DELPHI WHITE PAPER:

ESTABLISHING THRESHOLDS FOR BENEFICIAL USE PROTECTION AS IT RELATES TO THE CONCENTRATION OF TOTAL INORGANIC NITROGEN (TIN) AND TOTAL DISSOLVED SOLIDS (TDS) WHERE GROUNDWATERS ARE DESIGNATED FOR MUNICIPAL WATER SUPPLY (MUN) AND OVERLYING SURFACE WATERS ARE DESIGNATED FOR GROUNDWATER RECHARGE (GWR).

or... HOW HIGH IS UP?

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I. REGULATORY REQUIREMENTS

The enabling purpose of all water quality regulation is to protect the resource for all future uses. To that end, the federal Clean Water Act requires states to develop water quality standards consisting of a detailed description of the hydrologic descriptions of the waterbodies, the beneficial uses which apply to each waterbody, and the water quality criteria (objectives) which will protect those uses.

> *"Each state must specify appropriate water uses to be achieved and protected. The classification of the waters of the state must take into consideration the use and value of water for public water supplies, protection and propagation of fish, shellfish and wildlife, recreation in and on the water, agricultural, industrial and other purposes including navigation."* 40 CFR 131.10(a):

In addition, according to 40 CFR 131.11(a):

> *"States must adopt water quality criteria that protect the designated use."*

There are several specific regulatory obligations which should be highlighted:

1) States must designate beneficial uses for all surface waterbodies whether or not the uses are actually being attained.

2) Where beneficial uses already exist, they must be formally recognized and designated.

3) Water quality criteria must be established which protect the designated uses. And, the water quality criteria must protect the most sensitive of those uses.

4) The water quality criteria must be based on EPA guidance [304(a)] or other scientifically defensible methods.

Most important, when setting standards, the state must ensure that downstream uses are also protected.

> *"In designating uses of a waterbody and the appropriate criteria for those uses, the state shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters." 40 CFR 131.10(b)*

In California, groundwater aquifers are considered "downstream" from the surface waters which are tributary to those groundwaters. This relationship has been codified in a special beneficial use classification called GWR: Groundwater Recharge. This designation refers to:

> *"...waters used for natural or artificial recharge of groundwater for purposes that may include, but are not limited to, future extraction, maintaining water quality or halting saltwater intrusion into freshwater aquifers." (SAR Basin Plan, 1995, p. 3-2)*

All of the groundwater basins in the Santa Ana watershed are used to provide municipal water supplies and were formally designated "MUN" for that beneficial use by the Regional Water Quality Control Board. As such, the upstream surface waters which provide recharge for the groundwaters must be regulated so as to fully protect the subsurface drinking water supply.

Several of the largest stream segments in the Santa Ana watershed are exempt from the MUN designation in accordance with California's "Sources of Drinking Water Policy." Nevertheless, these same stream segments must meet many of the primary and secondary drinking water standards because they are tributary to municipal drinking water supplies.

Although federal rule-making does not generally apply to groundwaters, the EPA does have the power to review state regulations and enforcement. Their authority is defined in 40 CFR 131.5:

> *"Under Section 303(c) of the Clean Water Act, EPA is to review and to approve or disapprove state-adopted water quality standards. The review involves a determination of (a) Whether the state has adopted water uses which are consistent with the requirements of the Clean Water Act; (b) Whether the state has adopted criteria that protect the designated water uses; (c) Whether the State has followed its legal procedures for revising or adopting standards..."*

The point of this discussion is to demonstrate that federal guidance may be applied to the question of protecting groundwaters when the state has designated those groundwaters for specific beneficial uses (MUN) and created a special surface water classification (GWR) which acknowledges the hydrologic connection between the two. This is important because federal guidance is generally more detailed on the subject of designating uses, developing protective water quality criteria, and precluding water quality degradation.

In 1968, before the Clean Water Act or EPA existed, California's Water Resources Control Board adopted a policy to maintain high water quality where it existed and to discourage further degradation of water quality throughout the state. That policy states, in part:

> *"Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies became effective, such existing high quality will be maintained until it has been demonstrated to the state that any change will be consistent with the maximum benefit to the people of the state, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies."*

> *"Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that (a) a pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of California will be maintained."*

Eighteen years later, in 1986, the State Water Resources Control Board made two other important decisions. First, they interpreted 68-16 to incorporate federal anti-degradation policy in cases where the federal policy is applicable (WQ 86-17). And, second, they ruled that the state policy:

> *"...does not absolutely require that existing high water quality be maintained; rather, any change must be both consistent with maximum public benefit and not unreasonably affect beneficial uses...Resolution 68-16 is not a 'zero-discharge' standard but rather a policy statement that existing quality be maintained when is reasonable to do so." (WQ 86-8)*

This is consistent with the federal antidegradation policy which also allows water quality to become worse providing that:

> *"Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected...In allowing such degradation or lower water quality, the state shall assure water quality adequate to protect existing uses fully." (40 CFR 131.12)*

The state and federal regulations offer no further guidance on what scientific evidence is minimally sufficient to demonstrate that beneficial uses are still being protected even when lower water quality is proposed. That is the focus of Task 1 in Phase 1 of the TIN/TDS study effort ongoing in the Santa Ana watershed.

