

# CMP COMMON & UNCOMMON FAILURE MODES & REHABILITATION METHODS

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Harris & Associates



**NATIONAL PLANT SERVICES**  
*A Carylon Company*



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# TABLE OF CONTENTS

- Introductions
- CMP Characteristics
- Types of Failure in CMP Pipe
- Rehabilitation Methods
- Inspection Methods
- Project Examples



# INTRODUCTIONS

## MEET THE TEAM

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# CMP CHARACTERISTICS



# CORRUGATED METAL PIPE (CMP)

## CMP CHARACTERISTICS

Characteristic	Typical Options
<b>Sizing</b>	6-inch to 144-inch Diameter
<b>Pipe Shape</b>	Circular vs Arched
<b>Corrugation Pattern</b>	Circumferential (Annular) vs Helical (Spiral)
<b>Corrugation Dimensions</b>	Classified by Corrugation Depth & Spacing
<b>Steel Thickness</b>	18 – 8 Gage
<b>Coatings</b>	Galvanized Steel Aluminum Type 2 Polymer Coatings Asphalt



# THE ENEMIES OF CMP

## DESIGN CHALLENGES



### Corrosion & Abrasion – the enemies of CMP

- pH
- Environmental conditions
- Pipe coating
- Flow characteristics
- Backfill material
- Access

# TYPES OF FAILURE IN CMP



# TYPES OF FAILURE IN CMP

## DETERIORATED INVERTS (ABRASION & WEAR)

- Sediment and debris erodes the CMP invert
- Whether the CMP was coated or not, the CMP becomes susceptible to corrosion often resulting in the invert rusting out.
- **Prevention methods:**
  - Proper selection of CMP coating
  - Consideration of flow characteristics and quantities
  - Lining the CMP



# TYPES OF FAILURE IN CMP

## OPEN/OFFSET JOINTS

- Joints between sticks of CMP are weak points
- Ovality in the pipe due to buckling can result in offset joints
- Open joints compromise the structural integrity of the pipe
- **Prevention methods:**
  - High quality gaskets
  - Proper installation of CMP connecting bands
  - Proper compaction of backfill material
  - Installation of expansion joints
  - Regular inspections to monitor integrity of invert



# TYPES OF FAILURE IN CMP

## VOIDS – BURIED PIPES RELY ON GOOD SOIL/PIPE CONTACT

- Separated/offset joints or holes in the CMP will allow water to flow outside of the pipe.
- The flow of water will scour the area behind the pipe, resulting in soil loss and a void.
- The pipe will begin to change shape

### Prevention methods

- Correct selection of pipe coating, gage, etc. for the flow condition
- Adequate overlap or sealing at the pipe joints



# TYPES OF FAILURE IN CMP

## COLLAPSE

- All of the other modes of failure can eventually lead to:
  - Complete failure and collapse of the CMP pipe
  - Sinkholes
  - Damage to nearby structures
  - Damage to adjacent drainage structures



# REHABILITATION METHODS



# REHABILITATION METHODS FOR CMP

CENTRIFUGALLY CAST CONCRETE PIPE (SPRAY MORTAR)

SLIPLINING

CURED IN PLACE PIPE (CIPP)

