CA Regional Water Quality Control Board
San Diego Region

PUBLIC WORKSHOP:

TENTATIVE CLEANUP AND ABATEMENT ORDER (CAO) NO. R9-2005-0126

June 29, 2005

AQUATIC LIFE BENEFICIAL USES IMPAIRMENT

(Tentative CAO Findings 12 – 21)

Tentative CAO Finding 12

- **Aquatic Life Impairment**

  "Aquatic life beneficial uses designated for San Diego Bay are impaired due to the elevated levels of pollutants present in the marine sediment at the Shipyard Sediment Site."

Tentative CAO Finding 13

- **Multiple Lines of Evidence**

  Benthic Community

  (1) Sediment quality triad measurements

  (2) Bioaccumulation analyses

  (3) Pore water analyses

  Fish

  (4) Fish histopathology analyses

  (5) Analyses of PAH breakdown products in fish bile

Line of Evidence #1 of 5:

Sediment Quality Triad Approach

(Tentative CAO Findings 14 - 16)

Findings 13

- **Multiple Lines of Evidence**

Benthic Community

(1) Sediment quality triad measurements

(2) Bioaccumulation analyses

(3) Pore water analyses

Fish

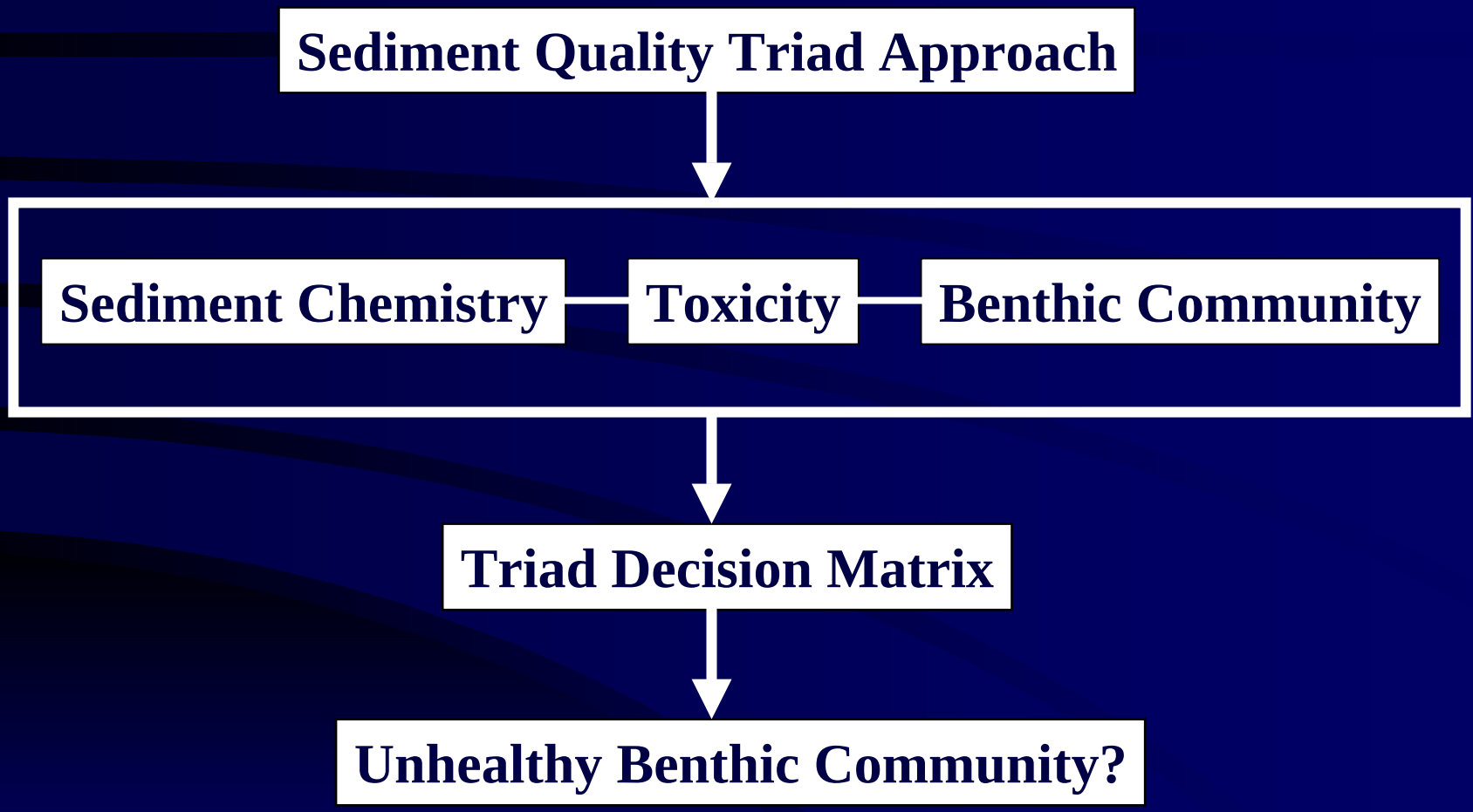
(4) Fish histopathology analyses

(5) Analyses of PAH breakdown products in fish bile

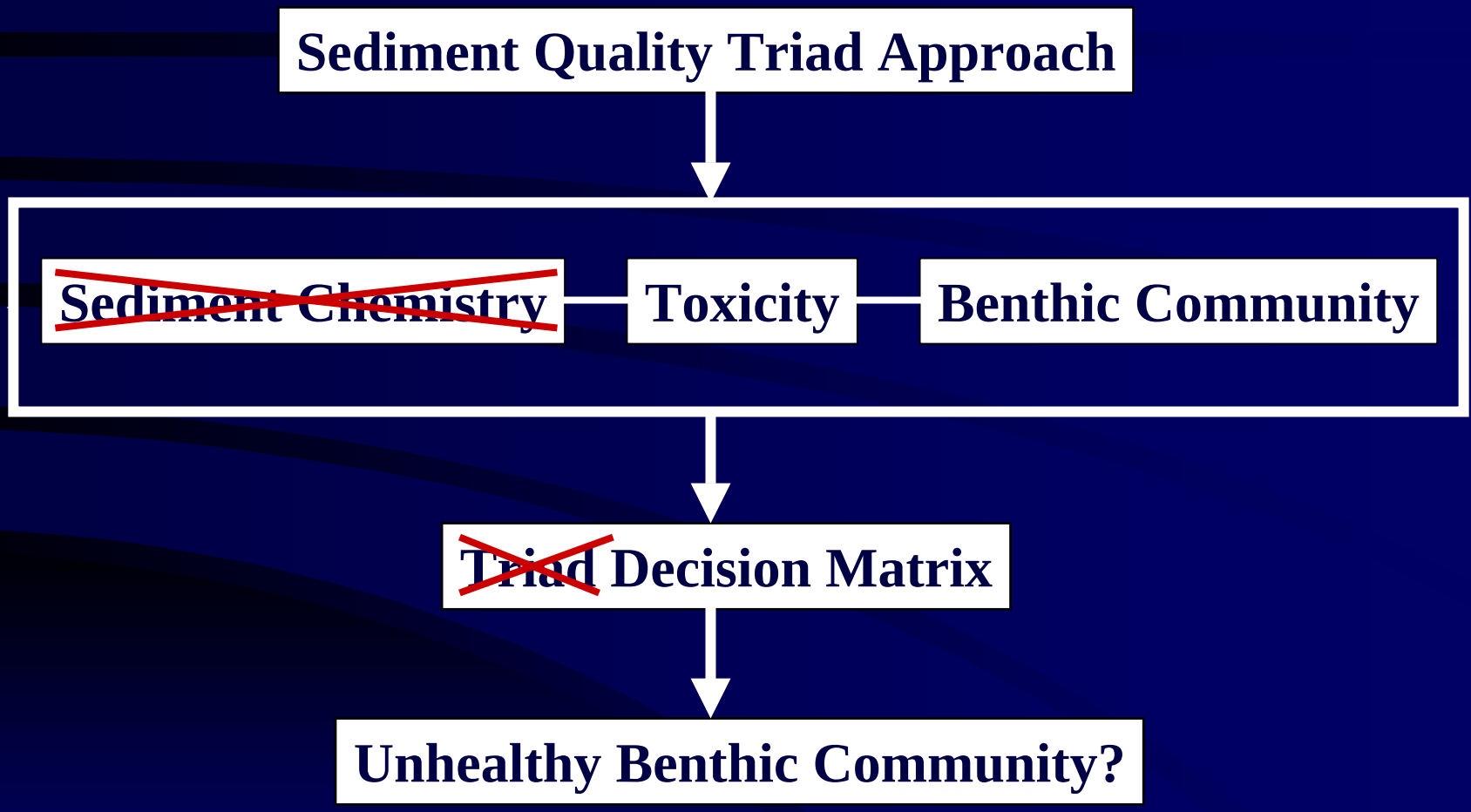
Key Differences

- **Weight-of-Evidence Decision Matrix**
  - SY Technical Report: toxicity & benthic community (2 legs of triad)
  - Regional Board: sediment chemistry, toxicity, and benthic community (3 legs of triad)
- **Reference Pool**
  - SY Technical Report: 22 reference stations
  - Regional Board: 18 reference stations

Regional Board's Process



SY Technical Report Process



Regional Board's Process

- **General Approach for 3 Legs of Triad:**
  - **Comparison to specific threshold value(s)**
  - **Comparison to baseline sediment quality condition (*key difference)**
- **Classifications assigned to each leg:**
  - **Low**
  - **Moderate**
  - **High**

Key Differences

- Shipyard Technical Report
  - Final Reference Pool
  - **N = 22**
  - **17** Bight 98 stations, **5** stations from Cholla/Paleta and shipyard study
- Regional Board
  - Baseline Condition Reference Pool
  - **N = 18**
  - **9** Bight 98 stations, **9** stations from Cholla/Paleta and shipyard study

Baseline Condition

- Baseline conditions originally established for Mouth of Chollas and Paleta Creek TMDL projects
- *Sediment Assessment for the Mouths of Chollas Creek and Paleta Creek, San Diego. Phase 1 Final Report, May 2005.*
  - http://www.waterboards.ca.gov/sandiego/programs/programs.html
  - Copy in NASSCO and SWM File

Baseline Condition

- Applicability to Shipyard Sediment Site study
  - Pool includes Shipyard Sediment Site reference stations
  - Chollas / Paleta and shipyard used the same reference stations
  - Chollas / Paleta and shipyard reference stations sampled in the same time frame
  - Chollas/Paleta, shipyard, and Bight 98 study sampling and analysis methods comparable

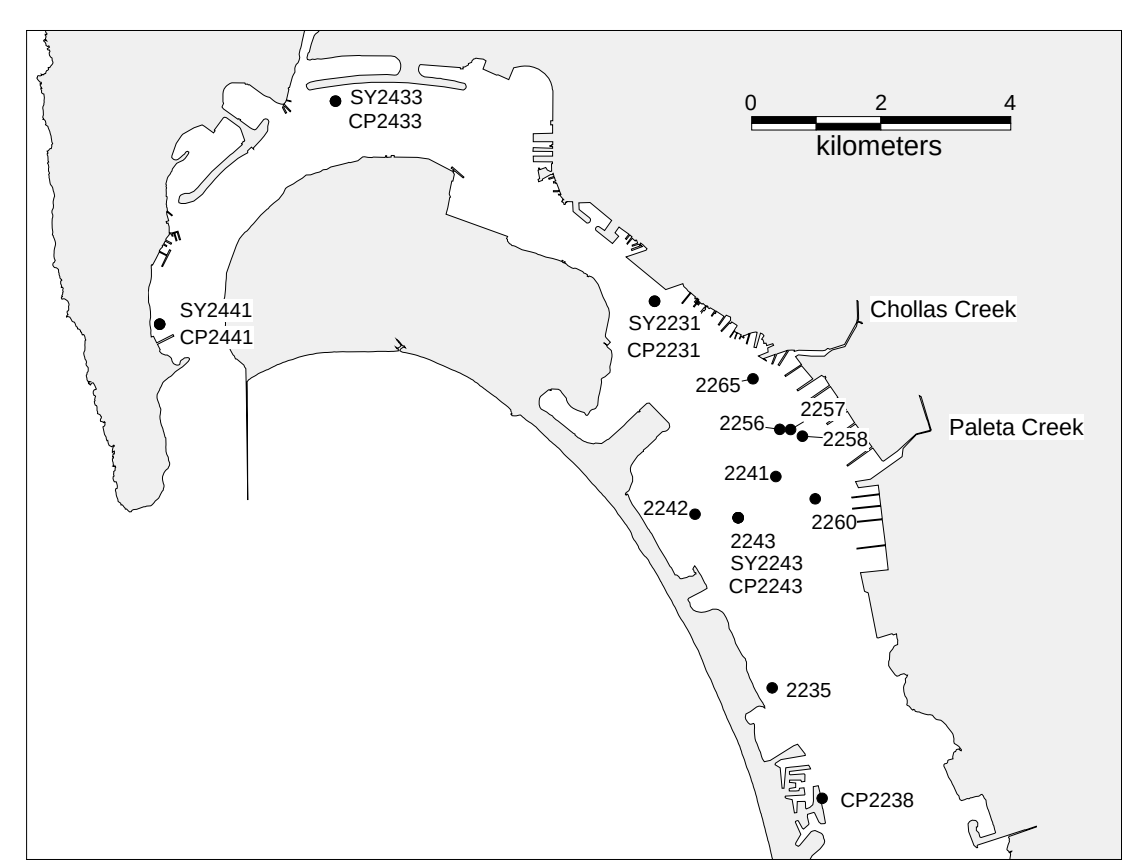
Baseline Sediment Quality Condition - Criteria

- **Station Selection**
  1. Low sediment contaminant concentrations
  2. Comparable habitat to investigation sites
  3. Data comparability (similar sampling and test methods)
- Adequate sample size for statistical analyses

Baseline Sediment Quality Condition - Stations

- NASSCO and SWM study 2001
  - 4 Stations
- Chollas/Paleta Creek TMDL study 2001
  - 5 Stations
- Southern Calif. Bight 1998 Regional Monitoring Survey (Bight 98)
  - 9 Stations
- Total # of Stations = 18
- Advantages of the Baseline Condition

Baseline Condition Stations



Location of reference stations included in the Baseline Pool. The station identifiers indicate whether the station was sampled during the present study (CP prefix), the shipyard study (SY), or the Bight'98 survey (no prefix).