Many of the reclamation projects under consideration in the watershed create potential for lower water quality in local surface waters and, therefore, in local groundwater basins. In particular, it is possible that increased wastewater reclamation and recharge will increase the concentration of total inorganic nitrogen (TIN) and total dissolved solids (TDS) in surface and subsurface waterbodies.

Before any of these water reclamation projects could be approved by the Regional Water Quality Control Board or the State Water Resources Control Board the project proponents must demonstrate that:

1) No significant water quality degradation would occur, or...

2) That beneficial uses would remain fully protected, despite limited water quality degradation, and that lower water quality is of maximum benefit to the people of California. (WQ 68-16)

Federal regulation and guidance uses similar language regarding anti-degradation:

> *"Where the quality of the waters exceed levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the state finds...that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located." (40 CFR 131.12(2)*

California's Water Code, provides some guidance as to how the Regional and State Water Boards should go about making the determination that lower water quality is necessary:

> *"...activities and factors which may affect the quality of the waters of the state shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." (Section 13000)*

> *"It is recognized that it may be possible for the quality of water to be changed to some degree without unreasonably affecting beneficial uses. Factors to be considered by a regional board in establishing water quality objectives shall include, but not necessarily be limited to, all of the following: (a) Past, present, and probable future beneficial uses of water. (b) Environmental characteristics of the hydrographic unit under consideration, including quality of water available thereto. (c) Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area. (d) Economic considerations. (e) The need for developing housing within the region. (f) The need to develop and use recycled water." (Section 13241).*

It is the last item, the need to develop and use recycled water, which bears most directly on the issues presently being reconsidered by the TIN/TDS Task Force. The Water Code specifies that:

> *"...adequately treated reclaimed water should, where feasible, be made available to supplement existing surface and underground supplies and to assist in meeting future water requirements of the coastal zone." (Water Code, Section 13142.5)*

In the state Water Reclamation Law, the state legislature declared that:

> *"...the people of the state have a primary interest in the development of facilities to reclaim water containing waste to supplement existing surface and underground water supplies and to assist in meeting the future water requirements of the state...it is the intention of the legislature that the state undertake all possible steps to encourage development of water reclamation facilities..." (Sections 13510 & 13512)*

While there is plenty of legal discretion to allow lower water quality, especially to encourage water reclamation, actual decisions by the State Water Resources Control Board demonstrate that they will not exercise their discretion at the expense of downstream beneficial uses.

The single most important case on the subject comes from the Santa Ana Region regarding a permit to discharge for Rancho Caballero Mobile Home Park. The State Board over-ruled the Regional Board. The state concluded that where water quality objectives are set to protect downstream beneficial uses, all upstream permits must be drafted in conformance with those objectives even when the quality of water discharged is better than the quality of groundwater where the treated effluent percolates and recharges the aquifer. (See State Water Resources Control Board Order No. 73-4)

In their written decision on the Rancho Caballero case, the State Board strongly implied that there was a way to permit the discharge as the Regional Board had intended, but that certain burdens of proof had not been met. Although unstated in this particular decision, we presume that evidence was required to demonstrate that:

1) Downstream uses would remain fully protected despite lower water quality, and...

2) The proposed discharge would be of maximum benefit to the people of California especially in the Santa Ana watershed (up and downstream).

Developing a systematic method for making the first demonstration is the subject of our first DELPHI. Establishing decision-systems to assess whether the second burden has been met is the subject of the DELPHI discussions scheduled for early this summer.

II. IMPAIRMENT BY TOTAL INORGANIC NITROGEN

The 1995 Santa Ana River Basin Plan establishes water quality criteria for nitrates in groundwaters designated MUN. The rationale is:

> "High nitrate concentrations in domestic water supplies can be toxic to human life. Infants are particularly susceptible and may develop methemoglobinemia (blue baby syndrome). The primary drinking water standard for nitrate (as NO_3) is 45 mg/L or 10 mg/L (as N)." (pg. 4-13)

This is consistent with EPA's most recent recommended water quality criteria document on nitrate/nitrite (December, 1990). The 45 & 10 standard is not new; it has been the recognized industry standard for finished drinking water for more nearly 40 years.

