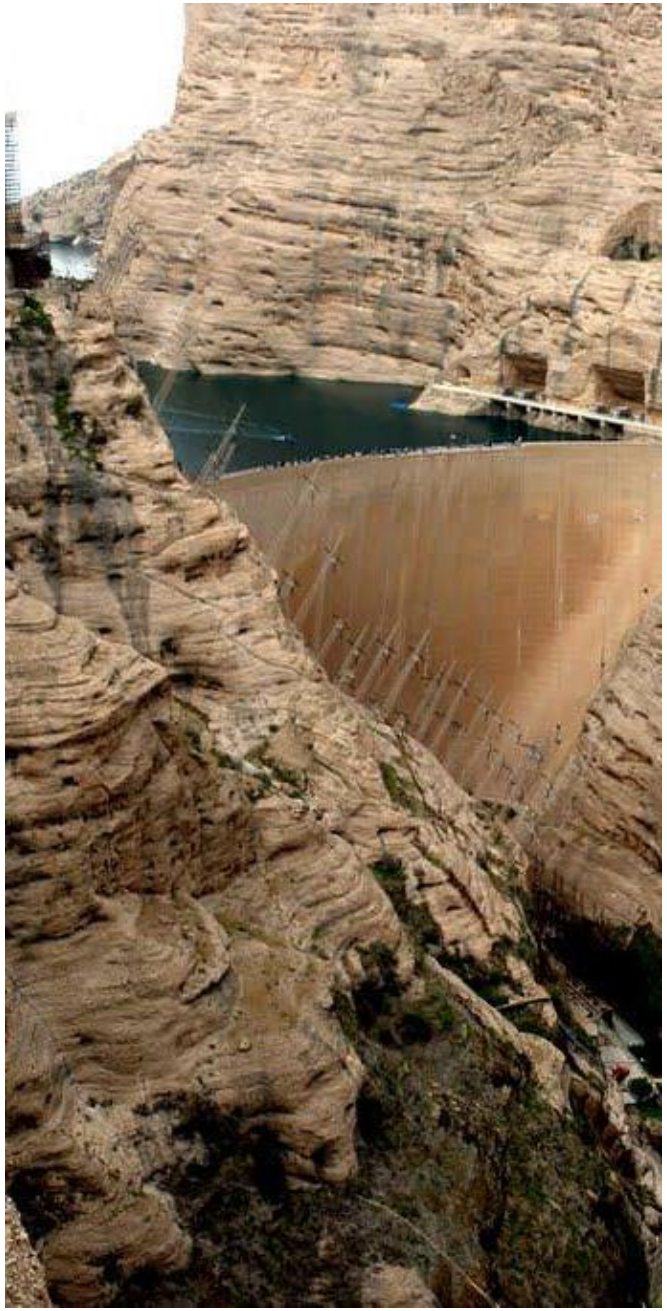
SCOUR CRITICAL BRIDGE MONITORING

PEDRAM MOJARRAD- DEZ PACIFIC,
MEHDI KALANTARI- RESENSYS LLC



Dez Pacific was founded late 2015, aiming to protect infrastructures as well as monitoring them.

Dez is the name of a concrete double arch dam in South of Iran.

RESENSYS

Resensys was founded in 2008 with the mission of protecting infrastructure systems against aging, deterioration, and collapse.

For this purpose, Resensys offers a range of structural monitoring solutions based on its award winning ultra low power wireless sensor network technology, known as SenSpot™.

SOLUTION: WIRELESS SENSPOT™ TECHNOLOGY

Green Technology

SenSpot™ Benefits

- Maintenance free, wireless low-power
- 10-year Battery life
- Small size and lightweight: 2in × 2in × 1in
- Easy mounting: self-adhesive
- Fully weather proof: Ingress Protection of IP65

Types of SenSpot™ Sensors

Strain (stress), tilt, temperature, humidity, displacement, vibration…

A COMPLETE BRIDGE MONITORING SYSTEM

Displacement SenSpot monitoring, movement, expansion

Tilt SenSpot
Monitoring pier movements/settling

Strain SenSpot
Monitoring stress on girders

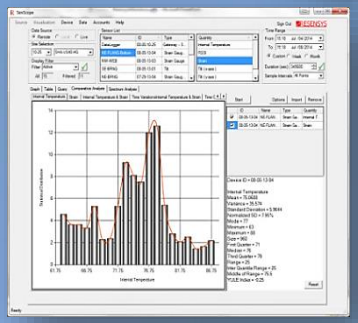
SeniMax
(Remote Transmission Gateway
< 2 pounds, solar powered, one per structure)

