

# Subsidence and Deformation Monitoring Studies 2018



OC Survey  
Geodetic Unit





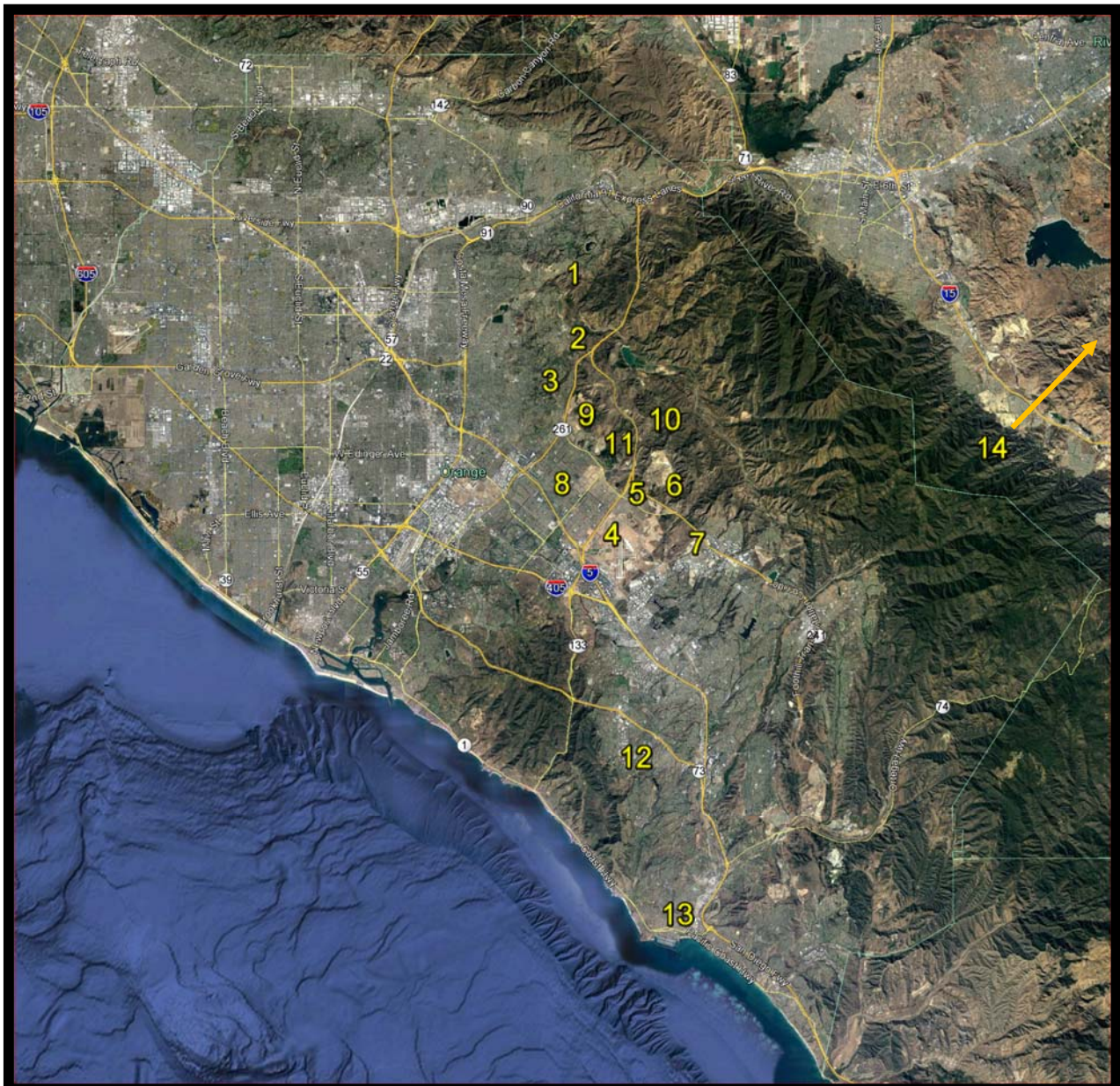
## **Facility Locations**

### **# FACILITY**

- 1 Villa Park Dam
- 2 Peters Canyon Dam
- 3 Lower Peters Canyon Dam
- 4 Marshburn Retarding Basin
- 5 Bee Canyon Retarding Basin
- 6 Round Canyon Retarding Basin
- 7 Agua Chinon Retarding Basin

### **# FACILITY**

- 8 Trabuco Retarding Basin
- 9 Orchard Estates Retarding Basin
- 10 Hicks Canyon Retarding Basin
- 11 East Hicks Canyon Retarding Basin
- 12 Sulphur Creek Dam
- 13 Cove Road – Crib Wall
- 14 Seven Oaks Dam



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This publication is a historical compilation of subsidence and deformation studies that are currently being performed.

## **Dam Monitoring Survey Reports**

### **Purpose:**

The State of California Division of Safety of Dams (DSOD) retains the responsibility of supervision of dams and reservoirs. DSOD requests periodic monitoring of dams to determine if they are stable. Monitoring may be requested at different intervals due to special circumstances such as earthquakes. OC Public Works Operations and Maintenance Division select which dams require monitoring and the elapsed time period for such surveys. Current dams being monitored with their interim are listed below:

#	Facility #	Dam	<u>2015</u>	<u>2016</u>	<u>2017</u>	<u>2018</u>	<u>2019</u>	<u>2020</u>	<u>2021</u>	<u>2022</u>
1	E08D01	Villa Park Dam	✓	✓	✓	✓	✓	✓	✓	✓
2	F06B03	Peters Canyon Dam	✓	✓	✓	✓	✓	✓	✓	✓
3	F06D02	Lower Peters Canyon Dam	✓			✓			✓	
4	F16B01	Marshburn Retarding Basin		✓			✓			✓
5	F16B02	Bee Canyon Retarding Basin		✓			✓			✓
6	F16B03	Round Canyon Retarding Basin		✓			✓			✓
7	F18B01	Agua Chinon Retarding Basin	✓			✓			✓	
8	F25B01	Trabuco Retarding Basin		✓			✓			✓
9	F26B02	Orchard Estates Retarding Basin		✓			✓			✓
10	F27B01	Hicks Canyon Retarding Basin		✓			✓			✓
11	F27B02	East Hicks Retarding Basin		✓			✓			✓
12	J03D01	Sulphur Creek Dam	✓	✓	✓	✓	✓	✓	✓	✓
13		Cove Road – Crib Wall		✓		✓		✓		✓
14	E01D01	Seven Oaks Dam	✓	✓	✓	✓	✓	✓	✓	✓



## Monitoring Procedures:

### PHASE I

Utilizing Global Navigation Satellite System (GNSS) Static survey techniques, measure at least two of the dam monitoring control stations to at least two Continuous Global Positioning System (cGPS) stations or two OCS horizontal control stations which are located outside of the dam area. GNSS data is post-processed and a minimally constrained adjustment is done constraining the same singular control station for each survey year. Positions are compared from each survey year. This data is used to check the stability, horizontally and vertically, of the two dam monitoring stations. This information is not included in the report unless significant movement is found but can be obtained at OC Survey Section, Geodetic Control Unit.

### PHASE II

Utilizing Precise leveling techniques following 2<sup>nd</sup> Order - Class II specifications, measure the vertical differences between all dam monitoring stations relative to at least two OCS Vertical control stations located outside the dam area. This data is used to monitor any subsidence and/or uplift on the dam monitoring stations.

### PHASE III

Utilizing terrestrial or GNSS surveying techniques, measure station and offsets for each dam monitoring stations from the dam monitoring control stations. This data is used to monitor the horizontal movement on the dam monitoring stations.

### COMMENTS:

Each annual survey is done using the same techniques with the same survey equipment if possible. Each survey report has a brief "Report Summary" that contains comments on each survey. Detailed information pertaining to monument descriptions and survey information are not included in the reports, but can be obtained at OC Survey Section, Geodetic Control Unit.

No evaluation of Subsidence or Deformation is determined by these reports. The intent of these reports are to provide survey data to assist the reader in the determination of the stability of these structures.

Four chart examples have been included explaining how to read and interpret each chart. These reports and data represent surveys made by me and/or under my direction.



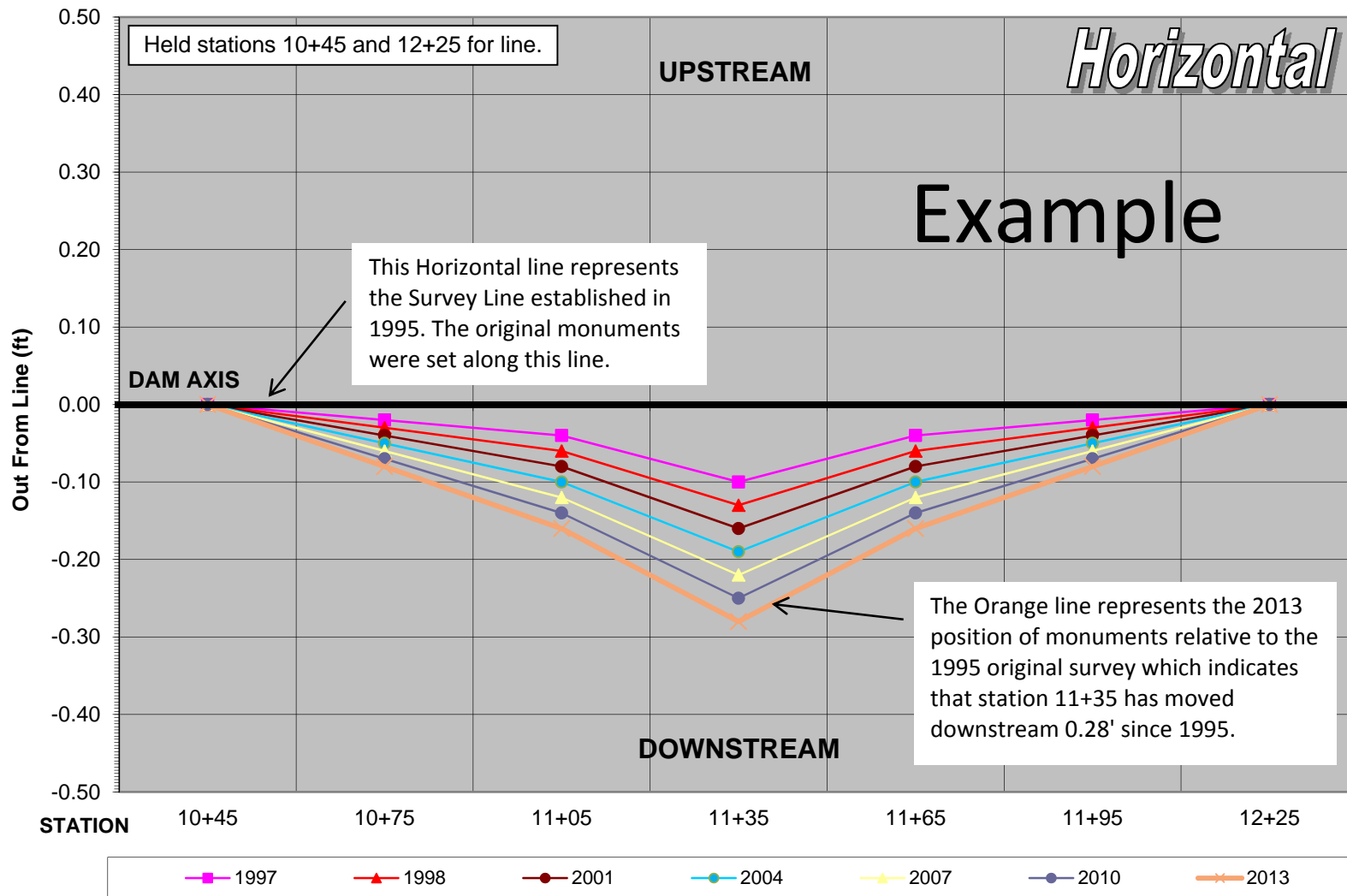
Arthur Ringland Andrew III, P.L.S. #7042



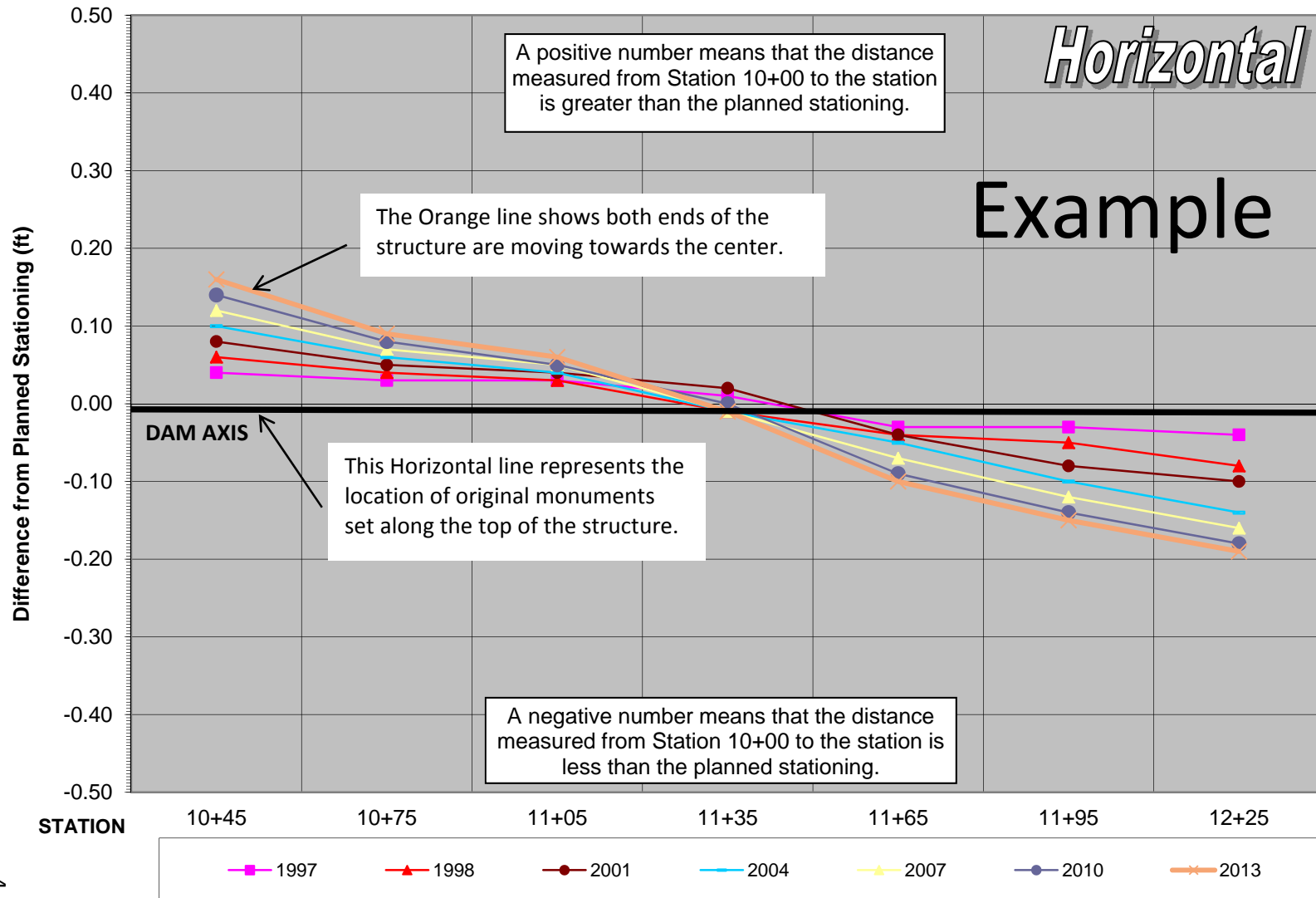
December 28, 2018

Date:

**EXAMPLE**  
**Horizontal Movement Perpendicular to Dam Axis (Out From Line) - Plan View**

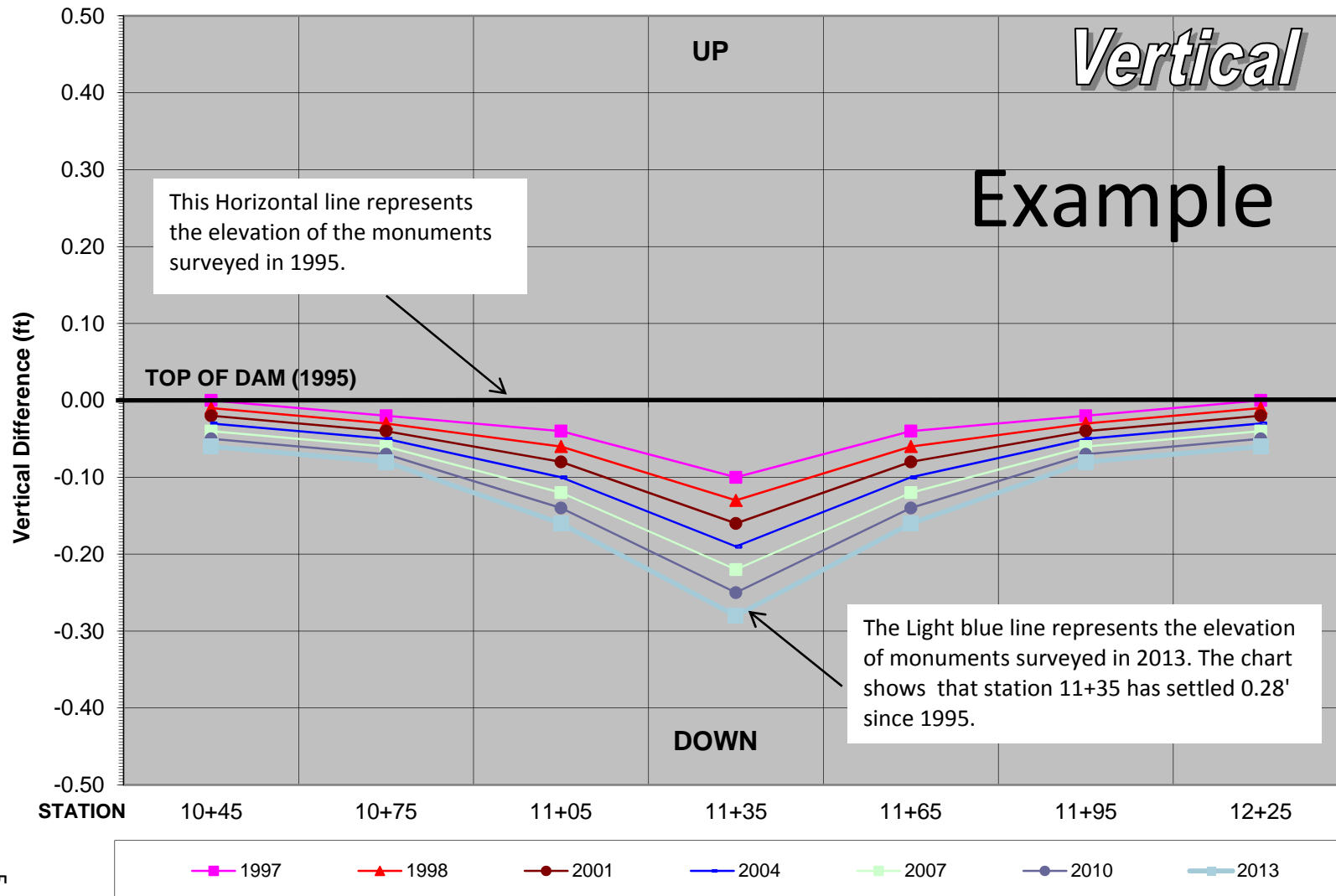


# **EXAMPLE** **Horizontal Movement Along Dam Axis (Difference from Planned Stationing)**

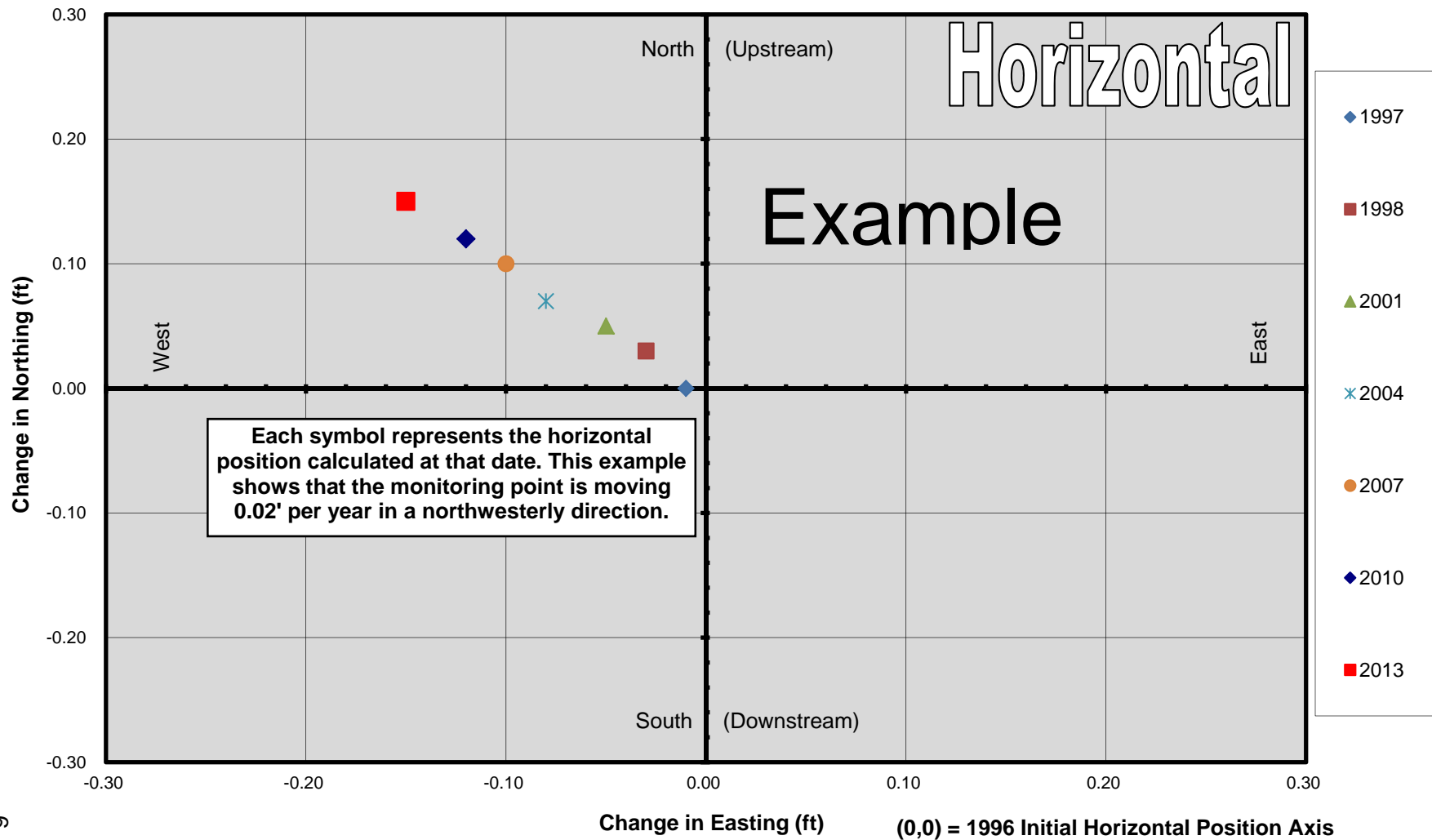




**EXAMPLE**  
**Vertical Movement (Difference from 1995 Elevations) - Profile View - *Looking Upstream***



**EXAMPLE**  
**Monitoring Point XXXX**  
**Horizontal Movement since the 1996 Initial Survey**



# 1

# VILLA PARK DAM



# Villa Park Dam

Monitoring Survey

## Legend

- Benchmarks
- Monitoring Stations

Google Earth

© 2018 Google  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
© 2018 INEGI  
Data LDEO-Columbia, NSF, NOAA

500 ft





# Villa Park Dam - Main Dam

Monitoring Survey

## Legend

■ Monitoring Stations

1+00 2+00 3+00 4+00 5+00 6+00 7+00 8+00 9+00 10+00 10+42

Google Earth

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© 2018 INEGI

Image Landsat / Copernicus

200 ft





## **Villa Park Dam (Main Dam) (E08D01) - Monitoring Survey**

This earthen dam was built in 1963. The first survey was performed in 1963. This report displays all surveys from 1963 to present. Horizontal displacement is compared to dam survey line. Vertical displacement are compared to the 1963 survey.

### **Chart Details**

#### **Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Control points "VP-18" ("VP-18A" after 1993) and "VP-19" are held for ***Out From Line*** and along line calculations.

Positive numbers represent monitored stations to the right of line (downstream), negative numbers represent monitored stations to the left of line (upstream).

#### **Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Control points "VP-18" ("VP-18A" after 1993) are held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing the elevation to the "1963 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Divison, Geodetic Control Unit.

All values are shown in U.S. Feet.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

**Vertical Datum = NGVD29, OCS 1976 Adjustment**



## **Villa Park Dam (Main Dam) (E08D01) - Monitoring Survey**

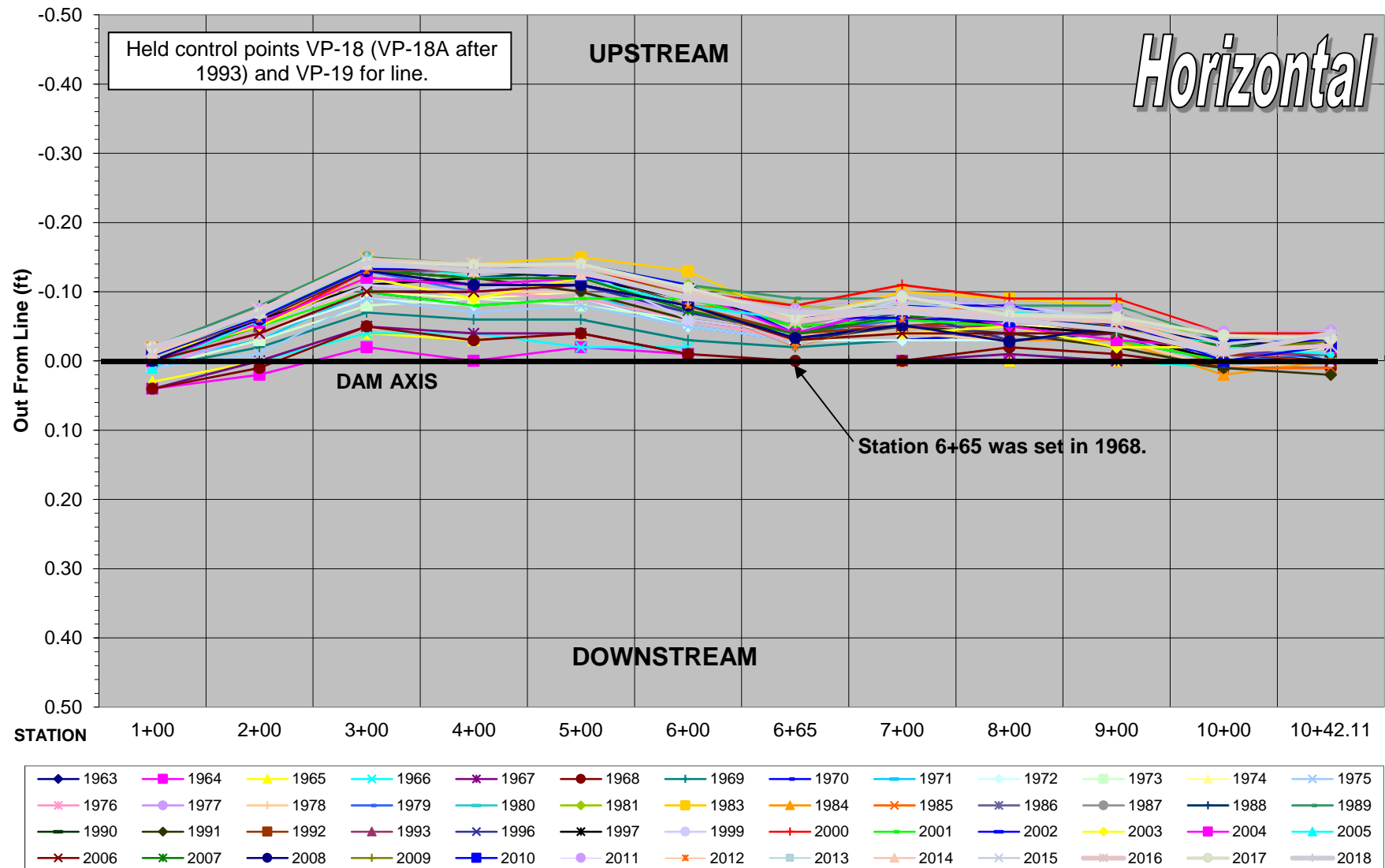
### **Report Summary**

<b>1963-1973</b>	Gradual subsidence measured due to settling of dam. Upstream horizontal movement measured, mostly concentrated around stations 3+00 thru 5+00.
<b>1974-1977</b>	Upstream horizontal movement and subsidence still measured. Rates are Gradually slowing.
<b>1978-1988</b>	Subsidence continues at a very slow rate. Horizontal appears stable.
<b>1989-2000</b>	Vertical subsidence has discontinued. Horizontal appears stable.
<b>2001</b>	No significant movement detected.
<b>2002</b>	No significant movement detected.
<b>2003</b>	No significant movement detected.
<b>2004</b>	No significant movement detected.
<b>2005</b>	No significant movement detected.
<b>2006</b>	No significant movement detected.
<b>2007</b>	No significant movement detected.
<b>2008</b>	No significant movement detected.
<b>2009</b>	No significant movement detected.
<b>2010</b>	No significant movement detected.
<b>2011</b>	No significant movement detected.
<b>2012</b>	No significant movement detected.
<b>2013</b>	No significant movement detected.
<b>2014</b>	No significant movement detected.
<b>2015</b>	No significant movement detected.
<b>2016</b>	No significant movement detected.
<b>2017</b>	No significant movement detected.
<b>2018</b>	No significant movement detected.
<b>2019</b>	
<b>2020</b>	

Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment

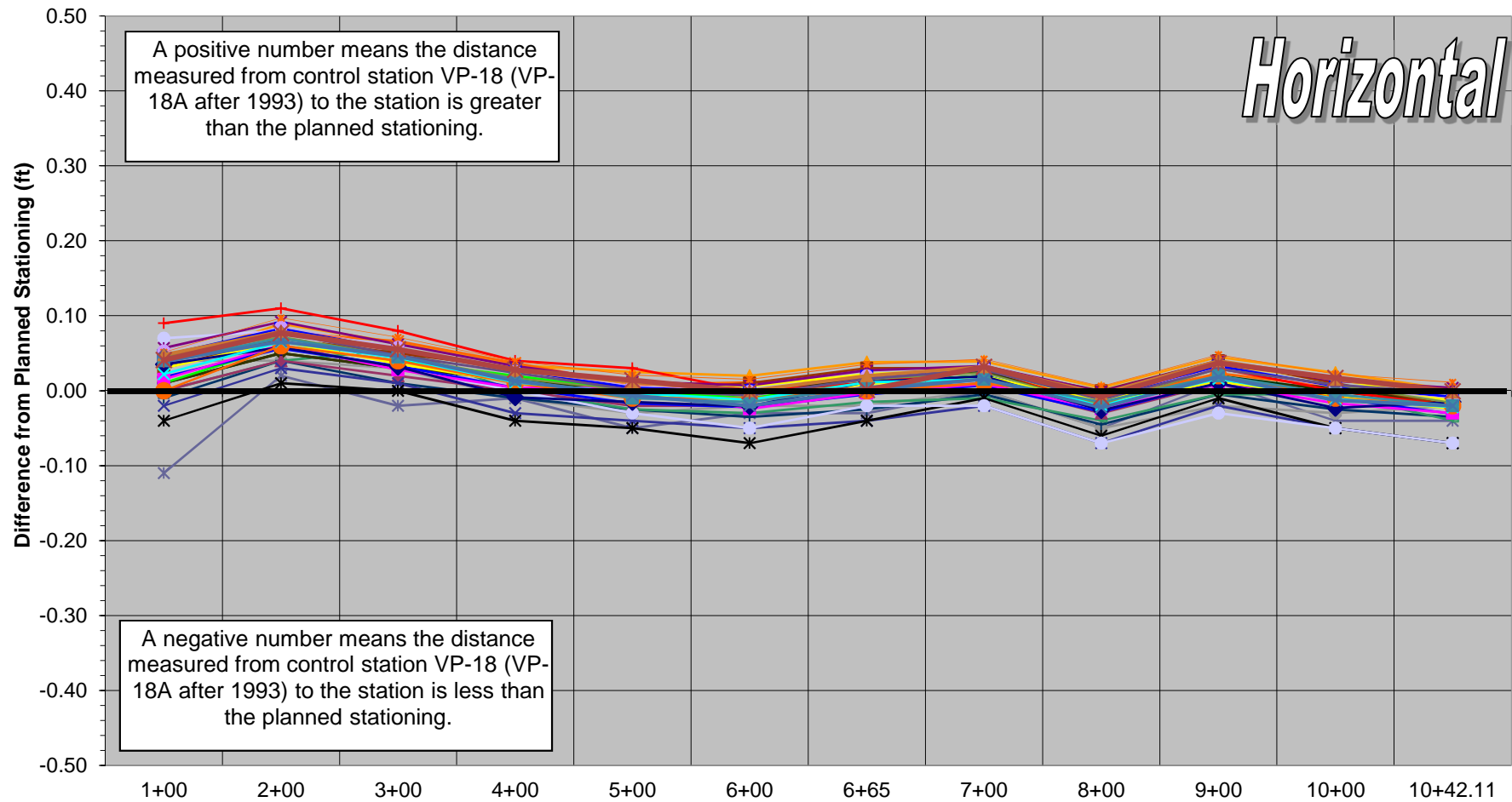
Vertical Datum = NGVD29, OCS 1976 Adjustment

# Villa Park (Main) Dam Horizontal Movement Perpendicular to Dam Axis (Out From Line) - Plan View

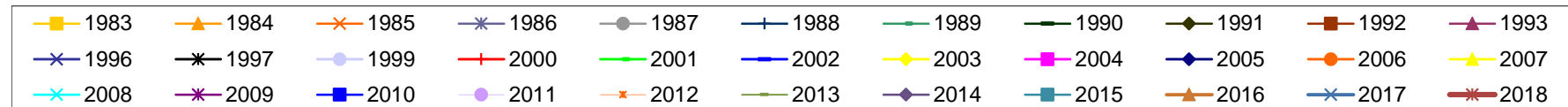


# Villa Park (Main) Dam Horizontal Movement Along Dam Axis (Difference from Planned Stationing)

*Horizontal*

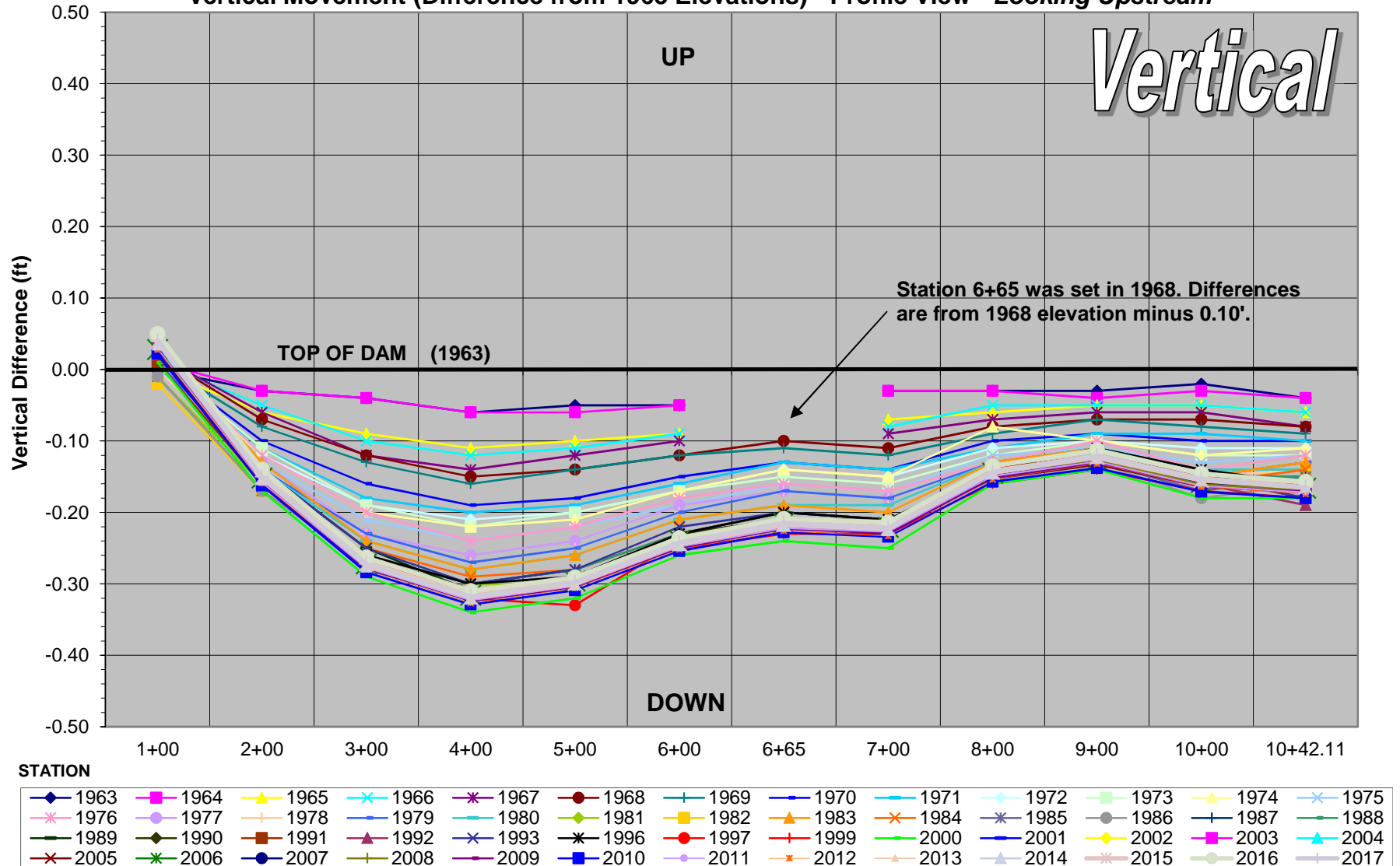


STATION





# Villa Park (Main) Dam Vertical Movement (Difference from 1963 Elevations) - Profile View - Looking Upstream





# Villa Park Dam - Auxillary Dam

Monitoring Survey

## Legend

■ Monitoring Stations

1590 (VP-32)

112+00

VP-31

110+00

109+00

108+00

107+00

106+00

105+00

104+00

1050 (VP-30)

1586 (VP-19)

101+00

1587 (100+00)

Google Earth

© 2018 Google

300 ft





## **Villa Park Dam (Auxiliary Dam) - Monitoring Survey**

The first survey was performed in 1980. This report displays surveys from 1980 to present.

Horizontal displacement is compared to dam survey line. Vertical displacement is compared to 1980 survey.

### **Chart Details**

#### **Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Station "100+00" and "VP-19" are held for ***Out From Line*** calculations for station 101+00.

Station "VP-19" and "VP-30" are held for ***Out From Line*** calculations for station 102+00.

Station "VP-30" and "VP-32" are held for ***Out From Line*** calculations for station 104+00 to 112+00.

Positive numbers represent monitored stations to the right of line, (upstream), negative numbers represent monitored stations to the left of line (downstream).

#### **Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Station "VP-30", VP-32 and "VP-19" are held for ***Along Line*** calculations.

Control point VP-30 and VP-19 are held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing the elevation to the "1980 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values are shown in U.S. Feet.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

**Vertical Datum = NGVD29, OCS 1976 Adjustment**

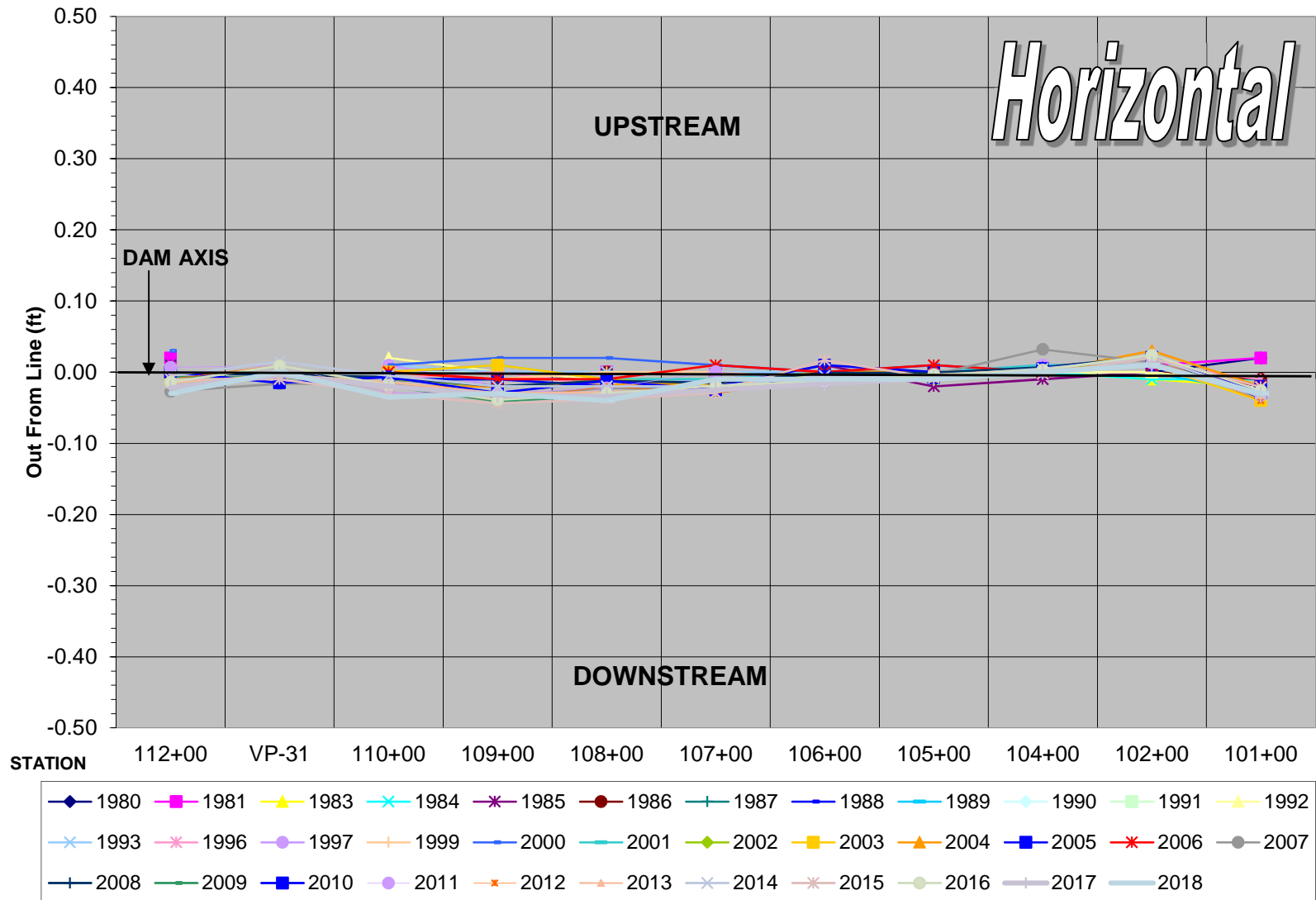


## **Villa Park Dam (Auxiliary Dam) - Monitoring Survey**

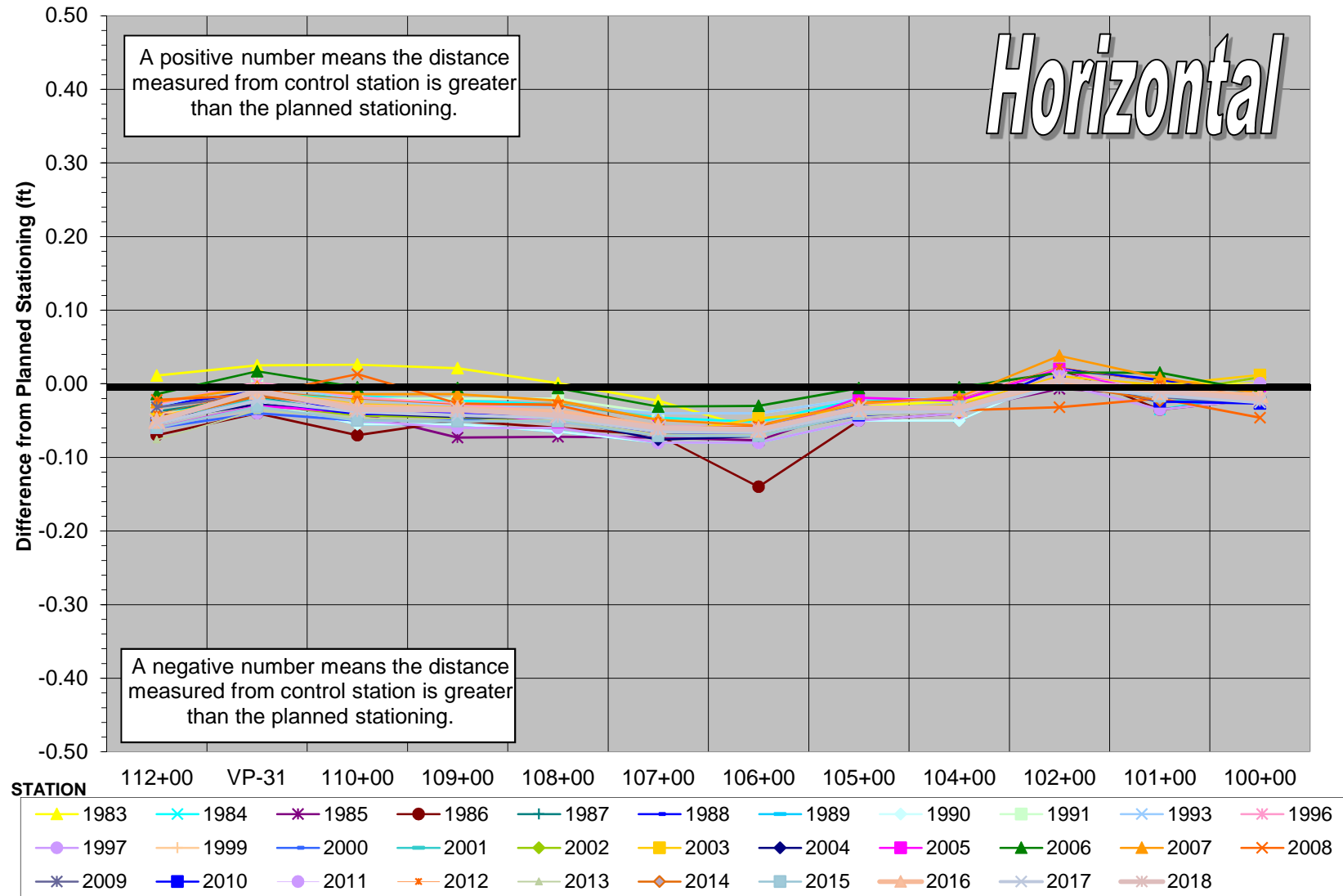
### **Report Summary**

<b>1980-1990</b>	Monuments appear to be stable horizontally and vertically. No significant movement detected.
<b>1991-2000</b>	Monuments continue to be stable horizontally and vertically. No significant movement detected.
<b>2001</b>	No significant movement detected.
<b>2002</b>	No significant movement detected.
<b>2003</b>	No significant movement detected.
<b>2004</b>	No significant movement detected.
<b>2005</b>	No significant movement detected.
<b>2006</b>	No significant movement detected.
<b>2007</b>	No significant movement detected.
<b>2008</b>	No significant movement detected.
<b>2009</b>	No significant movement detected.
<b>2010</b>	No significant movement detected.
<b>2011</b>	No significant movement detected.
<b>2012</b>	No significant movement detected.
<b>2013</b>	No significant movement detected.
<b>2014</b>	No significant movement detected.
<b>2015</b>	No significant movement detected.
<b>2016</b>	100+00 shows subsidence of 0.10'. No significant movement detected.
<b>2017</b>	No significant movement detected.
<b>2018</b>	No significant movement detected.
<b>2019</b>	
<b>2020</b>	

**Villa Park (Auxiliary) Dam**  
**Horizontal Movement Perpendicular to Dam Axis (Out From Line) - Plan View**

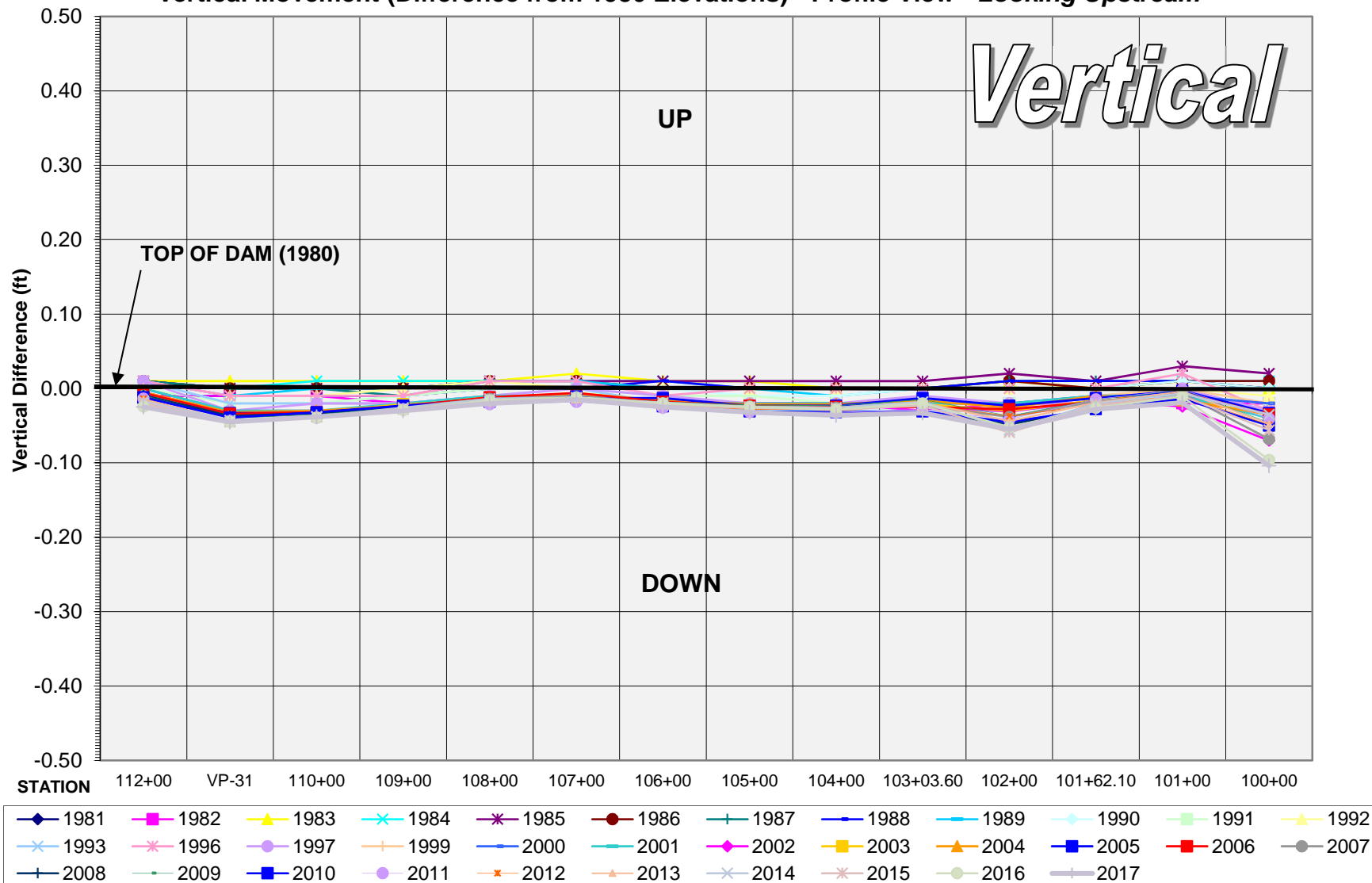


# Villa Park (Auxiliary) Dam Horizontal Movement Along Dam Axis (Difference from Planned Stationing)





# Vertical





# Villa Park Dam - Outlet Structure

Monitoring Survey

## Legend

■ Monitoring Stations



Google Earth

© 2018 Google



## **Villa Park Dam (Outlet Structure) - Monitoring Survey**

The first vertical survey was performed in 1964 and the first horizontal survey in 1965. This report displays all surveys from 1964 to present. Horizontal displacement is compared to dam survey line, vertical displacement is compared to 1964 survey.

### **Chart Details**

#### **Horizontal Movement Perpendicular to Tunnel Axis - shows all data from each year.**

Stations "VP16, VP16A, and VP16B" and "6+65" are held for ***Out From Line*** calculations. "VP-16B" was set in place of "VP-16A" in 2000 due to the instability of the ground around the monument. All ***Out From Line*** calculations will be done from "VP-16B" and "Main Dam 6+65" after 1999.

Positive numbers represent monitored stations to the right of line (northeasterly), negative numbers represent monitored stations to the left of line (southwesterly).

#### **Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Control point VP-16A / VP-16B is held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing the elevation to the "1964 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Divison, Geodetic Control Unit.

All values are shown in U.S. Feet.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

**Vertical Datum = NGVD29, OCS 1976 Adjustment**



## **Villa Park Dam (Outlet Structure) - Monitoring Survey**

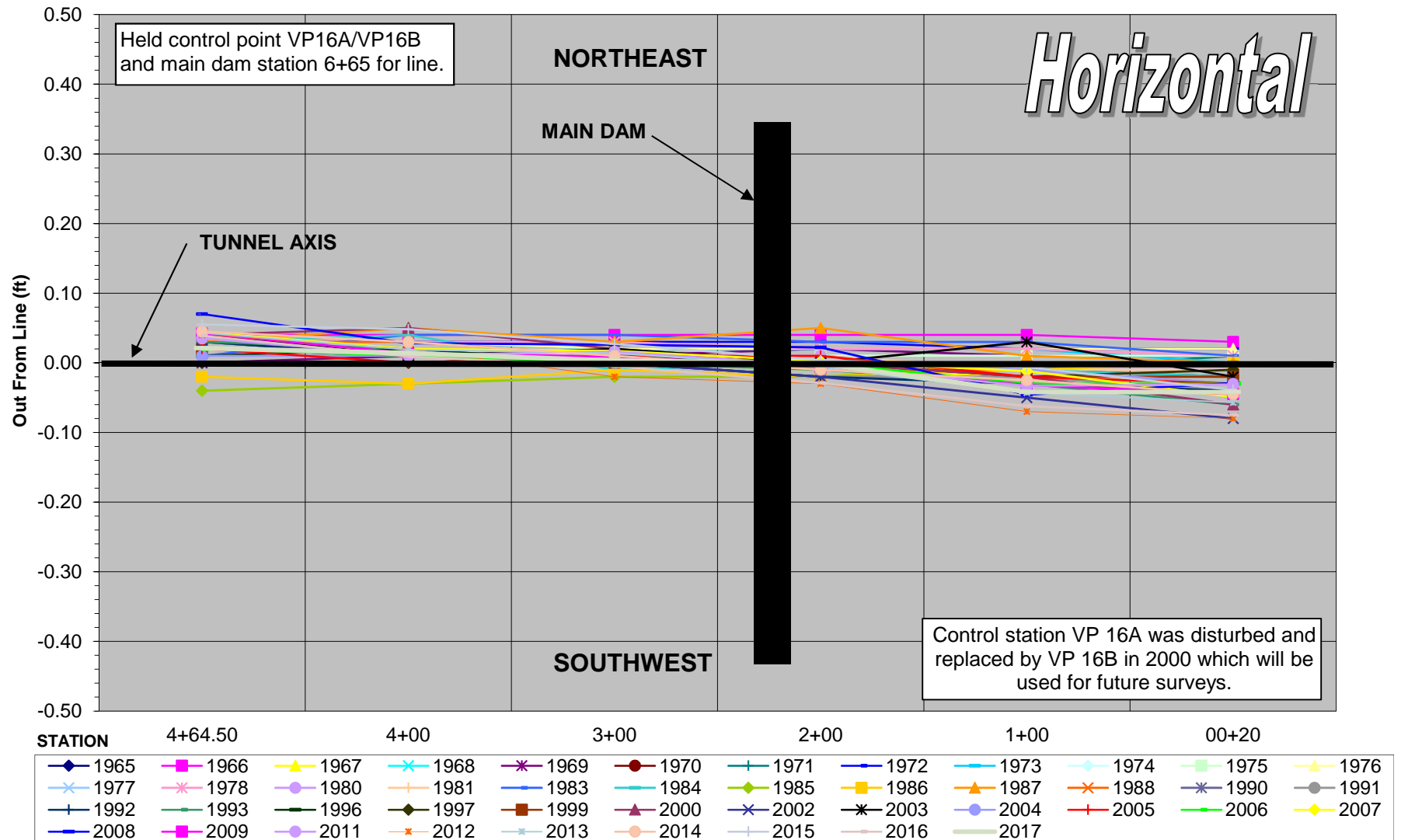
### **Report Summary**

<b>1964-1984</b>	Horizontally stable. Vertical subsidence occurs due to settling of dam
<b>1985-1999</b>	Horizontally stable. Vertical subsidence seems to stop. No significant movement detected.
<b>2000</b>	Horizontal chart differs from previous surveys due to change in control stations. Vertical appears stable. No significant movement detected.
<b>2001</b>	No survey performed due to excessive water in tunnel.
<b>2002</b>	No significant movement detected.
<b>2003</b>	No significant movement detected.
<b>2004</b>	No significant movement detected.
<b>2005</b>	No significant movement detected.
<b>2006</b>	No significant movement detected.
<b>2007</b>	No significant movement detected.
<b>2008</b>	No significant movement detected.
<b>2009</b>	No significant movement detected.
<b>2010</b>	VP Tunnel not monitored. GPS Point #1039 (VP-16B) was underwater; point is unusable until the water is drained from this area.
<b>2011</b>	No significant movement detected.
<b>2012</b>	No significant movement detected.
<b>2013</b>	No significant movement detected.
<b>2014</b>	No significant movement detected.
<b>2015</b>	No significant movement detected.
<b>2016</b>	No significant movement detected.
<b>2017</b>	No significant movement detected.
<b>2018</b>	Structure not monitored due to unsafe conditions.
<b>2019</b>	
<b>2020</b>	

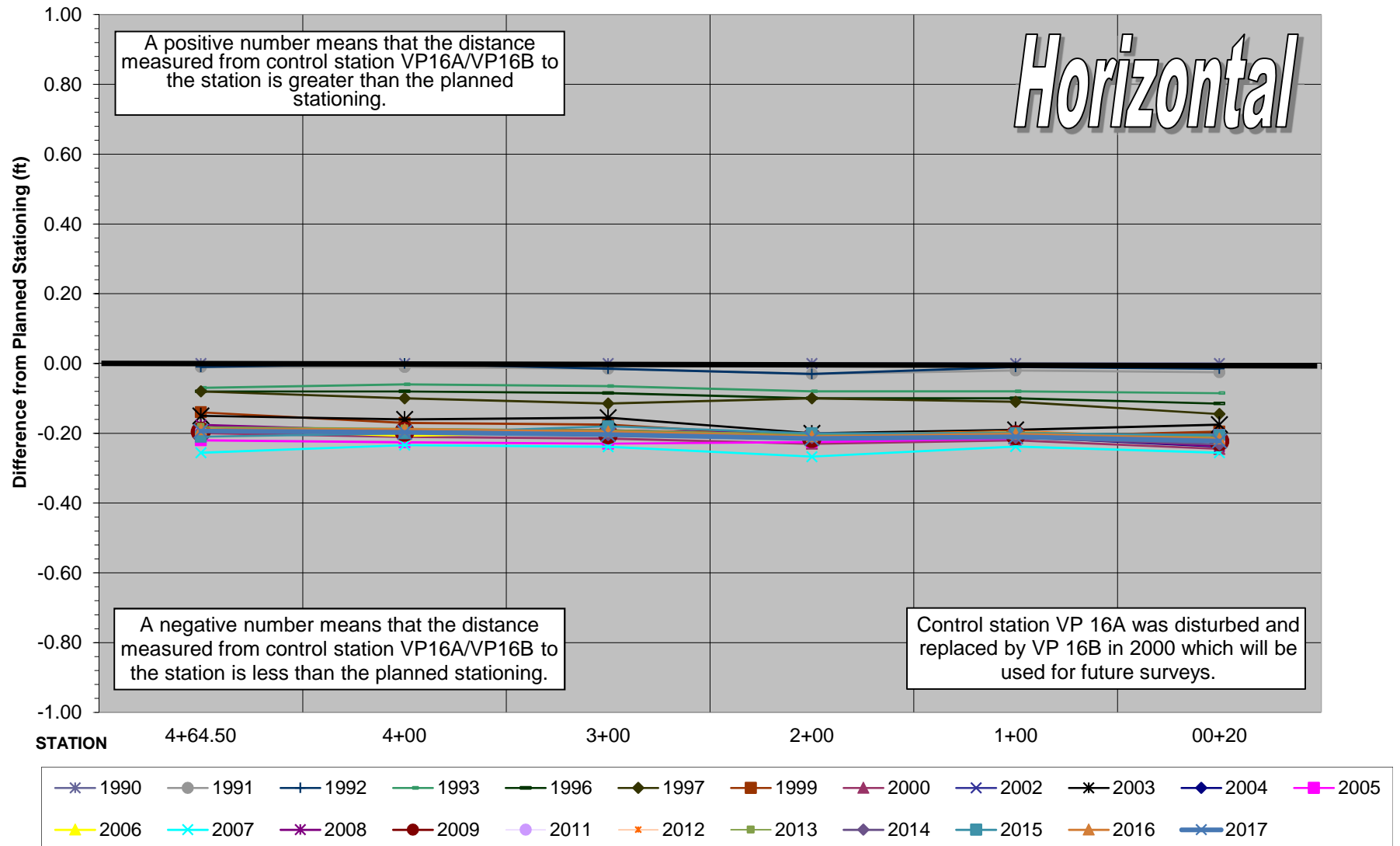
Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment

Vertical Datum = NGVD29, OCS 1976 Adjustment

# Villa Park (Outlet) Dam Horizontal Movement Perpendicular to Tunnel Axis (Out From Line) - Plan View

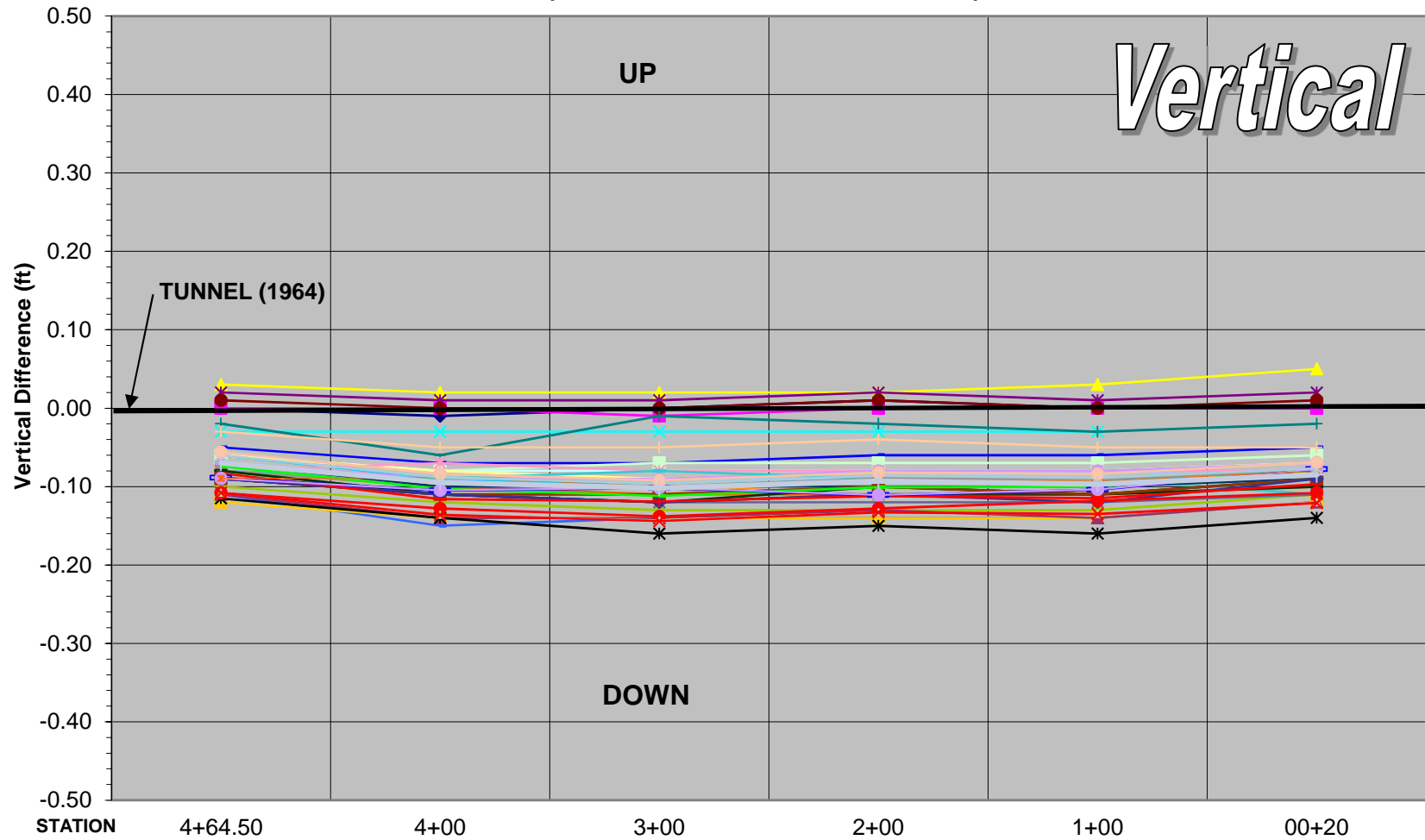


# Horizontal





**Villa Park (Outlet) Dam**  
**Vertical Movement (Difference from 1964 Elevations) - Profile View**



◆ 1965	■ 1966	▲ 1967	✕ 1969	✱ 1970	● 1971	✚ 1972	◆ 1973	✚ 1974	✚ 1975	■ 1976
▲ 1977	✕ 1978	✱ 1980	● 1983	✚ 1984	◆ 1985	✚ 1986	■ 1987	■ 1988	▲ 1990	✕ 1991
✱ 1992	● 1993	✚ 1996	✚ 1997	✚ 1999	■ 2000	■ 2002	▲ 2003	◆ 2004	✱ 2005	● 2006
✚ 2007	✚ 2008	◆ 2009	● 2011	✱ 2012	■ 2013	✱ 2014	✱ 2015	● 2016	◆ 2017	

# 2

# PETERS CANYON DAM



# Peters Canyon Dam

Monitoring Survey

## Legend

- Benchmarks
- ▲ Control Stations
- Monitoring Stations



Google Earth

Image Landsat / Copernicus

© 2018 Google



## **Peters Canyon Dam (F06D01) Monitoring Survey**

This earthen dam was built in 1932. The first surveyed was performed in 1996 and is used as the "benchmark" for all future surveys.