SPIRAL WOUND LINING



# **INSPECTION METHODS**



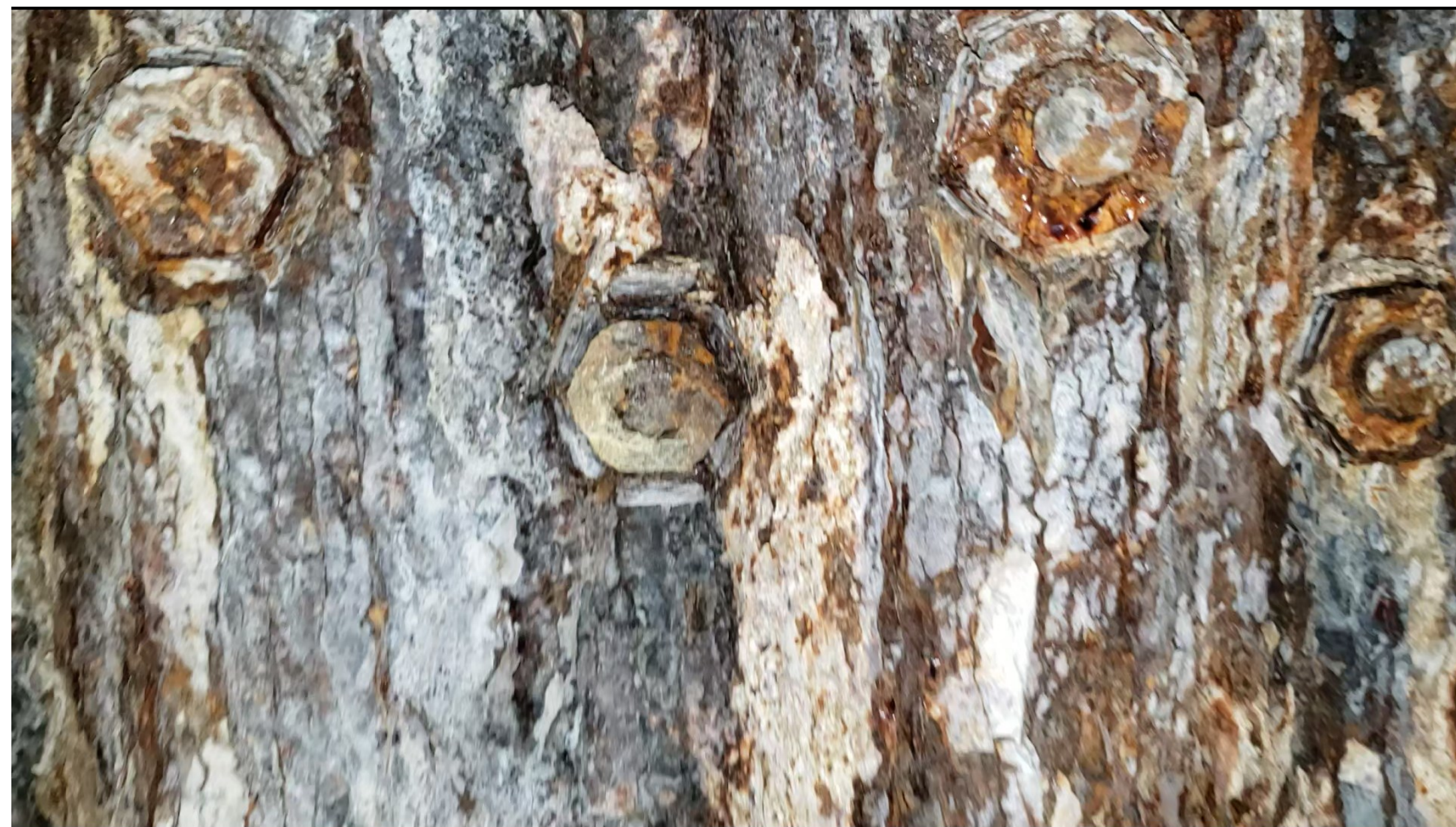
# INSPECTION METHODS

- Confined space entry
- Closed Circuit Television (CCTV)
- Lidar/Laser Inspection



# CONFINED SPACE ENTRY

- Able to measure the pipe, bolt sizes, and defects
- Can touch the pipe to determine integrity of the metal
- Can measure voids behind the pipe walls
- Able to view from multiple angles



# SOUNDING FOR VOIDS

- GPR or PPR can be used to find voids but is not always reliable.
- Good old-fashioned soundings using a hammer work great