EPA's criteria document summarizes the most significant research regarding nitrates' effect on human beings. Infants (<3 mos. old) are deemed most susceptible because the low pH of their intestinal tracts tends to support bacteria which turn nitrate into nitrite. Nitrite converts hemoglobin to methemoglobin which prevents the blood from transporting oxygen properly. Older children (> 6 mos.) and adults are not nearly so vulnerable.

The 10 mg/L nitrate-nitrogen criteria was established based on a comprehensive review of several studies which showed that there was no recorded incidence of methemoglobinemia due to drinking water where the concentration of nitrate was at or below that concentration. This "no-observed-effect-level" was deemed presumptively safe and, therefore, fully protective of the drinking water beneficial use.

All of the recorded cases of methemoglobinemia, except one, occurred where the infant was fed water from shallow agricultural wells which were heavily contaminated by nitrates and bacteria from livestock. Subsequent studies have demonstrated that the bacterial contamination is, by far, the more significant factor and can cause methemoglobinemia independently (even when nitrate is not present). The bacterial infection can cause diarrhea which, in turn, can result in endogenous nitrate formation. Some studies demonstrated that infants with diarrhea excreted up to ten times more nitrate then they ingested (400% more than normal). The combination of high concentrations of nitrate in contaminated drinking water compounds the risk factors.

In 1995, at the request of EPA, the National Research Council undertook an independent review of the recommended water quality criteria for nitrate/nitrite. The NRC confirmed the original recommendations. The Research Council noted that the national drinking water criteria for nitrates would protect the most sensitive beneficial use: infant formula feeding. It is important to recognize that the 10 mg/L nitrate-nitrogen is a primary drinking water standard applicable to finished water at the tap. Therefore, by deduction, if that same standard is applied to groundwater aquifers and tributary surface streams, then the MUN and GWR beneficial uses are fully protected as well.

Both the EPA and NRC noted that there were other impairments (and potential hazards) associated with high nitrate concentrations. In some cases, such as cancer risks, they agreed that there was insufficient reliable evidence to draw any conclusion. In all other cases, such as livestock feeding, the threat-thresholds were considerably higher than the concentrations needed to protect the most sensitive use (human infants). Hence, our discussion of safety factors (in section IV) is confined to that problem alone.

III. IMPAIRMENT BY TOTAL DISSOLVED SOLIDS

Total dissolved solids (TDS), also known as total filterable residue, is a secondary drinking water standard because it poses little direct threat to human health. The principle concerns relate to reduced taste acceptability and shorter appliance lifetimes as TDS concentrations increase.

The 1995 Santa Ana River Basin Plan states:

> “The Department of Health Services recommends that the concentration of total dissolved solids in drinking water be limited to 1000 mg/L (secondary drinking water standard) due to taste considerations. For most irrigation uses, water should have a TDS concentration under 700 mg/L. Quality-related consumer cost analyses have indicated that a benefit to consumers exists if water is supplied at or below 500 mg/L.” (pg. 4-7)

More specifically, in Title-22 of California's drinking water regulations, the Department of Health Services states that 500 mg/L TDS is the recommended maximum contaminant level. 1000 mg/L TDS is the "upper" maximum contaminant level and 1,500 is the "short term" maximum contaminant level. They also say:

> *"For constituent (such as TDS), no fixed consumer acceptance contaminant level has been established. Constituent concentrations lower than the Recommended contaminant level are desirable for a higher degree of consumer acceptance. Constituent concentrations ranging to the Upper contaminant level are acceptable if it is neither reasonable nor feasible to provide more suitable waters. Constituent concentrations ranging to the Short-Term contaminant level are acceptable only for existing systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources." (Title-22, Section 64449{f}{1-3})*

The question of taste is highly subjective. Nevertheless, serious research has been conducted to correlate specific TDS concentrations with subjective perceptions of water quality (excellent, good, fair, poor, unacceptable). The best work comes from Drs. Bruvold and Daniels published in 1990.

Examining the results from thirteen separate studies, they constructed a model which relates TDS concentration of perceptual quality. In general, they concluded that 75% of a given population will rate public water supplies as "good to excellent" if the TDS concentration remains below 450 mg/L. Not coincidentally, approximately 26% of the population will elect to use bottled water when the TDS concentration exceeds 450 mg/L. This threshold is remarkably close to the secondary drinking water standard of 500 mg/L.