### **Chart Details**

#### **Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Control points # 1 and # 2 are held for ***Out From Line*** calculations.

Positive numbers represent stations right of line (upstream), negative numbers represent stations left of line (downstream).

#### **Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Control point # 1 is held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing each elevation to the "1996 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values are shown in U.S. Survey feet. Station name is shown in meters.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

**Vertical Datum = NAVD88, OCS 1995 Adjustment**



## **Peters Canyon Dam (F06D01) Monitoring Survey**

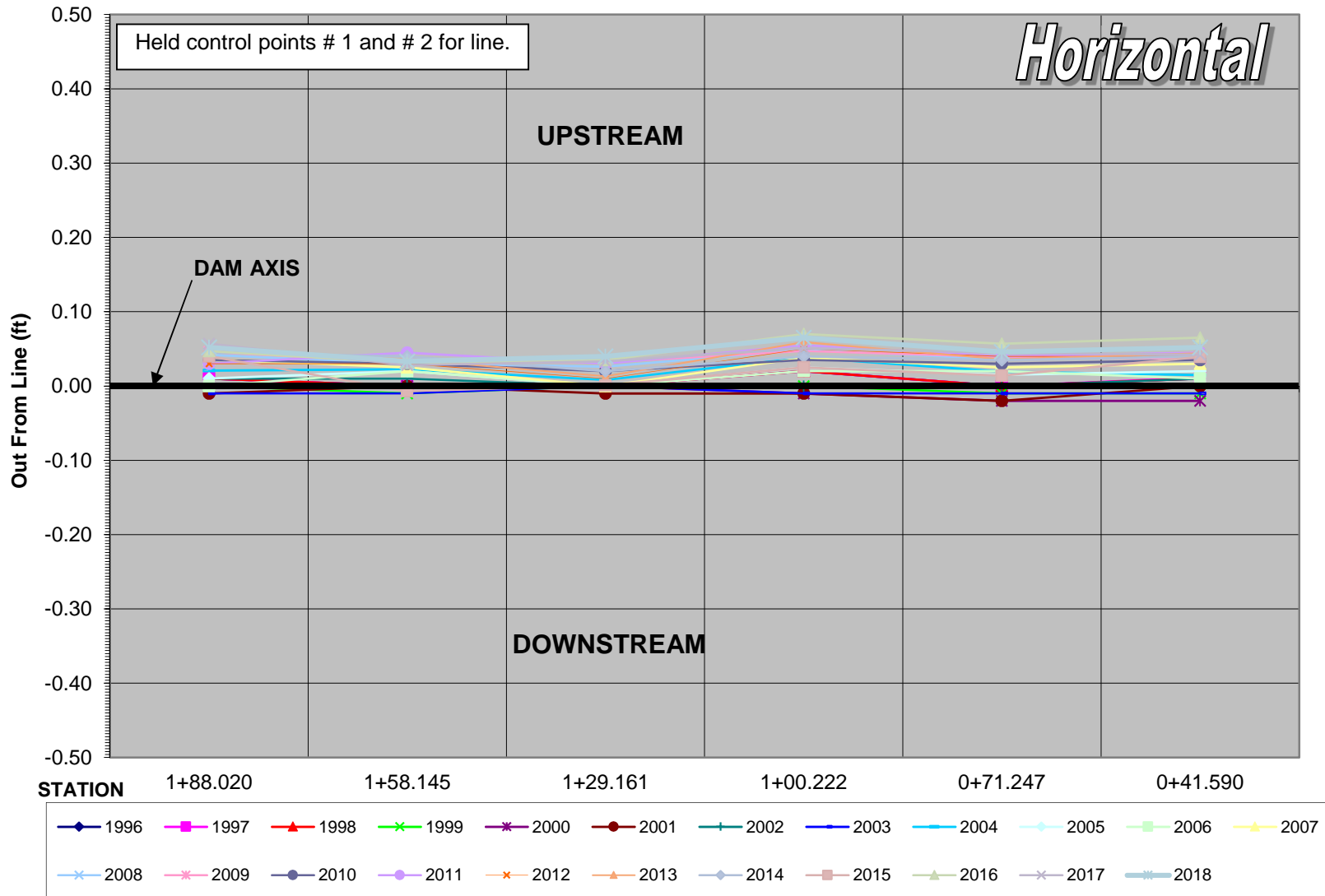
### **Report Summary**

<b>1996</b>	Initial survey performed
<b>1997</b>	No significant movement detected, all monuments appear stable.
<b>1998</b>	No significant movement detected, all monuments appear stable.
<b>1999</b>	No significant movement detected, all monuments appear stable.
<b>2000</b>	No significant movement detected, all monuments appear stable.
<b>2001</b>	No significant movement detected, all monuments appear stable.
<b>2002</b>	No significant movement detected, all monuments appear stable.
<b>2003</b>	No significant movement detected, all monuments appear stable.
<b>2004</b>	No significant movement detected, all monuments appear stable.
<b>2005</b>	No significant movement detected, all monuments appear stable.
<b>2006</b>	No significant movement detected, all monuments appear stable.
<b>2007</b>	No significant movement detected, all monuments appear stable.
<b>2008</b>	No significant movement detected, all monuments appear stable.
<b>2009</b>	No significant movement detected, all monuments appear stable.
<b>2010</b>	No significant movement detected, all monuments appear stable.
<b>2011</b>	No significant movement detected, all monuments appear stable.
<b>2012</b>	No significant movement detected, all monuments appear stable.
<b>2013</b>	No significant movement detected, all monuments appear stable.
<b>2014</b>	No significant movement detected, all monuments appear stable.
<b>2015</b>	No significant movement detected, all monuments appear stable.
<b>2016</b>	Questionable data seen on "Difference From Stationing" chart. Possibly due to instrument not setup on #1595 correctly.
<b>2017</b>	No significant movement detected, all monuments appear stable.
<b>2018</b>	No significant movement detected, all monuments appear stable.
<b>2019</b>	
<b>2020</b>	

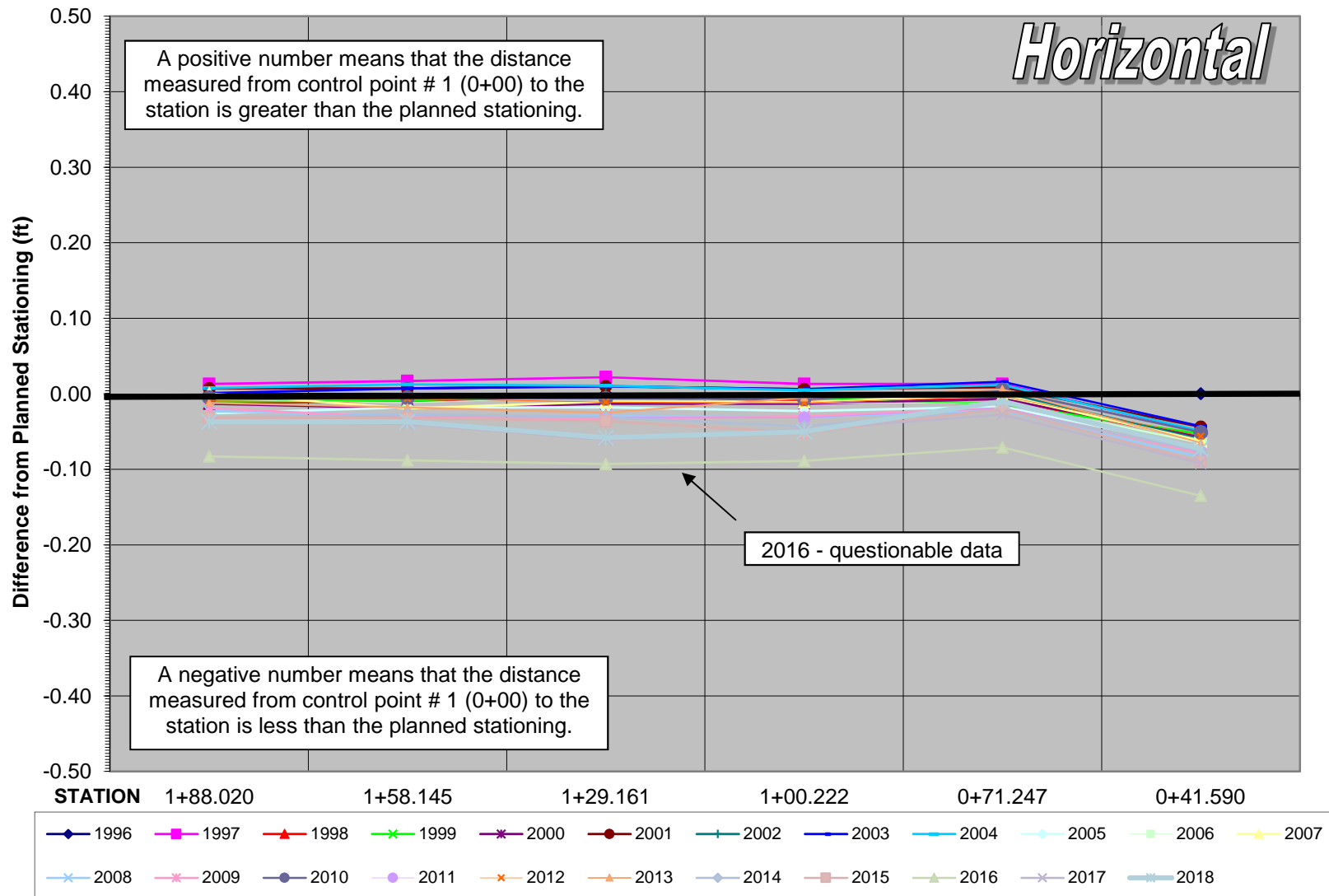
Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment

Vertical Datum = NAVD88, OCS 1995 Adjustment

**Peters Canyon Dam  
Horizontal Movement Perpendicular to Dam Axis (Out From Line) - Plan View**

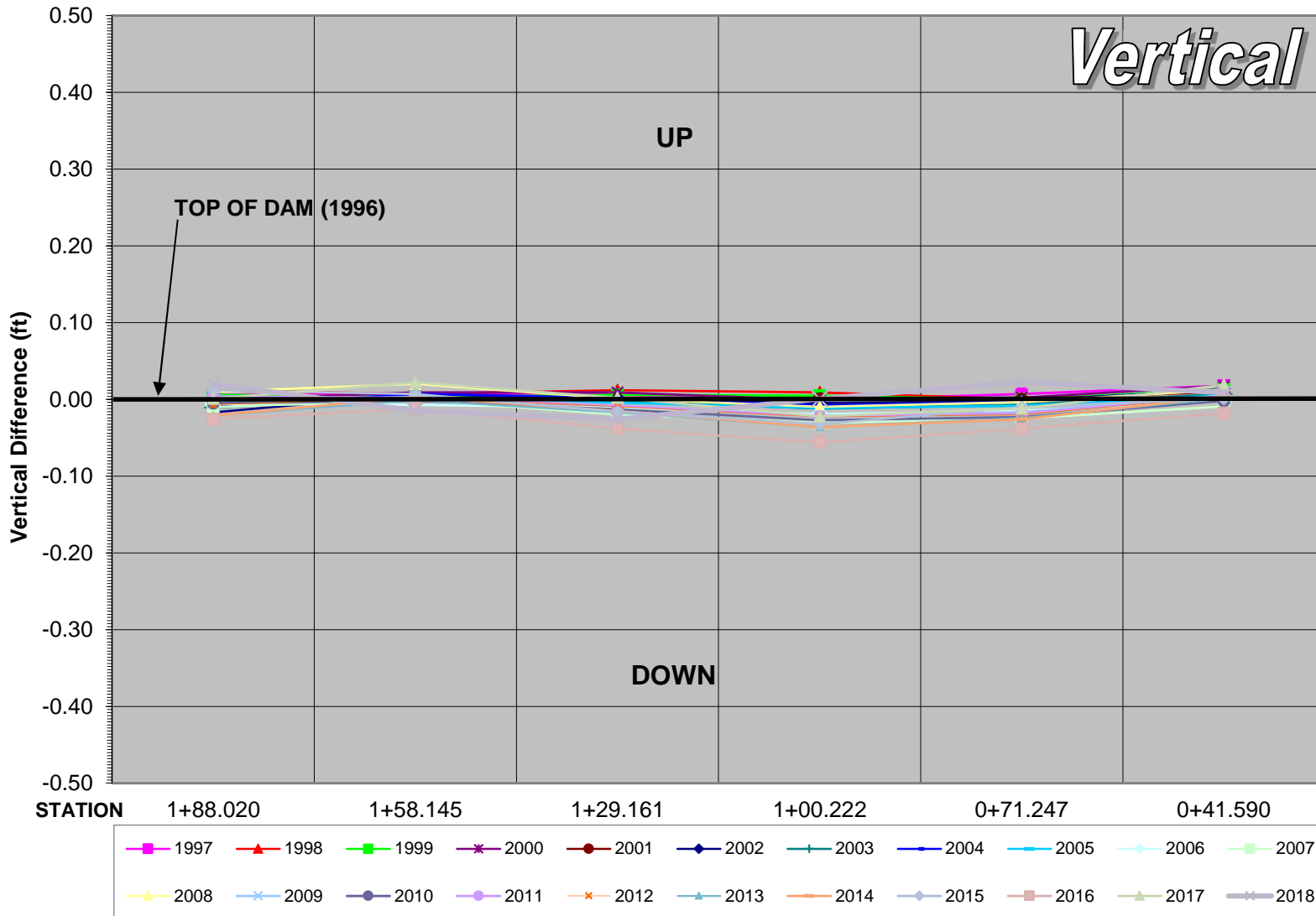


# Peters Canyon Dam Horizontal Movement Along Dam Axis (Difference from Planned Stationing)





**Peters Canyon Dam**  
**Vertical Movement (Difference from 1996 Elevations) - Profile View - *Looking Upstream***



# 3

# LOWER PETERS CANYON DAM



# Lower Peters Canyon Dam

Monitoring Survey

## Legend

- Benchmarks
- Monitoring Stations



Google Earth

© 2013 Google  
Image Landsat / Copernicus



## **Lower Peters Canyon Dam (F06D02) Monitoring Survey**

10/2/2018

Seven survey monuments were set along the top of levee in 1990. The 2004 survey will be used as the "benchmark" for all future surveys.

### **Chart Details**

Seven monuments were three-dimensionally positioned utilizing GPS Static survey techniques. Because of the layout of the monuments, horizontal comparisons will be shown as differences in the northing and easting, instead of the station and offset method.

Vertical differences are calculated comparing the elevation to the "2004 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values are shown in U.S. Survey feet.

## **Lower Peters Canyon Dam (F06D02) Monitoring Survey**

10/2/2018

### **Report Summary**

**2004** Initial survey performed.

**2005** No significant movement detected.

**2006** No significant movement detected.

**2009** No significant movement detected.

**2012** No significant movement detected. There is some vertical movement of benchmarks to watch in the future.

**2015** No significant movement detected. Possible settling of #2230.

**2018** No significant movement detected.

**2021**

**2024**

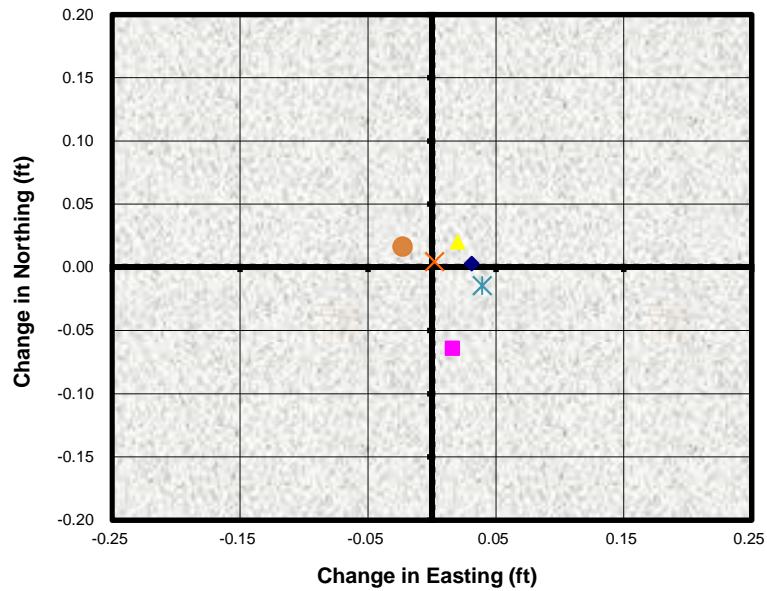
Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment

Vertical Datum = NAVD88, OCS 1995 Adjustment

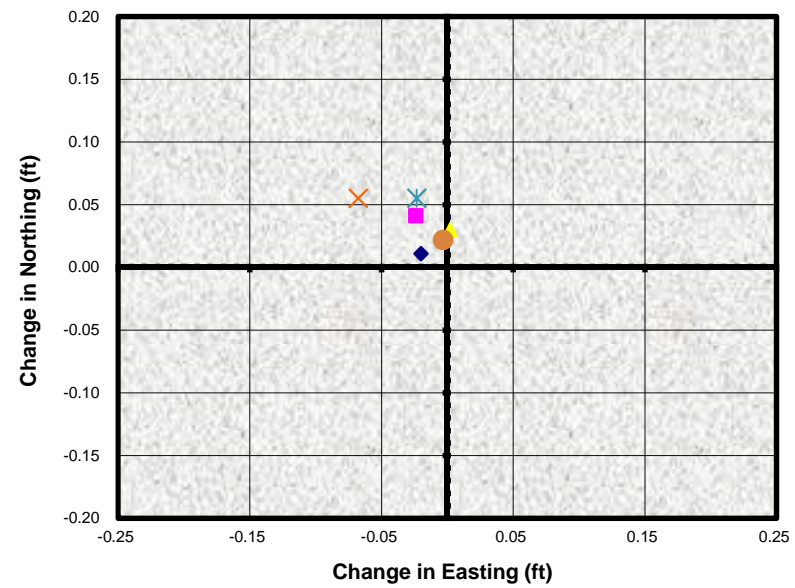
Lower Peters GPS

# Lower Peters Canyon Dam - (Horizontal) Horizontal Movement since 2004 Initial Survey

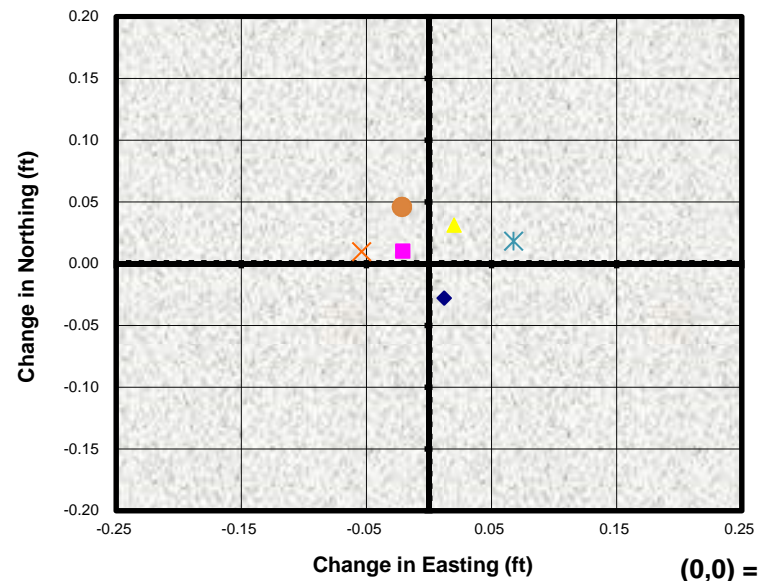
GPS 2225 (#1)



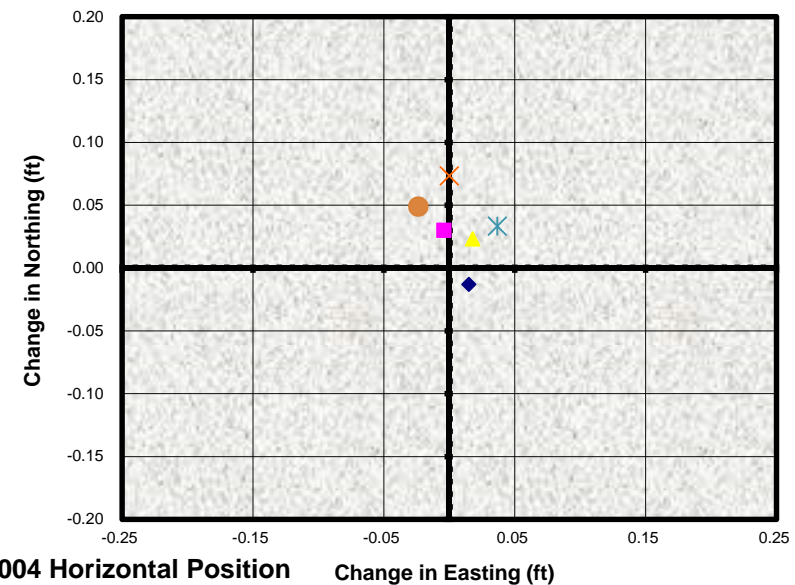
GPS 2226 (#2)



GPS 2227 (#3)



GPS 2228 (#4)

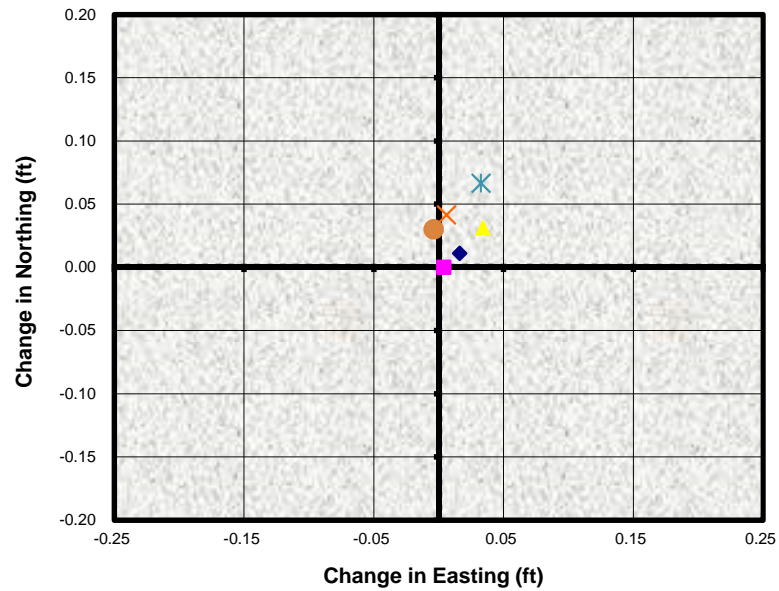


(0,0) = January 2004 Horizontal Position

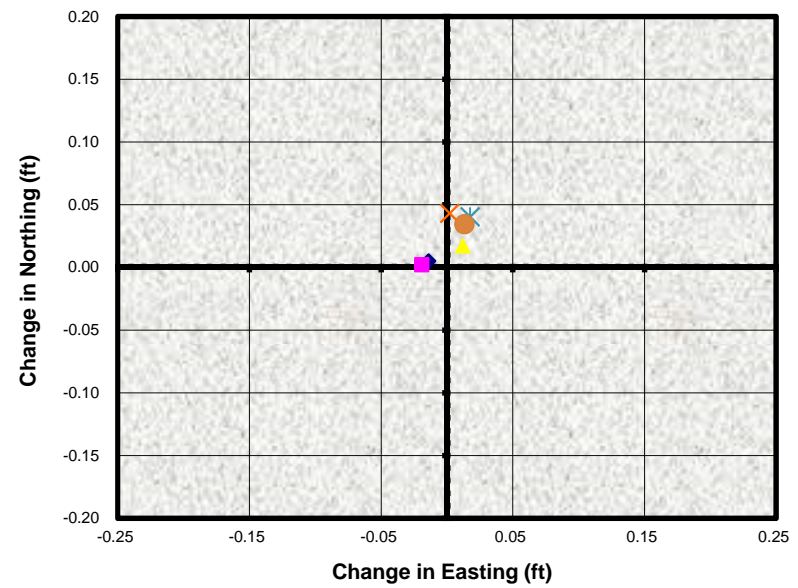


# Lower Peters Canyon Dam - (Horizontal) Horizontal Movement since 2004 Initial Survey

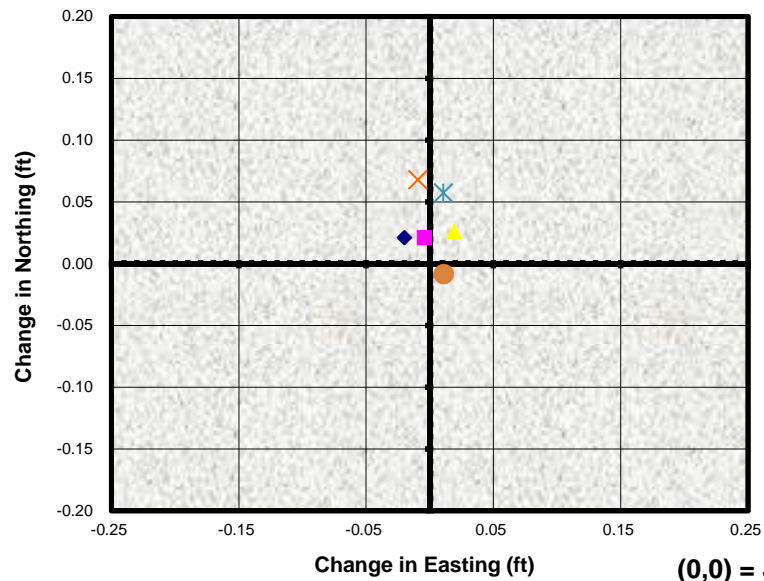
GPS 2229 (#5)



GPS 2230 (#6)

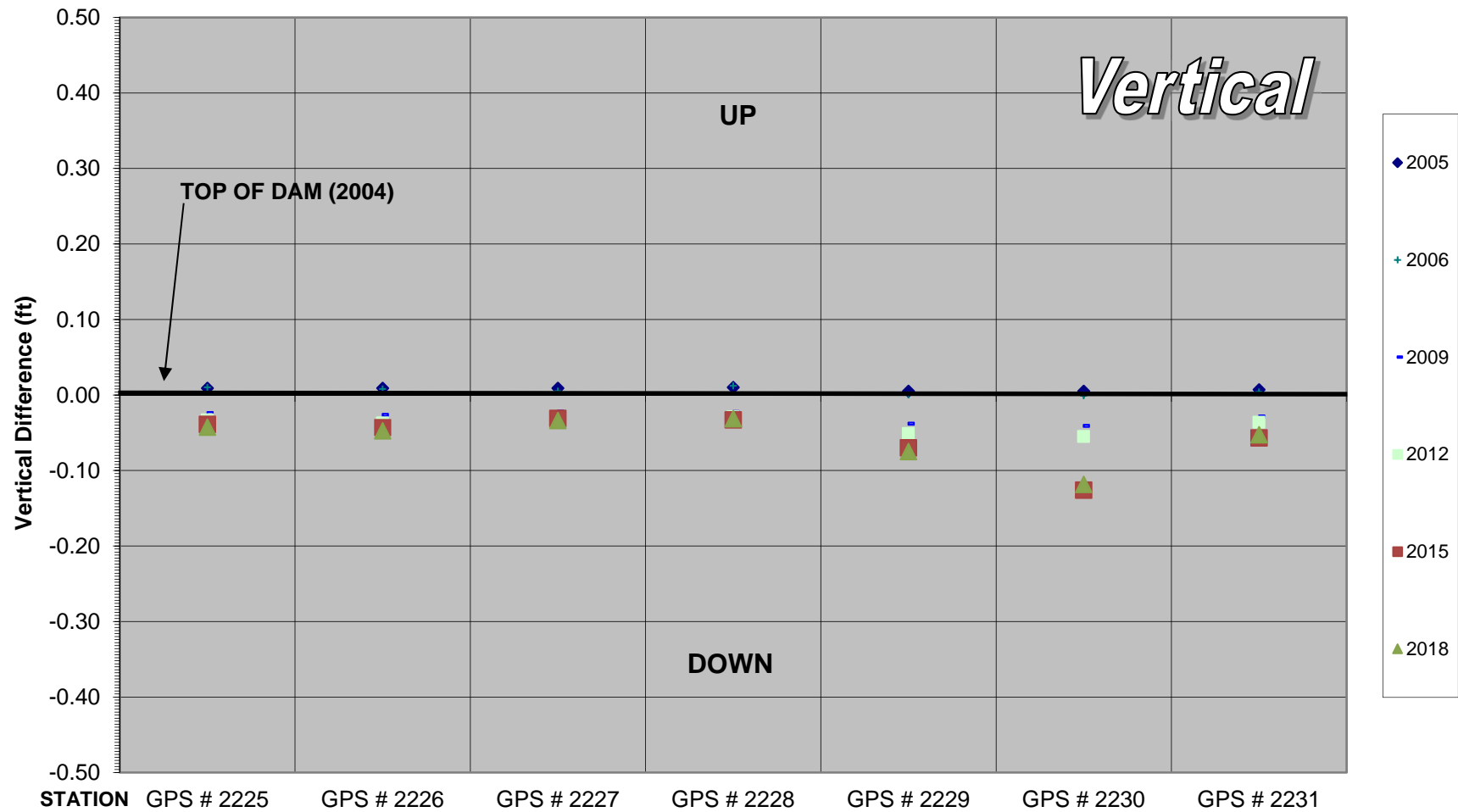


GPS 2231 (#7)



(0,0) = January 2004 Horizontal Position

Lower Peters Canyon Dam  
Vertical Movement (Orthometric Height Difference from 2004 Elevations)  
Profile View - Looking Upstream



# 4

# MARSHBURN RETARDING BASIN



# Marshburn Retarding Basin

Monitoring Survey

## Legend

- Benchmarks
- Monitoring Stations





## **Marshburn Retarding Basin (F16B01) Monitoring Survey**

Six survey monuments were set along the top of levee in 2001. This survey will be used as the "benchmark" for all future surveys.

### **Chart Details**

Six monuments were three-dimensionally positioned utilizing GPS Static survey techniques. Because of the layout of the monuments, horizontal comparisons will be shown as differences in the northing and easting, instead of the station and offset method.

Vertical differences are calculated comparing the elevation to the "2001 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values are shown in U.S. Survey feet.

Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment  
Vertical Datum = NAVD88, OCS 1995 Adjustment

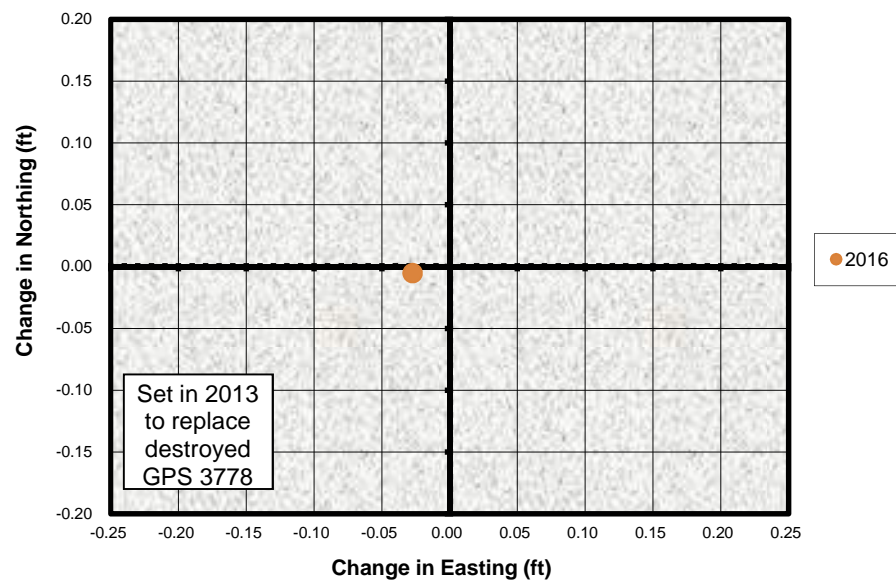
## **Marshburn Retarding Basin (F16B01) Monitoring Survey**

### **Report Summary**

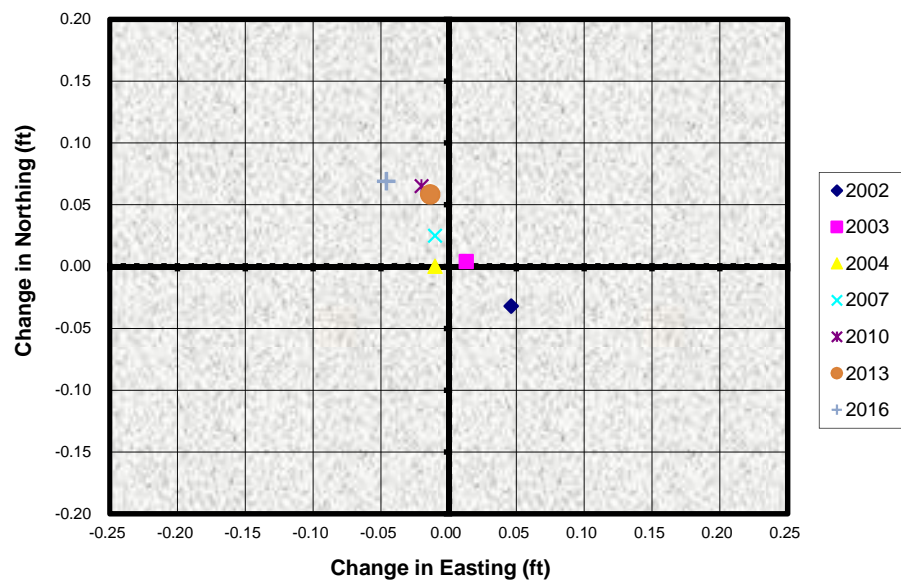
- 2001** Initial survey performed.
- 2002** No significant movement detected.
- 2003** No significant movement detected.
- 2004** No significant movement detected.
- 2007** GPS 3779, 3780 & 3781 have moved vertically -0.05' to -0.08' +/- from 2004 survey. GPS #3778 was destroyed.
- 2010** GPS 3779, 3780 & 3781 have moved vertically -0.02' +/- from 2007 survey.
- 2013** Set GPS #3766 to replace GPS #3778. No significant movement detected.
- 2016** No significant movement detected.
- 2019**
- 2022**
- 2025**

# Marshburn Retarding Basin - (Horizontal) Horizontal Movement since 2001 Initial Survey

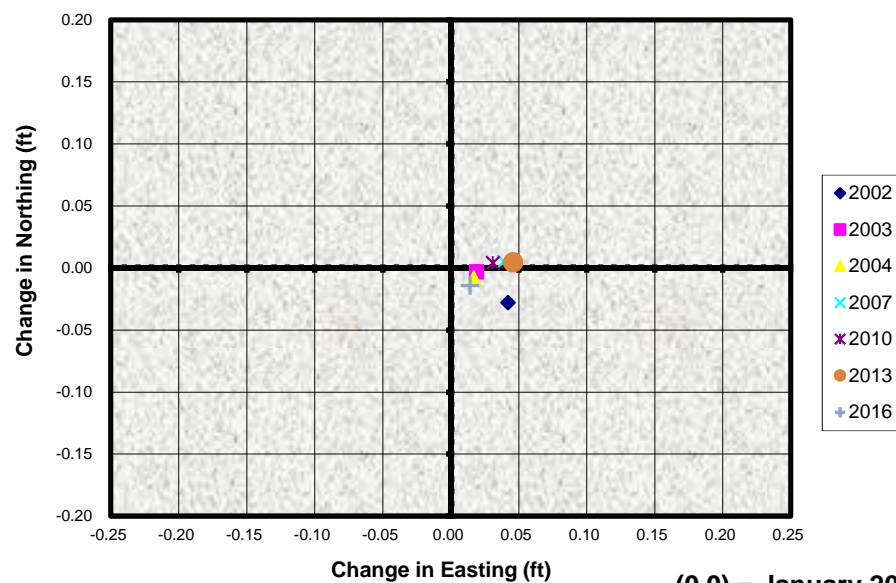
## GPS 3766



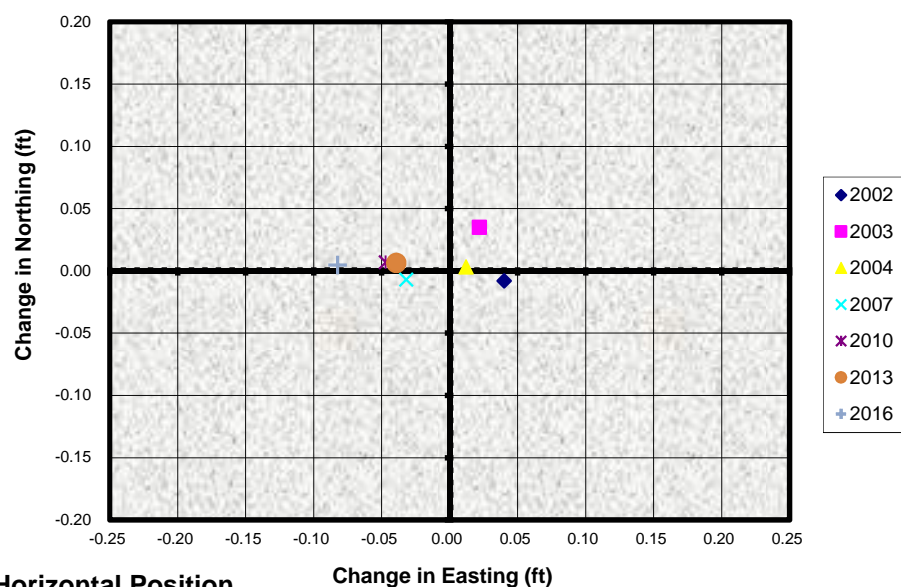
## GPS 3779



## GPS 3780



## GPS 3781

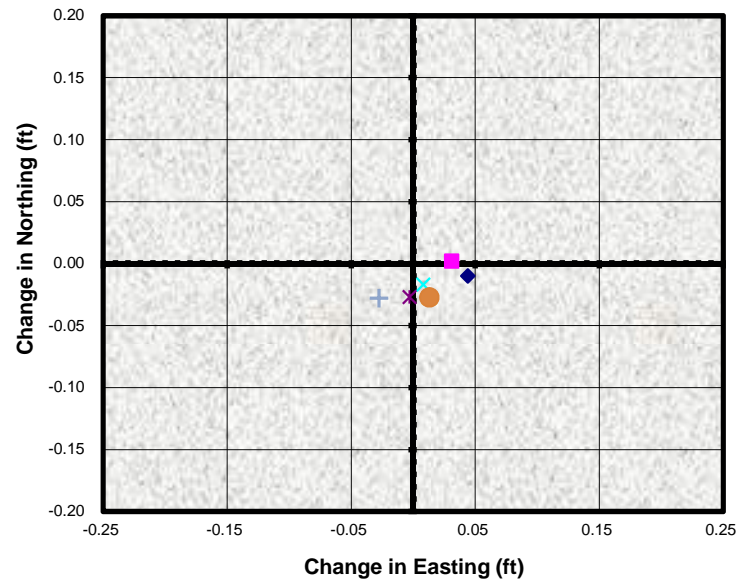


(0,0) = January 2001 Horizontal Position

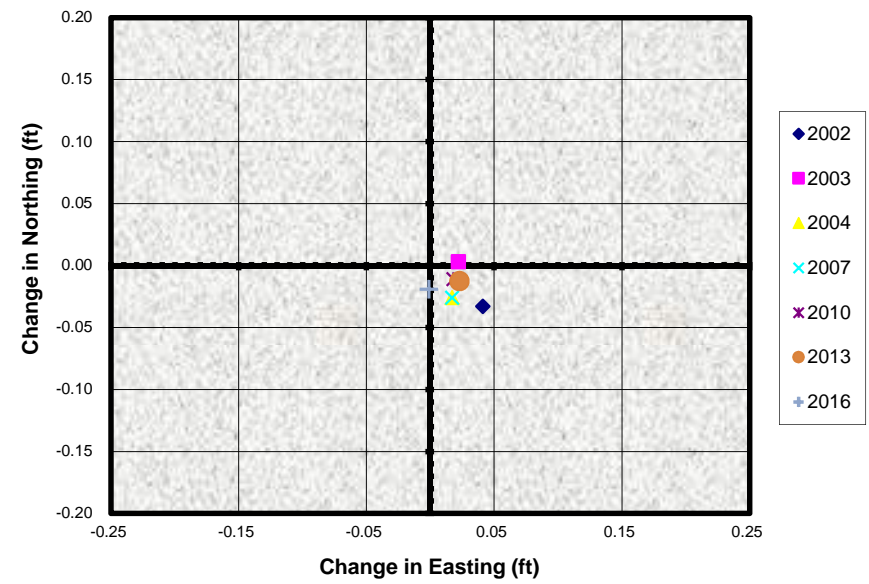


**Marshburn Retarding Basin - (Horizontal)**  
**Horizontal Movement since 2001 Initial Survey**

**GPS 3782**

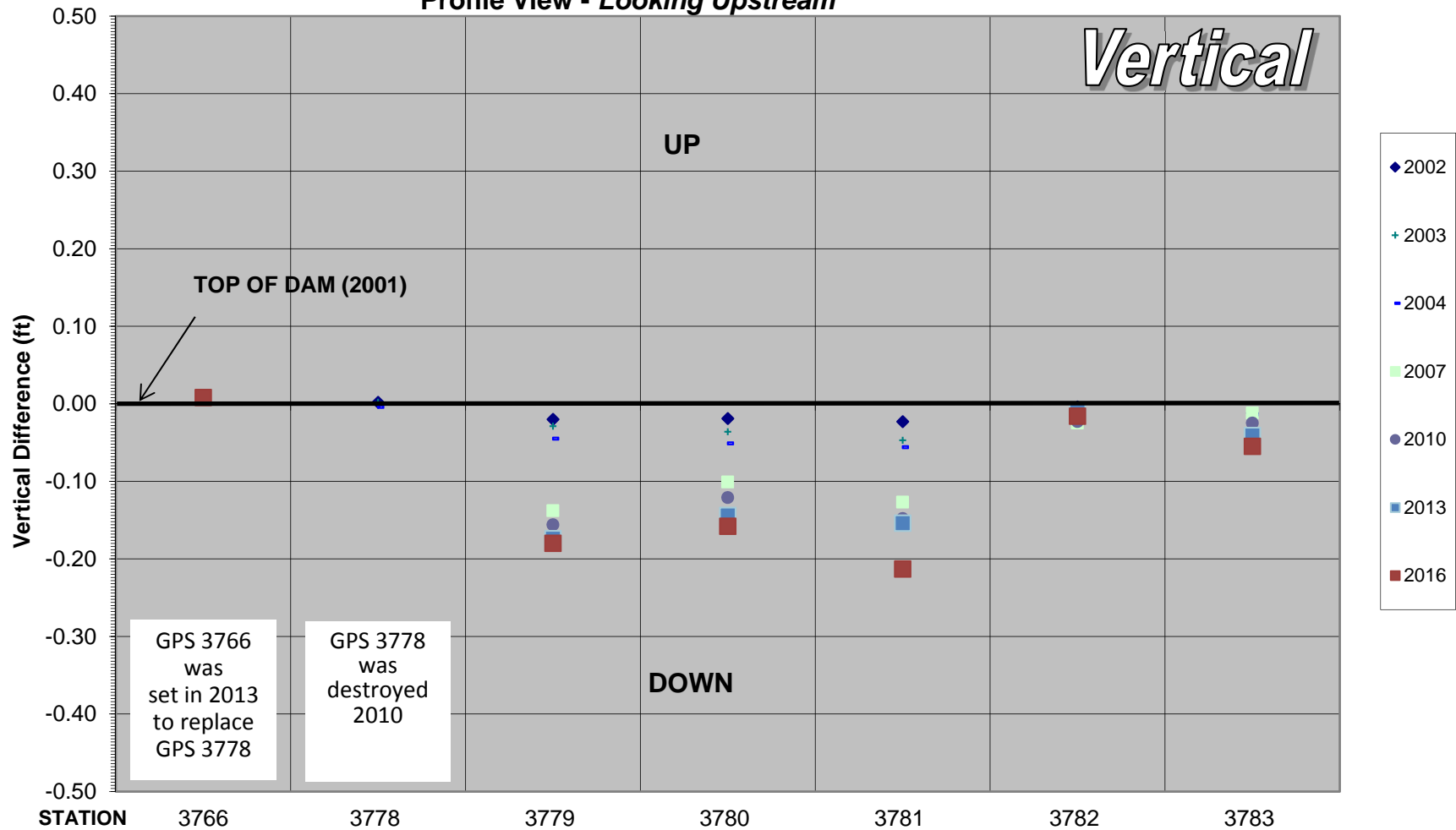


**GPS 3783**



**(0,0) = January 2001 Horizontal Position**

Marshburn Retarding Basin  
Vertical Movement (Orthometric Height Difference from 2001 Elevations)  
Profile View - Looking Upstream



# 5

# BEE CANYON RETARDING BASIN

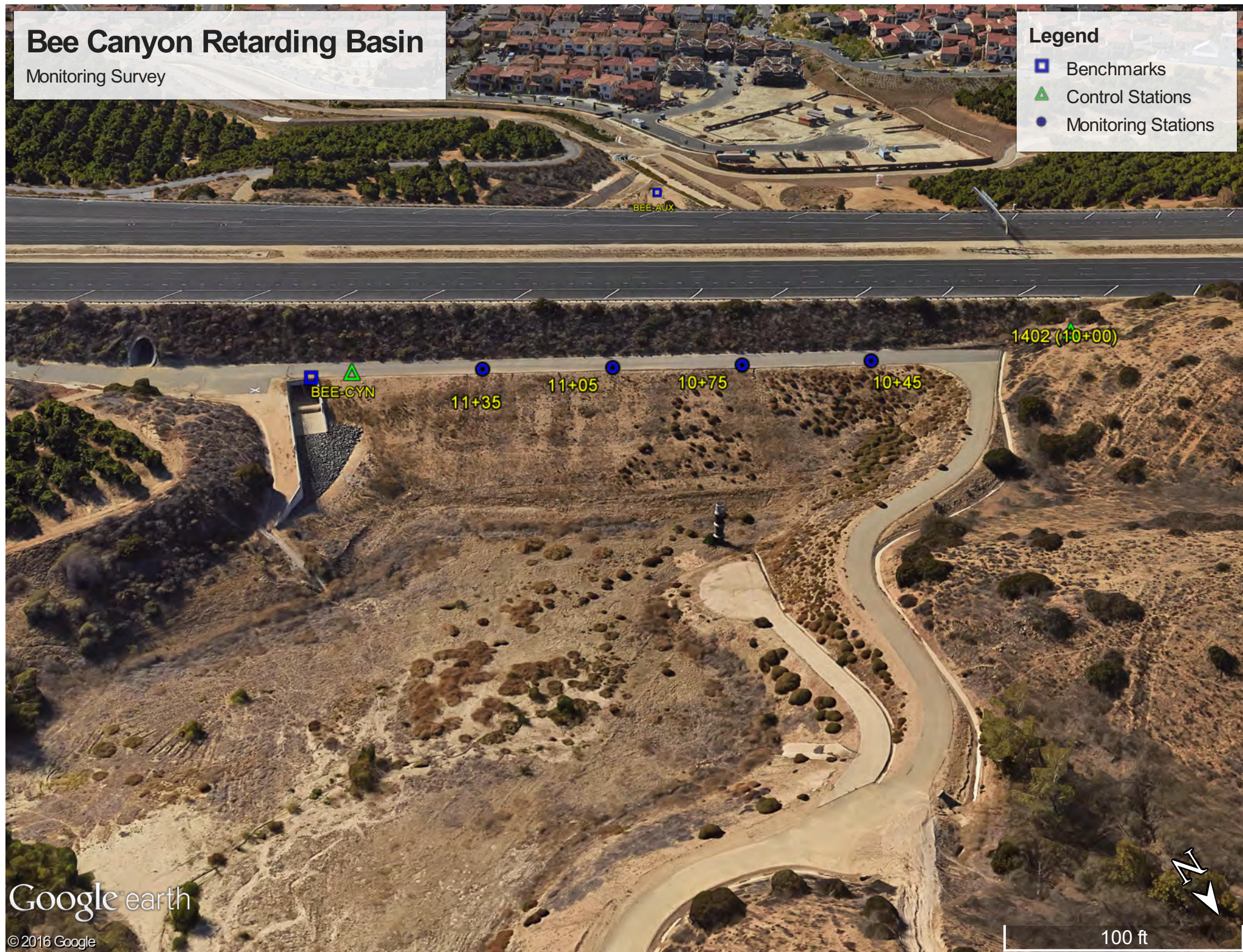


# Bee Canyon Retarding Basin

Monitoring Survey

## Legend

- Benchmarks
- ▲ Control Stations
- Monitoring Stations





## **Bee Canyon Retarding Basin (F16B02) Monitoring Survey**

This earthen dam was built in 1995. The first surveyed was performed in 1995 and is used as the "benchmark" for all future surveys.

### **Chart Details**

#### **Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Stations 10+00 and 11+65 are held for ***Out From Line*** calculations.

Positive numbers represent stations left of line (upstream), negative numbers represent stations right of line (downstream).

#### **Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Station 10+00 is held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing the elevation to the "1995 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values shown are in U.S. Survey feet. Station names are in meters.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

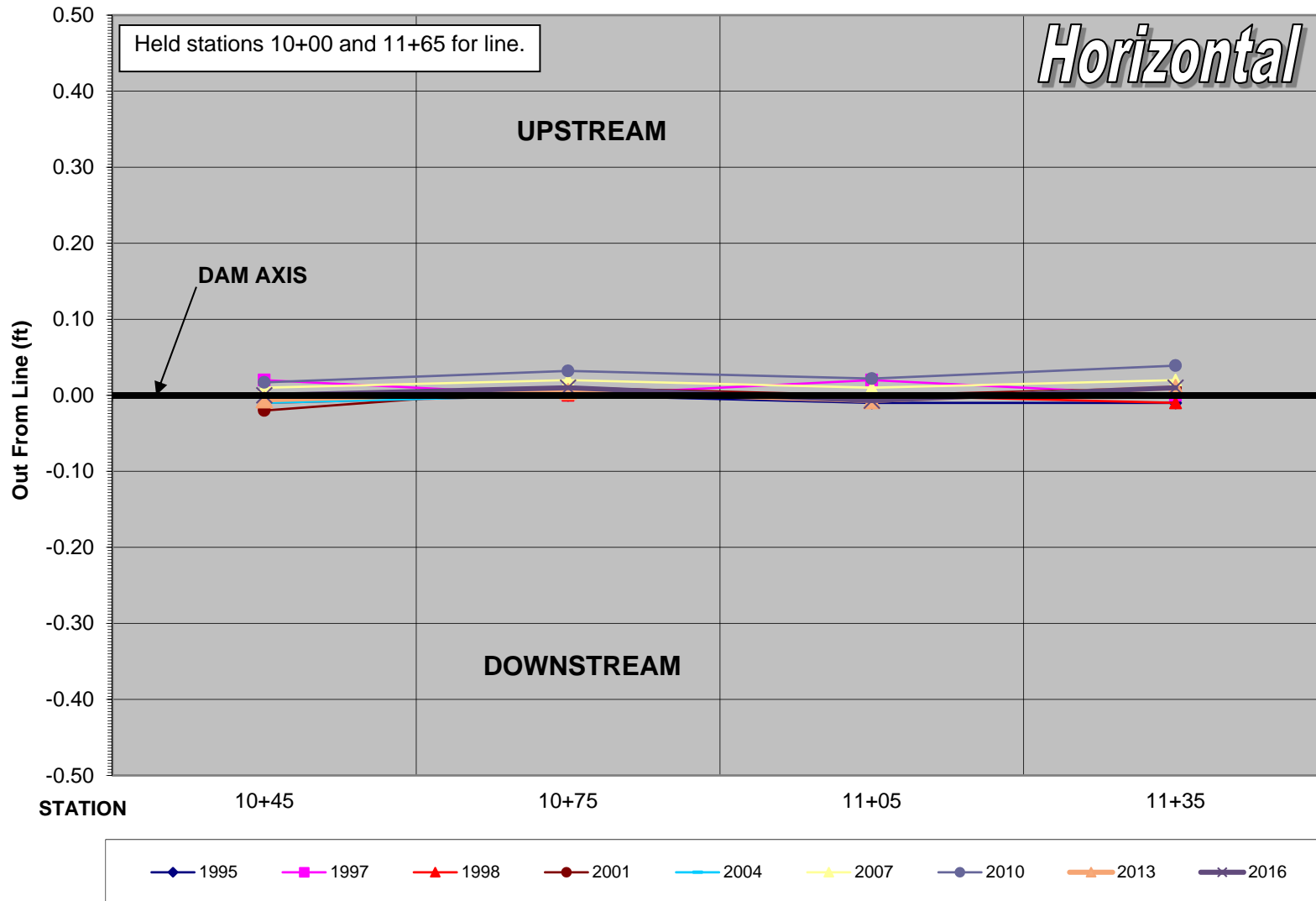
**Vertical Datum = NAVD88, OCS 1995 Adjustment**

## **Bee Canyon Retarding Basin (F16B02) Monitoring Survey**

### **Report Summary**

<b>1995</b>	Initial survey performed
<b>1996</b>	No survey performed
<b>1997</b>	Stations 10+75 and 11+05 subside approximately 0.07 feet. 11+35 subsides 0.04 feet. This could be due to settlement of the dam.
<b>1998</b>	Elevations for stations 10+75, 11+05, and 11+35 agree with the 1997 elevations within 0.01 ft. The 1997 movement seems to have stopped which was probably due to settlement of the earthen dam. Construction has been continual for the last two years for the Foothill Transportation Corridor which abutts up against the downstream side of the dam.
<b>2001</b>	No significant movement detected. Vertical subsidence trend continues.
<b>2004</b>	No significant movement detected.
<b>2007</b>	No significant movement detected.
<b>2010</b>	No significant movement detected. Corrected data errors discovered in the "Horizontal Movement Perpendicular to Dam Axis" for 2007.
<b>2013</b>	No significant movement detected.
<b>2016</b>	No significant movement detected.
<b>2019</b>	

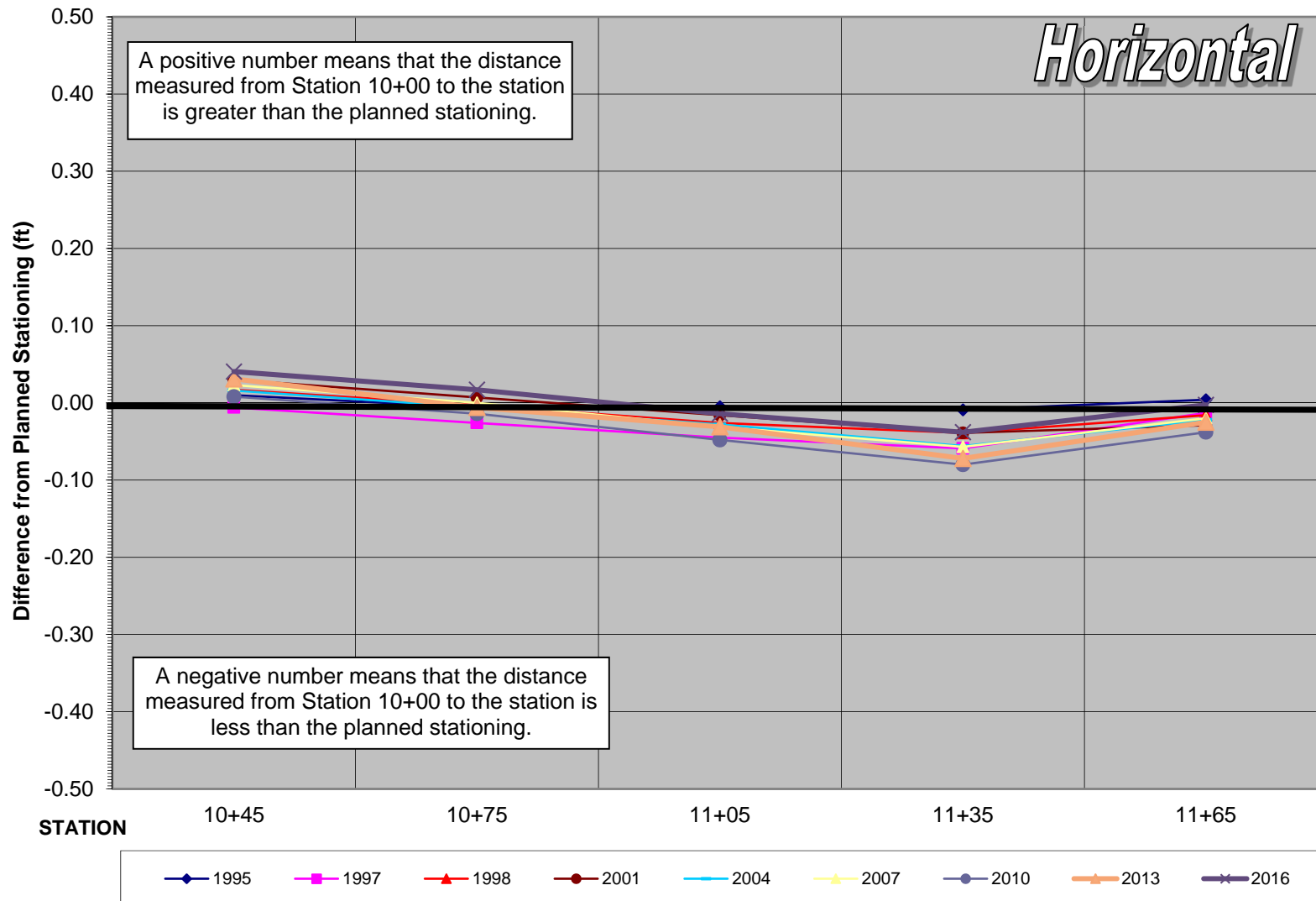
**Bee Canyon Dam**  
**Horizontal Movement Perpendicular to Dam Axis (Out From Line) - Plan View**



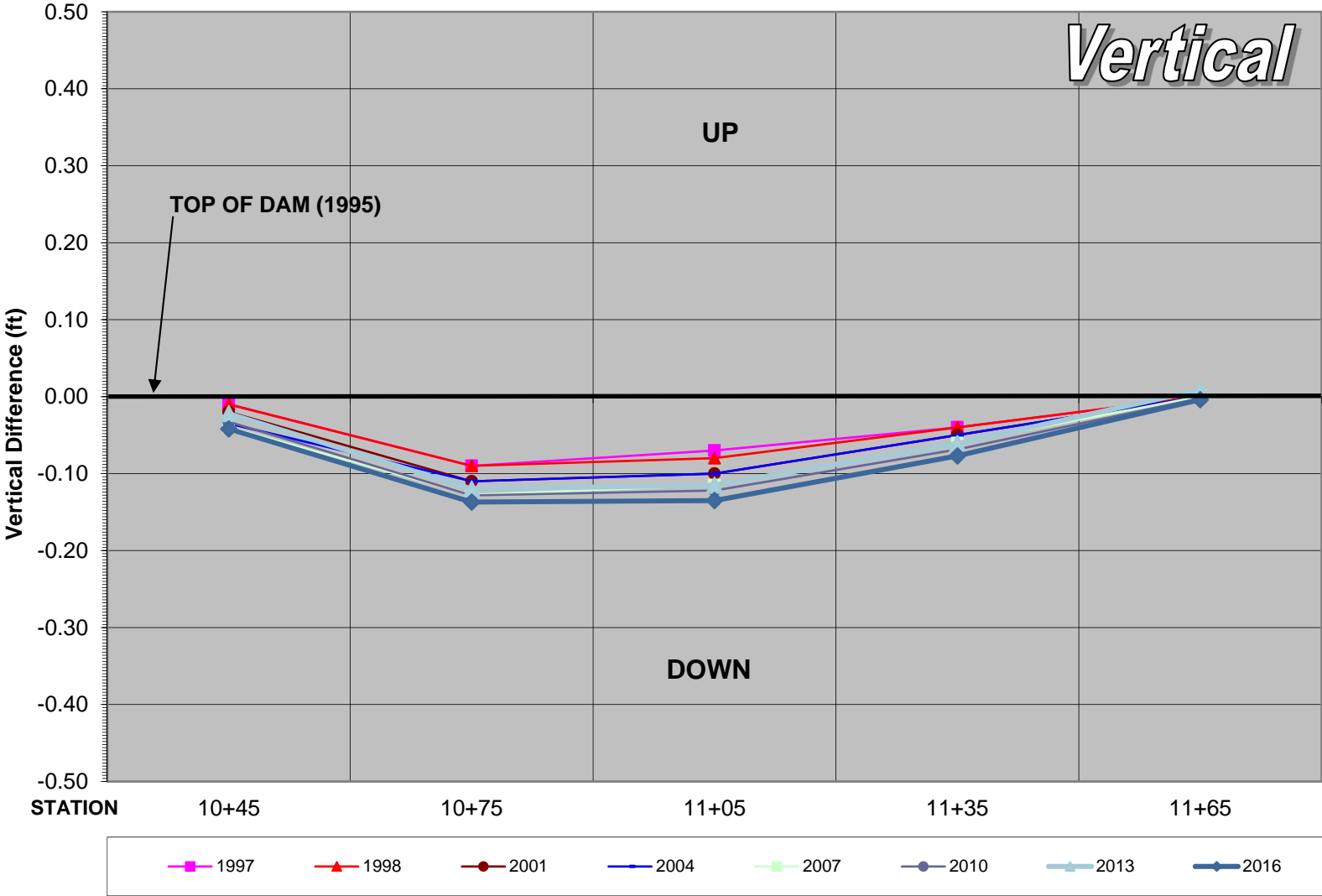


# Bee Canyon Dam

## Horizontal Movement Along Dam Axis (Difference from Planned Stationing)



**Bee Canyon Dam**  
**Vertical Movement (Difference from 1995 Elevations) - Profile View - *Looking Upstream***



# 6

# ROUND CANYON RETARDING BASIN

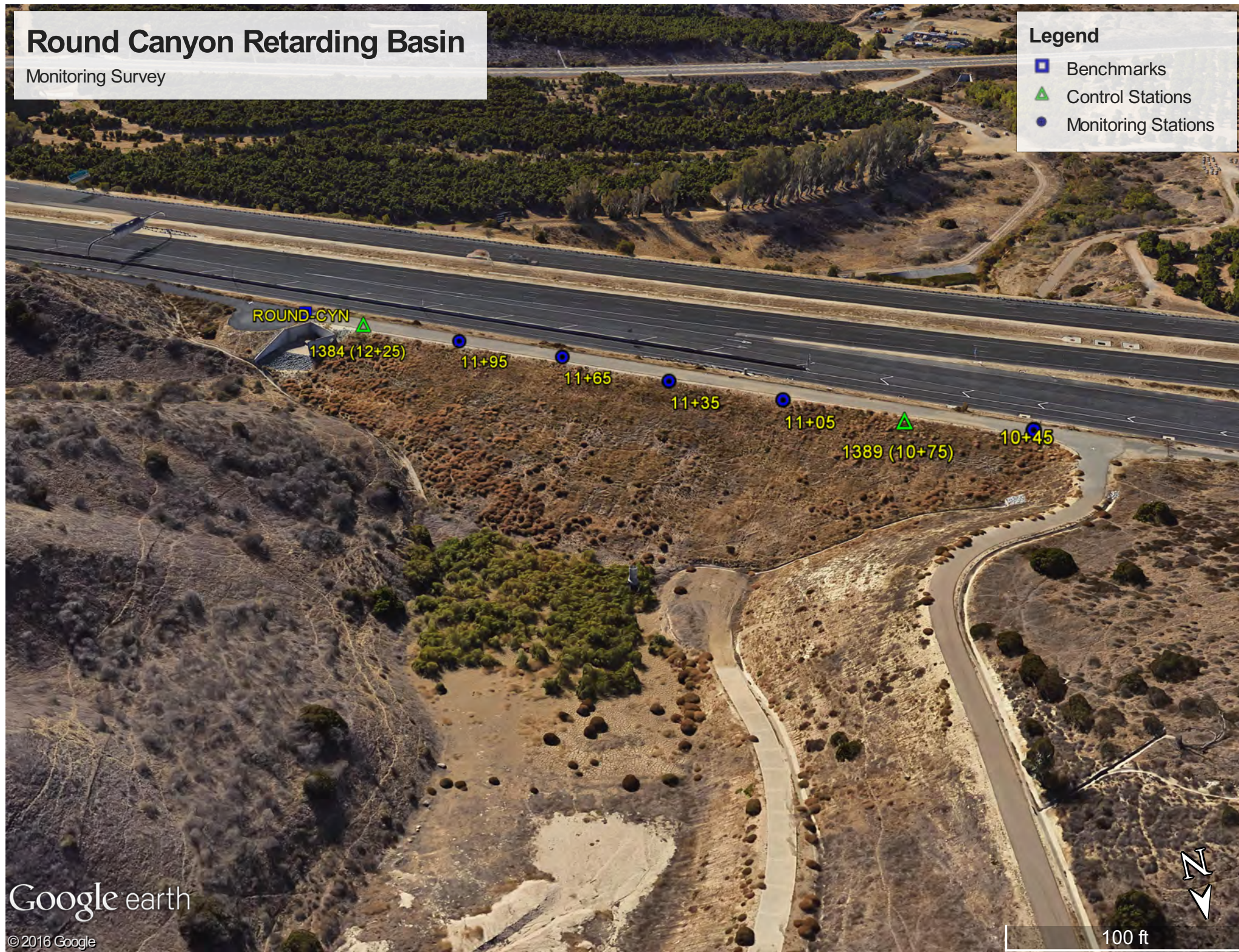


# Round Canyon Retarding Basin

Monitoring Survey

## Legend

- Benchmarks
- ▲ Control Stations
- Monitoring Stations





## **Round Canyon Retarding Basin (F16B03) Monitoring Survey**

This earthen dam was built in 1995. The first surveyed was performed in 1995 and is used as the "benchmark" for all future surveys.

