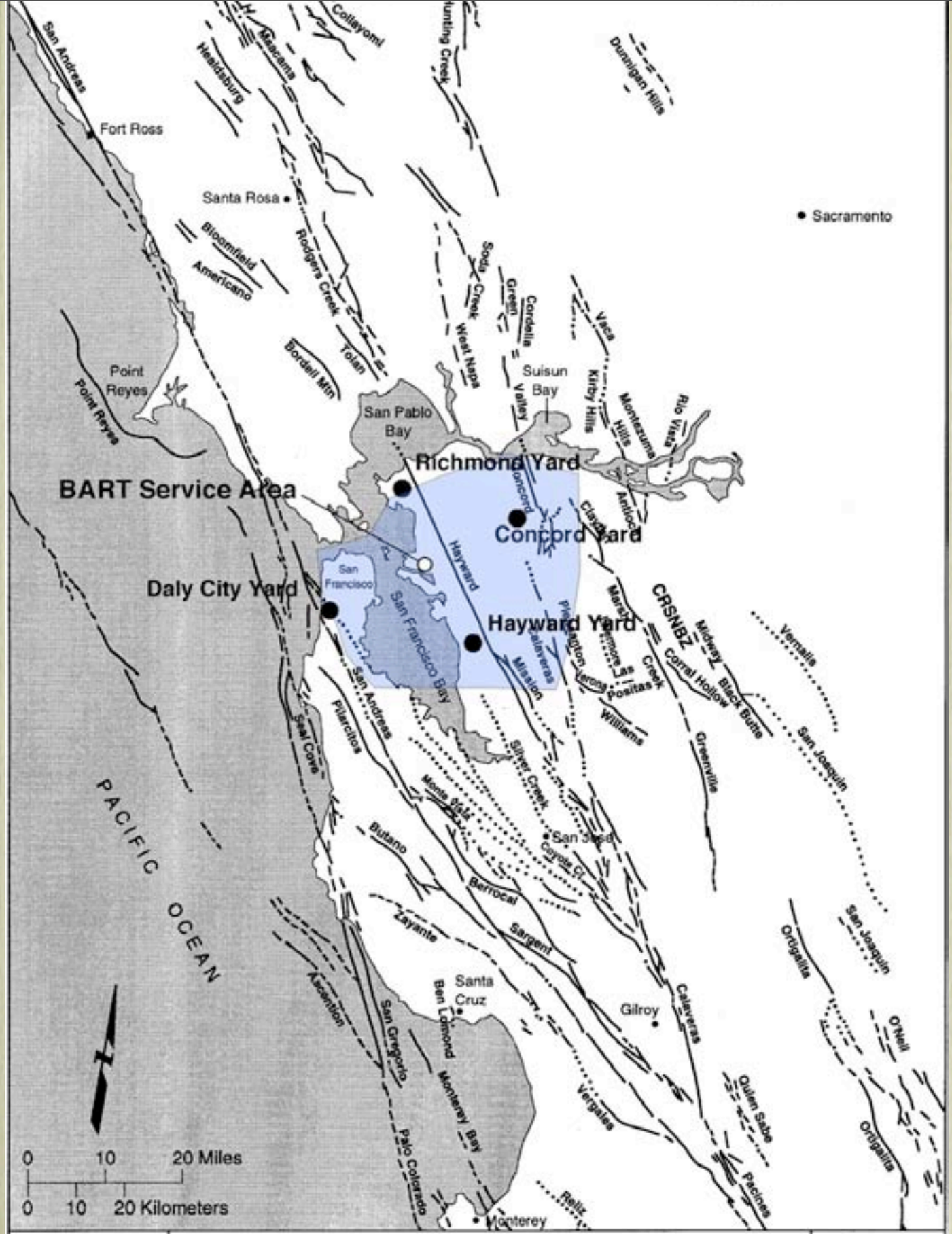
Non-Structural Components, FEMA, and BART

John Eidinger, G&E

eidinger@geEngineeringSystems.com

FEMA and BART

- Pre-Disaster Mitigation Program
- Overall BART program is over $1,000,000,000
- BART has obtained $9,000,000 grants from FEMA to date (BART is FEMA's best customer)
- Today, we discuss how BART assessed 25,000 non-structural components, and got $3,000,000 from FEMA to implement 3,571 non-structural seismic upgrades



G&E Engineering Systems	**Figure 3-1. Map of Regional Earthquake Faults**	R55.03.04
		1/2/2007

SAN FRANCISCO BAY AREA RAPID TRANSIT DISTRICT

N

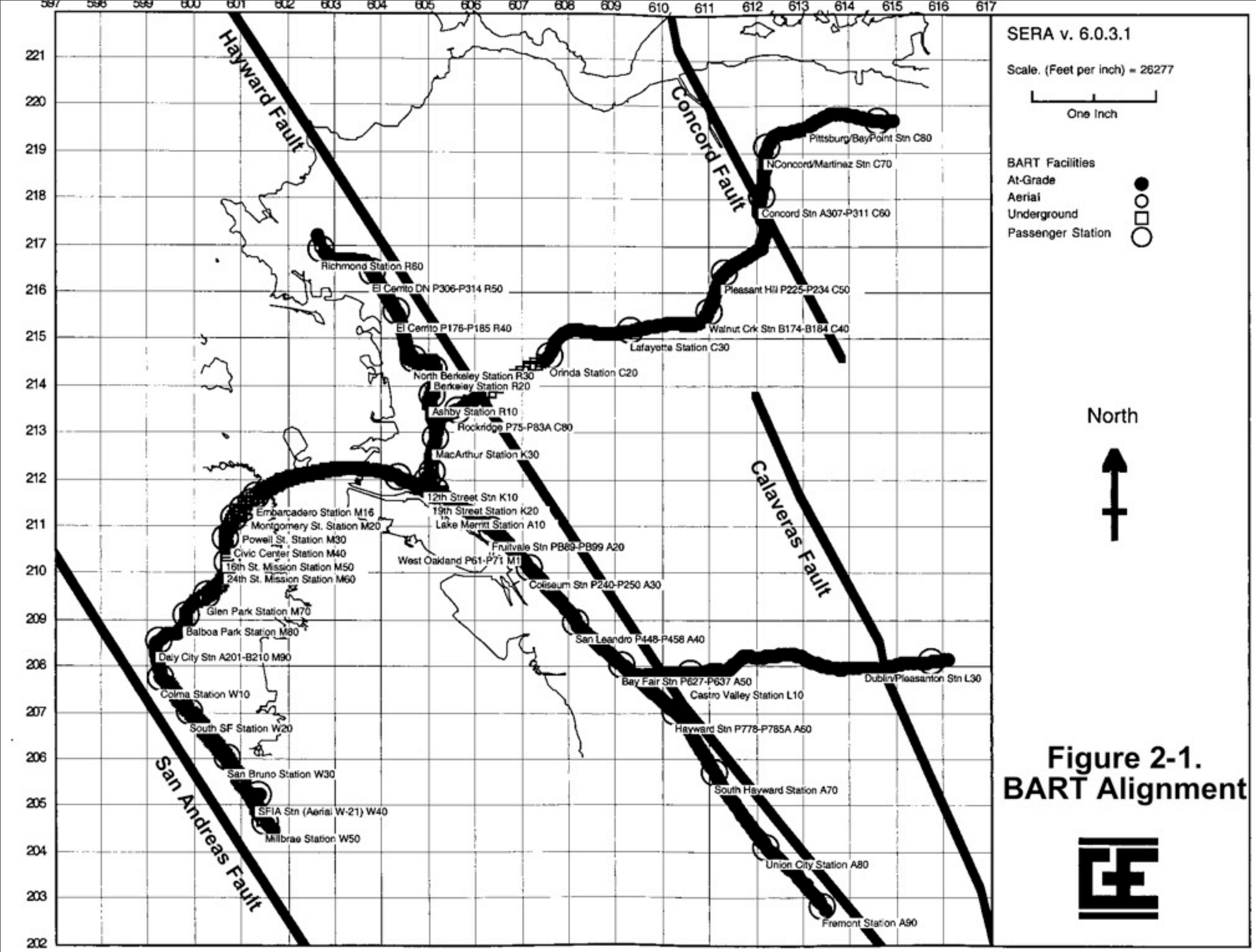
Core System
Non-Core System
New (no upgrade)

