Sanchez has worked on the characterization biodegradation process of several contaminants of concern.

Josh Teves, B.S., Hydrogeologist and Project Manager

Mr. Teves works on several remediation sites in California and Texas and is currently managing the Purity Oil Superfund Site. At Purity Oil, Mr. Teves is currently working with the EPA to change the groundwater remedy from pump and treat to enhanced reductive dechlorination. Mr. Teves works in PNL's San Francisco bay area office and his remedial action experience in northern California will be valuable to this Project.

Halil Kavak, Ph.D., GIS and Database Engineer

Dr. Kavak is an expert in GIS data management and 3-dimensional visualization of subsurface conditions. Dr. Kavak's skills will be utilized primarily during the Data Review and Analysis portion of the Project. Dr. Kavak currently provides data management services at other major remediation projects.

Theodore T. Tsotsis, Ph.D., Advisor

Professor Tsotsis is the Chair of the Mork Department of Chemical Engineering and Material Science at the University of Southern California. Professor Tsotsis has 25 years of expertise in the design and applications of reactive barriers. Theodore will provide in-kind consulting advice and laboratory facilities for the project.

TABLE 1

Project Cost Proposal

TASK	PNL					LABOR TOTAL	EQUIPMENT	LAB SAMPLING	TOTAL
	PRINCIPAL	PROJECT MANAGER	STAFF ENGINEER	USC SUPPORT	GRAPHICS SUPPORT				
	hr	hr	hr	LS	hr				
	\$190	\$165	\$100	\$50,000	\$89				
Task 1: Meetings						\$3,240			\$3,240
Kick off Meeting PNL/Port of SD	8	8	4			\$3,240			\$3,240
Task 2: Procurement of Equipment and Design of Experimental Setup						\$15,100	\$20,000		\$35,100
Design of Experimental Setup	10	10	40			\$7,550			\$7,550
Design of Comprehensive Mathematical Model of System	10	10	20			\$5,550			\$5,550
Procurement of Lab Equipment			20			\$2,000			\$2,000
Cost of Laboratory Equipment						\$0	\$20,000		\$20,000
Task 3: Experimental Setup									\$23,480
Experimental Setup	4	20	40			\$8,060			\$8,060
Collect Samples from Port of SD	4	4	40			\$5,420		\$10,000	\$15,420
Task 4: Performing Experiments and Running Software									\$103,175
Performing Experimental Program	20	40	350	1		\$95,400			\$95,400
Running Software	5	5	60			\$7,775			\$7,775
Task 6: Presentation and Written Report									\$16,020
Report	8	20	40		20	\$10,600			\$10,600
Presentation	8	8	8		20	\$5,420			\$5,420
Matching Funds - Project Navigator Ltd.									\$25,000
Matching Funds - University of Southern California									\$35,000
Matching Funds - Chevron and FMC									\$20,000
Total Hours	77	125	622	1	40				
Total Cost of Project	\$14,630	\$20,625	\$62,200	\$50,000	\$3,560	\$151,015	\$20,000	\$10,000	\$181,015
Matching Funds (cash + in-kind)									\$80,000
Port of San Diego Total Cost									\$101,015

Ian A. Webster, Sc.D.



Ian A. Webster, Sc.D.
President, Senior Project Manager

B.Sc.
Strathclyde University, UK, 1976

M.S.
Cornell University, 1979

Sc.D.
MIT, 1984

All degrees in chemical engineering.

Focused Experience

- Remediation strategy development and planning
- Groundwater remedies
- Business and technical oversight at major remediation projects
- Risk based remediation planning
- Development of remedial options
- Regulatory negotiations
- Risk management
- Cost and schedule computations
- Implementation logistics
- Cost avoidance strategies
- Optimizing "pace to closure"
- Data mining
- Site conceptual models
- Advocacy presentations
 - Public agencies
 - Cities & municipalities
- Meeting facilitation
- Resource utilization
- Design and construction oversight

Skills

- Expert in remedial options for sediments sites
- Extensive and sophisticated understanding of project environmental conditions and possible remedial approaches
- Remediation strategies and development of remedial options
- Remedial alternatives formulation for both soils and groundwater impacts
- Site strategy planning consistent with ultimate objective of determining most cost-effective solutions
- Client management, and facilitation towards decision-making
- Knowledge of regulatory strategies
- Formulation of risk based closure approaches
- Compliance assessment and methods to achieve compliance
- Site knowledge assessment and data gap analysis
- Site conceptual model formulation
- Data mining and re-use via such techniques as GIS
- Project scheduling, logistics and critical path analysis
- Visual representation of complex technical concepts and scenarios
- Preparation of effective and audience accessible technical reports and presentations
- Project advocacy to agencies and community groups. Extensive experience with US EPA Region 9 and CA RWQCB
- Resource selection, team building and management
- Project presentations in public forums