### **Chart Details**

#### **Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Stations 10+75 and 12+25 are held for ***Out From Line*** calculations starting 1997. The original monitoring stations were destroyed shortly after 1995 survey.

Positive numbers represent stations left of line (upstream), negative numbers represent stations right of line (downstream).

#### **Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Station 12+25 is held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing the elevation to the "1995 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be at OC Survey Division, Geodetic Control Unit.

All values shown are in U.S. Survey feet. Station names are in meters.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

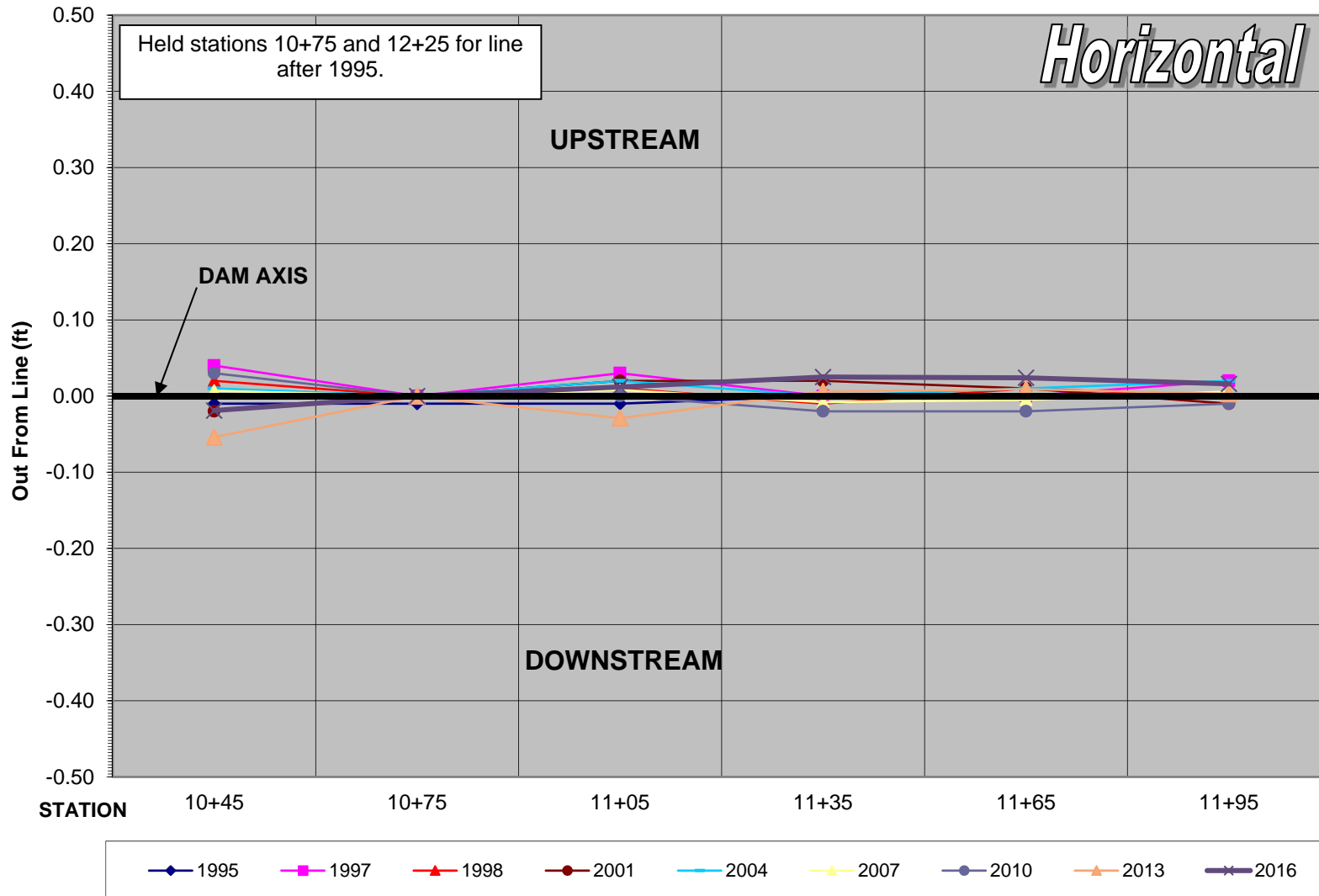
**Vertical Datum = NAVD88, OCS 1995 Adjustment**

## **Round Canyon Retarding Basin (F16B03) Monitoring Survey**

### **Report Summary**

<b>1995</b>	Initial survey performed.
<b>1996</b>	No survey performed.
<b>1997</b>	All stations show subsidence of approximately 0.05 feet. 12+25 shows none. This is probably due to settlement of the dam. Horizontal positions seem stable.
<b>1998</b>	The same stations from the 1997 survey show a decrease in the subsidence down to approximately 0.02 feet. Horizontal positions seem stable. Construction has been continual for the last two years for the Foothill Transportation Corridor which abuts up against the downstream side of the dam.
<b>2001</b>	No significant movement detected. Vertical subsidence trend continues.
<b>2004</b>	No significant movement detected.
<b>2007</b>	No significant movement detected.
<b>2010</b>	No significant movement detected.
<b>2013</b>	No significant movement detected.
<b>2016</b>	No significant movement detected. Vertical subsidence trend continues.
<b>2019</b>	

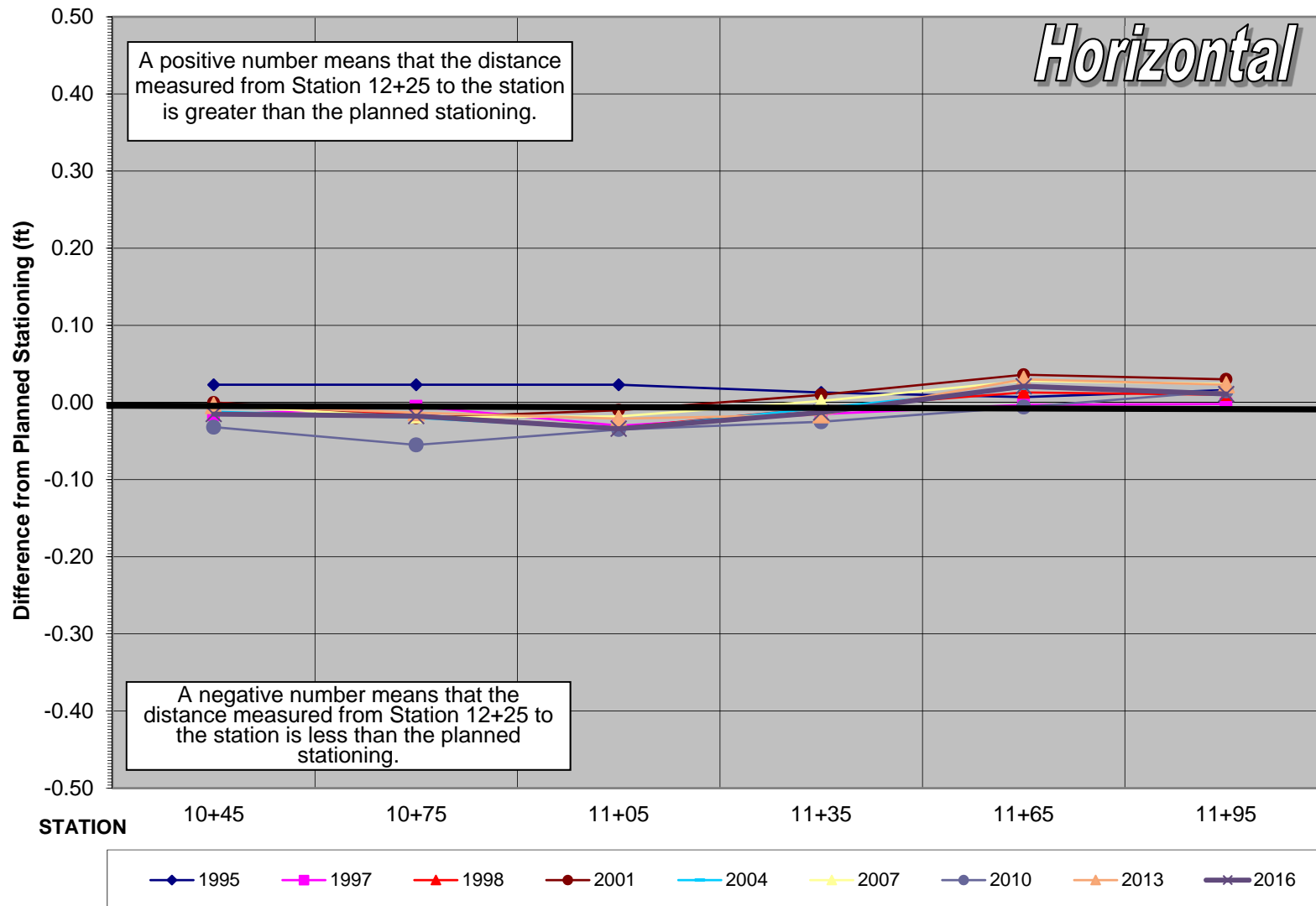
**Round Canyon Dam**  
**Horizontal Movement Perpendicular to Dam Axis (Out From Line) - Plan View**



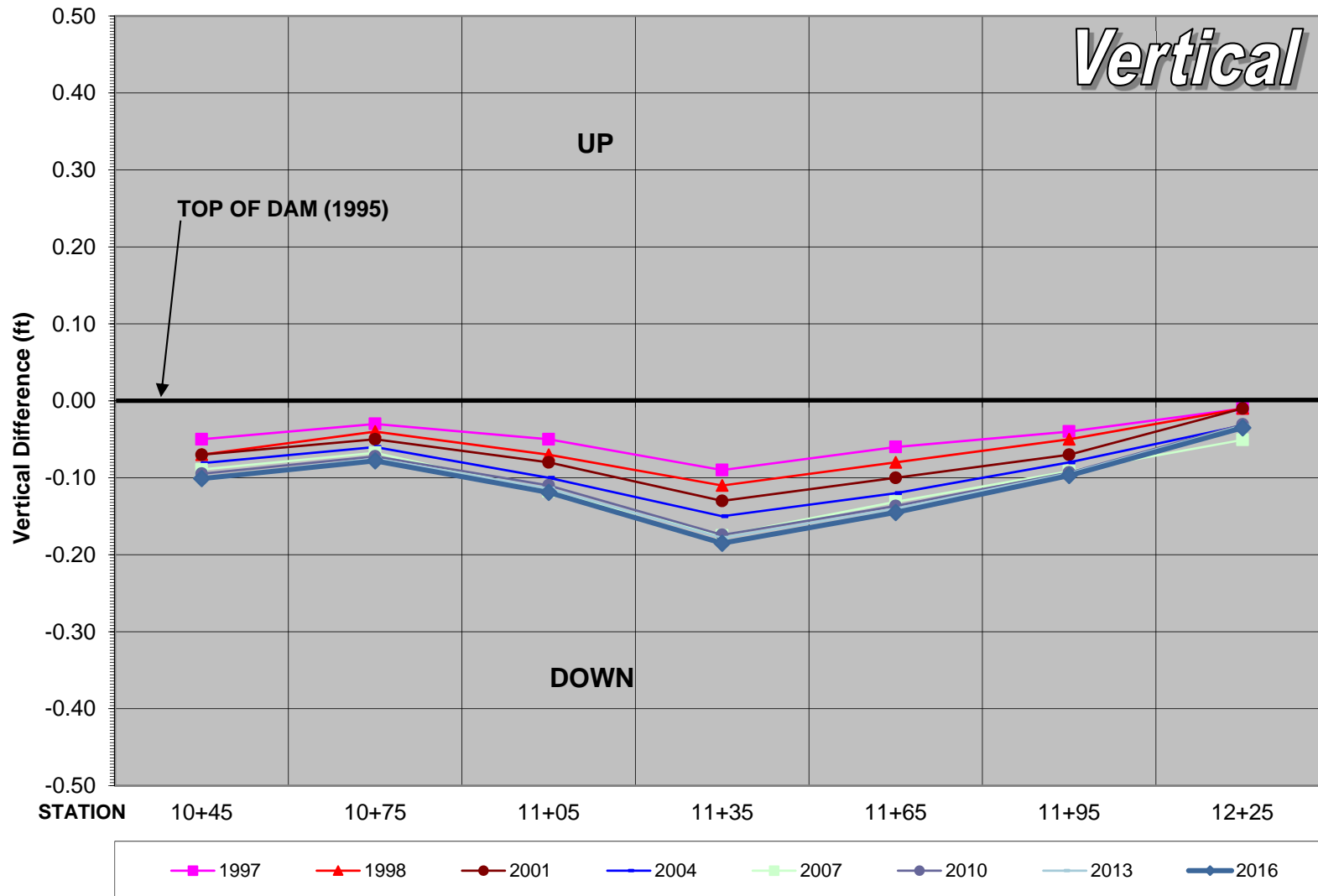


# Round Canyon Dam

## Horizontal Movement Along Dam Axis (Difference from Planned Stationing)



Round Canyon Dam  
Vertical Movement (Difference from 1995 Elevations) - Profile View - *Looking Upstream*



# 7

# AGUA CHINON RETARDING BASIN



# Agua Chinon Retarding Basin

Monitoring Survey

## Legend

- Benchmarks
- Monitoring Stations



Google Earth

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Image Landsat / Copernicus



## **Agua Chinon Retarding Basin (F18B01) Monitoring Survey**

10/1/2018

This earthen dam was built and first surveyed in 1998. This survey will be used as the "benchmark" for all future surveys.

### **Chart Details**

Four monuments were three-dimensionally positioned utilizing GPS Static survey techniques. Because of the layout of the monuments, horizontal comparisons will be shown as differences in the northing and easting, instead of the station and offset method.

Vertical differences are calculated comparing the elevation to the "1998 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values are shown in U.S. Survey feet.

## **Agua Chinon Retarding Basin (F18B01) Monitoring Survey**

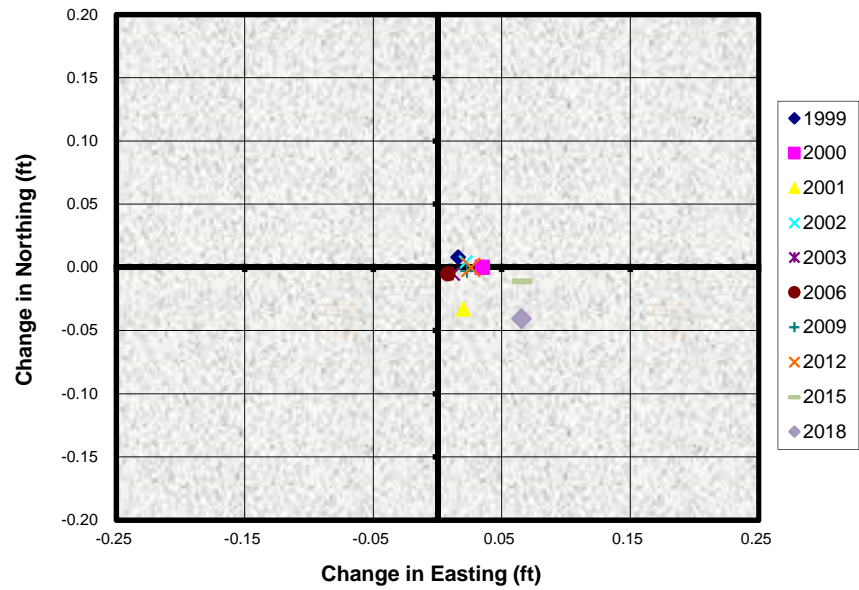
10/1/2018

### **Report Summary**

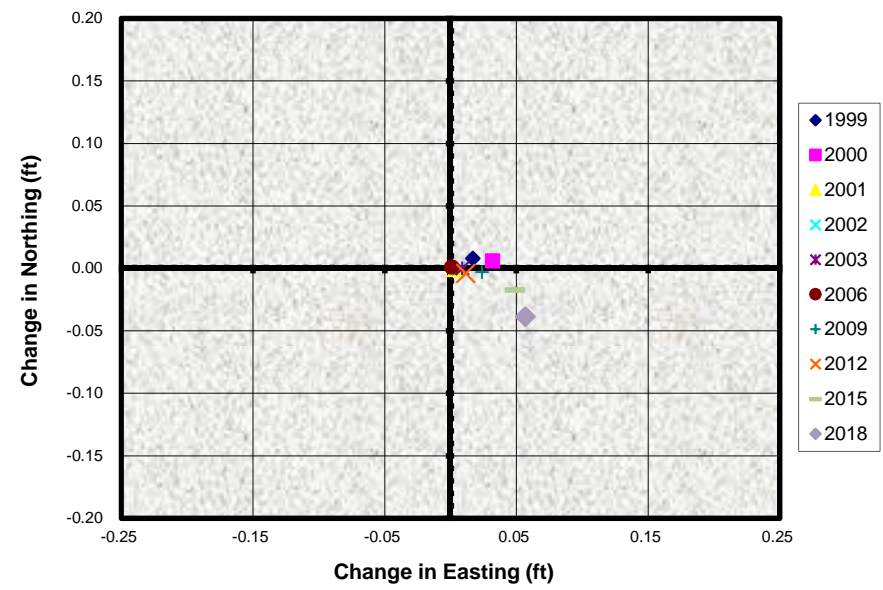
**1998** Initial survey performed  
**1999** No significant movement detected.  
**2000** No significant movement detected.  
**2001** No significant movement detected.  
**2002** No significant movement detected.  
**2003** No significant movement detected.  
**2006** No significant movement detected.  
**2009** No significant movement detected.  
**2012** No significant movement detected.  
**2015** No significant movement detected.  
**2018** All monuments show slight southeast shift which may be due to land deformation between basin and OEOC.  
**2021**  
**2024**

# Agua Chinon Dam - (Horizontal) Horizontal Movement from 1998 Initial Survey

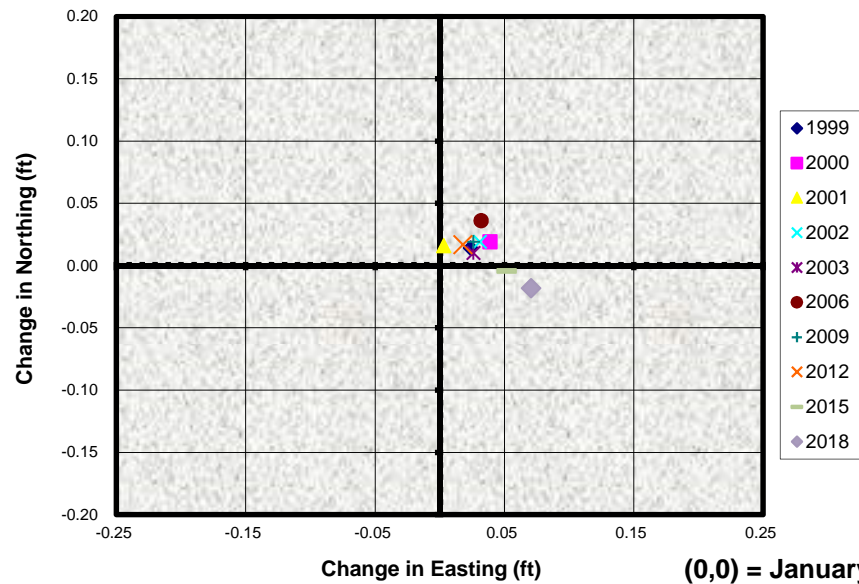
GPS 0980 (14+39)



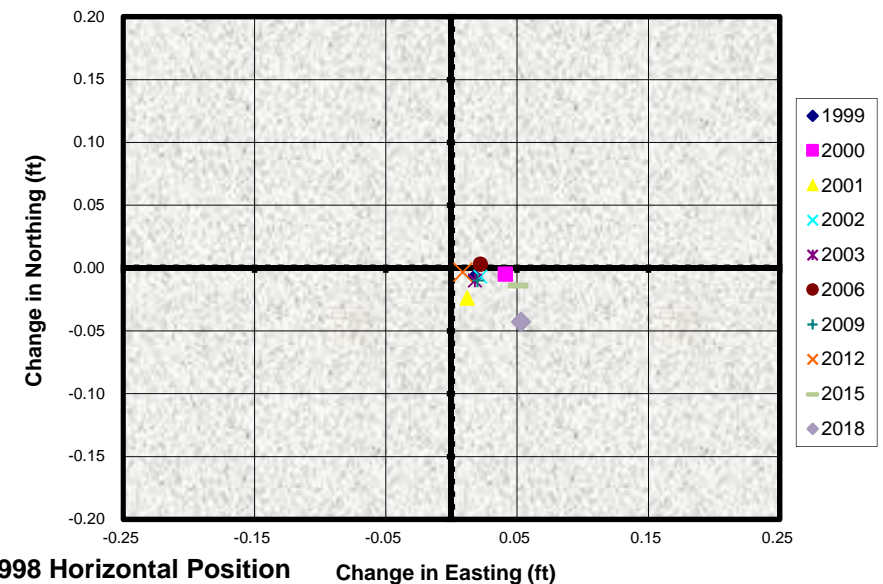
GPS 0981 (12+64)



GPS 0982 (11+46)



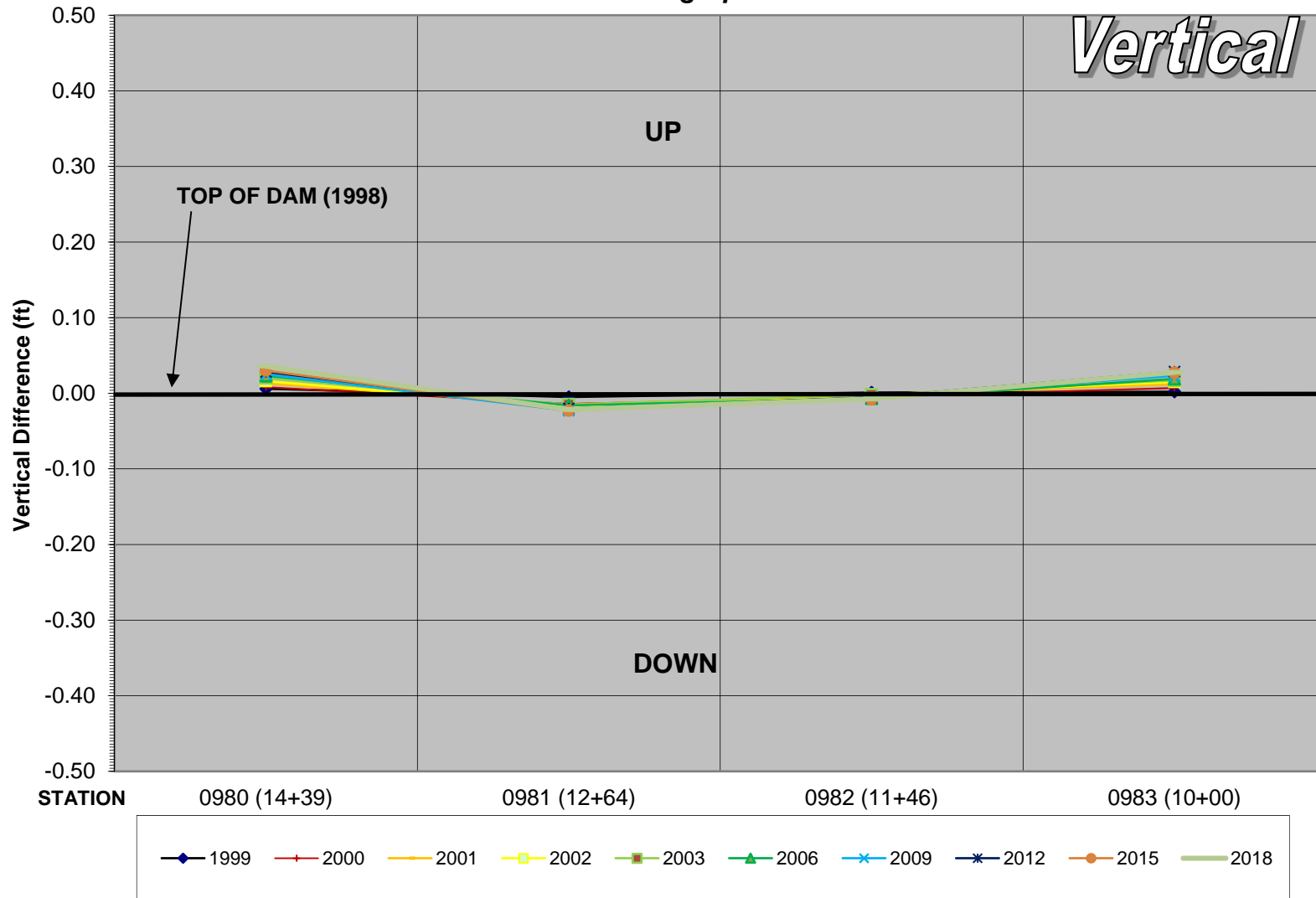
GPS 0983 (10+00)



(0,0) = January 1998 Horizontal Position



**Agua Chinon Dam**  
**Vertical Movement (Orthometric Height Difference from 1998 Elevations)**  
**Profile View - Looking Upstream**



# 8




# TRABUCO RETARDING BASIN



# Trabuco Retarding Basin

Monitoring Survey

## Legend

-  Benchmarks
-  Control Stations
-  Monitoring Stations



Google earth

© 2016 Google



## **Trabuco Retarding Basin (F25B01) Monitoring Survey**

Seven survey monuments were set along the top of levee in 2001. This survey will be used as the "benchmark" for all future surveys.

### **Chart Details**

Seven monuments were three-dimensionally positioned utilizing GPS Static survey techniques. Because of the layout of the monuments, horizontal comparisons will be shown as differences in the northing and easting, instead of the station and offset method.

Vertical differences are calculated comparing the elevation to the "2001 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values are shown in U.S. Survey feet.

Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment  
Vertical Datum = NAVD88, OCS 1995 Adjustment

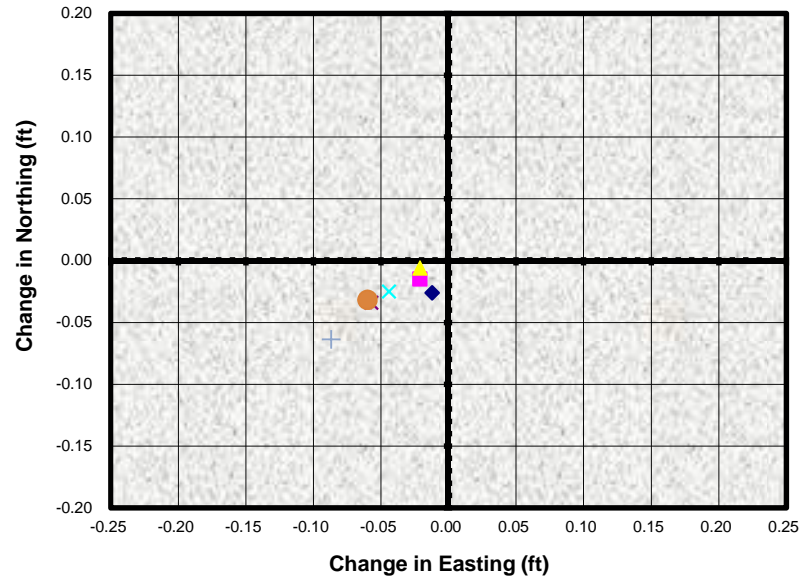
## **Trabuco Retarding Basin (F25B01) Monitoring Survey**

### **Report Summary**

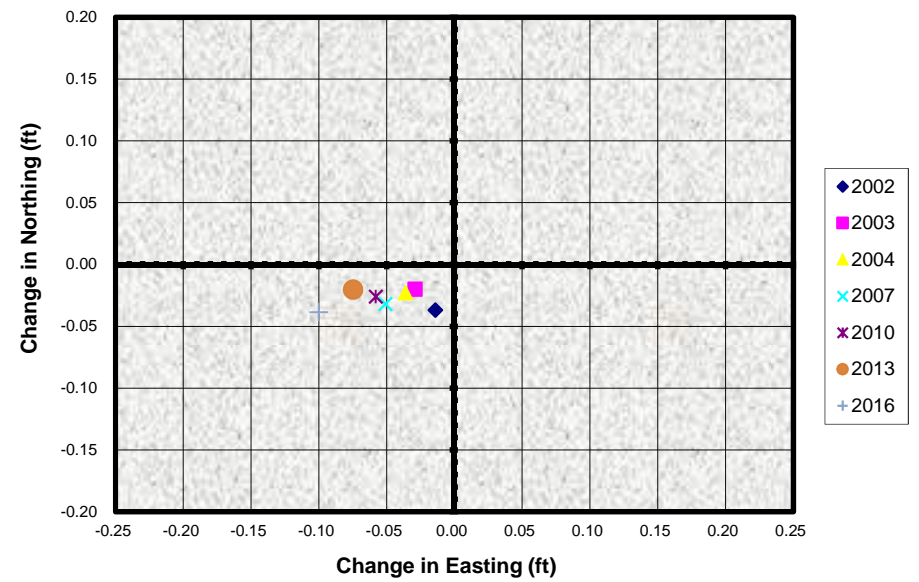
<b>2001</b>	Initial survey performed.
<b>2002</b>	No significant movement detected.
<b>2003</b>	No significant movement detected.
<b>2004</b>	No significant movement detected.
<b>2007</b>	No significant movement detected. GPS # 3774 appears to have disturbed by construction.
<b>2010</b>	GPS #3773 & #3776 were destroyed by construction.
<b>2013</b>	Set GPS #3764 & #3765 to replace monuments destroyed in 2010. No significant movement detected.
<b>2016</b>	GPS #3764 not found. Possible SW movement on GPS#3770.
<b>2019</b>	

# Trabuco Retarding Basin - (Horizontal) Horizontal Movement since 2001 Initial Survey

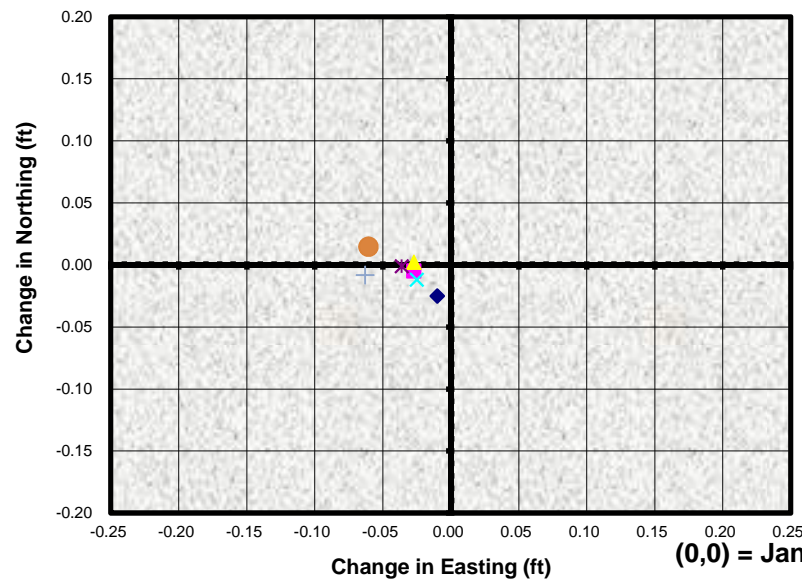
## GPS 3770



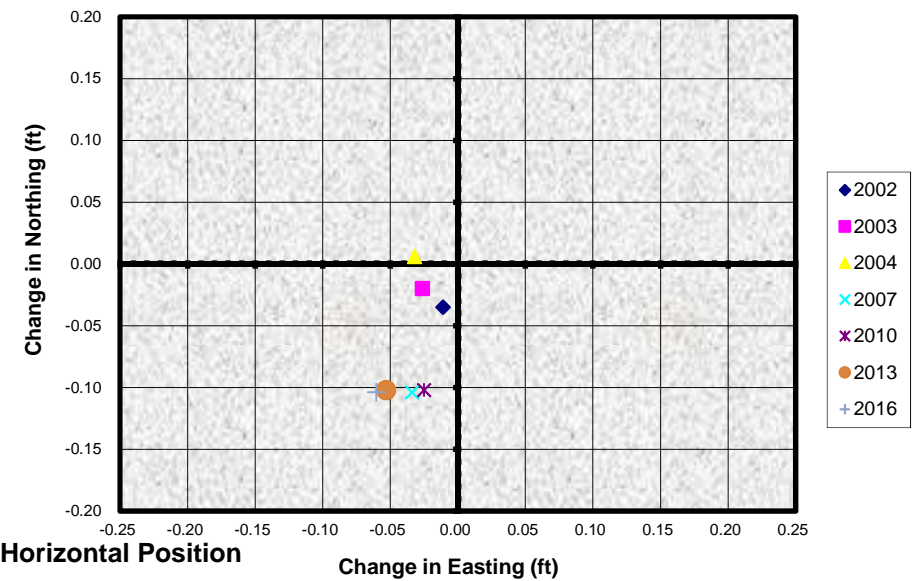
## GPS 3771



## GPS 3772



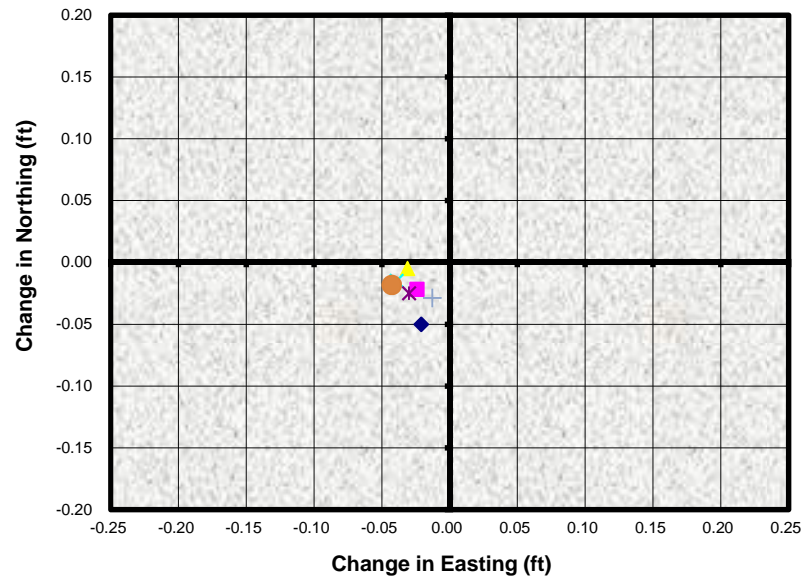
## GPS 3774



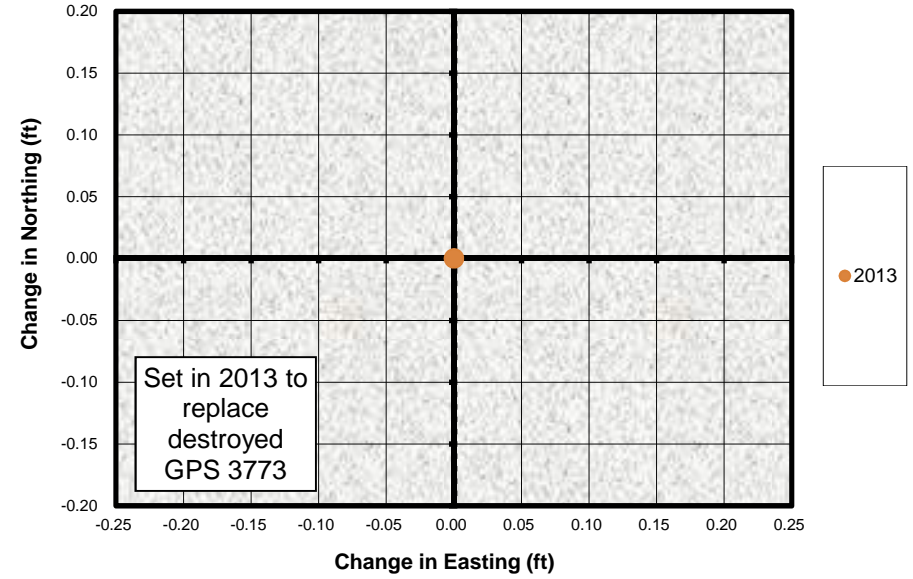
(0,0) = January 2001 Horizontal Position

# Trabuco Retarding Basin - (Horizontal) Horizontal Movement since 2001 Initial Survey

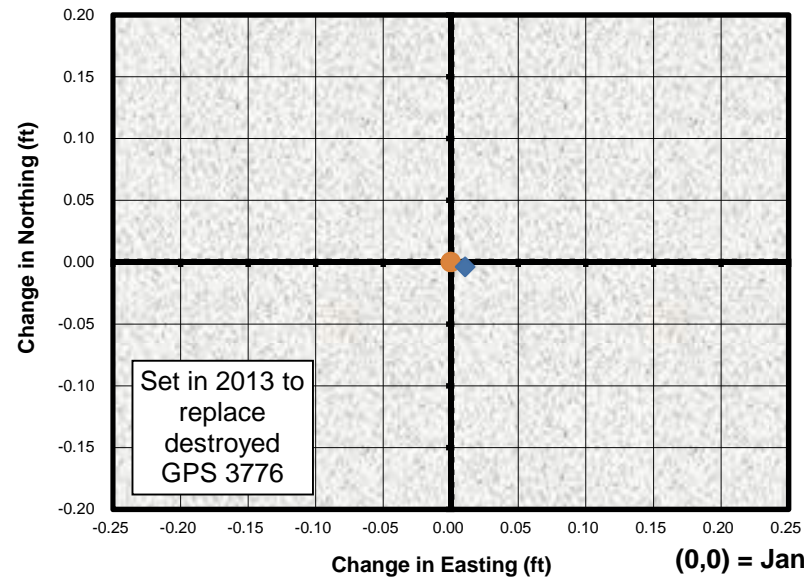
## GPS 3775



## GPS 3764



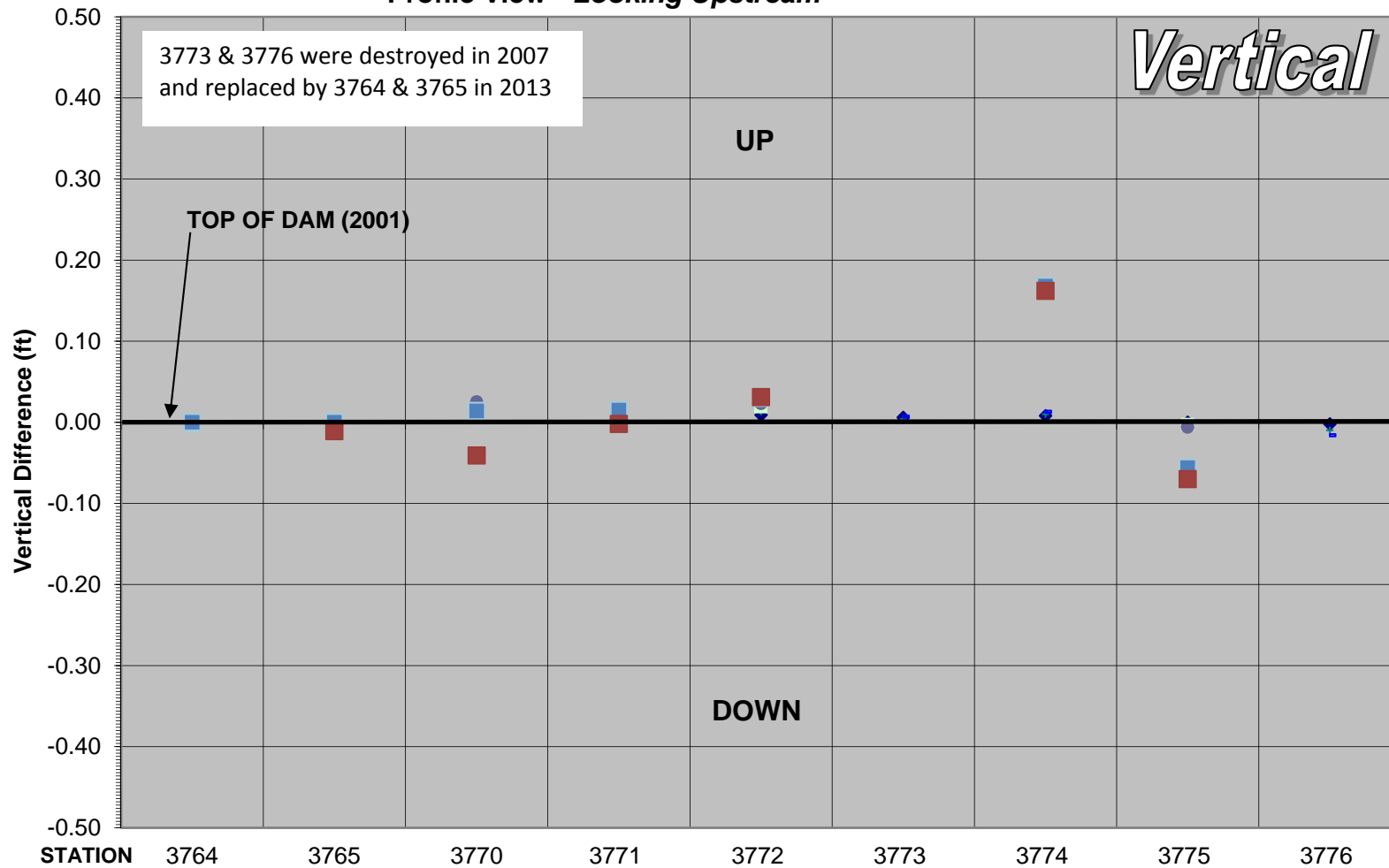
## GPS 3765



(0,0) = January 2001 Horizontal Position



**Trabuco Retarding Basin**  
**Vertical Movement (Orthometric Difference from 2001 Elevations)**  
**Profile View - Looking Upstream**



◆ 2002

+ 2003

- 2004

■ 2007

● 2010

■ 2013

■ 2016

# 9




# ORCHARD ESTATES RETARDING BASIN



# Orchard Estates Retarding Basin

Monitoring Survey

## Legend

-  Control Stations
-  Benchmarks
-  Monitoring Stations



Google earth

© 2016 Google

600 ft



## **Orchard Estates Retarding Basin (F26B02) Monitoring Survey**

Seven survey monuments were set along the top of levee in 2001. This survey will be used as the "benchmark" for all future surveys.

### **Chart Details**

#### **Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Stations 1+00 and 10+00 are held for ***Out From Line*** calculations.

Positive numbers represent stations right of line (upstream), negative numbers represent stations left of line (downstream).

#### **Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Station 1+00 is held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing each elevation to the "2001 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values are shown in U.S. Survey feet.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

**Vertical Datum = NAVD88, OCS 1995 Adjustment**

## **Orchard Estates Retarding Basin (F26B02) Monitoring Survey**

### **Report Summary**

<b>2001</b>	Initial survey performed. Comparisons will begin 2002.
<b>2002</b>	No Significant Movement Detected on dam monitoring points. 2002 height of benchmark "Orchard" located on spillway headwall differs by -0.10' than 2001 height.
<b>2003</b>	Stations 7+00 and 8+50 show gradual settling.
<b>2004</b>	No Significant Movement Detected.
<b>2007</b>	No Significant Movement Detected.
<b>2010</b>	No Significant Movement Detected.
<b>2013</b>	Station 7+00 shows slight horizontal movement downstream. Stations 7+00 and 8+00 show continual vertical settling.
<b>2016</b>	Stations 7+00 and 8+00 show continual vertical settling.
<b>2019</b>	

Held stations 1+00 and 10+00 for line.

*Horizontal*

UPSTREAM

DAM AXIS

DOWNSTREAM

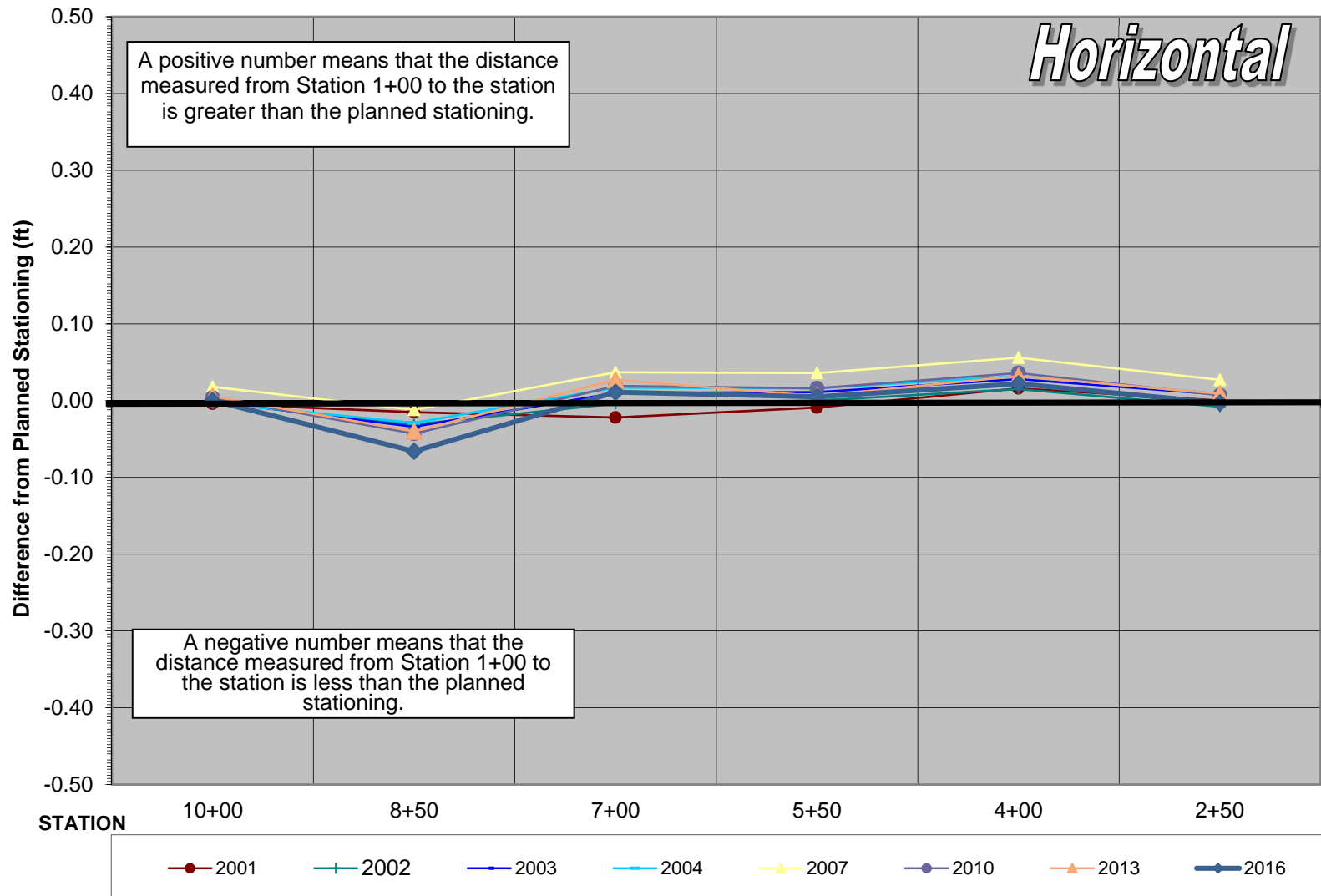
STATION

8+50 7+00 5+50 4+00 2+50

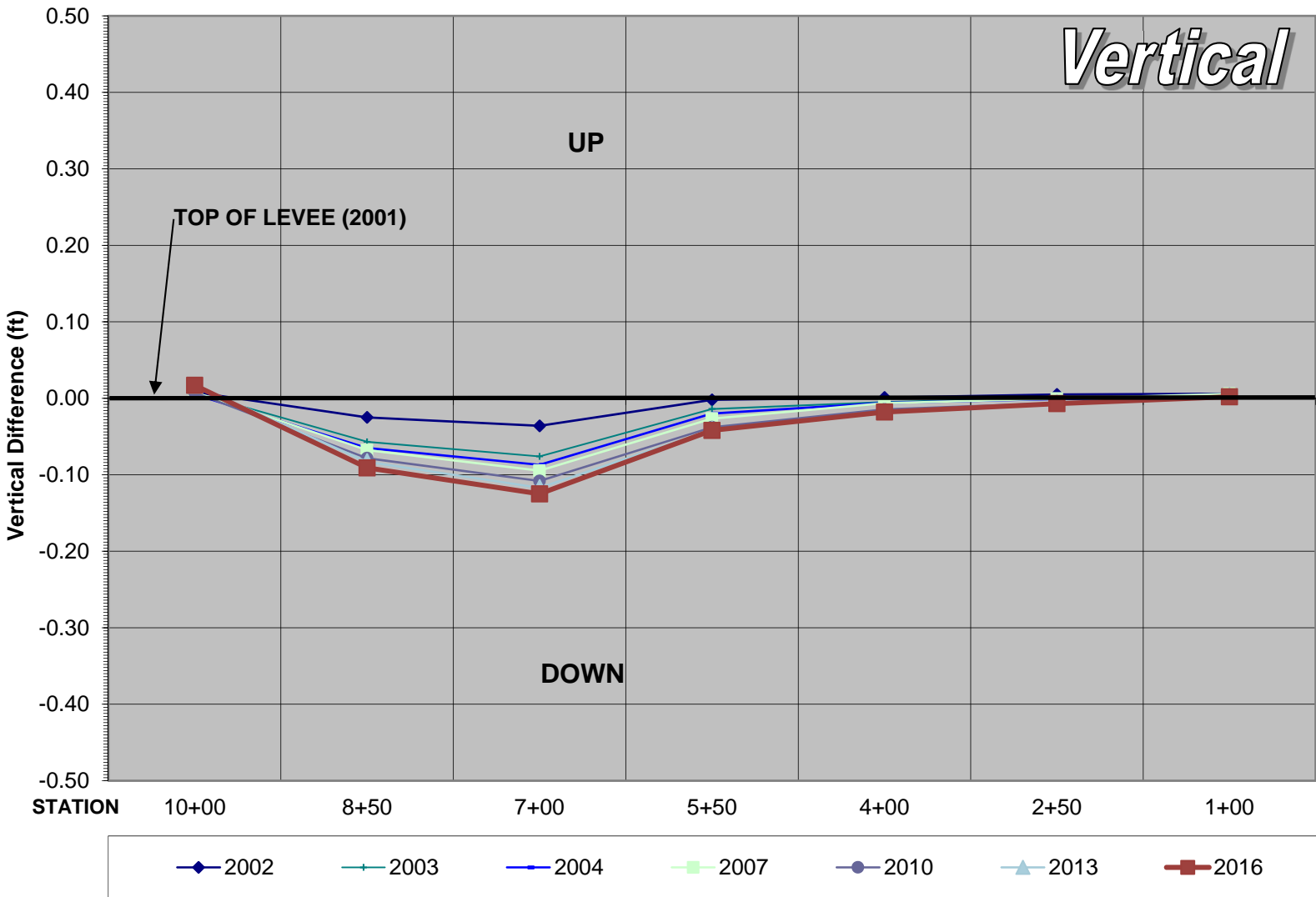
2001 2002 2003 2004 2007 2010 2013 2016



# Orchard Estates Retarding Basin Horizontal Movement Along Dam Axis (Difference from Planned Stationing)



**Orchard Estates Retarding Basin**  
**Vertical Movement (Difference from 2001 Elevations) - Profile View - *Looking Upstream***



# 10

# HICKS CANYON RETARDING BASIN



# Hicks Canyon Retarding Basin

Monitoring Survey

## Legend

- Benchmarks
- ▲ Control Stations
- Monitoring Stations



Google earth

© 2016 Google

100 ft



## **Hicks Canyon Retarding Basin (F27B01) Monitoring Survey**

This earthen dam was built in 1997. The first survey was performed in 1997 and is used as the "benchmark" for all future surveys.

### **Chart Details**

#### **Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Stations 6+00 and 8+00 are held for ***Out From Line*** calculations.

Positive numbers represent stations right of line (upstream), negative numbers represent stations left of line (downstream).

#### **Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Station 6+00 is held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing the current elevation to the "1997 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values shown are in U.S. Survey feet. Station names are in meters.

Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment

Vertical Datum = NAVD88, OCS 1995 Adjustment

## **Hicks Canyon Retarding Basin (F27B01) Monitoring Survey**

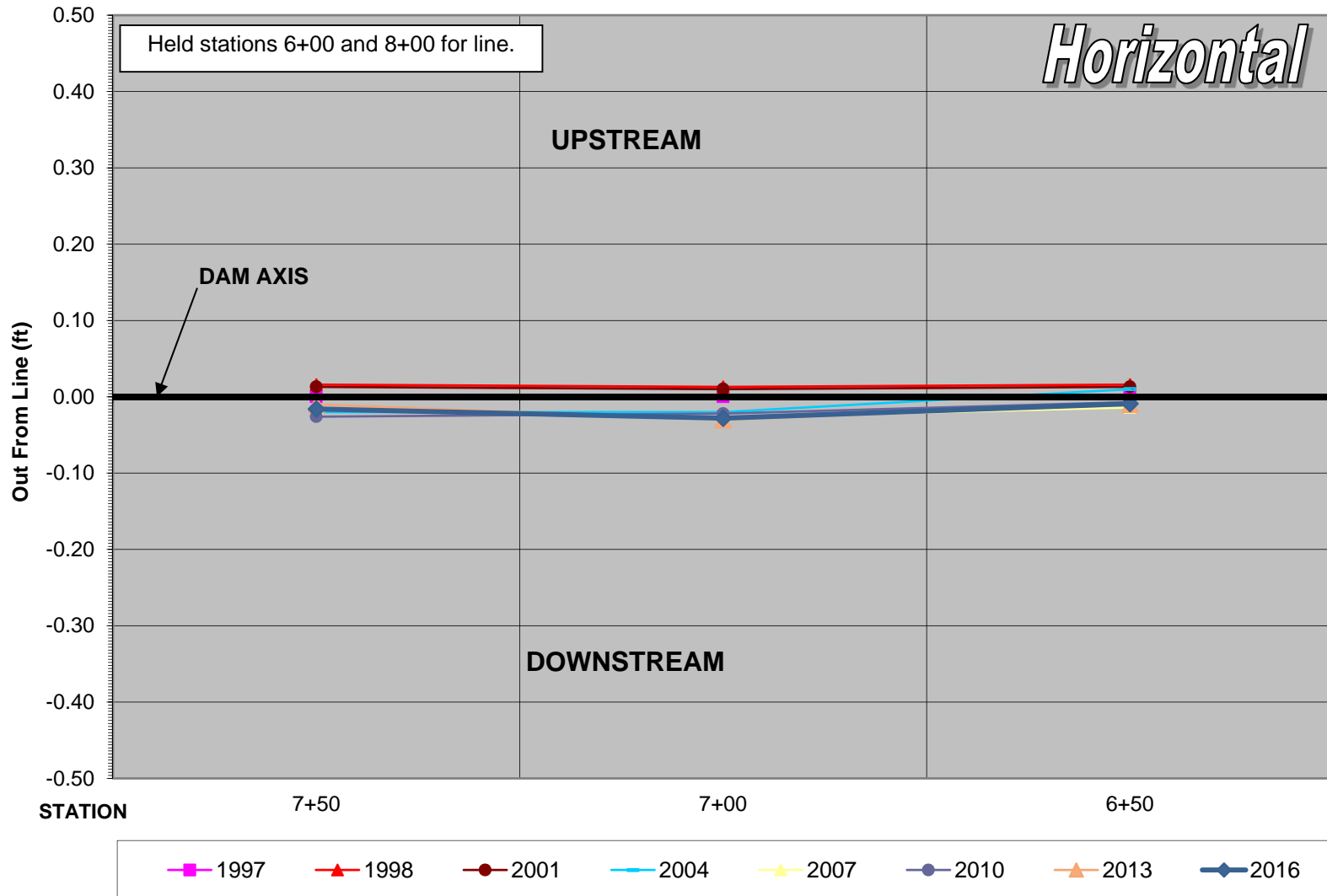
### **Report Summary**

<b>1997</b>	Initial survey performed.
<b>1998</b>	All distances measured from station 6+00 differ from 0.02 to 0.03 feet. This could indicate that station 6+00 may be settling. Construction has being continual this past year for the Eastern Transportation Corridor. These differences are not significant but will be watched closely in the future.
<b>2001</b>	No significant movement. Dam monument elevations show settling trend. "Difference From Stationing" measurement for 7+00 is questionable.
<b>2004</b>	No significant movement. Difference from planned stationing are larger than expected.
<b>2007</b>	No significant movement. Difference from planned stationing are larger than expected.
<b>2010</b>	No significant movement.
<b>2013</b>	No significant movement.
<b>2016</b>	No significant movement.
<b>2019</b>	

Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment

Vertical Datum = NAVD88, OCS 1995 Adjustment

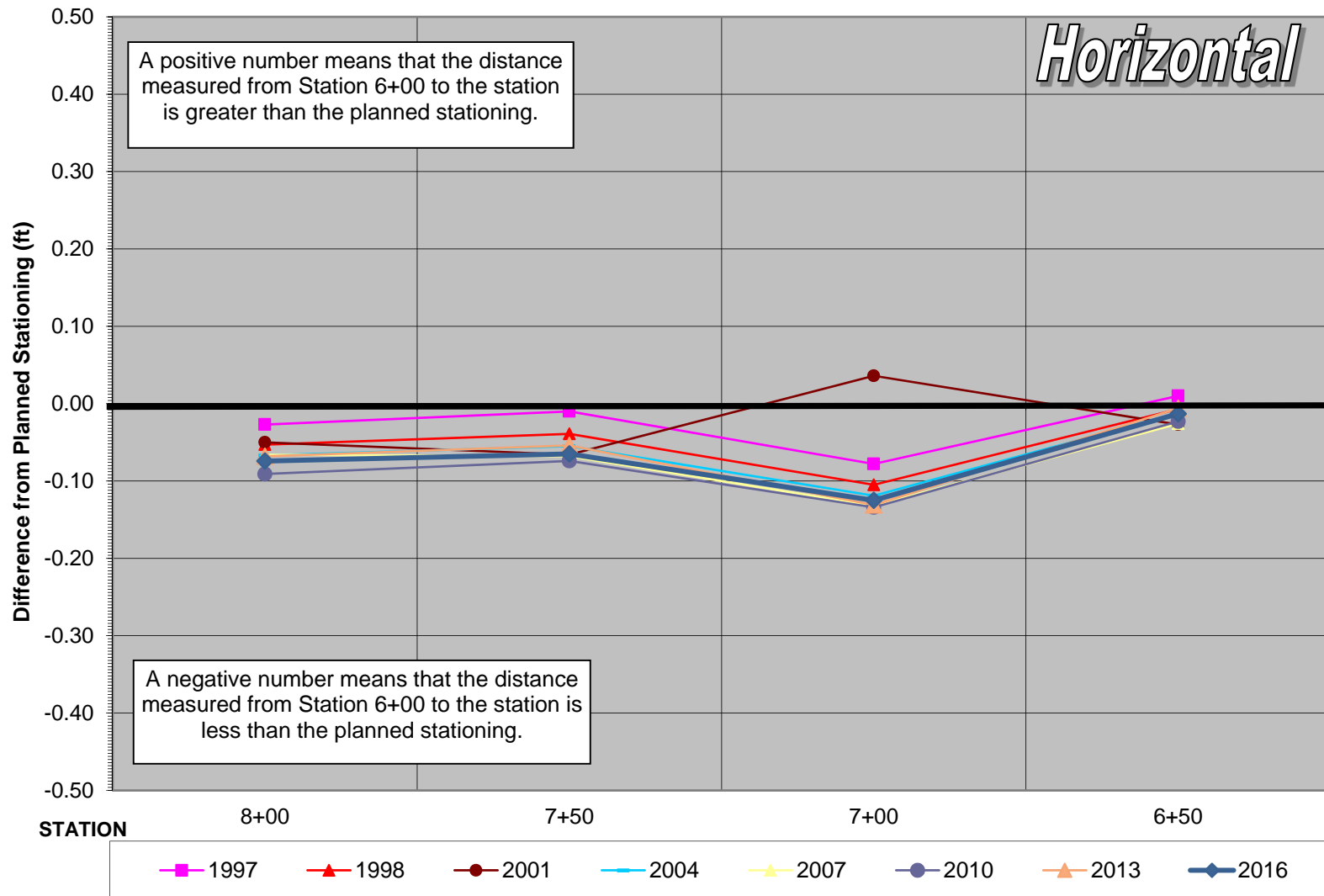
Hicks Canyon Dam  
Horizontal Movement Perpendicular to Dam Axis (Out From Line) - Plan View





# Hicks Canyon Dam

## Horizontal Movement Along Dam Axis (Difference from Planned Stationing)



**Vertical**

**UP**

**DOWN**

**TOP OF DAM (1997)**

**STATION**

8+00 7+50 7+00 6+50 6+00

1998 2001 2004 2007 2010 2013 2016

# 11

EAST HICKS  
CANYON  
RETARDING BASIN



# East Hicks Canyon Retarding Basin

Monitoring Survey

## Legend

- Benchmarks
- ▲ Control Stations
- Monitoring Stations

0088 (1+00) EAST-HICKS-6-97 1+50 2+00 2+50 3+00 3+50 4+00 0089 (4+50)

Google earth

© 2016 Google



300 ft



## **East Hicks Canyon Retarding Basin (F27B02) Monitoring Survey**

This earthen dam was built in 1997. The first survey was performed in 1997 and is used as the "benchmark" for all future surveys.

### **Chart Details**

**Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Stations 1+00 and 4+50 are held for ***Out From Line*** calculations.

Positive numbers represent stations right of line (upstream), negative numbers represent stations left of line (downstream).

**Horizontal Movement Along Dam Axis (difference from planned stationing) - shows all data from each year.**

Station 1+00 is held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than planned stationing, negative number means less than planned stationing.

**Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing the current elevation to the "1997 survey" elevation.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Division, Geodetic Control Unit.

