



# Southwestern Watersheds

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## A New Look

Our original newsletter, established some eight or so years ago, was the first to discuss water quality-related issues in those extremely important watersheds surrounding the Greater Phoenix Metro area in a comprehensive way. Specifically, it was established as part of a scope of work examining a broad array of water quality issues in all the reservoirs on the Salt and Verde Rivers as well as Lake Pleasant and the CAP Canal. This project was the most comprehensive in its scope and scale either before or since and evolved as a natural extension of the original taste and odor study established in 1996; the first study to bring several Valley Cities together to address the ubiquitous problem of mib and geosmin production in common waterways.

Since the end of the original Comprehensive Watershed study, I've had numerous requests to re-publish the newsletter. With time being a constraint for all of us, and since moving on to other projects, the newsletter fell victim to a preoccupation with other aquatic-related issues; not from disinterest.

So, with input from several of you reading this now, I made the decision to re-publish the newsletter. Since we're working on aquatic-related projects throughout Arizona and the arid southwest, this newsletter will focus on topics unique to these watersheds.



Sampling from the Santa Cruz River

And these watersheds truly are unique. Much of our current knowledge regarding hydrology, limnology, ecology, physicochemistry, etc. of lakes, streams, and reservoirs was derived from research done long ago on north temperate counterparts. Several of these ecological ideals either simply don't hold up in waters of

arid regions, or need to be greatly refined. Researchers often believe a topic completely understood and delve into extreme specialization. Certainly, there are times when this approach is warranted, however, without an understanding of over-arching ecological principles, results from extremely specialized studies



The Colorado River/Marble Canyon at Navajo Bridge.

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often end in frustration. It's akin to being a well-disciplined watch maker, without knowing how to tell time.

Our knowledge of the structure and function of any aquatic system, arid or other, is far from complete yet we often perform research or management as if it were. Certainly, we learn from what, at first glance, appear to be disparate bodies of work but they should all be viewed from the ecological context of what a system currently is, or isn't. Additionally, aquatic ecosystems change over time due to anthropogenic and natural perturbations. Terms like ecosystem "equilibrium", "balance", "integrity", and "health" are indefinable, subjective and anthropocentric misnomers. Knowing where an aquatic ecosystem lies in its inherent continuum from creation to senescence, without subjectivity, sheds light on its feasibility of attaining whatever designated use we need it to provide.

The crux of our research has always been to determine those factors responsible for a given problem (or set of problems) and then try to find solutions along the path of least resistance. This often requires more specialized study, but only *after* defining what an ecosystem is, or isn't.

## Common Misconceptions About "New and Emerging" Contaminants

We've been examining the effect of endocrine-disrupting compounds (EDCs) on fish since 2003 and are the first to examine these effects on native southwestern species in a controlled environment (this work was recently submitted for publication so stay tuned). With the current media interest, and yes even sensationalism, problems associated with EDCs may seem like a "new" finding to many but research on the biological effect of EDCs was prevalent in the 1980's and 1990's. *Our Stolen Future* was written 12 years ago but our understanding of EDC's long-term effects on species, any species, is still woefully lacking. Recent research has largely focused on the identification and quantification of EDCs and pharmaceuticals in waters of the US. This research is essential, however, extraordinarily little research dollars are spent on determining what should be, in my opinion, the most critical question: What are the long-term, generational effects at both the individual and population level of exposure to ultra-low levels of environmentally-persistent compounds in a matrix of other compounds? Understanding the environmental fate and transport of these compounds is important but without some requisite knowledge of physiological effect, essentially meaningless in the long run.

To put some contextual framework around the problem requires relevant background information. This newsletter, however, is far too small to hold even a fraction of this information. It may be more meaningful to discuss many of the misconceptions currently surrounding both EDC's and pharmaceuticals in aquatic systems.

### Misconception 1: EDCs are synonymous with pharmaceuticals.

There are some pharmaceuticals (prescription and non-prescription) that have an effect on endocrine system functioning, however, the majority of them likely do not. For example, in our research we've found that the antibiotic sulfamethoxazole (used to treat urinary tract infections) and the anti-epileptic drug carbamazepine is persistent and prevalent in the Santa Cruz River near Tucson. The physiological effect of low doses (< 1 ppb) of these compounds is not well understood; they are not, however, known EDCs. Persistent EDCs commonly found in the aquatic environment include certain detergent metabolites, plasticizers, fragrances, flame and fire retardants, household wastewater compounds, and herbicides/insecticides to name a few.

### Misconception 2: The only pharmaceutical drug of concern is ethinyl-estradiol (birth control) or other types of estrogens.

While estrogens in the aquatic environment are certainly cause for concern, they are outnumbered by many other organic compounds having either an estrogenic, androgenic, or anti-estrogenic effect. In other words, this problem is much larger than ethinylestradiol being eliminated or flushed directly into the sewer systems.

