# Underground Cable Failure Tracking
# Underground Cable Failure Rates

Jon Erickson – San Diego Gas & Electric

ICC Educational Program
November 3, 2004

SDGE
A Sempra Energy utility™

# Topics

- Background on SDG&E electric system
- Cable failure tracking method
  - Data collection
  - Cable failure database
- Cable failure rates
  - Use of cable failure database
  - Statistical method for determining failure rates
  - Examples of cable failure rates
  - Feeder and branch circuit reliability model

# SDG&E Electric System

2003 totals

Number of electric customers – 1,290,168

Number of electric distribution circuits – 952

4 kV circuits – 262

12 kV circuits – 690

Underground cable circuit miles – 8882

Underground cable conductor miles – 22059

# SDG&E Electric System (cont).

- Unjacketed HMWPE cable miles – 3700
  Installed 1963 – 1979
  Remaining HMWPE cable miles – 3260
- Unjacketed XLPE cable miles – 3400
  Installed 1968 – 1985
  Remaining XLPE cable miles – 2969
- Jacketed XLPE/TRXLPE cable miles – 15700
  Installed XLPE 1978 – 1999
  Installed TRXLPE 1998 to present
- Jacketed EPR cable miles – 130
- PILC cable miles – 189

# SDG&E Electric System (cont).

- 57 % of system underground
- 99+ % of cable in conduit or cable in conduit
- Cable failure replacement – all cables in conduit replaced

# Cable Failure Tracking

- Use Distribution System Operating Report
- Research failed segment
  - Identify segment on operating map
  - Determine work order installation date
  - Obtain equipment failure report from operating district
  - Enter data in cable failure database

# Distribution Systems Operating Report

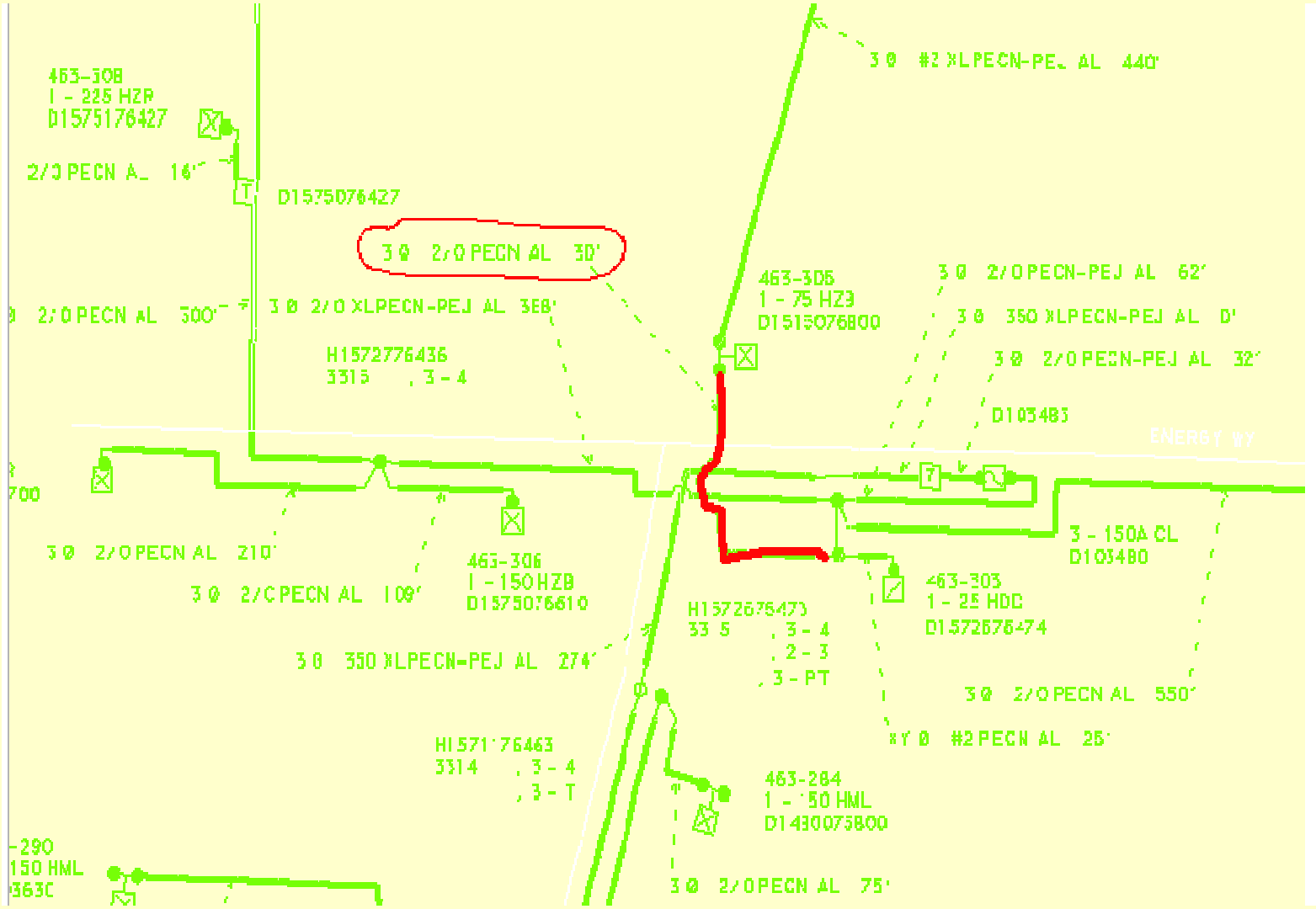
## Individual Outages

| | | | | | |
|---|---|---|---|---|---|
| OUTAGE ID | 030829E7101 | Time ETM called | 0049 | First manual operation | 0225 |
| OUTAGE TYPE | BRAN | Time ETM on scene | 0151 | First SCADA operation | N/A |
| CIRCUIT ID | 463 | Time crew requested | 0049 | Damaged device | UG CABLES |
| Substation | SAN YSIDRO | Time crew En-route | N/A | Damaged from structure | H1572676473 |
| Time occurred | 0047 | Time crew on scene | 0500 | Damaged to structure | D1515076800 |
| 1st o/s | 0249 | Time fault van requested | 0049 | | |
| Time restored | 0655 | Time fault van on scene | 0157 | | |
| Cause | UG CABLE FAILURE | | | | |
| Area affected | ENERGY WAY B/O NIRVANA AVE | | | | |

