WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Whole Effluent Toxicity (WET)

Program Evaluation

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Washington State Department of Ecology
Water Quality Program

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Program Evaluation

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Table of Contents

I. Introduction

The Water Quality Program Permit Management Section has planned from the beginning to evaluate the implementation of the state's regulation on Whole Effluent Toxicity (WET). The WET regulation was adopted in October 1993, and we have managed to capture into a database most of the WET tests conducted to meet its requirements. We have also been very active in evaluating the performance of WET tests and have developed a detailed review process for the WET test results. A critical evaluation of the regulatory program involving WET testing seemed possible and desirable in our effort to improve the effectiveness and efficiency of the state's regulatory programs.

Recent events have made this document more difficult to write. WET is nationally one of the most controversial elements of water quality-based permitting. Concerned representatives have introduced individual bills on the subject of WET alone in congress. Environmental Protection Agency (EPA) has responded by consulting stakeholders and the scientific community, especially the Society of Environmental Toxicology and Chemistry (SETAC). The document is forced by these responses to the national WET controversy to discuss changes that would not necessarily arise out of our own experience with WET in Washington State.

SETAC conducted the Pellston Workshop on WET testing in September 1995, in order to resolve important scientific issues involving the regulatory application of WET testing. In September 1996, EPA hosted the WET Stakeholder's Meeting to get broader input in developing the Pellston Workshop recommendations into a new strategy for regulating WET. EPA has drafted a new WET implementation strategy in response to Pellston and the Stakeholder's Meeting that, if followed, would create a complicated regulatory system. This document discusses our experiences with WET and charts potential future courses primarily from a regulatory perspective. Some scientific issues related to the national controversy are explained below in Section V. Supporting Discussions and General Conclusion.

II. History and Background

A. What is WET Testing?

Chemical analysis of wastewater discharges is inadequate by itself for regulating toxicity. Many toxic pollutants cannot be detected by commonly available detection methods. Many of the chemicals that can be detected have little, or no, toxicity information available on them. Many of the chemicals with known toxicity have unknown additive or synergistic effects when present in complex mixtures such as wastewater. In practice, chemical analysis can only detect toxicity indirectly through previous studies of the effects of the chemicals detected. Because chemical analysis results in a list of individual compounds, which are evaluated separately for toxicity, this approach is called chemical specific toxicity.

The toxicity of complex mixtures like effluents or ambient waters can be measured directly by exposing living organisms and measuring their response. The exposure of the test organisms to the effluent usually occurs in a laboratory, but can also be accomplished in the wastestream (onsite flow-through tests) or in the environment (*in situ* testing). Toxicity tests measure the combined effects of all toxic constituents of the sample, which is why it is called WET testing.

Acute WET tests involve exposing test organisms to serial dilutions of effluent in order to determine survival at 48 or 96 hours. The acute tests use the death of a test organism as the endpoint for scoring a positive response to effluent toxicity. Dischargers who monitor their wastewater with acute toxicity tests are providing an indication of the potential lethal effect of the effluent to organisms in the receiving environment.

Death as a direct response, however, is only one of many toxic effects that a discharge can have on receiving water organisms. Toxic substances in an effluent could, for example, have sublethal effects such as interference with normal reproduction or development of organisms with consequences just as undesirable as direct lethality. The end result of the disrupted reproduction or development of a receiving environment species can be the same as direct lethality for that species--the population of the species is reduced or eliminated. Obviously, acute toxicity tests by themselves are insufficient indicators of potential environmental harm from effluent toxicity.

The category of toxicity tests used to measure these various sublethal toxic responses is known as chronic toxicity tests, but in general, these tests don't measure traditional chronic toxicity. Chronic toxicity, according to the traditional meaning, measures the long-term effects on the organ systems of exposed organisms which result in death, or impaired function. Toxicity tests intended to measure traditional chronic effects involve testing organisms for long time periods. Such long-term toxicity tests are inappropriate for a wastewater discharge monitoring system because the results of the test are available long after the sampled discharge has entered the environment. These tests are also too expensive for routine use. In response to these problems, aquatic toxicologists have developed several short-term chronic or critical life stage toxicity tests, which are available for use in monitoring wastewater discharges for sublethal toxic effects. Even though these sublethal toxicity tests are measuring short-term effects of the effluent, they are still called 'chronic' to distinguish them from the acute toxicity tests, which measure short-term lethality.

EPA’s water quality criteria have acute and chronic points of compliance. The chronic point of compliance is the edge of a mixing zone where receiving water must be suitable for long-term habitation. Inside of the mixing zone and close to the discharge point is the acute point of compliance where there must be no lethality. The area between these points of compliance need not be fit for long-term habitation but must not be lethal to passing organisms. WET tests only assessing survival apply at the acute point of compliance. Short-term chronic and critical life stage tests apply at the chronic point of compliance to assess suitability for long-term habitation by aquatic species.

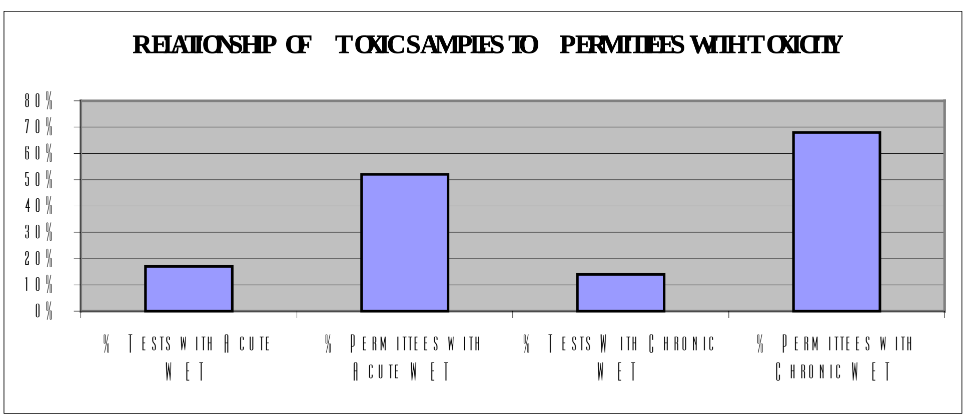
B. How Toxic are Effluents in this State?

An important conclusion from examining the occurrence of acute and chronic toxicity in effluents in Washington State is that the technology-based permitting program was fairly successful in controlling toxicity. Treatment plants may not be designed to control toxicity, but they often do a very good job of removing toxicity anyway. The only problem is that these treatment plants are not consistent, and many produce occasional excursions of toxicity.

Forty-seven percent of 1,853 acute tests had 100 percent survival in 100 percent effluent, and 72 percent had 90 percent survival or better in 100 percent effluent. Eighty-three percent of these tests met the state's acute toxicity performance standard of at least 65 percent survival in 100 percent effluent with a median percent survival of 80 percent. However, the 19 percent of acute tests, which failed to meet the performance standard, were distributed throughout 52 percent of permittees.

Chronic toxicity is also adequately controlled much of the time by current levels of treatment. A large majority of these chronic tests show no toxicity at levels of regulatory concern. The average effluent concentration at the edge of an acute mixing zone in our state is 17 percent effluent. The edge of the acute mixing zone is used in our state as the cutoff for regulatory significant chronic toxicity and the need for a chronic WET limit. Eighty-four percent of 2049 NOECs in the database were greater than or equal to 17 percent effluent and estimated to be of no regulatory concern. The NOEC or "no observed effects concentration" is the highest concentration of effluent showing no statistically significant difference from the control in the test. A fair number of chronic tests also show no toxicity at end-of-pipe. Fifty-nine percent of chronic NOECs were 100 percent effluent. The bivalve development and echinoderm fertilization tests are the exceptions with only 30 percent of 151 tests clearly having NOECs above concentrations of regulatory concern mostly due to the toxicity of the industrial effluents commonly evaluated with these tests.

The bad news associated with our experience with WET test results is the wide distribution amongst permittees of those tests showing significant toxicity. Only 48 percent of permittees have never shown acute WET at levels of regulatory concern, and only 39 percent have never reported chronic WET test results at levels of regulatory concern. The 11 percent of chronic tests with toxicity of regulatory concern were distributed across 68 percent of the permittees in the database. These occasional excursions have unknown duration and environmental impact because of inadequate monitoring frequencies.



C. Laws and Regulations of Importance

In accordance with the State of Washington Pollution Disclosure Act of 1971, and the Federal Water Pollution Control Act Amendments of 1972 and 1977, the Industrial Section of the Ecology began in late 1970 to require toxicity testing of pulp mill discharges in the state. This toxicity testing was technology-based and derived from Canadian research that demonstrated that if a pulp mill treatment plant was operated correctly, then a 65 percent concentration of effluent would cause less than 20 percent mortality to rainbow trout. This test was eventually applied to other industrial dischargers.

On February 3, 1984, U.S. EPA's Assistant Administrator for Water signed the Policy for the Development of Water Quality-Based Permit Limitations for Toxic Pollutants. This policy required EPA and the States to meet water quality standards by limiting the discharge of toxic material based on the narrative water quality standard of no toxic material in toxic amounts. The policy specified monitoring wastewater using acute and chronic toxicity tests to detect violations of the water quality standards, and where such violations exist, using NPDES permit limits to control the toxicity in order to maintain the designated use of the receiving water. In March 1991, U.S. EPA published the latest Technical Support Document (TSD) for Water Quality-Based Toxics Control which describes the process for monitoring discharges with whole effluent toxicity tests and developing permits which protect water quality.