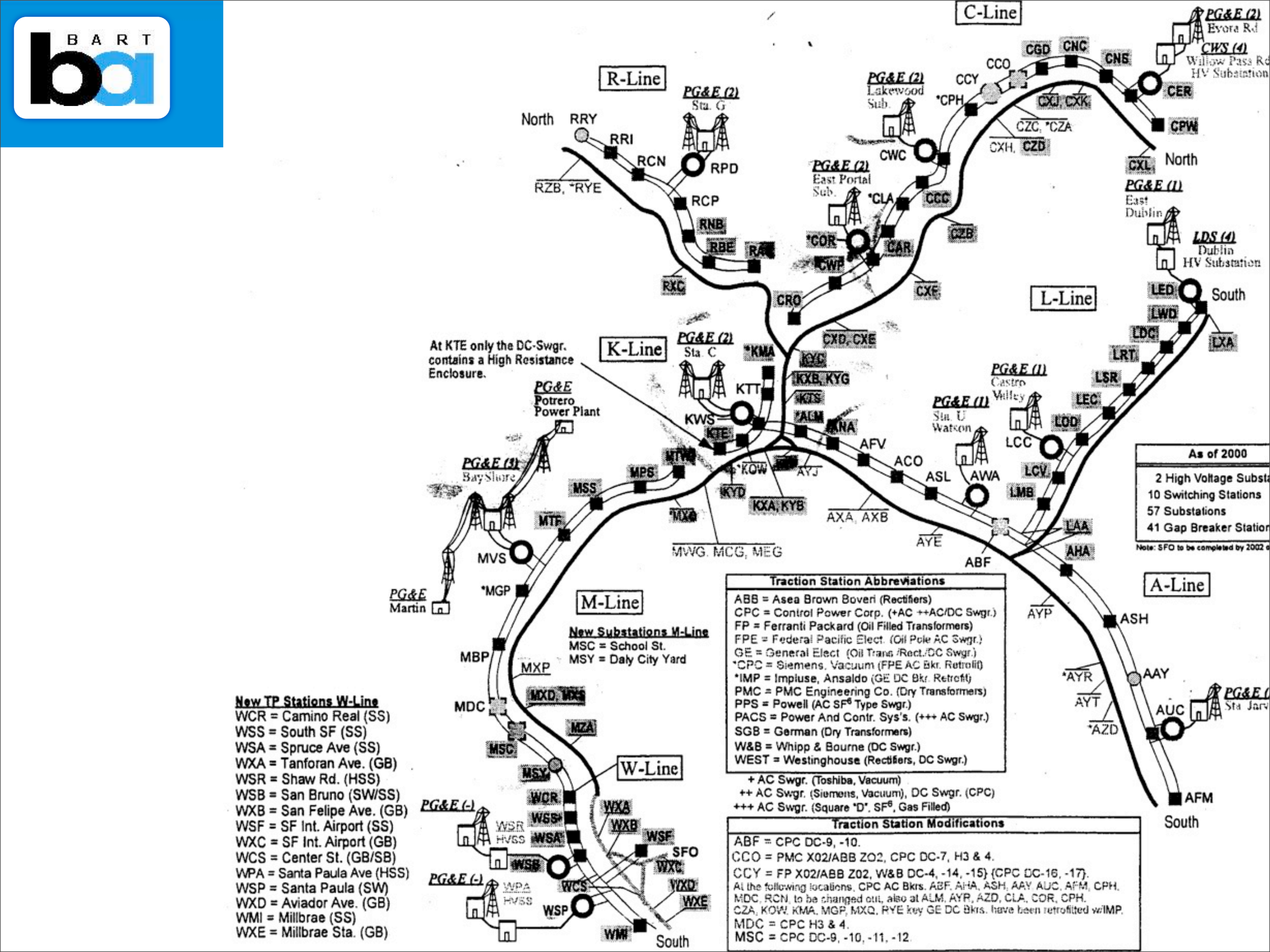
Non Core
Non Core
Core
Non Core

SAN PABLO BAY
RICHMOND YARD
RICHMOND
EL CERRITO DEL NORTE
Kearny St. Overpass R-30
Interstate 80 R-12
EL CERRITO PLAZA
Marin Ave. R-6
NORTH BERKELEY
MARIN COUNTY
BERKELEY
ASHBY
ROCKRIDGE
Maritime Overpass M-5
34th St. C-5
MACARTHUR
Northgate Overpass C-3
19TH ST. OAKLAND
EMBARCADERO
OAKLAND CITY CENTER 12TH ST.
MONTGOMERY ST.
LAKE MERRITT
16th St. A-4
CIVIC CENTER
POWELL ST.
FRUITVALE
SAN FRANCISCO COUNTY
16TH ST. MISSION
24TH ST. MISSION
WEST OAKLAND
COLISEUM
Pedestrian Overpass M-25
GLEN PARK
Hegenberger Expressway A-7
SAN LEANDRO
BALBOA PARK
BAYFAIR
DALY CITY
CASTRO VALLEY
DUBLIN/ PLEASANTON
COLMA
School St. M-34
Redwood Rd.
San Ramon Valley Blvd.
Junipero Serra M-34
DALY CITY YARD
SOUTH SAN FRANCISCO
HAYWARD
ALAMEDA COUNTY
238 Highway A-12 & L-2
SAN BRUNO
Pedestrian xing A-13
Pedestrian xing A-15
SAN FRANCISCO INTERNATIONAL AIRPORT
SOUTH HAYWARD
MILLBRAE INTERMODAL
HAYWARD YARD
Whipple Ave. A-18
PACIFIC OCEAN
SAN FRANCISCO BAY
UNION CITY
SAN MATEO COUNTY
Niles Blvd. A-19
FREMONT

