Sediment Survey: Ocean Dredged Material Disposal Site, Miami, Florida

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United States Environmental Protection Agency, Region 4
Water Management Division, Atlanta, Georgia
Science and Ecosystem Support Division, Athens, Georgia

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The goal of the study was to provide scientifically-based data, data interpretation, and rationale to manage and monitor the Miami ODMDS in the most environmentally protective manner. The objectives of the study were three-fold: 1) characterize selected representative areas of the sea floor from a sedimentological and chemical perspective; 2) explore new methods of sediment collection and characterization where deep sea technology is required; and 3) compare the results of this study against a previous site survey (Conservation Consultant, Inc in 1986). The results and conclusions of this study will be utilized as guidance for future site management to develop and refine new methods of deep sea exploration and sediment characterization and to "ground-truth" sidescan sonar records from the 1998 survey.

The study area was within and surrounding the Miami, FL ODMDS located offshore Virginia Key (Figure 1). The ODMDS is approximately 3.4 km^2 (1.0 square nautical mile, NM), with stations extending up to 5.6 km (3 NM) to each cardinal point of the compass.

A total of fourteen discrete samples were collected from fourteen stations which were established based on:

- A subset of seven stations previously sampled by Conservation Consultants, Inc. (CCI 1985) (MIA01-MIA05, MIA07, MIA14);
- Active disposal area (station MIA08);
- Sidescan sonar interpretation (MIA09-MIA11, MIA13); and
- Randomly placed (MIA06 and MIA12).

Bottom sampling at each station was accomplished by deploying a Young grab (modified Van Veen). Samples were collected for sediment particle size analyses and sediment chemistry. Both wet sieve and laser particle size analyses were conducted on sediment samples. Based on assumptions of normality, appropriate statistical analyses were employed to compare data between sample stations and against the previous site survey (CCI 1985). Significance was tested at a 95% confidence level ($\alpha = 0.05$).

Based on the on-site sediment characterization and sediment particle size analyses (wet sieve and laser), dredged material can be distinguished from the native marine sediments at the Miami ODMDS as follows:

- On-site sediment characterization: In general, stations MIA01 and MIA02 exhibited characteristic native, tropical marine sediments including near white color (5Y 6/2, Munsell Value 6), fine sandy clay loam texture, no strata, no odor, no shell fragments, and benthic organisms (polychaetes). In contrast, marine sediment collected from Stations MIA03 and MIA08 through MIA13 were characteristically stratified, and were slightly darkened with organic matter or minerals not normally associated with tropical marine sediments (i.e., calcites);

- Based on wet sieve particle size analysis alone: Variation in percent particle size classes (inorganic and volatile solids fractions) was observed between Stations MIA01, MIA02, MIA06, MIA07, and MIA14 as compared to Stations MIA03 to MIA05 and MIA08 to MIA13;

- Particle size analysis (laser): By inspection of percent particle size class distribution and percent cumulative finer distribution, Stations MIA01, MIA02, MIA06, MIA07, and MIA14 exhibited finer-grained marine sediment. In addition based on evenness of distribution (skewness and kurtosis), Stations MIA04 and MIA05 were relatively more evenly distributed as compared to other stations; and

- EPA versus CCI (wet sieve): Seven of the fourteen sites (MIA01-MIA05, MIA07, and MIA14) sampled during this EPA study overlapped with the stations sampled in 1985 by CCI. By inspection of the differential distribution of particle size classes, EPA sediment samples were coarser grained as compared to CCI sediment samples. In addition, as evidenced by the cumulative percent distribution curves, this shift was especially pronounced in samples collected from Stations MIA03, MIA04, and MIA05.

Based on the interpretation of the on-site sediment characterization, examination of percent PSC (wet sieve and laser methods), cumulative percent curves, and skewness, samples stations were stratified as native marine sediments, dredged material, and mixed sediments as follows:

Native Marine Sediments:		*Dredged Material:*		*Mixed Sediments:*
MIA01	MIA07	MIA03	MIA11	MIA04
MIA02	MIA14	MIA08	MIA12	MIA05
MIA06		MIA09	MIA13	
			MIA10	

Also, the data indicate that areas identified by sidescan sonar as potential dumps of dredged material outside the ODMDS are in fact errant dumps that have occurred.
The chemical data showed that four metals (barium, chromium, manganese, and sodium) could be used to distinguish native sediments from the dredged materials. It is possible that this difference is a result of the higher percentages of finer particles (sites available for sorption) found in the native sediments.

The laser was observed to be more sensitive to subtle variation in particle size distribution as compared to the wet sieve method. Consequently, Stations MIA04 and MIA05 could be separated from the other stations. Wet sieve alone was not adequate to distinguish between these subtle variations in particle size distribution.

In conclusion, the methods used in this study are sufficient to distinguish dredged material from native marine sediments at the Miami ODMDS. This can in large part be attributed to the differences in sediment characteristics of the deep slope sediments found at the Miami ODMDS contrasted with the material being dredged for the Miami Harbor area.

Statement of the Problem. Ocean disposal of dredged materials can affect the environment of a disposal site by disturbing the benthic community and potentially causing long-term reduction of oxygen in the pore waters of the sediments and the overlying waters. Natural oceanographic processes can also be responsible for transporting disposed materials offsite into nearby habitats.

Once a site is chosen for ocean disposal of dredged material, the U.S. Environmental Protection Agency, in cooperation with the U.S. Army Corps of Engineers, is responsible for the management and monitoring of the site. A critical component of Region 4's monitoring program is the characterization and tracking of sediments in and around each Ocean Dredged Material Disposal Site (ODMDS).

Traditional techniques have employed the use of gamma radiation and x-ray fluorescence analyses to discriminate between native and dredged material. However, the Miami ODMDS presents a unique problem in discriminatory analysis given the extreme depths are beyond the physical capabilities of traditional techniques commonly utilized. Consequently, alternate techniques were explored during this study. Results and conclusions derived from this effort will have utility in future monitoring of deeper ocean dredged material disposal activities within Region 4 (e.g., Port Everglades and Palm Beach) and other deep ocean monitoring efforts elsewhere.

Background. The Miami ODMDS was designated in 1995 and a site characterization study was conducted in 1985. Since then over 2.3 million m^3 (3 million cubic yards) of dredged material has been disposed at the site. Over 459,000 m^3 (600,000 cubic yards) of this material was from an uncharacterized portion of the Miami Harbor West Turning Basin. This material was uncharacterized due to a permitting error. In 1998 a sidescan survey of the ODMDS was conducted to identify the footprint of the disposal mound to aid in future benthic sampling. Several apparent disposal mounds were identified outside of the site boundaries in addition to those identified within the site.

Survey Justification and Rationale. The purpose of this survey was to determine what changes may have occurred to the sediment chemistry and grain size distributions at the disposal site as a consequence of the disposal activity. Sampling station selection were based on previous surveys as well as sidescan data indicating the possibility that some material may have been dumped outside the ODMDS.

Objectives. The goal of the study was to manage and monitor the Miami ODMDS in the most environmentally protective manner. The objectives of the study were three-fold (see Table 1 for Data Quality Objectives): 1) characterize selected representative areas of the sea floor from a sedimentological and chemical perspective; 2) explore new methods of sediment collection and characterization where deep sea technology is required; and 3) compare the results of this study against a previous site survey (Conservation Consultant, Inc in 1985). The results and conclusions of this study will be utilized as guidance for future site management, to develop and refine new methods of deep sea sediment exploration, and to "ground-truth" sidescan sonar records from the 1998 survey. Additional uses of the results will be to determine if there is a need for a biological impact study and if disposal of the uncharacterized material caused any adverse environmental impact (such as would be indicated by elevated chemical values).

Survey Location and Description. The study area is within and surrounding the Miami, FL ODMDS located offshore Virginia Key (Figure 1). The ODMDS is approximately 3.4 km^2 (1.0 square nautical mile, NM), with stations extending up to 5.6 km (3 NM) to each cardinal point of the compass. Seven stations were selected to coincide with stations sampled by Conservation Consultant, Inc in 1986. One station was positioned in the center of the active disposal area (northwest corner of the ODMDS), whereas four stations were positioned into areas identified by sidescan sonar as possible offsite dumps. The other two stations were a result of improper trans-positioning of coordinates from the survey plan into the navigation system, and were maintained as additional data. The ODMDS boundary coordinates are:

25º45.50'N 80º03.90'W
25º45.50'N 79º02.83'W
26º44.50'N 79º02.83'W
26º44.50'N 80º03.90'W

Hypothesis/ Statistical Tests. The particle size distributions (PSD) of each station and specific size classes across stations were tested for normality using normal probability plots. For normally distributed data, statistical significance was tested using t-tests for dependent samples at a level of significance $p < 0.05$ (parametric). For data sets that were not normally distributed, chi square analysis was used at a level of significance of $p < 0.05$ (non-parametric). Testable hypotheses were formulated as:

Hypothesis Set 1:
H_o = There is no significant difference between physical and chemical analyses of native marine sediments (reference) versus dredged material

H_1 = There is a significant difference between physical and chemical analyses of native marine sediments (reference) versus dredged material

Hypothesis Set 2:
H_o = There is no significant difference between historic (CCI) and present (EPA) particle size analysis of native marine sediments (reference) versus dredged material

H_2 = There is a significant difference between historic (CCI) and present (EPA) particle size analysis of native marine sediments (reference) versus dredged material

Initially, sample stations representative of native marine stations and dredged material were identified by interpretation of previous sidescan sonar records, location with respect to the designated, active disposal area, and disposal records.

As an integral part of the Miami Ocean Dredged Material Disposal Site Sediment Survey conducted June 13-14, 2000, marine sediment samples were collected to meet the objective of this report. A total of fourteen discrete samples were collected from fourteen stations which were established based on:

- A subset of seven stations previously sampled by Conservation Consultants, Inc. (CCI 1985) (MIA01-MIA05, MIA07, MIA14);
- Active disposal area (station MIA08);
- Sidescan sonar interpretation (MIA09-MIA11, MIA13); and
- Randomly placed (MIA06 and MIA12).

Sampling procedures and sample preservation for analyses were be according to the Science and Ecosystem Support Division (SESD) Standard Operating Procedures (SOP), (US EPA 1996, 1998). However, traditional remote techniques of collecting grab samples were inadequate in meeting the project goals specific to the deep-sea conditions encountered on the Miami ODMDS. Consequently, new methods of deep-sea technology and sediment characterization were employed which went beyond marine sediment procedures previously required and employed in Region 4.

Bottom sampling at selected stations was accomplished by deploying the Young grab (modified Van Veen). Samples were collected for sediment particle size analyses and sediment chemistry. The sampling device and handling/preservative protocol for each type of sample follows.

Sediment Particle Size Analysis. Sediment laboratory analysis included particle size and volatile solids analyses in the SESD-EAB Sediment Characterization Laboratory (SCL). Samples for particle size were collected with acrylic 5.1 cm (2-inch) coring tubes penetrating 15 cm (or to the point of refusal if less than 15 cm) into the substrate within the grab. Precautions taken to ensure consistent sample volume collected in the Young grab and sub-samples using coring tubes from the grab included:

- To ensure minimal cable scope, current conditions were examined at each sample location, including opposing currents beneath the pyncnocline;
- Special attention was given to depth, cable-wrap counts, and cable tension; and

- To prevent loss of vertical horizons and contamination of the chemical samples, smaller cores were collected during subsampling within the center of the grab.

With the exception of Station MIA10, consistent sampling volumes among the various stations were obtained at all stations.

After settling, the structure and texture of the sediment were observed and recorded, then the clear water decanted and the sediment core placed in a whirl pack, labeled, and frozen for return to the lab. Two replicate samples were obtained at each station. Particle size analyses were determined using a Coulter™ Laser Particle Size Analyzer (Model LS200) in the Sediment Characterization Laboratory (SCL) of the Ecological Assessment Branch (EAB). Volatile solids analyses were determined on seven particle sizes using a modified Wet Sieve Method (*Ecological Assessment Branch, Standard Operating Procedures* , EAB 2000 as modified from *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents*, EPA-670/4-73-001).

Prior to particle size analysis, sediment material for particle size distribution (PSD) utilizing the Coulter™ Laser Particle Size Analyzer (Model LS200) was dispersed by adding a dispersing agent (sodium metaphosphate) and placed on an automated shaker overnight. In contrast, in order to be consistent with methods used in the past, no dispersing agent or shaking was conducted on sediment material prior to wet sieve analysis.

Sediment Chemical Analysis. Sediment chemical analysis included pesticides/PCB scan, extractables, metals scan, and classic nutrients (ammonia, nitrates/nitrites, total kjeldahl nitrogen, and total phosphorus) (Appendix A). At each station, samples for metals, nutrient and extractable organic analysis were collected by using 5.1 cm Teflon coring tubes until sufficient volume was obtained. Volatile organic samples were collected in two pre-cleaned and weighed 40 ml vials with a septum seal at each station, with the addition of a 59.1 ml (2 oz.) container at six stations for quality control. Sample handling of cores was similar to that specified above for particle size. The core samples for metals, nutrients and extractable organic compounds were transferred to a glass pan or teflon lined pan and thoroughly mixed. Aliquots of the sample were placed into two 236.6 ml (8 oz.) glass containers. The sample aliquot for nutrients and metals analysis was preserved by freezing. The sample aliquot for pesticides and extractables were preserved at 4EC. VOC collection was conducted utilizing an adaptation to SW846

Method 5035 to limit the loss of volatile organics and reduce the possibility of contamination from site conditions, (i.e. diesel fumes from ship operations). Water vials (40 mls) were pre-weighed and filled in the lab with milli-Q water. Sediment was removed directly from the grab at each station, filling the vials one quarter full of sediment. In the ship board lab, approximately 20 mls of sea water was removed utilizing a pipette, leaving approximately 10 mls of sea water over the undisturbed sediment. The standard method of VOC preservation utilizes sodium bisulfate as a preservative. Sodium bisulfate effervesces when it comes in contact with the calcium carbonate found in all marine sediments in the Southeast. The effervescent action then causes a loss of volatile organics. Therefore, once the 20 mls of sea water were removed, and the samples tagged, the samples were preserved by freezing. Samples were placed on their side in the freezer in a protective container to help prevent breakage from freezing.