The CWA Amendments of 1987 further directed EPA and the states to identify waters and discharges with a toxic pollutant problem and to develop a control strategy including individual permit limits to attain water quality standards. In July 1989, U.S. EPA promulgated regulations (40 CFR 122.44) which require states to place limits on whole effluent toxicity in NPDES permits when a reasonable potential to exceed water quality standards has been determined.

The State of Washington has added its own legal requirements for acute and chronic biomonitoring through both law and regulation. RCW 90.48.520 require that the overall toxicity of effluents be controlled through NPDES permit requirements. RCW 90.48.520 is essentially a technology-based approach (AKART). RCW 90.48.520 says in part:

> In order to improve water quality by controlling toxicants in wastewater, the Department of Ecology shall in issuing and renewing state and federal wastewater discharge permits review the applicant's operations and incorporate permit conditions which require all known, available, and reasonable methods to control toxicants in the applicant's wastewater. Such conditions may include, but are not limited to limits on the overall toxicity of the effluent. The toxicity of the effluent shall be determined by techniques such as chronic or acute bioassays. Such conditions shall be required regardless of the quality of the receiving water and regardless of the minimum water quality standards...

Chapter 173-201A WAC, Water Quality Standards, contains requirements for each of the different criteria classes of water to have concentrations of toxics below levels, which cause acute or chronic damage to the aquatic biota. In addition to these standards, Section 173-220-130 WAC, Effluent limitations, water quality standards and other requirements for permits, instructs Ecology to apply the requirements of RCW 90.48.520 to any permit issued under the NPDES.

The Puget Sound Water Quality Authority also included biomonitoring in the 1989 Puget Sound Water Quality Management Plan. Program Element P-6, Toxicant Effluent Limits in Permits, requires Ecology to include limits on toxics in NPDES permits. Program Element P-8, Monitoring Requirements in Permits, requires Ecology to include acute and chronic toxicity tests in the periodic monitoring of permitted discharges.

D. The State's WET Rule

In October 1993, Ecology adopted a WET regulation (Chapter 173-205 WAC) that was written to satisfy the laws and regulations discussed above. It was also written as a part of an agreement to settle appeals of NPDES permits. The appellants were dissatisfied with being required to conduct WET testing and not having a state regulation, which detailed the use of the test results and consequences for effluent toxicity. The regulation is very thorough in providing these details. Much effort was given to preventing undue consequences for permittees while meeting the requirements of the important laws and regulations.

The state's WET regulation received support in writing from cities, industries, and environmental groups. Our approach was developed using common sense and the best information on the performance of WET testing available at the time. Chapter 173-205 WAC was developed using extensive input from an advisory committee. As much as possible in the rulemaking, we based decisions on WET test data. The broad-based support for our WET program demonstrates that WET need not be controversial. There have been no serious appeals of the WET requirements in our permits in five years.

The regulation complies with the national WET policy described below, but it is also innovative in containing incentives to reduce toxicity beyond what is necessary to meet WET limits and having as a goal the elimination of all acute WET. The WET regulation implements RCW 90.48.520 through an incentive system not technology-based permit limits on WET. Permittees are protected by the regulation from excessive consequences arising from single WET test failures, and can interrupt a Toxicity Identification Evaluation (TIE) if the toxicity disappears. There are other mechanisms built into the regulation to make the system fair and enforceable.

A WET limit will be eligible for removal upon permit renewal if the permittee has consistently attained a level of toxicity so low that no reasonable potential exists to violate water quality standards. This level of toxicity is the same as was used to determine the need for the WET limit in the first place. The opportunity to routinely remove permit limits that are no longer necessary is unique to this rule and provides permittees with an economic and legal incentive to control toxicity at levels lower than necessary to meet permit limits. Both permittees and the environment benefit from this provision of the rule.

The permitting process under the WET Rule works as follows:

Step 1 - The process begins with a National Pollutant Discharge Elimination System (NPDES) permit application.

Step 2 - Section 173-205-040 of the WET rule contains a list of circumstances under which a discharge is required to be characterized for WET.

Step 3 - WET testing usually begins with an effluent characterization in the first year of the permit term. Effluent characterization establishes the baseline toxicity level and determines the need for WET limits.

Step 4 - The permit will require that the permittee determine at the end of effluent characterization whether the WET performance standards have been met for acute and chronic toxicity. The performance standard for acute toxicity is a median of at least 80 percent survival in 100 percent effluent with no single test showing less than 65 percent survival in 100 percent effluent. The performance standard for chronic toxicity is no chronic toxicity in a concentration of effluent representing the edge of the acute mixing zone or the Acute Critical Effluent Concentration (ACEC). Those permittees who meet the performance standards will not get WET limits or compliance monitoring (will go straight to Step 7).

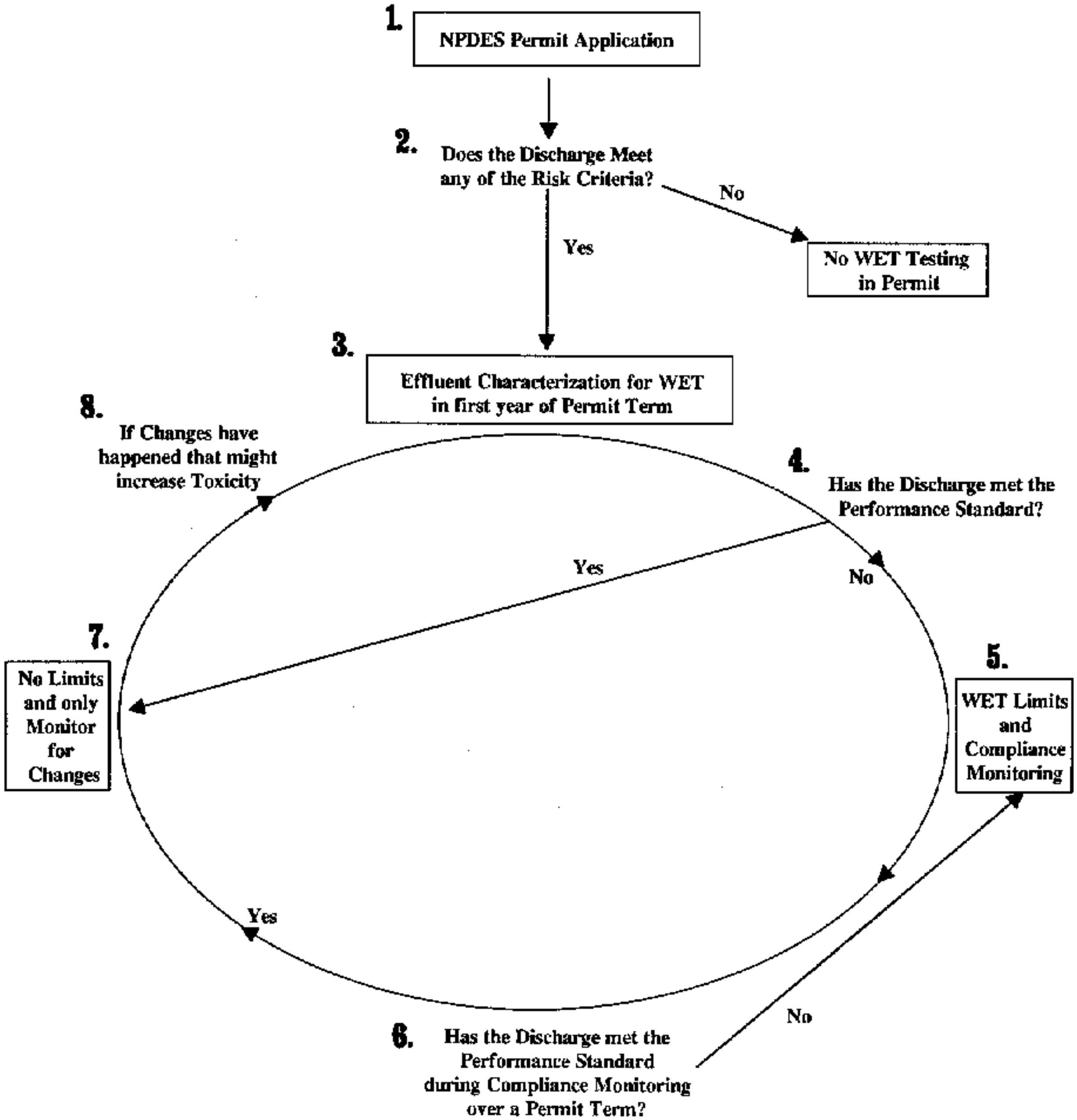
Step 5 - Those permittees who do not meet a performance standard during effluent characterization will receive WET limits. Acute WET limits are met by showing no statistically significant toxicity in the ACEC. Chronic WET limits are met by showing no statistically significant toxicity in the CCEC Chronic Critical Effluent Concentration (CCEC) which represents the edge of the chronic mixing zone). Failing a compliance test for a WET limit will trigger additional WET testing, and if any of the additional tests fail to meet the WET limit, a toxicity identification/reduction evaluation (TI/RE) will be required to find and fix the source of toxicity.

Step 6 - If a permittee with a WET limit meets the performance standard for an entire permit term, then the WET limit will not be placed into subsequent permits. If a permittee fails to meet the performance standard during compliance monitoring, then the WET limit and compliance monitoring will remain in future permits until the performance standard is met.

Step 7 - Permittees who have attained the performance standards can remain indefinitely without WET limits or compliance monitoring. The only WET testing requirement will be a set of WET tests submitted with each permit application. Some permittees will be required to conduct rapid screening testing. All facility changes must be evaluated for increases in toxicity.