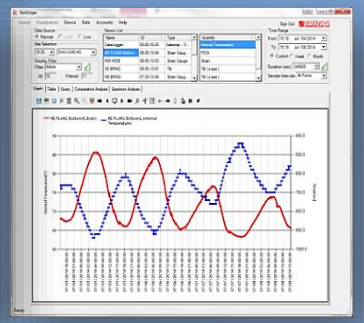
Cellular/WiFi

Internet

Cloud / Server storage

SenScope



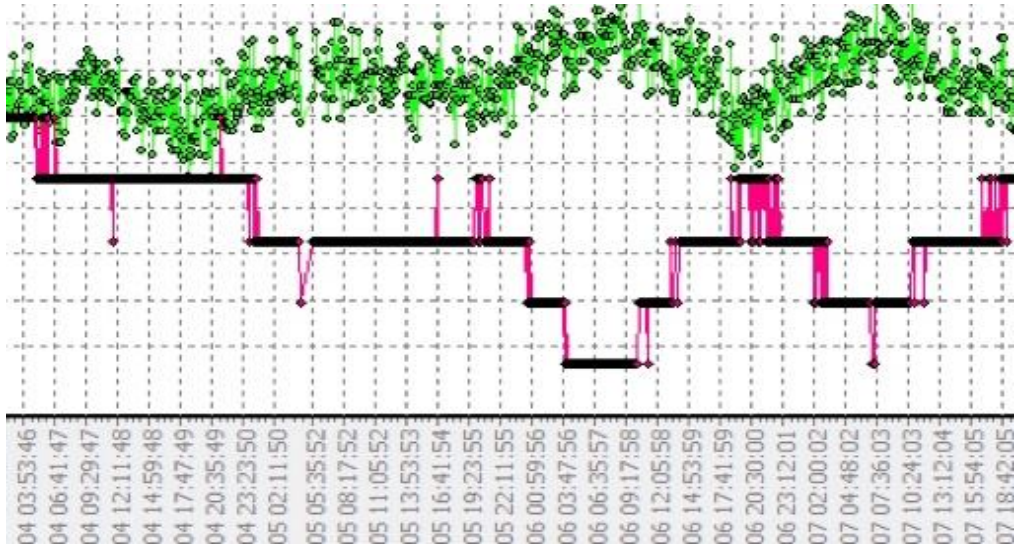


SENIMAX & SENSCOPE

SeniMax

- Cellular
- WiFi
- Ethernet
- Satellite
- USB Sink

SenScope



EXAMPLES OF APPLICATIONS

- **Bridges monitoring:** tilt, settling, instability, strain, vertical displacement, deformation, vibration, scour
- **Buildings:** settling, vibration, etc.
- **Machinery:** Tilt, displacement, vibration
- **Aircraft:** strain (fatigue), vibration
- **Oil and gas:** monitoring pipelines for fatigue, vibration, etc.
- **Other structures:** tunnels, sign structures, wind turbines, power plants, etc.
- **New solutions:**

Pier (tilt, deformation)

Vibration & Strain in structural members

Bearing (tilt, temperature)

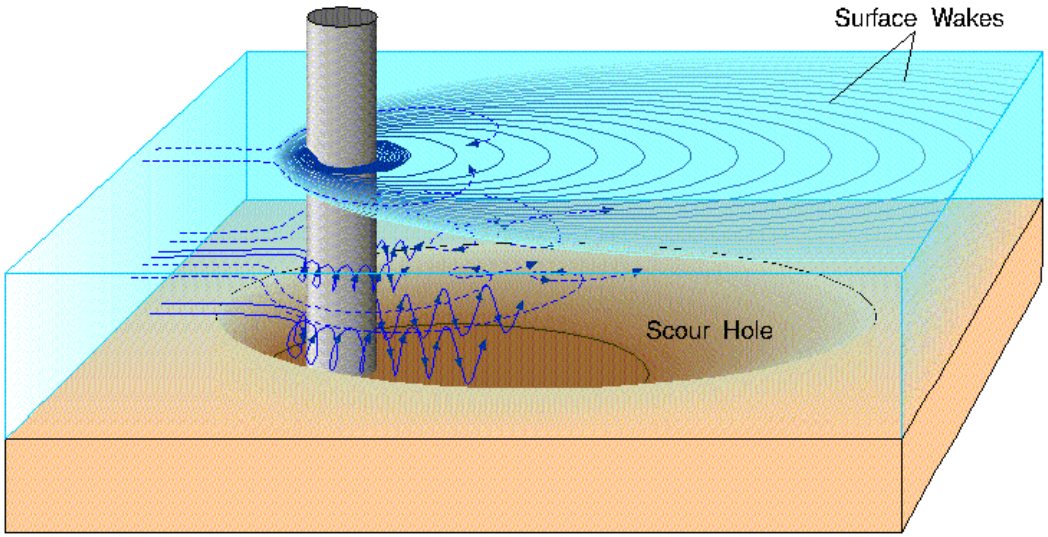
Bottom flange

SCOUR MONITORING- BACKGROUND

- Only during the two-year period, April 2010 to April 2012, a series of extreme weather events occurred in Queensland. Extensive flooding and cyclonic conditions, the majority of the state was declared a natural disaster zone. *In* excess of **$7 billion** with local authorities suffering additional damage of similar magnitude in monetary terms.

MOTIVATION

According to the Federal Highway Administration (FHWA) scour is the leading bridge failure cause in the United States. According to the National Bridge Failure Database, 58% of bridge failures in the US are due to hydraulic conditions.



