DEPARTMENT OF THE ARMY
SAN FRANCISCO DISTRICT, U.S. ARMY CORPS OF ENGINEERS
455 MARKET STREET
SAN FRANCISCO, CALIFORNIA 94103-1398

AND

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 HAWTHORNE STREET
SAN FRANCISCO, CALIFORNIA 94105

June 9, 2011

Mr. Robert S. Hoffmann
Assistant Regional Administrator for Habitat Conservation
National Marine Fisheries Service, Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

SUBJECT: Agreement on Programmatic EFH Conservation Measures for Maintenance Dredging Conducted Under the LTMS Program (Tracking Number 2009/06769)

Dear Mr. Hoffman:

The Long Term Management Strategy (LTMS Program) has been remarkably successful in significantly reducing the effects of dredging on fisheries and aquatic habitat in San Francisco Bay, as well as enhancing the quality and quantity of aquatic habitat. Today, the LTMS agencies[i] are pleased to build upon that success with the enclosed comprehensive suite of conservation measures developed with your staff pursuant to the Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). These measures complete our programmatic consultation covering all maintenance dredging projects conducted under the LTMS Program. While we formally initiated consultation by our letter of July 21, 2009, this product represents a collaborative effort with your Santa Rosa office staff dating back to 2004. We very much appreciate the tremendous amount of work put in by everyone concerned to finish this major effort.

Completion of this programmatic EFH consultation is a significant milestone for the LTMS program, and for the health of the Bay. The conservation measures will further protect and enhance essential fish habitat, increase predictability for dredging projects, further streamline the regulatory process, and reduce agency and project sponsor workloads. In particular, the LTMS Program will:

- Work to reduce the frequency of dredging where practicable
- Continue to reduce in-Bay disposal and increase beneficial reuse of dredged material where practicable
- Ensure that direct and indirect effects to eelgrass are minimized through use of appropriate Best Management Practices, monitoring, and mitigation
- Conduct scientific studies to better understand recolonization of soft-bottom habitats in the Bay following disturbance from dredging
- Increase the predictability of in-Bay testing requirements by establishing numeric sediment chemistry guidelines for bioaccumulation testing and post-dredge sediment surface characterization (residual or "z-layer" sampling)

- Improve annual reporting to NMFS by the federal agencies, especially concerning any projects affecting eelgrass or encountering elevated levels of chemicals of concern in the sediment

We agree that the measures described in detail in the enclosure are appropriate and are feasible to implement, subject to availability of funding. We look forward to continuing to work closely with the National Marine Fisheries Service to protect and enhance fishery habitat in San Francisco Bay, while managing necessary maintenance dredging projects in a practicable, sustainable and environmentally sensitive manner.

If there are any questions regarding this letter, please contact us, or Ms. Cynthia Jo Fowler of the USACE (415.503.6870, or Cynthia.J.Fowler@usace.army.mil); Mr. Robert Lawrence of the USACE (415.503.6808, or Robert.J.Lawrence@usace.army.mil); or Mr. Brian Ross of the USEPA (415.972.3475, or Ross.Brian@epa.gov).

Sincerely Yours,

Alexis Strauss
Director, Water Division
U.S. EPA Region 9

Torrey DiCiro
Lieutenant Colonel, U.S. Army
Commander, San Francisco District

Enclosure

A copy of this letter was sent to Mr. Chris Yates, Mr. Bryant Chesney, and Mr. Dick Butler of the NMFS; Mr. Bruce Wolfe, Ms. Beth Christian, and Ms. Naomi Feger of the SFRWQCB; Mr. Will Travis, Mr. Steve Goldbeck, and Ms. Brenda Goeden of BCDC; Ms. Susan Moore and Mr. Ryan Olah of the USFWS; Ms. Maria Vojkovich and Ms. Vicki Frey of the CDFG; and Mr. Cy Oggins and Mr. Donn Oetzel of the SLC.

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[i] The LTMS agencies include the United States Army Corps of Engineers (USACE) and the United States Environmental Protection Agency (USEPA), the San Francisco Bay Conservation and Development Commission (BCDC) and the San Francisco Regional Water Quality Control Board (RWQCB)

Programmatic EFH Conservation Measures for the LTMS Program Agreed-upon by USACE, EPA, and NMFS

The following conservation measures apply to all maintenance dredging and disposal operations conducted in accordance with the LTMS program. The NMFS's original Conservation Recommendations (CR) are summarized below, followed by a description of the measures USACE, EPA and NMFS have agreed will satisfy each CR. (Note that in some cases the original CRs' measures differ substantially from what the agencies ultimately agreed is appropriate to implement under the LTMS Program.)

A. Soft bottom habitat permanent disturbance (prey loss)

1. To minimize adverse effects to soft bottom benthic foraging habitat, NMFS recommends that the USEPA and USACE conduct a benthic recovery study to validate the assumptions in the effects analysis that recovery of benthic community occurs in areas that are dredged less frequently than once per year. If the results of the study indicate that recovery takes 1 to 2 years, minimization measures will be required to account for approximately 664 acres of soft bottom foraging habitat; if the study indicates that recovery takes longer than 3 years, minimization or mitigation will be required for up to 3,312.3 acres of soft bottom foraging habitat; if the study indicates that recovery takes 1 year or less, then effects may be considered accounted for by current LTMS Environmental Protective Measures and no further actions will be required.

USACE, EPA and NMFS agree that at this time compensatory mitigation for periodic disturbance of soft bottom benthic habitat by routine navigation maintenance dredging under the LTMS Program is not recommended under this programmatic EFH consultation. However, the LTMS Program will develop and implement a benthic community disturbance and recolonization study for San Francisco Bay in order to advance the state of knowledge concerning this issue. This multi-year study will evaluate differences in soft bottom benthic communities in areas dredged at different frequencies and in different sediment types and depths, in comparison to similar areas not disturbed by dredging. Seasonal differences will also be addressed. The study will also evaluate recolonization by natives versus non-natives in the areas sampled. Study design and management questions will be developed beginning in 2011, with study implementation beginning in 2012, depending on availability of funding. At the completion of the study, the LTMS Program will present the initial findings to NMFS and the public, and will coordinate scientific peer-review. The relevance of original CR 10 (Enhancement of Native Benthic Species) will be reconsidered based on the results of this benthic disturbance and recolonization study.

2. To minimize adverse effects to soft bottom benthic foraging habitat, NMFS recommends that the USACE and USEPA encourage practices that reduce the frequency of dredging in an area when possible and when not in conflict with sensitive areas (i.e., eelgrass) recommendations. This may include:

Programmatic EFH Conservation Measures for the LTMS Program
Agreed-upon by USACE, EPA, and NMFS

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a. Dredging areas to the authorized design depth (not including overdepth) in a single episode, rather than dredging to lesser depths in multiple episodes.

We agree. We already implement this practice where possible, and will continue to do so. Unnecessary dredging in the Bay is not encouraged; however, we cannot require project proponents to dredge more than their economics allow. Only those areas that are shallower than the design depth are authorized to be dredged – dredging only the overdepth is not authorized. This minimizes impacts by decreasing the footprint of the dredge area and minimizing the volume dredged and placed at aquatic disposal sites. However, an overdepth allowance must always be included in project authorizations and in fact helps to reduce the need for more frequent dredging. In addition, we consider authorizing "advance maintenance" dredging in instances where it has the potential to reduce dredging frequency in the future.

b. Discourage the initiation of dredging at times when it is unlikely that dredging will be completed in a single episode.

We agree. We already implement this practice where possible, and will continue to do so. When projects are proposed late in the dredging work window, the DMMO requests that the project proponent provide evidence that the project can be completed within the work window. If dredging on the project must begin but cannot be completed within the work window, it is required to stop at the end of the work window and resume the following year when the work windows reopen, unless it is granted an extension from NMFS based on project-specific ESA consultation.

c. Rotating areas within a project footprint to be dredged when the entire area cannot be dredging to the authorized design depth (not including overdepth) in a single episode. This would result in the dredging of one area to design depth in a single episode and dredging of another area to design depth in a subsequent episode rather than dredging smaller amounts from both areas simultaneously in multiple episodes.

We agree. We already implement this practice where possible, and will continue to do so. Project proponents typically do not dredge the same area in subsequent episodes, unless that area continually shoals. Shoaling patterns in the Bay are dynamic and, as a result, we cannot dictate where dredging needs to take place. In some cases, a hazardous shoal occurs in the same place every year and it must be removed to allow safe navigation. In addition, project proponents will sometimes phase the work for reasons such as economics, equipment availability, or logistics. In such a situation, project proponents will sometimes fully dredge one area as a single episode, and another area will be dredged in a subsequent episode. Depending on deposition rate, several years might pass before a given area is dredged again, or the same area may require dredging every year. Whatever the necessary frequency, as noted above, an overdepth allowance must always be included in project authorizations and in fact helps to reduce the need for more frequent dredging at that location.

3. To minimize or mitigate for uncompensated adverse effects to soft bottom benthic foraging habitat, NMFS recommends that the USACE and USEPA fund a single NMFS fishery biologist position to specialize in all dredge related activities. This position would help address loss of fish foraging habitat by allowing NMFS to actively participate in the LTMS Science Committee. The USACE, USEPA and NMFS are authorized to enter into an Interagency Reimbursable Agreement pursuant to the Economy Act (31 U.S.C. 1535), which provides that an agency may place an order with a major organizational unit within another agency for goods or services.

In previous meetings and discussions we highlighted a number of legal difficulties that could constrain our ability to comply with this request, and provided supporting discussion about relevant provisions of the Economy Act for NMFS's information. We also discussed concerns about whether NMFS's request would constitute an inappropriate augmentation of Congressional appropriations. Basically, an inappropriate augmentation of appropriations occurs when the work to be done is for the benefit of the agency receiving the augmentation, as opposed to benefitting the agency providing the augmentation. In this case NMFS has asked for USACE and USEPA to fund a NMFS position in order to allow NMFS to better carry out its own responsibilities, by participating more fully in DMMO and LTMS activities.

Even though we will not fund a NMFS fishery biologist position, the LTMS agencies have always encouraged and continue to encourage NMFS's active participation in DMMO and the LTMS Program. We hope that completion of this programmatic EFH consultation (along with the separate, pending programmatic Endangered Species Act consultation) may help allow NMFS staff to participate more often.

B. Eelgrass indirect effects (refugia loss)

4. To avoid and minimize adverse effects of turbidity on eelgrass, NMFS recommends that the following BMPs be implemented for any dredge project identified as having the potential to indirectly affect eelgrass (Table 6). To determine which BMP is appropriate for an individual project, a systematic approach has been developed as an easy to use flowchart (Appendix 2).

a. <u>Avoidance:</u> Under the following conditions, no turbidity effects are expected, therefore no additional minimization BMPs required:

(i) Using a hydraulic dredge, no overflow,
(ii) Dredging in sand (>80% sand) substrate,
(iii) Physical barriers or site-specific hydrodynamics prevent turbidity plumes from dispersing to the adjacent eelgrass.

b. <u>Minimization:</u> Under the following conditions, turbidity effects are expected, therefore additional minimization BMPs are required:

(i) Using a mechanical dredge
(ii) Dredging in fine sediment (<80% sand) substrate
(iii) Currents may disperse suspended sediments to adjacent eelgrass.

For projects listed in Table 6 of NMFS's July 14, 2010 consultation response (reproduced here as **Attachment 1**), the LTMS Program will implement the avoidance and minimization measures discussed below, in a manner consistent with the flowchart in Appendix 2 of NMFS's July 14, 2010 consultation response (reproduced here as **Attachment 2**).

Examples of turbidity minimization measures include silt curtains, light monitoring, and any other operational control, subject to NMFS approval.

(a) Silt Curtains

There are approximately 40 dredging project listed in Attachment 1 as having potential indirect impacts on eelgrass beds within 250 meters of the project. While this table lists projects individually, some have several components such as the Port of San Francisco or Port of Oakland. In these cases, only certain areas within the overall project are within 250 meters of eelgrass. In addition, in some cases the use of turbidity curtains is limited or inappropriate due to current speed or other specific conditions of the site. Therefore, the LTMS Program will require turbidity curtains on a case-by-case basis, and report on which projects utilize them in the annual report discussed later in this response.