Baseline Sediment Quality Condition

- **Purpose**
  - Defines existing ambient condition in San Diego Bay
  - Acknowledges potential of background contamination
  - Acknowledges natural variability in toxicity and benthic communities

Baseline Sediment Quality Condition

- **Purpose - Continued**
  - Used as a reference pool in the weight of evidence approach
  - Determination of statistical significant differences through use of 95% prediction limits
  - 95% PL allows single site station to pool of reference stations

Alternate Reference Pools

- Alternative reference station pools considered
  - Regional Board – Final Reference Pool
  - San Diego Bay Council
  - NOAA
- Weight of evidence results on the 4 pools

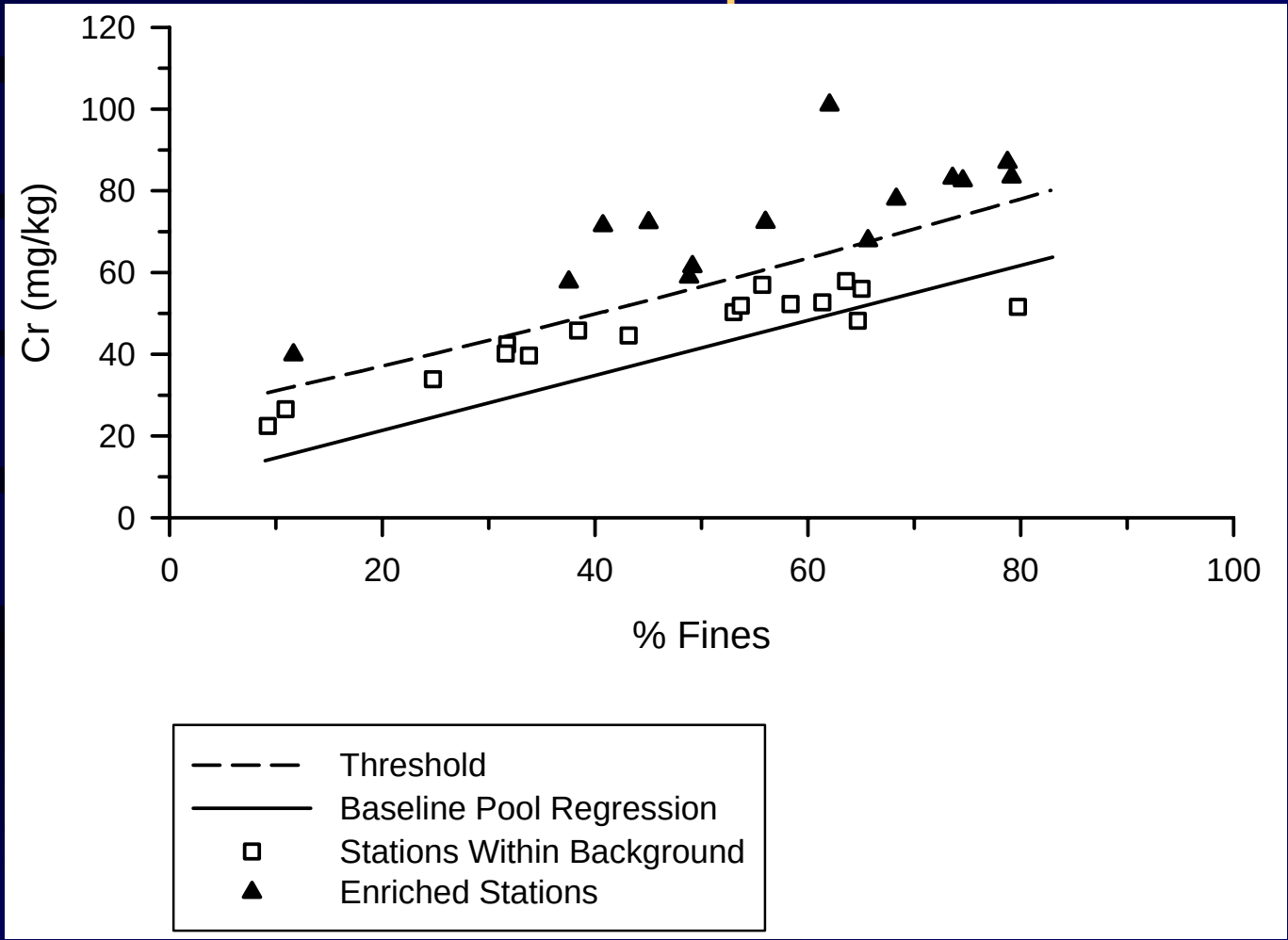
Baseline Condition –Metals Sediment Chemistry

- Percent fine grains sediment to metals plots
- Metals impairment determined on a moving scale depending on grain size
- Metals concentration and percent fines used to determine 95% UPL threshold values

Baseline Condition –Metals Sediment Chemistry

- Methods for determining enrichment
  - Eliminate data from the baseline pool not normally distributed
  - Identify background levels of metals
  - Compare station metals concentrations to a 95% UPL threshold value based on percent fines measured at each station
- Exceedance & Non Exceedence of metal 95% UPL threshold value factored into chemistry decision matrix
- *Sediment Assessment for the Mouths of Chollas Creek and Paleta Creek, San Diego. Phase 1 Final Report, May 2005. App. E*

Metals-Fines Regression Normalization - Example



Baseline Condition – Metals Sediment Chemistry

	As	Cd	Cu	Pb	Hg	Zn
Units	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg
95% UPL	10*	1.0*	200*	90*	0.7*	300*

N = 18

* Number based on 50% fines

Baseline Condition – Sediment Chemistry

	PCB	PPAH	TBT
	ug/kg	ug/kg	ug/kg
95% UPL	84	1234	22

N = 18

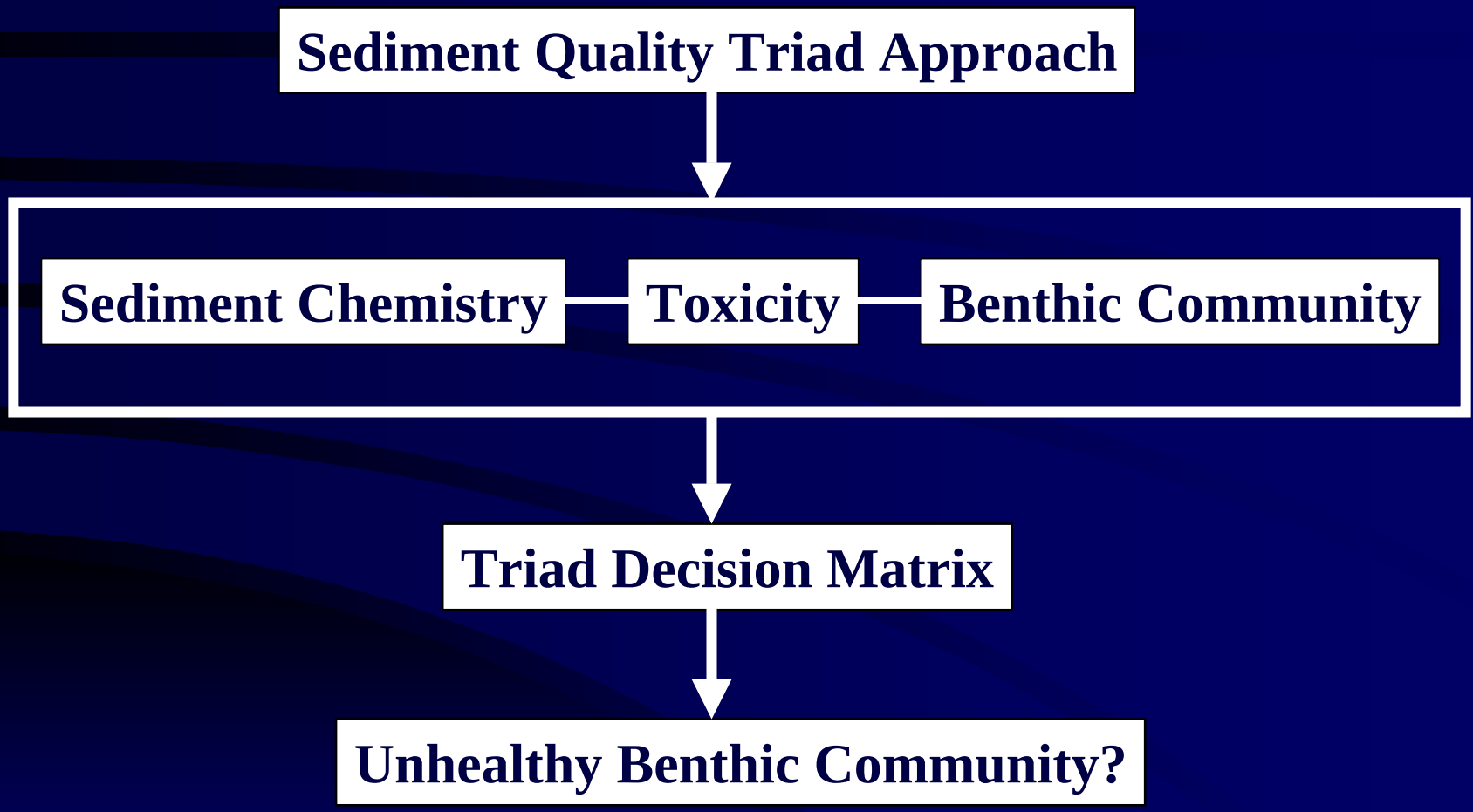
Baseline Condition - Toxicity

	Amphipod Survival	Urchin Fertilization	Bivalve Development
n	18	9	4
95 % Lower Prediction Limit	**72.9**	**41.9**	**37.4**

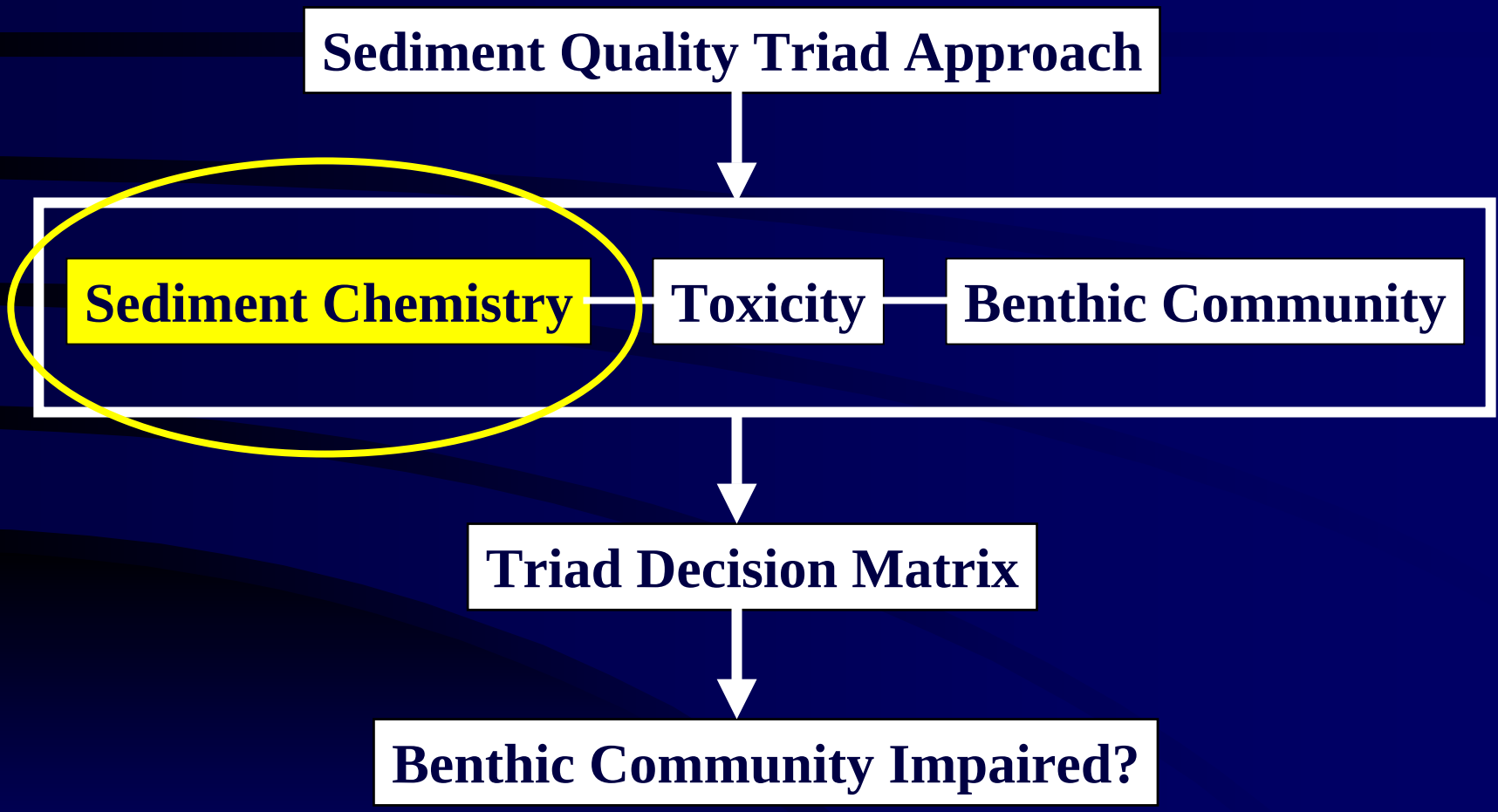
Baseline Condition – Benthic Community

	Benthic Response Index	Abundance	# of Taxa	Shannon Wiener Index
n	**16**	**16**	**16**	**16**
95% Prediction Limit	57.7	239	22	1.8

