Lower Duwamish Waterway Group

Port of Seattle · City of Seattle · King County · The Boeing Company

TASK 2: SITE CHARACTERIZATION – TECHNICAL MEMORANDA:

1. CRITERIA FOR EVALUATING AND ACCEPTING DATA SETS
2. LIST OF REPORTS FOR HISTORICAL SITE CHARACTERIZATION
3. CONCEPTUAL DESIGN FOR DATABASE

Prepared for

The U.S. Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Field Office
Bellevue, WA

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Acronyms

DGPS	differential global positioning system
DQO	data quality objective
GIS	geographic information system
LDW	Lower Duwamish Waterway
MTCA	Model Toxics Control Act
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RI	remedial investigation
SAP	sampling and analysis plan
SOW	statement of work

1.0 Introduction

The primary goal for Phase 1 of the Lower Duwamish Waterway Remedial Investigation (LDW RI) is to quickly identify candidate sites for early remedial actions. Sites will be identified using a risk-based framework consisting of scoping-phase human health and ecological risk assessments. Data necessary for these risk assessments are being compiled as part of Task 2, which indicates that the following types of data will be assembled from relevant studies and databases, and evaluated for possible inclusion in the RI:

1. Sediment chemistry (both bulk and porewater), including sediment grain size
2. Sediment toxicity test data
3. Benthic community analyses
4. Tissue chemistry
5. Salmon life history data
6. Abundance and distribution of biological resources
7. Important riparian and aquatic habitat areas
8. Fish and marine invertebrate home range data/projections
9. Fish histopathology and biomarker data
10. Site use information (i.e., public access, commercial and recreational fish and shellfish consumption, etc.)
11. Demographic data including socio-economic and ethnicity information
12. Summary of pertinent quality assurance/quality control (QA/QC) information from each study
13. Potential contaminant sources, including a summary of individual outfalls, surface water, groundwater, stormwater, CSO discharges, and identification of contaminated shoreline fill

All data types listed above, with the exception of potential contaminant sources, will be included in the scoping-phase risk assessments. A discussion of potential contaminant sources associated with the proposed early action sites will be included in the identification of early action sites technical memorandum (Task 5). Additional information on this topic will be provided in the Phase I RI report. Sources and source control efforts at sites for which remedial actions are planned or ongoing under regulatory programs other than Superfund will be summarized in the RI. The data types to be included in the risk assessments fall into two categories. Category 1 data types are those where repeated measurements of a consistent list of parameters are made over space and time. Data from category 1 data types will be compiled into a relational database. Category 1 consists of the following four data types:

1. Sediment chemistry
2. Sediment toxicity
3. Benthic community
4. Tissue chemistry

The remaining nine data types (numbers 5 through 13 on the list above) are included in Category 2. Data from Category 2 data types will be used for the scoping-phase risk assessments or in the RI, but not compiled into a relational database at this time because the studies typically do not contain repeated measures of a consistent list of parameters. LDWG will discuss with the agencies whether data for any Category 2 data type will be compiled into a relational database for use in the Phase I RI subsequent to the scoping-phase risk assessments. Comprehensive documentation is being collected regarding source and methods of data reduction and analysis for Category 2 data types.

The dates by which data from each of the 13 data types listed above will be submitted to EPA and Ecology are given in Table 1. The three date categories given in Table 1 are database, GIS, and analysis. The dates given for the database and GIS are when the relational database and GIS files would be delivered to the agencies. The last date category includes the first deliverable in which data for that data type would be analyzed. Multiple deliverables will include analysis for some data types; only the first deliverable is listed in Table 1.

The Statement of Work (SOW) for the LDW RI specifies six deliverables for Task 2 Site Characterization.

1. Criteria for evaluating and accepting data sets
2. List of reports for historical site characterization
3. Conceptual design for the database
4. Summary of environmental data in the database
5. GIS-based maps of stations and chemical distributions within the LDW
6. Electronic copy of the final database and GIS files

This memorandum includes the first three deliverables listed above. The remaining Task 2 deliverables will be delivered to agencies according to the following schedule: fourth and fifth deliverables on May 31, 2001; sixth deliverable on June 15, 2001.

Table 1. Deliverable dates for each data type to be evaluated in the Phase I RI

DATA TYPE	CATEGORY	DATABASE	GIS	ANALYSIS
Sediment chemistry	1	June 15, 2001	June 15, 2001	May 11, 2001[a]
Sediment toxicity	1	June 15, 2001	June 15, 2001	July 10, 2001[b]
Benthic community	1	June 15, 2001	June 15, 2001	July 10, 2001[b]
Tissue chemistry	1	June 15, 2001	June 15, 2001	May 11, 2001[a]
Salmon life history	2	n/a	n/a	May 31, 2001[d]
Abundance and distribution of biological resources	2	n/a	June 15, 2001	May 31, 2001[d]
Important riparian and aquatic habitat areas	2	n/a	June 15, 2001	July 10, 2001[b]
Fish and marine invertebrate home range	2	n/a	n/a	July 10, 2001[b]
Fish histopathology and biomarker data	2	n/a [e]	n/a [e]	July 10, 2001[b]
Site use information	2	n/a	June 15, 2001	May 11, 2001[a]
Demographic data	2	n/a	n/a	May 11, 2001[a]
Summary of pertinent QA/QC information	2	n/a	n/a	May 11, 2001[a]
Potential contaminant sources	2	n/a	June 15, 2001	Oct 18, 2001[c]

[a] Conceptual model, exposure and toxicity assessment for scoping-phase HHRA
[b] Effects and exposure assessment for scoping-phase ERA
[c] Phase I RI report
[d] Problem formulation for scoping-phase ERA
[e] Most of the published reports on fish histopathology and biomarker data do not contain raw data. These data may be placed in a relational database if raw data can be obtained.

Section 2 of this document includes the first Task 2 deliverable, "Criteria for evaluating and accepting data sets," which presents data quality objectives (DQOs) for each of the four data types being loaded in the relational database. Section 3 of this document presents the second Task 2 deliverable, "List of reports for historical site characterization." Separate tables describing available data sources are provided for each of the four data types being loaded into the relational database. Section 3 also contains a comprehensive bibliography for all data types. The types of data potentially relevant to the RI that are contained in each document are indicated at the end of each bibliographic citation. Section 4 of this document presents the third Task 2 deliverable, "Conceptual design for database." This deliverable includes a graphical representation of the relationship between tables and key fields in the database.

2.0 Task 2, Deliverable 1: Criteria for Evaluating and Accepting Data Sets

This section presents a process for compiling existing LDW data for Category 1 data types (i.e., sediment chemistry, tissue chemistry, benthic macroinvertebrates, and sediment toxicity) for use in identifying potential early action sites. Data are being loaded to the database described in Section 4 of this document. A two-step screening process is being used to assess the suitability of data for inclusion in the database: 1) identify the primary sources of historical data and 2) screen those data against a defined set of data quality objectives (DQOs). The process is designed to be flexible and to identify as many suitable data records as possible for the RI. Attributes of specific locations, samples, and results are being added to the database, as described below. These attributes are being used to identify data appropriate for specific uses in the RI. For example, some location records will have an attribute indicating that the sediment collected from that location has subsequently been dredged. Chemistry data associated with these locations may be analyzed differently in the RI from data associated with locations that have not been dredged.

Data sets added to the database following application of the DQOs described below will be described in detail in the Task 2 deliverable called "Summary of environmental data in the database." Entire data sets not added to the database at this time will also be listed in that memo, with a rationale for their exclusion. Some data will not be added at the present time because they are not needed for the scoping-phase risk assessments in the Phase I of the RI, not because they are of poor quality. For example, data collected more than 10 years ago may not be relevant for characterizing current conditions in surface sediments. Data sets that are not necessary for the scoping-phase risk assessments may be useful for identifying data gaps that could be filled during Phase II of the RI. Consequently, additional data sets from pre-1990 sampling events and characterizations of subsurface sediment will be added the database prior to Task 7 of the Phase I RI, i.e., identification of data gaps. At such time, addenda to the last three deliverables in Task 2, i.e., summary of data, GIS maps, and electronic copy of the database, will be distributed.