(b) Light Monitoring

When turbidity curtains are not employed, light monitoring will be required as described in the July 14, 2010 NMFS consultation letter. In general, examination of light monitoring data from three episodes of a project will be used to determine the necessity of further light monitoring that and similar projects. However, in addition the LTMS Program will compile and analyze data from all light monitoring projects to determine whether we may recommend programmatic reconsideration of the size of the indirect effects buffer area needed in the future. It is anticipated that such information will take a few years to gather. Once available, the LTMS Program will present the initial findings to NMFS and the public, and will coordinate scientific peer-review as appropriate.

(c) <u>**Additional Operational Controls:**</u> **The following list of operational BMPs should be employed maximally for all dredging projects. However, they should be applied more judiciously when indirect turbidity effects on eelgrass are possible. When implementation of any of the above avoidance and minimization BMPs is not feasible, then the following should be considered in combination with light monitoring to verify their effectiveness.**

- **(i) Increased cycle time / reduced bucket deployment: longer cycle times reduce the velocity of the ascending bucket through the water column, which reduces potential sediment wash from the bucket.**
- **(ii) Consider alternate equipment: if all other avoidance and minimization measures have failed to effectively reduce turbidity effects on eelgrass, consider equipment with lower likelihood of generating turbidity, *e.g.*, use an environmental bucket instead of an excavator.**

The LTMS program will include such additional operational controls for projects deemed to have potential indirect impacts to eelgrass, as appropriate.

c. <u>Exclusion:</u> If USACE or USEPA determine that none of the above avoidance or minimization measures are implementable or provide sufficient turbidity reduction for a specific project, then that project is not covered by this programmatic consultation and must undergo individual consultation with NMFS.

USACE will conduct separate consultation with NMFS for projects (or episodes) in Table 6 that it determines cannot implement sufficient turbidity reduction measures.

C. Eelgrass direct effects (refugia loss)

5. In all cases where eelgrass is found directly in the dredge project area, NMFS recommends that every effort be made to avoid direct removal or burial. In cases where avoidance is not possible, impacts to eelgrass must be mitigated for to achieve no net loss of eelgrass or suitable eelgrass habitat. Populations of eelgrass are highly dynamic, and the exact location and extent of eelgrass beds can change across seasons and years. As discussed in V.D.3.b above, the 45 m buffer around the 2003/2009 mapped eelgrass extent accounts for areas between patches, temporal variation in bed extent, and area for potential bed expansion. Therefore, in all cases where the project area overlaps with the 45 m buffer around eelgrass (table 6) NMFS recommends that the project must mitigate for those direct effects using one of the options described below.

Independent of which mitigation option is chosen, a mitigation plan shall be prepared in accordance with the USACE's 2004 Final Mitigation Guidelines and Monitoring Requirements, acknowledging that mitigation within subtidal and marine waters does not always fit well within all aspects of this guidance.

Mitigation Option #1

USACE and USEPA may establish an eelgrass mitigation bank to compensate for direct impacts to eelgrass within their project footprints that they are unable to avoid.

Mitigation Option #2

The USACE and USEPA may continue to mitigate on a project-by-project basis:

a. **For individual projects with eelgrass occurring in the project footprint, prior to the start of dredging operations, eelgrass and potential eelgrass habitat directly within and adjacent to the dredge footprint will be mapped and measured for area and density. The extent of adjacent areas to be mapped should be determined on project-by-project basis depending on site-specific conditions. An area and density survey report of the eelgrass will be submitted to NMFS for approval within 30 days of the start of dredging activities.**

b. **To protect eelgrass outside the project footprint, BMPs to avoid and minimize indirect effects of turbidity (section VI.B.4, Appendix 2) will be strictly employed as appropriate.**

c. **Eelgrass directly adjacent to the dredge footprint will be marked with buoys to ensure vessel traffic/barges avoid those areas. Dredging equipment will not be located to the maximum extent possible, temporarily or at anchor, in eelgrass areas outside the project footprint.**

d. **If NMFS determines dredging has adversely impacted eelgrass in the project area based on monitoring observations or comparison of pre- and post-dredging surveys, the applicant must provide NMFS with an eelgrass Mitigation Plan within 60 days of completing the post- dredge survey. All Mitigation Plans that have not been previously approved by NMFS will be subject to any existing or forthcoming NMFS Eelgrass Mitigation Policies (currently the Southern California Eelgrass Mitigation Policy, Appendix 4).**

Mitigation Option #3

Alternative mitigation plan: The USACE and USEPA may develop an alternative in-kind mitigation plan for impacts to eelgrass from dredge related activities subject to NMFS approval. This programmatic consultation will not cover projects listed in table 6 with direct impacts to eelgrass as determined by direct overlap with the 45 m buffer until the alternative mitigation plan is approved by NMFS and implementation is successful. Until the alternative plan is developed, approved, and implemented, mitigation will be done on a project-by-project basis as described in Mitigation Option #2.

At this time the LTMS Program will continue to work with NMFS to require mitigation on a project-by-project basis as described in Option #2. We will require projects whose proposed dredge footprint intersects the 45 meter buffer described above to conduct surveys (within the proposed dredge footprint only). We will provide information annually to NMFS regarding eelgrass directly impacted by dredging projects and the mitigation that was subsequently required. Also, in conjunction with NMFS and potentially with LTMS stakeholders, the LTMS Program will pursue Option 3 by evaluating the feasibility of developing a mitigation bank that could be used in the future by the federal government and/or the non-federal dredging community as a potential alternative to conducting continued project-specific surveys and mitigation.

D. Turbidity

6. <u>Reduce in-Bay disposal:</u> To avoid or minimize adverse effects from disposal related turbidity, NMFS recommends that USACE and USEPA further reduce in-Bay disposal. This may include:

(a) Outfitting USACE hopper dredges to be compatible with and to use offloader equipment for out-of-Bay placement of sediment.

Possible hopper dredge retrofit is out of local USACE control, but is being considered separately by USACE (nationally).

(b) Encouraging or facilitating non-federal dredge projects to use available offloaders for out-of-Bay placement of sediment.

We agree. We already implement this practice where possible, and will continue to do so. USACE was able to successfully include provisions in the most recent federal contract for operation of the offloader at the Hamilton Wetland Restoration Project that allowed non-federal dredging projects to offload suitable material to the site at a predictable cost. This provision made non-federal use of the offloader more feasible for this project, and may serve as a model for future federal offloader contracts in the region.

E. Contaminants

7. <u>Bioaccumulation testing:</u> NMFS recommends that USEPA and USACE discretionary authority to require bioaccumulation evaluations (and/or alternatives to in-Bay disposal) be more clearly defined, with clear triggers for testing and subsequent permitting decisions. Specifically, bioaccumulation testing should be required for in-Bay disposal when dredged material contains PCBs, PAHs, DDTs, Dieldrin, chlordane, dioxins/furans, or mercury above Bay ambient levels or above bioaccumulation triggers used elsewhere in the Northern Pacific. If bioaccumulation is confirmed, the dredged material must be declared unsuitable for in-Bay disposal. This procedure is to remain in place until other sediment bioaccumulation trigger levels, or other tools to assess bioavailability, are developed.

We agree with the need to more clearly define when bioaccumulation testing will be required for dredging projects proposing placement at in-Bay disposal sites. However, neither Bay ambient sediment concentrations, nor bioaccumulation triggers used elsewhere in the Northern Pacific, are necessarily the most appropriate triggers for all of the bioaccumulative compounds listed. For example, for some chemicals Bay ambient sediment concentrations are not expected to result in bioaccumulation to levels of significant concern for biological effects, and the increased expense of bioaccumulation testing would not be justified in such cases. Therefore we will implement an approach that uses a variety of bases for establishing initial trigger levels for the different contaminants, as follows. (The resulting initial trigger levels are presented in **Table 1** below.)

Mercury, PAHs, and PCBs

For mercury, PAHs and PCBs we will use current San Francisco Bay ambient sediment concentrations (a non-degradation approach appropriate when ambient concentrations are elevated above desirable levels or above TMDL targets). We will follow an approach consistent with that used in the Pacific Northwest's Sediment Evaluation Framework (SEF). Specifically, as described in **Attachment 3**, San Francisco Bay ambient sediment concentrations will be calculated regularly for mercury, PAHs and PCBs as the 90^{th} percent upper confidence level (CL) of the 90th percentile of the most recent 10-years[1] of data from the Regional Monitoring Program (RMP) sediment sampling stations, after removal of statistical outliers to eliminate any highly contaminated samples. This approach results in a "reference" ambient condition for regulatory use that is different from the Bay-wide average sediment concentrations reported by the San Francisco Estuary Institute (SFEI) in its RMP "Pulse of the Estuary" reports (which are calculated as means, and without removing outliers). It also results in bioaccumulation triggers below each year's TMDL limits for mercury and PCBs, which are based on the 99^{th} percentile of the running 10-year RMP results.

DDTs, Chlordane, and Dieldrin

For DDTs and total Chlordane, we will use the bioaccumulation trigger levels (BTs) for Puget Sound marine sediments currently published in the DMMP Users Manual (November 2009). However, there is no established Puget Sound BT for Dieldrin. So for Dieldrin we will initially use the marine sediment screening level (SL) published in the Sediment Evaluation Framework for the Pacific Northwest (SEF, May 2009) as a BT. (The Puget Sound DMMP agencies recently proposed to revise their SL for Dieldrin to use the same value as the SEF.)

1 Beginning in 2002, the RMP improved the manner in which stations were selected by randomizing stations to remove any regional bias. This change makes it inappropriate to include pre-2002 data. Therefore ambient values will initially be based on only the post-2002 samples. By the time 2011 data are collected and included in the calculations, a full 10-year running average will again be the basis of these ambient calculations.

Dioxins/Furans

For dioxins/furans we will use a bioaccumulation trigger value of 10 pptr TEQ, which is slightly above national and west coast background concentrations, but well below the USFWS-established maximum value for wetland restoration at the local Hamilton Wetland Restoration Project (20 pptr TEQ). The bioaccumulation trigger value is consistent with the Puget Sound limit for unconfined aquatic placement of individual Dredged Material Management Units (10 pptr TEQ). EPA's extensive survey of San Francisco Bay sediment for dioxins/furans in 2000 found that less than 10 percent of all the stations sampled exceeded 10 pptr TEQ. [2]

Table 1. Initial (2011) Sediment Chemistry Bioaccumulation Trigger (BT) Levels, for Unconfined in-Bay Placement at Designated San Francisco Bay Disposal Sites

	Mercury (mg/kg)	**Total PAHs** (µg/kg)	**Total PCBs** (µg/kg)	**Total DDTs** (µg/kg)	**Total Chlordane** (µg/kg)	**Dieldrin** (µg/kg)	**Dioxins/ Furans** (pg/g)
Bioaccumulation Trigger (Initial)	0.33	4800	16	50	37	1.9	10
Basis	a	a	a	b	b	c	d

Notes:

a) Ambient sediment concentration for total mercury in *mg/kg* (parts per million) dry wt, and for PAHs and PCBs in *µg/kg* (parts per billion) dry wt, defined as the 90^{th} upper CL of the 90^{th} percentile of the most recent 10 years of data from the RMPs randomized Bay-wide sediment sampling (currently for the years 2002-2009), after removal of statistical outliers.

b) Published bioaccumulation trigger for the chemical class for Puget Sound marine sediments, in *µg/kg* (parts per billion) dry wt.

c) Published marine SL value from the Pacific Northwest Sediment Evaluation Framework, in *µg/kg* (parts per billion) dry wt.

d) Toxicity Equivalency Quotient (TEQ), in *pg/g* (parts per trillion) dry wt calculated based on WHO 1998 Toxicity Equivalency Factors (TEFs). Value is consistent with the published Puget Sound limit for unconfined aquatic disposal, and is ½ the established limit for placement at the Hamilton Wetlands Restoration Project site.

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2 Note that both sediment chemistry analysis and bioaccumulation testing for dioxins/furans will only be required in areas that are expected or have been shown (e.g., via EPA's 2000 Estuary-wide survey, ongoing RMP monitoring, or past project-specific testing) to have elevated dioxin/furan levels.