Regional Board's Process



Regional Board's Process



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- **Results of Sediment Chemistry Leg**
  - 30 triad stations sampled at Shipyard Sediment Site
  - 2 of 30 categorized as “moderate” likelihood chemicals adversely impacting benthic community
  - 28 of 30 categorized as “high” likelihood chemicals adversely impacting benthic community

Sediment Chemistry Comparisons

- **Comparison to Sediment Quality Guidelines:**
  - **Effects range medians (ERMs) for metals**
  - **Consensus midrange effects concentrations for PAHs and PCBs**
  - **Sediment quality guideline quotients (SQGQ1) for chemical mixtures**
- **Comparison to 95% UPL Baseline Pool Sediment Chemistry Values**

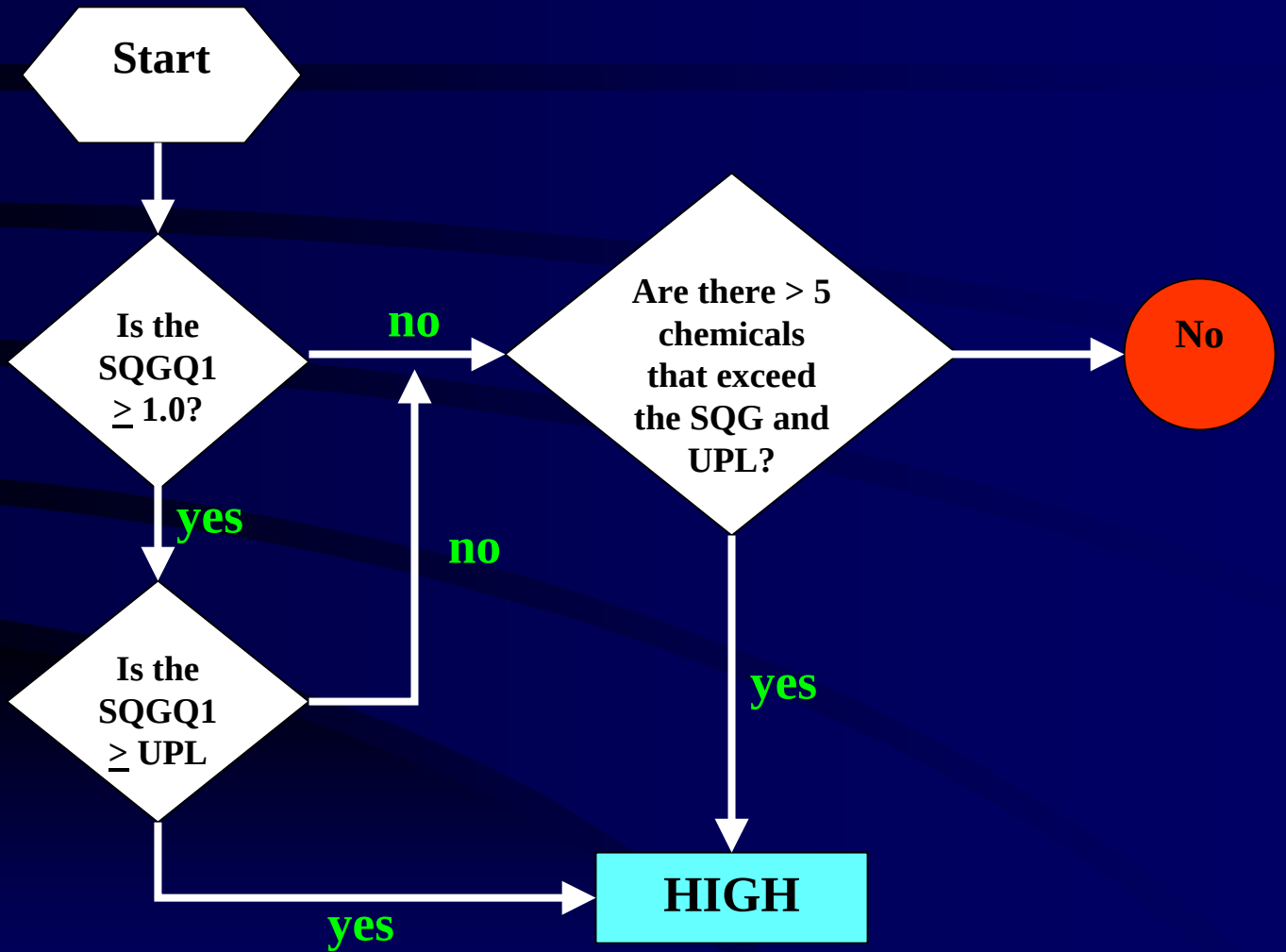
Site	Station	SQGQ1			SQGQ1 ≥ SQGQ1 UPL	# Chemicals > SQG and UPL	Class. Result
		< 0.25	0.25 – 1.0	> 1.0			
NASSCO	NA01		X		Yes	9	High
	NA03		X		Yes	10	High
	NA04		X		Yes	9	High
	NA05		X		Yes	4	High
	NA06		X		Yes	11	High
	NA07		X		Yes	10	High
	NA09		X		Yes	9	High
	NA11		X		Yes	7	High

Site	Station	SQGQ1			SQGQ1 ≥ SQGQ1 UPL	# Chemicals > SQG and UPL	Class. Result
		< 0.25	0.25 – 1.0	> 1.0			
NASSCO	NA12		X		Yes	5	Moderate
	NA15		X		Yes	9	High
	NA16		X		Yes	10	High
	NA17			X	Yes	13	High
	NA19			X	Yes	11	High
	NA20		X		Yes	6	Moderate
	NA22		X		Yes	8	High

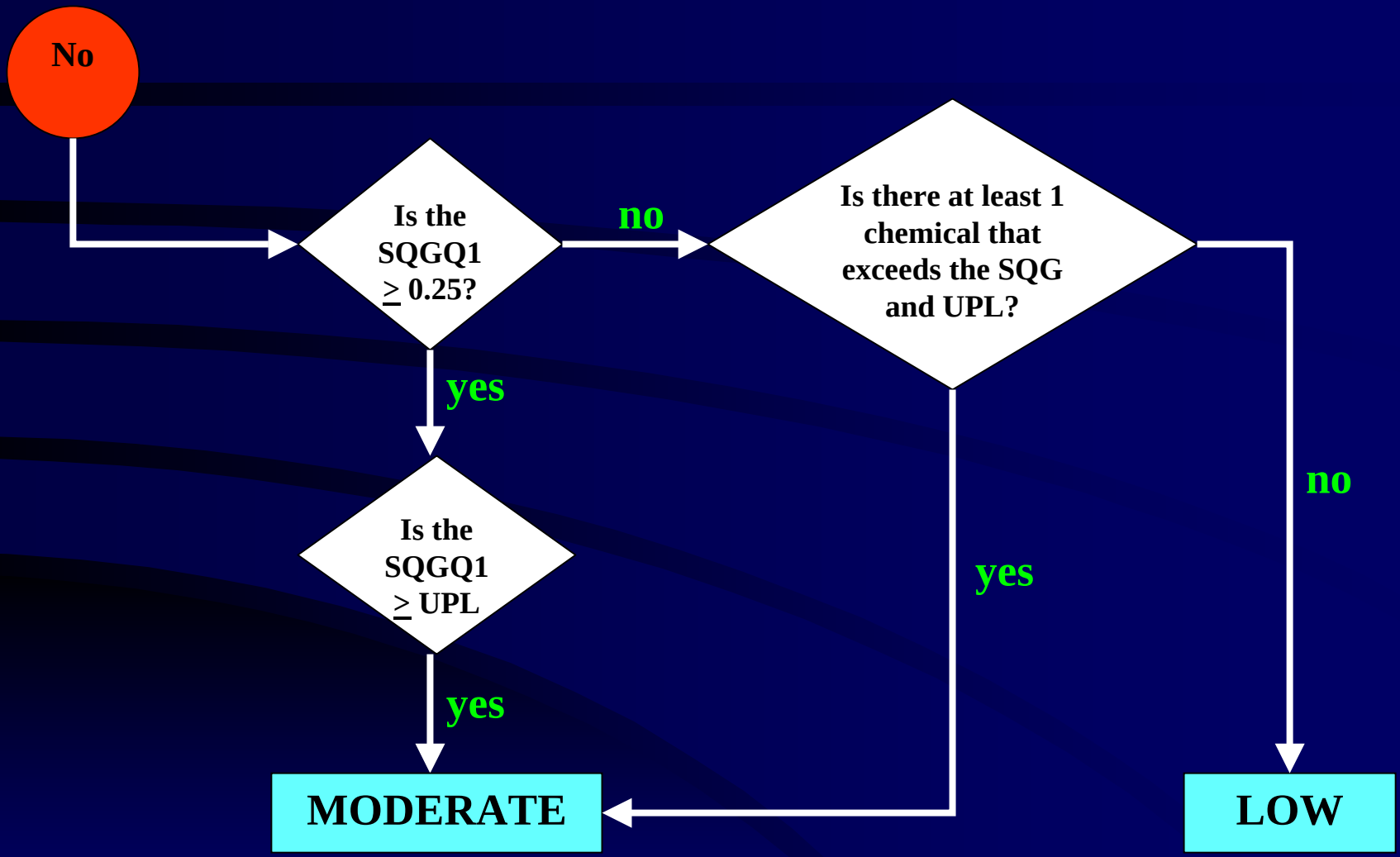
Site	Station	SQGQ1			SQGQ1 ≥ SQGQ1 UPL	# Chemicals > SQG and UPL	Class. Result
		< 0.25	0.25 – 1.0	> 1.0			
SWM	SW02			X	Yes	17	High
	SW03		X		Yes	10	High
	SW04			X	Yes	17	High
	SW08			X	Yes	17	High
	SW09			X	Yes	15	High
	SW11		X		Yes	8	High
	SW13			X	Yes	16	High

Site	Station	SQGQ1			SQGQ1 ≥ SQGQ1 UPL	# Chemicals > SQG and UPL	Class. Result
		< 0.25	0.25 – 1.0	> 1.0			
SWM	SW15		X		Yes	9	High
	SW17		X		Yes	11	High
	SW18		X		Yes	7	High
	SW21			X	Yes	13	High
	SW22			X	Yes	10	High
	SW23			X	Yes	13	High
	SW25		X		Yes	10	High
	SW27		X		Yes	7	High

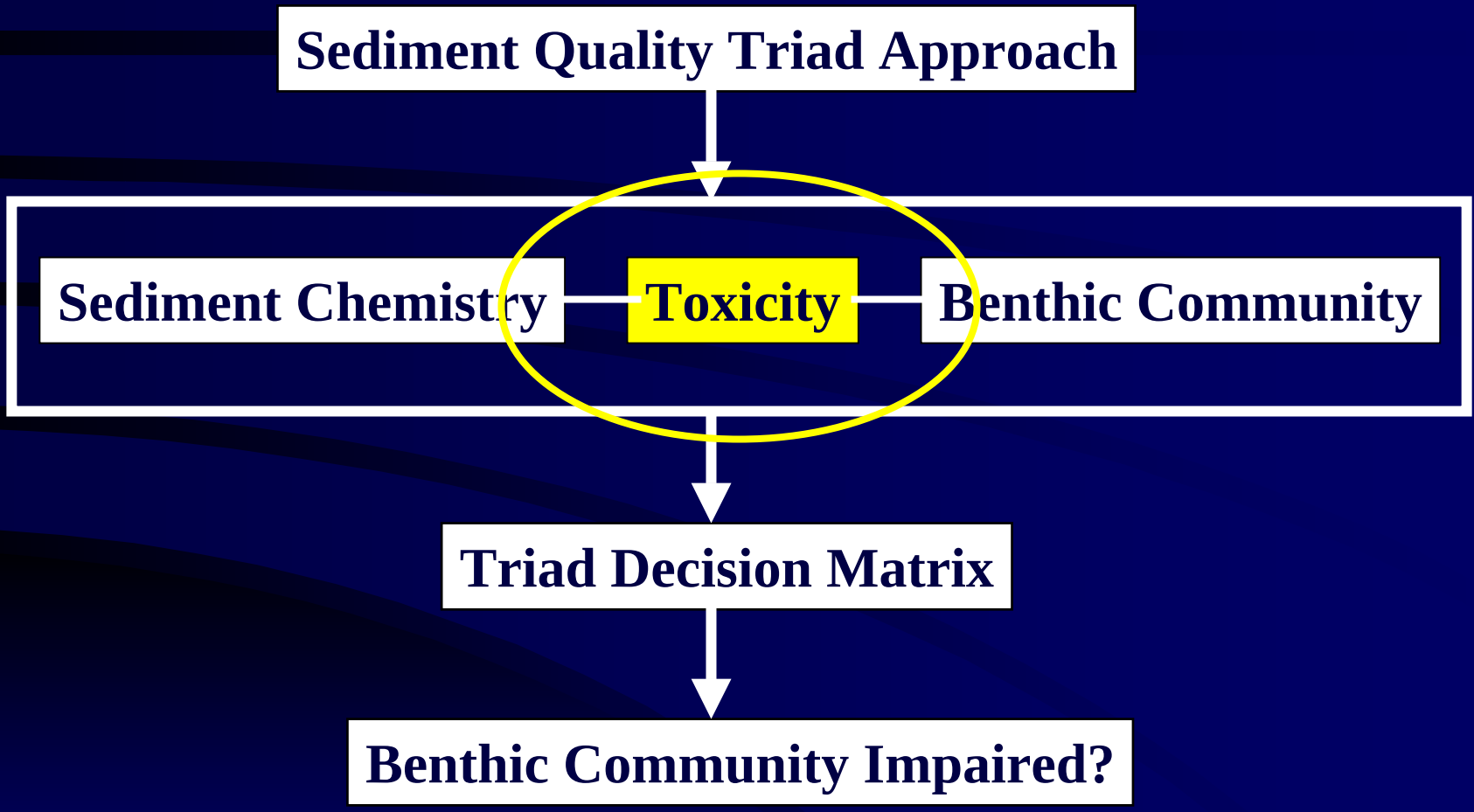
Sediment Chemistry Classification



Sediment Chemistry Classification



Regional Board's Process



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- **Results of Toxicity Leg**
  - 30 triad stations sampled at Shipyard Sediment Site
  - 17 of 30 categorized as “low” likelihood of toxic effects
  - 13 of 30 categorized as “moderate” likelihood of toxic effects