All values shown are in U.S. Survey feet. Station names are in meters.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

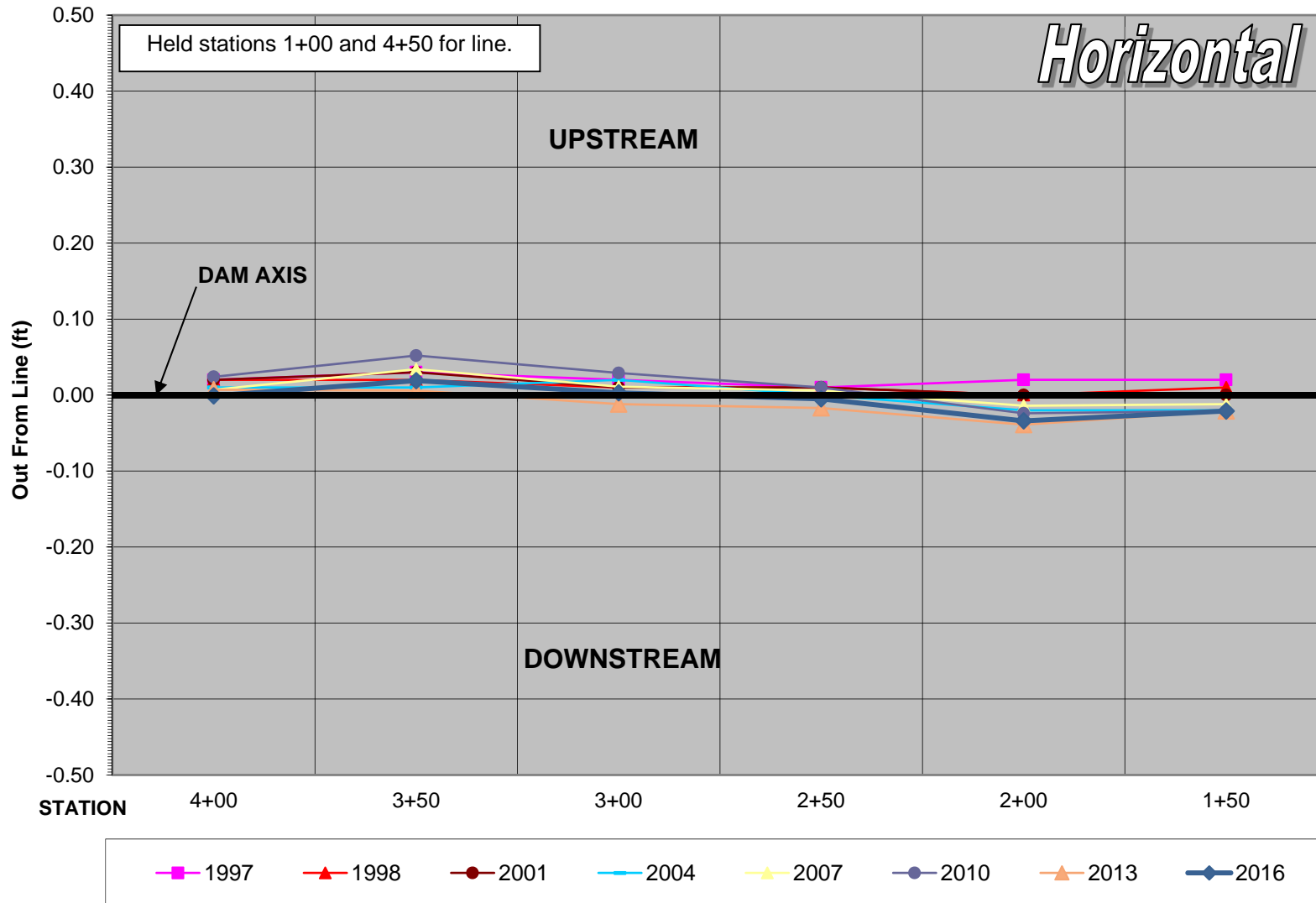
**Vertical Datum = NAVD88, OCS 1995 Adjustment**

## **East Hicks Canyon Retarding Basin (F27B02) Monitoring Survey**

### **Report Summary**

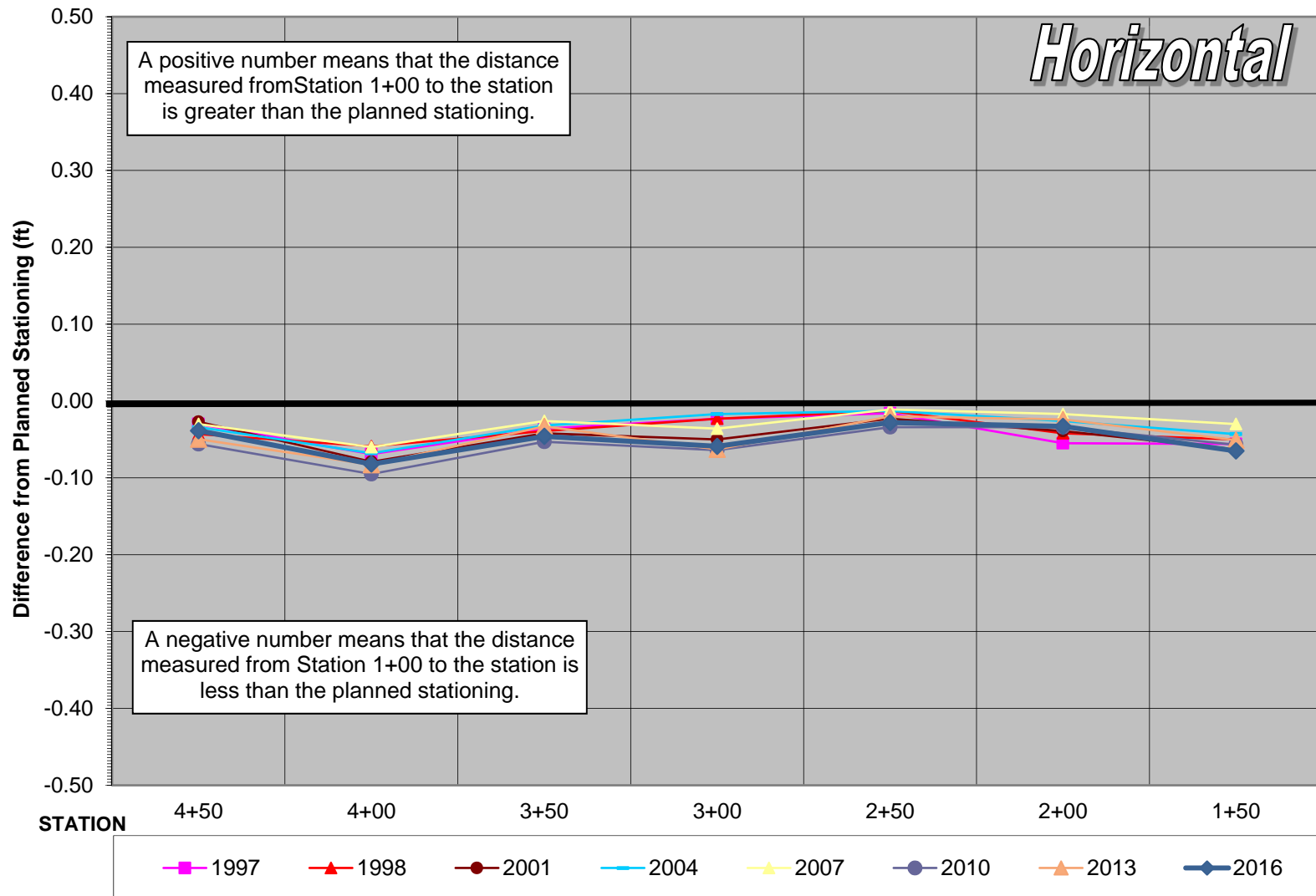
<b>1997</b>	Initial survey performed.
<b>1998</b>	Most stations show subsidence with an average of 0.02 feet. This could be due to settlement of the dam. Horizontal positions seem stable. Construction has been continual for the last two years for the Eastern Transportation Corridor which abuts up against the downstream side of the dam.
<b>2001</b>	No significant movement detected.
<b>2004</b>	Nov-2003, The lids have been scraped off and the last monument may have been disturbed. No significant movement detected.
<b>2007</b>	Elevations appear to have a systematic difference of +0.03'. No horizontal significant movement detected.
<b>2010</b>	No significant movement detected.
<b>2013</b>	All well lids are missing and well monuments appear to have been disturbed from heavy equipment scrapping the asphalt surface. Monuments appear stable horizontally but 3+00 has sank 0.05'.
<b>2016</b>	No significant movement detected. The 3+00 comment in 2013 appears to be an error.
<b>2019</b>	

**East Hicks Canyon Dam**  
**Horizontal Movement Perpendicular to Dam Axis (Out From Line) - Plan View**



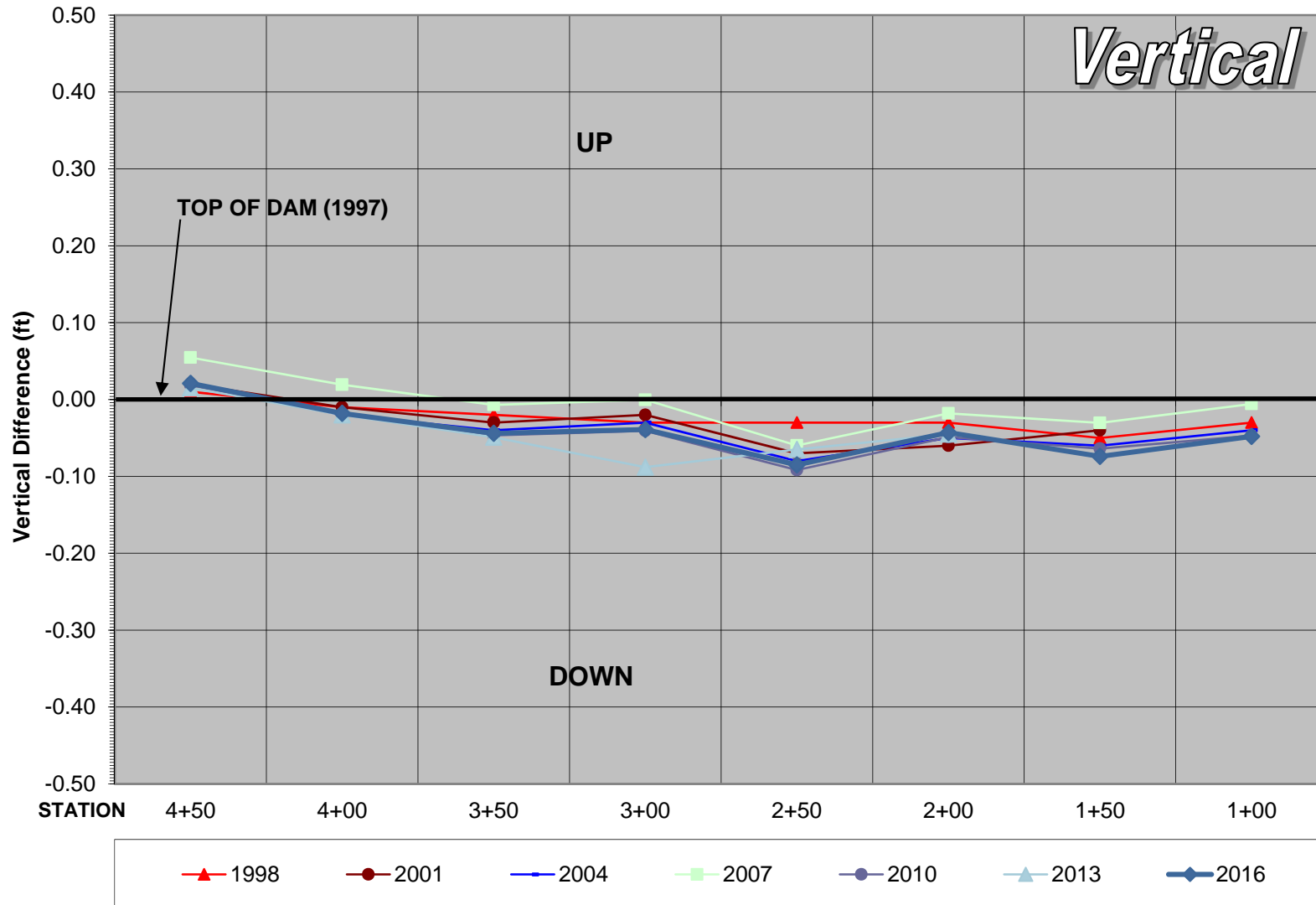
# East Hicks Canyon Dam

## Horizontal Movement Along Dam Axis (Difference from Planned Stationing)





**East Hicks Canyon Dam**  
**Vertical Movement (Difference from 1997 Elevations) - Profile View - *Looking Upstream***



# 12

# SULPHUR CREEK DAM



# Suphur Creek Dam

Monitoring Survey

## Legend

- ▲ Control Stations
- Benchmarks
- Monitoring Stations

0249 (SC-1)

M-1

M-2

0251 (M-3)

M-4

C-5

C-8

0259 (C-7)

3XX-4-84

3XX-5-84

Google earth

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Image Landsat / Copernicus

Data LDEO-Columbia, NSF, NOAA

© 2016 Google

200 ft



## **Sulphur Creek Dam (J03D01) Monitoring Survey**

This earthen dam was built in 1966. The first vertical monitoring survey was performed in 1979. The first horizontal survey was performed in 1981.

Horizontal displacement is compared to dam survey line. Vertical displacement is compared to 1968 elevations from 1984 Subsidence Report.

### **Chart Details**

#### **Control Station Checks - Horizontal**

Due to the instability of the dam control stations which are measured using GPS, this chart will be included to help in identifying actual dam movement or perceived movement caused from "C-7" moving in a southwesterly direction.

#### **Horizontal Movement Perpendicular to Dam Axis - shows all data from each year.**

Control points "SC-1" and "SC-2" are held for *Out From Line* calculations until 1993. In 1993, "SC-2" was found disturbed and replaced by "C-7" for line. Negative numbers represent stations right of line (downstream), positive numbers represent stations left of line (upstream).

#### **Horizontal Movement Along Dam Axis (difference from 1985 survey) - shows all data from each year.**

GPS 0249 (SC-1) Control point is held for stationing calculations.

Positive numbers mean that the distances measured to each station are greater than 1985 survey, negative number means less than 1985 survey.

#### **Vertical Movement - shows all data from each year.**

Vertical differences are calculated comparing the elevation to the "1968 survey" elevation.

#### **Control Checks - shows all data from each year.**

Horizontal movement of control stations in a cardinal direction relative to the initial 1995 GPS survey.

Detailed information pertaining to monument descriptions and survey information can be found at OC Survey Divison, Geodetic Control Unit.

All values are shown in U.S. Survey feet.

**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

**Vertical Datum = NGVD29, OCS 1976 Adjustment**



## **Sulphur Creek Dam (J03D01) Monitoring Survey**

### **Report Summary**

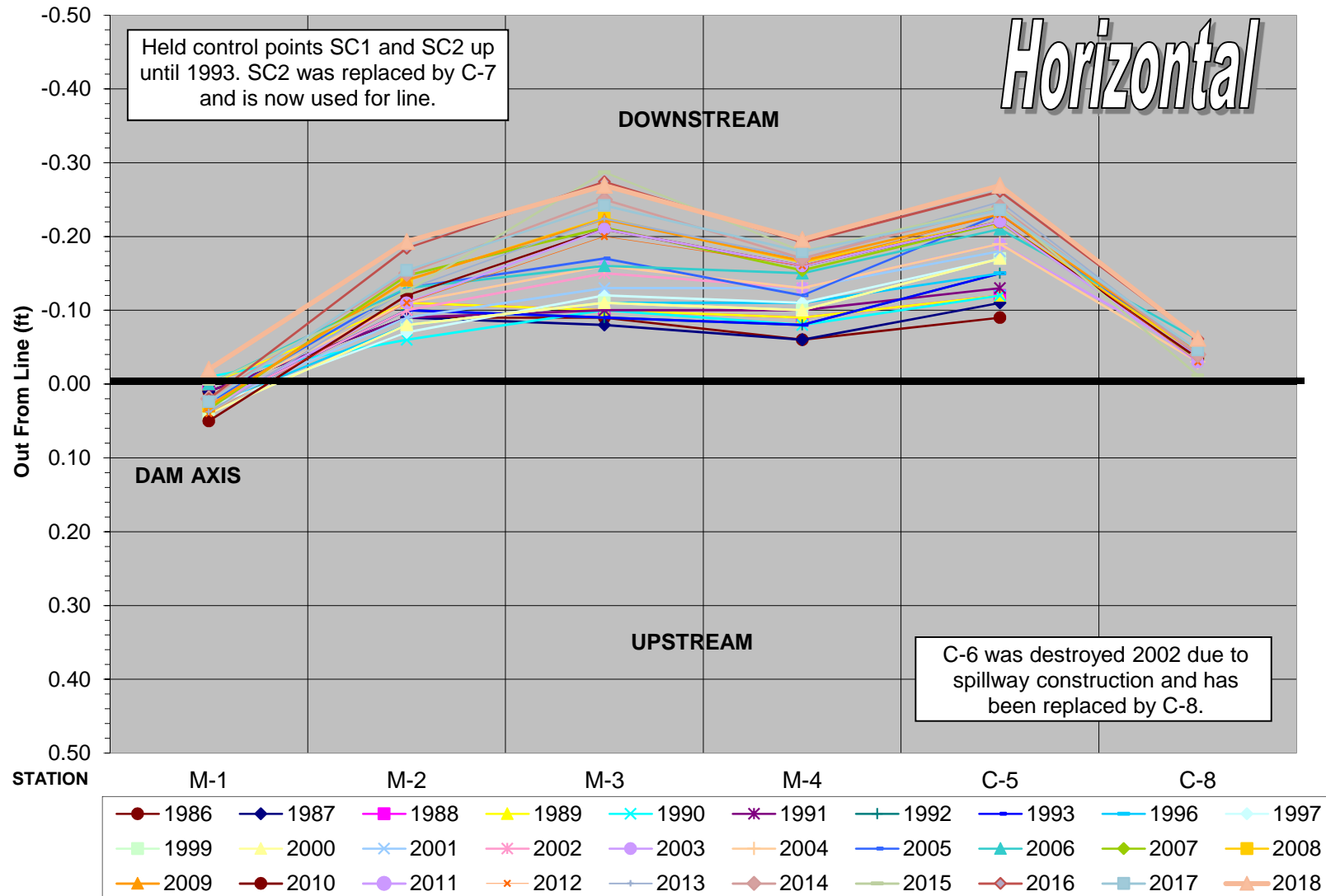
<b>1981-1990</b>	Downstream horizontal movement measured on all stations located on top of dam. Vertical uplift is found on all stations.
<b>1990-2000</b>	Downstream horizontal movement continues with the greatest amount at station C-5. Vertical uplift also continues with the greatest amount at both end stations, M-1 and C-7.
<b>2001</b>	Same horizontal and vertical trends continue
<b>2002</b>	Same horizontal trend continues. Vertical appears stable. C-6 was destroyed due to spillway construction and has been replaced by C-8.
<b>2003</b>	Same horizontal trend continues. Vertical appears stable.
<b>2004</b>	No significant movement found.
<b>2005</b>	C-5 shows downstream horizontal movement. Vertical uplift also continues with the greatest amount at both end stations, M-1 and C-7.
<b>2006</b>	All stations except M-3 show vertical uplift. M-3 shows settling.
<b>2007</b>	M-3 shows vertical settlement for past 7 years.
<b>2008</b>	M-3 continues to settle, all other monuments show uplift with the greatest amount on M-1 and C-7. All stations show slight downstream movement.
<b>2009</b>	M-3 continues to settle, all other monuments show uplift with the greatest amount on M-1 and C-7. All stations show slight downstream movement.
<b>2010</b>	M-3 appears to have vertically stabilized. C-7 shows horizontal movement in a southwest direction based on "Control Checks" chart.
<b>2011</b>	C-7 shows horizontal movement in a southwest direction based on "Control Checks" chart.
<b>2012</b>	No significant movement found.
<b>2013</b>	No significant movement found.
<b>2014</b>	M-3 continues to settle, all other monuments show uplift with the greatest amount on M-1 and C-7. All stations show slight downstream movement.
<b>2015</b>	All stations continue to show slight downstream movement with the greatest being M-3. See note below.
<b>2016</b>	No significant movement found.
<b>2017</b>	No significant movement found.
<b>2018</b>	No significant movement found.
<b>2019</b>	

**Note:** "Out From Line" chart shows downstream movement. Some of this movement may be related to the instability of control station C-7 that has appears to be moving southwesterly at a small rate.

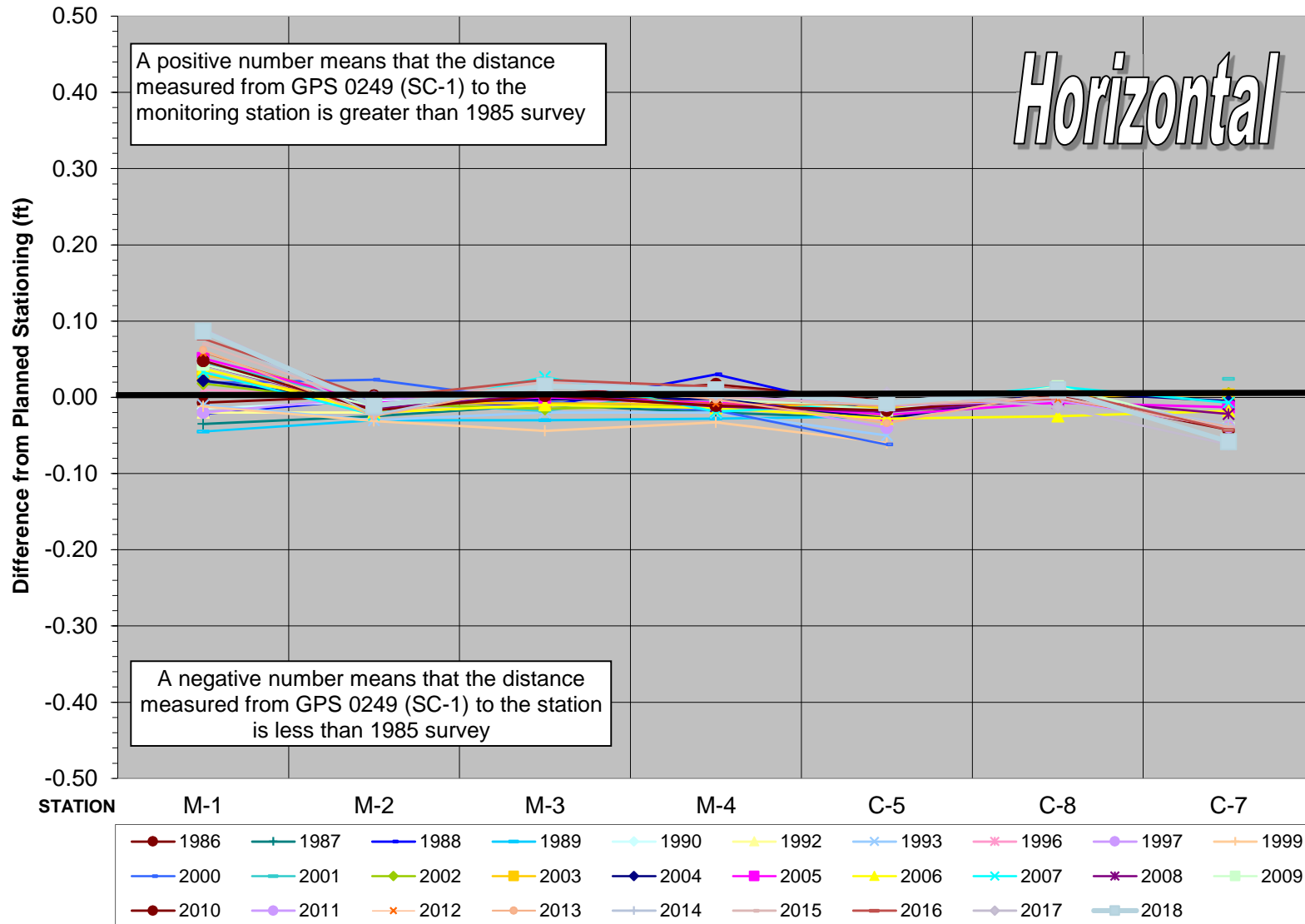
**Horizontal Datum = CCS83, zone VI, 1991.35 Epoch Adjustment**

**Vertical Datum = NGVD29, OCS 1976 Adjustment**

# Sulphur Creek Dam Horizontal Movement Perpendicular to Dam Axis (Out From Line) Plan View

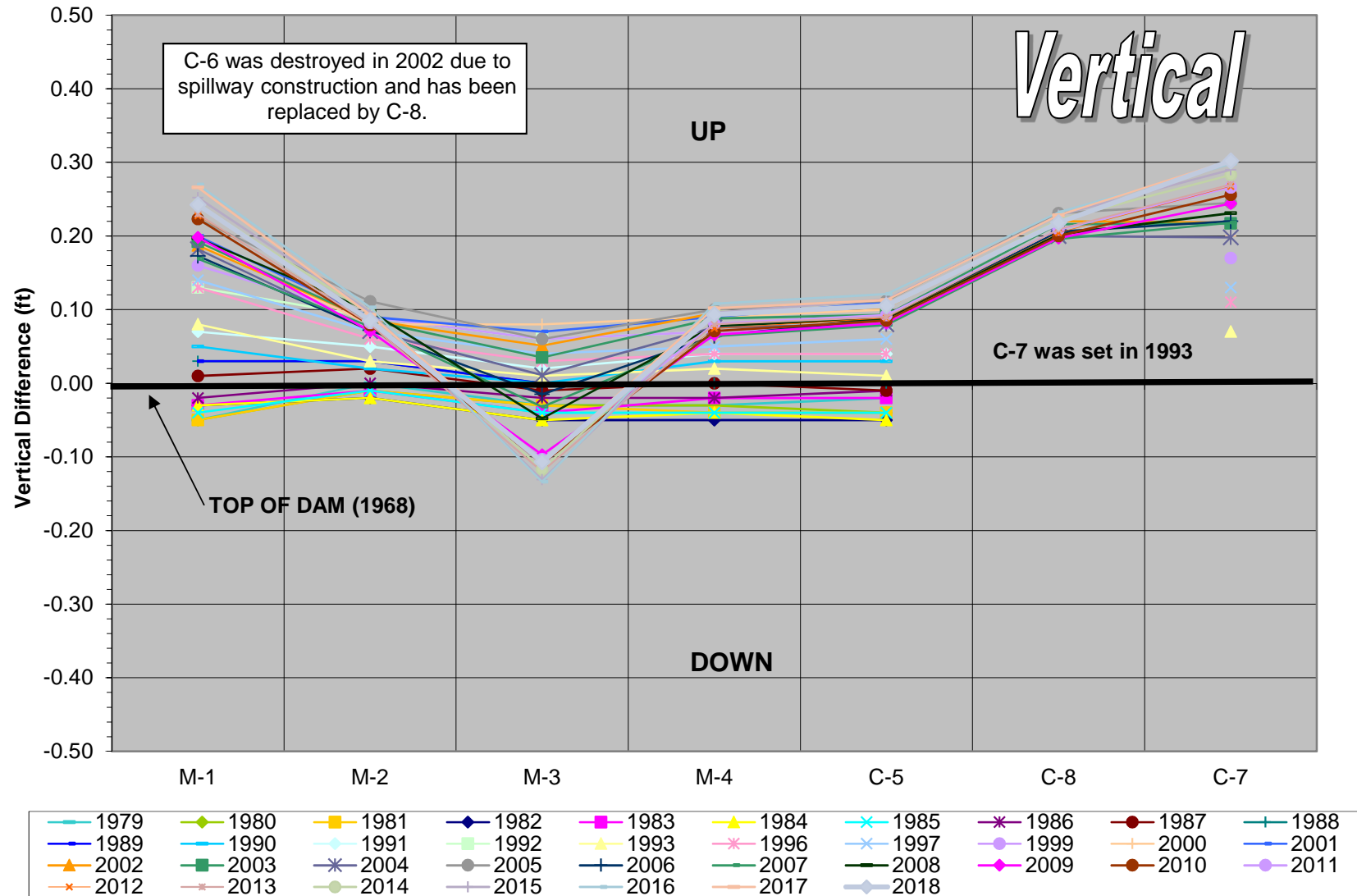


# Sulphur Creek Dam Horizontal Movement Along Dam Axis (Difference from 1985 Survey)



# Sulphur Creek Dam

## Vertical Movement (Difference from 1968 Elevations) - Profile View - Looking Upstream





# 13

# COVE ROAD CRIB WALL



# Cove Road - Crib Wall

Monitoring Survey



Google earth

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

© 2016 Google

Data CSUMB SFML, CA OFC

Image Landsat / Copernicus

70 ft

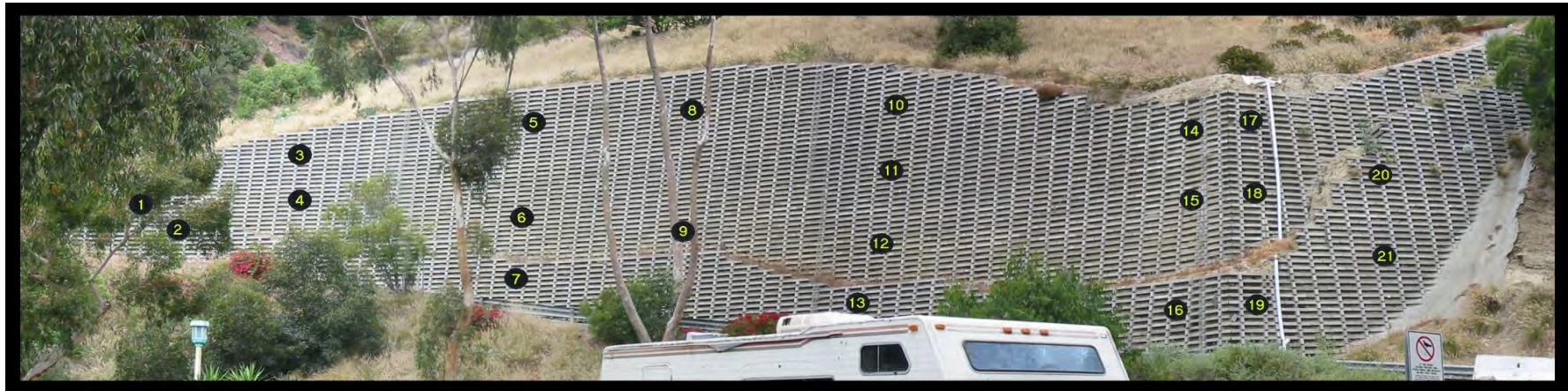


## **Cove Road - Crib Wall Monitoring Survey**

This crib-type retaining wall was built in 1985 after the top of the bluff located under Cannons Restaurant failed during heavy rains in the winter of 1980-1981.

### **Chart Details:**

Each chart contains movement (change in northing, easting, elevation) from each survey relative to the 1997 base survey for each station. All data is shown in U.S. Survey Feet.



21 mini-prisms were set into the Crib Wall for monitoring targets July, 1997.

See following sheet for procedures and chart details.

Horizontal Datum = CCS83, Zone VI, OCS 1991.35 Adjustment  
Vertical Datum = NAVD88, OCS 1995 Adjustment

## **Cove Road - Crib Wall Monitoring Survey**

### **Monitoring Procedures:**

All surveys are performed following the steps listed below:

#### **STEP # 1**

Utilizing GPS Static survey techniques, measure stations "CRBX", "A" and "D" to two OCS CGPS Horizontal control stations SBCC & TRAK which are located outside of the project area. GPS data is post-processed and a minimally constrained adjustment is done constraining the same control station (SBCC) each survey if possible. Positions are compared to the 1997 survey. This data is used to check the stability, horizontally and vertically, of the three monitoring stations. Positions for stations "B", "C", and "BH3" are verified from the GPS stations using conventional techniques.

#### **STEP # 2**

Utilizing Precise leveling techniques following 2nd Order - Class II specifications, measure the vertical differences between all monitoring stations relative to four OCS Vertical control stations. This data is used to monitor any subsidence and/or uplift on the monitoring stations.

#### **STEP # 3**

Utilize conventional surveying techniques with a Total Station. Measure each target 4 times (2 direct, 2 reverse).

All 5 control stations observe all possible targets to achieve sufficient redundancy. The observations are then entered into a StarNet least-squares adjustment for calculation of final positions.

### **Comments:**

Each survey is done using the same techniques with the same survey equipment if possible. A "Report Summary" is given on the first sheet and contains a short comment on each survey. Detailed information pertaining to monument descriptions and survey information are not included in this report, but can be obtained at OC Survey Division, Geodetic Control Unit.



## **Cove Road - Crib Wall Monitoring Survey**

### **Survey Report Summary**

**Aug 1997:** Initial survey performed.

**Nov 1998:** No significant movement found.

**May 1999:** No significant movement found.

**May 2000:** No significant movement found.

**May 2001:** No significant movement found.

**July 2002:** No significant movement found.

**June 2004:** No significant movement found.

**June 2006:** No significant movement found. Heights on all targets show an average change of -0.02' which is related to the recomputed height of control point "CRIB" and is not movement of the crib wall.

**May 2008:** No significant movement found.

**June 2010:** No significant movement found. The Leica TCA 1100 Total Station was serviced for calibration in March 2010.

**June 2012:** No significant movement found. Leica TCA had a card reading problem-gun not used. TPS 1203 (SN: 214338) was used.

**Sep 2014:** No significant movement found. Trimble S8 was used for this survey. Survey delayed due to trimming trees.

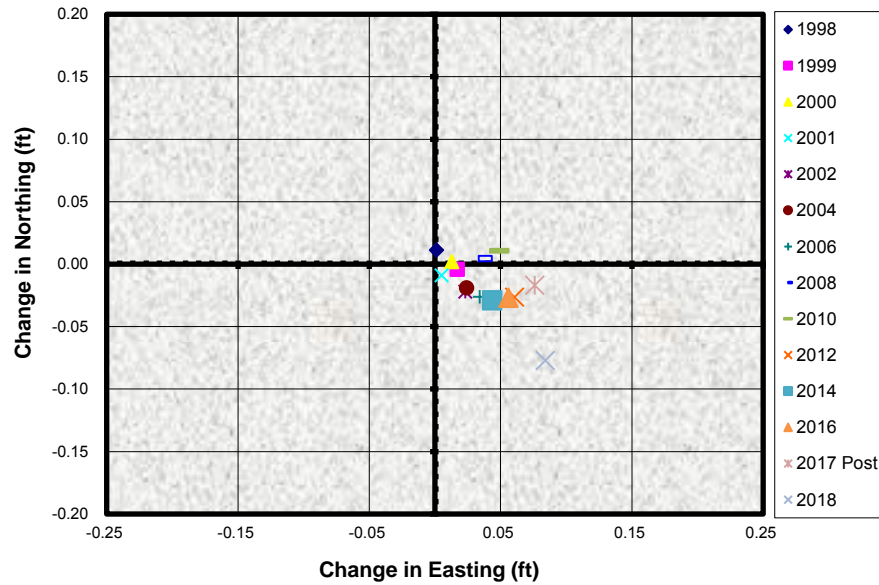
**Dec 2016:** Targets located along the top of the Crib wall have shown slight downslope horizontal movement in the last two surveys with the largest amount being targets 14 and 17 located at the top corner of the wall. Survey delayed due to trimming trees.

**Aug 2017:** (Post-Construction) Survey was performed to monitor the wall during the Erosion Repair and Drain Modification project. Targets 17, 19, 20, and 21 show questionable movement.

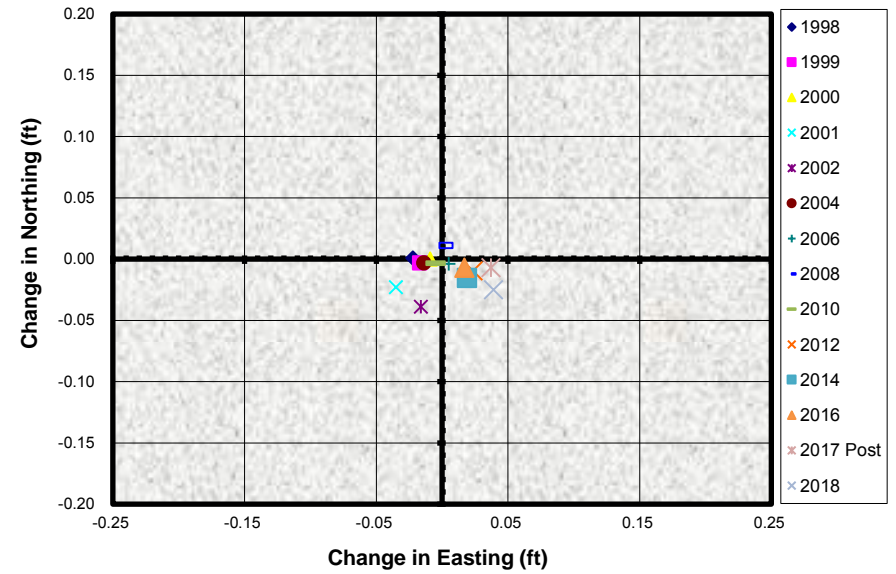
**Sept 2018:** Same slight downslope movement as seen in 2016 continues. Control level network differed by 0.09' from previous surveys. This MUST be watched closely in future surveys.

