VIADUCT REPLACEMENT ALTERNATIVES FOR THE EAST SPANS OF THE SAN FRANCISCO - OAKLAND BAY BRIDGE

Ray Zelinski

Senior Bridge Engineer
Chief, SFOBB Special Analysis Branch
May 13, 1997

CALIFORNIA DEPARTMENT OF TRANSPORTATION
SFOBB EAST SPANS REPLACEMENT PROJECT

SCOPE OF PROJECT

- ➡Develop 3 "Cost Estimate Design" alternatives for a new east SFOBB
- ➡Provide a cost estimate *range;* varying construction types and alignments
- ➡Design as stand alone units that can be mixed and matched
- ➡Develop 10% design alternatives quickly

Outline

- Assumptions
- Analysis
- Alignment
- Substructure
- Superstructure
  - 3 Alternatives
- Preliminary Sensitivity Studies
- Arched Viaduct Alternative
- Conclusion

Assumptions/ Goals

- use representative ARS curves developed for retrofit
- column ductility ≤ 2.5
- use high strength concrete (10,000 psi)
- minimize foundations by maximizing spans
- take advantage of repetitive construction techniques
- lateral seismic loads control foundations
- match existing vertical clearances
- 6 lanes each direction; full shoulders
- 4-diameter pile spacing
- use conservative d/s ratios

Analysis

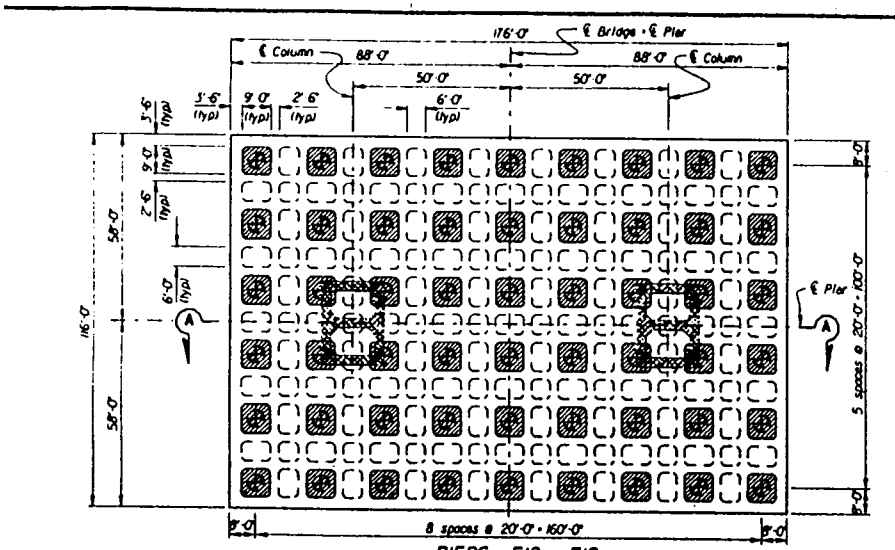
- Substructure
  - 'Group' program; linear elastic pile properties, nonlinear soil properties
    - 3 soil profiles used for varying deep soil foundation effects
- Superstructure
  - 'GTSTRUDL' linear elastic static push analysis
    - towers and "Alternative 2" truss

Alignments

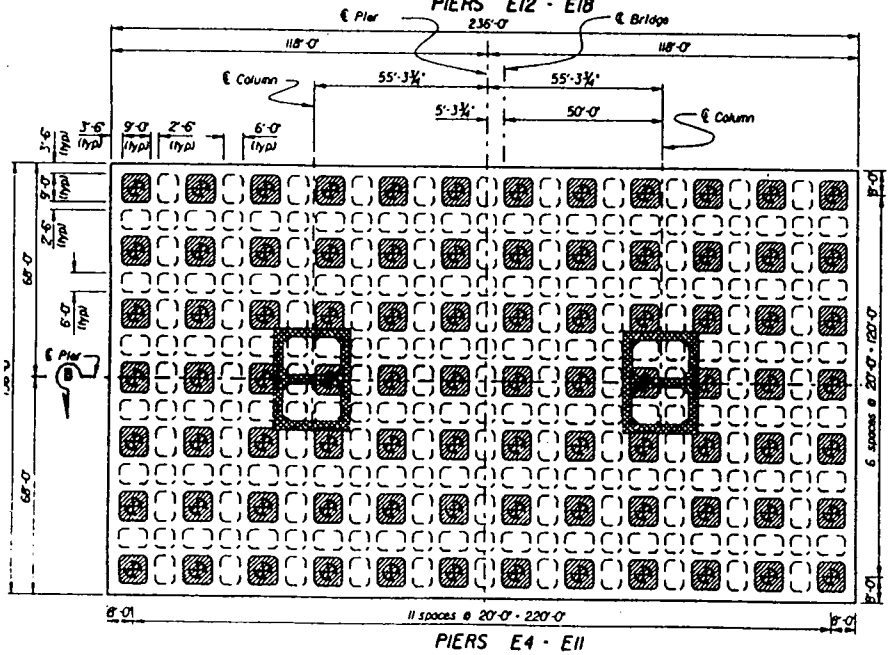
- Far-North
  - longest; clear of most utilities; historic building impact; wetlands impact.
- Mid-North
  - mid-length; minor electric cable conflict; historic building impact; wetlands impact.
- Near-South
  - shortest length; sewer and communications cable conflicts; less sensitive landings.

Substructures

- Cellular pre-cast pier cap
  - floated out to site, used as a driving template
- 5'-diameter Steel pipe piles, partially filled with concrete; hollow center
- Fixed pile cap to pile connection
- Rectangular, hollow columns
- Vertical pre-stressing in taller columns
  - overturning tension resistance



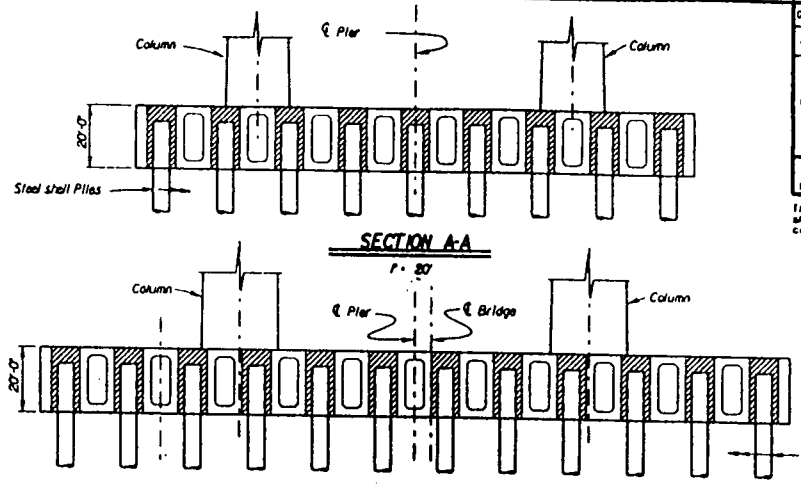
PIERS E12 - E18



PIERS E4 - E11

PIER CAP

1" = 20'

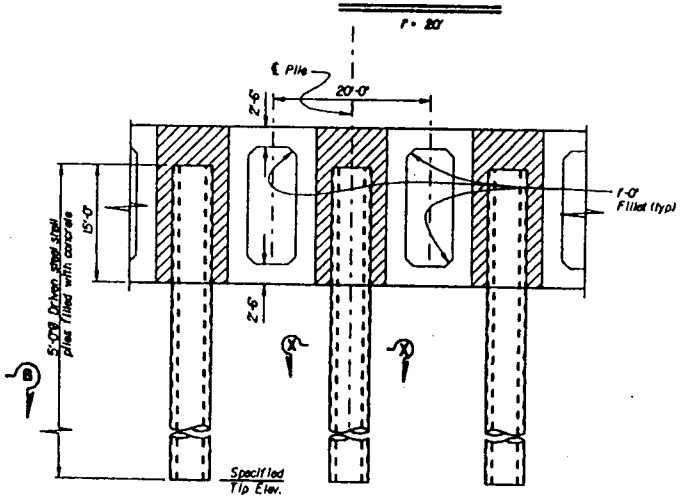


SECTION A-A

1" = 20'

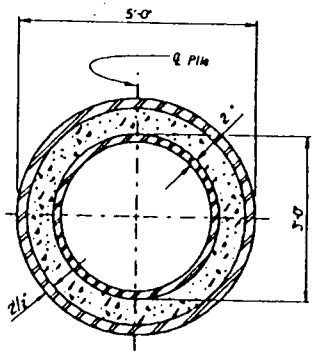
SECTION B-B

1" = 20'



PILE DETAIL

1/8" = 1'-0"



SECTION X-X

¾" = 1'-0"

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
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Legend:

Denotes pier cap cell filled with concrete after placement of pile.

