Duwamish River Cleanup Coalition

Community Coalition for Environmental Justice • Duwamish Tribe• Georgetown Community Council • IM-A-PAL Foundation • ECOSS • People for Puget Sound • Puget Soundkeeper Alliance • South Park Neighborhood Association • Washington Toxics Coalition • Waste Action Project

January 15, 2008

Ms. Allison Hiltner
U.S. EPA Region X
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RE: Draft Lower Duwamish Waterway Remedial Investigation

Dear Allison:

The Duwamish River Cleanup Coalition (DRCC) is EPA's Community Advisory Group for the Lower Duwamish River Superfund Site, and is supported by the DRCC Technical Advisory Group (DRCC/TAG), EPA's Technical Assistance Grant recipient for the site. DRCC and DRCC/TAG's technical consultants have reviewed the Draft Remedial Investigation, Ecological Risk Assessment and Human Health Risk Assessment for the Lower Duwamish River, released in November 2007. DRCC submits the following comments and questions on behalf of its member organizations and community representatives.

General Issues

The Lower Duwamish Waterway Group's Draft Remedial Investigation details the process of estimating the risks from contaminants in the Lower Duwamish, but does not quantify the risks from dioxins and furans or from mixtures of chemicals. At the same time, the Draft RI states that the cleanup will be conducted only for chemicals above "background" contaminant inputs. Thus, the effort to

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characterize and quantify risks is framed as secondary to the determination of "background" contaminant inputs and concentrations.

The section dealing with background levels of contaminants is fraught with problems, including the misleading use of the term "background," failure to generally characterize the types of non-site sources affecting the site, and the inability to account for all current data on chemical inputs from stormwater. Furthermore, source control efforts have been underfunded throughout the entire process to date and sources are poorly quantified at this point.

The section on "background" levels makes no effort to estimate future – presumably lower – levels of contamination from non-site sources, which is necessary to setting a cleanup level that will protect the river for future uses. If the cleanup levels are to be limited by "background," or non-site sources, then there must be a concerted effort to estimate what those non-site sources will be in future when the cleanup is in place and completed. In addition, in order to confidently assign responsibility to "site" or "non-site" sources, the report **must** describe the types of non-site sources that are being defined as "background." The failure to investigate and identify current sources of contaminants to the river is not sufficient to characterize those contaminants as "background."

There are no natural sources of PCBs or dioxins (except for ball clay that contains dioxin). These contaminants do not have "natural background" levels. We understand that this term is a product of EPA's regulatory terminology, but it remains misleading and confusing for the reader, and should be properly defined in the report. Since EPA and Washington State use different regulatory terminology for background conditions, use of a more appropriate and accurate term that captures the meaning of both is recommended. We suggest the RI use the term "ambient." This distinction is critical under the approach used in the RI.

The Sediment transport study presented in the RI is summarized from an earlier investigation and does not reflect DRCC's or the Trustees' comments (summer 2007) on the newest sediment modeling draft documents. The sedimentation rates are based on historical information and sediment core information. In the time that has passed since the initiation of the RI, another method of verification could have been used. Sediment traps could and should have been deployed on the river to collect current sediment input. Further, this investigation does not predict sedimentation rates under future conditions when stormwater and erosion controls are improved.

The Groundwater section in section 2.5 tries to argue that natural attenuation occurs in groundwater, despite limited data to support this notion. The argument is spurious and tries to argue two sides of the case. Overall, groundwater quality has been inadequately characterized. Using seep data – from a limited number of locations that were selected based on visible seeps, rather than geology – only characterizes the water quality from a limited horizon and limited locations. Further, the seep samples include tidal water that is re-entering the river during the low tide sampling regime. A more concerted effort is needed to address groundwater, particularly water that might enter the river from below and downriver from the identified sources (e.g., Boeing Plant 2).

The Ecological Risk Assessment (ERA) excludes shrimp from detailed analysis, despite the abundant presence of shrimp at several sampling sites. Nor does the ERA evaluate many chemicals in the vast majority of species because of a lack of direct data. The toxicity is addressed only in the uncertainty section.

There is no real attempt to compare the ecological fauna in the Duwamish now with a reference location or historical information. The ERA should examine what should be there, based on comparison with a reference location. In addition, there is no attempt to quantify the loss of prey species (due to toxic pollution) that therefore suppresses population abundance of higher trophic level species.

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Disproportionate sampling and modeling efforts and resources have been devoted to quantifying contamination in the river as compared to the emphasis on source detection. This is particularly evident in reviewing the source control section of the Draft RI, which relies on generalities and sketchy descriptions of source chemical pathways. The PRPs should be responsible for significantly strengthening the source control investigation, rather than relying on Ecology's limited resources, to begin a more concerted effort to sample, analyze and track chemicals in the pathways leading to the river (air, soil, sediment, stormwater, and groundwater).

Executive summary

The Executive Summary (ES) is a critically important section of the RI – many readers will only have the time or opportunity to review this section alone. Policy makers are not likely to read anything more, and frequently will rely on a staff summary of the ES. These reviewers generally do not have the technical experience or expertise to fully evaluate the rest of the document. Therefore, the substance and tone of the ES are critically important. The tone of parts of the draft ES is inappropriate and some of the substance requires correction.

The language clearly attempts to minimize problems of contamination and effects on human health and wildlife. The ES describes the river's contamination and risks as a minimal problem. The revision of this section should correct this bias and remove or change language that trivializes the extent of the problem.

The ES also glosses over Tribal use of the river. Traditional or historical use of the river by the Suquamish, Muckleshoot and Duwamish Tribes should be described and the existence of treaty rights, as appropriate, should be recognized (at minimum, those Tribes that have treaty rights to the river should be listed, even if statements about the exercise of those treaty rights cannot be agreed upon with the Tribes). These facts are of central important to the contextual description of the Duwamish, past and present.

Specific Comments on the Executive Summary

- ES.1: This section fails to give adequate attention to recreational and other non-commercial uses of the river. The RI should acknowledge that once the river is cleaned up, the public can be expected to make even greater recreational use of the Duwamish than it does today. The last paragraph on page ES-2 should add language to anticipate increased use, and note the current shoreline uses. Add language to indicate what uses currently exist and that increasing use of the river and shorelines by recreational users can be expected as areas at or near Early Action Areas (e.g., Slip 4 and Malarkey) are enhanced with parks and publicly accessible habitat. Also note the existing public parks, publicly accessible shorelines, and recreational areas.

