UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Landslide investigations, southern Cianjur Regency, West Java Province, Indonesia-- A progress report

by

John R. Ege 1/

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

1/ U.S. Geological Survey, Denver, Co

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REGENCY, WEST JAVA PROVINCE, INDONESIA--

A PROGRESS REPORT

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ABSTRACT

Two landslide-monitoring sites have been established for a minimum 2-year investigation near the villages of Pasirpari and Cibacang in southern Cianjur Regency, West Java, Indonesia. Surveyed-in lines will measure amounts of surface movement and tilt, borings that produced exploratory cores now serve as slip-surface detectors and open-pipe piezometers, and rain gages will record rainfall at both sites.

Exploratory cores and field observations located upper slip surfaces ranging in depth between 4 and 14 m. Rises of borehole-water levels of as much as 63 cm during drilling suggest that pore pressures exist at the inferred-slip surfaces. Sliding along slip surfaces and slope failures occurred during the rainy season between November 1980 and April 1981.

INTRODUCTION

In 1980 the U.S. Geological Survey (USGS), through the U.S. Agency for International Development (USAID) and the Ministry of Research and Technology of the Government of Indonesia (GOI), began a cooperative study of the characteristics, distribution, and mechanisms of landslides in southern Cianjur Regency (fig. 1). The landslide study was conducted as part of GOI/USAID/USGS Science and Technology Project, Activity "4-5." Slope-movement investigations in southern Cianjur Regency have been conducted over the past decade by The Directorate of Environmental Geology. The Division of Engineering Geology, through its Landslide Section, has been responsible for

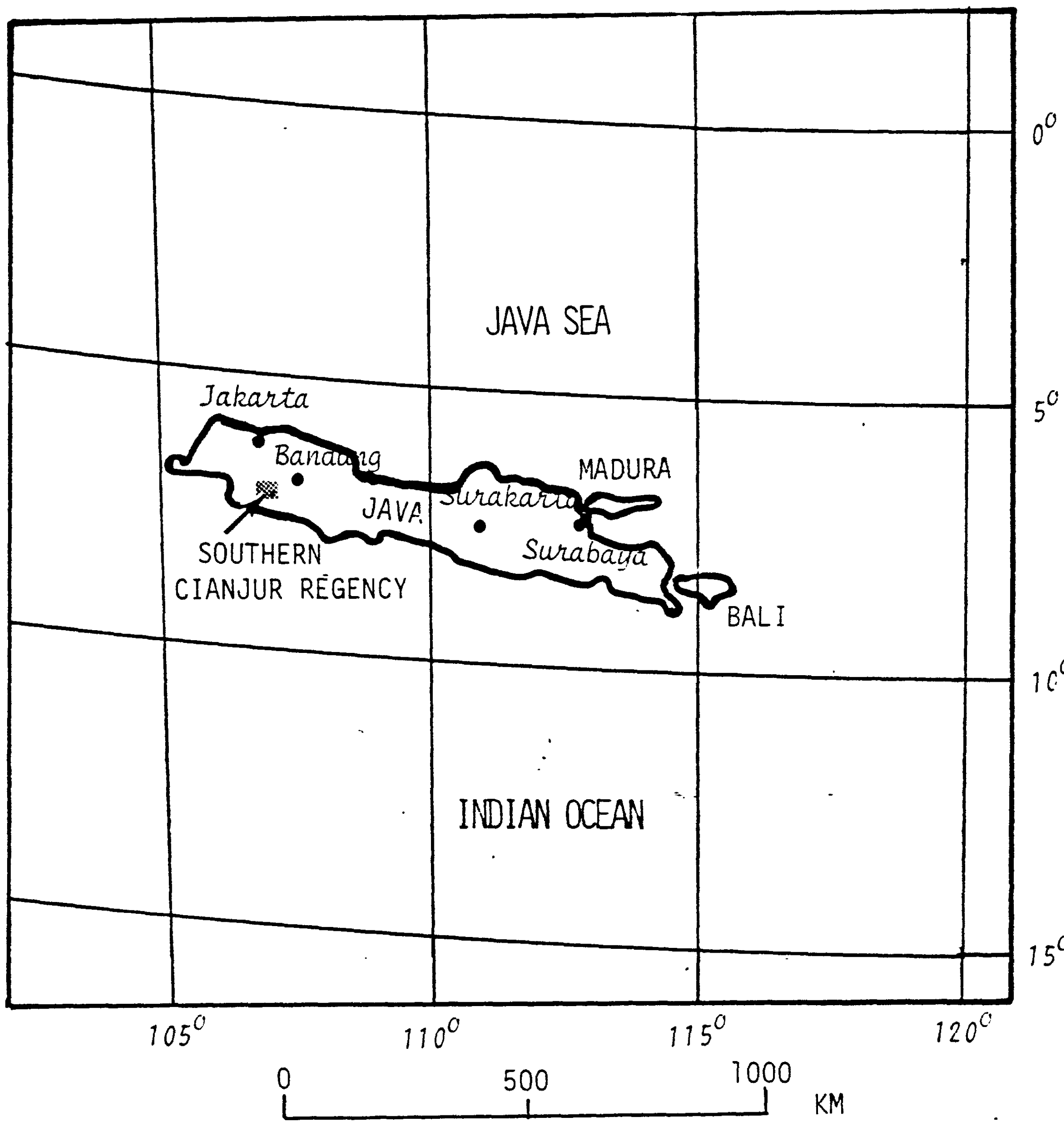


Figure 1. Location of southern Cianjur Regency, West Java, Indonesia.

directing the studies. Participation by USGS personnel has consisted of advising professional personnel of the Landslide Section and Division of Engineering Geology in specific techniques of landslide-hazards mapping, landslide instrumentation for monitoring movements and stress conditions, and presentation of the observed data in such form that it can be used for the public benefit.

The first part of the cooperative landslide investigation, the study of characteristics and distribution of landslides, was initiated in June 1980 and completed in September 1980. W. E. Davies, U.S. Geological Survey, working with Indonesian geologists from the Landslide Section, mapped the landslide-deposits map and the landslide-hazards zones in southern Cianjur Regency.

The landslide mechanism investigation, the second phase of the landslide study, commenced October 4, 1980, with the arrival in Indonesia of J. R. Ege, U.S. Geological Survey. Two sites located near the villages of Pasirpari and Cibacang (fig. 2) had been selected by the Landslide Section study group as representative landslide areas suitable for a long-term geomechanics study. Although the mechanism research is expected to last 2 years before conclusions will be reported, early results from the field investigations, measuring depth of slip surface and amount of short-term movement and the observation of pore-pressure changes at the Pasirpari site, have been used by the Chief of the Engineering Geology Division in formulating interim solutions and procedures for correcting and mitigating landslide damage in West Java.