Implementation and Interpretation of Bioaccumulation Testing

We will require up front bioaccumulation testing for dredging projects proposing placement at in-Bay disposal sites when we determine (e.g., based on recent testing) there is reason to believe that sediment concentrations are likely to exceed any of the trigger levels in Table 1.[3] If we did not initially require bioaccumulation testing for a project, but the sediment chemistry results show unexpected exceedences of the trigger levels in Table 1, we will generally allow the project proponent the following options:

1) initiate bioaccumulation testing on that sediment if archived samples are still within bioassay holding times (8 weeks since sample collection), or
2) conduct higher-resolution chemical evaluation in order to identify the smallest volume needing bioaccumulation testing; and/or
3) propose an alternative to in-Bay placement.

However, if only very minor exceedences of the trigger levels in Table 1 are found in limited areas, we may in some cases determine that additional testing is not needed to reach a suitability determination. This may particularly be the case for "small dredger" projects, as defined in the LTMS Management Plan. The small dredger class is generally exempt from alternatives analysis requirements, and as a group accounts for an average of only 250,000 cubic yards of dredging per year or less. Individual projects are generally much smaller than this; and the risks associated with placement of small volumes of material with only small exceedences of the trigger levels in Table 1 are minimal. However, even small dredger projects will be required to conduct bioaccumulation testing when larger or widespread exceedences of the values in Table 1 are expected or found, especially if the dredging episode volume is relatively large. In such cases we would expect to offer small dredgers the same options as described above.

In the longer term, modifications/improvements to this general testing approach (including to the trigger levels in Table 1) may be made based on evaluation of accumulated testing results, advancements in testing or evaluation tools, changes in Bay ambient sediment concentrations, implementation of new sediment TMDLs, etc.

Note that interpretation of bioaccumulation results is rarely straightforward. It involves case-by-case consideration of laboratory bioaccumulation test results (tissue concentrations) relative to reference results, appropriate toxicity reference values (TRVs), estimates of expected organism exposure (areal and temporal), and other factors. In addition, our final suitability determinations also must take into account project-specific issues such as practicability of available alternatives, aquatic placement volumes, and other factors that may affect whether risks associated with disposal are avoidable or unacceptable. Since this evaluation must occur on a case-by-case basis, we generally cannot establish bright-line thresholds for bioaccumulation results that would pre-determine sediments to be unsuitable for in-Bay placement in all cases.

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[3] Where we have adequate information from past bioaccumulation testing, or from recent testing at representative adjacent projects, we may determine that testing is not needed for every episode of every such project.

8. **<u>Residuals:</u> NMFS recommends that if dredging results in the exposure of new surface material having higher chemical concentrations than the sediment that was dredged or which exceeds the ambient concentration of surrounding areas for the contaminants of concern listed in CR 7 above, then the parcel must be managed to prevent exposure to the contamination and further degradation of EFH if testing of the new sediments exposed shows toxicity or bioaccumulation of contaminants. This may warrant over-dredging and subsequent backfill to planned project depth. The exact details will need to be determined on a case-by-case basis.**

We agree with the need to make the collection and analysis of residuals samples (representing the sediment surface expected to be exposed after dredging is completed, defined here as the 6-inch layer immediately below permitted overdepth) more systematic. We will implement an appropriate testing approach as described below. This approach will be based on the same sediment chemistry bioaccumulation trigger levels discussed above for the Bay overall (as opposed to requiring dredging projects to determine more specific local background concentrations in their vicinity).

The LTMS agencies will require collection, archival, and analysis of residual-depth sediment samples (the 6-inch layer immediately below permitted overdepth), generally as follows:

1) For all dredging projects where we have reason to believe (e.g., based on recent testing) that overlying sediment concentrations may exceed any of current the bioaccumulation testing trigger levels, residual samples will be collected at each core location and archived separately from the overlying portion of the sample. If testing of the overlying sediment (typically an area composite) confirms that any of the bioaccumulation testing trigger values is exceeded, analysis of a composite of the archived residual samples underlying that sediment will be required.
2) If higher-resolution sampling of a composite test area is conducted for chemical evaluation (e.g., to more precisely identify the extent of contamination), residual samples will also be collected from each such core location and analyzed separately from, but in the same manner as, the overlying sediment samples (e.g., as individual cores, or smaller composited areas).
3) If residual samples were not required initially, but the overlying sediment chemistry results show unexpected exceedences of the current trigger levels, we will require separate pre- or post-dredge sampling and testing of the residual surface to confirm whether contamination persists at depth. (However, if only very minor exceedences of the trigger levels are found in limited areas of the overlying sediment, we may in some cases determine that follow-up residual sampling and testing is not warranted.)
4) If residual layer contamination is greater than that in the overlying sediment and exceeds the current trigger values, consideration of the need for potential management actions to address the residual contamination will be done on a case-by-case basis. However, LTMS is not a remediation program. In general, where sediment contaminant concentrations are found to be substantially elevated at depth, and the source and extent are unknown, the LTMS agencies would typically refer the project to other programs for further investigation.

9. To minimize or mitigate for adverse effect to EFH from contaminants, NMFS recommends that the USACE and USEPA fund a single NMFS fishery biologist position to specialize in dredged related activities. This position would minimize adverse effects from contaminants by allowing the NMFS to actively participate in the DMMO. The USACE, USEPA and NMFS are authorized to enter into an Interagency Reimbursable Agreement pursuant to the Economy Act (31 U.S.C. 1535) which provides that an agency may place an order with a major organizational unit within another agency for goods or services.

Please see response to CR 3, above.

F. Invasives

10. To minimize adverse effects to EFH from invasive species, NMFS recommends that the USACE and USEPA establish a working group tasked with evaluating the feasibility of enhancing native benthic invertebrate species in the San Francisco Estuary. The working group should assess methodologies, enhancement sites, suitable species, and appropriate monitoring. Based on the outcome of the working group, a pilot study should be designed to determine if reintroduction of the native benthic invertebrate species into the estuary is feasible. If the results of the pilot study determine that this is feasible, then a program should be implemented that will fully compensate for the annual impact to benthic habitat from dredging activities. If determined infeasible, or the scope does not fully compensate for impacts, then the USACE and USEPA will develop alternative measures to compensate for impacts to EFH.

USACE, EPA and NMFS acknowledge that there are significant uncertainties surrounding the degree to which disturbance from routine maintenance dredging may be related to any increase in the presence of non-native benthic species in San Francisco Bay. We have agreed that this CR will be held in abeyance pending the outcome of the benthic disturbance and recolonization investigation discussed in CR 1 above. At that time we will reconsider this issue to the extent appropriate.

11. To minimize or mitigate for adverse effect to EFH from invasive species, NMFS recommends that the USACE and USEPA fund a single NMFS fishery biologist position to specialize in dredge related activities. This position would account for adverse effects from invasive species by allowing the NMFS to actively participate in the LTMS Science Committee.

Please see response to CR 3, above.

G. Other Submerged Vegetation

12. To avoid adverse effects to EFH and HAPC, in all cases where native submerged aquatic vegetation, other than eelgrass, (e.g., *Ruppia*, *Stuckenia/Potamogetan*), is found directly in the dredge project area, NMFS recommends that every effort be made to avoid direct removal or burial. In cases where avoidance is not possible, mitigation should occur to compensate for adverse effects:

a. For individual projects with native submerged aquatic vegetation occurring in the project footprint, prior to the start of dredging operations, native submerged aquatic habitat directly within and adjacent to the dredge footprint will be mapped and measured for area and density. The extent of adjacent areas to be mapped should be determined on project- by-project basis depending on site-specific conditions. An area and density survey report of the native submerged aquatic vegetation will be submitted to NMFS for approval within 30 days of the start of dredging activities.

b. If NMFS determines dredging has adversely impacted native submerged aquatic vegetation in the project area based on monitoring observations or comparison of pre- and post-dredging surveys, the applicant must provide NMFS with a Mitigation Plan within 60 days of completing the post-dredge survey. The mitigation plan should be prepared in accordance with the U.S. Army Corps of Engineers' (USACE) 2004 Final Mitigation Guidelines and Monitoring Requirements, acknowledging that mitigation within subtidal and marine waters does not always fit well within all aspects of this guidance.

NMFS has now contracted with San Francisco State University to conduct a qualitative survey of sago pondweed and widgeon grass in San Francisco Bay. This information will be provided to USACE and EPA as soon as it is available, to assist in project assessments under the LTMS Program. At that time, the LTMS Program may conduct follow-up surveys, and/or require dredging projects in the immediate vicinity of initially-mapped submerged vegetation to conduct surveys and take avoidance, minimization, or mitigation measures as appropriate.

H. Reporting Requirements

13. To avoid adverse effects to EFH that may occur from improper utilization of this programmatic consultation, NMFS recommends that the USACE provide annual reports to the NMFS on all activities conducted under this programmatic consultation. Reports should be submitted to the NMFS within 90 days of the end of each calendar year.

We agree. For its federal dredging, the USACE will provide the information recommended in this Conservation Recommendation. For non-federal dredging, 90 days might not be enough time to collect all the requested information. The DMMO will provide this information to the

NMFS as soon as the information is compiled and available for distribution. The federal dredging reports may be provided separately from the non-federal dredging reports.

14. To avoid adverse effects to EFH that may occur from improper utilization of this programmatic consultation, NMFS recommends that the USACE notify the NMFS of (a) when a project will indirectly affect eelgrass and which BMP is being used (inclusion of the BMP in the Public Notice and submission of the notice to the NMFS is satisfactory); (b) when a project will directly impact eelgrass and what mitigation is proposed; and (c) when a project has contaminant loads above those indicated in Conservation Recommendation 7 and how the material will be disposed.

For its federal dredging, the USACE will provide notification to the NMFS prior to dredging. The notification will include which projects may directly and/or indirectly impact eelgrass and which BMPs and mitigation measures will be employed as part of the dredging. USACE will also supply the NMFS with federal project sediment sampling and testing reports, and indicate where dredged sediment will be placed.

For non-federal dredging, the NMFS will receive Public Notices for new permits which will include general EFH discussions (potential impacts, and mitigation measures) as appropriate. However, for individual dredging episodes under existing long term maintenance permits NMFS will also receive copies of Dredge Operation Plan (DOP) approvals from USACE, which are notices to proceed with dredging. The DOP approvals will include any specific requirements necessary to comply with the terms of this consultation.

Suitability of sediment for in-Bay placement is determined via the DMMO sampling and testing process. NMFS is welcome at DMMO meetings to participate in suitability discussions directly, but NMFS will receive copies of all DMMO letters regarding sampling and testing results. In particular, DMMO will notify NMFS when sediment chemistry bioaccumulation trigger levels are exceed, the testing required in those cases, the results of any such testing, the DMMO suitability determination, and the placement location. However, it is not always known whether unsuitable material will be immediately dredged, or where it will be disposed.

ATTACHMENT 1

List of current projects with potential direct and indirect impacts to eelgrass, and estimated acreage of eelgrass impacted for direct effects (Table 6 from NMFS's July 14, 2010 consultation response).