APPROACH

- **Approach**: long-term monitoring of:
  - **Tilt** in scour critical piers (Changes in pier orientation, as small as 0.00016 degrees, can be monitored by these wireless sensors, and such changes are an early result of settling structural deformation caused by hydraulic damage)
  - **Wireless water level sensor:** feedback from water level in creek/river
  - **Visual feedback:** wireless, solar powered cameras, taking regular pictures from scour-critical spots
  - **Deflection**, tilting and deformation in piers

MONITORING APPROACH

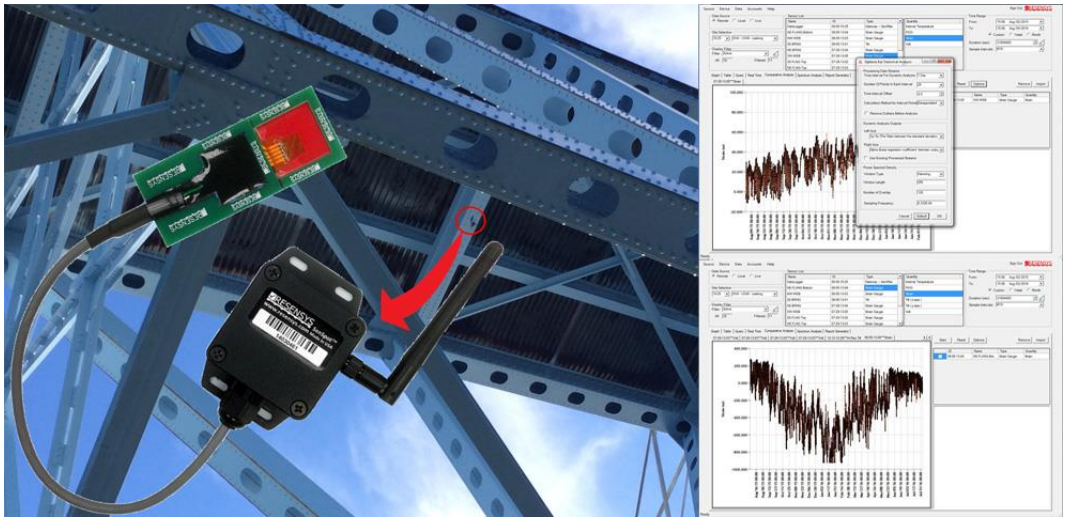
Monitoring approach:

- **Monitoring tilt/inclination (sub arc second accuracy):** on piers and abutments to detect instability, settling
- **Wireless water level monitor:** to monitor flood condition
- **Wireless camera:** visual feedback

CAPABILITIES

- Automated alert generation:

Very low (red alert)-Alarm
Low (orange alert)-Warning
High (orange alert)-Warning
Very high (red alert)-Alarm



- Characterising temperature effect:
it is capable of characterising the pier tilting caused by temperature. This is a crucial function in case, bridge bearings/expansion joints are not fully operational.

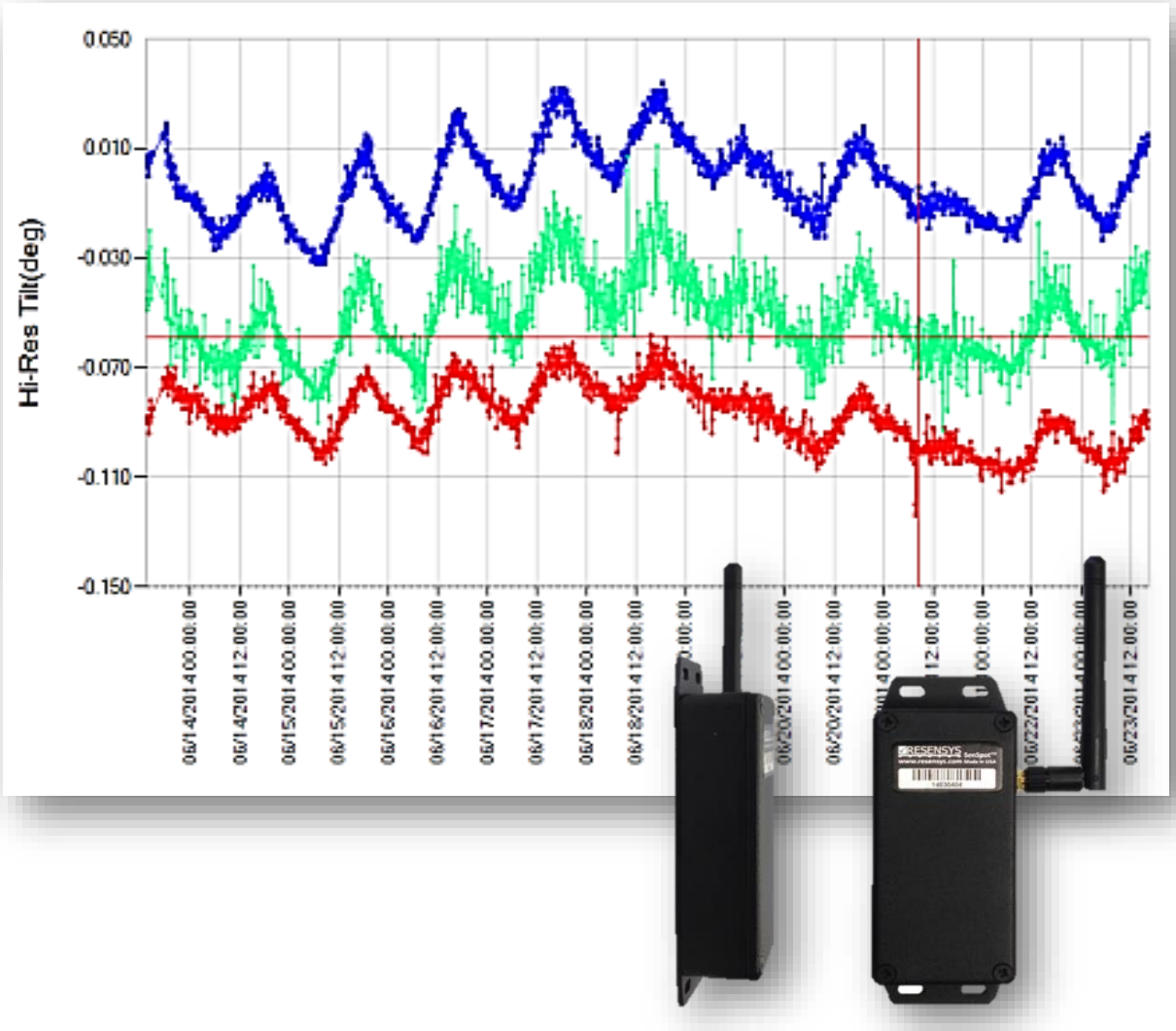
- **Adjustable measurement frequency:** by remotely sending commands