Step 8 - If changes have occurred which might increase toxicity, then the next permit will contain a requirement for a new effluent characterization. The new effluent characterization will start the process all over again beginning at Step 3. WET limits might result from the new effluent characterization, or the permittee could end up back at Step 7 with no WET limits.

WET PERMITTING SYSTEM DIAGRAM



The WET database works best when used to assess individual permittee records because the number of tests involved is small enough to evaluate and qualify with a reasonable amount of effort. Because the tests used in evaluating the WET program numbered in the thousands, it was not possible to do much fine-tuning. It is important to appreciate that the numbers given in this section are estimates. The ACEC and CCEC were known for only 55 percent of the permittees in the WET database causing the evaluation of the other 45 percent to be made using comparisons of test results to the average ACEC or CCEC. In addition to knowing the ACEC and CCEC, an accurate assessment is only possible when the step in the WET regulatory process outlined in the previous section is known for each permittee, and there is no automatic update of the WET database at present for permittee status. Treatment has been improved for many of the discharges and these effluents may not have been recharacterized yet. Many tests are several years old and may have been conducted according to obsolete methodology. Many of the tests in the database are 100 percent effluent screening tests and offer little useful information. Our approach to sampling and testing chlorinated discharges has changed a few times.

Given the cautions above, the projected status of Washington State permittees under the WET Rule is as follows:

An evaluation of the WET test data for all permittees represented in the database was conducted. The evaluation considered 132 permittees, 1100 chronic WET tests, and 1800 acute WET tests. There were 21 permittees with acute tests and no chronic tests. The data suggest the following:

- 52 percent of permittees are predicted to be assigned an acute WET limit.
- 61 percent of permittees are predicted to be assigned a chronic WET limit.
- About one third of the permittees are predicted to get both acute and chronic WET limits and another third may not get any WET limits.

Estimate of Number of Discharges Needing Acute WET Limits

Discharge Type	**# Permittees**	**# Acute Limits**	**% Acute Limits**
POTWs	53	30	57%
General Industry	33	12	36%
Power Plants	2	0	0%
Pulp Mills	16	9	56%
Oil Refineries	7	6	86%
Aluminum Smelters	7	5	71%
Treated Groundwater	1	1	100%
Ind. Process & Storm.	3	2	67%
Industrial Stormwater	10	4	40%
TOTAL	132	69	52%

Estimate of Number of Discharges Needing Chronic WET Limits

Discharge Type	**# Permittees**	**# Chronic Limits**	**% Chronic Limits**
POTWs	21	14	67%
General Industry	4	4	100%
Pulp Mills	13	7	54%
Oil Refineries	5	2	40%
Aluminum Smelters	6	2	33%
Noncontact Cooling Water	2	1	50%
Ind. Process & Storm.	3	3	100%
TOTAL	54 (with the ACEC known)	33	61%

All failures to meet the acute performance standard have been due to tests with less than 65 percent survival in 100 percent effluent; no discharge has ever failed to meet the median percent survival of at least 80 percent. Nineteen percent of 1800 acute WET tests from 132 permittees did not achieve at least 65 percent survival in 100 percent effluent. Between 25 percent and 55 percent of these tests failing to meet the acute toxicity performance standard were also toxic at effluent concentrations near the average acute WET limit (ACEC = 17.35 percent effluent) indicating that the acute performance standard is a reasonable indicator for many permittees of the potential to exceed water quality standards for toxicity. However, this predictive ability disappears as ACECs become much smaller than the average of 17.35 percent effluent. The inability of an acute toxicity performance standard based on 100 percent to predict toxicity at low concentrations was known when the WET Rule was written, but was ignored in order to provide an incentive for all dischargers to completely eliminate acute toxicity in accordance with the desires of RCW 90.48.520. An alternative to the incentive system based on 100 percent effluent would be an acute toxicity performance standard of no statistically significant toxicity at 5 times the ACEC. Because the current acute performance standard allows up to 35 percent mortality and statistical significance will often occur at mortality rates as low as 15 percent, the alternative performance standard would be slightly more stringent for dischargers with ACECs near or above the average of 17.35 percent effluent. Implementing the alternative would, of course, mean abandoning the incentive system, and dischargers with ACECs much below the average could continue to discharge acute toxicity with no discouragement.

Sixty-one percent of the 54 permittees with known ACECs and CCECs failed to meet the chronic toxicity performance standard of no statistically significant toxicity at the ACEC. Sixty percent of these permittees who failed to meet the chronic toxicity performance standard at the ACEC also had statistically significant toxicity at the CCEC (the chronic WET limit). The estimated noncompliance rate amongst permittees with chronic WET limits is therefore 60 percent and represents 30 percent of the total of 54 permittees. The chronic toxicity performance standard of no statistically significant toxicity at the ACEC is a very good predictor of chronic WET limit violations. These percentages also predict that many TI/REs will need to be conducted. The fact that few TI/REs have been done so far is mostly because the rewriting of permits to include WET limits is a slow process.

Three TI/REs have been initiated in Washington State in order to meet WET requirements in an NPDES permit. One TI/RE was stopped before completion because the point of compliance was changed when the permit was reissued. The other two were completed successfully.

The first discharger to conduct a successful TI/RE was also having trouble complying with a permit limit for Total Suspended Solids (TSS). When TSS levels rose, the discharger would add a big dose of flocculant to the settling pond. The flocculant would then cause toxicity to *Ceriodaphnia*. Improvements in the settling pond and installation of a device to provide a carefully metered dose of flocculant solved both the TSS and WET compliance problems.

The other discharger to successfully complete a TI/RE had one of the most toxic effluents seen in the state. The lowest concentration of effluent tested, five percent effluent would sometimes kill all *Ceriodaphnia* in less than 24 hours. Identifying the toxicant was difficult because effluent toxicity was episodic and frustrated efforts to schedule toxicity identification attempts. The initial toxicity identification evaluation found that a cationic organic was likely responsible for the effluent toxicity. However, recovering the specific cationic organic from the carbon column and identifying it required special arrangements between two labs that were complicated by the episodic occurrence of toxicity. Permittee time and money were expended in several fruitless attempts to sample the effluent, verify with a toxicity test that it was sufficiently toxic, and complete the identification of the toxic cationic organic. At this time, the WET Coordinator advised the permittee that examining production chemicals at the plant might reveal one with a cationic organic constituent. A material was soon discovered containing tetramethylammonium hydroxide. Tetramethylammonium hydroxide was verified as the toxicant, the expensive toxicity identification efforts were ceased, and effective treatment was determined.

E. EPA WET Policy

In July 1994, EPA published the final WET Control Policy Control Policy (EPA 833-B-94-002). The stated goal of this policy is to promote uniform nationwide requirements for the control of WET and to assist permits writers in implementing these requirements. The policy clarifies and consolidates the traditional EPA strategy for controlling WET.

The Wet Control Policy consists of eight statements of policy that either address a step in the general EPA process for WET control or address a controversial subject. Our program currently meets all eight statements. These eight policy statements are listed below:

1. Basis for WET Controls

The permitting authority should evaluate WET water quality criteria attainment for acute WET at the edge of the acute mixing zone and for chronic WET at the edge of the chronic mixing zone except where the State has different requirements for evaluating WET criteria. The permitting authority will develop WET effluent limitations based on the more stringent of the acute or chronic criterion applied at the edge of the respective mixing zone, or, alternatively, on both.

2. **Discharges to be Evaluated for a Reasonable Potential**

At a minimum, the permitting authority should review all major dischargers for reasonable potential to cause or contribute to exceedance of WET water quality criteria.

3. **Evaluating Reasonable Potential**

The permitting authority will consider available WET testing data and other information in evaluating whether a discharger has reasonable potential to cause or contribute to exceedance of WET water quality criteria**.**

4. **Establishing WET Limits for Discharges with a Reasonable Potential**

Upon finding reasonable potential to cause or contribute to exceedance of WET water quality criteria, the permitting authority will impose effluent limitations to control WET.

5. **Monitoring for Whole Effluent Toxicity**

Where appropriate, the permitting authority should impose WET monitoring conditions upon dischargers that do not have effluent limitations to control WET**.**

6. **Compliance Schedules to Meet WET Limits**

Where allowed under State and federal law, NPDES permits may contain schedules for compliance with WET effluent limitations**.**

7. **Whole Effluent Toxicity in Relation to Chlorine and Ammonia Toxicity**

The requirements of the water quality permitting regulations apply without regard to the pollutant(s) that may be causing toxicity, including ammonia and chlorine.

8. **Whole Effluent Toxicity Controls for Publicly Owned Treatment Works (POTWs)**

The requirements of the water quality permitting regulations apply to all dischargers, including POTWs.

F. Results of the EPA WET Stakeholder's Meeting

Because of continuing controversy surrounding EPA's WET program, two important meetings were held to evaluate current approaches and recommend changes where needed. The Society of Environmental Toxicology and Chemistry conducted the Pellston Workshop on WET testing in September 1995, in order to resolve important scientific issues involving the regulatory application of WET testing. In September 1996, EPA hosted the WET Stakeholder's Meeting to get broader input in developing the Pellston Workshop recommendations into a new strategy for regulating WET. The meeting was intended to address important issues in preparation for the development of a new national WET strategy by EPA. Participants represented states, cities from arid states, the pulp and paper industry, EPA, tribes, environmentalists, and interested scientists.