Toxicity Comparisons

- **Comparison to Negative Controls:**

  - 3 toxicity tests: amphipod survival, sea urchin fertilization, bivalve development

  - One tailed Student t-test

- **Comparison to 95% LPL Baseline Pool Toxicity Values (*key difference)**

Station	Amphipod Survival			Urchin Fertilization			Bivalve Development			Class. Result
	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	
NA01	Yes	No	No	Yes	No	No	Yes	No	No	Low
NA03	No	No	No	Yes	No	No	No	No	No	Low
NA04	Yes	No	No	Yes	No	No	Yes	No	No	Low
NA05	Yes	No	No	No	No	No	No	No	No	Low
NA06	Yes	No	No	No	No	No	No	No	No	Low
NA07	Yes	No	No	No	No	No	No	No	No	Low

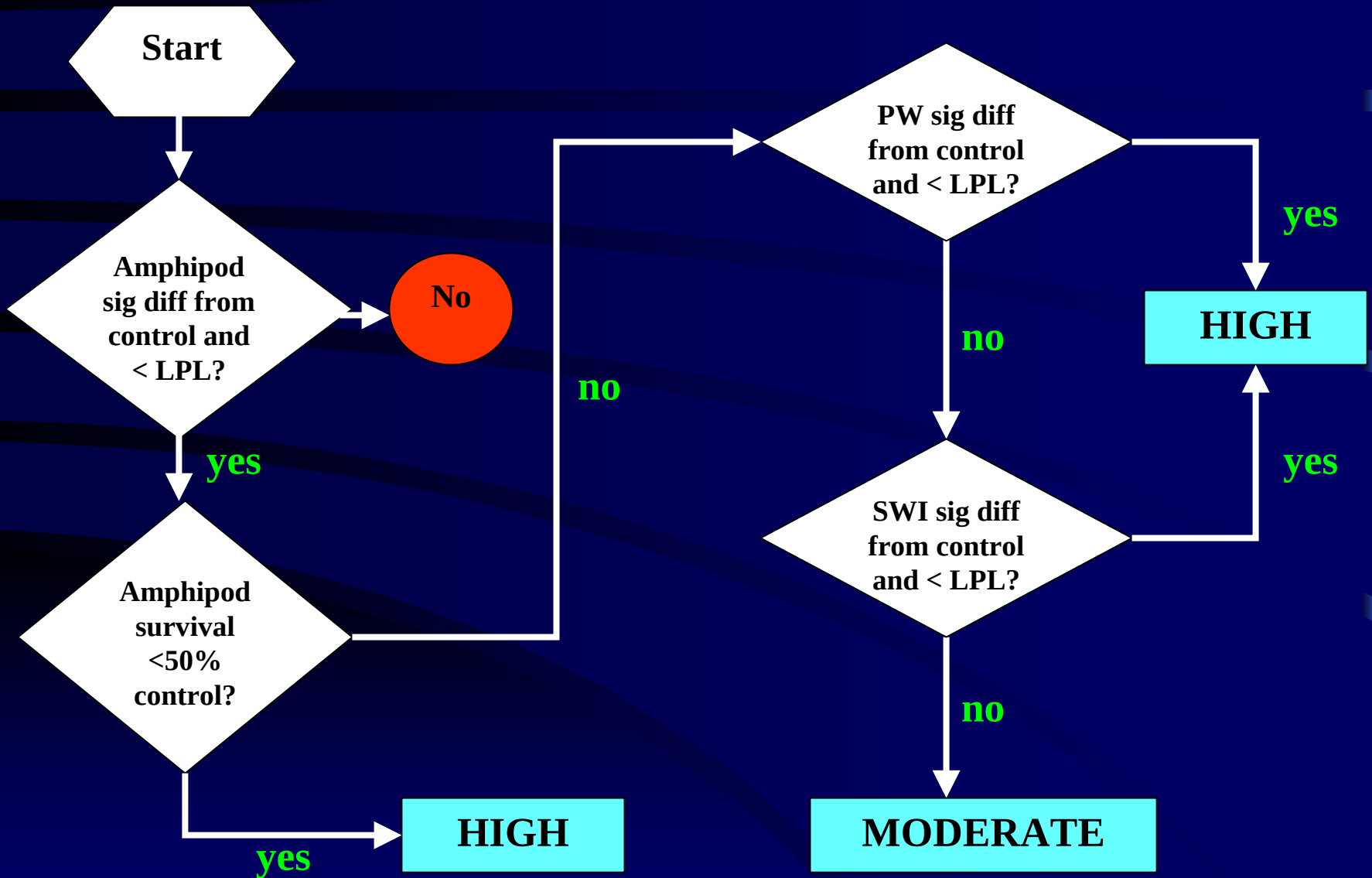
Station	Amphipod Survival			Urchin Fertilization			Bivalve Development			Class. Result
	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	
NA09	Yes	No	No	No	No	No	Yes	Yes	Yes	Moderate
NA11	Yes	Yes	No	No	No	No	No	No	No	Moderate
NA12	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Moderate
NA15	No	No	No	Yes	No	No	No	No	No	Low
NA16	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Moderate
NA17	No	No	No	Yes	No	No	Yes	No	No	Low

Station	Amphipod Survival			Urchin Fertilization			Bivalve Development			Class. Result
	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	
NA19	No	No	No	Yes	No	No	Yes	Yes	Yes	Moderate
NA20	Yes	No	No	Yes	No	No	Yes	No	No	Low
NA22	No	No	No	Yes	No	No	Yes	Yes	Yes	Moderate
SW02	Yes	No	No	No	No	No	No	No	No	Low
SW03	No	No	No	No	No	No	Yes	No	No	Low
SW04	No	No	No	Yes	No	No	Yes	No	No	Low

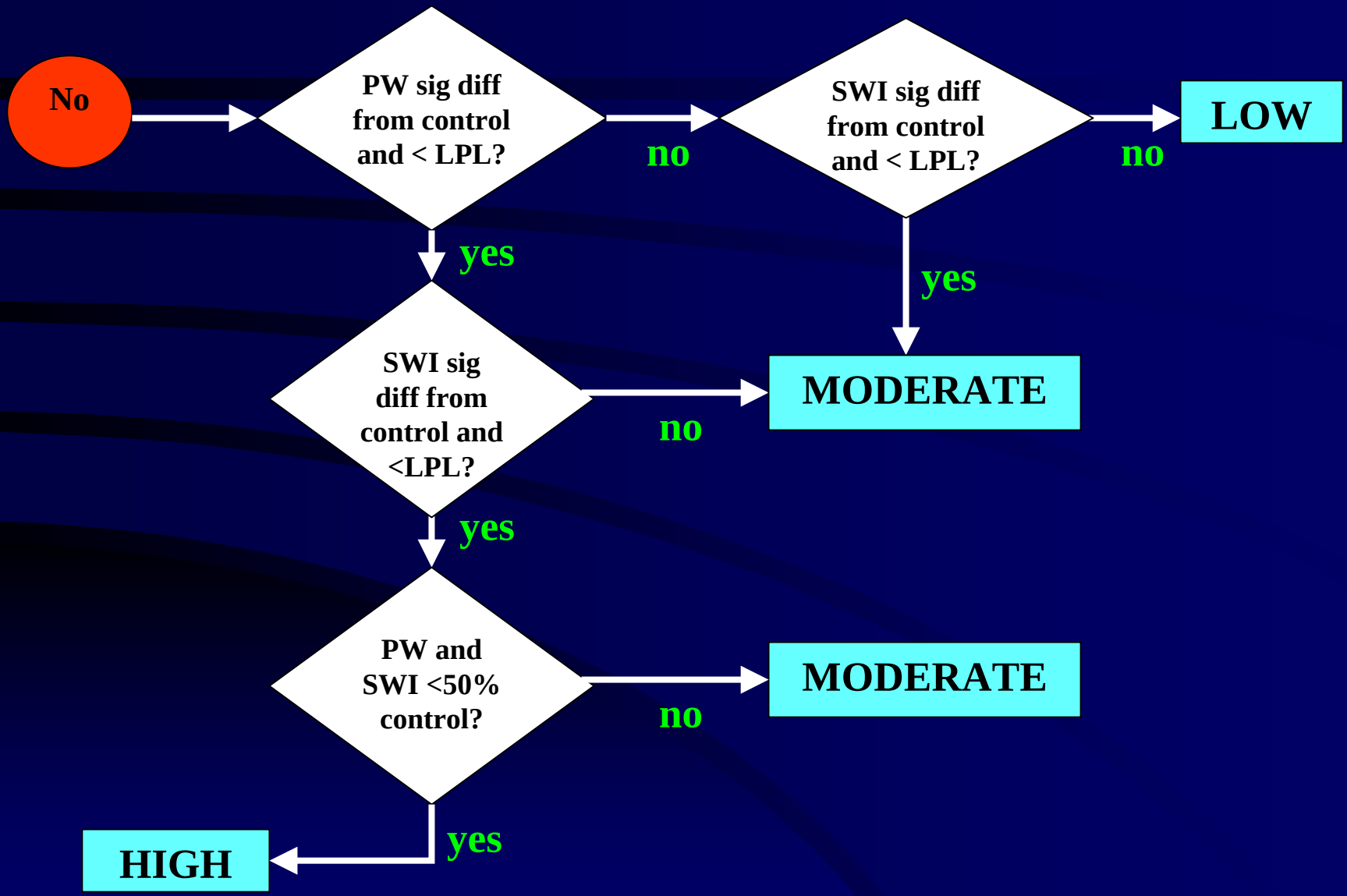
Station	Amphipod Survival			Urchin Fertilization			Bivalve Development			Class. Result
	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	
SW08	Yes	No	No	No	No	No	Yes	No	No	Low
SW09	No	No	No	No	No	No	Yes	No	No	Low
SW11	Yes	No	No	Yes	No	No	No	No	No	Low
SW13	Yes	No	No	No	No	No	Yes	Yes	Yes	Moderate
SW15	No	No	No	No	No	No	Yes	Yes	Yes	Moderate
SW17	No	No	No	Yes	No	No	Yes	Yes	Yes	Moderate

Station	Amphipod Survival			Urchin Fertilization			Bivalve Development			Class. Result
	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	Different from Control	< 95% LPL	< 50% Control	
SW18	No	No	No	Yes	No	No	Yes	No	No	Low
SW21	Yes	No	No	No	No	No	No	No	No	Low
SW22	Yes	No	No	No	No	No	Yes	Yes	Yes	Moderate
SW23	No	No	No	Yes	No	No	Yes	Yes	Yes	Moderate
SW25	Yes	No	No	No	No	No	Yes	Yes	Yes	Moderate
SW27	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Moderate

