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Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model

Office of Superfund Remediation and Technology Innovation

Quick Reference Fact Sheet

The U.S. Environmental Protection Agency (EPA) supports the use of best management practices (BMPs)* as a mechanism for maximizing technical effectiveness and resource efficiency in the execution of site assessment and cleanup projects. This fact sheet is the first in a series of documents that address conceptual site models (CSMs). A more comprehensive document is planned that will detail techniques to develop and maintain an accurate CSM as a primary planning and decision making tool used to identify and manage site uncertainty that can inhibit effective project decision making. This fact sheet summarizes how environmental practitioners can use CSMs to achieve, communicate, and maintain stakeholder consensus on site understanding, while satisfying the technical and quality objectives required for each stage of a cleanup project's life cycle. The focus is on defining stages and products of CSMs along with potential applications of CSMs at various stages of a project life cycle. Content herein is presented in a Superfund Program context; however, to the extent practical, text has been written to maximize applicability in other programs and regulatory frameworks. Other agencies and programs may find these concepts useful and environmental cleanup practitioners are encouraged to explore the utility and integration of a project life cycle CSM within their own program requirements and deliverable schedules.

* Best Management Practices (BMPs) are, in general, methods or techniques found to be the most effective and practical means in achieving an objective while optimizing the use of resources. BMPs, such as those described herein, however, are not programmatic requirements.

Purpose and Audience

The Conceptual Site Model (CSM) is an iterative, 'living representation' of a site that summarizes and helps project teams visualize and understand available information. This fact sheet demonstrates the utility of using the CSM to assist Superfund project teams, hazardous waste site cleanup managers, and decision makers throughout the life cycle stages of investigation and cleanup. It also encourages the creation and revision of a CSM as a primary project planning and management tool.

The ability to efficiently access and interpret data is essential to guiding project teams through the entire cleanup process, from project planning to site completion. Development and evolution of a CSM can address the unique needs of each stage in a project's life cycle, and provide a valuable tool for successful environmental cleanup. The level of effort necessary to develop specific CSM components should correlate with the level of site maturity, site complexity, and the magnitude of the characterization and cleanup challenges project teams face.

The CSM uses a concise combination of written and graphical work products to portray both known and hypothesized site information. At more mature sites, this information is often contained in a variety of reports, data sets, and electronic or hard copy formats where the construction and use of a CSM synthesizes multiple independent data sets and maximizes the value of historical information. A range of tools, from simplified renderings to more complex visualization tools, are used to capture and communicate existing information and focus future data collection to fill data gaps and reduce key site uncertainties. The CSM serves as the framework for incorporating new data as it becomes available during characterization and remediation. A detailed, up-to-date, and accurate CSM can be very beneficial in supporting decisions related to key project elements, such as cumulative risk, remedy selection, remedy implementation, site completion, and site reuse.

Effective use of the CSM is also a critical BMP that facilitates technical team decision making while supporting stakeholder communication and consensus building. By facilitating efficient real-time evaluation of data, CSM elements provide a platform to inform decision makers in a manner that can help limit the number of field mobilizations necessary to characterize a site, minimize the need to re-characterize a site late in a project's life cycle, and optimize elements of remedy implementation. A comprehensive CSM synthesizes chemical data with geologic, hydrogeologic, and other site information to enhance a project team's ability to develop solutions to ensure protectiveness, effectively manage resources, and limit the environmental footprint of site cleanup activities.

Conceptual Site Model Life Cycle

The life cycle of a CSM mirrors the common progression of the environmental cleanup process where available information is used, or new information acquired, to support a change in focus for a project. The focus of a CSM may shift from characterization towards remedial technology evaluation and selection, and later, remedy optimization. As a project progresses, decisions, data needs, and personnel shift as well to meet the needs of a particular stage of a project and the associated technical requirements.

Figure 1 shows the relationship of the CSM life cycle stages to various environmental regulatory programs and the applicability of other BMPs such as comprehensive systematic planning, use of dynamic work strategies, and real-time measurement technologies. Note that CSMs become increasingly quantitative and decreasingly conceptual in nature as data are collected, data gaps filled, and CSM elements that help depict site data mature.

The project life cycle CSM presented in this technical bulletin and summarized in the adjacent text box consists of six stages. These are not six different CSMs; rather, they are representations of the CSM as it is evolved through defined states of maturity and purposes over a project's life cycle. Whether early or late in the project life cycle, development of the preliminary and baseline CSMs necessitates an initial compilation, synthesis, and presentation of the CSM to the technical team and stakeholders to facilitate systematic planning. Regardless of where in the assessment and cleanup process a particular site resides these earliest CSM versions can potentially serve as milestone deliverables. These early stage versions take advantage of text, figures, tables, and potentially electronic 3-D data visualizations to compile, interpret, and present the CSM. Project teams are encouraged to consider existing schedules and scope of programmatic deliverables to integrate these CSM components early in the systematic planning process. Project teams can initiate development of a project life cycle CSM at any stage of an active project to serve as a tool to help facilitate site decision making. The phase of a project and the adequacy of the existing CSM or project data will indicate what stage of the CSM life cycle is most appropriate.

Simple drawings and concepts are commonly used to communicate early project stage CSMs. As the level of information and complexity increases, the ability of a CSM to capture and synthesize new data in support of decision making can be significantly improved through the use of visualization platforms, appropriate data management strategies, and decision support tools.[1] These tools and strategies enable the CSM to be revised as more site information is collected and adapted to support the changing decision making needs of a project.