Statistical Methods. Several methods were utilized to discriminate between native marine sediments and dredged material including (discussed below): on site sediment characterization, PSC within stations (wet sieve and laser), and EPA data versus CCI data (wet sieve). Ultimately, the results of the on site sediment characterization and the PSD analysis were used to stratify stations for interpretation of chemical analysis. Several discriminatory, statistical tests were used to aid in the interpretation of the above datasets including: skewness, standard deviation, t-tests, and chi-square distribution. Data were tested for normality using the Shapiro-Wilkes Test for Normality. Based on the results, parametric (t-tests) or nonparametric (chi-square distribution) tests were employed as appropriate. Data were tested at the 95 % confidence level ($\alpha = 0.05$).

In conjunction with on site sediment characterization, the relative degree of skewness (i.e., variation in PSC) of inorganic fractions plotted against the standard deviation of the means was used, in part, to discriminate between native marine sediment and dredged material. Skewness (third moment in calculus), is a measure of the asymmetry of the PSD in a sediment sample. In general, a frequency curve is skewed with the mode shifted to the right (positive skewness) for an abundance of coarse particles, and to the left (negative skewness) for an abundance of fine particles.

On Site Sediment Characterization. Marine sediments were visually and texturally characterized immediately following collection using a Young box dredge. Sediment characterization included strata, boundary, color (Munsell), texture by feel, and presence or absence of masses, gravel, shell fragments, odor, and benthic organisms.

Sediment Particle Size (Wet Sieve). Particle size distributions for both inorganic and volatile solids fractions were plotted on frequency and percent cumulative curves to aid in discriminating between native marine sediments and sediments altered by dredge disposal activities (Figures 2 to 14). Due to an oversight, wet sieve analysis was not conducted on Station MIA08 and is addressed below in *Sediment Particle Size (Laser - EPA Dataset).* Both differential percent (per class) and cumulative percent were plotted against seven particle size classes (PSC, mm): 0.002, 0.063, 0.125, 0.250, 0.500, 1.000, 2.000, 4.000, and 8.000. PSC were arranged on the ordinate axis from left to right (clay fraction to larger than sand fraction, respectively).

CCI (1985) followed, in general, the procedures outlined by Pequegnat et al. (1981) in U.S. Army Waterways Experiment Station Technical Report EL-81-1: **Procedural Guide for Designation Surveys of Ocean Dredged Material Disposal Sites.** The method consisted of wet sieving the sample through a 62 Fm using a 5 g/l sodium hexametaphosphate dispersant. The sand-shell fraction then underwent grain size analysis by sieving, while pipette analysis was used to quantify the silt-clay fraction. A Tyler Sieve Shaker (Model R-X24) and nested 20.32 cm (8-inch) brass sieves with mesh sizes of 2.0, 1.0, 0.5, 0.25, 0.177, 0.12, and 0.06 mm were used to conduct the sieve analysis. CCI (1985) reported their findings in greater than 2.0, 2.0, 0.50, 0.25, 0.063, and 0.002 mm PSCs. For comparison, the PSC used by EPA were adjusted (mathematically) to match the PSC used by CCI. EPA did not use a dispersing agent prior to wet sieving. Consequently, the assumption was made that the dispersant agent used by CCI did not significantly change the PSD. Three methods of determining relative PSD: skewness, standard deviation, and chi-square distribution.

On-Site Sediment Characterization. In general, Stations MIA01 and MIA02 exhibited characteristic native, tropical marine sediments including near white color (5Y 6/2, Munsell Value 6), fine sandy clay loam texture, no strata, no limestone gravel, no odor, no shell fragments, and benthic organisms (polychaetes) (Table 2). In contrast, marine sediment collected from Stations MIA03, MIA08 through MIA13 were characteristically stratified, and were slightly darkened with organic matter or minerals not normally associated with tropical marine sediments (Tables 2 and 3). Limestone gravel was observed in samples collected from Stations MIA08, MIA10, MIA11, and MIA14. As evidenced by uneven or wavy boundary and masses of different color, stratified samples did not form in place and are interpreted as dredged material.

Sediment Particle Size (Wet Sieve - EPA Dataset). Upon close examination of Figures 2 through 14, variation in percent PSC (inorganic and volatile solids fractions) was observed between Stations MIA01, MIA02, MIA06, MIA07, and MIA14 as compared to Stations MIA03 to MIA05 and MIA09 to MIA13.

Positive skewness was observed in the PSD of samples collected from all stations. However, the degree of skewness varied between stations and was used for discriminatory analysis in the following way. Native marine sediments were characterized by a predominance of fine-grained inorganic and organic material (< 0.125 mm), consequently, exhibited a high positive skewness (skewed right). Based on inspection of PSD (Figures 2 to 14) and skewness (Figure 15), native marine sediments were observed at Stations MIA01, MIA02, MIA06, MIA07, and MIA14. In contrast, marine sediments which were either altered by dredged materials or represented a different native bottom were characterized by the presence of larger particle sizes (> 0.125 mm) and exhibited lower skewness values. These stations included MIA03 through MIA5 and MIA09 through MIA13. This pattern was also observed in the frequency distribution of the volatile solids fractions (Figures 2 to 14).

Building on the interpretation of the on-site sediment characterization, examination of percent PSC (wet sieve method), cumulative percent curves, and skewness, samples stations were stratified as native marine sediments and dredged material initially as follows:

Native Marine Sediments:	*Dredged Material:*	
MIA01	MIA03	MIA10
MIA02	MIA04	MIA11
MIA06	MIA05	MIA12
MIA07	MIA09	MIA13
MIA14		

Since the dataset was not normally distributed across PSC, a chi-square distribution (non-parametric) was utilized as a confirmation test on the above findings. In this case, stations that were interpreted as native marine sediments (as shown above) were treated as expected PSC and compared against dredged material, observed PSC (Table 4). Stations MIA01, MIA02, MIA06 and MIA07 associated with native marine sediments were found to be significantly different ($p < 0.05$) from dredged material. Consequently, the results of the chi-square distribution confirmed, in part, the segregation of sample stations shown above.

The objective of the following statistical test was to determine which PSC (among sample stations) changed between native marine sediments and dredged material (shown above). The frequency distribution within specific particle size class was observed to be normally distributed (Appendix B) and the following hypothesis was tested by means of the t-test.

H_o = There is no significant difference between specific particle size classes of native marine sediments (reference) versus the dredged material (wet sieve dataset)

H_1 = There is a significant difference between specific particle size classes of native marine sediments (reference) versus the dredged material (wet sieve dataset)

Statistical tests were conducted on specific particle size classes (mm): 0.002, 0.063, 0.125, 0.250, 0.500, 1.000, and 2.000. Significant differences were observed in mid-range PSC (mm): 0.063, 0.125, 0.250, and 0.500. No significant difference was observed in PSC (mm): 0.002, 1.000, and 2.000. Thus, significant increases in mid-range PSC were observed at dredged material stations as compared wth native marine sediments. This results complements the relative difference in skewness reported above, in that, marine sediments influenced by dredged material exhibited a more normal PSD due to the introduction of mid-ranged PSC.

EPA versus CCI. Seven of the fourteen sites (MIA01-MIA05, MIA07, and MIA13) sampled during this EPA study overlapped with the stations sampled in 1985 by Conservation Consultants, Inc. (CCI). As discussed in Methods, CCI reported their findings in greater than 2.0, 2.0, 0.50, 0.25, 0.063, and 0.002 mm PSCs. For comparison, the PSC used by EPA were adjusted (mathematically) to match the PSC used by CCI. EPA did not use a dispersing agent prior to wet sieving. Consequently, the assumption was made that the dispersant agent used by CCI did not significantly change the PSD. Three methods of determining relative PSD: skewness, standard deviation, and chi-square.

By inspection, EPA sediment samples were shifted down-field (coarser PSC) as compared with CCI sediment samples (Figures 16–22). As evidenced by the cumulative percent distribution curves, this shift was especially pronounced in samples collected from Stations MIA03, MIA04, and MIA05. In order to emphasis this observation, skewness was plotted against standard deviation to determine the degree of separation between the EPA versus the CCI datasets (Figure 23). An excellent segregation of the EPA versus the CCI datasets was observed. Generally, EPA sediment samples were less skewed and had lower standard deviations as compared with CCI sediment samples. Consequently, EPA's dataset exhibited a more even PSD by the inclusion of coarser PSC with less deviation about the mean PSC as compared with the CCI dataset. As a final confirmation test of the above observations, chi-square distributions were compared between paired sets of data (EPA vs. CCI). Significant difference ($p < 0.025$) was observed in each of the seven paired datasets (Table 5b).

The above tests were not sensitive to a determination of which PSC was responsible for the difference between the datasets. Hence, the objective of next statistical test was to determine which PSC (between sample stations) were responsible for the significant different observed between the seven paired datasets. Using two-tailed t-tests of each PSC of EPA versus CCI, significant difference ($p < 0.025$) were observed in PSC 0.250, 0.500, 2.000, and greater than 2.000 mm. By inspection of the arithmetic means of paired PSC, the EPA means were higher than CCI in 0.063, 0.500, 2.000, and greater than 2.000 mm PSC (Table 5a).

Sediment Particle Size (Laser - EPA Dataset). PSD as determined by laser analyses were plotted on frequency and percent cumulative curves to distinguish between native marine sediments and sediments altered by dredge disposal activities (Figures 24-37). The patterns observed on these graphs show distinctive differences in how the PSC are distributed across the various stations related to their proximity to disposal activities as well as their position on the continental slope. Native marine sediments have distributions defined by smaller size fractions with little or no large particles present. This phenomenon is highlighted when D_{50} values (statistical median) for each station are compared (Figure 38). Stations that were located either within the active disposal area, or thought to have been erroneously dumped on, all have higher D_{50} values.

The relative degree of skewness was also plotted against the standard deviation to differentiate between native marine sediment and dredged material (Figure 39). The usefulness and value of comparing skewness and plotting it against the standard deviation has been previously discussed (see above discussion on wet sieve data). The clustering of stations as observed in Figure 39 show how the native marine sediments group together, differently from the other stations. The only anomalies seen are at Stations MIA04 and MIA05. The fact that MIA04 is shallower and closer to the continental shelf (tendency toward sandy sediments) would lead one to expect a less homogeneous PSD. The distribution of MIA05 sediments leads to the conclusion that the sample had a mixture of dredged material and native sediments.

Similar to wet sieve analysis, significant difference between stations on the laser generated analysis was tested using chi-square distribution ($\alpha = 0.05$, two-tailed) (Table 6). Significant difference was observed between MIA01, MIA03, MIA04, MIA05, MIA08, MIA09, MIA11, and MIA12. MIA02 was also observed to be significantly different from MIA10 and MIA13. However, no significant difference was observed between MIA01, MIA02, MIA06, MIA07, and MIA14. MIA03 was observed to be significantly different from MIA06, MIA07, and MIA14. However, no significant difference was observed between MIA03 as compared to MIA04 and MIA08 to MIA13. MIA04 and MIA05 were not significantly different from each other but were significantly different from MIA06, MIA07, MIA10, MIA12 to MIA14.

Based on the interpretation of the on-site sediment characterization, examination of percent PSC (wet sieve and laser methods), cumulative percent curves, and skewness, samples stations were stratified as native marine sediments, dredged material, and mixed sediments as follows:

Native Marine Sediments:		*Dredged Material:*		*Mixed Sediments:*
MIA01	MIA14	MIA03	MIA11	MIA04
MIA02		MIA08	MIA12	MIA05
MIA06		MIA09	MIA13	
MIA07		MIA10		

Sediment Chemical Analysis. No pesticides/ PCBs, extractables or nitrates/nitrites were observed above detection limits at the fourteen sample stations. Using a two-tailed t-test, a significant difference ($p < 0.025$) was observed between native versus dredged material for metals: barium, chromium, manganese, and sodium. By inspection of the means, the four metals were higher in native sediment as compared with dredged material (Table 7 and 8).

The only nutrient that was observed to be significantly different between native as compared with dredged material was total kjeldahl nitrogen (TKN). The mean TKN concentration in native sediments was nearly twice the mean concentration observed in dredged material (1128 versus 670 mg/kg, respectively).

In conjunction with on site sediment characterization, the particle size distribution of whole size classes and within specific particle size classes was significantly different between native marine sediments and dredged material.

A major finding of this study was observed by comparing the wet sieve analysis with the laser analysis. Through careful scrutiny of the laser data, two stations (MIA04 and MIA05) were found to be composed of "mixed" sediments. Consequently, the laser method provided better resolution demonstrating its ability to detect more subtle differences in PSD.

The two separate sediment grain size analyses, along with the follow-up statistical analyses, indicates that dredged material can be distinguished from the native marine sediments at the Miami ODMDS. The data also indicates that areas identified by sidescan sonar as potential dumps of dredged material outside the ODMDS are in fact errant dumps that have occurred. However, these types of conclusions should never be made based solely on a single method of analysis. An understanding of the whole environs (e.g., depth, location on the continental shelf vs. continental slope) is also critical to the data synthesis and interpretation for such a study.

The chemical data showed that four metals could be used to distinguish native sediments from the dredged materials. It is possible that this difference is a result of the higher percentages of finer particles (sites available for sorption) found in the native sediments.

The laser was observed to be more sensitive to subtle variation in particle size distribution as compared to the wet sieve method. Consequently, Stations MIA04 and MIA05 could be separated from the other stations. It should be pointed out that one shortfall of the laser analysis is the loss of comparability with the sample's size fraction above 2 mm. Wet sieve alone was not adequate to distinguish between these subtle variations in particle size distribution. However, depending upon the objectives of future studies, project leaders should use discretion in selecting the method that is best suited for meeting the data quality objectives and anticipated sediment properties encountered during the study.

Sediment samples were collected June 13, 2000 from the Miami Ocean Dredged Material Disposal by the US EPA, Region 4. The objectives of the study were to characterize selected representative areas of the sea floor from a sedimentological and chemical perspective, explore new methods of sediment collection and characterization where deep sea technology is required, and compare the results of this study against a previous site survey (Conservation Consultant, Inc in 1985). We hypothesized there was a significance difference between: 1) physical and chemical analyses of native marine sediments (reference) versus dredged material; and 2) historic (CCI) and current (EPA) particle size analysis of native marine sediments (reference) versus dredged material.

