Extant Criteria Evaluation: Executive Summary

Prepared for

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FORWARD

The Arid West Water Quality Research Project (AWWQRP or "Project") was established in 1995 as a result of a federal appropriation (Public Law 103-327) and the establishment of an Assistance Agreement between the U.S. Environmental Protection Agency (EPA) and Pima County Wastewater Management (PCWWM), Tucson, Arizona. The establishment of this Agreement provided a significant opportunity for western water resource stakeholders to (1) work cooperatively to conduct scientific research to recommend appropriate water quality criteria, standards and uses for effluent-dependent and ephemeral waters in the arid and semi-arid regions of the West ("arid West"), and (2) improve the scientific basis for regulating wastewater and stormwater discharges in the arid West. Effluent-dependent waters are created by the discharge of treated effluent into ephemeral streambeds or streams that in the absence of effluent discharge would have only minimal flow.

With the establishment of the AWWQRP, a management infrastructure was created to support the development of peer-reviewed research products. From within the Capital Development Division of PCWWM, the AWWQRP Project Director, Program Manager and support staff administer the Project. A Regulatory Working Group (RWG), comprised of 15 stakeholders representing both public and private interests, works to ensure that Project research has a sound regulatory basis and that research activities focus on important regulatory concerns. The Scientific Advisory Group, comprised of scientists with experience in water quality research, makes certain that project research has a sound scientific basis and that studies are properly designed and technically sound.

This report represents the third in a series of research reports produced by the AWWQRP, and builds upon already completed work. The first report in the series, *Pre-Research Survey of Municipal NPDES Dischargers in the Arid and Semi-Arid West*, resulted from an RWG recommendation that the Project survey arid West wastewater facilities to compile information about their effluent discharges and associated water quality concerns.

The second report, the *Habitat Characterization Study*, utilized the findings of the Discharger Survey. Recognizing that an understanding of the attributes of effluent-dependent waters was critical to the development of appropriate water quality criteria and standards for these waters, the RWG recommended that the AWWQRP commission a major study to describe the physical, chemical, and biological characteristics of effluent-created habitats.

The *Habitat Characterization Study* evaluated the physical, chemical and biological characteristics of effluent-dependent habitats at ten case study sites in the arid West: Santa Cruz River below Nogales and below Tucson, Arizona; Salt River below Phoenix, Arizona; Santa Ana River below San Bernardino, California; Fountain Creek below Colorado Springs, Colorado; South Platte River below Denver, Colorado; Las Vegas Wash below Las Vegas, Nevada; Santa Fe River below Santa Fe, New Mexico; Carrizo Creek below Carrizo Springs, Texas; and Crow Creek below Cheyenne, Wyoming (Figure 1). The primary objectives of this effort were to (1) review existing physical, chemical and biological data; (2) conduct a site reconnaissance to characterize habitats using established protocols and protocols adapted for arid West conditions; (3) identify similarities and differences among sites; (4) discuss potential approaches to protect these habitats in the context of existing regulatory programs; and (5) recommend areas for additional study. The final report may be downloaded from the AWWQRP website, www.co.pima.az.us/wwm/wqrp, or obtained from the AWWQRP Office in a CD hyperlinked format.

The purpose of the third report, *Extant Criteria Evaluation*, is to evaluate the applicability of national water quality criteria, as well as the methods to modify those criteria, to effluent-dependent and ephemeral waters in the arid West. This work builds upon the findings presented in the *Habitat Characterization Study* using the expertise of national water quality criteria researchers. The findings and recommendations contained in this evaluation are already being used to move forward the AWWQRP research agenda.

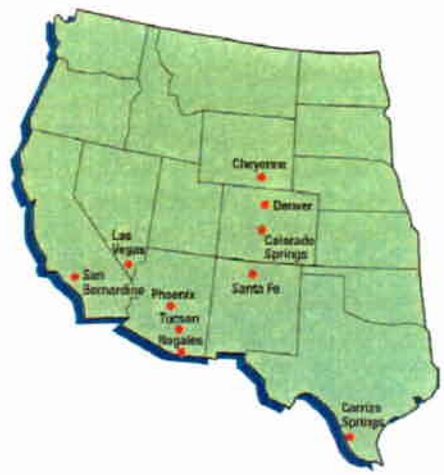

Figure 1. *Habitat Characterization Study* Case Study Sites.