Six Stages of the Project Life Cycle CSM

Key Points in the Development of a CSM

(1) **Preliminary CSM Stage** – Project milestone or deliverable based on existing data; developed prior to systematic planning to provide fundamental basis for planning effort.

(2) **Baseline CSM Stage** – Project milestone or deliverable used to document stakeholder consensus/divergence, identify data gaps, uncertainties, and needs; an outcome of systematic planning.

Key Points in the Evolution and Refinement of a CSM

(3) **Characterization CSM Stage** – Iterative improvement of CSM as new data become available during investigation efforts; supports technology selection and remedy decision making.

(4) **Design CSM Stage** – Iterative improvement of CSM during design of the remedy; supports development of remedy design basis and technical detail.

(5) **Remediation / Mitigation CSM Stage** – Iterative improvement of CSM during remedy implementation; supports remedy implementation and optimization efforts, provides documentation for attainment of cleanup objectives.

(6) **Post Remedy CSM Stage** – Comprehensive site physical, chemical, geologic, and hydrogeologic information of CSM supports reuse planning; documents institutional controls and waste left on site; and other key site attributes.

General Environmental Cleanup Steps	CSM Life Cycle	Best Management Practices SPP	Best Management Practices DWS/RTMT	CERCLA - Superfund	RCRA	Brownfields	UST	VCUP Varies by State	IRP/ERP	MMRP
Site Assessment	Conceptual **Preliminary CSM** **Baseline CSM**			Preliminary Assessment (PA) Site Inspection (SI) National Priorities List (NPL) No Further Remedial Action Planned (NFRAP)	Facility Assessment (RFA)	Phase I Environmental Site Assessment (ESA)	Initial Site Characterization Initial Response	PA SI	PA SI	PA SI MR Site Prioritization Protocol (MRSPP)
Site Investigation and Alternatives Evaluation	**Characterization CSM Stage**			Remedial Investigation/ Feasibility Study (RI/FS) Removal Actions - Emergency/ Time Critical/Non-Time-Critical	Facility Investigation (RFI) Corrective Measures Study (CMS)	Phase II ESA	SI Corrective Action Plan (CAP)	RI/FS	RI/FS NFRAP	RI/FS
Remedy Selection	**Design CSM Stage**			Proposed Plan Record of Decision (ROD)	Statement of Basis (SB) Final Decision and Response to Comments	Remedial Action Plan (RAP)	Cleanup Selection	ROD	Proposed Plan ROD	Remedy Selection
Remedy Implementation	**Remediation/ Mitigation CSM Stage**			Remedial Design (RD) Remedial Action (RA) – Interim and Final	Corrective Measure Implementation (CMI)	Cleanup and Development	Corrective Action - Low-impact site cleanup - Risk-based remediation - Generic remedies - Soil matrix cleanup	RD RA	RD RA – Interim and Final Remedy in Place (RIP)	RD Time Critical Removal Action (TCRA) RA RIP
Post-Construction Activities	**Post-Remedy CSM Stage**			Operational & Functional Period Operation & Maintenance (O&M) Long term monitoring (LTM) Optimization Long Term Response Action (Fund-lead groundwater/surface water restoration)	O&M On-site inspections and oversight	Property Management Long-term O&M Redevelopment Activities (Private- and Public-led)	LTM	O&M LTM	Shakedown period Operating Properly and Successfully O&M LTM	Shakedown period Long Term Management
Site Completion	Quantitative			Construction Complete (CC) Preliminary or Final Close Out Report (PCOR/FCOR) Site Completion - FCOR Site Deletion O&M as appropriate	Certification of Completion Corrective Action Complete with Controls or without Controls	CC Property Management	No Further Action (NFA)	CC	Response Complete (RC) NFA	RC NFA

Abbreviations:

SPP = Systematic Project Planning
DWS = Dynamic Work Strategies
RTMT = Real Time Measurement Technologies

CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
RCRA = Resource Conservation and Recovery Act

UST = Underground Storage Tanks
VCUP = Voluntarily Clean Up Programs

IRP/ERP = Installation Restoration Program/ Environmental Restoration Program
MMRP = Military Munitions Response Program

Figure 1. Crosswalk of Regulatory Program Stages and CSM Life Cycle Phases. Use of terminology from regulatory frameworks is not intended to supplement any specific programmatic requirements or guidance; however, use of CSM components in a flexible and comprehensive framework can facilitate site decision making during the entire site-cleanup process, irrespective of the environmental program driving site cleanup. Using SPP, evolving the CSM, and leveraging DWS and RTMT at each key project stage can improve project efficiency and effectiveness.

Note: The width and gradation of the blue arrows demonstrating BMPs indicate the relative level of effort applied and the resulting impact and value of performing the BMPs at the indicated project stages.

Where key stakeholders change, particularly project managers, regulatory personnel, and contractors, consistent use of a project life cycle CSM serves to document and maintain the "state of knowledge" about a site. Similarly, review of historical iterations of the project life cycle CSM provides context for new team members to understand previous site decisions and can facilitate effective transition of supporting data sets, data management strategies, and visualization platforms.

Preliminary CSM

EPA requires that a systematic planning process be employed to plan all environmental data operations.[2] The Preliminary CSM, therefore, can act as a starting point for compiling and synthesizing existing information to support building stakeholder consensus, identifying data gaps and uncertainties, and determining subsequent data needs.

