CAPITOL CAMPUS GREENHOUSE SOIL STABILITY INVESTIGATION STATUS REPORT

January 19, 1995

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Introduction and Scope of Work

Over the past number of years, the foundations of the Capitol Campus Greenhouse and Conservatory buildings have undergone severe distress due to soil movement. Significant cracking of the concrete walls of both buildings has occurred, and distortion of window frames in the Greenhouse has required that replacement panes be cut out of square. Likewise, the pavement of the streets and parking areas adjacent to the Greenhouse and Conservatory has been severely cracked and distressed. During the summer of 1993 the Capitol Grounds staff noticed water seeping through cracks in the floor of the Conservatory garage area, and an apparent increase in the separation of existing cracks as well as the formation of new cracks in the garage floor and the adjacent parking area.

Soon after this occurrence, the Department of General Administration (GA) requested that staff from the Geology and Earth Resources Division, Department of Natural Resources, investigate the potential cause of the soil instability in the Greenhouse area through an existing contract to evaluate geotechnical factors affecting construction projects on the Capitol Campus. This report summarizes the findings of the investigation to date, and presents recommendations for further work.

The initial investigation of the site included: (1) review of previous geotechnical investigations and reports, and discussions with employees familiar with the history of the site (i.e. Ken Zugner, former manager of greenhouse and grounds operations); (2) field reconnaissance of the existing slope conditions, (3) drilling of a boring near the west side of the Greenhouse building for the purpose of investigating stratigraphy and for soil properties testing; (4) construction of cross sections traversing and paralleling the ravine based on existing drill hole data and surface morphology; (5) installation of a slope inclinometer in this newly drilled boring, and regular monitoring of the lateral movement of the soil mass beneath the Greenhouse building, and, (6) reactivation of a previously-drilled inclinometer boring located at the base of the slope beneath the retaining wall west of the General Administration building.

The initial investigation of the site has been completed, and the inclinometers have been monitored since April, 1994. No detectable downslope movement has been detected in the two inclinometers from May, 1994, to January, 1995. A small amount of downslope movement was measured in the inclinometer located at the base of the GA retaining wall slope between May, 1988, and May, 1994. A preliminary analysis of stability conditions of the slope adjacent the west side of the Greenhouse indicates that it is currently stable. A summary of work to be completed is presented.

Location and Site Description

The Capitol Campus Greenhouse lies southwest of the General Administration (GA) Building at the intersection of 11th Avenue and Cherry Street (see Figure 1). The site overlooks Capitol Lake from an elevation of approximately 100 feet above sea level at the edge of a north-facing bluff. The head of a ravine lies immediately west of the Greenhouse building at the edge of the bluff. A much larger ravine extended back to the area east of the Temple of Justice prior to filling in the early 1900's. The fill was brought to the ravine dump site during numerous Capitol Campus construction and renovation projects. Fill material consists primarily of silty clay and clayey silt with zones of slightly coarser material and organic material, brick pieces, and other building material debris. The dominant fine-grained material is probably derived from late glacial lake sediments deposited in small ponds and bogs that developed on the upland surface behind the bluffs bordering Capitol Lake.

Site History

Prior to development of the Capitol Campus, a large ravine extended from the Winged Victory Monument northward past the Greenhouse and Conservatory to Capitol Lake (Figure 1). Figure 2 shows a portion of a topographic map from the Olympia area from the late 1800's, prior to development of the Capitol Campus. Figure 3 is a map of the same part of Olympia taken from a recent 1:24,000 topographic quadrangle. Comparison of these maps indicates that the original ravine (circa 1880) was much more pronounced and extensive than at present. The head of the ravine was located approximately east of the Temple of Justice building, draining almost directly north. Hand augering at the Winged Victory Monument found approximately 9 feet of blue-gray clayey silt overlying brown sandy soils, indicating that the ravine fill (and consequently the ravine) may have extended as far south as the monument. Fill depths exceeding 65 feet are found in the deepest portions of the original ravine; similar fill material was placed along the mouth of the original ravine at the level of Capitol Lake as a base for the railroad tracks. Estimates of the fill depth have been reported in previous geotechnical investigations in the vicinity of the Greenhouse/Conservatory and the Temple of Justice. All of the existing boring data, including the results of boring DH-2, are presently being incorporated in the production of a fill depth map.

Figure 4 is a picture of a landslide failure on the slope north of the Temple of Justice that occurred during the winter of 1958/59, and Figure 5 is a picture taken recently from approximately the same vantage point. Ritchie and Cashman (1959) report that this particular failure was caused by overflow of surface runoff from the Temple of Justice parking lot onto the slope, which resulted in saturation of the soils and consequent strength loss. They recommended removal of the slide material, and construction of a rock-filled trench cut down to the underlying consolidated sandy silts. No rock-filled trench was observed during our inspection of this slope.

Figure 6 is a picture of the landslide that occurred in the fall of 1987 west of the GA building. To stabilize this failure, a retaining wall was constructed along the north edge of the fill and west of the GA parking lot. Comparison of Figures 4 and 6 shows that these landslides had a similar failure mechanism. They are both the result of rotational failures that occur on oversteepened slopes in either the fill material or the native soils. These landslides are progressive, in that an initial large landslide had previously created an oversteepened slope in the area of the head scarp. This oversteepened slope is then prone to smaller failures similar to those shown in Figures 4 and 6. These smaller landslides will continue to occur as long as the oversteepened conditions are preserved, and will result in the rapid retreat of the top of the bluff.

Results of Field Reconnaissance

A sequence of seeps and springs were observed during slope traverses made in the fall of 1993. These zones where the water table intersects the ground surface are located along and slightly to either side of the main axis of the ravine (about 80 feet down from the head of the ravine), as well as at the base of the slope below the retaining wall. As a result, horsetails and other hydrophilic plants grow in abundance in these areas.

During the reconnaissance a significant landslide was observed on the slope below the retaining wall. The slope is extremely hummocky, and a 2 foot high scarp was observed at the head of the slide (see Figure 7). The pipe draining the gravel backfill of the retaining wall was separated at the headscarp by the downslope movement. The pipe separation indicated that the soil mass slipped 3 feet, and that this slippage was parallel to the existing slope. Drain water leaking out of the severed pipe caused deep erosion of the soils beneath the separation. At that time, we recommended that the pipe be repaired, and the void beneath the pipe filled with suitable soil. This recommended work was quickly performed by the Capitol Grounds staff. We estimate that this failure probably occurred sometime between the fall of 1992 and the spring of 1993.

During the reconnaissance we observed that large depressions had formed in the retaining wall backfill, requiring periodic refilling by grounds personnel. It is not clear whether this material is being removed from behind the wall (e.g., by piping), or if the original material was insufficiently compacted and is still settling.

Results of Drilling and Inclinometer Monitoring Near the Greenhouse Building

As a result of the historical review of landslide failures in the vicinity of the Temple of Justice and the GA Building, our concern is the possibility that the soil movement causing the damage to the

Greenhouse and Conservatory buildings' foundations could accelerate into a large landslide. This slope is very steep, and a number of springs and wet areas were observed along it during the reconnaissance. The soil movement damaging the west side of the Greenhouse might be related to downslope creep; Ritchie and Cashman (1959) noted evidence of gradual slope movement preceding the initiation of the major landslide north of the Temple of Justice.

A landslide failure similar to those at the Temple of Justice and the GA Building could result in serious damage to the west end of the Greenhouse building if it were to occur. We decided that a borehole inclinometer needed to be installed near the west end of the Greenhouse in order to detect any lateral movement of the slope. This inclinometer would be monitored regularly, and would be read immediately if any further cracking or structural damage was observed, or after a severe precipitation event.

Boring DH-2 is located approximately 6 feet from the northwest corner of the Greenhouse building (see Figure 1). It was drilled in April, 1994, and reached a final depth of 91.8 feet. This site was chosen to capture the predicted maximum displacement direction of slope movement, given the limitations in drilling rig access. During drilling, disturbed samples with corresponding Standard Penetration Test blow counts were collected every 2 to 5 feet using a 2 inch OD split-spoon sampler. Undisturbed samples were collected for strength and consolidation testing. A boring log for DH-2 is presented in Figure 8. Table 1 reports gradation data and Atterburg limits for six samples selected from boring DH-2. All of these samples are ML soils, and are either non-plastic or have low plasticity.

The upper approximately 65 feet of D-2 were drilled through fill material comprised primarily of clayey silt. Occasional zones of gravel, coarse sands, organic material, and construction debris were also encountered. Specific mention should be made of a zone between depths of 39 to 41 feet where drilling circulation was lost, indicating a zone of high permeability. This zone appeared to be a void space, and drill samples above and below this zone suggest that the void may be a rubble of bricks and building debris in which the fine material has been washed away by piping.