- ES.2: The statement in the last paragraph that most sediment comes from the Green River and is only minimally contaminated has no reference to factual information. If this statement is based on empirical data, provide citations for the referenced documents, otherwise restate as an assumption.

- ES.3 page 5, top: The statement that most contamination is historical and recent deposits are cleaner is presented here as a hypothesis and needs to be reframed and placed elsewhere. This central hypothesis drives much, if not all of the RI, and will greatly affect the FS. The problem is that the hypothesis is buried and not clearly presented as a central hypothesis of the RI.

- ES.4: Phthalates are inadequately addressed in the RI as a whole and in the ES. On page ES-4,phthalates are identified as a “key” chemical. Later the text states that not only are phthalates in sediment (81% of surface sediment samples: pg. 228) but are also found in clams and benthic organisms. In the map section, phthalates are inadequately mapped and difficult to discern.

- Page 5, last paragraph, last sentence: The elevated PCB levels in 2005 following dredging may have been caused by the dredging and subsequent resuspension mentioned here. But without better data, this statement is speculation and needs that qualifier in the ES. Alternative explanations need to be presented as well, especially for areas far upstream of the dredging. There were other ongoing sources of PCBs to the river, such as at Boeing Plant 2, North Boeing Field and Norfolk, as well as potentially other sources that have not yet been identified.

- ES.4: The comment that the baseline Ecological Risk Assessment (ERA) is a “conservative risk-based screening process” makes a lot of assumptions and is not warranted. please remove the assumption of conservatism. Our technical advisor’s analysis of the Ecological Risk Assessment is that toxicity of TCDD’s, PCB’s, and TBT are all *under*estimated.

- Page ES-7, last line: “The highest LOAEL- based HQ for fish, crabs and wildlife…were estimated to be relatively low considering the uncertainties…” is an inappropriate summation of the data in Table ES2. It would be more accurate to state that PCBs are a risk and metals may present a lower risk, although existing literature suggests that TBT is a serious threat to some invertebrates.

- Page ES-8: The absence of analysis of the effects of dioxins and furans on wildlife is a major omission. There is an abundance of data indicating several dioxins and furans are more toxic to fish, birds or other mammals than to humans. By omitting wildlife, the risk analysis is biased. The lack of direct data on PCDD/F chemicals requires the assumption that they are excessive and will be cleaned up. This assumption needs to be clearly stated here.

- Some of the animals that are most sensitive to tributyltin (TBT) are molluscs, thus their absence in the list of risk drivers for TBT is problematic. The literature on TBT toxicity, sediment to water fluxes, and the sediment TBT levels in the LDW indicate a toxicity problem from TBT. Water quality standards for this endpoint tend to be in the order of ppt.

- ES.5: If the statement about overestimating risks for many individuals is included, it must be paired with a statement that risks may be underestimated for other people. These exposures are represented in a distribution in which some portion of the population that experiences the highest levels may not be adequately protected by these estimates.

- Page ES-12, last sentence: All COCs posting a cancer risk of greater than 1 in 1,000,000 should be identified as risk drivers in the HHRA. Relying on a 5-year post-cleanup review to address risks remaining from these chemicals is insufficient. The community does not want nor should the agencies accept a delay in cleanup until the next 5 years have elapsed. The chemicals that contaminate the river need attention now, based on the present analysis.

- ES.7, page 15 Table ES-7: There is no reasonable explanation for not calculating the risks for the scenarios presented in this table. What sediment concentrations would result in unacceptable risk levels for cancer from PCBs? The results are not encouraging at all, and would lead to an expectation of greater cleanup. The RI needs to provide this analysis and include it in the report.

- The table should to use 1 meal/week, not 1/month – an unrealistically low value, especially for the community on the river. Understanding that these numbers are for “illustrative purposes” only, there is all the more reason for the values to be realistic for the community members.

- Page ES-16: The terminology of “natural background” for chemicals that are completely anthropogenic is inappropriate. The appropriate term is “ambient” to refer to levels present in the environment absent the influence of site activities.

- Please provide a reference for Table ES 8.

- Page ES-33: PCBs are described as being immobile in sediments. The next paragraphs then describe the large amount of contaminated groundwater with other chemicals that could potentially mobilize PCBs. This failure to consider cumulative or synergistic effects appears to be another example of the bias in RI.

Sediment Dynamics

This section summarizes and interprets the work that was conducted over the past few years to understand and quantify the movement of sediments in the Duwamish. It does not appear to address our recent significant comments on the Sediment Modeling and the STAR document, especially our concerns about the lack of description of uncertainties in the calculated numbers.

The chapter relies heavily on the previous reports from Windward regarding the data obtained from the sediment cores. The basic assumption in this section comes from the Conceptual Site Model (CSM). These assumptions are: 1) sediment deposits accumulate in the Duwamish River when the river is analyzed as a single entity (*overall, the river accumulates sediments but some locations are actually eroding*), 2) local places in the river have sediments depositing or are at equilibrium (sediments are not eroding nor depositing), and 3) erosion of deeper sediments only happens during major storms or other similar events, and is primarily local.

In addition to taking cores of the sediment to determine sediment deposition, LDWG also has conducted two major modeling activities. One effort was the Sediment Transport Analysis Report (STAR) and the other was the Sediment Transport Model (STM). Together, these two efforts provide information on sediment movement both riverwide and locally, as a result of ship traffic and tides. As of this draft, ship scour is still completely inadequately addressed.

The chapter reaches the conclusion that most of the Duwamish is not a source of sediments washing into Elliot Bay, but that sediments build up in the river. The navigational channel is one place where sediments do not build up because the flow is higher in the deeper area. Some of the localized areas in the shallow waters deposit or erode at a different level or rate than the rest of the river. The sediment deposits at a maximum rate of 2-3 cm (about an inch) per year. Coupled with some episodic scouring in places when there is a storm or a flood from the Green River, the Duwamish River system is not a highly depositional environment.

As anticipated, the sections read as though the PRPs are trying to build a case that natural recovery will be sufficient to remediate significant portions of the river. This bias needs to be corrected; the RI needs to take a more objective approach.

An investigation into the efficacy of “natural recovery“ for two other rivers with PCB contamination do not justify the approach in the Draft RI. The public record for the Fox River in Wisconsin and the Housatonic River in Massachusetts and Connecticut provide supporting documentation.