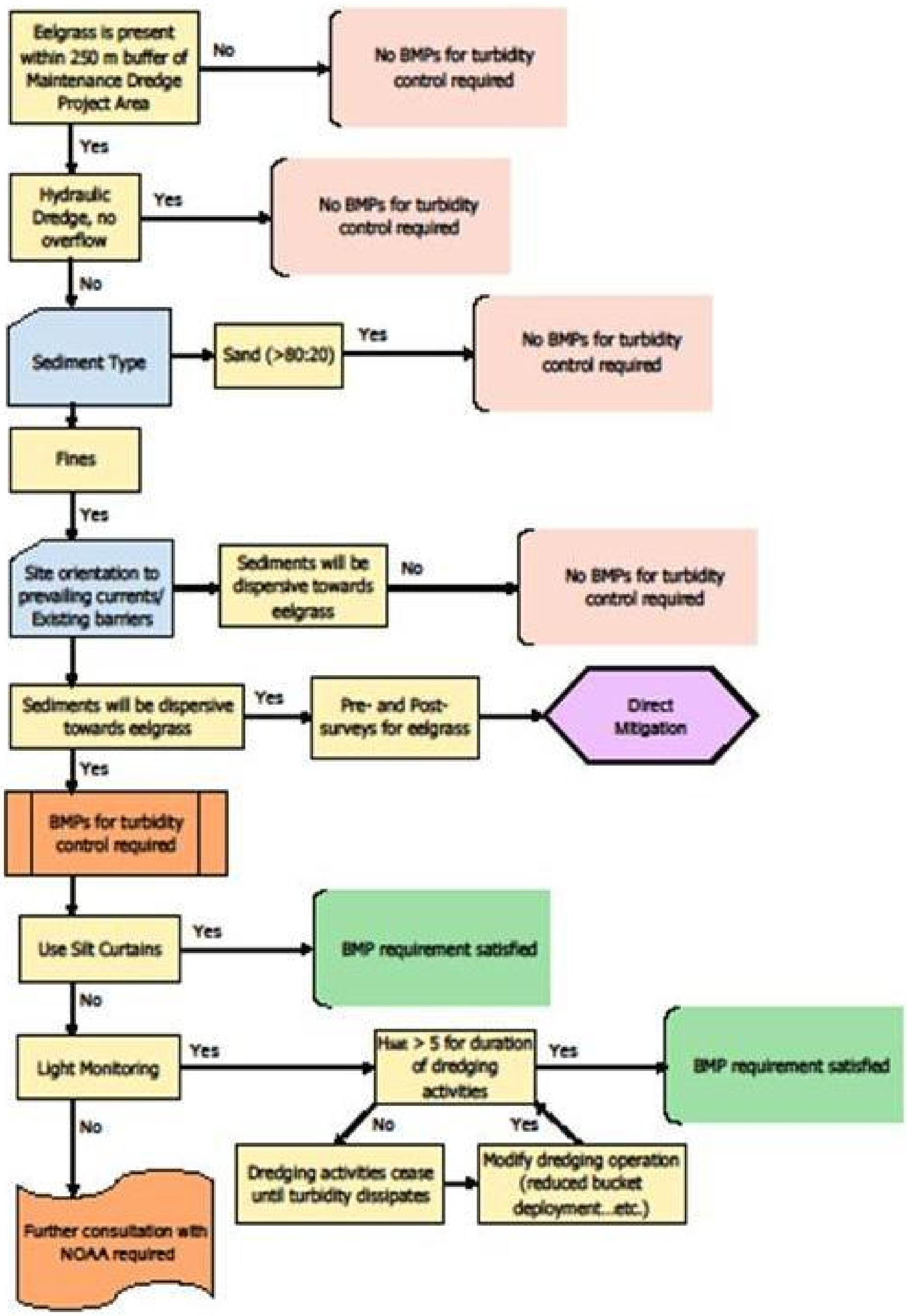
Table 6. List of projects with potential direct and indirect impacts to eelgrass, and estimated acreage of eelgrass impacted for direct effects. Data presented here were derived from NMFS spatial analysis (V.D.3).

		Potential direct effects		Potential indirect effects
Name	Type	Acres of direct overlap with eelgrass	Acres of direct overlap with 45m buffer	Eelgrass within 250m of project
Richmond Harbor	Dredge (USACE)	0	0.003	yes
San Francisco Harbor	Dredge (USACE)	0	0	yes
Oakland Harbor	Dredge (USACE)	0	0	yes
Glen Cove Marina	Dredge (non-USACE)	0.01	2.94	yes
C&H Sugar Company	Dredge (non-USACE)	0	0	yes
San Rafael Rock Quarry	Dredge (non-USACE)	0	0	yes
Coast Guard Station, Golden Gate	Dredge (non-USACE)	0	0.51	yes
Sausalito Yacht Club	Dredge (non-USACE)	0	1.44	yes
Schoonmaker Point Marina	Dredge (non-USACE)	0	0.83	yes
Galilee Harbor	Dredge (non-USACE)	0	0.38	yes
Kappas Marina	Dredge (non-USACE)	0.01	1.66	yes
Strawberry Recreation District	Dredge (non-USACE)	0.29	1.03	yes
Clipper Yacht Harbor	Dredge (non-USACE)	0	0.35	yes
Paradise Cay Yacht Club	Dredge (non-USACE)	0	0	yes
Paradise Cay Homeowners Assoc	Dredge (non-USACE)	0	0	yes
Timmers Landing	Dredge (non-USACE)	0	0	yes
Corinthian Yacht Club	Dredge (non-USACE)	0	0	yes
San Francisco Yacht Club	Dredge (non-USACE)	0.01	4.32	yes
Belvedere Land Company	Dredge (non-USACE)	0.25	0.88	yes
Port of San Francisco	Dredge (non-USACE)	0	0	yes
CG Station, Yerba Buena Island	Dredge (non-USACE)	0.47	1.85	yes
Point San Pablo Yacht Club	Dredge (non-USACE)	0	0.39	yes
Berkeley Marina	Dredge (non-USACE)	0	0	yes
Richmond Yacht Club	Dredge (non-USACE)	0	0.18	yes
Aeolian Yacht Club	Dredge (non-USACE)	0	0.12	yes
Emery Cove Marina	Dredge (non-USACE)	0	0	yes
Port of Oakland	Dredge (non-USACE)	0	0	yes
Ballena Isla Townhomes	Dredge (non-USACE)	0.01	1.36	yes
Ron Valantine Boat Dock	Dredge (non-USACE)	0	0	yes
Redwood City Marina	Dredge (non-USACE)	0	0	yes
Coyote Point Marina	Dredge (non-USACE)	0	0	yes
Ballena Isla Marina	Dredge (non-USACE)	0	0	yes
Harbor Bay Ferry Channel	Dredge (non-USACE)	0	0.18	yes
Bellevue Channel	Dredge (non-USACE)	0.36	0.68	yes
Johnson Property	Dredge (non-USACE)	0.66	0.66	yes
Sausalito Marina Properties	Dredge (non-USACE)	0.08	0.83	yes
CA Maritime Academy	Dredge (non-USACE)	0.03	0.9	yes
Marina Bay Yacht Harbor	Dredge (non-USACE)	0	0.01	yes
Emery Access Chanel	Dredge (non-USACE)	0	0	yes
Chevron Rod and Gun	Dredge (non-USACE)	0	0	yes

ATTACHMENT 2

Flowchart depicting step-wise decision making process for avoidance, minimization, and implementation of Best Management Practices (BMPs) for indirect effects of turbidity on eelgrass (Appendix 2 from NMFS's July 14, 2010 consultation response).

Appendix 2. Eelgrass Indirect Effects Flowchart
Flowchart depicting step-wise decision making process for avoidance, minimization, and implementation of Best Management Practices (BMPs) for indirect effects of turbidity on eelgrass.



ATTACHMENT 3

Recommended Methods for Outlier Detection
and
Calculations of Tolerance Intervals and Percentiles – Application to RMP Data
for
Mercury-, PCBs-, and PAH-Contaminated Sediments

Recommended Methods for Outlier Detection

and

Calculations of Tolerance Intervals and Percentiles –

Application to RMP data

for

Mercury-, PCBs-, and PAH-contaminated Sediments

Final Report

May 27th, 2011

Prepared for:

Regional Monitoring Program for Water Quality in San Francisco Bay, Oakland CA

Prepared by:

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Introduction

This report presents results of a review of existing methods for outlier detection and for calculation of percentiles and tolerance intervals. Based on the review, a simple method of outlier detection that could be applied annually as new data becomes available is recommended along with a recommendation for a method for calculating tolerance intervals for population percentiles. The recommended methods are applied to RMP probability data collected in the San Francisco Estuary from 2002 through 2009 for Hg, PCB, and PAH concentrations.

Outlier detection

There is a long history in statistics of attempts to identify outliers, which are in some sense data points that are unusually high or low. Barnett and Lewis (1994) define an outlier in a set of data as "an observation (or subset of observations) which appears to be inconsistent with the remainder of that set of data. This captures the intuitive notion, but does not provide a constructive pathway. Hawkins (1980) defined outliers as data points which are generated by a different distribution than the bulk observations. Hawkins definition suggests something like using a mixture distribution to separate the data into one or more distributions, or, if outliers are few relative to the number of data points, to fit the "bulk" distribution with a robust/resistant estimation procedure, and then determine which points do not conform to the bulk distribution. This approach assumes that a suitable parametric distribution can be determined.

Previous work attempted to separate some contaminant distributions into "ambient" and "impacted" components using a mixture distribution approach. Unfortunately, the distributions did not resolve into something that could clearly be interpreted as an ambient and an impacted distribution. Furthermore, none of the data sets evaluated (Hg, PCB, and PAH) exhibited distributions that could be reasonably modeled by parametric methods. Most outlier detection methods either rely on a parametric distribution (e.g., assume underlying normality) or rely on visual inspection and interpretation of graphical representations (e.g., Tukey's box plots (Tukey, 1997)). Inasmuch as the aim of the current exercise is to identify a procedure that can be applied to future data sets with minimal human intervention, the more common outlier detection methods do not seem suitable.

Last & Kandel (2001) proposed using an approach based on fuzzy set theory (Zadeh, 1985). Their approach identifies data points that are separated from the main body of the data. It seems particularly suited for the present application, where we wish to identify and remove unusually large values. Their method uses a measure of conformity that compares the distance between a point and its next smaller neighbor to the average distance between next m smaller points. This is essentially a comparison of local point densities that identifies abrupt changes in point density.

The measure of conformity for value v_j used by Last and Kandel is

$$\rho_j = \frac{2}{1 + \exp\left(\dfrac{\beta m(v_j - v_{j-1})}{n_j(v_{j-1} - v_{j-m-1})}\right)}$$

where n_j is the number of times value v_j occurs, and β is a user-defined parameter that controls sensitivity. The default value of β is set to detect a relative difference of 10, i.e., the distance between a value and its next lower neighbor is 10 times the average distance between the next lower m values. The parameter m should be set so that a reasonably stable average density is obtained. With the data sets in hand, I set m to include 2.5% of the data or at least 12 points. A point is deemed to be non-conforming if ρ is small. Here I used the criterion $\rho \leq 0.05$.

The appendix includes R code (R Development Core Team (2009)) that implements Last & Kandel auto detect algorithm.

Percentiles and Tolerance Intervals

A percentile is a number such that a specified proportion of the population has values equal to or less than that number. As with outlier detection, there are both parametric and non-parametric methods to estimate percentiles. Because the contaminant concentrations are not easily fit with a parametric model, non-parametric methods are preferable. The simplest non-parametric estimator of a percentile is simply to sort the data in ascending order, calculate an index for the j^{th} order point given by $\frac{100j}{N}$, and take the first point with an index exceeding the target percentile as the estimate.

The above procedure works so long as the data can be considered a simple random sample from the population, but does not take into account weights that result from more complex survey designs. The procedure implemented by the USEPA's EMAP draws on an estimate of the cumulative distribution function to estimate percentiles (Diaz-Ramos, et al.,1996). The CDF is essentially a complete collection of percentiles, with a percentile being calculated for each unique data value. Specific percentiles are calculated by interpolation if they do not happen to coincide with a data value. This is the recommended procedure, because the CDF as calculated by the R survey analysis package *spsurvey* (Kincaid, et al., 2010) is appropriate for complex survey designs as well as simple random sampling.

A tolerance interval is essentially a confidence interval on a specified proportion of a population distribution. An upper tolerance limit is a number such that there is a specified level of confidence that a specified proportion of the population has values at or below that number. Figure 1 illustrates the distinction between the confidence interval around a cumulative distribution function and tolerance intervals using the data for Hg concentration. The CDF gives the proportion of the population with Hg concentrations less than or equal to the values on the x-axis. The 95% confidence limits give bounds on that estimated proportion. A 95% tolerance limit, on the other hand, is a concentration such that some specified proportion of the population is less than or equal to that concentration with 95% confidence. For example, we can estimate a 95% tolerance limit on the 90th percentile of Hg concentration by drawing a line parallel to the x-axis at the level where the CDF = 0.9, finding the intersection of that line with the lower 95% confidence limit on the CDF, and then dropping down to the corresponding Hg concentration (in this case, 0.340). This is essentially the manner in which the USEPA's EMAP estimates confidence limits on percentiles. It is the method implemented in the R survey analysis package *spsurvey* (Kincaid, et al., 2010). Because it is based on *spsurvey*'s estimate of the CDF and confidence limits, it is appropriate for complex as well as simple survey designs.

There are several other non-parametric methods available for estimating tolerance intervals (Hahn and Meeker, 1991; Wald, 19143; Wilks, 1941). These are based on the binomial distribution and assume simple random sampling. They also require large data sets to work well, especially for high confidence on extreme percentiles. Although I recommend EMAP's procedure, the Hahn & Meeker estimator (implemented in the R package *tolerance* (Young, 2009)) was also calculated for comparison. For the most part, the two estimators were in good agreement; differences showed up primarily for high confidence or high percentile tolerance limits. Only the results for the *spsurvey* method are presented here.