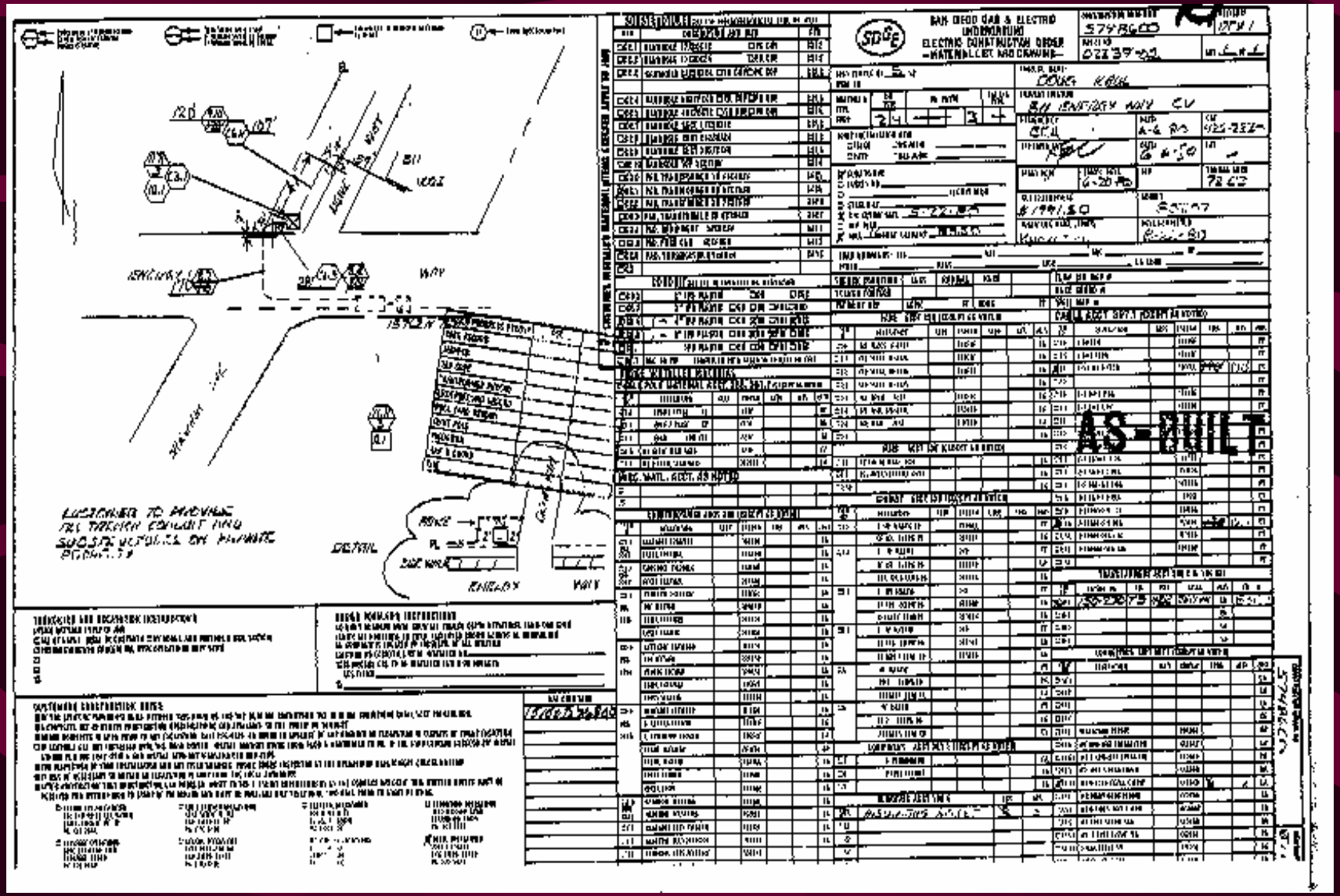
## Major steps taken in restoring service:

| | | |
|---|---|---|
| 0047 | Initial Alarm | OUTAGE GENERATED BY SWITCHING CENTER, FUSE D103480 |
| 0048 | Confirm | OUTAGE CONFIRMED @ 00:48, FUSE D103480, ENERGY WAY EAST OF NIRVANA AVE |
| 0049 | Requested | FAULT VAN HAS BEEN REQUESTED |
| 0049 | Requested | UNDERGROUND CREW HAS BEEN REQUESTED |
| 0151 | On Scene | 1ST ETM IS NOW ON THE SCENE |
| 0157 | On Scene | FAULT VAN IS NOW ON THE SCENE |
| 0225 | Close Manual | 1-150A CLF @ D103480, TO FAULT INDICATORS IN PLACE & FUSE BLEW |
| 0227 | Remarks | WITH INDICATION BETW H1572676473 & STA 463-305. CREW HAD TO OPEN REMAINING 3-150A CLF FOR SAFETY DUE TO ILLEGAL HANDHOLE, NO ROOM TO WORK |
| 0241 | Open Manual | OPEN FUSES @ D103480. OPENED REMAINING 2-150A CLF FOR SAFETY |
| 0243 | Open Manual | LOAD BREAK ELBOWS IN H1572676473, ISOLATING FAULTED CABLE TO D1515076800 |
| 0245 | Cause | EQUIPMENT, OTHER CONNECTOR UG, DAMAGED |
| 0247 | Remarks | FAULTED UG CABLE LOACTED BETW H1572676473 & STA 473-305 |
| 0249 | Close Manual | CLOSE 3-150A CLF TO OPEN ELBOWS IN H1572676473, RESTORING ALL BUT 3 STAS |
| 0500 | On Scene | UNDERGROUND CREW IS NOW ON THE SCENE |
| 0655 | Close Manual | LOAD BREAK ELBOWS IN H1572676473 |
| 0655 | Restored | THE OUTAGE WAS FULLY RESTORED AT 0655 |
| End | 030829E7101 | |

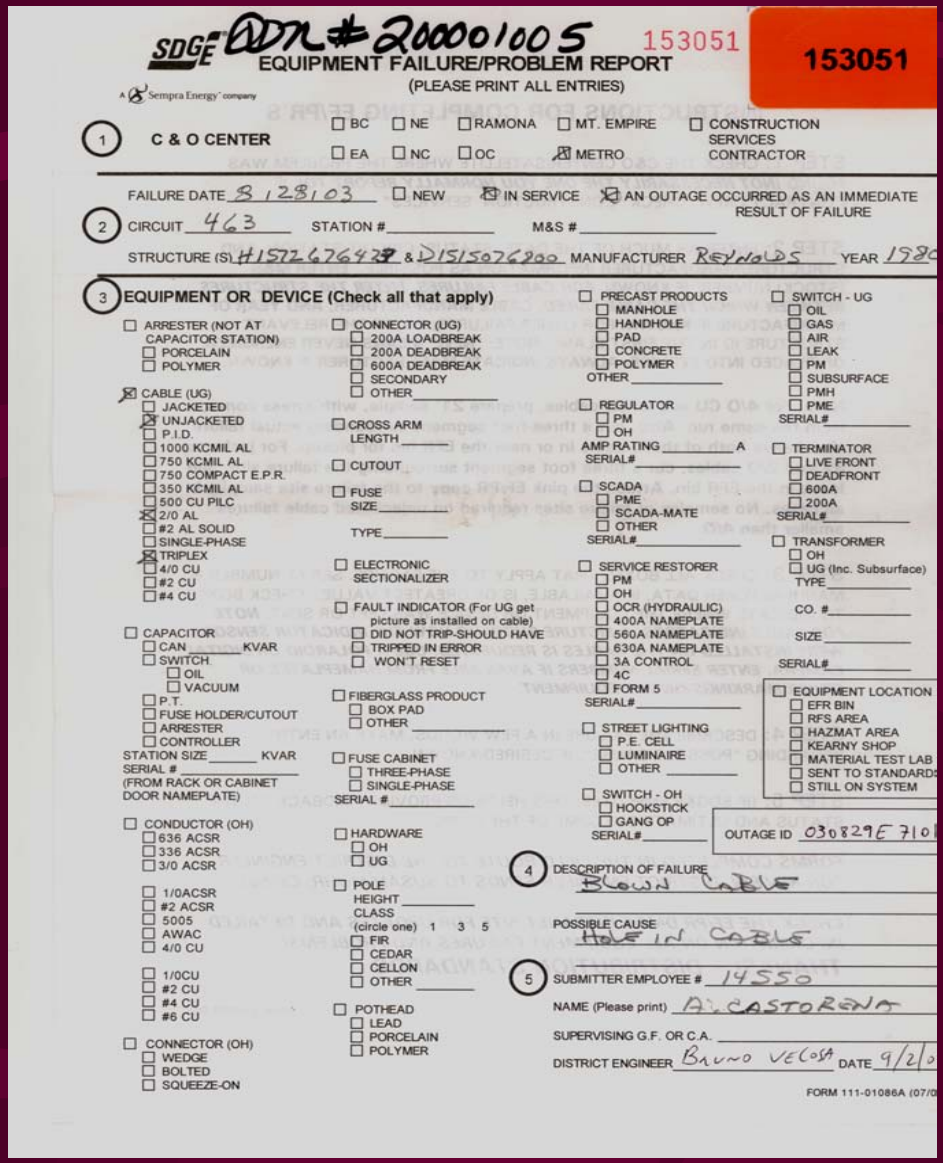
# Underground Operating Map



# Work order Information



# Equipment Failure/Problem Report



SDGE QDN # 20000100 5 153051

153051

EQUIPMENT FAILURE/PROBLEM REPORT

(PLEASE PRINT ALL ENTRIES)

