Review of the Environmental Monitoring Program

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The Interagency Ecological Program (IEP) has a policy that requires review of each IEP monitoring program once every five years. The intent of this policy is to provide a means for considering the structure and function of ongoing, and in most cases longstanding, monitoring programs to ensure they remain relevant and effective. In 2001 the IEP requested a review of the Environmental Monitoring Program (EMP).

Although operated under the auspices of the IEP, the CA Department of Water Resources (DWR) and the US Bureau of Reclamation (USBR) are required to implement the EMP as a condition of CA State Water Resources Control Board (SWRCB) Water Right Decision 1641 (D-1641)[1]. This water right decision prescribes conditions

that regulate operations of the State Water Project (SWP) and Central Valley Project (CVP). Under D-1641, a review of the EMP is required every three years with the first review due in December 2002. Thus, review of the EMP was intended to satisfy the requirements of the IEP and D-1641.

Review of a comprehensive monitoring program that spans four decades, has an annual operating budget of about $2 million, and employs about 20 staff from four different agencies is not a trivial matter. However, the EMP is fairly representative of the effort and resources the IEP dedicates to its monitoring programs, so the issues addressed in the EMP review reflect issues germane to the review of many IEP monitoring programs. In this article we describe the process used to complete a comprehensive programmatic review of the EMP. We describe the general features of the review and focus on the key elements of each feature. Several written documents were produced during the EMP review. Final versions of these documents along with other program information and EMP monitoring data are available at http://iep.water.ca.gov/emp.

I. EMP Background in Brief

The EMP was initiated in 1971 in compliance with SWRCB Water Right Decision 1379. Currently mandated by D-1641, the program is carried out jointly by the two water right permittees, DWR and USBR, with assistance from the CA Department of Fish and Game (DFG) and the US Geological Survey (USGS). The EMP is one of the oldest interagency monitoring programs operated under IEP.

The goals of the EMP given in D-1641 are to (1) ensure compliance with flow-related water quality objectives; (2) identify meaningful changes in any significant water quality parameters potentially related to operation of the SWP or the CVP; and (3) reveal trends in ecological changes potentially related to SWP/CVP operations. The EMP collects data on a wide range of physical, chemical, and biological constituents used to monitor the status and trends of environmental conditions in San Pablo Bay, Suisun Bay, and the Sacramento-San Joaquin Delta (collectively referred to as the upper San Francisco Estuary or upper estuary). Discrete water quality samples are collected once a month by boat or van at 11 stations located throughout the upper estuary. Several constituents are also monitored continuously at seven shore-based stations (Table 1). While some discrete sample analysis is completed in the field, most analyses are conducted by DWR's Bryte Chemical Laboratory (water chemistry and phytoplankton samples), DFG's laboratory in Stockton (zooplankton samples), and a contract laboratory (benthos samples). The resulting data are stored in the Bay-Delta Tributaries database and the DWR Water Data Library. Continuous data are available on a near real-time basis through the IEP Hydrologic Engineering Center Data Storage System (HEC-DSS) time-series database. Monitoring data are analyzed and summarized in annual and occasional multi-year reports, IEP Newsletter articles, IEP technical reports, and peer-reviewed journal articles

1. California State Water Resources Control Board, Water Right Decision 1641, Revised March 15, 2000.

Table 1 A listing of the various subject areas considered part of the EMP and the frequency of sampling before and after the 1995 program review.

EMP Subject Area	*Sampling Frequency 1971-1995*	*Sampling Frequency 1996-Present*
Continuous Water Quality[a]	Continuous	Continuous
Discrete Water Quality[b]	Monthly or semi-monthly	Monthly
Phytoplankton	Monthly or semi-monthly	Monthly
Zooplankton	Monthly – separate survey	Monthly – combined with discrete water quality
Benthos	Semi-annual or monthly	Monthly
Heavy metals and pesticides	Semi-annual	Discontinued

[a] The following constituents are monitored continuously at fixed, shore-based stations: air and water temperature, electrical conductivity, pH, dissolved oxygen, water stage, chlorophyll fluorescence, wind speed and direction, and solar irradiance. Not all constituents are monitored at all stations.