# CCTV AND LIDAR INSPECTIONS



HD CCTV

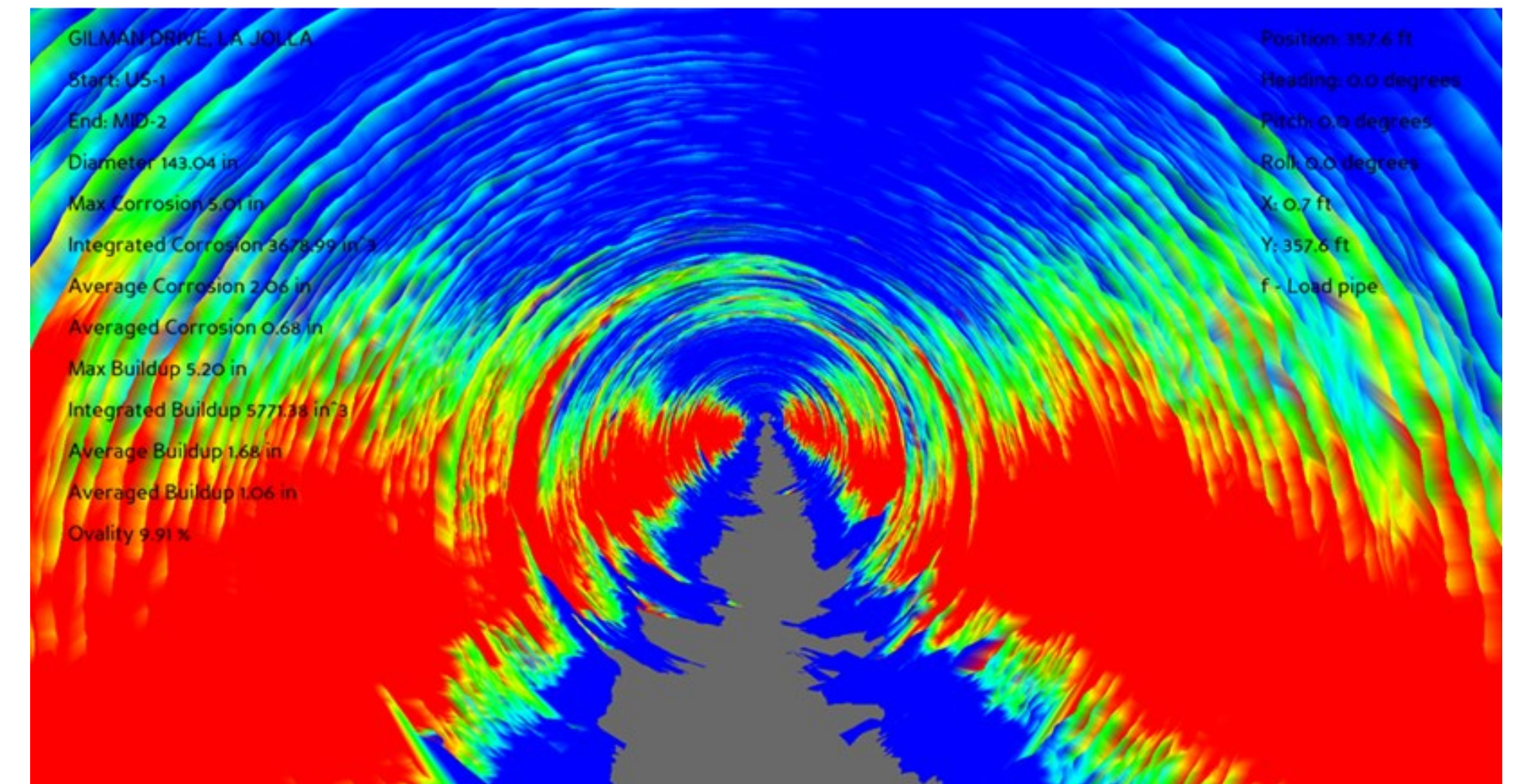
# CCTV AND LIDAR IN CMP

- PACP-coded CCTV provides visual identification with location.
- LiDar/Laser scanning can measure the deformation that has occurred, allowing us to prioritize rehabilitation.

Start (ft)	End (ft)	Ovality (%)
3	11	<10
12	192	10-20
193	206	20-30
207	250	30-40
257	268	20-30
269	410	10-20
411	447	<10
448	1685	10-20
1686	1796	20-30
1797	1883	10-20
1884	1931	<10
1932	1966	10-20
1967	2039	20-30
2040	2060	30-35
2061	END	20-30
	<b>AVERAGE</b>	<b>16.19</b>
	<b>MAXIMUM</b>	<b>38.26</b>

**USE TO SEQUENCE AND SCHEDULE REHAB!**

CMP with over a 20% change in ovality is at risk for buckling/collapse.



