



STEP UP
YOUR GAME



Monitoring of Real-Time Conditions with Remote Instrumentation for Slope Stability at Waste Disposal Facilities

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Landfill Slope Failures

- Potential for Environmental Releases
- Massive Financial Implications
- Loss of Human Life



Landfill Slope Failures



Traditional Slope Monitoring Methods

- Routine Visual Observation
- Slope Observation Checklists
- Crack Monitors
- Tiltmeters
- Survey Monitoring Points



Issues with Traditional Slope Monitoring Methods

- Visual observations are subjective.
- Personnel put in dangerous situations.
- Time delays with reducing survey data.
- Data is limited by frequency of surveys/visual observation.

Need for Better Monitoring Methods

- CEC secured a project to support coal combustion residual (CCR) excavation project in North Carolina in 2022.
 - Changing Federal Regulations
 - Several sites with recent slope failures and environmental releases led to rigorous safety program.
- Client requests for the installation of geotechnical monitoring instrumentation to support recommendations from stability analyses.



Remote Monitoring Instrumentation System

- CEC found an equipment vendor, Navstar Geomatics, in British Columbia
- Mobile Gateway
- Geotechnical Instrumentation
 - Vibrating Wire Piezometers
 - Shape Arrays
 - Global Navigation Satellite System (GNSS)
- GeoExplorer Data Reduction Software