[b] The following constituents are measured at specific locations: air and water temperature, electrical conductivity, chloride concentration, dissolved oxygen, turbidity, secchi disk depth, suspended solids, inorganic and organic nitrogen concentration, inorganic phosphorus concentration, silica concentration, chlorophyll *a*, pH, water depth to 1% light level. Monitoring of air temperature, pH, and water depth to 1% light level was discontinued in 1995.

In its 32 years of existence, the EMP design has remained relatively unchanged. The greatest revisions came about in 1978 with the enactment of Water Right Decision 1485 and in 1996 after a major program review in 1995. The main goal of the 1995 revisions was to streamline the existing program for more efficient budget and resource allocation (Table 1). As a result, the number of discrete water quality monitoring stations was reduced from 26 to 11 sites, contaminants monitoring was discontinued, changes were made to the zooplankton and benthos monitoring elements, and substantial upgrades were made to vessel-based horizontal and vertical profile instrumentation.

II. Review Foundation

To initiate the EMP review, we worked to provide a solid foundation upon which to base the review. Here we list the key elements of this foundation, followed by brief explanations.

Establish a review Core Team: This is the first and most important step in conducting any sort of program review. The Core Team is responsible for completing the review, which ultimately comes down to taking the various bits of information and input received from a variety of groups and individuals and transforming them into meaningful results.

The EMP review Core Team included each of the DWR and USBR program managers for the monitoring program and one senior technical staff person each from DWR and USGS. A senior technical staff person from USBR joined the Core Team about midway through the review as the result of a new hire at USBR. This Core Team had several attributes that led to a high degree of effectiveness: (1) the team was small; (2) each team member had a strong, but not necessarily identical, interest in completing a successful review; (3) the team contained a mixture of program managers who had the authority to make programmatic decisions and very knowledgeable technical staff; and (4) the Core Team accepted full responsibility for completing the review.

Obtain a clear directive from management: IEP has a standing review policy for its monitoring programs, which provided the main directive for our review. However, this policy is general and does not provide clear guidance on the specific aspects of a review. For example, several IEP monitoring programs contain sub-elements or subject areas. Past reviews of some monitoring programs have only considered specific subject areas within the program rather than the entire program. In addition, some past reviews have emphasized the data and information aspects of the monitoring program and spent less time considering other factors such as sampling design, customer needs, or resource and staff allocations. In reality, the variety, complexity, and emphasis of different IEP monitoring programs means we cannot use exactly the same approach in all reviews. Thus, it was necessary that the Core Team work with management early on to develop a clear and specific directive detailing the scope of the EMP review.

The EMP contains four subject areas: environmental water quality, phytoplankton, zooplankton, and benthos. Comprehensive data analyses were fairly up-to-date with at least one comprehensive report on each element completed within the last 10 years; however, the program was three years behind in its annual reporting requirements. We also knew of several concerns related to sampling design and techniques, inadequate data management and dissemination infrastructure, a slow rate of transferring data to information, unclear or missing conceptual models, and a general lack of confidence that the EMP was monitoring the appropriate constituents at the proper spatial and temporal scales. Based on this knowledge, the Core Team and IEP management determined that a comprehensive programmatic review of the EMP was necessary.

Develop a clear goal for the review: The importance of having a clear statement of goals is well known. Also, questions like "what's your goal?" are usually among the first asked when meeting with people to discuss the review. Yet, we often make short shrift of this step, leading to unclear or inappropriate goals. A clear statement of goals should guide the review, help track and evaluate review progress, and focus review discussions.

