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COLLIDER HALL PIT FLOOR ELEVATIONS DURING THE MARKII AND SLD MOVES*

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ABSTRACT

This report contains measurements of the SLAC Linear Collider Experimental Hall pit floor elevations made at times when the large detectors, Mark II and the SLD, were moved back and forth. Precision water level systems, having rms repeatability of about 50 micrometers, were employed. Measurements were made over periods of time (about two months) which illustrate the elastic and inelastic deformation of the floor. Local deformations were measured using classical optical leveling techniques.

For objects weighing several thousand tons (US short), the observed global deflections were in the millimeter range. Deformations around the detector feet range up to almost one centimeter. Typical settling periods range up to about one month. The results of this experiment are to be compared with simulations performed with finite element analysis[1] computer programs using as input the known geometries of the configurations and the properties of supporting soils.

*Work supported by Department of Energy contract DE–AC03–76SF00515.

1. INTRODUCTION

Linear Colliders are "open ended" high energy particle accelerators in which two particle beams possessing minute crossection are made to collide more or less head on[2]. By open ended, it is meant that the two arms of the accelerator are basically separate machines that have no common closed orbit. For this reason fairly tight requirements are placed on the spatial alignments of these machines, in particular on the symmetry of those optical steering and focussing elements near the interaction point (IP) called the "final focus"[3]. In order to study the reaction products of the particle collisions at the IP, a detector will be mounted there. Ironically, modern detectors containing massive magnets and iron shielding may be so heavy as to deform the footings of the civil structures and upset the carefully positioned elements when the detectors are moved onto the beam line. It is the purpose of this note to document the experiences obtained at the Stanford Linear Collider Experimental Pit in these respects and to provided data that can be compared with computer simulation, thereby setting a scale to the problem for future colliders.

2. GEOMETRY OF THE DETECTOR LOCATIONS

2.1 Epoch 1, for 6 months prior to Sept 18 1987

Figure 1 depicts a plan view of the collider hall pit floor as it was occupied by the Mark II detector in 1987 prior to its first installation on the beam line. The pit floor is about 56 feet below grade. The distance along the beam line between the north and south walls is 65 ft. The east and west walls are 233 feet apart. The central portion of the hall is separated from the east and west areas by two concrete shielding walls that reach to grade level. Each wall (shown hatched) consists of the equivalent of 27 concrete blocks each weighing 75,200 pounds. Each wall (1015 US short tons) is supported (presumably uniformly by the introduction of a thin plywood sheet) by the floor and is kept from falling down in an earthquake by fitting into north and south wall slots. Note that the east wall is mounted in its alternate slot placing it closer to the IP than its opposite. The two dotted lines show the projected location of the centerlines of the wall spreaders at grade level.

2.2 Epoch 2, Following Dec 16th 1987

Figure 2 depicts the layout with the Mark II detector installed on the beam line. The weight of the Mark II detector is estimated[4], including its side muon walls, to be 1900 (US short) tons. To accomplish the move onto the beam line, the east shielding wall was temporarily disassembled and then reconstructed. Also shown are the locations of 6 water levels located in both the north and south beam tunnels[5]. The two wells in the pit are mounted on the piers that support the final focus lenses also shown in Figure 3. The outer portion of these piers remain fixed when the Mark II moves. The height of water in these wells could be read continuously by means of acoustic distance gauges. The resolution of these gauges was of order .001 inches, the data was corrected for density fluctuations by monitoring the temperature of the wells.

2.3 Epoch 3, For 6 months prior to November 26 1990

Figure 4 depicts the locations of the major heavy objects (as they were at the beginning of this experiment on November 26th 1990). The SLD magnet is shown in the west pit. Its weight estimated at 3400[6] (US short) tons is evenly distributed among its four feet marked with crosses. (For foot details see section 7.) Just west of the SLD is a light clean room which remains in place. In the pit at the far west end are two beam-line shielding shells, called Pacmen, weighing a total of 148 tons. Their mates are parked on the pit apron on the south-west corner.

Also indicated are the 17 water level vials used in this experiment. The are of a design used to level the storage ring PEP[7]. Well No.'s 16 and 3 are mounted on the pit walls. The remainder are all mounted flush on the pit floor. Generally the interconnecting water hoses are mounted by being hung on the pit walls just below the floor. In some places they have been pushed into the drainage gutter. Maximum height between the level of the water in the wells does not exceed about 10 cm. Hoses circle the pit. The upper portion of the wells were vented to the atmosphere. The system can be filled by means of a 40 gallon container near well No. 14, and can be drained by a valve near well No. 1.

2.4 Epoch 4, November 26 to December 31st 1990

Figure 5 depicts the floor configuration on December 31st 1990 after the completion of the moves in December. The following sequence of events occurred.

1. November 26 - End of running period, begin removal of MarkII roof blocks.
2. November 29 - Roof blocks removed, both shielding walls in place.
3. December 1 - 3 East wall blocks removed, 1 West wall block removed

4. December 5 - 15 East wall blocks removed
5. December 7 - All East wall blocks removed
6. December 8 - 4 West wall blocks removed
7. December 11 - 9 West wall blocks removed
8. December 12 - 15 West wall blocks removed
9. December 14 - All west wall blocks removed
10. December 17 12:00 noon Mark II detector 7 feet East
11. December 17 18:00 Mark II 17 feet East
12. December 18 16:45 Mark II 36 feet East
13. December 19 16:09 Mark II 52 feet East, in final location. Piers B removed, Piers A in place.

2.5 Epoch 5, January 1 to April 1991

Figure 6 depicts the configuration on the pit floor after the end of March 1991, after the SLD detector is on beam line, the north and south beam shield plugs (Pacmen) are in place and no further major floor loading changes are planned to take place. The SLD detector is "selfshielding" ie. the east and west shielding walls, used during the earlier Mark II operation, will not be reconstructed. The sequence of SLD installation events is as follows:

1. January 10 - North Pier A removed
2. January 13 - South Pier A removed
3. February 12 - Water level well system restored to operation with well numbers 5,7,9,10,11,12 remounted after work related to "Pacman" shielding equipment partially completed. Well 6 permanently removed.
4. February 21 Both SLD endcaps closed for the last time prior to move.
5. February 28 - SLD moved 18" to the east. Well No. 8 permanently removed.
6. March 1 6pm - SLD halfway to new location
7. March 2 6pm - SLD 6" beyond beamline
8. March 4 7am - Remove Well No.10 and move SLD 18" beyond beam line
9. March 10 - New well No.10 installed, system flushed
10. March 12 - North West 65 ton PACMAN and 7.5 ton carriage installed on its tracks.
11. March 22 - North East 82.5 ton PACMAN and 7.5 ton carriage installed.

3. PROPERTIES OF THE UNDERLYING SOILS

Borings made prior to construction of the hall and other evidence[8] indicates that the stratum of tertiary miocene is at least 400 feet below grade. Interpretation of the borings by Earth Sciences Associates[9] led to the Engineering Properties of the miocene sandstone listed in their reports as Table B-1 and which is reproduced below.

Table B-1

ENGINEERING PROPERTIES AND GEOTECHNICAL DESIGN RECOMMENDATIONS FOR MIOCENE SANDSTONE AT COLLIDER EXPERIMENTAL HALL SITE

Property*	Units	Value	Remarks
Density	pcf	125 130	
Unconfined Compressive Strength	psi	0–20 50–100	
Effective Friction** Angle, ϕ'	degrees	35 (38) 42 (46)	
Effective Cohesion, c'	psi	0	
Allowable Bearing*** Pressure	ksf	16 10	Shallow footings: width $\geq$ 2 feet; depth $\geq$ 2 feet
		40	Deep footings: width $\geq$ 2 feet; depth $\geq$ 30 feet
Coefficient of Active Lateral Earth Pressure, K_A	—	0.27 (0.24) 0.20 (0.16)	
Coefficient of Lateral Earth Pressure at Rest, K_O	—	0.43 0.33	
Bond Stress Between Tieback Anchor Grout and Sandstone	psf	1000 5000	
Compressional Wave Velocity at Low Strain Level, V_p	ft/sec	1928 (top 35') 3370 (35'–90')	
Shear Wave Velocity at Low Strain Level, V_s	ft/sec	1225 (top 35') 1952 (35'–90')	

*First value is for sandstone with little to no cementation; second value is for moderately to well cemented sandstone.

**Values in parentheses correspond to earthquake loading conditions.

***Values only apply to moderately to well-cemented sandstone.

Earth Sciences Associates

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4. CONSTRUCTION OF THE PIT FLOOR

Details of the pit floor slab construction are best seen by entering pages S-8,S-9,S-5A,S-5B of the "as built" construction drawing package of the Collider Hall[10]. Basically the floor is a 2 foot thick reinforced concrete slab that was poured (independently of the walls) directly onto the recently (in terms of geologic times) exposed tertiary miocene sandstone foundation rock. One might also note that not only is the pit floor 55 feet below present grade level, some 44 feet of overburden was removed from the site of the building before the pit excavation was begun.

In those regions of the floor upon which very heavy objects are to roll on, 2" thick steel plates, generally about 4' wide, are provided to distribute local loads, prevent concrete spalling and provide anchors for earthquake resistant tiedowns. A representative schedule and notes for their installation are depicted in Appendix 1.

5. DATA FROM THE BEAM LINE WELLS DURING MARK II ROLL IN

Figure 7 displays a three month portion of data from the "beam line" water levels during the roll-in of the Mark II detector and subsequent rebuilding of the east shielding wall. The units in these original figures are inches.

The display on the left shows the average depression of the two piers that rest on the floor. Relative to the outermost wells in the tunnel the total motion is about 2 millimeters. Noteworthy is the fact that the south side of the pit was initially more depressed. This is shown more dramatically in Figure 8. Further there is a marked upward distortion on the piers when the east shielding wall was reconstructed. One might estimate that the settling time after major construction ceased to be of the order of 30 days. It is tempting to see some sag in the elevation of the tunnel lips. The difficulty in making temperature corrections to this data, however, suggests that this apparent deformation is probably not significant.

6. DATA FROM THE FLOOR WELLS DURING MARK II ROLL OUT AND SLD ROLL IN

6.1 MARK II ROLLOUT, NOVEMBER 26 TO DECEMBER 31 1990

Data from the 17 floor wells was taken by reading the well micrometers (a) when the pin touched the water and a meniscus formed (b) when the pin was retracted to the point when the meniscus broke. The difference between the readings was generally about 0.4 mm. The readings were averaged.

Well No. 16, mounted on the east wall, was used as a reference, ie. all elevations are calculated relative to the water level in this well. To display the variation of levels with time on a sufficiently magnified scale, further arbitrary constant normalizations are introduced before plotting.

To pinpoint problem wells with pinched hoses, the overall level of water was lowered after each set of readings by about 1 mm by letting out some water at the drain. Although the settling time of the system is estimated to be several hours, readings were generally taken early in the morning so the system could equilibrate during the night, a time during which little construction activity took place on the floor.