A Sempra Energy company

1 C & O CENTER ☐ BC ☐ NE ☐ RAMONA ☐ MT. EMPIRE ☐ CONSTRUCTION SERVICES CONTRACTOR ☐ EA ☐ NC ☐ OC ☒ METRO

FAILURE DATE 8/28/03 ☐ NEW ☒ IN SERVICE ☒ AN OUTAGE OCCURRED AS AN IMMEDIATE RESULT OF FAILURE

2 CIRCUIT 463 STATION # _____ M&S # _____

STRUCTURE (S) #1572676437 & #1515076200 MANUFACTURER REYNOLDS YEAR 1980

3 EQUIPMENT OR DEVICE (Check all that apply)

☐ ARRESTER (NOT AT CAPACITOR STATION)
☐ PORCELAIN
☐ POLYMER

☒ CABLE (UG)
☐ JACKETED
☒ UNJACKETED
☐ P.I.D.
☐ 1000 KCMIL AL
☐ 750 KCMIL AL
☐ 750 COMPACT E.P.R.
☐ 350 KCMIL AL
☐ 500 CU PILC
☒ 2/0 AL
☐ #2 AL SOLID
☐ SINGLE-PHASE
☒ TRIPLEX
☐ 4/0 CU
☐ #2 CU
☐ #4 CU

☐ CAPACITOR
☐ CAN _____ KVAR
☐ SWITCH
☐ OIL
☐ VACUUM
☐ P.T.
☐ FUSE HOLDER/CUTOUT
☐ ARRESTER
☐ CONTROLLER
STATION SIZE _____ KVAR
SERIAL # _____
(FROM RACK OR CABINET DOOR NAMEPLATE)

☐ CONDUCTOR (OH)
☐ 636 ACSR
☐ 336 ACSR
☐ 3/0 ACSR
☐ 1/0ACSR
☐ #2 ACSR
☐ 5005
☐ AWAC
☐ 4/0 CU
☐ 1/0CU
☐ #2 CU
☐ #4 CU
☐ #6 CU

☐ CONNECTOR (OH)
☐ WEDGE
☐ BOLTED
☐ SQUEEZE-ON

☐ CONNECTOR (UG)
☐ 200A LOADBREAK
☐ 200A DEADBREAK
☐ 600A DEADBREAK
☐ SECONDARY
☐ OTHER _____

☐ CROSS ARM
LENGTH _____

☐ CUTOUT

☐ FUSE
SIZE _____
TYPE _____

☐ ELECTRONIC SECTIONALIZER

☐ FAULT INDICATOR (For UG get picture as installed on cable)
☐ DID NOT TRIP-SHOULD HAVE
☐ TRIPPED IN ERROR
☐ WON'T RESET

☐ FIBERGLASS PRODUCT
☐ BOX PAD
☐ OTHER _____

☐ FUSE CABINET
☐ THREE-PHASE
☐ SINGLE-PHASE
SERIAL # _____

☐ HARDWARE
☐ OH
☐ UG

☐ POLE
HEIGHT _____
CLASS
(circle one) 1 3 5
☐ FIR
☐ CEDAR
☐ CELLON
☐ OTHER _____

☐ POTHEAD
☐ LEAD
☐ PORCELAIN
☐ POLYMER

☐ PRECAST PRODUCTS
☐ MANHOLE
☐ HANDHOLE
☐ PAD
☐ CONCRETE
☐ POLYMER
OTHER _____

☐ REGULATOR
☐ PM
☐ OH
AMP RATING _____ A
SERIAL# _____

☐ SCADA
☐ PME
☐ SCADA-MATE
☐ OTHER
SERIAL# _____

☐ SERVICE RESTORER
☐ PM
☐ OH
☐ OCR (HYDRAULIC)
☐ 400A NAMEPLATE
☐ 560A NAMEPLATE
☐ 630A NAMEPLATE
☐ 3A CONTROL
☐ 4C
☐ FORM 5
SERIAL# _____

☐ STREET LIGHTING
☐ P.E. CELL
☐ LUMINAIRE
☐ OTHER _____

☐ SWITCH - OH
☐ HOOKSTICK
☐ GANG OP
SERIAL# _____

☐ SWITCH - UG
☐ OIL
☐ GAS
☐ AIR
☐ LEAK
☐ PM
☐ SUBSURFACE
☐ PMH
☐ PME
SERIAL# _____

☐ TERMINATOR
☐ LIVE FRONT
☐ DEADFRONT
☐ 600A
☐ 200A
SERIAL# _____

☐ TRANSFORMER
☐ OH
☐ UG (Inc. Subsurface)
TYPE _____
CO. # _____
SIZE _____
SERIAL# _____

☐ EQUIPMENT LOCATION
☐ EFR BIN
☐ RFS AREA
☐ HAZMAT AREA
☐ KEARNY SHOP
☐ MATERIAL TEST LAB
☐ SENT TO STANDARDS
☐ STILL ON SYSTEM

OUTAGE ID 030829E 710

4 DESCRIPTION OF FAILURE Blown Cable

POSSIBLE CAUSE Hole in Cable

5 SUBMITTER EMPLOYEE # 14550

NAME (Please print) A. CASTORENA

SUPERVISING G.F. OR C.A. _____

DISTRICT ENGINEER Bruno Vecosa DATE 9/2/0

FORM 111-01086A (07/0

# Cable Classification

| Feeder cable | Branch Cable |
| --- | --- |
| 350 Al | # 4 Cu |
| 4/0 Cu | # 2 Cu |
| 500 Cu | # 2 Al |
| 750 Al | 2/0 Al |
| 750 compact Al | |
| 1000 Al | |