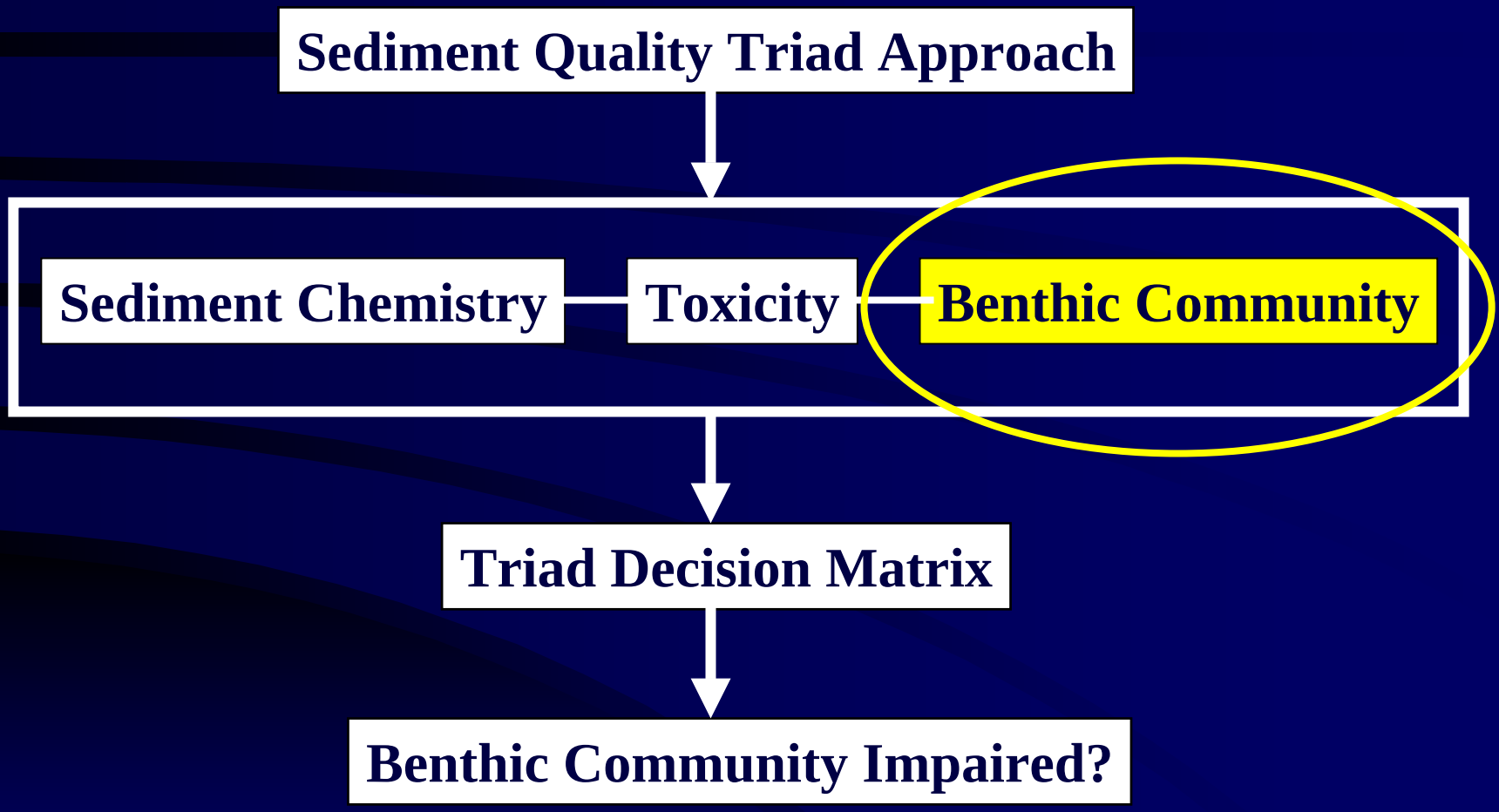
Toxicity Classification



Toxicity Classification



Regional Board's Process



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- **Results of Benthic Community Leg**
  - 30 triad stations sampled at Shipyard Sediment Site
  - 27 of 30 categorized as “low” likelihood of benthic community degradation
  - 3 of 30 categorized as “moderate” likelihood of benthic community degradation

Benthic Community Comparisons

- **Comparison to Benthic Response Index for Embayments**
  - Developed by SCCWRP
- **Comparison to 95% PL Baseline Pool Benthic Community Metrics (*key difference)**
  - Total abundance
  - Total taxa richness
  - Shannon-Wiener Diversity Index
  - Benthic Response Index

Station	Benthic Response Index				Abundance	# Taxa	S-W Diversity	Class. Result
	≥ 73	≥ 53	≥ 42	≥ 95% UPL	≤ 95% LPL	≤ 95% LPL	≤ 95% LPL	
NA01	No	No	Yes	No	No	No	No	Low
NA03	No	No	Yes	No	No	No	No	Low
NA04	No	No	Yes	No	No	No	No	Low
NA05	No	No	Yes	No	No	No	No	Low
NA06	No	Yes	Yes	No	No	No	No	Low

Station	Benthic Response Index				Abundance	# Taxa	S-W Diversity	Class. Result
	≥ 73	≥ 53	≥ 42	≥ 95% UPL	≤ 95% LPL	≤ 95% LPL	≤ 95% LPL	
NA07	No	No	Yes	No	No	No	No	Low
NA09	No	No	Yes	No	No	No	No	Low
NA11	No	No	Yes	No	No	No	No	Low
NA12	No	No	Yes	No	No	No	No	Low
NA15	No	No	Yes	No	No	No	No	Low

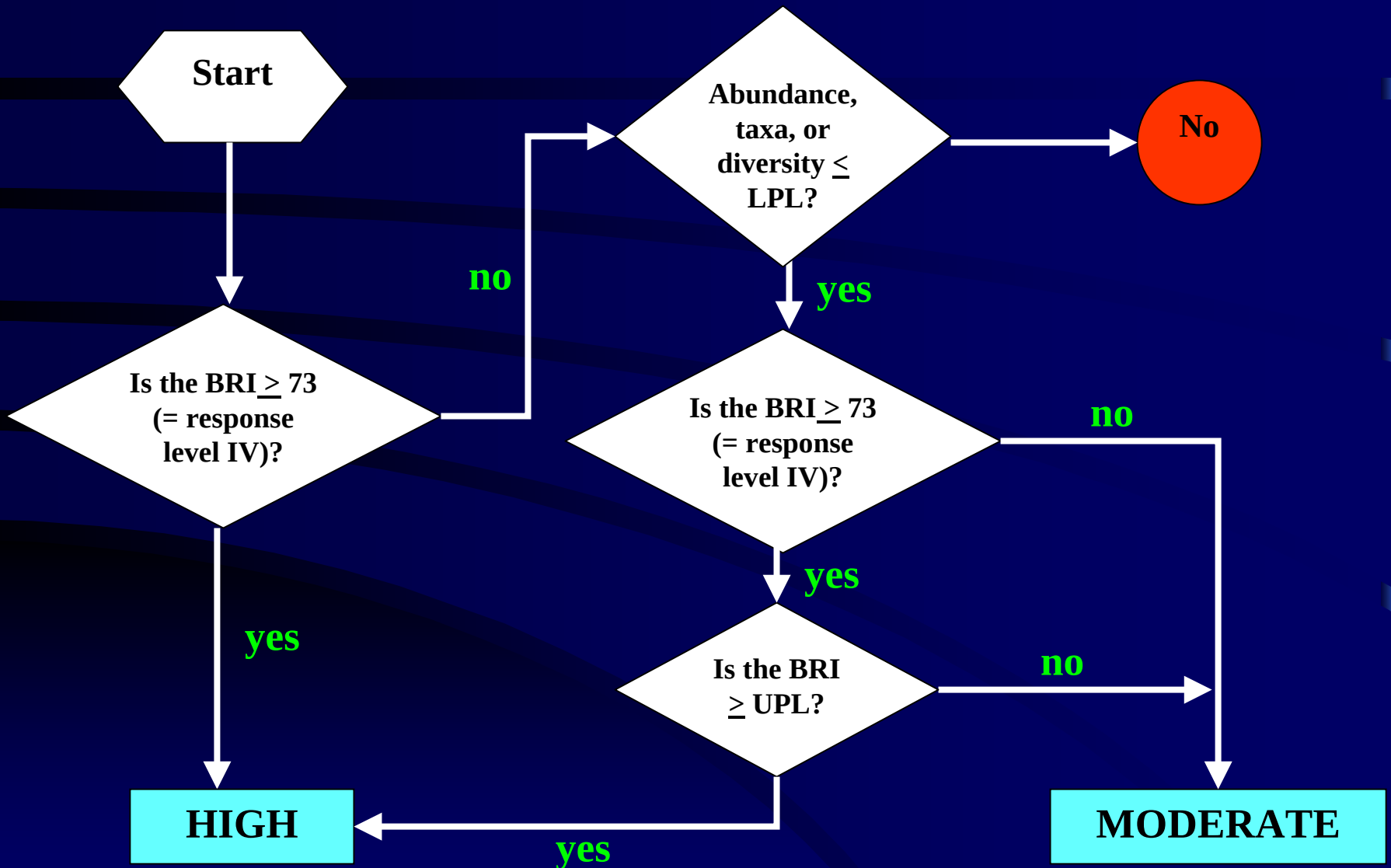
Station	Benthic Response Index				Abundance	# Taxa	S-W Diversity	Class. Result
	≥ 73	≥ 53	≥ 42	≥ 95% UPL	≤ 95% LPL	≤ 95% LPL	≤ 95% LPL	
NA16	No	No	Yes	No	No	No	No	Low
NA17	No	Yes	Yes	No	No	No	No	Low
NA19	No	No	Yes	No	No	No	No	Low
NA20	No	Yes	Yes	No	No	Yes	No	Moderate
NA22	No	No	Yes	No	Yes	Yes	No	Moderate

Station	Benthic Response Index				Abundance	# Taxa	S-W Diversity	Class. Result
	≥ 73	≥ 53	≥ 42	≥ 95% UPL	≤ 95% LPL	≤ 95% LPL	≤ 95% LPL	
SW02	No	No	Yes	No	No	No	No	Low
SW03	No	No	Yes	No	No	No	No	Low
SW04	No	No	No	No	No	No	Yes	Moderate
SW08	No	No	No	No	No	No	No	Low
SW09	No	Yes	Yes	No	No	No	No	Low

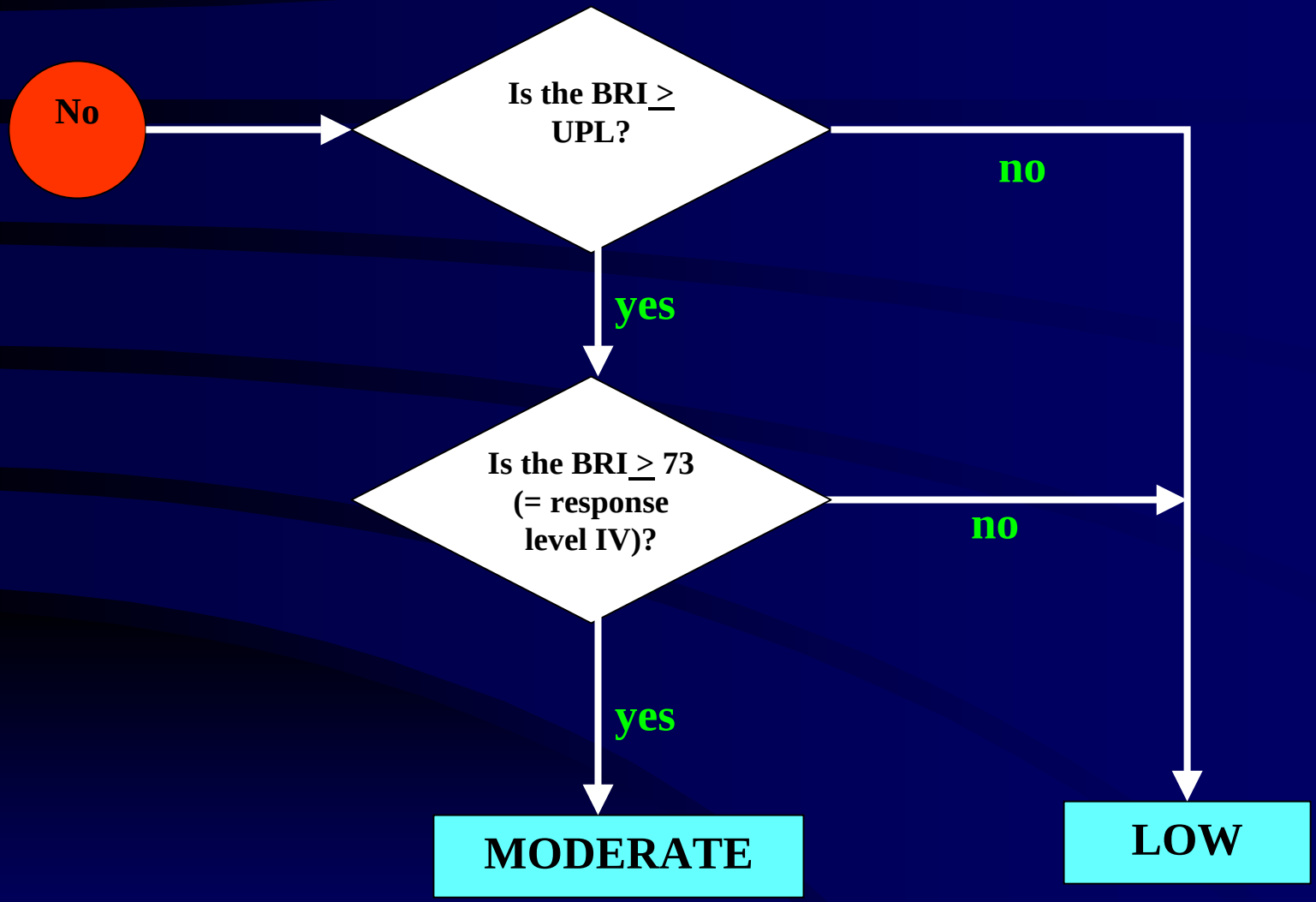
Station	Benthic Response Index				Abundance	# Taxa	S-W Diversity	Class. Result
	≥ 73	≥ 53	≥ 42	≥ 95% UPL	≤ 95% LPL	≤ 95% LPL	≤ 95% LPL	
SW11	No	No	Yes	No	No	No	No	Low
SW13	No	No	Yes	No	No	No	No	Low
SW15	No	No	No	No	No	No	No	Low
SW17	No	No	Yes	No	No	No	No	Low
SW18	No	No	No	No	No	No	No	Low

