

Comparative Testing of Corexit EC9500A, Finasol OSR 52, Accell Clean DWD, and ZI 400 at Ohmsett in a Simulated Arctic Environment

Steffek, Timothy
Bittler, Kimberly
Guarino, Alan (MAR Inc)

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This test program was conducted to better understand the effectiveness of various commercially available dispersants under arctic test conditions, and do a comparative study on the products. Four dispersants were selected from the Environmental Protection Agency's (EPA) National Contingency Plan (NCP) Product Schedule and were tested on an Alaskan crude oil. To capture operational effectiveness issues, the dispersants were applied to a surface slick using Ohmsett's spray bar, which simulated a system similar to a boat spraying system.

Executive Summary

Over 30 years of dispersant effectiveness research has been conducted in laboratory, wave basin, and field studies, including under arctic-like conditions. The majority of this research evaluated one or more of the Corexit™ family of dispersant formulations. However, other dispersant formulations have recently seen increased interest domestically. These emerging dispersant formulations are included in the Environmental Protection Agency's (EPA) National Contingency Plan (NCP) Product Schedule of approved technologies for oil spill response and mitigation. Accordingly, a need was identified to compare the effectiveness of available dispersant formulations under simulated Arctic conditions.

In February of 2014, the U.S. Department of Interior's Bureau of Safety and Environmental Enforcement (BSEE) conducted independent dispersant effectiveness testing to compare available formulations. Several products were tested under mesoscale simulated arctic conditions at the Ohmsett facility. The study was conducted to better understand and compare the effectiveness of various dispersants under simulated arctic test conditions. Four dispersants were selected from the EPA's NCP Product Schedule and tested on an Alaskan crude oil: Corexit® EC9500A, Finasol® OSR 52, Accell® Clean DWD, and ZI 400. To capture operational effectiveness, the dispersants were applied to a surface slick using Ohmsett's spray bar, which simulated a boat spraying system. Data collected included droplet size distribution of the dispersed oil, measured at one meter and two meters below the water's surface and using two LISST-100x instruments from Sequoia Scientific. Dispersant Effectiveness (DE) was measured using the volume of the oil, which remained on the surface after the test as compared to the total volume dispensed onto the surface for the test.

The performance of the products was quantified and compared to each other based on DE and the droplet size of dispersed oil. Corexit EC9500A and Finasol OSR52 performed very well in this study as compared to the other dispersants, producing the highest average DE, and the most improvement in droplet size as compared to the tests with untreated oil. The performance for Accell fell between that of Finasol and ZI 400. ZI 400 performed poorly relative to the other products tested.

Contents

Executive Summary..... 1

List of Figures..... 3

Abbreviations, Acronyms, and Nomenclature..... 3

Introduction 4

 Summary on Dispersants 5

Methods 6

 Selection of Dispersants..... 6

 Ohmsett Testing Facility..... 8

 Test Oil 9

 Triplicate Testing..... 11

 Test Procedures..... 11

 Warming of the Dispersants..... 12

 Collection of Remaining Surface Oil..... 12

 Dispersant Effectiveness and Dispersant to Oil Ratio Calculations..... 12

 Data Selection Procedures 13

 Dispersed Droplet Size Cutoff 13

 Data Selection 14

 Statistical Analysis..... 14

Results 16

 Experimental Conditions Observed 16

 Experimental and Ambient Conditions Controlled for in Analysis 16

 Dispersion Effectiveness..... 17

 Droplet Size Distribution..... 19

Discussion..... 23

 General Observations about Each Product..... 23

 Conclusions..... 26

 Recommendations..... 27

References 28

Test Procedures..... Appendix A

Test Conditions, DE, and DOR Summary Tables..... Appendix B

Droplet Size Distribution Curves by Product..... Appendix C

Data Selection by Test..... Appendix D

EPA NCP Technical Bulletins for Products Tested..... Appendix E

List of Figures

FIGURE 1- MECHANISM OF CHEMICAL DISPERSION (NATIONAL RESEARCH COUNCIL, 2005)	5
FIGURE 2 - SCHEMATIC OF THE OHMSETT FACILITY	9
FIGURE 3 - TEST OIL VISCOSITY FROM 10 °C TO -1.5 °C	10
FIGURE 4 - EXAMPLE OF DATA SELECTION TO BE ANALYZED	14
FIGURE 5 - MEAN DISPERSANT EFFICACY (DE, %) OF EACH DISPERSANT TREATMENT.	18
FIGURE 6 - DROPLET SIZE DISTRIBUTION - CURVES BASED ON MEAN OF PRODUCT TESTS	19
FIGURE 7 - DROPLET SIZE DISTRIBUTION - CUMULATIVE CURVES	19
FIGURE 8 - SIMPLIFIED DROPLET SIZE DISTRIBUTION WITH TWO PARTICLE SIZE RANGES	19
FIGURE 9 - THE MEAN CONCENTRATION OF OIL DROPLETS LESS THAN 70MICRONS IN SIZE	21
FIGURE 10 - PROPORTION OF DROPLETS MEASURED BY THE LISST DEVICE BELOW 70 MICRONS. .	22
FIGURE 11 - SPC1000 AFTER CIRCULATING THROUGH THE DISPERSANT PUMPING SYSTEM.	24
FIGURE 12 - FOAM THAT APPEARED AFTER THE INTRODUCTION OF ACCELL	25
FIGURE 13 - COMPARISON OF ZI 400 AND FINASOL WHILE RECIRCULATING.....	26
TABLE 1 - TEST OIL PROPERTIES	10
TABLE 2 - API GRAVITY AND SULFUR CONTENT OF THE TEST OIL AS COMPARED TO U.S. ARCTIC OILS AND THE GULF OF MEXICO	11
TABLE 3 - SIGNIFICANCE OF VARIABLES ON OUTCOME.....	17
TABLE 4 – DISPERSANT EFFECTIVENESS SUMMARY FOR EACH PRODUCT	17
TABLE 5 - MEDIAN DROPLET SIZES.....	20

Abbreviations, Acronyms, and Nomenclature

ANCOVA	Analysis of Covariance	°C	Celsius
ANOVA	Analysis of Variance	°F	Fahrenheit
API	American Petroleum Institute	µm	Micrometer
ASTM	ASTM International, An international standards organization that develops and publishes voluntary consensus technical standards	cP	Centipoise
BSEE	Bureau of Safety and Environmental Enforcement	gpm	Gallons per minute
CFR	Code of Federal Regulations	pH	A numeric scale used to specify the acidity or basicity(alkalinity) of an aqueous solution
DE	Dispersant Effectiveness	ppb	Parts per billion
DOR	Dispersant to Oil Ratio	ppm	Parts per million
EPA	Environmental Protection Agency	psi	Pounds per square inch
LISST	LISST-100X, Laser in-Situ Scattering and Transmissometry	wt%	Percent by weight
NCP	National Contingency Plan		
NJ	New Jersey		
OLS	Ordinary Least Squares		
OSRO	Oil Spill Removal Organization		
Tukey HSD	Tukey Honestly Significant Difference		
U.S.	United States		

Introduction

Expansion of oil exploration in Arctic regions with the associated increases in production, storage, and transport has fueled continued interest in gathering data and field experience in oil spill mitigation in these environmental conditions. The effects of low temperature, the presence and concentration of ice, severe weather conditions, and the logistical isolation of arctic production areas continue to present challenges for effective clean-up and recovery efforts in the event of significant oil releases. One of the major technologies available to planners and responders for arctic oil spills is the use of dispersants. There has been over 30 years of previous dispersant effectiveness data collected in arctic conditions through laboratory, wave basin, and field studies. The majority of these studies involved the use of one or more of the Corexit™ family of dispersant formulations.

Recently, dispersant formulations, such as Finasol OSR 52 produced by Total Fluides of France, have seen increased domestic interest and are included in the Environmental Protection Agency's (EPA) National Contingency Plan (NCP) Product Schedule of approved technologies for oil spill response and mitigation. Accordingly, a need was identified to conduct comparative studies in dispersant effectiveness in cold water using multiple dispersant products.

This study compared the performance of four commercially available dispersant formulations, as measured by Dispersant Efficiency (DE) and the size distribution of dispersed oil droplets in the water column. The goal was to conduct repeatable, large scale tests to obtain performance data about each product. These tests were not meant to fully replicate any specific environmental or operational conditions. The results will aid BSEE and other federal agencies in their decision making regarding dispersant use in the U.S. Arctic. In addition to providing up-to-date performance data of the products in pseudo-field conditions, operational performance was also captured as a general discussion in relation to the ease of use, limitations, and concerns about the products in the environment simulated by the test conditions.

Summary on Dispersants

Dispersant is a term used to label oil spill treating chemicals that promote the breakdown of a surface slick into small droplets of oil, which more readily diffuse into the water column. (Fingas M. , 2011) Dispersants contain surfactants; these are molecules with both a water-soluble (hydrophilic) and oil-soluble (lipophilic) component. By aligning themselves along the oil-water interface, dispersants reduce the interfacial tension (Figure 1), which reduces the amount of mixing energy needed to entrain the droplets into the water column (National Research Council, 2005). The purpose of dispersant usage is to promote biodegradation of the oil by creating oil droplets of less than 70µm in diameter. Droplets of this size can be consumed by organisms, and zooplankton have been observed to consume oil droplets in experiments (e.g. (Lee, Koster, & Paffenhofer, 2012), (Almeda, Baca, Hyatt, & Buskey, 2014)) and in the field (Conover, 1971). Droplets of this size also act neutrally buoyant and tend to remain suspended in the water column. Dispersants work best when applied to fresh oil (National Research Council, 2005).

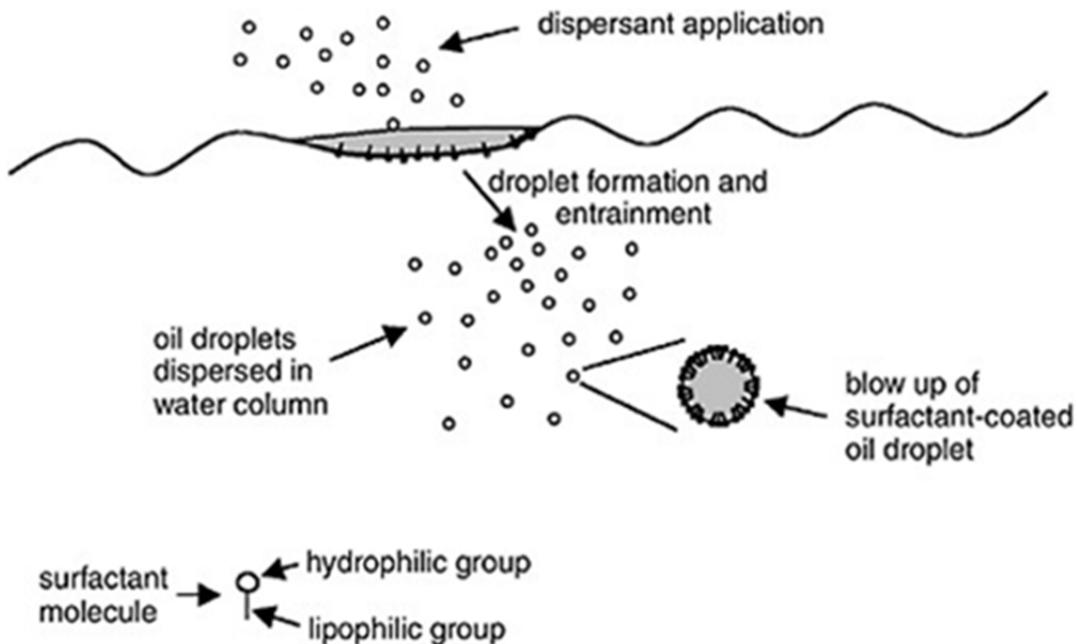


Figure 1- Mechanism of chemical dispersion: surfactant accumulates at the oil-water interface, facilitating formation of small oil droplets that become entrained in the water column. (National Research Council, 2005)

There are seven requirements for a dispersant to work effectively (National Research Council, 1989). They are:

1. The dispersant must hit the target oil at the desired dosage.
2. The surfactant molecules must have time to mix into the oil.
3. The surfactant molecules must orient at the oil-water interface with the hydrophilic groups in the water phase and the lipophilic group in the oil phase.

4. The oil-water interfacial tension must decrease to sufficiently weaken the cohesive strength of the oil slick.
5. Sufficient mixing energy must be applied to allow the generation of smaller oil droplets.
6. The droplets must disperse throughout the water column by a combination of diffusion and advection processes to minimize the formation of larger droplets through coalescence, which may resurface in the absence of turbulence.
7. The droplets must be diluted to nontoxic concentrations and remain in the water column for sufficient time for the majority to be biodegraded.

Methods

Four dispersants were selected from the EPA's NCP Product Schedule and tested on an Alaskan crude oil. They include Corexit® EC9500A, Finasol® OSR 52, Accell® Clean DWD, and ZI 400. To capture operational effectiveness issues, the dispersants were applied to a surface slick using Ohmsett's spray bar, which simulated a system similar to a boat spraying system. Data collected included droplet size distribution of the dispersed oil, as well as the volume of the oil which remained on the surface after the test as compared to the total volume dispensed onto the surface for the test. Droplet size distribution was captured at one meter and two meters below the water's surface and using two LISST-100x instruments from Sequoia Scientific. LISST instruments, or Laser In-Situ Scattering and Transmissometry instruments, are used to measure the concentration of various particle sizes of a sample in a fluid medium. As the fluid carries the sample past the window of the instrument, the particles are hit with a laser. Depending on the size of the particles, the laser will scatter at specific angles, which the instrument then uses to determine the size of the particles and concentration of the particles in the sample being measured. For dispersant testing, these instruments allowed researchers to quantify the performance of each individual dispersant by quantifying the droplet size distributions of the dispersed oil into the tank water. For this test program, droplets sizes of 70 microns (μm) or smaller are considered to be fully dispersed because they are assumed to stay suspended in the water column, whereas the larger droplets may resurface and coalesce into a new slick (National Research Council, 2005) (Lunel, 1993) (Neff, 1990).

Selection of Dispersants

For this test program the products selected all appear on the EPA's NCP Product Schedule. A product being listed on the NCP Product Schedule does not mean that EPA approves, recommends, licenses, certifies, or authorizes the use of that product on an oil discharge. The listing only signifies that data has been submitted to the EPA as required by Subpart J of the National Oil and Hazardous Substances Pollution Contingency Plan, Section 300.915. (40 CFR §300.920 (e), 2014). The following information is required for a dispersant to be listed on the NCP Product Schedule. (40 CFR §300.915 , 2014)

1. Name, brand, or trademark, if any, under which the dispersant is sold.
2. Name, address, and telephone number of the manufacturer, importer, or vendor.

3. Name, address, and telephone number of primary distributors or sales outlets.
4. Special handling and worker precautions for storage and field application. Maximum and minimum storage temperatures, to include optimum ranges as well as temperatures that will cause phase separations, chemical changes, or other alterations to the effectiveness of the product.
5. Shelf life.
6. Recommended application procedures, concentrations, and conditions for use depending upon water salinity, water temperature, types and ages of the pollutants, and any other application restrictions.
7. Effectiveness. Manufacturers shall use the Swirling Flask effectiveness test methods. A dispersant must attain an effectiveness value of 45 percent or greater to be added to the NCP Product Schedule. Manufacturers are encouraged to provide data on product performance under conditions other than those captured by these tests.
8. Dispersant Toxicity. For those dispersants that meet the effectiveness threshold manufacturers shall submit test results and supporting data, along with a certification signed by responsible corporate officials of the manufacturer and laboratory stating that the test was conducted on a representative product sample, the testing was conducted using generally accepted laboratory practices, and they believe the results to be accurate.
9. The following data requirements:
 - a. Flash Point
 - b. Pour Point
 - c. Viscosity
 - d. Specific Gravity
 - e. pH
10. Dispersing Agent Components. Manufacturers shall identify the major components in at least the following categories: surface active agents, solvents, and additives.
11. Heavy Metals, Cyanide, and Chlorinated Hydrocarbons.

The products selected for this study included:

- Nalco - Corexit® EC9500A (Corexit)
- Total Fluides - Finasol® OSR 52 (Finasol)
- Advanced BioCatalytics Corp. – Accell® Clean DWD (Accell)
- Z.I. Chemical – ZI 400

Two of the products used in this study, Corexit and Finasol, represent large portions of dispersant stockpiles in the United States and Europe. These products have been used in actual spill events and have been studied extensively. On the NCP Product Schedule, Corexit and Finasol have a reported effectiveness on Prudhoe Bay Crude of 45.3 and 32.5 respectively. Accell is a product which U.S. oil spill removal organizations (OSRO) are beginning to stockpile and as a U.S. regulator, BSEE felt it was important to include it in this test program. As listed on the NCP Product Schedule, of the products tested, Accell has the highest effectiveness on Prudhoe Bay Crude with 58.7.

Dispersit SPC1000 by U.S. Polychemical Corporation (effectiveness on Prudhoe Bay Crude of 40.0) was initially selected for this program, but was replaced by ZI 400 due to operational difficulties. ZI 400 has a reported effectiveness on Prudhoe Bay Crude of 50.1. Except for Corexit, all of the products were purchased new, either direct from the manufactures or through a distributor. Because of difficulty in purchasing Corexit from Nalco, an existing supply at Ohmsett was used.

Ohmsett Testing Facility

All testing was conducted in the Ohmsett testing facility in Leonardo, NJ. Ohmsett's above ground concrete test tank is one of the largest of its kind, measuring 203 meters long by 20 meters wide by 3.4 meters deep. The tank is filled with 2.6 million gallons of saltwater. The Ohmsett test tank allows testing of full-scale equipment in a contained environment capable of closely simulating an open ocean spill. The tank's wave generator creates realistic sea environments, while state-of-the-art data collection and video systems record test results. The tank's water was not changed between testing. Previous studies have shown that dispersant concentrations maintained below 400 parts per billion (ppb) do not affect the outcome of tests at this site (SL Ross Environmental Research, 2000). Ohmsett's features and capabilities include:

- A main towing bridge capable of towing test equipment at speeds up to 6.5 knots
- A wave generator capable of simulating regular waves up to one meter in height, as well as a simulated harbor chop, FM Slides with selectable: slue rates, start and stop; Pierson-Moskowitz & JONSWAP spectra parameterized by wind speed & scale
- A movable, wave-damping artificial beach
- An oil distribution and recovery system that can handle heavy, viscous oils and emulsions
- A control tower with a fully-computerized 32-channel data collection system as well as above-and below-water video
- A centrifuge system to recover and recycle test oil
- Blending tanks with a water and oil distribution system to produce custom oil/water emulsions for testing
- A filtration and oil/water separator system
- An electrolytic chlorinator to control biological activity
- Permanent and mobile storage tanks that can hold over 227,000 liters of test fluids

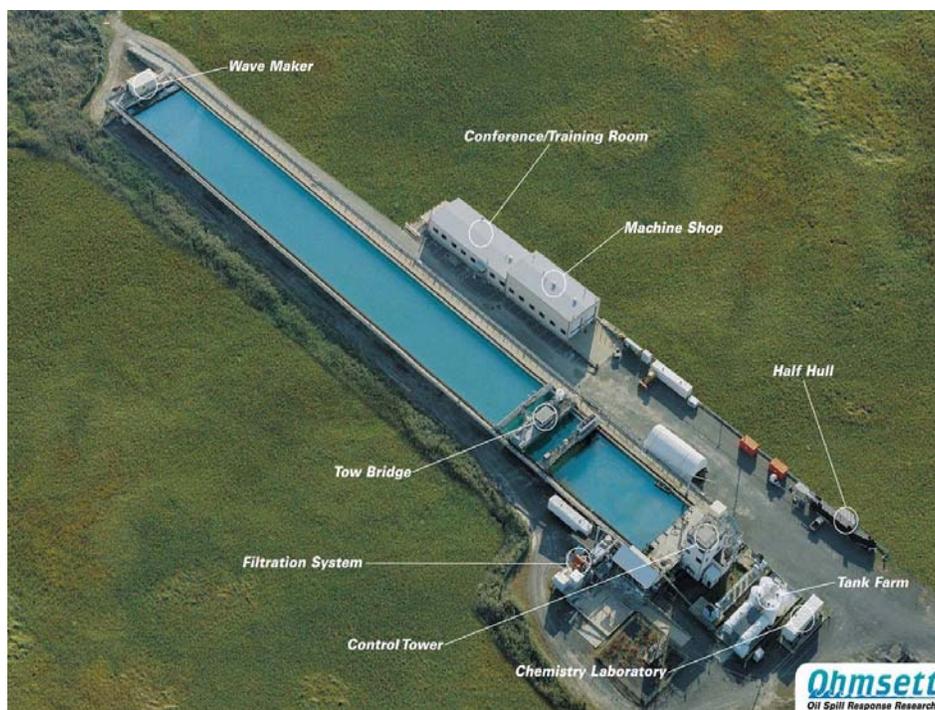


Figure 2 - Schematic of the Ohmsett Facility

Test Oil

Alaskan North Slope oil was the original oil selected for this testing, but was unable to be delivered in time. To successfully complete the test program, two crude oils, which were readily available at Ohmsett, were blended into a homogeneous test oil in an effort to create a large enough volume to complete the 15 planned tests. The test oil was stored and applied at ambient temperature during the duration of this test program. A sample of the test oil was sent to Petroleum Laboratories Inc. for composition analysis (Table 1), and Ohmsett's on site laboratory performed viscosity testing on the oil at 20°C and found that the mean viscosity was 158.8±12 centipoise (cP). To be able to calculate the viscosity of the oil once it was applied to the water's surface, Ohmsett also measured a temperature-viscosity curve from 10°C to -1.5°C (Figure 3). The best-fit trend line for this curve for the viscosity temperature relationship is provided below. The equation had a coefficient of determination of $R^2=98.7\%$, which demonstrates a very good agreement between the measured viscosity and the best-fit equation.

$$\text{Equation 1: } V = 855.02e^{-0.113t}$$

Where t is temperature in degrees Celsius and V is viscosity in centipoise (cP).

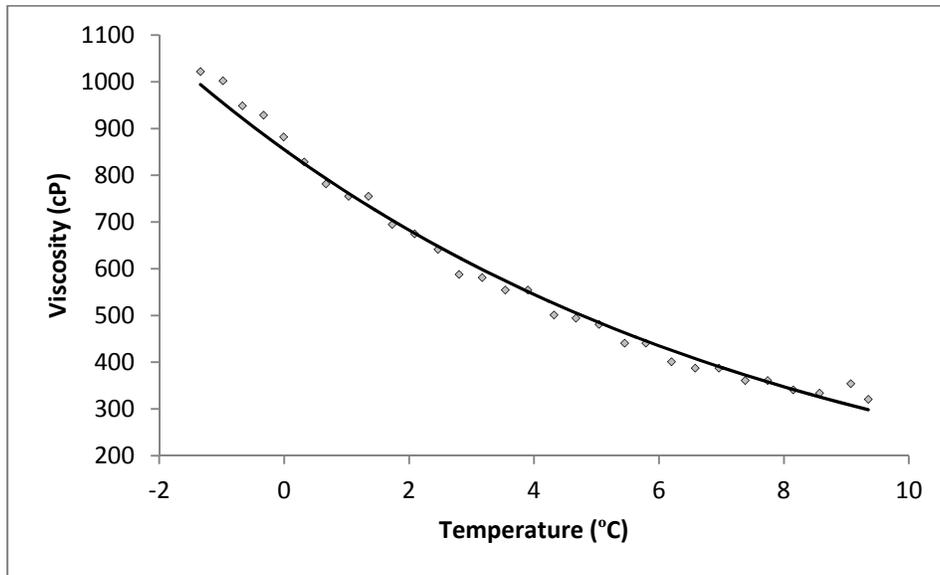


Figure 3 - Test Oil Viscosity in Centipoise (cP) from 10 °C to -1.5 °C. The empirically measured viscosity are shown as individual data points, and solid line shows the best-fit curve (Equation 1)

Parameters	Method	Results
API Gravity	ASTM D287	22.7°
Flash Point, Closed Cup	ASTM D93	30°C (86°F)
Pour Point	ASTM D97	10°C (50°F)
Paraffin – wt% (percent by weight)	---	2.77
Sulfur – wt%	ASTM D4294	1.66
Saturates – wt%	ASTM D2007	25.94
Aromatics – wt%	ASTM D2007	52.58
Asphaltenes – wt%	ASTM D2007	1.16
Polar Compounds (Resins) – wt%	ASTM D2007	20.31

Table 1 - Test Oil Properties

API gravity is a scale used to measure the density of oil as compared to water. A higher API gravity is less dense or “lighter” where as a lower API gravity is more dense or “heavy”. With a specific gravity (SG) of 1.0, water has an API gravity of 10°.

$$API\ gravity = \frac{141.5}{SG} - 131.5$$

The oil tested had a viscosity and API gravity that makes it not as readily dispersible as some oils. However, as reflected in Table 2, it is representative of oils which exist in the near-shore Beaufort Sea (National Research Council, 2014).

Region	API Gravity	Sulfur Content
Chukchi Sea	32-57°	0.0 – 0.2%
Beaufort Sea, Further Offshore	30-40°	0.0 – 0.5%
Beaufort Sea, Near-Shore	25-30°	1.0 – 2.0%
TEST OIL	22.7°	1.66%
Gulf of Mexico, Gulf Coast Refinery Input	29-34°	1.2 – 1.8%

Table 2 - API Gravity and Sulfur Content of the test oil as compared to U.S. Arctic Oils and the Gulf of Mexico. (National Research Council, 2014) (U.S. Energy Information Administration, 2014)

Triplicate Testing

Each dispersant was tested on the oil in three separate replicates, and three controls of untreated oil were distributed throughout the test schedule. The replications were intended to avoid confounding effects of weather changes, human error, operational variations, and property changes of the tank water. These items were controlled for in the analysis, if significant. Control runs were used for calculating the volume of oil lost to natural dispersion and the operation of the test itself. The same instrumentation used during the control runs was also used for the dispersant runs to establish a baseline oil concentration and droplet size distribution at the instrument depths. Additionally, the controls were used to determine trends affecting the test results, such as tank condition, weather, and operational changes.

Test Procedures

For the purposes of this program, the test procedure was adapted from the Ohmsett dispersant effectiveness test protocol developed between 2000 and 2003 by MAR Inc. and SL Ross and documented in “Dispersant Effectiveness Testing on Alaskan Oils in Cold Water” (SL Ross Environmental Research & MAR Incorporated, 2003). An established test area was cleared with the use of Ohmsett’s fire monitors prior to beginning each test and the waves were generated so that every fourth to sixth wave was a breaking wave. Oil was applied through a manifold roughly 0.25 meters above the water’s surface and dispersants were applied by a bar utilizing 15 evenly spaced nozzles which produce a fan pattern. Once dispersants were applied, tests would continue for 20 minutes to allow for mixing and dispersion to take place. Two LISST devices were utilized for each test. One was positioned roughly 1 meter below the water’s surface while the other was positioned roughly 2 meters below the surface. Once a test ended, the remaining surface oil was collected and the tank was allowed to settle for three hours before preparing for the next test. Step-by-step procedures can be found in Appendix A.