This report describes the physical settings of the Cibacang and Pasirpari sites and the restraints imposed by the physical characteristics of the area on geomechanical research in the field. The goals of the project are listed and the method of study, based on field conditions and availability of personnel and equipment, is outlined. Lastly, the results of fieldwork at

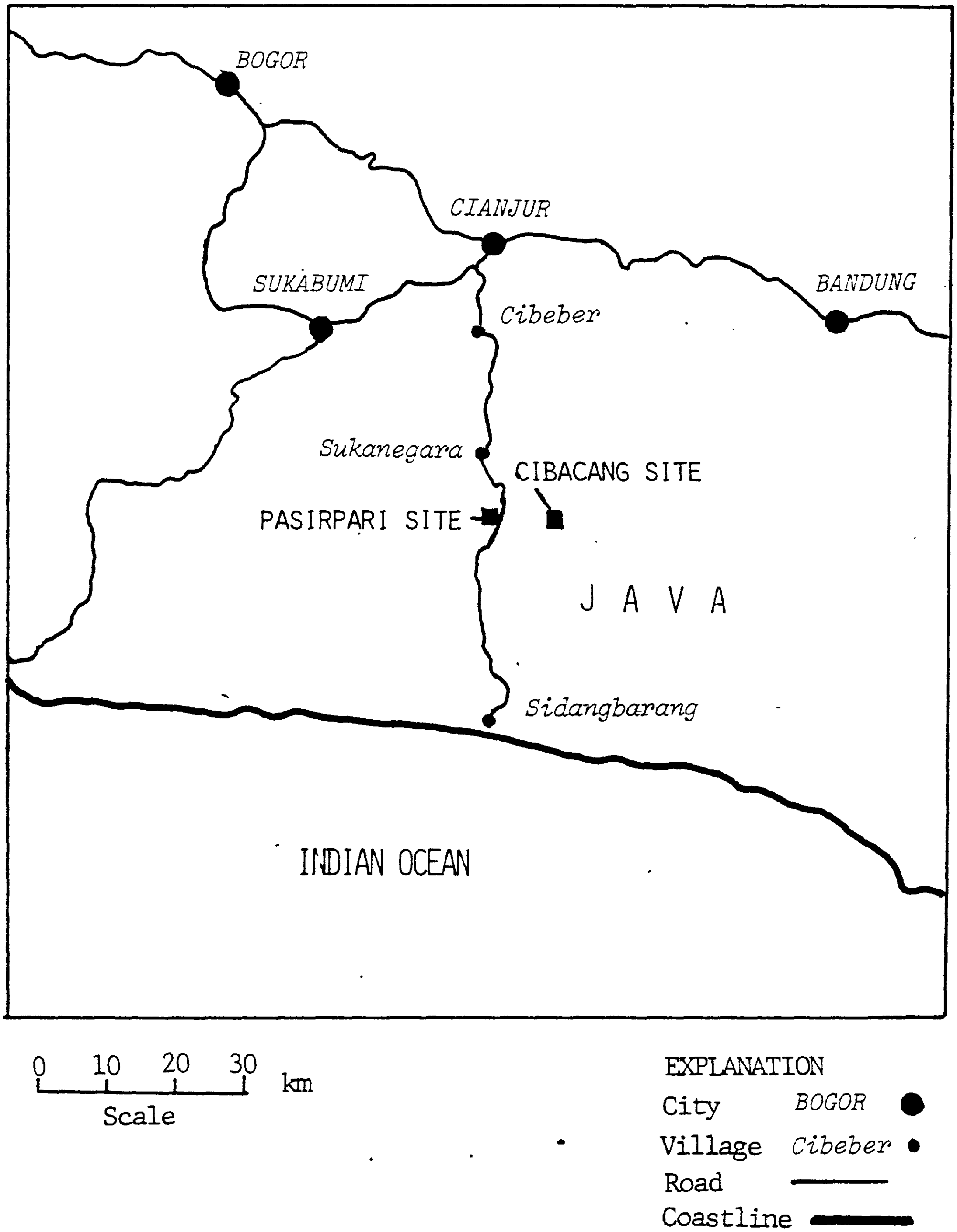


Figure 2. Locations of Pasirpari and Cibacang landside monitoring sites in southern Cianjur Regency, West Java, Indonesia.

Pasirpari and Cibacang covering the period between October 1, 1980 and February 4, 1981, are summarized.

Scope of investigation

Although individual slope failures generally are not so spectacular nor so costly as certain other natural disasters, such as earthquakes, major floods, and tornadoes, they are more widespread, and total financial loss due to slope failures probably is comparable to, or greater than, that of any other single natural hazard to mankind. Moreover, much of the damage that occurs in conjunction with earthquakes and floods is due to landslides instigated by earth tremors or flood waters (Schuster, 1978).

Recognition of the presence or the potential development of slope movement and identification of the types and causes of the movement are important in developing procedures for the prevention or correction of a slide (Rib and Liang, 1978). Field investigation is the central and decisive part of a study of landslides and landslide-prone areas for use in land-use planning, construction, and hazards zonation, in that the investigation serves (a) to identify areas subject to sliding, (b) to define features of an existing slide, (c) to ascertain the environmental and mechanical factors involved in the slide area, and (d) to determine what corrective measures are appropriate to prevent or minimize continuing movements and to mitigate further hazard or damage caused by movement (Sowers and Royster, 1978).

The following five steps have been selected as a basis on which to design and execute the study of landslide processes in southern Cianjur Regency:

1. Determine the configuration, causes, and mechanism of slope movement at two typical landslide sites in southern Cianjur.

2. Measure rates of movement and amount of surface tilt and land subsidence at the landslide sites.

3. Establish warning procedures that will alert local and regional authorities of impending hazardous-slope movements and ground failures.

4. Propose methods and procedures that may mitigate landslide hazards.

5. Document, report, and publish the results of the landslide investigation.

Continuous monitoring of the landslide sites will be performed over a 2-year period, encompassing two cycles of rainy and dry seasons. Further monitoring of the sites on a less frequent basis is being considered as a means of establishing a long-term research effort of slope movement in West Java.

PHYSICAL SETTINGS OF THE PASIRPARI AND CIBACANG SITES

The Pasirpari and Cibacang landslide sites are in the Pagelaran District of Cianjur Regency, about 50 km south of the city of Cianjur (fig. 2). The landslide region in the Pagelaran District, an area of about 100 km^2, contains a village and surrounding rural population totaling about 90,000. The district was selected for study because of the need for quantitative data on slope movements and because the landslides of the area are representative of landslides in West Java (Soemodipoero and others, 1976, p. 8).

Field reconnaissance of both sites were made on October 14, 21, and 24, 1980, in order to become acquainted with the terrain and dimensions of the slide area, accessibility and land use, and availability of supplies and local labor for site construction and equipment haulage. The two study sites are in a terraced, wetland, rice-growing region which is partially flooded all year round. A paved highway extends southward from Cianjur to Sindangbarang on the Indonesian Ocean and passes through the district capital of Pagelaran. Both landslide-study sites lie within a 25-km radius of Pagelaran near the villages of Pasirpari and Cibacang. Both sites can be reached only by foot trails, the Pasirpari site being 1 km and the Cibacang site 6 km from the nearest roads.