Based on the interpretation of the on-site sediment characterization, statistical analysis of percent particle size classes and cumulative percent curves (wet sieve and laser methods), samples stations were stratified as native marine sediments, dredged material, and mixed sediments as follows:

Native Marine Sediments:		*Dredged Material:*		*Mixed Sediments:*
MIA01	MIA14	MIA03	MIA11	MIA04
MIA02		MIA08	MIA12	MIA05
MIA06		MIA09	MIA13	
MIA07		MIA10		

A careful examination of the sediment regimes that are associated with native marine sediments (Stations MIA01, MIA02, MIA06, MIA07, and MIA14) shows those areas to be located along a similar depth profile on the continental slope. The physical characteristics of different sediment grain sizes means that each would be expected to have different erosional traits and settling rates. Areas such as the five stations listed above which are under similar physical processes, and outside the influence of different sources of material such as dredged material disposal, would be expected to show similar grain size distributions. This explains why these stations, while located far apart, exhibit the same distribution patterns seen in this study.

Seven of the fourteen sites (MIA01-MIA05, MIA07, and MIA13) sampled during this EPA study overlapped with the stations sampled in 1985 by CCI. By inspection of the differential distribution of particle size classes, EPA sediment samples were coarser grained as compared to CCI sediment samples. In addition, as evidenced by the cumulative percent distribution curves, this shift was especially pronounced in samples collected from Stations MIA03, MIA04, and MIA05. Using a chi-square distribution, EPA sediment samples at the seven common stations were significantly different from the CCI sediment samples.

We found the Young grab useful in sampling the deep sea stations of this study. However, the following cautionary measures are recommended when attempting to duplicate:

- Carefully exam the current conditions that exist at each location, including opposing currents beneath the pyncnocline, to ensure that minimal scope on the cable exists. If too much scope (angle on the cable) exists upon impact, the device will not 'grab' sufficient amounts of material and may not close properly. This type of occurrence will result in lost sediments on the retrieve or inadequate amounts of material, necessitating redeployment;

- Unless the device has a bottom pinger to warn of impending impact, careful attention to present depth, present cable-wrap counts, and tension on the cable are essential. Should you allow the device to sit on the bottom for any extended period of time, vessel movement may tip over the device and waste the time it took for that deployment. Additionally, stopping the cable from paying out any extra length beyond impact could result in cable weight tipping over the device or fouling; again, time wasted on deployment; and

- Special care is needed when subsampling the grab with smaller cores to prevent loss of vertical horizons and contamination of the chemical samples.

Because sampling in depths such as those at the Miami ODMDS requires significant amounts of time due to cable pay-out and retrieval, it is essential that each deployment not be wasted. Following the above recommendations can reduce the amount of ship time necessary to complete such a study.

In conclusion, the methods used in this study are sufficient to distinguish dredged material from native marine sediments at the Miami ODMDS. This can in large part be attributed to the differences in sediment characteristics of the deep slope sediments found at the Miami ODMDS contrasted with the material being dredged for the Miami Harbor area.

CCI.1985. Environmental Survey in the Vicinity of An Ocean Dredged Material Disposal Site, Miami Harbor, Florida. Report to EPA by Conservation Consultants, Inc. December, 1985. 55 pgs.

USEPA. 1996. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. US Environmental Protection Agency, Region 4. Athens, GA.

USEPA. 1998. Draft Standard Operation Procedures Ecological Assessment Branch. US Environmental Protection Agency, Region 4. Athens, GA.

USEPA. 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. EPA-670 / 4-73-001.

Table 1. Data quality objectives.

DQO Step	DQO Description	Remarks
Statement of Problem	Disposal of dredged materials can adversely affect ocean benthic communities	
Decision	Management decision on future disposal practices at the site	
Objective	Characterize selected representative areas of the seafloor from a sedimentological and chemical perspective	
Testable Hypothesis 1	Null: No significant difference native marine sediments (reference) and dredged material (physical and chemical analysis)	Alternative: significant difference between reference and disposal site
Testable Hypothesis 2	Null: No significant difference between historic (CCI) and present (EPA) particle size analysis of native marine sediments (reference) versus the dredged material	Alternative: significant difference between historic and present PSD
Statistical Tests	Descriptive, Normality, skewness, Chi-Square, t-test of means	
Acceptable Error and Limits	$\alpha = 0.05$	MDL: Wet Sieve = 2 µm Laser = 0.375 µm
Sample Size	Variance about the mean	

Table 2: On-site, visual and textural sediment characterization: Miami, Florida ocean dredged material disposal site (Page 1 of 2).

STA	LAT/LONG	WATER DEPTH (ft)	STRATA	MUNSELL COLOR	TEXTURE	REMARKS
MIA01	25º47.079' / 80º03.383'	605	None	5Y 6/2	Fine Sandy Clay Loam	No Strata; Few masses (5/10B); No limestone gravel; No shell fragments; No odor
MIA02	25º46.117' / 80º03.432'	570	None	5Y 6/2	Fine Sandy Clay Loam	No Strata; Few masses (5/10B); No limestone gravel; No shell fragments; No odor
MIA03	25º45.388' / 80º03.360'	566	Surface	5Y 6/2	Fine to Medium Sandy Clay Loam	Infrequent shell fragments; No odor; No limestone gravel
			Subsurface	5/10B	Fine to Medium Sandy Clay Loam	Common Shell Fragments 1-3mm; No odor; No limestone gravel
MIA04	25º44.999' / 80º04.461'	270	None	5Y 7/1	Fine Sandy Loam	No Strata; No limestone gravel; Infrequent small shell fragments; no odor; large polychaete
MIA05	25º45.311' / 80º03.413'	550	Surface	5Y 6-7/1	Fine Sand	Thin veneer
			Subsurface	5Y 5/1	Silt Loam	No distinct boundary; Calcareous clays mixed with numerous shell fragments; No odor; No limestone gravel
MIA06	25º45.00' / 80º02.58'	720	None	5Y 6/3	fine Sandy Clay Loam	No Strata; Infrequent, small shell fragments <2mm, no odor; No limestone gravel; plasticity; calcareous sediment; no benthic
MIA07	25º44.00' / 80º03.367'	550	None	5Y 6/1	fine Sandy Clay Loam	No Strata; Infrequent, small shell fragments 2-4 mm; few masses (5/5BG); whole small shells on surface; no odor; No limestone gravel; possibly one polychaete
			masses	5/5BG		

Table 3: On-site, visual and textural sediment characterization: Miami, Florida ocean dredged material disposal site (Page 2 of 2).

STA	LAT/LONG	WATER DEPTH (ft)	STRATA	MUNSELL COLOR	TEXTURE	REMARKS
MIA08	25º45.337' / 80º03.777'	440	Surface	5Y 6/2	Fine to Medium Sandy Clay Loam	Infrequent shell fragments; No odor; Common small to medium limestone gravel
			Subsurface	5/10B	Fine to Medium Sandy Clay Loam	Common shell fragments 1-3mm; Some HS^- odor on underside of bluish-green limestone gravel
MIA09	25º45.894' / 80º04.315'	310	none	5Y 6/2	Fine to Medium Sandy Clay Loam	No Strata; No limestone gravel; Infrequent shell fragments; No odor
MIA10	25º45.357' / 80º04.227'	321	None	n/a	n/a	Limestone gravel sized on-site; representative sample returned to EAB Sediment Laboratory
MIA11	25º45.043' / 80º04.009'	373	None	5Y 5/2	Fine-Med. Sandy Clay Loam	No Strata; Common limestone gravel; Infrequent shell fragments; No odor; Frequent polychaetes
MIA12	25º44.467' / 80º03.561'	500	Surface	5Y 6/3	Sandy Loam	Stratified; infrequent small shell fragments 1-3 mm; No odor; No limestone gravel
			Subsurface	2.5Y 6/1	Silt Loam	Frequent shell fragments 1-3mm; No odor; No limestone gravel
MIA13	25º44.396' / 80º03.976'	370	None	5Y 6/2	Silt Loam w/ Fine Sand	No Strata; Small shell fragments <2mm; No odor; Plasticity; calcareous sediment; No benthic; No limestone gravel
MIA14	25º45.070' / 80º03.027'	795	Surface	5Y 6/3	Fine Sand	Numerous small shell fragments; No odor; No benthic
			Subsurface	5Y 6/1-2	Fine-coarse Sandy Loam	Larger shell fragments (2-4mm) than surface strata; Common limestone gravel; Calcareous sand

Table 4. Chi-square distribution, wet sieve method using all particle size classes (highlighted values not significant at $p < 0.025$).

Station	MIA01	MIA02	MIA03	MIA04	MIA05	MIA06	MIA07	MIA09	MIA10	MIA11	MIA12	MIA13	MIA14
	MIA01	9.1	136.4	155.4	135.1	1.1	18.6	44.5	90.8	81.3	83.7	12228	49.3
		MIA02	82.8	96.5	81.1	19.4	6.2	20.9	55.9	43.2	44.9	8873	36.4
			MIA03	8.6	12.5	190	76.1	28.8	75.9	19	29	1215.6	212.6
				MIA04	2.7	215.3	72.2	24.6	53	11.8	28	2990	142.3
					MIA05	215	56.5	23.7	56	4.4	14.4	2966	113.6
						MIA06	17.8	38.5	88.1	75.1	82	13419	45.1
							MIA07	20.1	50.4	35.3	28.6	4697	38.4
								MIA09	41.9	11.2	28.5	9507	60.4
									MIA10	66.2	127.3	1540	19.7
										MIA11	6.5	4107	66.2
											MIA12	1828	57.9
												MIA13	195.6
													MIA14

Table 5a. Descriptive statistics: EPA versus CCI (wet sieve)

Size Class	Valid N	Mean	Median	Minimum	Maximum	Variance	Std.Dev.	Skewness	Kurtosis
EPA 0.002	7	0.9	0.8	0.6	1.3	0.07	0.27	0.83	-0.78
CCI 0.002	7	2.0	0.0	0.0	14.0	28.00	5.29	2.65	7.00
EPA 0.063	7	31.3	32.7	15.1	53.9	219.17	14.80	0.45	-1.23
CCI 0.063	7	24.3	24.0	9.0	38.0	73.57	8.58	-0.35	2.38
EPA 0.25	7	44.8	46.3	23.4	57.7	127.78	11.30	-1.09	1.71
CCI 0.25	7	69.9	73.0	61.0	75.0	28.14	5.30	-1.04	-0.50
EPA 0.5	7	12.5	13.1	2.7	20.3	29.38	5.42	-0.66	1.71
CCI 0.5	7	2.2	2.0	0.3	7.0	4.92	2.22	2.17	5.22
EPA 2	7	6.3	6.2	1.1	11.3	17.52	4.19	-0.20	-1.82
CCI 2	7	1.5	1.0	0.3	5.0	2.48	1.57	2.50	6.48
EPA >2	7	4.2	1.8	0.1	20.6	53.58	7.32	2.51	6.44
CCI >2	7	0.2	0.0	0.0	1.0	0.14	0.38	2.14	4.49

Table 5b. Chi-square distribution

(EPA vs. CCI, wet sieve)

Station	Chi-Square	p-value
MIA01	31.78	0.0000
MIA02	169.85	0.0000
MIA03	191.57	0.0000
MIA04	38.90	0.0003
MIA05	467.12	0.0000
MIA07	92.56	0.0000
MIA13	79.55	0.0000

Table 6. Chi-square distributions, laser particle size using < 2 mm fraction (highlighted values not significant at $p < 0.025$).

Station	MIA01	MIA02	MIA03	MIA04	MIA05	MIA06	MIA07	MIA08	MIA09	MIA10	MIA11	MIA12	MIA13	MIA14
MIA01		10.6	20.4	64.3	62.7	0.6	1.2	25.7	26.1	10	28.5	14.8	9.6	7.6
MIA02			40.4	101	85.7	7.1	4	44.1	45.3	31	54.6	26.2	26.5	4
MIA03				13.7	16.2	31	39.6	5.5	4.6	5.3	4.8	7.8	4.6	72
MIA04					4.3	112.1	122.4	14.2	12.1	48.7	11.3	253.2	33.6	185.9
MIA05						127.7	146.5	10	8.7	343.5	9.4	3694.2	49.5	194
MIA06							1.5	26	26	12.5	29.9	14.7	10.2	8.6
MIA07								29.6	30.4	14.6	35	16.4	13.2	3.9
MIA08									0.4	354.3	1	4095.8	18.9	90.5
MIA09										290	0.5	3350.3	14.7	88
MIA10											7.7	3.8	3.1	38.5
MIA11												3512.7	15.8	92.2
MIA12													7.1	63.8
MIA13														43
MIA14														

Table 7. Metals and nutrient scans, Miami ODMDS, flagged values removed (Page 1 of 2).

Station	Analyte																			
	Al	**Al-DM**	**Sb**	**Sb-DM**	**As**	**As-DM**	**Ba**	**Ba-DM**	**Ca**	**Ca-DM**	**Cr**	**Cr-DM**	**Fe**	**Fe-DM**	**Pb**	**Pb-DM**	**Mg**	**Mg-DM**	**Mn**	**Mn-DM**
MFL1	2100		0.11		1.2		18		340000		11		1500		2.8		11000		29	
MFL2	1900		0.1		1.4		15		280000		9.9		1500		2.9		9100		22	
MFL3		1900				2.3		6.6		130000		7.8		2200		3.8		2700		12
MFL4		800		0.11				11		360000		8.8		730		1.6		13000		15
MFL5		1600				2.3		5.7		150000		7.6		2100		4.3		2400		9.2
MFL6	2200		0.15		1.4		20		340000		12		1600		1.7		9600		32	
MFL7	1700		0.15		1.3		14		270000		9.2		1400		2.2		7800		22	
MFL8		1400		0.12		1.5		5.7		160000		6.3		1200		1.8		3000		9
MFL9		1200		0.16				11		350000		9.8		910		2.1		12000		19
MFL10		1100				1.1		9.5		270000		7.8		940		1.9		8700		18
MFL11		1400		0.11				8.9		250000		7.9		1000		1.9		7200		17
MFL12		1300		0.1		1.4		8.6		220000		7.3		1200		1.8		5900		15
MFL13		1400						11		320000		8.8		1000		1.9		10000		20
MFL14	1300						11		220000		7.7		1200		1.6		5400		19	
min	1300	800	0.1	0.1	1.2	1.1	11	5.7	220000	130000	7.7	6.3	1200	730	1.6	1.6	5400	2400	19	9
max	2200	1900	0.15	0.16	1.4	2.3	20	11	340000	360000	12	9.8	1600	2200	2.9	4.3	11000	13000	32	20
Arith. Mean	1840	1344	0.13	0.12	1.3	1.7	16	8.7	290000	245556	9.96	8.01	1440	1253	2.24	2.34	8580	7211	24.80	14.91
Std. Dev.	358	309	0.03	0.02	0.1	0.5	4	2.2	50990	87050	1.65	1.01	152	529	0.60	0.98	2115	4022	5.45	4.07

Table 8. Metals and nutrient scans, Miami ODMDS, flagged values removed (Page 2 of 2).