There is no reliable evidence that the process of natural recovery is effective in any reasonable time period, and in some cases may not work at all. A fishing advisory is still in place for the Kepone on the James River in Virginia, despite controlling the contamination source more than 30 years ago. The sedimentation rate and sediment dynamics in that system have not been sufficient to prevent sediment contaminants in the Kepone from entering the river food web as layers of fresh sediment have deposited on top of the contaminated sediment, in spite of predictions that sediment deposition would isolate contaminants within the Kepone.

Ecological Risk Assessment

Shrimp:

Shrimp are not very abundant riverwide, but were highly abundant in several of the lower station trawls. Shrimp were not identified as a species of interest, despite the importance of shrimp in ecological systems and for humans. They are critical to conducting accurate risk assessments for both humans and wildlife since shrimp are a significant source of food to both. Shrimp also play a key role in the trophic system of the Duwamish River. This omission is significant and needs to be remedied.

Benthic organisms:

The benthic survey results are presented in a semi-quantitative fashion; the presentation in the ERA itself is substantially better than in the RI. However, the results on species abundance and diversity reported in the RI are not compared with reference sites. The results need to be compared with a reference site, or a historical database in order to determine if the existing fauna is normal in diversity and abundance (see chapter 8.3.5). This comparison should be conducted and included in the RI.

Endpoints:

Biomarkers, behavioral and histological abnormalities were not included as endpoints in the risk assessment because EPA only uses population measures, not measures of health for ecological receptors. This approach is a serious limitation and should be corrected. As a result, TRVs were accepted for only a few chemicals for which there is a clear connection between population measures and chemical concentrations. Thus, the ERA ignores endpoints such as the toxicity of TBT to snails that may have little or slow population impacts, but will sustain populations of unhealthy and even deformed animals that have an increased vulnerability to other stresses. In addition, researchers have noted population level impacts in Japan as a result of imposex (deFur et al 1999).

Dioxin/Furans:

The RI ERA fails to quantify the effects of dioxin/furans on the ecological resources of the Lower Duwamish. There are no estimates of toxicity to fish, mammals, birds or clams and mussels, although the scientific literature provides ample evidence of the sensitivity of these animals to dioxins and furans. Dioxins and furans can also act synergistically with PCBs and some other chemicals such as TBT (see below). While the document states an assumption of unacceptable risk, without data, there is no way to specifically assess the risk from dioxin/furans.

Cumulative risk:

There is little to no consideration of the cumulative risks from multiple chemical exposures for ecological resources. Fish, invertebrates, mammals and birds are all exposed to the suite of organic chemicals and metals from the Duwamish. These chemicals include phthalates, PCBs, dioxins, PAHs, arsenic, mercury, lead and others. Two aspects of this failing that need to be addressed are (1) the cumulative risks and (2) the multiple chemical exposures. The potential cumulative risks include changes in species abundance and diversity, trophic structure, prey availability, nesting, and feeding behaviors, none of which are addressed in the RI.

Multiple chemical exposures present an additional problem because several chemicals that target the same endpoint may not individually register as a risk, but may combine to cause impairment. This has been described by Garman et al. for fish in the James River in Virginia (1998). Garman reported sub-toxic levels of DDT (total), PCBs (total), TBT and mercury in catfish tissues, yet reported that a large percentage of the mature catfish failed to develop gonads in the spawning season.

Ecological Effects of TBT:

The analysis of the effects of TBT on vertebrates and invertebrates is not sufficient and does not provide the information or justification necessary to conclude that TBT is not a serious risk. The assessment of TBT impacts indicates effects on at least one species of snail; other invertebrate species were not evaluated in toxicity tests.

The focus on sediment concentrations of TBT to the exclusion of concentrations available in the water column is also an issue. The majority of toxicological studies performed in the scientific literature examined the effects of low concentrations of TBT in the water column or in tissue on various endpoints such as imposex. The failure of the ERA to collect and report these data is a major shortcoming. TBT contamination is a well known issue in harbors worldwide and should have been examined more thoroughly in this document.

These shortcomings extend to other benthic invertebrates as well. The benthic invertebrate TRVs were based on a polychaete species (*Armandia brevis*) that has "relatively little ability to metabolize TBT." TRVs should be based on data that are representative of the taxonomic group of interest. The LOAEL TRV (2.36) is significantly higher than values reported in the literature for other species. One study found significant dose-related impaired reproductive success in *Ruditapes philippinarum* at body burdens less than 1 ppm (Inoue et al 2006). In the same study, of all clam embryos that were exposed to both maternal and waterborne TBT, *none* survived. These findings support a number of other studies involving other species (Bellas et al 2005, Leung et al 2004, Inoue et al 2006, McAllister and Kime 2003). Data in the literature suggest that the TRVs selected for benthic invertebrates are completely inappropriate and the resulting hazard quotients are likely not representative of actual risks in the Duwamish River.

Risks from TBT to fish are also insufficiently addressed in the RI/ERA. References to TBT toxicity in fish are ubiquitous in a review of recently published articles in peer reviewed journals. Low levels of TBT in the water column present their own risks to fish as well as invertebrates and should be evaluated as well. TBT is well documented to cause a variety of adverse effects to both individual fish and to populations. TBT demonstrates significant endocrine disrupting behavior in fish, particularly inhibiting the creation of steroids (Lyssimachou et al 2006, Kuhl and Brouwer 2006). Reproductive endpoints are especially sensitive to endocrine disruption, and TBT exposure has been documented to damage sperm in zebrafish, while also inducing masculinization. (McAllister and Kime 2003, Nakayama et al 2004). All of these effects have been demonstrated to occur in salmon, a high priority ecological endpoint in the Duwamish, when they are exposed to only nominal doses of TBT (Lyssimachou et al 2006). The well established interaction of TBT with one of the most common contaminants in the Duwamish River, PCBs, is also not accounted for in the ERA.

The above effects are amplified when fish are exposed to PCBs in conjunction with TBT. The combined presence of TBT and PCBs have been linked to the absence of gonads in large portions of catfish populations in the James River and reduced reproductive success and mating behaviors in *Oryzias latipes* (Garman et al 1998, Nakayama et al 2004). Neurological endpoints are also affected by the combination, with exposures linked to abnormal swimming behavior in carp (Schmidt et al 2004). Given the contaminant profile within the Duwamish, peer reviewed literature suggests that TBT may be a major driver of risk to all wildlife within the Duwamish, and that the ERA significantly underestimates these risks.