### Misconception 3: Those compounds with "potent" estrogenic/androgenic properties are of the greatest concern.

At the landscape scale, those compounds that may not necessarily

be the most potent, but are the most environmentally persistent, may be more problematic than those compounds that are less persistent. The caveat is that we currently do not know all the degradates, and/or re-formation compounds that, exist.

### Misconception 4: Presence of EDCs or pharmaceuticals in streams, lakes, or rivers infers biological significance.

As previously mentioned, the long-term effects to individuals or populations is presently unknown so finding these compounds is a fact that, in and of itself, does nothing to determine their effects. We are working on the generational effects on fish in a controlled environment, one of only a few projects to address this issue, however, research addressing the long-term effects on other species, including humans, is lacking. With EDCs and pharmaceuticals showing up in so many places around the globe, we should, in my opinion, accept the fact that they are extraordinarily ubiquitous and examine the physiological consequences of this exposure in a multitude of species, including humans.

### Misconception 5: The dose-response effect is the same whether we are examining compounds in isolation or in a matrix of other compounds.

Several studies have shown that the physiological response following exposure to low levels of compounds in a matrix can be greater than the response following exposure to a greater concentration of a singular compound. Regulatory agencies, however, do not consider conducting cumulative risk assessments for mixtures of compounds because they still consider that chemicals will act independently and that effects are not additive. Classic dose-response curves of increasing concentration and increasing effect often do not work when examining the effect of EDCs. This makes experimental design difficult to say the least. For example, if an organism is exposed to a matrix of EDCs one compound of which has a concentration 5 times that of the others, we should never assume that is the compound causing physiological impairment. In the case of EDCs, we need to re-think the way in which toxicological testing has traditionally been conducted.

### Misconception 6: There is a canary-in-the-coal-mine species that will inform us of physiological effects.

The endocrine system of species is, to a large extent, what determines individual personality traits. Impairment of this system will affect a species perception of its surroundings, interaction with other individuals and species, decision-making capabilities for mating, spawning, aggression, territoriality, etc. These changes can occur even without outward signs of morphological impairment.



Pulling blood for biomarker analyses of fish exposed to treated municipal effluent.

## Common Misconceptions About "New and Emerging" Contaminants

### **Misconception 6: There is a canary-in-the-coal-mine species that will inform us of physiological effects (cont.)**

For example, in our experiments using native fish species, there was clear hormonal impairment, when compared to controls, of fish exposed to low levels (no compound > 1 ppb) of EDCs, yet, no gross morphological changes were noted. Every metric of "fitness" was the same between control and treatment fish yet clear behavioral differences existed. With behavioral and morphological differences being so great across many different species and phyla, the effects of EDCs will probably affect them all at different levels and in myriad different ways.

### **Misconception 7: Field-based screening tools are able to determine physiological responses to EDCs or pharmaceuticals.**

Such screens are valuable tools in determining if an estrogenic/androgenic, or anti-estrogenic effect is present in a water supply. They are relatively inexpensive and a good alternative to low-level sampling of many individual compounds. They do not, however, assess long-term effects of ultra-low exposure nor do they assess behavioral changes that might occur as a result of this exposure.

### **Misconception 8: Field-based studies of aquatic organisms (including fish) give us a mechanistic understanding of the effect(s) of EDCs.**

The news media has been replete with findings of intersex (males with female attributes or vice versa) condition in wild fish. Such findings are certainly cause for consternation, however, fish are highly mobile organisms and it is difficult to determine when or where exposure(s) occurred. Additionally, temporal variability between the occurrence of external cues for reproduction, the release of various neuro-endocrine stimulatory compounds, production of steroidal hormones, and eventual protein development and sexual differentiation means that impairment can occur anywhere along this path. Finding late-stage impairment, such as intersex or other gross morphological changes, offers little mechanistic understanding of how individuals achieved this condition. True control or replication is not possible in the field so, often, there is little basis for comparison in biomarkers between what are believed to be affected versus "normal" fish. Laboratory studies with control and replication, however, often suffer from a perceived lack of ecological significance. We have attempted to strike some degree of balance between real-world relevance and mechanistic understanding in our research with fish exposed to treated municipal effluent.

### **Misconception 9: The main route of exposure to humans is through water (drinking or other).**

There really should be at least two main focal areas in research dealing with EDCs or pharmaceuticals. These two areas, while related, are different enough to be considered separately. The first deals with the effect on aquatic ecosystems (and the organisms therein) and the second deals with human exposure. Certainly fish or other wholly aquatic species have a much higher incidence of exposure to EDCs in aquatic systems because they are constantly immersed, and surrounded by, the medium containing the contami-

nant. Humans, on the other hand, have a multitude of exposure routes besides an aqueous medium. The clothes we wear contain many flame and fire retardants as do the chairs we are seated in, the interiors of our cars, airplanes, etc. We are all exposed to detergent metabolites and omni-present plasticizers (including but not limited to bisphenol-A) as part of our daily lives. For example, I recently noticed toothpaste that contained the known endocrine-disrupting compound triclosan. Effect studies for triclosan were conducted at the part per billion level but concentrations in the toothpaste, to be used against the most vascular part of our bodies and incidentally ingested, were in the *parts per hundred* range. The water we ingest contains but a fraction of all the organic compounds known to cause physiological harm that we are exposed to on a daily basis.