Figure 9 depicts the behaviour of the central portion of the floor during the time when the shielding walls were removed and the Mark II rolled east. The following observations may be made at this time:

1. The data from well No.6 was found to be reliable only after its hoses were unpinched. It showed a 1 mm rebound after the 1000 t wall was removed, and another 1/4 mm when the Mark II was rolled out.
2. The floor almost directly under the Mark II, (Well No.10) rebounded during wall removal and 1/2 mm during Mark II roll out. It appears to be still moving 15 days after the major displacement.
3. Both north and south pillar wells show about 1/2 mm rebound, although the south pillar deflection is larger instantaneously and the north pillar appears to have a longer drift. These motions are not inconsistent with the downward deflections observed during Mark II roll-in.

Figure 10 shows the behaviour of wells along the East wall. One would not expect these wells to move much when the floor is being disturbed as much as 100 feet away. In fact the scatter of the points (relative to the nearby reference on the wall is about .050 mm. Only after the Mark II rolled east and pushed its "LEACH" (local electronics acquisition house) up to the east wall are any changes noted. Unfortunately shortly after the move the weather turned very cold, (the worst freeze in northern California since 1888) which may have changed the temperature distribution in the hall.

Figure 11 depicts the behaviour of the west wall wells. The scatter of points has an rms spread of about 0.15 mm. relative to the east wall reference which is over 200 feet away. Data taken after the move also indicates an abrupt shift.

The behaviour of the remaining wells is depicted in Figure 12. Numbers 5,7 and 12 all appear to drift up slightly (observe scale change) when shielding wall removal began, No.13 (South east) appeared to be pushed down when the Mark II was moved opposite its location.

It remains to be seen whether these smaller motions are truly manifestations of floor motion or artifacts of the measurement system or choice of reference.

6.2 SLD Roll-in, January 1 1991 onward

Since there is nothing special about the beginning of the new calender year, the data of Figures 9,10,11 and 12 are simply extended into the year 1991. Fewer readings were taken over the holidays and as already mentioned, the whole well system was flushed and cleaned. Whenever the wells were remounted, the data was "renormalised". Some care was taken that this process occurred during times when no major changes in floor loading took place. It was very difficult to maintain the system during the new year due to intense construction activity on the floor. Well No.6 had to be abandoned, and after the SLD was moved on February 28th, well No.8 suffered a similar fate. Fortunately the renormalization of well No. 10 took place only after the SLD was substantially in place. Nevertheless the lack of data between March 4th and 10th is regrettable but could not be avoided since the door tracks had to be grouted in place under the SLD.

Although many wells behaved as expected two remarks need to be made.

1. The "elastic" downward deflection of the center of the pit due to the SLD is nearly the same as the elastic rebound of the MarkII detector; – although their weights differ substantially. (Fig. 10)
2. The behavior of the western most wells during the SLD move is difficult to understand. (Fig. 11)

7. LOCAL DEFORMATIONS OF PLATES AROUND DETECTOR FOOTING

It has been pointed out that the measurements made by using the water wells are characteristic of "global" floor and soils deformations. However the very highest stresses occur under and around the feet of the detectors. These local deformations were measured using classical optical level and rod techniques.

Figure 13 shows a plan view of the central portion of the Collider Hall floor at which the elevations of points were measured prior to and after the SLD was moved on beam line. The first map was made on January 18th 1991, a time after which most of the relaxation due to the removal of the Mark II detector had supposedly already taken place. The optical levelling instrument was mounted directly below the IP. Some 8 scribe marks on the pit walls (at eye level and nominally 144" below beam height) were also remeasured. These were used later as elevation references when the central region became inaccessible. The second mapping took place on March 5th, some 72 hours after the SLD was in place. For this measurement three setups were employed; one, from the center of where the SLD used to be, and one each at the north-east and south-east corners of the location where the SLD ended up. Elevation reductions generally made use of overlapping wall references. Where applicable, readings agree to within less than 0.1 mm.

The difference between floor elevations before and after the SLD move, ie. the deformation, is plotted in Figure 14 and is shown numerically on the previous map. The data show, assuming that the floor is equally strong at the four corners, that each of the eight detector feet is approximately equally loaded. The figure also shows how local the maximum depressions are. In fact the regions between feet have suffered relatively little deformation at this early time. This is in line with the relatively small deflection seen by the water level under the center of the detector at coordinates x=0, z=0.

It should be pointed out that a careful examination of the concrete floor, presumably designed to act as an elastic membrane, now shows a tributary of cracks running along a south - north line through the center of the pit. Further, some of the steel floor plates, presumably embedded into the concrete, now sound hollow in places as if no longer in contact with the supporting material.

8. CONCLUSIONS

A program carried out to monitor the behaviour of the SLC Collider Experimental Hall floor elevations during times when large changes in loading take place due to the replacement of heavy detectors leads to the following general conclusions:

1. For objects weighing several thousand tons (US short), the observed global (ie. long-range) deflections were generally in the millimeter range.
2. Local deformations around the detector supports range up to one centimeter.
3. Typical settling periods, (1/e) last about one month.

9. ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the help of many members of the SLAC staff. In particular, I wish to thank Jim Ferrie for the use of his unpublished data and graphics for the period between epochs 1 and 2, Chris Dudley for installing the wells and maintaining them during periods of intense activity on the floor, Tony King for assisting with the optical leveling, and Dan Alzofon and Bob Bell for their management support.

The interest shown by the Shimizu Corporation[11] in this problem and their efforts to understand the behaviour of the floor through theoretical analysis is gratefully acknowledged.

10. APPENDIX: DETAILS OF FLOOR PLATES

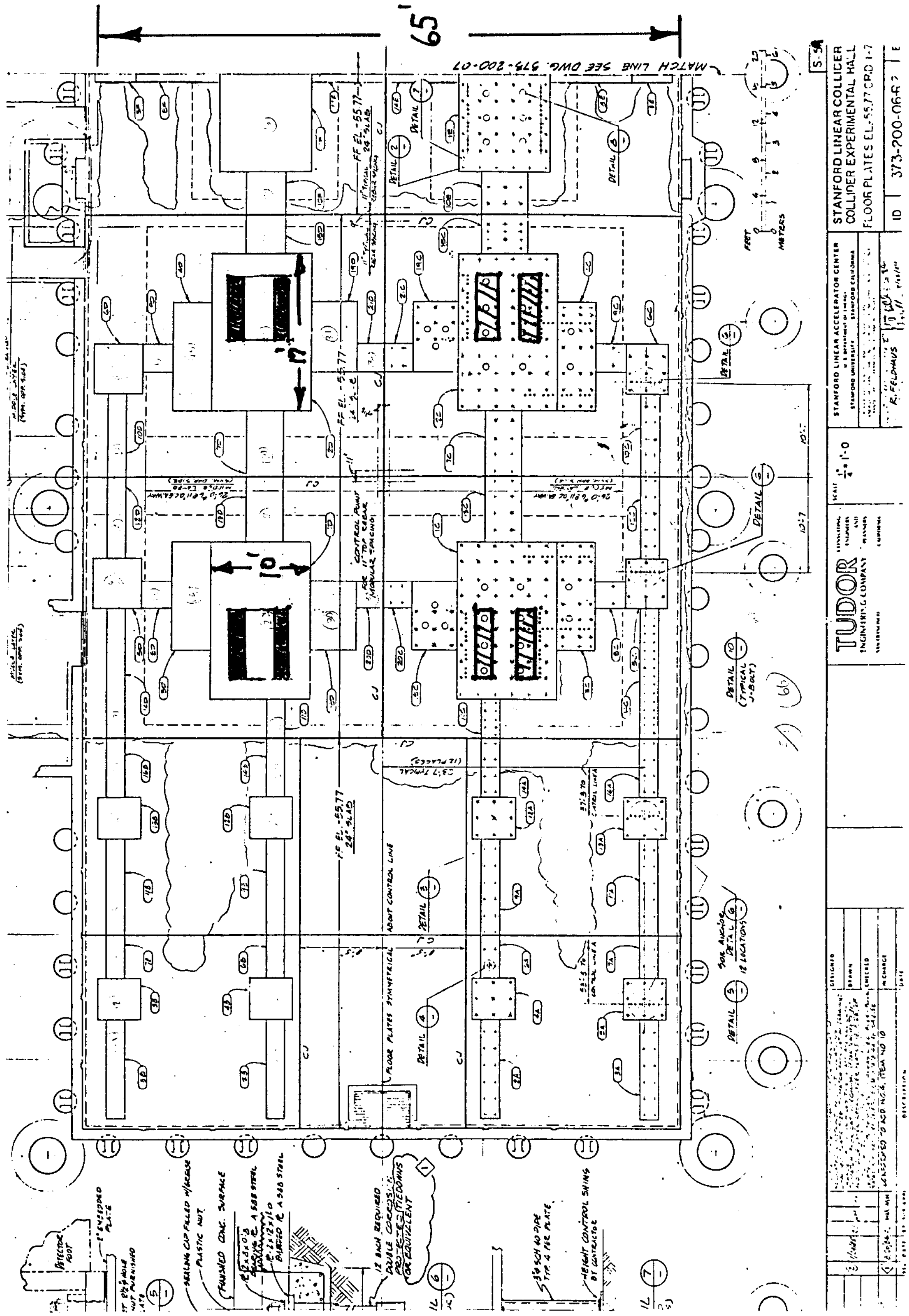
NOTES:

1. Temporary support is provided at four corners of each plate by a 3" diam. steel pipe. The contractor shall supply additional supports such that the support spacing shall not exceed 10 ft. along the edge of any plate.
2. All "J" bolts and studs are spaced at 11" O.C. to match the upper rebar layer. If the upper rebar layer is positioned relative to the control lines as shown on the drawing, then any interference between the bolt and stud pattern with the rebar pattern will be minimized.
3. Installation tolerances:
   a. Elevation - ±1/8" measured at a support point.
   b. Horizontal location - ±1/4" as measured from the control lines to the scribe marks on the plate.
   c. Plate to plate - match elevation at jack points to ±1/32", match scribe marks for horizontal control to ±1/8". Tack weld of edges or clips or other temporary supports is acceptable. At mid-point between jack locations match plate to plate levels to the extent possible by the use of a 2000# weight to deflect the higher plate. Tack weld or clip weld.
4. Areas that are otherwise inaccessible are provided with 6" access holes for use by a concrete pumper hose.
5. The plates are provided with nuts tack-welded to the underside of the plate. The holes and nut are provided with protective plugs to prevent concrete from entering the hole or nut during the concrete pour. The contractor shall preserve and replace any plugs that are damaged or lost during construction. The contractor shall clean out any holes or nut threads that are contaminated by concrete or by grout.
6. The plates are provided with a series of 2½" diam. holes spaced approx. 35" O.C. longitudinally along some of the plates. These holes may be used by the contractor as observation and vibrating access holes during the concrete pour. All holes must be cleaned of all concrete to a 2½" depth after the concrete pour is complete and again after pressure grouting.
7. Approx. one week after the concrete pour, the contractor shall pressure grout under the plates at no less than 50 psi pressure. Grout shall be a cement slurry. Any area further than 30% from an accessible edge shall be grouted; points of application shall be no greater than 6 feet on center. Cement slurry shall have a 7-day compressive stress of 3000 psi and 4000 psi at 27 days.
8. All cracks between plates greater than 1/16" wide shall be cleaned of any concrete to a depth of 1" immediately after the pour and before the concrete sets up.
9. All exposed installation tack welds and clip welds to be ground smooth after concrete has been placed.
10. The contractor shall ground all plates to the building ground system with embedded #4/0 bare grounding cable as per details on sht. 373-500-03.
11. The contractor shall notify the University 24 hours in advance of any concrete pour to allow time for University survey check of plate location and elevations.
12. University will furnish all plates fabricated completely with anchors attached ready for installation by the contractor.