PITTSBURG/BAY POINT
Canal Rd.
NORTH CONCORD/MARTINEZ
Mt. Diablo St. C-30
CONCORD
Systron Dr. C-28
Oak Grove Rd. C-26
CONCORD YARD
El Curtola C-21
PLEASANT HILL
Charles Hill Rd. C-15
WALNUT CREEK
LAFAYETTE
ORINDA
Highway No. 24 C-11
CONTRA
Palomares Rd.

0 1 2 3 6 9 MILES
GRAPHIC SCALE


SERA v. 6.0.3.1
Scale. (Feet per inch) = 26277
One Inch
BART Facilities
At-Grade
Aerial
Underground
Passenger Station
North
Hayward Fault
Concord Fault
Calaveras Fault
San Andreas Fault
Pittsburg/Bay Point Stn C80
NConcord/Martinez Stn C70
Concord Stn A307-P311 C60
Pleasant Hill P225-P234 C50
Walnut Crk Stn B174-B184 C40
Lafayette Station C30
Orinda Station C20
Richmond Station R60
El Cerrito DN P306-P314 R50
El Cerrito P176-P185 R40
North Berkeley Station R30
Berkeley Station R20
Ashby Station R10
Rockridge P75-P83A C80
MacArthur Station K30
12th Street Stn K10
19th Street Station K20
Lake Merritt Station A10
Fruitvale Stn PB89-PB99 A20
West Oakland P61-P71 M1
Coliseum Stn P240-P250 A30
Embarcadero Station M16
Montgomery St. Station M20
Powell St. Station M30
Civic Center Station M40
16th St. Mission Station M50
24th St. Mission Station M60
Glen Park Station M70
Balboa Park Station M80
Daly City Stn A201-B210 M90
Colma Station W10
South SF Station W20
San Bruno Station W30
SFIA Stn (Aerial W-21) W40
Millbrae Station W50
San Leandro P448-P458 A40
Bay Fair Stn P627-P637 A50
Castro Valley Station L10
Dublin/Pleasanton Stn L30
Hayward Stn P778-P785A A60
South Hayward Station A70
Union City Station A80
Fremont Station A90
Figure 2-1.
BART Alignment



New TP Stations W-Line

WCR = Camino Real (SS)
WSS = South SF (SS)
WSA = Spruce Ave (SS)
WXA = Tanforan Ave. (GB)
WSR = Shaw Rd. (HSS)
WSB = San Bruno (SW/SS)
WXB = San Felipe Ave. (GB)
WSF = SF Int. Airport (SS)
WXC = SF Int. Airport (GB)
WCS = Center St. (GB/SB)
WPA = Santa Paula Ave (HSS)
WSP = Santa Paula (SW)
WXD = Aviador Ave. (GB)
WMI = Millbrae (SS)
WXE = Millbrae Sta. (GB)

New Substations M-Line

MSC = School St.
MSY = Daly City Yard

Traction Station Abbreviations

ABB = Asea Brown Boveri (Rectifiers)
CPC = Control Power Corp. (+AC ++AC/DC Swgr.)
FP = Ferranti Packard (Oil Filled Transformers)
FPE = Federal Pacific Elect. (Oil Pole AC Swgr.)
GE = General Elect. (Oil Trans./Rect./DC Swgr.)
*CPC = Siemens, Vacuum (FPE AC Bkr. Retrofit)
*IMP = Impluse, Ansaldo (GE DC Bkr. Retrofit)
PMC = PMC Engineering Co. (Dry Transformers)
PPS = Powell (AC SF^6 Type Swgr.)
PACS = Power And Contr. Sys's. (+++ AC Swgr.)
SGB = German (Dry Transformers)
W&B = Whipp & Bourne (DC Swgr.)
WEST = Westinghouse (Rectifiers, DC Swgr.)

+ AC Swgr. (Toshiba, Vacuum)
++ AC Swgr. (Siemens, Vacuum), DC Swgr. (CPC)
+++ AC Swgr. (Square "D", SF^6, Gas Filled)

Traction Station Modifications

ABF = CPC DC-9, -10.
CCO = PMC X02/ABB ZO2, CPC DC-7, H3 & 4.
CCY = FP X02/ABB Z02, W&B DC-4, -14, -15} (CPC DC-16, -17).
At the following locations, CPC AC Bkrs. ABF, AHA, ASH, AAY, AUC, AFM, CPH, MDC, RCN, to be changed out, also at ALM, AYR, AZD, CLA, COR, CPH, CZA, KOW, KMA, MGP, MXQ, RYE key GE DC Bkrs. have been retrofitted w/IMP.
MDC = CPC H3 & 4.
MSC = CPC DC-9, -10, -11, -12.