The AWWQRP has made a significant effort to share Project results and their implications in a variety of technical, regulatory, industry and public interest forums. This outreach effort is designed to create a broader understanding of water quality issues unique to the arid West and provide scientific and regulatory data in support of a regional approach to the development of water quality criteria, standards and uses. Heightened interest in arid West water quality issues also has been fueled by the recognition that treated effluent can have a valuable role in the support and enhancement of riparian ecosystems, particularly in light of increasingly limited water resources. With interest in the Project growing, the AWWQRP looks forward to continuing its support of research that not only provides critical data to address unique western water quality issues, but also supports the development of innovative solutions.

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency's (USEPA) National Ambient Water Quality Criteria (AWQC) are used as the basis for state water quality regulations, including protection of beneficial uses and derivation of National Pollutant Discharge Elimination System (NPDES) discharge permit levels. These set maximum threshold concentrations of contaminants for both freshwater and marine environments. Numeric AWQC are derived using a well-defined process that relies on the collection of mostly laboratory-derived toxicity data, which are then used to calculate both an acute and a chronic criterion. Narrative AWQC are created for constituents that are not appropriate to this process (e.g., pH, temperature, total dissolved solids).

One major difficulty in applying AWQC to surface waters in the arid West is that they are derived chiefly from standardized toxicity tests using aquatic species that may not be representative of aquatic biota in this region. Furthermore, the physical and chemical characteristics of surface waters in the arid West differ substantially from those in more mesic regions. AWQC thus may not provide an appropriate or consistent level of protection for aquatic ecosystems in arid regions that are subject to these unique environmental conditions.

The goal of the Extant Criteria Evaluation (ECE) was to evaluate the relevance of selected USEPA ambient water quality criteria (AWQC) to ephemeral and effluent-dependent watercourses in the arid West. We placed more emphasis on considering modifications to AWQC duration and frequency periods to better reflect the biotic and hydrologic conditions encountered in these systems. To test this approach, we evaluated four AWQC as "models" for several important contaminant classes of interest to dischargers in the arid West, including: copper, selenium, diazinon, and ammonia.

RELEVANCE OF AWQC MAGNITUDES TO EPHEMERAL AND EFFLUENT-DEPENDENT STREAMS

Our analysis suggests that changes in default national AWQC magnitudes are probably warranted to maximize the accuracy by which water quality standards protect aquatic life in the arid West. For the most part, existing site-specific criteria modification methods (i.e., recalculation procedure, water-effect ratio procedure, and resident species procedure) may adequately address these proposed changes. Therefore, a "regional" approach may not be necessary or possible in many cases, and may depend mostly upon the ability to generalize the composition of biotic assemblages for use with a Recalculation Procedure.

While existing methods for criteria derivation and/or modification appear to be relevant for most of the chemicals we evaluated, existing derivation approaches clearly need to be modified for the bioaccumulative metal, selenium. In contrast to the approach taken in the existing AWQC, the available scientific evidence supports significant changes in how both the acute and chronic criteria might be derived. Similar changes are being proposed for use by USEPA in a draft update to this AWQC. The new approaches suggested in this report are relevant to any surface water throughout the U.S., but may be particularly relevant to the biotic communities encountered in ephemeral and/or effluent-dependent waters.

Copper

Copper was evaluated as a model to represent metals for which aquatic impacts depend most strongly on bioavailability which is under the control of site-specific water quality characteristics (e.g., hardness, alkalinity, pH, etc.). Metal toxicity varies most consistently as a function of hardness, and so AWQC for metals—including copper—are typically derived as a mathematical function of hardness. In contrast, in arid west streams it may be that copper AWQC should be set and/or modified on the basis of water quality characteristics other than hardness (such as alkalinity). This is because alkalinity can be a better predictor of copper toxicity in very hard waters, and because alkalinity and hardness are not always mathematically correlated in waters of the arid West (e.g., Las Vegas Wash). Thus, setting or modifying AWQC on the basis of hardness may be inappropriate for waters of the arid West.