Warming of the Dispersants

Due to the cold air temperatures, dispersant spray performance was inconsistent and presented a challenge for calculating dosage. The most common issue was nozzles producing streams rather than a fan spray pattern, specifically from the nozzles on the edges of the spray bar. To aid in the consistency of the tests, a small electric heater was placed in the reservoir of the spray system to warm the dispersants while they circulated prior to application. The dispersants were brought to a temperature of 20°C, roughly the same temperature they were calibrated at while indoors. It is assumed that once applied, the dispersant temperature quickly dropped to that of the oil/water surface due to the small droplet size the nozzle produced.

Collection of Remaining Surface Oil

At the conclusion of each test, the waves persisted until the bridge returned to the south end of the tank. The waves were then deactivated and fire monitors were initiated to sweep the surface oil to the northeast corner of the tank for collection. It is assumed that any oil that resurfaced after the sweep was completed (due to calm tank conditions) would stay dispersed in the water column in open ocean conditions. The resurfaced oil was removed from the test area prior to each new test. As the focus of this research effort was a side-by-side comparison of the dispersant products, this resurfaced oil was not measured. It is acknowledged that recoalescence of oil droplets is possible, but is beyond the scope of this effort. Tests of a longer duration would be difficult because of the movement of the oil due to wind and wave action as well as the current in the test basin, which is caused by the filtration system.

Dispersant Effectiveness and Dispersant to Oil Ratio Calculations

Dispersant Effectiveness (DE) is described as the percentage of oil which no longer remains on the surface as compared to the original volume of oil spilled. For this study, DE is calculated as;

$$\text{Equation 2: } DE = \left[\frac{V_{od} - V_{or}}{V_{od}} \right] * 100$$

where

V_{od} (volume of oil distributed)

= Volume of source oil applied * (1 - % water in source oil)

V_{or} (volume of oil recovered)

= Volume of emulsion recovered * (1 - % water in emulsion)

The water content of the source oil, as well as the recovered emulsions for each test, was analyzed at Ohmsett.

The dispersant to oil ratio (DOR) was also calculated for each test as the volume of dispersant applied to V_{od} . DOR was not a variable for this test program. The dispersant application system was calibrated to deliver a DOR of 1:20 or 5%. This DOR is a generally rule of thumb used for dispersant operations. Due to the operational realities of testing at Ohmsett, a “true DOR”, representing the volume of dispersant which was actually applied to the oil slick was calculated.

The true DOR was calculated using the following method and the spray system was calibrated for each dispersant to obtain the flow rate. The width of the spray bar and the speed of the bridge were constant for every test, so

$$\text{Equations 3: } Dose = q_{dispersant} / (W_{spray} * v_{bridge})$$

where

$q_{dispersant}$ is the flow rate of the dispersant through the spray system in liters per second

W_{spray} is the width of the spray on the water's surface in meters

v_{bridge} is the speed of the bridge in meters per second

$Dose$ is the volume of dispersant applied to a given area in liters per square meter.

The **Dose** was then applied to the surface area of the slick to determine the volume of dispersant (V_{disp}) applied to the oil. The slick width was measured from the bridge as the dispersant was being applied. The slick length was measured from the location of the Ohmsett bridge during the time the oil was dispensed.

$$\text{Equation 4: } V_{disp} = Dose * Slick Area$$

DOR is then calculated using the Volume of Dispersant (V_{disp}) applied to the oil and the volume of oil distributed (V_{od})

$$\text{Equation 5: } DOR = V_{disp} / V_{od}$$

Data Selection Procedures

Dispersed Droplet Size Cutoff

For the purposes of this test, 70 μ m was used as a cutoff point for considering droplets to be dispersed. This is based on several precedents in published literature. The National Research Council review indicated that droplets above 60-80 μ m in size would be expected to resurface when the turbulent regime subsides (National Research Council, 2005). Field studies have validated this cutoff; Lunel reports that 99% of the oil droplets contained within a good dispersion are <70 μ m (Lunel, 1993). Additionally, this benchmark has been used rather consistently for numerous BSEE sponsored studies performed by SL Ross Environmental Research Ltd (SL Ross Environmental Research & MAR Incorporated, 2007) (SL Ross Environmental Research & MAR Incorporated, 2009) (SL Ross Environmental Research & MAR Incorporated, 2010) (SL Ross Environmental Research & MAR Incorporated, 2011).

Data Selection

The LISST-100x captures particle sizes from 2.5 μm to 500 μm and outputs the volumetric concentration of particles in 32 log-spaced size bins (Sequoia Scientific, Inc.) All droplet size distribution data and analysis presented in this report is based on population captured within the limitation of these instruments. Two LISST devices were utilized for each test. One was positioned roughly 1 meter below the water's surface while the other was positioned roughly 2 meters below the surface. Data was collected from approximately five (5) minutes prior to oil release through the end of each test; lasting between fifteen and twenty minutes. The raw LISST data was then placed into a Microsoft Excel spreadsheet and the data samples which were collected while the LISST was in the oil plume, were isolated for analysis. The selection of these data samples was done using field notes based on observations of the instrument operators who were on the Ohmsett bridge during testing, as well as observations of the patterns created by the total droplet concentration data when plotted against time (sample number). The plots in Appendix D show the full range of data samples collected with the analyzed samples highlighted. The Y-axis of these plots is the total concentration (ppm by Volume) of oil measured by the LISST for that test, and the X-axis is the sample number taken by the LISST and is analogous to time. Upper and lower LISST data for each test were then averaged to generate data for analysis. An example is presented below in Figure 4. In this example you can clearly see the individual passes made by the LISST through the plume.

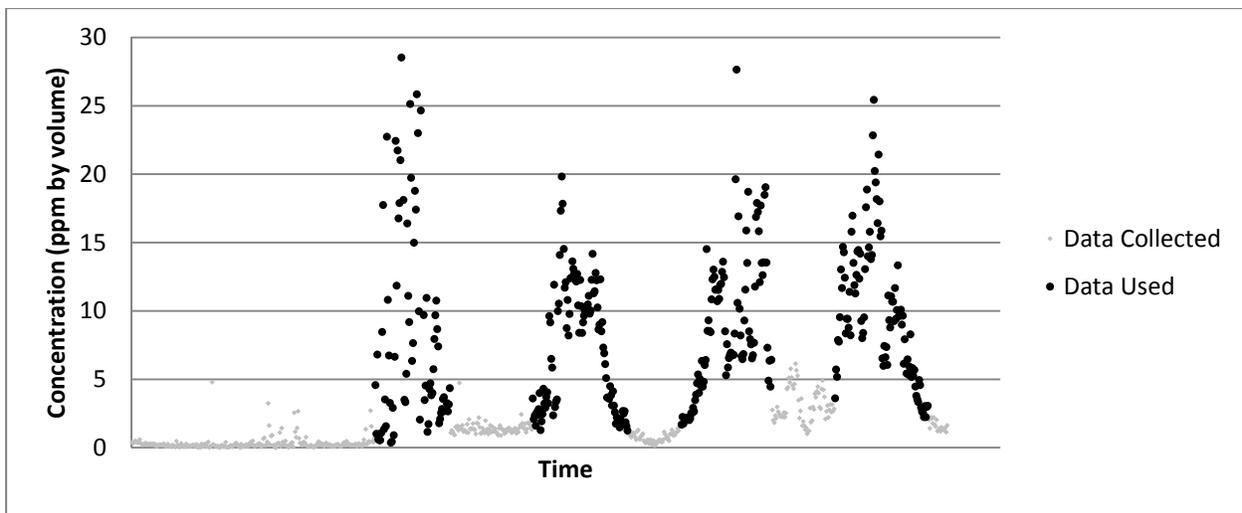


Figure 4 - Example of data selection to be analyzed

Statistical Analysis

All statistical analyses were conducted in R (R Core Team, 2014). An Analysis of Covariance (ANCOVA) was performed to determine if there were significant differences between any of the treatments when controlling for confounding factors, followed by the Tukey Honestly Significant Difference (HSD) test to determine which pairwise comparisons were

significant between different dispersant products and the control. The Tukey HSD test was used in lieu of a series of t-test comparisons to control the inflation of Type II error due to multiple testing. An alternate pairwise t-test procedure is the Dunnett's t-test, which compares each treatment to the control only. The Dunnett's t-test was not used in this analysis, as the pairwise comparisons between different dispersant treatments was also of interest to the research team; not just performance distinct from the control treatment. The control was statistically treated as a distinct treatment group in the analysis to capture and compare the variability in the control tests to the variability seen in the dispersant tests. This analysis allows a more conservative and robust comparison of treatments and the ability of a dispersant to enhance natural dispersion, which is a key metric of concern to oil spill responders.

The analysis of variance (ANOVA) has several assumptions that were not met by the testing procedure, such as independence of replicates and absence of other confounding variates. The Ohmsett tank facility offers a unique opportunity to test the performance of dispersants at large scales. However, this tank facility is exposed to ambient weather conditions and other factors that cannot be controlled through the experimental procedure, such as the influence of past tests on future tests (or "tank memory" due to potential buildup of dispersant and oil throughout the testing period). In order to control for environmental and tank conditions that may vary between tests, a stepwise procedure was used to isolate the impact of tank conditions from true statistical differences in performance. The intent of the analysis of additional covariates is not to suggest additional drivers of dispersant performance, but to isolate potential confounding variables from true trends in outcomes. The stepwise procedure considers the potential effects of salinity, viscosity, temperature, and interfacial tension. The stepwise procedure selects the best-fit model, keeping only the covariates that explain significant variability in the data, and controls for confounding effects (Graham, McNeney, & Seillier-Moiseiwitsch, 2005). The variable of interest, treatment was tested using the ANCOVA approach followed by appropriate post-hoc tests.

There was some concern that, due to the repeated testing nature of the experimental protocol, past tests could impact the following results violating the assumption of independence for linear regression. This type of pattern can be tested for and explained by the autocorrelation model. The best-fit model, identified by the stepwise procedure, was tested for autocorrelation with the Breusch-Godfrey test (Godfrey, 1978) (Breusch, 1979). No significant autocorrelation was indicated, therefore, the tests in the tank can be statistically treated as independent replicates. This finding is consistent with SL Ross' observation, that as long as the dispersant concentration in the tank remains below 400 ppm, previous dispersant use does not impact current tests (SL Ross Environmental Research, 2000).

While a simple ANOVA was considered, the full stepwise model was analyzed as an Analysis of Covariance (ANCOVA) to control for the confounding factors discussed above. The ANCOVA blends the analytical procedures of ANOVA and regression, and both statistical procedures are based on Ordinary Least Squares (OLS) estimation. To test for differences

between specific treatments, the Tukey Honestly Significant Difference (Tukey HSD) test was performed (Hothorn, Bretz, & Westfall, 2008) on the ANCOVA. The Tukey HSD test evaluated the differences between treatments in the best-fit models, which account for all covariates of concern and controls for the effects of multiple testing. This approach is appropriate over a simple ANOVA, as the simple ANOVA's violated assumptions may contribute to misleading statistical results.

Results

Experimental Conditions Observed

One of the main limitations of Ohmsett is that it is an outdoor facility exposed to the elements. In this particular sequence of tests, the weather was similar to some arctic conditions. Air temperature varied from -4.9°C to 8.7°C , with an average of 1.2°C over the course of the study, falling within temperatures that are typically observed in the Arctic from June through September (National Research Council, 2014). The tank's water temperature ranged from -1.2°C to 1.3°C and water surface temperature for each test ranged from -3.3°C to 0.0°C . The tank's water salinity ranged from 26.7 parts per thousand (ppt) to 28.4 ppt. Appendix B shows the meteorological and tank conditions for each test run, as well as the date of the run and the product used.

Experimental and Ambient Conditions Controlled for in Analysis

To control for the impact of potential confounding variables on the results of the treatments, a stepwise ANCOVA analysis was used. The stepwise procedure was used to identify variables that had an impact on the outcomes of this study and to control for their effects. An ANCOVA was performed on the best fit linear models, and indicated if there were significant differences between at least one of the treatments when potentially confounding factors were controlled for. The post-hoc Tukey HSD test on the controlled comparisons of the ANCOVA indicated which treatments were statistically distinct. This analytical approach was used for each of the outcomes that estimate the effectiveness of dispersants for this study.

A stepwise regression was used to identify any covariates that may need to be accounted for when interpreting the differences between dispersants. The results of the regression for the measures of dispersant performance of interest are presented in Table 3. The dispersant treatment was significant across all measures of performance, and salinity and viscosity were important covariates explaining variability in the percentage of oil droplets below $70\ \mu\text{m}$. The stepwise regression only includes predictive variables that significantly increase the predictive ability of the model, and the regression models for each response variable was unique. For best-fit models that did not include one of the three predictive variables on the table below, the cell is blank, indicating that the predictor was not included in the model.

Response Variable	Treatment	Viscosity	Interfacial Tension	Salinity
% below 70 μm	(p=0.0002)***	0.0004919 (p=0.0059)***		-0.0830988 (p=0.0145)***
Dispersant Effectiveness	(p=0.0163)***		2.563 (p=0.2782)	19.228 (p=0.0688)
Concentration below 70 μm	(p=0.0125)***			0.9361 (p=0.2538)

Table 3 - Significance of Variables on Outcome (***) Indicates a Significant Effect)

The effect of residual dispersant and oil in the water from the previous tests was a concern. This was partially captured by measuring the interfacial tension of the water prior to testing each morning. The stepwise regression procedure indicated that interfacial tension had little to no effect of the outcomes of this study. This effect was also tested through the autocorrelation testing, which was also found to be non-significant in this study.

Dispersion Effectiveness

Dispersant performance was captured by calculating the Dispersant Effectiveness (DE) and by volumetric droplet size distribution and median droplet size, which are given by the LISST devices. Overall, when appropriate confounding covariates were controlled for, treatment significantly impacted DE (ANCOVA, $F = 5.91$, $df = 4$, $p = 0.0163$). Confounding variables were identified using the stepwise procedure, which selected the best-fit model based on Akaike information criterion (AIC) (Akaike, 1974). This best-fit model explained 76% of the variation in DE and controlled for the influence of interfacial tension and salinity (Table 3). The influence of dispersant treatment alone explained 63% of the variation in DE in this study.

	Dispersant Effectiveness		
	Lowest	Mean	Highest
Corexit	66.0	72.7	76.4
Finasol	68.1	72.2	78.9
Accell	28.7	51.3	64.3
ZI400	36.3	45.7	51.6
Control	43.0	49.8	59.7

Table 4 - DE summary for each product

As shown in Table 4 and Figure 5, Corexit and Finasol dispersed the highest percentage of the oil based on the average of three tests. As compared to the untreated control (DE=49.8%), the oil treated with Corexit demonstrated a 46% improvement for dispersing the surface slick into the water column, although this difference was not strongly statistically significant (Tukey HSD test, $p = 0.0908$). Based on DE calculations, Finasol performed almost identically to Corexit with a DE=72.2% and a 45% improvement over the untreated oil and a mean DOR

slightly lower than Corexit (1:20 for Corexit, 1:33 for Finasol). This difference was also nearly statistically significant (Tukey HSD test, $p = 0.0987$).

Accell demonstrated only a marginal improvement of 3% over the untreated control with DE=51.3%. An anomalous result was observed in test 10, on Accell, which produced the lowest DE of any test run (28.7%) including the control runs, and may have impacted the mean DE for Accell.

ZI 400 performed poorly and was very close to the DE observed in the Control treatment. Both Corexit and Finasol significantly outperformed the ZI 400 treatment in terms of DE (Tukey HSD test, $p=0.0438$, and $p = 0.0476$ respectively).

A summary is provided in Table 4 and data for each test is available in Appendix B.

	Sum of Squares	df	Mean Square	F value
Treatment	2053.37	4	513.32	5.3353
Interfacial Tension	139.79	1	139.79	1.4529
Salinity	286.06	1	286.06	2.9732
Residual	769.09	8	96.21	

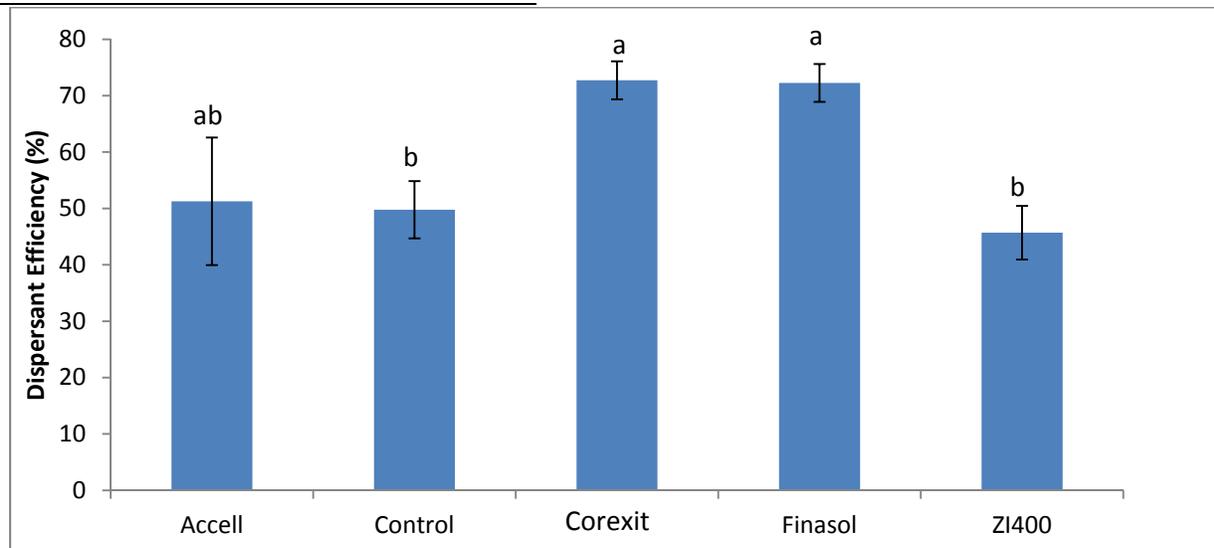


Figure 5 - Mean Dispersant Efficacy (DE, %) of each dispersant treatment. Letters delineate statistically significant differences as measured with the Tukey HSD test ($n = 3$, $\alpha = 0.10$). Group "ab" is not significantly different from groups "a" or "b".

Droplet Size Distribution

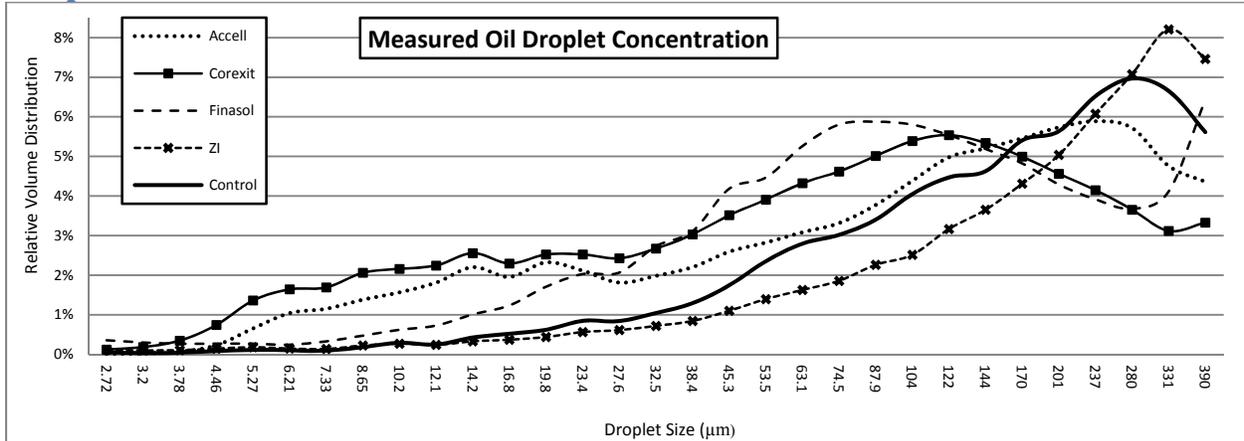


Figure 6 - Droplet size distribution - Curves based on mean of product tests

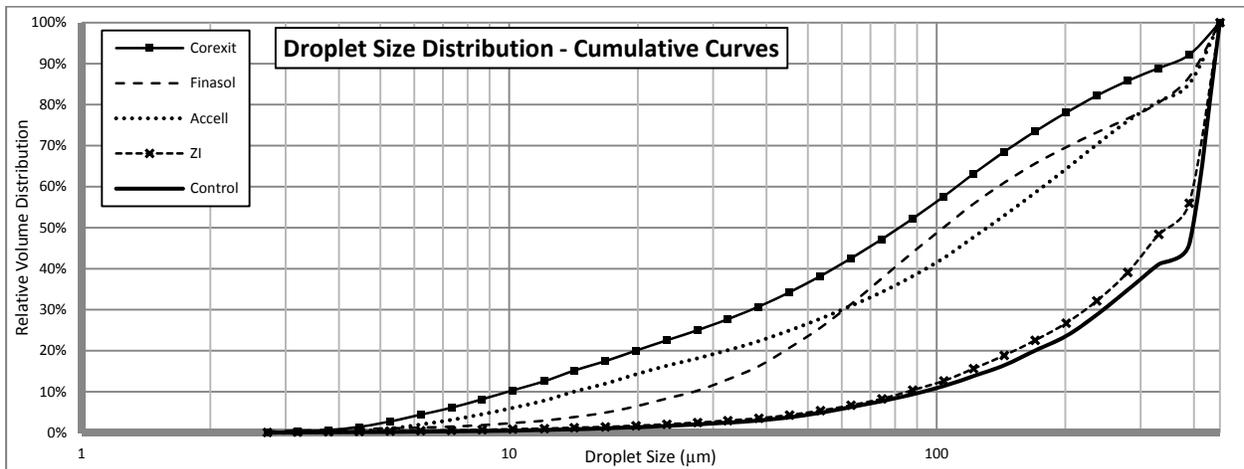


Figure 7 - Droplet size distribution - Cumulative curves based on mean of product tests

Droplet size distribution data was collected during each test. This data allowed for the calculation of median droplets sizes, as well as determined what percentage of measured droplets fell below $\leq 70\mu\text{m}$. Figure 6 shows the relative droplet size distribution (within the detection range of the LISST 100x) for each treatment while Figure 7 illustrates the information cumulatively based on the mean values for the three tests.

Corexit EC9500A had a higher distribution of small droplet sizes ($<70\mu\text{m}$) over the other products (Figure 8). Corexit produced a significantly higher percentage of droplets below $70\mu\text{m}$ than the control ($p=0.001$), and ZI400

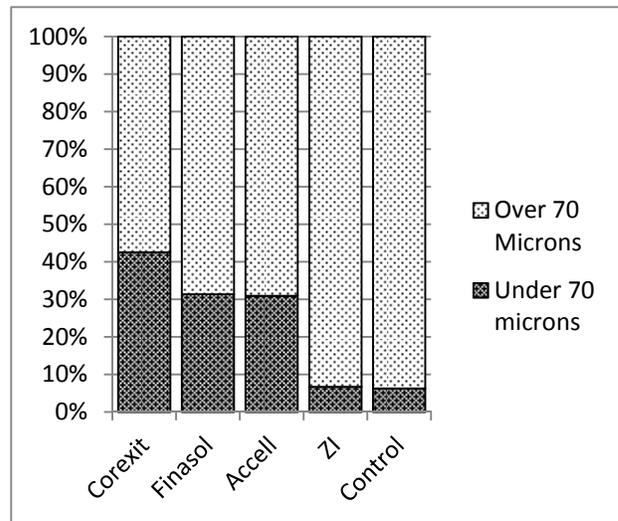


Figure 8 - Simplified droplet size distribution with two particle size ranges, 2.5-70µm and 70-500µm.

($p < 0.001$). Finasol OSR 52, which had effectiveness almost identical to that of Corexit, also had a greater portion of the dispersed droplets within the 50-100 μm range. Finasol produced a significantly higher percent of droplets below 70 μm than the control ($p = 0.014$), and ZI400 ($p = 0.004$). Accell Clean DWD was not as effective as Corexit or Finasol, but the droplet size distribution reveals that the oil that was dispersed consisted of a larger percentage of very small droplets (10-50 μm) over the dispersed oil from Finasol. Accell produced significantly higher percentage of droplets below 70 μm than ZI 400 ($p = 0.004$) and the control ($p = 0.17$). However, both Accell and Finasol had roughly 30% of all measured droplets below 60 μm , with Finasol having only slightly more at the 70 μm cutoff.

ZI 400, which demonstrated no improvement over natural dispersion as measured by DE, also did not improve the droplet size distribution of the dispersed oil. Distribution curves for each product can be found in Appendix C.

From the droplet size distributions, the median droplet size of the plume (based of the range of droplet measured by the LISST) can be calculated and is summarized in Table 5. The average median droplet size for the control tests is 457.26 μm . ZI 400 was only marginally better, with a median droplet size of 382.98 μm . Corexit and Finasol showed significant reduction in median droplet size with 83.85 μm and 95.28 μm , respectively. Accell did not demonstrate as large of a reduction, but still reduced the median droplet size to 138.37 μm .

Product	Median Droplet Size (μm)
Corexit	83.85
Finasol	95.28
Accell	138.37
ZI 400	382.98
Control	457.26

Table 5 - Median Droplet Sizes

The ANCOVA analysis indicated that treatment significantly impacted the droplet size distribution of oil dispersed below the surface, as summarized by the concentration of droplets below 70 μm (ANCOVA, $F = 5.97$, $df = 4$, $p = 0.0125$). The stepwise procedure identified salinity as a necessary covariate to control for in the analysis. The full ANCOVA model explained 73.8% of the variation in the concentration of droplets below 70 μm , and dispersant treatment alone accounted for 69% of the total variation (Figure 9). Finasol and Corexit produced the highest concentration of droplets below the cutoff, while the control and ZI400 produced a far lower concentration of droplets below the cutoff. The difference between Finasol and the Control and ZI400 was statistically significant (Tukey HSD test, $p = 0.0217$ and $p = 0.0276$ respectively), and the difference between Corexit and the Control was nearly significant (Tukey HSD test, $p = 0.0878$).

June 2, 2016

	Sum of Squares	df	Mean Square	F value
Treatment	49.360	4	12.340	5.969
Salinity	3.073	1	3.072	1.486
Residual	18.606	9	2.067	

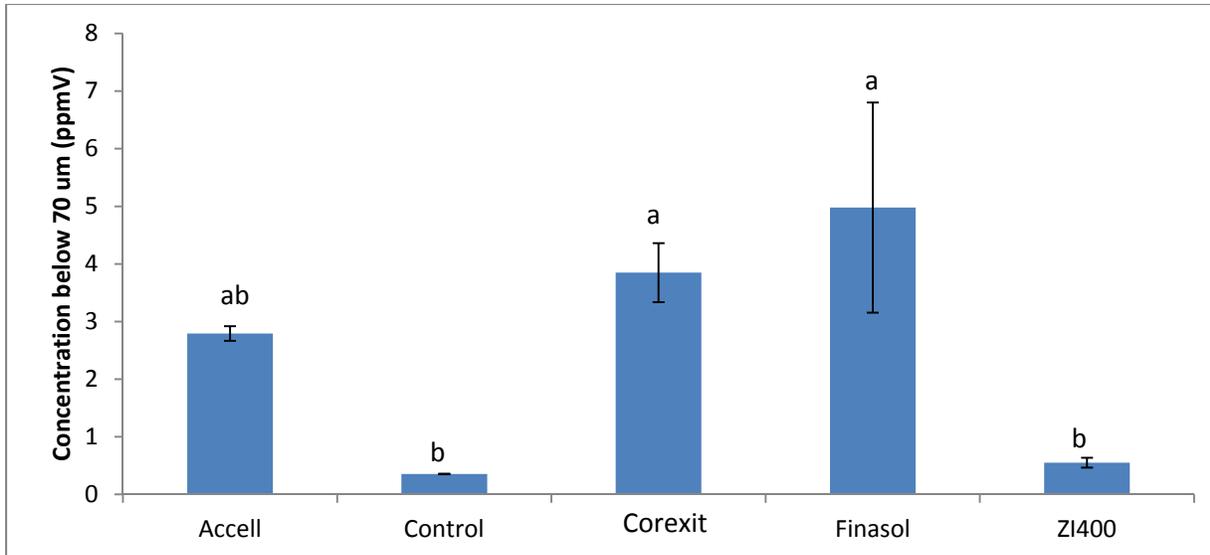


Figure 9 - The mean concentration of oil droplets less than 70 µm in size (ppm volume) as a function of dispersant treatment. Letters delineate statistically significant differences as measured with the Tukey HSD test ($n = 3$, $\alpha = 0.10$). Group “ab” is not significantly different from groups “a” or “b”.