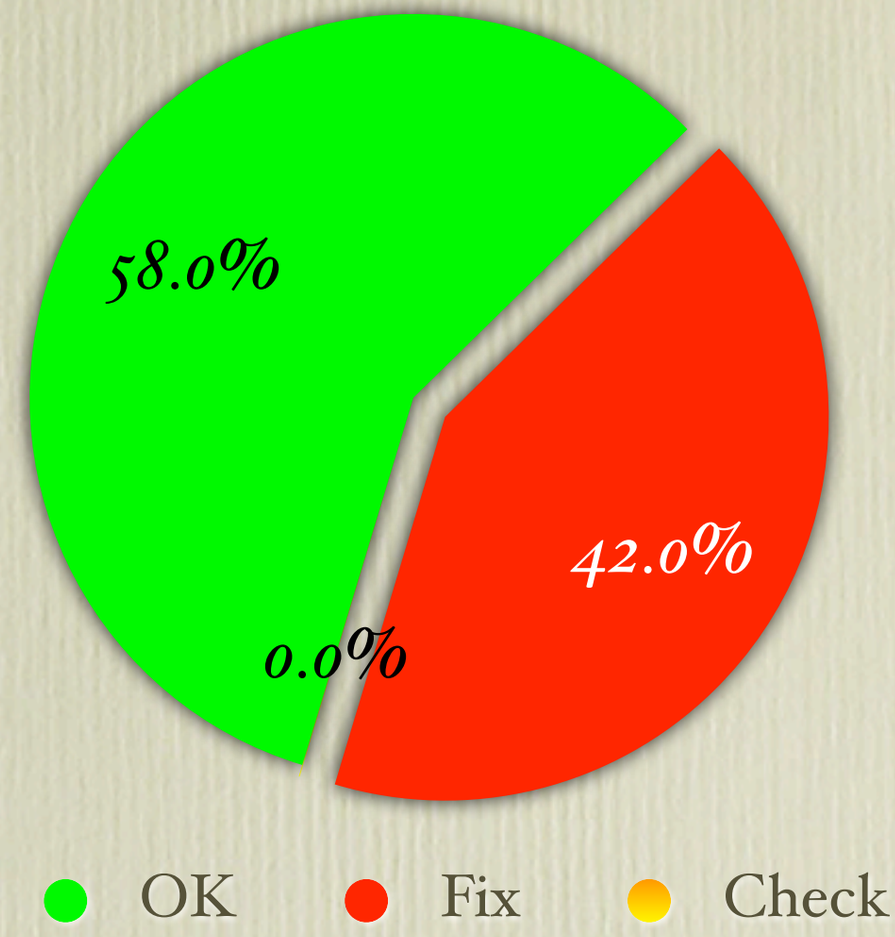
As of 2000

2 High Voltage Substa
10 Switching Stations
57 Substations
41 Gap Breaker Station

Note: SFO to be completed by 2002 o

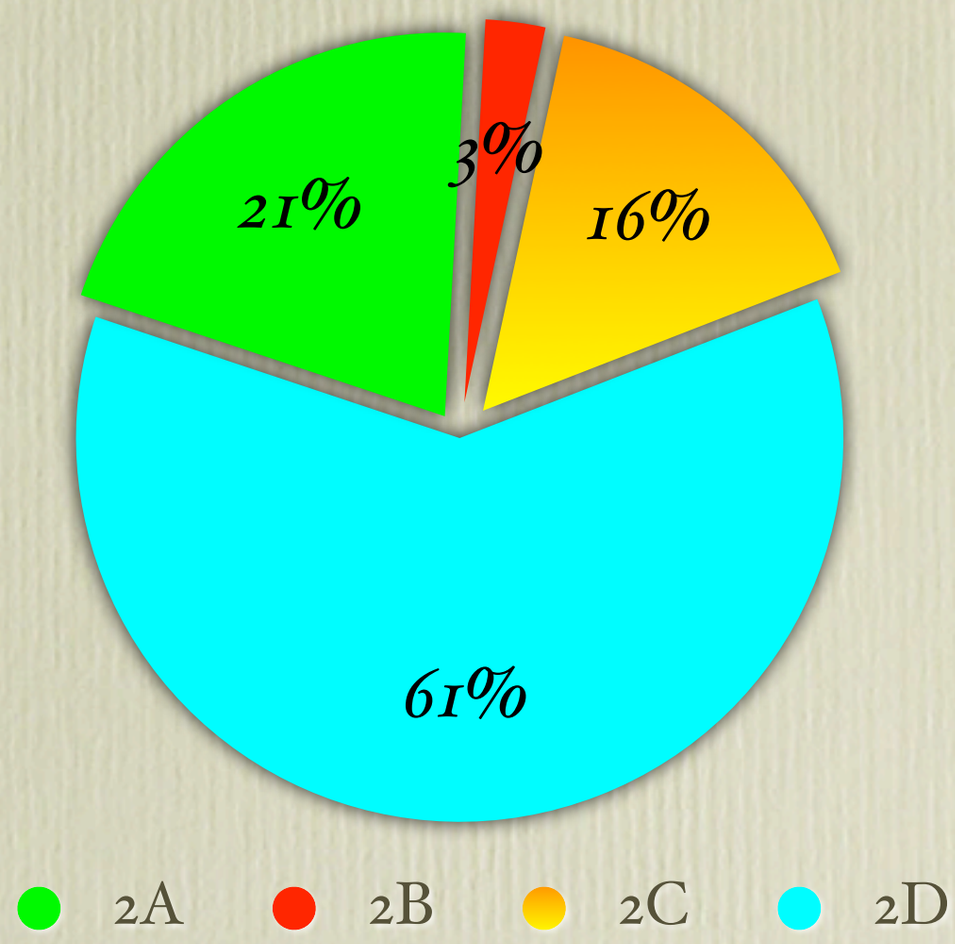
Non-Structural Components

- 25,679 items
  - 14,889 items Category 1 (OK)
  - 10,779 items Category 2 (Fix)
    - 9 items Category 3 (8 cranes, 1 transformer)
- Plus ~500 changed supports for aerial 34.5 kV Commodities



Category 2 Components

- 10,779 items
  - 2,267 2A - Essential
  - 275 2B - Life Safety
  - 1,716 2C - 2 over 1
  - 6,665 2D - Housekeeping
- Plus ~500 supports for aerial 34.5 kV commodities



Database

No Fix

Record ID 1105

Site Name: MTW Baytube West Substn | By: DLH | Date: 12/28/05 | Site _ID: 2474

Site Type: Substation | Checked: DMD | Date: 12/30/05 | Eastings: 6014375

Line: M | Station_Pair: M10-M16 | Northings: 2117375

Location: Rectifier Room | Floor No. in Bldg.: 4

Photo Number: 100_8206.JPG, 100_8207.JPG | Photo Date: 12/20/05 | No. of Floors in Bldg.: 6

System: Emergency Uninterruptible Power Supply

Equipment Type: EL-FLR 1 | Fragility ID: 1 | Med 2.5 | Beta .5 | lowG .55 | Function 1.0 | Life Safety 1

Unit Cost Upgrade 1000 | Short Term Cost 1000 | Long Term Cost 25000

Number Similar: 1 | Fragility Description: Tall electrical cabinet, well-anchored to floor and/or wall | FEMA Type: GBWP

Comments:

Photo 1

Photo 2

Qualification Group: 1 OK as-is

Operability: Full Operability

Fix_Override:

BART Category Grouping Assignment

P1	P2	P3	P4	P5	P6	P7	P8	P9
0	0	0	0	0	0	0	0	0

Earthquake	Median PGA	Amplified Motion	As Is Prob failure	Upgraded Prob failure	Q=2,3 Only As Is Item failures	Q=2,3 Only Upgraded Item failures	Q=2,3 Only Upgrade Test	Q=2,3 Only Upgrade Cost
Hayward 7 Event	0.27 g	0.51	0.00%	0.00%	0.00	0.00	5%	$0
SanAndreas 8 Event	0.40 g	0.76	0.86%	0.00%	0.00	0.00	5%	$0
Calaveras 6.8 Event	0.11 g	0.21	0.00%	0.00%	0.00	0.00	5%	$0
Concord 6.8 Event	0.10 g	0.19	0.00%	0.00%	0.00	0.00	5%	$0
Maximum, Any Earthquake or Cost if Fix_Override=Yes								$0