Denotes 5'-0"⌀ Pile, steel case filled with concrete and reinforcement.

VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 2

SFOBB EAST REPLACEMENT

PIER CAP AND PILE LAYOUT

DESIGN	BY Phil Lutz 5-96	CHECKED M. Van De Pol 5-9	
DETAILS	BY [signature] 5-96	CHECKED M. Van De Pol 5-9	
QUANTITIES	BY Phil Lutz 5-96	CHECKED M. Van De Pol 5-9	

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DIVISION OF STRUCTURES
STRUCTURE DESIGN 9

BRIDGE NO. 33-0025
POST MILE 1.15

CU 04
EA 01200K

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS

DISREGARD PRINTS BEARING EARLIER REVISION DATES

REVISION DATES (PRELIMINARY STAGE ONLY)

SHEET 6 OF 6

USERNAME = ? DIISER

Superstructure Alternatives

- Alternative #1
  - single level PC/ PS concrete viaduct
  - Far-North alignment
- Alternative #2
  - double deck steel warren truss viaduct
  - Far-North alignment
- Alternative #3
  - double deck CIP pre-stressed concrete viaduct
  - Near-South alignment

Alternative #1
Superstructure

- Pre-cast, pre-stressed, segmentally constructed concrete viaduct, 500' spans
- 1 tall, 1 intermediate, and 1 short column frame analyzed
- Minimum depth/span ratio = 0.04
- ARS varied from .85g for tall columns to 1.2g for short columns

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
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REGISTERED PROFESSIONAL ENGINEER
B. MARCHET
35754
Exp. 12-31-97
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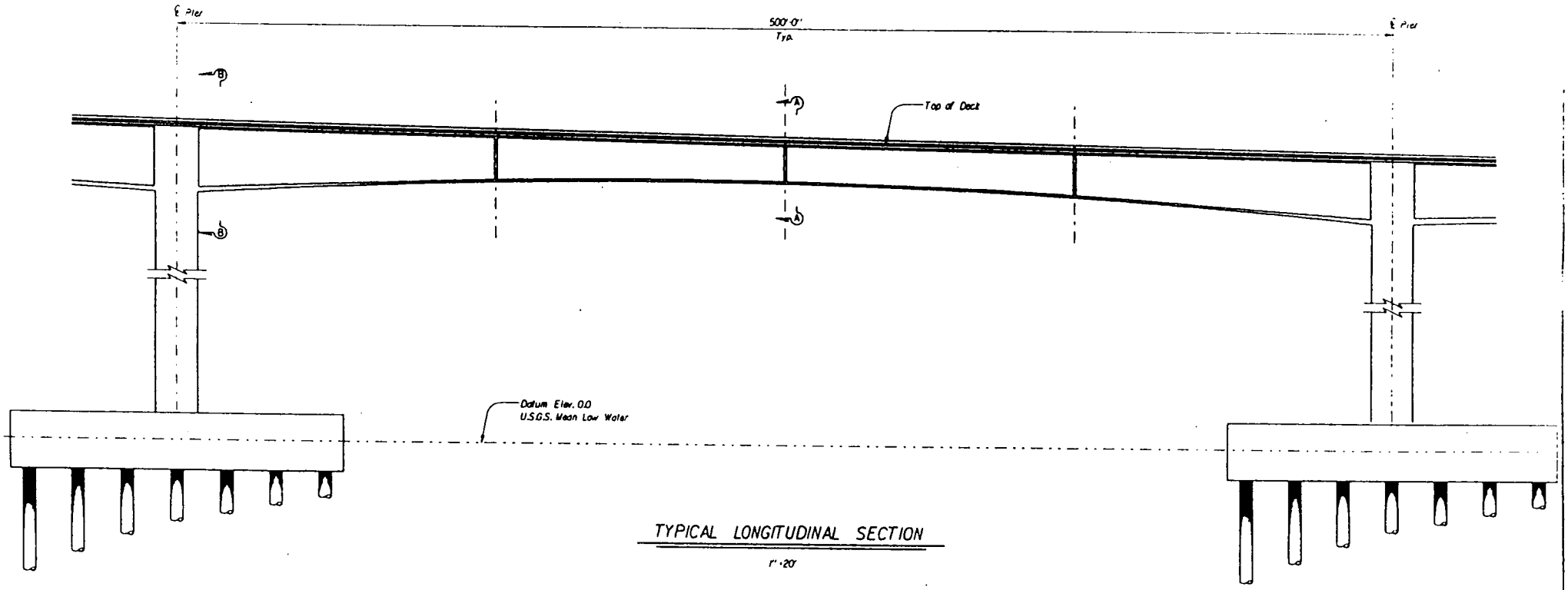

TYPICAL LONGITUDINAL SECTION

1" = 20'

VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 1

SFOBB EAST REPLACEMENT

TYPICAL LONGITUDINAL SECTION

DESIGN	BY Mario N. Velado	CHECKED Viet Han	
DETAILS	BY R. A. Sorte 8/96	CHECKED Mario N. Velado	
QUANTITIES	BY Mike Nguyen	CHECKED Mario N. Velado	

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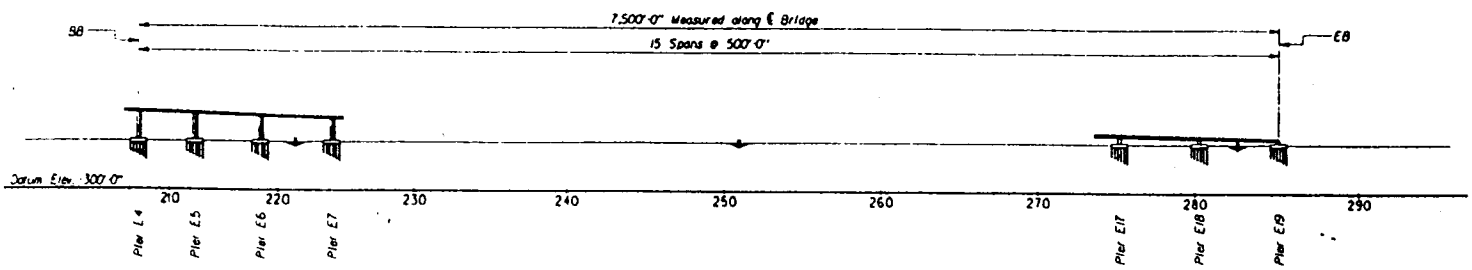
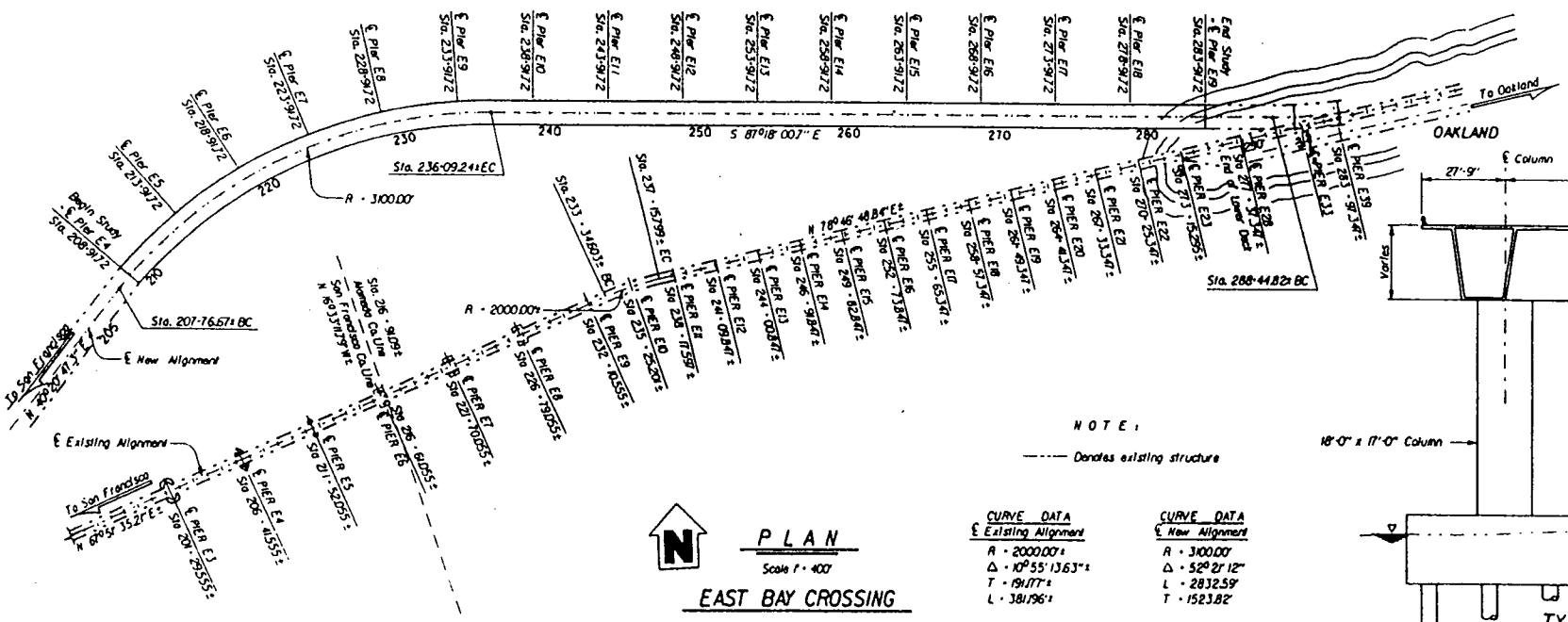