The proportion of droplets less than 70 µm in size, as measured with the LISST (which only observes particles up to 500 µm in size), was also analyzed as a metric to estimate dispersant performance. The ANCOVA analysis indicated that the impact of dispersant treatment has a strongly significant influence on the proportion of oil droplets below the cutoff (ANCOVA, $F = 22.599$, $df = 4$, $p < 0.001$). The stepwise procedure identified viscosity and salinity as significant covariates to control for in the analysis (ANCOVA, $p = 0.006$ and $p = 0.014$, respectively). The full ANCOVA model explained 93% of the variation in the proportion of observed droplets below 70 µm, and dispersant treatment alone explained 74% of the variation in the full dataset. Corexit, Accell, and Finasol all produced significantly higher proportions of droplets below 70 µm in the Control (Tukey HSD test, $p < 0.001$, $p = 0.017$, and $p = 0.0138$ respectively) and then ZI400 (Tukey HSD test, $p < 0.001$, $p = 0.004$, and $p = 0.004$ respectively).

June 2, 2016

	Sum of Squares	df	Mean Square	F value
Treatment	.2217	4	.0554	22.599
Viscosity	.0338	1	.0338	13.790
Salinity	.0236	1	.0236	9.6454
Residual	.0196	8	.0024	

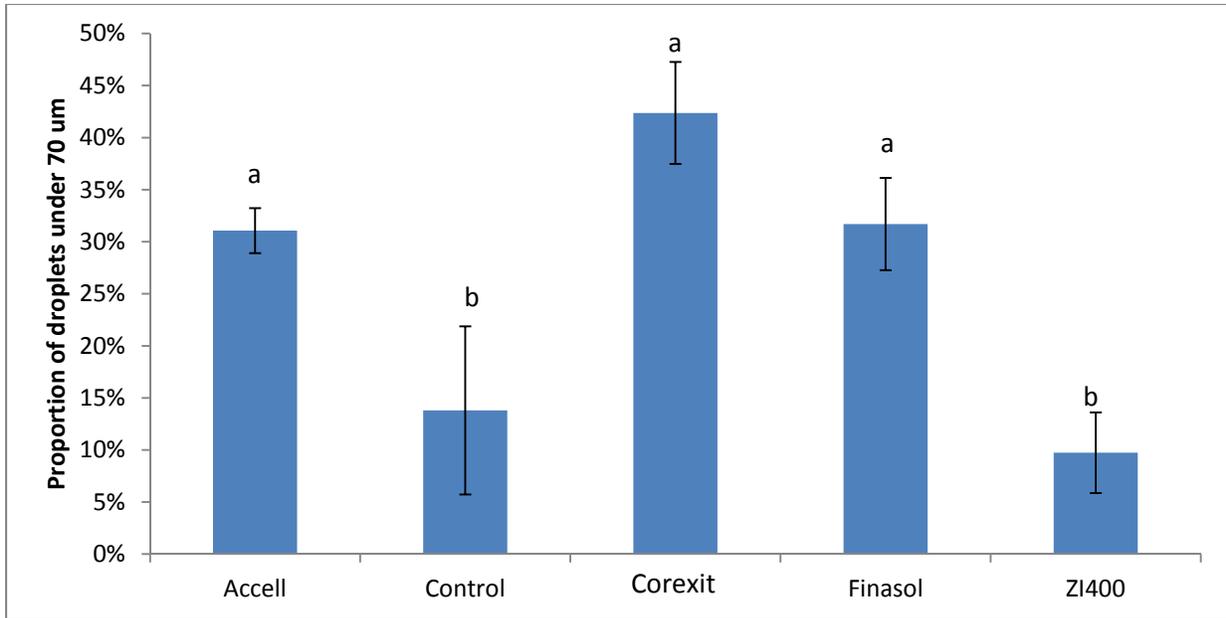


Figure 10 - The proportion of droplets measured by the LISST device below 70 μm in size. The LISST device only measures droplets between 2 and 500 μm in size, and will not capture the largest droplet sizes. Letters delineate statistically significant differences as measured with the Tukey HSD test (n = 3, α = 0.10). Group “ab” is not significantly different from groups “a” or “b”.

Discussion

General Observations about Each Product

Dispersit SPC1000 became problematic during equipment calibration for two reasons. First, while trying to determine the parameters necessary to produce an aerial spray-fan pattern (nozzle size and pressure) of the product in its neat undiluted form, the product would simply flow out of the nozzles as a solid stream. The other dispersants were able to produce this fan pattern when pumped between 40-60 psi using 80015 nozzles (80° spray pattern, 0.15gpm flow rate of water at 40psi), whereas SPC1000 was increased to 70psi without success using nozzles with calibrated flow rates of 0.15gpm, 0.39gpm, and 0.8gpm. Although the recommended application method includes aerial and boat spraying (U.S. Environmental Protection Agency, 2014), there is no specific guidance on how to spray this specific product in its neat form. The product received by the manufacturer was tested at Ohmsett's laboratory and was found to have a viscosity of 228cP at 20°C, rather than 144cP as reported on the NCP Product Schedule. After confirming with the manufacturer that the product is water soluble, SPC1000 was diluted with tap water at a product to water ratio of about 2:1 to reduce the viscosity to a level similar to the other products. The diluted form of SPC1000 was able to produce a fan pattern through the nozzles, but it was found that the closed loop pumping system being used would introduce air and turbulent flow to the products being tested. Unlike the other products, some of which produced foam on the surface of the product in the reservoir, SPC1000 created a thick foamy liquid by amalgamating air bubbles throughout the product. (See Figure 11) This foam was found to be very stable as air bubbles remained in the samples for a few days. This became an issue for testing because actual product dosing was not able to be calculated due to the unknown volume of air. Accell was chosen as a replacement for this product. A phone call to SL Ross later confirmed that Dispersit SPC1000 was tested at Ohmsett for the BSEE sponsored project "Comparison of Small-Scale Dispersant Testing Methods to Ohmsett: Effect of Dispersant Type and Oil Properties" (SL Ross Environmental Research Ltd, 2013). For their testing, SL Ross used the same pumping system and 80015 nozzles and 40psi with no reported issues. The air temperature for that program was 25-30°C. Possible explanations for the increased viscosity include improper storage, shelf life issues, viscosity changes due to the cold, or quality control issues.

June 2, 2016



Figure 11 - The beaker on the left shows a sample of SPC1000 after it had circulated through the dispersant pumping system. The beaker on the right is the product in its neat form from the manufacturer's container.

While circulating Corexit through the Ohmsett pumping system, it produced no foam and did not freeze in the system. Visually, the resulting oil droplets dispersed deep into the tank and the deepest instrument recorded a fair amount of data. The amount of oil that resurfaced after the waves were turned off was minimal compared to the other products.

Finasol is slightly more viscous than the Corexit and required about 5% more pressure to spray through the same nozzles, otherwise this product behaved similar to Corexit. There was very good dispersion and little resurfacing oil.

Accell produced a small amount of surface foaming in the reservoir, but this quickly dissipated and did not affect the product. Based on visual observation the product produced a good dispersion, but the instrument readings indicate the droplets appear to remain closer to the water's surface than the plumes created by Corexit or Finasol. During collection of the surface oil, there was a large amount of café-latte colored froth floating on the water surface as shown in Figure 12. This froth continued to resurface throughout the test program and seemed to increase after each test conducted with Accell. A sample of the froth showed that it contained very little oil by volume. This was not further investigated so it cannot be definitively associated with Accell; however it is recommended that any future work with this product at Ohmsett is observed mindfully for surface froth after dispersion in an effort to determine if the product causes it or if it was a combination of other impinging factors present during this test series.



Figure 12 - An example of the foam that appeared after the introduction of Accell to the Ohmsett tank.

ZI 400 created a large amount of foam on the surface of the liquid in the reservoir. This foam was very stable and continued to grow without intervention. This foam did not affect the liquid product in the reservoir or the performance of the product. Figure 13 shows the difference in behavior of ZI 400 and Finasol while recirculating in the reservoir and pumping system. The dispersion created by ZI 400 appeared to be much more superficial. The oil would break up and spread along the surface, but did not appear to disperse deep into the water. Also, the lower LISST recorded a significant reduction in concentration data indicating the oil droplets did not mix into the water column to the level of that LISST. There was also much more oil resurfacing after the test was completed as compared to the other products. Additionally, although tests were conducted above the manufacturer's stated freezing point of the product, the product in the nozzles became frozen. Twice, this resulted in the nozzles becoming clogged and the system having to be thawed to remove the product.



Figure 13 - Comparison of ZI 400 and Finasol while recirculating through the pump and reservoir.

The control tests demonstrated higher than expected natural dispersion. At the same time, the LISST data shows that the created plume was made up of very large droplets. These results are captured in the same way as tests which included dispersant application and are reported as such.

Conclusions

The goal of this test program was to conduct comparative dispersant effectiveness testing at the Ohmsett facility in an effort to capture both qualitative and quantitative data for multiple commercially available dispersant products. Based on the metrics captured, the following conclusions can be made:

Corexit and Finasol produced the highest average DE, which was significantly higher than the ZI 400 treatment ($p=0.0438$ and $p=0.0476$ respectively). While these did not perform at a level statistically significant from the Control treatment, the improvement in performance over the control was strong. Corexit increased DE from 49.8 to 72.7, an improvement of 46% ($p=0.0908$), and Finasol increased DE from 49.8 to 72.2, and improvement of 45% ($p=0.0987$). Accell, Corexit and Finasol all produced significantly greater proportion of droplets under $70\ \mu\text{m}$ compared to the Control (Accell: $p=0.0169$, Corexit: $p=0.0007$, Finasol: $p=0.0138$) and compared to ZI 400 (Accell: $p=0.0049$, Corexit: $p=0.0003$, Finasol: $p=0.0041$).

Finasol OSR 52 and Corexit EC9500A demonstrated the best performance of the group of dispersants. Both dispersants were among the easiest to work with. Finasol and Corexit did not entrain any air while being pumped and maintained consistency throughout the tests. Accell

did entrain some air, but it is believed that this did not impact the test since the foam remained on the surface of the product in the reservoir and was not pulled into the pumping system.

Recommendations

During the test program, issues came to light that may require additional testing. In general, it is recommended that dispersants, which are listed on the National Contingency Plan Product Schedule, be tested on a variety of oils in large scale tests such as those conducted at Ohmsett. It would be beneficial to conduct similar comparative testing of the dispersants tested here during warm weather conditions on similar oil. This could be important for ZI 400 specifically, which not only performed poorly, but also was complicated to handle in a cold environment.

Additionally, further investigation is recommended to explain the cause of the brown froth that appeared on top of Ohmsett's water surface throughout the testing. It has been documented to have started after the introduction of Accell Clean DWD into the system, but in no way can the two be linked. Accell has been tested at Ohmsett before and none of the individuals involved with that test recall any issues. It is possible that a combination of the various dispersants being present at once may have been the root cause.

Although Dispersit SPC1000 was not able to be included in this test program, the team's experiences with the product provided additional recommendations. The sample provided by the manufacturer was significantly more viscous than the other products, as well as what had been reported for use on the National Contingency Plan (NCP) Product Schedule. Dispersit's manufacturer, US Poly Chemical Corp, suggested that we may have received products from an older batch. The technical bulletin for Dispersit on the NCP states that the product has an unlimited shelf life. This suggestion leads to a few additional recommendations. Samples of different ages from a single dispersant product should be tested to determine shelf life. This can be accomplished at the lab scale and should include both effectiveness testing as well as changes in physical properties. Claims made to the EPA regarding these products should be independently verified and be subject to recurring testing for validity. Also, the information reported to the EPA should be standardized so that the technical bulletins for all products provide consistent information. As an example, the viscosities for the products involved with this test program were tested by their manufactures at different temperatures and are reported with different units. It is recommended that a standard test and reporting format be required.

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Appendix A – Test Procedure

Each test was conducted following the below procedure.

1. The test area of approximately 160 by 20 meters was established in the Ohmsett tank by placing a length of boom across the north and south ends of the tank.
2. Prior to each test, the test area was prepared by using water spray from the fire monitors to push any surface oil and residual dispersant out of the test area.
3. The new test oil and dispersant were loaded into their respective supply tanks on the main bridge deck.
4. The dispersants were circulated through the pumping system until they were heated to approximately 20°C.
5. The main bridge was positioned in the southern third of the tank.
6. The wave paddle was started with a six-inch stroke and at a rate of 33^{1/3} strokes per minute. Waves were allowed to develop to a stage just prior to the formation of breaking waves. Depending on wind conditions, the wave paddles were adjusted to maintain the creation of a breaking wave at a rate of every 4th to 6th wave.
7. The bridge was moved south at one knot. The oil was pumped at 20 gallons per minute onto the surface through the discharge manifold mounted on the south side of the bridge.
8. After the bridge passed over the oil, the dispersant was applied onto the oil slick from the spray bar system mounted on the north side of the bridge. This was accomplished in the same pass as the oil discharge.
9. Once breaking waves were present in the area of the oil, measurement passes were made. Two LISST-100x devices were positioned roughly 1 meter below the water's surface and 1 meter from the bottom of the tank.
10. A minimum of three passes were made down the tank during the 20 minute mixing



Figure A1 - Oil Manifold on South side of Bridge



Figure A2 - Dispersant spray bar on North side of bridge

Appendix A – Test Procedure

period with instrumentation towed through the water to measure oil concentration and oil droplet sizes. If time allowed, a fourth pass was made.

11. The waves were generated for 20 minutes, after which the wave paddle was stopped.
12. After the last wave passed the bridge, water spray from the bridge fire monitors was used to sweep any surface oil remaining on the water surface at the end of the test to a common collection area at one corner of the containment boom.
13. Each test was videotaped for visual reference.
14. The oil was then removed from the water surface using a double-diaphragm pump and suction wand and placed in a collection drum. A small quantity of emulsion breaker was thoroughly mixed into the contents of the drum and the mixture was allowed to settle for a few days to accommodate the oil/water separation. The free water present was decanted from drums.



Figure A3 - Surface oil is collected in drums

15. The remaining oil and water were well mixed and a sample was taken for water content (“Recovered oil Water”) and physical property determination.
16. The quantity of liquid in the drum was measured (“Volume of Emulsion Recovered”) and then adjusted by subtracting the amount of water in the oil as determined by a water content analysis. This final volume is the actual volume of oil recovered from the surface (“Recovered Oil”).

Appendix B - Test Conditions Tables

Test	Date	Description	Air Temp	Wind Direction	Wind Speed	Salinity	Interfacial Tension	Tank Temp (@4')	Water Surface Temp	Oil Viscosity
			<i>C</i>	<i>Degrees</i>	<i>m/s</i>	<i>ppt</i>	<i>dynes/cm</i>	<i>C</i>	<i>C</i>	<i>cP</i>
1	2/2/2014	Control	-4.6	40.0	2.7	26.7	33.6	-0.8	-3.3	1241
2	2/2/2014	Corexit	-4.9	96.0	3.1			-0.6	-2.2	1096
3	2/17/2014	Finasol	0.1	330.0	2.7	27.2	27.0	-0.6	-2.8	1173
4	2/18/2014	ZI400	1.4	85.0	2.5	27.5	25.8	-0.8	-1.1	968
5	2/18/2014	Corexit	5.0	330.0	3.1			-0.2	-3.1	1214
6	2/19/2014	Accell	5.6	132.0	5.4			-0.1	-1.1	968
7	2/19/2014	Finasol	5.5	330.0	0.9			0.5	-0.5	905
8	2/20/2014	Control	8.7	293.0	1.6	27.5	23.9	0.8	-1.0	957
9	2/20/2014	Corexit	7.4	70.0	2.7			1.3	-0.8	936
10	2/21/2014	Accell	3.1	75.0	5.8	27.0	20.9	1.2	0.0	855
11	2/26/2014	ZI400	-2.8	235.0	2.2	28.4	19.4	-0.3	-2.5	1134
12	2/26/2014	Finasol	0.2	270.0	7.8			0.3	-2.2	1096
13	2/27/2014	Accell	-3.7	190.0	4.0	28.2	18.6	-0.7	-2.2	1096
14	2/27/2014	Control	-0.1	218.0	5.4			-0.3	-2.2	1096
15	2/28/2014	ZI400	-3.7	330.0	3.8	28.2	25.9	-1.2	-3.1	1214

Summary table of weather and tank conditions for each table

- Oil viscosity for each test was calculated using the water surface temperature.
- Water salinity and interfacial tension was taken each day prior to testing. Samples were mistakenly not taken on 2/19/2014.

Appendix B - Test Conditions Tables

Test	Date	Description	Oil Viscosity	Volume of Source Oil Distributed	Source Oil Water	Volume of Oil (Corrected for Water Content)	Oil Emulsion Recovered	Recovered Oil Water	Final Volume of Recovered Oil	Volume of Oil Dispersed	Dispersant Effectiveness
			cP	L	%	L	L	%	L	L	%
1	2/2/2014	Control	1241	49.6	9%	45.1	42.4	60%	18.2	27.0	59.7
2	2/2/2014	Corexit	1096	66.2	9%	60.3	31.0	34%	20.5	39.8	66.0
3	2/17/2014	Finasol	1173	49.6	9%	45.1	24.4	61%	9.5	35.6	78.9
4	2/18/2014	ZI400	968	54.5	9%	49.6	35.8	33%	24.0	25.6	51.6
5	2/18/2014	Corexit	1214	28.0	9%	25.5	12.9	52%	6.2	19.3	75.8
6	2/19/2014	Accell	968	74.2	9%	67.5	53.0	50%	26.5	41.0	60.8
7	2/19/2014	Finasol	905	56.4	9%	51.3	30.9	47%	16.4	34.9	68.1
8	2/20/2014	Control	957	55.3	9%	50.3	53.8	50%	26.9	23.4	46.6
9	2/20/2014	Corexit	936	59.1	9%	53.7	24.4	48%	12.7	41.0	76.4
10	2/21/2014	Accell	855	57.2	9%	52.0	65.1	43%	37.1	14.9	28.7
11	2/26/2014	ZI400	1134	56.4	9%	51.3	45.4	28%	32.7	18.6	36.3
12	2/26/2014	Finasol	1096	55.3	9%	50.3	18.5	18%	15.2	35.1	69.8
13	2/27/2014	Accell	1096	51.1	9%	46.5	27.6	40%	16.6	29.9	64.3
14	2/27/2014	Control	1096	52.2	9%	47.5	51.1	47%	27.1	20.5	43.0
15	2/28/2014	ZI400	1214	55.3	9%	50.3	51.1	50%	25.6	24.7	49.2

Summary table of dispersant effectiveness relevant information

- The test oil was found to contain 9% water. All dispersant effectiveness calculations were made using the volume of oil once corrected for water content.

Appendix B - Test Conditions Tables

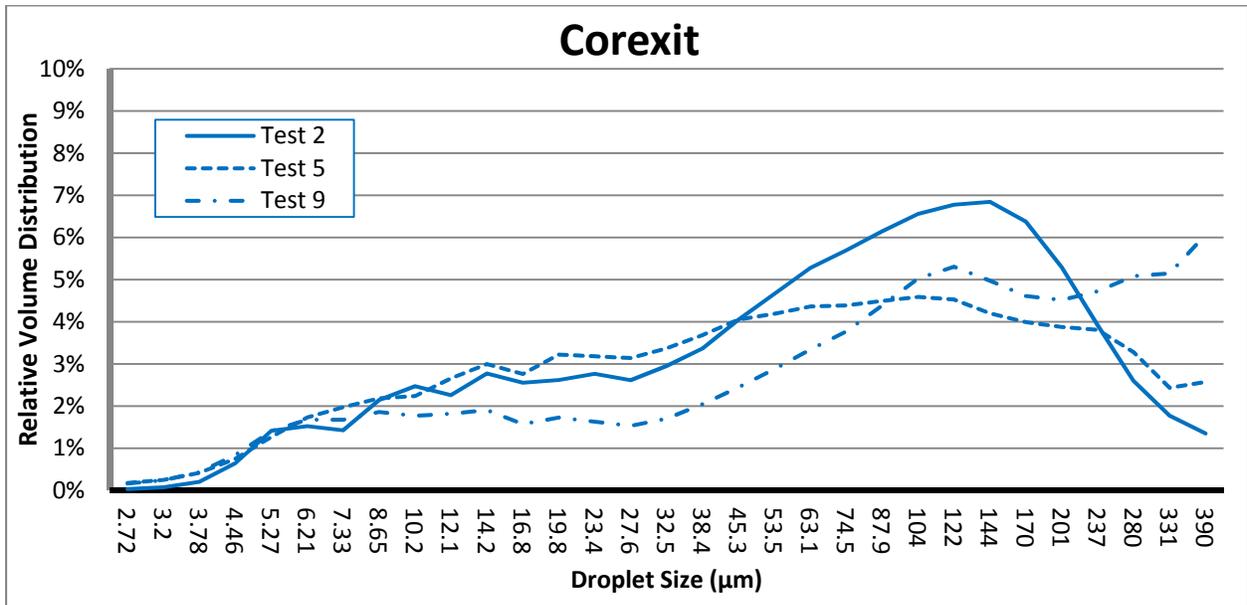
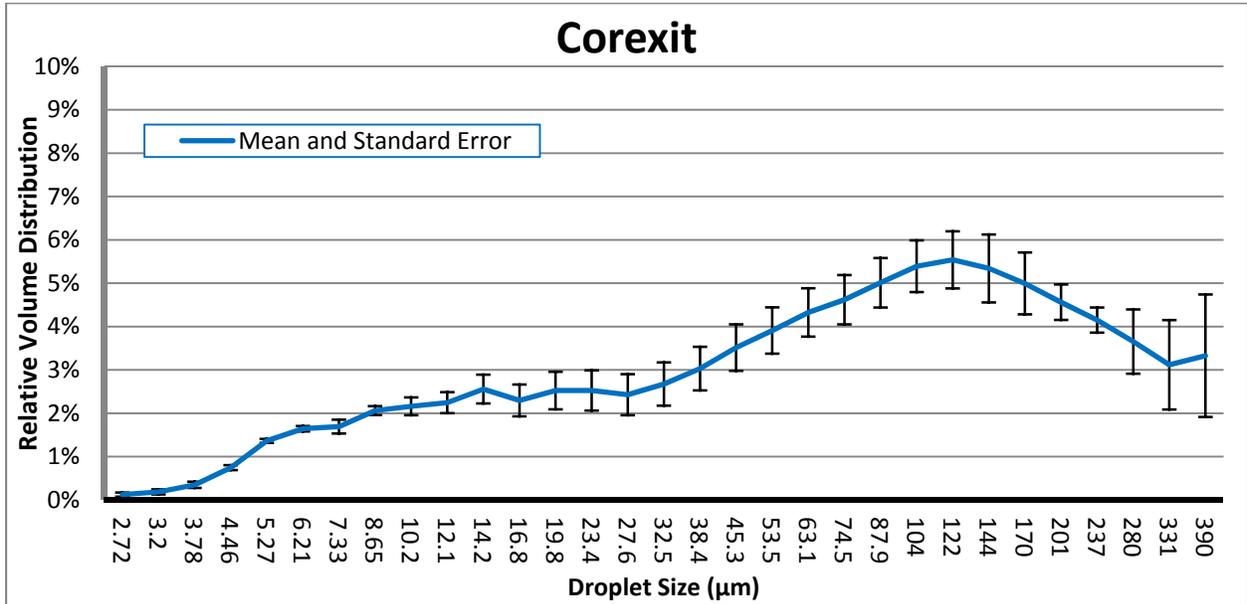
Test	Date	Description	Volume of Oil (Corrected for Water Content)		Slick Width <i>m</i>	Slick Length <i>m</i>	Slick Area <i>m</i> ²	Volume of Dispersant <i>L</i>	Time of Dispersant Application <i>minutes</i>	Dispersant Effective Dosage <i>L/m</i> ²	Volume of Dispersant Applied to Slick <i>L</i>	DOR	
			<i>L</i>	<i>m</i>								<i>decimal</i>	<i>ratio</i>
1	2/2/2014	Control	45.1	2.3	19.5	44.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	2/2/2014	Corexit	60.3	2.6	22.9	59.9	3.3	1.0	0.06	0.9	0.02	1:50	
3	2/17/2014	Finasol	45.1	2.7	23.5	62.6	3.5	0.9	0.06	1.1	0.03	1:33	
4	2/18/2014	ZI400	49.6	3.3	31.1	102.3	4.9	1.0	0.05	2.4	0.05	1:20	
5	2/18/2014	Corexit	25.5	3.9	23.8	92.8	5.5	1.1	0.06	2.3	0.09	1:11	
6	2/19/2014	Accell	67.5	3.3	23.2	75.5	4.1	1.0	0.05	1.5	0.02	1:50	
7	2/19/2014	Finasol	51.3	3.9	23.8	92.8	3.5	0.9	0.04	1.7	0.03	1:33	
8	2/20/2014	Control	50.3	3.0	23.2	70.6	N/A	N/A	N/A	N/A	N/A	N/A	
9	2/20/2014	Corexit	53.7	3.7	20.1	75.4	3.9	0.9	0.05	1.5	0.03	1:33	
10	2/21/2014	Accell	52.0	3.7	23.8	89.1	3.2	1.0	0.04	1.4	0.03	1:33	
11	2/26/2014	ZI400	51.3	4.4	24.1	105.0	N/A	N/A	N/A	N/A	N/A	N/A	
12	2/26/2014	Finasol	50.3	3.3	23.5	77.3	4.1	1.0	0.05	1.6	0.03	1:33	
13	2/27/2014	Accell	46.5	3.9	24.4	95.1	3.5	0.9	0.04	1.9	0.04	1:25	
14	2/27/2014	Control	47.5	3.9	23.8	92.8	N/A	N/A	N/A	N/A	N/A	N/A	
15	2/28/2014	ZI400	50.3	3.7	26.2	95.9	4.1	1.1	0.04	1.6	0.03	1:33	