Furthermore, a simple hardness equation may not accurately represent the more realistic and complex factors that may control metal toxicity in very hard waters. To further evaluate these more complex factors controlling copper toxicity, we evaluated the Biotic Ligand Model (BLM) for use in site-specific AWQC modification. The BLM is a mechanistic model of metal bioavailability that simulates metal interactions with specific receptors (the "biotic ligand") in aquatic organisms associated with metal toxicity. Even though this model was developed using data from relatively soft to moderately-hard waters, our studies suggest that model predictions are still accurate in very hard waters characteristic of the arid West. This predictive power is important because the BLM is being considered by USEPA as an alternative to water-effect ratio (WER) studies in their anticipated revision to the copper AWQC. BLM model predictions for several arid west sites also suggest that copper criteria magnitudes may be five- to ten-fold overprotective, and that the magnitude of this effect can be dependent on variable stream flows. However, neither of these characteristics may necessarily be unique to ephemeral and effluent-dependent waters in the arid West.

The other key consideration for the relevance of copper AWQC magnitudes in the arid West is the presence vs. absence of cladocerans (i.e., water fleas) and, to a lesser extent, salmonid fishes. Differences in species composition between ephemeral and effluent-dependent waters and the toxicity database used to derive the AWQC suggest that at least for ecosystems without salmonids and cladocerans, criteria magnitudes could be increased by several µg/L, depending on hardness. The absence of salmonids alone, however, would have little if any impact on copper criteria magnitudes, so the most critical taxonomic group for potential AWQC recalculations are the cladocera because of their unique sensitivity to copper.

Selenium

Selenium was used as a model to represent inorganics for which aquatic impacts depend most strongly on dietary intake and/or food chain bioaccumulation. Our analysis was based on a significant number of new toxicity studies conducted since publication of the 1987 AWQC and on a recent draft 2002 AWQC from USEPA. Inclusion of these data in derivation of a revised AWQC is strongly recommended, as is the calculation of separate acute criteria (criterion maximum concentrations, or CMCs) for selenite and selenate. Some studies suggest a CMC for selenate should be sulfate-dependent, with criteria concentrations increasing as a function of increasing sulfate. Because sulfate concentrations tend to be higher in arid west streams than in waters used in the most sensitive toxicity tests, acute criteria thus may be overly conservative. However, data are too few to make a firm recommendation at this time.

We also recommend changes in the methods by which the chronic AWQC (i.e., the criterion continuous concentration, or CCC) should be derived, with fish tissue residue-based thresholds being the basis of criteria calculations and compliance monitoring. USEPA also recommends use of this improved approach in the new draft AWQC, although the proposed criterion of 7.9 mg/kg (dry weight) is based on the results of only a single study that evaluated the combined effects of selenium and low-temperature stress. This tissue-based criterion may not, however, be appropriate for waters in the arid West that do not reach temperatures as cold as those used in this study. Finally, our preliminary analyses suggest that a tissue-based criterion will provide adequate protection of aquatic communities in ephemeral and effluent-dependent streams, as well as aquatic-dependent avian wildlife.

Similar to copper, a revised selenium AWQC would depend strongly on cladocerans (e.g., *Ceriodaphnia dubia*) for deriving the acute criterion. Therefore, acute selenium criteria might have to be recalculated for sites (e.g., ephemeral waters) should they be shown not to contain cladocera. Also similar to copper, the lack of salmonid fishes in most warmwater ephemeral and effluent-dependent streams would have little impact on our proposed chronic criterion. Only if anadromous salmonids are present would we recommend a lower chronic threshold (e.g., 4 – 6 mg/kg) than 7.9 mg/kg.

