PRELIMINARY REPORT OF THE CALIFORNIA INTEGRATED WATER QUALITY SYSTEM (CIWQS) REVIEW PANEL

Southern California Coastal Water Research Project

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Table of Contents

Introduction

This report presents the preliminary findings and recommendations of the California Integrated Water Quality System (CIWQS) Review Panel (Appendix 1), which was convened in response to a request from the State Water Resources Control Board (State Water Board) to conduct an external review of CIWQS. This review was prompted by concerns about the State Water Board's and Regional Water Quality Control Boards' (Regional Water Boards) ability to use CIWQS to fulfill their responsibilities regarding water quality permitting, enforcement, and reporting. The panel was presented with a list of four specific questions (Appendix 2), three of which focused on CIWQS' design and its ability to meet the Water Board's goals for the system. The fourth question focused on whether resource needs for system design and implementation have been adequately identified and met.

The Panel heard presentations over a two-day meeting in May 2007 from the Water Boards' staff, the US Environmental Protection Agency (USEPA), and representatives from the discharger and environmental community, and then met in executive session on the third day to develop its preliminary findings and recommendations. Between May and December 2007, Water Board staff will consider the content of this preliminary report and demonstrate progress toward specific benchmarks associated with the recommendations. The Panel will then reconvene on December 19 and 20 to hear a formal response to the recommendations and to review progress. This response will include specific actions, timelines, and additional suggested benchmarks or performance measures by which CIWQS' performance over the next year can be assessed. The Panel will then prepare a final report that will judge the adequacy of the Water Boards' response and make final recommendations about the project's future direction.

Overview

The presentations at the May 2007 meeting, as well as the background documentation provided to the Panel, showed that there was a clear need to replace the original System for Water Information Management (SWIM) database. Because of its antiquated programming code and design lineage, the system was difficult to maintain and adapt to new requirements and business practices. It did not support electronic reporting of monitoring data, nor did it mesh well with current World Wide Web based methods and security practices. In addition, SWIM did not provide for integration with other State Water Board information systems. These shortcomings made it difficult for the Water Boards to fulfill critical aspects of their mission related to permitting, compliance, and reporting.

In making the decision to replace SWIM with SWIM 2, the State Water Board had a choice between two basic strategies for information system design. The first design strategy focuses on the detailed requirements of a specific application, while the second is a more generalized design that provides greater flexibility for adaptation to a wider range of potential future user needs. Systems with greater flexibility are attractive because of their broader applicability. However, their complexity makes them extremely challenging to design, requiring large investments of time and expertise to ensure that all processes are handled with the rigor needed to maintain the database's essential integrity. In basing CIWQS on the Enterprise Data Model (EDM) originally developed for SWIM 2, the State Water Board chose the latter, generalized strategy, but with a budget that was only adequate for the former, more targeted strategy.

As a result of this mismatch between the database design's complexity and the resources available for the CIWQS project, the State Water Board has encountered predictable problems with adapting the highly abstract and complex system, populated with erroneous historical data, to specific water quality management functions. These problems were compounded by poor implementation decisions that created continuing difficulties with usability, data integrity, and user confidence. In particular, CIWQS was released before it was fully ready for use (e.g., there was no capability to produce reports), user input was inadequate and/or disregarded, and the business rules that are essential for defining data processing procedures were never completed. As a result of these factors, the State Water Board has a less functional system for water quality management than it had before CIWQS was implemented.

The Panel developed several recommendations intended to rebuild the Water Boards' ability to fulfill their essential requirements for acquiring, managing, and reporting on water quality information. The Panel considers all seven recommendations to be necessary for achieving this goal. Disregarding any one recommendation would dramatically reduce the chances for the ultimate success of the CIWQS project.

The Panel's recommendations, which are discussed more fully in the following sections, are:

Recommendation 1: Reduce the project's scope.
The original, broad scope cannot be achieved with the project's available budget. Therefore, the project should focus on a core set of functions related to permitting and compliance, identifying

other systems that will remain external to CIWQS at the present time, and defining the major external interfaces required to exchange data with other key state and federal systems[1].

Recommendation 2: Restructure CIWQS' project management.
Many of the decisions that led to CIWQS' current problems were the result of a poorly structured decision process. Management control should be centralized in a single dedicated project lead accountable to the State Water Board's management mission.

Recommendation 3: Validate the system's requirements.
There are residual concerns about how well the highly abstract EDM fits users' specific requirements while maintaining essential data integrity. CIWQS' business rules should be fully defined and the system's basic functionality should be assessed with an empirical test using a representative subset of complex permits. This and all future design and implementation efforts should be conducted using formal systems engineering best practices.

Recommendation 4: Rebuild key constituencies.
Key user constituencies have abandoned the system as they have progressively lost confidence since CIWQS' release in 2005. Therefore, the project should create a Steering Committee that includes a broad cross-section of key user groups, reports directly to the State Water Board's Chief Deputy Director, and is required to sign off on design and implementation decisions.