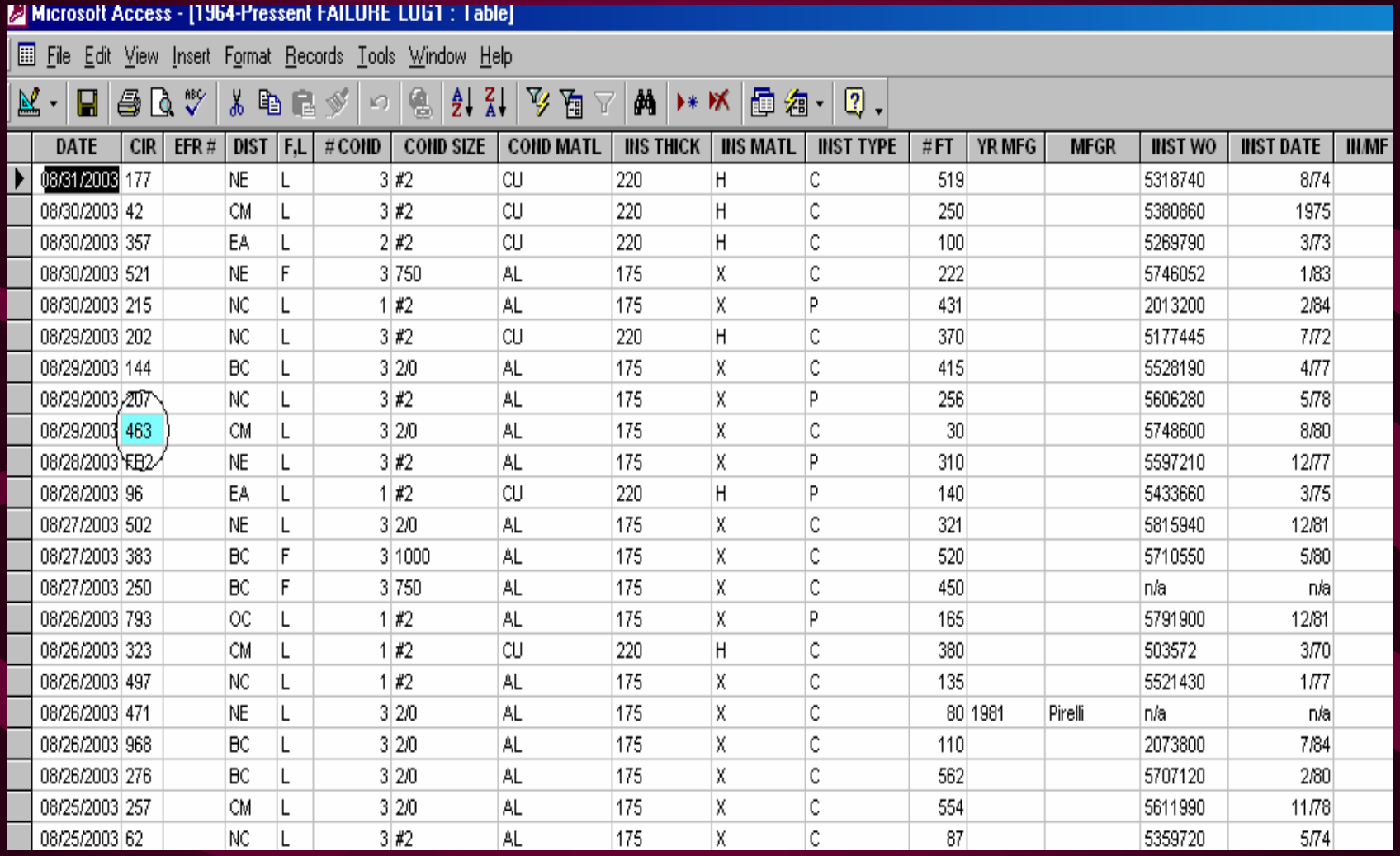
# Cable Failure Database

Microsoft Access - [1964-Present FAILURE BY CIRCUIT # : Select Query]

File Edit View Insert Format Records Tools Window Help

| DATE | CIR | EFR # | DIST | F,L | # C( | COND S | COND | INS THI | INS N | INST | # FT | YR MF | MFGR | INST WO | INST D | IN/MF Y | OUTAGE ID |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 07/18/1997 | 463 | | CM | L | 3 | 2/0 | AL | 175 | X | C | 380 | | | 2271590 | 1/78 | | |
| 09/29/2000 | 463 | 147672 | CM | L | 3 | 2/0 | AL | 175 | H | C | 475 | 1974 | ROME | 5415990 | 12/76 | | 000929E7802 |
| 10/09/2000 | 463 | | CM | F | 0 | | | | | | 0 | | | | | | 001010E7601 |
| 05/01/2001 | 463 | 152105 | CM | L | 3 | 2/0 | AL | 175 | H | C | 360 | 1974 | | | | | 010501E7801 |
| 08/29/2003 | 463 | | CM | L | 3 | 2/0 | AL | 175 | X | C | 30 | | | 5748600 | 8/80 | | 030829E7101 |
| | 0 | | | | 0 | | | | | | 0 | | | | | | |

# Cable Failure Database


Microsoft Access - [1964-Present FAILURE LOGT : Table]

File Edit View Insert Format Records Tools Window Help

| DATE | CIR | EFR # | DIST | F,L | # COND | COND SIZE | COND MATL | INS THICK | INS MATL | INST TYPE | #FT | YR MFG | MFGR | INST WO | INST DATE | IN/MF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08/31/2003 | 177 | | NE | L | 3 | #2 | CU | 220 | H | C | 519 | | | 5318740 | 8/74 | |
| 08/30/2003 | 42 | | CM | L | 3 | #2 | CU | 220 | H | C | 250 | | | 5380860 | 1975 | |
| 08/30/2003 | 357 | | EA | L | 2 | #2 | CU | 220 | H | C | 100 | | | 5269790 | 3/73 | |
| 08/30/2003 | 521 | | NE | F | 3 | 750 | AL | 175 | X | C | 222 | | | 5746052 | 1/83 | |
| 08/30/2003 | 215 | | NC | L | 1 | #2 | AL | 175 | X | P | 431 | | | 2013200 | 2/84 | |
| 08/29/2003 | 202 | | NC | L | 3 | #2 | CU | 220 | H | C | 370 | | | 5177445 | 7/72 | |
| 08/29/2003 | 144 | | BC | L | 3 | 2/0 | AL | 175 | X | C | 415 | | | 5528190 | 4/77 | |
| 08/29/2003 | 207 | | NC | L | 3 | #2 | AL | 175 | X | P | 256 | | | 5606280 | 5/78 | |
| 08/29/2003 | 463 | | CM | L | 3 | 2/0 | AL | 175 | X | C | 30 | | | 5748600 | 8/80 | |
| 08/28/2003 | FB2 | | NE | L | 3 | #2 | AL | 175 | X | P | 310 | | | 5597210 | 12/77 | |
| 08/28/2003 | 96 | | EA | L | 1 | #2 | CU | 220 | H | P | 140 | | | 5433660 | 3/75 | |
| 08/27/2003 | 502 | | NE | L | 3 | 2/0 | AL | 175 | X | C | 321 | | | 5815940 | 12/81 | |
| 08/27/2003 | 383 | | BC | F | 3 | 1000 | AL | 175 | X | C | 520 | | | 5710550 | 5/80 | |
| 08/27/2003 | 250 | | BC | F | 3 | 750 | AL | 175 | X | C | 450 | | | n/a | n/a | |
| 08/26/2003 | 793 | | OC | L | 1 | #2 | AL | 175 | X | P | 165 | | | 5791900 | 12/81 | |
| 08/26/2003 | 323 | | CM | L | 1 | #2 | CU | 220 | H | C | 380 | | | 503572 | 3/70 | |
| 08/26/2003 | 497 | | NC | L | 1 | #2 | AL | 175 | X | C | 135 | | | 5521430 | 1/77 | |
| 08/26/2003 | 471 | | NE | L | 3 | 2/0 | AL | 175 | X | C | 80 | 1981 | Pirelli | n/a | n/a | |
| 08/26/2003 | 968 | | BC | L | 3 | 2/0 | AL | 175 | X | C | 110 | | | 2073800 | 7/84 | |
| 08/26/2003 | 276 | | BC | L | 3 | 2/0 | AL | 175 | X | C | 562 | | | 5707120 | 2/80 | |
| 08/25/2003 | 257 | | CM | L | 3 | 2/0 | AL | 175 | X | C | 554 | | | 5611990 | 11/78 | |
| 08/25/2003 | 62 | | NC | L | 3 | #2 | AL | 175 | X | C | 87 | | | 5359720 | 5/74 | |