# Cove Road Crib Wall Movement from 1997 Initial Survey

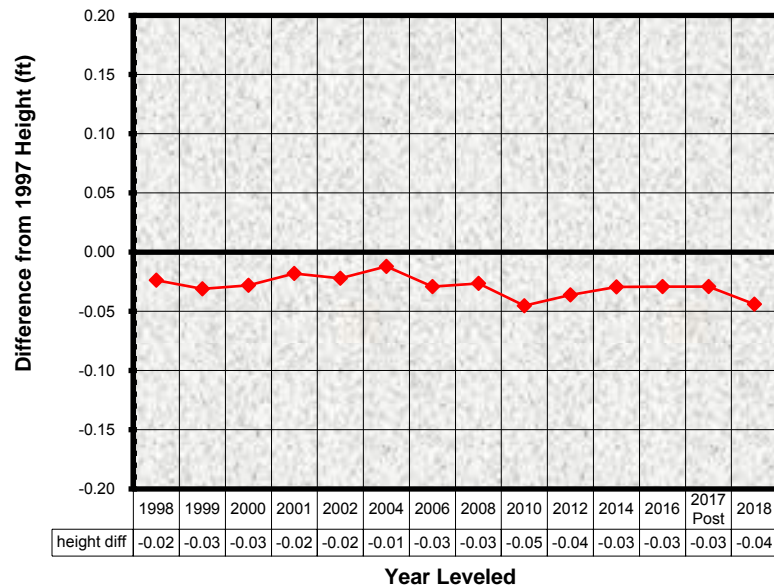
## Station # 1 - Horizontal



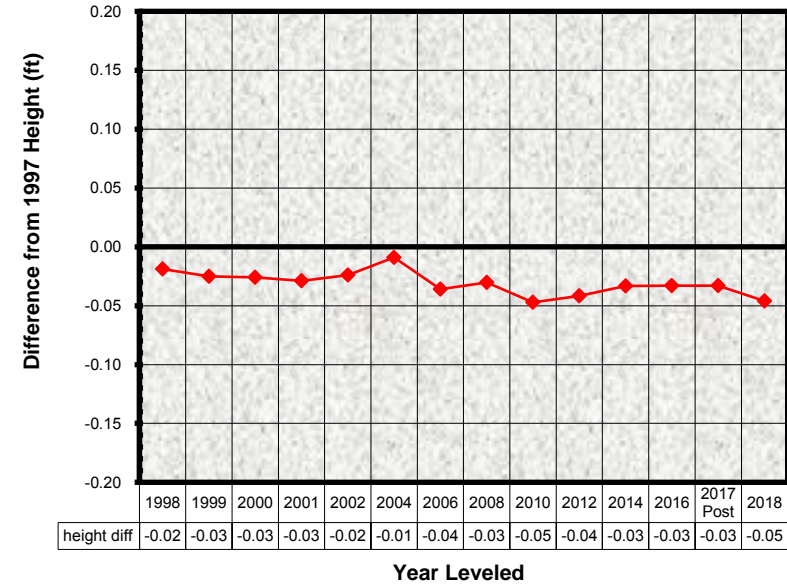
## Station # 2 - Horizontal



## Station # 1 - Vertical

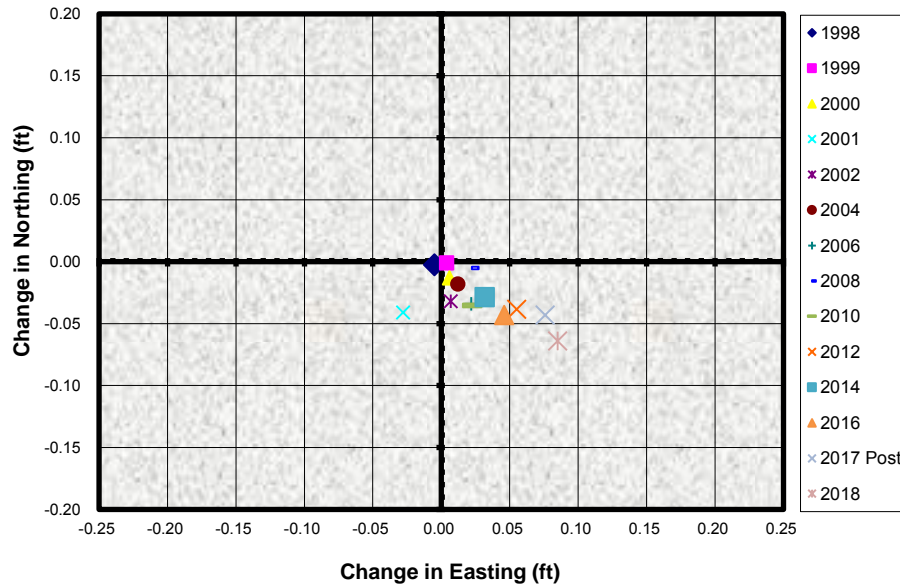


## Station # 2 - Vertical

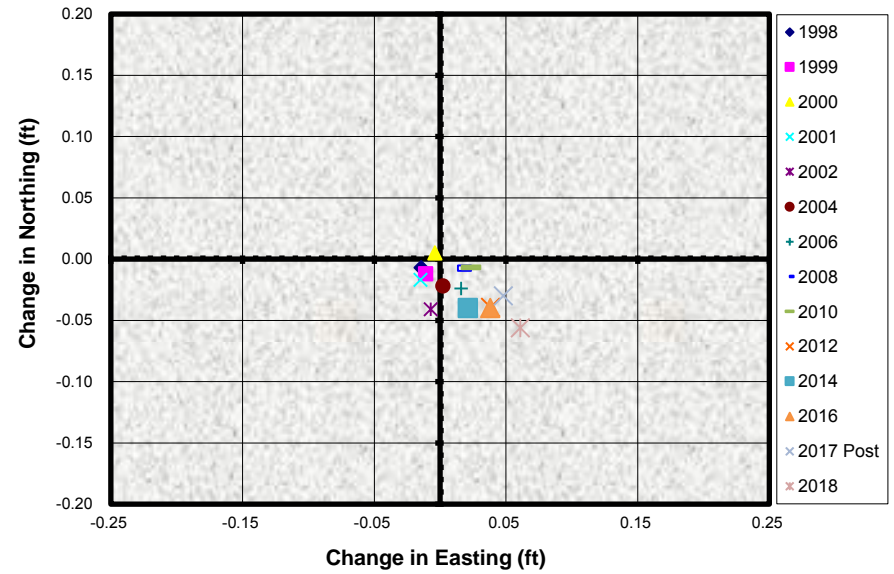


# Cove Road Crib Wall Movement from 1997 Initial Survey

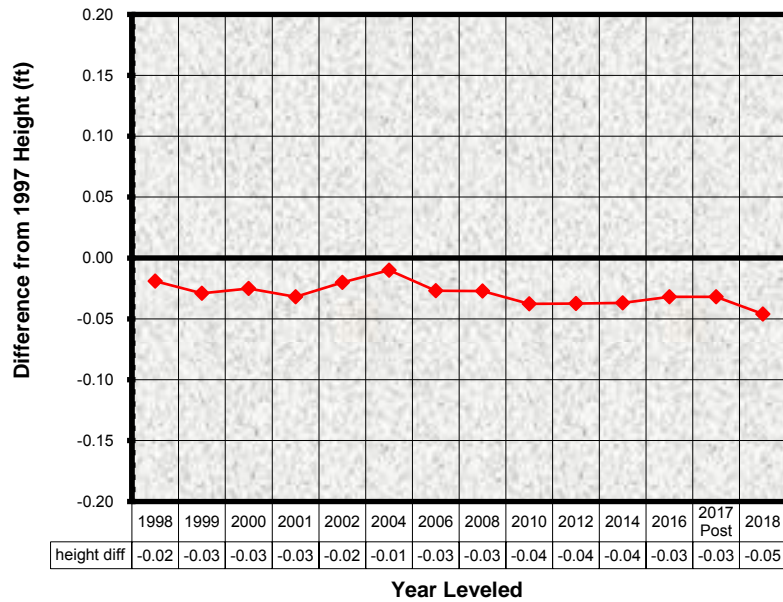
## Station # 3 - Horizontal



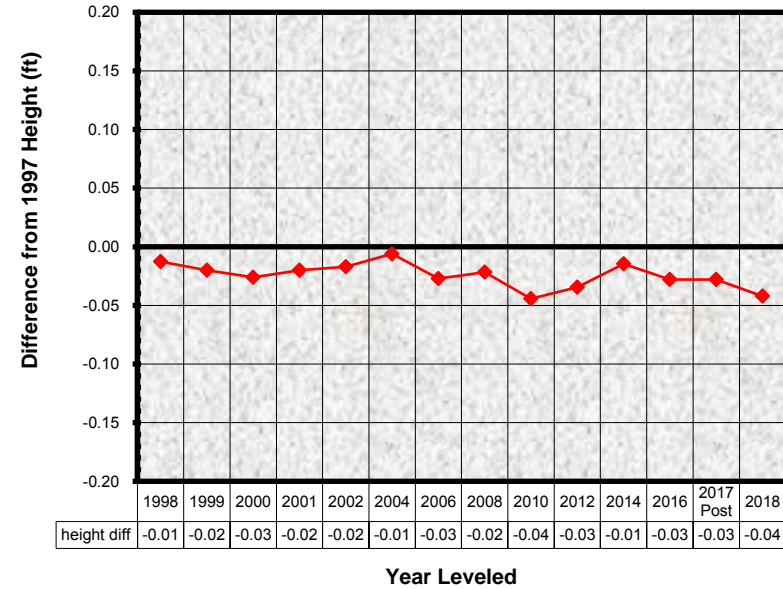
## Station # 4 - Horizontal



## Station # 3 - Vertical

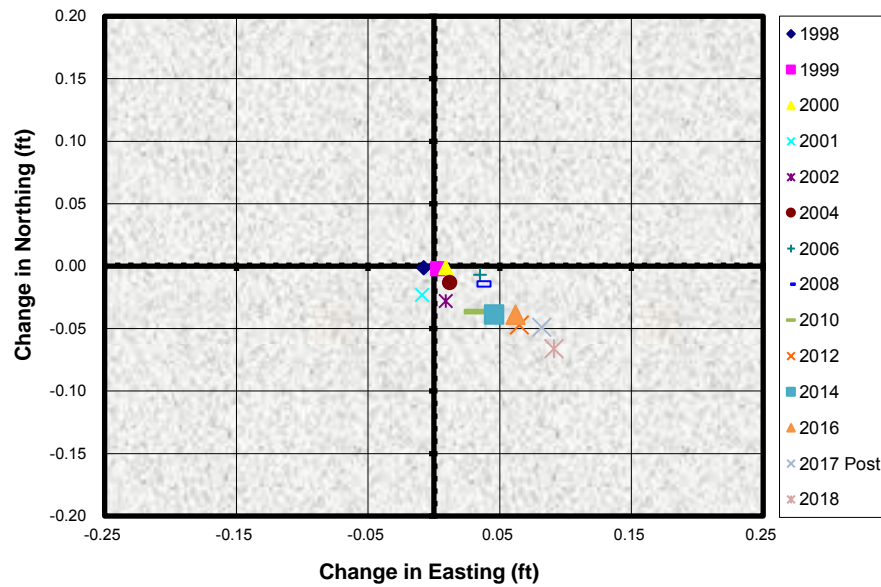


## Station # 4 - Vertical

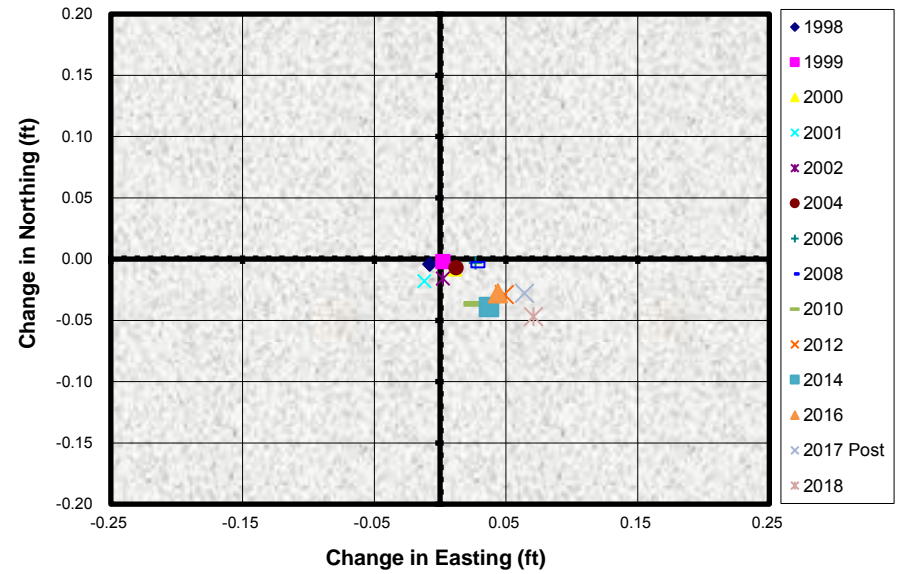


# Cove Road Crib Wall Movement from 1997 Initial Survey

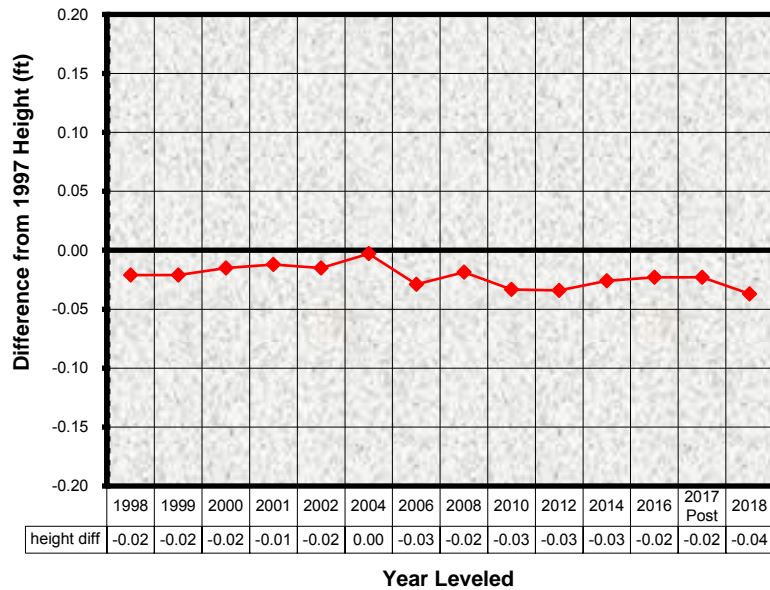
## Station # 5 - Horizontal



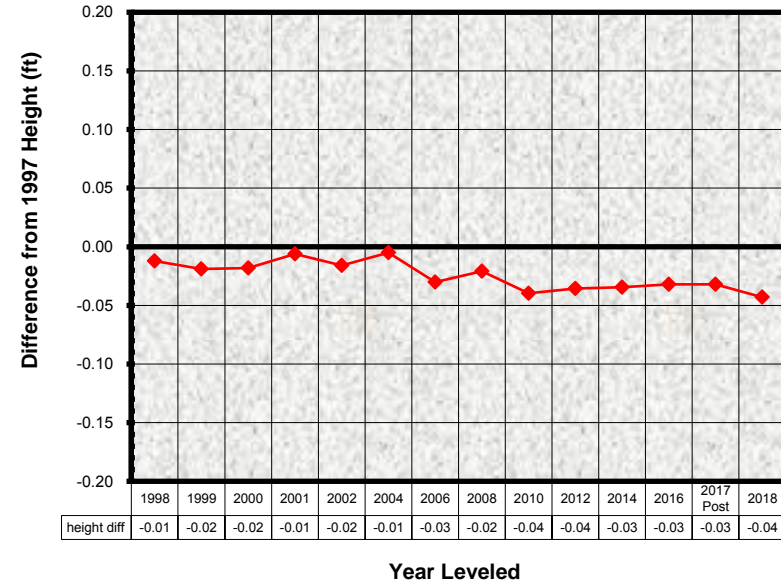
## Station # 6 - Horizontal



## Station # 5 - Vertical



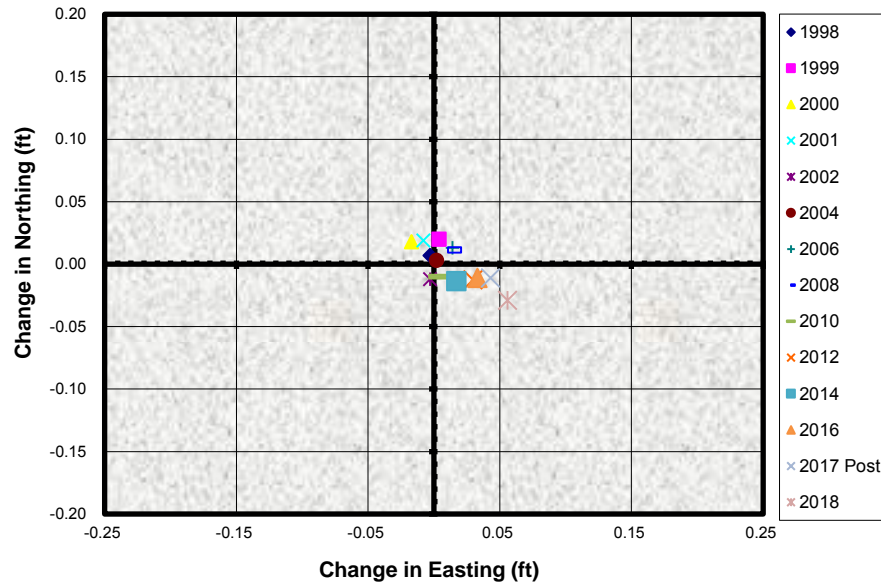
## Station # 6 - Vertical



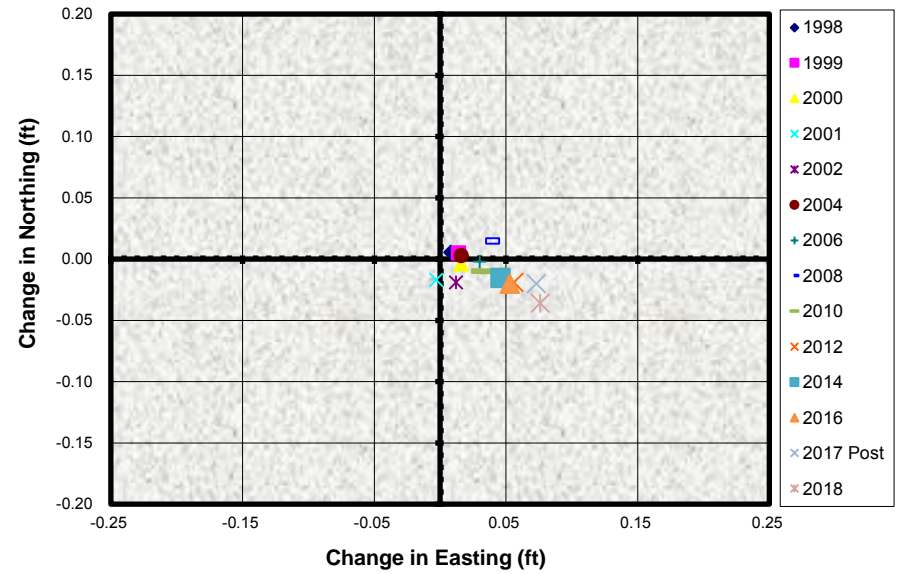


# Cove Road Crib Wall Movement from 1997 Initial Survey

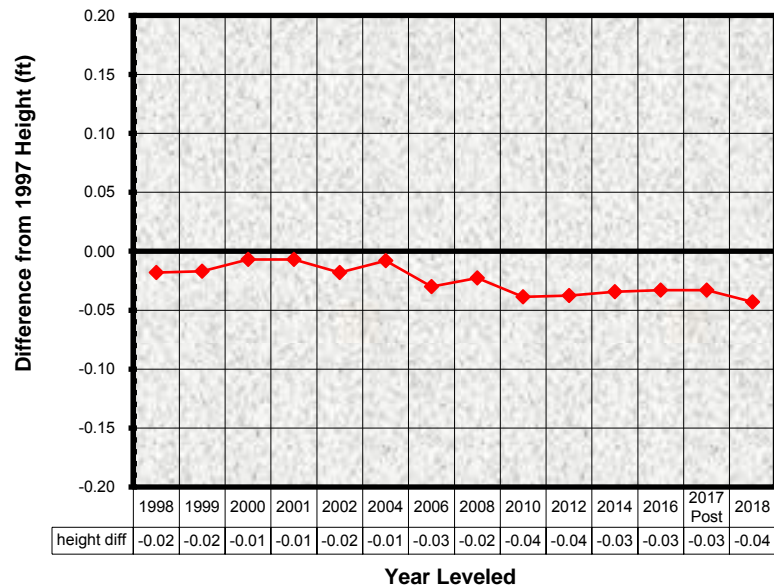
## Station # 7 - Horizontal



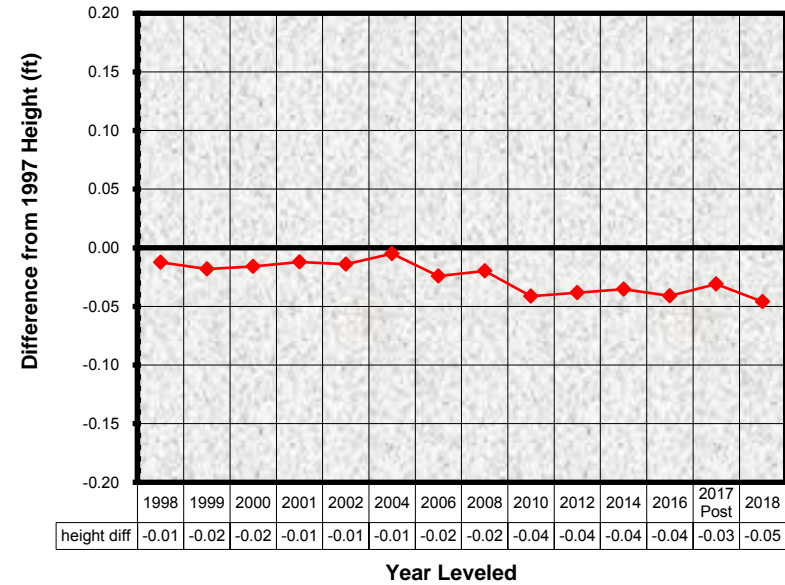
## Station # 8 - Horizontal



## Station # 7 - Vertical

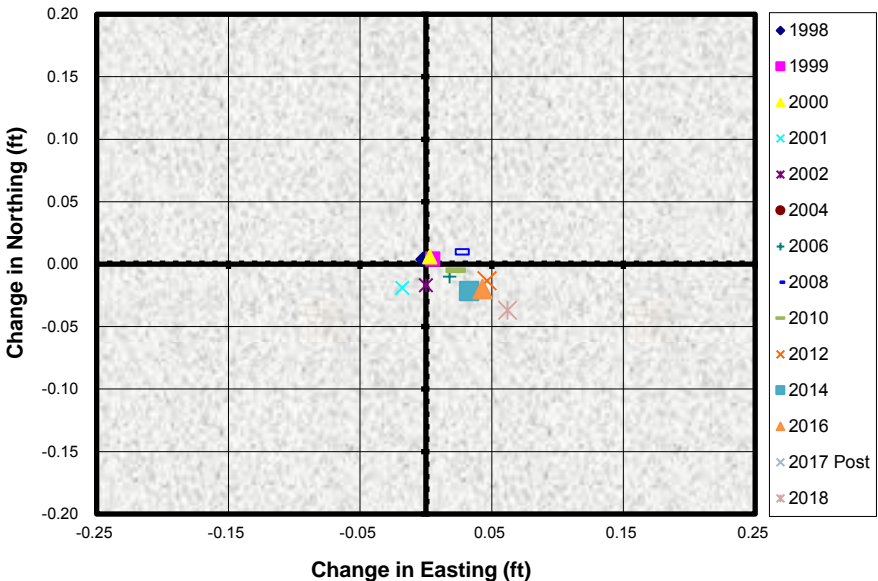


## Station # 8 - Vertical

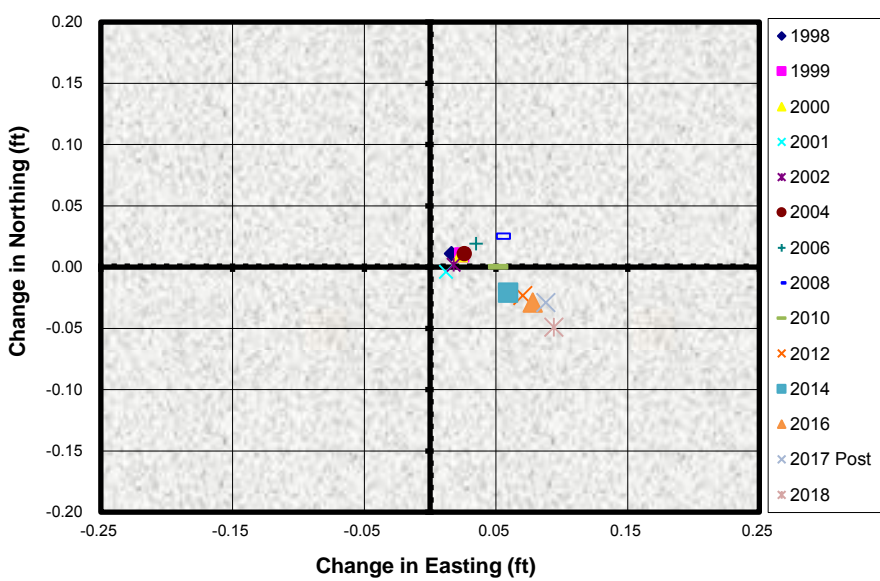


**Cove Road Crib Wall  
Movement from 1997 Initial Survey**

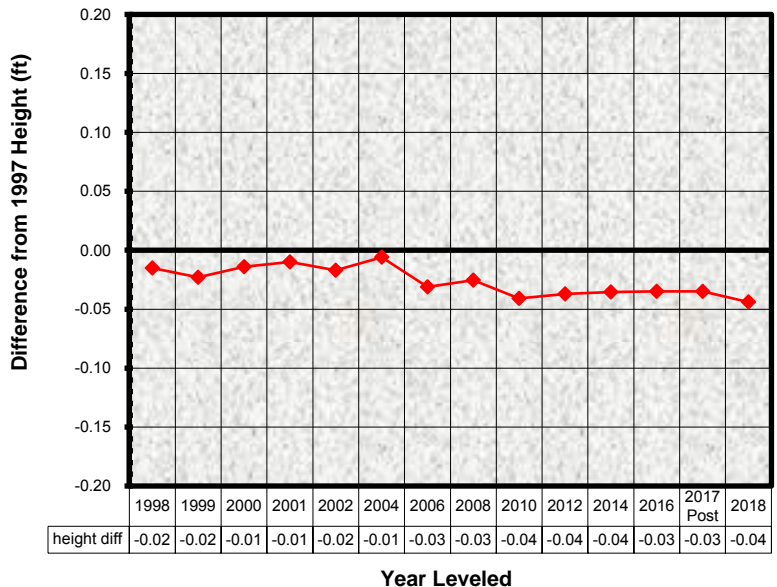
**Station # 9 - Horizontal**



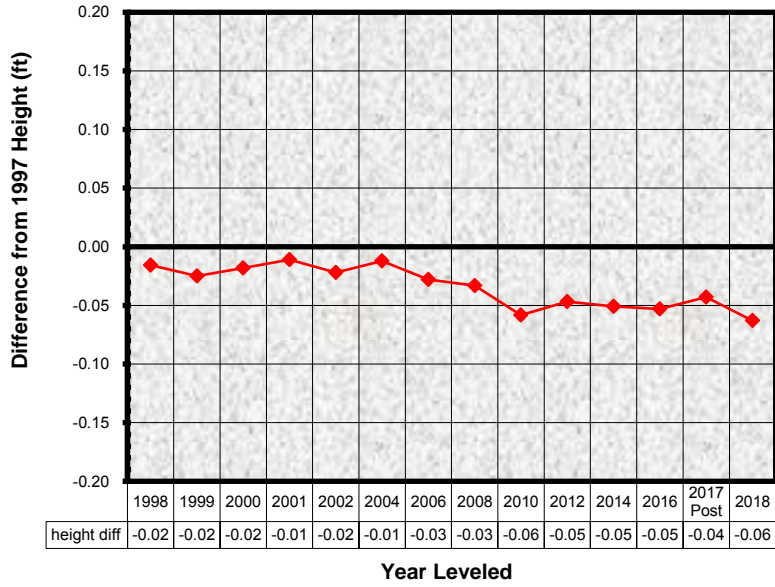
**Station # 10 - Horizontal**



**Station # 9 - Vertical**

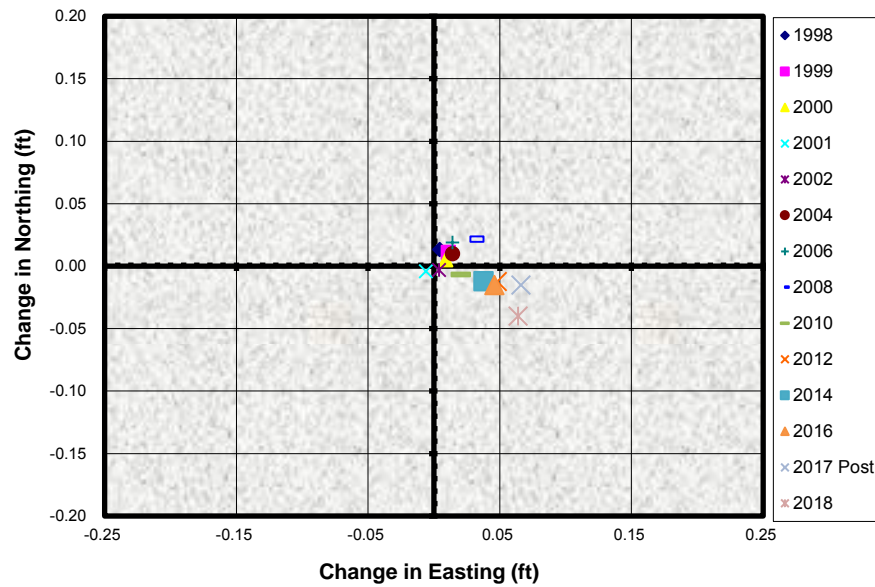


**Station # 10 - Vertical**

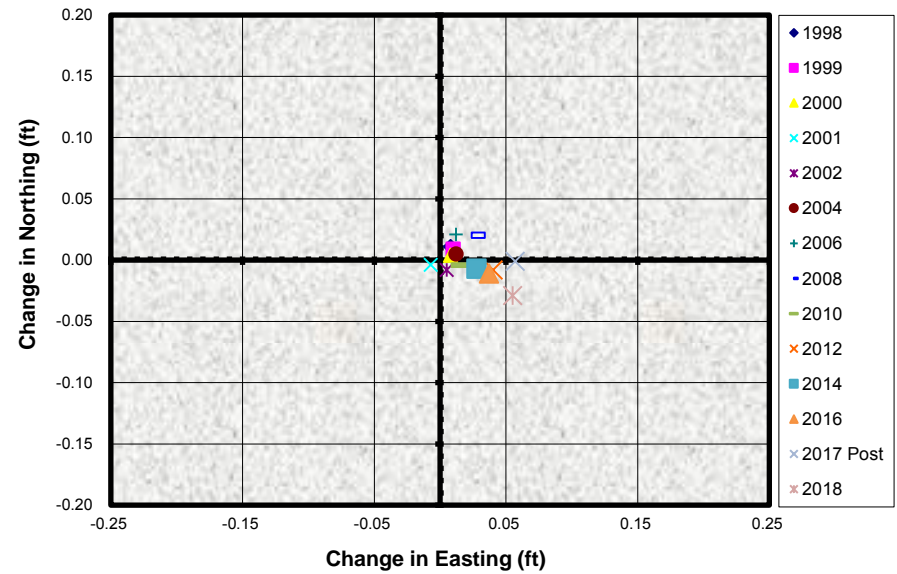


# Cove Road Crib Wall Movement from 1997 Initial Survey

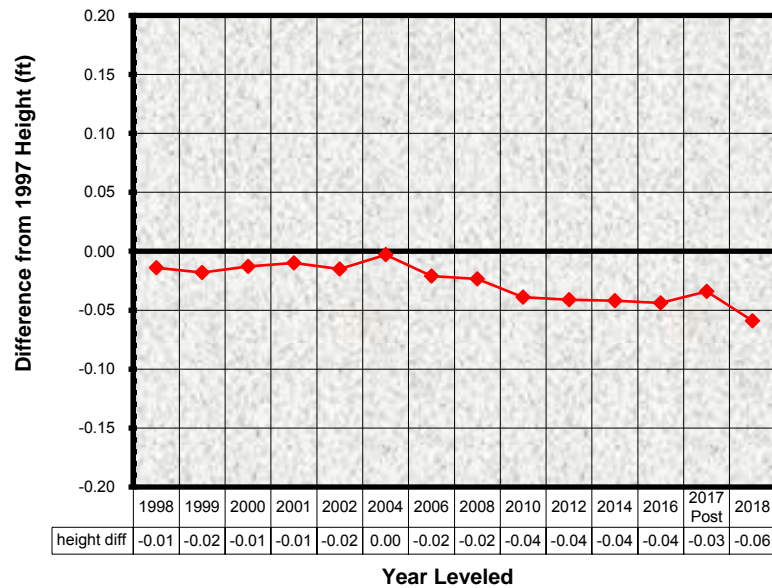
## Station # 11 - Horizontal



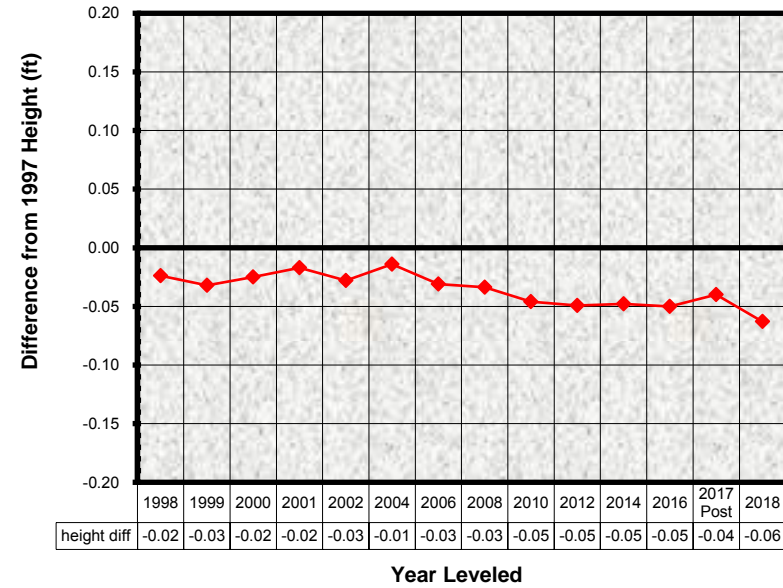
## Station # 12 - Horizontal



## Station # 11 - Vertical

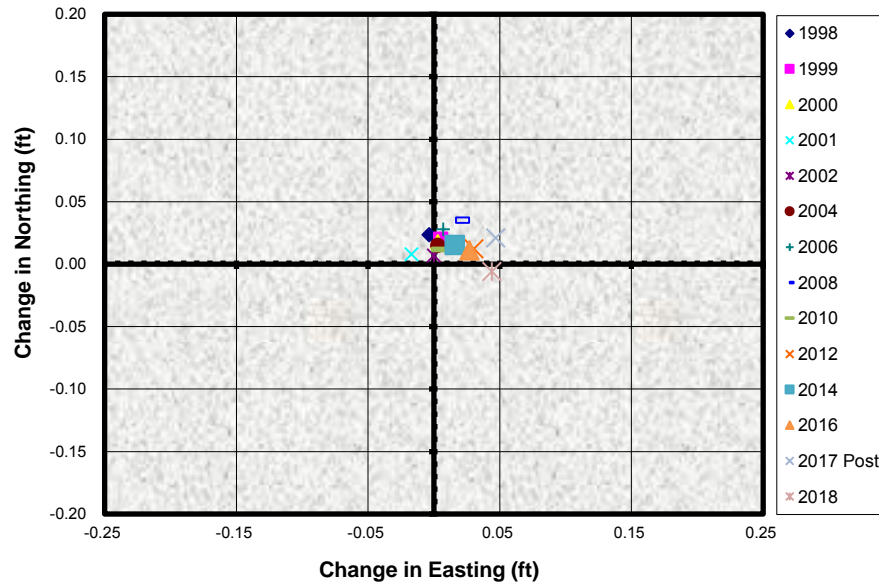


## Station # 12 - Vertical

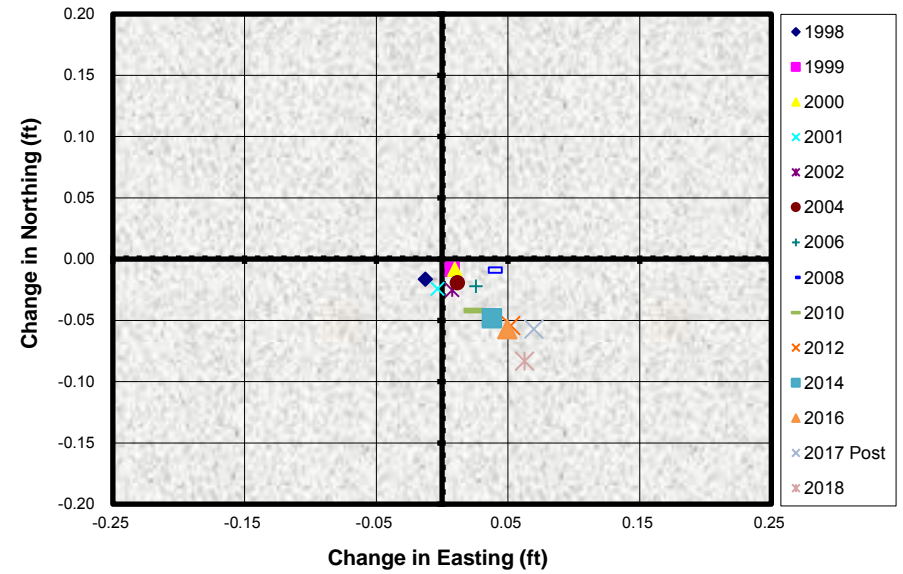


# Cove Road Crib Wall Movement from 1997 Initial Survey

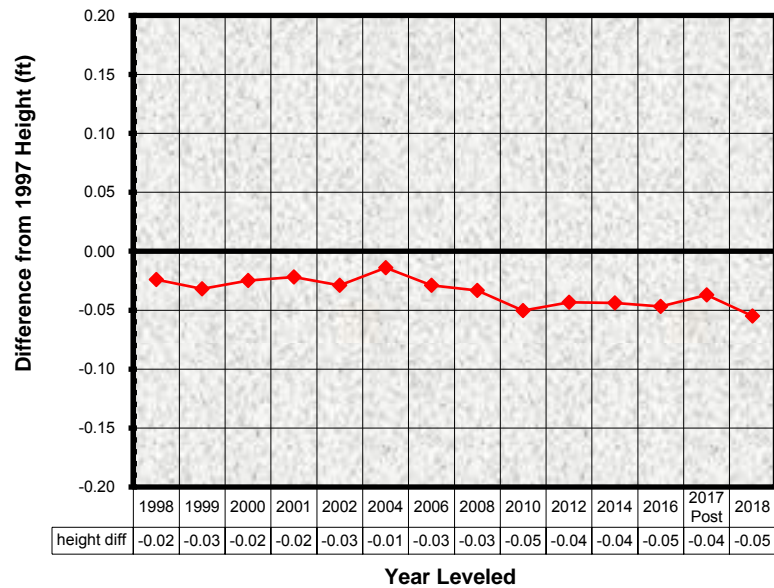
## Station # 13 - Horizontal



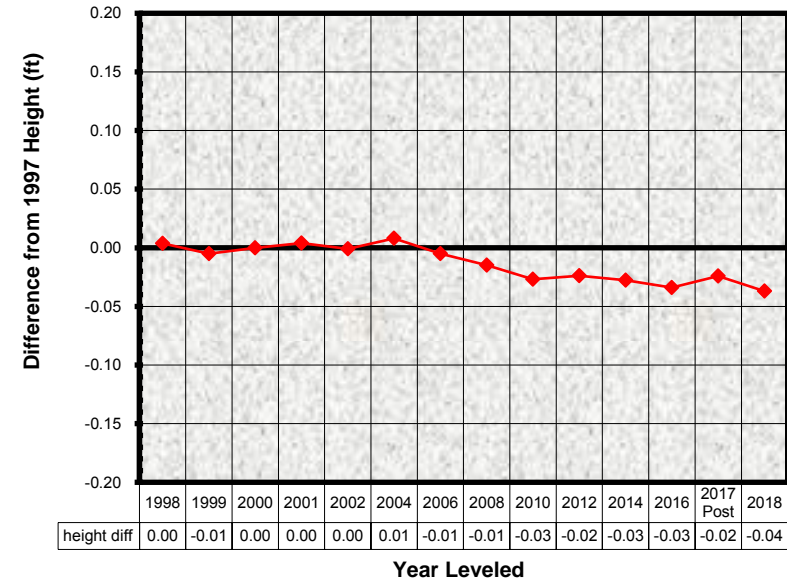
## Station # 14 - Horizontal



## Station # 13 - Vertical



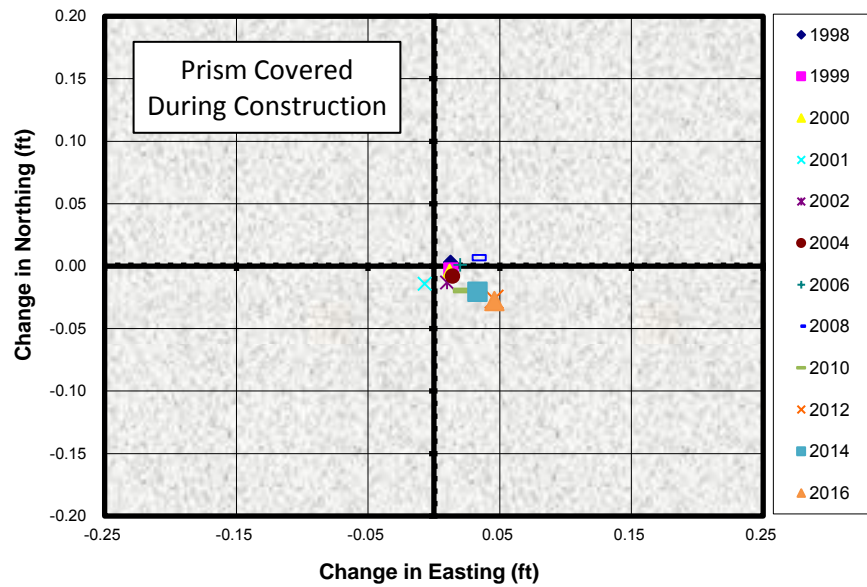
## Station # 14 - Vertical



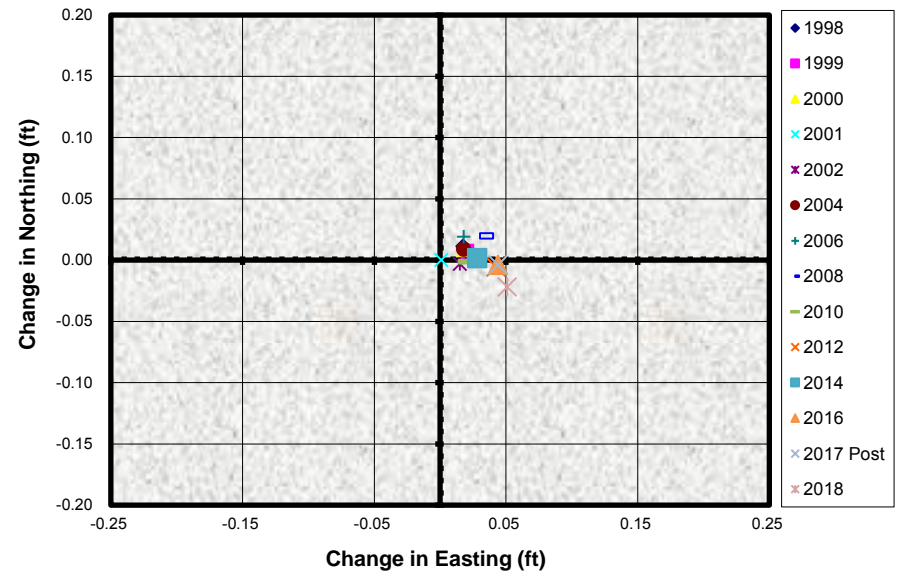


# Cove Road Crib Wall Movement from 1997 Initial Survey

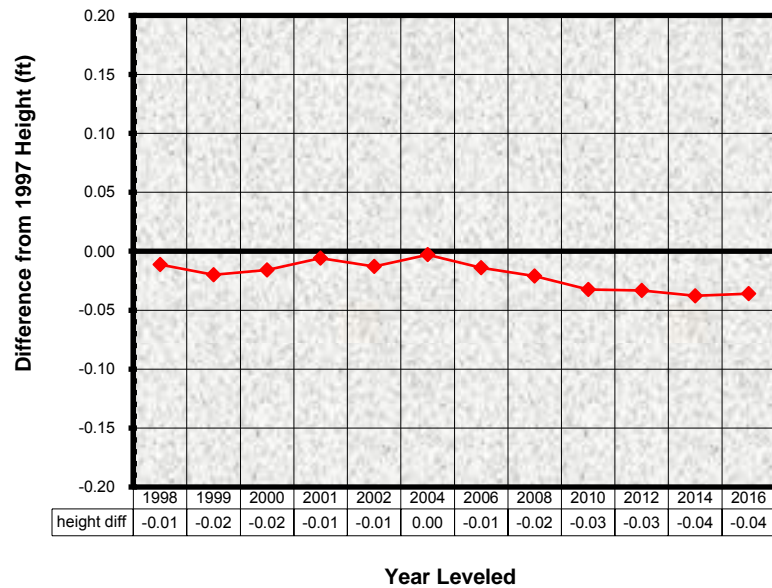
## Station # 15 - Horizontal



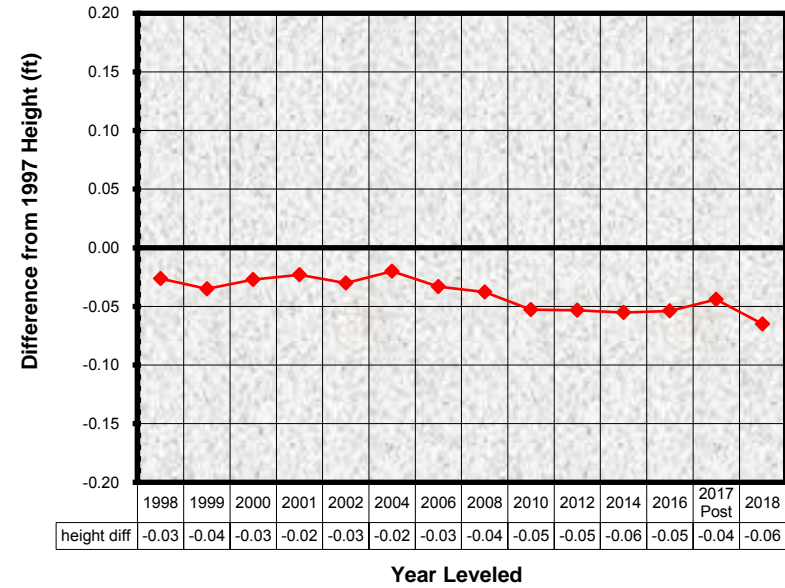
## Station # 16 - Horizontal



## Station # 15 - Vertical

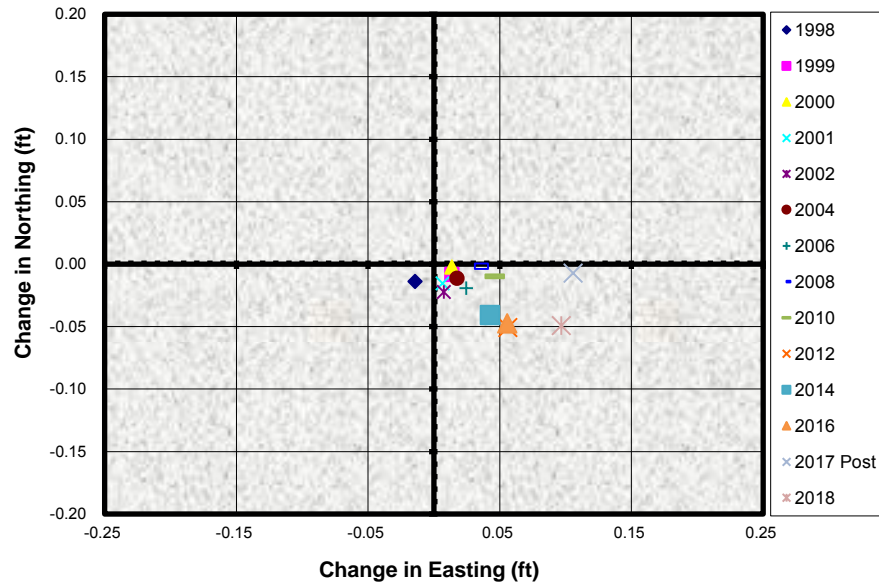


## Station # 16 - Vertical

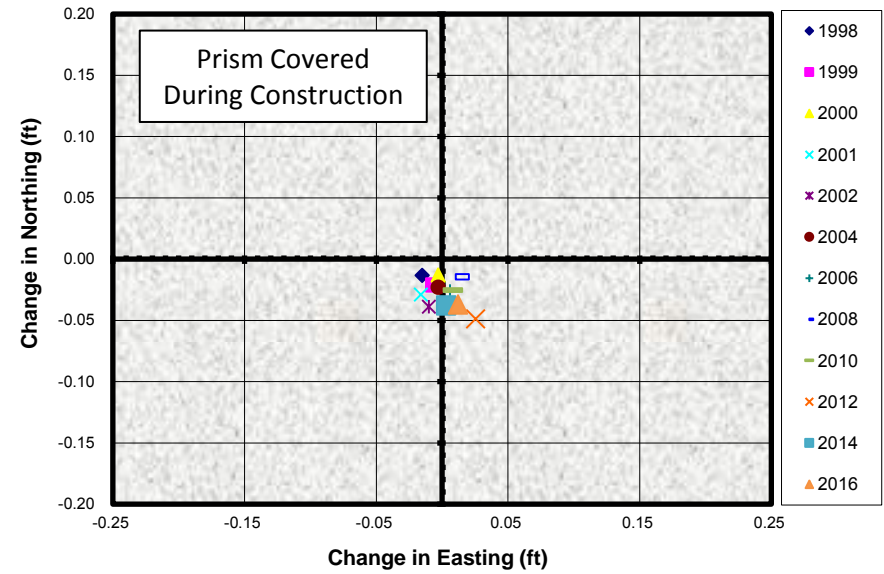


# Cove Road Crib Wall Movement from 1997 Initial Survey

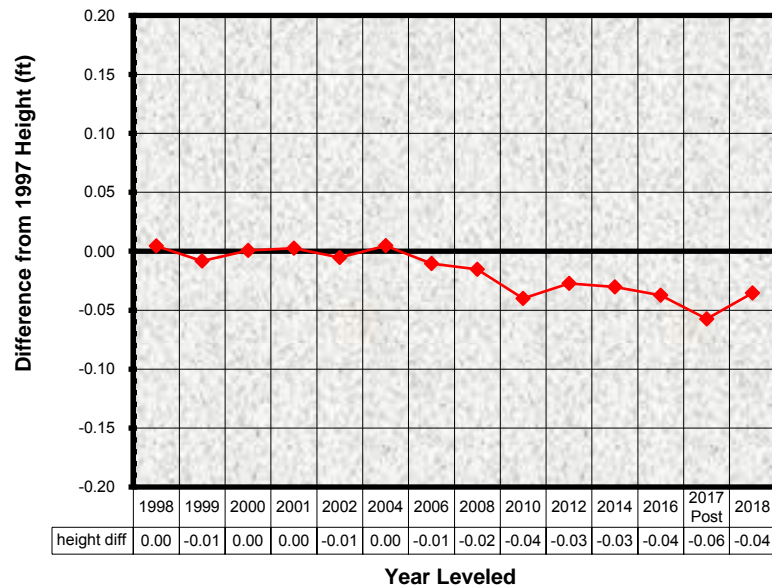
## Station # 17 - Horizontal



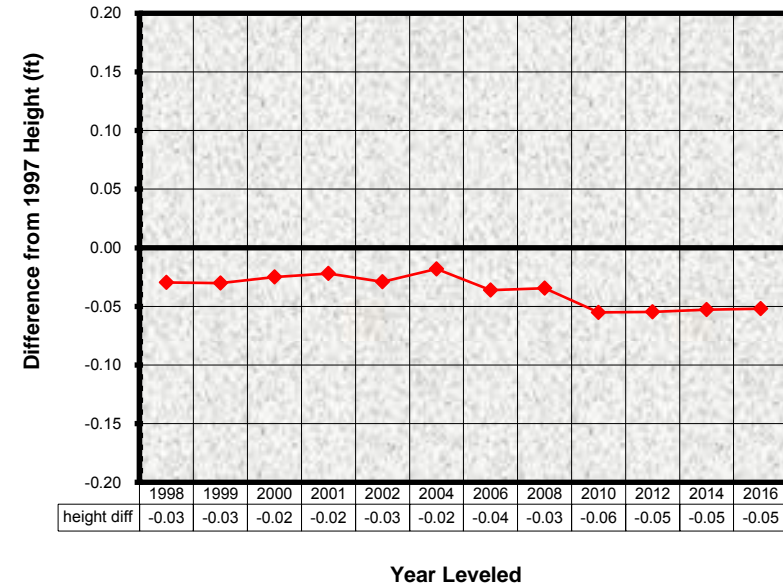
## Station # 18 - Horizontal



## Station # 17 - Vertical

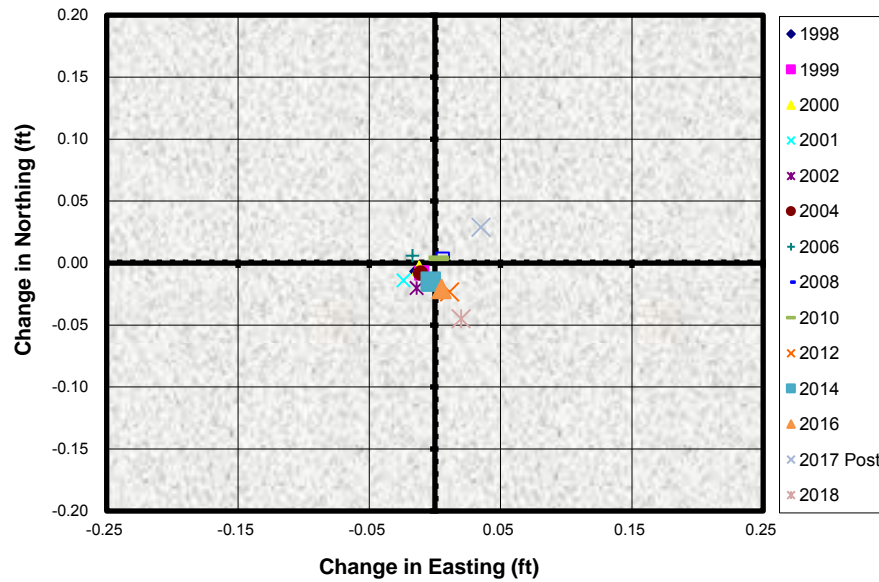


## Station # 18 - Vertical

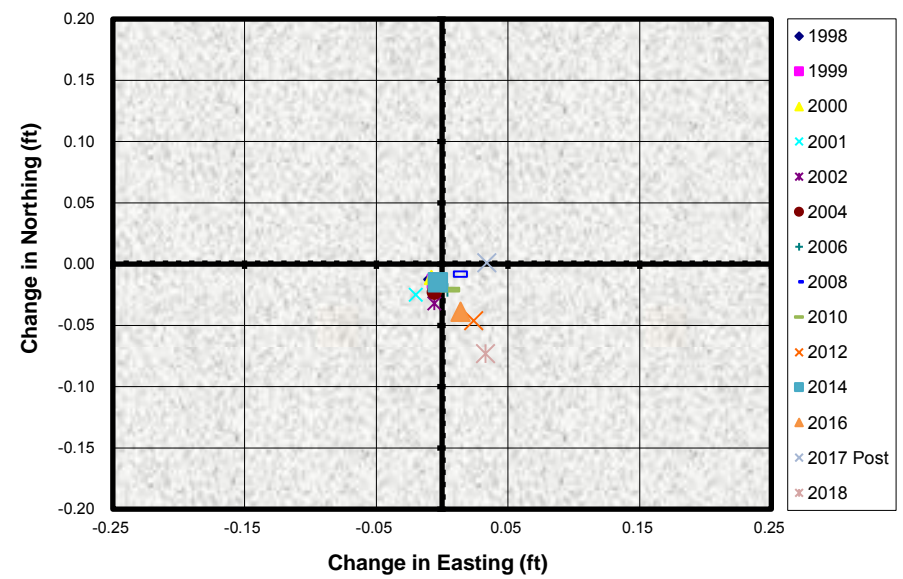


# Cove Road Crib Wall Movement from 1997 Initial Survey

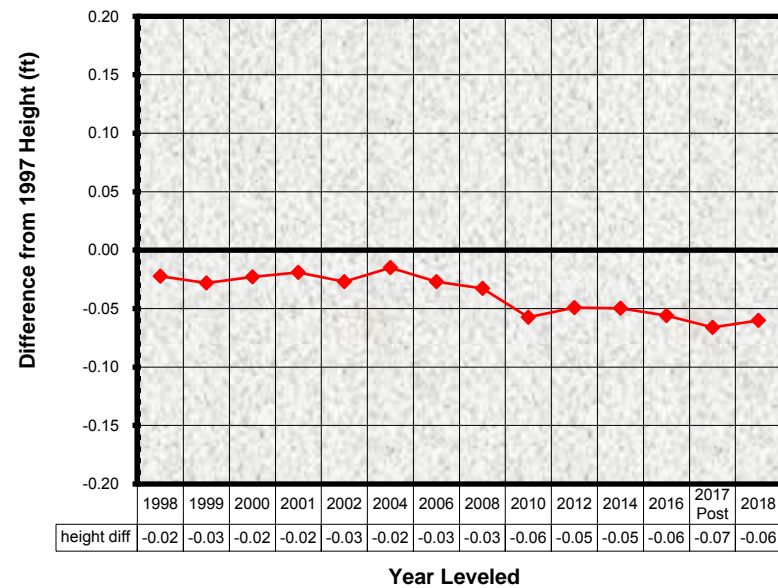
## Station # 19 - Horizontal



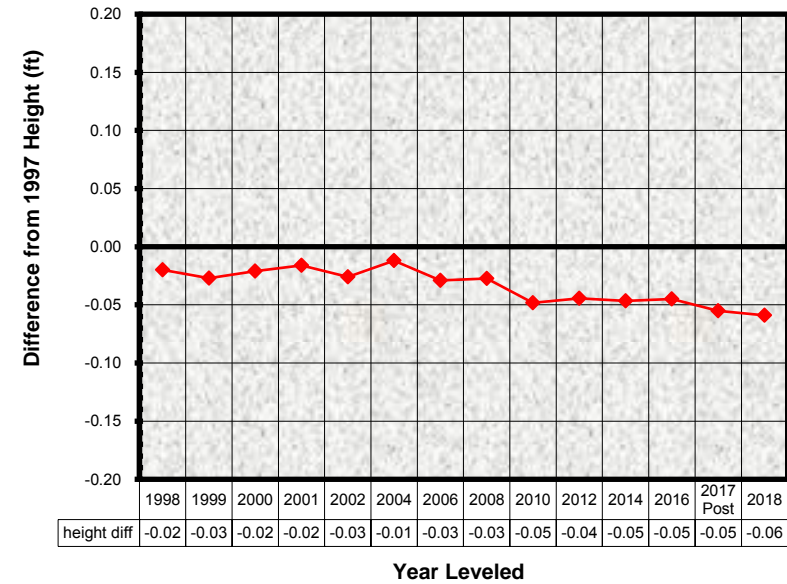
## Station # 20 - Horizontal



## Station # 19 - Vertical

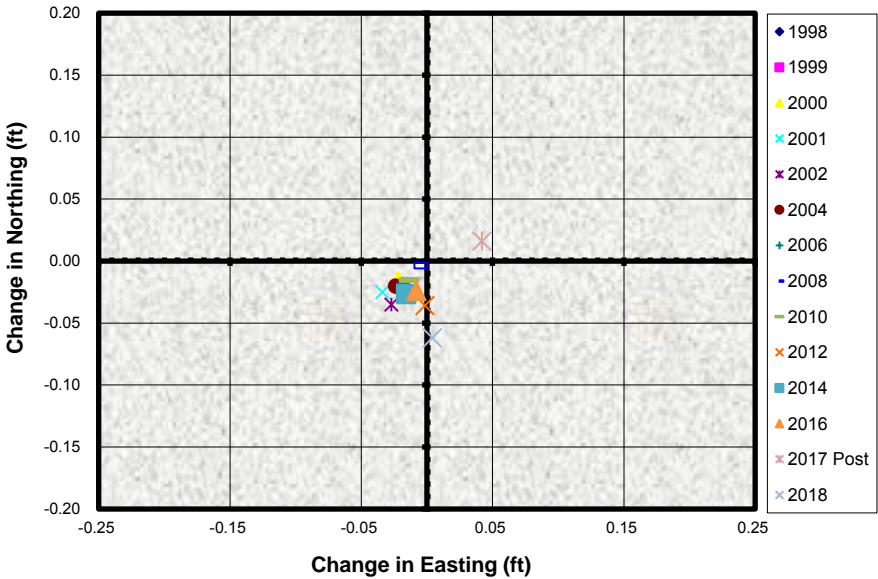


## Station # 20 - Vertical

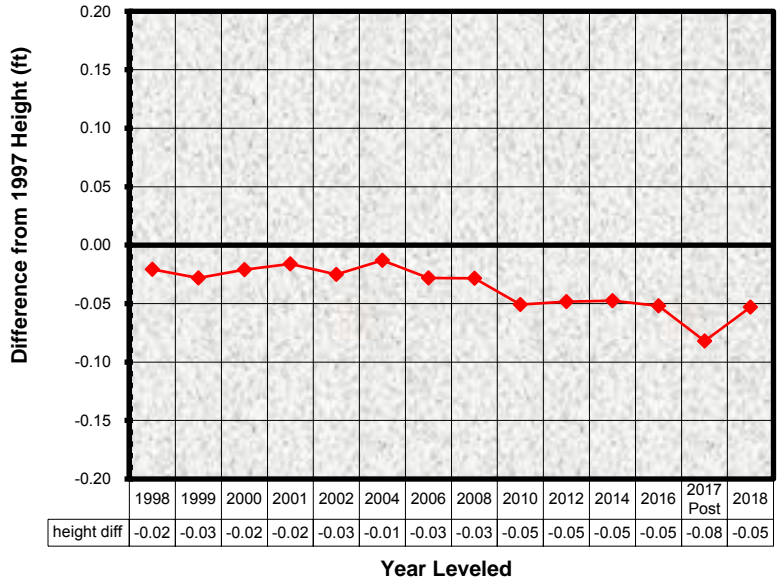


# Cove Road Crib Wall Movement from 1997 Initial Survey

Station # 21 - Horizontal



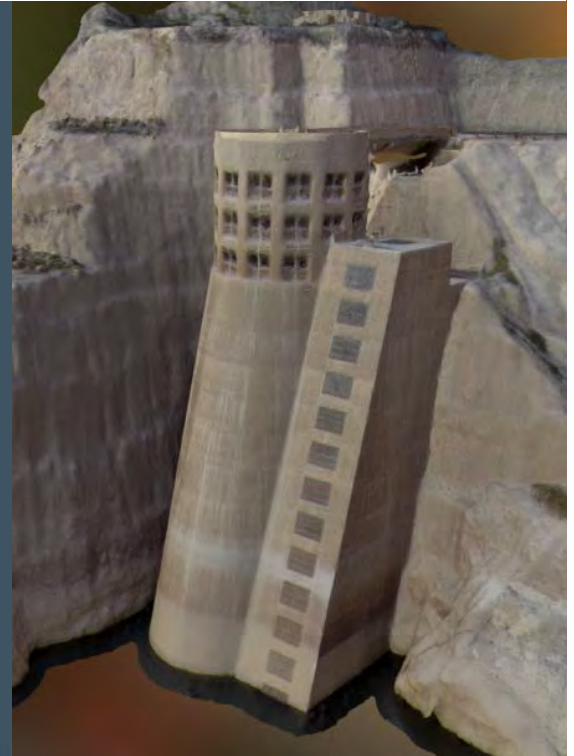
Station # 21 - Vertical





# 14

# SEVEN OAKS DAM



## Seven Oaks Dam Monitoring Report 2018

OC Survey  
Geodetic Unit



**Seven Oaks Dam, San Bernardino California**

**Final Report for October 2018 Survey**

**History**

The Seven Oaks Dam (SOD) was constructed by the United States Army Corps of Engineers (USACE), Los Angeles District and was completed November 15, 1999. The dam is located on the Santa Ana River in the upper Santa Ana Canyon about 8 miles northeast of the City of Redlands. This dam is planned to operate in tandem with Prado Dam, which is located on the Santa Ana River approximately 40 miles downstream. Together, these dams will provide flood protection to Orange County.

The SOD is an earth and rock fill dam with a crest elevation of 2610 feet NGVD29. The maximum height above the streambed is 550 feet. The crest length is 2980 feet. The intake tower is 225.5 feet high with a tower deck elevation of 2302 feet NGVD29.

A significant factor of SOD is that it is located near the San Andreas Rift zone. Here the San Andreas Fault interacts with other faults (most notably the San Jacinto fault zone and the Pinto Mountain fault) and thereby becomes somewhat fractured. Ancient and inactive strands of the San Andreas Fault can be found in this area. Although this area has been inactive for some time, there is concern that a significant earthquake could damage and affect SOD.

**Monitoring Plan**

Please see the “Seven Oaks Dam – Survey Monitoring Procedures and Guidelines-October 2018” document for details pertaining to monitoring the dam.

**Horizontal Control Datum**

The horizontal control datum to be used for this project is the “CCS83, Zone VI, 1998.5 Epoch” as described in the “Final Survey Report” prepared by Towill Inc. This epoch was calculated by transforming all record horizontal coordinates from the NGS/CORS stations used in the initial base and control survey using the NGS HTDP program.

NAD27 project coordinates are also calculated. The transformation from NAD83 to NAD27 is done using the following conversion from the “Final Survey Report” prepared by Towill Inc.,

NAD83 North: 2350217.575 = NAD27 North: 709771.99 (Difference = 1640445.585)

NAD83 East: 6304283.766 = NAD27 East: 1742874.80 (Difference = 4561408.966)

No rotation, no scale change.

It should be noted that on page 6 of the Towill Inc. “Final Survey Report”, the NAD27 North 7079771.99, should be North 709771.99. This was a typographical error and was found while verifying the transformation.

### **Vertical Control Datum**

The vertical control datum to be used for this project is the “NGVD29” as described in the “Final Survey Report” prepared by Towill Inc. This datum is based on control pillar GPS# 5009, SO2001-363 which has an elevation written on the monument plate, being 2608.130 feet. This elevation best fit the record settlement monument elevation. All other monument elevations were calculated from this origin through the direct level differences.

### **Survey Accuracies**

The accuracies stated here are based on the published manufacture equipment accuracies and the survey methodology used. These accuracies are *estimates* and should be used cautiously.

Elevations using the Leica 3003 precise level	+/- 0.01’
Horizontal positions using GPS receivers	+/- 0.03’
Horizontal positions using Leica TCA 1103 total station	+/- 0.02’

### **October 2018 Survey Results**

All monitoring points were surveyed as described in the “Seven Oaks Dam – Survey Monitoring Procedures and Guidelines - October 2018” document. All results from all previous annual surveys including the October 2018 survey are shown relative to the initial January 2001 survey.

### **Dam Monitoring Points - Vertical**

The dam shows continual settling movement (vertical), although slowing down in the last few years, with the greatest emphasis being at the center and decreasing to the outside. The largest vertical difference being -0.59’ (SM151) at the center (upstream) top of dam and decreasing to -0.12’ (SM143) and -0.10’ (SM160) at the outside edge of the dam.



### **Dam Monitoring Points – Horizontal**

The horizontal positions were measured using GPS methodology. There are a number of monitoring points located on the easterly and westerly sides of the dam that are showing slight horizontal movement roughly towards the center of the dam and are worth noting. This movement correlates with the settling of the dam and has been apparent in almost all of the previous surveys, but the amounts are very small. Below is a list of monitoring points with a displacement  $\geq 0.10'$ .

#### **Bench Level:**

Downstream 2310' level	None
Downstream 2510' level	SM110, SM111, SM114, SM115, SM117, SM119
Downstream 2560' level	SM122, SM124
Downstream Top of Dam	SM127, SM128, SM131, SM137, SM140
Upstream Top of Dam	SM146, SM148, SM154, SM156
Upstream 2530' level	SM161, SM162, SM163, SM169, SM171
Upstream 2360' level	None

### **Outlet Structure Monitoring Points**

The outlet structure appears relatively stable. All horizontal and vertical measurements agree with previous surveys to within  $0.03'$  +/- . No significant movement has been detected.

### **Intake Structure Monitoring Points**

The intake structure appears relatively stable. Station "SO2001-3" located at the bottom of the tower has proven to be a difficult monument to level due to its location. There was no monitoring of this monument (SO2001-3) because it was underwater during this year's survey. The height of this station is more than likely less accurate than the station located at the top of the tower SO2001-4. The horizontal positions are very stable. No significant movement has been detected.

### **Inclinometer Monitoring Points - Vertical**

The 6 inclinometer monitoring points show the same vertical movement as their surrounding dam monitoring points.

### **Inclinometer Monitoring Points - Horizontal**

The horizontal positions were measured using GPS methodology. All SI monitoring points located on the east and west sides of the dam show the same amount and direction

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of horizontal movement as the adjacent monitoring points being roughly towards the center of the dam.

**Date of Surveys**

Phase I & II – Horizontal positioning of monitoring points and control stations (GPS)

November 5, 6, 14, 15, 28, December 3, 4

Phase III – Differential leveling on all points

November 5, 6, 7, 8, 13, 27

Phase VI – Horizontal positioning of tunnel settlement points (Conventional)

November 7

All measurements shown are in U.S. Survey feet unless otherwise stated. If there are any questions pertaining the report or survey, please call me, Art Andrew @ (714) 967-0823.

Please see the “Overview” section, which details how the data was divided into sections and where the data can be found.

This report has been prepared by me or under my direction.



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Art Andrew, P.L.S. 7042

December 28, 2018

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Date:



**Seven Oaks Dam, San Bernardino, California**

**Survey Monitoring Procedures and Guidelines – October 2018**

This document describes the survey procedures currently being used to monitor the Seven Oaks Dam (SOD). The procedures will continually be updated due to the advancement in methodology and instrumentation.

**SOD Monitoring Frequency**

The Operations & Maintenance Manual calls for semi-annual monitoring surveys for the first three years and annual for the next five years. The Initial survey was performed by Towill Inc., January 2001 with 2 follow up surveys being March 2001 and June 2001. Orange County Geomatics followed this schedule and monitored SOD bi-annually for 2002 and 2003, then annually from 2004 – 2008. Annual monitoring will continue unless directed differently by OC Flood. If movement is found that differs from the expected characteristics of this dam, the frequency could be modified.

<b><u>Performed By:</u></b>	<b><u>Date of Survey</u></b>	<b><u>Remarks:</u></b>
Towill Inc.	Jan-2001	Initial Survey
Towill Inc.	Mar-2001	Follow Up
Towill Inc.	Jun-2001	Follow Up
OC Survey	Jul-2002	Bi-annual
Towill Inc.	Apr-2003	Bi-annual
OC Survey	Oct-2003	First Annual
OC Survey	Oct-2004	Annual
OC Survey	Oct-2005	Annual
OC Survey	Oct-2006	Annual
Johnson Frank & Assoc.	Oct-2007	Annual
Johnson Frank & Assoc.	May-2008	Annual
Johnson Frank & Assoc.	Oct-2009	Annual
San Bernardino County	Oct-2010 thru Oct-2017	Annual
San Bernardino County	Oct-2018	Planned Annual

## **Monitoring Plan**

SOD has been monitored three times by Towill, Inc. for the United States Army Corps of Engineers (USACE). An initial survey was performed followed by 2 monitoring surveys. The County will now manage the monitoring of SOD. This monitoring plan will be used as guidelines and procedures for future monitoring of SOD. They will be based on, Towill's methodology, available publications and reports on monitoring dams, and on the County's own experience in monitoring. These procedures may change in time as new methods are developed, with changing technology and from the learning experience in monitoring SOD.

## **Monitoring Station Selection:**

### **Vertical Monitoring – Station Selection**

It was decided by USACE that all monitoring stations would be vertically positioned every time SOD was surveyed. This would be done utilizing precise leveling.

### **Horizontal Monitoring – Station Selection**

A total of 68 monitoring stations will be horizontally positioned every time SOD is surveyed. The breakdown is as follows:

Dam Monitoring Stations – 33

USACE selected a subnet of 33 of the total 78 dam monitoring stations to be surveyed horizontally every time.

Inclinometer Monitoring Stations – 6

All inclinometers are included.

Cross-section @ Monitoring Stations – 7

USACE requested these additional stations be included in every survey.

Intake Tower Monitoring Stations – 2

One monument is located on top of the tower, the other located at the bottom.

Tunnel Monitoring Stations – 21

All stations set in the outlet tunnel will be included in every survey.



## **Survey Details:**

### **Horizontal Control Datum**

The horizontal control datum to be used for this project is the “CCS83, zone VI, 1998.5 epoch” as described in the “Final Survey Report” prepared by Towill Inc. This epoch was calculated by transforming all record horizontal coordinates from the NGS/CORS stations used in the initial base and control survey using the NGS HTDP program.

NAD27 project coordinates are also calculated. The transformation from NAD83 to NAD27 is done using the following conversion from the “Final Survey Report” prepared by Towill Inc.

NAD83 North: 2350217.575 = NAD27 North: 709771.99 (Difference = 1640445.585)  
NAD83 East: 6304283.766 = NAD27 East: 1742874.80 (Difference = 4561408.966)  
No rotation, no scale change.

It should be noted that on page 6 of the Towill Inc. “Final Survey Report”, the NAD27 North 709771.99, should be North 709771.99. This was a typographical error and was found while verifying the transformation.

### **Vertical Control Datum**

The vertical control datum to be used for this project is the “NGVD 29” as described in the “Final Survey Report” prepared by Towill Inc. This datum is based on control pillar GPS# 5009, SO2001-363 which has an elevation written on the monument plate, being 2608.130 feet. This elevation best fit the record settlement monument elevation. All other monument elevations were calculated from this origin through the direct leveling differences.

### **Survey Accuracies**

The accuracies stated here are based on the published manufacture equipment accuracies and the survey methodology used. These accuracies are *estimates* and should be used cautiously.

Elevations using the Leica NA3003 precise level	+/- 0.01’
Horizontal positions using GPS receivers	+/- 0.03’
Horizontal positions using Leica TCA 1103 total station	+/- 0.02’

**Monitoring Phases, General Description:**

The monitoring plan is divided into phases I thru IV listed below:

**Phase I:** Horizontally position the 5 control stations along with 2 Intake tower points utilizing GPS – this will verify the stability of the control stations

**Phase II:** Horizontally position the following monitoring points utilizing GPS:

33 - subnet of 78 dam monitoring points.

**Note: The horizontal reference point is to the center of the vertical bolt welded to the top of well cap and not to the monument inside the pipe. Hand tighten the well cap and then match the two scribed reference marks of the cap and the pipe so they are correctly aligned for the vertical bolt to be in the correct position.**

6 - inclinometer monitoring points.

**Note: The horizontal & vertical reference point is the punch mark located on the northerly portion of the lid ring.**

7 - cross-section monitoring points.

**Note: The horizontal reference point is to the center of the vertical bolt welded to the top of well cap and not to the monument inside the pipe. Hand tighten the well cap and then match the scribed reference marks of the cap and the pipe so they are correctly aligned for the vertical bolt to be in the correct position.**

**Phase III:** Establish elevations on all monitoring points utilizing precise differential leveling.

**Note: The vertical reference point is to the top of monument inside monument wells.**

**Phase IV:** Horizontally position the 21 tunnel settlement points utilizing terrestrial surveying methodology

**Note: The horizontal and vertical reference point is the top center of the PK nails set in lead on top of concrete outlet box in tunnel.**

**Monitoring Phases, Detailed Description:**

**Phase I – Horizontal positioning and Verifying Control Stations (GPS)**

**(See Attachment I for diagram)**

Utilizing static GPS, observe all control stations listed below simultaneously with 5007 and 5008 using the following setups:

Day 1 (4 hours in AM): Setup on GPS 5006, 5007, 5008 & 5503

Day 1 (4 hours in PM): Setup on GPS 5007, 5008, 5009 & 5511

Day 2 (4 hours in AM): Setup on GPS 5007, 5008, 5009 & 5511

Day 2 (4 hours in PM): Setup on GPS 5006, 5007, 5008 & 5503

\*\*Day 3 (4 hours in PM): Setup on GPS 5007, 5008, & 5502

\*\*Day 3 (4 hours in PM): Setup on GPS 5007, 5008, & 5502

<b>GPS#</b>	<b>STATION NAME</b>	<b>MONUMENT TYPE</b>
5006	SO2001-334	concrete pillar
5007	SO2001-356	concrete pillar
5008	SO2001-359	concrete pillar
5009	SO2001-363	concrete pillar
5511	SO2001-12 (SM200)	brass disk (front of tunnel)
5502**	SO2001-3	brass disk (bottom of intake tower)
5503	SO2001-4	brass disk (top of intake tower)

\*\* = Due to the uncertainty of the water level, GPS 5502 maybe underwater and unusable for this survey. At the beginning of the flood season (October 1<sup>st</sup>), water release is halted and water is retained behind the dam and released in spring the following year.

Perform two least squares adjustments being;

1. A minimally constrained adjustment holding control station 5007 with CCS83 zone VI, 1998.5 epoch values listed below per Towill Inc. initial survey.
2. A constrained adjustment holding control stations 5007 and 5008 with CCS83 zone VI, 1998.5 epoch values listed below per Towill Inc. initial survey.

<b>GPS #</b>	<b>Name</b>	<b>Latitude</b>	<b>Longitude</b>	<b>North (ft)</b>	<b>East (ft)</b>	<b><u>Ellipsoid</u> Ht. (ft)</b>	<b><u>NGVD29</u> Ht. (ft)</b>
<b>5007</b>	SO2001-356	34 06 59.28391	117 05 35.91623	2350923.584	6306400.252	2500.362	2604.352
<b>5008</b>	SO2001-359	34 06 52.13049	117 06 01.01829	2350217.575	6304283.766	2145.822	2250.036

**Phase II – Horizontal positioning the Monitoring Points (GPS)**

**(See Attachment II for diagram)**

Utilizing static GPS, observe all monitoring points listed below simultaneously with 5007 and 5008:

This includes the following stations:

33-point subnet - This 33-point subnet is approximately 35% of the total monitoring points and was approved by USACE.

SM101, SM103 (bolt missing), SM105, SM107, SM109, SM111, SM113, SM115, SM117, SM119, SM122, SM124, SM127, SM131, SM133, SM135, SM137, SM140, SM146, SM148, SM150, SM152, SM154, SM156, SM161, SM163, SM165, SM167, SM169, SM171, SM173, SM175, SM177

6-inclinometer points being;

SI1, SI2, SI3, SI4, SI5, SI6

7-cross-section points being;

SM104, SM110, SM114, SM128, SM151, SM162, SM166

Perform a constrained adjustment holding control stations 5007 and 5008 with CCS83 zone VI, 1998.5 epoch values listed below per Towill Inc. initial survey.

<b><u>GPS #</u></b>	<b><u>Name</u></b>	<b><u>Latitude</u></b>	<b><u>Longitude</u></b>	<b><u>North (ft)</u></b>	<b><u>East (ft)</u></b>	<b><u>Ellipsoid Ht. (ft)</u></b>	<b><u>NGVD29 Ht. (ft)</u></b>
<b>5007</b>	SO2001-356	34 06 59.28391	117 05 35.91623	2350923.584	6306400.252	2500.362	2604.352
<b>5008</b>	SO2001-359	34 06 52.13049	117 06 01.01829	2350217.575	6304283.766	2145.822	2250.036

**Phase I and II - GPS Static Survey Procedures**

All requested points will be positioned horizontally utilizing GPS static methodology excluding the tunnel points. Equipment used will be GPS dual-frequency receivers with geodetic quality antennas.

Phase I - Control point observations will be double occupied. Observation length should be a minimum of 4 hours. It is suggested that these occupations are done while field crews are running precise levels.



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Phase II – Monitoring point observations will be single occupied. Observation lengths should be a minimum of 20 minutes \*(see note below) on all monitoring points located along the upstream and downstream faces of the dam and for the monitoring points located along the top of dam.

Repeat observations will not be performed on the monitoring stations. A single observation will be done and the position will be analyzed with the previous surveys. If the current position does not agree with the previous characteristics of the monument (movement or stability), a repeat observation will be performed to verify the first observation. This method will be used to increase the efficiency of the survey.

\*(Note:) Observation lengths should be long enough to obtain fixed ambiguity baseline solutions. If repeat observations are necessary, vectors must agree horizontally 0.03' and vertically 0.06'. If these agreements are not met, re-observations must be performed until the required precisions are achieved.

Control stations (5007) SO2001-356 and (5008) SO2001-359 will be used for all GPS surveys for consistency with previous surveys.

The GPS network will be designed to include only non-trivial baselines. Baselines between monitoring points will not be used, only baselines between control stations and monitoring points.

### **Phase III – Precise Leveling of all Monitoring Points**

**(See Attachment III for diagram)**

All monitoring points will be vertically positioned utilizing precise differential leveling. Equipment used will be the Leica NA3003 digital level (or equivalent), which has a stated accuracy of 0.4mm per 1 km double run. Bar code rods will be used. Invar rods will be used between benchmark checks if needed. Fiberglass bar code rods will be used on the monitoring points due to the fact that the Invar rods are too wide to fit inside the monument wells.

All level runs will be performed by starting from 3 benchmarks and ending on 3 different benchmarks. If the run cannot be ended on 3 different benchmarks, the run will loop and close back on the 3 starting benchmarks. Leveling closures will be based on 1<sup>st</sup> order specifications where the maximum allowable misclosure is 3mm per 1 km (0.017 foot per mile). If the closure exceeds the maximum allowable misclosure, the line must be rerun to verify the 1<sup>st</sup> run or to identify problems with the benchmarks.

**Monitoring Points – Precise Level Runs**

**DOWNSTREAM 2310' LEVEL**

Start at and level thru: BM SO2001-116, BM SO2001-117, BM SO2001-118, SM100, SM101, SM 102, SO2001-119, SM103, SM104, SM105, SM106, SM107, SM108, SM107, SM106, SM105, SM104, SM103, SO2001-119, SM102, SM101, BM S02001-118, BM S02001-117, BM S02001-116

**DOWNSTREAM 2510' LEVEL**

Start at and level thru: BM SO2001-123, BM SO2001-124, BM SO2001-125, SM109, SM110, SM111, SM112, SM113, SM114, SM115, SO2001-120, SM116, SM117, SM118, SM119, SI4, SM120, BM SO2001-126, BM SO2001-127, BM SO2001-128

**DOWNSTREAM 2560' LEVEL**

Start at and level thru: BM SO2001-110, BM SO2001-111, BM SO2001-112, SM124, SM123, SM122, SM121, SM122, SM123, SM124, BM SO2001-112, BM SO2001-111, BM SO2001-110

**DOWNSTREAM TOP OF DAM LEVEL**

Start at and level thru: BM SO2001-102, BM SO2001-100, BM SO2001-101, SI1, SI2, SM125, SM126, SM127, SI3, SM128, SM129, SM130, SM131, SM132, SM133, SM134, SM135, SM136, SM137, SM138, SM139, SI5, SM140, SM141, SI6, SM142, BM SO2001-105, BM SO2001-104, BM SO2001-103

**UPSTREAM TOP OF DAM LEVEL**

Start at and level thru: BM SO2001-105, BM SO2001-104, BM SO2001-103, SM160, SM159, SM158, SM157, SM156, SM155, SM154, SM153, SM152, SM151, SM150, SM149, SM148, SM147, SM146, SM145, SM144, SM143, BM SO2001-102, BM SO2001-100, BM SO2001-101

**UPSTREAM 2530' LEVEL**

Start at and level thru: BM SO2001-131, BM SO2001-132, BM SO2001-133, SM161, SM162, SM163, SO2001-121, SM164, SM165, SM166, SM167, SM168, SM169, SM170, SM171, SM172, SM171, SM170, SM169, SM168, SM167, SM166, SM165, SM164, SO2001-121, SM163, SM162, SM161, BM SO2001-133, BM SO2001-132, BM SO2001-131

**UPSTREAM 2360' LEVEL**

Start at and level thru: BM SO2001-113, BM SO2001-114, BM SO2001-115, SM177, SM176, SM175, SM174, SM173, SM174, SM175, SM176, SM177, BM SO2001-115, BM SO2001-114, BM SO2001-113

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**INTAKE TOWER**

Start at and level thru: BM SO2001-113, SO2001-4, BM SO2001-113, SO2001-3\*\* (GPS 5502), BM SO2001-113

\*\* = Due to the uncertainty of the water level, SO2001-3 (GPS 5502) maybe underwater and unusable for this survey.

**OUTLET TUNNEL**

Start at and level thru: BM SO2001-106, BM SO2001-107, SM200, SM201, SM202, SM203, SM204, SM205, SM206, SM207, SM208, SM209, SM210, SM211, SM212, SM213, SM214, SM215, SM216, SM217, SM218, SM219, SM220, SM221, SM222, SM221, SM220, SM219, SM218, SM217, SM216, SM215, SM214, SM213, SM212, SM211, SM210, SM209, SM208, SM207, SM206, SM205, SM204, SM203, SM202, SM201, SM200, BM SO2001-107, BM SO2001-106

**Benchmark Record Heights**

The NGVD 29 heights listed below are from the Towill Inc. initial survey performed January 2001 and will be used for all leveling calculations.

<b>Benchmark ID</b>	<b>NGVD 29 Ht. (ft)</b>	<b>Benchmark ID</b>	<b>NGVD 29 Ht. (ft)</b>
SO2001-100	2610.939	SO2001-116	2308.420
SO2001-101	2610.469	SO2001-117	2310.690
SO2001-102	2610.782	SO2001-118	2313.909
SO2001-103	2611.235	SO2001-119	2309.598
SO2001-104	2610.786	SO2001-120	2507.470
SO2001-105	2610.472	SO2001-121	2531.745
SO2001-106	2068.848	SO2001-123	2519.552
SO2001-107	2069.723	SO2001-124	2516.432
SO2001-108	Destroyed 2009	SO2001-125	2511.044
SO2001-109	2456.110	SO2001-126	2509.260
SO2001-110	2563.745	SO2001-127	2513.900
SO2001-111	2561.949	SO2001-128	2515.721
SO2001-112	2559.528	SO2001-130	2302.265
SO2001-113	2337.645	SO2001-131	2535.582
SO2001-114	2347.930	SO2001-132	2534.581
SO2001-115	2343.842	SO2001-133	2532.391

Treat all Benchmark points located in the asphalt on the dam as turning points; ignoring the published elevation listed above.

**Phase IV - Horizontally position tunnel settlement points utilizing terrestrial surveying methodology**

**(See Attachment IV for diagram)**

The outlet tunnel contains 21 monitoring points, which are PK nails set in the floor of the tunnel which is the top, outside surface of the outlet structure. These points are set along the center of the tunnel every 30 feet. The points are monitored from control station SM200 while backsighting a painted target which was set by Geomatics on the back wall of the tunnel. Control station SM200 and the painted target have an azimuth of 47-59-37.0 and is used for positioning the monitoring points.

There are two parts to monitoring the tunnel points. First is to verify the stability of control station SM200 conventionally, which is also done with GPS, and verify the survey line azimuth to the painted target set on the back wall of the tunnel. Second is to measure (station and out) each monitoring station relative to control station SM200 and the painted target/survey line azimuth.

Below describes the two parts:

**Part 1**

SM200 is surveyed utilizing static GPS during phase I which will verify the stability of the monument. Once this is done, the painted target/survey line azimuth of 47-59-37.0 is verified. This is done by using a Leica TCA-1103 total station (or an instrument with the equivalent stated accuracies). This instrument will be set over control station SM200, backsight control station SO2001-359 and have azimuth 277-01-20.2 set into the instrument. The instrument will then turn 4 sets of angles (1 set equals 1 direct and 1 reverse) to two different painted marks set by Geomatics as reference points on the east and west leg of an electrical transmission tower located southerly 1360' +/- on the side of a mountain which is not connected to any part of SOD. The azimuths will be checked at these reference marks to again verify the stability of control station SM200. The instrument will then turn 4 sets of angles to the painted target/survey line azimuth of 47-59-37.0 at the end of the tunnel.

**Part 2**

A Leica TCA-1103 total station (or an instrument with the equivalent stated accuracies) will be used for the tunnel monitoring points "station and out" calculations. The instrument will be set on control station SM200. This control station will be used as the primary control station for the tunnel monitoring. The instrument will sight the painted



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target/survey line. A horizontal distance will be measured to each station (direct and reverse) for the stationing. Outs will be measured by having the Instrument man putting the rodman with a target online at each point. The rodman will then measure the difference and note if it is left or right of line. This will be done twice.

Example of Field Procedure:

With the instrument setup at SM200 and being in the direct mode, starting at the closest station being SM201, measure a direct horizontal distance to the target. Then the Instrument man will put the rodman target on line. Rodman will then record the distance and direction from line to point. Continue doing this on all stations to the end station being SM221. Instrument man will then flop gun into reverse mode and re-sight the painted target. Repeat observations in the reverse mode with the instrument being in the reverse mode.

The October 2018 SOD survey monitoring procedures and guidelines were reviewed and revised by myself.

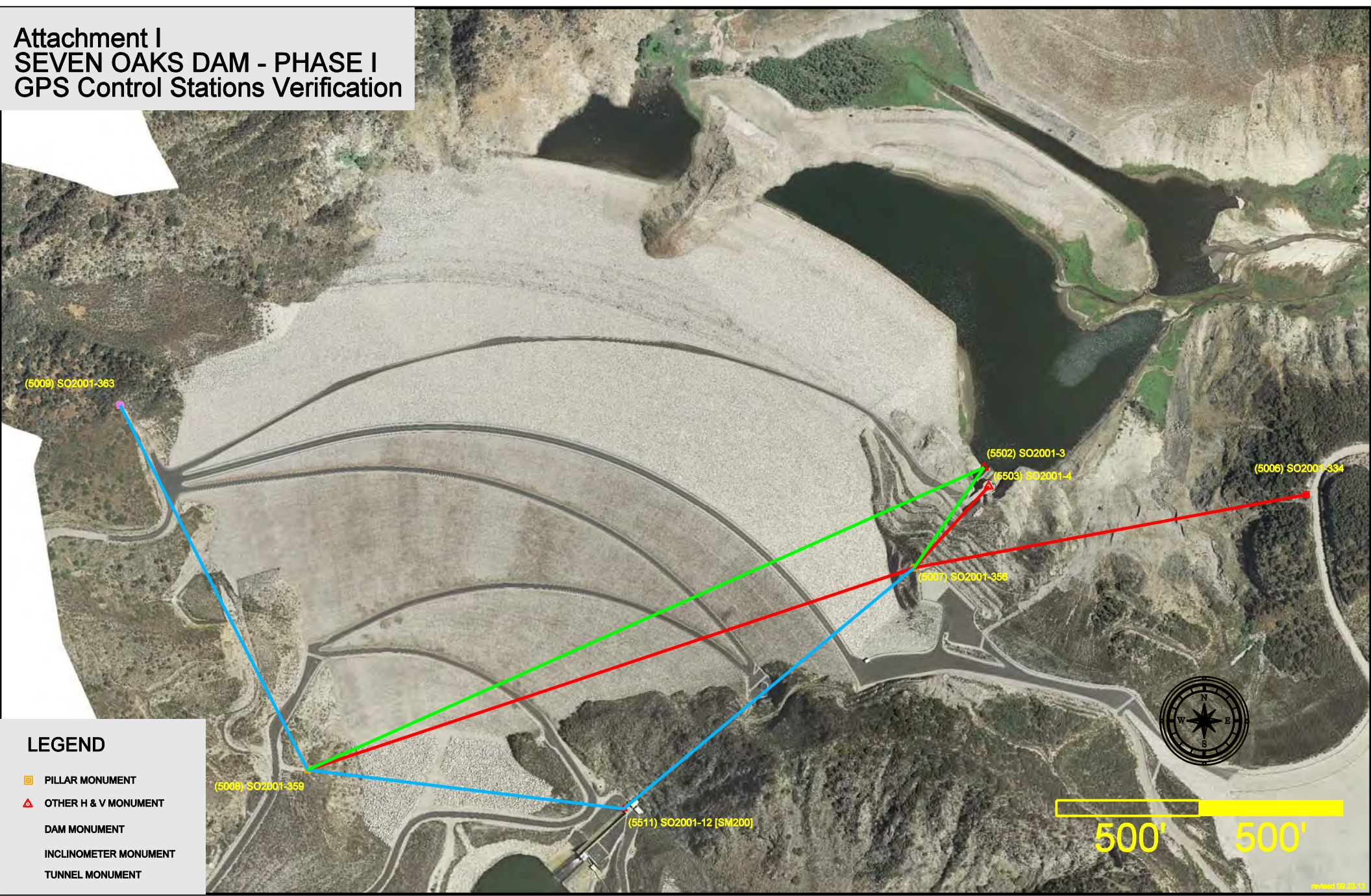


October 1, 2018

Arthur Ringland Andrew III

Date:

Attachment I  
SEVEN OAKS DAM - PHASE I  
GPS Control Stations Verification





# Attachment II SEVEN OAKS DAM - PHASE II GPS Monitoring Stations

LEGEND

RED = ROVA

PINK = ROVB

BLUE = ROVC

GREEN = BASC

BROWN = BASA & BASB

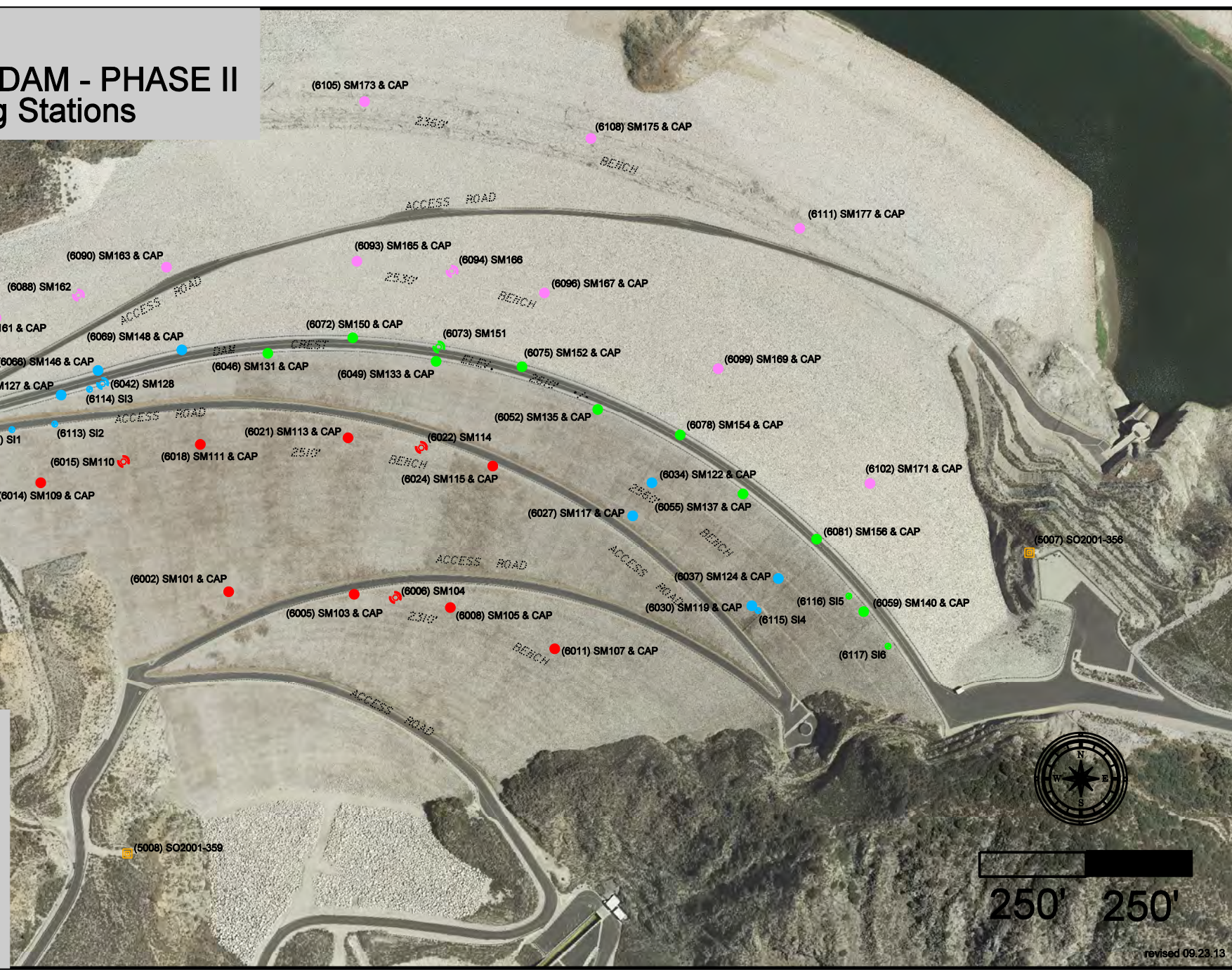
PILLAR MONUMENT

OTHER H & V MONUMENT

SETTLEMENT H & V MONUMENT

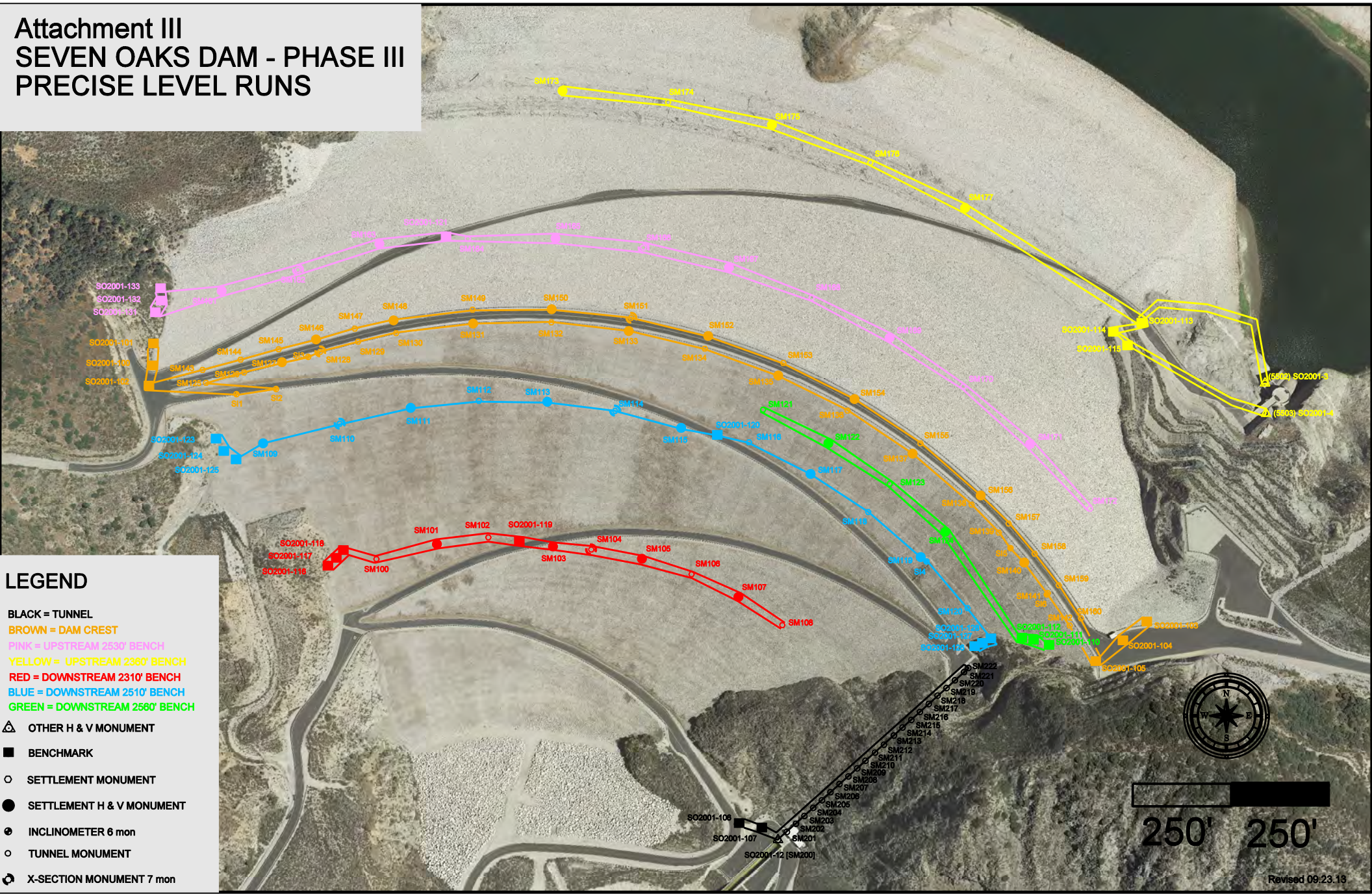
INCLINOMETER 6 mon

X-SECTION MONUMENT 7 mon





Attachment III  
SEVEN OAKS DAM - PHASE III  
PRECISE LEVEL RUNS





## PHASE IV

### TUNNEL MONITORING - AZIMUTH SHOTS

- = FD PILLER MONUMENT
- ▲ - FD. 2-1/2" USCE BRASS DISK SET FLUSH IN CONC. STRUCTURE

SET PAINTED TARGET  
@ END OF TUNNEL AS  
SHOWN BELOW:



TARGET  
[SM 222]

S02001-359 (GPS 5008)



277-01-20.2

47-59-37.0 (use for monitoring)  
**TUNNEL**



N.T.S.