P.C. Mark	Plate Size
	Areas A and B
2A	1"x2'-0"x11'-0"
2B	"
3A	"
3B	"
4A	2½"x4'-8"x4'-8"
4B	"
5A	"
5B	"
6A	1"x2'-0"x4'-6"
6B	"
7A	"
7B	"
9A	1"x2'-0"x10'-10"
9B	"
11A	"
11B	"
12A	2½"x4'-8"x4'-8"
12B	"
13A	"
13B	"
14A	1"x2'-0"x6'-6"
14B	"
16A	"
16B	"
	Areas G and H
1G	2"x4'-0"x24'-2"
1H	"
2G	2"x4'-0"x15'-6"
2H	"
3G	1"x1'-0"x8'-8"
3H	"

P.C. Mark	Plate Size
	Areas C and D
1C	2"x10'-0"x17'-6"
1D	"
2C	"
2D	"
3C	2"x4'-2"x12'-0"
3D	"
4C	"
4D	"
5C	2½"x4'-8"x5'-6"
5D	"
6C	"
6D	"
7C	2"x4'-0"x7'-4"
7D	"
8C	1"x3'-0"x3'-4"
8D	"
9C	"
9D	"
10C	1"x2'-0"x9'-2"
10D	"
11C	1"x2'-0"x4'-4"
11D	"
12C	1"x2'-0"x9'-2"
12D	"
13C	2"x4'-0"x7'-4"
13D	"
14C	1"x2'-0"x14'-6"
14D	"
15C	2"x4'-4"x5'-0"
15D	"
18C	2"x5'-0"x7'-8"
18D	"
19C	"
19D	"
20C	1"x3'-0"x3'-0"
20D	"
21C	"
21D	"

P.C. Mark	Plate Size
	Areas E and F
1E	2"x10'-0"x15'-6"
1F	"
2E	"
2F	"
3E	2½"x4'-8"x5'-6"
3F	"
4E	"
4F	"
5E	2"x5'-0"x9'-[illegible]"
5F	"
6E	"
6F	"
8E	1"x3'-0"x3'-4"
8F	"
9E	"
9F	"
10E	2"x4'-5"x5'-0"
10F	"
13E	2"x4'-0"x4'-5"
13F	"
14E	1"x3'-0"x8'-0"
14F	"
15E	"
15F	"
	Areas J and K
1J	1"x1'-0"x17'-3"
1K	"
2J	1"x2'-6"x20'-0"
3J	1"x2'-0"x12'-6"
4J	1"x2'-6"x20'-0"


65'
STANFORD LINEAR COLLIDER
COLLIDER EXPERIMENTAL HALL
STANFORD LINEAR ACCELERATOR CENTER
TUDOR
ENGINEERING COMPANY

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11. Particular thanks to Dr. Tetsuo Saito, Manager of Foreign Affairs, Planning Department, Institute of Technology, Shimizu Corporation 4 - 17 Etchujima 3 Chome, Koto-ku, Tokyo 135, Japan for his role in setting up the Shimizu/SLAC Joint effort.

FIGURE CAPTIONS

1) Layout of the SLAC Linear Collider Experimental Hall Pit. Epoch 1.
2) Layout of the Collider Hall Floor during Epoch 2 – Mark II installed.
3) Isometric sketch showing the locations of the six "beam line" water wells
4) Floor configuration at the end of Mark II running period. November 26 1990.
5) Configuration of Collider Pit Floor following the removal of Mark II. December 31st 1990
6) Configuration of the Collider Pit Floor after end of March 1991.
7) Graphical display of beam line water level data during Mark II roll-in
8) Isometric display of Mark II roll-in data, Oct - Nov 1987
9) Floor deflection data during Mark II Rollout. Nov.26 1990 - Mar.31 1990 (Data from wells in the central region)
10) Elevation Data from wells along the East wall.
11) Elevation Data from wells along the West wall
12) The behaviour of the remaining central wells.
13) Map of CEH floor showing locations of points whose elevations were measured prior to and after SLD was moved on beam line. Elevation changes are indicated in millimeters. The locations of the SLD foot shims are also indicated.
14) Plot of floor deformation around SLD "footings".

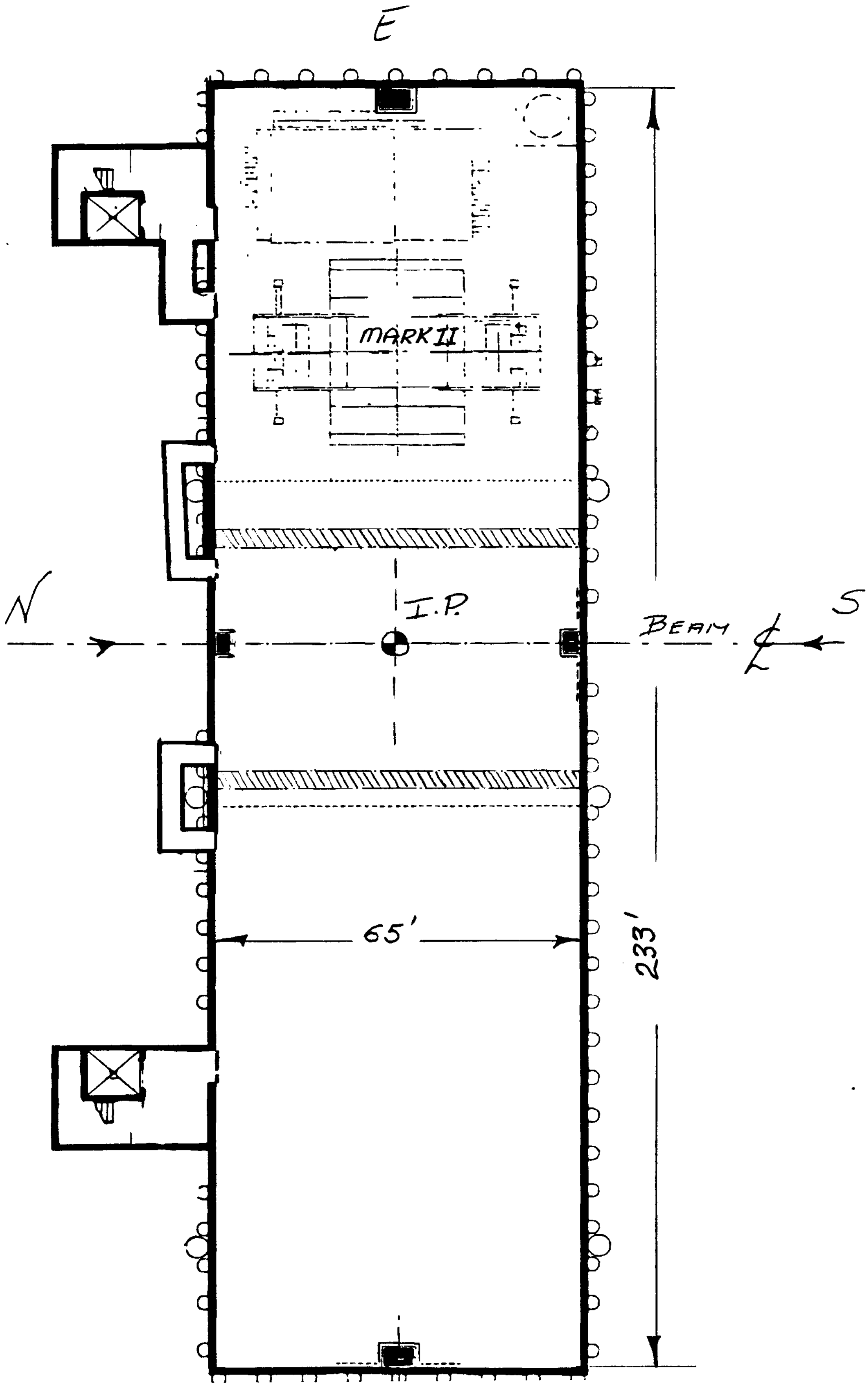


Figure 1. Layout of the SLAC Linear Collider Experimental Hall Pit. Epoch 1.

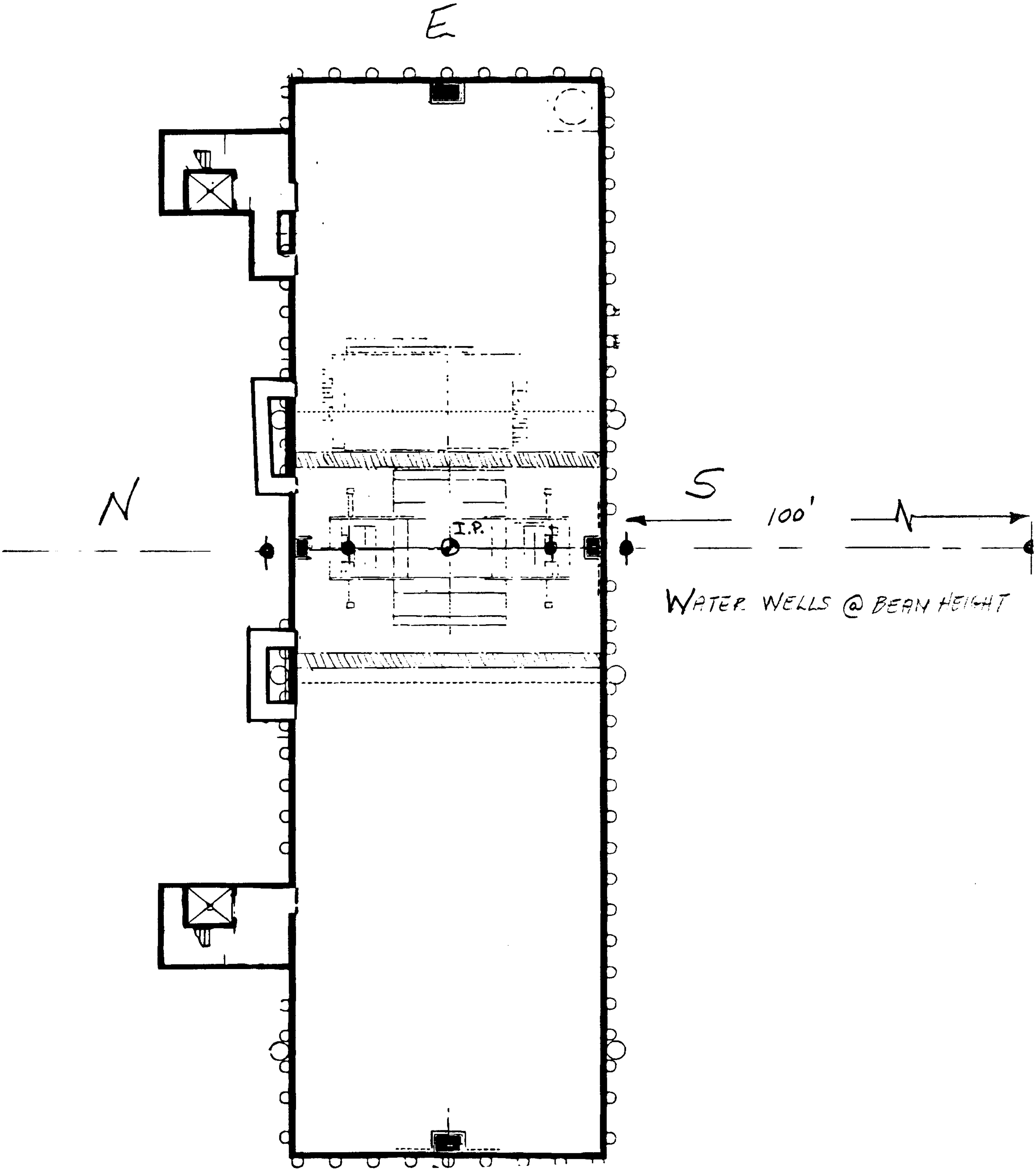


Figure 2. Layout of the Collider Hall Floor during Epoch 2 – Mark II installed.