EPA is working on a new WET implementation strategy, which is now out in draft. They hope to develop an approach that is generally acceptable and based on the recommendations of the stakeholders. One very important element, a weight-of-evidence approach to water quality violations, has been removed from the new WET implementation strategy and will be developed as a part of the revision of the water quality standards regulations. In a weight-of-evidence approach, the results of WET testing, chemical analysis, bioassessments, and other assessment techniques can be considered collectively in deciding if water quality standards are being met instead of separately as in the current policy of independent application. Generally speaking, the proposed changes would make the use of WET testing and other biological assessment techniques more complicated and perhaps not less controversial. The following items briefly discuss some elements of the new WET strategy:

- Independent applicability (which means that the results of WET testing, bioassessment, or chemical analysis are considered separately from one another) might be replaced by weight-of-evidence (where the results of all types of evaluation are considered together). EPA will work out the details for weight-of-evidence, and they promise to set high standards for the quantity and quality of information involved in weight-of-evidence. When the minimum information necessary for weight-of-evidence is unattainable, independent applicability will be used. One advantage that independent applicability had for us was that we could develop WET testing, evaluation of the chemical-specific water quality criteria, and the bioassessment/biocriteria process separately. We will be forced by weight-of-evidence to integrate these approaches. The WET Rule was written to meet the demands of independent applicability including the EPA requirement that one test failure represents an enforceable permit limit violation.

- Narrative WET criteria are preferred because they allow the regulatory flexibility necessary for weight-of-evidence. Because we currently have narrative toxicity criteria in our Water Quality Standards, we already have the flexibility to use either WET or chemical-specific limits when a reasonable potential to exceed has been demonstrated. Federal regulations allow us to use chlorine limits instead of WET limits for any chlorinated discharge by taking samples for WET before the chlorinator or by dechlorinating the sample. See 40 CFR 122.44(d)(1)(v).

- WET criteria should take into consideration beneficial uses and use attainability. These considerations must especially be taken into account in order to avoid unnecessarily burdening discharges to low (or no) flow streams.

- Site-specific WET criteria and the use of enforcement discretion are also included in the draft strategy.

III. How Does Our WET Program Work?

A. WET Test Review and Report

The Water Quality Program has over 3,000 WET tests from about 120 permittees in a database. These tests were reviewed for consistency with the test method and to see that any adverse effects detected were due to toxicity and not to variability or another source of organism stress. We believe that our database is the most extensive in the nation. The database allows us to provide a valuable service to permit managers and permittees who can request a summary table of WET test results. This service saves permit managers and permittees the time of compiling the WET test results from their own files. In addition, not all labs use EPA approved statistics to get the numbers that they report to permittees. We recalculate the WET test results using EPA approved statistics. A table produced from our database has accurate numbers and focuses on the information that will be used to make regulatory decisions.

WET test review by the WET Coordinator is a necessary and time-consuming activity. WET test results should not be accepted from labs at face value without a quality assurance review. Labs send the WET test report first to the permittee whose effluent was tested. Very few permittees have the time or expertise to review a WET test report. The permittee then sends the WET test report to the Ecology regional office responsible for issuing and enforcing the permit (or to the Industrial Section if the permittee is a pulp mill, oil refinery, or aluminum smelter) where a record is made of the receipt of a test report submitted in order to meet a permit requirement. The regional offices and Industrial Section generally lack the time, expertise, and tools to conduct a detailed review of a WET test report. The test report is then forwarded to the Water Quality Program's Permit Management Section where the WET Coordinator conducts a detailed review of test quality and makes a database entry.

Test reviews always begin with the raw data on the lab bench sheets in order to check for entry errors and arithmetic mistakes by the lab. Data entry and arithmetic errors are the most common mistakes currently being made by labs now that problems with sample handling and test conditions have been reduced by conducting a detailed review of all WET test reports received for the last three years. Less detailed reviews were conducted on some WET tests as long as five years ago but were not as effective in improving lab performance. Sample handling and test conditions such as temperature, test containers, number of replicates, and age of test organisms are checked and occasional problems are still found. Control performance and reference toxicant testing are noted when deficient.

Another important reason for WET test review is the identification of anomalous test results where adverse effects on test organisms do not fit a concentration-response relationship. Factors other than toxicity (disease, contaminated glassware, test method variability, etc.) can produce adverse effects on test organisms, but only toxicity tends to produce a concentration-response relationship. A concentration-response relationship where response increases with concentration is a good identifier of toxicity as opposed to other sources of organism stress. Excluding tests without a good concentration-response relationship greatly reduces the chance for a false positive. We do not usually reject an anomalous test and ask for it to be repeated unless the anomalous test result would have consequences for the permittee. Many anomalous test results occur in tests on effluents that do not appear to be toxic at levels of regulatory concern and nothing is gained by test rejection.

Test review and database entry is closely integrated and has many activities in common. This means that for a slight effort beyond database entry we also get a detailed test review, and for a slight increase in effort over a detailed test review we get a database entry. The database records include test data and a few of the important test conditions. Entry errors and arithmetic mistakes by the lab are discovered and corrected during our database entry process. Entry of the test conditions contained in the database accounts for a good fraction of our checklist of required test conditions.

The next step after making an accurate data entry and checking the test conditions is to recalculate statistics. Even when labs have made an accurate data entry that we don't need to correct, they will perform inappropriate statistics at times. Not all labs understand the statistics in the EPA toxicity test manuals or know what to do if the data presents special problems. Sometimes the statistical software used by the lab won't perform the correct statistics. We must currently use two different statistics applications in order to meet all of our needs, and most labs have standardized on only one statistics package for the sake of efficiency.

The WET test and its review are actually recorded in two separate databases at the present time. One database stores test data and runs statistics. The other database stores the results of the detailed test review and generates a summary report of the review. The summary report along with a printout of the test data and statistics is sent to the regional office responsible for the permit or to the Industrial Section. From there, the test review summary is intended to be sent to the permittee whose effluent was tested.

B. Services provided to Ecology Staff, Permittees, and Labs

The WET Coordinator in the Permit Management Section of the Water Quality Program provides the following technical assistance to other Ecology staff, to permittees, and to labs:

- Ecology staff in the regional offices and Industrial Section is assisted with establishing permit conditions for WET. In addition to the standard permit language discussed below in D. Status of the Tools to provide these Services, staff are provided with guidance on selection of test species, setting of monitoring frequencies, and handling of atypical situations such as incomplete effluent characterizations. WET test results are reviewed, compiled, and interpreted in light of WET Rule requirements.

- Permittees are advised on selecting a lab and how to use test review summaries to track lab performance. Permittees are also assisted in understanding permit requirements and the purposes and techniques for WET testing. Guidance is provided to permittees on how to instruct the lab to use a dilution series that will give the most fair and accurate measurement of effluent toxicity. Permittees may request a table of their compiled WET test results and receive assistance in interpreting these results.

- Ecology staff is assisted with review and implementation of TI/RE plans. Permittees and labs are given advice on TI/RE strategies. Permittees are assisted in tracking and evaluating lab performance of TI/REs. A permittee gave Water Quality Program staff credit in a report for giving them advice that saved much time and money in finishing a difficult TI/RE.

- Labs are assisted in understanding permit requirements so they can perform tests that best meet the needs of their clients, the permittees. Labs call for advice when unanticipated events will prevent performance of the test as planned. If possible, they are told how to modify the test conditions to adapt to the unfortunate circumstances and still provide an acceptable test to the permittee. Labs are kept informed of their test performance by the test review summaries. The WET test database is sometimes used to provide a lab with information on how their test performance compares to other labs in order to encourage improvement.

C. Services provided to EPA, States, and the Scientific Community

Because the database of WET test results is so comprehensive and accurate, it provides useful information far beyond the borders of the state. Examples of the uses for the data include:

- A panel of scientists from California, Oregon and Washington reviewed bivalve development test control results to determine if mussels and oysters really do perform differently as had been assumed. They discovered that mussel controls perform as well as oyster controls. The test method will be revised to reflect this fact.

- The State of Wisconsin requested all of the *Selenastrum* test results from the database in order to assist in a decision on whether to implement the use of this test in their program.

- EPA has contracted a statistician to develop a bioequivalence approach for WET tests. Bioequivalence is a promising statistical technique, which could reduce both false positive and false negative WET test results and has been recommended by scientists at the Pellston Workshop as a potential solution to problems with WET test statistics. The statistician will be using *Ceriodaphnia* and fathead minnow chronic test results from our database in this effort.

- The Water Quality Program will be using the database to inform interested parties around the nation that monitoring frequencies are too low because of WET test cost. Expensive WET tests are being used to generate mostly negative results, which is not a cost-effect approach. Effluent toxicity is usually episodic and common monitoring frequencies are inadequate for characterizing or even reliably detecting it. Rapid screening tests are a potential solution to both the cost and monitoring frequency issues, which will be framed using the database.

D. Status of the Tools to provide these Services

We have developed standard permit language, internal guidance in the *Permit Writer's Manual*, two levels of guidance for permittees, detailed guidance for labs, and the nation's largest and most comprehensive database of test results. The status of each of these tools is discussed below:

- The permit language has recently been revised to be shorter and simpler. New permit and fact sheet standard language was distributed in April 1997. The switch to West Coast species was begun in the newly revised permit language. West Coast species are preferable in order to reduce the potential for the release of an exotic species or a disease. The new language also implemented a more common sense approach to WET testing of chlorinated discharges.

- The *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* document (canary book) was finalized and given a July 15, 1997, effective date. The canary book was developed with input from the accredited labs and based on our experience with WET test reviews. It provides instructions on everything from sample handling to report submission. The canary book also identifies problem areas and comprehensively lists our test review criteria. This document will not only result in WET test results that are more reliable, but will also allow simplification of permit language by directly communicating to labs instructions that we previously delivered indirectly through permit language.