	Analyte															
Station	**Na**	**Na-DM**	**Sr**	**Sr-DM**	**V**	**V-DM**	**Y**	**Y-DM**	**Zn**	**Zn-DM**	**NH3-N**	**NH3-N-DM**	**TKN**	**TKN-DM**	**TP**	**TP-DM**
MFL1	12000		4300		5.5		5.3		11		11		1300		340	
MFL2	11000		3300		5.4		4.7		13		14		1200		320	
MFL3		6400		910		5		4.6		11		5.9		530		470
MFL4		9200		4800				4.7				10		530		290
MFL5		5800		910		4.7		4		9.4				480		260
MFL6	12000		4100		6.3		5.7		12		9		1200		340	
MFL7	9400		3100				4.1		14		12		1100		290	
MFL8		5100		890		4.3		4.2		9.1		11		390		390
MFL9		11000		4400				4.8				13		810		290
MFL10		13000		2800				3.9		12		18		960		340
MFL11		8800		2600		4		4.2				8.9		690		340
MFL12		8300		2500		3.9		3.2				6.9		730		200
MFL13		10000		3800				4.6				10		910		280
MFL14	8300		2200		3.8		3.3				11		840		190	
min	8300	5100	2200	890	3.8	3.9	3.3	3.2	11	9.1	9	5.9	840	390	190	200
max	12000	13000	4300	4800	6.3	5	5.7	4.8	14	12	14	18	1300	960	340	470
Arith. Mean	10540	8622	3400	2623	5.3	4.4	4.6	4.2	12.5	10.4	11.4	10.5	1128	670	296	318
Std. Dev.	1643	2562	843	1508	1.0	0.5	1.0	0.5	1.3	1.4	1.8	3.8	176	200	63	79

Figure 1. Miami ODMDS station locations.

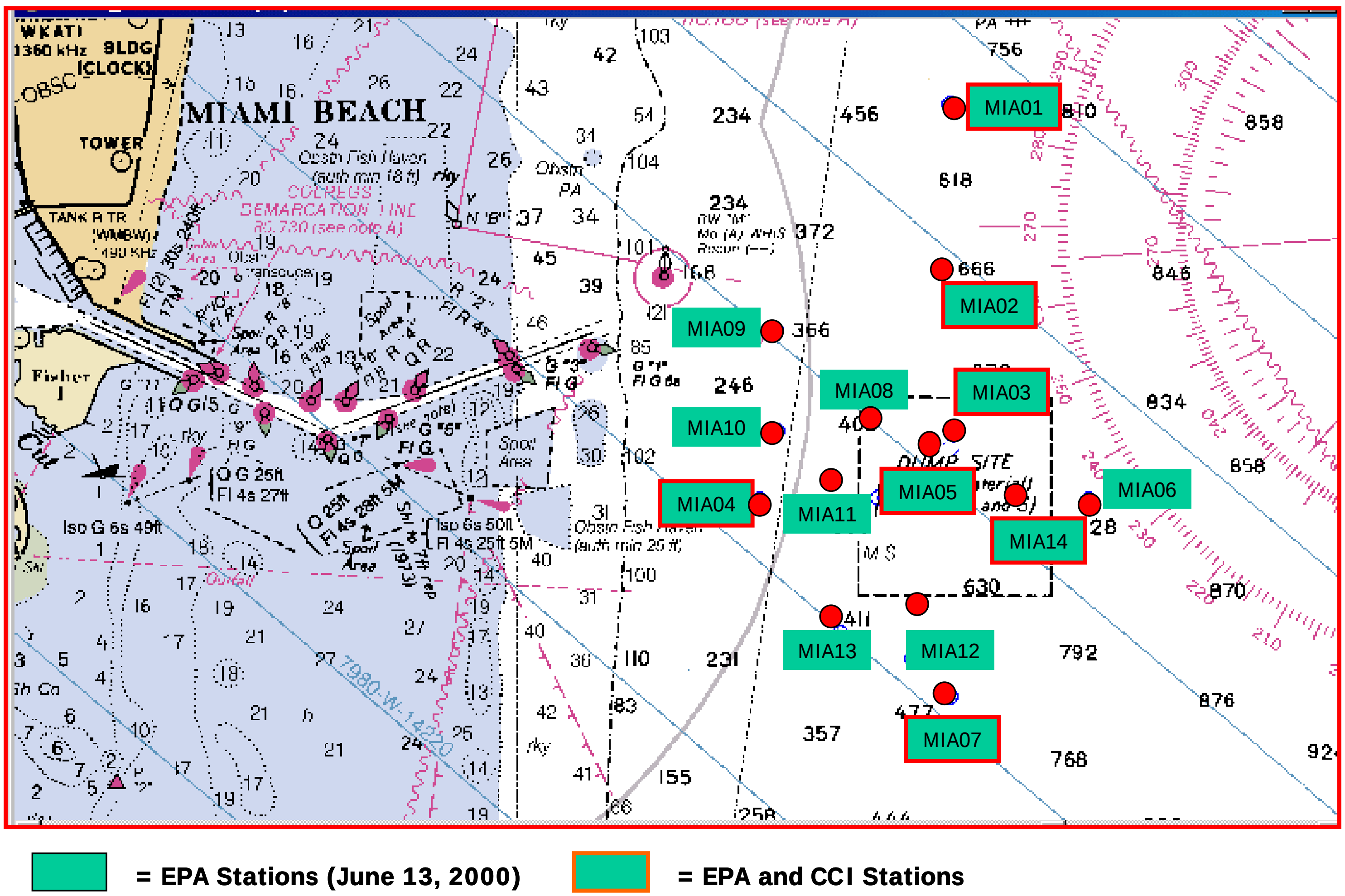


Figure 2. Wet Sieve Particle Size Distribution - Station MIA01 (Miami ODMDS)

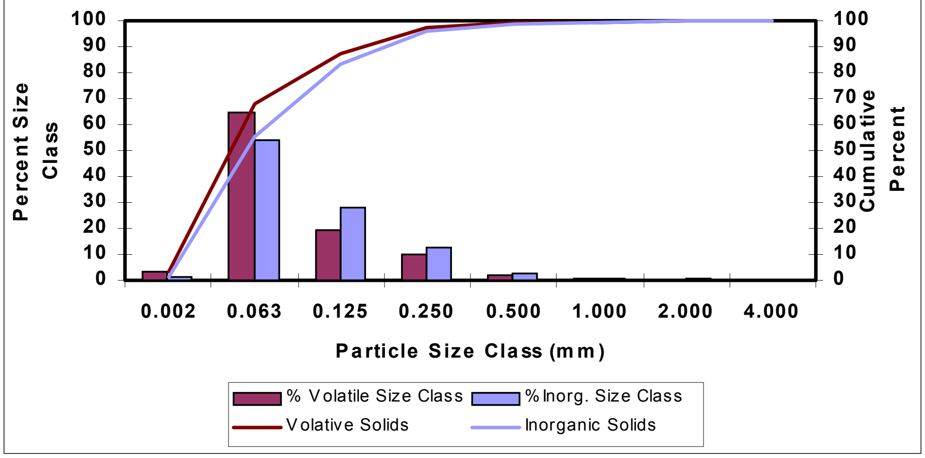


Figure 3. Wet Sieve Particle Size Distribution - Station MIA02 (Miami ODMDS)

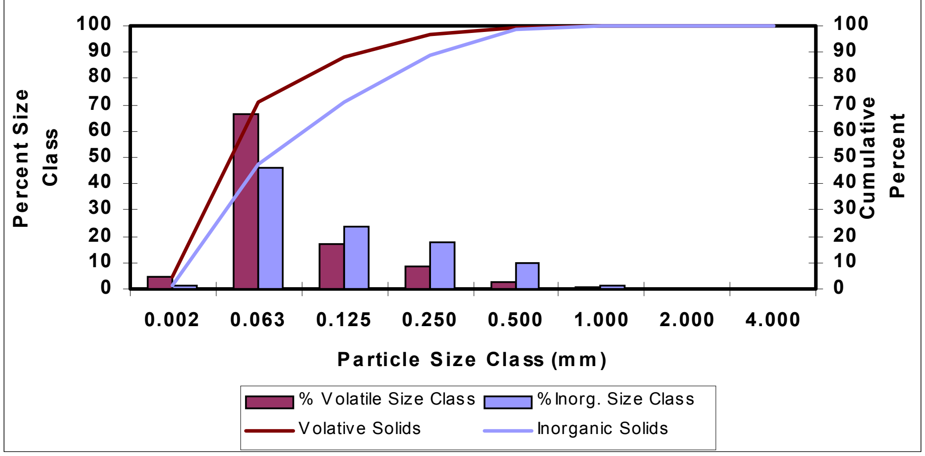


Figure 4. Wet Sieve Particle Size Distribution - Station MIA03 (Miami ODMDS)

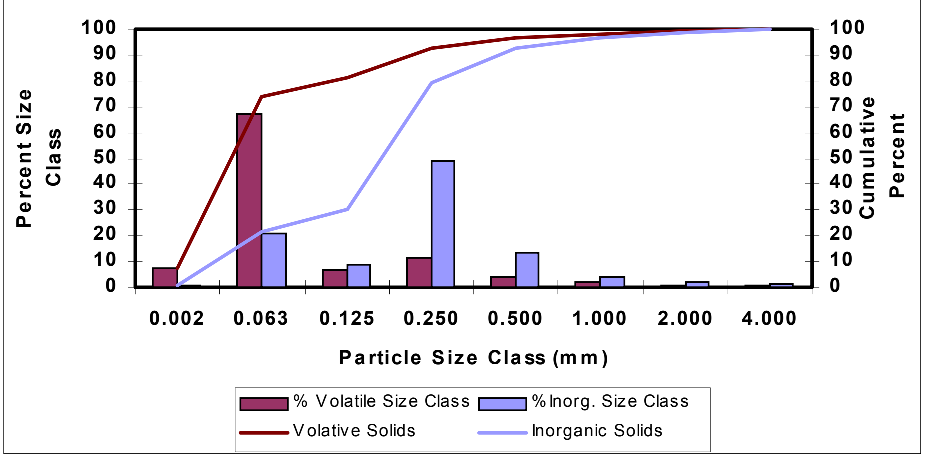


Figure 5. Wet Sieve Particle Size Distribution - Station MIA04
(Miami ODMDS)

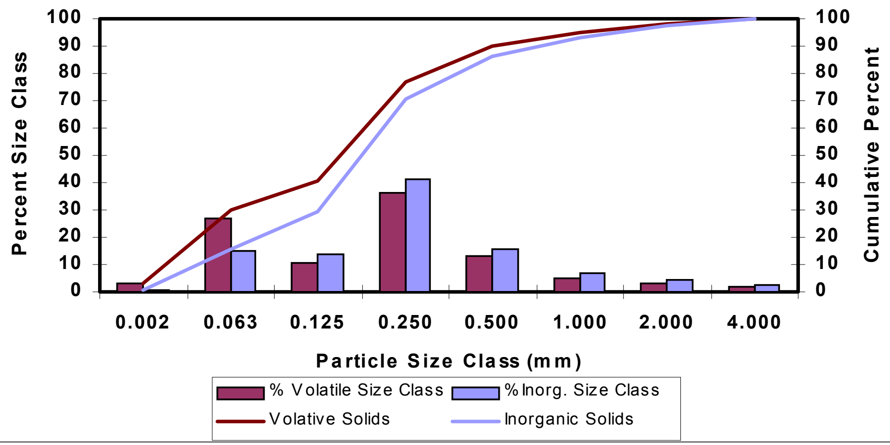


Figure 6. Wet Sieve Particle Size Distribution - Station MIA05
(Miami ODMDS)

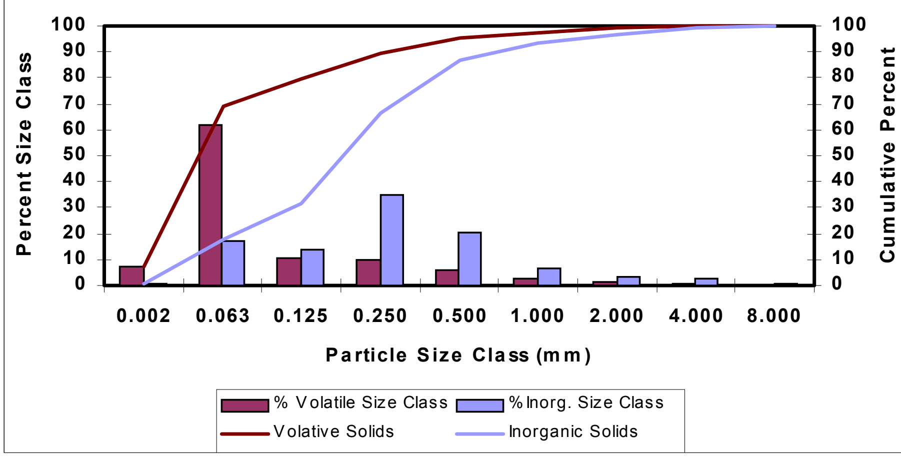


Figure 7. Wet Sieve Particle Size Distribution - Station MIA06
(Miami ODMDS)