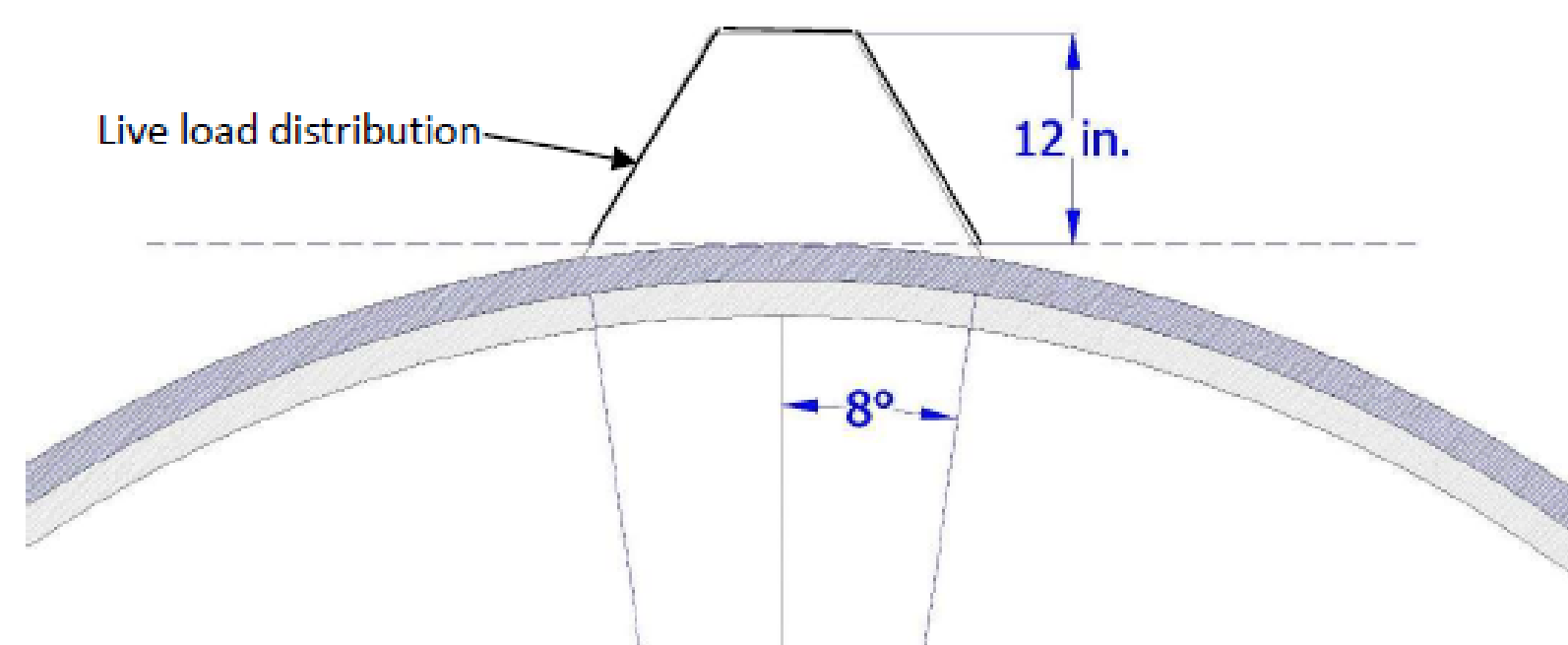
The color ramp graduates automatically depending on the range of measurements outside the reference circle/as-built (or the amount of concrete corrosion in RCP Pipes).

- Green indicates as-built pipe size/condition, or pipe in better condition than the rest
- Yellow indicates minor deviation from as-built
- Orange indicates more deviation from as-built
- Red indicates more major deviation from as-built
- Blue indicates buildup, or where pipe is inside as-built measurements.



# ARCH PIPE DEFORMATION

In an arch pipe, most of the load is concentrated at the top of the pipe.



An existing wall thickness of 2.0-inches had been applied to get the needed 0.5-in. cover over the projecting assembly bolts (note that this installation occurred before the design method was developed)...

The spread of the live load at the top of the pipe produces a semi-vertex angle of only  $8^\circ$  (0.140 rad).

$\lambda = \frac{0.140^2 \times 77}{2.0} = 0.75$ ; which indicates that the load response mode will be the classic beam in bending behavior (i.e. behaves like a beam under a uniform line load,  $q$ , to the classic  $Mc/I$  form of the bending stress at the arch crown) and the limit state solutions will be those for a small arch rise parameter.