Recommendation 5: Address data quality issues.
Uncorrected data errors, and the system's propensity to create new ones, are a primary cause of users' loss of confidence. Therefore, the project should resolve fundamental data quality issues stemming from both legacy data and current flaws or gaps in data structures and data entry procedures.

Recommendation 6: Produce key reports.
The absence of a fully developed reporting capability has prevented users from fulfilling their analysis and management responsibilities. Therefore, reports to support internal system management and to meet the needs of key user groups should be identified, prioritized, and produced on an explicit schedule.

Recommendation 7: Improve user interface.
Poorly designed and implemented user interfaces have hampered users' ability to use CIWQS effectively. Therefore, user interfaces should be redesigned to better reflect users' workflow and to simplify data entry and retrieval procedures. These changes should be evaluated with formal usability testing.

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[1] Throughout this report, "system" is used as shorthand for information management system.

CIWQS Background and History

State and federal water quality regulations define a permitting, enforcement, and reporting structure that requires collecting and integrating data from across the state and depends on effective information management for its efficient and accurate functioning. The actions in this process include:

- Issuing permits
- Assisting permittees with compliance
- Inspecting facilities
- Reviewing discharger self monitoring reports
- Investigating complaints
- Taking enforcement action against violators
- Tracking results of compliance and enforcement
- Meeting state and federal reporting requirements

The State Water Board and the nine semi-independent Regional Water Boards have addressed these requirements in the past in a variety of ways. Beginning in the late 1990s, several, but not all, of these functions were incorporated into SWIM. While it represented an improvement over prior approaches, it had significant limitations that increased as time went on, including duplication of data entry and reporting efforts, significant difficulties maintaining legacy database systems, gaps in the coverage of key functions such as permitting, poor access to data for decision making, inconsistent systems at different Regional Water Boards and limitations on World Wide Web access.

Given the ongoing pressure to meet key management and statutory requirements, the Water Boards continued to develop and use a variety of hardware and software systems, along with paper tools, to fulfill these requirements. Such approaches, including SWIM, were partly effective, but did not enable the standardization, integration, or sharing of data. Nor did they provide a basis for resolving fundamental inefficiencies and sources of inaccuracy in the water quality regulation system. As a result, the Water Boards had failed to fully meet their basic water quality mission and California routinely failed to report monitoring results to USEPA.

In response to these acknowledged problems, the State Water Board in 2001-2002 defined the specifications of a new system, called SWIM 2. This new system was intended to encompass not only the permitting and enforcement tasks described above, but all water quality related data, including ambient monitoring and assessment functions. The data definitions and program processes involved in these functions were captured in a formal Enterprise Data Model (EDM) that was to form the basis for the detailed development and implementation of the SWIM 2 information management system. However, SWIM 2's broad scope meant that the EDM did not directly reflect the specifics of the business practices in any of the Water Boards' individual programs. Rather, the EDM was abstract and generalized in ways that required extensive standardization and the precise definition of business rules for its successful use, efforts that have not yet been completed.

SWIM 2 was budgeted at just over $6 million, but funds were never approved by the Legislature. Because of the need to move beyond SWIM, the State Water Board accepted an offer from the USEPA to jointly fund the development of a more limited information management system that would focus more narrowly on permitting and enforcement and on reporting key compliance data to USEPA's Permitting and Compliance System (PCS). USEPA committed approximately $1 million and the State Water Board approximately $0.5 million to this new system, which was called the California Integrated Water Quality System (CIWQS). Following this agreement, a Feasibility Study Report (FSR) was developed in 2003 to guide CIWQS' development.

Because the State Water Board hoped at some point in the future to expand CIWQS beyond the core permitting and enforcement functions, it retained the broader EDM as the basis of the system design. This required the use of generic data models, parameter names, data entry screens, and other system features, a decision that later led to problems with training, user satisfaction, and data quality that have yet to be resolved. Finally, in hindsight, it is apparent that the roughly $1.5 million budget was inadequate for both design and implementation. As a result, when the system went "live" on July 1, 2005, there were key features, such as reporting, that were not completed. Much of the subsequent effort devoted to CIWQS has focused on completing the implementation process, correcting problems caused by apparent incompatibilities between the EDM and the more restricted set of core permitting functions, and addressing users' concerns about the system's usability and the integrity of its data.

Recommendations and Supporting Findings

The Panel agreed that the decision to develop CIWQS was a response to a valid need within the Water Boards. The existing database, SWIM, had a number of limitations that reduced its effectiveness and its increasingly obsolete technology made it extremely difficult to address these limitations. In this context, many aspects of CIWQS represented a logical step forward in improving the state's ability to manage and report on water quality data.

The Panel also found, however, that CIWQS' implementation was flawed in important ways virtually from its inception. Critical aspects of user buy-in and support, along with the system's ability to integrate with other databases, have been damaged or not adequately developed. These problems, combined with the project's limited budget, have resulted in persistent uncertainty about the system's fundamental integrity, a legacy of damaged relationships with the user community, and slow progress toward resolving problems and meeting users' needs. In order to accomplish their responsibilities, the Water Boards' staff have often resorted to the use of an inconsistent collection of other databases and tools, as well as paper-based processes. The Panel agrees with the Legislative Analyst that as a result of these problems, permit management is less functional now than it was before CIWQS was implemented.