Results

Outlier Results

One or more outliers were identified in each of the three contaminant data sets. Three outliers were identified for Hg: site codes (CB016S), (SPB018S), and (CB044S) with values 0.610, 0.780 and 0.942, respectively. Figure 2 is a histogram of the Hg distribution with the outliers identified. Three outliers were identified for PCB: site codes SPB018S, CB034S, and SB011S with values 25.1293, 26.5817, and 29.8293, respectively. Figure 3 is a histogram of the PCB distribution with the outliers identified. Only one outlier was identified for PAH: site code CB044S with 43046.9. Figure 4 is a histogram of the PAH distribution with the outlier identified.

Percentiles & Tolerance Interval Results

All outliers were removed before this part of the analysis. Also, all non-detect values were replaced with the detection limit. Because the focus is on the upper percentiles, the actual value used for the non-detects is immaterial: it has no effect on upper percentile calculation so long as it is small.

Percentiles were calculated using the interpolation algorithm from *spsurvey*. Tolerance intervals were calculated using *spsurvey* methodology. That is, the tolerance intervals were based on cdf's and confidence limits calculated using survey weights and the variance estimator developed for Generalized Random Tessellation Stratified (GRTS) designs (Stevens & Olsen, 2003). Results for multiple percentiles and tolerance levels are presented in Tables 1 through 3. Figures 5 through 7 are histograms with outliers removed, and the with the median and 90% tolerance limit on the 90th percentile identified. (NB: These histograms are based a counts, not survey weights, so they are not an unbiased representation of the population distribution. They are provided to illustrate where the tolerance limit lies relative to the sample data. The medians and tolerance limits were estimated using the survey weights.)

Table 1: Upper tolerance limits for Hg						
Percentile Level	Percentile Estimate	Confidence Level				
		80	85	90	95	99
80	0.300	0.301	0.302	0.302	0.305	0.310
85	0.309	0.313	0.314	0.317	0.321	0.328
90	0.328	0.332	0.333	0.334	0.340	0.343
95	0.347	0.351	0.351	0.352	0.357	0.364
99	0.440	0.468	0.470	0.472	0.474	0.478

Table 2: Upper tolerance limits for PCB						
Percentile Level	Percentile Estimate	Confidence Level				
		80	85	90	95	99
80	9.6	10.0	10.2	10.2	10.3	11.0
85	10.7	11.6	11.8	12.0	12.1	12.4
90	12.4	13.7	14.0	15.7	15.8	15.9
95	16.6	18.0	18.1	18.2	18.3	18.5
99	19.0	19.4	19.4	19.5	19.5	19.6

Table 3: Upper tolerance limits for PAH						
Percentile Level	Percentile Estimate	Confidence Level				
		80	85	90	95	99
80	3488	3517	3517	3531	3540	3815
85	3828	3904	3963	4072	4182	4357
90	4476	4556	4690	4847	5062	5276
95	6203	6483	6643	6837	7742	9155
99	12461	16594	16822	17057	17332	17695

References

Diaz-Ramos, S., D.L. Stevens, Jr., and A.R. Olsen. (1996). *EMAP Statistical Methods Manual.* EPA/620/R-96/XXX. Corvallis, OR: U.S. Environmental Protection Agency, Office of Research and Development, National Health Effects and Environmental Research Laboratory, Western Ecology Division.

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Stevens, Jr., D.L., and A.R. Olsen (2003). Variance estimation for spatially balanced samples of environmental resources. Environmetrics **14**: 593–610

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Zadeh, L.A. (1985). Syllogistic Reasoning in Fuzzy Logic and its Application to Usuality and Reasoning with Dispositions. IEEE Transactions on Systems, Man, and Cybernetics, SMC-15, 6, 754-763.