**BULGE WAS 14.25 inches – THIS WAS CUT OUT AND PATCHED WITH A NEW PIECE OF CMP**

# PROJECT EXAMPLES



***SCHOENBAR CULVERT, SHOENBAR CREEK,  
KETCHIKAN, ALASKA, JUNE 2024***



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# 1. PUA NANI 84-INCH CMP REHAB, LIHUE, KAUAI

METHOD: CCCP USING PERMACAST PL-8000



## 2. SCHOENBAR CULVERT (7 FT X 12 FT), KETCHIKAN, AK

METHOD: CCCP USING PERMACAST PL-8000



# 3. 132-INCH CMP REPLACEMENT, SOUTHERN CA

## METHOD: CCCP USING VORTEX GEOPOLYMER



- 132-inch diameter CMP pipe had failed
- Ground settlement, cave in, and sinkhole
- CMP pipe had collapsed entirely
- Previously had been repaired with concrete invert lining
- Pipe had corroded along the edge of the invert lining
- Close proximity to apartment buildings
  - Required daily settlement surveys to monitor building foundations

# 3. 132-INCH CMP REPLACEMENT, SOUTHERN CA

## CCTV/LIDAR INSPECTION



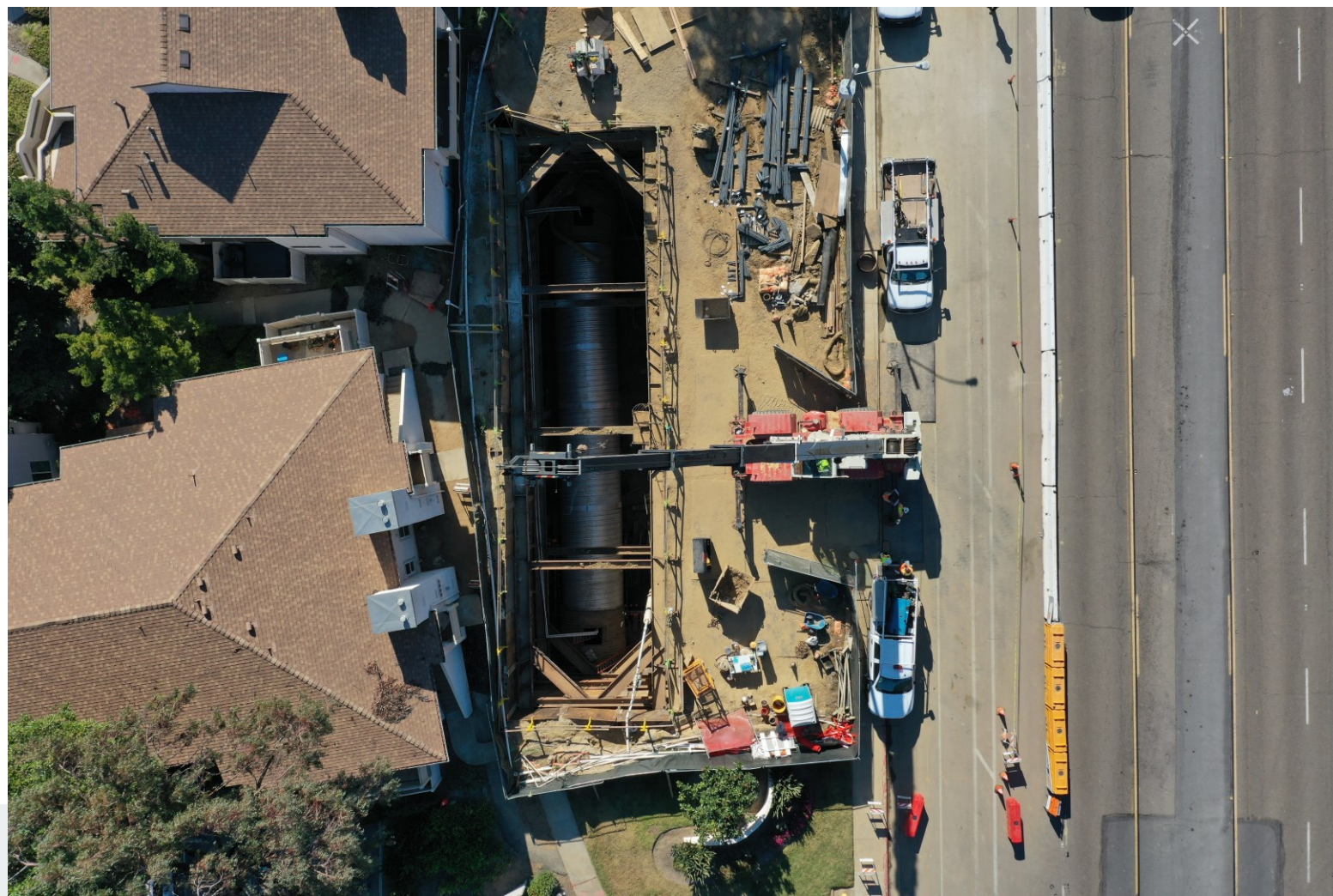
**132" to 180" Storm Culvert  
Southern California**