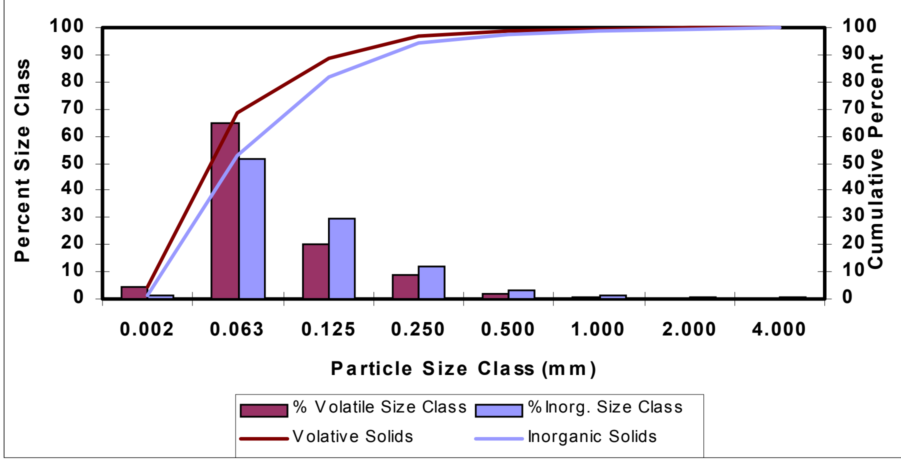


Figure 8. Wet Sieve Particle Size Distribution - Station MIA07
(Miami ODMDS)

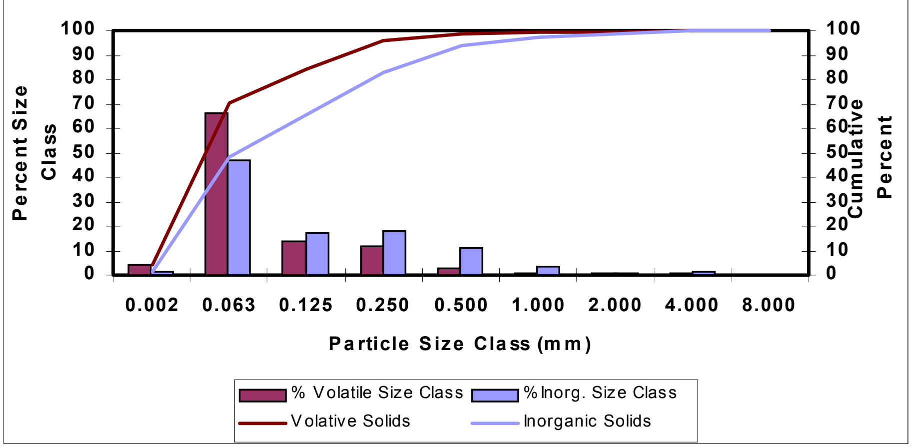


Figure 9. Wet Sieve Particle Size Distribution - Station MIA09
(Miami ODMDS)

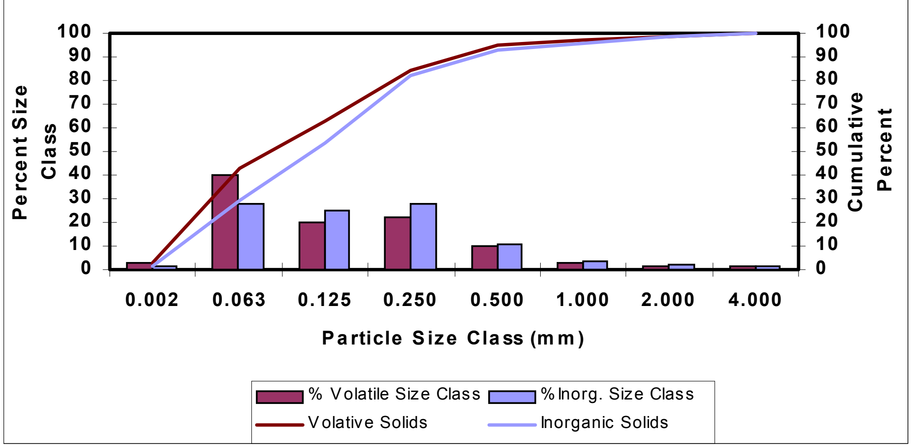


Figure 10. Wet Sieve Particle Size Distribution - Station MIA10
(Miami ODMDS)

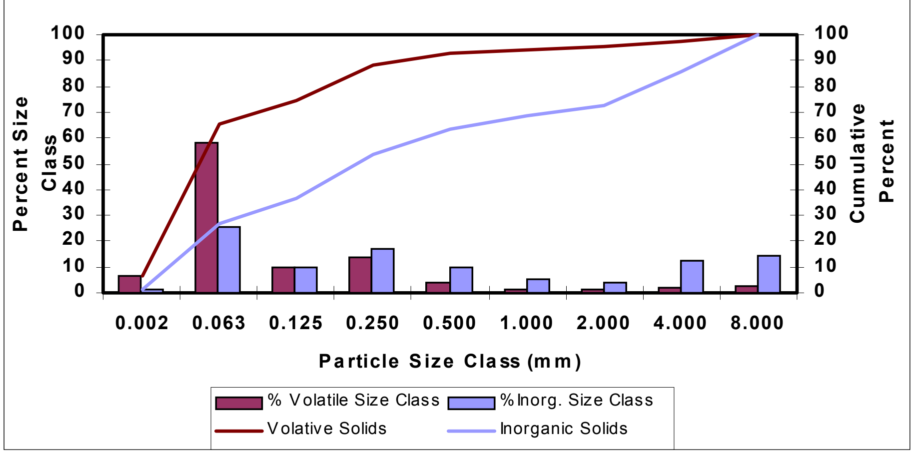


Figure 11. Wet Sieve Particle Size Distribution - Station MIA11 (Miami ODMDS)

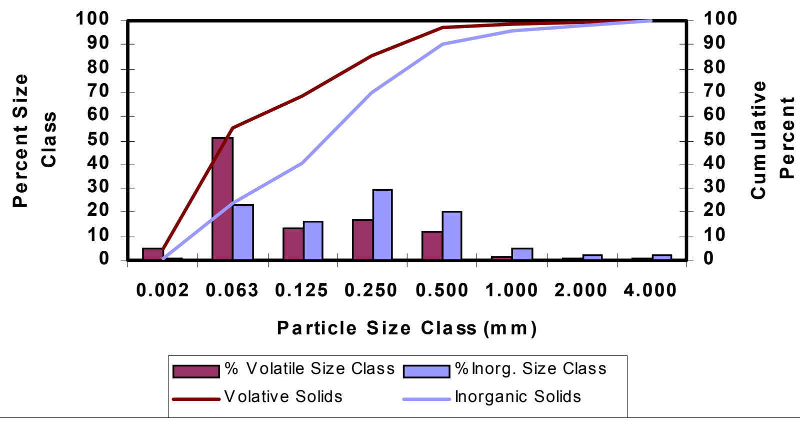


Figure 12. Wet Sieve Particle Size Distribution - Station MIA12 (Miami ODMDS)

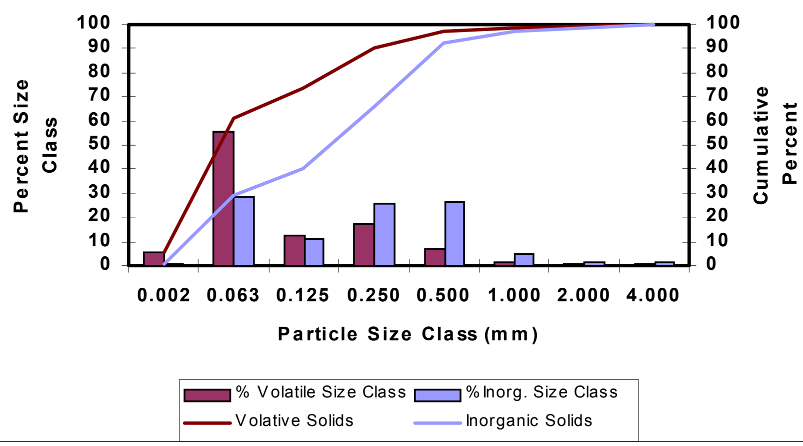


Figure 13. Wet Sieve Particle Size Distribution - Station MIA13 (Miami ODMDS)

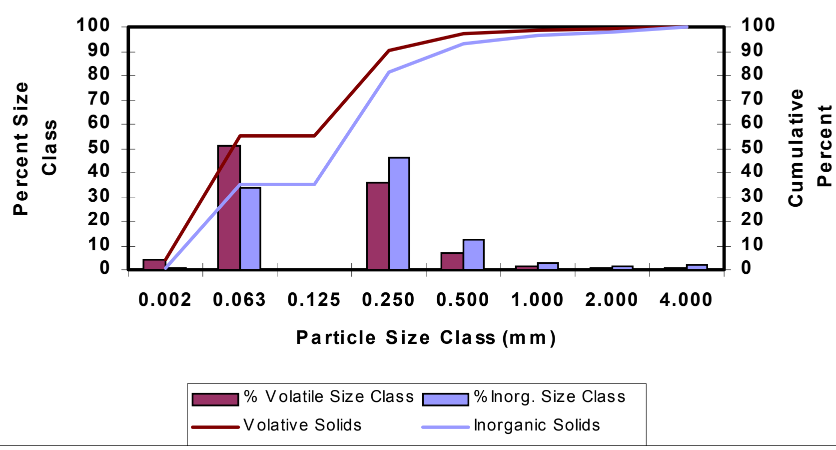


Figure 14. Wet Sieve Particle Size Distribution - Station MIA14 (Miami ODMDS)

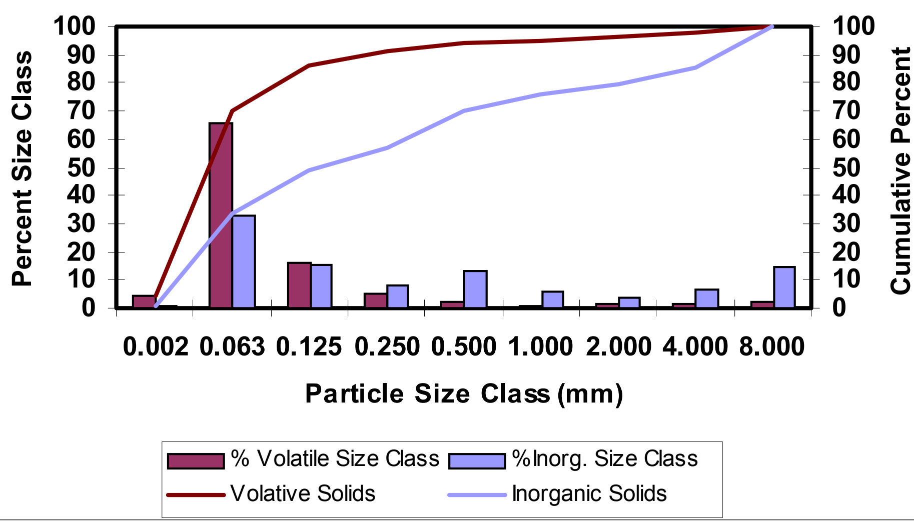


Figure 15. Wet Sieve Particle Size Distribution Using Skewness
(EPA Data, All Particle Size Classes)

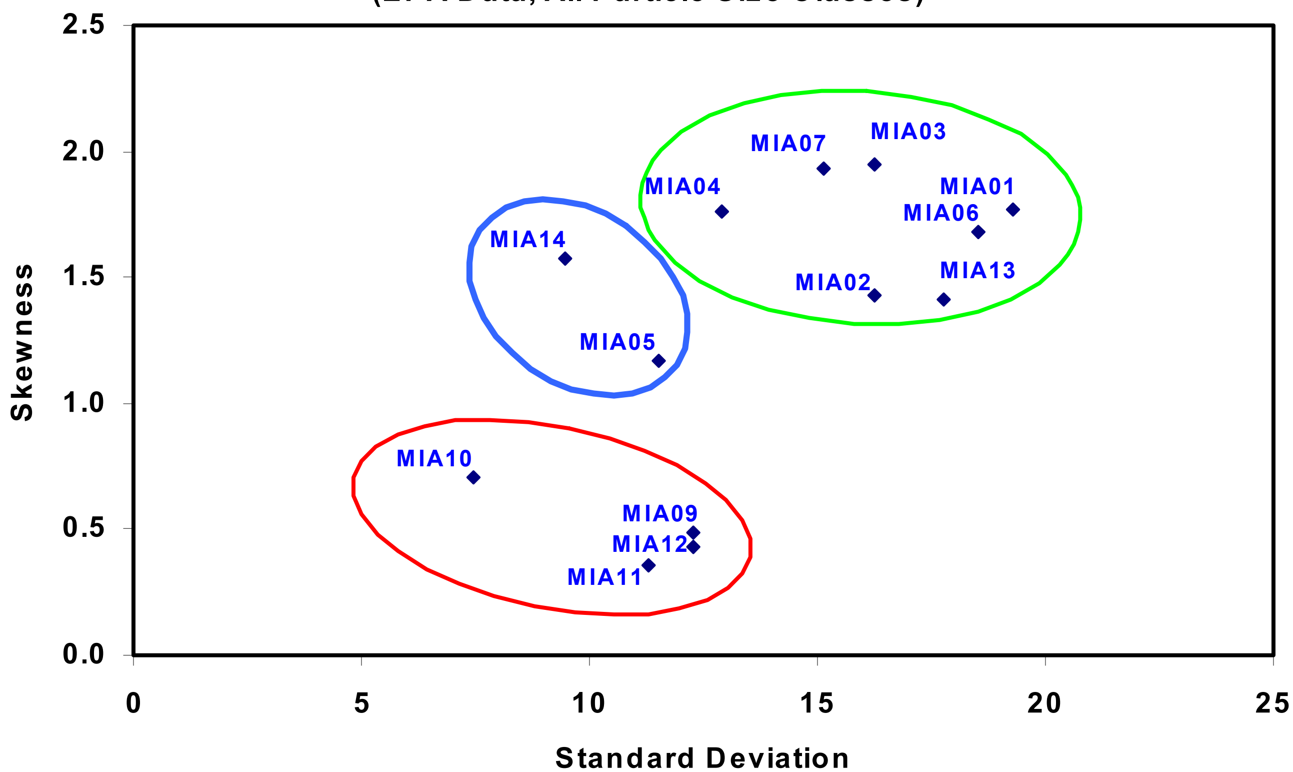


Figure 16. Wet Sieve Particle Size Distribution - Station MIA01 (EPA vs. CCI)