Developing a clear goal for the EMP review was among the first tasks of the Core Team. Ultimately we developed the following goal:

> The goal of the review is to recommend a balanced, scientifically sound, implementable environmental monitoring program design to fulfill water right permit conditions and address

the needs of current and potential users identified during this review.

Determine expected products up front: Any review of an IEP monitoring program will result in at least one report describing the review process and results, which often include recommendations for change. In some cases, an intense period of data analysis and reporting precedes or is part of the actual review. Since the reviews largely rely on existing staff, IEP managers are generally forced into a situation that requires delaying work in order to complete new analyses and reports for the review. Building this part of the foundation comes down to matching expectations with reality. This requires meeting with key groups (managers, advisory groups, etc.) and key individuals (supervisors, program managers, and staff) to make sure everyone understands what products are required to meet the goals of the review and who will complete those products.

In the case of the EMP review, the Core Team met with IEP managers and the Science Advisory Group at the beginning of the review to determine the necessary products. Some IEP managers expected staff to complete new analyses and reports. The Core Team argued that several fairly recent comprehensive analyses of EMP data already existed, mainly in the form of technical reports. Although some of these reports were up to 10 years old, they provided a fairly complete understanding of the state of knowledge and the types of information available from the EMP. Ultimately, it was determined that a concise description of the EMP, including its history and regulatory basis, was essential information for this review[1], but that new data analyses were not.

Identify the major constraints upfront: From a practical standpoint, all monitoring programs are constrained by one or more factors. Limited funding and resources are often the ultimate constraint. Common constraints that are dependent on funding include geographic scope, sampling frequency, number of sampling sites, and number and type of constituents monitored. In addition, the strong desire to maintain data continuity is a constraint common to long-term monitoring programs. Preserving data continuity limits program redesign based on technical issues or program modifications to address changing management priorities and customer needs. Finally, some monitoring programs are legally required and any program modifications may have legal ramifications. Identifying these types of constraints early on in the review process provides reviewers with an appreciation for the limits to the types of changes possible.

The following constraints applied to the EMP review:

1. Total ongoing program costs would not increase. This did not preclude the potential redistribution of funds among subject areas or obtaining funds from outside sources to cover the cost of one-time expenditures (e.g., new equipment purchases).
2. Maintaining historical data continuity had priority over program redesign due to technical issues or changing customer needs.
3. The program would continue to fulfill the requirements set forth in D-1641.

Identify staff commitment: Completing an in-depth review of any IEP monitoring program is a substantial undertaking. For several years IEP has tried to complete these reviews as a task added to staff's existing workload. This has met with mixed success. The program manager or project supervisor is in the best position to establish this part of the review foundation. Program managers must work with their staff to estimate the number of staff and amount of effort necessary to complete the program review based on decisions about management directive, review goals, constraints, expected products, and timeline. Generally, at least one staff person will spend the majority of their time on the review, with an additional time commitment from the program manager(s) and other core staff. Often the issue comes down to securing a consistent amount of staff time over the full duration of the review. Underestimating necessary staff commitment or total review time undermines the ability to clarify staff commitment. The IEP management team can help program managers develop accurate estimates of the staff commitment necessary to complete a monitoring program review.

For the EMP review, the two program managers spent about 20% of their time on the review. They were assisted by three senior technical staff who spent between 10% and 80% of their time on the EMP review, as well as by other EMP personnel. In addition, the EMP review also relied on the work of ad hoc "subject area" teams (see below), with team leaders dedicating up to 50% of their

1. CA DWR. 2001. Background Information for the 2001 Review of the IEP Environmental Monitoring Program. Available at http://iep.water.ca.gov/emp/about%20the%20EMP.html

time over a five-month period and team members dedicating 5-10% of their time over the same period.