At a depth of approximately 65 feet there is an increase in blow counts and a change in soil type from the blue-grey silts to tan fine-medium grained sands. This transition is interpreted as the boundary between the fill and the native soils, so that the fill thickness in boring DH-2 is about 65 feet.

Several saturated zones encountered during drilling are interpreted as perched groundwater zones. The base level of the unconfined groundwater table in the vicinity of the Campus bluffs is controlled by the elevation of Capitol Lake. Consequently, the unconfined groundwater table lies below the final depth of boring DH-2.

Figure 9 presents the inclinometer monitoring results of boring DH-2 from April 28 to January 6, 1995. These measurements indicate that there was no lateral movement of the soil mass surrounding the inclinometer casing. This monitoring period included a very dry summer in Olympia, and moderately rainy weather from mid-October to mid-November. Late November and December had a combination of heavy rain and snow storms, with precipitation well above average.

Results of Inclinometer Monitoring at the Base of the Retaining Wall Slope

Boring J-1 was drilled by the Department of Transportation (WSDOT) in 1987 at the base of the retaining wall slope, as shown on Figure 1. This boring was drilled to a total depth of 36 feet, and inclinometer casing set to 34 feet. This inclinometer was reactivated for this investigation with an initial reading made on May 23, 1994. Boring J-1 encountered loose silty sand in the upper 18 feet, and stiff silts between 18 and 36 feet. The loose silty sand unit is either unconsolidated landslide debris fill.

The inclinometer installed in J-1 was re-initialized on May 23, 1994. The first reading was made on November 1, 1994; a survey performed in July did not satisfy data quality standards. Figure 10 displays the results of the November 10 inclinometer survey. The incremental displacement curves indicate that there has been no movement between May 23 and November 1, 1994.

Figure 11 presents an inclinometer survey performed on December 12, 1994, and referred to an initial reading made on May 2, 1988. The figure shows that the soil mass adjacent to J-1 has moved downslope during this 6 year period, causing approximately 2 inches of downslope deflection of the inclinometer casing. Two observations can be made about this movement: (1) the movement is occurring only in the soft soil unit, and, (2) the movement is not along a sharp failure plane but is distributed throughout the lower half of the soft soil unit. We interpret the inclinometer displacement as being the result of slow creep of the lower portion of the soft soil unit, and not indicative of the soil mass slipping along a discreet failure plane. However, the inclinometer data and the landslide that occurred upslope of J-1 during 1992 or 1993 demonstrate active downslope movement.

Discussion of Cross Sections and Interpretation of Fill Thickness

Prior to drilling, several traverses were run parallel to and intersecting the trend of the ravine. The information gathered during these traverses was then combined with data from a topographic map produced circa 1919, presumably prior to emplacement of the majority of the fill. The compiled data is presented in this report in two cross sections. Section line A-A' (Figure 12) runs from approximately 50' east of the northeast corner of the Temple of Justice building, down the axis of the ravine to the edge of Capitol Lake. Section line D-D' (Figure 13) starts at boring DH-2, and runs downslope to the axis of the ravine. Both sections incorporate information from pre-existing borings which are described in detail in Dames& Moore (1965), Geolabs-Washington, Inc. (1973), and Washington Department of General Administration (1988).

The elevation of the contact between fill and native soil shown in Section A-A' (Figure 12) was obtained from the circa 1919 topographic map. This contact correlates well to the fill/native soil contact interpreted from five borings located along the profile line. The cross section shows the maximum fill thickness is about 65 feet, and is located just west of the Greenhouse building.

The present-day ground surface reconstructed for Section D-D' is approximated from three survey points combined with qualitative field observations, and is consequently poorly constrained. The original ground surface on Section D-D' is again reconstructed using the circa 1919 topographic map. Boring DH-2, drilled for this study, shows the thickness of fill to be about 65 feet, whereas the reconstructed ground surface requires a fill thickness of only about 25 feet. This discrepancy may result from fill placed in this area prior to 1919, possibly associated with early Campus construction activities including the initial excavation of the Capitol Building foundation and the construction of the Temple of Justice. Thus, the topography shown on the circa 1919 map may not reflect the true original ground surface, which might lie at a greater depth.

Results of Preliminary Slope Stability Modeling

These data were applied to two different computerized slope stability modeling programs. The first modeling program used was LISA (Level I Stability Analysis), developed by the US Forest Service Intermountain Research Station. LISA performs an series of infinite slope stability analyses using slope conditions randomly sampled from user-defined ranges of these conditions. The second modeling program used was XSTABL, developed by Sunil Sharma at the University of Idaho. This program evaluates more complex slope stability geometries in which movement may occur along non-planar failure surfaces using a more complex geometric model of the soil and groundwater conditions.

Preliminary results of analyses from each of the slope stability modeling programs suggest that the slopes adjacent to the Greenhouse are stable under present conditions. That is, that there should be no measurable movement of the soils comprising this slope. This apparent stability is confirmed by the lack of measured movement from the inclinometer surveys to date. These slope stability modeling results do not account for potential future instability caused by changes in groundwater levels or other conditions, slow downslope creep of the soil mass, or static settling of fill material.

Future Work

We will be working on a number of tasks to monitor and evaluate the stability of the soil slopes adjacent to the Greenhouse and other structures nearby to the filled ravine.

Monitoring will consist of:

- regular monitoring of the inclinometers by the Greenhouse and at the base of the GA retaining wall slope,

- monitoring of cracks in Greenhouse building and parking lot.

Since it is possible that the Greenhouse foundation distress may be due to static settlement of the bearing soils, we will be considering monitoring vertical displacements in the soils adjacent to the most severely distressed sections of the Greenhouse foundation.

Further tasks required for evaluating the stability of the Greenhouse slope include:

- developing a better topographic map of the ravine for use in estimating fill thickness, and constructing more accurate soil profiles,
- modeling of the 1992-1993 failure on the slope below the GA retaining wall to obtain estimates of strength parameters,
- further evaluation of the lateral movements measured in boring J-1 between 1987 and 1994,
- more refined modeling of Greenhouse slope using back-calculated strength parameters, and more accurate soil and slope profiles.

References

Dames & Moore , 1965, Report of soils investigation, proposed garage site, State Capitol grounds, Olympia, Washington: Dames & Moore [under contract to] Washington Department of General Administration, 1 v.

Geolabs-Washington, Inc., 1973, Subsurface investigation, canyon fill, Capitol Campus, Olympia, Washington: Geolabs-Washington, Inc. [under contract to] Washington Department of General Administration, 17 p.

Ritchie, A.M., Cashman, J.B., January 15, 1959, letter to Earnest Dore, 4 p.

Washington Department of General Administration, 1988, Emergency hillside stabilization, Capitol Campus, Olympia, Washington, project no. 88-112, plans and specifications: Washington Department of General Administration, 1 v., 4 plates.

Table 1 Gradation data and Atterburg limits for six samples from boring DH-2. All samples are classified as ML soils and are either non-plastic or have low plasticity.