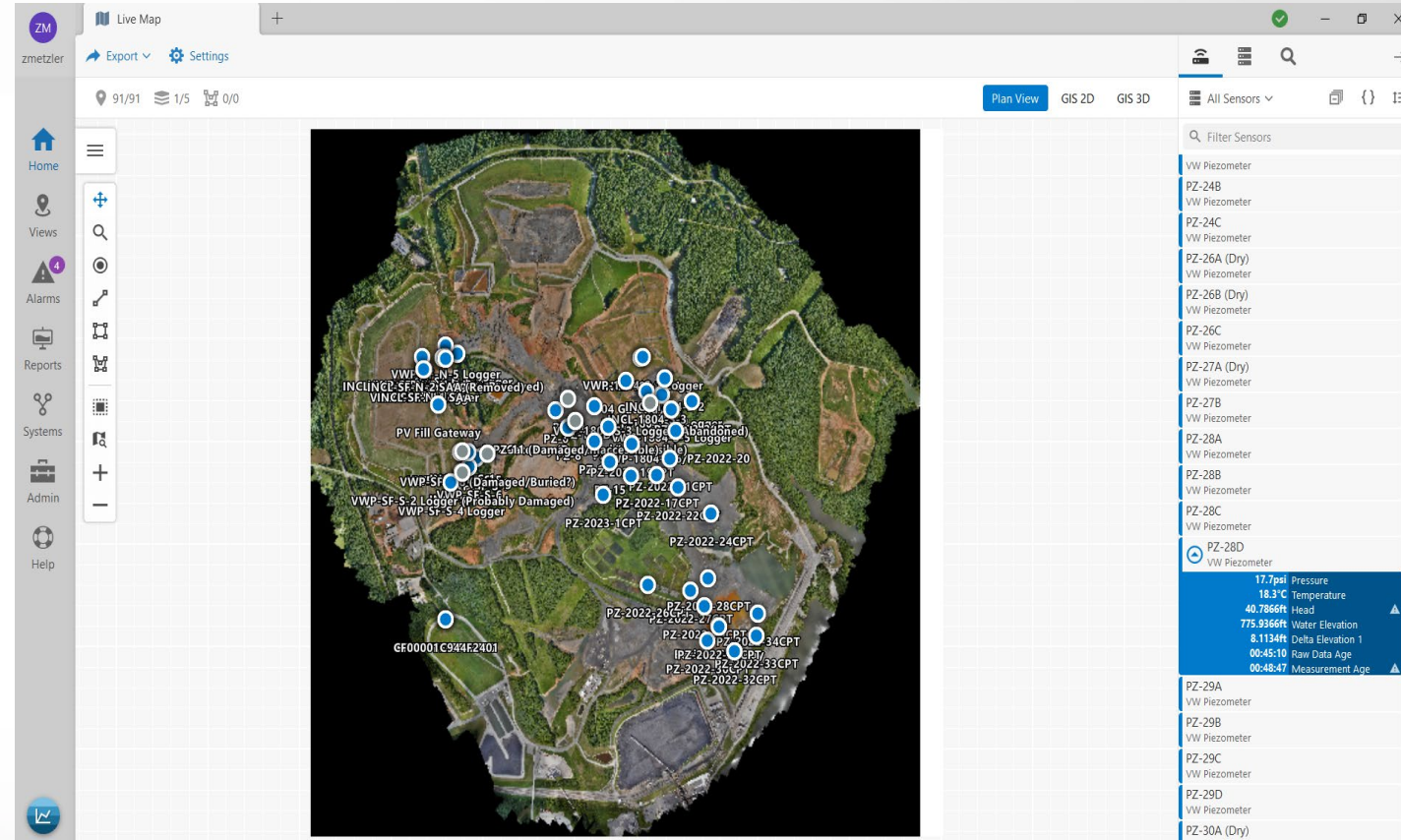
Mobile Gateway

- Main “hub” of transmission system
- Powered by 100W solar panel and marine battery
- Uses cellular connection
- Receives information from data loggers at user-specified interval