These issues aside, the Panel believes that the system's basic architecture, despite its shortcomings, provides a basis for moving forward, and recommends a number of specific steps the State Water Board must take to meet its goals with respect to CIWQS. The following subsections discuss each of the Panel's recommendations. The recommendations are interdependent and mutually supportive. They are not intended to be considered and/or implemented in isolation from one another.

Recommendation 1: Reduce the project's scope

Finding and analysis

The rescoping that carved CIWQS from the original SWIM 2 design did not narrow the system's scope sufficiently, with the result that the available budget was inadequate for accomplishing essential design, development, and implementation tasks. When the Legislature did not fund SWIM 2, CIWQS was funded with approximately $1.5 million of USEPA and State Water Board funds. Because the bulk of these were federal, rather than state, funds, the project did not require legislative budget approval, but the FSR did undergo the usual review and approval process by the Department of General Services. Despite this review, the project's assumptions about the level of effort needed to design, build, and then implement the system were not seriously challenged.

Despite the rescoping that created CIWQS, SWIM 2's broad EDM was retained to provide the basis for expanding the system's scope again in the future should adequate funding become available. In addition, as the FSR shows, both the GeoTracker groundwater management system and ambient monitoring of surface water were retained within the new CIWQS design. Thus, while the scope to be implemented was reduced from what was envisioned for SWIM 2, the underlying system development philosophy remained similar to that which motivated SWIM 2,

namely to develop the ability to house and integrate the full range of California's water quality data.

The degree of generality and centralization envisioned for SWIM 2, and apparently still underlying CIWQS, requires a level of control that can be extremely challenging to achieve in a complex environment such as California's water quality management system. Different business processes, and their attendant data types and formats, can be incompatible in multiple ways. These differences can only be accommodated within a single system by either enforcing an unrealistic degree of standardization, or making design compromises that can themselves be problematic. In contrast, an alternative system design philosophy, termed federalism, involves constructing separate systems that are designed for specific business processes and then implementing interfaces between these systems that allow for data transfer and integration. For example, under a federalism approach, CIWQS might use XML-based protocols to query an independent Surface Water Ambient Monitoring Program (SWAMP) system about ambient monitoring data, and SWAMP could automatically query CIWQS about permit information.

Many of the comments heard by the Panel during the May 2007 meeting acknowledged that, if CIWQS were to be designed now, federated systems architecture would be more appropriate than the centralized one originally envisioned. Tetra Tech's 2006 report to USEPA and the State Water Board proposes moving directly to a federated approach by abandoning, for now, the EDM and rewriting CIWQS with a separate data model focusing strictly on the core regulatory functions: permitting, enforcement, and reporting.

Recommendations

CIWQS should move away from a strictly centralized design philosophy to include elements of a federated system structure. CIWQS' scope should be redefined to focus on what have been called its "core regulatory" functions, including permitting, enforcement, reporting, and electronic self-monitoring tasks. In addition to the original functions included in SWIM, the State Water Board has completed two stormwater modules and a sanitary sewer module. These modules should be retained, since they are operating and focus on regulatory issues. However, the planned ambient monitoring module should not be implemented, and the SWAMP's existing efforts to develop an information management system for ambient monitoring data should be continued as a separate effort at the present time. Similarly, the GeoTracker system should be kept as a separate system for the present, with dedicated resources for its maintenance.

More specifically, in terms of the functional requirements defined in Table 2 of the FSR, this would involve:

- 2.D.1. – 1.   Refocus to exclude GeoTracker and GeoWBS
- 2.D.1. – 5.   Refocus to include only data related to core regulatory functions
- 2.D.1. – 21. Refocus to include only data related to core regulatory functions
- 2.D.1. – 23. Delete functions related to ambient monitoring data
- 2.D.3.   Refocus to include only data related to core regulatory functions.

Reducing CIWQS' scope will require the project to define major external interfaces with other systems so that data can be readily transferred as needed. Such interfaces will necessarily include

data transfer standards and protocols. Since reporting to USEPA's PCS is a core CIWQS function, an explicit interface with PCS should be defined and implemented as soon as possible. Concepts for interfacing with other State systems such as SWAMP's ambient monitoring database, GeoTracker, and the California Environmental Data Exchange Network (CEDEN) should be developed and detailed interface procedures then implemented once CIWQS can demonstrate the ability to perform the core regulatory functions.

Benchmarks

The following benchmarks should be met by the December 2007 progress review:

- An explicit definition of CIWQS' core regulatory functions has been established
- The Steering Committee has reviewed and approved this definition
- All members of the CIWQS team understand and agree with the redefined scope

Recommendation 2: Restructure CIWQS project management

Finding and analysis

The implementation of the CIWQS project was flawed in several important respects that in combination made it extremely difficult for the project to succeed. These failings can be traced to a series of decisions, most of which stemmed from four related causes:

- An ineffective division of labor and responsibility between the State Water Board's and USEPA's contractors
- A fundamental split in the project's management structure between the Division of Water Quality (DWQ) and the Office of Information Technology (OIT)
- A model of compelling institutional change in the Regional Water Boards' business processes through the implementation of new information management systems
- Imposition of artificial deadlines that led to ineffective pressure to deliver on schedule. A combination of inadequate resources and a tight deadline led to implementation decisions that violated the data base design

The following paragraphs describe the series of problematic decisions and the ways in which they either flowed from, or were exacerbated by, the project's management structure and its model of change.