When TDS concentrations fall between 451 and 760 mg/L, up to one-third of the population will rate the taste unfavorably (fair, poor, or unacceptable). Nearly 100% of the population will rate the water taste as unacceptable when the TDS concentration exceeds 1000 mg/L. It would appear that there is a good empirical basis for the secondary drinking water standards for TDS based on taste considerations.

The same cannot be said for the claims regarding appliance lifetimes. There are very few studies of the impact high TDS concentrations have on water heaters, dishwashers, clothes washers, garbage disposals, or car radiators. Most such studies were conducted in the late 60's and early 70's. In retrospect, many of the assumptions and methods appear to be flawed. And, more important, the technology has greatly improved in the intervening two decades.

An independent review of the scientific literature on economic damages which result from residential use of mineralized water was conducted by the Colorado Water Resources Research Institute at Colorado State University and published in August, 1993. Among the most critical conclusions highlighted in the complex and detailed report are:

1) Most of the negative impact of high TDS concentrations occurs between zero and 500 mg/L. There is negligible marginal negative impact to residential consumers above 500 mg/L TDS (pg.

2) The previous studies falsely assumed that the impact relationship was linear throughout the entire TDS concentration range. Evidence then, and more recently, indicates that the actual function is non-linear. The result is that previous studies overestimated annual excess costs per household by 200-400% (pgs. 81, 83).

3) Reducing TDS from 1000 mg/L to 500 mg/L would produce an annual average estimated household benefit of only $11.60; reducing TDS from 1000 to 200 mg/L would provide an estimated annual average benefit of $25.68 per household (pg. 82)

4) Previous studies "assumed" many of the most crucial variables such as reduced clothing lifetimes or appliance lifetimes. Or, else, they relied on subjective estimates by plumbers or appliance retailers which have since been demonstrated unreliable.

5) The average water heater lasted 16 years in 1974; today the average new hot water heater lasts more than 26 years. The average clothes washer lasted 11 years in 1974; new washers last more than 20 years today. Two decades ago, the average garbage disposal lasted almost 10 years; newer model now last more than 19 years (pg. 69). By contrast, the expected improvement in mean service life for modern appliances if TDS concentrations were reduced from 1000 mg/L to 500 mg/L is approximately 1-2 years (pg. 67 & 68).

Since much of the previous economic impact analysis regarding TDS in the Santa Ana watershed is based on the older studies, and since recent review indicate that these studies no longer provide a sound scientific and technical basis for regulation, this issue must be carefully re-evaluated during the DELPHI discussion. Considerable emphasis must also be placed on providing detailed technical documentation for any claims made regarding the consumer related costs of higher or lower TDS concentrations.

IV. SAFETY FACTORS

Because water quality criteria must be set at a level which will "fully protect" the beneficial use(s), and because there is frequently considerable uncertainty in determining what constitutes "full protection," policymakers and regulators often apply conservative assumptions when developing the criteria. The result of this conservatism is a safety factor around the water quality objective.

When water quality is at or below the water quality objective, it is presumed that beneficial uses can be fully attained. When water quality is worse than the applicable criteria, then beneficial uses are threatened, impaired or precluded. The degree of impairment depends on the size of the safety factor inherent in the water quality objective.

Safety factors tend to vary by the nature of the hazard to be avoided and the degree of uncertainty surrounding the most appropriate criteria. Generally, the greater the threat the larger the safety factor. The less data available, and greater the amount of assumptions (guesswork), the larger the safety factor.

In the case of nitrates and the risk of methemoglobinemia, the hazard represents in intolerable risk to society. No politician, regulator, parent or decent human being would argue that there is an “acceptable” level of preventable blue baby syndrome. The primary drinking water objective for nitrate was established at a level below which there were no recorded incidents of the methemoglobinemia: 10 mg/L nitrate-nitrogen.

In fact, the nitrate objective was set at a level below which the formation of methemoglobin in the blood of infants is no greater than normal background levels when nitrate exposures are near zero. This means the average infant concentration of methemoglobin ins approximately 1%. Adults routinely run about 2-3% methemoglobin in their blood. The scientific literature shows no clinical symptoms of hemoglobinemia until bloodstream concentrations exceed 10%.

In general, and with rare exception, the “lowest observed effect concentration” for the formation of methemoglobin in infant bloodstreams occurs at approximately 20 mg/L nitrate-nitrogen. Hence, the safety factor is approximately 100% when measured in mg/L.

Studies show that when very young infants (< 3mos.) are fed a steady diet of nitrate-nitrogen at 20 mg/L their blood concentration of methemoglobin rises to approximately 3-7%. This implies that the safety factor may be closer to 200% when measured as the probability of achieving blood concentrations which would produce clinically detectable symptoms.