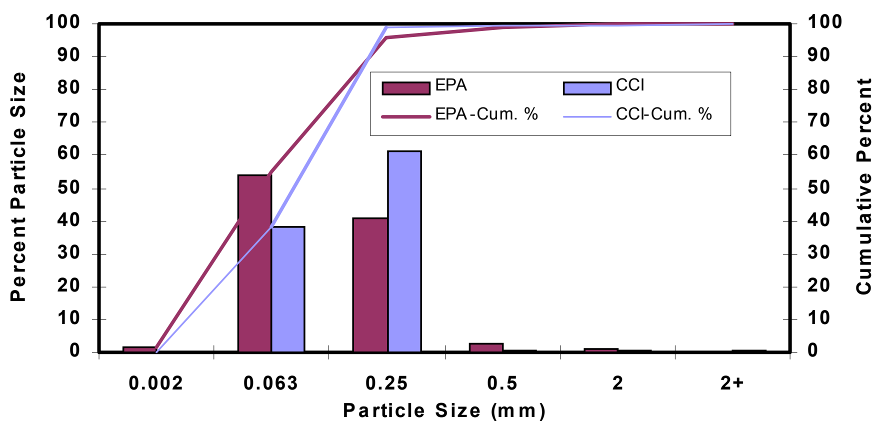


Figure 17. Wet Sieve Particle Size Distribution - Station MIA02 (EPA vs. CCI)

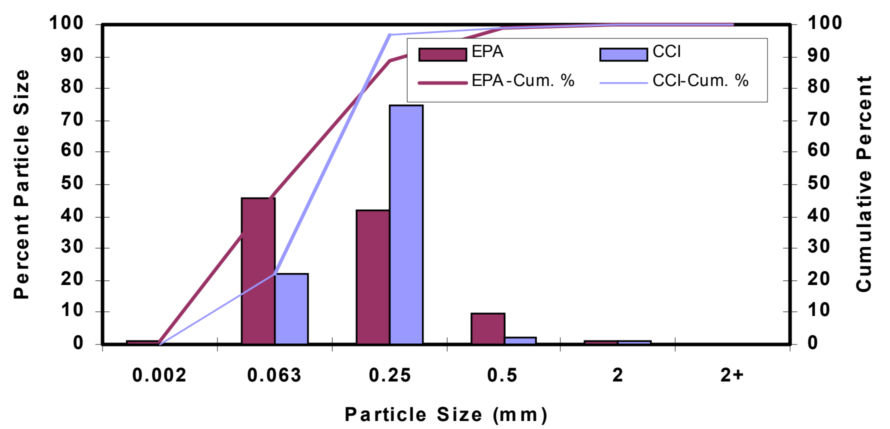


Figure 18. Wet Sieve Particle Size Distribution - Station MIA03 (EPA vs. CCI)

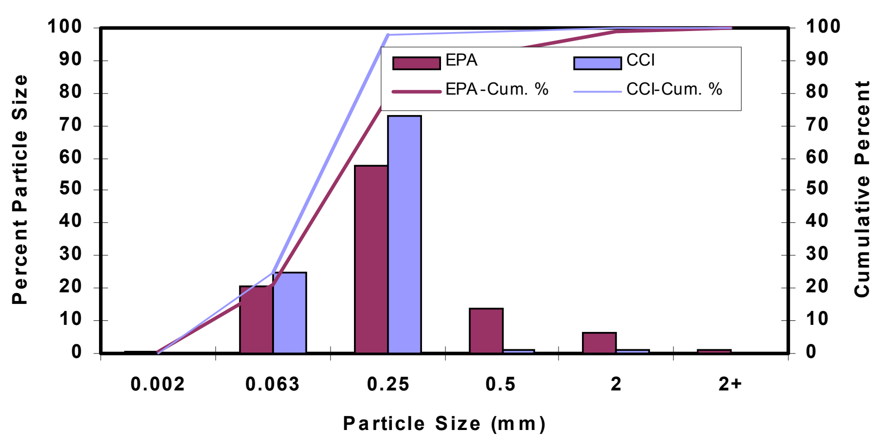


Figure 19. Wet Sieve Particle Size Distribution - Station MIA04
(EPA vs. CCI)

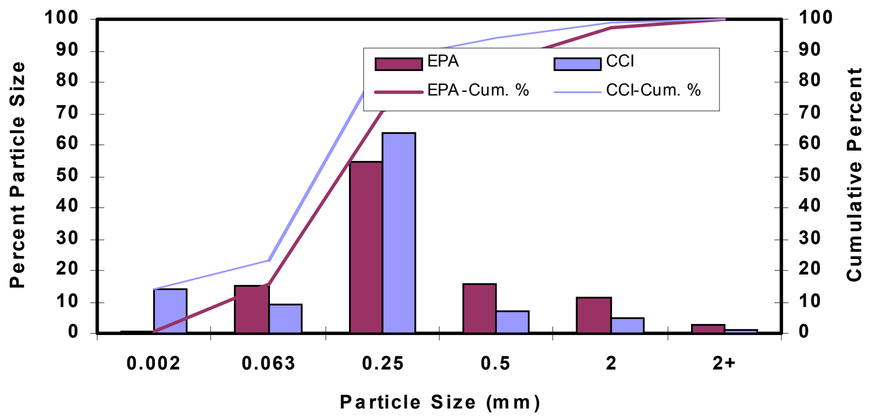


Figure 20. Wet Sieve Particle Size Distribution - Station MIA05
(EPA vs. CCI)

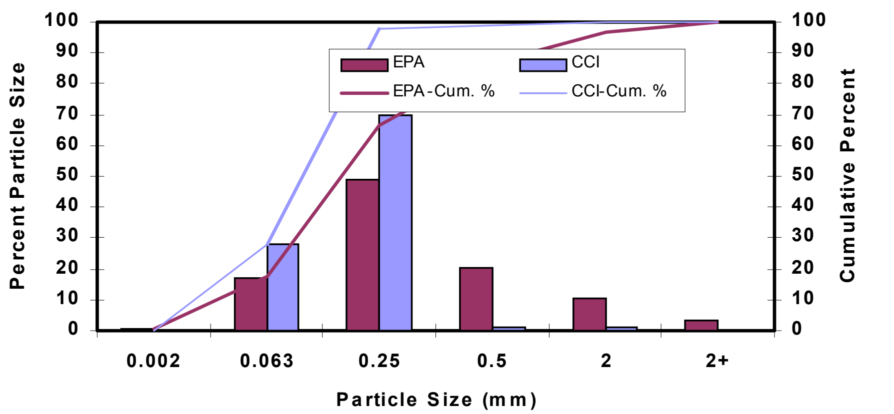


Figure 21. Particle Size Distribution - Station MIA07
(EPA vs. CCI)

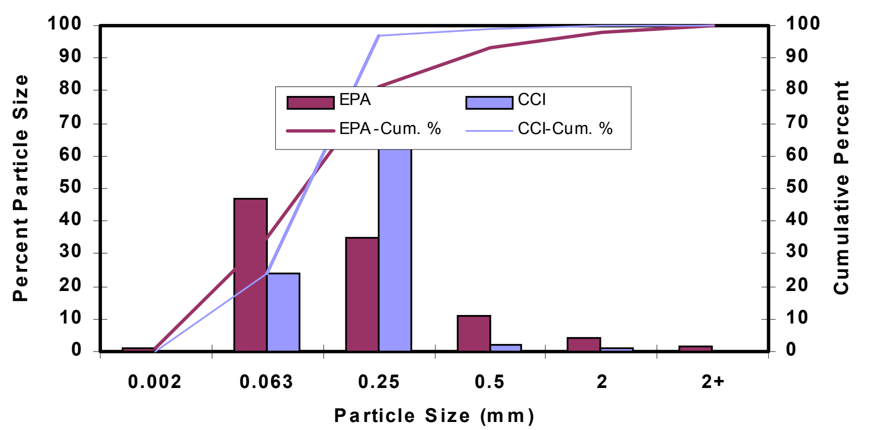
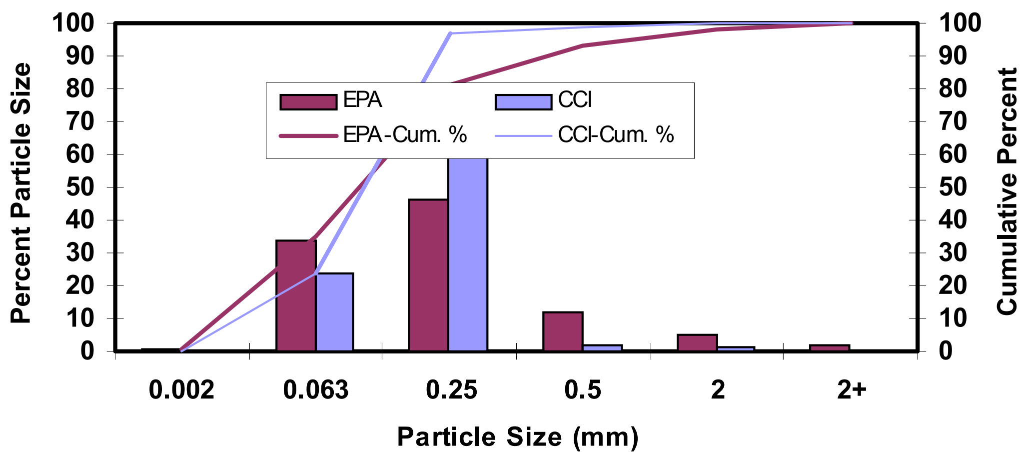


Figure 22. Particle Size Distribution - Station MIA13
(EPA vs. CCI)



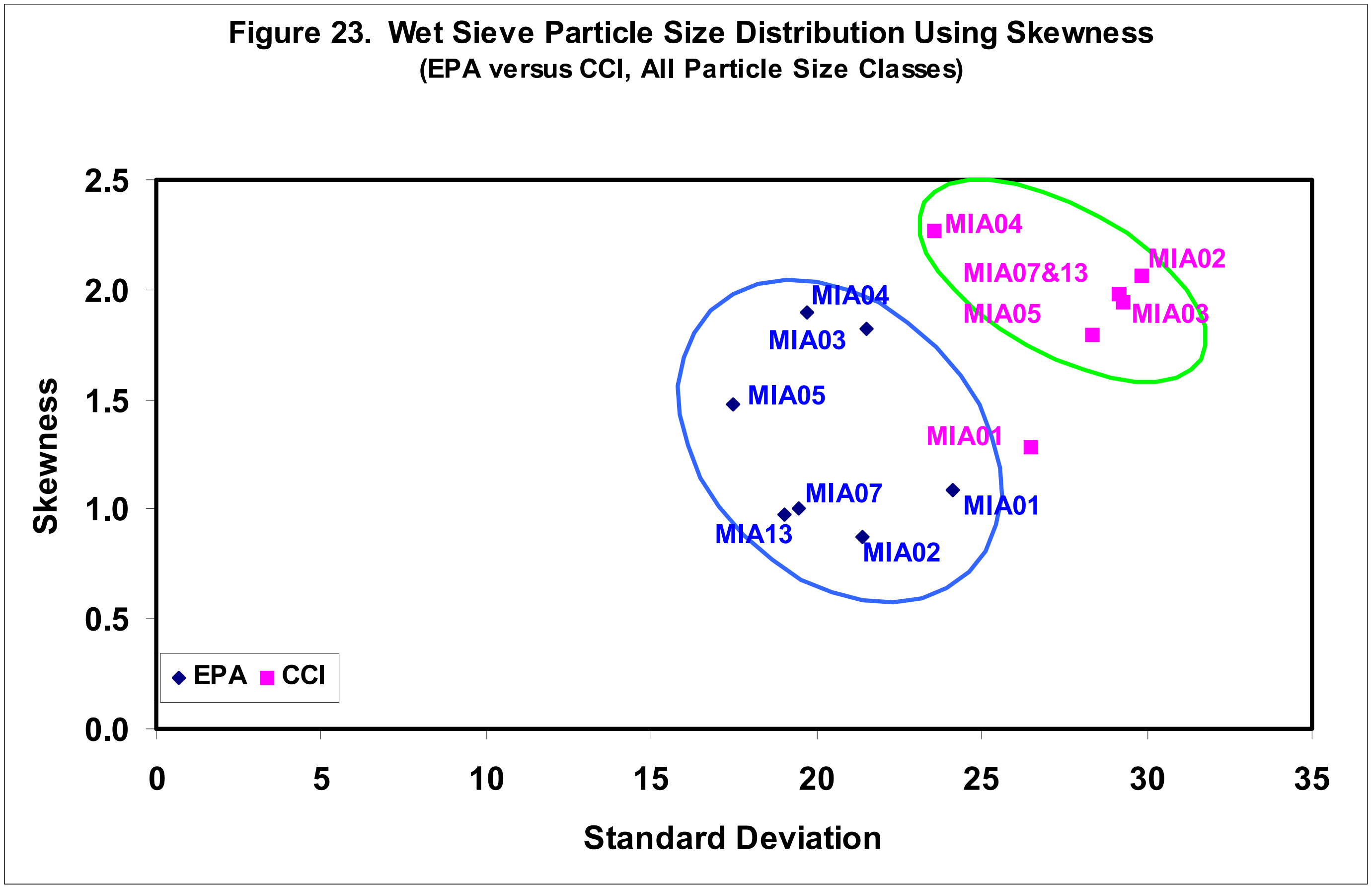


Figure 23. Wet Sieve Particle Size Distribution Using Skewness
(EPA versus CCI, All Particle Size Classes)
Skewness
Standard Deviation
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
25
30
35
MIA04
MIA03
MIA05
MIA07
MIA13
MIA02
MIA01
MIA04
MIA07&13
MIA02
MIA05
MIA03
MIA01
EPA
CCI

Figure 24. Particle Size Distribution < 2 mm - Station MIA01 (Miami ODMDS)

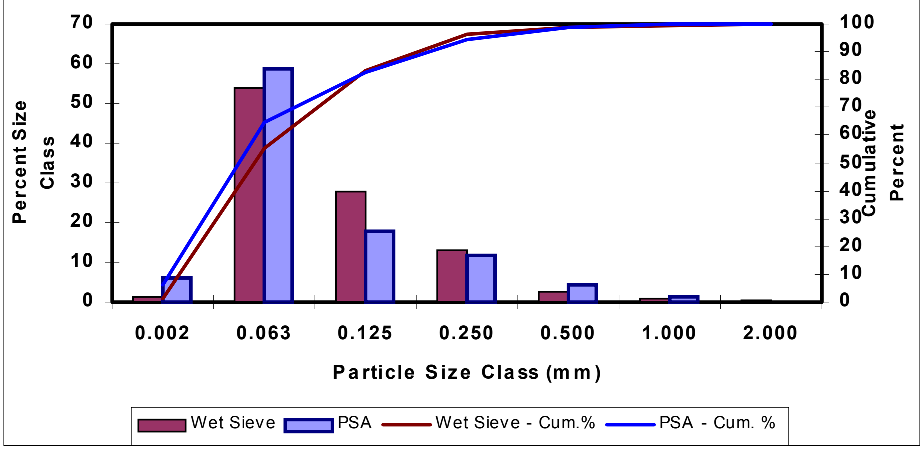


Figure 25. Particle Size Distribution < 2 mm - Station MIA02 (Miami ODMDS)