Water Samples:

The RI gave no measurements of TBT or total tin in water, as noted in the RI page 218 section 4.2.5.4. This omission is a problem because much of the literature uses water levels as the measurement of exposure dose. Several animals are exposed primarily via water, not sediment.

Water levels of TBT can be estimated from the sediment data by first converting from dry weight to wet weight and then converting from sediment to water. The first conversion was made by multiplying the dry weight sediment data by 0.5, based on a 50% water content (Table 2). Conversion to water concentrations from sediment concentrations is done using literature values from Unger (1988) who reported an absorption of 1000 fold. Based on Unger (1988), the water levels of TBT may reach 1150 ng/L, whereas Literature searches on the toxicity of TBT indicate that water concentrations as low as 1 ng/L can have adverse effects on both gastropods and chordates (Table 1). The effects summarized in Table 1 were observed in fish, snails, oysters, and crabs. These analyses indicate that the RI and ERA fail to account for the known toxicity of TBT.

Gastropods:

Too few gastropod snails were analyzed to make any conclusions about toxic effects on these populations. No females were collected from the two sites with the highest concentrations of TBT in sediment. Female snails should have been present if the populations are "normal." These sites with elevated TBT should have been the ones with the highest incidence of imposex, and therefore the sampling should have been designed to obtain a minimum number of specimens of males and females. The sampling conducted was inadequate to address the effects of TBT in the Duwamish on gastropod species. It is possible that no females were collected at these sites because the females were affected and changed into males. Leung et al (2006) discovered a strong relationship between increasing tissue body burdens of TBT and an altered female:male sex ratio in Hong Kong Harbor (Leung et al 2006) making this a likely possibility.

Human Health Risk Assessment

Cumulative risk:

The Draft RI Human Health Risk Assessment (HHRA) ignores cumulative risk for residents and workers who are on the river. EPA has developed initial procedures for preparing cumulative risk assessments and this HHRA should use that work to include a discussion of cumulative risk, at least for area residents. This assessment must recognize the combined long-term effects of multiple chemical exposures from the pathways indicated, as well as from land-based (e.g., T117, Boeing, etc.) and air exposures (e.g., LaFarge, port-related emissions) that are also present and may contribute contaminants to the Superfund site. The "site" being evaluated for the HHRA includes the sediments and sources to the sediments: the HHRA should include all of these related and cumulative exposures.

Dioxin/Furans:

The omission of dioxins and furans from quantitative consideration is a major weakness of the HHRA and should be corrected. EPA has been working on a reassessment of the health effects of dioxin since 1991, and the scientific literature on dioxin and related compounds is abundant. There is no doubt that dioxins are carcinogenic and cause a range of effects, from reproductive problems to liver problems and immune suppression. The HHRA should at least provide a summary of the health effects from dioxins and related compounds. The HHRA should obtaine data on existing dioxin/furan levels and develop estimates of health risks. Nor does the HHRA combine PCBs with dioxins and furans in the TEQ analysis for the common mode of action. The HHRA should include the additive impact of the dioxins, furans and PCBs to provide an estimate of risk or harm.

Tribal Fish Consumption Rates:

The HHRA uses a fish consumption rate for the Tribal scenario that is derived from the Tulalip Tribe data, not from the Suquamish Tribe, who have treaty rights to fish the Duwamish River and currently fish at the river's mouth. The Duwamish is within the Usual and Accustomed Harvesting Area (UAA) of the Suquamish Tribe. Recent documents on determining fish consumption in Tribal waters recommend using local specific data (Harper et al In Press), and EPA's own Tribal Fish Consumption Framework for Puget Sound lists reliable data from local Tribes whose UAA includes the site as the highest priority for selection of consumption data. The higher value from the local tribe needs to be used to estimate tribal exposures from fish consumption in the lower Duwamish. This is perhaps the single greatest flaw of the Draft RI.

EPA has stated that the lower Tulalip Tribe consumption rates should be used because the lower Duwamish River has limited shellfish habitat, as compared with the unaltered Duwamish River of 100 years ago. This comparison to historical conditions is irrelevant to selecting current seafood consumption rates. The Framework clearly states that the size of the site is not a factor for consideration under the framework – in other words, if the site only accounts for a small portion of the Tribes UAA, the local Tribe's seafood consumption rate should still be used.

In addition, the Framework states that EPA should assume that if one type of seafood is not available, tribal consumers will switch to another seafood type (resource-switching), but the amount of seafood consumed will **remain the same**: "it is assumed that Tribal members substitute different types of fish and shellfish when those that would preferentially be harvested are unavailable" (EPA, August 2007). EPA's decision to disregard the Suquamish Tribe's consumption rate is in conflict with the clear guidance of the framework in these regards.

The Framework permits Tulalip consumption rates to be applied to areas with limited shellfish habitat, but if this is appropriate at all in an area within a tribe's UAA when that tribe has reliable data on consumption rates, it would only be appropriate when the area under consideration has naturally limited habitat, not when habitat is degraded, but can be reasonably expected to improve and expand in the future. Further, EPA recognizes that the Tulalip Tribe's consumption rates are *artificially suppressed* due to habitat degradation. The Framework quotes the National Environmental Justice Advisory Council: "When agencies set environmental standards using a fish consumption rate based on artificially diminished consumption level, they may set in motion a downward spiral whereby the resulting standards permit further contamination and/or depletion of fish and aquatic resources," and concludes that "Cleanup levels...based on current fish and shellfish consumption rates in the vicinity of a cleanup site, may not reflect the potential for the water body to rebound from its current, relatively contaminated state," and "Where Tribal members have already reduced their harvest of fish and shellfish from impaired habitat, the use of current consumption rates could result in underestimations of potential fish and shellfish consumption rates" (EPA, August 2007). This is true of both the Duwamish River's current sediment quality and its habitat conditions (see below). Application of the Tulalip rates are inappropriate in this context.

In addition, EPA has assumed that future shellfish habitat in the Duwamish will be insufficient to support the Suquamish tribe's consumption rates. Independent of the framework's guidance to apply local rates regardless of the size of the site, there is no basis for EPA's assumption. As the lower Duwamish River is remediated and restored, the potential for at least 10 river miles (five miles x 2 banks) of intertidal shellfish habitat, plus anticipated off-channel restoration areas, exists for the river's future conditions, which the Framework states should be considered. Much of the current shoreline infrastructure is deteriorating, and as shipping and industrial infrastructure is replaced and upgraded, available materials and fish-friendly design alternatives that currently exist can and likely will make shipping, industrial activity, and shoreline habitat compatible along the length of the lower Duwamish. NRDA mandated habitat restoration projects will also provide for substantial new habitat along and in off-channel areas adjacent to the lower Duwamish River. Specific goals to restore a minimum of 30% habitat already exist for the saltwedge portion of the river (WRIA 9), and much more may ultimately be restored by City, County, Port and State initiatives, as well as by Tribal, private and non-governmental organizations with an interest in the restoration of the Duwamish River and Puget Sound.