Summary table of dispersant to oil ration (DOR) relevant information

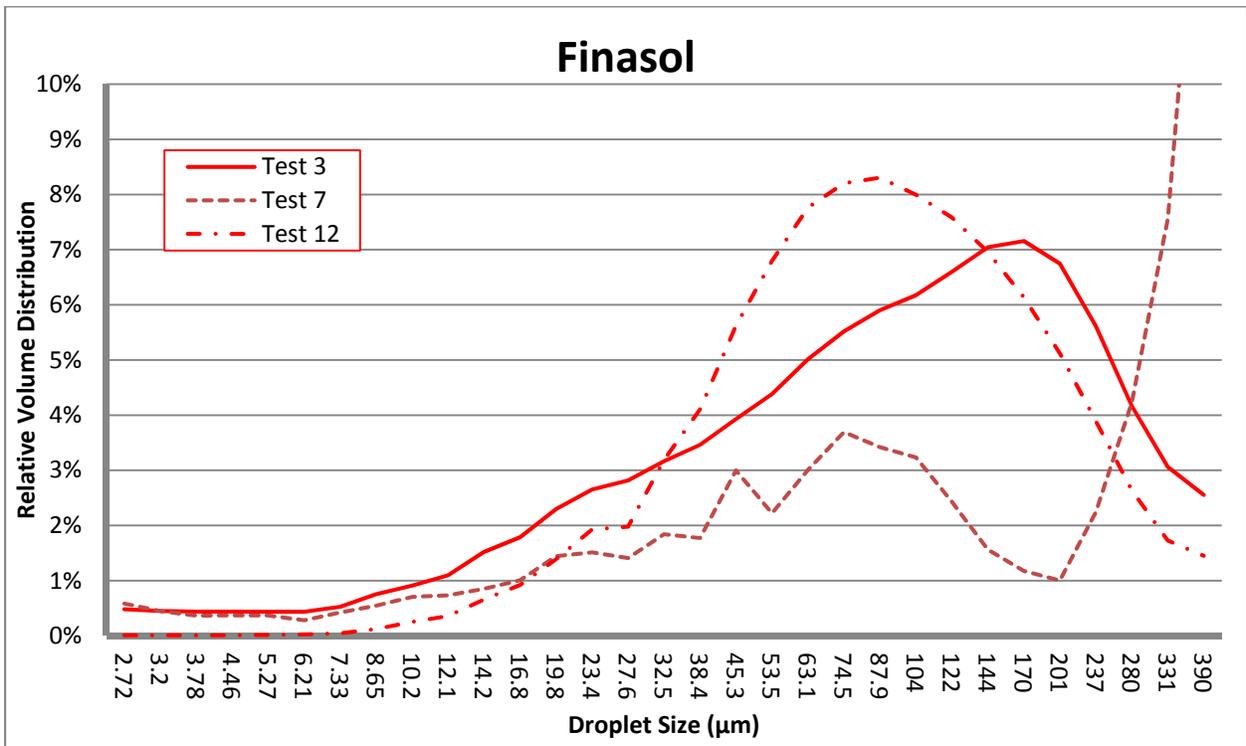
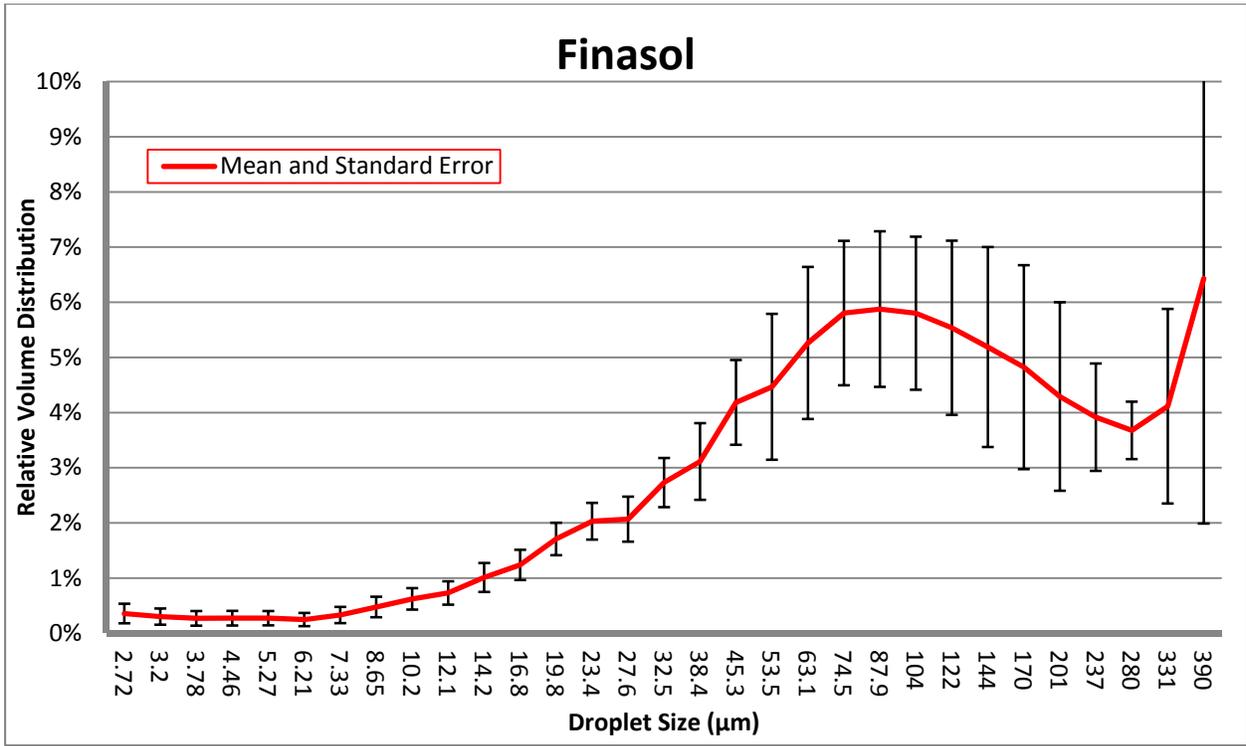
- Test 11 – Dispersant level was not reported prior to testing. No dispersant dosage data is available.
- Dispersant effective dosage is the dosage of dispersant to actually be applied to the slick.
- All DOR calculations were made using the volume of oil once corrected for water content.

Appendix C – Distribution Curves by Product

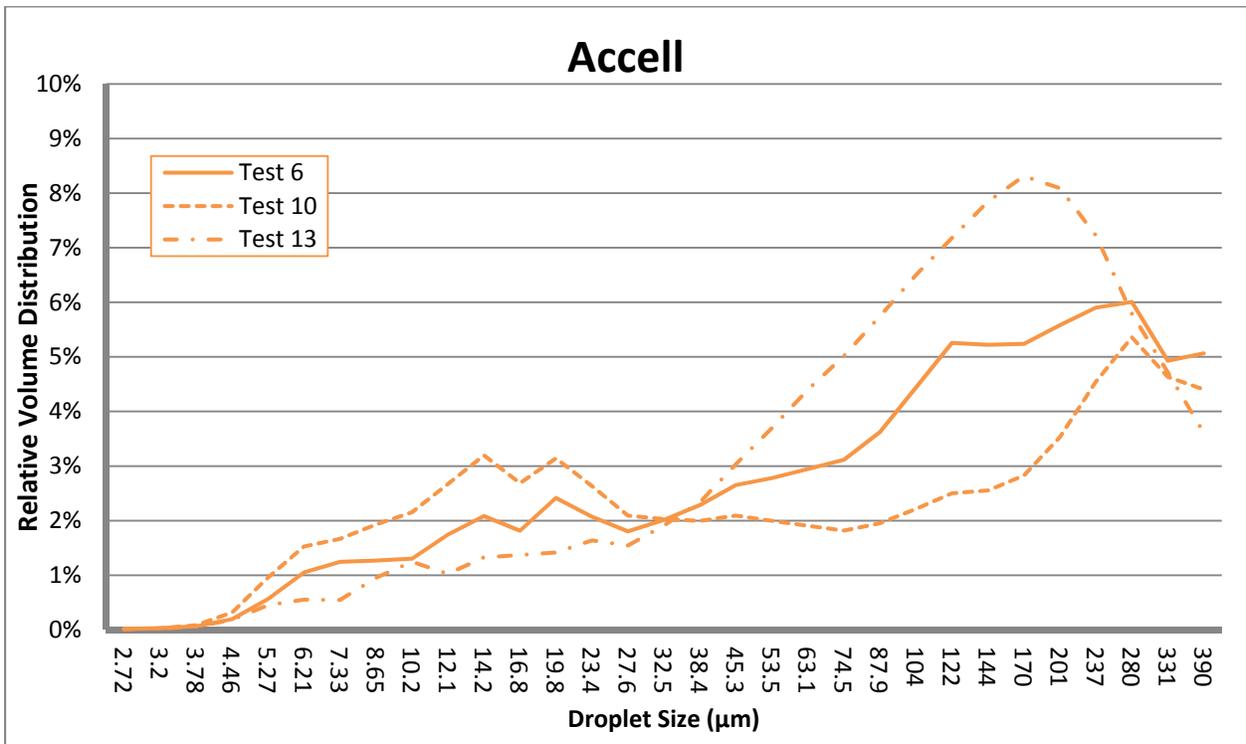
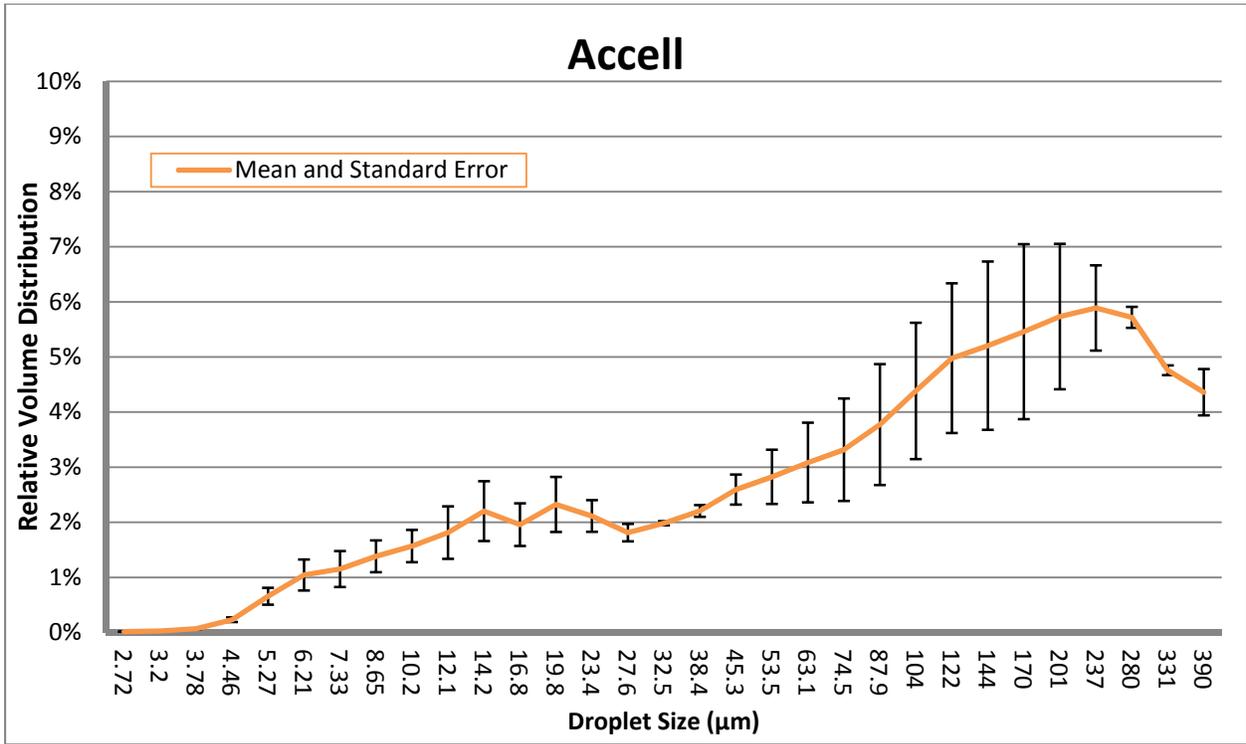
The plots that follow represent the droplet size distributions for each dispersant product as well as the control runs. For each treatment, there is a figure which shows the mean and standard error for the replicate tests, as well as a figure which has the data from each individual test.



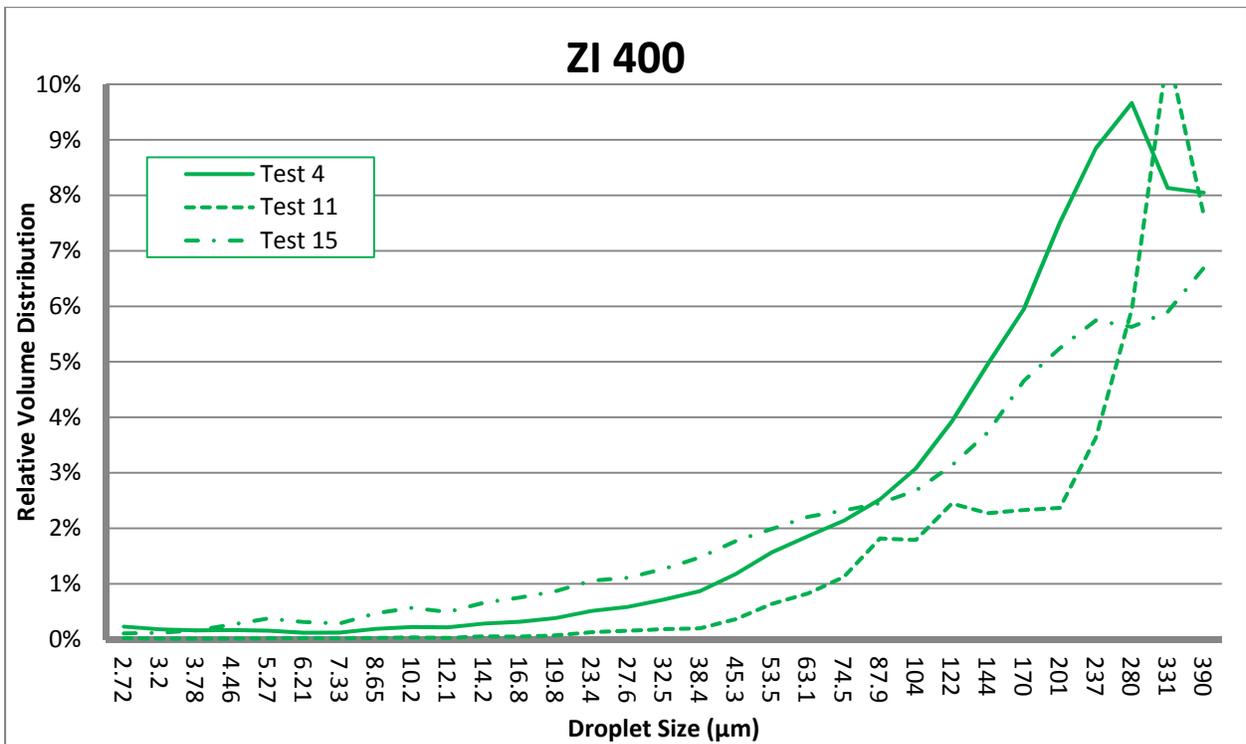
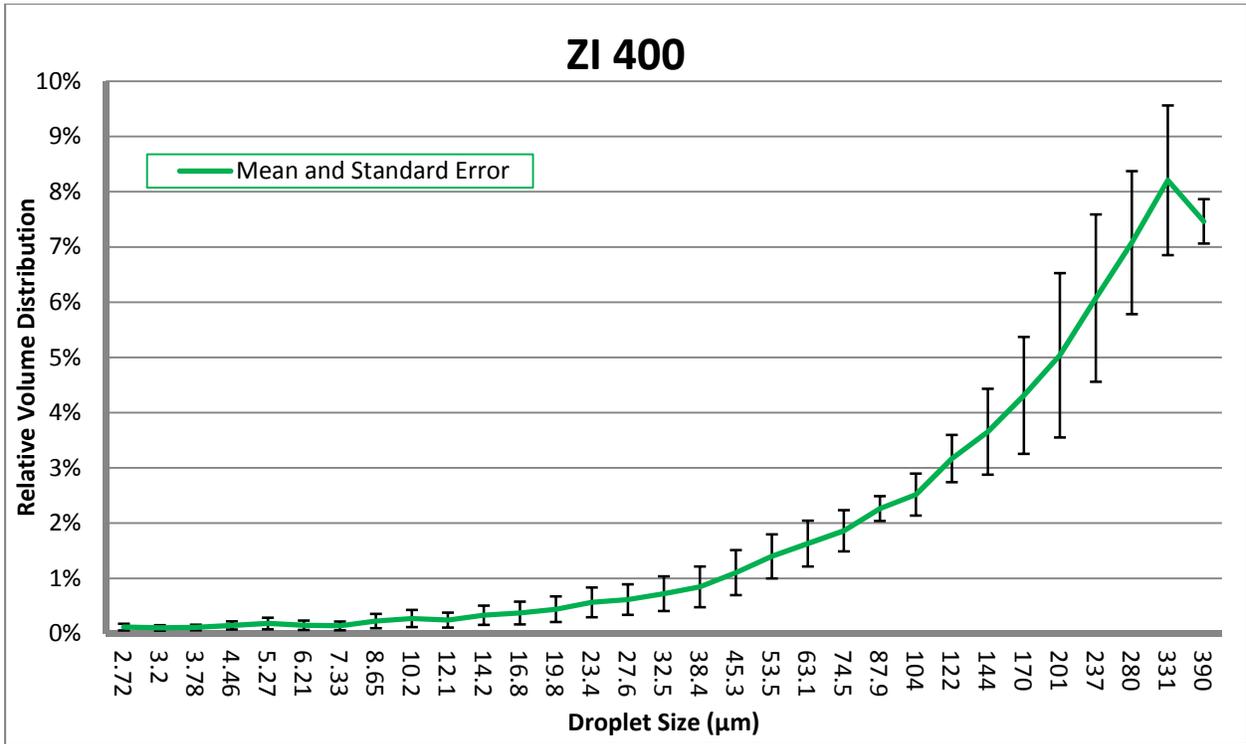
Appendix C – Distribution Curves by Product



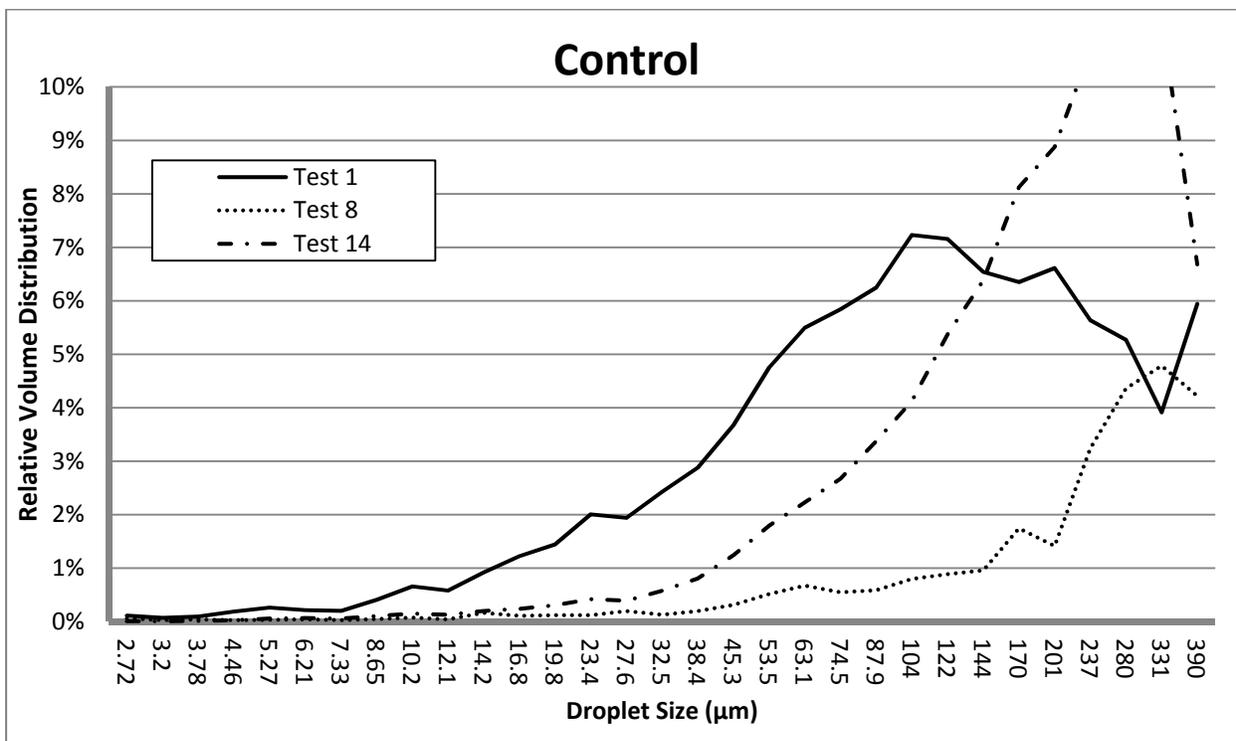
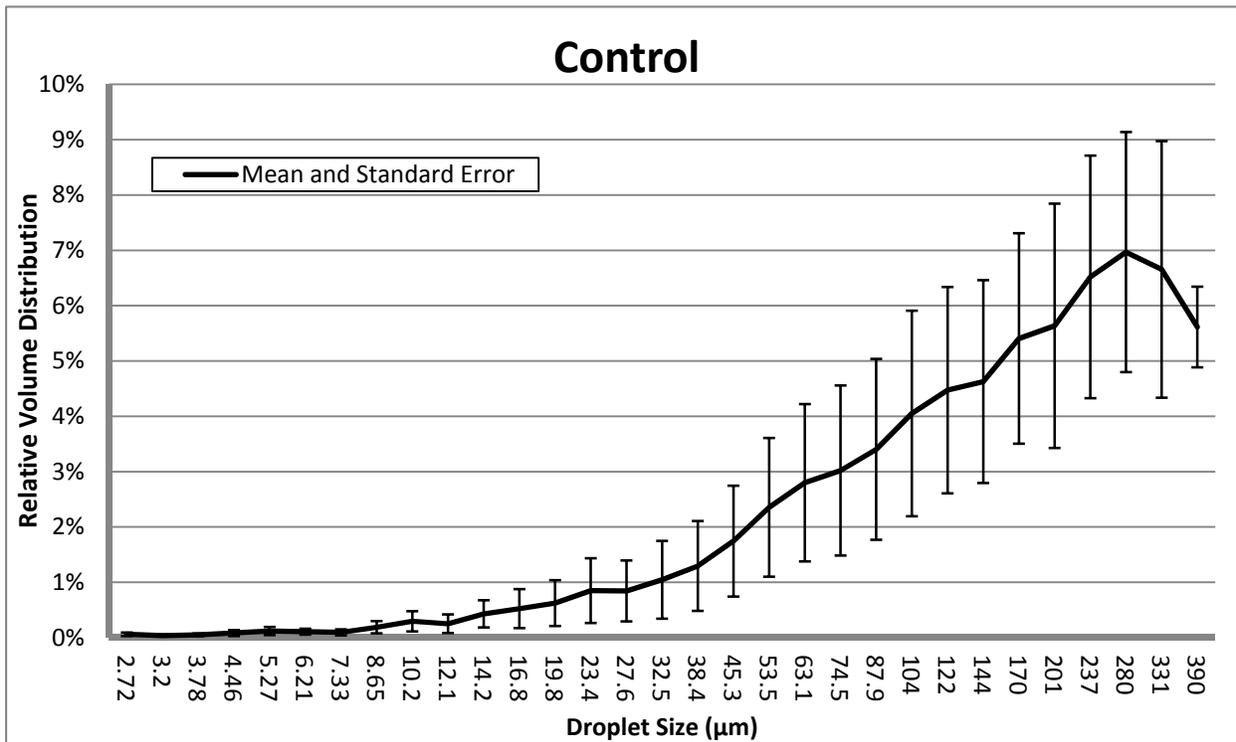
Appendix C – Distribution Curves by Product



Appendix C – Distribution Curves by Product

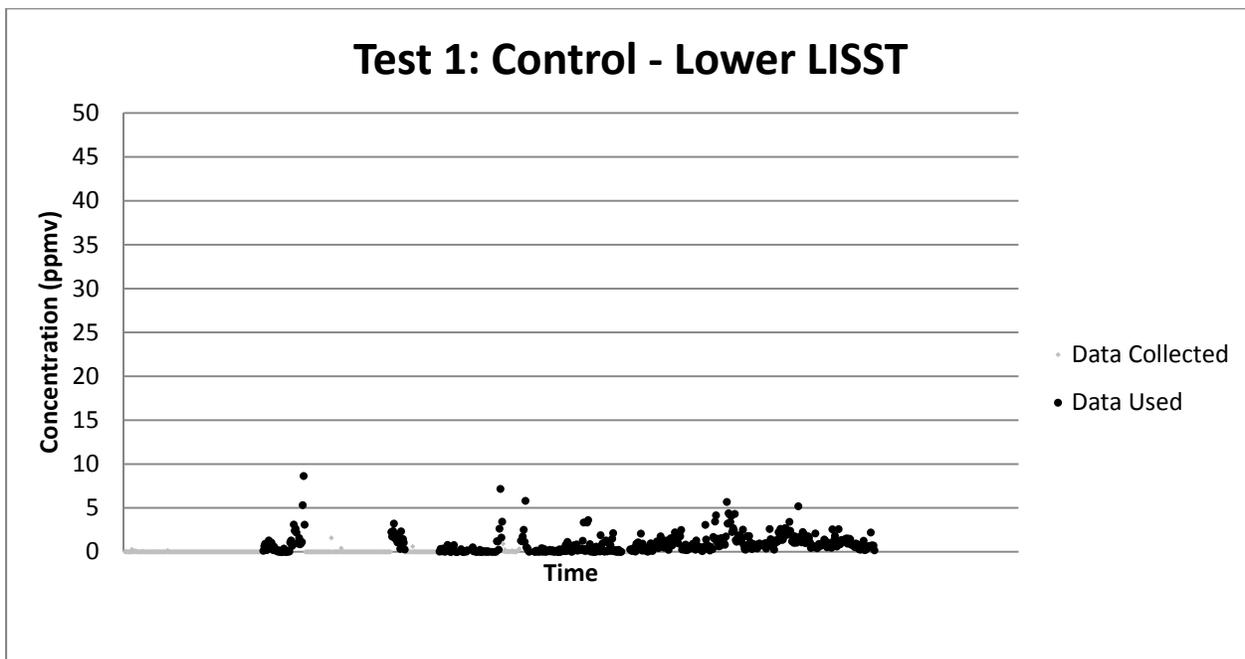
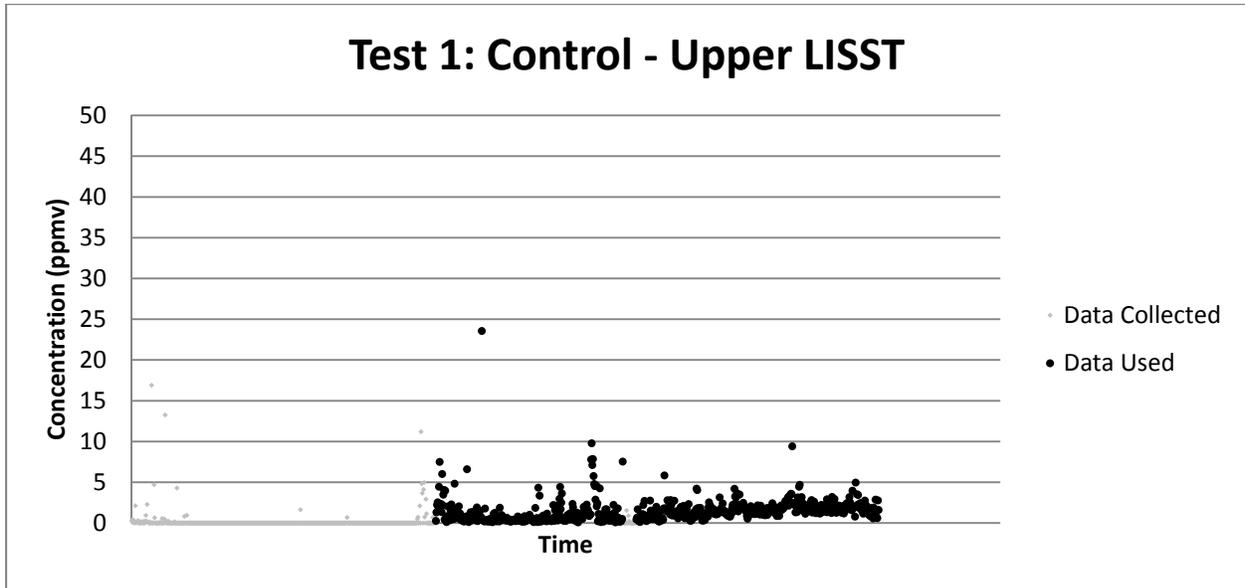


