

## Appendix I Accuracy of Measurement of the Permanent Ground Displacements in Noshiro City

The accuracy of the measurement of the permanent ground displacements was basically examined by the following procedure :

Step 1 : Several datum points were selected in the area of the measurement including the triangulation points. Figure I-1 shows one example of the locations of the datum points in the northern area of the city in the case of pre-earthquake survey.

Step 2 : The coordinates of the datum points were measured independently by two methods, a survey on

the ground surface using transit and geodimeter, and an aerial photographic survey.

Step 3 : Under an assumption that the coordinates measured by the on-ground survey were correct, the error of the coordinates by the aerial survey were distributed to each datum point to minimize the mean value of the squares of the differences of the coordinates by the two surveys. This distribution of the error was conducted by an adjustment of the location and the angle of the aerial photographs.

Step 4 : The accuracy of the aerial survey was determined as a standard deviation of the differences between the coordinates by the on-ground survey and the corrected coordinates of the aerial survey.

Step 5 : The accuracy of the measurement of the permanent ground displacements by the earthquake was calculated as the square root of the sum of squared accuracy of two aerial surveys before and after the earthquake.

The accuracy of the permanent ground displacements in Noshiro City, estimated by taking these five steps, is shown in Tables I-1 and II-2. In the northern area of the city, the accuracy is  $\pm 17$  cm and 28 cm in the horizontal and the vertical directions, respectively.

As a matter of course, the accuracy of the permanent ground displacements, estimated by the procedure, depends heavily on the accuracy of the on-ground survey. However, in the present case, accuracy of the on-ground survey was higher,  $\pm 8.1$  cm in the horizontal direction, than those of aerial surveys and so its effect was neglected.

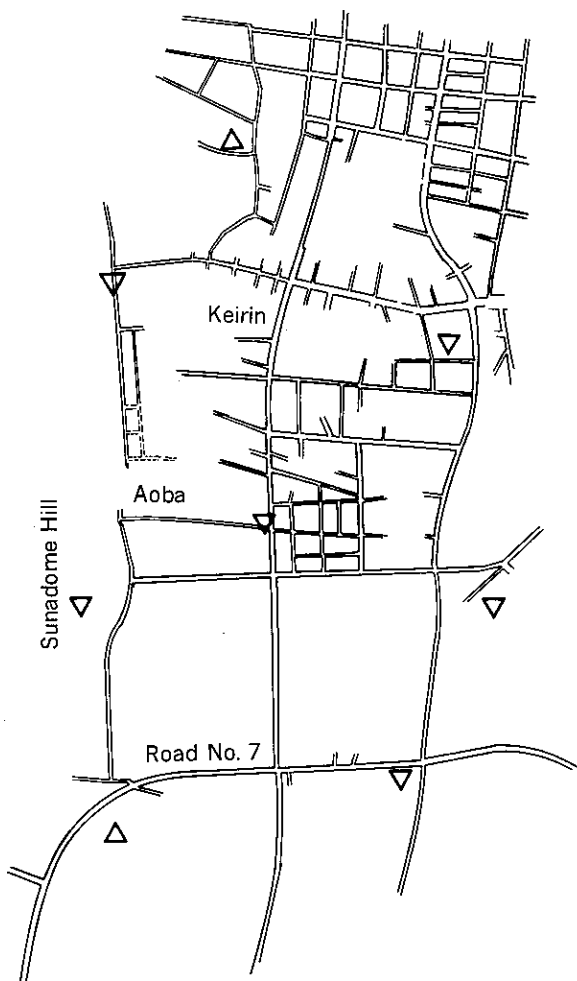


Fig. I-1 Datum points for aerial survey in northern area of Noshiro City

In addition to the examination of the measurement accuracy of the permanent ground displacements mentioned above, the traverse and the plane table survey were conducted in a part of the southern area of Noshiro City in order to verify the results of the aerial survey. Figure I-2 shows the area by the plane table survey and the three datum points, Taya, Otomonuma and Garyuzan, for the traverse survey. The accuracy of the traverse survey was controlled within 1/10,000 and the error was estimated as less than  $\pm 10$  cm in the measured area.

And also the error of the plane table survey itself was estimated as  $\pm 10$  cm mainly because of the 1/500 reduction scale for the mapping. Therefore the total error is considered to be within  $\pm 20$  cm, somewhat

larger than the error of the aerial survey shown in Table I-1 (b).

Figure I-3 shows a comparison of the results by the aerial survey with the ones by the traverse and the plane table survey. The pre-earthquake map,\* shown in the figure was made in 1977, six years before the earthquake, also by a traverse and plane table survey and since then, it has been revised several times whenever the land boundaries were changed.