EPA also apparently assumes that shellfish will not grow as salinity decreases in the upper portions of the LDW, but shellfish beds historically extended much farther upriver than the boundaries of the current site, and mussels are currently found at the northern/upriver boundary of the LDW. If substrate conditions in the current LDW are inhospitable to preferred shellfish, habitat restoration and management by Tribes and others can easily address these issues, much as commercial growers do throughout Puget Sound. Further, the assumption that insufficient habitat is available to sustain Suquamish rates of harvest appears to treat tribal harvest as a population-level consideration, rather than an individual one, which would be appropriate for an ERA but not for an HHRA. Regardless of the number of tribal consumers harvesting from the Duwamish, the HHRA should ensure that the impact on their health is adequately evaluated. Whether 1, 10 or 100+ tribal consumers ultimately harvest fish and shellfish from the river, EPA has a responsibility to ensure that the HHRA accurately assesses their risks.

DRCC does not think that the complexity and expense of a "sustainability analysis" is necessary to establish this future potential. The uncertainty alone about future conditions is sufficient to reject EPA's assumptions. We believe that EPA has intentionally underestimated the potential for habitat restoration and shellfish production along the river, and that the agency has predetermined that background levels of contaminants make the development of an HHRA that protects tribal fish consumers a moot and unnecessary exercise. We disagree, and strongly object to this dismissive approach to evaluating risks to the river's most exposed and at-risk users. The Suquamish Tribe's seafood consumption rates should be used in this and all areas of Puget Sound within their UAA.

Recreational Exposure:

The recreational/child play scenario is improved from earlier drafts, but is still insufficient to protect the health of local residents and families. The HHRA uses too few days per year to estimate recreational exposure. These recreational areas are within walking distance of residences, making daily use of the river a possible, and in fact, locally reported scenario that needs to be evaluated in the HHRA. Both the dog walker and recreational child play scenario need to use higher values. For a resident family within walking distance of the Duwamish, a value of 300 (or more) days is more appropriate as a maximum value (RME). Substitution of recreational data from Lake Washington, which reflects a majority of visitors that travel to its beaches as a summer destination, rather than local residents who have daily access, is not appropriate. EPA has indicated that it believes the rate is protective because it is balanced by an assumption of full skin contact. DRCC does not believe that this is an appropriate correction for underestimating exposure frequency. Dermal exposure may be reduced in non-summer months, which can be reflected in the HHRA, but the reasonable potential for year-round recreational play needs to be included in the document. The omissions in the current HHRA mischaracterize local use, may underestimate potential risks for local children, and, given the low-income status and diversity of the community, raises many environmental justice concerns that further elevate the significance of this issue. Locally reported use must be reflected in the RI/HHRA.

Tribal Clamming:

The HHRA in the RI dismisses high end tribal clamming (183 days/year) as the RME in favor of a lower rate (120 days/year) for the same reason that it fails to use Suquamish fish consumption rates in favor of non-local Tulalip tribal rates, and because the resulting risk estimates would exceed the selected RME. The RI makes a serious error in this regard for several reasons. First of all, the tribal clamming values for both consumption and direct exposure (dermal, incidental ingestion, etc.) are data from the loca, Tribes whose UAA includes the site. Second, a recent report indicates the necessity of obtaining and using local data that have been obtained from and for use in the tribal areas of concern. If data indicate that local tribal members are or may be experiencing greater exposures than the RME, then the RME is obviously incorrect. Data cannot be disregarded simply because they contradict original assumptions.

Section 7. Background Section

The section dealing with "background" is very troublesome and has numerous technical problems. It is DRCC's understanding that background levels will not be determined until the release of the Draft Feasibility Study next year. The discussion in the RI appears intended to influence this future decision, but is biased and incomplete, leaving a misleading impression that background must fall within a range that has not yet been vetted or determined. Several lines of evidence are omitted (i.e., sediment in storm drain catch basins), a description of types of sources for contaminant levels described as "background" is not provided, and some of the text is in direct contradiction to information provided to the community by EPA and Ecology. We recommend that the background section be eliminated from the RI because the text is misleading and unsubstantiated at this point.

To date, DRCC and the trustees have not been adequately involved in the background discussion, including the selection of data and reference locations. We disagree that appropriate “urban” areas have been selected for dioxin and that the area background approach for PCBs and other chemicals is adequate.

It must be clarified for the reader that there are no “natural” background concentrations of PCBs, nor for dioxins/furans in the Seattle area. These compounds are entirely anthropogenic, or nearly so for dioxin/furan: PCBs are entirely a manufactured chemical; dioxins are only known to occur naturally in ball clay, in deposits that are mined for industrial uses. The term “natural” background does not apply; the correct scientific term is “ambient.” The language in the RI should be corrected, particularly since the LDW site is a joint federal-state site, and Washington State does not use the term “natural” for ambient soil or sediment background conditions.

The data selected as “lines of evidence” for estimating ambient concentrations of arsenic, PCBs and dioxins is also problematic. Various existing databases and sampling efforts were sought to determine if sources of chemical data could be found provide information on areas unaffected by this or other contaminated sites. Yet the effort also attempts to distinguish between urban and rural (or non-urban) background areas. This effort would have been better served by a fresh sampling effort with sites chosen for their known and specific characteristics.

One example of using inappropriate sample results from existing data sets is the use of data from another contaminated site, the former Rayonier paper mill in Port Angeles. The data obtained from Dungeness Bay has been incorporated into this data set as an “unaffected” or “background” site. Incidentally, the Dungeness Bay data has not yet been released publicly, so cannot even be reviewed for its application here. Dungeness Bay is down-flow from the Rayonier site and discharge outfall, and thus has been used to determine the extent of contamination from the Rayonier site. While it is true that the Freshwater Bay site was selected as one unaffected by Rayonier activities, the Dungeness site was selected to determine potential impacts on natural resources and on usual and customary fishing resources of the Lower Elwah Klallam Tribe. To our knowledge, no final determination has been made on whether the Dungeness Bay location is affected by the Rayonier site or not. Thus, the use of data from the Rayonier investigation is premature at best. The data from Dungeness Bay obtained from the Rayonier site need to be removed from the analysis.