USEPA contributed the bulk of the project's funding, but this support was provided as contractor labor. The USEPA and State Water Board contractors and staff worked independently, with poorly defined system requirements and a lack of both strong engineering leadership and clear systems engineering procedures. This predictably resulted in a separation of responsibility and authority that was reflected in divergent goals for the system. Those responsible for the underlying data structure disagreed about fundamental engineering issues with those responsible for application development. It is likely that much of the confusion apparent in aspects of the system design was due to the allocation of design and implementation tasks to these two inadequately coordinated teams.

As it became clear that the project's budget was inadequate for completing all elements defined in the FSR, the system's scope was progressively trimmed over the months leading up to the formal release date of July 1, 2005. By all accounts, this decision process was disorganized, not well informed by user input, and beset by conflicts between DWQ, OIT staff and the federal contractor doing the implementation about priorities (the lack of a consistent process for prioritizing system changes continues to bedevil the project). CIWQS was initially released in July 2005 without a reporting function. From a program perspective, this meant that the system had minimal functionality. However, the system had been judged ready for release by OIT, which in part reflected differences in perspectives inherent between program staff and OIT that were never reconciled.

Just prior to July 2005, the Regional Water Boards' Executive Officers recommended strongly to the Management Coordinating Committee that CIWQS not be released and that SWIM continue to be used in parallel until CIWQS reached full functionality. Despite this recommendation, CIWQS was released as planned and SWIM almost simultaneously shut down, which forced use of CIWQS, even though it was not yet fully functional. The Executive Officers' recommendation was disregarded for two main reasons. First, pressures to meet the FSR's schedule and budget had more weight than concerns (primarily from the Regions) about the system's functionality. Second, State Water Board staff were determined to foster change in the Regional Water Boards' business practices. Past conflicts between the State Water Board and the Regional Water Boards over centralization and coordination contributed to the State Water Board's determination to force this issue by shutting down SWIM, despite the risks involved in the startup of any major new information management system.

The decision to release CIWQS in July 2005 was made in concert with the related decision not to submit a Special Project Report (SPR) to the Department of Finance seeking a budget and schedule extension. Within state agencies, submitting such a report can have unpredictable results, but typically involves stopping work on the project. The desire to maintain momentum, and to avoid the unpredictable consequences of an SPR, led to a further cascade of problematic decisions as the State Water Board attempted to complete the system while it was operating. Consequently, the project fell further and further behind as problems mounted, resulting in some users abandoning the system and confidence in the system's usability declining.

Recommendations

The State Water Board must ensure that users' needs have a central place in management decisions about system design and implementation. Thus, project control should reside with those who have knowledge of the business mission and direct responsibility for its implementation and success. This could be accomplished by establishing a CIWQS team, consisting of staff from DWQ and OIT, with a dedicated project lead drawn from DWQ and reporting to the Chief Deputy Director. Subsequent to the May review meeting, Panel members learned that the State Water Board has an existing mechanism, termed an "enterprise-level technical project with executive level sponsorship," for implementing such an approach.

This restructuring will provide immediate benefits. It will identify a single point of accountability for decision-making and for ensuring that these decisions adequately reflect users' needs. Creating a distinct CIWQS team will alleviate tensions stemming from DWQ's and OIT's

different institutional priorities. In addition, in the event that a future case must be made for a Special Project Report to the Department of Finance, it should be made by a project lead from the perspective of the involved business group.

In future attempts to foster change in business practices within the Water Boards, the State Water Board should use an approach that integrates attention to both business practices and their supporting information technology. The Panel believes that the lesson apparently being drawn from CIWQS, namely that change should be driven primarily through business processes rather than through information technology, is equally mistaken. Changing existing business processes without taking account and advantage of available information technology runs the risk of embedding existing inefficiencies in the new system.

Finally, a balanced approach to improving business practices would provide a useful framework for more directly involving the Regional Water Boards' Executive Officers in fundamental information management decisions. Had that been the case historically, the Executive Officers' recommendation in July 2005 may well have carried more weight with the State Water Board.

Benchmarks

The following benchmarks should be met by the December 2007 progress review:

- A CIWQS project lead has been identified and empowered within a month of this report having been delivered
- The new project structure is fully operational, with CIWQS team members identified and assigned project responsibilities

Recommendation 3: Validate the system requirements

Finding and analysis

As described above, the CIWQS design is at one end of the spectrum from very generalized, flexible designs to very specific, targeted designs. The State Water Board's objective, beginning with the definition of the EDM for SWIM 2, and continuing into the implementation of CIWQS, was to develop a system that would accommodate a broad range of water quality data and business functions (see Recommendation 1 for more detail). This decision is the ultimate source of concerns about and difficulties with the project's scope (Recommendation 1), key constituencies' lack of confidence in the system (Recommendation 4), problems with data quality (Recommendation 5), the lack of reporting capability (Recommendation 6), and ineffective user interfaces (Recommendation 7).