Representative Experience

Formulated site strategy development at complex remediation projects, such as Cooper Drum Superfund Site, South Gate, CA; Waste Disposal Inc. Superfund Site, Santa Fe Springs, CA; BKK Landfill, West Covina, CA; El Monte and South El Monte Operable Units of the San Gabriel Valley Superfund Sites; Newark Bay Study Area, NJ; Tex Tin Superfund Site, Texas City, TX; Cox Road Landfill, Liberty County, TX; and other complex remediation projects in Emeryville, and Carson, CA.



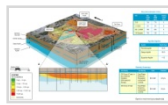
Operating Industries Inc. (OII) Superfund Site, Monterey Park, California

President of New Cure, Inc., (NCI) from 1997 to 2000, and 2005 to 2006. NCI was a company established by the major PRPs to oversee and manage their remediation programs at the Operating Industries Inc (OII) Superfund Site Landfill in Los Angeles. Ian was the "owners' representative" for a \$100MM design and construction phase where a landfill cap and gas collection system was installed. This site is the west coast's most expensive and complex superfund remediation project. Work involved alternatives analysis, EPA negotiations, design/build programs and cost/schedule controls. Continuing to provide advice and technical services.



Ascon Landfill Site, Huntington Beach, California

Currently working with the Project Navigator team on site data collection via field programs, data interpretation and development of remedy alternatives for site closure. Options range from excavation of up to 1.3MM cu.yds. of oil impacted wastes to cap and contain remedies. Our major clients on this project are ConocoPhillips and Chevron. Providing input on remedial options and project strategies.



Cooper Drum Superfund Site, South Gate, California

Led the PNL team which consulted for a group of PRPs who wished to increase their understanding of site conditions prior to the issuance of a CERCLA 106 Order. The Cooper Drum site has both soils and groundwater impacted with chlorinated solvents. The proposed EPA remedy is complex involving *in situ* treatment and the construction of a biowall. PNL reviewed site data for the PRPs, developed a site conceptual model and evaluated the efficiency and costs of the proposed solution.

Employment History

1997 to Present Project Navigator, Ltd.

Founder and President. Since founding PNL, Ian has worked to establish the firm as a respected team of problem solvers who focus on large, complex, regulatory impacted, remediation projects. Ian has created a company culture that strongly relies on the use of visual techniques to promote site conditions understanding, options development and, project problem solving with the client. Project Navigator, Ltd. has developed an excellent problem-solving reputation with Fortune 100 companies.

1984 to 1997 UNOCAL Corporation

Entered the company as a research engineer in the Brea, CA facility. Promoted into the Corporate Environmental Department in Los Angeles and from there into, what was formerly known as, Corporate Environmental Remediation and Technology. Focused on projects in California, and the Gulf Coast and for a time supported O&G new ventures on projects in Argentina and India. Resigned from Unocal with title of Chief Engineer, Superfund Projects in 1997 to establish Project Navigator.

Other

Author of more than 30 peer reviewed technical papers

Adjunct Professor of Chemical Engineering at University of Southern California

Testified before Senate and House Committees on Superfund Reauthorization issues

References supplied on request



Raudel Sanchez, Ph.D.



Raudel Sanchez
Project Manager

Ph.D.
University of Southern California,
Los Angeles, Chemical
Engineering, 2008

B.S.
California State University Long
Beach, Chemical Engineering,
2002

Focused Experience

- Project Metrics and Forecasting
- Data Analysis
- Data Mining
- Project Cost Analysis
- Remedial solutions
- Groundwater Modeling
- Artificial Neural Networks Applications
- Site conceptual models
- Environmental site assessment

Skills

- Biodegrading characteristics modeling
- Engineering and logistical support on major Superfund EPC projects
- Use of Artificial Neural Network to forecast temperature, methane and carbon dioxide distribution in landfills
- Hazardous waste site assessment and numerical simulation
- Site conceptual models (SCMs)
- Information and data visualization
- Gas migration assessment and modeling
- Design of landfill gas and liquids management systems
- Remedy construction logistics
- Compliance
- Site knowledge assessment and data gap analysis
- Data mining and re-use via such techniques as GIS
- Preparation of effective and audience accessible technical reports and presentations
- Project advocacy to agencies and public
- Project presentations in public forums