As can be seen from the figure, the magnitudes and the directions of the permanent ground displacements measured by the aerial survey mostly coincides with those by the traverse and the plane table surveys.

Table I-1 Accuracy of Measurement of the Permanent Ground Displacement  
(a) North Area of Noshiro City

| Aerial Survey   | Pre-earthquake   | Post-earthquake                          |
|---|--|--|
| Total Number of Datum Points  | 8  | 9  |
| Accuracy of Aerial Survey<br>(Standard deviation of differences of coordinates by on-ground and aerial surveys) | $\pm 0.14$ (Hori.)<br>$\pm 0.26$ (Vert.)   | $\pm 0.10$ (Hori.)<br>$\pm 0.12$ (Vert.) |
| Accuracy of Measurement of Permanent Ground Displacement  | $\pm \sqrt{(0.14)^2 + (0.10)^2} = \pm 0.17$ (Hori.)<br>$\pm \sqrt{(0.26)^2 + (0.12)^2} = \pm 0.28$ (Vert.) |  |

\* The 1/500 scale pre-earthquake map was originally made by Noshiro City Government.

Table I-1 Accuracy of Measurement of the Permanent Ground Displacement

(b) South Area of Noshiro City

| Aerial Survey   | Pre-earthquake   | Post-earthquake                          |
|---|--|--|
| Total Number of Datum Points  | 21   | 5  |
| Accuracy of Aerial Survey<br>(Standard deviation of differences of coordinates by on-ground and aerial surveys) | $\pm 0.08$ (Hori.)<br>$\pm 0.16$ (Vert.)   | $\pm 0.14$ (Hori.)<br>$\pm 0.12$ (Vert.) |
| Accuracy of Measurement of Permanent Ground Displacement  | $\pm \sqrt{(0.08)^2 + (0.14)^2} = \pm 0.16$ (Hori.)<br>$\pm \sqrt{(0.16)^2 + (0.12)^2} = \pm 0.20$ (Vert.) |  |