The Panel heard from USEPA and its contractor, Tetra Tech, that the EDM was not appropriate to the functions CIWQS was intended to support and that continued reliance on the EDM would prevent CIWQS' effective implementation. They have argued that the database design underlying CIWQS is so convoluted and abstract, and so detached from the specifics of actual users' needs, that it is extremely difficult for programmers to understand and accurately employ. Compounding this underlying problem is the fact that the business rules, reflecting both user requirements and programming logic constraints, do not exist. These business rules are needed to

compensate for the abstraction of the database and the poor quality of the legacy data, as well as to ensure the overall integrity of the database.

The absence of standardized business rules creates the possibility that data entry will create new errors as users draw different conclusions about how to interpret the generalized data structures and entry screens, which do not match program-specific terminology used by permit managers. The generalized data model, with its ability to integrate data from multiple State Water Board programs, also creates the possibility that users can change key fields (e.g., facility or place name) entered by other users, thus corrupting reports or queries needed to fulfill statutory reporting requirements. This concern has created a great deal of uncertainty within USEPA Region IX regarding the basic legitimacy of California's water quality data.

The Panel agrees that the EDM is far more generalized than is suited to the budget and time allocated to the project, or to the reduced scope described in Recommendation 1. A more targeted data model focused on specific water quality applications would have been easier to design, more efficient to implement, and more readily secured data integrity. The Panel also agrees that the EDM's complexity led to many implementation problems. However, a subcommittee of the Panel, working with USEPA and State Water Board staff, and the contractors involved in subsequent additional phases of the project, found that there are no fundamental flaws that would prevent CIWQS from working within the existing EDM design. CIWQS will, however, inherently be somewhat inefficient to operate and maintain. For example, the complexity of the underlying database structure will require strict constraints on data entry procedures and additional effort to map the generalized data model onto the Water Boards' specific requirements and business practices.

Recommendations

Despite the inefficiencies inherent in CIWQS' current design, the Panel does not believe the system should be abandoned. The enthusiasm of the CIWQS team, their awareness of the database's problems, and their confidence that these issues can be successfully addressed, leads us to conclude that the State Water Board deserves the opportunity to demonstrate they can succeed in making CIWQS fully workable. Thus, the Panel recommends moving forward with the existing data model, even though it is not optimal, provided three essential steps are taken.

First, the business rules must be completed. These must reflect users' business practices, down to the lowest level of raw data entry by both dischargers and Regional Water Board staff. They must also reflect the more global constraints on system procedures and administration required to ensure data integrity as the generalized data model is adapted to the core regulatory functions defined in Recommendation 1.

Second, State Water Board staff must conduct a cradle-to-grave test to empirically demonstrate CIWQS' full functionality. This test should include a representative sample of the most complex permits from multiple regions. Each permit should be worked through the system from its inception, through data entry and QA/QC, to final reporting. This test should document all deficiencies at a level of detail adequate for developing plans to address them.

Third, in order to help prevent a reoccurrence of the design and implementation problems that have hampered CIWQS' development, the State Water Board should establish and implement a formal system engineering process. This would involve, at a minimum, clear definitions of users' requirements, including for report output; procedures for identifying, defining, prioritizing, and tracking system modifications; and an overall plan for integrating system design, development, implementation, and updating. All implementation plans need to be carefully reviewed and approved by CIWQS project lead.

Benchmarks

The following benchmarks should be met by the December 2007 progress review:

- Business rules have been established
- The cradle-to-grave test has been completed and assessed, with all deficiencies documented in detail
- A formal system engineering process, including an implementation plan review by the CIWQS project lead, has been initiated

Recommendation 4: Rebuild key constituencies

Finding and analysis

CIWQS' key constituencies have become skeptical of the system's functionality and reliability. This has resulted in damaged working relationships at many different levels and reduced confidence in the accuracy and reliability of the data currently in the system. For example, one major discharger stated that they no longer enter their monitoring data into CIWQS because incorrect algorithms for calculating violations result in false violations being posted to a public database. USEPA remains frustrated that California does not report NPDES compliance data to PCS in a timely or accurate manner. Many of the Regional Water Boards are hampered in their day-to-day activities by the absence of the information management tools needed to fulfill their responsibilities.

Recommendations

The State Water Board should act immediately to rebuild the constituency for CIWQS by creating a Steering Committee drawn from the user community. The Steering Committee should include representatives of Regional Water Boards, USEPA Region IX, dischargers, and the public, at a minimum. The committee should include skeptics as well as supporters of CIWQS and should report to the State Water Board's Chief Deputy Director. While the Panel appreciates that such committees can be challenging to manage, it is crucial that users' needs and perspectives be directly included over the next year as CIWQS' problems are dealt with. Therefore, the Panel recommends that the Steering Committee should explicitly sign off on both CIWQS' system requirements (as redefined under Recommendation 1) and the design and implementation priorities (as defined under Recommendations 5 – 7) established to fulfill these requirements.