The assessment of urban sediment conditions also uses data from Commencement Bay, a contaminated site, presumably under the assumption that the data are from areas already remediated. The data from both lakes are from waterways that have no hydrographic characteristics in common with the Lower Duwamish and no justification is given for including them in this assessment.

The sediment data for this section specifically excludes data from CERCLA or MTCA sites that have not been remediated and this exclusion needs to be applied to other data as well. For example, there are tissue data from crabs at the Dungeness Bay/Rayonier Mill site that cannot be used as “reference” data.

The strategy of setting cleanup targets based on a dataset that includes contaminated reference sites or samples is inappropriate. According to this approach, the RI will accept sampling data from urban areas as the baseline against which to compare cleanup of the Lower Duwamish, even if that baseline represents site-specific and unacceptable human and ecological risks and present threats for future generations. This approach will allow contaminated conditions to persist because the contamination is already present, rather than setting cleanup goals to achieve environmental conditions (water, sediment and tissue levels) that protect human health and ecosystems into the future.

Table 7.3 presents the preliminary "background" (ambient) levels of arsenic, PAHs, PCBs and dioxins/furans that will be used to determine cleanup levels for the Lower Duwamish, as discussed in the RI. These values are set with 3 different criteria: 90^{th} percentile of samples, 4 x the 50^{th} percentile, and the mean of a sample set taken by Ecology. The justification for using three different approaches is insufficient and unconvincing.

The PCB analysis is problematic because of the low number of samples (7.1% according to Table 7.2) that actually had PCBs detected above the detection limit. 92.9% of collected samples had no detectable PCBs. One conclusion from this low detection frequency is that background levels of PCBs are usually low to non-detect and may in fact approach zero. PCBs are exclusively anthropogenic in origin and the true natural background condition is zero.

The RI needs to provide the data from which the values in Table 7.3 were determined, for the public to make an assessment of the validity of the data. Similarly, a better explanation and justification must be provided for using 4 x the 50^{th} percentile of a data set, rather than the 50^{th} percentile or 95^{th} C.I. of the mean. The entire explanation on this section asks the reader to accept these numbers on faith.

The RI has not justified the use of the 90^{th} percentile of data for representing the ambient, reference site conditions. If the goal is to truly represent these conditions, then the numerical value should be indicative of average conditions, not the worst of the average conditions. Mean values (arithmetic, geometric or harmonic) are considered representative in a statistical representation, or possibly the upper or lower 95^{th} confidence limit of the mean.

This section fails to account for future background conditions that will be present in 10 or more years. If the goals are to achieve protective conditions and prevent recontamination, then target cleanup levels must make estimates of levels that protect current *and* future conditions. This section relies on past conditions, historical inputs and current conditions, rather than on predicting ambient concentrations of key contaminants (PAHs, PCBs, As, PCDDs/Fs) in 10+ years. This is a particularly glaring omission given the arguments presented elsewhere in the RI that current surface contamination levels are expected to decline; it follows logically that future ambient concentrations are expected to decline as well, particularly for chemicals that are no longer entering the environment, such as PCBs. Indeed, the RI provides some data in Section 9 (Source Control) that indicates inputs of various chemicals are declining and Ecology is seeking to control sources. Based on these efforts, the RI needs to anticipate lower ambient conditions, not constant levels. The data presented in Section 7 do provide some basis for making such estimates and the RI needs to determine those values in developing applicable "background."

Overall, the RI uses higher levels of contamination in local urban waters as justification for setting cleanup values that will maintain a status quo environment, regardless of the harm to human health or the environment. Interestingly, this approach ignores the national policy set out in the Clean Water Act of achieving fishable, swimmable waters. This policy also precludes anticipation future use of the Lower Duwamish River for various recreational, commercial and subsistence uses, despite the known use of the river as such and despite the existence of tribal treaty rights to harvest seafood from the river.

Section 9.0 Potential Pathways, Source Identification, and Source Control Efforts

This section describes an incomplete source control effort and gives it less attention than the other investigative efforts. The focus is on historical contamination with a limited explanation of current conditions. As useful and interesting as the historical information is, addressing historical deposits is only is a small part of the source control required to prevent recontamination. The major purpose of source control is pollution prevention–to keep the river clean once the cleanup has been completed.

The description of the strategy in section 9.2 discusses only sediments and contaminated sites, not discharges into the river, erosion, runoff, stormwater or any comprehensive tracking system for identifying sources based on existing contaminated areas in the river. It is clear that a major re-thinking is needed to address source control for the Duwamish – including shifting more responsibility for funding the sampling and source tracing to the PRPs, rather than continuing to place most of the burden on an underfunded state agency.

The basic strategy for source control does not appear to be focused on the goal of identifying and eliminating ongoing sources. The strategy should have two emphases: 1) tracking back from known contaminated areas to determine the primary sources, and 2) pollution minimization plans on the part of each and every facility along the river or in the river's drainage basin that is known to discharge directly or indirectly into the river.

The first element in the source control description should be the stormwater and effluent discharges described in section 9.4.4. An analysis of the composition of these inputs and determination of the facilities that contribute to these inputs will provide information essential to identifying the primary sources. There is scant evidence in the RI that these sources have been the focus of the source control to date. Table 9.7, showing the CSO outfalls, indicates that, as a group, the CSOs are major contributors to contaminant loading in the Lower Duwamish and require focused attention.

Table 9.9 provides the type of data for just two CSO outfalls that should be presented for all outfalls and effluent discharges. The data in Table 9.9 clearly indicate that these CSOs are major sources of metals and phthalates and must be controlled as aggressively and rapidly as possible.

Knowing that major pollutants are PCBs, phthalates, PAHs, arsenic, TBT, lead and several other compounds provides a starting point for investigating which facilities might be significant ongoing sources.

The RI discusses an investigative effort by Ecology to assess the geographic extent of contamination from the Asarco and Harbor Island smelters. These facilities have both been closed for a long enough period that Ecology should have more information available on the "footprint" from each of these facilities. At the same time, the RI mentions the cleanup standards for lead and arsenic, but these values are not relevant to determining the extent of contamination from the smelters. The data that are relevant are soil lead and arsenic levels as a function of distance and direction from the smelters.

Air sources overall have been inadequately assessed to date. The toxic chemicals of concern from these facilities should be quantified as well as the footprint of their deposition plumes. As an example, why has soil sampling for dioxin/furans not been conducted within the source control area?