Job No.
Hole No. **DH-2**
Project

Date **August 23, 1994**
Sheet **1** of **2**

Laboratory Summary

Washington State Department of Transportation

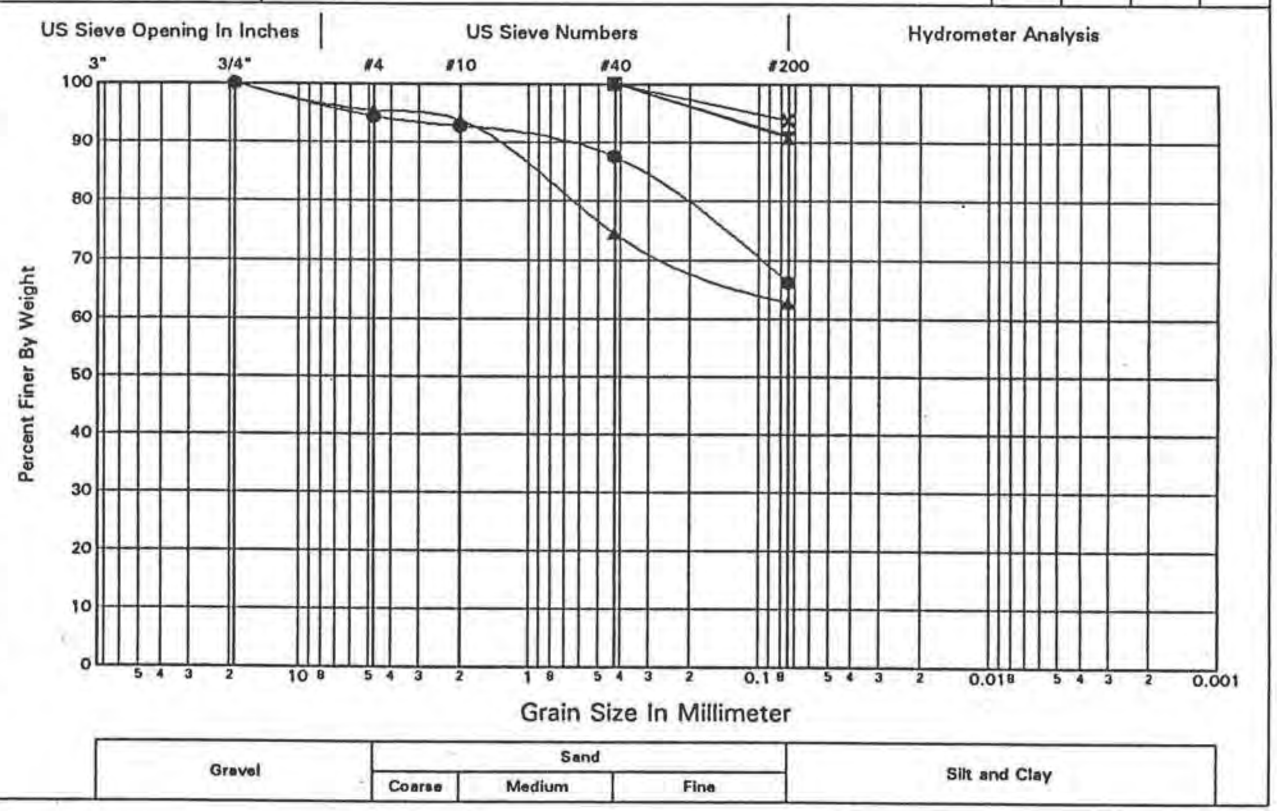
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	13.5	4.11	D-5	ML	DARK GRAY	SANDY SILT w/root hairs	33	NP	NP	NP
⊠	27.0	8.23	D-9	ML	GREENISH GRAY	SILT	38	31	23	8
▲	37.0	11.28	D-14	ML	GRAY,D & GRNISH GRAY	SANDY SILT w/fibrous organic material & root hairs	33	34	27	7
★	63.0	19.20	D-20	ML	OL TO GRY & D YEL BR	SILT	37	NP	NP	NP
✕	78.0	23.77	D-23	ML	OLIVE GRAY	SILT	36	NP	NP	NP

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cu	Cc
●	5.7	28.0	66.3		
⊠	0.0	9.2	90.8		
▲	4.6	32.6	62.8		
★	0.0	8.8	91.2		
✕	0.0	6.2	93.8		

GRADATION VALUES

	D60	D50	D30	D20	D10
●					
⊠					
▲					
★					
✕					



Job No.
Hole No. **DH-2**
Project

Date **August 23, 1994**
Sheet **2** of **2**

Laboratory Summary

Washington State Department of Transportation

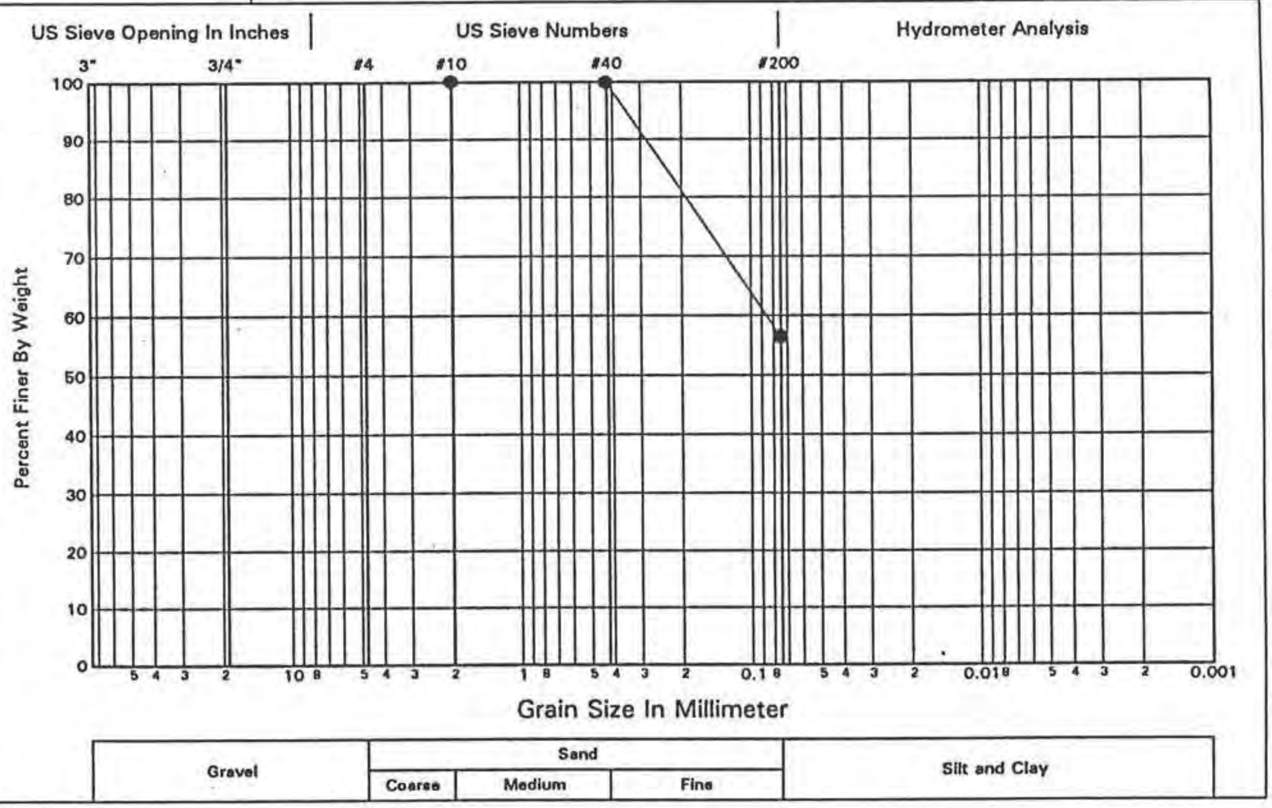
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	90.0	27.43	D-26	ML	GRAY	SANDY SILT	28	NP	NP	NP