- Minimal lane closure/access equipment: sensors are very quick to install

SCOUR / WATER LEVEL MONITORING

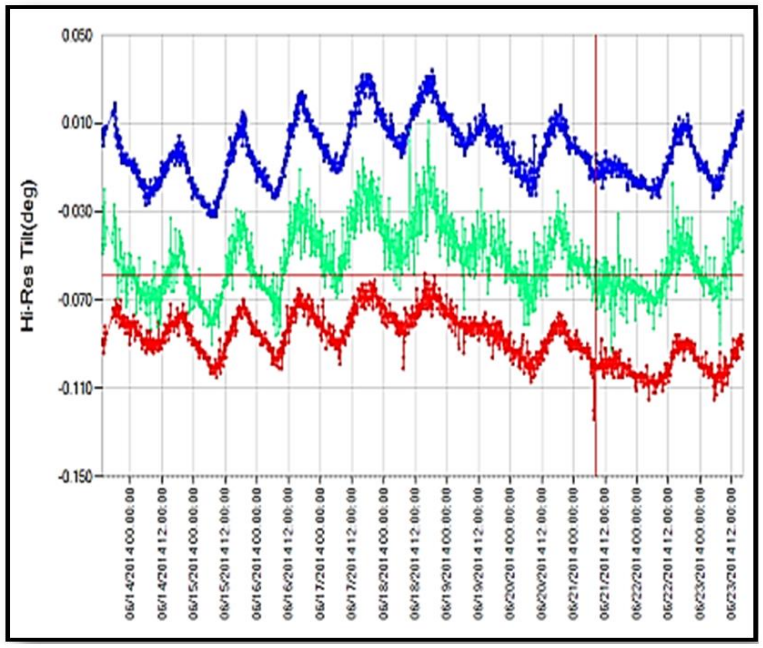
California and Maryland

MONITORING PIERS

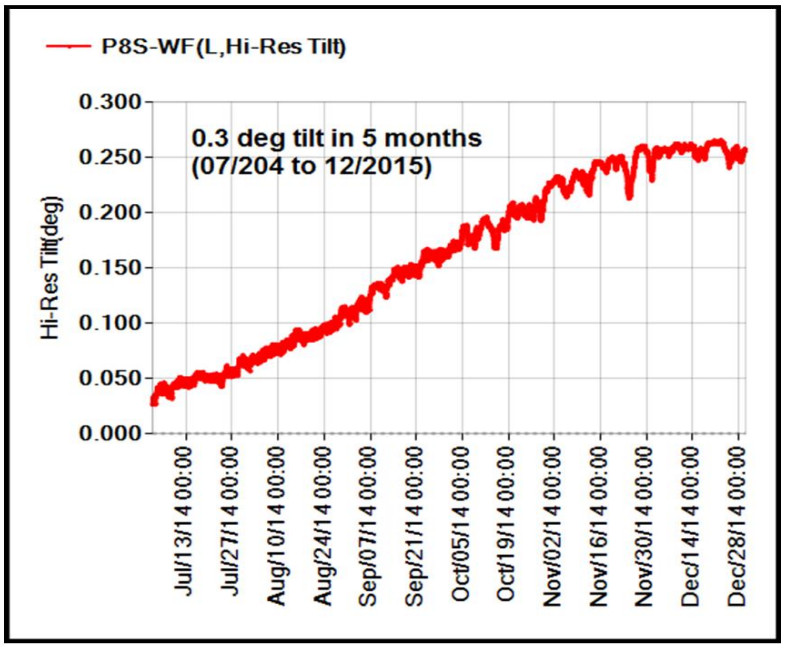


- Monitor tilt or piers, resolution 0.00016 degree (0.5 arc second)
- Monitor settling, bending, displacement, deformation