Representative Experience

Operating Industries Inc. (OII) Superfund Site, Monterey Park, California



Currently provides project engineering support to the Project Manager at this 190 Acre Superfund Site where PNL continues to work with New Cure Inc. (NCI) to manage operations and development. Evaluated construction bids and selected company for construction for North Parcel. Worked with project engineer to get permits approved for cap design from EPA and Caltrans for North Parcel. Assisted project engineer on the remedy design of the north section of the site 2008-2009. Created construction schedule for cap design. Evaluated temperature, methane and oxygen data for assessment of enhanced oxidation study.

Confidential Client

Site data interpretation and conceptual model formulation for allocation negotiations.

Employment History

2008-Present Project Navigator, Ltd., Brea, CA *Project Manager*

2003-2008 University of Southern California, Los Angeles, CA *Research Assistant*

- Developed gas and liquids migration software for municipal solid waste landfills
- Use genetic algorithms to optimize complex functions
- Use Super Computers to perform landfill simulations involving two-phase flow
- Use Artificial Neural Networks to forecast the future conditions of CVX Sites
- Chevron-USC-Project Navigator, Ltd., Digital Site and Visualization Project

Publications & Conferences

Sanchez R, Mehrdad, Tsotsis T, Sahimi M., *Computer Simulation of Gas Generation and Transport in Landfills II: Dynamic Conditions*, Chemical Engineering Science (CES) Vol. 61 (2006) 4750-4761

Sanchez R, Mehrdad, Tsotsis T, Sahimi M., *Computer Simulation of Gas Generation and Transport in Landfills III: Development of Landfills' Optimal Mode*, Chemical Engineering Science, Vol. 62 (2007) 6378-6390

Development of Optimal Model of a Landfill Using Massively-Parallel Computers
AIChE Annual Meeting Nov. 2004 Austin, Texas

Modeling Landfills as Large-Scale Bioreactors. A Tool for Predicting Landfill Gas Production and Addressing Safety Issues
AIChE Annual Meeting Nov. 2007 Salt Lake City, Utah

Joshua A. Teves, B.S.



Joshua A. Teves
Project Manager

B.S. Geology
University of California,
Berkeley, CA 2002

Focused Experience

- Remedial investigations
- Project Management
- 3rd-party facilitation
- Budget analysis
- Regulatory compliance
- Project advocacy
- Remediation strategy development and planning
- Resource procurement
- Environmental Site Assessments (ESAs)
- Technical Report Writing
- Risk based remediation planning
- Field Investigations
- Risk management
- Remedial solutions
- Data mining
- Site conceptual models

Certifications

- 40-Hour HAZWOPER
- 8-Hour HAZWOPER refresher
- Risk Reduction Program Training - Modules 1,2, and 3

Skills

- Project management of environmental investigations and remediation programs
- RI/FS, RD/RA management and peer review
- Regulatory compliance experience with USEPA, DTSC and RWQCBs
- Project scheduling and logistics
- Remedial oversight and remedial alternative analysis
- Technical reporting to State and Federal Regulatory Agencies
- Management experience involving contaminated soil and groundwater
- Project advocacy to agencies and public
- Remediation strategies and development of remedial options
- Organization and management of field investigations
- Site knowledge assessment, waste volume assessment, and data gap analysis
- Data mining and re-use via such techniques as GIS
- Visual representation of complex technical concepts and scenarios
- Project presentations in public forums

Representative Experience



Purity Oil Sales Superfund Site, Fresno, CA

Currently serving as a member of the Project Coordinator team for the 7-acre federal Superfund site. The site formerly operated as a used-oil recycling facility where sludge was stored in several unlined pits. PNL is serving as the Project Coordinator for the site. PNL is in the process of changing the GW remedy for the site from Pump and Treat to enhanced reductive dechlorination and MNA. PNL negotiated the remedy change with EPA Region 9 and is currently overseeing a GW pilot study to demonstrate the effectiveness of the proposed remedy change.



Cooper Drum Superfund Site, South Gate, CA

Served as the hydrogeologist for this federal Superfund site with chlorinated solvent-impacted groundwater. Evaluated existing groundwater data and remediation designs in order to make recommendations to the PRP group regarding more efficient and cost-effective remedial solutions.