2.1 Identification of Source Documents

Hundreds of samples from the LDW have been collected and analyzed. Consequently, locating electronic data for the various data sets is a critical step for efficient construction of a database. Much of the historical data for the LDW reside in Washington Department of Ecology's SEDQUAL database. Windward is compiling a document library that includes hard copies describing results of each LDW sampling event contained in SEDQUAL. Documents and electronic data for sampling events not contained in SEDQUAL are being identified with the help of LDWG members, the US Army Corps of Engineers (ACOE), and other entities who may have collected data from the LDW.[1] The source documents used to conduct the review are listed in Section 3.

Data contained in electronic databases such as SEDQUAL are being compared to the original study reports to verify transcriptional accuracy. Another objective of the hard copy verification is to identify attributes of the data that may not be captured in the electronic data set, but may be necessary for analysis and interpretation of the data. Data for the event, station, and sample levels—location, date, number and type of stations and samples—are being confirmed for each data set in its entirety. If any inaccuracies are found during this screen, the original author will be contacted to resolve errors. The accuracy of analytical results will be reviewed following a tiered structure, to balance effort with accuracy. For all but two of the data sets identified in Section 3, 20% of the analytical result records[2] in the electronic data set will be compared to the hard-copy equivalent. If any inaccuracies are found, 100% of the result records will be verified. Two data sets[3] contain more than 15,000 analytical results, which makes a 20% verification impractical. For these data sets, 10% of the analytical results will be verified. If any inaccuracies are found during this screen, then 20% of the result records will be verified. If additional errors are found, then the appropriate data manager will be contacted to obtain a corrected electronic data set.

A second type of verification will be conducted during construction of the GIS. Potentially anomalous results, such as station locations that map on land, or very different chemical concentrations for samples located close to each other, will be verified using the appropriate combination of original hard copies and electronic data sets.

During the data verification process, the original authors will be contacted to obtain a corrected data set if errors are detected. Any detected errors will be corrected in the electronic source file and a note will be added to the appropriate location, sample, or result record noting the correction. The original authors will also be notified if any errors are found so that appropriate corrections can be made to the original source files.

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[1] For the purposes of compilation of historical data, the geographical extent of the LDW extends from the southern end of Harbor Island to the North Winds Weir just upstream (south) of the Norfolk CSO. Data collected from outside this area will be added to the database only if insufficient data were collected within this area. A complete list of data being evaluated for inclusion in the database is provided in Section 3.

[2] A result record for chemistry is a single concentration reported for a single chemical in a single sample. For a benthic invertebrate data set, a result record is a count of abundance for a single taxon in a single replicate sediment sample.

[3] Boeing RCRA Plant 2 (1995) and EPA Site Inspection (1998)

2.2 DQO DESCRIPTION AND RATIONALE

The DQOs were designed to identify data that may be used in the RI. The DQOs, grouped into four categories, are described below. The categories refer to the level at which each DQO would be applied: event, station, sample, or result. For example, a DQO applied at the result level could cause a result record to be qualified for a particular chemical, but not for other chemicals analyzed during a particular study. DQOs applicable only to a particular data type are being identified; otherwise, it can be assumed that each DQO is applicable to all data types.

2.2.1 Event level

Hard copy or original electronic copy of data report must be available

Data verification of electronic data sets is only possible if the original data report is reviewed. This data report should also contain information related to field and laboratory methods. Data are being included in the database if the report documents that they have met minimum QA/QC requirements[4] and are considered valid for use based on a data validation conducted by the authors or an independent party. A summary of QA/QC data for each sampling event will be provided in the fourth Task 2 deliverable, "Summary of environmental data in the database."

Field coordinates must be available

The construction of a GIS for the project is a major element of Task 2. The GIS will be used extensively in conducting the scoping-phase risk assessments. Accurate coordinates are necessary for constructing a usable GIS. The methods used to generate the field coordinates are being clearly identified in the database. Most sediment investigations conducted in the last 10 years in Puget Sound have utilized differential global positioning system (DGPS) methods. The nominal accuracy of coordinates obtained using DGPS equipment is 1 – 5 m. Ideally, sediment data for inclusion in the database will be associated with DGPS coordinates. Samples associated with GPS coordinates that have not been differentially corrected (non-DGPS), or with coordinates that were not measured in the field, are being included in the database, but are being distinguished from the DGPS coordinates by the positioning method.

Precise field coordinates for tissue chemistry sampling events may not be readily available given the mobility of the target organisms and collection gear that may be deployed over a wide area. In many cases, the capture location is described as an area rather than as a single position. A sufficient number of coordinates are being added to the database so that the capture location may be accurately described in the GIS. For example, a trawl transect may

[4] Minimum QA/QC guidelines for this project are QA1, as defined by the Washington Department of Ecology

be described by two points – the beginning and end of the transect line. Other net deployments, such as beach seines, may be described as a single point unless multiple coordinates are available.

All coordinates are being added to the database in the original coordinate system and units used in the electronic file. For location records with a coordinate system that does not match the coordinate system being used for the project GIS (i.e., Washington State Plane North, NAD 83, US survey feet), an additional set of coordinates is being added for each station record to make all data compatible within the GIS.

Data must have been collected since 1990

Within the past 10 years, a large quantity of data has been collected from the LDW. Data collected prior to 1990 may be of historical interest, but due to the potential for physical, chemical, and biological transport and transformations, these data are less likely to be representative of current conditions than more recent data. Data older than 10 years are not being added to the database at the present time. These data will be added at a future date in order to identify data gaps pursuant to Task 7 of the Phase I RI.

Data must have been collected using appropriate sampling methods

Surface sediment is typically characterized using a surface grab sampler, although the top section of a core sample may also adequately represent surface sediment. The van Veen grab is probably the most commonly used sampler in Puget Sound, but ponar, Ekman, or box corers can also yield acceptable samples. Data collected using other methods are being evaluated on a case-by-case basis. Data collected using sampling methods that may not provide an undisturbed sample from the sediment surface, such as samples hand-collected by divers, may be added to the database, but will be distinguished from data collected using other methods.

Chemistry data from sediment porewater are being added to the database. The porewater extraction method can influence the results, so the method is being clearly documented in the database.

Various types of gear may have been deployed for collection of tissue samples. Each type of gear has a specific bias toward certain types of organisms. This bias is very important to consider when characterizing populations or communities, but may be less important when collecting samples for chemical analysis. The collection gear deployed for each tissue sampling event will be clearly documented in the database, as will the type of tissue preparation.

Sampler type and sieve size can influence the suite of organisms obtained in a sample of benthic infauna. The database will include all benthic infauna data, but the type of sampling gear deployed may influence the usability of the data. The sampling gear and sieve size for benthic invertebrate sampling events will be clearly documented.

2.2.2 Station level

Stations located within dredge prisms or remediated areas should be identified (applicable to sediment chemistry, benthic macroinvertebrate, bioassay data only)

Sediment characterization almost always precedes remediation or maintenance dredging projects. For navigational dredging, the material to be dredged is characterized to determine what disposal options are possible. Environmental dredging or capping occurs only after a characterization effort has determined that the sediments represent an unacceptable ecological or human health risk. Sediment data collected prior to a remediation or dredging event may no longer reflect current conditions. Data from locations that have been remediated or dredged are being added to the database, but attributes are being added to these location records so they may be distinguished from locations that have not been dredged or remediated.

The dredge prisms for dredging events that have occurred within the last 10 years are being incorporated into the project GIS. For all events except the Army Corps of Engineers 1999 maintenance dredging, the dredge prisms are being approximated from the dredge plan maps in the dredged materials characterization reports. The location of the 1999 ACOE maintenance dredging will be transferred from an AutoCAD file obtained from the Corps. LDWG will attempt to obtain as-built drawings or post-project summaries from the Corps to verify the dredge prisms and GIS bathymetry.