The Preliminary CSM provides a comprehensive overview of the site, based on available site-related documents, with information relevant to the identified problems. Interviews with site owners and other stakeholders, historical or regional geologic/hydrogeologic information, and third-party information such as historical aerial photographs, electronic environmental databases, property tax maps, and Sanborn Maps are also considered. The evaluation and synthesis of this information forms the basis for developing and presenting the Preliminary CSM to systematic planning participants.

Figure 2 shows a pathway network receptor diagram, which is commonly used as a CSM to support risk assessment. A project life cycle CSM includes this information, and to support investigation, design, and remedy implementation project phases, it also includes other elements, such as known and suspected contaminants of potential concern (COPCs), locations of probable source areas, the mechanisms and timing of historical and potential releases, affected environmental media, contaminant distribution data, potential migration pathways, and potential receptors.

Visual elements of a Preliminary CSM can range from simple sketches, to basic two-dimensional (2-D) graphics such as maps and cross sections, to more advanced three-dimensional (3-D) visualizations. The complexity of the CSM at this stage depends on the volume and state of data (electronic or hard copy) along with any prior CSM component development.

Baseline CSM

A critical strategic output of a systematic planning effort, the Baseline CSM is an improved, more informative version of the Preliminary CSM used to

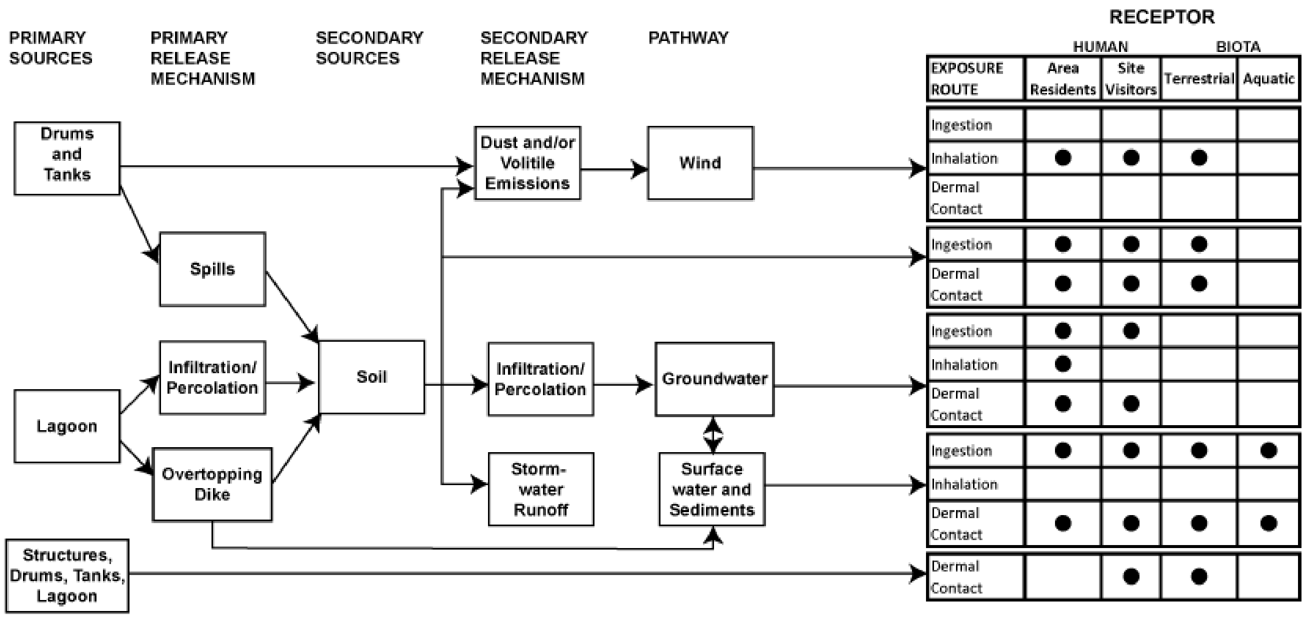

Figure 2. Example Pathway Receptor Network Diagram. Commonly referred to as a CSM, the pathway receptor network diagram is an important element of the project life cycle CSM, used to ensure the incorporation of human and ecological exposure information in project planning and implementation.

help identify data gaps and information needed to meet key project objectives. The Baseline CSM documents stakeholder consensus (or divergence) on known site conditions; uncertainty hypotheses; data gaps, needs, and collection plans; and potential remedial challenges. Armed with this knowledge, project teams can leverage the Baseline CSM to identify needs for data types, density, quality objectives, and quality indicators such as precision and accuracy.

At this point in the project planning process, the project team can also consider the need for collaborative data to support hypotheses testing and uncertainty reduction, risk assessment, technology evaluation and selection, and design for the most-probable remedial technologies. The scale and distribution of data gaps identified provides the basis for designing a dynamic work strategy and subsequent data collection efforts. The need to perform a demonstration of methods applicability[3] to understand site and matrix specific analytical performance or optimize sampling strategies, is generally identified at this stage of the planning process.

A 2-D diagram used to depict the Preliminary CSM for the Cache La Poudre River Site[4] project in Colorado is shown in Figure 3. The diagram and supporting CSM components effectively facilitated an agreement between the project team to follow separate, but related, paths to address questions posed by stakeholder groups with differing views of site conditions and processes. During systematic planning, the project team did not reach consensus on a single Baseline CSM; however, the team agreed to use divergent CSM viewpoints to identify all data and information needs necessary to resolve to one CSM version and facilitate key project decision making.