- The two guidance documents for permittees are three years old and could be updated and expanded. A helpful addition would be guidance on choosing a lab. Guidance could be written on how to use our test reviews to evaluate a lab's ongoing performance. The permittee guidance needs to explain the purpose and general contents of the canary book.

- The *Permit Writer's Manual* is being updated to explain the use of West Coast species, to give instructions on the new strategy for handling chlorinated effluents, and to address the withdrawal of Appendix C of 40 CFR Part 403 which is referenced in the WET Rule. The most recent update was accomplished in July 1997. The database might be able to provide useful information on what types of discharges do and do not need WET testing. Any new information to supplement WAC 173-205-040 in deciding which discharges should have WET testing will be incorporated into the *Permit Writer's Manual* this coming winter.

- The WET information system is divided into two incompletely integrated databases, which rely upon two statistical packages, only one of which can update a database. One database interacts with the test data and statistics and the other keeps records of test reviews and permittee information. The statistical package that interacts with the database cannot be used to determine compliance with our WET limits, and has other flaws as well. This flawed statistics package has been dropped by its producer and is very inflexible in test setup and endpoint calculations which will cause trouble because there will be no updates when test methods change. The statistics package that analyzes tests properly is also flexible with test setup and endpoints, but won't work with a database. Our test review system would be more time-efficient and our database would be more useful and accurate if the databases were completely integrated and combined with the correct statistics package. A commercial software producer is currently adding database capability to the more useful statistics package. When ready, it will be available for about $2,000 and will justify the expense though increased efficiency and productivity.

In 1995, we recorded and reviewed 333 acute WET tests and 165 chronic tests. That represents an average of 15 hours per week of staff time. This time may increase due to the growing inefficiencies described above. If the measures described above to increase efficiency are implemented, the 15 hours per week will move down closer to 10 hours per week. This improvement is especially needed since test processing and basically one person now performs all other WET activities.

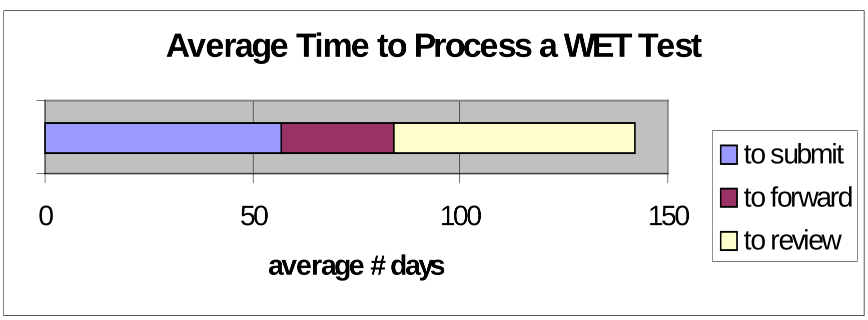
IV. Future Directions for the WET Program

A. Improvements to the Existing Program

Better Information Flow

The most critical problem facing the WET program is poor information flow. The inefficient information flow creates backlogs of test reports waiting review and slows the review process. Permittees may have trouble demonstrating compliance with permit requirements as a result. Incorrect information reaches too many people while accurate information sometimes does not reach everyone who should see it.

The average length of time in 1996 from test start date to submission to the WET Coordinator for review is 88 days and is often much longer. Permits require permittees to take action in response to effluent toxicity within a specified number of days. We may not have reached a decision on test acceptability or even received the test results before most of these time limits have expired. This is especially true for transient toxicity report and toxicity identification/reduction evaluation plan submittals. If the permittee responds on the basis of a poorly understood and possibly poorly prepared lab report, then they run the risk of wasting their time and money or incorrectly ignoring an important regulatory requirement. If the permittee waits for the summary report from the Ecology facility manager, then the time limit will sometimes have expired without the required response. As permit limits for WET become more common, this situation is likely to cause trouble.



Another aspect of the information flow problem is that the results of a WET test are not considered final until the WET Coordinator has reviewed the test report, checked data entry and statistics, evaluated concentration-response, and provided a regulatory interpretation of the results. Each place to which the test report is sent prior to submission for review adds time to the process and increases exposure to potentially faulty or incomplete information. The test review summaries should retrace the path completely, but frequently the test review summaries do not reach the permittees. They even more rarely get back to the labs conducting the tests.

WPLCS (Water Quality Permit Life Cycle System) is the information system, which tracks the status of permits and of permittee compliance with the permits. WPLCS coordinators around the state make entries based on submission of WET test reports by permittees. The WPLCS coordinators have difficulty making accurate entries for WET test submissions because the reports are complex and the review by the WET coordinator has not happened yet. Entries are made inconsistently around the state. An incomplete entry might someday cause a permittee to be assumed by the public to have not complied with a permit requirement for WET testing.

The first step toward resolving the information flow problem is to shorten the path for WET test reports as much as possible. The shortest and most efficient path would be from the lab directly to the WET Coordinator in the Water Quality Program. The lab could send a simultaneous report to the permittee. If direct submission from the labs is not acceptable, then permittees should send the WET test reports directly to the WET Coordinator for test entry and review. In either case, the WET Coordinator should send the WET test review summaries simultaneously to the staff who issues and enforces the permits and to the permittees themselves. Labs should also get copies of the test review summaries in order to be able to evaluate their performance of the tests.

The next step would be to improve the WET Test Information Management System (WETTIMS) to automatically generate cover letters for transmitting WET test review summaries to permittees and labs. A link would also be needed between WETTIMS and WPLCS. A set of consistent standard fields for statewide use in tracking WET information in WPLCS should be implemented. Scripts could then be written to automatically update these fields from WETTIMS entries. WPLCS would be kept updated with complete and timely information, and the WPLCS coordinators would have extra time for more appropriate projects than attempting to figure out WET test reports.

Test review and database entry by the WET Coordinator since January 1996 added an average of 58 days to the process. The goal is to shorten this to 14 days. The *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* document will streamline test review decisions and reduce the amount of effort for substandard tests (more will be rejected) after the July 15, 1997, effective date. WET test performance and reporting has generally improved over the years making test review easier. The speed of test processing has also been improved by computer upgrades and will improve again when obsolete software is replaced. The WET Coordinator will primarily be concentrating on test review, technical assistance, updating the *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* document, and coordinating the evaluation of rapid screening tests. These duties should be compatible with a 14-day test turn-around time.

B. Improvements Possible with Changes in State Regulations

Use WET to Evaluate Metals Compliance

WAC 173-201A-040 could be revised to allow consistent passing of the acute WET performance standard to substitute for evaluating the discharge for the acute water quality criteria for metals. The environment would still be protected because the acute WET performance standard is applied to 100 percent effluent and the tests used to measure its attainment often exceed the duration of exposure of organisms within the mixing zone. About 50 percent of the permittees represented in the WET database have consistently met the acute performance standard and this percentage could improve as anomalous test identification becomes easier because WET tests using a dilution series have replaced single concentration tests. This action can save many permittees the cost of monitoring for metals because the acute metals criteria more often result in permit limits than the chronic metals criteria do. It will also simplify the writing of those permits. Allowing passed WET tests to count for compliance with metals criteria is a more efficient approach than repeated development of site-specific criteria or water effects ratios. The incentive system in chapter 173-205 WAC will be strengthened because the reward for meeting the acute WET performance standard will be substantially increased.

Give More Realistic Credit for Dilution

The 1000:1 credit for dilution contained in WAC 173-205-040(3), which was taken from a recommendation in EPA's *Technical Support Document*, is in error. The WET database contains several tests which showed statistically significant toxicity at a dilution of around 1000:1 or lower. The worst case WET test had statistically significant toxicity at a 4000:1 dilution (0.025 percent effluent). The dilution credit in WAC 173-205-040(3) needs to be lowered to at least 4000:1 for the industries demonstrating toxicity at very low levels.

On the other hand, the WET database could be examined for justification to raise the 1000:1 dilution in WAC 173-205-040(3) for Public Owned Treatment Works (POTW). The same criterion used by EPA to determine the 1000:1 cutoff recommended in the *Technical Support Document* for chronic WET testing would apply. If an adequate number of toxicity tests are present in the database to define a "worst case" toxicity for POTWs as a category of dischargers, then effluent concentrations below the "worst case" could be considered likely to be safe and no chronic WET testing would be required.

An initial review of the database indicates that the worst case might be close to 150:1 dilution, and even though only about 10 POTWs have this dilution ratio, the cost saving would be considered significant by them.

C. New Strategies for Regulating Effluent and Receiving Water Toxicity

The new effluent monitoring and toxicity control strategy proposed below would require revision of Chapter 173-205 WAC. The benefits gained would include more realistic monitoring frequencies, avoidance of the controversy associated with water quality-based WET limits, knowing the pattern of toxicity before beginning a TI/RE, and use of more cost-effective toxicity measurement and control techniques. A gradual shift in emphasis from point source discharges to direct evaluations of state waters is also involved.

Effluent Monitoring and Toxicity Control

1. Evaluate NPDES permit applicants in accordance with WAC 173-205-040 (either revised as above or the same as today) to determine if an effluent characterization for WET is necessary.

2. Discharges determined to need an effluent characterization for WET are required to conduct rapid screening tests at some frequency such as monthly or every other week. These rapid screening tests are initially conducted in as high a concentration of effluent as practical in order to maximize test sensitivity. More discussion of the use of rapid screening tests is contained below in section V. D. Variability of Effluent Toxicity and the Use of Rapid Screening Tests.