PIER TILT INSTABILITY



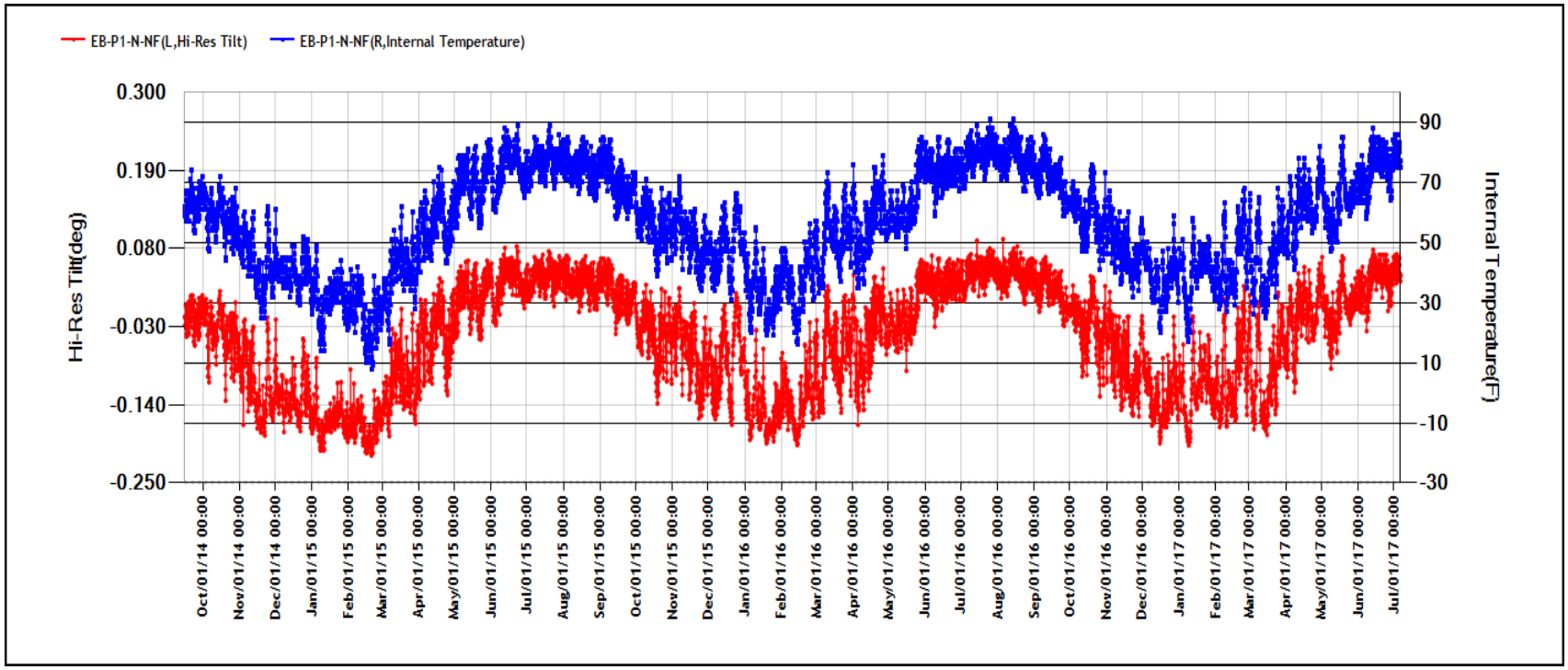
Healthy



Unhealthy

- **Scour lead to instability and settling of bridge piers**

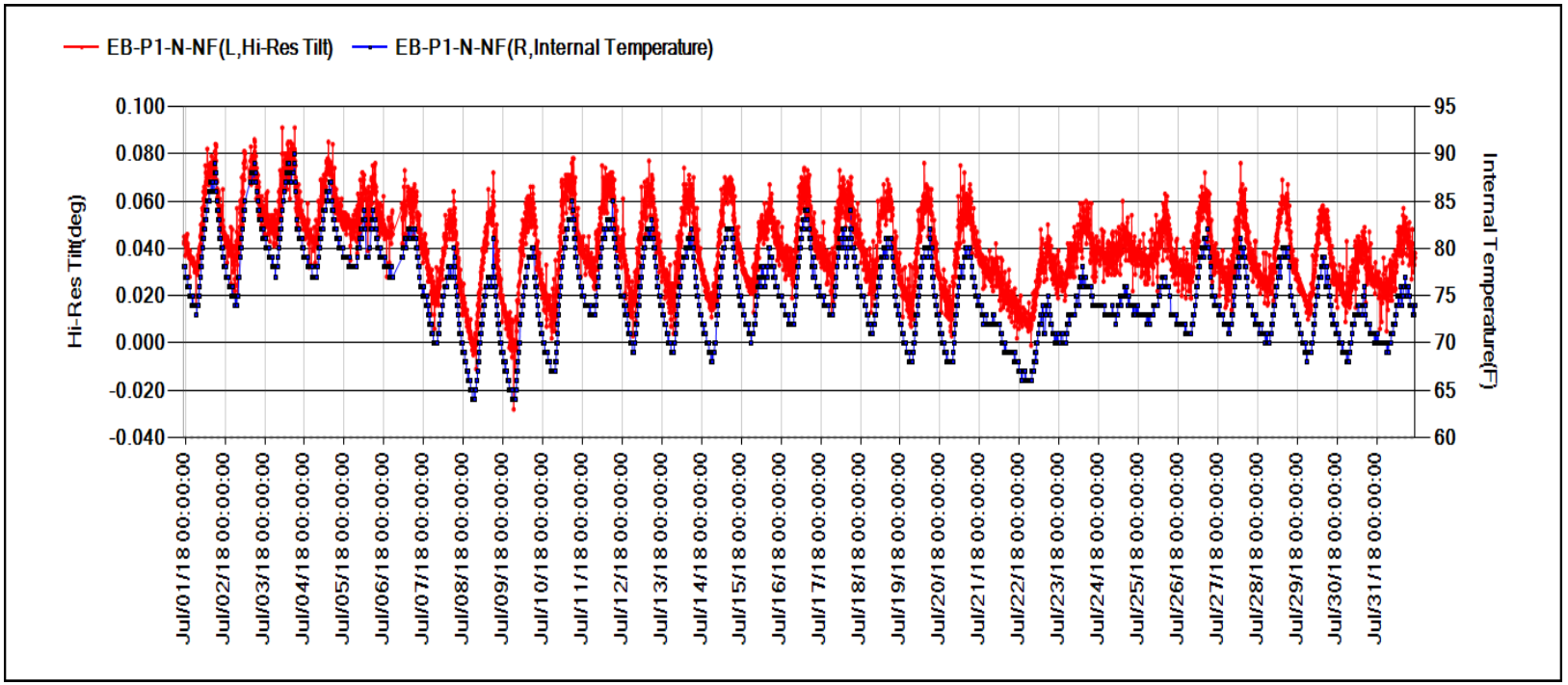
LONGER TERM PIER TILT (3-YEAR DATA)



Blue: temperature Red: tilt

Tilt variation of about 0.2degrees is observed over time (seasonal changes can be observed on the data)