Appendix C – Distribution Curves by Product

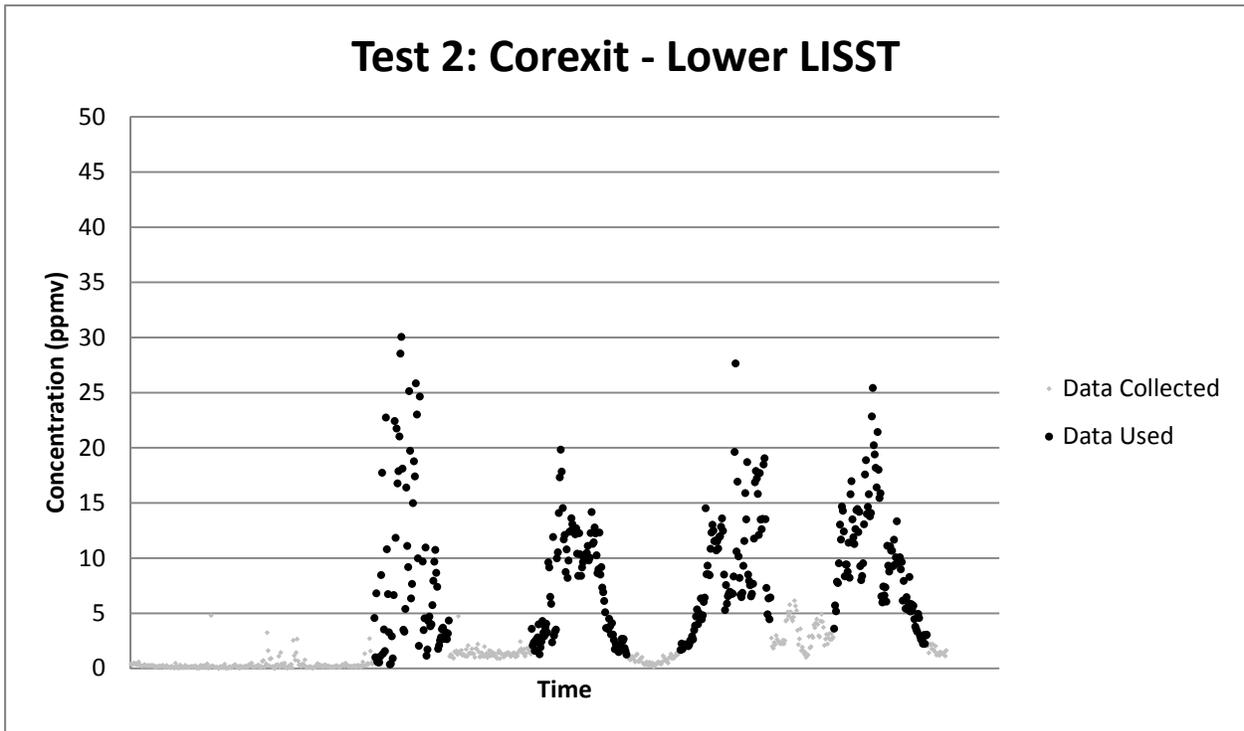
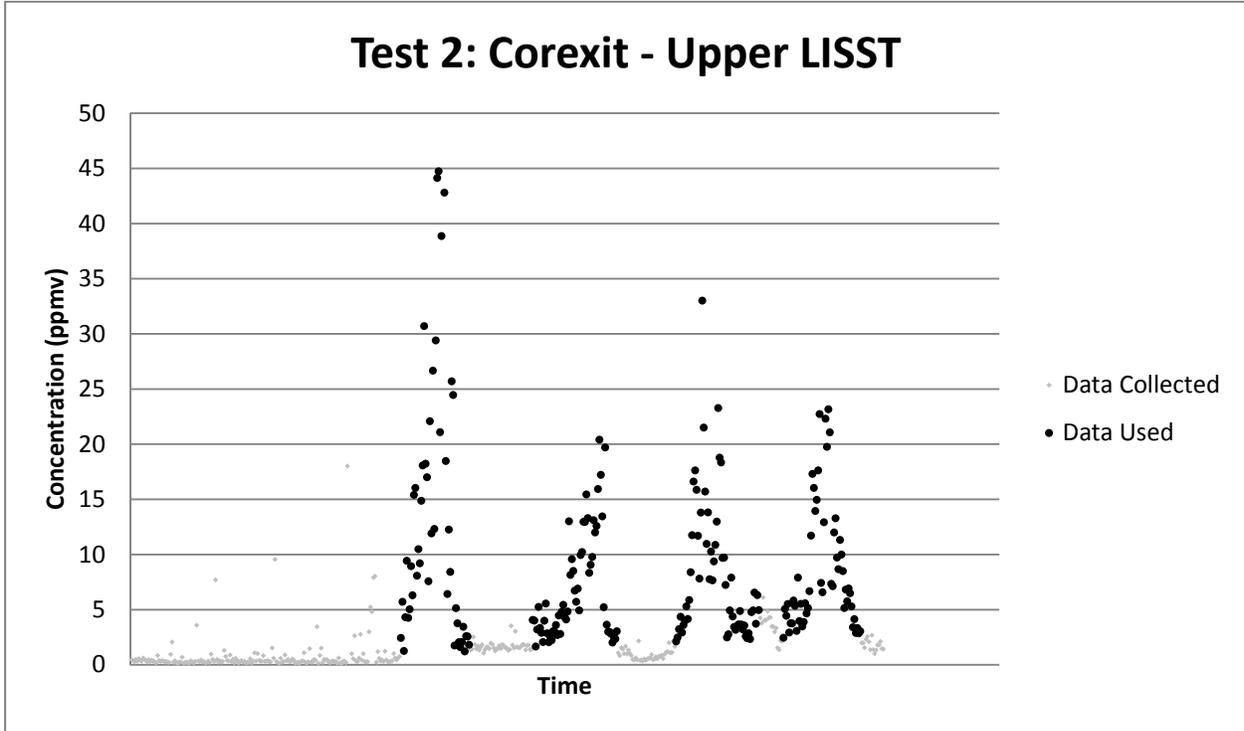


Appendix D – Selected Data Points

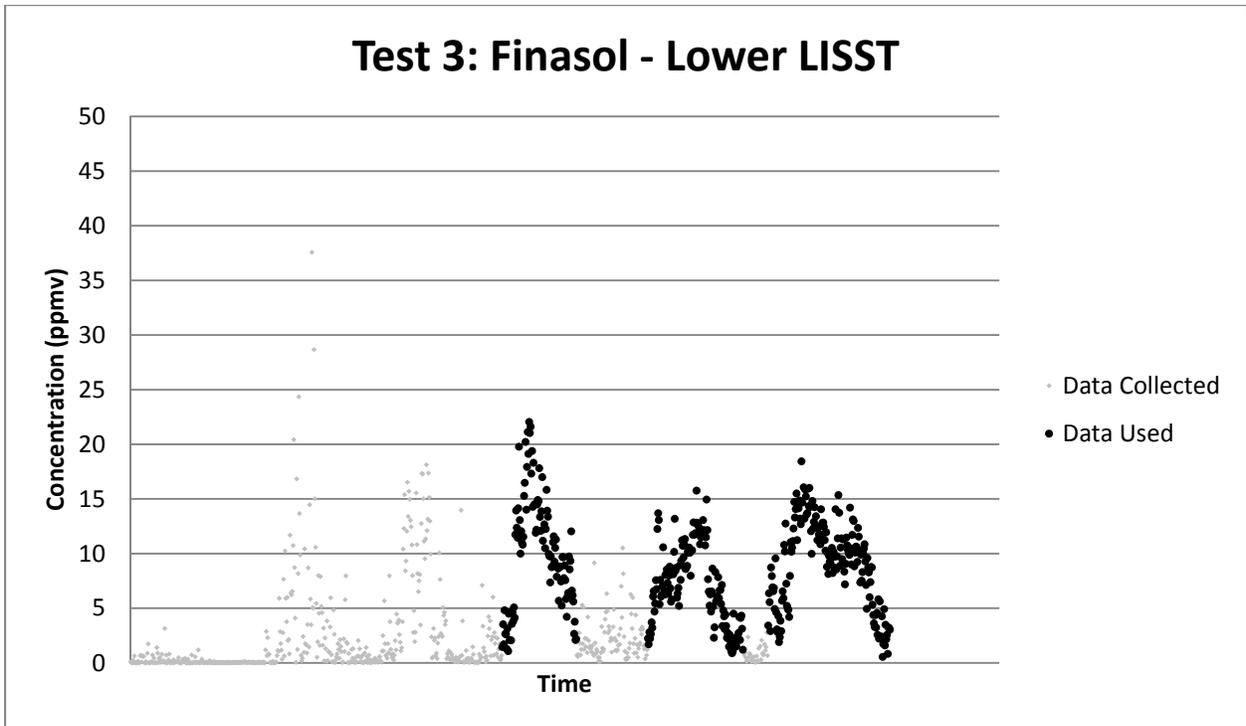
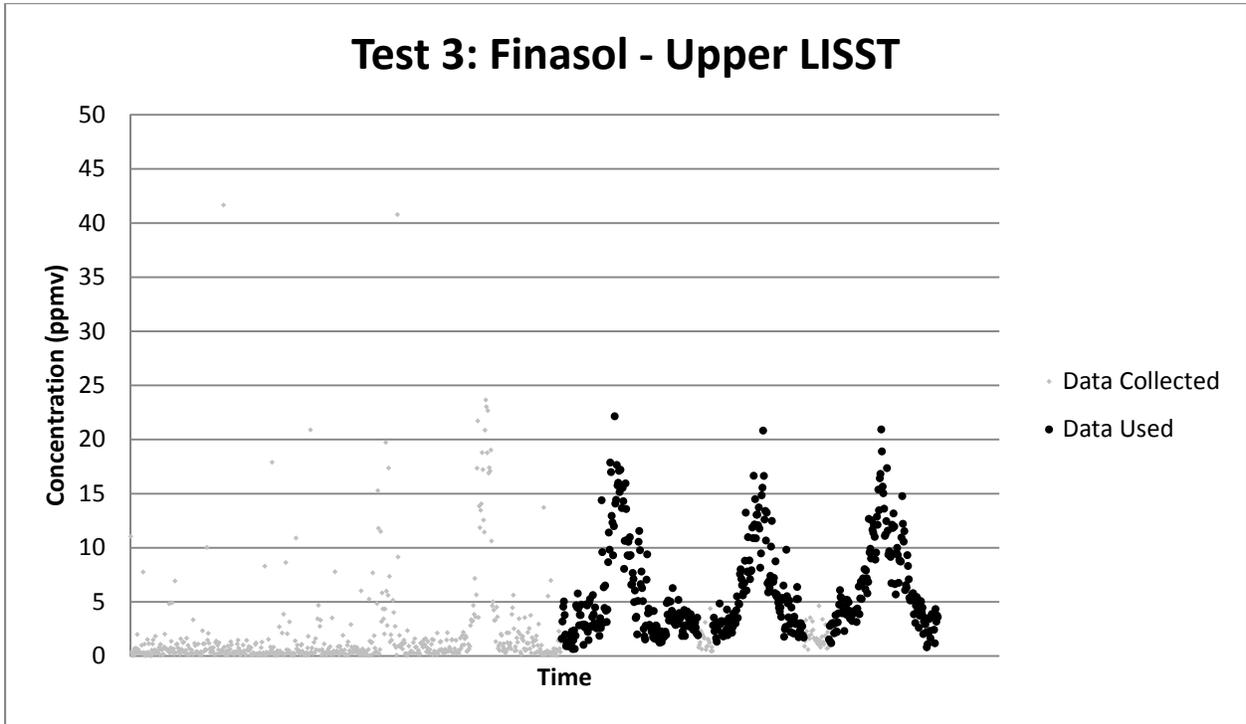
Concentration in the figures below is the total volume of oil droplets within the range of detectability of the LISST (2.5-500 μ m) captured during any single sample and represented as parts per million by volume. The total concentration of each data sample was used in conjunction with observation notes, video, and photos to separate plume data from background data. The increasing concentration for the lower LISST in test 8 was believed to be sensor creep or fouling. The LISST was removed after this test and cleaned. A clear pattern was still identifiable to capture data points with relevant droplet size distributions.



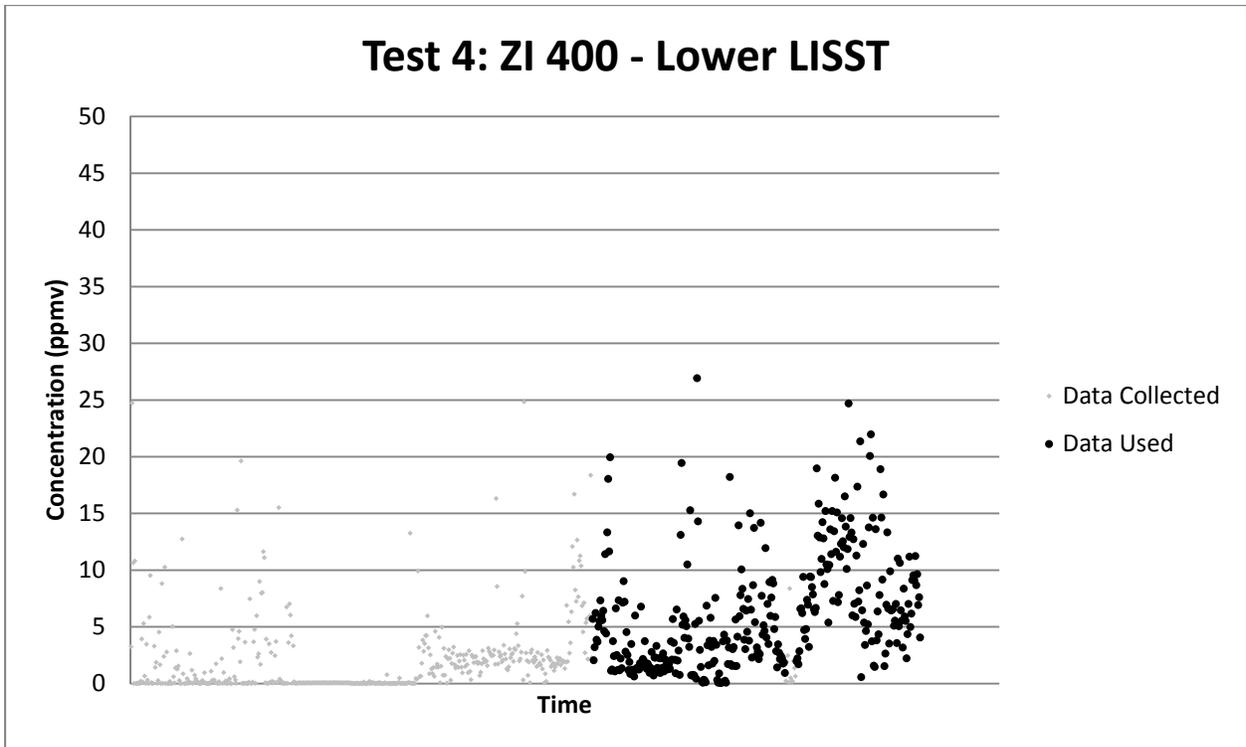
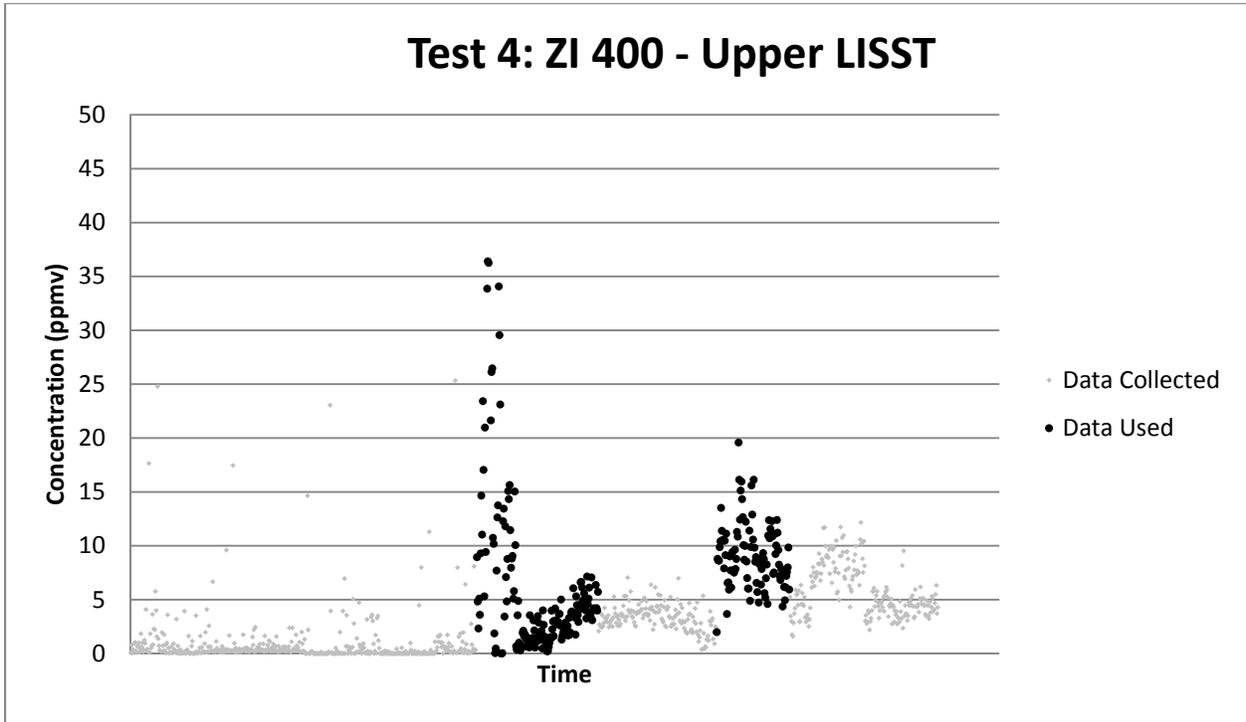
Appendix D – Selected Data Points