Co-located samples will be identified

A large number of environmental samples have been collected from the LDW. Most sampling events involve collection of samples where few samples have been collected before, but there are likely to be surveys where newer samples were collected in locations that have been sampled previously. Using GIS, stations located within 5 m of newer sampling locations are being identified. These samples are being evaluated on a case-by-case basis to determine whether newer data better reflect current conditions. If so, older co-located data are being qualified appropriately.

Station type must be clearly identified (applicable to bioassay and benthic macroinvertebrate data only)

Data from an appropriately matched reference station are often required to evaluate sediment toxicity[5] and benthic invertebrate[6] data. Reference station samples for a given event are being identified as such in the database. Events lacking reference station samples are being included in the database and evaluated on a case-by-case basis for use in characterizing current conditions.

2.2.3 Sample level

Sediment depth should be identified (applicable to sediment chemistry, benthic macroinvertebrate, bioassay data only)

Organisms may be exposed to sediment-associated contaminants as a function of the location of the contaminants in the sediment column coupled with their behavior. A depth of approximately 10-15 cm is generally considered to comprise the ecologically available horizon in areas without active erosion, although some burrowing invertebrates may be found at greater depths. The collection depths of all sediment samples are being identified in the database. Specific definitions of "surface samples" will be provided in each case where such data are used in the RI.

Sample type should be clearly identified

Environmental samples may represent various areal extents depending on whether the sample was collected from a single location or was a composite of subsamples collected from different locations. Data from both discrete and composite samples are suitable for the RI, but the sample type may be relevant for evaluating the uncertainty across small spatial scales associated with chemistry data. Sample matrix and preparation method are also being clearly identified in the database.

Number of replicates should be identified (applicable to benthic invertebrate and bioassay data only)

Replicate samples are typically analyzed for bioassay (laboratory replicates) and benthic invertebrate (field replicates) sampling events. For benthic invertebrate data, the number of replicate samples should be identified. For bioassay data, the number of replicates is generally specified in the method. Individual replicate data are being included for both data types in the database. Details of subsampling methods that are employed during sorting of benthic samples are being added to the database, as appropriate.

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[5] Appropriate reference samples are matched to site samples on the basis of grain size.

[6] Because physical characteristics of the environment can influence the distribution of benthic organisms, appropriate reference samples are matched to site samples on the basis of grain size, salinity, and water depth.

2.2.4 Result level

Detection limits (applicable to chemistry data only)

For data reported as non-detected, detection limits are being reported and appropriate qualifiers indicating that the true value is less than the detection limit are being included. In addition, detection limits greater than the respective SQS[7] are being identified. These data are being included in the database and may be used in the RI; the added attribute describing potentially elevated detection limits may be useful in the uncertainty analysis.

Calculated values (applicable to chemistry data only)

Sums such as HPAHs and total PCBs are being recalculated from the raw data to ensure that consistent rules regarding detection limits and summation are followed. Summation rules specified by the Ecology in their Sediment Management Standards rule are being applied. Sums not defined by Ecology in their sediment rule (e.g., total PCBs based on congeners) are not being stored in the database at this time. LDWG will consult with the agencies on summation methods before they are applied to data in the database and will clearly describe the method in the document in which they are used.

Chemistry data may be presented on a normalized basis, either to organic carbon (sediment) or lipid (tissue). Normalized data are not being added to the database since it may not be clear which concentrations were used to normalize. Normalized concentrations will be recalculated from the raw data following the conventions specified by Ecology.

Data that represent averages of two or more values will not be added to the database because it may not be clear how these averages were derived. If averages are needed for data analysis, they will be recalculated from the raw data using conventions that will be discussed between LDWG and the agencies prior to their application to data in the database.

Analytical methods

Chemistry data may be generated by many different analytical methods. Concentrations reported for a given analyte may or may not be comparable for different methods. Consequently, it is critical that the precise analytical method be documented for all data included in the database. In cases where multiple methods were used for a single analyte in a single sample, the usability of data generated by the different methods is being determined by comparing the results to each other. Any decisions to exclude data based on the analytical method will be thoroughly documented in the deliverable in which these data are used.

[7] Washington Department of Ecology Sediment Quality Standards, Chapter 173-204 WAC, December 1995

In Puget Sound, most bioassays are conducted according to methods specified in the Sediment Management Standards. Any data collected using non-standard methods are being coded as such in the database.

Puget Sound protocols outline the methods and QA/QC requirements for benthic invertebrate organism identification, enumeration, and biomass determination. The methods employed for each sampling event are being reviewed and documented in the database. All appropriate benthic survey results are being included in the database, although results obtained using non-standard protocols are being included in the database with appropriate qualifiers.

QA/QC information must be available

As stated above, only previously validated data are being added to the database. Validation results are typically in the form of data qualifiers. The data qualifiers given by the data validators are being preserved in the database, but an additional field called "Interpreted Data Qualifier" is being populated for each result record that includes a data qualifier. The intent of this additional field is to provide qualifiers with a consistent definition across all sampling events. The mapping of the original data qualifiers to the interpreted data qualifiers for each sampling event will be provided in the fourth Task 2 deliverable, "Summary of environmental data in the database."

In cases where data validation was performed by a third party, the qualifiers in the electronic data set are being compared to qualifiers included in the data validation report. If the data validation qualifiers are not included in the electronic data set, they are being added.

3.0 Task 2, Deliverable 2: List of Reports for Historical Site Characterization

A large library of documents describing environmental conditions within the LDW has been compiled. Tables 2 to 5 list key documents in this library that contain sediment chemistry, tissue chemistry, benthic macroinvertebrate, and bioassay data, respectively. Document numbers in these tables refer to the bibliography included at the end of this section. The DQO process described in Section 2 is being applied to each of the data sets listed in Tables 2 to 5.

An LDW bibliography is given following Table 5. Documents will be added to the library throughout the project as they become available. Data type codes are given at the end of each citation to identify the type of information contained in each document. The data types are listed in Section 1. The definition of each code is provided below:

Category 1 data types	
SEDCHEM	Sediment chemistry
TISSUECHEM	Tissue chemistry
BIOASSAY	Sediment toxicity
BENTHIC	Benthic community
Category 2 data types	
SALMON	Salmon life history
ABUND	Abundance and distribution of biological resources
SPHAB	Important riparian and aquatic habitat areas
HOMERANGE	Fish and marine invertebrate home range
HISTO	Fish histopathology and biomarker data
SITEUSE	Site use information
DEMOGRAPH	Demographic data
QAQC	Summary of pertinent QA/QC information
SOURCES	Potential contaminant sources

Table 2. List of sediment chemistry data sets to be considered for inclusion in database

Report Title	Year Published	Survey description	Sampling description	Document number	Sponsor	Prepared By
Duwamish/Diagonal Cleanup Study-Draft	2000	Report characterizes the spatial extent and magnitude of sediment contamination resulting from Duw/Diag outfall discharges. Assists in selecting cleanup alternatives.	Three sampling phases conducted from 1994-1996 to determine and refine the boundaries of the contaminated areas. Sediments from 58 surface (10 cm) and 14 subsurface (up to 9 ft) stations were collected.	93, 105	Elliott Bay/ Duwamish Restoration Program Panel (EBDRP)	King County Department of Natural Resources (KCDNR)
Norfolk CSO Sediment Remediation Project Five-Year Monitoring. Annual Monitoring Report- Year One, April 2000	2000	Results of the third sampling event of the five-year monitoring program monitoring for chemical characteristics of backfill material compared to the baseline chemical conditions.	Eight surficial sediment samples colleted from 4 stations using 0.1-m^2 van Veen grab sampler. Sediment collected from the top 2 and 10 cm.	104	EBDRP	KCDNR
Norfolk Sediment Cleanup Study - Supplemental Nearshore Sampling	2000	Results of supplemental sampling performed for the purpose of assessing potential sources of PCBs which were detected on the surface of the backfill material during the Oct 1999 monitoring event at the Norfolk CSO	Surficial sediments (2 cm) were collected at seven stations using either 0.1-m^2 van Veen grab sampler or a hand grab from shore. Samples were split into two for analysis at separate laboratories.	102, 104	EBDRP	KCDNR
Sediment Quality in Puget Sound. Year 2 – Central Puget Sound	2000	Determine the quality of sediments in terms of the severity, spatial extent and patterns of chemical contamination, toxicity, and adverse alterations to benthic infauna.	One station was sampled in the LDW with a 0.1-m^2 van Veen grab sampler. The top 2-3 cm were collected.	44	NOAA and DOE	National Oceanic and Atmospheric Administration (NOAA) and Washington State Department of Ecology (DOE)
Dredge Material Characterization Duwamish Yacht Club	1999	Results of the PSDDA sediment characterization at the Duwamish Yacht Club in support of maintenance dredging. Samples were analyzed for DMMP-specified chemical parameters.	Two core samples (up to 4 ft) were collected from each of six DMMUs at the Duwamish Yacht Club.	70	Peratrovich, Notingham & Drage	Hart Crowser