S02001-12  
[SM 200]  
(GPS 5511)

### TUNNEL MONITORING PROCEDURES:

INST TCA-1103 @ SM 200

1. SET AZIMUTH BACKSIGHTING 5008 OF 277-01-20.2
2. CHECK AZIMUTH BY SIGHTING EAST & WEST TOWER LEGS (4 SETS)
3. TURN TO PAINTED TARGET ON TUNNEL WALL (4 SETS)
4. VERIFY AZIMUTH OF "47-59-37.0" TO PAINTED TARGET

INST TCA-1103 @ SM 200

1. BACKSIGHT PAINTED TARGET ON WALL
2. SET AZIMUTH "47-59-37.0" IN INSTRUMENT
3. MEASURE STATION & OUTS TO ALL MONITORING POINTS (2 SETS)

178-27-04.5  
178-01-02.0

TOWER  
WEST LEG

TOWER  
EAST LEG

ELECTRICAL  
TRANSMISSION  
TOWERS

(PAINTED AZIMUTH MARKS)  
SCRIBED VERTICAL LINE IN STEEL TOWER  
PAINTED TARGET AS SHOWN BELOW:



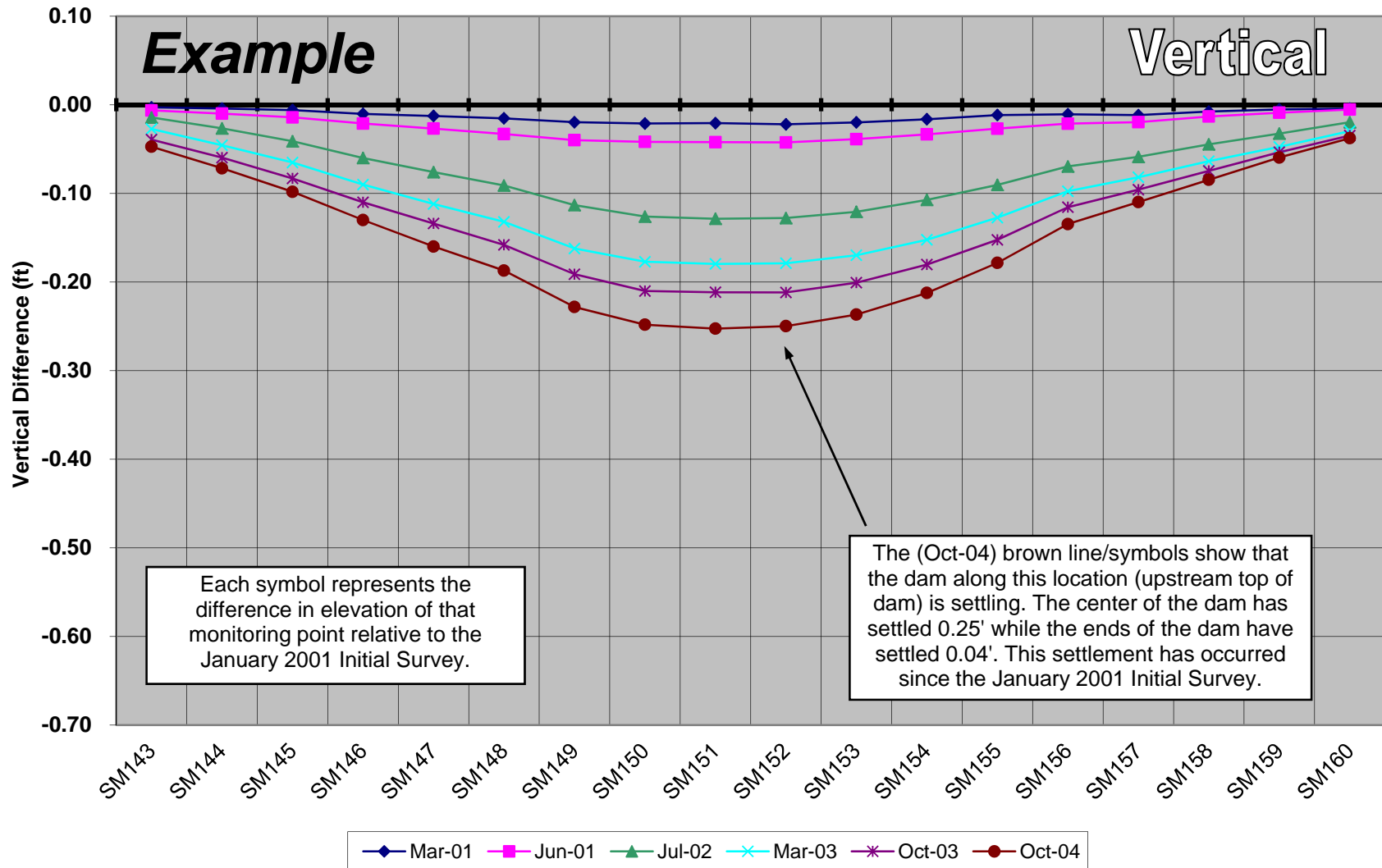
# EXAMPLE GRAPHS

The following examples are designed to graphically show what might be seen if displacement at station 11+35 had occurred.

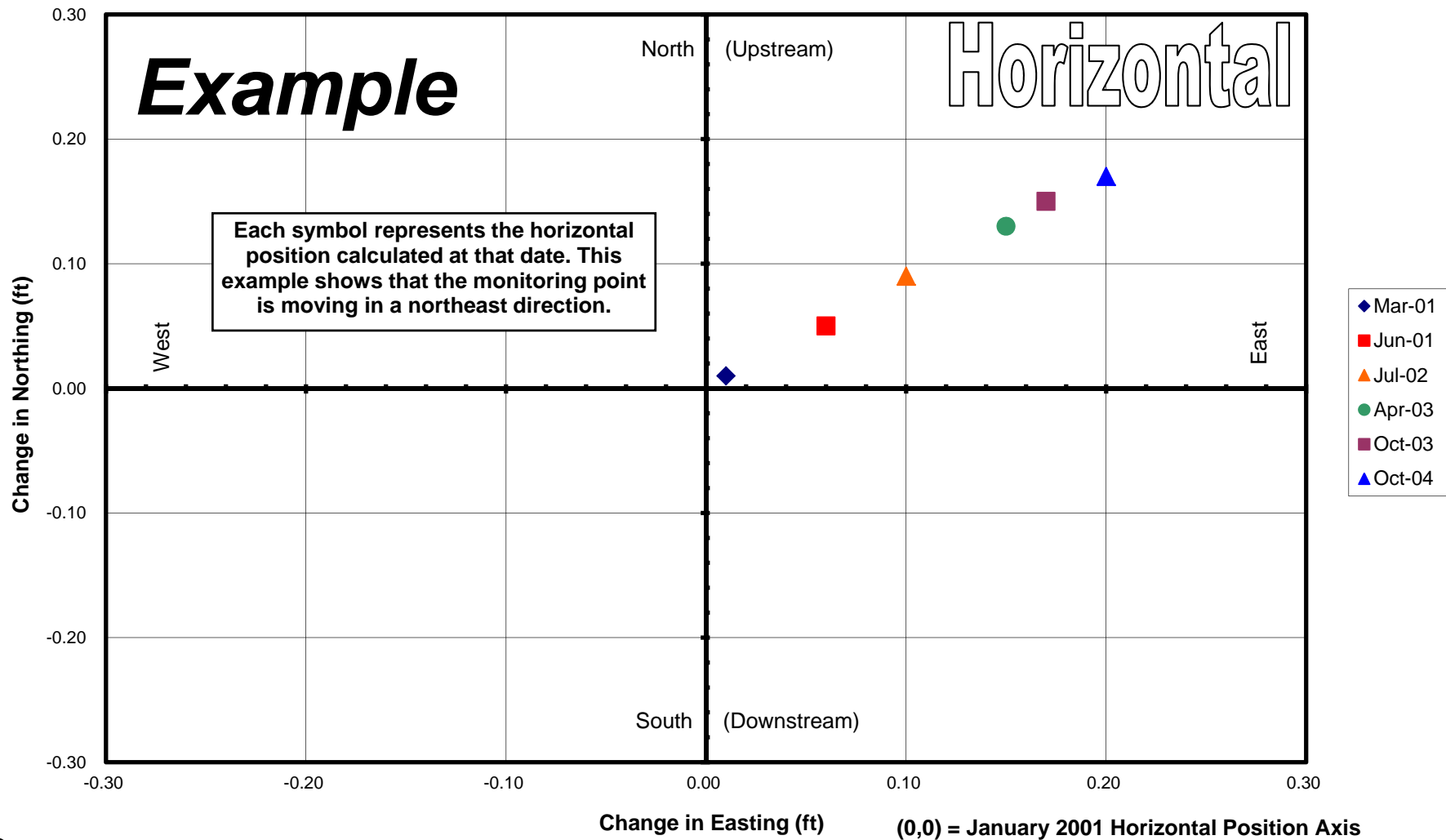
The “Vertical Movement” graph shows that station 11+35 has subsided about 0.28’ since 1995.

The “Horizontal Movement” graph shows a monitoring point’s movement of about 0.02’ per year in a Northeasterly direction.

# **Seven Oaks Dam** **Vertical Movement since January 2001 Initial Survey** **Profile View - Looking Upstream**



**EXAMPLE**  
**Monitoring Point**  
**Horizontal Movement since January 2001 Initial Survey**





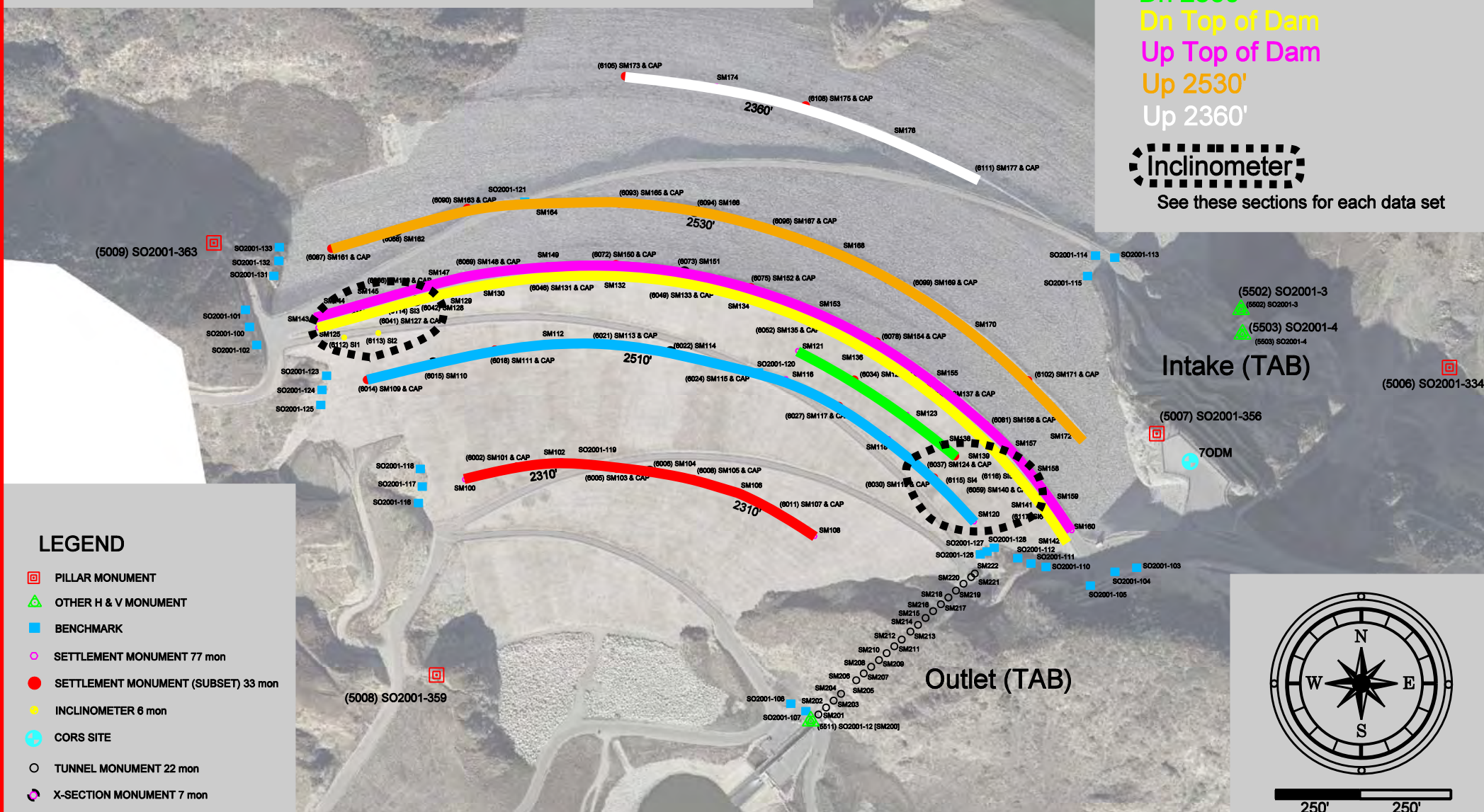
# Seven Oaks Dam Monitoring Survey Dam Overview - Data Index Map

## Data Index (TAB)

Dn 2310'  
Dn 2510'  
Dn 2560'  
Dn Top of Dam  
Up Top of Dam  
Up 2530'  
Up 2360'

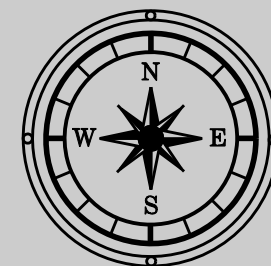


See these sections for each data set



## LEGEND

- PILLAR MONUMENT
- OTHER H & V MONUMENT
- BENCHMARK
- SETTLEMENT MONUMENT 77 mon
- SETTLEMENT MONUMENT (SUBSET) 33 mon
- INCLINOMETER 6 mon
- CORS SITE
- TUNNEL MONUMENT 22 mon
- X-SECTION MONUMENT 7 mon



250' 250'

# Seven Oaks Dam Monitoring Survey 2018

## Dam Monitoring Points

Horizontal Datum = CCS83, Zone VI, 1998.5 Epoch and CCS27, Zone VI Project Coordinates

Vertical Datum = None

<u>GPS#</u>	<u>NAME</u>	<u>(NAD83) NORTH (ft)</u>	<u>(NAD83) EAST (ft)</u>	<u>(NAD27) NORTH (ft)</u>	<u>(NAD27) EAST (ft)</u>	<u>Description</u>
5007	SO2001-356	2350923.584	6306400.252	710477.999	1744991.286	Control Pillar
5008	SO2001-359	2350217.575	6304283.766	709771.990	1742874.800	Control Pillar
5006	SO2001-334	2351183.477	6307768.983	710737.892	1746360.017	Control Pillar
5009	SO2001-363	2351492.223	6303627.940	711046.638	1742218.974	Control Pillar
5502	SO2001-3					Brass Disk
5503	SO2001-4	2351215.595	6306645.540	710770.01	1745236.574	Brass Disk
5511	SO2001-12 / SM200	2350081.764	6305386.402	709636.179	1743977.436	Brass Disk
	Downstream 2310 Level					
6002	SM101	2350831.892	6304519.915	710386.307	1743110.949	BOLT IN TOP CAP
6005	SM103	2350825.845	6304815.305	710380.260	1743406.339	TOP CAP NO BOLT
6006	SM104	2350818.322	6304912.431	710372.737	1743503.465	BOLT IN TOP CAP
6008	SM105	2350794.687	6305041.300	710349.102	1743632.334	BOLT IN TOP CAP
6011	SM107	2350698.318	6305286.128	710252.733	1743877.162	BOLT IN TOP CAP
	Downstream 2510 Level					
6014	SM109	2351088.918	6304079.802	710643.333	1742670.836	BOLT IN TOP CAP
6015	SM110	2351137.377	6304274.046	710691.792	1742865.080	BOLT IN TOP CAP
6018	SM111	2351177.494	6304453.774	710731.909	1743044.808	BOLT IN TOP CAP
6021	SM113	2351193.260	6304801.113	710747.675	1743392.147	BOLT IN TOP CAP
6022	SM114	2351170.209	6304972.993	710724.624	1743564.027	BOLT IN TOP CAP
6024	SM115	2351126.926	6305140.349	710681.341	1743731.383	BOLT IN TOP CAP
6027	SM117	2351011.187	6305469.231	710565.602	1744060.265	BOLT IN TOP CAP
6030	SM119	2350799.242	6305748.528	710353.657	1744339.562	BOLT IN TOP CAP
	Downstream 2560 level					
6034	SM122	2351088.943	6305514.593	710643.358	1744105.627	BOLT IN TOP CAP
6037	SM124	2350863.933	6305811.131	710418.348	1744402.165	BOLT IN TOP CAP

## Seven Oaks Dam Monitoring Survey 2018

### Dam Monitoring Points

Horizontal Datum = CCS83, Zone VI, 1998.5 Epoch and CCS27, Zone VI Project Coordinates

Vertical Datum = None

<u>GPS#</u>	<u>NAME</u>	<u>(NAD83) NORTH (ft)</u>	<u>(NAD83) EAST (ft)</u>	<u>(NAD27) NORTH (ft)</u>	<u>(NAD27) EAST (ft)</u>	<u>Description</u>
	Top of Dam-South side					
6041	SM127	2351293.743	6304128.071	710848.158	1742719.105	BOLT IN TOP CAP
6042	SM128	2351319.876	6304224.610	710874.291	1742815.644	BOLT IN TOP CAP
6046	SM131	2351392.804	6304613.547	710947.219	1743204.581	BOLT IN TOP CAP
6049	SM133	2351373.020	6305007.932	710927.435	1743598.966	BOLT IN TOP CAP
6052	SM135	2351260.216	6305386.224	710814.631	1743977.258	BOLT IN TOP CAP
6055	SM137	2351060.891	6305727.132	710615.306	1744318.166	BOLT IN TOP CAP
6059	SM140	2350786.345	6306011.054	710340.760	1744602.088	BOLT IN TOP CAP
	Top of Dam-North Side					
6066	SM146	2351352.737	6304215.603	710907.152	1742806.637	BOLT IN TOP CAP
6069	SM148	2351400.753	6304411.049	710955.168	1743002.083	BOLT IN TOP CAP
6072	SM150	2351428.768	6304813.047	710983.183	1743404.081	BOLT IN TOP CAP
6073	SM151	2351406.559	6305013.586	710960.974	1743604.620	BOLT IN TOP CAP
6075	SM152	2351360.627	6305210.089	710915.042	1743801.123	BOLT IN TOP CAP
6078	SM154	2351200.154	6305579.778	710754.569	1744170.812	BOLT IN TOP CAP
6081	SM156	2350956.622	6305900.919	710511.037	1744491.953	BOLT IN TOP CAP
	Upstream 2530 level					
6087	SM161	2351474.899	6303975.377	711029.314	1742566.411	BOLT IN TOP CAP
6088	SM162	2351527.947	6304168.088	711082.362	1742759.122	BOLT IN TOP CAP
6090	SM163	2351594.796	6304374.075	711149.211	1742965.109	BOLT IN TOP CAP
6093	SM165	2351608.887	6304822.514	711163.302	1743413.548	BOLT IN TOP CAP
6094	SM166	2351584.342	6305044.551	711138.757	1743635.585	BOLT IN TOP CAP
6096	SM167	2351533.554	6305261.717	711087.969	1743852.751	BOLT IN TOP CAP
6099	SM169	2351356.070	6305670.931	710910.485	1744261.965	BOLT IN TOP CAP
6102	SM171	2351086.547	6306026.383	710640.962	1744617.417	BOLT IN TOP CAP

## Seven Oaks Dam Monitoring Survey 2018

### Dam Monitoring Points

Horizontal Datum = CCS83, Zone VI, 1998.5 Epoch and CCS27, Zone VI Project Coordinates

Vertical Datum = None

<u>GPS#</u>	<u>NAME</u>	<u>(NAD83) NORTH (ft)</u>	<u>(NAD83) EAST (ft)</u>	<u>(NAD27) NORTH (ft)</u>	<u>(NAD27) EAST (ft)</u>	<u>Description</u>
	Upstream 2360 level					
6105	SM173	2351982.798	6304840.760	711537.213	1743431.794	BOLT IN TOP CAP
6108	SM175	2351892.236	6305368.693	711446.651	1743959.727	BOLT IN TOP CAP
6111	SM177	2351683.257	6305862.378	711237.672	1744453.412	BOLT IN TOP CAP
	Inclinometers					
6112	SI1	2351212.352	6304012.146	710766.767	1742603.180	PUNCH MARK IN RIM
6113	SI2	2351225.118	6304112.486	710779.533	1742703.520	PUNCH MARK IN RIM
6114	SI3	2351306.886	6304194.408	710861.301	1742785.442	PUNCH MARK IN RIM
6115	SI4	2350787.372	6305764.212	710341.787	1744355.246	PUNCH MARK IN RIM
6116	SI5	2350820.828	6305976.166	710375.243	1744567.200	PUNCH MARK IN RIM
6117	SI6	2350705.293	6306067.338	710259.708	1744658.372	PUNCH MARK IN RIM
The values are from the Control Trimble-Business Center Software adjustment constraining						
GPS #5007 fixed 3-dimensionally and #5008 fixed horizontally, per November 2018 San Bernardino Surveyor GPS Survey.						



# **Seven Oaks Dam Monitoring Survey 2018**

## **Dam Monitoring Points**

**Vertical Datum = NGVD29**

<b><u>Designation</u></b>	<b><u>Elevation (ft)</u></b>
<b>SI-1</b>	2595.926
<b>SI-2</b>	2588.270
<b>SI-3</b>	2611.227
<b>SI-4</b>	2510.550
<b>SI-5</b>	2611.321
<b>SI-6</b>	2611.022
<b>SM-100</b>	2307.287
<b>SM-101</b>	2306.710
<b>SM-102</b>	2306.727
<b>SM-103</b>	2306.984
<b>SM-104</b>	2306.507
<b>SM-105</b>	2306.470
<b>SM-106</b>	2306.509
<b>SM-107</b>	2306.536
<b>SM-108</b>	2306.828
<b>SM-109</b>	2507.261
<b>SM-110</b>	2506.894
<b>SM-111</b>	2506.618
<b>SM-112</b>	2506.482
<b>SM-113</b>	2506.457
<b>SM-114</b>	2506.481
<b>SM-115</b>	2506.569
<b>SM-116</b>	2506.065
<b>SM-117</b>	2506.094
<b>SM-118</b>	2506.365
<b>SM-119</b>	2506.644
<b>SM-120</b>	2507.078
<b>SM-121</b>	2556.412
<b>SM-122</b>	2556.610
<b>SM-123</b>	2556.507
<b>SM-124</b>	2556.915
<b>SM-125</b>	2609.665
<b>SM-126</b>	2609.583
<b>SM-127</b>	2609.733
<b>SM-128</b>	2609.977
<b>SM-129</b>	2610.078
<b>SM-130</b>	2610.587
<b>SM-131</b>	2611.244
<b>SM-132</b>	2611.288
<b>SM-133</b>	2611.207
<b>SM-134</b>	2611.225
<b>SM-135</b>	2611.183
<b>SM-136</b>	2611.138
<b>SM-137</b>	2610.822
<b>SM-138</b>	2610.517
<b>SM-139</b>	2610.382
<b>SM-140</b>	2610.194
<b>SM-141</b>	2609.912

# **Seven Oaks Dam Monitoring Survey 2018**

## **Dam Monitoring Points**

**Vertical Datum = NGVD29**

<b>SM-142</b>	2609.477
<b>SM-143</b>	2609.473
<b>SM-144</b>	2609.447
<b>SM-145</b>	2609.687
<b>SM-146</b>	2609.747
<b>SM-147</b>	2610.219
<b>SM-148</b>	2610.253
<b>SM-149</b>	2611.113
<b>SM-150</b>	2611.499
<b>SM-151</b>	2611.329
<b>SM-152</b>	2611.305
<b>SM-153</b>	2611.265
<b>SM-154</b>	2611.095
<b>SM-155</b>	2610.884
<b>SM-156</b>	2610.589
<b>SM-157</b>	2610.353
<b>SM-158</b>	2610.285
<b>SM-159</b>	2609.904
<b>SM-160</b>	2609.545
<b>SM-161</b>	2526.246
<b>SM-162</b>	2525.990
<b>SM-163</b>	2525.746
<b>SM-164</b>	2525.453
<b>SM-165</b>	2525.320
<b>SM-166</b>	2525.250
<b>SM-167</b>	2525.436
<b>SM-168</b>	2525.439
<b>SM-169</b>	2525.551
<b>SM-170</b>	2525.790
<b>SM-171</b>	2526.142
<b>SM-172</b>	2526.513
<b>SM-173</b>	2356.904
<b>SM-174</b>	2356.995
<b>SM-175</b>	2357.000
<b>SM-176</b>	2356.711
<b>SM-177</b>	2356.759
<b>SM-200</b>	2067.990
<b>SM-201</b>	2068.034
<b>SM-202</b>	2068.371
<b>SM-203</b>	2069.163
<b>SM-204</b>	2069.971
<b>SM-205</b>	2070.737
<b>SM-206</b>	2071.518
<b>SM-207</b>	2072.284
<b>SM-208</b>	2073.067
<b>SM-209</b>	2073.828
<b>SM-210</b>	2074.653
<b>SM-211</b>	2075.422
<b>SM-212</b>	2076.216

**Seven Oaks Dam Monitoring Survey 2018**

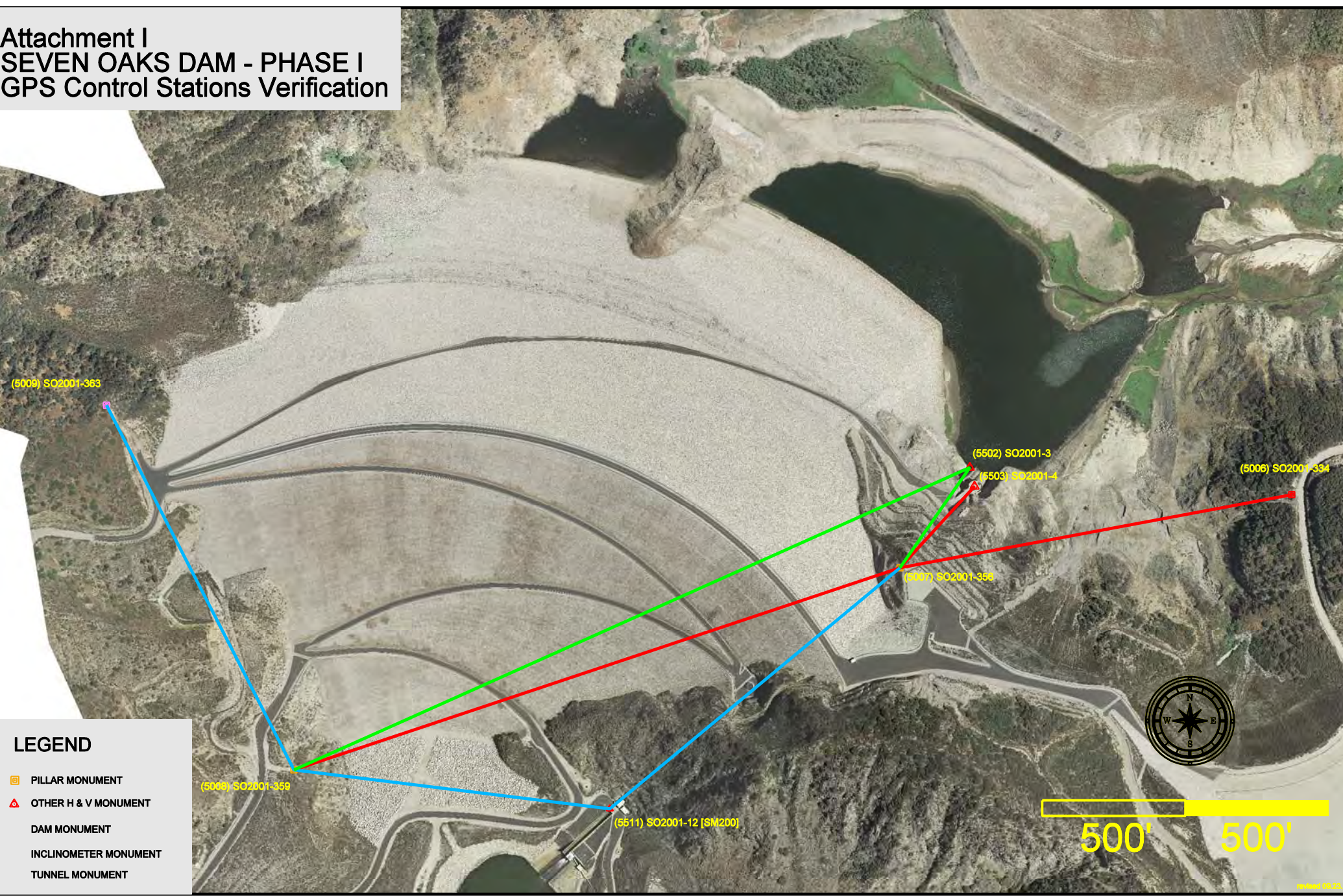
**Dam Monitoring Points**

**Vertical Datum = NGVD29**

<b>SM-213</b>	2077.127
<b>SM-214</b>	2077.874
<b>SM-215</b>	2078.702
<b>SM-216</b>	2079.454
<b>SM-217</b>	2080.239
<b>SM-218</b>	2081.495
<b>SM-219</b>	2083.052
<b>SM-220</b>	2084.293
<b>SM-221</b>	2085.066
<b>SM-222</b>	2093.479
<b>SO2001-4</b>	2302.209



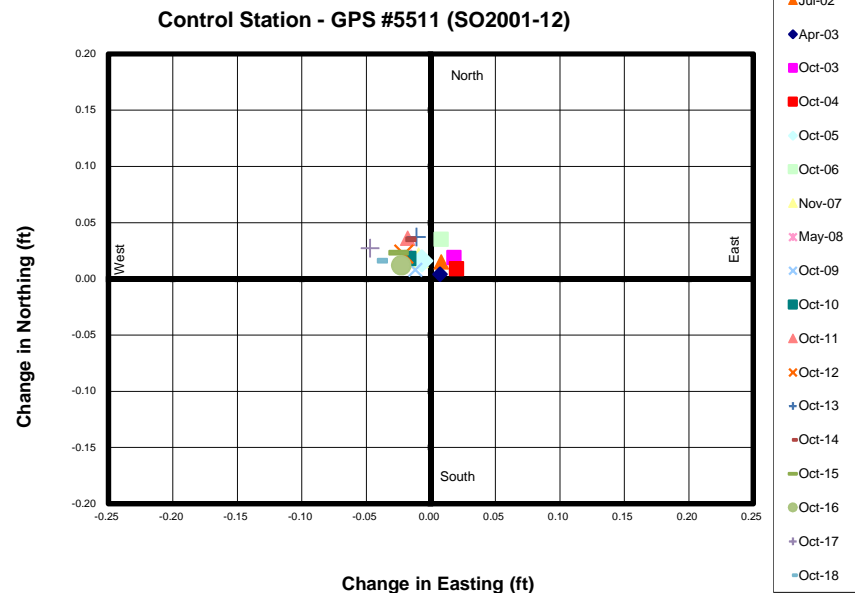
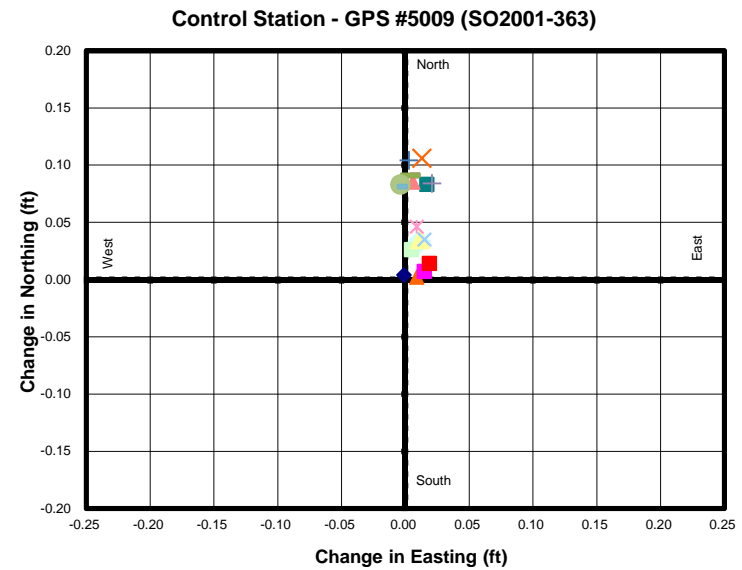
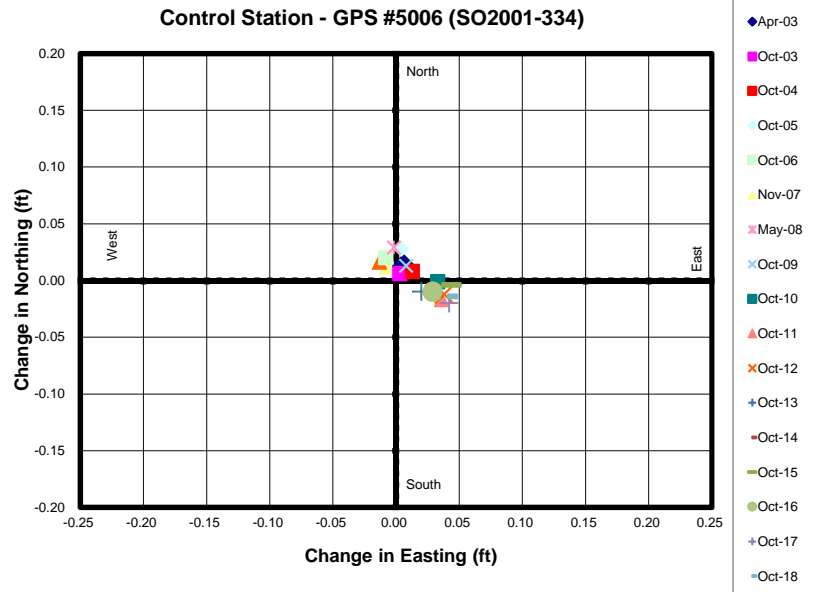
Attachment I  
SEVEN OAKS DAM - PHASE I  
GPS Control Stations Verification





# Seven Oaks Dam - Control Station Verification (Horizontal)

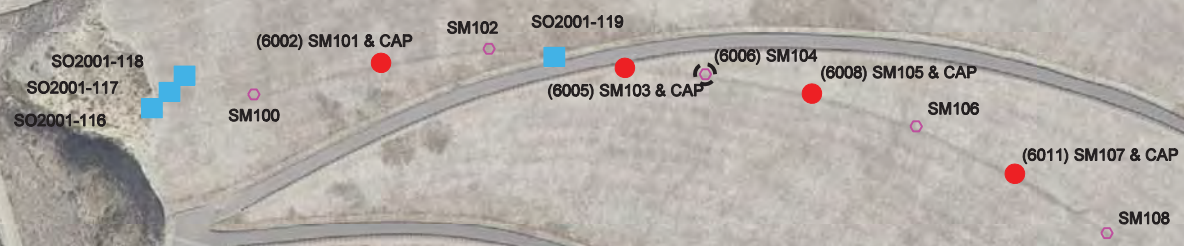
## Horizontal Movement since January 2001 Survey












(0,0) = January 2001 Horizontal Position

# Seven Oaks Dam Monitoring Survey

## Downstream 2310' Level - Monitoring Points



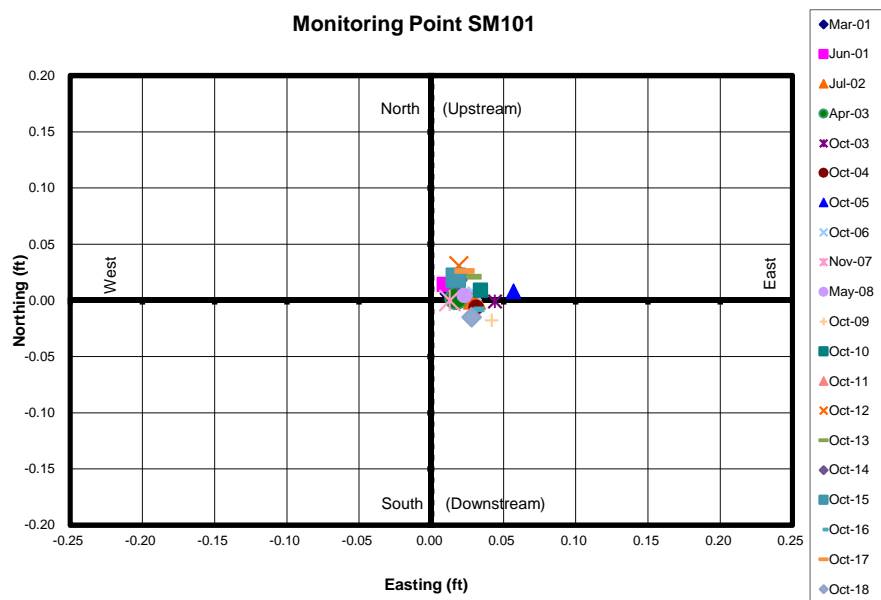
### LEGEND

-  PILLAR MONUMENT
-  OTHER H & V MONUMENT
-  BENCHMARK
-  SETTLEMENT MONUMENT 77 mon
-  SETTLEMENT MONUMENT (SUBSET) 33 mon
-  INCLINOMETER 6 mon
-  CORS SITE
-  TUNNEL MONUMENT 22 mon
-  X-SECTION MONUMENT 7 mon

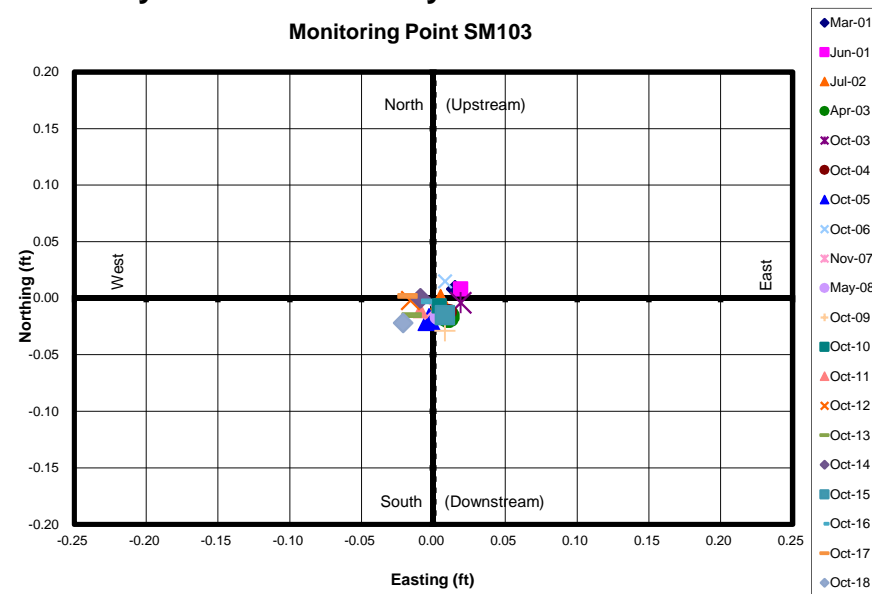


# Seven Oaks Dam - Downstream 2310' Level (Horizontal) Horizontal Movement since January 2001 Initial Survey

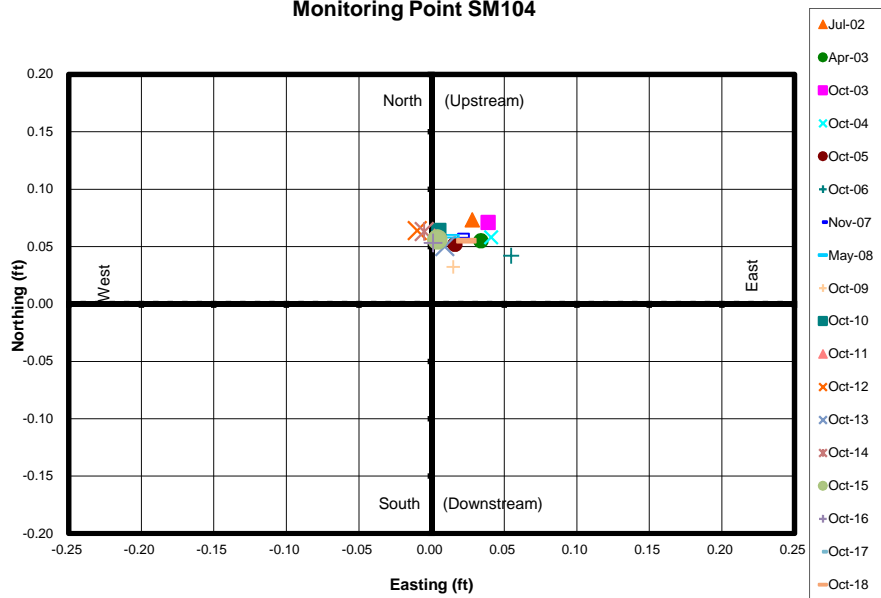
**Monitoring Point SM101**



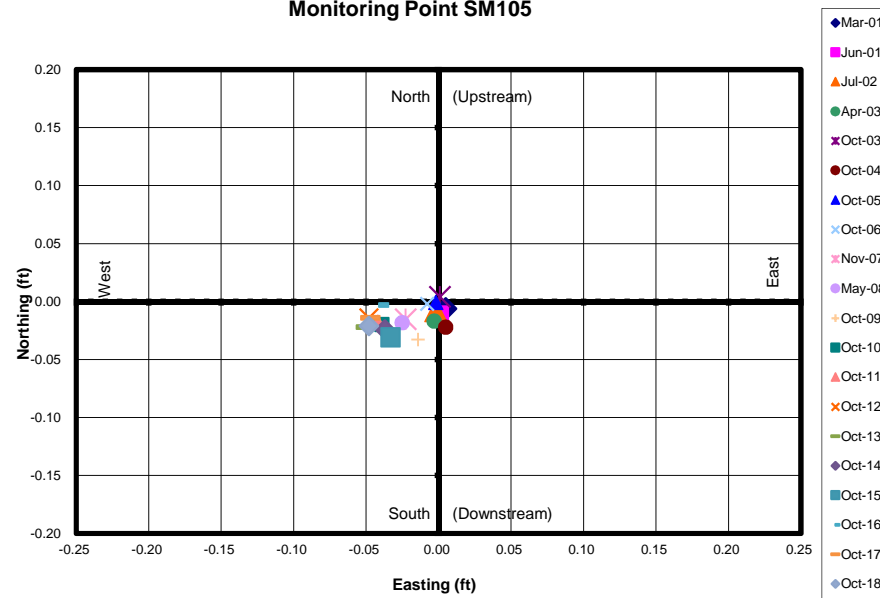
**Monitoring Point SM103**



**Monitoring Point SM104**

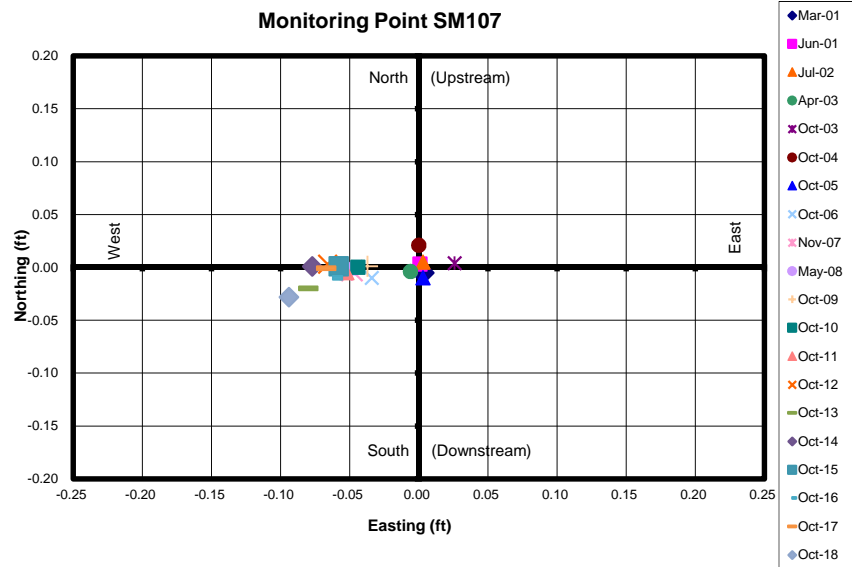


**Monitoring Point SM105**



**(0,0) = January 2001 Horizontal Position**

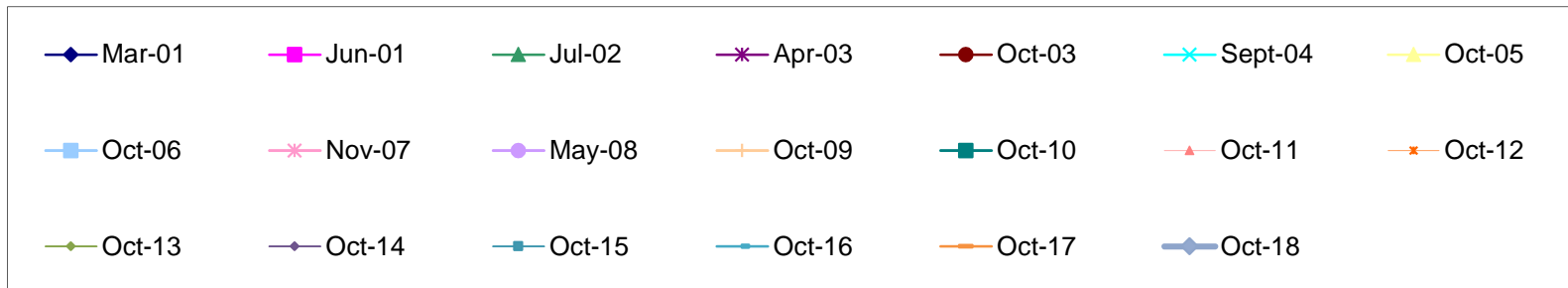
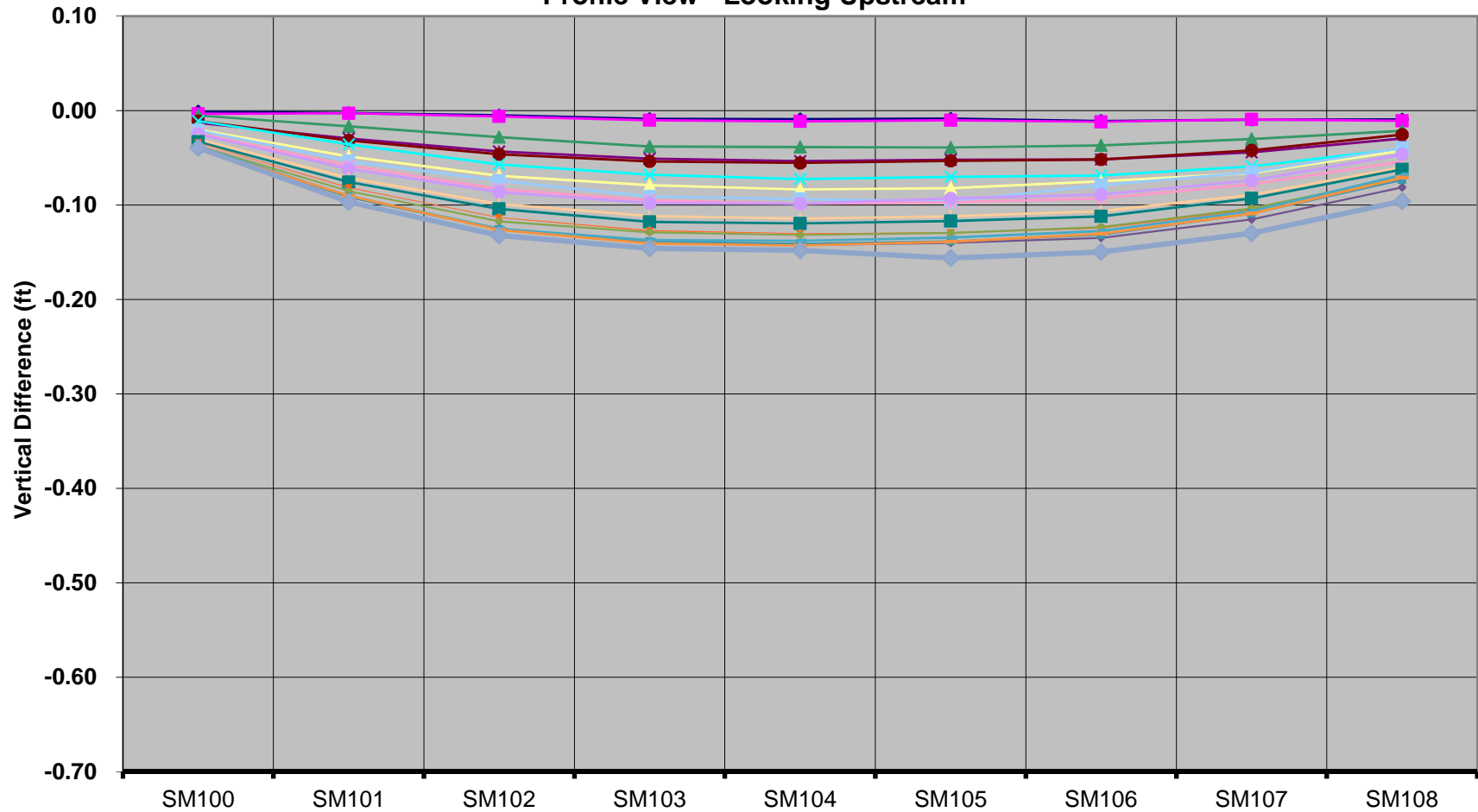
# Seven Oaks Dam - Downstream 2310' Level (Horizontal) Horizontal Movement since January 2001 Initial Survey



(0,0) = January 2001 Horizontal Position

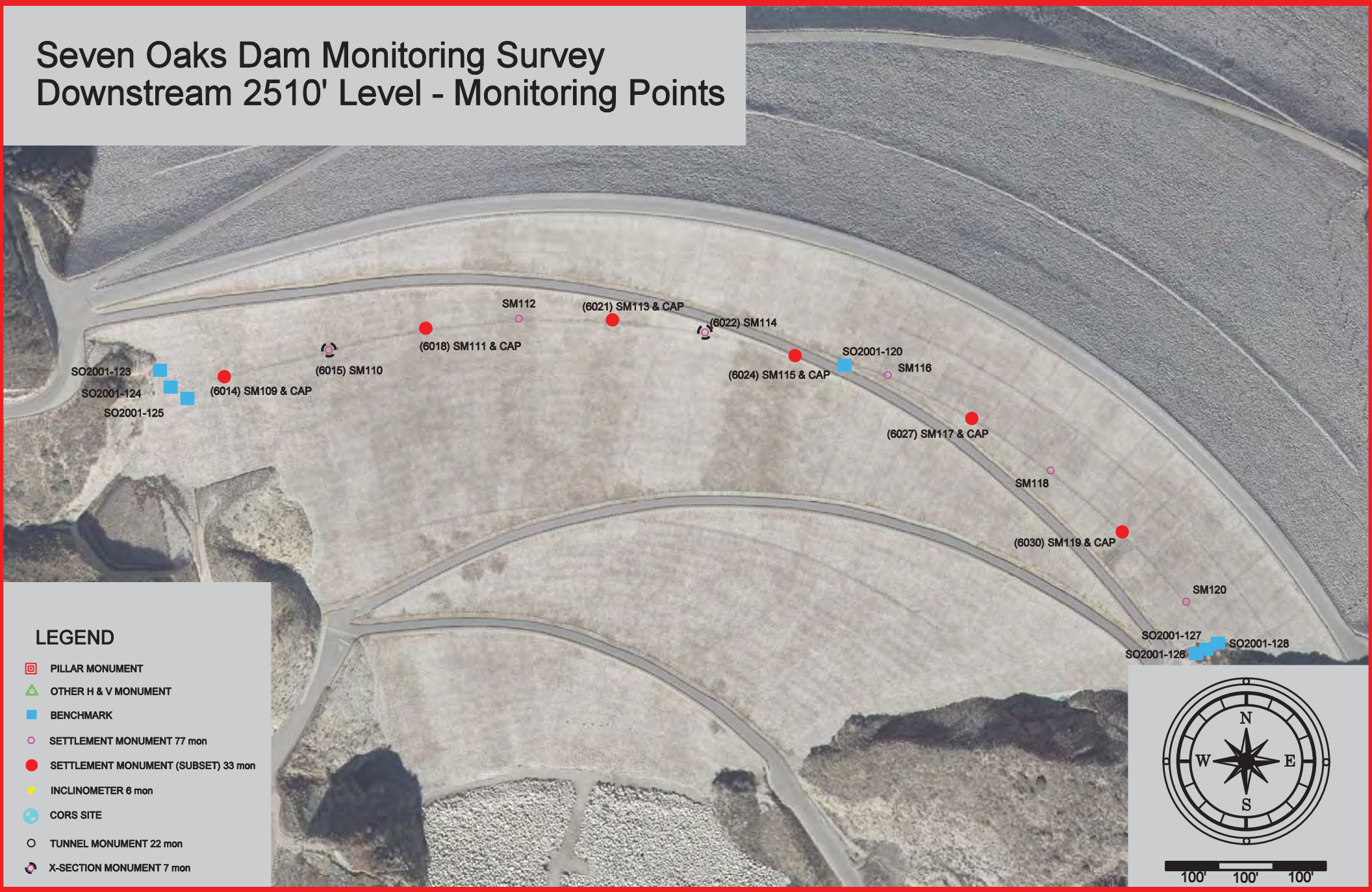


# Seven Oaks Dam - Downstream 2310' Level Vertical Movement since January 2001 Survey Profile View - Looking Upstream












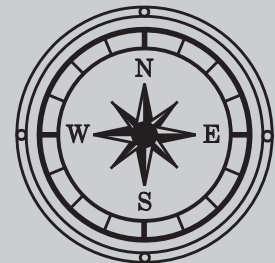
# Seven Oaks Dam Monitoring Survey

## Downstream 2510' Level - Monitoring Points



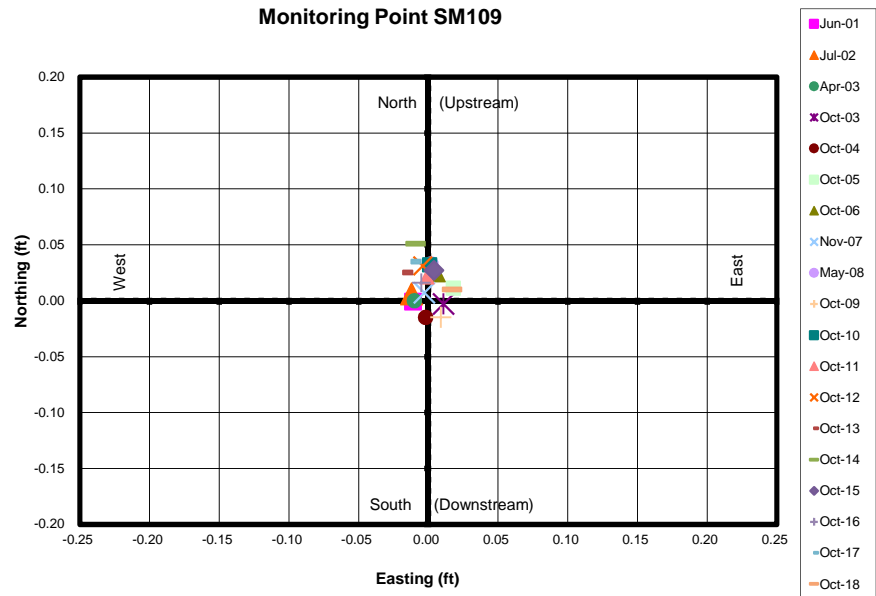
### LEGEND

-  PILLAR MONUMENT
-  OTHER H & V MONUMENT
-  BENCHMARK
-  SETTLEMENT MONUMENT 77 mon
-  SETTLEMENT MONUMENT (SUBSET) 33 mon
-  INCLINOMETER 6 mon
-  CORS SITE
-  TUNNEL MONUMENT 22 mon
-  X-SECTION MONUMENT 7 mon