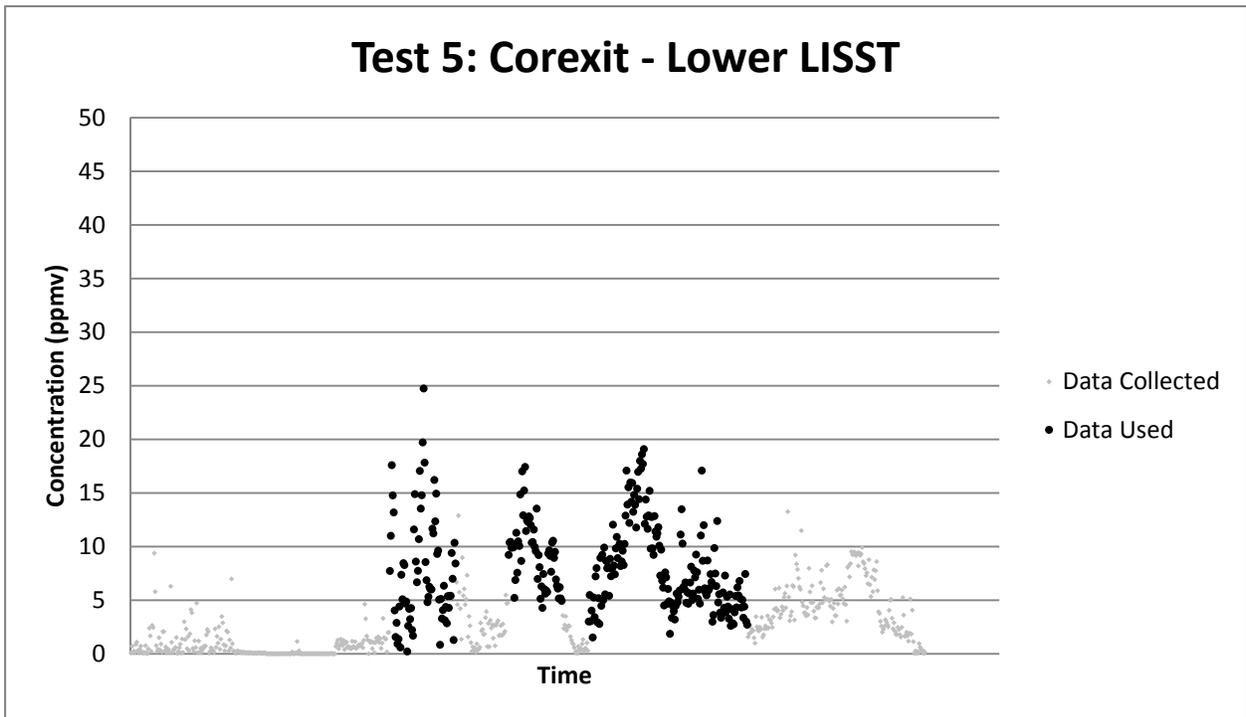
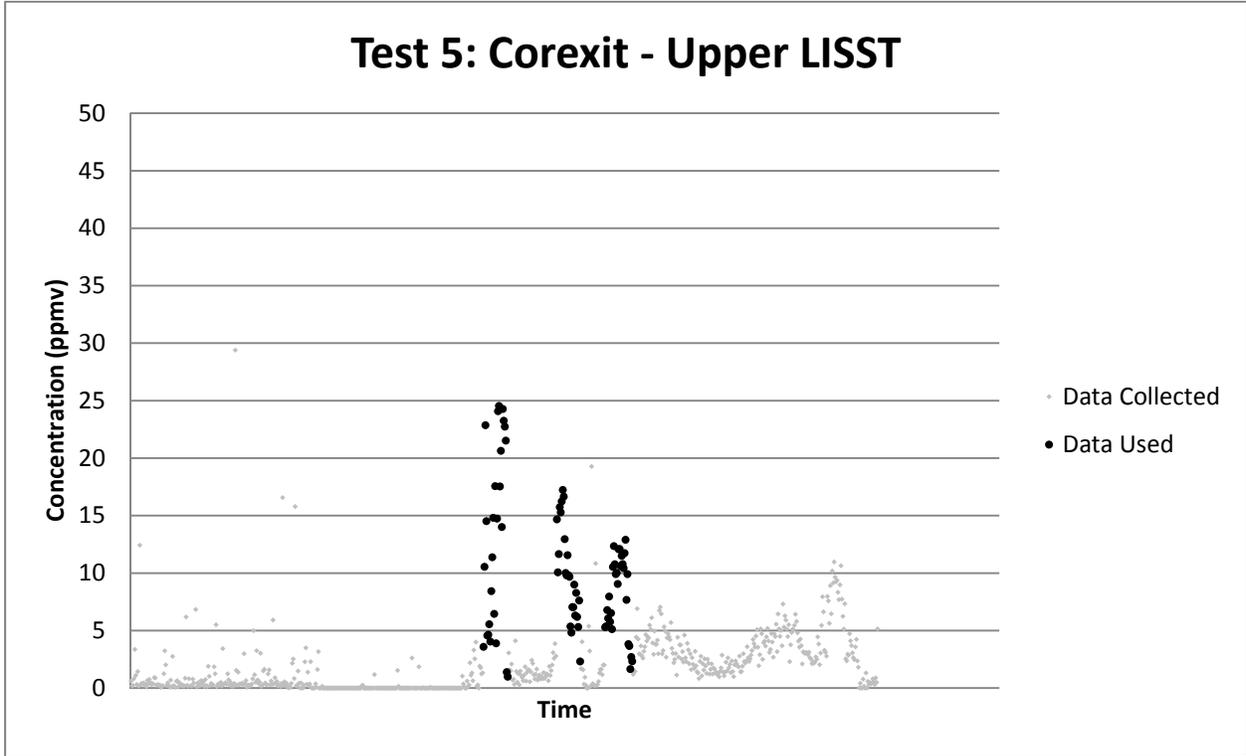
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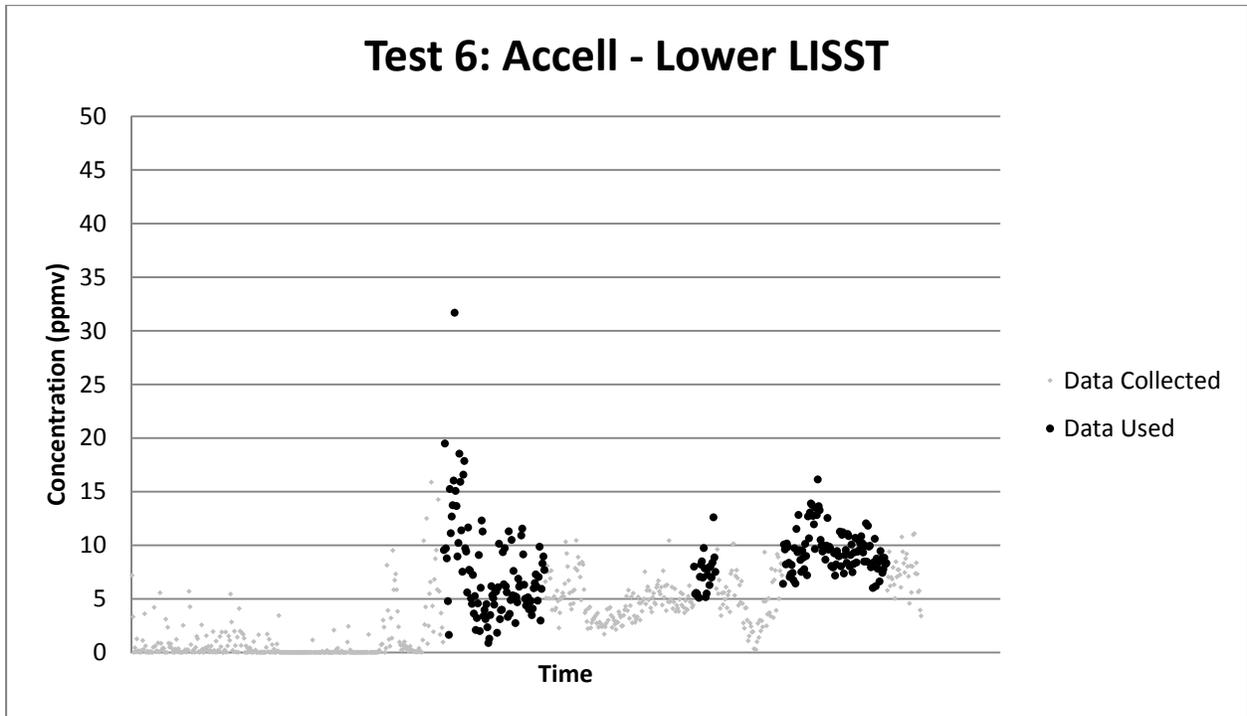
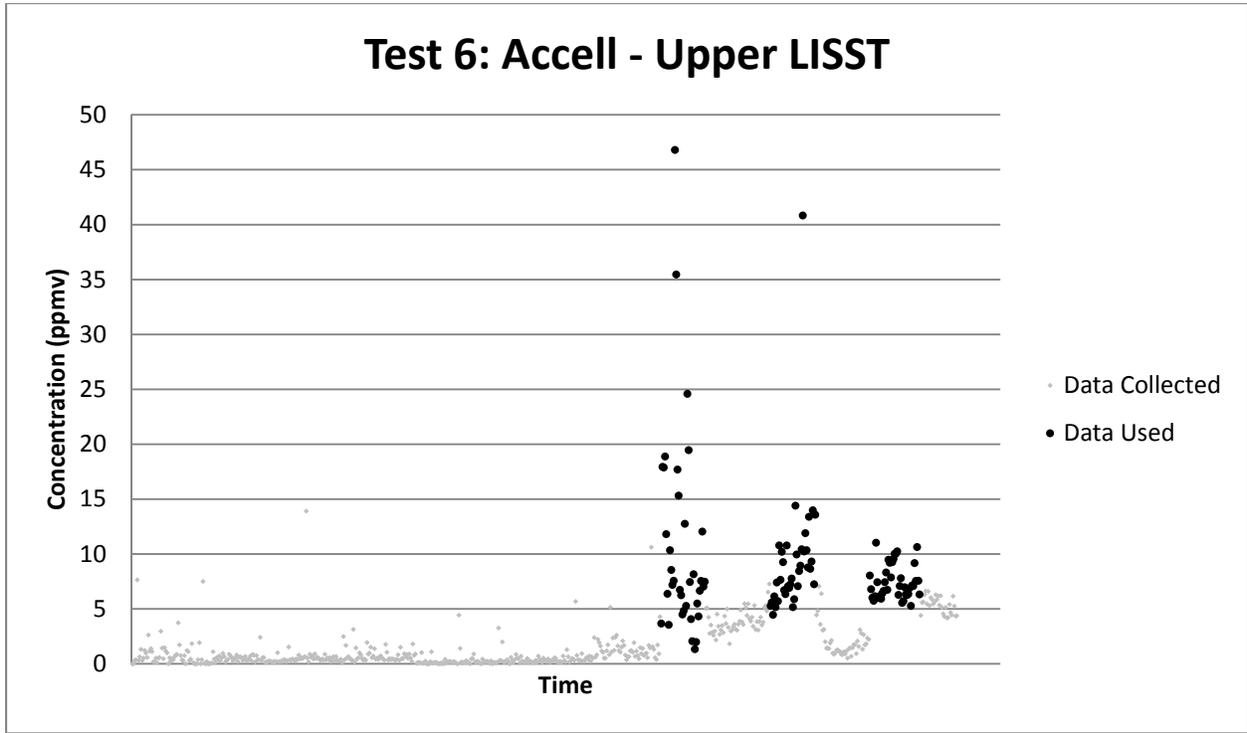
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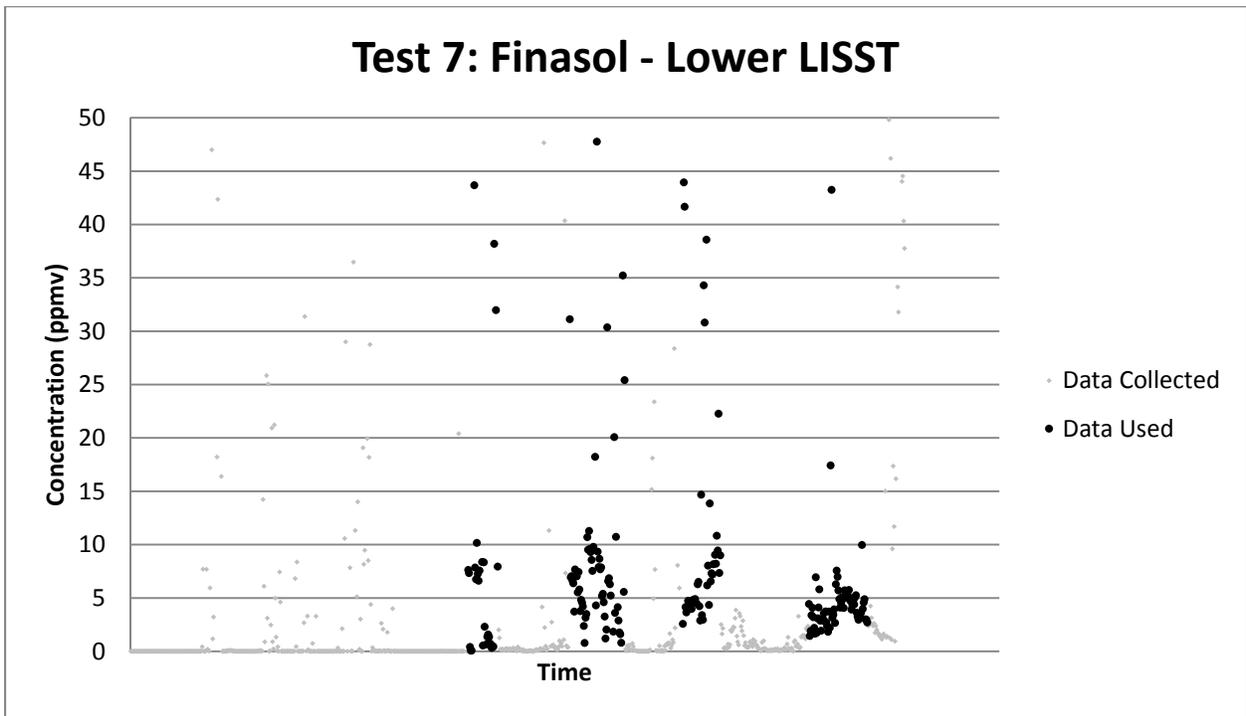
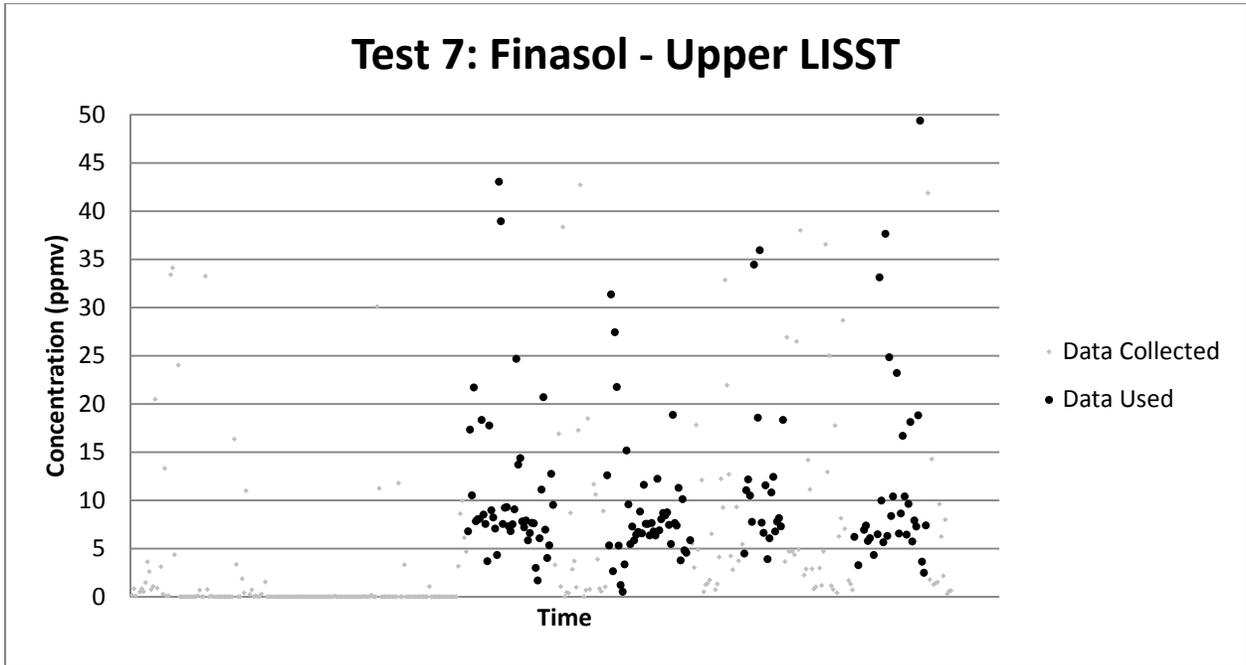
Appendix D – Selected Data Points