Station	Benthic Response Index				Abundance	# Taxa	S-W Diversity	Class. Result
	≥ 73	≥ 53	≥ 42	≥ 95% UPL	≤ 95% LPL	≤ 95% LPL	≤ 95% LPL	
SW21	No	Yes	Yes	No	No	No	No	Low
SW22	No	Yes	Yes	No	No	No	No	Low
SW23	No	No	Yes	No	No	No	No	Low
SW25	No	No	No	No	No	No	No	Low
SW27	No	No	Yes	No	No	No	No	Low

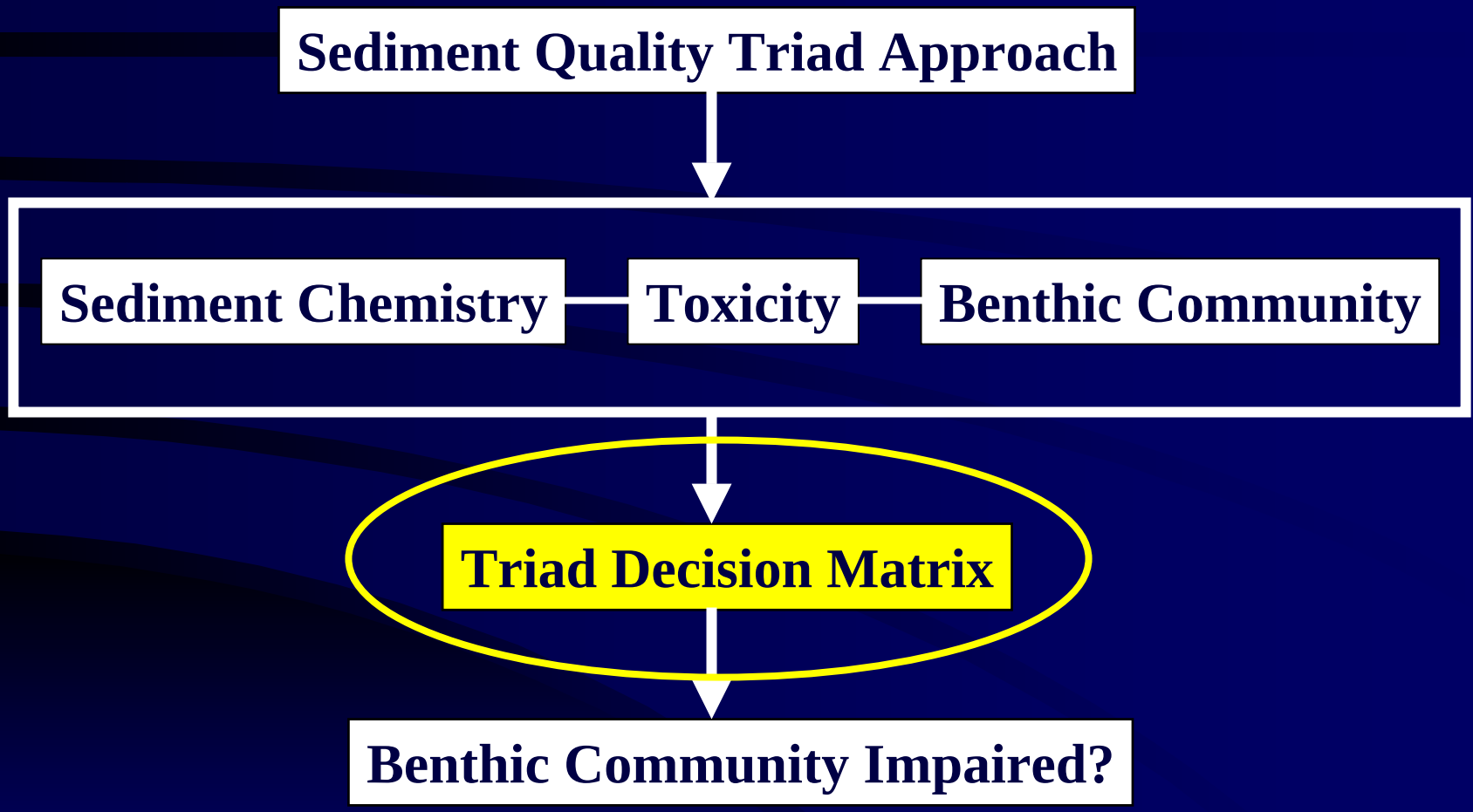
Benthic Community Classification



Benthic Community Classification



Regional Board's Process



Finding 16 - Page 9 of 34

- **Triad Results**
  - 30 triad stations sampled at Shipyard Sediment Site
  - Based on results of all 3 legs
  - 14 of 30 triad stations categorized as “likely” to adversely affect health of benthic community

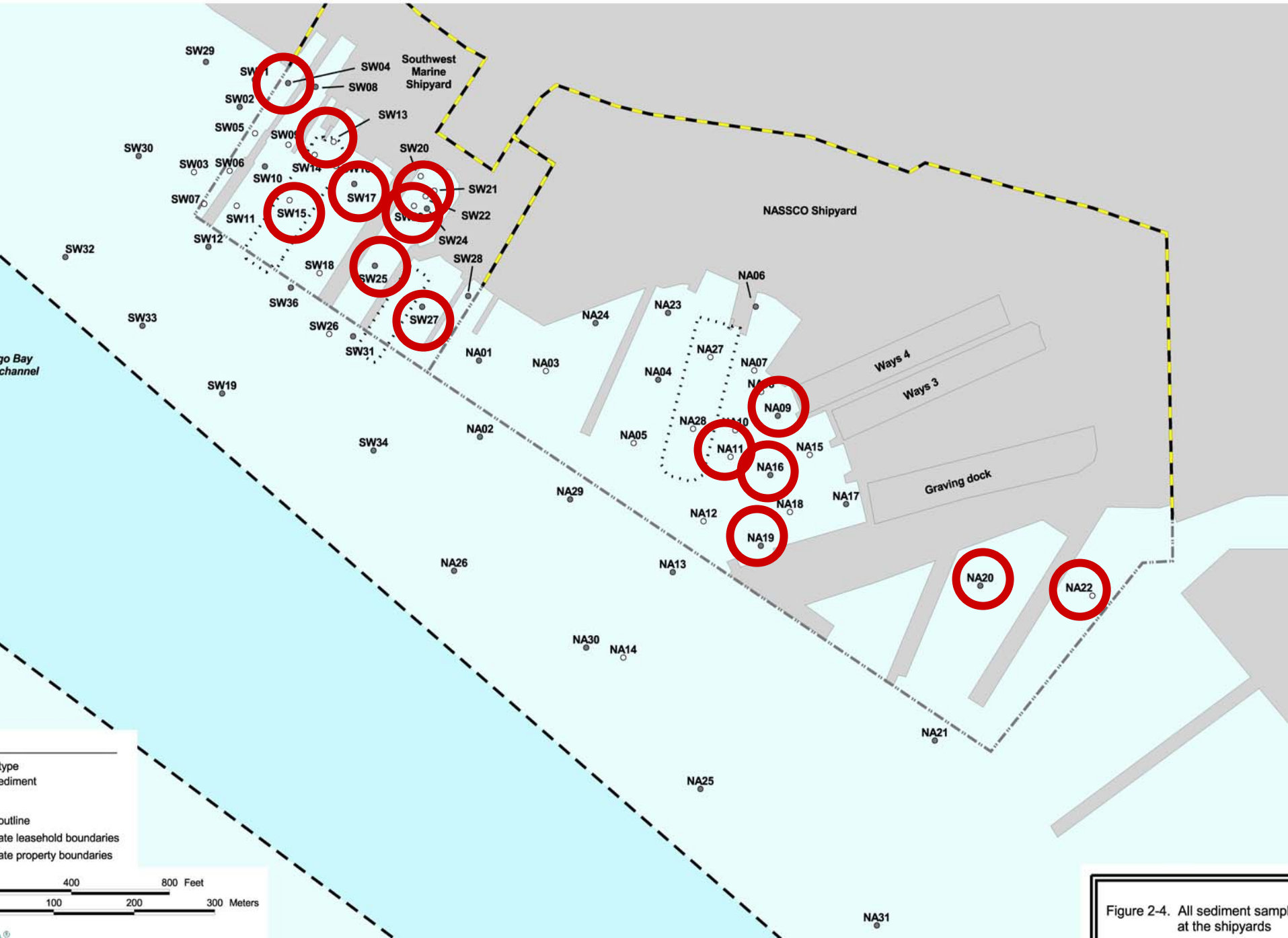


Figure 2-4. All sediment sampl
at the shipyards

Triad Decision Matrix

Sediment Chemistry	Toxicity	Benthic Community	Relative Likelihood of Benthic Community Impairment
High	High	High	**Likely**
High	High	Moderate	
High	Moderate	High	
Moderate	High	High	
High	High	Low	
High	Low	High	
High	Moderate	Moderate	
Moderate	High	Moderate	
Moderate	Moderate	High	
Moderate	Moderate	Moderate	
High	Moderate	Low	
High	Low	Moderate	
Moderate	High	Low	
Moderate	Low	High	

Triad Decision Matrix

Sediment Chemistry	Toxicity	Benthic Community	Relative Likelihood of Benthic Community Impairment
Moderate	Moderate	Low	**Possible**
Moderate	Low	Moderate	
High	Low	Low	
Low	High	High	**Unlikely**
Low	High	Moderate	
Low	Moderate	High	
Low	Moderate	Moderate	
Low	Low	High	
Low	High	Low	
Low	Low	Moderate	
Low	Moderate	Low	
Moderate	Low	Low	
Low	Low	Low	

Line of Evidence #2 of 5:

Bioaccumulation

(Tentative CAO Finding 17)

Finding 13

- **Multiple Lines of Evidence**

  Benthic Community

  (1) Sediment quality triad measurements

  (2) Bioaccumulation analyses

  (3) Pore water analyses

  Fish

  (4) Fish histopathology analyses

  (5) Analyses of PAH breakdown products in fish bile

Key Differences

- **No Differences**
  - **Finding 17 based on results in Shipyard technical report**

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- **Bioaccumulation Results**
  - Statistically significant relationships: arsenic, copper, lead, mercury, zinc, TBT, total PAHs, and HPAHs
  - Chemicals have bioaccumulation potential
  - Chemicals bioavailable to benthic community

Exposure/Effects to Benthic Community

- **28-day Laboratory Test using clam *Macoma Nasuta***
- **Linear Regression Models**
  - **Assess tissue:sediment relationship**
  - **Statistically significant relationship indicates bioaccumulation potential**