# Monthly Cable Failure Report

*September 27, 2004*

MONTHLY CABLE FAILURE REPORT (12KV)
August 2004 YTD

MONTHLY CABLE FAILURE REPORT (12KV)

AUGUST 2004 YTD

| TYPE OF INSULATION | | NUMBER OF FAILURES | | | |
|---|---|---|---|---|---|
| | | 2004 | | 2003 | |
| | | MONTH | YTD | MONTH | YTD |
| XLPE | FEEDER | 3 | 19 | 8 | 26 |
| | LATERAL | 44 | 195 | 43 | 157 |
| | **TOTAL** | **47** | **214** | **51** | **183** |
| HMWPE | FEEDER | 0 | 5 | 1 | 4 |
| | LATERAL | 15 | 116 | 15 | 97 |
| | **TOTAL** | **15** | **121** | **16** | **101** |
| XLPE | FEEDER | 0 | 6 | 3 | 8 |
| PEJ | LATERAL | 0 | 11 | 0 | 5 |
| | **TOTAL** | **0** | **17** | **3** | **13** |
| ALL | FEEDER | 3 | 30 | 12 | 38 |
| CABLES | LATERAL | 59 | 322 | 58 | 259 |
| | **TOTAL** | **62** | **352** | **70** | **297** |

% Increase/Decrease from previous year

| | | |
|---|---|---|
| TOTAL CABLE FAILURES | | 19% |
| XLPE | FAILURES | 17% |
| HMWPE | FAILURES | 20% |
| XLPE | FEEDER FAILURES | -27% |
| HMWPE | FEEDER FAILURES | 25% |
| XLPE-PEJ | LATERAL FAILURES | 120% |
| XLPE-PEJ | FEEDER FAILURES | -25% |
| TOTAL | FEEDER FAILURES | -21% |
| TOTAL | LATERAL FAILURES | 24% |

| XLPE-PEJ FAILURES: | |
|---|---|
| 2004 YTD | **17** |
| 2003 YTD | **13** |

2 REPORTED DIG-INS IN AUGUST 2004 – CIRCUITS 402, 985

4 FEEDER FAILURES:

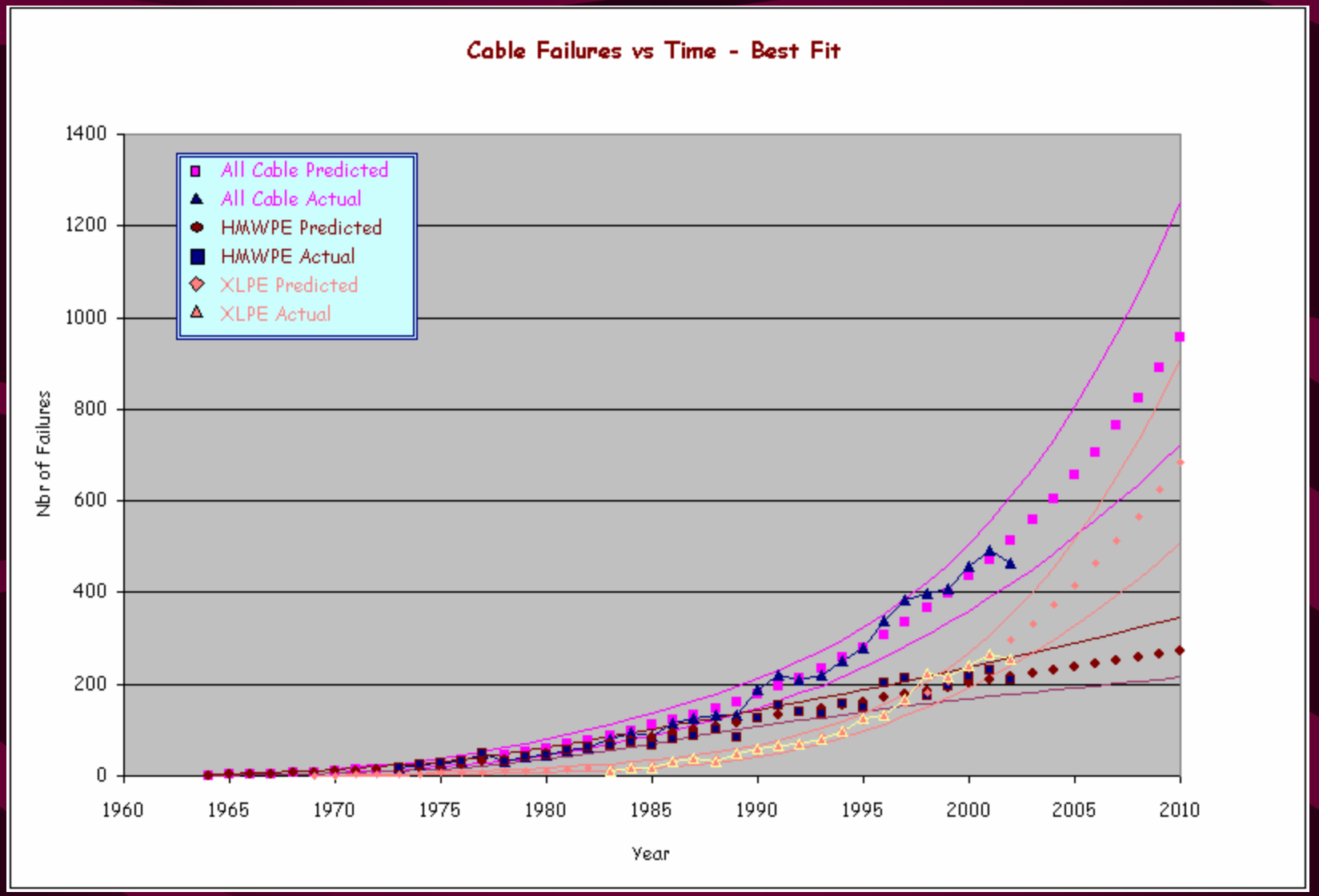
| DATE | SUBSTATION/CKT/DST | CABLE TYPE | MG/DATE | W/O # | W/O DATE |
|---|---|---|---|---|---|
| 8/15/04 | MIRAMAR/761/BC | 750 AL XLPE | | 5384660 | 8/74 |
| 8/29/04 | ROSE CANYON/65/BC | 750 AL XLPE | | 509545 | 1/71 |
| 8/31/04 | MELROSE/507/NC | 750 AL XLPE | | 5694310 | 4/80 |