ELEVATION

Scale 1" = 400'



NOTE:

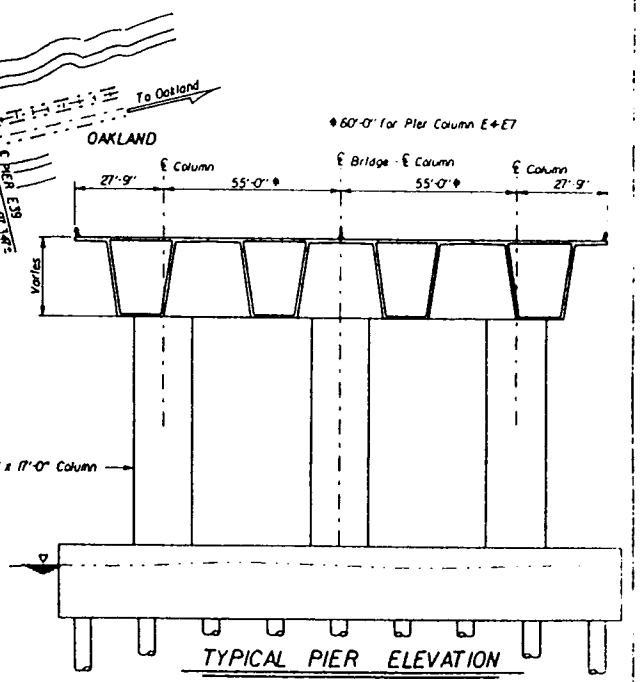
---- Denotes existing structure

PLAN

Scale 1" = 400'

EAST BAY CROSSING

CURVE DATA ℄ Existing Alignment	CURVE DATA ℄ New Alignment
R = 2000.00'±	R = 3100.00'
Δ = 10°55'13.63"±	Δ = 52°21'12"
T = 191.77'±	L = 2832.59'
L = 381.96'±	T = 1523.82'



TYPICAL PIER ELEVATION

1" = 20'

VIADUCT

DESIGN ENGINEER	DESIGN	Marlo N. Velado	CHECKED Vlad Ha X/96	LOAD FACTOR DESIGN	LIVE LOADING: HS20-44 AND ALTERNATIVE AND PERMIT DESIGN LOAD	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	DIVISION OF STRUCTURES STRUCTURE DESIGN 9
	DETAILS	R.A. Sarte 4/96	CHECKED Marlo N. Velado	LAYOUT			
	QUANTITIES	Mike Nguyen	CHECKED Marlo N. Velado	SPECIFICATIONS			

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

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REVISION DATES (PRELIMINARY STAGE ONLY)

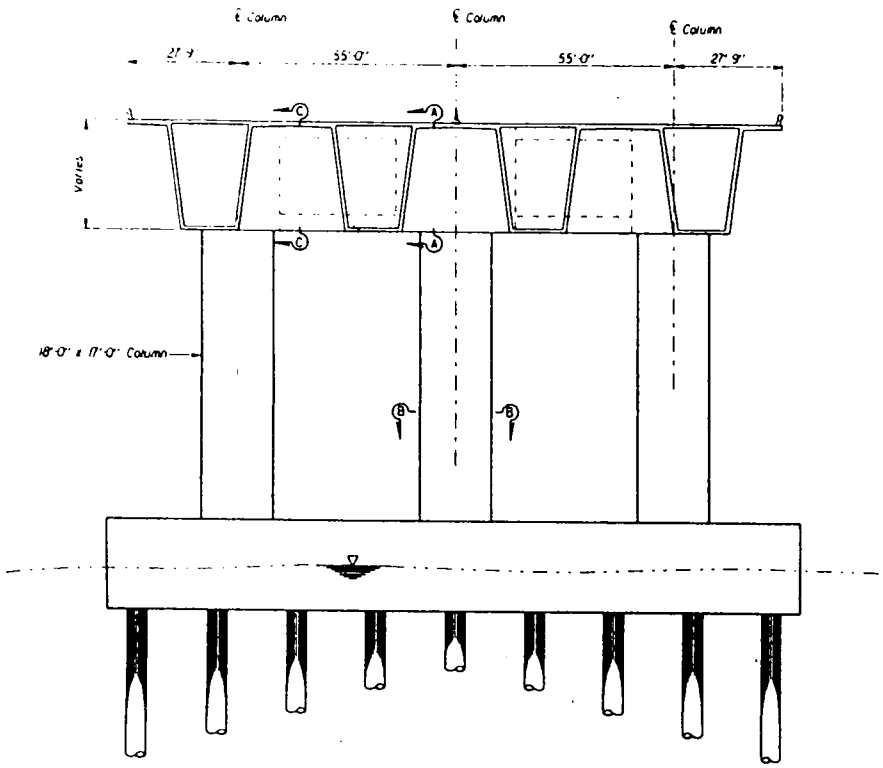
SHEET 1 OF 11

COST ESTIMATE DESIGN - ALTERNATIVE NO. 1

SFOBB EAST REPLACEMENT

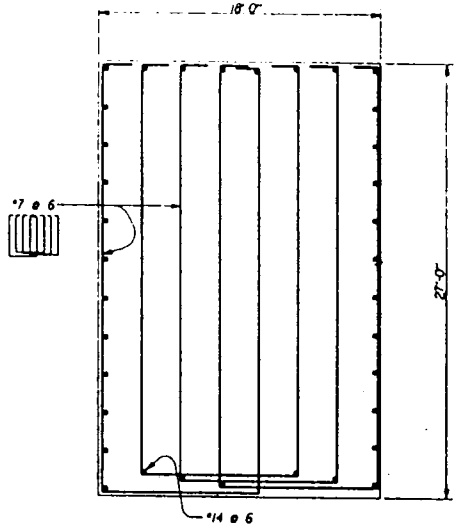
GENERAL PLAN

• Dimension varies between 20'-0" to 27'-0" structure depth



TYPICAL PIER ELEVATION

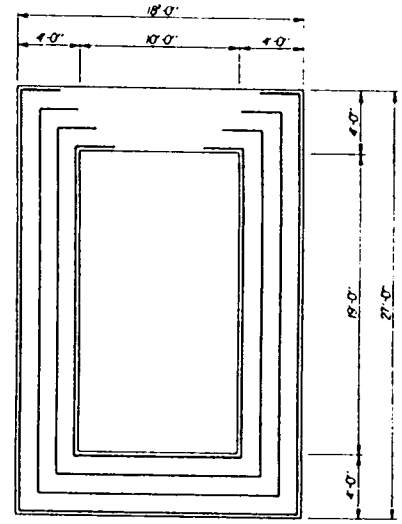
1/16" = 1'-0"



SECTION A-A

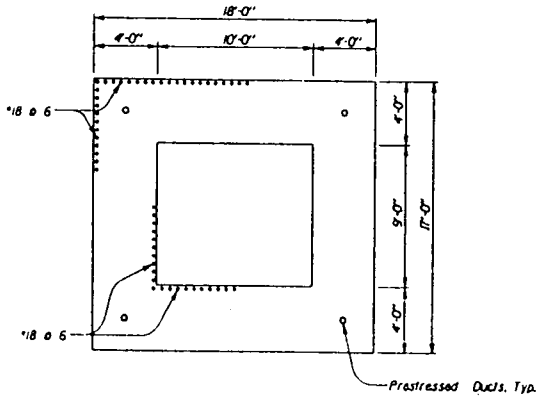
TYPICAL CAP SECTION

1/4" = 1'-0"



SECTION C-C

1/4" = 1'-0"



SECTION B-B

1/4" = 1'-0"

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.
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VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 1

SFOBB EAST REPLACEMENT

PIER CAP DETAIL

DESIGN	BY Mario N. Velado	CHECKED Viet Han	
DETAILS	BY R. A. Sarte 5/95	CHECKED Mario N. Velado	
QUANTITIES	BY Mike Nguyen	CHECKED Mario N. Velado	