REPORT TITLE	YEAR PUBLISHED	SURVEY DESCRIPTION	SAMPLING DESCRIPTION	DOCUMENT NUMBER	SPONSOR	PREPARED BY
King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay - Sediment Task	1999	Results of sediment sampling taken in support of modeling contaminants from CSOs in the LDW and Elliott Bay in support of a water quality assessment investigating the effects of CSOs in the LDW and Elliott Bay.	One surficial grab (2 cm) was taken weekly for from 5 to 17 weeks at each of 5 stations in the LDW using and 0.1-m^2 van Veen grab sampler.	97, 98	KCDNR	Duwamish River and Elliott Bay Water Quality Assessment Team (Parametrix, KCDNR)
Norfolk CSO Sediment Remediation Project, Five Year Monitoring Program - April 1999 Monitoring Baseline Report	1999	The results of the first sampling event of a five-year monitoring program at the Norfolk CSO sediment remediation site. The sampling was intended to collect baseline data on the chemical characteristics of the sediment used as backfill material at the site.	Three surficial grabs (10cm) were taken at each of three stations using a 0.1-m^2 van Veen sampler.	101	EBDRP	KCDNR
Norfolk CSO Sediment Remediation Project, Five Year Monitoring Program, Six-month Post-construction Monitoring Report, October 1999	1999	Results of the second sampling event of a five-year monitoring program at the Norfolk CSO site to monitor potential recontamination of sediment backfill material after six months.	Two composite surficial grab samples at 2 cm and 10 cm depth were collected using 0.1-m^2 van Veen grab sampler at each of four stations.	103	EBDRP	KCDNR
Sediment Sampling and Analysis James Hardie Gypsum Inc.	1999	Results of the PSDDA sediment characterization at James Hardie Gypsum facility in the LDW in support of maintenance dredging. Samples were analyzed for DMMP-specified chemical and biological parameters.	Core samples (up to 4 ft) were collected using an impact corer and composited from each of ten DMMUs.	181	James Hardie Gypsum Inc.	Jay W. Spearman Consulting Engineer
Site Inspection Report: Lower Duwamish River (RK 2.5-11.5) Seattle, Washington Volume 1-Report and Appendices	1999	Reports results of the EPA-funded SI for LDW from river kilometer 2.5-11.5. Survey was designed to characterize the nature and areal extent of contaminant distribution in surface sediments, and to preliminarily characterize vertical extent of contaminant distribution in localized areas. Obtain sediment porewater samples to evaluate the potential bioavailability of organotins and metals to aquatic receptors	Surface sediment samples (0 – 10 cm) were taken at each of 300 stations (duplicates taken at 17 of the 300 stations). 35 subsurface samples were taken at 17 stations, (17 samples and one duplicate at 0 - 0.6 m depth and 16 samples at 0.6 - 1.2 m depth), 16 sediment porewater samples (0 – 10 cm) were taken at 15 stations (one duplicate)	236	EPA	Roy F. Weston, Inc

Report Title	Year Published	Survey description	Sampling description	Document number	Sponsor	Prepared By
Duwamish Waterway Phase I Site Characterization Report	1998	Reports results of the phase 1 sediment sampling to characterize the scope and extent of COPCs in the LDW potentially released from Boeing facilities.	Three replicate surface samples (10 cm) were collected using a 0.06-m^2 van Veen grab sampler and composited into a single sample at each of 88 sediment stations adjacent to Boeing facilities and in Slips 4 and 6.	53	The Boeing Company	Exponent
Dredge Material Characterization Hurlen Construction Company & Boyer Alaska Barge Lines Berthing Area	1998	Results of the PSDDA sediment biological and chemical characterization at the two indicated sites in support of maintenance dredging. Samples were analyzed for DMMP-specified chemical parameters. Four of the samples were also subjected to biological toxicity testing.	Two core samples (2 – 4 ft) were collected from each of four DMMUs at the Hurlen site and from two DMMUs at the Boyer site.	69	Hurlen Const. Company and Boyer Alaska Barge Lines	Hart Crowser
Duwamish Waterway Sediment Characterization Study Report	1998	Results of NOAA sediment sampling to evaluate the extent and severity of PCB and PCT (polychlorinated terphenyl) contamination in LDW sediments.	328 surface samples (10 cm) were taken to characterize 90 substrata covering the LDW from the turning basin to Harbor Island.	142	NOAA	Industrial Economics, Inc.
Post-bioassay sediment sampling at Chelan, Connecticut, and Hanford CSO outfalls	1997	Presents analytical results and quality assurance review of sediment chemistry data collected adjacent to CSO outfalls in the LDW	Chemical analysis was completed on eight archived surface sediment samples (2 cm) collected September 1996 near the Chelan, Connecticut and Hanford CSO outfalls. Analyses were performed on sediments collected from sampling stations that failed one or more bioassay tests.	94	KCDNR	KCDNR
Seaboard Lumber Site, Phase II Site Investigation	1997	Site investigation report for EBDRP habitat improvement project at Seaboard Lumber site	Surface sediment (2 and 10 cm) samples collected at 20 stations and tested for SMS chemicals	73	City of Seattle and EBDRP	Herrera and Associates
Proposed Dredging of Slip No. 4, Duwamish River, Seattle, WA	1996	Reports the results of sediment chemical and biological testing from slip four in the LDW conducted to satisfy PSDDA.	Two sediment cores (3 - 6 ft) were composited from each of four DMMUs in slip four.	154, 155, 156	Crowley Marine Services	PTI Environmental Services
1996 USACE Duwamish O&M	1996	Results of PSDDA sediment biological and chemical characterization of the Duwamish Waterway and upper turning basin for maintenance dredging.	One composite of three core samples (4 ft) was collected from each of six DMMUs from slip six to the turning basin.	188	ACOE	Striplin Environmental Associates, Inc.