Diazinon

Because diazinon is an insecticide, invertebrates such as amphipods, cladocerans, and insect larvae are the most sensitive species that have been tested. Therefore, diazinon was evaluated to represent organic insecticides for which aquatic impacts depend most strongly on acute impacts to invertebrates. These classes of organisms are generally well represented in arid west streams, with the possible exception of cladocerans at times. Except perhaps for cladocerans, therefore, the species on which the draft AWQC for diazinon are based are generally relevant to arid west streams.

The second key factor that can influence the magnitude of the diazinon AWQC is chemical bioavailability as controlled by dissolved organic carbon (DOC). For organic chemicals, acute effects are likely to be associated with exposure to the free dissolved chemical concentration, which is that fraction of the dissolved chemical concentration that is not complexed to dissolved organic matter. The tendency for a neutral organic chemical to be complexed by natural organic matter is related to its octanol-water partition coefficient, or K_{OW}. The mitigating effect of organic matter complexation on toxicity is not likely to be important for compounds such as diazinon (i.e., those with log $K_{OW}<5$), at least at DOC levels representative of most natural waters. However, for high K_{OW} compounds, such as fenvalerate, the mitigating effect of DOC complexation on toxicity in comparison may be very important. Thus, DOC is likely to be the most important site-specific water quality characteristic to consider for most organic insecticides, at least those with high K_{OW} values.

Ammonia

Ammonia was evaluated as a naturally-occurring organic form of nitrogen for which its formation and discharge often are of significant concern to municipal wastewater treatment dischargers in the arid West. Of all the AWQC evaluated for this project, the 1999 update of the ammonia AWQC is perhaps the most readily applicable to arid west streams on a site- or region-specific basis. This is because 1) the major site-specific toxicity modifiers—pH and temperature—already are addressed explicitly in the equations used to set the CCC and CMC, and 2) some of the more significant issues of relative taxonomic sensitivity are addressed in the salmonid-present vs. salmonid-absent acute criterion, and in the early life stage (ELS)-present vs. ELS-absent provisions for the chronic criterion.

However, some of the most sensitive warmwater fishes that "drive" the acute non-salmonid criterion (*Notropis, Etheostoma*, and *Notemigonus*) may exhibit limited distribution in some arid west streams. This could diminish the relevance of the default AWQC, and thus a Recalculation Procedure might be necessary to modify these criteria on a site-specific basis. The apparent absence of the fingernail clam (*Musculium*) in ephemeral and effluent-dependent waters also may impact the relevance of the chronic ammonia criterion because it is the most chronically-sensitive taxa in the updated AWQC. Finally, it is possible that ammonia criteria magnitudes may be increased at elevated water hardness, but confirmatory data are few.

RELEVANCE OF AWQC DURATION AND FREQUENCY TO EPHEMERAL AND EFFLUENT-DEPENDENT STREAMS

Although a criterion magnitude determines what concentration should not be exceeded to protect aquatic organisms, criteria implementation (e.g., using criteria or standards to derive NPDES permit limits) also depends upon the duration and frequency components of an AWQC. Implicit in the duration value (also termed the "averaging period") is the assumption that aquatic populations and communities should not suffer unacceptable harm if the number of criteria exceedences are limited, and/or there are compensating periods of time when contaminant concentrations are below the criterion concentration. This is because most contaminants are more toxic when their concentrations fluctuate than if concentrations are constant over time. Thus to be conservative, the duration value is set to a period of time (one hour for CMC, four days for CCC) that is shorter than the time usually required to observe toxicity in a typical test under constant exposure conditions.

It is generally not possible to suggest modifications to AWQC duration values for conditions unique to the arid West. This is because default duration values are based entirely on laboratory toxicology and toxicokinetics data, and thus are not relevant to any particular site, including ephemeral and effluent-dependent streams. However, recent laboratory evidence suggests that these default duration values may be overly conservative (i.e., too short) in some cases. In particular, evidence exists that supports increasing duration values for copper, selenium, diazinon and ammonia, although data are few and, at times, contradictory (e.g., for copper).