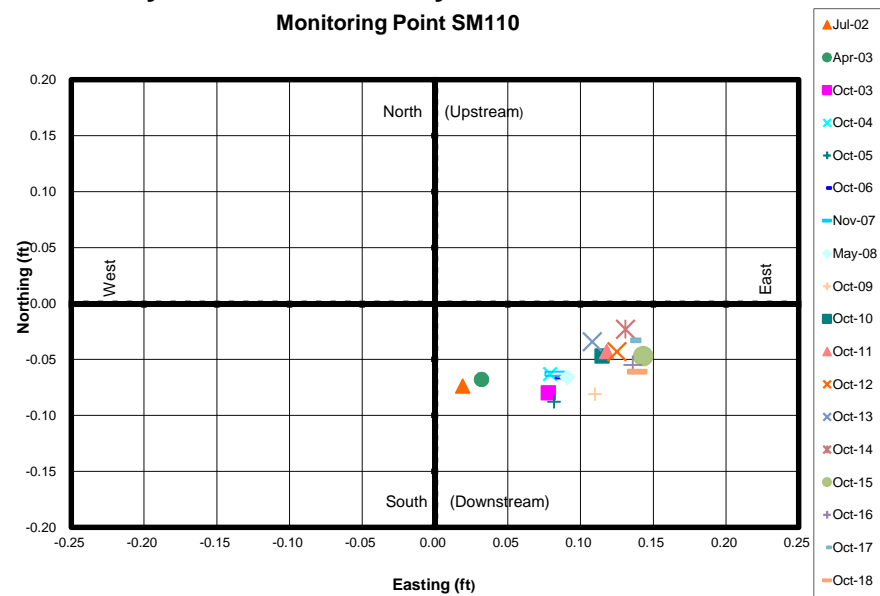


# Seven Oaks Dam - Downstream 2510' Level (Horizontal) Horizontal Movement since January 2001 Initial Survey

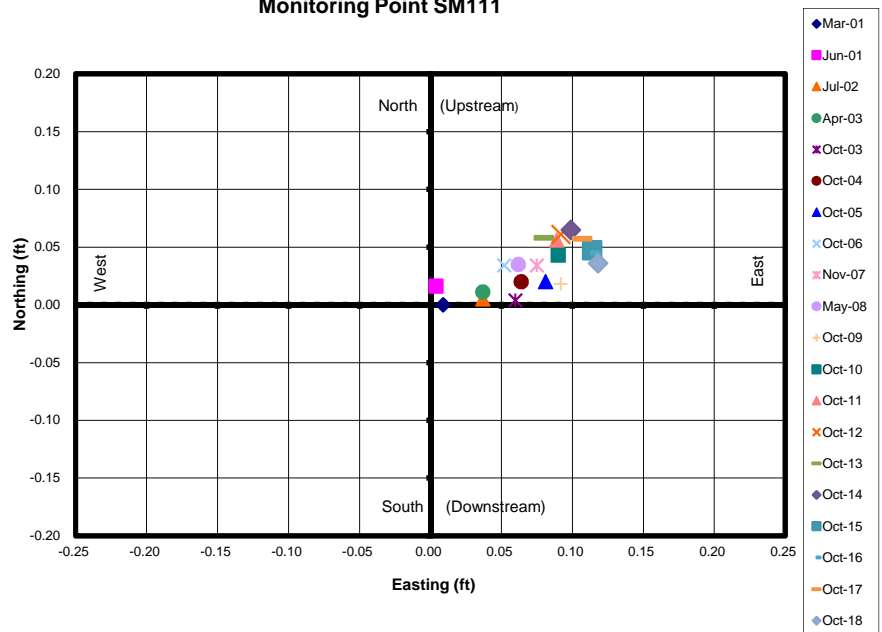
Monitoring Point SM109



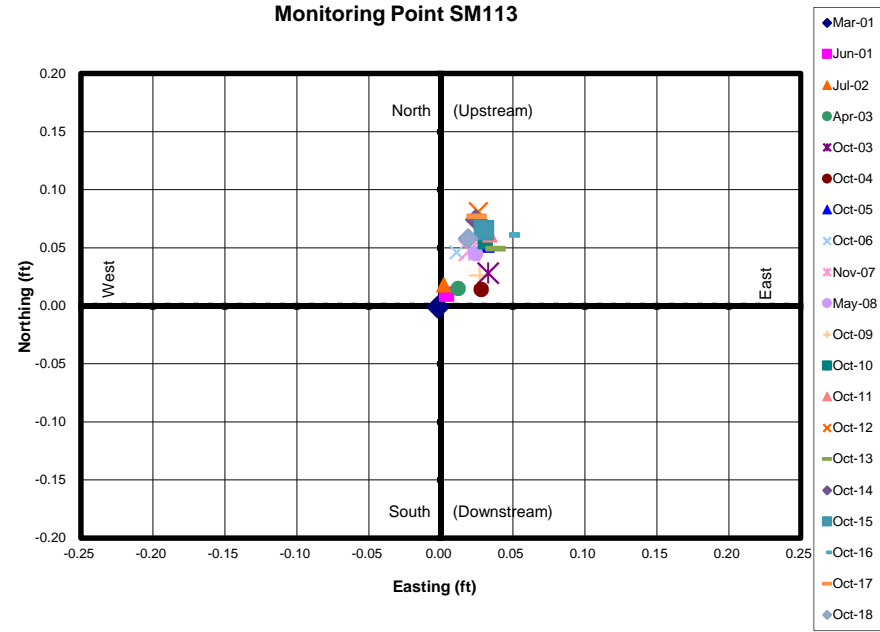
Monitoring Point SM110



Monitoring Point SM111

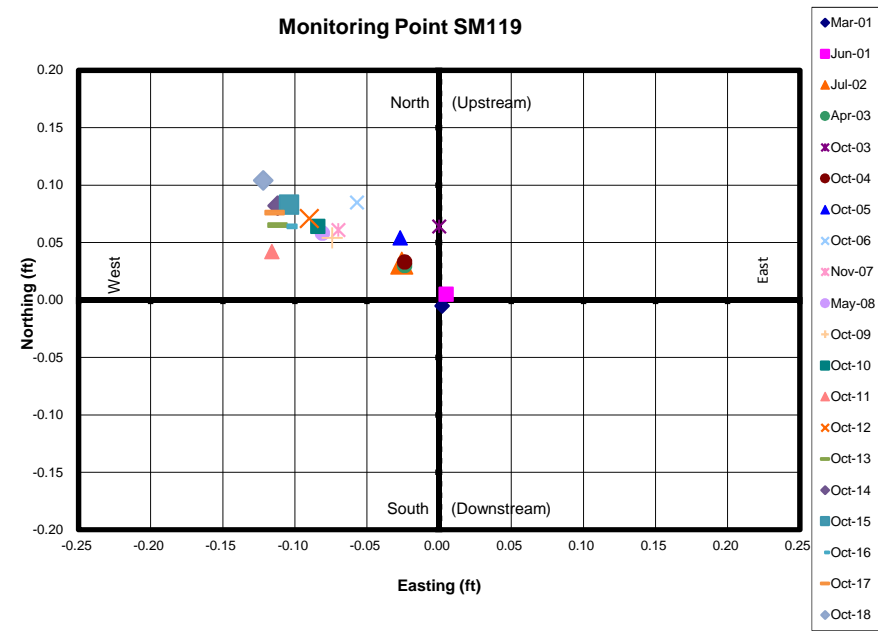
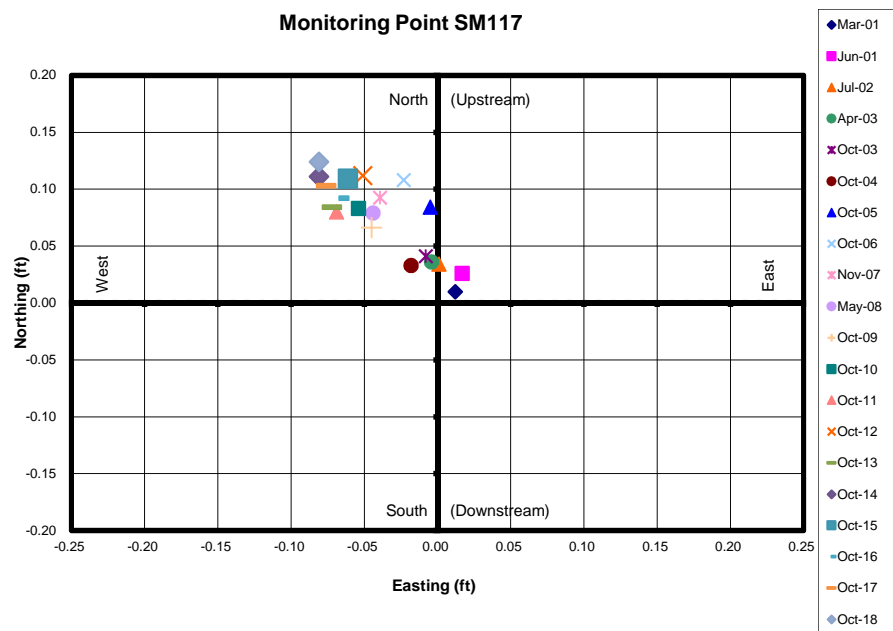
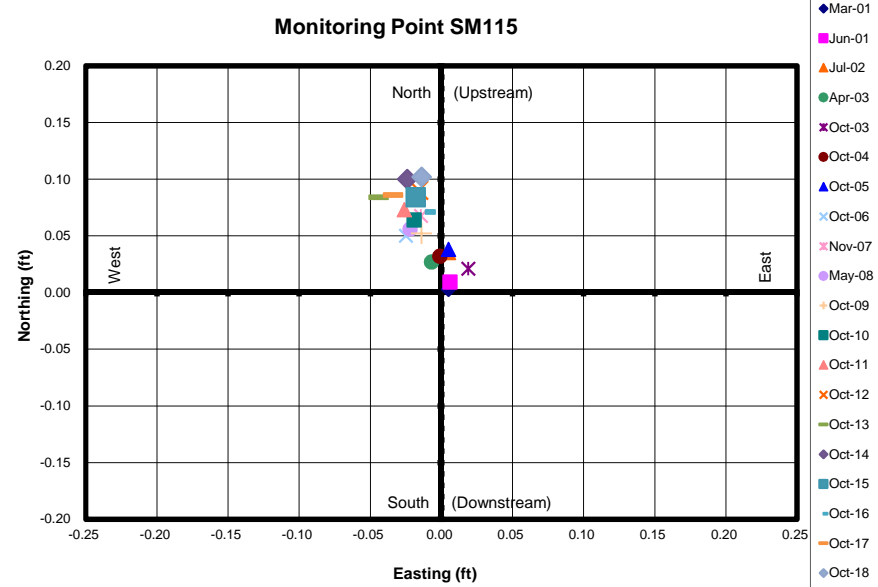
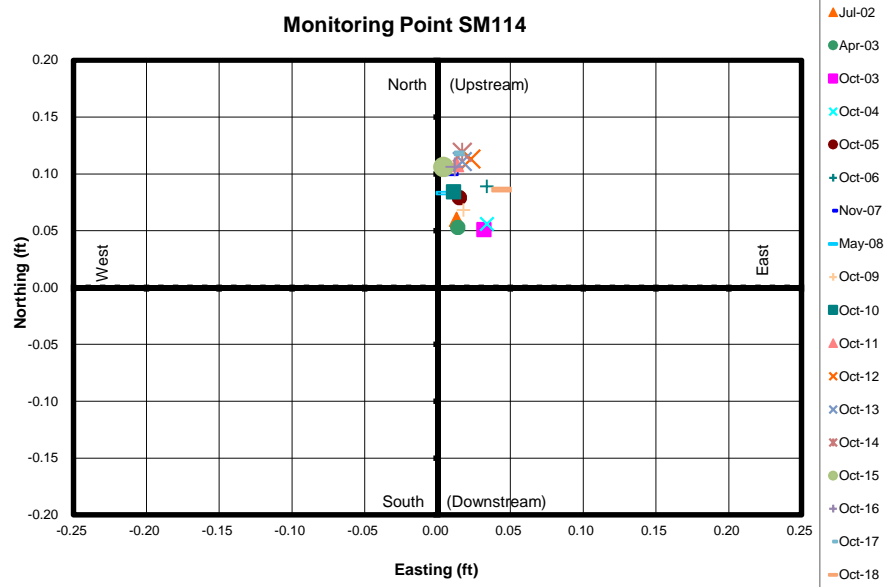


Monitoring Point SM113



(0,0) = January 2001 Horizontal Position

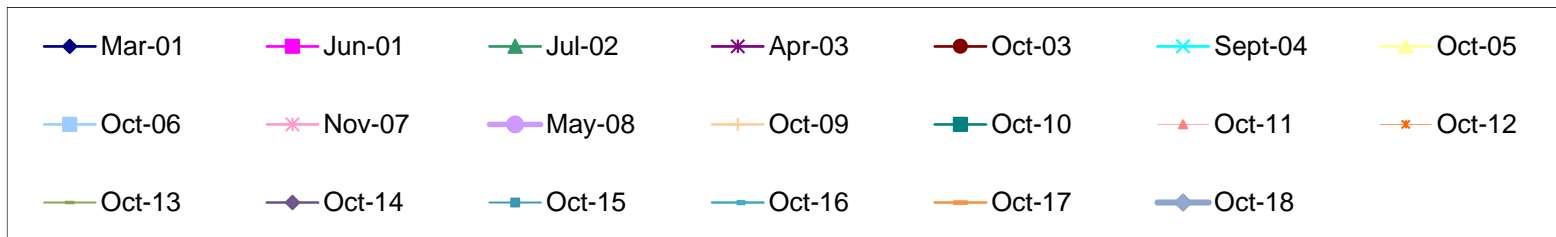
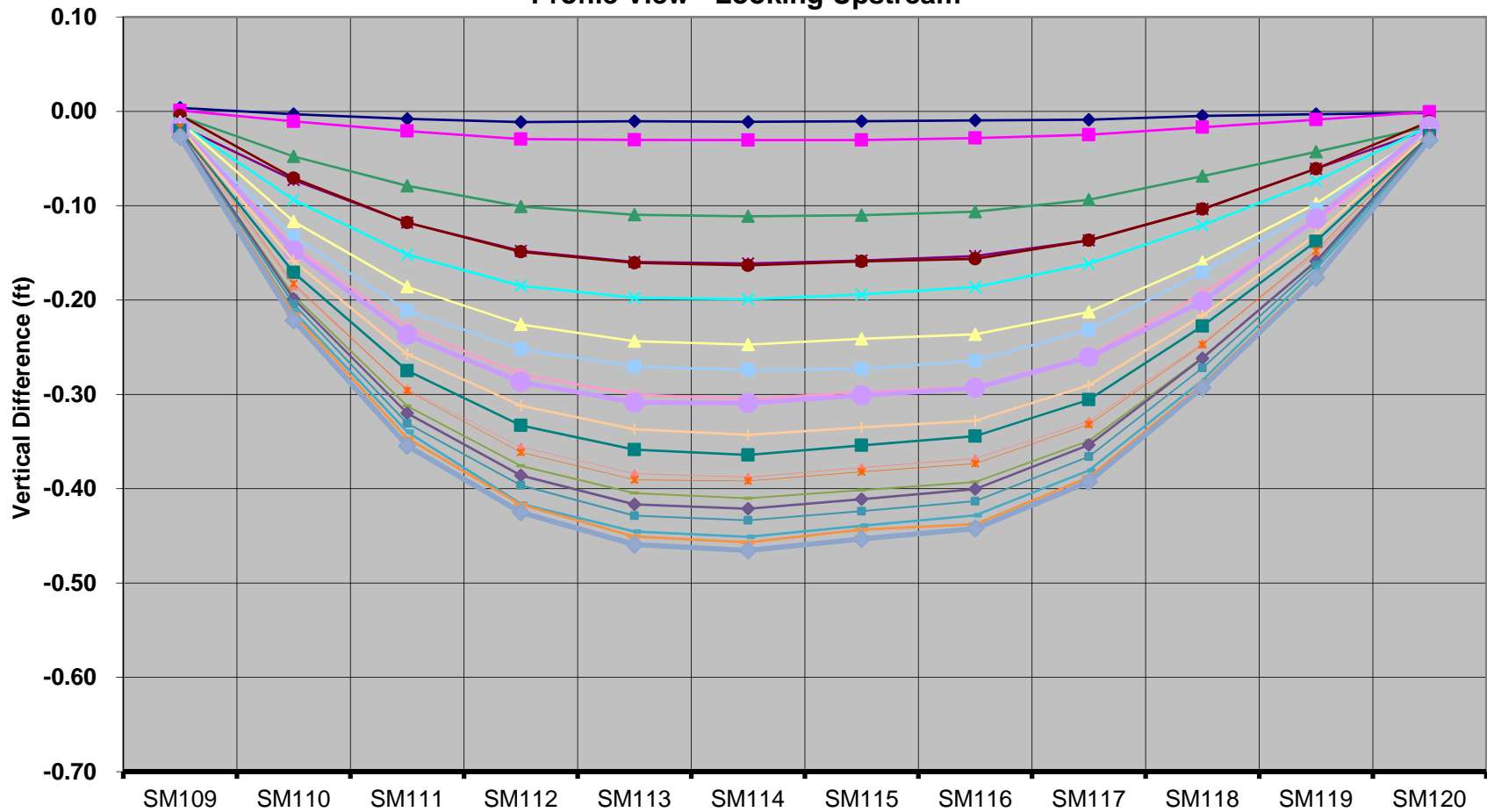
# Seven Oaks Dam - Downstream 2510' Level (Horizontal) Horizontal Movement since January 2001 Initial Survey



(0,0) = January 2001 Horizontal Position




# Seven Oaks Dam - Downstream 2510' Level Vertical Movement since January 2001 Survey Profile View - Looking Upstream





# Seven Oaks Dam Monitoring Survey


## Downstream 2560' Level - Monitoring Points


LEGEND


PILLAR MONUMENT


OTHER H & V MONUMENT


BENCHMARK


SETTLEMENT MONUMENT 77 mon

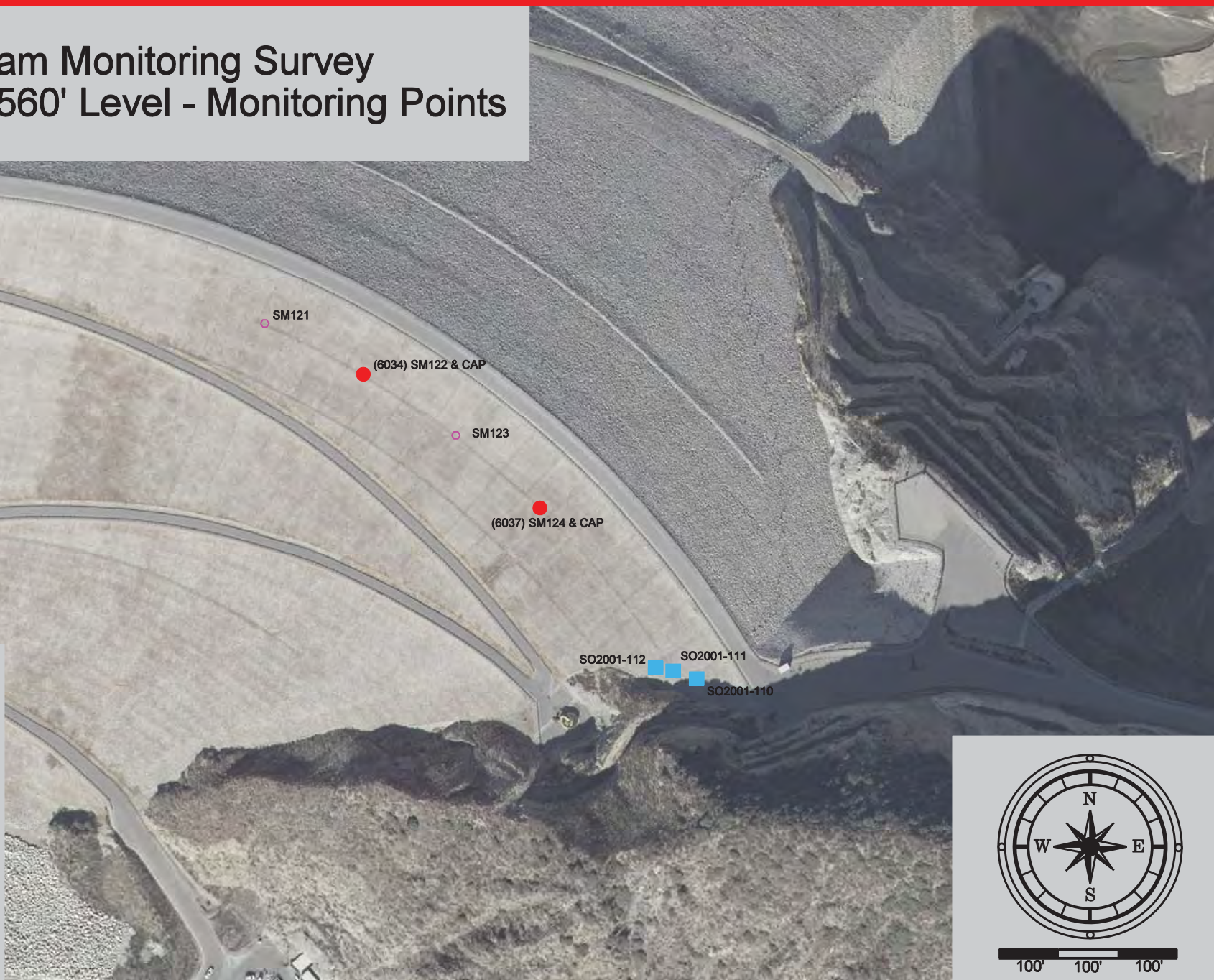
SETTLEMENT MONUMENT (SUBSET) 33 mon


INCLINOMETER 6 mon

CORS SITE

TUNNEL MONUMENT 22 mon

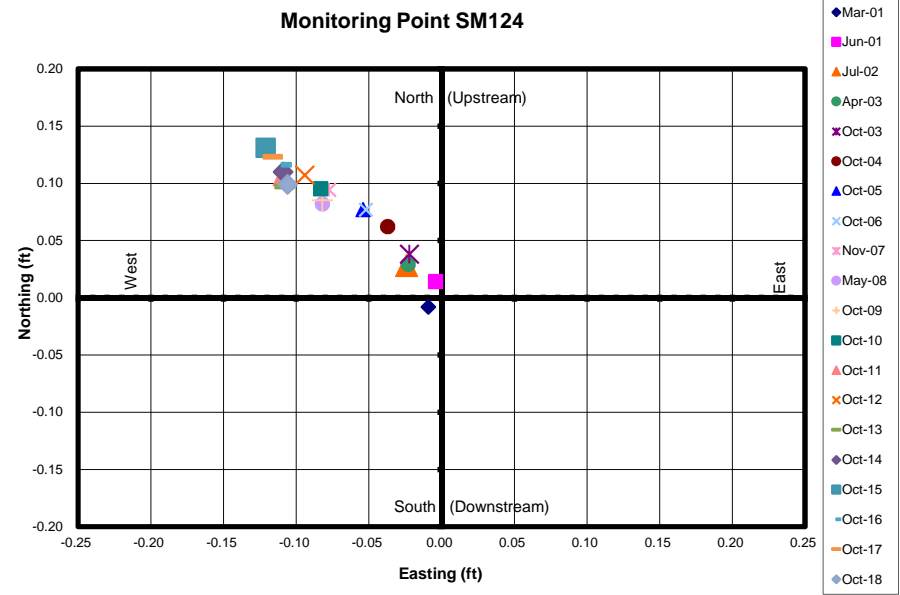
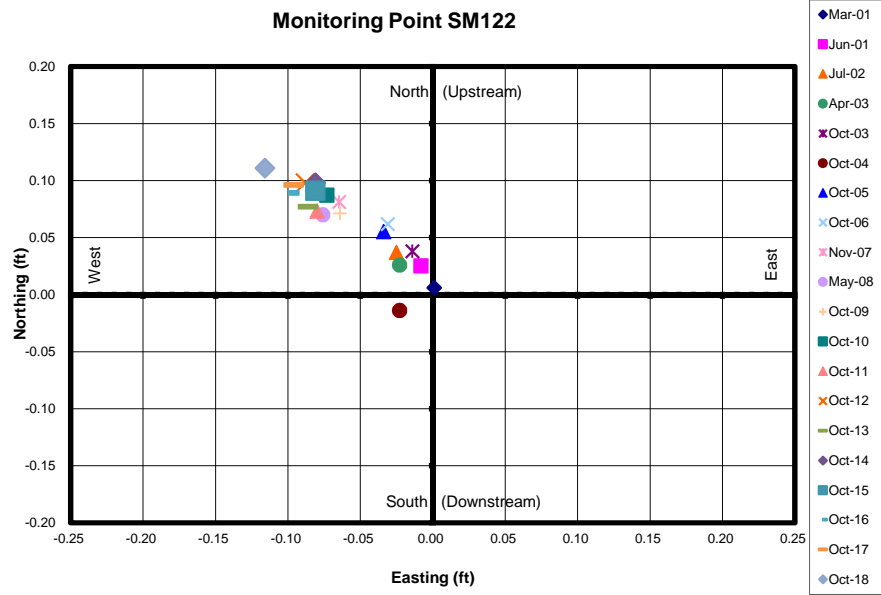
X-SECTION MONUMENT 7 mon





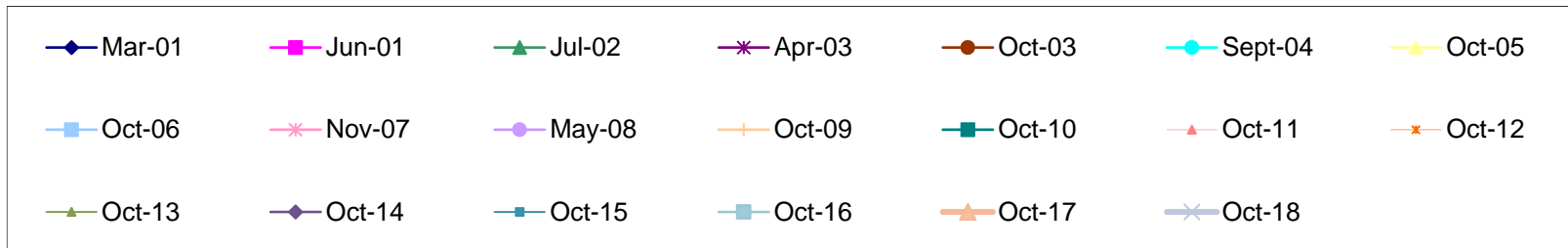
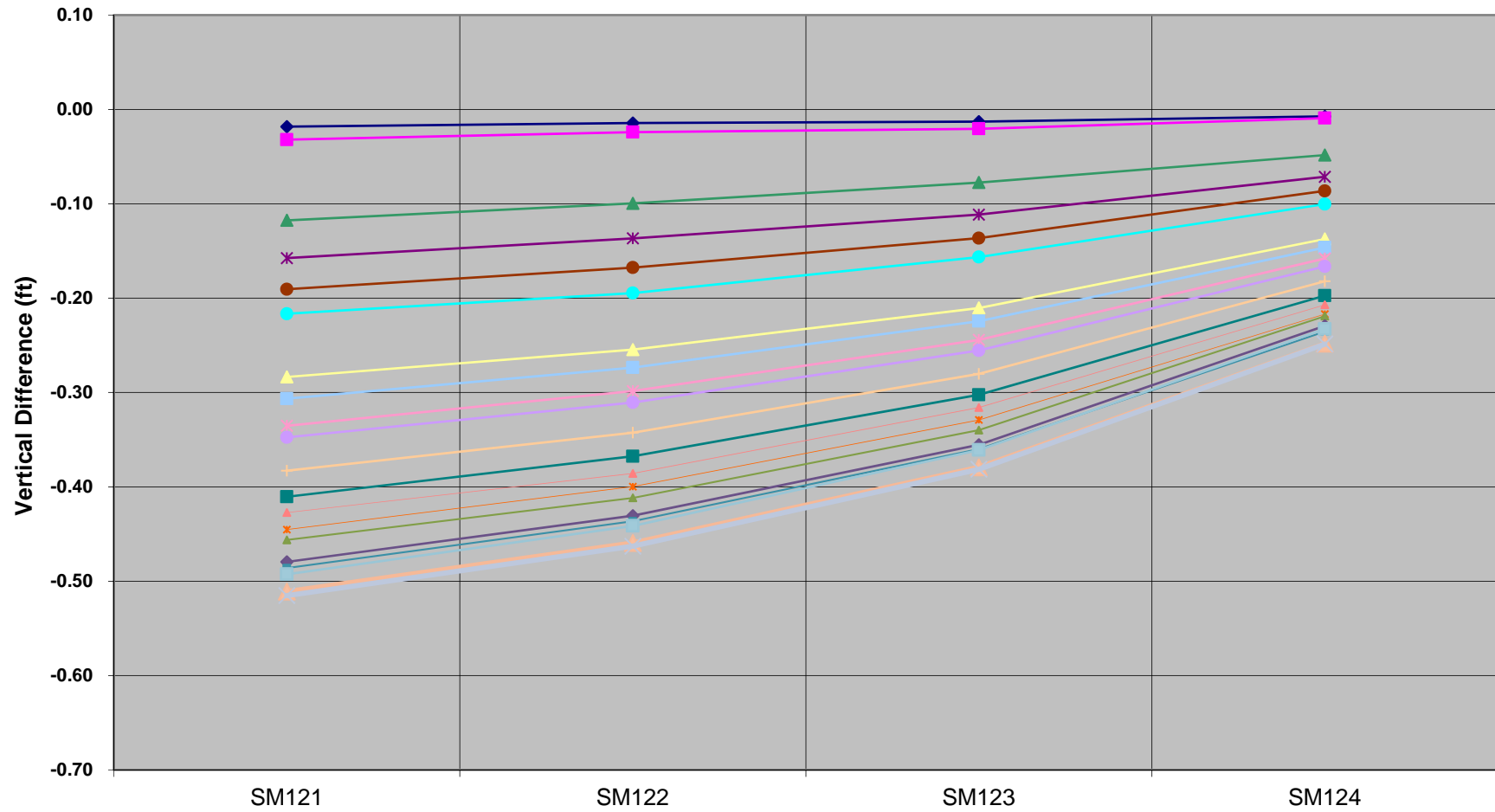


# **Seven Oaks Dam - Downstream 2560' Level (Horizontal)** **Horizontal Movement since January 2001 Survey**



**(0,0) = January 2001 Horizontal Position**

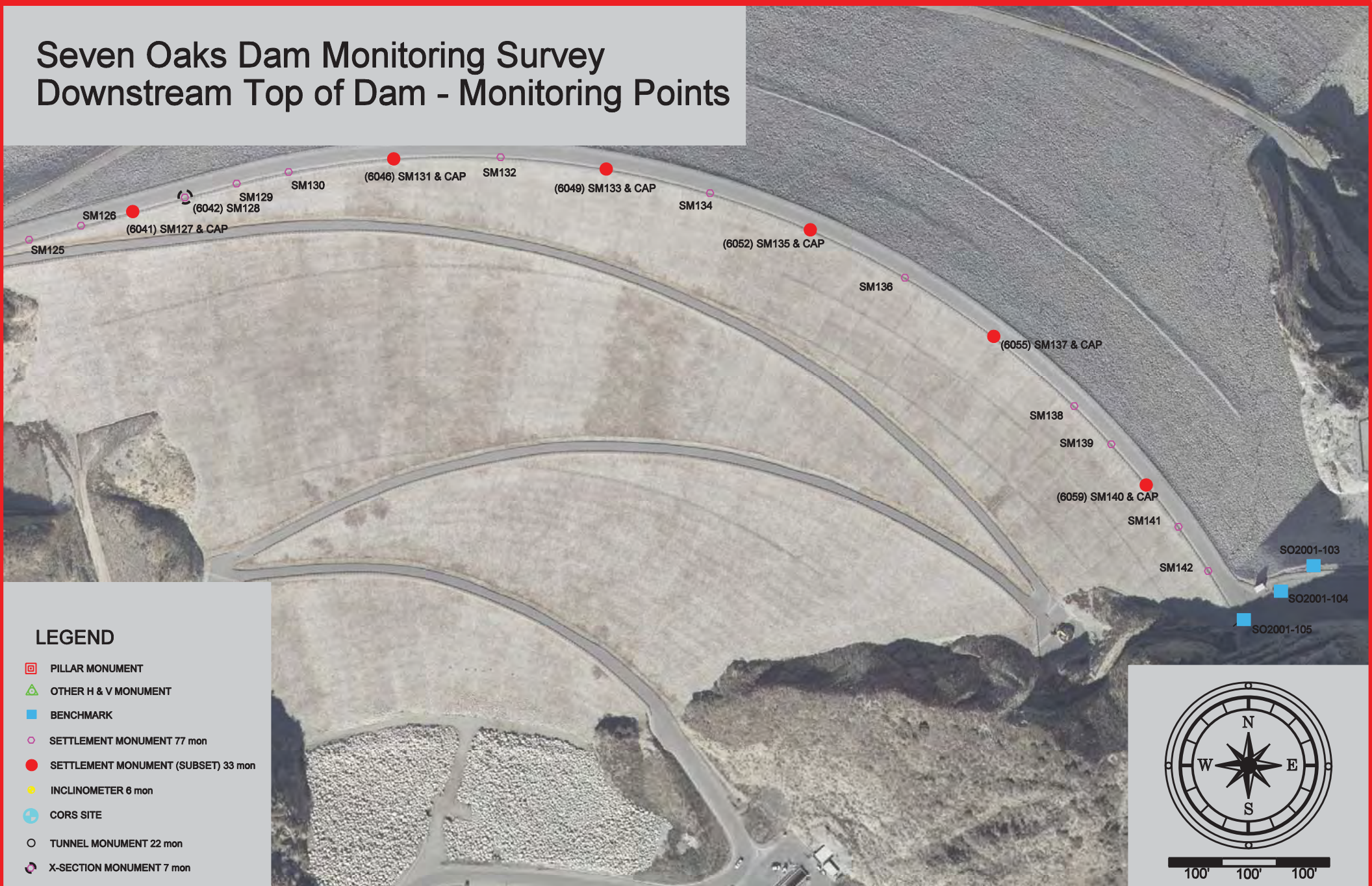
# Seven Oaks Dam - Downstream 2560' Level Vertical Movement since January 2001 Survey Profile View - Looking Upstream





# Seven Oaks Dam Monitoring Survey

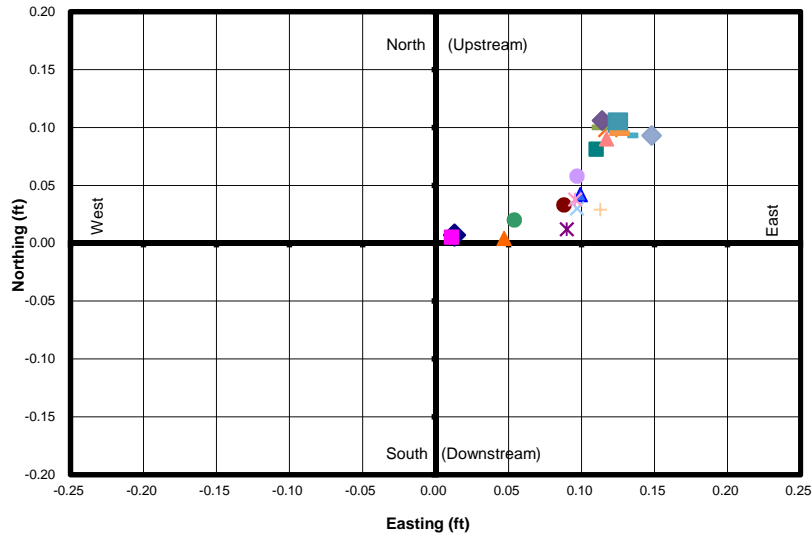
## Downstream Top of Dam - Monitoring Points



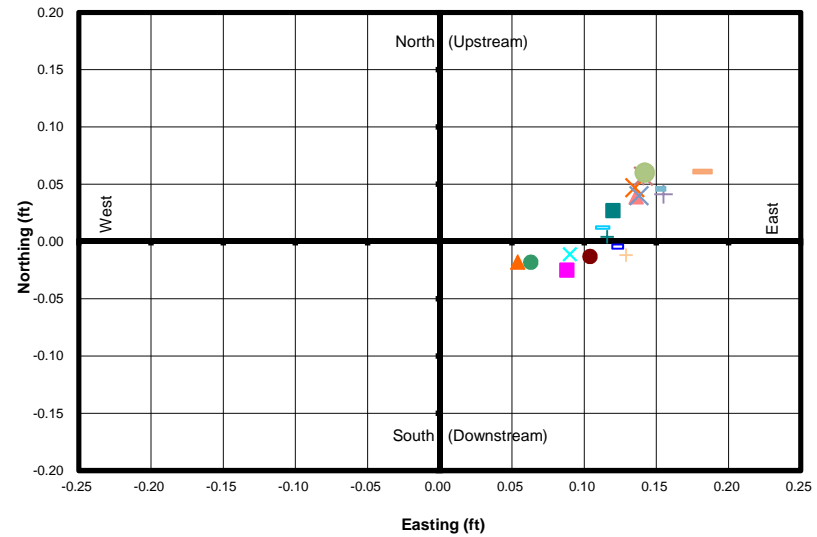
# Seven Oaks Dam - Downstream Top of Dam (Horizontal)

## Horizontal Movement since January 2001 Survey

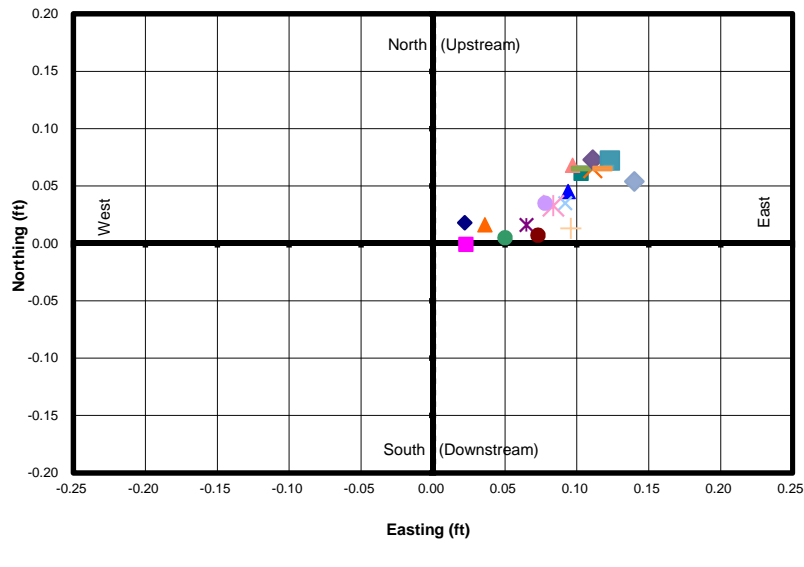
Monitoring Point SM127



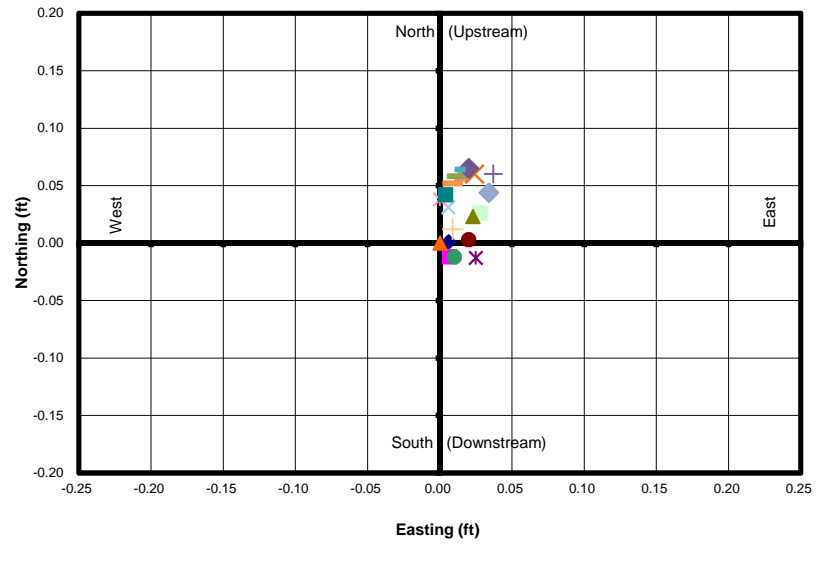
Monitoring Point SM128



Monitoring Point SM131



Monitoring Point SM133

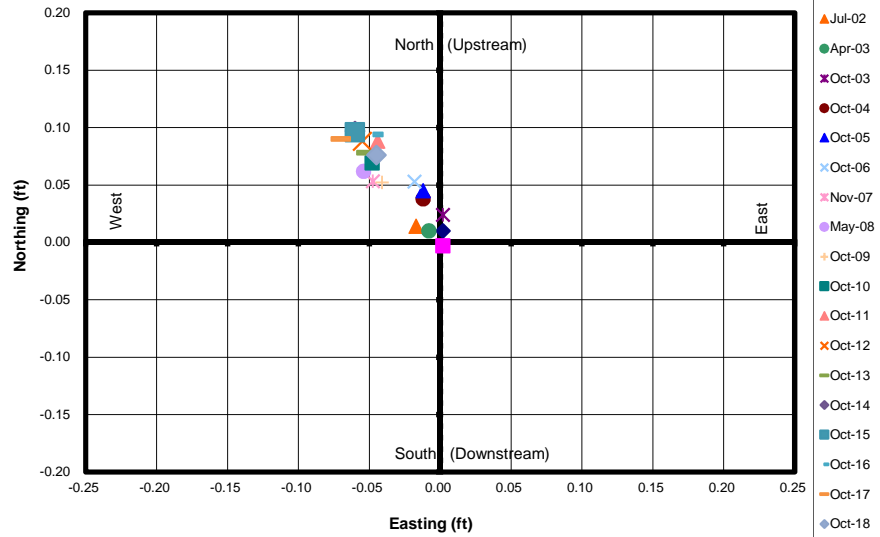


(0,0) = January 2001 Horizontal Position

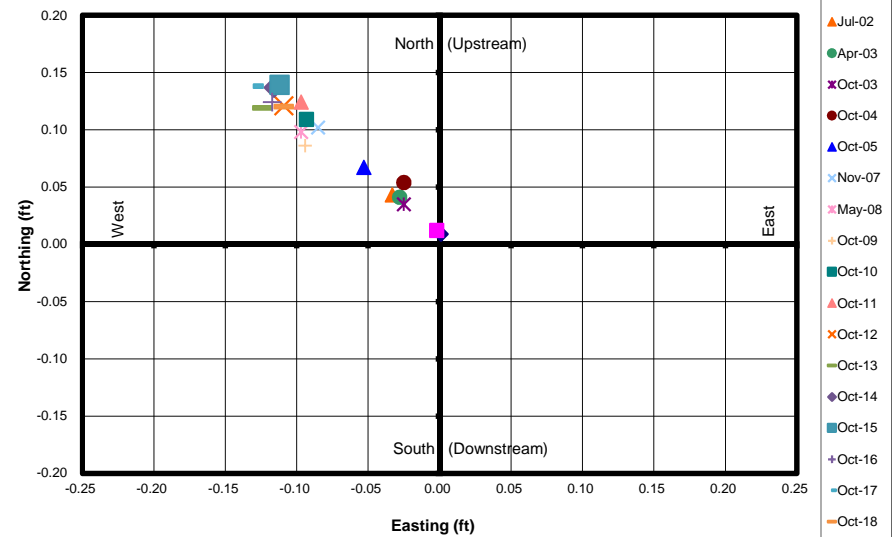
# Seven Oaks Dam - Downstream Top of Dam (Horizontal)

## Horizontal Movement since January 2001 Survey

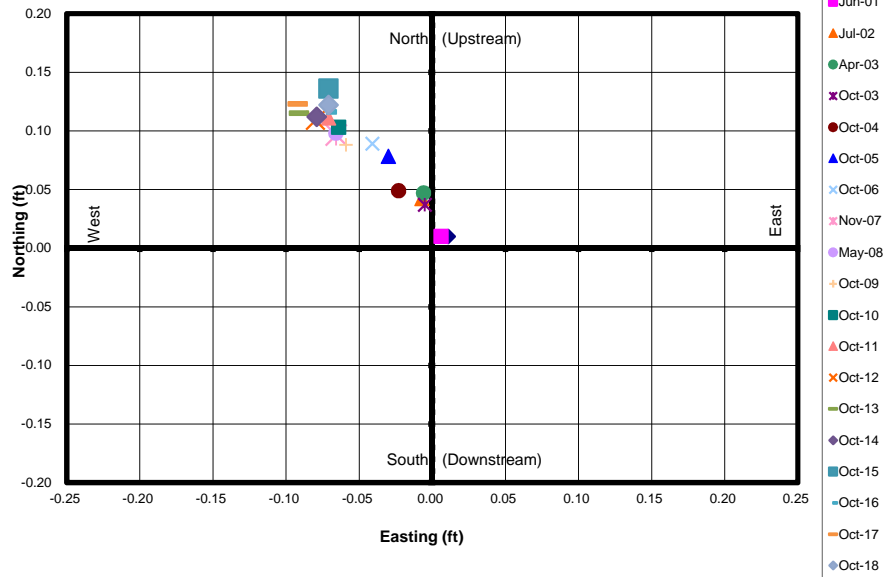
Monitoring Point SM135



Monitoring Point SM137

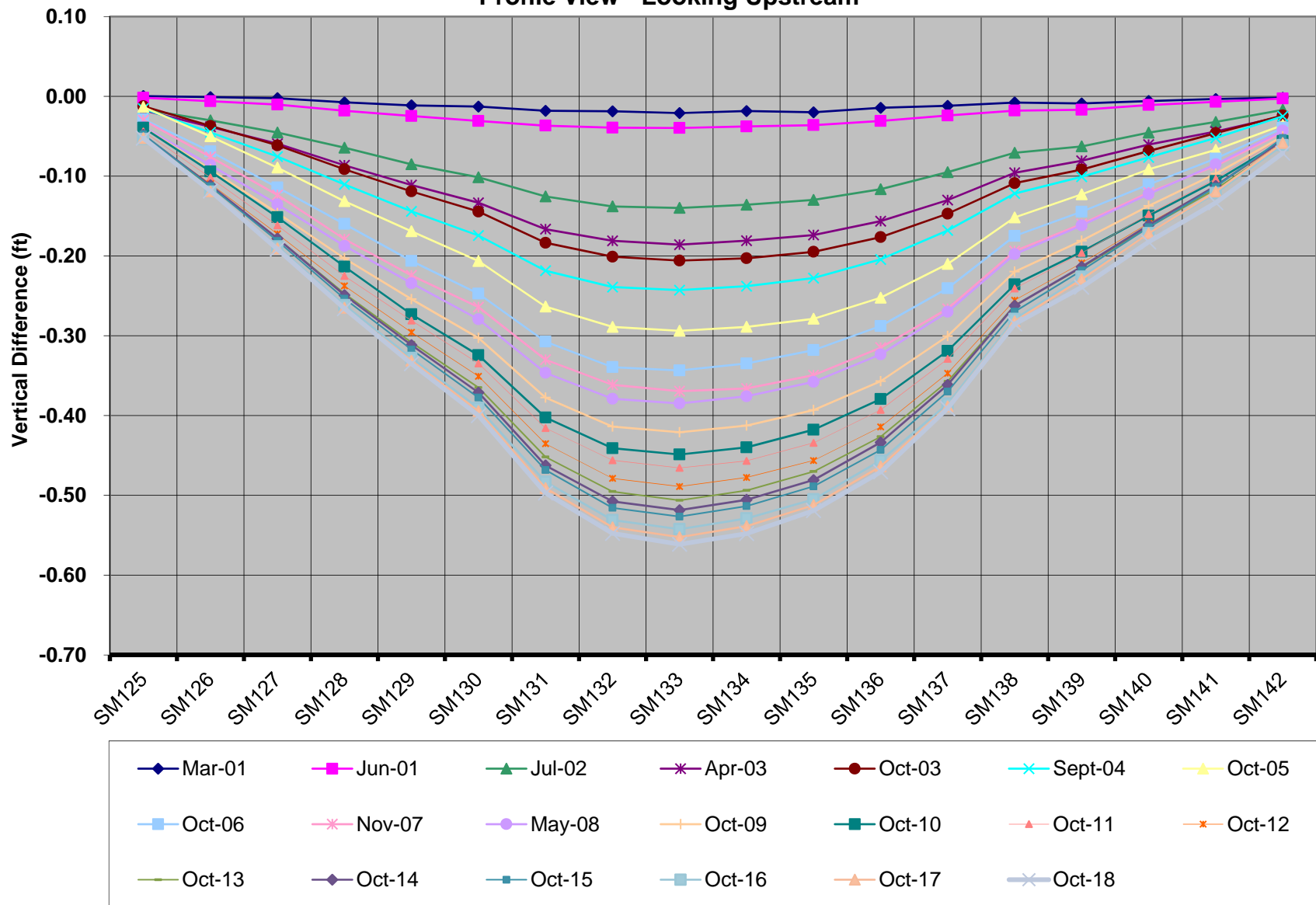


Monitoring Point SM140



(0,0) = January 2001 Horizontal Position

# Seven Oaks Dam - Downstream Top of Dam Vertical Movement since January 2001 Survey Profile View - Looking Upstream

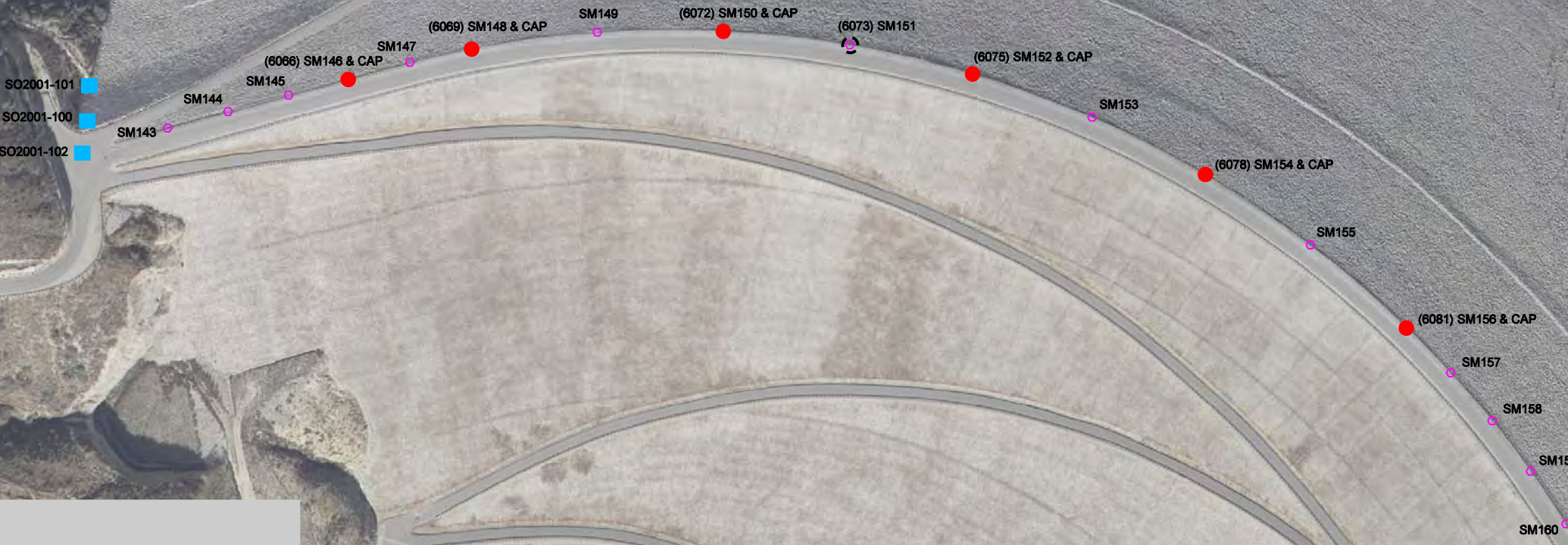













# Seven Oaks Dam Monitoring Survey

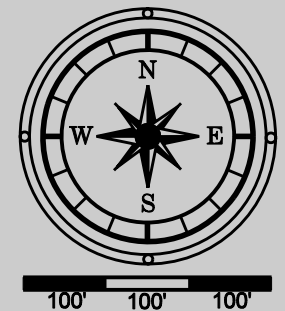
## Upstream Top of Dam - Monitoring Points

SO2001-101  
SO2001-100  
SO2001-102

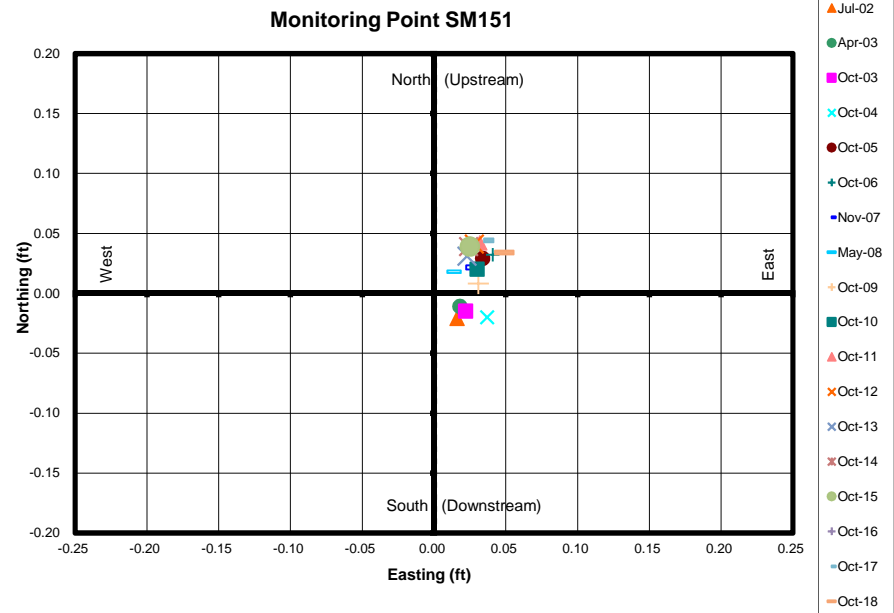
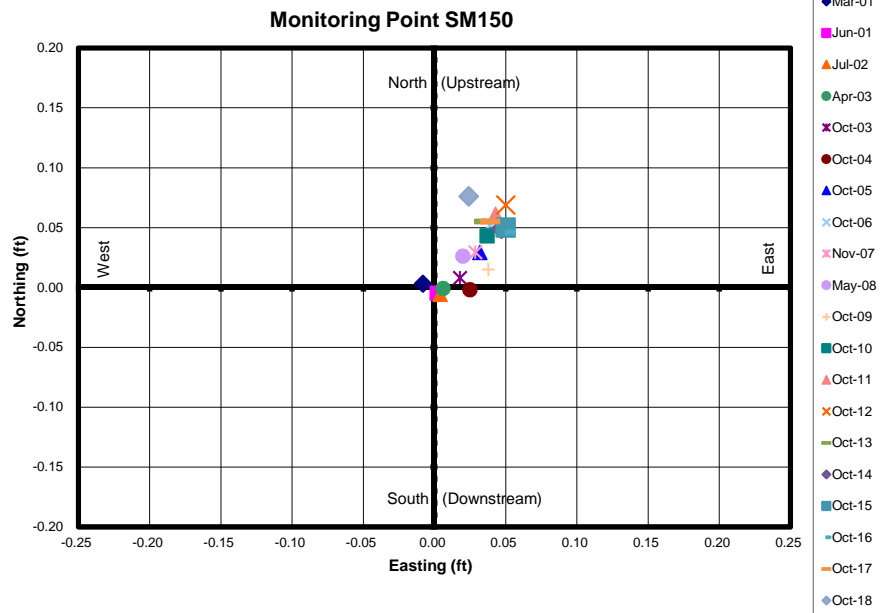
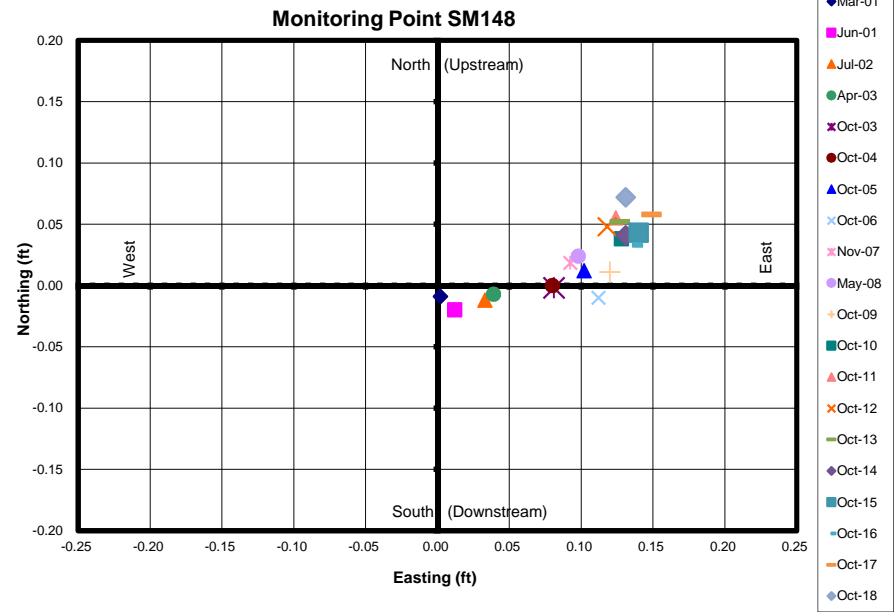
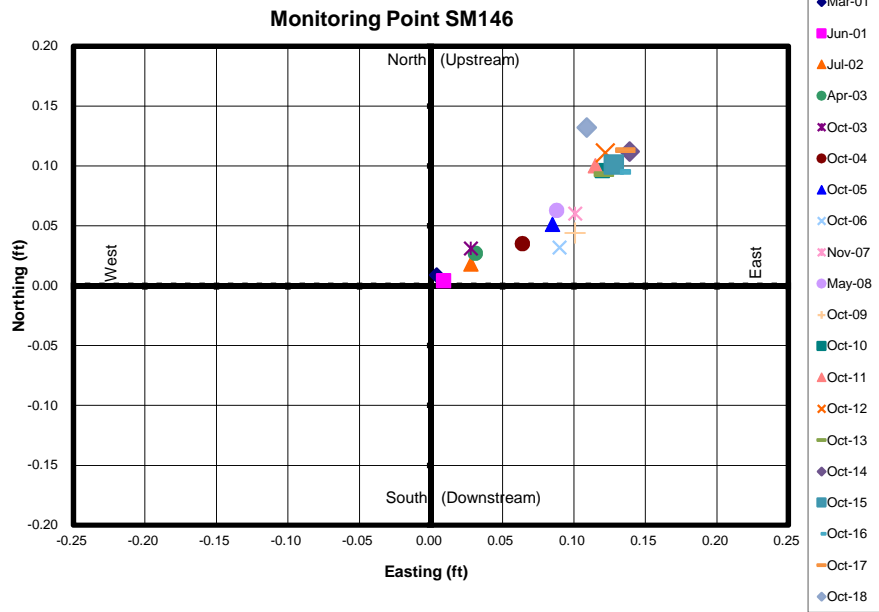


### LEGEND

-  PILLAR MONUMENT
-  OTHER H & V MONUMENT
-  BENCHMARK
-  SETTLEMENT MONUMENT 77 mon
-  SETTLEMENT MONUMENT (SUBSET) 33 mon
-  INCLINOMETER 6 mon
-  CORS SITE
-  TUNNEL MONUMENT 22 mon
-  X-SECTION MONUMENT 7 mon



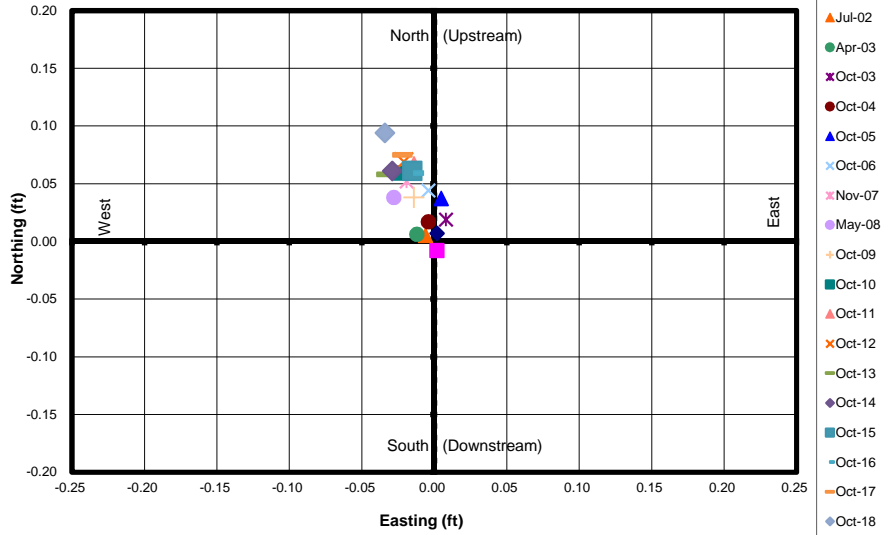
# Seven Oaks Dam - Upstream Top of Dam (Horizontal) Horizontal Movement since January 2001 Survey



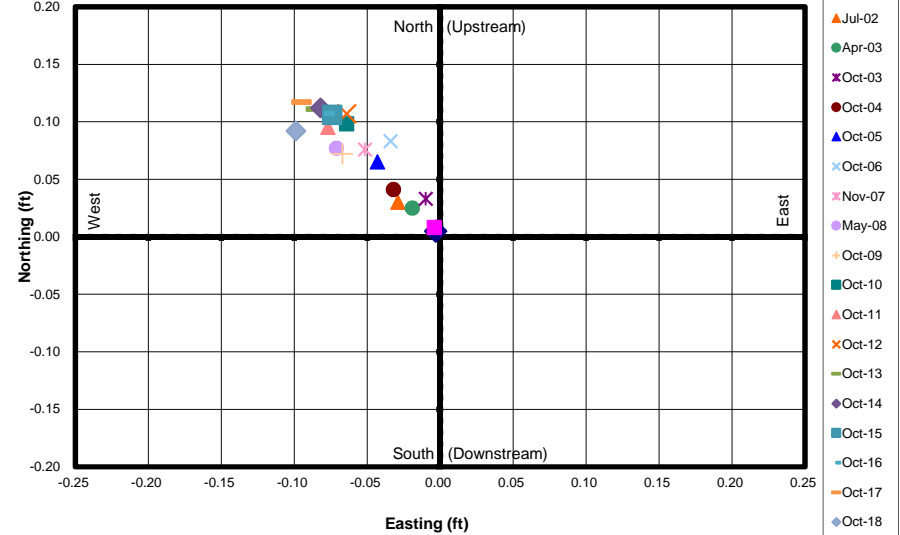
(0,0) = January 2001 Horizontal Position

# Seven Oaks Dam - Upstream Top of Dam (Horizontal) Horizontal Movement since January 2001 Survey

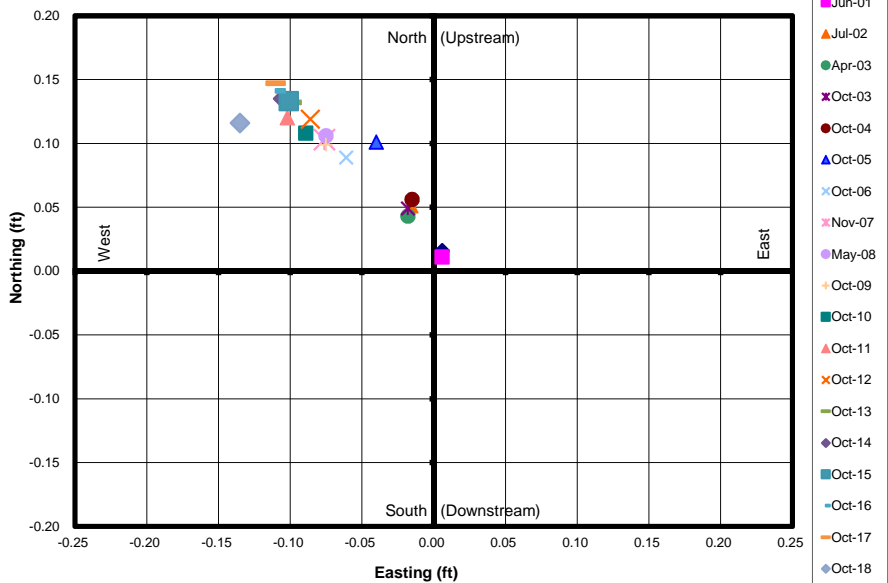
Monitoring Point SM152



Monitoring Point SM154

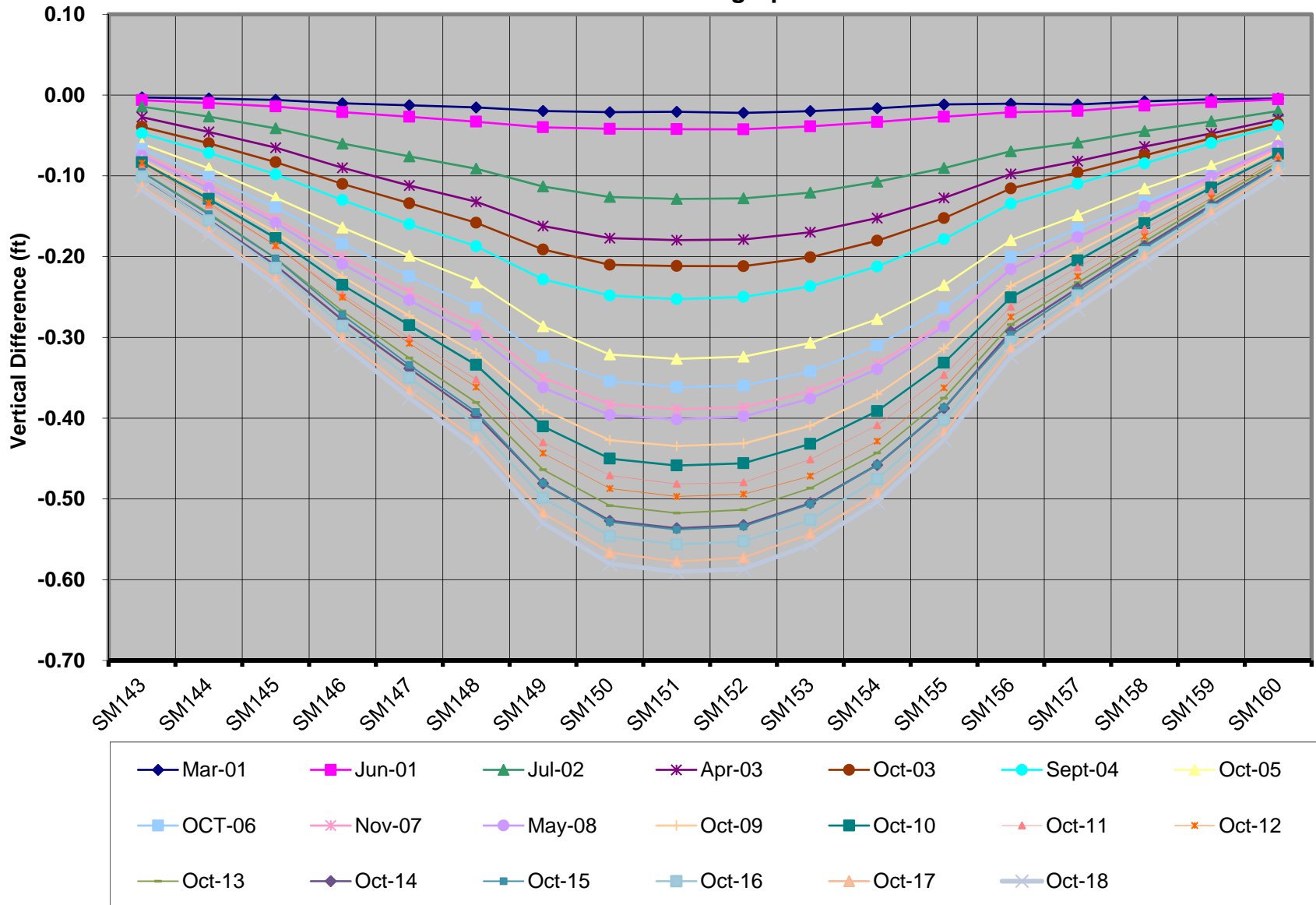


Monitoring Point SM156



(0,0) = January 2001 Horizontal Position

# Seven Oaks Dam - Upstream Top of Dam Vertical Movement since January 2001 Survey Profile View - Looking Upstream





# Seven Oaks Dam Monitoring Survey

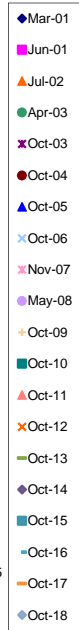
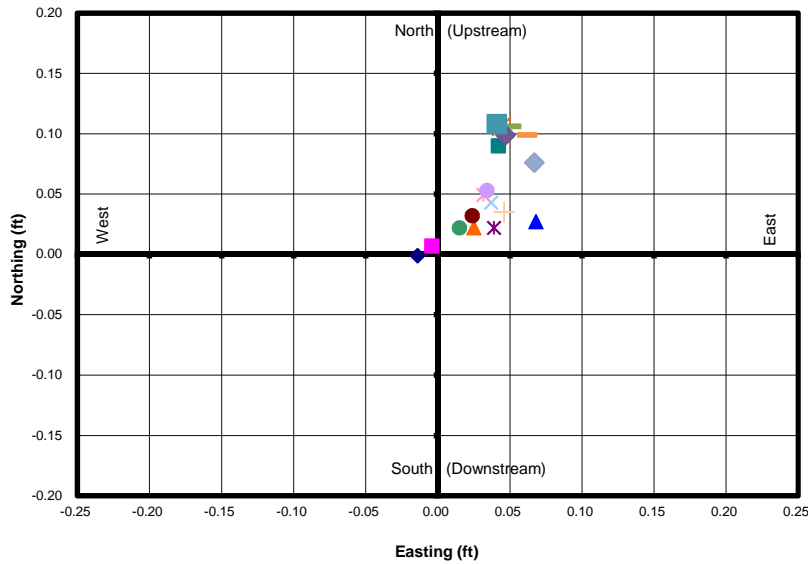
## Upstream 2530' Level - Monitoring Points