PIER TILT OFTEN RESPONDS TO TEMPERATURE



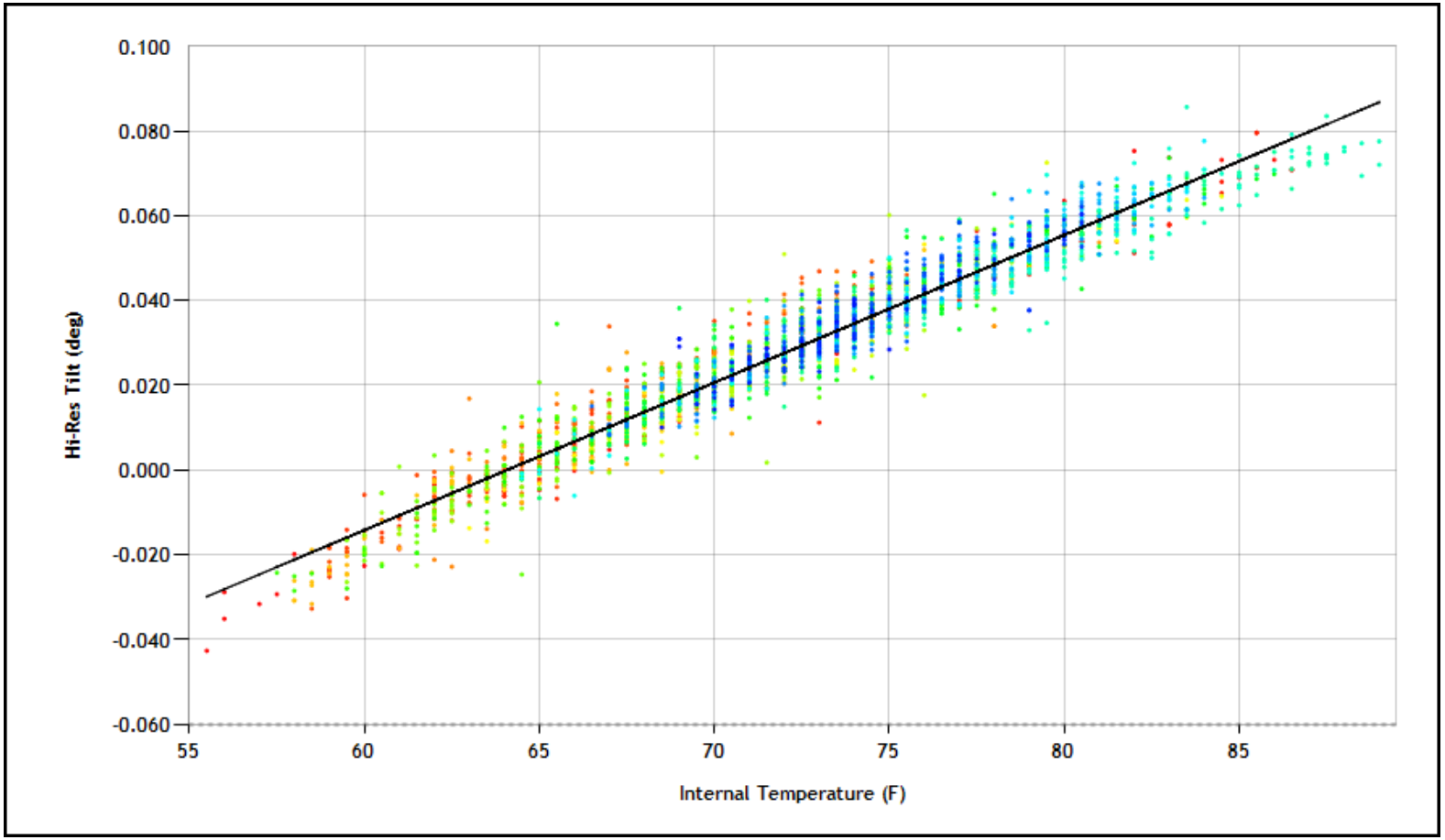
Blue: temperature **Red: tilt**

Tilt change of bout 0.02-0.05 degrees per day is observed

ISSUE: WHAT ALERT LEVEL ON TILT WORKS THE BEST?

- **Solution**: two dimensional threshold (i.e., threshold is a function of temperature).