Benchmarks

The following benchmarks should be met by the December 2007 progress review:

- The Steering Committee has been impaneled and has met at least twice
- Steering Committee members, or at least a representative subset, attend the December 2007 review and state that the project is making adequate progress

Recommendation 5: Address data quality issues

Finding and analysis

The data in CIWQS are of questionable quality. When data from SWIM were imported into CIWQS, existing inaccuracies were not corrected and forcing legacy data into the new CIWQS database structure created new errors. Such problems are not uncommon when data are migrated from one system to another. However, in this case, the data transfer was completed under time pressure without proper safeguards in place and neither the existing nor the newly created errors have been thoroughly catalogued and corrected. As a result, CIWQS contains many instances of duplicate records, inconsistent facility names, missing fields, incorrectly calculated results and incorrect violations.

The combination of poor data quality and its impact on user confidence has created a downward spiral for CIWQS. Thus, poor implementation led to data quality problems, which reduced user confidence, which then increased users' tendency to use shadow, or parallel, systems to meet their data management and reporting needs. The proliferation of shadow systems increased the likelihood of data quality problems (as data were increasingly stored in duplicate and/or uncoordinated databases), which reduced users' confidence in CIWQS even more. As described in Recommendation 4, the Panel heard a dramatic example of this at the May 2007 meeting, when a major discharger reported that they refuse to enter their monitoring data into CIWQS because false permit violations are generated and posted to a public database. In the Panel's view, such examples of refusal to use CIWQS reinforce the urgency of resolving data quality issues.

A major source of such errors, as well as a reason they have not been corrected, is the lack of consistent business rules that define the data fields, their relationships, and how they are associated with the Water Boards' business processes (see Recommendation 3 for more detail). The lack of formal and complete business rules also hinders the development and finalization of standardized data entry procedures that would act to prevent new errors from being created and then propagated within the database. For example, incomplete and/or inaccurate algorithms for calculating violations (a key business rule) continue to create fresh errors as new data are entered into the system. The Panel also heard that CIWQS lacks a formal QA/QC process that is linked to data entry to provide immediate feedback on errors and an opportunity to correct them as soon as possible.

Recommendations

The legacy data should be corrected and new errors prevented by completing and correcting the business rules (see Recommendation 3), including those that lead to inaccurate violations. Based

on the business rules, standardized data entry procedures should be developed and implemented. Quality control checks should be included as an integral part of the data entry process and be connected to a formal QA/QC process that addresses all aspects of the data flow. These efforts should be carried out in close coordination with the findings from the evaluation of the database structure described in Recommendation 3 to ensure that any potential problems inherent in the data structure are addressed by the business rules, data entry procedures, and QA/QC process.

Benchmarks

The following benchmarks should be met by the December 2007 progress review:

- Data quality issues have been categorized and quantified
- A detailed plan exists for addressing sources of continuing errors and correcting historical errors
- This plan has been validated with representative data samples
- Substantive progress has been made toward correcting major categories of errors
- The Steering Committee agrees that progress is being made and that there is a high probability that existing data problems will be resolved

Recommendation 6: Produce key reports

Finding and analysis

CIWQS does not presently produce the full range of reports needed to assist staff at the Water Boards in meeting their day-to-day responsibilities, fulfill the state's statutory requirements to report data to USEPA, or provide system managers with adequate feedback on key aspects of system function and status. As mentioned previously, CIWQS was released in July 2005 without a fully developed reporting capability and the system's developers have been playing catch-up with users' needs ever since. Because of the resulting priority placed on meeting such needs, there is a virtual absence of internal process reports on metrics related to data entry, system performance, and quality control.

In addition to preprogrammed reports that fill routine requirements, there is frequently a need for users to create ad hoc reports to obtain information about specific management issues or to review the status of a particular permit or compliance action. Because of the complex and generalized database structure (see Recommendation 3 for more detail), such reports require cumbersome queries, even when the request is conceptually simple.

Recommendations

The CIWQS team should work with the Steering Committee (see Recommendation 4) to prioritize the reports required by each major user group. A standard set of reports should be included as core tools available through the user interface. The CIWQS team and the Steering Committee should develop an explicit set of criteria for prioritizing reports and should devote a portion of the team's resources to developing these reports on an explicit schedule. The CIWQS team should ensure that internal system process reports are included on the prioritized list, in order to improve the team's ability to manage the system itself and to track progress toward benchmarks related to data entry, error correction, broader quality control measures, and other performance issues.