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS

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DIVISION OF STRUCTURES STRUCTURE DESIGN 9

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REVISION DATES PRELIMINARY STAGE ONLY

SHEET 7 OF 11

USERNAME

Alternative #2
Superstructure

- 700' spans, simply supported steel warren trusses
- truss types studied
  - straight segment
  - wider, curved segment
- Depth/span ratio = 0.10
  - Existing truss d/s = 0.15 average
- ARS varied from .75g for tallest columns to 1.0g for shortest columns

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
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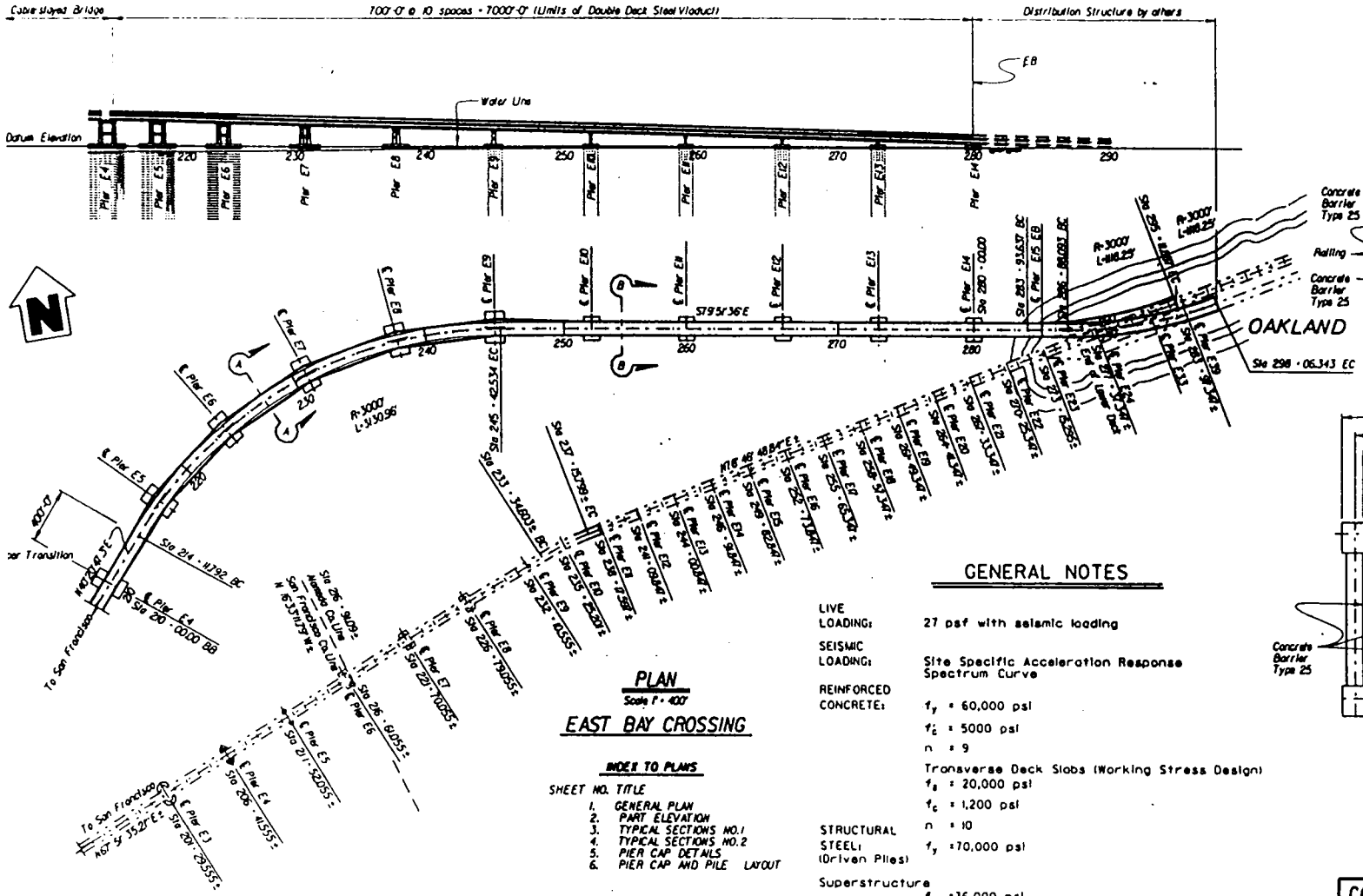


PLAN

Scale 1" = 400'

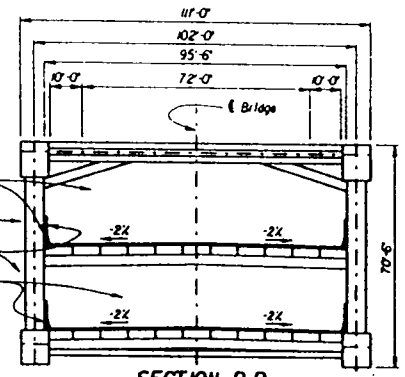
EAST BAY CROSSING

INDEX TO PLANS

SHEET NO.	TITLE
1.	GENERAL PLAN
2.	PART ELEVATION
3.	TYPICAL SECTIONS NO. 1
4.	TYPICAL SECTIONS NO. 2
5.	PIER CAP DETAILS
6.	PIER CAP AND PILE LAYOUT

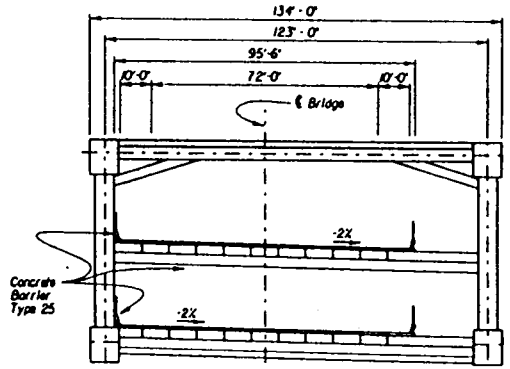
GENERAL NOTES

LIVE LOADING:	27 psf with seismic loading
SEISMIC LOADING:	Site Specific Acceleration Response Spectrum Curve
REINFORCED CONCRETE:	f_y = 60,000 psi
	f'_c = 5000 psi
	n = 9
	Transverse Deck Slabs (Working Stress Design)
	f_s = 20,000 psi
	f_c = 1,200 psi
	n = 10
STRUCTURAL STEEL: (Driven Piles)	f_y = 70,000 psi
Superstructure	f_y = 36,000 psi



SECTION B-B

1" = 20'



SECTION A-A

1" = 20'

VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 2

DESIGN	Phillutz 5-96	M. Van De Pol 5-96	LOAD FACTOR DESIGN	LIVE LOADING HS20-44 AND ALTERNATIVE AND PERMIT DESIGN LOAD	
DETAILS	Phillutz 5-96	M. Van De Pol 5-96	LAYOUT	Phillutz 5-96	M. Van De Pol 5-96
QUANTITIES	Phillutz 5-96	M. Van De Pol 5-96	SPECIFICATIONS		

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BRIDGE NO. 33-0025
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SFOBB EAST REPLACEMENT