Start (ft)	End (ft)	Ovality (%)
3	11	<10
12	192	10-20
193	206	20-30
207	250	30-40
257	268	20-30
269	410	10-20
411	447	<10
448	1685	10-20
1686	1796	20-30
1797	1883	10-20
1884	1931	<10
1932	1966	10-20
1967	2039	20-30
2040	2060	30-35
2061	END	20-30
<b>AVERAGE</b>		<b>16.19</b>
<b>MAXIMUM</b>		<b>38.26</b>

# 3. 132-INCH CMP REPLACEMENT, SOUTHERN CA

## DESIGN APPROACH

- 40-foot-deep excavation and extensive shoring
- Replacement of the 132-inch diameter CMP
- 2 large storm drain clean-outs with multiple access manways, safety ladders, observation platforms, handrailing
- Application of a geopolymer lining to protect the new CMP



# 4. VALLEY VIEW 88-INCH CMP REHAB, RICHMOND, CA

METHOD: CCCP USING GEOTREE SOLUTIONS FIBER-REINFORCED GEOPOLYMER

- 88-inch CMP pipe was beginning to fail
- Large void under AC discovered by PG&E
- Emergency repair filled void with CDF
- Up to 7% Ovality



# 4. VALLEY VIEW 88-INCH CMP REHAB, RICHMOND, CA

METHOD: CCCP USING GEOTREE SOLUTIONS FIBER-REINFORCED GEOPOLYMER



- Site constraints
  - Continuous flow
  - Length only 50 feet.
  - 18-foot depth to invert or 11 feet of cover
  - Limited access
  - Partially submerged outfall at creek



# 4. VALLEY VIEW 88-INCH CMP REHAB, RICHMOND, CA

METHOD: CCCP USING GEOTREE SOLUTIONS FIBER-REINFORCED  
GEOPOLYMER

- Rehabilitation Method: Spray-On Fiber Reinforced Geopolymer
- Required 28-day Compressive Strength = 8,000 PSI



# 5. CITY OF EL CERRITO STORM DRAIN REHAB PROGRAM

## METHOD: SLIPLINING

- Problem
  - 1000 feet of 48-inch CMP
  - Invert had completely corroded
  - Some ovality was discovered
- Solution
  - Sliplining using 42-inch I.D. Vylon Pipe (44.48-inch avg O.D.)
  - 16-foot segments of pipe were slipped in using existing drainage flows and supplemental water flows to assist in placement.
  - Annular space was grouted with a cellular concrete.