Benchmarks

The following benchmarks should be met by the December 2007 progress review:

- A prioritized list of reports has been compiled and agreed to by the Steering Committee
- A schedule for report production that is agreed to by the Steering Committee has been established
- A plan for standard report access in the interface has been established
- Example reports that demonstrate the team's approach to report design and production are available

Recommendation 7: Improve user interfaces

Finding and analysis

There is broad discontent among CIWQS users with the user interface. Data entry screens are confusing, generic terminology does not match that typically used by current users, pull-down lists do not always contain appropriate choices, and linking among related aspects of the data entry process is poorly designed. Many of these characteristics reflect the project's initial decision to base CIWQS on the EDM and to design data entry screens and other elements of the user interface in a nonspecific manner so that they would be applicable to a wide range of water quality applications. As a result, CIWQS introduces a nomenclature that is alien to many of the people using the system and it is unproductive to expect them to adopt the generalized nomenclature upon which EDM depends. In addition, contextual help is not available within the system. For example, clicking on "help" in many cases brings up a nine-megabyte users manual.

The existing user interfaces require an unacceptably long and complex training period, which adds to the burden on project staff. Users' difficulties are compounded by the project's inability to respond quickly to users' questions and requests for help. In response to such problems, many users employ an inconsistent collection of alternative databases, tools, and paper-based processes.

Recommendations

The CIWQS team should improve the system's user interfaces. The team, together with the Steering Committee, should agree on an explicit and prioritized list of revisions and actual changes should be based on input from a subset of representative users. User interfaces should reflect the business rules and processes that are directly relevant to users and revisions should focus, at a minimum, on simplifying data entry forms, redesigning linking to be easier, prompting for linkage (where required) to reduce errors, and developing contextual help and more appropriate pull-down lists.

The CIWQS team should implement formal usability testing to obtain relevant feedback about how and where user interfaces are confusing or create other problems for users. Formal testing typically includes giving test subjects specific data entry and retrieval assignments and observing them while they complete, or fail to complete, the assignment. The process provides an objective means of determining how well an interface meets its desired purpose. This will involve a shift in the direction of information flow, from the top-down flow that characterized the prior

emphasis on training to a more interactive and predominantly bottom-up flow that emphasizes users' experience in actual work settings.

Benchmarks

The following benchmarks should be met by the December 2007 progress review:

- A prioritized list of revisions endorsed by the Steering Committee has been compiled
- A sample of prototype screens is available
- An explicit plan for usability testing has been endorsed by the Steering Committee

GeoWBS

The Geospatial Water Body System (GeoWBS) was in past years an integral element in the development of the State's 305(b) report to USEPA. This system provided the Regional Water Boards the ability to georeference information from the 303(d) listing process and to aggregate it by waterbody in order to assess which water bodies were meeting which beneficial uses. Once reported to USEPA, the Office of Management and Budget (OMB) uses this information to track performance by USEPA and the various states in meeting the requirements of the Clean Water Act (CWA).

GeoWBS was used by the Regional Water Boards through the 2002 305(b) reporting process. However, the 303(d) and 305(b) reporting efforts were centralized at the State Water Board in 2004 and 2006 and, during that time frame, the GeoWBS functionality was lost as CIWQS was developed. The State Water Board has decided to once again involve the Regional Water Boards in these reporting efforts, but the Regional Water Boards no longer have GeoWBS, or any other comparable capability, to perform this function.

Due to the limited time frame of the CIWQS review, the Panel did not directly evaluate the GeoWBS database. However, the Panel understands that this capability is critical to the State's ability to prepare the required 303(d) and 305(b) reports due in 2008, which USEPA now requires be integrated. The Panel understands that there are a number of options for resolving this problem, which include using USEPA's existing national database system or recreating GeoWBS in a design that will address the new integrated reporting requirements. The Panel does not have a specific recommendation on this issue, other than to highlight the importance of this functionality and to emphasize that it must be recreated in a timely manner.

Next Steps

The Panel identified two specific actions that will follow the May Panel meeting and lead up to the Panel's final recommendation on CIWQS' future direction:

- A second Panel meeting on December 19-20, 2007, to review progress on implementing recommendations demonstrated by:
    - A positive report from the project's Steering Committee
    - Examples of output reports addressing key users' needs
    - Successful completion of the cradle-to-grave test of representative permits
    - A clear plan for correcting the legacy data problem and substantive progress toward implementing this plan

- A final report from the Panel, following the December meeting, on the recommended future direction of CIWQS.

The Panel envisions the December 2007 meeting as the CIWQS project's opportunity to address issues raised in this preliminary report, demonstrate progress toward implementing the Panel's recommendations, and fully resolve concerns about its ability to effectively accomplish the project's goals and meet users' needs. The Panel's final report will assess progress toward each recommendation and provide any additional recommendations it believes are warranted based on new information presented at the December 2007 meeting.

Appendix 1: CIWQS Review Panel Members

Tony Lavoi

Tony is Chief of the Coastal Information and Application Division for NOAA's Coastal Services Center where he is responsible for managing their IT network and ensuring compliance with all IT security mandates. Tony serves as the NOAA representative to the Federal Geographic Data Committee (FGDC), the Geospatial One-Stop Board of Directors, and the Ocean.US Data Management and Communications Steering Team. He chairs both the NOAA GIS Committee and the Marine and Coastal Spatial Data Subcommittee of the FGDC, and leads development of the National Ocean Service Data Explorer GIS data portal.