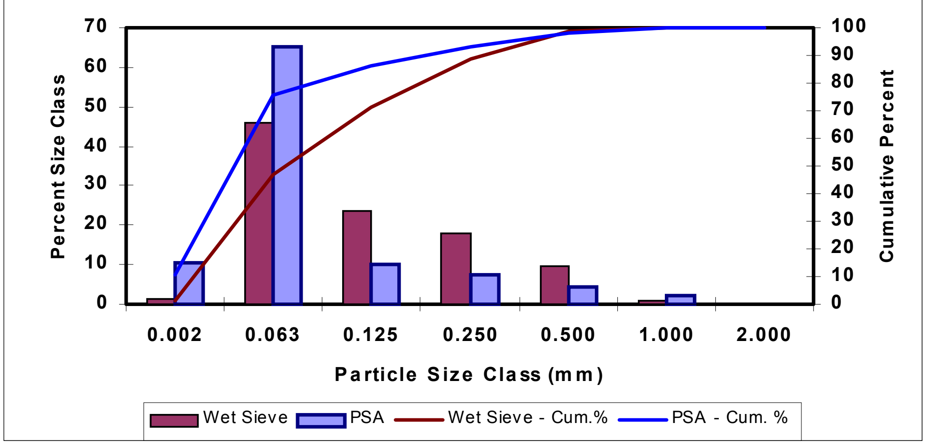


Figure 26. Particle Size Distribution < 2 mm - Station MIA03 (Miami ODMDS)

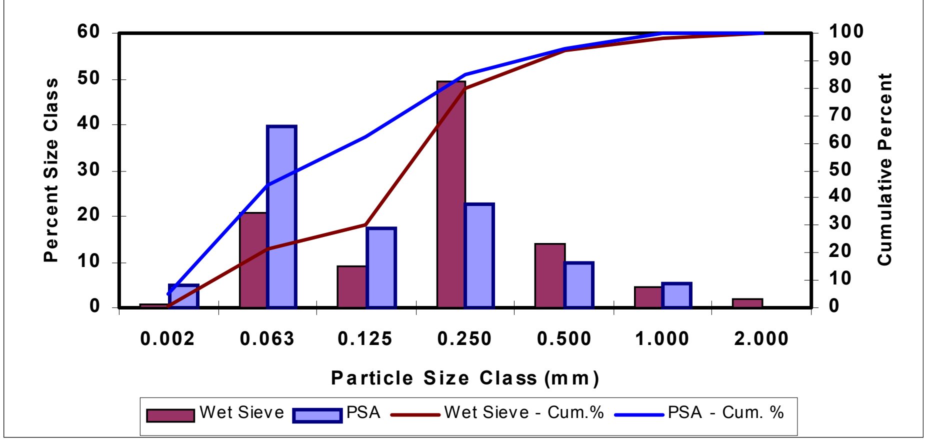


Figure 27. Particle Size Distribution < 2 mm - Station MIA04 (Miami ODMDS)

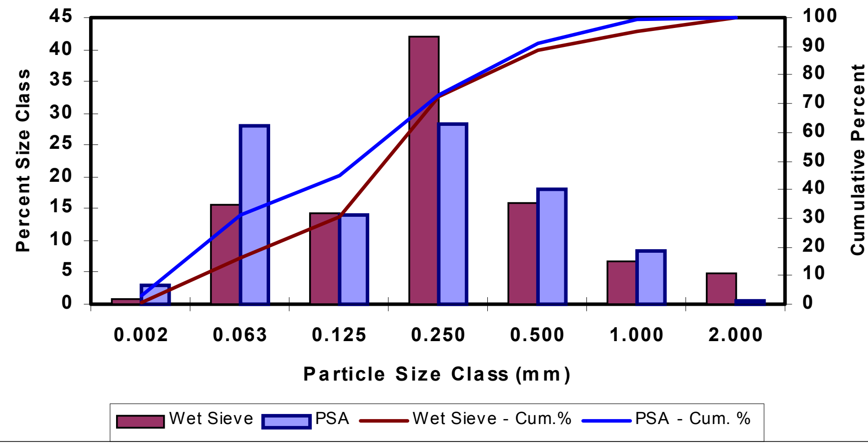


Figure 28. Particle Size Distribution < 2 mm - Station MIA05 (Miami ODMDS)

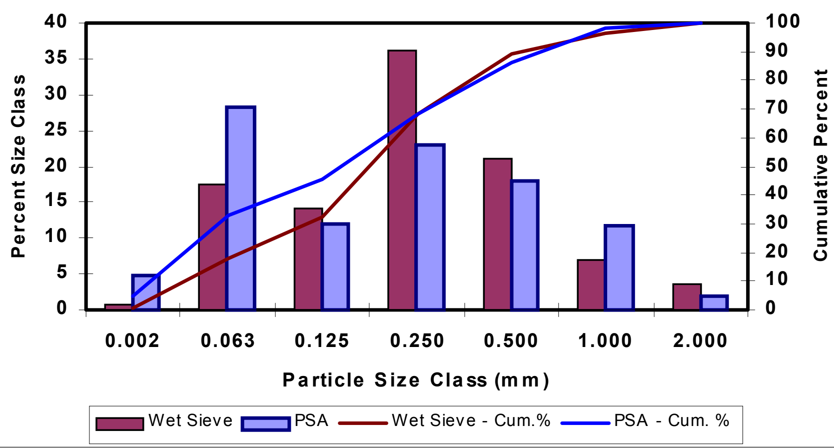


Figure 29. Particle Size Distribution < 2 mm - Station MIA06 (Miami ODMDS)

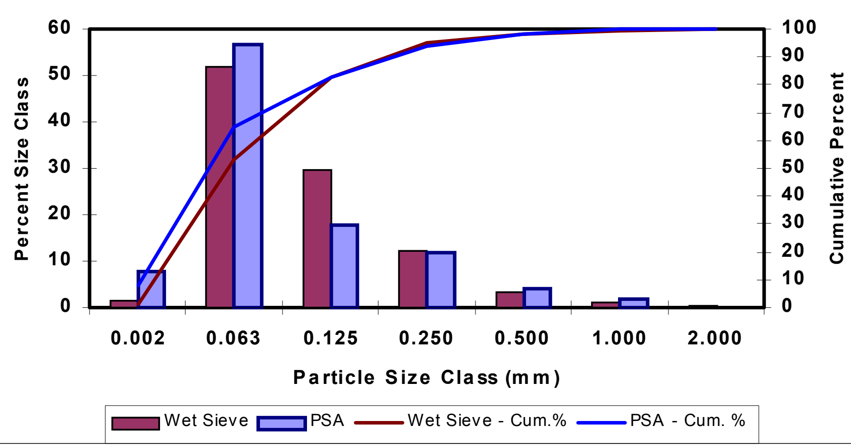


Figure 30. Particle Size Distribution < 2 mm - Station MIA07 (Miami ODMDS)

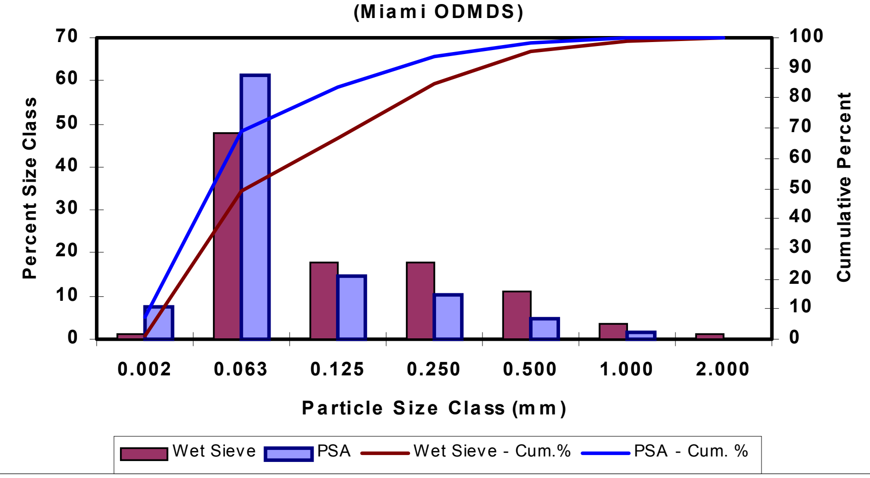


Figure 31. Particle Size Distribution < 2 mm - Station MIA08 (Miami ODMDS)

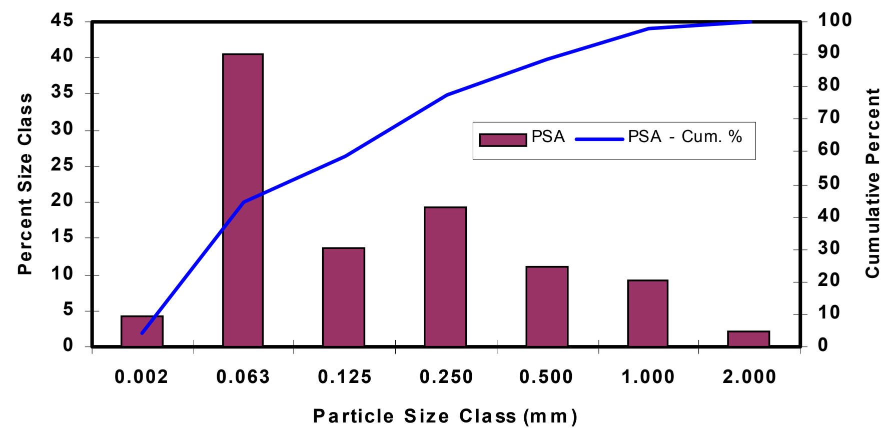


Figure 32. Particle Size Distribution < 2 mm - Station MIA09 (Miami ODMDS)

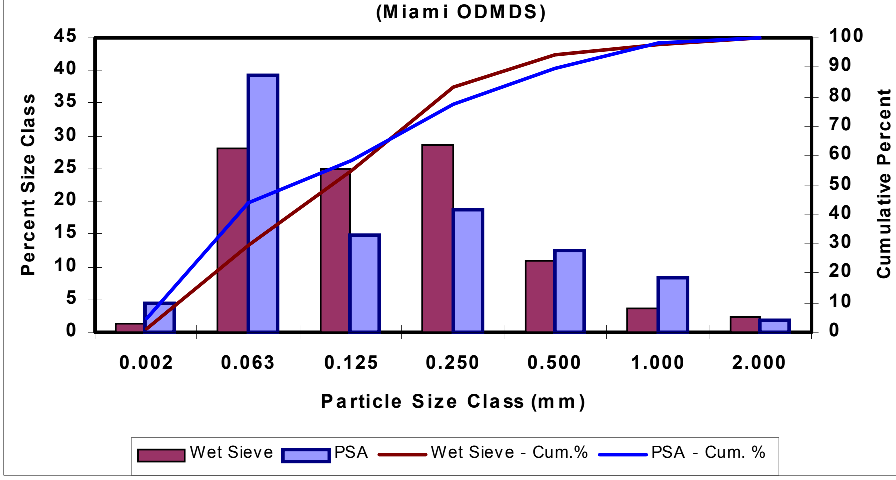


Figure 33. Particle Size Distribution < 2 mm - Station MIA10 (Miami ODMDS)

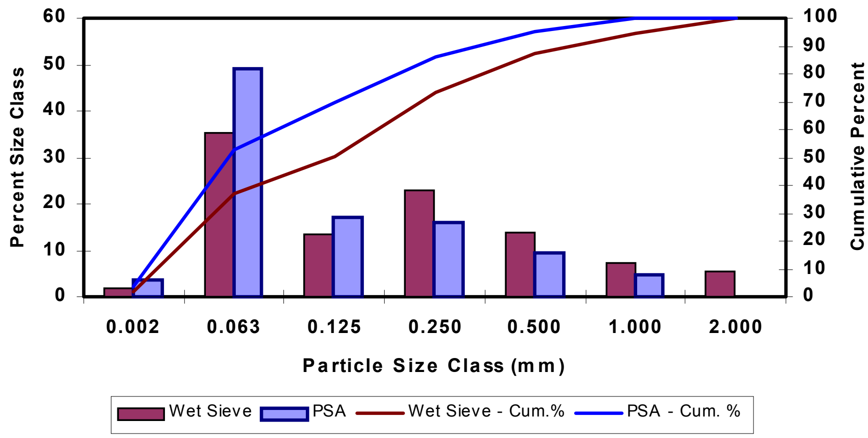


Figure 34. Particle Size Distribution < 2 mm - Station MIA11 (Miami ODMDS)

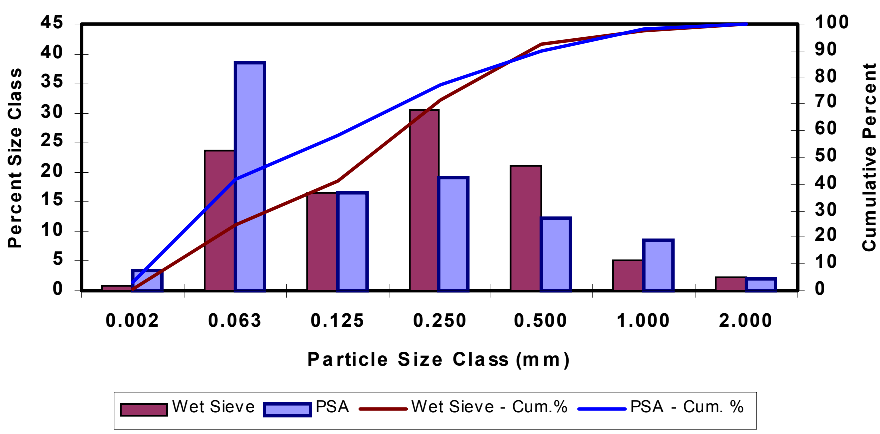
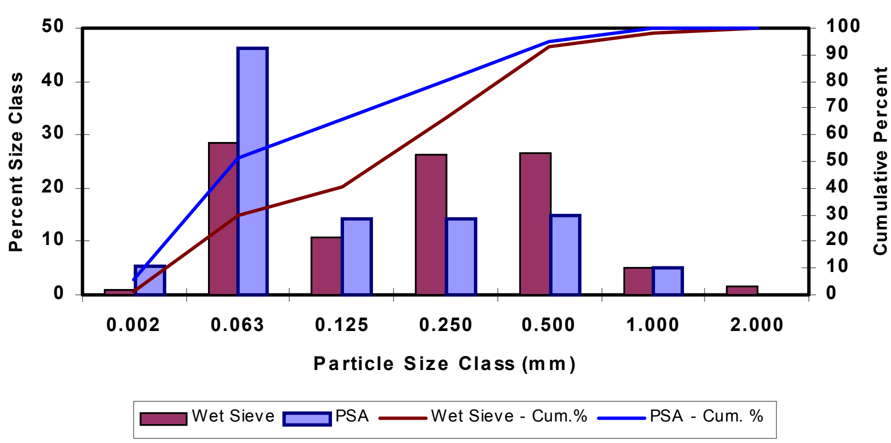