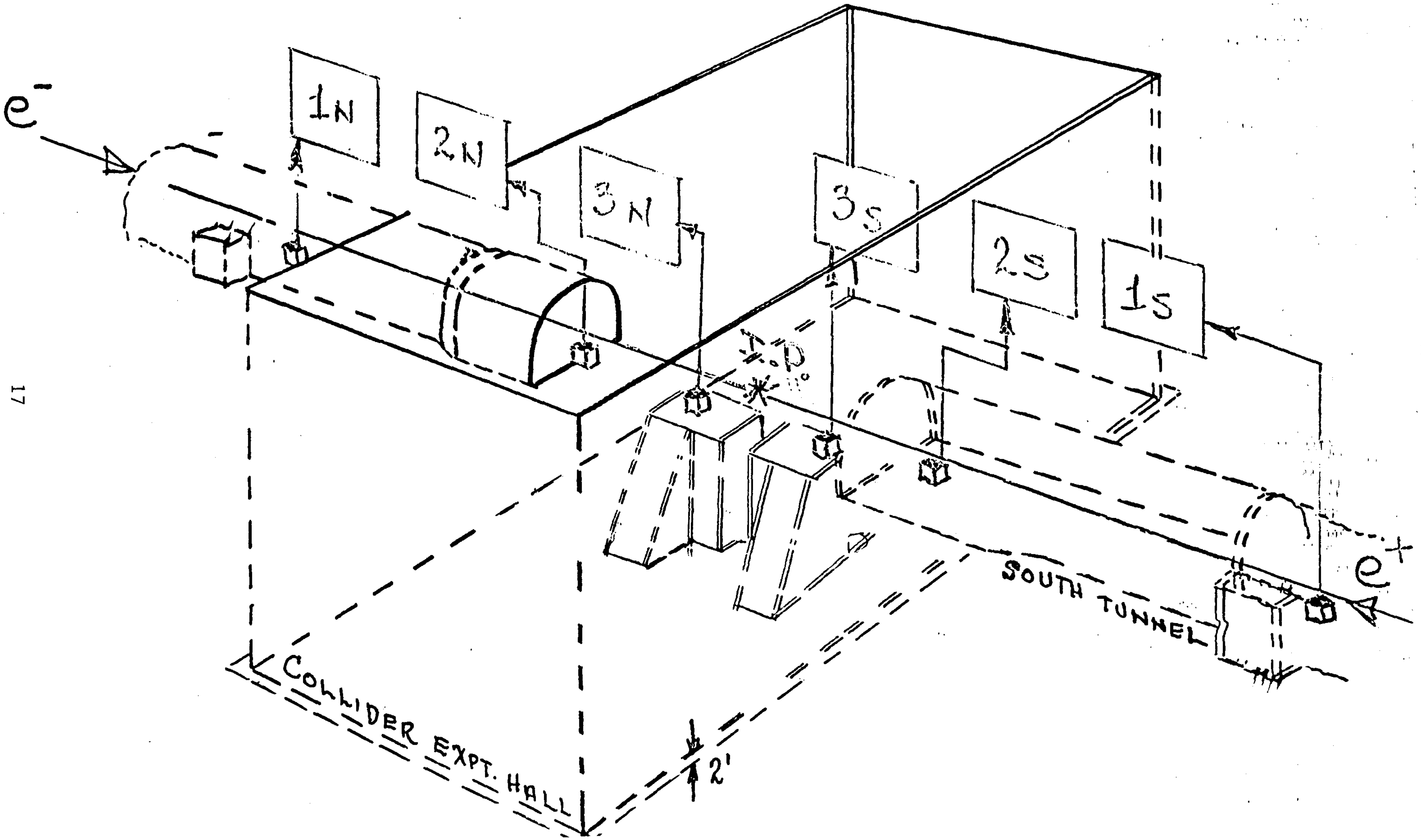


Figure 3. Isometric sketch showing the locations of the six "beam line" water wells

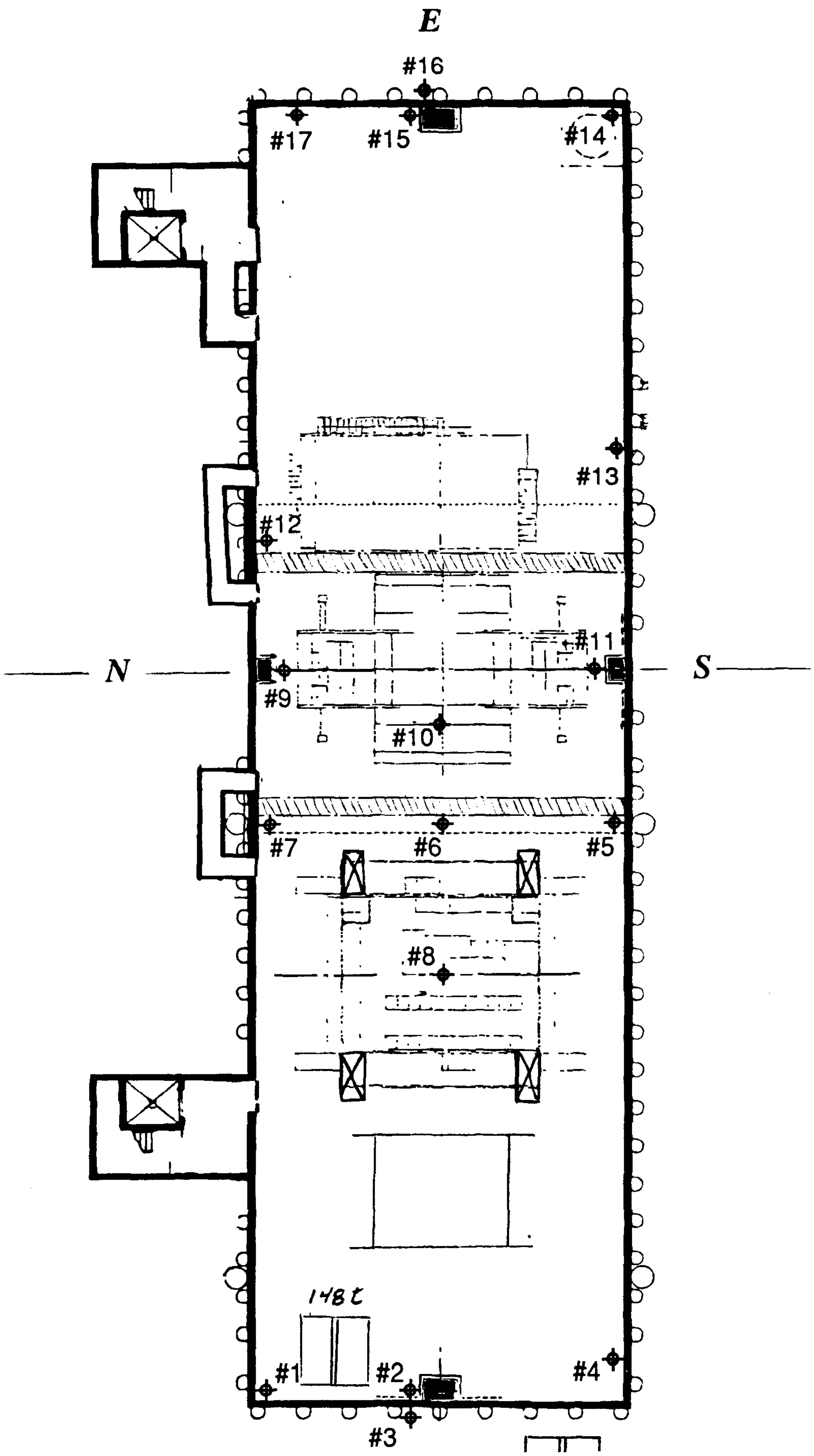


Figure 4. Floor configuration at the end of Mark II running period. November 26 1990.

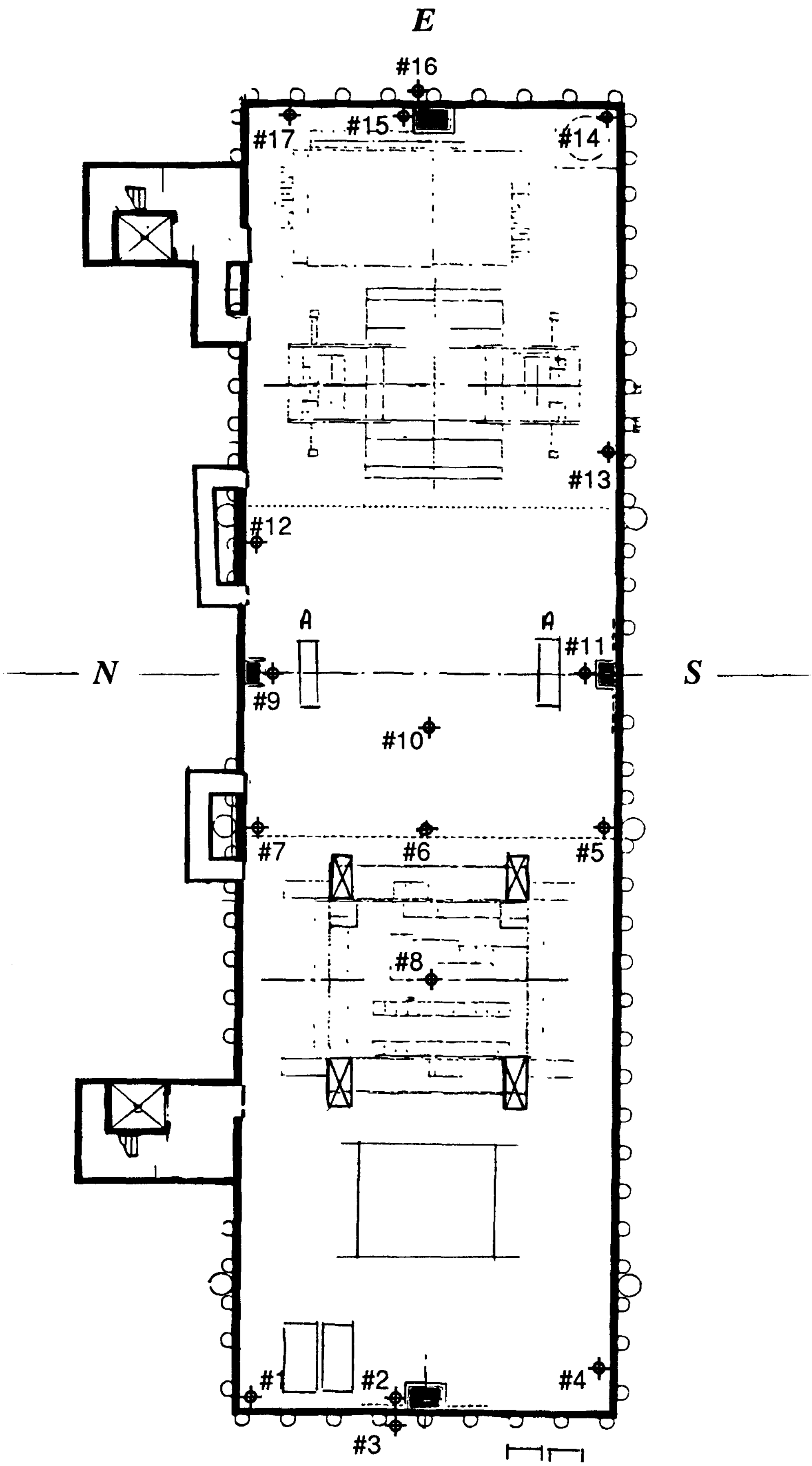


Figure 5. Configuration of Collider Pit Floor following the removal of Mark II. December 31st 1990