Establish a realistic timeline: As with determining the expected products, establishing a realistic timeline with key milestones comes down to matching expectations with reality. Generally, IEP management thinks in terms of one-year timelines for monitoring program reviews because they operate under a one-year program planning cycle. Yet the reality is that program complexities will often necessitate more than one year to complete a review. Setting a realistic timeline is highly dependent on decisions made for the other parts of the review foundation. The timeline may have to be revisited several times and adjusted as necessary throughout the course of the review.

Initially, the EMP review Core Team set a one-year timeline for completion of the review. Ultimately, however, it took 22 months to fully complete the review. Some of the delay was due to unrealistic estimates by the Core Team, while other delays were due to factors outside the control of the Core Team. For example, we grossly underestimated the amount of time necessary to complete the management review phase. In contrast, completing the independent review phase was delayed several months due to competing commitments for the time of the reviewers. Although delay in completing the written review products is a common occurrence in program reviews, this was not the case with the EMP review. The subject area reviews and synthesis reports were all completed within the original time allotted because of the tremendous efforts of the subject area teams and full dedication of Core Team time to complete the synthesis report.

III. Review Process

There are many levels of review possible for the types of monitoring programs within IEP. For the EMP review, the Core Team and IEP management determined a "program level" review was most appropriate. As such, the review examined all aspects of the monitoring program, including its overall structure, resource and staff allocation, funding allocation, underlying conceptual models, sampling design, data and information processes, customer needs, and the goals and objectives. Some aspects of the program were considered in greater detail than others, but we found this comprehensive approach provided the ability to identify more specific and meaningful recommendations for change.

In developing a review process for the EMP we wanted to ensure:

- An open and transparent process
- Substantial opportunity for local expert and key stakeholder input
- Inclusion of an independent technical review
- Clear and direct input from management
- Involvement of regulatory agency staff prior to formal submittal for regulatory approval. (Note: this last issue was EMP specific and does not apply to many of the IEP monitoring programs.)

To meet these multiple objectives, the EMP review process relied on a multi-tiered approach involving: (1) four subject area teams; (2) several open meetings, which allowed a broader base of participation; (3) the IEP Science Advisory Group; and (4) the EMP Core Team (Figure 1). Involvement and time commitment varied among the tiers throughout the review period (Figure 1). We further broke the review process down into a technical review phase followed by a management review phase.

The subject area teams (SATs) formed the backbone of the EMP review. The SATs were small, ad hoc teams composed of invited local experts and EMP staff. The main task of these teams was to complete a focused review of each EMP subject area (water quality, phytoplankton, zooplankton, and benthos). Although each team approached the subject review differently, the primary goal for all SATs was to produce a written subject area review based on a structured format. The SATs were asked to provide specific and prioritized recommendations for changes to the EMP, as well as recommendations and priorities for special studies needed to inform future decisions about the program. SAT members also participated in the open meetings, and SAT leaders assisted the Core Team in synthesizing the individual reports into a comprehensive review summary. The time commitment for the SATs was substantial in the early part of the review, but dropped off quickly after the first draft summary report was produced.