Similar to duration, the default frequency of allowed excursions used for both the CCC and CMC (three years) assumes that ecosystems will not be harmed if the number of excursions are limited, and/or there are compensating periods of time over which the ecosystem can recover from the negative impacts of contaminant exposure. We evaluated the relevance of the default three-year recovery period to arid west biotic assemblages both as a function of community recovery potential, and as a function of hydrologic disturbance frequency. Our analysis suggests that the frequency and duration of hydrologic events in ephemeral streams of the arid West have the potential to be of similar importance to biotic communities as are exposure to toxics. The frequency of natural hydrologic disturbance to ephemeral and effluent-dependent streams in the arid West certainly is high enough to suggest that these ecosystems may be disturbed more frequently than once every three years. Therefore, the default three-year AWQC frequency could be too long in ephemeral and/or effluent-dependent streams if it is confirmed these ecosystems are exposed to such frequent disturbance.

In contrast, the biotic assemblages of ephemeral and effluent-dependent streams may still require longer time periods (e.g., three years) to recover from disturbance even if a substantial number of endemic species still remain. Even though endemic fish species are adapted to rapid recovery from disturbance, extensive habitat alteration (i.e., loss of refugia) and introduction of exotic species have changed these ecosystems such that rapid recovery may no longer be possible in many cases. Therefore, it may be environmentally conservative to retain the default three-year frequency of allowed excursions except, perhaps, for relatively unmodified ephemeral streams. In these unmodified ephemeral systems, fish either are permanently absent, or adapted to rapid reintroduction during times of stream flow in response to precipitation. Thus, for relatively undisturbed ephemeral streams onto which significant hydrologic variability is usually imposed, the default three-year frequency value may be too conservative. Additional study is warranted to evaluate the relative significance of hydrologic disturbance frequency vs. the ability of non-endemic assemblages to recover from disturbance.

RECOMMENDED APPROACHES FOR MODIFYING AWQC IN THE ARID WEST

One of the main goals of our study was to evaluate whether a regional approach to criteria modification for ephemeral and effluent-dependent streams in the arid West might be warranted from a scientific point of view. In particular, we focused our evaluation on a better integration of all three components of an AWQC (magnitude, frequency, and duration). Therefore, below we summarize our recommendations (not ranked in order of preference) for potential criteria modification starting with magnitude modification, then with duration and frequency. All three also provide critical information needed for NPDES permit limit calculations, and so any criteria evaluation should focus on all three components, rather than only on criteria magnitudes as is typically done. Furthermore, because NPDES permit implementation is a function of designated uses for any given water body, we close this section with recommendations as to how AWQC might be applied to ephemeral and effluent-dependent waters via aquatic life use designations.

Recalculation Procedure

The Recalculation Procedure provides a means of correcting criteria magnitudes if the species at a particular site are substantially different from those used in the toxicity testing to derive the AWQC. Given the unique species assemblages sometimes encountered in arid west watercourses, this may be an appropriate approach for use in site-specific criteria modifications. However, because of the limited species richness sometimes encountered in these habitats, it may not always be possible to achieve USEPA's eight-family minimum data requirements (MDRs) for calculating acute criteria via Final Acute Value (FAV) calculations. According to species surveys conducted for the Pima County Wastewater Management Department (PCWMD) Habitat Characterization Study, this is not always achieved. In their analysis, salmonids were not found to be present in eight of their ten study sites, and records for the presence of cladocerans are not available for three sites. Otherwise, a sufficient total number of families appear to reside in ephemeral and effluent-dependent streams to allow recalculation of a site-specific FAV and, hence, acute criterion.

It should be kept in mind that just because there may be an adequate total number of appropriate families for acute criteria calculations, there may not be acceptable toxicity data for the particular members of these families known to be resident to a given site. Also, if less than eight families of aquatic animals occur at a site, USEPA guidance allows for use of a "simplified" Recalculation Procedure. In this simplified procedure, the FAV can be set to the lowest available species mean acute value (SMAV). The acute criterion (CMC) is then calculated as usual. According to USEPA guidance, however, this simplified method can only be used if data are available for at least one species in each of the families that actually occur at the site.