3. If toxicity is detected by a rapid screening test, then the monitoring frequency is increased in order to determine the pattern of toxicity. The length of time needed to develop a pattern of toxicity will vary. Continuous or frequent toxicity will move the investigation immediately into the next step. The pattern for infrequent toxicity will take longer to determine, but will make for more cost-effective use of standard WET tests and TIE procedures, which will be scheduled when effluent toxicity is more likely. The pattern itself may contain hints as to the source of toxicity.

4. When a pattern begins to emerge, the standardized WET tests are also conducted in order to develop a correlation with the rapid screening tests and determine the need for further investigation.

5. If a rapid screening test is significantly more sensitive than the standardized WET tests, then the concentration of effluent tested with the rapid screening test is lowered to be more equivalent to the WET test. Only the rapid screening tests and standardized WET tests providing a consistent response to toxicity are continued in use.

6. If a standardized WET test demonstrates toxicity at concentrations representing the point of compliance, i.e., edge of mixing zone during low flow conditions, then a TI/RE plan is developed and implemented. The TI/RE plan should focus primarily on identifying and reducing toxicants in the discharge, but should also not ignore other measures, which might be adequately protective such as restricting potentially toxic activities during low flows or increasing the monitoring frequency during low flows. A water quality-based WET limit would be a part of any toxicity remedial measure involving an increased monitoring frequency during low flows.

7. If a discharger believes that no remedy for toxicity is economically reasonable and the Water Quality Program agrees, then the discharger may begin gathering information to be used in a weight-of-evidence analysis of the potential impact of the discharge. The persistence and fate of the toxicant should be determined. Bioassessments, ambient toxicity testing and *in situ* toxicity testing should also be used if appropriate. The circumstances during low flow events must be considered. If the weight-of-evidence analysis demonstrates that indigenous organisms in the vicinity of the outfall have a negligible risk of adverse effects from the discharge during low flows, then toxicity reduction will be considered unnecessary.

8. Any information gathered by the Ecology as a part of an ambient monitoring program can be used to supplement or verify the weight-of-evidence information supplied by a discharger.

9. After completion of the TI/RE or weight-of-evidence analysis, the discharger will return to the original monitoring frequency with rapid screening tests. Only the rapid screening tests responding to effluent toxicity need be continued.

Shifting Focus to Evaluations of Ambient Waters

Routine ambient toxicity testing would identify toxicity hotspots allowing resources to be allocated to fixing problems sooner and more efficiently. Where there are no problems, then we would have justification for a lower commitment of agency or permittee resources. The database of ambient toxicity test results could become a success measure or environmental index. The ambient testing for a watershed should be centrally coordinated to be cost-effective and maintain a high level of confidence in the results. The case for regulating nonpoint sources (stormwater, agriculture, etc.) would also be strengthened by focusing on toxicity from all sources. Hall, *et al* demonstrated that ambient toxicity tests could be used to find exceedances of water quality criteria and detect unknown toxicants in Chesapeake Bay [1]. Hartwell, *et al* demonstrated that ambient toxicity test results correlated with fish community diversity in Chesapeake Bay [2].

The advantages of ambient toxicity testing are:

- Toxicity tests are broad spectrum and will detect any toxicant or toxicant combination. Chemical analysis is only efficient when all of the potential toxicants are known and the list is small in number. When there is a large number of potential toxicants or the possibility of unknown toxicants, toxicity testing is the best method for assessing water quality.

- Ambient toxicity tests assess environmental impacts under real world conditions. There is no need to worry whether the analytical method is over-estimating impacts by including nonbioavailable fractions in the evaluation. For example, the controversy over dissolved versus total recoverable metals is completely avoided. Watershed assessment and management would be more efficient. Assessment of impacts would be more real world and defensible.

- Toxicity tests can be chosen to fit specific circumstances. Testing can be done with important local species that were not necessarily used in deriving the chemical-specific water quality criteria. The variety of toxicity tests available for ambient testing is quite large since we are not confined to only those tests approved for NPDES compliance monitoring. Baskets of mussels can be placed in important areas of Puget Sound and collected later to provide data on mortality, growth, and bioconcentration. Bivalve embryo-larval development tests could provide warning of toxic dinoflagellate blooms resulting from pollution. Samples from estuaries can be routinely tested for impairment of salmon smoltification. Inland rivers could be monitored for acutely toxic effects to indigenous trout and their invertebrate prey. Ambient toxicity testing could be an important part of a salmon recovery strategy.

If managed correctly, an ambient toxicity testing program would better protect the environment and justify reducing permit requirements in some circumstances. The public would generally approve. In addition, we would be expanding the body of knowledge on state waters by continuing the tradition of using ambient toxicity tests to evaluate state waters [3-6].

Routine bioassessments of state waters would have many of the same benefits as ambient toxicity testing and would be a very relevant and comprehensive measure of water quality. Bioassessments could also be a success measure or part of an environmental index. All sources of water quality impairment would be simultaneously assessed. Ambient toxicity testing including *in situ* testing could help fill information gaps when bioassessment confidence is low. If NPDES permittees alone are relied upon to provide the bioassessments, then some areas will get more assessment than needed and other areas will get less. The assessments will not be coordinated and the overall picture will be fuzzy. The information quality will be lower if the bioassessments are not coordinated as a part of the evaluation of each watershed in the state.

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V. Supporting Discussions and General Conclusion

A. Biological Relevance of WET Tests

Each WET test has been standardized to measure one or two specific responses of a single test species of an exact age at an exact test temperature for a certain length of time. These and several other standard conditions for each test type were chosen to provide a successful test result. None were chosen to match receiving water conditions.

The primary purpose of the standard test conditions is to optimize test organism performance. The *Ceriodaphnia* and fathead minnow chronic tests are run at 25° C because neither reproduction nor growth will adequately occur at a lower temperature. These chronic tests are run for seven days to give enough time for quantifiable differences in reproduction and growth between test concentrations to develop. Test duration's longer than seven days would conform better to what are considered to be true chronic exposures, but timely response to toxicity would be hindered and the extra expense would discourage routine use of the test. Similar considerations in establishing standard test conditions have produced a suite of toxicity tests, which are as practical for use in routine monitoring as can be expected. A secondary, but equally important reason for standard test conditions is so that the tests perform predictably and consistently.

Many test species were chosen because they are available by culturing which keeps costs low and tends to provide uniform sensitivity. Test species must also be adaptable to handling within a lab environment. An age for testing was chosen to represent a sensitive life stage. The biological response to be assessed was selected to be both practical to measure and biologically important, but because of the huge number of potential toxic effects, most had to be neglected in the development of the testing program. Survival, growth, development, and various reproductive events (asexual production of neonates, fertilization, egg production) have been developed as test endpoints for a limited number of species.

The biological relevance of WET tests is an area of unavoidable uncertainty. The tests might be underprotective because only a few biological responses from a few test species are being measured. Test organisms are kept at ideal constant temperatures, handled gently, and fed regularly while receiving water organisms might be stressed, starving, and extremely susceptible to toxicity. Receiving water organisms can also be weakened by previous exposure to toxicity from another upstream effluent or from the same effluent in a marine bay with tidal recirculation.

On the other hand, the WET tests might be overprotective. Standard test duration usually greatly exceed the exposure that similar organisms receive in the effluent plume. Test solutions usually have higher temperatures and lower dissolved and suspended solids than the receiving water; these differences often increase toxicity in the WET test. Natural selection will weed weak individuals out of wild stocks while the ideal conditions of a lab culture allow them to survive, accumulate, and perhaps be more sensitive to the toxicity of an effluent sample. Receiving water organisms also have the ability to avoid effluent plumes while test organisms cannot escape the test container.

Clearly the standardized tests are preferable even though they rarely reproduce receiving water conditions. The standardized tests provide the most practical and consistent measurements of effluent or receiving water toxicity available. Toxicity identification evaluation (TIE) procedures have only been developed for the standardized tests. Bioassessments, indigenous species testing, and *in situ* testing can help resolve some of the uncertainties associated with the standardized tests if a reasonable weight-of-evidence approach is implemented, but any toxicity detected would be most efficiently identified using a TIE based on a standardized toxicity test. A TIE can become very expensive if the toxicant is not identified within a few attempts and should be performed using an established technique in a lab with experience with the technique.

B. Ecological Relevance of WET Tests

The validity of a test method is its ability to accurately measure or predict events in the real world. In the case of whole effluent toxicity testing, validity would relate to the ability of the tests to predict the presence or absence of adverse effects in the receiving water. Adverse effects in receiving waters are measured by bioassessments where the number and taxonomic diversity of receiving water organisms are compared to unimpacted reference sites. The validity of WET testing is evaluated by comparing the results of WET tests to bioassessments just downstream of the discharge.

Studies by U.S. EPA and the State of North Carolina have shown whole effluent toxicity tests to correlate well with negative impacts in the receiving water. U.S. EPA conducted studies on nine freshwater streams and has shown that whole effluent toxicity testing can predict adverse impacts on receiving water organisms [1 - 9]. The North Carolina study involved 43 permitted discharges with permit limits for chronic toxicity. *Ceriodaphnia* was used to test compliance with these permit limits and bioassessments were done to measure the impacts of the discharges. The test for compliance with the chronic toxicity limit was 88 percent successful in predicting the presence or absence of toxicity impacts in the receiving water downstream of the discharge. This is a good demonstration of the validity of WET testing and differences in timing between sampling of the wastewater and conducting of the instream survey could account for some of the failures in prediction [10].