Database

Fix

Record ID 1106

Site Name	MTW Baytube West Substn	By	DLH	Date	11/4/05	Site _ID	2474
Site Type	Substation	Checked	DMD	Date	12/30/05	Eastings	6014375
Line	M	Station_Pair	M10-M16			Northings	2117375
Location	Rectifier Room					Floor No. in Bldg.	4
Photo Number	100_3966.JPG, 100_3968.JPG	Photo Date	10/3/05			No. of Floors in Bldg.	6
System	Traction Power System						
Equipment Type	BR 2	Fragility ID	6				
Number Similar	1	Fragility Description	Battery rack, older, well-anchored, minor gaps between racks and batteries				
Comments	Styrofoam spacers degraded						

Med .9 Beta .5 lowG .2 Function 1.0 Life Safety 1

Unit Cost Upgrade 500 Short Term Cost 1000 Long Term Cost 10000

FEMA Type GEWU

Photo 1

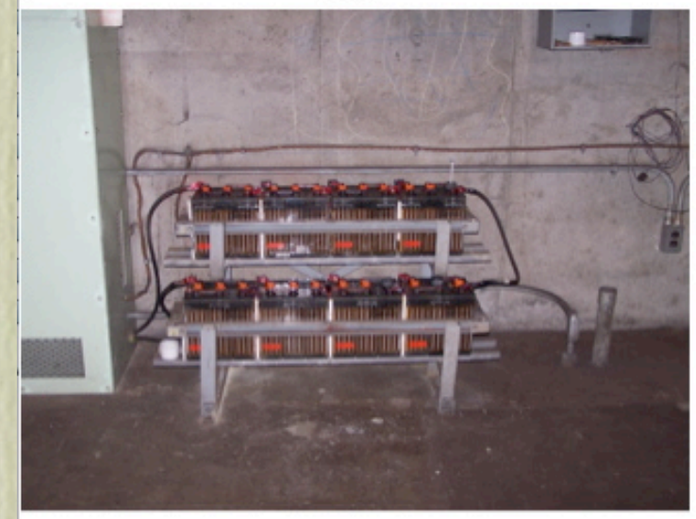


Photo 2

Qualification Group 2 Requires Modification

X Essential Equipment

Life Safety

2 over 1

None of the above

Operability Full Operability

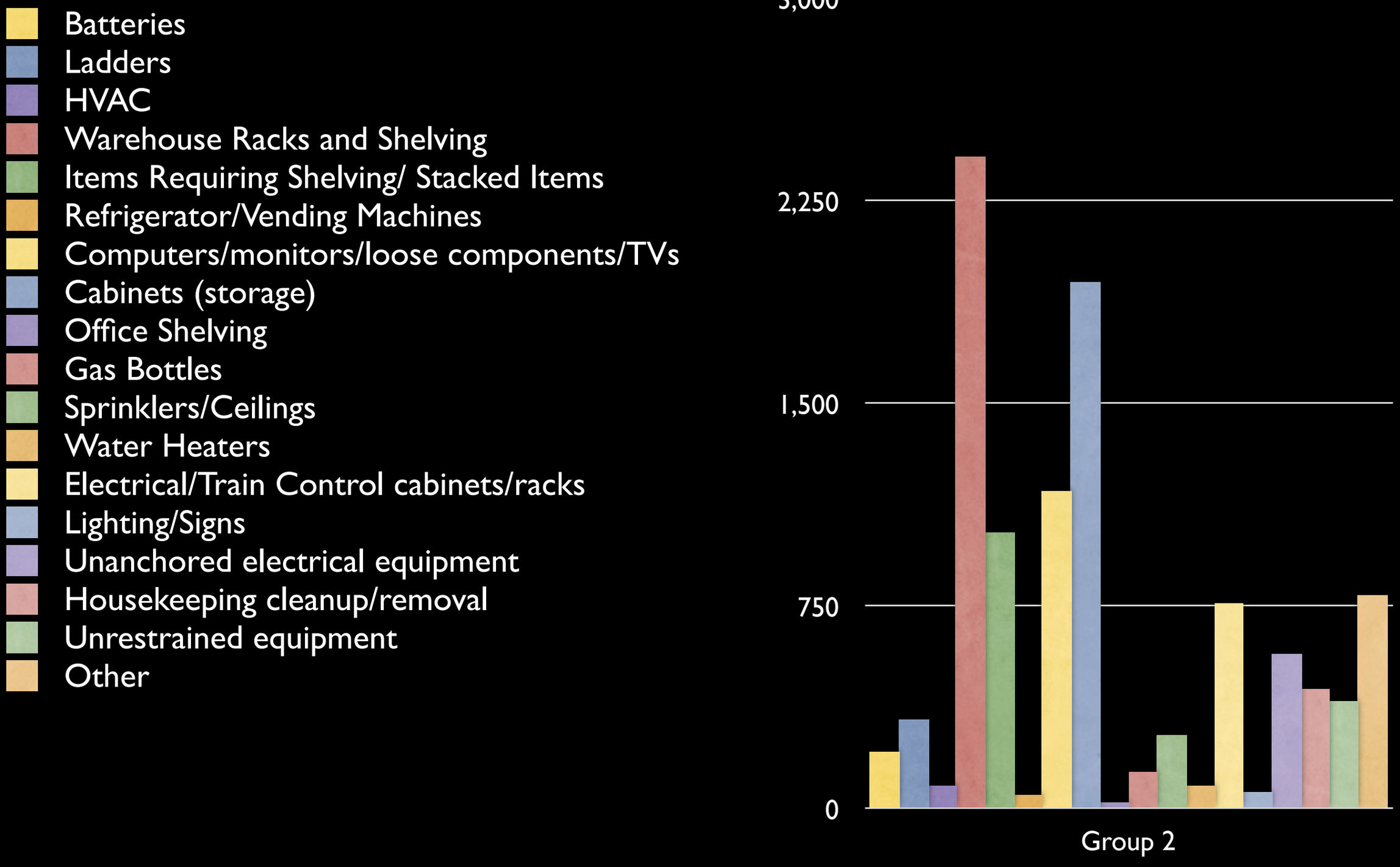
Fix_Override

BART Category Grouping Assignment

P1	P2	P3	P4	P5	P6	P7	P8	P9
1	0	0	0	0	0	0	0	0

Earthquake	Median PGA	Amplified Motion	As Is Prob failure	Upgraded Prob failure	Q=2,3 Only As Is Item failures	Q=2,3 Only Upgraded Item failures	Q=2,3 Only Upgrade Test	Q=2,3 Only Upgrade Cost
Hayward 7 Event	0.27 g	0.51	13.05%	0.33%	0.13	0.00	5%	$500
SanAndreas 8 Event	0.40 g	0.76	36.76%	2.65%	0.37	0.03	5%	$500
Calaveras 6.8 Event	0.11 g	0.21	0.17%	0.00%	0.00	0.00	5%	$0
Concord 6.8 Event	0.10 g	0.19	0.00%	0.00%	0.00	0.00	5%	$0
Maximum, Any Earthquake or Cost if Fix_Override=Yes								$500