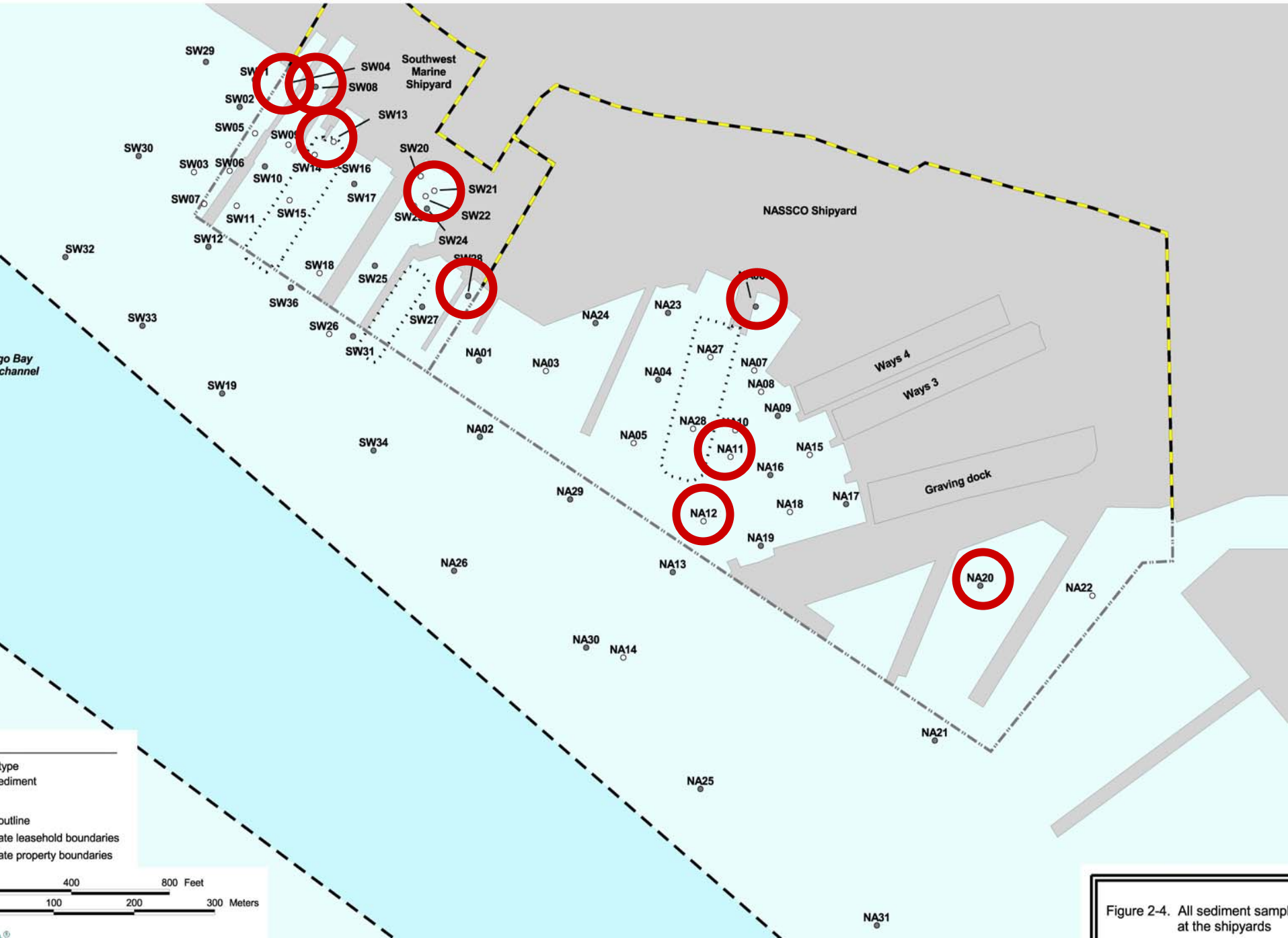
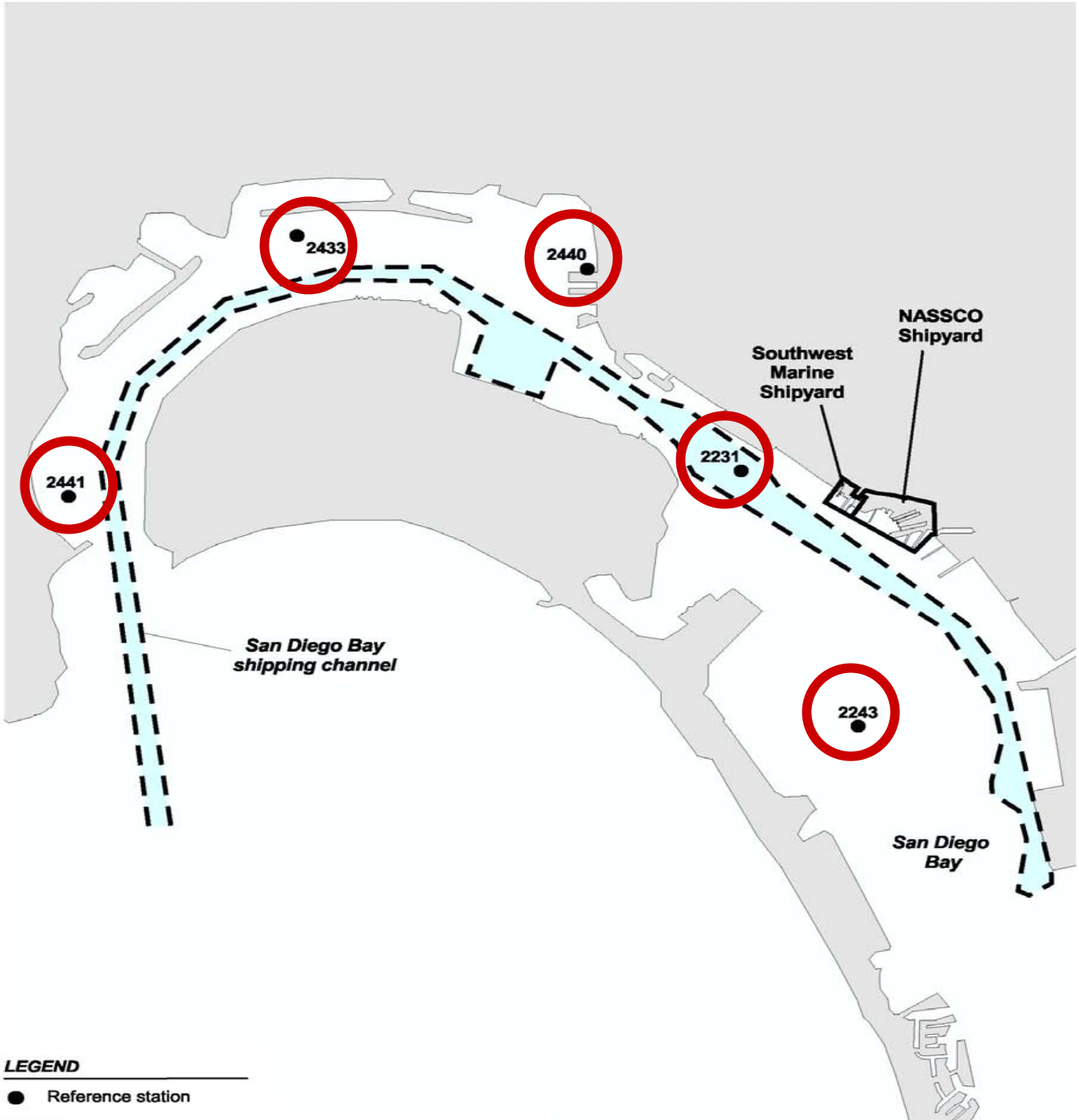


Figure 2-4. All sediment sampl
at the shipyards


2433
2440
2441
2231
2243
NASSCO
Shipyard
Southwest
Marine
Shipyard
San Diego Bay
shipping channel
San Diego
Bay
LEGEND
Reference station

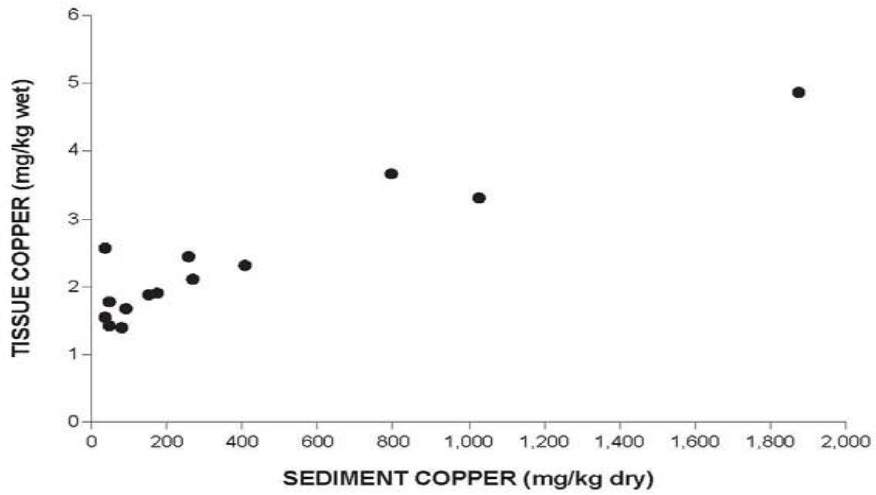


Figure 7-4. Tissue and sediment data for copper

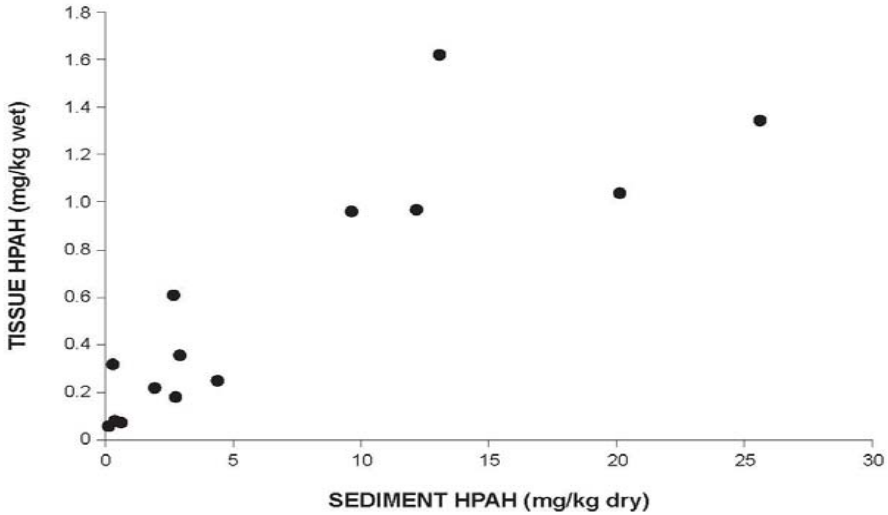


Figure 7-10. Tissue and sediment data for high-molecular-weight polycyclic aromatic hydrocarbons (HPAHs)

8601718.002 1201 - 8601731.002 1201 10/08/03 WA

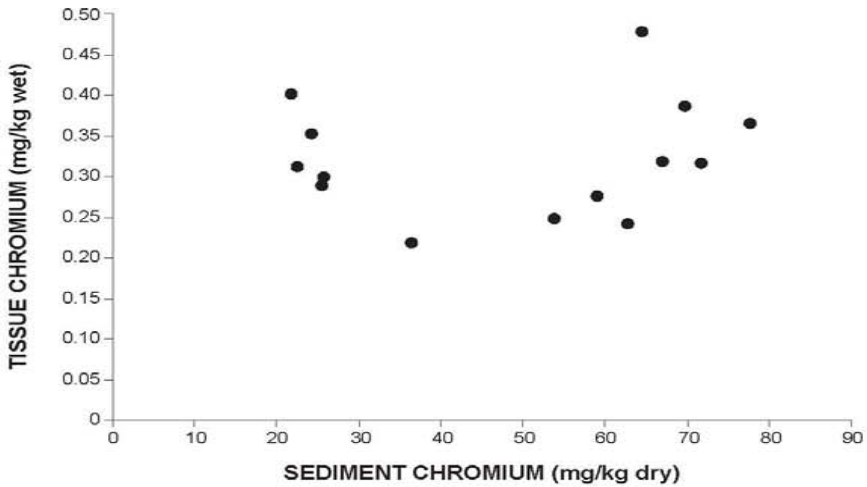


Figure 7-3. Tissue and sediment data for chromium

860171 8.002 1201 - 860173 1.002 1201 10/08/03 WA

Line of Evidence #3 of 5:

Pore Water

(Tentative CAO Finding 18)

Finding 13

- **Multiple Lines of Evidence**

  Benthic Community

  (1) Sediment quality triad measurements

  (2) Bioaccumulation analyses

  (3) Pore water analyses

  Fish

  (4) Fish histopathology analyses

  (5) Analyses of PAH breakdown products in fish bile

Key Differences

- **No Differences**
  - **Finding 18 based on results in Shipyard technical report**

Finding 18 - Page 10 of 34

- **Pore Water Results**
  - 12 site stations sampled for pore water (SW02 excluded)
  - All 12 site stations > copper CTR value
  - 6 site stations > lead CTR value
  - All 12 site stations > total PCBs CTR value

Exposure/Effects to Benthic Community

- Comparisons to California Toxics Rule
  - Criterion continuous concentration
  - Filtered and reported as dissolved fractions
- Site Pore Water
  - Unfiltered and reported as total concentrations
  - Concentrations may be biased high

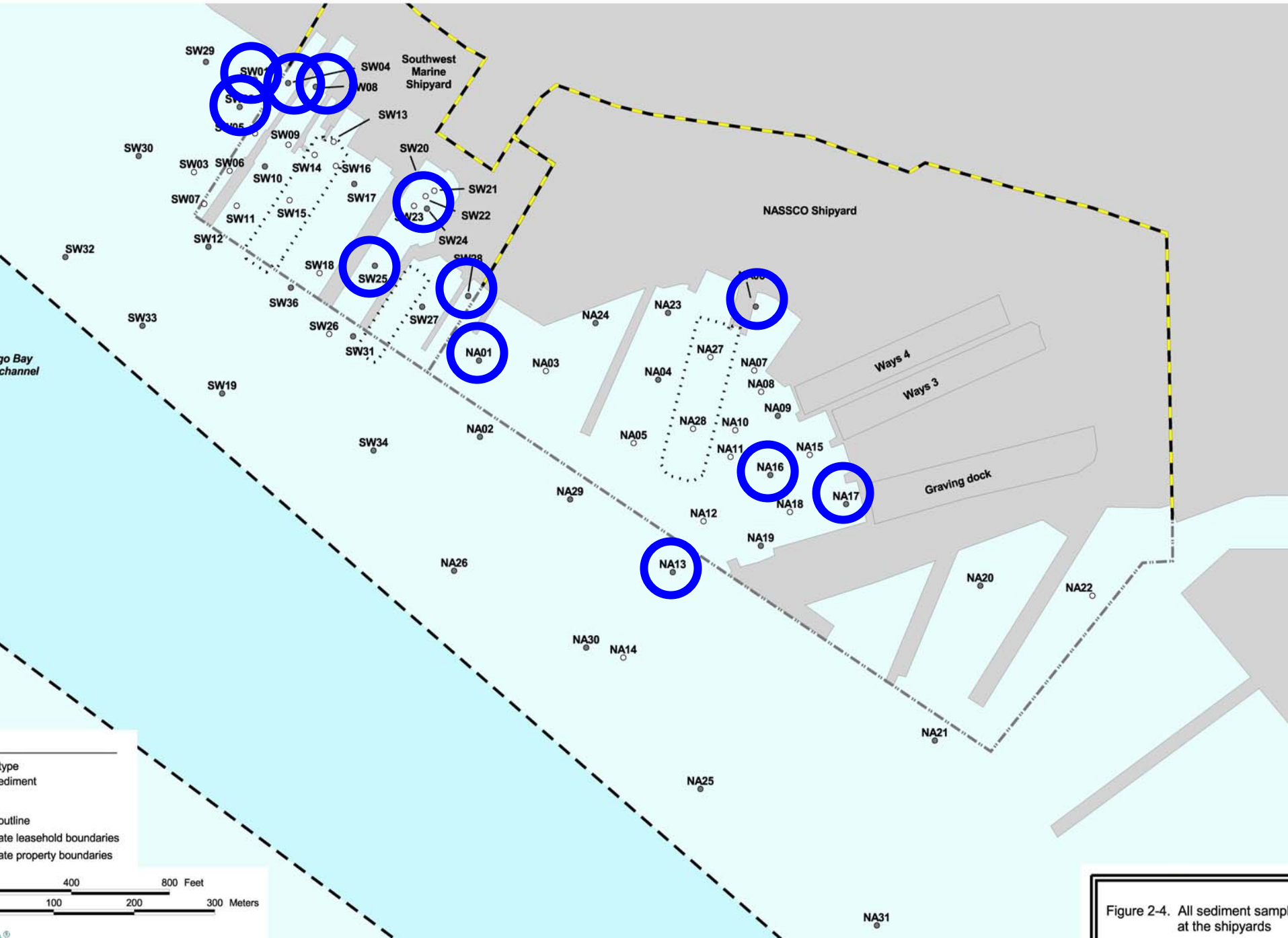


Figure 2-4. All sediment sampl
at the shipyards

Line of Evidence #4 of 5:

