Multiple Lines of Empirical Evidence Demonstrate an Absence of Adverse Effects from MGP Residues at PAH Concentrations Significantly Higher than Regulatory Screening Levels

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Presentation Overview

1. State oversight agency issued requirement to evaluate potential impairment of beneficial uses of the waterway due to PAHs in sediment
2. Addressed requirement using an empirical sediment evaluation framework based on multiple lines of evidence
3. Application of the framework found that common screening level values (e.g., ER-M) are poor predictors of potential impairment
4. Demonstrated absence of adverse effects at total PAH > 100,000 µg/kg significantly reduces area requiring remedial evaluation

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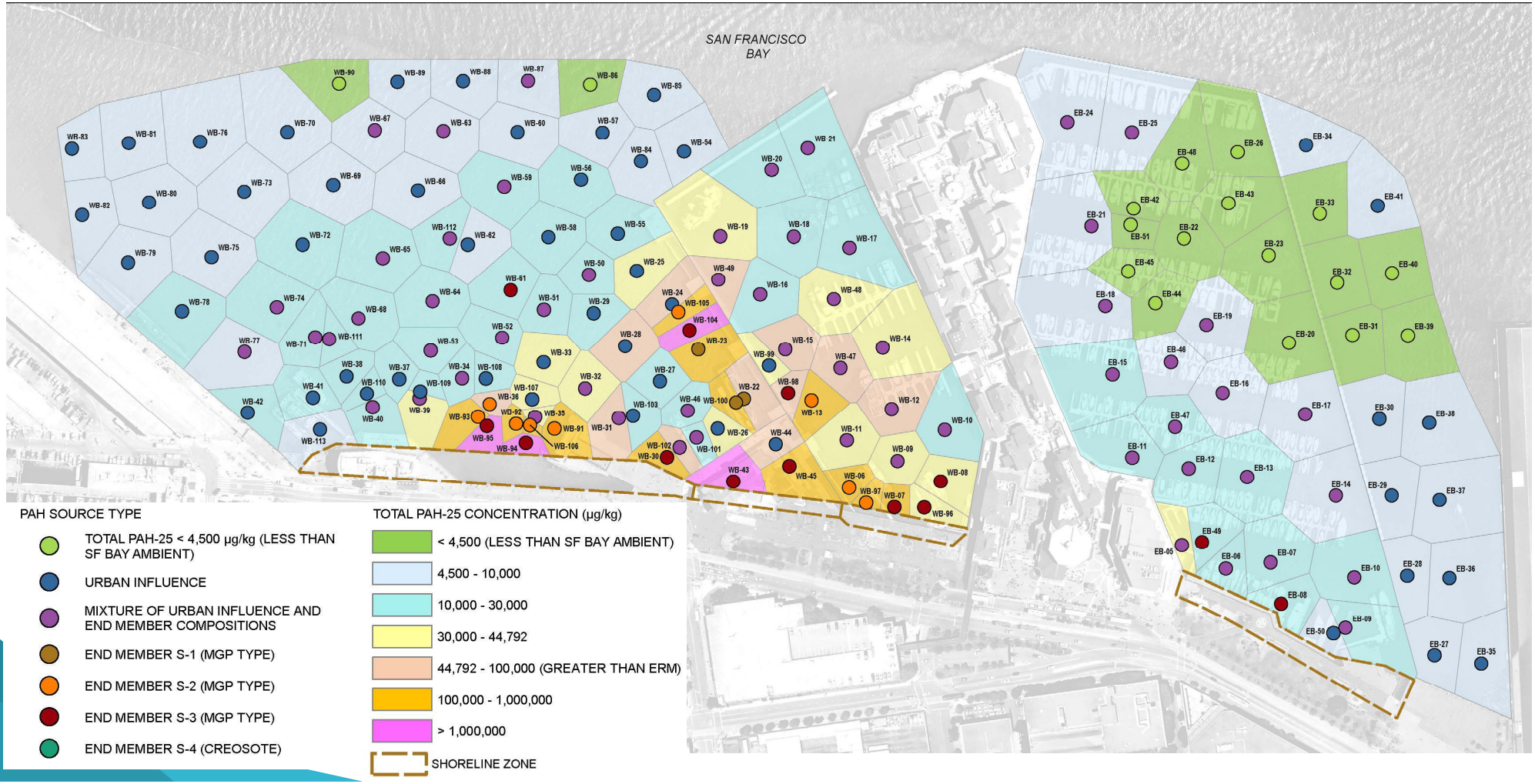
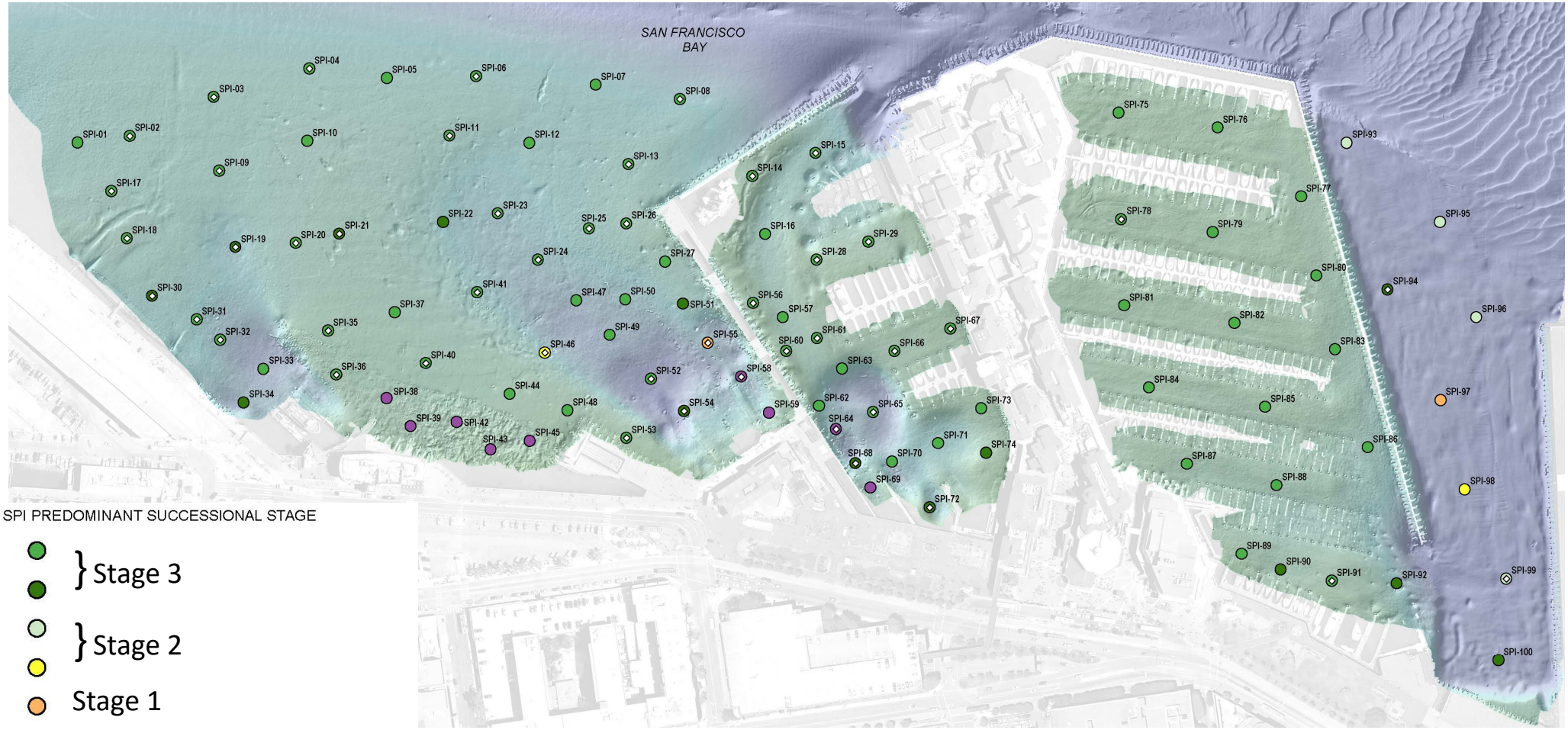
Total PAH concentrations in surface sediment well above ambient, even in areas with no MGP-related impacts



Healthy benthic community based on extensive sediment profile imaging



SPI PREDOMINANT SUCCESSIONAL STAGE

- } Stage 3
- } Stage 2
- Stage 1
- Unsuitable Substrate

Dot = evidence of physical disturbance

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The challenge - Urban/commercial waterfront in SF Bay with sediment PAHs >> Ambient (presumed former MGP source)