Characterization CSM Stage

Using the Baseline CSM as its starting point, the Characterization CSM is used to efficiently capture and synthesize data generated during site characterization efforts. This CSM is updated continually at an agreed upon frequency or in relation to key data collection efforts. When used effectively, the Characterization CSM helps to identify and manage stakeholder uncertainty associated with

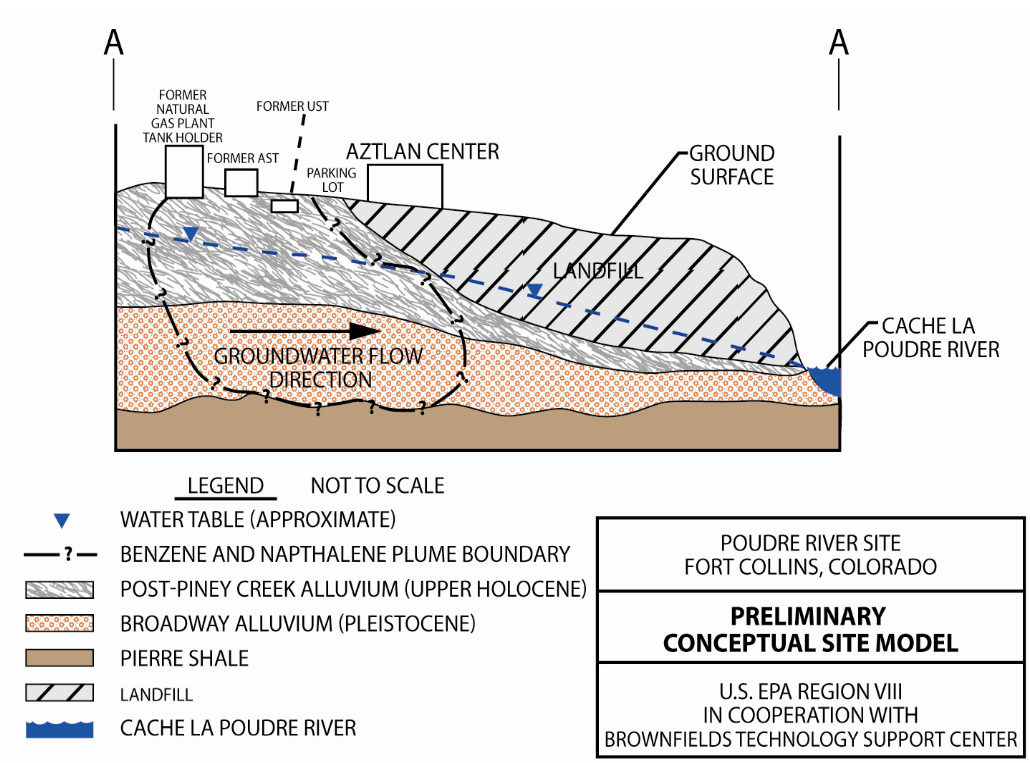

Figure 3. Preliminary CSM Representation. This Preliminary CSM summarizes general site information, including primary site attributes, geologic stratigraphy, groundwater potentiometric surface and flow direction, groundwater-surface water relationship, and presumed extent of soil and groundwater contamination. This representation of a CSM can be an effective method of communicating site conditions to a diverse audience in an easy-to-understand format.

principle study questions like the nature and extent of contamination, or identification of key geologic/hydrogeologic features controlling fate and transport processes.

Characterization CSM components capture and synthesize data that can be used to support estimates of cumulative risk and identification of immediate risks to human health and the environment. The Characterization CSM integrates key geologic, hydrogeologic, and chemical data that can also be used to support an effective screening of remedial alternatives.

Figure 4 is a representation of the Characterization CSM developed for the Poudre River Site project. The CSM indicated that site contaminant type, sources, and migration pathways were significantly more complex than originally understood, affecting the goals of subsequent characterization efforts. At this stage of the project, the use of collaborative data sets, comprised of field- and fixed-based laboratory analyses, improved risk characterization and facilitated collection of remedy design data during site characterization efforts.

Characterization efforts are becoming more comprehensive because of the availability of field-based, high-density data collection methods. These high-resolution tools effectively mature the CSM more quickly, particularly when data management strategies (such as use of electronic data deliverables and relational databases) are employed in conjunction with 3-D visualization platforms.

More than any other CSM life cycle stage, the use of real-time technologies for dynamic data collection efforts requires the Characterization CSM to be flexible and easily modified in 'real-time.' This need is driven by the fact that the nature and extent of contamination and related cumulative risks typically are not yet well defined at this stage, thus the evolution of significant site knowledge tends to occur rapidly as characterization data are collected. The tools used to frame, document, or depict the CSM must therefore be capable of quickly and efficiently capturing high-density data streams and translating those data streams into predetermined formats.

Once contamination and related risks have been adequately defined, projects typically shift focus to the collection of physical and chemical data needed to