GENERAL PLAN

SHEET 1 OF 6

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
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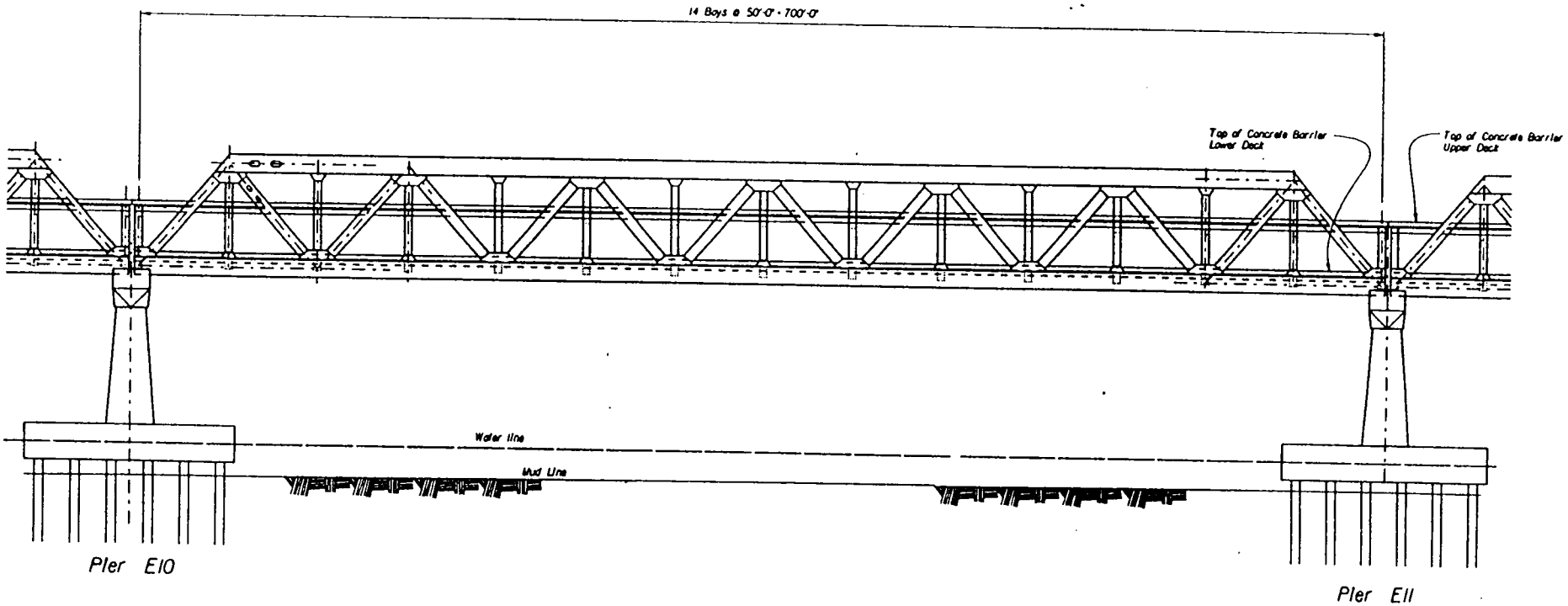

PART ELEVATION

1" = 30'-0"

VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 2

SFOBB EAST REPLACEMENT

PART ELEVATION

DESIGN	BY PhilLutz 5-96	CHECKED M. Van De Pol 5-96	
DETAILS	BY [signature] 5-96	CHECKED M. Van De Pol 5-96	
QUANTITIES	BY PhilLutz 5-96	CHECKED M. Van De Pol 5-96	

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS

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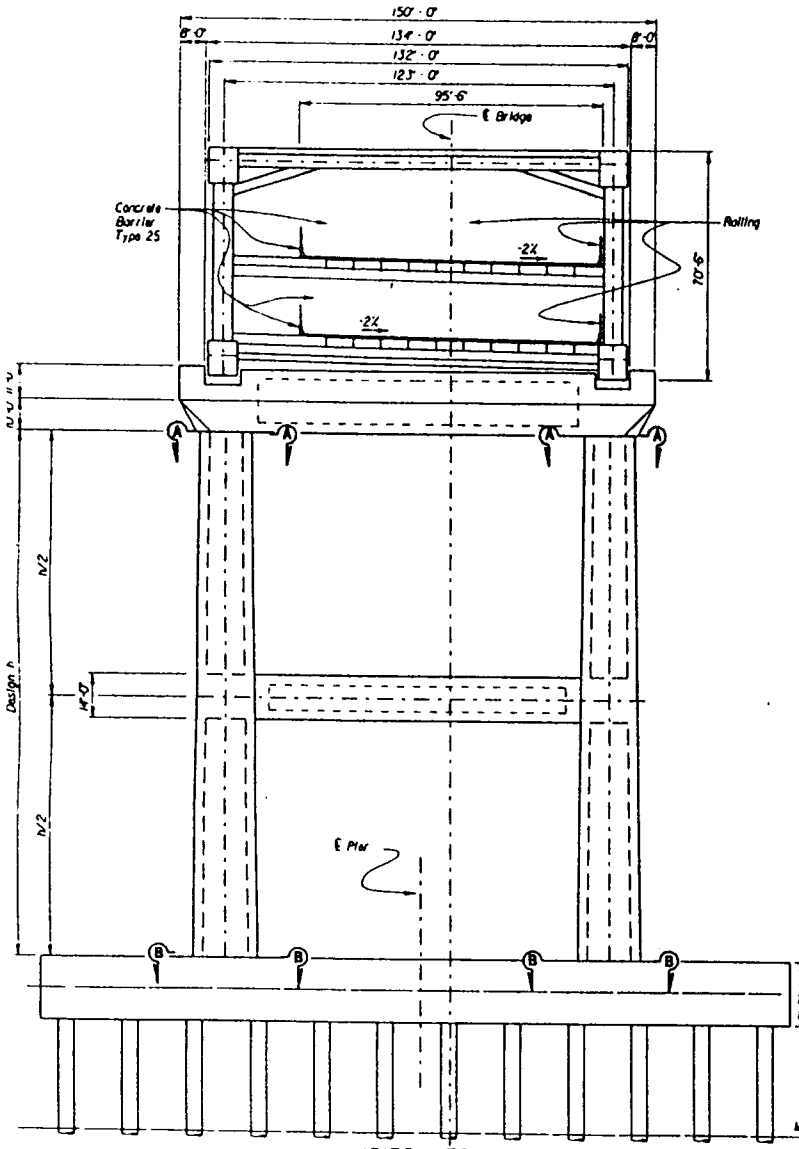
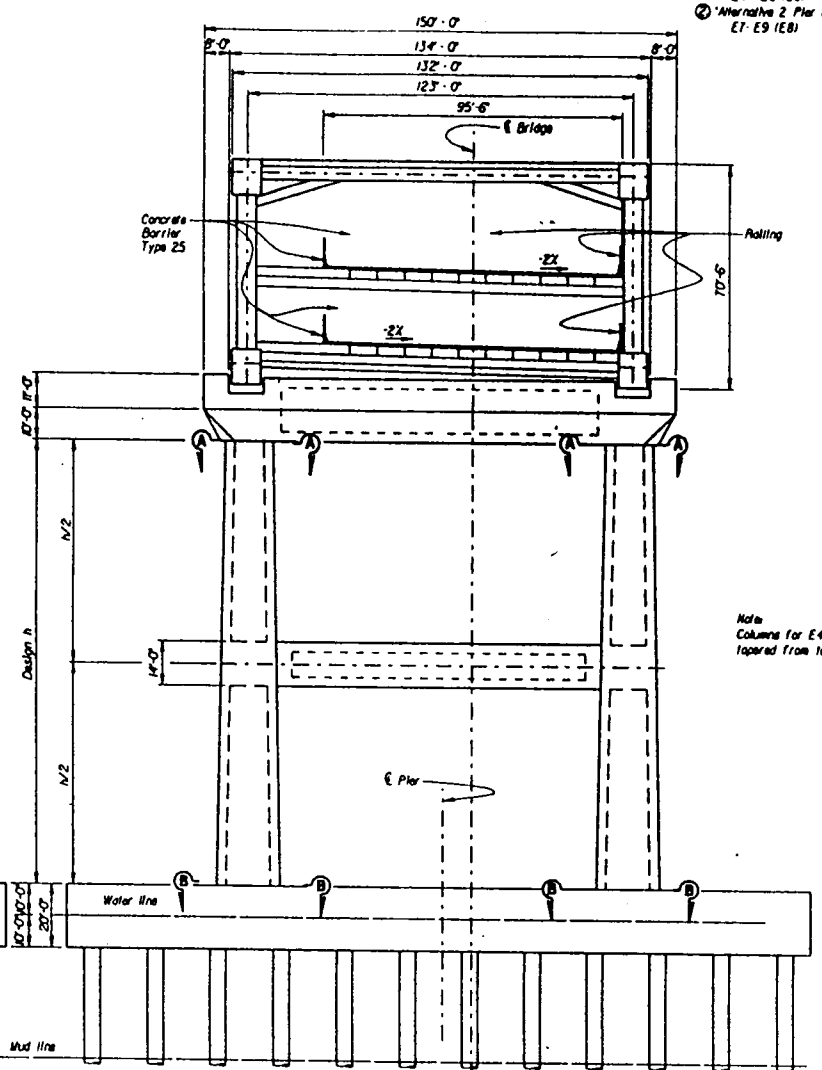
SHEET 2 OF 6

Alternative #3
Superstructure

- Double deck, single-cell, pre-stressed concrete, 500' spans
- Lower deck could be pre-cast and upper deck cast-in-place
- ARS force demands similar to Alternative #1
- Minimum depth/span ratio = 0.04



(PIER E6)
PIER E4 - PIER E6
1" = 20'



(PIER E8)
PIER E7 - PIER E9
1" = 20'

Design Notes:
① Alternative 2 Pier Push 1d
E4 - E6 (E6)
② Alternative 2 Pier Push 2d
E7 - E9 (E8)

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
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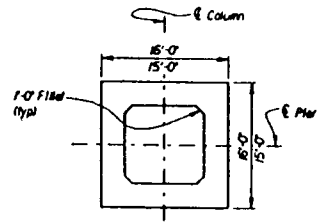
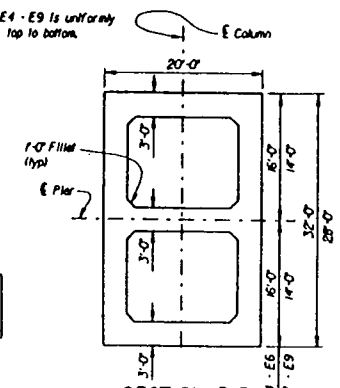
Piers (New)	Column Size (Hollow)	Strut Size (Hollow)
E4 - E6 (E4)	16'-0" x 16'-0" Top 20'-0" x 32'-0" Bott.	17'-0" x 14'-0"
E7 - E9 (E8)	15'-0" x 15'-0" Top 20'-0" x 28'-0" Bott.	15'-0" x 14'-0"



SECTION A-A
1/8" = 1'-0"

Note:
Columns for E4 - E9 is uniformly tapered from top to bottom.