The availability of local labor is plentiful; however, instruments and construction materials are very limited and must be brought in from either Cianjur or Bandung, provincial capital of West Java. Water is easily obtainable, but neither site is accessible to electricity.

The area of the landslide sites exceeds 16 km^2 at Pasirpari and 80 km^2 at Cibacang. There are high scarps at each site, which requires carrying equipment and supplies up and down precipitous trails. During the wet season, lasting from November until April, daily rains can hamper field operations.

METHOD OF STUDY

The field inspections clearly demonstrated that field and monitoring procedures, and instruments for recording, should be simple and rugged, and should utilize local materials, labor, and manpower as much as possible. Use of sophisticated electronic instruments was deemed inappropriate at this time because the universally flooded land surface and highly saturated clay-rich soil and rock make it highly probable there would be large slope movements and concomitant early destruction of borehole installations. With the exception of drilling and surveying equipment, it was decided to design, construct, and deploy all instruments in the field by utilizing local labor, supervised by the geological staff.

The only topographic maps readily obtainable are at a scale of 1:50,000 and were compiled by the U.S. Army Map Service (AMS) (1962) from original alidade and planetable maps made by the Topografische Dienst, Batavia (date unknown). The AMS maps include planimetric detail revision based on photo-planimetric methods. Prints of aerial photographs flown at 25,000 ft at an estimated scale of 1:50,000 are held by the Division of Engineering Geology, Directorate of Environmental Geology (Indonesia).

Considering the large size of the study areas, physical and geographic restraints, and administratively imposed time limitations for fieldwork a method of study was designed that was very specific in scope and goals. The items described below constitute the basic program designed for both sites.

Maps

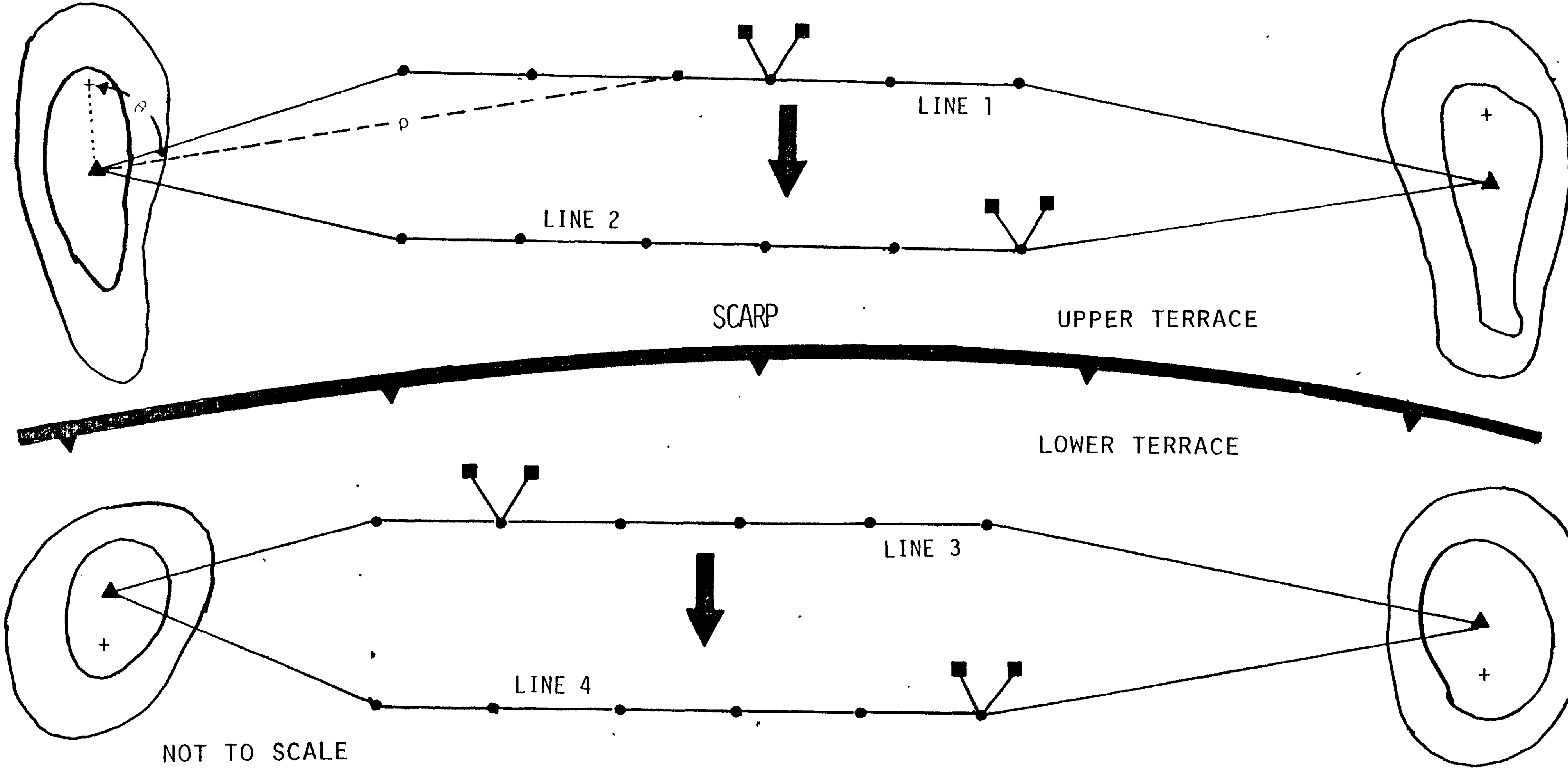
Topographic maps at a scale of 1:5,000, encompassing twice the distance of the instrumented area in all directions, will be constructed from field surveys performed by the Engineering Geology Division. Geologic and engineering geologic maps compiled on the 1:5,000-scale topographic base will show structure, rock and engineering soil types, sources of water, and cracks induced by landsliding.

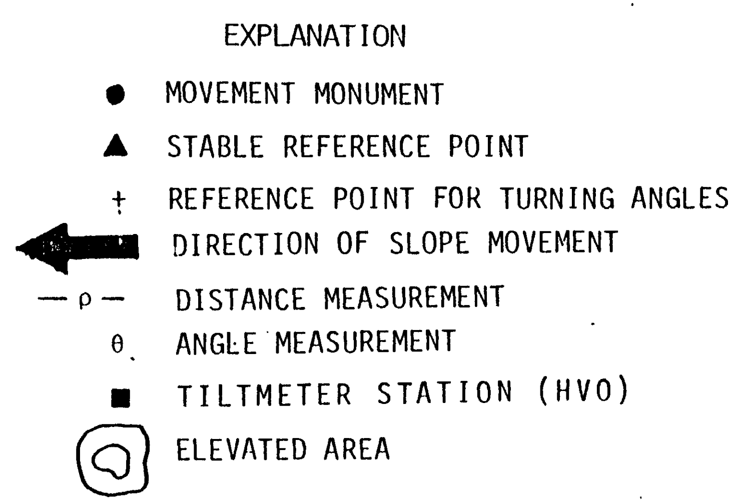
Landslide questionnaire

A systematic survey of local residents will be conducted by the geological staff for the purpose of gathering basic data for historic landslides.