Report Title	Year Published	Survey description	Sampling description	Document number	Sponsor	Prepared By
Norfolk CSO Sediment Cleanup Study, EBDRP	1996	Report characterizes the spatial extent of chemicals detected in sediments collected near the Norfolk CSO. Identifies sediment cleanup areas, evaluates alternatives and selects recommended alternative. Reports data from pre-phase 1, phases 1,2,3 of the Norfolk Cleanup study, Boeing data and habitat survey data.	Composites of from one to three surface samples (10 cm) were collected with a 0.1-m^2 van Veen grab sampler from each of approximately forty stations around the Norfolk CSO. Core samples were also taken at several stations.	92, 95	KCDNR/ EBDRP	King County Water Pollution Control Division
RCRA Facility Investigation Duwamish Waterway Sediment Investigation, Plant 2, October 1996	1996	Reports the results of upland media, groundwater seep and sediment chemical testing from the vicinity of the Boeing plant 2 facility	Bank material and surface sediment samples (0 – 10 cm) were collected from stations in the vicinity of Boeing plant 2 where upland media and groundwater seep sampling exceeded SMS or AET criteria.	228, 229, 230	The Boeing Company	Roy F. Weston, Inc
Rhône-Poulenc RCRA Facility Investigation (RFI) for the Marginal Way Facility, Round 3 data and sewer sediment technical memorandum	1996	Reports data for groundwater, seeps, sewer sediments, and intertidal sediments collected to supplement data collected from Rounds 1 and 2 of the RFI	Intertidal sediments samples (10 cm) were collected by hand from sixteen stations during a minus tide. Twelve stations were located in Slip No. 6; four were located in the Duwamish waterway.	159	Rhône-Poulenc	CH2M Hill
Rhône-Poulenc RCRA Facility Investigation (RFI) for the Marginal Way Facility. Volume 1: RFI results and conclusions	1995	Reports data for groundwater, soil, air, and sediments. Sampling occurred in two rounds.	Intertidal sediments samples (2 cm) were collected by hand from seven stations during a minus tide during both Round 1 (March 1994) and Round 2 (August 1994). All stations were located in the Duwamish waterway.	158	Rhône-Poulenc	CH2M Hill
Lone Star Northwest and James Hardie Gypsum-Kaiser Dock upgrade	1995	Reports the results of sediment chemical and biological testing from the vicinity of slip two in the LDW conducted to satisfy PSDDA.	One core sample (4 ft) was collected from each of four DMMUs in slip 2. One additional core was collected to characterize the subsurface DMMU.	72	Lone Star Northwest and James Hardie Gypsum	Hartman Associates, Inc.

Report Title	Year Published	Survey description	Sampling description	Document number	Sponsor	Prepared By
Sediment sampling at Chelan, Connecticut, and Hanford CSO outfalls	1995	Presents analytical results and quality assurance review of sediment chemistry data collected adjacent to CSO outfalls in the LDW	Six surface sediment samples (2 cm) were collected and analyzed from each of three CSO outfalls	89, 90	KCDNR	KCDNR
Lonestar Northwest - West Terminal U.S. ACOE – Seattle	1992	Analysis of sediments for maintenance dredge in front of Lone Star's West Terminal in the Duwamish River to meet PSDDA criteria	Two boring samples (6 ft) composited into one sample	71	Lone Star Northwest	Hartman Associates
PSDDA Bioassays for Duwamish Channel Sediments (O&M)	1991	Reports the results of sediment chemical and biological testing from the navigation channel to satisfy PSDDA	33 core samples (up to 14 ft) collected from the Duwamish Channel	165	ACOE	Science Applications International Corporation
Sediment Sampling Analysis Brown and Morton Properties Duwamish Waterway	1991	Results of the PSDDA sediment characterization at Brown and Morton Properties in the LDW in support of maintenance dredging. Samples were analyzed for DMMP-specified chemical and biological parameters.	Samples collected from three sites in the vicinity of Brown and Morton Properties. Samples collected with impact corer up to 6 ft.	179	Brown Morton Properties	Jay W. Spearman Consulting Engineer
South Park Marina maintenance dredging, 1991	1991	Analytical and biological results of sediment from the north half of South Park Marina to characterize suitability for disposal at Elliott Bay deepwater disposal site. Maintenance dredging	Sediment samples collected from two stations within each DMMU. Samples collected with impact corer up to 6 ft.	180	South Park Marina	Jay W. Spearman Consulting Engineer
Harbor Island Remedial Investigation Report (Part 2- Sediment)	1991	Reports the findings of the sediment investigation portion of the RI for the Harbor Island NPL site.	Surficial sediments (0 – 2 cm) were collected from 108 locations in the East and West waterways of the LDW, upstream between Harbor and Kellogg islands, Elliott Bay in the vicinity of North Harbor Island, and in Carr Inlet.	226	EPA	Roy F. Weston, Inc
Duwamish River Maintenance Dredge, Phase 1	1990	Reports the results of sediment chemical and biological testing from the navigation channel to satisfy PSDDA	Eight sediment samples (up to 14 ft) were collected with a vibracore sampler	152	ACOE	PTI Environmental Services

Report Title	Year Published	Survey description	Sampling description	Document number	Sponsor	Prepared By
Duwamish CSO Sediment Sampling - 1990	1990	Reports the results from sampling CSO sites to meet NPDES requirements.	Nine stations selected for sediment quality sampling. Top 2 cm analyzed	131, 132	METRO	Brown and Caldwell

Table 3. List of tissue chemistry data sets to be considered for inclusion in database

Report Title	Year Published	Survey description	Sampling description	Document number	Sponsor	Prepared By
King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay - Appendix B2, B3, & B4 Human Health, Wildlife, and Aquatic Life Risk Assessments	1999	Assesses the potential risks to ecological and human health from exposures (water, sediment, seafood) to contaminants due to the effects of CSOs in the LDW and Elliott Bay.	Analyzed tissue from chinook and coho salmon, rockfish, sole, perch, crab, mussels, squid, prawns, and amphipods from Elliott Bay and the Duwamish. Samples were analyzed for metals and organics.	96, 97	King County	Duwamish River and Elliott Bay Water Quality Assessment Team (Parametrix, KCDNR)
Waterway Sediment Operable Unit Harbor Island Superfund Site Assessing Human Health Risks from the Consumption of Seafood	1999	Analyzes and assesses the potential risk of consuming seafood for a baseline HHRA in the East and West waterways and the LDW	English sole, perch and crab were collected from the study area and analyzed for TBT, mercury, and Aroclors	48	Port of Seattle	Environmental Solutions Group
Puget Sound Ambient Monitoring Program – annual sampling	1992-1998	Annual sampling is conducted for chinook and coho salmon, English sole, and rockfish to evaluate bioaccumulation of certain bioaccumulative compounds throughout Puget Sound	Chinook and coho salmon, English sole collected from LDW annually; analyzed for PCBs and mercury; other chemicals measured for some samples	10-yr summary data report in preparation	Puget Sound Water Quality Action Team	Washington Department of Fish and Wildlife
Elliott Bay/Duwamish River Fish Tissue Investigation	1995-1996	English Sole fish tissue collected from Elliott Bay and Duwamish River in support of the Supplementary Remedial Investigation for Harbor Island	18 fish (English sole) tissue samples analyzed for PCB Aroclor, congeners, butyltin, and mercury	12, 51, 59	Port of Seattle	EVS
NOAA chinook salmon bioaccumulation study	1993	Interprets the results of chemical, biochemical, and biological studies on juvenile chinook salmon	Juvenile chinook were collected from hatcheries and estuaries of four Puget Sound river systems	218	NWMF-NWFSC	NOAA

Table 4. List of benthic macroinvertebrate data sets to be considered for inclusion in database