- Each inclinometer reports temperature as well as tilt measurement.
- The alert generation system adaptively sets the threshold as a function of temperature.
- Linear regression of tilt/temperature is used to implement the alert detection method

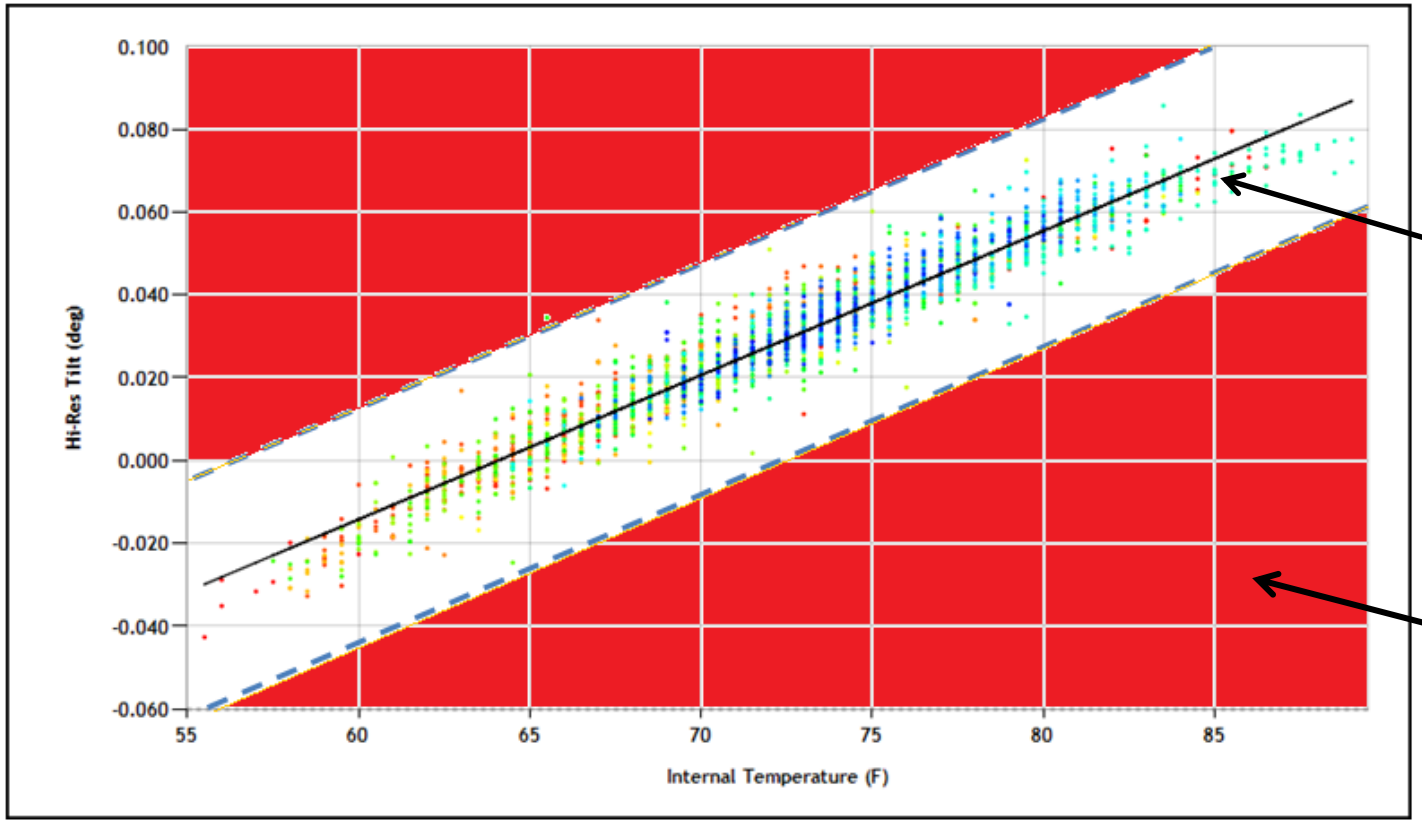
IMPLEMENTATION OF TWO DIMENSIONAL ALERTS