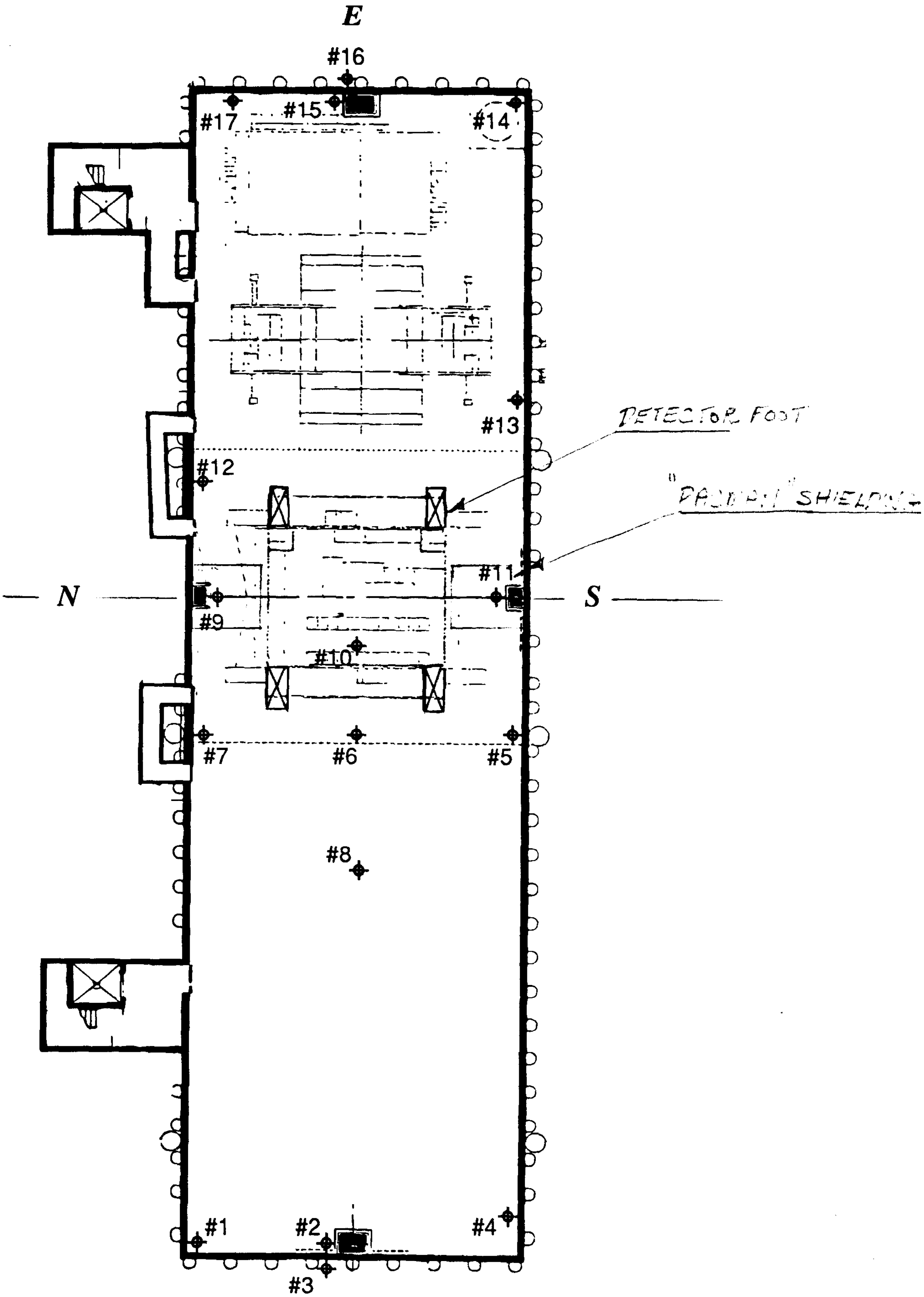


Figure 6. Configuration of the Collider Pit Floor after end of March 1991.