### **Misconception 10: The long-term physiological effect(s) of exposure to synthetic organic compounds, including degradates, are well-documented and understood.**

An individual organisms ability to better-exploit a resource (or group of resources) in the face of environmental stress and inter-specific competition, coupled with conservation of the genetic material enabling this exploitation, is what drives speciation. Conservation of inherited traits are dependent upon not only the genetic material being transferred, but also upon the cognitive ability of subsequent generations.

Catastrophic events happen; and while immediately noticeable they are generally not of a magnitude or duration that causes long-term, generational effects in populations. By the same token, our ability to realize, quantify, and predict, subtle generational effects has been and still is, poor. Increasing evidence suggests that certain learning disabilities, which are increasing at an alarming rate, not only have genetic, but



Some learning disabilities are now believed to have an environmental component of their etiology.

also environmental triggers. Unlike adults, fetuses have no functioning blood-brain barrier and therefore no protection against any type of toxic insult. Especially disconcerting is the notion that certain types of compounds, including EDCs, could cause such an insult the results of which might not be noticed until adolescence. In these cases, children could potentially grow into something other than they might have been. The insidious nature of so many different organic compounds should be taken very seriously. There is no doubt that we have benefitted from the production of many of these compounds. We need to fully understand, however, the costs associated with the benefits of whatever we create because the worst kind of pollutants are those which affect the cognitive capabilities of future generations.

## Seismic Profiling of Arizona Reservoirs

Of all the resources within our state, water is arguably the most precious. Whether for flood control, irrigation, or drinking water, reservoirs are what have enabled and driven regional population growth for the past 100 plus years. Reservoirs, however, are different limnologically and ecologically than lakes. This is especially true of reservoirs in arid regions where watershed to reservoir size ratios are very large.

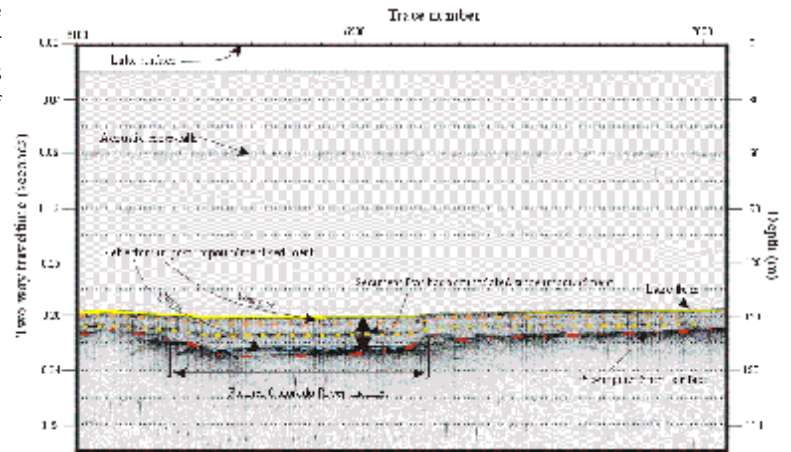
Knowing the condition of these reservoirs is extremely important to our understanding of their ability to provide the multitude of uses we require of them. Reservoirs are repositories of all the sediment in the watershed upstream of the dam. The amount of sediment delivered to a reservoir is dependent upon several watershed factors such as climate, topography, vegetation type and amount, frequency and magnitude of wildfire, etc. Reservoirs sediments are libraries regarding past watershed conditions. The extent, amount, and type of sediment also determines, to a large degree, water quality within a reservoir. Over time and under certain environmental conditions, in-loading and recycling of material from sediments within reservoirs occurs independent of loading via the watershed.

Side-scan sonar and seismic profiling are powerful tools for mapping the shape and stratigraphy of ocean and lake sediments. These instruments, when linked with spatial analysis software, are capable of producing highly accurate and detailed maps of bathymetry, sediment thickness, and sediment deposition characteristics. This information could be used to assess depletion in reservoir capacity and characteristics of sediment redistribution under conditions of changing reservoir level.

We are very fortunate to have within our state, Dr. Paul Gremillion from NAU. Working with Dr. Gremillion, we will be performing seismic profiling of some of the smaller reservoirs within the state. The extent and distribution of sediments within larger reservoirs (such as those surrounding the Phoenix Valley) is unknown. The opportunity now exists for seismic profiling of any reservoir within the state, large or small.



EdgeTech Corp. tow vehicle and processor for seismic profiling.



Typical seismic-profiler images of reservoir sediment, from Lake Mead, Nevada, Arizona (reproduced from Twichell et al., 1999).

## Upcoming Issues

- Climate Change Effects on Aquatic Ecosystems
- The "Eco" Prefix; Used and Abused
- Biotic Aspects of Flow Requirements and Water Rights
- The Ecology of Ephemeral and Intermittent Streams in Arid Regions