Slope movement

Surface-movement grids will be established, composed of two parallel lines each marked by five concrete monuments spaced approximately 200 m apart. The lines will be placed along both the upper and lower terraces of the scarp, perpendicular to the direction of slope movements (fig. 3). The two lines will be tied into stable geodetic reference points from which movement of the monuments will be calculated. Measurements will be made as polar coordinates (range and angle) and converted to vectors of movement (fig. 4). The long distances, rough terrain, and requisite precision of measurement





igure 3. Schematic of surface movement grid and tiltmeter stations.

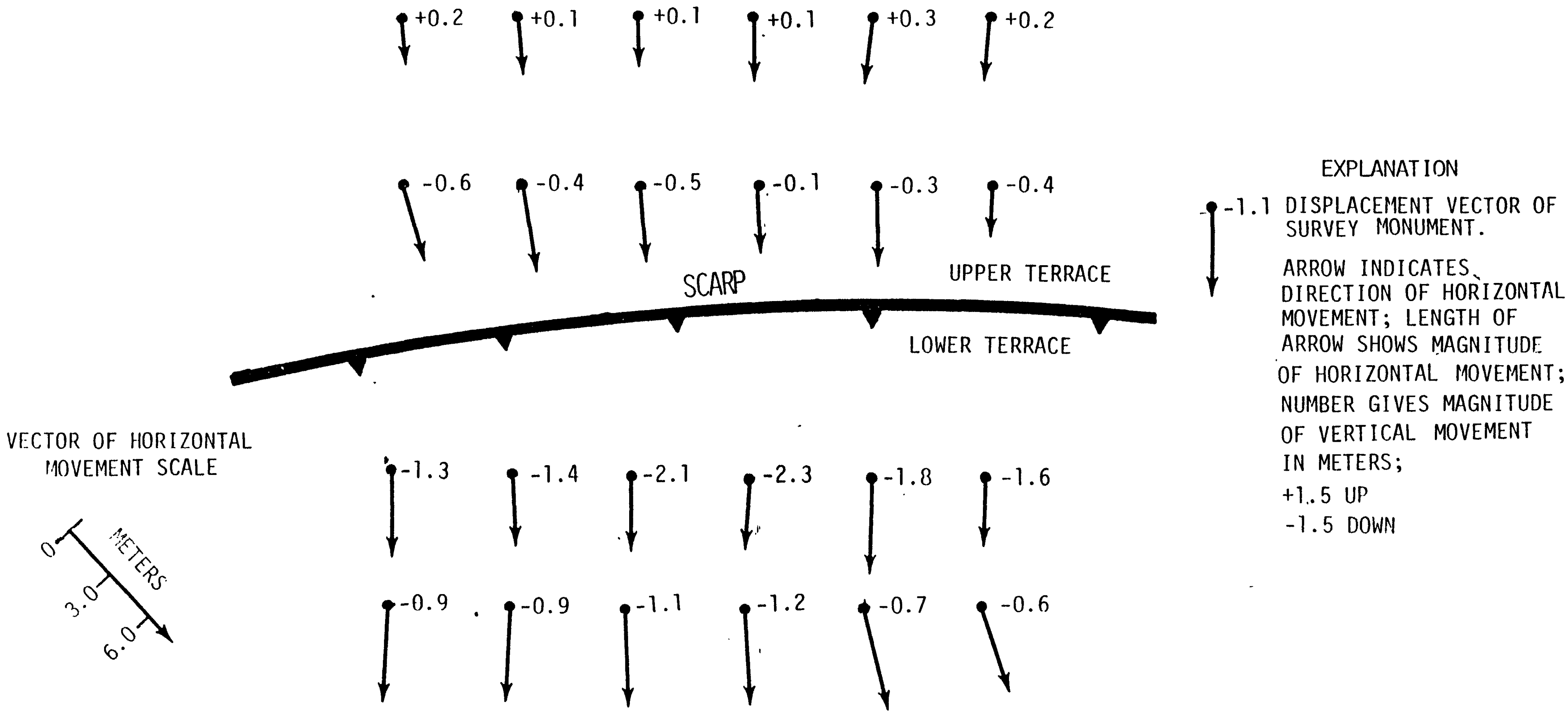


Figure 4. Slope displacement diagram (modified from Sowers and Royster, 1978).

require using a long-range (10 km) electronic-distance-measurement (EDM) device.

Surface-tilt measurements to determine direction and amount of rotational movement associated with slump blocks will be made by the Hawaiian Volcanic Observatory (HVO) dry-tiltmeter method (J. P. Lockwood, U.S. Geological Survey, written commun., 1980). This system employs a triangular surface grid in which periodic level measurements are made on the three points of the grid (fig. 5). Tilt stations will be incorporated into each surface-movement grid. Measured-tilt movements will be plotted as vectors in terms of azimuth and radians.