- Transmits data to cloud/GeoExplorer software at user-specified interval



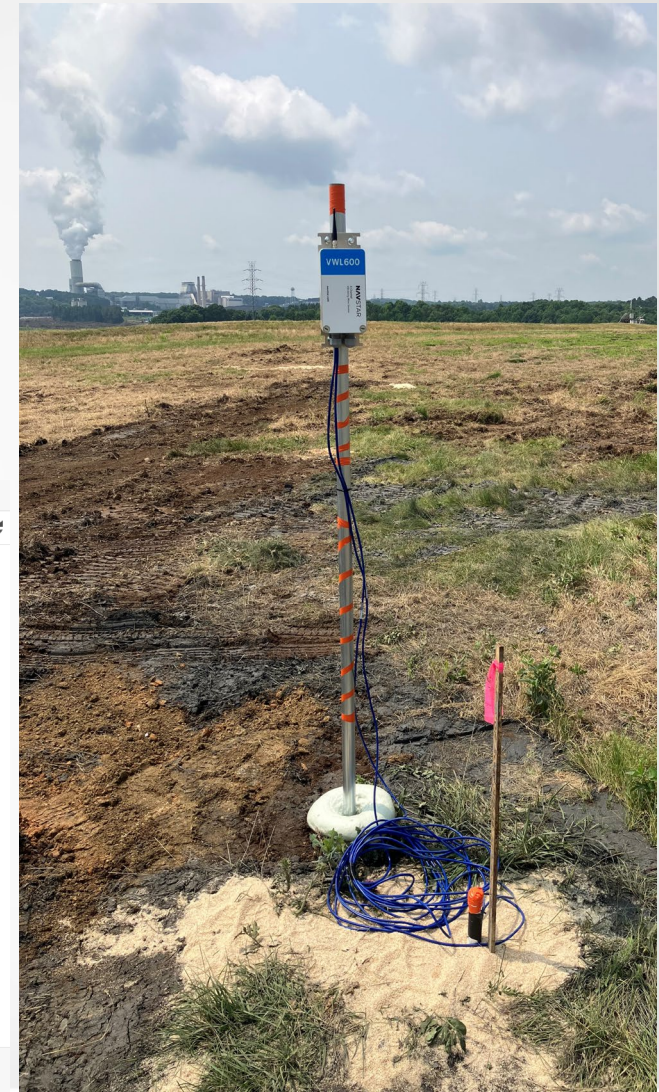
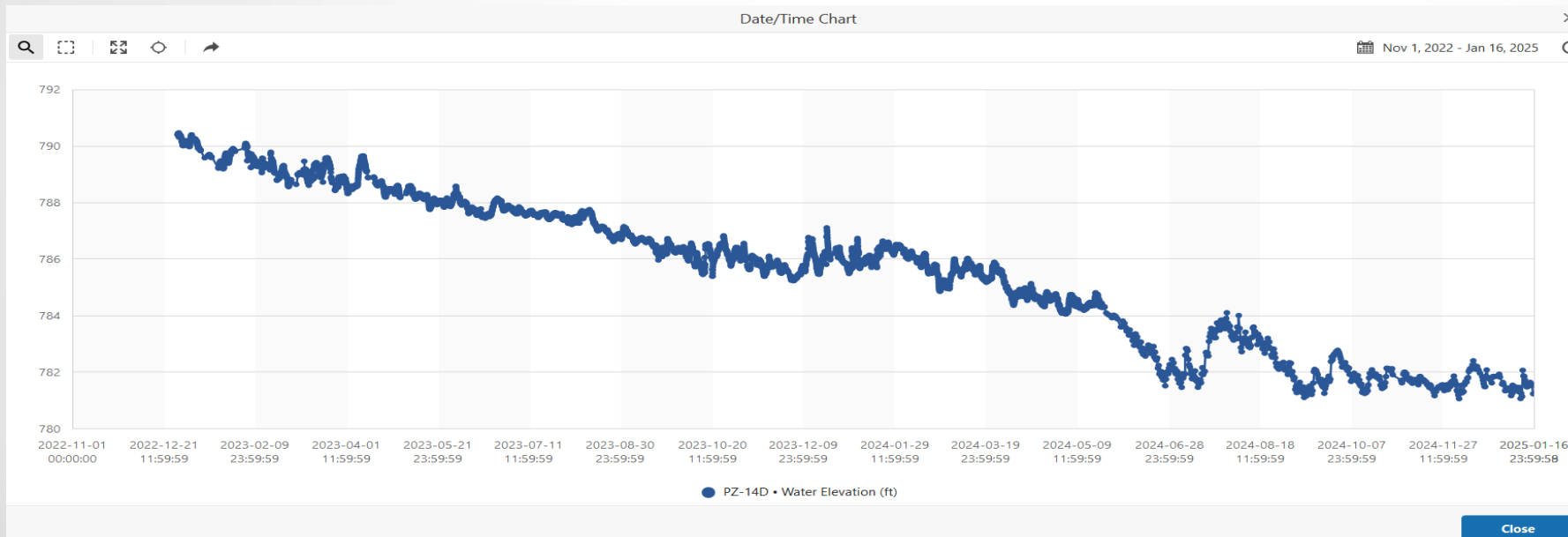
GeoExplorer Monitoring Software