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cu	Cc
●	0.0	43.5	56.5		

GRADATION VALUES

	D60	D50	D30	D20	D10
●	0.09				



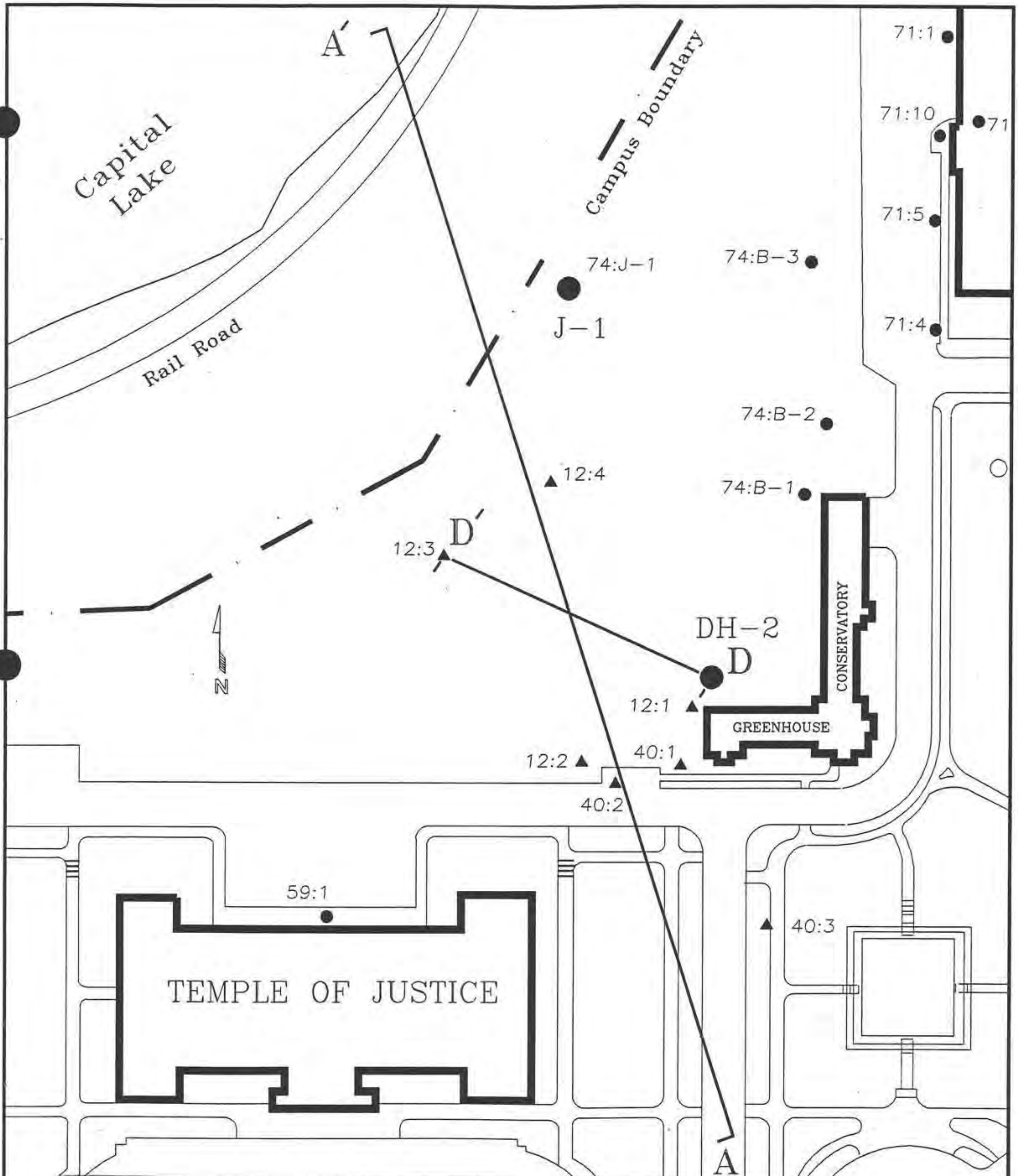


Figure 1 Location map of the Capitol Campus Greenhouse and Conservatory, including locations of borings DH-2 and J-1. Note that this map not to scale.

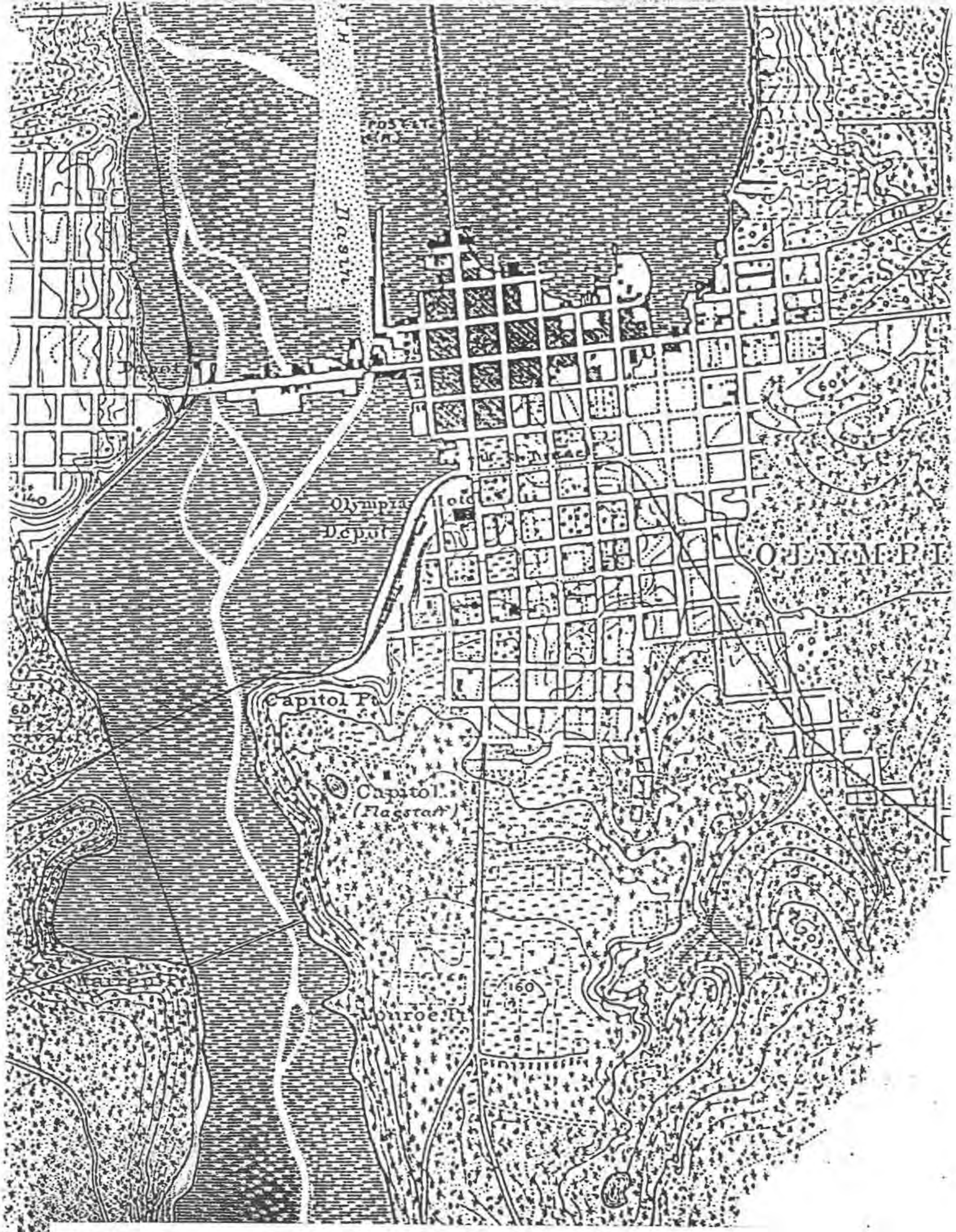


Figure 2 Portion of a topographic map of the Olympia area, circa 1880, showing the future location of the Capitol Campus. Scale approximately 1:12,000