SECTION B-B
1/8" = 1'-0"

VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 2

SFOBB EAST REPLACEMENT

TYPICAL SECTIONS NO. 1

DESIGN	BY Phil Lutz 5-96	CHECKED M. Van De Pol 5-96	
DETAILS	BY [signature] 04-96	CHECKED M. Van De Pol 5-96	
QUANTITIES	BY Phil Lutz 5-96	CHECKED M. Van De Pol 5-96	

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS

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SHEET 3 OF 6

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DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
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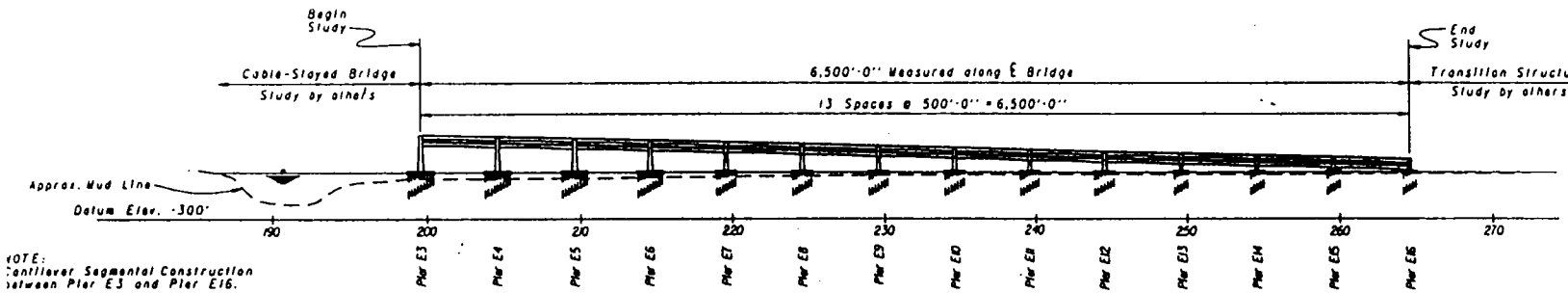


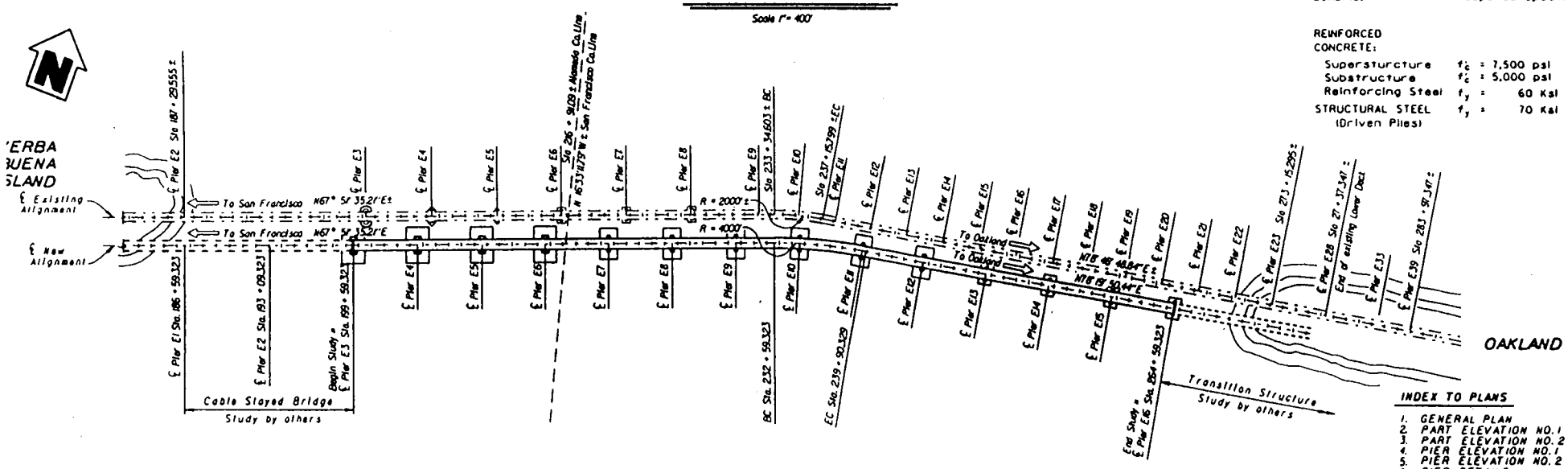
NOTE:
Cantilever Segmental Construction between Pier E3 and Pier E16.

DEVELOPED ELEVATION

Scale 1" = 400'

GENERAL NOTES

LIVE LOADING:	27 psf with seismic loading
SEISMIC LOADING:	Site Specific Acceleration Response Spectrum Curve
REINFORCED CONCRETE:	
Superstructure	f'_c = 7,500 psi n = 5.5
Substructure	f'_c = 5,000 psi n = 6.8
Reinforcing Steel	f_y = 60 Ksi
STRUCTURAL STEEL (Driven Piles)	f_y = 70 Ksi



PLAN

Scale 1" = 400'

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2. PART ELEVATION NO. 1
3. PART ELEVATION NO. 2
4. PIER ELEVATION NO. 1
5. PIER ELEVATION NO. 2
6. PIER DETAILS
7. PILE CAP AND PILE LAYOUT NO. 1
8. PILE CAP AND PILE LAYOUT NO. 2
9. PILE CAP AND PILE DETAILS
10. TYPICAL SECTION

CURVE DATA
℄ Existing Alignment
R = 2000'±
Δ = 10°55'13.63"±
T = 191,177'±
L = 381,196'±

CURVE DATA
℄ New Alignment
R = 4000'
Δ = 10°28'15.23"
T = 366,524'
L = 731,007'

NOTE:
- - - Denotes existing structure.
UD = Upper Deck
LD = Lower Deck

VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 3

SFOBB EAST REPLACEMENT

GENERAL PLAN

DESIGN	C. Townsend	4-96	S. Karimian	6-96	
DETAILS	B. Robinson	4-96	S. Karimian	7-96	
QUANTITIES	T. S. Hao	6-96	S. Karimian	7-96	
LOAD FACTOR DESIGN	LIVE LOADING: HS20-44 AND ALTERNATIVE AND PERMIT DESIGN LOAD				
LAYOUT	C. Townsend	4-96	S. Karimian	6-96	
SPECIFICATIONS					