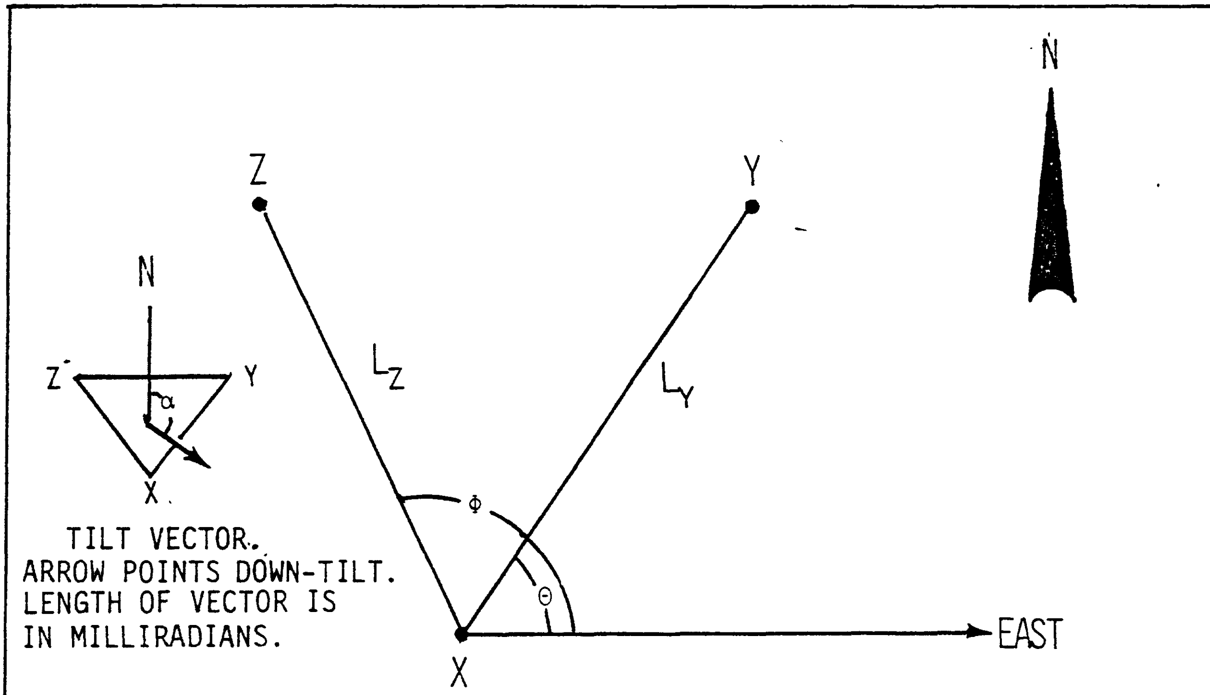
Subsurface exploration

Boreholes will be drilled to a minimum depth of 15 m and continuous 75-mm core taken throughout the total length in the upper- and lower-scarp terraces at each landslide site. At the drill site detailed geologic and engineering logs will be made of the cores, and soil penetrometer tests made on engineering soil samples. Representative soil and rock-core samples will be selected for the laboratory where engineering properties will be tested and clay mineralogy will be determined by X-ray analyses. Rock classification hammer (Schmidt Hammer) tests will be made on rock core samples and converted to estimated strength values.

Slip-surface locator borings

The inclinometer which measures the change in inclination of a casing in a borehole is commonly used to define slip surfaces or zones of movement. However, because of the complicated nature of the device, it was decided not to use it at this time in the monitoring program.

Instead, a simple borehole method will be designed to be emplaced in exploratory drill holes a minimum of 15 m deep. Previous field observations



This procedure calculates land-surface tilt as a vector in terms of azimuth (α) from north-south and tilt magnitude (T) in terms of milliradians.

$$T_{(n)} = -\frac{10\cos\phi}{L_y \sin(\phi-\theta)}\Delta(y-x) - \frac{10\cos\theta}{L_z \sin(\phi-\theta)}\Delta(x-z)$$

$$T_{(e)} = \frac{10\sin\phi}{L_y \sin(\phi-\theta)}\Delta(y-x) + \frac{10\sin\theta}{L_z \sin(\phi-\theta)}\Delta(x-z)$$

Where

$T_{(n)} = T_{(north)}$

$T_{(e)} = T_{(east)}$

x = southern-most point

y = next point in triangle counterclockwise

L_y = distance from x to y in meters

L_z = distance from x to z in meters

θ = angle measured from east to L_y

ϕ = angle measured from east to L_z

Δ(y-x) = new minus old differences of y elevation minus x elevation in centimeters

Δ(x-z) = new minus old differences of x elevation minus z elevation in centimeters

$$\text{Azimuth } (\alpha) = \tan^{-1}\frac{T_{(e)}}{T_{(n)}}$$

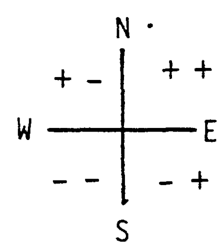
$$\text{Magnitude } (T) = [T_{(n)}^2 + T_{(e)}^2]^{1/2}$$

If $T_{(n)}$ is positive (+) n-vector component is down to north

If $T_{(n)}$ is negative (-) n-vector component is down to south

If $T_{(e)}$ is positive (+) e-vector component is down to east

If $T_{(e)}$ is negative (-) e-vector component is down to west



QUADRANT LOCATION OF VECTOR

Figure 5. Dry-tilt meter procedure, (Hawaiian volcanic observatory, U. S. Geological Survey, J. P. Lockwood, written comm., 1980).

in river channels indicated that large-slope movements often take place at depths less than 15 m. Time and physical restraints set this 15-m hole depth as a criterium. A brittle thin-walled plastic pipe will be inserted the full length of the boring and cemented in at both the top and bottom. Sand backfill will be placed between the pipe and borehole wall and the cement layers in order to protect against hole collapse. The slip surface, if it intersects the borehole, will eventually shear and displace the pipe. The depth to this slip surface, which would represent the uppermost zone, will be located by a rod with an attached disk being inserted periodically into the pipe until eventual hole displacement blocks the disk (fig. 6). Slip surfaces lying below the uppermost zone would, of course not be detected by this technique.

Ground-water and pore-pressure measurements

Next to gravity, water is the most important factor in slope instability. In most cases an increase in soil or rock moisture is accompanied by a decrease in strength. Water pressure within a soil or rock stratum, joint or crack, or along a slip surface or zone is a major factor in shear strength and one of the most significant single factors in landslide activity (Sowers and Royster, 1978). Information gathered from historical sources suggests that changes in land use, such as has taken place in West Java, from well-drained timbered areas to terraced ricefields, has certainly been a critical factor in augmenting regional landslide activity. The relation between agricultural practices, that is, dryland farming and wetland farming, must be studied.

The most common piezometric or water-level-recording technique is the observation of the water level in an uncased borehole or observation well. An open-stand-pipe piezometer will be placed in both upper- and lower-scarp