NO JACKETED LATERAL CABLE FAILURES IN AUGUST 2004

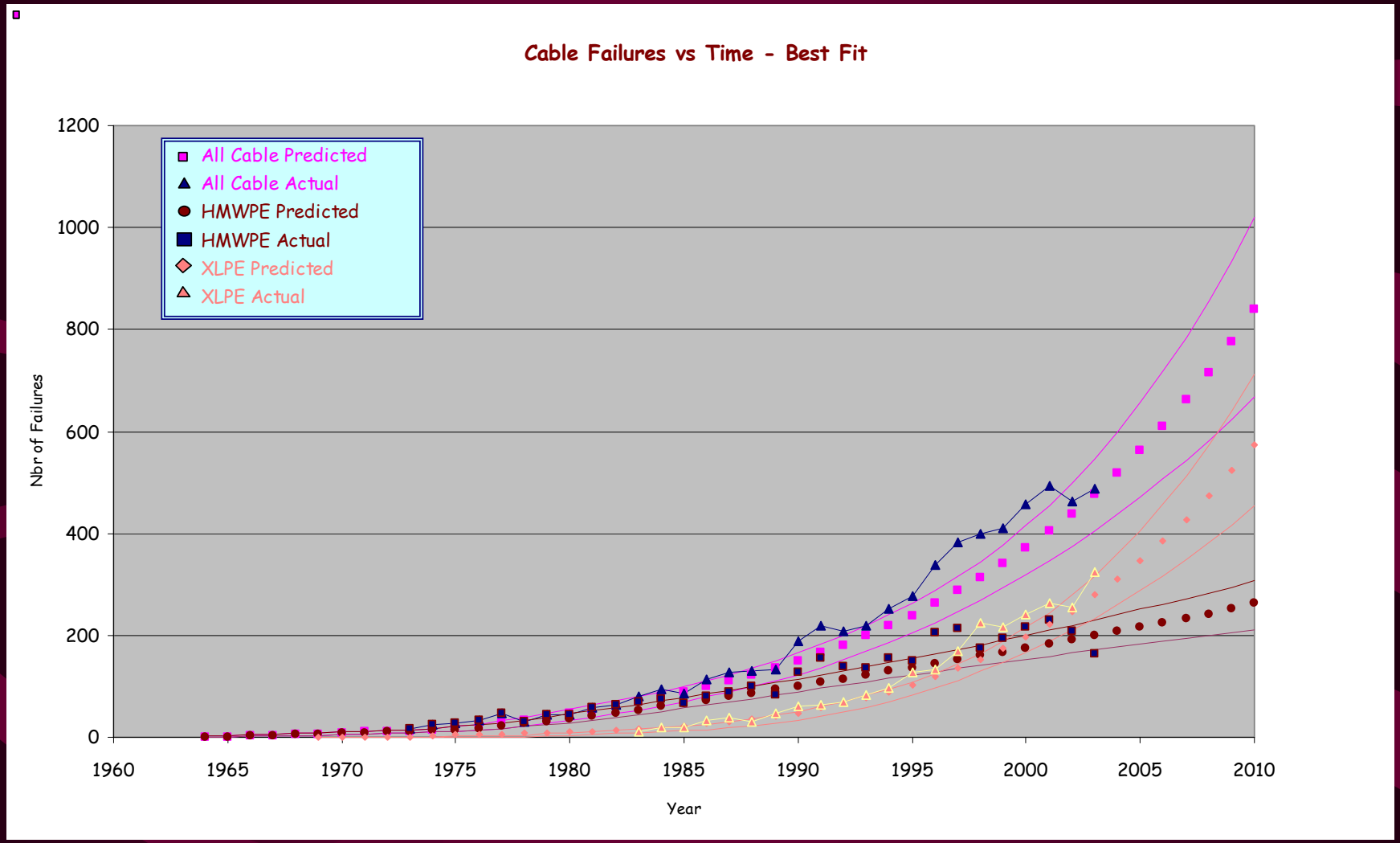
# Determining Cable Failure Rates

- Need to know amount and type of cable (HMWPE, XLPE, TRXLPE, EPR, jacketed) installed in a certain year.
- Need to know the amount and vintage of the cable that failed.
- Need to convince your operating people of the importance of collecting cable failure information.
- Need to develop a simple method of collecting cable failure data.
- Need to be able to account for any proactive cable replacements.
- Maintain an outage database (Access database).
- Utilize statistical software ( i.e. Weibull ++) to determine best fit for your data.
- Projections should include data confidence bounds ( i.e. 90%).

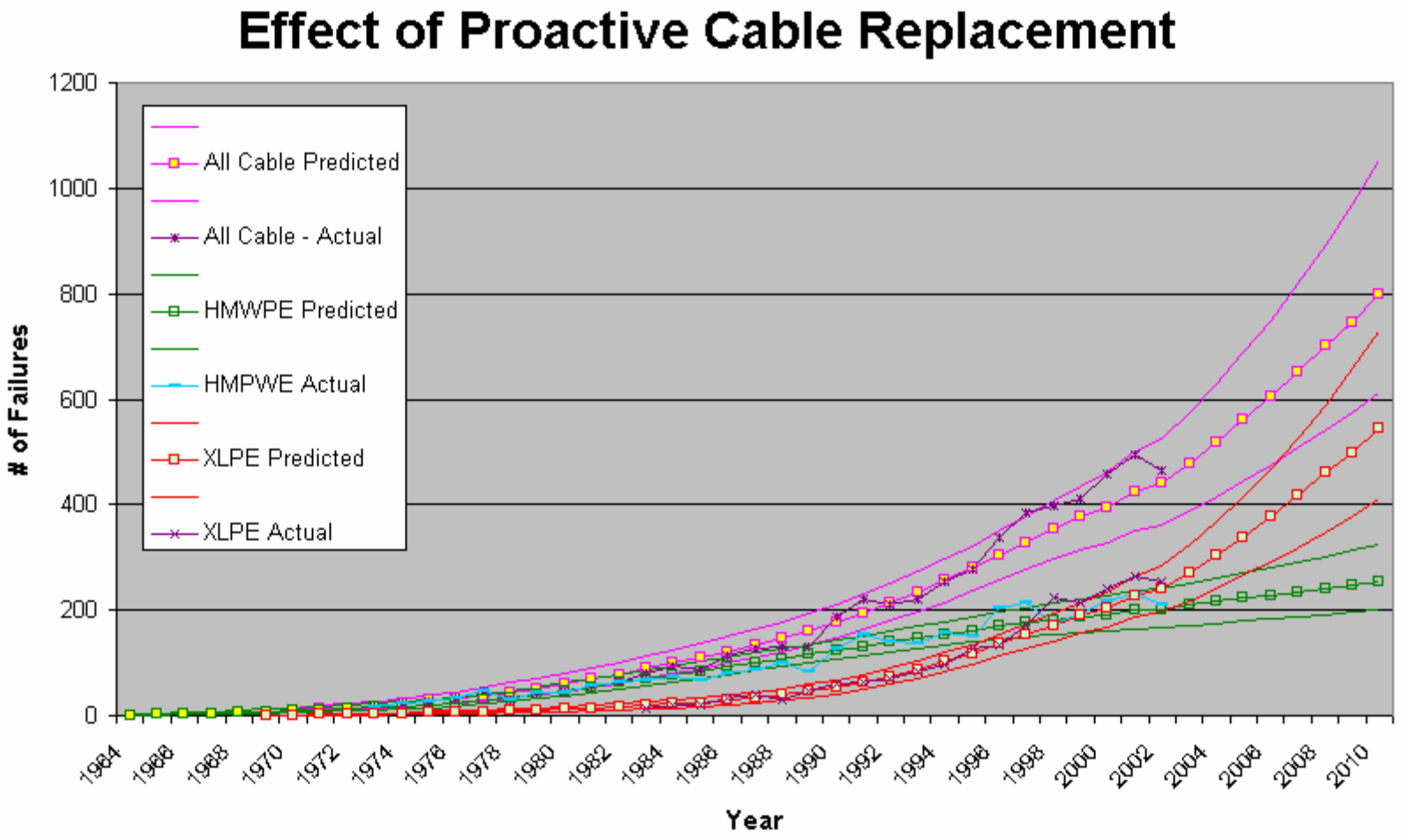
# Cable Failure Projections (2003)