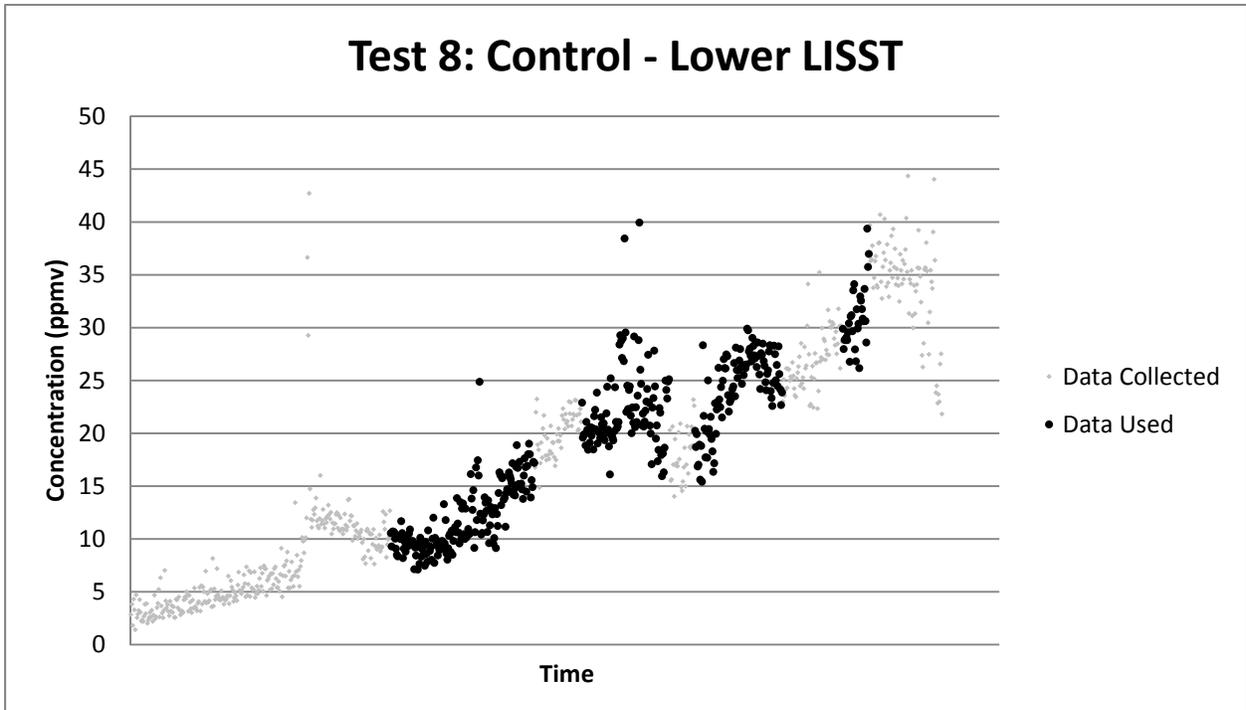
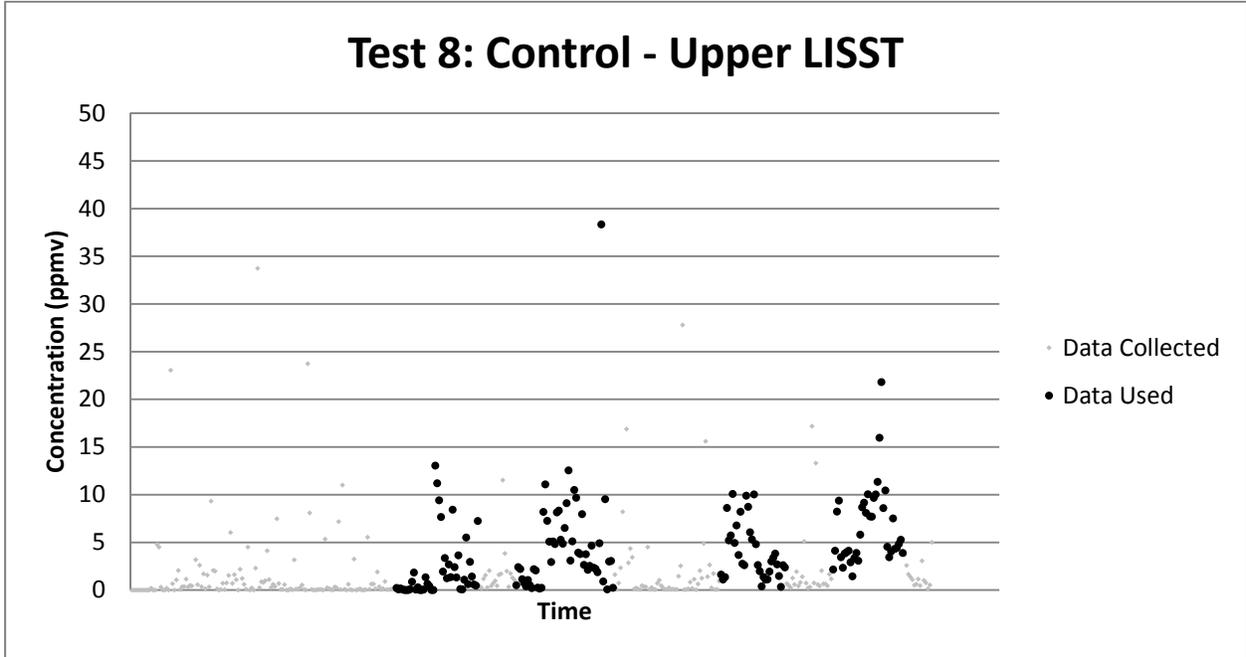
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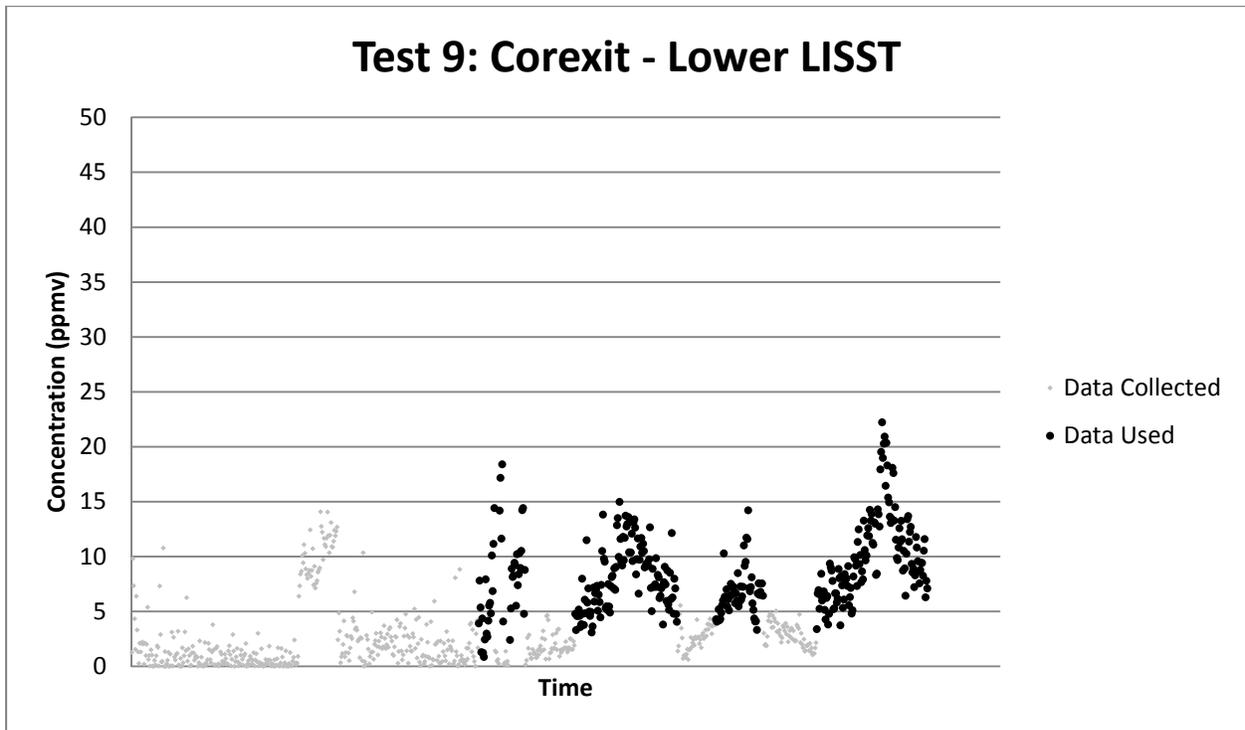
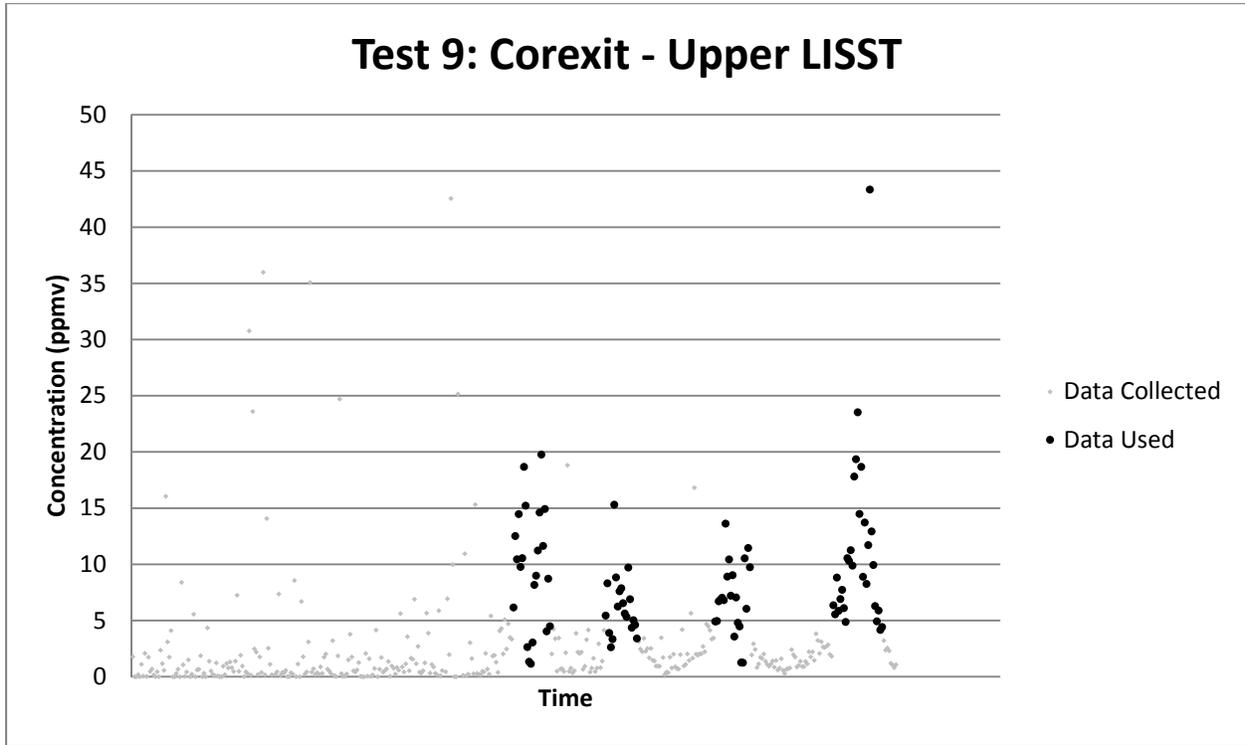
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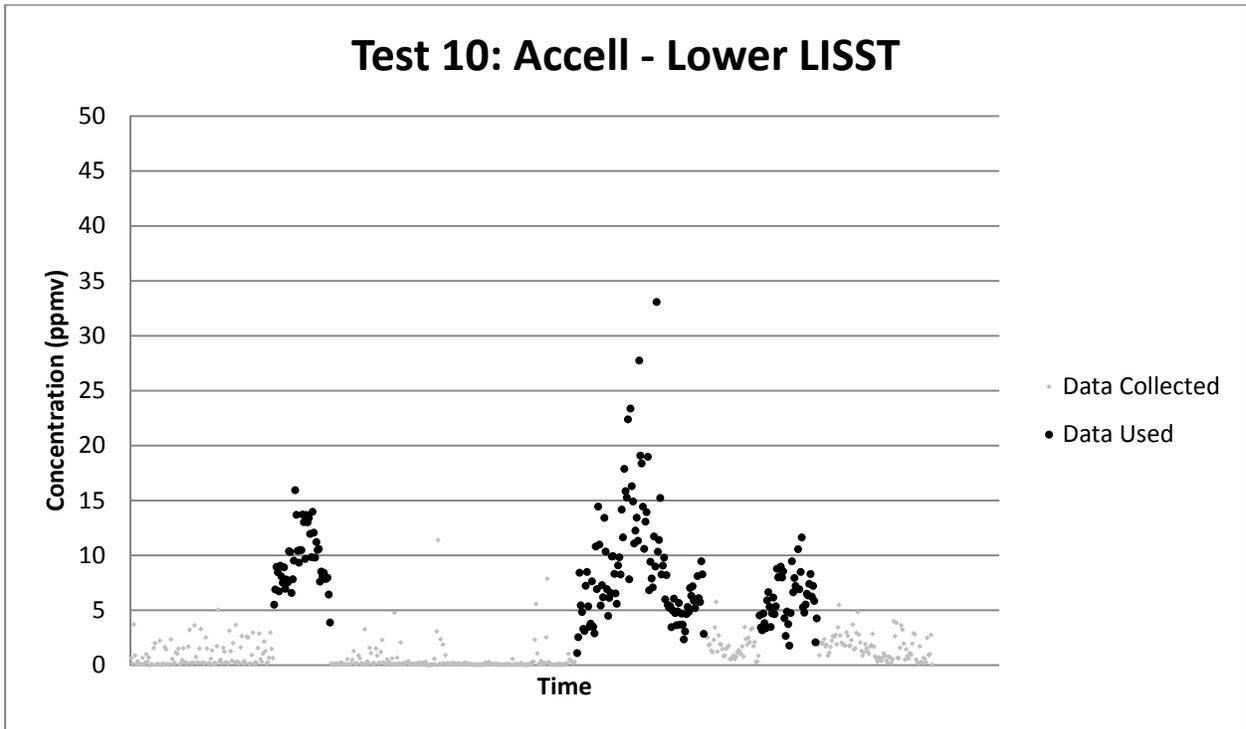
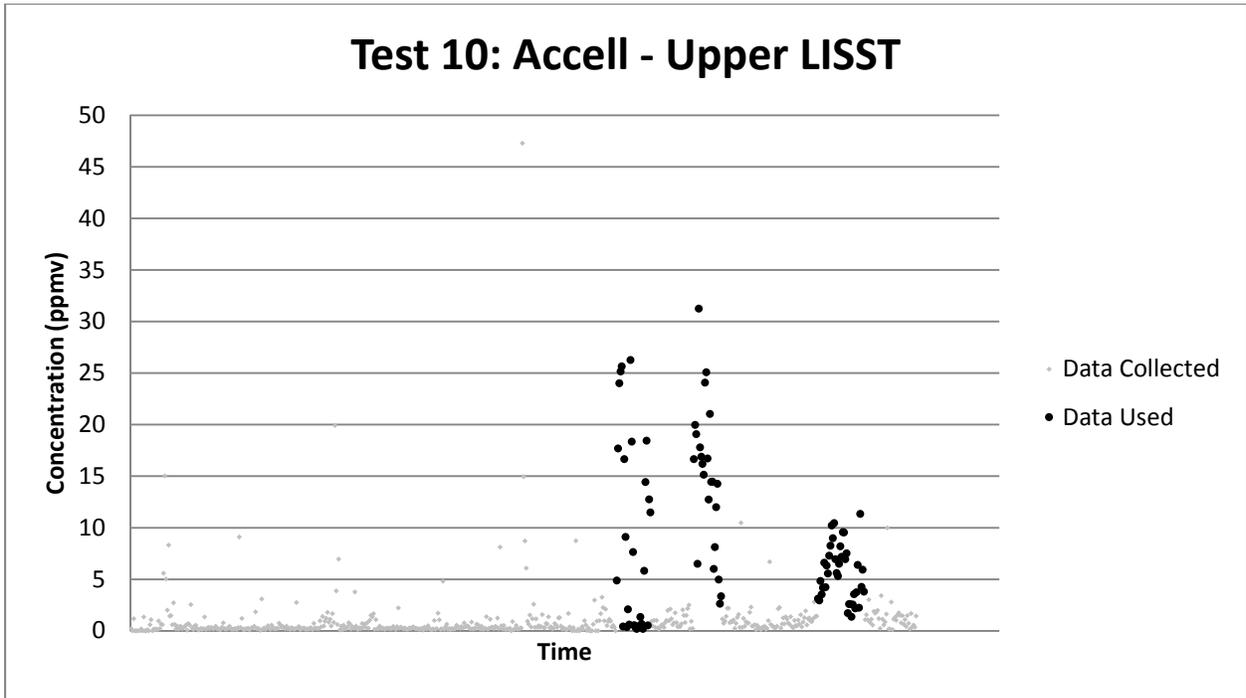
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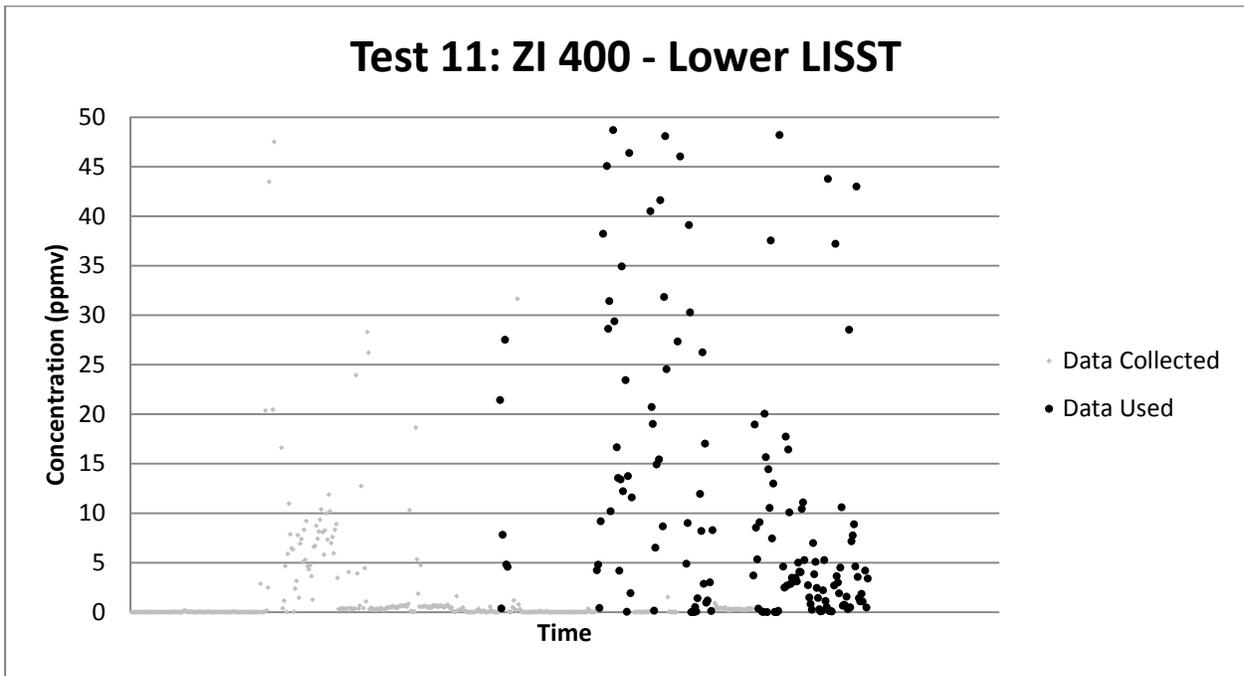
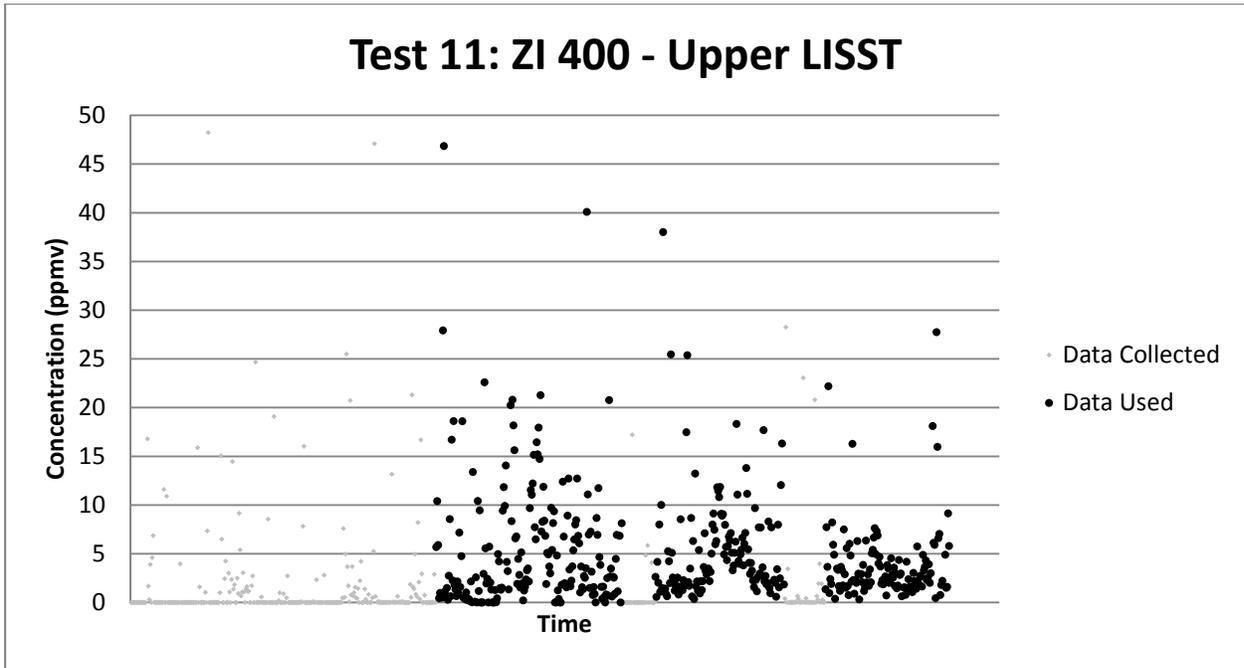
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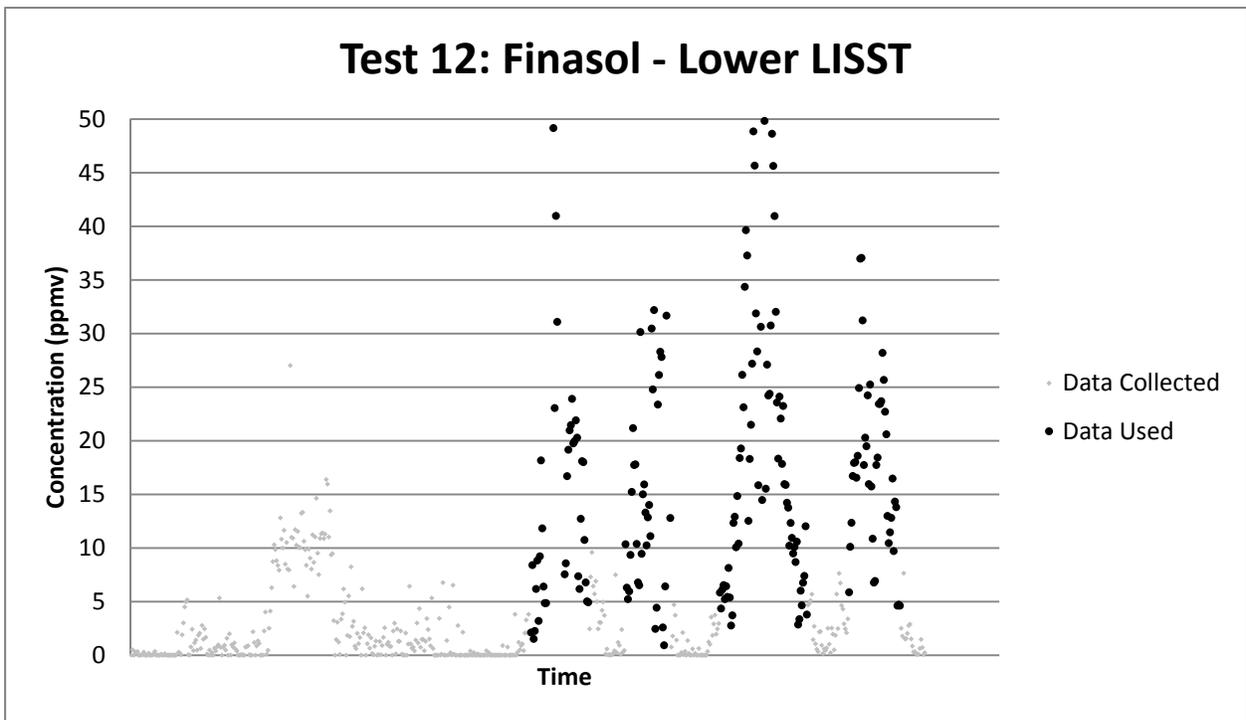
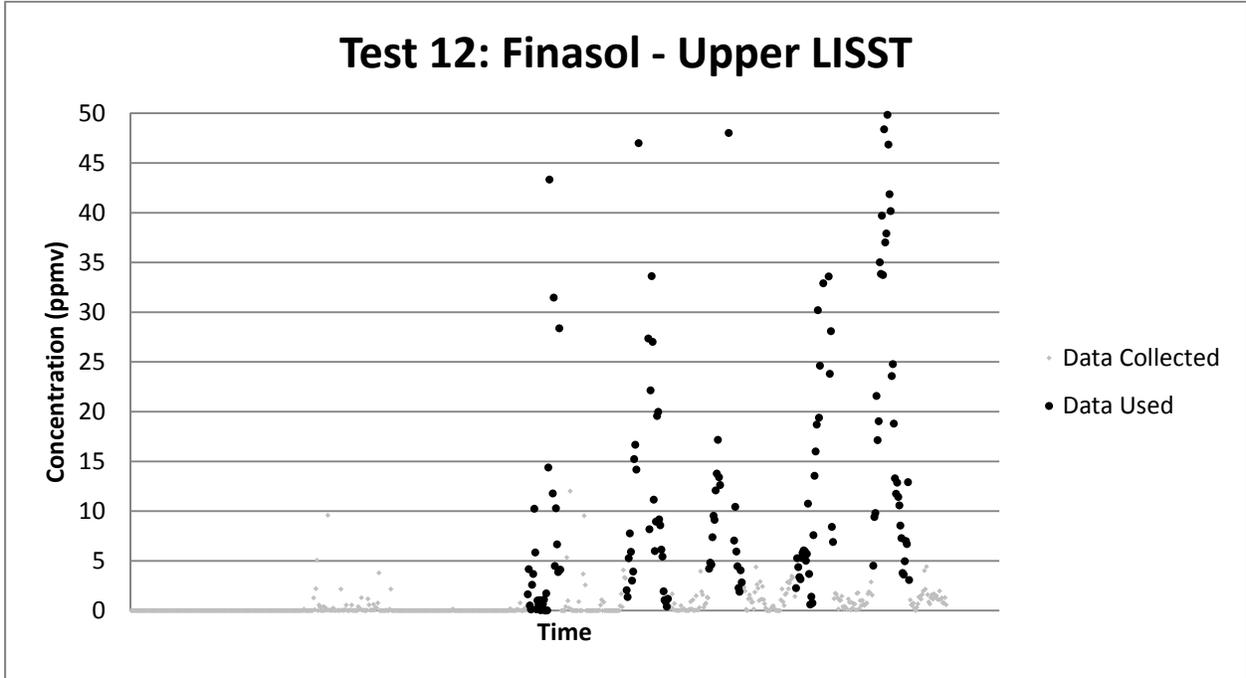
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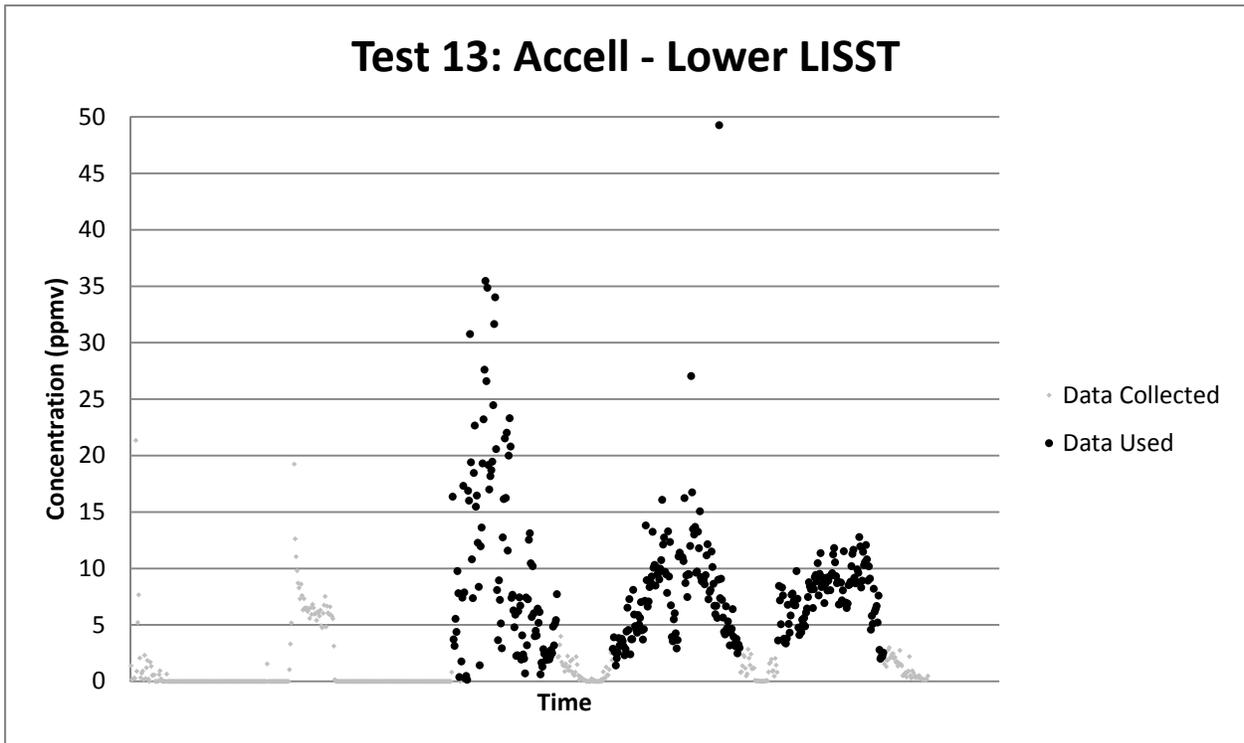
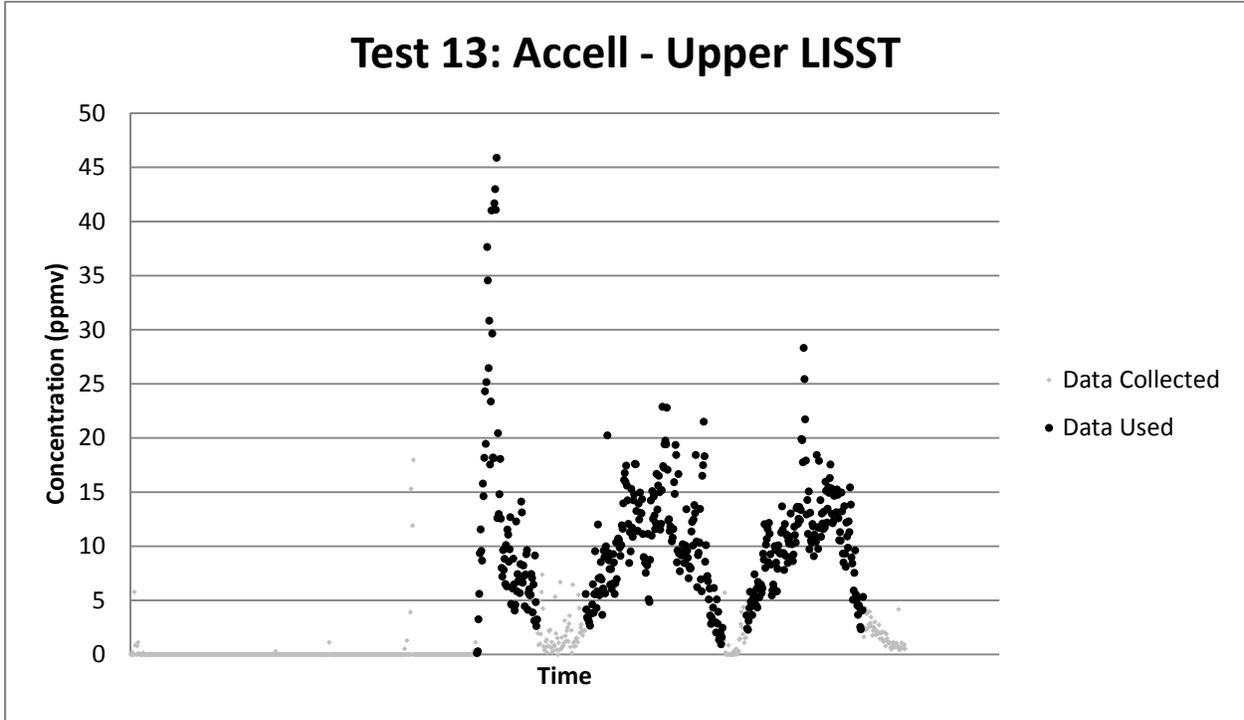
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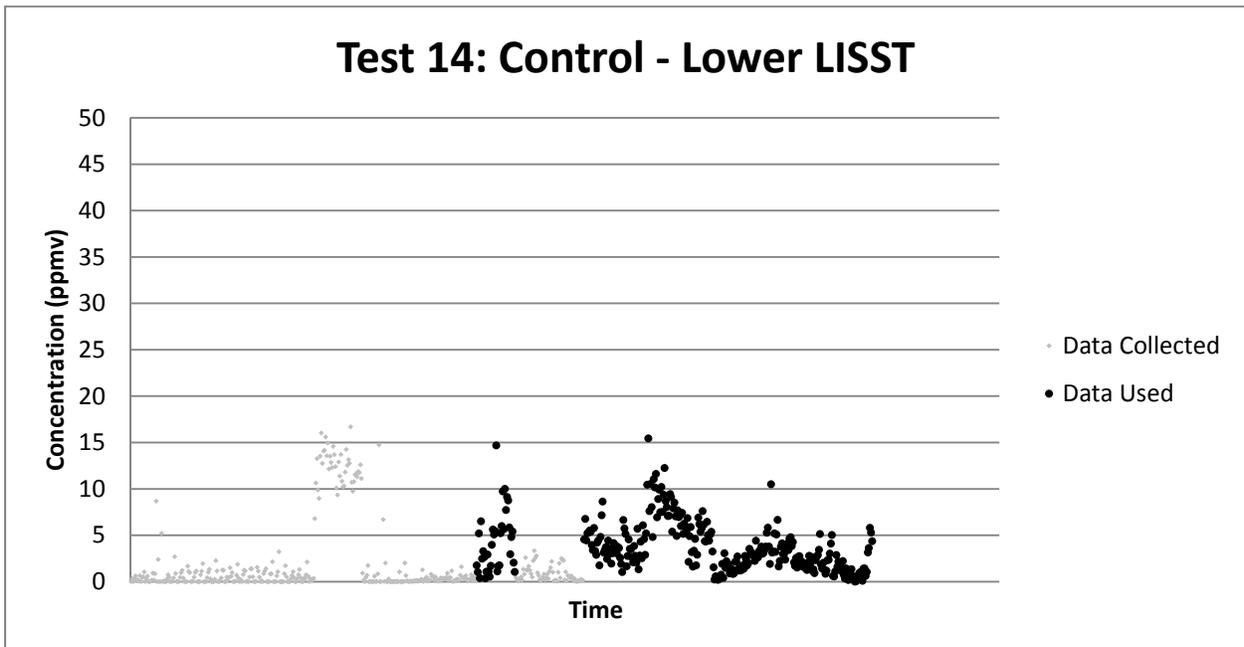
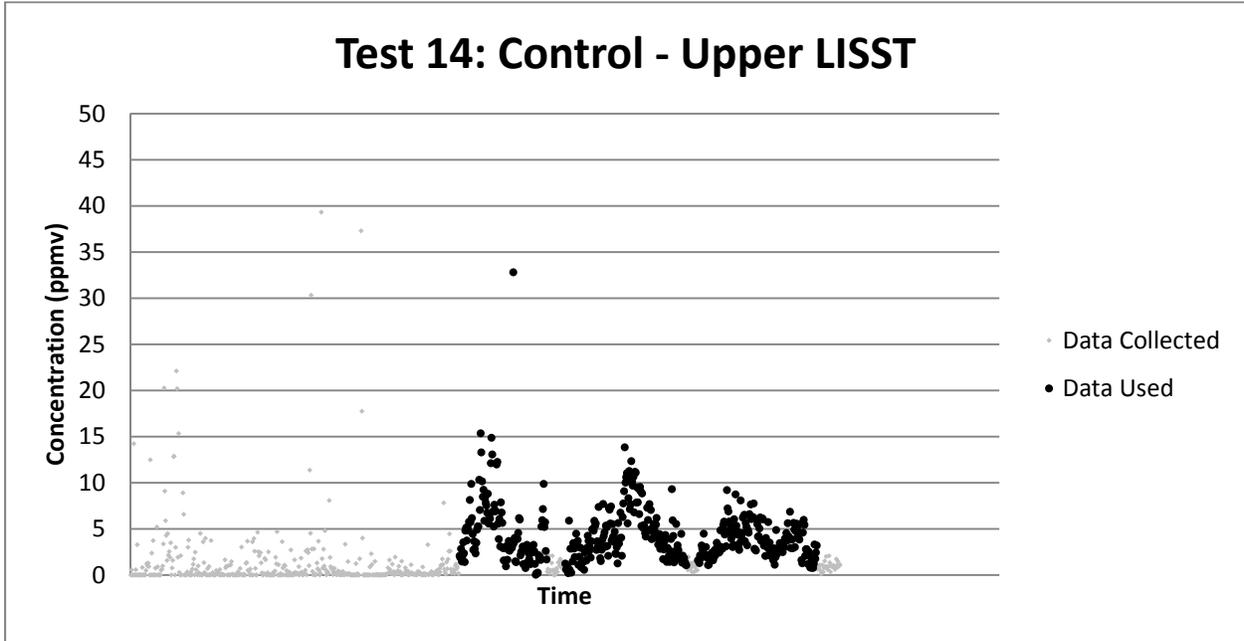
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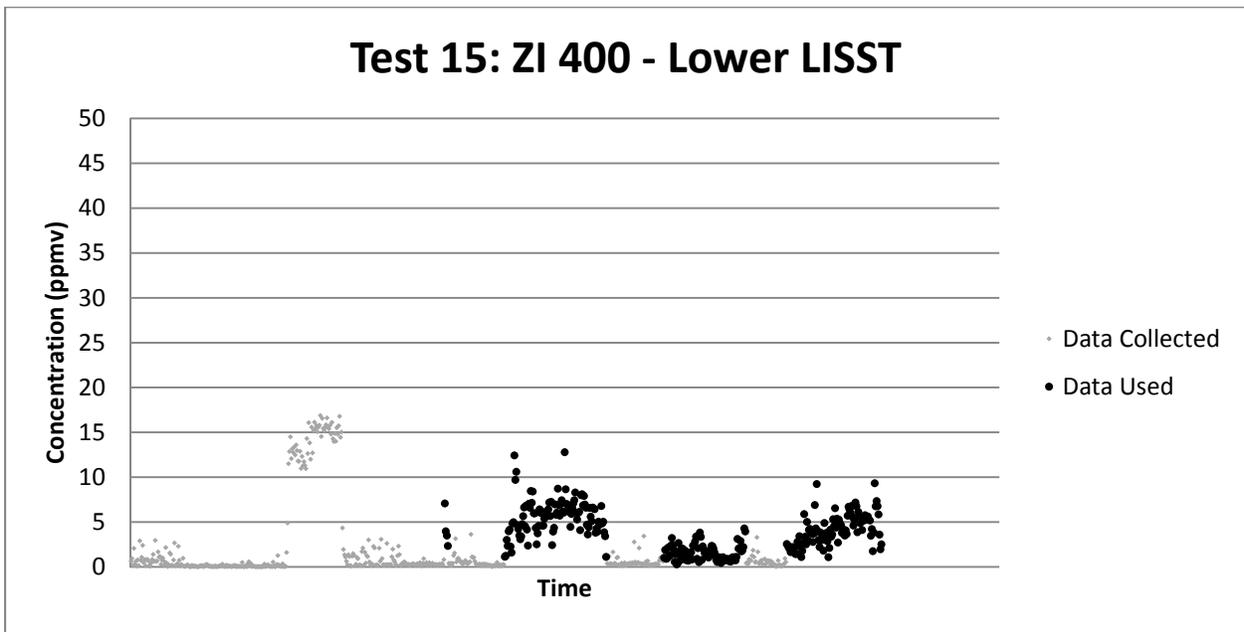
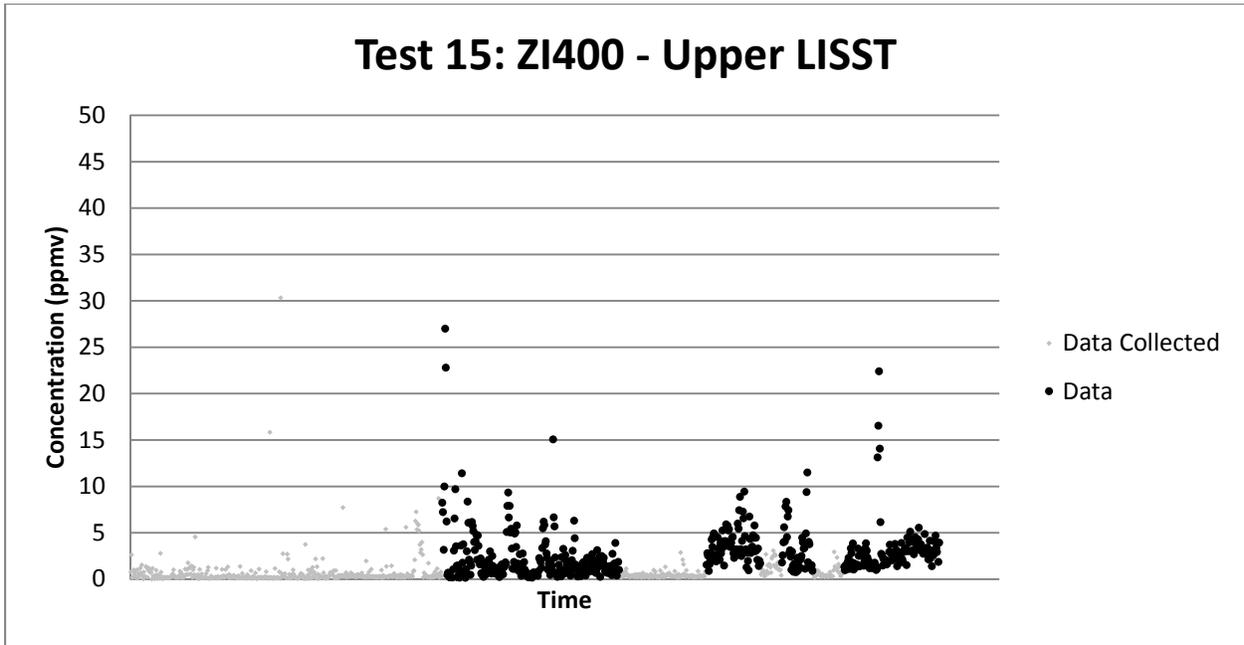
Appendix D – Selected Data Points



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Appendix D – Selected Data Points



Appendix F – Technical Product Bulletins

COREXIT® EC9500A

TECHNICAL PRODUCT BULLETIN #D-4
USEPA, OIL PROGRAM CENTER
ORIGINAL LISTING DATE: APRIL 13, 1994
REVISED LISTING DATE: DECEMBER 18, 1995
"COREXIT® EC9500A"
(formerly COREXIT 9500)

I. NAME, BRAND, OR TRADEMARK

COREXIT® EC9500A
Type of Product: Dispersant

II. NAME, ADDRESS, AND TELEPHONE NUMBER OF MANUFACTURER/CONTACT

Nalco Environmental Solutions LLC
7705 Highway 90-A
Sugar Land, TX 77478
Product Management:
Office: (281) 263-7709
Mobile: (832) 851-5164
E-mail: dalbright@nalco.com
(Ms. Debby Albright)

III. NAME, ADDRESS, AND TELEPHONE NUMBER OF PRIMARY DISTRIBUTORS

Nalco Environmental Solutions LLC
7705 Highway 90-A
Sugar Land, TX 77478
Product Management:
Office: (281) 263-7709
Mobile: (832) 851-5164
E-mail: dalbright@nalco.com
(Ms. Debby Albright)

IV. SPECIAL HANDLING AND WORKER PRECAUTIONS FOR STORAGE AND FIELD APPLICATION

1. Flammability:
IMO: Non-flammable; DOT: Non-hazardous.
2. Ventilation:
Use with ventilation equal to unobstructed outdoors in moderate breeze.
3. Skin and eye contact; protective clothing; treatment in case of contact:
Avoid eye contact. In case of eye contact, immediately flush eyes with large amounts of water for at least 15 minutes. Get prompt medical attention. Avoid contact with skin and clothing. In case of skin contact, immediately flush with large amounts of water, and soap if available. Remove contaminated clothing, including shoes, after flushing has begun. If irritation persists, seek medical attention. For open systems where contact is likely, wear long sleeve shirt, chemical resistant gloves, and chemical protective goggles.
- 4.a. Maximum storage temperature: 170°F
- 4.b. Minimum storage temperature: -30°F
- 4.c. Optimum storage temperature range: 40°F to 100°F

4.d. Temperatures of phase separations and chemical changes: None

V. SHELF LIFE

The shelf life of unopened drums of COREXIT® EC9500A is unlimited. Containers should always be capped when not in use to prevent contamination and evaporation of solvents.