Characterization of Temperature effect

Pier tilt (degrees)= 0.0036 x Temperature (deg. F)

IMPLEMENTATION OF TWO DIMENSIONAL ALERTS



Normal zone (99.98% of normal readings are here

Alert zone

Characterization of Temperature effect

Pier tilt (degrees)= 0.0036 x Temperature (deg. F)

WIRELESS WATER LEVEL MONITORING

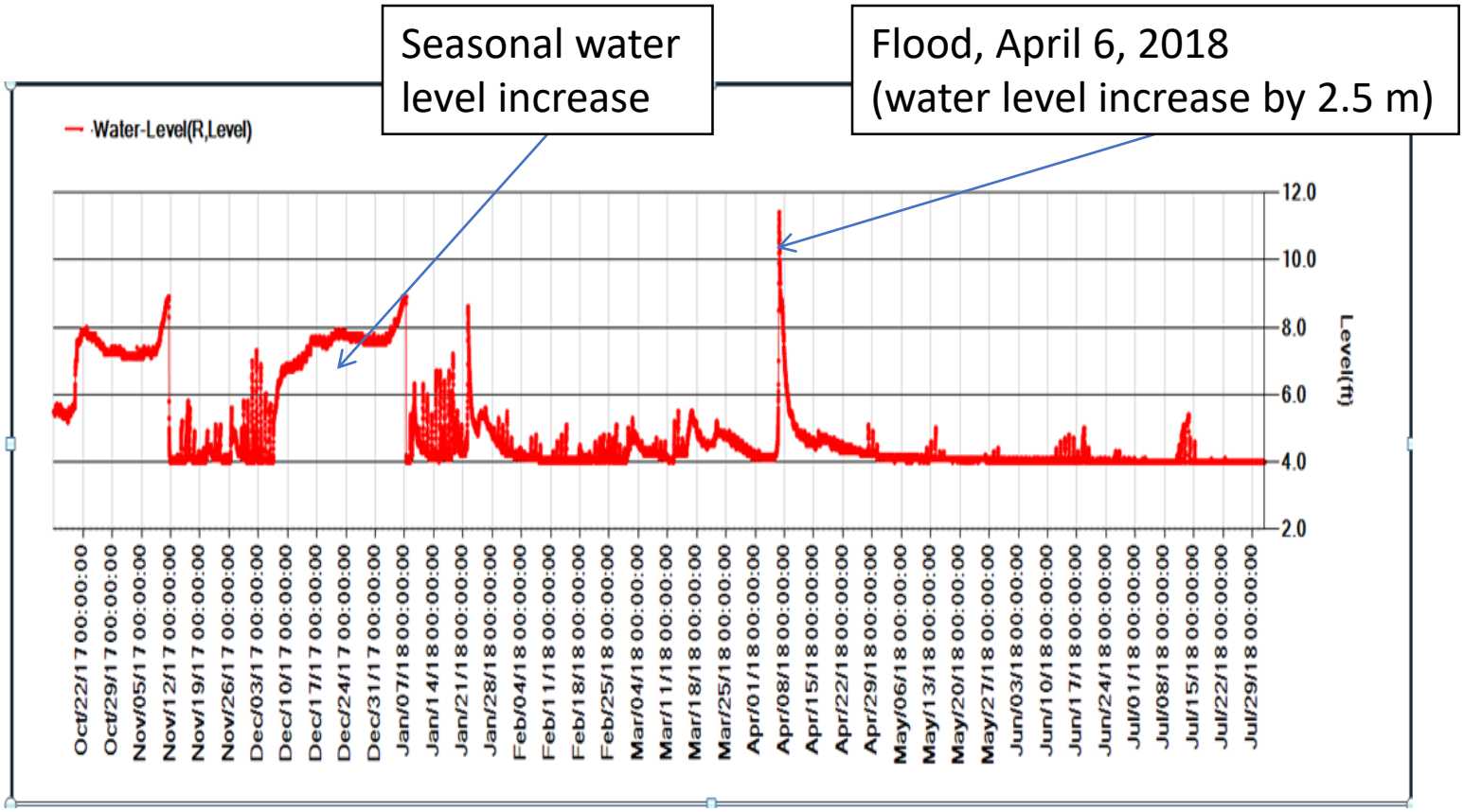
-Water level monitoring provides indication on flood condition

- Methodology: ultrasonic, non-contact measurement

- Solar powered wireless transmitter unit

Added benefit: taking immediate action once water level is too high

WIRELESS WATER LEVEL MONITORING (9-MONTH WATER LEVEL DATA)



9-month water level from a monitoring site (Oct 2017-July 2018)

WIRELESS SOLAR POWERED CAMERA SYSTEM

CONCLUSION

✓ SenSpot technology has proved to be cost effective, scalable scour critical bridge monitoring

✓ Monitoring settling and movements of Piers, Abutments

✓ Wireless, small, easy to install sensors, minimum lane closure

✓Wireless monitoring of water level, detecting flood condition

✓ Solar powered remote communication gateway (SeniMax)

✓ Powerful, user-friendly monitoring software, and analytical tools (SenScope)

✓ Reliable data reduction, detection, alert generation

THANKS

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