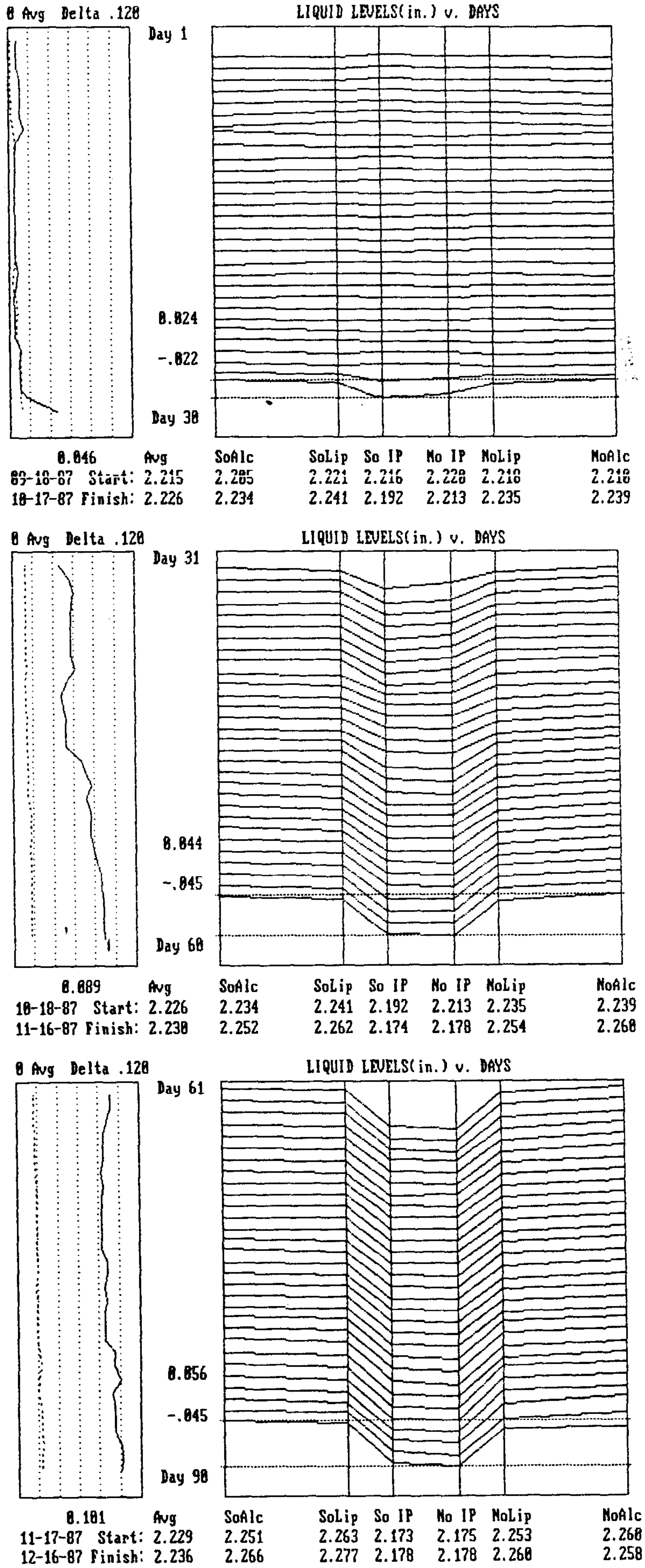


Figure 7. Graphic display of beam line water level data during Mark II roll-in

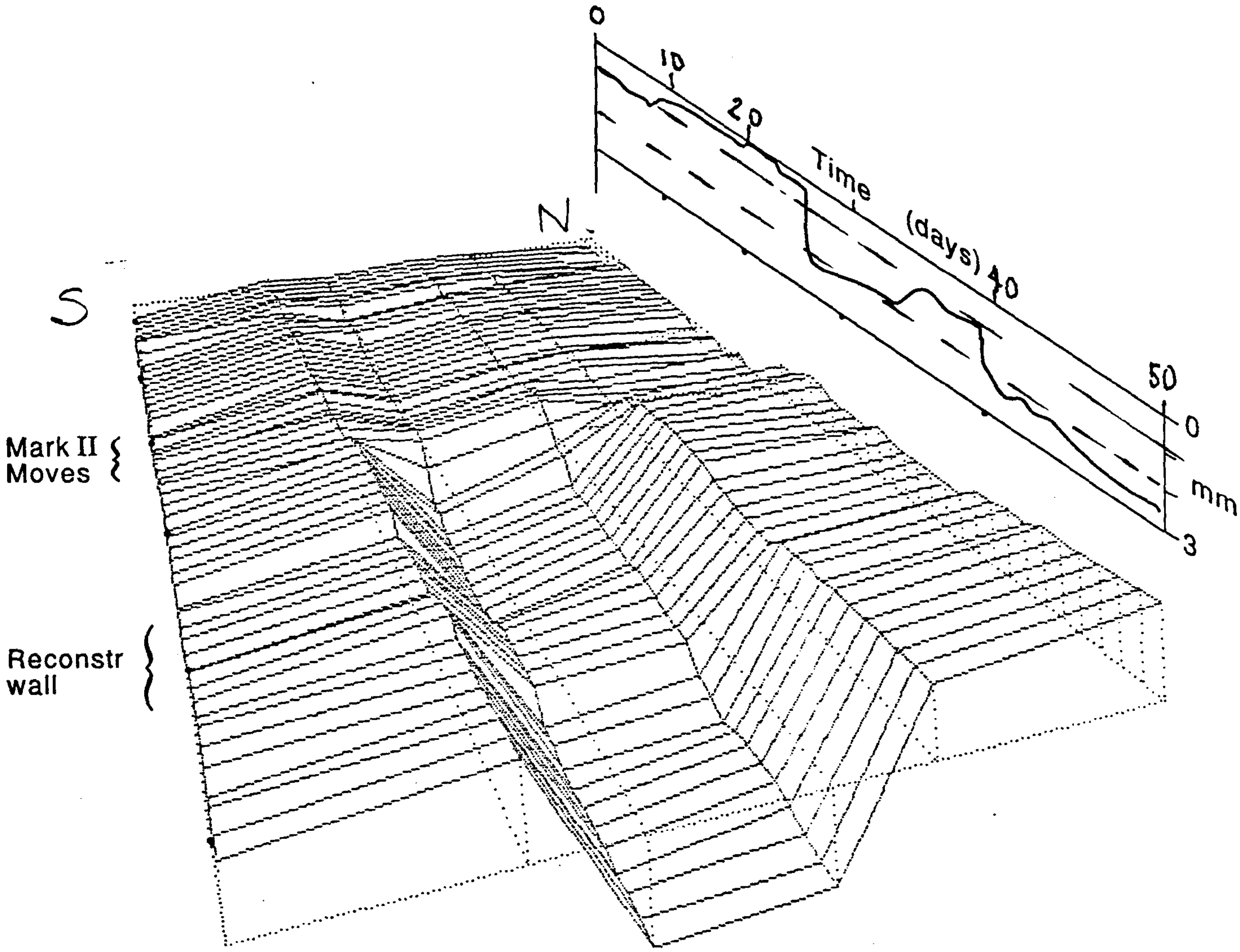


Figure 8. Isometric display of Mark II roll-in data, Oct - Nov 1987

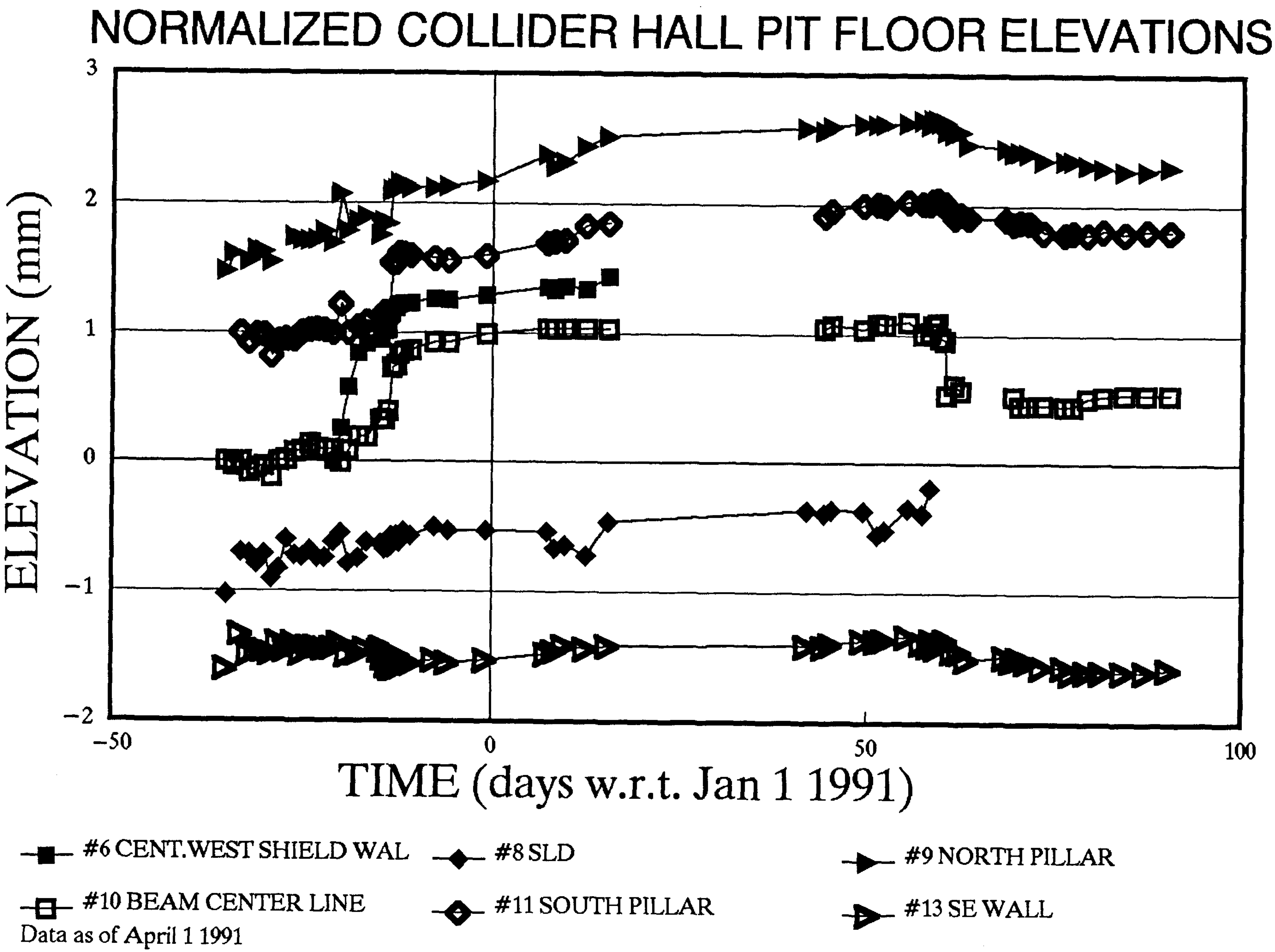


Figure 9. Floor deflection data during Mark II Rollout. Nov.26 1990 - Mar.31 199 (Data from wells in the central region)

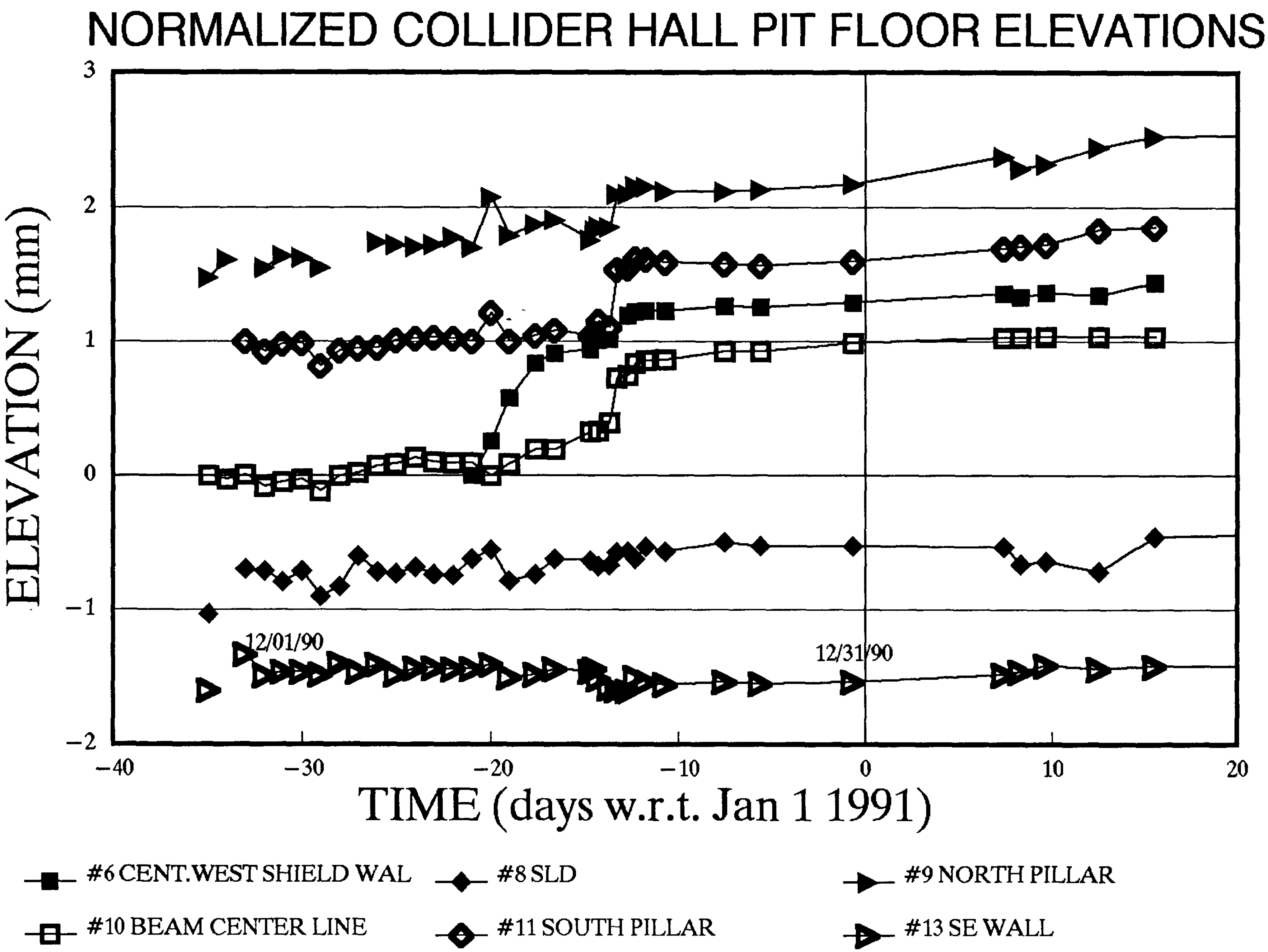

NORMALIZED COLLIDER HALL PIT FLOOR ELEVATIONS
ELEVATION (mm)
TIME (days w.r.t. Jan 1 1991)
3
2
1
0
−1
−2
−40
−30
−20
−10
0
10
20
12/01/90
12/31/90
#6 CENT.WEST SHIELD WAL
#8 SLD
#9 NORTH PILLAR
#10 BEAM CENTER LINE
#11 SOUTH PILLAR
#13 SE WALL