# 6. 36-INCH STORM DRAIN REPAIR, ALBANY, CA

## METHOD: WINCHED-IN CIPP LINING



### Project Details

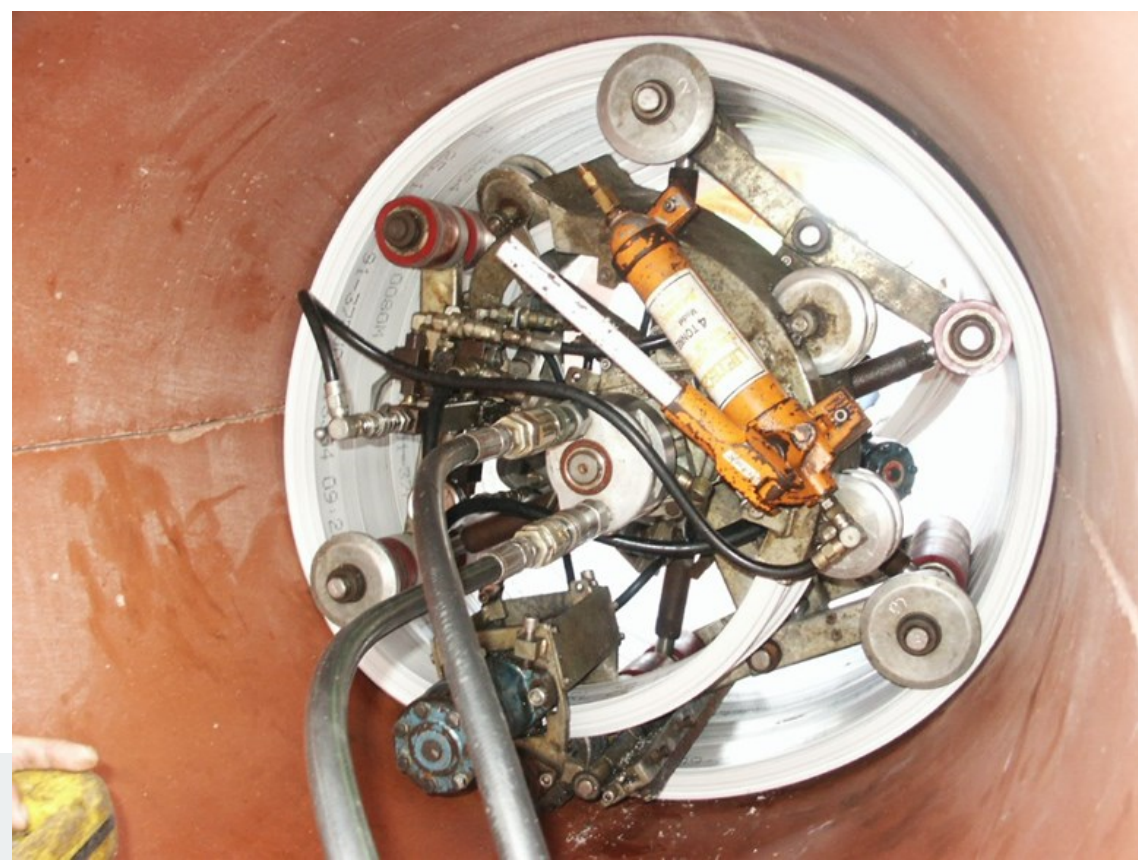
- 36-inch CMP was completely corroded
- Located in environmentally sensitive habitat
- Access was difficult and deep
- CIPP was the selected rehabilitation method
  - Steam cured
  - Winched-in installation

# 7. EARTHQUAKE DAMAGED PIPE REPAIR PROGRAM, SANTA MONICA, CA

## METHOD: SPIRAL WOUND LINING

### Project Details

- Northridge Earthquake in 1994 damaged sewer pipelines throughout the city
- City received \$78M from FEMA to perform repairs.
- Spiral Wound Pipe was used for a majority of the small diameter pipes < 48- inches





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# THANK YOU

QUESTIONS OR COMMENTS?



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# REHABILITATION METHODS FOR CMP

## CENTRIFUGALLY CAST CONCRETE PIPE (SPRAY MORTAR)

- 8,000 psi compressive strength.
- Install using existing manholes.
- Conforms to varying pipe shapes, including deflected pipe.
- Retains as much internal capacity as possible
- Great for limited access points, or if there are bends in the pipe.
- Pipe can stay in service – start and stop as needed

## SLIPLINING

- Smaller pipe is pulled or pushed through existing pipe
- Can result in reduced capacity depending on new vs existing roughness coefficient
- HDPE is often used as the new pipe material
- Possible to be done while pipe is in service (may need to limit quantity of flows)

## CURED IN PLACE PIPE (CIPP)

- Minimal reduction in diameter and capacity
- Invert or winch the liner in place
- Cured via hot water, steam, or UV
- Upfront costs for fabrication, equipment, mobilization, etc. – sometimes not cost complete on smaller runs of pipe
- Segmented liners can be used for quick point repairs

## SPIRAL WOUND LINING

- Strips of PVC are wound into the pipe shape to form a new pipe within the existing pipe
- Can be wound into a fixed diameter or can be expanded to the desired size
- Grooves on the PVC strips allow the strips to interlock and seal
- No chemicals required