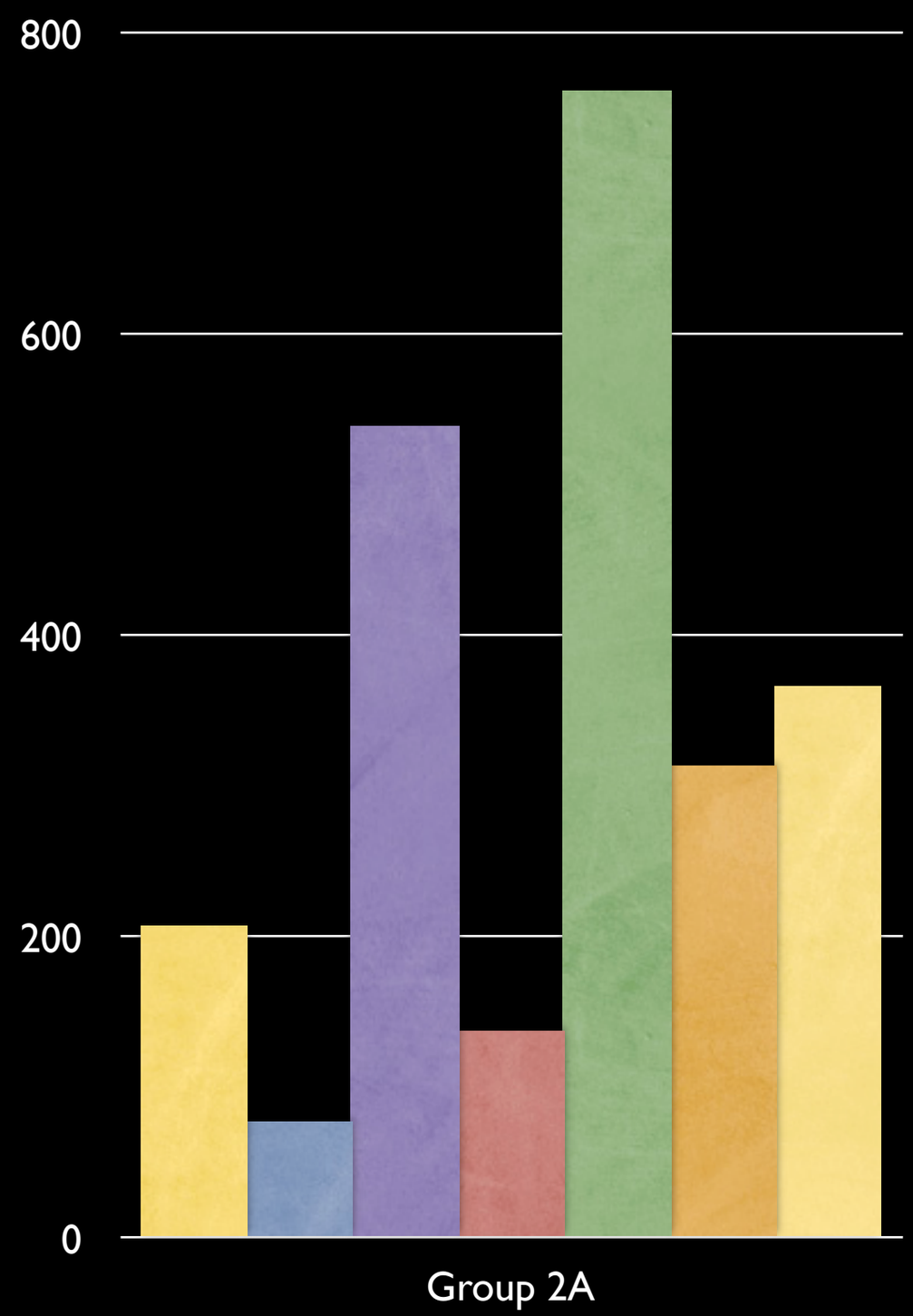
Category 2 Items



Category 2A Items

Essential Core and non-Core Items

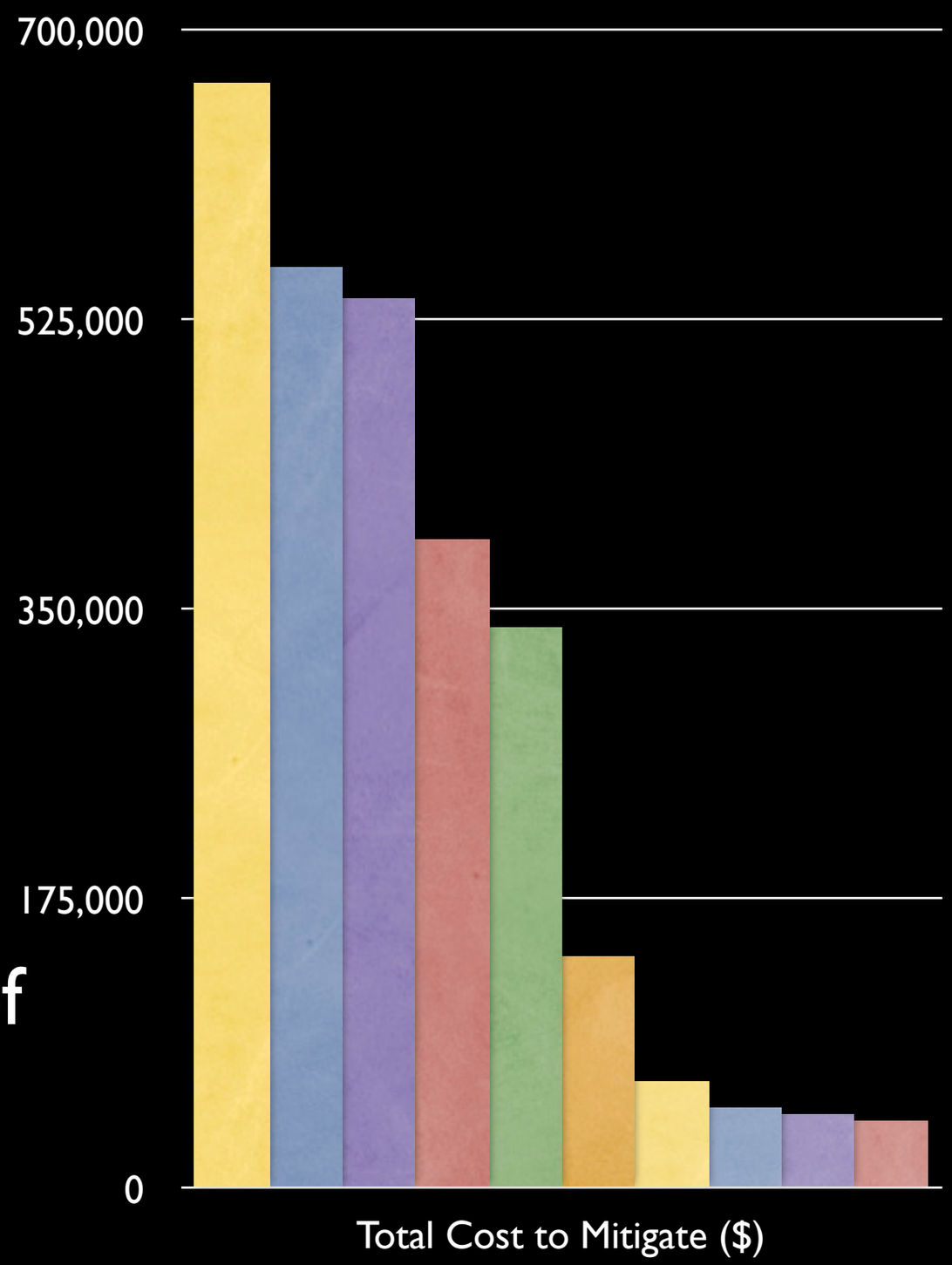
- Batteries
- HVAC
- Computers/monitors/loose components/TVs
- Gas Bottles
- Electrical/Train Control cabinets/racks
- Unanchored electrical equipment
- Other



Top 10 Cost Items

Basic Construction Cost

- Unanchored Tall Office and Storage Cabinets
- Aerial Commodities
- Multi-Level Warehouse Racks
- Tall Electrical Cabinets
- Suspended Ceilings
- Light Warehouse Racks
- Tall Bookshelves
- Raised Computer Floors
- Ladders
- Home Depot Racks



Top 10 items represent ~80% of total cost.

Tall Office / Storage Cabinet

Tall Office / Storage Cabinet

Typical Aerial Commodity

Two-Story Warehouse Rack

Tall Electrical Cabinets

Tall Electrical Cabinets

Suspended Ceilings

Light Warehouse Racks

Tall Bookshelves

Raised Computer Floors

HVAC
- Over 50 fans to be fixed

Office Equipment
- Over 500 like this

Fire Piping

Supports on Valve Yokes - over 40 like this

Batteries - over 100 like this

Water heaters - over 90 like this

Passenger Stations

Passenger Station	Designation	Number of Components	Numbers of Components in each Qualification Group					
			OK	ES	LS	EL	Other	Uncertain
Lake Merritt	A10	335	194	41	1	35	53	0
Fruitvale	A20	189	161	4	0	12	12	0
Coliseum	A30	290	251	6	1	14	18	0
San Leandro	A40	184	150	11	0	12	11	0
Bay Fair	A50	450	353	27	4	28	38	0
Hayward	A60	268	220	21	0	8	18	0
South Hayward	A70	188	145	19	1	9	14	0
Union City	A80	234	186	15	3	26	4	0
Fremont	A90	248	193	18	0	26	10	0
Rockridge	C10	291	224	24	0	2	41	0
Orinda	C20	230	161	26	0	30	13	0
Lafayette	C30	443	254	24	1	159	5	0
Walnut Creek	C40	302	246	26	7	14	13	0
Pleasant Hill	C50	403	263	18	0	11	111	0