For reasons discussed below, studies of impacts on marine organisms near discharges to saltwater are more difficult than studies of impacts in freshwater. In order to make a comparison between WET and receiving water impacts in saltwater, U.S. EPA sampled the wastewater from seven industrial and municipal discharges and found that the WET test results usually agreed with toxicity tests on ambient samples taken in the discharge plume. The WET test results usually agreed with the toxicity testing of receiving water samples. 73 percent of the receiving water samples predicted by the whole effluent tests to be toxic were toxic and 92 percent of the receiving water samples predicted by the whole effluent tests to be nontoxic were nontoxic [11].

In spite of the successful comparisons discussed above, it is not a reasonable expectation that WET tests should be completely predictive of receiving water impacts. A link between WET and receiving water impacts cannot be demonstrated in many cases because of the complexity of the relationship between the discharge and the receiving environment. Benthic organisms are by far the easiest organisms to survey for impacts because they are less mobile than organisms, which swim or drift in the water column. These benthic organisms sustain a nearly constant exposure by remaining relatively stationary in the effluent plume and are easy to collect and quantify. However, if the effluent is less dense than the receiving water and rises after discharge, then benthic organisms are poor indicators because they have little exposure to the effluent. In deeper freshwaters or in marine waters, effluents will rise and any effects on receiving water organisms will be difficult to measure.

This is especially true for discharges to marine water where currents and water depth vary twice a day with the tides making exposure durations and concentrations difficult to assess. In addition, most effluents are freshwater which is less dense than saltwater and rises in the water column spreading out in a layer instead of mixing. Effluents can also be less dense when they are warmer than the receiving water regardless of whether the receiving water is freshwater or saltwater. All of these factors can make it impossible to predict exactly where the toxic impacts will occur.

Another difficulty in establishing the link between WET tests and receiving water impacts is the mobility of organisms within the environment. In large bodies of water, organisms can be recruited into the vicinity of a discharge from unaffected areas. The effluent may be having a severe impact on sensitive organisms in the vicinity of the discharge, but these organisms are continually being replaced with organisms, which are less sensitive because they are older, larger, or a different species. Under these circumstances, a toxic impact, if present, can be hidden from observation and measurement in the environment. A toxic impact from a wastewater discharge can also be hidden from observation if the receiving water is already seriously degraded by other sources or by habitat alteration.

A link between WET and receiving water impacts should not be assumed to exist in those circumstances discussed above where it cannot be measured. It is also true that the inability to detect an adverse effect does not mean that an effluent is not causing one. The EPA and North Carolina validity studies demonstrated a link between toxicity testing and receiving water impacts under those circumstances (mostly single discharges to effluent-dominated streams) where it was reasonable to expect to have measurable effects that correlated with WET tests. The inability under many circumstances to detect the impact of effluent toxicity on receiving water organisms results in uncertainty about the presence or absence of such impacts and the need for regulatory action.

Ambient toxicity testing (testing a sample of ambient water) and *in situ* toxicity testing (placing test organisms in cages in the ambient water) can fill information gaps left by traditional WET testing and bioassessments or help resolve conflicting results. They will be valuable components in a weight-of-evidence approach. These techniques move the measurement of toxicity into the ecosystem being protected and can help better establish the role of effluent toxicity in environmental degradation, but they cannot remove all uncertainty and may become expensive in the attempt to do so.

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C. Variability of WET Tests

One measure of test method's reliability is its precision. The precision of a test method is the ability to produce the same result over time within the same lab (intralaboratory) or between different labs (interlaboratory) and is usually quantified as the coefficient of variation (standard deviation ÷ the mean and expressed as a percent) obtained during the precision study of the method. Intralaboratory precision is the ability of a single laboratory to obtain consistent results with repeated performance of a test method. Interlaboratory precision is the ability of several laboratories to obtain consistent results when all are using the same test method. Consistent results have low coefficients of variation.

As a part of an agreement settling permit appeals by the marine discharging pulp mills, a study was conducted in this state to evaluate four marine chronic WET tests to determine the variability of these tests when testing several pulp mill effluents. The study was designed and evaluated by a Biomonitoring Science Advisory Board (BSAB) of five highly regarded toxicologists from the West Coast. The board members were chosen with industry input. These four WET tests included two that are among the most sensitive WET tests in use, and test variability tends to rise with sensitivity. Even so, both of these highly sensitive toxicity tests (bivalve development and echinoderm fertilization tests) were recommended for regulatory use by the BSAB. [1 - 3]

The BSAB decided that tests with an intralaboratory coefficient of variation ≤ 85 percent (95 percent for interlaboratory) were acceptable, and those tests with an intralaboratory coefficient of variation ≤ 60 percent (70 percent for interlaboratory) were considered good. Excellent toxicity tests are considered to have intralaboratory coefficients of variation ≤ 35 percent (45 percent for interlaboratory). The highest average interlaboratory coefficients of variation for the bivalve development test were 59 percent ($CdCl_2$) and 52 percent (pulp mill effluent). The highest average interlaboratory coefficients of variation for the echinoderm fertilization test were 70 percent ($CdCl_2$)

and 54 percent (pulp mill effluent). The highest average intralaboratory coefficient of variation for the bivalve development test was 54 percent ($CdCl_2$) and for the echinoderm fertilization test was 58 percent ($CdCl_2$). U.S. EPA has measured the variability of their acute and chronic toxicity test methods and produced coefficients of variation that were also acceptable according to the BSAB criteria and generally as good as chemical analysis. [4 - 9]

[1] Pastorak, R.A., et. al. West Coast Marine Species Chronic Protocol Variability Study. PTI Environmental Services, Bellevue, WA, February 1994.

[2] Biomonitoring Science Advisory Board. BSAB Report #1, Criteria for Acceptable Variability of Marine Chronic Toxicity Test Methods. Washington Dept. of Ecology. February 1994.

[3] Biomonitoring Science Advisory Board. BSAB Report #2, Evaluation of Results and Recommended Test Methods. Washington Dept. of Ecology. February 1994.

[4] Chapman, G.A., et. al. (ed). Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms, EPA/600/R-95/136, August 1995.

[5] Klemm, D.J., et. al. (ed). Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms, Second Edition, EPA-600/4-91/003, U.S. EPA, Environ. Res. Lab., Gulf Breeze, FL, July 1994.

[6] Weber, C.I. (ed). Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms, Fourth Edition, EPA 600/4-90/027F. Office of Research and Development, Cincinnati, OH, August 1993.

[7] Lewis, P.A., et. al. (ed.), Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Third Edition, EPA 600/4-91/002. Office of Research and Development, Cincinnati, OH, July 1994.

[8] DeGraeve, G.M., et. al. Variability in the performance of the seven-day fathead minnow (*Pimephales promelas*) larval survival and growth test: An intra- and interlaboratory study. *Environ. Toxicol. Chem.* 10:1189-1201, 1991.

[9] DeGraeve, G.M., et. al. Precision of the EPA seven-day *Ceriodaphnia dubia* test: Intra- and Interlaboratory study to determine the reproducibility of the seven-day *Ceriodaphnia dubia* survival and reproduction tests. EPRI EN-6469. Electric Power Institute, Palo Alto, CA, 1989.

D. Variability of Effluent Toxicity and the Use of Rapid Screening Tests

The current EPA WET tests are so expensive that quarterly testing is the most common frequency in the nation and frequencies above monthly are rare. Toxicity is usually episodic causing detection using such low monitoring frequencies to be mostly due to chance. These occasional excursions have unknown duration and environmental impact because of inadequate monitoring frequencies. Monitoring frequency was not much discussed at the Pellston Workshop, but the scientists did conclude that a single excursion of chronic WET would not impact the environment. Such a conclusion is, of course, invalid if the duration of the excursion was not considered.

As discussed in section II. B. Above, episodes of toxicity occur in about half of the permitted discharges most often at a low frequency. The true percentage of permittees with these episodes is likely to be somewhat higher because quarterly or monthly monitoring leave most of the days of a year without an evaluation for toxicity. An effluent that is toxic 10 percent of the time would have a 66 percent chance of passing all four quarterly tests in one year. An effluent that is toxic 20 percent of the time would have a 41 percent chance of passing all four quarterly tests in one year. An effluent that is toxic 10 percent of the time would have a 28 percent chance of passing all monthly tests for a year. However, sampling every other week (26 samples per year) would have about a 95 percent chance in a year of catching at least one toxic episode in a discharge toxic 10 percent of the time. Our database has shown that an average effluent in this state is toxic at levels of regulatory concern in about 10 percent of samples. This estimate of toxic episodes might be low since quarterly testing is the most common frequency.

Differences in species sensitivity are another factor that reduces the chance for finding toxicity unless every sample is tested for toxicity using a variety of species. The tetramethylammonium hydroxide found in the effluent described in section II. D. Above quickly killed *Ceriodaphnia* but had no effect on fathead minnows. Monitoring of this effluent with fathead minnows contributed nothing to finding or fixing toxicity.

When monitoring of the effluent containing tetramethylammonium hydroxide was temporarily increased from quarterly to weekly, the effluent was nontoxic during the first week and was very toxic continuously for the next three weeks. Neither quarterly nor monthly testing could have discovered the duration of this toxic episode. Quarterly monitoring might have missed the toxic episode all together.

A good strategy for assessing the duration of a toxic episode might be to immediately resample and conduct another toxicity test in response to the failure of a routine quarterly or monthly test. However, an immediate repeat test cannot be arranged except by preparing in advance for the possibility of another sample and test. This preparation would increase the cost of every test, in addition, both the lab and permittee would have to respond automatically without much consideration of the quality of the first test result. Because of concerns over WET limits, citizen suits, and toxicity identification evaluation expense, permittees would prefer to have WET test results subjected to a detailed review as described in section III. A. Above before accepting additional cost and liability.