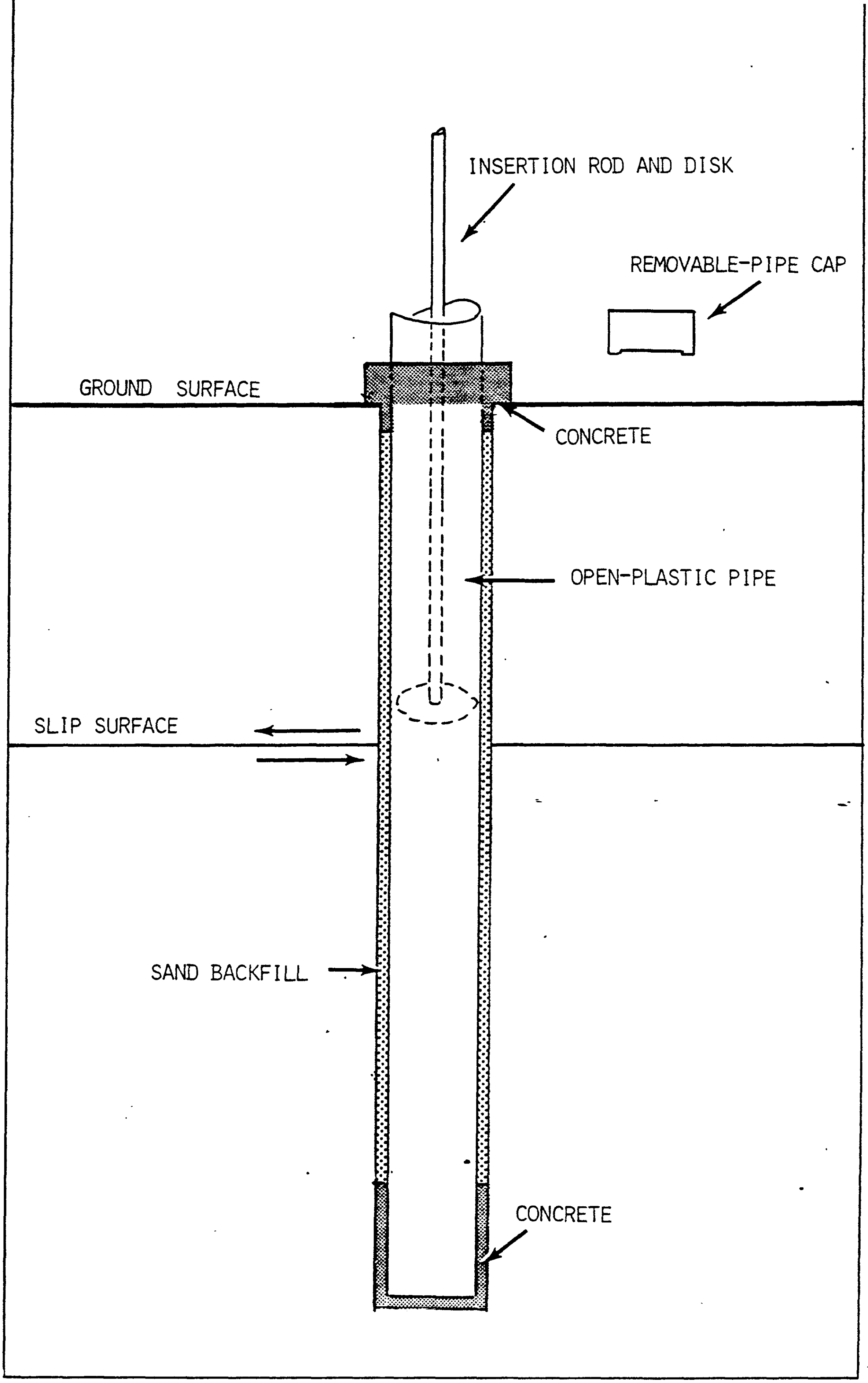


Figure 6. Schematic of slip-surface-detector hole.

terraces at each monitoring site. A plastic pipe will be slotted at the desired depth of measurement, at the slip surface if known, and inserted into the water observation hole (fig. 7). Sand will be packed between the slotted portion of pipe and borehole wall to provide a permeable collecting chamber. The slotted zone will be sealed off from the rest of the hole by isolating it from above by a layer of concrete. The remainder of the hole annulus will then be backfilled with sand.

Water-level measurements will be taken and recorded on a daily basis through two cycles of rainy and dry seasons. The water-level measurements will be correlated with amounts of rainfall and magnitude of slope movement. Changes in water level will be used in estimating pore pressures by the relation.

$$u = \gamma_w (h_{piez} - h_{point}) \quad (1)$$

where

u = water pressure at a point

γ_w = unit weight of water

h_{piez} = elevation of piezometer level

h_{point} = elevation of the point

Rainfall gages

The effect and amount of rainfall on an area may be the ultimate factor that triggers many landslides. Regions that were once stable in a dry climate may become areas of slope movement as the climate evolves into a humid one. As the amount of ground water increases, the landscape becomes less stable. In regions that experience dry and wet cycles, the additional water supplied during the rainy season to the hydrologic system may be sufficient to start landslide activity.

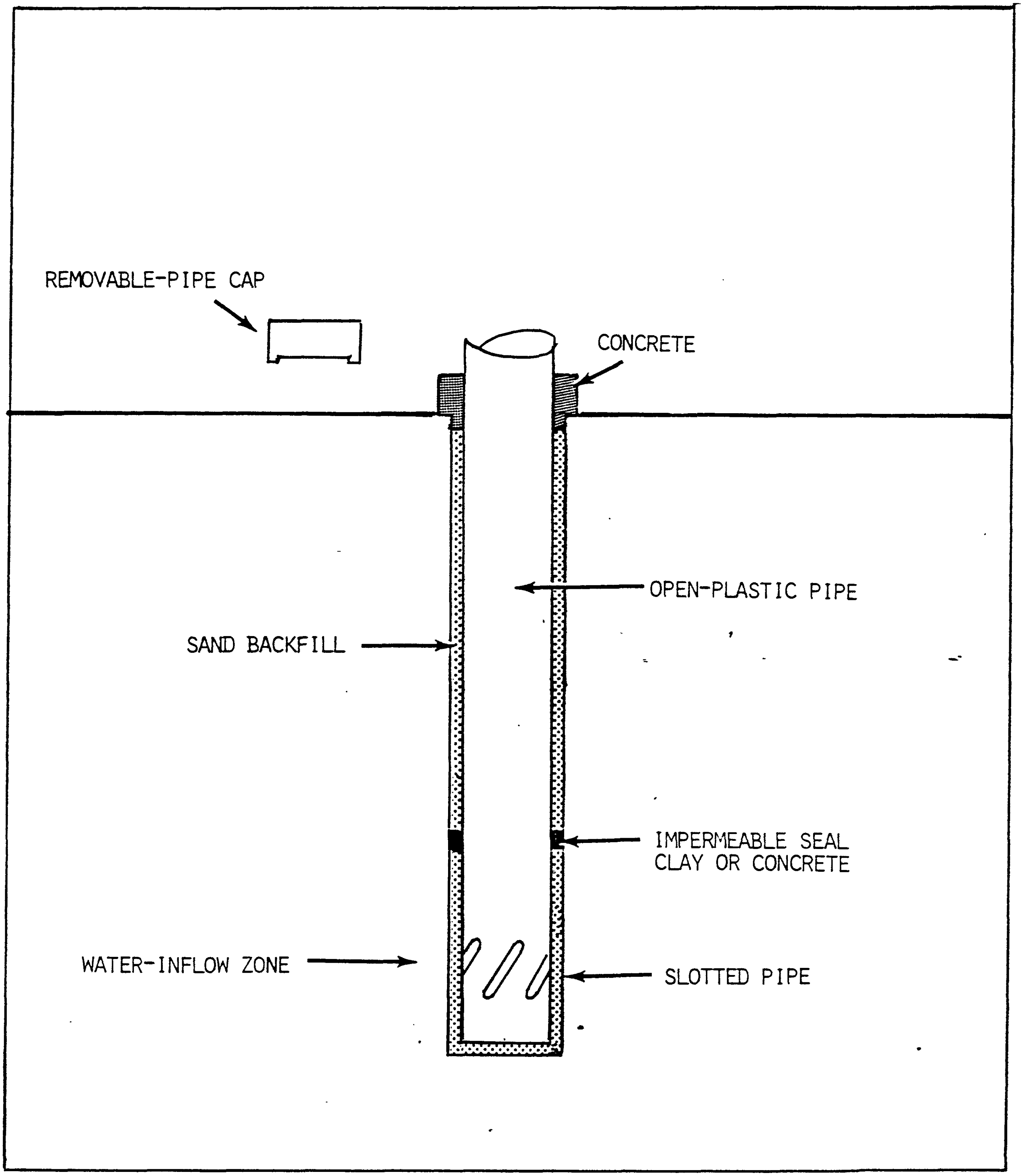


Figure 7. Schematic of open-stand-pipe piezometer.