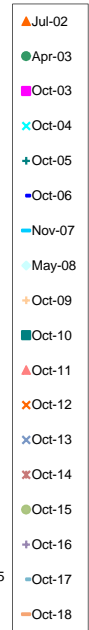
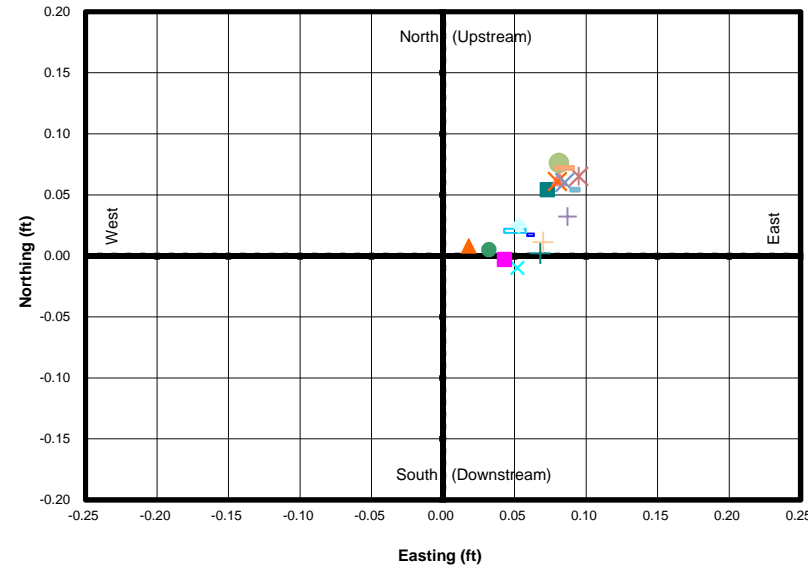
# Seven Oaks Dam - Upstream 2530' level (Horizontal)

## Horizontal Movement since January 2001 Survey

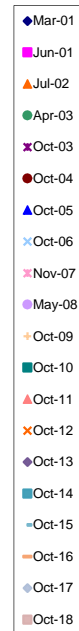
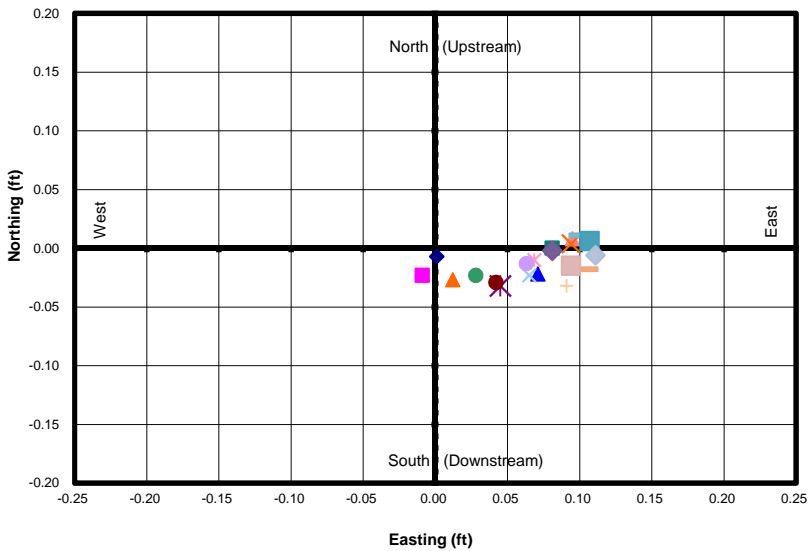
Monitoring Point SM161



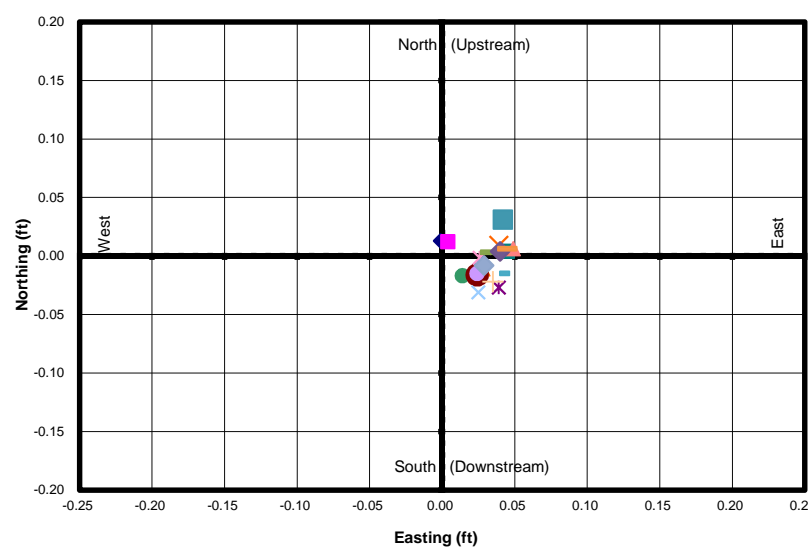
Monitoring Point SM162



Monitoring Point SM163



Monitoring Point SM165

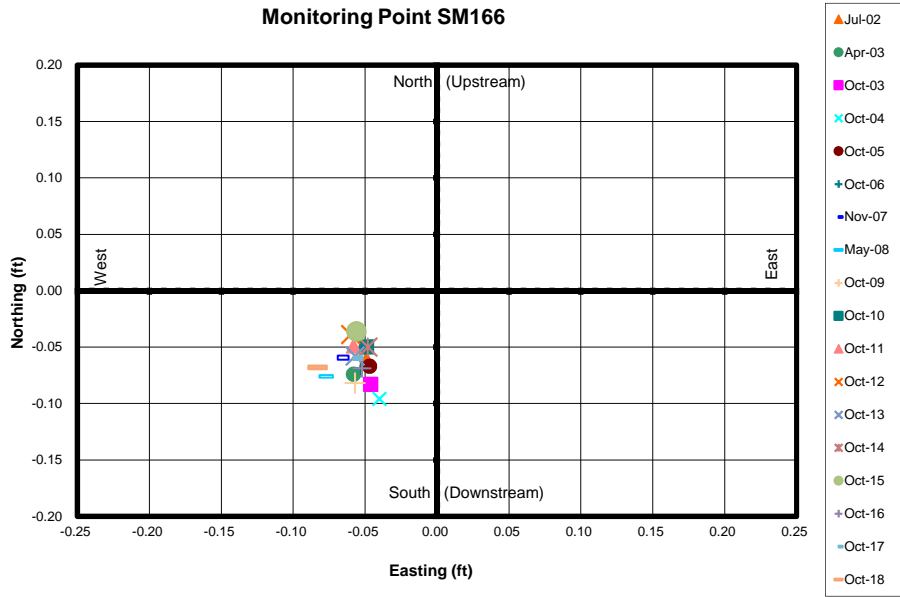


(0,0) = January 2001 Horizontal Position

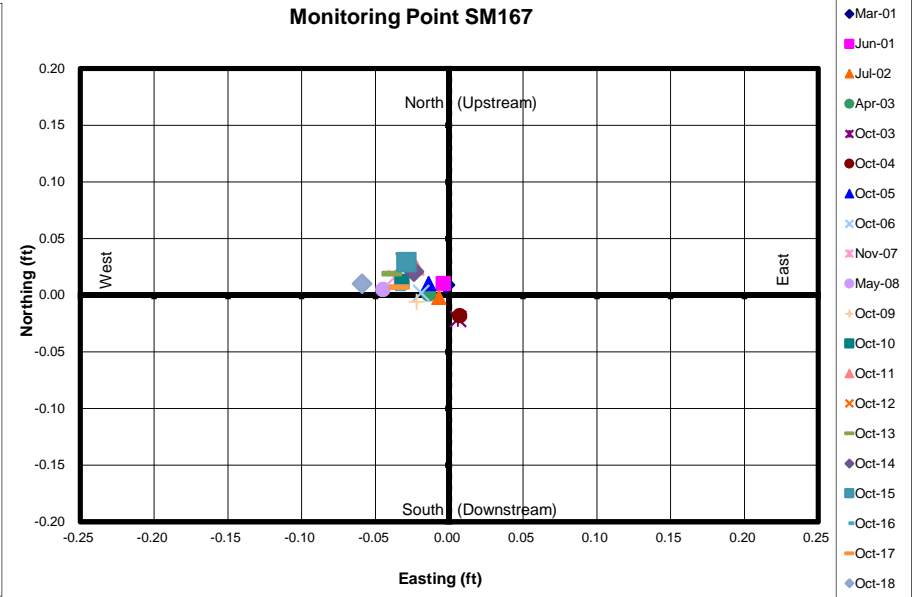
# Seven Oaks Dam - Upstream 2530' level (Horizontal)

## Horizontal Movement since January 2001 Survey

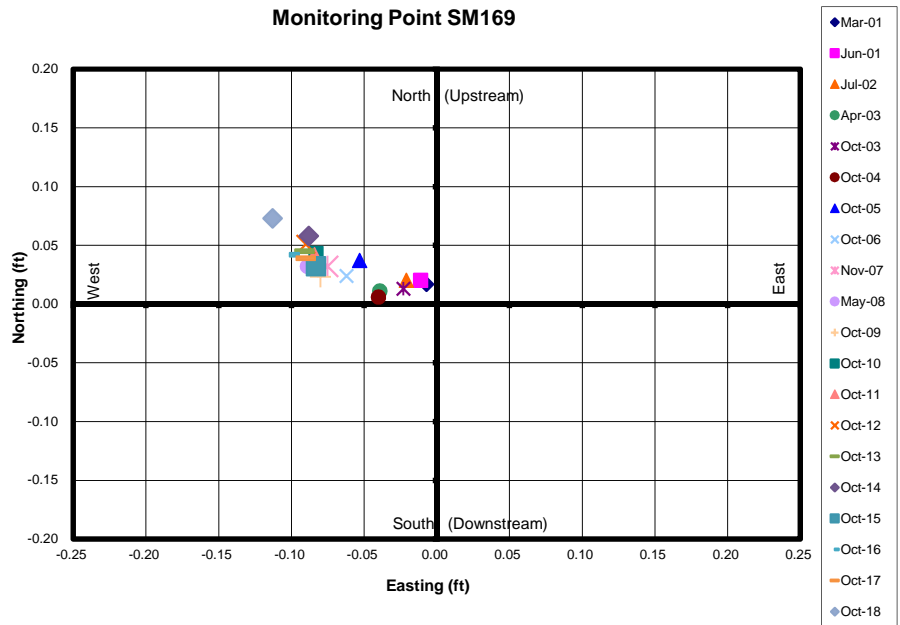
Monitoring Point SM166



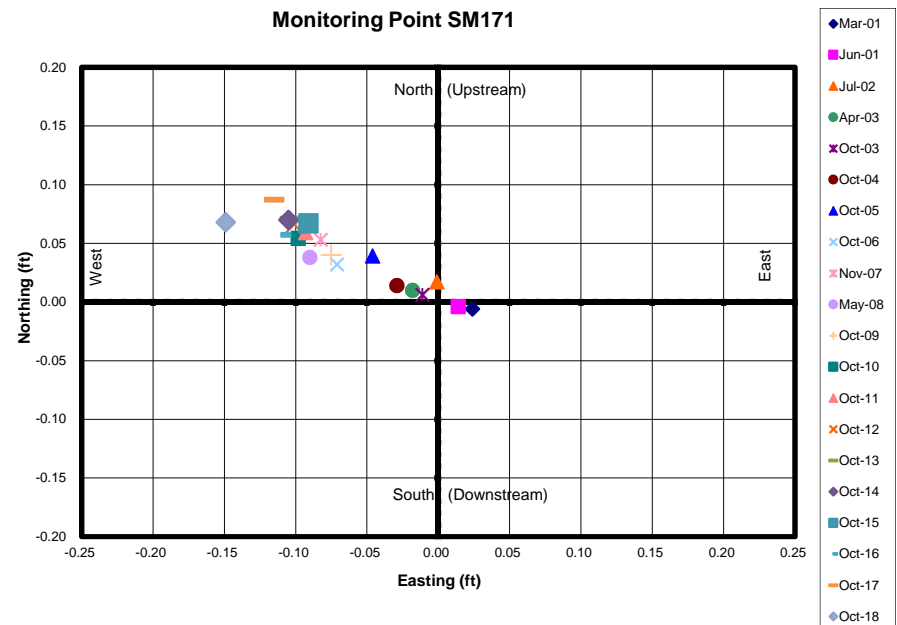
Monitoring Point SM167



Monitoring Point SM169

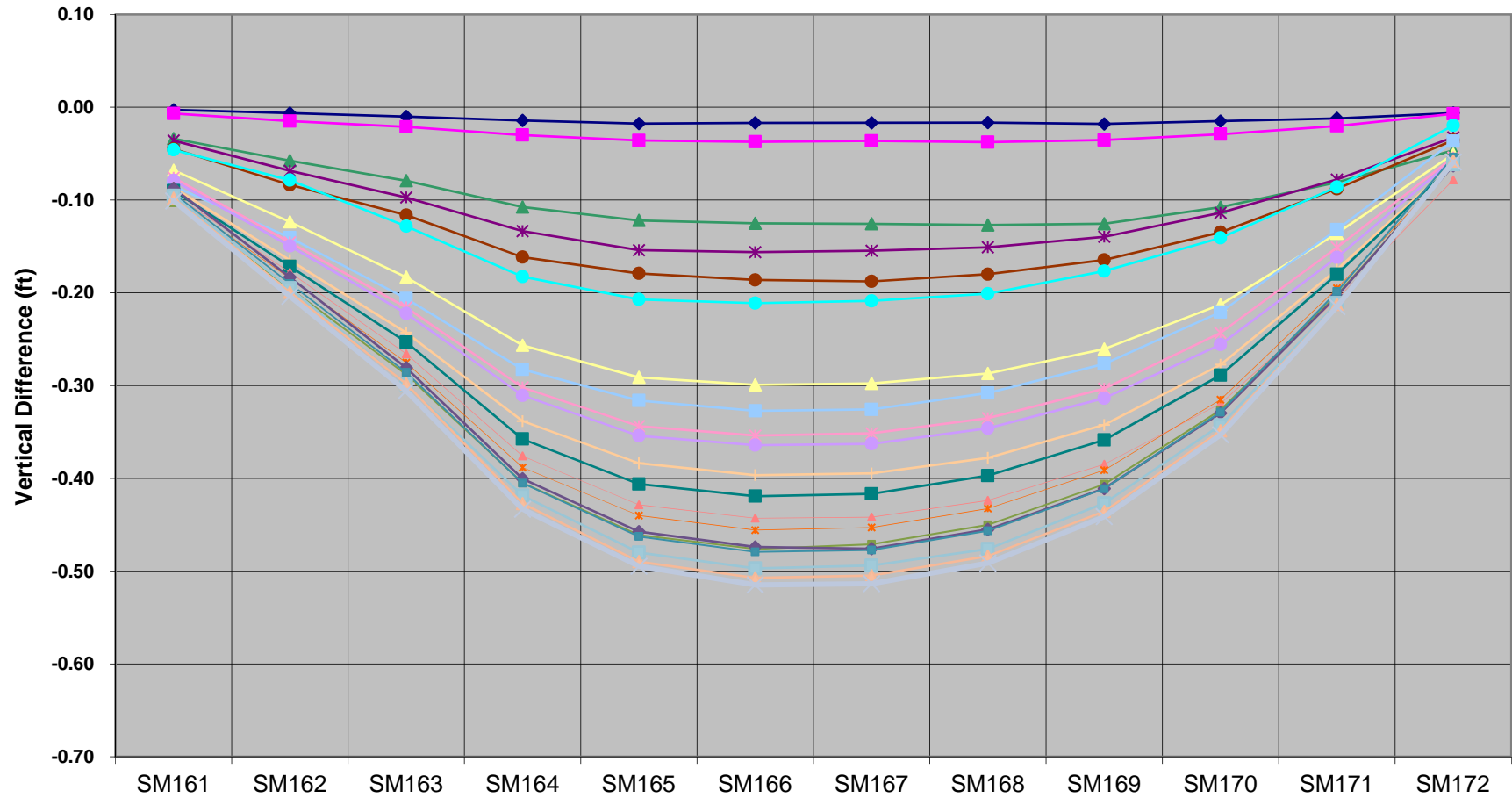


Monitoring Point SM171



(0,0) = January 2001 Horizontal Position

**Seven Oaks Dam - Upstream 2530' Level**  
**Vertical Movement since January 2001 Survey**  
**Profile View - Looking Upstream**



Mar-01

Jun-01

Jul-02

Apr-03

Oct-03

Sept-04

Oct-05

Oct-06

Nov-07

May-08

Oct-09

Oct-10

Oct-11

Oct-12

Oct-13

Oct-14

Oct-15

Oct-16

Oct-17

Oct-18



# Seven Oaks Dam Monitoring Survey

## Upstream 2360' Level - Monitoring Points

(6105) SM173 & CAP

SM174

(6108) SM175 & CAP

SM176










(6111) SM177 & CAP

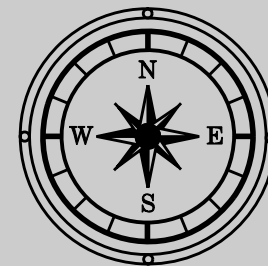
SO2001-113

SO2001-114

SO2001-115

### LEGEND

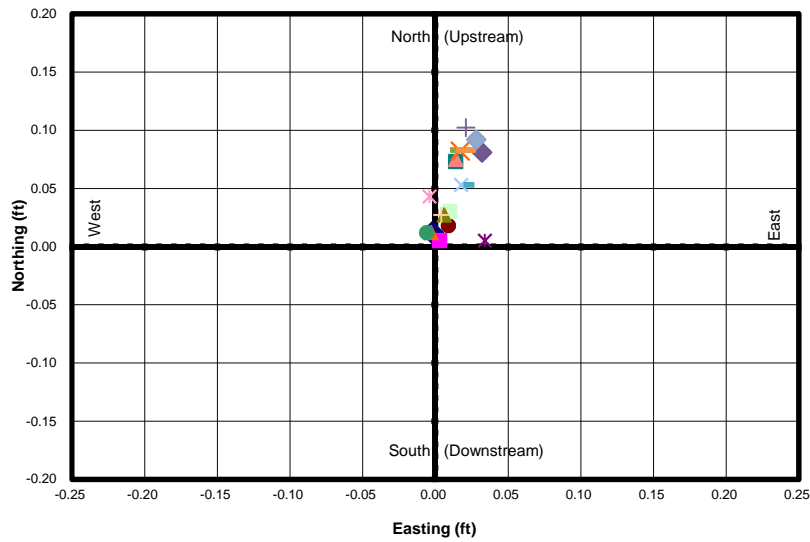
-  PILLAR MONUMENT
-  OTHER H & V MONUMENT
-  BENCHMARK
-  SETTLEMENT MONUMENT 77 mon
-  SETTLEMENT MONUMENT (SUBSET) 33 mon
-  INCLINOMETER 6 mon
-  CORS SITE
-  TUNNEL MONUMENT 22 mon
-  X-SECTION MONUMENT 7 mon



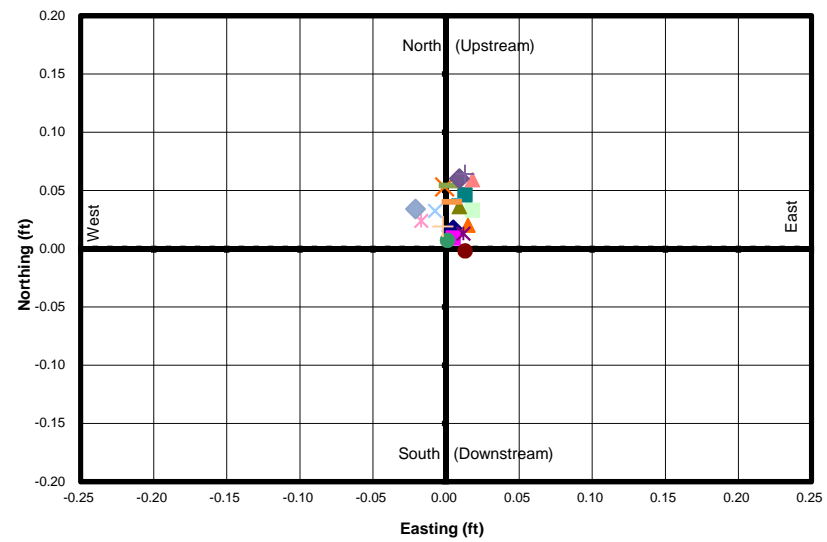
100' 100' 100'

# Seven Oaks Dam - Upstream 2360' level (Horizontal) Horizontal Movement since January 2001 Survey

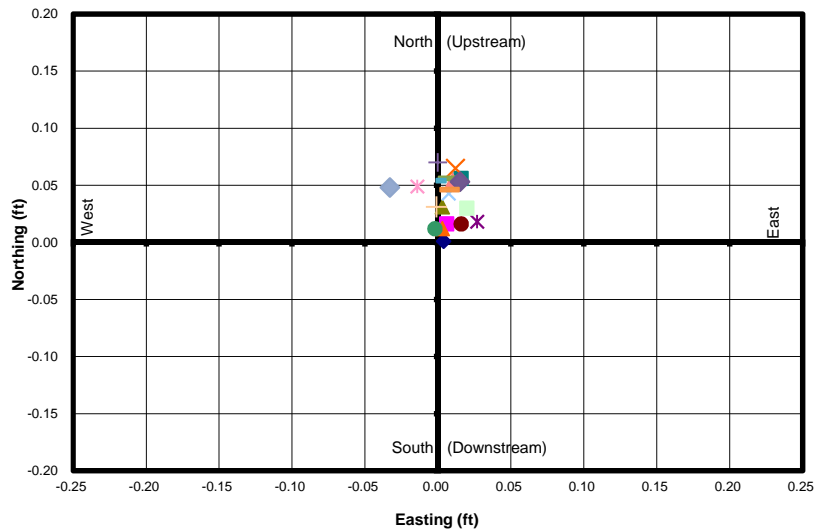
Monitoring Point SM173



Monitoring Point SM175

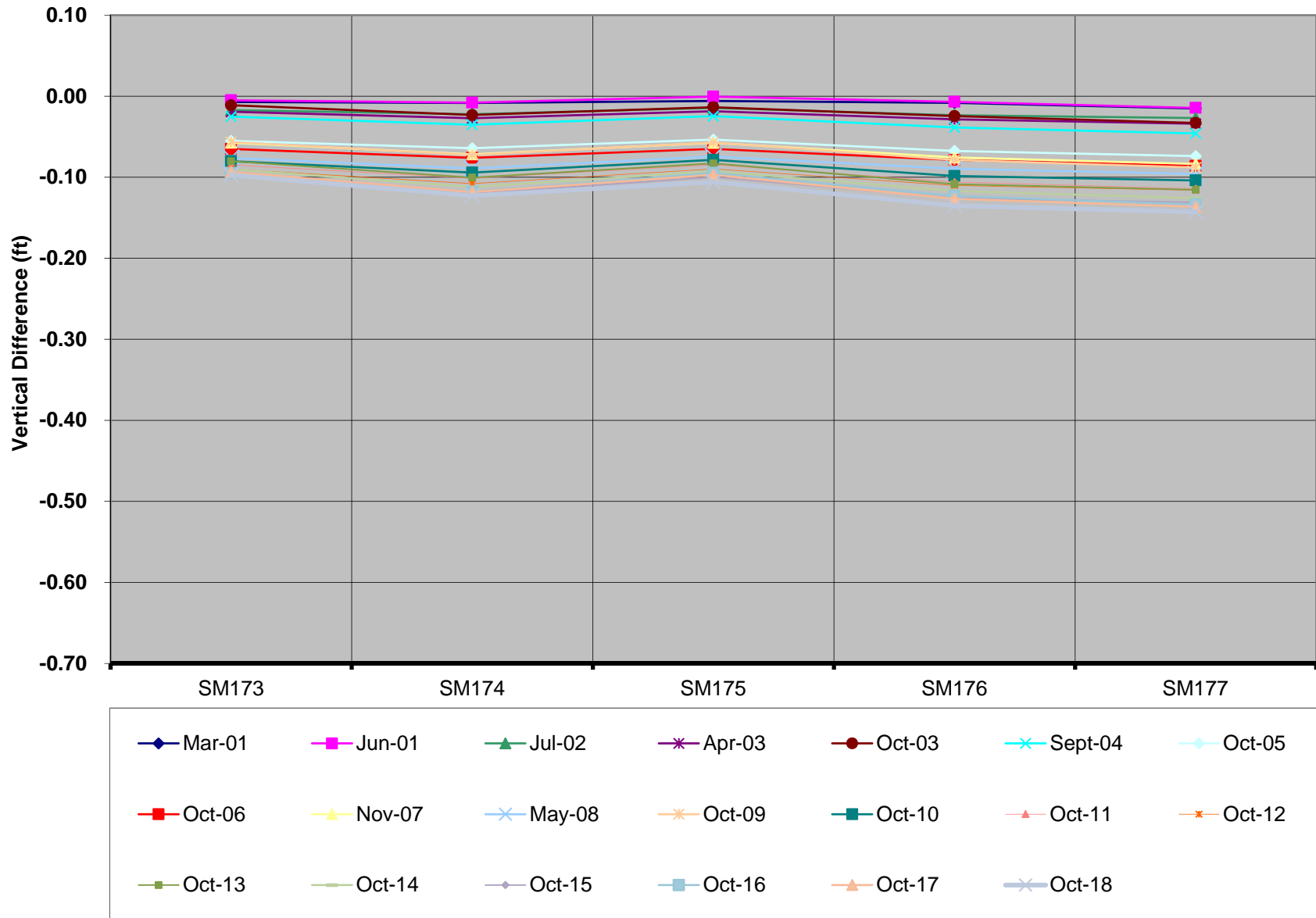


Monitoring Point SM177



(0,0) = January 2001 Horizontal Position

**Seven Oaks Dam - Upstream 2360' Level**  
**Vertical Movement since January 2001 Survey**  
**Profile View - Looking Upstream**














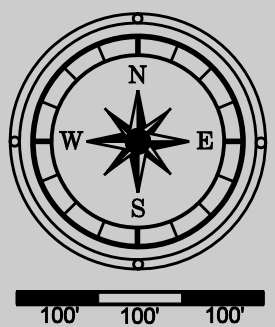
# Seven Oaks Dam Monitoring Survey

## Inclinometer Locations - Monitoring Points



### LEGEND

-  PILLAR MONUMENT
-  OTHER H & V MONUMENT
-  BENCHMARK
-  SETTLEMENT MONUMENT 77 mon
-  SETTLEMENT MONUMENT (SUBSET) 33 mon
-  INCLINOMETER 6 mon
-  CORS SITE
-  TUNNEL MONUMENT 22 mon
-  X-SECTION MONUMENT 7 mon

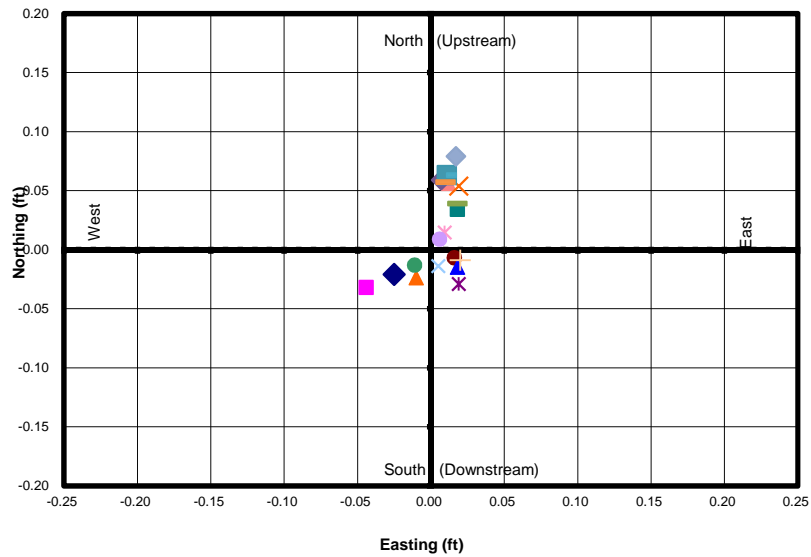




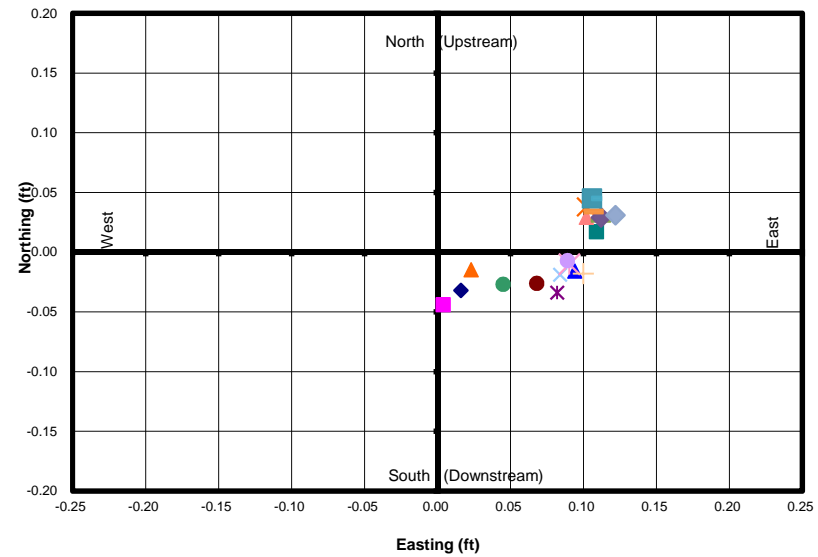
# Seven Oaks Dam - Inclinometers (Horizontal)

## Horizontal Movement since January 2001 Survey

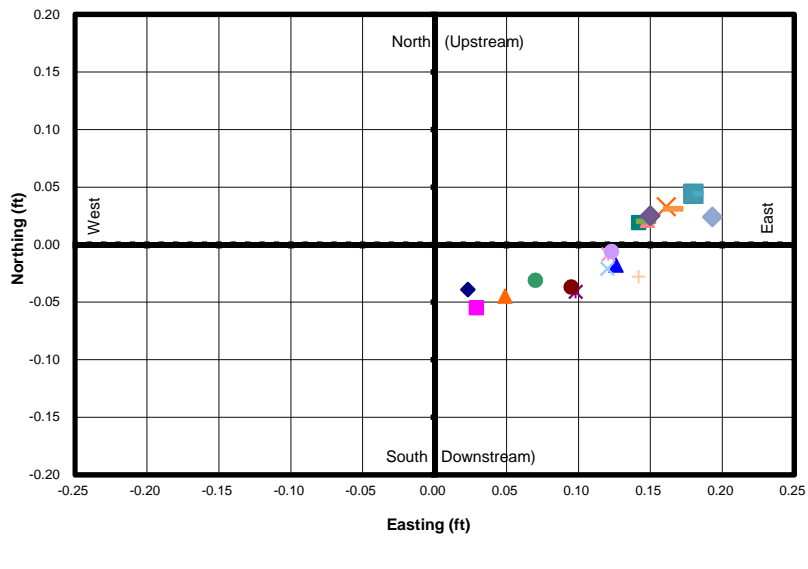
Inclinometer Monitoring Point SI-1



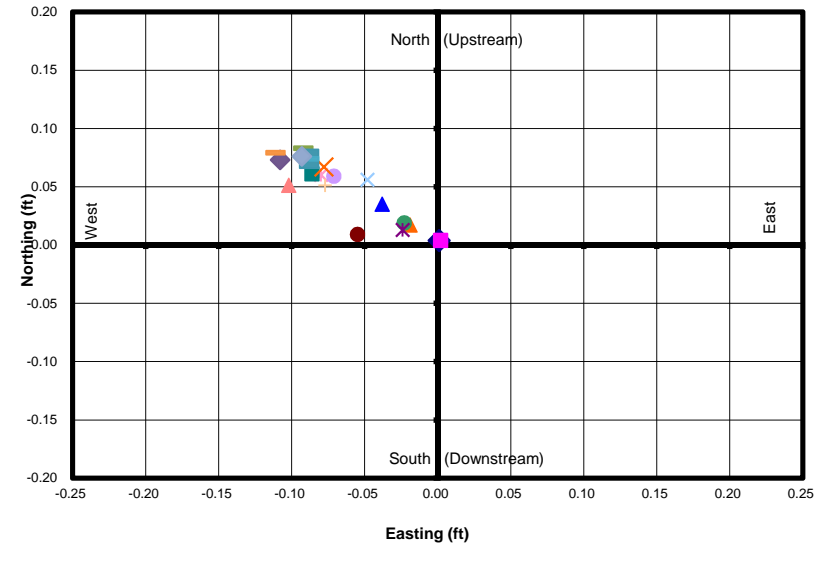
Inclinometer Monitoring Point SI-2



Inclinometer Monitoring Point SI-3



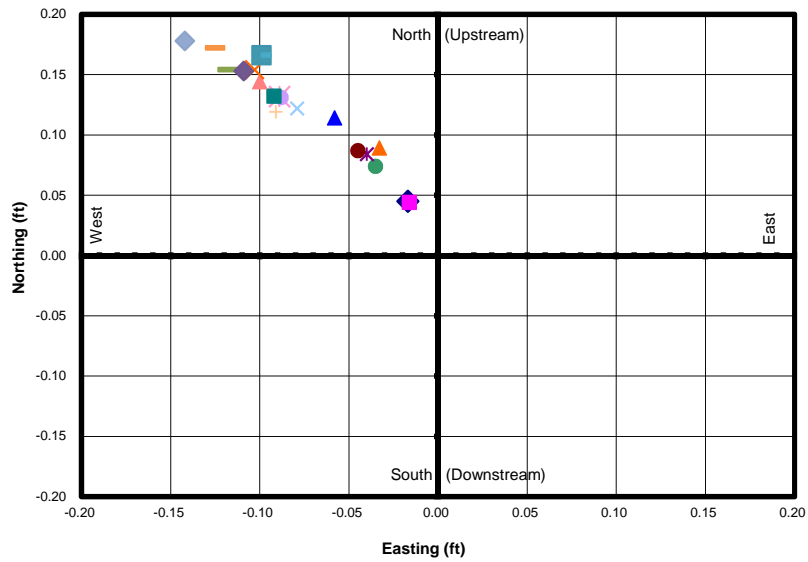
Inclinometer Monitoring Point SI-4



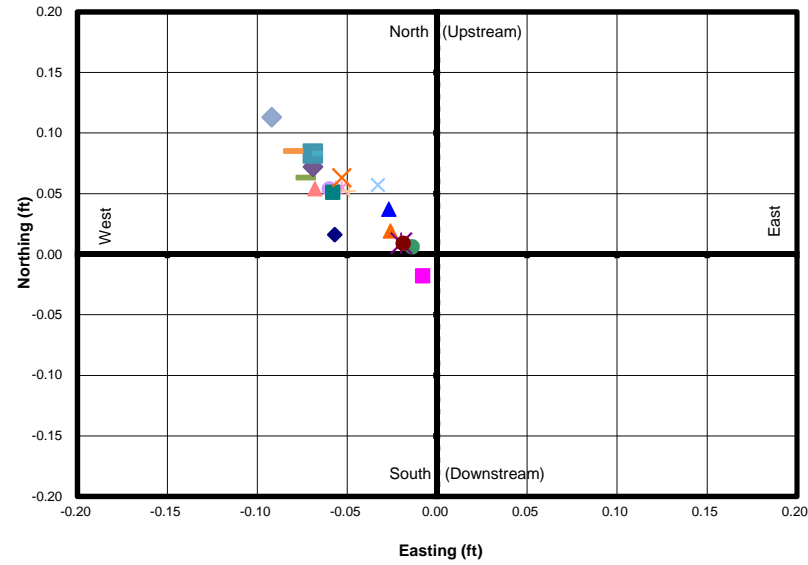
(0,0) = January 2001 Horizontal Position

# **Seven Oaks Dam - Inclinerometers (Horizontal)** **Horizontal Movement since January 2001 Survey**

**Inclinometer Monitoring Point SI-5**

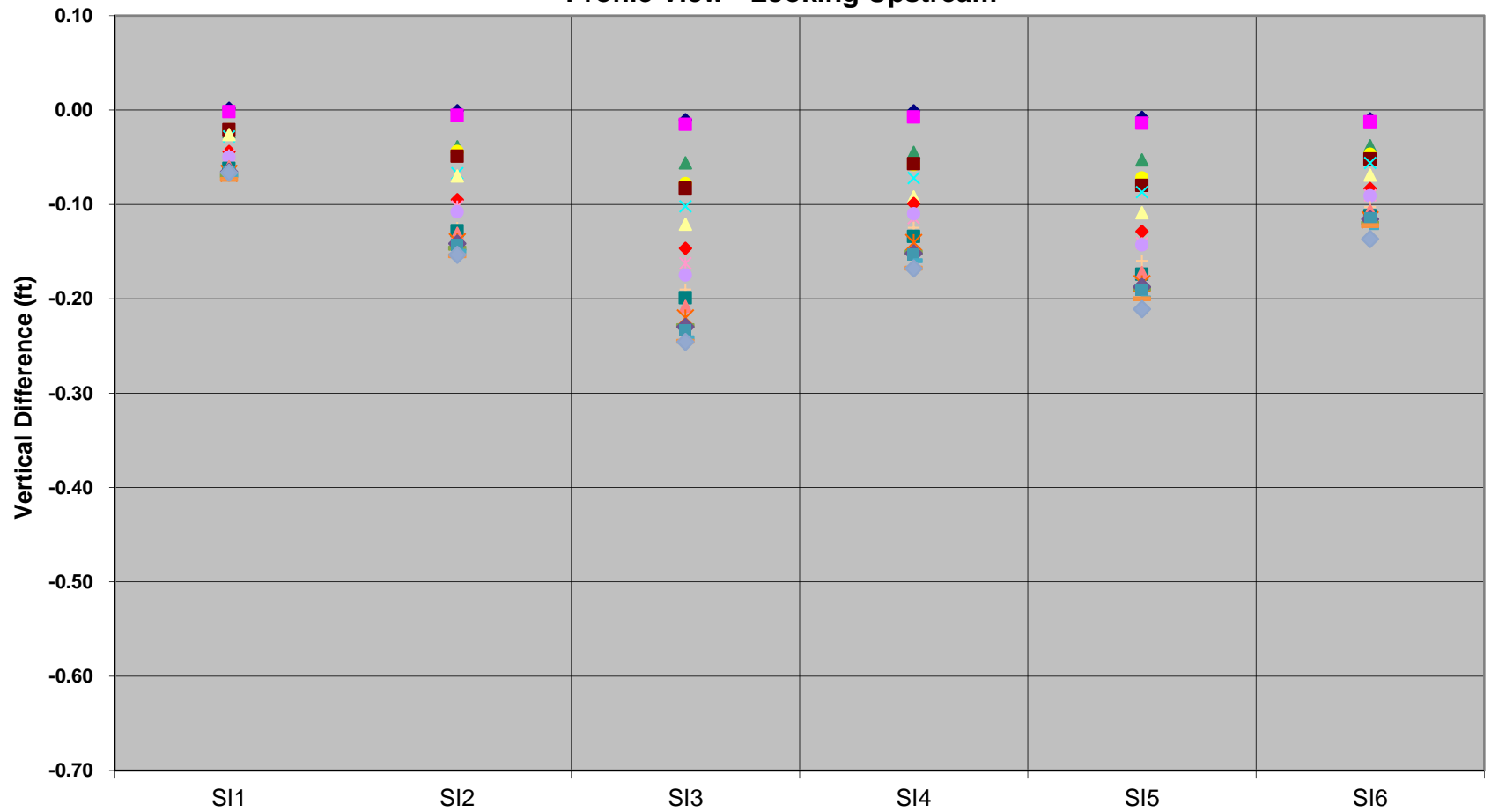


**Inclinometer Monitoring Point SI-6**



**(0,0) = January 2001 Horizontal Position**

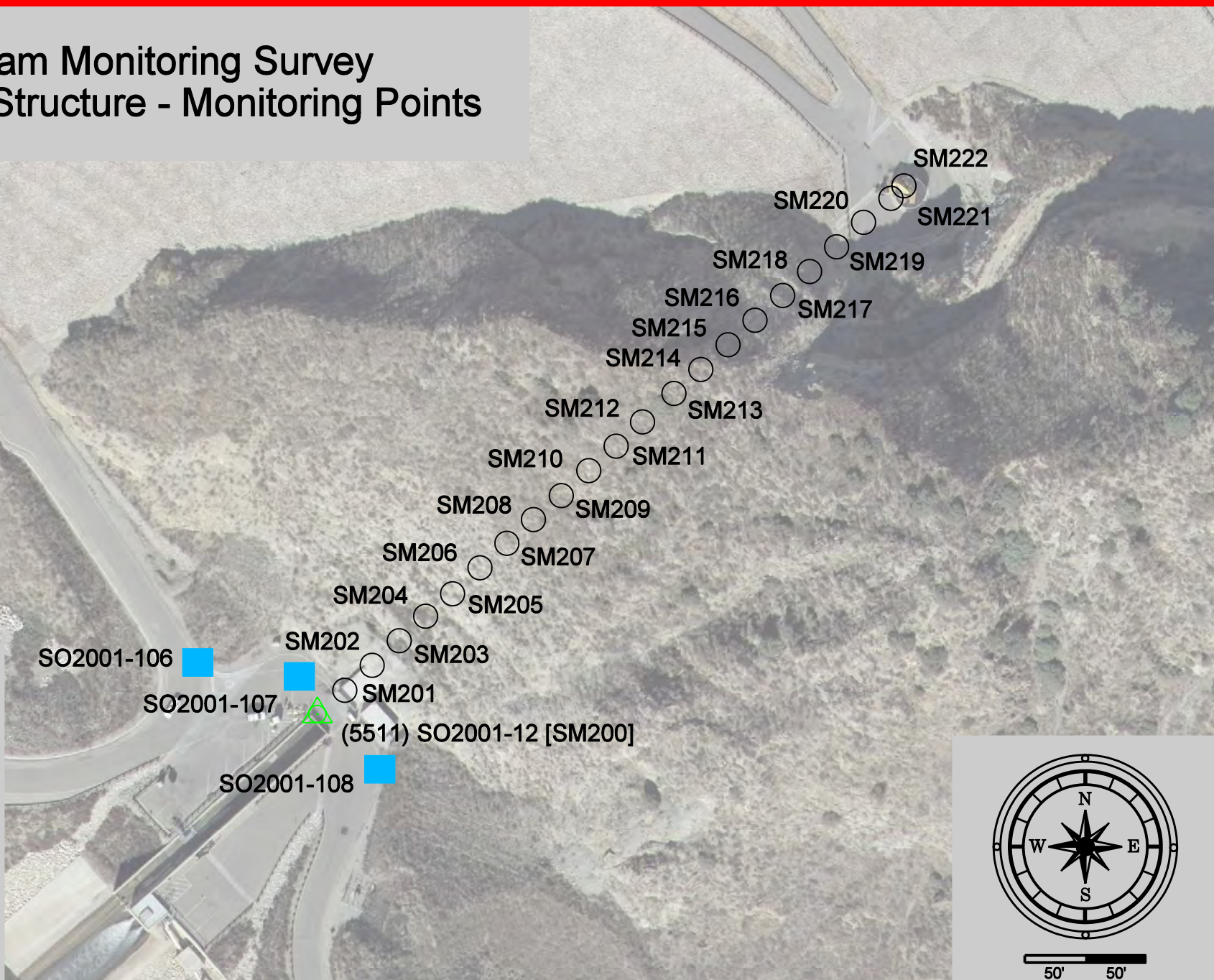
# Seven Oaks Dam - Inclinator Vertical Movement since January 2001 Survey Profile View - Looking Upstream



◆ Mar-01    ◆ Jun-01    ▲ Jul-02    ● Apr-03    ■ Oct-03    × Sept-04    ▲ Oct-05    ◆ Oct=06    × Nov-07    ● Oct-08  
 + Oct-09    ■ Oct-10    ▲ Oct-11    × Oct-12    — Oct-13    ◆ Oct-14    ■ Oct-15    — Oct-16    — Oct-17    ◆ Oct-18

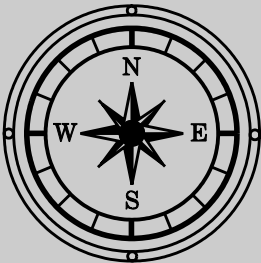
# Seven Oaks Dam Monitoring Survey

## Outlet Tunnel Structure - Monitoring Points



### LEGEND

- PILLAR MONUMENT
- OTHER H & V MONUMENT
- BENCHMARK
- SETTLEMENT MONUMENT 77 mon
- SETTLEMENT MONUMENT (SUBSET) 33 mon
- INCLINOMETER 6 mon
- CORS SITE
- TUNNEL MONUMENT 22 mon
- X-SECTION MONUMENT 7 mon



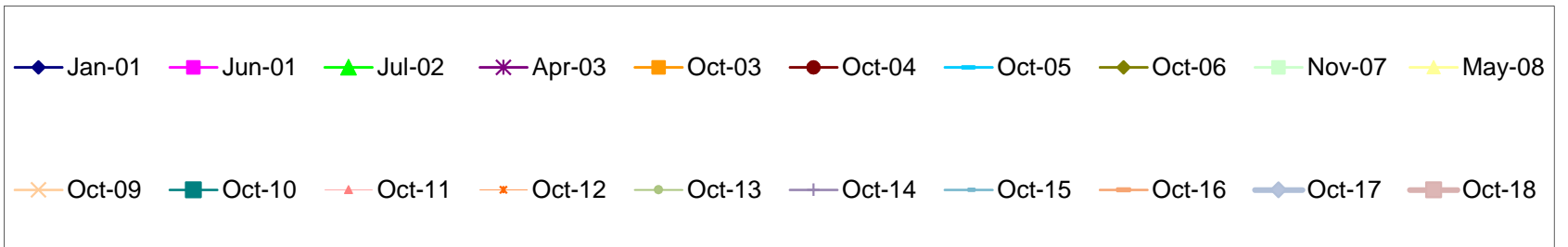
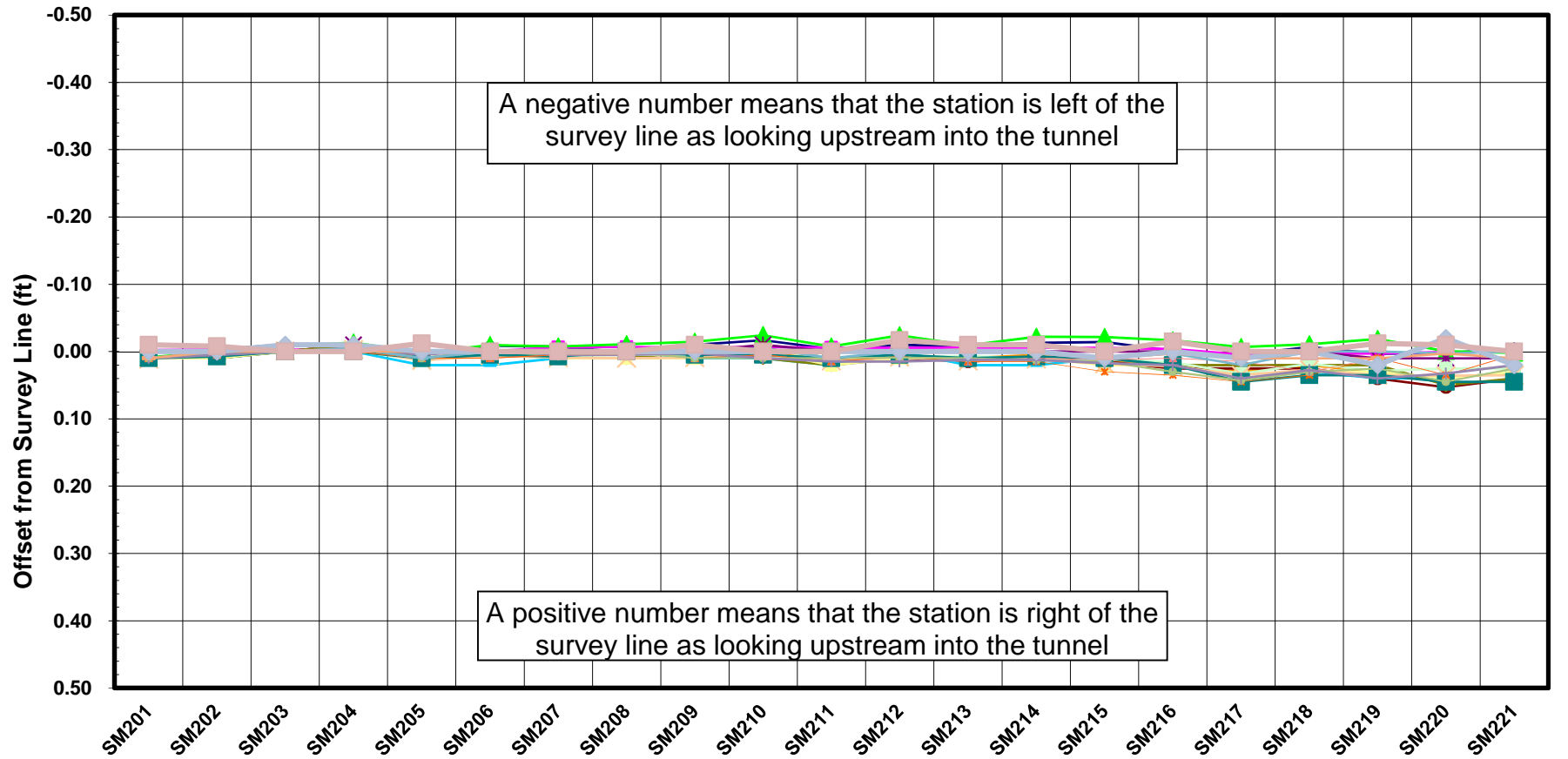
50' 50'



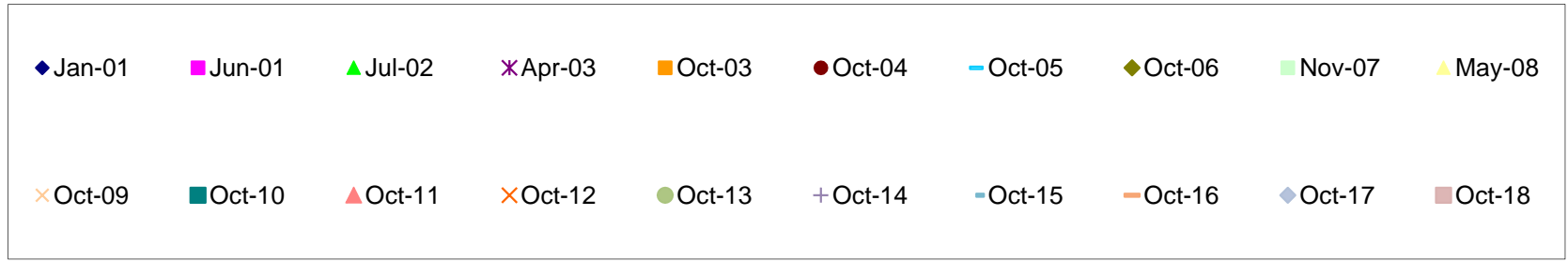
# Seven Oaks Dam - Outlet Tunnel Structure

## Horizontal Movement Since January 2001

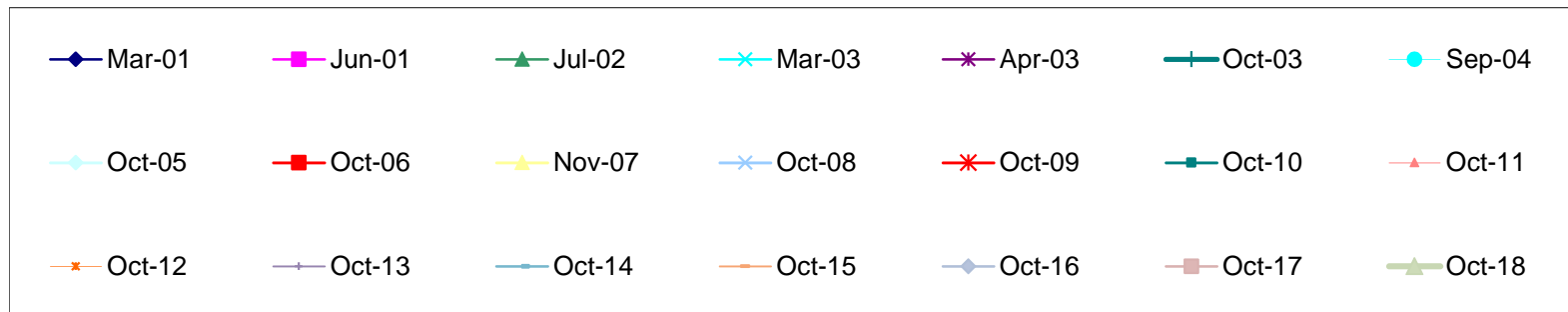
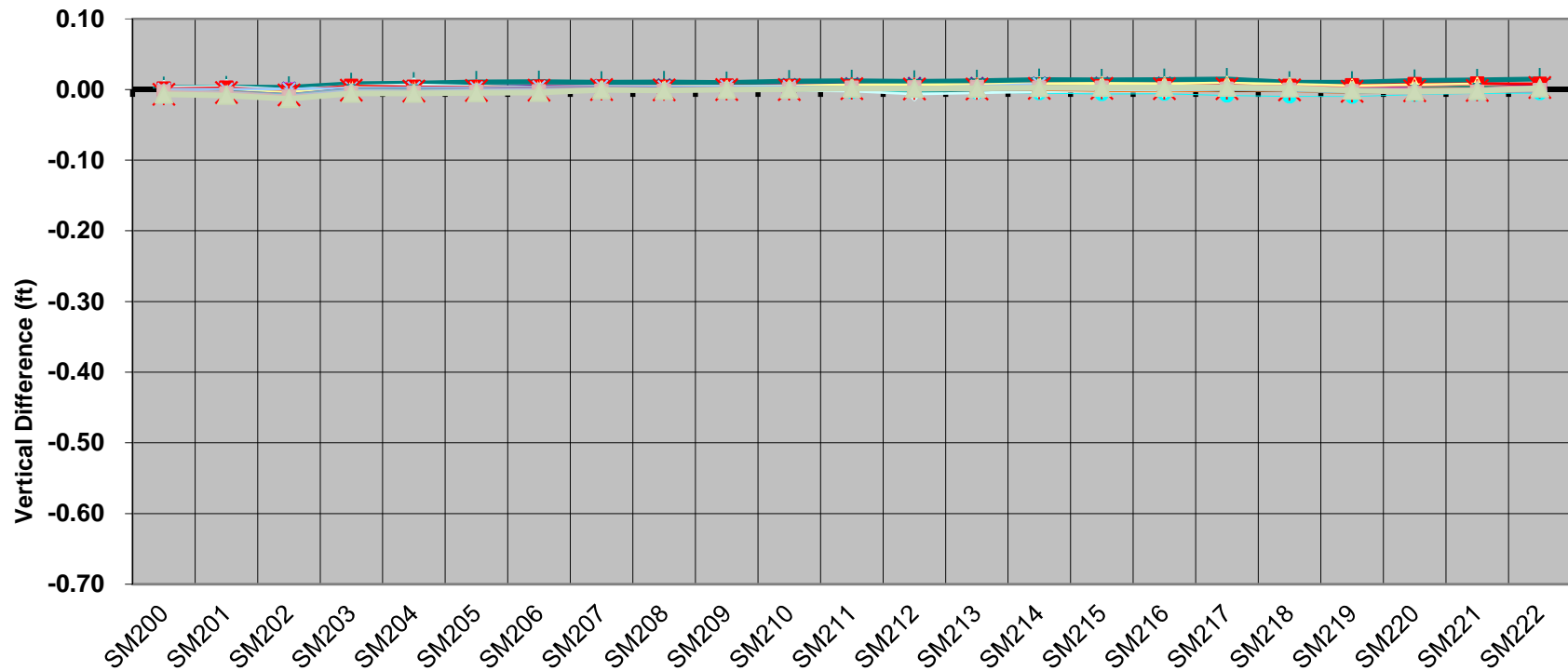
### Tunnel Alignment - Outs from Survey Line



### Tunnel Alignment - Difference from original distance



# Seven Oaks Dam - Outlet Tunnel Structure Vertical Movement since January 2001 Survey Profile View - Looking from Right Side



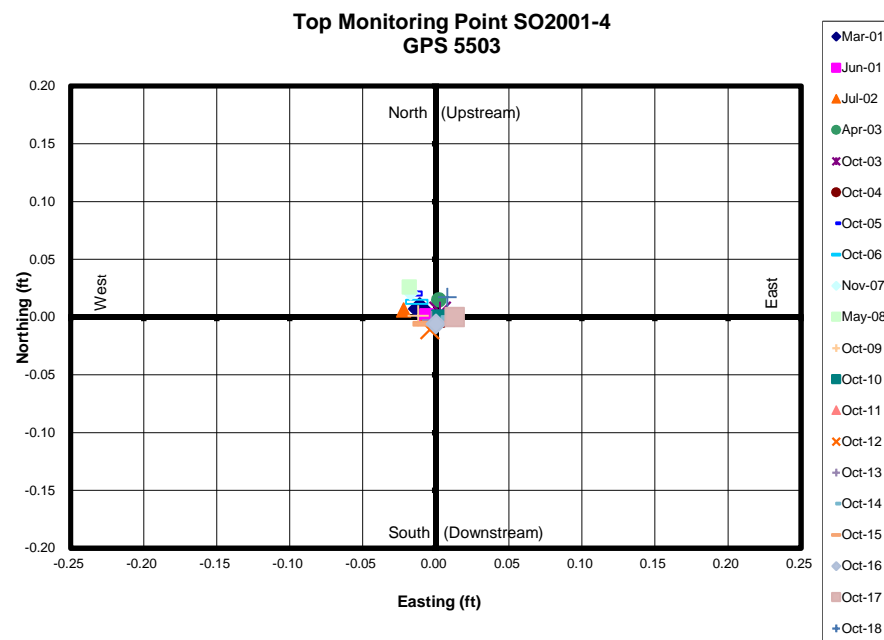
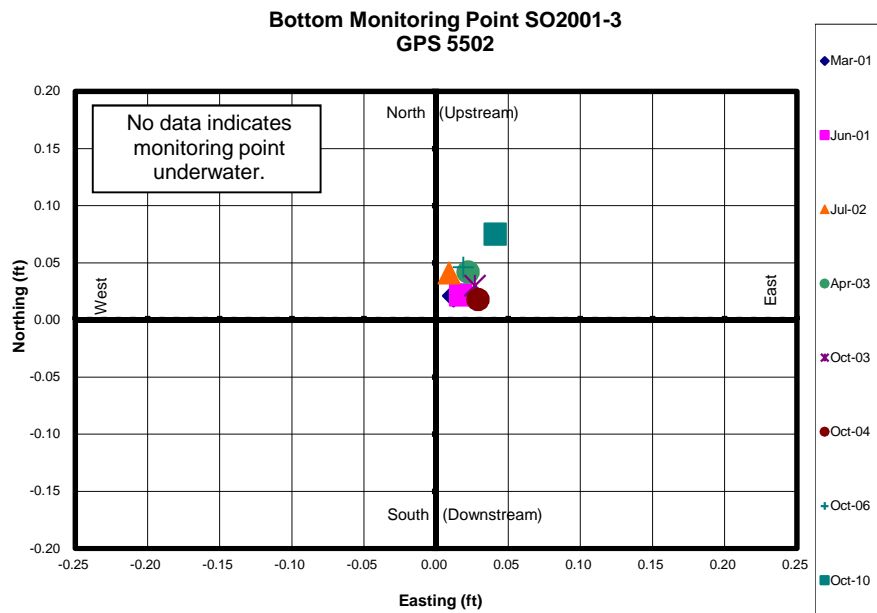
# ***Seven Oaks Dam Monitoring Survey Intake Tower - Monitoring Points***





# Seven Oaks Dam - Intake Tower Structure (Horizontal)

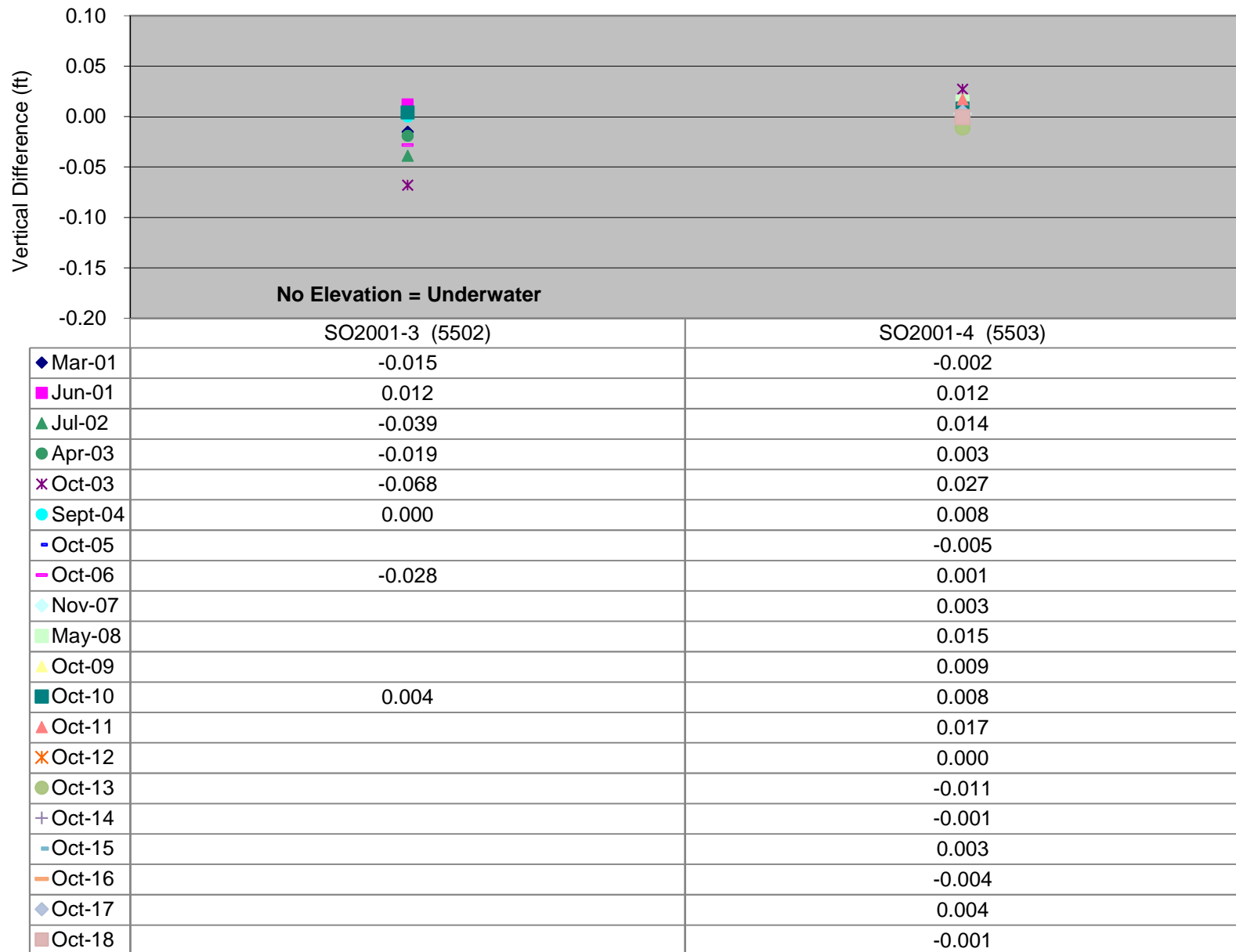
## Horizontal Movement since January 2001 Initial Survey



(0,0) = January 2001 Horizontal Position

# Seven Oaks Dam - Intake Structure

## Vertical Movement since January 2001 Survey





## Department of Public Works

- Flood Control
- Operations
- Solid Waste Management
- Surveyor
- Transportation

Kevin Blakeslee, P.E.  
Director

October 22, 2018

Art Andrew  
County of Orange Public Works  
300 N Flower Street, Room 252  
Santa Ana, CA. 92703

**Re: Seven Oaks Dam 2017 Annual Survey Cost Estimate**

Dear Mr. Andrew,

Thank you for your consideration of our department for the performance of the 2018 Annual Monitoring Survey at the Seven Oaks Dam site, per the scope of work provided on October 1, 2018 which reflects monitoring of phases I through IV per the provided specifications. We are pleased to provide a cost estimate of \$29,692.00 for the Annual Monitoring survey. This is an estimated cost only – if our crews and office staff are able to complete the project in less time than estimated, we will only bill for the actual time spent working on your project. Below is a breakdown of the charges:

**Office:**

Process GPS files; review level runs; review data files; process, prepare survey data; prepare deliverables (64 hrs)

**Field:**

Horizontal positioning of monuments and vertical positioning – level runs as specified (two man crew 90 hrs)

Total office time: 64 Hours @ \$(varies)/ Hr. \$ 8,812.00

Total two man crew field time: 90 Hours @ \$232/ Hr. \$ 20,880.00

Total Cost: \$ 29,692.00

Our billing rates have remained unchanged from last year, and as with previous years we anticipate completion of the project well under this estimate if no problems are encountered. If our estimate is acceptable, please let us know when you would like to commence the 2018 Annual monitoring survey. We will be able to complete this job within 20 working days after being given permission to proceed, given no unforeseen circumstances arising during the course of the work. If you have any questions, please do not hesitate to call me at (909)387-8147.

Sincerely,

**Thomas P. Herrin**

County Surveyor

San Bernardino County Surveyor's Office

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