REPORT TITLE	YEAR PUBLISHED	SURVEY DESCRIPTION	SAMPLING DESCRIPTION	DOCUMENT NUMBER	SPONSOR	PREPARED BY
Sediment Quality in the Puget Sound	2000	Determine the quality of sediments in terms of the severity, spatial extent and patterns of chemical contamination, toxicity, and adverse alterations to benthic infauna.	Descriptive statistics calculated for species richness, total abundance, major species	44	Washington Department of Ecology	NOAA and Washington Department of Ecology
Alternative Dredge Disposal Sites	1999	Evaluation of the intertidal habitats that could be potentially affected by deepening of the East Waterway.	15 epibenthic samples were collected from slip 27, terminal 5 and pier 90/91, Kellogg Island and other sites in the LDW.	202	Port of Seattle	Taylor Associates, Inc.
King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay - Benthic Task	1999	Results of benthic invertebrate surveys conducted in support of a water quality assessment investigating the effects of CSOs in the LDW and Elliott Bay.	Surface sediment samples were collected near the Duwamish/Diagonal CSO and the north end of Kellogg Island. Both sampling sites included a transect of five grab stations. Samples were analyzed for benthic invertebrate community.	96	King County	Duwamish River and Elliott Bay Water Quality Assessment Team (Parametrix, KCDNR)
Duwamish Coastal America Restoration and Reference Sites: Results from 1997 monitoring studies	1998	Results from biological monitoring at three wetland restoration sites in the LDW: Kellogg Island, south of T-105 and turning basin 3	Benthic macro- and meiofauna analyzed for taxa richness, composition and densities. Stomach contents of Juvenile salmonids were also analyzed.	31	Coastal America	Wetland Ecosystem Team (University of Washington)
Duwamish Coastal America Restoration and Reference Sites: Results from 1996 monitoring studies	1997	Results from biological monitoring at three wetland restoration sites in the LDW: Kellogg Island, south of T-105 and turning basin 3	Benthic macro- and meiofauna analyzed for taxa richness, composition and densities. Stomach contents of Juvenile salmonids were also analyzed.	32	Coastal America	Wetland Ecosystem Team (University of Washington)
Duwamish Coastal America Restoration and Reference Sites: Results from 1995 monitoring studies	1996	Results from biological monitoring at three wetland restoration sites in the LDW: Kellogg Island, south of T-105 and turning basin 3	Benthic macro- and meiofauna analyzed for taxa richness, composition and densities. Stomach contents of Juvenile salmonids were also analyzed.	33	Coastal America	Wetland Ecosystem Team (University of Washington)
Kellogg Island Intertidal Habitat Restoration Pre-project Assessment	1990	Evaluation of the potential for restoration of filled intertidal area on Kellogg Island	Abundance of epibenthos per sq. meter was determined for several stations and zones around the island	199	Port of Seattle	Parametrix

Table 5. List of sediment bioassay data sets to be considered for inclusion in database

Report Title	Year Published	Survey description	Sampling description	Document number	Sponsor	Prepared By
Sediment Quality in the Puget Sound	2000	Determine the quality of sediments in terms of the severity, spatial extent and patterns of chemical contamination, toxicity, and adverse alterations to benthic infauna.	Amphipod 10-day mortality, sea urchin fertilization, Human Reporter Gene System, and Microtox bioluminescence	44	WSDOE	NOAA WSDOE
Sediment sampling and analysis - James Hardie Gypsum Inc.	1999	Results of the PSDDA sediment characterization at James Hardie Gypsum facility in the LDW in support of maintenance dredging. Samples were analyzed for DMMP-specified chemical and biological parameters.	Three tests run for amphipod 10-day mortality, echinoderm embryo mortality/abnormality, and juvenile Neanthes 20-day biomass.	181	James Hardie Gypsum Inc.	Jay W. Spearman Consulting Engineer
Dredge Material Characterization Hurlen Construction Company & Boyer Alaska Barge Lines Berthing Area	1998	Results of the PSDDA sediment biological and chemical characterization at the two indicated sites in support of maintenance dredging. Samples were analyzed for DMMP-specified chemical parameters. Four of the samples were also subjected to biological toxicity testing.	10-day amphipod mortality, 20-day Neanthes biomass	69	Hurlen Construction Company and Boyer Alaska Barge Lines	Hart Crowser
Hanford, Chelan, Connecticut sediment results	1996	Reports the results of biological testing from sediment collected adjacent to CSO outfalls in the LDW	Rhepoxynius mortality, Ampelisca mortality, Echinoderm embryo effective mortality, and Neanthes biomass	90, 91	KCDNR	KCDNR
Proposed Dredging of Slip No. 4, Duwamish River, Seattle, WA	1996	of sediment chemical and biological testing from slip four in the LDW conducted to satisfy PSDDA.	Amphipod 10-day mortality, 48-hr echinoderm mortality, Neanthes 20-day biomass.	154, 155, 156	Crowley Marine Services	PTI Environmental Services
1996 USACE Duwamish O&M	1996	Results of PSDDA sediment biological and chemical characterization of the Duwamish Waterway and upper turning basin for maintenance dredging.	Amphipod 10-day mortality, Neanthes 20-day biomass, echinoderm abnorm/mortality and Microtox for three sediment samples.	188	Army Corps of Engineers	Striplin Environmental associates, Inc.
Lone Star Northwest and James Hardie Gypsum-Kaiser Dock upgrade	1995	Reports the results of sediment chemical and biological testing from the vicinity of slip two in the LDW conducted to satisfy PSDDA.	Amphipod 10-day mortality, juvenile Neanthes biomass, echinoderm abnormality/mortality, and Microtox on four sediment samples	72	Lone Star Northwest and James Hardie Gypsum	Hartman Associates
Lonestar Northwest - West Terminal USACE – Seattle	1992	Analysis of sediments for maintenance dredge at Lone Star's West Terminal in the Duwamish River to meet PSDDA criteria	Four samples for amphipod mortality, Neanthes 20-day biomass, echino. mortality/abnormality and Microtox	71	Lone Star Northwest	Hartman Associates

Report Title	Year Published	Survey description	Sampling description	Document number	Sponsor	Prepared By
South Park Marina maintenance dredging, 1991	1991	Analytical and biological results of sediment from the north half of South Park Marina to characterize suitability for disposal at Elliott Bay deep-water disposal site.	Sediment samples collected from two stations with in each of the DMMUs. Four tests run for amphipod 10-day mortality, echinoderm embryo mortality/abnormality, juvenile Neanthes 20-day biomass and Microtox bioluminescence.	180	South Park Marina	Jay W. Spearman Consulting Engineer
Sediment Sampling Analysis Brown and Morton Properties Duwamish Waterway	1991	Results of the PSDDA sediment characterization at Brown Morton Properties in the LDW in support of maintenance dredging. Samples were analyzed for DMMP-specified chemical and biological parameters.	Three bioassays for 4-day amphipod survival, Neanthes survival, and echinoderm	179	Brown Morton Properties	Jay W. Spearman Consulting Engineer
PSDDA Bioassays for Duwamish Channel Sediments (O&M)	1991	Reports the results of sediment chemical and biological testing from the navigation channel to satisfy PSSDA criteria	Four tests run for amphipod 10-day mortality, echinoderm abnormality/mortality, juvenile Neanthes mortality, and Microtox bioluminescence	165, 166	Army Corps of Engineers	Science Applications International Corporation
Duwamish River Maintenance Dredge, Phase 1	1990	Reports the results of sediment chemical and biological testing from the navigation channel to satisfy PSSDA	Four tests run for 10-day amphipod mortality, oyster larvae abnormality, juvenile Neanthes mortality, Microtox bioluminescence	152, 153	Army Corps of Engineers	PTI Environmental Services

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4.0 Task 2, Deliverable 3: Conceptual Design for Database

LDWG is using a database system[8] originally developed by Floyd & Snider, Inc. and Rolling Bay Software for use on complex environmental projects. The data system is a relational database in Microsoft's SQL Server 7® and includes a database structure (a simplified data model is shown in Figure 1); a series of custom applications for data import, export, maintenance, and reporting; and the ability to perform ad-hoc queries using SQL.

LDWG will prepare a test data set that EPA and Ecology can import to their databases as a test of compatibility between LDWG and agency data management systems. This data set will be delivered to the agencies by April 30 and will include chemistry data for multiple events and chemicals.

This database structure is capable of holding Project, Event, Location, and Sampling data for environmental projects, as well as physical and chemical data for samples, including sufficient meta-data for an independent data validation to be performed if necessary. The latter feature distinguishes this system from other database systems containing Duwamish data that are currently in existence, such as Ecology's SEDQUAL, and NOAA's Query Manager. The system is also capable of holding chemical data for biological tissue, including sampling methods, preparation details, and QC information. The system can also hold bioassay and benthic infauna results, but is not yet able to accommodate full meta-data for these data types. The structure is currently being upgraded to house meta-data for biological monitoring, *in situ* monitoring data, and biological/habitat survey data.

The data system interacts with additional stand-alone graphics, statistical, and modeling programs (including AutoCad®, ArcView®, Surfer®, S-Plus®, SAS®, MTCAStat®, and various custom models for fate and transport modeling, exposure modeling, and risk evaluation) by generating Excel® export files in custom formats that are, in turn, imported into the stand-alone applications.