Therefore, the potential exists that if accurate species lists can be generated for ephemeral and/or effluent-dependent waters in any given state or region, then the Recalculation Procedure (either standard or simplified) may be a useful means of modifying AWQC to be more accurately protective of aquatic life and their uses. The accuracy of this procedure, however, depends on the reliability of the species list (i.e., how well does it represent similar waters throughout the region), and the availability of acceptable toxicity data for the types of species resident to such a site.

Water-Effect Ratio

The Indicator Species, or "Water-effect Ratio" (WER), procedure is intended to take into account how water quality characteristics affect the toxicity of contaminants (most typically metals) in laboratory dilution water relative to that in site water. Given that arid west surface waters tend to be alkaline and/or have elevated hardness, WERs likely provide a useful approach for modifying criteria in ephemeral and effluent-dependent waters. Using the BLM to predict WERs for several waters in the arid West, for example, we demonstrated that at least for copper, median WERs of approximately five to ten might be anticipated. These WERs also were predicted to vary as a function of flow and the concentrations of important water quality characteristics (e.g., hardness, dissolved organic carbon), but these relationships are not necessarily unique to arid west streams.

Therefore, the WER procedure is likely to be a reliable method for conducting site-specific criteria modifications in ephemeral and effluent-dependent waters, but there is no unique set of characteristics that appear to make it more or less likely to be reliable than in other regions. Just as in any region, the WER procedure is most likely to be useful with metals, but some potential also may exist for its use with ammonia (as a function of hardness), selenium (as a function of sulfate for selenate toxicity), or organophosphate insecticides (as a function of dissolved organic carbon).

It is doubtful, however, that WERs could be applied on a regional scale because they are based on empirical studies that quantify how the characteristics of particular site water modify toxicity. While the distributions of BLM-predicted WERs we generated for copper could be used to estimate mean or median WERs, such values may be not be useful in an applied context. This is because a criterion based on a median WER may not protect against enhanced bioavailability that might occur, for example, under conditions of extreme (low or high) stream flows. However, these kinds of predictive distributions may help identify which key environmental characteristics (e.g., flow, or chemical factors most likely modify toxicity) would need to be evaluated in an empirical WER study at a given site.

Resident Species Procedure

In some situations, species resident to a particular site may be uniquely adapted to local conditions and, as a result, be more or less sensitive to elevated contaminant concentrations than the species used to derive the National AWQC. The Resident Species Procedure provides a means of taking into account the differential sensitivity of resident species to chemical stressors. The required database for generating a national AWQC is regenerated using resident species exposed to the material in question in site water. However, recent USEPA guidance also allows the Recalculation Procedure and WER to be combined as an alternative to generating a site-specific criterion using the Resident Species Procedure.

Because of this change in USEPA guidance, and because of the logistic difficulty in testing with resident species, this procedure has rarely been used, particularly in the arid West. However, this procedure may still hold promise for generating site- or even regional-specific criteria for ephemeral and effluent-dependent streams in the arid West. Species that are resident (or endemic) to these waters are likely to be acclimated or adapted to water quality characteristics that would influence their sensitivity to chemical contaminants (e.g., elevated hardness for metals toxicity). Acclimation, and to a greater extent adaptation, are not taken into account by either the Recalculation Procedure or WER. If confirmed by additional study, testing with resident species thus may derive unique and more accurate AWQC than with these more widely used methods.