Section 9.4.4.2 discusses a modeling effort for sediment contamination from CSOs. The problem with this modeling effort is two-fold. First, the empirical data indicate that the CSOs make significant contributions of metals and organics to the Lower Duwamish, providing sufficient evidence to require controls on these sources. Second, the endpoint apparently used is the sediment standard, rather than the anticipated cleanup level or health protective level. Use of the past modeling appears to be an effort to justify not taking measures to control the CSOs before cleanup.

While it is true that enforceable permit limits are an important tool in reducing contaminant inputs from CSO (and other) discharges, as discussed in 9.4.4.3, the most effective way to control contaminant discharges is eliminating inputs at the source. This source control strategy requires a source tracking effort that identifies the original source. The source control strategy in the RI simply does not give sufficient attention to tracking, identifying and controlling the original sources.

The results of the effluent sampling from the CSO and stormwater system (figures 9-4 through 9-8 and Table 9-8) indicate the extent to which these systems continue to contaminate the Lower Duwamish. The analysis compares the effluent concentrations to the SQS, which are not expected to be sufficient to meet LDW site cleanup levels. A more valuable data set would be total loadings from the stormwater and CSO systems to the river. The RI must quantify the total loadings of these systems to the river because the contamination is an accumulative process that results from the annual loadings and accumulation, not simply the effluent concentrations provided in the report, particularly for persistent and bioaccumulative chemicals.

The business inspection program is a positive step, and needs to be focused on those businesses in the drainage areas of the outfalls of greatest concern. But absent a source tracing effort, much of this program is shooting in the dark for the purposes of achieving source control needed now to protect current and near-term cleanup efforts. Efforts to date have also erred in focusing almost exclusively on business sources while doing little to control other, perhaps more important, sources of chemicals of concern in the river's drainage area.

The description of the inspection program in the RI raises questions regarding the usual and customary practices for inspections of businesses. Facilities that use toxic chemicals, especially those identified as water pollutants in nearby waters, need to be involved in routine programs to prevent pollution via updating operating practices. The Port of Seattle's program of self inspections and permit writing needs more comprehensive oversight and inspection by Ecology. State and federal programs to control and prevent pollution are designed to involve both the permit holder and regulatory agencies. Self-monitoring programs with little or no oversight or inspection component are not as likely to have the same long term success as programs with comprehensive agency inspection.

The data on groundwater measurements provides some of the more useful information on sources of contamination. Ecology should follow up with an assessment of chemical characterization of seeps from these sites into the river. Further chemical analysis of all areas of contaminated groundwater is needed and each site with chemical contaminants should have a remediation plan in place and implement that plan as quickly as possible. Furthermore, the RI makes the error of comparing the groundwater levels to sediment standards when the appropriate comparison is to unaffected groundwater (real background for uncontaminated groundwater). The question here is whether these groundwaters will continue to be sources of chemical contamination for the Lower Duwamish. The data in Table 9-11 indicate that the major contaminants in the Lower Duwamish are present in the contaminated groundwaters, which may be a significant ongoing source. Thus, the long term loadings of chemicals from the groundwater to the Duwamish are a critical issue. The RI did not assess loadings via this pathway and such assessment is necessary in order to determine the role of groundwater as an ongoing source.

Section 9.4.6.2 on porewater, and section 9.4.6.3 on seeps as pathways for contamination provide a small data set that is not sufficient to reach the conclusions contained in the RI. The RI concludes that VOC and metal levels are too low to be of concern as sources, yet there is no quantitative estimate of total loadings to the river. As noted in several sections of these comments, the RI must estimate total loadings to the river system over time because the critical issue in the Lower Duwamish is long term accumulation of chemicals in sediments and biota. The RI explains away the role of seeps and groundwater by assessing concentrations without accounting for flow or long term accumulation. The fact that seep water and pore water contain elevated levels of organic chemicals and metals that are COCs is a clear indication that these sources/pathways must be evaluated more comprehensively before being dismissed as insignificant elements of the source problem. In addition, the RI lacks an assessment of the ability of other contaminants existing in groundwater to mobilize PCBs.

Section 11 Summary of Findings:

The summary needs to include dioxins and furans as risk drivers for both humans and ecological receptors. Having failed to collect additional data because dioxin/furans are known to be elevated, the RI must then accept these chemicals as risk drivers and clearly identify them as such. Dioxins and furans are known to be highly toxic to marine mammals, fish eggs and larvae, developing fetuses, and even clams and mussels. Thus, dioxins/furans must be included as risk drivers in the ecological section, as for human health protection.

The Summary continues to emphasize the importance of "background," "natural background" and non-site related sources of contamination. This discussion makes it clear in this RI that LDWG considers that the determination has been made that cleanup decisions will be based on background levels of contaminants. This is premature. The problem is further compounded by the RIs failure to present a proper assessment of ambient conditions, "dumbing down" the risk assessments contained in the RI. Recent statement from EPA and Ecology appear to confirm that the regulatory agencies have accepted this approach, which would consequently lead to unacceptable, and possibly avoidable, permanent risks to the environment and human health

Maps

3-Dimensional Maps. Please provide maps that show the contamination at depth in a 3-d profile so that the viewer can better picture the configuration and extent of contamination.

Additional maps. DRCC requests that maps similar to ES-2a-c be prepared for all chemicals of concern, especially phthalates.

Sediment Transport Maps. These maps should be recalculated to show ranges of uncertainty.

Map 9.9 (Groundwater). This map should be significantly improved and should include contaminants of concern at each site, as well as including more sites.

Map 11.1. This map should be removed or, if retained, should be recalculated to show uncertainties. This map is premature at this time.

Thank you for the opportunity to provide comments on the Draft RI and Risk Assessments. Please let us know if you have any questions about the points raised above. We look forward to working with you to strengthen and improve the RI and RAs to assure a solid basis for developing a protective cleanup plan for the lower Duwamish River.

Sincerely,

BJ Cummings

BJ Cummings
Coordinator

References

Alzieu C, P Michel, I Tolosa, E Bacci, LD Mee, and JW Readman. 1991. Organotin compounds in the Mediterranean: a continuing cause for concern. Marine Environmental Research. 32: 261-70.

Bauer B, P Fioroni, I Ide, S Liebe, J Oehlmann, E Stroben, and B Watermann. 1995. TBT Effects on the female genital system of Littorina littorea: a possible indicator of tributyltin pollution. Hydobiologia. 309: 15-27.