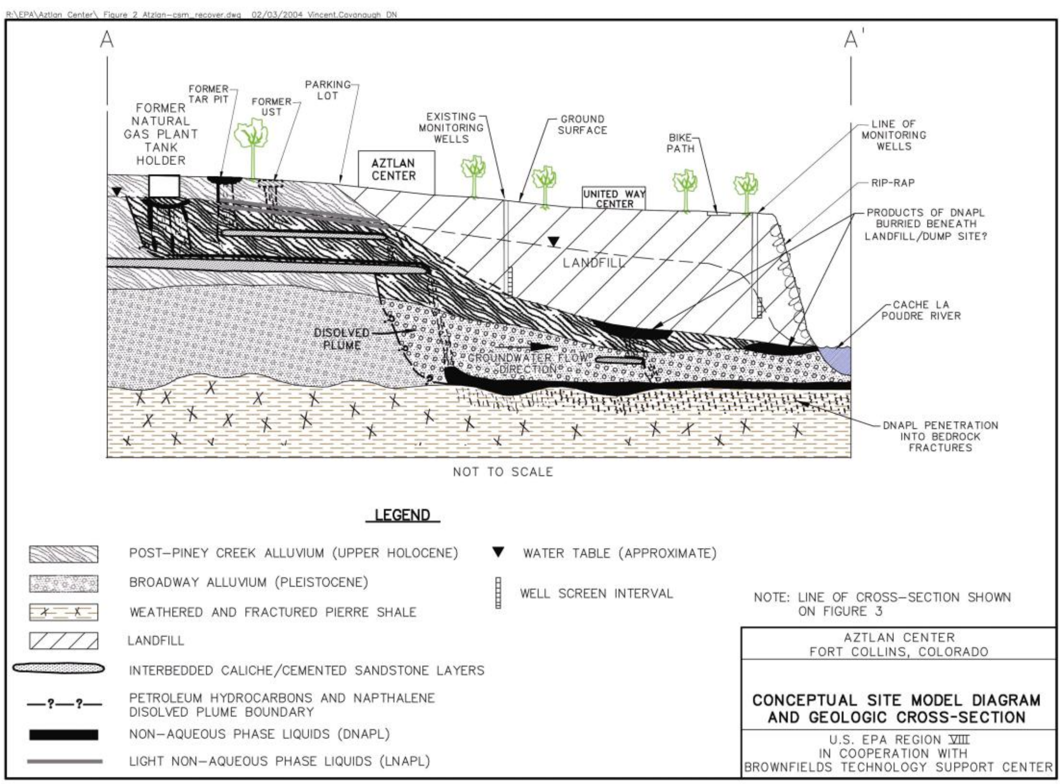

Figure 4. 2-D Component of Characterization CSM. The Characterization CSM serves as a repository for the integration of site attributes with field observation and measurement data. Depictions of integrated data guide investigation efforts and support technology selection and remedy decision-making.

support technology selection and remedy design. These data may be of a different focus or density scale than characterization efforts aimed solely at delineation. For example, additional physical property testing of the matrix or refinement of treatment zones, source zones, residual phase, and dissolved plume components is used support feasibility studies and future design considerations. Information from these efforts can be incorporated into the Characterization CSM and used for subsequent decision-making.

Collection, evaluation, and synthesis of data used to refine the Characterization CSM also supports the development of key remedial project support documents such as the Record of Decision (ROD) or intermediate decisions such as the need for implementation of an interim remedy.

Design CSM Stage

CSM elements are used in the design stage to help identify additional information requirements and synthesize data supporting the implementation of a selected remedy. The Design CSM directly supports the design basis for implementation of both pilot and full-scale remedies at a site. Physical property data, geologic and hydrogeologic conditions, or contaminant concentrations and distribution may need to be refined to optimize remedy design. For example, elements of the Design CSM might be used to plan and incorporate the results of hydraulic conductivity profiling or geochemical parameters testing to support the design of an *in situ* treatment strategy. Geologic and hydrogeologic Design CSM components support evaluation of important design considerations such as radius of influence, tracer tests, or aquifer geochemical characteristics like pH, oxidation/reduction potential, and dissolved oxygen.

For performance-based projects, the Design CSM can support development of metrics for system installation and performance. The Design CSM typically can be developed using the same data management and 3-D tools as those used during the characterization effort. Elements of the Design CSM such as concentration ranges, mass estimates, location, and spatial dimensions of source materials can be used to help establish initial benchmarks, as well as short-, medium-, and long-term metrics, to measure and evaluate remedy/system performance. This capability has direct application to support documentation and data analysis for Five Year Review, remediation optimization efforts, or both.

For project managers, elements of the Design CSM can be used to develop supporting documentation for solicitation of final design and construction contracts.

Figure 5 depicts elements of the Design CSM developed for the Cache La Poudre River Site project.