FIG 9A

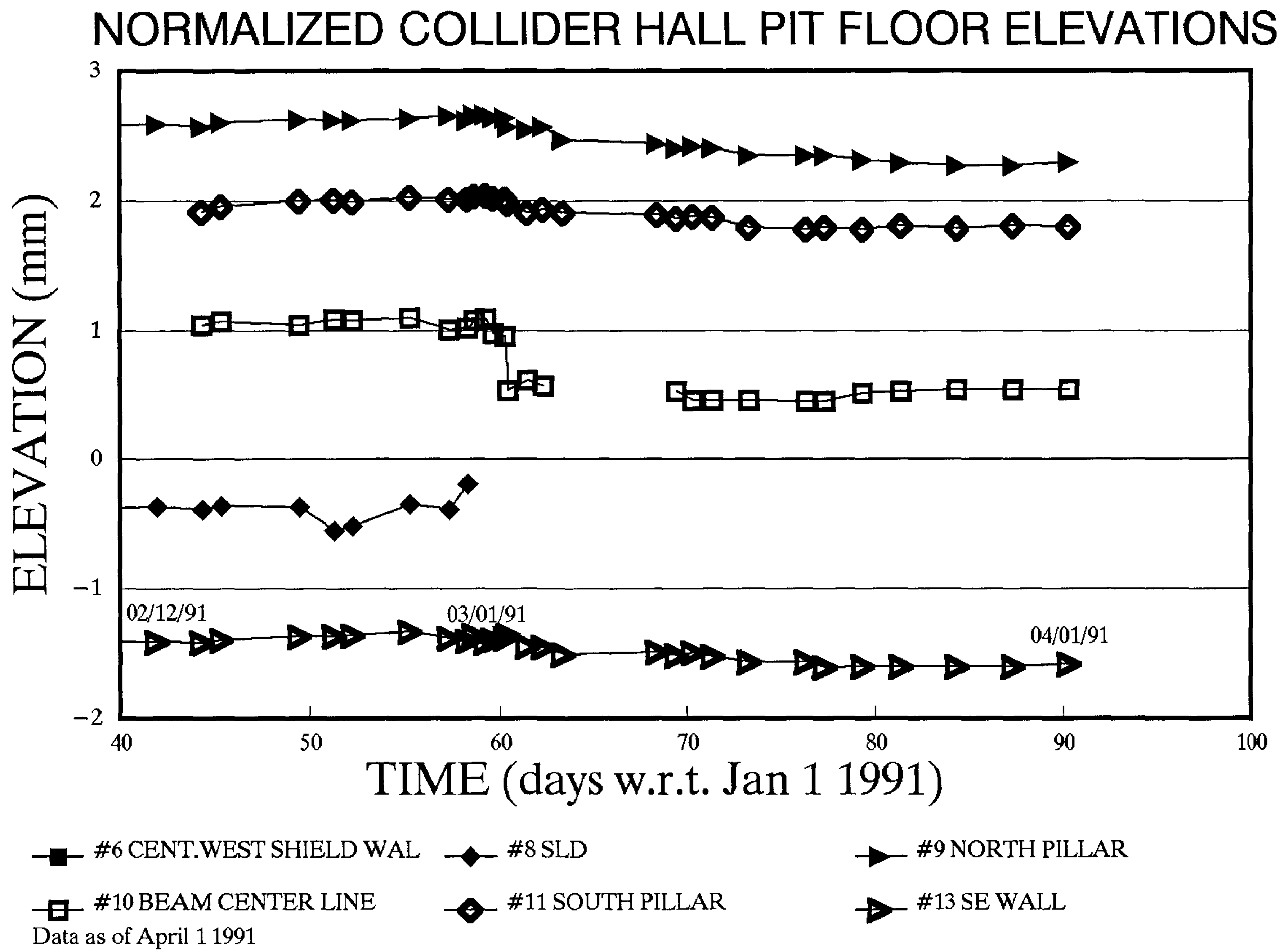

NORMALIZED COLLIDER HALL PIT FLOOR ELEVATIONS
ELEVATION (mm)
3
2
1
0
−1
−2
40
50
60
70
80
90
100
TIME (days w.r.t. Jan 1 1991)
02/12/91
03/01/91
04/01/91
#6 CENT.WEST SHIELD WAL
#8 SLD
#9 NORTH PILLAR
#10 BEAM CENTER LINE
#11 SOUTH PILLAR
#13 SE WALL
Data as of April 1 1991

FIG. 9B

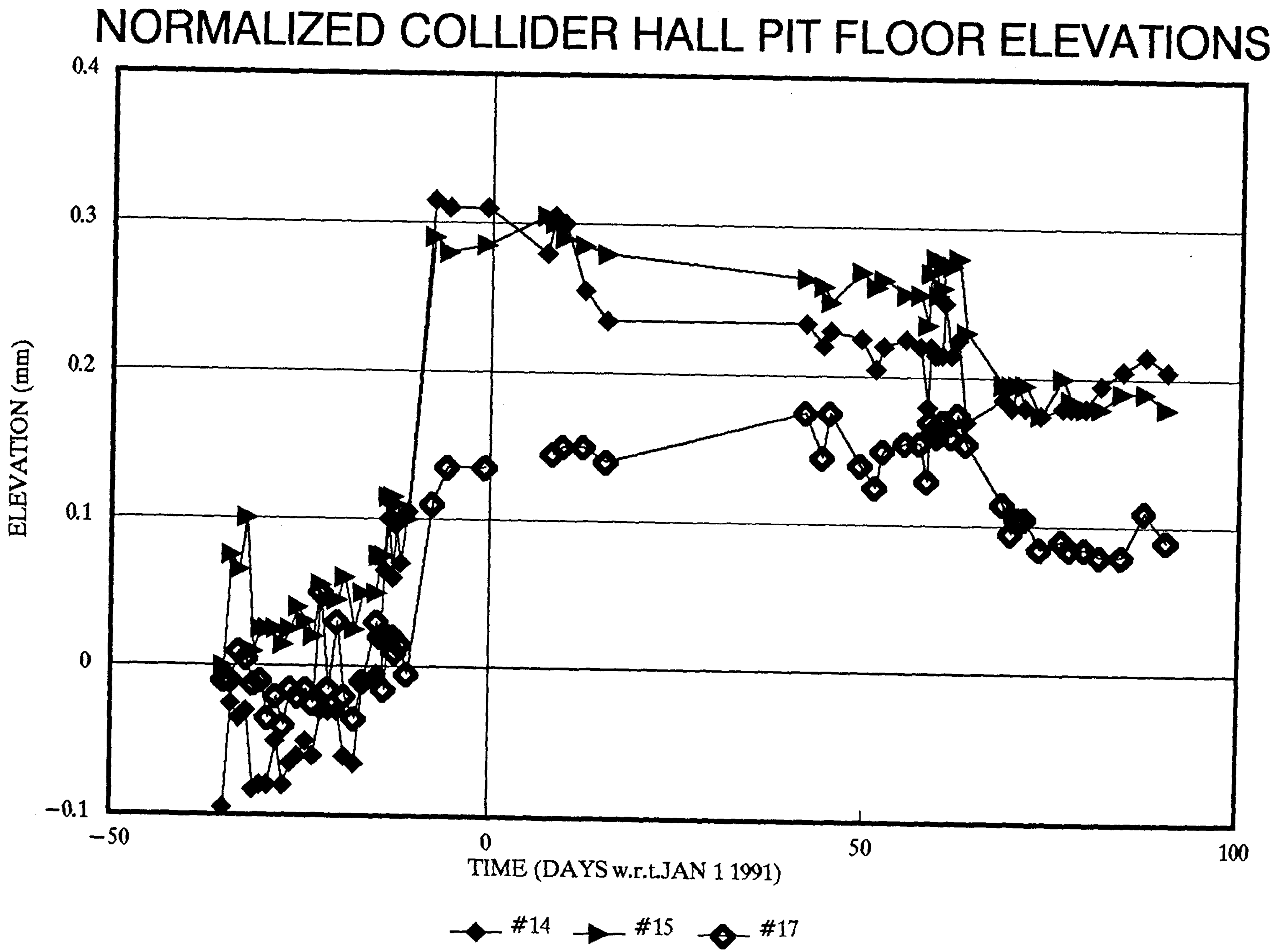
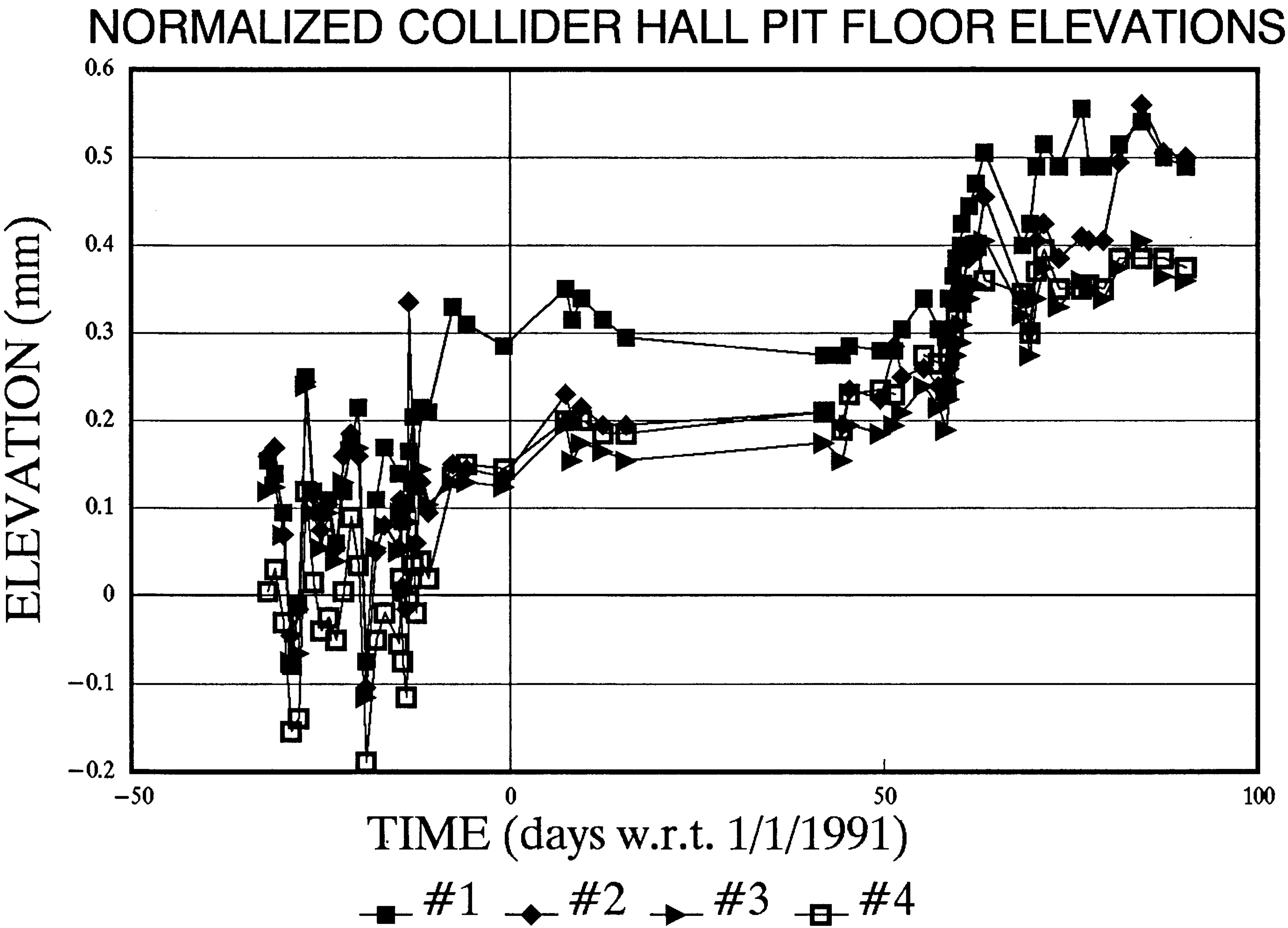


Figure 10. Elevation Data from wells along the East wall.