Figure 1: CDF of Hg with Lower 95% Confidence Limit

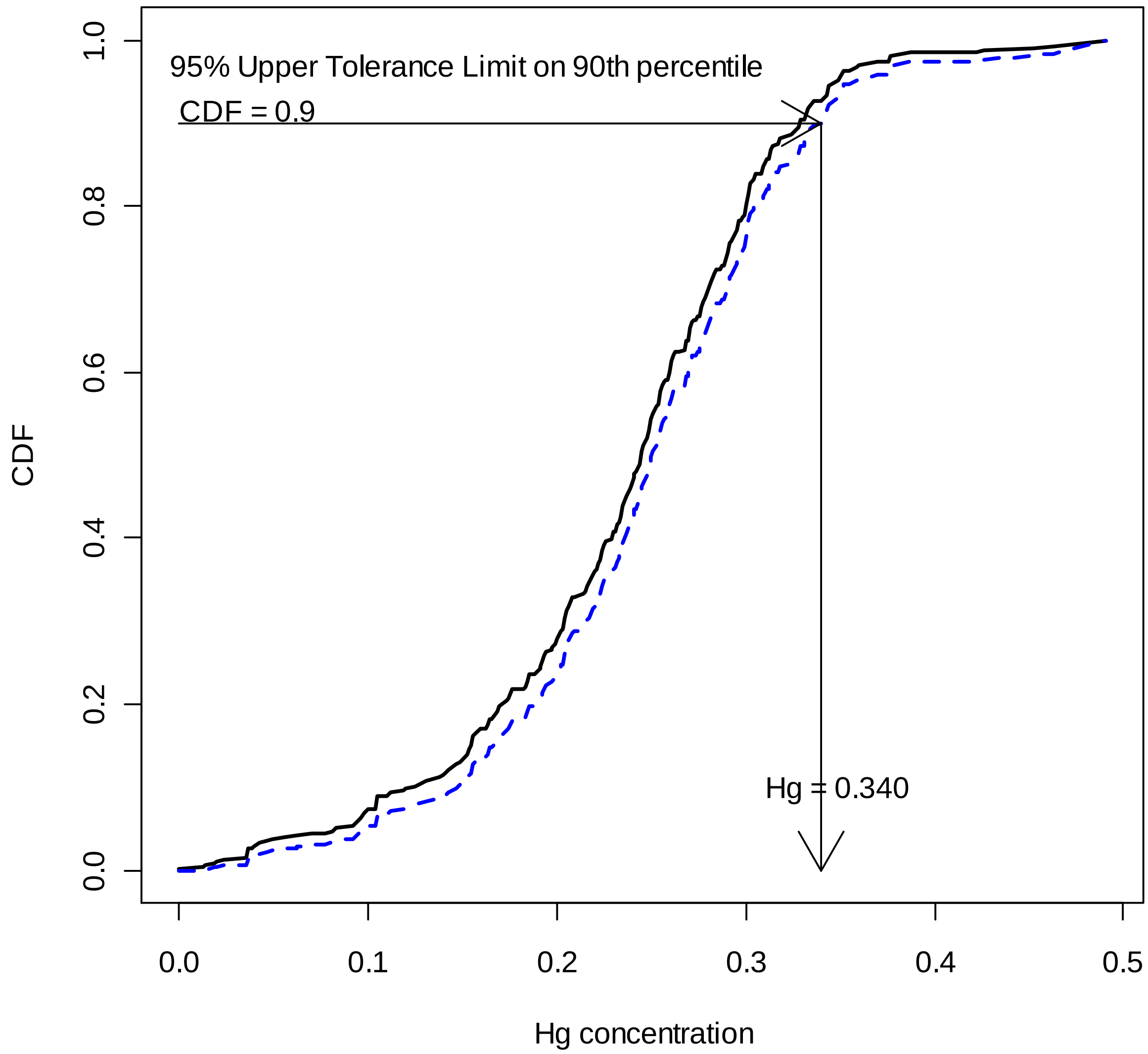


Figure 2: Histogram of Hg with outliers identified

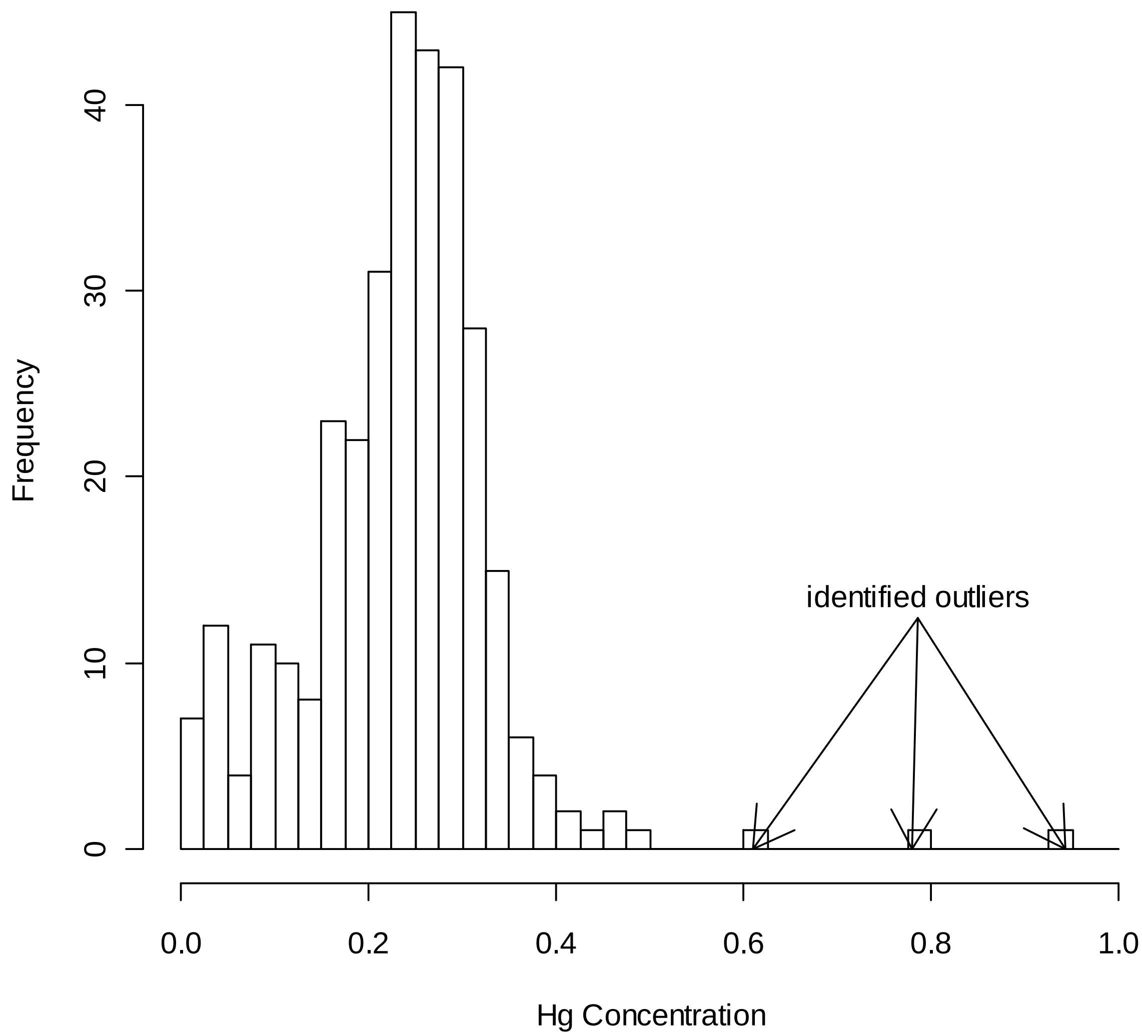


Figure 3: Histogram of PCB with outliers identified

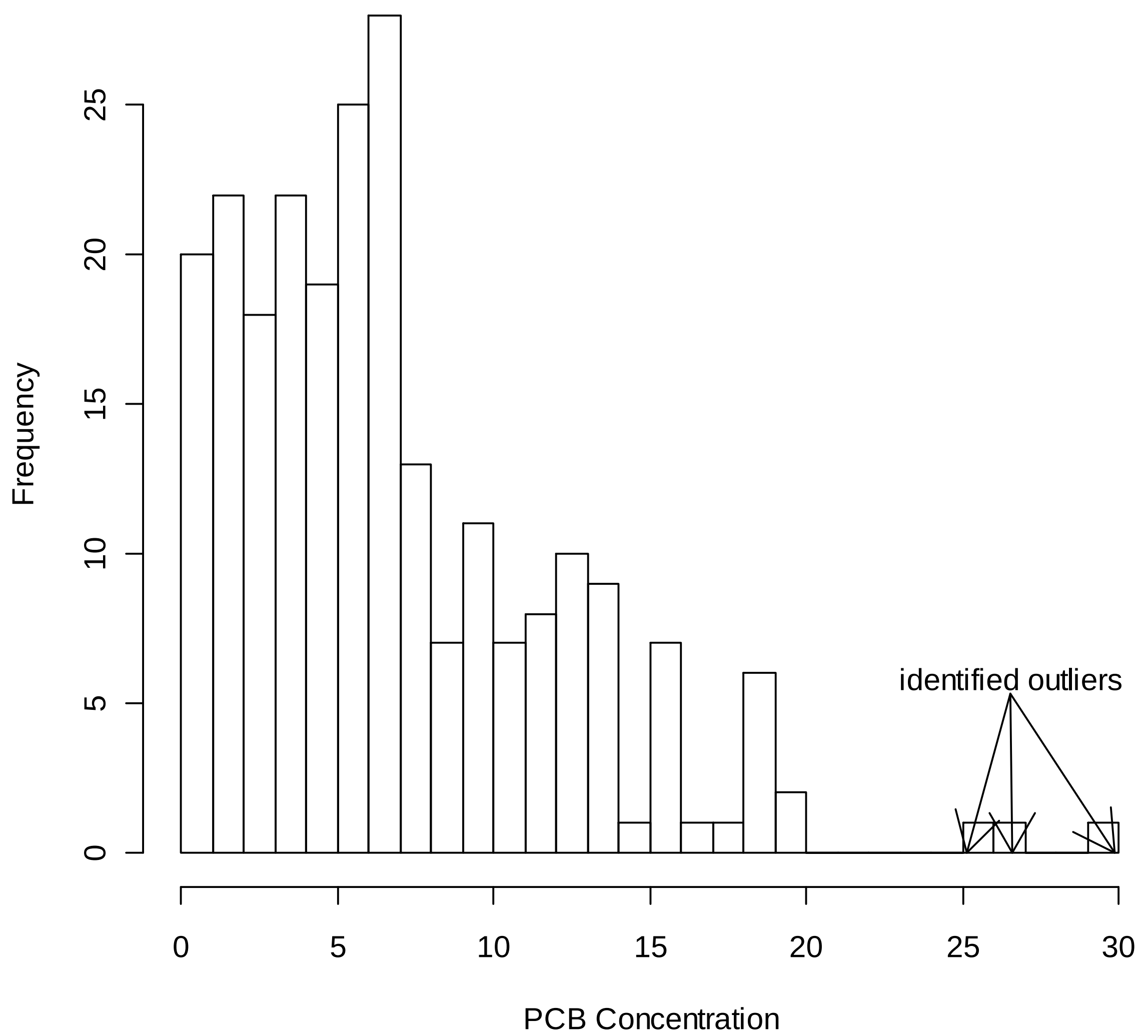


Figure 4: Histogram of PAH with outlier identified

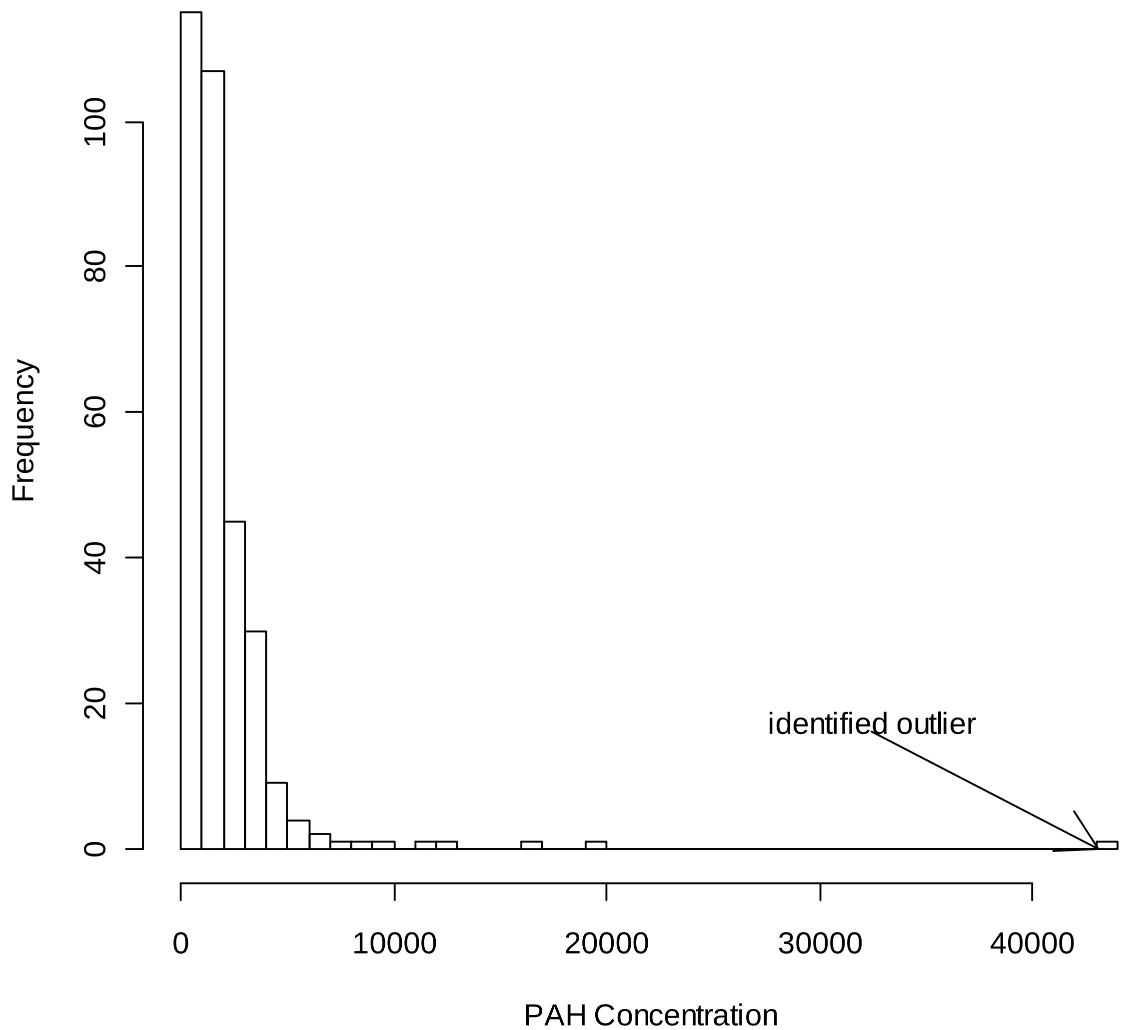
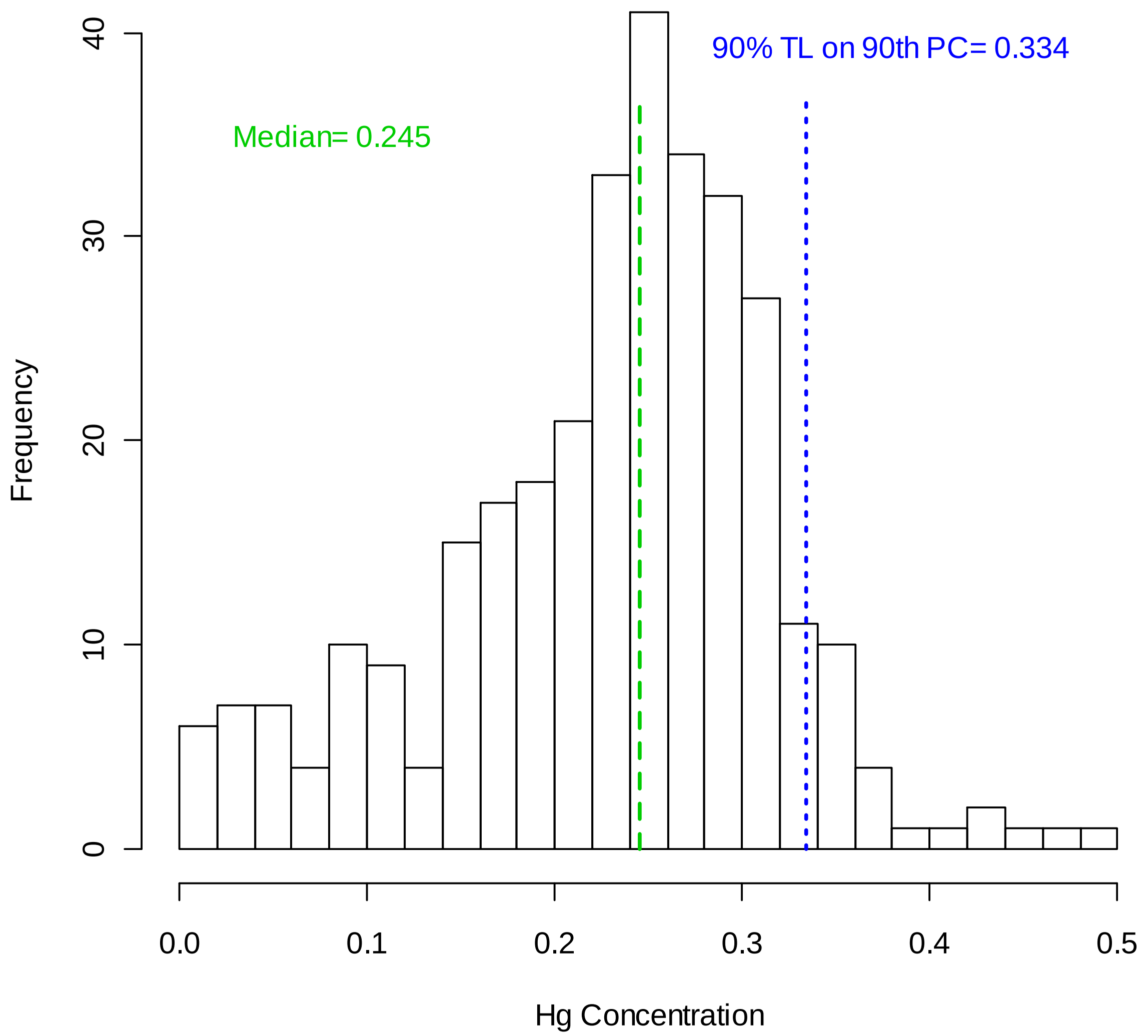