Former Railyard, Houston, TX

Served as the oversight geologist for a 50-acre tract of land north of downtown Houston which operated as a railyard since the early 1900s. Soil and groundwater are impacted with diesel fuel, chlorinated solvents, metals, and PCBs. The diesel plume exceeded 12 feet in thickness in some locations. The groundwater contamination was treated by a NAPL recovery system which included over 30 recovery wells and an above-ground treatment system. Shallow soil was excavated and hauled off and later replaced with clean fill material.



Sierra Telephone, Oakhurst, CA

Served as the project manager for an active maintenance yard with impacted groundwater that extended into several different aquifer systems. Worked with RWQCB to implement an air-sparge, vapor extraction system with an MNA component in lieu of the more expensive pump and treat option.



Various UST Sites, California

Served as project manager for over 15 UST sites throughout California. Site remedies included ozone and peroxide injection, pump & treat, ERD, air-sparging, and MNA.

Employment History

2006 to Present Project Navigator, Ltd., Project Manager

Responsibilities include: Project Management of multi-party sites under regulation by USEPA, DTSC, RWQCBs, and TCEQ; Supervising subcontractors during assessment and remedial action activities; Technical report writing and review; Scheduling, permitting, and budget preparation/analysis; Preparation of contaminant fate and transport models; Preparation of presentations, web sites, and models for agency submittals, client meetings, and public meetings.

2003 to 2005 HerSchy Environmental, Project Geologist

2005 to 2006 SKA Consulting, Project Manager

Responsibilities include: Soil, groundwater, and vapor sampling; Supervising drilling and excavation subcontractors; lithologic borehole logging; installation of monitoring and remediation systems; Technical Report writing under state and federal regulatory framework; Project Management; permitting, budget analysis, scheduling field work, regulatory compliance; working in conjunction with Regulatory Agencies (DTSC, RWQCBs, TCEQ, RRC, USEPA) for clients per CERCLA, Voluntary Cleanup Program (VCP), Innocent Owner Program (IOP), and Leaking Petroleum Storage Tanks (LPST) program; performing Phase I and II Environmental Site Assessments (ESAs), preparing APARs (new form), RAPs, and RACRs in order to attain Certificates of Completion for residential and commercial/industrial land use. Projects were remediated for beneficial re-use.

Halil I. Kavak, Ph.D.



Halil I. Kavak, Ph.D.
Director of GIS

- B.S. Chemical Engineering**
Ankara University, Turkey, 1986
- M.S. Applied Sciences**
Ankara University, Turkey, 1988
- M.S. Chemical Engineering**
Illinois Institute of Technology, 1991
- Ph.D. Chemical Engineering**
University of Southern California, 1998

Focused Experience

- Geographic Information System (GIS)
- Environmental Visualization System (EVS)
- Soil lithology
- Global Positioning System (GPS)
- ArcPad GPS solutions
- Database management
- Data analysis
- Data conversion
- Data mining
- Risk-based remediation
- Clustering analysis
- Conceptual site modeling
- Conceptual site design
- Site characterization
- 3D visualization
- 3D animation
- Land use planning
- Engineering support
- Litigation support
- Knowledge management
- Aerial photography analysis

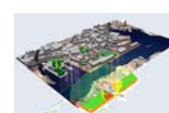
Skills

- Data management, analysis and display of geographic and environmental knowledge via Geographic Information System (GIS)
- 3D visualization of subsurface contaminated soils and groundwater plume via Environmental Visualization System (EVS)
- Site lithology visualization via EVS and Rockworks systems
- Visual graphic and animation production for litigation support
- Site conceptual modeling by using hard and digital modeling techniques
- Site characterization
- Engineering calculation and visualization via AutoCAD
- Conversion, mining and analysis of large quantity of data
- Landfill gas and groundwater flow simulation
- Aerial photography analysis
- Knowledge management and database structuring
- Data entry and QA/QC process management
- Historical site condition visualization

Representative Experience



Ascon Landfill Site, Huntington Beach, California
Site characterization, site conceptual model, and remediation cost calculations.



IDPP, Honolulu, Hawaii
Managing IDPP electronic and physical repositories on PNL secure website, www.projecttoolbox.com.



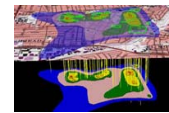
Waste Disposal, Inc., Santa Fe Springs, California
Site characterization, site conceptual model, and remediation cost calculations.