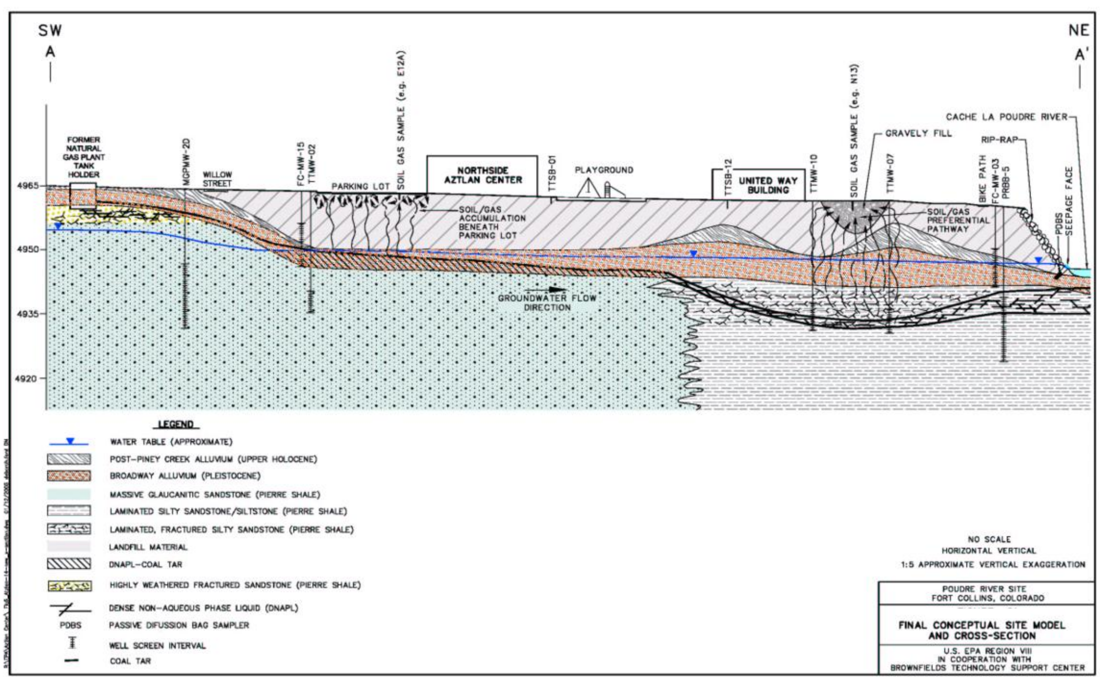

Figure 5. 2-D Component of Design CSM. The Design CSM captures key design considerations, such as site attributes; geologic, hydrogeologic, and chemical information; and fate and transport processes, in support of remedy design.

CSM Case Study: NASA Ames Research Center / Naval Air Station Moffett Field

NASA and the U.S. Navy (USN) undertook a joint effort at their adjacent installations in Mountain View, California, to inhibit the migration of a trichloroethene (TCE) groundwater contamination plume from NASA property onto the adjacent USN facility. The project involved designing an air sparging/soil vapor extraction (AS/SVE) system across a buried sedimentary paleochannel to intercept the plume and limit the spread of contamination. A Remediation/Mitigation CSM was used to visualize real-time field data to verify site geology, optimize the remedy design, and ensure its successful implementation.

Initial characterization was completed using cone penetrometer testing (CPT) and 3-D visualization to identify optimized sampling locations to verify the adequacy of remedy design. CPT data were used collaboratively with soil cores and air sparging test results to optimize air sparging well construction. Core recoveries were poor because of the consistency of sands within the paleochannel, making the CPT data essential to the proper design of the sparging system.

The project team verified the CPT data to optimize the AS/SVE systems design in real-time. Data were introduced into 3-D visualization software, and images of subsurface lithology developed from CPT data at locations where air sparging wells were also installed. The 3-D visualizations, such as Figure 6, provided the basis for optimizing the air sparging system through reduction in well point quantities and provided assurance that the remedy would accomplish project goals.

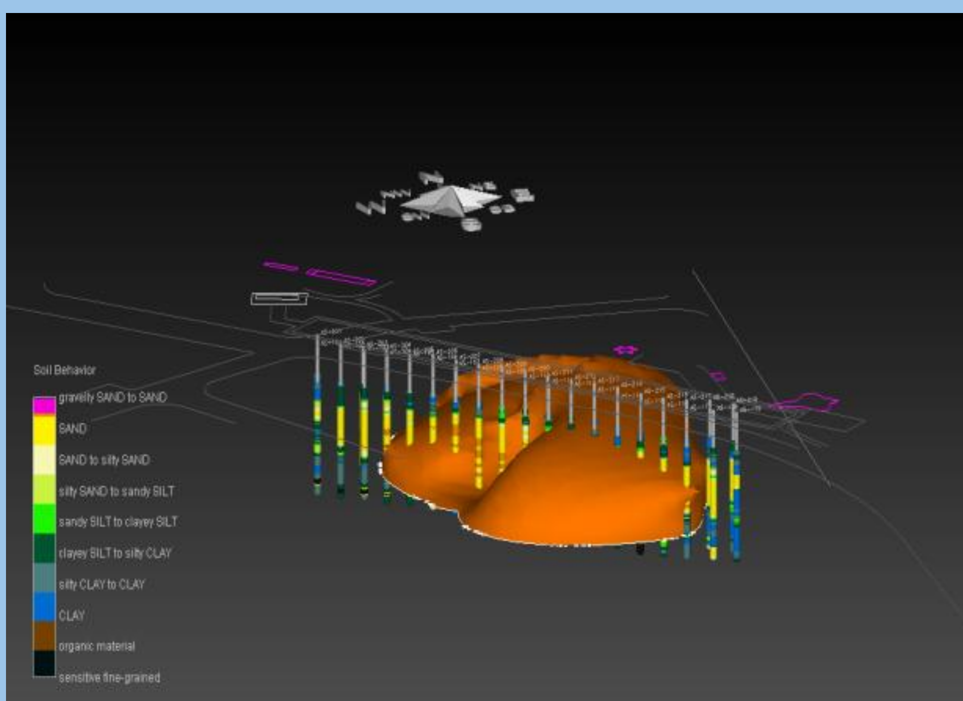

Figure 6. 3-D Visualization Component of Remediation/Mitigation CSM. The Remediation/Mitigation CSM enhances a project team's ability to evaluate and modify remedial designs during implementation to minimize resources and maximize remedy effectiveness.

Data from 1-foot sparging screened intervals were correlated with geologic logs and CPT data to identify the specific design modifications needed. The data were also used to optimize the long-term monitoring program for groundwater. Project results confirmed that using a real-time evolving CSM to manage and visualize collaborative data enabled the cost-effective development of a sound design basis, design, and successful remedy implementation.