Figure 5: Histogram of Hg with outliers removed



Median and 90% Tolerance Limit on 90th Percentile are identified

Figure 6: Histogram of PCB with outliers removed

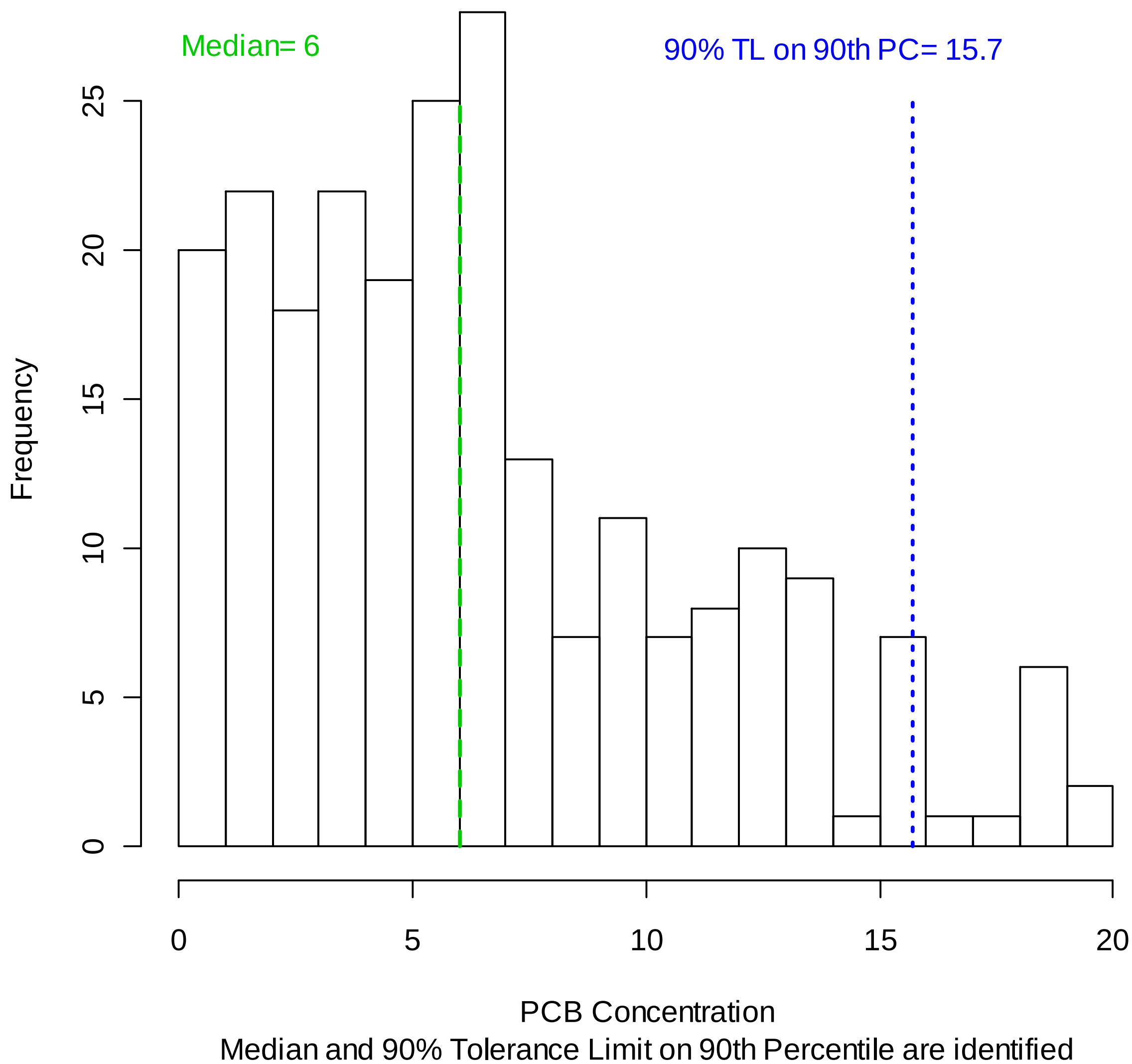
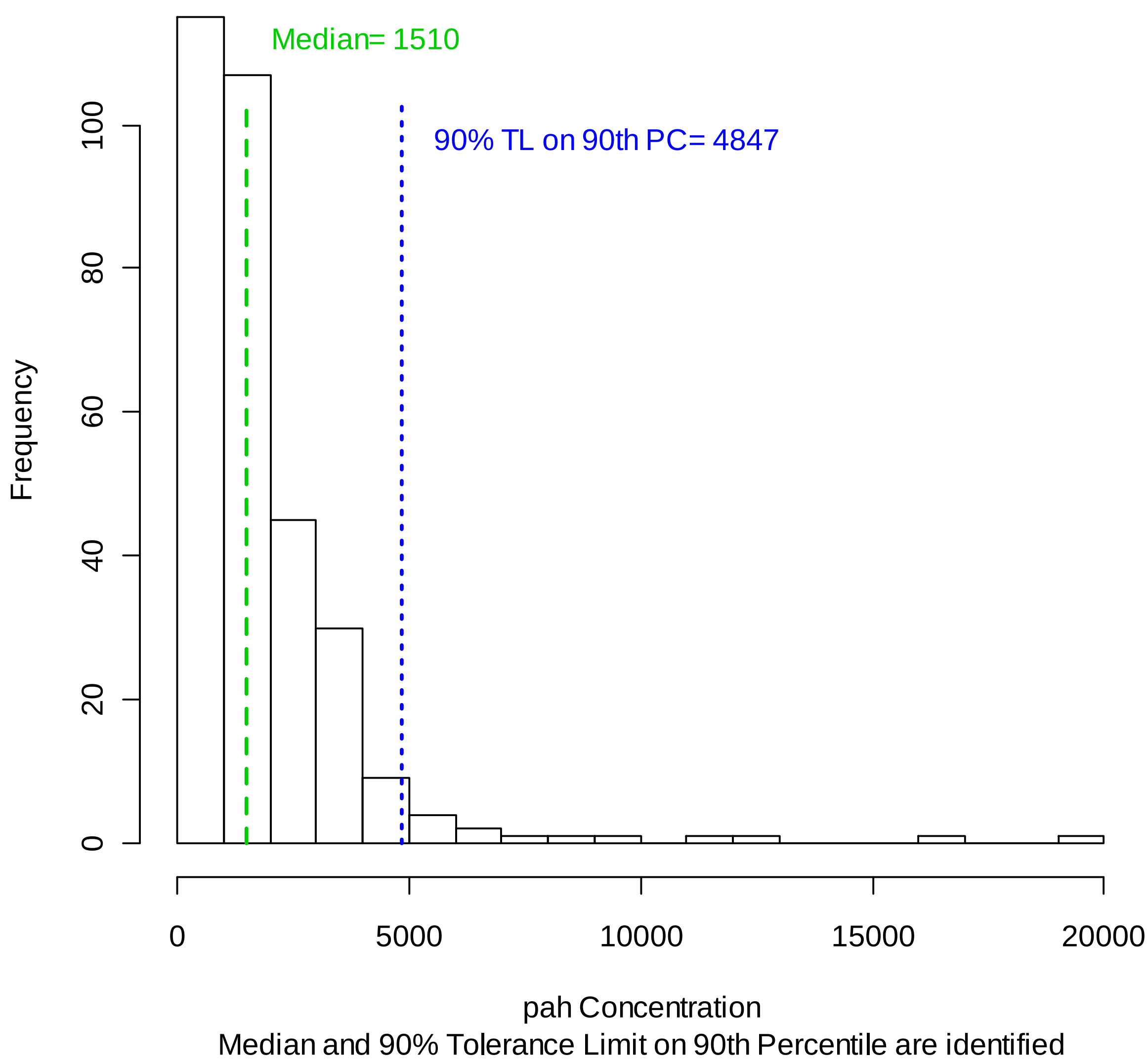


Figure 7: Histogram of pah with outliers removed



Appendix: R code for outlier detection & tolerance interval calculation

A data file must be in the directory in which R was opened. Data can be downloaded from the Web Query Tool: http://www.sfei.org/tools/wqt.

Select the following options from the Web Query Tool interface

Search Parameters:
Test Material:
Sediment
Program/Project:
Regional Monitoring Program
Start Year:
2002
End Year:
2009

Then either:

Parameter Type:		
Trace Elements	Polychlorinated Biphenyls (PCB)	Polycyclic Aromatic Hydrocarbons (PAH)
Parameter:		
Mercury	Sum of 40 PCBs (SFEI)	Sum of PAHs (SFEI)

Save the file as “Hg_Sediment_2002-2009_out.xls”, or a similar name, in the same directory as the source code. Open to the sheet “Results – flat file” and save the worksheet as a “.csv” by the same name. R can read Excel files directly, but it’s easier to first save as a .csv file.