Cal Compact, Carson, California
Litigation support. Site condition during operation years. Material balance calculation at Cal Compact site.



MAR Services Site, Cankton, Louisiana
Site characterization and site remediation.



El Monte Operable Unit, El Monte, California
Visualization of plume location in groundwater via GIS techniques.



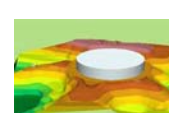
PAB Oil and Chemical Site, Abbeville, Louisiana
Site characterization and site remediation.



South El Monte Operable Unit, South El Monte, California
Visualization of plume location in groundwater via GIS techniques.



Operating Industries, Inc., Monterey Park, California
Calculation and visualization of landfill gas escape at south parcel. Aerial photography analysis to locate historical site condition.



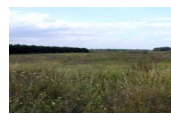
Brea Water Tank, Brea, California
Litigation support. Aerial photography and site topology were used to find optimum project cost.



Tex Tin, Texas City, Texas
Site conceptual modeling and site characterization.



IWC, South Gate, California
Contaminated groundwater volume calculation via EVS.



Kerr McGee, Hendry County, Florida
Contaminated groundwater volume calculation via EVS.

Theodore Tsotsis, Ph.D.



Theodore Tsotsis

Department Chair Chemical Engineering and Material Science at University of Southern California

Ph.D.

University of Illinois, Urbana, Chemical Engineering, 1978

M.S.

University of Illinois, Urbana, Chemical Engineering, 1976

B.S.

Chemical Engineering, National Technical University, Athens, Greece, Chemical Engineering, 1974

Focused Experience

- Catalytic Reactive Barriers
- Membranes Separations
- Environmental Reaction Engineering

Funding:

DOE, DTRA, NASA, NSF, California Energy Commission, METRANS and Chevron

Representative Experience

Environmental Reaction Engineering

We are interested in the remediation of landfill sites. Our work involves the detailed modeling of landfill gas and leachate generation and transport in these sites. We also study novel means for getting rid of the various heteroatom-containing VOC found in landfill gas and biogas.

In addition, we are interested in the development and use of novel adsorbent and membranes for the elimination of toxic pollutants from drinking water and industrial wastewaters. Our current project in this area involves the elimination of heavy toxic metals like As, Se, and Hg from power-plant effluents.

Transport and Reaction in Membranes and Catalysts

Key research interested include the study of transport and reaction phenomena in membranes, adsorbents, and catalysts. Membranes are of interest because of their application in reactive separation applications (e.g., membrane reactors), but also because they serve as model systems for the study of such phenomena in other porous systems like adsorbents and catalysts. The studies are both of experimental and theoretical character. Experiments involve carbon molecular sieve, SiC, and layered-double-hydroxide type membranes. To model the transport phenomena, we use non-equilibrium molecular dynamics (NEMD) techniques. The use of reactive separations, involving high temperature membranes, to power generation applications is also currently under investigation.

High Temperature Reactions

We are interested in power generation applications involving renewable fuels like landfill gas and biodiesel. We study the combustion characteristics of these fuels, and the environmental implications of their use in power generation. The experiments are carried out in an experimental set-up, which allows us to measure the fluid mechanics, temperature, and composition of the reactive flows. Experiments are coupled to complete numerical simulations of 2-D and 3-D reactive flows involving full chemistry.

Selected Publications:

- Ostwal, M.M, Pellegrino, J., Norris, I., Tsotsis T.T., Sahimi, M., and Mattes, B.R., "Water Sorption of Acid-Doped Polyaniline Hollow Fibers: Equilibrium and Kinetic Response," *Ind. Eng. Chem. Res.*, 45, 6021, 2006.
- Elyassi, B., Sahimi, M., and Tsotsis, T.T., "Silicon Carbide Membranes for Gas Separation Applications," *J. Membrane Sci.*, 288, 290, 2007.
- Wang, Y. L., Holley, A. T., Andac, M.G., Egolfopoulos, F. N. , and Tsotsis, T.T., "Studies of Combustion Characteristics of Biofuels in Premixed and Non-premixed Flames," Paper A18 (Session on Laminar Flames), Proceedings of the 5th US Combustion Conference, San Diego, CA 2007.
- Bagheri-Tar, F., Sahimi, M., and Tsotsis, T.T., "Preparation of Polyetherimide Nanoparticles by an Electrospray Technique," *Ind. Eng. Chem. Res.*, 46, 3348, 2007.
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