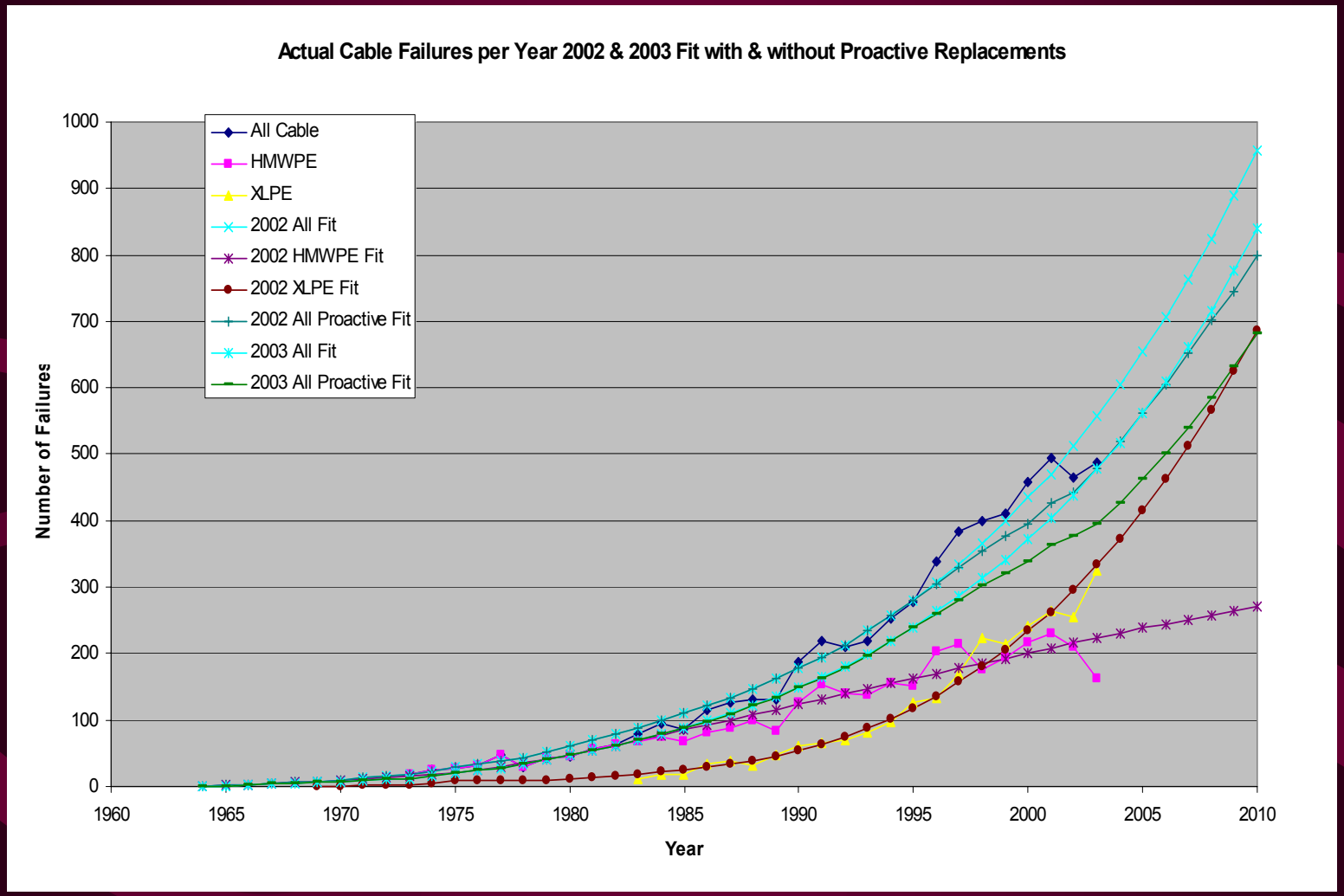
# Cable Failure Projections (2004)



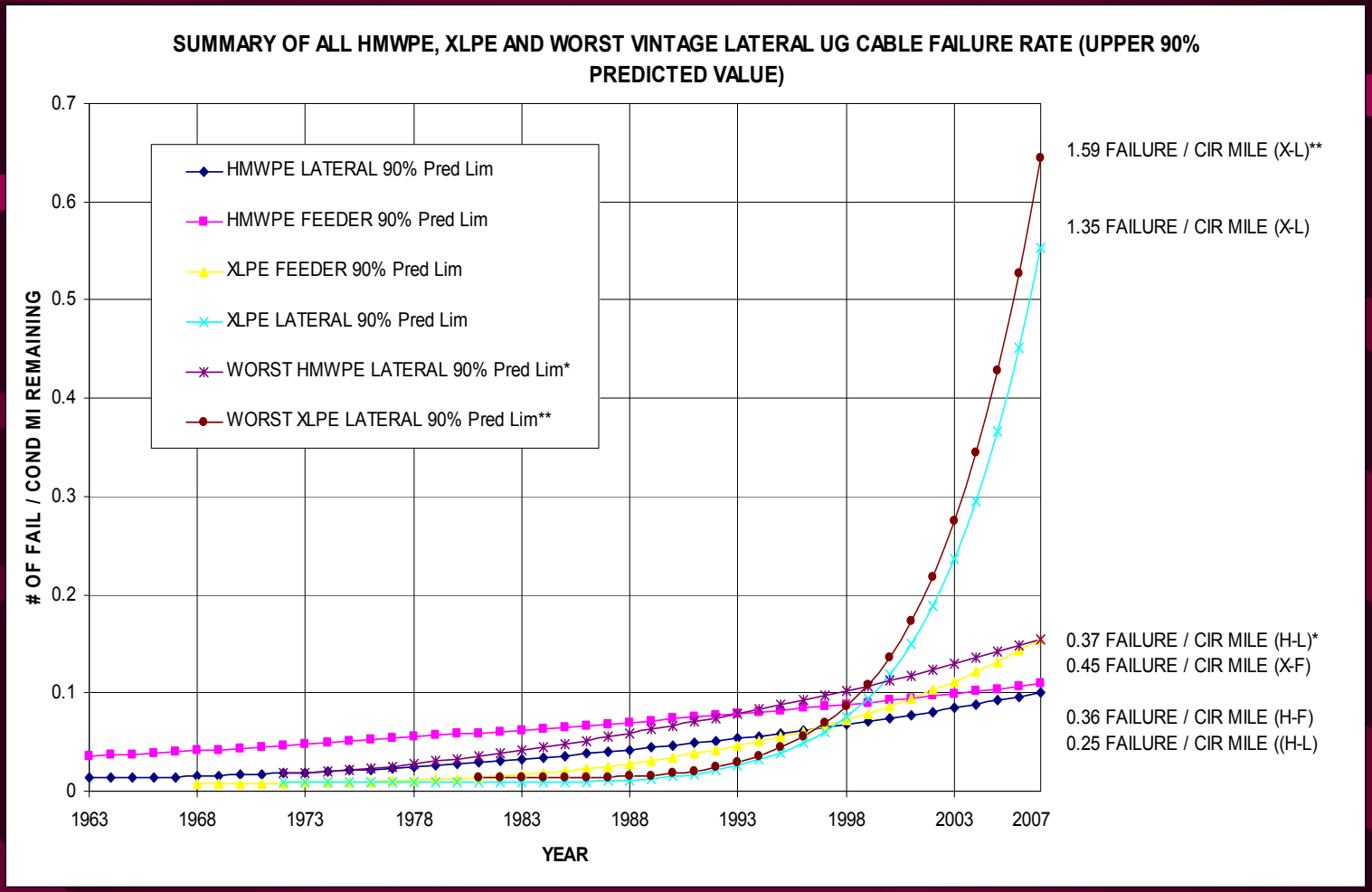
# Cable Failure Projections (2003)