Curtis Cude

Curtis is an environmental information exchange expert with the Oregon Department of Environmental Quality. He is project manager for development and implementation of the Pacific Northwest Water Quality Data Exchange. He is the Chair of the Information Strategies Work Group for the National Water Quality Monitoring Council. He co-chaired (with Ken Lanfear) the Data Management and Access Team for the development of the National Monitoring Network for U.S. Coastal Waters and their Tributaries, and co-chaired the Water Team for development of the Environmental Sampling, Analysis and Results standards for the Environmental Data Standards Council.

Jeffrey Rosen

Jeff is Vice President of Environmental Information Services for Clancy Environmental Consultants. Prior to that, he was Vice President of the Environmental Information Services Division for Perot Systems Government Services. Mr. Rosen specializes in the processing and analysis of environmental data. His principal areas of expertise are marine monitoring and drinking water. Mr. Rosen was responsible for establishing the data management system for the EMAP Coastal Resources component and served as liaison with information management efforts within NOAA, USGS, and the EPA National Estuaries Program. He currently supports both the American Water Works Association and USEPA on a number of data management and analysis projects related to drinking water monitoring and regulation development. He is also supporting the development of permitting systems and compliance monitoring for the Papa-hānau-moku-ākea Marine National Monument.

Ken Lanfear

Until his retirement in 2006, Ken served as Chief of the Water Information and Computer Applications Support Group within the US Geological Survey. Mr. Lanfear managed Unix systems that support water researchers at USGS Headquarters, and directed the *water.usgs.gov* website. He consulted on a variety of projects to increase the use of USGS water data, and coordinated with EPA to establish a common USGS/EPA interface for water data. Mr. Lanfear is a past president of the American Water Resources Association and, since his retirement, he has served as editor for the Journal of the American Water Resources Association.

Dwane Young

Dwane is an IT Specialist at EPA and is the technical lead for EPA's Water Quality Exchange. He currently manages EPA's STORET database and is overseeing transition of that system to a new XML-based data flow. His previous experience includes developing database applications for the National Park Service and U.S. Environmental Protection Agency (EPA), including EPA's effort to georeference state's Water Quality Standards, 303(d) Impaired Waters, and 305(b) Assessed Waters to the National Hydrography Dataset.

Deb Soule

Deb is a Business Systems Analyst for the State of New Hampshire where she supervises the Data Management Section, including GIS services. She is the project manager for the State's Environmental Monitoring Database and the STORET conversion to the Water Quality Exchange. Other data systems she oversees include beach monitoring and notification, shellfish shoreline inspection and boat wastewater inspection databases, as well as a supplemental assessment database to automate waterbody assessments.

Dr. John Helly

John is Associate Director of Computing for the National Science Foundation Center for Multi-scale Modeling of Atmospheric Processes. He is also Laboratory Director for Earth and Environmental Science at the UCSD Supercomputer Center. John has a Ph.D in Computer Science from UCLA with research interests in environmental modeling, remote sensing, and visualization.

Dr. Brock Bernstein

Brock was a member of a National Academy of Sciences panel on data integration in the climate change research program. For that project, he was the primary author for the section on data integration challenges and also authored three of the six case studies, on the CalCOFI Program, the Carbon Dioxide Information Analysis Center, and the ISLSCP field experiment (a complex data gathering and modeling effort across many spatial scales). Brock has also provided external peer review for the State of Alaska's regional monitoring and research information management system in Prince William Sound and managed the design of the Orange County Stormwater Program's comprehensive monitoring and reporting database.

Dr. Stephen Weisberg

Steve is the facilitator for the review panel. He is Executive Director of the Southern California Coastal Water Research Project Authority, where he specializes in designing, implementing and interpreting data from environmental monitoring programs. He serves on a variety of federal advisory committees, including the National Science and Technology Council's Ocean Research and Resources Advisory Panel and the Alliance for Coastal Technology Stakeholders Council. He also serves on numerous state/regional advisory committees, including those for the University of Southern California Sea Grant Program, the State of California's Clean Beach Task Force and the California Ocean Science Trust.

Appendix 2: Questions Posed to the CIWQS Review Panel

1. Are the Water Boards' goals for CIWQS clearly articulated and appropriate?

    a. Have users been adequately identified, and do they agree with existing goals?
    b. Are the performance measures appropriate, and are they being met?

2. Is the Enterprise Data Model and server network effective for accomplishing the Water Boards' goals for CIWQS?

    a. Are there adequate provisions to ensure the desired level of data quality?
    b. Are there adequate provisions in the technology solution to ensure security, privacy, and confidentiality of information?
    c. Does the system have the potential to meet goals for viewing geospatial (GIS) information?
    d. Is the data entry work-flow appropriate for the required work load?
    e. Are the reporting capabilities of the system adequate to meet the needs of staff, management, and the public?

3. Is the implementation strategy for CIWQS appropriate?

    a. Is communication effective between CIWQS staff and data providers?
    b. Is communication effective between CIWQS staff and data users?
    c. Is documentation and training effective in meeting data provider and user needs?

4. Have resource needs been adequately identified and met?

    a. Have resource needs for CIWQS development, maintenance and outreach been identified?
    b. Have existing resources been optimally leveraged through coordination with other programs?