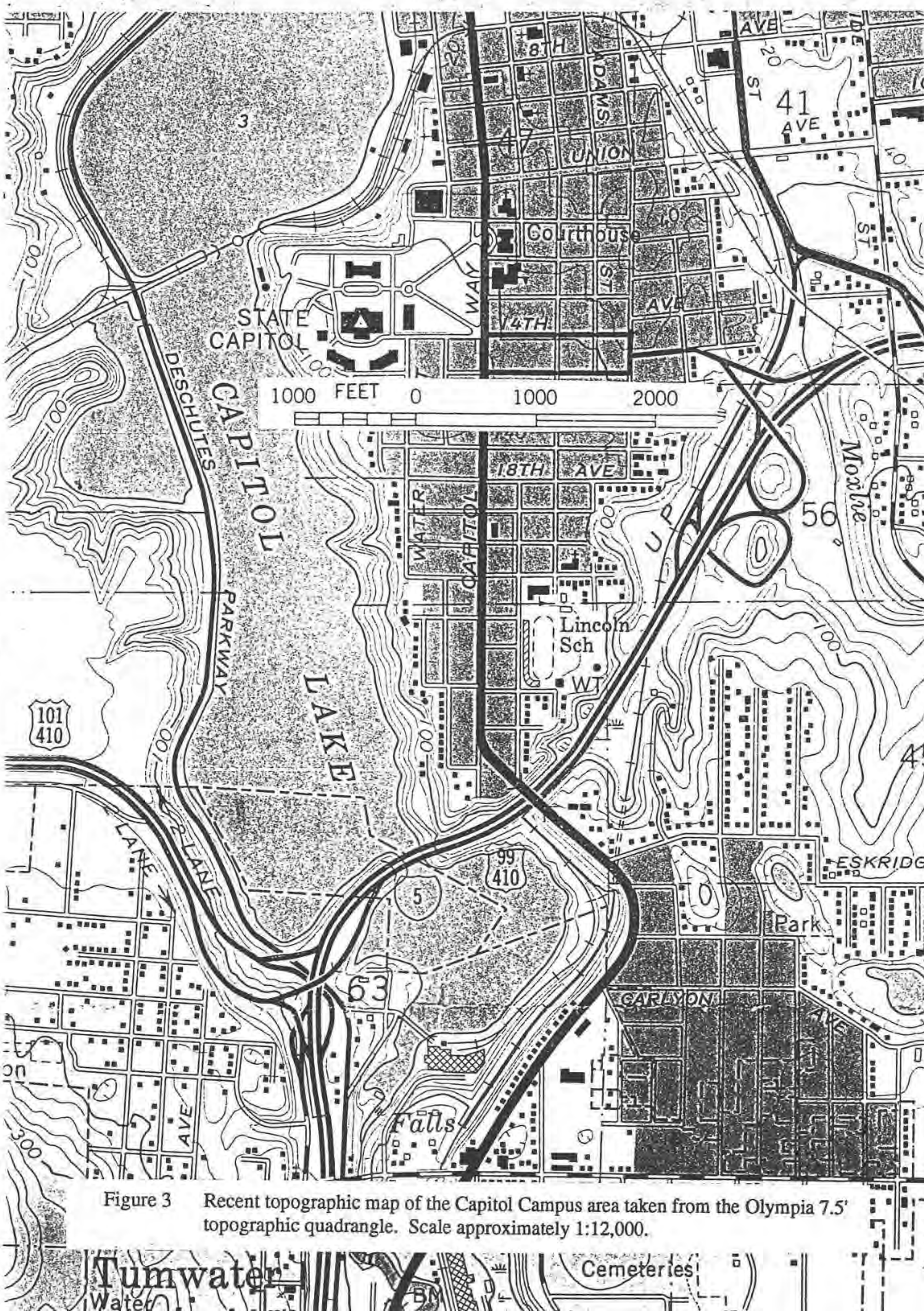


Figure 3 Recent topographic map of the Capitol Campus area taken from the Olympia 7.5' topographic quadrangle. Scale approximately 1:12,000.

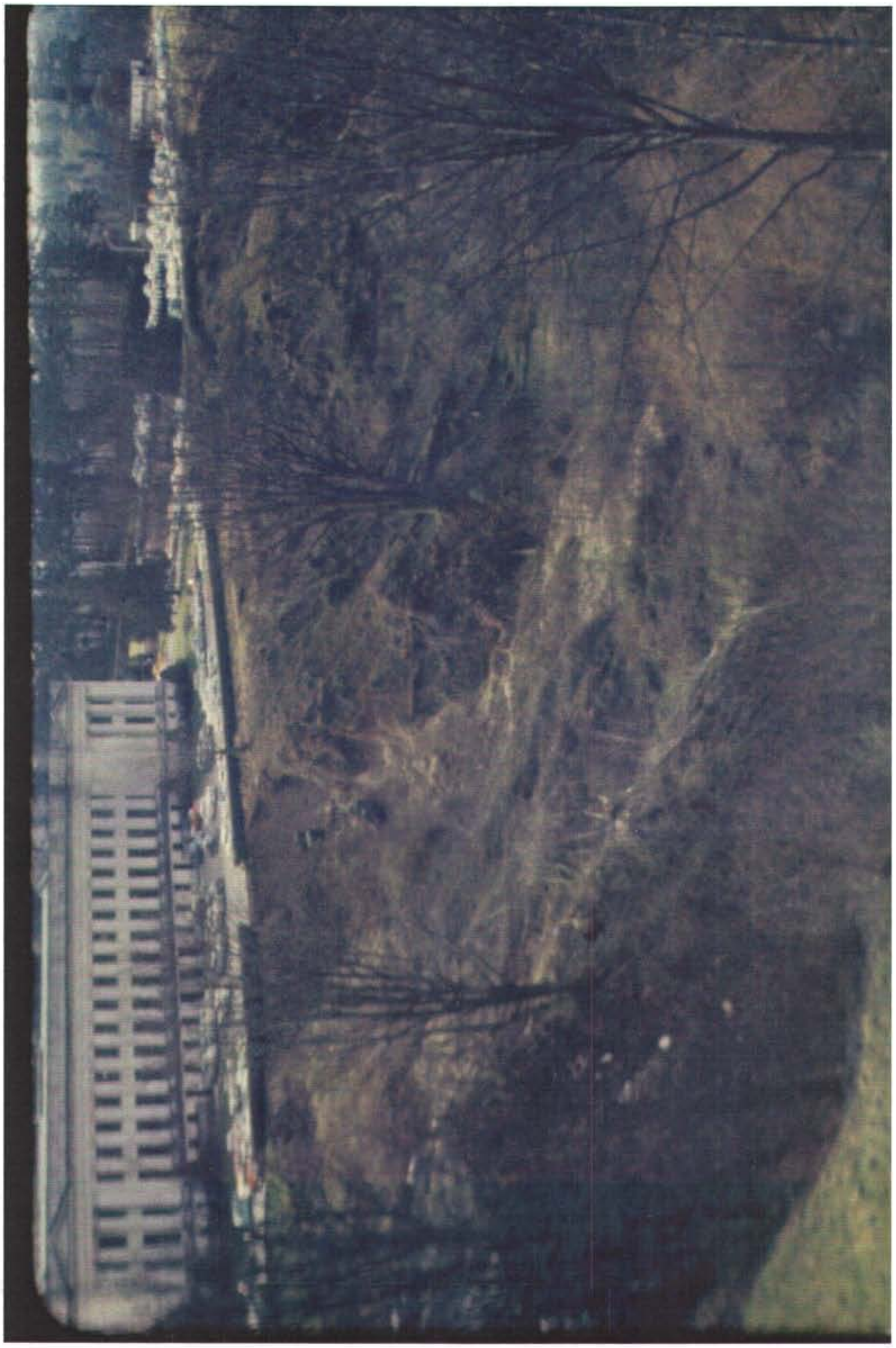


Figure 4 Landslide failure on the slope north of the Temple of Justice that occurred during the winter of 1958/59. View from north near the Conservatory.

Figure 5 Photograph of the existing slope north of the Temple of Justice from approximately the same vantage point as Figure 4. Note the dense growth of alder and blackberries covering the old landslide scar.

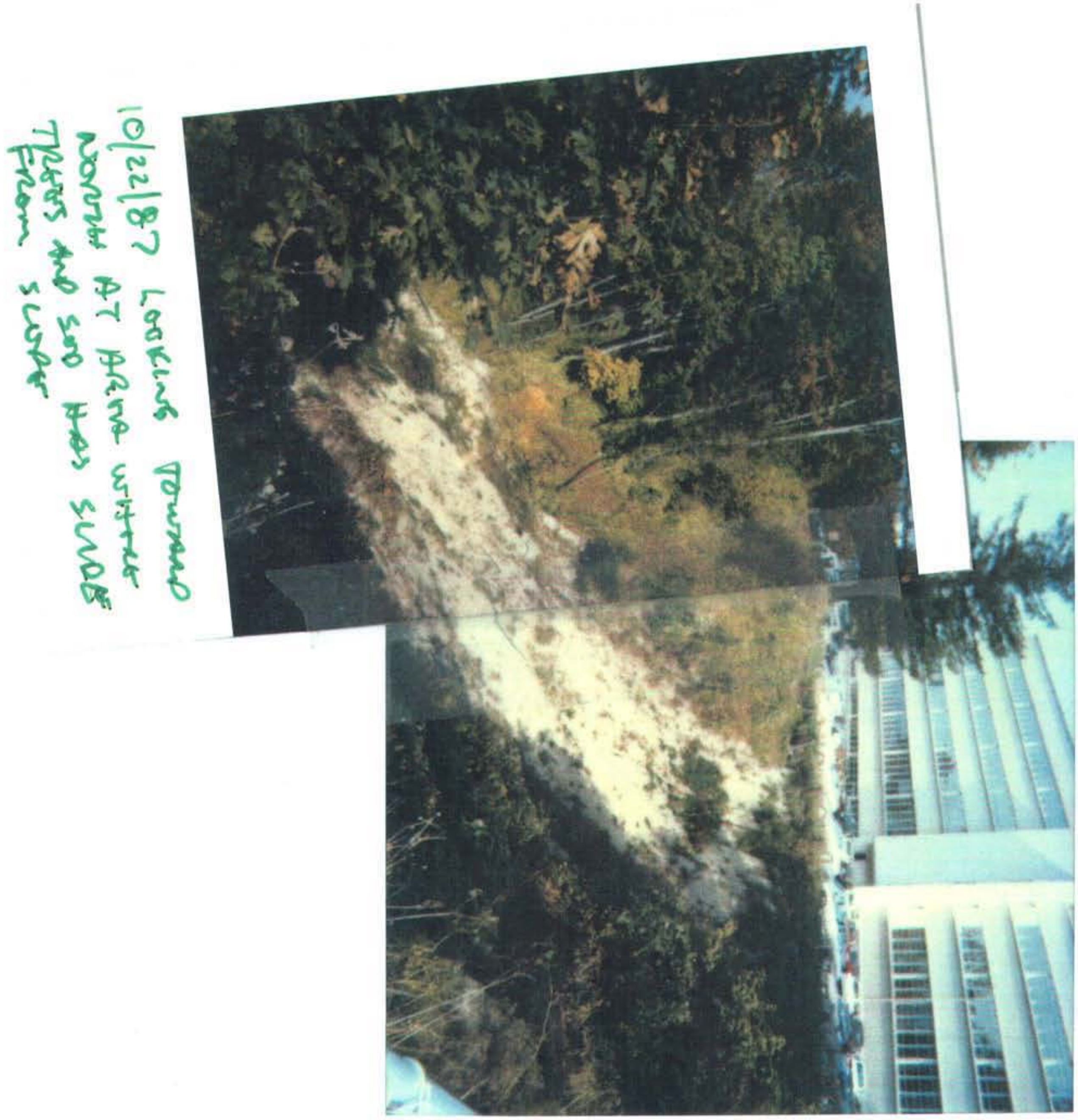


Figure 6 Photograph of the landslide that occurred in the fall of 1987 on the slope west of the GA building. Failure of this slope was resolved by construction of a high retaining wall west of the GA building and north of the Conservatory.