Figure 35. Particle Size Distribution < 2 mm - Station MIA12 (Miami ODMDS)



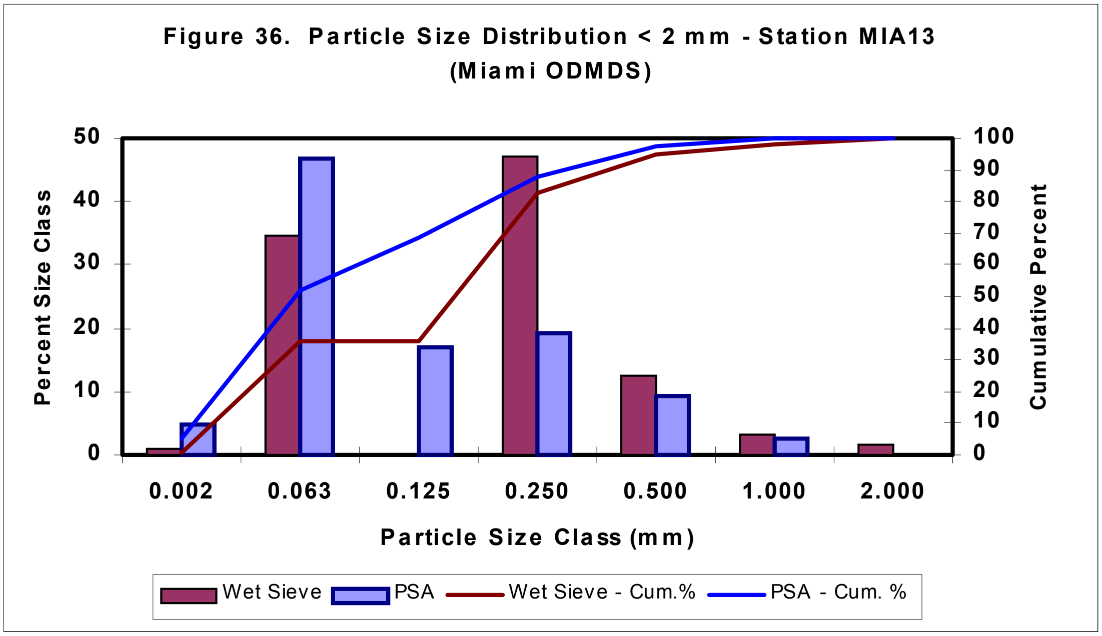


Figure 36. Particle Size Distribution < 2 mm - Station MIA13
(Miami ODMDS)
Percent Size Class
Cumulative Percent
Particle Size Class (mm)
0.002
0.063
0.125
0.250
0.500
1.000
2.000
Wet Sieve
PSA
Wet Sieve - Cum.%
PSA - Cum. %

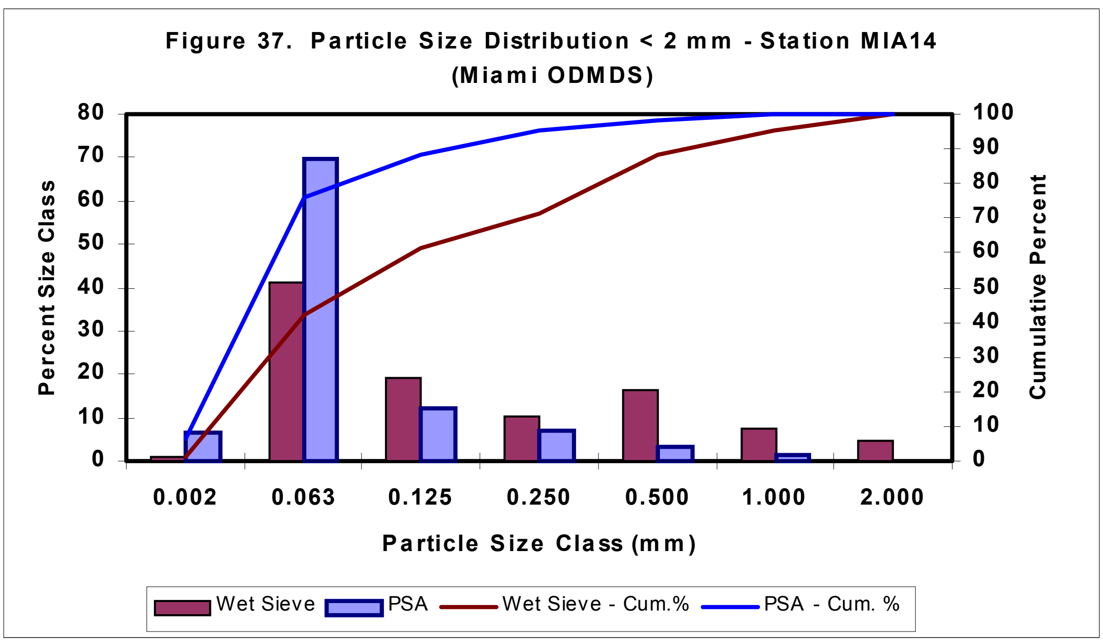
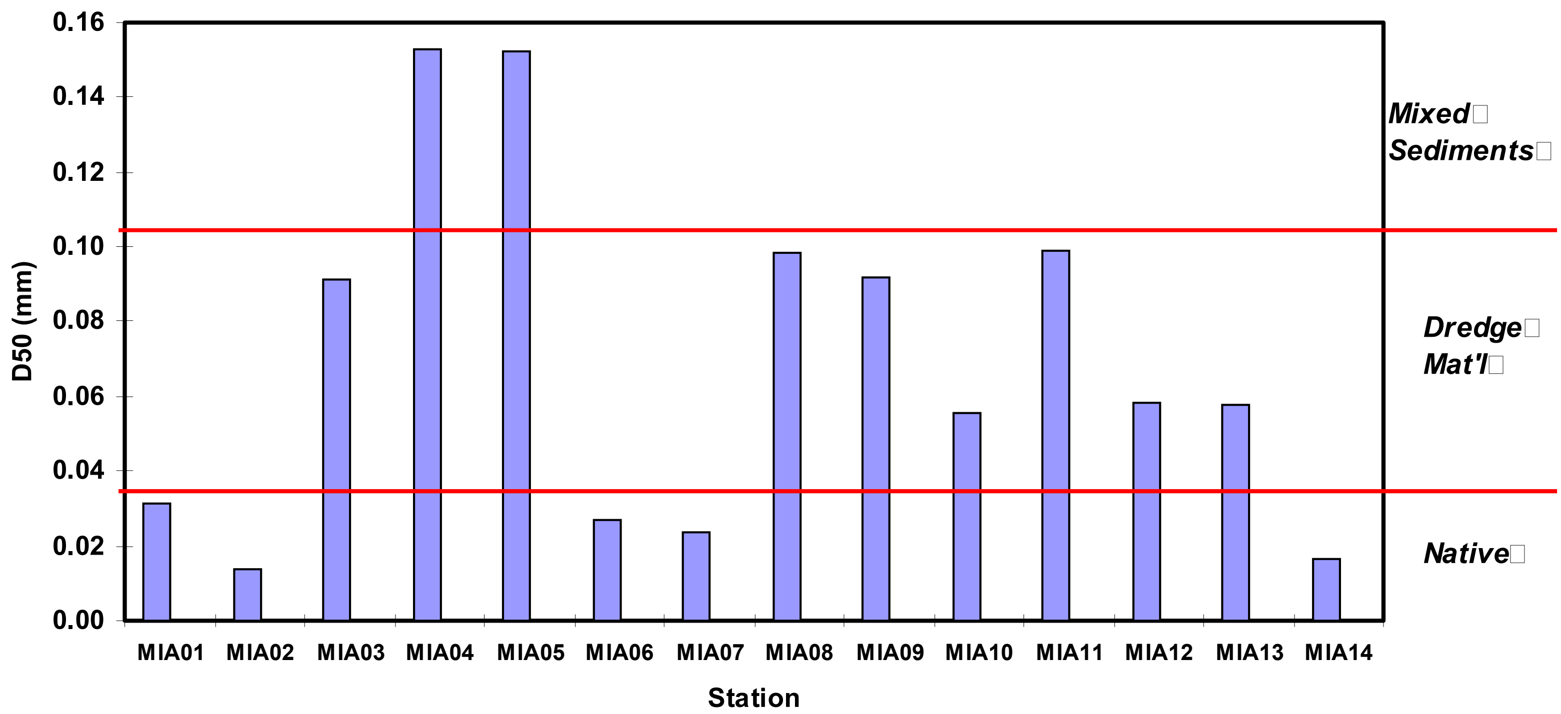


Figure 37. Particle Size Distribution < 2 mm - Station MIA14
(Miami ODMDS)
Percent Size Class
Cumulative Percent
Particle Size Class (mm)
0.002
0.063
0.125
0.250
0.500
1.000
2.000
Wet Sieve
PSA
Wet Sieve - Cum.%
PSA - Cum. %

Figure 38. Particle Size Distribution by D50 - Laser
(Miami ODMDS)



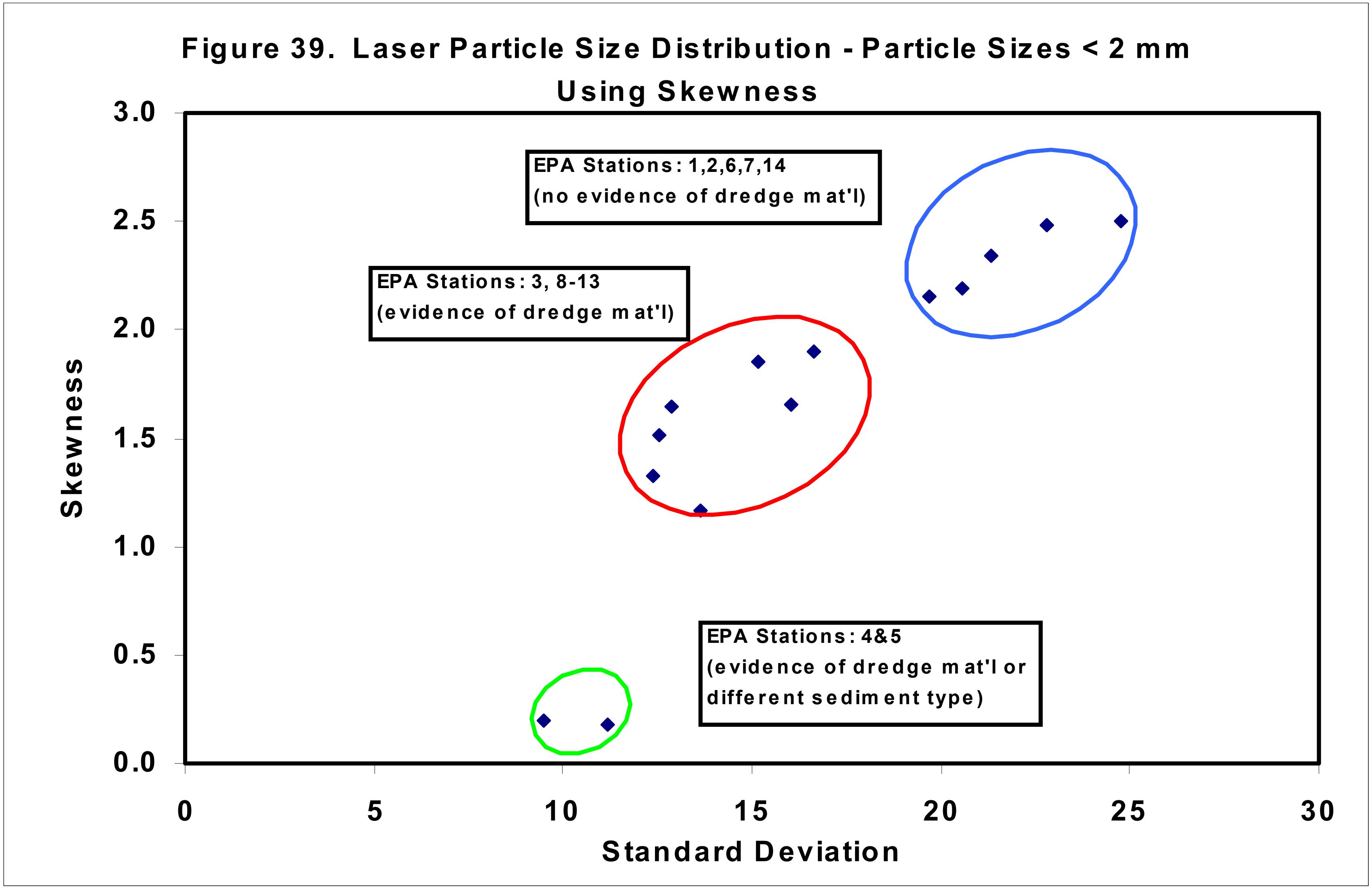


Figure 39. Laser Particle Size Distribution - Particle Sizes < 2 mm
Using Skewness
EPA Stations: 1,2,6,7,14
(no evidence of dredge mat'l)
EPA Stations: 3, 8-13
(evidence of dredge mat'l)
EPA Stations: 4&5
(evidence of dredge mat'l or
different sediment type)
Skewness
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
25
30
Standard Deviation