- Maintenance dredging permitting encountered sediment with PAHs exceeding acceptable in-Bay disposal (~4,600 µg/kg bioaccumulation threshold)
- State oversight agency issued conditional water quality certification for permit renewal, requiring evaluation of potential impairment of beneficial uses of the waterway by PAHs
- 4,600 µg/kg threshold exceeded throughout study area from multiple sources including complex “urban influence”

The approach – An empirical evaluation of beneficial use impairment

- Ten site-specific assessment methods
- Receptor-appropriate comparison criteria
- Conservative binary outcomes (no adverse effects vs. potential adverse effects)
- Integrative data evaluation matrix for remedial decision-making

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Empirical testing – toxicity and bioaccumulation

Objective: Evaluate relationship between PAHs in sediment and adverse effects

- Develop lowest site-specific effects concentration (LSSEC) for PAHs
- Perform bioassays over a graduated range of total PAH concentrations

- Benthic acute toxicity testing (amphipod and polychaete)
- Sediment-water interface (SWI) acute and chronic toxicity testing
  - Sheepshead minnow and Blue mussel embryos – survival and growth/development
- Dredge residual elutriate testing (DRET)
  - Resulting water column total PAH concentrations
  - Acute toxicity using larval Inland silverside
- Bioaccumulation testing (polychaete and clam)
  - Compare to TRVs (invertebrates), human health consumption criteria, and site-specific risk-based concentrations from food web modeling (fish, birds, and marine mammals)

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Empirical assessment methods and binary outcomes

Eight methods link adverse effects to total PAH concentration

Two methods involve direct observations

	A. Water Column Toxicity Bioassay	B. Elutriate Total PAH Concentration		C. Acute Benthic Invertebrate Toxicity Sediment Bioassay (2 endpoints)	D. Sediment-Water Interface Test with Larval Fish (2 endpoints)	E. Sediment-Water Interface Test with Mussel Embryos (2 endpoints)	F. Survival and Body Burden from Bioaccumulation Testing, Protective of Invertebrates (2 endpoints)		G. PAH Concentrations in Tissue from Bioaccumulation Testing, Protective of Fish, Birds, and Marine Mammals (2 endpoints)	H. PAH Concentrations in Tissue from Bioaccumulation Testing, Protective of Humans (2 endpoints)	I. Sediment Profile Imaging (SPI) Survey	J. Pore Water and Surface Water Total PAH Concentrations	
		B1. Ecological Receptors	B2. Human Receptors				F1. Survival	F2. Tissue Concentrations				J1. Ecological Receptors	J2. Human Receptors
No Adverse Effects	Non-toxic	Below SF Bay Water Quality Objective	Below Site-Specific Risk-Based Human Direct Contact Exposure Criteria	Both Endpoints (species) = Non-toxic	Both Endpoints (survival, growth) = No Significant Impacts	Both Endpoints (survival, growth) = No Significant Impacts	Both Test Species Survive	Both Test Species Below TRVs Protective of Invertebrates	Both Test Species Below Site-Specific Risk-Based Tissue Criteria	Both Test Species Below Human Health Consumption Criteria	Infaunal Succession Stage 2 or 3; or Stage 1 with physical disturbance	Below SF Bay Water Quality Objective	Below Site-Specific Risk-Based Human Direct Contact Exposure Criteria
Potential Adverse Effects	Toxic	Above SF Bay Water Quality Objective	Above Site-Specific Risk-Based Human Direct Contact Exposure Criteria	One or Both Endpoints (species) = Toxic	One or Both Endpoints (survival, growth) = Significant Impacts	One or Both Endpoints (survival, growth) = Significant Impacts	One or More Test Species Don't Survive	One or Both Test Species Greater Than TRVs Protective of Invertebrates	One or Both Test Species Greater Than Site-Specific Risk-Based Tissue Criteria	One or Both Test Species Greater Than Human Health Consumption Criteria	Infaunal Succession Stage 1 with absence of physical disturbance	Above SF Bay Water Quality Objective	Above Site-Specific Risk-Based Human Direct Contact Exposure Criteria

Comparison criteria protective of fish and wildlife were developed via food-web modelling

Risk-based direct contact exposure criteria were developed for the protection of recreational swimmers and commercial/maintenance workers

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Lowest site specific effect concentration (LSSEC) based on outcomes of empirical assessment methods