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STRUCTURE DESIGN 9

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SHEET 1 OF 10

USERNAME +3 dirsfr

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
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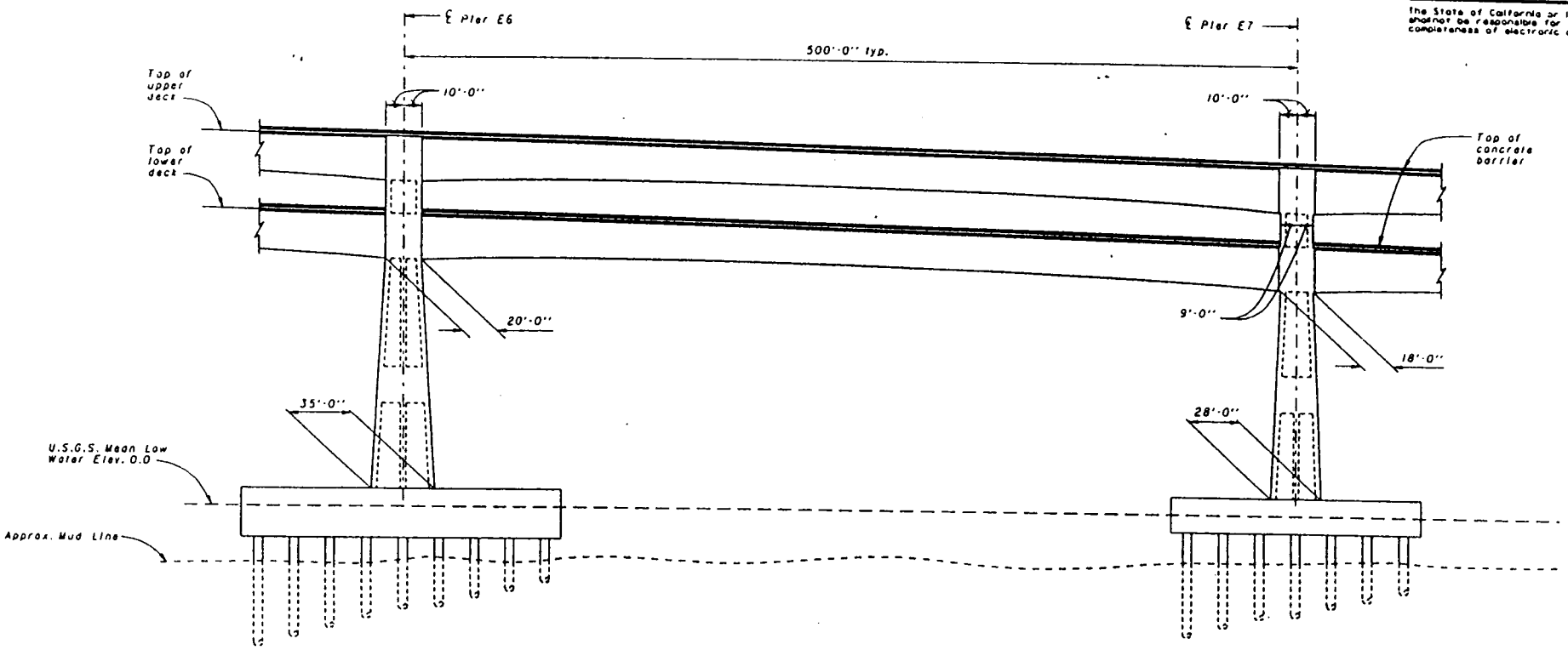


NOTE:

Pier E6 shown Pier E3 - E5 are similar

NOTE:

Pier E7 shown Pier E8 - E12 are similar

NOTE:

All columns are symmetrical about ℄ Pier.

TYPICAL PART ELEVATION

1" = 30'

VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 3

SFOBB EAST REPLACEMENT

PART ELEVATION NO. 1

DESIGN	BY C. Townsend	4-96	CHECKED S. Karimian	6-96
DETAILS	BY B. Robinson	4-96	CHECKED S. Karimian	7-96
QUANTITIES	BY Y. S. Hao	6-96	CHECKED S. Karimian	7-96

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DIVISION OF STRUCTURES
STRUCTURE DESIGN 9

CU 04
EA 01200K

BRIDGE NO. 33-0025
POST MILE 1.15

DISREGARD PRINTS BEARING EARLIER REVISION DATES

SHEET 2 OF 10

USERNAME => BUSER

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04					

REGISTERED ENGINEER - CIVIL

PLANS APPROVAL DATE

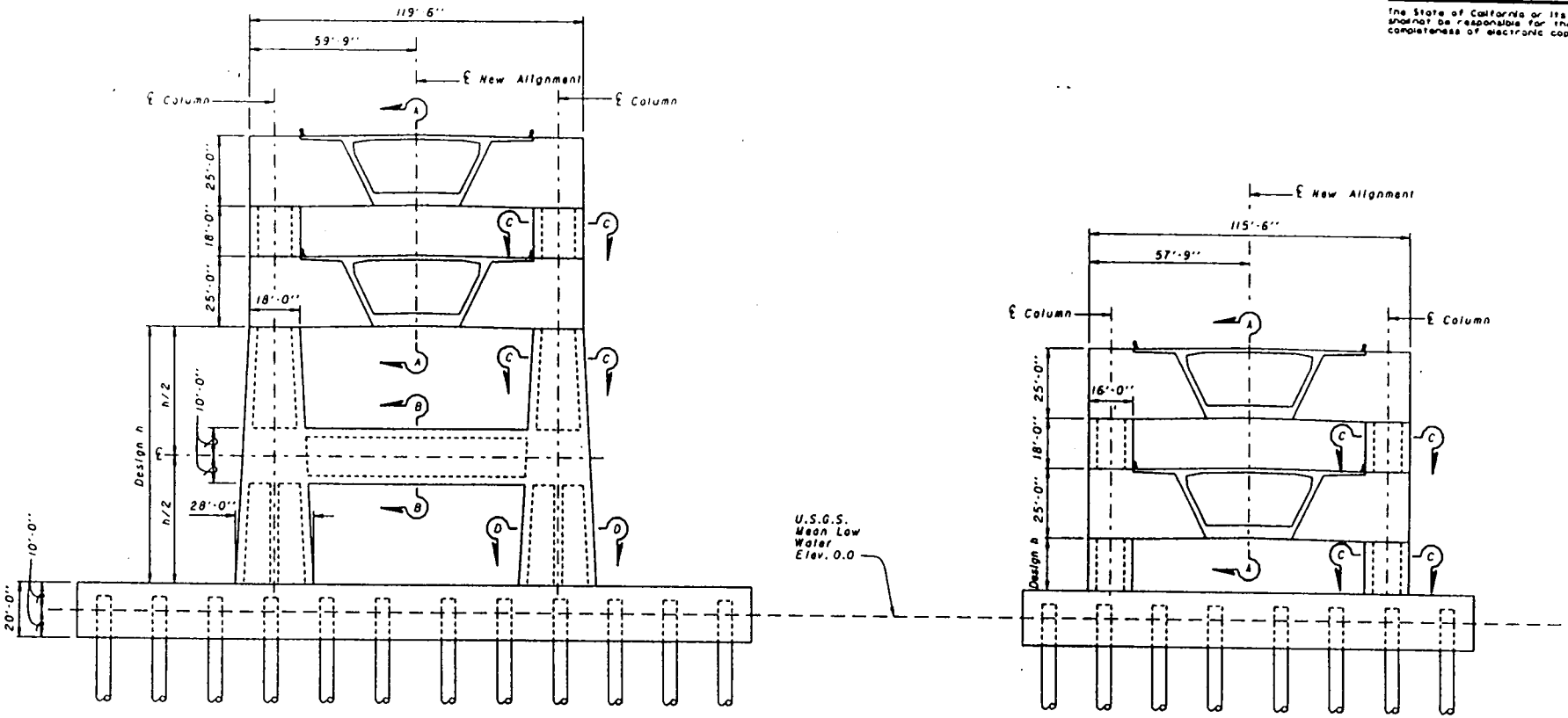
The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet

NOTE:

Bridge is symmetrical about ℄ New Alignment.

All Columns are symmetrical about ℄ Column

For Section A-A, B-B, C-C, and D-D, see "Pier Details" sheet.



NOTE:

Pier E9 shown others similar.

Pier E7 - Pier E12

NOTE:

For details not shown see Typical Pier Elevation, Pier E3 - Pier E6, on "Pier Elevation No. 1" sheet.

NOTE:

Pier E15 shown others similar.

Pier E13 - Pier E16

TYPICAL PIER ELEVATION

1" = 20'

VIADUCT

COST ESTIMATE DESIGN - ALTERNATIVE NO. 3

SFOBB EAST REPLACEMENT

PIER ELEVATION NO. 2

DESIGN	BY C. Townsend 4-96	CHECKED S. Karimian 6-96		
DETAILS	BY B. Robinson 4-96	CHECKED S. Karimian 7-96		
QUANTITIES	BY Y. S. Hao 6-96	CHECKED S. Karimian 7-96		

STATE OF CALIFORNIA
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ORIGINAL SCALE IN INCHES FOR REDUCED PLANS

DISREGARD PRINTS BEARING EARLIER REVISION DATES

SHEET 5 OF 10

USERNAME -> BUSER

Preliminary Sensitivity Studies

- Team #1 studied both 5' and 10' diameter steel pipe piles
- Team #3 investigated lowering the maximum vertical clearance by 40', achieving a cost savings of 13%
- Team #2 investigated 14', 16', and 18' diameter columns as well as equivalent rectangular shapes
- Teams #1 & #3 investigated 300' and 500' spans; team #2 investigated 500' and 700' spans