Alternative Approaches for Modifying AWQC Magnitudes

We also evaluated two alternative approaches that might be useful in the derivation or modification of AWQC in the arid West. First, the BLM was discussed as a powerful new tool for site-specific modification of metals criteria. This is important for all regions of the US because the BLM is currently being considered by USEPA for use in an expected revision to the copper AWQC. Even though this model was developed using data from relatively soft to moderately-hard waters, our empirical studies with *Ceriodaphnia dubia* suggest that BLM predictions are still accurate in very hard waters characteristic of the arid West. Therefore, it is likely that the BLM may gain wide acceptance for use in site-specific modifications on a nation-wide basis. In fact, the BLM could be particularly relevant for use with the hard and alkaline waters of this region in part because it takes into account the effects of both alkalinity and hardness (or correlated factors).

Second, in our evaluation of the selenium AWQC, we addressed the utility of bioaccumulation models for use in deriving chronic criteria for inorganic elements for which dietary intake and/or food chain bioaccumulation are significant pathways for toxic exposure. Such an approach constitutes a significant departure from the standard methods for deriving chronic criteria, which are based on the toxicity of aqueous exposures only. For selenium, such an approach is clearly not consistent with the recent literature that emphasizes the importance of dietary intake to chronic toxicity. Ultimately, we recommended that for bioaccumulative inorganics, tissue residue-based thresholds should form the basis of chronic criteria calculations and compliance monitoring. An initial analysis shows this approach to provide adequate protection of aquatic communities in ephemeral and effluent-dependent streams, as well as aquatic-dependent avian wildlife. Therefore, bioaccumulation models may be very useful in deriving or modifying chronic AWQC that are more accurately protective of aquatic life for these kinds of chemicals.

Importance of Duration and Frequency to NPDES Permit Calculations

The hydrology and ecology of western streams may result in toxic events of different duration and frequency from those deemed to be acceptable in mesic systems. This would have important implications for calculating wasteload allocation in NPDES permitting because the receiving water discharge may vary considerably depending on both the duration and recurrence interval (i.e., frequency) of the acceptable stream flow. At a given effluent flow rate, changes in receiving water flow would change effluent dilution rates and, subsequently, effluent design flows as defined under the NPDES program.

Effluent design flows represent conservative estimates of receiving stream flows used for wasteload allocation modeling. Design flows are typically calculated using steady-state models that are based either purely on Pearson Type III summary statistics ("hydrologically-based" design flows), or on the default, AWQC duration and frequency values ("biologically-based" design flows). Although each are based on fundamentally different assumptions, USEPA found that certain hydrologic flows (e.g., $7Q_{10}$) and important biologically-based flows (e.g., relevant to the chronic four-day duration and three-year frequency) are strongly correlated. Because of this correlation, USEPA typically advocates the use of hydrologically-based design flows, as they are simpler to calculate than biologically-based ones.

To illustrate the potential impact of changes in criteria duration and frequency values on design flows, we estimated biologically-based design flows for three arid west effluent-dependent streams using the DFLOW program recommended by USEPA. Simply by increasing the default duration value from four days to 30 days (as is now recommended in the 1999 AWQC for ammonia) can increase design flows by nearly two times. Decreasing default frequency values from 3 to 1.5 years (e.g., for aquatic communities that recover rapidly from disturbance) had a similar, but relatively minor, impact (design flow increases in most cases by 1.1 – 1.5 times). However, this suggests that permit conditions can be affected if biologically-based design flow calculations are used. It is also important to note that, in contrast to hydrologically-based design flows, biologically-based design flow calculations estimate the exact number of allowable exceedences at a given site as called for by the AWQC duration and frequency values. Therefore, we suggest that biologically-based calculations should be coupled with a critical evaluation of potential changes in AWQC duration and frequency to help derive more accurate permit limits. While this could be recommended for streams in any ecoregion, the unique flow characteristics of arid west streams make this a particularly important consideration.

Even this steady-state modeling approach, however, may not be the most accurate for streams with highly variable hydrology, particularly ephemeral streams with significant numbers of zero-flow days. Dynamic models (e.g., Monte Carlo or Lognormal Probabilistic Dilution models) instead may be more appropriate for use in these situations, at least for chronic criteria.