The updated CSM includes new information on water levels, well locations, soil gas, and a critical dense non-aqueous phase liquid (DNAPL) migration pathway identified in fractured bedrock. Using the Design CSM as a guide, remedial efforts were targeted to address a variety of site concerns. Elements included: defining spatial dimensions for source areas to aid hydraulic isolation; identification of DNAPL migration pathways and river discharge locations to design a sheet pile wall barrier and hydraulic control system to limit DNAPL migration to the Poudre River; and supporting the design of vapor intrusion mitigation systems at some site buildings.

Remediation/Mitigation CSM Stage

The Remediation/Mitigation Stage CSM can be used to guide remediation/mitigation efforts, such as:

(1) Directing and documenting excavation activities;
(2) Managing phased remediation programs;
(3) Managing remediation at separate operable units or subunits of a site;
(4) Responding to changed conditions encountered in the field; and
(5) Optimizing *in situ* and *ex situ* treatment remedy implementation

This stage also includes operation and maintenance (O&M), and long-term monitoring activities. Continuous updating of the CSM during this stage can be used to maintain stakeholder consensus, identify potential challenges as remediation/mitigation progresses, and support future remediation optimization efforts.

The same CSM platform and data management system employed during the previous CSM stages typically can be used as the basis for the Remediation/Mitigation CSM. Consistent platform use may help project teams realize significant cost savings during remediation/mitigation. For example, efforts could be limited to minor modifications to data fields or the addition of new software for system evaluations.

The Remediation/Mitigation CSM also can be used to assess performance metrics to help ensure that remedies are operating according to design or other project parameters. For example, information about changing concentrations in a monitoring well can be indicative of source depletion, rebound, or other important processes effecting assessment of remedy performance. Similar to the Design CSM, the Remediation/Mitigation CSM can be used to refine further the scale of design to ensure remediation approaches are sized appropriately to limit costly over- or under-designed systems. The higher resolution areas of the CSM also serve to identify focus areas of sites that may warrant special design considerations, such as source zones, NAPL areas, dissolved phase contamination, and residual contamination. When the Remediation/Mitigation CSM is updated as a remedy is implemented or optimized, system design specifications and operating protocols can be modified in real-time to adapt to small-scale variations in site conditions.

As a remedy begins to achieve performance goals such as cleanup or action levels, components of the Remediation/Mitigations CSM can be used to support documentation of site completion activities, including issuance of the final close-out report and site deletion under the CERCLA program; or certifying completion or making a No Further Action determination under other regulatory programs.

Post Remedy CSM Stage

While use of the CSM in the Remediation/Mitigation stage can help project teams document the attainment of remediation goals, the utility of a life cycle CSM does not end here. The Post Remedy CSM provides integrated and synthesized information that can assist project teams with a variety of documentation and redevelopment planning needs. When the Remediation/Mitigation CSM is appropriately and fully evolved throughout the performance of a remedial action project, its end state will generally serve as a Post Remedy CSM.

Applications of the Post Remedy CSM can help:

(1) Provide a basis for using statistical methods to programmatically evaluate remedy effectiveness and performance for sites meeting cleanup goals;

(2) Document and leverage identified best management and technical practices associated with a remedy success;

(3) Document site remediation activities including locations, dimensions, and concentrations of waste left on site; institutional/engineering controls; and other important remedy features; and

(4) Facilitate reuse planning by providing detailed understanding of geologic/hydrogeologic site conditions and key site physical or chemical features.

Figures 7a and 7b are 'during and after' photographs of the investigation and river restoration effort at the Poudre River Site, which served as components of the Post Remedy CSM, visually documenting the completed site remediation and restoration effort.

Summary

The project life cycle CSM is a versatile and powerful tool than can be used to support project and site decisions unique to each stage of a cleanup project. A CSM developed and maintained on a single platform is highly effective at integrating new information into existing data sets. This enables project teams to understand the significance of new data in the context of existing site understanding. Environmental cleanup practitioners can use CSMs to achieve, communicate, and maintain stakeholder consensus on site understanding, while satisfying the technical and quality objectives required to perform the project successfully.

This fact sheet highlights CSM life cycle stages and provides examples of how CSM components can be leveraged to answer principal study questions and address key site challenges. From documenting and spatially defining the nature and extent of contamination and providing key system design and optimization parameters, to facilitating reuse planning, the project life cycle CSM provides a platform to capture, synthesize, and readily use important site data and information.

Figure 7a. Poudre River Site Restoration Effort. Photographs of active restoration efforts can be shared with stakeholders, general public, and media to demonstrate activities being conducted at sites.

References

Direct References

[1] Decision support tools are interactive software tools used by decisions makers to help answer questions, solve problems, and support or refute conclusions. For examples of available tools, visit www.frtr.gov/decisionsupport/index.htm

[2] EPA Requirements for Quality Assurance Project Plans, EPA QA/R5 March 2001, page 2. EPA/240/B-01/003. www.epa.gov/quality/qs-docs/r5-final.pdf

[3] Information on addressing site uncertainty, developing DWS, and demonstrating methods applicability can be found in the following resource: U.S. EPA. 2008. *Demonstrations of Method Applicability under a Triad Approach for Site Assessment and Cleanup — Technology Bulletin*; August. www.clu-in.org/download/char/demonstrations_of_methods_applicability.pdf

[4] A full case study of the Cache La Poudre River Site project can be accessed at: *Innovations in Site Characterization Case Study: The Role of a Conceptual Site Model for Expedited Site Characterization Using the Triad Approach at the Poudre River Site, Fort Collins, Colorado.* www.cluin.org/download/char/poudre_river_case_study.pdf