The discussion in Sections 4.1 to 4.5 describes the data model and the manner in which various types of environmental data are stored. In general:

- The data model is designed to be extremely flexible so that it can be adapted for different projects.

[8] The Appendix A Data System

- Most major tables in the database come in a three-table group: Main table, group table, and attribute table. The Project tables are a good example of this:
  - The main Project Table contains critical fields that uniquely describe a Project and/or are commonly used to query project information from the database.
  - The Group table allows the user to define groups of projects that may be rapidly queried together. A specific project may be a member of any number of project groups.
  - The Attribute table holds additional characteristics of a project that may be interesting and useful but not critical.
- The Business Rules System applies "rules" for each of the fields in the main table. It is also able to "expect and apply rules" to specific attributes based on the type of project (ProjectTypeCode).

4.1 DOCUMENTS

The Document, DocumentGroup, and DocumentAttribute tables are used to store bibliographic information about documents, maps, files, photographs, etc. The specific document may or may not be available electronically. The "location" field describes where the document is physically located; it may be a physical description, a document number in a library, a web page, or file path, etc.

The Document Table is recursive to ease in the filing of multi-volume documents. For example, appendices in large reports or field notes are often filed as children of the main report. Documents are classified as either "Library Holdings" or "Project Documents." Document grouping allows for quick associations of documents being used on a specific project or references to a specific report.

Document Attributes allow for user-defined characteristics to be added to the information that is tracked for specific documents. In general, Document Attributes are only used and available for ad-hoc queries and custom reports.

4.2 PROJECTS AND EVENTS

4.2.1 Project tables

The Project, ProjectGroup, and ProjectAttribute tables are used to store information about a specific project. The LDW RI is being identified as a single project. The Project table is recursive; subprojects or tasks are stored as children. Grouping allows for Projects to be grouped based on specific characteristics selected by the database administrator. The ProjectAttribute table is used to store user-defined information about a project and information needed to link a project in the system to project information in other project management tools including corporate accounting and scheduling systems, and client contact managers such as Outlook.

The ProjectNum and ProjectGroupNum fields are populated automatically by the data system and assigned unique values. Other fields allow for the user to assign more recognizable names and "nicknames" to the project.

4.2.2 Event tables

The Event, EventGroup, and EventAttribute tables are used to store information about specific events. Events are tied to Projects through the ProjectNum field in the event table. An Event cannot be loaded into the system without the ProjectNum field matching an existing ProjectNum in the system. Events are typically tied to a specific Task within the Project.

The loading of data associated with historical Events is typically setup as a Task within the Project. Because Documents, lab records, and field records are all currently tied at the Event level, there should be a one-to-one relationship between Events as defined in the data system and the historical sampling events. This will make it easier to keep track of the various documents associated with an Event and to tie these documents to the results that are collected as part that Event.

The EventGroup and EventAttribute tables work in a similar manner to the ProjectGroup and ProjectAttribute tables described above. Common event groups might tie together all events with fish tissue data, or all events performed by NOAA, etc. Events should be tied to the Documents[9] that support that Event. This can be done through either the EventAttribute table or through the Master Association Table.

4.3 LOCATION AND SAMPLE TABLES

4.3.1 Locations vs. samples

The data system considers a location to be an object fixed in space. Currently the system supports point objects (x,y,z) and line objects (x1,y1,z1,x2,y2,z2). Locations can exist in the

[9] e.g., Work Plan, Sampling and Analysis Plan, Quality Assurance Plan, Health and Safety Plan, Field Records, Lab Reports, Data Validation Reports, Data Reports, Project Reports

system without any association to a Project, Event, or Samples. Locations are defined in this manner to facilitate the use of location objects in GIS.

Samples occur when a person goes to a location and collects physical material, places it in a container, and records some observable information about it. Usually the observable information is part of a sample analysis performed in a lab, but it can also be a field observation, such as color or odor. Samples cannot exist within the system without an Event, and therefore a project, and a Location.

4.3.2 Location tables

Locations are defined in Section 4.3.1. The Location table lists each location and location group. Samples are tied to locations through the location field in the Sample table. The location type (e.g., point location, line location, transect) and the location status (e.g., proposed, pending, available, remediated, abandoned, inactive) must be defined when the location is setup and may be changed during data maintenance.

4.3.3 Location groups

The data system supports the formation of Location Groups. Location groups are defined for convenience and used as appropriate for the project. Once defined, they do not have to be used. A location group is a specific type of location that contains members that are also locations. Because a location group is a location itself, it can have an associated set of coordinates that are defined when the group is defined.

Some examples of the use of location groups include the following:

- Location groups can be formed to facilitate the rapid querying of the data. For example, a group may be formed of all upgradient groundwater wells, or for all intertidal sediment locations, or for all locations located within a specific operable unit.
- Location groups can be formed when samples are composited, and information is available on the locations of the individual grab samples used to form the composite. In this case, it is common that the location that is the group becomes more important than the individual locations that are members of the group. There is no default rule within the database to identify the location for the composite sample. For this project, the centroid of the locations of the individual members of the group will be used to identify the location group, i.e, the composite sample.
- Location groups can be formed when samples are collected from adjacent sites but are viewed as co-located samples. These samples may be collected over time and by

different parties. For example, a location group could have four members that were the specific locations of samples collected by three different parties over a 5-year time period. The coordinates of the group location could be the centroid of the coordinates of the individual locations. The results for any of the sampling events could be plotted on the same group location on maps; however, the details of the "true" location of the individual sample for any event would be retained in the database and could be accessed if needed. There is no default rule in the database on when to form a location group for co-located samples. For this project, all historical sample locations will be plotted and specific recommendations for locations that could be considered co-located and therefore grouped will be made.

- Location groups can be formed for replicate samples; however, this should only be done when individual coordinates are available for the collection of each replicate. If only one set of coordinates is collected in the field, then this is a single location, and it is the samples that are replicates, not the locations.

Location groups are used to aggregate multiple locations, not to average or manipulate the results from samples collected at these locations.

4.3.4 Sample tables

Samples are defined in Section 4.3.1. The Sample table lists each sample and sample group, and contains critical sample collection information, such as sample collection date.

Some important relationships for sample include:

- A sample is tied to a location through the location field in the Sample table.
- A sample is also tied to a sample collection method through an attribute in the SampleAttribute table.[10]
- A sample is tied to an event through the event field in the Sample table.
- A sample can be tied to documents such as Work Plans, SAP, QAPP, field records, and photographs at the event level only.

4.3.5 Special considerations

1. *Grab sampling for biological and chemical analyses:* This is treated in the system as a single sample at a single location, where material from the sample is placed in sample jars and shipped to the labs for various chemical, physical, and biological analyses. The Sampling Method or the Event SAP should describe the details.

[10] Through release 1.08; release 2.0 has this information in a new field in the sample table – SampleCollection MethodNum.

2. *Core sampling for biological and chemical analyses:* Each core segment is treated in the system as a single sample. However, all segments are assigned to the same line location that extends from the beginning of the core to the end of the core. Sample attributes contain information on sample depth and/or core segment. If the core segment is split among several jars for the different analyses, then the core is one sample with multiple analyses. If different core segments are used for different analyses, then each core segment is its own sample. Finally, if multiple cores are collected, and the equivalent segments from each core are composited to produce a sufficient volume of material for the multiple analyses, then the database rules for forming a composite sample apply.

3. *Biological Samples for Tissue Analysis:* For large biological samples such as plants, fish, or mammals, the parent sample is the animal or plant collected in the field. The Sampling Method or the Event SAP should describe the details. If the whole sample is ground and homogenized, then this sample should be associated with SampleAnalysis. If the plant or animal is sectioned into specific subsamples (e.g., fat sample, liver sample, etc.), the subsample becomes a child sample in the data system and the SampleMethod for the Child describes how the sample was sectioned.