Concord	C60	235	176	43	2	11	3	0
North Concord	C70	451	338	48	1	37	7	0
Oakland 12th St.	K10	797	621	48	1	99	28	0
Oakland 19th St.	K20	526	392	59	0	35	47	0
MacArthur	K30	290	240	20	0	10	20	0
West Oakland	M10	311	240	29	0	23	19	0
Embarcadero	M16	516	427	43	7	22	22	0
Montgomery St.	M20	790	676	41	4	33	36	0
Powell St.	M30	656	506	52	2	15	81	0
Civic Center	M40	564	377	61	0	13	113	0
16th St. Mission	M50	473	416	36	0	9	12	0
24th St. Mission	M60	462	393	38	0	19	12	0
Glen Park	M70	244	196	33	0	8	7	0
Balboa Park	M80	408	319	32	0	42	15	0
Daly City	M90	643	458	46	1	101	37	0
Ashby	R10	287	243	24	0	8	12	0
Berkeley	R20	499	421	42	1	11	24	0
North Berkeley	R30	203	178	7	0	6	12	0
El Cerrito Plaza	R40	325	271	30	0	10	14	0
El Crto del Norte	R50	404	312	34	7	17	34	0
Richmond	R60	312	233	21	0	31	27	0

Substations

Sub/Switching Station	Number of Components	Numbers of Components in each Qualification Group					
		OK	ES	LS	EL	Other	Uncertain
AAY	67	63	2	0	2	0	0
ABF	15	11	2	0	1	0	0
ACO	9	6	2	0	0	0	1
AFM	21	18	2	0	0	1	0
AFV	35	9	1	0	24	0	1
AHA	23	16	1	0	6	0	0
ALM	47	34	2	0	11	0	0
ANA	55	50	1	0	3	1	0
ASH	15	13	2	0	0	0	0
ASL	15	11	1	0	3	0	0
AUC	14	10	2	0	2	0	0
AWA	15	13	2	0	0	0	0
CAR	30	28	2	0	0	0	0
CCC	41	37	2	0	2	0	0
CCO	60	57	3	0	0	0	0
CCY	71	59	2	0	8	1	1
CGD[1]	2	0	2	0	0	0	0
CLA	33	29	2	0	2	0	0
COR	33	29	2	0	2	0	0
CPH	17	15	1	0	1	0	0
CRO[2]	31	23	2	0	3	3	0
CWC	36	28	2	0	6	0	0
CWP[2]	62	54	5	0	3	0	0
KMA	38	30	3	0	2	2	1
KOW	18	13	1	0	4	0	0
KTE	53	21	2	0	0	0	30
KTT	12	12	0	0	0	0	0
KWS	30	23	3	0	4	0	0
MBP	21	18	2	0	1	0	0
MDC	62	57	3	0	2	0	0
MGP	45	31	6	0	6	2	0
MPS	48	28	1	0	19	0	0
MSC	110	81	19	0	5	5	0
MSS	51	39	8	0	4	0	0
MSY	109	57	3	0	10	37	2
MTF	61	43	9	0	8	1	0
MTW	38	24	4	0	8	0	2
RAS	19	15	3	0	1	0	0
RBE	30	24	4	0	1	1	0