- Automated Data Receiving
- Automated Data Processing
- Automated Alerts
- Automated Reporting



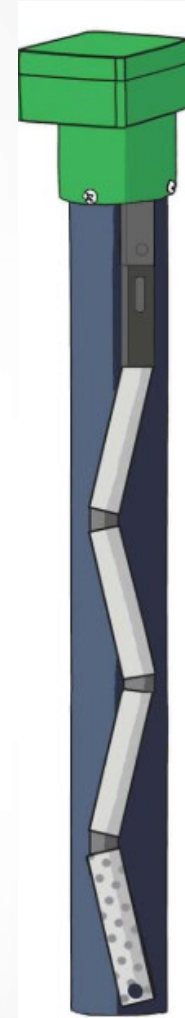
Vibrating Wire Piezometers

- Used to monitor subsurface pore pressures
- Pore pressures have significant impact on stability



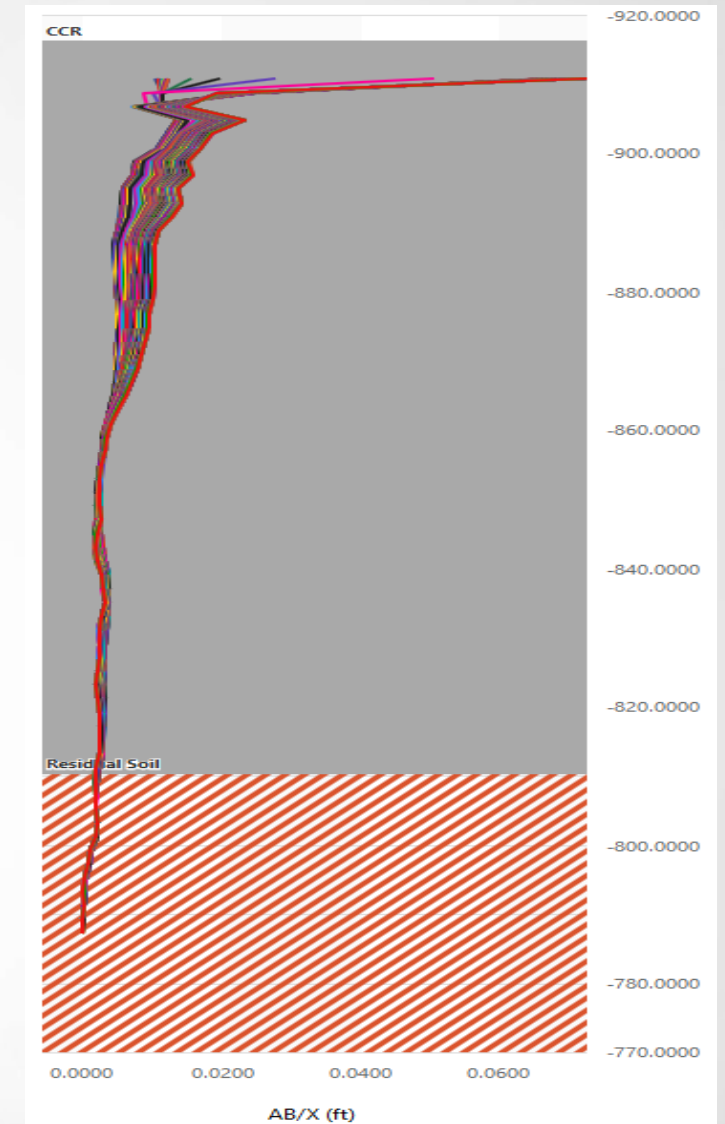
Shape Arrays

- Similar to in-place inclinometer
- Allows to monitor subsurface movements
- Can be installed in inclinometer casing or other casing 1 to 4 inches diameter



Shape Arrays

- Records centerline position of casing
- Can take readings up to every minute
- Automatic alerts if slope movement is detected
- Can detect multiple failure zones
- Precision of 0.5mm per 100 feet