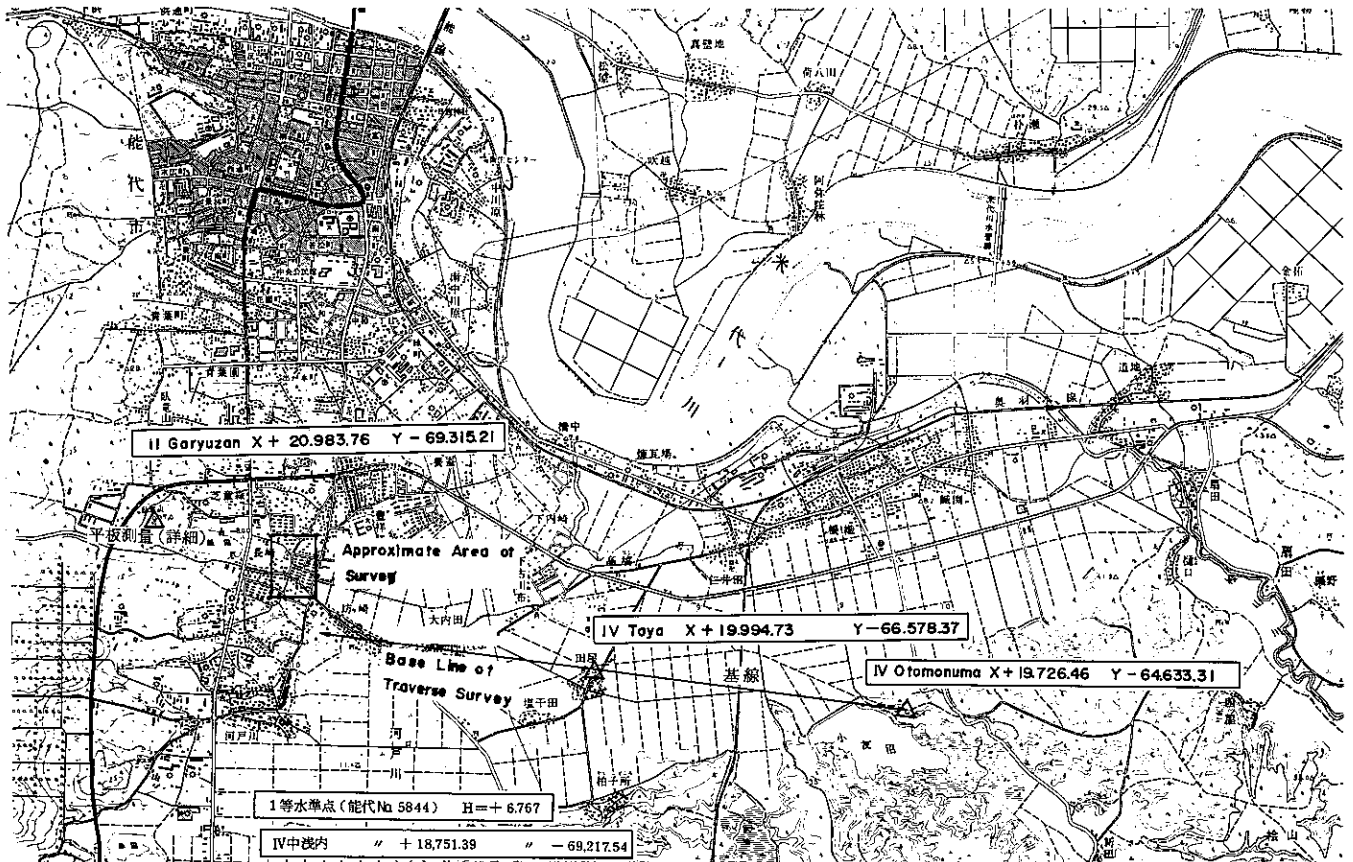


Fig. I-2 Area of Traverse and Plane Table Survey

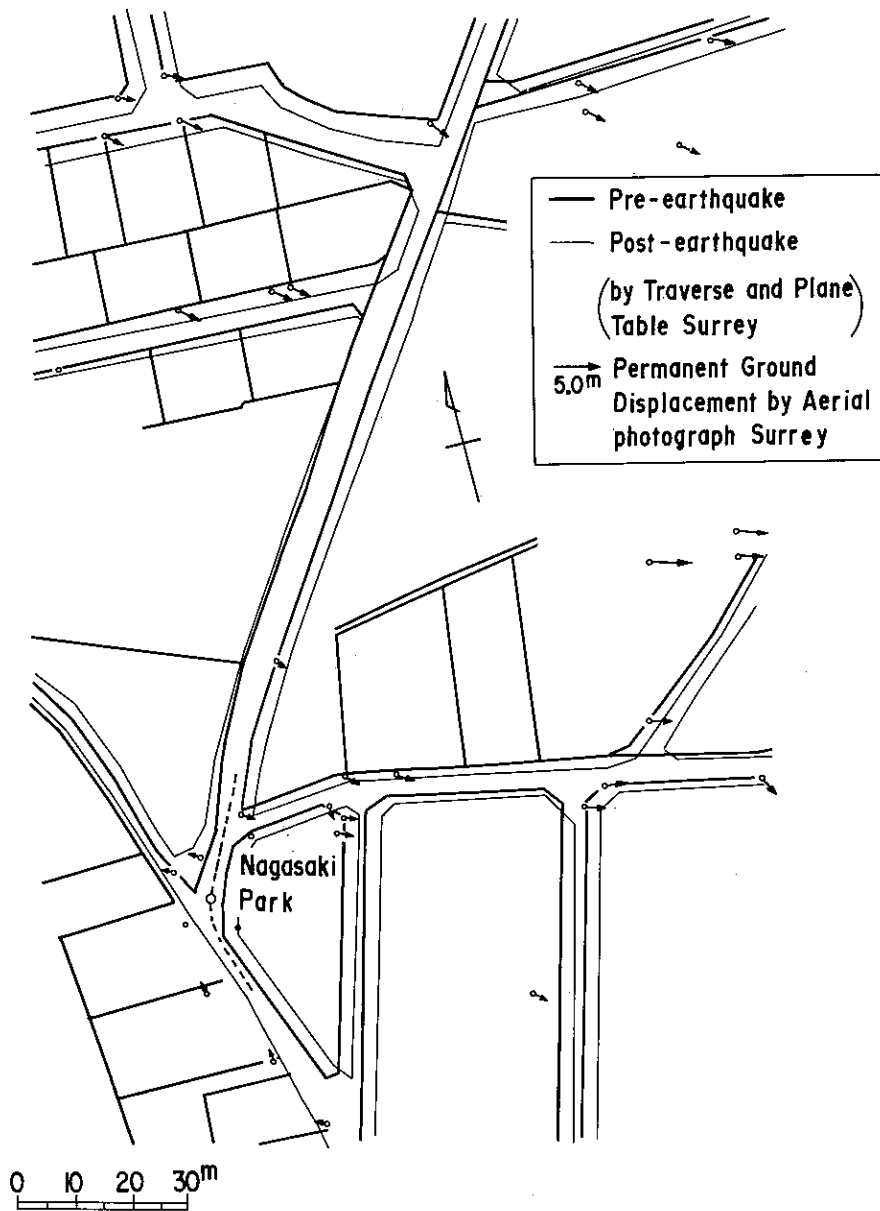


Fig. I-3 Comparison between the Aerial Survey and the Plane Table Survey