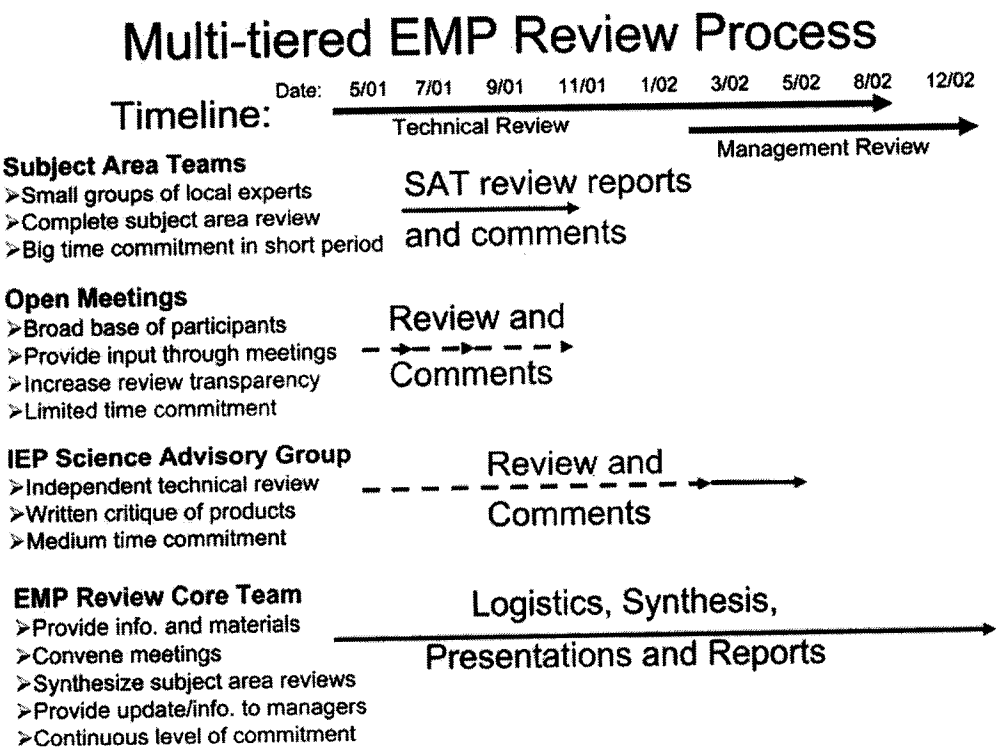

Figure 1 Diagram of the multi-tiered approach used in review of the EMP. Entities or forums listed on the left-hand side formed one of the four tiers. See text for a complete description of each tier. Solid lines constitute time spent directly involved in the review. Dashed lines constitute time spent indirectly or occasionally involved in the review.

Three open meetings where scheduled over the first seven months of the review. The open meetings provided a forum for information exchange and comments from a broader audience of stakeholders, agency staff, and the interested public. These meetings allowed for discussion of all aspects of the EMP and the review, but at a lower level of detail than the SAT review or independent technical review. Participants in the open meetings were expected to read the appropriate materials before the meeting and provide the majority of their input at the meeting (although we did provide means to send in comments anytime during the review process). The open meetings were an efficient way to communicate with a large number of interested individuals. We hired a professional facilitator for these meetings to provide a respectful, productive, and non-threatening environment. EMP staff also prepared poster summaries for each EMP subject area, which served as a great information resource at the meetings. The open meetings and establishment of a Web page with information and materials provided an effective way to maintain a transparent review.

The IEP Science Advisory Group was asked to provide an independent technical review of the individual SAT reports and the EMP review synthesis report. Up to three Science Advisory Group members also participated in the open meetings, providing key guidance in the structure and scope of the review. The group also brought in three additional scientists with expertise specific to EMP subject areas to complete this review. The Core Team participated in a one-day meeting with the Science Advisory Group to provide specific information about the EMP and the review results. Group members were also provided with relevant written materials in advance of the meeting. The Science Advisory Group was free to comment on any aspect of the program or the review, but in particular we asked the group to consider and comment on: (1) program design (current and proposed), (2) information synthesis and subject area integration, and (3) resource allocation. We also asked the group to be as specific as possible in any recommendations it made. The Science Advisory Group provided a written report to the Core Team about one month after our meeting. Overall, the Science Advi-

sory Group contributions were vital to the success of the EMP review. Early and continued involvement by some advisory group members, clear communication of expectations, and timely response to the Science Advisory Groupís review were all key to this success. We are certain that any future review of an IEP monitoring program will greatly benefit from early and thoughtful interaction with the Science Advisory Group.

Core EMP staff from DWR, USBR, and USGS worked across all review levels. The Core Team provided all information and background materials for the review. The team convened the open meetings with the help of a facilitator. Three of the Core Team members participated in the SATs. Team members were responsible for synthesizing review products into a single report, as well as providing the many progress reports requested throughout the review. The Core Team also completed the management-level review, which included briefings for key stakeholders. Finally, the Core Team prepared a formal request to the SWRCB for modifications to the D-1641 condition specifying the EMP design.