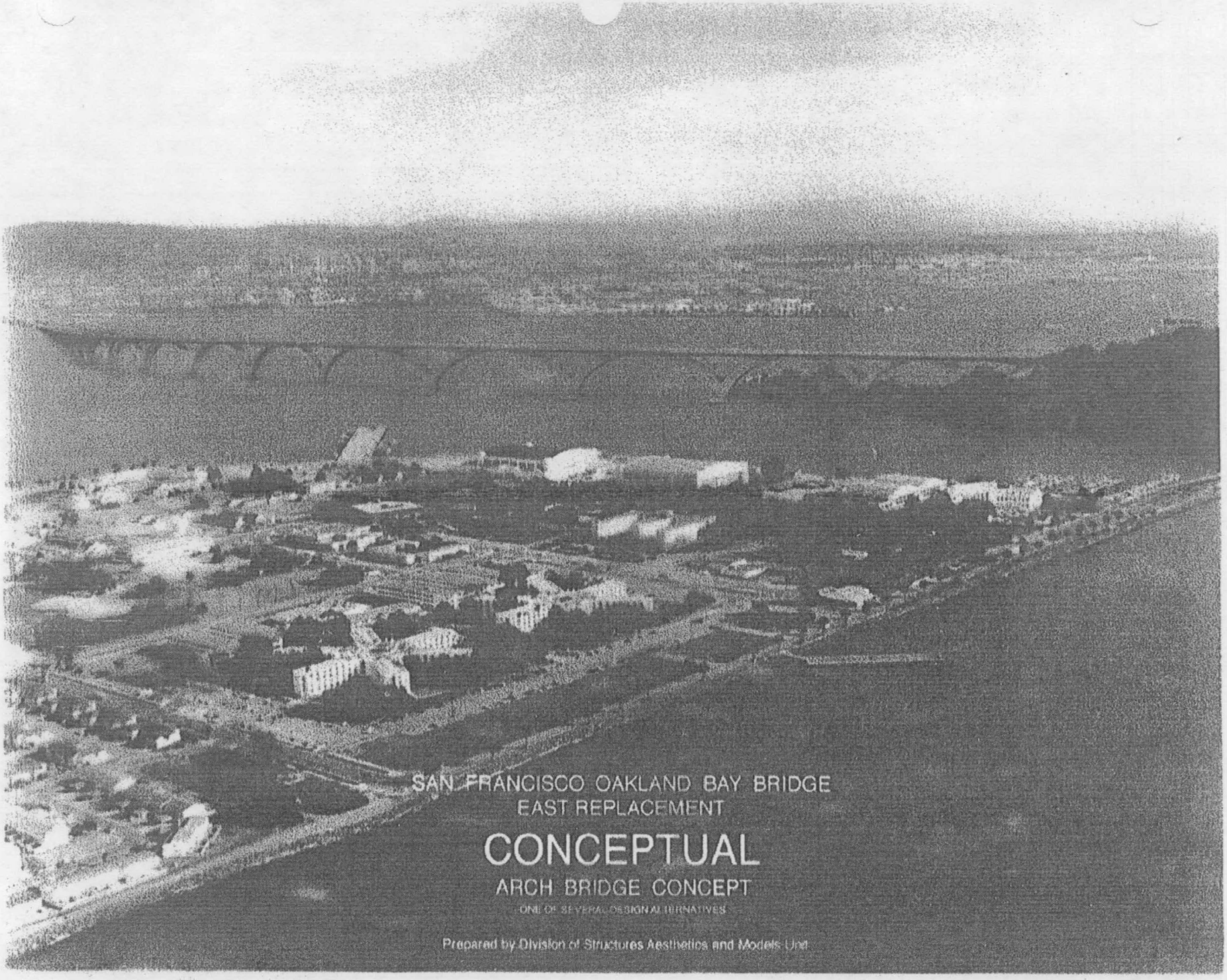
Preliminary Sensitivity Studies

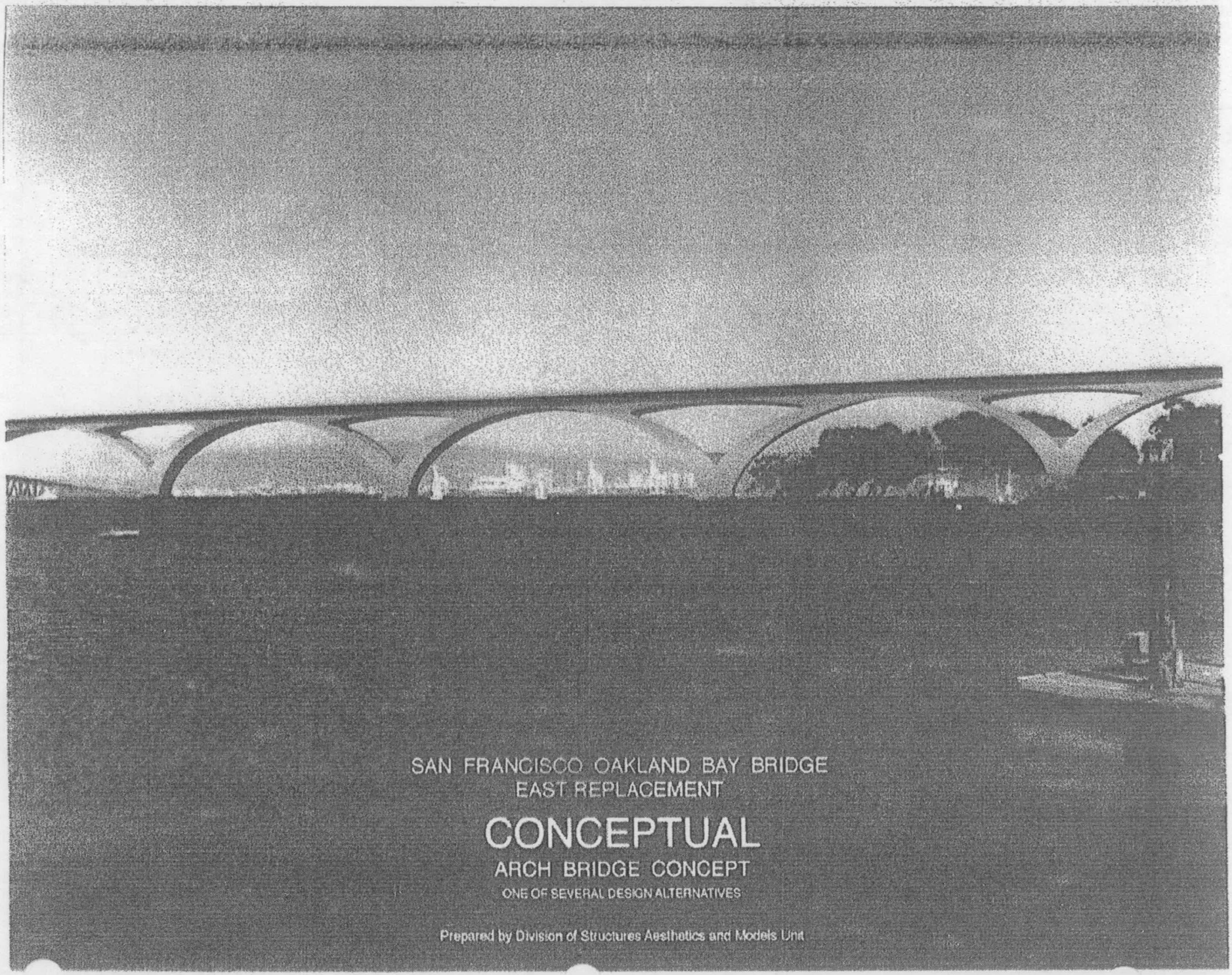
(CONTINUED)

- Team #3 investigated a mid-North alignment, achieving a 5% cost savings
- Team #2 investigated use of lightweight concrete in the substructure
- Team #2 investigated traffic/seismic and vertical acceleration effects on truss

ARCHED VIADUCT ALTERNATIVE

- Recent entry at MTC request
  - conceptual only
  - first level feasibility
  - no engineering studies


SAN FRANCISCO OAKLAND BAY BRIDGE
EAST REPLACEMENT
CONCEPTUAL
ARCH BRIDGE CONCEPT
ONE OF SEVERAL DESIGN ALTERNATIVES
Prepared by Division of Structures Aesthetics and Models Unit


SAN FRANCISCO OAKLAND BAY BRIDGE
EAST REPLACEMENT
CONCEPTUAL
ARCH BRIDGE CONCEPT
ONE OF SEVERAL DESIGN ALTERNATIVES
Prepared by Division of Structures Aesthetics and Models Unit

Conclusion

- Viaduct studies did not include:
  - connectors or touchdowns at east end
  - sensitivity studies for minimum structure depth
  - consideration for location/details of thermal expansion joints
- Aesthetics was not a prominent goal in the studies
  - public competition was not a goal in May 1996
- Emphasize primary goals for studies
  - range of realistic, conservative cost estimates
  - feasible, tested construction techniques

Box 2, Folder 3

Item 2

ACCNO_000022