P1 to P8 Upgrades

Package Priority	Number of Items to be upgraded	Total Cost	Cumulative Cost
P1	1,896	$3,322,923	$3,322,923
P2	832	$1,254,695	$4,577,618
P3	1,009	$1,344,132	$5,921,750
P4	1,334	$1,574,405	$7,496,155
P5	335	$126,893	$7,623,047
P6	561	$275,161	$7,898,209
P7	530	$182,664	$8,080,872
P8	1,882	$573,447	$8,654,319
Low Risk Items	2,400	$1,782,331	$10,436,650

Since FEMA will only co-fund $3,000,000 in one grant, we asked FEMA for $ for for the "worst" 3,571 items. Internally to BART, we decided not to upgrade P6, P7, P8 and other Low Risk Items

FEMA "DEFAULT" Fragilities

(see on-line reports for development and details)

Input to ATC 58

Item	FEMA A As Is	FEMA A Upgraded
Generic bottom weight unanchored	0.75	1.50
Generic bottom weight poor anchored	0.88	1.50
Generic even weight unanchored	0.60	1.50
Generic even weight poor anchored	0.73	1.50
Generic top weight unanchored	0.40	1.50
Generic top weight poor anchored	0.49	1.50
Parapet walls URM extensive damage	0.40	1.10
Parapet walls URM complete damage	0.60	1.50
Racks – shelves	0.60	1.00
Generators on isolators	0.25	0.60
Elevators moderate	0.35	0.90
Elevators extensive	0.75	1.50
Fire sprinklers limited	0.25	0.52
Fire sprinklers widespread	0.50	1.00
Fire sprinklers extensive	0.75	1.50
HVAC Fans	0.30	1.00
HVAC Ductwork Rod hung extensive	1.25	2.38
HVAC Ductwork rod hung complete	1.88	3.00
HVAC ductwork rod hung in penthouse extens.	0.50	0.96
HVAC ductwork rod hung in penthouse compl.	0.75	1.50
Suspended ceiling wire hung moderate	0.25	1.50
Suspended ceiling wire hung extensive	0.50	>1.50
Suspended ceiling wire diagonals moderate	0.50	1.50
Suspended ceiling wire diagonals extensive	0.90	>1.50
Suspended ceiling comp struts moderate	0.80	1.50
Suspended ceiling comp struts extensive	1.30	>1.50
Electrical cabinets unanchored	0.60	3.00
Electrical cabinets poorly anchored	1.00	3.00

BART Equipment - Assignment to FEMA Fragility Values

BART Item (BART component ID number)	FEMA A As is
Wheel mounted top heavy test equipment (226)	0.40
Table top item, unrestrained (14)	0.40
Wall mounted item, unrestrained (26)	0.40
Unanchored tall cabinet (2)	0.40
HVAC on springs (8)	0.25
Tall top heavy rack unanchored (42)	0.40
Unrestrained desk top monitors (45)	0.40
Work table tools, unrestrained (46)	0.40
Light metal shelving, tall, unanchored (50)	0.60
Heavy racks, damaged (105)	0.60
Tall top heavy equipment unanchored (41)	0.40
Tall wheeled cart, unrestrained (48)	0.40
Tall bookcases (91)	0.40
Batteries, unrestrained (263)	0.60
Cabinet, short, unrestrained (5)	0.60
Ladders, unrestrained (9)	0.60
Suspended ceiling, light supports (39)	0.50
Large warehouse storage racks, contents unrestrained (103)	0.60
Cantilever shelving, items unrestrained (120)	0.60
Train car topples off lift stands (121)	0.60
Tall electrical cabinet, unanchored (125)	0.60
Horizontal fan on springs, unanchored (189)	0.25
HVAC fan unit, spring-hung (190)	0.30
Unrestrained gas cylinders (397)	0.60
Air compressor on springs, not snubbed (432)	0.25
Battery rack, unanchored (440)	0.60
Small cabinet, unanchored, wide legs (116)	0.60
Medium storage rack, unanchored (451)	0.60
Rigid plastic pipe next to tank that rocks (459)	0.75
Rod hung HVAC ductwork (top floor) (20)	0.75
Battery in old rack with spacer gaps (6)	0.60
Lightly anchored transformer (27)	0.73
Bus duct, hanger support, fragile rigid bus inside (29)	0.75

Project Costs (3,571 items)

Item	Cost	Unit Cost (3,571 items)
A. Construction Cost ($2006) (see Table 6-2)	$2,982,287	$835.14
B. Mobilization (5%) plus profit (10%)	$447,343	
C. Total construction (2006)	$3,429,630	
D. Final Design, including modifications during construction for custom installations (18% of C)	$617,333	
E. Design support during construction (4% of C)	$137,185	
F. Access monitors (6% of C)	$205,778	
G. Project Management (5% of C)	$171,482	
H. Total Soft Costs (D + E + F + G)	$1,131,778	
I. Escalation to mid-point of construction (2008) (5% of C + H)	$228,070	
J. Total (C + H + I)	$4,789,478	$1,341.21

Project Benefits (3,571 items)

Type of Non Structural Item	Concord	Richmond	Hayward	Daly City
ECU			33,621	42,841
FS			824	1,703
GBWP	53		63	562
GBWU			289	3,299
GEWP	177	217	16,691	69,554
GEWU	47,555	151,509	131,121[1]	392,902
GTWP			0	6,626
GTWU	183,653	326,424	395,812	386,265
GI	21,573	5,964	22,507	75,962
HVACDP			477,406	30,294
HVACF			1,221	
RS	2,791	8,301	998,621	2,129
SCWH		34,590	164,376	60,405
Loss of Services[2]			9,793,445	
Total	$255,802	$527,005	$12,035,997	$1,072,542

Total Benefits: $13.9 Million. Costs: $4.8 Million. BCR = 2.90

Conclusions

- Benefit Cost Analysis helps decide what to be done
- FEMA spends more than $100,000,000 per year on mitigation projects that require BCR
- The fragility models are listed in the paper, and described in detail in on-line documentation
- BART is a healthy example of using FEMA money to implement a rational and cost effective seismic upgrade program