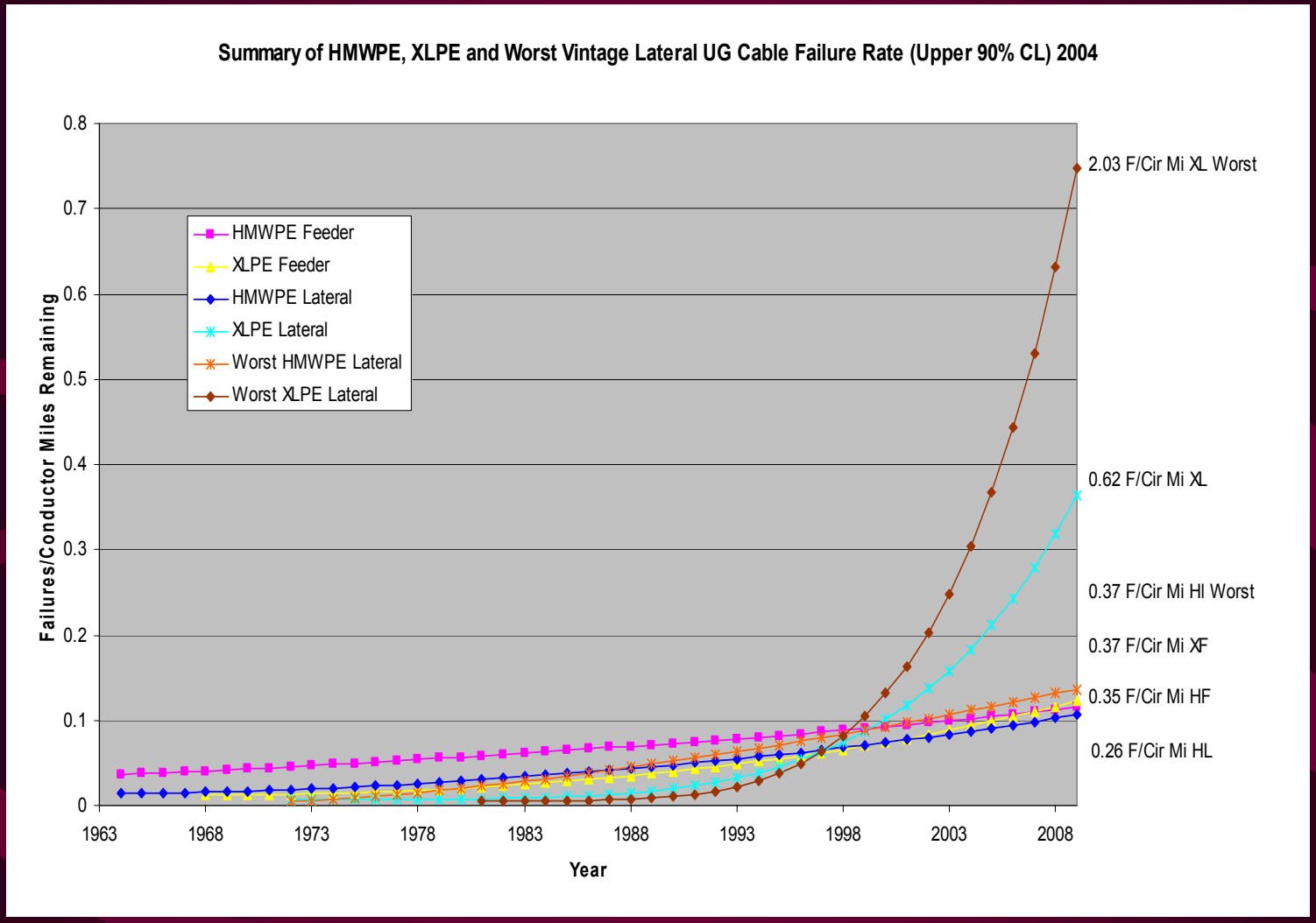
# Cable Failure Projections (2004)



# Cable Failure Rates (2003)



# Cable Failure Rates (2004)



# Branch Circuit Reliability Model

| Failure rates by conductor mile in outages/year | | |
|---|---|---|
| Cable Type | All vintages | Bad vintages |
| XLPE-PEJ | 0.00073 | N/A |
| XLPE | 0.554 | 0.643 |
| HMWPE | 0.102 | 0.155 |

| Options | CAIDI Gain | Units |
|---|---|---|
| Sub-Fusing | N/A | N/A |
| Looping | 48 | minutes |
| Fault Indicator Addition | 20 | minutes |
| Cable Change Out | N/A | N/A |

| Other Constants | |
|---|---|
| System Average CAIDI (min) | 217 |
| System Customers | 1,300,000 |
| LACC Factor | 0.1211 |

| Annualized Cost Savings per circuit foot: | | |
|---|---|---|
| Cable Type | vintages | Bad vintages |
| XLPE | $ 3.40 | $ 3.96 |
| HMWPE | $ 0.63 | $ 0.95 |

| | | Phase |
|---|---|---|
| Cable Replacement Cost (per foot) | $ 6.50 | Single phase |
| | $ 9.30 | 2-phase |
| | $ 12.00 | 3-phase |

**DO NOT CHANGE ANY DATA ABOVE THIS GRAY LINE.**

| Cable Change Out | | |
|---|---|---|
| Item | Phase | Quantity |
| Main Branch Total Footag | Single | - |
| | 2-phase | - |
| | 3-phase | - |
| Replaced Branch Footage | Single | - |
| | 2-phase | - |
| | 3-phase | - |
| Failure Rate | | 0.643 |
| Annualized Cost Savings Rate | | $ 3.96 |
| Branch Total Customers | | 272 |
| Cable Replacement Cost | | $ - |
| Other Costs | | $ - |
| Project Cost | | $ - |
| Gain In Number of Failures | | 0.00000 |
| SAIDI Gain | | - |
| SAIFI Gain | | - |
| PBR Gain | | $ - |
| Annualized Cost Savings | | $ - |
| RTR | | 0.000 |

| Sub-Fusing | | |
|---|---|---|
| Item | Phase | Quantity |
| Main Branch Total Footage | Single | - |
| | 2-phase | - |
| | 3-phase | - |
| Sub-fused Branch Footage | Single | - |
| | 2-phase | |
| | 3-phase | - |
| Failure Rate | | 0.643 |
| Branch Total Customers | | 272 |
| Sub-fused Branch Customers | | 58 |
| Project Cost | | $ 25,000 |
| SAIDI Gain | | - |
| SAIFI Gain | | - |
| PBR Gain | | $ - |
| RTR | | 0.000 |

| Looping | | |
|---|---|---|
| Item | Phase | Quantity |
| Main Branch Total Footag | Single | - |
| | 2-phase | - |
| | 3-phase | - |
| Failure Rate | | 0.643 |
| Branch Total Customers | | 272 |
| Project Cost | | $ 25,000 |
| SAIDI Gain | | - |
| PBR Gain | | $ - |
| RTR | | 0.000 |

| Fault Indicator Addition | | |
|---|---|---|
| Item | Phase | Quantity |
| Main branch total footage | Single | - |
| | 2-phase | - |
| | 3-phase | - |
| Failure Rate | | 0.643 |
| Branch Total Customers | | 272 |
| Project Cost | | $ 8,000 |
| SAIDI Gain | | - |
| PBR Gain | | $ - |
| RTR | | 0.000 |

| 436 | d2721874412 |
|---|---|

**INPUT IS ONLY REQUIRED IN THE TAN CELLS.**

# Feeder Circuit Reliability Model