Fish Histopathology

(Tentative CAO Finding 19)

Finding 13

- **Multiple Lines of Evidence**

  Benthic Community

  (1) Sediment quality triad measurements

  (2) Bioaccumulation analyses

  (3) Pore water analyses

  Fish

  (4) Fish histopathology analyses

  (5) Analyses of PAH breakdown products in fish bile

Key Differences

- **Fish Histopathology**
  - **Regional Board: Considered additional lesions in data analysis.**

Finding 19 - Page 11 of 34

- Fish Histopathology Results

Fish Histopathology

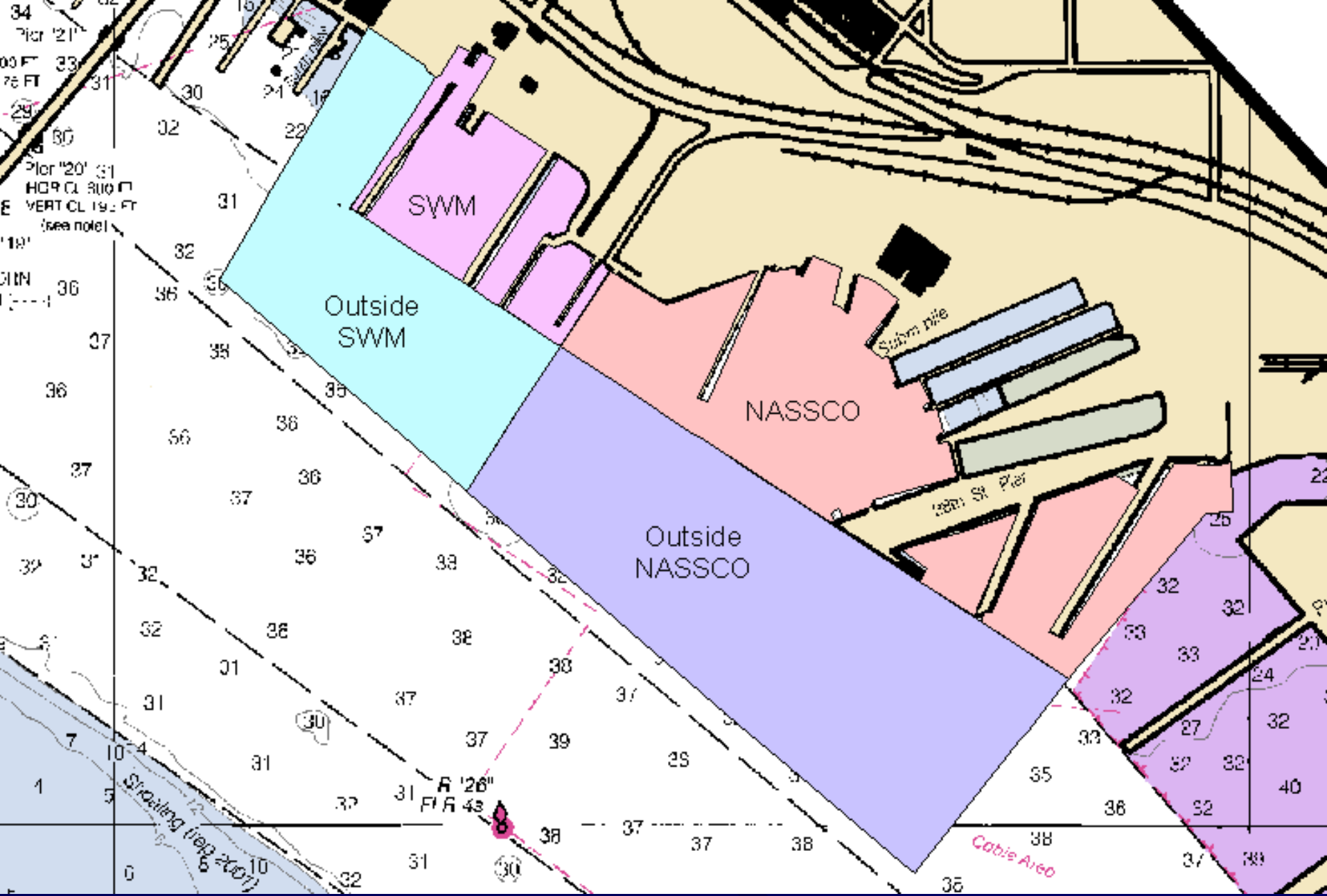
- Fish Histopathology
  - Evaluate potential fish exposure to sediment contaminants from Shipyard Sediment Investigation site.
- Resource agencies input
  - DFG, NOAA, USFW
  - Assisted with study and sampling methods

Fish Histopathology

- Species Collected
  - Spotted Sand Bass
- Areas Collected
  - Inside and Outside Shipyard Investigation Site
  - Reference Area
- Numbers of samples
  - Minimum number of fish = 50 from each area
  - 250 total required, 253 collected

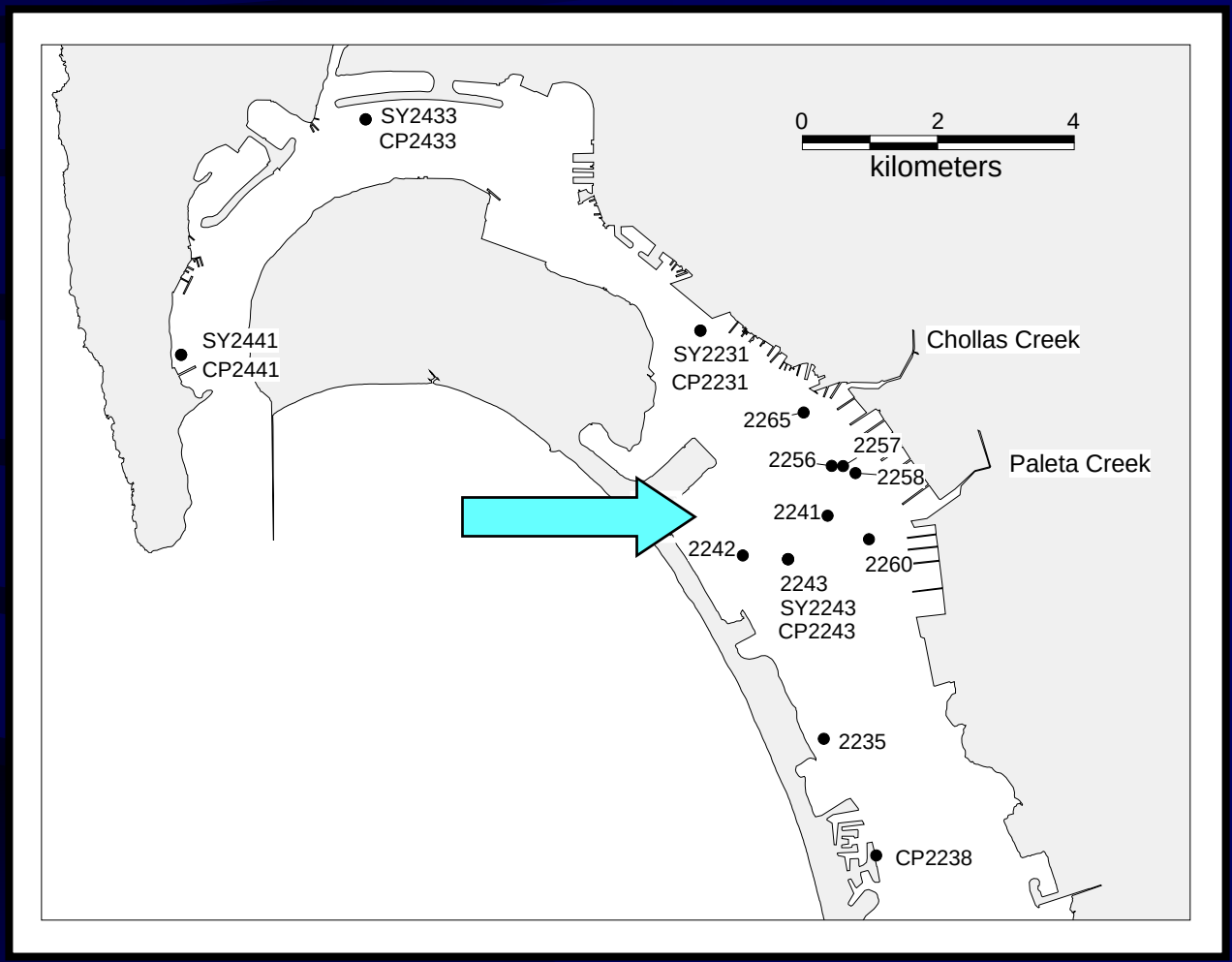
Fish Histopathology – *Spotted Sand Bass*

Paralabrax maculatofasciatus



Sub-sections of study area.

Reference Area – Fish Study



Location of reference stations included in the Baseline Pool. The station identifiers indicate whether the station was sampled during the Chollas/Paleta TMDL study (CP prefix), the Shipyard study (SY), or the Bight'98 survey (no prefix).

Fish Histopathology - Results

- 70 lesions identified
- 5 lesions found to be statistically significant from reference area

Fish Histopathology - Lesions

		NASSCO		SWM	
Organ	Lesion	Inside	Outside	Inside	Outside
Liver	Lipofuscin	Yes		Yes	
	Hemosiderin		Yes		
	CBH*	Yes			
Kidney	Nephritis	Yes			
Gill	Shiny Gill Foci			Yes	

*Cholangitis Biliary Hyperplasia
(Key Difference)

Line of Evidence #5 of 5:

Fish Bile

(Tentative CAO Finding 20)

Finding 13

- **Multiple Lines of Evidence**

  Benthic Community

  (1) Sediment quality triad measurements

  (2) Bioaccumulation analyses

  (3) Pore water analyses

  Fish

  (4) Fish histopathology analyses

  (5) Analyses of PAH breakdown products in fish bile

Key Differences

- **No Differences**
  - **Finding 20 based on results in Shipyard technical report**

Finding 20 - Page 13 of 34

- Fish Bile Results

Fish Bile

- Purpose of fish bile analysis
  - PAHs do not bioaccumulate
  - Determine recent exposure to PAH compounds
- PAHs metabolites found in fish bile
  - Naphthalene
  - Phenanthrene
  - Benzo(a)pyrene
- 2 PAH metabolites found to be significantly elevated compared to reference

Fish Bile

	NASSCO		SWM	
Metabolites	**Inside**	**Outside**	**Inside**	**Outside**
Naphthalene				
Phenanthrene		Yes		
Benzo(a)pyrene		Yes		Yes

Spotted Sand Bass – Age, Length, Weight

- Age, length, and weight data collected
- Same fish that were used for histopathology
- No significant differences found between the 4 shipyard areas and reference area

Indicator Sediment Chemical

(Tentative CAO Finding 21)

Key Differences

- **No Differences**
  - **Finding 21 based on results in Shipyard technical report**

Indicator Sediment Chemical

- **Two Step Approach**
  - **(1) Chemicals representative of major classes**
  - **(2) Relationships between chemicals and biological responses**
- **Step One**
  - **Metals: all metals except selenium**
  - **Butyltins: TBT**
  - **PCBs and PCTs: PCB homologs, PCT aroclors**
  - **PAH: Total HPAH**
  - **Petroleum Hydrocarbons: DRO and RRO**

Indicator Sediment Chemical

- **Step Two**
  - **Statistical correlations between chemicals and biological effects**
  - **Identify chemicals potentially causing adverse effects**

Table 9-8. Relationships of sediment chemicals to biological effects

Chemical	Related to: Amphipod toxicity	Echinoderm toxicity	Bivalve toxicity	Benthic macroinvertebrate total abundance	Benthic macroinvertebrate total richness	*Macoma* tissue bioaccumulation	Selected for derivation of a cleanup level
Arsenic	No	No	No	No	No	Yes[a]	Yes
Cadmium	No	No	No	No	No	No	No
Chromium	No	No	No	No	No	No	No
Copper	No	No	No	No	No	Yes	Yes
Lead	No	No	No	No	No	Yes	Yes
Mercury	No	No	No	No	No	Yes	Yes
Nickel	No	No	No	No	No	No	No
Silver	No	No	No	No	No	No	No
Zinc	No	No	No	No	No	Yes[a]	Yes
Tributyltin	No	No	No	No	No	Yes	Yes
HPAH	No	No	No	No	No	Yes	Yes
Total PCB homologs	No	No	No	No	No	Yes	Yes
Polychlorinated terphenyls	No	No	No	No	No	No	No
Diesel-range organics	No	No	No	No	Yes	--[b]	Yes
Residual-range organics	No	No	No	Yes	Yes	--[b]	Yes

Note: HPAH - high-molecular-weight polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl

[a] The relationship is controlled by a single point

[b] Not evaluated