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		B1. Ecological Receptors	B2. Human Receptors				F1. Survival	F2. Tissue Concentrations		
No Adverse Effects	No toxicity for elutriate from sediment with 87,200 ug/kg	Elutriate from sediment with 87,200 ug/kg had 1,087 ng/L; below SF Bay WQO and Site-specific risk-based criteria for human direct contact exposure		Non-toxic to both species for sediment concentrations up to 425,000 ug/kg	No observed effect for sediment concentrations up to 427,000 ug/kg	No observed effect for sediment concentrations up to 427,000 ug/kg	Both species survive for sediment concentrations up to 425,000 ug/kg	Both Test Species Below TRVs for sediment concentrations up to 224,000 ug/kg	Tissue concentrations for both species below all Site-specific tissue criteria for sediment concentrations up to 224,000 ug/kg	Tissue concentrations for both species below EPA HH Criterion for sediment concentrations up to 224,000 ug/kg
Potential Adverse Effects	No higher sediment concentration tested	No higher sediment concentration tested		No higher sediment concentration tested	No higher sediment concentration tested	No higher sediment concentration tested	No higher sediment concentration tested	Multiple TRVs exceeded, in *Macoma* tissue only, for sediment with 425,000 ug/kg	One protective prey tissue criterion for birds exceeded, in *Macoma* tissue only, for sediment with 425,000 ug/kg	EPA HH criterion exceeded, in *Macoma* tissue only, for sediment with 425,000 ug/kg

Based on available data, the LSSEC is 425,000 µg/kg dry wt. It may be lower than 425,000 µg/kg , but no lower than 87,200 µg/kg dry wt.

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Data evaluation framework combines three components:

Bulk sediment PAH concentration relative to LSSEC (lowest site specific effects concentration)

PAH source type

Direct measurement of benthic condition and pore water PAH concentrations.

Sediment Condition[1]	Empirical Evaluation of Potential Impairment of Beneficial Uses Bulk Sediment Concentration (µg/kg total PAHs)	PAH Source Type	Potential Impairment of Benthic Community, Habitat and/or Water Quality[2]	Management Recommendation (Priority for Remedial Evaluation)
1	< 4,500	Any	Any	No Remediation
2	4,500 - 44,792 (ERM)[3]	Urban Influence (UI)	Any	No Remediation
3	4,500 - 44,792 (ERM)[3]	Mixture of UI and Likely MGP-Related	None	No Remediation
4	4,500 - 44,792 (ERM)[3]	Likely MGP-Related	None	No Remediation
5	4,500 - 44,792 (ERM)[3]	Mixture of UI and Likely MGP-Related	Yes	High Priority
6	4,500 - 44,792 (ERM)[3]	Likely MGP-Related	Yes	High Priority
7	44,792 (ERM) - LSSEC	Urban Influence (UI)	None	No Remediation
8	44,792 (ERM) - LSSEC	Mixture of UI and Likely MGP-Related	None	No Remediation[4]
9	44,792 (ERM) - LSSEC	Likely MGP-Related	None	No Remediation[4]
10	44,792 (ERM) - LSSEC	Urban Influence (UI)	Yes	Low Priority
11	44,792 (ERM) - LSSEC	Mixture of UI and Likely MGP-Related	Yes	High Priority
12	44,792 (ERM) - LSSEC	Likely MGP-Related	Yes	High Priority
13	> LSSEC	Urban Influence (UI)	Any	Low Priority
14	> LSSEC	Mixture of UI and Likely MGP-Related	Any	High Priority
15	> LSSEC	Likely MGP-Related	Any	High Priority

Data used in evaluation framework

- Sediment PAH nature and extent delineation
  - 129 sediment grab samples, 776 discrete sediment samples from vibracores
- PAH source evaluation
- Toxicity testing to empirically evaluate potential impairment
  - Water column, sediment-water interface, and benthic toxicity bioassays
- Bioaccumulation testing
- Sediment profile imaging (100 stations)
- Pore water sampling
  - 21 Pore water/ surface water stations; co-located gravity cores
  - Analyzed three depth intervals: 0-0.5, 1.0-1.5, and 2.0-3.0 feet below mudline