Figure 7 Photograph of the headscarp of a landslide failure that occurred on the slope below the retaining wall west of the GA building. This failure occurred sometime between the fall of 1992 and the spring of 1993.

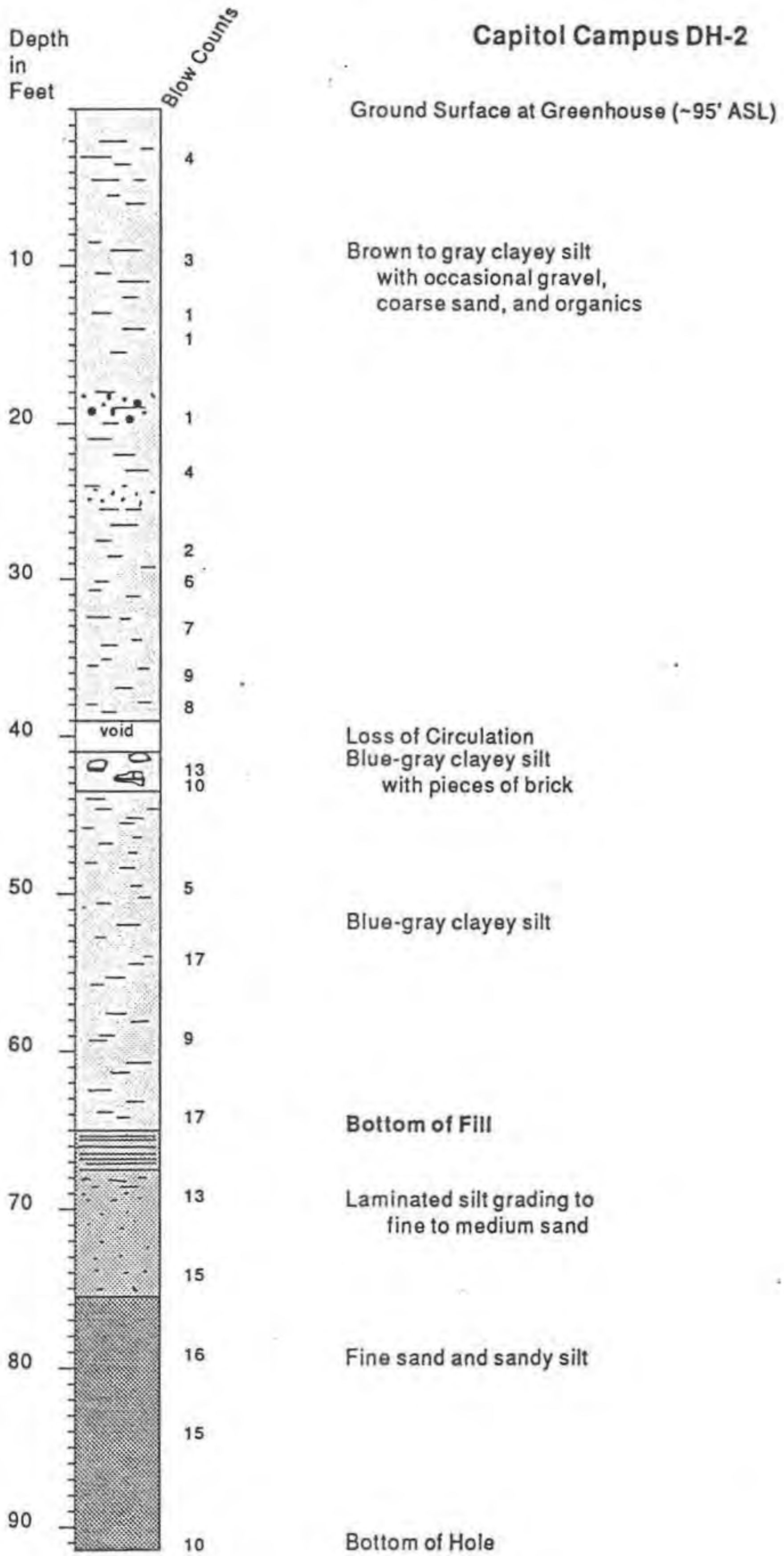
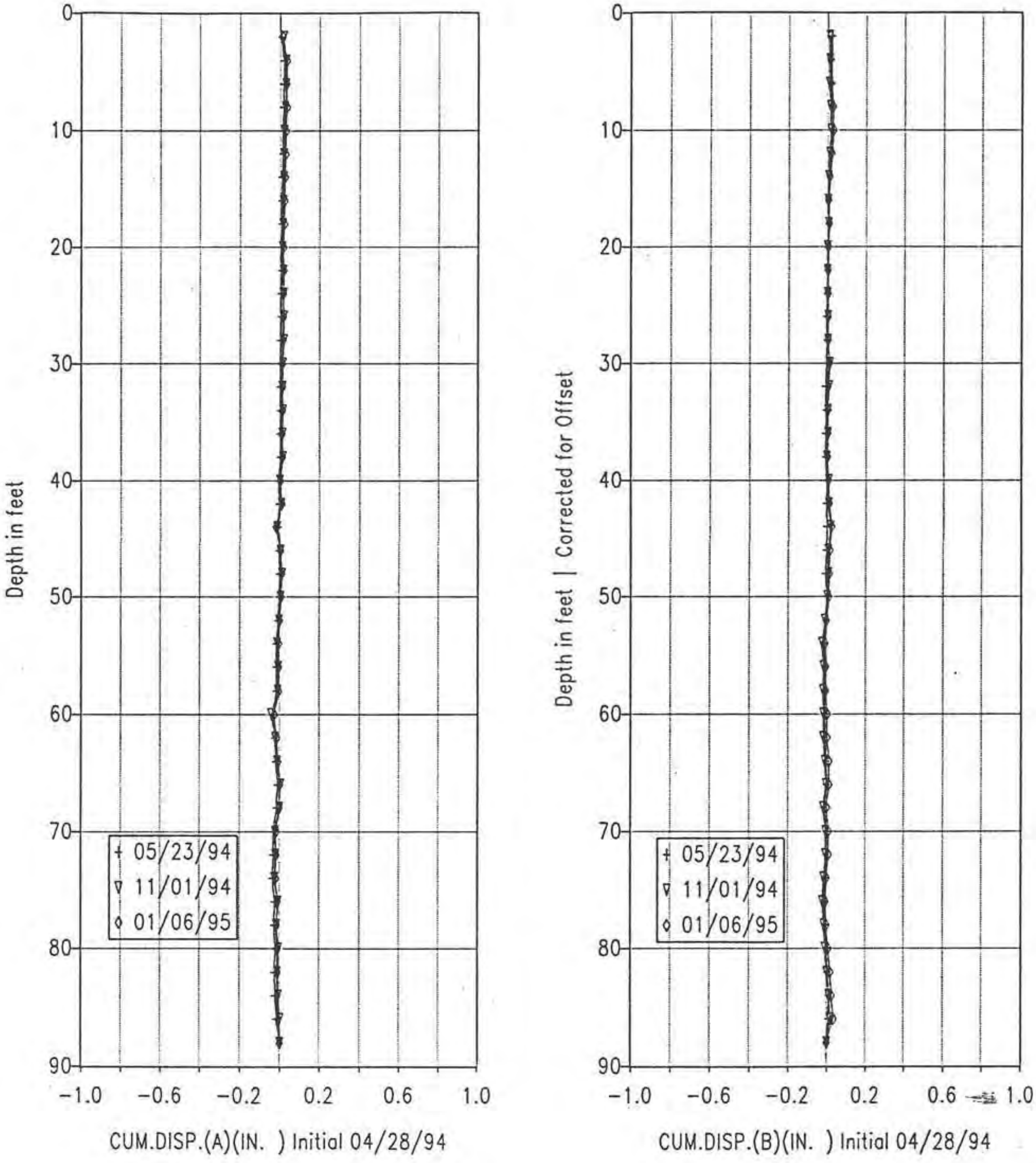


Figure 8 Boring log for DH-2, drilled in April, 1994, near the northwest corner of the Greenhouse building.