Integrated Models

Even though frequency and duration values are intended to derive AWQC that integrate across temporal scales, the default values for each are derived separately using different approaches. However, ecological approaches and models exist that may better integrate the effects of a contaminant across time scales that include both stress (toxicity) and recovery. Such approaches would have the advantage of explicitly deriving magnitude, duration, and frequency values that represent specific concentrations and times required to manifest a toxic effect, along with the specific time required for recovery from this same stressor. This could significantly increase the accuracy by which AWQC protect aquatic life in ephemeral and effluent-dependent streams owing to the highly variable hydrological and biological conditions often encountered in these systems. Recent efforts by both the USEPA and the Water Environment Research Foundation (e.g., WERF project 98-HHE-3) have illustrated the potential power of these more sophisticated approaches. Thus, scientific developments continue that ultimately will improve the accuracy with which truly integrated AWQC can protect aquatic organisms.

APPLICATION OF AWQC TO DESIGNATED USE CATEGORIES

Another mechanism by which AWQC may be modified to reflect local/regional variation in biological, hydrological, or physico-chemical conditions are by applying different water quality standards to different beneficial use designations. For the most part, States apply national AWQC without modification to all designated use categories regardless of differences that might exist in stream characteristics. This is also usually true in arid west states, with a few notable exceptions (e.g., recalculated acute copper and selenium standards for ephemeral and effluent-dependent waters in Arizona).

Even though it has only rarely been applied, modifying numeric water quality standards as a function of a designated use category is perhaps the most straightforward regulatory mechanism available for modifying AWQC on a "regional" basis. No new scientific or regulatory guidance would need to be developed, and presumably, any scientifically valid approach for modifying AWQC could be used to develop designated use-specific water quality standards. Below we summarize some of the key considerations for use in the development or review of designated use-specific water quality standards for ephemeral and effluent-dependent streams in the arid West.

Ephemeral

For ephemeral waters, perhaps the most relevant approach for modifying AWQC to set water quality standards for this use category would be the Recalculation Procedure. For example, Arizona applied a simplified Recalculation Procedure to set water quality standards based on the generic species list for ephemeral streams (Aquatic and Wildlife—Ephemeral; A&We). Such an approach is promising, but the accuracy by which it modifies AWQC for protection of aquatic life uses depends strongly on the scientific reliability of generic species lists for all ephemeral streams in a State. Furthermore, regulatory acceptance of the Recalculation Procedure also depends on whether enough toxicity data of acceptable quality exist for taxa included in a generic listing for ephemeral waters.

We also have argued that at least for relatively undisturbed ephemeral streams, the default frequency of allowed criteria excursions may be overly conservative (i.e., could be reduced from three years) for endemic stream assemblages. This is particularly true for fish assemblages that are shown to consist mostly of small-bodied endemic species with limited habitat modification, or if an ephemeral assemblage is dominated by invertebrate species with relatively short life cycles. If the ability of such communities to quickly recover from acute disturbance is further confirmed by field or experimental study, it may be possible to use a less than three-year criteria frequency in deriving more accurate state water quality standards for ephemeral streams. However, for ephemeral streams with highly-modified aquatic habitat and/or a significant percentage of non-native fish species, the default three-year frequency is probably still appropriate.

Effluent-Dependent

In contrast to ephemeral streams, fewer opportunities probably exist for modifying national AWQC for use with an effluent-dependent designated use category. The imposition of effluent tends to stabilize variable stream flows to some extent, and also modifies aquatic habitat providing opportunity for colonization of exotic, non-native species. This more stable and less complex aquatic habitat thus can support a more diverse aquatic community. Therefore, more limited opportunities may exist to modify water quality standards on the basis of a Recalculation Procedure for effluent-dependent waters.

The introduction of effluent into otherwise ephemeral streams also tends to modify water quality characteristics, which could lead to changes in contaminant bioavailability and, hence, AWQC magnitudes. However, such modifications may only be practical on a site-specific basis unless effluent-dependent stream water quality characteristics can be reliably generalized. Given the diversity in the types of industrial and municipal discharges, as well as differences in effluent treatment levels between individual facilities, such a generalization may not be possible.