VI. RECOMMENDED APPLICATION PROCEDURE

1. Application Method:

COREXIT® EC9500A contains the same surfactants present in COREXIT® EC9500A and a new improved oleophilic solvent delivery system.

Aerial Spraying - Aircraft provide the most rapid method of applying dispersants to an oil spill and a variety of aircraft can be used for spraying. For aerial spraying, COREXIT® EC9500A is applied undiluted. Typical application altitudes of 30 to 50 feet have been used, although higher altitudes may be effective under certain conditions. Actual effective altitudes will depend on the application equipment, weather and aircraft. Careful selection of spray nozzles is critical to achieve desired dose levels, since droplet size must be controlled. Many nozzles used for agricultural spraying are of low capacity and produce too fine a spray. A quarter-inch open pipe may be all that is necessary if the aircraft travels at 120 mph (104 knots) or more, since the air shear at these speeds will be sufficient to break the dispersant into the proper sized droplets.

Boat Spraying - COREXIT® EC9500A may also be applied by workboats equipped with spray booms mounted ahead of the bow wake or as far forward as possible. The preferred and most effective method of application from a workboat is to use a low-volume, low-pressure pump so the chemical can be applied undiluted. Spray equipment designed to provide a five to ten percent diluted dispersant solution to the spray booms can also be used. COREXIT® EC9500A 9500 should be applied as droplets, not fogged or atomized. Natural wave or boat wake action usually provides adequate mixing energy to disperse the oil. Recent tests have indicated that a fire monitor modified with a screen cap for droplet size control may also be useful for applying COREXIT® EC9500A. Due to the increased volume output and the greater reach of the fire monitor, significantly more area can be covered in a shorter period of time.

System Calibration - Spray systems should be calibrated at temperatures anticipated to insure successful application and dosage control. Application at sub-freezing temperatures may require larger nozzle, supply lines and orifices due to higher product viscosity.

2. Concentration/Application Rate:

A treatment rate of about 2 to 10 U.S. gallons per acre, or a dispersant to oil ratio of 1:50 to 1:10 is recommended. This rate varies depending on the type of oil, degree of weathering, temperature, and thickness of the slick.

3. Conditions for Use:

As with all dispersants, timely application ensures the highest degree of success. Early treatment with COREXIT® EC9500A, even at reduced treat rates, can also counter the "mousse" forming tendencies of the spilled oil. COREXIT® EC9500A is useful on oil spills in salt water.

VII. TOXICITY AND EFFECTIVENESS

a. Toxicity

Material Tested	Species	LC50 (ppm)
COREXIT® EC9500A	Menidia beryllina	25.20 96-hr
	Mysidopsis bahia	32.23 48-hr
No. 2 Fuel Oil	Menidia beryllina	10.72 96-hr
	Mysidopsis bahia	16.12 48-hr

COREXIT® EC9500A & No. 2 Fuel Oil (1:10)	Menidia beryllina	2.61 96-hr
	Mysidopsis bahia	3.40 48-hr

Reference Toxicant (SDS)	Menidia beryllina	7.07 96-hr
	Mysidopsis bahia	9.82 48-hr

NOTE: This toxicity data was derived using the concentrated product. See Section VI of this bulletin for information regarding the manufacturer's recommendations for concentrations and application rates for field use.

b. Effectiveness:

SWIRLING FLASK DISPERSANT EFFECTIVENESS TEST WITH SOUTH LOUISIANA (S/L) AND PRUDHOE BAY (P/B) CRUDE OILS

Oil	Effectiveness (%)
Prudhoe Bay Crude	45.3%
South Louisiana Crude	54.7%
Average of Prudhoe Bay and South Louisiana Crudes	50.0 %

VIII. PHYSICAL PROPERTIES

1. Flash Point: 181.4°F
2. Pour Point: Less than -71°F
3. Viscosity: 22.5 cst at 104°F
4. Specific Gravity: 0.949 at 60°F
5. pH: 6.2
6. Chemical Name and Percentage by Weight of the Total Formulation: CONFIDENTIAL
7. Surface Active Agents: CONFIDENTIAL
8. Solvents: CONFIDENTIAL
9. Additives: None
10. Solubility: Miscible

IX. ANALYSIS FOR HEAVY METALS, CYANIDE, AND CHLORINATED HYDROCARBONS

Compound	Concentration (ppm)
Arsenic	0.16
Cadmium	N/D
Chromium	0.03
Copper	0.10
Lead	N/D
Mercury	N/D
Nickel	N/D
Zinc	N/D
Cyanide	N/D
Chlorinated Hydrocarbons	N/D

N/D = Not detected

FINASOL OSR 52

TECHNICAL PRODUCT BULLETIN #D-11
USEPA, OIL PROGRAM CENTER
ORIGINAL LISTING DATE: JANUARY 30, 2003
REVISED LISTING DATE:
"FINASOL OSR 52"
(aka, SEACARE ECOSPERSE 52)

I. NAME, BRAND, OR TRADEMARK

FINASOL OSR 52
Type of Product: Dispersant

II. NAME, ADDRESS, AND TELEPHONE NUMBER OF MANUFACTURER/CONTACT

TOTAL FLUIDES
24 cours Michelet La Défense 10
92069 Paris La Défense Cedex
France
Phone: +33-141-35-31-01
United States: (713) 483-5712
24-hour Emergency Number: +33-1-41-35-65-00
E-mail: abdallah.bouhlassi@total.com
Web Site: www.totalspecialfluids.com
(Mr. Abdallah Bouhlassi)

III. NAME, ADDRESS, AND TELEPHONE NUMBER OF PRIMARY DISTRIBUTORS

TOTAL PETROCHEMICALS USA, INC.
1201 Louisiana St., Suite 1800
Houston, TX 77002
Phone: (713) 483-5712
Fax: (713) 483-5700
Web Site: www.totalspecialfluids.com
(Mr. Peter Egan)

IV. SPECIAL HANDLING AND WORKER PRECAUTIONS FOR STORAGE AND FIELD APPLICATION

1. Flammability:
Keep well away from sources of ignition and heat. Avoid the accumulation of static electricity. Provide grounding.
2. Ventilation:
Keep containers closed when not in use. Do not inhale vapors, fumes, or mists. In case of inhalation, take the person into fresh air. Ensure adequate ventilation is provided if there is any risk of vapors, mists, or aerosols forming. In the event of serious problems, call a doctor or summon medical assistance urgently.
3. Skin and eye contact; protective clothing; treatment in case of contact:
Wear appropriate long sleeve shirts, chemical resistant gloves and goggles. Avoid contact with skin and eyes. In case of contact, wash immediately with plenty of water. Avoid contact with clothing. In case of contact, wash immediately and remove contaminated clothing. Prolonged and repeated contact with the skin may cause skin disorders. In case of ingestion, do not induce vomiting to prevent aspiration into the respiratory tract.
- 4.a. Maximum storage temperature: 65°C

- 4.b. Minimum storage temperature: -20°C
 4.c. Optimum storage temperature range: 5 - 35°C
 4.d. Temperatures of phase separations and chemical changes: NA

V. SHELF LIFE

The shelf life of unopened drums of FINASOL OSR 52 is three years from the production date when the product is stored indoors in optimum conditions between 5 and 35°C. The shelf life can be extended after effectiveness testing.

VI. RECOMMENDED APPLICATION PROCEDURE

1. Application Method:

FINASOL OSR 52 is applied effectively by aircraft or from boats. It can also be applied by hand held sprayers as well as with backpack spray units. Spraying must not give too fine or atomized droplets as in fog. It must be done as moderately coarse droplets, with diameters in the range of 500 - 1000 µm, whether application is by surface vessel, aircraft, or land-based equipment.

2. Concentration/Application Rate:

Use FINASOL OSR 52 from 1:5 to 1:50, according to the nature of the oil, its state of weathering, temperature, thickness of the slick, and other circumstances of the spill. A 1:10 ratio would correspond appreciatively to 26 gallons per ton of oil.

Aerial spraying - FINASOL OSR 52 is sprayed undiluted when applied from aircrafts, usually between 30 and 50 feet altitude, or at higher altitude in poor weather conditions.

Boat spraying - FINASOL OSR 52 is sprayed undiluted using a low-pressure system. Spraying equipment providing 5 to 10% dilution of FINASOL OSR 52 can also be used.

3. Conditions for Use:

Diluted application in low salinity water is not recommended. Use only receptacles, joints, pipes, etc. which are resistant to hydrocarbons. Do not spray at high pressure (> 3 bar). FINASOL OSR 52 is designed to treat spills in salt water.

VII. TOXICITY AND EFFECTIVENESS

a. Toxicity:

Material Tested	Species	LC50 (ppm)
FINASOL OSR 52	Menidia beryllina	11.66 96-hr
	Mysidopsis bahia	9.37 48-hr
No. 2 Fuel Oil	Menidia beryllina	5.95 96-hr
	Mysidopsis bahia	2.37 48-hr
FINASOL OSR 52 & No. 2 Fuel Oil (1:10)	Menidia beryllina	5.40 96-hr
	Mysidopsis bahia	2.37 48-hr
Reference Toxicant (SDS)	Menidia beryllina	8.54 96-hr
	Mysidopsis bahia	21.81 48-hr

b. Effectiveness:

SWIRLING FLASK DISPERSANT EFFECTIVENESS TEST WITH SOUTH LOUISIANA (S/L) AND PRUDHOE BAY (P/B) CRUDE OIL

VENDOR LAB REPORT:

Oil	Effectiveness (%)
Prudhoe Bay Crude	32.50
South Louisiana Crude	71.60
Average of Prudhoe Bay and South Louisiana Crudes	52.10

VIII. MICROBIOLOGICAL ANALYSIS

NA

IX. PHYSICAL PROPERTIES

1. Flash Point, ASTM Method D-3278-89: 110°C
2. Pour Point, ASTM Method D-97-87: -27°C
3. Viscosity, ASTM Method D-445-88: 58.5 cSt
4. Specific Gravity, ASTM Method D-1298-85 (90): 1.01
5. pH, ASTM Method D-1293-84 (90): 8.57
6. Surface Active Agents: CONFIDENTIAL
7. Solvents: CONFIDENTIAL
8. Additives: CONFIDENTIAL
9. Solubility: Dispersable in water.

X. ANALYSIS FOR HEAVY METALS AND CHLORINATED HYDROCARBONS

Compound	Concentration (ppm)
Antimony	<10.0
Arsenic	<10.0
Barium	<10.0
Cadmium	<10.0
Chromium	<10.0
Copper	<10.0
Lead	<10.0
Mercury	<1.0
Nickel	<10.0
Selenium	<10.0
Silver	<10.0
Zinc	<10.0
Cyanide	<0.4
Chlorinated Hydrocarbons	<4.4



ACCELL® CLEAN DWD

TECHNICAL PRODUCT BULLETIN #D-16
 USEPA, OIL PROGRAM CENTER
 ORIGINAL LISTING DATE: JULY 18, 2011
 “ACCELL® CLEAN DWD”

I. NAME, BRAND, OR TRADEMARK

ACCELL® CLEAN DWD

Type of Product: Dispersant

II. NAME, ADDRESS, AND TELEPHONE NUMBER OF MANUFACTURER/CONTACT

Advanced BioCatalytics Corporation

18010 Skypark Circle, #130

Irvine, California 92614-6456

Office Phone: (949) 442-0880

General E-mail: info@abiocat.com

Web Site: www.abiocat.com [Exit](#)

Product Management:

Mobile: (949) 981-6510

Email: cpodella@abiocat.com

(Mr. Carl Podella)

III. NAME, ADDRESS, AND TELEPHONE NUMBER OF PRIMARY DISTRIBUTORS

Advanced BioCatalytics Corporation

18010 Skypark Circle, #130

Irvine, California 92614-6456

Office Phone: (949) 442-0880

General E-mail: info@abiocat.com

Web Site: www.abiocat.com [Exit](#)

Product Management:

Mobile: (949) 981-6510

Email: cpodella@abiocat.com

(Mr. Carl Podella)

IV. SPECIAL HANDLING AND WORKER PRECAUTIONS FOR STORAGE AND FIELD APPLICATION

1. Flammability: Combustible as defined by DOT and USCG.
2. Ventilation: Use in well ventilated areas.
3. Skin and eye contact; protective clothing; treatment in case of contact: Protective clothing is recommended. Avoid eye contact. In case of eye contact, immediately flush with large amounts of water for at least 15 minutes. Get prompt medical attention. Avoid direct contact with skin and clothing. In case of skin contact, immediately flush

with large amounts of water. Remove contaminated clothing, including shoes, after flushing has begun. If irritation persists, seek medical attention. For open systems where contact is likely, wear long sleeve shirt, chemical resistant gloves, and protective chemical goggles.

4.a. Maximum storage temperature: 130°F/55°C

4.b. Minimum storage temperature: 30°F/-1°C

4.c. Optimum storage temperature range: 40°F to 100°F/4°C to 38°C

4.d. Temperatures of phase separations and chemical changes: None

V. SHELF LIFE

The shelf life of unopened drums of ACCELL® CLEAN DWD is unlimited.

Containers should always remain capped when not in use to prevent contamination and evaporation.

VI. RECOMMENDED APPLICATION PROCEDURE

1. Application Method: Aircrafts provide the most rapid method of applying dispersants to an oil spill and a variety of aircraft can be used for spraying. For aerial spraying, ACCELL® CLEAN DWD is applied undiluted. Typically application altitudes of 30 to 50 feet are recommended, although higher altitudes may be effective under certain conditions. Actual effective altitudes will depend on the application equipment, weather and aircraft. Careful selection of spray nozzles is critical to achieve desired dose levels, since droplet size must be controlled. A quarter-inch open pipe may be all that is necessary if the aircraft travels at 120 mph (104 knots) or more, since the air shear at these speeds will be sufficient to break the dispersant into the proper sized droplets. Agricultural spray delivery systems may not be suitable because of too fine of spray and too little delivery of ACCELL® CLEAN DWD to the affected area.

Boat Spraying: ACCELL® CLEAN DWD may also be applied from boats equipped with spray booms mounted ahead of the bow wake or as far forward as possible. The most effective method of application from a boat is to apply ACCELL® CLEAN DWD using a low-volume, low-pressure pump so the ACCELL® CLEAN DWD can be applied undiluted. ACCELL® CLEAN DWD should not be fogged or atomized. Natural wave or boat wake action usually provides adequate mixing energy to disperse the oil. Application at sub-freezing temperatures may require larger nozzle, supply lines and orifices due to higher product viscosity.

2. Concentration/Application Rate: A treatment rate of about 10 gallons per acre, or a dispersant to oil ratio of 1:10 is optimal. The rate varies depending on the type of oil, degree of weathering, temperatures, and thickness of the slick.

3. Conditions for Use: For optimal results, ACCELL® CLEAN DWD early treatment of oil-contaminated waters is beneficial. ACCELL® CLEAN DWD can be used on weathered oils.

VII. TOXICITY AND EFFECTIVENESS

a. Toxicity:

Material Tested	Species	LC50 (ppm)
	Menidia	

ACCELL® CLEAN DWD	beryllina Mysidopsis bahia	5.66 96-hr 2.07 48-hr
No. 2 Fuel Oil	Menidia beryllina Mysidopsis bahia	11.10 96-hr 1.68 48-hr
ACCELL® CLEAN DWD & No. 2 Fuel Oil (1:10)	Menidia beryllina Mysidopsis bahia	8.05 96-hr 1.32 48-hr
Reference Toxicant (DDS)	Menidia beryllina Mysidopsis bahia	6.60 96-hr 30.80 48-hr

b. Effectiveness:

SWIRLING FLASK DISPERSANT EFFECTIVENESS TEST WITH SOUTH LOUISIANA (S/L) AND PRUDHOE BAY (P/B) CRUDE OIL

Oil	Effectiveness (%)
Prudhoe Bay Crude	58.70
South Louisiana Crude	96.03
Average of Prudhoe Bay and South Louisiana Crudes	77.37

VIII. MICROBIOLOGICAL ANALYSIS

NA

IX. PHYSICAL PROPERTIES

- Flash Point: 130°F/55°C
- Pour Point: -20.2°F/-29°C
- Viscosity: 130 SUS @100°F
- Specific Gravity: 1.0329 @60°F
- pH: 5.8
- Surface Active Agents: CONFIDENTIAL
- Solvents: CONFIDENTIAL
- Additives: CONFIDENTIAL
- Solubility: Miscible

X. ANALYSIS FOR HEAVY METALS, CYANIDE, AND CHLORINATED HYDROCARBONS

Compound	Concentration (ppm)
Arsenic	ND
Cadmium	ND
Chromium	ND
Copper	ND
Lead	ND
Mercurv	ND

Nickel	ND
Zinc	ND
Cyanide	ND
Chlorinated Hydrocarbons	ND

Last updated on June 4, 2013

ZI-400

TECHNICAL PRODUCT BULLETIN #D-13
USEPA, OIL PROGRAM CENTER
ORIGINAL LISTING DATE: JUNE 16, 2005
REVISED LISTING DATE:
"ZI-400"
(a/k/a ZI-400 OIL SPILL DISPERSANT)

I. NAME, BRAND, OR TRADEMARK

ZI-400
Type of Product: Dispersant

II. NAME, ADDRESS, AND TELEPHONE NUMBER OF MANUFACTURER/CONTACT

Z.I. Chemicals
8605 Santa Monica Boulevard, #38201
Los Angeles, CA 90069
Phone: (818) 827-1301
Email: sales@zichemicals.com
Web Site: www.zichemicals.com 
(Mr. Barnaby Zelman)

III. NAME, ADDRESS, AND TELEPHONE NUMBER OF PRIMARY DISTRIBUTORS

Z.I. Chemicals
8605 Santa Monica Boulevard, #38201
Los Angeles, CA 90069
Phone: (818) 827-1301
Email: sales@zichemicals.com
Web Site: www.zichemicals.com 
(Mr. Barnaby Zelman)

IV. SPECIAL HANDLING AND WORKER PRECAUTIONS FOR STORAGE AND FIELD APPLICATION

1. Flammability:
Non-flammable (DOT: Non-Hazardous).
2. Ventilation:
No special requirements.
3. Skin and eye contact; protective clothing; treatment in case of contact:
No special equipment or clothing required; however, goggles are recommended. If eye or skin irritation occurs flush with plenty of water.
- 4.a. Maximum storage temperature: 120°F continuous, 140°F up to 5 days
- 4.b. Minimum storage temperature: 35°F
- 4.c. Optimum storage temperature range: 40 - 120°F
- 4.d. Temperatures of phase separations and chemical changes: Stable

V. SHELF LIFE

Unlimited in sealed polydrums of totes (as delivered).

VI. RECOMMENDED APPLICATION PROCEDURE

1. Application Method:

ZI-400 may be applied by the usual method of aerial or boat spraying. For smaller spills a drum pump with sprayer may be used, mixing with water as required depending on the type and viscosity of oil being treated.

2. Concentration/Application Rate:

On heavy oils use ZI-400 directly on the spill, or up to approximately a 1:10 dilution ratio (product:water). Lighter oils will require a 1:10 to 1:30 product to water dilution ratio. Warmer waters (greater than 78°F) and/or good agitation during application will require less product.

3. Conditions for Use:

No limitations as to usage within in optimum temperature parameters (application may be made at or above 35°F, with optimum above 48°F).

VII. TOXICITY AND EFFECTIVENESS

a. Toxicity

Material Tested	Species	LC50 (ppm)
ZI-400	Menidia beryllina	31.76 96-hr
	Mysidopsis bahia	20.96 48-hr
No. 2 Fuel Oil	Menidia beryllina	18.05 96-hr
	Mysidopsis bahia	2.66 48-hr
ZI-400 & No. 2 Fuel Oil (1:10)	Menidia beryllina	8.35 96-hr
	Mysidopsis bahia	1.77 48-hr
Reference Toxicant (SLS)	Menidia beryllina	16.13 96-hr
	Mysidopsis bahia	27.80 48-hr

b. Effectiveness:

SWIRLING FLASK DISPERSANT EFFECTIVENESS TEST WITH SOUTH LOUISIANA (S/L) AND PRUDHOE BAY (P/B) CRUDE OIL

VENDOR LAB REPORT:

Oil	Effectiveness (%)
Prudhoe Bay Crude	50.10
South Louisiana Crude	89.80
Average of Prudhoe Bay and South Louisiana Crudes	69.90

VIII. MICROBIOLOGICAL ANALYSIS

NA

IX. PHYSICAL PROPERTIES

1. Flash Point, ASTM D-56: >93°C
2. Pour Point, ASTM D-97: 12.6°F
3. Viscosity, ASTM D-445: 18.80 cSt @40°C
4. Specific Gravity, ASTM D-1298: 1.026 @60°F

5. pH, ASTM 1293: 10.9
6. Surface Active Agents: Proprietary.
7. Solvents: Proprietary.
8. Additives: None.
9. Solubility: Miscible in oil, water, and solvents.

X. ANALYSIS FOR HEAVY METALS, CYANIDE, AND CHLORINATED HYDROCARBONS

Compound	Concentration (ppm)
Arsenic	<10
Cadmium	<10
Chromium	<10
Copper	<10
Lead	<10
Mercury	<1
Nickel	<10
Zinc	<10
Cyanide	<0.5
Chlorinated Hydrocarbons	<1

DISPERSIT SPC 1000™

TECHNICAL PRODUCT BULLETIN #D-5

USEPA, OIL PROGRAM CENTER

ORIGINAL LISTING DATE: APRIL 22, 1999

REVISED LISTING DATE:

"DISPERSIT SPC 1000™"

(a/k/a SEACARE E.P.A. (ECOSPERSE™ POLLUTION ABATEMENT))

I. NAME, BRAND, OR TRADEMARK

DISPERSIT SPC 1000™

Type of Product: Dispersant (Water Based)

II. NAME, ADDRESS, AND TELEPHONE NUMBER OF MANUFACTURER/CONTACT

U.S. Polychemical Corp.

584 Chestnut Ridge Road

Chestnut Ridge, NY 10977

Phone: (845) 356-5003

Fax: (845) 356-6656

Email: bruceg@uspoly.com

(Mr. Bruce Gebhardt)

III. NAME, ADDRESS, AND TELEPHONE NUMBER OF PRIMARY DISTRIBUTORS

Maritime Solutions, Inc.

17 Battery Pl. Suite 913

New York, NY 10004

Phone: (201) 541-0939

(212) 747-9044

Fax: (212) 747-9240

(Mr. Chris Constantine / Mr. Richard Fredricks)

IV. SPECIAL HANDLING AND WORKER PRECAUTIONS FOR STORAGE AND FIELD APPLICATION

1. Flammability:

IMO: Non-flammable

DOT: Non-hazardous

2. Ventilation:

None normally required. Adequate to maintain fume levels below the TLV.

3. Skin and eye contact:

Avoid prolonged contact with skin and eyes. Flush eyes with plenty of water for at least 15 minutes. Get medical attention. Wear long sleeve shirt, chemical resistant gloves, and chemical protective goggles in case of exposure to mist.

4.a. Maximum storage temperature: 180°F

4.b. Minimum storage temperature: -25°F

4.c. Optimum storage temperature range: 40°F to 140°F

4.d. Temperatures of phase separations and chemical changes: None

V. SHELF LIFE

The shelf life of Dispersit SPC 1000™ is unlimited in unopened containers. Containers must be kept closed

when not in use to prevent contamination.

VI. RECOMMENDED APPLICATION PROCEDURE

1. Application Method:

The dispersant may be applied by any conventional methods such as 1) aerial spraying and 2) boat spraying to accommodate weather conditions.

2. Concentration/Application Rate:

A dispersant to oil ratio ranging from 1 part dispersant to 50 parts oil to 1 part dispersant to 10 parts oil; or an application rate of about 2-10 gallons (7.6 liters- 37.9 liters) per acre (4840 square meters) is suggested. These rates will be dependent on the type of oil, degree of weathering, temperature and extent of oil slick.

3. Conditions for Use:

Timely application ensures the highest degree of successful dispersion of the oil spill.

VII. TOXICITY AND EFFECTIVENESS

a. Toxicity

Material Tested	Species	LC50 (ppm)
DISPERSIT SPC 1000™	Menidia beryllina	3.5 96-hr
	Mysidopsis bahia	16.6 48-hr
No. 2 Fuel Oil	Menidia beryllina	11.6 96-hr
	Mysidopsis bahia	11.7 48-hr
DISPERSIT SPC 1000™ & No. 2 Fuel Oil (1:10)	Menidia beryllina	7.9 96-hr
	Mysidopsis bahia	8.2 48-hr
Reference Toxicant (SDS)	Menidia beryllina	6.3 96-hr
	Mysidopsis bahia	11.7 48-hr

b. Effectiveness:

SWIRLING FLASK DISPERSANT EFFECTIVENESS TEST WITH SOUTH LOUISIANA (S/L) AND PRUDHOE BAY (P/B) CRUDE OIL

Oil	Effectiveness (%)
Prudhoe Bay Crude	40%
South Louisiana Crude	105%
Average of Prudhoe Bay and South Louisiana Crudes	73%

VIII. MICROBIOLOGICAL ANALYSIS

Not applicable

IX. PHYSICAL PROPERTIES

1. Flash Point, ASTM D-56-87: 208°F
2. Pour Point, ASTM D-97-87: < -20°C
3. Viscosity, ASTM D-445-88: 144CPS, @ 68°F

4. Specific Gravity, ASTM D-1298-85(90): 0.995, @ 68°F
5. pH, ASTM D-1293-84(90): 10.0
6. Surface Active Agents: Anionic and non-ionic, proprietary, surfactants
7. Solvents: Proprietary, non-petroleum based
8. Additives: None
9. Solubility in Water: Complete

X. ANALYSIS FOR HEAVY METALS, CYANIDE, AND CHLORINATED HYDROCARBONS

Compound	Concentration (ppm)
Arsenic	< 1.00
Cadmium	< 2.00
Chromium	< 2.00
Copper	< 2.00
Lead	< 1.00
Mercury	< 0.04
Nickel	< 10.00
Zinc	< 2.00
Cyanide	< 2.00
Chlorinated Hydrocarbons	< 5.00