4. *Porewater samples and lab QC samples associated with Bioassays*: Porewater samples collected from sediments prior to bioassay analyses are simply a case of subsampling. They are child samples to the sample collected in the field. The grain size, TOC, and chemical data are simply additional analyses of the same sample. If bioassays are run on 5 replicate samples (all of which are stored in the data system) and the chemical analyses are run on a composite of the five replicates, then a sample group should be formed to describe the compositing process. By forming the sample group, the mean bioassay result can be associated with the chemistry results by tying the mean bioassay result to the sample group.

4.3.6 Sample types

Information regarding sample type exists in two fields in the Sample table: SampleTypeCode and SampleFieldQCCode. The use of these two code fields is illustrated in Table 6.

Lab QC samples: Any one of the sample types may be selected by the laboratory as a lab QC sample. For example, there is no reason a field duplicate could not also be selected by the lab as a lab duplicate or even a lab matrix spike sample. Additionally, there is no reason that the same samples should be picked as lab QC samples in different analyses. Therefore, the lab QC code is contained in the SampleAnalysis table.

Sample recursion: The sample table is a recursive table. This was designed to handle the collection of subsamples. The recursion feature has been used to handle the following situations:

- Laboratory separation of sediment samples into a drier solid phase sample and porewater – the sample method then refers to the method used by the lab to perform the separation (e.g., centrifigation vs. vacuum filtration). Both samples refer back to the parent sample that was collected in the field.
- Treatability study results performed on samples that were originally collected in the field, but have been through one or more treatment steps.

4.4 SAMPLE ANALYSIS, SAMPLE RESULT, AND METHOD TABLES

4.4.1 Method tables

The Method table is used to store information about field and analytical methods. Method information may be limited such as "Unknown volatile method" or may include references to published analytical methods, SAPs, or lab SOPs. The table may even include descriptions of method modifications. The sample results are tied to the method through the method field in the SampleAnalysis table. Method groups are used for extraction and analysis methods that are commonly used together.

4.4.2 SampleAnalysis tables

The SampleAnalysis table is used to store information about laboratory analyses. Separate records are created for each laboratory QC sample and for laboratory reanalysis.

Some important relationships for SampleAnalysis include:

- A sample analysis is tied to a sample through the sample field in the SampleAnalysis table.
- A sample analysis is tied to an analytical and/or extraction method through the method field in the SampleAnalyis table.
- A sample analysis is tied to a laboratory through the laboratory field in the SampleAnalysis table.

4.4.3 SampleResult tables

The SampleResult table is used to store analytical results, including field measurements, chemistry data, biological data and radiological data. Field observations which are not numeric in nature, such as color or odor, or which are considered descriptions of sample collection conditions, such as weather and temperature, are stored as sample attributes.

The SampleResult table is tied to the SampleAnalysis table through the SampleAnalysis field in the SampleResult table; and to the parameter table through the parameter field in the SampleResult table.

4.4.4 Special considerations

SampleBatch and SampleAnalysis batch tables

The SampleBatch and SampleAnalysisBatch tables are specialized grouping tables. These tables are used to group field and laboratory quality control samples with their associated samples; for example a trip blank will be grouped with all the samples that traveled with it from the field to the laboratory. These associations are necessary to determine the impact of quality control outliers on the reported sample results.

Laboratory reanalysis

Laboratory reanalysis performed for the purpose of lab QC is tracked through the LabQCCode in the SampleAnalysis table. When laboratories include multiple results for one field sample, i.e., the group of analytes is reported at two different dilutions or a re-extraction and reanalysis was performed, a new sample analysis record is created. The InterpretedQual field should be used to make it clear which result should be reported for each analyte. This is critical; otherwise both sample results can appear in queries of the data.

When analytical information, i.e., analysis dates, dilution factors, is not available, such as for historical data, multiple results for one sample may be tracked through the instance field.

Averaging of sample results

The data system does not automatically average samples. For field replicates, the data system typically houses SampleResults that are the average of the replicates, in addition to the individual replicate values themselves. Averaging is currently done manually, with the averaging procedure, i.e., how are non-detects handled, listed in the comment field.

Other averaging is also done manually. For example, the following rule may be used for the Duwamish project: first average lab replicates, then average field splits, then average field replicates to produce a final result for the sample. In the current data system, averaging across lab duplicates and across splits is not automatically supported. Averaging across lab duplicates could be accomplished by treating the lab duplicates as lab replicates. Averaging across field splits would probably require the use of sample groups, and specifications regarding handling differences in data quality.

4.5 Parameter and Criteria Table

4.5.1 Parameter table

The parameter table lists chemical compounds and other measurable parameters. The parameter table includes a "default" or standardized name for each compound, as well as alternative names or spellings that are associated with the default name through the ParameterParent field. Additionally, parameter abbreviations required for certain import and/or export functions, such as to SEDQUAL or GISKey, are stored here. The sample results are tied to the parameter through the parameter field in the SampleResult table. Parameter groups are used for reporting and calculating purposes.

4.5.2 Criteria tables

The Criteria table is used to store regulatory and project-specific criteria. These are used extensively in evaluating the data and are primarily for querying and reporting functions.

Published criteria are not necessarily listed as "measurable parameters." For example, MTCA contains criteria for both "Nickel, soluble salts" and "Nickel, refinery dust." Both of these CriteriaParameters are related to the measurable parameter "Total nickel" in the CriteriaParameterMap table.

Calculated parameters: Summation

Combining results is potentially just as problematic as averaging results. For example, there are many ways in which one might form the parameter "total PCBs" from results on individual Aroclors or congeners. The data system does not assume how to do this. These parameters are defined as "calculated parameter groups"; rules for forming them and the parameter members that form the calculation must be specified in advance. Calculated parameters are currently formed by exporting the required information into Excel, calculating the new parameters, and then importing the new results back into the database.

4.6 Export to Other Systems

Export to other data systems is performed through either ad-hoc queries or custom reports. The data system currently supports export to SEDQUAL (Ecology's default Excel Import files) and to GISKey (chemistry; no biology). Export capabilities to other systems are currently under development.

Table 6. Sample types and their codes

COMMON NAME	SAMPLETYPECODE	FIELDQC	COMMENTS
Grab sample	Grab	Sample	This is a simple sample.
Composite of several grab samples	Composite	Sample	Composites are a special case of sample grouping where only a single sample analysis is performed and only a single result is expected.
Replicate samples – individual results	Grab	Field replicate	Each replicate is treated as an individual sample; but the fieldQC field indicates that this is one of a set of replicate samples. During sample loading the business rules checker asks for the Parent Sample number – the sample number of the combined result should be used.
Replicate sample – combined result	Mean Results	Sample	Mean results is the SampleTypeCode for results that are averaged. For replicate samples, replicate samples are included as separate records. The average of each concentration is calculated and included as the mean result. A fieldQCCode of sample is used so that the averaged results are included when sample results are queried. A field QCCode of Field replicate should be used for all of the unaveraged samples (including the first one).
The split of a grab sample	Grab	Field Split	Note that composite samples can also be split. During sample loading the business rules checker asks for the Parent Sample number – the sample number of the original sample should be used.
Field duplicate of a grab sample	Grab	Field Duplicate	Note that composites can also be duplicates. They are split after the compositing step. During sample loading the business rules checker asks for the Parent Sample number – the sample number of the original sample should be used. Note that field duplicates that are intended to be "averaged" should be treated as replicates.
Trip blanks	Grab	Trip Blank	The use of trip blanks triggers the "batch" table to associate which group of field samples go with which trip blank.
Field blanks	Grab	Field Blank	The use of field blanks triggers the "batch" table to associate which group of field samples go with which field blank.

Note: Samples are formed when material is collected in the field at a location.

Note regarding Lab QC: With the exception of trip blanks, any one of these sample types may be selected by the laboratory as a lab QC sample. For example, there is no reason that a field duplicate couldn't also be selected by the lab as a lab duplicate or even a lab matrix spike sample. All lab QC information is contained in the SampleAnalysis table.