Increasing monitoring frequency with the current WET tests would be considered too expensive, labs usually charge from $500 to $1,500 per test depending on the type of test requested. Some tests can cost as much as $2,000. An average of $10,800 was spent to find each occurrence of chronic toxicity in the database based on a cost of $1,200 per test estimated by a recent survey of five labs. Increasing the demand for tests would tend to increase the cost of toxicity testing. Increasing the number of species tested on routine samples would have the same effect on monitoring cost. Any increase in WET testing would also increase the burden to the Ecology for WET test review. Because a majority of effluent samples will be nontoxic, the most cost-effective approach would avoid using expensive tests until less expensive screening tests have demonstrated effluent toxicity.

The state's waters could be better protected if we used rapid screening tests to establish the pattern of occurrence of episodes of effluent toxicity before testing with the more expensive WET tests. The cost of higher monitoring frequencies would be acceptable with rapid screening tests. Permittees with lower risk could stay at quarterly or monthly testing and save money with rapid screening tests. Using rapid screening tests to better assess the pattern of occurrence of effluent toxicity would make TI/REs more efficient by allowing sampling to better coincide with peak toxicity and perhaps providing suggestions as to the cause of toxicity based on its relationship to facility activities and other circumstances.

In order to allow adequate effluent monitoring frequencies and improve the cost-effectiveness and efficiency of the regulation of effluent toxicity, a selection of rapid screening toxicity tests that are quicker and cheaper than standard toxicity tests needs to be established. In one evaluation, Toussaint *et al* compared the response of 5 rapid screening tests to the response of 5 standard acute toxicity tests using 11 chemicals. Three of the rapid screening tests performed similarly to the standard tests. [1]

Rapid screening tests would be an excellent bottom layer in a tiered approach. EPA would not object as long as the WET tests were also included in the next layer of a tiered approach and all significant dischargers had at least some WET testing. Using a rapid screening test would easily compensate any loss in sensitivity by using a rapid screening test by a higher monitoring frequency. Given the ecological and biological uncertainties discussed above, some loss in sensitivity may not be important. The number of devices that assess toxicity using light output from test organisms (bacteria, algae, daphnids, and fish) has recently increased and a few of them are petitioning U.S. EPA for acceptance. In addition, the echinoderm fertilization test could also be a convenient, quick, and sensitive rapid screening test in addition to being a standard WET test. [2] Labs, which specialize in the echinoderm fertilization test and take advantage of the newest techniques, can do the test for as low as $200 if provided with regular business. A good selection of rapid screening tests is likely to be available in the near future for effluent monitoring.

[1] Toussaint, M.W., T.R. Shedd, W.H. van der Schalie and G.R. Leather. 1995. A comparison of standard acute toxicity tests with rapid-screening toxicity tests. *Environ. Toxicol. Chem.* 14:907-915.

[2] Dinnel, P.A., Q.J. Stober, J.M. Link, M.W. Letourneau, W.E. Roberts, S.P. Felton, and R.E. Nakatani. Methodology and Validation of a Sperm Cell Toxicity Test for Testing Toxic Substances in Marine Waters. Fisheries Research Institute, School of Fisheries, University of Washington, FRI-UW-8306, November 1983.

E. General Conclusion

Controversy over WET testing arises from the attempt to unite two incompatible goals. One goal is the detection and elimination of effluent toxicity. The other goal is the evaluation of the toxicological health of the state's waters. Both are worthy goals, but the techniques necessary for each are not readily interchangeable. In addition, the proper use of the information gained in pursuit of each goal is specific to that goal. Pursuing each goal separately avoids conflicts between regulators and dischargers over the proper use of WET test results.

Monitoring effluents for toxicity is necessary in order to detect, identify, and eliminate toxic substances or combinations of toxic substances that would otherwise be missed. Effluents thoroughly characterized chemically and considered safe can still be toxic due to unknown constituents. Low stream flows do occasionally occur, and can they be stressful to receiving water organisms. Stream temperatures can come closer to the standard test temperatures during low flows. Unless a discharge is expected to cease during low flow events, toxicity must be detected and controlled in anticipation of low flows, which may occur only every few years. The WET tests can do this by creating effluent concentrations in the lab that occur occasionally in the receiving environment. With this in mind, it is understandable that effluent toxicity, as measured by standardized WET testing, may need to be reduced even when ambient testing, *in situ* testing and bioassessments indicate no problem.

A regulatory program to control effluent toxicity needs standardized tests, which are reasonably available, affordable, and consistent. The current WET tests were developed to meet these requirements not to reflect receiving water conditions. These considerations in establishing test conditions have produced a suite of standard toxicity tests which are practical for monitoring effluents when testing is done quarterly or sometimes monthly. These standard tests have also been shown by U.S. EPA and North Carolina to have some ecological relevance.

Toxicity Identification Evaluations (TIEs) are another important factor in favor of the use of standardized tests for monitoring effluents. TIEs are often difficult and can get very expensive when the toxicant is not identified within a few tries. Procedures for TIEs are worked out for the standard WET tests. Labs have experience in conducting TIEs mostly using the standard WET tests. Toxicants detected by other techniques such as bioassessments will be most readily identified if captured in a standard toxicity test and subjected to a TIE.

Developing sublethal endpoints and toxicity identification evaluation procedures for effluent toxicity tests with site-specific test conditions using indigenous species would be a large expense that would have to be borne locally (most likely by permittees). The standardized tests are preferred for monitoring effluent toxicity because they are readily available and are reasonably capable in a TIE. The results of the standard EPA WET tests can be weighted based on their relative value to the other assessment techniques in weight-of-evidence, but nothing can replace them (except perhaps rapid screening tests) for monitoring effluents and identifying sources of toxicity.

On the other hand, if a toxicity test is to be used for assessing the health of a body of water, then the test should be performed on an ambient water sample using the most ecologically relevant test species available in order to reflect conditions in that water body as much as possible. *In situ* toxicity testing moves another step closer to a direct assessment of the health of receiving water organisms by exposing test organisms under environmental conditions while retaining some of the control of a lab test. Ambient and *in situ* toxicity tests detect toxicity from all sources: point sources (industries and POTWs), nonpoint sources (stormwater and agriculture), and natural (toxic phytoplankton). Bioassessments are the most direct measure available of ecosystem health. Bioassessments, and to a lessor extent *in situ* toxicity testing, also detect adverse effects that are not related to toxicity such as siltation, scouring by floods, diseases, or natural population cycles.

As the assessment of toxicity moves from the lab to environment, the information becomes more ecologically relevant, but loss of controlled condition makes drawing conclusions more complicated. Because of the multiplicity of potential sources for toxicity and the increased potential for adverse effects from causes other than toxicity, ambient toxicity testing, *in situ* toxicity testing, and bioassessments may cause at least a few debates and additional testing before any decisions are made as to the causes and solutions to any problem encountered. Even the presence or absence of adverse effects can be uncertain due to the disadvantages in trying to prove a negative given the limited situations where bioassessments give useful information and the limited availability of toxicity test species and endpoints. Examining the interaction between the natural and human worlds in all of its complexity and developing a description gradually and deliberately is the practice of science. Science like this should be done more often; we need to learn more about the health of our waters, about nonpoint sources of pollution, and about the capabilities of assessment techniques.

The regulatory program for WET gets into trouble when it implies unnecessary wider scientific significance through the use of "water quality-based" WET limits and the policy of independent application. WET testing is not a water quality assessment, but it is a measure of the potency of effluent toxicity. Fathead minnows, *Ceriodaphnia*, and the other established tests are the standard yardsticks against which toxicity is compared in both effluent monitoring and TIEs. The assessment and control of effluent toxicity is mostly based on the performance of these standard tests and need not be completely water quality-based in order to be justified.

WET testing should be done to discover unknown toxicants and to detect effluent toxicity at levels of concern for future low flow events. Any WET detected could be investigated as to cause and potential solution. A reasonable and flexible approach to finding a solution could be applied that combines both environmental (fate of toxicant, results of bioassessments, etc.) and economic factors before choosing reduction of effluent toxicity, improved dilution, or increased monitoring during low flows. Such a regulatory system acknowledges the importance of WET testing and control without making it out to be something it is not.

RCW 90.48.520 instructs Ecology to require all known, available, and reasonable methods to control toxicants in order to limit the overall toxicity of an effluent. The current WET Rule implements this state law through an incentive system that is based on water quality-based WET limits which can be removed from permits upon attainment of the WET performance standards. There are proposals in this document for enhancing the current incentive system by allowing meeting of the acute WET performance standard to substitute for evaluating the discharge for the acute metals criteria and by determining a more attainable dilution ratio than 1000:1 for demonstrating the need for only acute WET testing.

Another proposal in this document would implement RCW 90.48.520 with reduced emphasis on WET limits, and instead incorporate a tiered response system which begins with rapid screening testing to discover toxicity, continues with the standard WET tests to determine the need for a toxicity identification/reduction evaluation, and allows weight-of-evidence to be considered if toxicity remediation costs are high. Increased monitoring of effluent toxicity during low flows would be allowed as an alternative remedial measure in some circumstances.

The lesson learned in Washington State during the years of accumulating a database of WET test results is that discharges meeting current technology-based requirements also tend to pass the standardized EPA WET tests at or near the end-of-pipe much of the time. The only major improvement needed for regulating WET is rapid screening tests to catch the toxicity that is being missed and sometimes reduce monitoring cost. Otherwise, additional efforts in evaluating whole effluent toxicity are not justified especially if these efforts increase the cost or complexity of the program. More emphasis should be placed on evaluating state waters and finding other sources of water quality impairment.