The lines below constitute a script in R – they can be copied directly into the command line interface. Beforehand, the custom functions must be saved in the working directory with the file names “auto_detect_outlier.R” and “albers_proj.R”, as indicated. The packages *spsurvey* and *tolerance* (and any packages they are dependent on) must be installed as well. Parameters above the “Do Not Adjust Code Below this Line” mark should be adjusted as necessary.

```
#################### R code below #####################

# Script: Calculation of Ambient Sediment Thresholds

# based on code from Don Stevens' report: "Recommended Methods for Outlier
# Detection and Calculations of Tolerance Intervals and Percentiles -
# Application to RMP data for Mercury-, PCBs-, and PAH-contaminated Sediments"

# created May 2011
# revised 6/6/2011

# load packages needed for the custom functions
require("spsurvey", quietly=TRUE)
require("tolerance", quietly=TRUE)
```

```
# set working directory
setwd('S:\\RMP Documents\\Ambient Sediment Conditions discussion\\thresholdCalculation')

# load custom functions
source('auto_detect_outlier.R')
source('albers_proj.R')

# load in data
sed.data <- read.csv("Hg_Sediment_2002-2009_out.csv")
# The value of the contaminant concentration is in the field named Result

# set user parameters
analyte_name <- 'Hg' # options = 'Hg' or 'PCB' or 'PAH'

# set the percentile levels and the confidence intervals
tolval <- c(80, 85, 90, 95, 99)
conf <- c(80, 85, 90, 95, 99)

#---- Do Not Adjust Code Below this Line------#
# Set analyte names from data sets based on user parameter
if (analyte_name == "Hg") {
		analyte = 'Mercury'
} else if (analyte_name == "PCB") {
		analyte = c('Sum of PCBs (SFEI)', 'Sum of 40 PCBs (SFEI)')
  # Sum of 209 PCBs should not be included
  # prior to 2009, all sums of PCBs were sum of 40 PCBs
} else if (analyte_name == "PAH") {
		analyte = 'Sum of PAHs (SFEI)'
} else {
		analyte = NULL
}

# convert results to numeric if data is not read in as "numeric"
if (!is.numeric(sed.data$Result)) {
		lev <- sub(",","",levels(sed.data$Result)[as.integer(sed.data$Result)]); # take out 
commas from the results
		sed.data$Result <- as.numeric(lev);
}

# extract year from Cruise Number
ychar <- substr(levels(sed.data$Cruise.Number)[as.integer(sed.data$Cruise.Number)],1,4);
sed.data$Year <- as.numeric(ychar);

# remove 2002 from PCB data - data is not compatible
if (analyte_name == "PCB") {
		idx <- which(sed.data$Year != "2002")
		sed.data <- sed.data[idx,]
}
```

```
 # remove nontarget sample frames
tst <- sed.data$Region == 'Southern Sloughs';
sed.data <- sed.data[!tst,];
tst <- sed.data$Region == 'Rivers';
sed.data <- sed.data[!tst,];
tst <- sed.data$Region == 'Carquinez Strait';
sed.data <- sed.data[!tst,];

# remove historical stations (based on B... site code)
hist <- substr(levels(sed.data$Site.Code)[as.integer(sed.data$Site.Code)],1,1);
tst <- which(hist == "B");
if (length(tst) != 0) sed.data <- sed.data[-tst,];

# remove non-target parameters
contam <- levels(sed.data$Parameter)[as.integer(sed.data$Parameter)]
tst <- which(contam == analyte[1]| contam == analyte[2]);
sed.data <- sed.data[tst,];

# find number of data points
nr <- nrow(sed.data)

                # define frame area for sediment in sq km
frameArea <- c('Lower South Bay'=7.642,
                                        'South Bay'=185.171,
        'Central Bay'=396.442,
                                        'San Pablo Bay'=226.821,
        'Suisun Bay'=80.357);
                            # 'Carquinez Strait'=21.289, 'Southern Sloughs'=1.733,'Rivers'=16.478);

# compute the weight for each sample, based on frame area
idx.region <- match(sed.data$Region, names(frameArea))
sed.data.num <- table(sed.data$Region)
sed.region <- match(sed.data$Region,names(sed.data.num) )
sed.wt <- frameArea[idx.region]/sed.data.num[sed.region]


  # Convert lat/long to equal-area projection.  (Albers, in this case)
clon <- -122
clat <- 38
sp1 <- 37
sp2 <- 40
sed.xy <- albxy(sed.data$Actual.Latitude, sed.data$Actual.Longitude,
   clon = clon, clat=clat, sp1 = sp1, sp2 = sp2)

# Find the non-detects, and replace with MDL
idx <- which(is.na(sed.data$Result))
sed.data$Result[idx]<- sed.data$MDL[idx] # replace non detects with MDL

# find the outliers
o_idx <-auto_detect_outlier.fcn(x=sed.data$Result)
```

```
# "o_idx" contains the indices of any points identified as outliers (or is NULL).

# Now calculate cdf & spsurvey-type tolerance limits for confidence intervals and percentiles as
set above
if (!is.null(o_idx)) {
          data.cdf.tol <- cdf.tol.est.fcn(sed.data$Result[-o_idx],conf=conf,
            tolval = tolval, vartype = "Local",
  x = sed.xy[-o_idx,1], y = sed.xy[-o_idx,2], wt = sed.wt[-o_idx])
} else {
          data.cdf.tol <- cdf.tol.est.fcn(sed.data$Result,conf=conf,
            tolval = tolval, vartype = "Local",
  x = sed.xy[,1], y = sed.xy[,2], wt = sed.wt)

}
data.cdf <- data.cdf.tol$cdf

# For reference, calculate the Hahn-Meeker tolerance limits
data.hm.tol <- matrix(0,nrow = length(tolval),ncol = length(conf) +1)
data.hm.tol[,1] <- data.cdf.tol$tol[,1,1]
pctval <- as.character(tolval/100)
dimnames(data.hm.tol) <- list( pctval,c("PCT", conf))
if (!is.null(o_idx)) {
  for(j in 1:length(conf)) {
    for(i in 1:length(tolval)) {
      tmp <- nptol.int(sed.data$Result[-o_idx],P=tolval[i]/100, alpha = 1-conf[j]/100,
      method="HM")[[4]]
      data.hm.tol[i,j+1] <- tmp
  }}
 } else {
  for(j in 1:length(conf)) {
    for(i in 1:length(tolval)) {
      tmp <- nptol.int(sed.data$Result,P=tolval[i]/100, alpha = 1-conf[j]/100,
      method="HM")[[4]]
      data.hm.tol[i,j+1] <- tmp
  }}
 }
 data.hm.tol

# This table has the percentile level in the first column, the percentile value
# in the second column, and upper tolerance limits in the succeeding columns
# for the confidence levels in the top row.
# print out 2 significant figures for regulatory threshold
signif(cbind(data.cdf.tol$tol[,1,1],data.cdf.tol$tol[,2,]),digits =2)
# round to the appropriate number of digits for easy viewing
ndig <- switch(analyte_name, "Hg" = 3, "PCB" = 1, "PAH" = 0)
round(cbind(data.cdf.tol$tol[,1,1],data.cdf.tol$tol[,2,]),ndig)
```

```
#auto_detect_outlier.R
auto_detect_outlier.fcn <- function(x,m =NULL,alpha =0.05, beta = NULL, dif.detect = 10) {
# detect outliers in the vector v by comparing lag 1 difference to
#   lag m difference
# dif.detect controls sensitivity to the relative distance magnitude. Default
#  value of 10 detects a relative magnitude of 10, e.g., a difference that is
#  10 times the local average difference.
#
# alpha controls the level of conformity that is deemed to be outlying. Lower
#  values will cause fewer values to be recognized as outliers.
# default value for m is at least 12 or ceiling(length(x)*0.025),
#  i.e., about 2.5% of data
# function returns the indices of high outliers, or NULL if none are detected

 if(is.null(m)) m <- max(12, ceiling(length(x)*0.025))
 if(is.null(beta)) beta <- log(2/alpha -1)/dif.detect
 ord <- order(x)
 sx <- x[ord]
 tst <- tapply(sx, sx)
 tbx <- table(x)
 v<- unique(sx)
 nv <- length(v)
 nv1<- nv-1
 nm <- nv-m
 cfl <- cfh <- rep(1, nv)
 dif1 <- diff(v)
 difm <- (v[-(1:(m))]-v[1:nm]) /m
 cfh[(m+2):nv] <- 2/(1+exp(beta*dif1[(m+1):nv1]/(tbx[(m+2):nv]*difm[-nm])))
 idx <-which(cfh < alpha)
 if(length(idx)==0) return(NULL) else return(ord[match(min(idx):nv,tst)])

 }
# CDF, percentile, & tolerance interval calculation

cdf.tol.est.fcn <-function(z, conf=95,tolval=95,wt=NULL,vartype = "SRS",
  zrng=NULL,x=NULL, y=NULL ) {
# z   vector of observed values
# conf a single value or a vector of confidence levels
# tolval a single value or vector of percentile levels
# wt  a vector of same length as z with survey weight values. The default
#  value NULL results in equal weighting
# vartype specifies type of variance calculation. Default uses the SRS
#  variance estimator (see package spsurvey documentation for more details)
#  the alternative is "Local" which uses the local variance estimator. If
#  the local estimator is used, x and y coordinates must be supplied.
# zrng is vector of values at which the cdf is estimated. Default uses
#  the sorted unique values of z
# x, y are coordinates of the z observations. Only needed if vartype = "Local"
#
```

```
#  gets estimate of the cumulative distribution function, its standard deviation,
#  and 1-sided lower confidence limits.
# Also estimates percentiles and upper tolerance limits
# confidence limits will be estimated for all levels specified in conf
# Returned value is a list with components "CDF" and "tol". CDF is a matrix
#   with values of the cdf and upper confidence limits; tol is a three dimensional
#   array row = percentile, column = tolerance limits, and sheet = confidence
#
 if(vartype =="Local" & (is.null(x) | is.null(y) )) {
   return("x & y coordinates must be supplied for local variance estimator")
   }
 conf <- conf/100
 tolval <- tolval/100
 n <- length(z)
 if(is.null(zrng)) zrng <- sort(unique(z))
 m <- length(zrng)
 ym <- matrix(rep(zrng, n), nrow = n, byrow = T)
 zm <- matrix(rep(z, m), nrow = n)
 if(is.null(wt)) wt <- rep(1, length(z))
 wm <- matrix(rep(wt, m), nrow = n)
 cdf <- apply(ifelse(zm <= ym, wm, 0), 2, sum)/sum(wt)
 tw2 <- (sum(wt))^2
 im <- ifelse(matrix(rep(z, m), nrow = n) <= matrix(rep(zrng, n), nrow = n,
   byrow = T), 1, 0)
 rm <- (im - matrix(rep(cdf, n), nrow = n, byrow = T)) * matrix(rep(wt, m),
   nrow = n)
 if (vartype == "Local") {
   weight.lst <- localmean.weight(x, y, 1/wt)
   varest <- apply(rm, 2, localmean.var, weight.lst)/tw2
   } else {
   varest <- n * apply(rm, 2, var) / tw2
    }
 sd <- sqrt(varest)
 mult <- qnorm(conf)
 cint <- matrix(0,nrow =m,ncol=length(mult))
 for(i in 1:length(mult)) {
  cint[,i] <- pmax(0,cdf - sd*mult[i])
  }
 CDF <- cbind(cbind(zrng, cdf, sd, cint) )
 dnm <- paste(100*conf, "%UCB",sep = "")
 dimnames(CDF) <- list(NULL, c("Value", "CDF", "SD",as.vector(t(dnm))))
 tol <- array(0, c(length(tolval), 2,length(conf)))
 dimnames(tol) <- list(100*tolval, c("PCT","UPPER TL"),100*conf)
 for (j in 1:length(conf)) {
   tol[,,j] <- pctol.est.fcn(cbind(zrng, cdf,cint[,j]),tolval)
  }
 list(cdf =CDF, tol=tol)
 }
```

```
pctol.est.fcn <- function(cdfest, tolpct) {
# calculates percentile & upper tolerance liimit
# input is estimated cdf with upper confidence limit, and vector of percentiles
rslt <- matrix(0, nrow=length(tolpct),ncol=2)
for(i in 2:3) {
 for (j in 1:length(tolpct)) {
 hdx <- which(cdfest[,i] >= tolpct[j])
 high <- ifelse(length(hdx) >0, min(hdx), NA)
 ldx <- which(cdfest[,i] <= tolpct[j])
 low <- ifelse(length(ldx) >0, max(ldx), NA)
 if (is.na(high)) {
  rslt[j,i-1] <- NA
       }  else if (is.na(low)) {
  rslt[j,i-1] <- cdfest[high,1]
   } else {
     if (high > low)
      ival <- (tolpct[j] - cdfest[low,i])/ (cdfest[high,i] - cdfest[low,i])
       else ival <- 1
      rslt[j,i-1] <- ival * cdfest[high,1] + (1 - ival) * cdfest[low,1]
       }
 }
 }
 rslt
 }
```

```
# albers_proj.R

  albxy <<- function(lat, lng,sph = "Clarke1866", clon = -96, clat = 23, sp1 = 29.5,
    sp2 = 45.5)
{
    if (sph == "Clarke1866") {
        a <- 6378206.4
        b <- 6356583.8
    }
    else if (sph == "GRS80") {
        a <- 6378137
        b <- 6356752.31414
    }
    else if (sph == "WGS84") {
        a <- 6378137
        b <- 6356752.31424518
    }
    else {
        stop("\nSpheroid does not match available options")
    }
    RADDEG <- (180/pi)
    DEGRAD <- (pi/180)
#
                    #  ec = eccentricity = sqrt(1-(b/a)^2)
                    #
                    ec <- sqrt(1-(b/a)^2)
                    dgrd <- pi/180.
                    ph0 <- clat * dgrd
                    ph1 <- sp1 * dgrd
                    ph2 <- sp2 * dgrd
                    l0 <- clon * dgrd
                    q0 <- alb.que(ph0,ec)
                    q1 <- alb.que(ph1,ec)
                    q2 <- alb.que(ph2,ec)
                    m0 <- alb.em(ph0,ec)
                    m1 <- alb.em(ph1,ec)
                    m2 <- alb.em(ph2,ec)
                    lat <- lat * dgrd
                    lng <- lng * dgrd
                    q <- alb.que(lat, ec )
                    m <- alb.em(lat, ec)
                    n <- (m1^2. - m2^2.)/(q2 - q1)
                    cn <- m1^2. + n * q1
                    r0 <- (a * sqrt(cn - n * q0))/n
                    th <- n * (lng -l0)
                    r <- (a * sqrt(cn - n * q))/n
                    x <- r * sin(th)
                    y <- r0 - r * cos(th)
                    cbind(x, y)
}
```

```
alb.em <- function(z, ec )
{
		cos(z)/sqrt(1. - (ec * sin(z))^2.)
}


alb.que <- function(z, ec )
{

		snlt <- sin(z)
		esnlt <- ec * snlt
		(1. - ec^2.) * (snlt/(1. - esnlt^2.) - logb((1. - esnlt)/(1. + esnlt))/(2. * ec))
}


 albersgeod <<-
function (x, y, sph = "Clarke1866", clon = -96, clat = 23, sp1 = 29.5,
    sp2 = 45.5)
{
    if (sph == "Clarke1866") {
        a <- 6378206.4
        b <- 6356583.8
    }
    else if (sph == "GRS80") {
        a <- 6378137
        b <- 6356752.31414036
    }
    else if (sph == "WGS84") {
        a <- 6378137
        b <- 6356752.31424518
    }
    else {
        stop("\nSpheroid does not match available options")
    }
    RADDEG <- (180/pi)
    DEGRAD <- (pi/180)
    clat <- clat * DEGRAD
    clon <- clon * DEGRAD
    sp1 <- sp1 * DEGRAD
    sp2 <- sp2 * DEGRAD
    e2 <- 1 - (b * b)/(a * a)
    e4 <- e2 * e2
    e6 <- e4 * e2
    e <- sqrt(e2)
    t1 <- 1 - e2
    t2 <- 1/(2 * e)
    sinlat <- sin(clat)
    t3 <- 1 - e2 * sinlat * sinlat
    q0 <- t2 * log((1 - e * sinlat)/(1 + e * sinlat))
```

```
    q0 <- t1 * (sinlat/t3 - q0)
    sinlat <- sin(sp1)
    t3 <- 1 - e2 * sinlat * sinlat
    q1 <- t2 * log((1 - e * sinlat)/(1 + e * sinlat))
    q1 <- t1 * (sinlat/t3 - q1)
    m1 <- cos(sp1)/sqrt(t3)
    sinlat <- sin(sp2)
    t3 <- 1 - e2 * sinlat * sinlat
    q2 <- t2 * log((1 - e * sinlat)/(1 + e * sinlat))
    q2 <- t1 * (sinlat/t3 - q2)
    m2 <- cos(sp2)/sqrt(t3)
    n <- (m1 * m1 - m2 * m2)/(q2 - q1)
    C <- m1 * m1 + n * q1
    rho0 <- a * sqrt(C - n * q0)/n
    rho <- sqrt(x * x + (rho0 - y) * (rho0 - y))
    theta <- atan(x/(rho0 - y))
    q <- (C - (rho * rho * n * n)/(a * a))/n
    lon <- clon + theta/n
    lat <- asin(q/(1 - (t1/(2 * e)) * log((1 - e)/(1 + e))))
    s2 <- sin(2 * lat) * (e2/3 + 31 * e4/180 + 517 * e6/5040)
    s4 <- sin(4 * lat) * (23 * e4/360 + 251 * e6/3780)
    s6 <- sin(6 * lat) * (761 * e6/45360)
    lat <- lat + s2 + s4 + s6
    data.frame(lon = lon * RADDEG, lat = lat * RADDEG)
}
```