Overall, this multi-tiered review process required substantial effort. Yet, it was a great success because we were able to achieve all of the review objectives and reap some unexpected benefits, such as greater recognition for the EMP and reinvigorated staff enthusiasm.

IV. Expect the Unexpected

The staff involved in any IEP monitoring program will have a good sense of program strengths and limitations even before the review is started. The review process is a good opportunity to critically evaluate these perceptions and address some of the perceived limitations. We identified several limitations at the beginning of the EMP review, including:

- Limited staff time and expertise for data analysis
- Ineffective data management processes
- Limited integration among subject areas

These limitations were also identified in the Subject Area Team and Science Advisory Group reports, reinforcing the significance of these limitations. However, several unexpected events occurred during the course of the review that allowed us to address these limitations even before the review was completed. In contrast, some events occurred over the course of the review that created some new and continuing challenges for the EMP.

On the positive side, the EMP was successful in obtaining a position from the CALFED Science Program that was dedicated to efforts aimed at improving data management and data to information transfer. The departure of three existing staff during the review also resulted in DWR and USBR hiring three staff scientists with PhDs in various fields of aquatic ecology, increasing the "intellectual investment" in the program.

The review reinvigorated staff interest and commitment to the EMP. Existing EMP staff became very engaged in the review, contributing substantially to the information and historical knowledge base needed to complete the review. This staff involvement was instrumental in the formation of the IEP Water Quality Project Work Team, which continues to meet and guide the EMP to this day.

Although several positive unexpected events occurred during the EMP review, some unexpected challenges also occurred. We grossly underestimated the time necessary to complete the management level review. This was due in part to the fact that IEP does not have a well-defined process for dealing with the results of technical program reviews at the management levels of IEP and the individual agencies. In addition, the legally mandated nature of the EMP increased the number of management review levels we had to navigate. The extra time spent in the management review phase was beneficial, and hopefully any future reviews of the EMP can benefit from our experiences.

At this time, the state budget crisis is probably the greatest challenge to implementing recommended changes to the EMP. Delays in passing the state budget, budget cuts, and a prolonged hiring freeze will undoubtedly affect the timeline for implementation of the approved changes. Further, reductions in IEP funding will affect the potential to fund special studies needed to determine the best methods for making approved changes and confirming the results of any changes made. These serious budgetary constraints will require creative solutions by program managers and staff to effect meaningful changes to the EMP.

V. The Importance and Utility of Review Products

Preparation of review products is a key part of any IEP monitoring program review. Typically, there is a report that contains a description of the review and any recommended changes. Other products might include reports of data analyses and synthesis. Over the course of the EMP review several products were produced that we expect to have utility beyond the review.

Specific statements of EMP goals, objectives, and questions: The fact that the EMP lacked clear program aims was a major concern identified in the Science Advisory Group review. General goals for the EMP are listed in the water right decision, but beyond this we did not find any specific statements of program aims or goals. As a result, the Core Team spent substantial time developing more specific objectives and questions, which build on the more general goals stated in D-1641. This was not a trivial matter, even for a small, but motivated, Core Team. Guidance from the Science Advisory Group was critical to our efforts, and ultimately we were able to develop a set of realistic and specific objectives. Questions were also developed to focus future reporting, but we expect the questions will change as new issues and management priorities emerge.

Conceptual models: The Water Quality SAT devoted a great deal of effort to developing a conceptual model that describes the underlying physical processes occurring in the upper estuary and how those physical processes affect water quality. The other SATs were able to use this model in understanding how physical processes affect phytoplankton, zooplankton, and benthos ecology. This was the first time a comprehensive set of conceptual models has been developed for the EMP, and these models served as the foundation for recommended changes in the EMP sampling design. We expect these models will be revisited as the program moves forward and particularly during the next EMP review.