Select EPA Superfund References Pertaining to CSMs

"The CSM is a three-dimensional "picture" of site conditions that illustrates contaminant distributions, release mechanisms, exposure pathways and migration routes, and potential receptors. The CSM documents current site conditions and is supported by maps, cross

Figures 7b. Poudre River Site Post-Restoration. Photographs of the site after completion of restoration efforts serve as partial documentation of this phase of remedy completion.

sections, and site diagrams that illustrate human and environmental exposure through contaminant release and migration to potential receptors. Developing an accurate CSM is critical to the proper implementation of the Soil Screening Guidance." (Section 2.1, p. 5)

Soil Screening Guidance: User's Guide, July 1996, Publication 9355.4-23 (EPA 540-R-96-018). www.epa.gov/superfund/resources/soil/ssg496.pdf

"Analyses of the data collected should focus on the development or refinement of the conceptual site model by presenting and analyzing data on source characteristics, the nature and extent of contamination, the contaminated transport pathways and fate, and the effects on human health and the environment" (Ref 7, p. 3-19).

Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA. October 1988. OSWER Directive No. 9355.3-01. www.epa.gov/superfund/policy/remedy/pdfs/540g-89004-s.pdf

"A conceptual site model is a useful tool for selecting sampling locations. It helps ensure that sources, pathways, and receptors throughout the site have been considered before sampling locations are chosen. The conceptual model assists the Site Manager in evaluating the interaction of different site features. Risk assessors use conceptual models to help plan for risk assessment activities. Frequently, a conceptual model is created as a site map (see Figure 1) or it may be developed as a flow diagram which describes potential migration of contaminants to site receptors."

Superfund Program Representative Sampling Guidance, OSWER Directive 9360.4-10 (EPA 540-R-95-141). www.epa.gov/tio/download/char/sf_rep_samp_guid_soil.pdf

"The site conceptual model synthesizes data acquired from historical research, site characterization, and remediation system operation. The conceptual model, like any theory or hypothesis, is a dynamic tool that should be tested and refined throughout the life of the project. As illustrated in Figure 5, the model should evolve in stages as information is gathered during the various phases of site remediation. This iterative process allows data collection efforts to be designed so that key model hypotheses may be tested and revised to reflect new information." (Section 4.4.3, p. 13)

"Conceptual Model Provides Basis for:

- *Early Action/Removal of Near Surface Materials*
- *Site Characterization Studies (RI/FS, RFI)*
- *Removal of Subsurface Sources*
- *Pilot Studies*
- *Interim Ground-Water Actions*
- *Evaluation of Restoration Potential (or TI)*
- *Full-Scale Treatment System Design and Implementation*
- *Performance Monitoring and Evaluations*
- *Enhancement or Augmentation of Remediation System, if Required*
- *Future Evaluation of TI, if Required"*

(Figure 5. Evolution of the Site Conceptual Model)

Guidance for Evaluating the Technical Impracticability of the Ground-Water Restoration, September 1993, publication 9234.2-25 www.clu-in.org/download/contaminantfocus/dnapl/Policy_and_Guidance/TI_guidance.pdf

"*In addition to the items discussed in more detail below, it is important to keep in mind that remedial action costs are influenced, in general, by the quality of the conceptual site model (CSM), which is a three-dimensional 'picture' of site conditions that illustrates contaminant distributions, release mechanisms, exposure pathways and migration routes, and potential receptors… It is initially developed during the scoping phase of the RI/FS, and modified as additional information becomes available. Careful evaluation of site risks, incorporating reasonable assumptions about exposure scenarios and expected future land use, and the definition of principle threat waste generally warranting treatment, help to prevent implementation of costly remediation programs that may not be warranted."* (Section 1, p. 2)

The Role of Cost in the Superfund Remedy Selection Process, Quick Reference Fact Sheet. Publication 9200.3-23FS (EPA 540-F-96-018). September 1996. www.epa.gov/superfund/policy/cost_dir/cost_dir.pdf

Additional CSM References:
Improving Sampling, Analysis, and Data Management for Site Investigation and Cleanup (EPA 542-F-04-001a) April 2004. www.triadcentral.org/ref/ref/documents/2004triadfactsheeta.pdf

Triad Issue Paper: Using Geophysical Tools to Develop the Conceptual Site Model (EPA 542-F-08-007). December 2008. www.brownfieldstsc.org/pdfs/Geophysics Issue Paper FINAL Dec 3 20081.pdf

Innovations in Site Characterization, Streamlining Cleanup at Vapor Intrusion and Product Removal Sites Using the Triad Approach: Hartford Plume Site, Hartford, Illinois. (EPA 542-R-10-006). September 2010. www.brownfieldstsc.org/pdfs/Hartford Case Study FINAL 9-30-10.pdf

Streamlining Site Cleanup in New York City (EPA 542-R-10-005) August 2010. www.brownfieldstsc.org/pdfs/Streamlining_Site_Cleanup_in_NYC_Final.pdf

Best Management Practices: Use of Systematic Project Planning Under a Triad Approach for Site Assessment and Cleanup (EPA-542-F-10-010). September 2010. www.clu-in.org/download/char/epa-542-f-10-010.pdf

Improving Decision Quality: Making The Case For Adopting Next-Generation Site Characterization Practices (EPA-542-F-03-012). 2003. http://nepis.epa.gov

Additional Resources:

Triad Resource Center Web site (www.triadcentral.org)

Contaminated Site Clean-Up Information Network Web site (www.cluin.org)

The Brownfields and Land Revitalization Technology Support Center (www.brownfieldstsc.org)

EPA Superfund (www.epa.gov/superfund)

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