This is not a justification for raising the primary drinking water criteria for nitrate, because the safety factor represent an important element in the risk assessment associated with that criteria. It is however, an argument that appropriate safety factors have already been included in the water standard and additional conservative assumptions must be defended acknowledging that fact.

The "hazards" associated with higher concentrations of TDS are far less threatening to most people. The secondary drinking water standards reflect the lower risk levels. Essentially, water concentrations below 500 mg/L of TDS are deemed fully protective of the beneficial use. Water concentrations above 500 mg/L, but below 1000 mg/L, TDS are deemed impaired. And, water concentrations above 1000 mg/L TDS are believed to preclude the drinking water beneficial use.

The best evidence for this characterization is that people shift rapidly to bottled water when TDS concentrations rise above 1000 mg/L TDS. Thus, be behavior definition, the drinking water use is "precluded" when people choose to spend significantly more money to find better-tasting source water.

Although, at first glance, it might appear that taste is merely an aesthetic concern and that safety factors should not apply, public acceptance is still the best measure of whether the MUN beneficial use is protected. The fact that taste is highly subjective does not mean that it cannot be objectively quantified and correlated with TDS concentrations.

Attempting to avoid the subjective by shifting focus to more "tangible" concerns, such as appliance lifetimes, undermines the integrity and credibility of the standard-setting process. The newest data suggests that the public economic benefits from these other concerns are relatively trivial especially when compared to taste acceptance.

Later in the process, during the antidegradation review, there will be an opportunity to consider the cost-benefit allocations for achieving higher or lower public acceptance. But, at the outset, the TIN/TDS Task Force must recognize that certain minimum thresholds should apply as a matter of beneficial use protection alone.

Determining what these thresholds are, for both TIN and TDS, is the primary purpose of the follow-on DELPHI discussions. To facilitate those discussion, we have prepared a short list of questions to be considered and answered by the DELPHI participants.

V. PRELIMINARY DELPHI DISCUSSION QUESTIONS

1) At what concentration of TIN should groundwater no longer serve as municipal source water without additional treatment or blending? Why?

2) What "safety factor" is most appropriate for protecting human health when measured as a risk of methemoglobinemia occurring? Why?

3) At what concentration of TDS should groundwater no longer serve as municipal source water without additional treatment or blending? Why?

4) At what concentration of TDS is source water no longer suitable to blend with other source waters with even higher TDS to augment municipal supplies?

5) Assuming that groundwater must be desalinated from its original concentration of 1,000 - 1,200 mg/L TDS, what percentage reduction should be sought?

6) What should be the minimum life expectancy of household appliances?

7) Where should beneficial use attainment be assessed for MUN? Why?

8) At what maximum concentration of TIN is the MUN use "fully protected?"

9) At what minimum concentration of TIN is the MUN use "precluded?"

10) At what maximum concentration of TDS is the MUN use "fully protected?"

11) At what minimum concentration of TDS is the MUN use "precluded?"

12) What is the highest and lowest concentration of TIN served by your agency during the last 5-years for any continuos 90-day period to any given customer group?

13) What is the highest and lowest concentration of TDS served by your agency during the last 10 years (measured as continuous 1 year averages)?

14) Who has the burden-of-proof for demonstrating that a proposed water reclamation project protects or fails to protect beneficial uses? For demonstrating that the project is "of maximum benefit to the people of California?"

15) What evidence is required to meet that burden-of-proof?

16) What thresholds define when the burden-of-proof has been met?

17) Should reclamation of municipal effluent and recharge of other non-effluent source waters (such as Colorado River water) be subject to different requirements for the same pollutant constituent?

VI. CONCLUSION

After carefully searching state and national indices and databases on the subjects of TIN and TDS, and reading hundreds of administrative decisions, court judgments, technical articles and guidance documents, we are sad to report that there just isn't much out there to aid us in determining when beneficial uses are protected or precluded?

As usual, the Santa Ana watershed will assume a pioneering role in surface water standards established and enforced to protect groundwater resources. The good news is that, in the absence of detailed state or federal guidance, there is plenty of room to develop a scientifically-sound, highly-customized solution which balances the competing interests in the basin. That is, afterall, what was intended in 68-16's requirement to benefit all the people in the state. The bad news is that, the void in guidance tends to produce a vacuum which will be filled by differing (and admittedly self-serving) interpretations.

If we cannot agree on certain minimum standards for protecting water quality, and certain maximum thresholds for evaluating the attainment of beneficial uses, then the next group won’t face the same problems we did. For, they will have the various court decisions which arise from the Santa Ana disputes to guide them.