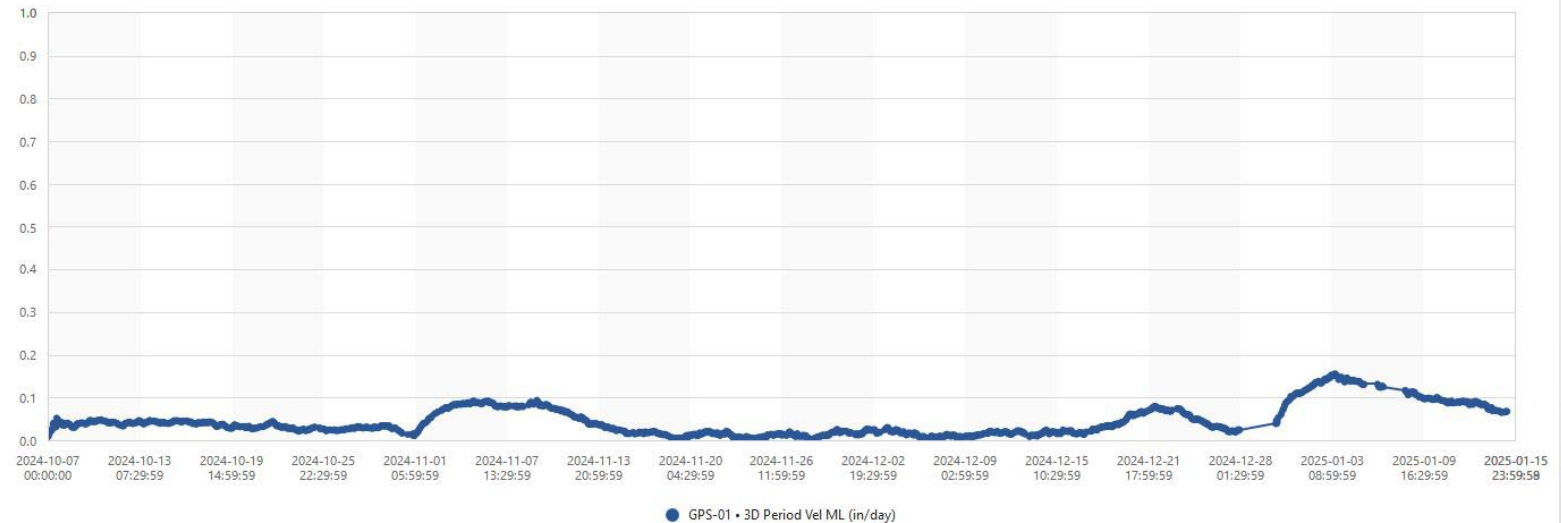
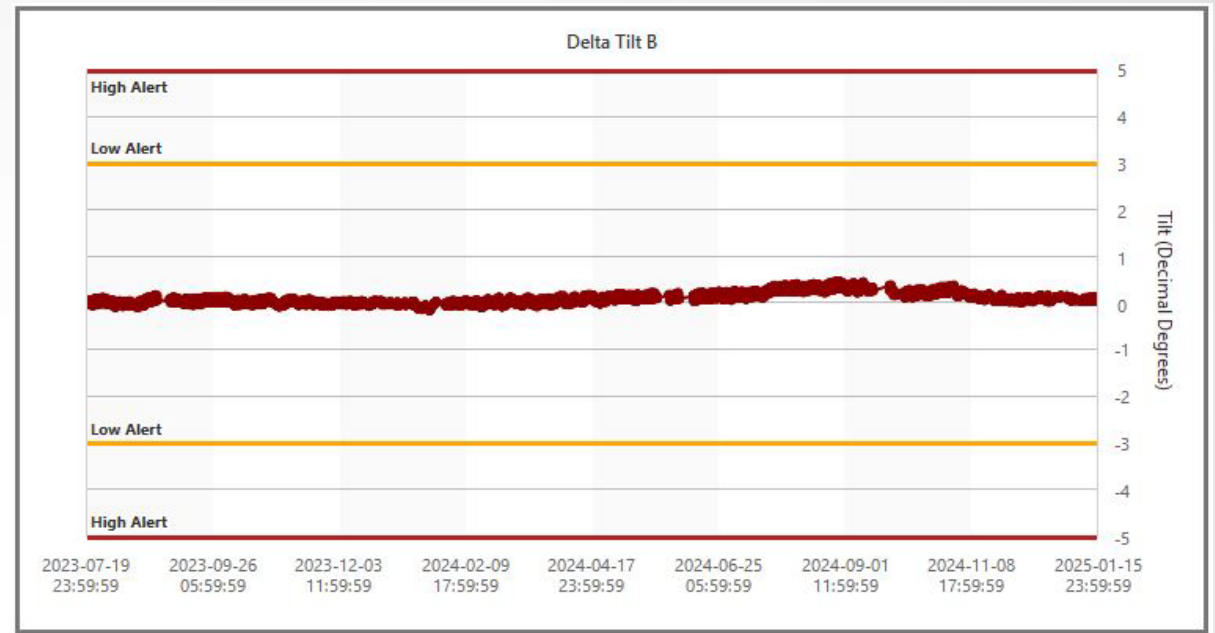
GNSS/GPS Units

- Used to track slope movement
 - Pre-Movement Monitoring
 - Post-Movement Monitoring
- Can be useful for constant monitoring
 - Moving Averages
- Show movement that other methods may not
 - Tilt
 - Rotational Movements



GNSS/GPS Units

- Data Analysis
 - Northing/Easting
 - Displacement
 - Tilt
 - Velocity
 - Period Velocity
 - Machine Learning



What This Means For Client

- Better Data
 - Objective, measurable results
 - Increased monitoring frequency identifies issues quicker
- Increased Personnel Safety
 - GeoExplorer software allows for “alarm” thresholds to be assigned to several criteria
 - GeoExplorer software allows for alerts to be sent via text or email to project personnel
 - Allows for personnel to evacuate slope if concerning signs are observed.

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QUESTIONS?