Bauer B, P Fioroni, U Schulte-Oehlmann, J Oehlmann, and W Kalbfus. 1997. The use of Littorina littorea for tributyltin (TBT) monitoring: results from the German TBT survery 1994/1995 and laboratory experiments. Environmental Pollution. 96: 299-309.

Bellas J, R Beiras, JC Mariño-Balsa, and N Fernández. 2005. Toxicity of organic compounds to marine invertebrate embryos and larvae: a comparison between the sea urchin embryogenesis bioassay and alternative test species. Ecotoxicology. 14(3): 337-53.

Coelho MR, WJ Langston, and MJ Bebianno. 2006. Effect of TBT on Ruditapes decussatus juveniles. Chemosphere. 63(9): 1499-505.

deFur PL, M Crane, C Ingersoll, and L Tattersfield eds. 1999. Endocrine Distruption in Invertebrates: Endocrinology, Testing, and Assessment. SETAC Press. Pensacola, FL.

EPA. August 2006. Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia.

Garman G, R Hale, M Unger, and G Rice. 1998. Fish Tissue Analysis for Chlordecone (Kepone) and Other Contaminants in the Tidal James River, Virginia. Report to the Environmental Protection Agency. Center for Environmental Studies: Virginia Commonwealth University. Richmond, VA.

Gibbs PE, PL Pascoe, and GR Burt. 1987. The use of dog-whelk, Nucella lapillus, as an indicator of tributyltin (TBT) contamination. Marine Biological Association (UK) 67: 507-23.

Gooding MP, VS Wilson, LC Folmar, Marcovich DT, and GA LeBlanc. 2003. The biocide tributyltin reduces the accumulation of testosterone as fatty acid esters in the mud snail (Ilyanassa obsoleta). Environmental Health Perspectives. 111(4): 426-30.

Hagger, JA, MH Depledge, J Oehlmann, S Jobling, and TS Galloway. 2006. Is there a causal association between genotoxicity and the imposex effect? Environmental Health Perspectives. 114 Suppl 1: 20-6.

Harper BL, AK Harding, T Waterhous, and SG Harris. In Press. Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual. EPA Grant EPA-STAR-J1-R831046.

Inoue S, Y Oshima, H Usuki, M Hamaguchi, Y Hamamura, N Kai, Y Shimasaki, and T Tsuneo. 2006. Effects of tributyltin maternal and/or waterborne exposure on the embryonic development of the Manila clam, Ruditapes philippinarum. Chemosphere. 63(5): 881-8.

Inoue S, Y Oshima, K Nagai, T Yamamoto, J Go, N Kai, and T Honjo. 2004. Effect of maternal exposure to tributyltin on reproduction of the pearl oyster (Pinctada fucata martensii). Environmental Toxicology and Chemistry. 23(5):1276-81.

Kuhl, AJ and M Brouwer. 2006. Antiestrogens inhibit xenoestrogen-induced brain aromatase activity but do not prevent xenoestrogen-induced feminization in Japanese medaka (Oryzias latipes). Environmental Health Perspectives. 114(4): 500-6.

Leung KMY, NJ Morley, EPM Grist, D Morritt, and M Crane. 2004. Chronic toxicity of tributyltin on development and reproduction of the hermaphroditic snail Physa fontinalis: Influence of population density. Marine Environmental Research. 58: 157-62.

Leung KMY, RPY Kwong, WC Ng, T Horiguchi, JW Qiu, R Yang, M Song, G Jiang, GJ Zheng, and PKS Lam. 2006. Ecological risk assessments of endocrine disrupting organotin compounds using marine neogastropods in Hong Kong. Chemosphere. 65(6): 922-38.

Leung KMY, EPM Grist, NJ Morley, D Morritt, and M Crane. 2007. Chronic toxicity of tributyltin to development and reproduction of the European freshwater snail Lymnaea stagnalis (L.). Chemosphere. 66(7): 1358-66.

Lyssimachou A, BM Jenssen, and A Arukwe. 2006. Brain cytochrome P450 aromatase gene isoforms and activity levels in atlantic salmon after waterborne exposure to nominal environmental concentrations of the pharmaceutical ethynylestradiol and antifoulant tributyltin. Toxicological Sciences. 91(1): 82-92

McAllister BG and DE Kime. 2003. Early life exposure to environmental levels of the aromatase inhibitor tributyltin causes masculinisation and irreversible sperm damage in zebrafish (Danio rerio). Aquatic Toxicology. 65(3): 309-16.

Nakayama K, Y Oshima, T Yamaguchi, Y Tsuruda, IJ Kang, M Kobayashi, N Imada, and T Honjo. 2004. Fertilization success and sexual behavior in male medaka, Oryzias latipes, exposed to tributyltin. Chemosphere. 55(10): 1331-7.

Oliveira Ribeiro CA, F Filipak Neto, M Mela, PH Silva, MAF Randi, IS Rabbito, JRM Alves Costa, and P Pelletier. 2006. Hematological findings in neotropical fish Hoplias malabaricus exposed to subchronic and dietary doses of methylmercury, inorganic lead, and tributyltin chloride. Environmental Research. 101(1): 74-80.

Reddy PS, R Sarojini, and R Nagabhushanam. 1991. Impact of tributyltin oxide (TBTO) on limb regeneration of the prawn Cardina rajadhari, after exposure to different time intervals of amputation. Journal of Tissue Research. 1:35-39

Santos MM, MA Reis-Henriques, MN Vieira, and M Solé. 2006. Triphenyltin and tributyltin, single and in combination, promote imposex in the gastropod Bolinus brandaris. Ecotoxicology and Environmental Safety. 64(2): 155-62.

Schmidt K, CEW Steinberg, S Pflugmacher, and GBO Staaks. 2004. Xenobiotic substances such as PCB mixtures (Aroclor 1254) and TBT can influence swimming behavior and biotransformation activity (GST) of carp (Cyprinus carpio). Environmental Toxicology. 19(5): 460-70.

Unger MA, WG MacIntyre, and RJ Huggett. 1988. Sorption behavior of tributyltin on estuarine and freshwater sediments. Environmental Toxicology and Chemistry. 7:907-15.

Weis JS, J Gottlieb, and J Kwiatkowski. 1987. Tributyltin retards regeneration and produces deformities in the fiddler crab, Uca pugilator. Archives of Environmental Contamination and Toxicology. 16:1287-1294.