Assessment of customer needs: At the first open meeting, one of the members of the Science Advisory Group urged us to include an evaluation of customer needs during the EMP review. We developed a table for use in each subject area that asked for customer identification and the met and unmet needs of these customers. Although the results were qualitative, they were very useful in determining the most important attributes and the most critical unmet needs of the EMP from the "customers" perspective. Results from this assessment were used in developing recommendations for changes to the monitoring program, as well as specific goals and objectives.

Specific recommendations for changes to the EMP: In reviewing the history of the EMP it was quite clear that many past recommendations for changes to the monitoring program were never implemented because the recommendations were too vague or general. As a result, the Core Team continually pressed for specific recommendations from all parties. In addition, the Core Team asked the SATs to prioritize any recommendations provided in the subject area reviews, and the Core Team developed an overall list of prioritized recommendations in the synthesis report. We are hopeful that these two features--specificity and prioritization--will increase the likelihood that recommended program changes will be implemented.

Specific recommendations for EMP special studies: Review of the EMP history also confirmed that the EMP has never had a special studies plan. Through the EMP review we came to recognize that special studies to improve monitoring and better understand monitoring results are an essential part of comprehensive monitoring programs like the EMP. Many of the recommended changes require focused special studies to determine the exact methods of implementation and verify the results of any changes. In addition, new technologies in water quality monitoring, data acquisition, and data transfer continue to emerge; all of which must receive some testing before making decisions on implementation. And finally, monitoring will always generate new questions and hypotheses that can only be tested through applied research. Information gained through this research can tell us if we are monitoring the right things the right way. Thus, the Core Team again turned to the SATs and asked for prioritized recommendations for special studies. In the phytoplankton and benthos subject areas, virtually all of the recommendations revolved around the need to complete focused special studies to refine sampling and analytical strategies and clarify the meaning of the data. However, during discussions with management about the EMP review, it became clear to us that IEP does not have an effective means of integrating ongoing monitoring with special studies intended to directly inform the monitoring program. This is a pressing issue for IEP because each monitoring program review will undoubtedly generate a list of needed special studies.

VI. Conclusions

1. An in-depth review of any IEP monitoring program is a staff intensive and time-consuming effort. In addition, we found that some expenditure above ongoing program costs is necessary for a successful review. Throughout the EMP review, the Core Team had to continually work to resist succumbing to one of Murphyís Laws: "There is never enough time to do it right the first time, but there is always time to do it over again." IEP must carefully consider staff, time, and funding commitments when making decisions that obligate a program to review.

2. A strong commitment to implementing the recommended monitoring program changes is essential. Substantial effort by many people is required to complete meaningful program reviews. Failure to implement program changes inhibits program progress and jeopardizes the commitment to future IEP monitoring program reviews.

3. We realized many benefits to completing an open, multi-level program review beyond the specific recommendations for changes to the monitoring program. The chief benefits include: (a) reinvigorating staff interest in the program and building staff respect, (b) increasing public and agency knowledge about the monitoring program, (c) developing a robust conceptual basis for the sampling design, and (d) developing a prioritized special studies plan.

4. Involvement of the independent IEP Science Advisory Group was critical to the success of the EMP review. Early and continued involvement by some advisory group members, clear communication of expectations, and timely response to the advisory group's recommendations were all key to this success.

VII. Acknowledgements

The EMP review and the contents of this article would not have been possible without the participation of the other Core Team members: Jon Burau (USGS), Ken Lentz (USBR), and Erwin Van Nieuwenhuyse (USBR).

This article is dedicated to Kitty (Katherine) Triboli of DWR. Much of the success the EMP enjoys today is due to her unwavering support and dedication to the EMP over the last three decades. Kitty, we wish you all the best in your future endeavors.