Figure 9 Display of inclinometer survey results in boring DH-2. No indication of slope movement is indicated between April 28 and January 6, 1995.



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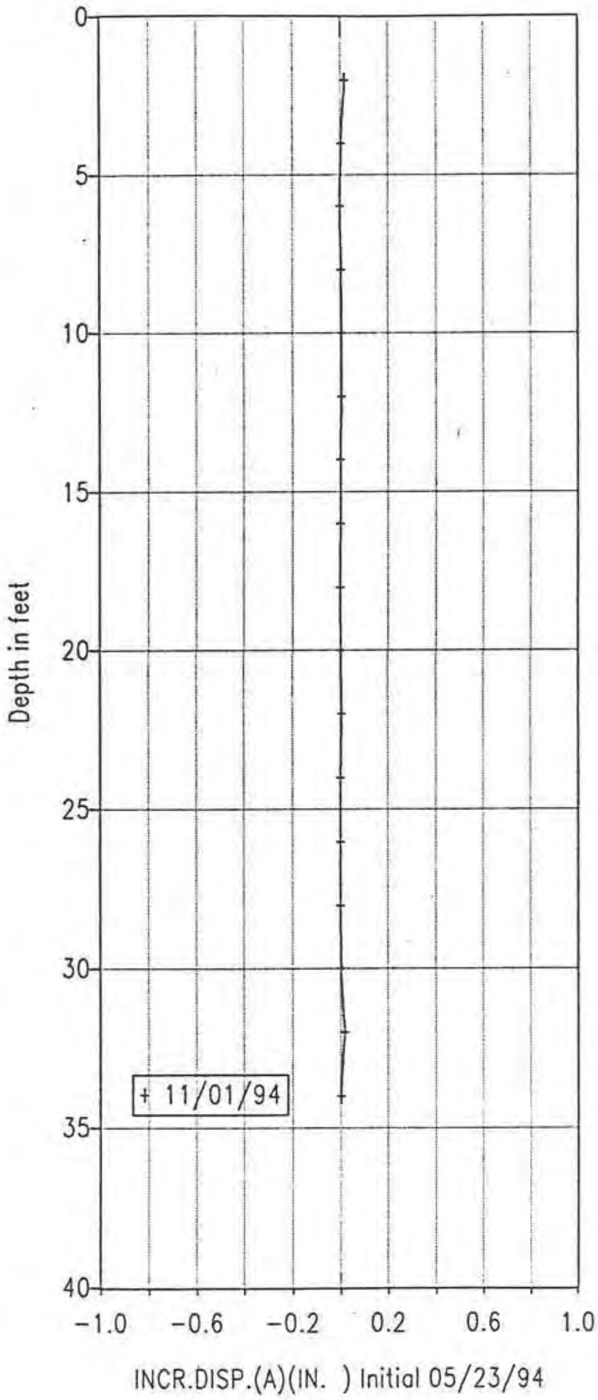
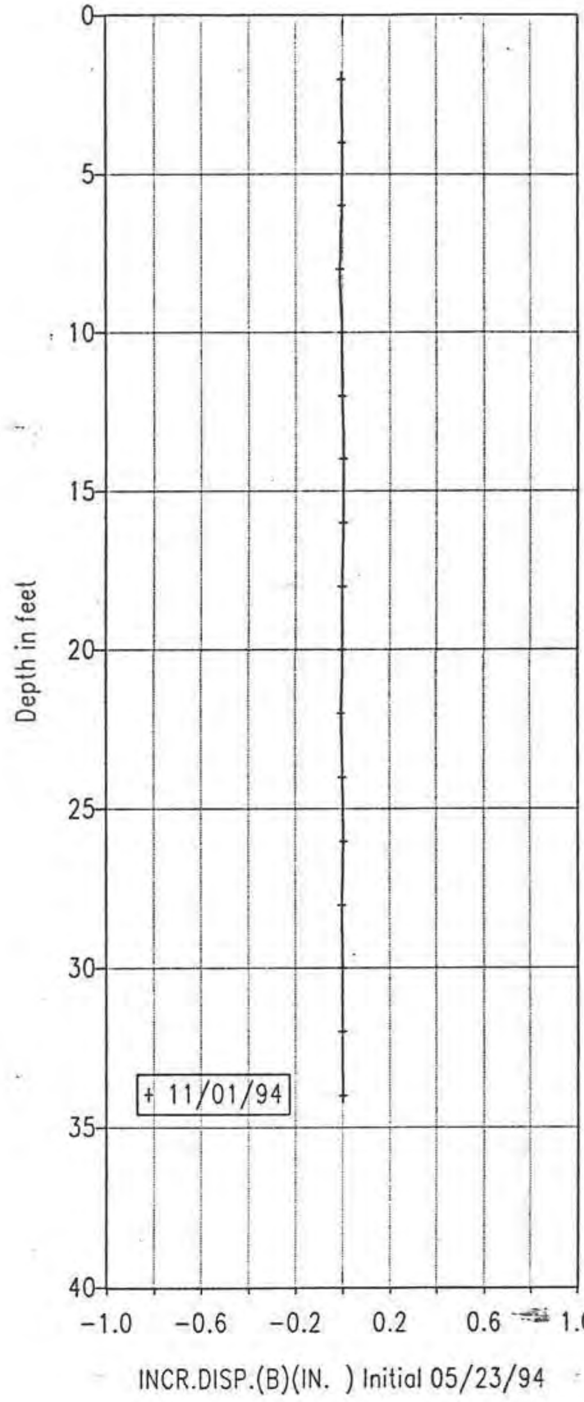
DH-2

Figure 10 Display of inclinometer survey results in boring J-1. No indication of slope movement is indicated between May 23 and November 1, 1994.





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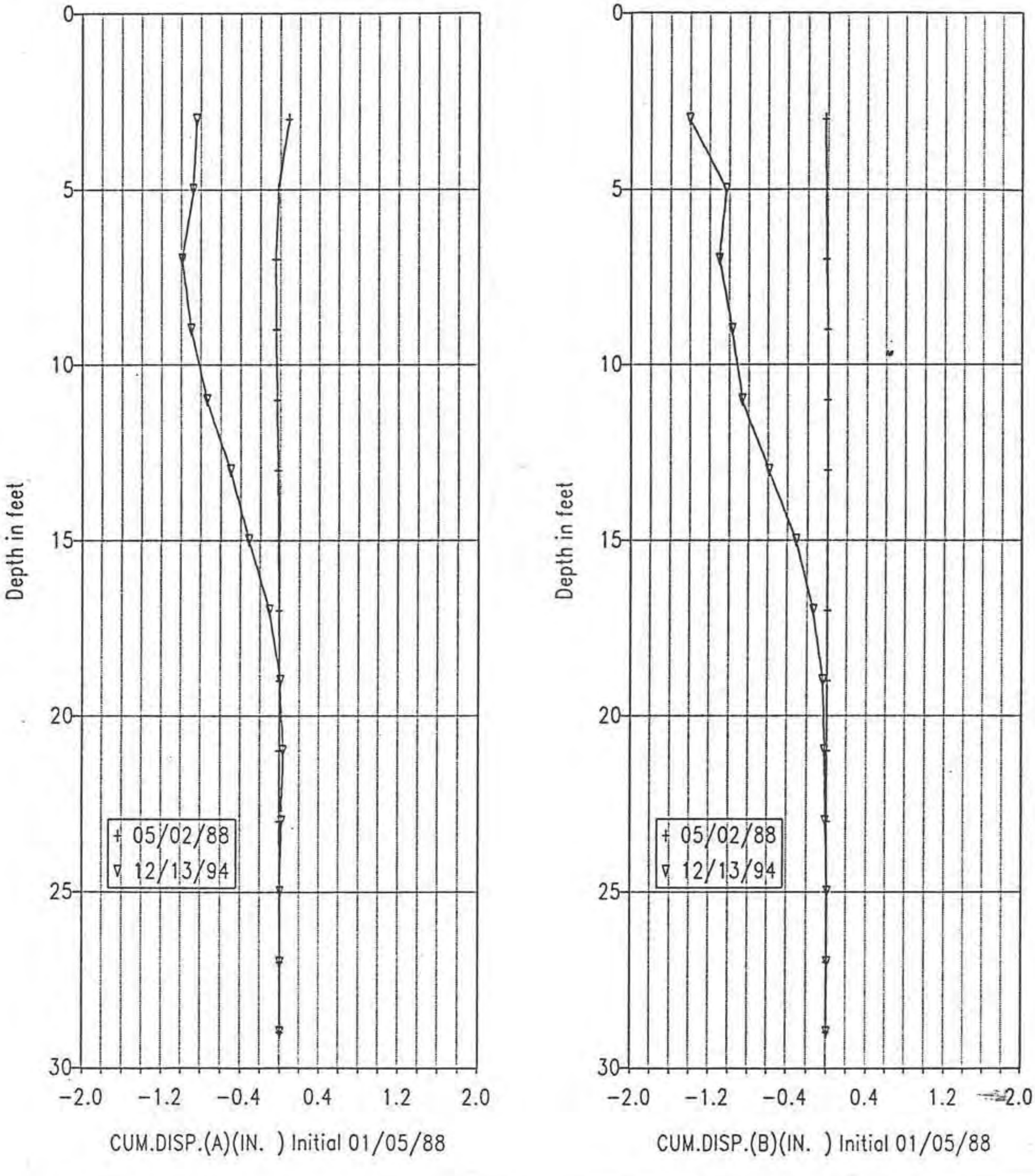
J−1