Data as of April 1 1991

Figure 11. Elevation Data from wells along the West wall

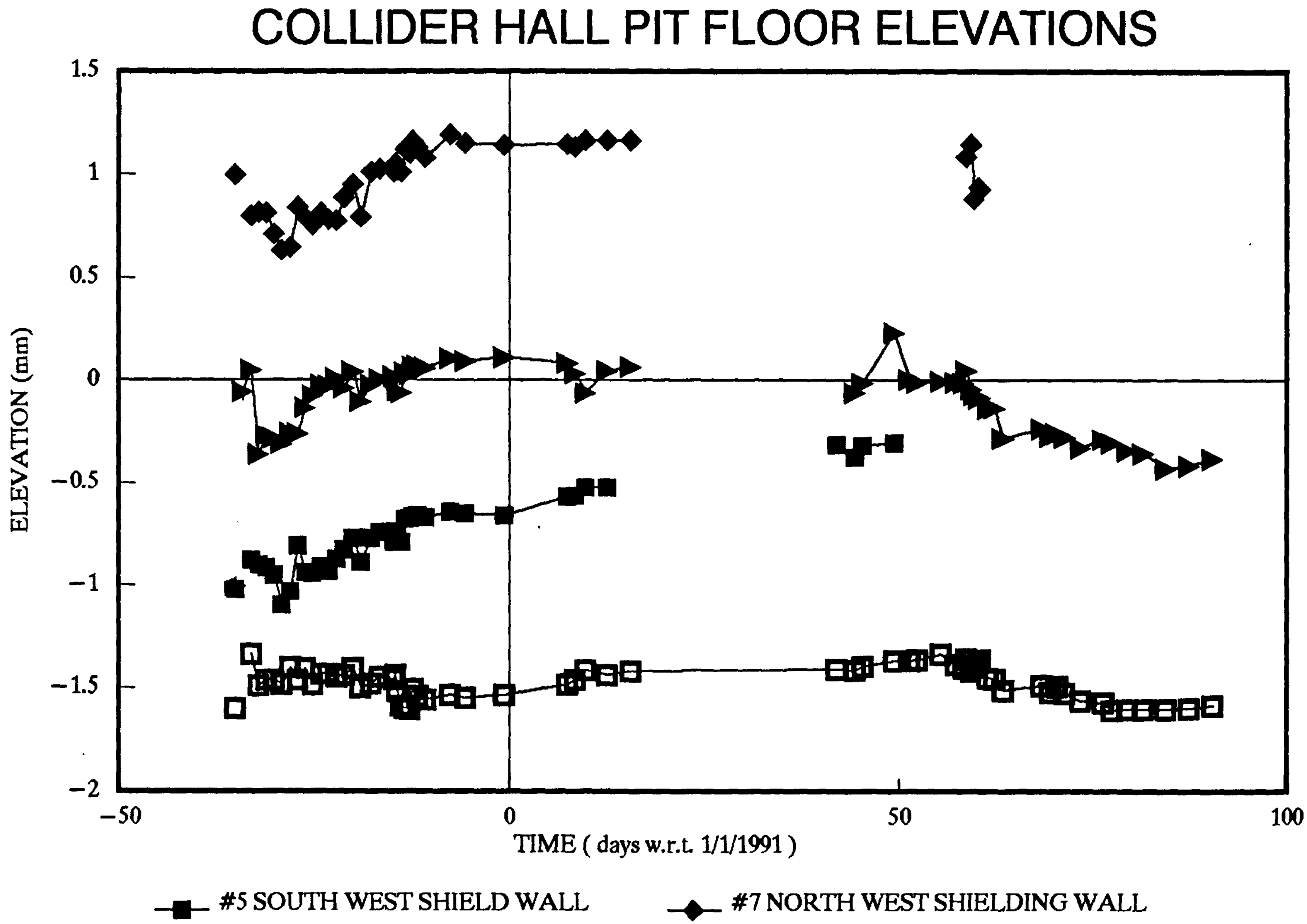


Figure 12. The behaviour of the remaining central wells.

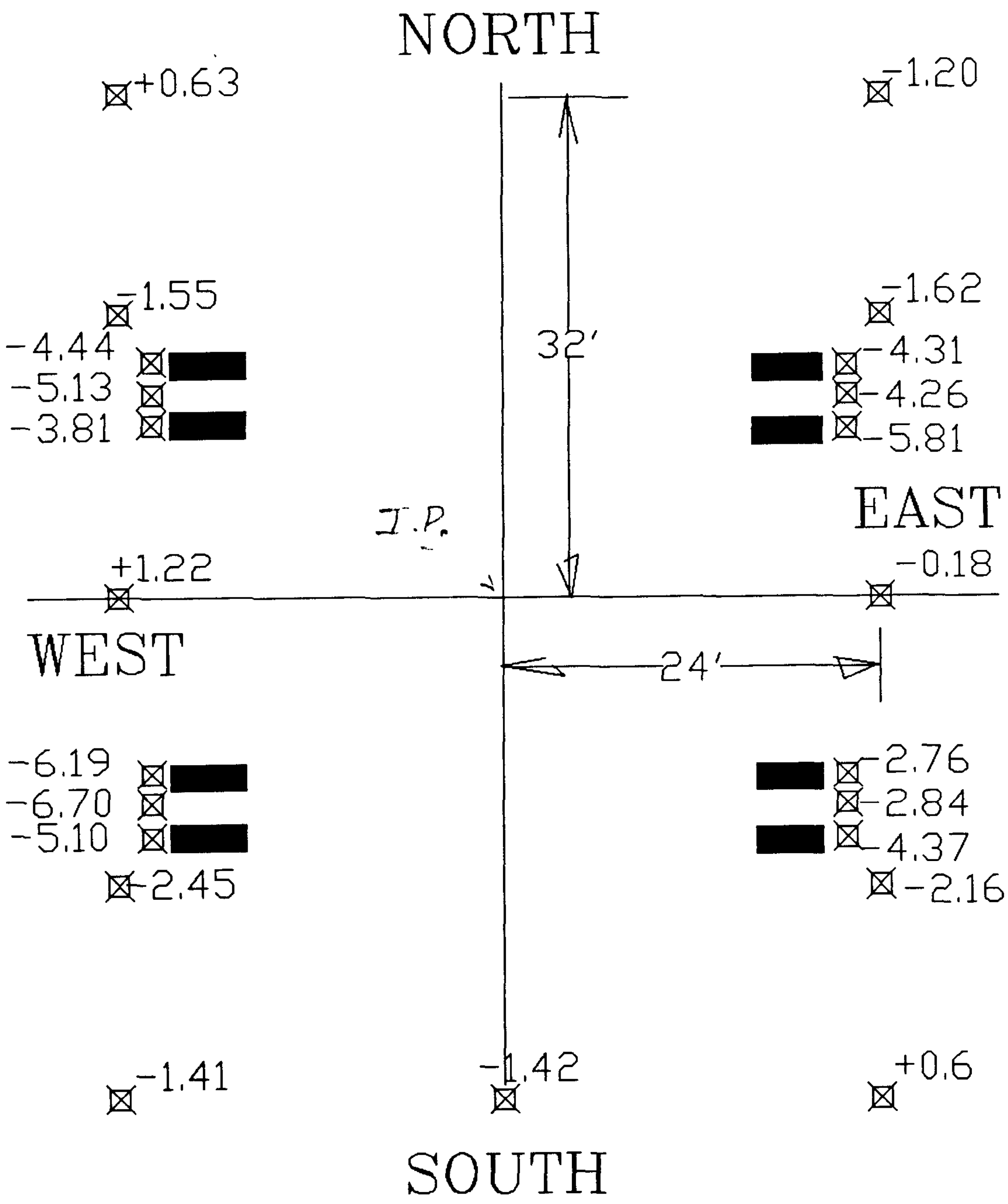


Figure 13. Map of CEH floor showing locations of points whose elevations were measured prior to and after SLD was moved on beam line. Elevation changes are indicated in millimeters. The locations of the SLD foot shims are also indicated.

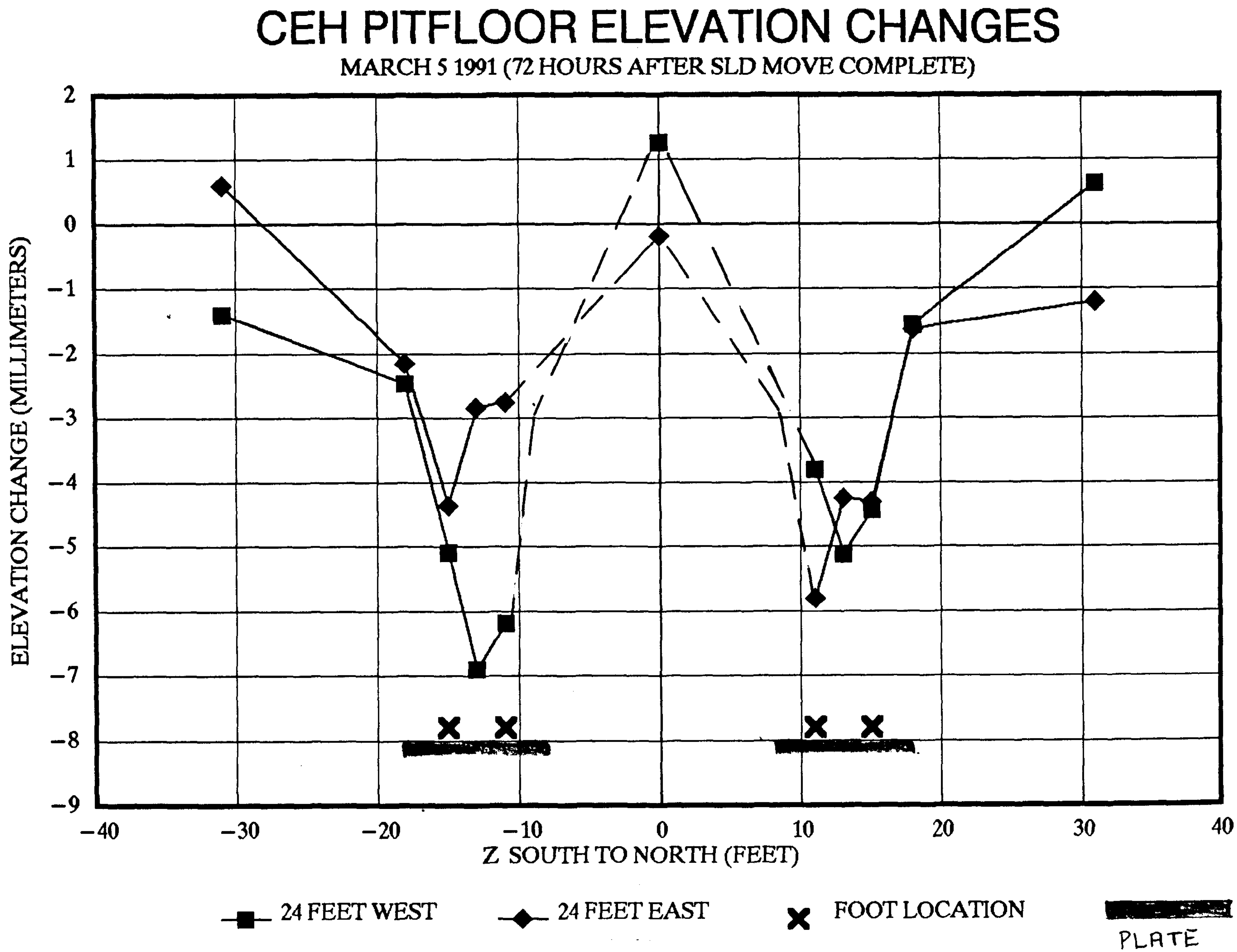


Figure 14. Plot of floor deformation around SLD "footings".