There is a Government of Indonesia rainfall gage located in front of the District Headquarters building in Pagelaran. This rain station, which has been operating for several years, is close enough (2.5 km) to the Pasirpari site to serve as a rainfall-data point for Pasirpari. In addition, a standard-GOI rainfall gage has been purchased and installed by the Landslide Section in the village of Cibacang. Arrangements have been made for recording daily rainfall. This rain gage will serve as the rainfall-data point for the Cibacang site.

Ground stress measurements

Gravity, the major force acting in slope movements, can be resolved into a component of driving force parallel to the slip surface and a component of resisting force perpendicular to the slip surface. However, the natural state of stress in earth masses is often characterized by large horizontal stresses, which exceed the vertical stress by several times. This state probably results either from the position of the site with respect to the general tectonic structure of the area, or is a remnant of the stress field that existed before the area had been laid bare by denudation, or is connected with large ancient inactive landslides (Záruba and Mencl, 1969, p. 23).

Wirasuganda and others (in press) speculate that there may be a large regional-horizontal stress acting on the rock masses in the landslide area. They hypothesize that the stress is induced by movement of the South Java tectonic plate. Those authors also suggest that additional stress created by a thick, heavy caprock of andesitic lava, which overlies the relatively weak tuffaceous materials of the Bentang Formation of Miocene age, may be causing lateral spreading of the more plastic ash-fall tuff of the Bentang. This lateral spreading is manifested by bulges along the face of the eastern scarp bounding the landslide region.

Two hydraulic borehole-load cells, flatjack type (fig. 8), that can be grouted inside a borehole are being considered for emplacement at the Cibacang site. The borehole-load cells would be used to measure seasonal changes in stress and possible correlation with slope movements. One load cell would be placed at the village of Cibacang; the second at the foot of the andesitic-lava escarpment 3 km east of Cibacang. The flat side of each cell should be oriented perpendicular to the scarp and direction of slope movement. Pressures, read on hydraulic gages, ought to be recorded at 2-week intervals during the rainy season (November through April) and monthly during the dry season. The hydraulic-load cells will have to be custom ordered from the United States.

Soil and rock property tests

Engineering soil and rock samples, preserved in the as-recovered state, will be submitted to the engineering laboratory for determining water content, unit weight, porosity, grain size, and Atterberg limits. Strength tests, to include unconfined compression, triaxial compression and direct shear, will be made on both soil and rock samples. Rock samples will be measured for specific gravity.

Geophysics

Geophysics may be useful for field determination of rock and soil properties at depth. Surface-resistivity surveys, centered around the exploratory boreholes in the upper- and lower-scarp terraces are recommended for each landslide site. The resistivity traverses must be calibrated with the recovered cores and borehole logs.

An experimental-magnetic survey that may locate and measure the amount of movement along a buried slip surface is suggested. Two boreholes, one bottomed in slide material and the other in the underlying firm bedrock should

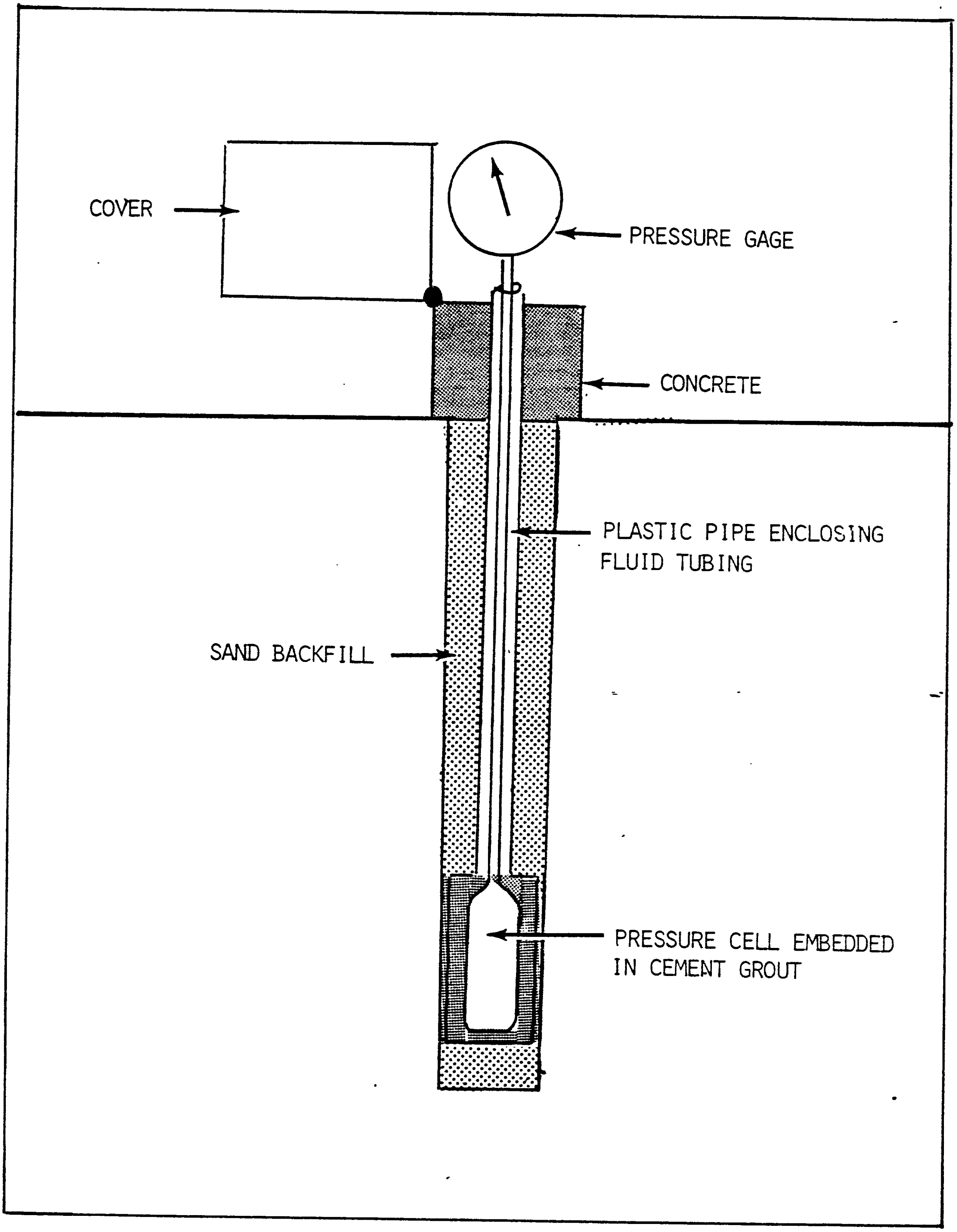


Figure 8. Schematic of a borehole-hydraulic-flatjack pressure cell.

be spaced at least 100 m apart at each landslide site. Iron pipe or other highly magnetic material should be placed in the holes to a height of 1 m above the bottom of the borehole. Each hole should be located by precise surveys. Once a year a magnetic survey should be conducted at the borehole sites with a sensitive portable magnetometer, and the position of maximum magnetic intensity marked and accurately surveyed. The procedure should be repeated for at least 5 years to see if the magnetometer survey is sufficiently sensitive to locate the buried magnetic material and to differentiate between a moving and stationary magnetic body below the surface.