Figure 11 Display of inclinometer results for J-1 from 1987 to 1994. Cumulative displacements in both the A and B directions are about 1 in, with a resultant downslope movement of approximately 1.5 in during this seven year period.



Washington State Department of Transportation

J-1

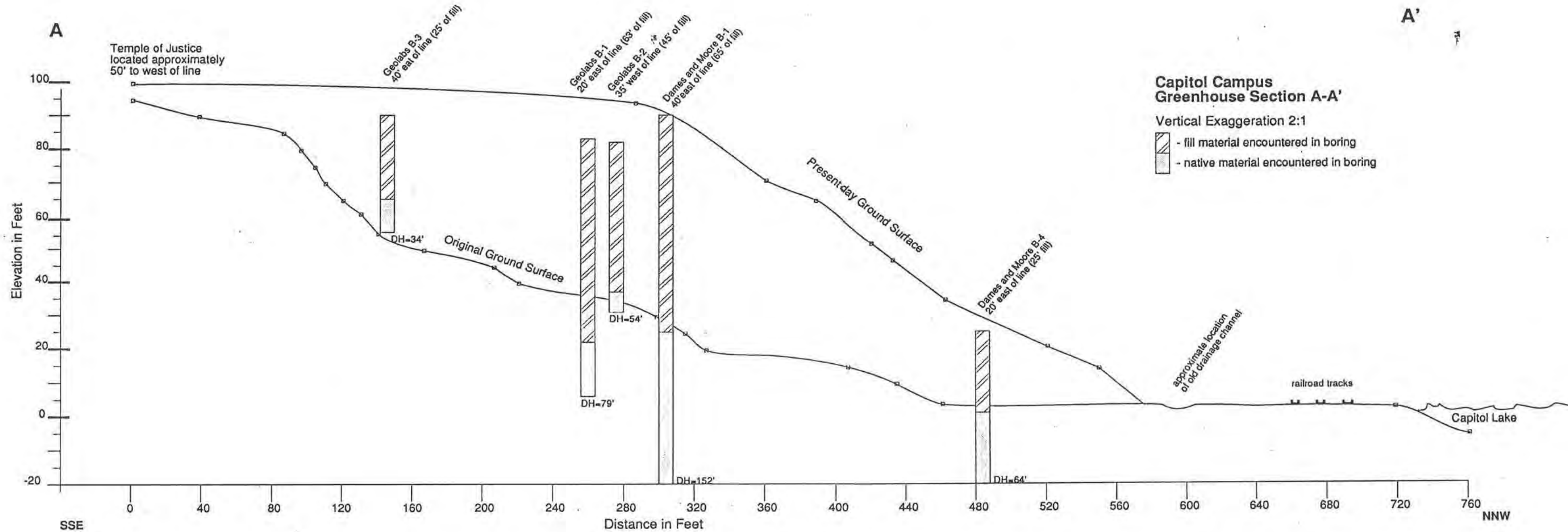


Figure 12 Cross-section A-A'; approximate location shown on Figure 1.

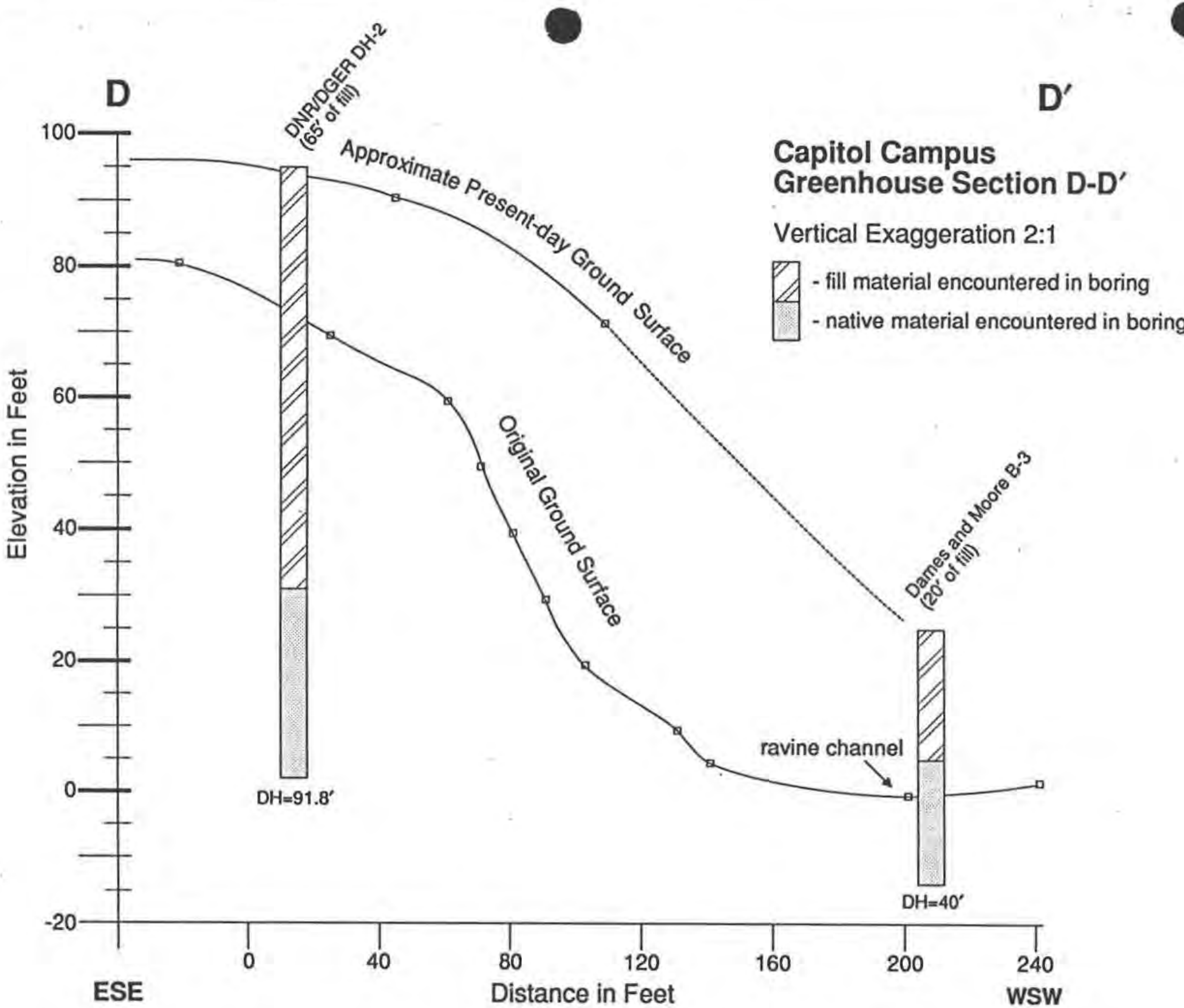


Figure 13 Cross-section D-D'; approximate location shown on Figure 1.