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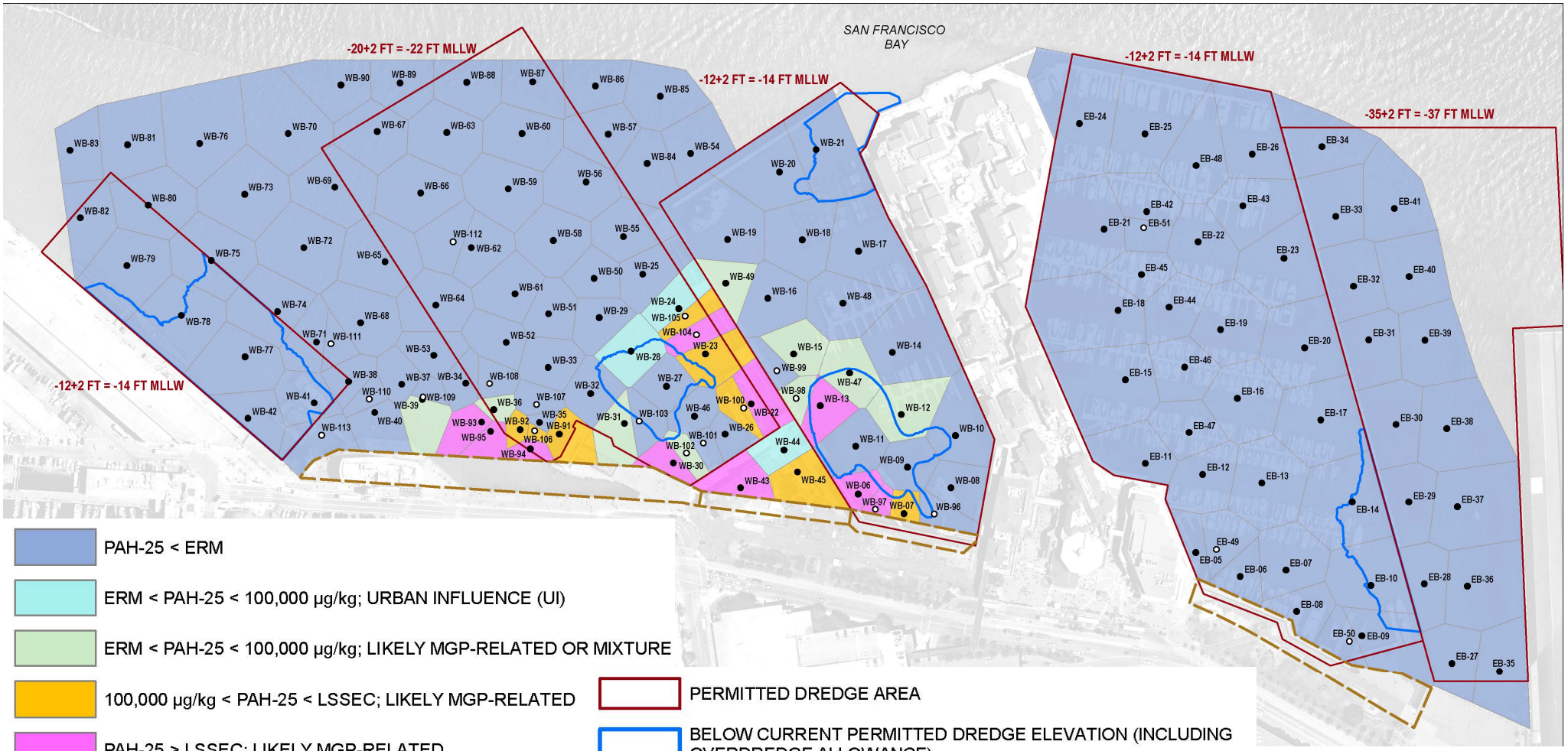
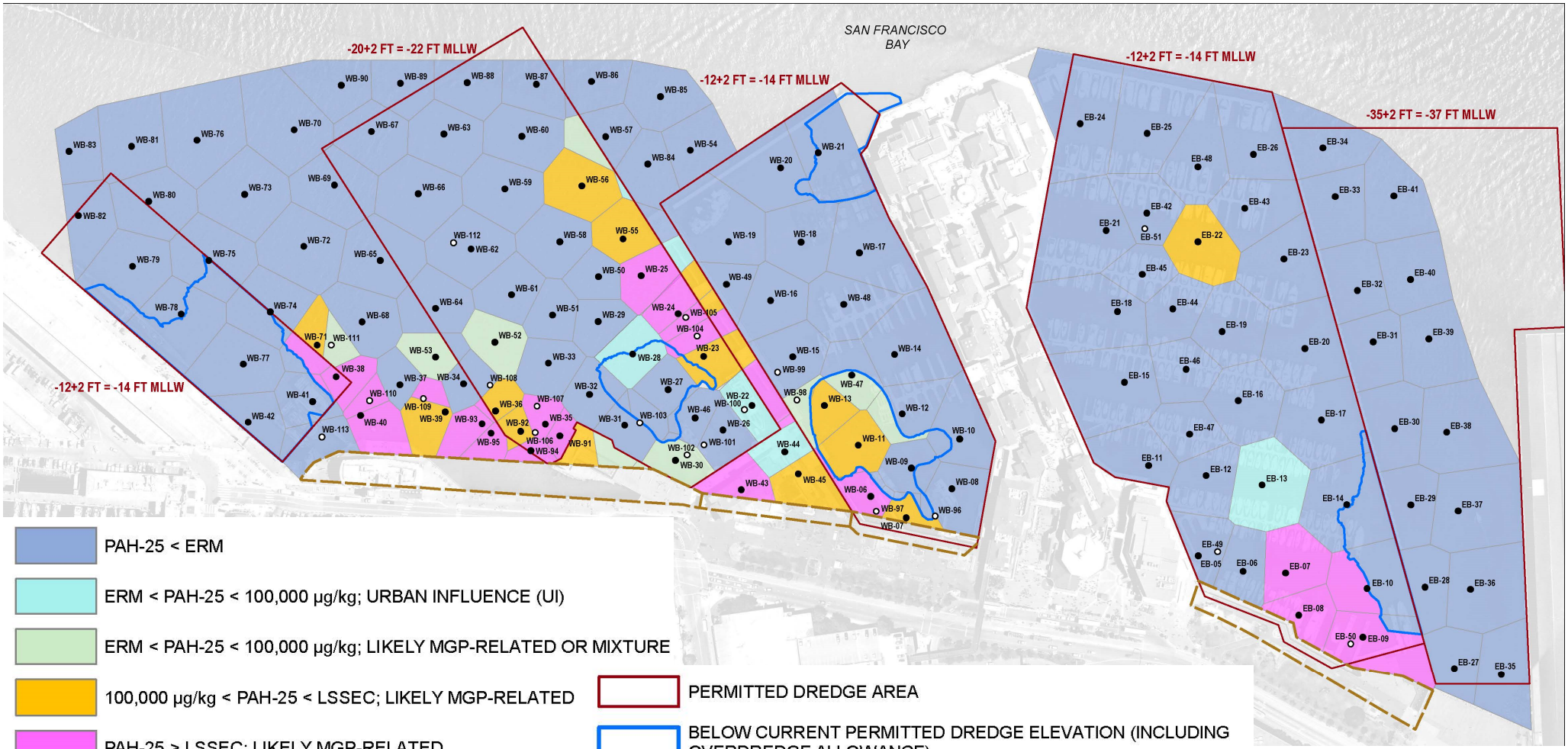
Application of framework to surface sediment conditions



Application to conditions in 3 feet below dredge elevation



Conclusions

- Site sediments with total PAH concentrations >100,000 µg/kg did not demonstrate potential impairment to beneficial uses of the waterway
- No adverse effects at PAH concentrations much higher than "Ambient/BT" or other common screening values (e.g., ER-M = 44,800 µg/kg)
- Attributable to sorptive properties of SF Bay mud, reducing bioavailability – consistent with pore water measurements
- Empirical investigation approach, supplemented with food-web modeling, focused remedial evaluation on areas with conservative potential for impairment of beneficial uses

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Other presentations related to this investigation

- Platform presentation by R. Jordan, Wednesday at 1:50pm in session A6 : "PAH source evaluation of sediment in the vicinity of Pier 39, San Francisco Bay"
  - Identified three likely MGP-related PAH sources, a creosote source; both distinguishable from "urban influence"
- Platform presentation by L. McWilliams, Thursday 9:40am in session E6 : "In-situ pore water sample collection from multiple depth intervals to monitor contaminant bioavailability and/or remedial performance"
  - Innovative device collects in-situ pore water from three depth intervals
  - Focuses "effectiveness" monitoring on most bioavailable (i.e., dissolved) phase

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