PROGRESS REPORT ON PASIRPARI AND CIBACANG MONITORING RESULTS FOR THE PERIOD NOVEMBER 1980 TO FEBRUARY 4, 1981

Pasirpari

On November 12, 1980, a geodetic point installed by the Topografische Dienst 2.5 km north of Pasirpari was recovered by the Engineering Geology Division surveyor. A series of stable reference points were then located from which the whole of Pasirpari monitoring site could be seen. The stable-reference points were tied into the geodetic section, thereby establishing the exact positions of the reference points. Beginning November 15, four movement lines were surveyed, two in the upper-scarp terrace and two in the lower. Each line comprised five monuments spaced as close to 200 m apart as possible. The terrain roughness and line-of-site requirement between movement monuments and stable points, however, caused deviation from an absolute 200-m interval between a few of the movement stations. The irregularities in no way affect the validity of measurements.

The reference and movement points are set with concrete monuments that are emplaced vertically 1 m in depth into the ground and extend 40 cm above ground. The horizontal cross section is a square 15 cm on a side.

Each movement line contains an Hawaiian Volcanic Observatory (HVO) tiltmeter station as shown in the example in figure 3. The length of the sides of the triangular tilt grids are approximately 50 m.

Exploratory core drilling started in the upper-scarp terrace on November 26. The drilling equipment had to be carried in from the highway along foot trails by 24 bearers, a process taking 2 days. A total of 10.64 m of continuous core was recovered and logged in detail for determining lithologic and engineering properties. Water-level measurements were taken in borehole after each core run was removed from the ground.

Interpretation of the core and water-level data resulted in placing the depth of slip surface in the upper-scarp site at 4.06 m. Water levels rose dramatically at this depth, 63 cm, indicating that pore pressure was acting along the inferred-slip surface.

After completion of the exploratory borehole, two water-level holes were drilled for measuring water levels at the slip surface (4.50 m below surface) and in bedrock (13.50 m below surface), respectively. Plastic pipes, slotted at the monitoring depths, were emplaced in the water holes and sealed. A 15-m plastic pipe was inserted in the exploratory hole to function as a slip-plane locator.

The drill rig was moved from the Pasirpari upper-scarp terrace to the lower terrace and set up on December 13. Coring began on December 14, and the hole was completed on December 16 at a depth of 15 m. The slip surface was tentatively placed at a depth of 6.0 m, which is also the location of the contact between engineering soil and bluish-gray ash-fall bedrock. Engineering soil includes any loose, unconsolidated, or poorly cemented aggregate of solid particles (Varnes, 1978, p. 24). A 15-m plastic pipe was cemented into the core hole on December 17, to function as a slip-surface locator.

On December 20, two water-level holes were completed and fitted with open-plastic pipes slotted between depths of 6 and 7 m and 13 and 14 m, respectively. These water-monitoring levels are at the estimated slip-surface depth of 6 m and at a fractured zone in lower bedrock located between depths of 13 and 14 m.

A topographic survey of the Pasirpari site was begun on November 12, 1980, that encompasses an area extending 200 m outward on all sides from the instrumented zone. Office compilation of data, plotting, drafting and elevation contouring have been completed.

Cibacang

On December 2, 1980, reconnaissance of the Cibacang site for movement lines and tiltmeter stations commenced. All the monuments for the movement-line grids and tiltmeter points in the lower scarp were set and completed by December 24. A special movement line also was established across the Cibadak River, which flows through the monitoring site, to determine what effect the downcutting river has on slope movement. Movement lines and tiltmeter stations had not yet been established in the upper scarp.

Problems arose in trying to locate stable reference points that were visible to all monuments. It was finally decided to set "intermediate" stable points, or sites that seem to be more stable than the surrounding slope-movement ground. Movement-line monuments were then joined to the intermediate points. These intermediate stable points will be tied to a geodetic point located about 3 km east of Cibacang situated on the high andesitic lava escarpment. The geodetic point will be connected to the Cibacang site as soon as the Engineering Geology Division receives the electronic-distance-measuring device, which is on order from the United States.

The drill rig was carried in by bearers to Cibacang, a distance of 5 km from the nearest road. Exploratory core drilling started on December 27, 1980, and was completed on January 14, 1981. At a depth of 10 m, in hole collapse and required extensive remedial drilling and replacement of casing. A rise in water level took place at the collapse zone. Beneath the collapse zone lies andesitic lava, and the slip surface is inferred to be at a depth of 10 m in the lower scarp. The remainder of the hole stayed in the lava and the boring was completed at a depth of 24.25 m. The exploratory boring was fitted with a plastic pipe and now serves as a slip-surface locator hole.

Drilling of the water-level hole was started on January 15, 1981, and finished on January 19; the completed hole is 13 m deep. A plastic pipe slotted between 11 and 12 m was inserted and sealed off for piezometric measurements.

In the upper scarp, drilling of the exploratory core hole began on January 25, 1981, and was completed on January 31 at a depth of 18 m. The recovered core indicated that the boring was in engineering soil for its entire length; however, hole collapse and rapid rise in water level at 14 m may signal a region of high stress and shear movement. The hole was fitted with a plastic pipe for slip-surface detection.

A piezometric hole drilled to a depth of 16 m was started on February 1, 1981, and completed on February 4. A plastic stand pipe, slotted between 14 and 15 m, was emplaced in the boring and sealed. The slot depth spans the material where water level rose during drilling of the exploratory borehole.

A Government of Indonesia rain gage has been installed in the village of Cibacang, and topographic surveys of the Cibacang site have been completed.

REFERENCES CITED

Rib, H. T. and Liang, Ta, 1978, Recognition and identification, _in_ Schuster, R. L. and Krizek, R. J., eds., Landslide analyses and control: United States National Academy of Sciences, Transportation Research Board Special Report 176, p. 34-80.

Schuster, R. L., 1978, Introduction, _in_ Schuster, R. L. and Krizek, R. J., eds., Landslide analyses and control: United States National Academy of Sciences, Transportation Research Board Special Report 176, p. 1-10.

Soemodipoero, K., and others, 1976, Laporan penyimpulan pertama hasil survai gerakan tanah Cianjur Selatan [Preliminary report of landslide survey of southern Cianjur]: Indonesia Geological Survey, Engineering Geology, Hydrology Division, no. 1977, 38 p.

Sowers, G. F., and Royster, D. L., 1978, Field investigation, _in_ Schuster, R. L. and Krizek, R. J., eds., Landslide analysis and control: United States National Academy of Sciences, Transportation Research Board Special Report 176, p. 81-111.

Varnes, D. J., 1978, Slope movement types and processes, _in_ Schuster, R. L., and Krizek, R. J., eds., Landslides analysis and control: United States National Academy of Sciences, Transportation Research Board Special Report 176, p. 12-33.

Záruba, Quido, and Mencl, Vojtech, 1969, Landslides and their control: Amsterdam, Elsevier, 201 p.